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19th December 2013

Intertek Project G101129165
Report Number 101129165LHD-009c
Revised: 6th January 2014

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Subject: Summary Report for the C&F Green Energy CF12 tested at the C&F test location in Ballyspellan, Ireland.

Dear Mr. Young,

This report summarizes the results of the evaluation and tests of the above referenced equipment to the requirements contained in the following standards:

Title	Reference	Date	Revision
BWEA Small Wind Turbine Performance and Safety Standard		*29 Feb 2008*	
Wind turbines – Part 2:Design requirements for small wind turbines	*IEC 61400-2*	*March 2006*	*Second edition*
Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines	*IEC 61400-12-1*	*December 2005*	*First edition*
Wind turbine generator systems – Part 11: Acoustic noise measurement techniques	*IEC 61400-11*	*November 2006*	*Edition 2:2002 consolidated with amendment 1:2006*

The original investigation was authorized by signed proposal number 500441083, dated 7th March, 2013. A production sample was installed at the test location in Ballyspellan, Ireland and all testing was conducted on this site.

If there are any questions regarding the results contained in this report, or any of the other services offered by Intertek, please do not hesitate to contact the signatories on this report.

Please note, this report on its own does not represent authorization for the use of any Intertek certification marks. Completed test reports for Duration, Power Performance and Acoustic testing, as well as a Strength and Safety Report, are required to complete the Microgeneration Certification Scheme (MCS) certification process.

Completed by:	Kevin Sweeney
Title:	Business Development Director
Signature:	Kevin Sweeney

Reviewed by:	Nick Jones
Title:	Consultant Engineer
	N.A. Jones

C&F Green Energy Ltd

Report No. 101192165LHD-009c
Issued: 19 December 2013
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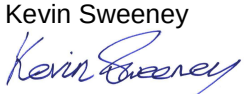
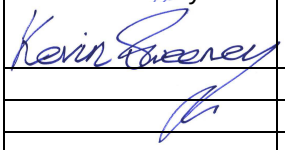
Wind Turbine Generator System
Summary Test Report
for the
C&F Green Energy CF12

Revision history page

Revised by	Section	Description of change	Date
Kevin Sweeney 	Entire document	New report	19 December 2013
Kevin Sweeney 	Page 5 Table 1 Page 17 10.2	Minor revisions Removed drawing reference Corrected reference to CF12	6 January 2014

Master Reports

Report	Report Title	Date
101129165LHD-006c	Wind Turbine Generator System Duration Test Report for the C&F Green Energy CF12	16 December 2013
101129165LHD-008c	Wind Turbine Generator System Strength and Safety Test Report for the C&F Green Energy CF12	19 December 2013
101129165MKS-007c	Wind Turbine Generator System Acoustics Test Report for the C&F Green Energy CF12	18 December 2013
101129165LHD-005c	Wind Turbine Generator System Power Performance Test Report for the C&F Green Energy CF12	16 September 2013 (Revised 19 December 2013)

1.0 Background

1.1 General

This Summary Report details the main characteristics of the CF12 turbine. The CF12 was installed at the C&F Green Energy testing location in Ballyspellan, Ireland, and was tested alongside two other C&F Green Energy turbines; the CF20 and CF25 (Phase A machines)

Full details of testing and evaluation performed are covered by the Master Reports detailed in the table above.

1.2 Changes to the Certified Product

The C& F Green Energy CF12 is a development of the CF15 turbine. The C& F Green Energy CF15 is currently the Subject of MCS Certification (Intertek Certificate nos. INT WT20879/1 & INT WT20879/2). This report has been issued to detail changes to the Certified Product and has been prepared in accordance with the requirements of the BWEA Small Wind Turbine Performance and Safety Standard (2008), Section 8 as detailed below:

8.1.1 A full study of the Power performance has been undertaken and is detailed in Section 5.0 of this report.

8.1.2 A full study of the Acoustics performance has been undertaken and is detailed in Section 4.0 of this report.

8.1.3 A full review of the Design File has been conducted and a new Wind Turbine Generator System Strength and Safety Test Report has been produced. The main findings are detailed in Section 8.0

8.1.4 Given the nature of the changes and the full design file review, a limited Duration test was performed in order to investigate any possible power degradation. Results are detailed in Section 10.0

1.3 Description of the wind turbine

The CF12 is designed for grid-connected power delivery, with a manufacturer's declared rated power output of 12 kW. The CF12 is a horizontal axis machine with a 3-blade upwind rotor with active speed and power control through active blade pitch actuation and turbine yaw control. The CF12 has a three-phase permanent magnet variable-speed generator directly coupled to the rotor, the output of which is fully converted in the inverter. The inverter output is configured for connection to a three-phase, 50 Hz, 230V electrical network. Normal electrical network operating voltage and frequency ranges are 207 – 253 V and 49.8 to 50.2 Hz, respectively.

A summary of the test turbine configuration and manufacturer's declared ratings can be found in Table 1 below.

Table 1: Turbine Characteristics	
Manufacturer :	C&F Green Energy
Model No.	CF12 (Phase A)
Date of Manufacture :	2013, 1st quarter
Description:	Horizontal axis wind turbine with active blade pitch and active yaw
Rotor Diameter :	11.15 m (verified by measurement)
Rotor Swept Area :	97.6 m³
Number of Blades :	3
Hub Height :	15.65 m
Tower :	Tubular steel monopole (not guyed)
Rated Power :	12 kW (nominal)
Rated Wind Speed :	9 m/s
Wind Class :	III (V_{ave} = 7.5 m/s)
Survival Wind Speed :	70 m/s
Cut-in Wind Speed :	2.2 m/s
Cut-out Wind Speed :	25 m/s
Rotor Speed Range :	0 - 75 rpm (normal operating range), maximum 110 rpm
Low Speed Shaft Speed :	N/A (generator runs at Rotor speed)
Speed Reduction Method :	N/A
Yaw Control :	Active
Blade Pitch Control :	Active
Blades specification :	Closed mould infusion of glass-filled vinylester resin over a polyurethane foam core with double spar, 7°twist from root to tip, airfoil geometry based on NACA 5415
Blade Identification :	Blade set no. CFGE-BS-5-0170, individual blade serial nos. 4712306, 4712310 & 4712312
Generator Type :	Permanent magnet, asynchronous, ac 3-phase, radial flux
Generator Identification :	CFGE1302E01 3PH 11KW
Power Conversion :	Solid-state inverter
Inverter Type :	ABB-ACS-800-11-40, 3-phase output
Inverter Software :	12kw_parameter.txt
Grid Protection Method :	Separate G59/2 relay
Grid Protection Type :	ComAp Mainspro
Turbine Controller :	Phoenix Contact PLC-ILC-150-GSM
Turbine Controller Software :	ABB_PLC_V6_Kilkenny.zwt

2.0 Objective

The purpose of this report is to provide a summary of the following:

Section	Summary Results	Reference[1]
3.0	Power Performance Test Summary	6.1.2
4.0	Acoustic Test Results including noise label	6.1.3
5.0	BWEA Reference Annual Energy	6.1.4
6.0	BWEA Reference 60m Sound Level, Lp,60m	6.1.5
7.0	BWEA Reference Power, at 11.0 m/s (24.6 mph)	6.1.6
8.0	Wind Turbine Strength and Safety Report	6.1.7
9.0	Top tower design loads	6.1.7.1
10.0	Duration Test Summary	6.1.8

Note 1: Reference - *BWEA Small Wind Turbine Performance and Safety Standard 29 Feb 2008*

3.0 Power Performance Test Summary

Table 2 below shows the normalized and averaged results of the power performance test for the CF12 turbine based on the analysis of 19,674 1-minute data sets (total 328 hours) collected between 01-May2013 00:00 and 31-May-2013 23:59.

Table 2: CF12 performance at sea-level air density; 1.225 kg/m^3

Presentation of data in the measured power curve (database A)							
Reference air density: 1.225 kg/m^3							
Bin (m/s)	Bin Average Wind Speed (m/s)	Power output (W)	Cp	Number of 1-Minute Data Sets	Category A Standard Uncertainty (W)	Category B Standard Uncertainty (W)	Combined Standard Uncertainty (W)
1	0.57	-41	-3.67	40	0	6	6
2	0.99	-41	-0.70	87	0	6	6
3	1.50	-41	-0.20	95	0	6	6
4	2.03	-41	-0.08	116	0	6	6
5	2.54	-41	-0.04	233	0	6	6
6	2.99	-20	-0.01	288	3	8	9
7	3.50	145	0.06	281	9	41	42
8	4.02	558	0.14	429	11	104	105
9	4.51	1048	0.19	682	10	137	138
10	5.01	1637	0.22	876	10	167	168
11	5.50	2312	0.23	828	14	203	203
12	6.00	3146	0.24	850	15	255	255
13	6.50	4042	0.25	890	17	288	288
14	7.01	5096	0.25	988	17	346	346
15	7.50	6230	0.25	970	19	397	397
16	7.99	7505	0.25	865	26	467	468
17	8.50	9100	0.25	969	28	579	579
18	9.00	10616	0.24	1059	26	594	594
19	9.49	11714	0.23	1029	21	466	466
20	9.99	12246	0.21	874	14	283	284
21	10.50	12431	0.18	803	7	204	204
22	11.00	12479	0.16	698	6	191	192
23	11.49	12510	0.14	710	4	191	191
24	12.00	12519	0.12	670	2	191	191
25	12.50	12502	0.11	693	15	191	191
26	12.99	12517	0.10	634	3	191	191
27	13.51	12503	0.08	602	4	191	191
28	13.99	12469	0.08	567	17	191	192
29	14.49	12470	0.07	440	3	190	190
30	15.00	12425	0.06	403	19	191	192
31	15.48	12430	0.06	314	4	190	190
32	15.98	12431	0.05	276	4	190	190
33	16.49	12425	0.05	219	4	189	190
34	17.00	12426	0.04	196	4	189	189

Figure 1 below shows the graphical results of the power performance test for the CF12. The uncertainty of each wind speed bin is shown as error bars on the graph.

Figure 1: CF12 power curve corrected to sea-level air density; 1.225 kg/m^3 (database A)

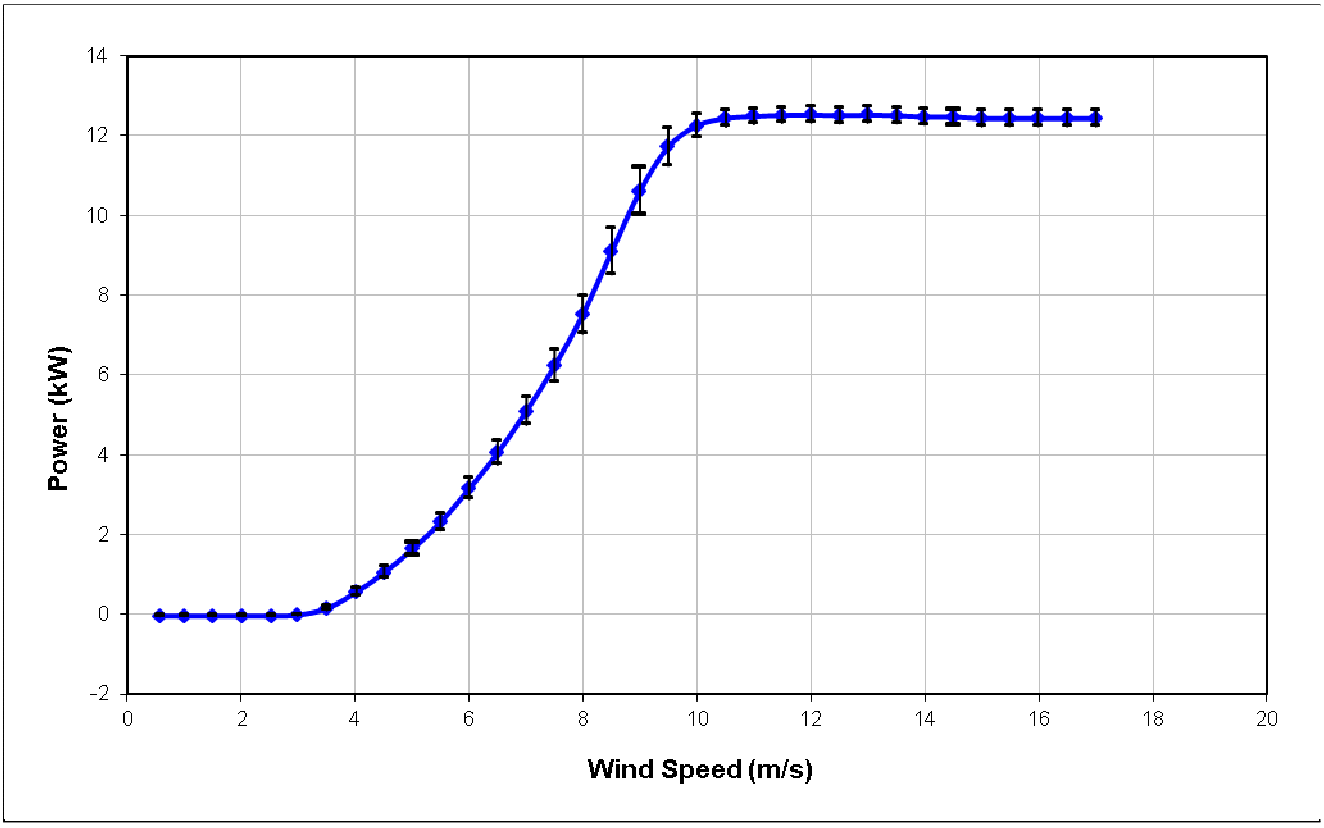
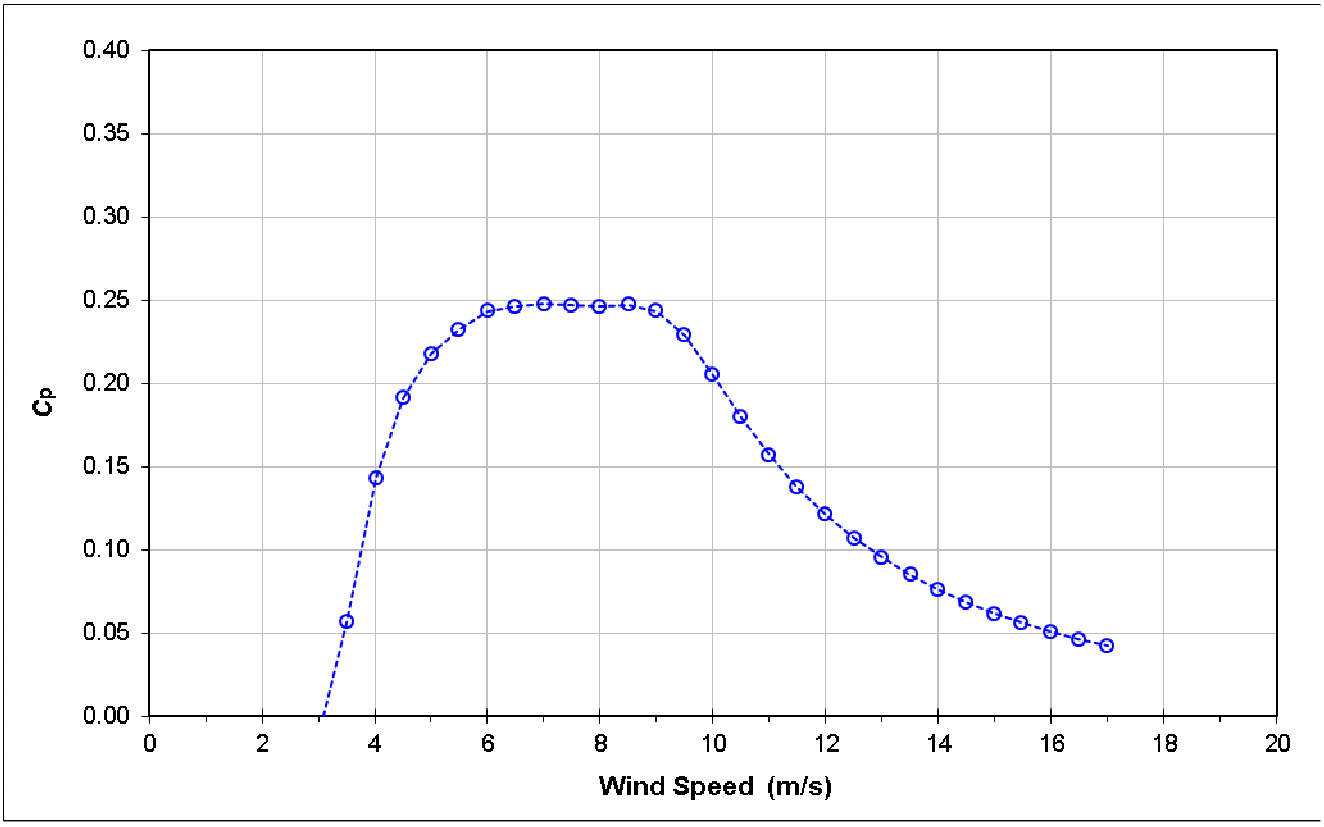


Figure 2 below shows the coefficient of performance at sea-level air density.

Figure 2: Coefficient of performance of the CF12 with swept area of 97.6 m^2 at sea-level air density of 1.225 kg/m^3



4.0 Acoustic Test Results including Noise label

This is a summary of the evaluation of the CF12 wind turbine noise over a range of wind speeds and directions. Characterizations of the turbines apparent sound power level, 1/3 octave bands, and tonality are made.

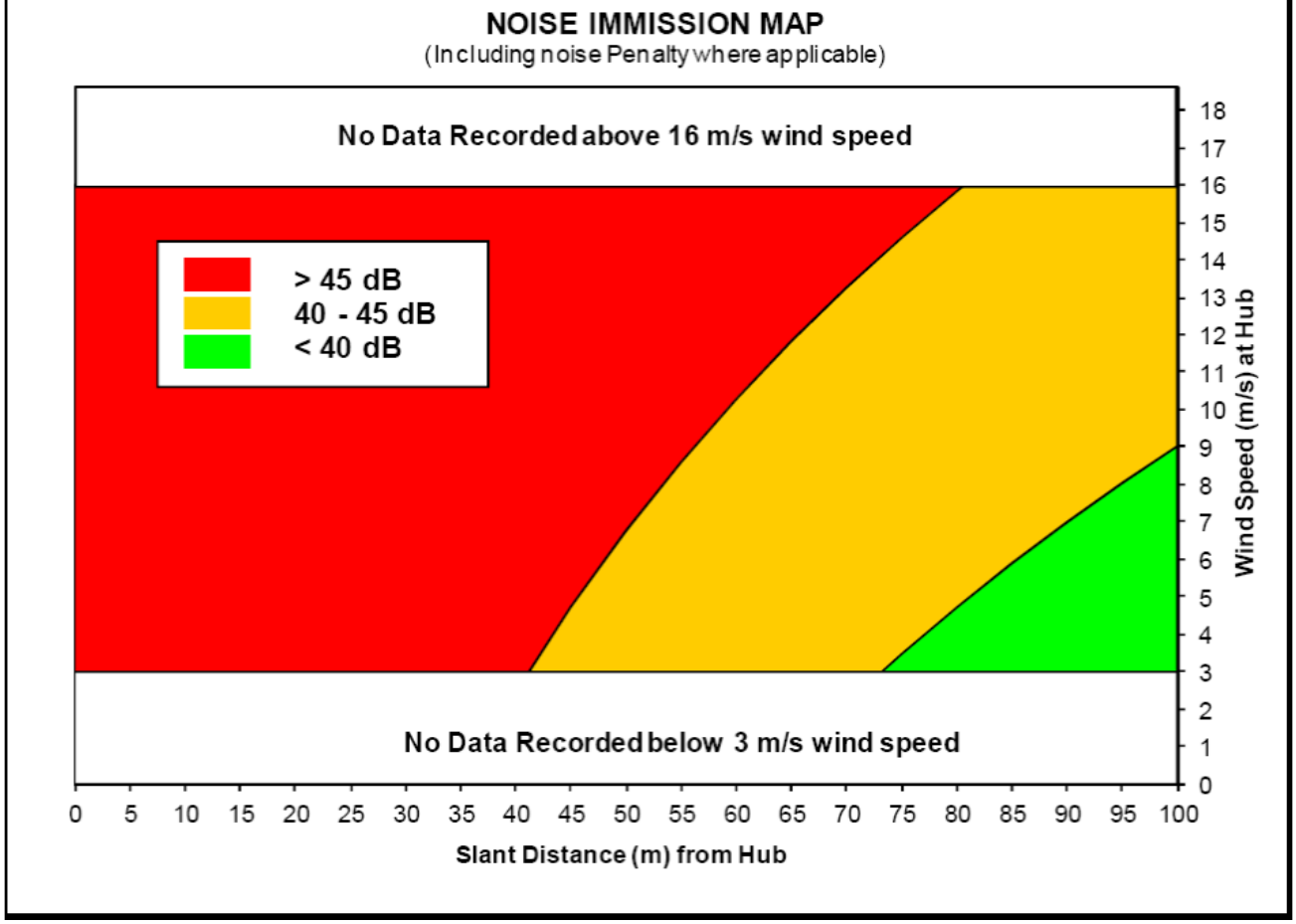
Acoustic noise data was gathered on six separate days in September and October 2013. Over the six days, the wind direction varied from 10° to 330° with respect to true North. Meteorological and wind turbine data has been gathered continuously since commissioning of the CF12.

The resulting acoustic performance for normal operation in accordance with the BWEA standard is as follows:

Wind speed dependence	**0.45 dB/m/s**
Immission Sound Pressure Level at 60m $L_{p,60m}$	**44.04 dBA**
Immission Sound Pressure Level at 25m $L_{p,25m}$	**51.54 dBA**

Figure 3: Noise Immission Map for CF12

ACOUSTIC NOISE LEVELS				
Turbine Make	C&F Green Energy		Model	CF12
NOISE EMISSION LEVEL				NOISE PENALTY
Sound Power LWd,8m/s (dBA)	88	Noise Slope SdB (dB/m/s)	0.45	NO



5.0 BWEA Reference Annual Energy

Table 3 below summarizes the estimation of expected annual energy production (AEP) at sea-level air density.

Table 3: Estimated annual energy production of the CF12 at sea-level air density

Estimated annual energy production
(database A)
Reference air density: 1.225 kg/m³
Cut-out wind speed: 25 m/s
(extrapolation by constant power from last bin)

Hub height annual average wind speed (Rayleigh)	*AEP*-measured (measured power curve) [note 1]	Standard uncertainty in *AEP* $ [note 4]	Standard uncertainty in *AEP* $ [note 4]	*AEP*-extrapolated (extrapolated power curve) [note 2]	Complete if *AEP*-measured is at least 95% of *AEP*-extrapolated [note 3]
m/s	kWh	kWh	%	kWh	
4	13553	1059	8	13553	Complete
5	**25230**	**1544**	**6**	**25243**	**Complete**
6	37214	1862	5	37412	Complete
7	47424	2022	4	48477	Complete
8	54767	2066	4	57851	Incomplete
9	59079	2034	3	65425	Incomplete
10	60789	1954	3	71227	Incomplete
11	60540	1848	3	75327	Incomplete

Note 1: AEP-measured assumes zero power below cut-in (2.5 m/s) and zero power above the range of the database (17.0 m/s).

Note 2: AEP-extrapolated assumes zero power below cut-in (2.5 m/s) and constant (maximum) power up to cut-out (25 m/s).

Note 3: "Incomplete" means that AEP-measured is not within 95% of AEP-extrapolated. This does not imply that the database is incomplete.

Note 4: The uncertainty figures in the above table are based on a coverage factor of 1.

BWEA Reference Annual Energy: 25,230 kWh @ 5m/s

6.0 BWEA Reference 60m Sound Level, $L_{p,60m}$

From the summary presented in section 4.0 of this report:

BWEA Reference 60m Sound Level, $L_{p,60m}$ 44.04 dBA

7.0 BWEA Reference Power at 11.0m/s (24.6mph)

From the data summarised in the table in Section 2.0 of this report:

BWEA reference output power (11.0m/s) is 12.5kW

The power curve and power coefficient plots are included in Section 2.0 of this report

8.0 Strength and Safety Test Results

8.1 Mechanical Safety

The mechanical safety of the turbine system was assessed according to the requirements in section 4 of the BWEA Small Wind Turbine Performance and Safety Standard 29 Feb 2008. This standard further references IEC 61400-2 Wind turbines – Part 2: Design requirements for small wind turbines – Clause 7.4, 7.8 and 7.9 (Mechanical Safety).

The load cases defined in the standards were evaluated according to the simplified load model defined in the standards listed from Design Calculations submitted by C&F Green Energy.

The design file details analysis of the simplified load model including ultimate and fatigue loading analysis, as well as final material and load factors of safety. The design file was found to be in compliance with all requirements of the Standards regarding structural integrity. All supporting documentation is maintained within the project file.

8.2 Visual inspection

The machine was inspected both before and after testing and the condition documented. No significant damage or wear was noted. Photographs of the condition after testing of the principal components are included in 101192165LHD-006c

No adverse faults, deterioration or malfunction due to wind turbine performance were recorded during the test period.

8.3 Safety and Function

A Safety and Function test in accordance with *IEC 61400-2 Wind turbines – Part 2:Design requirements for small wind turbines – Clause 9.6* was completed. The results of this test are reported in the Intertek Strength and Safety Test Report 101192165LHD-008c

No adverse faults, control problems or safety issues were raised during the observation period.

9.0 Tower Top Loads

Table 4 below summarizes the top tower topple moment and tower data. This data has been supplied by C&F Green Energy

Table 4: Tower Data	
Turbine Class	III
Average Wind Speed, V_{ave}	7.5 m/s
Reference Wind Speed, V_{ref} (m/s)	37.5 m/s
50 year extreme Wind Speed, V_{e50}	52.5 m/s
Total Topple Moment	516.6 kNm
Wind force on nacelle	1720 N
Wind force on blades	24210 N
Wind force on mast	21040 N
Mass of nacelle	2100 kg
Mass of blades	285 kg
Mass of tower	3200 kg
Height of Tower	15 m
Tower Base Diameter	877 mm
Tower Top Diameter	490 mm
Sheet Steel Thickness	6 mm to 8 mm

10.0 Duration Test Summary

Intertek report 101129165LHD-006c provides full details of this analysis

10.1 Hours of Power Production

Table 5 below indicates the number of power production hours that were observed during the 6 month test duration.

Table 5: Hours of Power Production CF12 IEC SWT Class III – V_{ave} = 7.5 m/s			
Wind Speed	**Measured**	**Required**	**Pass/Fail**
> 0 m/s	2059.8	2500	N/A
> 1.2 V_{ave}	405.7	250	Pass
> 1.8 V_{ave}	84.2	25	Pass
> 15 m/s	36.2	25	Pass

Note that even with the reduced overall test period, the required hours of operation at wind speeds above V_{ave} exceeded the requirements for the 6-month test period specified by BSEN 61400-2:2006

10.2 Operational Time Fraction

The operational time fraction is defined by the following equation:

$$O = \frac{T_T - T_N - T_U - T_E}{T_T - T_U - T_E} \times 100\ \%$$

where:

T_T is the total time period under consideration,
T_N is the time during which the turbine is known to be non-operational,
T_U is the time during which the turbine status is unknown, and
T_E is the time which is excluded in the analysis.

The **overall operational time fraction** of the combined wind turbine system in the total test period was **99.9%.** The pass criteria for this parameter is 90% (*IEC 61400-2 Wind turbines – Part 2:Design requirements for small wind turbines Clause 9.4.2.1)* so the CF12 is deemed to **PASS**

10.3 Environmental Conditions

In order to understand environmental conditions over the testing period, several wind speed statistics were required by the Standard. These values are summarized in Table 6 below.

Environmental Conditions During Test Period	
Description	**Value**
Highest instantaneous wind speed	24.9 m/s
Average turbulence intensity at 15 m/s	7.9%

Table 6 – Environmental conditions during test

10.4 Power Degradation

No significant power degradation over the test period at comparable wind speeds was recorded.

10.5 Dynamic Behavior

During the test period the turbine and tower were observed for any potentially harmful turbine or tower dynamics. The turbine was observed over a wide range of wind speeds. During these observations there was no presence of any observable problems.

10.6 Post-Test Inspection

The machine was inspected both before and after testing and the condition documented. No significant damage or wear was noted. Photographs of the condition after testing of the principal components are included in 101192165LHD-006c