leanwind

Logistic Efficiencies And Naval architecture for Wind Installations with Novel Developments

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Summary description of LEANWIND 8 MW reference turbine

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Version	Date	Description			
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Support by:

1. Introduction

The design of the LEANWIND 8 MW turbine (LW) is primarily based on published data relating to the Vestas V164 – 8 MW turbine [3]. Where data were not available, they were derived by scaling between the NREL and DTU turbines and by using engineering judgement. The LW turbine design has been validated by DNV-GL using their internal turbine Engineering tool Turbine.Architect (TA) [4].

The description of the LW 8MW turbine contained in this document is intended to expedite dissemination. A full description of the turbine and the scaling methodology used to derive its features is the subject of a publication currently under review for the Journal of Wind Engineering and Industrial Aerodynamics.

2. Turbine Description

2.1 General overview

A summary of the main characteristics of the LW reference wind turbine is given in *Table 1*. For reference, details are also provided for the NREL [1] and DTU [2] turbines.

Turbine	NREL	LW	DTU
Rating	5 MW	8 MW	10 MW
Rotor Orientation, Configuration	Upwind, 3 blades	Upwind, 3 blades	Upwind, 3 blades
Rotor Diameter	126 m	164 m	178.3 m
Hub height	90 m	110 m	119 m
Cut-in, Rated, Cut-out wind speed	3 m/s , 11.4 m/s, 25 m/s	4 m/s , 12.5 m/s, 25 m/s	4 m/s , 11.4 m/s, 25 m/s
Rotor speed range	6.9 – 12.1 rpm	6.3 - 10.5 rpm	6 – 9.6 rpm
Hub mass	56,780kg	90,000 kg	105,520 kg
Nacelle mass	240,000 kg	285,000 kg	446,036 kg
Blade mass	17,740 kg	35,000 kg	41,716 kg
Nacelle dimensions (L x W x H)	NA[1]	20 m x 7.5 m x 7.5 m	NA[1]
Tower Mass	347,460 kg	558,000 kg	605, 000 kg
Tower Height	87.6 m	106.3 m	115.6 m
Tower top thickness, diameter	20 mm, 3.87 m	22 mm, 5 m	20 mm, 5.5 m
Tower bottom thickness, diameter	27 mm, 6 m	36 mm, 7 m	38 mm, 8.3 m
Overall Centre of Mass	-0.2 m , 0.0 m 64.0 m	0 m, 0 m, 77 m	NA[1]

Notes: [1] Data not available.

Table 1: Summary of NREL, LW and DTU wind turbine characteristics.

2.2 Power & thrust curves

The power and thrust curves for the LW reference wind turbine are detailed in Figure 1 and Figure 2 respectively. Data are also provided for the NREL and the DTU turbines for reference.

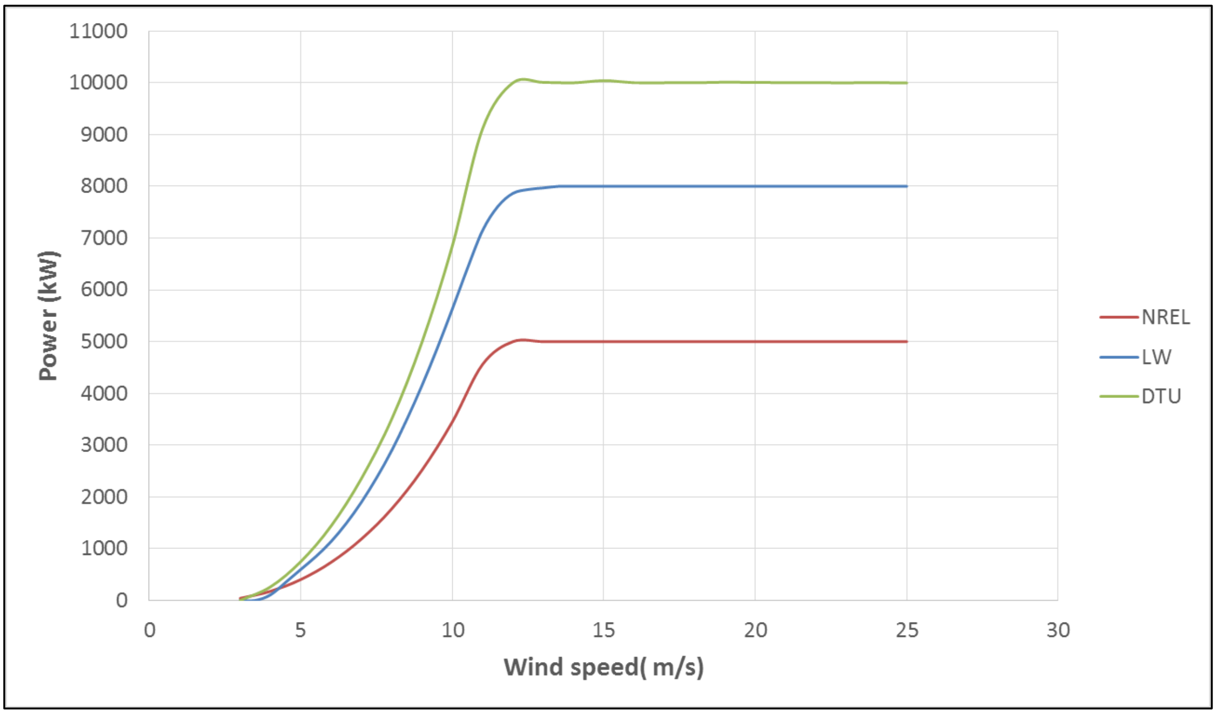


Figure 1: Power curves for the NREL, LW and DTU wind turbines.

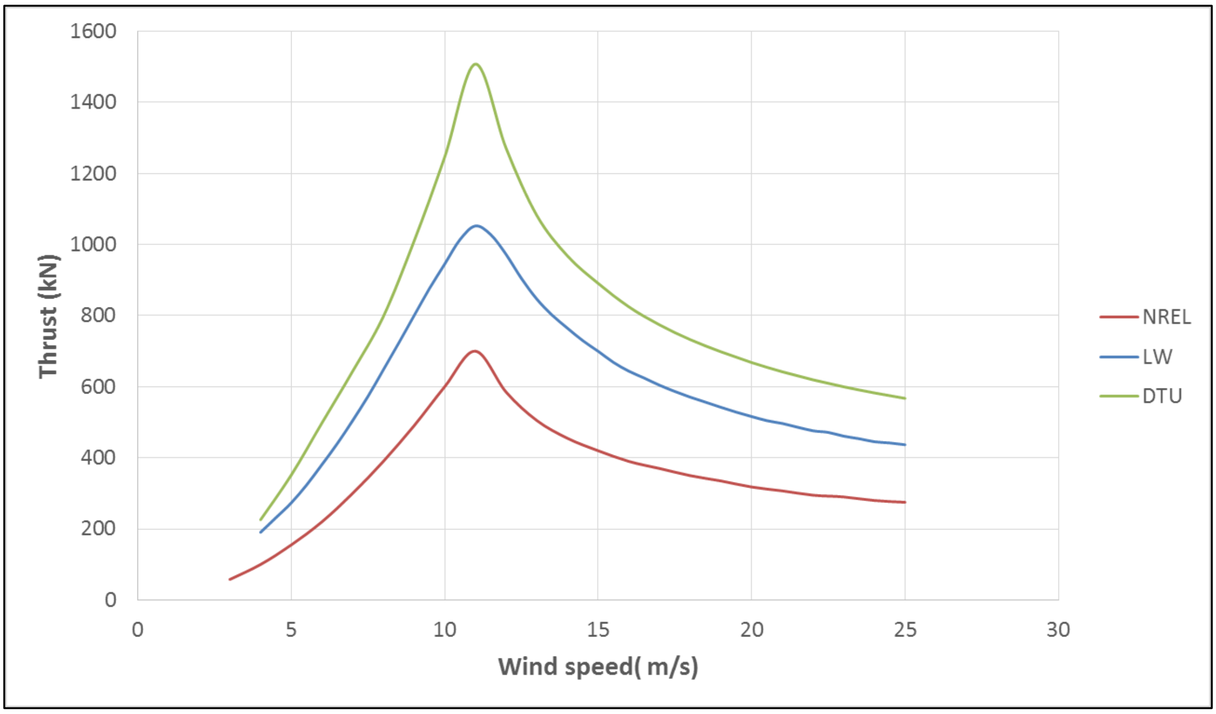


Figure 2: Thrust curves for the NREL, LW and DTU wind turbines.

Power production and thrust data for the LW 8 MW turbine are also presented in *Table 2*.

Wind speed [m/s]	Power [kW]	Cp [-]	Thrust [kN]	Ct [-]
4	110	0.13	190	0.92
4.5	350	0.30	232	0.88
5	600	0.37	273	0.85
5.5	850	0.39	324	0.83
6	1140	0.41	381	0.82
6.5	1490	0.42	440	0.81
7	1900	0.43	505	0.80
7.5	2370	0.43	573	0.79
8	2900	0.44	648	0.78
8.5	3500	0.44	723	0.77
9	4155	0.44	800	0.76
9.5	4870	0.44	876	0.75
10	5630	0.44	945	0.73
10.5	6420	0.43	1014	0.71
11	7150	0.42	1052	0.67
11.5	7610	0.39	1028	0.60
12	7865	0.35	972	0.52
12.5	7940	0.31	905	0.45
13	7970	0.28	847	0.39
13.5	8000	0.25	801	0.34
14	8000	0.23	765	0.30
14.5	8000	0.20	730	0.27
15	8000	0.18	700	0.24
15.5	8000	0.17	668	0.22
16	8000	0.15	644	0.19
16.5	8000	0.14	624	0.18
17	8000	0.13	604	0.16
17.5	8000	0.12	587	0.15
18	8000	0.11	571	0.14
18.5	8000	0.10	557	0.13
19	8000	0.09	542	0.12
19.5	8000	0.08	528	0.11
20	8000	0.08	516	0.10
20.5	8000	0.07	505	0.09
21	8000	0.07	497	0.09
21.5	8000	0.06	486	0.08
22	8000	0.06	476	0.08
22.5	8000	0.05	472	0.07
23	8000	0.05	461	0.07
23.5	8000	0.05	454	0.06
24	8000	0.04	445	0.06
24.5	8000	0.04	442	0.06
25	8000	0.04	437	0.05

Note: Cp – Power coefficient.
Ct – Thrust coefficeint.

Table 2: Summary of the LW 8 MW Power and Thrust Curves.

2.3 Design loads

The design loads incident on the structure will be dependent on the support structure design and the metocean conditions present at the site under consideration. Given time and resource limitations, it is not possible to devise a full description of the LW 8 MW turbine control strategy which would allow the use of dynamic aero-elastic analysis software packages such as FAST [5]. Therefore, in this report we will employ the extreme tower top thrust load calculated by the DNV-GL TA software.

The TA load predictions for the NREL, LW and DTU turbines are given in *Table 3*.

Turbine	Approximated maximum tower top thrust (kN)
NREL 5 MW	1619
LW 8 MW	2743
DTU 10 MW	3242

Note: The values given in this table include safety factors.

Table 3: Summary of the maximum tower top thrusts estimated for the NREL, LW and DTU turbines [4].

2.4 Dimensions and weights

The dimensions and weights of the key componets of the LW turbine are detailed in the following subsections.

2.4.1 Blade

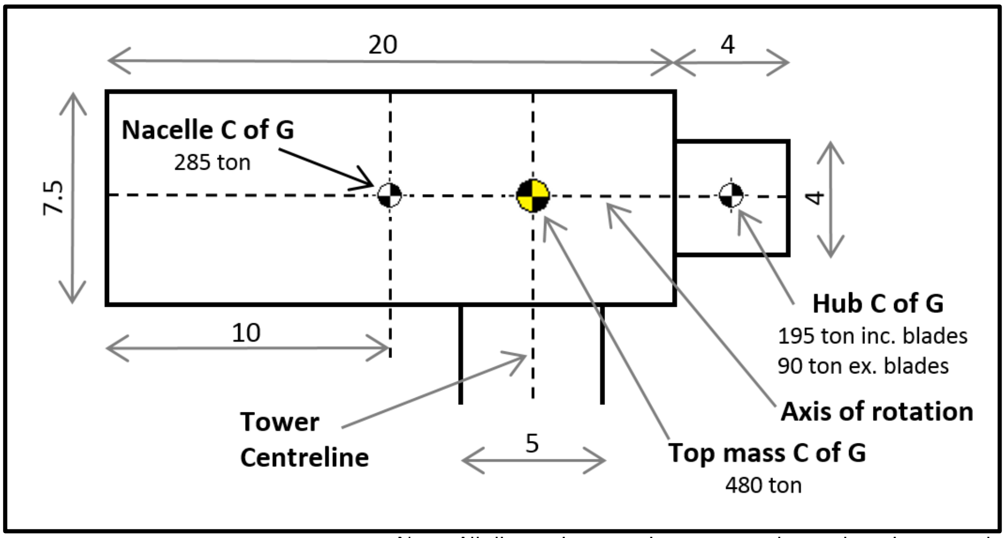
The key dimensions for the LW turbine's blades are presented in *Table 4*. These values have been scaled from the values presented for the NREL turbine in [1] .

Length (w.r.t Root along pre cone axis)	80 m
Mass	35,000 kg
C of G (w.r.t Root along pre cone axis)	25.8 m
Second Mass Moment of Inertia	37,398,334 kg.m^2
First Mass Moment of Inertia	915,514 kg.m

Table 4: LW turbine blade properties.

2.4.2 Nacelle & Hub

The mass distribution of the LW turbine nacelle and hub are given in *Figure 3.*



Note: All dimensions are in metres unless otherwise stated.

Figure 3. Top mass distribution for the LW turbine.

The dimesions of the nacelle are 20 m x 7.5 m x 7.5 m. The hub is taken to be a cylinder of height 4 m and diameter 4 m.

2.4.3 Tower

DNV-GL have provided a tower description for the LW turbine based on the TA analysis. The properties of this tower are summarised in Table 5.

Height	106.3 m
Mass	558,000 kg
C of G (above base)	46 m

Table 5. LW turbine tower properties.

Additional details relating to the LW tower are given in Figure 4 and Table 6.

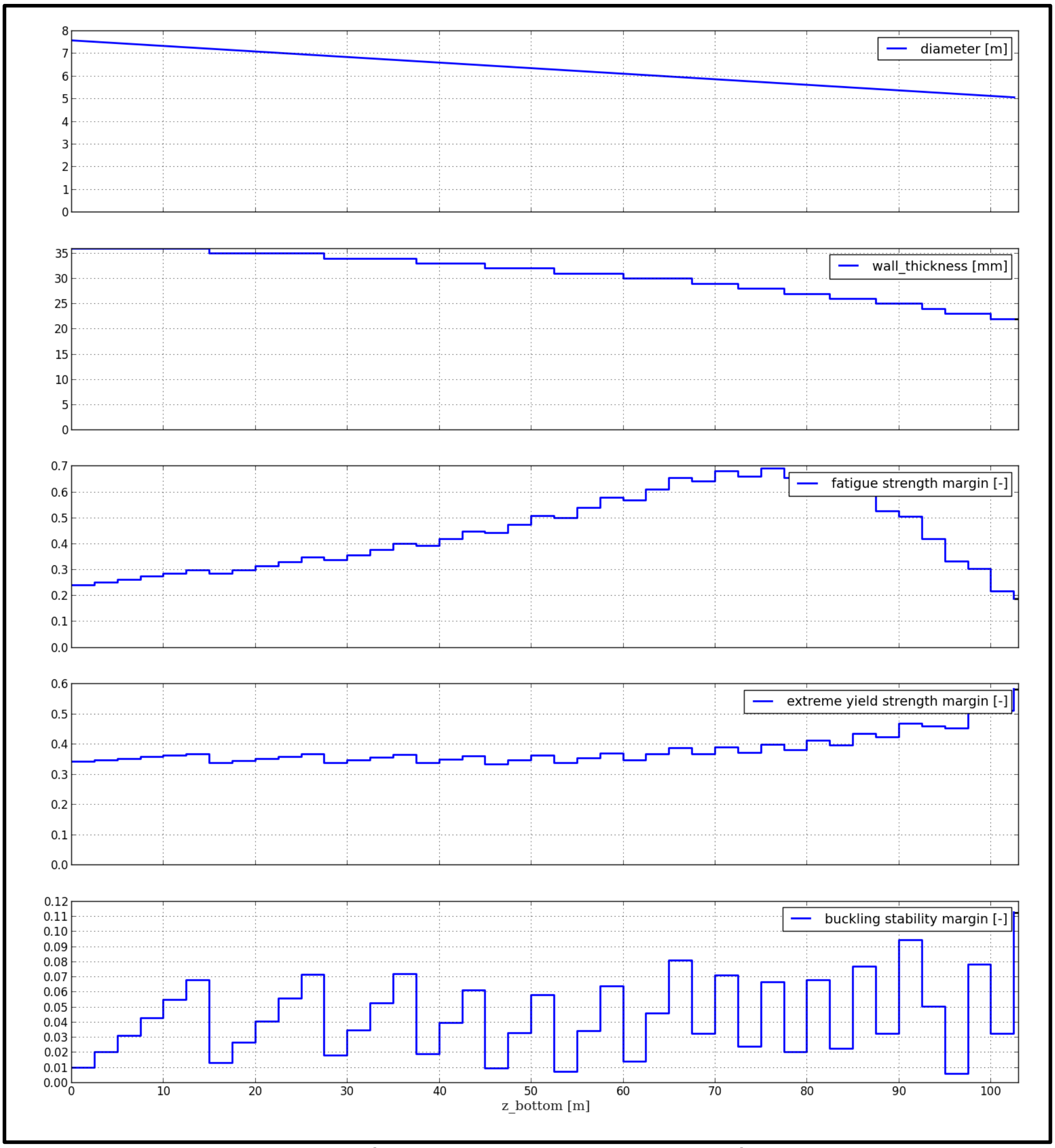


Figure 4. LW turbine design parameters [4].

z_can_bottom [m]	z_can_top [m]	D_can_outer_ bottom [m]	D_can_outer_ top [m]	can_length [m]	wall thickness [mm]	can mass [kg]
0.0	2.5	7.690	7.628	2.5	36	16919
2.5	5.0	7.628	7.566	2.5	36	16782
5.0	7.5	7.566	7.504	2.5	36	16645
7.5	10.0	7.504	7.442	2.5	36	16507
10.0	12.5	7.442	7.380	2.5	36	16370
12.5	15.0	7.380	7.319	2.5	36	16233
15.0	17.5	7.319	7.257	2.5	35	15650
17.5	20.0	7.257	7.195	2.5	35	15517
20.0	22.5	7.195	7.133	2.5	35	15383
22.5	25.0	7.133	7.071	2.5	35	15250
25.0	27.5	7.071	7.009	2.5	35	15116
27.5	30.0	7.009	6.947	2.5	34	14557
30.0	32.5	6.947	6.885	2.5	34	14427
32.5	35.0	6.885	6.824	2.5	34	14297
35.0	37.5	6.824	6.762	2.5	34	14168
37.5	40.0	6.762	6.700	2.5	33	13627
40.0	42.5	6.700	6.638	2.5	33	13501
42.5	45.0	6.638	6.576	2.5	33	13375
45.0	47.5	6.576	6.514	2.5	33	13249
47.5	50.0	6.514	6.452	2.5	32	12728
50.0	52.5	6.452	6.390	2.5	32	12606
52.5	55.0	6.390	6.329	2.5	32	12484
55.0	57.5	6.329	6.267	2.5	31	11977
57.5	60.0	6.267	6.205	2.5	31	11859
60.0	62.5	6.205	6.143	2.5	31	11741
62.5	65.0	6.143	6.081	2.5	30	11249
65.0	67.5	6.081	6.019	2.5	30	11135
67.5	70.0	6.019	5.957	2.5	30	11020
70.0	72.5	5.957	5.895	2.5	29	10544
72.5	75.0	5.895	5.834	2.5	29	10434
75.0	77.5	5.834	5.772	2.5	28	9969
77.5	80.0	5.772	5.710	2.5	28	9862
80.0	82.5	5.710	5.648	2.5	27	9408
82.5	85.0	5.648	5.586	2.5	27	9305
85.0	87.5	5.586	5.524	2.5	26	8863
87.5	90.0	5.524	5.462	2.5	26	8764
90.0	92.5	5.462	5.400	2.5	25	8333
92.5	95.0	5.400	5.339	2.5	25	8238
95.0	97.5	5.339	5.277	2.5	24	7818
97.5	100.0	5.277	5.215	2.5	24	7727
100.0	102.5	5.215	5.153	2.5	23	7318
102.5	105.0	5.153	5.091	2.5	22	6918
105.0	106.0	5.091	5.066	1	22	2744

Table 6. Tower can data. Mass of flanges are not included in this table [4].

3. References

[1] Jonkman, J., et al., "Definition of a 5-MW Referecne Wind Turbine for Offshore Systems Development". NREL, Colorado, 2005.

[2] Bac, C., et al., "Description of the DTU 10 MW Reference Wind Turbine". DTU Wind Energy Report-I-0092, 2013.

[3] Vestas, "Offshore V164-8.0 MW, V112-3.3 MW". Vestas Wind Systems, Available online: [http://pdf.directindustry.com/pdf/vestas/offshore-v164-80-mw-v112-33-mw/20680-310439.html]

[4] Blonk, L., Haans, W., "Technical note: Leanwind 8 MW benchmark to TES TA data". DNV-GL – Energy, 28 May 2015.

[5] Jonkman, J. M., "Dynamics Modeling and Loads Analysis of an Offshore Floating Wind Turbine". Technical Report NREL/TP-500-41958, 2007