Form A2-3: Compliance Verification Report for Type A Inverter Connected Power Generating Modules

This form should be used by the **Manufacturer** to demonstrate and declare compliance with the requirements of EREC G99. The form can be used in a variety of ways as detailed below:

1. To obtain **Fully Type Tested** status

   The **Manufacturer** can use this form to obtain **Fully Type Tested** status for a **Power Generating Module** by registering this completed form with the Energy Networks Association (ENA) Type Test Verification Report Register.

2. To obtain **Type Tested** status for a product

   This form can be used by the **Manufacturer** to obtain **Type Tested** status for a product which is used in a **Power Generating Module** by registering this form with the relevant parts completed with the Energy Networks Association (ENA) Type Test Verification Report Register.
   Where the **Manufacturer** is seeking to obtain **Type Tested** status for an **Interface Protection** device the appropriate section of Form A2-4 should be used.

3. One-off Installation

   This form can be used by the **Manufacturer** or **Installer** to confirm that the **Power Generating Module** has been tested to satisfy all or part of the requirements of this EREC G99. This form shall be submitted to the **DNO** as part of the application.

A combination of (2) and (3) can be used as required, together with Form A2-4 where compliance of the **Interface Protection** is to be demonstrated on site.

Note:

Within this Form A2-3 the term **Power Park Module** will be used but its meaning can be interpreted within Form A2-3 to mean **Power Park Module**, **Generating Unit or Inverter** as appropriate for the context. However, note that compliance shall be demonstrated at the **Power Park Module** level.

If the **Power Generating Module** is **Fully Type Tested** and registered with the Energy Networks Association (ENA) Type Test Verification Report Register, the Installation Document (Form A3-1 or A3-2) should include the **Manufacturer's** reference number (the Product ID), and this form does not need to be submitted.

Where the **Power Generating Module** is not registered with the ENA Type Test Verification Report Register or is not **Fully Type Tested** this form (all or in parts as applicable) needs to be completed and provided to the **DNO**, to confirm that the **Power Generating Module** has been tested to satisfy all or part of the requirements of this EREC G99.

PGM technology		For all C30 Variants	
Manufacturer name		Capstone Green Energy	
Address		16640 Stagg Street Van Nuys, CA91406	
Tel	+18664227786	Web site	www.capstonegreenenergy.com
E:mail	Service@cgrnenergy.com		
Registered Capacity		30kW	

There are four options for Testing: (1) **Fully Type Tested**, (2) Partially **Type Tested**, (3) one-off installation, (4) tested on site at time of commissioning. The check box below indicates which tests in this Form have been completed for each of the options. With the exception of **Fully Type Tested PGM**s tests may be carried out at the time of commissioning (Form A4).
Insert Document reference(s) for **Manufacturers' Information**

Tested option:	**1. Fully Type Tested**	**2. Partially Type Tested**	**3. One-off Manufacturers'. Info.**	**4. Tested on Site at time of Commissioning**
0. **Fully Type Tested** - all tests detailed below completed and evidence attached to this submission	✓	**N/A**	**N/A**	**N/A**
1. Operating Range	**N/A**			
2. PQ – Harmonics				
3. PQ – Voltage Fluctuation and Flicker				
4. PQ – DC Injection (**Power Park Module**s only)				
5. **Power Factor** (PF)				
6. Frequency protection trip and ride through tests				
7. Voltage protection trip and ride through tests				
8. Protection – Loss of Mains Test, Vector Shift and RoCoF Stability Test				
9. **LFSM-O** Test				
10. Protection – Reconnection Timer				
11. Fault Level Contribution				

There are four options for Testing: (1) **Fully Type Tested**, (2) Partially **Type Tested**, (3) one-off installation, (4) tested on site at time of commissioning. The check box below indicates which tests in this Form have been completed for each of the options. With the exception of **Fully Type Tested PGM**s tests may be carried out at the time of commissioning (Form A4).
Insert Document reference(s) for **Manufacturers' Information**

Tested option:	**1. Fully Type Tested**	**2. Partially Type Tested**	**3. One-off Manufacturers'. Info.**	**4. Tested on Site at time of Commissioning**
12. Self-monitoring Solid State Switch			✓	
13. Wiring functional tests if required by para 15.2.1 (attach relevant schedule of tests)				Required on site
14. Logic Interface (input port)			✓	

Manufacturer compliance declaration. - I certify that all products supplied by the company with the above **Type Tested Manufacturer**'s reference number will be manufactured and tested to ensure that they perform as stated in this document, prior to shipment to site and that no site **Modification**s are required to ensure that the product meets all the requirements of EREC G99.

Signed		On behalf of	Capstone Green Energy.

Digitally signed by Paul Keates
DN: cn=Paul Keates, o=Capstone Turbine, ou, email=pkeates@capstoneturbine.com, c=GB
Date: 2022.07.04 11:27:17 +01'00'

Note that testing can be done by the **Manufacturer** of an individual component or by an external test house.

Where parts of the testing are carried out by persons or organisations other than the **Manufacturer** then that person or organisation shall keep copies of all test records and results supplied to them to verify that the testing has been carried out by people with sufficient technical competency to carry out the tests.

A2-3 Compliance Verification Report –Tests for Type A Inverter Connected Power Generating Modules – test record

1. Operating Range: Five tests should be carried with the **Power Generating Module** operating at **Registered Capacity** and connected to a suitable test supply or grid simulation set. The power supplied by the primary source shall be kept stable within ± 5 % of the apparent power value set for the entire duration of each test sequence.

Frequency, voltage and **Active Power** measurements at the output terminals of the **Power Generating Module** shall be recorded every second. The tests will verify that the **Power Generating Module** can operate within the required ranges for the specified period of time.

The **Interface Protection** shall be disabled during the tests.

In case of a PV **Power Park Module** the PV primary source may be replaced by a DC source.

In case of a full converter **Power Park Module** (eg wind) the primary source and the prime mover I**nverter**/rectifier may be replaced by a DC source.

Test 1 Voltage = 85% of nominal (195.5 V), Frequency = 47 Hz, **Power Factor** = 1, Period of test 20 s	Confirmed always connected
Test 2 Voltage = 85% of nominal (195.5 V), Frequency = 47.5 Hz, **Power Factor** = 1, Period of test 90 minutes	Confirmed always connected
Test 3 Voltage = 110% of nominal (253 V)., Frequency = 51.5 Hz, **Power Factor** = 1, Period of test 90 minutes	Confirmed always connected
Test 4 Voltage = 110% of nominal (253 V), Frequency = 52.0 Hz, **Power Factor** = 1, Period of test 15 minutes	Confirmed always connected
Test 5 RoCoF withstand Confirm that the **Power Generating Module** is capable of staying connected to the **Distribution Network** and operate at rates of change of frequency up to 1 Hzs^{-1} as measured over a period of 500 ms. Note that this is not expected to be demonstrated on site.	Confirmed always connected

2. Power Quality – Harmonics:

For **Power Generating Module**s of **Registered Capacity** of less than 75 A per phase (ie 50 kW) the test requirements are specified in Annex A.7.1.5**.** These tests should be carried out as specified in BS EN 61000-3-12 The results need to comply with the limits of Table 2 of BS EN 61000-3-12 for single phase equipment and Table 3 of BS EN 610000-3-12 for three phase equipment.

For **Power Generating Module**s of **Registered Capacity** of greater than 75 A per phase (ie 50 kW) the installation shall be designed in accordance with EREC G5.

Power Generating Module tested to BS EN 61000-3-12

Power Generating Module rating per phase (rpp)			10	kVA	Harmonic % = Measured Value (A) x 23/rating per phase (kVA)	
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	%	Measured Value MV in Amps	%	1 phase	3 phase
2	0.012	0.05	0.0174	0.04	8%	8%
3	0.134	0.56	0.1913	0.44	21.6%	Not stated
4	0.0096	0.04	0.0174	0.04	4%	4%
5	0.72	3.01	1.3304	3.06	10.7%	10.7%
6	0.0024	0.01	0.0087	0.02	2.67%	2.67%
7	0.246	1.03	0.4217	0.97	7.2%	7.2%
8	0.0096	0.04	0.0130	0.03	2%	2%
9	0.0478	0.2	0.0957	0.22	3.8%	Not stated
10	0.134	0.056	0.0174	0.04	1.6%	1.6%
11	0.0694	0.29	0.0913	0.21	3.1%	3.1%
12	0.0071	0.03	0.0174	0.04	1.33%	1.33%
13	0.024	0.1	0.0609	0.14	2%	2%
THD[17]	0.782	3.27	1.4304	3.29	23%	13%
PWHD[18]	n/a	n/a	n/a	n/a	23%	22%

[17] THD = Total Harmonic Distortion: Lab results show less than 1%THD from the C30

[18] PWHD = Partial Weighted Harmonic Distortion: CE certified; extra filtration added to EU/UK systems to remove high order harmonics: Lab results show less than 1% PWHD from the C30

3. Power Quality – Voltage fluctuations and Flicker:

For **Power Generating Module**s of **Registered Capacity** of less than 75 A per phase (ie 50 kW) these tests should be undertaken in accordance with Annex A.7.1.4.3. Results should be normalised to a standard source impedance, or if this results in figures above the limits set in BS EN 61000-3-11 to a suitable Maximum Impedance.

For **Power Generating Module**s of **Registered Capacity** of greater than 75 A per phase (ie 50 kW) the installation shall be designed in accordance with EREC P28.

	Starting			Stopping			Running	
	d max	d c	d(t)	d max	d c	d(t)	P st	P lt 2 hours
Measured Values at test impedance	2.4%	0.15%	1.84%	1.184%	1.05%	1.016%	0.517	0
Normalised to standard impedance	2.304%	0.144%	1.766%	1.136%	1.008%	0.975%	0.496	0
Normalised to required maximum impedance	2.4%	0.15%	1.84%	1.184%	1.05%	1.016%	0.517	0
Limits set under BS EN 61000-3-11	4%	3.3%	3.3%	4%	3.3%	3.3%	1.0	0.65

Test Impedance	R	0.25	Ω	Xl	0.156	Ω
Standard Impedance	R	0.24 * 0.4 ^	Ω	Xl	0.15 * 0.25 ^	Ω
Maximum Impedance	R	0.25	Ω	Xl	0.16	Ω

* Applies to three phase and split single phase **Power Generating Module**s.

^ Applies to single phase **Power Generating Module** and **Power Generating Module**s using two phases on a three phase system

For voltage change and flicker measurements the following formula is to be used to convert the measured values to the normalised values where the **Power Factor** of the generation output is 0.98 or above.

Normalised value = Measured value x reference source resistance/measured source resistance at test point

Single phase units reference source resistance is 0.4 Ω

Two phase units in a three phase system reference source resistance is 0.4 Ω

Two phase units in a split phase system reference source resistance is 0.24 Ω

Three phase units reference source resistance is 0.24 Ω

Where the **Power Factor** of the output is under 0.98 then the Xl to R ratio of the test impedance should be close to that of the Standard Impedance.

The stopping test should be a trip from full load operation.

The duration of these tests need to comply with the particular requirements set out in the testing notes for the technology under test. Dates and location of the test need to be noted below

Test start date	Mon 13th Dec 2021 10:00	Test end date	Mon 13th Dec 2021 13:00
Test location	Mill Hill Place. London		

4. Power quality – DC injection: The tests should be carried out on a single **Generating Unit**. Tests are to be carried out at three defined power levels ±5%. At 230 V a 50 kW three phase **Inverter** has a current output of 217 A so DC limit is 543 mA. These tests should be undertaken in accordance with Annex A.7.1.4.4.

Test power level	10%	55%	100%
Recorded value in Amps	0.00164A	0.01105A	0.01412A
as % of rated AC current	0.0007%	0.004%	0.0058%
Limit	0.25%	0.25%	0.25%

5. Power Factor: The tests should be carried out on a single **Power Generating Module**. Tests are to be carried out at three voltage levels and at **Registered Capacity**. Voltage to be maintained within ±1.5% of the stated level during the test. These tests should be undertaken in accordance with Annex A.7.1.4.2.

Voltage	0.94 pu (216.2 V)	1 pu (230 V)	1.1 pu (253 V)
Measured value	1	1	1
Power Factor Limit	>0.95	>0.95	>0.95

6. Protection – Frequency tests: These tests should be carried out in accordance with the Annex A.7.1.2.3.

Function	Setting		Trip test		"No trip tests"	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
U/F stage 1	47.5 Hz	20 s	L1 47.504 L2 47.504 L3 47.504	20.234s	47.7 Hz 30 s	Confirmed
U/F stage 2	47 Hz	0.5 s	L1 47.006 L2 47.006 L3 47.006	0.74s	47.2 Hz 19.5 s	Confirmed
					46.8 Hz 0.45 s	Confirmed

O/F	52 Hz	0.5 s	L1 59.995 L2 59.995 L 3 59.995	0.782s	51.8 Hz 120.0 s	Confirmed
					52.2 Hz 0.45 s	Confirmed

Note. For frequency trip tests the frequency required to trip is the setting ± 0.1 Hz. In order to measure the time delay a larger deviation than the minimum required to operate the projection can be used. The "No trip tests" need to be carried out at the setting ± 0.2 Hz and for the relevant times as shown in the table above to ensure that the protection will not trip in error.

7. Protection – Voltage tests: These tests should be carried out in accordance with Annex A.7.1.2.2.

Function	Setting		Trip test		"No trip tests"	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
U/V	0.8 pu (184 V)	2.5 s	L1 183.7 L2 183.05 L 3 182.6	2.544s	188 V 5.0 s	Confirmed
					180 V 2.45 s	Confirmed
O/V stage 1	1.14 pu (262.2 V)	1.0 s	L1 261.01 L2 261.05 L 3 260.99	1.092s	258.2 V 5.0 s	Confirmed
O/V stage 2	1.19 pu (273.7 V)	0.5 s	L1 272.54 L2 272.48 L 3 272.52	0.547s	269.7 V 0.95 s	Confirmed
					277.7 V 0.45 s	Confirmed

Note for Voltage tests the Voltage required to trip is the setting ±3.45 V. The time delay can be measured at a larger deviation than the minimum required to operate the protection. The No trip tests need to be carried out at the setting ±4 V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.

8.Protection – Loss of Mains test: These tests should be carried out in accordance with BS EN 62116. Annex A.7.1.2.4.

The following sub set of tests should be recorded in the following table.

Test Power and imbalance	33% -5% Q Test 22	66% -5% Q Test 12	100% -5% P Test 5	33% +5% Q Test 31	66% +5% Q Test 21	100% +5% P Test 10
Trip time. Limit is 0.5s	0.101s	0.106s	0.250s	0.101s	0.104s	0.201s

Loss of Mains Protection, Vector Shift Stability test. This test should be carried out in accordance with Annex A.7.1.2.6.

	Start Frequency	Change	Confirm no trip

Positive Vector Shift	49.5 Hz	+50 degrees	Confirmed
Negative Vector Shift	50.5 Hz	- 50 degrees	Confirmed

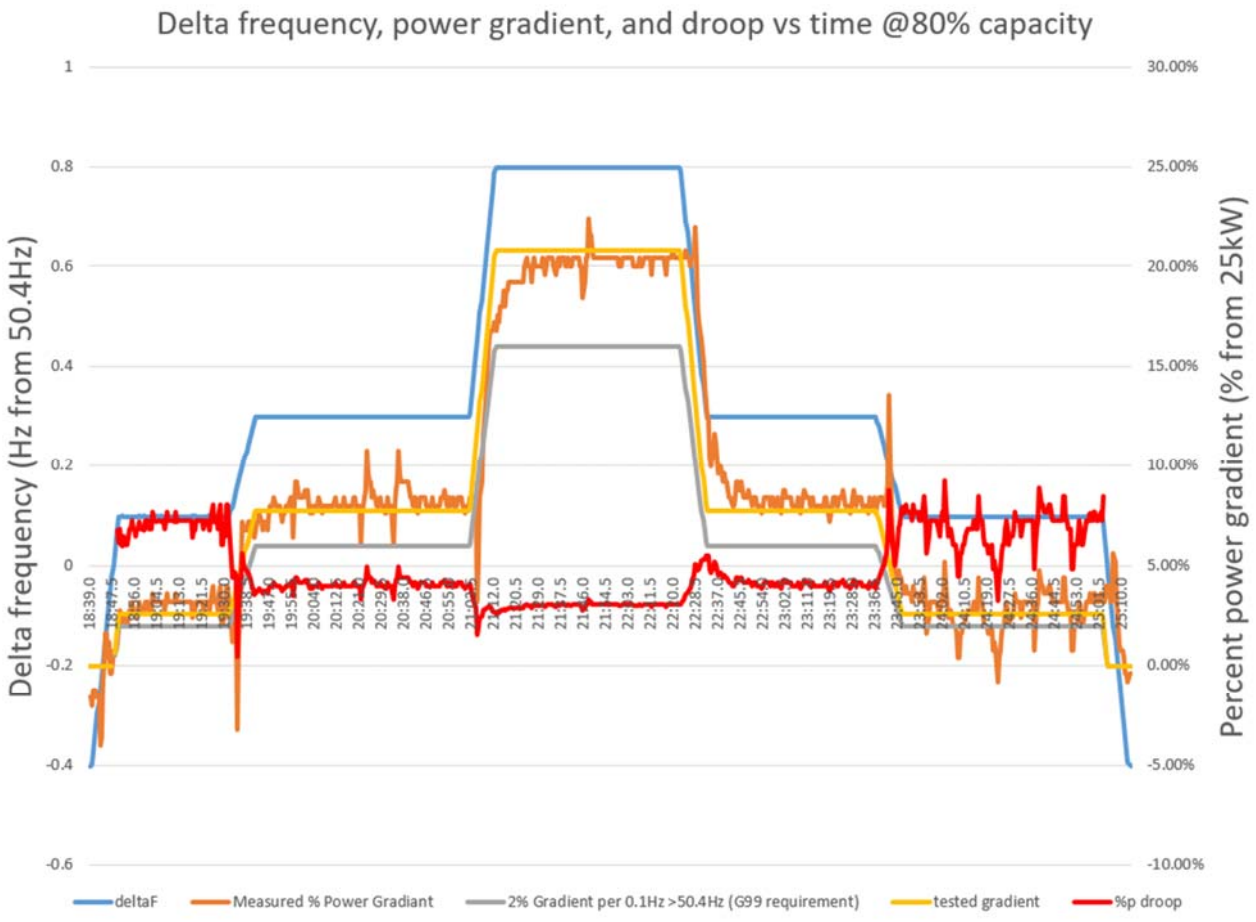
Loss of Mains Protection, RoCoF Stability test: This test should be carried out in accordance with Annex A.7.1.2.6.

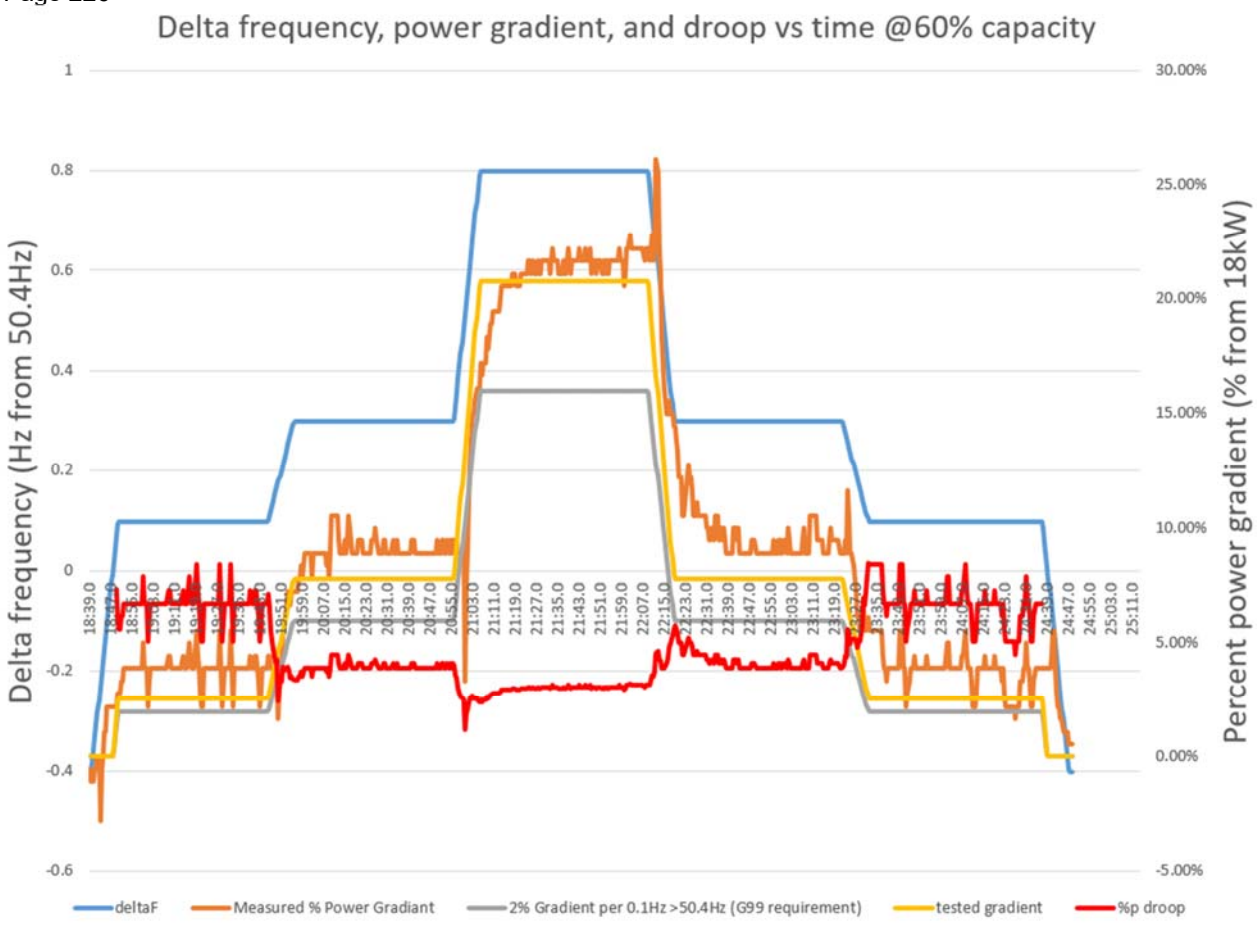
Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+0.95 Hzs^{-1}	2.1 s	Confirmed
51.0 Hz to 49.0 Hz	-0.95 Hzs^{-1}	2.1 s	Confirmed

9. Limited Frequency Sensitive Mode – Over frequency test: The test should be carried out using the specific threshold frequency of 50.4 Hz and **Droop** of 10%.

This test should be carried out in accordance with Annex A.7.1.3.

Active Power response to rising frequency/time plots are attached if frequency injection tests are undertaken in accordance with Annex A.7.2.4.	**Y/~~N~~**




Delta frequency, power gradient, and droop vs time @60% capacity
Delta frequency (Hz from 50.4Hz)
Percent power gradient (% from 18kW)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
-5.00%
deltaF
Measured % Power Gradiant
2% Gradient per 0.1Hz >50.4Hz (G99 requirement)
tested gradient
%p droop

Alternatively, test results should be noted below:				
Test sequence at **Registered Capacity** >80%	Measured **Active Power** Output	Frequency	Primary Power Source	**Active Power** Gradient
Step a) 50.00Hz ±0.01Hz	24.400kW	50	C65 SA MT inverter grid forming output through resistive load bank. Frequency out adjustable to 1dp.	-0%
Step b) 50.45Hz ±0.05Hz	23.200kW	50.5		-3.2%
Step c) 50.70Hz ±0.10Hz	22.200kW	50.7		-7.2%
Step d) 51.15Hz ±0.05Hz	19.2kW	51.2		-19.2%
Step e) 50.70Hz ±0.10Hz	22.1kW	50.7		-7.6%
Step f) 50.45Hz ±0.05Hz	23.3kW	50.5		-2.8%
Step g) 50.00Hz ±0.01Hz	24.2kW	50		0%
Test sequence at **Registered Capacity** 40% - 60%	Measured **Active Power** Output	Frequency	Primary Power Source	**Active Power** Gradient
Step a) 50.00Hz ±0.01Hz	17.5kW	50	C65 SA MT inverter grid forming output through resistive load bank. Frequency out adjustable to 1dp.	-0%
Step b) 50.45Hz ±0.05Hz	16.8kW	50.5		-3.89%
Step c) 50.70Hz ±0.10Hz	15.9kW	50.7		-8.89%
Step d) 51.15Hz ±0.05Hz	13.6kW	50.2		-21.67%
Step e) 50.70Hz ±0.10Hz	15.9kW	50.7		-8.89%
Step f) 50.45Hz ±0.05Hz	16.8kW	50.5		-3.89%
Step g) 50.00Hz ±0.01Hz	17.4	50		-0.56%

10. Protection – Re-connection timer.		
Test should prove that the reconnection sequence starts after a minimum delay of 20 s for restoration of voltage and frequency to within the stage 1 settings of Table 10.1.		
Time delay setting	Measured delay	Checks on no reconnection when voltage or frequency is brought to just outside stage 1 limits of Table 10.1.

5mins	300s	At 1.16 pu (266.2 V)	At 0.78 pu (180.0 V)	At 47.4 Hz	At 52.1 Hz
Confirmation that the **Power Generating Module** does not re-connect.		Confirmed	Confirmed	Confirmed	Confirmed

11. Fault level contribution: These tests shall be carried out in accordance with EREC G99 Annex A.7.1.5

For **Inverter** output

Time after fault	Volts	Amps
20ms	0	0
100ms	0	0
250ms	0	0
500ms	0	0
Time to trip	0.009	In seconds

12. Self-Monitoring solid state switching: No specified test requirements. Refer to Annex A.7.1.7.	
It has been verified that in the event of the solid state switching device failing to disconnect the **Power Park Module**, the voltage on the output side of the switching device is reduced to a value below 50 volts within 0.5 s.	~~Yes~~/ NA
13. Wiring functional tests: If required by para 15.2.1.	
Confirm that the relevant test schedule is attached (tests to be undertaken at time of commissioning)	~~Yes~~ / NA
14. Logic interface (input port).	
Confirm that an input port is provided and can be used to shut down the module.	Yes / ~~NA~~
Additional comments.	

System designed iaw. EREC G5, and P28.

Installers, please verify nominal site voltage to determine relay settings.
DNOs: If external G99 relay is not being used: please visually ensure that the attached screenshot "Screenshot G99 C30 GC_Settings.jpg" is followed correctly on site in the installers software settings.

2-4. **Power Quality (Harmonics, Flicker and DC injection).** The Capstone C30 system is a discontinued product at Capstone. To support our UK legacy product customers G99 testing was conducted on site by Capstone as manufacturer rather than at the factory on our test grid. The results listed here are inclusive of other grid quality contributors and despite this handicap they still fall well within the limits defined by EU RfG and EREC G99. PWHD was not tested on site (due to the need for extremely high order harmonics to be analysed). Instead, we can declare that they have previously been tested at factory to consistently perform at well below 1%PWHD, and that we have then also included an additional high order harmonics filter (dubbed the "CE filter") to our product to lower these even further.

5. **Power factor:** Reactive current is used to provide a trip of loss of current if one phase is removed (it is detectable). So with no real power we still push reactive current in order to detect loss of single phase. This will be detectable at low power outputs.

11. Fault level contribution peaked at 300Apk for (9.1mS)

12. solid state IGBT switching device is zero within 400mS and is also isolated via the output contactor (0 within 180mS), annex A.7.1.7 not yet written to define test.

14. Input port can be always digital i/o or often with the option of Modbus depending on installation.