TREVIenergy

Rif – SEO-PR001-07 - RT - AE

Data: 06/11/07	**Versione:** 00	**Modifiche:** Versione Originale
File: PR002-07 - CENTRALE EOLICA CHIEUTI _Allegato E		

Redatto da:	**Verificato da:**	**Approvato da:**
Fabio Pallotti	-	Davide Trevisani

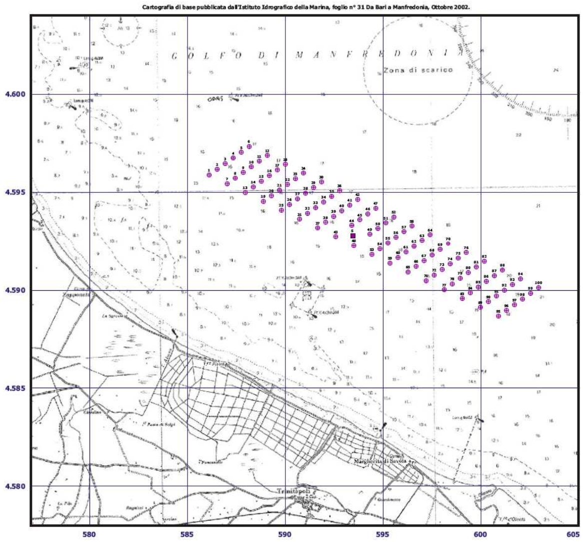
Committente: TREVI Energy S.p.A
Via Larga, 201 – 47023 CESENA (FC)

Opera: *"CENTRALE EOLICA OFF-SHORE CHIEUTI"*.

Capitaneria di Porto di Manfredonia (FG)

Oggetto: Documentazione tecnica illustrativa aerogeneratori Vestas V90 3.0 MW.

Cartografia di base pubblicata dall'Istituto Idrografico della Marina, foglio n° 31 Da Bari a Manfredonia, Ottobre 2002.



Redattore: Trevi Energy SpA
Via Larga, 201
47023 Cesena (FC)

Ing. Fabio Pallotti

Revisioni

Versione	Data	Totale Pagine	Modifiche
00	06/11/2007	2	Versione Originale

Lista degli Allegati.

Allegato E1

Class I Item no. 950011.R9 2005-11-16
General Specification V90 – 3.0 MW 50 Hz, OptiSpeedTM Wind Turbine

Autore: Vestas Wind Systems AS.
Versione: 00

Allegato E2

Class I EDB-no. 962676.R1 2006-08-02
Foundation Loads V90 – 3.0 MW VCS HH80, IEC1A IEC61400-1 Edition 3

Autore: Vestas Wind Systems AS.
Versione: 00

Class I
Item no. 950011.R9
2005-11-16

General Specification

V90 – 3.0 MW

50 Hz, OptiSpeed™ Wind Turbine

Contents .... Page

1. General Description 4
1.1 Nacelle Description 4
1.2 Rotor V90 6
1.3 Control and Regulation 7
The VMP controller is equipped with a battery backup system. 8
1.4 Monitoring 8
1.5 Lightning Protection 9
1.6 Service 10
2. Main Data 11
2.1 Power Curve, Calculated 11
2.2 Annual Production V90 - 3.0MW 17
2.3 Noise Curves V90 - 3.0 MW 18
3. Micro Siting and Network Connection 23
3.1 Siting in Wind Farms 23
3.2 Terrain Conditions 23
3.3 Connection to the Electrical Power Grid 23
4. General Ambient Design Criteria 24
4.1 General Conditions 24
4.2 Wind Conditions 24
5. Type Approvals 25
6. Options 25
6.1 Advanced Grid Option 2 25
6.2 Extended UPS 25
6.3 High Voltage Switchgear 26
6.4 Obstruction Light 26
The options are designed according to the ICAO and the FAA codes. 26
6.5 Service Lift inside the Tower 26
6.6 Wind Turbine Colour 26
7. Technical Specifications and Diagrams 27
7.1 Rotor 27
7.2 Hub 27
7.3 Blades 27
7.4 Bearings 27
7.5 Sensors 27
7.6 Generator 28
7.7 Transformer 28
7.8 Switchgear, Electrical Characteristics 29
7.9 Yaw System 29
7.10 Yaw Gears 29
7.11 Gearbox 30
7.12 Parking Brake 30
7.13 Hydraulics 30
7.14 Cooling System 30
7.15 Nacelle Bedplate 30
7.16 Nacelle 31
7.17 Tower 31
7.18 Weight and Dimensions 31

8. General Reservations, Notes and Disclaimers 33

1. General Description

The Vestas V90 - 3.0 MW is a pitch regulated upwind wind turbine with active yaw and a three-blade rotor.

The Vestas V90 - 3.0 MW has a rotor diameter of 90 m with a generator rated at 3.0 MW.
The turbine utilises the OptiTip® and OptiSpeed™ concepts. With these features the wind turbine is able to operate the rotor at variable speed (RPM), maintaining the output at rated power even in high wind speeds. At low wind speeds, the OptiTip® and OptiSpeed™ systems work together to maximise the power output by giving the optimal RPM and pitch angle, which also helps to minimise the sound emission from the turbine.

1.1 Nacelle Description

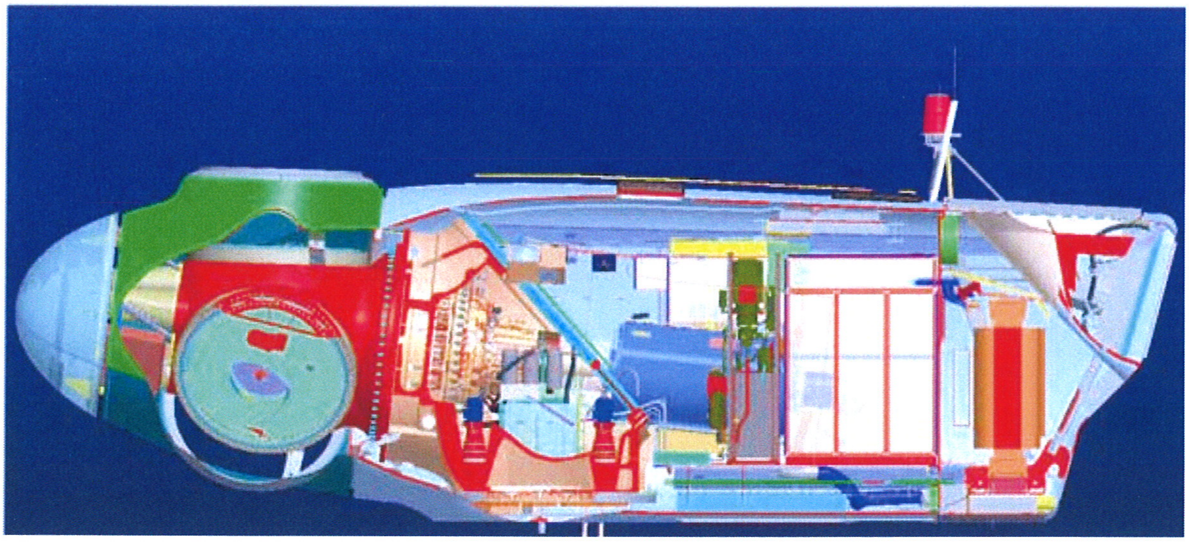


Figure 1 V90 - 3.0MW nacelle

The nacelle cover is made of fibreglass. An opening in the floor provides access to the nacelle from the tower.
The roof section is equipped with skylights which can be opened to access the roof and the wind sensors.
Wind sensors are mounted on the nacelle roof. Aviation lights, if any, are also placed on top of the nacelle.

1.1.1 Machine Foundation (Bedplate)

The front of the nacelle bedplate is the foundation for the drive train, which transmits forces and torque from the rotor to the tower through the yaw system. The front of the nacelle bedplate is made of cast steel. The nacelle cover is mounted on the nacelle bedplate.

The nacelle bedplate is in two parts consisting of a cast iron part and a girder structure.
The cast iron part serves as the foundation of the main gear and the generator.
The bottom surface is machined and connected to the yaw bearing. The crane beams are attached to the top structure. The lower beams of the girder structure are connected at the rear end. The rear part of the bedplate serves as the foundation for the controller panels, cooling system and transformer.
The six yaw gears are bolted to the nacelle bedplate.

The nacelle houses the internal 800 kg Safe Working Load (SWL) service crane.
The crane is a single system chain hoist. If any parts heavier than this need service, the service crane can be upgraded to 1600/12000 kg SWL.
The upgraded crane is able to lift and lower large elements, such as parts of the gearbox and the generator.

1.1.2 Gearbox

The main gear transmits the torque from the rotor to the generator.
The gear unit is a combination of a 2-stage planetary gear and a 1-stage helical gear. The gear housing is bolted to the bedplate. The low speed input shaft is bolted directly to the hub without the use of a traditional main shaft.
The gearbox lubrication system is a forced feed system without the use of an integrated oil sump.

1.1.3 Yaw System

The yaw bearing system is a plain bearing system with built-in friction. The six electrical yaw gears with motor brakes enables the nacelle to rotate on top of the tower.
The system transmits the forces from the turbine rotor/nacelle to the tower.

1.1.4 The Brake System

The turbine brakes by full-feathering the rotor blades. The individual pitch cylinders ensure triple braking safety.

Furthermore, a hydraulic system supplies pressure to a disc brake located on the main gear high-speed shaft. The disc brake system consists of three hydraulic brake callipers and serves as the parking brake. The parking brake can only be activated manually by pressing an emergency stop button inside the turbine.

1.1.5 Generator

The generator is an asynchronous 4-pole generator with a wound rotor.

OptiSpeed™ enables the turbine to operate with variable speed. This reduces power fluctuations in the power grid system as well as minimises the loads on vital parts of the turbine. Furthermore, the OptiSpeed™ system optimises the power pro-

duction, especially at low wind speeds. The OptiSpeed^{TM} technology enables control of the turbine reactive power factor between 0.96 inductive and 0.98 capacitive measured on the low voltage side.
The generator is water-cooled.

1.1.6 Transformer

The step-up transformer is located in a separate compartment to the rear of the nacelle. The transformer is a three-phase dry-type cast resin transformer specially designed for wind turbine applications.
The windings are delta connected on the high voltage side, unless otherwise specified. The windings are connected in star on the low voltage side (1000 V and 400 V). The 1000 V and 400 V systems in the nacelle are a TN system, where the star point is connected to ground.
Surge arresters are mounted on the high voltage (primary) side of the transformer.
The output voltages available are in 0.5 kV steps from 10 to 33 kV, where 36kV (U_m) is the highest equipment peak voltage.

The transformer room is equipped with arc detection sensors.

1.1.7 The Cooling and Air Conditioning System

If the inside air temperature of the nacelle exceeds a certain level, flap valves will open to the outside. A fan engine will draw in outside air for cooling the nacelle air.

Gear lubrication oil, generator cooling water and the OptiSpeed^{TM} unit are cooled from a separate air intake, using separate water/air cooling systems. Water coolers are thermally insulated from other parts of the nacelle.
A separate fan cools the transformer.

The heat exchanger system is mounted in a separate compartment in the upper rear section of the nacelle.

1.2 Rotor V90

1.2.1 Hub / Nose Cone

The hub is mounted directly onto the gearbox, hereby eliminating the main shaft traditionally used to transmit the wind power to the generator through the gearbox.

1.2.2 Pitch Regulation

The V90 is equipped with a microprocessor-controlled pitch control system called OptiTip®. Based on the prevailing wind conditions, the blades are continuously positioned at the optimum pitch angle.
The pitch mechanism is placed in the hub. Changes of the blade pitch angle are made by hydraulic cylinders, which are able to rotate the blade 95°. Each blade has its own hydraulic pitch cylinder.

1.2.3 Hydraulics

A hydraulic system generates hydraulic pressure for the pitch systems in the hub. In case of grid failure or leakage, a backup accumulator system provides sufficient pressure to pitch the blades and stop the turbine.
A collector system prevents oil leaks, if any, from spreading outside the hub.

1.2.4 Blades

The blades are made of fibreglass and carbon fibre reinforced epoxy. Each blade consists of two blade shells bonded to a supporting spar. The blades are designed for optimum output and minimum noise and light reflection. The V90 blade design minimises the mechanical loads applied to the turbine.

The blade bearing is a double raced 4-point ball bearing bolted to the blade hub. Each blade has a lightning protection system consisting of lightning receptors on the blade tip and a copper wire conductor inside the blade.

1.3 Control and Regulation

1.3.1 OptiSpeed™ Description

OptiSpeed™ ensures a steady and stable electric power production from the turbine.

The OptiSpeed™ system consists of an asynchronous generator with wound rotor and slip rings. A back-to-back power converter with IGBT switches, contactors and protection enables the turbine to operate with variable speed.

The OptiSpeed™ and OptiTip® systems ensure energy optimisation, low noise operation and reduction of loads on all vital components.

The system controls the current in the rotor circuit of the generator giving precise control of the reactive power and provides for a smooth connection sequence when the generator is connected to the grid.

The reactive power control is as default set at 0 kVAr export/import at 1000 V.

1.3.2 Vestas Multi Processor Controller

All functions of the wind turbine are monitored and controlled by microprocessor based control units called VMP (Vestas Multi Processor).
The VMP controller consists of several individual sub-controller systems. Each system has separate operation tasks and communicates via an optical-based network (ArcNet).
The controller enclosures are located in the bottom of the tower, in the nacelle and in the hub.
The operating system is VxWorks®, which fulfils the demands for stability, flexibility and security that are expected in a modern, intelligent wind turbine.
Digital and analogue input/output functions in the turbine are interfaced via the use of distributed units communicating on the CAN-open protocol.

The VMP controller is equipped with a battery backup system.

The VMP controller serves the following functions:

- Monitoring and supervision of overall operation.
- Synchronising the generator to the grid during the connection sequence in order to limit the inrush current.
- Operating of the turbine during various fault situations.
- Automatic yawing of the nacelle in accordance to the wind direction.
- OptiTip® - blade pitch control.
- OptiSpeed™ - reactive power control and variable speed operation.
- Noise emission control.
- Monitoring of ambient conditions (wind, temperature etc).
- Monitoring of the grid.
- Monitoring and logging of lightning strikes.
- Supervision of the smoke detection system.
- De-rating in case of critically high temperatures.

1.3.2.1 Active Damping of Drive Train Torsional Oscillations in OptiSpeed™ Controlled Turbines

Oscillations which may occur in the drive train can be monitored by measuring the number of revolutions and can be damped via an active control of the generator. If the oscillations exceed a certain limit, the Active Control system is activated in order to stop further escalations of the drive train oscillations.

1.3.2.2 Improving Grid Quality (Active Harmonics Damping) in OptiSpeed™ Controlled Turbines

OptiSpeed™ contributes to reducing the 5^{th} and 7^{th} harmonic components on the grid and to reducing the interharmonic components produced by the induction generator slip. The compensation reduces the network harmonics to below 2% of nominal current.

1.4 Monitoring

1.4.1 Sensors

Data for controlling the turbine and the energy production is received from different sensors measuring:

- Weather conditions: Wind direction, wind speed and temperature.
- Machine conditions: Temperatures, oil level and pressure, cooling water level.
- Rotor activity: Speed and pitch position.
- Construction: Vibrations, lightning detectors.
- Grid connection: Active power, reactive power, voltage, current, frequency, Cosφ.

1.4.2 Sensor Features

1.4.2.1 Ultrasonic Wind Sensors

The nacelle is equipped with two redundant ultrasonic wind sensors in order to increase the reliability and accuracy of the wind measurements. The wind sensors measure the wind direction and wind speed.

The sensor is self-testing, and if the sensor signal is defective, the turbine will be brought to a safe condition.
To improve performance during icy conditions, the sensors are equipped with a heating element.
The sensors are located on top of the nacelle and are protected against lightning strokes.

1.4.2.2 Smoke Detectors

The tower and nacelle are equipped with optical smoke sensors. If smoke is detected, an alarm is sent via the remote control system and the main switcher is activated. The detectors are self-controlling. If a detector becomes defective, a warning is sent via the remote control system.

1.4.2.3 Lightning Detectors

Lightning detectors are located in each rotor blade.

1.4.2.4 Accelerometers

Accelerometers register the movements of the tower top. The registrations are intelligent controlled by the VMP and used to stop the turbine if the movements and vibrations excides predefined limits. The accelerometers allow turbines with high towers to run with a rotor RPM closer to the tower natural frequency.

1.4.2.5 GPS (Real Time Clock)

The GPS is primarily used to synchronise the turbine clock. The GPS accuracy is within 1 second. Via this system it is possible to compare the various log observations with other turbines within the same area/site. E.g. fluctuations in the power, grid or lightning activity.

1.4.2.6 Arc Protection

The transformer and the low voltage switchboards are protected by an arc protection system. In case of an electrical arc, the system will instantly open the main breaker downstream from the turbine.

1.5 Lightning Protection

The V90 wind turbine is equipped with Vestas Lightning Protection, which protects the entire turbine from the tip of the blades to the foundation. The system enables the lightning current to by-pass all vital components within the blade, nacelle and tower without causing damage. As an extra safety precaution, the control units and processors in the nacelle are protected by an efficient shielding system.

The lightning protection is designed according to IEC 61024 - "Lightning Protection of Wind Turbine Generators".
Lightning detectors are mounted on all three rotor blades. Data from the detectors are logged and enable the operator to identify which of the blades were hit, the exact time of the stroke and how powerful the lightning was.
These data are very useful for making a remote estimate of possible damages to the turbine and the need for inspection.

1.6 Service

The turbine will need a scheduled Service check every 12 months.

1.6.1 Lubrication of Components

- Blade bearings: Automatic lubrication from an electrically driven unit. Re-fill every 12 months.
- Generator bearings: Automatically lubricated via the gear oil system.
- Gearbox: The oil is collected in a tank. From the collection tank the oil is pumped to a heat exchanger and back to the gearbox. The pumps distribute the oil to the gear wheels and bearings.
- Yaw gear: Lubrication in sealed oil bath, which is inspected every 12 months.
- Yaw system: Lubricated with an automatic grease system
- Hydraulic system: The oil level is inspected every 12 months.

2. Main Data

2.1 Power Curve, Calculated

Calculated at 1000V / 400V, low voltage side of the high voltage transformer.

2.1.1 Power Curve, Mode 0 - 109.4 dB(A)

V90 - 3.0 MW, 50 Hz, Mode 0 - 109.4 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	59	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	482	497	512	528	543	558	574	581	589	604
8	691	714	737	760	783	806	829	852	875	886	898	921
9	995	1028	1061	1093	1126	1159	1191	1224	1257	1273	1289	1322
10	1341	1385	1428	1471	1515	1558	1602	1645	1688	1710	1732	1775
11	1686	1740	1794	1849	1903	1956	2010	2064	2118	2145	2172	2226
12	2010	2074	2137	2201	2265	2329	2392	2454	2514	2544	2573	2628
13	2310	2382	2455	2525	2593	2658	2717	2771	2817	2837	2856	2889
14	2588	2662	2730	2790	2841	2883	2915	2940	2958	2965	2971	2981
15	2815	2868	2909	2939	2960	2975	2984	2990	2994	2995	2996	2998
16	2943	2965	2979	2988	2993	2996	2998	2999	2999	3000	3000	3000
17	2988	2994	2997	2998	2999	3000	3000	3000	3000	3000	3000	3000
18	2998	2999	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
19	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Wind speed as 10 minute average value at hub height and perpendicular to the rotor plane.

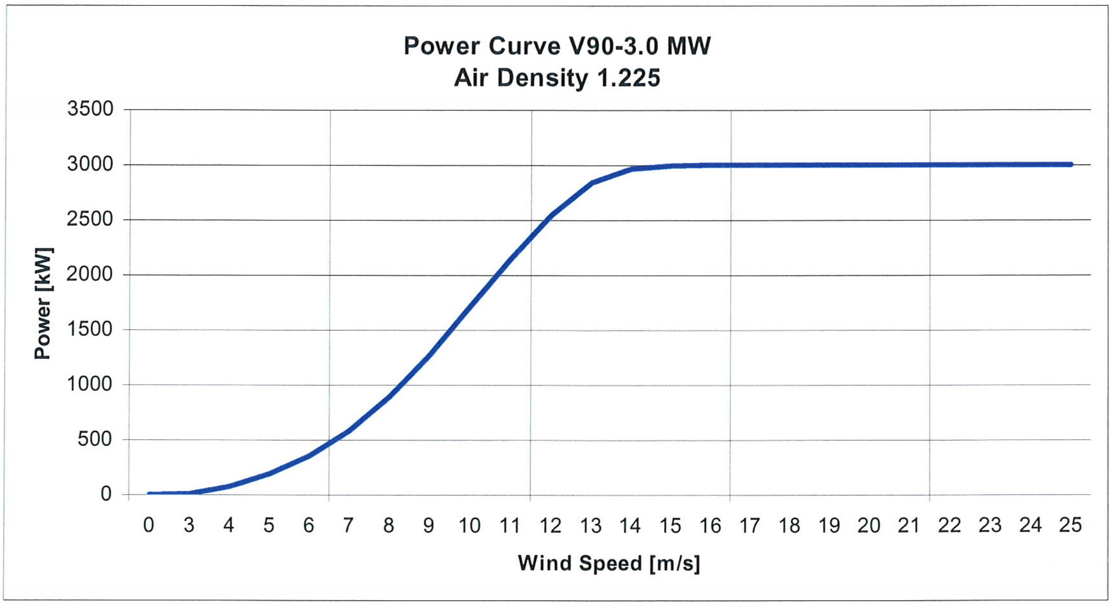


Figure 2 Power curve for Vestas V90 - 3.0 MW, 50 Hz Mode 0 - 109.4 dB(A).

2.1.2 Power Curve, Mode 1 - 107.8 dB(A)

V90 - 3.0 MW, 50 Hz, Mode 1 - 107.8 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	59	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	482	497	512	528	543	558	574	581	589	604
8	691	714	737	760	783	806	829	852	875	886	898	921
9	994	1027	1060	1092	1125	1157	1190	1223	1255	1272	1288	1321
10	1330	1373	1416	1460	1503	1546	1589	1632	1675	1696	1718	1761
11	1656	1709	1762	1815	1868	1921	1974	2027	2080	2106	2133	2186
12	1963	2026	2088	2151	2213	2276	2338	2399	2459	2489	2518	2575
13	2258	2329	2400	2470	2539	2605	2666	2723	2774	2797	2818	2856
14	2539	2614	2684	2748	2804	2851	2889	2919	2942	2951	2959	2971
15	2778	2837	2883	2919	2946	2964	2977	2985	2991	2993	2994	2996
16	2925	2953	2971	2983	2990	2994	2997	2998	2999	2999	2999	3000
17	2983	2991	2995	2997	2999	2999	3000	3000	3000	3000	3000	3000
18	2997	2999	2999	3000	3000	3000	3000	3000	3000	3000	3000	3000
19	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Wind speed as 10 minute average value at hub height and perpendicular to the rotor plane.

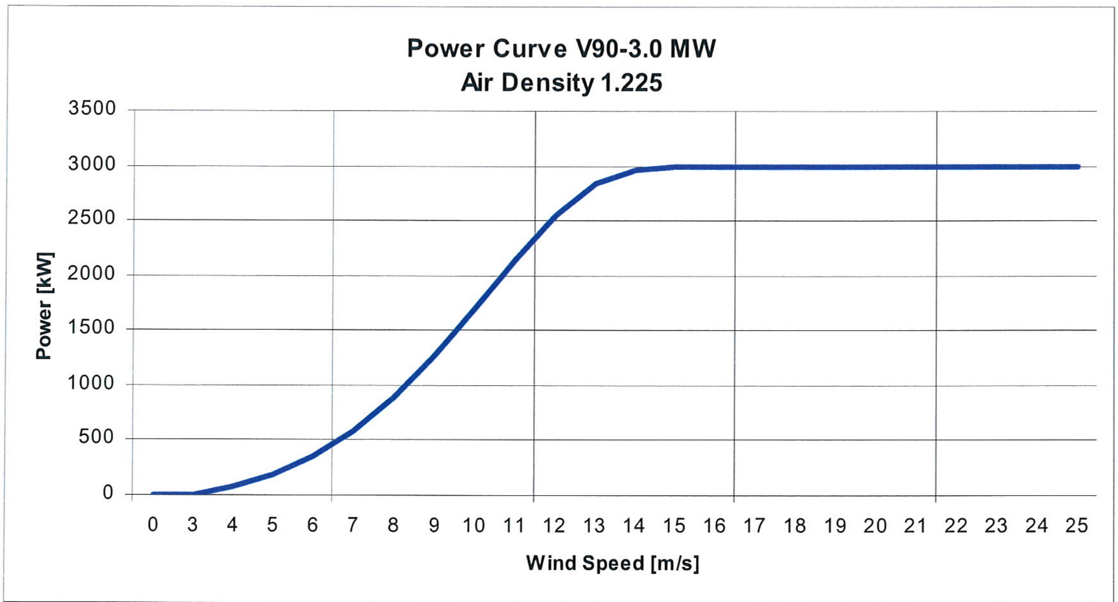


Figure 3 Power curve for Vestas V90 - 3.0 MW, 50 Hz, Mode 1 - 107.8 dB(A).

2.1.3 Power Curve, Mode 2 - 106.8 dB(A)

V90 - 3.0 MW, 50 Hz, Mode 2 - 106.8 dB(A)

	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	59	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	482	497	512	528	543	558	574	581	589	604
8	691	713	736	759	782	805	828	851	874	885	897	920
9	984	1016	1048	1080	1113	1145	1177	1209	1242	1258	1274	1306
10	1286	1328	1370	1412	1453	1495	1537	1578	1620	1641	1662	1703
11	1575	1625	1676	1726	1777	1827	1878	1928	1979	2004	2029	2080
12	1852	1911	1970	2029	2088	2147	2206	2265	2324	2353	2382	2439
13	2119	2186	2253	2320	2387	2453	2518	2581	2642	2671	2699	2749
14	2376	2451	2524	2595	2662	2724	2781	2829	2871	2888	2904	2928
15	2624	2697	2763	2820	2867	2905	2934	2955	2970	2976	2981	2987
16	2828	2879	2917	2946	2965	2978	2987	2992	2995	2997	2997	2998
17	2944	2966	2980	2989	2994	2996	2998	2999	2999	3000	3000	3000
18	2987	2993	2996	2998	2999	3000	3000	3000	3000	3000	3000	3000
19	2998	2999	2999	3000	3000	3000	3000	3000	3000	3000	3000	3000
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Wind speed as 10 minute average value at hub height and perpendicular to the rotor plane.

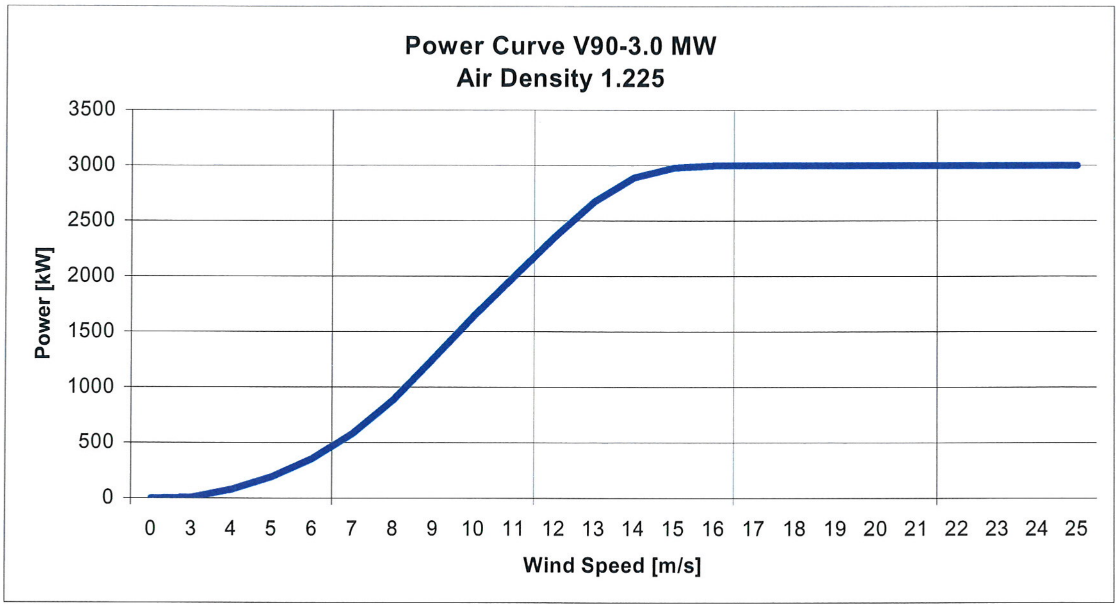


Figure 4 Power curve for Vestas V90 - 3.0 MW, 50 Hz, Mode 2 - 106.7.

2.1.4 Power Curve, Mode 3 - 104.4 dB(A)

V90 - 3.0 MW, 50 Hz, Mode 3 - 104.4 dB(A)												
	Air Density [kg/m^3]											
Wind Speed [m/s]	**0.97**	**1**	**1.03**	**1.06**	**1.09**	**1.12**	**1.15**	**1.18**	**1.21**	**1.225**	**1.24**	**1.27**
4	53	56	58	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	451	466	481	497	512	527	543	558	573	581	588	604
8	680	703	725	748	770	793	815	838	860	872	883	906
9	920	950	980	1011	1041	1071	1101	1131	1162	1177	1192	1222
10	1149	1186	1224	1261	1298	1335	1373	1410	1447	1466	1484	1522
11	1361	1405	1449	1493	1536	1580	1624	1667	1711	1733	1755	1798
12	1493	1541	1588	1636	1684	1732	1780	1827	1875	1899	1923	1971
13	1575	1625	1676	1726	1776	1826	1876	1926	1976	2001	2026	2075
14	1818	1873	1927	1980	2033	2084	2135	2185	2234	2259	2283	2330
15	2265	2314	2361	2404	2446	2485	2522	2558	2590	2607	2623	2653
16	2697	2724	2749	2770	2790	2807	2823	2838	2851	2858	2864	2875
17	2918	2927	2935	2941	2947	2952	2956	2960	2963	2964	2966	2968
18	2984	2986	2988	2989	2990	2991	2992	2993	2993	2993	2994	2994
19	2998	2998	2998	2998	2999	2999	2999	2999	2999	2999	2999	2999
20	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
21	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Wind speed as 10 minute average value at hub height and perpendicular to the rotor plane.

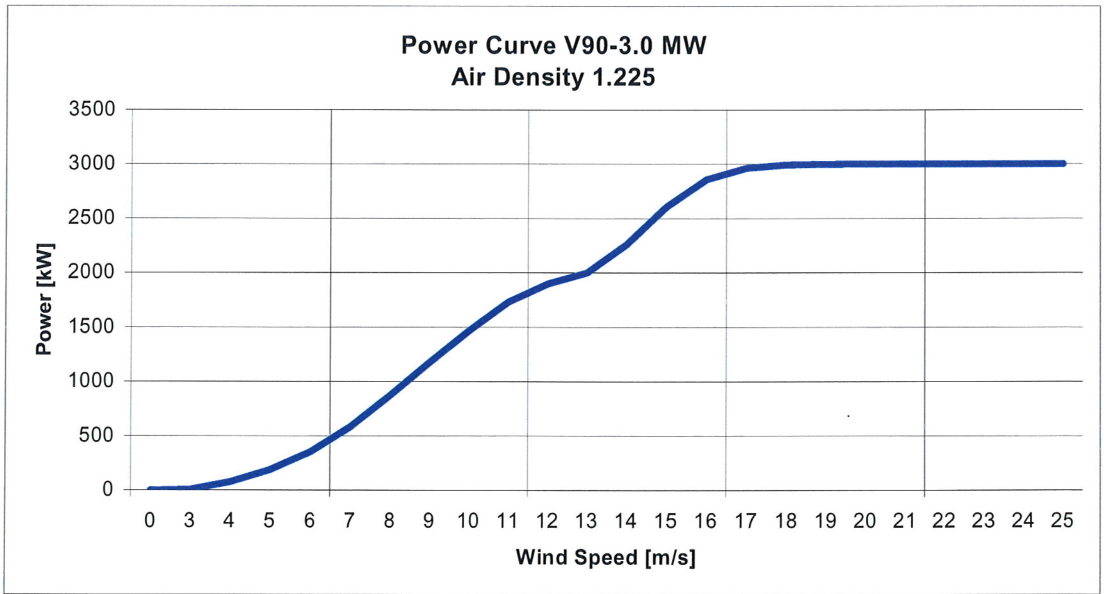


Figure 5 Power curve for Vestas V90 - 3.0 MW, 50 Hz, Mode 3 - 104.4 dB(A).

2.1.5 Power Curve, Mode 4 - 102.8 dB(A)

V90 - 3.0 MW, 50 Hz, Mode 4 - 102.8 dB(A)

Wind Speed [m/s]	Air Density [kg/m^3]											
	0.97	1	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.225	1.24	1.27
4	53	56	58	61	64	67	70	72	75	77	78	81
5	142	148	153	159	165	170	176	181	187	190	193	198
6	271	281	290	300	310	319	329	339	348	353	358	368
7	449	464	479	495	510	525	540	555	571	578	586	601
8	656	677	699	721	742	764	786	807	829	840	851	873
9	856	884	912	940	968	996	1024	1052	1080	1094	1108	1137
10	1047	1081	1115	1149	1183	1217	1251	1285	1319	1336	1353	1387
11	1231	1271	1311	1350	1390	1430	1469	1509	1549	1568	1588	1628
12	1391	1436	1480	1525	1569	1614	1658	1703	1748	1770	1792	1837
13	1503	1551	1599	1647	1695	1743	1791	1839	1887	1911	1935	1983
14	1544	1593	1642	1691	1740	1789	1838	1886	1935	1960	1984	2033
15	1647	1695	1742	1789	1835	1881	1926	1971	2016	2038	2061	2104
16	2064	2104	2141	2179	2213	2248	2281	2313	2345	2361	2376	2406
17	2579	2601	2621	2641	2658	2675	2691	2706	2721	2728	2736	2748
18	2874	2882	2889	2896	2901	2907	2912	2916	2921	2923	2925	2929
19	2973	2975	2976	2978	2979	2980	2982	2983	2984	2984	2984	2985
20	2995	2996	2996	2996	2997	2997	2997	2997	2997	2997	2997	2998
21	2999	2999	2999	2999	3000	3000	3000	3000	3000	3000	3000	3000
22	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
23	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
24	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
25	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000

Wind speed as 10 minute average value at hub height and perpendicular to the rotor plane.

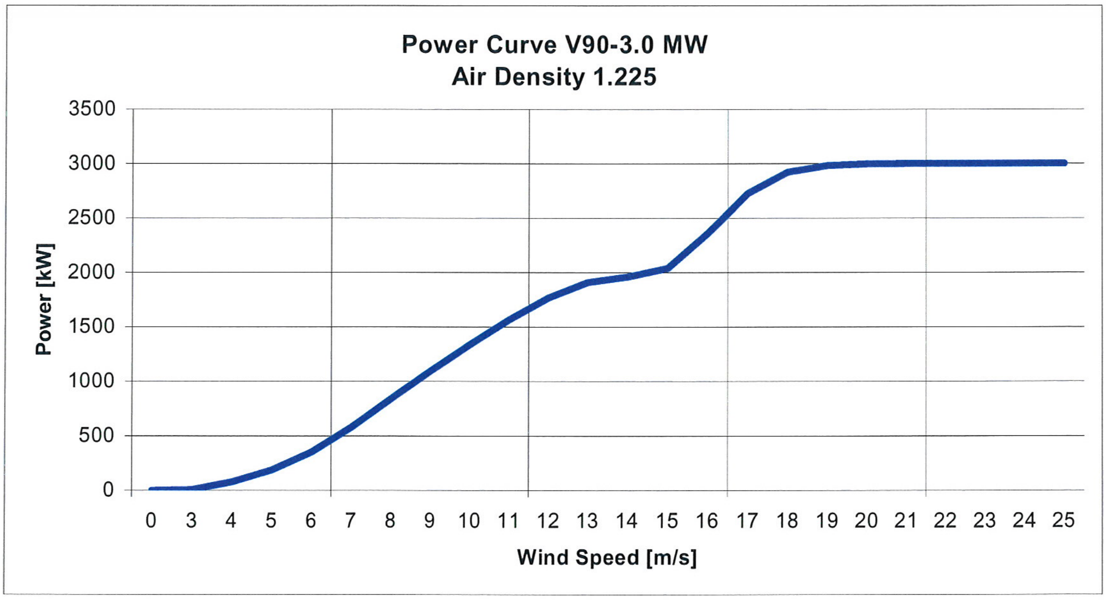


Figure 6 Power curve for Vestas V90 - 3.0 MW, 50 Hz, Mode 4 - 102.8 dB(A).

2.2 Annual Production V90 - 3.0MW

Below the annual outputs for different wind distributions are listed. All calculations are based on:

Wind conditions with 10% turbulence and an air density of 1.225 kg/m3
80m tower
100% availability.

C=1.5						
	5 m/s	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**
Wind Turbine	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**
Mode 0	3997	5882	7695	9300	10627	11660
Mode 1	3972	5842	7644	9240	10563	11594
Mode 2	3892	5718	7485	9057	10365	11390
Mode 3	3554	5162	6741	8174	9391	10363
Mode 4	3340	4807	6252	7576	8713	9631

C=2.0						
	5 m/s	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**
Wind Turbine	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**
Mode 0	3277	5338	7553	9706	11650	13298
Mode1	3262	5302	7497	9633	11567	13210
Mode 2	3214	5191	7321	9408	11312	12941
Mode 3	3027	4737	6559	8377	10092	11610
Mode 4	2897	4458	6095	7730	9290	10699

C=2.5						
	5 m/s	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**
Wind Turbine	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**
Mode 0	2768	4798	7184	9654	11987	14058
Mode 1	2763	4774	7131	9573	11888	13951
Mode 2	2742	4694	6965	9326	11586	13622
Mode 3	2660	4394	6305	8267	10201	12031
Mode 4	2583	4187	5912	7651	9359	11004

2.3 Noise Curves V90 - 3.0 MW

2.3.1 Noise Curve V90 - 3.0 MW, 50 Hz, Mode 0 - 109.4 dB (A)

Guaranteed Sound Power Level at Hub Height: Noise mode 0				
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 2 2002 Wind shear: 0.16 Max. turbulence at 10 meter height: 16% Inflow angle (vertical): 0 ± 2° Air density: 1.225 kg/m³			
Hub Height	65m	80m	90m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.4 5.4	97.0 5.6	97.5 5.7	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	101.5 6.8	102 7.0	102.4 7.1	103.0 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.3 8.1	105.8 8.4	106.1 8.5	106.5 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.8 9.4	108.2 9.8	108.3 9.9	108.6 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	109.1 10.8	109.3 11.2	109.4 11.4	109.4 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	109.4 12.1	109.4 12.6	109.2 12.8	109.0 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	108.0 13.5	106.7 14.0	106.5 14.3	106.3 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.1 14.8	105.9 15.3	105.9 15.6	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.8 16.2	105.7 16.7	105.7 17.1	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.6 17.5	105.7 18.1	105.7 18.5	105.7 18.9

The noise level is guaranteed for the turbine configuration as described in the general specification.
The noise guarantee will be regarded as fulfilled, if a measured sound power level minus the inaccuracy of the measurement result is lower than the guaranteed value.

2.3.2 Noise Curve V90 - 3.0 MW, 50 Hz, Mode 1 - 107.8 dB (A)

Guaranteed Sound Power Level at Hub Height: Noise mode 1				
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 2 2002 Wind shear: 0.16 Max. turbulence at 10 meter height: 16% Inflow angle (vertical): 0 ± 2° Air density: 1.225 kg/m³			
Hub Height	65m	80m	90m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.4 5.4	97.0 5.6	97.5 5.7	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	101.5 6.8	102 7.0	102.4 7.1	103.0 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.3 8.1	105.8 8.4	106.1 8.5	106.5 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.5 9.4	107.7 9.8	107.8 9.9	107.8 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.8 10.8	107.8 11.2	107.8 11.4	107.8 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.8 12.1	107.8 12.6	107.8 12.8	107.7 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	107.2 13.5	106.7 14.0	106.5 14.3	106.3 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.1 14.8	105.9 15.3	105.9 15.6	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.8 16.2	105.7 16.7	105.7 17.1	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.6 17.5	105.7 18.1	105.7 18.5	105.7 18.9

The noise level is guaranteed for the turbine configuration as described in the general specification.
The noise guarantee will be regarded as fulfilled, if a measured sound power level minus the inaccuracy of the measurement result is lower than the guaranteed value.

2.3.3 Noise Curve V90 - 3.0 MW, 50 Hz, Mode 2 - 106.8 dB (A)

Guaranteed Sound Power Level at Hub Height: Noise mode 2				
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 2 2002 Wind shear: 0.16 Max. turbulence at 10 meter height: 16% Inflow angle (vertical): 0 ± 2° Air density: 1.225 kg/m³			
Hub Height	65m	80m	90m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.4 5.4	97.0 5.6	97.5 5.7	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	101.5 6.8	102 7.0	102.4 7.1	103.0 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.2 8.1	105.6 8.4	105.8 8.5	106.3 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 9.4	106.8 9.8	106.8 9.9	106.8 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 10.8	106.8 11.2	106.8 11.4	106.8 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 12.1	106.8 12.6	106.8 12.8	106.8 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.8 13.5	106.8 14.0	106.5 14.3	106.3 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	106.1 14.8	105.9 15.3	105.9 15.6	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.8 16.2	105.7 16.7	105.7 17.1	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.6 17.5	105.7 18.1	105.7 18.5	105.7 18.9

The noise level is guaranteed for the turbine configuration as described in the general specification.
The noise guarantee will be regarded as fulfilled, if a measured sound power level minus the inaccuracy of the measurement result is lower than the guaranteed value.

2.3.4 Noise Curve V90 - 3.0 MW, 50 Hz, Mode 3 - 104.4 dB (A)

Guaranteed Sound Power Level at Hub Height: Noise mode 3				
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 2 2002 Wind shear: 0.16 Max. turbulence at 10 meter height: 16% Inflow angle (vertical): 0 ± 2° Air density: 1.225 kg/m³			
Hub Height	65m	80m	90m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.4 5.4	97.0 5.6	97.5 5.7	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	101.5 6.8	102.0 7.0	102.4 7.1	102.9 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 8.1	104.4 8.4	104.4 8.5	104.4 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 9.4	104.4 9.8	104.4 9.9	104.4 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 10.8	104.4 11.2	104.4 11.4	104.4 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 12.1	104.0 12.6	104.4 12.8	104.4 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 13.5	104.1 14.0	104.4 14.3	104.4 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	104.4 14.8	104.9 15.3	105.2 15.6	105.8 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.8 16.2	105.7 16.7	105.7 17.1	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.6 17.5	105.7 18.1	105.7 18.5	105.7 18.9

The noise level is guaranteed for the turbine configuration as described in the general specification.
The noise guarantee will be regarded as fulfilled, if a measured sound power level minus the inaccuracy of the measurement result is lower than the guaranteed value.

2.3.5 Noise Curve V90 - 3.0 MW, 50 Hz, Mode 4 - 102.8 dB (A)

Guaranteed Sound Power Level at Hub Height: Noise mode 4				
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 2 2002 Wind shear: 0.16 Max. turbulence at 10 meter height: 16% Inflow angle (vertical): 0 ± 2° Air density: 1.225 kg/m³			
Hub Height	65m	80m	90m	105m
L_{wA} @ 4 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	96.4 5.4	97.0 5.6	97.5 5.7	98.2 5.8
L_{wA} @ 5 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	101.5 6.8	102.0 7.0	102.2 7.1	102.4 7.3
L_{wA} @ 6 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 8.1	102.8 8.4	102.8 8.5	102.8 8.7
L_{wA} @ 7 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 9.4	102.8 9.8	102.8 9.9	102.8 10.2
L_{wA} @ 8 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 10.8	102.8 11.2	102.8 11.4	102.8 11.7
L_{wA} @ 9 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 12.1	102.8 12.6	102.8 12.8	102.8 13.1
L_{wA} @ 10 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 13.5	102.8 14.0	102.8 14.3	102.8 14.6
L_{wA} @ 11 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	102.8 14.8	102.8 15.3	102.9 15.6	103.6 16.0
L_{wA} @ 12 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	103.9 16.2	105.0 16.7	105.7 17.1	105.7 17.5
L_{wA} @ 13 m/s (10 m above ground) [dBA] Wind speed at hh [m/sec]	105.6 17.5	105.7 18.1	105.7 18.5	105.7 18.9

The noise level is guaranteed for the turbine configuration as described in the general specification.
The noise guarantee will be regarded as fulfilled, if a measured sound power level minus the inaccuracy of the measurement result is lower than the guaranteed value.

3. Micro Siting and Network Connection

3.1 Siting in Wind Farms

Often wind turbines are placed in wind farms where park turbulence must be taken into account.

If the wind conditions of section 4.2 and a uniform wind rose apply, the wind turbines can be sited in a wind farm with a distance of at least 5 rotor diameters (450 m) between the wind turbines.

If the wind turbines are placed in one row in a site with the wind conditions of section 4.2 and a uniform wind rose, the distance between the wind turbines should be at least 4 rotor diameters (360 m).

With the above in mind, it is recommended that Vestas participates in the micro siting evaluation of the wind turbines.

3.2 Terrain Conditions

If the terrain does not live up to the specifications listed below or if the terrain otherwise seems complex, particular considerations may be necessary and Vestas must be contacted.

- Within a radius of 100 meters from the turbine, max. slope of 10°.
- Within a radius of 100 to 500 meters from the turbine, max. slope of 15°.
- Within a radius of 500 to 2000 meters from the turbine, max. slope of 20°.

3.3 Connection to the Electrical Power Grid

The transformer in the nacelle is manufactured to meet the nominal voltage of the interconnection grid (see section 7.7 for acceptable grid voltage range without further transformation). The voltage of the high voltage grid must be within +5/-5% of nominal voltage. Steady variations within +1/-3 Hz (50 Hz) are acceptable. Intermittent or rapid grid frequency fluctuations may cause serious damage to the turbine. Averaged over the wind turbine's lifetime, grid failure must not occur more than once a week (e.g. a maximum of 52 occurrences within a year).
A ground connection of maximum 10 Ω must be present.
The customer's earthing system must be designed for local soil conditions. The resistance to neutral earth must be in accordance with the requirements of the local authorities.

NB: When ordering, please provide VESTAS with precise information about grid voltage in order to facilitate specification of the transformer's nominal voltage and winding connection (delta connection on the high voltage winding is supplied as default, unless otherwise specified). As an option, VESTAS offers a high voltage switchgear.

4. General Ambient Design Criteria

4.1 General Conditions

The wind turbine is designed for operation in ambient temperatures ranging from -20°C to +40°C. All components including liquids, oil etc. are designed to survive temperatures as low as -40°C. Special precautions must be taken outside these temperatures. If the temperature inside the nacelle exceeds 50°C, the turbine is paused.
The relative humidity can be 100% (max. 10% of the lifetime). Corrosion protection is according to ISO 12944-2 or corrosion class C5M (outside) and C3 to C4 (inside). All corrosion protections are designed for long lifetime (more than 15 years). See special differentiation on the tower in section 7.17 Tower.

4.2 Wind Conditions

The wind conditions can be described by a Weibull distribution where the annual average wind speed and a shape parameter (C) describe the wind distribution. Furthermore, the wind climate can be described by maximum wind speeds and the turbulence. Turbulence is a factor describing short-term wind variations/fluctuations. Below, the design conditions assumed for the operating environment for the Vestas V90-3.0 MW 50 Hz wind turbine are listed.

- Standard IEC IA
- Average wind speed 10.0 m/s
- C-parameter 2
- Turbulence I_{15}*) 18%
- Max. average wind **) 50.0 m/s
- Max. wind gust ***) 70.0 m/s

*) The turbulence is wind dependent and varies from 34.1 - 16.1% at wind speeds between 4 - 25 m/s. At 15 m/s the turbulence is 18%.
**) 10 min, 50 years' mean wind speed.
***) 3 sec, 50 years' gust wind speed.

Wind speed and turbulence refer to hub height.
The wind conditions listed above are design parameters as is the cut out wind speed. Other parameters can also influence the turbine lifetime and the following values should not be exceeded.

- Cut out wind speed 25 m/s
- Restart wind speed 20 m/s

5. Type Approvals

The V90 - 3.0 MW wind turbine is type approved in accordance with:

- IEC WT01
- DS472
- NVN 11400-0
- DIBt Richtlinie für Windkraftanlagen

6. Options

6.1 Advanced Grid Option 2

Wind turbines with the advanced grid option are specially designed to tolerate short time voltage reductions due to grid faults. With the grid option the turbines generate a capacitive short circuit current, improve the grid stability and resume power production almost instantly after a grid fault.

The turbine is equipped with a reinforced Vestas Converter System in order to gain better control of the generator during grid faults. The controllers and contactors have a UPS backup system in order to keep the turbine control system running during grid faults.
The pitch system is optimized to keep the turbine within normal speed conditions and the generator is accelerated in order to store rotational energy and be able to resume normal power production after a fault.

6.2 Extended UPS

The UPS system consists of one UPS from which the power is distributed to a number of strings. Some of these strings have a timer controlled relay function which disconnects the power to the devises on the string. The control for the timer is managed by the turbine control system and some preset timers. The reason for disconnecting some strings is different demands on the length of backup time needed for the different devises. Disconnecting some strings allows the remaining strings to run for a longer time without draining the battery too fast, which would close down the UPS and no power would be available.

When the grid supply is present, the power flows through the UPS and it uses the grid supply to charge the batteries. When the grid supply is not present, the UPS takes the power from the batteries and supplies all components connected to the UPS.

The UPS system is designed as a basic system to which a number of options can be added. It is also designed as a modular system thus enabling UPS output and backup time to be changed without a major redesign.

6.3 High Voltage Switchgear

The high voltage SF_6 fully insulated switchgear consists of two separate cubicles. The two cubicles are a feeder panel with a load breaker switch and a circuit breaker. The load breaker switch has 3 positions: closed, open and earthed. When the breaker is in earthed position, the grid cable is connected to earth. The circuit breaker cubicle contains a load breaker switch and a circuit breaker with a self-powered relay. The load breaker is also a 3-positioned breaker, which can earth the transformer cable through the circuit breaker. The relay provides the opportunity of tripping the circuit breaker externally (230 V) either by the VMP controller, arc detector, smoke detector or manually from the nacelle.
The purpose of the switchgear is to protect the turbine against over current, short-circuit and earth faults.
Both cubicles can be equipped with capacitive voltage indicators, motorisation and tank manometers.
The cable connection on the switchgear is standard 630 A elbow cone connectors.
Loop in and out option is available.

6.4 Obstruction Light

Vestas is capable of delivering optional obstruction lighting for the V90 3MW turbine. The turbine will be equipped with 2 obstruction lights on the nacelle, placed in such a manner that at least one light will always be visible.

The following standard integrated aviation light options are available:

1. Low intensity. Red 10-200 cd.
2. Medium intensity. Red/white/dual 200-2000 cd.
3. Medium intensity. Red/white/dual 2000-20000 cd.

The options are designed according to the ICAO and the FAA codes.

When using obstruction light delivered by Vestas, a range of additional features are offered: Remote monitoring of light function, supervision of remaining lifetime, alarm if a lamp failure occurs and intensity control according to weather visibility.
When installed in a wind farm, the obstruction light flashes can be synchronised throughout the whole wind farm.

6.5 Service Lift inside the Tower

The turbine can be delivered with a service lift inside the tower.

6.6 Wind Turbine Colour

Default colour Ral 7035 (light grey) and optional Ral 9010 (white) are available.

7. Technical Specifications and Diagrams

7.1 Rotor

Diameter:	90 m
Swept area:	6362 m^2
Rotational speed static, rotor:	16.1 RPM
Speed, dynamic operation range:	8.6 - 18.4 RPM
Rotational direction:	Clockwise (front view)
Orientation:	Upwind
Tilt:	6°
Blade coning:	4°
Number of blades:	3
Aerodynamic brakes:	Full feathering

7.2 Hub

Type:	SG Cast Iron
Material:	GJS-400-18U-LT
Weight:	8000 kg

7.3 Blades

Principle:	Airfoil shells bonded to supporting spar
Material:	Fibreglass and carbon fibre reinforced epoxy
Blade connection:	Steel root inserts
Air foils:	RISØ P + FFA-W3
Length:	44 m
Chord at blade root:	3.512 m
Chord at blade tip:	0.391 m
Twist (blade root/blade tip):	17.5°

7.4 Bearings

Type:	4-point ball bearing

7.5 Sensors

7.5.1 Lightning Detector

Appellation:	Lightning detector
Signal:	Optical analogue

7.5.2 Wind Sensor

Appellation:	Acoustic resonance (2 units)
Signal:	RS485
Accuracy:	+/- 0.5 m/s, less than 15 m/s +/- 4%, more than 15 m/s

7.5.3 Smoke Detector

Appellation:	Smoke detector
Signal:	Digital 24 V

7.5.4 Movements and Vibrations

Appellation:	Accelerometer, tower
Signal:	RS485

7.6 Generator

Rated power:	3.0 MW
Type:	Asynchronous with wound rotor, slip rings and VCS
Voltage:	1000 VAC
Frequency:	50 Hz
No. of poles:	4
Protection class:	IP54
Rated speed:	1680
Rated power factor, default at 1000 V:	1.0
Power factor range at 1000 V:	0.98_{CAP} - 0.96_{IND}

7.7 Transformer

Type:	Cast resin
Rated power:	3140 kVA
High voltage:	10 – 33,0 kV
Frequency:	50 Hz
Vector group:	Dyn
HV - Tappings:	±2 x 2.5%
Low voltage:	1000 V
Power at 1000 V:	2835 kVA
Low voltage:	400 V
Power at 400 V:	305 kVA

7.8 Switchgear, Electrical Characteristics

7.8.1 Feeder Function

Rated voltage [kV] (Max. system voltage)	24	36
Rated current [A]	400/630	400/630
Short time withstand current (1 or 3 s) [kA]	16/20	16/20
Insulation level:		
Power frequency (1 min) [kV]	50	70
Lightning impulse [kV_{peak}]	125	170
Making capacity [kA_{peak}]	40/50	40/50
Breaking capacity:		
Mainly active current [A]	400/630	400/630
Capacitive current [A]	31.5	31.5
Inductive current [A]	16	16

7.8.2 Circuit Breaker Function

Rated voltage [kV] (Max. system voltage)	24	36
Rated current [A]	400/630	400/630
Short time withstand current (1 or 3 s) [kA]	12.5/16/20	12.5/16/20
Insulation level:		
Power frequency (1 min) [kV]	50	70
Lightning impulse [kV_{peak}]	125	170
Making capacity [kA_{peak}]	31/40/50	31/40/50
Breaking capacity [kA]	12.5/16/20	12.5/16/20

7.9 Yaw System

Type:	Plain bearing system with built-in friction
Material:	Forged yaw ring, heat-treated. Plain bearings PETP
Yawing speed:	<0.5°/sec

7.10 Yaw Gears

Type:	4-step planetary gear with motor brake
Motor:	2.2 kW, 4-pole, asynchronous

7.11 Gearbox

Type:	2 planetary stages + 1 helical stage
Type no.:	EF901
Shaft distance:	461 mm
Ratio:	1:104.5 (50 Hz)

7.12 Parking Brake

Type:	PZ.I.4420.2802.10
Brake pad type:	MPM 030
Supply:	Separate hydraulic pump unit

7.13 Hydraulics

Pressure:	260 bar
Location:	The hydraulic power unit is located in the nacelle. A pipe connects the hydraulic power unit in the nacelle with a manifold for the pitch system in the hub.

7.14 Cooling System

Gear oil cooling:	2 water/air cooling units located above the transformer room. Connected to the oil/water heat exchanger located by the gear oil tank.
Generator cooling:	2 water/air coolers located above the transformer room.
Water cooling:	Coupled on generator cooler.
Transformer cooling:	Cooling air is blown through the windings from the bottom of the transformer.
Nacelle cooling:	Cooling of the nacelle is done by leading air through an opening in the fibreglass floor behind the tower. Outgoing air is led through a fan to the transformer room and blown out at the rear end of the nacelle. The air intake and outlet are controlled by flap valves, which open when the nacelle temperature reaches a certain level.

7.15 Nacelle Bedplate

Front part:	Spheroidal graphite iron GJS-400-18U-LT Foundation for gear, generator, yaw bedding, crane girders and rear foundation.
Weight:	8500 kg
Rear part:	Welded gratings integrated with crane girders. Foundation for electrical panels, transformer and cooling room.

7.16 Nacelle

Material:	Fibreglass.

7.17 Tower

Type:	Conical tubular
Material:	S355 J2G3/NL
Surface treatment:	Painted
Corrosion class, outside:	C4 (ISO 12944-2)/offshore C5-M
Corrosion class, inside:	C3 (ISO 12944-2)/offshore C4
Top diameter for all towers:	2.3 m
Bottom diameter for all towers:	4.15 m
Hub height:	
3-parted, modular tower (IEC I / DiBT III)	80 m
5-parted, modular tower (105 m DiBt II)	105 m

The exact hub heights listed include a distance from the foundation section to the ground level of 0.55 m and a distance from the tower top flange to the centre of the hub of 1.95 m.

7.18 Weight and Dimensions

7.18.1 Nacelle

Including hub and nose cone:

Length:	13.25 m
Width:	3.6 m
Height:	4.05 m
Weight app.	91000 kg +/- 3000 kg

Without hub and nose cone:

Length:	9.65 m
Width:	3.6 m
Height:	4.05 m
Weight app.:	70000 kg +/- 2000 kg

7.18.2 Gearbox

Length:	2100 mm
Diameter:	2600 mm
Max weight:	23000 kg

7.18.3 Generator

Max length:	2800 mm
Max diameter:	1100 mm
Max weight:	8600 kg

7.18.4 Transformer

Length:	2340 mm
Width:	1090 mm
Height:	2150 mm
Max weight:	8000 kg

7.18.5 Rotor Blades

Length:	44 m
Max weight:	6600 kg/pcs. +/- 400 kg

7.18.6 Switchgear, Feeder Function (Option)

Rated voltage [kV]	24	36
Width [mm]	370	420
Height [mm]	1400	1800
Depth [mm]	850	850
Weight [kg]	135	140

7.18.7 Switchgear, Circuit Breaker Function (Option)

Rated voltage [Kv]	24	36
Width [mm]	480	600
Height [mm]	1400	1800
Depth [mm]	850	850
Weight [kg]	218	238

7.18.8 Towers

3-parted, modular tower (80 m IEC I / DIBt III):	160 t
5-parted, modular tower (105 m DiBt II):	235 t

8. General Reservations, Notes and Disclaimers

- All data are valid at sea level (ρ=1.225 kg/m^3).
- Periodic operational disturbances and generator power de-rating may be caused by a combination of high winds, low voltage or high temperature.
- Vestas recommends that the electrical grid is as close to nominal as possible with little variation in frequency.
- A certain time allowance for turbine warm-up must be expected following a grid dropout and/or periods of very low ambient temperature.
- If the wind turbine is sited at elevations greater than 1000 m (3300 ft) above sea level, a higher temperature rise than usual may occur in the electrical components. In such cases, a periodic power reduction from rated electrical output may occur. This may occur even when the ambient temperature remains within specified limits.
- Furthermore, sites situated more than 1000 m (3300 ft.) above sea level usually experience an increased risk of icing in most climates.
- Because of continuous development and product upgrade, Vestas reserves the right to change or alter these specifications at any time.
- All listed start/stop parameters (e. g. wind speeds and temperatures) are equipped with hysteresis control. This can, in certain borderline situations, result in turbine stops even though the ambient conditions are within the listed operation parameters.
- Vestas Optispeed™ technology is not available in the United States of America and Canada.

Class I
EDB-no. 962676.R1
2006-08-02

Foundation Loads

V90 – 3.0 MW VCS

HH80, IEC1A

IEC61400-1 Edition 3

Contents……………………………………………………………………………………..Page

1. Introduction 3
2. References..3
3. Extreme Loads...4
4. Fatigue Loads 5
4.1 Equivalent and Mean Load 5
5. Rainflow Spectrum..6
6. Stiffness of Foundation 7
Appendix A. Co-ordinate Systems 8

1. Introduction

This document presents the foundation loads from the V90 - 3.0MW VCS HH80m, IEC1A load spectrum. The loads are simulated in accordance with IEC61400-1 ed.3, ref. [1]. The geometry of the connection between the tower and foundation section can be found in ref [4].

2. References

Reference	Document	Doc. No.	Revi-sion
[1] Design Code	IEC 61400-1 Edition 3		
[2] Load Spectrum	Load Spectrum V90 – 3.0 MW WCT VCS HH80 IEC1A	962670	0
[3] Load Spectrum	Load Spectrum V90 – 3.0 MW PP VCS HH80 IEC1A	962665	0
[4] Foundation drawing	Embedment V90 3MW HH80m IEC IA	960561	0

Table 2.1 References.

3. Extreme Loads

Foundation loads components at the instant of extreme resulting bending moment are given in Table 3.1. Own weight moment contribution due to tower out of vertical (0.008 m/m) is included with PLF 1.0 in below resultant moments.

Extreme Foundation Loads	
	Extreme load case
LC	61E50a008a.int - 61E50a008f.int
F_x (kN)	-754
F_y (kN)	302
F_z (kN)	-2564
M_x (kNm)	-15117
M_y (kNm)	-55475
M_z (kNm)	-571
PLF	1.35

Table 3.1 Extreme foundation loads. Partial load Factor not included.

The own weight moment contribution due to tower out of vertical is listed in Table 3.2.

Tower own weight moment	
Tower out of vertical:	0.008 m/m
Partial load factor:	1.10
Mown	1106 kNm

Table 3.2 Tower own weight moment. PLF not included.

4. Fatigue Loads

4.1 Equivalent and Mean Load

For the foundation the mean loads have to be considered. The mean loads must be combined with either the equivalent loads or the fatigue load spectrum.

The equivalent loads given may be used only if the material property can be characterised by an S/N-curve with the same slope as given for the equivalent loads.

Equivalent and Mean Fatigue Foundation Loads			
	Mean load	Range m = 4	Range m = 7
F_x (kN)	-	-	-
F_y (kN)	195	312	294
F_z (kN)	-2761	113	95.4
M_x (kNm)	-14878	16945	18822
M_y (kNm)	-	-	-
M_z (kNm)	-84.0	2934	2587

Table 4.1 Equ. fatigue foundation loads. Neq=1e7.

5. Rainflow Spectrum

Foundation Fatigue Load Spectrum					
Tower shear, bottom F_y [kN]			Tower bending, bottom M_x [kNm]		
Range	**N**	**Nacc.**	**Range**	**N**	**Nacc.**
1042.20	7	7	74342.00	33	33
1021.30	7	14	72855.00	16	49
1000.50	17	31	71368.00	16	64
979.66	9	39	68395.00	117	181
958.82	18	57	66908.00	50	231
937.97	24	81	65421.00	43	274
917.13	59	140	63934.00	57	331
896.28	105	245	62447.00	34	365
875.44	42	286	60961.00	35	400
854.60	57	343	59474.00	8	408
833.75	29	371	57987.00	35	443
812.91	17	388	56500.00	65	507
792.06	71	459	55013.00	53	560
771.22	87	546	53526.00	65	625
750.38	17	562	52040.00	38	663
729.53	76	638	50553.00	75	737
708.69	83	721	49066.00	99	836
687.85	112	833	47579.00	67	903
667.00	108	941	46092.00	74	977
646.16	41	981	44605.00	133	1109
625.31	141	1122	43118.00	86	1195
604.47	88	1209	41632.00	212	1407
583.63	103	1312	40145.00	323	1730
562.78	190	1502	38658.00	435	2165
541.94	575	2077	37171.00	731	2896
521.10	1688	3765	35684.00	968	3863
500.25	1990	5755	34197.00	967	4830
479.41	2776	8531	32711.00	2057	6887
458.56	6609	15139	31224.00	934	7821
437.72	17317	32456	29737.00	4480	12301
416.88	26493	58949	28250.00	2590	14891
396.03	54017	112966	26763.00	16131	31022
375.19	126060	239026	25276.00	107610	138632
354.34	232500	471526	23789.00	137510	276142
333.50	423430	894956	22303.00	221890	498032
312.66	588440	1483396	20816.00	362310	860342
291.81	827810	2311206	19329.00	499270	1359612
270.97	1266100	3577306	17842.00	671780	2031392

250.13	1890400	5467706	16355.00	1101800	3133192
229.28	2763400	8231106	14868.00	1458500	4591692
208.44	3808500	12039606	13381.00	2320600	6912292
187.59	5742500	17782106	11894.00	3128700	10040992
166.75	8379200	26161306	10407.00	4494600	14535592
145.91	13182000	39343304	8921.10	6182200	20717792
125.06	23033000	62376304	7434.20	8502700	29220492
104.21	44913000	107289304	5947.40	12697000	41917492
83.38	88029000	195318304	4460.50	24826000	66743492
62.53	166930000	362248320	2973.70	84163000	150906496
41.69	276750016	638998336	1486.80	397750016	548656512
20.84	409360000	1048358336			

6. Stiffness of Foundation

The spring stiffness of the foundation must be at least $C_{\varphi,dyn} \geq 40$ GNm/rad and not higher than $C_{\varphi,dyn} \leq 550$ GNm/rad.

If pile foundation is needed, the following minimum horizontal stiffness for the total pile system must be achieved.

Weight from tower and nacelle at tower interface: $G_{tower/nac}$ = 227.000 kg

Weight of foundation plate: 850.000 kg
Total weight: 1.077.000 kg ⇒ $C_{h,dyn} \geq 2.60 * 10^8$ N/m

Weight of foundation plate: 1.000.000 kg
Total weight: 1.227.000 kg ⇒ $C_{h,dyn} \geq 3.00 * 10^8$ N/m

Weight of foundation plate: 1.150.000 kg
Total weight: 1.377.000 kg ⇒ $C_{h,dyn} \geq 3.40 * 10^8$ N/m

Values in between can be linearly interpolated.

Alternatively, the natural frequency of the total system can be verified.

Appendix A. Co-ordinate Systems