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PARCO EOLICO BORGO MEZZANONE S.r.l.

PROGETTO PER LA REALIZZAZIONE DI UN IMPIANTO PER LA PRODUZIONE DI ENERGIA MEDIANTE LO SFRUTTAMENTO DEL VENTO NEL TERRITORIO COMUNALE DI FOGGIA E MANFREDONIA

PROGETTO DEFINITIVO

2019

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PD.R. ELABORATI DESCRITTIVI

R.3.1 SCHEDA TECNICA AEROGENERATORE

GE Renewable Energy

– Original –

Technical Documentation Wind Turbine Generator Systems 5.5-158 - 50/60 Hz

Calculated Power Curve and Thrust Coefficient

Mode:	Normal Operation (NO)
Eng.-Rev:	Rev. 03
LEP:	Without
Thrust:	700 kN
Noise:	106 dB
Rev. 01 - EN	2018-12-05

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1 Calculated Power Curves

Wind turbine type: 5.5-158 (106 dB max. sound power level)
Grid standard: 50 Hz and 60 Hz
Rotor diameter: 158 m

The calculated power curves at an average air density of 1.225 kg/m^3 are listed in Table 1. These power curves are consistent with the power curve definition in the IEC 61400-12-1 for hub height wind speed.

Turbulence intensity (TI) ranges are defined in section 3. The method for selecting the appropriate turbulence intensity is provided in section 6.

Wind Speed at Hub Height [m/s]	**Electrical Power [kW] with**			**$C_{p,e}$ Medium TI**
	Medium TI Band	**Low TI Band**	**High TI Band**	
3.0	90	76	129	0.28
3.5	188	172	234	0.37
4.0	314	296	364	0.41
4.5	471	452	527	0.43
5.0	664	642	729	0.44
5.5	902	875	978	0.45
6.0	1182	1151	1270	0.46
6.5	1513	1477	1613	0.46
7.0	1896	1856	2009	0.46
7.5	2337	2293	2440	0.46
8.0	2819	2783	2907	0.46
8.5	3322	3300	3380	0.45
9.0	3809	3800	3825	0.43
9.5	4266	4263	4249	0.41
10.0	4680	4695	4607	0.39
10.5	5010	5061	4892	0.36
11.0	5266	5330	5145	0.33
11.5	5425	5471	5320	0.30
12.0	5493	5500	5412	0.26
12.5	5500	5500	5472	0.23
13.0	5500	5500	5500	0.21
13.5	5500	5500	5500	0.19
14.0	5500	5500	5500	0.17
14.5	5500	5500	5500	0.15
15.0	5500	5500	5500	0.14
15.5	5500	5500	5500	0.12
16.0	5500	5500	5500	0.11
16.5	5500	5500	5500	0.10
17.0	5500	5500	5500	0.09

Wind Speed at Hub Height [m/s]	Electrical Power [kW] with			$C_{p,e}$ Medium TI
	Medium TI Band	Low TI Band	High TI Band	
17.5	5500	5500	5500	0.09
18.0	5500	5500	5500	0.08
18.5	5500	5500	5500	0.07
19.0	5500	5500	5500	0.07
19.5	5500	5500	5500	0.06
20.0	5500	5500	5484	0.06
20.5	5500	5500	5440	0.05
21.0	5452	5498	5339	0.05
21.5	5390	5444	5277	0.05
22.0	5252	5305	5156	0.04
22.5	5065	5092	5009	0.04
23.0	4850	4839	4852	0.03
23.5	4688	4642	3945	0.03
24.0	4556	4497	4626	0.03
24.5	4462	4410	4542	0.03
25.0	4388	4367	4442	0.02

Table 1: Calculated power curve table as a function of hub height wind speed for standard air density

2 Power Curves for different Air Densities and Turbulence Intensities

Following tables show the calculated power curves for different air density values and turbulence intensity classes. The Excel file embedded with this document contains power curves for a larger range of air densities than in the tables below.

Wind Speed at Hub Height [m/s]	Electrical Power [kW]										
	Air density ρ = 1.02 kg/m³	Air density ρ = 1.04 kg/m³	Air density ρ = 1.06 kg/m³	Air density ρ = 1.08 kg/m³	Air density ρ = 1.1 kg/m³	Air density ρ = 1.12 kg/m³	Air density ρ = 1.14 kg/m³	Air density ρ = 1.16 kg/m³	Air density ρ = 1.18 kg/m³	Air density ρ = 1.2 kg/m³	Air density ρ = 1.225 kg/m³
3.0	64	67	69	72	74	77	79	82	84	86	90
3.5	146	151	155	159	163	167	171	175	179	183	188
4.0	251	257	263	270	276	282	288	294	300	306	314
4.5	382	390	399	408	416	425	434	442	451	460	471
5.0	541	553	565	577	589	601	613	625	637	649	664
5.5	738	754	770	786	802	818	834	850	866	882	902
6.0	970	991	1012	1032	1053	1074	1094	1115	1135	1156	1182
6.5	1245	1271	1298	1324	1350	1376	1402	1429	1455	1481	1513
7.0	1565	1598	1630	1663	1695	1727	1759	1792	1824	1856	1896
7.5	1936	1976	2015	2055	2094	2133	2172	2211	2250	2289	2337
8.0	2355	2402	2448	2495	2542	2587	2632	2676	2721	2766	2819
8.5	2822	2875	2928	2981	3034	3081	3128	3175	3222	3269	3322
9.0	3318	3373	3428	3483	3538	3583	3627	3672	3716	3761	3809
9.5	3823	3875	3926	3978	4029	4068	4108	4147	4187	4226	4266
10.0	4306	4351	4397	4442	4488	4520	4552	4584	4616	4648	4680
10.5	4721	4758	4796	4833	4871	4894	4917	4941	4964	4987	5010
11.0	5056	5084	5112	5140	5168	5185	5202	5218	5235	5252	5266
11.5	5304	5322	5339	5357	5374	5383	5392	5400	5409	5418	5425
12.0	5433	5441	5450	5458	5466	5470	5475	5479	5484	5488	5493
12.5	5499	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
13.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
13.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
14.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
14.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
15.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
15.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
16.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
16.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
17.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
17.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
18.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500

Wind Speed at Hub Height [m/s]	Electrical Power [kW]										
	Air density ρ = 1.02 kg/m³	Air density ρ = 1.04 kg/m³	Air density ρ = 1.06 kg/m³	Air density ρ = 1.08 kg/m³	Air density ρ = 1.1 kg/m³	Air density ρ = 1.12 kg/m³	Air density ρ = 1.14 kg/m³	Air density ρ = 1.16 kg/m³	Air density ρ = 1.18 kg/m³	Air density ρ = 1.2 kg/m³	Air density ρ = 1.225 kg/m³
18.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
19.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
19.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
20.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
20.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
21.0	5446	5446	5447	5447	5448	5449	5450	5450	5451	5452	5452
21.5	5380	5381	5382	5383	5384	5385	5386	5387	5388	5389	5390
22.0	5237	5239	5240	5242	5243	5245	5246	5248	5249	5251	5252
22.5	5048	5049	5050	5051	5052	5054	5056	5058	5060	5062	5065
23.0	4840	4840	4841	4841	4841	4842	4844	4845	4847	4848	4850
23.5	4678	4678	4679	4679	4680	4681	4682	4684	4685	4686	4688
24.0	4548	4549	4549	4550	4551	4552	4553	4553	4554	4555	4556
24.5	4456	4457	4457	4458	4458	4459	4459	4460	4460	4461	4462
25.0	4387	4387	4387	4387	4387	4387	4387	4388	4388	4388	4388

Table 2: Calculated power curve for different values of the air density for medium turbulence intensity

Wind Speed at Hub Height [m/s]	Electrical Power [kW]										
	Air density ρ = 1.02 kg/m³	Air density ρ = 1.04 kg/m³	Air density ρ = 1.06 kg/m³	Air density ρ = 1.08 kg/m³	Air density ρ = 1.1 kg/m³	Air density ρ = 1.12 kg/m³	Air density ρ = 1.14 kg/m³	Air density ρ = 1.16 kg/m³	Air density ρ = 1.18 kg/m³	Air density ρ = 1.2 kg/m³	Air density ρ = 1.225 kg/m³
3.0	52	54	56	59	61	63	66	68	70	73	76
3.5	134	137	141	145	149	152	156	160	164	167	172
4.0	237	242	248	254	260	265	271	277	283	289	296
4.5	366	374	382	391	399	408	416	424	433	441	452
5.0	523	535	547	558	570	581	593	605	616	628	642
5.5	716	731	747	762	778	793	809	825	840	856	875
6.0	944	965	985	1005	1025	1045	1065	1086	1106	1126	1151
6.5	1216	1241	1267	1292	1318	1343	1369	1394	1420	1445	1477
7.0	1531	1563	1594	1626	1658	1690	1721	1753	1784	1816	1856
7.5	1895	1934	1973	2012	2051	2090	2129	2167	2206	2245	2293
8.0	2311	2358	2404	2451	2498	2544	2590	2635	2681	2727	2783
8.5	2778	2833	2887	2942	2996	3045	3095	3144	3194	3243	3300
9.0	3287	3345	3402	3460	3518	3565	3612	3658	3705	3752	3800
9.5	3811	3864	3918	3971	4025	4065	4104	4144	4183	4223	4263
10.0	4310	4356	4403	4449	4496	4529	4562	4595	4628	4661	4695
10.5	4760	4799	4837	4876	4914	4938	4963	4987	5012	5036	5061
11.0	5118	5146	5175	5203	5232	5249	5265	5282	5298	5315	5330
11.5	5357	5375	5394	5412	5431	5437	5443	5450	5456	5462	5471
12.0	5476	5483	5491	5498	5500	5500	5500	5500	5500	5500	5500
12.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
13.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
13.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
14.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
14.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
15.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
15.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
16.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
16.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
17.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
17.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
18.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
18.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
19.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
19.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
20.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
20.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
21.0	5491	5492	5492	5493	5494	5495	5495	5496	5496	5497	5498

Wind Speed at Hub Height [m/s]	Electrical Power [kW]										
	Air density ρ = 1.02 kg/m³	Air density ρ = 1.04 kg/m³	Air density ρ = 1.06 kg/m³	Air density ρ = 1.08 kg/m³	Air density ρ = 1.1 kg/m³	Air density ρ = 1.12 kg/m³	Air density ρ = 1.14 kg/m³	Air density ρ = 1.16 kg/m³	Air density ρ = 1.18 kg/m³	Air density ρ = 1.2 kg/m³	Air density ρ = 1.225 kg/m³
21.5	5428	5430	5431	5433	5434	5436	5437	5439	5440	5442	5444
22.0	5280	5282	5283	5285	5287	5290	5293	5296	5299	5302	5305
22.5	5063	5066	5068	5071	5073	5076	5079	5082	5085	5088	5092
23.0	4814	4816	4818	4820	4822	4825	4828	4830	4833	4836	4839
23.5	4623	4625	4626	4628	4629	4631	4633	4636	4638	4640	4642
24.0	4489	4489	4490	4490	4491	4492	4493	4494	4495	4496	4497
24.5	4404	4405	4405	4406	4406	4407	4407	4408	4408	4409	4410
25.0	4366	4366	4366	4366	4366	4366	4366	4366	4366	4366	4367

Table 3: Calculated power curve for different values of the air density for low turbulence intensity

Wind Speed at Hub Height [m/s]	Electrical Power [kW]										
	Air density ρ = 1.02 kg/m³	Air density ρ = 1.04 kg/m³	Air density ρ = 1.06 kg/m³	Air density ρ = 1.08 kg/m³	Air density ρ = 1.1 kg/m³	Air density ρ = 1.12 kg/m³	Air density ρ = 1.14 kg/m³	Air density ρ = 1.16 kg/m³	Air density ρ = 1.18 kg/m³	Air density ρ = 1.2 kg/m³	Air density ρ = 1.225 kg/m³
3.0	98	101	104	107	110	113	116	119	122	125	129
3.5	184	189	194	199	204	209	213	218	223	227	234
4.0	293	300	307	314	321	328	335	342	349	356	364
4.5	428	438	448	457	467	476	486	496	505	515	527
5.0	595	608	621	634	647	660	674	687	700	713	729
5.5	802	819	836	853	870	888	905	922	939	956	978
6.0	1045	1067	1089	1111	1133	1155	1177	1199	1221	1243	1270
6.5	1331	1359	1386	1414	1442	1469	1497	1524	1552	1579	1613
7.0	1662	1696	1731	1765	1799	1833	1866	1900	1933	1967	2009
7.5	2043	2083	2123	2163	2203	2241	2279	2318	2356	2394	2440
8.0	2464	2509	2555	2600	2646	2688	2731	2773	2816	2858	2907
8.5	2919	2969	3019	3069	3119	3162	3204	3247	3289	3332	3380
9.0	3383	3433	3483	3533	3583	3623	3663	3702	3742	3782	3825
9.5	3849	3895	3942	3988	4034	4070	4105	4141	4176	4212	4249
10.0	4264	4306	4347	4389	4430	4459	4488	4517	4546	4575	4607
10.5	4618	4653	4687	4722	4756	4778	4801	4823	4846	4868	4892
11.0	4930	4958	4985	5013	5041	5058	5076	5093	5111	5128	5145
11.5	5172	5192	5213	5233	5254	5265	5276	5286	5297	5308	5320
12.0	5321	5335	5348	5362	5375	5381	5387	5393	5399	5405	5412
12.5	5425	5431	5436	5442	5447	5450	5453	5457	5460	5463	5472
13.0	5474	5479	5484	5489	5494	5496	5499	5500	5500	5500	5500
13.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
14.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
14.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
15.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
15.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
16.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
16.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
17.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
17.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
18.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
18.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
19.0	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
19.5	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500	5500
20.0	5491	5490	5489	5488	5487	5487	5486	5486	5485	5485	5484
20.5	5447	5446	5445	5444	5443	5443	5442	5442	5441	5441	5440
21.0	5364	5359	5354	5349	5344	5343	5342	5341	5340	5339	5339

Wind Speed at Hub Height [m/s]	Electrical Power [kW]										
	Air density ρ = 1.02 kg/m³	Air density ρ = 1.04 kg/m³	Air density ρ = 1.06 kg/m³	Air density ρ = 1.08 kg/m³	Air density ρ = 1.1 kg/m³	Air density ρ = 1.12 kg/m³	Air density ρ = 1.14 kg/m³	Air density ρ = 1.16 kg/m³	Air density ρ = 1.18 kg/m³	Air density ρ = 1.2 kg/m³	Air density ρ = 1.225 kg/m³
21.5	5301	5298	5294	5291	5287	5285	5283	5282	5280	5278	5277
22.0	5173	5170	5168	5165	5163	5160	5158	5155	5153	5150	5156
22.5	5020	5017	5015	5012	5010	5010	5010	5009	5009	5009	5009
23.0	4835	4783	4730	4678	4626	4671	4716	4762	4807	4852	4852
23.5	4757	4755	4752	4750	4748	4588	4428	4267	4107	3947	3945
24.0	4498	4341	4183	4026	3868	4020	4172	4325	4477	4629	4626
24.5	4411	4256	4100	3945	3789	3940	4091	4242	4393	4544	4542
25.0	4467	4464	4460	4457	4453	4452	4450	4449	4447	4446	4442

Table 4: Calculated power curve for different values of the air density for high turbulence intensity

3 Applicability

The power curve information provided in this document applies under the following conditions:

- Hub heights at or above: 120 m. Lower hub heights require site specific power curve.
- The mean air density falls inside the range of air densities specified in section 2, including the wider range of air densities in the embedded Excel spreadsheet.
- The measured power curve data shall be density corrected to the nearest 0.01 kg/m³ of the average test period air density. The calculated power curve reference at the same nearest 0.01 kg/m³ density shall be used either directly from the reference power curve tables provided here or interpolated linearly between the provided densities. If the measured average air density during a power performance test falls out of the range of provided densities, data shall be density-corrected to the nearest density provided in Tables 2 through 4 (including the embedded files) by employing air density correction specified by the IEC standard 61400-12-1.
- The site is characterized by one of the following turbulence intensity categories.

TI Band	Lower TI bound	Upper TI bound
Low	$2.5\ (0.75V_{hub} + 5.6)/V_{hub}$	$12.5\ (0.75V_{hub} + 5.6)/V_{hub}$
Medium	$5\ (0.75V_{hub} + 5.6)/V_{hub}$	$15\ (0.75V_{hub} + 5.6)/V_{hub}$
High	$10\ (0.75V_{hub} + 5.6)/V_{hub}$	$20\ (0.75V_{hub} + 5.6)/V_{hub}$

Measured power curve data points for 10-minute average mean turbulence intensities that fall outside the applicable TI band would be filtered out for the purpose of power curve applicability, see Figure 1.

The reference power curve is to be selected from the power curves of the TI class having the largest number of post-filtering data points (upmost coverage). Section 6 of this document gives an example outlining how to determine the TI class with the upmost coverage. The reference power curve is referred to as the calculated power curve in GE's Technical Documentation Machine Power Performance Test. This document also outlines the data filtering requirements, which have to be met prior to determining the TI class.

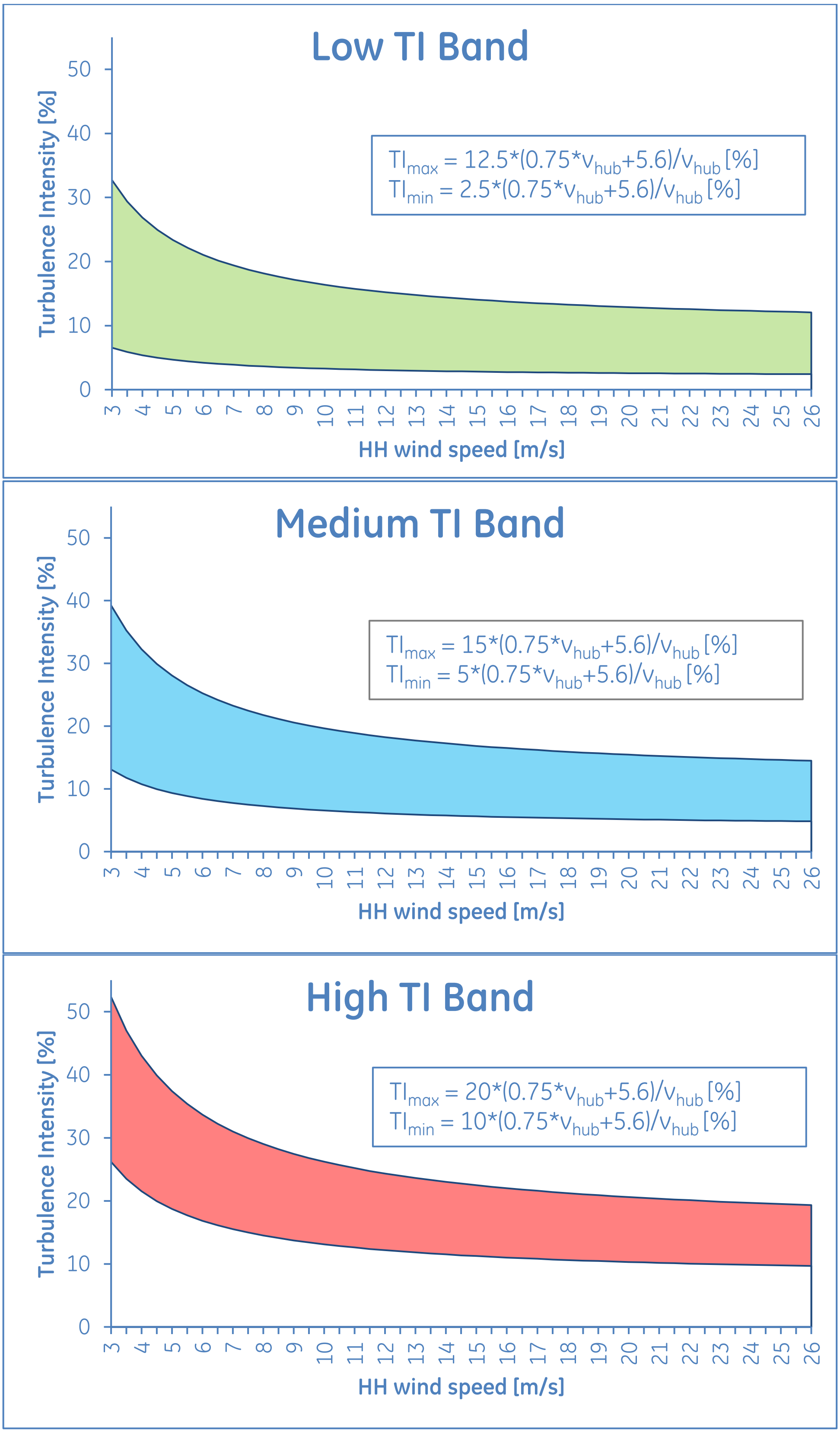

Figure 1: Applicable Turbulence Intensity Range

- Non-degraded and uncontaminated blade surfaces with no icing
- Power shall be measured on the generator side of the transformer unless the net electric power output is referenced otherwise in this document.
- Wind-speed labels are mid-bin values; for example, the 5.0 m/s bin extends from 4.75 to 5.25 m/s.
- Measured wind shear (10-minute average data) such that -0.1 <= shear <= 0.5.
- The wind turbine generator system whose power output is not being actively regulated or curtailed for any reason.
- Information on the cold or hot weather and high altitude operation capabilities for specific operation modes is provided in the documents "Technical Description – Cold Weather Adaptations" and "General Description High Temperature, High Altitude Operation".
- Information on the reactive power capabilities for specific operation modes is provided in the 'Grid Interconnection Document.

4 Cut-Out and Re-Cut-In Wind Speeds

The wind turbine generator system will shut down when the average wind speed exceeds

- 25 m/s average in a 600-second time interval,
- 30 m/s average in a 30-second time interval, or
- 34 m/s average in a 3-second time interval.

After the turbine has been shut-down, it will restart when the 4-minute rolling average wind speed drops below 22 m/s.

A site-specific Mechanical Loads Analysis (MLA) is required to determine the turbine suitability and whether the above-listed cut-out and re-cut-in wind speeds require adjustment to mitigate site-specific loads. If, for example, the MLA concludes that curtailment is needed to reduce loads, the MLA report will state the reduced 600-second cut-out wind speeds and the applicable wind direction sector(s). The remaining cut-out and re-cut-in wind speeds will be reduced by the same amount that the 600-second wind speed is reduced. Any reduction of the wind speeds listed in this section may be turbine location-specific. Refer to the site-specific MLA report for details.

5 Calculated Thrust Coefficient

Wind Speed at Hub Height [m/s]	Thrust Coefficient [ct]	Wind Speed at Hub Height [m/s]	Thrust Coefficient [ct]
3.0	0.91	14.5	0.19
3.5	0.89	15.0	0.17
4.0	0.88	15.5	0.16
4.5	0.85	16.0	0.14
5.0	0.83	16.5	0.13
5.5	0.82	17.0	0.12
6.0	0.82	17.5	0.11
6.5	0.81	18.0	0.10
7.0	0.81	18.5	0.09
7.5	0.80	19.0	0.09
8.0	0.78	19.5	0.08
8.5	0.74	20.0	0.07
9.0	0.68	20.5	0.07
9.5	0.62	21.0	0.06
10.0	0.56	21.5	0.06
10.5	0.50	22.0	0.06
11.0	0.45	22.5	0.05
11.5	0.40	23.0	0.05
12.0	0.35	23.5	0.04
12.5	0.31	24.0	0.04
13.0	0.27	24.5	0.04
13.5	0.24	25.0	0.03
14.0	0.21		

Table 5: Calculated thrust coefficient table; as a function of hub height wind speed

Calculated using Standard Atmospheric Conditions according to ISO 2533 for geometric altitude of 0.

6 Guidelines for Pre-construction Energy Assessment

The following guidelines are offered for selecting power curves from this document for measurement purposes or assessment of the energy production of a new wind plant.

The air density should be the annual average air density expected at the site of the new wind plant over the life of the wind turbine.

The reference power curve for warranty purposes shall be chosen for the turbulence intensity range covering the largest fraction of data points from the measured data set of the power curve test. Figure 2 depicts one example to illustrate this guideline. The mean turbulence intensity distribution for the site is plotted over the low, medium, and high turbulence intensity ranges. As shown in Figure 2, the site has a mean turbulence intensity distribution that is most common to the low turbulence intensity range. Accordingly, the low turbulence PCs from Table 3 should be used for this example site.

For site energy assessment purposes the turbulence intensity range between low, medium, and high may also be selected based on comparing the measured 10 min averaged scatter plot in each wind speed bin expected individually to represent the conditions at the site of the new wind plant over the life of the wind turbine.

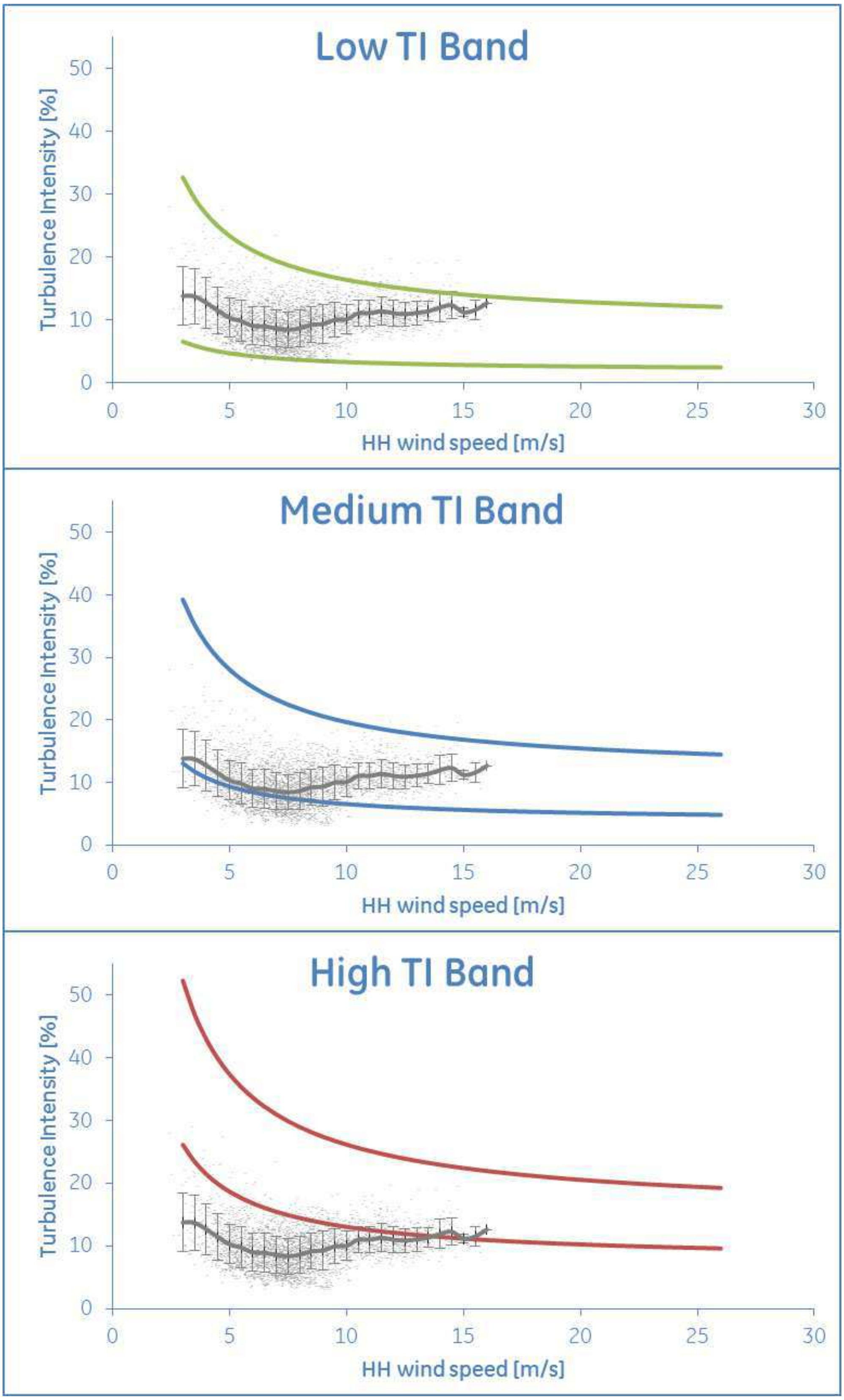

Figure 2: Example of site specific turbulence distribution with mean turbulence data and standard deviation relative to high TI (9%), medium TI (71%) and low TI (98%) band (figures in parenthesis represent the coverage rate)

GE Renewable Energy

-Original-

Technical Documentation
Wind Turbine Generator Systems
5.3-158 - 50 Hz

Technical Description and Data

N.B.: La piattaforma GE 5.3 può essere tarata con potenze variabili in un range di 0,5 MW.
Nel progetto in esame è stata individuata la potenza di 5,425 MW

imagination at work

GE Renewable Energy

All technical data is subject to change in line with ongoing technical development!

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Table of Contents

1 Introduction

This document summarizes the technical description and specifications of the 5.3-158 wind turbine.

2 Technical Description of the Wind Turbine and Major Components

The 5.3-158 is a three-bladed, upwind, horizontal-axis wind turbine with a rotor diameter of 158 meters. The turbine rotor and nacelle are mounted on top of:

- a tubular steel tower with a hub height of 101 m
- a tubular steel tower with a hub height of 120.9 m
- a concrete hybrid tower with a hub height of 150 m
- a concrete hybrid tower with a hub height of 161 m

The 5.3-158 turbine employs active yaw control (designed to steer the wind turbine with respect to the wind direction), active blade pitch control (to regulate turbine rotor speed) and a variable speed generator with a power electronic converter system.

The 5.3-158 turbine features a modular drive train design where the major drive train components, including main shaft bearing, gearbox, generator and yaw drives, are attached to a bedplate.

2.1 Rotor

Rotor speed is regulated by a combination of blade pitch angle adjustment and generator/converter torque control. The rotor spins in a clockwise direction under normal operating conditions when viewed from an upwind location.

Full blade pitch angle range is approximately 90 degrees, with the zero degree position being with the blade flat to the prevailing wind. Pitching the blades to a full feather pitch angle of approximately 90 degrees accomplishes aerodynamic braking of the rotor, thus reduces the rotor speed.

2.2 Blades

There are three logistics optimized rotor blades used on the 5.3-158 wind turbine. The airfoils transition along the blade span and with the thicker airfoils being located inboard towards the blade root (hub) and gradually tapering to thinner cross sections out towards the blade tip. Values below are typically needed to perform shadow casting calculations.

	Rotor Diameter
	158 m
Longest chord	4.0 m
Chord at 0.9 x rotor radius	1.35 m

In order to optimize noise emissions, the rotor blades are equipped with Low-Noise-Trailing-Edges (LNTEs) at the pressure side of the blade's rear edge. LNTEs are thin jagged plastic strips. The rotor blades of the 5.3-158 are equipped with these strips at the factory.

Fig. 1: LNTEs at the wind turbine rotor blade

2.3 Blade Pitch Control System

The rotor utilizes a pitch system to provide adjustment of the blade pitch angle during operation.

The active pitch controller enables the wind turbine rotor to regulate speed, when above rated wind speed, by allowing the blade to "spill" excess aerodynamic lift. Energy from wind gusts below rated wind speed is captured by allowing the rotor to speed up.

Independent back up is provided to drive each blade in order to feather the blades and shut down the wind turbine in the event of a grid line outage or other fault. By having all three blades outfitted with independent pitch systems, redundancy of individual blade aerodynamic braking capability is provided.

2.4 Hub

The hub is used to connect the three rotor blades to the turbine main shaft. The hub also houses the blade pitch system and is mounted directly to the main shaft. To carry out maintenance work, the hub can be entered through one of three hatches at the area close to the nacelle roof.

2.5 Gearbox

The gearbox in the wind turbine is designed to transmit torsional power between the low-rpm turbine rotor and high-rpm electric generator. The gearbox is a multi-stage planetary/helical design. The gearbox is mounted to the wind turbine bedplate. The gearbox mounting is designed to reduce vibration and noise transfer to the bedplate. The gearbox is lubricated by a forced, cooled lubrication system and a filter assist to maintain oil cleanliness.

2.6 Bearings

The blade pitch bearing is designed to allow the blade to pitch about a span-wise pitch axis. The inner race of the blade pitch bearing is outfitted with a blade drive gear that enables the blade to be driven in pitch. The main shaft is supported with a two-bearing system (one external and one at front of gearbox), designed to provide bearing and alignment of the internal gearing shafts and accommodate radial and axial loads.

2.7 Brake System

The blade pitch system acts as the main braking system for the wind turbine. Braking under normal operating conditions is accomplished by feathering the blades out of the wind. Only two feathered rotor blades are required to decelerate the rotor safely into idling mode, and each rotor blade has its own backup to drive the blade in the event of a grid line loss.

2.8 Generator

The generator is a doubly fed induction generator. It is mounted to the generator frame with a mounting designed to reduce vibration and noise transfer to machine.

2.9 Gearbox/Generator Coupling

To protect the drive train from excessive torque loads, a special coupling including a torque-limiting device is provided between the generator and gearbox output shaft.

2.10 Yaw System

A bearing positioned between the nacelle and tower facilitates yaw motion. Yaw drives mesh with the gear of the yaw bearing and steer the wind turbine to track the wind in yaw. The yaw drive system contains an automatic yaw brake. This brake engages when the yaw drive is not operating and prevents the yaw drives from being loaded due to turbulent wind conditions.

The controller activates the yaw drives to align the nacelle to the wind direction based on the wind vane sensor mounted on the top of the nacelle.

The wind turbine records nacelle yaw position following excessive rotation in one direction, the controller automatically brings the rotor to a complete stop, untwists the internal cables, and restarts the wind turbine.

2.11 Tower

The wind turbine is mounted on top of a tubular steel tower (101 m or 120.9 m hub height) or a hybrid tower (150 m or 161 m hub height). Access to the turbine is through a door at the base of the tower. Internal service platforms and interior lighting is included. A ladder provides access to the nacelle and also supports a fall arrest safety system.

Optional climb assist or service lifts are available upon request.

2.12 Nacelle

The nacelle houses the main components of the wind turbine generator. Access from the tower into the nacelle is through the bottom of the nacelle. The nacelle is ventilated, and illuminated by electric lights. A hatch provides access to the blades and hub.

2.13 Wind Sensor and Lightning Rod

An ultrasonic wind sensor and lightning rod are mounted on top of the nacelle housing. Access is accomplished through the hatch in the nacelle.

2.14 Lightning Protection (according to IEC 61400-24 Level I)

The rotor blades are equipped with lightning receptors mounted in the blade. The turbine is grounded and shielded to protect against lightning; however, lightning is an unpredictable force of nature and it is possible that a lightning strike could damage various components notwithstanding the lightning protection employed in the wind turbine.

2.15 Wind Turbine Control System

The wind turbine can be controlled locally. Control signals can also be sent from a remote computer via a Supervisory Control and Data Acquisition System (SCADA), with local lockout capability provided at the turbine controller.

Service switches at the tower top prevent service personnel at the bottom of the tower from operating certain systems of the turbine while service personnel are in the nacelle. To override any wind turbine operation, emergency-stop buttons located in the tower base and in the nacelle can be activated to stop the turbine in the event of an emergency.

2.16 Power Converter

The wind turbine uses a power converter system that consists of a converter on the rotor side, a DC intermediate circuit, and a power inverter on the grid side.

The converter system consists of a power module and the associated electrical equipment.

2.17 Medium Voltage Transformer and Switch Gear

To connect each turbine to the collector system each unit is equipped with a medium voltage transformer and medium-voltage switchgear.

3 Technical Data for the 5.3-158

Turbine	5.3-158
Rated output [MW]	5.3
Rotor diameter [m]	158
Number of blades	3
Swept area [m²]	19607
Rotational direction (viewed from an upwind location)	Clockwise
Maximum speed of the blade tips [m/s]	80.3
Orientation	Upwind
Speed regulation	Pitch control
Aerodynamic brake	Full feathering
Color of outer components	RAL 7035 (light grey) and RAL 7023 (concrete grey, for concrete sections of hybrid tower only)
Reflection degree/Gloss degree Steel tower	30 - 60 gloss units measured at 60° as per ISO 2813
Reflection degree/Gloss degree Rotor blades, Nacelle, Hub	60 - 80 gloss units measured at 60° as per ISO 2813
Reflection degree/Gloss degree Hybrid Tower	Concrete gray (similar RAL 7023); gloss matte

Table 1: Technical data 5.3-158 wind turbine

Atmospheric corrosion protection (corrosion categories as defined by ISO 12944 2:1998)	
Corrosion protection - Tower internal/external	C-2/C-3 (standard) C-4/C-5M (enhanced)
Corrosion protection - Nacelle & spinner fasteners internal/external	C-4/C-4 (standard) C-4/C-5 (enhanced)
Corrosion protection - Auto lube system (option) internal/external	C-3/C-3 (standard) C-5/C-5 (enhanced)
Corrosion protection: hub, bedplate, generator frame, main shaft, pillow block, gearbox, fasteners throughout the tower, nacelle and hub	C-4 (standard & enhanced)

Table 2: Atmospheric corrosion protection

3.1 Operational Limits

Turbine	**5.3-158**
Hub height	101 m tubular steel tower* 120.9 m tubular steel tower*/** 150 m hybrid tower** 161 m hybrid tower**
Wind turbine design standard	* IEC 61400-1, Ed. 3 ** DIBt 2012
Height above sea level	Maximum 1000 m with the maximum standard operational temperature of +40 °C. Above 1000 m, the maximum operational temperature is reduced per DIN IEC 60034 1 (e.g., maximum operational temperature reduced to +30 °C at 2000 m). For installations above 1000 m isolation distances of medium voltage terminals must also be re-evaluated.
Standard Weather Option (STW)	Full power operation from -15 °C to +40 °C, resp. +5 °F to +104 °F. Survival temperature of -20 °C to +50 °C, resp. -4 °F to +122 °F without the grid. Survival means: turbine not in operation including the heat transfer system due to lack of energy supply by the grid.
Cold Weather Option (CW)	Full power operation from -30 °C to +40 °C resp. -22 °F to +104 °F. Survive extreme temperature of -40 °C to +50 °C, resp. -40 °F to +122 °F without the grid. Survive means: turbine not in operation including the heat transfer system due to lack of energy supply by the grid.
Wind class	IEC S + WZ (S)

Table 3: Operational limits