ENA G59-3-4

Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators

Report reference No. ..... :	P2018062804	
Tested by (printed name and signature) ..... :	Daniel Keis	..... :
Approved by (printed name and signature) ..... :	Manuel Shimasaki	..... :
Date of issue ..... :	28 June 2018	

Testing Laboratory Name ..... :	EnTEST Laboratories
	Test indicated as traceable only are outside the scope of the laboratories accreditation. **Accreditation number: 1273**
Address ..... :	1 Treffers Road, Wigram, Christchurch, New Zealand 8042
Testing location/procedure ..... :	NZ ☒
Other (please explain) ..... :	

Applicant's Name ..... :	Enphase Energy
Address ..... :	1420 North McDowell Boulevard, Petaluma, CA 94954, USA.

Test specification

Standard ..... :	ENA G59-3-4
Test procedure ..... :	EnTEST Laboratories
Non-standard test method ..... :	

Test Report Form No. ..... :	ENA G59-3-4
TRF originator. ..... :	EnTEST Laboratories
Master TRF ..... :	June 2018

Test item description ..... :	Solar Micro Inverter
Trademark ..... :	ENPHASE.
Manufacturer ..... :	Enphase Energy
Model and/or type reference ..... :	IQ7-60- X-Y-Z
Rating(s) ..... :	See rating table

Copy of marking plate

Model: **IQ7-60-X-INT**

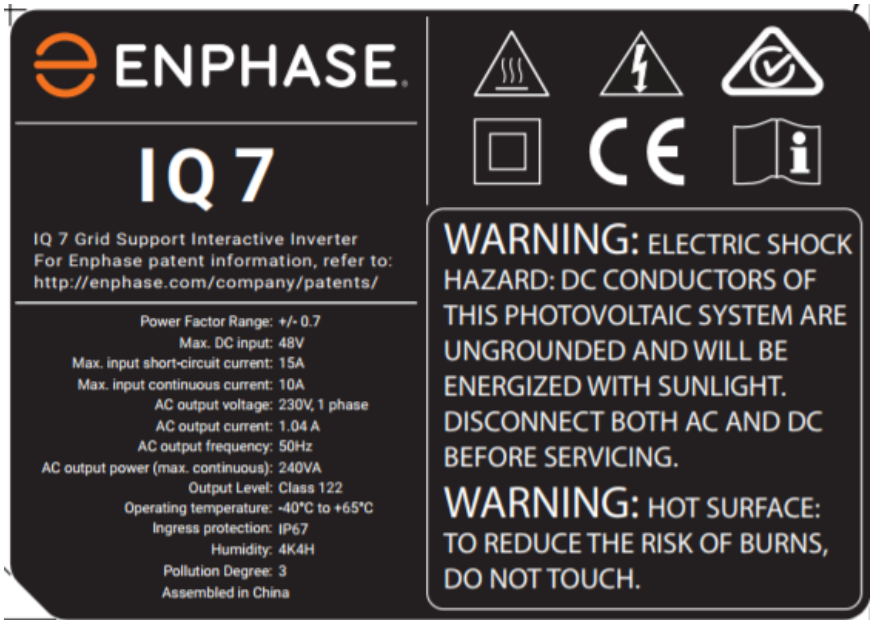

Figure 1: IQ7 marking plate

Copy of marking plate

Model: **IQ7-ACM-INT**

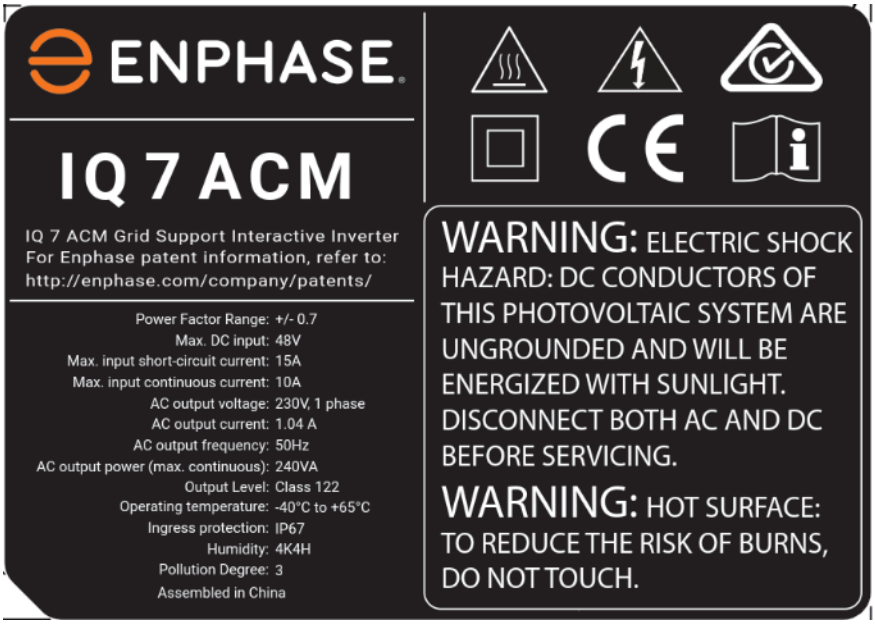

Figure 2: IQ7 ACM marking plate

Worst case uncertainty of Measurements

Parameter	Range	Instrument accuracy of Measuring Range
Voltage		
- Up to 1000 V	up to 1 kHz	±1,5 %
	1kHz up to 5 kHz	±2 %
	5 kHz up to 20 kHz	±3 %
	20 kHz and above	±5 %
- 1000 V and above	dc up to 20 kHz	±3 %
	20 kHz and above	±5 %
Current		
- Up to 5 A	up to 60 Hz	±1,5 %
	above 60 Hz up to 5 kHz	±2,5 %
	5 kHz up to 20 kHz	±3,5 %
	20 kHz and above	±5 %
- Above 5 A	up to 5 kHz	±2,5 %
	5 kHz up to 20 kHz	±3,5 %
	20 kHz and above	± %
Leakage (Touch) current[1]	50 Hz up to 60 Hz	±3,5 %
	greater 60 Hz up to 5 kHz	±5 %
	greater 5 kHz up to 100 kHz	±10 %
	greater 100 kHz up to 1 MHz	under consideration
Power (50/60 Hz)	up to 3 kW	±3 %
	above 3 kW	±5 %
Power Factor (50/60 Hz)		±0,05
Frequency	up to 10 kHz	±0,2 %
Resistance	1 mW up to 100 mΩ and above 1 MΩ up to 1 TΩ	±5 %
	above 1 TΩ	±10 %
	for all other cases	±3 %
Temperature [2,3]		
	- 35°C to below 100° C	±2° C
	100° C up to 500° C	±3 %
	below - 35°C ± 3°C	±3° C
Time	10 ms up to 200 ms	±5 %
	200 ms up to 1 s	±10 ms
	1 s and above	±1 %
Linear dimensions	up to 1 mm	±0,05 mm
	1 mm up to 25 mm	±0,1 mm
	25 mm and above	±0,5 %
Mass	above 10 g and up to 100 g	±1 %
	100 g up to 5 kg	±2 %
	5 kg and above	±5 %
Force	for all values	±6 %
Mechanical energy	for all values ± 10%	±10 %
Torque		±10%
Angles		±1 degree
Relative humidity	30% to 95% RH	±6% RH
Barometric air pressure		±10 kPa

1. The stated tolerances apply to the total tolerance of the leakage (touch) current circuit and metering Instrument.
2. Thermocouple not included in the Instrument accuracy of measuring range. Thermocouples type “T” premium grade, are recommended.
3. Not for measurements related to relative humidity.

SUMMARY OF COMPLIANCE WITH ENA G59-3-4

All tests passed the requirements of the ENA G59-3-4 within the required limits and within the equipment uncertainties.

The Photovoltaic Micro-inverters, model numbers IQ7-60-X-Y-Z **COMPLIED** with the applicable clauses of ENA G59-3-4

Possible test case verdicts:

- test case does not apply to the test object ..... : N/A
- test object does meet the requirement ..... : P(Pass)
- test object does not meet the requirement ..... : F(Fail)

Testing ..... :

Date of receipt of test item..... : April 2018

Date (s) of completion of tests..... : April – June 2018

General remarks:

1. The test results presented in this report relate only to the objects tested.
2. This report shall not be reproduced, except in full, without the written approval of the issuing testing laboratory.
3. If the measured result complies up to the limit of acceptance, the result shall be reported along with our uncertainty of measurement. e.g. results to state window of uncertainty.
4. "(see Enclosure #)" refers to additional information appended to the report.
5. "(see appended table)" refers to a table appended to the report.

General product information:

The EUT (Equipment Under Test), known as Photovoltaic Micro-inverters, model number IQ7 was supplied for testing to ENA G59-3-4 by Enphase Energy Inc of 1420 North McDowell Boulevard, Petaluma, CA 94954, USA.

Model rating table:

Specification	Units	IQ7
Rated output active power	W	240
Output apparent power	VA	240
Nominal output voltage	V_{rms}	230
Output voltage range	V_{rms}	230 / 184 to 276
Nominal output frequency	Hz	50
Output frequency range	Hz	45-55
AC output current	A_{rms}	1.04
EN50530 efficiency	%	96.5
Full power MPPT input voltage range	V	27-37
Input operating range	V	16-48
Input current limit region	V	16-27
Input frequency	Hz	DC
Input maximum continuous current	A	10
DC LSC input maximum	A	15
Ingress protection		IP67
Environmental category		Outdoor
Wet locations		suitable
Pollution degree		PD3
Ambient temperature		-40C to +65C
Relative humidity		4K4H
Maximum altitude		Not rated
Overvoltage category		OVC III

IQ7-60-X-Y-Z Model nomenclature details:
X = 2, 5 or B
- 2 = Multicontact PV connector
- 5 = Amphenol PV connector
- B = Friends PV connector

Y = blank or ACM (X marking not required)
Z = blank or any letter for country of intended installation (eg: US for North America, INT for International)

Firmware version:

520-00082-r01-v02.12.02

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APPENDIX A: Table of Results

13.1 Generating Unit Type Test Sheet

Type Tested Generating Unit(>16A per phase but ≤ 50 kW 3 phase or 17 kW 1 phase)

TYPE TEST SHEET

This Type Test sheet shall be used to record the results of the type testing of Generating Unit between 16A per phase and 17kW per phase maximum output at 230V (17kW limit single phase, 34kW limit split phase, 50kW limit 3 phase) It includes the **Generating Unit**s supplier declaration of compliance with the requirements of Engineering Recommendation G59/3			
Type Tested reference number	IQ7-60-2-INT, IQ7-60-5-INT, IQ7-60-B-INT, IQ7-ACM-INT		
Generating Unit technology	Microinverter		
System supplier name	Enphase Energy Inc		
Address	1420, N. McDowell Blvd Petaluma, CA 94954, USA		
Tel	(877) 797-4743	Fax	
E:mail	dkeis@enphaseenergy.com	Web site	enphase.com
Maximum export capacity, use separate sheet if more than one connection option.	≤ 17	kW single phase, single, split or three phase system	
	≤ 50	kW three phase	
		kW two phases in three phase system	
		kW two phases split phase system	
System supplier declaration. - I certify on behalf of the company named above as a supplier of a **Generating Unit**, that all products supplied by the company with the above Type Test 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 modifications are required to ensure that the product meets all the requirements of EREC G59/3.			
Signed		On behalf of	ENPHASE.
Note that testing can be done by the manufacturer of an individual component, by an external test house, or by the supplier of the complete system, or any combination of them as appropriate. Where parts of the testing are carried out by persons or organisations other than the supplier then the supplier 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.			

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Power Quality. Harmonics. These tests should be carried out as specified in 61000-3-12 or 61000-3-2. Only one set of tests is required and the **Manufacturer** should decide which one to use and complete the relevant table. The chosen test should be undertaken with a fixed source of energy at two power levels a) between 45 and 55% and b) at 100% of maximum export capacity.

The test should be carried out on a single **Generating Unit.** The results need to comply with the limits of table 2 of BS EN 61000-3-12 for single phase equipment, to table 3 of BS EN 61000-3-12 for three phase equipment or to table 1 of BS EN 61000-3-2 if that standard is used.

Note that Generating Units meeting the requirements of BS EN 61000-3-2 will need no further assesment with regards to harmonics. Generating Units with emissions close to the limits laid down in BS EN 61000-3-12 may require the installation of a transformer between 2 and 4 times the rating of the **Generating Unit** in order to accept the connection to a **DNO**'s network.

Generating Unit tested to BS EN 61000-3-2

Generator Unit rating per phase (rpp)			0.24 kW			
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value MV in Amps		Measured Value MV in Amps		Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.003	P	0.0066	P	1.080	
3	0.0029	P	0.0035	P	2.300	
4	0.0001	P	0.0004	P	0.430	
5	0.0159	P	0.0335	P	1.140	
6	0.0001	P	0.0003	P	0.300	
7	0.0009	P	0.0005	P	0.770	
8	0.0001	P	0.0002	P	0.230	
9	0.0013	P	0.0005	P	0.400	
10	0.0001	P	0.0002	P	0.184	
11	0.0012	P	0.0012	P	0.330	
12	0.0001	P	0.0002	P	0.153	
13	0.001	P	0.0008	P	0.210	
14	0.0001	P	0.0002	P	0.131	
15	0.0008	P	0.0012	P	0.150	
16	0.0001	P	0.0002	P	0.115	
17	0.0008	P	0.0009	P	0.132	
18	0.0001	P	0.0002	P	0.102	

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19	0.0007	P	0.0007	P	0.118	
20	0.0001	P	0.0001	P	0.092	
21	0.0007	P	0.0006	P	0.107	0.160
22	0.0001	P	0.0002	P	0.084	
23	0.0005	P	0.0004	P	0.098	0.147
24	0.0001	P	0.0001	P	0.077	
25	0.0003	P	0.0007	P	0.090	0.135
26	0.0001	P	0.0001	P	0.071	
27	0.0004	P	0.0009	P	0.083	0.124
28	0.0001	P	0.0001	P	0.066	
29	0.0003	P	0.0008	P	0.078	0.117
30	0.0001	P	0.0001	P	0.061	
31	0.0005	P	0.0011	P	0.073	0.109
32	0.0001	P	0.0001	P	0.058	
33	0.0003	P	0.001	P	0.068	0.102
34	0.0001	P	0.0001	P	0.054	
35	0.0003	P	0.0009	P	0.064	0.096
36	0.0001	P	0.0001	P	0.051	
37	0.0005	P	0.0009	P	0.061	0.091
38	0.0001	P	0.0001	P	0.048	
39	0.0002	P	0.0003	P	0.058	0.087
40	0.0001	P	0.0002	P	0.046	

Note the higher limits for odd harmonics 21 and above are only allowable under certain conditions, if these higher limits are utilised please state the exemption used as detailed in part 6.2.3.4 of BS EN 61000-3-2 in the box below.

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APPENDIX A: Table of Results

Power Quality. Voltage fluctuations and Flicker. The tests should be carried out on a single **Generating Unit.** 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.

Traceable results only	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	0.18	0.14	0.00	0.16	0.03	0.00	0.10	0.09
Normalised to standard impedance	0.18	0.14	0.00	0.16	0.03	0.00	0.10	0.09
Normalised to required maximum impedance	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
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	0.4	Ω	XI	0.25	Ω
Standard Impedance	R	0.24 * 0.4 ^	Ω	XI	0.15 * 0.25 ^	Ω
Maximum Impedance	R	N/A	Ω	XI	N/A	Ω

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APPENDIX A: Table of Results

* Applies to three phase and split single phase **Generating Unit**s

^ Applies to single phase **Generating Unit**s and **Generating Unit**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*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	4 May 2018	Test end date	4 May 2018
Test location	1 Treffers Rd., Wigram, Christchurch, NZ		

Power quality. DC injection. The tests should be carried out on a single **Generating Unit** Tests are to be carried out three power defined levels ±5%. At 230V a 2kW single phase inverter has a current output of 8.7A so DC limit is 21.75mA, a 10kW three phase inverter has a current output of 43.5A at 230V so DC limit is 108.75mA

Test power level	10%	55%	100%	
Recorded value in Amps	0.0004	0.0002	0.0016	
as % of rated AC current	0.005%	0.002%	0.018%	
Limit	0.25%	0.25%	0.25%	

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Power Quality. Power factor. The tests should be carried out on a single Generating Unit. Testa are to be carried out at three voltage levels and at full output. Voltage to be maintained within + or – 1.5% of the stated level during the test.

	216.2V	230V	253V	Measured at three voltage levels and at full output. Voltage to be maintained within + or – 1.5% of the stated level during the test.
Measured value	1.00	1.00	1.00	
Limit	>0.95	>0.95	>0.95	

Protection. Frequency tests

Function	Setting		Trip test		“No-trip tests”	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
O/F stage 1	51.5Hz	90s	51.48 Hz	91.26 s	51.3Hz 95s	Confirmed
O/F stage 2	52Hz	0.5s	51.98 Hz	0.57 s	51.8Hz 89.98s	Confirmed
					52.2Hz 0.48s	Confirmed
U/F stage 1	47.5Hz	20s	47.52 Hz	20.3 s	47.7Hz 25s	Confirmed
U/F stage 2	47Hz	0.5s	47.02 Hz	0.57 s	47.2Hz 19.98s	Confirmed
					46.8 Hz 0.48s	Confirmed

Note. For frequency Trip tests the Frequency required to trip is the setting ± 0.1Hz. 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 ± 0.2Hz and for the relevant times as shown in the table above to ensure that the protection will not trip in error.

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Protection. Voltage tests						
Function	Setting		Trip test		“No trip-tests” All phases at same voltage	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
O/V stage 1	262.2V	1.0s	262.3 V	1.06 s	258.2V 2.0 sec	Confirmed
O/V stage 2	273.7V	0.5s	273.8 V	0.56 s	269.7V 0.98s	Confirmed
					277.7V 0.48s	Confirmed
U/V stage 1	200.1V	2.5s	200.7 V	2.56 s	204.1V 3.5s	Confirmed
U/V stage 2	184V	0.5s	183.8 V	0.56 s	188V 2.48s	Confirmed
					180v 0.48 sec	Confirmed
Note. For voltage tests the voltage required to trip is the setting plus or minus 3.45V. The time delay can be measured at a larger deviation than the minimum required to operate the projection. The No-trip tests need to be carried out at the setting ±4V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						

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a) Protection. Loss of Mains test and single phase test. The tests are to be To be carried out at three output power levels plus or minus 5%, an alternative for inverter connected Generating Units can be used instead.

To be carried out at three output power levels plus or minus 5%, an alternative for inverter connected Generating Units can be used instead.

Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded network	95% of **Generating Unit** output	95% of **Generating Unit** output	95% of **Generating Unit** output	105% of **Generating Unit** output	105% of **Generating Unit** output	105% of **Generating Unit** output
Trip time. Limit is 0.5s	3.6 ms	3.2 ms	6.0 ms	3.6 ms	3.6 ms	6.0 ms

Note. For technologies which have a substantial shut down time this can be added to the 0.5s in establishing that the trip occurred in less than 0.5s maximum. Shut down time could therefore be up to 1.0s for these technologies.

Indicate additional shut down time included in above results	0 s

Note as an alternative, inverters can be tested to BS EN 62116. 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	142 ms	180 ms	176 ms	153 ms	185 ms	188 ms

Single phase test for multi phase **Generating Units**. Confirm that when generating in parallel with a network operating at around 50Hz with no network disturbance, that the removal of a single phase connection to the **Generating Unit**, with the remaining phases connected causes a disconnection of the generating unit within a maximum of 1s.

	Ph1 removed	Confirm Trip Confirmed	Ph2 removed	Confirm Trip Confirmed	Ph3 removed	Confirm Trip Confirmed

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b) Protection. Frequency change, Stability test				
	Start Frequency	Change	End Frequency	Confirm no trip
Positive Vector Shift	49.5Hz	+50 degrees		Confirmed
Negative Vector Shift	50.5Hz	- 50 degrees		Confirmed
Positive Frequency drift	49.0Hz	+0.95Hzs^{-1}	51.0Hz	Confirmed
Negative Frequency drift	51.0Hz	-0.95Hzs^{-1}	49.0Hz	Confirmed

c) **Protection. Re-connection timer**. The tests should prove that the reconnection sequence starts in no less than 20s for restoration of voltage and frequency to within the stage 1 settings of table 10.5.7.1					
Test should prove that the reconnection sequence starts in no less than 20s for restoration of voltage and frequency to within the stage 1 settings of table 10.5.7.1					
Time delay setting (s)	Measured delay (s)	Checks on no reconnection when voltage or frequency is brought to just outside stage 1 limits of table 10.5.7.1.			
20 s	28 s	At 266.2V	At 196.1V	At 47.4Hz	At 51.6Hz
Confirmation that the **Generating Unit** does not re-connect		Confirmed	Confirmed	Confirmed	Confirmed

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d) Fault level contribution.					
For machines with electro-magnetic output			For Inverter output		
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	i_p	5.78	20ms	0	0
Initial Value of aperiodic current	A	3.29	100ms	0	0
Initial symmetrical short-circuit current*	I_k	2.48	250ms	0	0
Decaying (aperiodic) component of short circuit current*	i_{DC}	0	500ms	0	0
Reactance/Resistance Ratio of source*	X/R	2.5	Time to trip	0.01	In seconds
For rotating machines and linear piston machines the test should produce a 0s – 2s plot of the short circuit current as seen at the **Generating Unit** terminals. * Values for these parameters should be provided where the short circuit duration is sufficiently long to enable interpolation of the plot					

e) Self Monitoring solid state switching	Yes/NA
It has been verified that in the event of the solid state switching device failing to disconnect the **Generating Unit**, the voltage on the output side of the switching device is reduced to a value below 50 Volts within 0.5 seconds	Yes

Additional comments

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APPENDIX B: Photographic record of sample

IQ7 Photos:

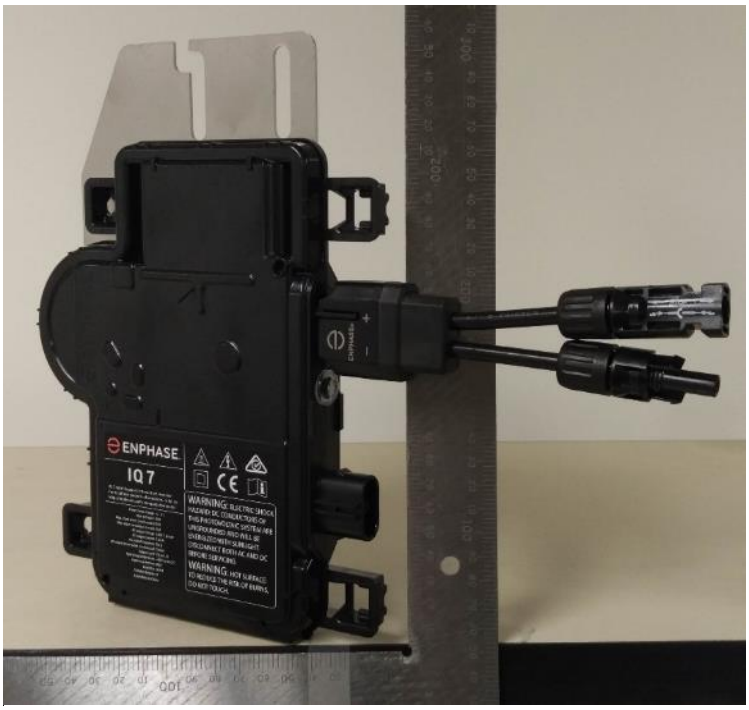

Figure 3: IQ7 general view

Figure 4: IQ7 Bottom

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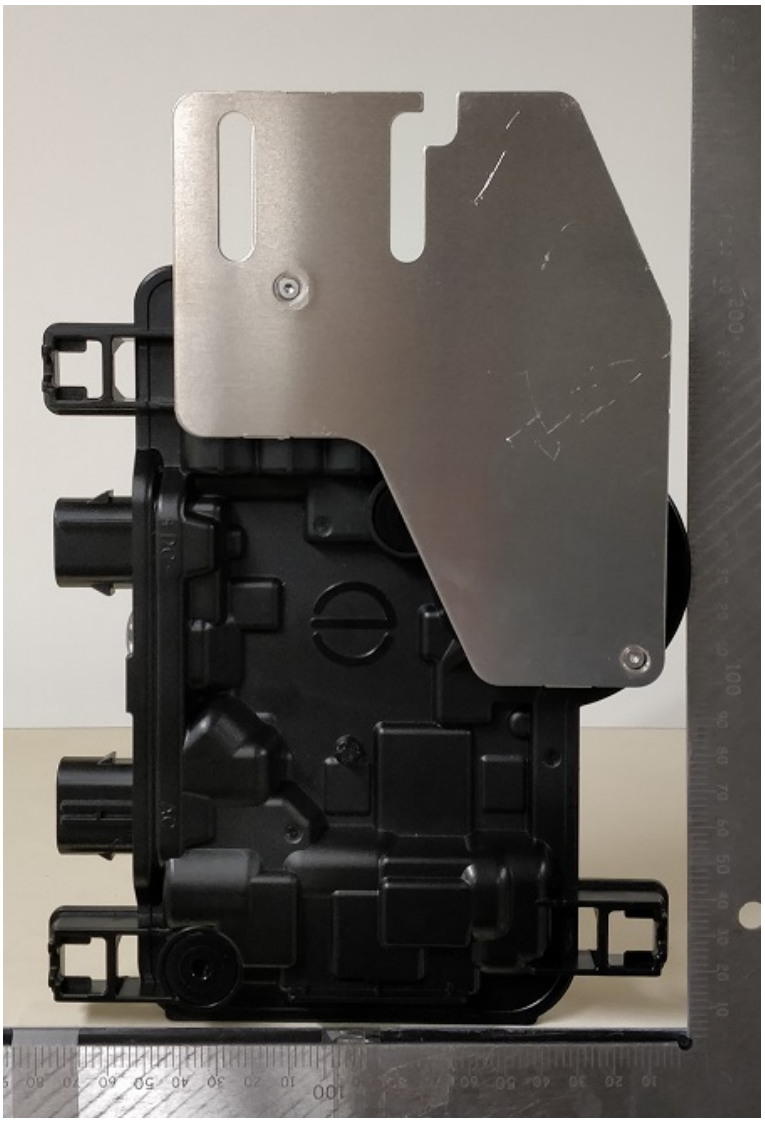

Figure 5: IQ7 Top

Figure 6: IQ7 Cable side

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APPENDIX B: Photographic record of sample

Figure 7: IQ7 Right side

Figure 8: IQ7 Label side

Figure 9: IQ7 mounting plate side

End of report