



REGIONE BASILICATA



Comune principale impianto

COMUNE DI MONTEMILONE
PROVINCIA DI POTENZA

Opere connesse



COMUNE DI VENOSA
PROVINCIA DI POTENZA



COMUNE DI SPINAZZOLA
PROVINCIA DI BAT



COMUNE DI BANZI
PROVINCIA DI POTENZA



COMUNE DI GENZANO DI LUCANIA
PROVINCIA DI POTENZA

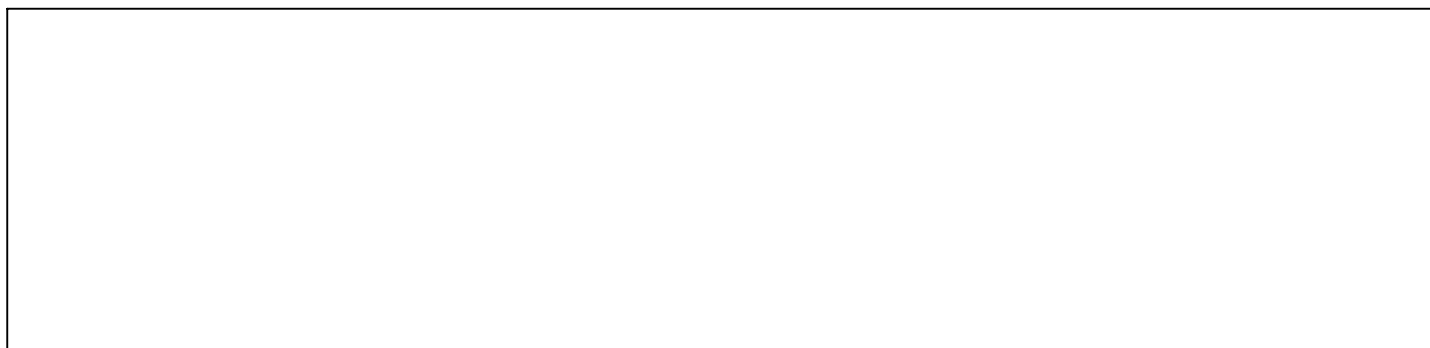


COMUNE DI PALAZZO SAN GERVASIO
PROVINCIA DI POTENZA



PROGETTO PER LA REALIZZAZIONE DI UN IMPIANTO PER LA PRODUZIONE DI ENERGIA ELETTRICA DA FONTE EOLICA, AI SENSI DEL D.LGS N. 387 DEL 2003, COMPOSTO DA N° 17 AEREOGENERATORI, PER UNA POTENZA COMPLESSIVA DI 71.4 MW, SITO NEL COMUNE DI MONTEMILONE (PZ) E OPERE CONNESSE NEI COMUNI DI VENOSA (PZ), PALAZZO SAN GERVASIO (PZ), BANZI (PZ), GENZANO DI LUCANIA (PZ) E SPINAZZOLA (BT)

COD.REG	DESCRIZIONE	SCALA DI RAPP.
A.16.b.3/2	Schede tecniche e di funzionamento aerogeneratore	
COD. INT. AT9		



REDATTO	VERIFICATO	APPROVATO	REVISIONE
VESTAS	VESTAS	VESTAS	Revisione 0
			DATA
			11/2019

Restricted
Document no.: 0067-7067 V08
2017-12-21

Performance Specification

V150-4.0/4.2 MW 50/60 Hz



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13.2 CT VALUES, SOUND OPTIMIZED MODE SO1334

13.3 SOUND CURVES, SOUND OPTIMIZED MODE SO1335

Recipient acknowledges that (i) this Performance Specification is provided for recipient's information only, and, does not create or constitute a warranty, guarantee, promise, commitment, or other representation (Commitment) by Vestas Wind Systems or any of its affiliated or subsidiary companies (Vestas), all of which are disclaimed by Vestas and (ii) any and all Commitments by Vestas to recipient as to this Performance Specification (or any of the contents herein) are to be contained exclusively in signed written contracts between recipient and Vestas, and not within this document.

See general reservations, notes and disclaimers (including, Section 5, p. 11) to this Performance Specification.

1 General Description

The Vestas V150-4.0/4.2 MW wind turbine is a pitch regulated upwind turbine with active yaw and a three-blade rotor. The Vestas V150-4.0/4.2 MW turbine has a rotor diameter of 150 m and a rated power of 4.0 MW.

Vestas offers an optional Power Optimized (PO) mode at 4.2 MW for the V150-4.0 MW variant.

2 Type Approvals and Available Hub Heights

The standard turbine is type certified according to the certification standards and available hub heights listed below:

Certification	Wind Class	Hub Height		
		Tower type	Standard	Large diameter (split)
IEC61400-22	IEC III B/IEC S	105 m		155 m
DIBt 2012	WZ2(S), GK2		123 / 145 / 166 m	

Table 2-1: Type approval data and available hub heights

⁽¹⁾: These towers require special transport conditions as the bottom diameter is above 5 m and are not available as standard to the US/Canadian market, but can be evaluated on a case-by-case basis.

The hub height can be increased by up to 3 m by use of raised foundation. Use of raised foundation is subject to site-specific evaluation and is not available for all soil conditions.

3 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

3.1 Climate and Site Conditions

The standard turbine is designed for the wind climate conditions listed below. Values refer to hub height.

Wind Climate	IEC III B	IEC S
Hub Height	105/155m	105/155m
Power Rating	4.0MW	4.2MW
Extr Wind Speed (10 min average), V_{50}	37.5 m/s	37.5 m/s
Survival Wind Speed (3 s gust), V_{e50}	52.5 m/s	52.5 m/s
Turbulence Intensity, I_{V50}	11%	11%

Table 3-1: Extreme design parameters – IEC

Wind Climate	IEC IIIB	IEC S
Hub Height	105/155m	105/155m
Power Rating	4.0MW	4.2MW
Wind Speed (10 min average), V_{ave}	7.5 m/s	7.0 m/s
Weibull Scale Factor, C	8.5 m/s	7.9 m/s
Weibull Shape Factor, k	2.0	2.0
I_{ref} acc. to IEC 61400-1	0.14	0.14
Turbulence Intensity acc. to IEC 61400-1, Including Wind Farm Turbulence (@15 m/s) I_{90} (90% quantile)	15.7%	15.7%
Wind Shear, α	0.20	0.20
Inflow Angle (vertical)	8°	8°

Table 3-2: Average design parameters – IEC

Wind Climate	WZ2(S)	WZ2(S)	WZ2(S)	WZ2(S)	WZ2(S)	WZ2(S)
Hub Height	123 m	123 m	145 m	145 m	166 m	166 m
Power Rating	4.0MW	4.2MW	4.0MW	4.2MW	4.0MW	4.2MW
Extr Wind Speed (10 min average), V_{50}	37.45 m/s	37.45 m/s	37.50 m/s	37.50 m/s	37.50 m/s	37.50 m/s
Survival Wind Speed (3 s gust), V_{e50}	52.43 m/s	52.43 m/s	52.50 m/s	52.50 m/s	52.50 m/s	52.50 m/s
Turbulence intensity, $I_{v(z)}$	12.7%	12.7%	12.4%	12.4%	12.1%	12.1%

Table 3-3: Extreme design parameters – DIBt

Wind Climate	WZ2(S)	WZ2(S)	WZ2(S)	WZ2(S)	WZ2(S)	WZ2(S)
Hub Height	123 m	123 m	145 m	145 m	166 m	166 m
Power Rating	4.0MW	4.2MW	4.0MW	4.2MW	4.0MW	4.2MW
Wind Speed (10 min average), V_{ave}	7.4 m/s	7.0 m/s	7.5 m/s	7.0 m/s	7.05 m/s	7.0 m/s
I_{ref} acc. to IEC 61400-1	0.14	0.14	0.14	0.14	0.14	0.14
Turbulence Intensity, I_{90} (90% quant.)	15.7%	15.7%	15.7%	15.7%	15.7%	15.7%

Table 3-4: Average design parameters – DIBt

3.1.1 Complex Terrain

Classification of complex terrain according to IEC 61400-1:2005 Chapter 11.2. For sites classified as complex, appropriate measures are to be included in site assessment. Positioning of each turbine must be verified via Vestas Site Check.

3.1.2 Altitude

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

3.1.3 Wind Power Plant Layout

Turbine spacing is to be evaluated site-specifically. Spacing below two rotor diameters (2D) may require sector-wise curtailment.

NOTE As evaluation of climate and site conditions is complex, consult Vestas for every project. If conditions exceed the above parameters, Vestas must be consulted.

3.2 Operational Envelope – Wind

Values refer to hub height and are determined by the sensors and control system of the turbine.

Wind Climate	IEC III B/ IEC S
Hub Height	105 / 155 m
Cut-In, V_{in}	3 m/s
Cut-Out (10 min exponential avg.), V_{out}	24.5 m/s
Re-Cut In (10 min exponential avg.)	22.5 m/s

Table 3-5: Operational envelope – wind – IEC

Wind climate	WZ2(S)
Hub height	123 / 145 / 166 m
Cut-In, V_{in}	3 m/s
Cut-Out (10 min exponential avg.), V_{out}	24.5 m/s
Re-Cut In (10 min exponential avg.)	22.5 m/s

Table 3-6: Operational envelope – wind – DIBt

3.3 Operational Envelope – Conditions for Power Curve and Ct Values (at Hub Height)

Consult Section 6 and following sections, p. 12 for power curves and C_t values.

Conditions for Power Curve and C_t Values (at Hub Height)	
Wind Shear, α	0.00-0.30 (10 minute average)
Turbulence Intensity, I	6-12% (10 minute average)
Blades	Clean
Rain	No
Ice/Snow on Blades	No
Leading Edge	No damage
Terrain	IEC 61400-12-1
Inflow Angle (Vertical)	$0 \pm 2^\circ$
Grid Voltage	Nominal Voltage $\pm 2.5\%$
Grid Frequency	Nominal Frequency ± 0.5 Hz
Grid Active Power (LV-side)	Per tabulated values in Section 6 and following sections
Grid Reactive Power (LV-side)	Power Factor 1.0

Table 3-7: Conditions for power curve and C_t values

3.4 Sound Modes

The sound modes listed below are available for the turbine.

Sound modes			
Mode No.	Maximum Sound Level	Serrated trailing edges	Available hub heights
0	104.9 dBA	Yes (standard)	105 / 123 / 145 / 155 / 166 m
0-0S	108.0 dBA	No (option)	105 / 123 / 145 / 155 / 166 m
PO1	104.9 dBA	Yes (standard)	105 / 123 / 145 / 155 / 166 m
PO1-0S	108.0 dBA	No (option)	105 / 123 / 145 / 155 / 166 m

Table 3-8: Available sound performance

NOTE

The turbine is as standard equipped with serrated trailing edges on the blades. Optionally, Mode 0-0S can be offered without serrated trailing edges mounted on the blades.

In addition, Sound Optimized (SO) modes as listed below are available as options for the turbine.

Sound Optimized (SO) modes			
Mode No.	Maximum Sound Level	Serrated trailing edges	Available hub heights
SO1	103.4 dBA	Yes	105 / 123 / 155 / 166 m
SO2	102.0 dBA	Yes	105 / 123 / 166 m
SO3	99.5 dBA	Yes	105 / 123 / 145 / 155 / 166 m
SO11	99.2 dBA	Yes	105 m
SO12	99.9 dBA	Yes	105 m
SO13	97.0 dBA	Yes	105 m

Table 3-9: Available Sound Optimized modes

NOTE Sound Optimized (SO) modes are only available with serrated trailing edges on the blades. For further details on sound performance and in case of specific requests for sound modes per tower, please contact Vestas Wind Systems A/S.

3.5 Load Modes

The Load Optimized (LO) modes listed below are available for the turbine.

Load Optimized (LO) modes				
Mode No.	Power	Maximum Sound Level	Serrated trailing edges	Available hub heights
LO1	3.8 MW	104.9 dBA	Yes	105 / 123 / 145 / 155 / 166 m
LO2	3.6 MW	104.9 dBA	Yes	105 / 123 / 145 / 155 / 166 m

Table 3-10: Available Load Optimized modes

NOTE Load Optimized (LO) modes are only available with serrated trailing edges mounted on the blades.

4 Drawings

4.1 Structural Design – Illustration of Outer Dimensions

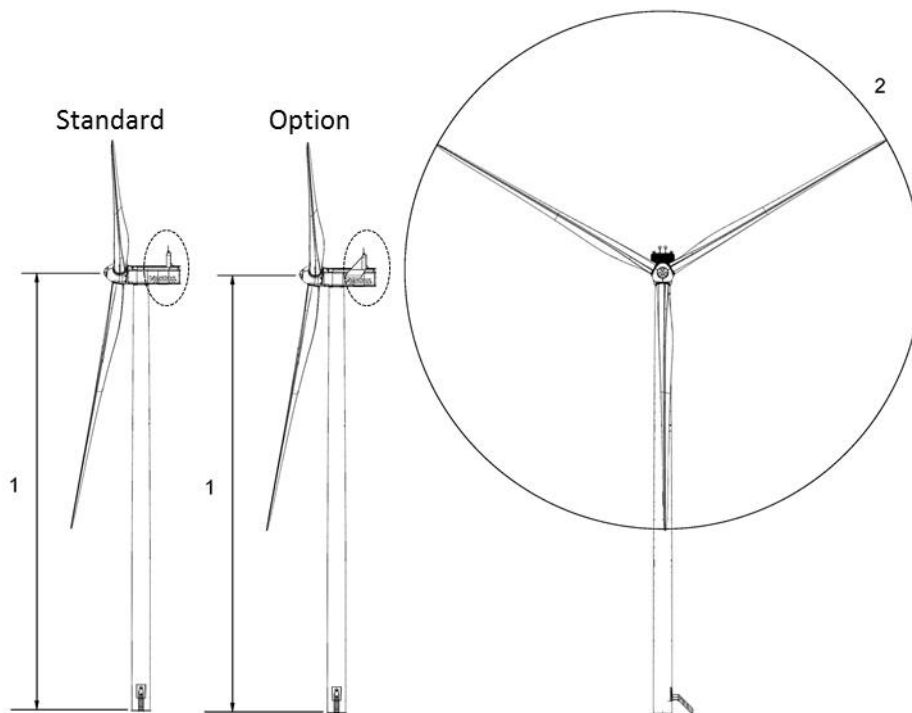


Figure 4-1: Illustration of outer dimensions – structure.

- | | |
|-----------------------|--------------------|
| 1 Hub height: | 2 Diameter: |
| 105/123/145/155/166 m | 150 m |

NOTE The turbine to the right is shown with side panels on the cooler top (Option).

5 General Reservations, Notes and Disclaimers

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- The performance specifications described in this document apply to the current version of the V150-4.0/4.2 MW wind turbine. Updated versions of the V150-4.0/4.2 MW wind turbine, which may be manufactured in the future, may differ from these performance specifications. In the event that Vestas supplies an updated version of the V150-4.0/4.2 MW wind, Vestas will provide an updated performance specification applicable to the updated version.
- All listed start/stop parameters (e.g. wind speeds) 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.
- This document, Performance Specification, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method). Any guarantee, warranty and/or verification of the power curve and sound (including, without limitation, the power curve and sound verification method) must be agreed to separately in writing.

6 Power Curves, Ct Values and Sound Curves, Mode 0/0-0S

6.1 Power Curves, Mode 0/0-0S

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	285	210	217	224	231	238	244	251	258	265	272	278	292	299
4.5	424	318	328	337	347	357	366	376	386	395	405	415	434	443
5.0	597	452	465	478	491	505	518	531	544	557	571	584	610	623
5.5	809	616	633	651	669	686	704	721	739	756	774	792	827	844
6.0	1062	813	835	858	881	904	926	949	972	994	1017	1040	1085	1108
6.5	1361	1045	1074	1103	1131	1160	1189	1218	1246	1275	1304	1332	1389	1418
7.0	1709	1317	1353	1389	1425	1460	1496	1532	1568	1603	1638	1674	1744	1779
7.5	2101	1628	1671	1715	1759	1802	1845	1888	1931	1974	2016	2058	2143	2185
8.0	2545	1982	2034	2085	2137	2189	2240	2292	2343	2394	2444	2495	2594	2644
8.5	3014	2375	2435	2496	2556	2617	2675	2733	2791	2848	2904	2959	3067	3120
9.0	3458	2791	2856	2921	2986	3052	3112	3172	3232	3292	3348	3403	3510	3561
9.5	3778	3181	3246	3312	3378	3444	3498	3552	3606	3660	3699	3739	3807	3836
10.0	3934	3543	3596	3650	3704	3758	3789	3821	3852	3884	3901	3917	3944	3953
10.5	3981	3807	3835	3864	3892	3921	3932	3943	3954	3965	3971	3976	3984	3987
11.0	3999	3953	3962	3970	3979	3987	3990	3992	3995	3997	3998	3998	4000	4000
11.5	4000	3990	3992	3994	3996	3998	3999	3999	3999	4000	4000	4000	4000	4000
12.0	4000	3998	3999	3999	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
12.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
13.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
13.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
14.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
14.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
15.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
15.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
16.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
16.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
17.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
17.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
18.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
18.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.5	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995
21.0	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742
21.5	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309
22.0	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730
22.5	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154
23.0	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805
23.5	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526
24.0	1284	1284	1284	1284	1284	1284	1284	1284	1284	1284	1284	1284	1283	1283
24.5	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116

Table 6-1: Power curve, Mode 0/0-0S

6.2 Ct Values, Mode 0/0-0S

Air density kg/m³

Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.850	0.850	0.849	0.849	0.848	0.848	0.847	0.847	0.846	0.847
4.0	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830
4.5	0.828	0.831	0.831	0.831	0.830	0.830	0.830	0.830	0.830	0.829	0.829	0.829	0.828	0.828
5.0	0.823	0.828	0.827	0.827	0.826	0.826	0.826	0.825	0.825	0.824	0.824	0.824	0.823	0.822
5.5	0.820	0.824	0.824	0.823	0.823	0.823	0.822	0.822	0.821	0.821	0.821	0.820	0.819	0.819
6.0	0.815	0.821	0.820	0.820	0.819	0.819	0.818	0.818	0.817	0.816	0.816	0.815	0.814	0.813
6.5	0.809	0.817	0.816	0.815	0.815	0.814	0.813	0.813	0.812	0.811	0.810	0.810	0.808	0.807
7.0	0.803	0.812	0.811	0.810	0.809	0.809	0.808	0.807	0.806	0.806	0.805	0.804	0.802	0.801
7.5	0.794	0.807	0.805	0.804	0.803	0.802	0.801	0.800	0.799	0.798	0.797	0.796	0.793	0.792
8.0	0.786	0.801	0.800	0.799	0.798	0.796	0.795	0.793	0.792	0.790	0.789	0.787	0.784	0.782
8.5	0.758	0.797	0.794	0.792	0.789	0.786	0.783	0.779	0.775	0.772	0.767	0.763	0.754	0.749
9.0	0.697	0.767	0.761	0.755	0.749	0.743	0.737	0.730	0.724	0.717	0.711	0.704	0.691	0.684
9.5	0.615	0.707	0.700	0.693	0.685	0.678	0.669	0.661	0.653	0.644	0.634	0.625	0.604	0.594
10.0	0.523	0.645	0.635	0.625	0.615	0.605	0.593	0.582	0.570	0.559	0.547	0.535	0.511	0.500
10.5	0.439	0.574	0.561	0.548	0.535	0.522	0.510	0.497	0.485	0.472	0.461	0.450	0.429	0.419
11.0	0.372	0.499	0.486	0.472	0.458	0.445	0.434	0.422	0.411	0.400	0.391	0.381	0.364	0.356
11.5	0.319	0.426	0.414	0.402	0.391	0.379	0.370	0.360	0.351	0.342	0.334	0.327	0.312	0.306
12.0	0.277	0.366	0.356	0.346	0.337	0.327	0.319	0.311	0.304	0.296	0.290	0.283	0.271	0.266
12.5	0.243	0.318	0.310	0.301	0.293	0.285	0.278	0.272	0.265	0.259	0.253	0.248	0.238	0.233
13.0	0.214	0.279	0.272	0.265	0.258	0.251	0.245	0.239	0.234	0.228	0.224	0.219	0.210	0.206
13.5	0.191	0.247	0.240	0.234	0.228	0.222	0.217	0.213	0.208	0.203	0.199	0.195	0.187	0.184
14.0	0.171	0.219	0.214	0.209	0.204	0.198	0.194	0.190	0.186	0.181	0.178	0.174	0.167	0.164
14.5	0.153	0.197	0.192	0.187	0.183	0.178	0.174	0.170	0.167	0.163	0.160	0.157	0.151	0.148
15.0	0.139	0.177	0.173	0.169	0.165	0.160	0.157	0.154	0.150	0.147	0.144	0.141	0.136	0.134
15.5	0.126	0.160	0.156	0.153	0.149	0.145	0.142	0.139	0.136	0.133	0.131	0.128	0.124	0.121
16.0	0.115	0.145	0.142	0.139	0.135	0.132	0.129	0.127	0.124	0.121	0.119	0.117	0.113	0.111
16.5	0.105	0.133	0.130	0.127	0.124	0.121	0.118	0.116	0.113	0.111	0.109	0.107	0.103	0.101
17.0	0.096	0.121	0.119	0.116	0.113	0.111	0.108	0.106	0.104	0.102	0.100	0.098	0.095	0.093
17.5	0.089	0.112	0.110	0.107	0.105	0.102	0.100	0.098	0.096	0.094	0.092	0.091	0.088	0.086
18.0	0.082	0.103	0.101	0.099	0.096	0.094	0.092	0.091	0.089	0.087	0.085	0.084	0.081	0.080
18.5	0.076	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.078	0.075	0.074
19.0	0.071	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.073	0.072	0.069	0.068
19.5	0.066	0.082	0.080	0.078	0.077	0.075	0.073	0.072	0.071	0.069	0.068	0.067	0.065	0.064
20.0	0.061	0.076	0.075	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.064	0.063	0.060	0.059
20.5	0.057	0.071	0.070	0.068	0.067	0.065	0.064	0.063	0.062	0.060	0.059	0.058	0.057	0.056
21.0	0.051	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.055	0.053	0.053	0.052	0.050	0.049
21.5	0.043	0.052	0.051	0.050	0.049	0.048	0.047	0.047	0.046	0.045	0.044	0.043	0.042	0.041
22.0	0.034	0.041	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.033	0.033
22.5	0.025	0.031	0.031	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025
23.0	0.021	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.022	0.022	0.022	0.021	0.021	0.020
23.5	0.018	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017
24.0	0.015	0.018	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.014
24.5	0.013	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.013

Table 6-2: C_t values, Mode 0/0-0S

6.3 Sound Curves, Mode 0/0-0S

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Mode 0 (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Mode 0-0S (Blades without serrated trailing edge)
3	91.1	93.4
4	91.3	94.0
5	93.2	97.1
6	96.4	100.5
7	99.9	103.8
8	103.3	106.6
9	104.9	108.0
10	104.9	108.0
11	104.9	108.0
12	104.9	108.0
13	104.9	108.0
14	104.9	108.0
15	104.9	108.0
16	104.9	108.0
17	104.9	108.0
18	104.9	108.0
19	104.9	108.0
20	104.9	108.0

Table 6-3: Sound curves, Mode 0/0-0S

7 Power Curves, Ct Values and Sound Curves, Power Optimized Mode PO1/PO1-0S

7.1 Power Curves, Power Optimized Mode PO1/PO1-0S

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	285	210	217	224	231	238	244	251	258	265	272	278	292	299
4.5	424	318	328	337	347	357	366	376	386	395	405	415	434	444
5.0	597	452	465	478	492	505	518	531	544	557	571	584	610	623
5.5	809	616	633	651	669	686	704	721	739	757	774	792	827	844
6.0	1062	813	835	858	881	904	926	949	972	995	1017	1040	1085	1108
6.5	1361	1045	1074	1103	1131	1160	1189	1218	1247	1275	1304	1332	1389	1418
7.0	1709	1317	1353	1389	1425	1461	1496	1532	1568	1603	1639	1674	1744	1779
7.5	2101	1628	1671	1715	1758	1802	1845	1888	1931	1974	2016	2058	2143	2185
8.0	2545	1982	2034	2086	2137	2189	2240	2292	2343	2394	2444	2494	2594	2644
8.5	3014	2375	2435	2496	2556	2616	2674	2732	2790	2848	2904	2959	3067	3120
9.0	3458	2791	2856	2921	2986	3052	3112	3172	3232	3292	3348	3403	3510	3562
9.5	3807	3180	3246	3312	3377	3443	3499	3556	3613	3669	3715	3761	3845	3884
10.0	4038	3543	3602	3662	3722	3781	3824	3866	3909	3951	3980	4009	4059	4079
10.5	4143	3842	3884	3926	3969	4012	4035	4059	4083	4107	4119	4131	4150	4158
11.0	4191	4055	4078	4100	4122	4145	4154	4162	4171	4180	4184	4187	4193	4195
11.5	4199	4152	4160	4168	4176	4185	4188	4190	4193	4196	4197	4198	4199	4200
12.0	4200	4185	4188	4191	4194	4198	4198	4199	4199	4200	4200	4200	4200	4200
12.5	4200	4197	4197	4198	4199	4200	4200	4200	4200	4200	4200	4200	4200	4200
13.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
13.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
14.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
14.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
15.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
15.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
16.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
16.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
17.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
17.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
18.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
18.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
19.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
19.5	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
20.0	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200	4200
20.5	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186	4186
21.0	3870	3870	3870	3870	3870	3870	3870	3870	3870	3870	3870	3870	3870	3870
21.5	3373	3373	3373	3373	3373	3373	3373	3373	3373	3373	3373	3373	3373	3373
22.0	2745	2745	2745	2745	2745	2745	2745	2745	2745	2745	2745	2745	2745	2744
22.5	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154
23.0	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805
23.5	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526
24.0	1283	1283	1283	1283	1283	1283	1283	1283	1283	1283	1283	1283	1283	1283
24.5	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116

Table 7-1: Power curve, Power Optimized Mode PO1/PO1-0S

7.2 Ct Values, Power Optimized Mode PO1/PO1-0S

Air density kg/m³

Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.847	0.853	0.852	0.851	0.850	0.850	0.849	0.849	0.848	0.847	0.847	0.847	0.847	0.847
4.0	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830
4.5	0.828	0.831	0.831	0.831	0.830	0.830	0.830	0.830	0.830	0.829	0.829	0.829	0.828	0.828
5.0	0.823	0.828	0.827	0.827	0.827	0.826	0.826	0.825	0.825	0.824	0.824	0.824	0.823	0.822
5.5	0.820	0.824	0.824	0.823	0.823	0.823	0.822	0.822	0.822	0.821	0.821	0.820	0.819	0.819
6.0	0.815	0.821	0.820	0.820	0.819	0.819	0.818	0.817	0.817	0.816	0.816	0.815	0.814	0.813
6.5	0.809	0.817	0.816	0.815	0.815	0.814	0.813	0.813	0.812	0.811	0.810	0.810	0.808	0.807
7.0	0.803	0.812	0.811	0.810	0.810	0.809	0.808	0.807	0.806	0.806	0.805	0.804	0.802	0.801
7.5	0.795	0.806	0.805	0.804	0.803	0.802	0.801	0.800	0.799	0.798	0.797	0.796	0.793	0.792
8.0	0.785	0.802	0.800	0.799	0.798	0.797	0.795	0.794	0.792	0.791	0.789	0.787	0.783	0.781
8.5	0.759	0.797	0.794	0.792	0.789	0.786	0.783	0.779	0.775	0.772	0.767	0.763	0.754	0.749
9.0	0.698	0.767	0.761	0.755	0.749	0.743	0.737	0.730	0.724	0.718	0.711	0.704	0.691	0.684
9.5	0.621	0.707	0.700	0.692	0.685	0.678	0.670	0.662	0.654	0.646	0.638	0.629	0.612	0.603
10.0	0.540	0.645	0.636	0.627	0.619	0.610	0.600	0.590	0.580	0.570	0.560	0.550	0.530	0.520
10.5	0.460	0.581	0.570	0.559	0.548	0.537	0.526	0.515	0.504	0.493	0.482	0.471	0.450	0.441
11.0	0.393	0.515	0.503	0.491	0.479	0.466	0.455	0.444	0.433	0.422	0.412	0.402	0.384	0.376
11.5	0.337	0.447	0.435	0.424	0.412	0.400	0.390	0.380	0.371	0.361	0.353	0.345	0.330	0.322
12.0	0.292	0.386	0.376	0.366	0.355	0.345	0.337	0.329	0.320	0.312	0.305	0.299	0.286	0.280
12.5	0.255	0.336	0.327	0.318	0.309	0.300	0.293	0.287	0.280	0.273	0.267	0.261	0.250	0.245
13.0	0.225	0.294	0.286	0.279	0.271	0.264	0.258	0.252	0.246	0.240	0.235	0.230	0.221	0.216
13.5	0.200	0.260	0.253	0.247	0.240	0.234	0.229	0.224	0.218	0.213	0.209	0.205	0.196	0.193
14.0	0.179	0.231	0.225	0.220	0.214	0.208	0.204	0.199	0.195	0.190	0.187	0.183	0.176	0.172
14.5	0.161	0.207	0.202	0.197	0.192	0.187	0.183	0.179	0.175	0.171	0.168	0.164	0.158	0.155
15.0	0.145	0.186	0.182	0.177	0.173	0.168	0.165	0.161	0.158	0.154	0.151	0.148	0.143	0.140
15.5	0.132	0.168	0.164	0.160	0.156	0.152	0.149	0.146	0.143	0.140	0.137	0.134	0.129	0.127
16.0	0.120	0.153	0.149	0.146	0.142	0.139	0.136	0.133	0.130	0.127	0.125	0.122	0.118	0.116
16.5	0.110	0.139	0.136	0.133	0.130	0.126	0.124	0.121	0.119	0.116	0.114	0.112	0.108	0.106
17.0	0.101	0.127	0.124	0.122	0.119	0.116	0.114	0.111	0.109	0.107	0.105	0.103	0.099	0.097
17.5	0.093	0.117	0.115	0.112	0.110	0.107	0.105	0.103	0.101	0.098	0.097	0.095	0.091	0.090
18.0	0.086	0.108	0.106	0.103	0.101	0.099	0.097	0.095	0.093	0.091	0.089	0.088	0.085	0.083
18.5	0.080	0.100	0.098	0.096	0.093	0.091	0.089	0.088	0.086	0.084	0.083	0.081	0.078	0.077
19.0	0.074	0.092	0.090	0.088	0.086	0.084	0.083	0.081	0.079	0.078	0.076	0.075	0.072	0.071
19.5	0.069	0.086	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.070	0.067	0.066
20.0	0.064	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.067	0.066	0.065	0.063	0.062
20.5	0.060	0.074	0.073	0.071	0.069	0.068	0.067	0.065	0.064	0.063	0.062	0.061	0.059	0.058
21.0	0.052	0.065	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051
21.5	0.043	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.045	0.044	0.043	0.042
22.0	0.034	0.041	0.041	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.033	0.033
22.5	0.026	0.031	0.031	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025
23.0	0.021	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.022	0.022	0.022	0.021	0.021	0.020
23.5	0.018	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017
24.0	0.015	0.018	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.014
24.5	0.013	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.012

Table 7-2: C_t values, Power Optimized Mode PO1/PO1-0S

7.3 Sound Curves, Power Optimized Mode PO1/PO1-0S

Sound Power Level at Hub Height		
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³	
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Power Optimized Mode PO1 (Blades with serrated trailing edge)	Sound Power Level at Hub Height [dBA] Power Optimized Mode PO1-0S (Blades without serrated trailing edge)
3	91.1	93.4
4	91.3	94.0
5	93.2	97.1
6	96.4	100.5
7	99.9	103.8
8	103.3	106.6
9	104.9	108.0
10	104.9	108.0
11	104.9	108.0
12	104.9	108.0
13	104.9	108.0
14	104.9	108.0
15	104.9	108.0
16	104.9	108.0
17	104.9	108.0
18	104.9	108.0
19	104.9	108.0
20	104.9	108.0

Table 7-3: Sound curves, Power Optimized Mode PO1/PO1-0S

8 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO1

8.1 Power Curves, Sound Optimized Mode SO1

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	285	210	217	224	231	238	244	251	258	265	272	278	292	299
4.5	424	318	328	337	347	357	366	376	386	395	405	414	434	443
5.0	597	452	465	478	491	505	518	531	544	557	571	584	610	623
5.5	809	616	633	651	669	686	704	721	739	756	774	791	826	844
6.0	1062	812	835	858	881	904	926	949	972	994	1017	1039	1085	1107
6.5	1361	1045	1074	1102	1131	1160	1189	1217	1246	1275	1303	1332	1389	1418
7.0	1706	1316	1351	1387	1423	1458	1494	1530	1565	1601	1636	1671	1742	1776
7.5	2076	1610	1653	1696	1739	1782	1824	1866	1909	1951	1993	2035	2118	2159
8.0	2461	1920	1970	2019	2069	2119	2168	2217	2266	2316	2364	2412	2509	2557
8.5	2862	2243	2300	2357	2415	2472	2528	2584	2640	2697	2752	2807	2915	2968
9.0	3257	2587	2652	2716	2781	2846	2907	2968	3030	3091	3146	3202	3308	3358
9.5	3540	2968	3032	3096	3159	3223	3273	3323	3373	3423	3462	3501	3570	3599
10.0	3712	3352	3398	3444	3490	3536	3566	3597	3628	3658	3676	3694	3724	3735
10.5	3793	3634	3658	3680	3704	3726	3738	3749	3760	3771	3778	3786	3797	3802
11.0	3842	3798	3805	3813	3821	3828	3831	3834	3837	3839	3840	3841	3843	3843
11.5	3866	3851	3854	3857	3860	3863	3864	3864	3865	3866	3866	3866	3866	3866
12.0	3888	3884	3884	3885	3886	3887	3887	3888	3888	3888	3888	3888	3887	3887
12.5	3905	3904	3904	3905	3905	3905	3905	3905	3905	3905	3905	3905	3905	3905
13.0	3916	3916	3916	3916	3916	3916	3916	3916	3916	3916	3916	3916	3915	3915
13.5	3924	3925	3925	3925	3925	3925	3925	3924	3924	3924	3924	3924	3923	3923
14.0	3934	3937	3937	3936	3936	3936	3936	3935	3935	3935	3934	3934	3934	3933
14.5	3946	3949	3949	3949	3949	3948	3948	3948	3948	3947	3947	3946	3946	3946
15.0	3955	3958	3957	3957	3957	3957	3956	3956	3956	3956	3956	3955	3955	3955
15.5	3964	3967	3967	3966	3966	3966	3966	3965	3965	3965	3964	3964	3964	3963
16.0	3975	3979	3978	3978	3978	3978	3977	3977	3976	3976	3976	3975	3974	3974
16.5	3986	3989	3988	3988	3988	3988	3988	3987	3987	3987	3986	3986	3985	3985
17.0	3993	3995	3995	3995	3994	3994	3994	3994	3994	3994	3994	3993	3993	3992
17.5	3998	3999	3999	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998	3998
18.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	3999
18.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
19.5	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.0	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000	4000
20.5	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995	3995
21.0	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742	3742
21.5	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309	3309
22.0	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730	2730
22.5	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154	2154
23.0	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805	1805
23.5	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526	1526
24.0	1284	1284	1284	1284	1284	1284	1284	1284	1284	1284	1284	1284	1283	1283
24.5	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116	1116

Table 8-1: Power curve, Sound Optimized Mode SO1

8.2 Ct Values, Sound Optimized Mode SO1

Air density kg/m ³														
Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.850	0.850	0.849	0.848	0.848	0.847	0.847	0.847	0.846	0.847
4.0	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830
4.5	0.828	0.831	0.831	0.830	0.830	0.830	0.830	0.830	0.830	0.829	0.829	0.829	0.828	0.828
5.0	0.823	0.828	0.827	0.827	0.826	0.826	0.826	0.825	0.825	0.824	0.824	0.823	0.823	0.822
5.5	0.820	0.824	0.824	0.823	0.823	0.823	0.822	0.822	0.821	0.821	0.820	0.820	0.819	0.819
6.0	0.814	0.821	0.820	0.820	0.819	0.819	0.818	0.817	0.817	0.816	0.816	0.815	0.814	0.813
6.5	0.808	0.816	0.815	0.815	0.814	0.813	0.813	0.812	0.811	0.811	0.810	0.809	0.808	0.807
7.0	0.796	0.805	0.804	0.803	0.802	0.802	0.801	0.800	0.799	0.798	0.797	0.797	0.795	0.794
7.5	0.758	0.768	0.767	0.766	0.766	0.765	0.764	0.763	0.762	0.761	0.760	0.759	0.757	0.756
8.0	0.706	0.716	0.715	0.715	0.714	0.713	0.712	0.711	0.710	0.709	0.708	0.707	0.705	0.704
8.5	0.659	0.670	0.669	0.668	0.667	0.666	0.665	0.664	0.663	0.662	0.661	0.660	0.658	0.656
9.0	0.613	0.632	0.631	0.630	0.629	0.628	0.626	0.625	0.623	0.621	0.619	0.616	0.609	0.605
9.5	0.550	0.608	0.604	0.601	0.597	0.594	0.588	0.582	0.576	0.570	0.564	0.557	0.542	0.534
10.0	0.479	0.583	0.574	0.565	0.556	0.547	0.537	0.528	0.518	0.508	0.498	0.489	0.469	0.459
10.5	0.411	0.536	0.523	0.511	0.498	0.485	0.474	0.462	0.451	0.440	0.430	0.420	0.402	0.393
11.0	0.354	0.475	0.462	0.448	0.435	0.422	0.412	0.401	0.391	0.380	0.371	0.363	0.346	0.338
11.5	0.306	0.408	0.397	0.386	0.374	0.363	0.355	0.346	0.337	0.328	0.321	0.313	0.300	0.293
12.0	0.268	0.354	0.344	0.335	0.325	0.316	0.308	0.301	0.293	0.286	0.280	0.274	0.262	0.257
12.5	0.236	0.309	0.301	0.293	0.285	0.277	0.271	0.264	0.258	0.252	0.246	0.241	0.231	0.227
13.0	0.209	0.272	0.265	0.258	0.251	0.245	0.239	0.234	0.228	0.223	0.218	0.214	0.205	0.201
13.5	0.187	0.241	0.235	0.229	0.224	0.218	0.213	0.208	0.203	0.199	0.195	0.191	0.183	0.180
14.0	0.167	0.216	0.210	0.205	0.200	0.195	0.191	0.186	0.182	0.178	0.175	0.171	0.164	0.161
14.5	0.151	0.194	0.189	0.185	0.180	0.175	0.172	0.168	0.164	0.161	0.157	0.154	0.148	0.146
15.0	0.137	0.175	0.171	0.167	0.163	0.159	0.155	0.152	0.149	0.145	0.143	0.140	0.134	0.132
15.5	0.125	0.159	0.155	0.151	0.148	0.144	0.141	0.138	0.135	0.132	0.130	0.127	0.122	0.120
16.0	0.114	0.145	0.141	0.138	0.135	0.131	0.129	0.126	0.123	0.121	0.118	0.116	0.112	0.110
16.5	0.104	0.132	0.129	0.126	0.123	0.120	0.118	0.115	0.113	0.111	0.109	0.106	0.103	0.101
17.0	0.096	0.121	0.119	0.116	0.113	0.110	0.108	0.106	0.104	0.102	0.100	0.098	0.094	0.093
17.5	0.089	0.112	0.110	0.107	0.105	0.102	0.100	0.098	0.096	0.094	0.092	0.091	0.087	0.086
18.0	0.082	0.103	0.101	0.099	0.096	0.094	0.092	0.091	0.089	0.087	0.085	0.084	0.081	0.080
18.5	0.076	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.078	0.075	0.074
19.0	0.071	0.088	0.086	0.084	0.082	0.081	0.079	0.077	0.076	0.074	0.073	0.072	0.069	0.068
19.5	0.066	0.082	0.080	0.078	0.077	0.075	0.073	0.072	0.071	0.069	0.068	0.067	0.065	0.064
20.0	0.061	0.076	0.075	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.064	0.063	0.060	0.059
20.5	0.057	0.071	0.070	0.068	0.067	0.065	0.064	0.063	0.062	0.060	0.059	0.058	0.057	0.056
21.0	0.051	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.055	0.053	0.053	0.052	0.050	0.049
21.5	0.043	0.052	0.051	0.050	0.049	0.048	0.047	0.047	0.046	0.045	0.044	0.043	0.042	0.041
22.0	0.034	0.041	0.040	0.040	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.033	0.033
22.5	0.025	0.031	0.031	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.025	0.025
23.0	0.021	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.022	0.022	0.022	0.021	0.021	0.020
23.5	0.018	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017
24.0	0.015	0.018	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.014
24.5	0.013	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.013

Table 8-2: C_t values, Sound Optimized Mode SO1

8.3 Sound Curves, Sound Optimized Mode SO1

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO1 (Blades with serrated trailing edge)
3	91.1
4	91.3
5	93.2
6	96.4
7	99.9
8	102.7
9	103.3
10	103.3
11	103.3
12	103.3
13	103.4
14	103.4
15	103.4
16	103.4
17	103.4
18	103.4
19	103.4
20	103.4

Table 8-3: Sound curves, Sound Optimized Mode SO1

9 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO2

9.1 Power Curves, Sound Optimized Mode SO2

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	285	210	217	224	231	238	244	251	258	265	272	278	292	299
4.5	424	318	328	337	347	357	366	376	386	395	405	414	434	443
5.0	597	452	465	478	491	505	518	531	544	557	571	584	610	623
5.5	809	616	633	651	669	686	704	721	739	756	774	791	826	844
6.0	1062	812	835	858	881	904	926	949	972	994	1017	1039	1085	1107
6.5	1360	1045	1074	1103	1131	1160	1189	1218	1246	1275	1303	1332	1388	1417
7.0	1699	1317	1353	1389	1424	1460	1495	1530	1566	1601	1633	1666	1730	1760
7.5	2034	1627	1670	1712	1754	1796	1834	1872	1909	1946	1976	2005	2055	2076
8.0	2241	1969	2008	2046	2085	2124	2145	2167	2188	2210	2220	2231	2248	2256
8.5	2303	2220	2234	2249	2263	2278	2283	2289	2294	2300	2301	2302	2303	2303
9.0	2336	2326	2328	2330	2332	2335	2335	2335	2335	2336	2336	2336	2335	2335
9.5	2383	2380	2381	2382	2383	2384	2384	2384	2384	2384	2383	2383	2383	2382
10.0	2418	2422	2422	2422	2421	2421	2420	2420	2420	2419	2419	2418	2417	2417
10.5	2442	2454	2453	2452	2451	2450	2449	2447	2446	2445	2444	2443	2441	2440
11.0	2506	2552	2547	2542	2537	2532	2528	2524	2520	2516	2512	2509	2502	2499
11.5	2578	2693	2675	2658	2640	2622	2615	2608	2601	2593	2588	2583	2574	2570
12.0	2644	2754	2742	2730	2717	2705	2696	2687	2678	2668	2660	2652	2640	2635
12.5	2674	2767	2756	2746	2736	2726	2717	2709	2701	2692	2686	2680	2670	2666
13.0	2683	2764	2754	2745	2735	2725	2718	2710	2702	2695	2691	2687	2681	2678
13.5	2753	2860	2847	2833	2819	2806	2797	2789	2780	2772	2765	2759	2748	2743
14.0	2854	2970	2956	2941	2926	2912	2903	2895	2886	2878	2870	2862	2847	2840
14.5	2987	3082	3070	3058	3047	3035	3027	3020	3012	3005	2999	2993	2982	2977
15.0	3123	3166	3163	3159	3155	3151	3147	3144	3140	3136	3132	3128	3119	3115
15.5	3215	3255	3252	3248	3245	3242	3238	3235	3231	3228	3224	3219	3210	3206
16.0	3334	3365	3363	3360	3358	3356	3353	3350	3348	3345	3341	3338	3329	3325
16.5	3415	3431	3430	3429	3429	3428	3426	3425	3423	3421	3419	3417	3412	3410
17.0	3461	3468	3468	3468	3468	3468	3468	3467	3466	3465	3464	3462	3459	3458
17.5	3470	3478	3477	3477	3476	3476	3475	3474	3474	3473	3472	3471	3469	3468
18.0	3484	3494	3494	3492	3492	3490	3490	3489	3488	3487	3486	3485	3483	3482
18.5	3507	3517	3516	3516	3515	3514	3513	3512	3511	3510	3509	3508	3506	3504
19.0	3532	3534	3535	3535	3535	3535	3535	3534	3534	3534	3533	3532	3530	3529
19.5	3555	3556	3556	3556	3557	3557	3557	3557	3557	3556	3556	3556	3554	3554
20.0	3573	3570	3570	3571	3572	3573	3574	3574	3574	3574	3574	3574	3573	3573
20.5	3583	3575	3577	3578	3579	3580	3581	3582	3582	3583	3583	3583	3583	3583
21.0	3297	3296	3297	3297	3297	3297	3297	3297	3297	3297	3297	3297	3297	3297
21.5	2623	2630	2628	2627	2626	2625	2624	2624	2624	2623	2623	2623	2623	2623
22.0	2011	2019	2019	2018	2018	2018	2016	2015	2014	2012	2012	2011	2010	2010
22.5	1594	1596	1596	1596	1596	1596	1596	1596	1596	1596	1595	1595	1594	1594
23.0	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502	1502
23.5	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
24.0	1252	1252	1252	1252	1252	1252	1252	1252	1252	1252	1252	1252	1252	1252
24.5	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112	1112

Table 9-1: Power curve, Sound Optimized Mode SO2

9.2 Ct Values, Sound Optimized Mode SO2

Air density kg/m ³														
Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.850	0.850	0.849	0.848	0.848	0.847	0.847	0.847	0.846	0.847
4.0	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830
4.5	0.828	0.831	0.831	0.830	0.830	0.830	0.830	0.830	0.830	0.829	0.829	0.829	0.828	0.828
5.0	0.823	0.828	0.827	0.827	0.826	0.826	0.826	0.825	0.825	0.824	0.824	0.823	0.823	0.822
5.5	0.820	0.824	0.824	0.823	0.823	0.823	0.822	0.822	0.821	0.821	0.820	0.820	0.819	0.819
6.0	0.814	0.821	0.820	0.820	0.819	0.819	0.818	0.817	0.817	0.816	0.816	0.815	0.814	0.813
6.5	0.808	0.816	0.816	0.815	0.815	0.814	0.813	0.812	0.812	0.811	0.810	0.809	0.807	0.805
7.0	0.789	0.812	0.811	0.810	0.809	0.808	0.806	0.804	0.803	0.801	0.797	0.793	0.783	0.778
7.5	0.736	0.806	0.803	0.800	0.797	0.795	0.788	0.782	0.776	0.770	0.758	0.747	0.722	0.708
8.0	0.616	0.790	0.777	0.765	0.752	0.739	0.721	0.704	0.686	0.668	0.651	0.633	0.601	0.585
8.5	0.490	0.686	0.665	0.644	0.623	0.602	0.585	0.568	0.551	0.533	0.519	0.505	0.478	0.466
9.0	0.401	0.554	0.536	0.519	0.501	0.483	0.470	0.457	0.444	0.431	0.421	0.411	0.392	0.383
9.5	0.342	0.460	0.447	0.433	0.420	0.407	0.397	0.387	0.377	0.367	0.358	0.350	0.335	0.328
10.0	0.293	0.387	0.377	0.366	0.356	0.345	0.337	0.329	0.321	0.313	0.306	0.299	0.287	0.281
10.5	0.253	0.331	0.322	0.314	0.305	0.297	0.290	0.283	0.276	0.270	0.264	0.258	0.248	0.243
11.0	0.223	0.294	0.287	0.279	0.271	0.263	0.257	0.251	0.245	0.239	0.234	0.229	0.219	0.214
11.5	0.200	0.269	0.261	0.253	0.245	0.237	0.231	0.225	0.219	0.214	0.209	0.205	0.196	0.192
12.0	0.180	0.240	0.234	0.227	0.220	0.214	0.208	0.203	0.198	0.193	0.188	0.184	0.176	0.173
12.5	0.161	0.212	0.207	0.201	0.195	0.190	0.185	0.181	0.176	0.172	0.168	0.164	0.158	0.154
13.0	0.143	0.188	0.183	0.178	0.173	0.168	0.164	0.160	0.156	0.153	0.150	0.146	0.141	0.138
13.5	0.131	0.173	0.168	0.164	0.159	0.154	0.151	0.147	0.144	0.140	0.137	0.134	0.129	0.126
14.0	0.122	0.161	0.156	0.152	0.148	0.143	0.140	0.137	0.133	0.130	0.127	0.125	0.120	0.117
14.5	0.115	0.150	0.146	0.142	0.138	0.134	0.131	0.128	0.125	0.122	0.120	0.117	0.113	0.110
15.0	0.108	0.139	0.136	0.133	0.129	0.126	0.123	0.121	0.118	0.115	0.113	0.111	0.106	0.104
15.5	0.101	0.130	0.127	0.124	0.121	0.118	0.115	0.113	0.110	0.108	0.106	0.103	0.099	0.098
16.0	0.096	0.122	0.119	0.116	0.113	0.111	0.108	0.106	0.104	0.101	0.100	0.098	0.094	0.092
16.5	0.090	0.113	0.111	0.108	0.106	0.103	0.101	0.099	0.097	0.095	0.093	0.091	0.088	0.086
17.0	0.083	0.105	0.103	0.100	0.098	0.096	0.094	0.092	0.090	0.088	0.087	0.085	0.082	0.081
17.5	0.077	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.076	0.075
18.0	0.072	0.090	0.088	0.086	0.084	0.082	0.081	0.079	0.078	0.076	0.075	0.073	0.071	0.070
18.5	0.067	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.070	0.068	0.066	0.065
19.0	0.063	0.078	0.076	0.075	0.073	0.071	0.070	0.069	0.067	0.066	0.065	0.064	0.062	0.061
19.5	0.059	0.073	0.071	0.070	0.068	0.067	0.066	0.064	0.063	0.062	0.061	0.060	0.058	0.057
20.0	0.055	0.068	0.067	0.065	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.054	0.053
20.5	0.052	0.064	0.062	0.061	0.060	0.059	0.058	0.057	0.056	0.054	0.054	0.053	0.051	0.050
21.0	0.045	0.056	0.054	0.053	0.052	0.051	0.050	0.049	0.049	0.048	0.047	0.046	0.045	0.044
21.5	0.035	0.043	0.042	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.034
22.0	0.027	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026
22.5	0.020	0.024	0.024	0.024	0.023	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.020	0.020
23.0	0.018	0.022	0.022	0.021	0.021	0.020	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018
23.5	0.017	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.018	0.017	0.017	0.017	0.016	0.016
24.0	0.015	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.014	0.014
24.5	0.013	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.012

Table 9-2: C_t values, Sound Optimized Mode SO2

9.3 Sound Curves, Sound Optimized Mode SO2

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO2 (Blades with serrated trailing edge)
3	91.1
4	91.3
5	93.2
6	96.4
7	99.9
8	102.0
9	102.0
10	102.0
11	102.0
12	102.0
13	102.0
14	102.0
15	102.0
16	102.0
17	102.0
18	102.0
19	102.0
20	102.0

Table 9-3: Sound curves, Sound Optimized Mode SO2

10 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO3

10.1 Power Curves, Sound Optimized Mode SO3

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	285	210	217	224	231	238	244	251	258	265	272	278	292	299
4.5	424	318	328	337	347	357	366	376	386	395	405	415	434	443
5.0	597	452	465	478	491	505	518	531	544	557	571	584	610	623
5.5	809	616	633	651	669	686	704	721	739	756	774	792	827	844
6.0	1062	813	835	858	881	904	926	949	972	994	1017	1040	1084	1107
6.5	1338	1045	1073	1101	1130	1158	1185	1212	1239	1266	1290	1314	1359	1379
7.0	1517	1305	1334	1362	1391	1419	1436	1454	1471	1488	1498	1507	1523	1528
7.5	1546	1493	1502	1512	1521	1531	1534	1537	1541	1544	1544	1545	1546	1546
8.0	1546	1543	1544	1545	1545	1546	1546	1546	1546	1546	1546	1546	1546	1546
8.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
9.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
9.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
10.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
10.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
11.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
11.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
12.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
12.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
13.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
13.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
14.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
14.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
15.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
15.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
16.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
16.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
17.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
17.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
18.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
18.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
19.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
19.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
20.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
20.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
21.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
21.5	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
22.0	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546	1546
22.5	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545	1545
23.0	1511	1511	1511	1511	1511	1510	1511	1511	1511	1511	1511	1511	1511	1511
23.5	1414	1415	1415	1415	1415	1415	1415	1415	1415	1414	1414	1414	1414	1414
24.0	1264	1264	1264	1264	1264	1264	1264	1264	1264	1264	1264	1264	1264	1264
24.5	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115	1115

Table 10-1: Power curve, Sound Optimized Mode SO3

10.2 Ct Values, Sound Optimized Mode SO3

Air density kg/m³

Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.850	0.850	0.849	0.849	0.848	0.848	0.847	0.847	0.846	0.847
4.0	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.830	0.831	0.830	0.830	0.830	0.830
4.5	0.828	0.831	0.831	0.830	0.830	0.830	0.830	0.830	0.830	0.829	0.829	0.829	0.828	0.828
5.0	0.823	0.828	0.827	0.827	0.826	0.826	0.826	0.825	0.825	0.824	0.824	0.824	0.823	0.822
5.5	0.820	0.824	0.824	0.823	0.823	0.823	0.822	0.822	0.821	0.821	0.821	0.820	0.819	0.819
6.0	0.814	0.821	0.820	0.820	0.819	0.819	0.818	0.818	0.817	0.816	0.815	0.815	0.813	0.812
6.5	0.778	0.818	0.817	0.815	0.814	0.812	0.809	0.805	0.801	0.798	0.791	0.784	0.768	0.759
7.0	0.633	0.799	0.788	0.776	0.765	0.754	0.737	0.719	0.702	0.685	0.668	0.651	0.617	0.601
7.5	0.476	0.672	0.651	0.630	0.609	0.588	0.571	0.553	0.536	0.519	0.505	0.490	0.464	0.452
8.0	0.373	0.515	0.499	0.482	0.466	0.449	0.437	0.426	0.414	0.402	0.392	0.383	0.365	0.357
8.5	0.303	0.404	0.393	0.382	0.370	0.359	0.351	0.342	0.333	0.325	0.318	0.310	0.297	0.291
9.0	0.252	0.330	0.321	0.313	0.304	0.296	0.289	0.282	0.275	0.269	0.263	0.257	0.247	0.242
9.5	0.213	0.277	0.270	0.263	0.256	0.250	0.244	0.238	0.233	0.227	0.223	0.218	0.209	0.205
10.0	0.182	0.235	0.229	0.223	0.218	0.212	0.207	0.203	0.198	0.194	0.190	0.186	0.179	0.175
10.5	0.157	0.201	0.197	0.192	0.187	0.182	0.178	0.175	0.171	0.167	0.164	0.160	0.154	0.151
11.0	0.137	0.174	0.170	0.166	0.162	0.158	0.155	0.151	0.148	0.145	0.142	0.139	0.134	0.132
11.5	0.120	0.152	0.149	0.145	0.142	0.138	0.135	0.133	0.130	0.127	0.124	0.122	0.118	0.115
12.0	0.106	0.134	0.131	0.128	0.125	0.122	0.119	0.117	0.114	0.112	0.110	0.108	0.104	0.102
12.5	0.094	0.119	0.116	0.113	0.111	0.108	0.106	0.104	0.102	0.099	0.098	0.096	0.092	0.091
13.0	0.084	0.106	0.103	0.101	0.099	0.096	0.095	0.093	0.091	0.089	0.087	0.086	0.083	0.081
13.5	0.076	0.095	0.093	0.091	0.089	0.087	0.085	0.083	0.082	0.080	0.078	0.077	0.074	0.073
14.0	0.068	0.085	0.084	0.082	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.070	0.067	0.066
14.5	0.062	0.077	0.076	0.074	0.072	0.071	0.069	0.068	0.067	0.065	0.064	0.063	0.061	0.060
15.0	0.057	0.070	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.060	0.059	0.058	0.056	0.055
15.5	0.052	0.064	0.063	0.061	0.060	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.051	0.050
16.0	0.048	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046
16.5	0.044	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.045	0.043	0.043
17.0	0.041	0.050	0.049	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.040	0.040
17.5	0.038	0.046	0.046	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.039	0.038	0.037
18.0	0.036	0.043	0.042	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.035
18.5	0.033	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.032
19.0	0.031	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.032	0.032	0.032	0.031	0.030
19.5	0.029	0.035	0.034	0.034	0.033	0.033	0.032	0.032	0.031	0.031	0.030	0.030	0.029	0.028
20.0	0.028	0.033	0.032	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027	0.027
20.5	0.026	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.028	0.027	0.027	0.026	0.026	0.025
21.0	0.025	0.029	0.029	0.028	0.028	0.027	0.027	0.026	0.026	0.026	0.025	0.025	0.024	0.024
21.5	0.023	0.028	0.027	0.027	0.026	0.026	0.025	0.025	0.025	0.024	0.024	0.024	0.023	0.023
22.0	0.022	0.026	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.021	0.021
22.5	0.020	0.024	0.023	0.023	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.019
23.0	0.018	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.019	0.018	0.018
23.5	0.017	0.020	0.020	0.019	0.019	0.019	0.018	0.018	0.018	0.017	0.017	0.017	0.017	0.016
24.0	0.015	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.014	0.014
24.5	0.013	0.015	0.015	0.015	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.012

Table 10-2: C_t values, Sound Optimized Mode SO3

10.3 Sound Curves, Sound Optimized Mode SO3

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO3 (Blades with serrated trailing edge)
3	91.1
4	91.3
5	93.2
6	96.3
7	99.5
8	99.5
9	99.5
10	99.5
11	99.5
12	99.5
13	99.5
14	99.5
15	99.5
16	99.5
17	99.5
18	99.5
19	99.5
20	99.5

Table 10-3: Sound curves, Sound Optimized Mode SO3

11 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO11

11.1 Power Curves, Sound Optimized Mode SO11

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	277	210	217	224	231	237	243	250	256	262	267	272	282	286
4.5	403	318	327	337	346	356	363	371	379	387	392	398	406	409
5.0	579	452	465	478	491	504	516	528	540	552	561	570	585	590
5.5	740	615	632	648	664	681	692	703	713	724	730	735	743	745
6.0	861	800	811	822	833	845	848	851	855	858	859	860	861	862
6.5	982	966	969	973	976	979	980	980	981	982	982	982	982	982
7.0	1103	1103	1103	1103	1103	1103	1103	1103	1103	1103	1103	1103	1103	1103
7.5	1218	1218	1218	1218	1218	1218	1218	1218	1218	1218	1218	1218	1218	1218
8.0	1334	1334	1334	1334	1334	1334	1334	1334	1334	1334	1334	1334	1334	1334
8.5	1458	1458	1458	1458	1458	1458	1458	1458	1458	1458	1458	1458	1458	1458
9.0	1584	1584	1584	1584	1584	1584	1584	1584	1584	1584	1584	1584	1584	1584
9.5	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690	1690
10.0	1769	1769	1769	1769	1769	1769	1769	1769	1769	1769	1769	1769	1769	1769
10.5	1811	1811	1811	1811	1811	1811	1811	1811	1811	1811	1811	1811	1811	1811
11.0	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841	1841
11.5	1873	1873	1873	1873	1873	1873	1873	1873	1873	1873	1873	1873	1873	1873
12.0	1902	1902	1902	1902	1902	1902	1902	1902	1902	1902	1902	1902	1902	1902
12.5	1921	1921	1921	1921	1921	1921	1921	1921	1921	1921	1921	1921	1921	1921
13.0	1933	1933	1933	1933	1933	1933	1933	1933	1933	1933	1933	1933	1933	1933
13.5	1944	1944	1944	1944	1944	1944	1944	1944	1944	1944	1944	1944	1944	1944
14.0	1952	1952	1952	1952	1952	1952	1952	1952	1952	1952	1952	1952	1952	1952
14.5	1960	1960	1960	1960	1960	1960	1960	1960	1960	1960	1960	1960	1960	1960
15.0	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972	1972
15.5	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984	1984
16.0	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995	1995
16.5	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005	2005
17.0	2013	2013	2013	2013	2013	2013	2013	2013	2013	2013	2013	2013	2013	2013
17.5	2022	2022	2022	2022	2022	2022	2022	2022	2022	2022	2022	2022	2022	2022
18.0	2031	2031	2031	2031	2031	2031	2031	2031	2031	2031	2031	2031	2031	2031
18.5	2039	2039	2039	2039	2039	2039	2039	2039	2039	2039	2039	2039	2039	2039
19.0	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047	2047
19.5	2054	2054	2054	2054	2054	2054	2054	2054	2054	2054	2054	2054	2054	2054
20.0	2061	2061	2061	2061	2061	2061	2061	2061	2061	2061	2061	2061	2061	2061
20.5	2068	2068	2068	2068	2068	2068	2068	2068	2068	2068	2068	2068	2068	2068
21.0	2049	2049	2049	2049	2049	2049	2049	2049	2049	2049	2049	2049	2049	2049
21.5	1853	1853	1853	1853	1853	1853	1853	1853	1853	1853	1853	1853	1853	1853
22.0	1421	1421	1421	1421	1421	1421	1421	1421	1421	1421	1421	1421	1421	1421
22.5	950	950	950	950	950	950	950	950	950	950	950	950	950	950
23.0	816	816	816	816	816	816	816	816	816	816	816	816	816	816
23.5	758	758	758	758	758	758	758	758	758	758	758	758	758	758
24.0	683	683	683	683	683	683	683	683	683	683	683	683	683	683
24.5	614	614	614	614	614	614	614	614	614	614	614	614	614	614

Table 11-1: Power curve, Sound Optimized Mode SO11

11.2 Ct Values, Sound Optimized Mode SO11

Air density kg/m ³														
Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.89	0.89	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.85	0.85	0.849	0.848	0.848	0.847	0.847	0.846	0.845	0.845
4.0	0.774	0.83	0.829	0.828	0.827	0.826	0.82	0.814	0.808	0.802	0.793	0.784	0.76	0.746
4.5	0.723	0.831	0.828	0.825	0.822	0.819	0.808	0.797	0.786	0.775	0.758	0.74	0.704	0.686
5.0	0.755	0.829	0.827	0.825	0.823	0.822	0.815	0.808	0.802	0.795	0.782	0.768	0.736	0.717
5.5	0.669	0.824	0.818	0.811	0.805	0.799	0.782	0.765	0.748	0.731	0.711	0.69	0.649	0.628
6.0	0.549	0.782	0.76	0.737	0.715	0.692	0.67	0.647	0.624	0.602	0.584	0.566	0.534	0.519
6.5	0.468	0.677	0.652	0.627	0.603	0.578	0.56	0.543	0.525	0.507	0.494	0.481	0.457	0.445
7.0	0.406	0.564	0.545	0.527	0.508	0.489	0.476	0.463	0.45	0.437	0.426	0.416	0.397	0.388
7.5	0.356	0.481	0.467	0.452	0.438	0.424	0.414	0.403	0.392	0.382	0.373	0.365	0.348	0.341
8.0	0.316	0.42	0.409	0.397	0.386	0.374	0.365	0.356	0.347	0.338	0.331	0.323	0.31	0.303
8.5	0.285	0.375	0.365	0.355	0.345	0.335	0.327	0.32	0.312	0.304	0.298	0.291	0.279	0.273
9.0	0.258	0.337	0.329	0.32	0.311	0.303	0.296	0.289	0.282	0.275	0.269	0.264	0.253	0.248
9.5	0.234	0.304	0.296	0.289	0.281	0.273	0.267	0.261	0.255	0.249	0.244	0.239	0.229	0.225
10.0	0.209	0.27	0.264	0.257	0.25	0.244	0.238	0.233	0.228	0.222	0.218	0.214	0.205	0.201
10.5	0.185	0.237	0.231	0.226	0.22	0.214	0.21	0.205	0.201	0.196	0.192	0.188	0.181	0.178
11.0	0.163	0.208	0.204	0.199	0.194	0.189	0.185	0.181	0.177	0.173	0.17	0.166	0.16	0.157
11.5	0.145	0.185	0.18	0.176	0.172	0.168	0.164	0.161	0.157	0.154	0.151	0.148	0.142	0.14
12.0	0.13	0.165	0.161	0.157	0.153	0.15	0.147	0.144	0.141	0.138	0.135	0.132	0.127	0.125
12.5	0.116	0.147	0.144	0.141	0.137	0.134	0.131	0.128	0.126	0.123	0.121	0.119	0.114	0.112
13.0	0.104	0.132	0.129	0.126	0.123	0.12	0.118	0.115	0.113	0.11	0.108	0.106	0.103	0.101
13.5	0.094	0.119	0.116	0.113	0.111	0.108	0.106	0.104	0.102	0.1	0.098	0.096	0.093	0.091
14.0	0.085	0.107	0.105	0.102	0.1	0.098	0.096	0.094	0.092	0.09	0.089	0.087	0.084	0.082
14.5	0.078	0.097	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.08	0.079	0.076	0.075
15.0	0.071	0.088	0.087	0.085	0.083	0.081	0.079	0.078	0.076	0.075	0.074	0.072	0.07	0.069
15.5	0.065	0.081	0.079	0.078	0.076	0.074	0.073	0.072	0.07	0.069	0.068	0.066	0.064	0.063
16.0	0.06	0.074	0.073	0.071	0.07	0.068	0.067	0.066	0.065	0.063	0.062	0.061	0.059	0.058
16.5	0.056	0.069	0.067	0.066	0.064	0.063	0.062	0.061	0.06	0.059	0.058	0.057	0.055	0.054
17.0	0.052	0.063	0.062	0.061	0.06	0.058	0.057	0.056	0.055	0.054	0.053	0.053	0.051	0.05
17.5	0.048	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.05	0.049	0.048	0.047
18.0	0.045	0.055	0.054	0.053	0.052	0.051	0.05	0.049	0.048	0.047	0.047	0.046	0.044	0.044
18.5	0.042	0.051	0.05	0.049	0.048	0.047	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041
19.0	0.04	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.041	0.04	0.039	0.038
19.5	0.037	0.045	0.044	0.043	0.042	0.042	0.041	0.04	0.04	0.039	0.038	0.038	0.037	0.036
20.0	0.035	0.042	0.041	0.041	0.04	0.039	0.039	0.038	0.037	0.037	0.036	0.036	0.035	0.034
20.5	0.033	0.04	0.039	0.038	0.038	0.037	0.036	0.036	0.035	0.035	0.034	0.034	0.033	0.032
21.0	0.031	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.032	0.032	0.032	0.031	0.03
21.5	0.027	0.032	0.032	0.031	0.031	0.03	0.03	0.029	0.029	0.028	0.028	0.028	0.027	0.026
22.0	0.021	0.025	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.022	0.022	0.021	0.021	0.02
22.5	0.015	0.017	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015
23.0	0.013	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013
23.5	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012
24.0	0.011	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.01	0.01
24.5	0.009	0.011	0.011	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.009	0.009

Table 11-2: C_t values, Sound Optimized Mode SO11

11.3 Sound Curves, Sound Optimized Mode SO11

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO11 (Blades with serrated trailing edge)
3	91.1
4	91.3
5	93.0
6	94.4
7	95.6
8	96.8
9	98.0
10	98.8
11	99.0
12	99.2
13	99.2
14	99.2
15	99.2
16	99.2
17	99.2
18	99.2
19	99.2
20	99.2

Table 11-3: Sound curves, Sound Optimized Mode SO11

12 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO12

12.1 Power Curves, Sound Optimized Mode SO12

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	278	210	217	224	231	237	243	250	256	262	267	272	282	286
4.5	405	318	327	337	347	356	364	373	381	389	394	400	409	413
5.0	580	452	465	478	491	504	516	528	540	552	562	571	586	592
5.5	766	616	633	650	667	684	698	713	727	741	749	758	771	775
6.0	934	810	829	848	867	886	896	906	916	926	929	931	935	936
6.5	1108	1029	1044	1059	1074	1090	1093	1097	1101	1105	1106	1107	1108	1108
7.0	1301	1270	1278	1285	1293	1300	1300	1301	1301	1301	1301	1301	1301	1301
7.5	1516	1508	1510	1512	1514	1516	1516	1516	1516	1516	1516	1516	1516	1516
8.0	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695	1695
8.5	1810	1810	1810	1810	1810	1810	1810	1810	1810	1810	1810	1810	1809	1809
9.0	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884	1884
9.5	1936	1936	1936	1936	1936	1936	1936	1936	1936	1936	1936	1936	1936	1936
10.0	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976	1976
10.5	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
11.0	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020	2020
11.5	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035	2035
12.0	2048	2048	2048	2048	2048	2048	2048	2048	2048	2048	2048	2048	2048	2048
12.5	2057	2057	2057	2057	2057	2057	2057	2057	2057	2057	2057	2057	2057	2057
13.0	2066	2066	2066	2066	2066	2066	2066	2066	2066	2066	2066	2066	2066	2066
13.5	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078	2078
14.0	2092	2092	2092	2092	2092	2092	2092	2092	2092	2092	2092	2092	2092	2092
14.5	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108	2108
15.0	2123	2123	2123	2123	2123	2123	2123	2123	2123	2123	2123	2123	2123	2123
15.5	2132	2132	2132	2132	2132	2132	2132	2132	2132	2132	2132	2132	2132	2132
16.0	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140	2140
16.5	2148	2148	2148	2148	2148	2148	2148	2148	2148	2148	2148	2148	2148	2148
17.0	2158	2158	2158	2158	2158	2158	2158	2158	2158	2158	2158	2158	2158	2158
17.5	2168	2168	2168	2168	2168	2168	2168	2168	2168	2168	2168	2168	2168	2168
18.0	2179	2179	2179	2179	2179	2179	2179	2179	2179	2179	2179	2179	2179	2179
18.5	2188	2188	2188	2188	2188	2188	2188	2188	2188	2188	2188	2188	2188	2188
19.0	2197	2197	2197	2197	2197	2197	2197	2197	2197	2197	2197	2197	2197	2197
19.5	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205	2205
20.0	2212	2212	2212	2212	2212	2212	2212	2212	2212	2212	2212	2212	2212	2212
20.5	2220	2220	2220	2220	2220	2220	2220	2220	2220	2220	2220	2220	2220	2220
21.0	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190	2190
21.5	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951	1951
22.0	1460	1460	1460	1460	1460	1460	1460	1460	1460	1460	1460	1460	1460	1460
22.5	951	951	951	951	951	951	951	951	951	951	951	951	951	951
23.0	816	816	816	816	816	816	816	816	816	816	816	816	816	816
23.5	758	758	758	758	758	758	758	758	758	758	758	758	758	758
24.0	683	683	683	683	683	683	683	683	683	683	683	683	683	683
24.5	614	614	614	614	614	614	614	614	614	614	614	614	614	614

Table 12-1: Power curve, Sound Optimized Mode SO12

12.2 Ct Values, Sound Optimized Mode SO12

Air density kg/m ³														
Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.850	0.850	0.849	0.848	0.848	0.847	0.847	0.846	0.845	0.845
4.0	0.776	0.830	0.829	0.828	0.827	0.826	0.820	0.814	0.809	0.803	0.794	0.785	0.762	0.747
4.5	0.732	0.831	0.829	0.827	0.825	0.823	0.813	0.803	0.793	0.783	0.766	0.749	0.713	0.695
5.0	0.760	0.829	0.827	0.826	0.824	0.823	0.816	0.810	0.804	0.798	0.785	0.772	0.741	0.722
5.5	0.712	0.825	0.822	0.819	0.816	0.813	0.802	0.792	0.782	0.771	0.751	0.732	0.691	0.670
6.0	0.618	0.815	0.805	0.794	0.783	0.773	0.751	0.729	0.707	0.685	0.663	0.640	0.600	0.583
6.5	0.548	0.785	0.762	0.740	0.717	0.695	0.671	0.648	0.624	0.601	0.583	0.565	0.533	0.518
7.0	0.495	0.738	0.709	0.679	0.650	0.620	0.600	0.579	0.559	0.538	0.524	0.509	0.483	0.471
7.5	0.459	0.669	0.643	0.616	0.590	0.564	0.547	0.530	0.514	0.497	0.484	0.472	0.448	0.438
8.0	0.414	0.580	0.560	0.540	0.520	0.500	0.487	0.473	0.460	0.446	0.436	0.425	0.405	0.396
8.5	0.362	0.489	0.475	0.460	0.446	0.431	0.420	0.409	0.399	0.388	0.379	0.370	0.354	0.346
9.0	0.312	0.414	0.403	0.391	0.380	0.369	0.360	0.351	0.342	0.334	0.326	0.319	0.306	0.299
9.5	0.271	0.355	0.346	0.337	0.327	0.318	0.311	0.304	0.296	0.289	0.283	0.277	0.266	0.260
10.0	0.235	0.305	0.298	0.290	0.282	0.275	0.269	0.263	0.256	0.250	0.245	0.240	0.231	0.226
10.5	0.205	0.264	0.257	0.251	0.245	0.238	0.233	0.228	0.223	0.217	0.213	0.209	0.201	0.197
11.0	0.179	0.230	0.224	0.219	0.213	0.208	0.203	0.199	0.194	0.190	0.186	0.183	0.176	0.172
11.5	0.158	0.201	0.196	0.192	0.187	0.182	0.179	0.175	0.171	0.167	0.164	0.161	0.155	0.152
12.0	0.140	0.178	0.173	0.169	0.165	0.161	0.158	0.155	0.151	0.148	0.145	0.142	0.137	0.135
12.5	0.124	0.158	0.154	0.150	0.147	0.143	0.140	0.138	0.135	0.132	0.129	0.127	0.122	0.120
13.0	0.111	0.141	0.138	0.134	0.131	0.128	0.126	0.123	0.120	0.118	0.116	0.114	0.109	0.107
13.5	0.100	0.126	0.124	0.121	0.118	0.115	0.113	0.111	0.108	0.106	0.104	0.102	0.099	0.097
14.0	0.091	0.114	0.112	0.109	0.107	0.104	0.102	0.100	0.098	0.096	0.095	0.093	0.090	0.088
14.5	0.083	0.104	0.102	0.100	0.097	0.095	0.093	0.091	0.090	0.088	0.086	0.085	0.082	0.080
15.0	0.076	0.095	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.077	0.075	0.074
15.5	0.070	0.087	0.085	0.083	0.081	0.080	0.078	0.077	0.075	0.074	0.072	0.071	0.069	0.068
16.0	0.064	0.080	0.078	0.076	0.075	0.073	0.072	0.070	0.069	0.068	0.066	0.065	0.063	0.062
16.5	0.059	0.073	0.072	0.070	0.069	0.067	0.066	0.065	0.064	0.062	0.061	0.060	0.058	0.057
17.0	0.055	0.068	0.066	0.065	0.064	0.062	0.061	0.060	0.059	0.058	0.057	0.056	0.054	0.053
17.5	0.051	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050
18.0	0.048	0.059	0.058	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.050	0.049	0.047	0.047
18.5	0.045	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.044	0.044
19.0	0.042	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.045	0.044	0.043	0.043	0.041	0.041
19.5	0.040	0.048	0.047	0.046	0.045	0.044	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.038
20.0	0.037	0.045	0.044	0.043	0.042	0.042	0.041	0.040	0.040	0.039	0.038	0.038	0.037	0.036
20.5	0.035	0.042	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.036	0.035	0.034
21.0	0.033	0.039	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.032	0.032
21.5	0.028	0.034	0.033	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.029	0.028	0.028
22.0	0.021	0.025	0.025	0.024	0.024	0.024	0.023	0.023	0.023	0.022	0.022	0.022	0.021	0.021
22.5	0.015	0.017	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015
23.0	0.013	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013
23.5	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012
24.0	0.011	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.010	0.010
24.5	0.009	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.009	0.009

Table 12-2: C_t values, Sound Optimized Mode SO12

12.3 Sound Curves, Sound Optimized Mode SO12

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO12 (Blades with serrated trailing edge)
3	91.1
4	91.3
5	93.0
6	94.9
7	96.9
8	98.9
9	99.6
10	99.9
11	99.9
12	99.9
13	99.9
14	99.9
15	99.9
16	99.9
17	99.9
18	99.9
19	99.9
20	99.9

Table 12-3: Sound curves, Sound Optimized Mode SO12

13 Power Curves, Ct Values and Sound Curves, Sound Optimized Mode SO13

13.1 Power Curves, Sound Optimized Mode SO13

Air density [kg/m ³]														
Wind speed [m/s]	1.225	0.95	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	81	51	54	57	60	62	65	68	70	73	76	79	84	87
3.5	172	123	127	132	136	141	145	150	154	159	163	168	177	181
4.0	277	210	217	224	231	237	244	250	256	262	267	272	281	286
4.5	378	317	326	334	342	351	356	362	367	373	374	376	378	379
5.0	440	426	429	432	436	439	439	439	439	440	440	440	440	440
5.5	465	464	464	464	465	465	465	465	465	465	465	465	465	465
6.0	506	506	506	506	506	506	506	506	506	506	506	506	506	506
6.5	597	597	597	597	597	597	597	597	597	597	597	597	597	597
7.0	705	705	705	705	705	705	705	705	705	705	705	705	705	705
7.5	804	804	804	804	804	804	804	804	804	804	804	804	804	804
8.0	923	923	923	923	923	923	923	923	923	923	923	923	923	923
8.5	1069	1069	1069	1069	1069	1069	1069	1069	1069	1069	1069	1069	1069	1069
9.0	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200	1200
9.5	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290	1290
10.0	1355	1355	1355	1355	1355	1355	1355	1355	1355	1355	1355	1355	1355	1355
10.5	1409	1409	1409	1409	1409	1409	1409	1409	1409	1409	1409	1409	1409	1409
11.0	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455	1455
11.5	1480	1480	1480	1480	1480	1480	1480	1480	1480	1480	1480	1480	1480	1480
12.0	1492	1492	1492	1492	1492	1492	1492	1492	1492	1492	1492	1492	1492	1492
12.5	1499	1499	1499	1499	1499	1499	1499	1499	1499	1499	1499	1499	1499	1499
13.0	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505	1505
13.5	1512	1512	1512	1512	1512	1512	1512	1512	1512	1512	1512	1512	1512	1512
14.0	1522	1522	1522	1522	1522	1522	1522	1522	1522	1522	1522	1522	1522	1522
14.5	1535	1535	1535	1535	1535	1535	1535	1535	1535	1535	1535	1535	1535	1535
15.0	1547	1547	1547	1547	1547	1547	1547	1547	1547	1547	1547	1547	1547	1547
15.5	1555	1555	1555	1555	1555	1555	1555	1555	1555	1555	1555	1555	1555	1555
16.0	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560	1560
16.5	1568	1568	1568	1568	1568	1568	1568	1568	1568	1568	1568	1568	1568	1568
17.0	1577	1577	1577	1577	1577	1577	1577	1577	1577	1577	1577	1577	1577	1577
17.5	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587	1587
18.0	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595	1595
18.5	1599	1599	1599	1599	1599	1599	1599	1599	1599	1599	1599	1599	1599	1599
19.0	1603	1603	1603	1603	1603	1603	1603	1603	1603	1603	1603	1603	1603	1603
19.5	1610	1610	1610	1610	1610	1610	1610	1610	1610	1610	1610	1610	1610	1610
20.0	1618	1618	1618	1618	1618	1618	1618	1618	1618	1618	1618	1618	1618	1618
20.5	1629	1629	1629	1629	1629	1629	1629	1629	1629	1629	1629	1629	1629	1629
21.0	1636	1636	1636	1636	1636	1636	1636	1636	1636	1636	1636	1636	1636	1636
21.5	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550
22.0	1276	1276	1276	1276	1276	1276	1276	1276	1276	1276	1276	1276	1276	1276
22.5	941	941	941	941	941	941	941	941	941	941	941	941	941	941
23.0	816	816	816	816	816	816	816	816	816	816	816	816	816	816
23.5	758	758	758	758	758	758	758	758	758	758	758	758	758	758
24.0	683	683	683	683	683	683	683	683	683	683	683	683	683	683
24.5	614	614	614	614	614	614	614	614	614	614	614	614	614	614

Table 13-1: Power curve, Sound Optimized Mode SO13

13.2 Ct Values, Sound Optimized Mode SO13

Air density kg/m³

Wind speed [m/s]	1.225	0.950	0.975	1.0	1.025	1.05	1.075	1.1	1.125	1.15	1.175	1.2	1.25	1.275
3.0	0.888	0.893	0.893	0.892	0.892	0.891	0.891	0.891	0.890	0.890	0.889	0.889	0.888	0.888
3.5	0.846	0.853	0.852	0.851	0.850	0.850	0.849	0.848	0.848	0.847	0.847	0.846	0.845	0.845
4.0	0.774	0.830	0.829	0.828	0.827	0.826	0.820	0.814	0.809	0.803	0.793	0.783	0.759	0.745
4.5	0.642	0.825	0.816	0.808	0.799	0.791	0.772	0.753	0.734	0.715	0.690	0.666	0.622	0.602
5.0	0.490	0.724	0.698	0.671	0.644	0.618	0.597	0.576	0.555	0.534	0.519	0.505	0.479	0.467
5.5	0.369	0.505	0.490	0.474	0.458	0.442	0.431	0.419	0.408	0.396	0.387	0.378	0.361	0.353
6.0	0.298	0.395	0.384	0.373	0.363	0.352	0.344	0.336	0.327	0.319	0.312	0.305	0.292	0.286
6.5	0.270	0.355	0.345	0.336	0.327	0.317	0.310	0.303	0.296	0.288	0.282	0.276	0.265	0.259
7.0	0.251	0.328	0.319	0.311	0.303	0.294	0.288	0.281	0.274	0.268	0.262	0.256	0.246	0.241
7.5	0.230	0.299	0.291	0.284	0.276	0.269	0.263	0.257	0.251	0.245	0.240	0.235	0.225	0.221
8.0	0.215	0.279	0.272	0.265	0.258	0.251	0.246	0.240	0.235	0.229	0.224	0.220	0.211	0.207
8.5	0.206	0.267	0.260	0.254	0.247	0.240	0.235	0.230	0.225	0.219	0.215	0.211	0.202	0.198
9.0	0.194	0.250	0.244	0.238	0.232	0.226	0.221	0.216	0.211	0.206	0.202	0.198	0.190	0.187
9.5	0.178	0.229	0.223	0.218	0.212	0.207	0.202	0.198	0.194	0.189	0.185	0.182	0.175	0.171
10.0	0.160	0.205	0.200	0.195	0.190	0.186	0.182	0.178	0.174	0.170	0.167	0.163	0.157	0.154
10.5	0.144	0.183	0.179	0.175	0.171	0.166	0.163	0.159	0.156	0.152	0.150	0.147	0.141	0.139
11.0	0.129	0.164	0.161	0.157	0.153	0.149	0.146	0.143	0.140	0.137	0.134	0.132	0.127	0.125
11.5	0.115	0.146	0.143	0.140	0.136	0.133	0.130	0.128	0.125	0.122	0.120	0.118	0.113	0.111
12.0	0.103	0.130	0.127	0.124	0.121	0.118	0.116	0.113	0.111	0.109	0.107	0.105	0.101	0.099
12.5	0.092	0.116	0.113	0.111	0.108	0.105	0.103	0.101	0.099	0.097	0.095	0.094	0.090	0.089
13.0	0.082	0.103	0.101	0.099	0.097	0.094	0.093	0.091	0.089	0.087	0.085	0.084	0.081	0.080
13.5	0.074	0.093	0.091	0.089	0.087	0.085	0.084	0.082	0.080	0.079	0.077	0.076	0.073	0.072
14.0	0.068	0.084	0.083	0.081	0.079	0.077	0.076	0.074	0.073	0.071	0.070	0.069	0.067	0.066
14.5	0.062	0.077	0.075	0.074	0.072	0.071	0.069	0.068	0.067	0.065	0.064	0.063	0.061	0.060
15.0	0.057	0.071	0.069	0.068	0.066	0.065	0.064	0.062	0.061	0.060	0.059	0.058	0.056	0.055
15.5	0.052	0.065	0.063	0.062	0.061	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051
16.0	0.048	0.059	0.058	0.057	0.056	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047
16.5	0.045	0.055	0.054	0.053	0.052	0.051	0.050	0.049	0.048	0.047	0.046	0.046	0.044	0.044
17.0	0.042	0.051	0.050	0.049	0.048	0.047	0.046	0.045	0.045	0.044	0.043	0.042	0.041	0.041
17.5	0.039	0.048	0.047	0.046	0.045	0.044	0.043	0.043	0.042	0.041	0.041	0.040	0.039	0.038
18.0	0.037	0.045	0.044	0.043	0.042	0.041	0.041	0.040	0.039	0.038	0.038	0.037	0.036	0.036
18.5	0.034	0.042	0.041	0.040	0.039	0.039	0.038	0.037	0.037	0.036	0.036	0.035	0.034	0.034
19.0	0.032	0.039	0.038	0.037	0.037	0.036	0.035	0.035	0.034	0.034	0.033	0.033	0.032	0.031
19.5	0.030	0.037	0.036	0.035	0.035	0.034	0.033	0.033	0.032	0.032	0.031	0.031	0.030	0.030
20.0	0.029	0.034	0.034	0.033	0.033	0.032	0.032	0.031	0.031	0.030	0.030	0.029	0.028	0.028
20.5	0.027	0.033	0.032	0.031	0.031	0.030	0.030	0.029	0.029	0.029	0.028	0.028	0.027	0.027
21.0	0.026	0.031	0.030	0.030	0.029	0.029	0.028	0.028	0.027	0.027	0.027	0.026	0.026	0.025
21.5	0.024	0.028	0.027	0.027	0.027	0.026	0.026	0.025	0.025	0.025	0.024	0.024	0.023	0.023
22.0	0.019	0.023	0.022	0.022	0.022	0.021	0.021	0.021	0.020	0.020	0.020	0.020	0.019	0.019
22.5	0.015	0.017	0.017	0.017	0.016	0.016	0.016	0.016	0.016	0.015	0.015	0.015	0.015	0.015
23.0	0.013	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.014	0.013	0.013	0.013	0.013	0.013
23.5	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012
24.0	0.011	0.012	0.012	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.010	0.010
24.5	0.009	0.011	0.011	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.009	0.009

Table 13-2: C_t values, Sound Optimized Mode SO13

13.3 Sound Curves, Sound Optimized Mode SO13

Sound Power Level at Hub Height	
Conditions for Sound Power Level:	Measurement standard IEC 61400-11 ed. 3 Maximum turbulence at hub height: 30% Inflow angle (vertical): 0 ±2° Air density: 1.225 kg/m ³
Wind speed at hub height [m/s]	Sound Power Level at Hub Height [dBA] Sound Optimized Mode SO13 (Blades with serrated trailing edge)
3	91.1
4	91.3
5	91.9
6	92.1
7	93.1
8	94.2
9	95.8
10	96.5
11	96.9
12	97.0
13	97.0
14	97.0
15	97.0
16	97.0
17	97.0
18	97.0
19	97.0
20	97.0

Table 13-3: Sound curves, Sound Optimized Mode SO13

Restricted
Document no.: 0067-7060 V00
2017-06-21

General Description

4MW Platform



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See general reservations, notes and disclaimers (including, section 12, p. 37) to this general description.

1 Introduction

The 4MW Platform wind turbine configurations covered by this General Description are listed below with designations according to IEC61400-22.

DIBt 2012 wind classes are also listed where applicable.

Please refer to the Performance Specification for the relevant turbine variant for full wind class definition.

This General Description contains data and descriptions common among the platform variants.

The variant specific performance can be found in the Performance Specifications for the turbine variant and operational mode required.

Turbine Type Class	Turbine Type Operating Mode
V117-4.0/4.2 MW Strong Wind	V117-4.0 MW IEC IB / IEC IIA 50/60 Hz Mode 0
	V117-4.0 MW IEC IB / IEC IIA 50/60 Hz Reactive Power Optimized Mode (QO1)
	V117-4.2 MW IEC S / IEC IIA 50/60 Hz Power Optimized Mode (PO1)
	V117-3.8 MW IEC IB / IEC IIA 50/60 Hz Load Optimized Mode (LO1)
	V117-3.6/3.x MW IEC IB / IEC IIA+ 50/60 Hz Load Optimized Mode (LO2)
V117-4.0/4.2 MW Typhoon	V117-4.0 MW IEC IB-T / IEC IIA-T 50/60 Hz Mode 0
	V117-4.0 MW IEC IB-T / IEC IIA-T 50/60 Hz Reactive Power Optim. Mode (QO1)
	V117-4.2 MW IEC S-T / IEC IIA-T 50/60 Hz Power Optimized Mode (PO1)
	V117-3.8 MW IEC IB-T / IEC IIA-T 50/60 Hz Load Optimized Mode (LO1)
	V117-3.6/3.x MW IEC IB-T / IEC IIA+-T 50/60 Hz Load Optimized Mode (LO2)
V136-4.0/4.2 MW	V136-4.0 MW IEC IIB / IEC S 50/60 Hz Mode 0
	V136-4.0 MW IEC IIB / IEC S 50/60 Hz Reactive Power Optim. Mode (QO1)
	V136-4.2 MW IEC S 50/60 Hz Power Optimized Mode (PO1)
	V136-3.8 MW IEC IIB / IEC S 50/60 Hz Load Optimized Mode (LO1)
	V136-3.6 MW IEC IIB / S 50/60 Hz Load Optimized Mode (LO2)
	V136-4.0 MW DIBt S 50 Hz Mode 0
	V136-4.0 MW DIBt S 50 Hz Reactive Power Optimized Mode (QO1)
	V136-4.2 MW DIBt S 50 Hz Power Optimized Mode (PO1)
	V136-3.8 MW DIBt S 50 Hz Load Optimized Mode (LO1)
	V136-3.6 MW DIBt S 50 Hz Load Optimized Mode (LO2)
V150-4.0/4.2 MW	V150-4.0 MW IEC IIIB / IEC S 50/60 Hz Mode 0
	V150-4.0 MW IEC IIIB / IEC S 50/60 Hz Reactive Power Optim. Mode (QO1)
	V150-4.2 MW IEC S 50/60 Hz Power Optimized Mode (PO1)
	V150-3.8 MW IEC IIIB / IEC S 50/60 Hz Load Optimized Mode (LO1)
	V150-3.6 MW IEC IIIB / S 50/60 Hz Load Optimized Mode (LO2)
	V150-4.0 MW DIBt S 50 Hz Mode 0

Turbine Type Class	Turbine Type Operating Mode
V150-4.0/4.2 MW (cont'd)	V150-4.0 MW DIBt S 50 Hz Reactive Power Optimized Mode (QO1)
	V150-4.2 MW DIBt S 50 Hz Power Optimized Mode (PO1)
	V150-3.8 MW DIBt S 50 Hz Load Optimized Mode (LO1)
	V150-3.6 MW DIBt S 50 Hz Load Optimized Mode (LO2)

Table 1-1: 4MW Platform turbine configurations covered.

2 General Description

Vestas 4MW Platform comprises a family of wind turbines sharing a common design basis.

The 4MW Platform family of wind turbines includes V105-3.45/3.6 MW, V112-3.45/3.6 MW, V117-3.45/3.6 MW, V126-3.45 MW LTq, V126-3.45/3.6 MW HTq, V136-3.45/3.6 MW, V117-4.0/4.2 MW Strong Wind, V117-4.0/4.2 MW Typhoon, V136-4.0/4.2 MW and V150-4.0/4.2 MW.

For V105-3.45/3.6 MW, V112-3.45/3.6 MW, V117-3.45/3.6 MW, V126-3.45 MW LTq, V126-3.45/3.6 MW HTq and V136-3.45/3.6 MW, please refer to General Description 0053-3707.

This General Description only applies to V117-4.0/4.2 MW Strong Wind, V117-4.0/4.2 MW Typhoon, V136-4.0/4.2 MW and V150-4.0/4.2 MW.

These turbines are pitch regulated upwind turbines with active yaw and a three-blade rotor.

The turbines covered in this General Description are equipped with rotor with diameters residing in the range 117 m to 150 m and a rated output power of 4.0 MW.

A 4.0 MW Reactive Power Optimized Mode (QO1) is available for all variants.

A 4.2 MW Power Optimized Mode (PO1) is available for all variants.

Also, a 3.8 MW Load Optimized Mode (LO1) and a 3.6 MW Load Optimized Mode (LO2) is available for all variants. However, for V117, the LO2 power rating for the high turbulence intensity IEC 2A+ design climate is not yet fixed.

The wind turbine family utilises the OptiTip® concept and a power system based on an induction generator and full-scale converter. With these features, the wind turbine is able to operate the rotor at variable speed and thereby maintain the power output at or near rated power even in high wind speed. At low wind speed, the OptiTip® concept and the power system work together to maximise the power output by operating at the optimal rotor speed and pitch angle.

Operating the wind turbine in 4.0 MW Reactive Power Optimized Mode (QO1) is achieved by applying an extended ambient temperature derate strategy compared with 4.0 MW Mode 0 operation.

Operating the wind turbine in 4.2 MW Power Optimized Mode (PO1) is achieved by applying an extended ambient temperature derate strategy and reduced reactive power capability compared with 4.0 MW Mode 0 operation.

3 Mechanical Design

3.1 Rotor

The wind turbine is equipped with a rotor consisting of three blades and a hub. The blades are controlled by the microprocessor pitch control system OptiTip®. Based on the prevailing wind conditions, the blades are continuously positioned to optimise the pitch angle.

Rotor	V117	V136	V150
Diameter	117 m	136 m	150 m
Swept Area	10751 m ²	14527 m ²	17671 m ²
Speed, Dynamic Operation Range	6.7-17.5	5.6-14.0	4.9-12.0
Rotational Direction	Clockwise (front view)		
Orientation	Upwind		
Tilt	6°		
Hub Coning	4°	4°	5.5°
No. of Blades	3		
Aerodynamic Brakes	Full feathering		

Table 3-1: Rotor data

3.2 Blades

The blades are made of carbon and fibreglass and consist of two airfoil shells bonded to a supporting beam or with embedded structure.

Blades	V117	V136	V150
Type Description	Airfoil shells bonded to supporting beam	Prepreg or infused structural airfoil shell	Prepreg or infused structural airfoil shell
Blade Length	57.15 m	66.66 m	73.66 m
Material	Fibreglass reinforced epoxy, carbon fibres and Solid Metal Tip (SMT)		
Blade Connection	Steel roots inserted		
Airfoils	High-lift profile		
Maximum Chord	4.0 m	4.1 m	4.2 m
Chord at 90% blade radius	1.1 m	1.2 m	1.4 m

Table 3-2: Blades data

3.3 Blade Bearing

The blade bearings are double-row four-point contact ball bearings.

Blade Bearing	
Lubrication	Grease

Table 3-3: Blade bearing data

3.4 Pitch System

The turbine is equipped with a pitch system for each blade and a distributor block, all located in the hub. Each pitch system is connected to the distributor block with flexible hoses. The distributor block is connected to the pipes of the hydraulic rotating transfer unit in the hub by means of three hoses (pressure line, return line and drain line).

Each pitch system consists of a hydraulic cylinder mounted to the hub and a piston rod mounted to the blade bearing via a torque arm shaft. Valves facilitating operation of the pitch cylinder are installed on a pitch block bolted directly onto the cylinder.

Pitch System	
Type	Hydraulic
Number	1 per blade
Range	-10° to 95°

Table 3-4: Pitch system data

Hydraulic System	
Main Pump	Two redundant internal-gear oil pumps
Pressure	260 bar
Filtration	3 µm (absolute)

Table 3-5: Hydraulic system data.

3.5 Hub

The hub supports the three blades and transfers the reaction loads to the main bearing and the torque to the gearbox. The hub structure also supports blade bearings and pitch cylinders.

Hub	
Type	Cast ball shell hub
Material	Cast iron

Table 3-6: Hub data

3.6 Main Shaft

The main shaft transfers the reaction forces to the main bearing and the torque to the gearbox.

Main Shaft	
Type Description	Hollow shaft
Material	Cast iron or forged steel

Table 3-7: Main shaft data

3.7 Main Bearing Housing

The main bearing housing covers the main bearing and is the first connection point for the drive train system to the bedplate.

Main Bearing Housing	
Material	Cast iron

Table 3-8: Main bearing housing data

3.8 Main Bearing

The main bearing carries all thrust loads.

Main Bearing	
Type	Double-row spherical roller bearing
Lubrication	Automatic grease lubrication

Table 3-9: Main bearing data

3.9 Gearbox

The main gear converts the low-speed rotation of the rotor to high-speed generator rotation.

The disc brake is mounted on the high-speed shaft. The gearbox lubrication system is a pressure-fed system.

Gearbox	
Type	Planetary stages + one helical stage
Gear House Material	Cast
Lubrication System	Pressure oil lubrication
Backup Lubrication System	Oil sump filled from external gravity tank
Total Gear Oil Volume	1000-1500
Oil Cleanliness Codes	ISO 4406-/15/12
Shaft Seals	Labyrinth

Table 3-10: Gearbox data

3.10 Generator Bearings

The bearings are grease lubricated and grease is supplied continuously from an automatic lubrication unit.

3.11 High-Speed Shaft Coupling

The coupling transmits the torque of the gearbox high-speed output shaft to the generator input shaft.

The coupling consists of two 4-link laminate packages and a fibreglass intermediate tube with two metal flanges.

The coupling is fitted to two-armed hubs on the brake disc and the generator hub.

3.12 Yaw System

The yaw system is an active system based on a robust pre-tensioned plain yaw-bearing concept with PETP as friction material.

Yaw System	
Type	Plain bearing system
Material	Forged yaw ring heat-treated. Plain bearings PETP
Yawing Speed (50 Hz)	0.45°/sec.
Yawing Speed (60 Hz)	0.55°/sec.

Table 3-11: Yaw system data

Yaw Gear	
Type	Multiple stages geared
Ratio Total	944:1
Rotational Speed at Full Load	1.4 rpm at output shaft

Table 3-12: Yaw gear data

3.13 Crane

The nacelle houses the internal safe working load (SWL) service crane. The crane is a single system hoist.

Crane	
Lifting Capacity	Maximum 800 kg

Table 3-13: Crane data

3.14 Towers

Tubular towers with flange connections, certified according to relevant type approvals, are available in different standard heights. The towers are designed with the majority of internal welded connections replaced by magnet supports to create a predominantly smooth-walled tower.

Magnets provide load support in a horizontal direction and internals, such as platforms, ladders, etc., are supported vertically (that is, in the gravitational direction) by a mechanical connection. The smooth tower design reduces the required steel thickness, rendering the tower lighter compared to one with all internals welded to the tower shells.

Available hub heights are listed in the Performance Specification for each turbine variant. Designated hub heights include a distance from the foundation section to the ground level of approximately 0.2 m depending on the thickness of the bottom flange and a distance from tower top flange to centre of the hub of 2.2 m.

Towers	
Type	Cylindrical/conical tubular

Table 3-14: Tower structure data

3.15 Nacelle Bedplate and Cover

The nacelle cover is made of fibreglass. Hatches are positioned in the floor for lowering or hoisting equipment to the nacelle and evacuation of personnel. The roof section is equipped with wind sensors and skylights.

The skylights can be opened from inside the nacelle to access the roof and from outside to access the nacelle. Access from the tower to the nacelle is through the yaw system.

The nacelle bedplate is in two parts and consists of a cast iron front part and a girder structure rear part. The front of the nacelle bedplate is the foundation for the drive train and transmits forces from the rotor to the tower through the yaw system. The bottom surface is machined and connected to the yaw bearing and the yaw gears are bolted to the front nacelle bedplate.

The crane girders 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, the cooling system and transformer. The nacelle cover is installed on the nacelle bedplate.

Type Description	Material
Nacelle Cover	GRP
Bedplate Front	Cast iron
Bedplate Rear	Girder structure

Table 3-15: Nacelle bedplate and cover data

3.16 Thermal Conditioning System

The thermal conditioning system consists of a few robust components:

- The Vestas CoolerTop[®] located on top of the rear end of the nacelle. The CoolerTop[®] is a free flow cooler, thus ensuring that there are no electrical components in the thermal conditioning system located outside the nacelle.
- The CoolerTop[®] comes as standard in a “naked” form, with no side cover panels. Side cover panels are available as an option.
- The Liquid Cooling System, which serves the gearbox, hydraulic systems, generator and converter is driven by an electrical pumping system.
- The transformer forced air cooling comprised of an electrical fan.

3.16.1 Generator and Converter Cooling

The generator and converter cooling systems operate in parallel. A dynamic flow valve mounted in the generator cooling circuit divides the cooling liquid flow. The cooling liquid removes heat from the generator and converter unit using a free-air flow radiator placed on the top of the nacelle. In addition to the generator, converter unit and radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

3.16.2 Gearbox and Hydraulic Cooling

The gearbox and hydraulic cooling systems are coupled in parallel. A dynamic flow valve mounted in the gearbox cooling circuit divides the cooling flow. The cooling liquid removes heat from the gearbox and the hydraulic power unit through heat exchangers and a free-air flow radiator placed on the top of the nacelle. In addition to the heat exchangers and the radiator, the circulation system includes an electrical pump and a three-way thermostatic valve.

3.16.3 Transformer Cooling

The transformer is equipped with forced-air cooling. The ventilator system consists of a central fan, located below the converter and an air duct leading the air to locations beneath and between the high voltage and low voltage windings of the transformer.

3.16.4 Nacelle Cooling

Hot air generated by mechanical and electrical equipment is dissipated from the nacelle by a fan system located in the nacelle.

3.16.5 Optional Air Intake Hatches

Specific air intakes in the nacelle can optionally be fitted with hatches which can be operated as a part of the thermal control strategy. In case of lost grid to the turbine, the hatches will automatically be closed.

4 Electrical Design

4.1 Generator

The generator is a three-phase asynchronous induction generator with cage rotor that is connected to the grid through a full-scale converter. The generator housing allows the circulation of cooling air within the stator and rotor. The air-to-water heat exchange occurs in an external heat exchanger.

Generator	
Type	Asynchronous with cage rotor
Rated Power [P_N]	4230 / 4430 kW
Frequency [f_N]	0-100 Hz
Voltage, Stator [U_{NS}]	3 x 800 V (at rated speed)
Number of Poles	4/6
Winding Type	Form with VPI (Vacuum Pressurized Impregnation)

Generator	
Winding Connection	Star or Delta
Rated rpm	1450-1550 rpm
Overspeed Limit Acc. to IEC (2 minutes)	2400 rpm
Generator Bearing	Hybrid/ceramic
Temperature Sensors, Stator	3 PT100 sensors placed at hot spots and 3 as back-up
Temperature Sensors, Bearings	1 per bearing
Insulation Class	F or H
Enclosure	IP54

Table 4-1: Generator data

4.2 Converter

The converter is a full-scale converter system controlling both the generator and the power quality delivered to the grid. The converter consists of 3 machine-side converter units and 3 line-side converter units operating in parallel with a common controller.

The converter controls conversion of variable frequency AC power from the generator into fixed frequency AC power with desired active and reactive power levels (and other grid connection parameters) suitable for the grid.

The converter is located in the nacelle and has a grid side voltage rating of 720 V. The generator side voltage rating is up to 750 V dependent on generator speed.

Converter	
Rated Apparent Power [S_N]	5100 kVA
Rated Grid Voltage	3 x 720 V
Rated Generator Voltage	3 x 800 V
Rated Grid Current	4100 A ($\leq 30^\circ\text{C}$ ambient) / 4150 ($\leq 20^\circ\text{C}$ ambient)
Rated Generator Current	3600 A ($\leq 30^\circ\text{C}$ ambient) / 3650 ($\leq 20^\circ\text{C}$ ambient)
Enclosure	IP54

Table 4-2: Converter data

4.3 HV Transformer

The step-up HV transformer is located in a separate locked room in the back of the nacelle.

The transformer is a three-phase, two-winding, dry-type transformer that is self-extinguishing. The windings are delta-connected on the high-voltage side unless otherwise specified.

The transformer comes in different versions depending on the market where it is intended to be installed.

- For 50 and 60 Hz regions the transformer is as default designed according to IEC standards, but also complying to European Ecodesign regulation No 548/2014 set by the European Commission. Refer to Table 4-3.

4.3.1 Ecodesign - IEC 50 Hz/60 Hz version

Transformer	
Type description	Ecodesign dry-type cast resin transformer.
Basic layout	3 phase, 2 winding transformer.
Applied standards	IEC 60076-11, IEC 60076-16, IEC 61936-1, Commission Regulation No 548/2014.
Cooling method	AF
Rated power	4700 kVA
Rated voltage, turbine side	
U_m 1.1kV	0.720 kV
Rated voltage, grid side	
U_m 24.0kV	19.1-22.0 kV
U_m 36.0kV	22.1-33.0 kV
U_m 40.5kV	33.1-36.0 kV
Insulation level AC / LI / LIC	
U_m 1.1kV	3 ¹ / - / - kV
U_m 24.0kV	50 ¹ / 125 / 125 kV
U_m 36.0kV	70 ¹ / 170 / 170 kV
U_m 40.5kV	80 ¹ / 170 / 170 kV
Off-circuit tap changer	±2 x 2.5 %
Frequency	50 Hz / 60 Hz
Vector group	Dyn5
Peak Efficiency Index (PEI) ²	Ecodesign requirement
U_m 24.0kV	~ 99.348
U_m 36.0kV	~ 99.348
U_m 40.5kV	~ 99.158
No-load loss ²	
U_m 24.0kV	~ 8.2 kW
U_m 36.0kV	~ 8.2 kW
U_m 40.5kV	~ 9.8 kW
Load loss @ power consumption HV, 120°C	@4700kVA²
U_m 24.0kV	~ 29.0 kW
U_m 36.0kV	~ 29.0 kW
U_m 40.5kV	~ 37.45 kW
No-load reactive power ³	~20 kVAr
Full load reactive power ³	~390 kVAr
No-load current ³	~0.5 %
Positive sequence short-circuit impedance @ rated power, 120°C ⁴	9.0 %
Positive sequence short-circuit	~0.8 %

Transformer	
resistance@ rated power, 120°C ³	
Zero sequence short-circuit impedance@ rated power, 120°C ³	~8.2 %
Zero sequence short-circuit resistance@ rated power, 120°C ³	~0.7 %
Inrush peak current ³	
	Dyn5 5-8 x I_n
	YNyn0 8-12 x I_n
Half crest time ³	~ 0.6 s
Sound power level	≤ 80 dB(A)
Average temperature rise at max altitude	≤90 K
Max altitude ⁵	2000 m
Insulation class	155 (F)
Environmental class	E2
Climatic class	C2
Fire behaviour class	F1
Corrosion class	C4
Weight	≤10500 kg
Temperature monitoring	PT100 sensors in LV windings and core
Overvoltage protection	Surge arresters on HV terminals
Temporary earthing	3 x Ø20 mm earthing ball points

Table 4-3: Transformer data for Ecodesign IEC 50 Hz/60 Hz version.

- NOTE**
- ¹ @1000m. According to IEC 60076-11, AC test voltage is altitude dependent.
 - ² For Ecodesign transformers, PEI is the legal requirement and is calculated according to the Commission Regulation based on rated power, no-load and load losses. Losses are maximum values and will not simultaneously occur in a specific design as this will be non-compliant with the PEI requirement. All values are preliminary.
 - ³ Based on an average of calculated values across voltages and manufacturers. All values are preliminary.
 - ⁴ Subjected to standard IEC tolerances. All values are preliminary.
 - ⁵ Transformer max altitude may be adjusted to match turbine location. All values are preliminary.

4.4 HV Cables

The high-voltage cable runs from the transformer in the nacelle down the tower to the HV switchgear located at the bottom of the tower. The high-voltage cable is a four-core, rubber-insulated, halogen-free, high-voltage cable.

HV Cables	
High-Voltage Cable Insulation Compound	Improved ethylene-propylene (EP) based material-EPR or high modulus or hard grade ethylene-propylene rubber-HEPR
Pre-terminated	HV termination in transformer end. T-Connector Type-C in switchgear end.
Maximum Voltage	24 kV for 19.1-22.0 kV rated voltage 42 kV for 22.1-36.0 kV rated voltage
Conductor Cross Sections	3x70 / 70 mm ² (Single PE core) 3x70 + 3x70/3 mm ² (Split PE core)

Table 4-4: HV cables data

4.5 HV Switchgear

A gas insulated switchgear is installed in the bottom of the tower as an integrated part of the turbine. Its controls are integrated with the turbine safety system, which monitors the condition of the switchgear and high voltage safety related devices in the turbine. This system is named 'Ready to Protect' and ensures all protection devices are operational, whenever high voltage components in the turbine are energised. To ensure that the switchgear is always ready to trip, it is equipped with redundant trip circuits consisting of an active trip coil and an undervoltage trip coil.

In case of grid outage the circuit breaker will disconnect the turbine from the grid after an adjustable time.

When grid returns, all relevant protection devices will automatically be powered up via UPS.

When all the protection devices are operational, the circuit breaker will re-close after an adjustable time. The re-close functionality can furthermore be used to implement a sequential energization of a wind park, in order to avoid simultaneous inrush currents from all turbines once grid returns after an outage.

In case the circuit breaker has tripped due to a fault detection, the circuit breaker will be blocked for re-connection until a manual reset is performed.

In order to avoid unauthorized access to the transformer room during live condition, the earthing switch of the circuit breaker, contains a trapped-key interlock system with its counterpart installed on the access door to the transformer room.

The switchgear is available in three variants with increasing features, see Table 4-5. Beside the increase in features, the switchgear can be configured depending on the number of grid cables planned to enter the individual turbine. The design of the switchgear solution is optimized such grid cables can be connected to the switchgear even before the tower is installed and still maintain its protection toward weather conditions and internal condensation due to a gas tight packing.

The switchgear is available in an IEC version and in an IEEE version. The IEEE version is however only available in the highest voltage class. The electrical parameters of the switchgear are seen in Table 4-6 for the IEC version and in Table 4-7 for the IEEE version.

HV Switchgear			
Variant	Basic	Streamline	Standard
IEC standards	○	⊙	⊙
IEEE standards	⊙	○	⊙
Vacuum circuit breaker panel	⊙	⊙	⊙
Overcurrent, short-circuit and earth fault protection	⊙	⊙	⊙
Disconnecter / earthing switch in circuit breaker panel	⊙	⊙	⊙
Voltage Presence Indicator System for circuit breaker	⊙	⊙	⊙
Voltage Presence Indicator System for grid cables	⊙	⊙	⊙
Double grid cable connection	⊙	⊙	⊙
Triple grid cable connection	⊙	○	○
Preconfigured relay settings	⊙	⊙	⊙
Turbine safety system integration	⊙	⊙	⊙
Redundant trip coil circuits	⊙	⊙	⊙
Trip coil supervision	⊙	⊙	⊙
Pendant remote control from outside of tower	⊙	⊙	⊙
Sequential energization	⊙	⊙	⊙
Reclose blocking function	⊙	⊙	⊙
Heating elements	⊙	⊙	⊙
Trapped-key interlock system for circuit breaker panel	⊙	⊙	⊙
Motor operation of circuit breaker	⊙	⊙	⊙
Cable panel for grid cables (configurable)	○	⊙	⊙
Switch disconnector panels for grid cables – max three panels (configurable)	○	⊙	⊙
Earthing switch for grid cables	○	⊙	⊙
Internal arc classification	○	⊙	⊙
Supervision on MCB's	○	⊙	⊙
Motor operation of switch disconnector	○	○	⊙
SCADA operation and feedback of circuit breaker	○	○	⊙
SCADA operation and feedback of switch disconnector	○	○	⊙

Table 4-5: HV switchgear variants and features

4.5.1 IEC 50/60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEC 62271-103 IEC 62271-1, 62271-100, 62271-102, 62271-200, IEC 60694
Insulation medium	SF ₆
Rated voltage	
	U_r 24.0kV 19.1-22.0 kV
	U_r 36.0kV 22.1-33.0 kV
	U_r 40.5kV 33.1-36.0 kV
Rated insulation level AC // LI Common value / across isolation distance	
	U_r 24.0kV 50 / 60 // 125 / 145 kV
	U_r 36.0kV 70 / 80 // 170 / 195 kV
	U_r 40.5kV 85 / 90 // 185 / 215 kV
Rated frequency	50 Hz / 60 Hz
Rated normal current	630 A
Rated Short-time withstand current	
	U_r 24.0kV 20 kA
	U_r 36.0kV 25 kA
	U_r 40.5kV 25 kA
Rated peak withstand current 50 / 60 Hz	
	U_r 24.0kV 50 / 52 kA
	U_r 36.0kV 62.5 / 65 kA
	U_r 40.5kV 62.5 / 65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	
	U_r 24.0kV IAC A FLR 20 kA, 1 s
	U_r 36.0kV IAC A FLR 25 kA, 1 s
	U_r 40.5kV IAC A FLR 25 kA, 1 s
Connection interface	Outside cone plug-in bushings, IEC interface C1.
Loss of service continuity category	LSC2
Ingress protection	
	Gas tank IP 65
	Enclosure IP 2X
	LV cabinet IP 3X
Corrosion class	C3

Table 4-6: HV switchgear data for IEC version

4.5.2 IEEE 60Hz version

HV Switchgear	
Type description	Gas Insulated Switchgear
Applied standards	IEEE 37.20.3, IEEE C37.20.4, IEC 62271-200, ISO 12944.
Insulation medium	SF ₆
Rated voltage	
	U_r 38.0kV 22.1-36.0 kV

HV Switchgear	
Rated insulation level AC / LI	70 / 150 kV
Rated frequency	60 Hz
Rated normal current	600 A
Rated Short-time withstand current	25 kA
Rated peak withstand current	65 kA
Rated duration of short-circuit	1 s
Internal arc classification (option)	IAC A FLR 25 kA, 1 s
Connection interface grid cables	Outside cone plug-in bushings, IEEE 386 interface type deadbreak, 600A.
Ingress protection	
	Gas tank NEMA 4X / IP 65
	Enclosure NEMA 2 / IP 2X
	LV cabinet NEMA 2 / IP 3X
Corrosion class	C3

Table 4-7: HV switchgear data for IEEE version

4.6 AUX System

The AUX system is supplied from a separate 650/400/230 V transformer located in the nacelle inside the converter cabinet. All motors, pumps, fans and heaters are supplied from this system.

230 V consumers are generally supplied from a 400/230 V transformer located in the tower base. Internal heating and ventilation of cabinets as well as specific option 230 V consumers are supplied from the auxiliary transformer in the converter cabinet.

Power Sockets	
Single Phase (Nacelle)	230 V (16 A) (standard) 110 V (16 A) (option) 2 x 55 V (16 A) (option)
Single Phase (Tower Platforms)	230 V (10 A) (standard) 110 V (16 A) (option) 2 x 55 V (16 A) (option)
Three Phase (Nacelle and Tower Base)	3 x 400 V (16 A)

Table 4-8: AUX system data

4.7 Wind Sensors

The turbine is either equipped with two ultrasonic wind sensors or optional one ultrasonic wind sensor and one mechanical wind vane and anemometer. The sensors have built-in heaters to minimise interference from ice and snow. The wind sensors are redundant, and the turbine is able to operate with one sensor only.

4.8 Vestas Multi Processor (VMP) Controller

The turbine is controlled and monitored by the VMP8000 control system.

VMP8000 is a multiprocessor control system comprised of main controller, distributed control nodes, distributed IO nodes and ethernet switches and other network equipment. The main controller is placed in the tower bottom of the turbine. It runs the control algorithms of the turbine, as well as all IO communication.

The communications network is a time triggered Ethernet network (TTEthernet).

The VMP8000 control system serves the following main functions:

- Monitoring and supervision of overall operation.
- Synchronizing of the generator to the grid during connection sequence.
- Operating the wind turbine during various fault situations.
- Automatic yawing of the nacelle.
- OptiTip® - blade pitch control.
- Reactive power control and variable speed operation.
- Noise emission control.
- Monitoring of ambient conditions.
- Monitoring of the grid.
- Monitoring of the smoke detection system.

4.9 Uninterruptible Power Supply (UPS)

During grid outage, an UPS system will ensure power supply for specific components.

The UPS system is built by 3 subsystems:

1. 230V AC UPS for all power backup to nacelle and hub control systems
2. 24V DC UPS for power backup to tower base control systems and optional SCADA Power Plant Controller.
3. 230V AC UPS for power backup to internal lights in tower and nacelle. Internal light in the hub is fed from built-in batteries in the light armature.

UPS		
Backup Time	Standard	Optional
Control System* (230V AC and 24V DC UPS)	15 min	Up to 400 min**
Internal Lights (230V AC UPS)	30 min	60 min***
Optional SCADA Power Plant Controller (24V DC UPS)	N/A	48 hours****

Table 4-9: UPS data

**The control system includes: the turbine controller (VMP8000), HV switchgear functions, and remote control system.*

***Requires upgrade of the 230V UPS for control system with extra batteries.*

****Requires upgrade of the 230V UPS for internal light with extra batteries.*

*****Requires upgrade of the 24V DC UPS with extra batteries.*

NOTE For alternative backup times, consult Vestas.

5 Turbine Protection Systems

5.1 Braking Concept

The main brake on the turbine is aerodynamic. Stopping the turbine is done by full feathering the three blades (individually turning each blade). Each blade has a hydraulic accumulator to supply power for turning the blade.

In addition, there is a mechanical disc brake on the high-speed shaft of the gearbox with a dedicated hydraulic system. The mechanical brake is only used as a parking brake and when activating the emergency stop buttons.

5.2 Short Circuit Protections

Breakers	Breaker for Aux. Power.	Breaker 1 for Converter Modules	Breaker 2 for Converter Modules
Breaking Capacity Icu, Ics	TBD	TBD	TBD
Making Capacity Icm	TBD	TBD	TBD

Table 5-1: Short circuit protection data

5.3 Overspeed Protection

The generator rpm and the main shaft rpm are registered by inductive sensors and calculated by the wind turbine controller to protect against overspeed and rotating errors.

The safety-related partition of the VMP8000 control system monitors the rotor rpm. In case of an overspeed situation, the safety-related partition of the VMP8000 control system activates the emergency feathered position (full feathering) of the three blades independently of the non-safety related partition of VMP8000 control system.

Overspeed Protection	
Sensors Type	Inductive
Trip Level (variant dependent)	12.0-17.5 rpm / 2000 (generator rpm)

Table 5-2: Overspeed protection data

5.4 Arc Detection

The turbine is equipped with an Arc Detection system including multiple optical arc detection sensors placed in the HV transformer compartment and the converter cabinet. The Arc Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if an arc is detected.

5.5 Smoke Detection

The turbine is equipped with a Smoke Detection system including multiple smoke detection sensors placed in the nacelle (above the disc brake), in the transformer compartment, in main electrical cabinets in the nacelle and above the HV switchgear in the tower base. The Smoke Detection system is connected to the turbine safety system ensuring immediate opening of the HV switchgear if smoke is detected.

5.6 Lightning Protection of Blades, Nacelle, Hub and Tower

The Lightning Protection System (LPS) helps protect the wind turbine against the physical damage caused by lightning strikes. The LPS consists of five main parts:

- Lightning receptors. All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
- Down conducting system (a system to conduct the lightning current down through the wind turbine to help avoid or minimise damage to the LPS itself or other parts of the wind turbine).
- Protection against overvoltage and overcurrent.
- Shielding against magnetic and electrical fields.
- Earthing system.

Lightning Protection Design Parameters			Protection Level I
Current Peak Value	i_{max}	[kA]	200
Impulse Charge	$Q_{impulse}$	[C]	100
Long Duration Charge	Q_{long}	[C]	200
Total Charge	Q_{total}	[C]	300
Specific Energy	W/R	[MJ/Ω]	10
Average Steepness	di/dt	[kA/μs]	200

Table 5-3: Lightning protection design parameters

NOTE The Lightning Protection System is designed according to IEC standards (see section 8 Design Codes, p. 28).

5.7 EMC

The turbine and related equipment fulfils the EU Electromagnetic Compatibility (EMC) legislation:

- DIRECTIVE 2014/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.

5.8 Earthing

The Vestas Earthing System consists of a number of individual earthing electrodes interconnected as one joint earthing system.

The Vestas Earthing System includes the TN-system and the Lightning Protection System for each wind turbine. It works as an earthing system for the medium voltage distribution system within the wind farm.

The Vestas Earthing System is adapted for the different types of turbine foundations. A separate set of documents describe the earthing system in detail, depending on the type of foundation.

In terms of lightning protection of the wind turbine, Vestas has no separate requirements for a certain minimum resistance to remote earth (measured in ohms) for this system. The earthing for the lightning protection system is based on the design and construction of the Vestas Earthing System.

A primary part of the Vestas Earthing System is the main earth bonding bar placed where all cables enter the wind turbine. All earthing electrodes are connected to this main earth bonding bar. Additionally, equipotential connections are made to all cables entering or leaving the wind turbine.

Requirements in the Vestas Earthing System specifications and work descriptions are minimum requirements from Vestas and IEC. Local and national requirements, as well as project requirements, may require additional measures.

5.9 Corrosion Protection

Classification of corrosion protection is according to ISO 12944-2.

Corrosion Protection	External Areas	Internal Areas
Nacelle	C5-M	C3
Hub	C5-M	C3
Tower	C5-I	C3

Table 5-4: Corrosion protection data for nacelle, hub, and tower

6 Safety

The safety specifications in this section provide limited general information about the safety features of the turbine and are not a substitute for Buyer and its agents taking all appropriate safety precautions, including but not limited to (a) complying with all applicable safety, operation, maintenance, and service agreements, instructions, and requirements, (b) complying with all safety-related laws, regulations, and ordinances, and (c) conducting all appropriate safety training and education.

6.1 Access

Access to the turbine from the outside is through a door located at the entrance platform approximately 3 meter above ground level. The door is equipped with a lock. Access to the top platform in the tower is by a ladder or service lift. Access to the nacelle from the top platform is by ladder. Access to the transformer room in the nacelle is controlled with a lock. Unauthorised access to electrical switchboards and power panels in the turbine is prohibited according to IEC 60204-1 2006.

6.2 Escape

In addition to the normal access routes, alternative escape routes from the nacelle are through the crane hatch, from the spinner by opening the nose cone, or from the roof of the nacelle. Rescue equipment is placed in the nacelle.

The hatch in the roof can be opened from both the inside and outside. Escape from the service lift is by ladder.

An emergency response plan, placed in the turbine, describes evacuation and escape routes.

6.3 Rooms/Working Areas

The tower and nacelle are equipped with power sockets for electrical tools for service and maintenance of the turbine.

6.4 Floors, Platforms, Standing, and Working Places

All floors have anti-slip surfaces.

There is one floor per tower section.

Rest platforms are provided at intervals of 9 metres along the tower ladder between platforms.

Foot supports are placed in the turbine for maintenance and service purposes.

6.5 Service Lift

The turbine is delivered with a service lift installed as an option.

6.6 Climbing Facilities

A ladder with a fall arrest system (rigid rail) is installed through the tower.

There are anchor points in the tower, nacelle and hub, and on the roof for attaching fall arrest equipment (full-body harness). Over the crane hatch there is an anchor point for the emergency descent equipment. Anchor points are coloured yellow and are calculated and tested to 22.2 kN.

6.7 Moving Parts, Guards, and Blocking Devices

All moving parts in the nacelle are shielded.

The turbine is equipped with a rotor lock to block the rotor and drive train.

Blocking the pitch of the cylinder can be done with mechanical tools in the hub.

6.8 Lights

The turbine is equipped with lights in the tower, nacelle and hub.

There is emergency light in case of the loss of electrical power.

6.9 Emergency Stop

There are emergency stop buttons in the nacelle, hub and bottom of the tower.

6.10 Power Disconnection

The turbine is equipped with breakers to allow for disconnection from all power sources during inspection or maintenance. The switches are marked with signs and are located in the nacelle and bottom of the tower.

6.11 Fire Protection/First Aid

A handheld 5-6 kg CO₂ fire extinguisher, first aid kit and fire blanket are required to be located in the nacelle during service and maintenance.

- A handheld 5-6 kg CO₂ fire extinguisher is required only during service and maintenance activities, unless a permanently mounted fire extinguisher located in the nacelle is mandatorily required by authorities.
- First aid kits are required only during service and maintenance activities.
- Fire blankets are required only during non-electrical hot work activities.

6.12 Warning Signs

Warning signs placed inside or on the turbine must be reviewed before operating or servicing the turbine.

6.13 Manuals and Warnings

The Vestas Corporate OH&S Manual and manuals for operation, maintenance and service of the turbine provide additional safety rules and information for operating, servicing or maintaining the turbine.

7 Environment

7.1 Chemicals

Chemicals used in the turbine are evaluated according to the Vestas Wind Systems A/S Environmental System certified according to ISO 14001:2004. The following chemicals are used in the turbine:

- Anti-freeze to help prevent the cooling system from freezing.
- Gear oil for lubricating the gearbox.
- Hydraulic oil to pitch the blades and operate the brake.
- Grease to lubricate bearings.
- Various cleaning agents and chemicals for maintenance of the turbine.

8 Design Codes

8.1 Design Codes – Structural Design

The turbine design has been developed and tested with regard to, but not limited to, the following main standards:

Design Codes	
Nacelle and Hub	IEC 61400-1 Edition 3 EN 50308
Tower	IEC 61400-1 Edition 3 Eurocode 3
Blades	DNV-OS-J102 IEC 1024-1 IEC 60721-2-4 IEC 61400 (Part 1, 12 and 23) IEC WT 01 IEC DEFU R25 ISO 2813 DS/EN ISO 12944-2
Gearbox	ISO 81400-4
Generator	IEC 60034
Transformer	IEC 60076-11, IEC 60076-16, CENELEC HD637 S1
Lightning Protection	IEC 62305-1: 2006 IEC 62305-3: 2006 IEC 62305-4: 2006 IEC 61400-24:2010
Rotating Electrical Machines	IEC 34
Safety of Machinery, Safety-related Parts of Control Systems	IEC 13849-1
Safety of Machinery – Electrical Equipment of Machines	IEC 60204-1

Table 8-1: Design codes

9 Colours

9.1 Nacelle Colour

Colour of Vestas Nacelles	
Standard Nacelle Colour	RAL 7035 (light grey)
Standard Logo	Vestas

Table 9-1: Colour, nacelle

9.2 Tower Colour

Colour of Vestas Tower Section		
	External:	Internal:
Standard Tower Colour	RAL 7035 (light grey)	RAL 9001 (cream white)

Table 9-2: Colour, tower

9.3 Blade Colour

Blade Colour	
Standard Blade Colour	RAL 7035 (light grey). All lightning receptor surfaces on the blades are unpainted, excluding the Solid Metal Tips (SMT).
Tip-End Colour Variants	RAL 2009 (traffic orange), RAL 3020 (traffic red)
Gloss	< 30% DS/EN ISO 2813

Table 9-3: Colour, blades

10 Operational Envelope and Performance Guidelines

Actual climate and site conditions have many variables and should be considered in evaluating actual turbine performance. The design and operating parameters set forth in this section do not constitute warranties, guarantees, or representations as to turbine performance at actual sites.

10.1 Climate and Site Conditions

Values refer to hub height:

Extreme Design Parameters	
Wind Climate	All
Ambient Temperature Interval (Standard Temperature Turbine)	-40° to +50°C

Table 10-1: Extreme design parameters

10.2 Operational Envelope – Temperature and Altitude

Values below refer to hub height and are determined by the sensors and control system of the turbine.

Operational Envelope – Temperature	
Ambient Temperature Interval (Standard Turbine)	-20° to +45°C
Ambient Temperature Interval (Low Temperature Turbine)	-30° to +45°C

Table 10-2: Operational envelope – temperature

NOTE The wind turbine will stop producing power at ambient temperatures above 45°C. For the low temperature options of the wind turbine, consult Vestas.

The turbine is designed for use at altitudes up to 1000 m above sea level as standard and optional up to 2000 m above sea level.

10.3 Operational Envelope – Temperature and Altitude

Values below refer to hub height and are determined by the sensors and control system of the turbine. At ambient temperatures above the thresholds shown for each operating mode in Figure 10-1 below, the turbine will maintain derated production. Additional derating will take place at altitudes above 1000 m.a.s.l.

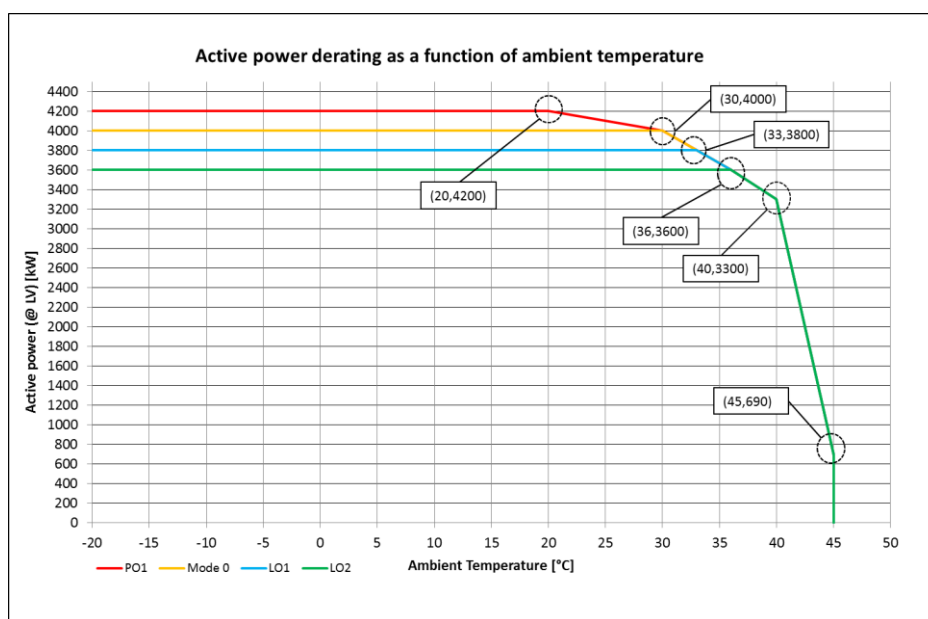


Figure 10-1: Temperature dependant derated operation.

NOTE All derating settings are preliminary and subject to change.

10.4 Operational Envelope – Grid Connection

Operational Envelope – Grid Connection		
Nominal Phase Voltage	[U _{NP}]	720 V
Nominal Frequency	[f _N]	50/60 Hz
Maximum Frequency Gradient	±4 Hz/sec.	
Maximum Negative Sequence Voltage	3% (connection) 2% (operation)	
Minimum Required Short Circuit Ratio at Turbine HV Connection	5.0 (contact Vestas for lower SCR levels)	
Maximum Short Circuit Current Contribution	1.05 p.u. (continuous) 1.45 p.u. (peak)	

Table 10-3: Operational envelope – grid connection

The generator and the converter will be disconnected if*:

Protection Settings	
Voltage Above 110%** of Nominal for 1800 Seconds	792 V
Voltage Above 116% of Nominal for 60 Seconds	835 V
Voltage Above 125% of Nominal for 2 Seconds	900 V
Voltage Above 136% of Nominal for 0.150 Seconds	979 V
Voltage Below 90%** of Nominal for 180 Seconds (FRT)	648 V
Voltage Below 85% of Nominal for 12 Seconds (FRT)	612 V
Voltage Below 80% of Nominal for 4 Seconds (FRT)	576 V
Frequency is Above 106% of Nominal for 0.2 Seconds	53/63.6 Hz
Frequency is Below 94% of Nominal for 0.2 Seconds	47/56.4 Hz

Table 10-4: Generator and converter disconnecting values

NOTE

* Over the turbine lifetime, grid drop-outs are to occur at an average of no more than 50 times a year.

** The turbine may be configured for continuous operation @ +/- 13 % voltage. Reactive power capability is limited for these widened settings to an extent that is yet to be determined.

All protection settings are preliminary and subject to change.

10.5 Operational Envelope – Reactive Power Capability in 4.0 MW Mode 0

The turbine has a reactive power capability in 4.0 MW Mode 0 on the low voltage side of the HV transformer as illustrated in Figure 10-2:

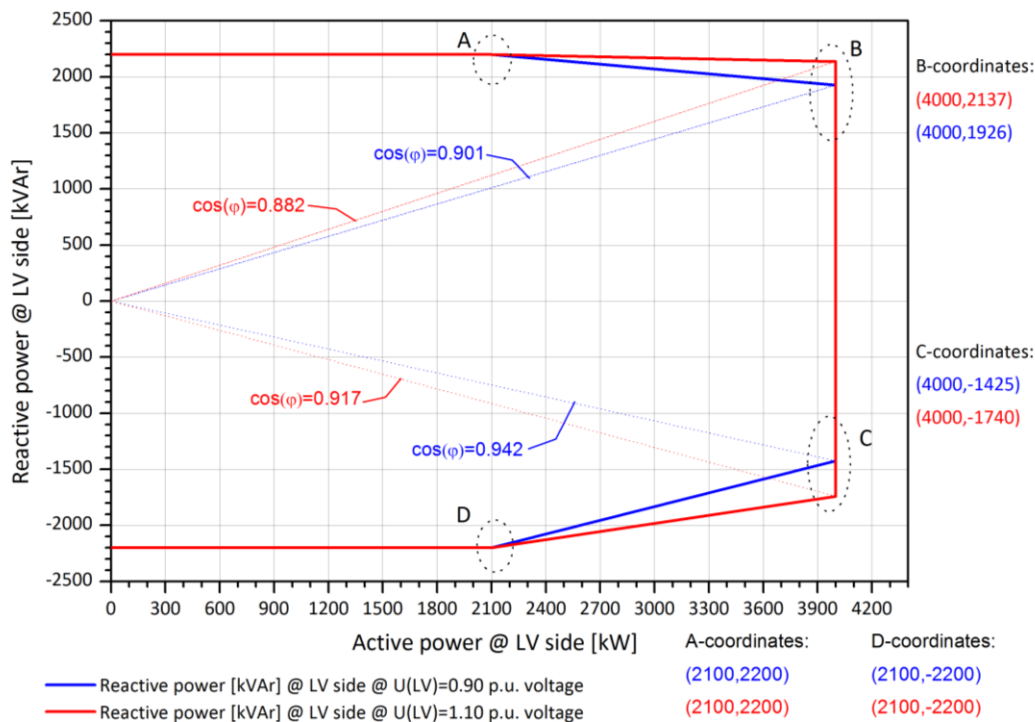


Figure 10-2: Reactive power capability for 4.0 MW Mode 0.

When operating at 4.0 MW nominal power at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.93/0.91$ capacitive/inductive @ $U(HV) = 0.90$ p.u. voltage
- $\cos\phi(HV) = 0.95/0.89$ capacitive/inductive @ $U(HV) = 1.10$ p.u. voltage

Reactive power is produced by the full-scale converter. Traditional capacitors are, therefore, not used in the turbine.

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE 4.0 MW Mode 0 derates above +30°C ambient temperature for ≤ 1000 m.a.s.l. according to Figure 10-1.

All reactive power capabilities are preliminary and subject to change.

10.6 Operational Envelope – Reactive Power Capability in 4.0 MW Reactive Power Optimized Mode (QO1)

An optional, extended reactive power capability is available with 4.0 MW Reactive Power Optimized Mode (QO1) when ambient temperature is below +20°C for ≤1000 m.a.s.l. The reactive power capability is as seen in Figure 10-3:

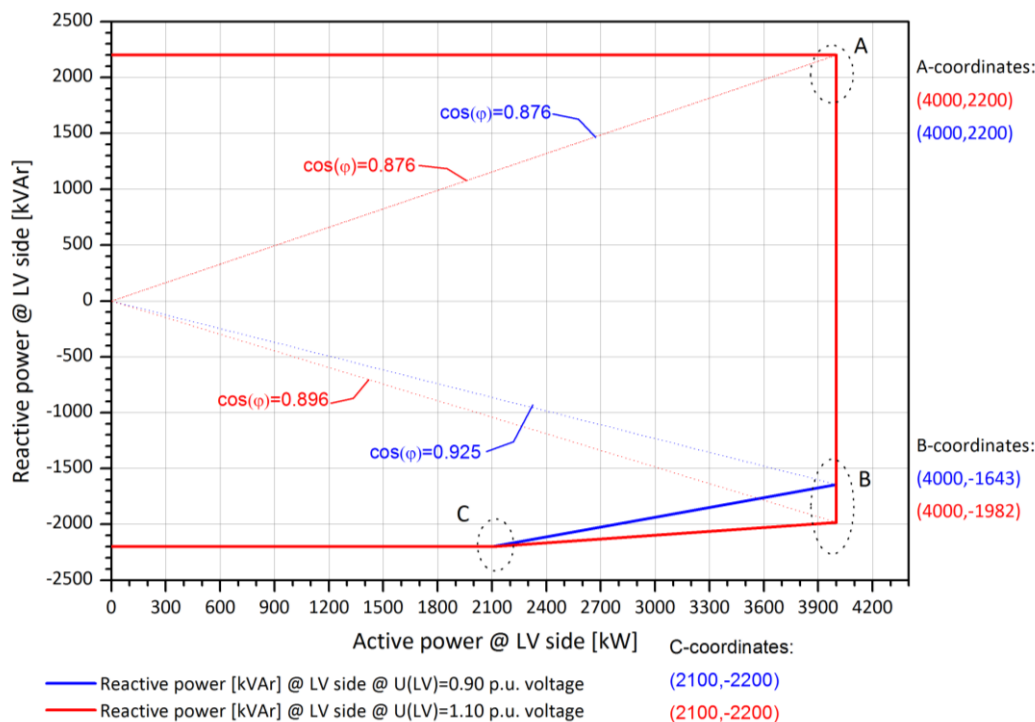


Figure 10-3: Reactive power capability for 4.0 MW Reactive Power Optimized Mode (QO1).

When operating at 4.0 MW in Reactive Power Optimized Mode (QO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(HV) = 0.91/0.90$ capacitive/inductive @ $U(HV) = 0.90$ p.u. voltage
- $\cos\phi(HV) = 0.94/0.87$ capacitive/inductive @ $U(HV) = 1.10$ p.u. voltage

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE 4.0 MW Reactive Power Optimized Mode (QO1) derates reactive power linearly above +20°C ambient temperature for ≤1000 m.a.s.l. to converge with the reactive power capability of 4.0 MW Mode 0 in Figure 10-2 at +30°C.
 All reactive power capabilities are preliminary and subject to change.

10.7 Operational Envelope – Reactive Power Capability in 4.2 MW Power Optimized Mode (PO1)

The reactive power capability for the 4.2 MW Power Optimized Mode (PO1) is as illustrated in Figure 10-4:

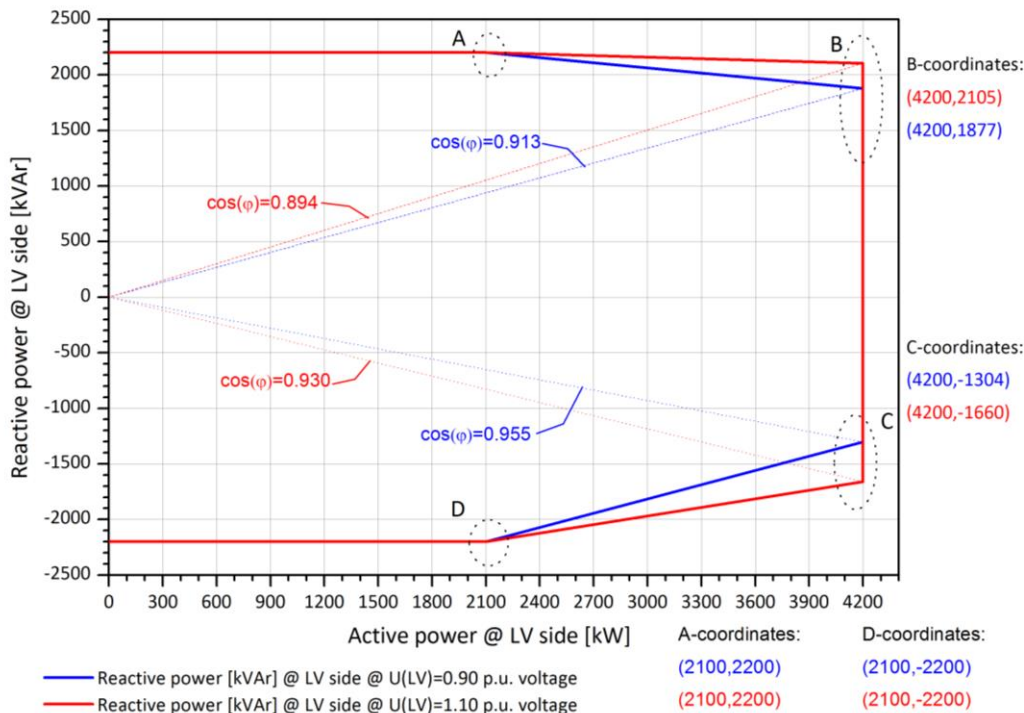


Figure 10-4: Reactive power capability for 4.2 MW Power Optimized Mode (PO1).

When operating at 4.2 MW in Power Optimized Mode (PO1) at LV side of the HV transformer, the reactive power capability on the high voltage side of the HV transformer is approximately:

- $\cos\phi(\text{HV}) = 0.95/0.92$ capacitive/inductive @ $U(\text{HV}) = 0.90$ p.u. voltage
- $\cos\phi(\text{HV}) = 0.96/0.91$ capacitive/inductive @ $U(\text{HV}) = 1.10$ p.u. voltage

The turbine is able to maintain the reactive power capability at low wind with no active power production.

NOTE 4.2 MW Power Optimized Mode (PO1) derates above +20°C ambient temperature for ≤ 1000 m.a.s.l. according to Figure 10-1.

4.2 MW Power Optimized Mode (PO1) is mutually exclusive with 4.0 MW Reactive Power Optimized Mode (QO1) (since Q is traded for P).

All reactive power capabilities are preliminary and subject to change.

10.8 Performance – Fault Ride Through

The turbine is equipped with a full-scale converter to gain better control of the wind turbine during grid faults. The turbine control system continues to run during grid faults.

The turbine is designed to stay connected during grid disturbances within the voltage tolerance curve as illustrated below:

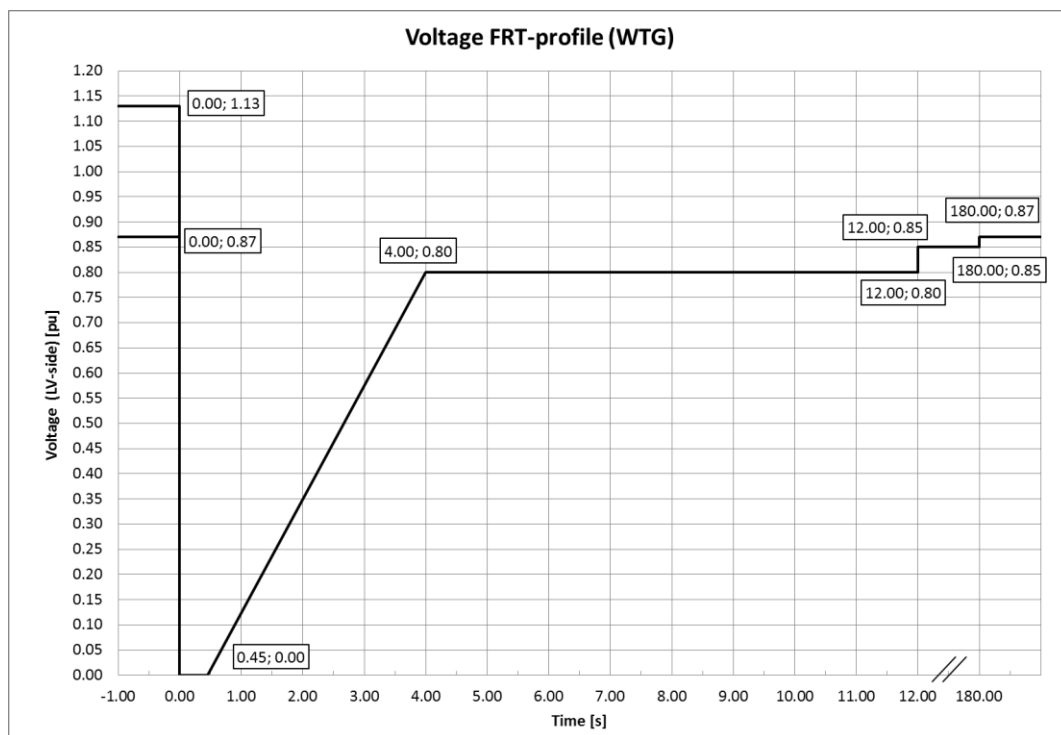


Figure 10-5: Low voltage tolerance curve for symmetrical and asymmetrical faults, where U represents voltage as measured on the grid.

For grid disturbances outside the tolerance curve in Figure 10-5, the turbine will be disconnected from the grid.

NOTE All fault ride through capability values are preliminary and subject to change.

Power Recovery Time	
Power Recovery to 90% of Pre-Fault Level	Maximum 0.1 seconds

Table 10-5: Power recovery time

10.9 Performance – Reactive Current Contribution

The reactive current contribution depends on whether the fault applied to the turbine is symmetrical or asymmetrical.

NOTE All reactive current contribution values are preliminary and subject to change.

10.9.1 Symmetrical Reactive Current Contribution

During symmetrical voltage dips, the wind farm will inject reactive current to support the grid voltage. The reactive current injected is a function of the measured grid voltage.

The default value gives a reactive current part of 1 p.u. of the rated active current at the high voltage side of the HV transformer. Figure 10-6, indicates the reactive current contribution as a function of the voltage. The reactive current contribution is independent from the actual wind conditions and pre-fault power level. As seen in Figure 10-6, the default current injection slope is 2% reactive current increase per 1% voltage decrease. The slope can be parameterized between 0 and 10 to adapt to site specific requirements.

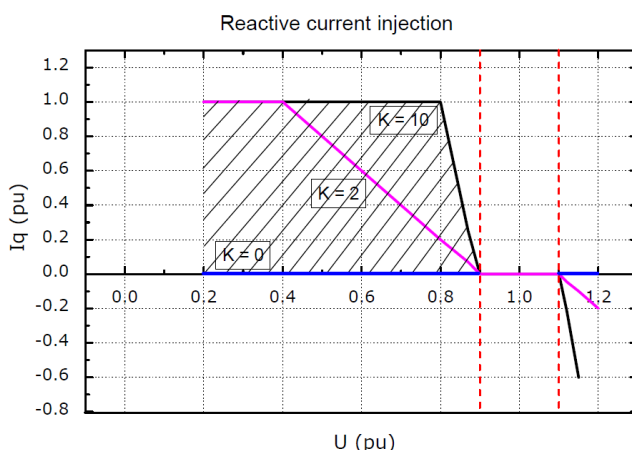


Figure 10-6: Reactive current injection

10.9.2 Asymmetrical Reactive Current Contribution

The injected current is based on the measured positive sequence voltage and the used K-factor. During asymmetrical voltage dips, the reactive current injection is limited to approximate 0.4 p.u. to limit the potential voltage increase on the healthy phases.

10.10 Performance – Multiple Voltage Dips

The turbine is designed to handle re-closure events and multiple voltage dips within a short period of time due to the fact that voltage dips are not evenly distributed during the year. For example, the turbine is designed to handle 10 voltage dips of duration of 200 ms, down to 20% voltage, within 30 minutes.

10.11 Performance – Active and Reactive Power Control

The turbine is designed for control of active and reactive power via the VestasOnline® SCADA system.

Maximum Ramp Rates for External Control	
Active Power	0.1 p.u./sec for max. power level change of 0.3 p.u. 0.3 p.u./sec for max. power level change of 0.1 p.u.
Reactive Power	20 p.u./sec

Table 10-6: Active/reactive power ramp rates (values are preliminary)

To support grid stability the turbine is capable to stay connected to the grid at active power references down to 10 % of nominal power for the turbine. For active power references below 10 % the turbine may disconnect from the grid.

10.12 Performance – Voltage Control

The turbine is designed for integration with VestasOnline® voltage control by utilising the turbine reactive power capability.

10.13 Performance – Frequency Control

The turbine can be configured to perform frequency control by decreasing the output power as a linear function of the grid frequency (over frequency). Dead band and slope for the frequency control function are configurable.

10.14 Distortion – Immunity

The turbine is able to connect with a pre-connection (background) voltage distortion level at the grid interface of 8% and operate with a post-connection voltage distortion level of 8%.

10.15 Main Contributors to Own Consumption

The consumption of electrical power by the wind turbine is defined as the power used by the wind turbine when it is not providing energy to the grid. This is defined in the control system as Production Generator 0 (zero).

The components in Table 10-7 have the largest influence on the own consumption of the wind turbine (the average own consumption depends on the actual conditions, the climate, the wind turbine output, the cut-off hours, etc.).

The VMP8000 control system has a hibernate mode that reduces own consumption when possible. Similarly, cooling pumps may be turned off when the turbine idles.

Main contributors to Own Consumption	
Hydraulic Motor	2 x 15 (V117) / 18.5 kW (V136 + V150) (master-slave)
Yaw Motors	Maximum 21 kW in total
Water Heating	10 kW
Water Pumps	2.2 + 5.5 kW
Oil Heating	7.9 kW
Oil Pump for Gearbox Lubrication	12.5 kW
Controller Including Heating Elements for the Hydraulics and all Controllers	Approximately 3 kW
HV Transformer No-load Loss	See section 4.3 HV Transformer, p. 13

Table 10-7: Main contributors to own consumption data (values are preliminary).

11 Drawings

11.1 Structural Design – Illustration of Outer Dimensions

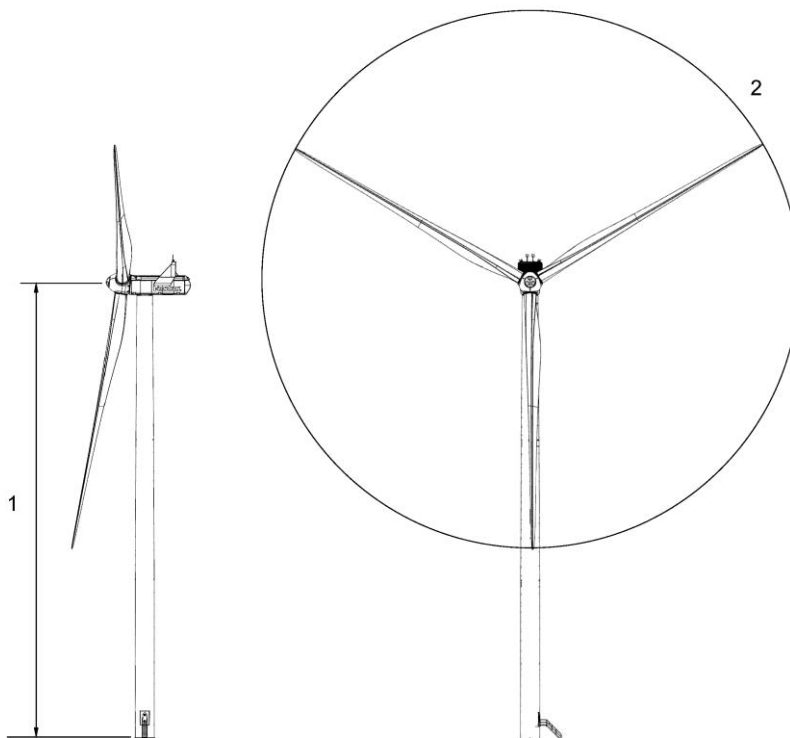


Figure 11-1: Illustration of outer dimensions – structure

- 1 Hub heights: See Performance Specification
- 2 Rotor diameter: 117-150 m

11.2 Structural Design – Side View Drawing

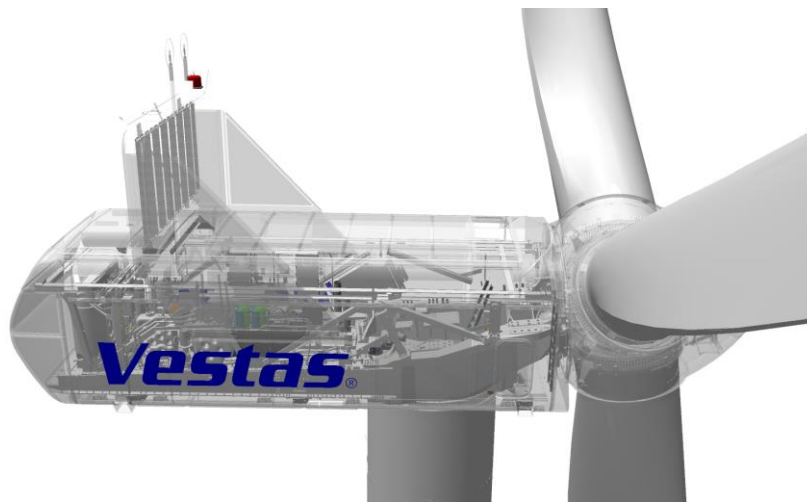


Figure 11-2: Side-view drawing

12 General Reservations, Notes and Disclaimers

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- The general descriptions in this document apply to the current version of the 4MW Platform wind turbines. Updated versions of the 4MW Platform wind turbines, which may be manufactured in the future, may differ from this general description. In the event that Vestas supplies an updated version of a specific 4MW Platform wind turbine, Vestas will provide an updated general description applicable to the updated version.
- Vestas recommends that the grid be as close to nominal as possible with limited variation in frequency and voltage.
- A certain time allowance for turbine warm-up must be expected following grid dropout and/or periods of very low ambient temperature.
- 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.
- The earthing system must comply with the minimum requirements from Vestas, and be in accordance with local and national requirements and codes of standards.
- This document, General Description, is not an offer for sale, and does not contain any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method). Any guarantee, warranty and/or verification of the power curve and noise (including, without limitation, the power curve and noise verification method) must be agreed to separately in writing.