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D5.5 MIMO units for on-field demonstration – II

January 2020

HEART

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HISTORY OF CHANGES

Version	Date	Comments	Main Authors
0.1	20/12/2019	First draft, establishing document structure	A. Krasnobeski
0.2	17/01/2020	First version, incorporating input from all participants.	A. Krasnobeski
0.3	21/01/2020	Revision of first version	A. Krasnobeski
0.4	25/01/2020	Quality review	S. Grillo, L. Piegari
1.0	30/01/2020	Final version addressing all further comments	A. Krasnobeski

TABLE OF CONTENTS

DISCLAIMER

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No 768921.

EXECUTIVE SUMMARY

This document presents features, changes and status of the Multi-Input Multi-Output (MIMO) converter which will be delivered in Bagnolo (Italy) for on-field demonstration. The final unit for the Bagnolo installation has been assembled and safety tested. Functional and safety testing of each MIMO port has been completed. Communication with Building Management System and control algorithms for the AC, PV, LHP, CHP and Battery ports have been implemented and tested with the exception of the PV algorithm which has been postponed due to test equipment availability. Unit 1 is being pre-compliance tested for the EMC conducted emissions testing while the low-frequency harmonics emissions test has been completed. Test results have been included in this document. Any issues encountered during the testing have been reported. Assembly procedures, Bill Of Materials (BOM) and Construction file documents are being updated.

Unit 1 will be shipped in February for the trial I. For trial II (Lyon case study) Unit 2 has been fully assembled and is fully operational while unit 3 is in the process of being build.

1 SYSTEM REQUIREMENTS AND CONVERTER TOPOLOGY

Finalised system requirements are presented in Figure 1. The system will interact with the following loads and power sources:

a) Heat pumps;

b) Smart fan coils;

c) Solar panels;

d) Batteries;

e) Utility network.

The utility network and the battery converter require bidirectional power flow.

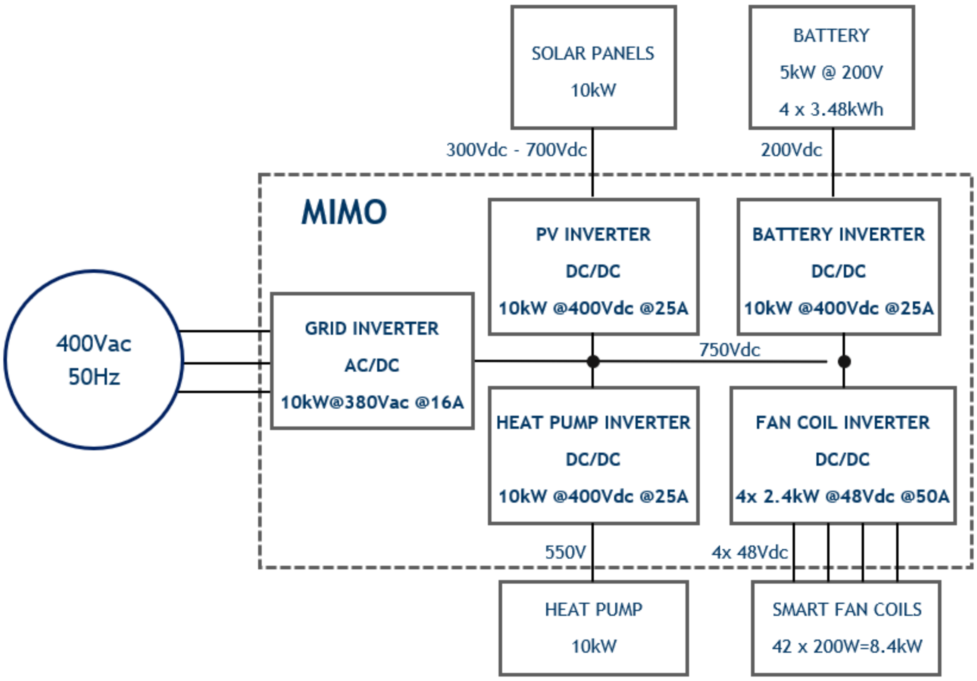

Figure 1 System requirements

Based on the requirements, the system subcomponents presented in Figure 2 have been selected as the final configuration. To decrease the size and the weight of the system compared with the traditional approach based on the off the shelf multiple converters, all the bespoke converters have been packaged into one enclosure. To increase system efficiency up to 99% per converter a new type of the Silicon Carbide (SiC) transistors have been used.

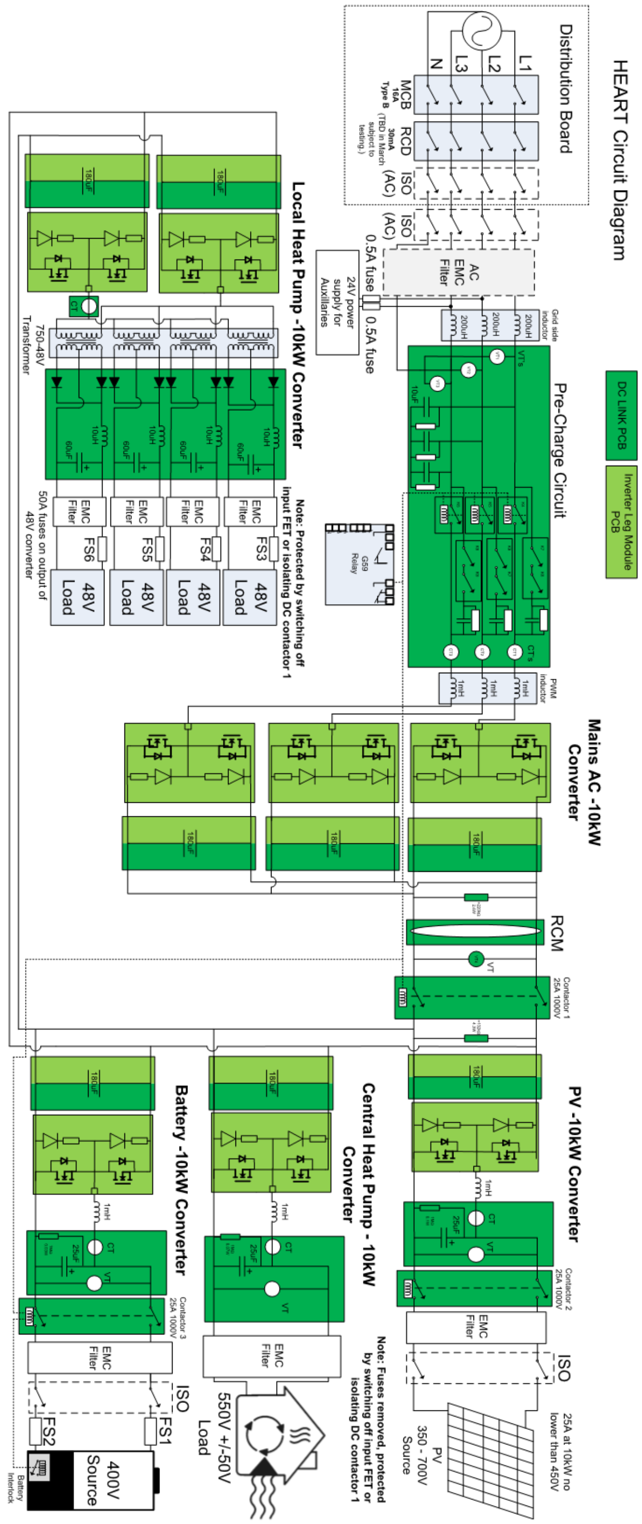

Figure 2 System topology

2 MANUFACTURING OF THE MIMO CONVERTERS

Figure 3 and Figure 4 present a fully assembled production unit 1 for the trial I (Italian case study).

Figure 3 Photo of the internal assembly of unit 1 for the trial

Figure 4 Photo fo the user interface(on the left) and the complete assembly of unit 1(on the right).

Figure 5 presents partially assembled unit 3 for the trial II (Lyon case study). Unit 3 is awaiting parts to finish the assembly.

Figure 5 Current assembly state of unit 3.

Figure 6 presents fully assembled and operational unit 2 and partially assembled unit 3 (on the right).

Figure 6 Fully assembled unit 2(on the left) and partially unit 3 (on the right) for trial II.

3 FUNCTIONAL AND COMPLIANCE TESTING OF UNIT 1 AND 2

Unit 1 and 2 have been successfully flash tested to validate the protection barriers and safety of the converters. Progress has been made in testing and implementation of the control algorithms for the AC, CHP, Battery, LHP ports which have been tested with the rated power. MPPT algorithm for the PV port will be tested in February when the PV simulator will be available.

Majority of the issues with the ports reliability have been rectified. One outstanding issue is the reliability of the LHP port which has failed during the testing. The second failure of the LHP port has happened after the introduction of the changes to fix the first failure which was caused by the diode overvoltage. The work is ongoing to identify the reason of the failure.

Efficiency testing revealed that, currently, peak case efficiency for the AC converter and CHP converter is respectively 98.2% and 98.7% against predicted 99%. This is 0.8% and 0.3% lower than expected. More work could be done to attain full efficiency, but it has been agreed, in order to avoid delays, that these values are satisfactory for the firts demo units.

Type testing of unit 1 is still ongoing. At the time of writing the report, unit 1 has passed low-frequency harmonics emissions according to the EN 61000-3-2. Ports: AC, CHP, PV and LHP have passed pre-compliance testing for the conducted emissions according to the EN 61000-6-3. To pass the emission levels all ports required modifications which will be also implemented in unit 2 and 3. Although Battery port does not require to be EMC tested as the cable length is less than 30m, if time allows the test will be conducted. Figure 7 presents the EMC test setup of the MIMO converter and Figure 8 to Figure 18 present test results for AC, CHP, PV and LHP ports for the quasi-peak conducted emissions.

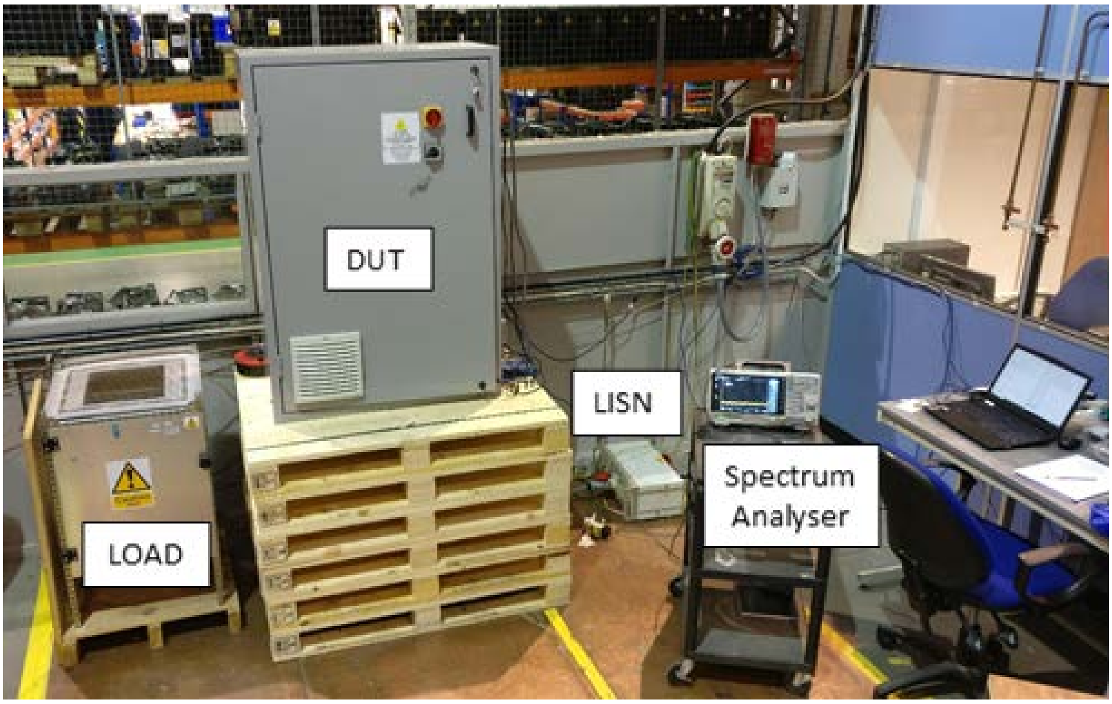

Figure 7 Compliance testing setup of unit 1. DUT stands for "device under test", and LISN stands for "line impedance stabilization network".

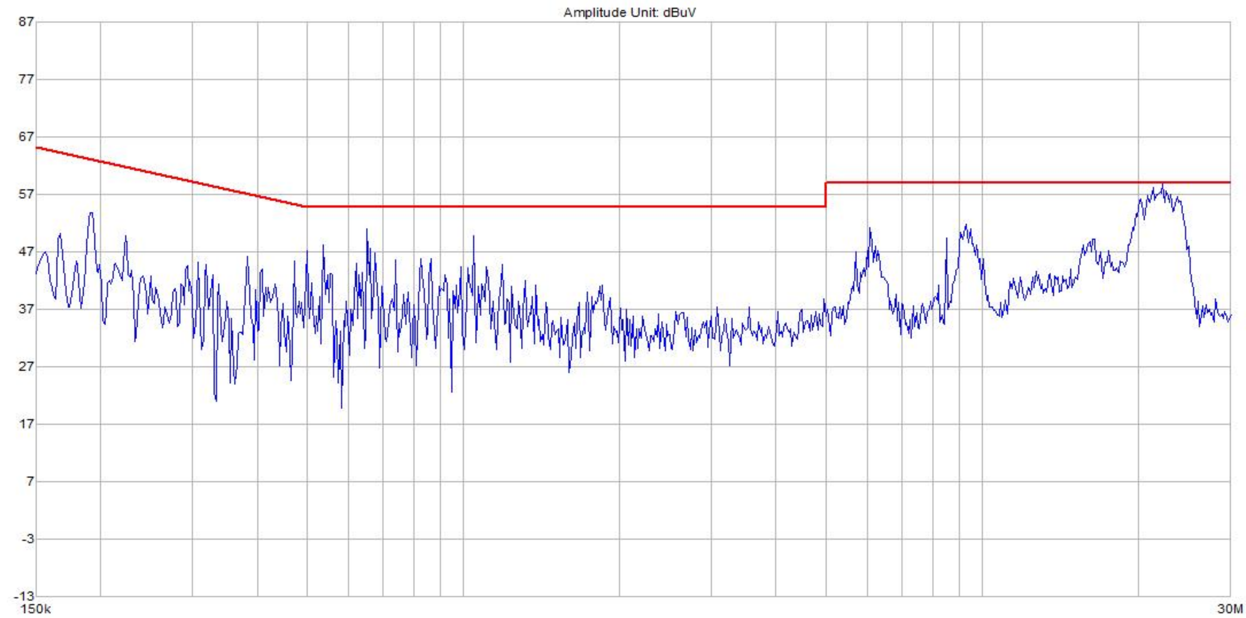

Figure 8 Test results of the quasi-peak conducted emissions of the L3 port. Red – limits, blue actual values.

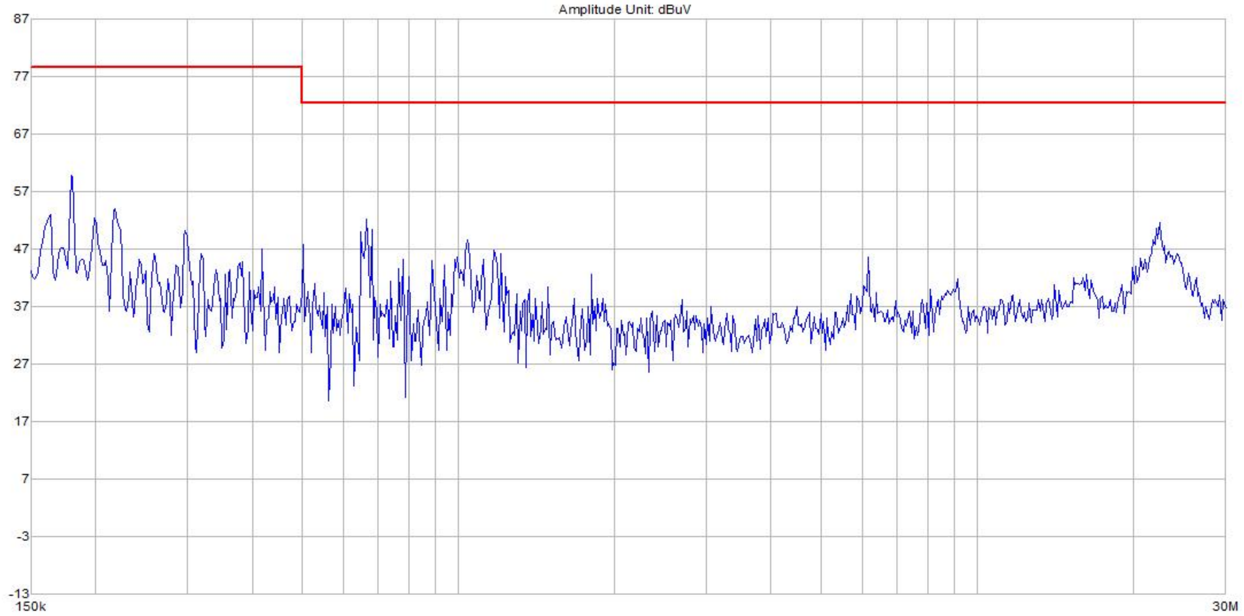

Figure 9 Test results of the quasi-peak conducted emissions for the CHP+. Red – limits, blue actual values.

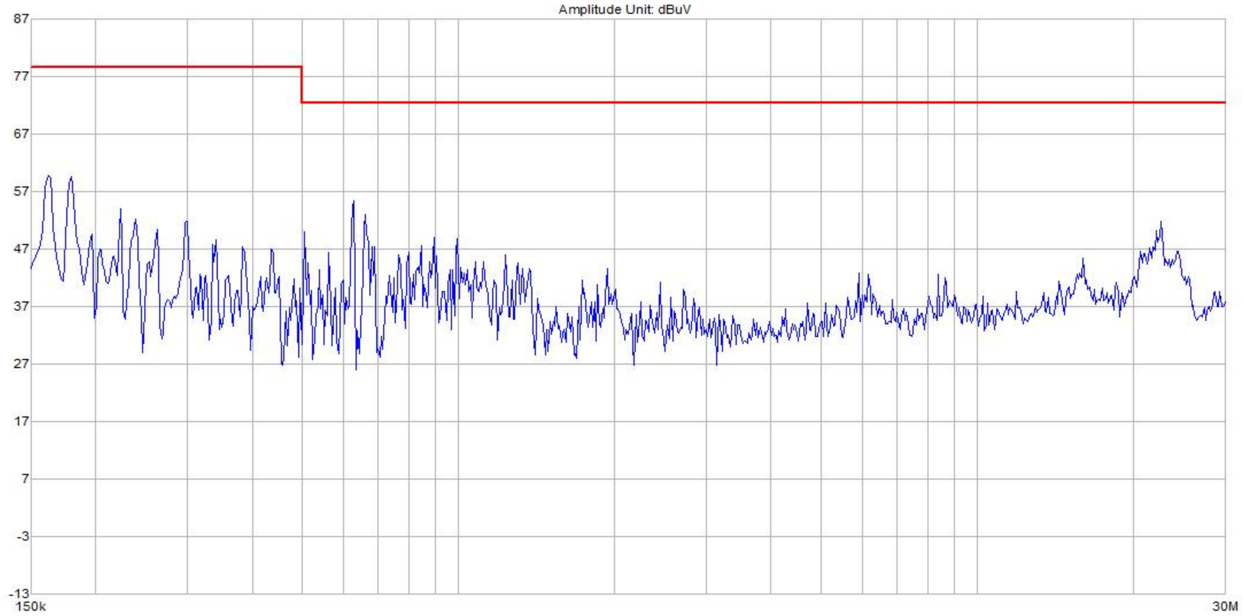

Figure 10 Test results of the quasi-peak conducted emissions for the CHP-. Red – limits, blue actual values.

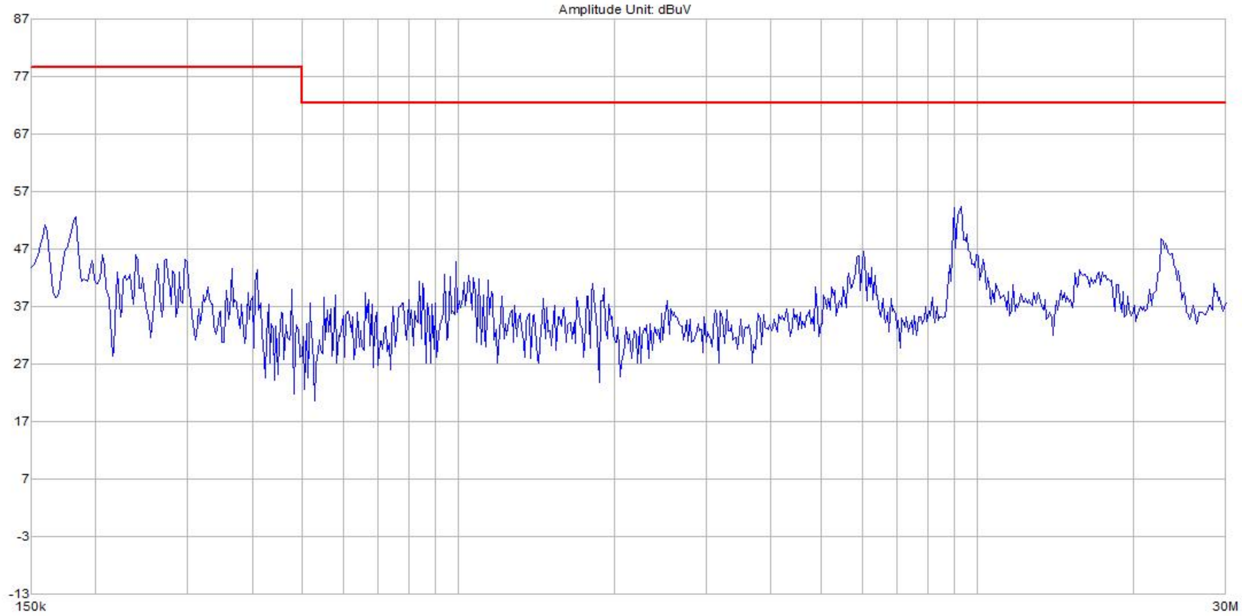

Figure 11 Test results of the quasi-peak conducted emissions for the PV+. Red – limits, blue actual values.

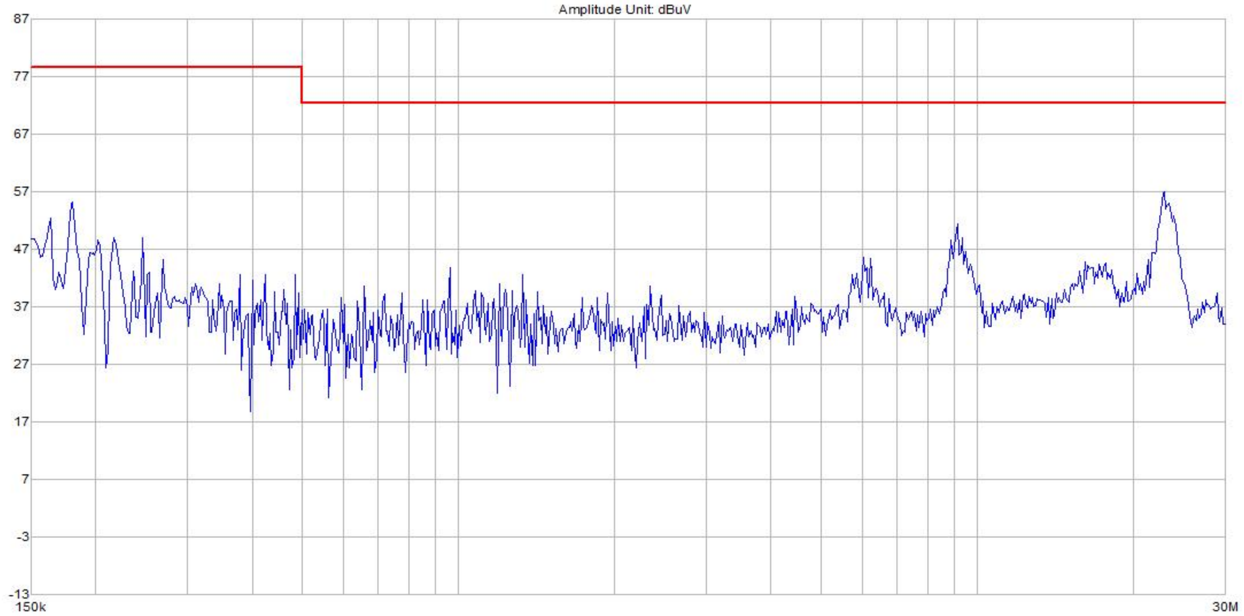

Figure 12 Test results of the quasi-peak conducted emissions for the PV-. Red – limits, blue actual values.

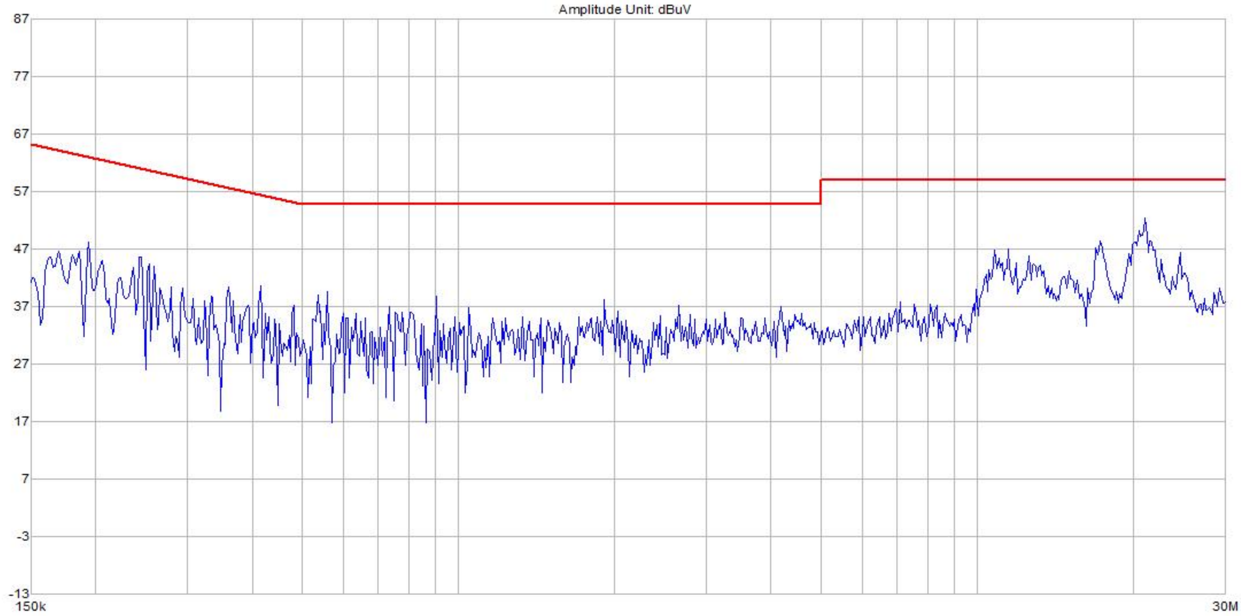

Figure 13 Test results of the quasi-peak conducted emissions for the AC port L1. Red – limits, blue actual values.

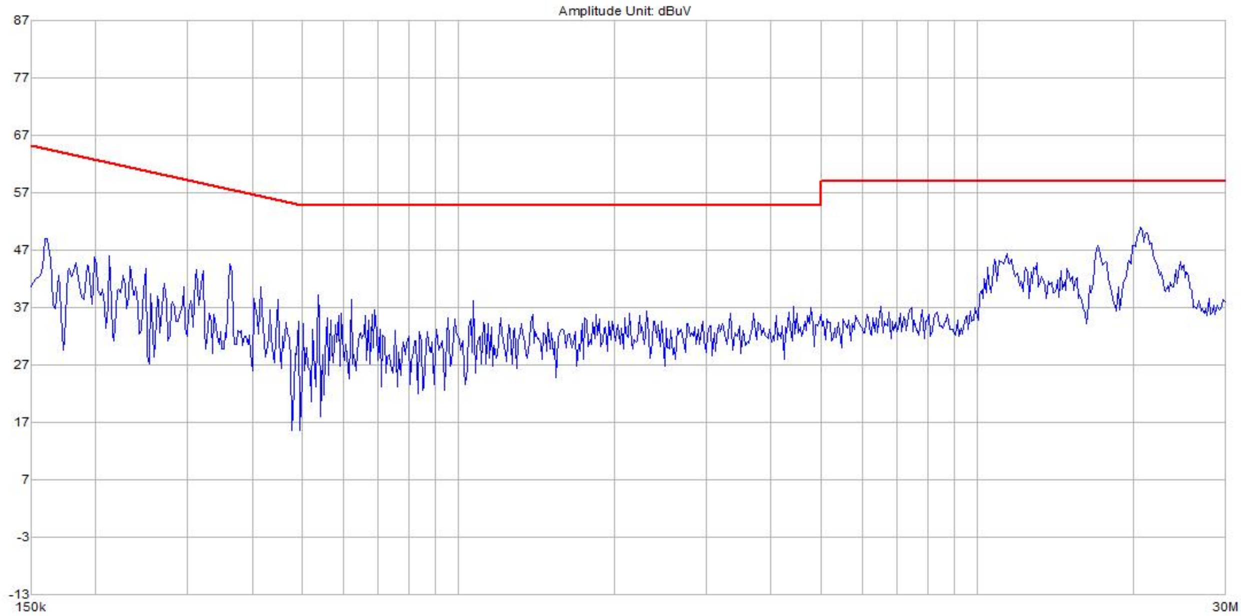

Figure 14 Test results of the quasi-peak conducted emissions for the AC port L2. Red – limits, blue actual values.

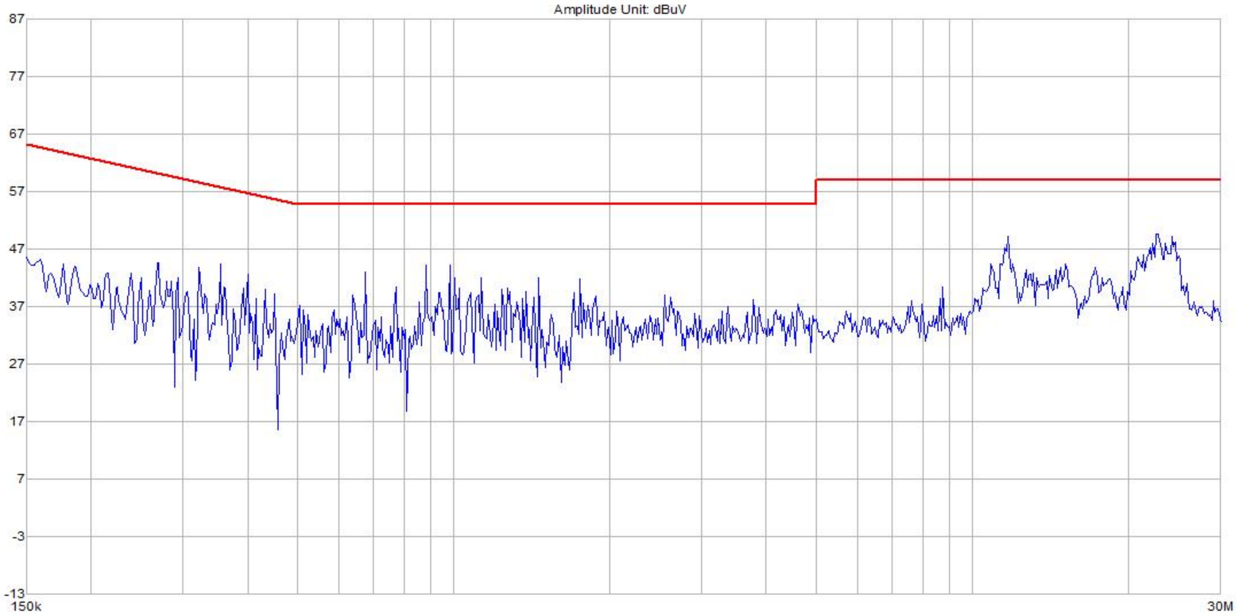

Figure 15 Test results of the quasi-peak conducted emissions for the AC port L3. Red – limits, blue actual values.

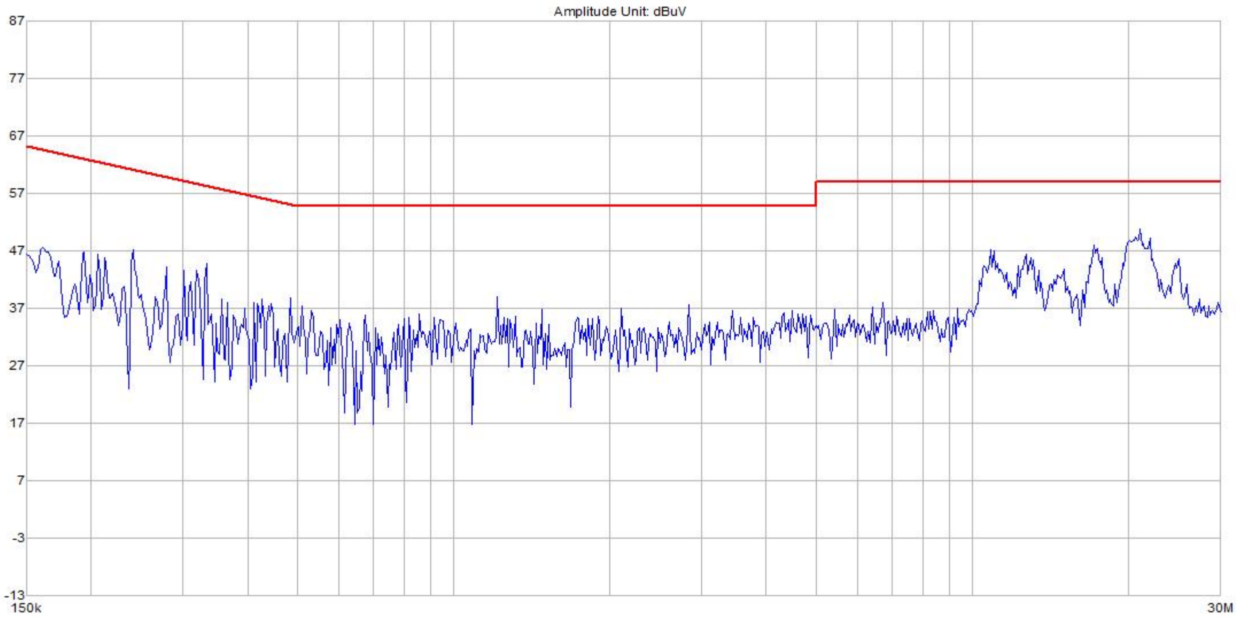

Figure 16 Test results of the quasi-peak conducted emissions for AC port the N. Red – limits, blue actual values.

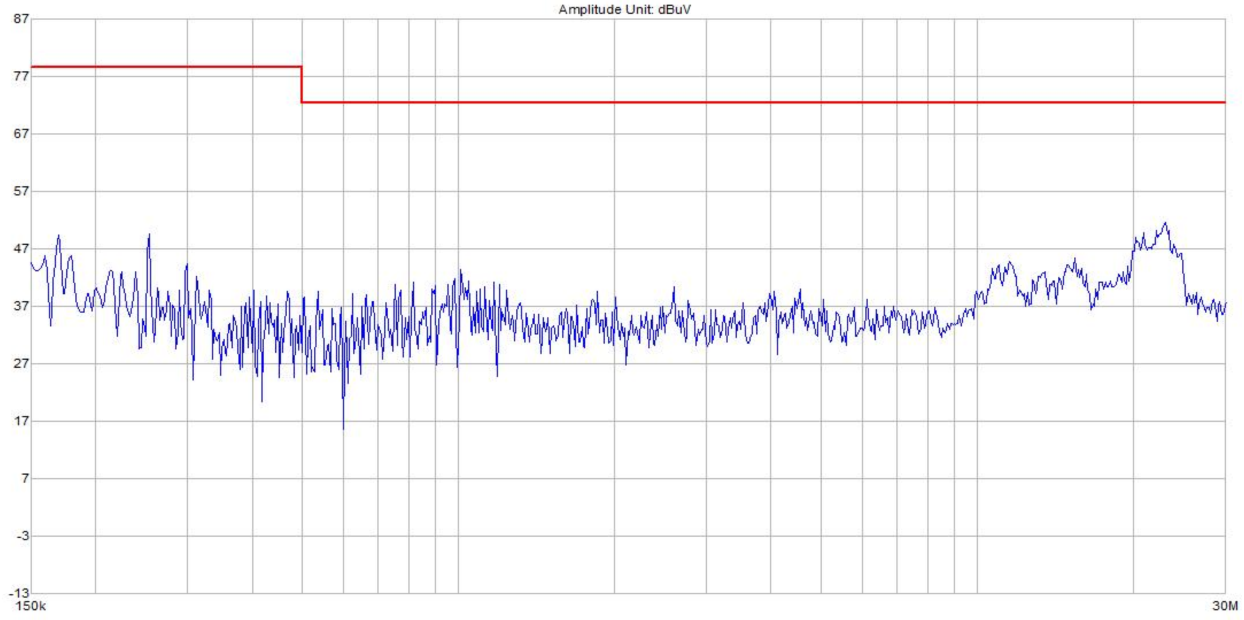

Figure 17 Test results of the quasi-peak conducted emissions for the LHP+ at 25% load. Red – limits, blue actual values.

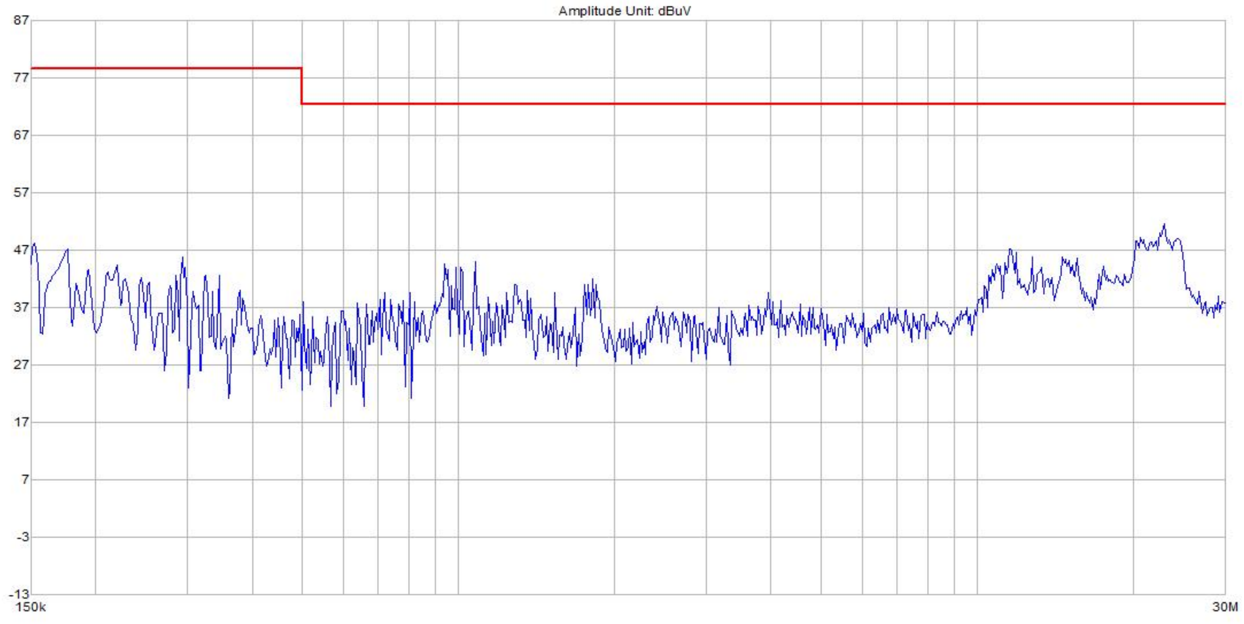

Figure 18 Test results of the quasi-peak conducted emissions for the LHP- at 25% load. Red – limits, blue actual values.

Table 1 presents test results and the limits for the AC port running at the rated power for the low-frequency harmonic emissions according to the EN 61003-2.

Harmonic order n	**100%** of Rated Capacity			Limit in BS EN 61000-3-2	
	Measured Value (A)			**Maximum permissible harmonic current**	**Pass/Fail**
	a	b	c	A	
0 (DC)	-0.102	-0.028	0.068	-	-
1	13.73	13.56	14.73	-	-
3	0.025	0.031	0.023	2.30	Pass
5	0.148	0.153	0.170	1.14	Pass
7	0.219	0.180	0.250	0.77	Pass
9	0.035	0.025	0.062	0.40	Pass
11	0.123	0.094	0.082	0.33	Pass
13	0.091	0.093	0.127	0.21	Pass
15	0.016	0.017	0.018	0.15	Pass
17	0.118	0.123	0.102	0.13	Pass
19	0.025	0.057	0.060	0.12	Pass
21	0.010	0.019	0.021	0.11	Pass
23	0.048	0.043	0.048	0.10	Pass
25	0.045	0.052	0.059	0.09	Pass
27	0.006	0.028	0.024	0.08	Pass
29	0.028	0.027	0.011	0.08	Pass
31	0.023	0.013	0.037	0.07	Pass
33	0.015	0.017	0.011	0.07	Pass
35	0.025	0.025	0.021	0.06	Pass
37	0.035	0.048	0.057	0.06	Pass
39	0.010	0.012	0.026	0.06	Pass
$15 \le n \le 39$				$0.15\,\frac{15}{n}$	
2	0.030	0.104	0.132	1.08	Pass
4	0.046	0.051	0.052	0.43	Pass
6	0.060	0.259	0.281	0.3	Pass
8	0.015	0.025	0.024	0.23	Pass
10	0.011	0.014	0.014	0.18	Pass
12	0.002	0.019	0.011	0.15	Pass
14	0.011	0.030	0.022	0.13	Pass
16	0.011	0.012	0.012	0.12	Pass
18	0.004	0.010	0.006	0.10	Pass
20	0.003	0.009	0.008	0.09	Pass
22	0.004	0.005	0.008	0.08	Pass
24	0.004	0.013	0.012	0.08	Pass
26	0.001	0.011	0.012	0.07	Pass
28	0.004	0.018	0.022	0.07	Pass
30	0.004	0.015	0.009	0.06	Pass
32	0.006	0.029	0.016	0.06	Pass
34	0.007	0.007	0.010	0.05	Pass
36	0.002	0.012	0.009	0.05	Pass
38	0.008	0.009	0.023	0.05	Pass
40	0.026	0.012	0.021	0.05	Pass
$8 \le n \le 40$				$0.23\,\frac{8}{n}$	
THD	4.624	4.303	4.404	-	-

Table 1 Total harmonics emissions at rated power for phase L1, L2, L3

Figure 19 presents currents and voltage waveforms of the AC port (grid-connected inverter)

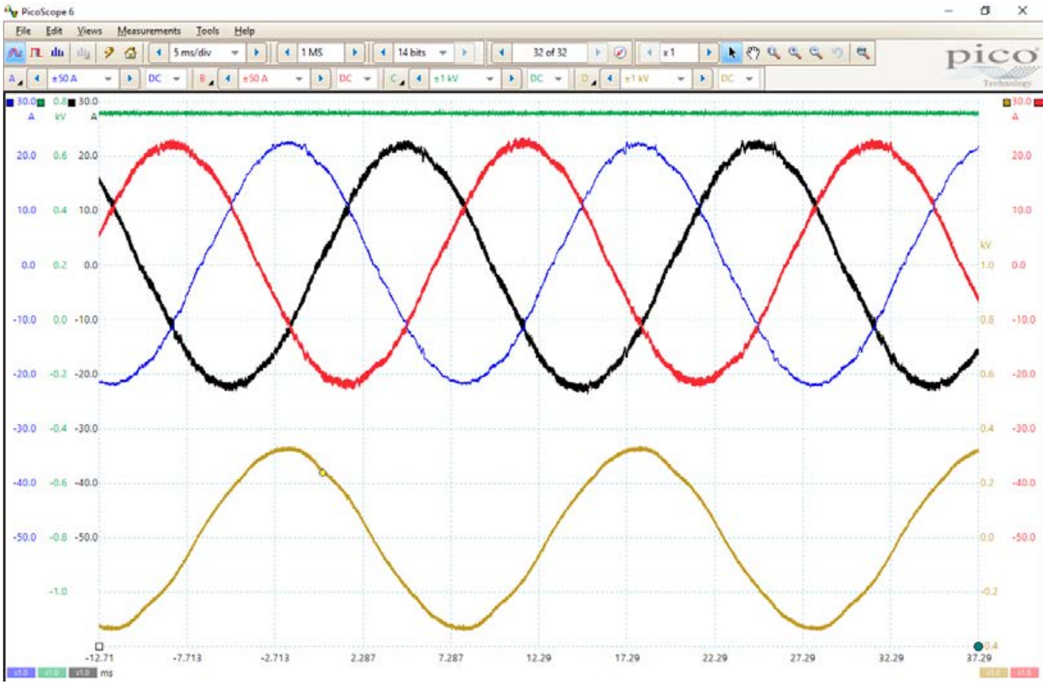

Figure 19 Current and voltage waveforms for the AC converter.Green - DC-link voltage 200V/div, Red – Current L1 10A/div, Blue – Current L2, 10A/div, Black – Current L3 10A/div, Yellow - Grid voltage L2

4 DELIVERY OF UNIT 1 FOR THE TRIAL I

Unit 1 for the trial I is fully assembled and is being type tested and it will be ready to be shipped by the end of February. Any encountered problems are resolved on the go. If any further adjustments will be needed, they will be implemented in situ during commissioning. All the modifications will be copied to unit 2 and 3.

5 OVERALL ACHIEVEMENTS

The main achievements are:

1. Unit 1 and unit 2 fully assembled.
2. Control algorithms for AC, CHP, LHP and Battery have been implemented and validated.
3. MPPT algorithm for the PV has been implemented.

4. Hyperdrive battery was malfunctioning during connection to the Battery port. TPS has helped the supplier investigate and rectify the issue with the Battery Management System.
5. Pre-compliance conducted emissions testing according to EN 61000-6-3 for the AC, LHP, CHP and PV ports have been successfully completed.
6. Low-frequency emissions testing according to EN 61000-3-2 for the AC port have been successfully completed
7. Start of the assembly of unit 3 for the trial II

6 ISSUES TO RESOLVE

One known issue is a recent fault of the LHP port which has been damaged during the testing. In the past, the failure of the diode component was caused by the overvoltage, which has been remedied by the snubber circuit, testing of the snubber circuit confirmed reduction of the overvoltage condition to the safe limits. Therefore, the second failure must have had a different root cause. It is believed that the failure has been caused by incorrect assembly of the diodes to the heatsink assembly. Currently, the issue is being investigated.