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# Lely Aircon LA30 Wind turbine

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## Summary Details for Performance, Duration and Acoustic Measurements

*Lely Aircon 30 Wind Turbine* UK MCS Certification Summary

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innovators in agriculture

Lely Industries N.V.

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## 1. List of included Amendments

2015-04-17

- Initial release (11 pages)
- Author: Oliver Hahn Lely Aircon B.V. (Technical Service and Support)

| Revision | Author | Number of pages | Date |
|---|---|---|---|
| Rev. 1 | Oliver Hahn | 11 | 05.10.15 |
| Rev. 2 | Oliver Hahn | 14 | 26.11.15 |
| Rev. 3 | Oliver Hahn | 15 | 21.01.16 |
| | | | |

- Name of authorization (created, approved and released)
  For all documents applicable
  oh: Oliver Hahn
  gr: Gerriet Janssen
  rh: Rene Hackmann
  vr: Willibald de Vries
  br: Kai-Uwe Broek

## 2. Introduction

This document summarizes the results of UK MCS product certification conducted on a Lely Aircon 30 wind turbine.

The tests, which are summarized in this report, are:

- the *Duration Test* carried out by Ingenieurbüro Dr. Ing. Dieter Frey
- the *Power and Performance Test* carried out by Ingenieurbüro Dr. Ing. Dieter Frey
- and the *Report of Acoustical Emissions* carried out by GL Garrad Hassan Deutschland GmbH

(Detailed information to the Report numbers and the entities involved, can be found in chapter 9: Reference Reports)

## 3. General information

The list below gives an overview over the general turbine specifications of the Lely Aircon LA30.

- Manufacturer: Lely Aircon B.V.
- Model: LA30
- Reference power: 27,2 kW at 11 m/s
- Rated power: 29,8 kW at 12 m/s
- Maximum output power: 34,2 kW at 16 m/s
- Rotor diameter: 13,12m
- Swept area: 135,1m²
- Switching on wind speed: 3,5 m/s
- Nominal wind speed: 12 m/s
- Switching off wind speed: 25 m/s (10 min average), Peak: 32 m/s
- Survival wind speed: 59,5 m/s
- Rotor rotations per minute: 35-68rpm
- Quantity of rotor blades: 3
- Up/downwind turbine: Upwind
- Design: HAWT
- Tower top weight: 2544kg
- Direction of rotation: clockwise
- Designed durability: 20years
- Small wind turbine class: IEC II A
- Remote control: via GSM or Internet
- Maximum output voltage: 400 VAC/50 Hz
- Maximum output current: 50A per phase
- Declared sound power level at 8m/s: 94,5dB (Report No. GLGH-4286 14 12454 293-A-0004-A)
- Rotor speed regulation: Active stall, controller aided overload regulation
- Brake systems: Hydraulic disc brake, generator overload regulation, and tip-brake system
- Wind tracking: Active controller aided wind tracking
- Supervision: Micro controller
- Generator: Permanent excited synchronous machine
- Operating temperature range: -20°C to +50°C

## 4. Tested turbine configuration

This chapter shows the turbine configuration as verified by the test organization in the duration test:

**Model name:** LA30

**Serial number:** LA30A001

**Support structure:** Lattice tower

**Hub height:** 26,5m

**General description of main components:**

- Rotor speed regulation: Active stall, controller aided overload regulation
- Brake systems: Hydraulic disc brake, generator overload regulation, and tip-brake system
- Wind tracking: Active controller aided wind tracking
- Supervision: Micro controller
- Generator: Permanent excited synchronous machine

**Rotor diameter (m):** 13,12m

**Swept area (m2):** 135,1m²

**Number of blades:** 3

**Upwind or downwind rotor:** Upwind

**Design:** HAWT

**Direction of rotation**: clockwise

**Cut-in wind speed (m/s):** 3,5m/s

**Cut-out wind speed (m/s):** 25m/s (10 min average) Peak 32 m/s

**Observed max. 3 s gust during duration test (m/s):** 27,48m/s

**Power form:** effective power of 29,8kW (400V~, 3 phases)

**Observed ambient temperature range during duration test (°C):** -4°c to +28°C

The picture below shows the tested turbine with the serial number LA30A001 in 26810 Ihrhove, Germany.

Figure 1: Tested wind turbine in 26810 Ihrhove, Germany

## 5. Power Curve

Table 1, 2 and Figure 2 are presenting the measured power curve of the Lely Aircon 30. The tables and figures presented are the outcome of the power and performance testing carried out by Ingenieurbüro Dr. Ing. Dieter Frey.

| POWER CURVE MEASUREMENT DATA | | | | | MEASUREMENT UNCERTAINTY | | |
|---|---|---|---|---|---|---|---|
| bin | wind speed | No. of bins | electrical power | power coefficient | Cat. A | Cat. B | Cat. A_B |
| i | $V_{Wind}$ [m/s] | N | $P_{el}$ [kW] | $C_P$ | Std. Dev. [kW] | Std. Dev. [kW] | Std. Dev. [kW] |
| 1 | 1,52 | 71 | -0,263 | -0,8633 | 0,025 | 0,055 | 0,061 |
| 2 | 2,00 | 91 | -0,385 | -0,5614 | 0,027 | 0,056 | 0,062 |
| 3 | 2,56 | 169 | -0,541 | -0,3752 | 0,013 | 0,053 | 0,055 |
| 4 | 3,02 | 332 | -0,327 | -0,1378 | 0,010 | 0,078 | 0,079 |
| 5 | 3,53 | 449 | 0,113 | 0,0299 | 0,014 | 0,115 | 0,116 |
| 6 | 4,00 | 545 | 0,732 | 0,1325 | 0,018 | 0,165 | 0,165 |
| 7 | 4,50 | 430 | 1,560 | 0,1982 | 0,026 | 0,247 | 0,249 |
| 8 | 4,99 | 500 | 2,821 | 0,2624 | 0,029 | 0,361 | 0,362 |
| 9 | 5,51 | 537 | 4,441 | 0,3074 | 0,040 | 0,430 | 0,432 |
| 10 | 6,00 | 586 | 5,976 | 0,3203 | 0,043 | 0,513 | 0,515 |
| 11 | 6,50 | 506 | 7,880 | 0,3321 | 0,060 | 0,673 | 0,676 |
| 12 | 6,99 | 473 | 10,190 | 0,3452 | 0,073 | 0,773 | 0,776 |
| 13 | 7,49 | 403 | 12,390 | 0,3418 | 0,097 | 0,824 | 0,830 |
| 14 | 8,01 | 383 | 14,840 | 0,3345 | 0,117 | 0,989 | 0,996 |
| 15 | 8,50 | 358 | 17,640 | 0,3320 | 0,130 | 1,041 | 1,049 |
| 16 | 9,01 | 417 | 19,960 | 0,3163 | 0,126 | 1,020 | 1,028 |
| 17 | 9,50 | 349 | 22,360 | 0,3021 | 0,121 | 0,978 | 0,985 |
| 18 | 10,00 | 274 | 24,240 | 0,2807 | 0,135 | 0,881 | 0,891 |
| 19 | 10,49 | 236 | 26,010 | 0,2607 | 0,147 | 0,762 | 0,776 |
| 20 | 10,99 | 155 | 27,210 | 0,2373 | 0,180 | 0,736 | 0,758 |
| 21 | 11,49 | 116 | 28,770 | 0,2195 | 0,177 | 0,670 | 0,693 |
| 22 | 12,00 | 121 | 29,620 | 0,1983 | 0,174 | 0,500 | 0,529 |
| 23 | 12,48 | 97 | 30,360 | 0,1807 | 0,189 | 0,485 | 0,521 |
| 24 | 12,96 | 107 | 31,040 | 0,1651 | 0,177 | 0,506 | 0,536 |
| 25 | 13,51 | 113 | 31,900 | 0,1498 | 0,184 | 0,375 | 0,417 |
| 26 | 13,97 | 100 | 31,990 | 0,1357 | 0,143 | 0,396 | 0,421 |
| 27 | 14,50 | 85 | 32,880 | 0,1249 | 0,141 | 0,451 | 0,473 |
| 28 | 14,99 | 80 | 33,140 | 0,1138 | 0,157 | 0,434 | 0,462 |
| 29 | 15,51 | 73 | 33,930 | 0,1053 | 0,170 | 0,464 | 0,494 |
| 30 | 15,99 | 80 | 34,230 | 0,0970 | 0,129 | 0,263 | 0,293 |
| 31 | 16,47 | 64 | 34,150 | 0,0885 | 0,156 | 0,282 | 0,322 |
| 32 | 16,95 | 45 | 33,900 | 0,0805 | 0,205 | 0,247 | 0,321 |
| 33 | 17,51 | 42 | 34,110 | 0,0736 | 0,193 | 0,289 | 0,348 |
| 34 | 17,96 | 20 | 33,530 | 0,0670 | 0,398 | 0,628 | 0,744 |
| 35 | 18,54 | 15 | 32,670 | 0,0594 | 0,306 | 0,679 | 0,745 |
| 36 | 18,96 | 9 | 32,920 | 0,0559 | 0,000 | 0,000 | 0,000 |
| 37 | 19,40 | 8 | 31,720 | 0,0503 | 0,000 | 0,000 | 0,000 |
| 38 | 20,23 | 3 | 31,340 | 0,0438 | 0,000 | 0,000 | 0,000 |

the table continues on next page

Table 1 Power performance results at sea Level air density, 1.225 kg/m³ (1/2)

| POWER CURVE MEASUREMENT DATA | | | | | MEASUREMENT UNCERTAINTY | | |
|---|---|---|---|---|---|---|---|
| bin | wind speed | No. of bins | electrical power | power coefficient | Cat. A | Cat. B | Cat. A_B |
| i | $V_{Wind}$ [m/s] | N | $P_{el}$ [kW] | $C_P$ | Std. Dev. [kW] | Std. Dev. [kW] | Std. Dev. [kW] |
| 39 | 20,50 | 2 | 28,630 | 0,0385 | 0,000 | 0,000 | 0,000 |
| 40 | 21,00 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| 41 | 21,72 | 1 | 24,910 | 0,0282 | 0,000 | 0,000 | 0,000 |
| 42 | 22,00 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| 43 | 22,50 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| 44 | 23,00 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| 45 | 23,50 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| 46 | 24,00 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| 47 | 24,50 | 0 | 0,000 | 0,0000 | 0,000 | 0,000 | 0,000 |
| number of bins = 8445 | | | | | | | |

Table 2 Power performance results at sea Level air density, 1.225 kg/m³

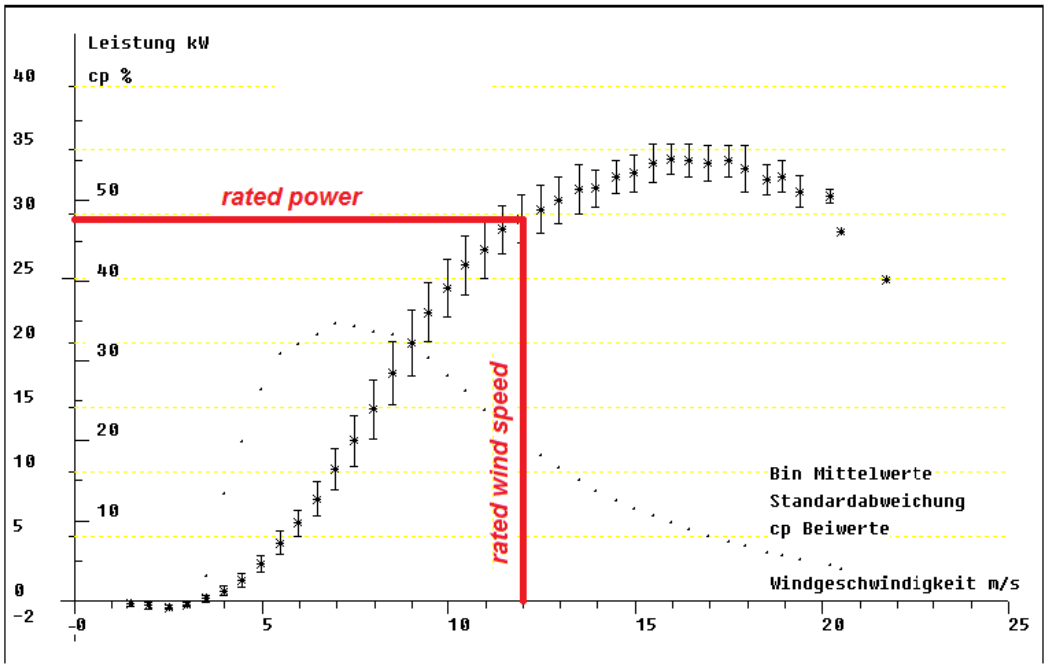


Figure 2 – Power curve with combined standard uncertainty

## 6. Annual Energy Production

Table 3 gives the Reference Annual Energy for the Lely Aircon 30. Table 4 shows the AEP estimations for hub height integer annual average wind speeds from 3m/s, up to the maximum wind speed for the turbine class IEC IIA at sea level air density. The tables presented are the outcome of the power and performance testing carried out by Ingenieurbüro Dr. Ing. Dieter Frey.

| Reference Annual Energy@5m/s | 48847[kWh] |
|---|---|

Table 3 – Reference Annual Energy

| Estimated Annual Energy Production<br>Reference Air Density: 1.225kg/m³<br>Cut Out Wind Speed: No cut out wind speed but extrapolation taken up to 25m/s | | | | | | |
|---|---|---|---|---|---|---|
| | extrapolated | | | measured | | |
| Wind-Rayleigh distribution | Annual production | Uncertainty of the measure (standard deviation) | | Annual production | Uncertainty of the measure (standard deviation) | |
| [m/s] | [kWh] | [kWh] | % | [kWh] | [kWh] | % |
| 3 | 6958 | 1417 | 20,4 | 6958 | 1417 | 20,4 |
| 4 | 24502 | 2555 | 10,4 | 24502 | 2555 | 10,4 |
| 5 | 48847 | 3590 | 7,3 | 48842 | 3589 | 7,3 |
| 6 | 75877 | 4295 | 5,7 | 75719 | 4292 | 5,7 |
| 7 | 102396 | 4691 | 4,6 | 101247 | 4667 | 4,6 |
| 8 | 126540 | 4882 | 3,9 | 122450 | 4797 | 3,9 |
| 9 | 147302 | 4957 | 3,4 | 137738 | 4758 | 3,5 |
| 10 | 164120 | 4968 | 3,0 | 146964 | 4612 | 3,1 |

Table 4 – Estimated annual energy production

Annual Energy Production from 3m/s to 8 m/s is complete (AEP measured is at least 95 % of AEP extrapolated)

## 7. Noise Immission

The noise immission map for the Lely Aircon 30 is presented in Figure 3 below. The plot shows sound pressure levels which are calculated from a declared apparent sound power level for a range of wind speeds and distances to the center of the wind turbine rotor. The figure presented in this chapter is the outcome of the Report of acoustical emissions carried out by GL Garrad Hassan Deutschland GmbH.

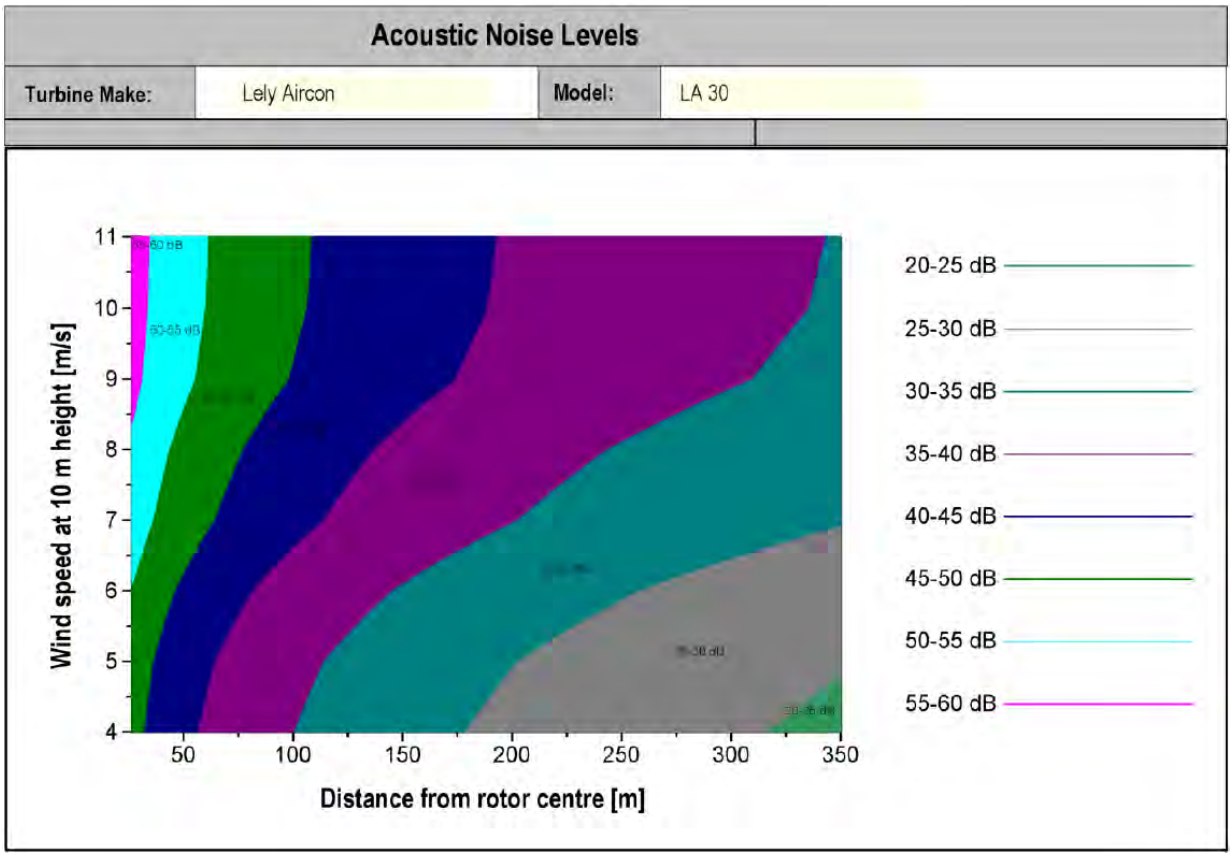


Figure 3 Acoustic noise levels

The measured and declared sound power level at a wind speed of 8m/s is: 94,5dB

## 8. Duration Test

This chapter summarizes the results of the duration test. All the requirements were successfully achieved. The turbine was tested according to the requirements of the IEC 61400-2 Ed.3 turbine class IEC IIA. The tables and figures presented in this chapter are the outcome of the duration test carried out by Ingenieurbüro Dr. Ing. Dieter Frey.

**Test data:**

Start date/time: 15/04/2014
End date/time: 01/04/2015
Mean hub height wind speed: 6.24m/s
Average turbulence intensity at 15m/s: 10.42%
Highest instantaneous wind speed: 27.48m/s
Maximum 1-minute average value: 21.72m/s
Wind from direction 278°..305° northbound; temperature > 2°

At begin of the period of the duration test is a period of unusual low wind speed from the measurement sector. Therefore the period for determining the power production degradation is between 01/10/2014 and 01/04/2015.

Table 5 shows the conditions of the wind turbine during the duration test. It also presents the availability of the Lely Aircon 30 within the duration test, which is in figures 99,8%. Table 6 is showing the operation hours at different wind speeds.

| month | working hours | | | | |
|---|---|---|---|---|---|
| | total time [ h ] | stand still [ h ] | unknown [ h ] | excluded [ h ] | operational time fraction [ % ] |
| | $T_T$ | $T_N$ | $T_U$ | $T_E$ | O |
| Oct. 2014 | 744 | 0 | 0 | 0 | 100,0 |
| Nov. 2014 | 720 | 8,68 | 0 | 0 | 98,8 |
| Dec. 2014 | 744 | 1,22 | 0 | 0 | 99,8 |
| Jan. 2015 | 744 | 0,30 | 10,27 | 0 | 100,0 |
| Feb. 2015 | 672 | 0 | 27 | 0 | 100,0 |
| March 2015 | 744 | 0,02 | 15 | 0 | 100,0 |
| total | 4368 | 10 | 53 | 0 | 99,8 |

Table 5 – Conditions of the wind turbine during duration test

| Month | Number of recorded BINS | | | | | max gust | $I_{15}$ |
|---|---|---|---|---|---|---|---|
| | | > 1,2 * $V_{AVE}$ | > 1,8 * $V_{AVE}$ | > 2,5 * $V_{AVE}$ | | | |
| | > 3,5 m/s | > 10,2 m/s | > 15,3 m/s | > 21,3 m/s | > 15,0 m/s | [ m/s ] | [ % ] |
| Oct. 2014 | 30440 | 868 | 21 | 0 | 39 | 18,43 | 9,44 |
| Nov. 2014 | 30131 | 56 | 0 | 0 | 0 | 12,79 | 0 |
| Dec. 2014 | 36971 | 6418 | 323 | 0 | 488 | 19,01 | 11,13 |
| Jan. 2015 | 36544 | 6698 | 920 | 6 | 1182 | 24,81 | 11,29 |
| Feb. 2015 | 30446 | 565 | 0 | 0 | 1 | 13,27 | 9,21 |
| March 2015 | 33203 | 3874 | 476 | 123 | 481 | 27,48 | 10,2 |
| Total | 197735 | 18479 | 1740 | 129 | 2191 | 27,48 | 10,32 |
| Total [ h ] | 3296 | 308 | 29 | 2 | 37 | | |

Table 6 – Results of the duration test

Figure 4 shows the potential power degradation within the measured period.

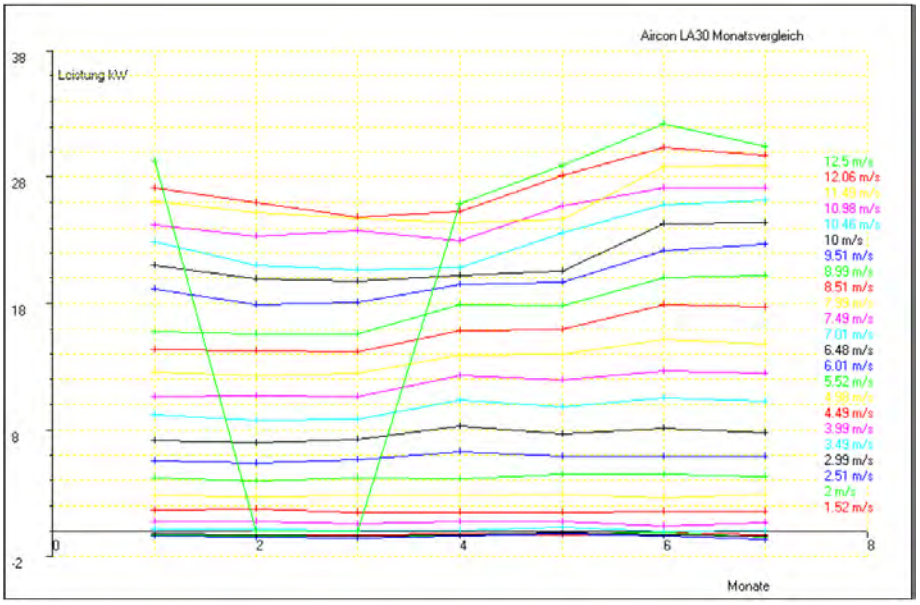


Figure 4 - monthly comparison of power production

**Dynamic behavior according to the IEC 61400-2 Chapter 13.4.3 (13.4.4)**

To determine the dynamic behavior of the wind turbine, an assessment during strong winds was performed in Dec. 2014. The results of the assessment are shown in the following:

**Examination of the wind turbine after eight months of operation, on 20/12/2014**

- High winds with 5 m/s to 20 m/s wind-speed in 1-min-average at ca. 8°C - 10°C, rain, wind direction west.
- The wind turbine works calm and stable in temporary stall mode.
- The rotor blades make a quiet hissing noise. The stall mode can be heard clearly.
- Down tower in the lattice strive are light vibrations, with no boundary to the rotor speed.
- In high gusts the tower oscillates in some of its instrinsically frequencies.
- The tower top makes no side or leeward movements in gusts. The tower looks stiff in stormy conditions.
- The nacelle executes no yaw movements with rotational speed of the rotor.
- The turbine follows precise the movements of the wind direction.
- There is no noise from machinery parts.

During the assessment the turbine shows no remarkable behavior.

## 9. Reference Reports

*1.) Power and Performance Test: Tested in Ihrhove/Germany; Report no.: 07x02x2014, Rev. 1, Date: 14/11/2015; Engineering Office Dr.-Ing. Frey*

"The setup and analysis of the measurement are made according to the following guidelines:

- IEC 61400-12-1, First Edition 2005-12
- MCS 006 Issue 2.1 ( 2014 ):
- IEC 61400-2 Edition 3.0
- RenewableUK (2014)"

Ingenieurbüro Dr. Ing. Dieter Frey is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-PL-11315-01-00

*2.) Duration Test: Tested in Ihrhove/Germany; Report no.: 09x04x2015; Date: 19/11/2015, Rev. 2, Engineering Office Dr.-Ing. Frey*

"The Duration Test is carried out according to the following guidelines:

- IEC 61400-2
- IEC 61400-12-1
- MCS 006 Issue 2.1 (2014)
- MCS 010 Issue 1.5 (2009)
- RenewableUK (2014)"

Ingenieurbüro Dr. Ing. Dieter Frey is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-PL-11315-01-00

*3.) Tests to verify design data: Tested in Ihrhove/Germany; Report no.: 11x11x2015, Rev. 0, Date: 14/11/2015; Engineering Office Dr.-Ing. Frey*

"The setup and analysis of the measurement are made according to the following guidelines:

- IEC 61400-12-1, First Edition 2005-12
- MCS 006 Issue 2.1 ( 2014 ):
- IEC 61400-2 Edition 3.0
- RenewableUK (2014)"

Ingenieurbüro Dr. Ing. Dieter Frey is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-PL-11315-01-00

*4.) Report of acoustical emissions: Tested in Ihrhove/Germany; Report no.: GLGH-4286 14 12454 293-A-0004-A; Date: 17/11/2015; GL Garrad Hassan Deutschland GmbH*

The measurements of the acoustical emissions are performed in accordance with the legacy GL GH management system procedure /2/. This test procedure is integral part of the management system of DNV GL.

All measurements and analysis described in this report were done in accordance with /2/ in combination with IEC 61400: Wind turbines – Part 11: Acoustic noise measurement techniques, Ed.

3 (/1/), as well as the MCS 006 standard /4/, the RenewableUK Small wind turbine standard /5/ and ISO 1996-2 /7/. In this report the sound power level and the tonality are given in the range of wind speeds from 2 m/s to 12 m/s at hub height. Additionally a declared sound power level for 8 m/s is given according to IEC 61400-2 /8/ and IEC TS 61400-14 /6/.

GL Garrad Hassan Deutschland GmbH is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-PL-11134-01-00

*5.) Report of safety and function test: Tested in Ihrhove/Germany; Report no.:* GLGH-4285 14 12455 258-R-0001-D; *Date: 23/11/2015; GL Garrad Hassan Deutschland GmbH*

All measurements and analysis described in this report were done in accordance with /2/ in combination with IEC 61400: Wind turbines – Chapter 9.6: Safety and function, Ed. 3 , as well as the MCS 006 standard, the RenewableUK Small wind turbine standard.

GL Garrad Hassan Deutschland GmbH is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-PL-11134-01-00

*6.) Report of power quality characteristics measurement: Tested in Ihrhove/Germany and Arnheim, Netherlands; Report no.:* GLGH-4280 14 12626 294-A-0001-A; *Date: 11/02/2015; GL Garrad Hassan Deutschland GmbH*

All measurements and analysis described in this report were done in accordance to the grid code VDE-AR-N 4105 /2/. The guideline which describes the needed measurements was the DIN VDE V 0124-100:2012-07 /1/.

GL Garrad Hassan Deutschland GmbH is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-PL-11134-01-00

*7.) Report of Rotorblade testing: Tested in Odder, Denmark; Report no.: 2333064-1-e*; *Date: 14/04/2015; TÜV Süd Industrie Service GmbH*

All measurements and analysis described in this report were done in accordance to61400-2:2013 in combination with 61400-22:2010.

TÜV Süd Industrie Service GmbH is an accredited company according to the DIN EN ISO/IEC 17025:2005 under number D-ZE-14153-01-02.