nabla wind hub

eta
WIND BLADES SOLUTIONS

eTa4x

TECHNICAL SPECIFICATIONS

RE-BLADING: THE LIFE EXTENSION SOLUTION

CONTENTS

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GENERAL DATA FOR THE ROTOR BLADES eTa4x

Designer: *ECN (Energy Center Netherland)*
Gurit (Structural Design)

Certifications: *Germanischer Lloyd*

Design class: *A1*

Rotor configuration:

Number of blades in rotor:	*3*
Hub connection:	*T-bolts*
Placement of rotor:	*Upwind*
Power control:	*Pitch*

Dimensions:

Blade length:	*23.9*	*m*
Max chord:	*1,836*	*m*
Blade weight (total – no bolt):	*1,300*	*kg*
Direction of rotation (downwind):	*Clockwise*	
Self-starting:	*Yes*	

Installation dimensions:

Bolt size:	*M20*
Number of bolts:	*60*

Materials used

Skin, spar and root:	*E-glass epoxy resin, carbon fibre, glass fibre*
Top coating:	*Top Coat Basf Relest Wind*

Technology: *Infusion / heated mouldings*

(Full data available upon request)

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eTa
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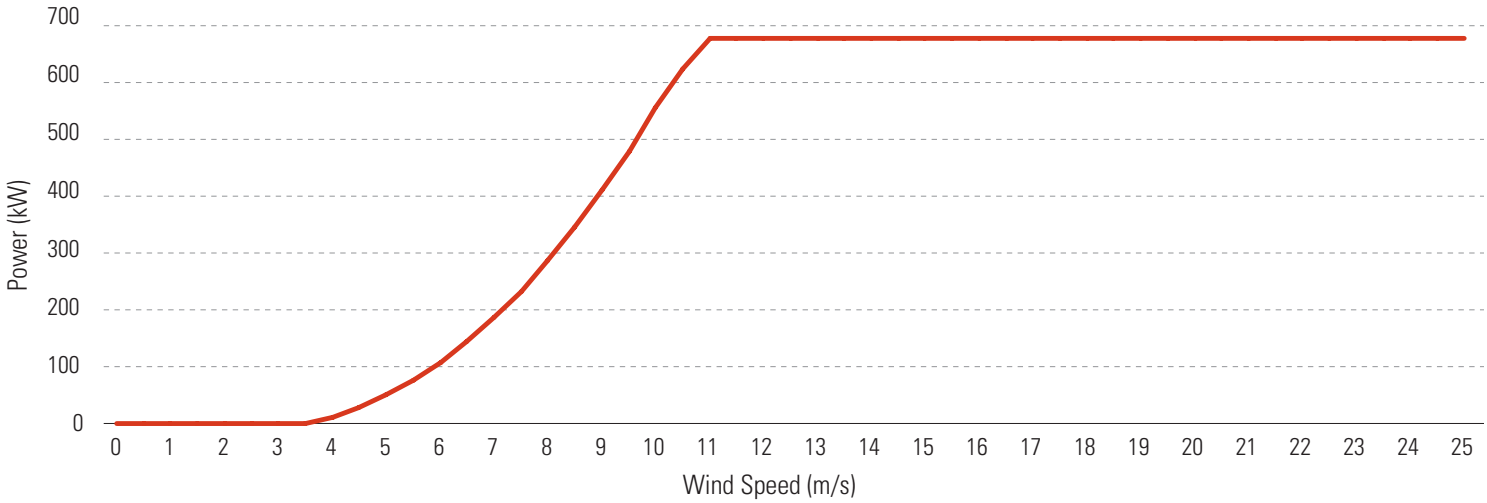
SPECIFICATIONS FOR ROTOR BLADE eTa4x-660KW

Theoretical Power Curve (18% turbolence)

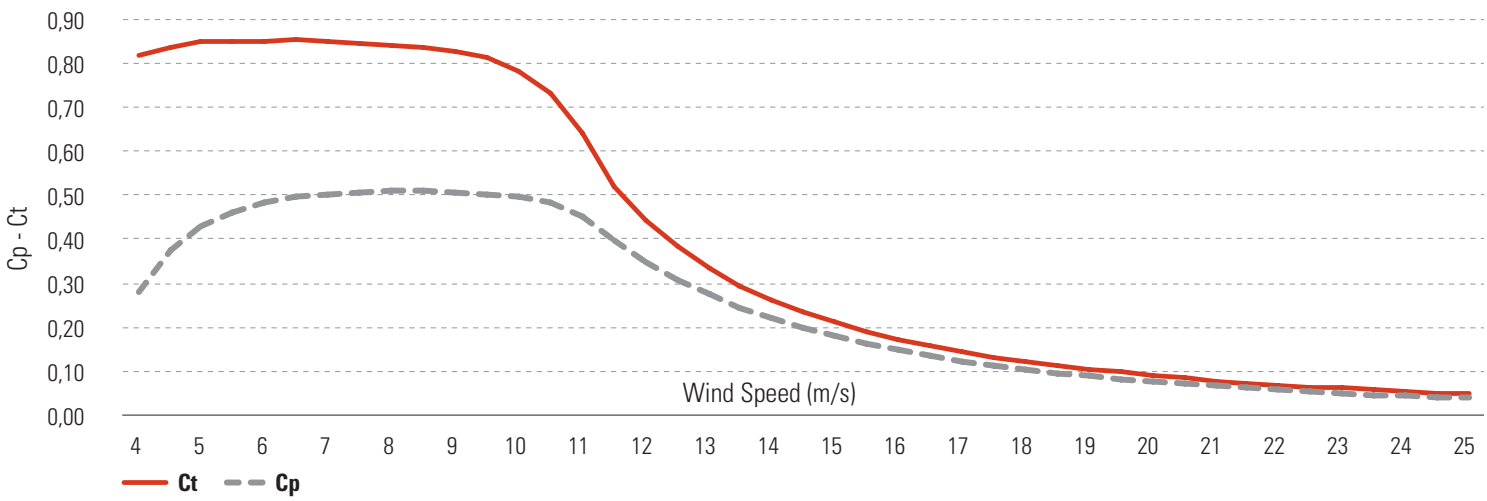
The eTa4x blade has been specifically designed for the re-blading of 600-800 kW turbine range. Its features allow the blade to be adapted to several turbine models.

Electric Power of a 660kW turbine equipped with eTa4X							
Wind Speed	**Air density (Kg / m3)**						
	1060	1090	1120	1150	1180	1210	1225
[m/s]	*[kW]*	*[kW]*	*[kW]*	*[kW]*	*[kW]*	*[kW]*	*[kW]*
4,0	7,3	7,8	8,2	8,7	9,2	9,7	10,0
4,5	22,6	23,5	24,4	25,4	26,3	27,2	27,7
5,0	41,3	42,8	44,2	45,7	47,1	48,6	49,3
5,5	63,7	65,8	67,8	69,9	72,0	74,1	75,1
6,0	90,0	92,8	95,7	98,5	101,3	104,2	105,6
6,5	120,6	124,3	128,0	131,7	135,4	139,1	140,9
7,0	155,7	160,4	165,1	169,8	174,5	179,2	181,5
7,5	195,6	201,4	207,2	213,0	218,9	224,7	227,6
8,0	240,4	247,5	254,6	261,6	268,7	275,8	279,4
8,5	290,2	298,7	307,2	315,7	324,2	332,7	337,0
9,0	345,0	355,1	365,1	375,2	385,2	395,3	400,3
9,5	404,3	416,0	427,8	439,5	451,2	462,9	468,8
10,0	466,8	480,3	493,8	507,3	520,8	534,3	541,0
10,5	526,5	541,7	556,9	572,0	587,2	602,4	610,0
11,0	573,4	589,9	606,4	623,0	639,5	656,0	660,0
11,5	619,5	637,3	655,1	660,0	660,0	660,0	660,0
12 - 25	660,0	660,0	660,0	660,0	660,0	660,0	660,0

Power Curve air density: 1225 Kg / m3



Curves Cp and Ct



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FIELD-TEST OUTCOMES CERTIFIED BY DEWI: 20% AEP INCREASE

The aim of the field test had several different objectives:

- *To measure loads and "stress" on the turbine given the new component (the rotor equipped with the eTa4x replacing the original blades)*
- *To identify the needed adaptations to the pitching of the turbine*
- *To verify if the power curve of the eTa4x was able to deliver a higher AEP than the original blades*

With regard to the last objective, the following table summarises the comparison between the real power curve measured on-site by DEWI during the field test and the original power curve.

In this case example, in order to show the real output enhancement, we have replicated the simulations carried out with our client, therefore adopting the site specific Weibull as assessed by DEWI. ***The AEP calculated with the eTa4x delivers around 20% more energy than the original one, when including aging degradation recovery.***

This result was made possible due to two main factors:

- *The use of airfoils and innovative shape which allowed eTa Blades to use a longer blade (1m longer than the original blade) with no additional loads or "stress" on the turbine*
- *A blade design optimized for low wind sites*

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Real Power Curve Comparison = does not take into account aging degradation

Wind Speed	eTa4x	600kW	Site Weibull	AEP eTa4x	AEP 600kW	Delta AEP
[m/s]	*[kW]*	*[kW]*	*[kW]*	*[kWh]*	*[kWh]*	*[kWh]*
4	11,9	2,9	1.225,7	14.585,8	3.554,5	11.031,3
5	59,8	43,8	1.183,5	70.773,3	51.837,3	18.936,0
6	125,2	96,9	950,0	118.940,0	92.055,0	26.885,0
7	215,6	166,0	734,5	158.358,2	121.927,0	36.431,2
8	312,6	252,0	554,0	173.180,4	139.608,0	33.572,4
9	406,3	348,0	388,8	157.969,4	135.302,4	22.667,0
10	508,3	441,0	285,0	144.865,5	125.685,0	19.180,5
11	568,2	515,0	206,7	117.446,9	106.450,5	10.996,4
12	589,0	562,0	142,8	84.109,2	80.253,6	3.855,6
13	596,0	585,0	93,3	55.606,8	54.580,5	1.026,3
14	598,0	595,0	73,7	44.072,6	43.851,5	221,1
15	600,0	599,0	41,8	25.080,0	25.038,2	41,8
16	600,0	600,0	25,7	15.420,0	15.420,0	-
			Total AEP	**1.180.408,2**	**995.563,5**	**184.844,7**
			% Difference			**18,6%**

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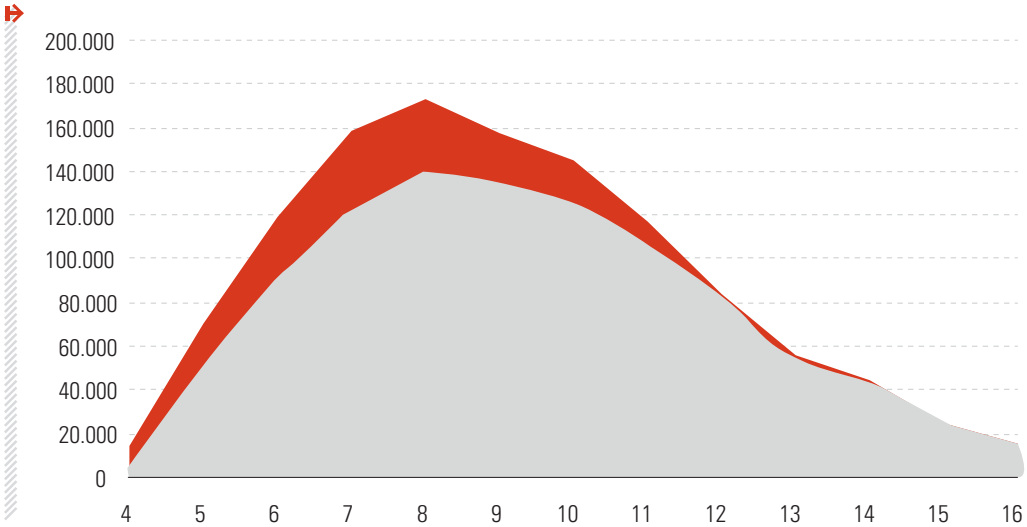
In more detail, the following chart and table summarizes the total AEP at each wind speed recorded during the test – note that, of course, the limit of the turbine is its nominal power, therefore above certain wind speeds the spread of the eTa4x diminishes while, instead, the most relevant enhancements are visible (in red) in the mid-speeds.

AEP Comparison

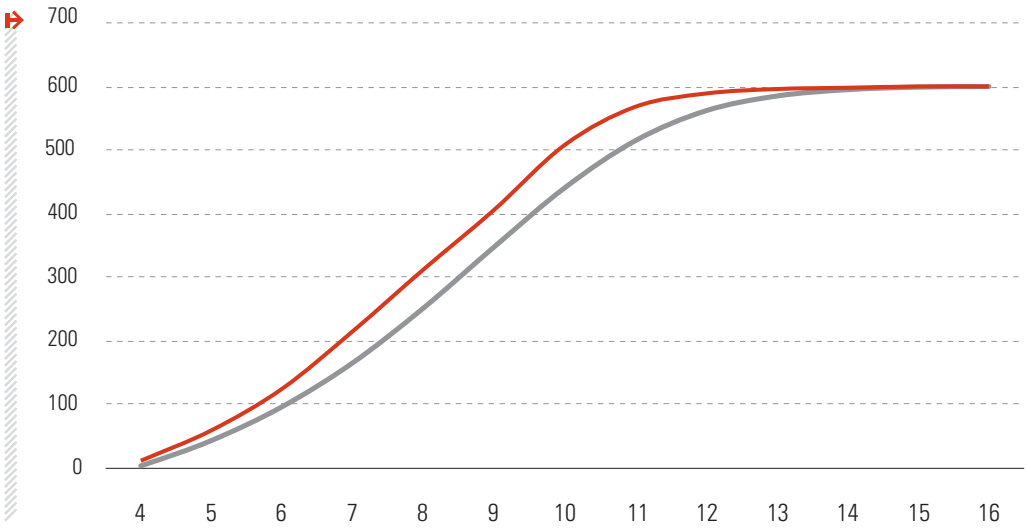
Wind in m/s	AEP eTa4x	AEP 600kW
4	14.585,83	3.554,53
5	70.773,30	51.837,30
6	118.940,00	92.055,00
7	158.358,20	121.927,00
8	173.180,40	139.608,00
9	157.969,44	135.302,40
10	144.865,50	125.685,00
11	117.446,94	106.450,50
12	84.109,20	80.253,60
13	55.606,80	54.580,50
14	44.072,60	43.851,50
15	25.080,00	25.038,20
16	15.420,00	15.420,00

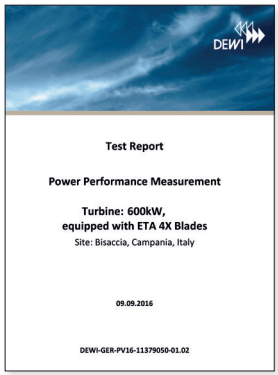


The result is provided by the shape of the Power Curve which has been designed to improve the output of the turbines between 5 and 9 m/s specifically, which represents the vast majority of the wind distribution in the wind-farms. In the following picture, the eTa4x power curve (in red) is compared with the original one (in gray).

Power Curve Comparison

Wind in m/s	eTa4x	600kW
4	11,90	2,90
5	59,80	43,80
6	125,20	96,90
7	215,60	166,00
8	312,60	252,00
9	406,30	348,00
10	508,30	441,00
11	568,20	515,00
12	589,00	562,00
13	596,00	585,00
14	598,00	595,00
15	600,00	599,00
16	600,00	600,00





Test Report

Power Performance Measurement

Turbine: 600kW,
equipped with ETA 4X Blades
Site: Bisaccia, Campania, Italy

09.09.2016

DEWI-GER-PV16-11379050-01.02

EXTRACT FROM THE DEWI TEST REPORT

Service:	Power performance measurement based on the procedure DEWI-06-PV, accredited by IEC 17025:2005
Site:	Bisaccia, Campania, Italy
Turbine No.:	IP_BS036
Measuring Period:	27.11.2015 – 17.03.2016
Order No.:	11379050
Project No.:	4787545360
Station No.:	767
Standards:	IEC 61400-12-1 (2005-12) [3] MEASNET Power Performance Measurement Procedure (Version 5), December 2009 [1]
Client:	eTa s.r.l. Via A. Lampredi, 81 57121 Livorno Italy
Testing laboratory	UL International GmbH DEWI Ebertstr. 96 26382 Wilhelmshaven Germany
Remarks:	The test results documented in this report relate only to the items tested. This document may not be reproduced other than in full except with the permission of UL International GmbH.

DAkkS Deutsche Akkreditierungsstelle D-PL-11095-01-00

UL International GmbH
DEWI
Wilhelmshaven, Germany, 09.09.2016

Expert in charge

M. Eichfeld

Dipl.-Ing. U. Eichfeld
Expert

Wilhelmshaven DEWI UL International GmbH

Approved by

H. Mellinghoff

Dipl.-Phys. H. Mellinghoff
Head of Expert Group

5.1.1 Scatter Data of Power Curve ($\rho_{measured}$ = 1.15 kg/m³)

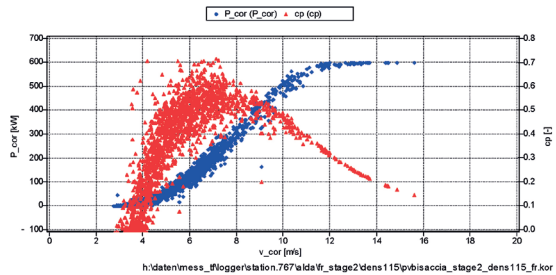


Fig. 5.1: Scatter data of net electric power and power coefficient versus wind speed at hub height. WT equipped with blades ETA 4X. Ten minutes averages for 2154 (359.00 hours, database A) are shown (anemometer of type Thies First Class Advanced 4.3351.00.000, effective rotor area of 1883.43 m²). The wind speed data are normalized to measured air density 1.15 kg/m³. Sampling rates: 1 Hz (meteorological signals), 100 Hz (WT-Signals).

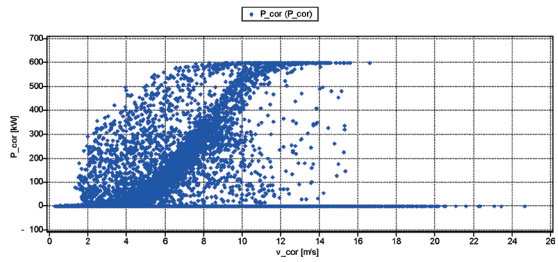


Fig. 5.2: Informative scatter plot of net electric power versus wind speed at hub height for the unfiltered database. WT equipped with blades ETA 4X. Ten minutes averages are shown (used data sets: 13042, anemometer type: Thies First Class Advanced 4.3351.00.000). The data are normalized to standard meteorological conditions (air density 1.225 kg/m³). Sampling rates: 1 Hz (meteorological signals), 100 Hz (WT-Signals).

The measured power curve has been evaluated for a bin width of 0.5 m/s (see section 5.1), as required by IEC 61400-12-1 [3]. As the wind speed distribution as well as the power curve provided by the WT manufacturer [12] are defined for a bin width of 1 m/s (see Tab. 8.2), the measured power curve has been re-calculated for a bin width of 1 m/s. Furthermore the average values per bin have been shifted to integer wind speed values (see Tab. 8.3), as this is the case for the wind speed table (see Tab. 8.2), too.

Nominal Wind Speed	Measured Power Curve (WT equipped with blades ETA 4X)		WT manufacturer provided Power Curve
	Power	Data	Power
[m/s]	[kW]	[-]	[kW]
3	-1.81	433	not defined
4	11.86	466	1.9
5	54.61	397	40.4
6	117.98	346	90.1
7	203.94	259	155
8	297.29	75	235
9	391.59	56	327
10	492.09	51	419
11	548.16	16	497
12	588.98	27	550
13	595.76	14	580
14	599.07	9	593
15	-	-	598
16	-	-	600
17	-	-	600
18	-	-	600
19	-	-	600
20	-	-	600
21	-	-	600
22	-	-	600
23	-	-	600
24	-	-	600
25	-	-	600

Tab. 8.3: Measured power curve (bin width: 1 m/s, air density: 1.15 kg/m³, bin center shifted to integer values, WT equipped with blades ETA 4X) and WT manufacturer (Vestas) provided power curve [12] which have been used for the AEP comparison. Assumed required completeness criteria for each wind speed bin: Minimum 6 data sets per bin for the measured power curve.

The power curves as given Tab. 8.3 and the wind speed distribution (see Tab. 8.2) have been used for the calculation of the AEP (see Tab. 8.4).

Wind speed	NWD	$Power_{measured}$	$AEP_{measured}$	$Power_{WTmanufacturer\ provided}$	$AEP_{WTmanufacturer\ provided}$	Difference ($AEP_{measured} - AEP_{WTmanufacturer\ provided}$)
[m/s]	[hours]	[kW]	[MWh]	[kW]	[MWh]	[MWh]
0	121.2	0 [1]	0	0 [1]	0	0.00
1	566.3	0 [1]	0	0 [1]	0	0.00
2	991.8	0 [1]	0	0 [1]	0	0.00
3	1138.3	-1.81	-2.06	0 [1]	0	-2.06
4	1225.7	11.86	14.54	1.9	2.33	12.21
5	1183.5	54.61	64.63	40.4	47.81	16.82
6	950.0	117.98	112.08	90.1	85.60	26.49
7	734.5	203.94	149.79	155	113.85	35.95
8	554.0	297.29	164.70	235	130.19	34.51
9	388.8	391.59	152.25	327	127.14	25.11
10	285.0	492.09	140.25	419	119.42	20.83
11	206.7	548.16	113.30	497	102.73	10.57
12	142.8	588.98	84.11	550	78.54	5.57
13	93.3	595.76	55.58	580	54.11	1.47
14	73.7	599.07	44.15	593	43.70	0.45
15	41.8	599.07 *	25.04	598	25.00	0.04
16	25.7	599.07 *	15.40	600	15.42	-0.02
17	14.7	599.07 *	8.81	600	8.82	-0.01
18	10.2	599.07 *	6.11	600	6.12	-0.01
19	5.7	599.07 *	3.41	600	3.42	-0.01
20	3.3	599.07 *	1.98	600	1.98	0.00
21	2.0	599.07 *	1.20	600	1.20	0.00
22	1.0	599.07 *	0.60	600	0.60	0.00
23	0.0	599.07 *	0.00	600	0.00	0.00
24	0.0	599.07 *	0.00	600	0.00	0.00
25	0.0	599.07 *	0.00	600	0.00	0.00

*: Extrapolation according to IEC 61400-12-1 [3]
[1]: Assumption by DEWI

Tab. 8.4: Comparison of AEP of the measured power curve (WT equipped with blades ETA 4X) and the WT manufacturer provided power curve, calculated by means of multiplication of hours of NWD and power value (bin width: 1 m/s, air density: 1.15 kg/m³).

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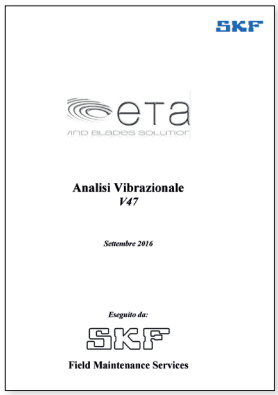
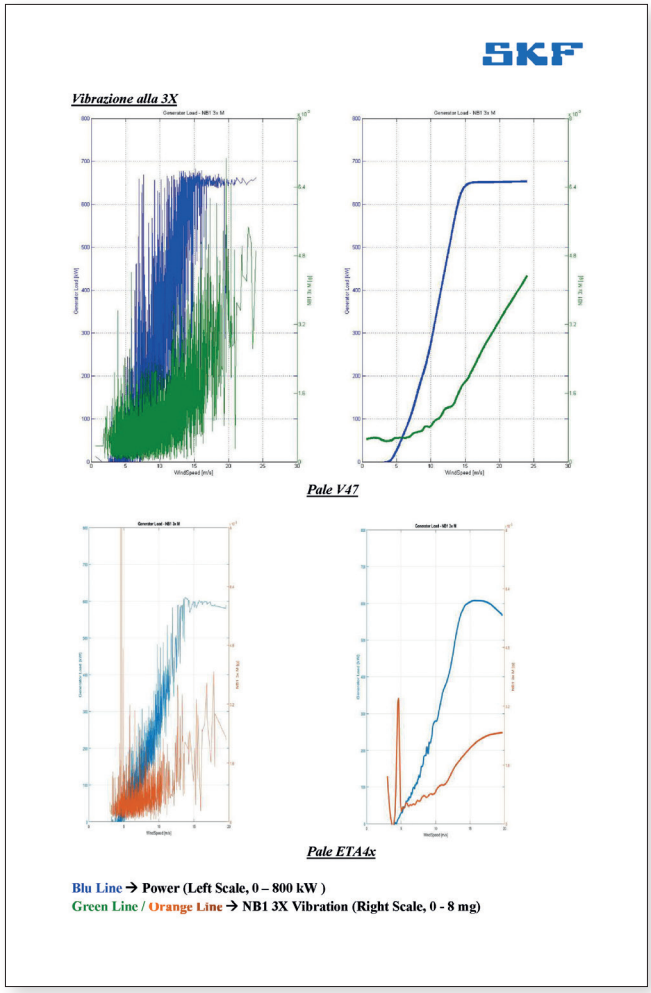
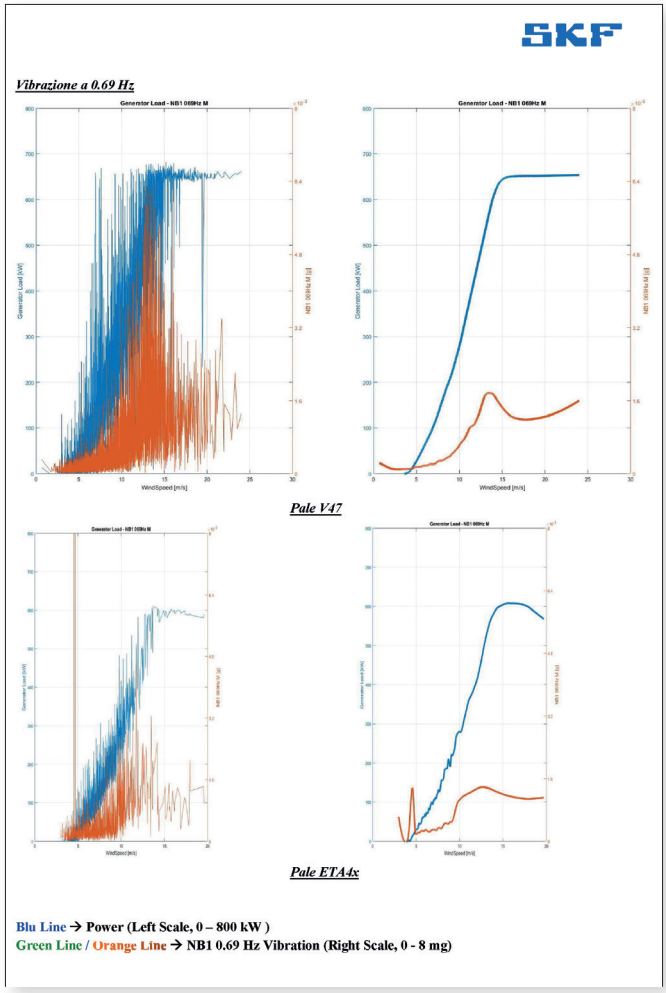


EXTRACT FROM THE SKF TEST REPORT

Comparison of frequencies / loads on the nacelle





Conformity Statment / Design Assessment DNV/GL

DNV·GL

CONFORMITY STATEMENT

Statement No.: ADA-GL-IV-1-03269-0
Issued: 2017-09-07

Issued for:

A-Design Assessment

of

Rotor blade

ETA 24m

Specified in Annex 1

Issued to:

eTa wind blade solutions s.r.l.

Via Papiria 92
61032 Fano, Italy

According to:

GL-IV-1: GL Rules and Guidelines - IV Industrial Services - Part 1 - Guideline for the Certification of Wind Turbines, Edition 2010

Based on the document:
CR-ADA-GL-IV-1-03269-0 A-Design Assessment, Certification Report dated 2017-09-07

Changes of the design are to be approved by DNV GL.

Hamburg, 2017-09-07
For DNV GL Renewables Certification

ppa. Mike Wöbbeking
Head of Certification Body

DAkkS Deutsche Akkreditierungsstelle D-ZE-11053-01-00
By DAkkS according DIN EN IEC/ISO 17065 accredited Certification Body for products. The accreditation is valid for the fields of certification listed in the certificate.

Hamburg, 2017-09-07
For DNV GL Renewables Certification

Markus Selinka

i.A. Markus Selinka
Senior Engineer Rotor Blades

DNV·GL

CONFORMITY STATEMENT – ANNEX 1

Blade Description

Length	23.9 m
Root flange outside diameter	0.940 m
Maximum chord	1.837 m
Maximum twist	21.0 deg
Material General	Glass fiber reinforced epoxy resin and SAN foam
Material Spar Cap	Carbon fiber reinforced epoxy resin
Blade mass	1,437 kg (± 2%)
Centre of gravity (from root)	16.00 m
Blade prebending at tip	0.0 m
1st flapwise natural frequency	1.34 Hz (± 5%)
2nd flapwise natural frequency	2.45 Hz (± 5%)
1st edgewise natural frequency	3.45 Hz (± 5%)
2nd edgewise natural frequency	7.65 Hz (± 5%)
Number of inserts	60
Bolt circle diameter	0.920 m
Bushing type	M20 Cross Bolts

Design loads

Design lifetime	20 years
Design load envelope	GU4507-4003 Rev. A

Environmental conditions

Minimum design temperature	-20°C
Maximum design temperature	+50°C

Interface to other components or systems

- The present assessment covers the blade including blade root with cross bolts and tension bolts.
- For every specific wind energy converter type which is intended to be equipped with ETA 24m rotor blades, the tower clearance has to be calculated and verified. Under consideration of the load case submitted for tip to tower clearance, a clearance between the unloaded rotor blade and the outer tower surface of 4.7 m is required.
- The lightning protection system is not covered in this assessment.
- Manuals are not covered in this assessment.
- Aerodynamic devices are not covered in this assessment.

The accredited certification body is Germanischer Lloyd Industrial Services GmbH, Brooktorkai 18, 20457 Hamburg.
DNV GL Renewables Certification is the trading name of DNV GL's certification business in the renewable energy industry.

Life-Extension and Performance Improvement methodologies, end-to-end solutions. Launched by eTa Blades and Nabla Wind Power, a network of Independent Technology and Service Providers aiming at maximising Wind-Farmers' IRRs through the optimal combination of: Life-Extension, Power Production Upgrades, Long-Term Tailored Maintenance, Damage Mitigation Upgrades.

www.windgainhub.com

Wind Blades in a Circular Economy. The Green arm of eTa Blades dealing with reuse, re-shape and re-cycle for a sustainable manufacturing process and wind resource exploitation.

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