Class 1
Item no. 950010.R1
2004-03-02

General Specification

V90 – 3.0 MW

60 Hz
Variable Speed Turbine

WWW.VESTAS.COM

Vestas Wind Systems A/S
Smed Soerensens Vej 5
DK-6950 Ringkoebing

Contents .... Page

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 the variable speed concepts. With these features rated power will be maintained even in high wind speeds, regardless of air temperature and air density, and the wind turbine is able to operate the rotor at variable speed (RPM). At low wind speeds the OptiTip® system and variable speed operation maximise the power output by giving the optimal RPM and pitch angle, which also minimises the sound emission from the turbine.

1.1 Nacelle Description

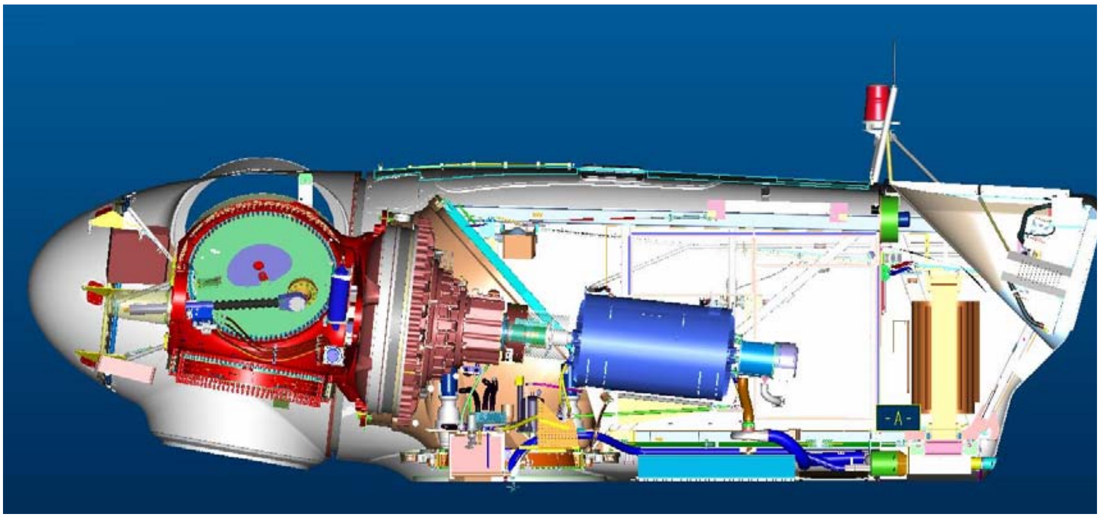

Fig. 1 V90 3.0 MW Nacelle

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 (the Bedplate)

The front of the nacelle bedplate is the foundation for the drive train, that 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 and consists 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 controller panels, cooling system and transformer.
The four yaw-gears are bolted to nacelle bedplate.

The nacelle houses the internal 800 kg SWL service crane. The crane is a single system chain hoist. If any heavier parts need service, the service crane can be upgraded to 1600/10000 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 system enables the nacelle to rotate on top of the tower. The system transmits the forces from the turbine-rotor/nacelle to the tower.

Four electrical yaw gears with motor brakes rotate the nacelle.

1.1.4 The Brake System

The turbine brakes by full-feathering of 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 3 hydraulic brake callipers.

The disc brake is considered as the parking brake.

1.1.5 Generator

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

Variable speed allows varying the rotor speed within a wide speed range. This reduces power fluctuations in the power grid system as well as minimises the loads on vital parts of the turbine. Furthermore, the variable speed system optimises the power production, especially at low wind speeds. Variable speed 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 medium 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 medium voltage (primary) side of the transformer.
The output voltages available are in 0.5 kV steps from 10 to 34.5 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 variable speed 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, thereby 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 to 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°. Every single blade has its own hydraulic pitch cylinder.

1.2.3 Hydraulics

A hydraulic system produces 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 fibre glass reinforced epoxy and carbon fibres. Each blade consists of an inner beam encircled by two shells. The blades are designed for optimised output and minimised noise and light reflection. The V90 blade design minimizes 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 Variable Speed Description

Variable speed ensures a steady and stable electric power production from the turbine.

The variable speed system consists of an asynchronous generator with wound rotor, slip rings and power converter. A power converter is connected to the rotor to control the generator at variable speed. In supersynchronous operation due to wind gusts, the excess rotor energy is dissipated in a chopper resistor.

The variable speed and the OptiTip system 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. This gives precise control of the reactive power, and gives 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 communicate 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 the operation.
- Synchronising the generator to the grid during the connection sequence, in order to limit the in rush current.
- Operating of the turbine during various fault situations.
- Automatic yawing of the nacelle in accordance to the wind direction.
- OptiTip® -Controlling the blade pitch.
- Reactive power control and variable speed.
- Noise emission control.
- Monitoring of ambient conditions (wind, temperature, etc).
- Monitoring of the grid.

- Monitoring and logging of lightning strikes.
- Supervising of the smoke detection system.
- De-rating in case of critical high temperatures.

1.3.2.1 Active Damping of Tower Oscillations

In the nacelle two accelerometers are mounted for monitoring longitudinal and transverse oscillations. Such oscillations can in certain situations be introduced when the rotational frequency of the rotor is close to the natural inherent frequency (natural oscillation) of the tower, but also high wind speeds in combination with high turbulence may cause tower oscillations.
If the oscillations exceed a certain limit, the system will bring the turbine back to normal operating conditions.
To avoid stopping the turbine, tower oscillations are damped by changing the rotational frequency of the rotor and by pitching the blades.

To damp longitudinal oscillations the blades are pitched synchronously. Transverse oscillations are damped by individual pitch.

The turbine is only stopped if the active damping is not successful.

1.3.2.2 Active Damping of Drive Train Torsional Oscillations on Variable Speed Controlled Turbines

Oscillations that may occur on 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 system is activated in order to stop further escalation of the drive train oscillations.

1.4 Monitoring

1.4.1 Sensors

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

- Weather conditions: Wind direction, wind speed and temperature.
- Machine conditions: Temperatures, oil level and pressure, cooling water level, vibrations.
- 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 strikes.

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 RCS (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 RCS.

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 remove unfavourable movements and vibrations.

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 one of the blades that 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 damage to the turbine and the need for inspection.

1.6 Service

Service interval: 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.
- 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 medium voltage transformer.

2.1.1 Power Curve, 109.4 dB(A)

V90 – 3.0 MW, 60 Hz, 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 minutes average value at hub height and perpendicular to the rotor plane

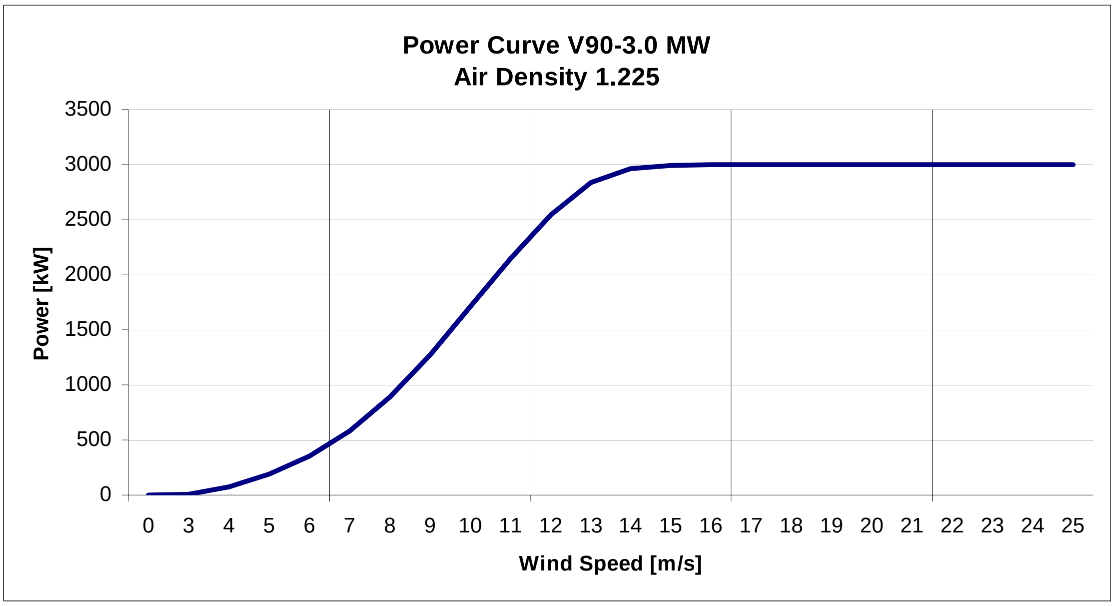

Fig. 2 Power curve for VESTAS V90 – 3.0 MW, 60 Hz 109.4 dB(A)

2.1.2 Power Curve, 107.8 dB(A)

V90 – 3.0 MW, 60 Hz, 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 minutes average value at hub height and perpendicular to the rotor plane

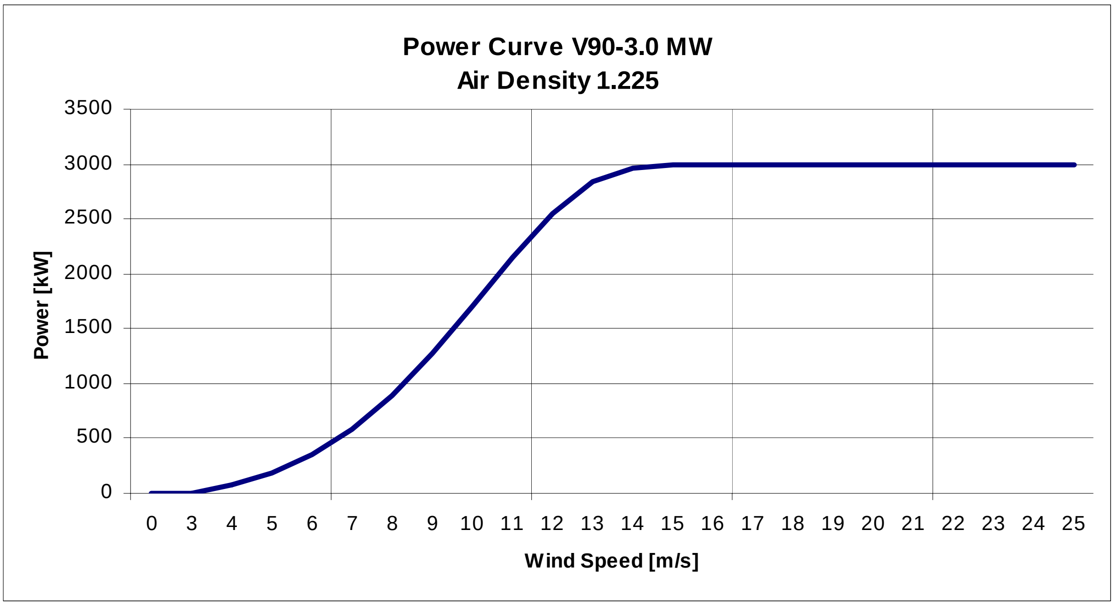

Fig. 3 Power curve for VESTAS V90 – 3.0 MW, 60 Hz, 107.8 dB(A)

2.1.3 Power Curve, 106.7 dB(A)

V90 – 3.0 MW, 60 Hz, 106.7 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 minutes average value at hub height and perpendicular to the rotor plane

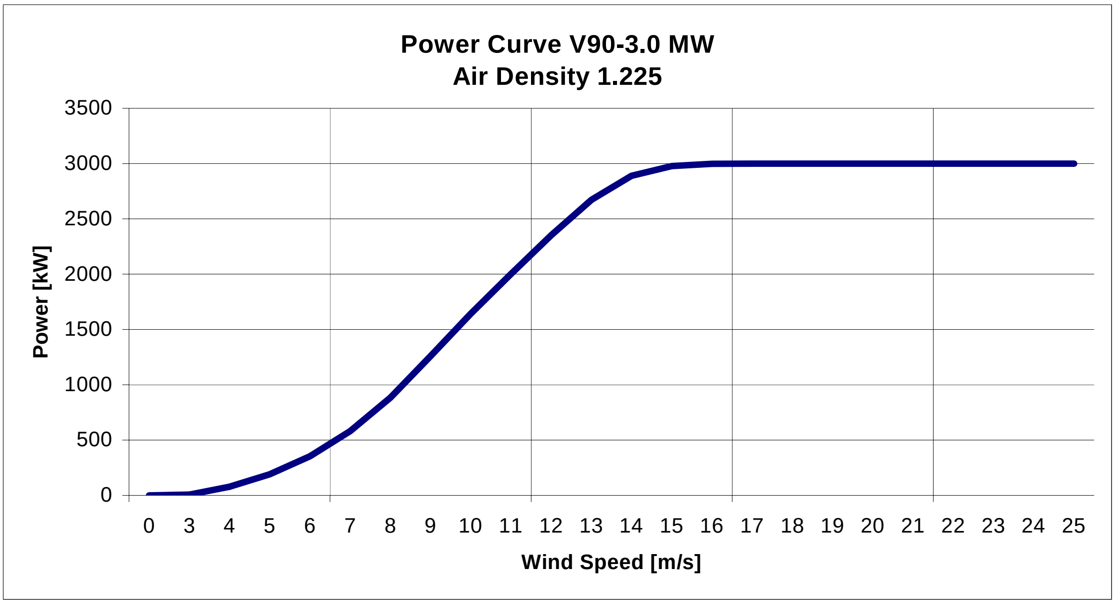

Fig. 4 Power curve for VESTAS V90 – 3.0 MW, 60 Hz, 106.7

2.1.4 Power Curve, 104.2 dB(A)

V90 – 3.0 MW, 60 Hz, 104.2 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	481	497	512	527	543	558	573	581	588	604
8	679	702	724	747	769	792	814	837	859	871	882	904
9	917	947	978	1008	1038	1068	1098	1128	1158	1173	1188	1218
10	1145	1182	1219	1256	1293	1330	1368	1405	1442	1460	1479	1516
11	1364	1408	1451	1495	1539	1583	1627	1670	1714	1736	1758	1802
12	1577	1627	1677	1728	1778	1828	1879	1929	1979	2004	2029	2080
13	1782	1839	1895	1952	2009	2065	2122	2179	2235	2263	2291	2344
14	1965	2027	2089	2152	2214	2276	2338	2400	2462	2492	2517	2556
15	2094	2160	2226	2293	2359	2425	2491	2557	2623	2653	2666	2682
16	2161	2229	2297	2366	2434	2502	2570	2638	2706	2735	2740	2744
17	2188	2257	2326	2395	2465	2534	2602	2671	2740	2771	2772	2772
18	2199	2268	2338	2407	2477	2546	2615	2685	2754	2786	2786	2786
19	2205	2274	2344	2414	2483	2553	2622	2692	2761	2794	2794	2794
20	2210	2280	2350	2420	2489	2559	2629	2698	2768	2800	2801	2801
21	2216	2286	2356	2426	2496	2566	2636	2706	2776	2808	2808	2808
22	2224	2294	2364	2434	2505	2575	2645	2715	2785	2817	2818	2818
23	2232	2302	2373	2443	2514	2584	2655	2725	2795	2829	2829	2829
24	2240	2311	2382	2452	2523	2594	2664	2735	2805	2840	2840	2840
25	2246	2318	2389	2459	2530	2601	2672	2743	2814	2848	2849	2849

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

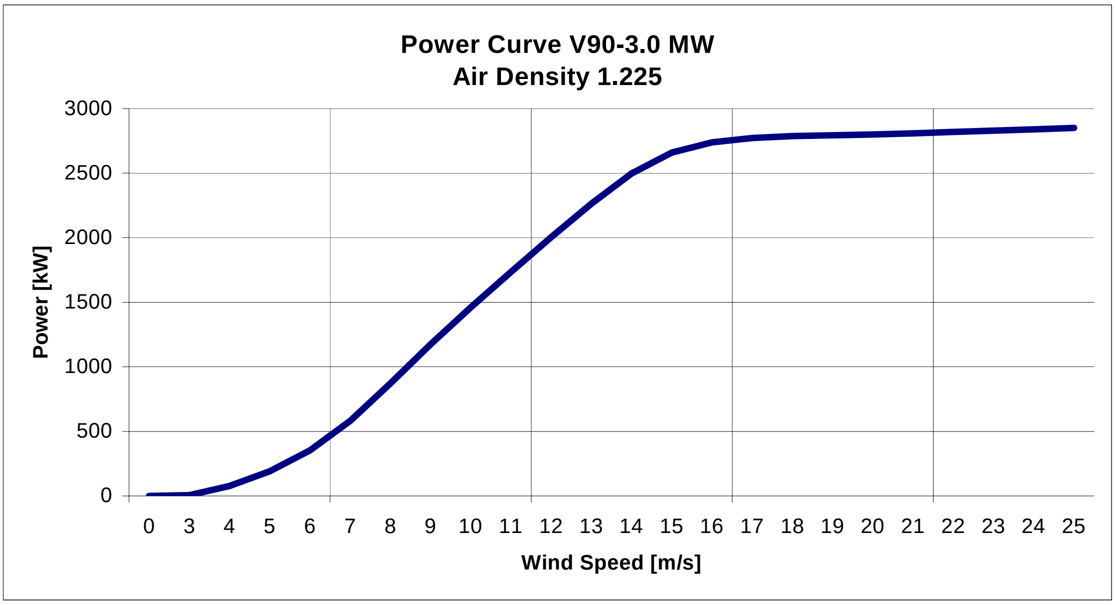

Fig. 5 Power curve for VESTAS V90 – 3.0 MW, 60 Hz, 104.2 dB(A)

2.1.5 Power Curve, 102.0 dB(A)

V90 – 3.0 MW, 60 Hz, 102.0 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	367
7	447	463	478	493	508	523	538	553	569	576	584	599
8	642	663	684	705	726	748	769	790	811	822	833	854
9	826	853	880	907	934	961	989	1016	1043	1056	1070	1097
10	1004	1037	1069	1102	1135	1167	1200	1233	1265	1282	1298	1331
11	1177	1215	1253	1291	1329	1367	1405	1443	1481	1500	1519	1557
12	1346	1389	1433	1476	1519	1562	1605	1648	1691	1713	1734	1777
13	1511	1559	1607	1656	1704	1752	1800	1848	1896	1920	1944	1992
14	1669	1723	1776	1829	1882	1935	1988	2041	2093	2120	2145	2190
15	1806	1863	1920	1977	2035	2092	2149	2206	2263	2291	2311	2340
16	1897	1957	2017	2077	2137	2196	2256	2316	2376	2404	2414	2425
17	1941	2002	2064	2125	2186	2248	2309	2370	2431	2459	2463	2465
18	1958	2020	2082	2144	2206	2268	2329	2391	2453	2481	2482	2483
19	1965	2027	2089	2151	2213	2275	2337	2399	2461	2490	2490	2490
20	1968	2031	2093	2155	2217	2279	2341	2403	2465	2495	2495	2495
21	1972	2035	2097	2160	2222	2284	2346	2408	2471	2500	2500	2500
22	1978	2040	2103	2166	2228	2290	2353	2415	2477	2507	2507	2507
23	1985	2047	2110	2173	2236	2298	2361	2423	2486	2516	2516	2516
24	1991	2054	2117	2180	2243	2306	2369	2431	2494	2525	2525	2525
25	1997	2060	2123	2186	2249	2312	2375	2438	2501	2532	2532	2532

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

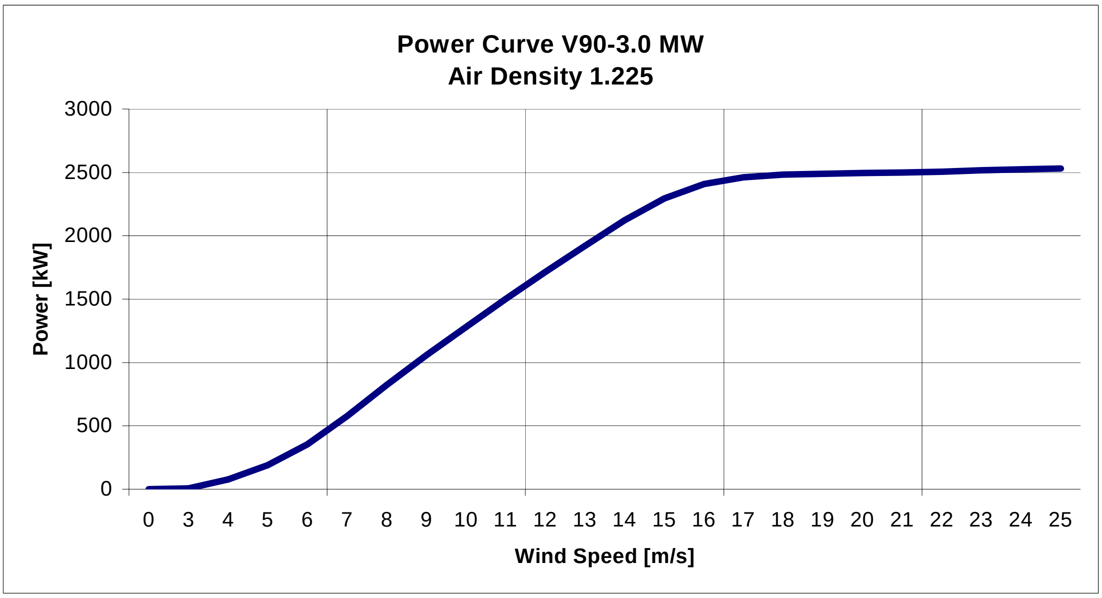

Fig. 6 Power curve for VESTAS V90 - 3.0 MW, 60 Hz, 102.0 dB(A)

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.

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**
V90 3 MW 109.4 dB (A)	4004	5889	7701	9305	10631	11664
V90 3 MW 107.8 dB (A)	3979	5849	7650	9245	10567	11598
V90 3 MW 106.7 dB (A)	3900	5725	7491	9063	10371	11395
V90 3 MW 104.2 dB (A)	3604	5231	6809	8222	9406	10340
V90 3 MW 102.0 dB (A)	3290	4710	6083	7312	8342	9156

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**
V90 3 MW 109.4 dB (A)	3114	5344	7559	9710	11654	13301
V90 3 MW 107.8 dB (A)	3101	5309	7502	9637	11571	13213
V90 3 MW 106.7 dB (A)	3057	5197	7326	9413	11317	12946
V90 3 MW 104.2 dB (A)	2903	4804	6672	8511	10208	11679
V90 3 MW 102.0 dB (A)	2724	4387	5997	7577	9041	10316

C=2.5						
Wind Turbine	**5 m/s**	**6 m/s**	**7 m/s**	**8 m/s**	**9 m/s**	**10 m/s**
	MWh	**MWh**	**MWh**	**MWh**	**MWh**	**MWh**
V90 3 MW 109.4 dB (A)	2776	4804	7189	9658	11990	14061
V90 3 MW 107.8 dB (A)	2770	4780	7136	9577	11891	13953
V90 3 MW 106.7 dB (A)	2750	4700	6970	9330	11590	13626
V90 3 MW 104.2 dB (A)	2668	4424	6400	8438	10409	12218
V90 3 MW 102.0 dB (A)	2553	4109	5805	7536	9212	10765

2.3 Noise curves V90-3.0 MW

2.3.1 Noise Curve V90 – 3.0 MW, 60 Hz, 109.4 dB (A)

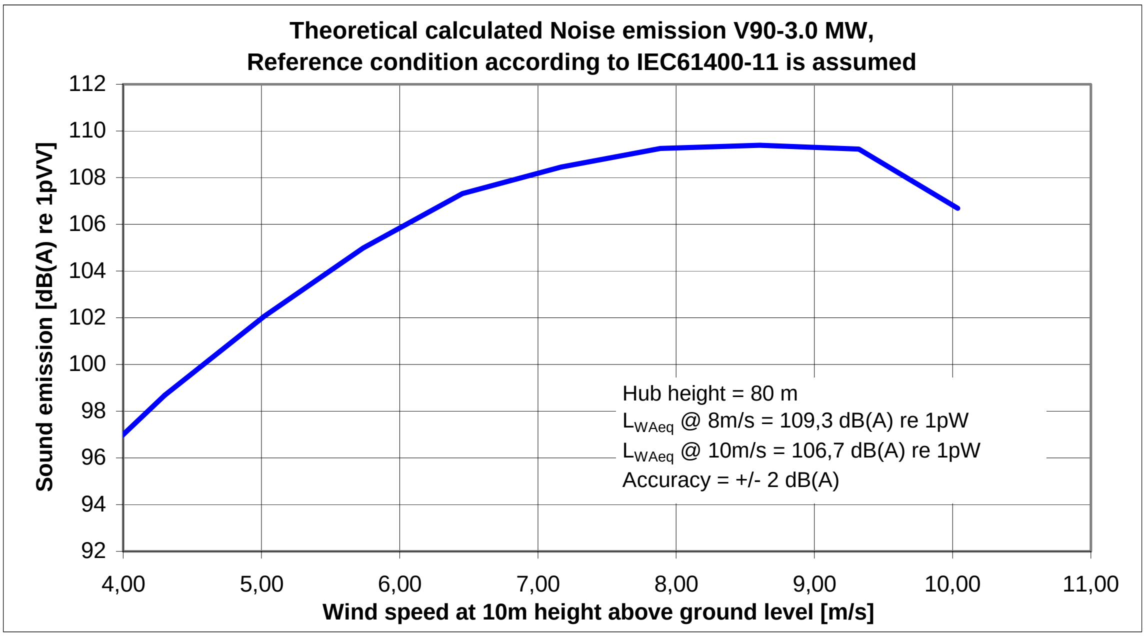

Fig. 7 Noise Emission V90 – 3.0 MW, 60 Hz: 109.4 dB (A) measures at 9 m/s in 10 m height

2.3.2 Noise Curve V90 – 3.0 MW, 60 Hz, 107.8 dB (A)

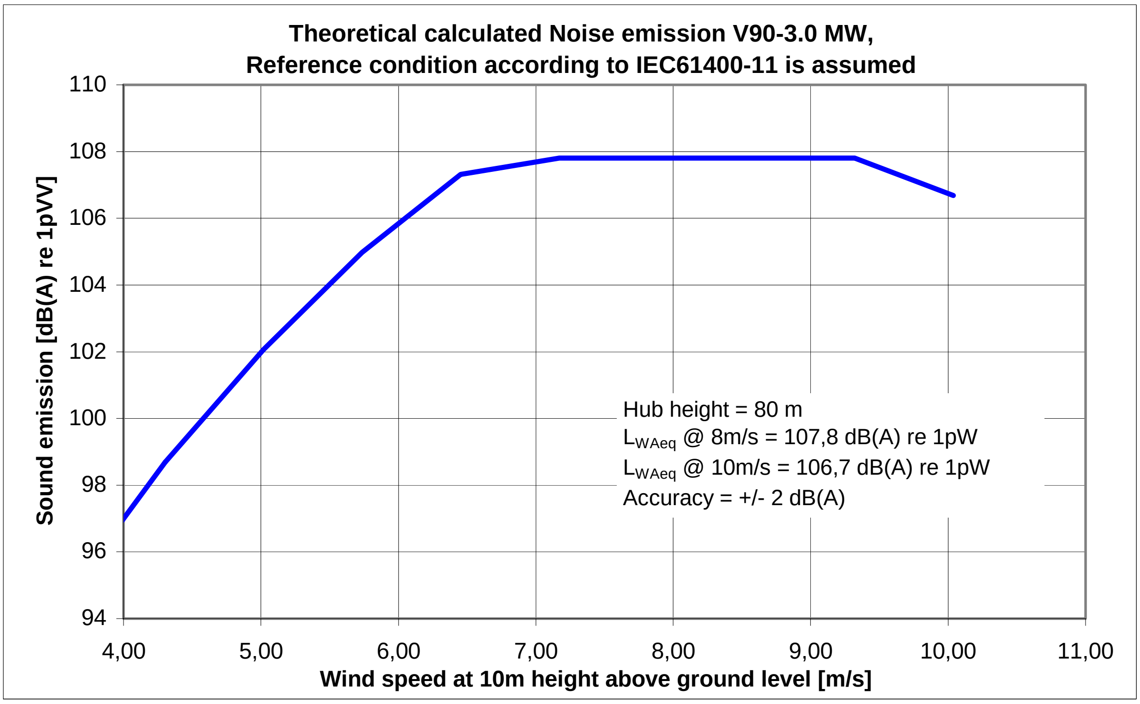

Fig. 8 Noise Emission V90 – 3.0 MW, 60 Hz: 107.8 dB (A) measures at 8 m/s in 10 m height

2.3.3 Noise Curve V90 – 3.0 MW, 60 Hz, 106.7 dB (A)

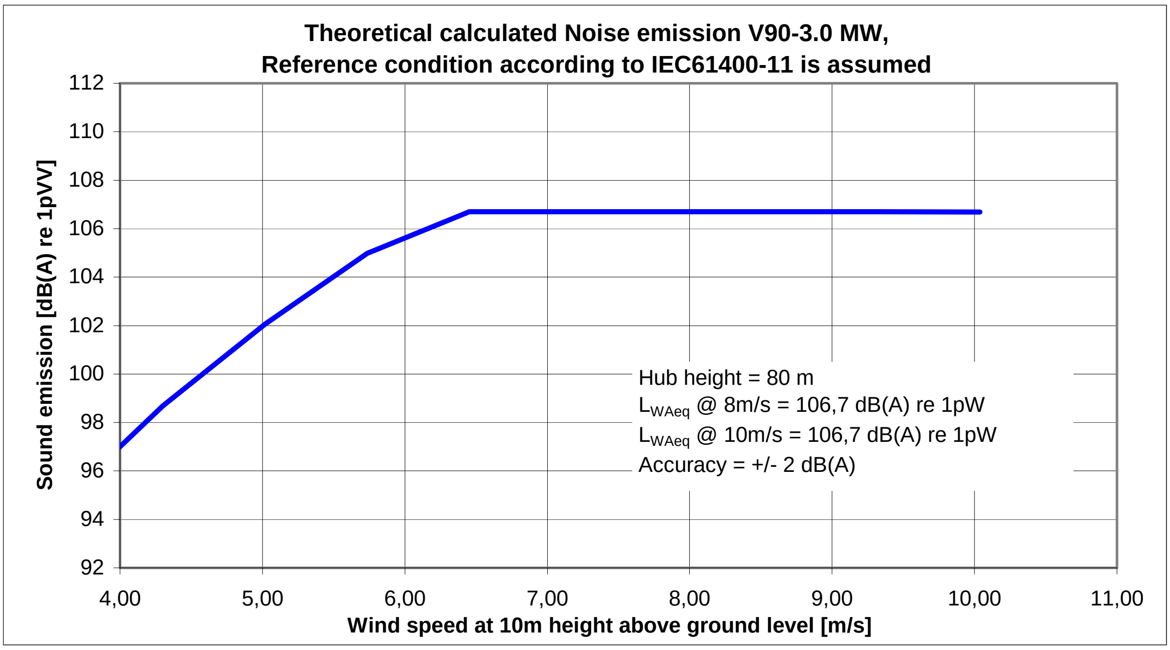

Fig. 9 Noise Emission V90 – 3.0 MW, 60 Hz: 106.7 dB (A) measures at 8 m/s in 10 m height

2.3.4 Noise Curve V90 – 3.0 MW, 60 Hz, 104.2 dB (A)

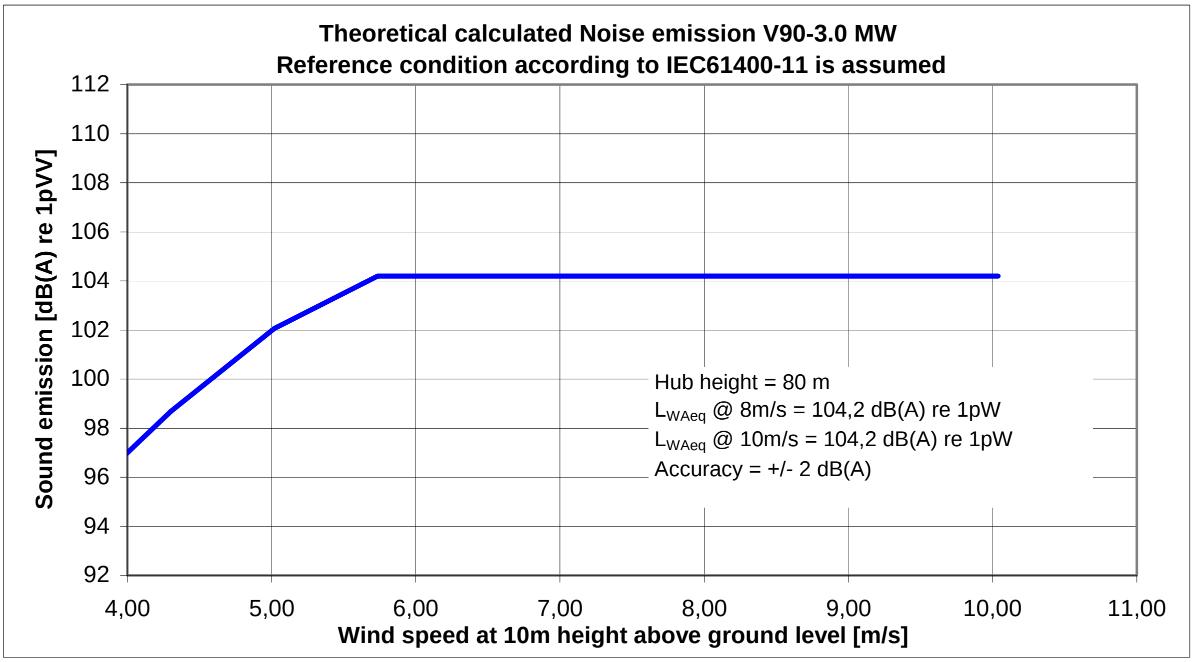

Fig. 10 Noise Emission V90 – 3.0 MW, 60 Hz: 104.2 dB (A) measures at 8 m/s in 10 m height

2.3.5 Noise Curve V90 – 3.0 MW, 60 Hz, 102.0 dB (A)

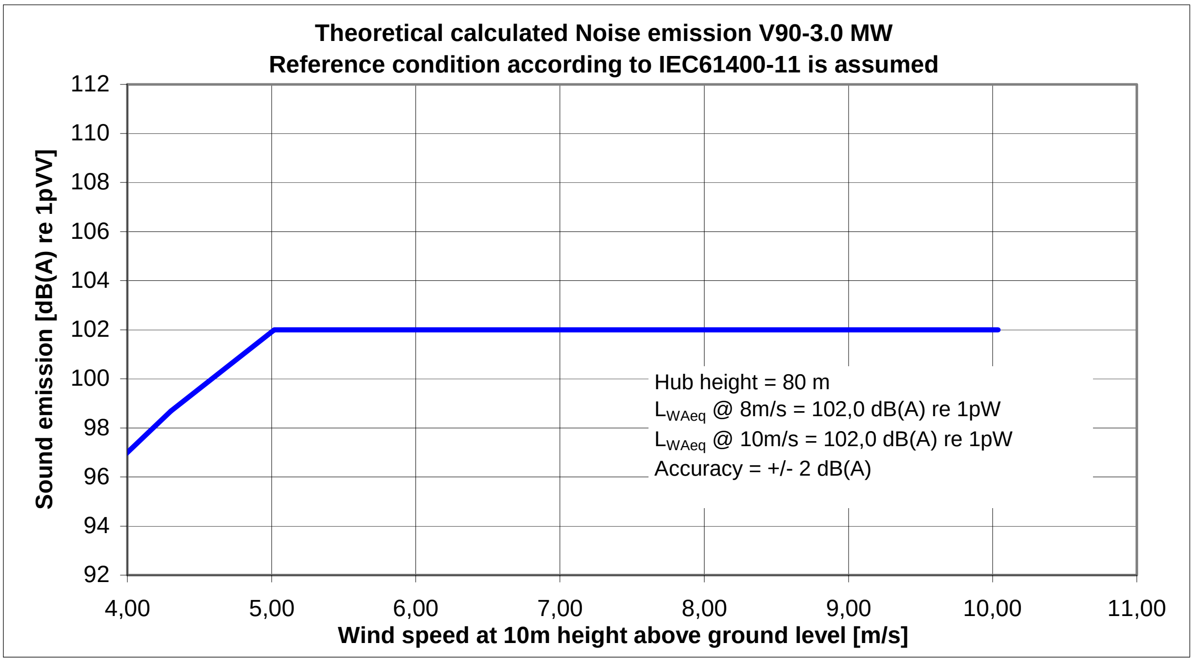

Fig. 11 Noise Emission V90 – 3.0 MW, 60 Hz: 102.0 dB (A) measures at 8 m/s in 10 m height

3. Micro Siting and Network Connection

3.1 Siting in Wind Farms

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

If the wind conditions of Section 4.2 and uniform wind rose apply, then 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 with the wind conditions of Section 4.2 and a uniform wind rose, then distance between the wind turbines should be at least 4 rotor diameters (360 m).

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

3.2 Terrain Conditions

If the terrain is outside the below listed rules or 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 radius from 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 medium voltage grid must be within +5/-5% of nominal voltage. Steady variations within +2/-3 Hz (60 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. maximum of 52 occurrences within a year).
A ground connection of maximum 10 Ω must be present.
The customer's grounding system must be designed for local soil conditions. The resistance to neutral ground 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 medium voltage winding is supplied as default, unless otherwise specified). As an option, VESTAS offers medium 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 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 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 describe the wind distribution. Further the wind climate can be described by maximum wind speeds and the turbulence. Turbulence is a factor to describe short-term wind variations/fluctuations. Below is listed the design conditions assumed for the operating environment for the Vestas V90-3.0 MW, 60 Hz wind turbine.

- Standard IEC IIA
- Average wind speed 8.5 m/s
- C-parameter 2
- Turbulence I_{15}*) 18%
- Max average wind **) 42.5 m/s
- Max wind gust ***) 59.5 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 above listed wind conditions 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.

- Max wind gust acceleration 10 m/s^2
- Cut out Wind Speed 25 m/s
- Restart Wind Speed 20 m/s

5. Type Approvals

The V90 – 3.0 MW wind turbine will be type approved in accordance with:

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

6. Options

6.1 Power Quality

The turbine is optionally equipped with a three-phase voltage- and current-measuring module.
The instrument transformers are located on the medium-voltage side, which afford the possibility to compensate the reactive power consumption in transformer and connection cables.

Based on measurements the following will be calculated:

- RMS active power
- RMS reactive power
- Phase angle (Cos Phi)
- Frequency
- Asymmetric ampere/voltage

From these calculations statistics are made on the power quality.

6.2 Medium Voltage Switch Gear

The purpose of the switch gear is to protect the turbine against over current, short circuit and ground faults. The switchgear consists of a gas-tight tank containing SF6 gas, a load-interrupter switch and a resettable fault interrupter, with visible open gaps (where required), integral visible grounds and a microprocessor-based overcurrent control. The load-breaker is also a 3-positioned breaker, which can earth the transformer cable through the circuit breaker. Load-interrupter switch terminals are equipped with bushings rated 600 amperes continuous, and fault-interrupter terminals that are equipped with bushing wells rated 200 amperes continuous or bushings rated 600 amperes continuous (as specified) to provide for elbow connection. Manual operating mechanisms and viewing windows are located to protect operating personnel from the bushings and bushing wells while performing any routine operations. A motor-operator is available for remote tripping of the switchgear, by the VMP controller, arc detector, smoke detector or manually from the nacelle.
Loop in and - out option is available.

6.3 Remote Control and Monitoring – VestasOnline™

The VestasOnline™ product family is the new generation of remote monitoring and control solutions from Vestas. It is based on field experience from the proven Vestas Remote Panel for Windows (WRPWin) and Vestas Graphical Control and Supervision (VGCS) programs. VestasOnline™ consists of three separate product packages:

VestasOnline™ Standard - designed for control and monitoring of single wind turbines and smaller wind power plants, typically consisting of up to 20 wind turbines.

VestasOnline™ Professional - designed for wind power plants that require additional functionality and flexibility as it includes a professional SQL database with capacity to store several years of wind power plant data. In addition, VestasOnline™ Professional also integrates and controls other wind power plant equipment such as substations, grid measurement stations, meteorological equipment and PLC systems. VestasOnline™ Professional is the recommended solution for single wind power plants consisting of up to 250 wind turbines.

VestasOnline™ Enterprise - is the high-end member of the product family. It contains all the features of VestasOnline™ Professional plus additional advanced software options for monitoring and managing multiple wind power plants.

VestasOnline™ Enterprise is the recommended solution for wind power plants consisting of up to 2000 wind turbines as well as for wind power plants with the highest demand for system availability.

6.4 Obstruction Light

At customer's request, Vestas is capable of delivering optional obstruction lighting for the V90 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 and UPS. When installed in a wind farm, the obstruction light flash can be synchronized throughout the whole wind farm.

6.5 Service lift inside the tower

The turbine can be delivered with a UL/CSA approved service lift inside the tower.

6.6 Wind turbine color

Ral 9010 (white) and Ral 7035 (light grey) is available.

7. Technical Specifications & Diagrams

7.1 Rotor

Diameter:	90 m
Swept area:	6362 m^2
Speed, nominal power:	16.1 RPM Speed, Dynamic operation range
rotor:	9.9 - 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:	8500 kg

7.3 Blades

Principle:	Airfoil shells bonded to supporting beam
Material:	Fibreglass reinforced epoxy and carbon fibres
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:	Ultrasonic wind sensor, (2 units)
Signal:	RS485/optical

Accuracy:	+/- 0.1 m/s, less than 5 m/s +/- 2 %, more than 5 m/s

7.5.3 Smoke

Appellation:	Smoke detector
Signal:	Digital 24 V

7.5.4 Movements and Vibrations

Appellation:	Accelerometer, tower
Signal:	RS485

7.6 Generator

	Generator 60 Hz
Rated power:	3.0 MW
Type:	Asynchronous with wound rotor, slip rings and VCRS
Voltage:	1000 VAC
Frequency:	60 Hz
No. of poles:	4
Class of protection:	IP54
Rated speed:	1758
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:	3160 kVA
High voltage:	10 – 34.5 kV
Frequency:	60 Hz
Vector group:	Dyn
HV – Tappings:	±2 x 2.5%
Low voltage:	1000 V
Power at 1000 V:	3326 kVA
Low voltage:	400 V
Power at 400 V:	168 kVA

7.8 Switch Gear Electrical Characteristics

7.8.1 Feeder Function

Rated voltage [kV] (Max. system voltage)	27	38
Rated current [A]	600	600
Short time withstand current (1 or 3 s) [kA]	25	25
Insulation level:		
Power frequency (1 min) [kV]	50	50
Lightning impulse [kV_{peak}]	125	150
Making capacity [kA_{peak}]	40	40
Breaking capacity:		
Mainly active current [A]	600	600

7.8.2 Circuit Breaker Function

Rated voltage [kV] (Max. system voltage)	27	38
Rated current [A]	600	600
Short time withstand current (1 or 3 s) [kA]	25	25
Insulation level:		
Power frequency (1 min) [kV]	50	50
Lightning impulse [kV_{peak}]	125	150
Making capacity [kA_{peak}]	40	40
Breaking capacity [kA]	25	25

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 stage + 1 helical stage
Type no.:	EF901AE55-K1
Shaft distance:	461 mm
Ratio:	1:109.0 (60 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:	250 bar
Placement:	The complete hydraulic system is mounted 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 the glassfibre floor behind the tower. Outgoing air is led through a fan to the transformer room and is later blown out at the rear end of the nacelle. The air intake is controlled by a flap valve, which opens 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
Surface treatment:	Painted
Corosion class, outside:	C4 (ISO 12944-2)/offshore C5-M
Corosion class, inside:	C3 (ISO 12944-2)/offshore C4
Top diameter for all towers:	2.3 m
Bottom diameter for all towers:	3.98 m
	Hub Height
3-parted, modular tower	65 m
3-parted, modular tower	80 m

The exact hub height listed includes 0.55 m distance from the foundation section to the ground level and 2.0 m distance from the tower top flange to the hub center.

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.	88000 kg +/- 3000 kg

Without hub and nose cone:

Length:	9.65 m
Width:	3.6 m
Height:	4.05 m
Weight app.:	68000 kg +/- 2000 kg

7.18.2 Gearbox

Length: 2100 mm
Diameter: 2600 mm
Weight max.: 23000 kg

7.18.3 Generator

Length max.: 2800 mm
Diameter max.: 1100 mm
Weight max: 8500 kg

7.18.4 Transformer

Length: 2340 mm
Width: 1090 mm
Height: 2150 mm
Weight max.: 8000 kg

7.18.5 Rotor Blades

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

7.18.6 Switch Gear, 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 Switch Gear, 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

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 combination of high winds, low voltage or high temperature.
- Vestas recommends that the electrical grid be as close to nominal as possible with little variation in frequency.
- A certain time allowance for turbine warm-up must be expected following 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 than usual temperature rise may occur in 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 at greater 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.

9. Performance Note

THE PERFORMANCE OF THE VESTAS V90-3.0 MW WIND TURBINES CAN AND WILL VARY DEPENDING ON NUMEROUS VARIABLES, MANY OF WHICH ARE CONSIDERED AS PART OF THE PERFORMANCE MEASUREMENT STANDARD SET FORTH IN THESE GENERAL SPECIFICATIONS. MANY OF THESE VARIABLES INCLUDING, BUT NOT LIMITED TO, SITE LOCATION, INSTALLATION, TURBINE CONDITION, TURBINE MAINTENANCE AND ENVIRONMENTAL/CLIMATIC CONDITIONS ARE BEYOND THE CONTROL OF VESTAS. UNLESS OTHERVISE CONTRACTUALLY AGREED IN WRITING, ALL PERFORMANCE SPECIFICATIONS SET FORTH IN THESE GENERAL SPECIFICATIONS INCLUDING, BUT NOT LIMITED TO, POWER CURVES, ANNUAL PRODUCTIONS AND NOISE EMISSIONS SHOULD BE USED FOR GUIDEANCE ONLY, AND NOT AS A PREDICTOR OR GUARANTEE OF FUTURE PERFORMANCE. FOR ADDITIONAL INFORMATION REGARDING THE INSTALLATION, MAINTENANCE AND PERFORMANCE OF THE VESTAS V90–3.0 MW WIND TURBINES, PLEASE CONTACT VESTAS DIRECTLY.