NBT WIND POWER PAKISTAN III (Pvt) LIMITED
CHINA MALAYSIA NORWAY PAKISTAN

Registrar

National Electric Power

Regulatory Authority (NEPRA)

NEPRA Tower Attaturk Avenue (East),

Sector G-5/1, Islamabad.

Letter No. NBT/21/NEPRA - NBT III

Dated: 22 Dec 2014

Subject: Application for the Licensee Proposed Modification (LPM) of the Generation License.

Sir,

It is submitted to the National Electric Power Regulatory Authority the attached application made pursuant to Section 26 of the Regulation of Generation, Transmission and Distribution of Electric Power Act 1997 ("Act"), read with regulation 10(2) of the National Electric Power Regulatory Authority Licensing (Application & Modification Procedure) Regulations, 1999 ("Regulations"), for a Licensee Proposed Modification of NBT Wind Power Generation License No. WPGL/27/2014, dated 16th September, 2014.

A Bank Draft/Pay Order 0045969 dated 18-12-2014 for the sum of Rupees Six Hundred and Ninety Thousand and Eighty (PKR 690,080/-) in favor of the National Electric Power Regulatory Authority, being the applicable Licensee Proposed License Modification Fee for the subject project in accordance with the Rules, Regulation & policy of the Authority, is appended.

We request the Authority to please consider our application for review and approval.

We are available to provide additional information and clarification of any matter raised in this latter and/or the Application.

Regards,

Sayyed Ali Mustafa Gillani

Legal Counsel

NBT Wind Power Pakistan III (Pvt.) Limited

NBT Wind Power Pakistan III (Pvt) Limited.

Application for the modification of its Generation Licence No. WPGL/27/2014. Dated 16th September, 2014.

1. Text of the proposed modification.

The following is the proposed modification in the text of the Table given on page – 10 of Schedule I Part (B) and (C).

(B). Wind Farm Capacity & Configuration

Wind Farm Capacity & Configuration			
		Data to be deleted	Replaced with
(i)	Wind Turbine Type, Make & Model	General Electric (G.E.) 1.6 – 82.5m	Gamesa G97
(ii)	Installed Capacity of Wind Farm (MW)	249.6 MW	250 MW
(iii)	Number of Wind Turbine Units/Size of each Unit (KW)	156 x 1.60 MW	125x 2.0MW

(C). Wind Turbine Details

(a). **Rotor**			
		Data to be deleted	Replaced with
(i)	Number of blades	3	3
(ii)	Rotor speed	9.8 — 18.7 rpm	9~19rpm
(iii)	Rotor diameter	82.5 m	97m
(iv)	Swept area	5346 m2	7389.8m3
(v)	Power regulation	Combination of blade pitch angle adjustment, and	Pitch control and variable

		generator / converter torque control.	speed.
(vi)	Cut-in wind speed	3 m/s	3m/s
(vii)	Cut-out wind speed	25 m/s	25m/s
(viii)	Survival wind speed	40 m/s, 3s average (40 m/s, 10min ave; 56 m/s, 3s ave)	37.5m/s(10min)
(ix)	Pitch regulation	Electric motor drives a ring gear mounted to the inner race of the blade pitch bearing.	Hydraulic
(b). Blades			
(i)	Blade length	40.3 m (GE has not yet defined what the blade variant will be for this project.)	47.5m
(ii)	Material	Fiberglass polyester resin	Glass fiber reinforced with epoxy
(c). Gearbox			
(i)	Type	Multi-stage planetary/helical gear design	1 stage planetary and 2parallel
(ii)	Gear ratio	1:107.1	1:106.8
(iii)	Main shaft bearing	Roller bearing mounted in a pillow-block housing arrangement.	2 spherical roller bearings
(d). Generator			
(i)	Power	1,600 kW	2070kW
(ii)	Voltage	690 V	690V
(iii)	Type	Doubly-fed induction type	DFIG
(iv)	Enclosure class	IP 54	IP54
(v)	Coupling	Flexible coupling	Flexible coupling
(vi)	Power factor	+0.95 to -0.95	-0.95~+0.95
(e). Yaw System			
(i)	Yaw bearing	Roller bearing	Friction bearings
(ii)	Brake	Planetary yaw drives (with brakes that engage when the drive is disabled)	5 Active brake

(iii)	Yaw drive	4 planetary yaw drives	4x2.5Kw motors
(iv)	Speed	0.5 degree/s	0.42Degree/s ; 1 turn every 15 min

(f). <u>Control System</u>			
(i)	Type	Automatic or manually controlled.	PLC
(ii)	Scope of monitoring	Remote monitoring of different parameters, e.g. temperature sensors, pitch parameters, speed, generator torque, wind speed and direction, etc.	Wind speed data, pitch control, yaw control, internal temperature control, remote control
(iii)	Recording	Production data, event list, long and short-term trends	WTG operation data
(g). <u>Brake</u>			
(i)	Design	Three independent systems, fail safe (individual pitch)	Aerodynamic brake and Mechanical brake
(ii)	Operational brake	Aerodynamic brake achieved by feathering blades	Aerodynamic brake
(iii)	Secondary brake	Mechanical brake on (high speed) shaft of gearbox	Mechanical brake in High speed shaft
(h). <u>Tower</u>			
(i)	Type	Tubular steel tower	Trunk-conical tubular
(ii)	Hub heights	80 m	78m

2. Statement of reason in support of modification

NBT WIND POWER PAKISTAN III (Pvt) Ltd (NBT III) is submitting this Application in order to cater to feasibility of the Project. Combined with NBT WIND POWER PAKISTAN II (Pvt) Ltd (NBT II) the total amount of Wind Turbine Generators (WTG) to be delivered is of such a large quantity, that NBT III fears that one single manufacturer would have constraints on delivering them for both projects in a manner that would enable both NBT II and NBT III to achieve Commercial Operations Date within the timelines stipulated in NEPRAs Tariff Determination. In order to achieve these timelines NBT III is requesting a change in the Generation License from GE 1.6 to Gamesa G97 WTGs

3. Statement on the Impact of the tariff, quality of service and Performance by the licensee of its obligation under the license

There will be no impact on the tariff by reason of acceptance of this application. NBT WIND POWER PAKISTAN III (Pvt) Ltd was awarded the upfront tariff it's 250MW project by NEPRA and the licensee proposed modification has no direct impact, nor any indirect impact on the tariff.

There will be no impact on the quality of service by reason of acceptance of this application

There will be a minor improvement in the performance of the wind farm by reason of this application as the total installed capacity will increase from 249.6 to 250MW.

INDICE

RECORD OF CHANGES

Rev.	Date	Author	Description
0	11/01/12	TGARCIA	Initial version
1	20/02/12	TGARCIA	Foundations info added
2	27/06/12	TGARCIA	Nacelle weights and LM blades dimensions updated

1 PURPOSE

During the logistics operation, GAMESA components (tower sections, foundation, nacelles, hubs and blades) are assembled with a corresponding toolkit.

The purpose of this document is to define for hoist and transport process:

- Dimensions
- Weight
- Interfaces (hoisting & support zones)

2 SCOPE

The scope is for all componets GAMESA transported by CTL of G9X series.

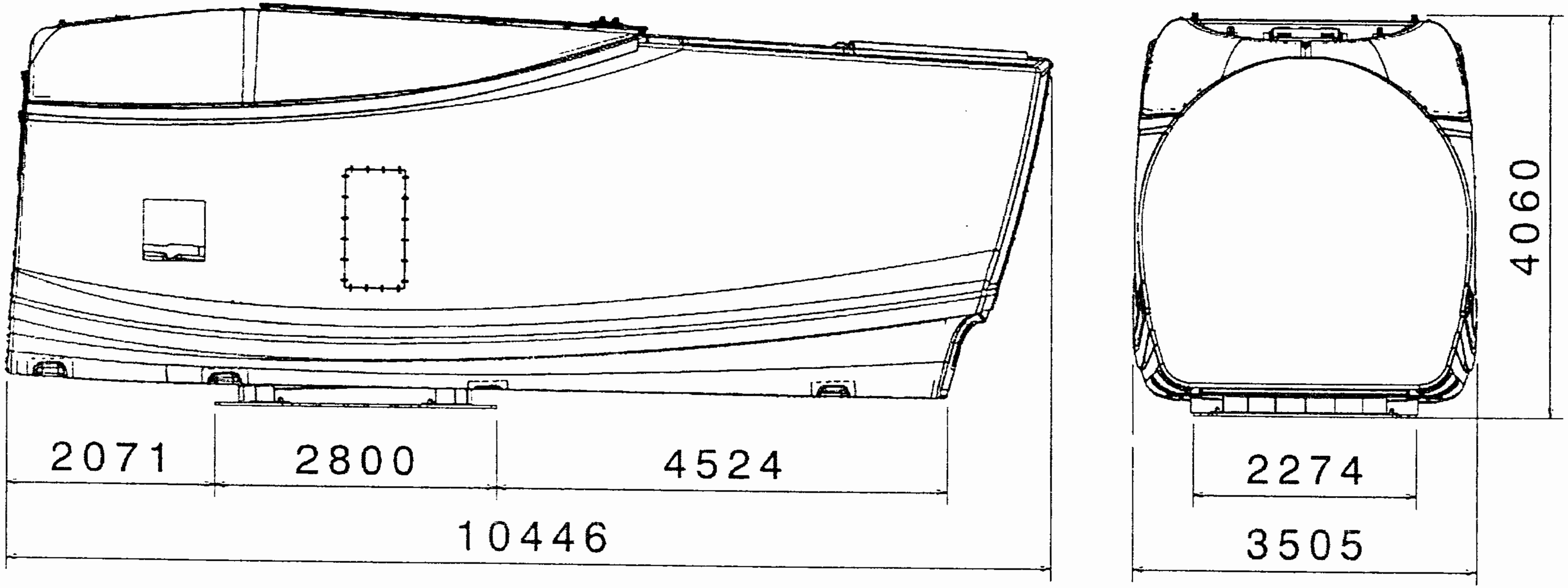
3 DESCRIPTION

Below there are sketches of components assembled with transport toolkit including relevant information:

3.1 NACELLE G9X + TRANSPORT RING

The Nacelle G8X is always assembled with transport ring (GP010273).

NOTE: For Lifting point information read document: OPERATIONS NACELLES G8X

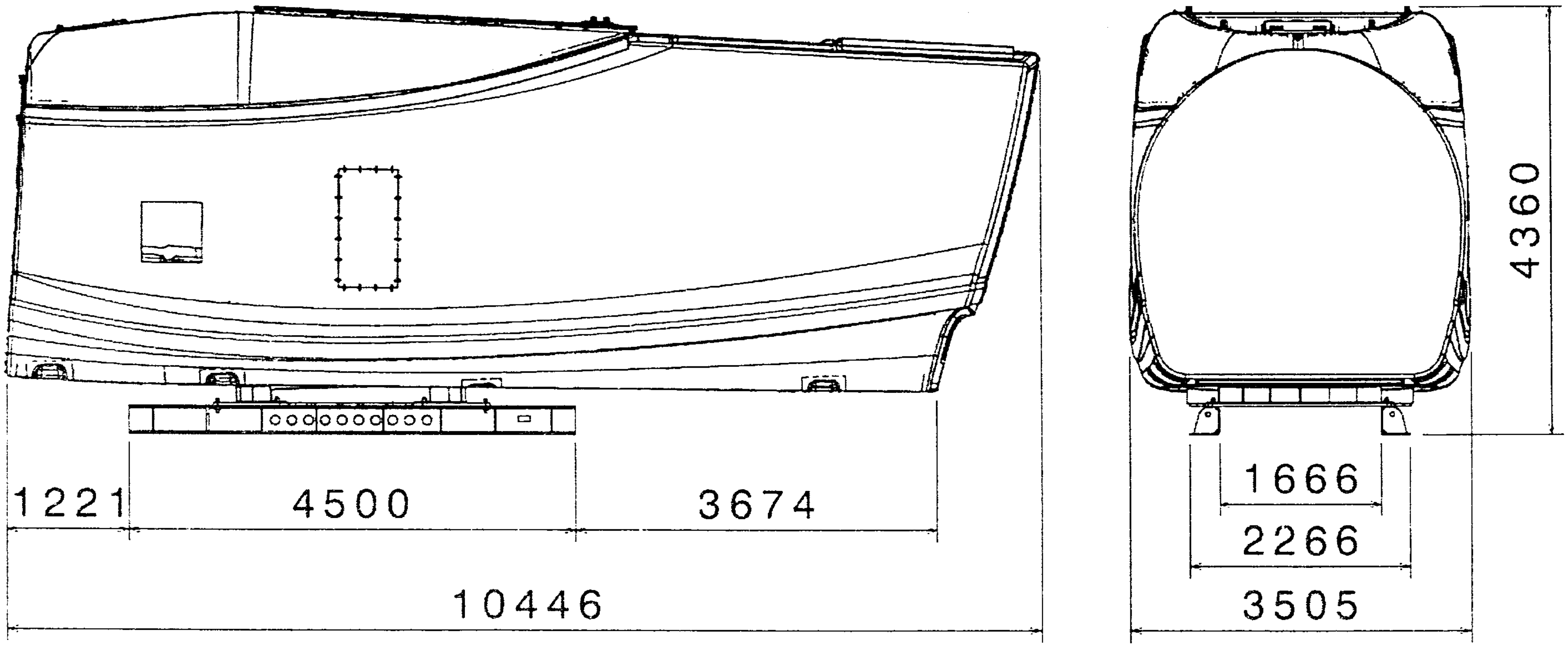


DIMENSIONS: 10446 x 3505 x 4060 mm

TOOLKIT CODE: Transport ring: GP118264 / GP128152 (Hybrid)
TOOLKIT WEIGHT: 1500 Kg

	WEIGHT (kg)	
NACELLE G8X CONFIGURATIONS	**Nacelle**	**T.Ring**
FULL	71332,638	**72832,638**
WITHOUT TRAFO	65780,866	67280,866
WITHOUT GENERATOR	64726,635	66226,635
WITHOUT TRAFO & CONVERTER	63980,862	65480,862
WITHOUT TRAFO, CONVERTER & GENERATOR	57374,859	58874,859

3.2 NACELLE G9X + TRANSPORT RING + CATAMARANS



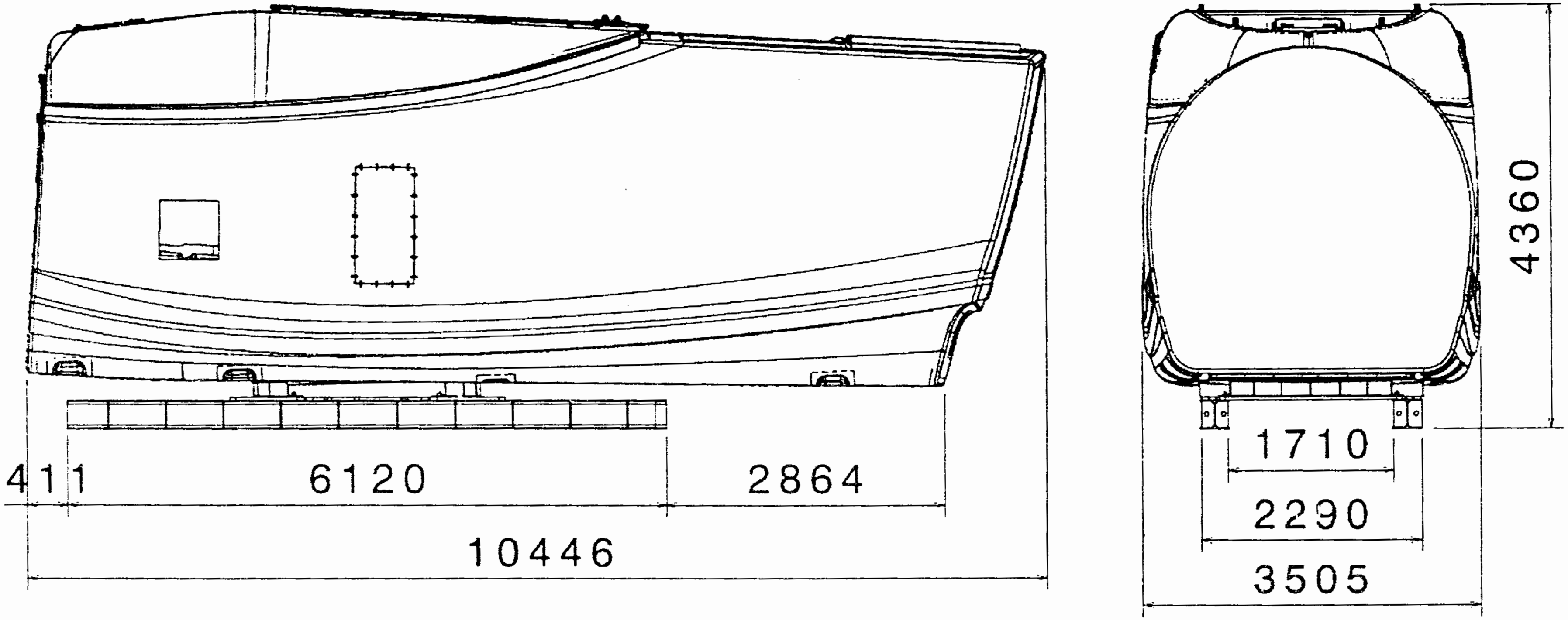
DIMENSIONS: 10446 x 3505 x 4360 mm

TOOLKIT CODE Transport ring: GP118264 / GP128152 (Hybrid)
Catamaran: GP022319

TOOLKIT WEIGHT Transport ring: 1500 Kg
2 Catamarans: 820 Kg

	WEIGHT (kg)	
NACELLE G8X CONFIGURATIONS	**Nacelle**	**T.Ring+Cat.**
FULL	71332,638	**73652,638**
WITHOUT TRAFO	65780,866	68100,866
WITHOUT GENERATOR	64726,635	67046,635
WITHOUT TRAFO & CONVERTER	63980,862	66300,862
WITHOUT TRAFO, CONVERTER & GENERATOR	57374,859	59694,859

3.3 NACELLE G9X+ TRANSPORT RING+ CHINESE CATAMARANS

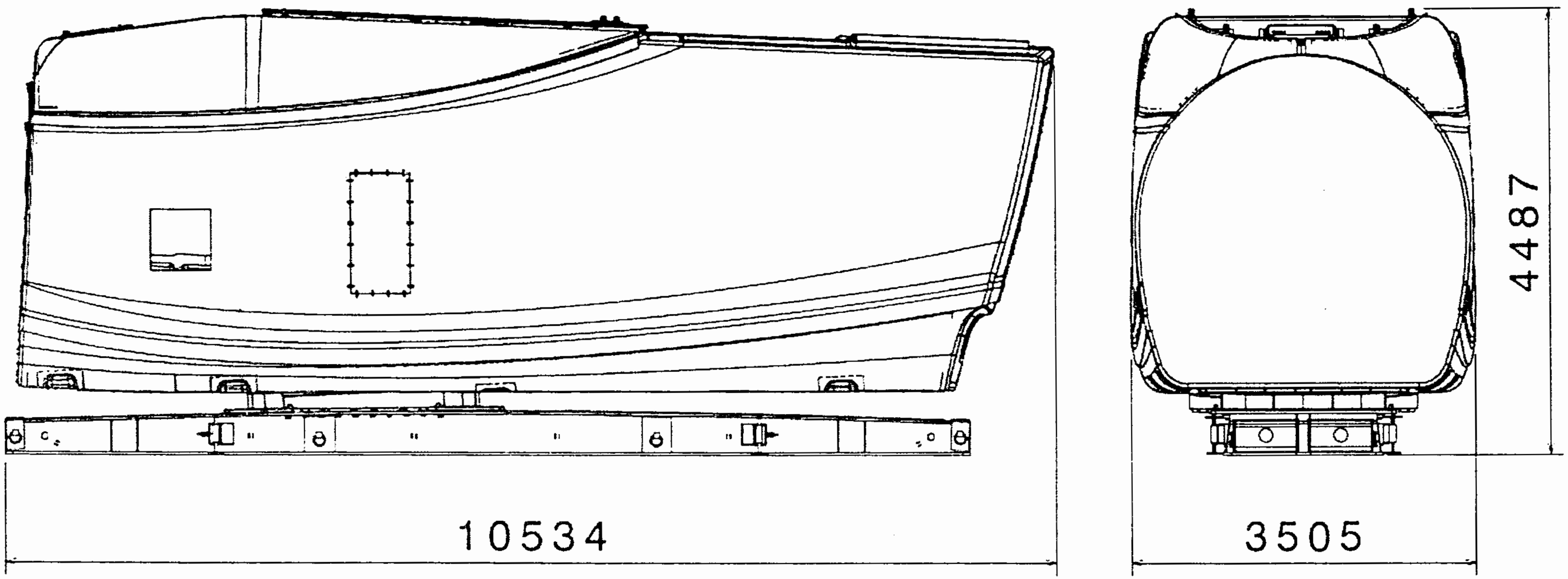


DIMENSIONS: 10446 x 3505 x 4360 mm

TOOLKIT CODE Transport ring: GP118264 / GP128152 (Hybrid)
TOOLKIT WEIGHT Transport ring: 1500 Kg
2 Catamarans: 1410 Kg

	WEIGHT (kg)	
NACELLE G8X CONFIGURATIONS	**Nacelle**	**T.Ring+Chinese Cat**
FULL	71332,638	**74332,638**
WITHOUT TRAFO	65780,866	68780,866
WITHOUT GENERATOR	64726,635	67726,635
WITHOUT TRAFO & CONVERTER	63980,862	66980,862
WITHOUT TRAFO, CONVERTER & GENERATOR	57374,859	60374,859

3.4 NACELLE G9X + TRANSPORT RING + TRANSPORT PLATFORM

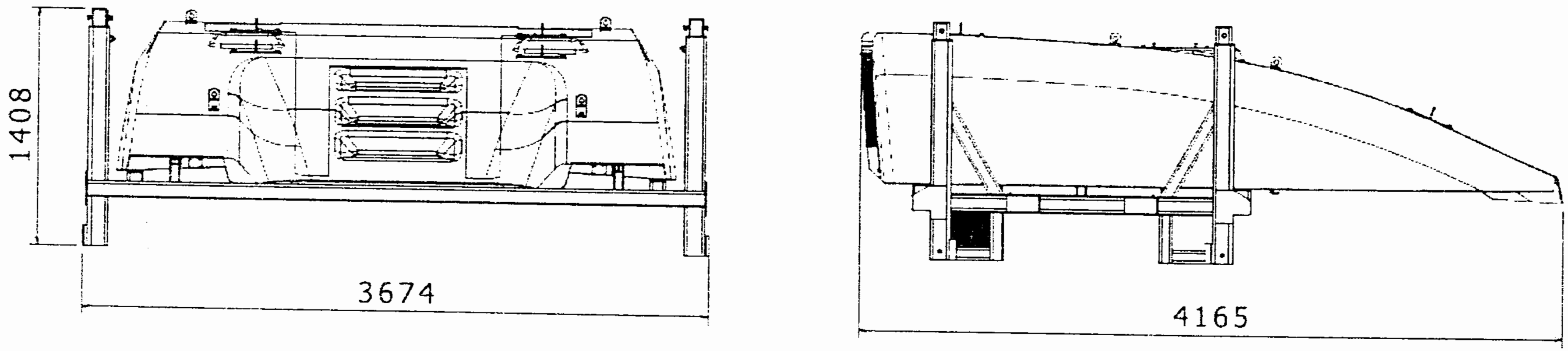


DIMENSIONS: 10534 x 3505 x 4487 mm

TOOLKIT CODE Transport ring: GP118264 / GP128152 (Hybrid)
Transport platform: GP022319
TOOLKIT WEIGHT Transport ring: 1500 Kg
Transport platform: 10000 Kg

	WEIGHT (kg)	
NACELLE G8X CONFIGURATIONS	**Nacelle**	**T.Ring+T.Platform**
FULL	71332,638	**82832,638**
WITHOUT TRAFO	65780,866	77280,866
WITHOUT GENERATOR	64726,635	76226,635
WITHOUT TRAFO & CONVERTER	63980,862	75480,862
WITHOUT TRAFO, CONVERTER & GENERATOR	57374,859	68874,859

3.5 HIGH TEMPERATURE MODULE G9X



DIMENSIONS: 4165 x 3674 x 1408 mm
WEIGHT: 1700 Kg

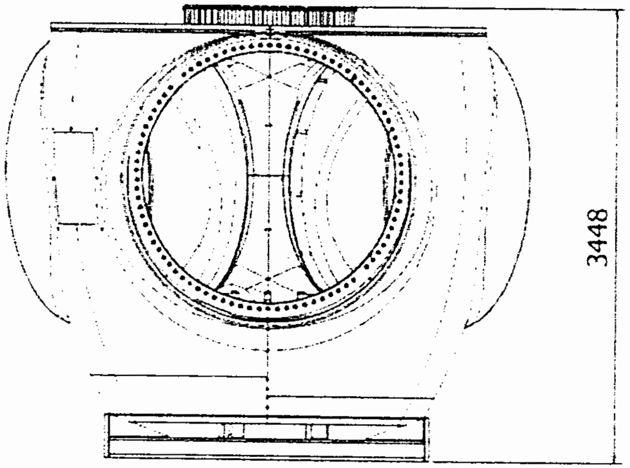
COMPONENT WEIGHT: 1000 Kg

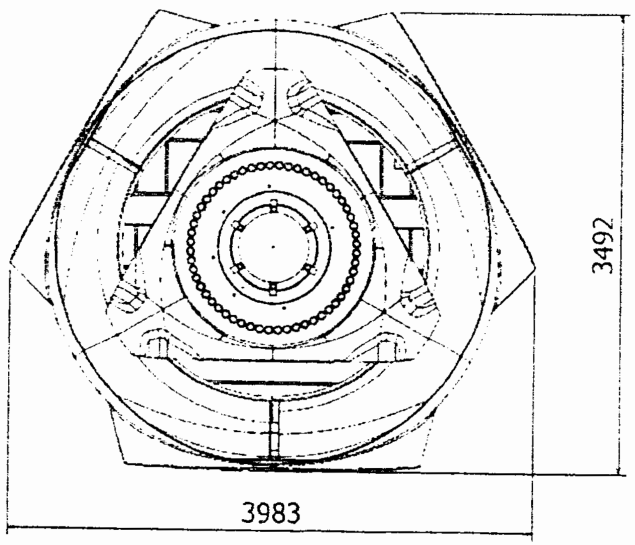
TOOLKIT CODEL: GP102206
TOOLKIT WEIGHT: 700 Kg

STACKING DIMENSION:

1 ALTURA: 1408 mm
2 ALTURAS: 2716 mm
3 ALTURAS: 4024 mm
4 ALTURAS: 5332 mm

3.6 ROTOR G9X + TOOLKIT



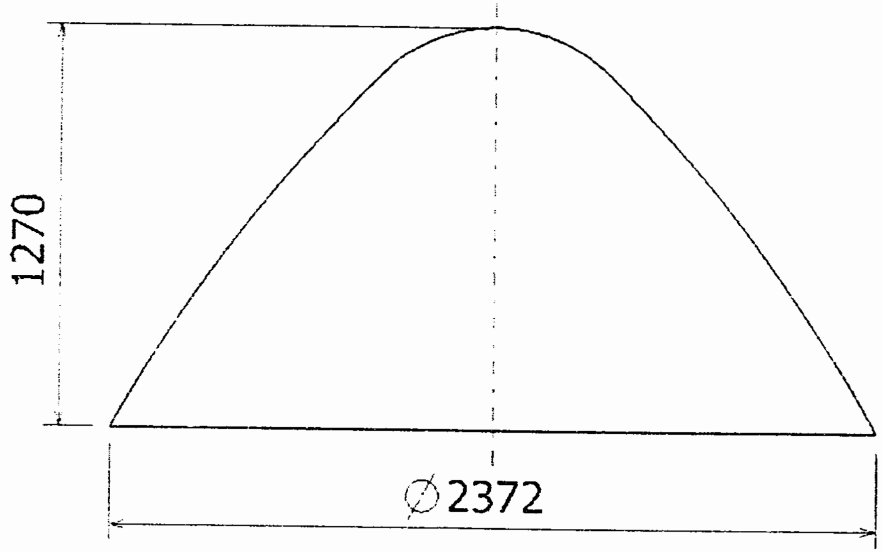


DIMENSIONS: 3983 x 3492 x 3448 mm
WEIGHT: 25850 Kg

COMPONENT WEIGHT: 24000 Kg
REFERENCE DOCUMENT: GD061947

TOOLKIT CODE: GP010359
TOOLKIT WEIGHT: 1850 Kg

3.7 ROTOR G9X NOSE CONE

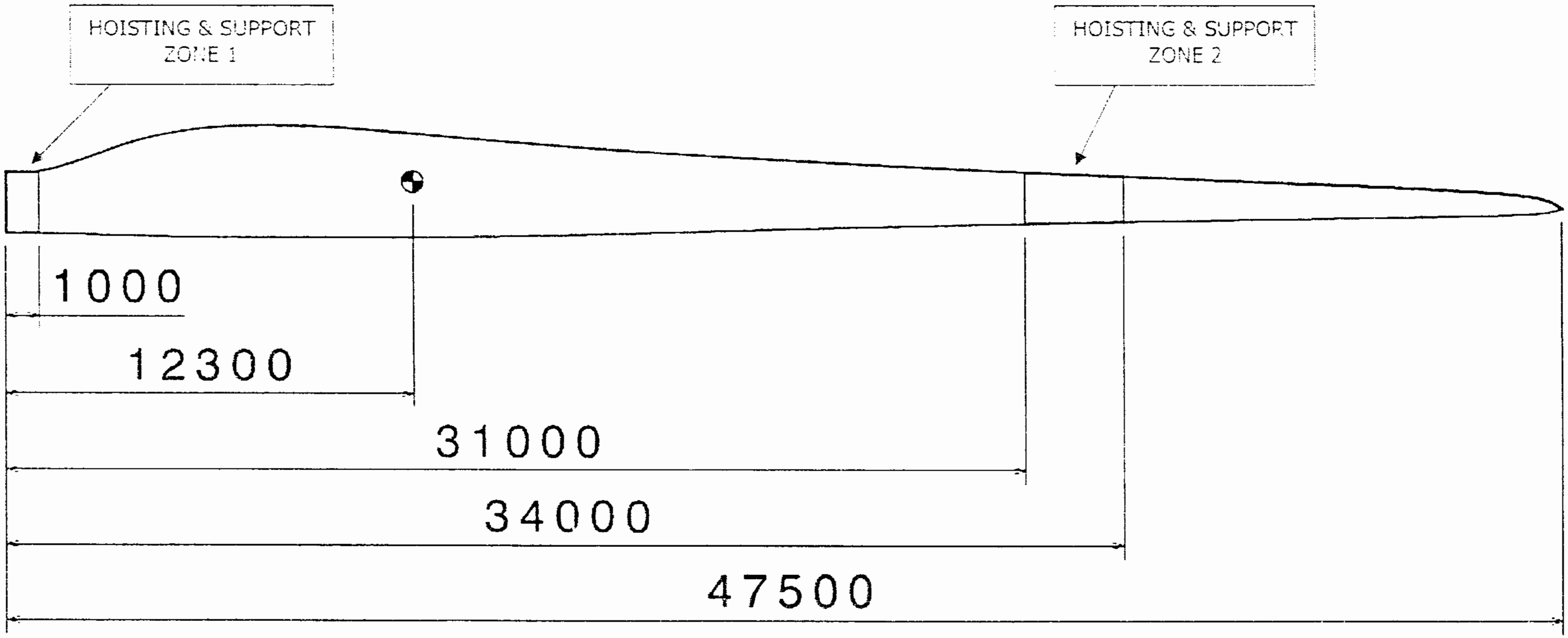


DIMENSIONS: 2372 x 2372 x 1270 mm

COMPONENT WEIGHT: 137 Kg

REFERENCE DOCUMENT: GD061955

3.8 BLADE G97



DIMENSIONS: 47500 x 3461 x 1880 mm

REFERENCE DOCUMENT: GP114538

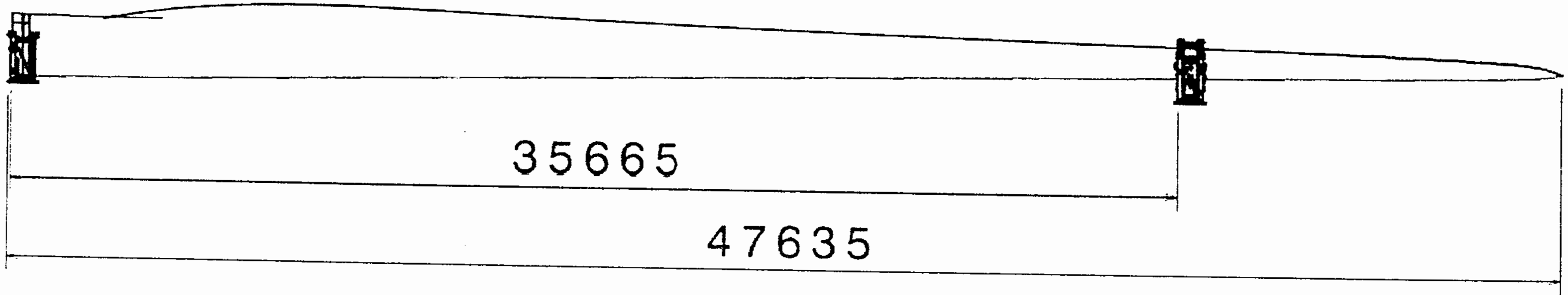
WEIGHT: 7200 Kg

COG: 12300 mm

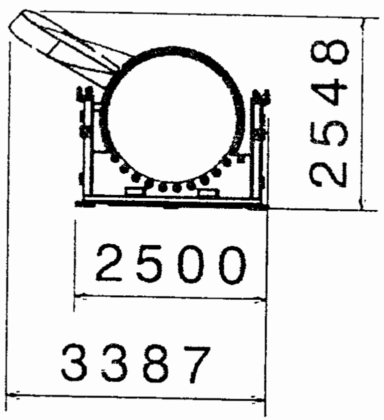
HOISTING & SUPPORT ZONE 1 (from root): 0 – 1000 mm

HOISTING & SUPPORT ZONE 2 (from root): 31000 – 34000 mm

3.9 BLADE G97 + TRANSPORT TOOLKIT

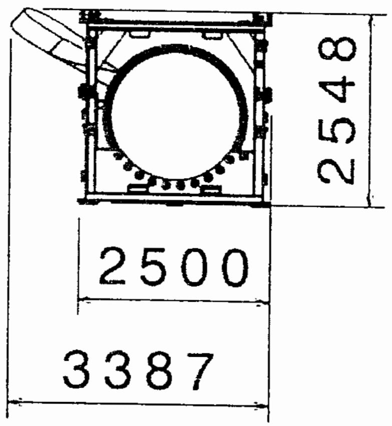


ROAD TRANSPORT
WITHOUT STACKING MODULE



WEIGHT: 9600 Kg

MARITIME TRANSPORT
STACKING



WEIGHT: 10700 Kg

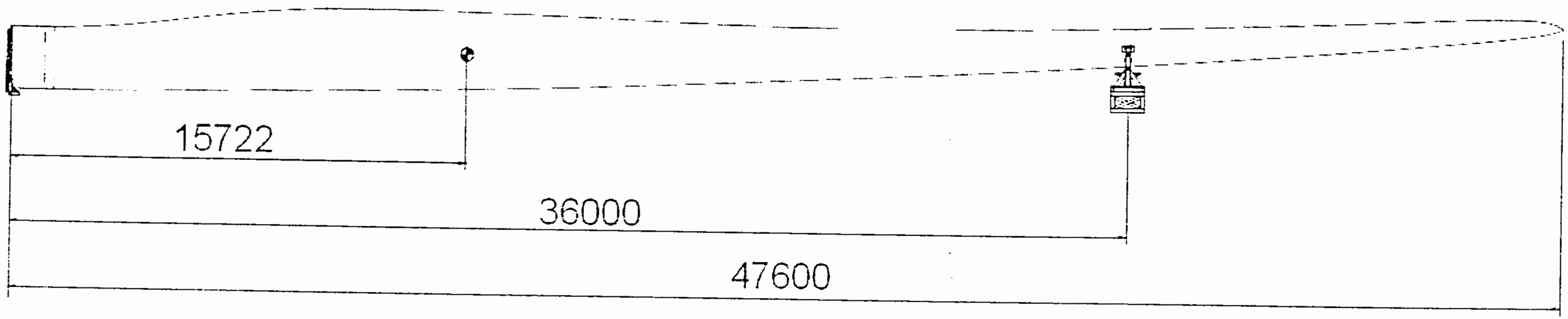
DIMENSIONS: 47650 x 3390 x 2550 mm

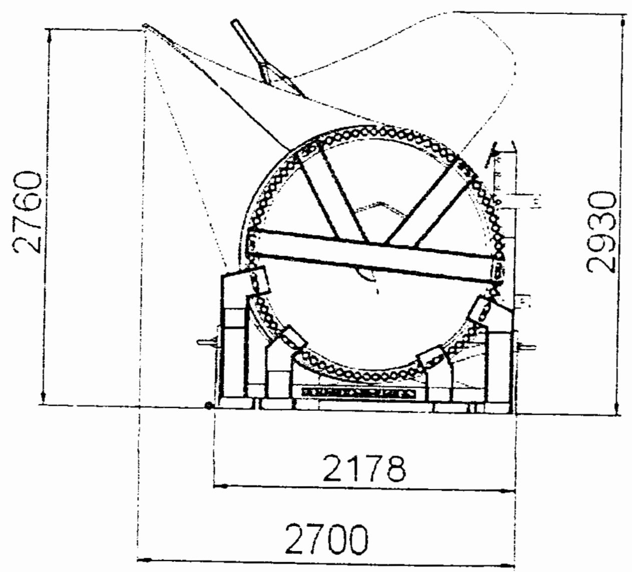
COMPONENT WEIGHT: 7200 Kg

TOOLKIT WEIGHT		
	Root support:	800 Kg
	Tip support+clamp:	1600 Kg
	Stacking module:	550kg

TOOLKIT CODE: GD112090

3.10 BLADE G97 GF + STORAGE & ROAD TRANSPORT TOOLKIT



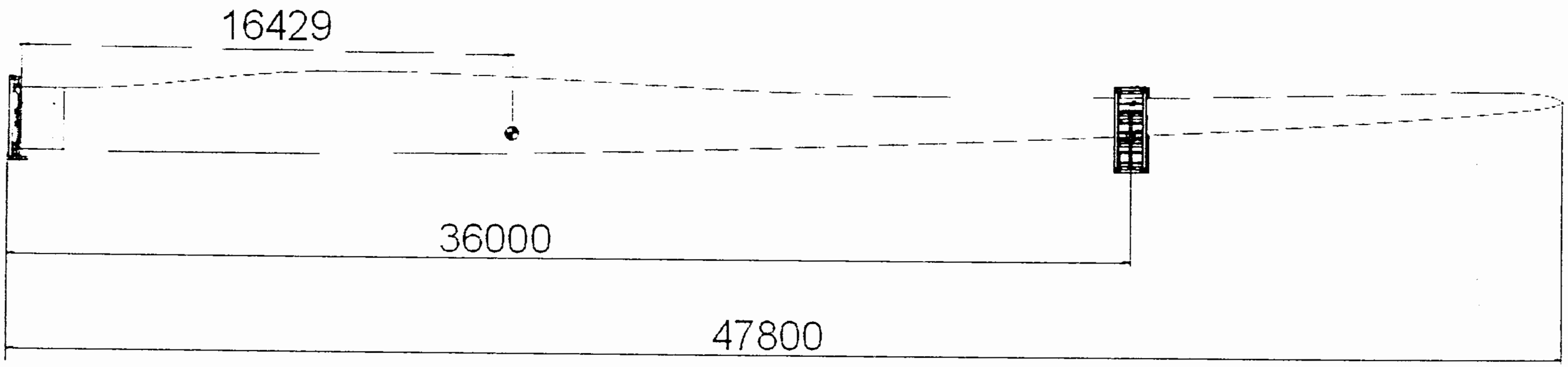


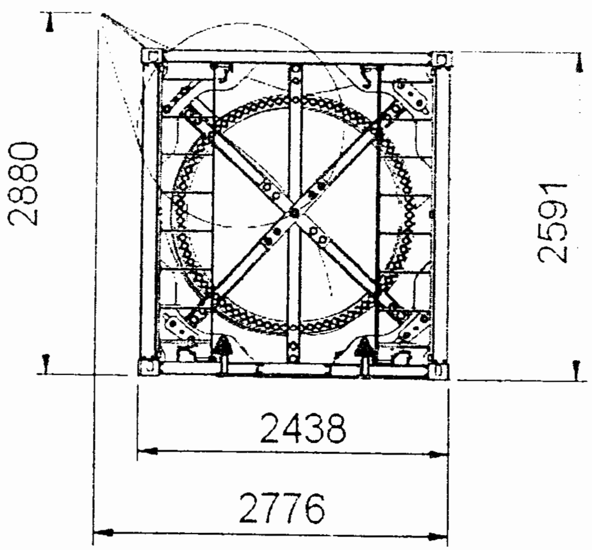
DIMENSIONS: 47600 x 2700 x 2930 mm
WEIGHT: 8550 Kg

COMPONENT WEIGHT: 8000 Kg

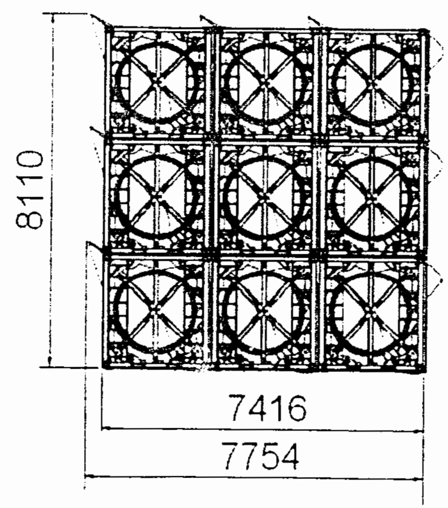
TOOLKIT WEIGHT Root support: 220 Kg
Tip support: 330 Kg

3.11 PALA G97 GF + STORAGE & MARITIME TRANSPORT TOOLKIT





Max. Stacking high 3 frames



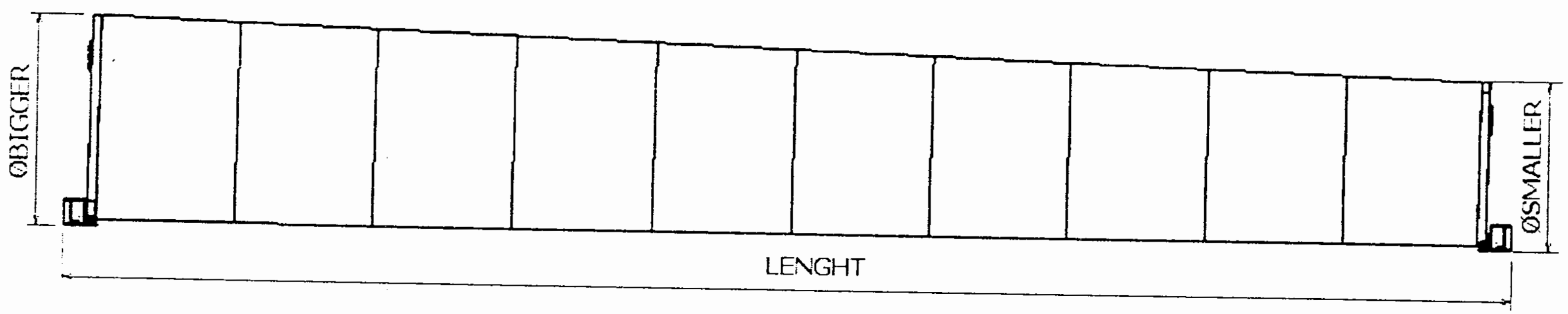
INDIVIDUAL DIMENSIONS:3160 x 2880 x 47800 mm
WEIGHT: 10100 Kg

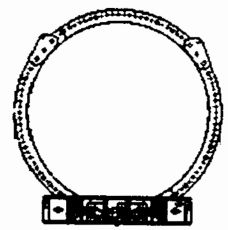
STACKING DIMENSIONS: 7754 x 8110 x 47800 mm

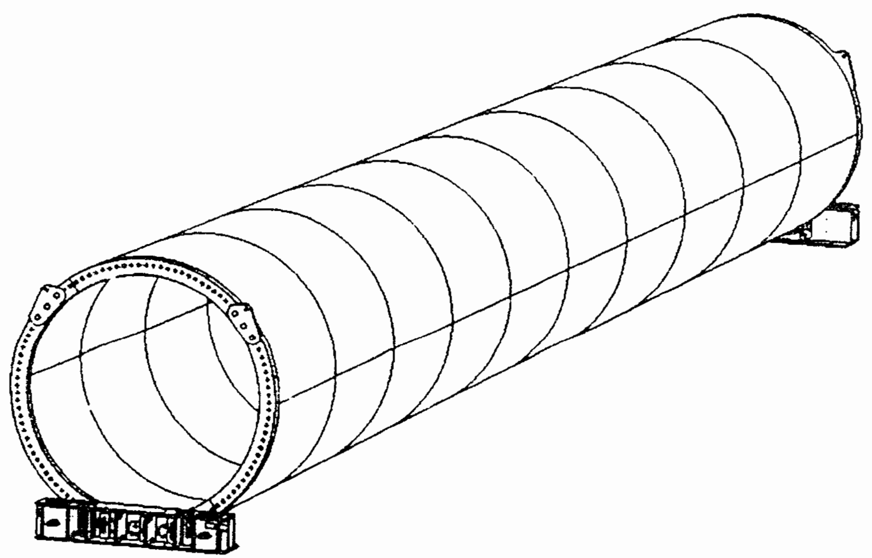
COMPONENT WEIGHT: 8000 Kg

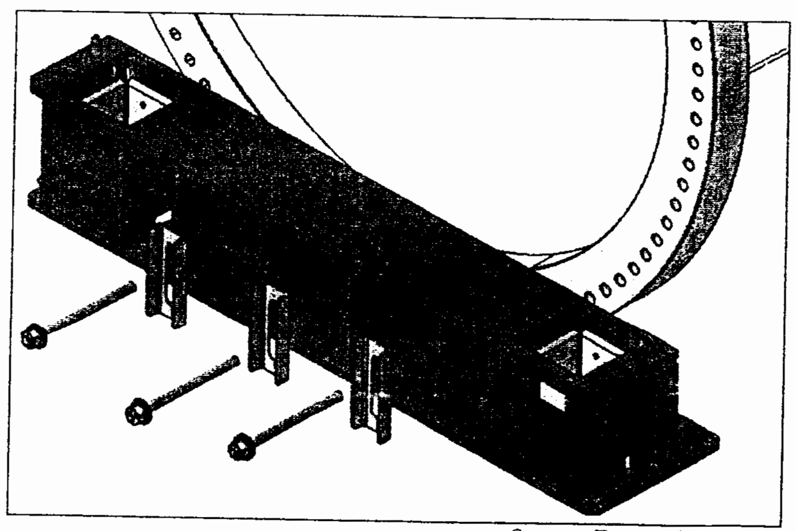
TOOLKIT WEIGHT Root support: 800 Kg
Tip support: 1300 Kg

3.12 TOWER SECTION









G9X

SECTION 1

HEIGHT	WIND CLASS	TOWER	SECTION	ASSEMBLY CODE	W (Kg)	L (mm)	Ø LOW.	Ø UPP.
78.3M	G8X T 128 AGUJEROS 50Hz 230V + G97	TX05C2015	SX05C0001	GP117889	59850 (0+2%)	18795 (±50)	4000 (±5)	3766 (±2)
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HC	TX05C2017		GP123036				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HD	TX05C2018	SX05C0001	GP117889				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2019		GP123036				
	G8X T 128 AGUJEROS 60Hz 120V + G97	TX06C2015	SX06C0009	GP122400				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HC	TX06C2017		GP123377				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HD	TX06C2018		GP122395				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2019		GP123377				
	TOWER G9X 50HZ -30ºC>>+45 03	T09X05C03	SX05C0009	GP157787				
	TOWER G9X 60HZ -30ºC>>+45	T09X06C05	S09X06C00	GP157786				
	TOWER G9X 60HZ -30ºC>>+45	TX06C2017	SX06C0014	GP123387				
90M	G8X T 148 AGUJEROS 50Hz 230V + G97	TX05C2016	SX05C0007	GP120976	64800 (0+2%)	15795 (±50)	4270 (±5)	3997 (±2)
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC	TX05C2020		GP123463				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HD	TX05C2021		GP120966				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2022		GP123463				
	G8X T 148 AGUJEROS 60Hz 120V + G97	TX06C2016	SX06C0001	GP116819				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC	TX06C2020		GP123524				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HD	TX06C2021		GP116650				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2022		GP123524				

SECTION 2

HEIGHT	WIND CLASS	TOWER	SECTION	ASSEMBLY CODE	W (Kg)	L (mm)	Ø LOW.	Ø UPP.
78.3M	G8X T 128 AGUJEROS 50Hz 230V + G97	TX05C2015	SX05C0002	GP117890	63110 (0+2%)	28500 (±50)	3766 (±2)	2923 (±2)
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HC	TX05C2017		GP123045				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HD	TX05C2018	SX05C0002	GP117890				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2019		GP123045				
	G8X T 128 AGUJEROS 60Hz 120V + G97	TX06C2015	SX06C0203	GP117203				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HC	TX06C2017		GP123378				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HD	TX06C2018		GP116659				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2019		GP123378				
	TOWER G9X 50HZ -30ºC>>+45 03	T09X05C03	SX05C0002	GP117890				
	TOWER G9X 60HZ -30ºC>>+45	T09X06C05	SX06C0203	GP117203				
	TOWER G9X 60HZ -30ºC>>+45	TX06C2017	SX06C0015	GP123388				
90M	G8X T 148 AGUJEROS 50Hz 230V + G97	TX05C2016	SX05C0008	GP120977	51560 (0+2%)	15610 (±50)	3997 (±2)	3766 (±2)
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC	TX05C2020		GP123464				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HD	TX05C2021		GP120967				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2022		GP123464				
	G8X T 148 AGUJEROS 60Hz 120V + G97	TX06C2016	SX06C0002	GP117017				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC	TX06C2020		GP123528				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HD	TX06C2021		GP116653				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2022		GP123528				

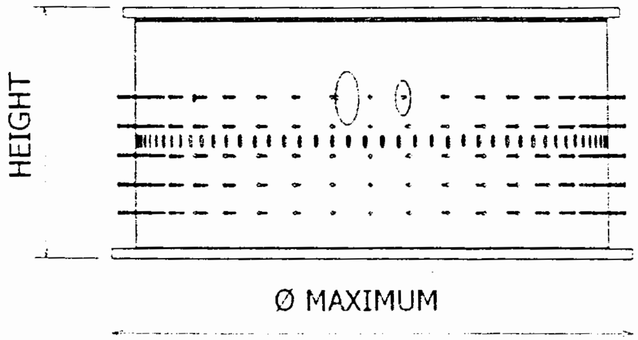
SECTION 3								
HEIGHT	**WIND CLASS**	**TOWER**	**SECTION**	**ASSEMBLY CODE**	**W (Kg)**	**L (mm)**	**Ø LOW.**	**Ø UPP.**
	G8X T 128 AGUJEROS 50Hz 230V + G97	TX05C2015	SX05C0003	GP117891				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HC	TX05C2017		GP123052				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HD	TX05C2018	SX05C0003	GP117891				
	G8X T 128 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2019		GP123052				
	G8X T 128 AGUJEROS 60Hz 120V + G97	TX06C2015	SX06C0304	GP117205				
78.3M	G8X T 128 AGUJEROS 60Hz 120V + G97 + HC	TX06C2017		GP123381	39790 (0+2%)	28500 (±50)	2923 (±2)	2322 (±2)
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HD	TX06C2018		GP116675				
	G8X T 128 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2019		GP123381				
	TOWER G9X 50HZ -30ºC>>+45 03	T09X05C03	SX05C0003	GP117891				
	TOWER G9X 60HZ -30ºC>>+45	T09X06C05	S09X06C02	GP191412				
	TOWER G9X 60HZ -30ºC>>+45	TX06C2017	SX06C0016	GP123389				
	G8X T 148 AGUJEROS 50Hz 230V + G97	TX05C2016	SX05C0007	GP117890				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC	TX05C2020		GP123045				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HD	TX05C2021		GP117876				
90M	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2022		GP123045	63110 (0+2%)	28500 (±50)	3766 (±2)	2923 (±2)
	G8X T 148 AGUJEROS 60Hz 120V + G97	TX06C2016	SX06C0203	GP117203				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC	TX06C2020		GP123378				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HD	TX06C2021		GP116659				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2022		GP123378				

SECTION 4								
HEIGHT	**WIND CLASS**	**TOWER**	**SECTION**	**ASSEMBLY CODE**	**W (Kg)**	**L (mm)**	**Ø LOW.**	**Ø UPP.**
	G8X T 148 AGUJEROS 50Hz 230V + G97	TX05C2016	SX05C0003	GP117891				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC	TX05C2020		GP123052				
	G8X T 148 AGUJEROS 50Hz 230V + G97 + HD	TX05C2021		GP117877				
90M	G8X T 148 AGUJEROS 50Hz 230V + G97 + HC+HD	TX05C2022		GP123052	39790 (0+2%)	28500 (±50)	2923 (±2)	2322 (±2)
	G8X T 148 AGUJEROS 60Hz 120V + G97	TX06C2016	SX06C0304	GP117205				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC	TX06C2020		GP123381				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HD	TX06C2021		GP116675				
	G8X T 148 AGUJEROS 60Hz 120V + G97 + HC+HD	TX06C2022		GP123381				

*NOTES: These dimensions are without transportation toolkits. These increase 400mm the length (per toolkit) and 70mm in height.

Reference document: GD065413 R1

3.13 CIMENTACIONES G9X

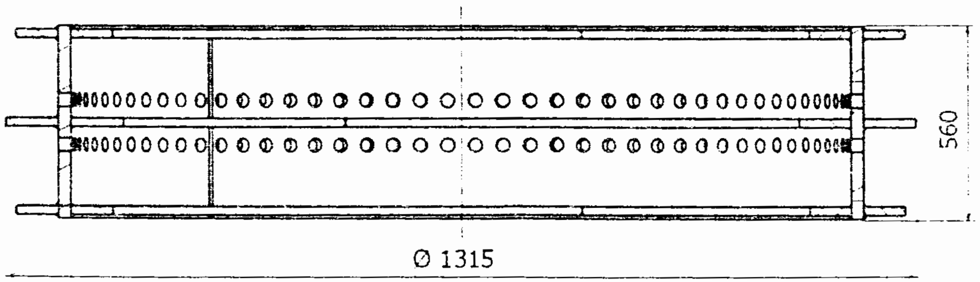


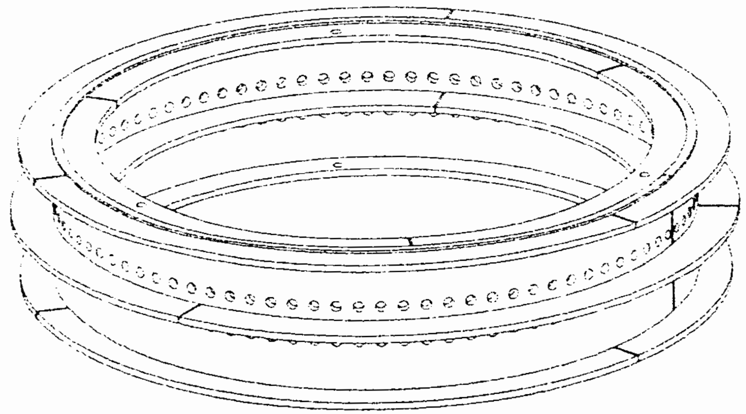
IF CODE	CODE	WEIGHT	DIMENSIONS	
			Ø MAX	HIGH
IF00S0014	GP111396	12721	4175	2125
IF00S0016	GP111401	17802	4500	2385
IF00S0052	GP105936	12106	4190	2115
IF00D0086	GP084256	12175	4450	2145
IF00S0085	GP084252	14744	4450	2025

* NOTE 1: The bolts never protrudes of inferior flange. Inferior flange have the maximum diameter.

Reference documents: GP111401, GP111396.

3.14 ANCHORAGE RING





DIMENSIONS: 1315 x 1315 x 560 mm
WEIGHT: 2183 Kg

REFERENCE DOCUMENT: GP017448

GL

Certification Report No.: IB0800/11
Measurement of power curve on a Gamesa G97-2.0 MW
at P.E. Las Balsas – Sierra de Alaiz I+D

Wind Turbine:

Type: .... G97-2.0 MW, 50 Hz
Manufacturer: .... Gamesa
Hub height (including foundation): .... 78 m
Rated power: .... 2000 kW
Rated wind speed: .... 10.5 m/s

Order number: 622 11 0381 252
Rotor diameter: .... 97 m
Rotor speed range: .... 9.831-17.790 rpm
Generator speed range: ...... 1680/1050-1900 rpm
Blade angle: .... Variable

Measurements:

The measurements were carried out according to IEC 61400-12-1 "Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines".

Deviations or restriction to IEC 61400-12-1:

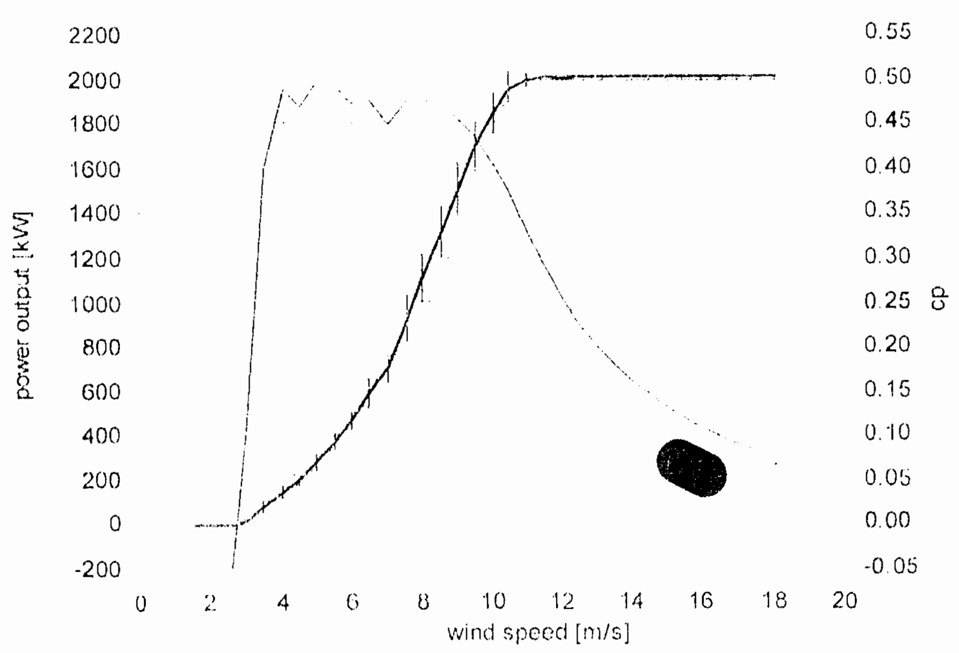
- The provision of the sensors in the meteorological mast has not been done by WINTEST but by accredited laboratory CENER.
- The site calibration was not performed by WINDTEST but by accredited laboratory CENER (report: 821.45078SCR).
- Following facts have not been measured by WINDTEST but delivered by the manufacturer: the swept area of the rotor, the hub height, the serial number of the turbine.
- The electric grid conditions are not documented in the final report.

Scope of measurements:

- period: 2011-10-18 to 2011-12-22, site calibration: 2009-12-30 to 2010-06-02.
- evaluated wind direction sector: [325° - 25°].
- wind speed measurements were carried out with an anemometer at hub height (78.6 m).
- accuracy of anemometer calibration: ±0.1 m/s (Vector-A100LK-PC3).
- wind speed normalised to reference air density ρ = 1.225 kg/m^3 (accuracy: ±0.25%).
- accuracy of the power transducers: ±0.5% related to a range of 3585.35 kW.

The complete procedure is documented in the report no. IB0788/11.

Power curve according to IEC: Gamesa G97-2.0 MW
Reference air density ρ_{air} =1.225 kg/m^3



MEASURED POWER CURVE: Gamesa G97-2.0 MW

Reference air density: 1.225 kg/m³
Cut-out wind speed: 25 m/s

Bin no.	Wind speed at hub height [m/s]	Power output [kW]	Cp [ ]	Nr. of datasets (10 min. avg.)	Category A Standard uncertainty [kW]	Category B Standard uncertainty [kW]	Combined uncertainty Standard uncertainty [kW]
3	1.55	-4.2	-0.247	4	0.9	10.4	10.4
4	1.98	-6.3	-0.178	6	2.0	10.4	10.6
5	2.57	-5.6	-0.073	18	2.5	10.4	10.6
6	3.02	12.8	0.102	30	5.1	12.8	13.8
7	3.48	76.3	0.400	44	7.2	28.5	29.4
8	4.01	142.7	0.489	65	5.6	27.2	27.8
9	4.52	195.5	0.469	54	7.6	24.0	25.2
10	5.00	282.4	0.498	63	8.1	40.1	40.9
11	5.50	370.0	0.491	67	7.7	40.9	41.7
12	6.01	464.8	0.473	48	9.9	45.0	46.1
13	6.50	592.7	0.476	46	15.0	63.5	65.2
14	7.01	699.2	0.449	44	19.4	54.3	57.7
15	7.54	925.4	0.476	49	17.6	110.3	111.7
16	8.01	1108.0	0.476	73	16.7	105.6	106.9
17	8.52	1311.9	0.469	66	26.3	112.4	115.4
18	9.00	1502.7	0.455	58	23.1	114.2	116.5
19	9.51	1691.7	0.435	79	17.3	111.6	112.9
20	10.03	1842.7	0.404	87	15.8	89.5	90.9
21	10.47	1951.5	0.375	48	10.5	78.1	78.8
22	11.00	1990.3	0.331	64	3.7	27.0	27.3
23	11.50	2003.1	0.291	52	0.6	14.8	14.8
24	12.02	2000.2	0.254	48	1.6	12.4	12.5
25	12.46	2003.9	0.229	47	0.3	12.6	12.6
26	12.98	2004.3	0.202	51	0.1	12.3	12.3
27	13.49	2004.4	0.180	37	0.1	12.3	12.3
28	14.02	2004.5	0.161	27	0.1	12.3	12.3
29	14.46	2004.7	0.147	16	0.1	12.3	12.3
30	14.96	2004.7	0.132	15	0.1	12.3	12.3
31	15.42	2003.9	0.121	8	0.6	12.3	12.3
32	15.96	2004.3	0.109	18	0.1	12.3	12.3
33	16.49	2004.2	0.099	15	0.2	12.3	12.3
34	17.01	2004.0	0.090	10	0.3	12.3	12.3
35	17.39	2004.0	0.084	9	0.3	12.3	12.3
36	17.99	2004.3	0.076	4	0.3	12.3	12.3

ESTIMATED ANNUAL ENERGY PRODUCTION (AEP)

Extrapolation of power curve between the highest measured wind speed and the cut-out wind speed considering the same power output as the measured at the highest measured wind speed

WT type: Gamesa G97-2.0 MW
Cut-out wind speed: 25 m/s
Reference air density: 1.225 kg/m³

Annual average wind speed at hub height (Rayleigh) [m/s]	AEP-measured (measured power curve) [MWh]	Uncertainty of measured power in terms of standard deviation of AEP [MWh]	[%]	AEP-extrapolated (extrapolated power curve) [MWh]
4.0	2139.6	266.4	12.5	2139.6
5.0	3861.5	358.0	9.3	3862.2
6.0	5689.8	412.4	7.2	5705.3
7.0	7330.4	430.0	5.9	7427.4
8.0	8599.0	422.9	4.9	8921.0
9.0	9431.3*	402.1	4.3	10150.4
10.0	9856.8*	374.9	3.8	11107.5
11.0	9953.5*	345.6	3.5	11795.9

Values marked with *: data base for AEP incomplete according to IEC criteria

This report is only valid in conjunction with the manufacturer certificate from 2011-12-13

WINDTEST Ibérica S.L.
C/ Valentín Beato 42,2º
E-28037 Madrid

date: 2011-12-22
responsible: Fernando Delgado
tel.: 0034 91 375 75 85
fax.: 0034 91 375 75 78

Ing.Ind. A. Ferreras

p.o. Ing. Ind. F. Delgado

Approval process:	Electronic: PDM Flow + Translation
Author:	MDANDRES
Revised:	BAJ
Approved:	CDC

Title:

Characteristics and general description of the Gamesa 2.0 MW wind turbine platform

SCOPE

Wind turbines of the **Gamesa-2.0 MW platform**, models:

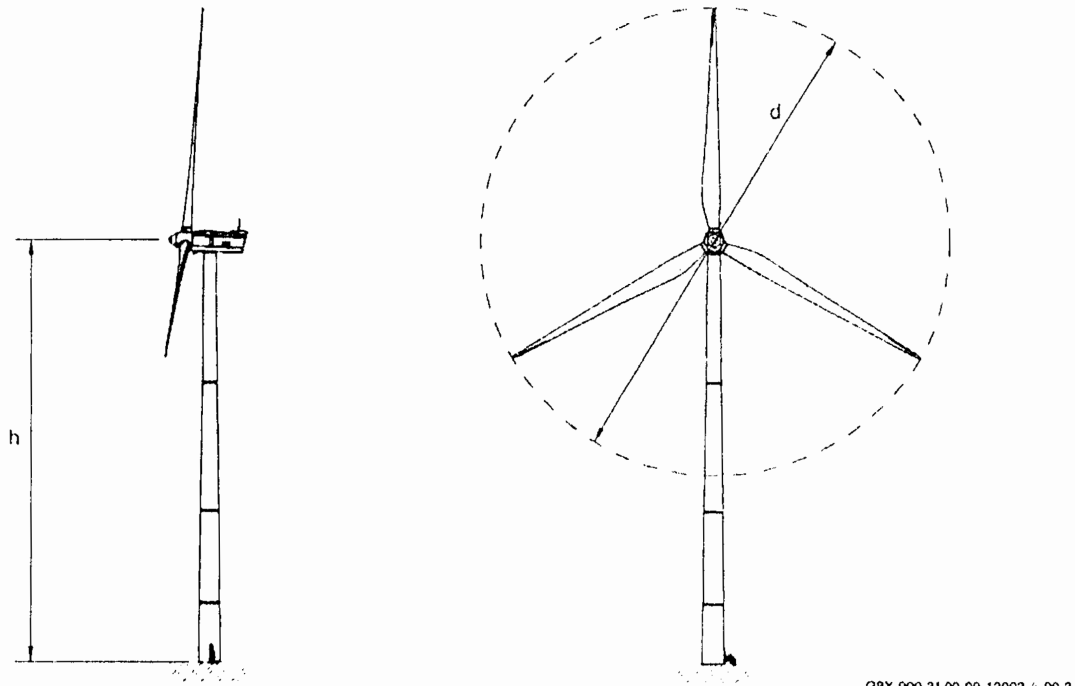
- **G80-2.0 MW**
- **G87-2.0 MW**
- **G90-2.0 MW**

RECORD OF CHANGES

Rev.	Date	Author	Description
0	15/04/2005	DGF/JRI/ALG	Initial version
1	26/07/2005	JMO/JAL/ACP/JME	Update of data
2	15/03/2006	JOL	Change of format/Inclusion of OPTIONS chapter
3	23/05/2007	MME/JMS	Modification of blade description. Points 1.2.1 Blades and 6.2 Blades. Format changed to Monolingual, modification of sections 3.1, 2, 4 and 6.18.
4	24/07/2008	MBU	Format updated. Section on power curves deleted. General document review.
5	12/01/2010	PCUENCA	References to G83 deleted. WINDNET updated. Inclusion of 35 kV transformer. HT and LT versions deleted. General document review.
6	12/07/2010	MDANDRES	Certificates for G90 class II updated. Update of template and figures and general document revision.
7	27/08/2010	MDANDRES	Modification of point 2.1: Grid connection. Modification of point 5.11: Generator (rated power). General document review.
8	19/04/2011	MDANDRES	General document review.
9	15/05/2012	MDANDRES	Change of name in Gamesa products.
10	20/08/2012	MDANDRES	Modificaction of point 2.1: Grid connection
11	11/07/2013	MDANDRES	Modificaction of point 5.17: Approximate weights

INDEX

1 DESCRIPTION OF GAMESA-2.0 MW WIND TURBINES (MODELS G80-2.0 MW, G87-2.0 MW AND G90-2.0 MW)



Position	Name
h	Hub height
d	Rotor diameter

Figure 1: Complete wind turbine

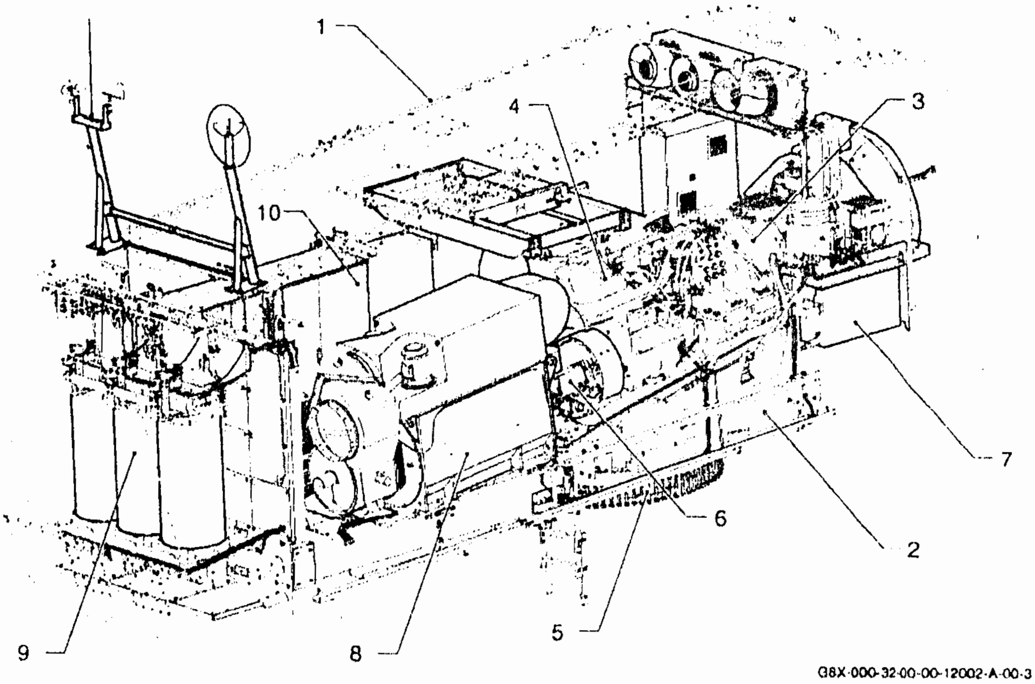
Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are of the three-bladed wind-facing rotor type and produce a rated power of 2 MW.

The platform consists of 3 wind turbine models with rotor diameters of 80n 87n and 90m (Position **d** in Figure 1) and hub heights of 60m, 67m, 78m and 100m (Position **h** in Figure 1), with the remaining mechanical, electrical and control components being common to all models. The various models are designed to operate in different wind conditions.

The platform's wind turbines are regulated by an independent pitch control system in each blade and have an active yaw system. The control system allows the wind turbine to be operated at variable speed, maximizing the power produced at all times and minimizing the loads and noise.

A general description is given below of the main components of the **Gamesa 2.0 MW** platform wind turbines (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**).

1.1 NACELLE DESCRIPTION



Position	Name
1	Cover
2	Frame
3	Main shaft
4	Gearbox
5	Yaw system
6	Mechanical brake
7	Hydraulic unit
8	Generator
9	Transformer
10	Electrical cabinets

Figure 2: Main components of the nacelle

1.1.1 Cover

The cover protects the wind turbine components within the nacelle from exposure to meteorological events and external environmental conditions. It is made of composite resin and reinforced with fiberglass.

Within the cover there is sufficient space in order to carry out wind turbine maintenance operations. The cover has three hatchways:

- Hatchway giving access to the nacelle from the tower, located on the nacelle floor.
- Hatchway giving access to the interior of the cone/hub, located in the front.
- Crane operating hatchway, located on the floor of the rear section.

There are two skylights on the roof allowing sunlight to enter during the day and providing additional ventilation and access to the exterior, where the wind measuring instruments and the lightning rod are located.

The revolving parts are duly protected to guarantee the safety of maintenance personnel.

The nacelle is equipped with an 800 kg service crane inside.

1.1.2 Frame

The frame of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) has been designed using the criteria of mechanical simplicity along with the appropriate robustness to be able to support the elements of the nacelle and transmit the loads to the tower. These loads are transmitted via the yaw system bearing.

The frame is divided into two parts:

- Front frame: cast iron bedplate to which the main shaft supports are fastened, where the gearbox torque arms and the yaw ring react.
- Rear frame: mechanically-welded structure formed by two beams joined at the front and the back.

The frame is subjected to exhaustive ageing tests at the frame test bench, Gamesa UPB, belonging to Gamesa. These tests mainly involve extreme load and fatigue cycles which reproduce, in an accelerated manner, the stresses and forces to which the frame will be subjected throughout its lifetime. This guarantees and improves the reliability of the component, validating its correct design. In addition, the test results are used for feedback and to correlate the simulation models of the frames developed by Gamesa, guaranteeing continuous improvement and greater precision of the designs.

1.1.3 Main shaft

The motor torque produced by the wind on the rotor is transmitted to the gearbox through the main shaft. The shaft is attached to the hub with a screwed-on flange and is supported on 2 bearings housed in cast-iron supports. The connection to the low speed input on the gearbox is made with a conical tightening collar that transmits the torque by friction.

The shaft is made from forged steel and has a longitudinal central opening to house the hydraulic hoses and control cables for the pitch control system.

The support of the main shaft on 2 bearings offers significant structural advantages. All the stress from the rotor is transmitted to the front frame, except for the torque, which is used downstream in the generator to produce electric power. This guarantees that the gearbox only transmits this torque and that the bending, axial and shear stress goes directly to the bed plate. In addition, the system makes maintenance easier, as the gearbox can be removed without having to dismount the main shaft or the rotor.

1.1.4 Gearbox

This transmits the main shaft's power to the generator. The gearbox consists of 3 combined stages, a planetary gear and two parallel shaft gears. The gearbox's cogs are designed for maximum efficiency and low noise and vibration levels. As a result of the gear ratio, part of the input torque is absorbed by the reaction arms. These reaction arms fix the gearbox to the frame by means of shock absorbers which minimize vibration transmission. The high-speed shaft is linked to the generator via a flexible coupling with torque limiter that prevents excess loads to the transmission chain.

Due to the modular design of the drive train, the gearbox weight is supported by the main shaft, while the gear tie rods react only to the torque, preventing the gearbox from rotating and ensuring the absence of unwanted loads.

The gearbox has a main lubrication system with a filtering system associated with the high-speed shaft. There is a secondary electrical filter which permits the cleaning of the oil to 3 μm, thus reducing the potential number of breakdowns, together with a third extra cooling circuit.

The gearbox's various components and operating parameters are monitored by different sensors, of both the control system and the **Gamesa PMS** predictive maintenance system.

All the gearboxes are subjected to load tests at rated power during their manufacture. These tests reduce the probabilities of failure during operation and guarantee product quality.

1.1.5 Gamesa Active Yaw system

The **Gamesa Active Yaw** system enables the nacelle to rotate around the axis of the tower. This is an active system and has four yaw gears electrically operated by the wind turbine control system according to the information received from the anemometers and wind vanes mounted on the upper section of the nacelle. The yaw system motors turn the gears of the yaw system, which engage with the cogs of the yaw ring mounted in the upper part of the tower, producing the relative rotation between the nacelle and the tower.

A friction bearing is used to obtain an adequate retention torque in order to control yaw rotation. In addition, the hydraulic brake, consisting of 5 active clamps, provides a greater retention torque to fix the wind turbine. The combined action of these 2 systems prevents fatigue and possible damage to the gears, thus ensuring stable and controlled yaw.

The ring is divided into 6 sectors to make it easier to repair possible damage to the teeth.

As with the frame, the **Gamesa Active Yaw** system is subjected to accelerated life cycle and ageing tests at the **Gamesa UPB** test bench. These tests consist mainly in orientation cycles with operating loads compressing the length of the durability or ageing tests in order to simulate the yaw system's service life. These tests guarantee and improve the reliability of the component, validating its correct design and providing feedback to the virtual models for subsequent redesign and improvements.

1.1.6 Brake system

The wind turbine primary brake is aerodynamic through the full-feathering blades. As the pitch control system is independent for each of the blades, it has a safety system with triple redundancy.

The mechanical brake consists of a hydraulically activated disc brake, which is mounted on the high-speed shaft of the gearbox. This mechanical brake is only used as a parking brake or if the emergency button is applied.

1.1.7 Hydraulic system

The hydraulic system supplies pressurized oil to the 3 independent pitch control actuators, the high-speed shaft mechanical brake and the yaw system brake system. It includes a *fail-safe* system which guarantees the required oil pressure and flow levels in the event of absence of current to activate the blade pitch control cylinders, the disc brake and the yaw system brake, switching the wind turbine to safe mode.

1.1.8 Generator

The generator is an asynchronous double-feed unit with 4 poles, coil rotor and slip rings. It is highly efficient and is cooled by an air-air exchanger. The control system permits operation at variable speeds using the rotor intensity frequency control.

The characteristics and functions introduced by this generator are:

- Synchronous behavior toward the grid.
- Optimal operation at any wind speed, maximizing production and minimizing loads and noise, thanks to variable speed operation.
- Control of active and reactive power via control of amplitude and rotor current phase.
- Smooth connection and disconnection from the electrical grid.

The generator is protected against short-circuits and overloads. The temperature is monitored continuously via probes at points on the stator, bearings and the slip ring box.

1.1.9 Transformer

The transformer is three-phase, dry encapsulated, with different output voltage options between 6.6 kV and 35 kV, different apparent power ranges and is particularly designed for wind energy applications. It is located in the rear section of the nacelle in a compartment separated by a metal wall which provides thermal and electrical insulation from the rest of the nacelle components.

As it is a dry type unit, the risk of fire is minimized. In addition, the transformer includes all the necessary protections against damage, including arc detectors and protection fuses.

The transformer's location in the nacelle prevents electrical losses thanks to the reduced length of the low-voltage cables, and also reduces visual impact.

1.1.10 Electrical cabinets for control and power

The electrical system's hardware is distributed into three cabinets:

1. **TOP** electrical cabinet located in the nacelle. In turn, this electrical cabinet is divided into three parts:
    - Control section: responsible for governing the nacelle, e.g., monitoring wind, changing pitch angle, yaw, interior temperature control, etc.
    - Frequency converter: this is responsible for controlling the power and managing the connection and disconnection of the generator to/from the grid.
    - Protections and busbar section: the output of the power produced, with the necessary electrical safeguards, is located here.

2. **GROUND** electrical cabinet located at the tower's base. From the GROUND electrical cabinet's touch screen it is possible to check the wind turbine's operating parameters, stop and start the wind turbine, test the various subsystems, etc. A touch screen can also be connected to the TOP electrical cabinet in order to perform these tasks.

3. **HUB** electrical cabinet located in the revolving part of the wind turbine. Primarily responsible for activating the pitch control system cylinders.

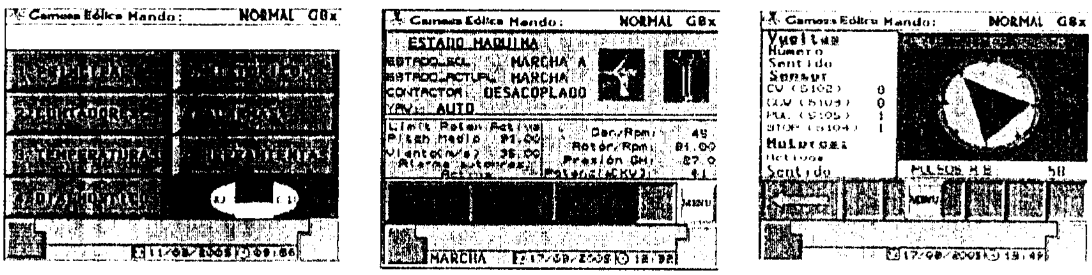
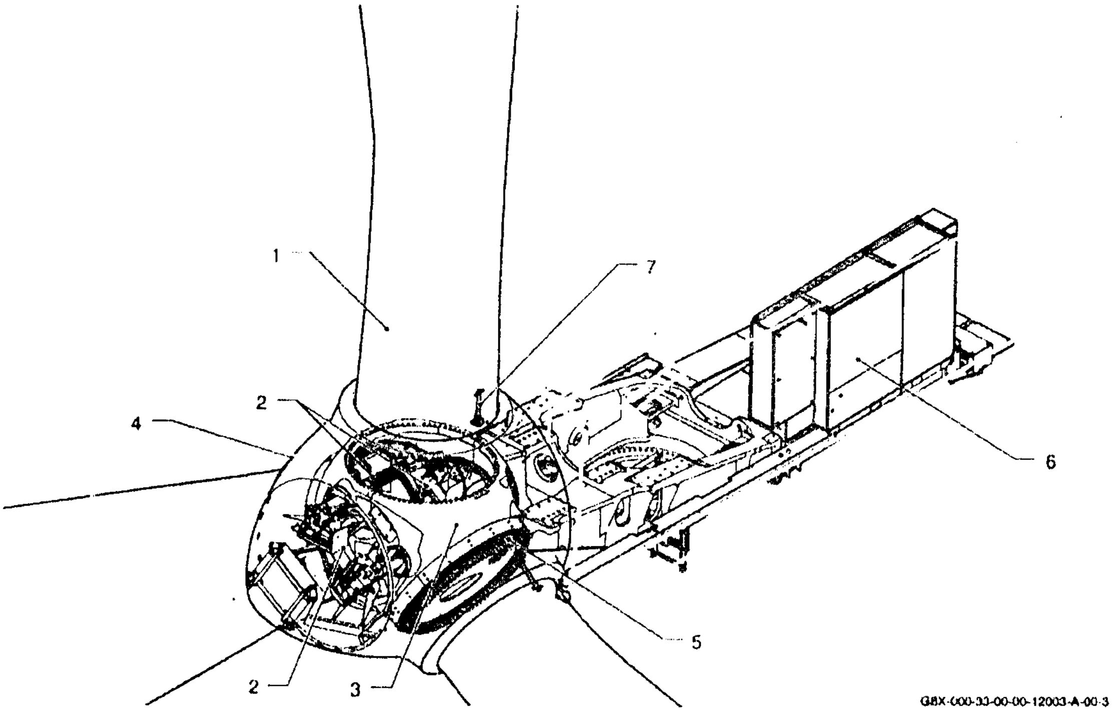


Figure 3: Examples of touch screen

1.2 ROTOR

The rotor of the **Gamesa-2.0 MW** platform wind turbines (models **G80-2.0 MW, G87-2.0 MW** and **G90-2.0 MW**) consists of three blades joined to a hub by blade bearings. The hub has a conical angle of 2° in the flanges attaching it to the blades, which keeps the tips of the blades away from the tower.

The rotor diameters of the different models in the platform are 80m, 87m and 90m.



Position	Name
1	Blade
2	Pitch control system
3	Hub
4	Cone
5	Blade bearing
6	Electrical cabinet
7	Lightning transmission system

Figure 4: Complete wind turbine

1.2.1 Blades

The wind turbine blades of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW, G87-2.0 MW** and **G90-2.0 MW**) are manufactured in an organic matrix composite material and reinforced with fiberglass or carbon fiber, which provides the necessary stiffness without increasing blade weight. Different blade models are available, manufactured solely with fiberglass or carbon fiber, or a combination of both.

The blades have pitch control along the whole length of the blade, thus maximizing energy production and reducing loads and noise emissions.

Blade lengths are 39m (**G80-2.0 MW**), 42.5m (**G87-2.0 MW**) and 44m (**G90-2.0 MW**). The distance from the blade root to the hub center is 1m in all cases.

The structure of each blade consists of two shells attached to a structural beam or internal rails. The blade is designed to fulfill two basic functions: structural and aerodynamic.

In addition, the blade is designed taking into account both the manufacturing method used and the materials chosen, in order to ensure the necessary safety margins.

The blades have a protection system against lightning which serves to conduct the ray from the receptor to the blade root where it is transmitted to the turbine to be discharged into the ground.

Additionally, the blades come with the necessary drains to prevent internal water retention, which can cause imbalance or structural damage due to water vaporization upon the impact of lightning.

1.2.2 Blade bearing

The blade bearings are the interface between the blade and the hub and permit the pitch control movement.

The blade is attached to the inner race of the blade bearing by tensioned bolts to facilitate inspection and removal.

1.2.3 Hub

The hub is manufactured in nodular cast iron. It is attached to the outer race of the three blade bearings and to the main shaft with bolted joints. It has an opening at the front to permit access to the interior for inspection and maintenance of the pitch control system's hydraulics and the tightening torque of the blades' bolts.

1.2.4 Cone

The cone protects the hub and the blade bearings from the atmosphere. The cone is bolted to the front of the hub and is designed to allow access to the hub for maintenance tasks.

1.2.5 Pitch control hydraulic system

This consists of independent hydraulic actuators for each blade that provide a rotation capacity of between –5° and 87° and a system of accumulators which ensure feathering in the event of an emergency.

The pitch control system acts according to the following setting:

- When the wind speed in less than rated, a pitch angle is selected that maximizes the electrical power obtained for each wind speed.
- When the wind speed is higher than nominal, the pitch angle is the one that provides the turbine's rated power.

In addition, it controls the activation of the aerodynamic brake in the event of an emergency, switching the wind turbine to a safe mode.

The hydraulic system acts more quickly than other systems. Due to the hydraulic accumulator system, it does not require batteries to operate, thus increasing its reliability in an emergency.

1.3 TOWER AND FOUNDATION

1.3.1 Tower

The wind turbine tower is made of tubular steel, in a truncated conical shape, divided into three, four or five sections, depending on the tower height. It is supplied with the corresponding platforms, ladders and emergency lighting.

Gamesa offers a cable guided elevator as standard to make maintenance of the wind turbine easier.

Gamesa offers a seismic tower of 78m and four sections for special sites.

1.3.2 Foundation

The standard foundations are of the slab type, made of concrete reinforced with steel. They have been designed using calculations based on the certified loads of the wind turbine and considering standard ground.

Where the hypothetical values used vary, the established standard values are useless and the foundations must be recalculated. Therefore, for each site, the ground characteristics and wind data should be reviewed in order to ensure that the most suitable foundation is selected.

1.4 CONTROL SYSTEM

The wind turbine functions are controlled in real time by a PLC-based system (Programable Logic Controller). The control system is made up of control and monitoring algorithms.

A) <u>Control system</u>

The control system selects the correct values for the rotor rotation, the blade pitch angle and the power settings. These are modified at all times depending on the wind speed reaching the turbine, thus guaranteeing safe and reliable operating in all wind conditions.

The main advantages of the wind turbine control system for the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are:

1. Maximization of energy production
2. Limitation of mechanical loads
3. Aerodynamic noise reduction
4. High energy quality

A-1) <u>Pitch control adjustment</u>

At wind speeds above the nominal speed, the control system and pitch control system keep the power at its rated value. At wind speeds below the rated speed, the variable pitch control system and the control system optimize energy production by selecting the optimum combination of rotor rotation speed and pitch angle.

A-2) <u>Power control</u>

The power control system ensures that the wind turbine's rotation speed and motor torque always supply stable electric power to the grid.

The power control system acts on a set of electrical systems consisting of a doubly-fed generator with wound rotor and slip rings, a 4-quadrant IGBT-based converter, contactors and electrical safeguards and software. Electrically, the generator-converter unit is equivalent to a synchronous generator and therefore it ensures optimum coupling to the electrical grid with smooth connection and disconnection processes.

The generator-converter unit is capable of working at variable speeds to optimize operation and to maximize the power generated for each wind speed. In addition, it makes it possible to manage the reactive power evacuated in collaboration with the **Gamesa Windnet®** remote control system.

B) Monitoring system

The monitoring system continuously checks the state of the different sensors and internal parameters:

- Environmental conditions: wind speed and direction or ambient temperature.
- Internal parameters of the various components, such as temperatures, oil levels and pressures, vibrations, mid-voltage cable winding, etc.
- Rotor state: rotation speed and pitch control position.
- Grid situation: active and reactive energy generation, voltage, currents and frequency.

1.5 GAMESA PMS PREDICTIVE MAINTENANCE SYSTEM

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) include the **Gamesa PMS** predictive maintenance system developed by Gamesa, based on the analysis of vibrations and optimized for use in wind turbines. The system can simultaneously manage and process the information from up to 8 accelerometers, which are located at strategic points on the turbine, such as the gearbox, the generator and the main shaft's front bearings.

The main characteristics of the **Gamesa PMS** are as follows:

- Continuous monitoring of the wind turbine's critical components
- Signal processing and alarm detection capability
- Integrated with the PLC and **Gamesa WindNet®** wind farm grids
- Easy maintenance
- Low cost

In general, the main purpose of a predictive maintenance system is the early detection of faults or wear in the main components of the wind turbine. The following are some of the important benefits of installing a system of this type:

- Reduction in major corrective actions required
- Protection of other wind turbine components
- Improvements in the wind turbine's useful life and operation
- Reduction in dedicated maintenance resources
- Access to markets with strict regulations, such as the *Germanischer Lloyds* certification
- Reduction in insurance company rates

1.6 GAMESA WINDNET® INTEGRATED MANAGEMENT SYSTEM FOR WIND FARMS

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) integrate into the **Gamesa WindNet® supervisory, control and data acquisition system (SCADA)**, which allows the wind farm information to be accessed easily and intuitively through a browser.

The **Gamesa WindNet®** system is easy to configure and adapt to any wind farm layout, including those with a wide variety of wind turbine models. It can quickly and reliably link up any wind farm topology based on Ethernet network technology. It can also integrate wind farm installations such as electrical substations, reactive power equipment, capacitor banks, etc.

The **Gamesa WindNet®** system supports a wide variety of communications protocols used in wind farm systems, such as OPC DA, MODBUS and DNP3. Communication with Gamesa wind turbines is based on a robust and efficient proprietary protocol.

With this tool, the user can perform the following tasks at any time:

- Track and monitor the wind farm's equipment.
- Be informed about the energy production of each wind turbine in the wind farm.
- Monitor the alarms for the different elements of the wind farm in real time and display the alarm log.
- Send direct orders to the wind turbines (start, pause or switch to emergency mode) and substation.
- Analyze the evolution of variables over time in a simple manner, thanks to the trend history graphs: **Gamesa Trend Viewer**.
- Create production and availability reports: **Gamesa Report Generator**.
- Send status messages and alarms to a cell phone using SMS text messaging.
- Integrate the reactive power compensation equipment (STATCOM and SVC).
- Manage predictive maintenance with the integration of **Gamesa PMS**.
- Manage different user profiles, thus maintaining security and simplifying at the same time the application's daily use.

The user interface has been designed using accessibility, user-friendly and simplicity criteria. The information is displayed in graph form. There is also Web access to up-to-date information through any device with a browser and Internet connection.

The **Gamesa WindNet®** system offers different user, administrator, configuration, developer and maintenance profiles for access to the specific functions and information required for each user type, thus increasing security and simplifying the daily use of the application.

Optionally, a series of modules are available to add advanced functions to the **Gamesa WindNet®** system:

- Active power limitation module.
- Generated reactive power control module.
- Frequency regulation module.
- Generation of customized reports with **Gamesa Information Manager**, through the categorization of energy losses.
- Wake control module.
- Noise control module: **Gamesa NRS®**.
- Shade control module.
- Ice control module.

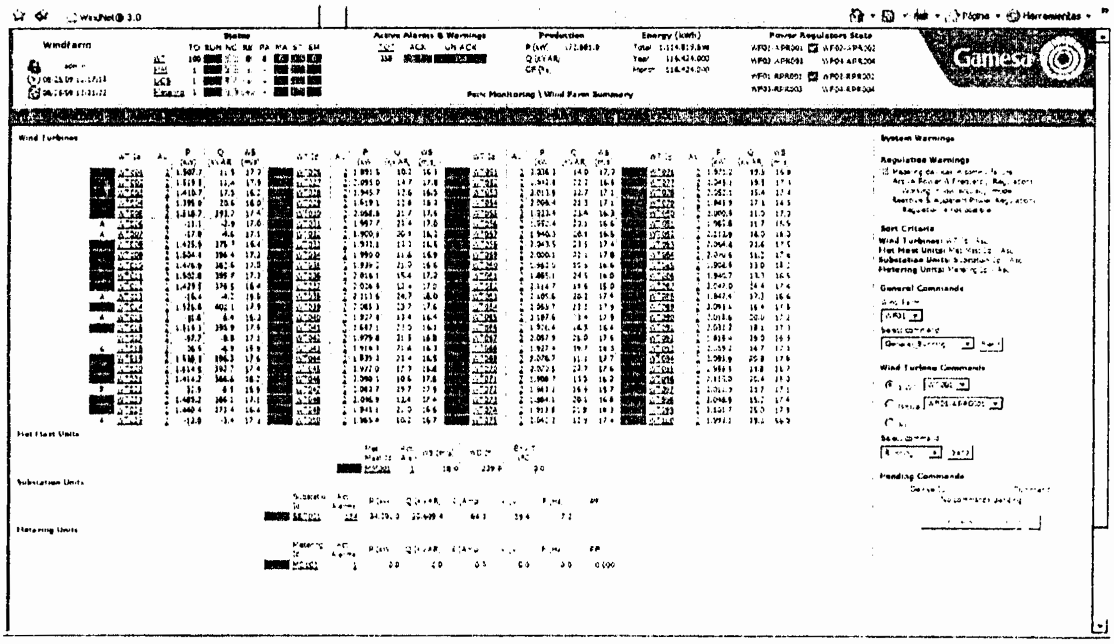


Figure 5: Example of a WindNet® screen accessed via the Web

1.7 SENSORS

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW, G87-2.0 MW** and **G90-2.0 MW**) are equipped with several sensors that continuously monitor different parameters. It has sensors that capture signals external to the wind turbine, for example, the outside temperature or the wind speed and direction. Other sensors record turbine operating parameters such as component temperatures, pressure levels, vibrations or blade position.

All of this information is recorded and analyzed in real time and fed into the monitoring and control functions of the control system.

1.8 LIGHTNING PROTECTION SYSTEM

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW, G87-2.0 MW** and **G90-2.0 MW**) are protected against lightning by a transmission system that runs from the blade and nacelle receptors through the cover, frame and tower to the foundation. This system prevents the passage of lightning through components which are sensitive to these discharges. The electrical system also has additional overvoltage protection.

All these protection systems are designed to obtain a maximum protection level Class I in accordance with standard IEC 62305. IEC 61400-24 and IEC61024 are considered reference standards.

2 GRID CONNECTION AND SITE

2.1 GRID CONNECTION

All models of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are available in versions capable of operating in 50Hz and 60Hz grids.

The wind turbine's transformer must be suitable for the grid's voltage. The voltage of the low-voltage grid must lie within the ± 10% range and the grid frequency must lie within the ± 3 Hz range in both 50 Hz and 60 Hz grids.

The grounding system included in the civil engineering project has two concentric rings with a global impedance according to the requirements established in IEC 62305. The pass-through and contact currents must comply with standards IEC 60478-1 and IEC 61936-1. Local regulations shall take precedence where these are more restrictive than the above international standards.

The grid voltage specified for **Gamesa-2.0 MW** wind turbines (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) is defined in section 4.6 of this document.

The power factor of all **Gamesa-2.0MW** models is between 0.95 capacitive and 0.95 inductive in the entire power range under the following conditions: ± 5% rated voltage for the corresponding temperature interval, as long as the transformer's apparent power is greater than 2,350 kVA. See special conditions for other transformer models.

2.2 ENVIRONMENTAL CONDITIONS

Standard version wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are designed to operate at external ambient temperatures between -20°C and +30°C. Turbine versions exist capable of withstanding more extreme ambient temperatures.

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are capable of operating continuously at ambient relative humidity of 95%, and are also capable of operating in conditions of 100% relative humidity for periods under 10% of operating time.

The degree of anti-corrosion protection of the various components of **Gamesa-2.0 MW** wind turbines (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) is, in accordance with standard ISO 12944-2, shown in the following table:

COMPONENTS	EXTERNAL	INTERIOR
Tower	C5-I/H	C3/H
Nacelle-Rotor	C4/H or C5/H [1]	C2/H or C3/H [1]

Table 1. Degrees of protection against corrosion

[1] According to components.

Gamesa has product versions designed specially for corrosive environments.

2.3 WIND CONDITIONS

The annual wind distribution for a site is normally specified by a *Weibull* distribution. This distribution is described by the scale factor A and the form factor k. The A factor is proportional to the average wind speed, and the k factor defines the form of the distribution for different wind speeds. Turbulence intensity is the parameter that quantifies the instant variations in wind speed.

The design conditions of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW, G87-2.0 MW** and **G90-2.0 MW**) according to these parameters are indicated below:

Standard	**IEC**			**DIBt**						
Class	**IA**	**IIA**	**IIIA**	**WZ II**				**WZ III**		
Hub height (m)				60	67	78	100	60	67	78
Average annual wind speed (m/s) [1]	10	8.5	7.5	5.9	6/6.7	6.2/6.9	6.4/7.2	8.3	8.4	8.6
Turbulence intensity I_{15} (%)	16			20	20/ 18/ 18			20		
Reference 10-minute wind speed in 50 years (m/s)	50	42.5	37.5	36.8	37.4	38.3	39.9	42.6	43.4	44.5
Extreme wind speed in 50 years over a 3-second average (m/s) [2]	70	59.5	52.5	48.2	48.8	49.6	51	55.8	56.5	57.4
Weibull Factor (K)	[2]									

Table 2. Design parameters. All speeds are referred to at hub height

[1] G87-2.0 MW and G90-2.0 MW wind turbines are in accordance with the DIBt March 2004 edition [average annual wind speed (m/s) 6.7 (height 67 m), 6.9 (height 78 m) and 7.2 (height 100 m)].March 2004 [average annual wind speed (m/s) 6.7 (height 67m), 6.9 (height 78m) and 7.2 (height 100m)].

[2] In the case of the DIBt March 2004 edition, the speed over 50 years is specified as a 3 second average.March 2004, the speed over 50 years is specified as a 3 second average.

2.4 VERIFICATION OF SITE CONDITIONS

As a general rule, the wind turbine should be installed in wind farms with a minimum distance of 5 rotor diameters between wind turbines facing the prevailing wind direction. If the wind turbines are located in rows, perpendicular to the direction of the prevailing wind, the distance between turbines should be a minimum of 2 rotor diameters. These criteria are subject to modification in certain conditions following a specific technical study for each case.

The wind turbines may be placed under different and varied weather conditions where the air density, turbulence intensity, average wind speed and the k form parameter are the main parameters to be considered. If the turbulence intensity is high, the fatigue loads on the wind turbine increase and turbine life decreases. On the other hand, the loads decrease and the turbine life increases if the average wind speed or turbulence intensity or both are low. Therefore, wind turbines may be placed on sites with high turbulence intensity if the average wind speed is fairly low.

Turbulence intensity (I) is the quotient of the standard deviation of the wind speed from the average measured or estimated speed (See IEC 61400-13). Turbulence intensity I15 is used as a characteristic value for the 10-minute average wind speed of 15m/s.

On complex ground, the wind conditions are checked on the basis of measurements taken on site. In addition, the effect of the topography on the wind speed and shear, the turbulence intensity and the wind flow inclination on each wind turbine should be considered.

The supply of the required data is necessary in order to assess the main characteristics of the site:

- Ambient conditions of temperature, density, salinity, dust and/or sand concentration, etc.
- Wind measured on the site, as well as the topographic plans and the layout of the wind turbines at a scale that will enable the site characteristics to be assessed.
- Grid voltage and frequency and service voltage.
- Any other information required by Gamesa for the correct definition of the wind turbine to be installed.

3 CERTIFICATES

Gamesa has certified the following wind turbine models:

Standard	**IEC** [1]										**DIBt** [2]						
Class	I A			II A				III A			WZ II				WZ III		
Hub height (m)	60	67	78	60	67	78	100	67	78	100	60	67	78	100	60	67	78
G80-2.0 MW	✓	✓	✓	✓	✓	✓	✓										
G87-2.0 MW					✓	✓	✓					✓	✓	✓			
G90-2.0 MW					✓	✓	✓	✓	✓	✓		✓	✓	✓			

Table 3. Product certifications table

[1] Certificate in accordance with standard IEC 61400-1 Ed. 2 and with the regulations of *Germanischer Lloyd* (GL Wind) 2003 Ed., 2004 supplement

[2] For the G87/G90s in accordance with the standard DIBt March 2004 Ed. and with the regulations of *Germanischer Lloyd* (GL Wind) 2003 Ed., 2004 supplement.

4 OPTIONS

4.1 EXTREME ENVIRONMENTAL CONDITIONS

Gamesa offers product versions specially designed for extreme temperature, dust and/or corrosion environmental conditions.

4.2 VOLTAGE DROPS

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW, G87-2.0 MW** and **G90-2.0 MW**) are capable of staying connected to the grid during voltage drops, thus contributing to guaranteeing power quality and supply continuity.

The wind turbines can optionally be equipped with **Gamesa Brake Chopper**, a device that is capable of withstanding more extreme drops and contributing to injecting reactive power as required by certain grid codes.

The **Gamesa-2.0 MW** platform wind turbines (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) have certificates issued by official institutes on compliance with voltage drops according to P.O.12.3 of REE and EON2003.

4.3 LOW-NOISE VERSIONS

Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) have different control versions to minimize noise emissions. The application of these versions may involve a modification to the power curve.

These noise-control versions are managed by the **Gamesa NRS®** system, which ensures optimization of production by maintaining previously programmed noise levels in accordance with local legislation.

4.4 BEACONS

As an option, Gamesa offers the inclusion of luminous beacon systems in accordance with the corresponding air traffic legislation and regulations. This is supplied exclusively by Gamesa.

These beacons may be powered by a UPS module, defined in accordance with client requirements. In addition, there is an option to include a flashing synchronization model.

4.5 MID-VOLTAGE SWITCHGEAR

Gamesa offers to supply the wind turbine connection unit to the mid-voltage electrical grid as an option. The mid-voltage wiring connection to the mid-voltage switchgear is at the bottom of the tower. Gamesa recommends a circuit breaker switch (not a breaker box).

Gamesa requires the necessary information to correctly define the switchgear unit. Where the client supplies the mid-voltage switchgear unit, this must comply with Gamesa's technical specifications for the rating and other aspects which may affect the wind turbine.

4.6 GRID VOLTAGE

Gamesa has various transformer options designed to be connected to 50Hz and 60Hz grids at different grid voltage levels in the range of 6.6 ~ 35 kV.

At the request of the client, Gamesa may design transformers with voltage levels not available within the previously specified range.

4.7 SERVICE VOLTAGE

Models of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are available in versions capable of operating with service voltage of 230V or 120V as an option.

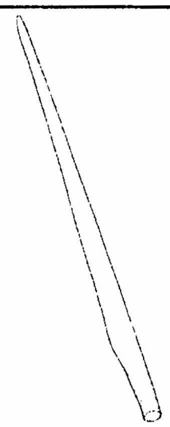
5 TECHNICAL DATA

The main technical data of the different components of the **Gamesa-2.0 MW** platform wind turbines (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are listed below.

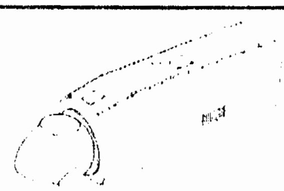
5.1 ROTOR

Wind turbine	G80	G87	G90
Rotor diameter (m)	80	87	90
Swept area (m^2)	5,026.5	5,944.7	6361.7
Operating rotational speed (rpm)	9 : 19	9 : 19	9 : 19

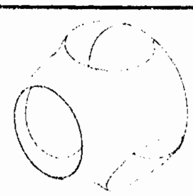
5.2 BLADES

Material		Organic matrix composite reinforced with fiberglass or carbon fiber. Different blade models are available, manufactured solely with fiberglass or carbon fiber, or a combination of both.	
Length (m)	**G80-2.0 MW**	39	
	G87-2.0 MW	42,5	
	G90-2.0 MW	44	
Blade chord (maximum/minimum) (m)	**G80-2.0 MW**	3.36/0.48	
	G87-2.0 MW	3.36/0.013	
	G90-2.0 MW	3.36/0.013	
Torsion (º)	**G80-2.0 MW**	18.74	
	G87-2.0 MW	15.74	
	G90-2.0 MW	15.74	

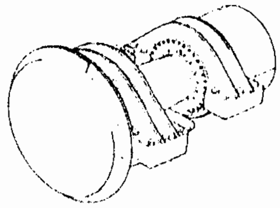
5.3 COVER

Approx. dimensions (m)	10.6 x 3.4 x 3.6	
Material	Organic matrix composite reinforced with fiberglass	

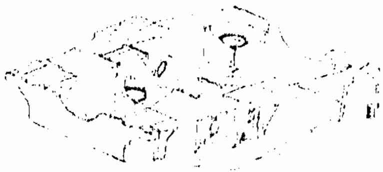
5.4 HUB

Material	Nodular cast iron	

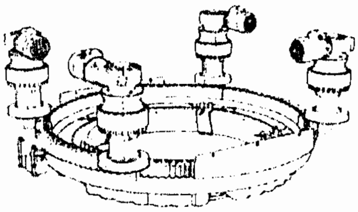
5.5 MAIN SHAFT

Type	Cast shaft	
Shaft support	Nodular cast iron	

5.6 FRONT FRAME

Material	Nodular cast iron	

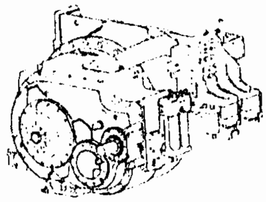
5.7 YAW SYSTEM

Type	Yaw ring with friction bearing	

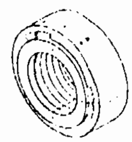
5.8 TOWER

Type	Conical barrel tube	
Material	Structural carbon steel	
Surface treatment	Painted	
Hub height (standard options) (m)	60	
	67	
	78	
	100	

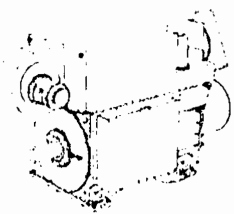
5.9 GEARBOX

Type	1 planetary stage/2 parallel stages	
Ratio	1: 100.5 (50Hz), 1:120.5 (60Hz)	

5.10 COUPLINGS

Main shaft	Cone collar	
High-speed shaft	Flexible coupling	

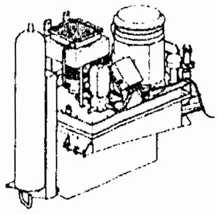
5.11 GENERATOR

Type	Doubly-fed with coil rotor and slip rings	
Nominal power (kW)	2070 (stator + rotor)	
Voltage (Vac)	690	
Frequency (Hz)	50/60	

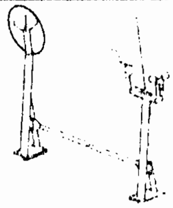
5.12 MECHANICAL BRAKE

Type	Disc brake	

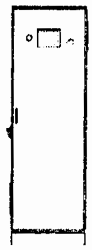
5.13 HYDRAULIC UNIT

Operating pressure (bar)	180 - 200	

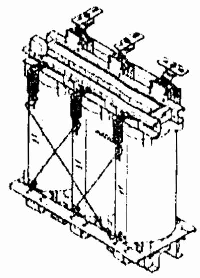
5.14 WIND SENSORS

Standard configuration	1 2D ultrasonic anemometer with simultaneous speed and direction measurement + 1 cup anemometer and wind vane	
Number	1 + 1	

5.15 CONTROL UNIT

Frequency (Hz)	50/60	
Voltage (Vdc)	24	
PLC (according to configuration)	Sisteam A *(Option A)* Phoenix Contact *(Option B)*	
Field buses	CAN *(Option A)* Interbus *(Option B)*	

5.16 TRANSFORMER

Type	Three-phase, dry-type encapsulated	
Rated power	Different options available	
Voltage in mid-voltage	Different options available	
Frequency (Hz)	50/60	
Insulation class	F or H	

5.17 APPROXIMATE WEIGHTS

Nacelle weight (t)	71

Rotor	G80-2.0 MW	G87-2.0 MW	G90-2.0 MW
Rotor weight (t)	41	41	41

Tower weight (t)		Flange type	G80-2.0 MW	G87-2.0 MW	G90-2.0 MW
IA Towers	60m	L and T	136	-	-
	67m	L and T	153	-	-
	78m	L and T	203	-	
IIA towers	60m	L and T	136	-	-
	67m	L and T	153	153	-
	78m	L and T	203	203	-
	100m	T	260	260	260
IIIA towers	67m	L and T	-	-	153
	78m	L and T	-	-	203
	100m	T	-	-	260

DIBt tower weight (t)		Flange type	G80-2.0 MW	G87-2.0 MW	G90-2.0 MW
Towers DIBt WZ III towers	60m	L	136	-	-
	67m	L	153	-	-
	78m	L	203	-	-
Towers DIBt WZ II towers	60m	L	136	-	-
	67m	L	153	153	153
	78m	L	203	203	203
	100m	T	260	260	260

NOTES:

- The weights of the standard towers are included.
- These weights do not include the mid-voltage switchgear and the GROUND electrical cabinet.
- The 100m type "T" flange is for GAMESA foundations, the remaining type "T" flanges are for USA foundations.
- All weights are generic or approximate and may vary.

6 GENERAL RESTRICTIONS

- All data shown is valid for conditions at sea level and standard air density.
- In periods of low wind speeds, an increase in power consumption for nacelle heating and dehumidification is to be expected.
- In the event of a build-up of large quantities of ice on blades or other wind turbine components, interruptions to the turbine operation should be expected. In addition, high winds in combination with the following conditions - high temperatures, low temperatures, low density and/or low grid voltage - may lead to a reduction in the rated power to ensure that the thermal conditions of certain principal components, such as the gearbox, generator, transformer, power cables, etc. are maintained within limits.
- It is usually recommended that the electrical grid voltage be kept as close as possible to the nominal value.
- In the event of a loss of electric power and very low temperatures, a certain period of time should be allowed for heating before the wind turbine starts to operate.
- If there is a slope of more than 10º within a radius of 100 meters of a wind turbine, special considerations may be necessary.
- Wind turbines of the **Gamesa-2.0 MW** platform (models **G80-2.0 MW**, **G87-2.0 MW** and **G90-2.0 MW**) are ready to operate up to 2500m above sea level. Up to 1000m the wind turbine operates in full-power conditions. From 1000m the wind turbine operates in production conditions with power derating based on ambient temperature. In addition, on sites above sea level, the risk of freezing is greater.
- All the parameters given for start up and stopping (temperatures, wind speeds, etc.) have an associated hysteresis in the control system. In certain conditions, this may involve a wind turbine being stopped, even when the instant ambient parameters are within the specified limits.
- Intermittent or rapid fluctuations in the electrical grid frequency may cause serious problems to the wind turbine.
- Drops in the electrical voltage should not occur more than 52 times per year.
- Due to modifications and updates to our products, Gamesa reserves the right to change the specifications.

Gamesa	**GENERAL CHARACTERISTICS MANUAL (GCM)**	*Code:* **GD086484-en** *Rev:* **0**
		Date: **20/09/2010** *Page* **1** *of* **5**
		Approval process: **Electronic: PDM Flow + Translation**
Type of Documentation: **PDTD - Product**	*Title:* **G97 2MW 50/60 Hz Wind Turbine Power Curve**	*Author:* **LGR**
Deliverable: **S12**		*Revised:* **IRS**
		Approved: **BLC**

INDEX

RECORD OF CHANGES

Rev.	Date	Author	Description
0	11/06/10	LGR	Initial version

1 OBJECT

This document shows the AEG G97 2MW power curves.

2 SCOPE

The values in the present document are applicable to all the existing configurations for the AEG G97 in standard operation mode.

3 DEFINITIONS AND ACRONYMS

- **WT**: Wind turbine.
- **Power (P):** Expressed in kW, this is the electric power obtained at the generator terminals without considering the losses in the transformer or high voltage cables of the wind turbine, or the occasional power consumption which may exist in the same to supply a component. Averaged every 10 minutes.
- **Wind Speed (W_S.)**, Expressed in m/s, this is the value of the horizontal wind component at hub height averaged every 10 minutes.
- **Power curve (CdP):** This represents the variation in P depending on W_S, for the different WT operating modes.
- **Annual Production (EAP)** expressed in MWh, this is the total electrical energy produced in a wind turbine during a one-year period, according to a given CdP and a given wind distribution.
- **Wind distribution**. The *Weibull* distribution is used for different parameters with the form *(K)*, and for average annual wind speed values (W_{ave}).
- **Power coefficient**: C_p
- **Thrust coefficient**: C_t

4 DESCRIPTION

All the values given in this document, unless expressly stated otherwise, refer to the values of the different parameters given on **Table 1**.

Table 1 Calculation parameter values for the G97 2MW wind turbine power curve

Rated Power	2.0 MW
Frequency	50 Hz/60 Hz
Rotor Diameter	97m
Angle of blade tip	Pitch control regulation
Turbulence intensity	10 % (for all wind speeds)
Air density reference	1,225 kg/m³

5 RESULTS

5.1. STANDARD POWER CURVE

Table 2 shows the electrical power [kW] according to horizontal wind speed [m/s] with respect to hub height W_S [m/s] for different air densities [kg/m^3].

P [kW]	***Density [kg/m^3]***												
Ws [m/s]	***1.225***	***0.94***	***0.97***	***1.00***	***1.03***	***1.06***	***1.09***	***1.12***	***1.15***	***1.18***	***1.21***	***1.24***	***1.27***
3	14	9	9	10	10	11	11	12	13	13	14	15	15
4	94	64	67	70	73	76	79	82	85	89	92	95	98
5	236	172	179	186	192	199	206	212	219	226	233	240	246
6	438	328	340	351	363	374	386	397	409	421	432	444	455
7	714	541	559	577	595	614	632	650	669	687	705	724	742
8	1084	822	849	877	905	932	960	987	1015	1043	1070	1097	1125
9	1507	1175	1213	1251	1289	1325	1360	1395	1429	1464	1493	1521	1550
10	1817	1546	1583	1620	1656	1687	1714	1740	1767	1793	1809	1826	1842
11	1951	1816	1837	1859	1880	1896	1908	1920	1931	1943	1949	1954	1959
12	1990	1943	1951	1959	1968	1973	1977	1980	1984	1987	1989	1990	1992
13	1998	1985	1988	1990	1993	1994	1995	1996	1997	1998	1998	1998	1998
14	2000	1997	1997	1998	1998	1999	1999	1999	1999	2000	2000	2000	2000
15	2000	1999	1999	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
16	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
17	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
18	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
19	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
20	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
21	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
22	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906
23	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681
24	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455
25	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230

Table 2 Power [kW] of the G97 2MW wind turbine calculated as a function of wind speed Ws [m/s], for different air densities [kg/m^3]

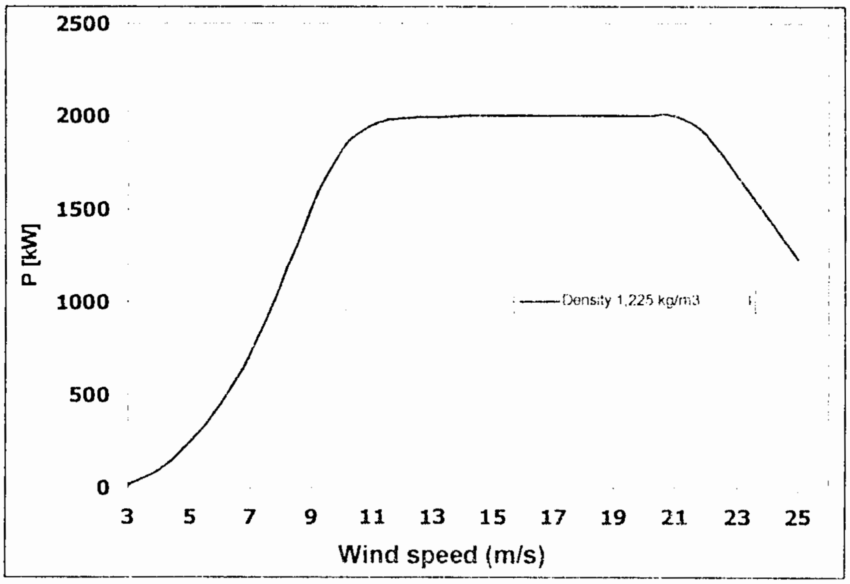


Figure 1 G97 2.0MW WT power curve for air density equal to 1.225 [kg/ m^3].

5.2. ANNUAL PRODUCTION.

Table 3 shows the annual production [MWh] of the G97 2.0 MW generator for different values of the *k* form *Weibull* parameter and average annual winds W_{ave} [m/s]. Values calculated for a standard density of 1,225 kg/m^3 and 10% Turbulence Intensity.

P [MWh]		W_{ave} [m/s]				
		5.5	6	6.5	7	7.5
Weibull K	1.6	4810	5590	6324	7004	7623
	2	4624	5542	6430	7269	8049

Table 3 Annual production [MWh] of the G97 2 MW WT calculated as a function of W_{ave}[m/s].

5.3. CP AND CT CURVES

Table 4 shows the values of Cp and Ct for the G97 2MW wind turbine.

W_S [m/s]	Cp	Ct
3	0.118	0.949
4	0.323	0.872
5	0.418	0.844
6	0.448	0.832
7	0.460	0.830
8	0.468	0.824
9	0.457	0.764
10	0.402	0.621
11	0.324	0.464
12	0.254	0.345
13	0.201	0.265
14	0.161	0.209
15	0.131	0.169
16	0.108	0.140
17	0.090	0.117
18	0.076	0.099
19	0.064	0.085
20	0.055	0.074
21	0.048	0.065
22	0.040	0.054
23	0.031	0.044
24	0.023	0.035
25	0.017	0.028

Table 4: Values for C_p and C_t for the G97 2MW WT.

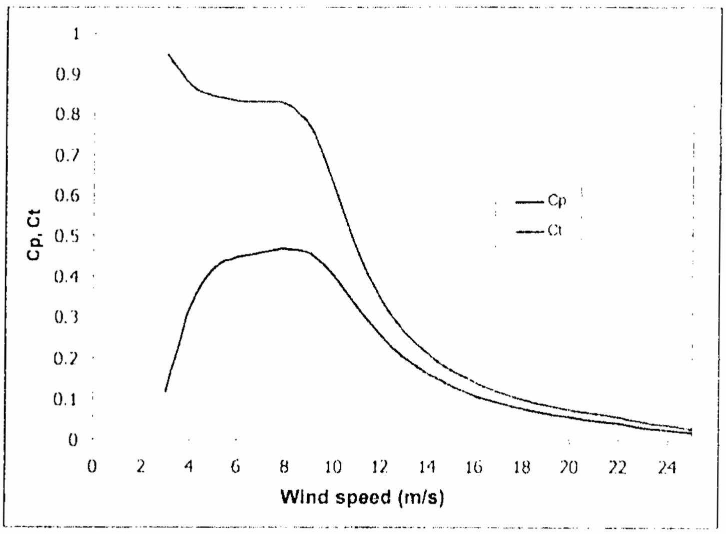


Figure 2 C_p and C_t curve values for the G97 2MW WT.

Gamesa 2.0 MW
Technological evolution

G80-2.0 MW
G87-2.0 MW
G90-2.0 MW
G97-2.0 MW
G114-2.0 MW

GLOBAL TECHNOLOGY
EVERLASTING ENERGY

INDEX

Economic progress & Sustainable development

These are the great challenges facing today's society. In the areas of energy management and power generation, Gamesa is tackling these challenges by developing technologies that foster energy sustainability in a clean, efficient and profitable manner.

By harnessing the best and most modern technologies in conjunction with its high industrial potential, Gamesa continues to improve the efficiency and capacity of its products and services by designing and manufacturing of ever more advanced wind turbines.

The drive behind our work to develop more efficient technologies, products and services is to ensure that Gamesa's range of offerings is the most comprehensive in terms of capabilities and the most competitive in the market. Our goal? Complete customer satisfaction.

Innovative Evolution

Technology is one of the fundamental focal points of Gamesa's activities, evidenced by the substantial research and development efforts employed by the company to continually improve its Gamesa 2.0 MW platform.

Gamesa wind turbine technology is characterized by its robustness, reliability and adaptability to all types of sites and wind conditions from the toughest, most demanding locations to those with medium to light winds. The Gamesa 2.0 MW technology has been very well received and has become an industry workhorse, as evidenced by the more than 12.500 MW of power installed in 24 countries*.

The company's significant experience base and its in-depth knowledge of market needs and demands have enabled it to develop technological improvements in this platform. The evolution and incorporation of substantial innovations in design, products and features have put the new Gamesa 2.0 MW platform on the path to leadership in the multi-megawatt segment.

2002 — The first G80-2.0 MW

2003 — The first G80-2.0 MW wtg 60 Hz installed

2004 — The first G87-2.0 MW wtg is installed

2005 — The first G90-2.0 MW wtg

The first GW installed

2007 — New Gamesa 2.0 MW farm installations

4 GW installed

The largest wind Gamesa 2.0 MW wind farm

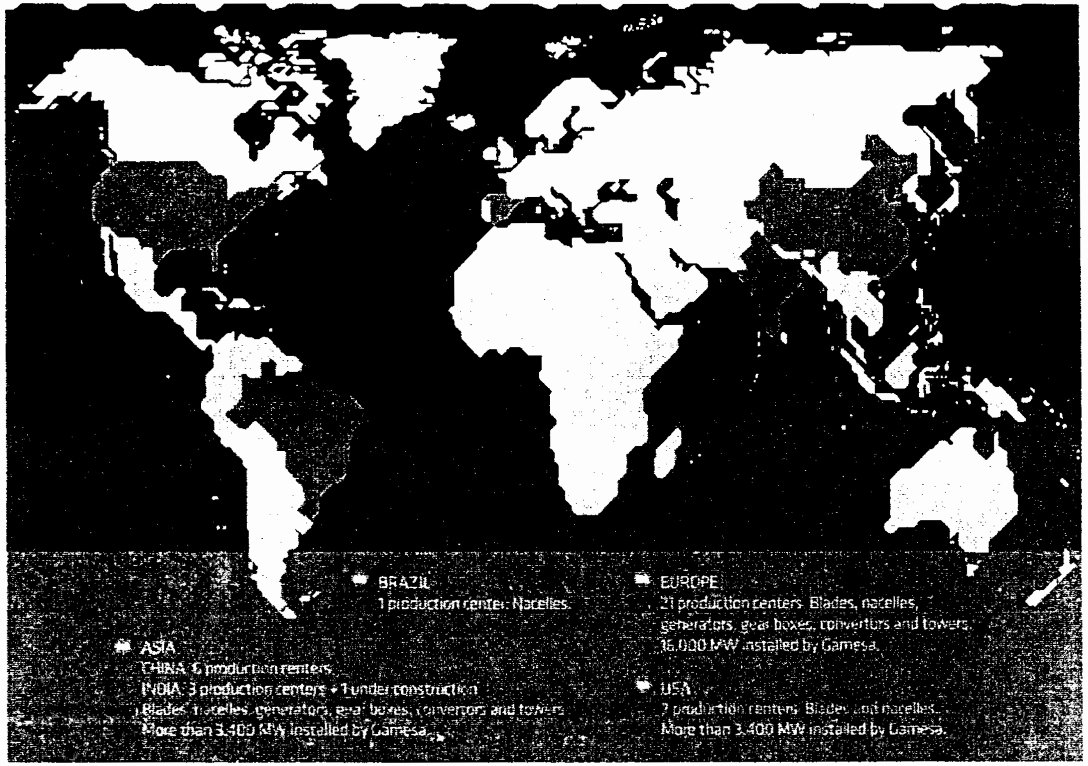
2009 — 8 GW installed

2010 — Launch of the new G97-2.0 MW

2011 — 12.5 GW installed Gamesa 2.0 MW

The first prototype G97-2.0 MW IIIA

2012 — Launch of the new G97-2.0 MW IIIA, G90-2.0 MW IA and G114-2.0 MW IIIA



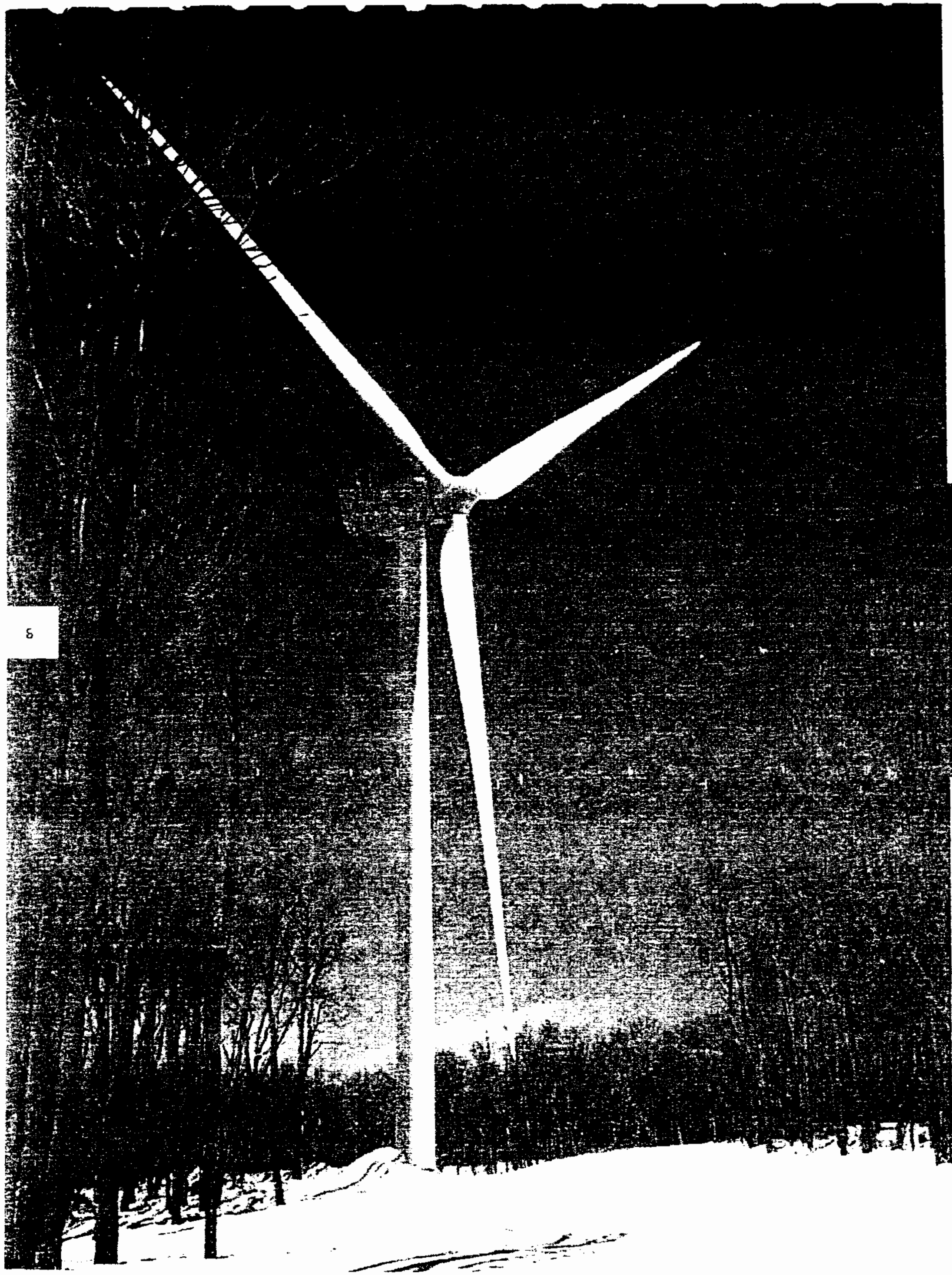
Global capacity for production, installation and operation and maintenance

Gamesa is a company specializing in technologies for sustainable energy, mainly wind energy, and is one of the world leaders in the manufacture of wind turbines. Within this sector, Gamesa manages the entire process, from the design, manufacture and installation of wind turbines, to their operation and maintenance.

The over 24.000 MW installed throughout the world is evidence of the excellent performance of Gamesa's wind turbines. This optimum behavior is only possible with a full command of the technology and of the product with all its critical components.

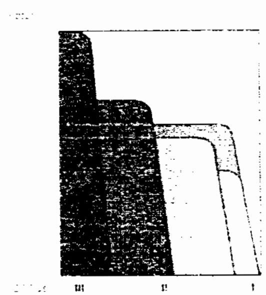
Gamesa has the capacity to design, manufacture, operate and maintain its wind turbines. The tailor-made development of the critical components of its turbines -from the gearbox to the blades- ensures excellence in the design and the very highest quality standards. At the same time, it permits the shortest delivery times and the fastest technical response during the maintenance period.

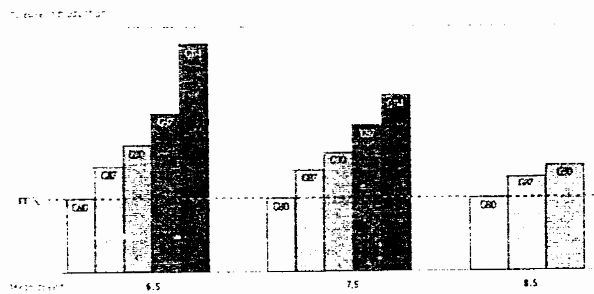
Research, Development and Innovation form an integral part of the company's processes and products as well as its tasks and operations all along the supply chain, ensuring customer satisfaction and the search for excellence. In addition to this high ability to innovate, Gamesa also has a remarkable production capacity. From over 30 production centers in Europe, the United States, China, India and Brazil, Gamesa fully controls the production process and attends to the needs of its clients on all five continents, offering its customers the highest quality standards and short customer response times.



Versatility

Gamesa 's 2.0 MW platform offers turbines in five rotor diameters -80, 87, 90, 97 and 114 meters. The availability of these different rotor diameters enables the platform to operate in IEC Class I, Class II and Class III environments, thus achieving maximum output for specific site wind conditions. Multi-megawatt wind turbines from the Gamesa 2.0 MW platform improve competitive investment ratios per MW installed and Cost of Energy produced.



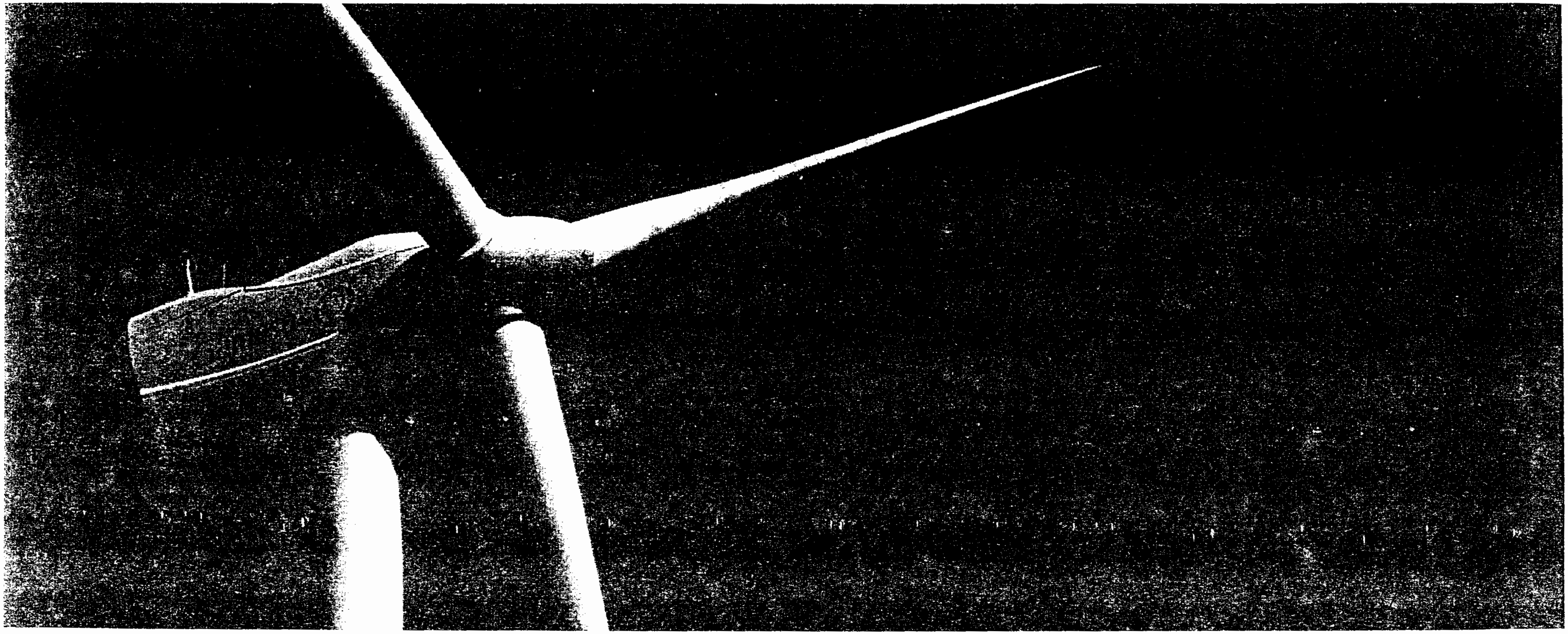


Discovering Gamesa 2.0 MW

The operational improvements of the Gamesa 2.0 MW drives are derived from its speed control and variable pitch technology enhancements, as well as other hardware and software design upgrades. Ongoing turbine upgrades ensure that maximum energy is extracted from the wind as efficiently as possible.

- Composite materials reinforced with glass and carbon fiber for lighter blades without sacrificing rigidity and strength.
- The Gamesa WindNet® remote control system.
- Gamesa SMP predictive maintenance
- Gamesa NRS® noise control.
- Solutions for optimum grid connection

Model	IEC	Rated Power	Grid Code	Tower Heights	Env / Opt [1]	Type certificate	50 Hz 60 Hz
G80	IA	2,000 kW	√	60, 67, 78, 100[2] m	√	√	√
G87	IA / IIA	2,000 kW	√	67, 78, 90, 100 m	√	√	√
G90	IA[4]/IIA/IIIA	2,000 kW	√	67[3], 78, 90[3], 100 m	√	√	√
G97	IIA/IIIA	2,000 kW	√	78, 90, 100, 120 m	√	√	√
G114[4]	IIIA	2,000 kW	–	93, 120, 140 m and site specific	–	–	–

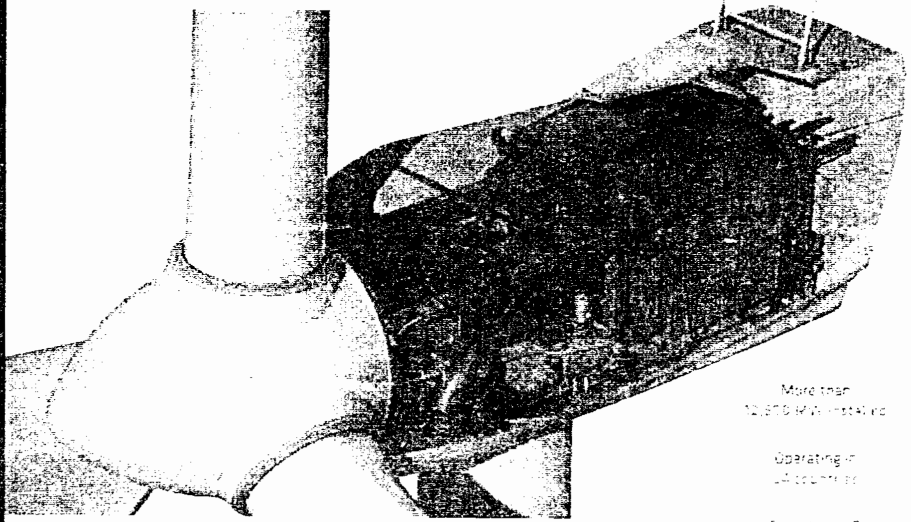


Innovative Evolution
Gamesa 2.0 MW.

One step forward.

Advantages of the new Gamesa 2.0 MW platform

The reliability of the Gamesa 2.0 MW, backed by broad experience and proven capacity to adapt, combines with Gamesa's technological advances to provide notable improvements in performance, optimized models, a new tower portfolio and an upgraded image.

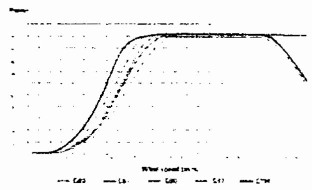


More than 12,870 MW installed

Operating in 24 countries

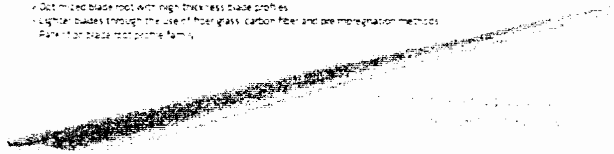
Established & vertically integrated manufacturing capabilities in the main wind markets

New features and improvements



- Maximum output under any wind condition.
- Enhanced power curves.
- Reduced noise levels:
  - Aerodynamic design.
  - Gamesa NRS® control system.
- Compliance with the main international grid connection requirements.
- Gamesa WindNet® remote control and monitoring system with web access.

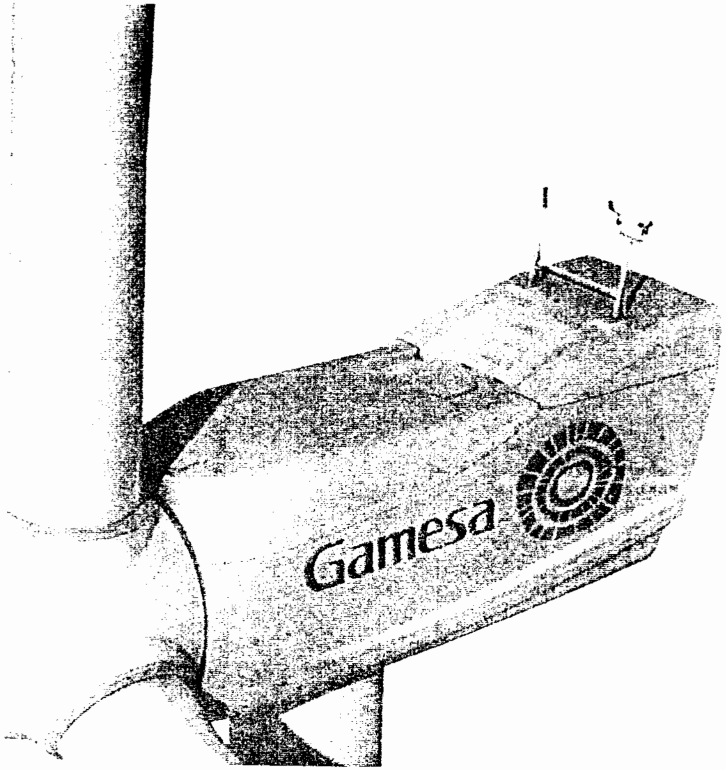
- New optimized blade profile for the new G97-2.0 MW and G114-2.0 MW:
  - Optimized blade root with high thickness blade profiles.
  - Lighter blades through the use of fiber glass, carbon fiber and pre-impregnation methods.
  - Patent on blade root profile family.



- New G114-2.0 MW IIIA.
- New G97-2.0 MW IIA/IIIA.
- New G87-2.0 MW IIA.
- New G80-2.0 MW IA.

- New 90, 100 and 120 meter towers for the G97-2.0 MW IIA/IIIA.
- New 93, 120 and 140 meter towers for the G114-2.0 MW IIIA.

- Newer, more attractive nacelle design.
- Improvements and capacity increases on key drive train components.
- Expanded space for nacelle maintenance tasks and operations.



Gamesa 2.0 MW

Technical specifications and services

The Gamesa 2.0 MW platform incorporates improved and increased mechanical capacity in key wind turbine components such as the yaw system, the framework, main axis, and blade bearings.

These improvements guarantee maximum reliability of the equipment and allow larger rotors to be used to increase the power generated in medium and light winds.

The main axis is supported by two spherical bearings that provide significant advantages since lateral loads are transmitted directly to the framework through a rack. This prevents the gear box from receiving additional unwanted loads, reduces the possibility of breakdown and provides a longer service life.

The Gamesa 2.0 MW platform uses the "Total Lightning Protection" system, designed according to the IEC 62305 standard. This system conducts the lightning from both sides of the tip of the blade to the root, and from there through the nacelle and the tower structure to the foundation grounding system. This protects the blade and prevents the lightning from going through the blade bearings and main axis, protecting sensitive electrical and electronic elements from damage.

The joint action of the primary aerodynamic brakes and mechanical emergency brake located at the output of the high-speed axis of the gear box, with a hydraulic control system, allows controlled braking that prevents damage due to excessive transmission load.

Gamesa WindNet®: Real-time Operation and Monitoring

The new generation SCADA wind farm system entirely developed by Gamesa, allows remote operation and the monitoring of the wind turbine, its meteorological mast and electrical substation in real time. Gamesa's WindNet® innovative, modular design is based on TCP/IP architecture. Control features include active and reactive power, voltage and frequency regulation tools and environmental options to optimize production while complying with current regulations.

Accessible anywhere through a Web browser, Gamesa WindNet® is simple to use and intuitive. It features the Report Generator and Information Manager decision-taking analytical tools as well as Trendviewer, an advanced tool to visualize trends.

Control system: Maximum output under any wind condition

Dual powered generator, speed and power controlled by IGBT converters and electronic PWM control (Pulse Width Modulation).

Advantages:
- Active and reactive power control.
- Low harmonic content and minimum losses.
- Increased efficiency and production.
- Improved useful life of the machine.

Predictive Condition Monitoring System for Predictive Maintenance (SMP)

Predictive maintenance system for premature detection of potential deterioration or faults in the main wind turbine components.

Advantages:
- Fewer large corrections
- Improved reliability, availability and useful life of the machine.
- Integration with the control system
- Risk mitigation provides preferential conditions in negotiations with insurance providers

Noise Reduction System: Minimum Noise Emission

New aerodynamic design of the blade tip and mechanical components design minimize noise emissions.

In addition, Gamesa has developed the Gamesa NRS® noise control system, which makes it possible to program the turbine to reduce noise emissions according to such criteria as the date, time or wind direction.

This achieves compliance with local regulations and enables maximum production.

Optimum electrical grid connection and stable production

Gamesa's Doubly Fed wind turbines, adopting Active Crowbar and DAL converter technologies, guarantee compliance with today's most demanding grid code requirements as well as future electrical grid and wind farm configurations, by offering full support for voltage dips and dynamic active and reactive power regulation.

The [illegible] Technology (Doubly Fed Induction [illegible]) in combination with Gamesa WindNet®, the new SCADA System developed by Gamesa, allows the regulation of active and reactive power via the injection of rotor currents with variable amplitude, frequency and phase.

Specifically, the injection of currents with variable amplitude allows the system to control the reactive power by varying the power factor, whereas the injection of currents with variable phase allows the system to control the active power.

With less than 25% of the generated power passing through the converter, the DFIM Technology guarantees that the harmonics generated are minimized.

Dynamic regulation of reactive power on the wind farm

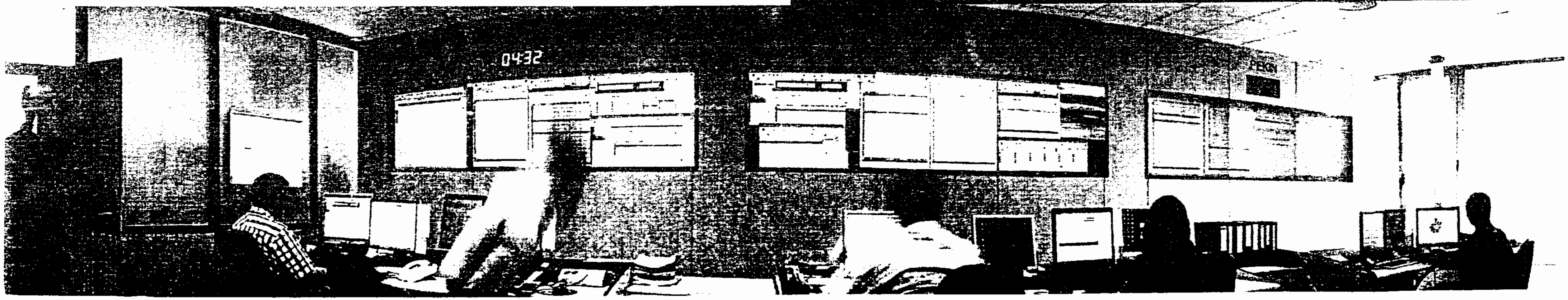
The on-site power measurement equipment monitors the high-voltage active and reactive power data at the output of the substation transformer and sends them to Gamesa WindNet® via the control unit of the substation.

Gamesa WindNet® dynamically calculates and corrects the power factor in accordance with the reference values of the System Operator.

Gamesa WindNet® actuates on both the reactive power regulation capability of the turbine and, where available, other equipment in the substation such as capacitor banks and FACTS systems.

Fulfillment of grid code requirements

REQUIREMENT	GAMESA FULFILLMENT[5]
Voltage ride-through	Low voltage ride-through capabilities covering the most important grid codes.
Reactive regulation[4]	Up to cos phi 0.95 (cap) – 0.95 (ind) in output terminals of the turbine.
Active regulation	110% GP and capacity to participate in primary regulation.
Operational frequency range	47.5–50 Hz / [illegible] Hz
Operational voltage range	±5% in normal operation and ±10% in specific periods.
Remote control	Control via Gamesa WindNet® of the active and reactive power with different set point options and the possibility of dealing dynamically with the commands for operation of the grid operator.



ROTOR

Diameter	80 m	87 m	90 m	97 m	114 m
Swept area	5,027 m²	5,945 m²	6,362 m²	7,390 m²	10,207 m²
Rotational speed	9.0 - 19.0 rpm	9.0 - 19.0 rpm	9.0 - 19.0 rpm	9.6 - 17.8 rpm	--

BLADES

Number of blades	3	3	3	3	3
Length	39 m	42.5 m	44 m	47.5 m	56 m
Airfoils	NACA 63.XXX + FFA-W3	DU + FFA-W3	DU + FFA-W3	Gamesa	Gamesa
Material	Pre-impregnated epoxy glass fiber	Pre-impregnated epoxy glass fiber	Pre-impregnated epoxy glass fiber	Pre-impregnated epoxy glass fiber + carbon fiber	Fiberglass reinforced with polyester resin

TOWER

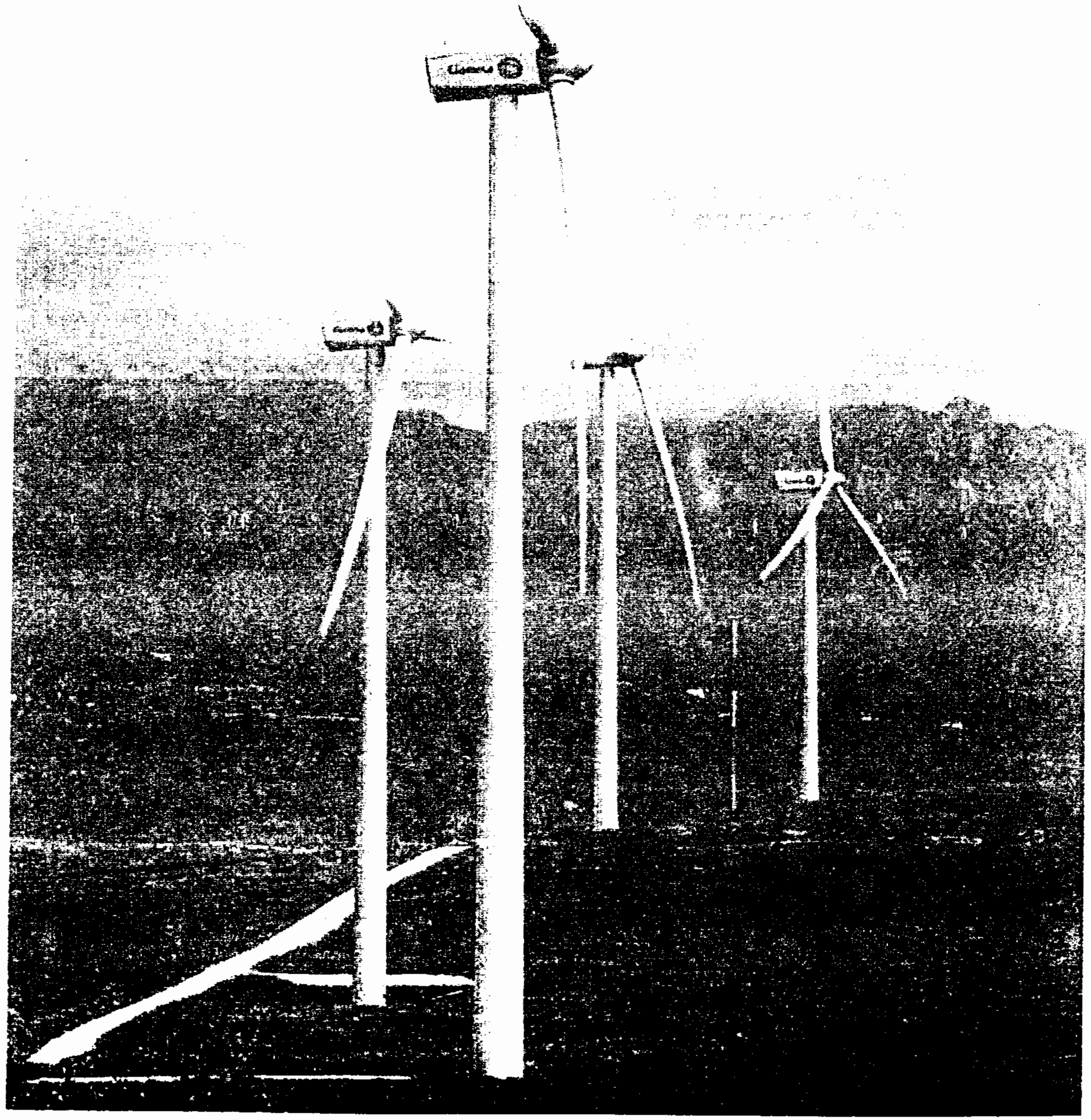
Type	Modular	Modular	Modular	Modular	Modular
Height	60, 67, 78 and 100 m	67, 78, 90 and 100 m	67, 78, 90 and 100 m	78, 90, 100 and 120 m	93, 120, 140 m and site specific

GEAR BOX

Type	1 planetary stage 2 parallel stages	1 planetary stage 2 parallel stages	1 planetary stage 2 parallel stages	1 planetary stage 2 parallel stages	1 planetary stage 2 parallel stages
Ratio	1:100.5 (50 Hz) 1:120.5 (60 Hz)	1:100.5 (50 Hz) 1:120.5 (60 Hz)	1:100.5 (50 Hz) 1:120.5 (60 Hz)	1:106.8 (50 Hz) 1:127.1 (60 Hz)	-- --

GENERATOR 2.0 MW

Type	Doubly-fed machine	Doubly-fed machine	Doubly-fed machine	Doubly-fed machine	Doubly-fed machine
Rated power	2.0 MW	2.0 MW	2.0 MW	2.0 MW	2.0 MW
Voltage	690 V AC	690 V AC	690 V AC	690 V AC	690 V AC
Frequency	50 Hz / 60 Hz	50 Hz / 60 Hz	50 Hz / 60 Hz	50 Hz / 60 Hz	50 Hz / 60 Hz
Protection class	IP 54	IP 54	IP 54	IP 54	IP 54
Power factor	0.95 CAP - 0.95 IND throughout the power range*	0.95 CAP - 0.95 IND throughout the power range*	0.95 CAP - 0.95 IND throughout the power range*	0.95 CAP - 0.95 IND throughout the power range*	0.95 CAP - 0.95 IND throughout the power range*



Gamesa

C/ Ciudad de la Innovación, 9-11
31621 Sarriguren (Spain)
Tel.: +34 948 771 000
Fax: +34 948 165 039
info@gamesacorp.com
www.gamesacorp.com

AUSTRALIA
Level 13, 167 Macquarie Street,
Sydney NSW 2000
Tel.: +61 (2) 8667 3000

BRAZIL
Rua Hungria 1240, 3° A
Jd. Europa
CEP 01455-000
São Paulo (SP)
Tel.: +5511 3096 4444

BULGARIA
53-55 Totleben Blvd.
Sofia 1606
Tel.: +359 2 805 71 73
Fax: +359 2 805 7001

CHILE
Av. Apoquindo, 3.600
9th floor, 904
Las Condes - Santiago
Tel.: +56 2 446 8485

CHINA
23/F, Tower 1,
Beijing Prosper Center No. 5
Guanghua Road,
Chaoyang District,
Beijing 100020
Tel.: +86 10 5789 0899
Fax: +86 10 5761 1996

EGYPT
3, 218 St. Degla,
Maadi, Cairo
Tel.: +20 225 211 048
Fax: +20 225 211 282

FRANCE
Parc Mail,
Bâtiment G
6 Allée Irène Joliot-Curie
69791 Saint Priest Cedex
Tel.: +33 (0) 4 72 79 49 39

GERMANY
Stadthausbrücke 1-3, 5 Stock
20355 Hamburg
Tel.: +49 (0) 403 7644 743

GREECE
23 Adrianiou str.
11525 Neo Psychiko, Athens
Tel.: +30 21067 48947
Fax: +30 21067 70167

INDIA
The Futura IT Park, B Block, 8th Floor
334, Rajiv Gandhi Salai
Sholinganallur,
Chennai - 600 119
Tel.: +91 44 3924 2424
sales.india@gamesacorp.com

ITALY
Via Pio Emanuelli 1
00143 Rome
Tel.: +39 0645543650-1
Fax: +39 0645553974

MEXICO
Torre Diana, Piso 14
Av. Pº de la Reforma 389
Colonia Cuahtemoc
06500 Mexico DF
Tel.: +52 55 5533 0810

MOROCCO
Immeuble Office Building
Angle Boulevard Mohamed V et
Rue Victor Hugo
2º Etage Apt. N 21
90000 Tanger
Tel.: +212 539 94 61 14
Fax: +212 539 94 59 69

POLAND
Ul. Galaktyczna 30A
80-299 Gdansk
Tel.: +48 58 766 62 62
Fax: +48 58 766 62 99
poland.wind@gamesacorp.com

ROMANIA
169A Calea Floreasca Street
Building A, 4th Floor,
office no 2069, Sector 1
014459 Bucharest
Tel.: +40 318 21 24
Fax: +40 318 60 21 00

SINGAPORE
3 Temasek Avenue
Centennial Tower, Level 34
Singapore 039190
Tel.: +65 6549 7763
Fax: +65 6549 7011

SOUTH AFRICA
The Colosseum
1st Floor, Century Way, Foyer 3
Century City
7441 Cape Town
Tel.: +27 0 215260300
Fax: +27 0 215260311

SWEDEN, FINLAND, NORWAY
Solna Strandvag 78
171 54 Solna (Sweden)
Tel.: +46 (0) 8 5052 00 00
Fax: +46 (0) 8 5052 10 10

TURKEY
Astoria
Buyukdere Cad. No. 127 Kule A, Kat 10
Esentepe
Istanbul 34394
Tel.: +90 212 340 76 00

UNITED KINGDOM
29 Napier Place
Wardpark North
Cumbernauld G68 0LL
Tel.: +44 1236 724890

UNITED STATES
1150 Northbrook Drive
Trevose, PA 19053
Tel.: +1 215 710 3100
Fax: +1 215 741 4048

DET NORSKE VERITAS

TYPE CERTIFICATE

G97-2MW IEC IIIA HH78&90m 50/60Hz

IEC TC-224901-0	2012-03-30
Type Certificate number	Date of issue

Manufacturer:
GAMESA TECHNOLOGIC CORPORATION, S.A.
Parque Tecnológico de Bizkaia, Edificio 222
48170 Zamudio (Vizcaya) - SPAIN

Valid until: 2017-03-30

Conformity evaluation has been carried out according to **IEC 61400-22: 2010 "Wind Turbines - Part 22: Conformity Testing and Certification"**. This certificate attests compliance with IEC 61400-1 ed. 2: 1999 and IEC 61400-22 concerning the design and manufacture.

Reference documents:

Design Basis Conformity Statement:	IEC DB-224901-0
Design Evaluation Conformity Statement:	IEC DE-224901-2
Type Test Conformity Statement:	IEC TT-224901-0
Manufacturing Conformity Statement:	IEC MC-224901-0
Final Evaluation Report:	PD-642249-12R6IEB-37 Rev 2

Wind Turbine specification:
IEC WT class: IIIA. For further information see Appendix 1 of this Certificate.

Date: 2012-03-30

Christer Eriksson
Management Representative
Det Norske Veritas, Danmark A/S

DANAK
PROD Reg no 7031

Date: 2012-03-30

Jóse Simon
Project Manager
Det Norske Veritas, Danmark A/S

APPENDIX 1 - WIND TURBINE TYPE SPECIFICATION

General:

IEC WT class acc. to IEC 61400-1 ed. 2: 1999:	IIIA
Rotor diameter:	97m
Rated power:	2000kW (derated between 21 m/s and 25 m/s)
Rated wind speed V_r:	10.5 m/s
Hub height(s):	78m and 90m
Operating wind speed range V_{in}-V_{out}:	3 m/s – 25 m/s (100 sec average)
Design life time:	20 years

Wind conditions:

V_{ref} (hub height):	37.5 m/s
V_{ave} (hub height):	7.5 m/s
I_{15} (V_{hub}=15 m/s) acc. to IEC 61400-1 ed. 2: 1999:	18% (a = 2)
Mean flow inclination:	8 deg

Electrical network conditions:

Normal supply voltage and range:	690 V ± 10%
Normal supply frequency and range:	50/60 Hz ± 2%
Voltage imbalance:	< 2%
Number of annual electrical network outages:	20

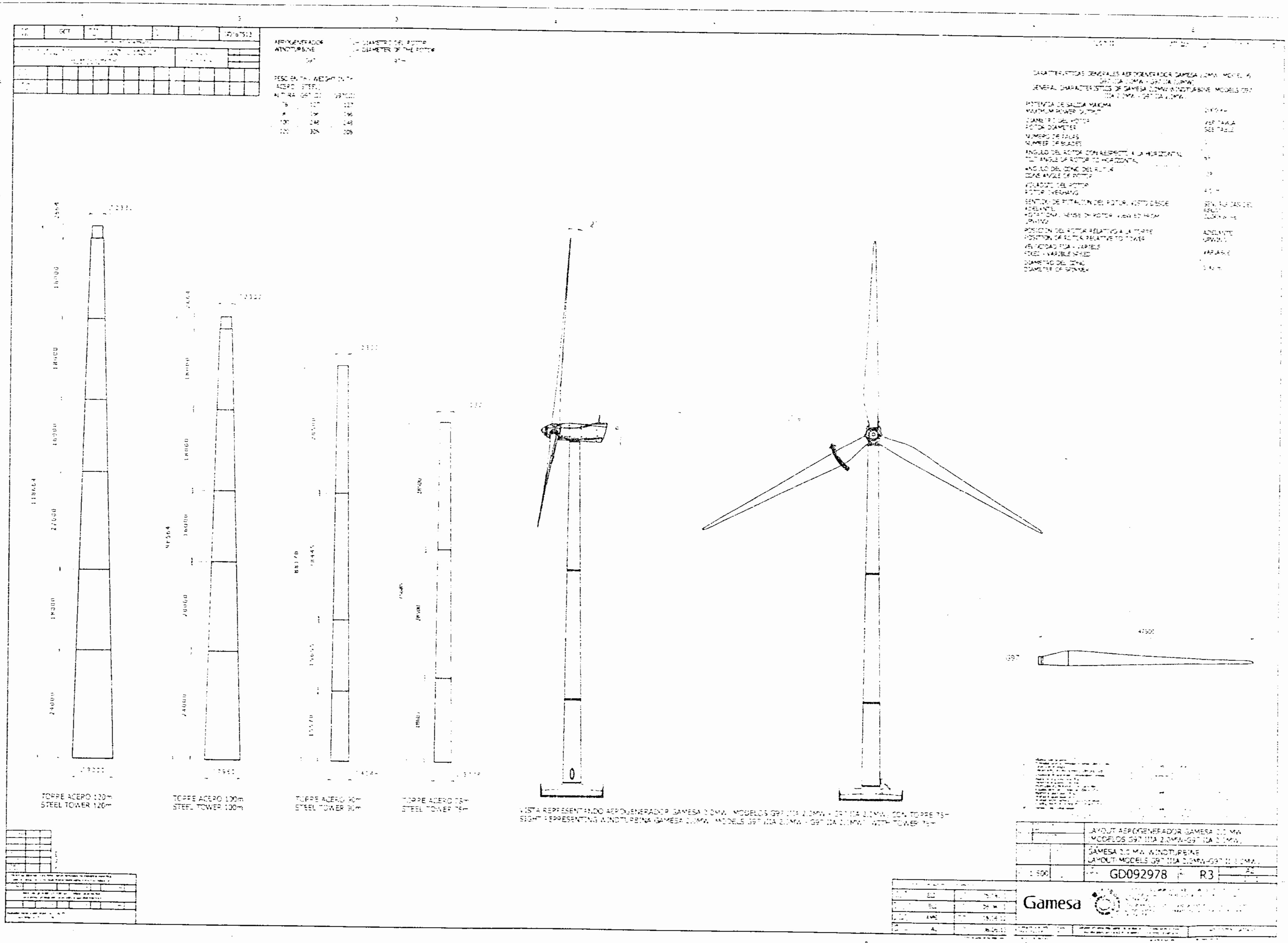
Other environmental conditions (where taken into account):

Air density:	1.225 kg/m^3
Normal and extreme temperature ranges:	-10°C to +40°C -20°C to +50°C
Relative humidity:	95%
Solar radiation:	1000 W/m^2
Description of lightning protection system:	Designed according to IEC61024-1 and IEC61400-24, Protection Level I

Main components:

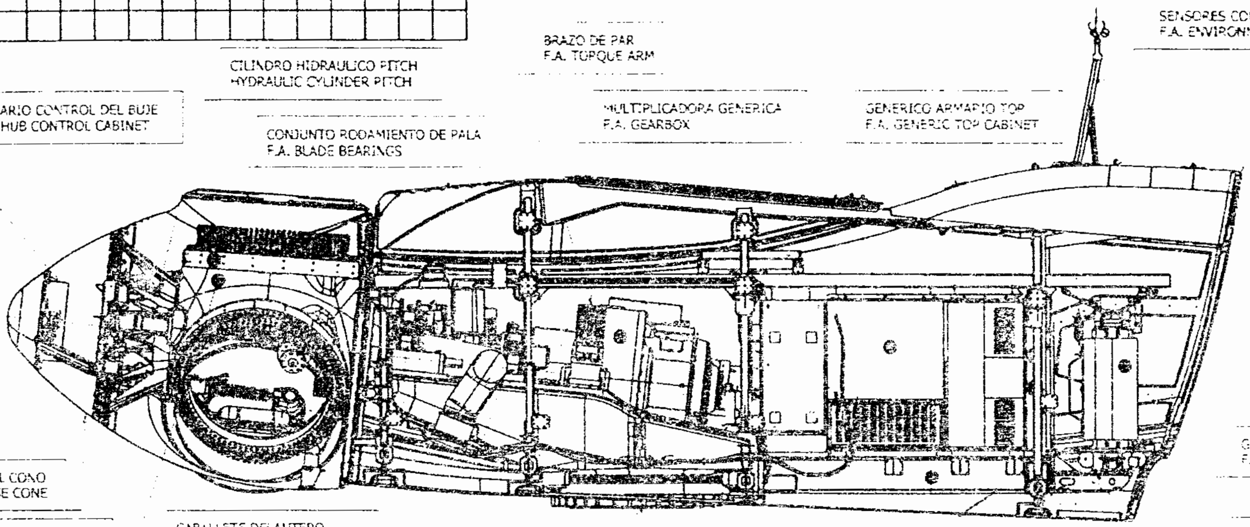
Blade type:	Pre-impregnated GFRP and CFRP Gamesa 47.5 m
Gear box type:	GE2000PL G9N 50Hz and 60Hz Planetary/helical gear (3 stages) 1:106.80@50Hz 1:127.19@60Hz
Generator type:	Cantarey Reinosa S.A. CR 20 2040 kW@50Hz 2070 kW@60Hz
Tower type:	Tubular Steel Tower

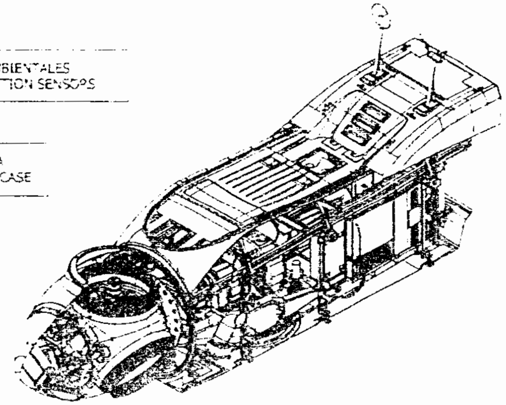
Service lift:	Not present
Crane:	Vicinay-Cemvisa, ABK 201 – 800 kg



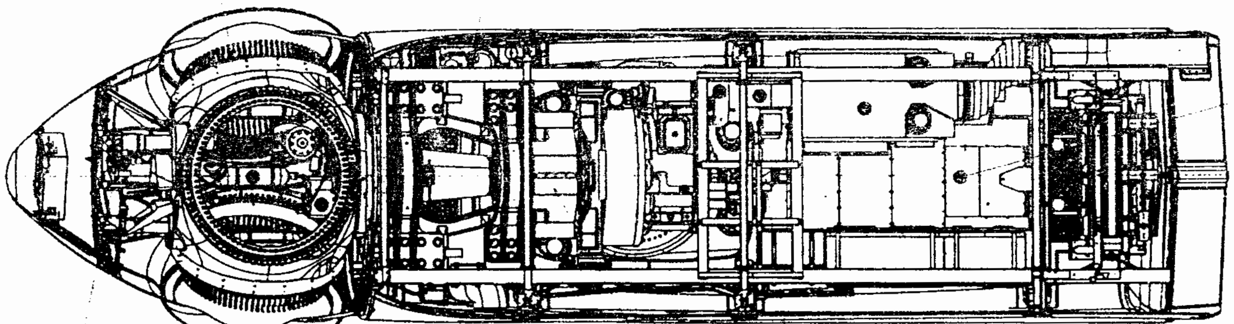
TORRE ACERO 120m
STEEL TOWER 120m
TORRE ACERO 100m
STEEL TOWER 100m
TORRE ACERO 75m
STEEL TOWER 75m
G97
LAYOUT AEROGENERADOR GAMESA 2.0 MW
GAMESA 2.0 MW WINDTURBINE
GD092978
R3
Gamesa

	GCT					GD167513





VISTA 3D
3D VIEW



HOJA 1	LAYOUT COMPONENTES PRINCIPALES
SHEET 1	MAIN COMPONENTS LAYOUT
HOJA 2	DIMENSIONES GENERALES VERSION HT
SHEET 2	HT VERSION MAIN DIMENSIONS
HOJA 3	DIMENSIONES GENERALES VERSION ST/LT
SHEET 3	ST/LT VERSION MAIN DIMENSIONS

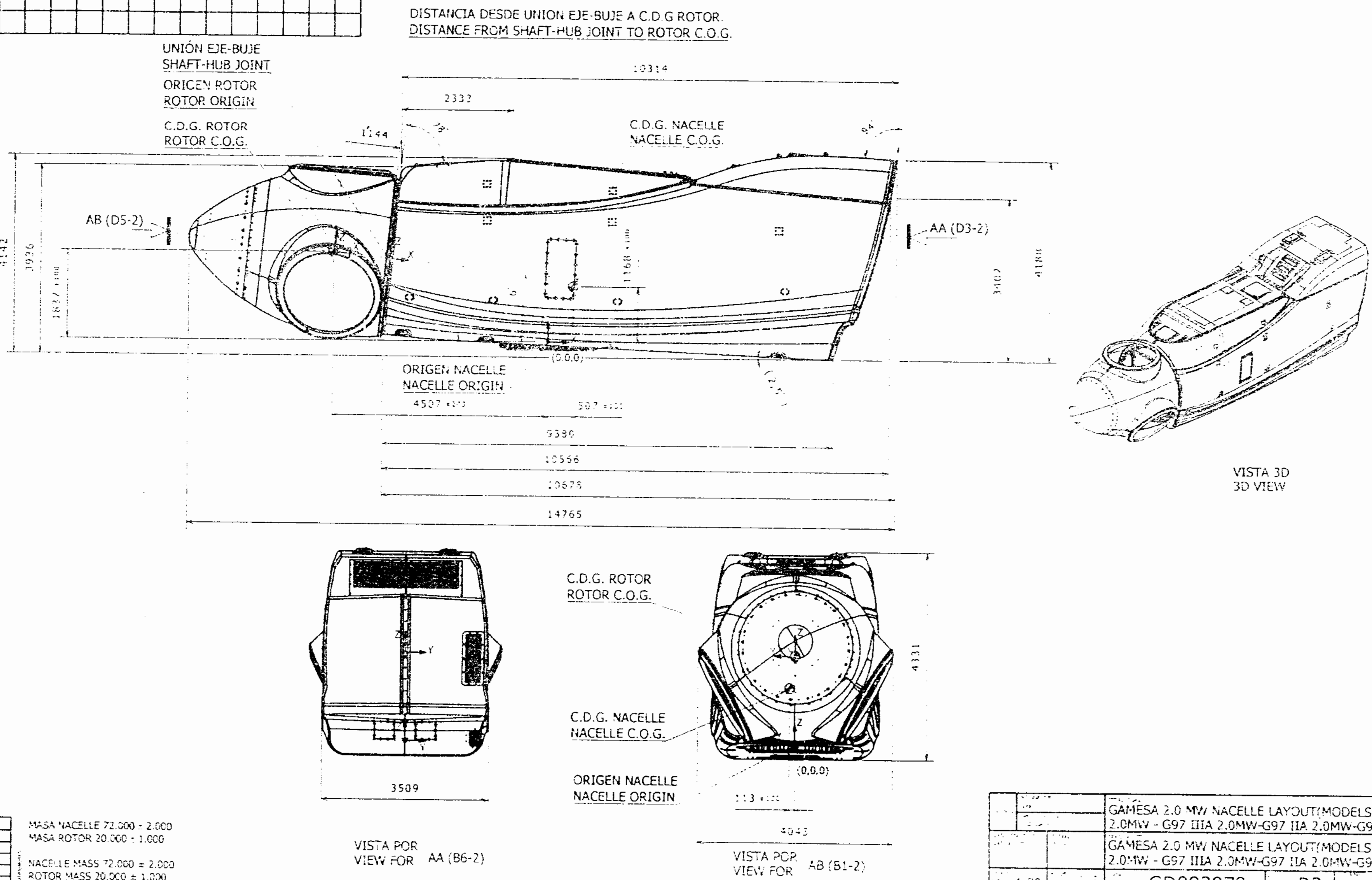
GAMESA 2.0 MW NACELLE LAYOUT(MODELS G87 S 2.0MW - G97 IIIA 2.0MW-G97 IIA 2.0MW-G90 IA)

GAMESA 2.0 MW NACELLE LAYOUT(MODELS G87 S 2.0MW - G97 IIIA 2.0MW-G97 IIA 2.0MW-G90 IA)

1:60	GD092979	R3	A3

	ELI	05.04.13
	HOC	05.04.13
	AME	08.04.13
	IEZ	05.04.13

Gamesa



MASA NACELLE 72.000 ± 2.000
MASA ROTOR 20.000 ± 1.000

NACELLE MASS 72.000 ± 2.000
ROTOR MASS 20.000 ± 1.000

GD167513

GAMESA 2.0 MW NACELLE LAYOUT(MODELS G87 S 2.0MW - G97 IIIA 2.0MW-G97 IIA 2.0MW-G90 IA)

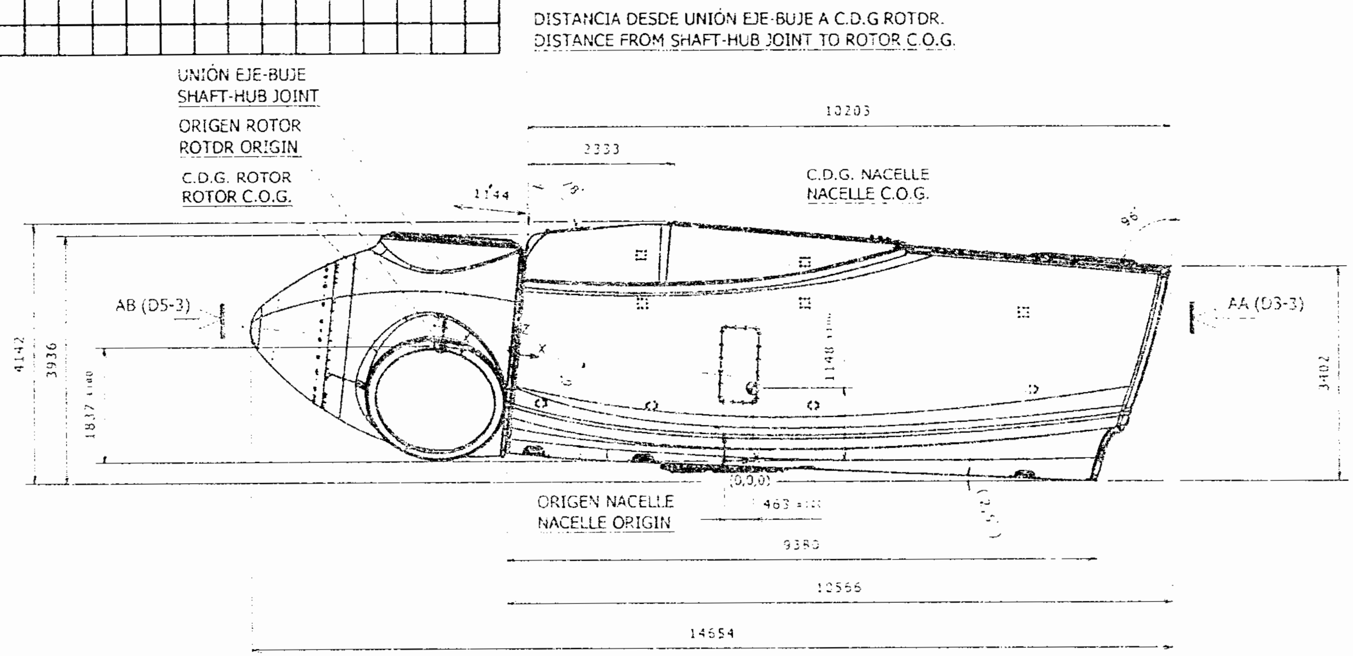
GAMESA 2.0 MW NACELLE LAYOUT(MODELS G87 S 2.0MW - G97 IIIA 2.0MW-G97 IIA 2.0MW-G90 IA)

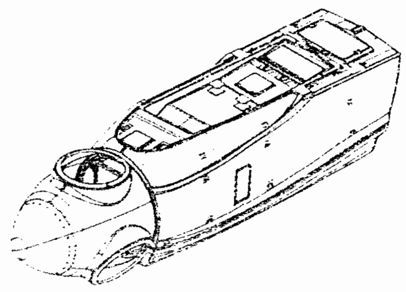
1:80 | GD092979 | R2 | A3

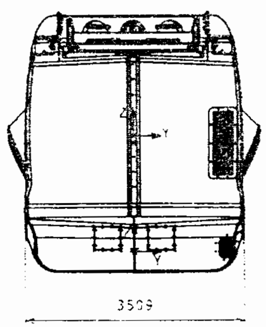
ELI	05.04.13
HDC	05.04.13
AME	08.04.13
JEC	08.04.13

Gamesa

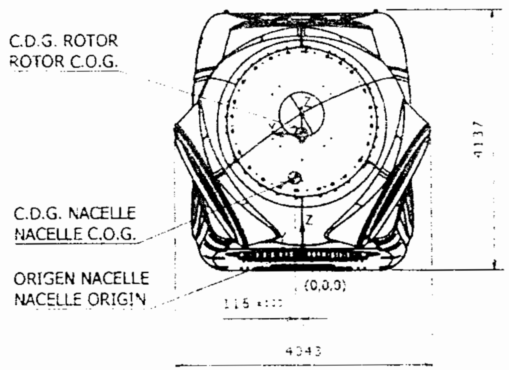
GCT | GD167513







VISTA POR
VIEW FOR
AA (B6-3)



VISTA POR
VIEW FOR
AB (B1-3)

MASA NACELLE 71.500 ± 2.000
MASA ROTOR 20.000 ± 1.000

NACELLE MASS 71.500 ± 2.000
ROTOR MASS 20.000 ± 1.000

ELI		05.04.13
HDC		05.04.13
AME		08.04.13
JEC		08.04.13

GAMESA 2.0 MW NACELLE LAYOUT(MODELS G87 S 2.0MW - G97 IIIA 2.0MW-G97 IIA 2.0MW-G90 IA)

GAMESA 2.0 MW NACELLE LAYOUT(MODELS G87 S 2.0MW - G97 IIIA 2.0MW-G97 IIA 2.0MW-G90 IA)

1:80	GD092979	R2	A3 / 3 : 3

Gamesa

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RECORD OF CHANGES

Rev.	Date	Author	Description
0	13/03/12	PSEGERS	Original version (Mark I)
1	10/08/12	PSEGERS	Update noise level table
2	23/10/12	PSEGERS	Update noise level table step
3	02/05/13	DSUN	Power curve for density 1.27kg/m^-3 corrected
4	25/10/2013	EMATA	Table of validity ranges of power curves added and paragraph of section 4 changed.
5	27/02/2014	EMATA	H=125m and H=80m towers added.

1 AIM

This document presents the power curves and noise emission levels for the WT G114 IIIA 2.0MW wind turbine.

2 SCOPE

The values shown in this document are applicable to all the existing configurations for the WT G114 IIIA 2.0MW, for standard operation mode and according to tower height. Tonality is not considered.

3 DEFINITIONS AND ACRONYMS

- **WT**: Wind turbine.
- **Power (P):** Expressed in kW, this is the electric power obtained at the generator terminals without considering the losses in the transformer or high voltage cables of the wind turbine, or the occasional power consumption which may exist in the same to supply a component. Averaged every 10 minutes.
- **Wind speed (W_S.):** Expressed in m/s, it is the horizontal wind component value at the height of the hub averaged every 10 minutes.
- **Power curve (CdP):** Represents the change in the P in accordance with the W_S for the different WT operating modes.
- **Annual Output / Annual Energy Production (AEP)**: Expressed in [MWh], it is the total electrical energy produced in a WT during a one-year period, in accordance with a given CdP and a given wind distribution.
- **Wind distribution:** the Weibull distribution is used for different K-distribution parameters and for annual average wind speed values (W_{ave}).
- **Wind speed W_{10} [m/s]:** The wind speed value, measured at 10m above ground level.
- **Tower height (H):** expressed in meters, is the height of the rotor centre above ground level.
- **Power coefficient:** C_p
- **Thrust coefficient:** C_T
- **Noise level:** The expected sound power level values, expressed in dB(A), represent the sound power that the WT emits at the height of the hub for a given wind speed. In accordance with the IEC standard, the wind speed value (W10) 10 m from the ground is used.

  The noise levels shown in this document are average expected values, called Lw in IEC-61400-14. To obtain the Lwd value, as defined in IEC-61400-14, an increase of 2 dB(A) shall be considered over said Lw values. This increase depends on the typical deviation of the samples being considered, and since no noise measurements exist for this turbine, the same values obtained for G90 are used in this document.
- **dB(A):** an A type frequency filter is applied, in accordance with the IEC standard.

4 DESCRIPTION

When not specified otherwise, data in following sections is calculated using the parameters from Table 1. All power curve and annual energy production values in this document are subject to the validity ranges presented in Table 2.

Rated Power	2.0 MW
Frequency	50 Hz/60Hz
Rotor Diameter	114 m
Angle of blade tip	Pitch control regulation
Air density	1.225 kg/m^3

Table 1: Calculation parameter values for the G114 IIIA 2.0MW power curve.

Wind Shear (10min average)	≤ 0.3
Turbulence intensity Ti [%] for bin i	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [º]	-2º ≤ β ≤ +2º
Grid frequency [Hz]	± 0.5 Hz

Table 2 Validity ranges of Power Curves for the G114 2.0MW CIIIA wind turbine power curve.

5 RESULTS

5.1 STANDARD POWER CURVES

Table 3 shows the electrical power [kW] in function of the horizontal wind speed at hub height W_S [m/s] for different air densities [kg/m^3].

P [kW]	Density [kg/m^3]												
Ws [m/s]	1.225	0.94	0.97	1.00	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3	32	21	22	23	24	26	27	28	29	30	31	32	33
4	146	104	109	113	118	122	126	131	135	140	144	148	153
5	342	254	263	273	282	291	300	309	319	328	337	346	355
6	621	469	485	501	517	533	549	565	581	597	613	629	645
7	1008	764	790	815	841	866	892	918	943	969	995	1021	1046
8	1486	1159	1196	1233	1270	1305	1340	1374	1408	1440	1471	1501	1530
9	1836	1590	1626	1659	1689	1718	1744	1768	1789	1810	1828	1844	1859
10	1965	1867	1885	1900	1914	1925	1935	1944	1951	1957	1963	1968	1972
11	1994	1969	1974	1979	1982	1985	1987	1990	1991	1993	1994	1995	1996
12	1999	1994	1995	1996	1997	1997	1998	1998	1999	1999	1999	1999	1999
13	2000	1999	1999	1999	1999	2000	2000	2000	2000	2000	2000	2000	2000
14	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
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19	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
20	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
21	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
22	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906
23	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681
24	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455
25	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230

Table 3 Electric power [KW] of the G114 IIIA 2.0MW wind turbine calculated in function of wind speed at hub height Ws [m/s], for different air densities [kg/m^3]. (*ref: 20120606G114AERPC*)

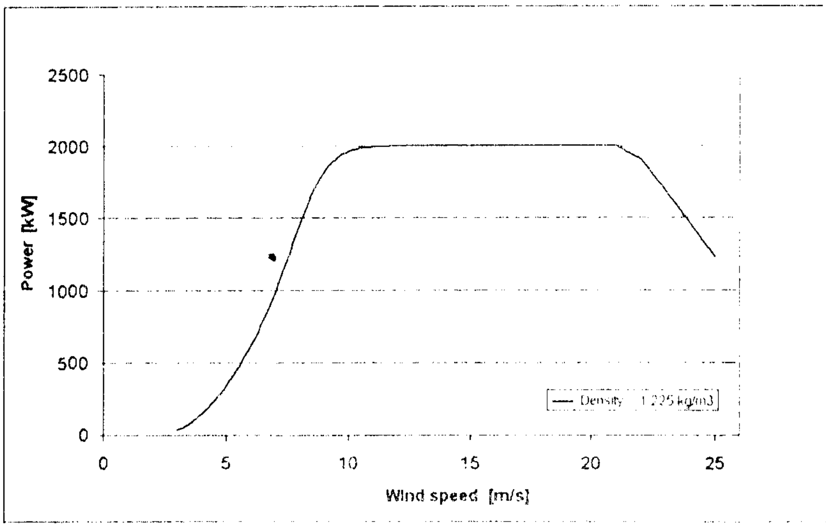


Figure 1 Power curve of the G114 IIIA 2.0MW wind turbine for an air density equal to 1.225 [kg/ m^3].
(*ref: 20120606G114AERPC*)

5.2 ANNUAL ENERGY PRODUCTION

Table 4 shows the annual output [MWh] for the G114 IIIA 2.0MW wind turbine for different Weibull K-distribution parameter values and annual average wind speeds W_{ave} [m/s]. The values are calculated for 1.225 kg/m^3 standard density and 10% turbulence intensity.

P [MWh]		*W_{ave} [m/s]*				
		5.5	*6*	*6.5*	*7*	*7.5*
Weibull K	*1.5*	5756	6520	7219	7848	8406
	2	5769	6751	7567	8507	9269
	2.5	5618	6767	7854	8856	9763

Table 4: Annual energy production [MWh] of the WT G114 IIIA 2.0MW calculated in function of W_{ave} [m/s].
(*ref: 20120606G114AERPC*)

5.3 CP AND CT CURVES

Table 5 shows the CP and CT values for the G114 IIIA 2.0MW wind turbine.

W_S [m/s]	CP	CT
3	0.187	0.934
4	0.366	0.861
5	0.437	0.834
6	0.460	0.824
7	0.470	0.822
8	0.464	0.778
9	0.403	0.621
10	0.314	0.444
11	0.240	0.320
12	0.185	0.240
13	0.146	0.187
14	0.117	0.149
15	0.095	0.122
16	0.078	0.101
17	0.065	0.086
18	0.055	0.073
19	0.047	0.064
20	0.040	0.057
21	0.035	0.048
22	0.029	0.041
23	0.022	0.033
24	0.017	0.028
25	0.013	0.023

Table 5: C_P and C_T values for the G114 IIIA 2.0MW wind turbine.
(ref: 20120606G114AERPC)

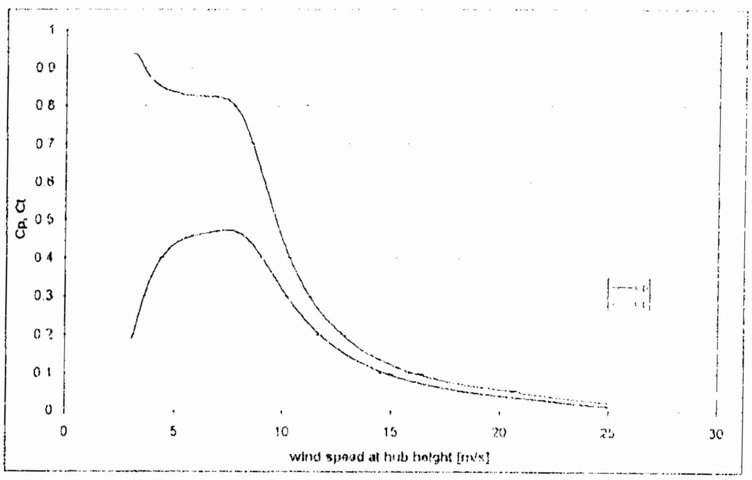


Figure 2 C_P and C_T curves of the G114 IIIA 2.0MW wind turbine.

5.4 NOISE LEVELS

Estimate of aeroacoustic noise emitted by the rotor of the G114 IIIA 2.0MW wind turbine, simulated for different tower heights (H) and wind speeds at 10m above ground level (W_{10}).

Table 6 includes the numerical values for the estimated Lw noise level in dB(A) for the different wind speeds, from the start-up speed, 3m/s.

	H = 80m		H = 93m		H = 125m	
W_{10}	W_S	SPL	W_S	SPL	W_S	SPL
[m/s]	[m/s]	[dB(A)]	[m/s]	[dB(A)]	[m/s]	[dB(A)]
3	4.2	95.8	4.3	95.3	4.5	95.8
3.5	4.9	95.8	5	95.8	5.2	95.8
4	5.6	96.3	5.7	96.8	6.0	98.0
4.5	6.3	99.0	6.4	99.5	6.7	100.6
5	7.0	101.4	7.1	101.9	7.5	103.0
5.5	7.7	103.6	7.9	104.1	8.2	105.2
6	8.4	105.6	8.6	106.0	9.0	106.0
6.5	9.1	106.0	9.3	106.0	9.7	106.0
7	9.8	106.0	10	106.0	10.5	106.0
7.5	10.5	106.0	10.7	106.0	11.2	106.0
8	11.2	106.0	11.4	106.0	12.0	106.0
8.5	11.9	106.0	12.1	106.0	12.7	106.0
9	12.6	106.0	12.9	106.0	13.5	106.0
9.5	13.2	106.0	13.6	106.0	14.2	106.0
10	13.9	106.0	14.3	106.0	15.0	106.0

Table 6: Noise levels of the G114 IIIA 2.0MW wind turbine for different H [m], W_{10} [m/s] and W_S [m/s]. (ref: *20140227G114AERPCNLEV*)

Gamesa	GENERAL CHARACTERISTICS MANUAL	Code: GD157870-en	Rev: 4
		Date: 27/11/13	Page 1 of 27
		Approval process:	Electronic: PDM Flow + Translation
Title: **Characteristics and general description of the G114-IIIA 2.0 MW and G114 IIA-2.0 MW wind turbines**		Author:	MDANDRES
		Revised:	BAJ
		Approved:	IRS

SCOPE

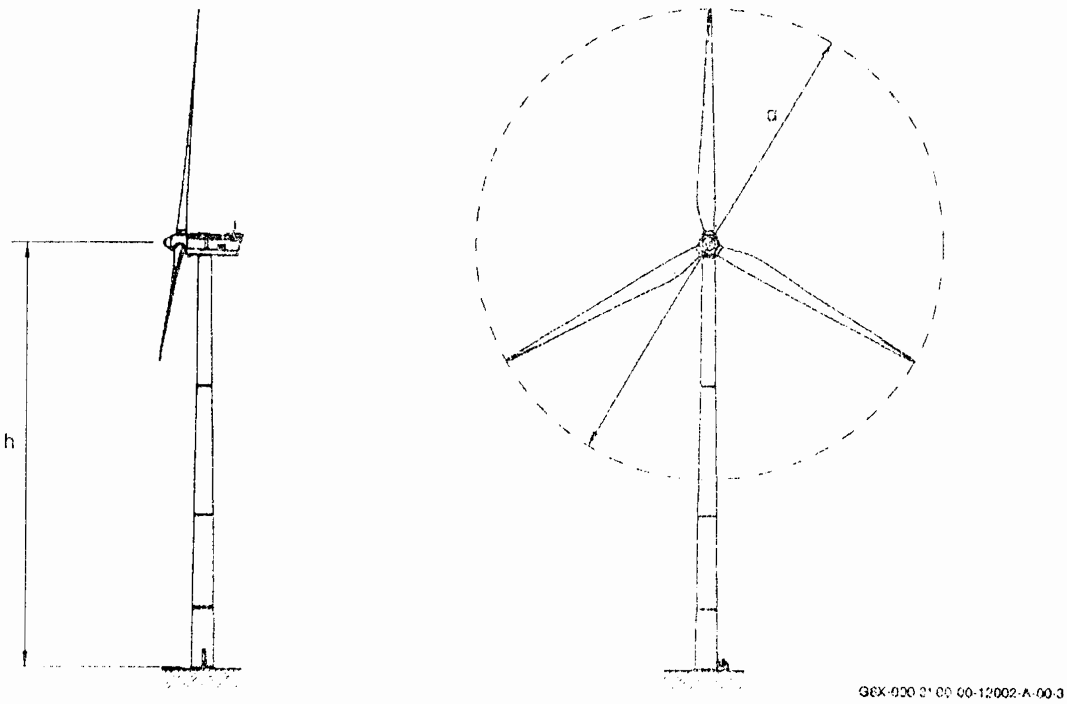
Wind turbines of the **Gamesa-2.0 MW** platform (**G114-IIIA** and **G114 IIA** models).

RECORD OF CHANGES

Rev.	Date	Author	Description
00	28/06/12	MDANDRES	Initial version
01	12/03/13	MDANDRES	Change of name in Gamesa product Modification of technical data
02	26/06/13	MDANDRES	Dimensions of the nacelle are included
03	11/07/13	MDANDRES	Modification of point 5.5: approximate weights
04	27/11/13	MDANDRES	Included G114-IIA 2.0 Mw wind turbine Section 5 is extended. Technical data Design standards are included

INDEX

1 DESCRIPTION OF THE GAMESA 2.0 MW (G114-IIIA AND G114-IIA MODELS) WIND TURBINES



Position	Name
h	Hub height
d	Rotor diameter

Figure 1: Complete wind turbine

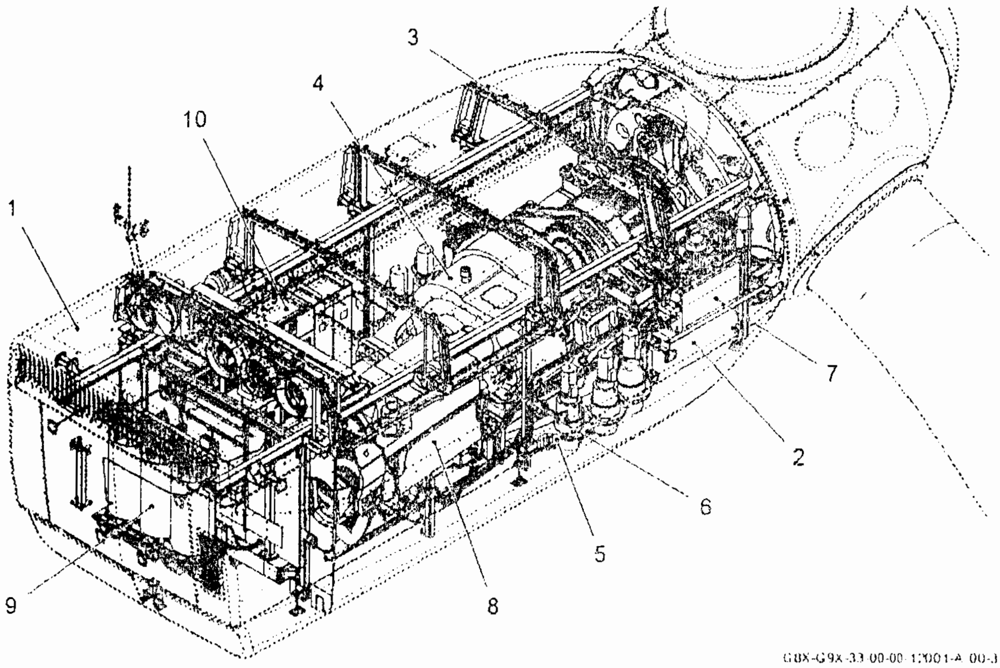
The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are of the three-bladed wind-facing rotor type with a rated power of 2 MW.

Its rotor diameter is 114m (position d in Figure 1) and hub height of 80m, 93m and 125m (position h in Figure 1).

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are regulated by an independent pitch control system in each blade and has an active yaw system. The control system allows the wind turbine to be operated at variable speed, maximizing the power produced at all times and minimizing the loads and noise.

A description is given below of the main components of the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines.

1.1 NACELLE DESCRIPTION



Position	Name
1	Cover
2	Frame
3	Main shaft
4	Gearbox
5	Yaw system
6	Mechanical brake
7	Hydraulic unit
8	Generator
9	Transformer
10	Electrical cabinets

Figure 2: Main components of the nacelle

1.1.1 Cover

The cover protects the wind turbine components within the nacelle from exposure to meteorological events and external environmental conditions. It is made of composite resin and reinforced with fiberglass.

Within the cover there is sufficient space in order to carry out wind turbine maintenance operations. The cover has three hatchways:

- Hatchway giving access to the nacelle from the tower, located on the nacelle floor.
- Hatchway giving access to the interior of the cone/hub, located in the front.

- Crane operating hatchway, located on the floor of the rear section.

There are two skylights on the roof allowing sunlight to enter during the day and providing additional ventilation and access to the exterior, where the wind measuring instruments and the lightning rod are located.

The revolving parts are duly protected to guarantee the safety of maintenance personnel.

The nacelle is equipped with an 1000 kg service crane inside.

1.1.2 Frame

The frame of the **Gamesa 2.0 MW (G114-IIIA** and **G114-IIA** models) wind turbines has been designed using the criteria of mechanical simplicity along with the appropriate robustness to be able to support the elements of the nacelle and transmit the loads to the tower. These loads are transmitted via the yaw system bearing.

The frame is divided into two parts:

- Front frame: Cast iron bedplate to which the main shaft supports are fastened, where the gearbox torque arms and the yaw ring react.
- Rear frame: Mechanically-welded structure formed by two beams joined at the front and the back.

The frame is subjected to exhaustive ageing tests at the frame test bench, Gamesa UPB, belonging to Gamesa. These tests mainly involve extreme load cycles which reproduce, in an accelerated manner, the stresses and forces to which the frame will be subjected throughout its lifetime. This guarantees and improves the reliability of the component, validating its correct design. In addition, the test results are used for feedback and to correlate the simulation models of the frames developed by Gamesa, guaranteeing continuous improvement and greater precision of the designs.

1.1.3 Main shaft

The motor torque produced by the wind on the rotor is transmitted to the gearbox through the main shaft. The shaft is attached to the hub with a screwed-on flange and is supported on 2 bearings housed in cast-iron supports. The connection to the low speed input on the gearbox is made with a conical tightening collar that transmits the torque by friction.

The shaft is made from forged steel and has a longitudinal central opening to house the hydraulic hoses and control cables for the pitch control system.

The support of the main shaft on 2 bearings offers significant structural advantages. All the stress from the rotor is transmitted to the front frame, except for the torque, which is used downstream in the generator to produce electric power. This guarantees that the gearbox only transmits this torque and that the bending, axial and shear stress goes directly to the bed plate. In addition, the system makes maintenance easier, as the gearbox can be removed without having to dismount the main shaft or the rotor.

1.1.4 Gearbox

This transmits the main shaft's power to the generator. The gearbox consists of 3 combined stages, a planetary gear and two parallel shaft gears. The gearbox's cogs are designed for maximum efficiency and low noise and vibration levels. As a result of the gear ratio, part of the input torque is absorbed by the reaction arms. These symmetrical reaction arms fix the gearbox to the frame by means of shock absorbers which minimize vibration transmission. The high-speed shaft is linked to the generator via a flexible coupling with torque limiter that prevents excess loads to the transmission chain.

Due to the modular design of the drive train, the gearbox weight is supported by the main shaft, while the gear tie rods react only to the torque, preventing the gearbox from rotating and ensuring the absence of unwanted loads.

The gearbox has a main lubrication system with a filtering system associated with the high-speed shaft. There is a secondary electrical filter which permits the cleaning of the oil to 3 µm, thus reducing the potential number of breakdowns, together with a third extra cooling circuit.

The gearbox's various components and operating parameters are monitored by different sensors, of both the control system and the **Gamesa PMS** predictive maintenance system.

All the gearboxes are subjected to load tests at rated power during their manufacture. These tests reduce the probabilities of failure during operation and guarantee product quality.

1.1.5 Gamesa Active Yaw system

The **Gamesa Active Yaw** system enables the nacelle to rotate around the axis of the tower. This is an active system and has six yaw gears electrically operated by the wind turbine control system according to the information received from the anemometers and wind vanes mounted on the upper section of the nacelle. The yaw system motors turn the gears of the yaw system, which engage with the cogs of the yaw ring, constituted of one piece and mounted in the upper part of the tower, producing the relative rotation between the nacelle and the tower.

A friction bearing is used to obtain an adequate retention torque in order to control yaw rotation. In addition, the hydraulic brake, consisting of 6 active clamps, provides a greater retention torque to fix the wind turbine. The combined action of these 2 systems prevents fatigue and possible damage to the gears, thus ensuring stable and controlled yaw.

The ring is divided into eight sectors to make it easier to repair possible damage to the teeth.

As with the frame, the **Gamesa Active Yaw** system is subjected to accelerated life cycle and ageing tests at the **Gamesa UPB** test bench. These tests consist mainly in orientation cycles with operating loads compressing the length of the durability or ageing tests in order to simulate the yaw system's service life. These tests guarantee and improve the reliability of the component, validating its correct design and providing feedback to the virtual models for subsequent redesign and improvements.

1.1.6 Brake system

The wind turbine primary brake is aerodynamic through the full-feathering blades. As the pitch control system is independent for each of the blades, it provides safety in the event of failure in any of them.

The mechanical brake consists of a hydraulically activated disk brake, which is mounted on the high-speed shaft of the gearbox This mechanical brake is only used as a parking brake or if an emergency push-button is applied.

1.1.7 Hydraulic system

The hydraulic system supplies pressurized oil to the 3 independent pitch control actuators, the high-speed shaft mechanical brake and the yaw system brake system. It includes a *fail-safe* system which guarantees the required oil pressure and flow levels in the event of absence of current to activate the blade pitch control cylinders, the disc brake and the yaw system brake, switching the wind turbine to safe mode.

1.1.8 Generator

The generator is an asynchronous double-feed unit with 4 poles, coil rotor and slip rings. It is highly efficient and is cooled by an air-air exchanger. The control system permits operation at variable speeds using the rotor intensity frequency control.

The characteristics and functions introduced by this generator are:

- Synchronous behavior toward the grid.
- Optimal operation at any wind speed, maximizing production and minimizing loads and noise, thanks to variable speed operation.
- Control of active and reactive power via control of amplitude and rotor current phase.

- Smooth connection and disconnection from the electrical grid.

The generator is protected against short-circuits and overloads. The temperature is monitored continuously via probes at points on the stator, bearings and the slip ring box.

1.1.9 Transformer

The transformer is three-phase, dry encapsulated, with different output voltage options between 6.6kV and 35kV, different apparent power ranges and is particularly designed for wind energy applications. It is located in the rear section of the nacelle in a compartment separated by a metal wall which provides thermal and electrical insulation from the rest of the nacelle components.

As it is a dry type unit, the risk of fire is minimized. In addition, the transformer includes all the necessary guards against damage, including arc detectors and protection fuses.

The transformer's location in the nacelle prevents electrical losses thanks to the reduced length of the low-voltage cables, and also reduces visual impact.

1.1.10 Electrical cabinets for control and power

The electrical system's hardware is distributed into three cabinets:

1. **TOP** electrical cabinet located in the nacelle. This electrical cabinet, in turn, is divided into three parts:
    - Control section: responsible for the tasks governed by the nacelle, such as monitoring wind, changing pitch angle, yaw, interior temperature control, etc.
    - Frequency converter: this is responsible for controlling the power and managing the connection and disconnection of the generator to/from the grid.
    - Protections and busbar section: the output of the power produced, with the necessary electrical safeguards, is located here.

2. **GROUND** electrical cabinet located at the tower's base. From the GROUND electrical cabinet's touch screen it is possible to check the wind turbine's different operating parameters, stop and start the wind turbine, test the various subsystems, etc. A touch screen can also be connected to the TOP electrical cabinet in order to perform these tasks.

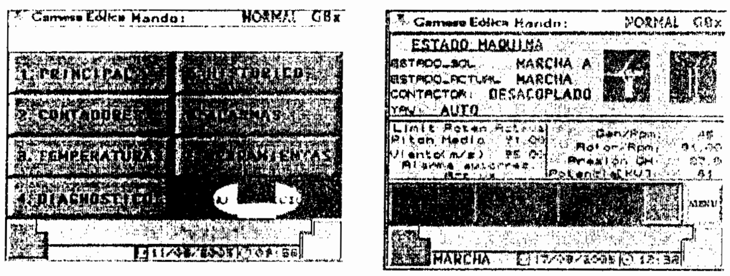


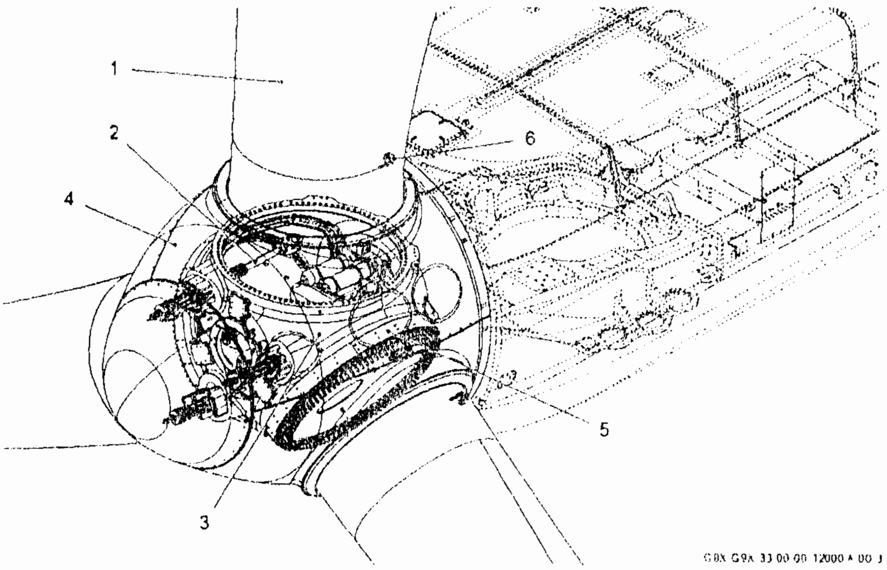
Figure 3: Examples of touch screen

3. **HUB** electrical cabinet located in the revolving part of the wind turbine. Primarily responsible for activating the pitch control system cylinders.

1.2 ROTOR

The rotor of the **Gamesa 2.0 MW (G114-IIIA** and **G114-IIA** models) wind turbines consists of three blades joined to a hub by blade bearings. The hub has a conical angle of 2º in the flanges attaching it to the blades, which keeps the tips of the blades away from the tower.

This wind turbine's rotor diameter is 114m.



Position	Name
1	Blade
2	Pitch control system
3	Hub
4	Cone
5	Blade bearing
6	Lightning transmission system

Figure 4 : Main rotor components

1.2.1 Blades

The blades of the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are manufactured in a matrix composite material reinforced with fiberglass through resin infusion technology, which provides the necessary rigidity without increasing blade weight. The blades have pitch control along the whole length of the blade, thus maximizing energy production and reducing loads and noise.

Blade length is 56m and an approximate weight of 13t. The distance from the blade root to the hub center is 1.230m.

The structure of each blade consists of two shells attached to a structural beam or internal rails. The blade is designed to fulfill two basic functions: structural and aerodynamic.

In addition, the blade is designed taking into account both the manufacturing method used and the materials chosen, in order to ensure the necessary safety margins.

The blades are equipped with a lightning protection system which conducts the lightning from the receptor to the blade root, where it is transmitted to the wind turbine to be discharged into the ground.

Additionally, the blades come with the necessary drains to prevent internal water retention, which can cause imbalance or structural damage due to water vaporization upon the impact of lightning.

1.2.2 Blade bearing

The blade bearings are the interface between the blade and the hub and permit the pitch control movement.

The blade is attached to the inner race of the blade bearing by means of tensioned bolts to facilitate inspection and removal.

1.2.3 Hub

The hub is manufactured in nodular cast iron. It is attached to the outer race of the three blade bearings and to the main shaft with bolted joints. It has an opening at the front to permit access to the interior for inspection and maintenance of the pitch control system's hydraulics and the tightening torque of the blades' bolts.

1.2.4 Cone

The cone protects the hub and the blade bearings from the atmosphere. The cone is bolted to the front of the hub and is designed to allow access to the hub for maintenance tasks.

1.2.5 Pitch control hydraulic system

This consists of independent hydraulic actuators for each blade that provide a rotation capacity of between –5º and 87º and a system of accumulators which ensure feathering in the event of an emergency.

The pitch control system acts according to the following setting:

- When the wind speed in less than rated, a pitch angle is selected that maximizes the electrical power obtained for each wind speed.
- When wind speed is higher than nominal, the pitch angle used provides rated power to the wind turbine.

In addition, it controls the activation of the aerodynamic brake in the event of an emergency, switching the wind turbine to a safe mode.

The hydraulic system acts more quickly than other systems. Due to the hydraulic accumulator system, it does not require batteries to operate, thus increasing its reliability in the event of an emergency.

1.3 TOWER AND FOUNDATION

1.3.1 Tower

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines tower is a structure of tubular steel, in a truncated conical shape, divided into three, four or five sections depending on the tower height:

- 80 m (steel structure): three sections.
- 93 m (steel structure): four sections.
- 125 m (steel structure): five sections.

It is supplied with the corresponding platforms, ladders and emergency lighting.

Gamesa offers a cable guided elevator as standard to make maintenance of the wind turbine easier.

1.3.2 Foundation

The standard foundations are of the slab type, made of concrete reinforced with steel. They have been designed using calculations based on the certified loads of the wind turbine and considering standard ground.

Where the hypothetical values used vary, the established standard values are useless and the foundations must be recalculated. Therefore, for each site, the ground characteristics and wind data should be reviewed in order to ensure that the most suitable foundation is selected.

1.4 CONTROL SYSTEM

The wind turbine functions are controlled in real time by a PLC-based system (Programable Logic Controller). The control system is made up of control and monitoring algorithms.

A) Control system

The control system selects the correct shaft torque values, the blade pitch angle and the power settings. These are modified at all times depending upon the wind speed reaching the wind turbine, thus guaranteeing safe and reliable operating in all wind conditions.

The main advantages of the regulation system for the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are:

1. Maximization of energy production.
2. Limitation of mechanical loads.
3. Aerodynamic noise reduction.
4. High energy quality.

A-1) Pitch control adjustment

At wind speeds above the rated speed, the control system and pitch control system keep the power at its rated value. At wind speeds below the nominal speed, the variable pitch control and control systems optimize energy production by selecting the optimum combination of rotor rotation speed and pitch angle.

A-2) Power control

The power control system ensures that the wind turbine's rotation speed and motor torque always supply stable electric power to the grid.

The power control system acts on a set of electrical systems consisting of a doubly-fed generator with wound rotor and slip rings, a 4-quadrant IGBT-based converter, contactors and electrical safeguards and software. Electrically, the generator-converter unit is equivalent to a synchronous generator and therefore it ensures optimum coupling to the electrical grid with smooth connection and disconnection processes.

The generator-converter unit is capable of working at variable speeds to optimize operation and to maximize the power generated for each wind speed. In addition, it makes it possible to manage the reactive power evacuated in collaboration with the **Gamesa Windnet®** remote control system.

B) Monitoring system

The monitoring system continuously checks the state of the different sensors and internal parameters:

- Environmental conditions: wind speed and direction or ambient temperature.
- Internal parameters of the various components, such as temperatures, oil levels and pressures, vibrations, mid-voltage cable winding, etc.
- Rotor state: rotation speed and pitch control position.
- Grid situation: active and reactive energy generation, voltage, currents and frequency.

1.5 GAMESA PMS PREDICTIVE MAINTENANCE SYSTEM

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines includes the **Gamesa PMS** Predictive Maintenance System, developed by Gamesa, based on the analysis of vibrations, and optimized for use in wind turbines. The system can simultaneously manage and process information from up to 12 accelerometers located at strategic points on the wind turbine, such as the gearbox, the generator and the main shaft's front bearings.

The main characteristics of the **Gamesa PMS** are as follows:

- Continuous monitoring of the wind turbine's critical components.
- Signal processing and alarm detection capacity.
- Integrated with the PLC and **Gamesa WindNet® wind farm networks.**
- Easy maintenance.
- Low cost.

In general, the main purpose of a predictive maintenance system is the early detection of faults or wear in the main components of the wind turbine. The following are some of the important benefits of installing a system of this type:

- Reduction in major corrective actions required.
- Protection of other components of the wind turbine.
- Improvements in the wind turbine's useful life and operation.
- Reduction in dedicated maintenance resources.
- Access to markets with strict regulations, such as the *Germanischer Lloyds, DNV Business Assurance* certification.
- Reduction in insurance company rates.

1.6 GAMESA WINDNET® INTEGRATED MANAGEMENT SYSTEM FOR WIND FARMS

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines integrates into the **Gamesa WindNet®, supervisory, control and data acquisition system (SCADA)**, which allows the wind farm information to be accessed easily and intuitively through a browser.

The **Gamesa WindNet®** system is easy to configure and adapt to any wind farm layout, including those with a wide variety of wind turbine models. It can quickly and reliably link up any wind farm topology based on Ethernet network technology. It can also integrate wind farm installations such as electrical substations, reactive power equipment, capacitor banks, etc.

The **Gamesa WindNet®** system supports a wide variety of communications protocols used in wind farm systems, such as OPC DA, MODBUS and DNP3. Communication with Gamesa wind turbines is based on a robust and efficient proprietary protocol.

With this tool, the user can perform the following tasks at any time:

- Track and monitor the wind farm's equipment.
- Be informed about the energy production of each wind turbine in the wind farm.
- Monitor the alarms for the different elements of the wind farm in real time and display the alarm log.
- Send direct orders to the wind turbines (start, pause or switch to emergency mode) and substation.

- Analyze the evolution of variables over time in a simple manner, thanks to the trend history graphs: Gamesa Trend Viewer.
- Create production and availability reports: Gamesa Report Generator.
- Send status messages and alarms to a cell phone using SMS text messaging.
- Integrate the reactive power compensation equipment (STATCOM and SVC).
- Manage predictive maintenance with the integration of Gamesa PMS.
- Manage different user profiles, thus maintaining security and simplifying at the same time the application's daily use.

The user interface has been designed using accessibility, user-friendly and simplicity criteria. The information is displayed in graph form. There is also Web access to up-to-date information through any device with a browser and Internet connection.

The **Gamesa WindNet®** system offers different user, administrator, configuration, developer and maintenance profiles for access to the specific functions and information required for each user type, thus increasing security and simplifying the daily use of the application.

Optionally, a series of modules are available to add advanced functions to the **Gamesa WindNet®** system:

- Active power limitation module.
- Generated reactive power control module.
- Frequency regulation module.
- Generation of customized reports with Gamesa Information Manager, through the categorization of energy losses.
- Wake control module.
- Noise control module: **Gamesa NRS®**.
- Shade control module.
- Ice control module.

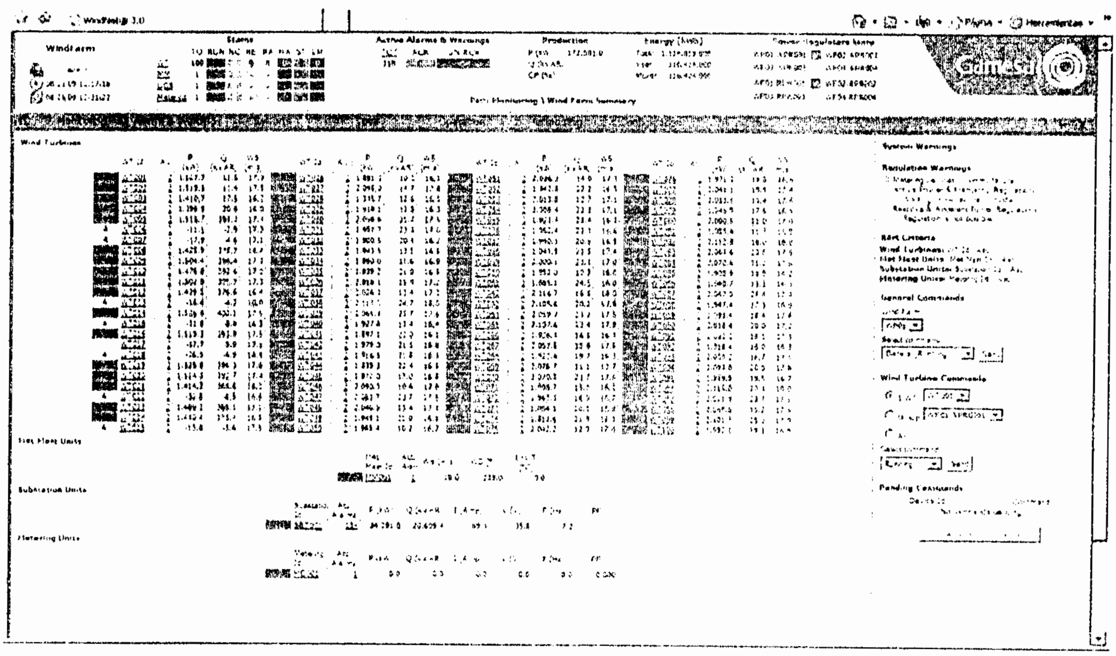


Figure 5: Example of a WindNet® screen accessed via the Web

1.7 SENSORS

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are fitted with various sensors that continuously monitor different parameters. It has sensors that capture signals external to the wind turbine, for example, the outside temperature or the wind speed and direction. Other sensors record the wind turbine's operating parameters, such as component temperatures, pressure levels, blade vibrations or positioning.

All of this information is recorded and analyzed in real time and fed into the monitoring and control functions of the control system.

1.8 LIGHTNING PROTECTION SYSTEM

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are protected against lightning by a transmission system that goes from the blade and nacelle receptors, passing through the cover, the frame and the tower to the foundation. This system prevents the passage of lightning through components which are sensitive to these discharges. The electrical system also has additional overvoltage protection.

All of these protection systems are designed to obtain a maximum protection in accordance with standard IEC 62305. IEC 61400 and IEC61024 are considered reference standards.

2 GRID CONNECTION AND SITE

2.1 GRID CONNECTION

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are available in versions capable of operating in 50 Hz and 60 Hz grids.

The wind turbine's transformer must be suitable for the grid's voltage. The voltage of the low-voltage grid must lie within the ± 10% range and the grid frequency must lie within the ± 3Hz range in both 50Hz and 60Hz grids.

The grounding system included in the civil engineering project has two concentric rings with a global impedance according to the requirements established in IEC 62305. The pass-through and contact currents must comply with standards IEC 60478-1 and IEC 61936-1. Local regulations shall prevail where these are more restrictive than the above international regulations.

The grid voltage specified for the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines is defined in section 4.6 of this document.

The power factor of the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines is between 0.95 capacitive and 0.95 inductive in the entire power range under the following conditions: ± 5% rated voltage for the corresponding temperature interval, as long as the transformer's apparent power is equal to or greater than 2,350 kVA. See special conditions for other transformer models.

2.2 ENVIRONMENTAL CONDITIONS

The standard version of the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines have been designed to operate at external ambient temperatures between -20°C and +30°C. There are wind turbine versions which are capable of withstanding more extreme ambient temperatures.

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines are capable of continuous operation at ambient relative humidity of 95%, and is capable of operating in conditions of 100% relative humidity for periods of time under 10% of operating time.

The degree of anti-corrosion protection of the various components of the Gamesa **2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbines, in accordance with standard ISO 12944-2, is shown in the following table:

COMPONENTS	**EXTERNAL**	**INTERIOR**
Tower	C5-I/H	C4/H
Nacelle-Rotor	C4/H or C5/H [1]	C2/H or C3/H [1]

Table 1. Degrees of protection against corrosion

[1] According to components.

Gamesa has product versions designed specially for corrosive environments.

2.3 WIND CONDITIONS

The annual wind distribution for a site is normally specified by a *Weibull* distribution. This distribution is described by scale factor A and form factor k. Factor A is proportional to the average wind speed and factor k defines the form of the distribution for different wind speeds. Turbulence intensity is the parameter that quantifies the instant variations in wind speed.

The design conditions of the **G114-IIIA 2.0 MW** wind turbine are indicated below:

Standard	**IEC - IIIA**
Average annual wind speed (m/s) [1]	7.5
Turbulence intensity I15 (%)	16
Reference 10-minute wind speed in 50 years (m/s).	37.5
Extreme wind speed in 50 years over a 3-second average (m/s)	52.5

Table 2. Design parameters for the G114-IIIA 2.0 MW wind turbine

*** Certification in accordance with design standard IEC61400-1 Ed.3.**

The design conditions of the **G114-IIA 2.0 MW** wind turbine are indicated below:

Standard	**IEC - IIA**
Average annual wind speed (m/s) [1]	8.5
Turbulence intensity I15 (%)	16
Reference 10-minute wind speed in 50 years (m/s).	42.5
Extreme wind speed in 50 years over a 3-second average (m/s)	59.5

Table 3. Design parameters for the G114-IIA 2.0 MW wind turbine

*** Certification in accordance with design standard IEC61400-1 Ed.3.**

2.4 VERIFICATION OF SITE CONDITIONS

As a general rule, the wind turbine may be installed in wind farms with a minimum distance of 5 rotor diameters between wind turbines facing the prevailing wind direction. If the wind turbines are located in rows, perpendicular to the direction of the prevailing wind, the distance between turbines should be a minimum of 2 rotor diameters. These criteria are subject to modification in certain conditions following a specific technical study for each case.

The wind turbines may be placed under different and varied weather conditions where the air density, turbulence intensity, average wind speed and the k form parameter are the main parameters to be considered. If the turbulence intensity is high, the loads on the wind turbine increase and the turbine life decreases. On the other hand, the loads decrease and the turbine life increases if the average wind speed or turbulence intensity or both are low. Therefore, wind turbines may be placed on sites with high turbulence intensity if the average wind speed is fairly low.

Turbulence intensity (I) is the quotient of the standard deviation of the wind speed from the average measured or estimated speed (See IEC 61400-13). Turbulence intensity I15 is used as a characteristic value for the 10-minute average wind speed of 15m/s.

On complex ground, the wind conditions are checked on the basis of measurements taken on site. In addition, the effect of the topography on the wind speed and shear, the turbulence intensity and the wind flow inclination on each wind turbine should be considered.

The supply of the required data is necessary in order to assess the main characteristics of the site:

- Ambient conditions of temperature, density, salinity, dust and/or sand concentration, etc.
- Wind measured on the site, as well as the topographic plans and the layout of the wind turbines at a scale that will enable the site characteristics to be assessed.
- Grid voltage and frequency and service voltage.
- Any other information required by Gamesa for the correct definition of the wind turbine to be installed.

3 DESIGN STANDARDS

The Gamesa-2.0 MW wind turbines (G114-IIIA and G114 IIA models) have been designed and validated using the following standards depending on the type of component:

3.1 WIND TURBINE

Standard	Description	Edition
Certification		
IEC 61400-1	Wind turbines - Design requirements	3
Design Validation & Testing		
IEC 61400-11	Acoustic noise measurement techniques	
IEC 61400-12	Power performance measurements of electricity producing wind turbines	
IEC 61400-13	Measurement of mechanical loads	
IEC 61400-21	Measurements ans assessment of power quality characteristics of grid connected wind turbines	
IEC 61400-22	Conformity testing and certification	

H & S [Health & Safety]		
EN 50308	Wind turbines – Protective measures – Requirements for design, operation and maintenance	2008
EN ISO 14122-1/2/3/4	Safety of machinery — Permanent means of access to machinery — Parts 1, 2, 3 & 4	2001
EN ISO 14738	Safety of machinery — Anthropometric requirements for the design of workstations at machinery	2008
EN ISO 61310-1/2/3	Safety of machinery — Indication, marking and actuation — Part 1, 2 & 3	2008
EN ISO 14121-1	Safety of machinery — Risk assessment — Part 1: Principles (ISO 14121-1:2007)	2007
EN 614-1/2	Safety of machinery — Ergonomic design principles — Parts 1 & 2	2009
EN ISO 12100-1/2	Safety of machinery — Basic concepts, general principles for design — Parts 1 & 2	2003
RMT [Reliability, Maintainability & Testability]		
IEC 60812	Analysis techniques for system reliability - Procedure for FMEA	2006
SAE JA1011	Evaluation Criteria for Reliability Centered Maintenance Processes	2009
NAVAIR 00-25-403	Guideline for the RCM Process	2005

3.2 STRUCTURAL DESIGN

Standard	Description	Edition
Common		
EN 1991 Eurocode 1.1-4	Actions on structures – Part 1-4: General actions – Wind actions	April 2005
EN 1993 Eurocode 3.1-1/6/8/9/10	Design of steel structures	2005
IEC 61400-1	Wind turbines - Design requirements	2005
VDI 2230 Part 1	Systematic calculation of high duty bolted joints - Joints with one cylindrical bolt.	2003
Tower		
CEB-FIB Mode	CEB-FIB Mode Code 1990	1990
DIBt	Ritchlinie für windenergieanlagen - Einwirkungen und Standsicherheitsnachweise für Turm und Gründung, 4th edition	October 2012
EN 14399	High-strength structural bolting assemblies for preloading	March 2005
EN 1992 Eurocode 2.1-1	Design of concrete structures – Part 1-1: General rules and rules for buildings	December 2004
En 1998 Eurocode 8	Design of structures for earthquake resistance	May 2005
ISO 898-1	Mechanical properties of fasterners made of carbon steel and alloy steel	January 2013

VDI 2230	Systematic calculation of high duty bolted joints - Joints with one cylindrical bolt	May 2005
Nacelle and Hub		
EN 13001-2-3	Cranes. General design. Limit states and proof of competence of wire ropes in reeving systems	
EN 13135	Cranes. Safety. Design. Requirements for equipment.	
EN 14492-1/2	Cranes – Power driven winches and hoists – Parts 1 & 2	2006
Directiva 97/23/EC	Directive 97/23/EC: Pressure equipment	

3.3 MECHANICAL COMPONENTS

Standard	Description	Edition
Blades		
DEFU R25	Lightning protection of wind turbines, Recommendation 25	
DNV OS J102	Design and Manufacturing of Wind turbines blades, offshore and onshore wind turbines	2006-10
IEC 1024-1	Protection of structures against lightning – General Principles	2007-11
IEC 60721	Classification of environmental conditions - Environmental conditions appearing in nature	2002-10
ISO 2813	Paints and varnishes - Determination of specular gloss of non-metallic paint films	
Main Shaft		
EN 1991 Eurocode 1.1-4	Actions on structures – Part 1-4: General actions – Wind actions	April 2005
EN 1993 Eurocode 3.1-1/6/8/9/10	Design of steel structures	2005
VDI 2230 Part 1	Systematic calculation of high duty bolted joints - Joints with one cylindrical bolt.	2003
Gearbox		
EN ISO 4871	Acoustics — Declaration and verification of noise emission values of machinery and equipment	2009
GL 2010	Guideline for the Certification of Wind Turbines	
IEC 61400-1/4	Wind turbines - Design requirements	
ISO 10816-1	Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts	
ISO 6336	Calculation of load capacity of spur and helical gears	
ISO 81400-4	Design and specification of gearboxes	

3.4 ELECTRICAL COMPONENTS

Standard	Description	Edition
Common		
IEC 60204-1	Safety of Machinery - Electrical Equipment of Machines	5
IEC 60228	Cables - Conductors of insulated cables	
IEC 60332	Tests on electric and optical fibre cables under fire conditions	1
IEC 60332-1/3	Cables - Tests on electric and optical fibre cables under fire conditions	
IEC 60364-5-52	Low voltage electrical installations - Selection and erection of electrical equipment - Wiring systems	
IEC 60502-2/4	Low voltage cables	
IEC 60909	Electrical installations - Short-circuit currents in three-phase AC systems	
IEC 61400-1	Wind turbines - Design requirements	3
IEC 61000-6-2	EMC	
Generator		
IEC 34	Rotating Electrical Machines	
IEC 60034 -1/2/18	Generator	12
IEC 72 & 72 A	Dimensions and output ratings for Rotating electrical machines	
IEC 85	Classification of Insulation, Materials for Electrical Machinery	
Converter and Electrical Cabinets		
BS EN 60071	Insulation Coordination	8
IEC 60185	Current transformers	
IEC 60186	Voltage transformers	
IEC 60269	Low-voltage fuses	5
IEC 60754-1	Cables - Tests on gases evolved during combustion of material from cables	
IEC 60831	Power Capacitors	
IEC 61439-1/2	Converter & auxiliary cabinets / Low voltage switchgear and control gear assemblies	
IEC 61800-3/5	Converter / Adjustable speed electrical power drive systems - EMC requirements and specific test methods	
IEC 62477	Converter / Safety requirements for power electronic converter systems and equipment	

Transformer and Switchgear		
IEC 60056	High voltage AC Circuit Breakers	
IEC 60060	High voltage testing techniques	
IEC 60076-11	Power transformers - Part 11: Dry-type transformers	1
IEC 60099-4/5	Surge arresters	
IEC 60137	Insulation Bushings for AC Voltage above 1kV	6
IEC 60265	High Voltage switches	
IEC 60376	Specification of technical grade sulfur hexafluoride (SF6) for use in electrical equipment	2
IEC 60840	MV cables over 36kV	
IEC 62271	MV switchgear / High Voltage Switches	
Earthing and Lightning		
IEC 61400-24	Wind turbines - Lightning protection	
BS EN 60129	AC Disconnectors and earth switches	
IEC 62305-1/3	Protection against lightning	
Control and Communications		
IEC 60068-2-1	Cold	
IEC 60068-2-14	Temperature Shock	
IEC 60068-2-2	Dry Heat	
IEC 60068-2-30	Damp Head, Cyclic	
IEC 60068-2-32	Free fall	
IEC 60068-2-52	Salt Mist Test	
IEC 60068-2-56	Damp Head, Steady State	
IEC 60068-2-6	Vibration Sinus	
IEC 60068-2-64	Vibration random	
IEC 60529	Enclosure	
IEC 61131	Programmable controllers	

4 OPTIONS

4.1 EXTREME ENVIRONMENTAL CONDITIONS

Gamesa has product versions specially designed for environmental conditions of extreme temperature, dust and/or corrosion.

4.2 VOLTAGE DROPS

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbine is capable of staying connected to the grid during voltage drops, thus contributing to guaranteeing power quality and supply continuity.

The wind turbines can optionally be equipped with **Gamesa Brake Chopper**, a device that is capable of withstanding more extreme drops and contributing to injecting reactive power as required by certain grid codes.

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbine has certificates issued by official institutes on compliance with voltage drops according to P.O.12.3 of REE and EON2003.

4.3 LOW-NOISE VERSIONS

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbine has different control versions to minimize noise emissions. The application of these versions may involve a modification to the power curve.

These noise-control versions are managed by the **Gamesa** NRS® system, which ensures optimization of production by maintaining previously programmed noise levels in accordance with local legislation.

4.4 BEACONS

As an option, Gamesa offers the inclusion of luminous beacon systems in accordance with the corresponding air traffic legislation and regulations. This is supplied exclusively by Gamesa.

These beacons may be powered by a UPS module, defined in accordance with client requirements. In addition, there is an option to indude a flashing synchronization model.

4.5 HIGH-VOLTAGE SWITCHGEAR

Gamesa offers to supply the wind turbine connection unit to the mid-voltage electrical grid as an option. The high-voltage wiring connection to the high-voltage switchgear is at the bottom of the tower. Gamesa recommends a circuit breaker switch (not a breaker box).

Gamesa requires the necessary information to correctly define the switchgear unit. Where the client supplies the high-voltage switchgear unit, this must comply with Gamesa's technical specifications for the rating and other aspects which may affect the wind turbine.

4.6 GRID VOLTAGE

Gamesa has various transformer options designed to be connected to 50 Hz and 60 Hz grids at different grid voltage levels in the range of 6.6 ~ 35 kV.

At the request of the client, Gamesa may design transformers with voltage levels not available within the previously specified range.

4.7 SERVICE VOLTAGE

The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbine is available in versions which are capable of operating with service voltage of 230 V or 120 V as an option.

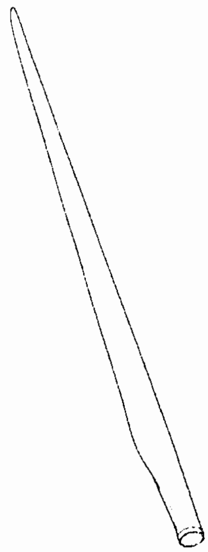
5 TECHNICAL DATA

The main technical data of the different components of the **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) wind turbine are listed below.

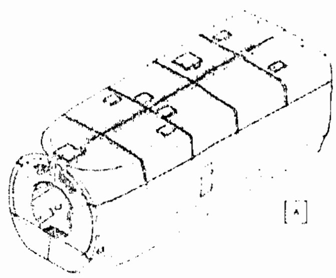
5.1 ROTOR

Wind turbine	G114-IIIA and G114-IIA 2.0 MW
Rotor diameter (m)	114
Swept area (m2)	10207
Wind speed in operation (rpm)	13.07

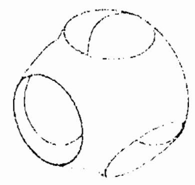
5.2 BLADES

Material		Composite material reinforced with fiberglass through resin infusion technology.	
Length (m)	**G114-IIIA 2.0 MW** **G114-IIA 2.0 MW**	56m	
Weight (t)	**G114-IIIA 2.0 MW** **G114-IIA 2.0 MW**	13 t	
Blade cord (maximum/ minimum) (m)	**G114-IIIA 2.0 MW** **G114-IIA 2.0 MW**	3.865m	
Torsion (°)	**G114-IIIA 2.0 MW** **G114-IIA 2.0 MW**	Max 25 , min -1.5	

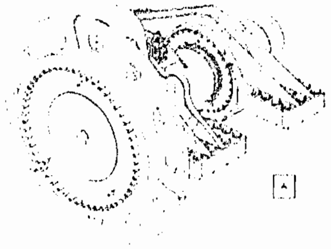
5.3 COVER

Approx. dimensions (m)	10.6 x 4.4 x 4.2	
Material	Organic matrix composite reinforced with fiberglass	

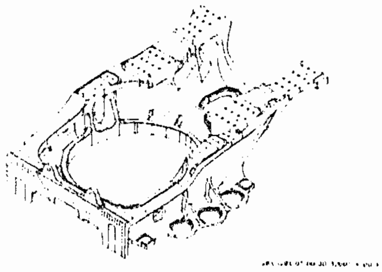
5.4 HUB

Material	Nodular cast iron	

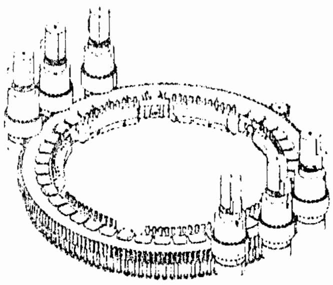
5.5 MAIN SHAFT

Type	Cast shaft	
Shaft support	Nodular cast iron	

5.6 FRONT FRAME

Material	Nodular cast iron	

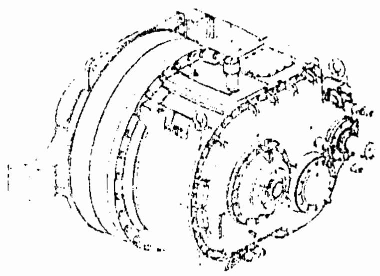
5.7 YAW SYSTEM

Type	Yaw ring with friction bearing	

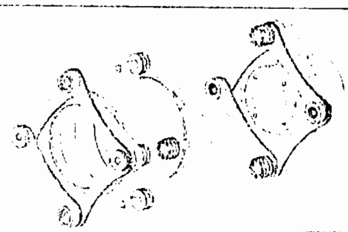
5.8 TOWER

Type	Conical barrel tube	
Material	Structural carbon steel	
Surface treatment	Painted	
Hub height (standard options) (m)	80 m (three steel sections)	
	93 m (four steel sections)	
	125 m (five steel sections)	

5.9 GEARBOX

Type	1 stage planetary / 2 parallel	

5.10 COUPLINGS

Main shaft	Cone collar	
High-speed shaft	Flexible coupling	

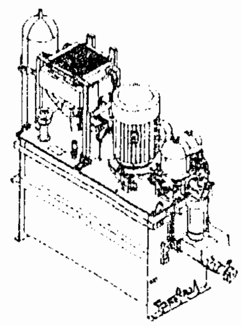
5.11 GENERATOR

Type	Doubly-fed with coil rotor and slip rings	
Nominal power (kW)	2,070 (stator + rotor)	
Voltage (Vac)	690	
Frequency (Hz)	50 / 60	

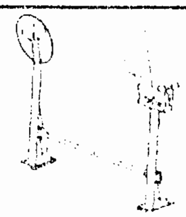
5.12 MECHANICAL BRAKE

Type	Disc brake	

5.13 HYDRAULIC UNIT

Operating pressure (bar)	220	

5.14 WIND SENSORS

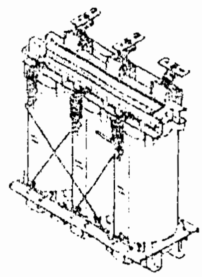
Standard configuration	1 2D ultrasonic anemometer with simultaneous speed and direction measurement + 1 cup anemometer and wind vane	
Number	1 + 1	

5.15 CONTROL UNIT

Frequency (Hz)	50 / 60
Voltage (Vdc)	24
PLC (according to configuration)	Sisteam A (*Option A*) Phoenix Contact (*Option B*)
Field buses	CAN (*Option A*)) Interbus (*Option B*)

5.16 TRANSFORMER

Type	Three-phase, dry-type encapsulated
Rated power	Different options available
Voltage in medium-voltage	Different options available
Frequency (Hz)	50 / 60
Insulation class	F or H



5.17 APPROXIMATE WEIGHTS

Nacelle	**G114-IIIA 2.0 MW G114-IIA 2.0 MW**
Nacelle weight (t)	99

Rotor	**G114-IIIA 2.0 MW G114-IIA 2.0 MW**
Rotor weight (t)	69

G114-IIIA 2.0 MW G114-IIA 2.0 MW		**Flange type**	**Tower weight (t)**
Tower weight (t)	80m IIIA	T	146
	93m (93.0)	T	203
	93m (93.1)	T	188
	125m	T	344
	125m (125.1)	T	320

NOTE:

- The weights of the standard towers are included.
- These weights do not include the mid-voltage switchgear and the GROUND electrical cabinet.
- All weights are generic or approximate and may vary.

6 GENERAL RESTRICTIONS

- All data shown is valid for conditions at sea level and standard air density.
- In periods of low wind speeds, an increase in power consumption for nacelle heating and dehumidification is to be expected.
- In the event of a build-up of large quantities of ice on blades or other wind turbine components, interruptions to the turbine operation should be expected. In addition, high winds in combination with conditions such as high temperatures, low temperatures, low density and/or low grid voltage may lead to a reduction in the rated power to ensure that the thermal conditions of certain main components (gearbox, generator, transformer, power cables, etc.) are maintained within limits.
- It is usually recommended that the electrical grid voltage be kept as close as possible to the nominal value.
- In the event of a loss of electric power and very low temperatures, a certain period of time should be allowed for heating before the wind turbine starts to operate.
- If there is a slope of more than 10° within a radius of 100 meters of a wind turbine, special considerations may be necessary.
- The **Gamesa 2.0 MW** (**G114-IIIA** and **G114-IIA** models) **wind turbines** have been conceived to operate up to 2500m above sea level. Up to 1000m the wind turbine operates in full-power conditions. From 1000m the wind turbine operates in production conditions with power *derating* based on ambient temperature. In addition, on sites above sea level, the risk of freezing is greater.
- All the parameters given for start up and stopping (temperatures, wind speeds, etc.) have an associated hysteresis in the control system. In certain conditions, this may involve a wind turbine being stopped, even when the instant ambient parameters are within the specified limits.
- Intermittent or rapid fluctuations in the electrical grid frequency may cause serious problems to the wind turbine.
- Drops in the electrical voltage should not occur more than 52 times per year.
- Due to modifications and updates to our products, Gamesa reserves the right to change the specifications.

Gamesa	GENERAL CHARACTERISTICS MANUAL	*Code:* **GD169130-en** *Rev:* **2**
		Date: **25/10/2013** *Pg.* **1** *of* **5**
		Approval process: **Electronic: PDM Flow**
Documentation Type: **PDTD - Product**	*Title:* **G90 IA 2.0MW 50/60 Hz Wind Turbine Power Curve**	*Prepared:* **EMATA**
Deliverable: **S12**		*Verified:* **PSEGERS**
		Approved: **JEJGUERRERO**

INDEX

RECORD OF CHANGES

Rev.	Date	Author	Description
0	23/10/12	PSEGERS	Initial Version
1	20/11/12	JOANAVARRO	Updated with corner improvement and new optitip
2	25/10/2013	EMATA	Table of validity ranges of power curves added and paragraph of section 4 changed.

1 AIM

This document presents the G90 IA 2.0MW wind turbine power curves.

2 SCOPE

The values shown in this document are applicable to all the existing configurations for the G90 IA 2.0MW in standard operation mode.

3 DEFINITIONS AND ACRONYMS

WT: Wind turbine.

Power (P): Expressed in kW, this is the electric power obtained at the generator terminals without considering the losses in the transformer or high voltage cables of the wind turbine, or the occasional power consumption which may exist in the same to supply a component. Averaged every 10 minutes.

Wind Speed (W_S): Expressed in m/s, this is the value of the horizontal wind component at hub height averaged every 10 minutes.

Power curve (CdP): Represents the change in the P in accordance with the W_S for the different WT operating modes.

Annual Energy Production (AEP): Expressed in [MWh], it is the total electrical energy produced in a WT during a one-year period, in accordance with a given CdP and a given wind distribution.

Wind distribution: Weibull distribution is used for different K-distribution parameters and for annual average wind speed values (W_{avg}).

Power coefficient: C_P

Thrust coefficient: C_T

4 DESCRIPTION

When not specified otherwise, data in following sections is calculated using the parameters from Table 1. All power curve and annual energy production values in this document are subject to the validity ranges presented in Table 2.

Rated Power	2.0 MW
Frequency	50 Hz/60Hz
Rotor Diameter	90 m
Angle of blade tip	Pitch control regulation
Air density	1.225 kg/m^3

Table 1 Calculation parameter values for the G90 2.0MW IA wind turbine power curve.

Wind Shear (10min average)	≤ 0.3
Turbulence Intensity TI [%] for bin i	$5\% \frac{(0.75v_i + 5.6)}{v_i} < TI_i < 12\% \frac{(0.75v_i + 5.6)}{v_i}$
Terrain	Not complex according to IEC 61400-12-1
Upflow β [°]	-2° ≤ β ≤ +2°
Grid frequency [Hz]	± 0.5 Hz

Table 2 Validity ranges of Power Curves for the G90 2.0MW CIA wind turbine power curve.

5 RESULTS

5.1 STANDARD POWER CURVES

Table 3 shows the electrical power [kW] in function of the horizontal wind speed [m/s] at hub height (W_S) for different air densities [kg/m^3].

P[kW]	Density [kg/m^3]												
W_S [m/s]	1.225	0.94	0.97	1	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.24	1.27
3	17	12	13	13	14	14	15	15	16	16	17	17	18
4	78	53	56	58	61	63	66	69	71	74	76	79	82
5	194	140	146	152	157	163	168	174	180	185	191	196	202
6	361	269	278	288	298	307	317	327	336	346	356	366	375
7	592	447	462	478	493	508	523	539	554	569	585	600	615
8	893	677	700	722	745	768	790	813	836	859	882	905	928
9	1244	940	972	1004	1035	1067	1099	1131	1163	1196	1228	1260	1292
10	1591	1212	1253	1294	1335	1376	1416	1456	1495	1534	1572	1609	1646
11	1862	1472	1520	1567	1613	1657	1699	1741	1778	1815	1848	1874	1896
12	1967	1701	1750	1795	1842	1877	1907	1931	1948	1958	1963	1970	1972
13	1988	1885	1923	1948	1961	1971	1978	1979	1983	1984	1986	1989	1991
14	1997	1972	1977	1982	1983	1987	1990	1992	1994	1995	1996	1997	1998
15	1999	1984	1988	1992	1994	1996	1997	1998	1998	1999	1999	1999	2000
16	2000	1994	1996	1998	1998	1999	1999	1999	2000	2000	2000	2000	2000
17	2000	1998	1999	1999	2000	2000	2000	2000	2000	2000	2000	2000	2000
18	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
19	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
20	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
21	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
22	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906	1906
23	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681	1681
24	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455
25	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230	1230

Table 3: Electric power [kW] of the G90 IA 2.0MW wind turbine calculated in function of wind speed a hub height W_S [m/s] for different air densities [kg/m^3]
(ref: *20121116G90C1AERPC*)

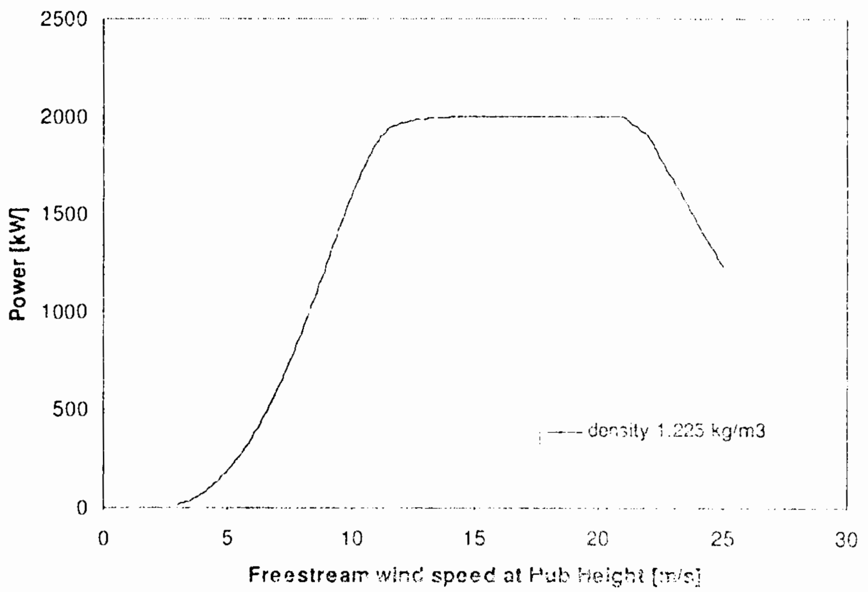


Figure 1: Power curve of the G90 IA 2.0MW wind turbine for standard atmosphere (density = 1.225 kg/m^3) (ref: *20121116G90C1AERPC*)

5.2 ANNUAL ENERGY PRODUCTION

Table 4 shows the annual energy output [MWh] for the G90 IA 2.0MW wind turbine calculated for different Weibull distribution parameters W_{ave} [m/s] and K. All values are calculated for 1.225 kg/m^3 standard density and 10% turbulence intensity.

P[MWh]		W_{ave} [m/s]				
		8.0	**8.5**	**9.0**	**9.5**	**10.0**
Weibull K	**1.5**	7356	7802	8189	8519	8796
	2.0	8007	8668	9264	9793	10253
	2.5	8264	9069	9806	10474	11072

Table 4: Annual energy production for the G90 IA 2.0MW wind turbine for different Weibull parameters W_{ave} [m/s] and K, in standard conditions. (ref: *20121116G90C1AERPC*)

5.3 CP AND CT CURVES

Table 5 represents the CP and CT values for the G90 IA 2.0MW wind turbine.

W_S[m/s]	C_P	C_T
3	0.163	0.900
4	0.312	0.843
5	0.397	0.815
6	0.429	0.804
7	0.443	0.807
8	0.448	0.790
9	0.438	0.726
10	0.408	0.632
11	0.359	0.523
12	0.292	0.404
13	0.232	0.309
14	0.187	0.243
15	0.152	0.195
16	0.125	0.160
17	0.104	0.133
18	0.088	0.113
19	0.075	0.098
20	0.064	0.086
21	0.055	0.071
22	0.046	0.060
23	0.035	0.048
24	0.027	0.038
25	0.020	0.030

Table 5: CP and CT values for the G90 IA 2.0MW wind turbine.
(ref: *20121116G90C1AERPC*)

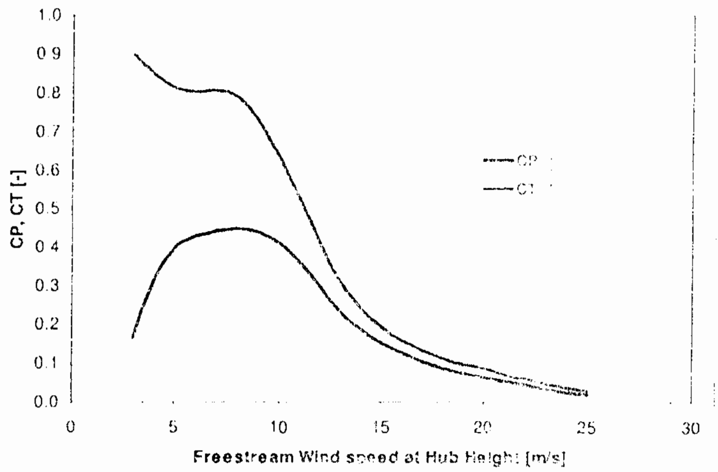


Figure 2: CP and CT curves of the G90 IA 2.0MW wind turbine
(ref: *20121116G90C1AERPC*)