TEST ACCORDING TO
EN 50530:2010/A1:2013
OVERALL EFFICIENCY OF GRID CONNECTED PHOTOVOLTAIC INVERTERS

Test Report Number .... : **GZES190201205401**

Tested Model.. : **Hiverter Si-70k**

Variant Model .... : **N/A**

APPLICANT

Name .... : Hitachi Hi-Rel Power Electronics Pvt. Ltd.

Address .... : SM 3 & 4, Sanand – II GIDC, Industrial Estate, Boll Village, Sanand – 382 110, Gujarat, India.

TESTING LABORATORY

Name .... : SGS-CSTC Standards Technical Services Co., Ltd. Guangzhou Branch

Address .... : 198 Kezhu Road, Science City, Economic & Technology Development Area, Guangzhou, Guangdong, China

Conducted (tested) by.................................. : Michael Tong (Project Engineer)

Reviewed & Approved by............................. : Roger Hu (Technical Reviewer)

Date of issue .... : **28/02/2019**

Number of pages .... : **33**

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Test Report Historical Revision:

Test Report Version	Date	Resume
GZES1902012054PV	28/02/2019	This report is a first issuance for a co-license based on report number GZES190201205201

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1 SCOPE

SGS-CSTC Standards Technical Services Co., Ltd. Guangzhou Branch has been contract by Hitachi Hi-Rel Power Electronics Pvt. Ltd., in order to perform the testing according to following standards:
:

- **EN 50530:2010/A1:2013**. Overall efficiency of grid connected photovoltaic inverters.

2 GENERAL INFORMATION

2.1 Testing Period and Climatic conditions

The necessary testing has been performed along 6 days between the14th of Feb. and the 20th of Feb. of 2019.

All the tests and checks have been performed in accordance with the reference Standard (the tests are done at 25 ± 5ºC, 96 kPa ± 10 kPa and 50% RH ± 10% RH).

SITE TEST

Name .... : Shenzhen BALUN Technology Co., Ltd

Address .... : Block B, 1st FL, Baisha Science and Technology Park, Shahe Xi Road, Nanshan District, Shenzhen, Guangdong Province, P. R. China

2.2 Equipment under Testing

<u>Test Item</u>

Apparatus type/ Installation ....: Solar Grid-tied Inverter
Manufacturer/ Supplier/ Installer.................: Hitachi Hi-Rel Power Electronics Pvt. Ltd.
Trade mark ....: HITACHI

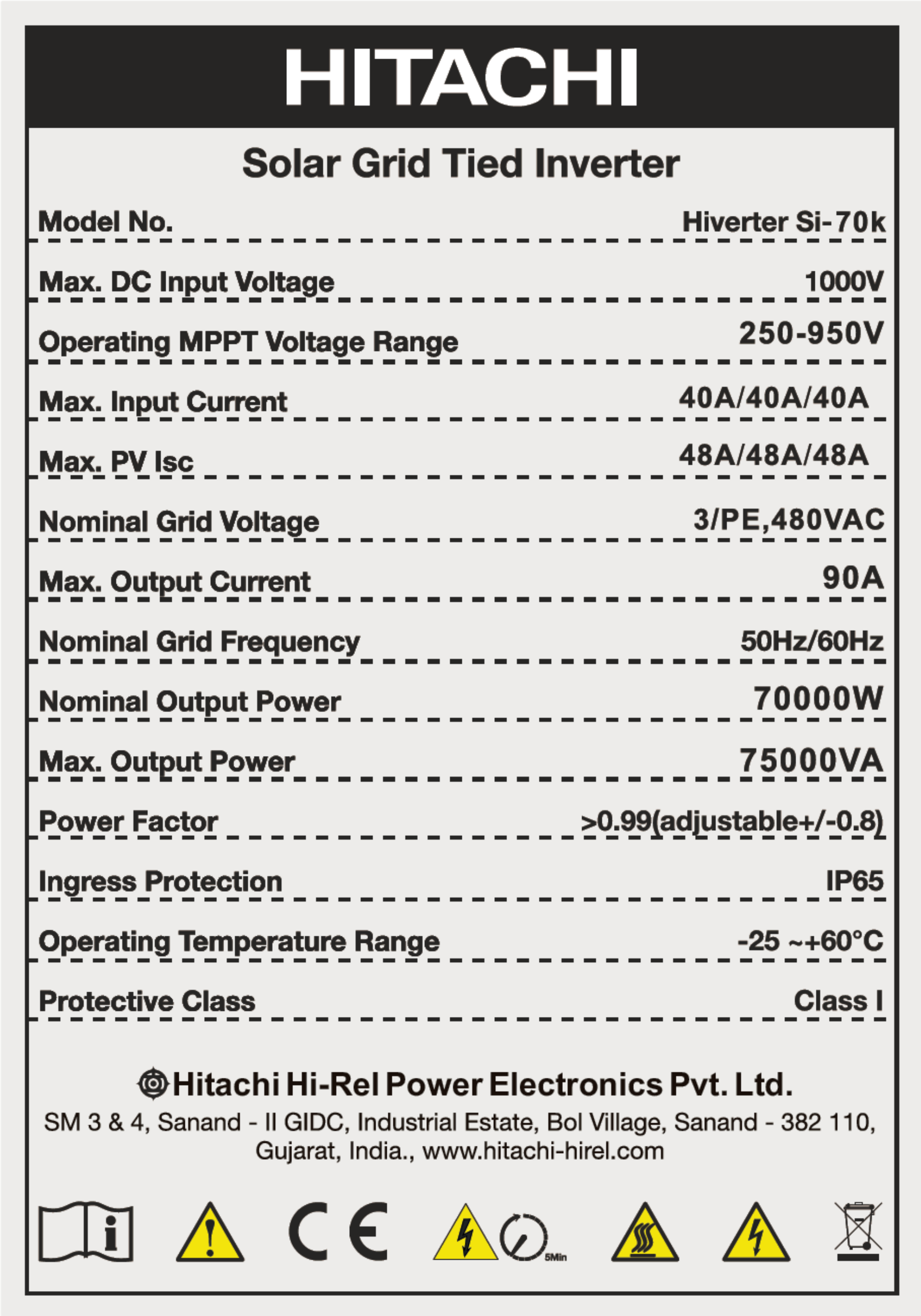
Type ....: Hiverter
Model...: Hiverter Si-70k

Serial Number..: ZJ2CS170J7A090
Software Version..: V1.10
Rated Characteristics.................................: DC input: 250-950V (1000V max.), Max. 40/40/40A
AC output: 3~/PE 480Vac, 50Hz, 90A, 70000W

Date of manufacturing: 2018

Test item particulars
Input .... DC
Output .... 3~/PE
Class of protection against electric shock.................... Class I
Degree of protection against moisture......................... IP 65
Type of connection to the main supply .... Three phase – Fixed installation
Cooling group .... Fans
Modular .... No
Internal Transformer .... No

Rating Plate:



Model fully tested:

- **Hiverter Si-70k**

The results obtained apply only to the particular sample tested that is the subject of the present test report. The most unfavorable result values of the verifications and tests performed are contained herein.
Throughout this report a point (~~comma~~) is used as the decimal separator.

2.3 Manufacturer and Factory information

Manufacturer Name.....................................: **Hitachi Hi-Rel Power Electronics Pvt. Ltd.**

Manufacturer Address ....: SM 3 & 4, Sanand – II GIDC, Industrial Estate, Boll Village, Sanand – 382 110, Gujarat, India.

Factory Name ....: **Dongguan SOFAR SOLAR Co., Ltd.**

Factory Address ....: 1F - 6F, Building E, No. 1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City, Guangdong Province,P.R. China.

2.4 Test Equipment List

	No.	Equipment Name	MARK/Model No.	Equipment No.	Equipment calibration due date
BALUN	1	Heating Recoder	Agilent / 34970A	BZ-SFT-L130	2019/03/14
	2	Power analyzer	HIOKI / PW6001-16	BZ-EP-L005	2019/05/22
	3	Temperature & Humidity meter	BENETECH/GM1360	BL-SFT-L055	2019/03/13
SGS	4	True RMS Multimeter	Fluke / 289C	GZE012-53 (22930028)	2019/03/05

2.5 Measurement Uncertainty

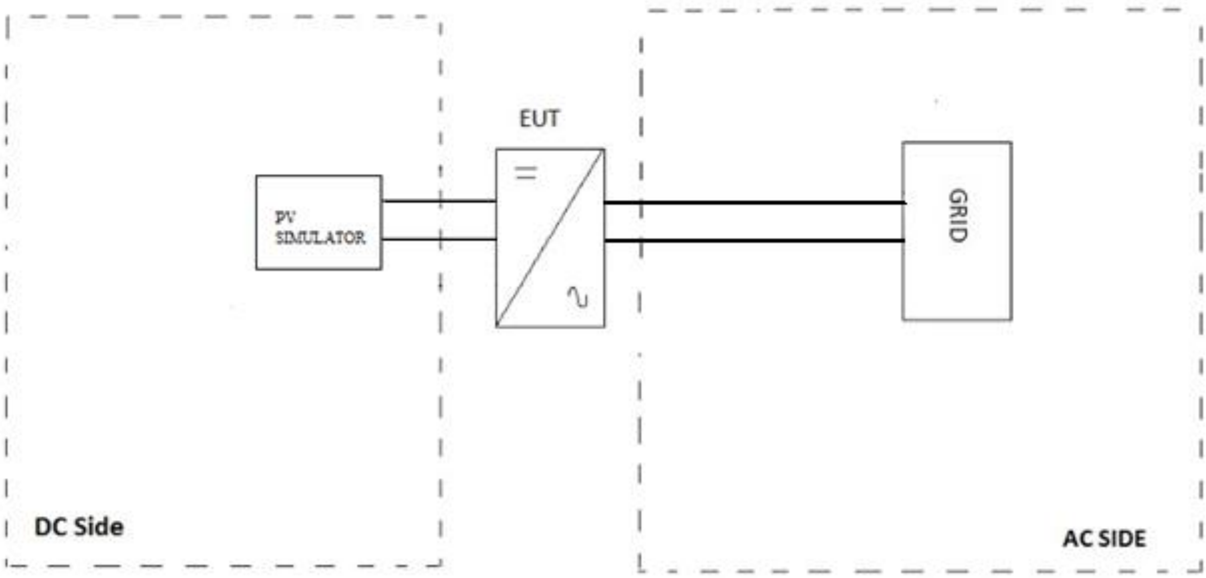
	Voltage measurement uncertainty	±1,5 %
	Current measurement uncertainty	±2,0 %
	Frequency measurement uncertainty	±0,2 %
	Time measurement uncertainty	±0,2 %
	Power measurement uncertainty	±2,5 %
	Phase Angle	±1º
	cosφ	±0,01
Note: The measurement uncertainties associated with other parameters measured during the tests are in the laboratory at disposal of the solicitant.		

2.6 Definitions

EUT	Equipment Under Testing	Qn	Nominal Reactive Power
$I_{DC,I}$	Sampled value of the inverter's input current	S_n	Nominal Apparent Power (Inverter)
		T_M	Overall measuring period
I_n	Nominal Current (Inverter)	$U_{DC,I}$	Sampled value of the inverter's input voltage
p.u	Per unit		
P_{DC}	Measured input power of the device under test	U_n	Nominal Voltage
		ΔT	Period between two subsequent sample values
$P_{MPP,PVS}$	MPP power provided by the PV simulator	η	Efficiency
P_n	Nominal Active Power (Inverter)		

2.7 TEST SET UP OF THE DIFFERENT STANDARDS.

Below is the simplified construction of the test set up.



Different equipment has been used to take measures as it shows in chapter 2.3. Current and voltage clamps have been connected to the inverter output for all the tests.

All the tests described in the following pages have used this specified test setup.

The test bench used includes:

EQUIPMENT	MARK / MODEL	RATED CHARACTERISTICS	OWNER / ID.CODE
AC source	Kewell / KACM-75-33	Voltage: 0-600 V 75kVA	Balun/BZ-EP-L001
PV source(*)	Kewell / IVS-60KW	Voltage: 0 - 1000 V 60kW	Balun/BZ-EP-L002
Programmable ac load	QUNLING / ACLT-3820	Voltage: 0-600 V 60kVA	Balun/BZ-EP-L003

(*) Validation by SGS. The report of verification is in the laboratory at disposal of the requestor.

3 RESUME OF TEST RESULTS

INTERPRETATION KEYS

Test object does meet the requirement .... **P** Pass

Test object does not meet the requirement .... **F** Fails

Test case does not apply to the test object.................. **N/A** Not applicable

To make a reference to a table or an annex. .... See additional sheet

To indicate that the test has not been realized .... **N/R** Not realized

STANDARD SECTION	STANDARD REQUIREMENTS EN 50530:2010/A1:2013	
4.3	**Static MPPT efficiency**	**P**
4.3.1	Test conditions for the Static MPPT efficiency	P
4.3.2	Measurement procedure	P
4.3.3	Evaluation – Calculation of static MPPT efficiency	P
4.5	**Static power conversion efficiency**	**P**
4.5.1	Test conditions for the static power conversion efficiency	P
4.5.2	Measurement procedure	P
4.5.3	Evaluation – Calculation of the static conversion efficiency	P
5	**Calculation of the overall efficiency**	**P**

4 TEST RESULTS

4.1 STATIC MPPT EFFICIENCY TEST

Static MPPT efficiency test has been performed according to point 4.3 of the standard.

The MPPT efficiency describes the accuracy of an inverter to set the maximum power point on the characteristic curve of a PV generator. It is determined from the sampled instantaneous values of voltage and current at the input.

$$\eta_{MPPTstat} = \frac{1}{P_{MPP,PVS} \cdot T_M} \sum_i U_{DC,i} \cdot I_{DC,i} \cdot \Delta T$$

See point 2.5 (Definitions) of this report

The following table shows the results of this test:

MPP voltage of the simu-lated *I/V*-characteristic	Simulated I/V characteristic	MPP power of the simulated *I/V* characteristic normal-ised to rated DC power, $P_{MPP,PVS}/P_{DC,}(\%)$							
		0.05	0.10	0.20	0.25	0.30	0.50	0.75	1.00
U min 700 Vdc	c-Si	99.93	99.96	99.97	99.98	99.98	99.98	99.98	99.98
U nom 750 Vdc		99.93	99.96	99.98	99.98	99.98	99.98	99.99	99.99
U max 800 Vdc		99.92	99.96	99.97	99.98	99.98	99.99	99.99	99.99
U min 700 Vdc	TF	99.94	99.96	99.98	99.98	99.98	99.98	99.98	99.98
U nom 750 Vdc		99.92	99.96	99.98	99.98	99.98	99.98	99.99	99.99
U max 800 Vdc		99.92	99.96	99.98	99.98	99.98	99.99	99.99	99.99

4.2 DYNAMIC MPPT EFFICIENCY TEST

Test for the dynamic MPPT efficiency are to be performed with the following sequences. The percentage specification of the radiation intensity is related to standard test conditions (STC). 100 % corresponds to 1 000 W/m² at 25 °C.

4.2.1 Test sequence with ramps 10 % - 50 % PDCn

The test has been performed according to point Annex B.2 of the standard.

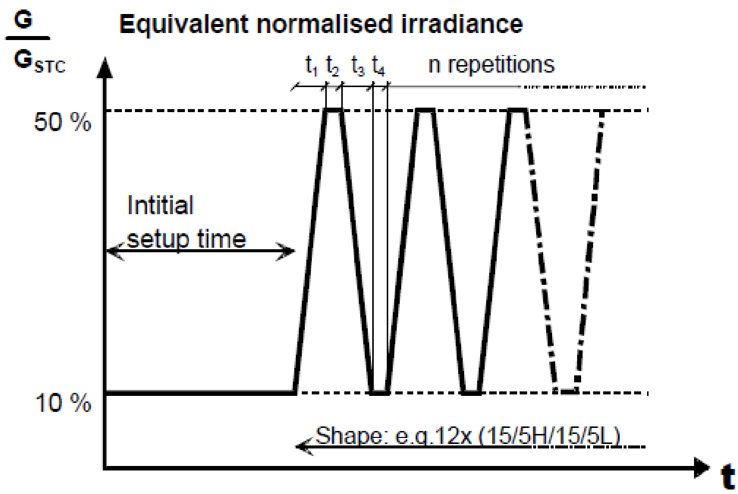


Figure B.1 – Test sequence for fluctuations between small and medium irradiation intensities

From-to W/m²	Delta W/m²					Waiting time setting s	
100-500	400					300	
# Number	**Slope** W/m²/s	**Ramp UP** s	**Dwell time** s	**Ramp DN** s	**Dwell time** s	**Duration** s	**Efficiency (%)**
2	0.5	800	10	800	10	3540	99.65
2	1	400	10	400	10	1940	99.17
3	2	200	10	200	10	1560	97.49
4	3	133	10	133	10	1447	97.94
6	5	80	10	80	10	1300	97.80
8	7	57	10	57	10	1374	97.72
10	10	40	10	40	10	1700	97.72
10	14	29	10	29	10	1071	97.66
10	20	20	10	20	10	900	97.54
10	30	13	10	13	10	767	97.55
10	50	8	10	8	10	660	97.69

4.2.2 Test sequence with ramps 30 % - 100 % P_{DCn}

The test has been performed according to point Annex B.3 of the standard.

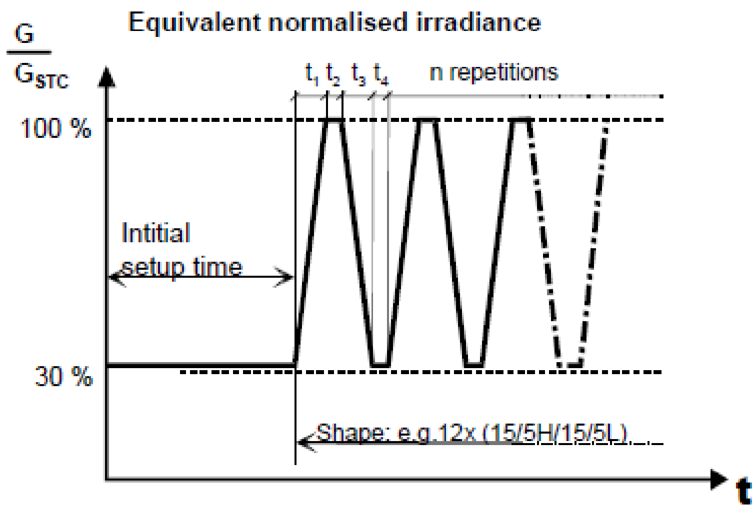


Figure B.2 – Test sequence for fluctuations between medium and high irradiation intensities

From-to W/m²	Delta W/m²					Waiting time setting s	
300-1000	700					300	
# Number	**Slope** W/m²/s	**Ramp UP** s	**Dwell time** s	**Ramp DN** s	**Dwell time** s	**Duration** s	**Efficiency (%)**
10	10	70	10	70	10	1900	99.83
10	14	50	10	50	10	1500	99.92
10	20	35	10	35	10	1200	99.84
10	30	23	10	23	10	967	99.82
10	50	14	10	14	10	780	99.86
10	100	7	10	7	10	640	99.88

4.2.3 Start-up and shut-down test with slow ramps

The test has been performed according to point Annex B.4 of the standard.

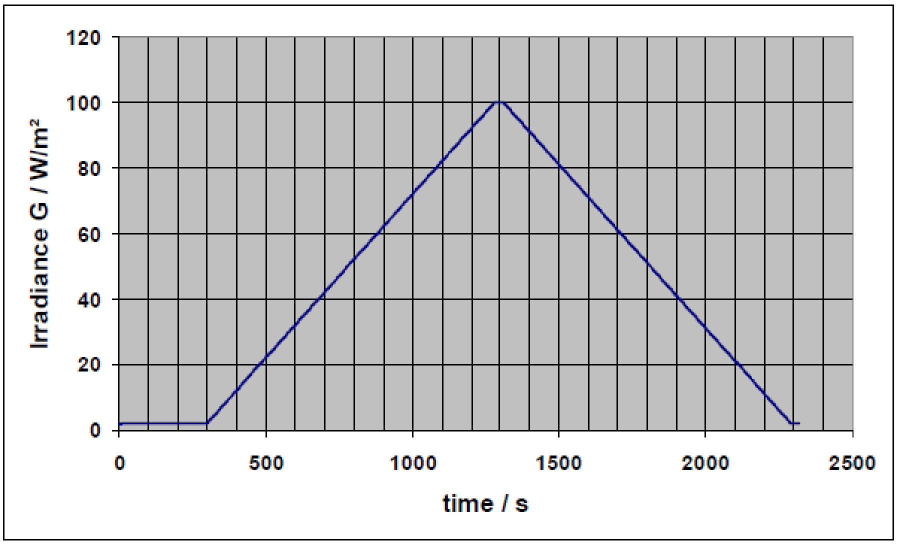


Figure B.3 – Test sequence for the start-up and shut-down test of grid connected inverters

From-to W/m²	Delta W/m²		**Dwell time setting** s			Waiting time setting s	
10-100	90		30			300	
# Number	**Slope** W/m²/s	**Ramp UP** s	**Dwell time** s	**Ramp DN** s	**Dwell time** s	**Duration** s	**Efficiency (%)**
1	0.1	980	30	980	30	2320	96.17

4.3 STATIC POWER CONVERSION EFFICIENCY

Static power conversion efficiency test has been performed according to point 4.5 of the standard.

Rated output efficiency shall be calculated from measured data as follows:

$$\eta_R = (P_o / P_i) \times 100$$

where

η_R is the rated output efficiency (%);
P_o is the rated output power from power conditioner (kW);
P_i is the input power to power conditioner at rated output (kW).

The following table shows the results of this test:

MPP voltage of the simu-lated *I/V*-characteristic	Simulated I/V characteristic	Power conversion efficiency(%)							
		0.05	0.10	0.20	0.25	0.30	0.50	0.75	1.00
U min 700 Vdc	c-Si	97.87	98.38	98.72	98.76	98.80	98.78	98.47	98.36
U nom 750 Vdc		96.89	98.13	98.50	98.70	98.74	98.69	98.39	98.29
U max 800 Vdc		96.05	97.85	98.24	98.28	98.31	98.29	98.25	98.12
U min 700 Vdc	TF	97.93	98.43	98.74	98.76	98.80	98.75	98.50	98.33
U nom 750 Vdc		97.05	98.17	98.52	98.72	98.74	98.71	98.48	98.29
U max 800 Vdc		96.14	97.94	98.16	98.24	98.27	98.29	98.22	98.10

4.4 OVERALL EFFICIENCY

Overall efficiency test has been performed according to point 5 of the standard.

The overall efficiency has been calculated according the following equation:

$$\eta_t = \eta_{conv} \cdot \eta_{MPPTstat} = \frac{P_{AC}}{P_{MPP,PVS}}$$

The following table shows the results of this test:

MPP voltage of the simu-lated *I/V*-characteristic	Simulated I/V characteristic	Overall efficiency (%)							
		0.05	0.10	0.20	0.25	0.30	0.50	0.75	1.00
U min 700 Vdc	c-Si	97.80	98.34	98.69	98.74	98.78	98.76	98.45	98.34
U nom 750 Vdc		96.83	98.09	98.48	98.68	98.72	98.67	98.38	98.28
U max 800 Vdc		95.98	97.81	98.21	98.26	98.29	98.28	98.24	98.11
U min 700 Vdc	TF	97.87	98.39	98.72	98.74	98.78	98.73	98.48	98.31
U nom 750 Vdc		96.97	98.13	98.50	98.70	98.72	98.69	98.47	98.28
U max 800 Vdc		96.06	97.90	98.14	98.22	98.25	98.28	98.21	98.09

4.5 EUROPEAN EFFICIENCY

European efficiency test has been performed according to point annex D.1 of the standard.

For the calculation of a weighted European MPPT and conversion efficiency the following formula and factors are to be applied:

$$\eta_{MPPTstat,EUR} = a_{EU\_1} \cdot \eta_{MPP\_1} + a_{EU\_2} \cdot \eta_{MPP\_2} + a_{EU\_3} \cdot \eta_{MPP\_3} + a_{EU\_4} \cdot \eta_{MPP\_4} + a_{EU\_5} \cdot \eta_{MPP\_5} + a_{EU\_6} \cdot \eta_{MPP\_6} \quad \text{(D.1)}$$

a_{EU_i} weighting factor

η_{MPP_i} static MPPT efficiency at partial MPP power MPP_i

Table D.1 – Weighting factors and partial MPP power levels for the calculation of the European efficiency

Weighting Factor	a_{EU_1}	a_{EU_2}	a_{EU_3}	a_{EU_4}	a_{EU_5}	a_{EU_6}
	0.03	0.06	0.13	0.1	0.48	0.2
Partial MPP power $P_{MPP,PVS}/P_{DC,r}$	MPP_1	MPP_2	MPP_3	MPP_4	MPP_5	MPP_6
	0.05	0.1	0.2	0.3	0.5	1

$$\eta_{MPPTstat,EUR(c\text{-}si)} = 98.41\%$$

$$\eta_{MPPTstat,EUR(TF)} = 98.41\%$$

4.6 CEC EFFICIENCY

European efficiency test has been performed according to point annex D.2 of the standard.

For the calculation of a weighted CEC MPPT and conversion efficiency the following formula and factors are to be applied:

$$\eta_{MPPTstat,CEC} = a_{CEC\_1} \cdot \eta_{MPP\_1} + a_{CEC\_2} \cdot \eta_{MPP\_2} + a_{CEC\_3} \cdot \eta_{MPP\_3} + a_{CEC\_4} \cdot \eta_{MPP\_4} + a_{CEC\_5} \cdot \eta_{MPP\_5} + a_{CEC\_6} \cdot \eta_{MPP\_6} \quad (D.2)$$

a_{CEC_i} weighting factor

η_{MPP_i} static MPPT efficiency at partial MPP power MPP_i

Table D.2 – Weighting factors and partial MPP power levels for the calculation of the CEC efficiency (California Energy Commission)

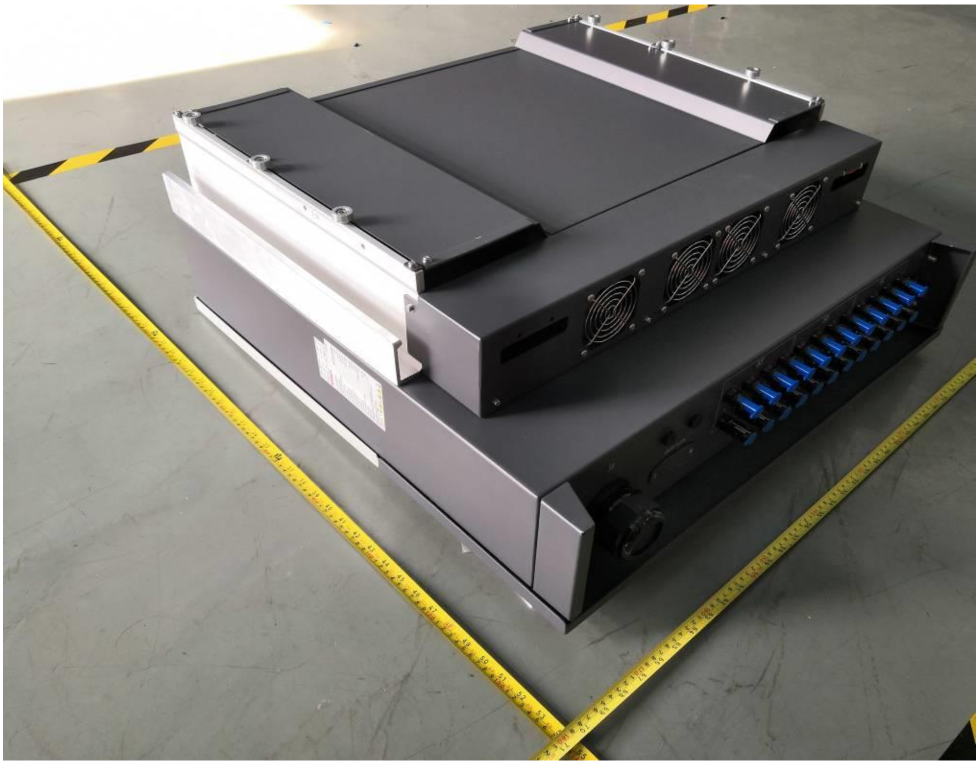
Weighting Factor	a_{CEC_1}	a_{CEC_2}	a_{CEC_3}	a_{CEC_4}	a_{CEC_5}	a_{CEC_6}
	0.04	0.05	0.12	0.21	0.53	0.05
Partial MPP power $P_{MPP,PVS}/P_{DC,r}$	MPP_1	MPP_2	MPP_3	MPP_4	MPP_5	MPP_6
	0.1	0.2	0.3	0.5	0.75	1

$$\eta_{MPPTstat,CEC(c\text{-}si)} = 98.42\%$$

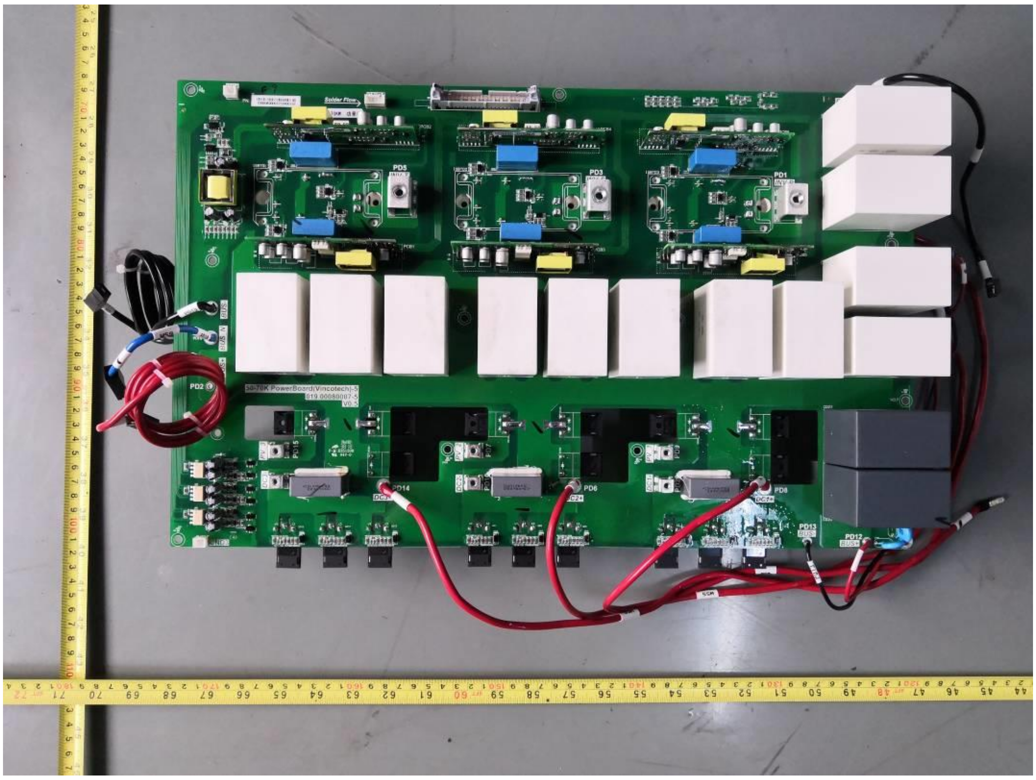
$$\eta_{MPPTstat,CEC(TF)} = 98.43\%$$

5 PICTURES

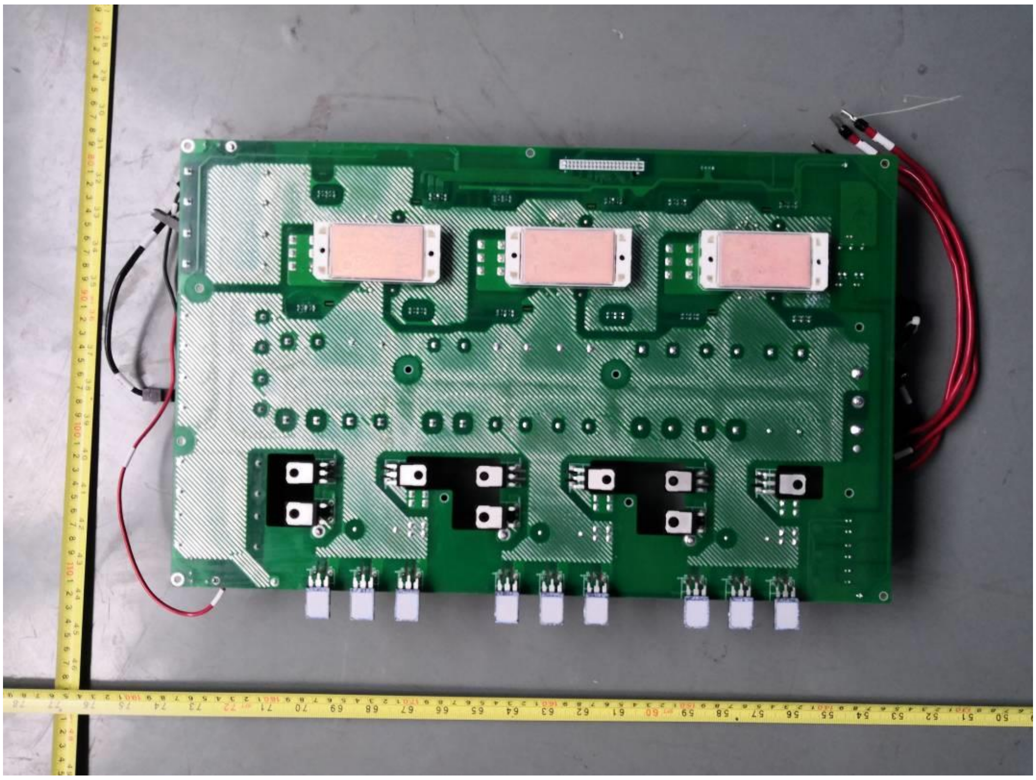
General view

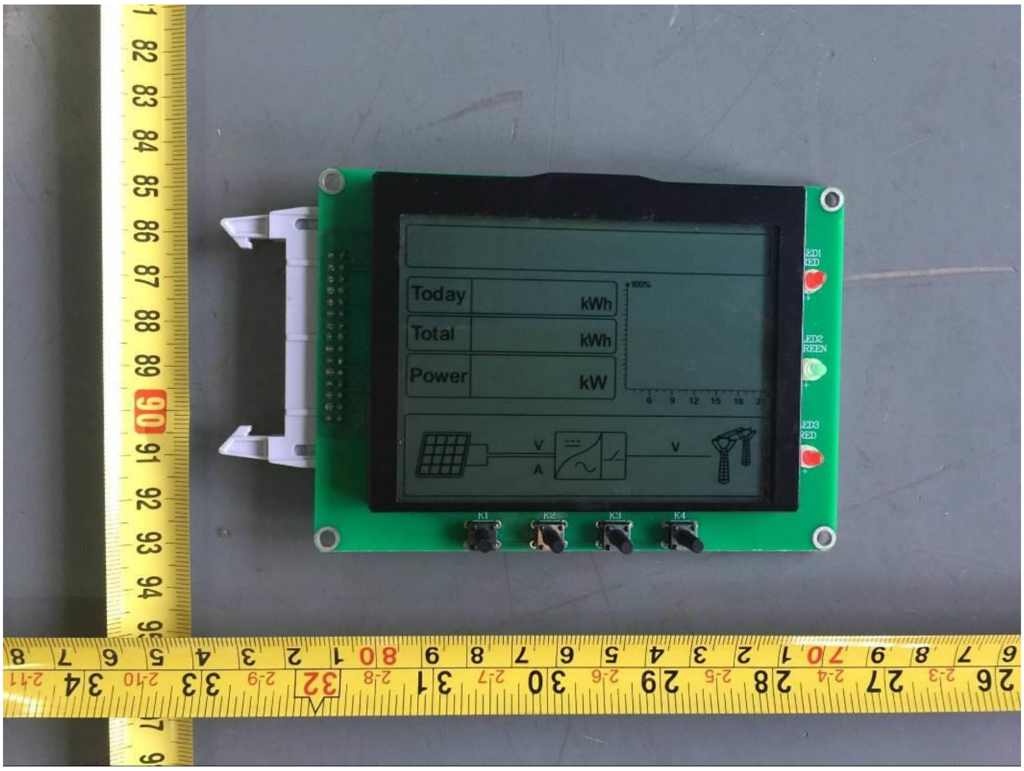
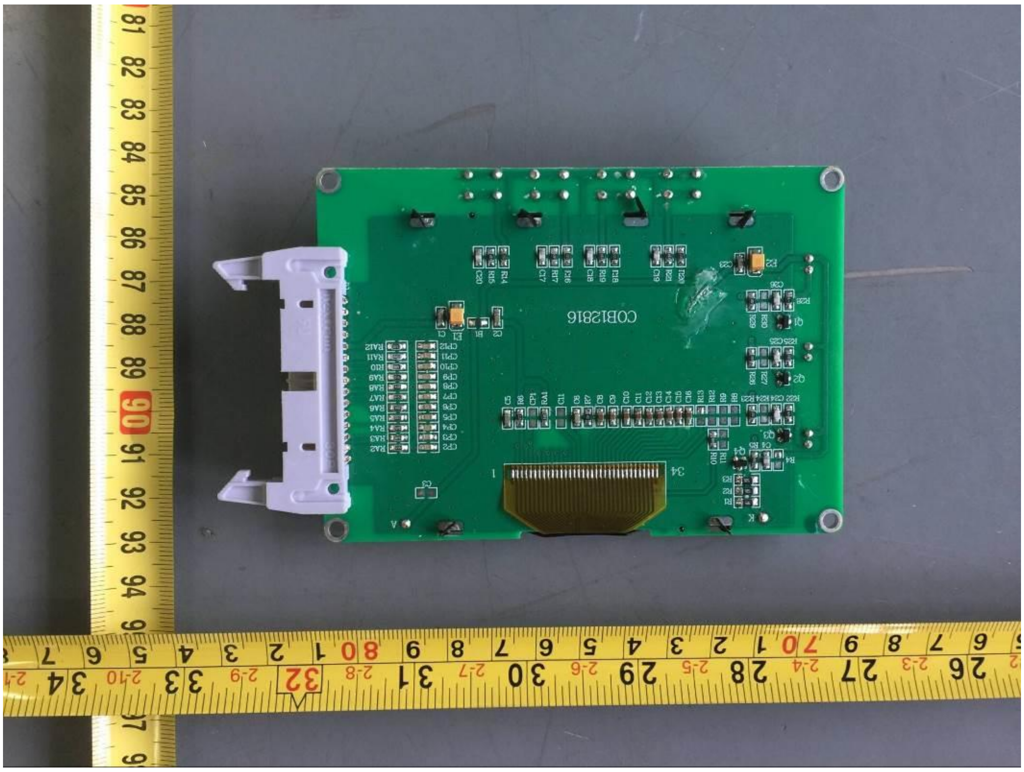
Back view


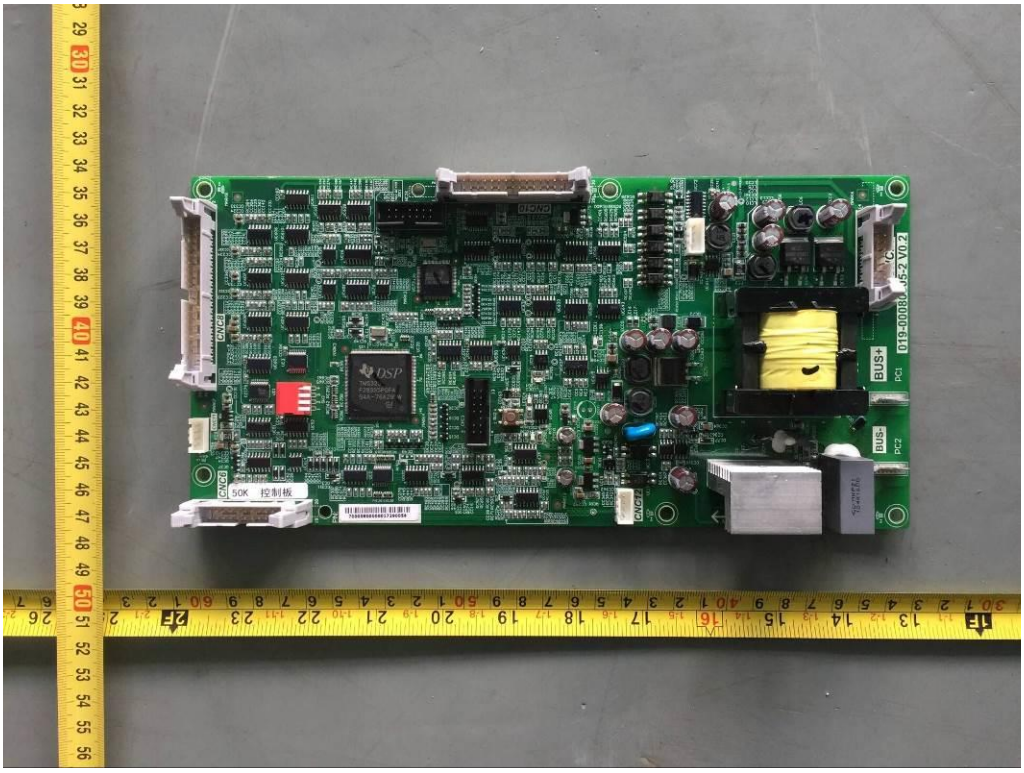
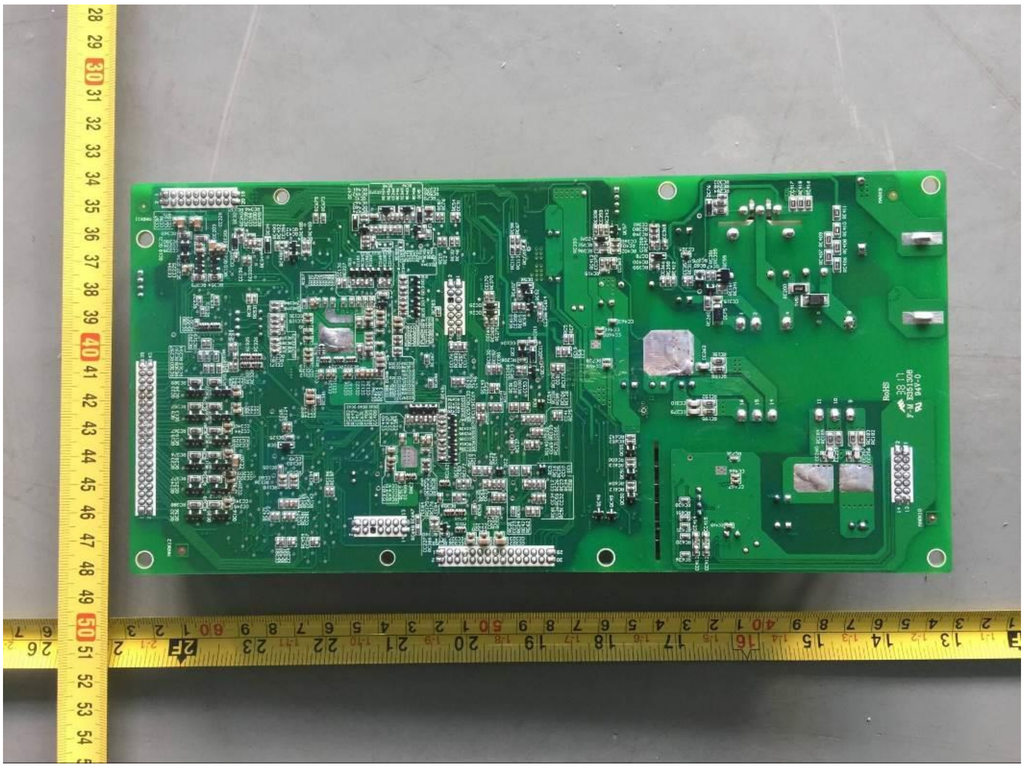
Front view of Main board

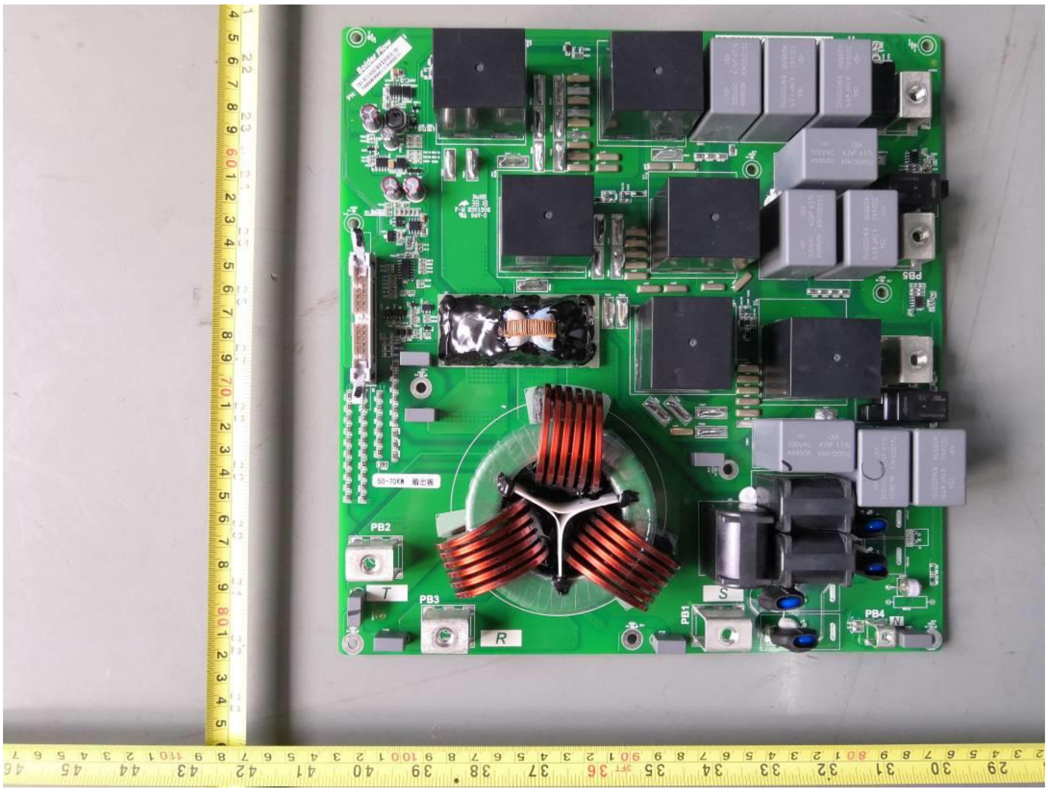
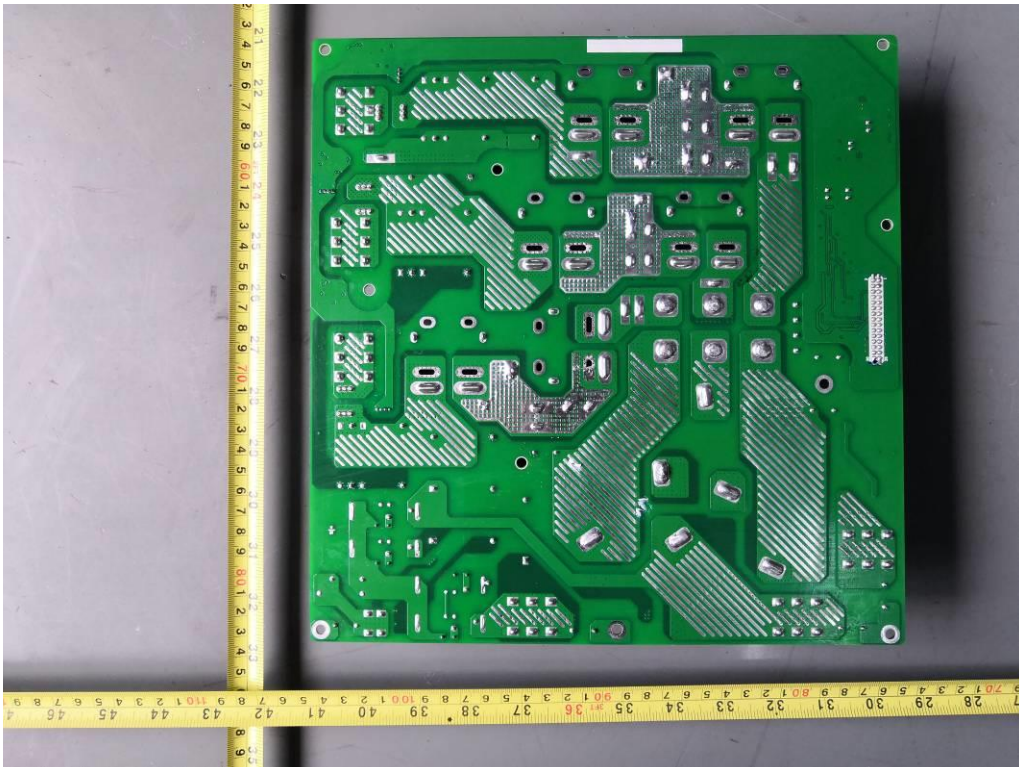


Back view of Main board

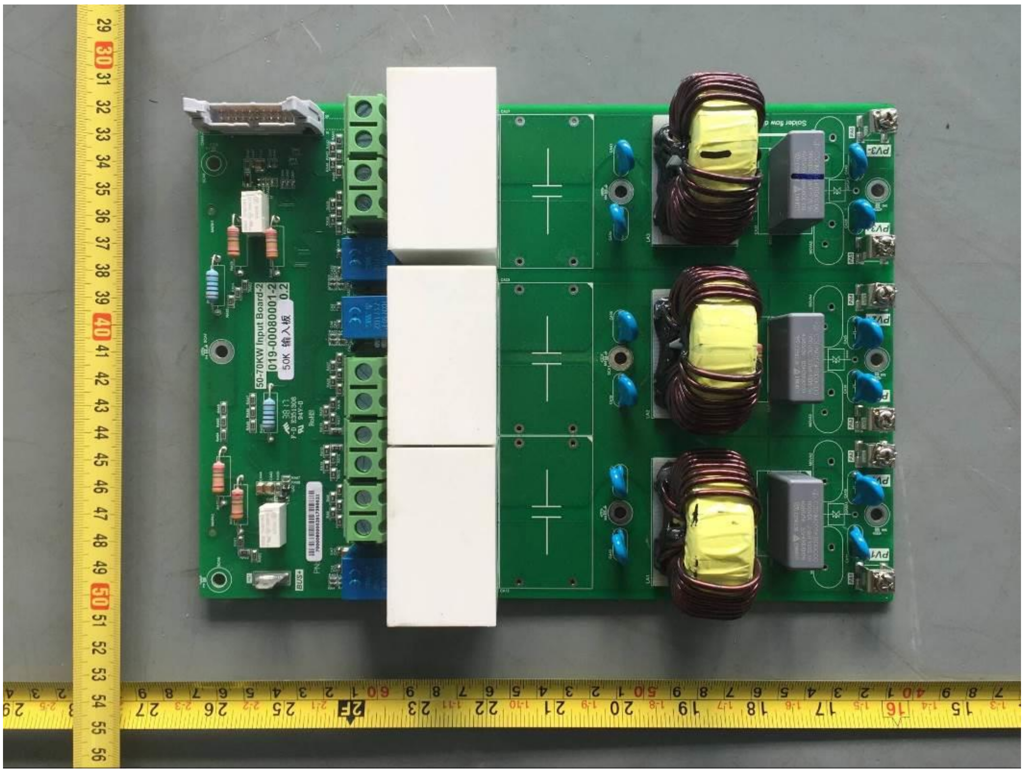


Front View of LCD board

Back View of LCD board


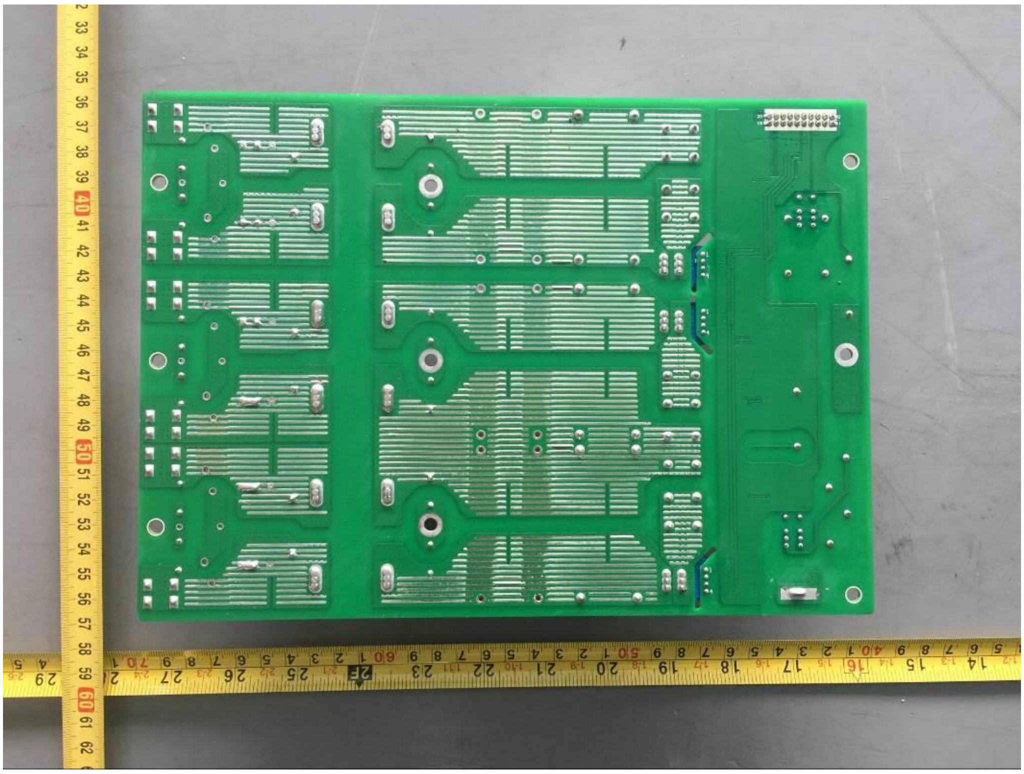
Front View of Control board

Back View of Control board


Front View of AC output board

Back View of AC output board


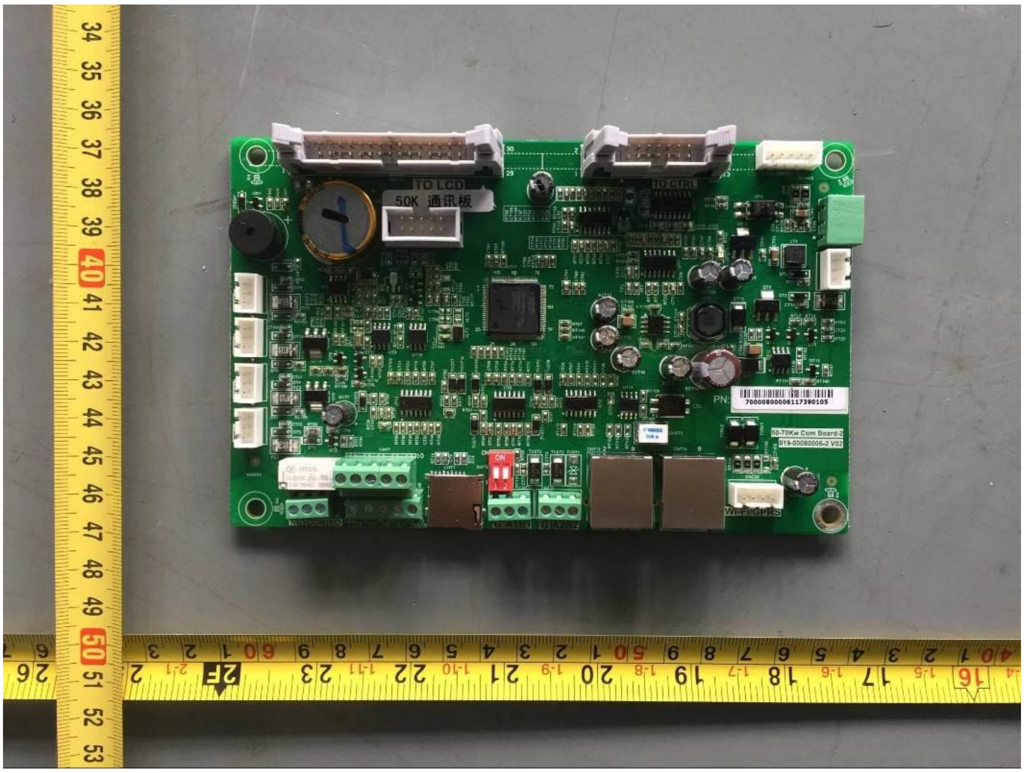
Front View of DC input board



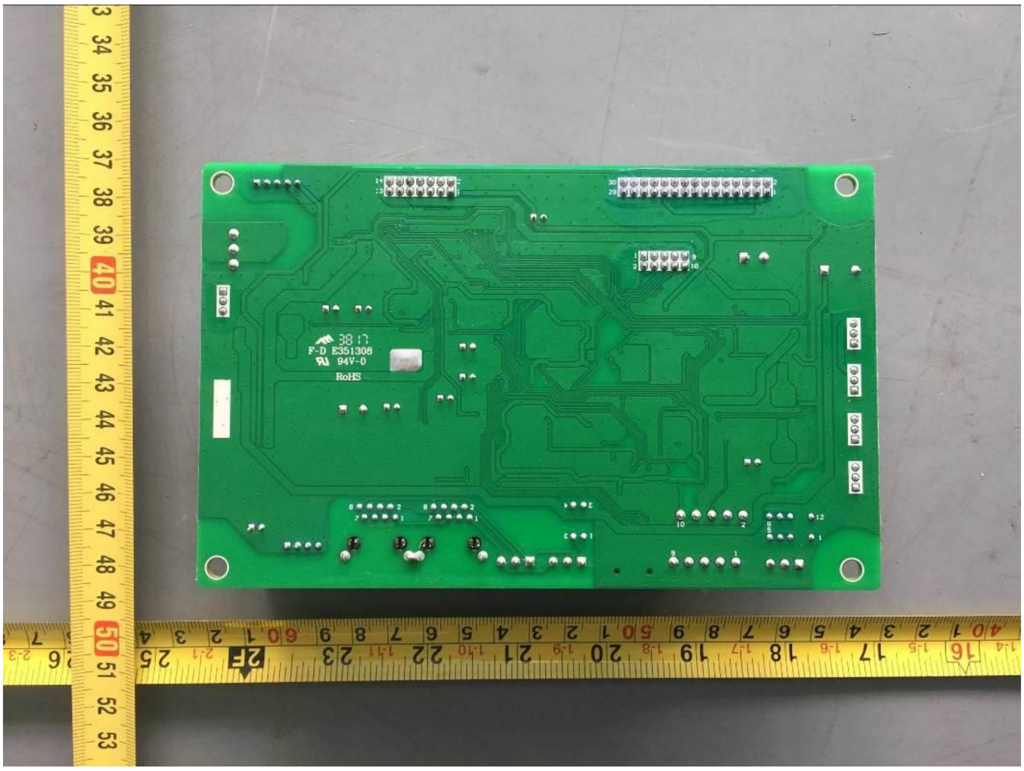
Back View of DC input board

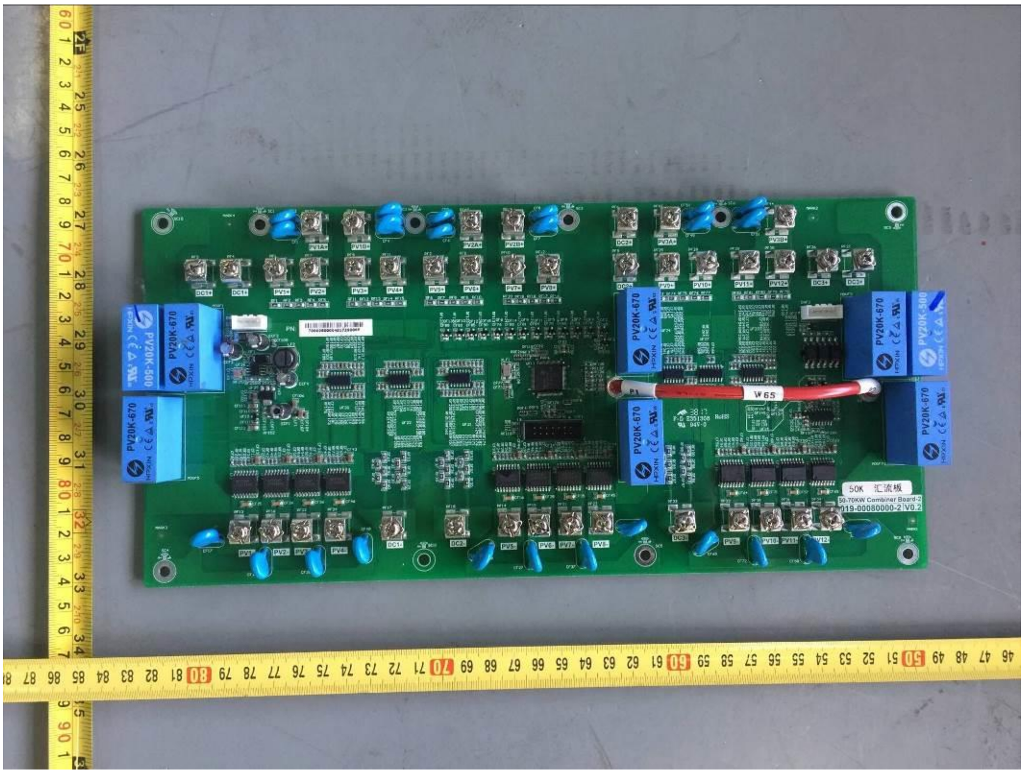
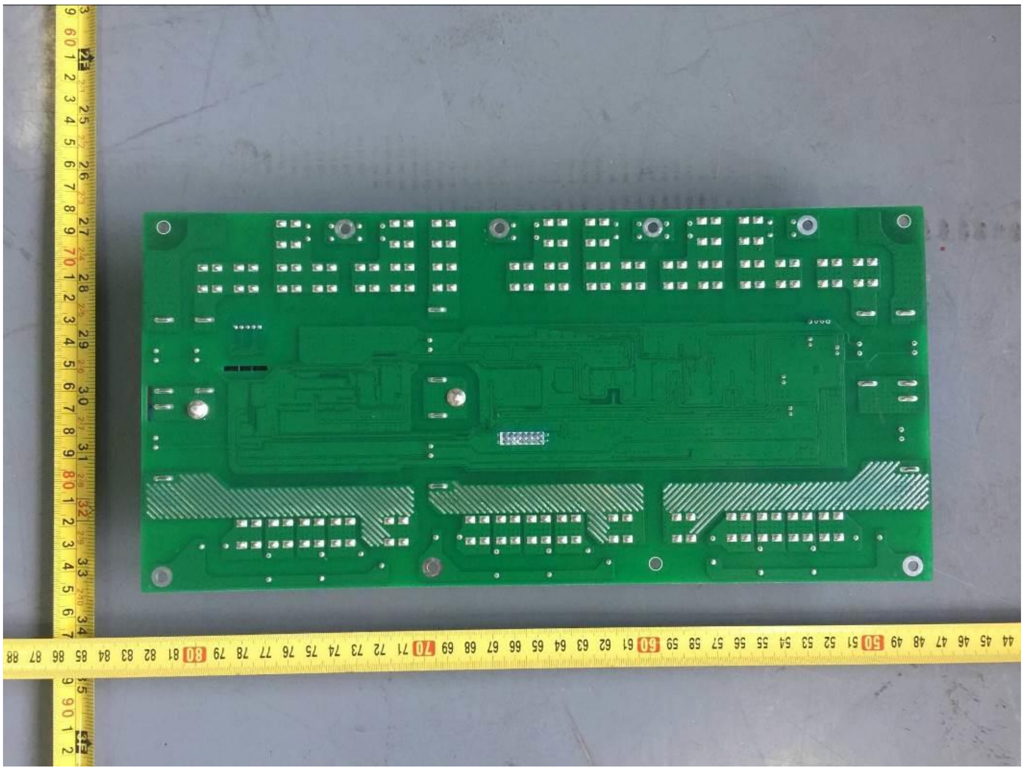


Front View of Communication board

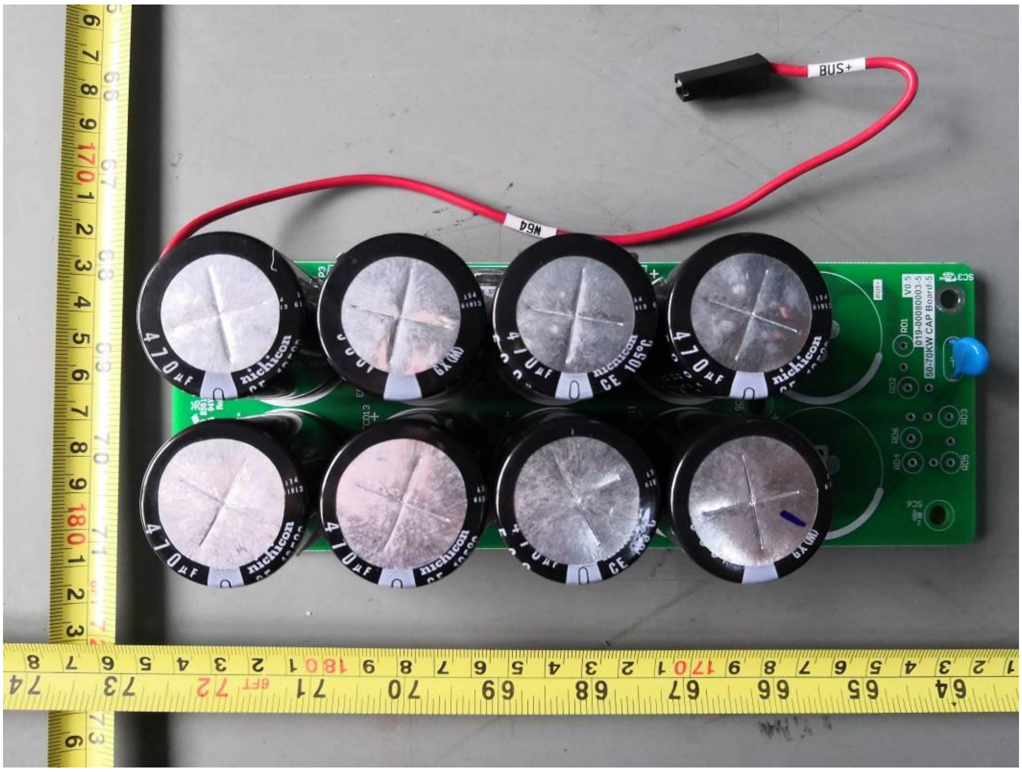


Back View of Communication board

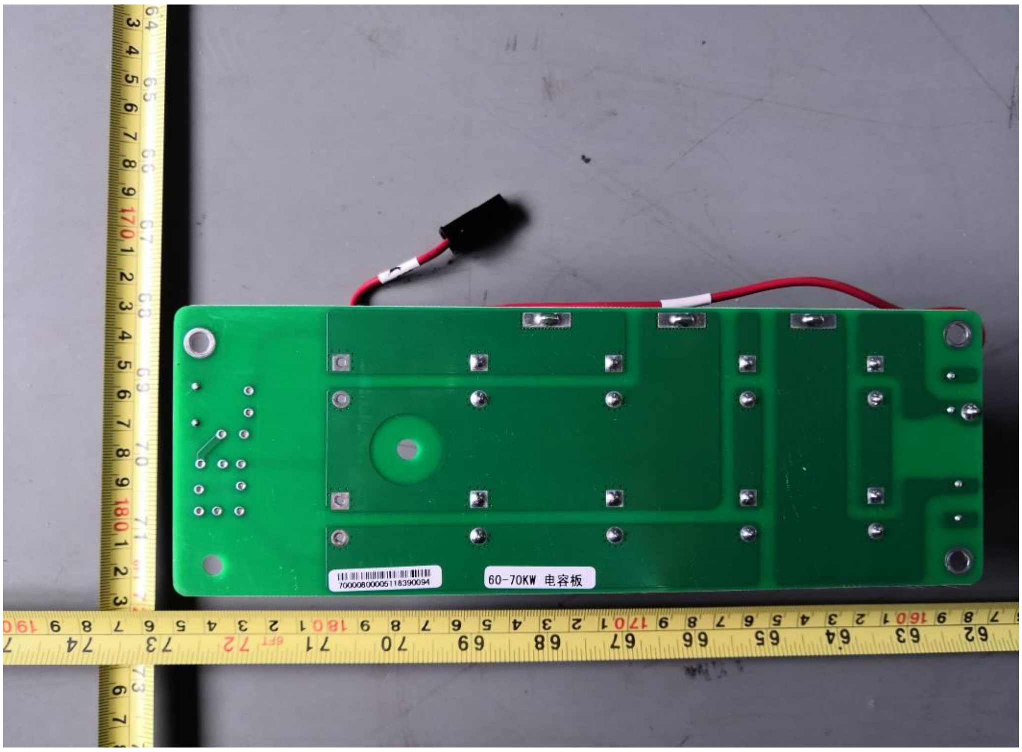


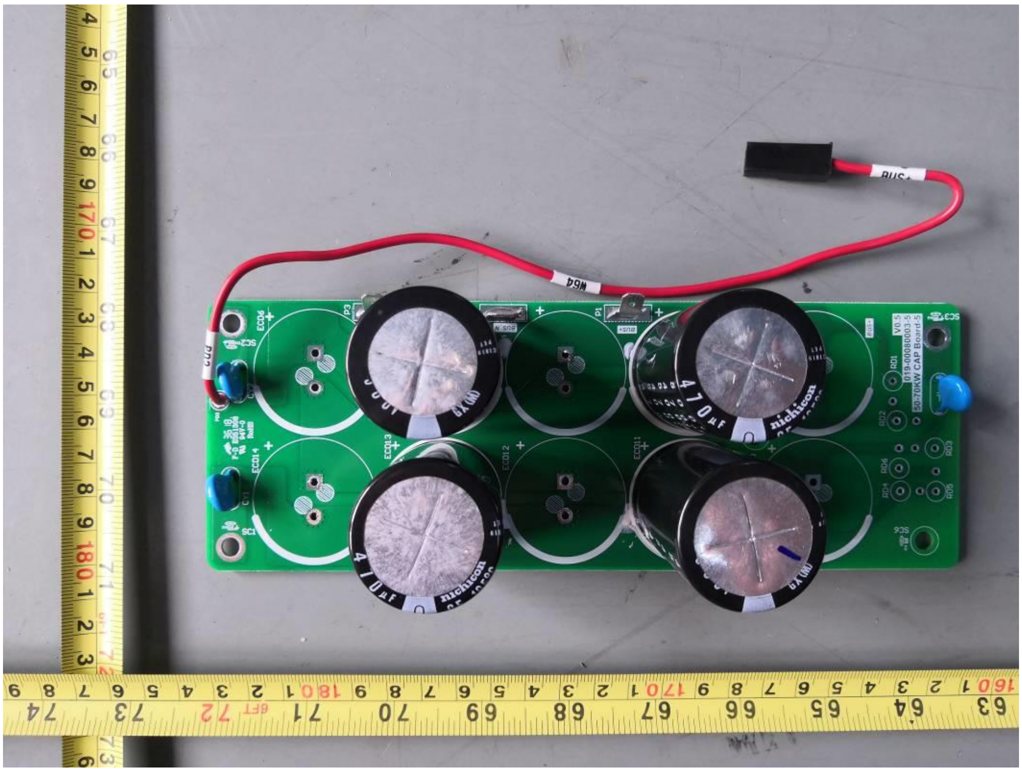
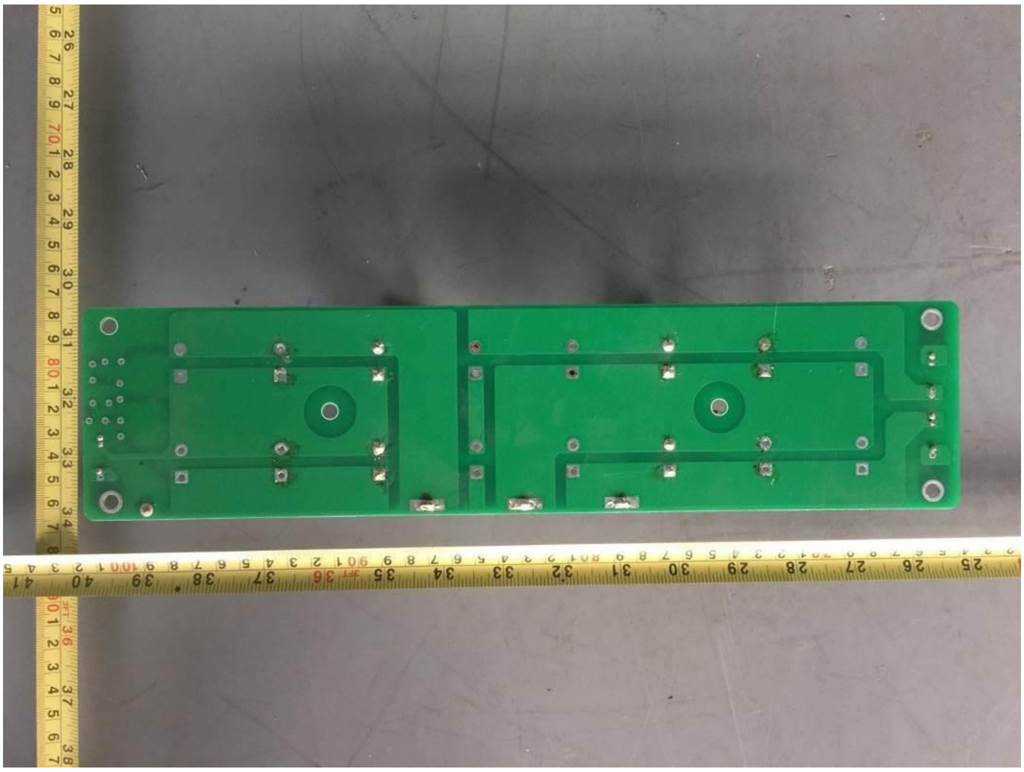
Front View of DC combine board

Back View of DC combine board


Front View of Hiverter Si-60k, Hiverter Si-70k Cap. board

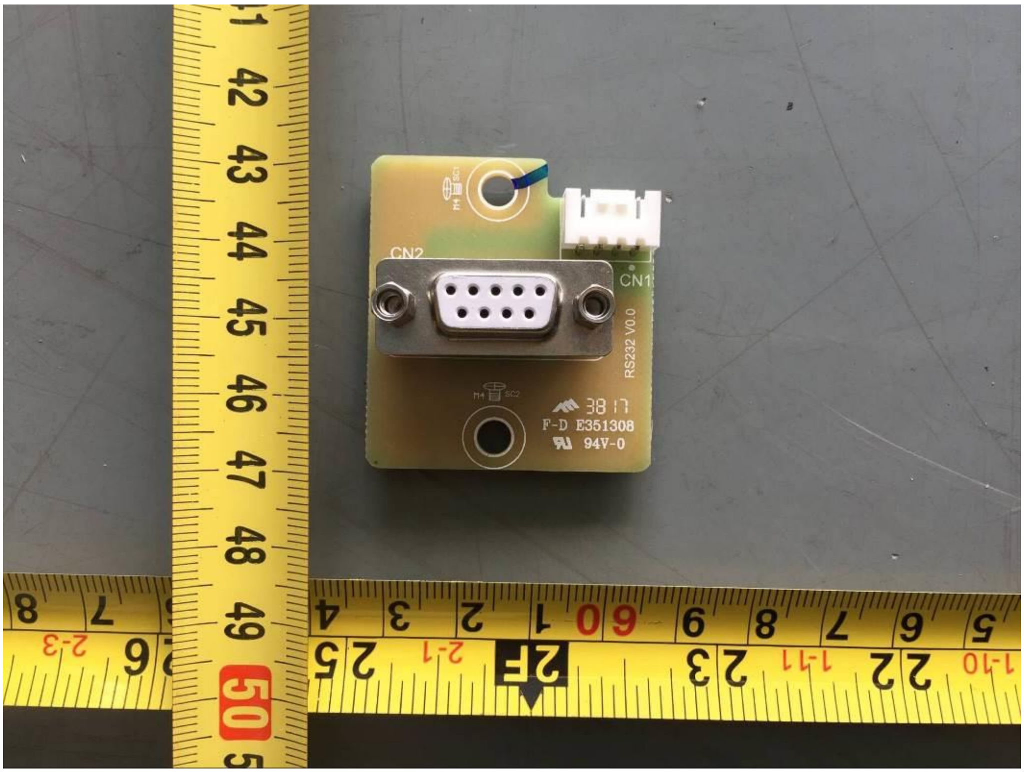


Back View of Hiverter Si-60k, Hiverter Si-70k Cap. board

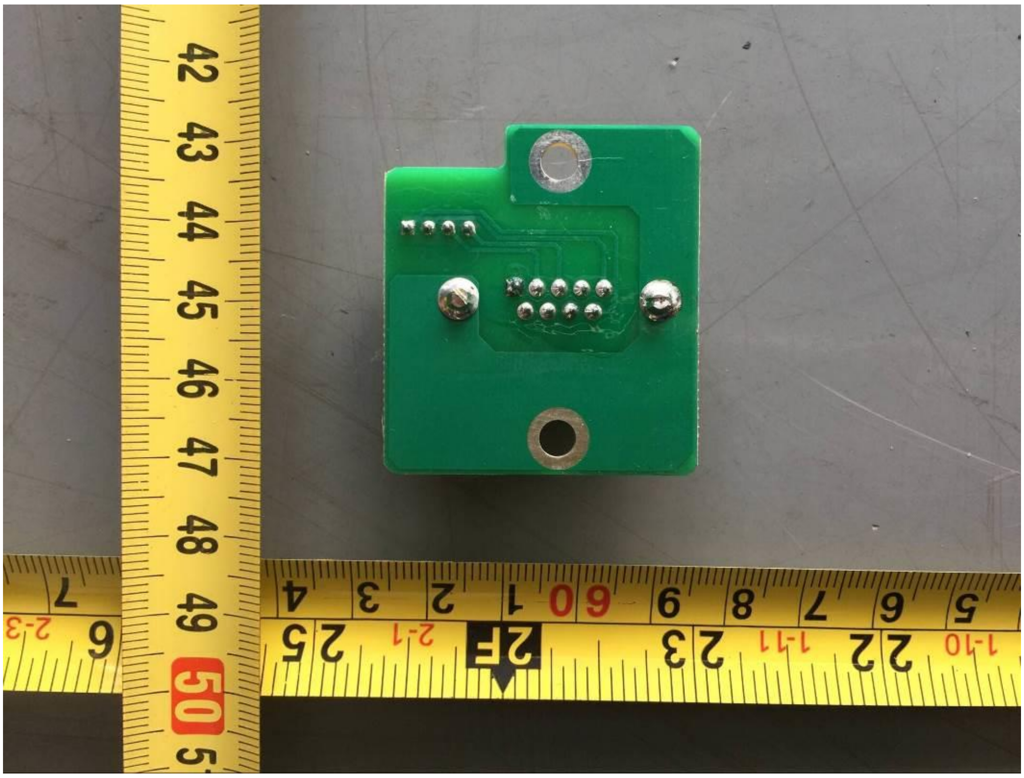


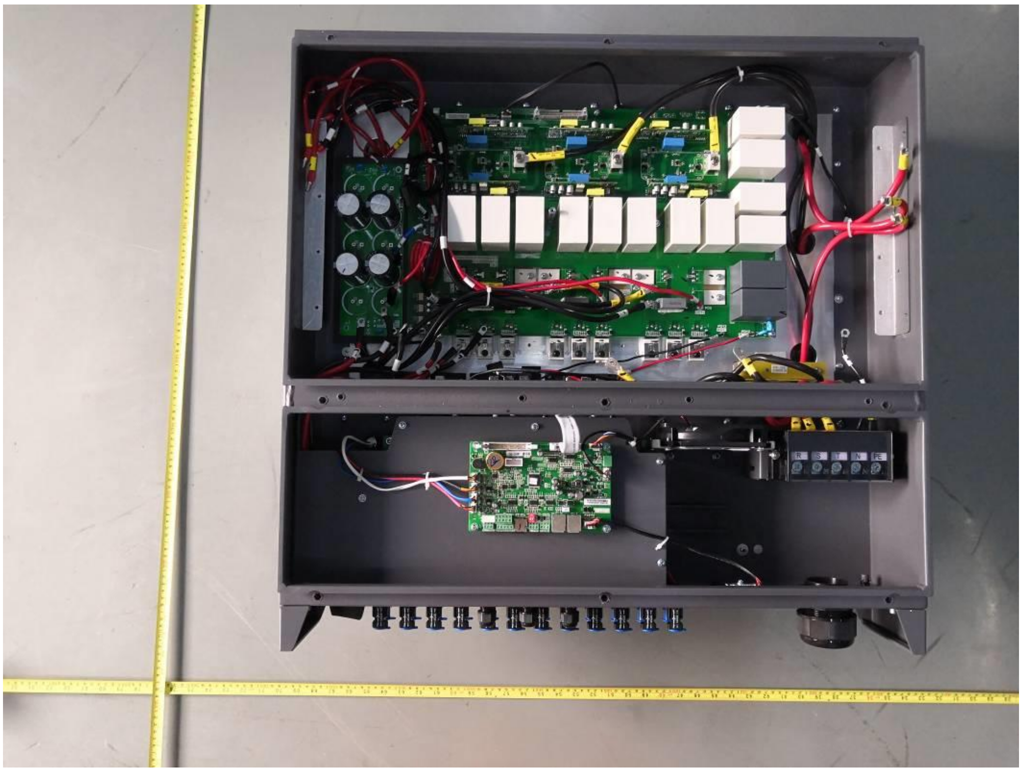
Front View of Hiverter Si-50k Cap. board

Back View of Hiverter Si-50k Cap. board


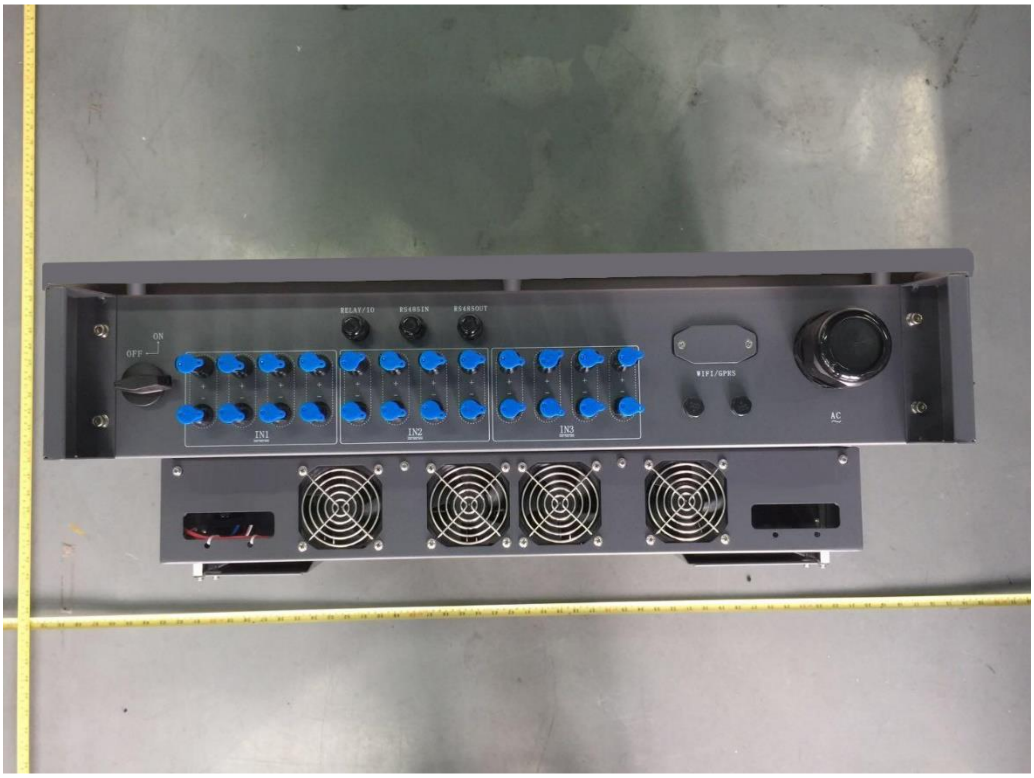
Front View of RS232 board

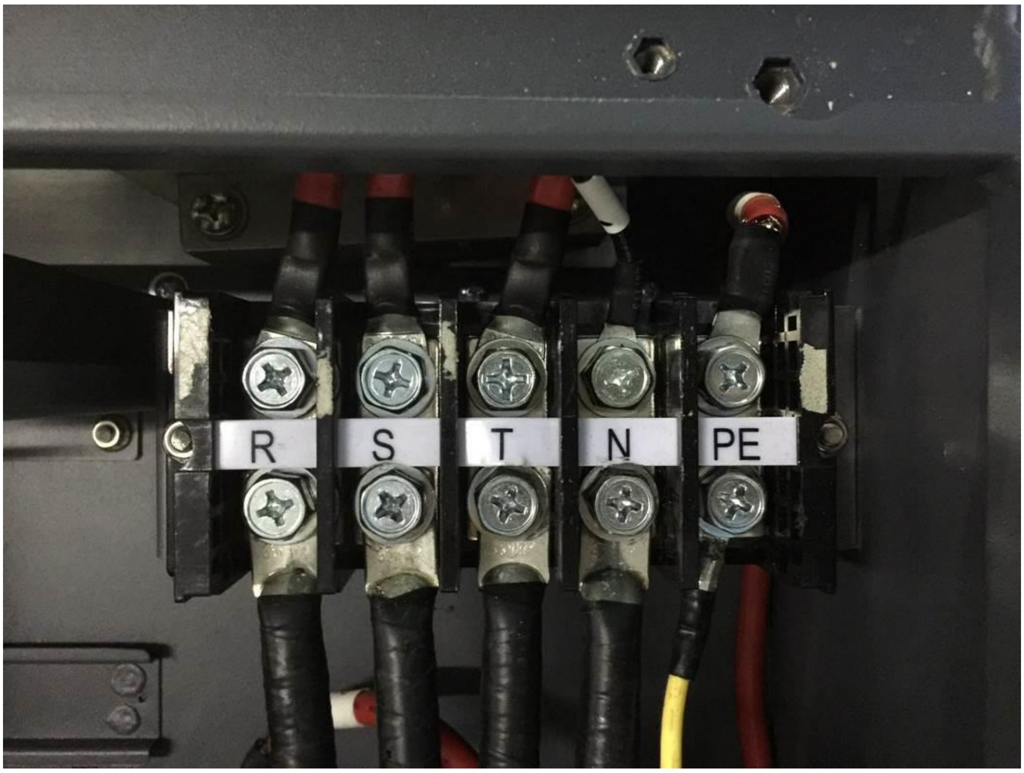
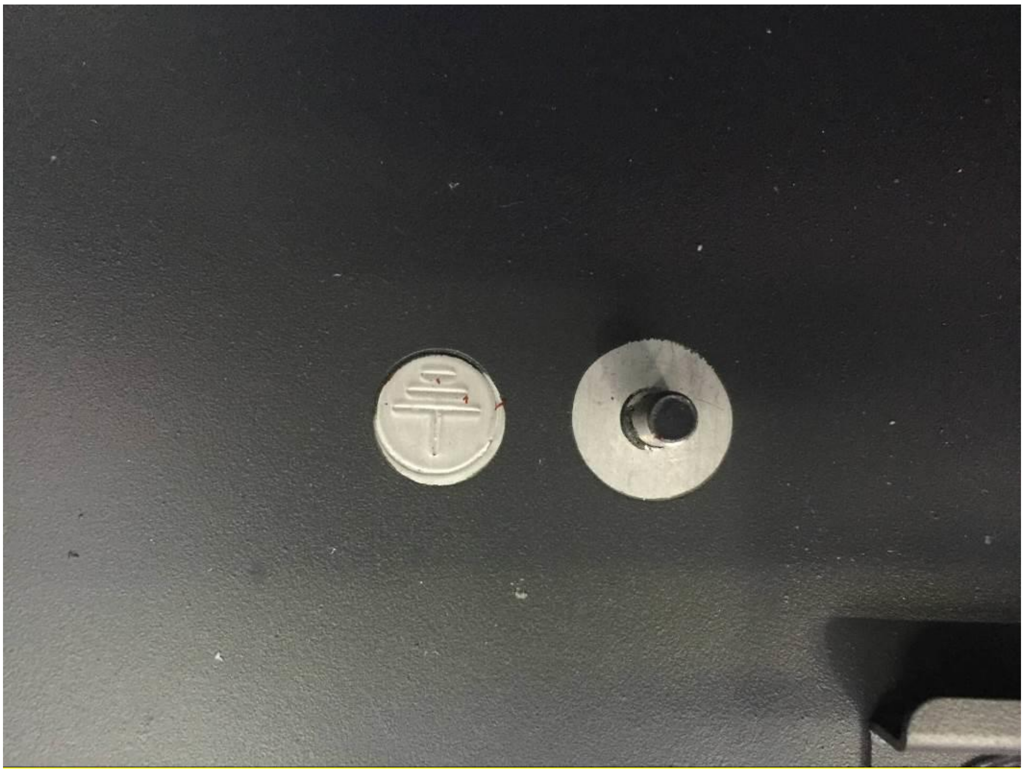


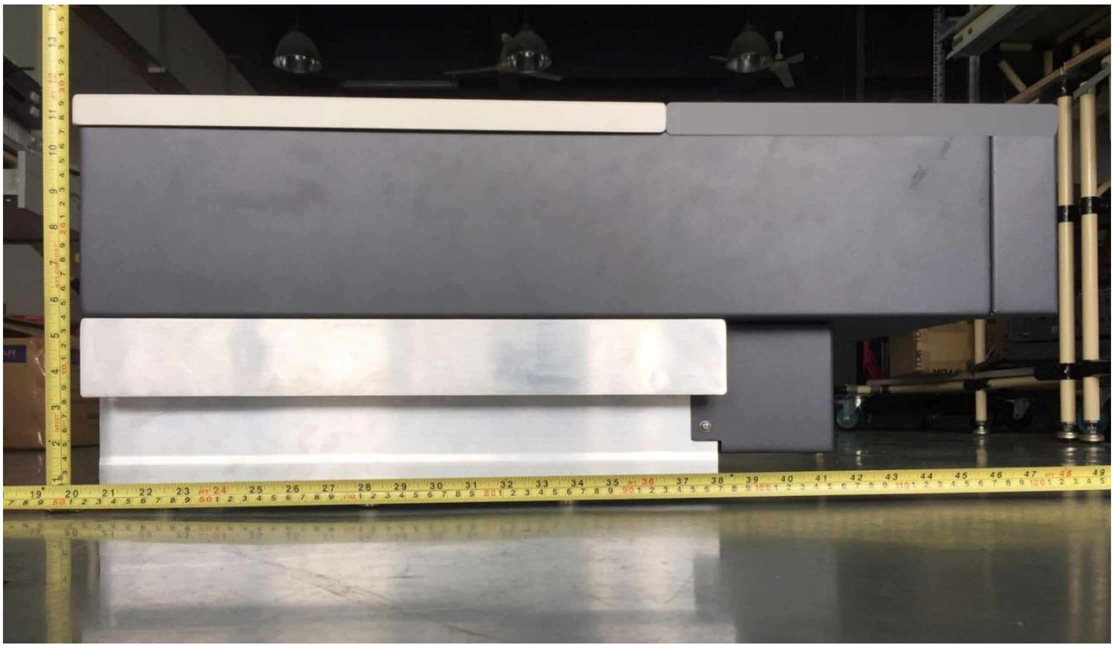
Back View of RS232 board



Intelnal View


Connection interface


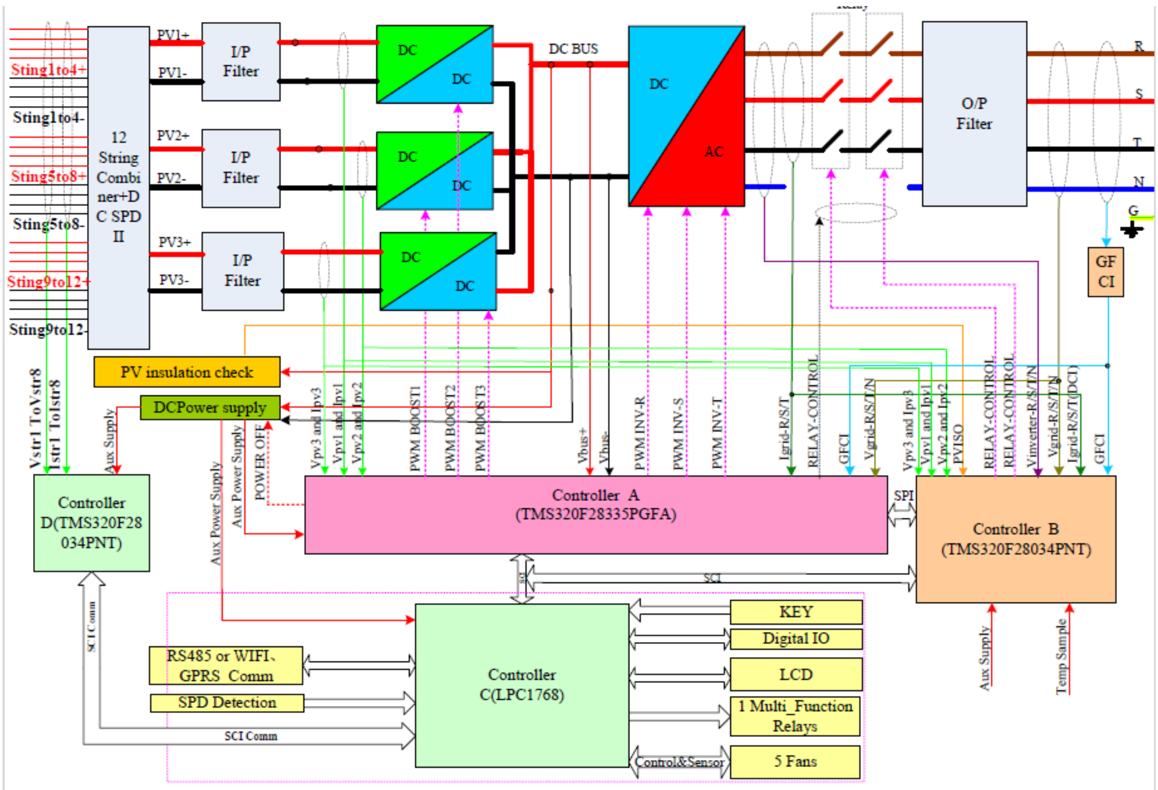
AC output connection

External Eathing connection terminal


Side view

Serial Number: ZJ2CS170J7A090


Software Version: V2.00


6 ELECTRICAL SCHEMES

EQUIPMENT UNDER TESTING



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