

Appendix G

Vestas Turbine Specs

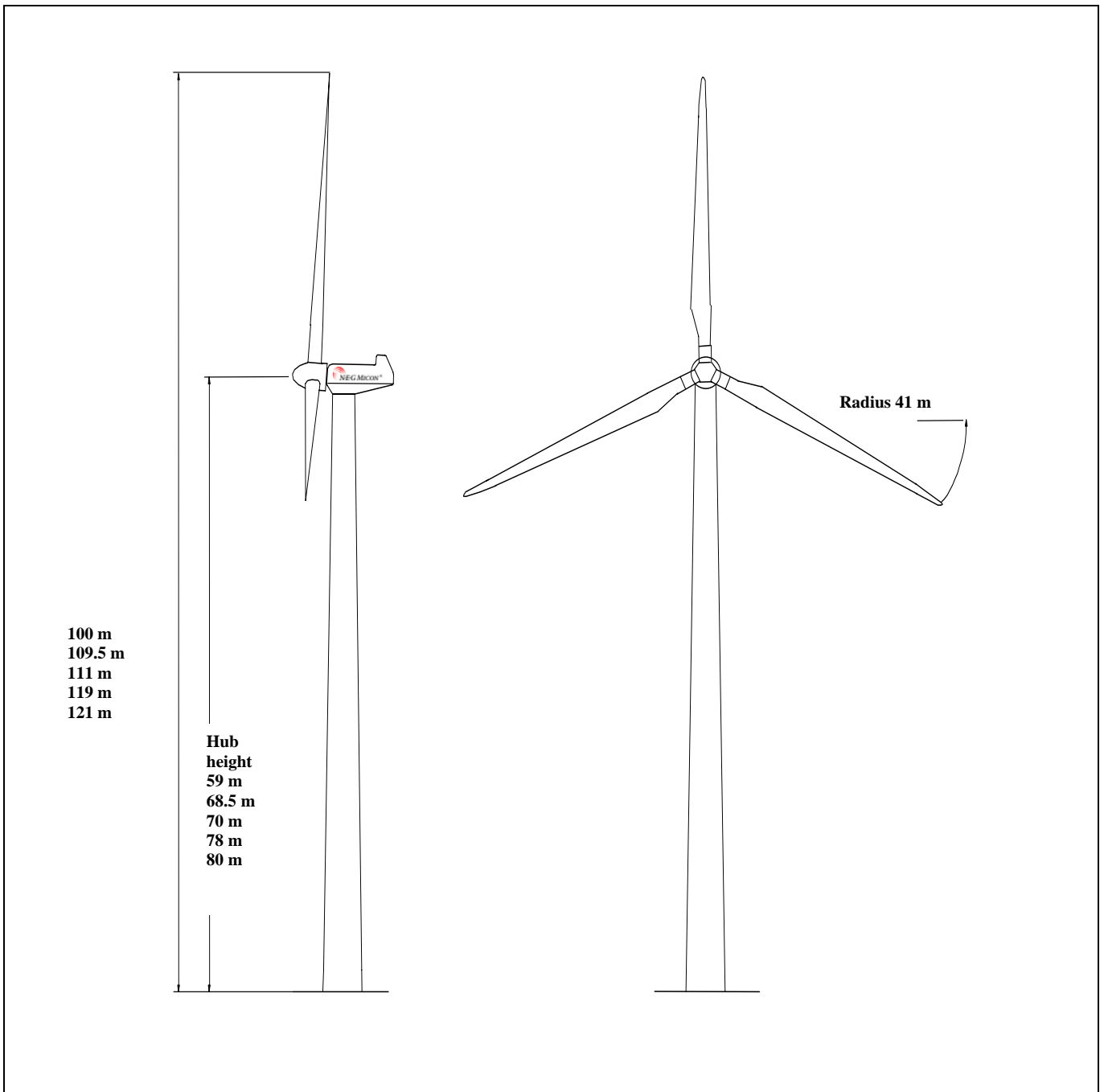
Class I
TSD 4000258-02 EN
2005-02-09

General Specification

V82-1.65 MW MK II

NM82/1650 Vers. 2

0	Illustration
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1 Main Data				
		50 Hz	60 Hz	60 Hz UL
Nominal Power		1650 kW	1650 kW	1650 kW
Rotor diameter		82 m	82 m	82 m
Swept area		5281 m ²	5281 m ²	5281 m ²
Hub height. IEC IIb		59 m, 68.5 m, 70 m, 78 m	70 m, 78 m.	59 m, 70 m, 80 m
Rotational speed		14.4 rpm	14.4 rpm	14.4 rpm

2 Nacelle Base Frame			
		50Hz	60Hz
Material		EN-GJS-400-18U-LT	EN-GJS-400-18U-LT
Standard colour		RAL 7035	RAL 7035
Corrosion class, outside		Acc. to DS EN ISO 12944:C5 I	Acc. to DS EN ISO 12944:C5 I

3 Rotor			
		50Hz	60Hz
Number of blades		3 pieces	3 pieces
Tip speed (synchronous)		61.8 m/s	61.8 m/s
Rotor shaft tilt		5°	5°
Eccentricity (tower center to hub center)		3447 mm	3447 mm
Solidity (Total blade area/rotor area)		5.0 %	5.0 %
Power regulation		Active Stall®	Active Stall®
Rotor orientation		Upwind	Upwind

4 Blades			
		50Hz	60Hz
Type description		AL 40	AL 40
Blade length		40 m	40 m
Material		Carbon/wood/glass/epoxy	Carbon/wood/glass/epoxy
Standard colour		RAL 7035	RAL 7035
Gloss		Class 2: (30-70%) in accordance with (1), to be measured acc. to DS/ISO2813	Class 2: (30-70%) in accordance with (1), to be measured acc. to DS/ISO2813
Type of rotor air brake		Full blade	Full blade
Blade profiles		• FFA -W3, NACA 63.4	• FFA - W3, NACA 63.4
Twist		20°	20°
Largest chord		3.08 m	3.08 m
Blade area (projected)		86 m ²	86 m ²
Note! (1) Technical Criteria for Danish Approval Scheme for Wind Turbines			

5	Blade bearing		
		50 Hz	60 Hz
	Type description	Ball bearing	Ball bearing
	Number of bearings	3 pcs.	3 pcs.
6	Hub		
		50Hz	60Hz
	Type description	Spherical	Spherical
	Material	EN-GJS-400-18U-LT	EN-GJS-400-18U-LT
	Corrosion class, outside	Acc. to DS EN ISO 12944:C5 I	Acc. to DS EN ISO 12944:C5 I
7	Main shaft		
		50Hz	60Hz
	Type description	Forged shaft and flange	Forged shaft and flange
	Material	34CrNiMo6 + QT	34CrNiMo6 + QT
	Corrosion class	Acc. to DS EN ISO 12944:C2	Acc. to DS EN ISO 12944:C2
8	Main Bearing		
		50Hz	60Hz
	Type description	Spherical roller bearing	Spherical roller bearing
	Number of	1 piece	1 piece
	Lubrication	Oil pump	Oil pump
9	Main Bearing Housing		
		50Hz	60Hz
	Type description	Flange bearing	Flange bearing
	Material	EN-GJS-400-18U-LT	EN-GJS-400-18U-LT
10	Gearbox		
		50 Hz	60Hz
	Type description	1. step planet, 2. step helical	1. step planet, 2. step helical
	Gear house material	Cast	Cast
	Ratio	1:70.2	1:84.3
	Mechanical power	1800 kW	1800 kW
	Bending strength acc. to ISO 6336	$S_F > 1.6$	$S_F > 1.6$
	Surface durability acc. to ISO 6336	$S_H > 1.25$	$S_H > 1.25$
	Scuffing safety acc. to DNV 41.2	$S_S > 1.3$	$S_S > 1.3$
	Shaft seals	Labyrinth	Labyrinth
	Oil sump	App. 250 l	App. 250 l
11	Cartridge Gear Heater - for Arctic Version only		
		50 Hz	60 Hz
	Rating	800 W/ pcs.	800 W/ pcs.
	Number of	4 pieces	4 pieces
12	Oil pump		
		50 Hz	60Hz
	Voltage	3 x 690 V	3 x 480 V
13	Heat Exchange Unit (Water/Oil)		
		50 Hz	60 Hz
	Cooling capacity	41.3 kW	41.3 kW

14	Oil Cooler		
		50 Hz	60 Hz
	Cooling capacity	37.5 kW	37.5 kW
15	Water Pump		
		50 Hz	60Hz
	Voltage	1 x 230 V	3 x 480 V
16	Water Cooler/ Radiator		
		50 Hz	60 Hz
	Cooling capacity	46.2 kW	46.2 kW
17	Electrical Nacelle Heater - for Arctic Version only		
		50 Hz	60Hz
	Voltage	3 x 690 V	3 x 600 V
	Power	20 kW	20 kW
	Number of heaters	2 pieces	2 pieces
18	Mechanical Shaft Brake		
		50 Hz	60Hz
	Type description	Active Brake	Active Brake
	Brake disc	Steel, mounted on high speed shaft	Steel, mounted on high speed shaft
	Number of calipers	2 piece	2 piece
19	Hydraulic Power Unit for Mechanical Shaft Brake		
		50 Hz	60Hz
	Voltage	3 x 690 V	3 x 480 V
	Working pressure range	140-150 bar	140-150 bar
	Oil capacity	11 l	11 l
20	Coupling		
		50 Hz	60Hz
	Type description	Flexible coupling, constant rpm	Flexible coupling, constant rpm

21 Generator			
		50 Hz	60 Hz
Type description		1 speed generator, water cooled	1 speed generator, water cooled
Rated power	P_N	1650 kW	1650 kW
Apparent power	S_N	1805 kVA	1808 kVA
Rated current	I_N	1510 A	1740 A
Max power at Class F	P_{Fmax}	1815 kW	1815 kW
Max current at Class F	I_{Fmax}	1661 A	1914 A
No load current	I_0	400 A	430 A
Reactive power consumption at rated power (tolerance. acc to IEC 60034-1)	Q_N	731 kvar	740 kvar
Reactive power consumption at no load (tolerance. acc to IEC 60034-1)	Q_0	478 kvar	447 kvar
Number of poles	P	6	6
Synchronous rotation speed	n_0	1000 rpm	1200 rpm
Rotation speed at rated power	n_N	1012 rpm	1214 rpm
Slip at rated power	s_N	1.20 %	1.17 %
Voltage	U_N	3 x 690 V	3 x 600 V
Frequency	F	50 Hz	60 Hz
Coupling		Δ	Δ
Enclosure		IP54	IP54
Insulation class/ Temperature increase		F/B	F/B

22 Yaw System – Ball Bearing Slewing Ring			
		50 Hz	60 Hz
Type description		Ball bearing, internal gearing	Ball bearing, internal gearing

23 Yaw System – Yaw Gear and Motors			
		50 Hz	60 Hz
Type description		Planetary gear motor	Planetary gear motor
Gear ratio of yaw gear unit		app. 1:1687	app. 1:1687
Voltage		3 x 690 V	3 x 480 V
Rotational speed at full load		920 rpm	1140 rpm
Number of yaw gears		6 pieces	6 pieces

24 Yaw System – Yaw Brake			
		50 Hz	60 Hz
Type Description		Hydraulic disc brake	Hydraulic disc brake
Number of Yaw Friction Units		6 pieces	6 pieces

25 Hydraulic Power Unit for Yaw Brake			
		50 Hz	60 Hz
Voltage		3 x 400/ 3x 690 V	3 x 480 V
Working pressure range		140-150 bar	140-150 bar
Oil capacity		App. 10 l.	App. 10 l.

26	Tower		
		50 Hz	60 Hz
Type Description	Conical, tubular		Conical, tubular
Material	Welded steel plate		Welded steel plate
Corrosion class, outside	Acc. to DS EN ISO 12944: C5 I		Acc. to DS EN ISO 12944: C5 I
Colour	RAL 7035		RAL 7035
Access conditions	Internal, safety harness, ladder cage		Internal, safety harness, ladder cage

27	Wind Turbine Main Panel/ Control panel/ phase comp. panel		
		50 Hz	60 Hz
Voltage	3 x 690 V		3 x 600 V
Frequency	50 Hz		60 Hz
Cut-in system	Soft with thyristors		Soft with thyristors
Design Standard	IEC		UL

28	Electrical Grid Requirements		
		50 Hz	60Hz
Max. voltage	+10 % (60 sec.)		+10 % (60 sec.)
Min. voltage	-10 % (60 sec.)		-10 % (60 sec.)
Max. voltage	+12.5 % (0.1 sec.)		+12.5 % (0.1 sec.)
Min. voltage	-15 % (0.1 sec.)		-15 % (0.1 sec.)
High frequency	+1 Hz (0.2 sec.)		+1 Hz (0.2 sec.)
Low frequency	- 2 Hz (0.2 sec.)		- 2 Hz (0.2 sec.)
Maximum asymmetri current	15 % (60 sec.) – phase to ground		15 % (60 sec.) – phase to ground
Maximum asymmetri voltage	2 % (60 sec.) – phase to ground		2 % (60 sec.) – phase to ground
Maximum short circuit current	25 kA at 690V		30 kA at 600V
Single harmonic	Max 1% of any single harmonic		Max 1% of any single harmonic
Total harmonic distortion	Max 3% total harmonic distortion		Max 3% total harmonic distortion
Connection	<ul style="list-style-type: none"> Solidly grounded wye at secondary (690 V) side of transformer 		<ul style="list-style-type: none"> Solidly grounded wye at secondary (600 V) side of transformer

29	Integrated Grid Connection System, IGC System, Transformer in tower - Optional (IGC is not delivered in the US)		
	Power Transformer incl. Metal Enclosure		
		50 Hz	60 Hz
Type description	Cast Resin (dry type)		Cast Resin (dry type)
Apparent power	1800 kVA		1800 kVA
Primary voltage	10 – 24 kV+/- 2 x 2.5 %		10 – 24 kV+/- 2 x 2.5 %
Secondary voltage	0.690 kV		0.600 kV
Frequency	50 Hz		60 Hz
Coupling group	Dyn, Solidly grounded wye at 690 V		Dyn, Solidly grounded wye at 600 V
Switch gear			
Type description	Gas insulated SF6 ring main unit		Gas insulated SF6 ring main unit
Nominal voltage	24 kV		24 kV
Frequency	50 Hz		60 Hz

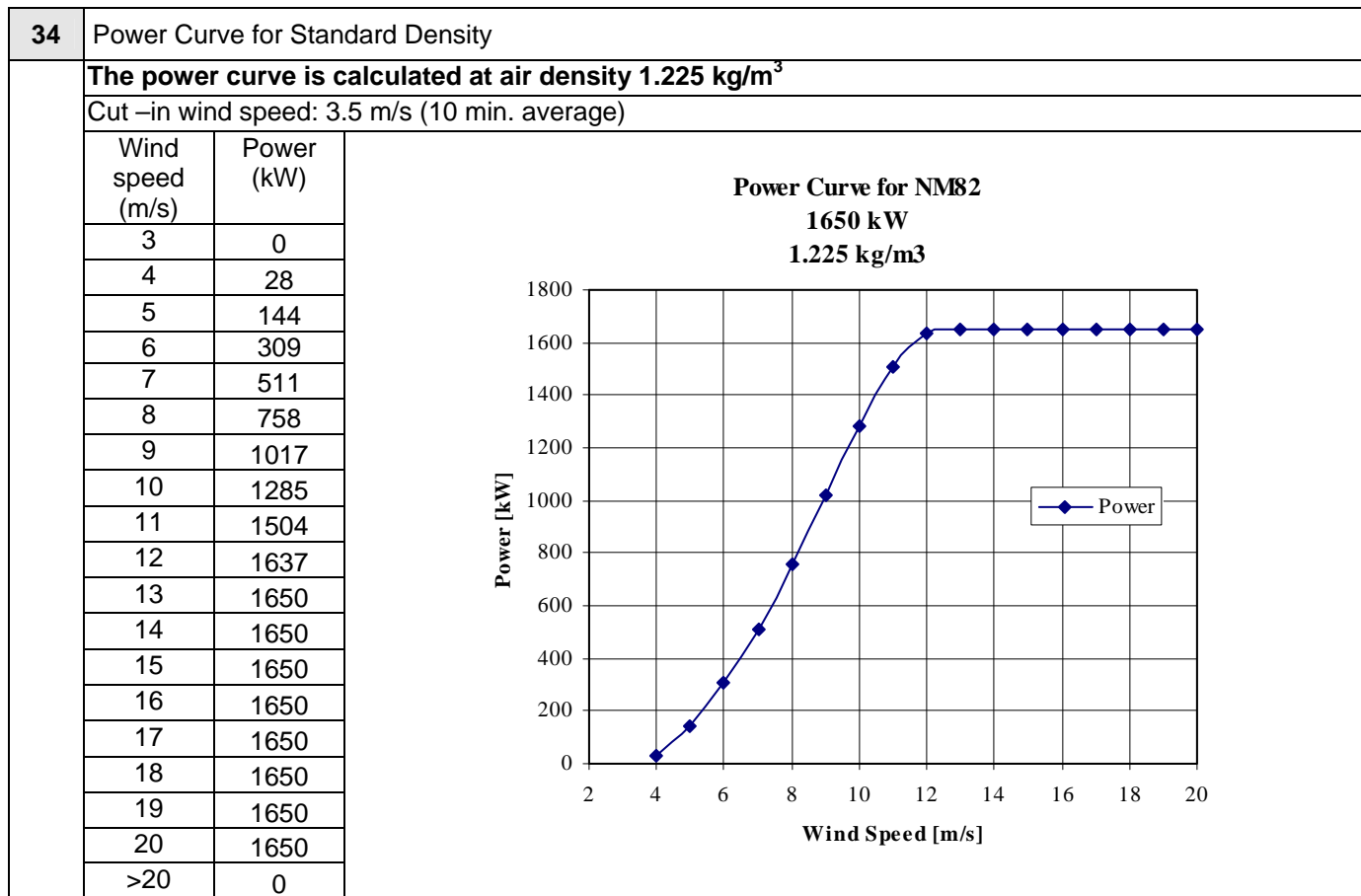
30a	Power Factor – No Load Compensation - Standard										
Preconditions											
Rated power	P_N	1650 kW					1650 kW				
Rated voltage	U_N	3 x 690V					3 x 600V				
Frequency	f	50 Hz					60 Hz				
Reactive power consumption. At rated power (tolerance. Acc to IEC 60034-1)	Q_N	731 kvar					740 kvar				
Reactive power consumption at no load (tolerance. Acc to IEC 60034-1)	Q_O	478 kvar					447 kvar				
Capacitor banks:											
Capacitors	550 kvar, split into steps					499.4 kvar, split into steps					
Capacitor banks resolution	2 x 25 kvar					2 x 22.7 kvar					
Min. regulation time (operation)	120 sec.					120 sec.					
Generator G, 6 poles, 1650 kW:											
Generator load	%	25	50	75	100	110	25	50	75	100	110
Power factor without phase compensation (tolerances acc to IEC 60034-1)	$\cos\varphi$	0.71	0.86	0.91	0.91	0.91	0.69	0.85	0.90	0.91	0.91
Power factor with phase compensation (tolerances acc to IEC 60034-1)	$\cos\varphi$	0.99	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98

30b	Power Factor – Full Load Compensation – Optional										
Preconditions											
Rated power	P_N	1650 kW					1650 kW				
Rated voltage	U_N	3 x 690V					3 x 600V				
Frequency	f	50 Hz					60 Hz				
Reactive power consumption. At rated power (tolerance. Acc to IEC 60034-1)	Q_N	731 kvar					740 kvar				
Reactive power consumption at no load (tolerance. Acc to IEC 60034-1)	Q_O	478 kvar					447 kvar				
Capacitor banks:											
Capacitors	850 kvar, split into steps					817 kvar, split into steps					
Capacitor banks resolution	2 x 25 kvar					2 x 22.7 kvar					
Min. regulation time (operation)	120 sec.					120 sec.					
Generator G, 6 poles, 1650 kW:											
Generator load	%	25	50	75	100	110	25	50	75	100	110
Power factor without phase compensation (tolerances acc to IEC 60034-1)	$\cos\varphi$	0.71	0.86	0.91	0.91	0.91	0.69	0.85	0.90	0.91	0.91
Power factor with phase compensation (tolerances acc to IEC 60034-1)	$\cos\varphi$	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

31	Climate and Site Conditions regarding structural design		
		50 Hz – IEC IIb	60 Hz – IEC IIb
	Design life time	20 years	20 years
	Temperature interval for operation	See specifications below	See specifications below
	Temperature interval for structure	See specifications below	See specifications below
	A-factor	9.59 m/s	9.59 m/s
	Form factor, c	2.0	2.0
	Annual average wind speed	8.5 m/s	8.5 m/s
	Wind shear	0.20	0.20
	Extreme wind speed	42.5 m/s (10 min. average)	42.5 m/s (10 min. average)
	Survival wind speed	59.5 m/s (3 sec. average)	59.5 m/s (3 sec. average)
	Automatic stop limit	20 m/s (10 min. average)	20 m/s (10 min. average)
	Automatic stop limit	24 m/s (1 min. average)	24 m/s (1 min. average)
	Automatic stop limit	32 m/s (1 s. average)	32 m/s (1 s. average)
	Re-cut in	18 m/s (10 min. average)	18 m/s (10 min. average)
	Characteristic turbulence intensity acc. to IEC 61400-1 (15 m/s)	16% (including wind farm turbulence)	16% (including wind farm turbulence)
	Air density	1.225 kg/m ³	1.225 kg/m ³
	Maximum in-flow angle	8°	8°

32	Specific Climate and Site Conditions			
		Standard (only 50 Hz)	Tropical -20 to +40°C (50 + 60 Hz)	Arctic (50 + 60 Hz)
	Temperature interval for operation ^{1,2,3}	-20 to +30°C	-20 to +35°C (+40°C)	-30 to +30°C
	Temperature interval for structure	-20 to +50°C	-20 to +50°C	-40 to +50°C
	¹ Note! For Tropical! Rated power is reduced to 1500 kW for temperature between +35°C and +40°C. ² Note! No operation if temperature is below -10°C in control panel or gear oil sump. Heating systems are optional. ³ Note! If the windturbine is placed more than 1000m above sea level, a higher temperature rise than usual might occur in the generator, the transformer and other electrical components. In this case a periodic reduction of rated power might occur, even if the ambient temperature is within specified limits. Furthermore increased risk of icing up occur at sites more than 1000m above sea level.			

33	Conditions for Power Curve (at hub height)		
		50 Hz	60Hz
	Air density	1.225 kg/m ³	1.225 kg/m ³
	Wind shear	0.12-0.16	0.12-0.16
	Turbulence intensity	11-16 %	11-16 %
	Blades	Clean	Clean
	Ice/snow on blades	No	No
	Leading Edge	No damage	No damage
	Rain	No	No
	Terrain	IEC 61400-12	IEC 61400-12
	Inflow angle	0±2 °	0±2 °
	Grid frequency	50 ±0.5	60±0.5 Hz
	Verification acc. to	IEC 61400-12	IEC 61400-12



35	Power Curve												
	Air density [kg/m³]	0.97	1.00	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.225	1.24	1.27
	Wind speed [m/s]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]	Power [kW]
	3	0	0	0	0	0	0	0	0	0	0	0	0
	4	15	16	18	19	21	22	24	25	27	28	29	30
	5	107	112	116	120	125	129	133	138	142	144	146	151
	6	238	246	255	263	271	280	288	296	305	309	313	321
	7	399	412	425	438	452	465	478	491	504	511	517	530
	8	589	608	627	645	664	683	702	722	746	758	767	788
	9	794	818	843	867	892	916	941	968	999	1017	1028	1058
	10	995	1025	1055	1085	1116	1147	1178	1217	1260	1285	1299	1333
	11	1191	1228	1266	1303	1341	1379	1417	1453	1489	1504	1518	1546
	12	1371	1415	1459	1504	1548	1588	1620	1628	1636	1637	1639	1642
	13	1520	1569	1616	1637	1642	1643	1645	1646	1647	1650	1650	1650
	14	1624	1635	1643	1650	1650	1650	1650	1650	1650	1650	1650	1650
	15	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650
	16	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650
	17	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650
	18	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650
	19	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650
	20	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650	1650

36		Cp											
Air density y [kg/m ³]	Wind speed [m/s]	0.97	1.00	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.225	1.24	1.27
		3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.092	0.095	0.103	0.106	0.114	0.116	0.123	0.125	0.132	0.135	0.138	0.140	
5	0.334	0.339	0.341	0.343	0.347	0.349	0.350	0.354	0.356	0.356	0.357	0.360	
6	0.430	0.431	0.434	0.435	0.436	0.438	0.439	0.440	0.442	0.442	0.443	0.443	
7	0.454	0.455	0.456	0.456	0.458	0.458	0.459	0.459	0.460	0.461	0.460	0.461	
8	0.449	0.450	0.450	0.450	0.451	0.451	0.452	0.453	0.456	0.458	0.458	0.459	
9	0.425	0.425	0.425	0.425	0.425	0.425	0.425	0.426	0.429	0.431	0.431	0.433	
10	0.388	0.388	0.388	0.388	0.388	0.388	0.388	0.391	0.394	0.397	0.397	0.398	
11	0.349	0.349	0.350	0.350	0.350	0.350	0.351	0.350	0.350	0.349	0.348	0.346	
12	0.310	0.310	0.310	0.311	0.311	0.311	0.309	0.302	0.296	0.293	0.290	0.283	
13	0.270	0.270	0.270	0.266	0.260	0.253	0.247	0.240	0.235	0.232	0.229	0.224	
14	0.231	0.226	0.220	0.215	0.209	0.203	0.198	0.193	0.188	0.186	0.184	0.179	
15	0.191	0.185	0.180	0.175	0.170	0.165	0.161	0.157	0.153	0.151	0.149	0.146	
16	0.157	0.153	0.148	0.144	0.140	0.136	0.133	0.129	0.126	0.125	0.123	0.120	
17	0.131	0.127	0.123	0.120	0.117	0.114	0.111	0.108	0.105	0.104	0.103	0.100	
18	0.110	0.107	0.104	0.101	0.098	0.096	0.093	0.091	0.089	0.087	0.086	0.084	
19	0.094	0.091	0.088	0.086	0.084	0.081	0.079	0.077	0.075	0.074	0.073	0.072	
20	0.081	0.078	0.076	0.074	0.072	0.070	0.068	0.066	0.065	0.064	0.063	0.062	

37		Ct											
Air density y [kg/m ³]	Wind speed [m/s]	0.97	1.00	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.225	1.24	1.27
		3	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979	0.979
4	1.105	1.106	1.107	1.108	1.108	1.109	1.110	1.110	1.111	1.111	1.112	1.112	
5	1.007	1.007	1.008	1.008	1.009	1.009	1.010	1.010	1.010	1.014	1.011	1.011	
6	0.922	0.922	0.923	0.923	0.923	0.924	0.924	0.924	0.925	0.925	0.925	0.925	
7	0.841	0.841	0.841	0.841	0.842	0.843	0.843	0.843	0.843	0.843	0.843	0.843	
8	0.765	0.765	0.765	0.766	0.766	0.766	0.767	0.767	0.767	0.768	0.768	0.773	
9	0.691	0.692	0.692	0.692	0.692	0.693	0.693	0.693	0.694	0.701	0.697	0.713	
10	0.619	0.620	0.620	0.620	0.621	0.621	0.621	0.621	0.626	0.642	0.634	0.649	
11	0.554	0.555	0.555	0.555	0.555	0.559	0.559	0.567	0.570	0.578	0.578	0.584	
12	0.494	0.494	0.494	0.495	0.495	0.498	0.501	0.506	0.507	0.509	0.509	0.509	
13	0.438	0.438	0.439	0.439	0.440	0.440	0.440	0.439	0.438	0.438	0.437	0.436	
14	0.386	0.386	0.385	0.384	0.383	0.382	0.381	0.380	0.380	0.379	0.379	0.378	
15	0.340	0.339	0.339	0.338	0.337	0.336	0.336	0.335	0.335	0.334	0.334	0.334	
16	0.302	0.302	0.301	0.301	0.300	0.300	0.300	0.300	0.299	0.299	0.299	0.299	
17	0.270	0.270	0.271	0.271	0.271	0.270	0.271	0.271	0.271	0.272	0.272	0.271	
18	0.248	0.248	0.249	0.248	0.249	0.248	0.249	0.249	0.249	0.249	0.250	0.249	
19	0.229	0.229	0.229	0.230	0.230	0.230	0.231	0.231	0.231	0.232	0.233	0.235	
20	0.213	0.213	0.214	0.214	0.215	0.215	0.216	0.216	0.218	0.218	0.218	0.220	

38	Guaranteed Sound Power Level at Hub Height					
Conditions for Sound Power Level:	Wind shear: 0.13 Max turbulence at 10 meter height: 16% Inflow angle (vertical): $0 \pm 2^\circ$ Air density: 1.225 kg/m^3					
Hub Height	HH 59 m	HH 68.5 m	HH 70 m	HH 78 m	HH 80 m	
Verification Report: WT SE03007 B2						
L _{WA} @ 3 m/s (10 meters above ground) (dB(A))	100.4	100.4	101.1	101.1	101.1	
L _{WA} @ 4 m/s (10 meters above ground) (dB(A))	100.9	100.9	100.9	101.4	101.4	
L _{WA} @ 5 m/s (10 meters above ground) (dB(A))	101.1	101.1	101.1	101.6	101.6	
L _{WA} @ 6 m/s (10 meters above ground) (dB(A))	101.3	101.3	101.3	101.8	101.8	
L _{WA} @ 7 m/s (10 meters above ground) (dB(A))	101.9	101.9	101.9	102.2	102.2	
L _{WA} @ 8 m/s (10 meters above ground) (dB(A))	102.9	102.9	102.9	103.2	103.2	
L _{WA} @ 9 m/s (10 meters above ground) (dB(A))	103.1	N/A	N/A	N/A	N/A	
L _{WA} @ 95% Rated Power (9.1 m/s. 10 meters above ground) (dB(A))	103.3	N/A	N/A	N/A	N/A	
L _{WA} @ 95% Rated Power (8.9 m/s 10 meters above ground) (dB(A))	N/A	103.3	103.3	103.3	N/A	
L _{WA} @ 95% Rated Power (8.8 m/s 10 meters above ground) (dB(A))	N/A	N/A	N/A	N/A	103.3	

**The Wind Turbine is designed according to Vestas design specifications.
 Vestas Wind Systems A/S reserves the right to change specifications without prior notice.**