TESTING FOR THE VERIFICATION OF COMPLIANCE OF PV INVERTER WITH :

ENGINEERING RECOMMENDATION G98 ISSUE 1-AMENDMENT 3 MARCH 2019,

REQUIREMENTS FOR THE CONNECTION OF FULLY TYPE TESTED MICRO-GENERATORS (UP TO AND INCLUDING 16 A PER PHASE) IN PARALLEL WITH PUBLIC LOW VOLTAGE DISTRIBUTION NETWORKS ON OR AFTER 27 APRIL 2019

Test Report Number	:	GZES200702291201
Type	:	SOFAR SOLAR
Tested Model	:	HYD 10KTL-3PH
Variant Models	:	HYD 5KTL-3PH, HYD 6KTL-3PH, HYD 8KTL-3PH

APPLICANT

Hired by	:	Shenzhen SOFAR SOLAR Co., Ltd.
Address	:	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen City, Guangdong Province, P.R. China.

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	:	Hugo Zhang (Project Engineer)
Approved by	:	Roger Hu (Technical Reviewer)

Date of issue	:	26 / 08 / 2020
Number of pages	:	128

Important Note:

- This document is issued by the Company under its General Conditions of service accessible at http://www.sgs.com/terms_and_conditions.htm. Attention is drawn to the limitation of liability, indemnification and jurisdiction issues defined therein. Any holder of this document is advised that information contained hereon reflects the Company's findings at the time of its intervention only and within the limits of Client's instructions, if any. The Company's sole responsibility is to its Client and this document does not exonerate parties to a transaction from exercising all their rights and obligations under the transaction documents.

- Any unauthorized alteration, forgery or falsification of the content or appearance of this document is unlawful and offenders may be prosecuted to the fullest extent of the law.

- Unless otherwise stated the results shown in this test report refer only to the sample(s) tested as received. **Information of derived or extension models of the range as provided by the applicant, (if any), is included in this report only for informative purposes.** The Company SGS shall not be liable for any incorrect results arising from unclear, erroneous, incomplete, misleading or false information provided by Client. This document cannot be reproduced except in full, without prior approval of the Company.

Test Report Historical Revision:

Test Report Version	Date	Resume
GZES200702291201	26 / 08 / 2020	First issuance

INDEX

1 SCOPE 4
2 GENERAL INFORMATION 5
2.1 Testing Period and Climatic conditions 5
2.2 Equipment under Testing 5
2.3 Test equipment list 9
2.4 Measurement uncertainty 10
2.5 Test set up of the different standard 11
2.6 Definitions 12
3 RESUME OF TEST RESULTS 13
4 TEST RESULTS 14
4.1 Operating Range 14
4.2 Power Quality 17
4.2.1 Current Harmonics 17
4.2.2 Voltage fluctuations and Flicker 21
4.2.3 DC Injection 27
4.2.4 Power Factor 29
4.3 Protection 31
4.3.1 Frequency tests 31
4.3.2 Voltage tests 52
4.3.3 Loss of Mains test 73
4.3.4 Frequency change, Vector Shift Stability test and RoCoF Stability test 102
4.4 Limited Frequency Sensitive Mode - Overfrequency test 105
4.5 Power output with falling frequency test 107
4.6 Re-connection timer 108
4.6.1 Voltage Reconnection Conditions 108
4.6.2 Frequency Reconnection Conditions 110
4.7 Fault level contribution 112
4.8 Self-Monitoring solid state switching 118
4.9 Electromagnetic Compatibility (EMC) 118
4.10 Logic Interface. 119
5 PICTURES 120
6 ELECTRICAL SCHEMES 128

1 SCOPE

SGS-CSTC Standards Technical Services Co., Ltd. Guangzhou Branch has been contract by Shenzhen SOFAR SOLAR Co., Ltd, in order to perform the testing according the “Engineering Recommendation G98 Issue 1 - Amendment 3 March 2019, Requirements For The Connection Of Fully Type Tested Micro-Generators (Up To And Including 16 A Per Phase) In Parallel With Public Low Voltage Distribution Networks On Or After 27 April 2019”.

2 GENERAL INFORMATION

2.1 TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed along between the 03rd of June to 13th of August of 2020. All the tests and checks have been performed at 25 ± 5ºC, 96 kPa ± 10 kPa and 50% RH ± 10% RH).

SITE TEST

Name.....: Shenzhen SOFAR SOLAR Co., Ltd.

Address .....: 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen City, Guangdong Province, P.R. China.

2.2 EQUIPMENT UNDER TESTING

Apparatus type ..... : Hybrid Inverter (Three phase)

Installation ..... : Fixed (permanent connection)

Manufacturer ..... : Shenzhen SOFAR SOLAR Co., Ltd.

Address ..... : 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen City, Guangdong Province, P.R. China.

Trade mark ..... :

Model / Type reference..... : HYD 10KTL-3PH

Serial Number ..... : SP1ES010H71002

Software Version ..... : V2.00

Rated Characteristics ..... : DC input: 180-960 V, Max. 2× 25 A
AC output: 3~/N/PE 230, 50 Hz, 3× 14.5A (max. 3× 16A), 10000 W

Date of manufacturing: 2020

Test item particulars

Input ..... : DC

Output..... AC

Class of protection against electric shock... : Class I

Degree of protection against moisture..... : IP 65

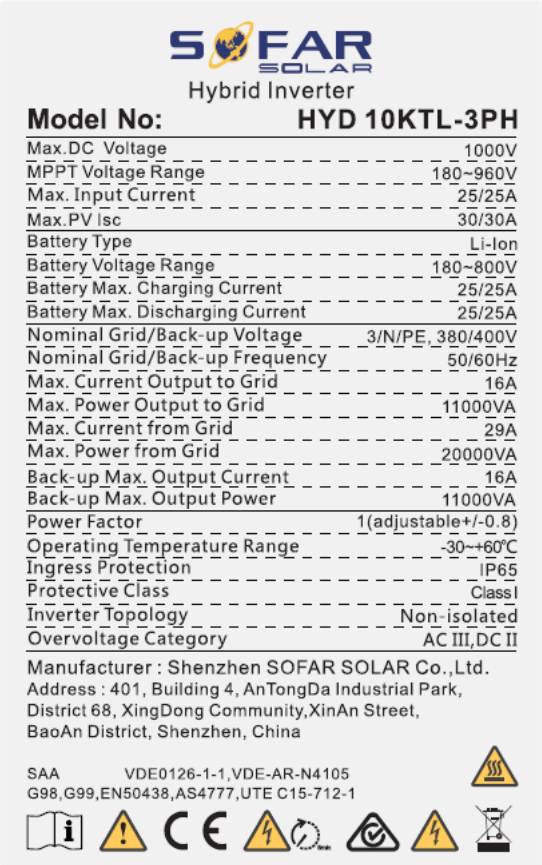
Type of connection to the main supply ..... : TN

Cooling group ..... : See model list on page 8

Modular ..... : No

Internal Transformer..... : No

Copy of marking plate（representative）:



Note:

1. The above markings are the minimum requirements required by the safety standard. For the final production samples, the additional markings which do not give rise to misunderstanding may be added.
2. Label is attached on the side surface of enclosure and visible after installation
3. Labels of other models are as the same with **HYD10KTL-3PH**'s except the parameters of rating.

Equipment Under Testing:

- HYD 10KTL-3PH;

The variants models are:

- HYD 5KTL-3PH;
- HYD 6KTL-3PH;
- HYD 8KTL-3PH;

Model	HYD 5KTL-3PH	HYD 6KTL-3PH	HYD 8KTL-3PH	HYD 10KTL-3PH
PV String Input Data				
Max. DC voltage	1000V			
MPPT voltage range	180V~960V			
Full power MPPT voltage range	250V~850V	320V~850V	360V~850V	220V~850V
Max. input current	12.5A/12.5A	12.5A/12.5A	12.5A/12.5A	25A/25A
Max. short current	15A/15A	15A/15A	15A/15A	30A/30A
Battery Input Data				
Battery voltage range	180V~800V			
Battery voltage range for full load	200V~800V	240V~800V	320V~800V	200V~800V
No. of battery input	1			2
Nominal charging/discharging power	5000W	6000W	8000W	10000W
Max. charging/discharging current	25A	25A	25A	50A (25A/25A)
AC Output Data (On-grid)				
Nominal AC power	5000W	6000W	8000W	10000W
Max. AC power output to utility grid	5500VA	6600VA	8800VA	11000VA
Max. AC power from utility grid	10000VA	12000VA	16000VA	20000VA
Max. AC current output to utility grid	8A	10A	13A	16A
Rated AC current output to utility grid	7.2A	8.7A	11.6A	14.5A
Max. AC Current from utility grid	15A	17A	24A	29A

Nominal output voltage	3/N/PE, 230Vac			
Nominal output freqency	50Hz			
Output power factor	1(0.8 leading to 0.8 lagging)			
AC Output Data (Back-up)				
Nominal output power	5000W	6000W	8000W	10000W
Max. output power	5500VA	6600VA	8800VA	11000VA
Rated. output current	7.2A	8.7A	11.6A	14.5A
Max. output current	8A	10A	13A	16A
Peak output current, Duration	15A, 60s	18A, 60s	24A, 60s	30A, 60s
Nominal output voltage	3/N/PE, 230Vac			
Nominal output freqency	50Hz			
Output power factor	~1(0.8 leading to 0.8 lagging)			
Operating temperature range	-30ºC ~60ºC			
Ingress protection	IP65			
Protective class	Class I			
Cooling method	Heat sink	Heat sink	Heat sink	Fan

The variants models are:

The variants models have been included in this test report without tests because the following features don´t change regarding to the tested model:

- Same connection system and hardware topology
- Same control algorithm.
- Output power within 1/√10 and 2 times of the rated output power or the EUT or Modular inverters.
- Same Firmware Version

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 TEST EQUIPMENT LIST

From	No.	Equipment Name	Model No.	Equipment No.	Calibration Date	Equipment calibration due date
Sofar Solar	1	Digital oscilloscope	DSOX3014A	MY58491772	2020/01/14	2021/01/13
	2	Voltage probe	SI-9110	111152	2020/1/14	2021/1/13
	3	Voltage probe	SI-9110	152627	2020/01/14	2021/01/13
	4	Voltage probe	SI-9110	111134	2020/01/14	2021/01/13
	5	Power analyzer	PA5000H	C820290908200211 0001	2020/03/02	2021/03/01
	6	Current probe	CP1000A	C181000922	2020/01/14	2021/01/13
	7	Current probe	CP1000A	C181000925	2020/01/14	2021/01/13
	8	Current probe	CP1000A	C181000929	2020/01/14	2021/01/13
	9	Temperature & Humidity meter	TH101B	ZB-WSDJ-001	2020/01/14	2021/01/13
	10	Power analyzer	WT3000	91N610888	2020/01/14	2021/01/13
	11	Digital oscilloscope	DSOX3014A	MY58101647	2020/01/14	2021/01/13
	12	Power analyzer	PA5000	C820290908200211 0002	2020/03/02	2021/03/01
SGS	13	True RMS Multimeter	Fluke / 187	GZE012-8	2019/12/05	2020/12/04

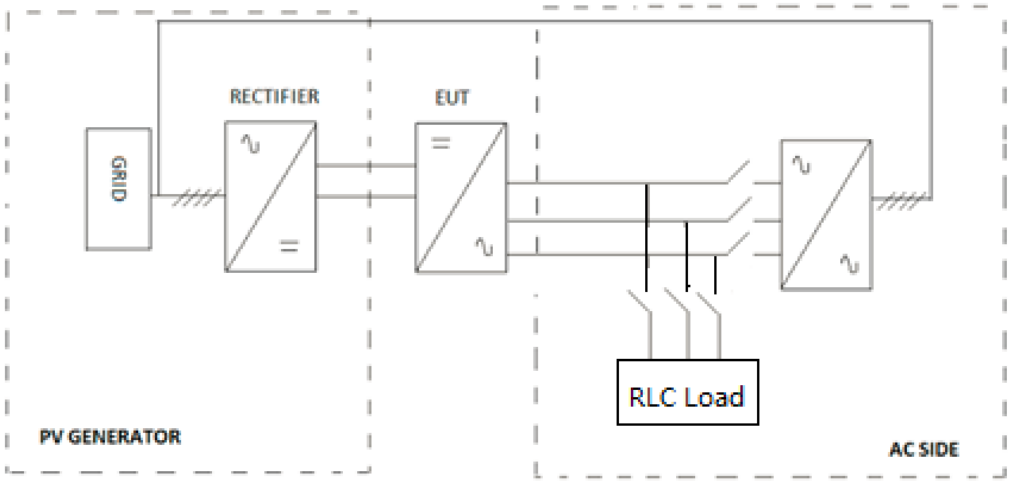
2.4 MEASUREMENT UNCERTAINTY

Associated uncertainties through measurements showed in this this report are the maximum allowable uncertainties.

Magnitude	Uncertainty
Voltage measurement	±0.05 %
Current measurement	±0.05 %
Frequency measurement	±0.001 Hz
Time measurement	±0.001s
Power measurement	±0.5 %
Phase Angle	±0.1º
Temperature	±3º C
Note1: Measurements uncertainties showed in this table are maximum allowable uncertainties. The measurement uncertainties associated with other parameters measured during the tests are in the laboratory at disposal of the solicitant. Note2: Where the standard requires lower uncertainties that those in this table. Most restrictive uncertainty has been considered.	

2.5 TEST SET UP OF THE DIFFERENT STANDARD

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 input / 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	Kwell / AFG-S-33800	Voltage: 0-600 V 750 kVA	Sofarsolar / EP-026
PV source	Kwell / TVS-630kW	Voltage: 0 - 1000 V 630 kW	Sofarsolar / EP-027
RLC load	Qunlin / ACLT3820H	68 kW, 68 kVAr	Sofarsolar / EP-029

2.6 Definitions

EUT	Equipment Under Testing	Hz	Hertz
A	Ampere	V	Volt
VAr	Volt-Ampere reactive	W	Watt
EMC	Electromagnetic Compatibility	p.u	Per unit
Un	Nominal Voltage	Pn	Nominal Active Power
In	Nominal Current	Qn	Nominal Reactive Power
Ia	Active Current	Sn	Nominal Apparent Power
Ir	Reactive Current	THD	Total Harmonic Distortion
I_h	Harmonic Current	TDD	Total Demand Distortion
PWHD	Partial Weighted Harmonic Distortion	PLT	Severity of Flicker Long-Term
		d(t)	Variation of Voltage
PST	Severity of Flicker Short-Term	OV	Over Voltage
d max	Maximum Absolute Value of Voltage Variation	OF	Over Frequency
UV	Under Voltage	UF	Under Frequency

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

STANDAARD CLAUSE	STANDARD REQUIREMENTS		RESULT
	G98 Issue 1 Amendment 3 March 2019		
	TEST	REMARKS	
EN 50438 D.3.1.	Operating Range		P
EREC G98 Annex A1 A1.3.1	Harmonics		P
EREC G98 Annex A1 A1.3.3	Voltage fluctuations and Flicker		P
EN 50438 Annex D.3.10	DC injection		P
EN 50538 Annex D.3.4.1	Power factor		P
EREC G98 Annex A1 A.1.2.3	Frequency tests		P
EREC G98 Annex A1 A.1.2.2	Voltage tests		P
BS EN 62116	Loss of Mains test		P
EREC G98 Annex A1 A.1.2.6	Frequency change, Vector Shift Stability test		P
EREC G98 Annex A1 A.1.2.6	Frequency change, RoCoF Stability test		P
EN 50438 Annex D.3.3	Overfrequency test		P
EN 50438 Annex D.3.2	Power output with falling frequency test		P
EN 50438 Annex A12	Re-connection timer.		P
EREC G98 Annex A1 A.1.3.5	Fault level contribution		P
EREC G98 Annex A1 A.1.3.6	Self-Monitoring solid state switching	No solid state switching devices	N/A
EREC G98 Annex A1 A.1.3.7	Electromagnetic Compatibility (EMC)		P

4 TEST RESULTS

4.1 Operating Range

This test should be carried out as specified in EN 50438 D.3.1.

Active Power shall be recorded every second. The tests will verify that the Micro-generator 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 Micro-generator the PV primary source may be replaced by a DC source.

In case of a full converter Micro-generator (eg wind) the primary source and the prime mover Inverter/rectifier may be replaced by a DC source.

In case of a DFIG Micro-generator the mechanical drive system may be replaced by a test bench motor.

Test 1:

Voltage = 85% of nominal (195.5 V)

Frequency = 47.5 Hz

Power factor = 1

Period of test 90 minutes

Test 2:

Voltage = 110% of nominal (253 V).

Frequency = 51.5 Hz

Power factor = 1

Period of test 90 minutes

Test 3:

Voltage = 110% of nominal (253 V).

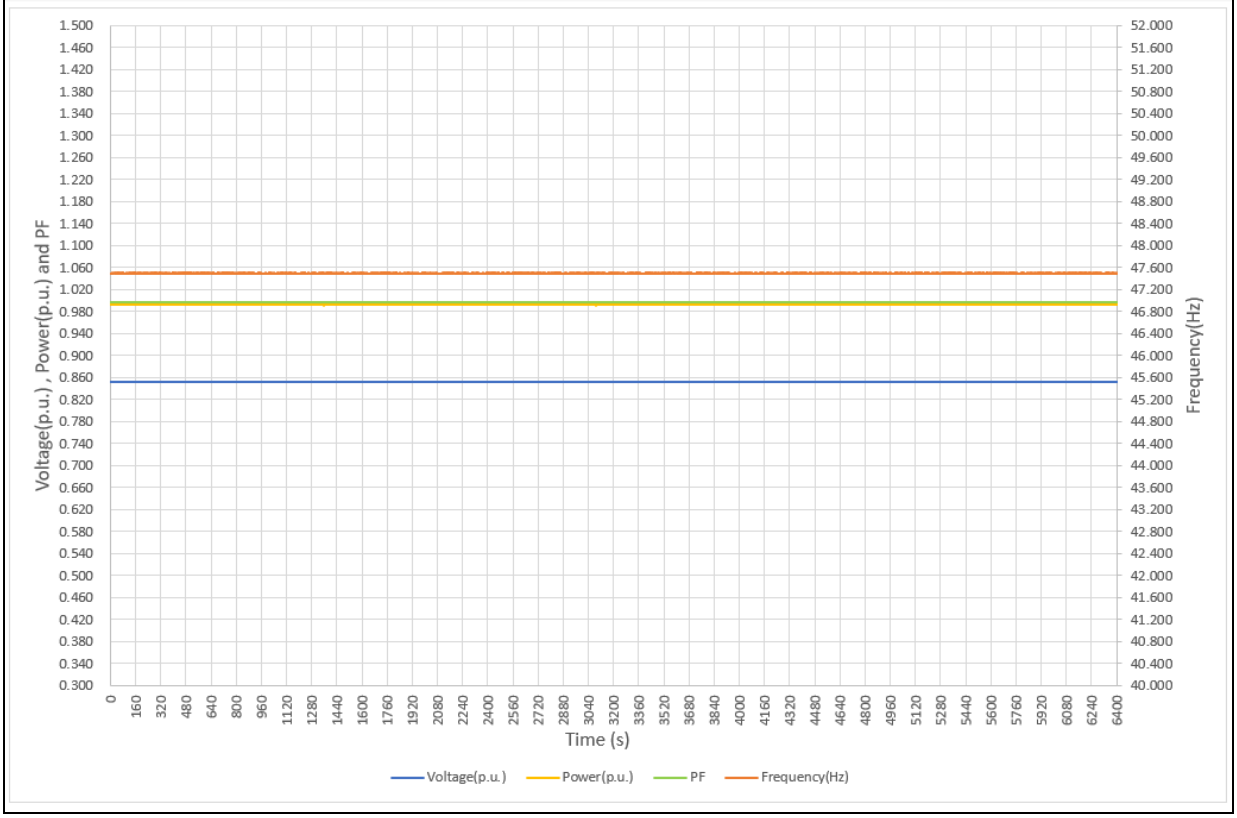
Frequency = 52.0 Hz

Power factor = 1

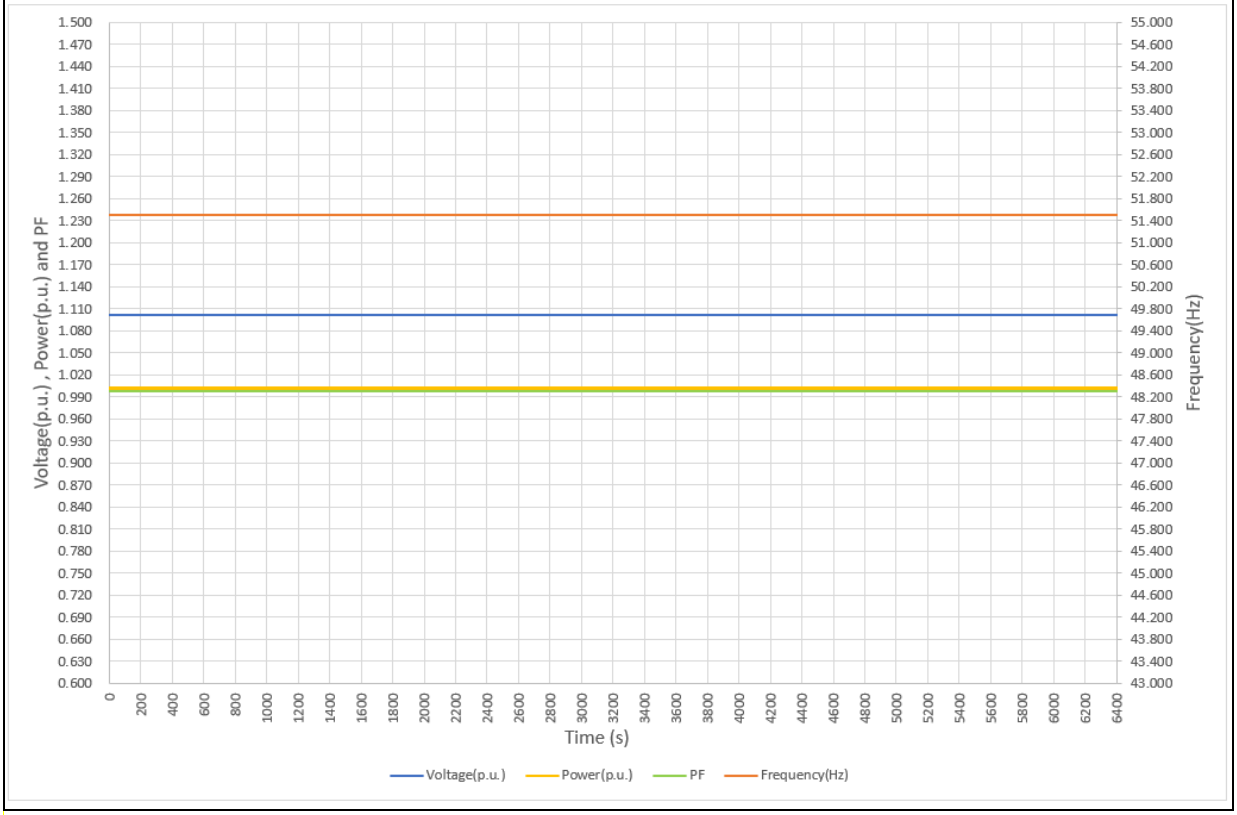
Period of test 15 minutes

Test results are graphically shown in following pages.

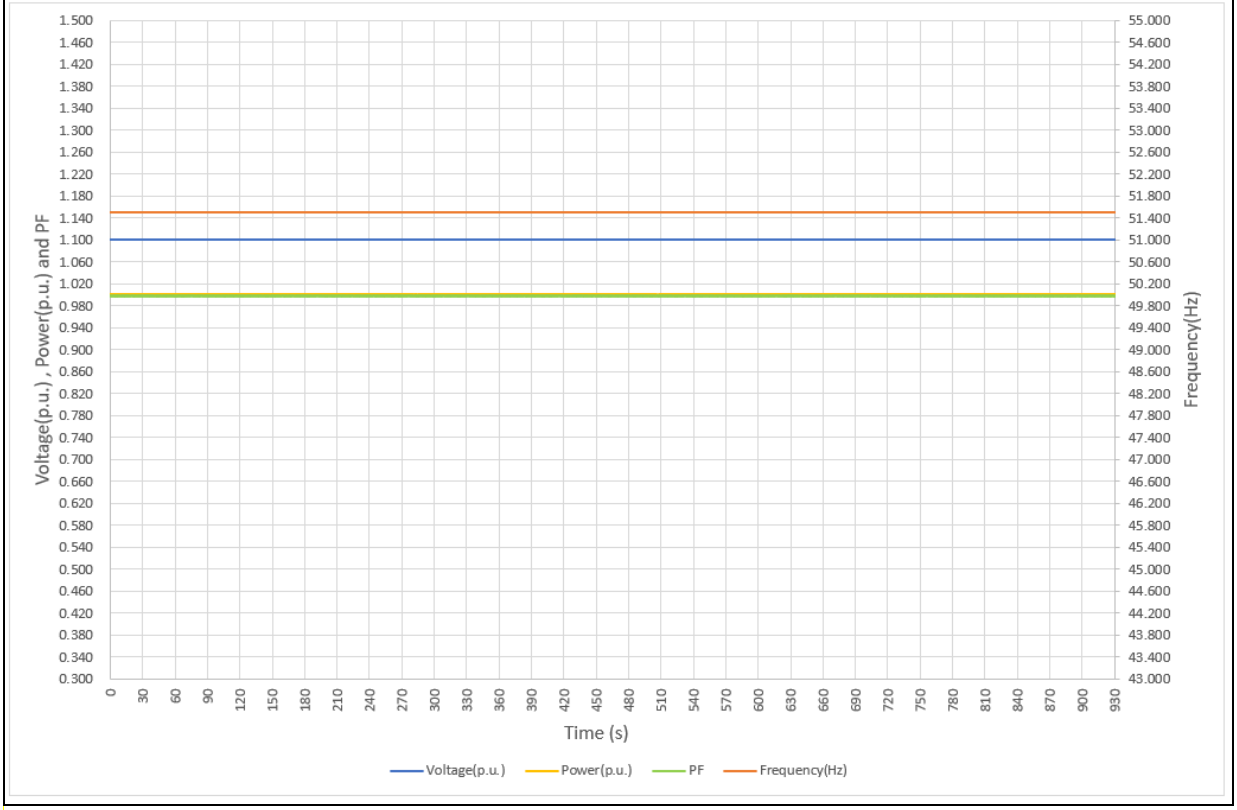
Test 1


Voltage(p.u.) , Power(p.u.) and PF
Frequency(Hz)
Time (s)
Voltage(p.u.)
Power(p.u.)
PF
Frequency(Hz)

Test 2


Voltage(p.u.) , Power(p.u.) and PF
Frequency(Hz)
Time (s)
Voltage(p.u.)
Power(p.u.)
PF
Frequency(Hz)

Test 3


Voltage(p.u.) , Power(p.u.) and PF
Frequency(Hz)
Time (s)
Voltage(p.u.)
Power(p.u.)
PF
Frequency(Hz)

4.2 POWER QUALITY

4.2.1 Current Harmonics

The tests should be carried out as specified in BS EN 61000-3-2 and can be undertaken with a fixed source of energy at two power levels firstly between 45 and 55% and at 100% of Registered Capacity. The test requirements are specified in Annex A1 A.1.3.1 (Inverter connected) or Annex A2 A.2.3.1 (Synchronous).

Measures have been repeated at 50%P_n and 100%P_n.

Following tables show the test results:

Micro-generator rating per phase (rpp)			10	kW		
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**			
Phase A						
	Measured Value MV in Amps	Ih(%)	Measured Value MV in Amps	Ih(%)	Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.009	0.060	0.024	0.165	1.080	
3	0.006	0.044	0.013	0.089	2.300	
4	0.006	0.041	0.014	0.097	0.430	
5	0.024	0.165	0.043	0.297	1.140	
6	0.006	0.044	0.004	0.027	0.300	
7	0.009	0.064	0.012	0.084	0.770	
8	0.004	0.027	0.004	0.031	0.230	
9	0.005	0.037	0.005	0.038	0.400	
10	0.003	0.020	0.012	0.082	0.184	
11	0.017	0.116	0.006	0.044	0.330	
12	0.002	0.014	0.002	0.013	0.153	
13	0.007	0.050	0.011	0.075	0.210	
14	0.002	0.014	0.002	0.017	0.131	
15	0.005	0.032	0.003	0.024	0.150	
16	0.002	0.016	0.002	0.011	0.115	
17	0.007	0.050	0.014	0.095	0.132	
18	0.001	0.008	0.001	0.008	0.102	
19	0.006	0.043	0.012	0.083	0.118	
20	0.001	0.010	0.002	0.015	0.092	
21	0.003	0.023	0.003	0.019	0.107	0.160
22	0.002	0.014	0.001	0.010	0.084	
23	0.004	0.027	0.011	0.078	0.098	0.147
24	0.001	0.004	0.001	0.007	0.077	
25	0.006	0.039	0.010	0.068	0.090	0.135
26	0.001	0.006	0.002	0.011	0.071	
27	0.003	0.020	0.004	0.029	0.083	0.124
28	0.002	0.014	0.001	0.006	0.066	
29	0.005	0.035	0.010	0.070	0.078	0.117
30	0.001	0.004	0.001	0.007	0.061	
31	0.005	0.033	0.008	0.056	0.073	0.109
32	0.002	0.014	0.001	0.009	0.058	
33	0.002	0.012	0.004	0.025	0.068	0.102
34	0.002	0.015	0.001	0.007	0.054	

35	0.004	0.025	0.007	0.048	0.064	0.096
36	0.001	0.004	0.001	0.007	0.051	
37	0.003	0.018	0.008	0.056	0.061	0.091
38	0.001	0.005	0.001	0.010	0.048	
39	0.001	0.008	0.004	0.029	0.058	0.087
40	0.002	0.014	0.001	0.008	0.046	

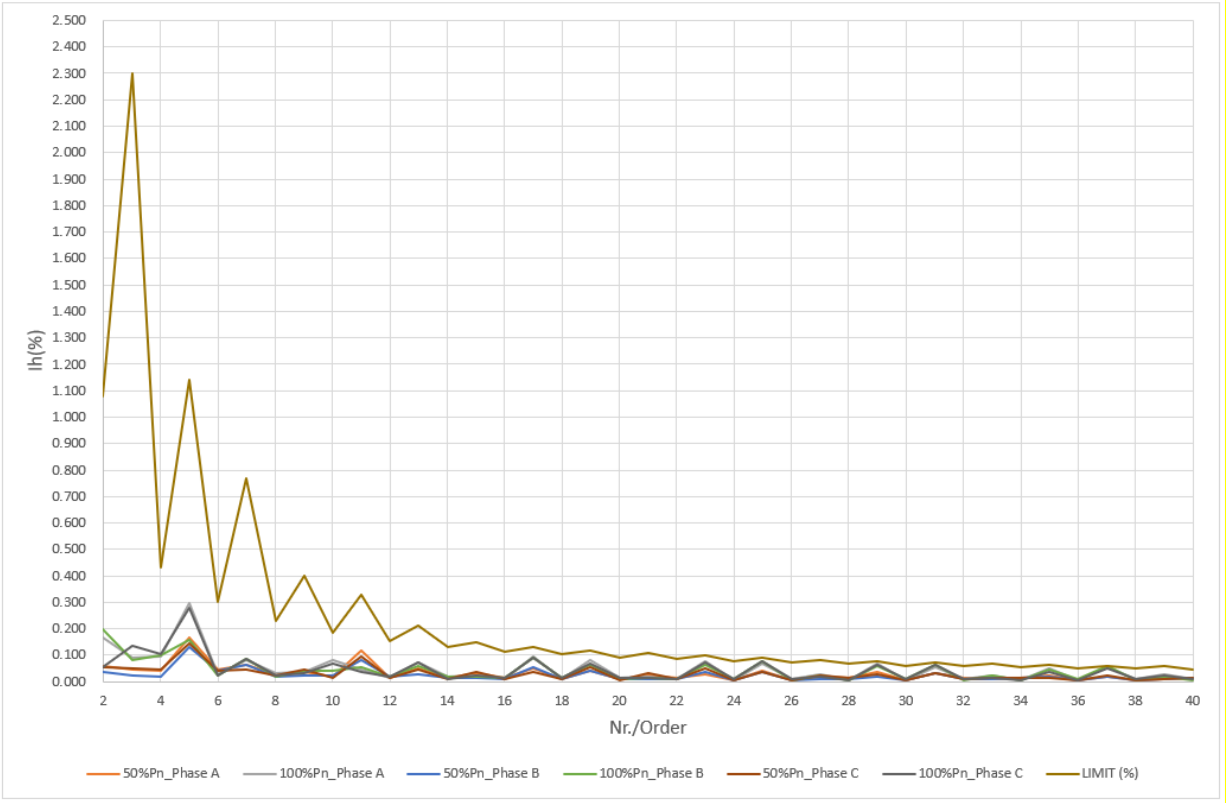
Phase B						
	Measured Value MV in Amps	Ih(%)	Measured Value MV in Amps	Ih(%)	Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.006	0.038	0.029	0.198	1.080	
3	0.004	0.025	0.012	0.083	2.300	
4	0.003	0.018	0.015	0.101	0.430	
5	0.019	0.132	0.023	0.160	1.140	
6	0.006	0.042	0.003	0.024	0.300	
7	0.009	0.065	0.013	0.087	0.770	
8	0.003	0.018	0.003	0.019	0.230	
9	0.003	0.023	0.006	0.041	0.400	
10	0.003	0.021	0.006	0.042	0.184	
11	0.012	0.082	0.008	0.054	0.330	
12	0.002	0.017	0.003	0.020	0.153	
13	0.004	0.030	0.008	0.057	0.210	
14	0.002	0.013	0.003	0.020	0.131	
15	0.002	0.013	0.003	0.021	0.150	
16	0.002	0.011	0.002	0.016	0.115	
17	0.008	0.053	0.013	0.088	0.132	
18	0.002	0.011	0.002	0.012	0.102	
19	0.006	0.041	0.010	0.066	0.118	
20	0.001	0.010	0.001	0.008	0.092	
21	0.001	0.008	0.002	0.016	0.107	0.160
22	0.001	0.009	0.002	0.012	0.084	
23	0.006	0.038	0.009	0.062	0.098	0.147
24	0.001	0.007	0.001	0.009	0.077	
25	0.005	0.038	0.011	0.078	0.090	0.135
26	0.001	0.007	0.001	0.006	0.071	
27	0.001	0.008	0.004	0.024	0.083	0.124
28	0.002	0.011	0.001	0.006	0.066	
29	0.002	0.017	0.008	0.057	0.078	0.117
30	0.001	0.005	0.001	0.010	0.061	
31	0.005	0.033	0.009	0.062	0.073	0.109
32	0.001	0.008	0.001	0.006	0.058	
33	0.001	0.008	0.003	0.022	0.068	0.102
34	0.002	0.013	0.001	0.005	0.054	
35	0.002	0.017	0.007	0.045	0.064	0.096
36	0.001	0.004	0.002	0.011	0.051	
37	0.003	0.019	0.009	0.059	0.061	0.091
38	0.001	0.006	0.001	0.006	0.048	
39	0.001	0.010	0.003	0.021	0.058	0.087
40	0.002	0.012	0.001	0.005	0.046	

Phase C

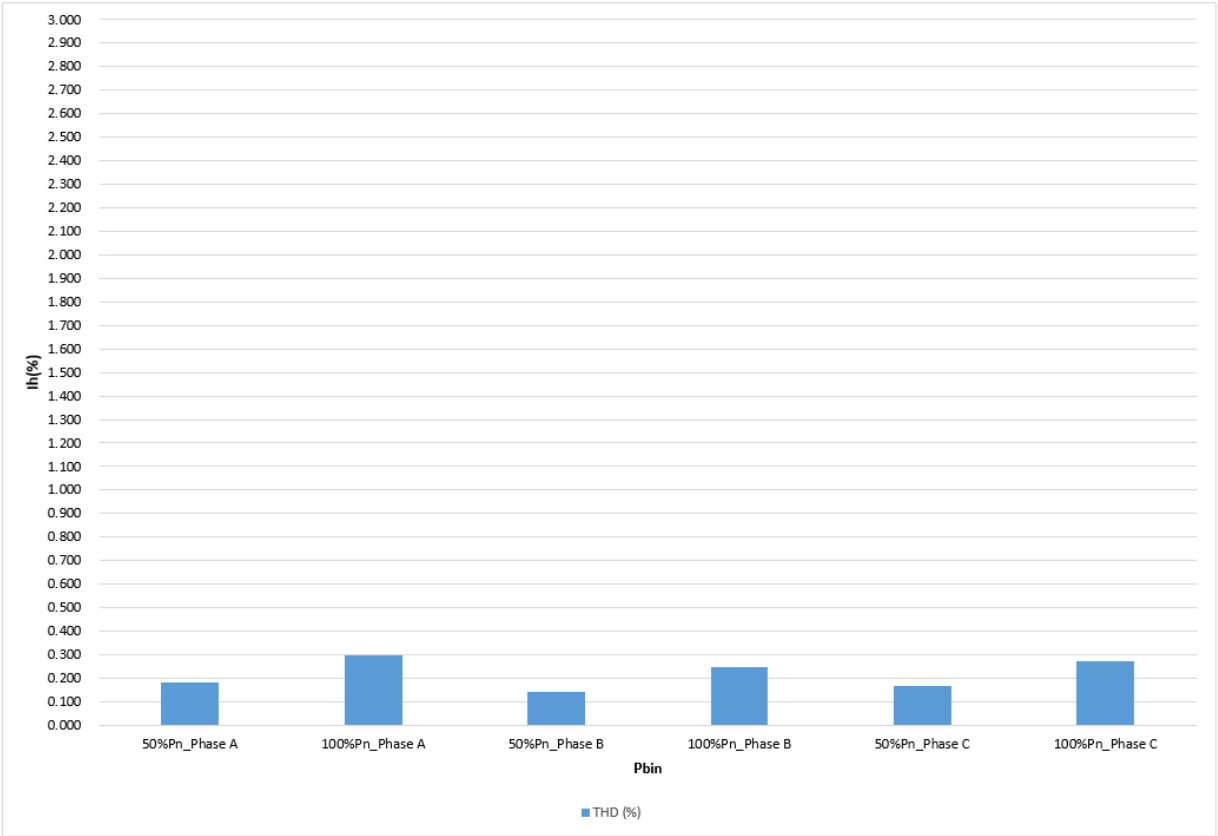
	Measured Value MV in Amps	Ih(%)	Measured Value MV in Amps	Ih(%)	Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.008	0.054	0.008	0.057	1.080	
3	0.007	0.050	0.020	0.135	2.300	
4	0.006	0.045	0.015	0.102	0.430	
5	0.021	0.146	0.040	0.278	1.140	
6	0.006	0.043	0.003	0.024	0.300	
7	0.007	0.046	0.012	0.084	0.770	
8	0.003	0.022	0.003	0.022	0.230	
9	0.007	0.045	0.005	0.033	0.400	
10	0.002	0.012	0.010	0.066	0.184	
11	0.014	0.095	0.005	0.037	0.330	
12	0.002	0.013	0.003	0.019	0.153	
13	0.007	0.047	0.010	0.071	0.210	
14	0.001	0.009	0.001	0.010	0.131	
15	0.005	0.036	0.003	0.023	0.150	
16	0.001	0.010	0.002	0.012	0.115	
17	0.005	0.035	0.013	0.093	0.132	
18	0.001	0.008	0.002	0.015	0.102	
19	0.008	0.056	0.010	0.069	0.118	
20	0.001	0.007	0.002	0.012	0.092	
21	0.005	0.034	0.002	0.014	0.107	0.160
22	0.002	0.011	0.002	0.012	0.084	
23	0.007	0.048	0.010	0.072	0.098	0.147
24	0.001	0.006	0.001	0.010	0.077	
25	0.006	0.039	0.011	0.078	0.090	0.135
26	0.001	0.005	0.001	0.008	0.071	
27	0.003	0.022	0.003	0.019	0.083	0.124
28	0.002	0.013	0.001	0.007	0.066	
29	0.004	0.027	0.009	0.064	0.078	0.117
30	0.001	0.006	0.001	0.008	0.061	
31	0.005	0.032	0.009	0.061	0.073	0.109
32	0.001	0.009	0.001	0.008	0.058	
33	0.002	0.015	0.002	0.015	0.068	0.102
34	0.002	0.014	0.001	0.007	0.054	
35	0.002	0.016	0.005	0.037	0.064	0.096
36	0.001	0.004	0.001	0.007	0.051	
37	0.003	0.022	0.007	0.049	0.061	0.091
38	0.001	0.005	0.001	0.009	0.048	
39	0.002	0.010	0.004	0.024	0.058	0.087
40	0.002	0.014	0.001	0.008	0.002	

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.

Current Harmonics



THD



4.2.2 Voltage fluctuations and Flicker

These tests should be undertaken in accordance with EREC G98 Annex A1 A.1.3.3 (Inverter connected) or Annex A2 A.2.3.3 (Synchronous).

The measurements of voltage fluctuations have been measured according to the standard, at 100 % of the nominal power value of the inverter.

The test impedance is recorded in the table below:

Test Impedance	R	0.4	Ω	X	0.25	Ω
Standard Impedance	R	0.4	Ω	X	0.25	Ω
Maximum Impedance	R	0.4	Ω	X	0.25	Ω

Starting operation and Stopping operation			
Pbin (%)	**100%**		
Phase A			
	Limit	**Starting measured values**	**Stopping measured values**
PST	≤ 1	0.058	0.059
PLT	≤ 0.65	0.059	0.059
dc	≤ 3.30%	0.094%	0.108%
d(t)	≤ 3.30%	0.00%	0.00%
dmax	4%	0.284%	0.353%
Phase B			
	Limit	**Starting measured values**	**Stopping measured values**
PST	≤ 1	0.135	0.135
PLT	≤ 0.65	0.135	0.135
dc	≤ 3.30%	0.034%	0.034%
d(t)	≤ 3.30%	0.00%	0.00%
dmax	4%	0.113%	0.101%
Phase C			
	Limit	**Starting measured values**	**Stopping measured values**
PST	≤ 1	0.042	0.042
PLT	≤ 0.65	0.043	0.043
dc	≤ 3.30%	0.019%	0.008%
d(t)	≤ 3.30%	0.000%	0.000%
dmax	4%	0.100%	0.112%

As it can be seen in the next screenshots, this test has two steps:

1. Starting operation
2. Stopping operation

All values are the most unfavorable of the two steps.

Starting operation and Stopping operation

100% Pn

Phase A

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:2	
No. 1	0.094	Pass	0.284	Pass	0.0	Pass	0.058	Pass		
2	0.108	Pass	0.353	Pass	0.0	Pass	0.059	Pass		
Result		Pass		Pass		Pass		Pass	0.059	Pass

Phase B

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:2	
No. 1	0.034	Pass	0.113	Pass	0.0	Pass	0.135	Pass		
2	0.001	Pass	0.101	Pass	0.0	Pass	0.135	Pass		
Result		Pass		Pass		Pass		Pass	0.135	Pass

Phase C

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:2	
No. 1	0.019	Pass	0.100	Pass	0.0	Pass	0.042	Pass		
2	0.008	Pass	0.112	Pass	0.0	Pass	0.043	Pass		
Result		Pass		Pass		Pass		Pass	0.043	Pass

Running operation 2 hours				
Pbin (%)	100%			
	Limit	Phase A	Phase B	Phase C
		Measured values	Measured values	Measured values
PST	≤ 1	0.044	0.139	0.048
PLT	≤ 0.65	0.032	0.137	0.046
dc	≤ 3.30%	0.114%	0.010%	0.020%
d(t)	≤ 3.30%	0.000%	0.000%	0.000%
dmax	4%	0.213%	0.119%	0.108%

As it can be seen in the next screenshots is running operation. The values took of Pst and Plt are the most unfavorable of the twelve steps.

Running operation

100% Pn

Phase A

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.114	Pass	0.159	Pass	0.0	Pass	0.044	Pass		
2	0.068	Pass	0.109	Pass	0.0	Pass	0.037	Pass		
3	0.092	Pass	0.132	Pass	0.0	Pass	0.027	Pass		
4	0.017	Pass	0.165	Pass	0.0	Pass	0.033	Pass		
5	0.098	Pass	0.213	Pass	0.0	Pass	0.025	Pass		
6	0.071	Pass	0.133	Pass	0.0	Pass	0.025	Pass		
7	0.078	Pass	0.171	Pass	0.0	Pass	0.026	Pass		
8	0.104	Pass	0.199	Pass	0.0	Pass	0.032	Pass		
9	0.036	Pass	0.151	Pass	0.0	Pass	0.027	Pass		
10	0.095	Pass	0.152	Pass	0.0	Pass	0.028	Pass		
11	0.081	Pass	0.146	Pass	0.0	Pass	0.030	Pass		
12	0.090	Pass	0.144	Pass	0.0	Pass	0.033	Pass		
Result		Pass		Pass		Pass		Pass	0.032	Pass

Phase B

Phase C

4.2.3 DC Injection

The DC component shall be measured under steady-state conditions for the following power levels: 20 %, 50 %, 75 %, and 100 % of nominal power with a tolerance of ± 5 % of nominal power and as far as adjustable for the tested micro-generator. These tests should be undertaken in accordance with Annex A1.3.4.

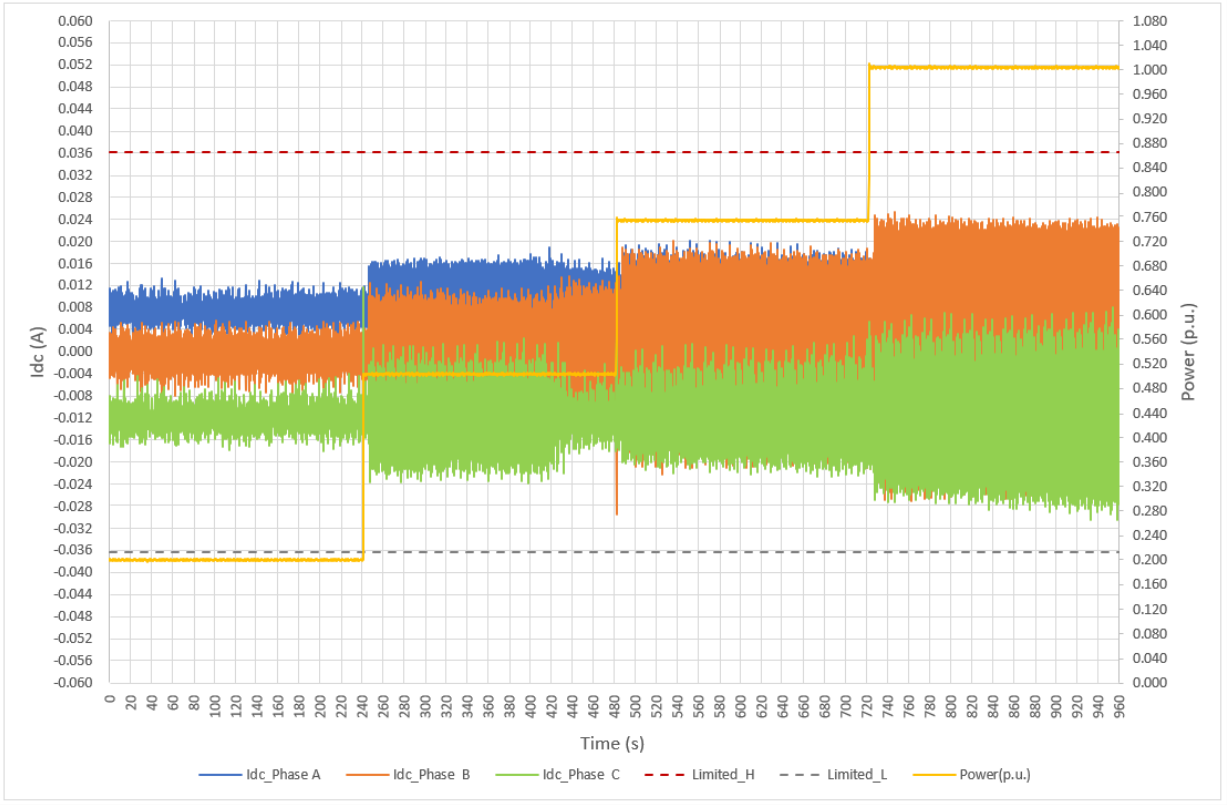
Following tables show the test results:

Power quality – DC injection: This test should be carried out in accordance with EN 50438 Annex D.3.10				
Phase A				
Test power level	20%	50%	75%	100%
Recorded value in Amps	0.008	0.008	0.009	0.010
as % of rated AC current	0.05%	0.05%	0.06%	0.07%
Limit	0.25%	0.25%	0.25%	0.25%

Phase B				
Test power level	20%	50%	75%	100%
Recorded value in Amps	0.003	0.007	0.012	0.015
as % of rated AC current	0.02%	0.05%	0.08%	0.11%
Limit	0.25%	0.25%	0.25%	0.25%

Phase C				
Test power level	20%	50%	75%	100%
Recorded value in Amps	0.012	0.012	0.011	0.013
as % of rated AC current	0.08%	0.08%	0.08%	0.09%
Limit	0.25%	0.25%	0.25%	0.25%

DC injection test result



4.2.4 Power Factor

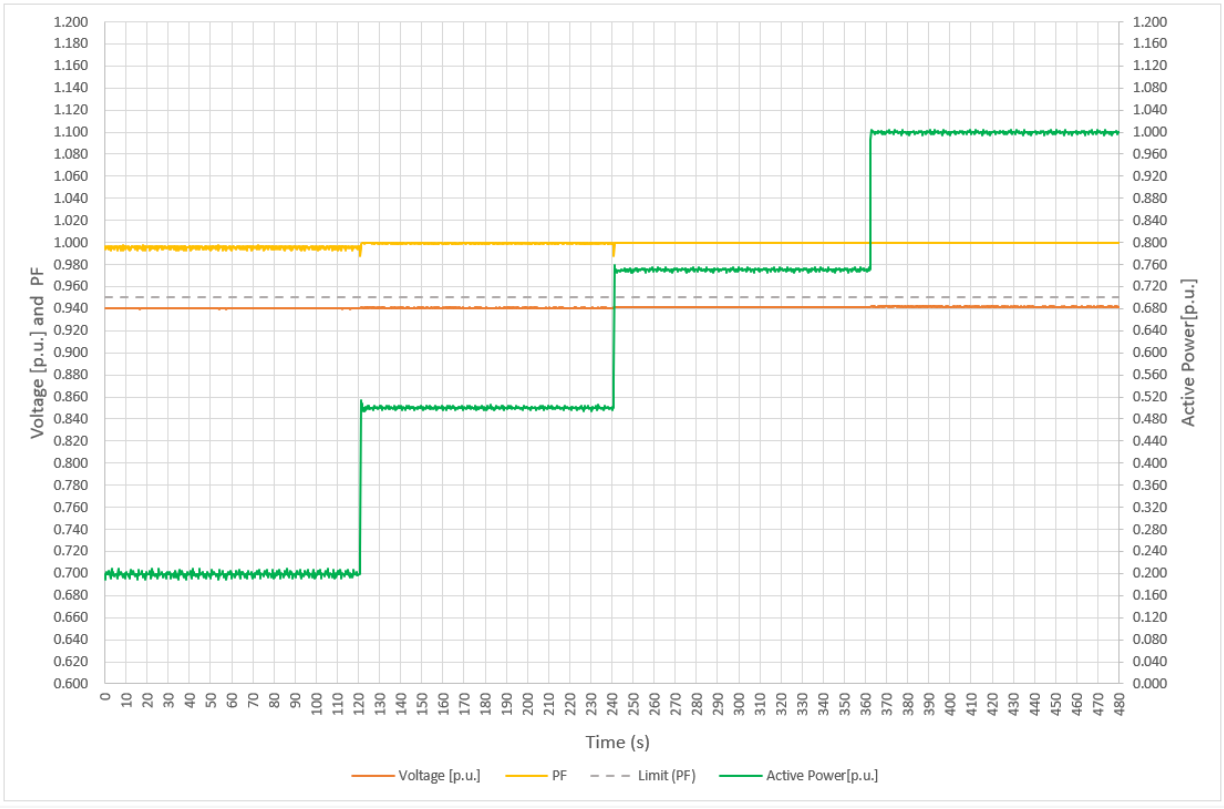
This test shall be carried out in accordance with EN 50538 Annex D.3.4.1 but with nominal voltage -6% and +10%. Voltage to be maintained within ±1.5% of the stated level during the test.

The following table shows the test results at required voltage levels:

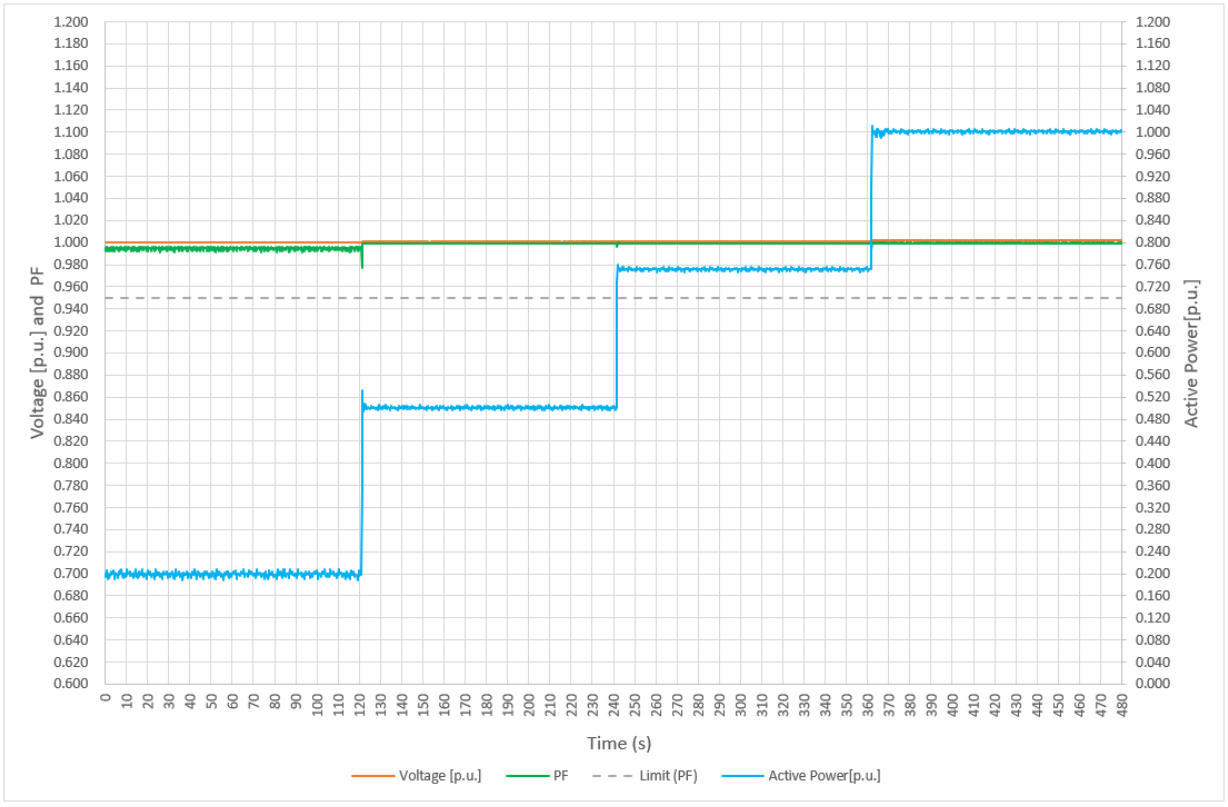
	216.2 V	230 V	253 V
20% of **Registered Capacity**	0.996	0.995	0.994
50% of **Registered Capacity**	0.999	0.999	0.999
75% of **Registered Capacity**	0.999	0.999	0.999
100% of **Registered Capacity**	0.999	1.000	0.999
Limit	>0.95	>0.95	>0.95

Test results are graphically shown below.

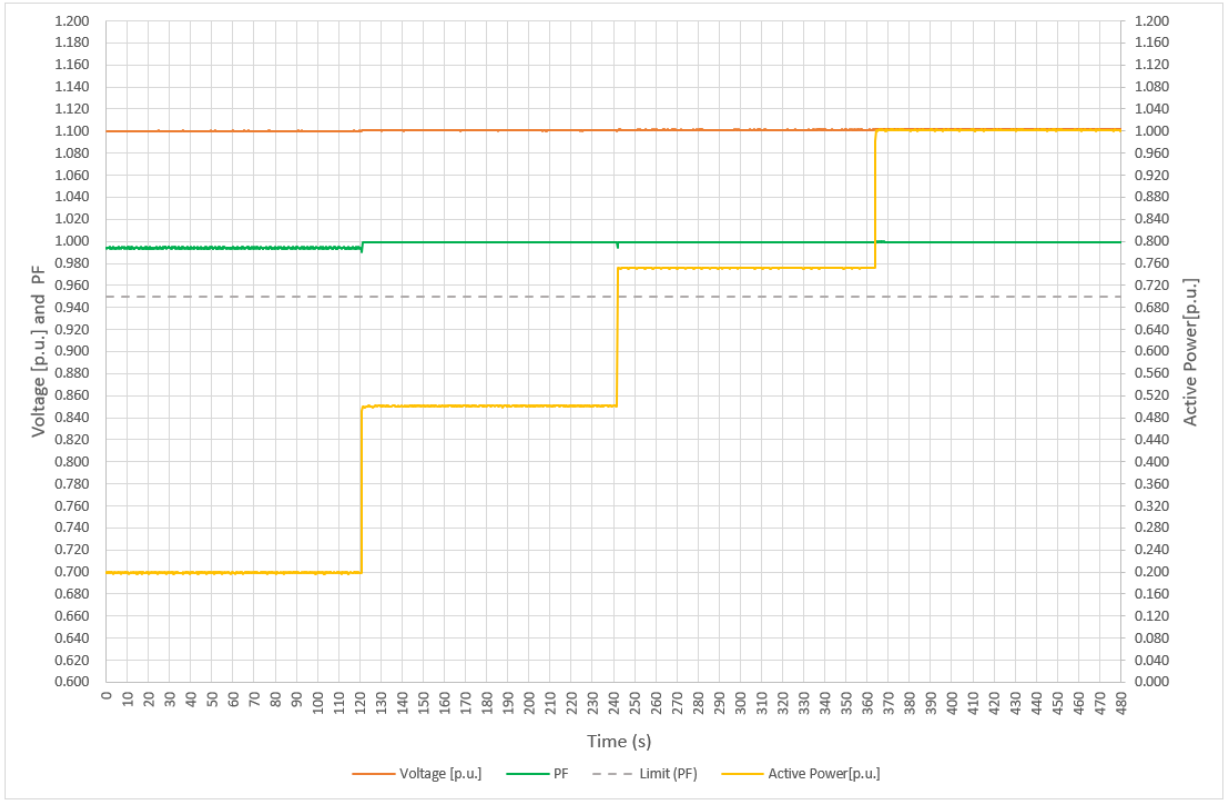
Power Factor 216.2V



Power Factor 230V



Power Factor 253V



4.3 PROTECTION

4.3.1 Frequency tests

These tests should be carried out in accordance with EN 50438 Annex D.2.4 and the notes in EREC G98 Annex A1 A.1.2.3 (Inverter connected) or Annex A2 A.2.2.3 (Synchronous).

To establish a trip frequency, the test frequency should be applied in a slow ramp rate of less than 0.1 Hz/s, or if this is not possible in steps of 0.05 Hz for a duration that is longer than the trip time delay.

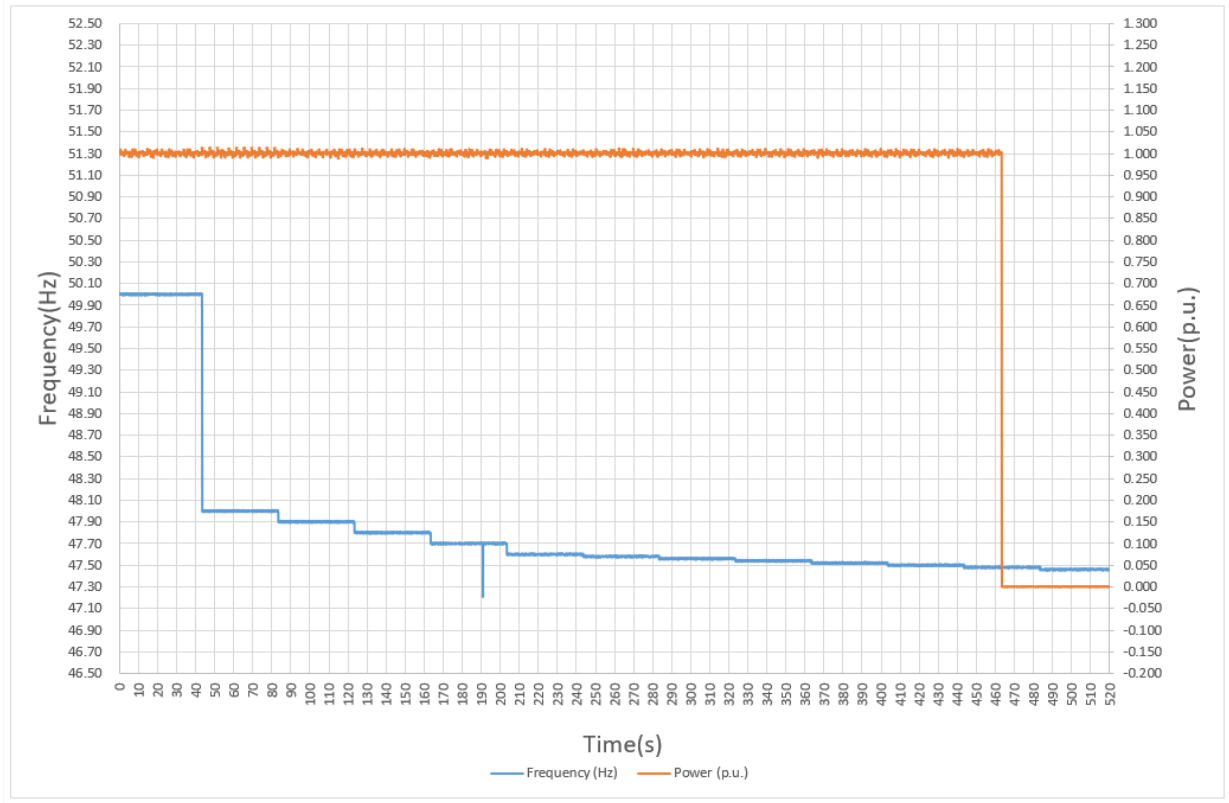
To establish the trip time, the test frequency should be applied starting from 0.3 Hz below or above the recorded trip frequency and should be changed to 0.3 Hz above or below the recorded trip frequency in a single step. For each trip setting five tests shall be carried out.

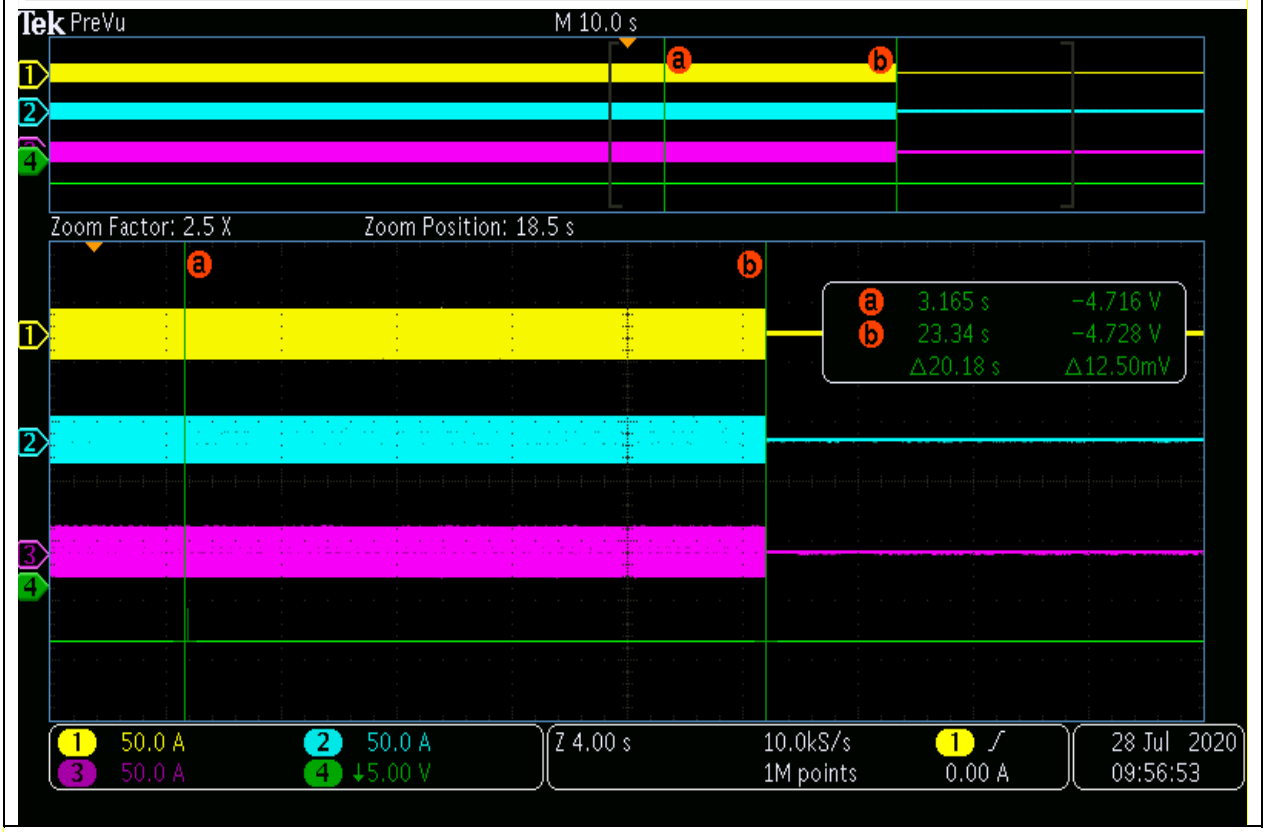
Following tables show the test results:

Function	Setting		Trip test (5 times)		"No trip tests"	
	Frequency	Time delay	Frequency (Hz)	Time delay (s)	Frequency /time	Confirm no trip
U/F stage 1	47.5 Hz	20 s	47.48	20.180	47.7 Hz / 25 s	Pass
			47.46	20.130		
			47.46	20.090		
			47.46	20.100		
			47.46	20.160		
U/F stage 2	47 Hz	0.5 s	46.96	0.496	47.2 Hz / 19.98 s	Pass
			46.98	0.520		
			46.96	0.492		
			46.98	0.516		
			46.96	0.486		
					46.8 Hz / 0.48 s	Pass
O/F stage 1	52 Hz	0.5 s	51.98	0.502	51.8 Hz / 89.98 s	Pass
			51.98	0.496		
			51.98	0.512		
			51.98	0.510		
			51.98	0.508		
					52.2 Hz / 0.48 s	Pass

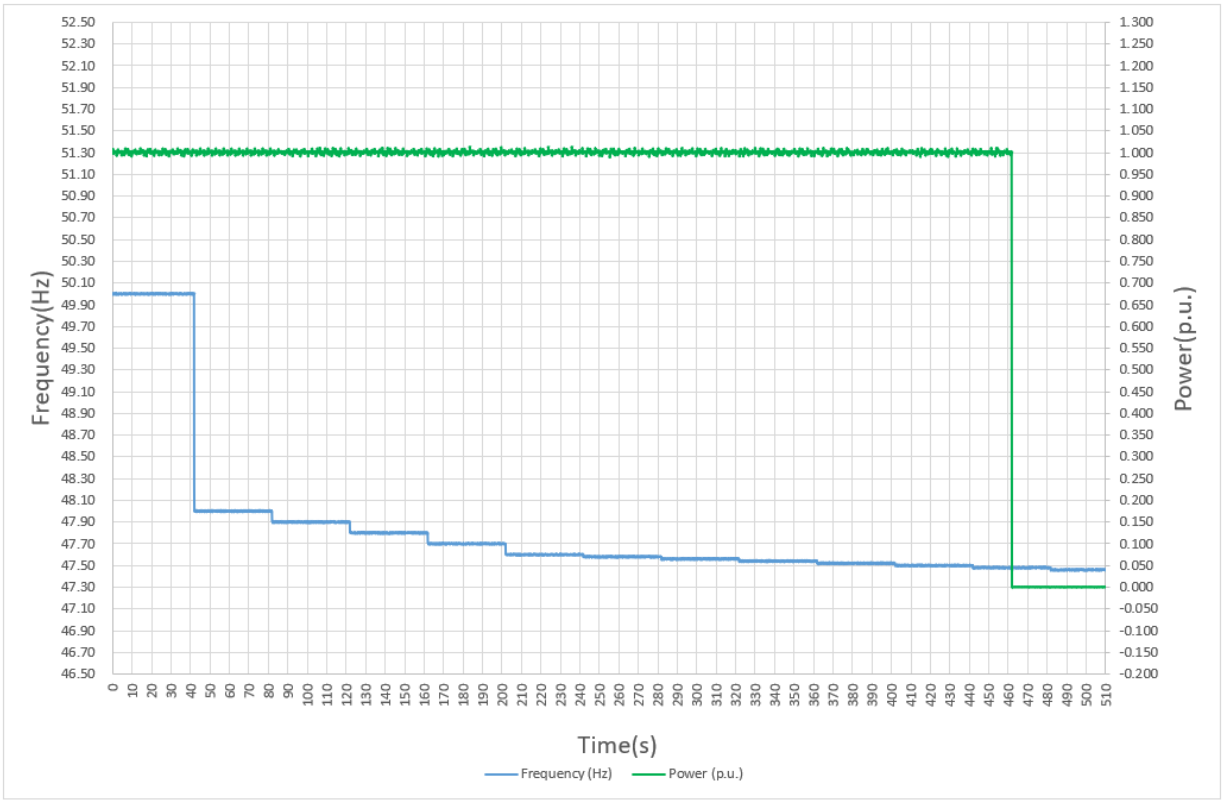
Test results are graphically shown below.

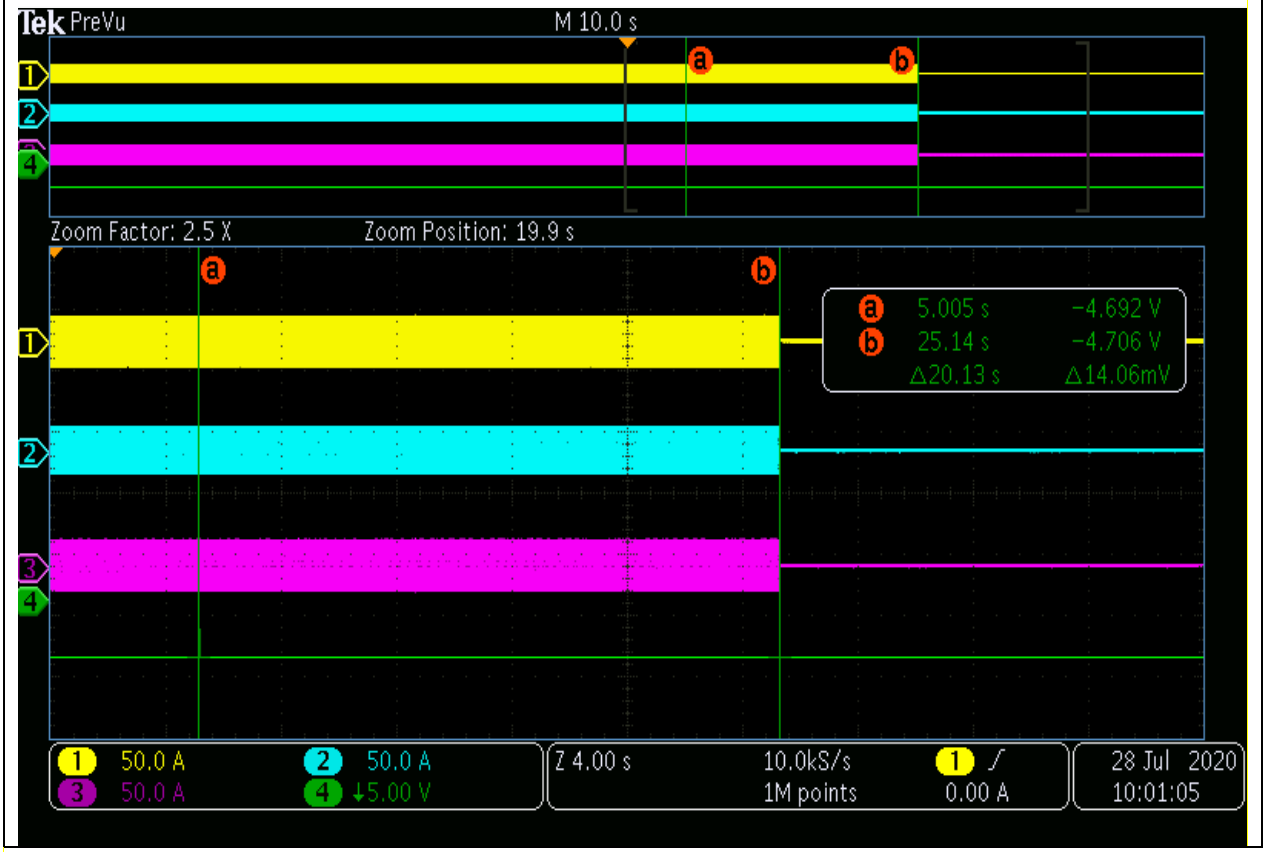
U/F stage 1-1



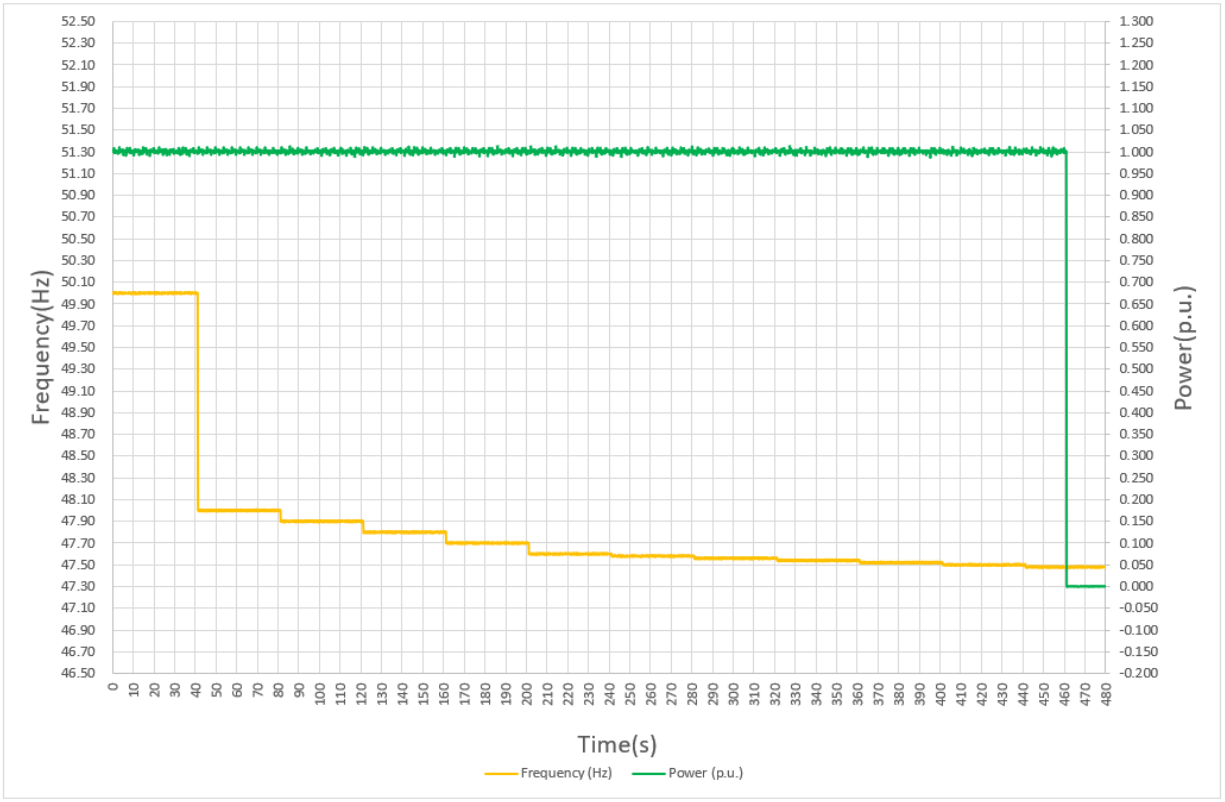


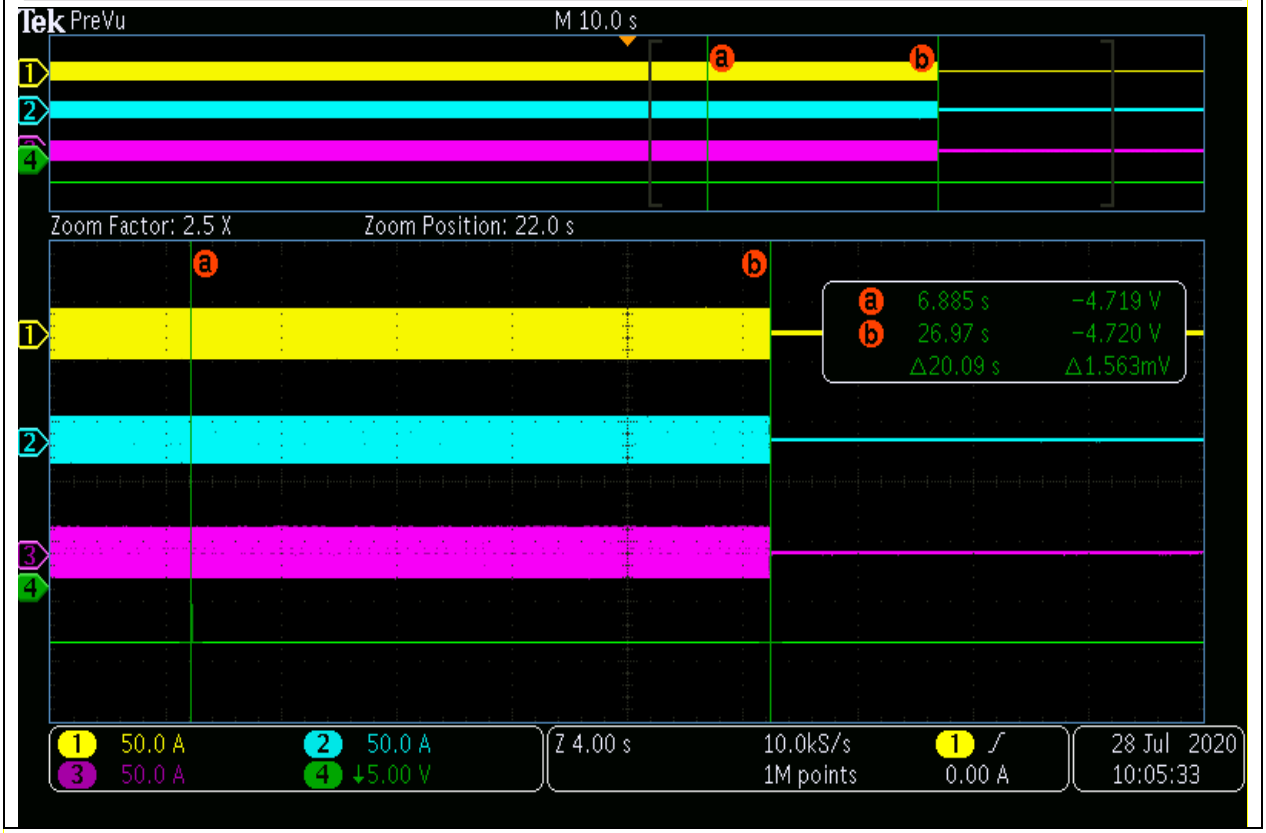
U/F stage 1-2


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

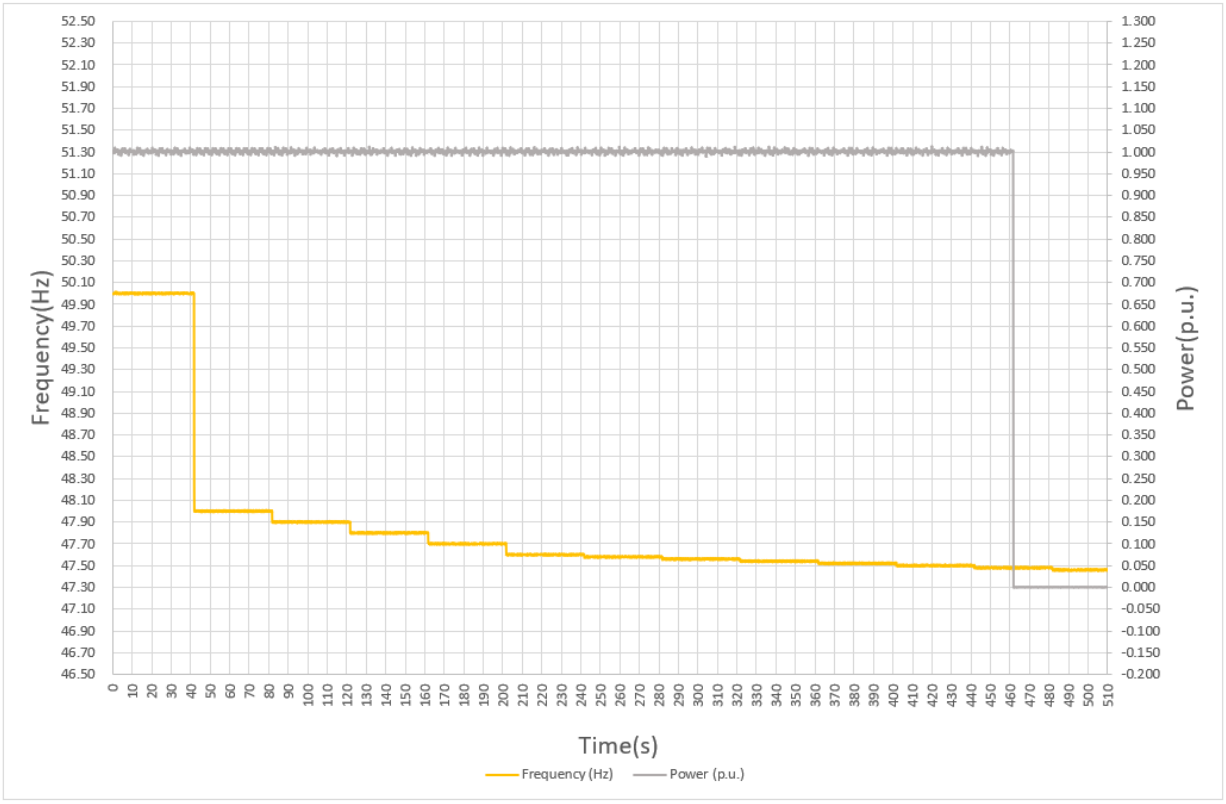

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: 19.9 s
a 5.005 s -4.692 V
b 25.14 s -4.706 V
Δ20.13 s Δ14.06mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
28 Jul 2020
10:01:05

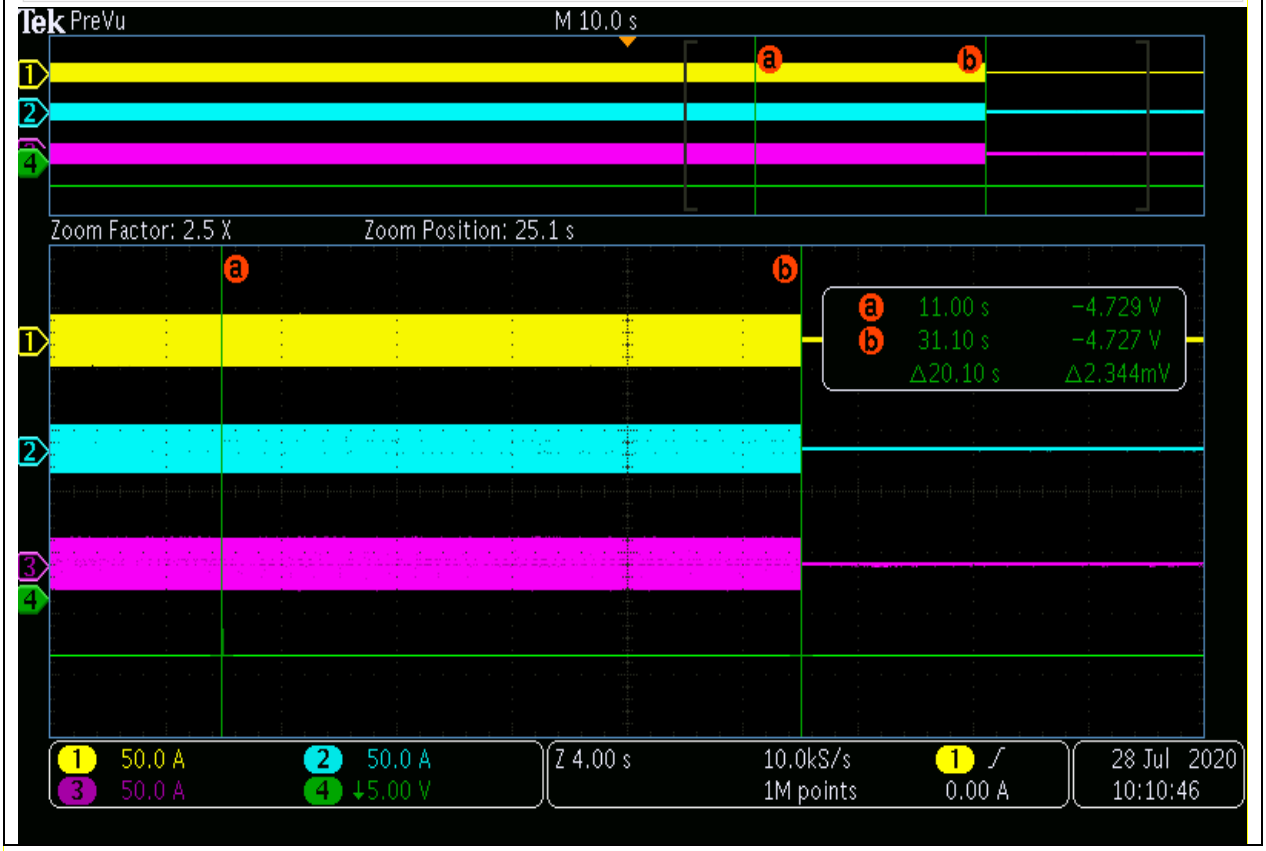
U/F stage 1-3


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

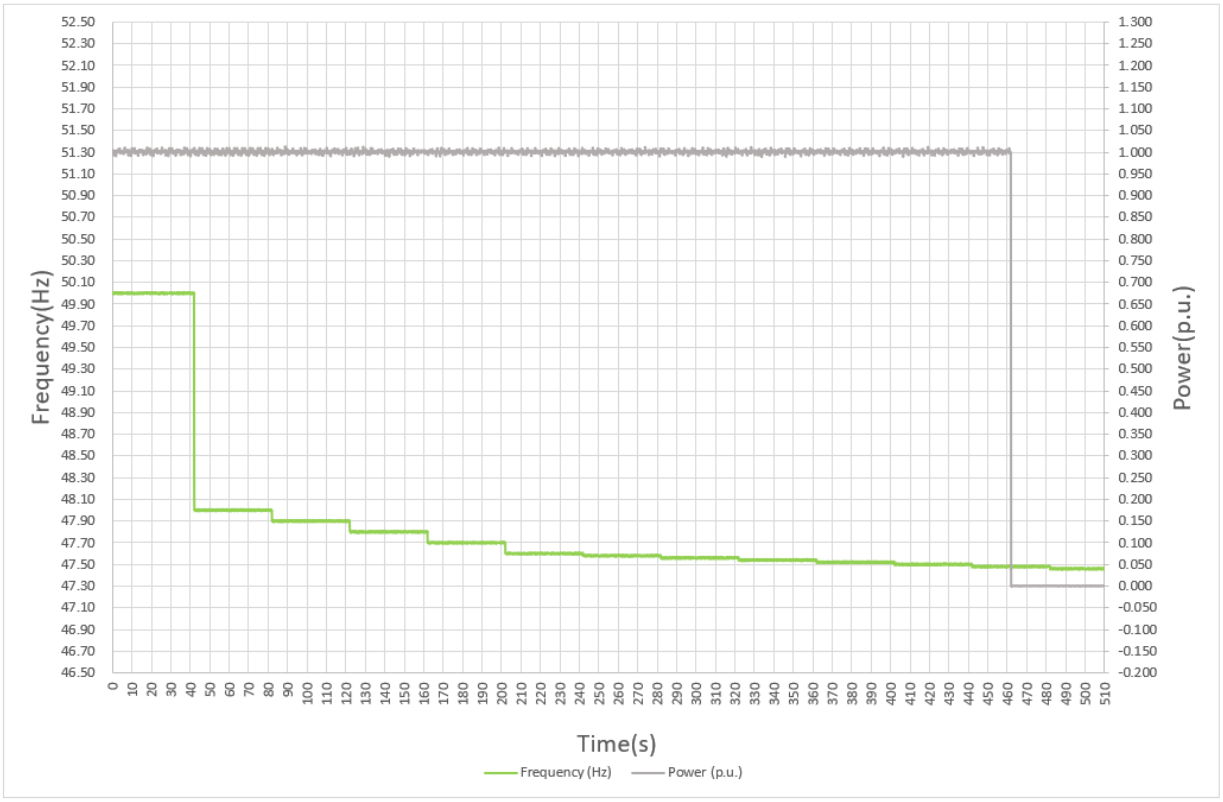

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: 22.0 s
a 6.885 s -4.719 V
b 26.97 s -4.720 V
Δ20.09 s Δ1.563mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
28 Jul 2020
10:05:33

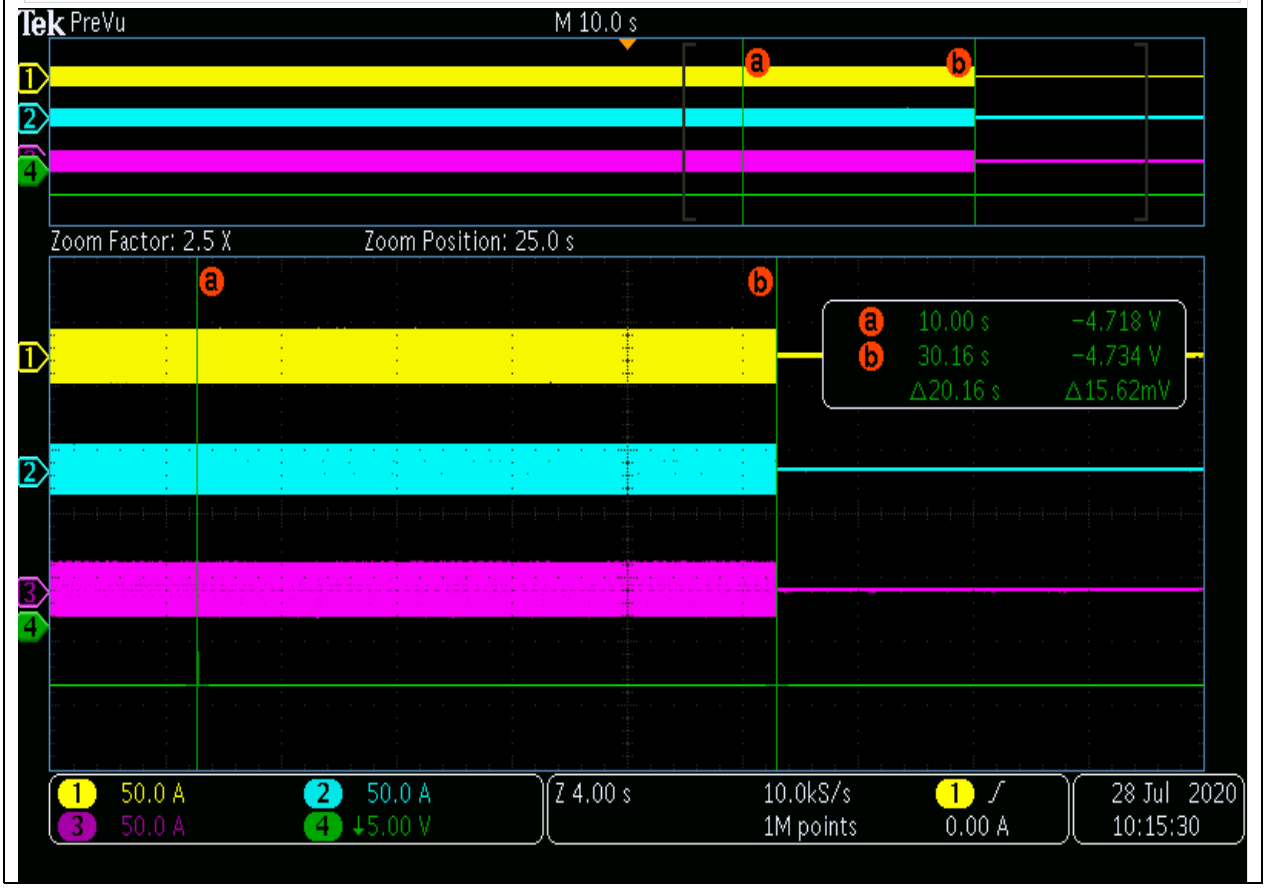
U/F stage 1-4


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

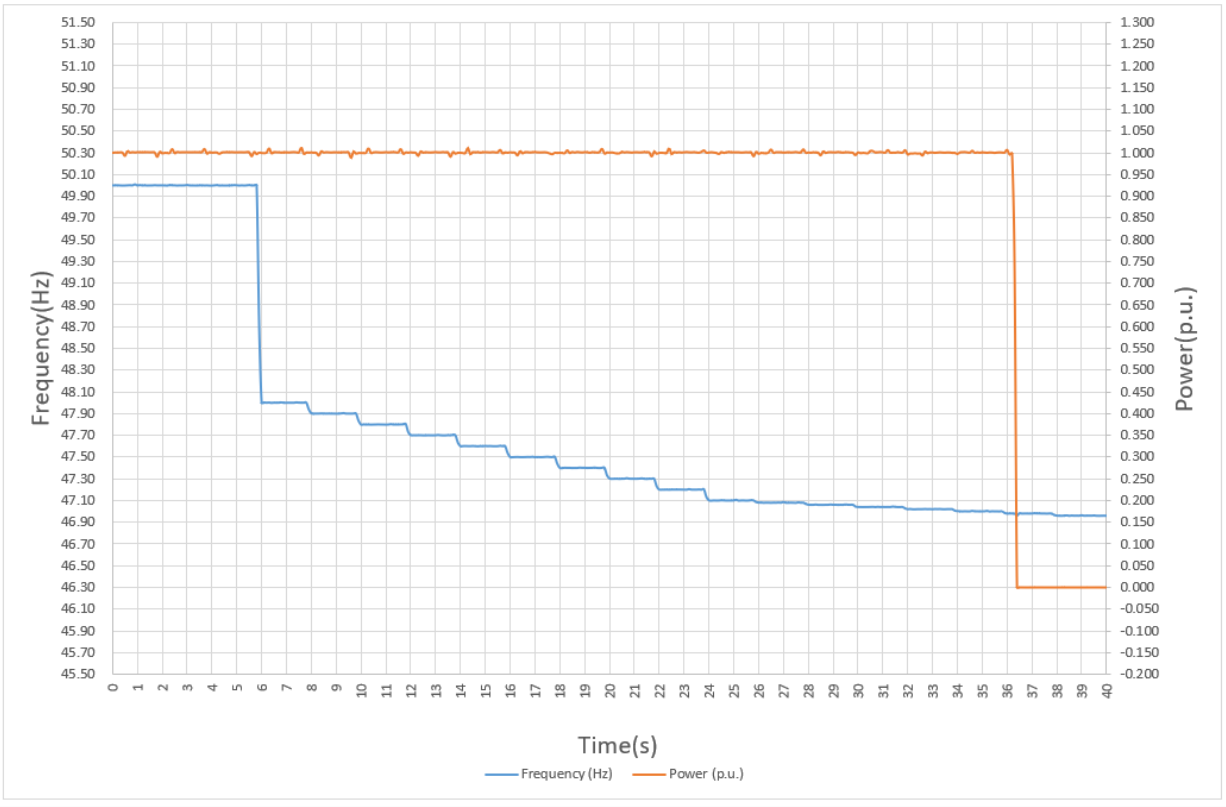

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: 25.1 s
a 11.00 s -4.729 V
b 31.10 s -4.727 V
Δ20.10 s Δ2.344mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
28 Jul 2020
10:10:46

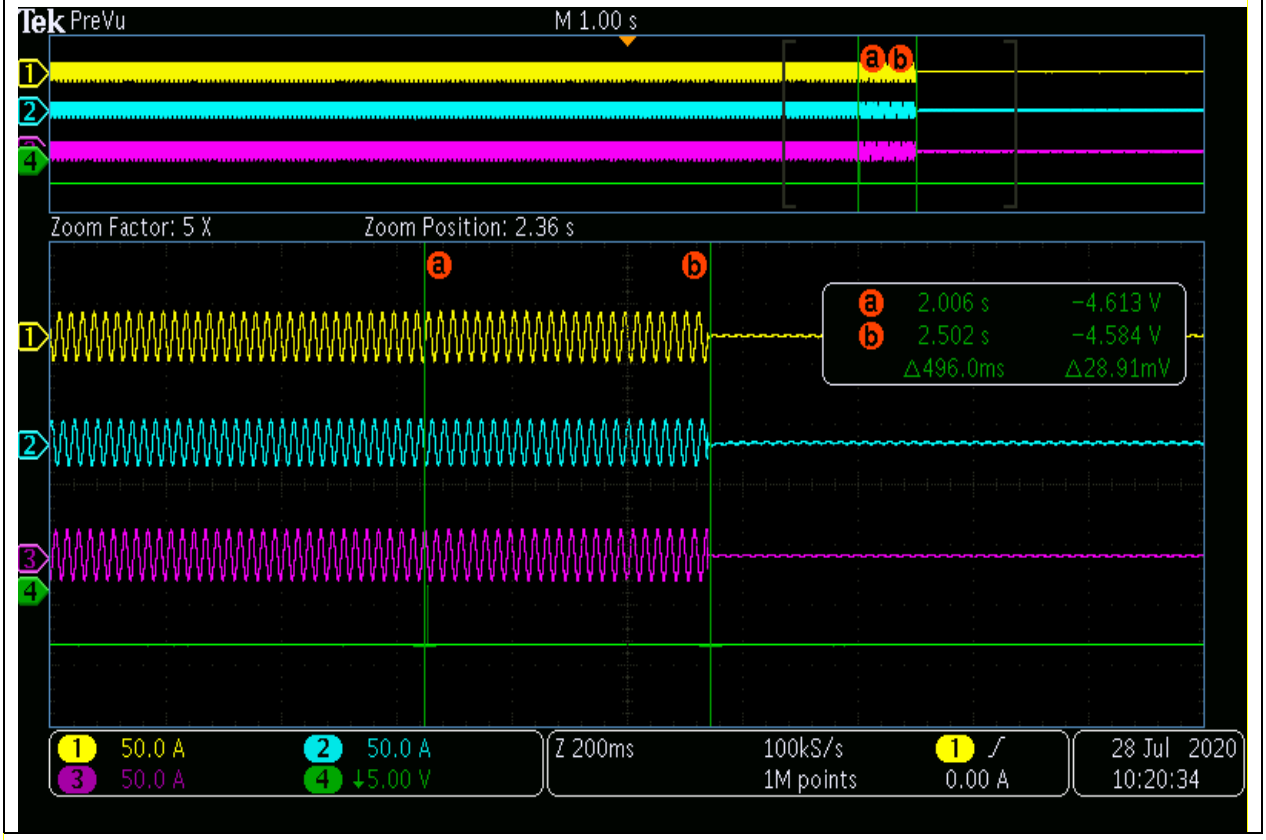
U/F stage 1-5


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

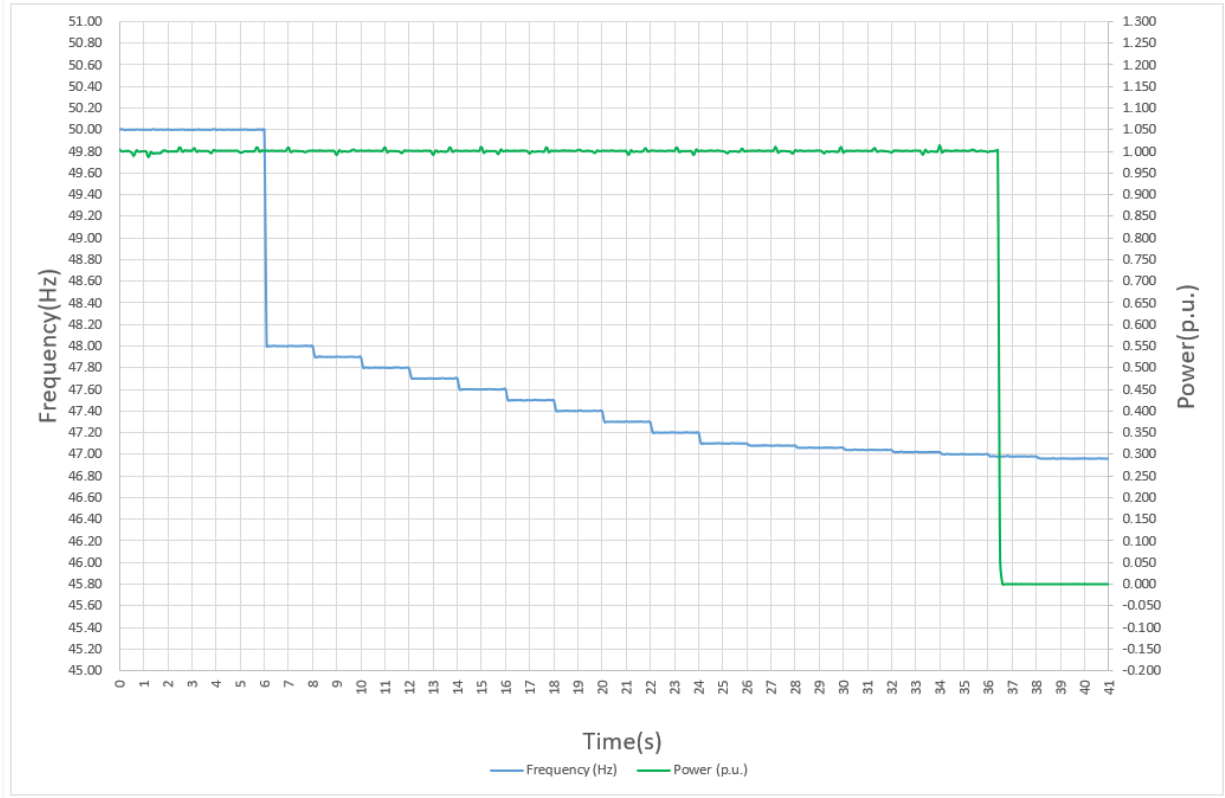

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: 25.0 s
a 10.00 s -4.718 V
b 30.16 s -4.734 V
Δ20.16 s Δ15.62mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 4.00 s
10.0kS/s
1M points
1 ⁄ 0.00 A
28 Jul 2020
10:15:30

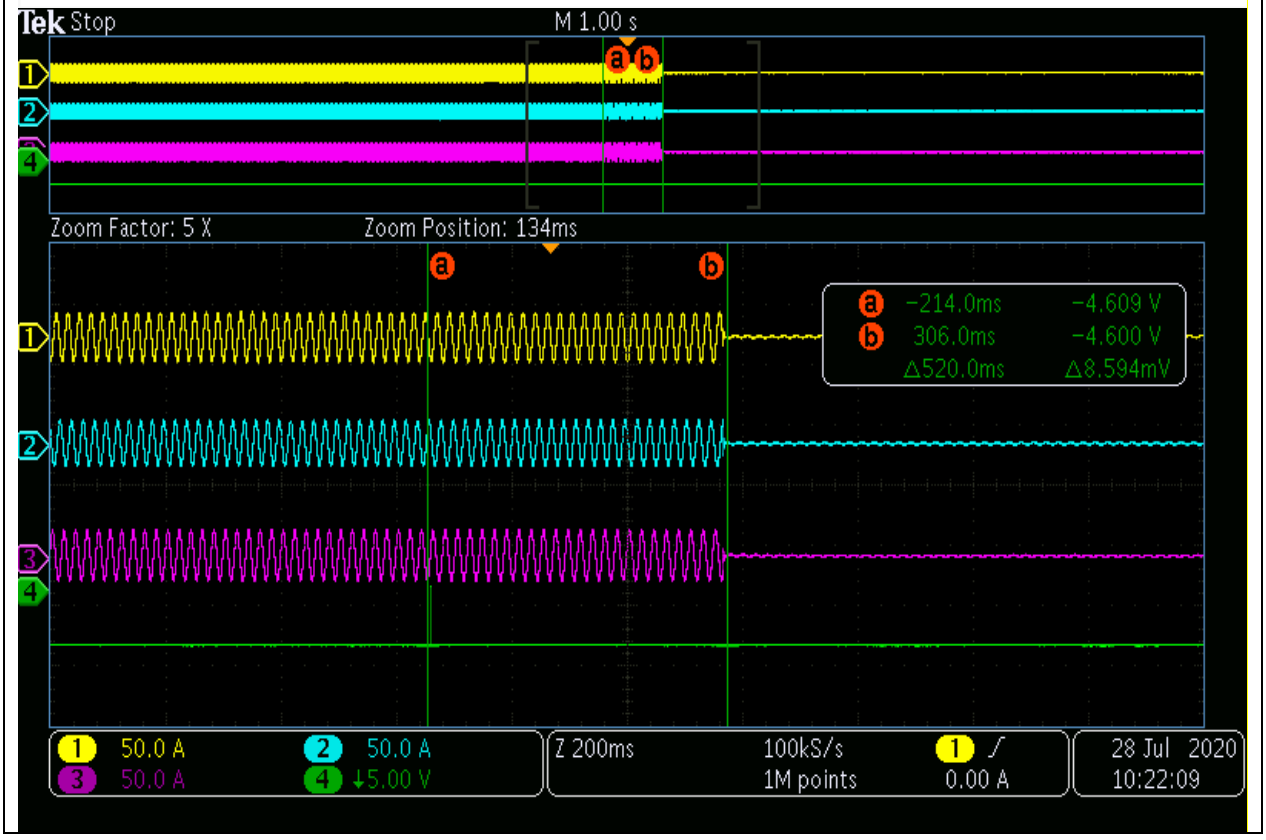
U/F stage 2-1


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

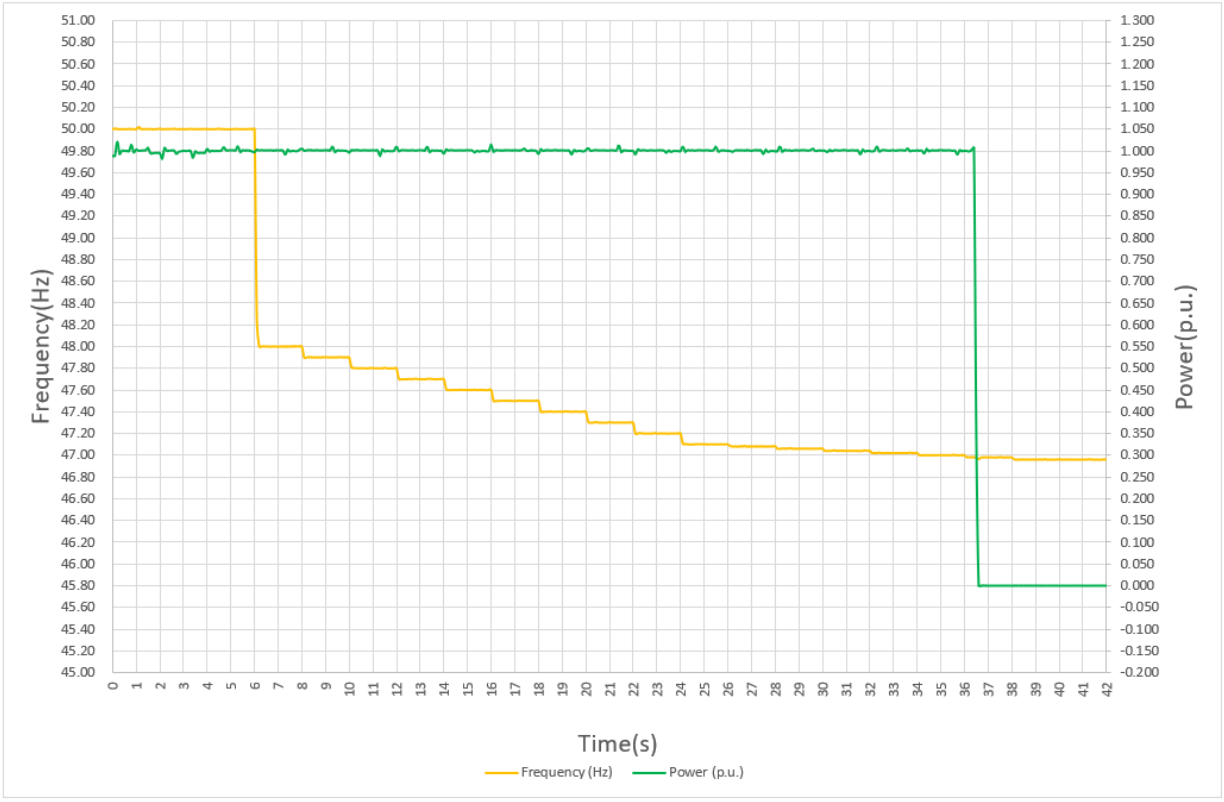

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 2.36 s
a 2.006 s -4.613 V
b 2.502 s -4.584 V
Δ496.0ms Δ28.91mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⨍
0.00 A
28 Jul 2020
10:20:34

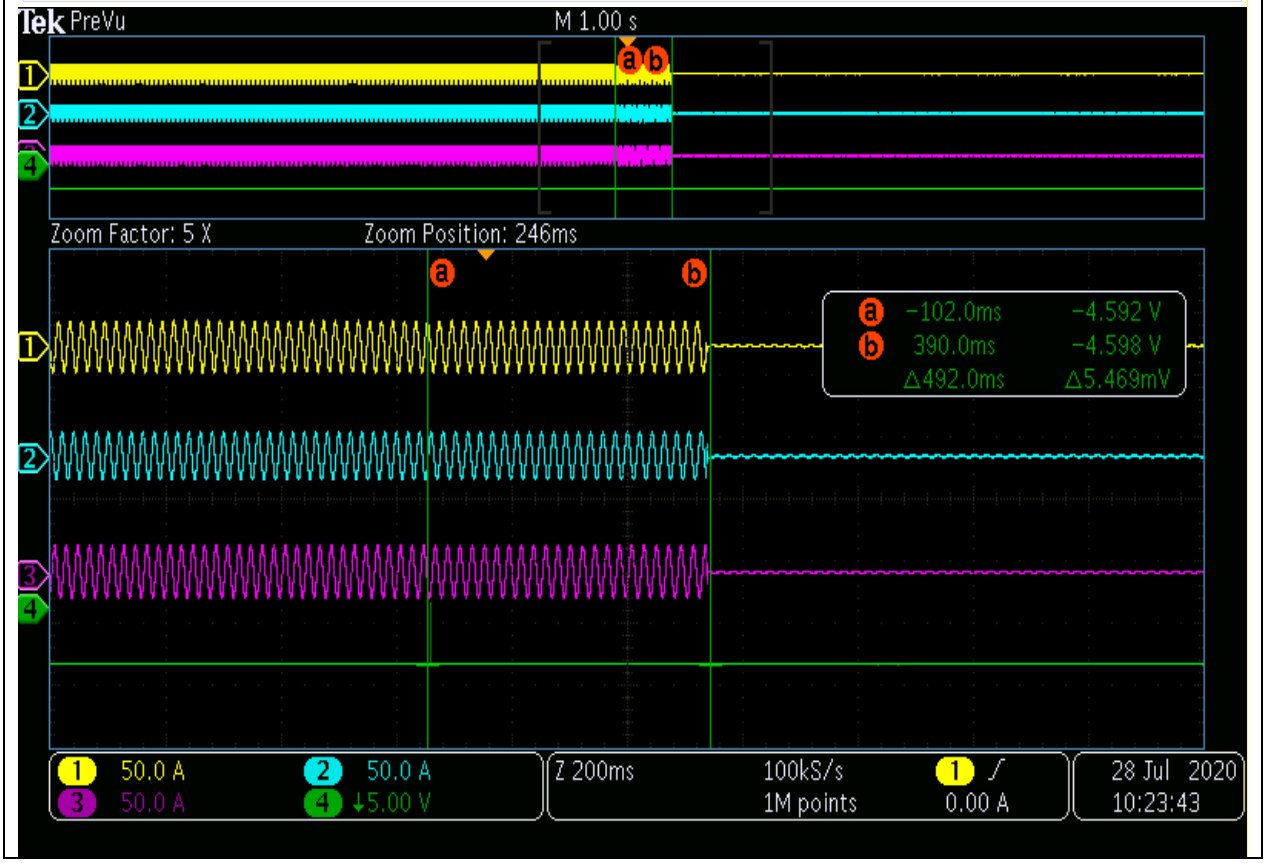
U/F stage 2-2


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

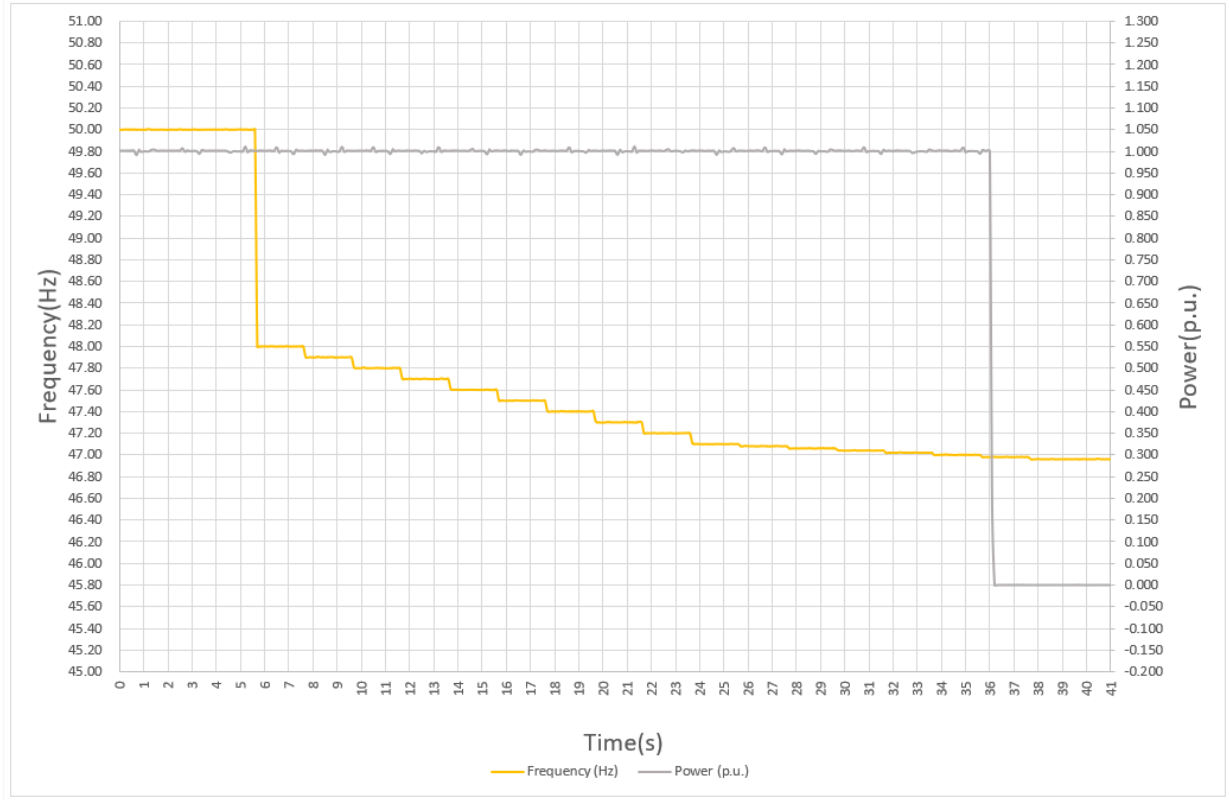

Tek Stop
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 134ms
a -214.0ms -4.609 V
b 306.0ms -4.600 V
Δ520.0ms Δ8.594mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄ 0.00 A
28 Jul 2020
10:22:09

U/F stage 2-3


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

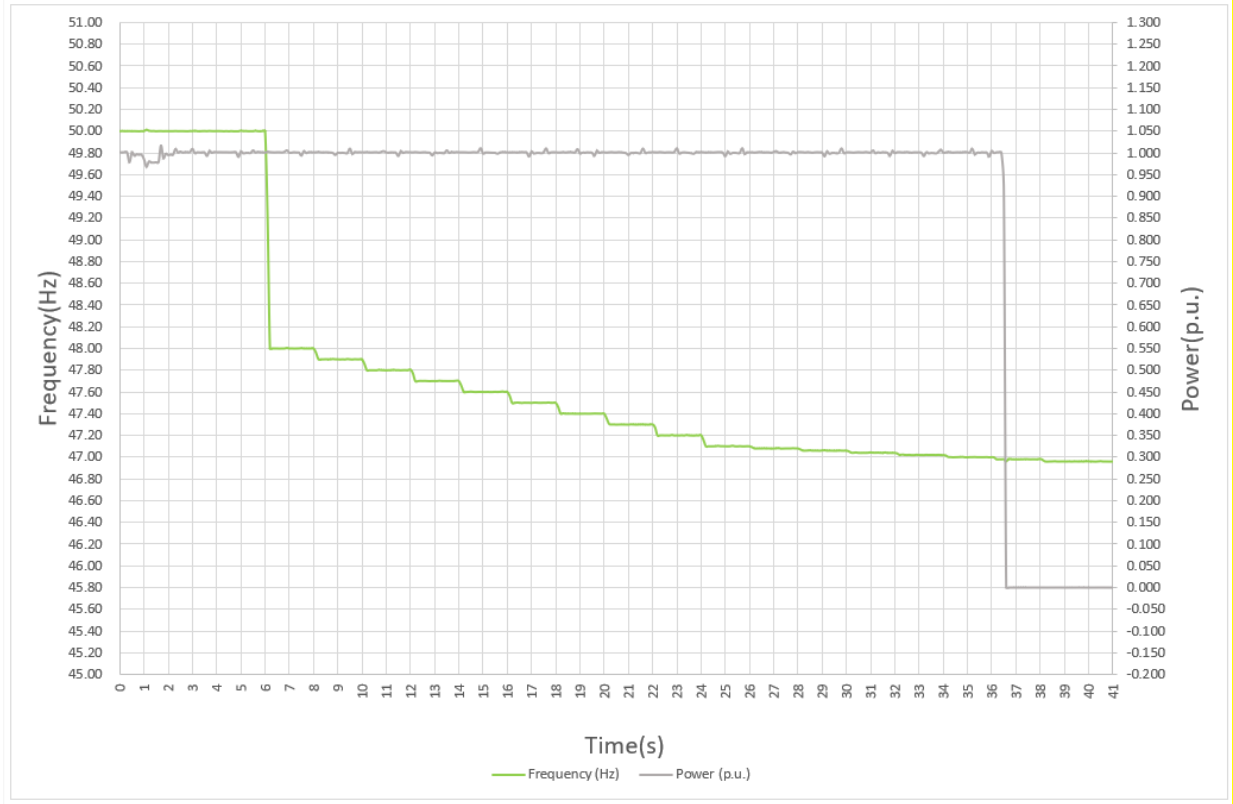

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 246ms
a -102.0ms -4.592 V
b 390.0ms -4.598 V
Δ492.0ms Δ5.469mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄ 0.00 A
28 Jul 2020
10:23:43

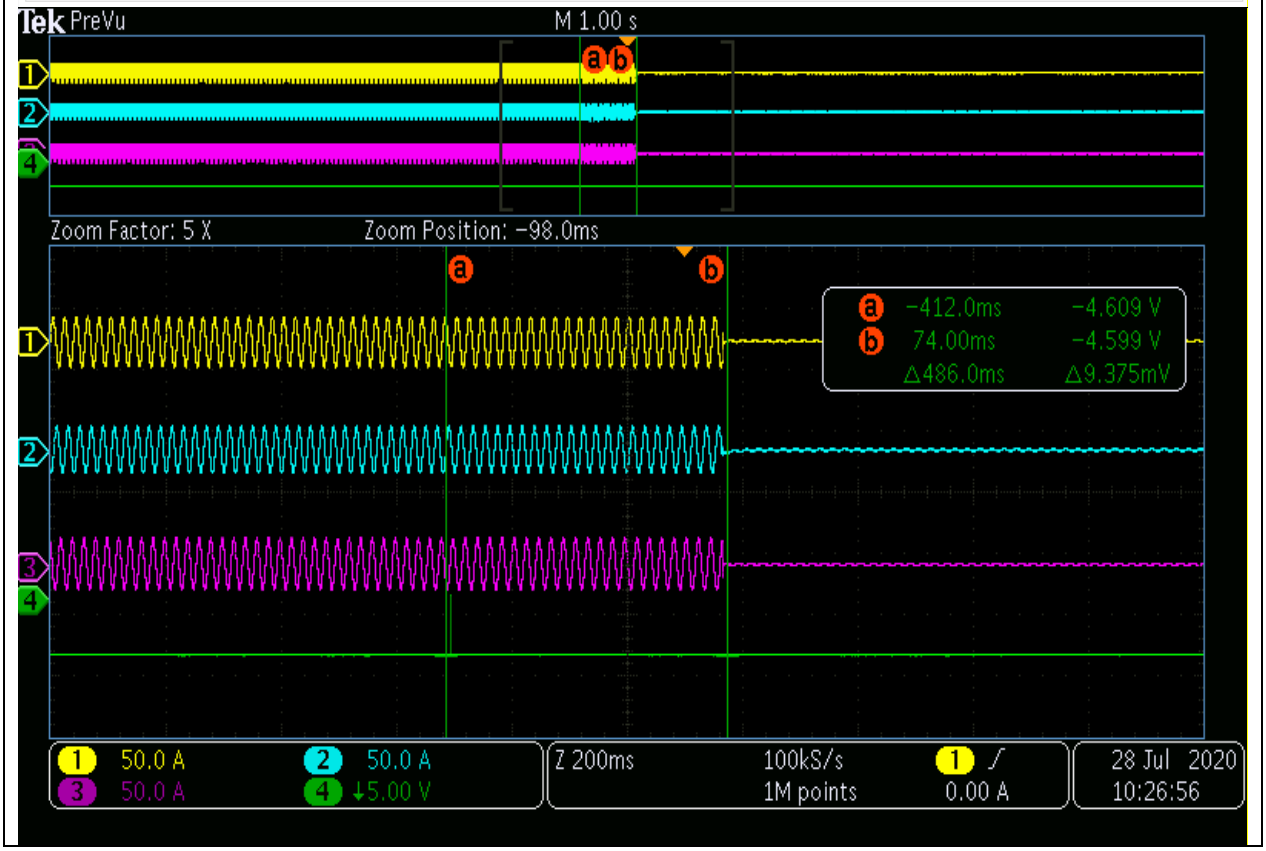
U/F stage 2-4


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

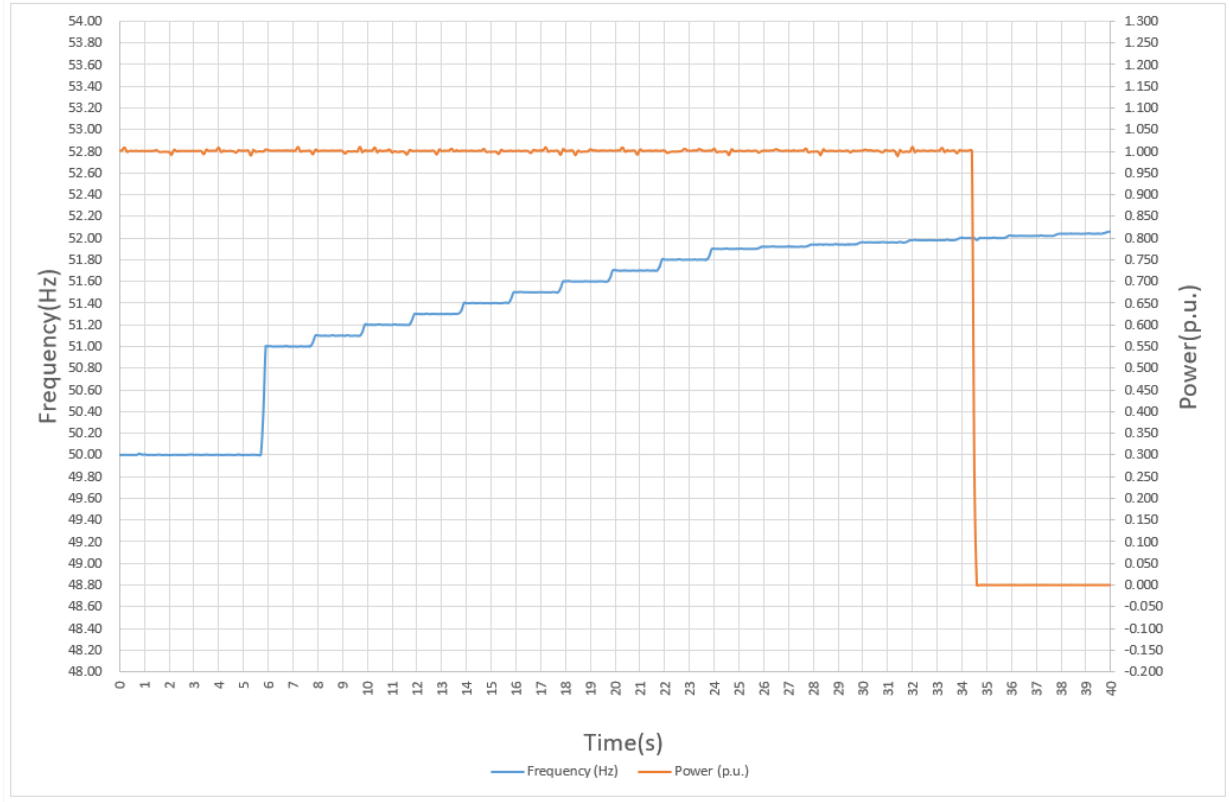

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 0.00 s
a -334.0ms -4.602 V
b 182.0ms -4.598 V
Δ516.0ms Δ3.125mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄
0.00 A
28 Jul 2020
10:25:17

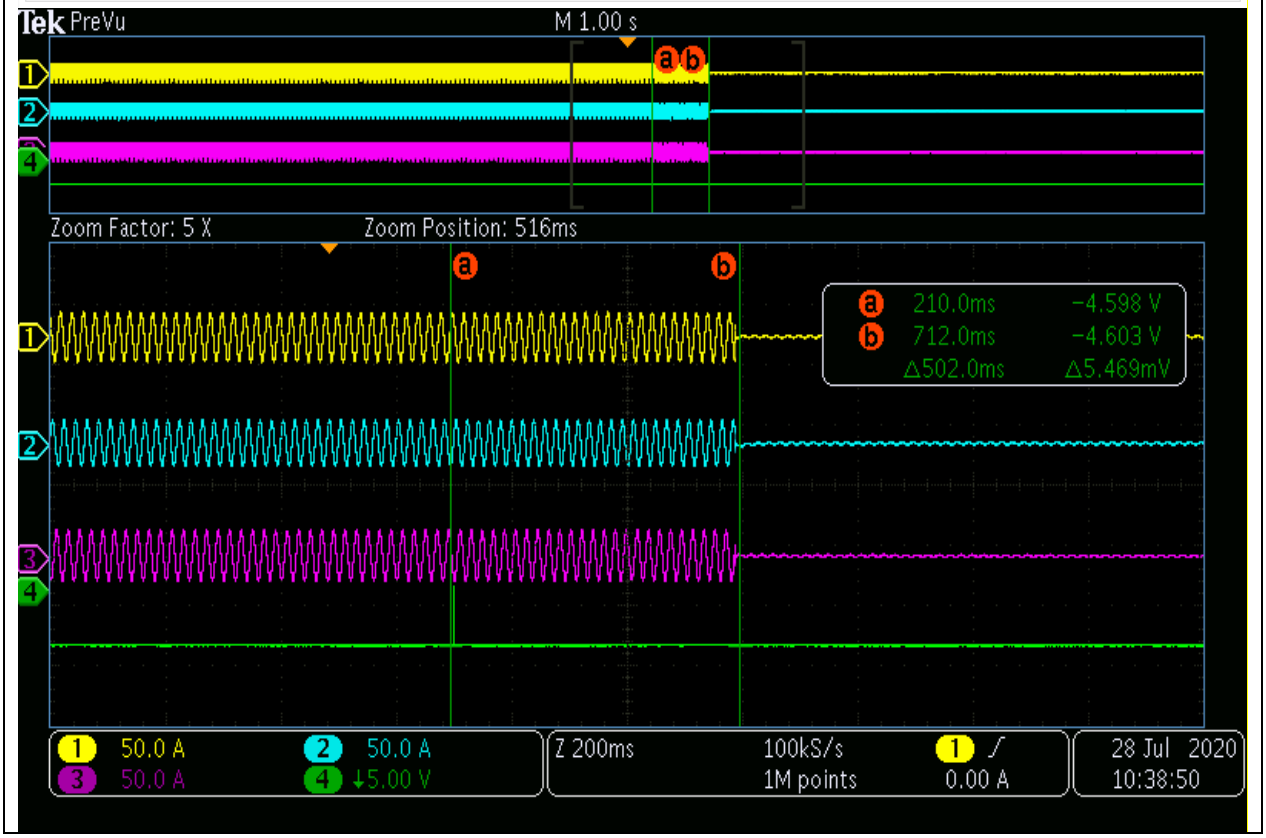
U/F stage 2-5


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

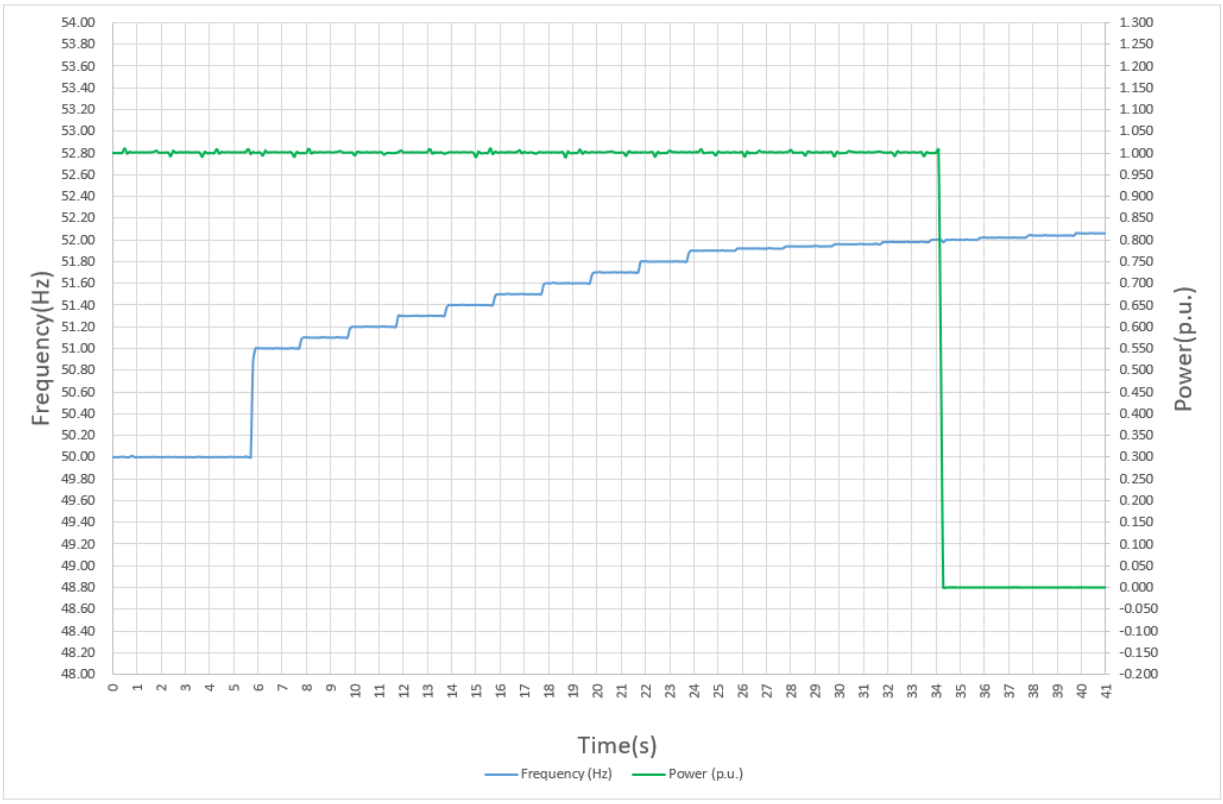

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: -98.0ms
a -412.0ms -4.609 V
b 74.00ms -4.599 V
Δ486.0ms Δ9.375mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄
0.00 A
28 Jul 2020
10:26:56

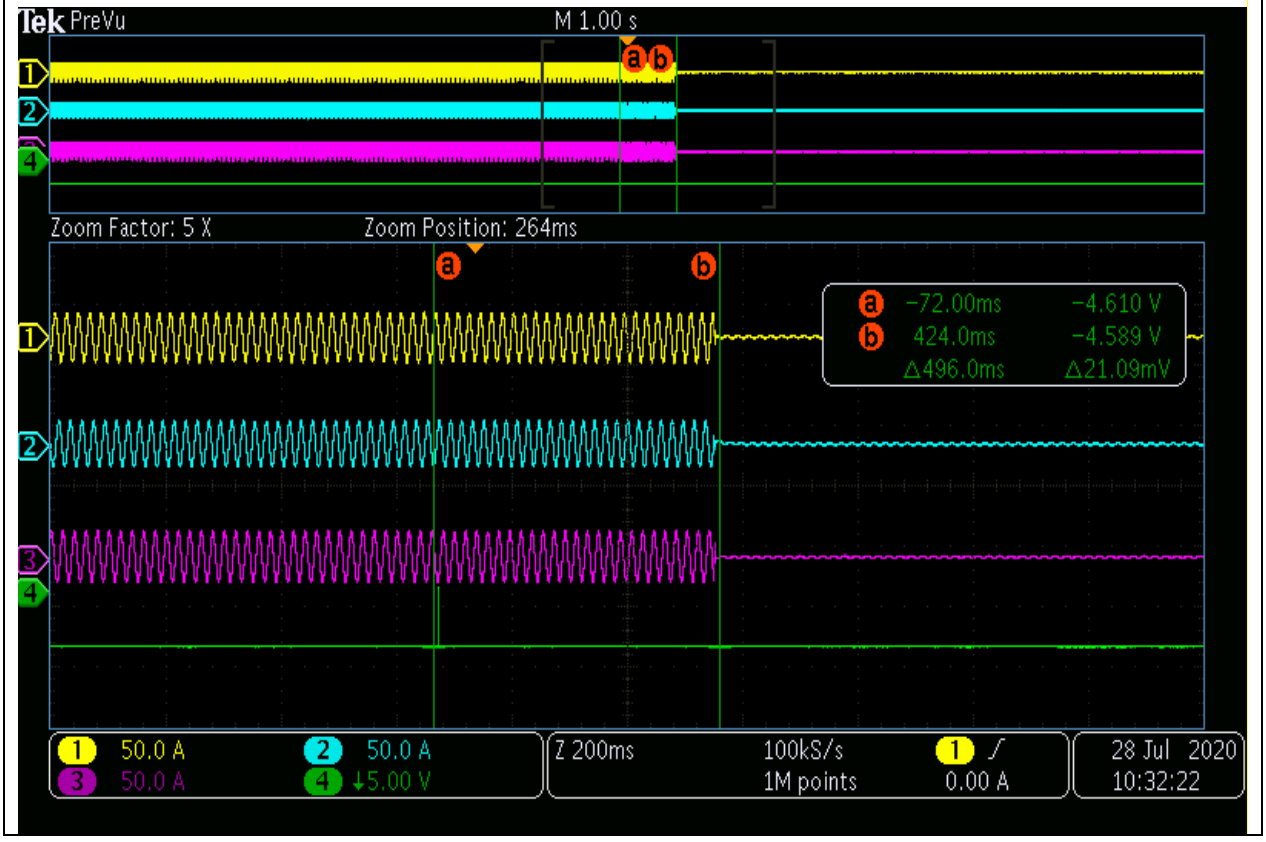
O/F stage 1-1


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

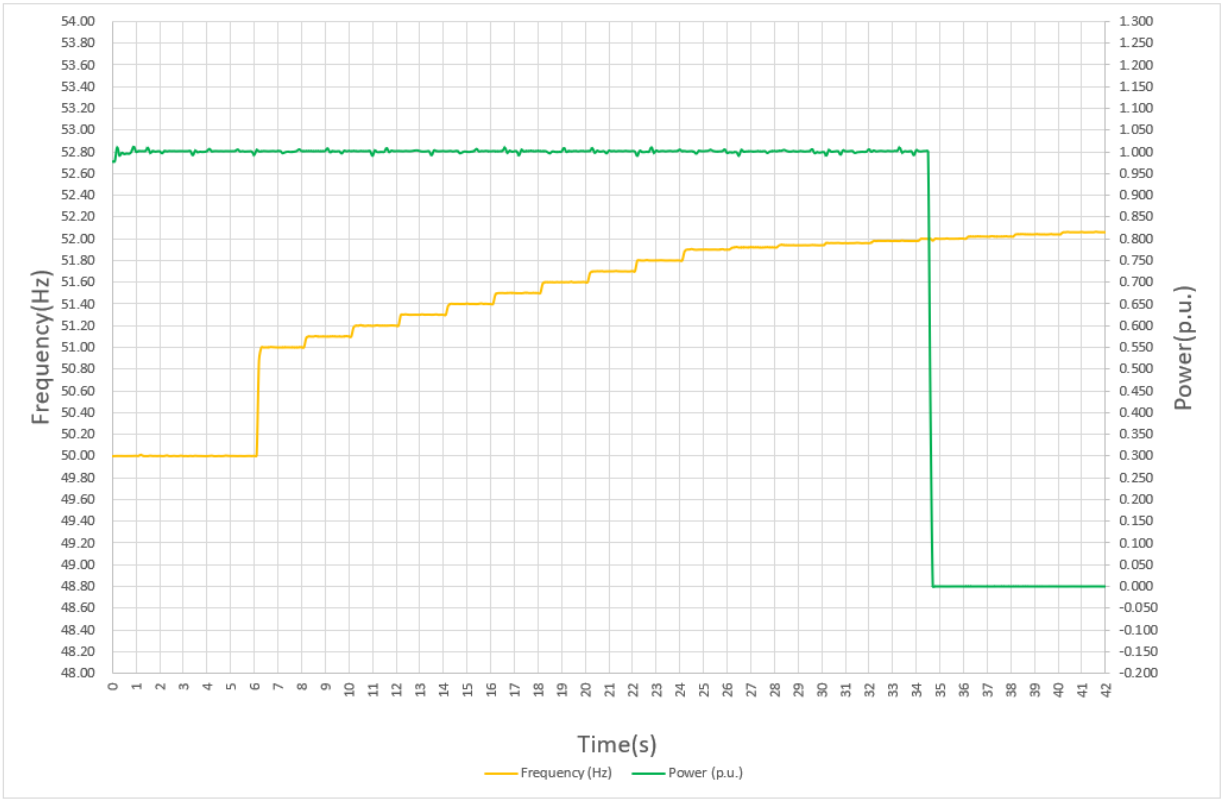

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 516ms
a 210.0ms -4.598 V
b 712.0ms -4.603 V
Δ502.0ms Δ5.469mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄ 0.00 A
28 Jul 2020
10:38:50

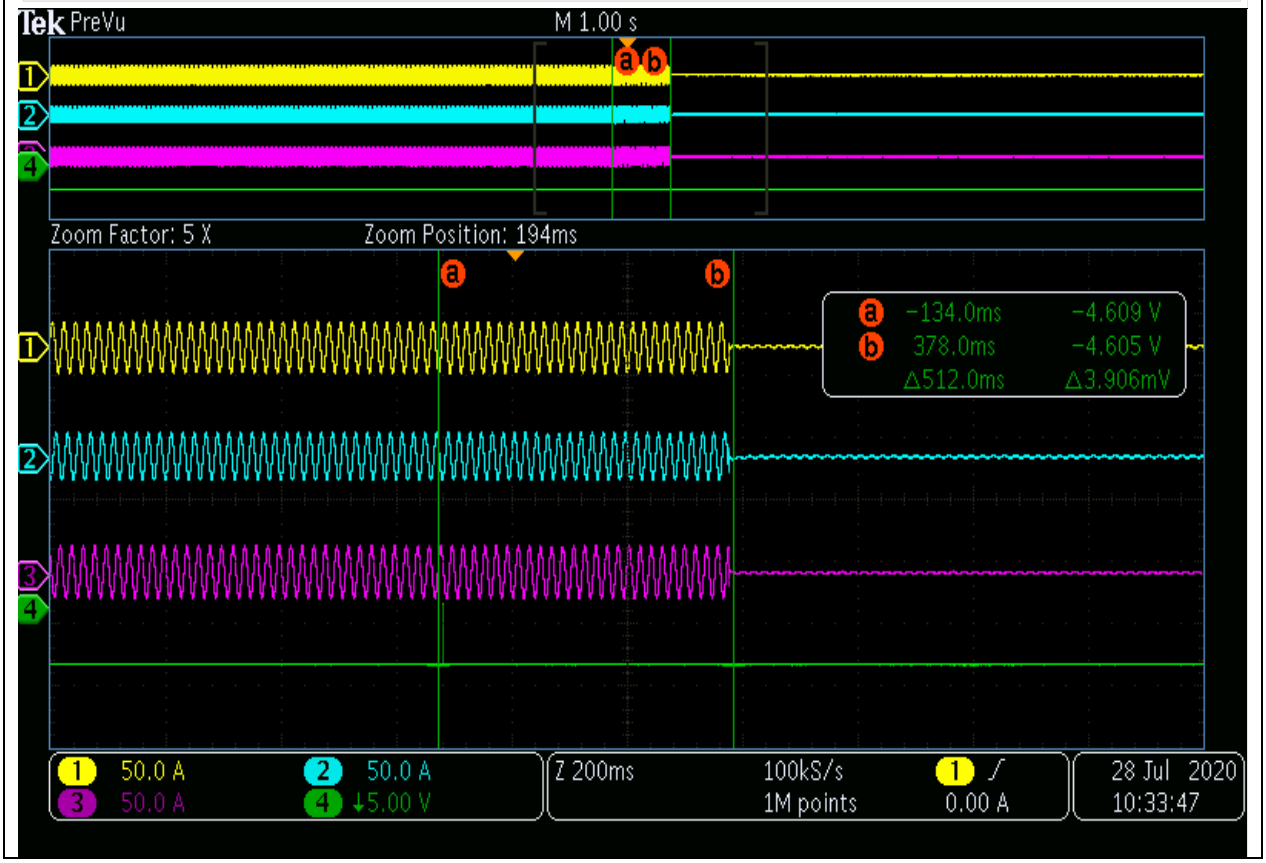
O/F stage 1-2


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

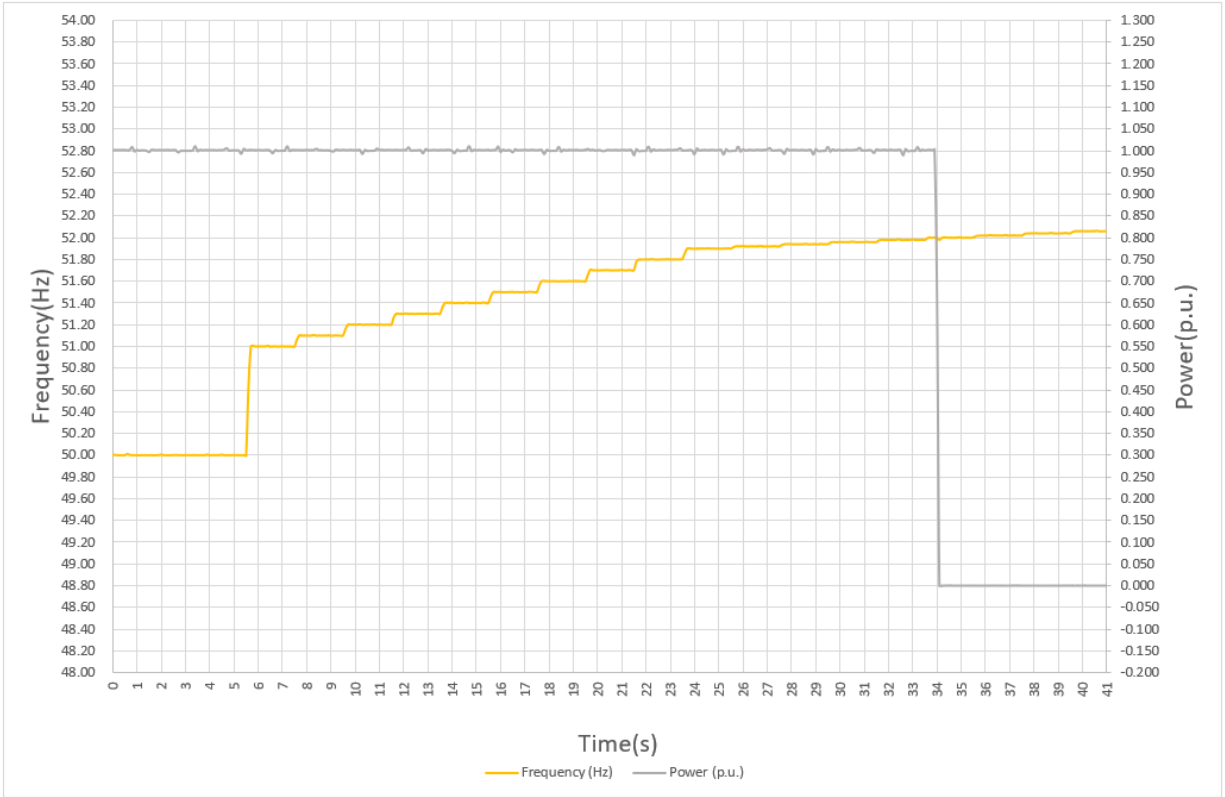

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 264ms
a -72.00ms -4.610 V
b 424.0ms -4.589 V
Δ496.0ms Δ21.09mV
50.0 A
50.0 A
50.0 A
↓5.00 V
Z 200ms
100kS/s
1M points
0.00 A
28 Jul 2020
10:32:22

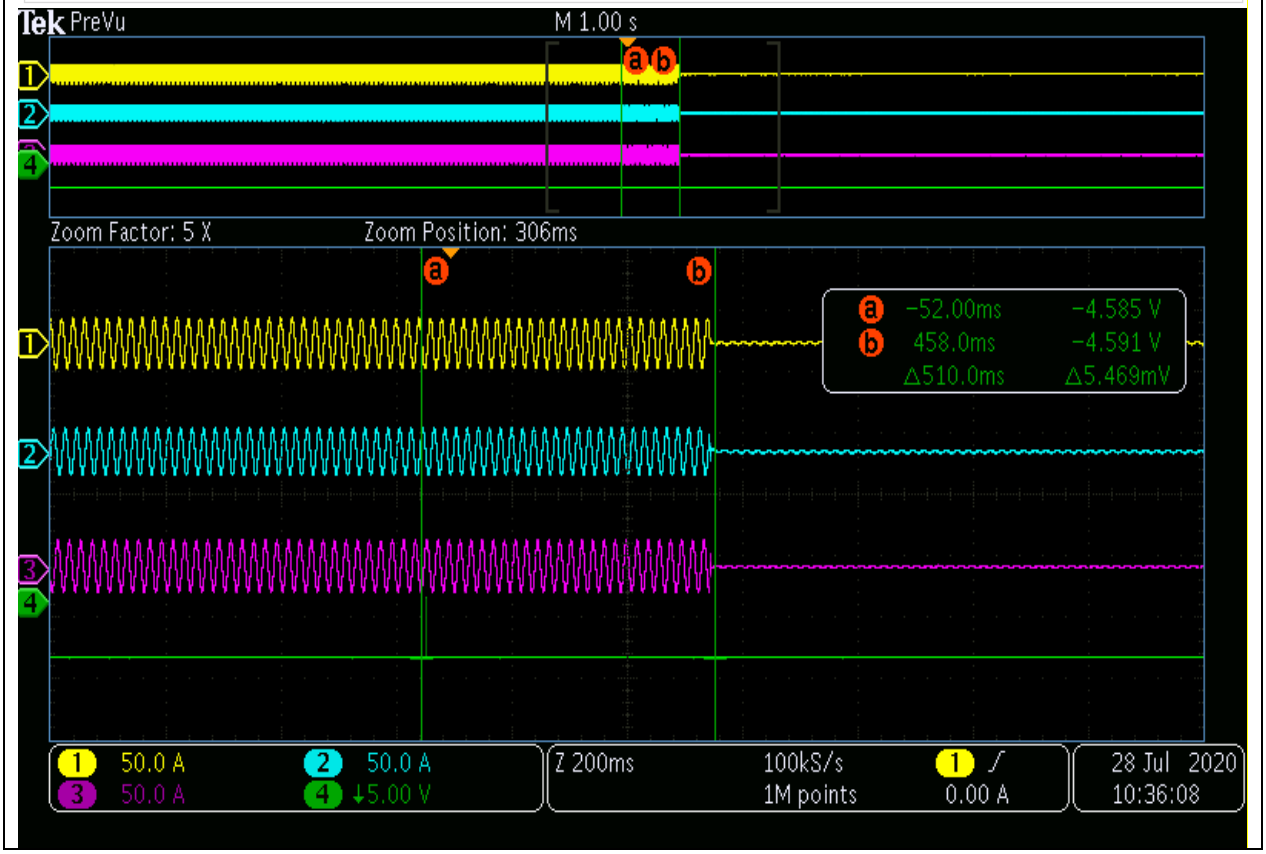
O/F stage 1-3


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

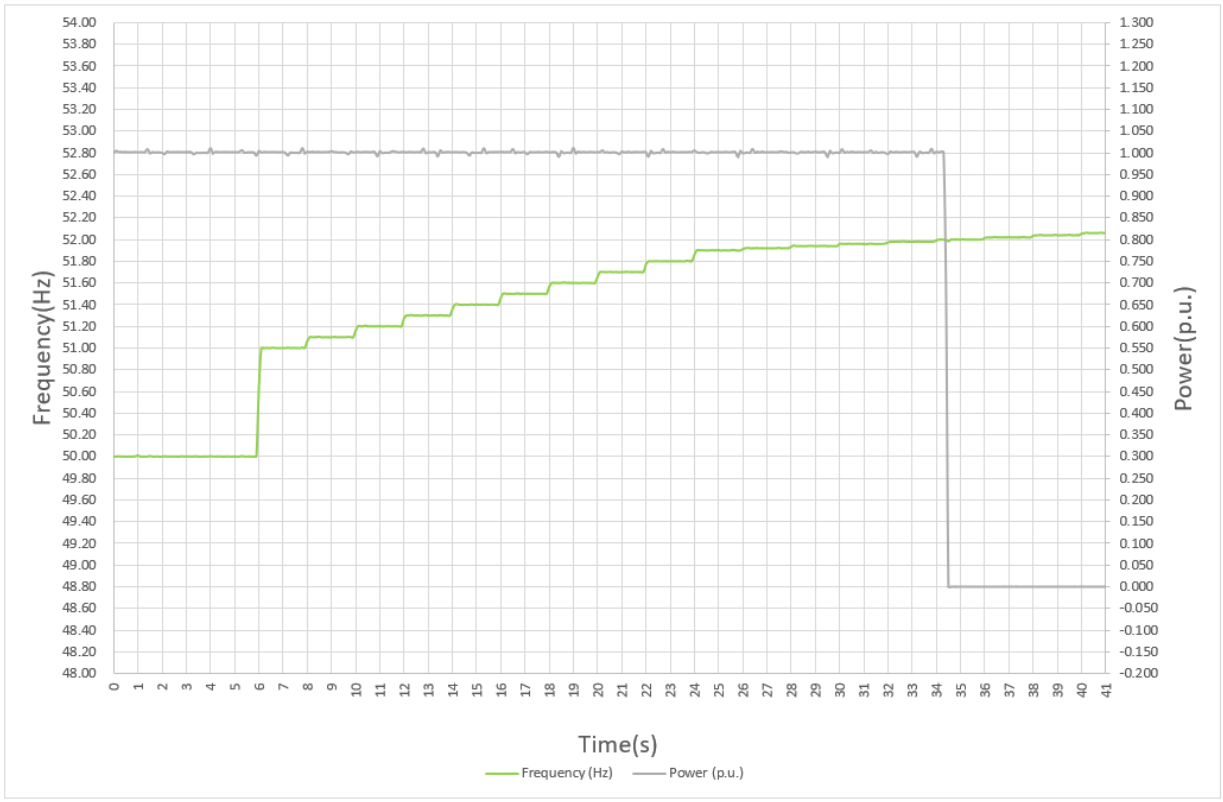

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 194ms
a -134.0ms -4.609 V
b 378.0ms -4.605 V
Δ512.0ms Δ3.906mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⎍
0.00 A
28 Jul 2020
10:33:47

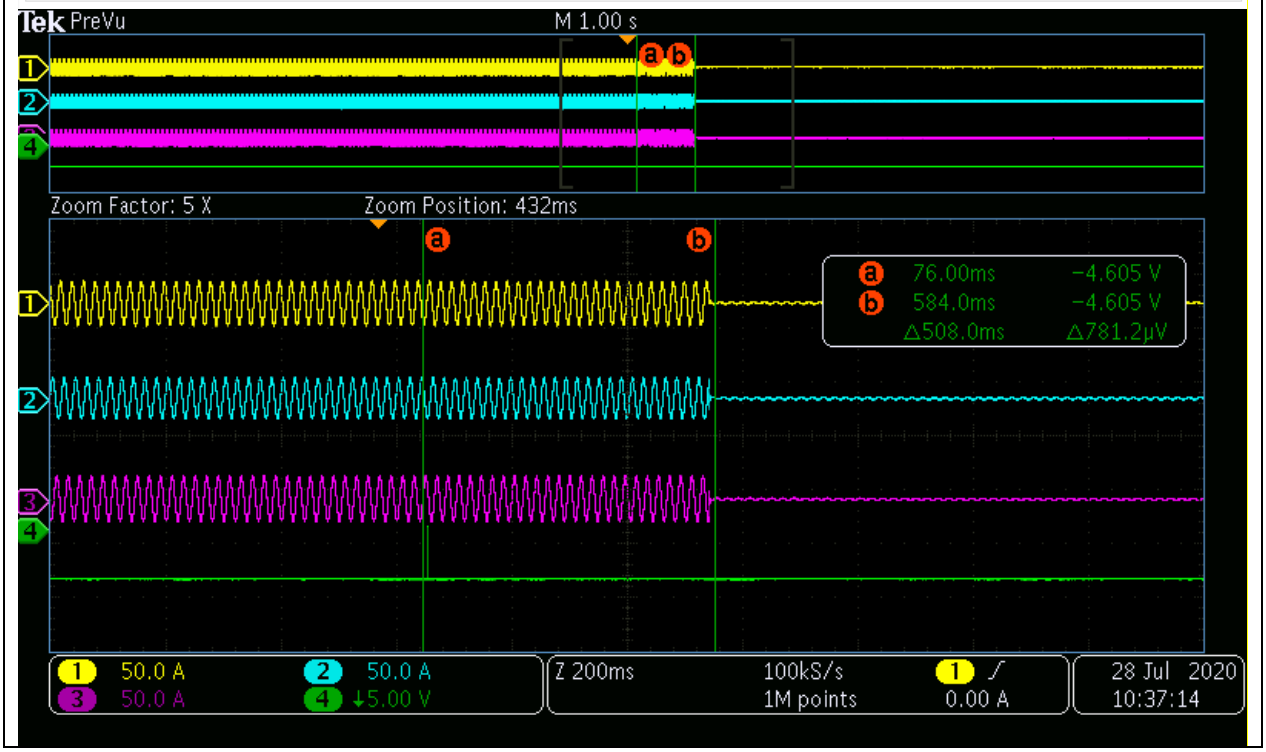
O/F stage 1-4


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

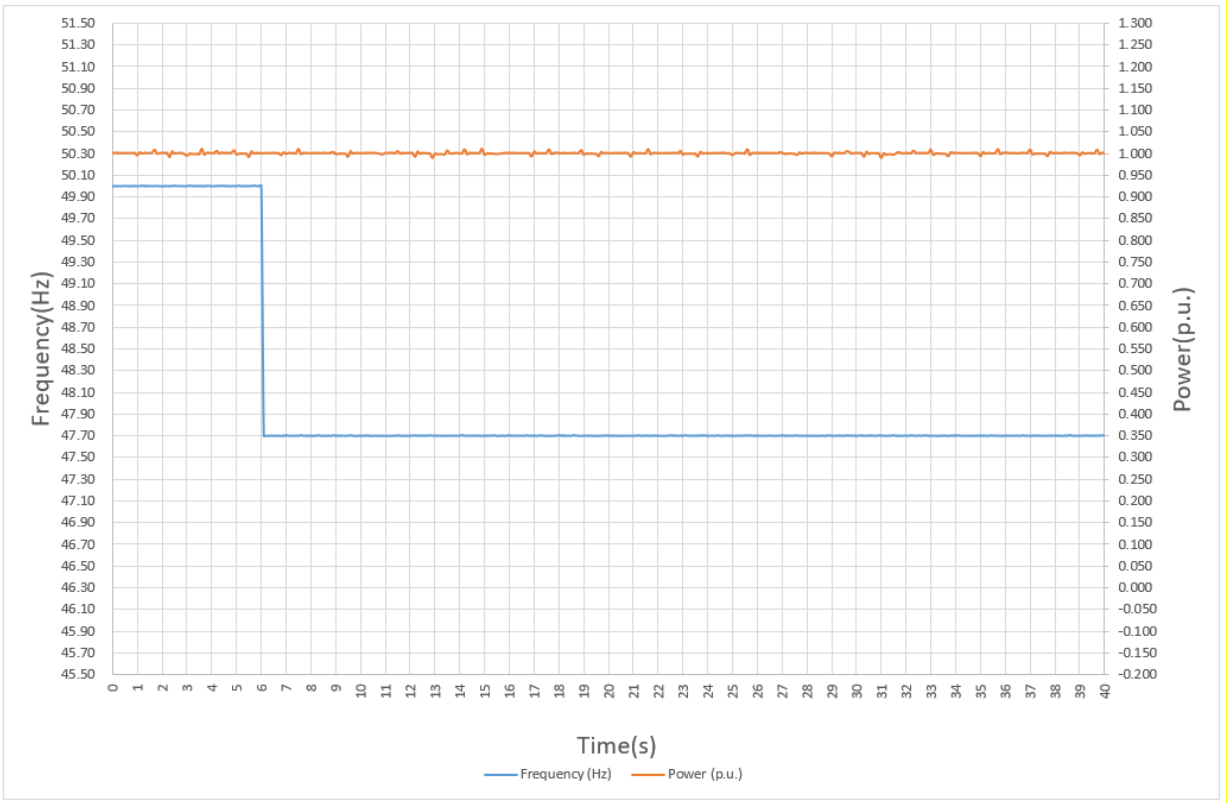

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 306ms
a -52.00ms -4.585 V
b 458.0ms -4.591 V
Δ510.0ms Δ5.469mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄ 0.00 A
28 Jul 2020
10:36:08

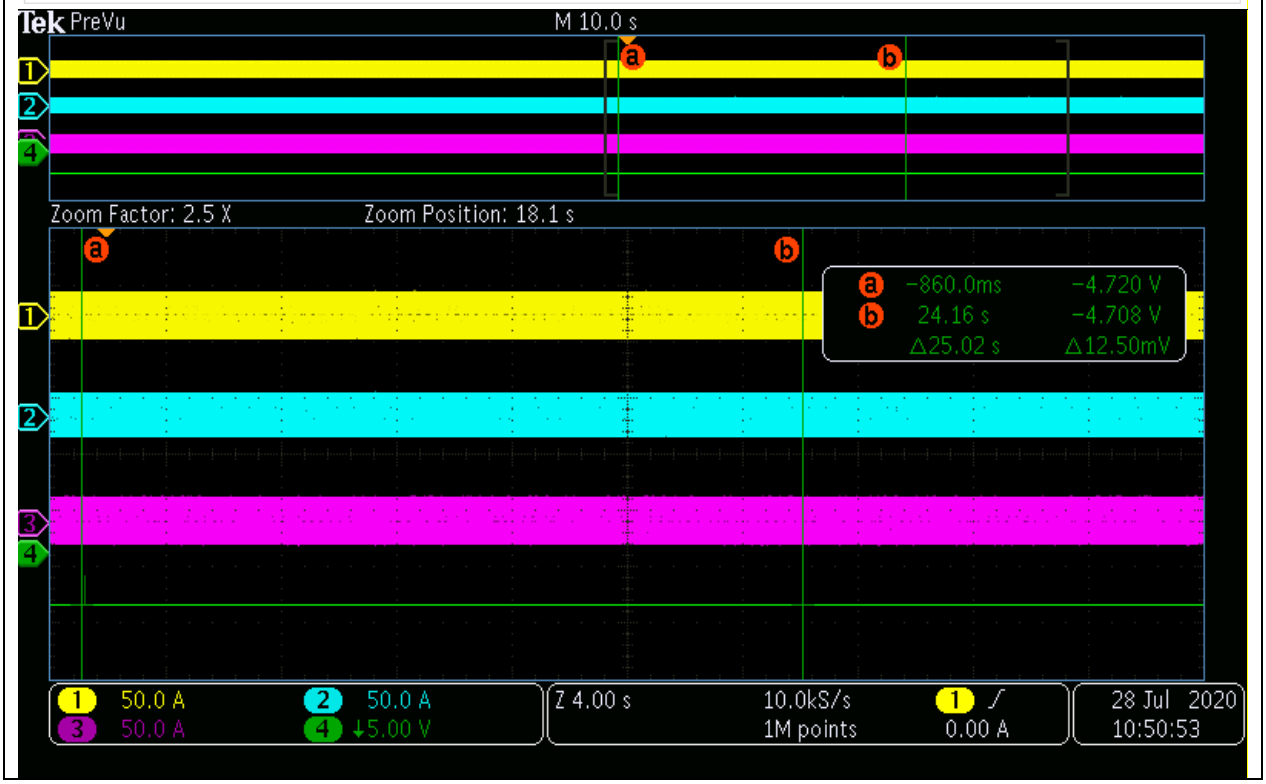
O/F stage 1-5


Frequency(Hz)
Power(p.u.)
Time(s)
Frequency (Hz)
Power (p.u.)

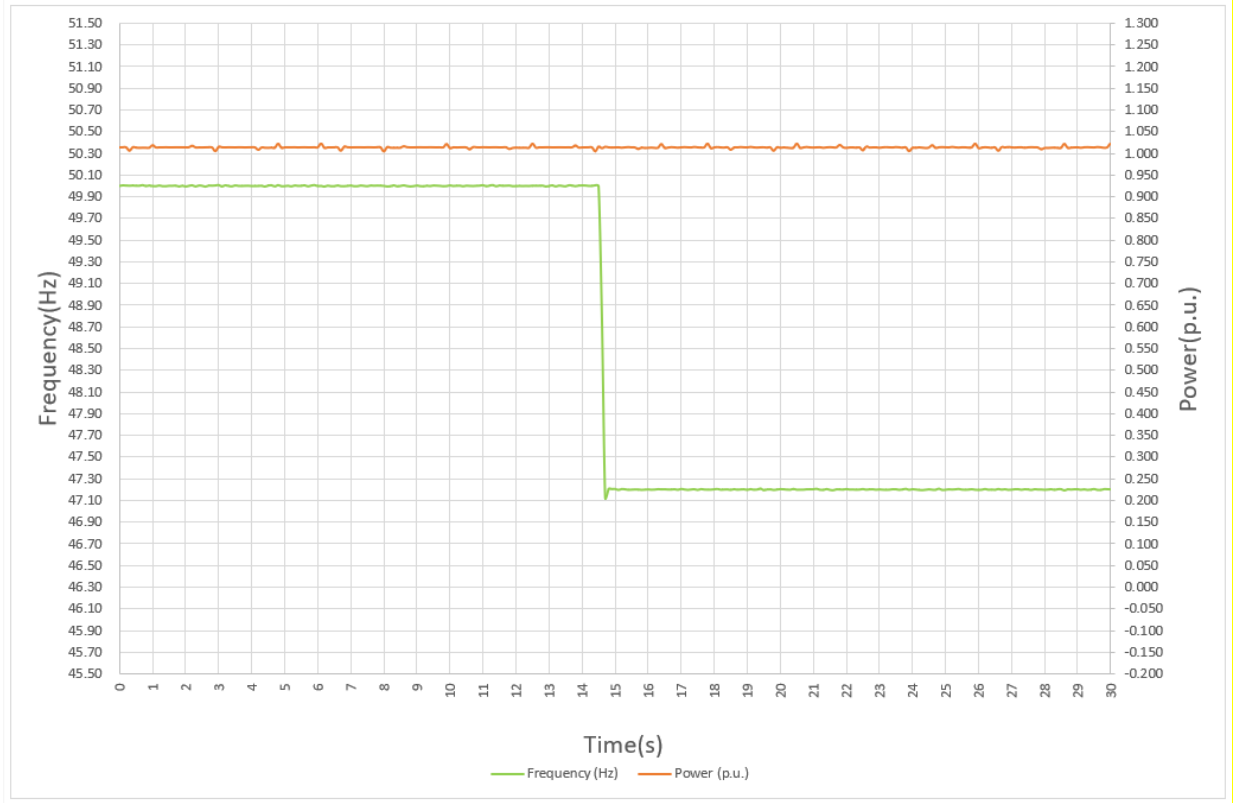

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 432ms
a 76.00ms -4.605 V
b 584.0ms -4.605 V
Δ508.0ms Δ781.2µV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⎍
0.00 A
28 Jul 2020
10:37:14

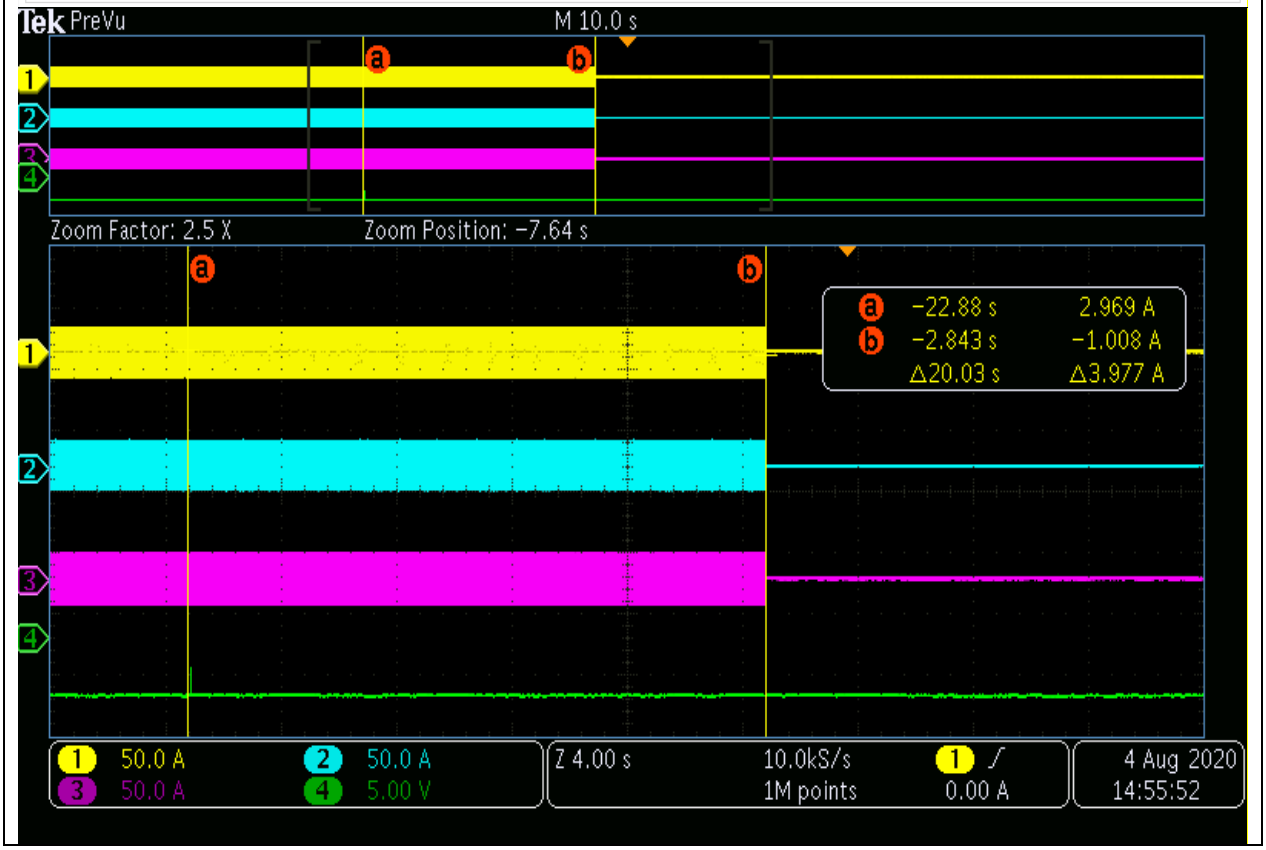
No trip tests - 47.7Hz



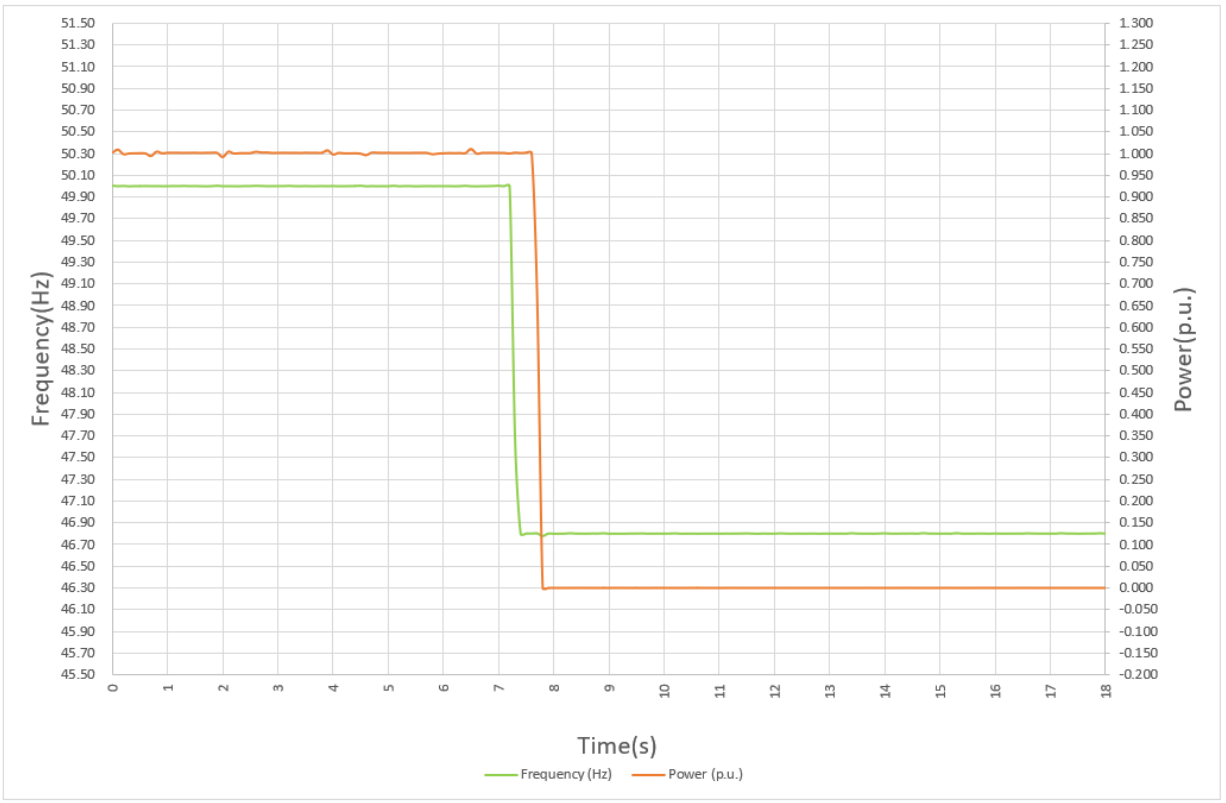


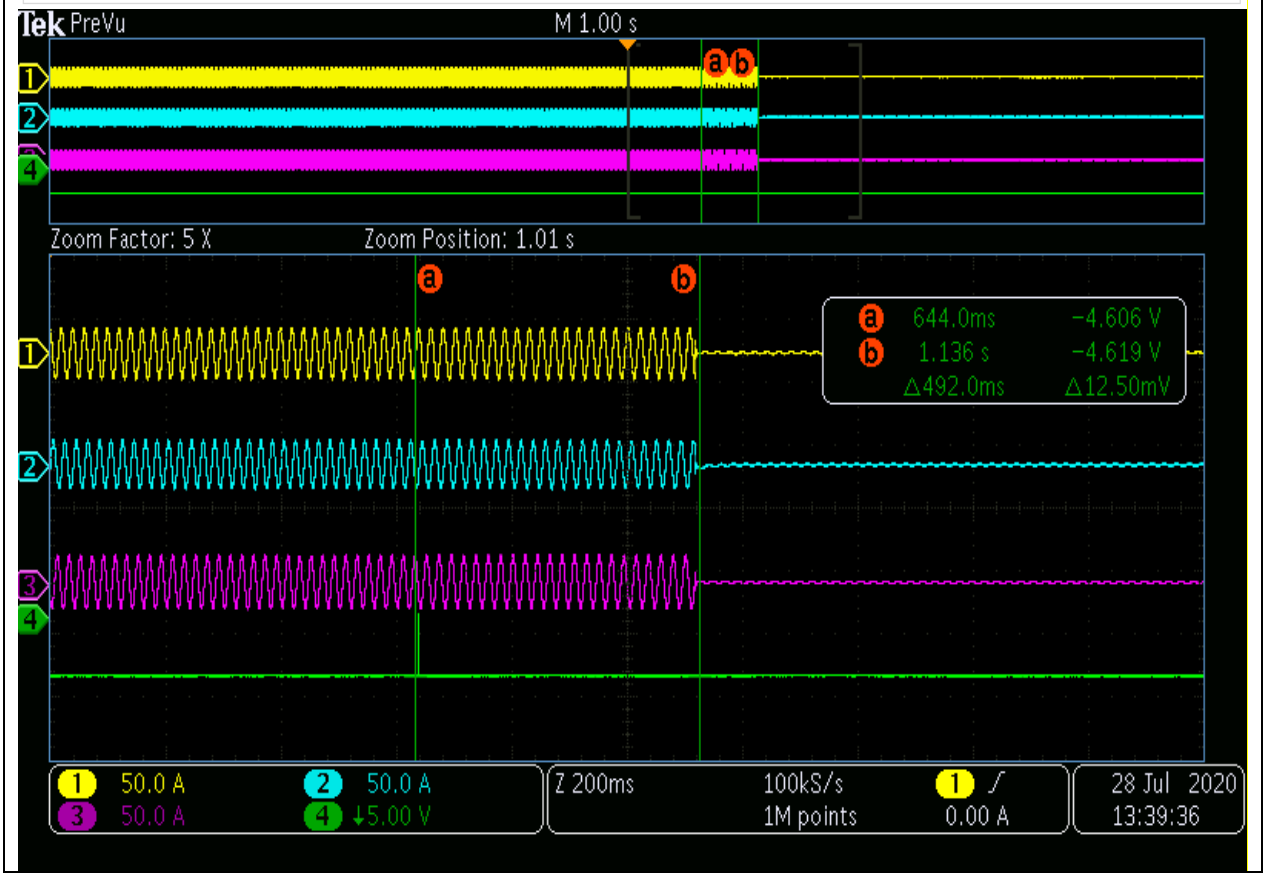
No trip tests – 47.2Hz



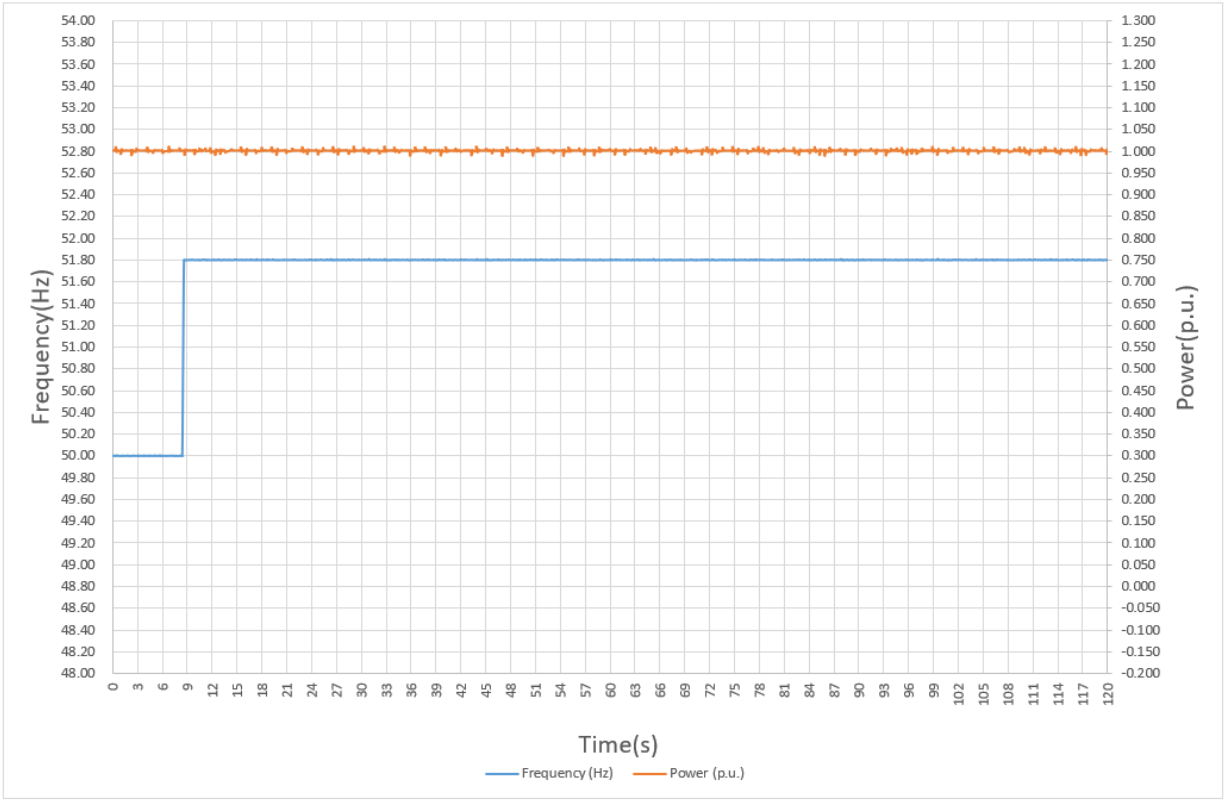


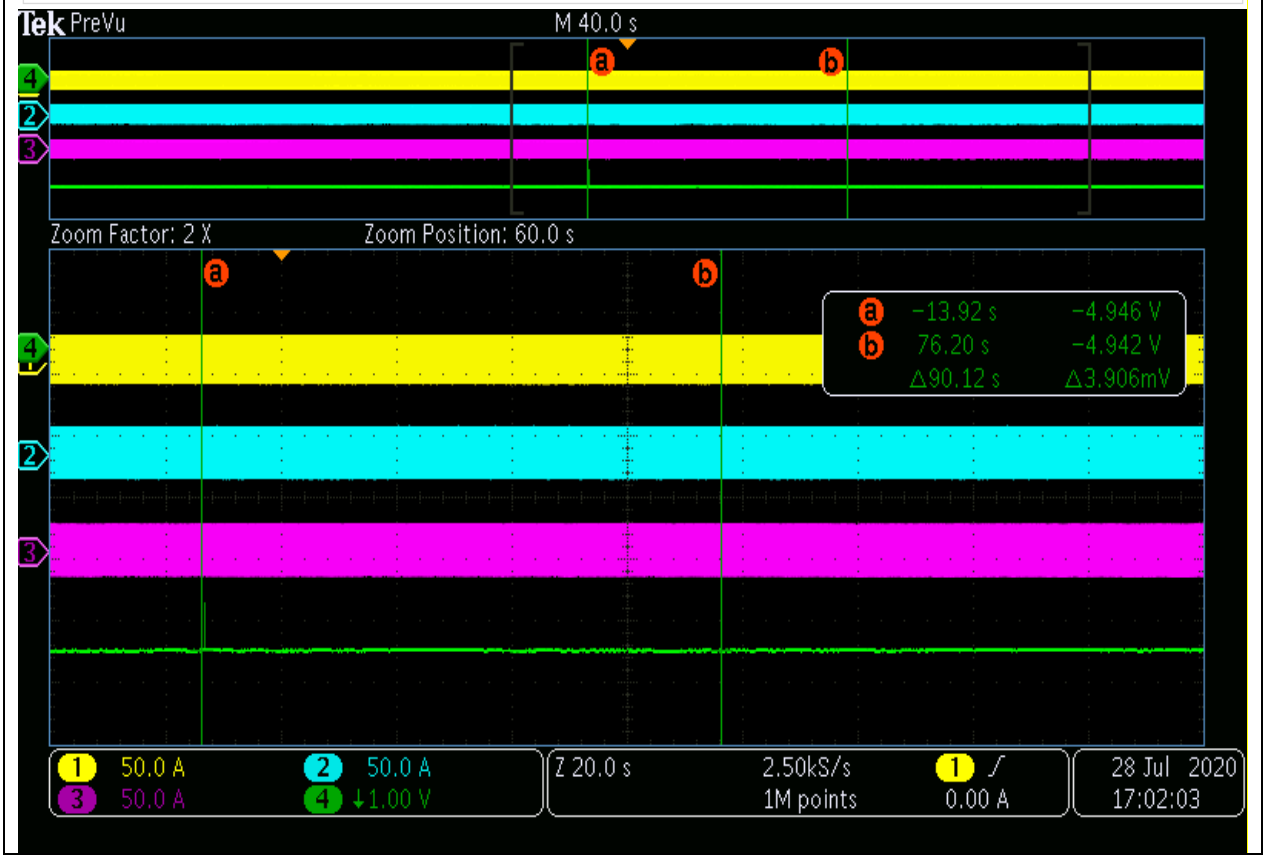
No trip tests – 46.8Hz



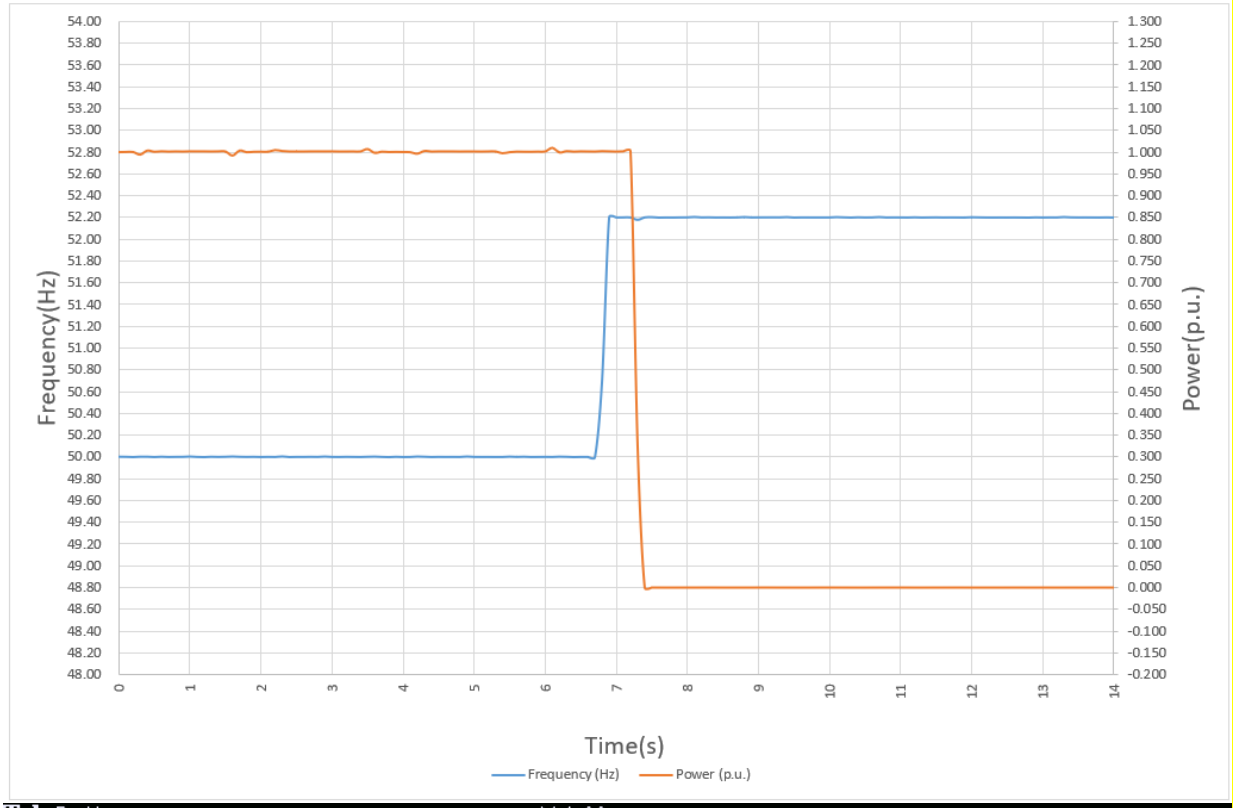


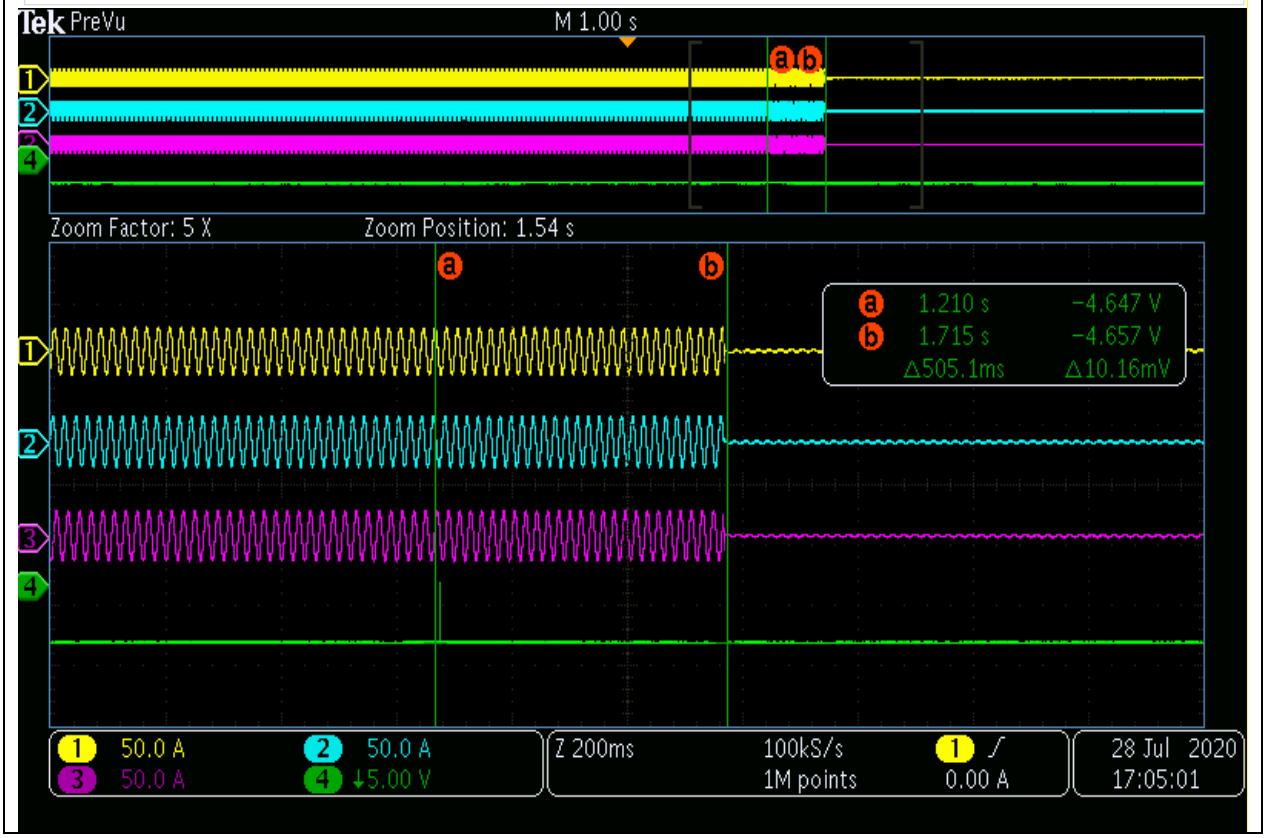
No trip tests - 51.8Hz





No trip tests – 52.2Hz





4.3.2 Voltage tests

To establish the certified trip voltage, the test voltage should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay.

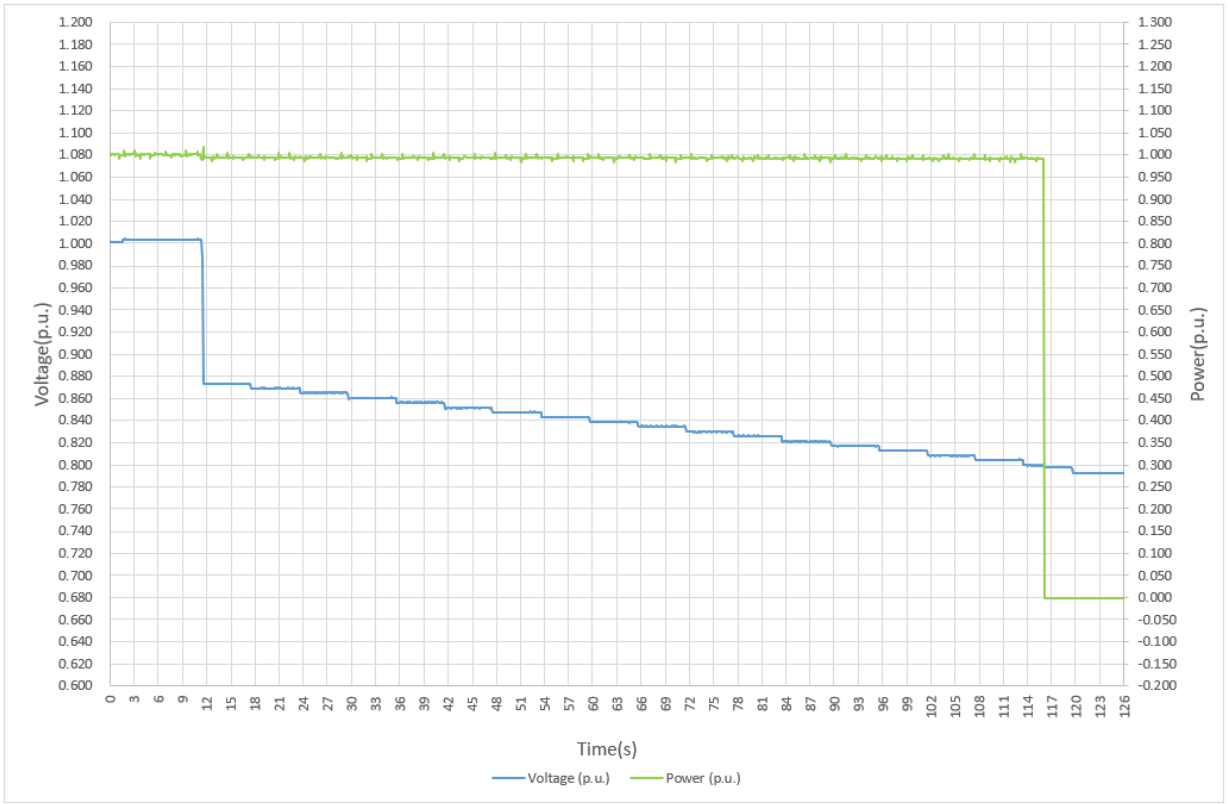
To establish the certified trip time, the test voltage should be applied starting from ± 1.8% below the certified trip voltage in a step of at least ± 0.5% of setting for a duration that is longer than the trip time delay. For each trip setting five tests shall be carried out.

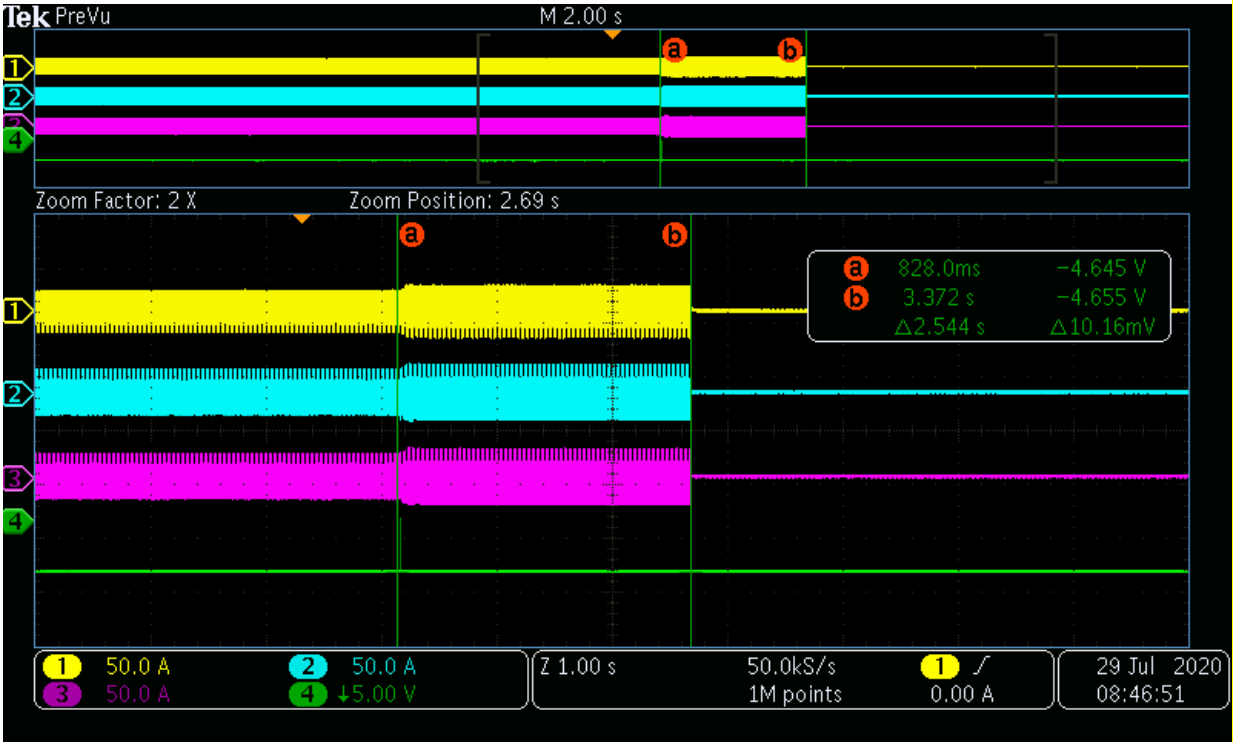
Following tables show the test results:

Function	Setting		Trip test		"No trip tests"	
	Voltage	Time delay	Voltage (V)	Time delay (s)	Voltage /time	Confirm no trip
U/V	184 V	2.5 s	183.3	2.544	188 V / 3.50 s	Pass
			183.3	2.517		
			183.3	2.524		
			183.3	2.527		
			183.3	2.532		
					180 V / 2.48 s	Pass
O/V stage 1	262.2 V	1.0 s	262.4	1.034	258.2 V / 2.0 s	Pass
			262.5	1.017		
			262.5	1.016		
			262.5	1.021		
			262.5	1. 015		
O/V stage 2	273.7 V	0.5 s	273.5	0.505	269.7 V / 0.98 s	Pass
			273.5	0.501		
			273.5	0.493		
			273.5	0.489		
			273.5	0.503		
					277.7 V / 0.48 s	Pass
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.						

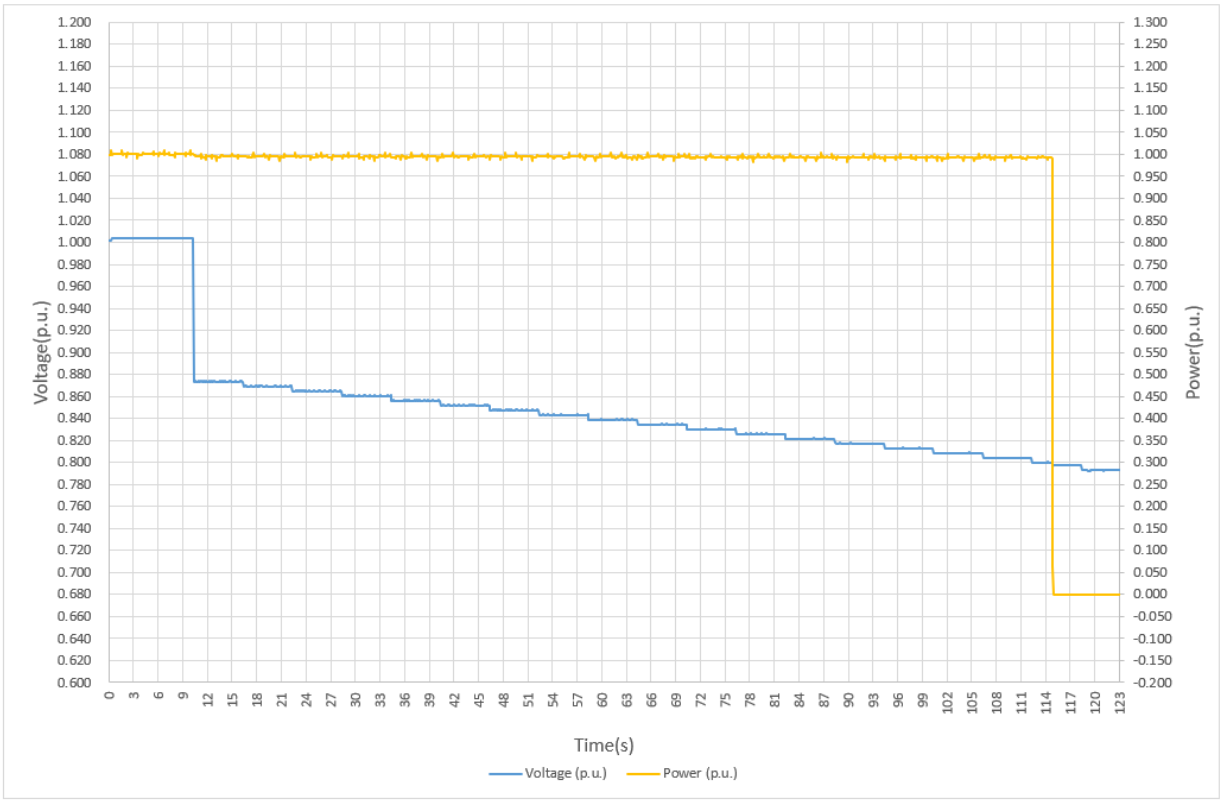
Test results are graphically shown in following pages.

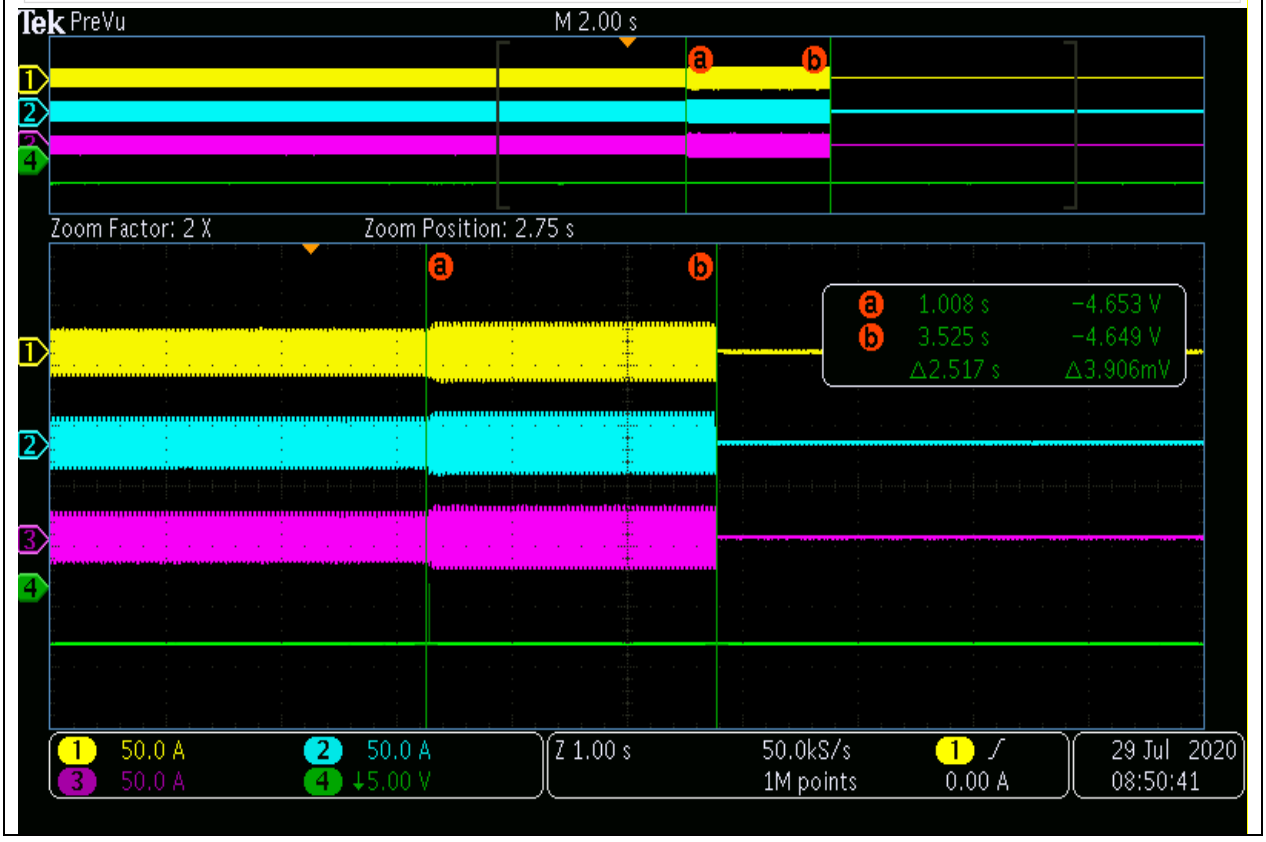
U/V -1



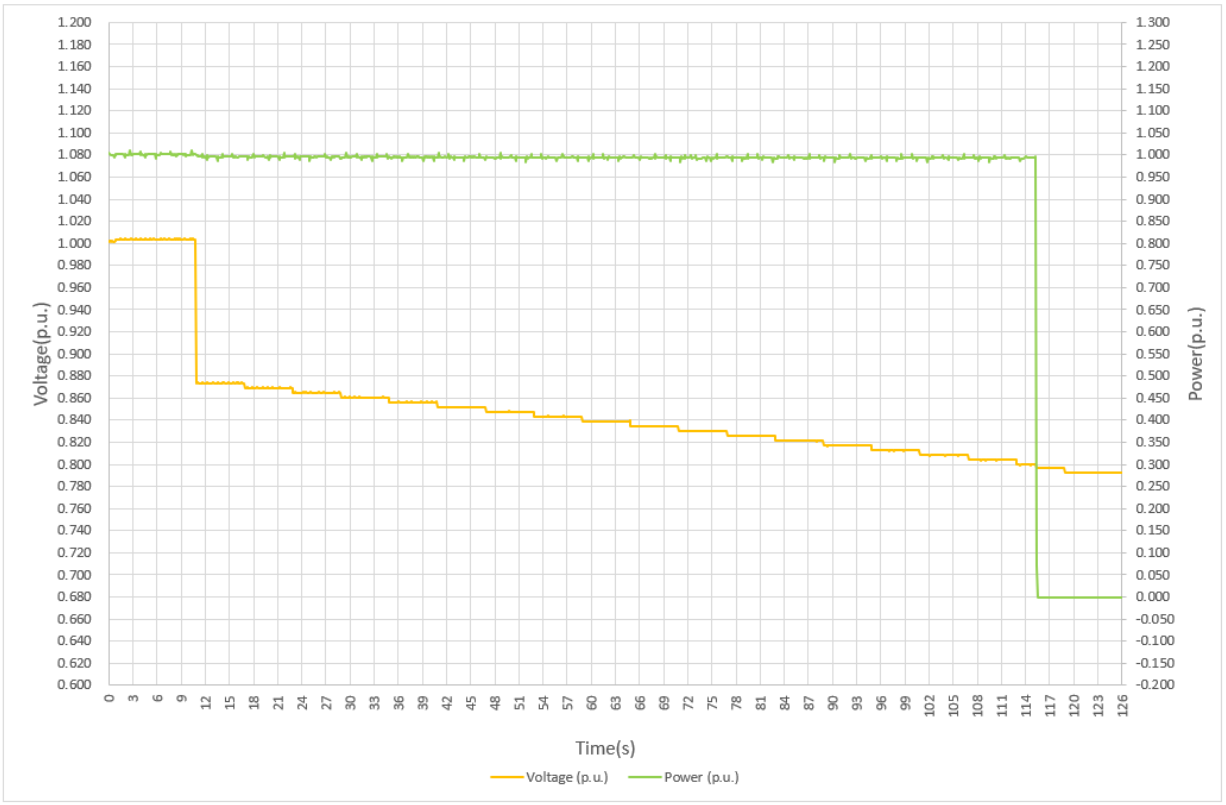


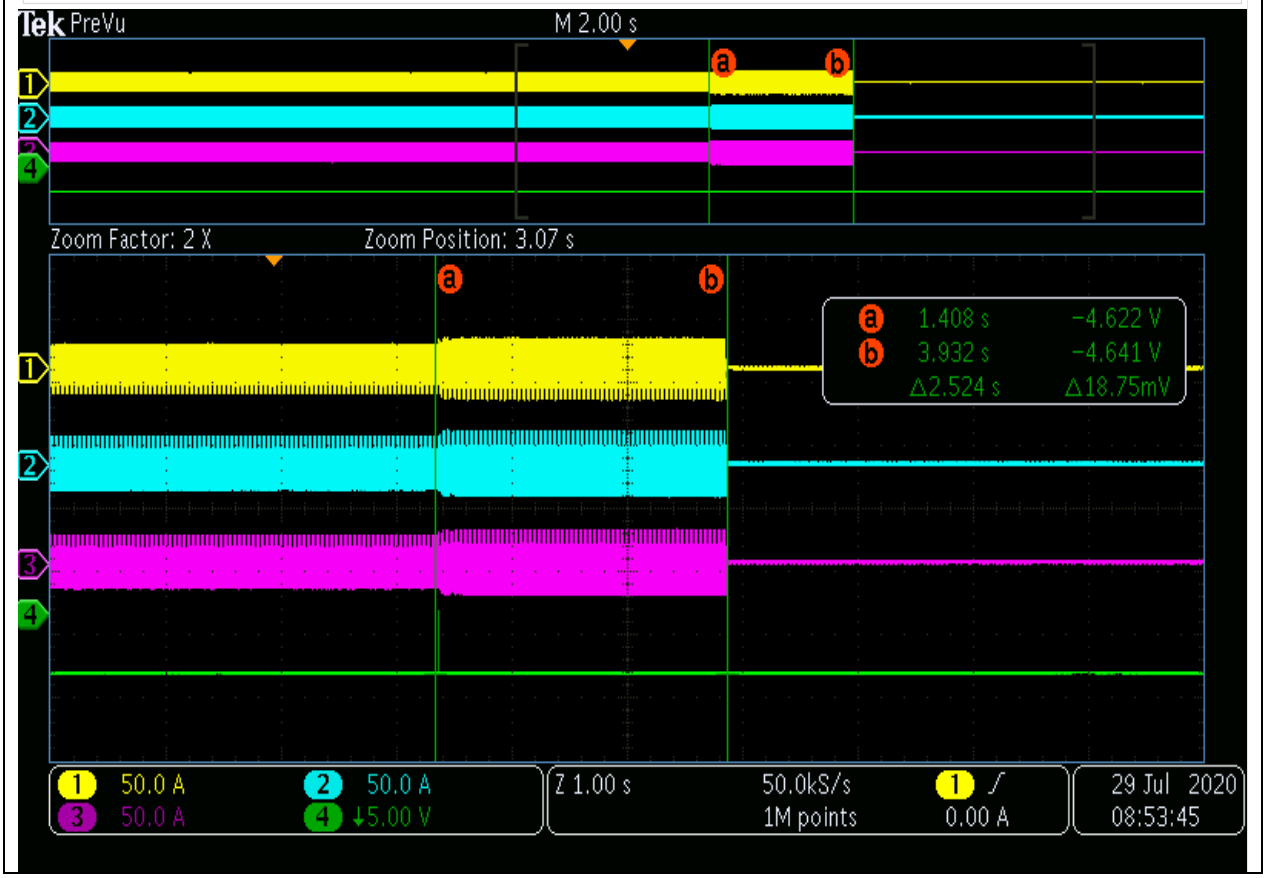
U/V -2


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

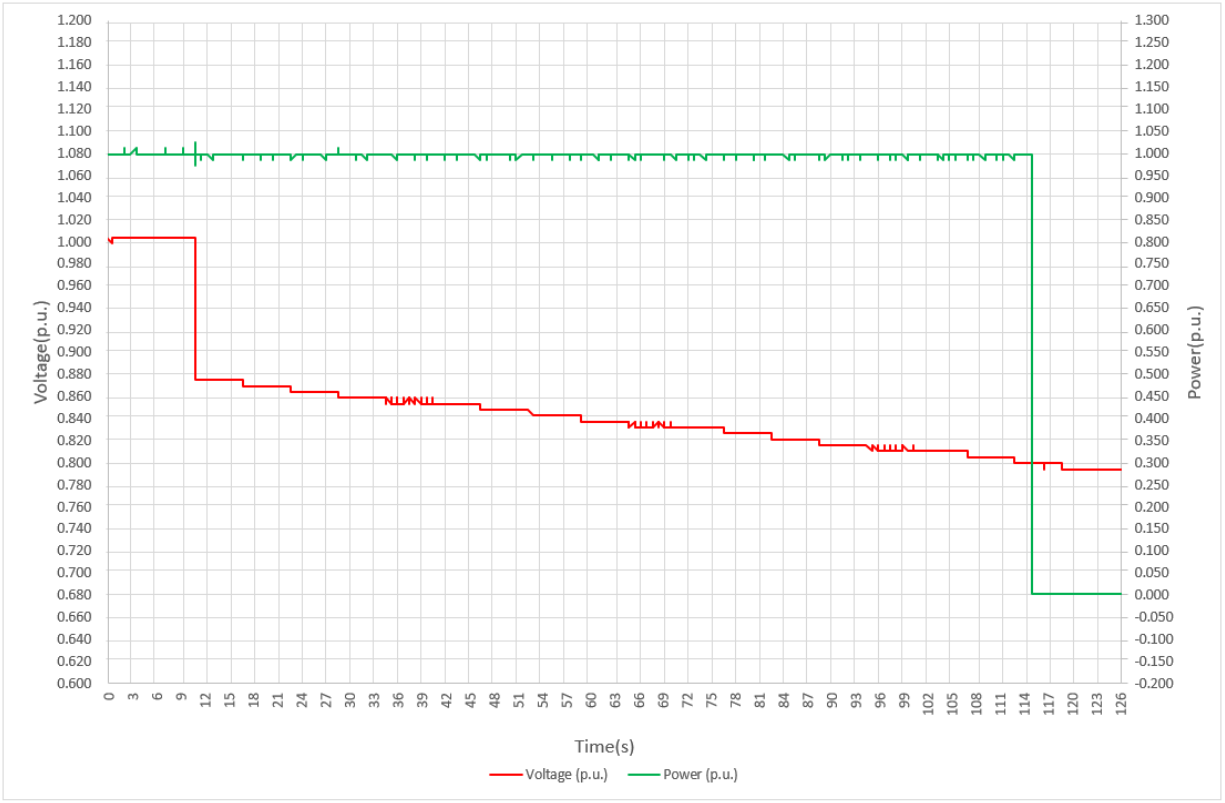

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 2.75 s
a 1.008 s -4.653 V
b 3.525 s -4.649 V
Δ2.517 s Δ3.906mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 1.00 s
50.0kS/s
1M points
0.00 A
29 Jul 2020
08:50:41

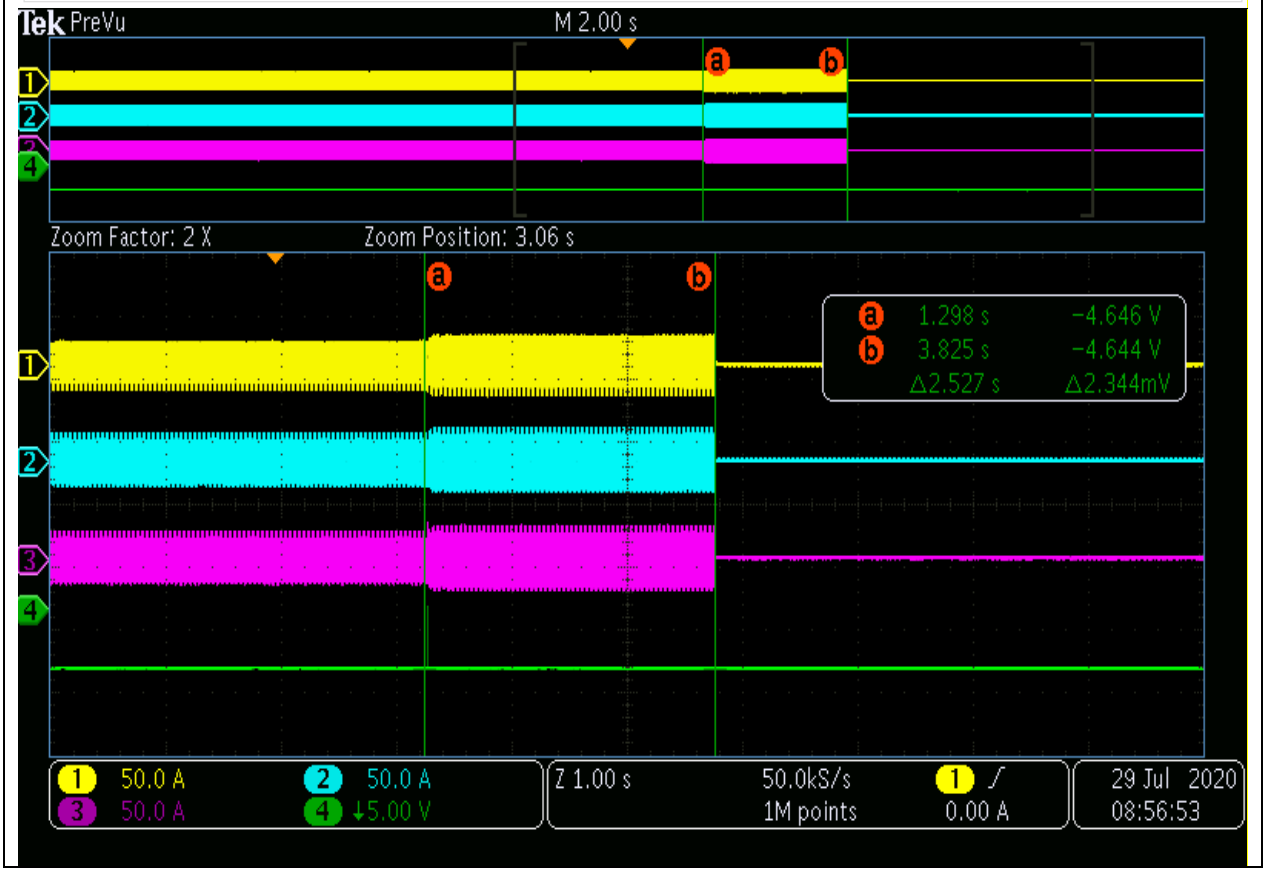
U/V -3


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

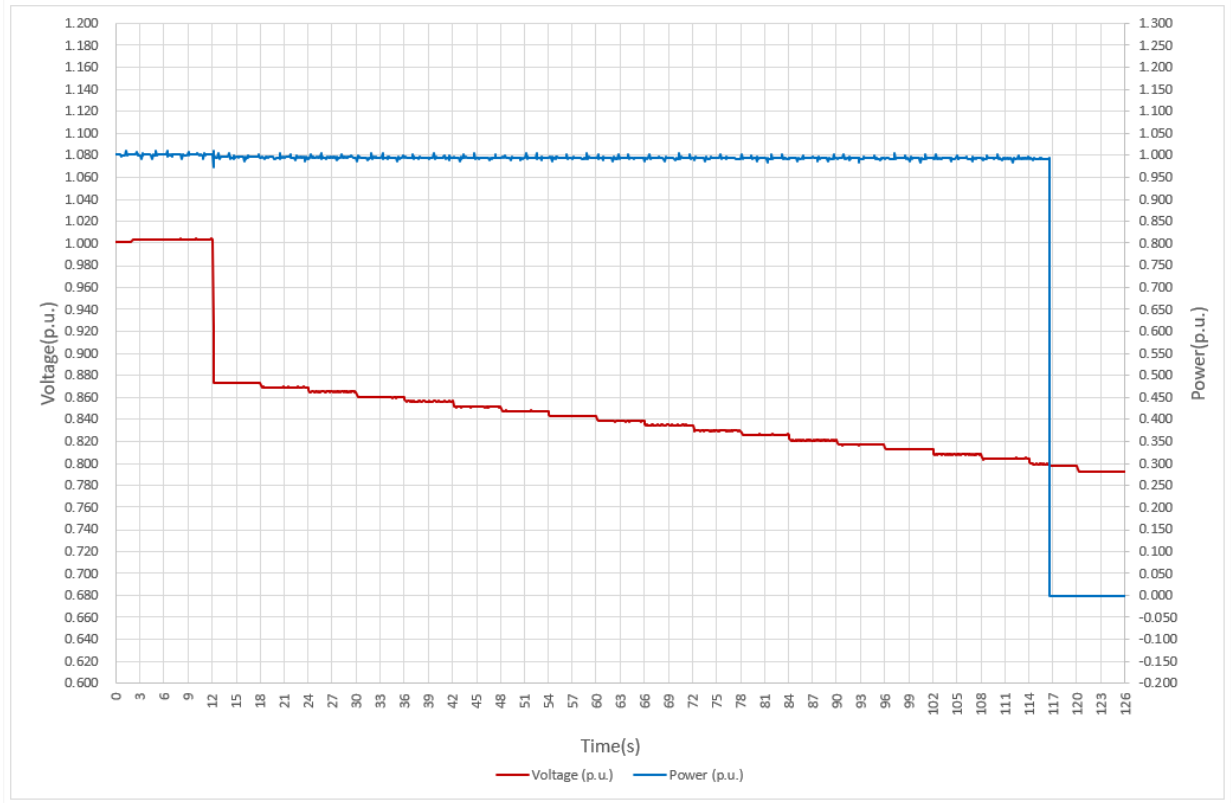

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 3.07 s
a 1.408 s -4.622 V
b 3.932 s -4.641 V
Δ2.524 s Δ18.75mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 1.00 s
50.0kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
08:53:45

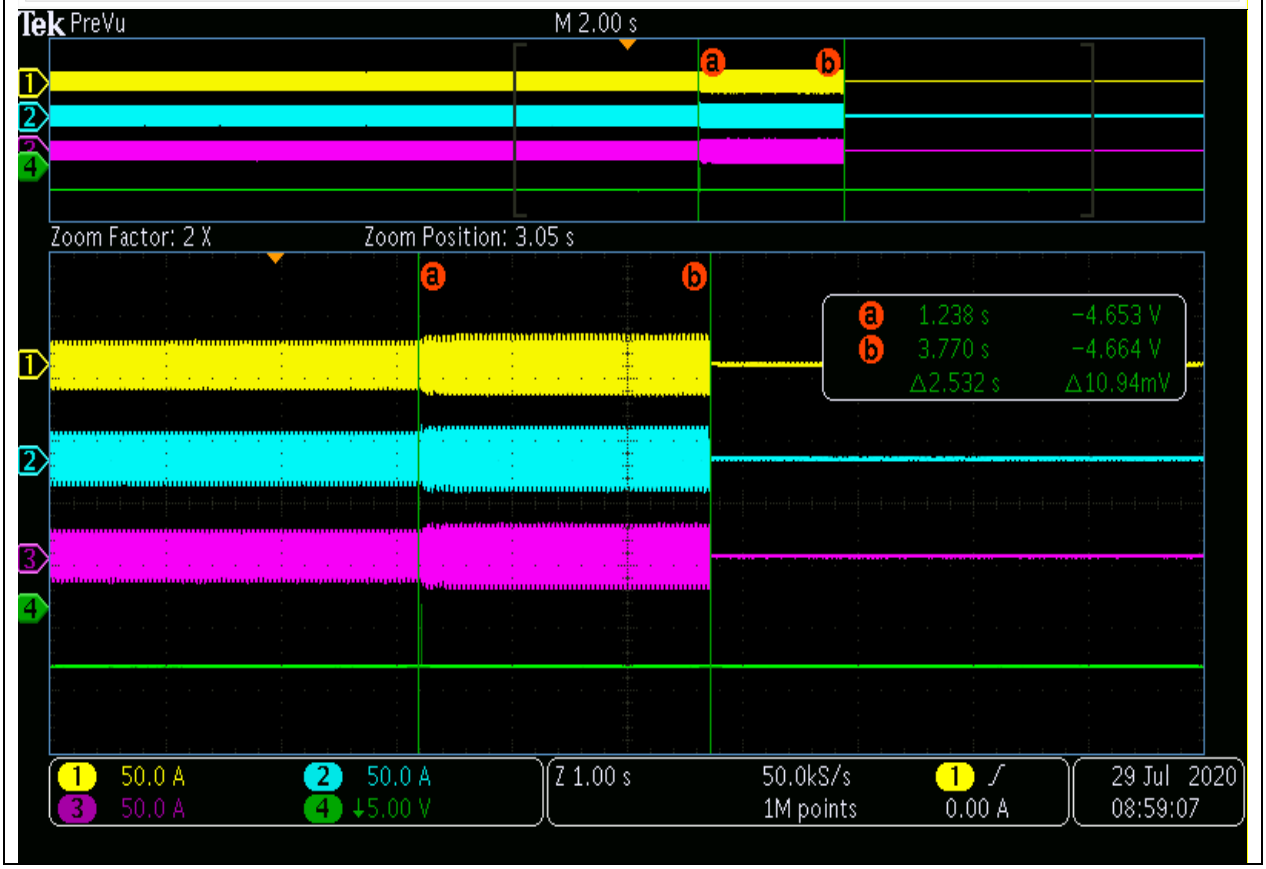
U/V -4


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

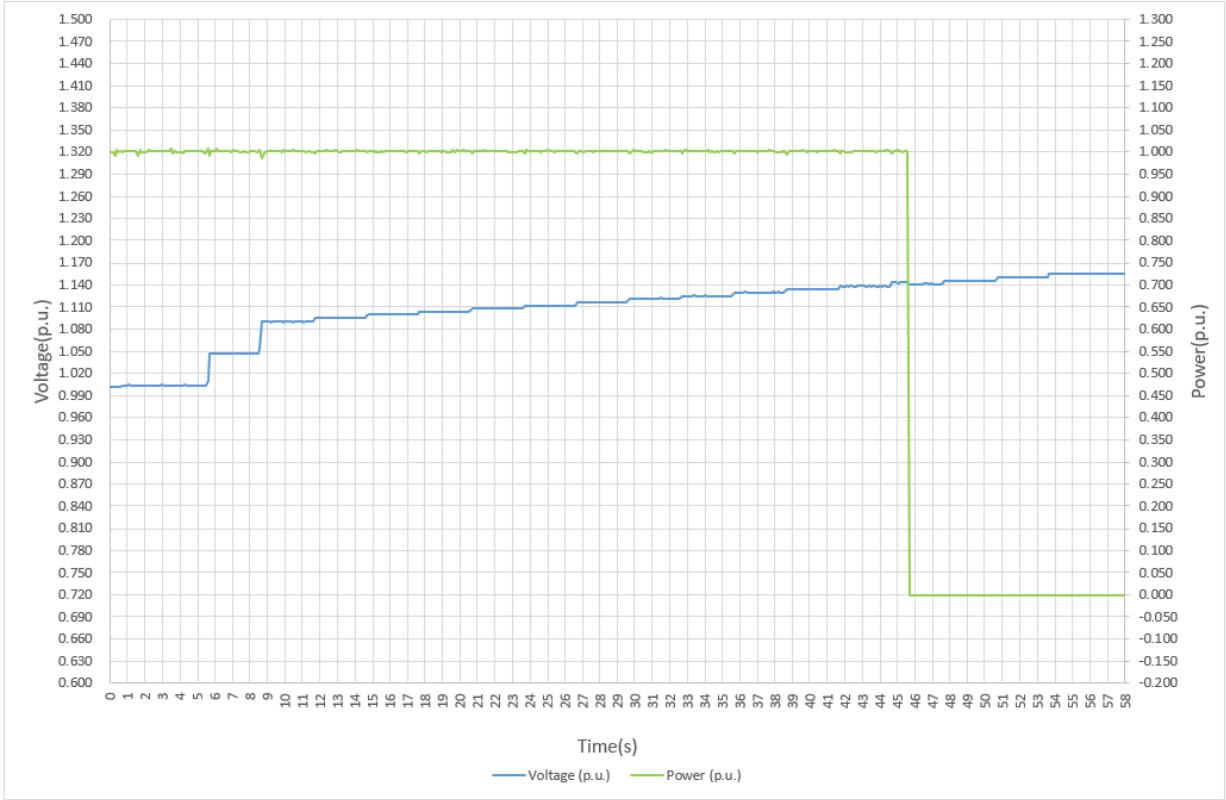

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 3.06 s
a 1.298 s -4.646 V
b 3.825 s -4.644 V
Δ2.527 s Δ2.344mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 1.00 s
50.0kS/s
1M points
0.00 A
29 Jul 2020
08:56:53

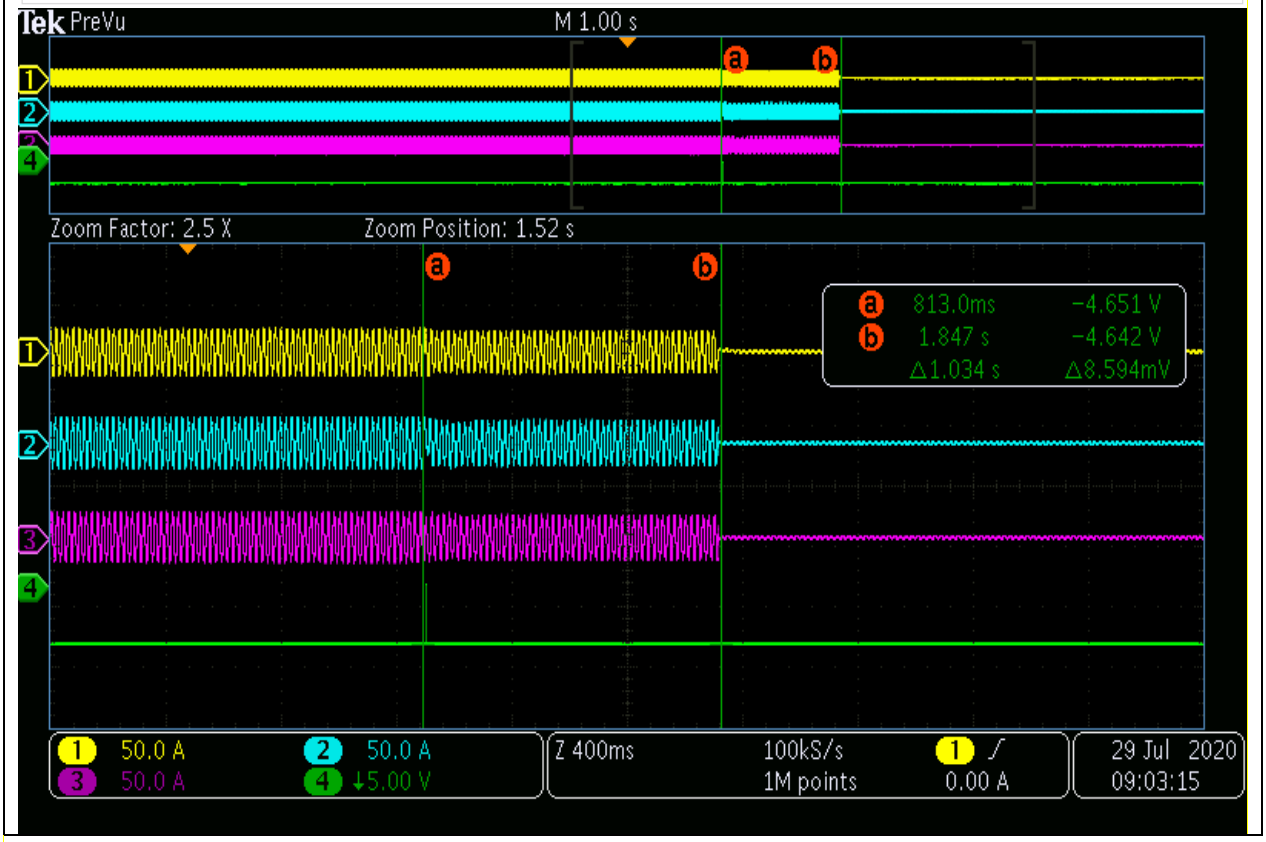
U/V -5


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

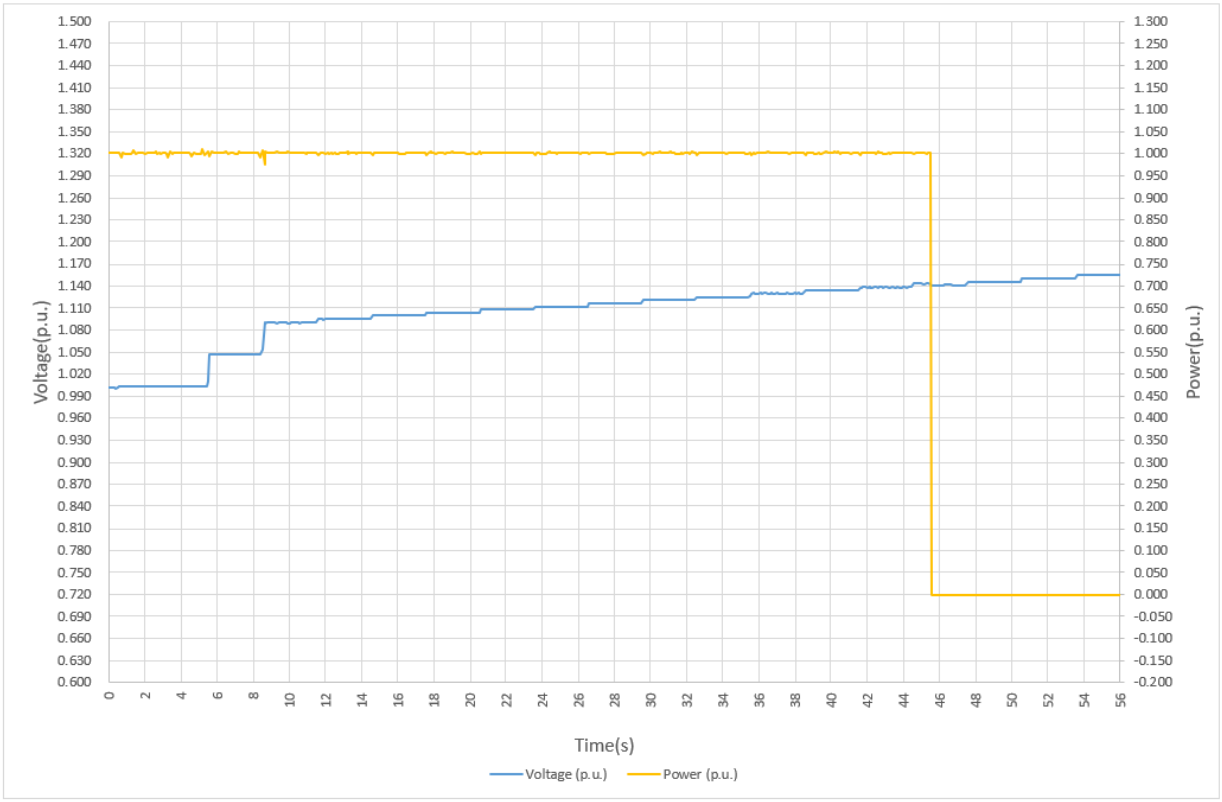

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 3.05 s
a 1.238 s -4.653 V
b 3.770 s -4.664 V
Δ2.532 s Δ10.94mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 1.00 s
50.0kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
08:59:07

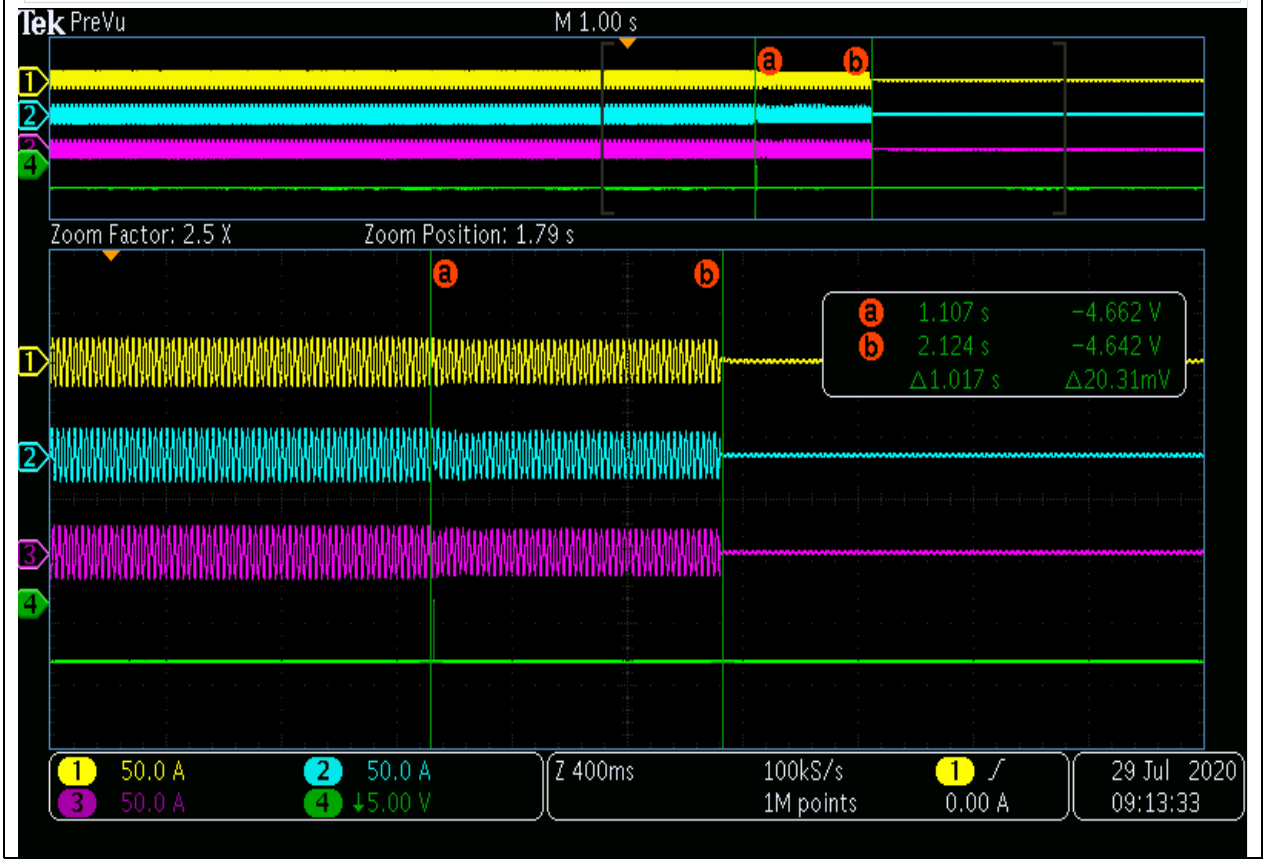
O/V stage 1-1


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

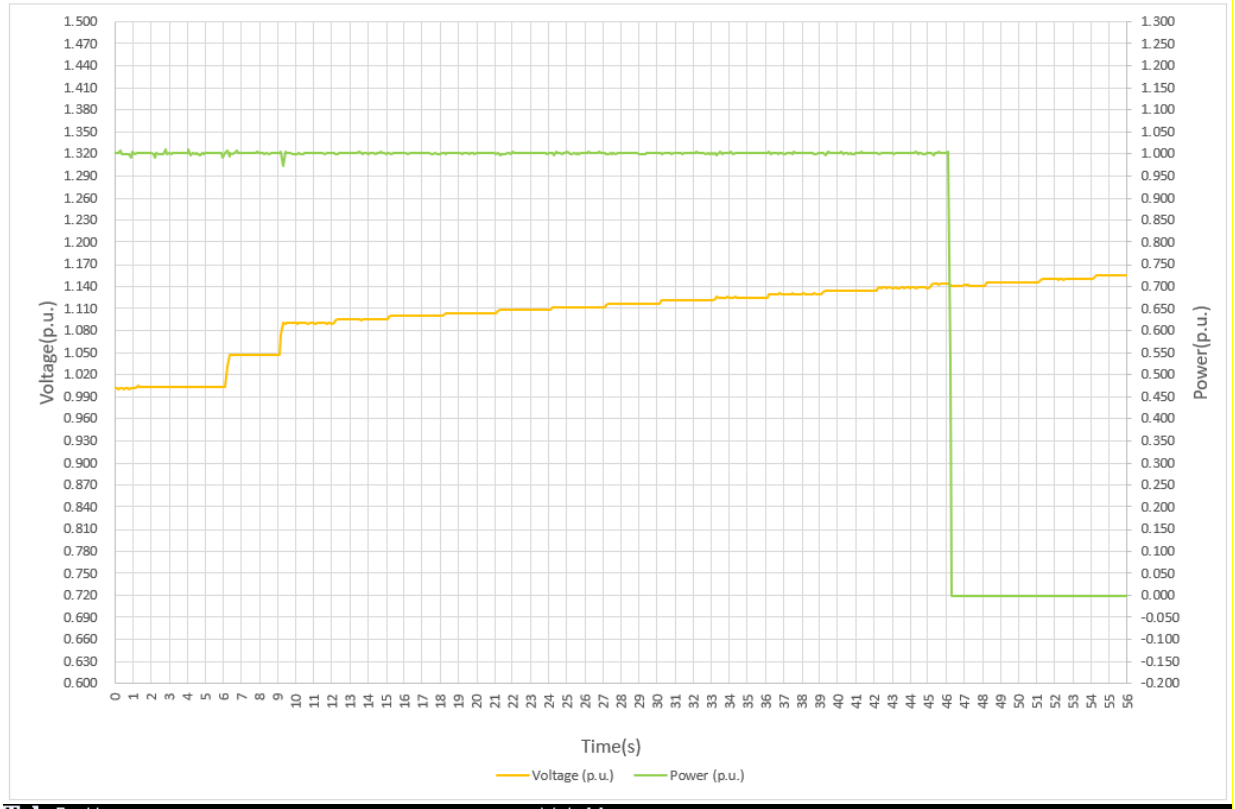

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 1.52 s
a 813.0ms -4.651 V
b 1.847 s -4.642 V
Δ1.034 s Δ8.594mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 400ms
100kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
09:03:15

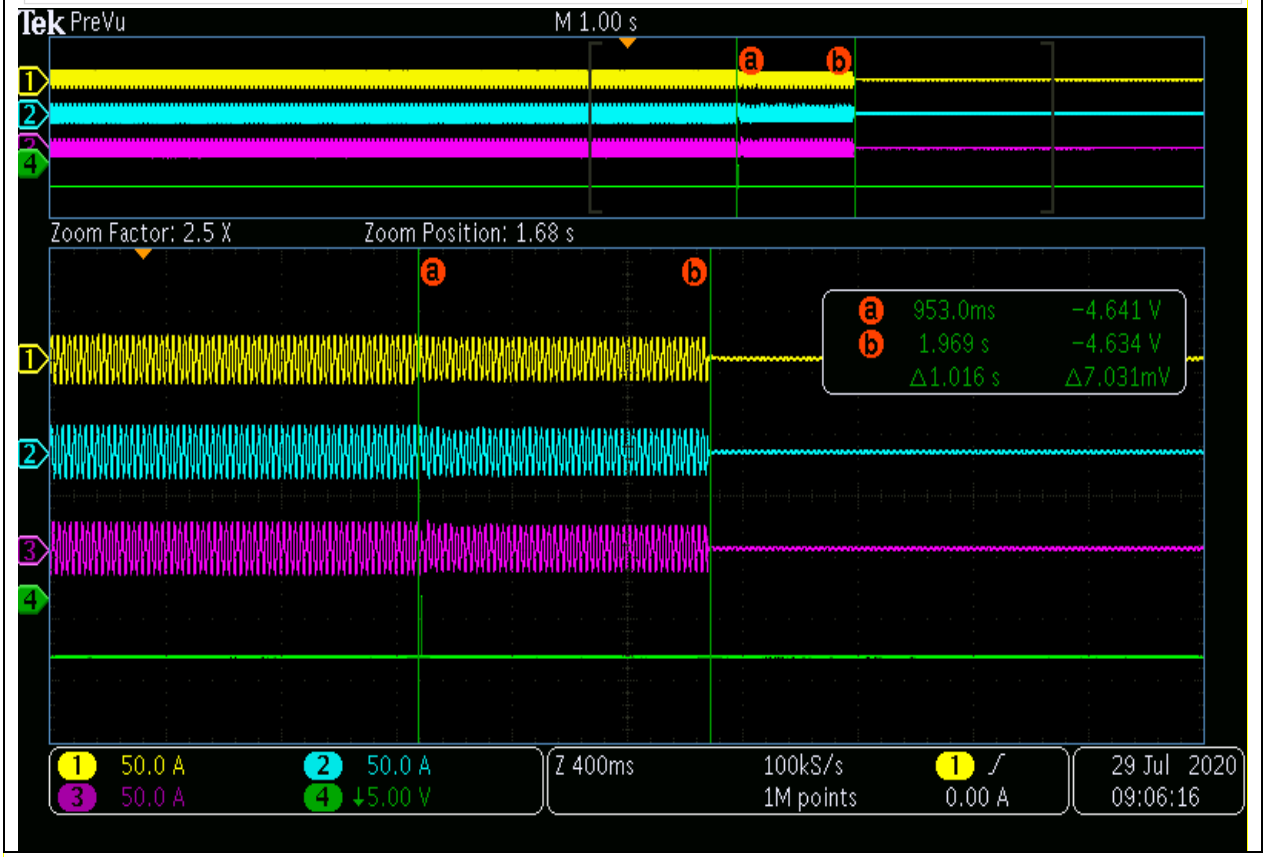
O/V stage 1-2


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)


Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 1.79 s
a 1.107 s -4.662 V
b 2.124 s -4.642 V
Δ1.017 s Δ20.31mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 400ms
100kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
09:13:33

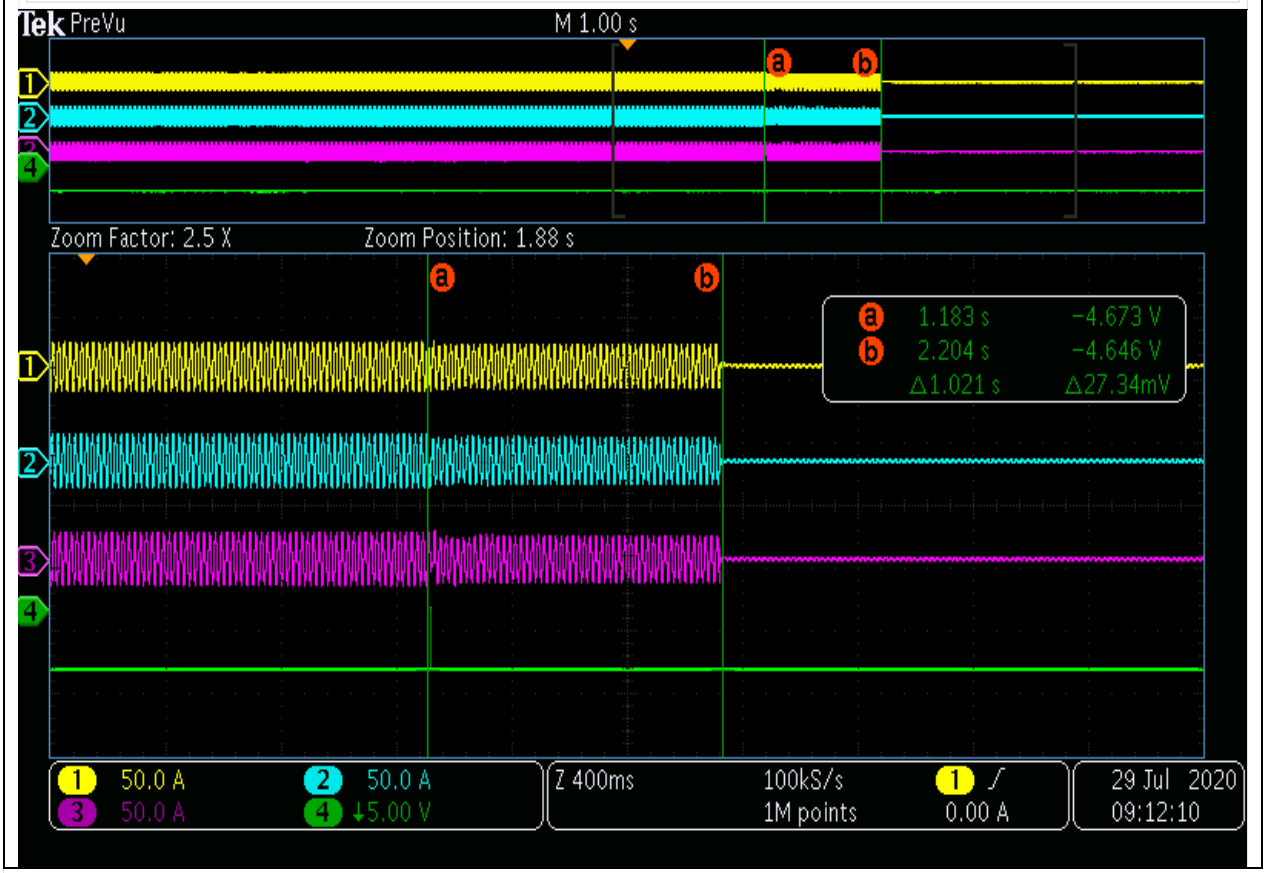
O/V stage 1-3


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

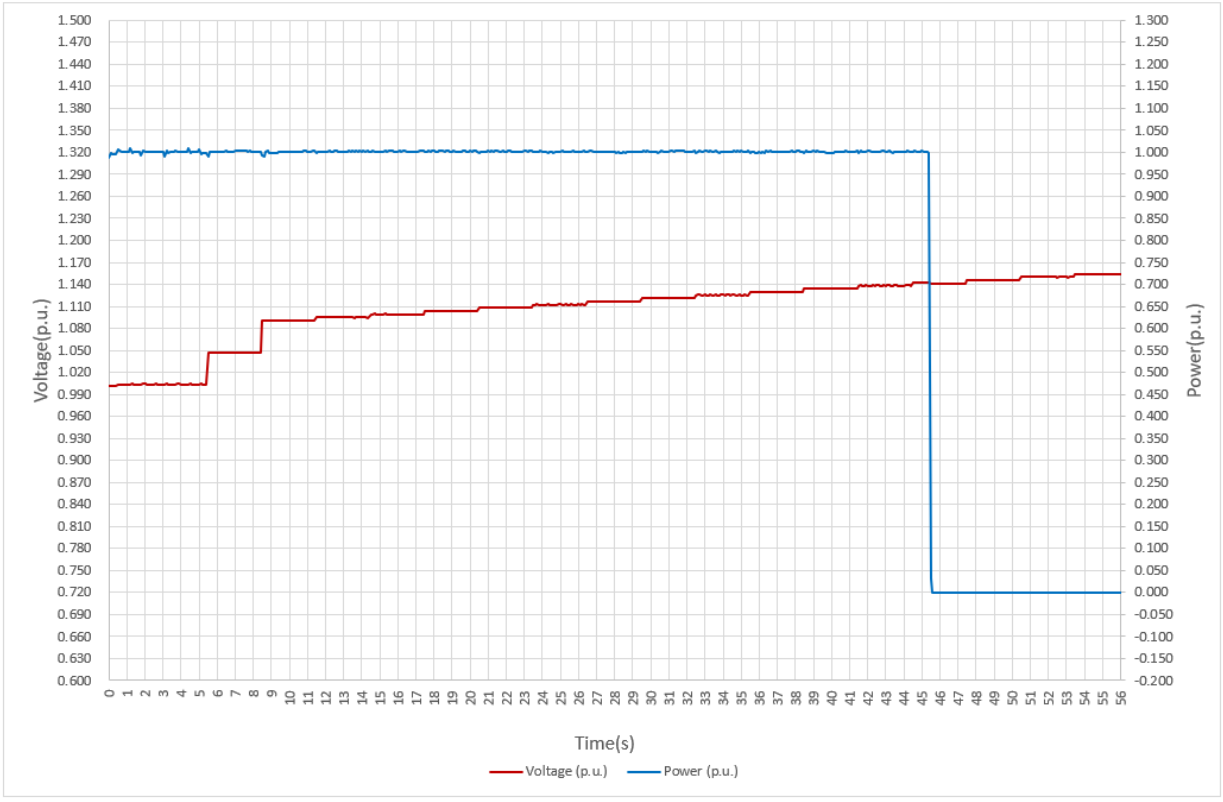

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 1.68 s
a 953.0ms -4.641 V
b 1.969 s -4.634 V
Δ1.016 s Δ7.031mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 400ms
100kS/s
1M points
1 ⁄
0.00 A
29 Jul 2020
09:06:16

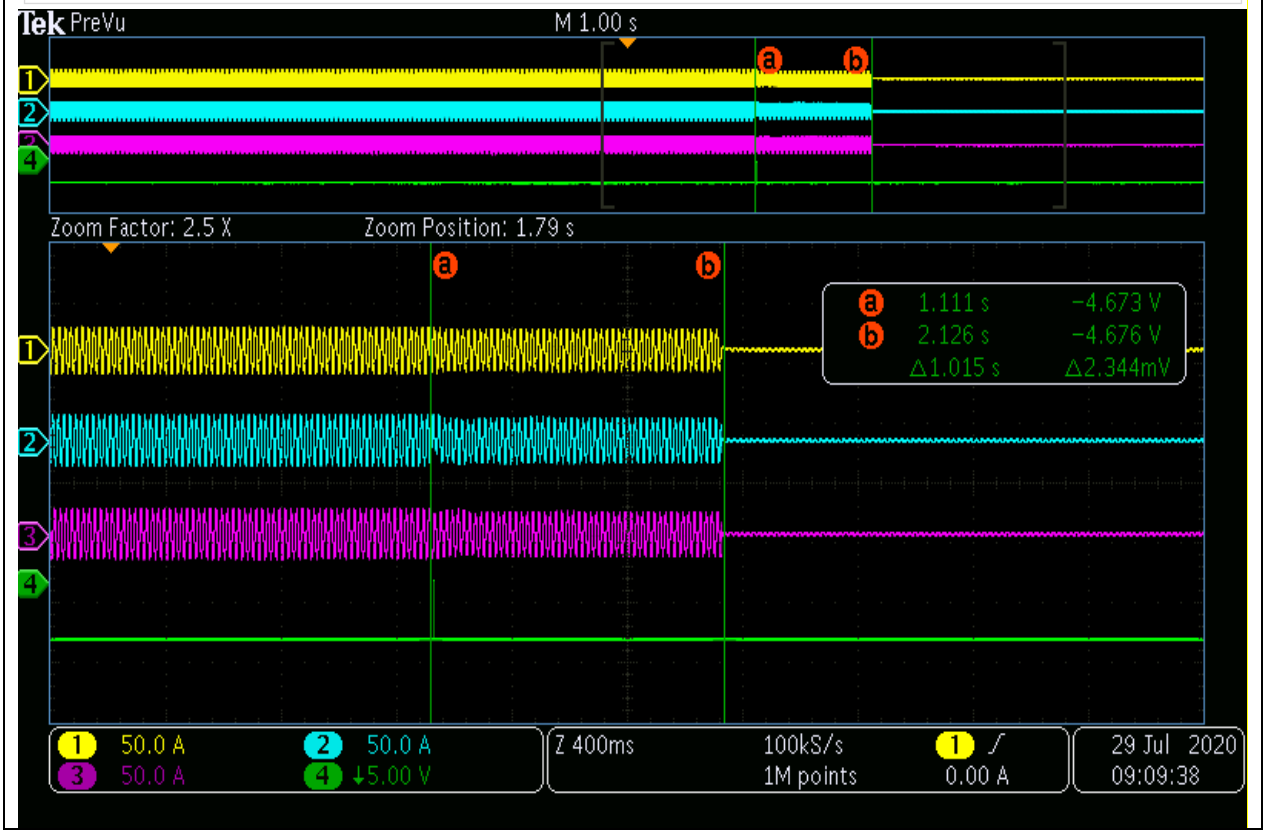
O/V stage 1-4


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

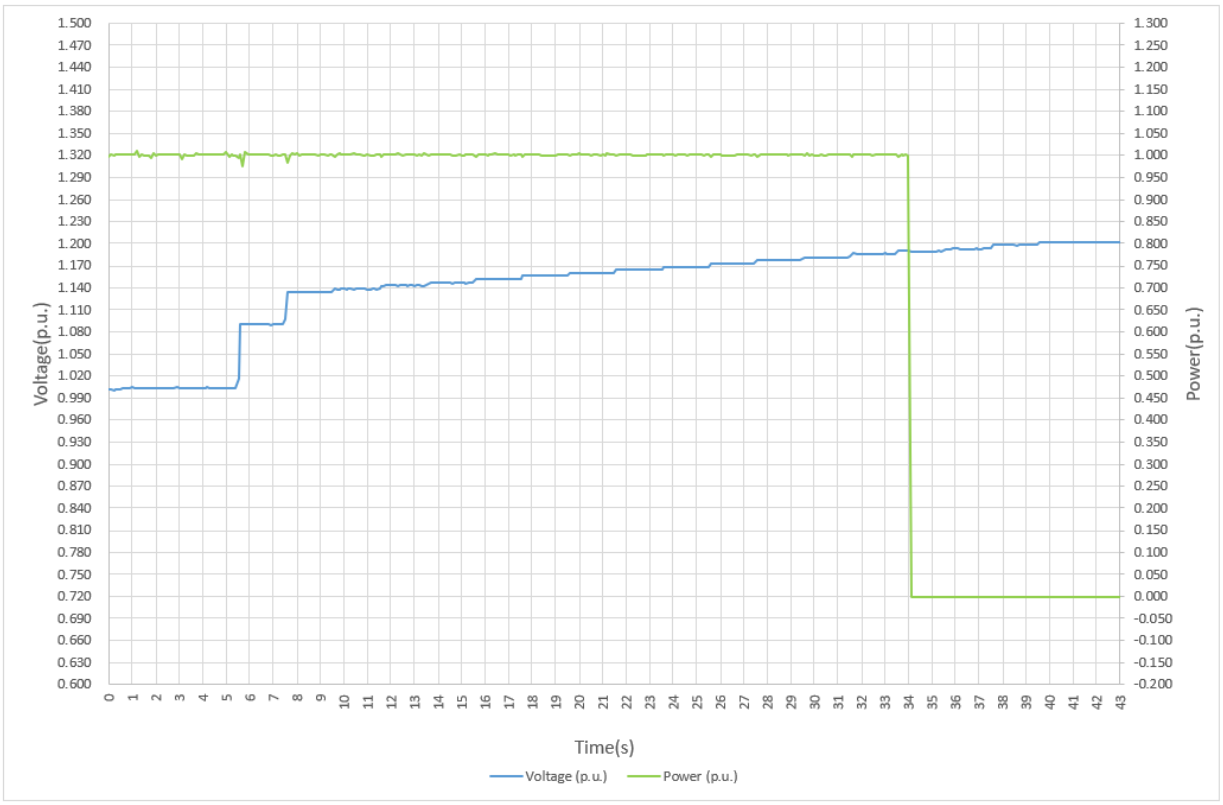

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 1.88 s
a 1.183 s -4.673 V
b 2.204 s -4.646 V
Δ1.021 s Δ27.34mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 400ms
100kS/s
1M points
0.00 A
29 Jul 2020
09:12:10

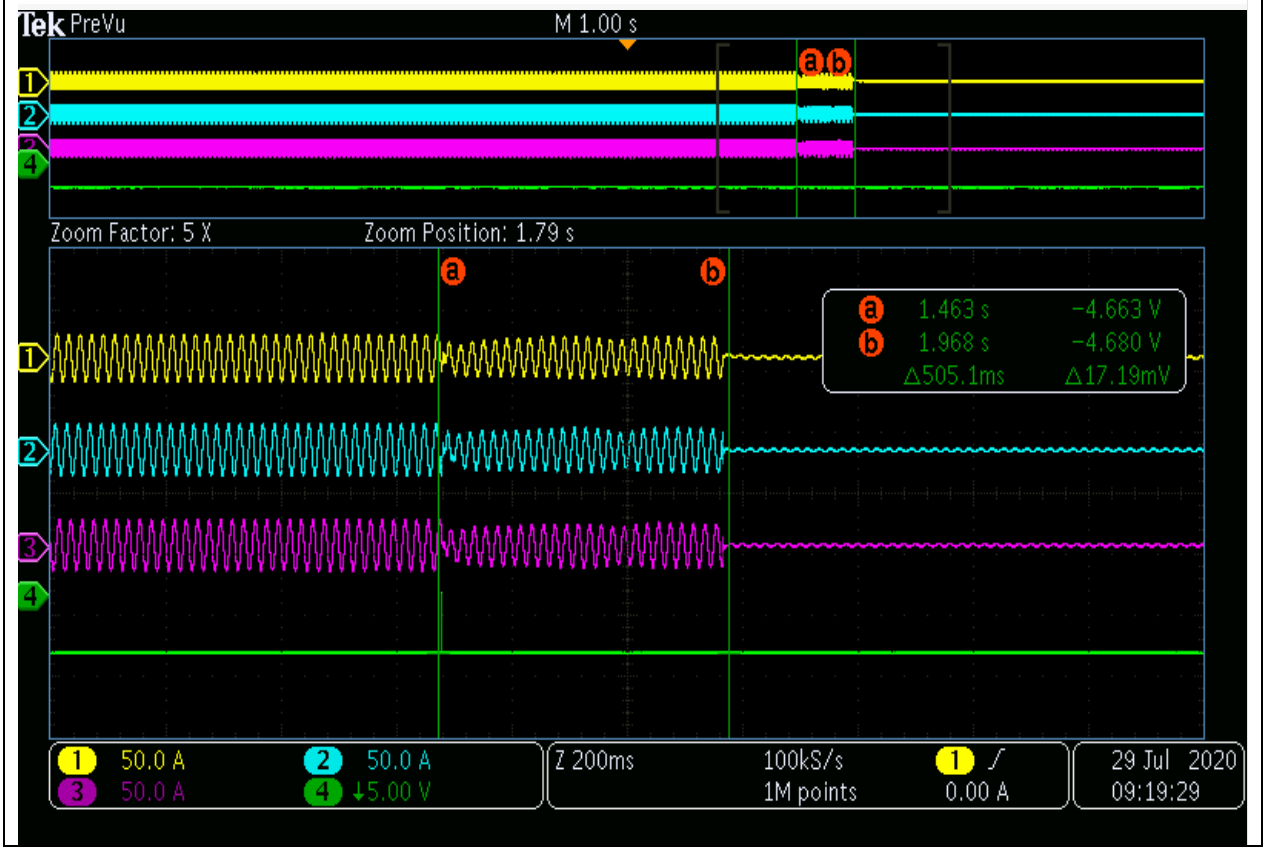
O/V stage 1-5


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

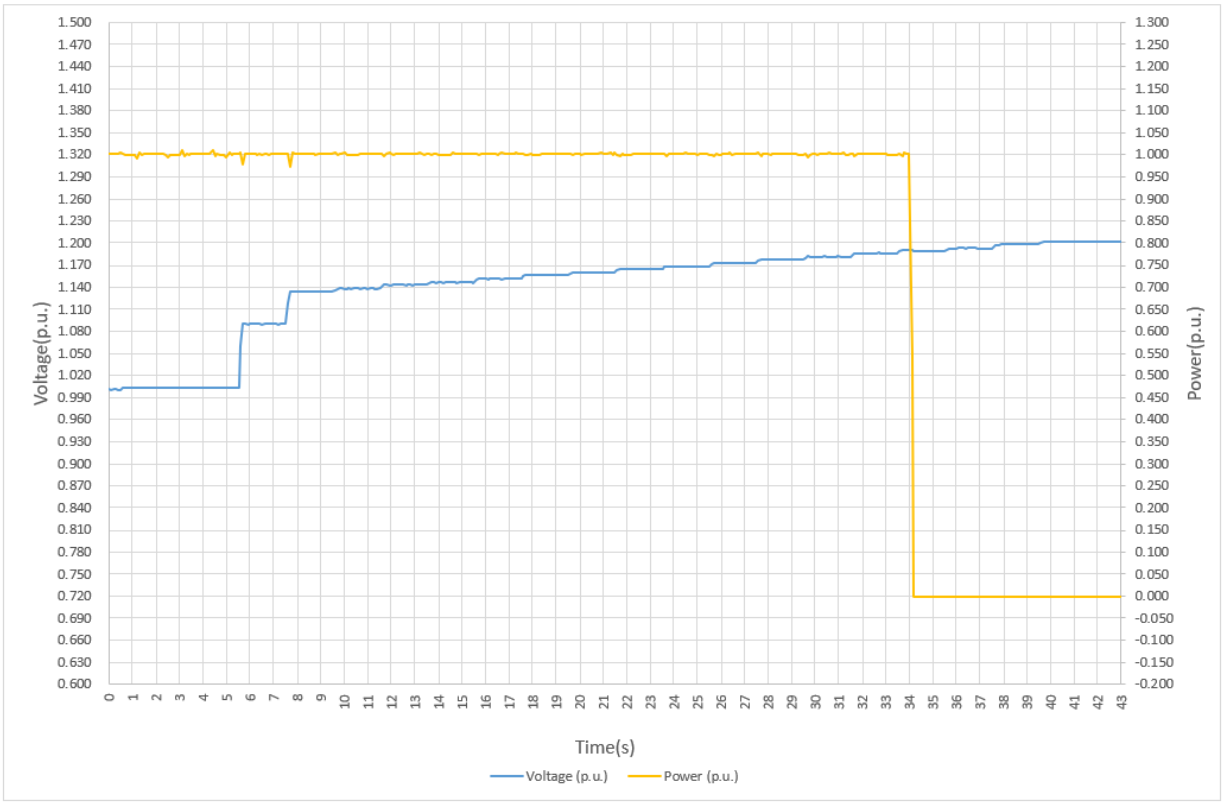

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 1.79 s
a 1.111 s -4.673 V
b 2.126 s -4.676 V
Δ1.015 s Δ2.344mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 400ms
100kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
09:09:38

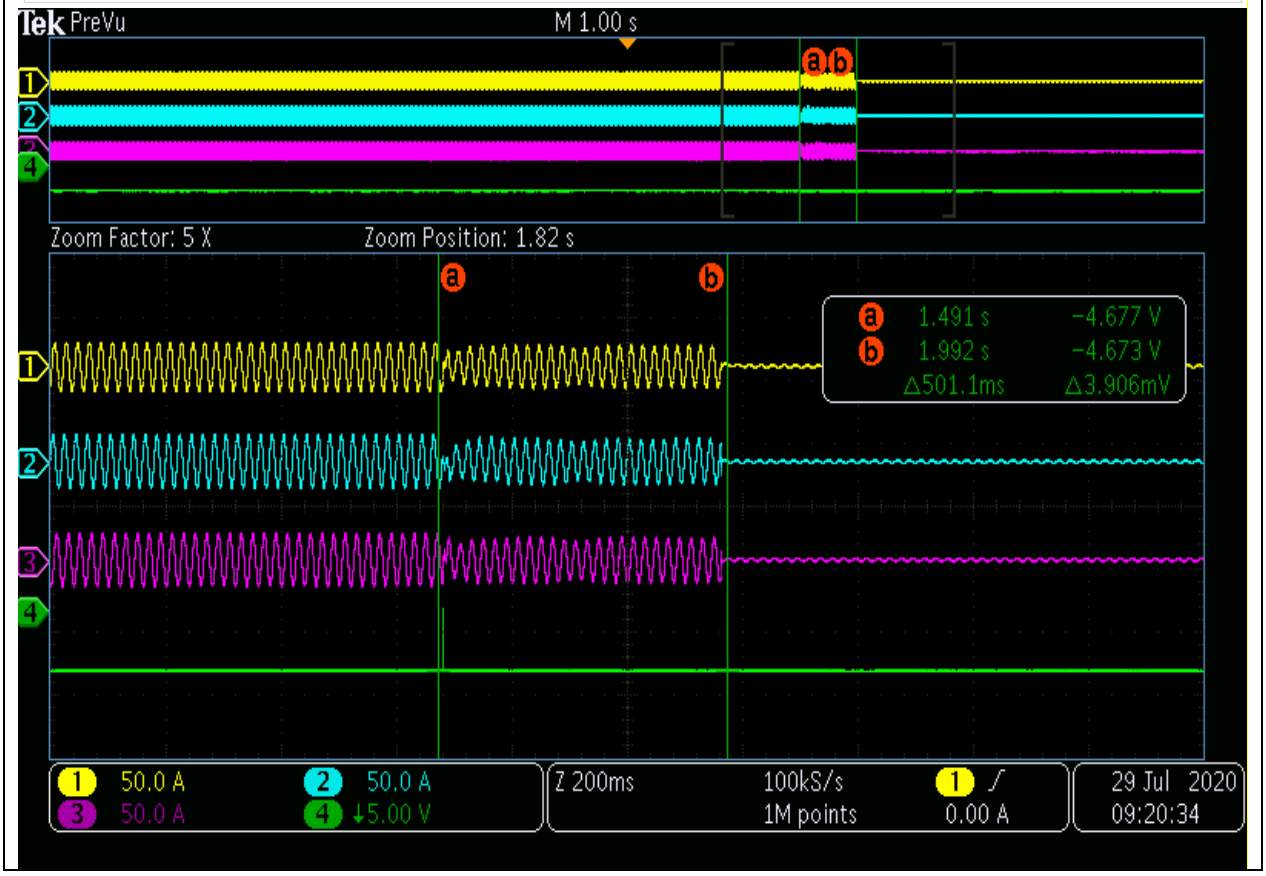
O/V stage 2-1


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

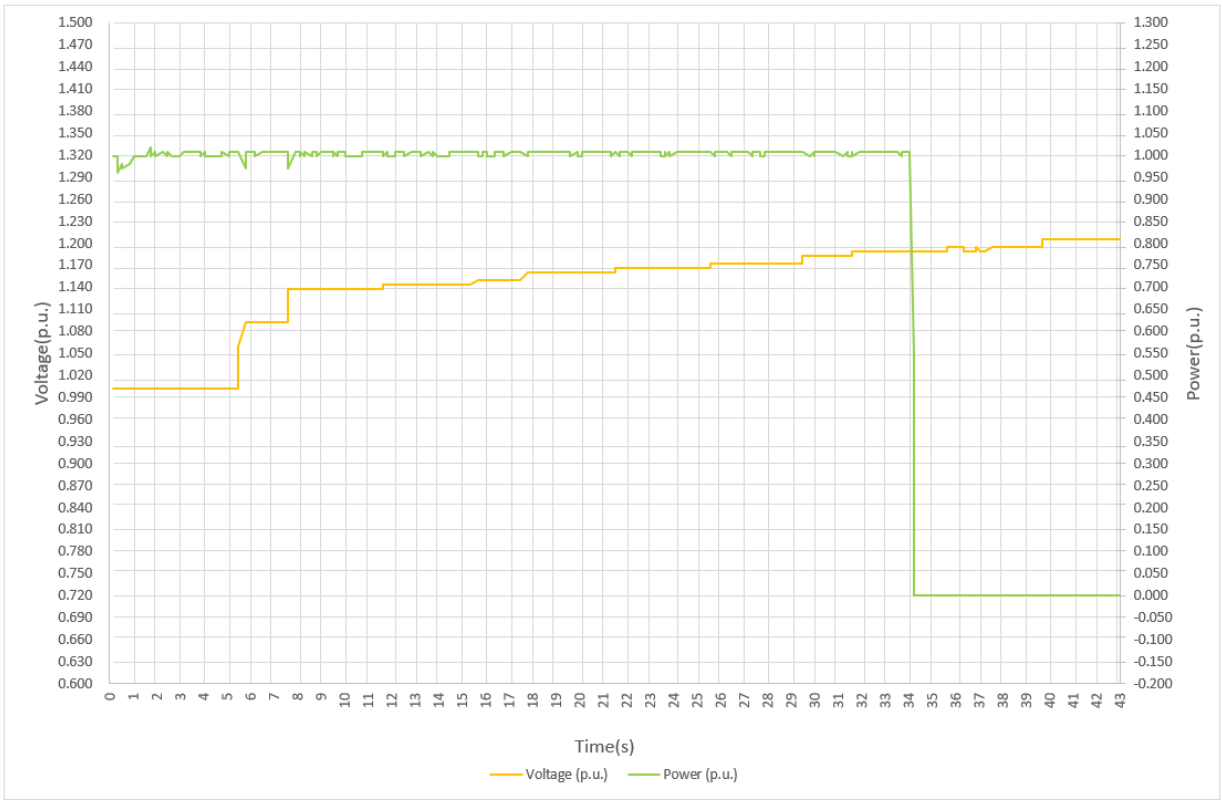

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.79 s
a 1.463 s -4.663 V
b 1.968 s -4.680 V
Δ505.1ms Δ17.19mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⎍
0.00 A
29 Jul 2020
09:19:29

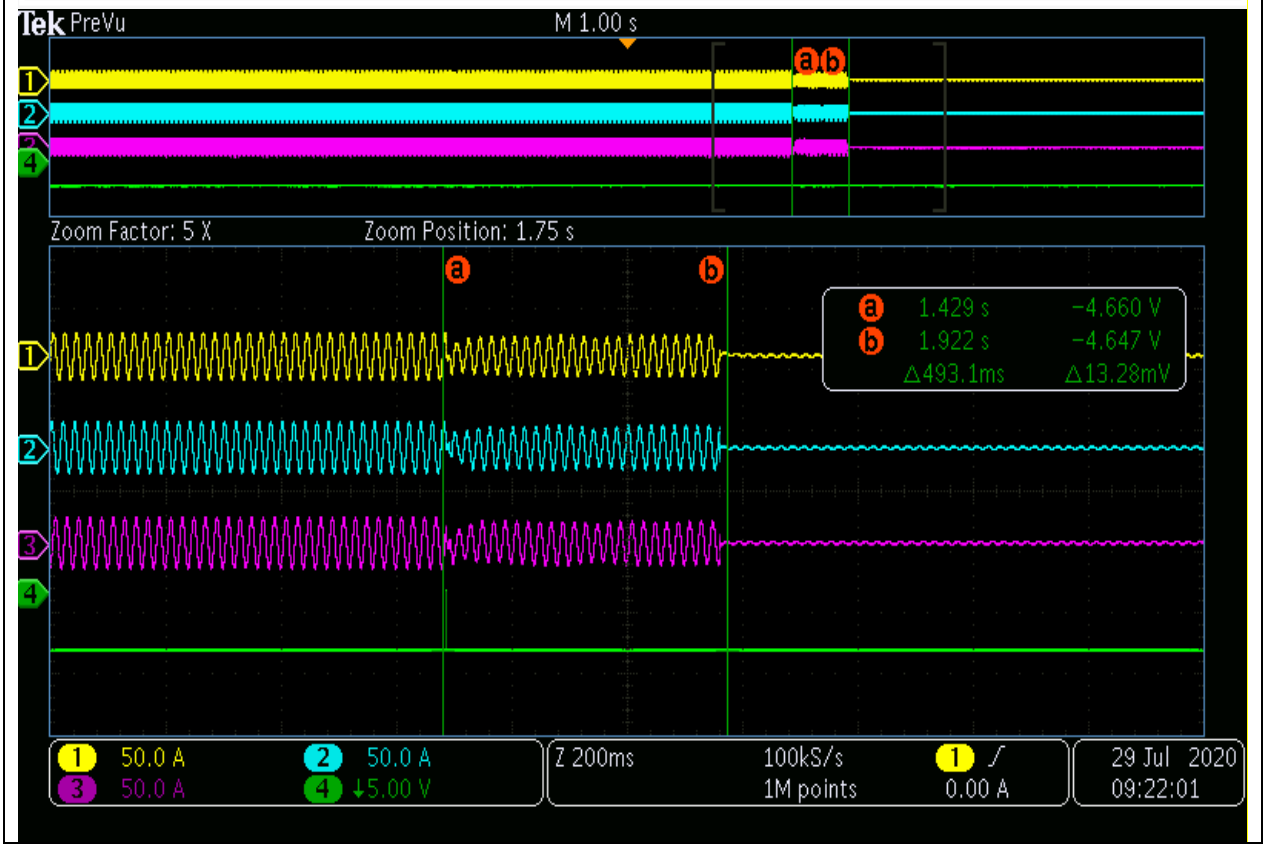
O/V stage 2-2


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)


Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.82 s
a 1.491 s -4.677 V
b 1.992 s -4.673 V
Δ501.1ms Δ3.906mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
09:20:34

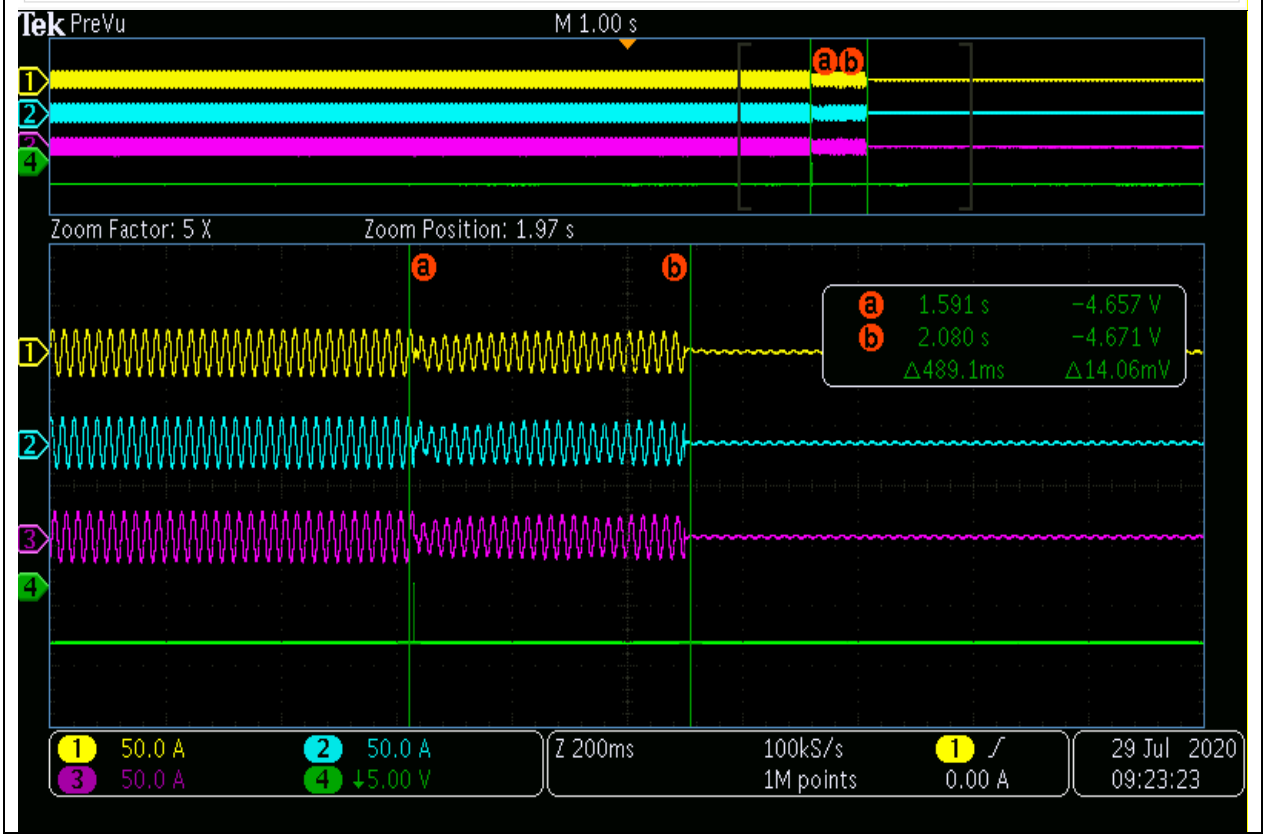
O/V stage 2-3


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

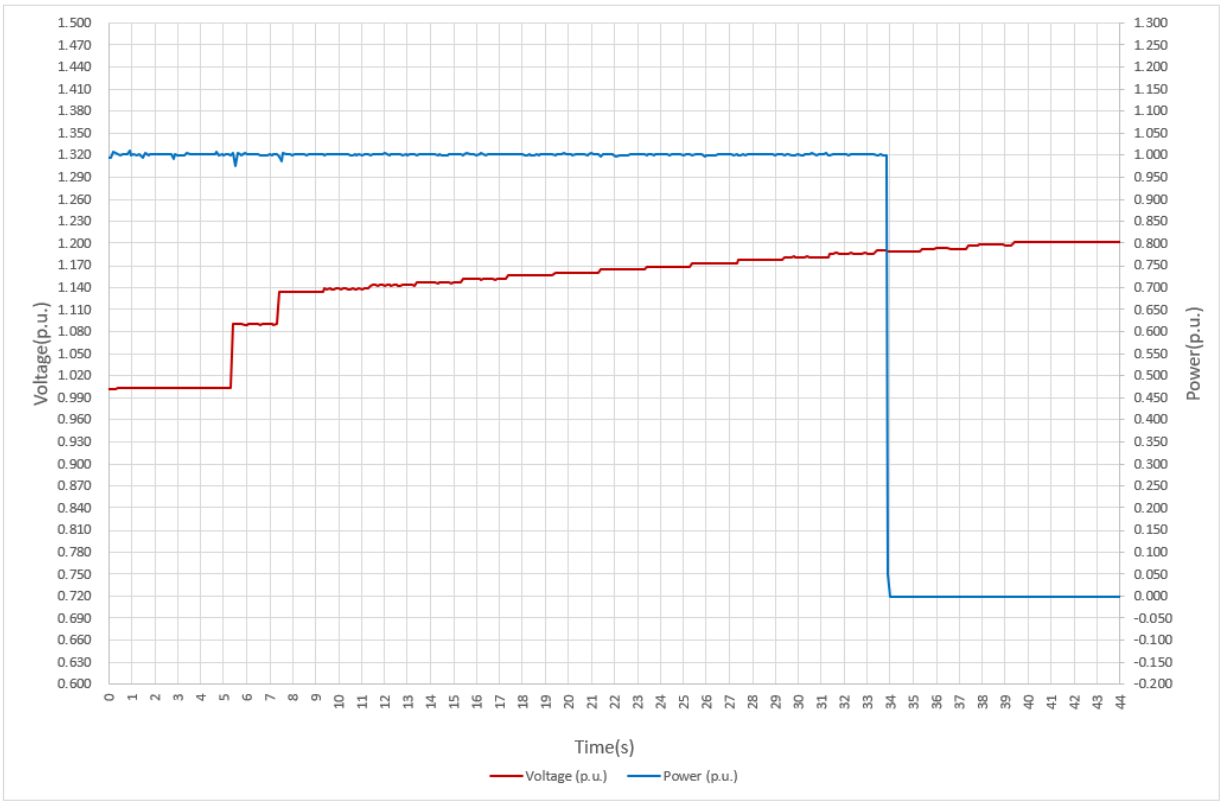

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.75 s
a 1.429 s -4.660 V
b 1.922 s -4.647 V
Δ493.1ms Δ13.28mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
1 ⁄ 0.00 A
29 Jul 2020
09:22:01

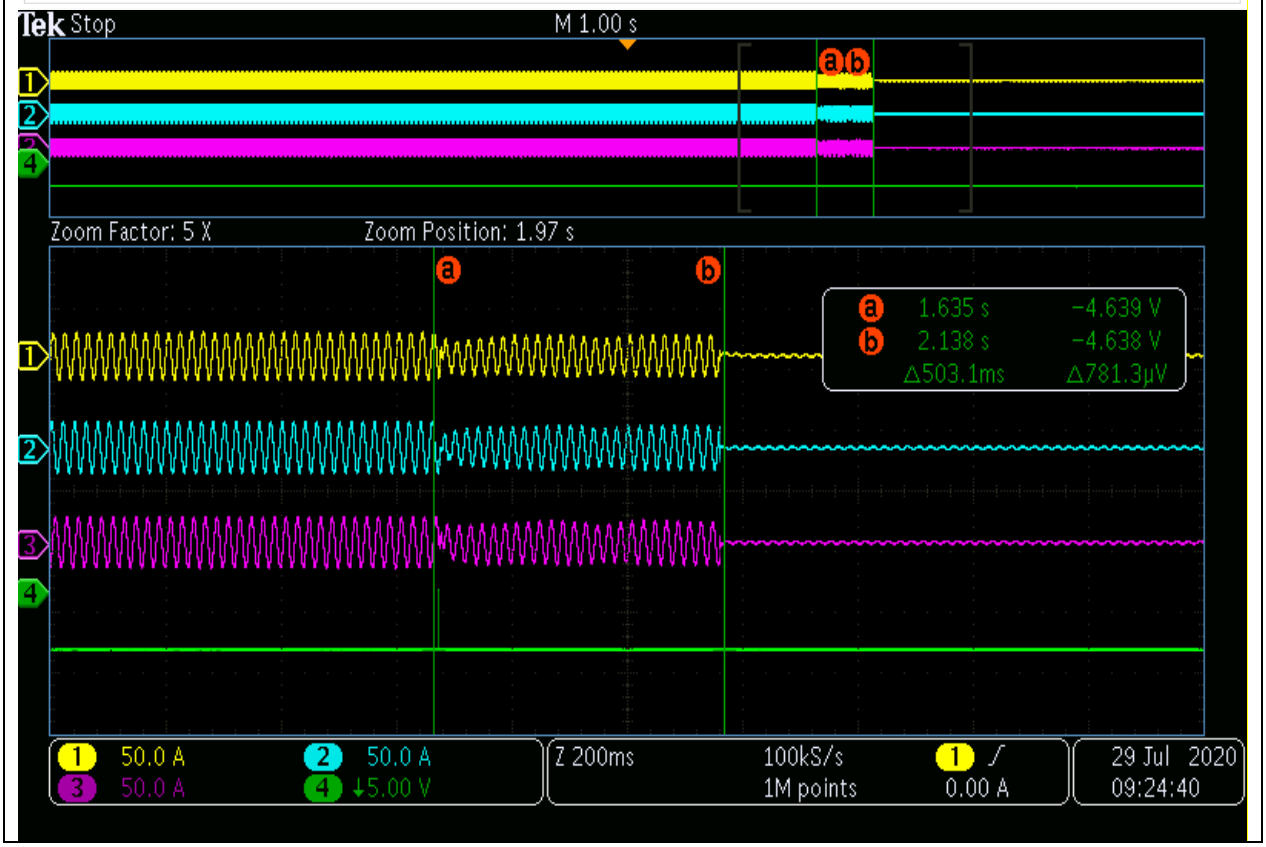
O/V stage 2-4


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

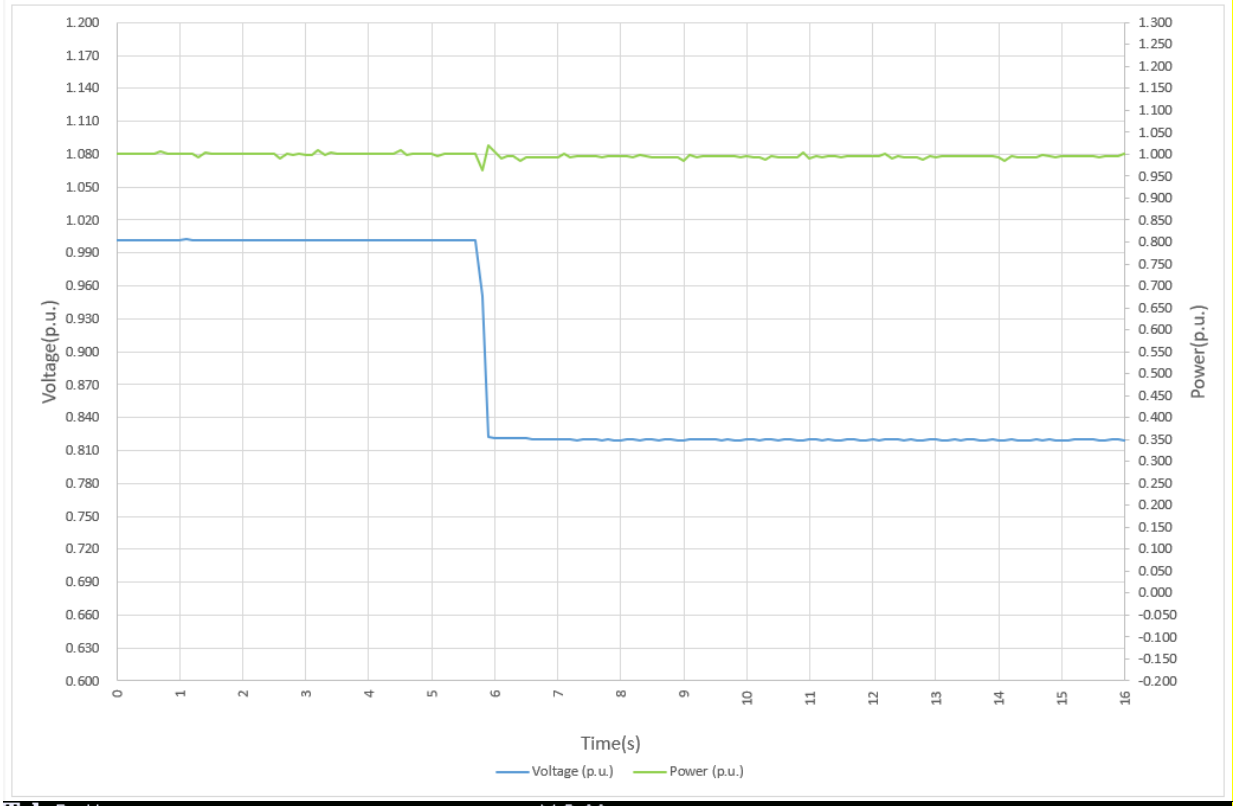

Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.97 s
a 1.591 s -4.657 V
b 2.080 s -4.671 V
Δ489.1ms Δ14.06mV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
0.00 A
29 Jul 2020
09:23:23

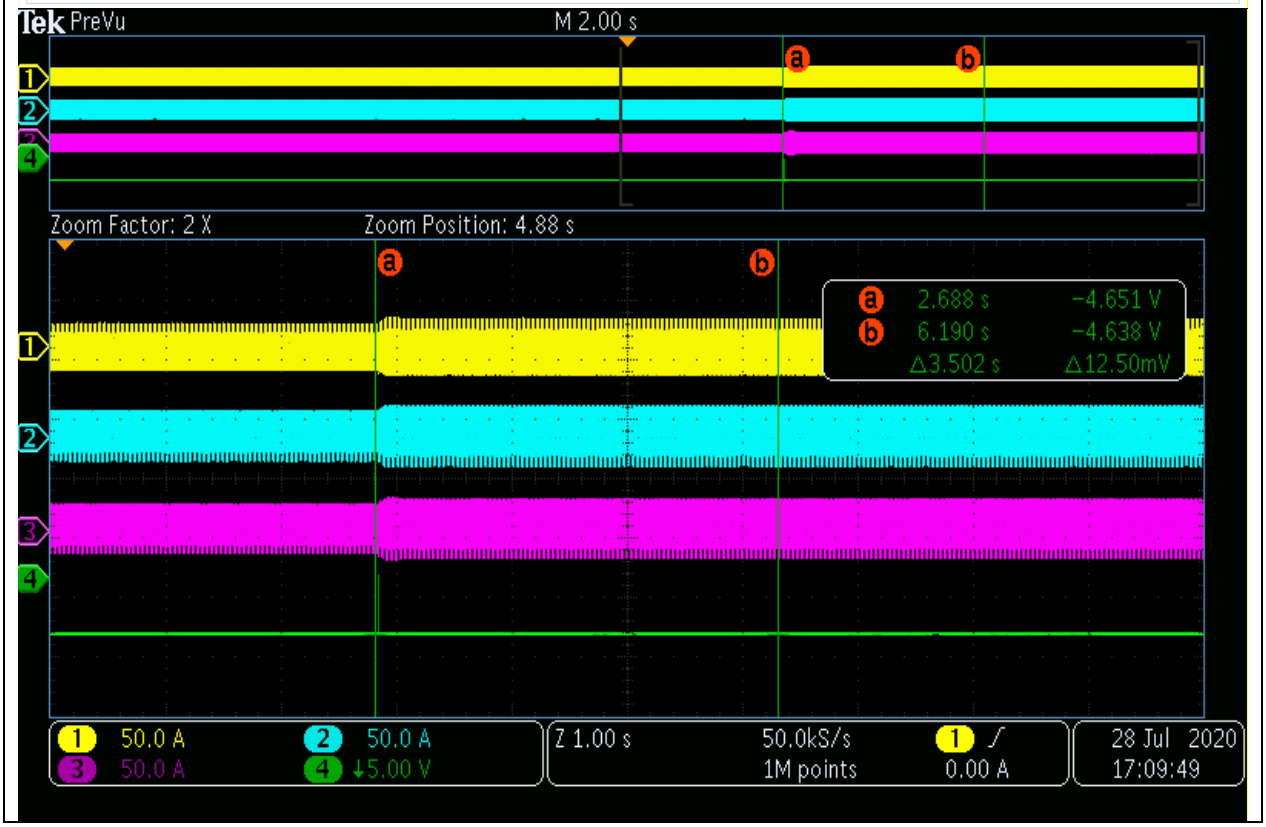
O/V stage 2-5


Voltage(p.u.)
Power(p.u.)
Time(s)
Voltage (p.u.)
Power (p.u.)

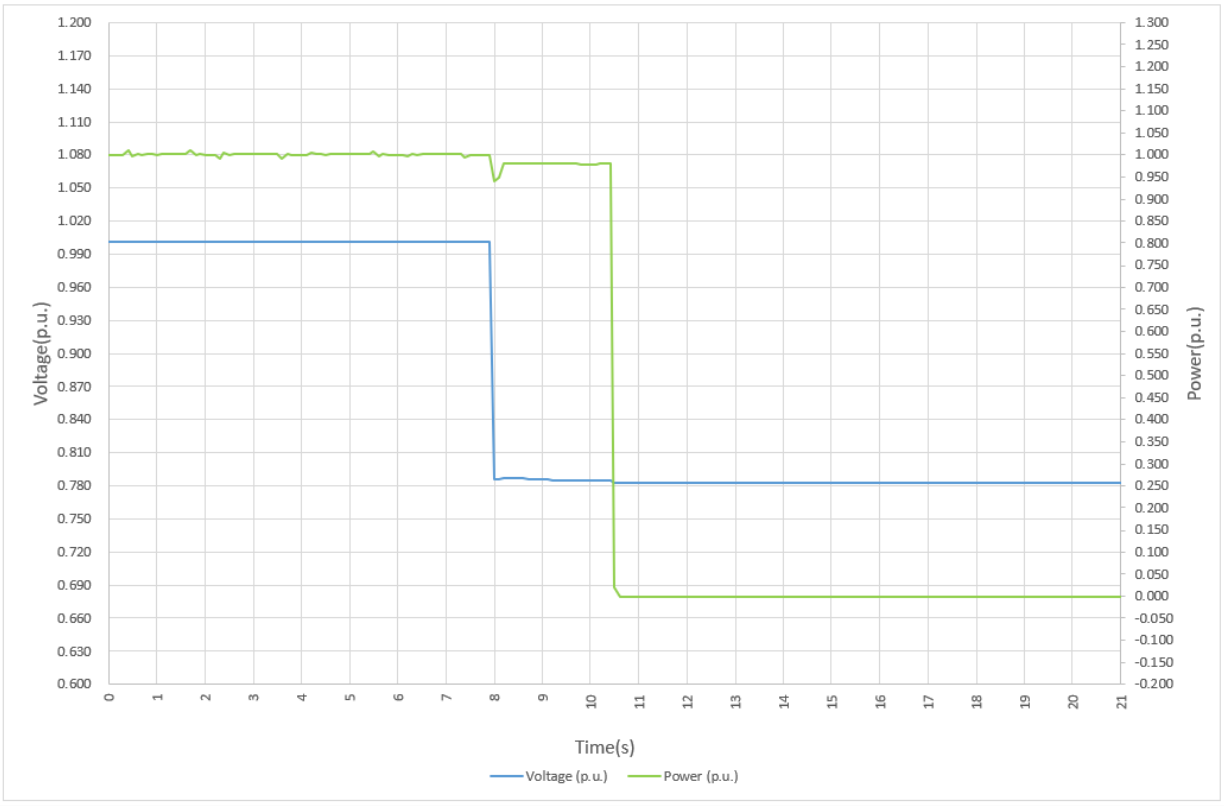

Tek Stop
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.97 s
a 1.635 s -4.639 V
b 2.138 s -4.638 V
Δ503.1ms Δ781.3µV
1 50.0 A
2 50.0 A
3 50.0 A
4 ↓5.00 V
Z 200ms
100kS/s
1M points
0.00 A
29 Jul 2020
09:24:40

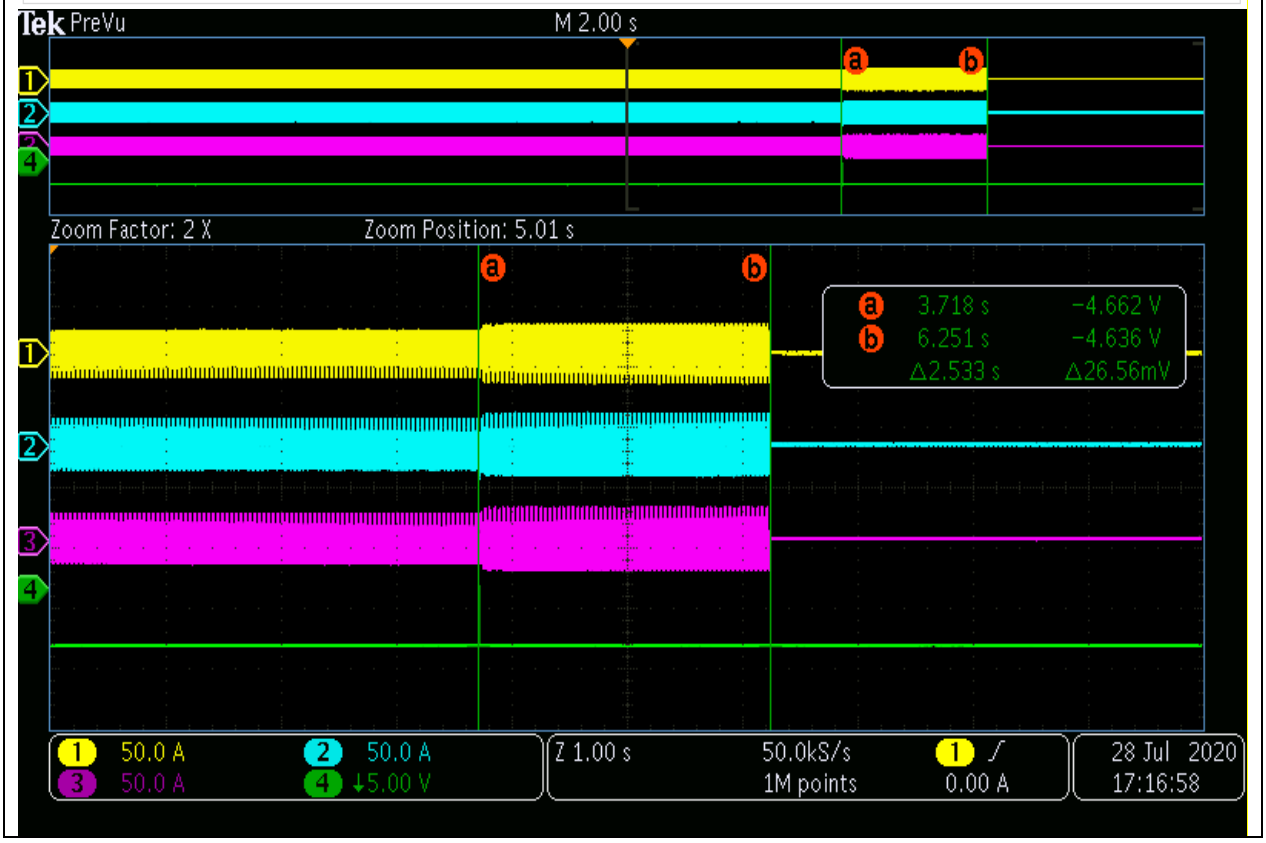
No trip tests – 188V



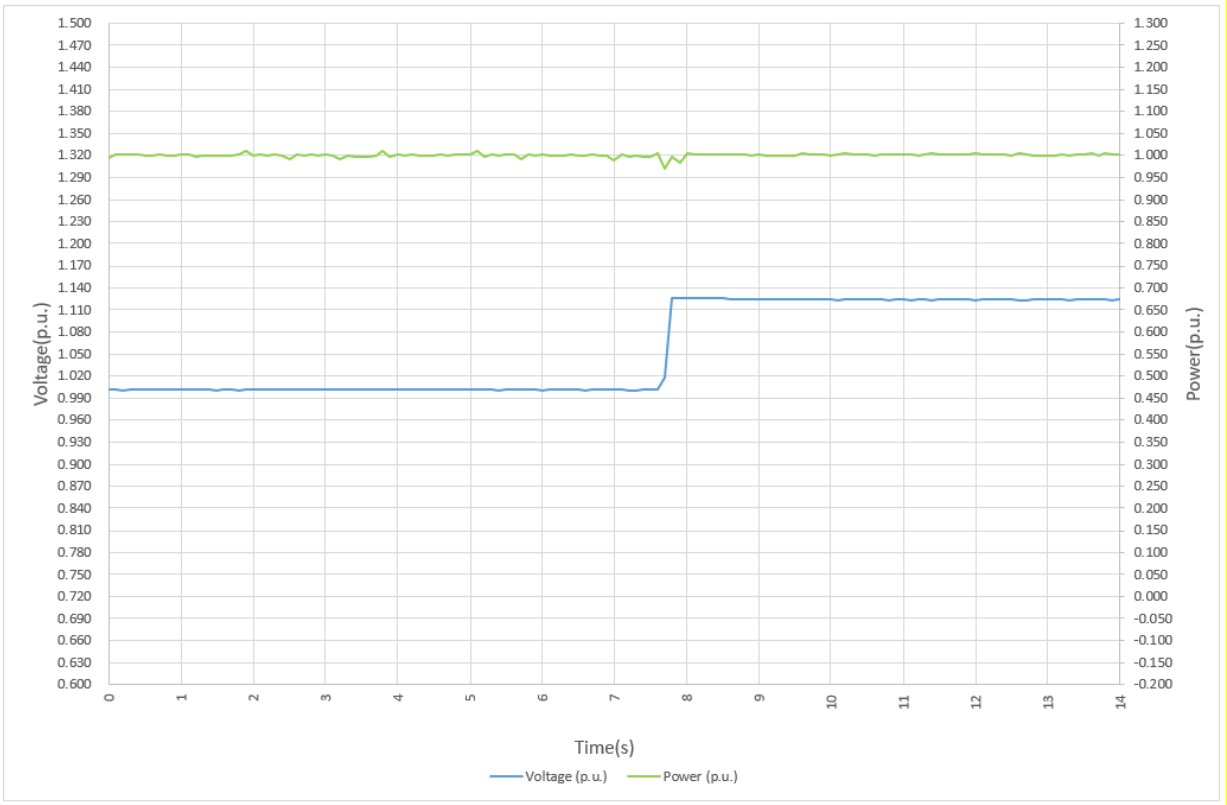


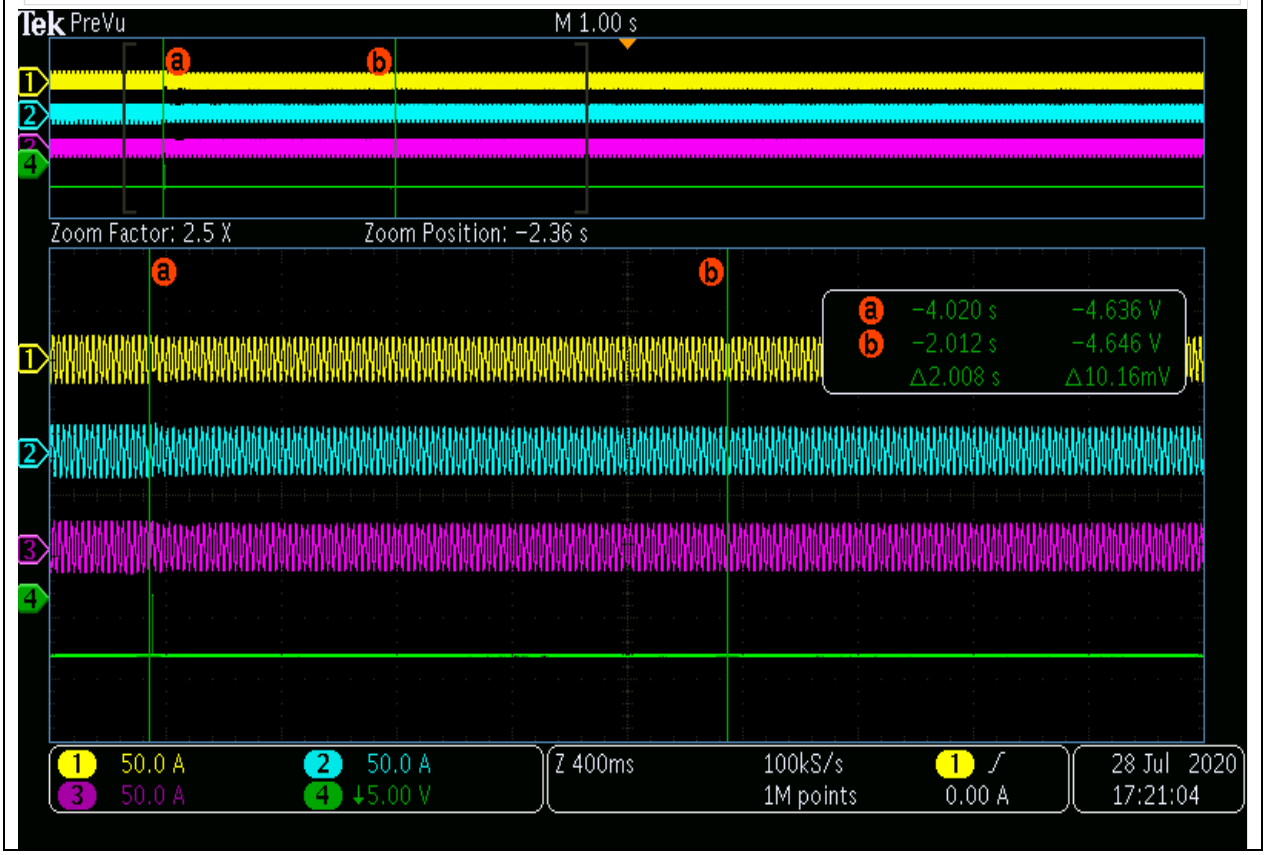
No trip tests – 180V



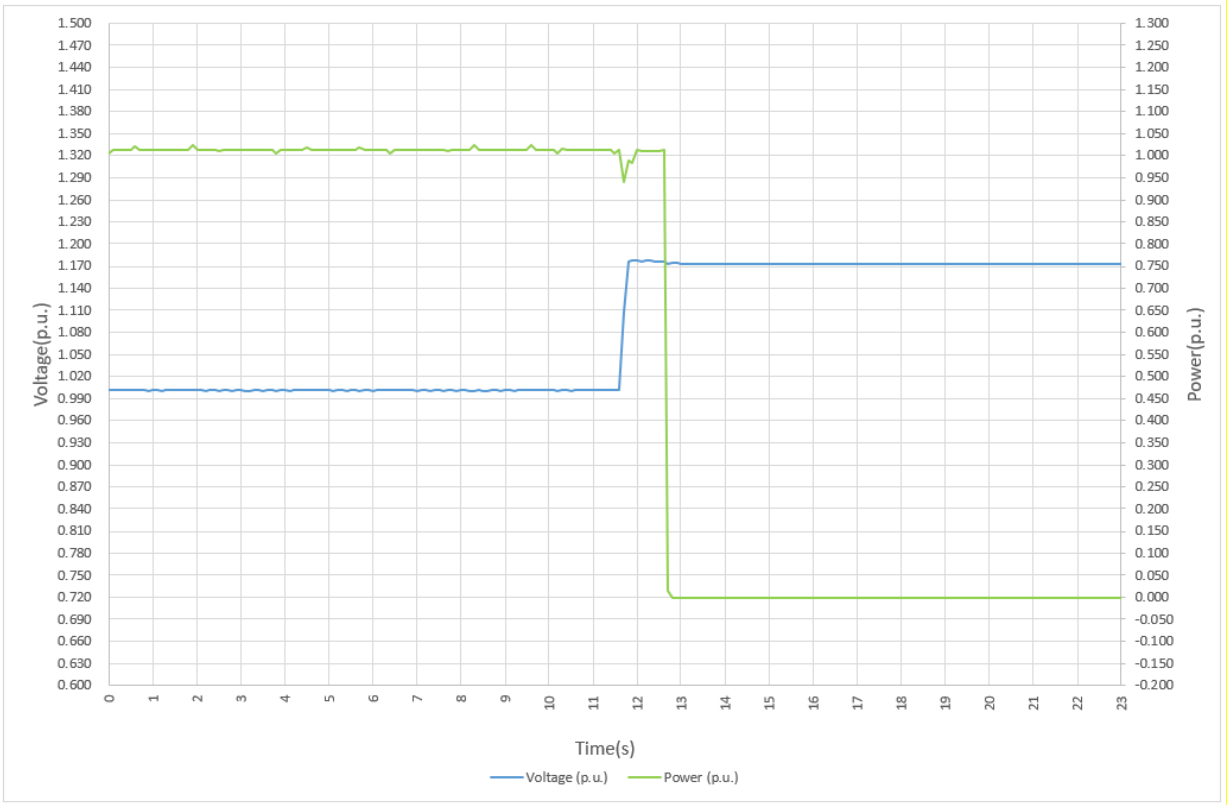


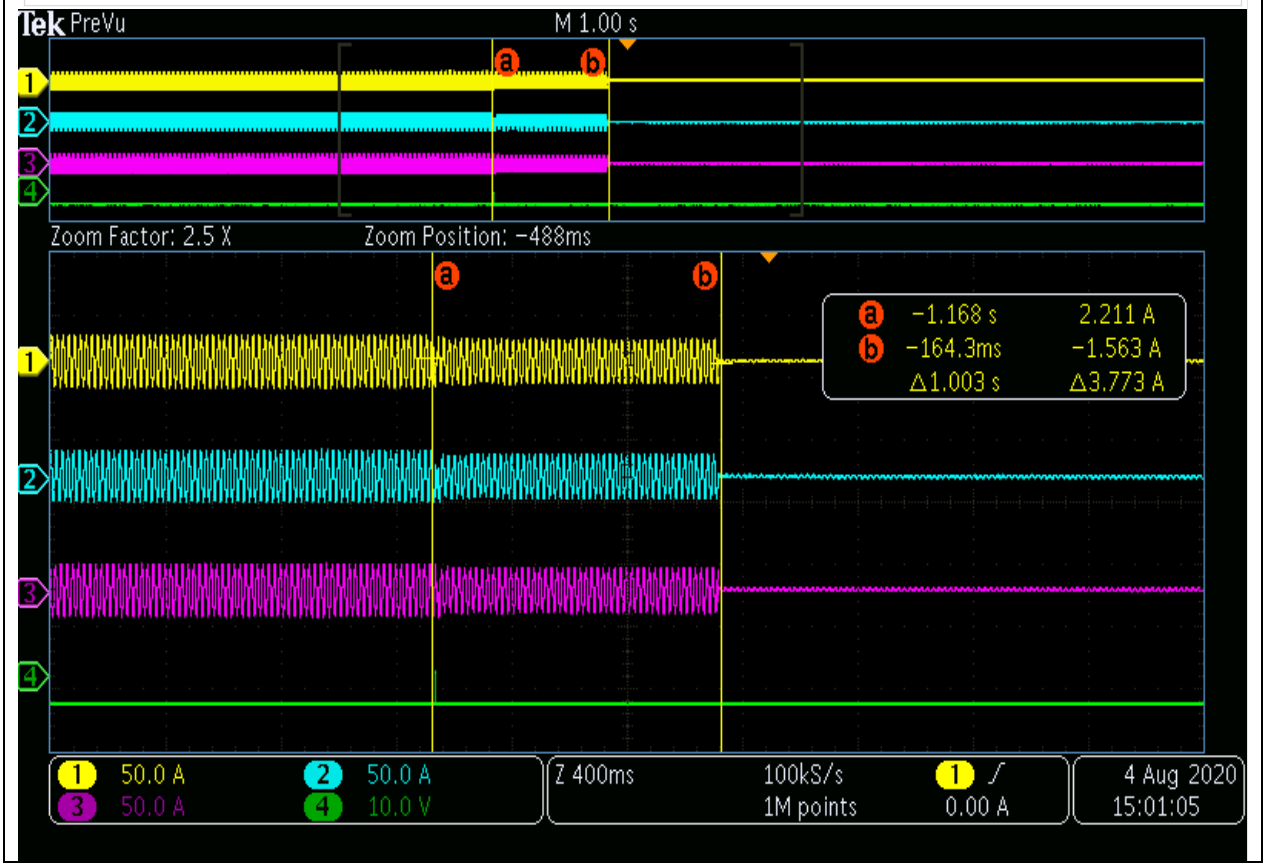
No trip tests – 258.2V



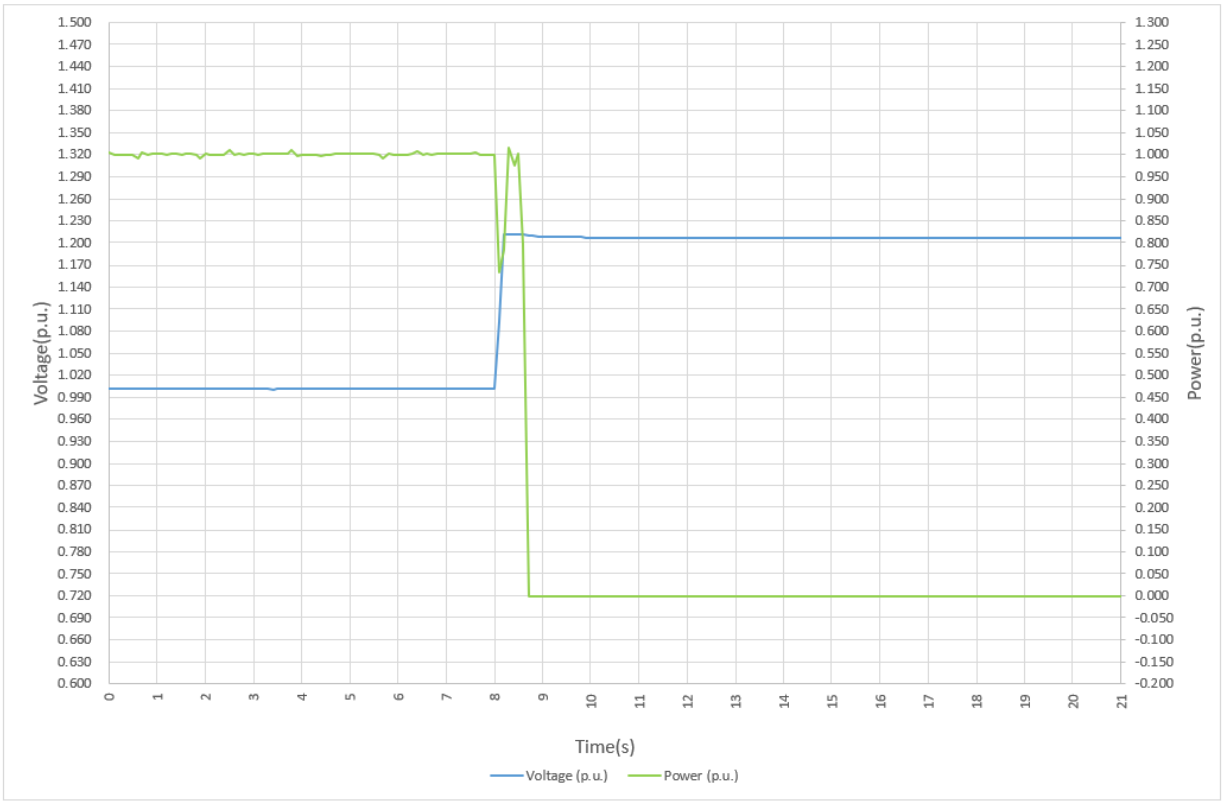


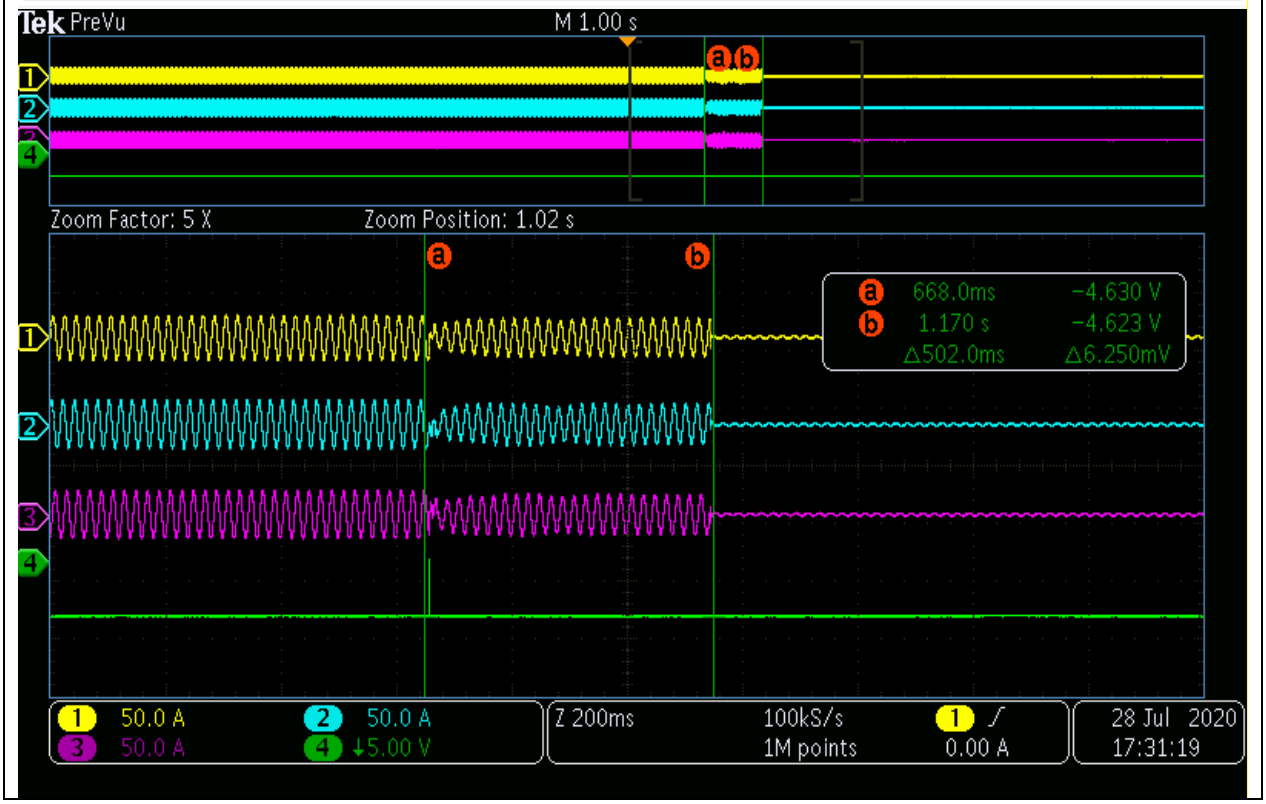
No trip tests – 269.7V





No trip tests – 277.7V





4.3.3 Loss of Mains test

For PV Inverters shall be tested in accordance with BS EN 62116.

The maximum trip time is 0.5 s.

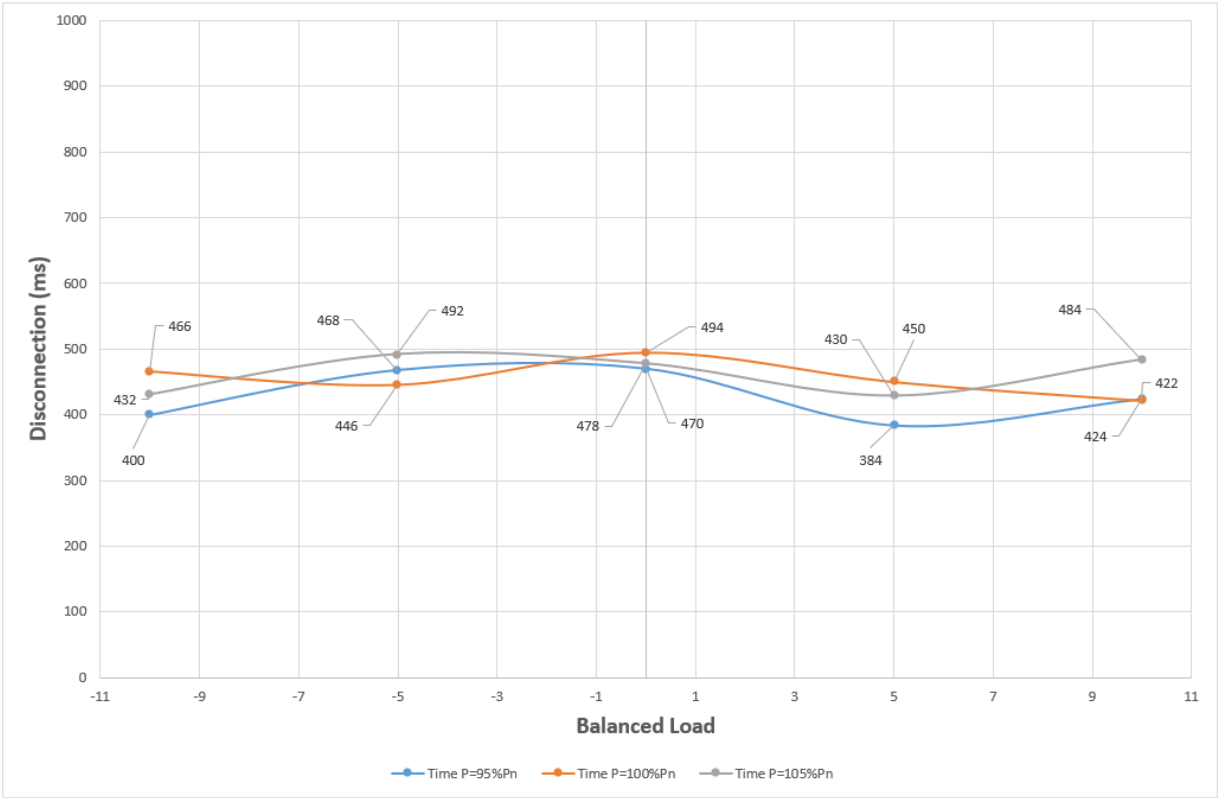
Note for technologies which have a substantial shut down time this can be added to the 0.5 s in establishing that the trip occurred in less than 0.5 s. Maximum shut down time could therefore be up to 1.0 s for these technologies.

Following tables show the test results:

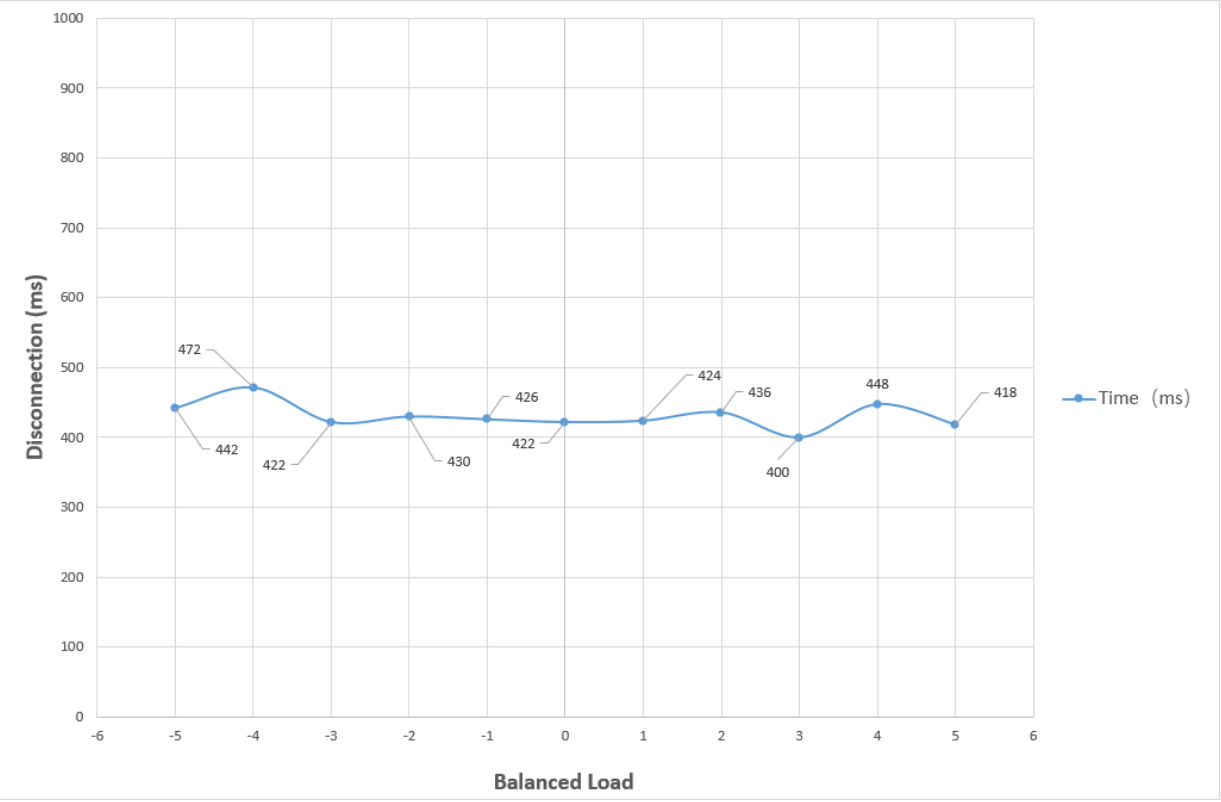
	Table: tested condition and trip time					P
No.	P_{EUT} (% of EUT rating)	Reactive load (% of normial)	P_{AC}	Q_{AC}	Trip time(s)	Which load is selected to be adjusted (R or L)
Test condition A						
1	100	100	0	0	494	--
2	100	100	-5	-5	468	R/L
3	100	100	-5	0	470	R
4	100	100	-5	+5	384	R/L
5	100	100	0	-5	446	L
6	100	100	0	+5	450	L
7	100	100	+5	-5	492	R/L
8	100	100	+5	0	478	R
9	100	100	+5	+5	430	R/L
10	100	100	-10	+10	408	R/L
11	100	100	-5	+10	424	R/L
12	100	100	0	+10	422	L
13	100	100	+10	+10	470	R/L
14	100	100	+10	+5	436	R/L
15	100	100	+10	0	470	R
16	100	100	+10	-5	474	R/L
17	100	100	+10	-10	476	R/L
18	100	100	+5	-10	432	R/L
19	100	100	+5	+10	484	R/L
20	100	100	0	-10	466	L
21	100	100	-5	-10	400	R/L
22	100	100	-10	-10	450	R/L
23	100	100	-10	-5	424	R/L
24	100	100	-10	0	472	R
25	100	100	-10	+5	388	R/L
Test condition B						
1	66	66	0	0	422	--
2	66	66	0	-5	442	L
3	66	66	0	-4	472	L
4	66	66	0	-3	422	L
5	66	66	0	-2	430	L
6	66	66	0	-1	426	L
7	66	66	0	1	424	L
8	66	66	0	2	436	L
9	66	66	0	3	400	L
10	66	66	0	4	448	L
11	66	66	0	5	418	L
Test condition C						
1	33	33	0	0	486	--
2	33	33	0	-5	422	L
3	33	33	0	-4	454	L
4	33	33	0	-3	466	L
5	33	33	0	-2	422	L
6	33	33	0	-1	458	L
7	33	33	0	1	472	L
8	33	33	0	2	432	L
9	33	33	0	3	438	L
10	33	33	0	4	436	L
11	33	33	0	5	416	L

Test results are graphically shown in following pages.

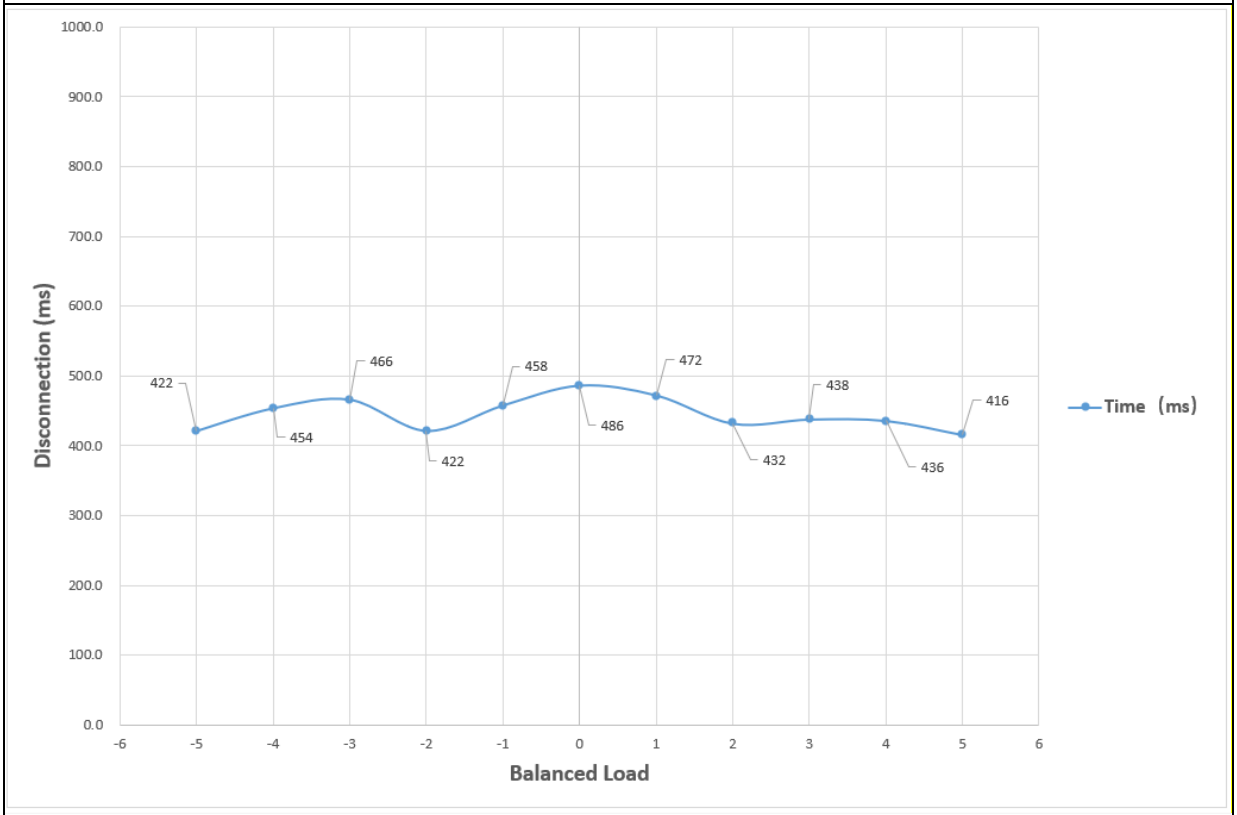
Test Condition A



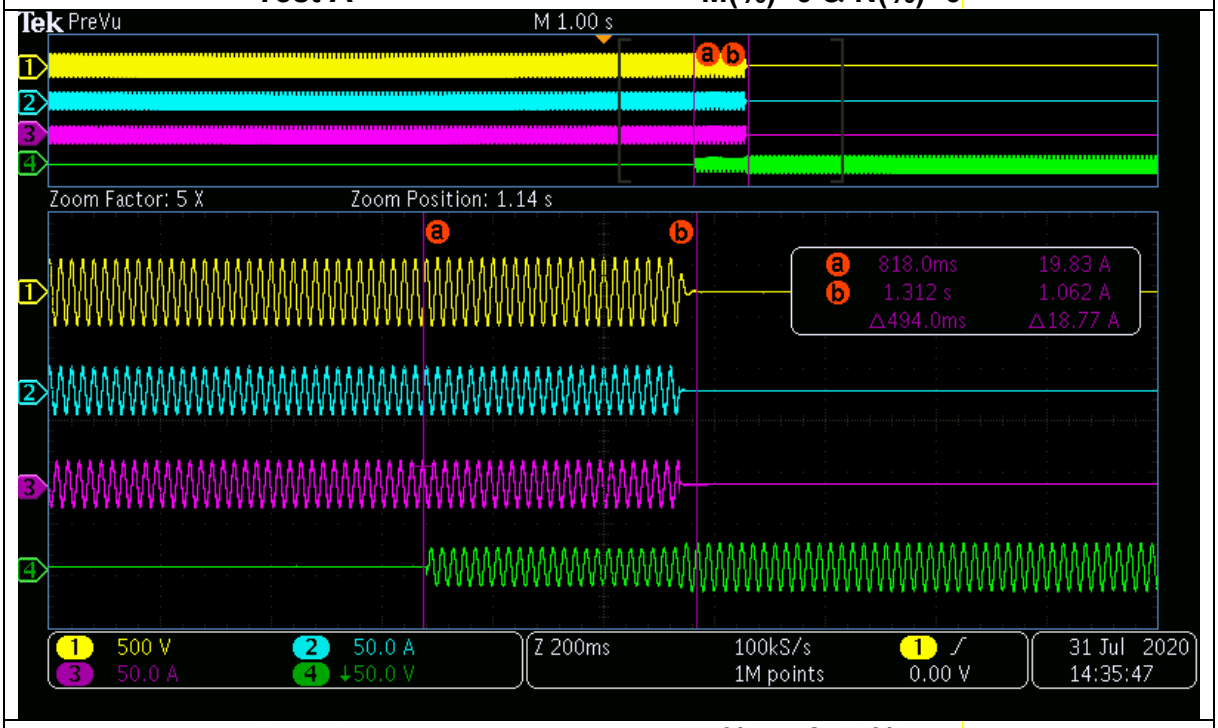
Test Condition B



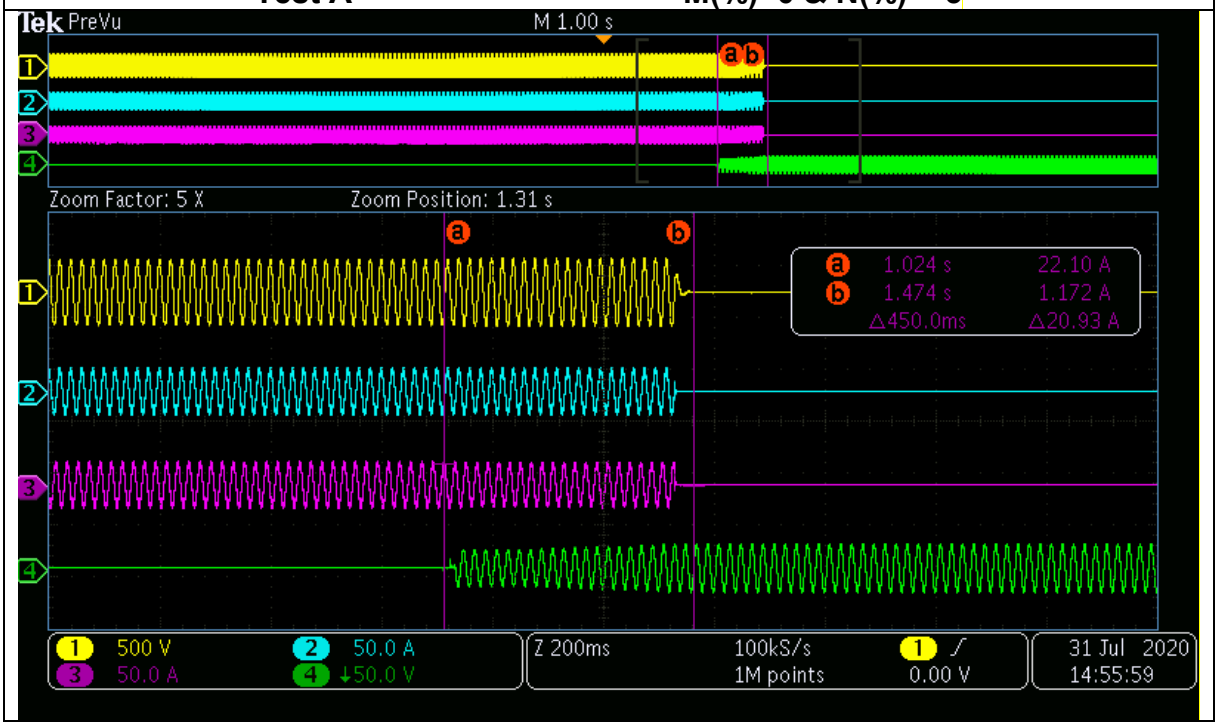
Test Condition C



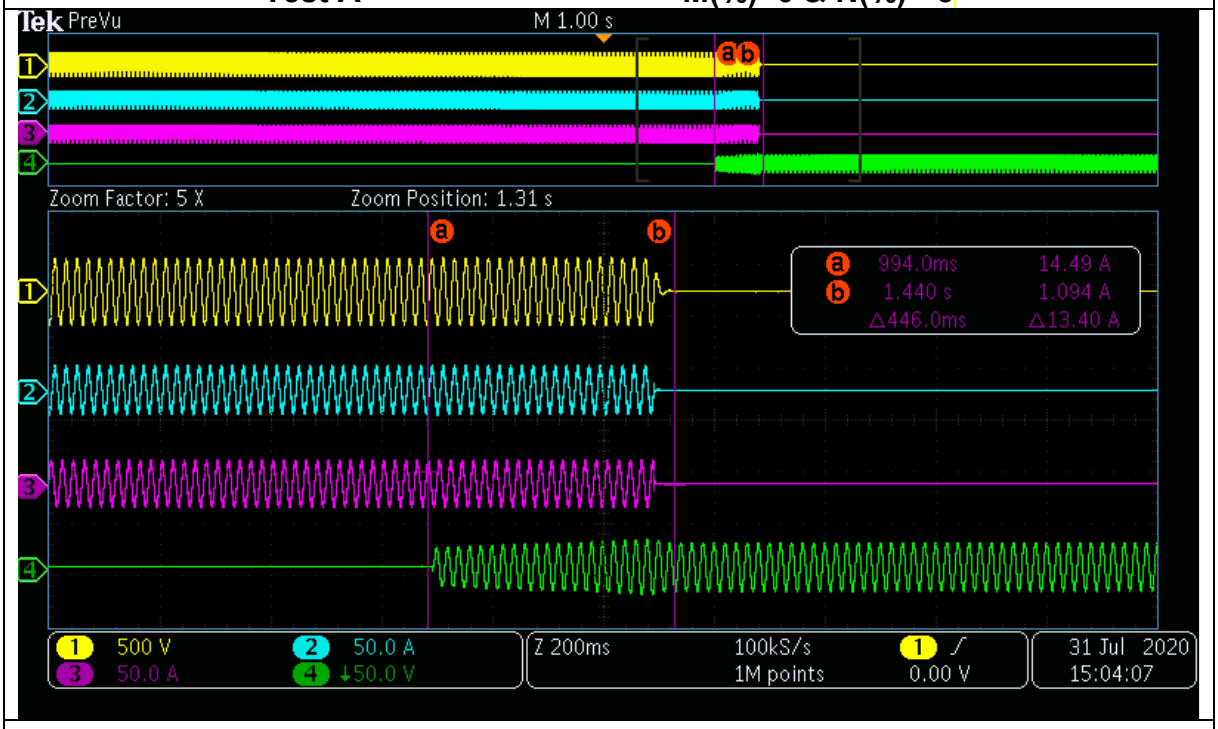
Test A **M(%)=0 & N(%)=0**



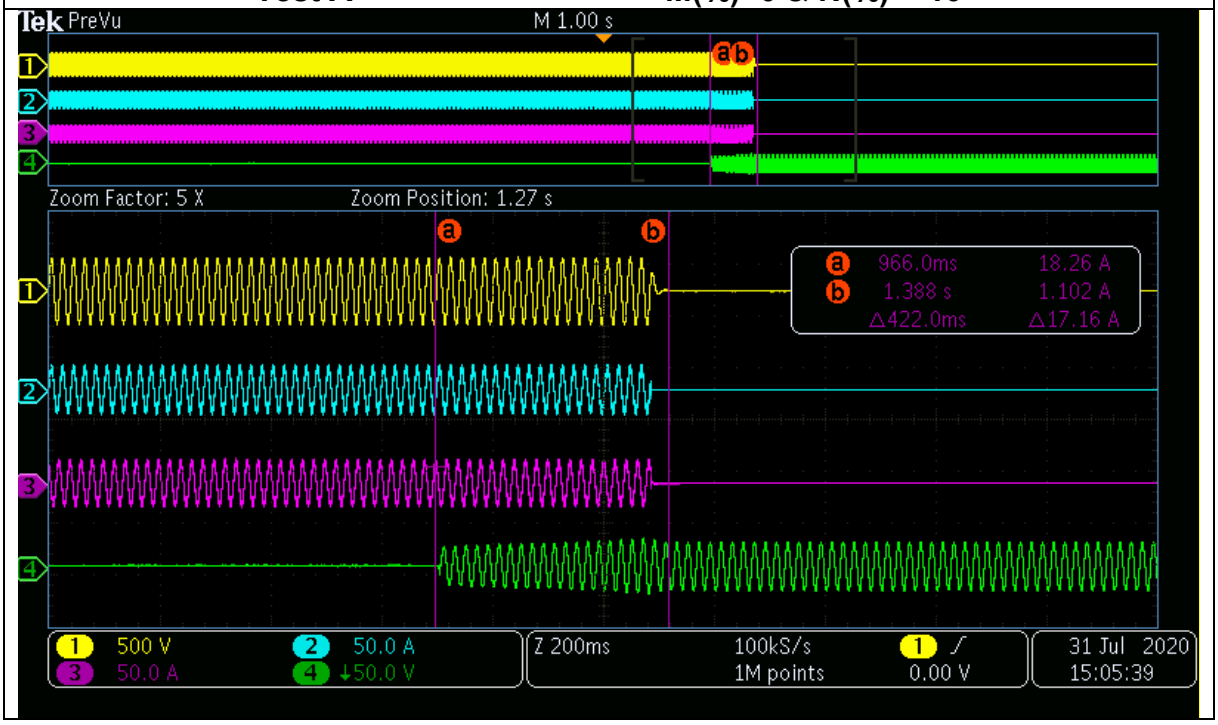
Test A **M(%)=0 & N(%)=+5**



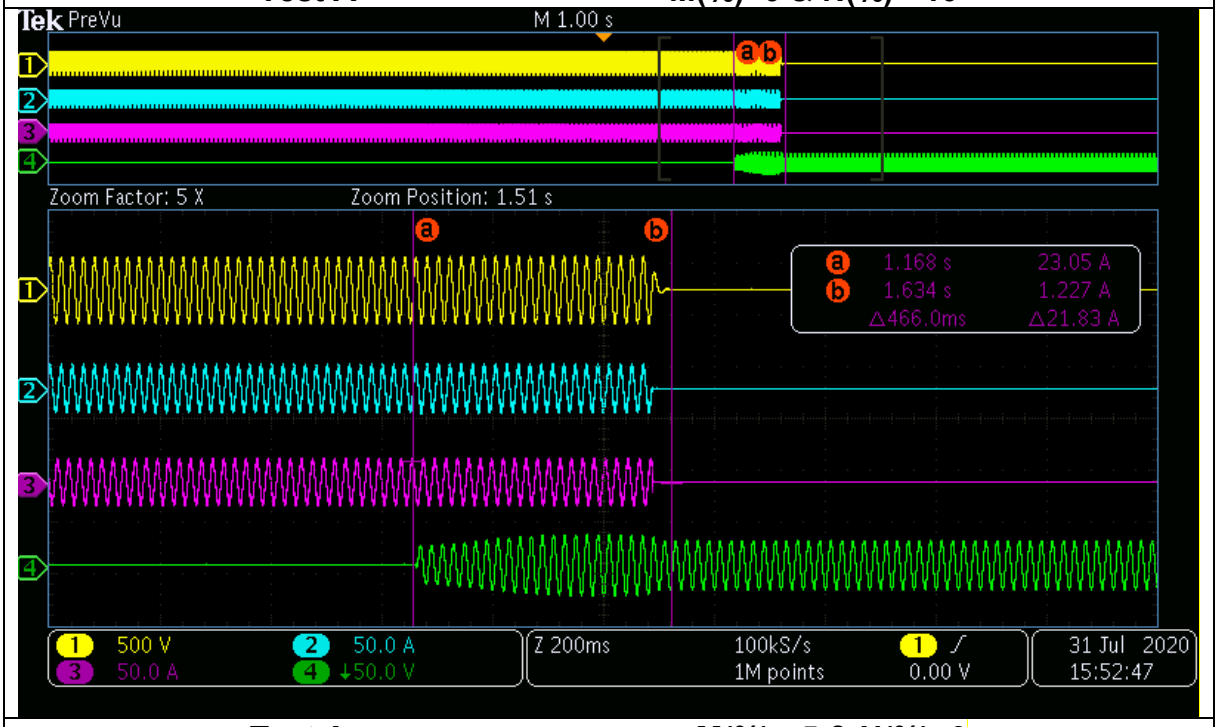
Test A **M(%)=0 & N(%)=-5**



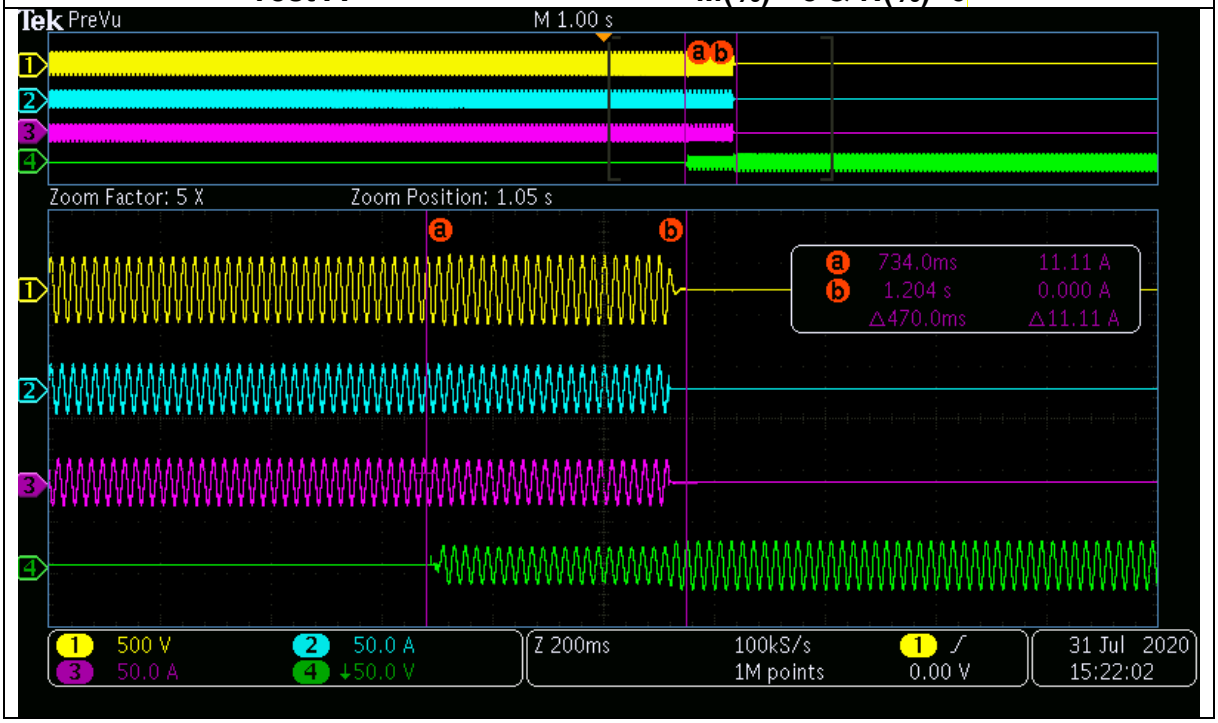
Test A **M(%)=0 & N(%)=+10**



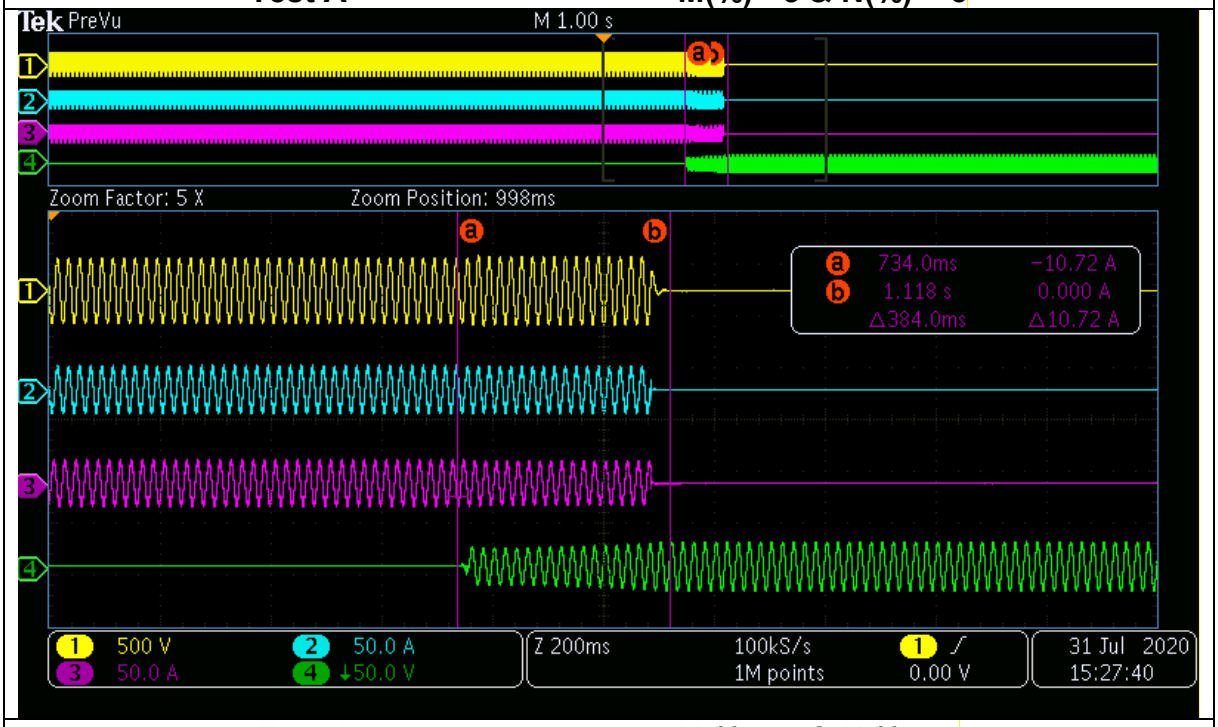
Test A **M(%)=0 & N(%)=-10**



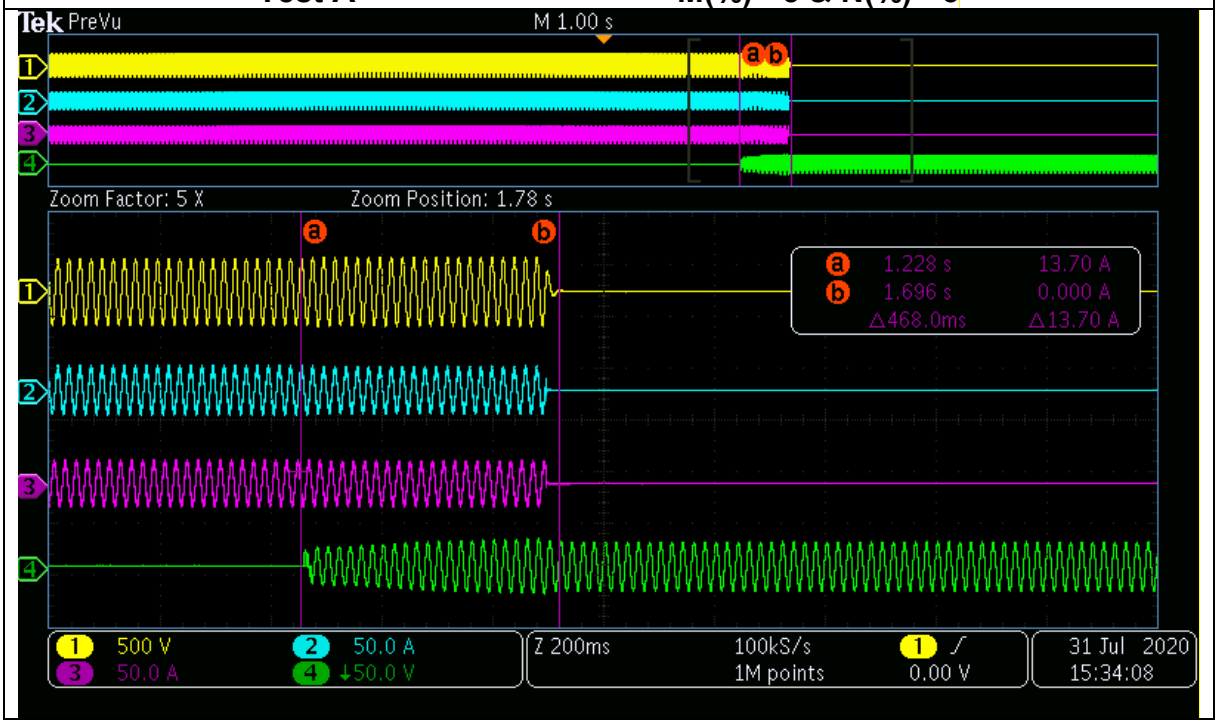
Test A **M(%)=-5 & N(%)=0**



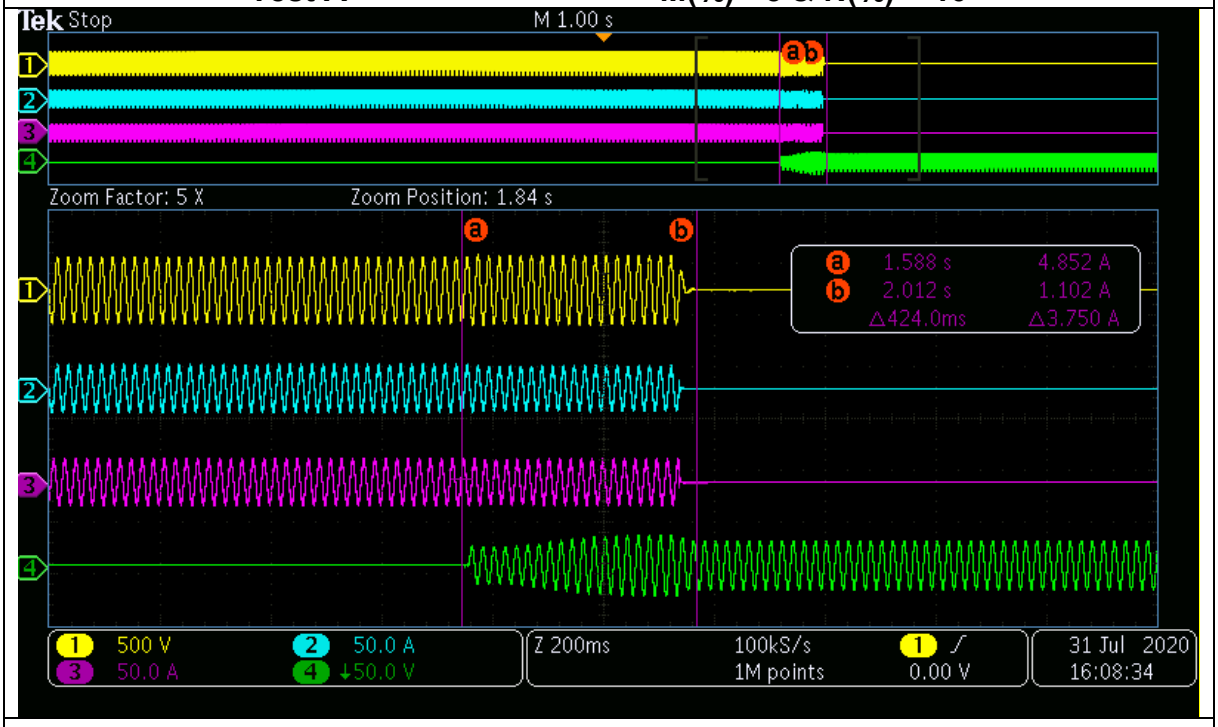
Test A **M(%)=-5 & N(%)=+5**



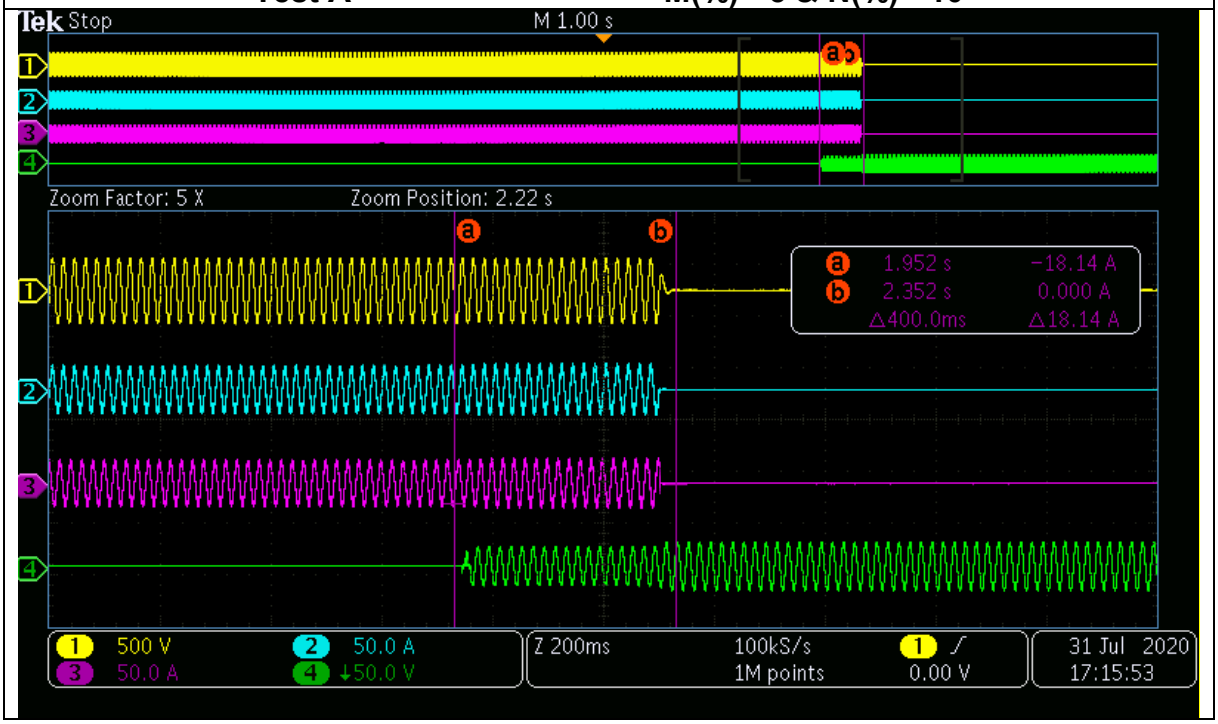
Test A **M(%)=-5 & N(%)=-5**



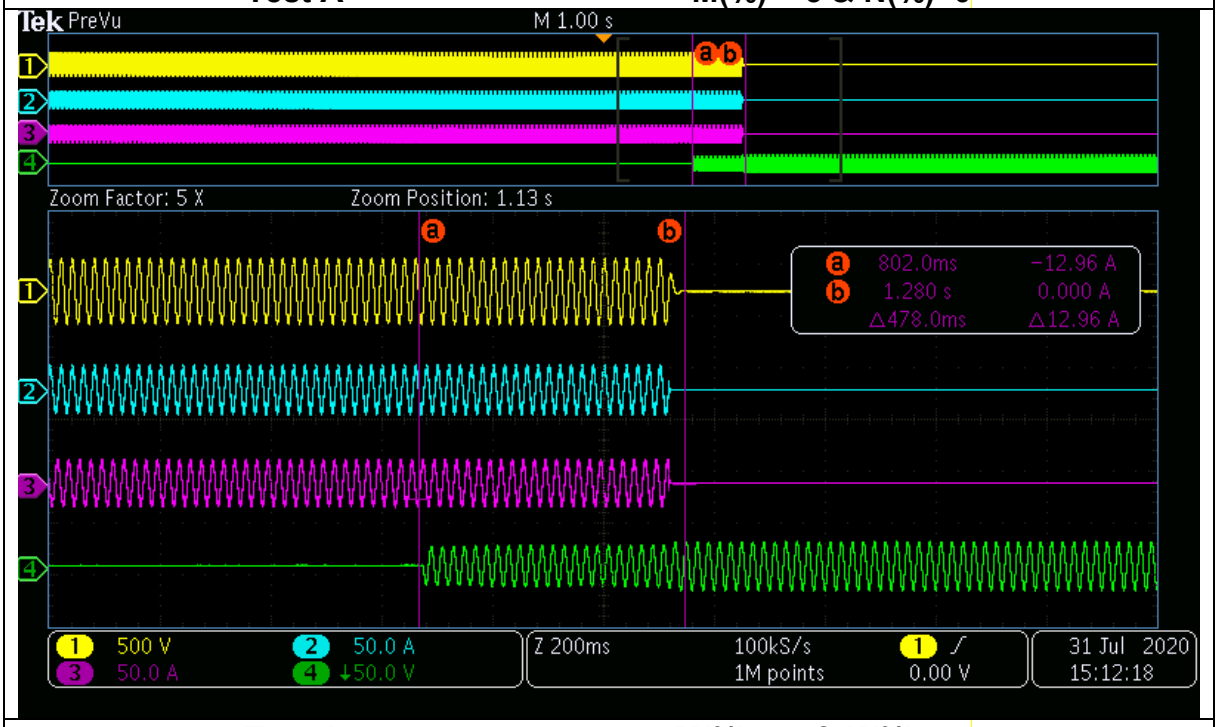
Test A **M(%)=-5 & N(%)=+10**



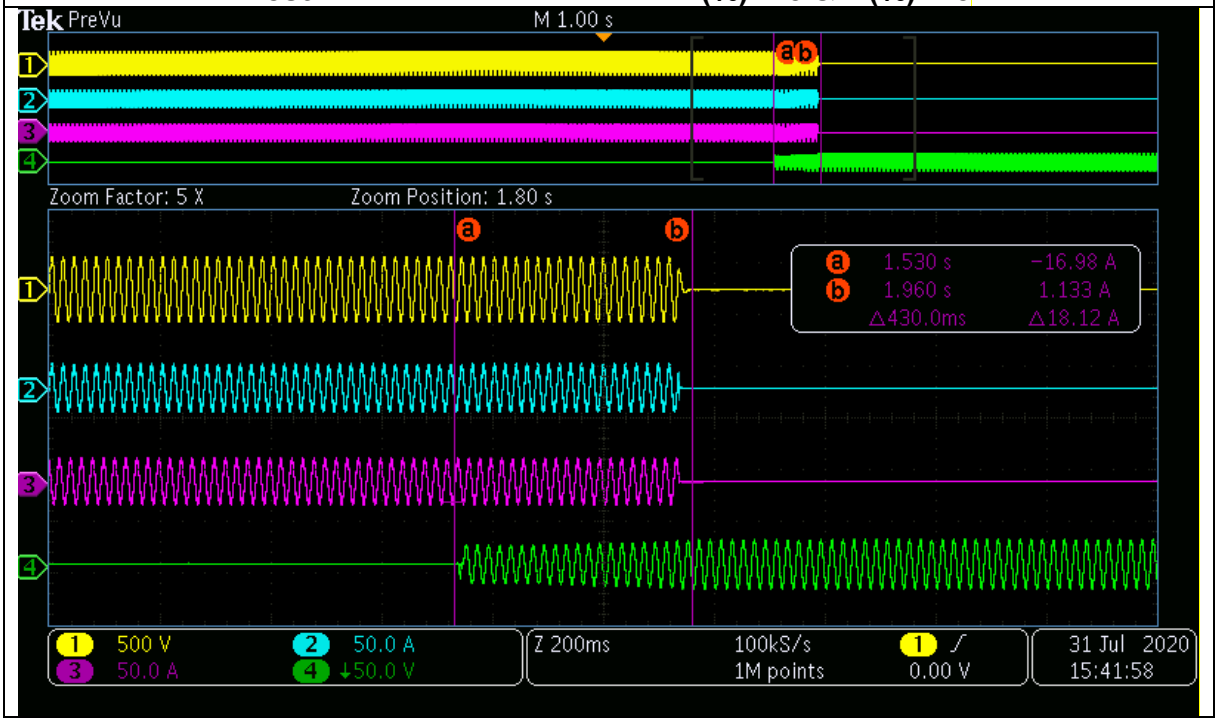
Test A **M(%)=-5 & N(%)=-10**



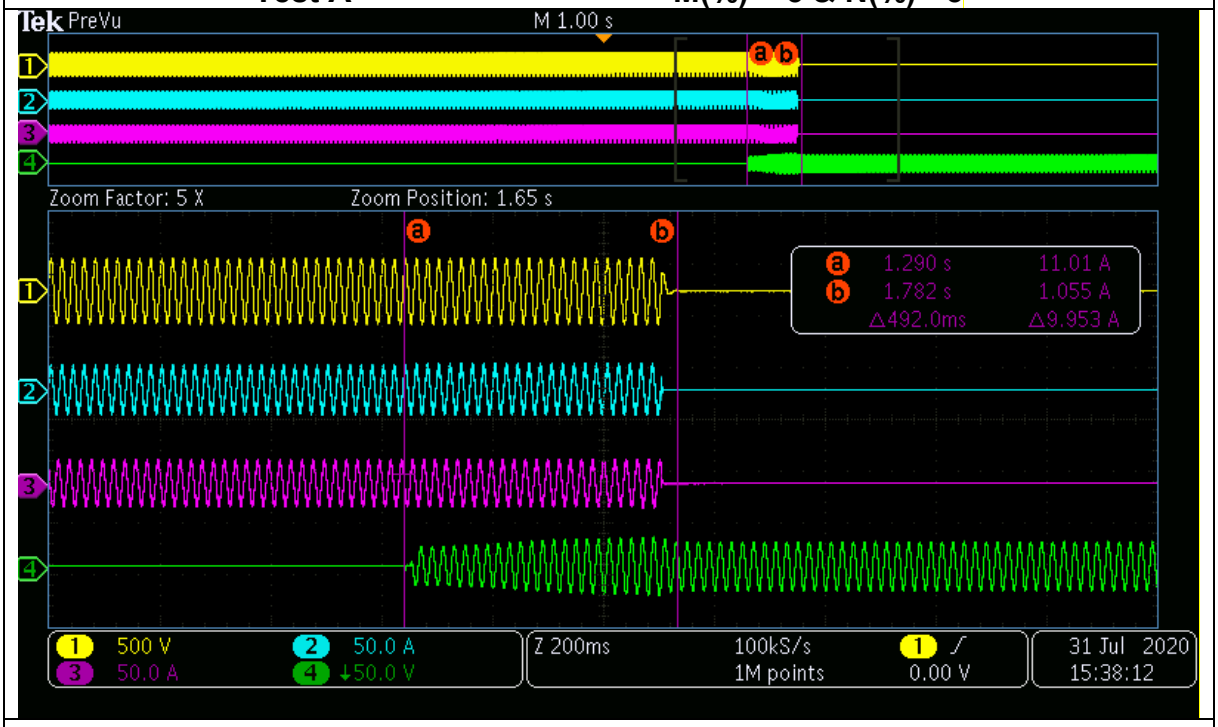
Test A **M(%)=+5 & N(%)=0**



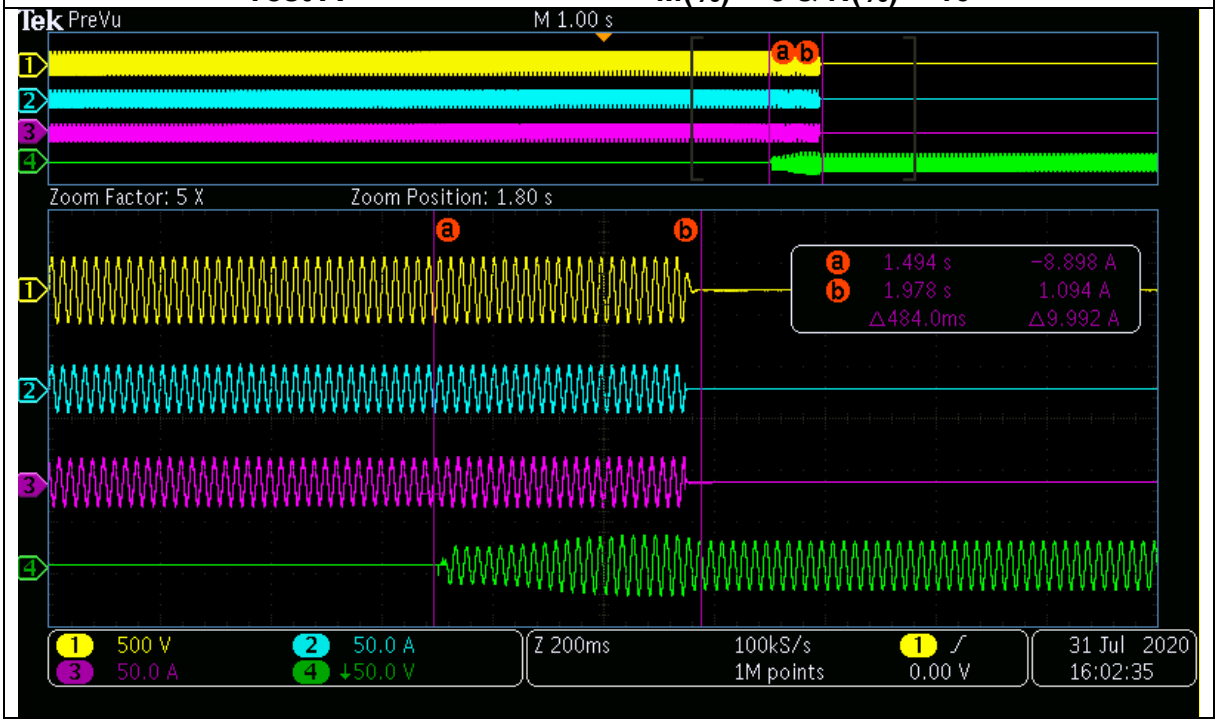
Test A **M(%)=+5 & N(%)=+5**



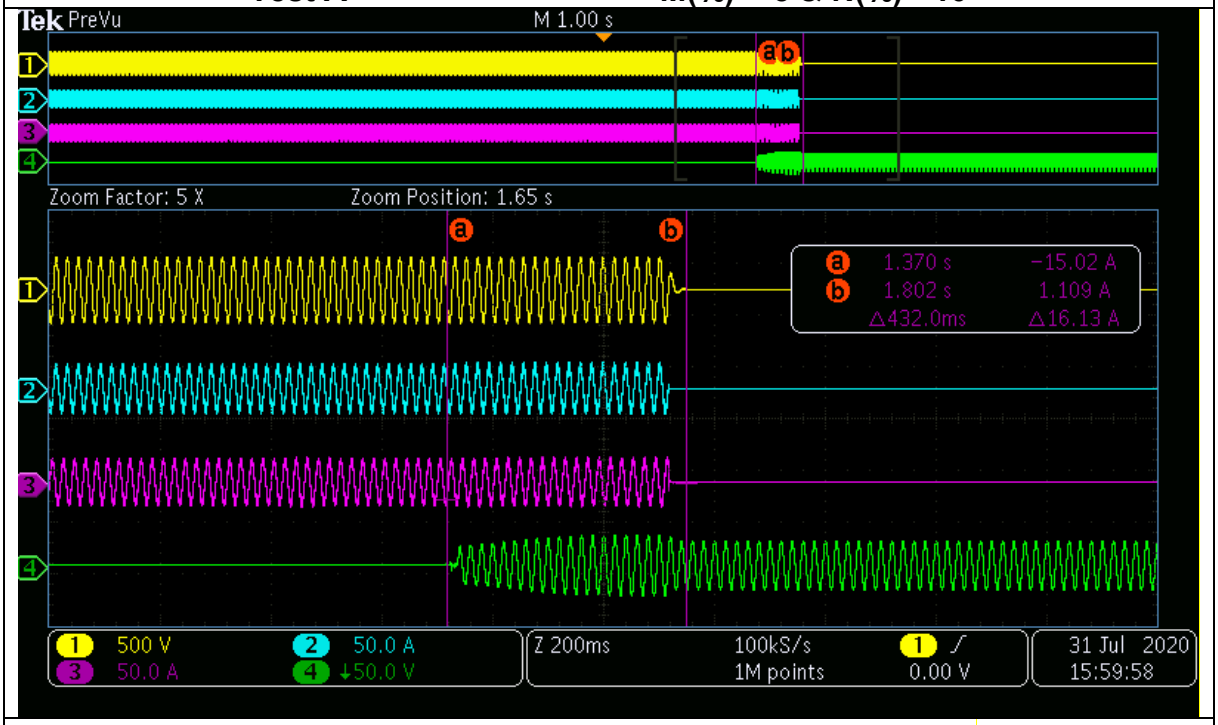
Test A **M(%)=+5 & N(%)=-5**



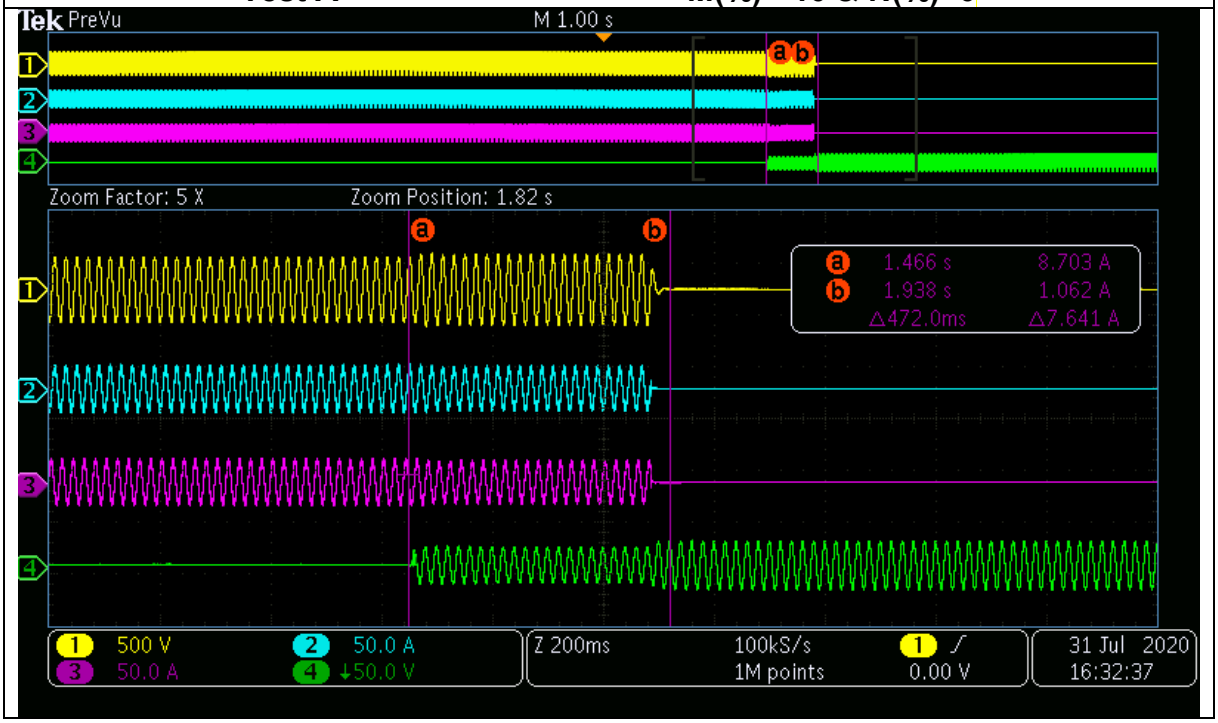
Test A **M(%)=+5 & N(%)=+10**



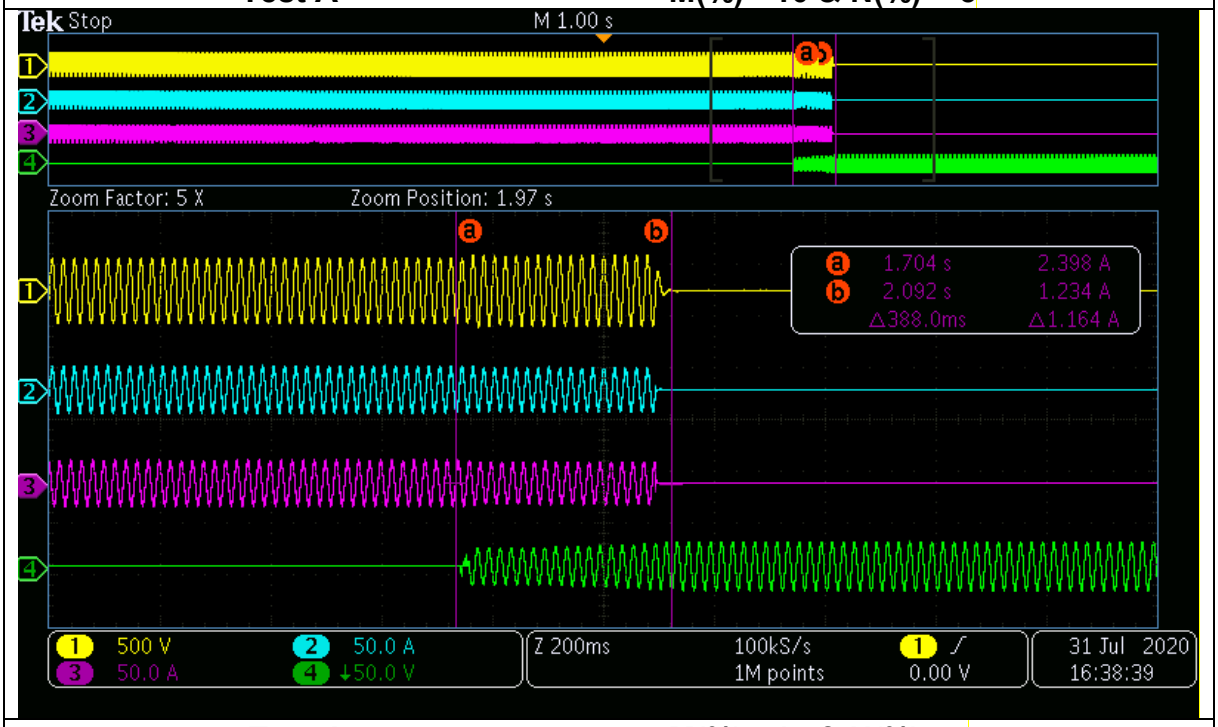
Test A **M(%)=+5 & N(%)=-10**



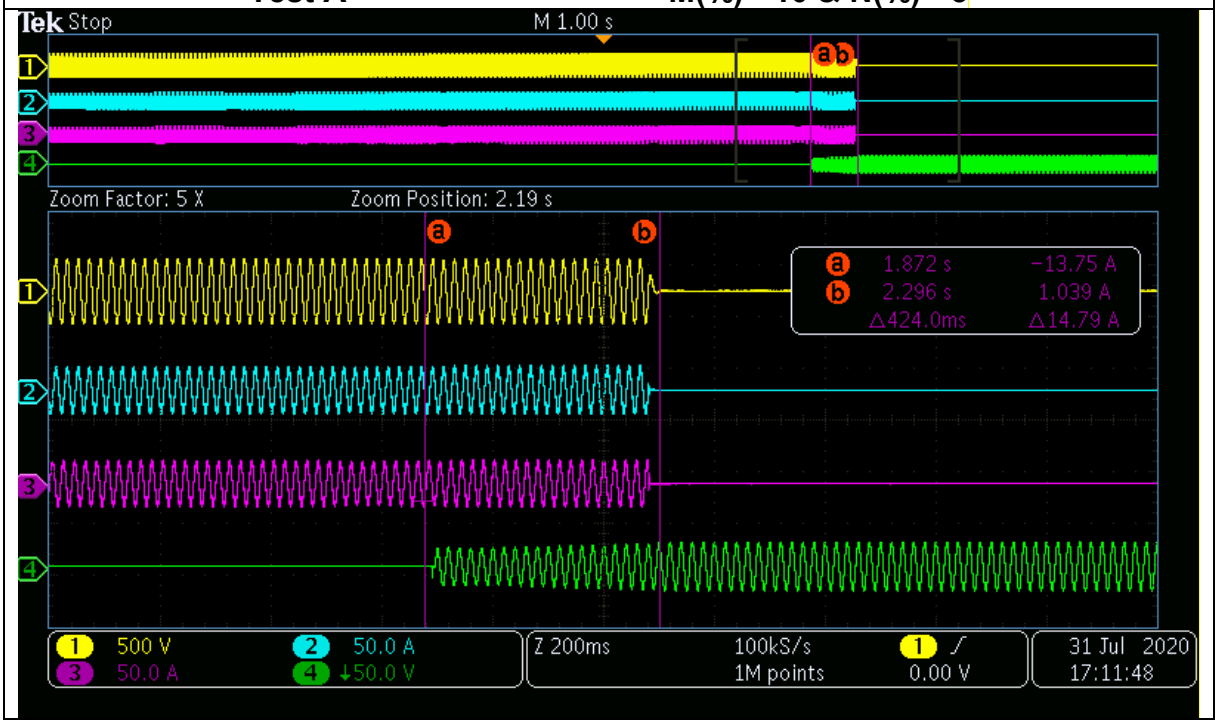
Test A **M(%)=-10 & N(%)=0**



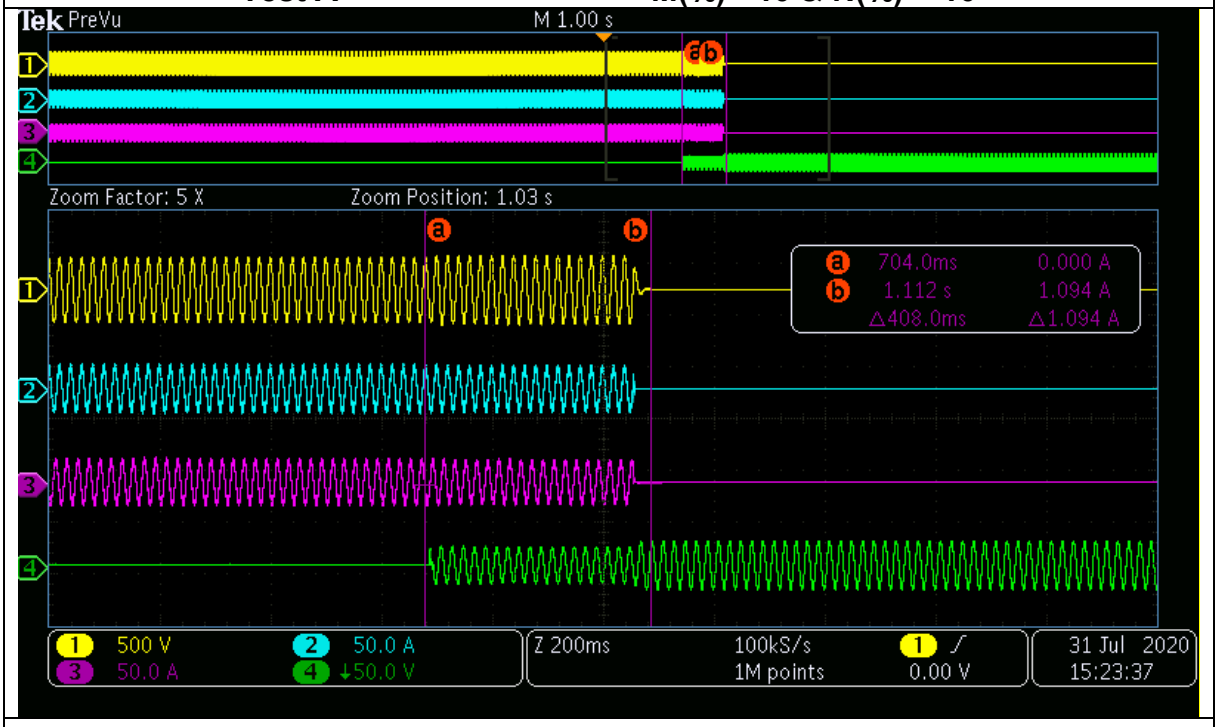
Test A **M(%)=-10 & N(%)=+5**



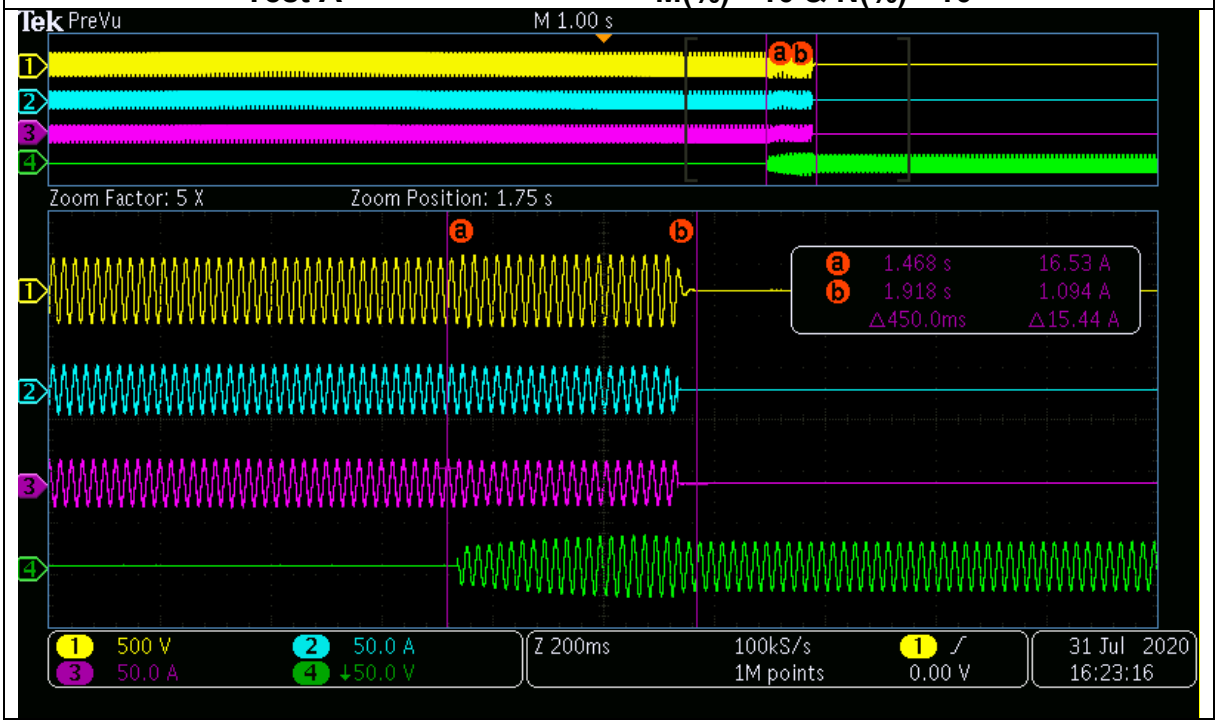
Test A **M(%)=-10 & N(%)=-5**



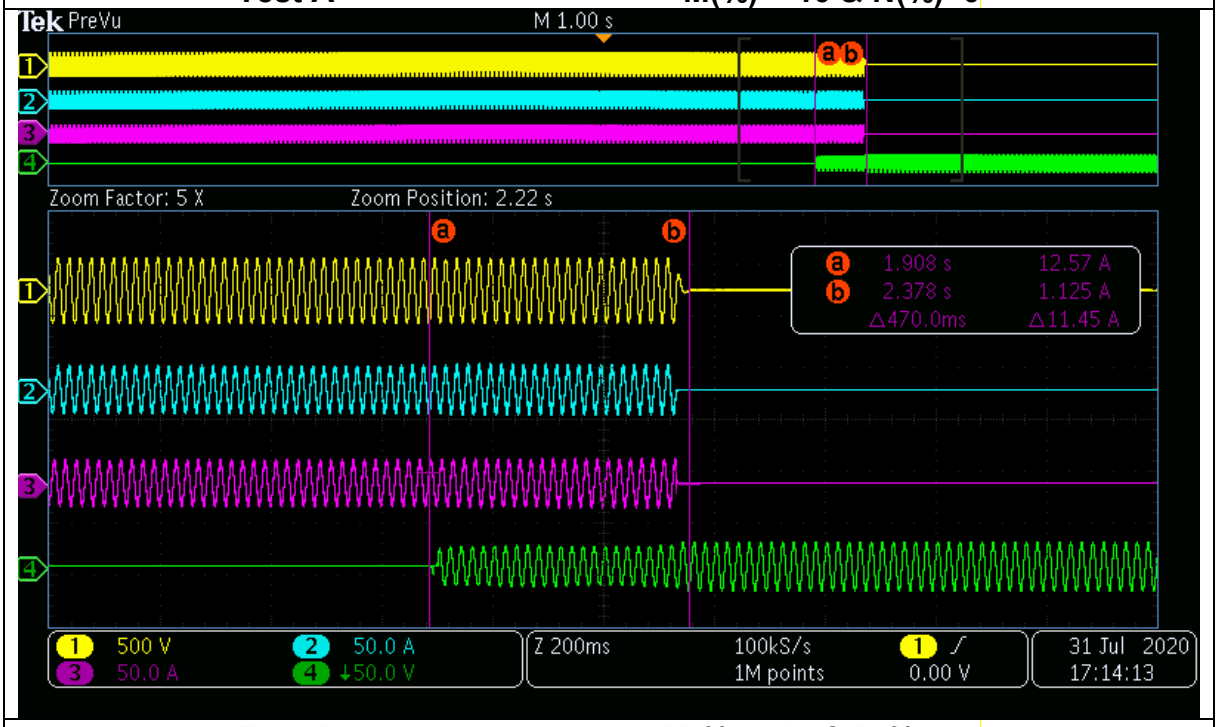
Test A **M(%)=-10 & N(%)=+10**



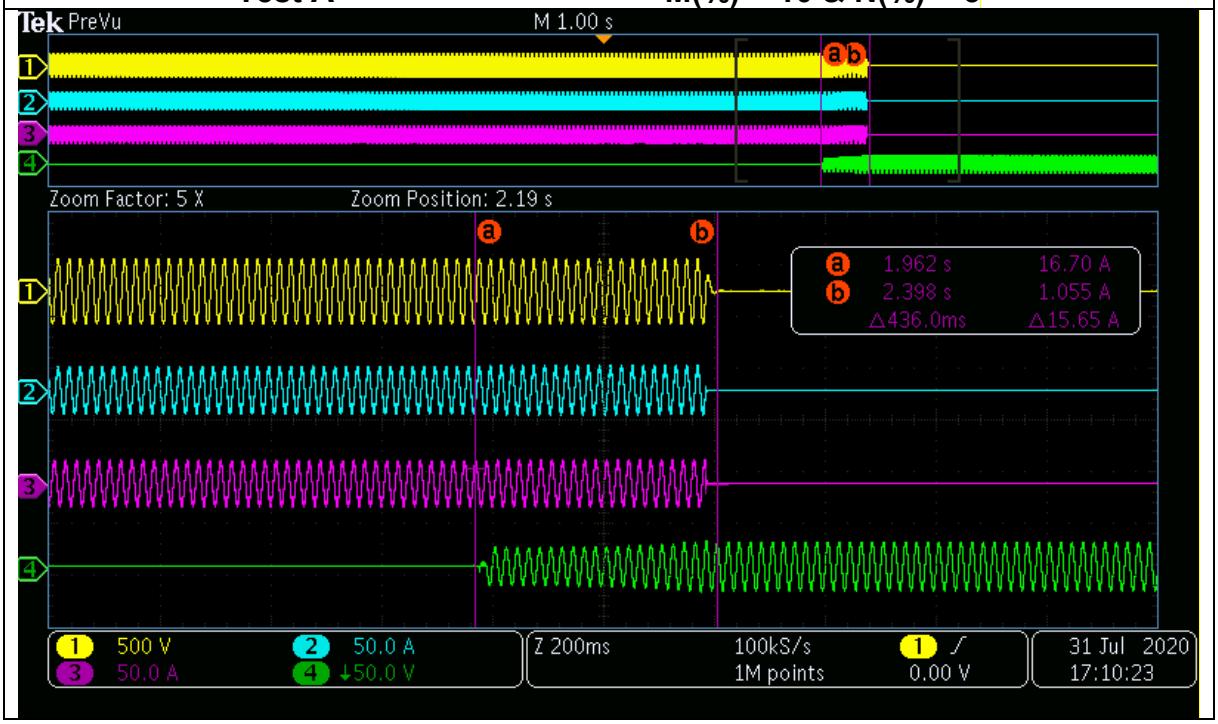
Test A **M(%)=-10 & N(%)=-10**



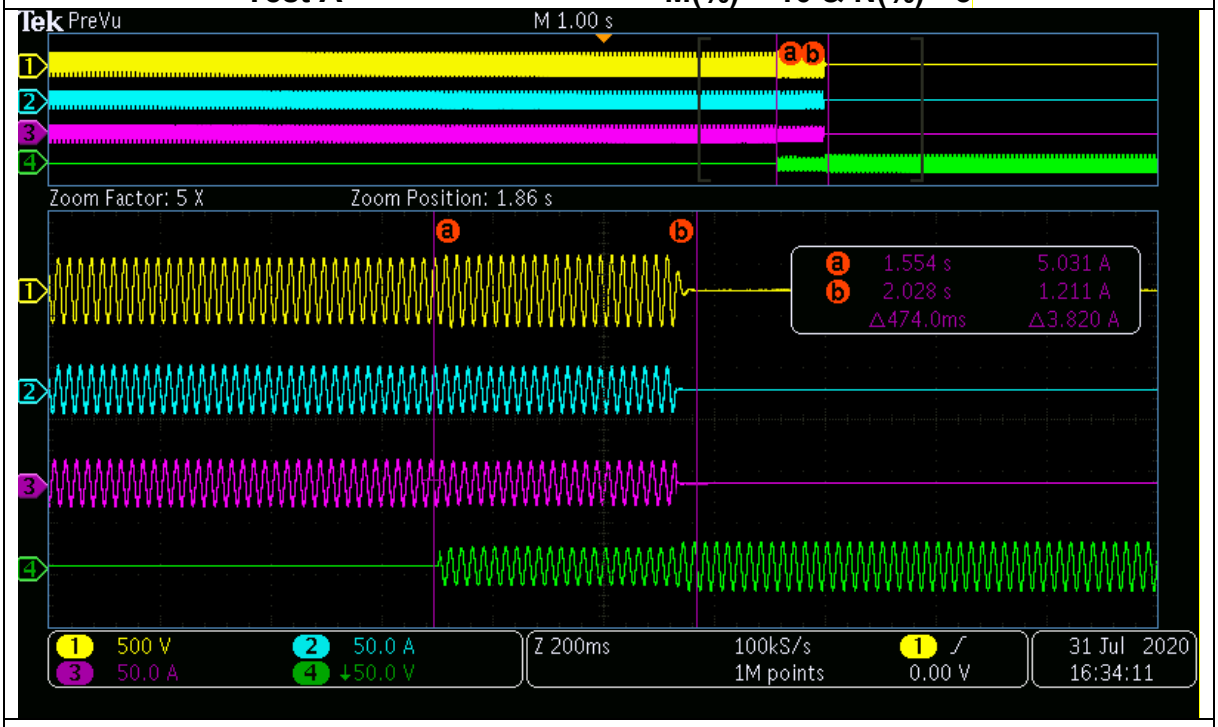
Test A **M(%)=+10 & N(%)=0**



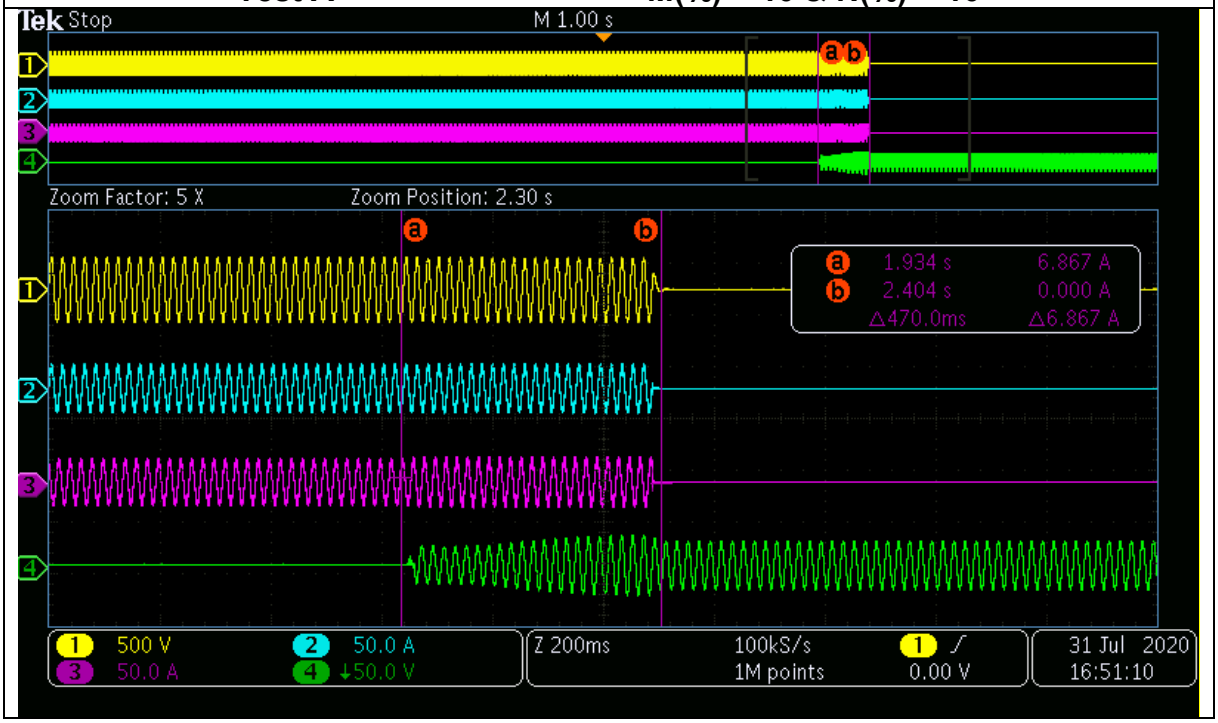
Test A **M(%)=+10 & N(%)=+5**



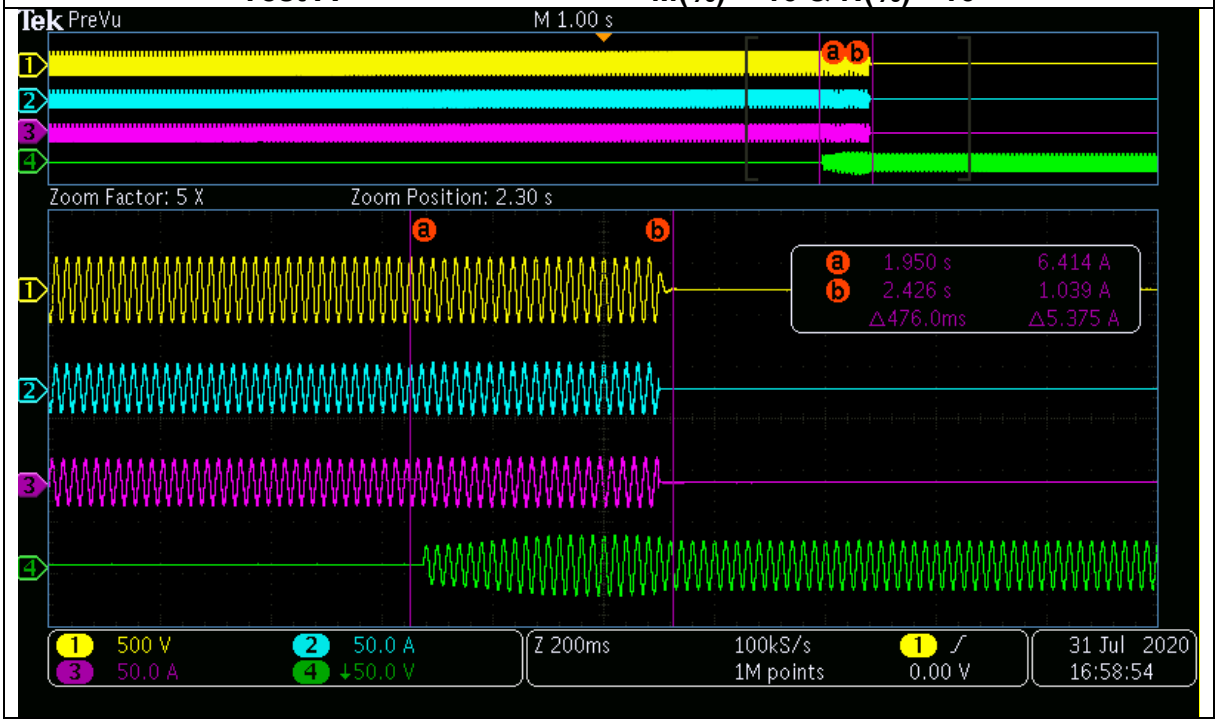
Test A **M(%)=+10 & N(%)=-5**



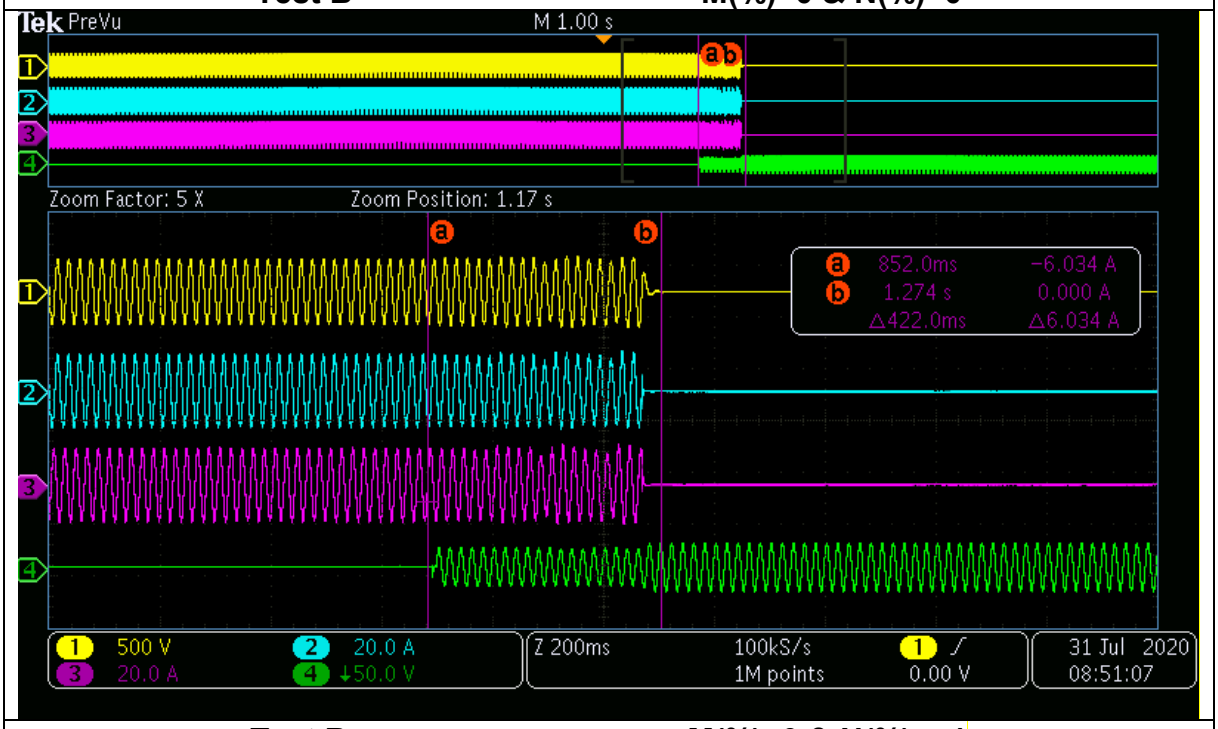
Test A **M(%)=+10 & N(%)=+10**



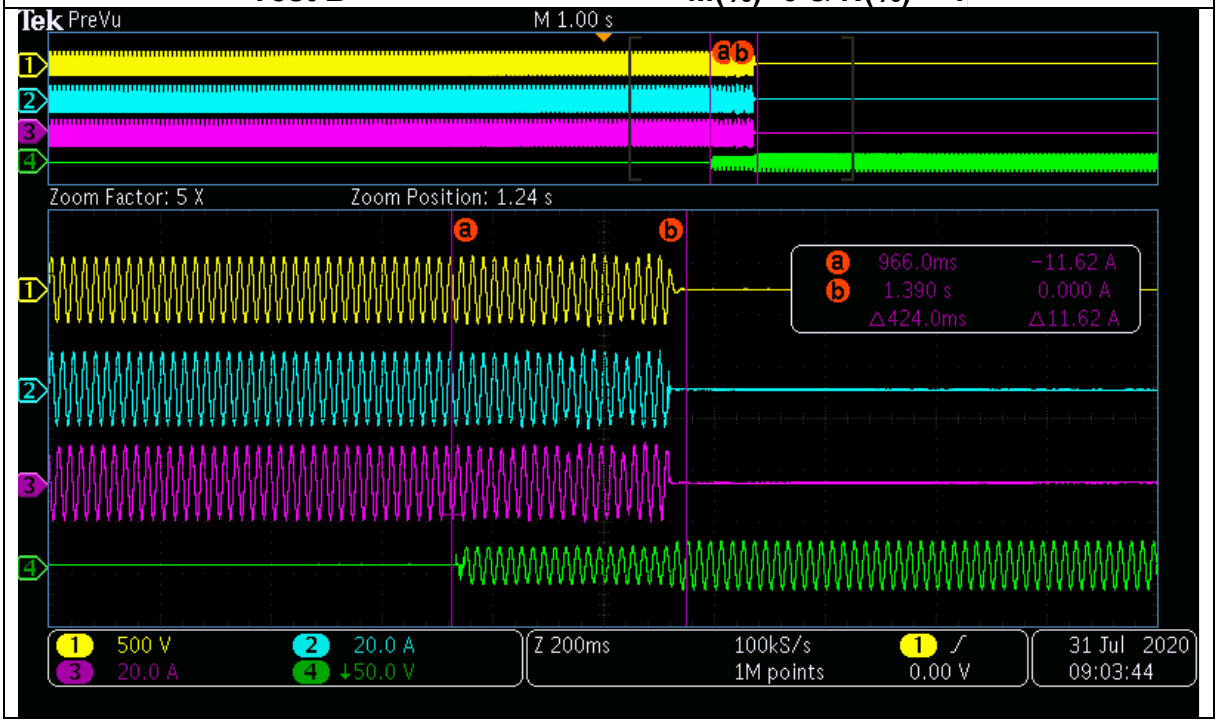
Test A **M(%)=+10 & N(%)=-10**



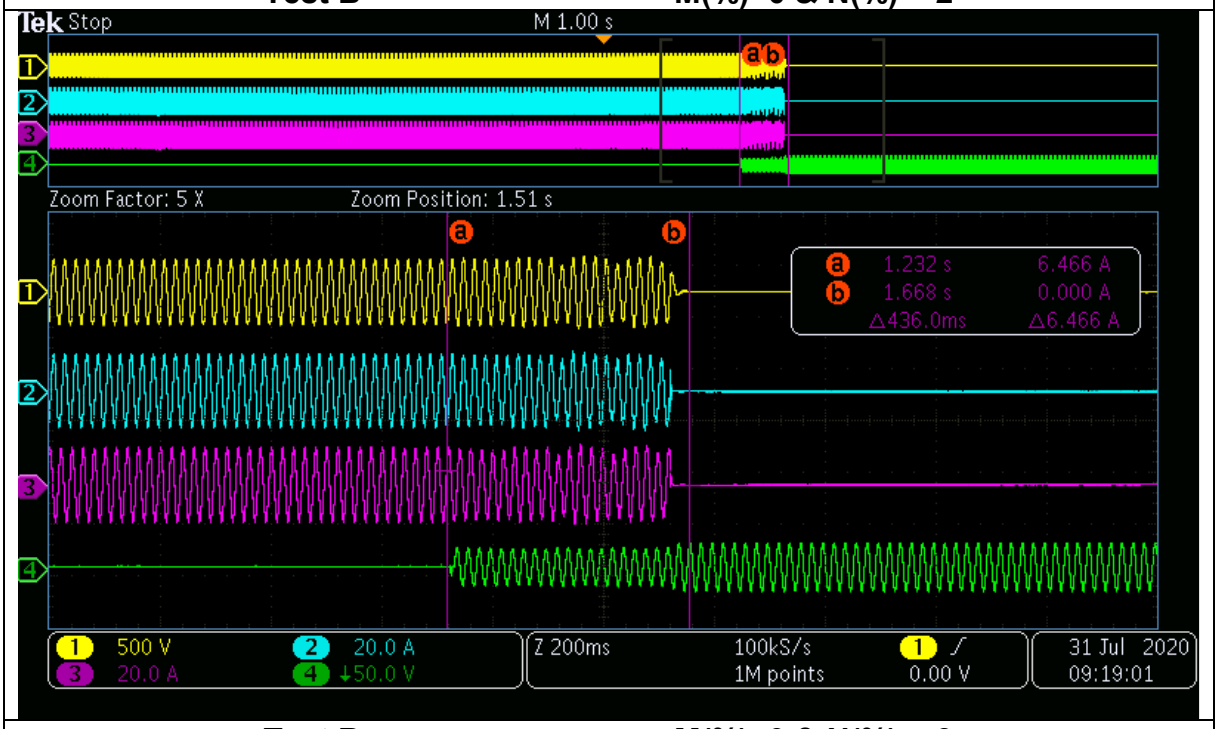
Test B **M(%)=0 & N(%)=0**



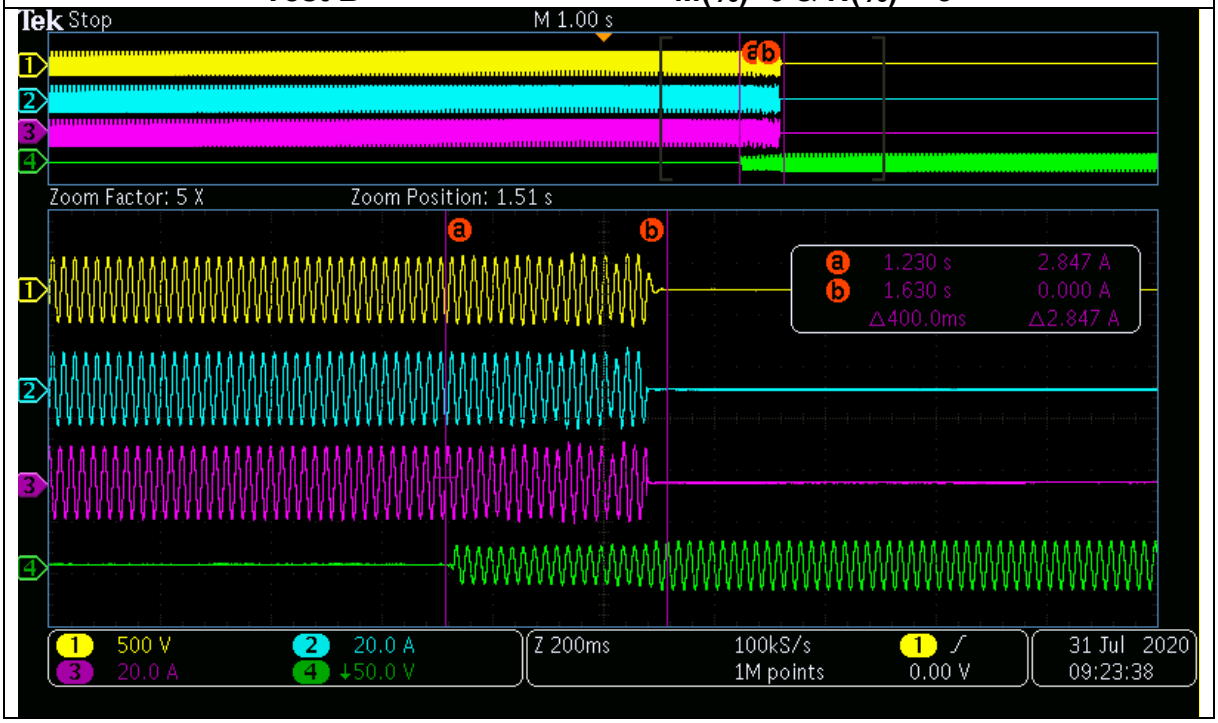
Test B **M(%)=0 & N(%)=+1**



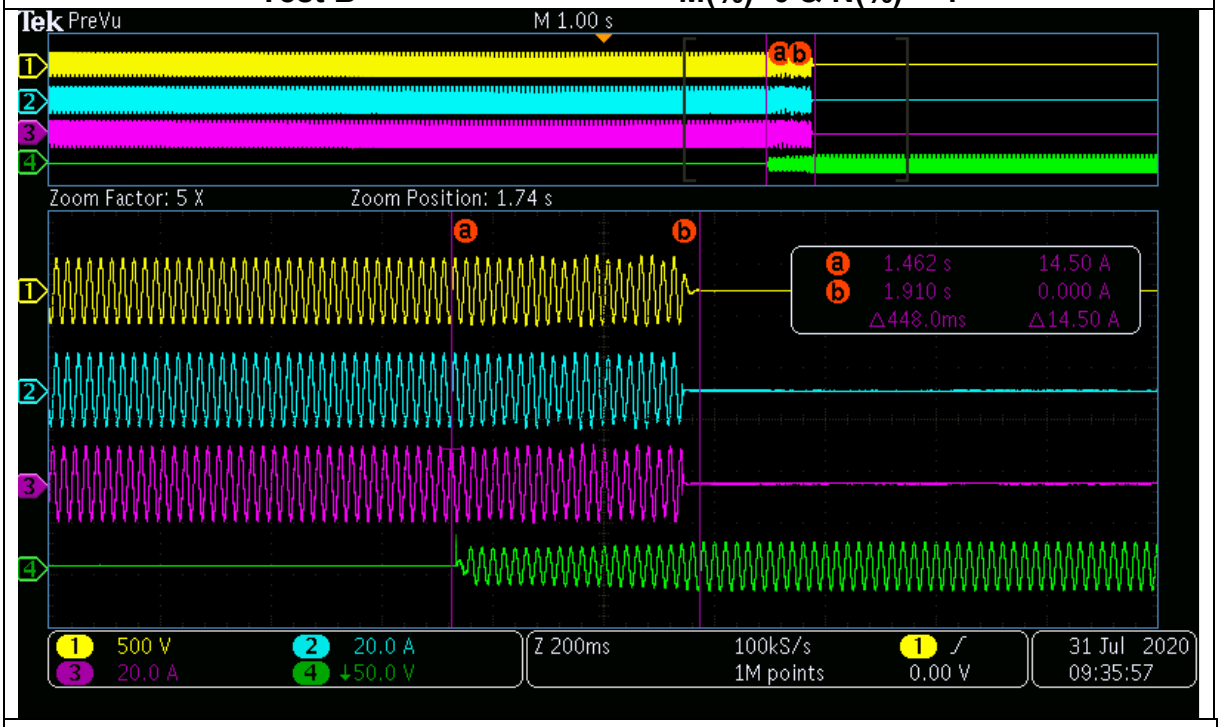
Test B **M(%)=0 & N(%)=+2**



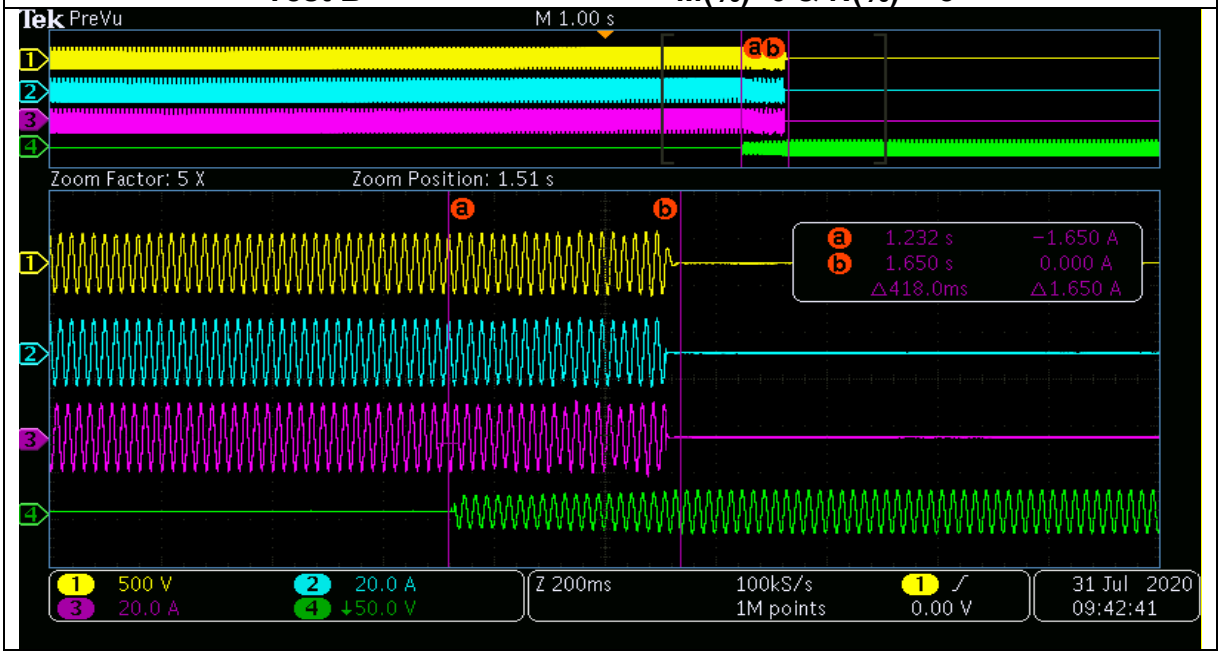
Test B **M(%)=0 & N(%)=+3**



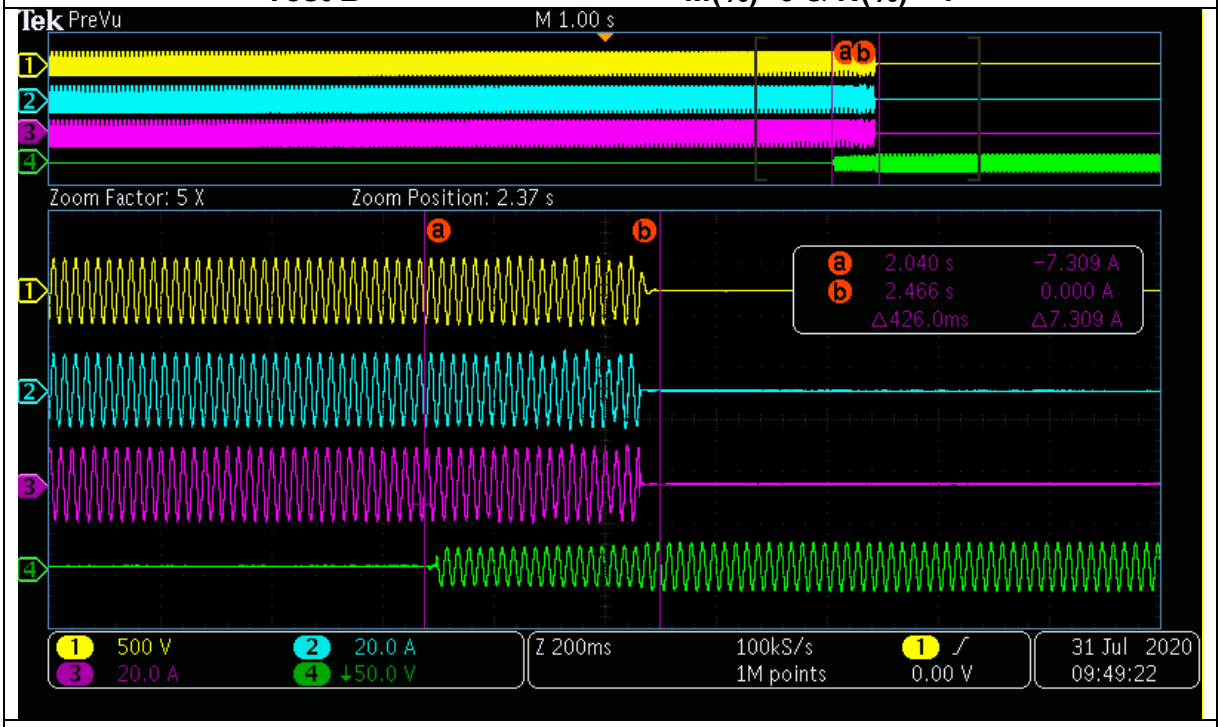
Test B **M(%)=0 & N(%)=+4**



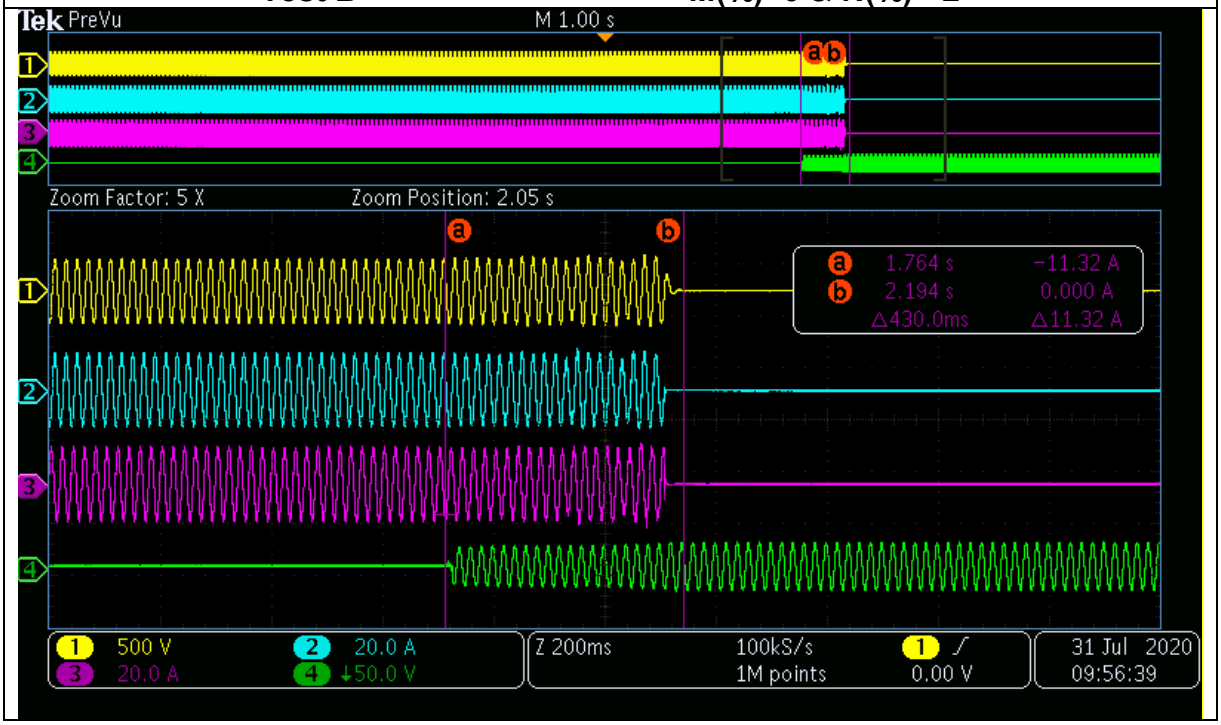
Test B **M(%)=0 & N(%)=+5**



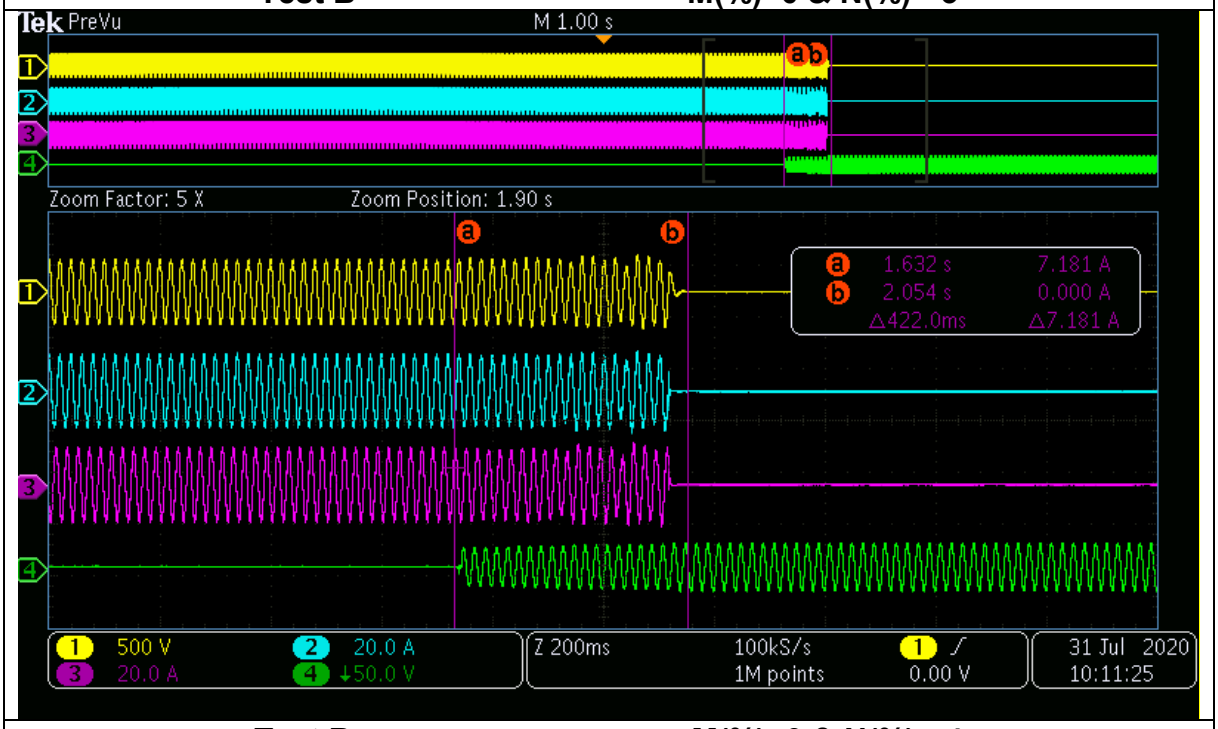
Test B **M(%)=0 & N(%)=-1**



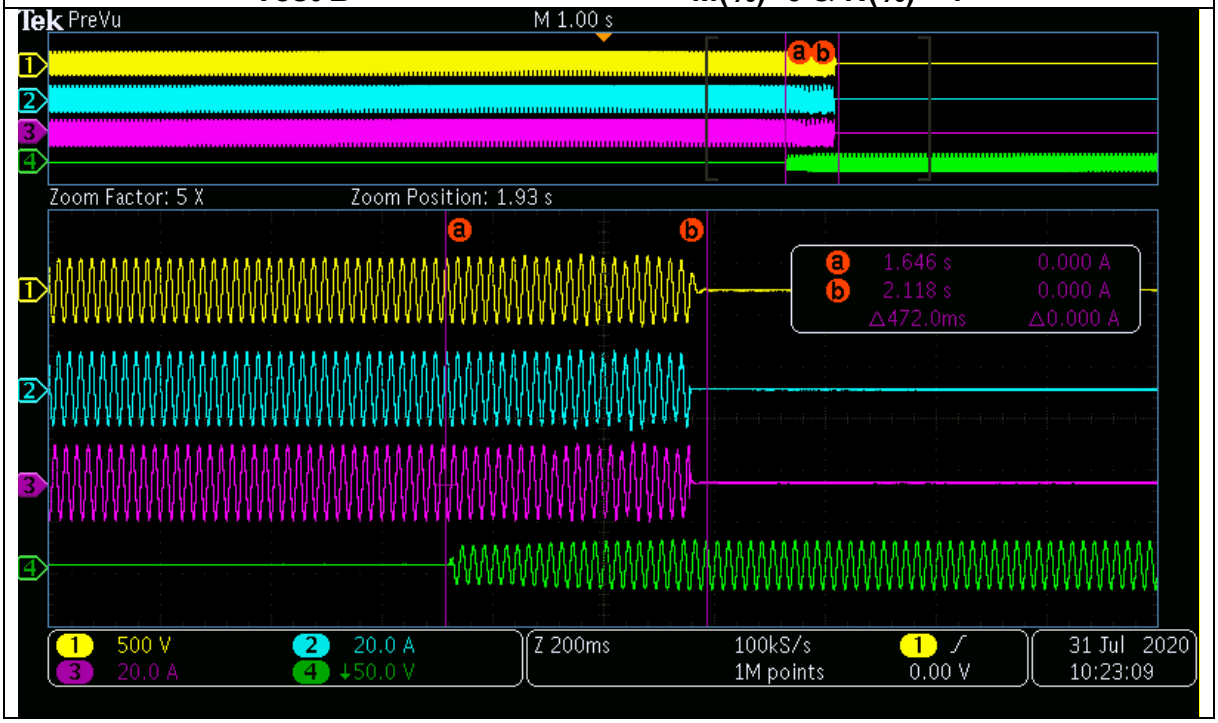
Test B **M(%)=0 & N(%)=-2**



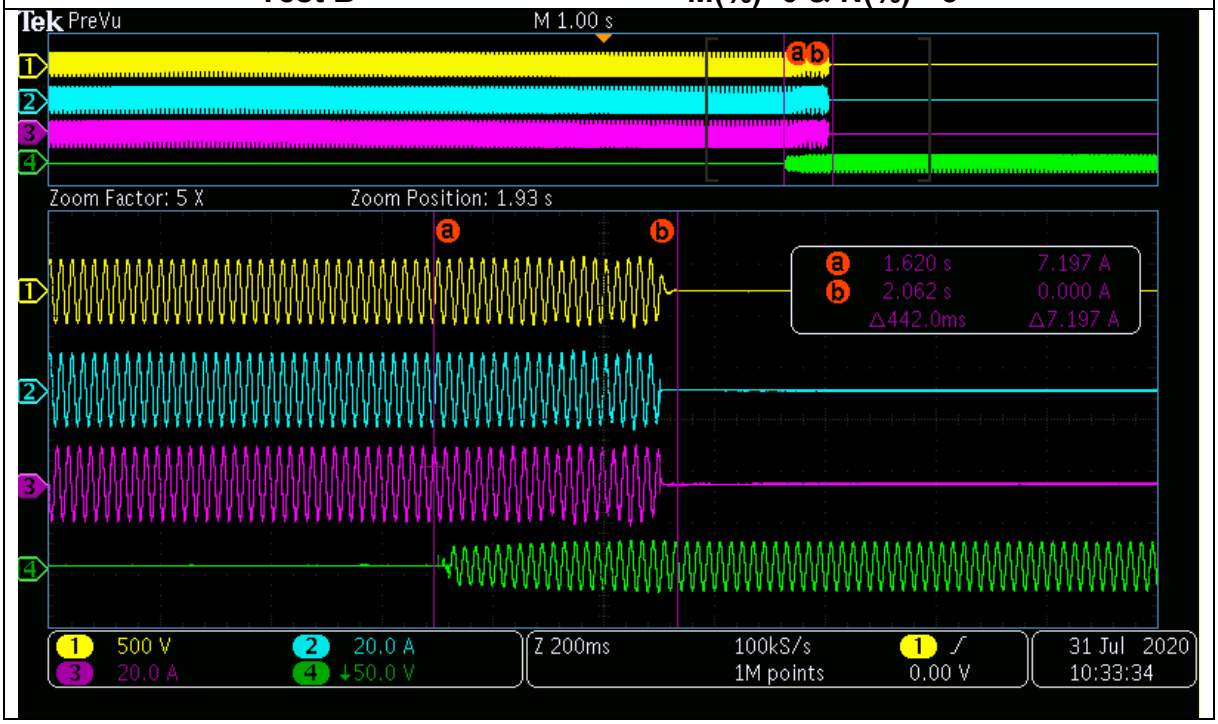
Test B **M(%)=0 & N(%)=-3**



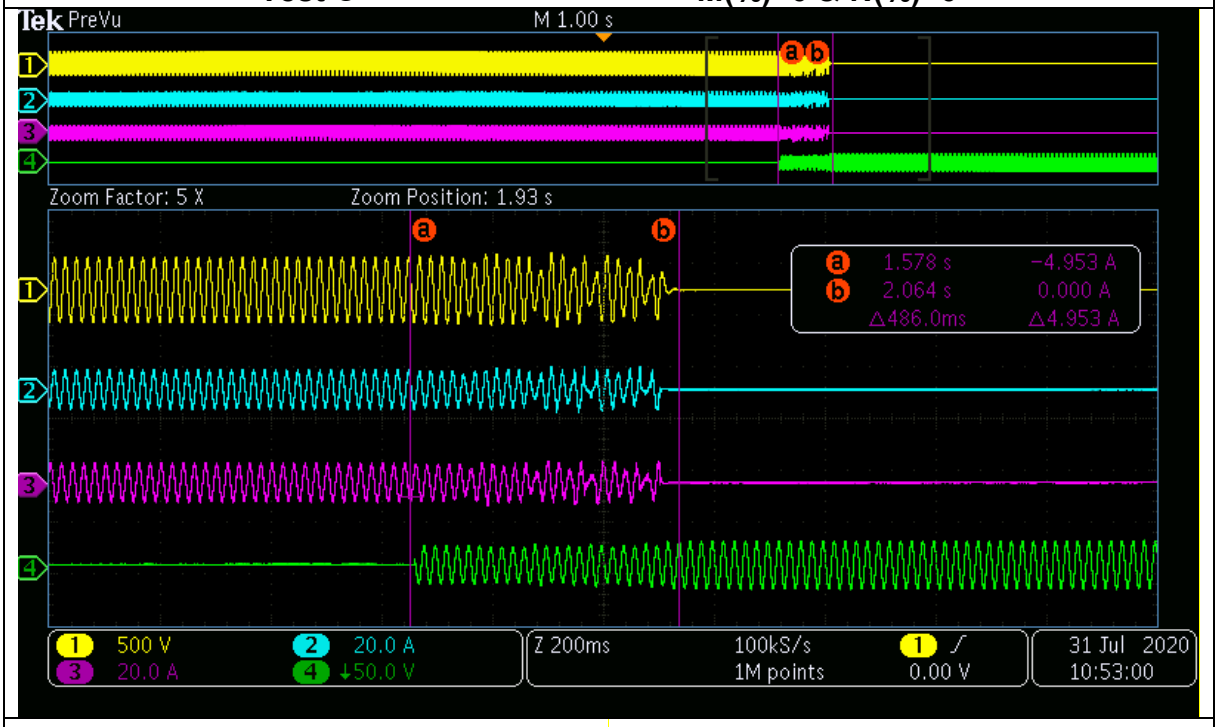
Test B **M(%)=0 & N(%)=-4**



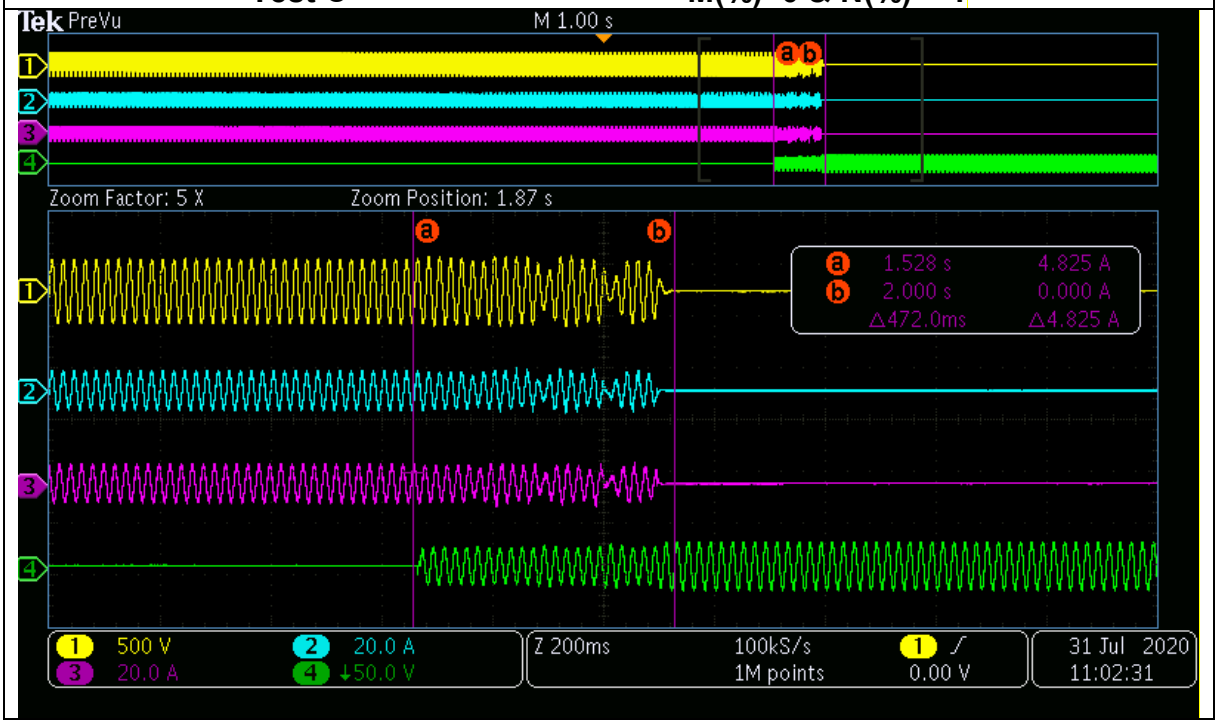
Test B	M(%)=0 & N(%)=-5


Tek PreVu
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.93 s
a 1.620 s 7.197 A
b 2.062 s 0.000 A
Δ442.0ms Δ7.197 A
1 500 V
3 20.0 A
2 20.0 A
4 ↓50.0 V
Z 200ms
100kS/s
1M points
1 ⎍
0.00 V
31 Jul 2020
10:33:34

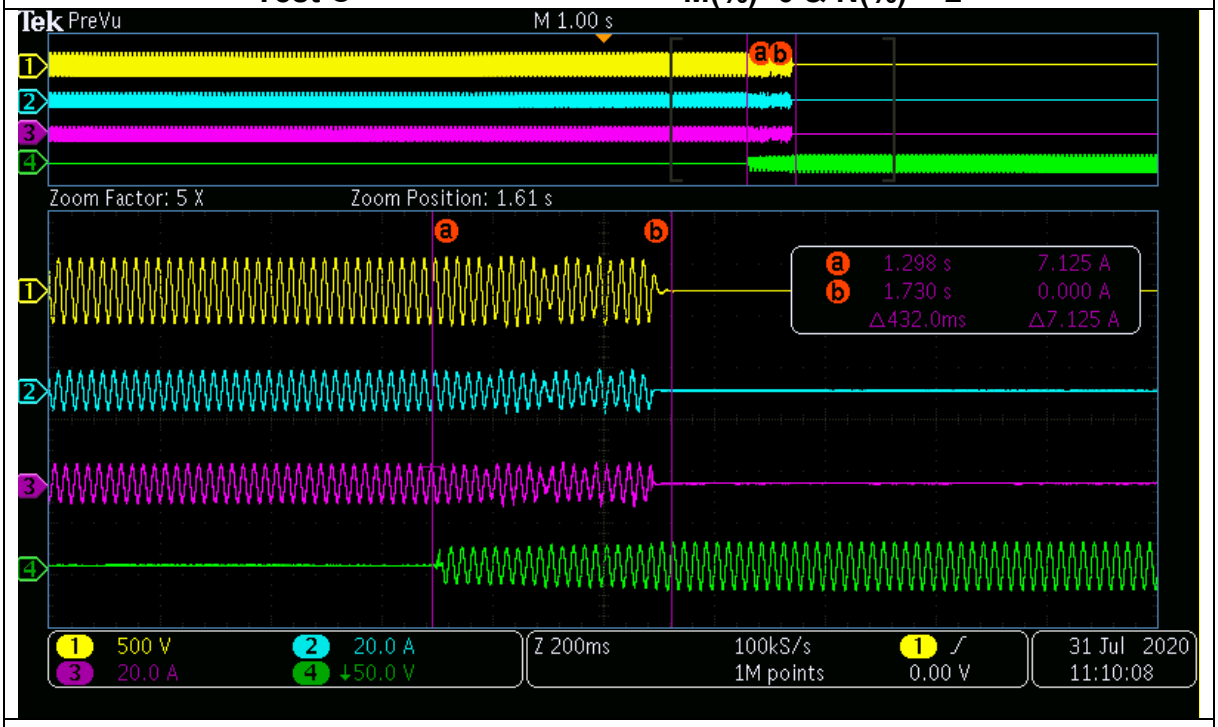
Test C **M(%)=0 & N(%)=0**



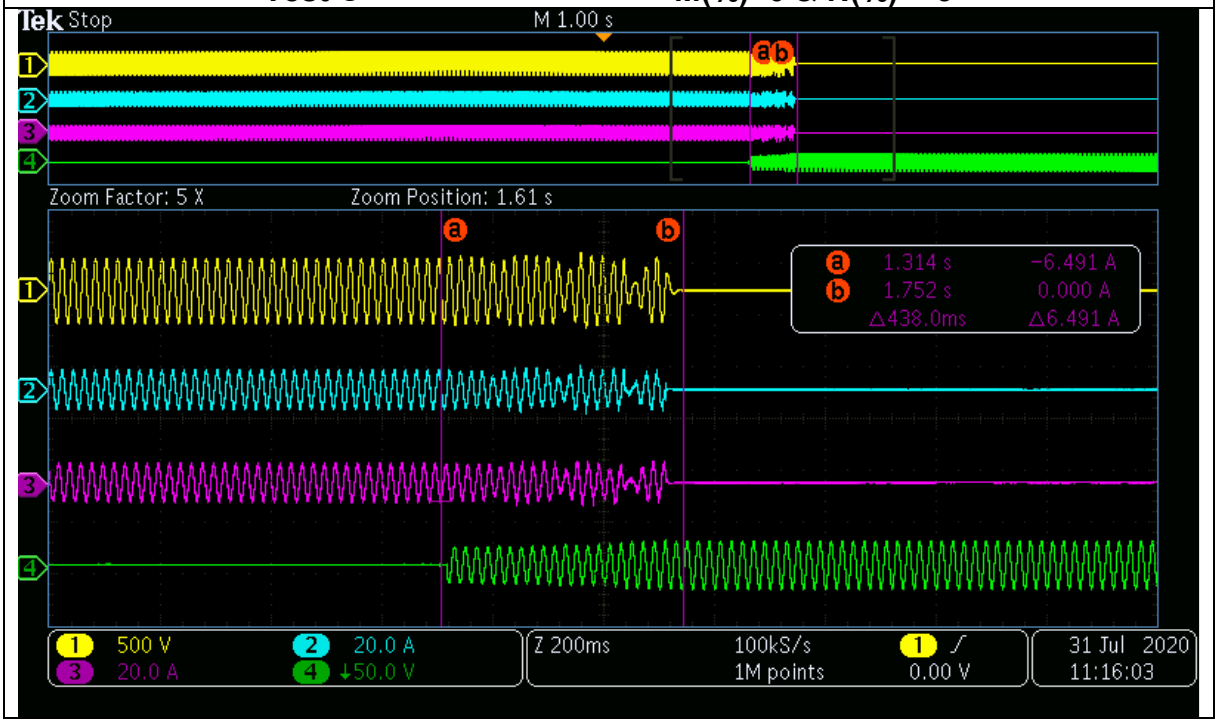
Test C **M(%)=0 & N(%)=+1**



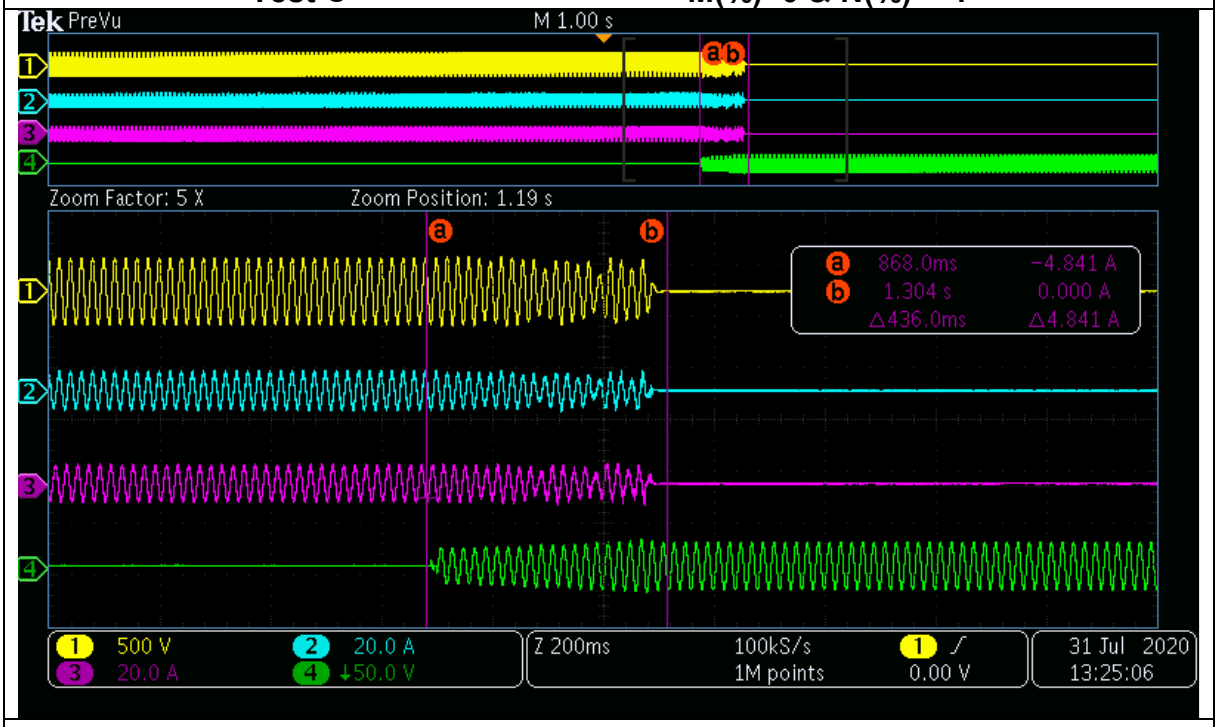
Test C **M(%)=0 & N(%)=+2**



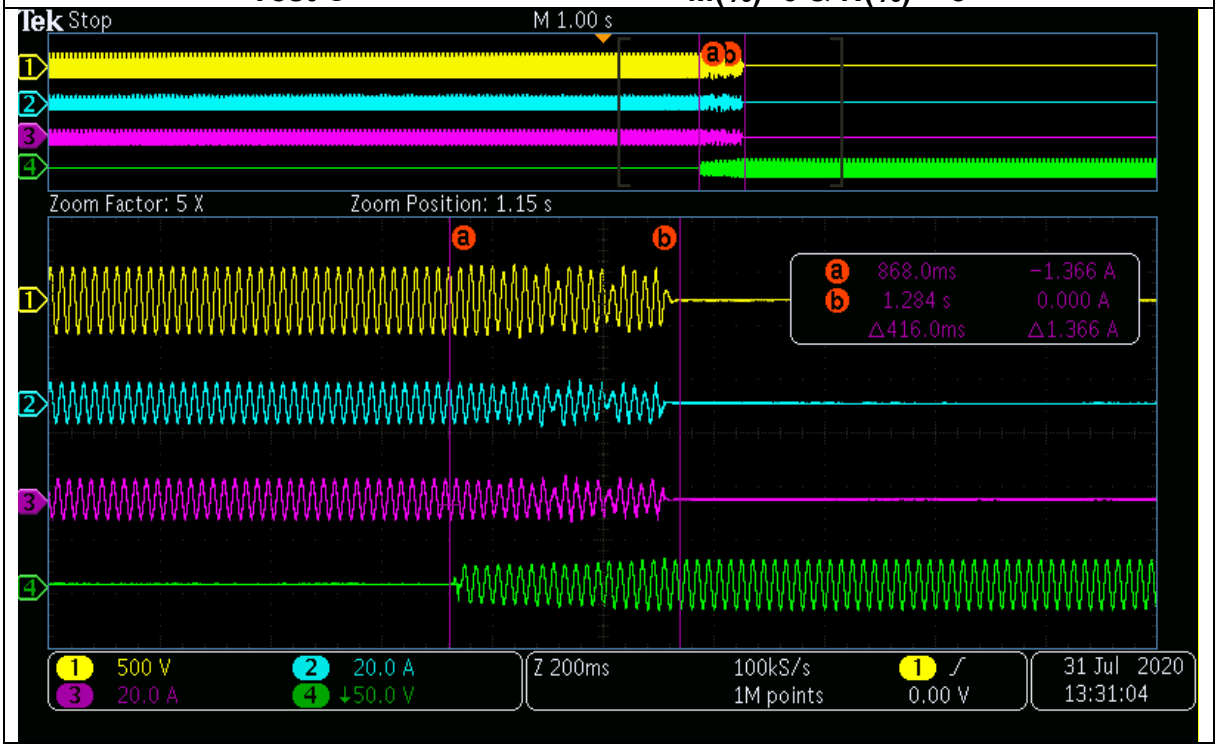
Test C **M(%)=0 & N(%)=+3**



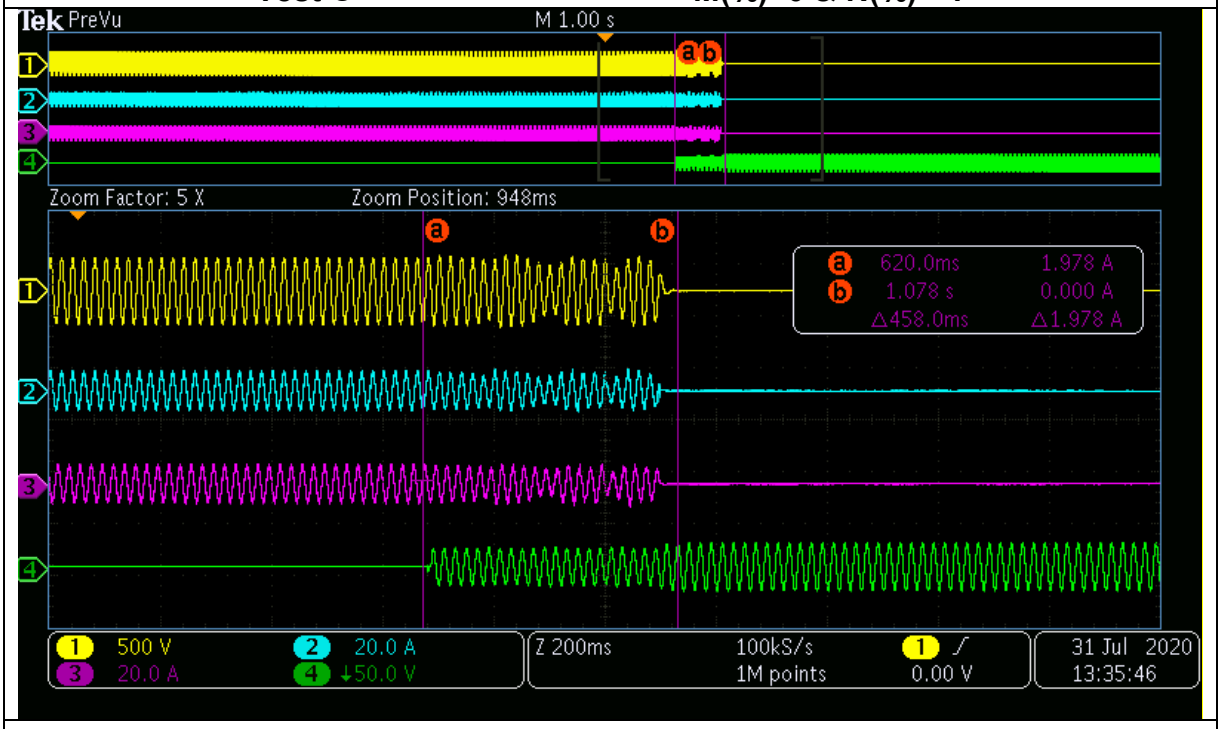
Test C **M(%)=0 & N(%)=+4**



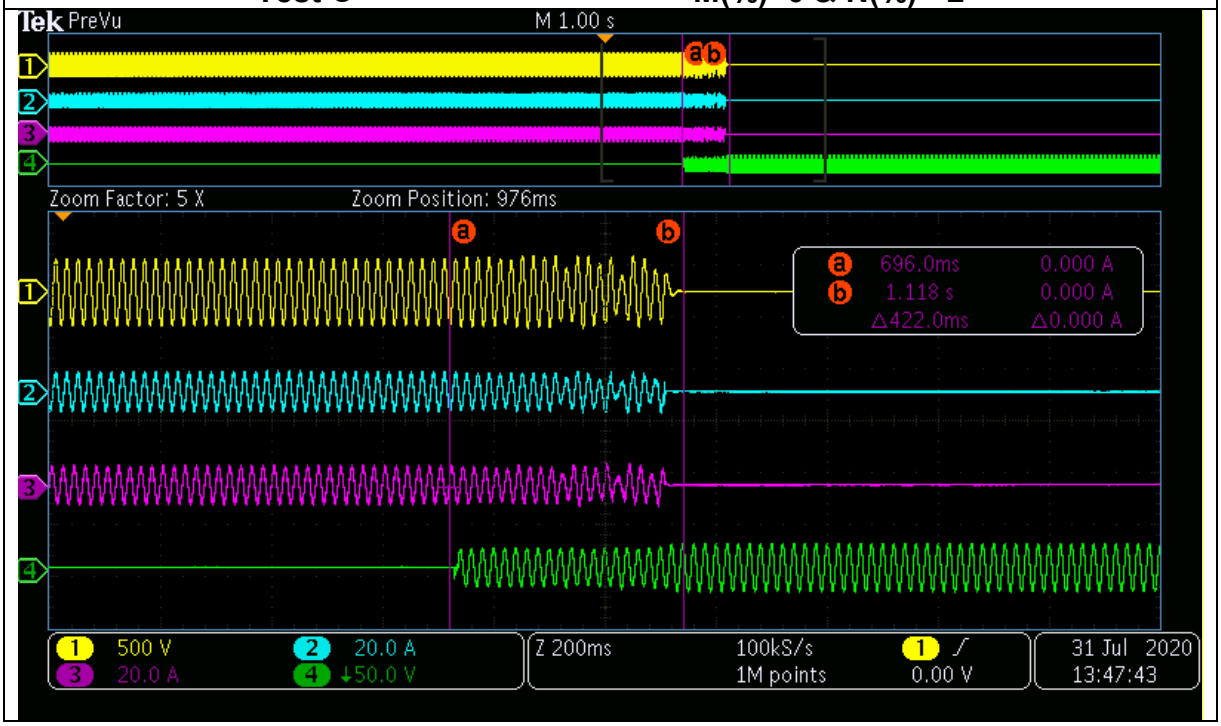
Test C **M(%)=0 & N(%)=+5**



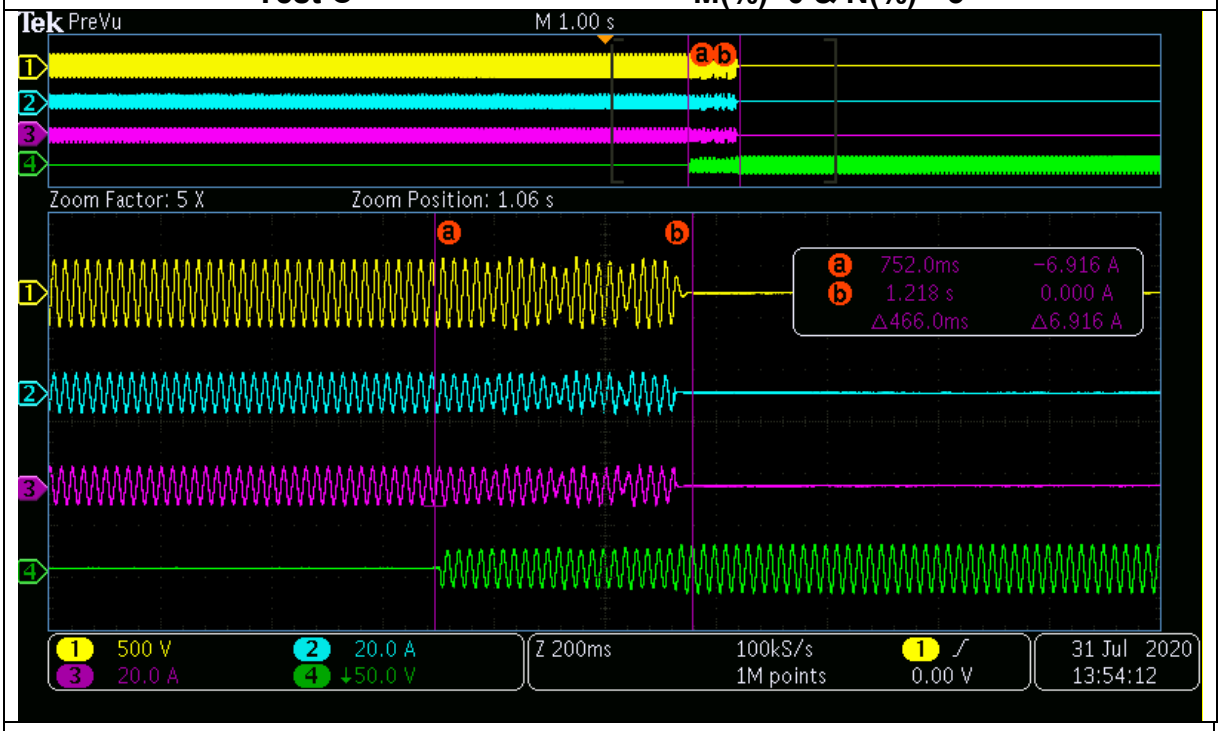
Test C **M(%)=0 & N(%)=-1**



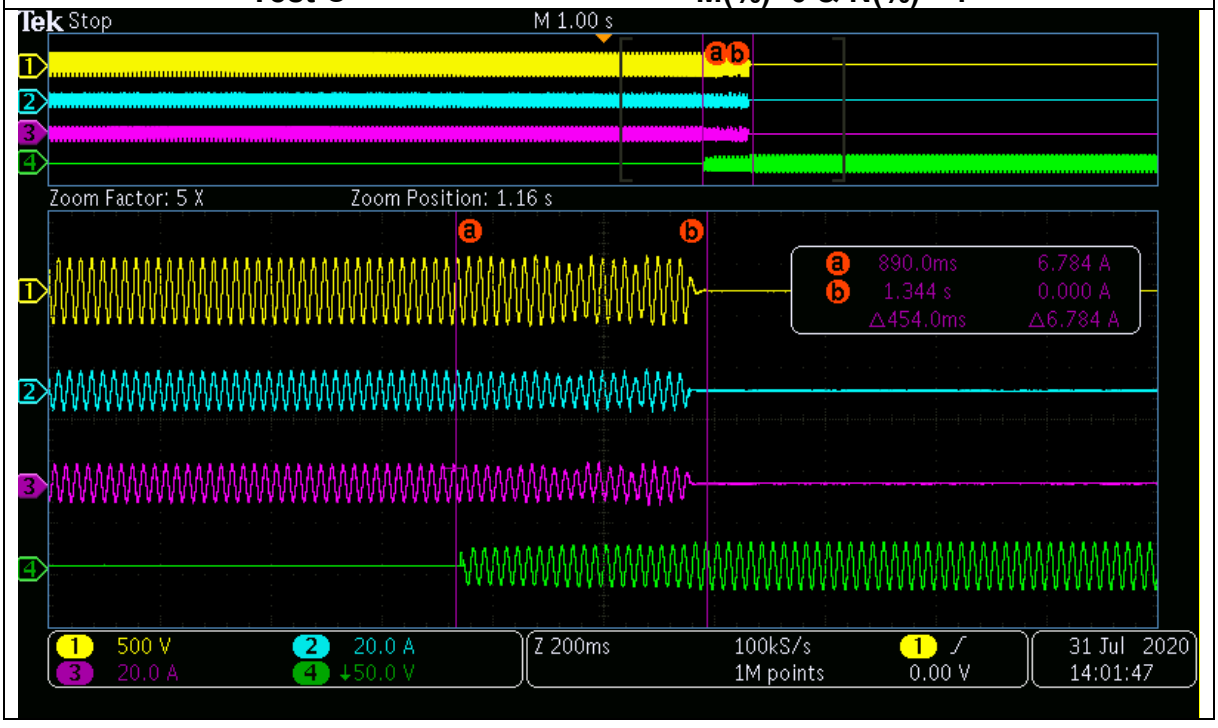
Test C **M(%)=0 & N(%)=-2**



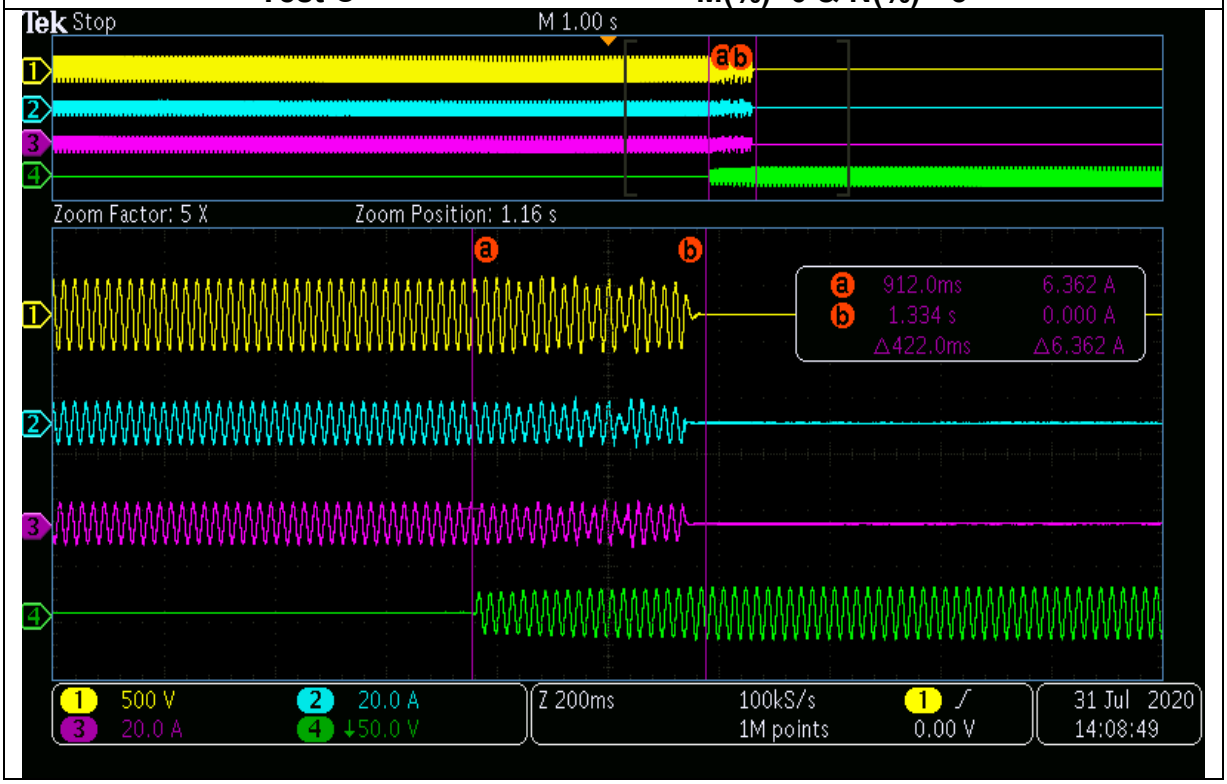
Test C **M(%)=0 & N(%)=-3**



Test C **M(%)=0 & N(%)=-4**



Test C	M(%)=0 & N(%)=-5


Tek Stop
M 1.00 s
Zoom Factor: 5 X
Zoom Position: 1.16 s
a 912.0ms 6.362 A
b 1.334 s 0.000 A
Δ422.0ms Δ6.362 A
1 500 V
2 20.0 A
3 20.0 A
4 ↓50.0 V
Z 200ms
100kS/s
1M points
1 ⁄
0.00 V
31 Jul 2020
14:08:49

4.3.4 Frequency change, Vector Shift Stability test and RoCoF Stability test

Four tests are required to be carried out with all protection functions enabled including loss of mains. For each stability test the Micro-generator should not trip during the test.

For the step change test the Micro-generator should be operated with a measurable output at the start frequency and then a vector shift should be applied by extending or reducing the time of a single cycle with subsequent cycles returning to the start frequency. The start frequency should then be maintained for a period of at least 10 s to complete the test. The Micro-generator should not trip during this test.

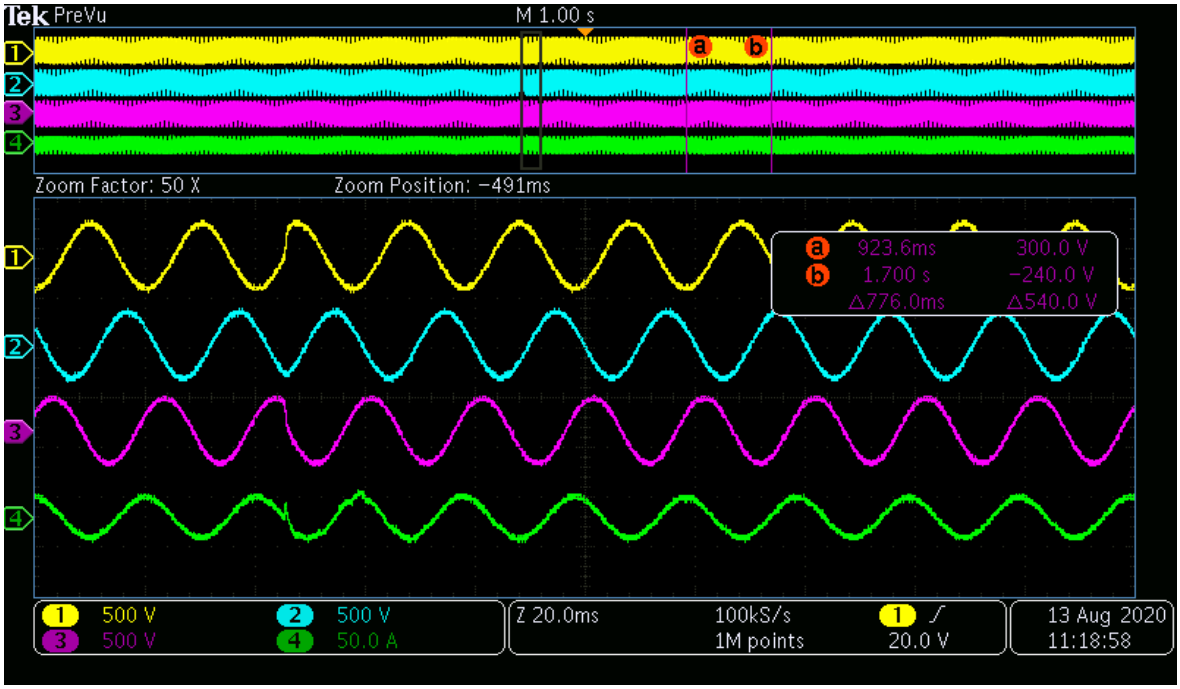
For frequency drift tests the Micro-generator should be operated with a measurable output at the start frequency and then the frequency changed in a ramp function at 0.95 Hzs-1 to the end frequency. On reaching the end frequency it should be maintained for a period of at least 10 s. The Micro-generator should not trip during this test.

Test results are graphically shown in following pages.

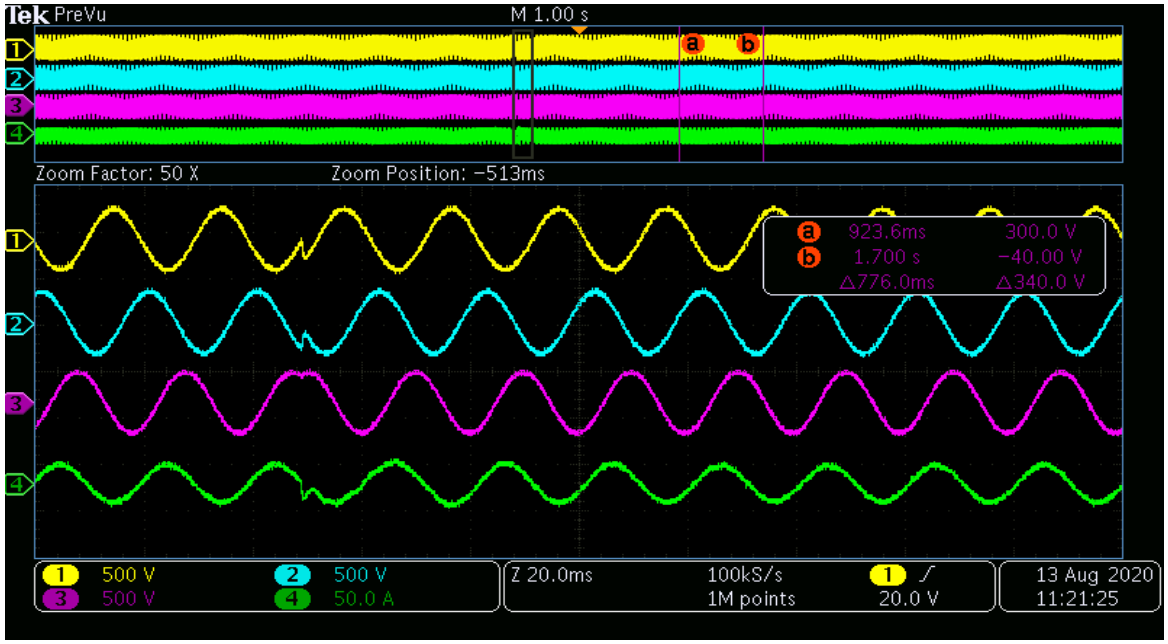
Protection – Frequency change, Vector Shift Stability test: This test should be carried out in accordance with EREC G98 Annex A1 A.1.2.6 (**Inverter** connected) or Annex A2 A.2.2.6 (Synchronous).

	Start Frequency	Change	Confirm no trip
Positive Vector Shift	49.0 Hz	+50 degrees	Pass
Negative Vector Shift	50.0 Hz	- 50 degrees	Pass

Positive Vector Shift:

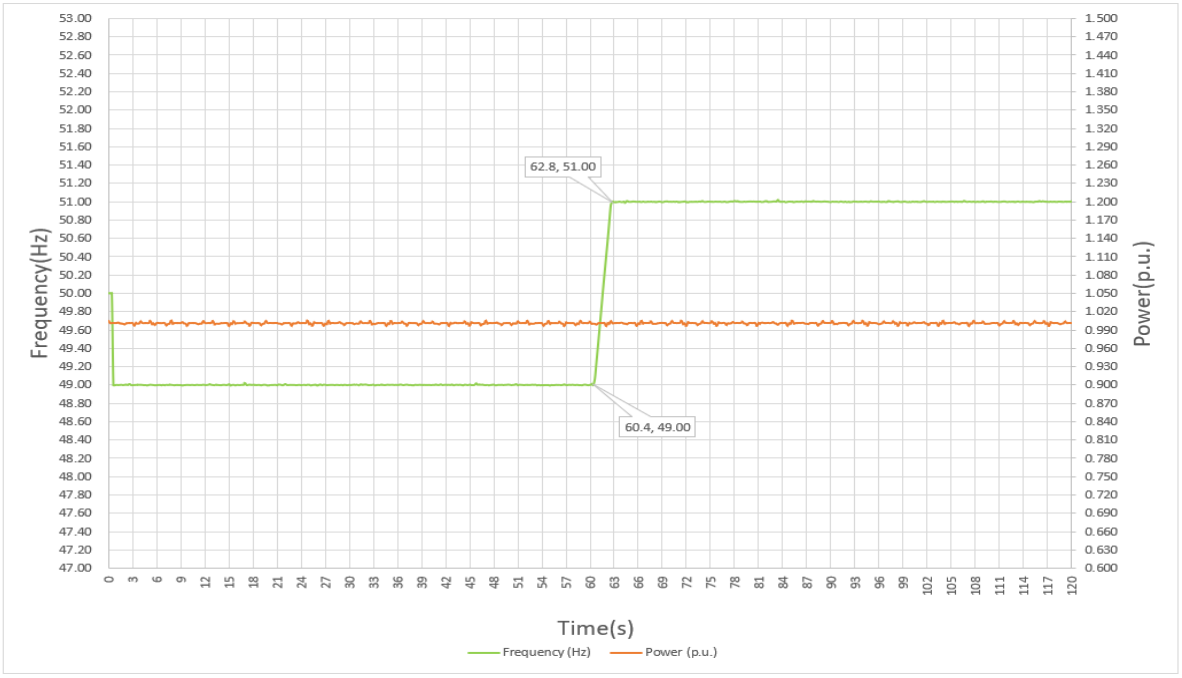


Negative Vector Shift:

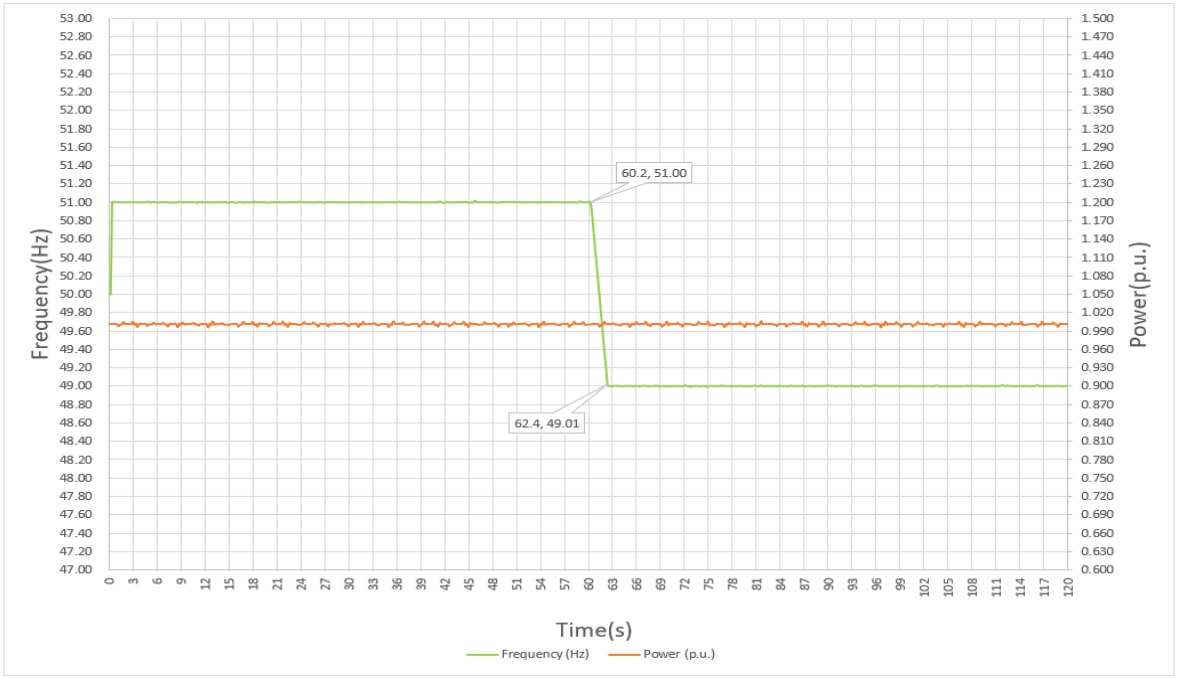


Protection – Frequency change, RoCoF Stability test: The requirement is specified in section 11.3, test procedure in Annex A.1.2.6 (**Inverter** connected) or Annex A2 A.2.2.6 (Synchronous).			
Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+0.95 Hzs^{-1}	2.4 s	Pass
51.0 Hz to 49.0 Hz	-0.95 Hzs^{-1}	2.1 s	Pass

+0.95 Hz/s:



-0.95 Hz/s:



4.4 Limited Frequency Sensitive Mode - Overfrequency test

The test serves to verify the active power reduction of the micro-generator at over-frequency. We perform the test according to EN 50438 Annex D.3.3 Power response to over-frequency.

The tests for providing evidence of the frequency dependent active power feed-in of the micro-generator shall be carried out on a network simulator.

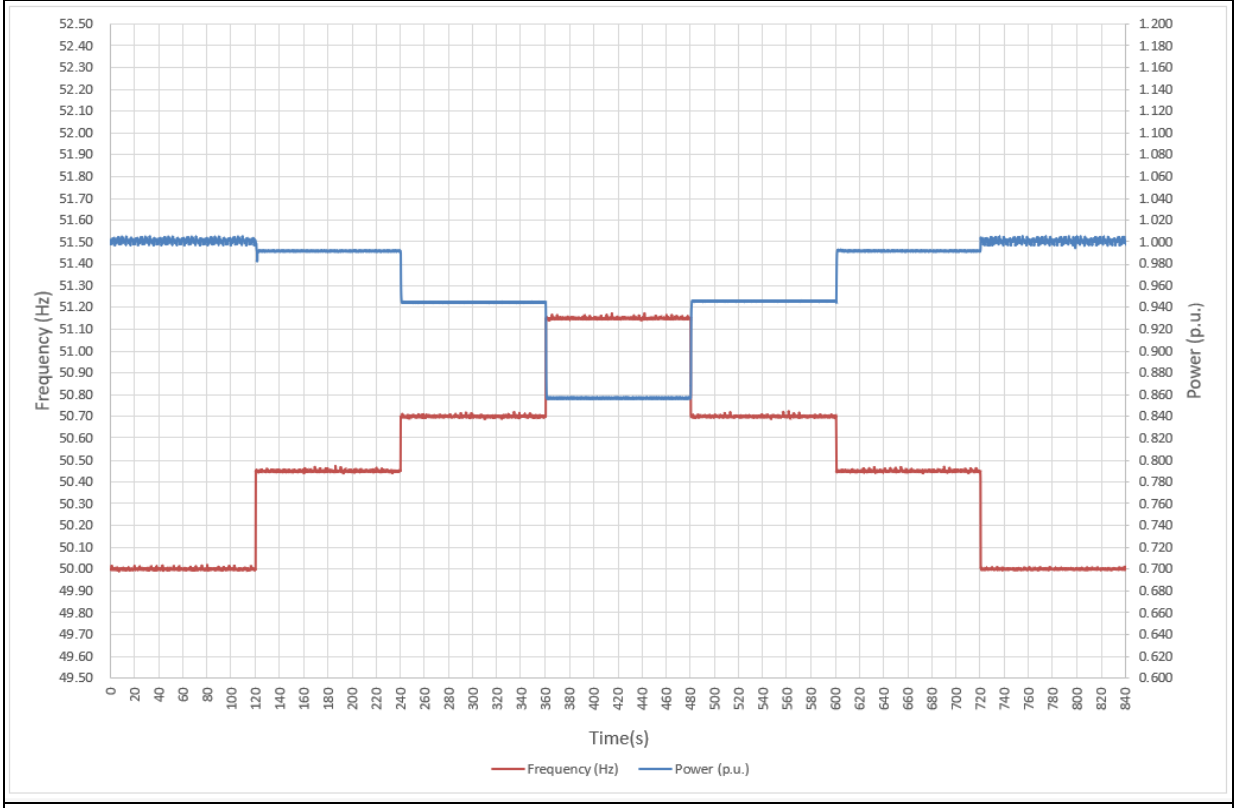
The test should be carried out using the specific threshold frequency of 50.4 Hz and Droop of 10%.

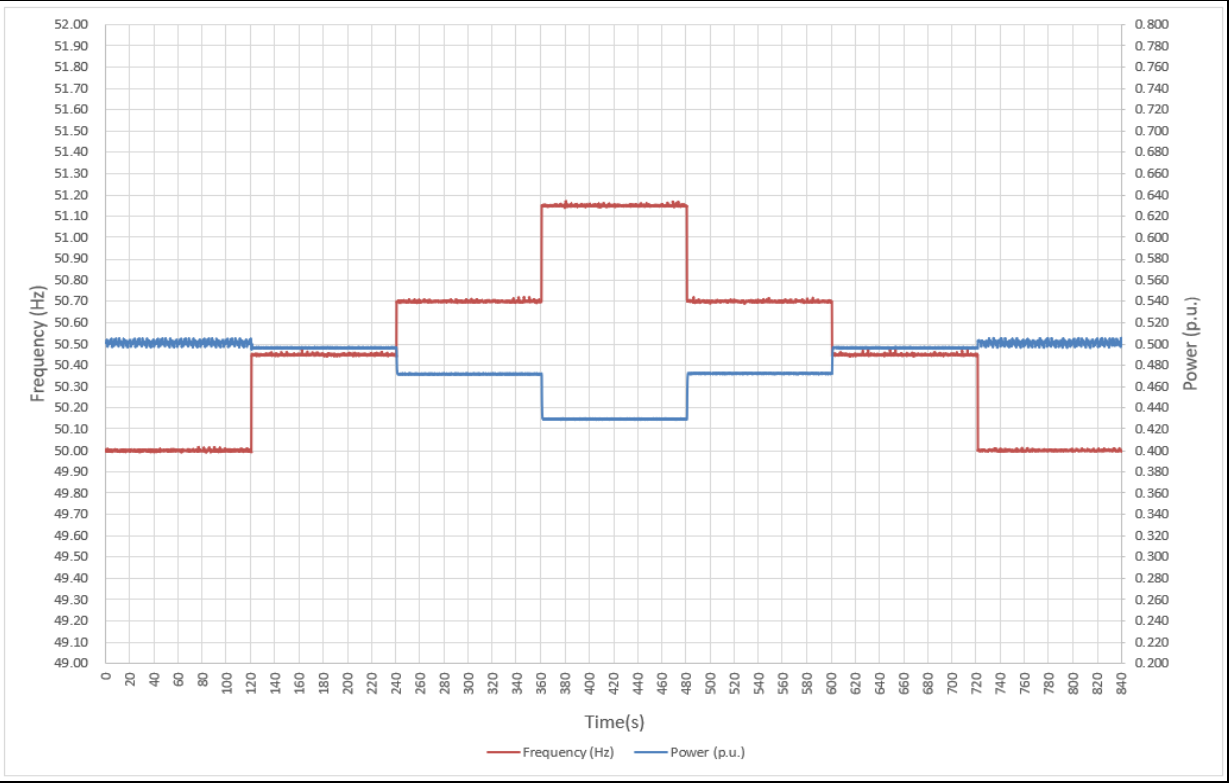
Following tables show the test results:

Test sequence at Registered Capacity >80%	Measured Active Power Output (W)	Frequency (Hz)	Primary Power Source	Active Power Gradient(%)
Step a) 50.00 Hz ±0.01 Hz	10011.3	50.00	DC Source	N/A
Step b) 50.45 Hz ±0.05 Hz	9917.0	50.45		10.6
Step c) 50.70 Hz ±0.10 Hz	9447.6	50.70		10.7
Step d) 51.15 Hz ±0.05 Hz	8570.5	51.15		10.4
Step e) 50.70 Hz ±0.10 Hz	9455.2	50.70		10.8
Step f) 50.45 Hz ±0.05 Hz	9916.7	50.45		10.6
Step g) 50.00 Hz ±0.01 Hz	10010.3	50.00		N/A

Test sequence at Registered Capacity >80%	Measured Active Power Output (W)	Frequency (Hz)	Primary Power Source	Active Power Gradient(%)
Step a) 50.00 Hz ±0.01 Hz	5012.28	50.00	DC Source	N/A
Step b) 50.45 Hz ±0.05 Hz	4964.39	50.45		10.5
Step c) 50.70 Hz ±0.10 Hz	4719.23	50.70		10.3
Step d) 51.15 Hz ±0.05 Hz	4296.13	51.15		10.5
Step e) 50.70 Hz ±0.10 Hz	4721.55	50.70		10.3
Step f) 50.45 Hz ±0.05 Hz	4963.73	50.45		10.3
Step g) 50.00 Hz ±0.01 Hz	5011.21	50.00		N/A

Test results are graphically shown in following pages.

Over-frequency curve (droop of 10 % at 100% Pn)

Remark:Test for frequency threshold 50.4Hz with droop 10%, intentional delay is setting to 0s.

Over-frequency curve (droop of 10 % at 50% Pn)

Remark:Test for frequency threshold 50.4Hz with droop 10%, intentional delay is setting to 0s.

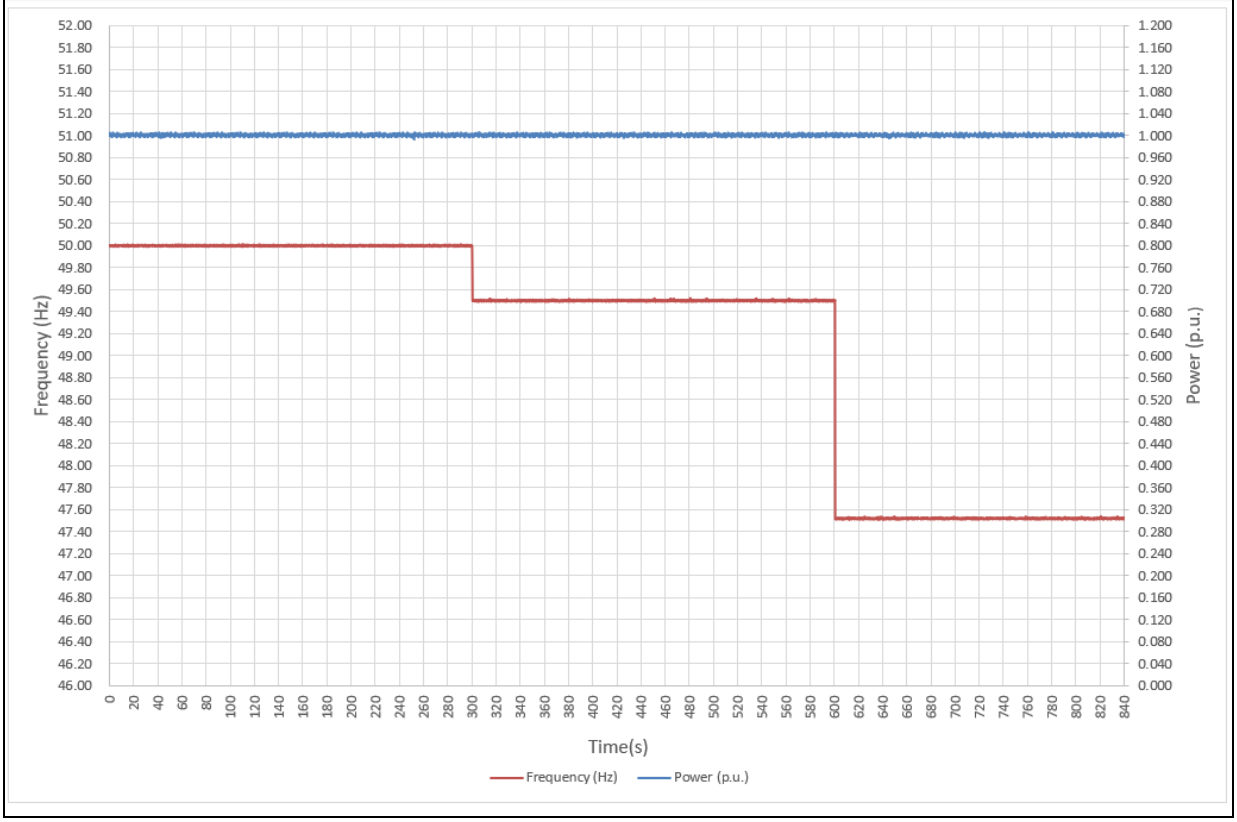
4.5 Power output with falling frequency test

This test should be carried out in accordance with EN 50438 Annex D.3.2 active power feed-in at under-frequency.

Test sequence	Measured Active Power Output (W)	Frequency (Hz)	Primary power source
Test a) 50 Hz ± 0.01 Hz	10013.0	50.0	-
Test b) Point between 49.5 Hz and 49.6 Hz	10012.6	49.5	-
Test c) Point between 47.5 Hz and 47.6 Hz	10010.7	47.5	-
NOTE: The operating point in Test (b) and (c) shall be maintained for at least 5 minutes			

Test results are graphically shown in following pages.

POWER OUTPUT WITH FALLING FREQUENCY TEST



4.6 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 2. These tests should be undertaken in accordance with Annex A.2.2.5.

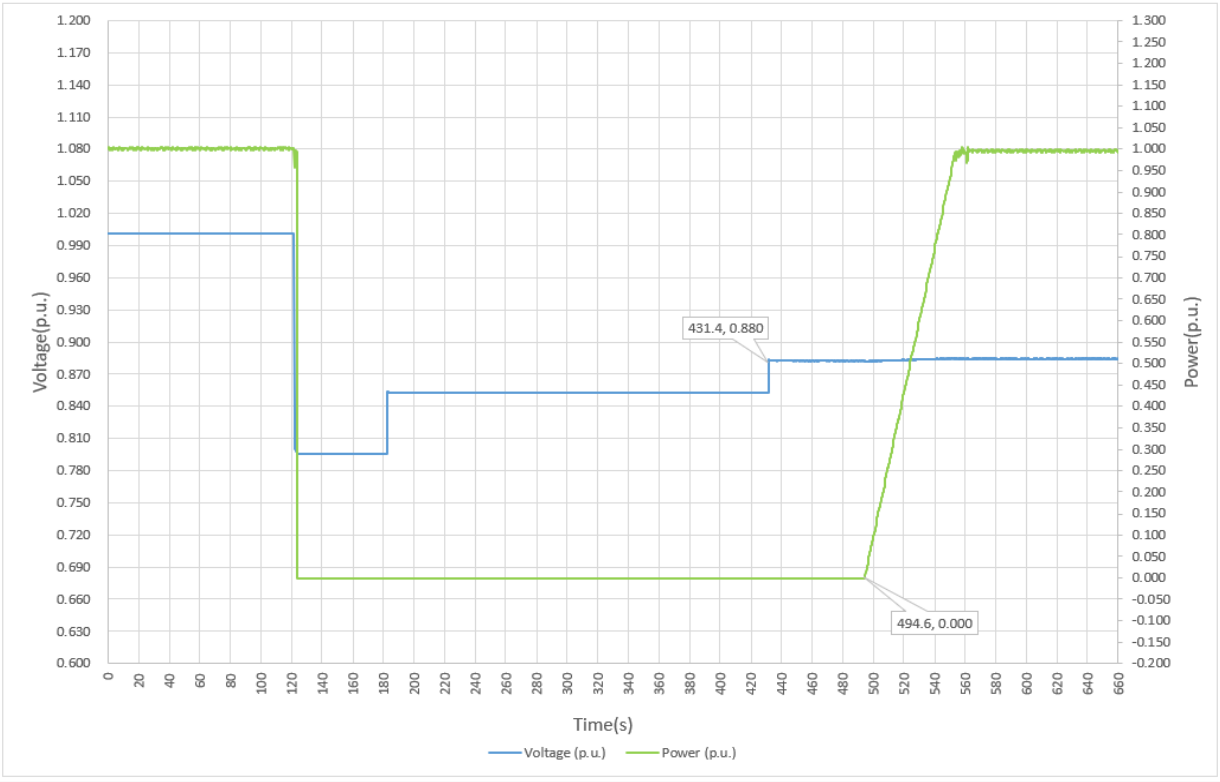
4.6.1 Voltage Reconnection Conditions

The following table detail tests performed.

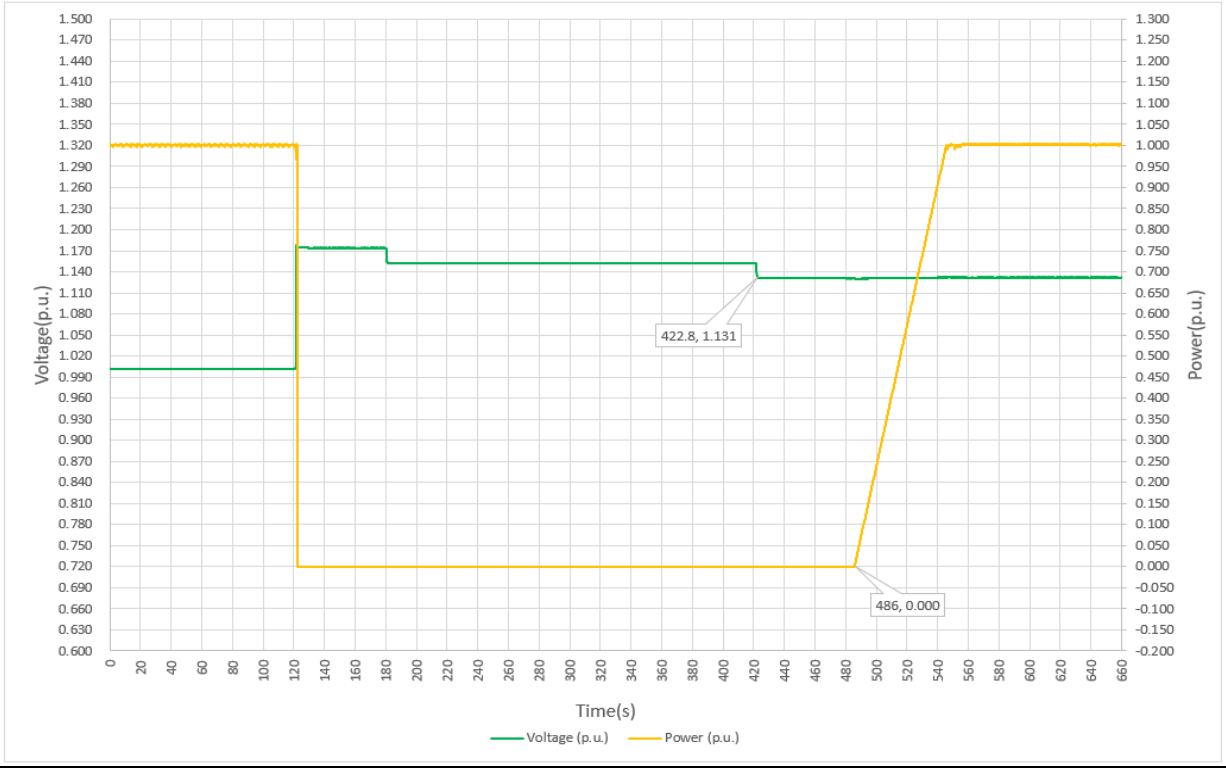
Test at	Time delay setting(s)	Measured delay(s)	Checks on no reconnection when voltage is brought to just outside stage 1 limits of table 1.	
UV	60.0	63.2	At 266.2V	At 196.1V
OV	60.0	63.2		
Confirmation that the Micro-generator does not re-connect.			Not reconnection	Not reconnection

Test results are graphically shown below.

Under voltage reconnection



Over voltage reconnection



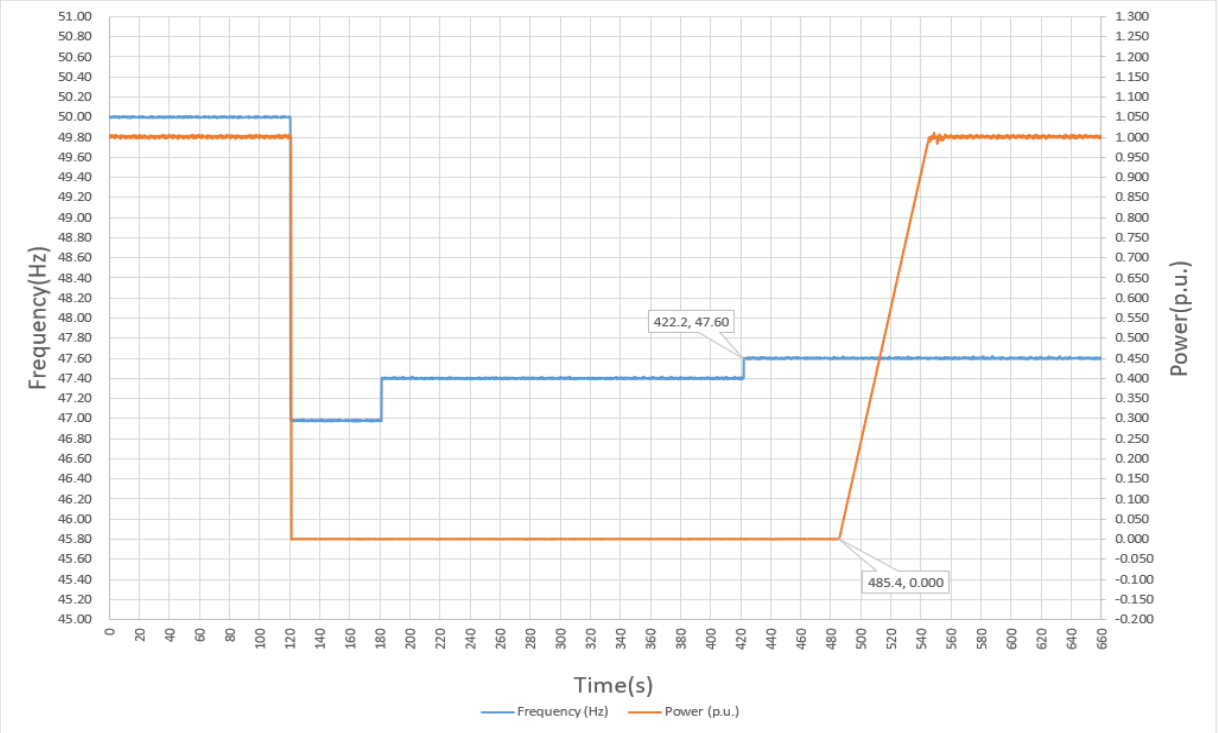
4.6.2 Frequency Reconnection Conditions

The following table detail tests performed.

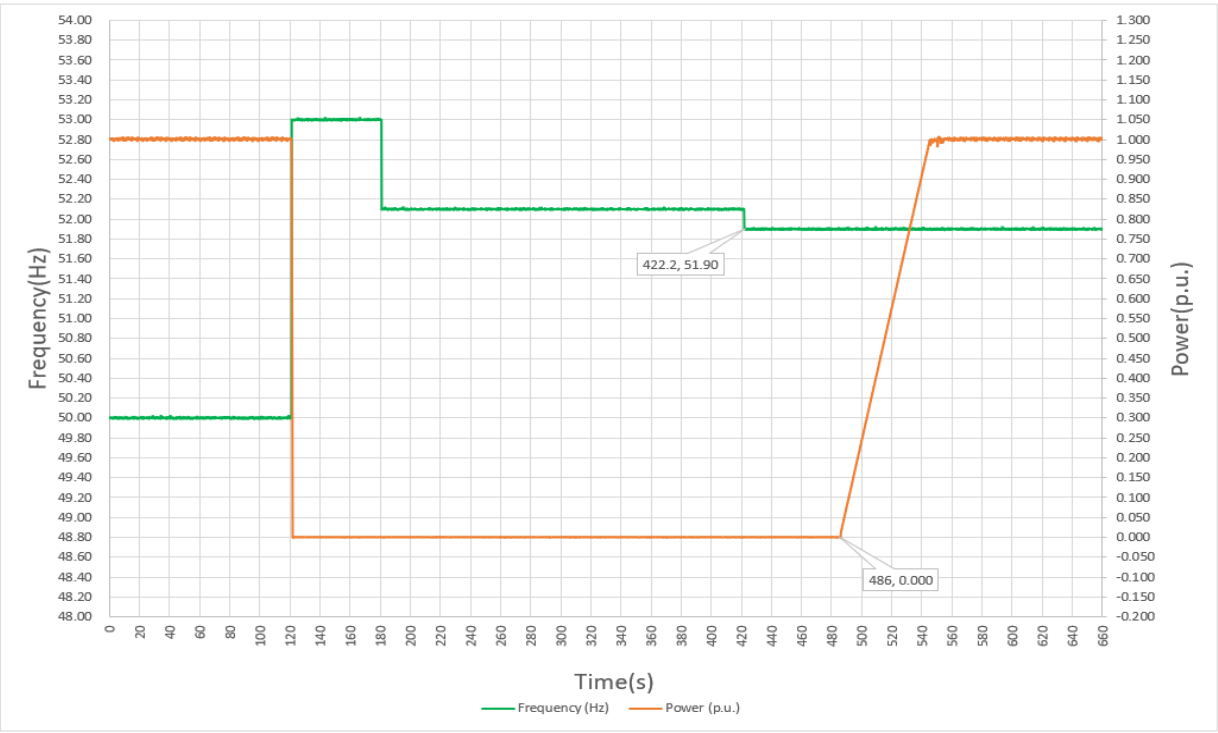
Test at	Time delay setting(s)	Measured delay(s)	Checks on no reconnection when frequency is brought to just outside stage 1 limits of table 1.	
UF	60	63.2	At 47.4Hz	At 52.1Hz
OF	60	63.8		
Confirmation that the Micro-generator does not re-connect.			Not reconnection	Not reconnection

Test results are graphically shown below.

Under frequency reconnection



Over frequency reconnection



4.7 Fault level contribution

These tests shall be carried out in accordance with EREC G98 Annex A1 A.1.3.5 (Inverter connected) and Annex A2 A.2.3.4 (Synchronous).

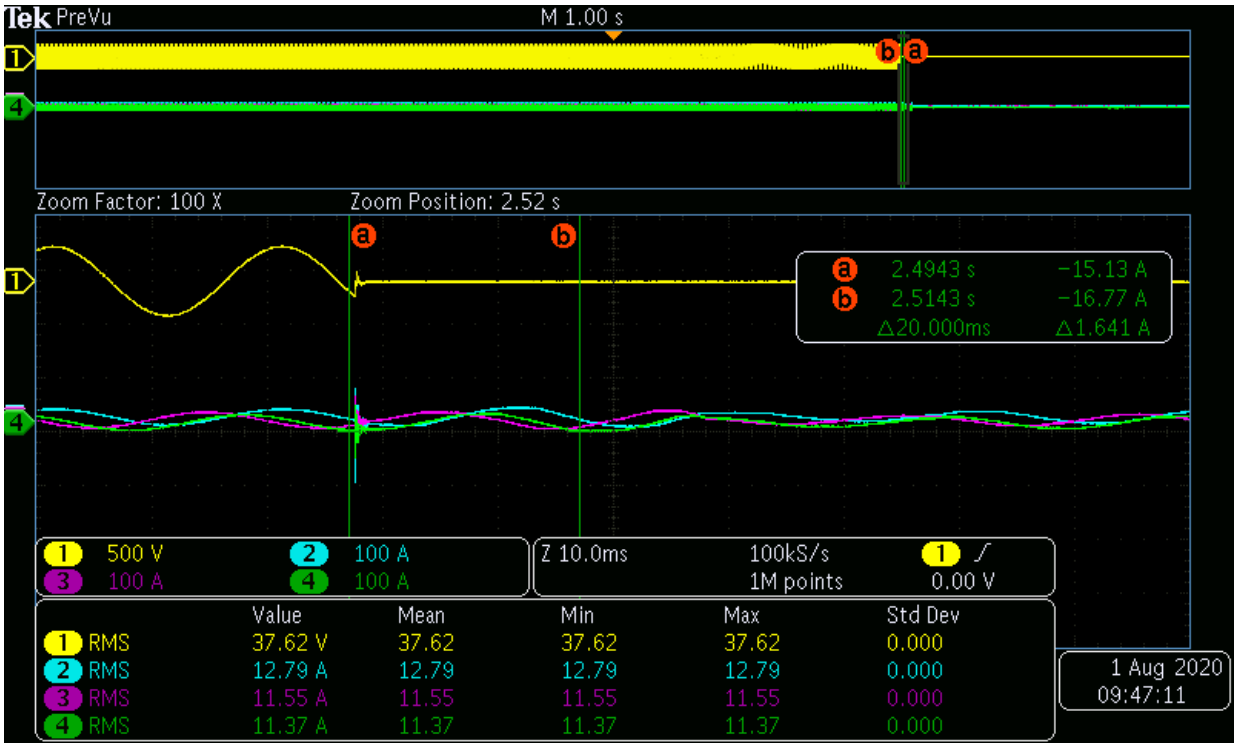
They have been performed different short circuit tests that are detailed in the table and pictures below.

Short circuit current		
L1-N		
Time after fault	**Volts(V)**	**Amps(A)**
20ms	37.6	12.79
100ms	0	9.76
250ms	0	0
500ms	0	0
Time to trip	0	In seconds

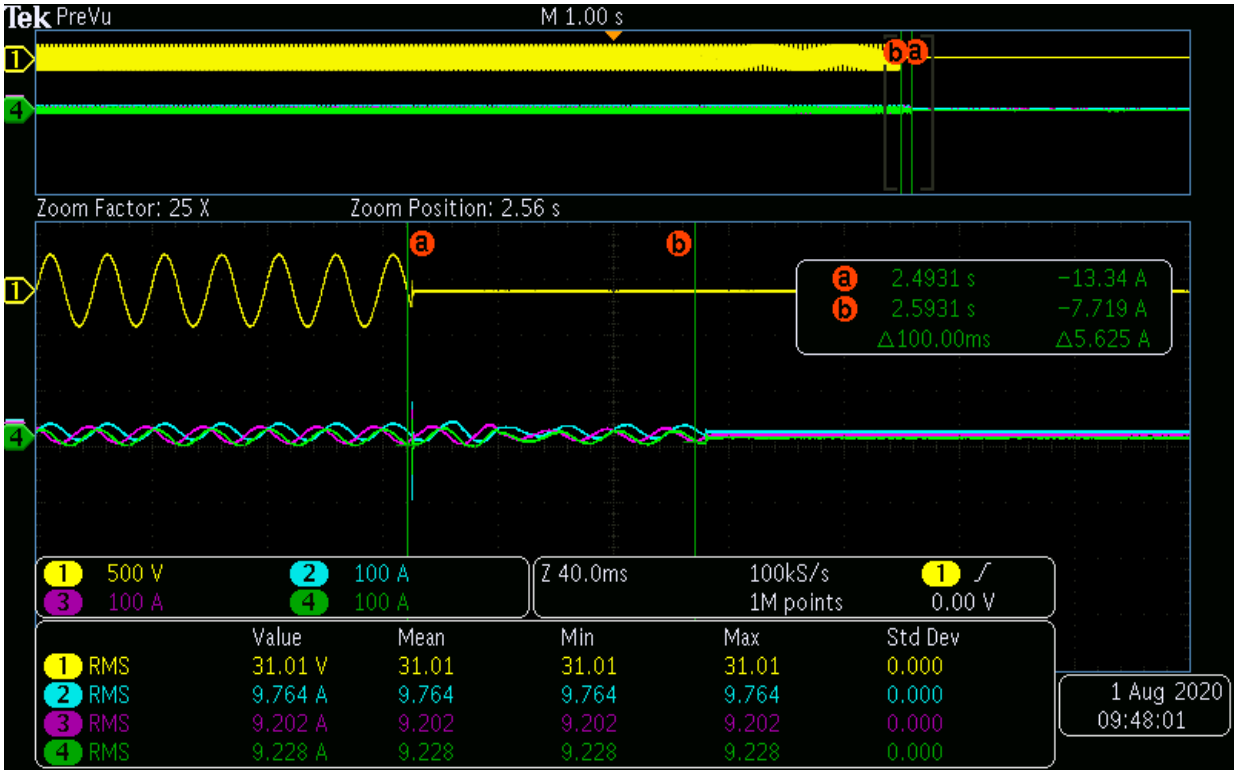
Short circuit current		
L2-L3		
Time after fault	**Volts(V)**	**Amps(A)**
20ms	223.8	13.31
100ms	265.1	14.39
250ms	0	0
500ms	0	0
Time to trip	0	In seconds

L1-N

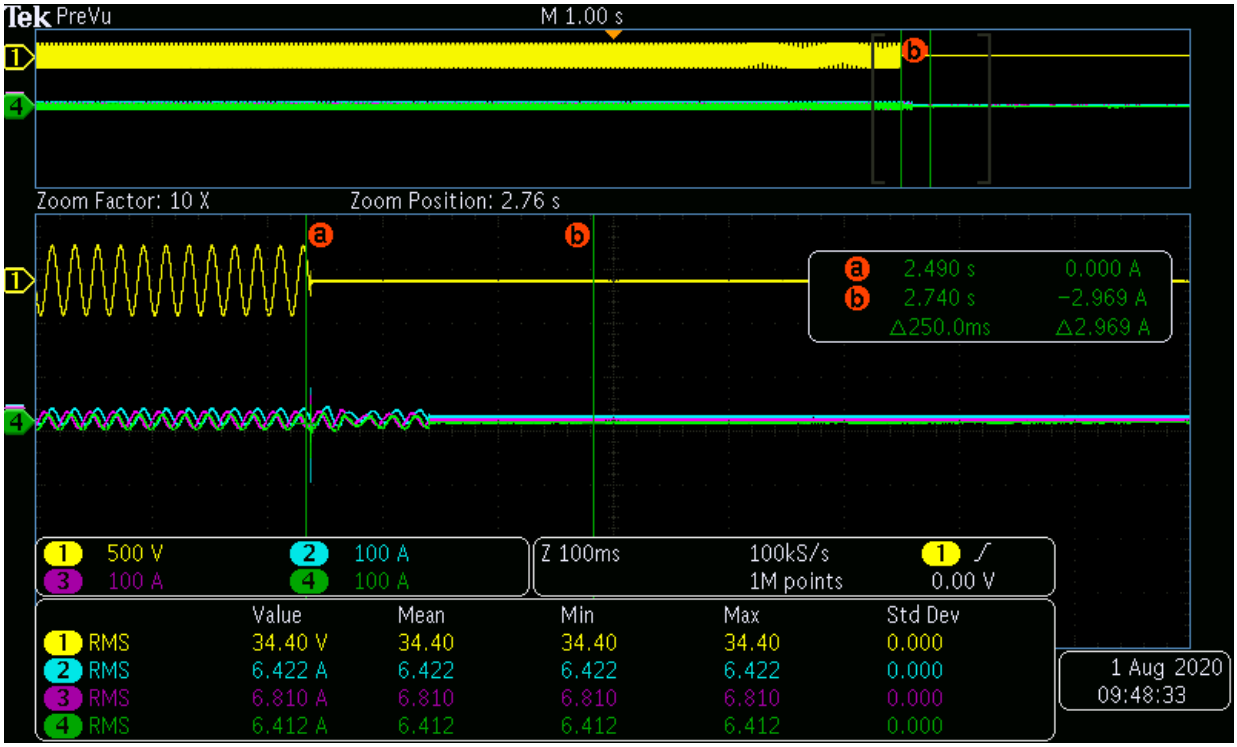
Time after 20ms fault



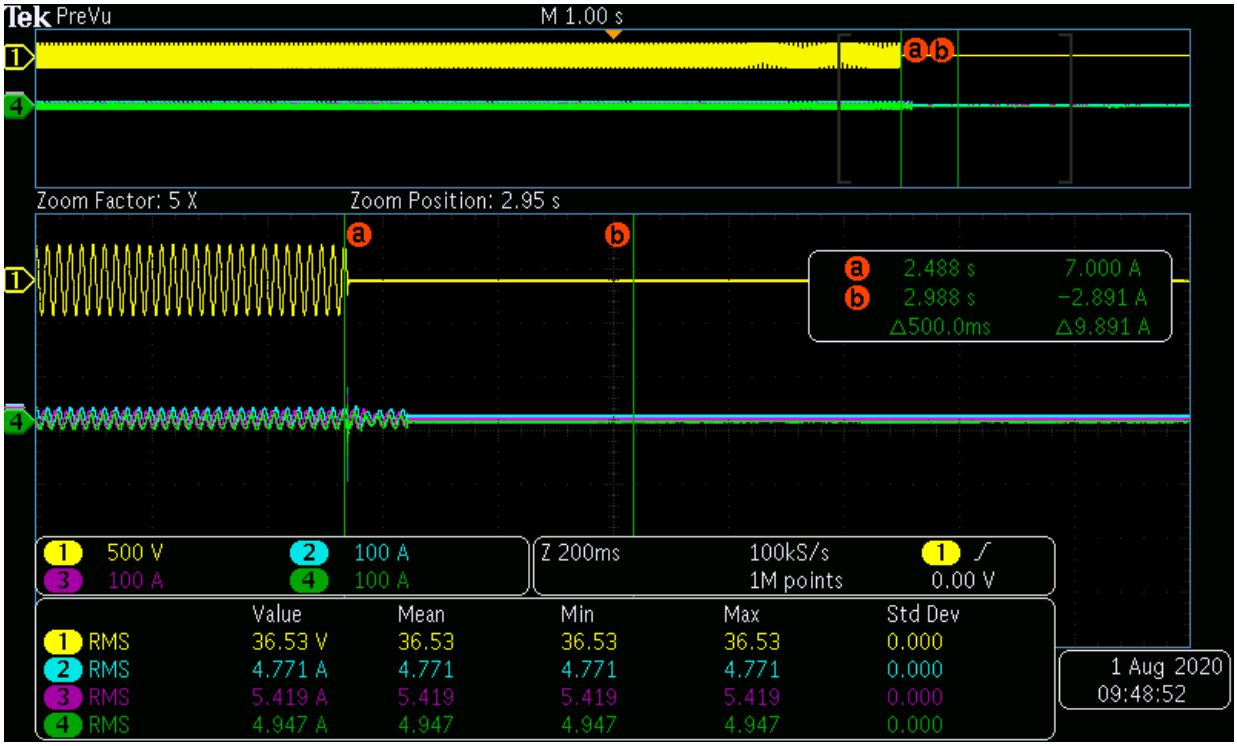
Time after 100ms fault



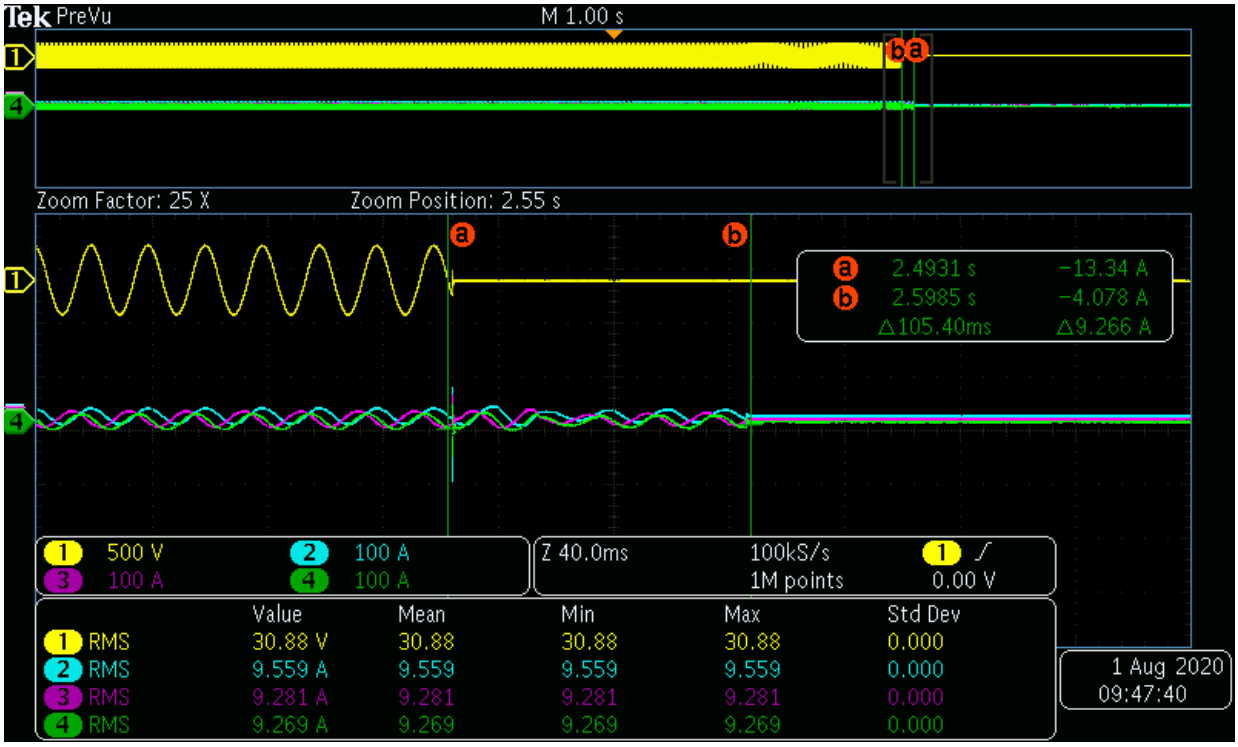
Time after 250ms fault



Time after 500ms fault

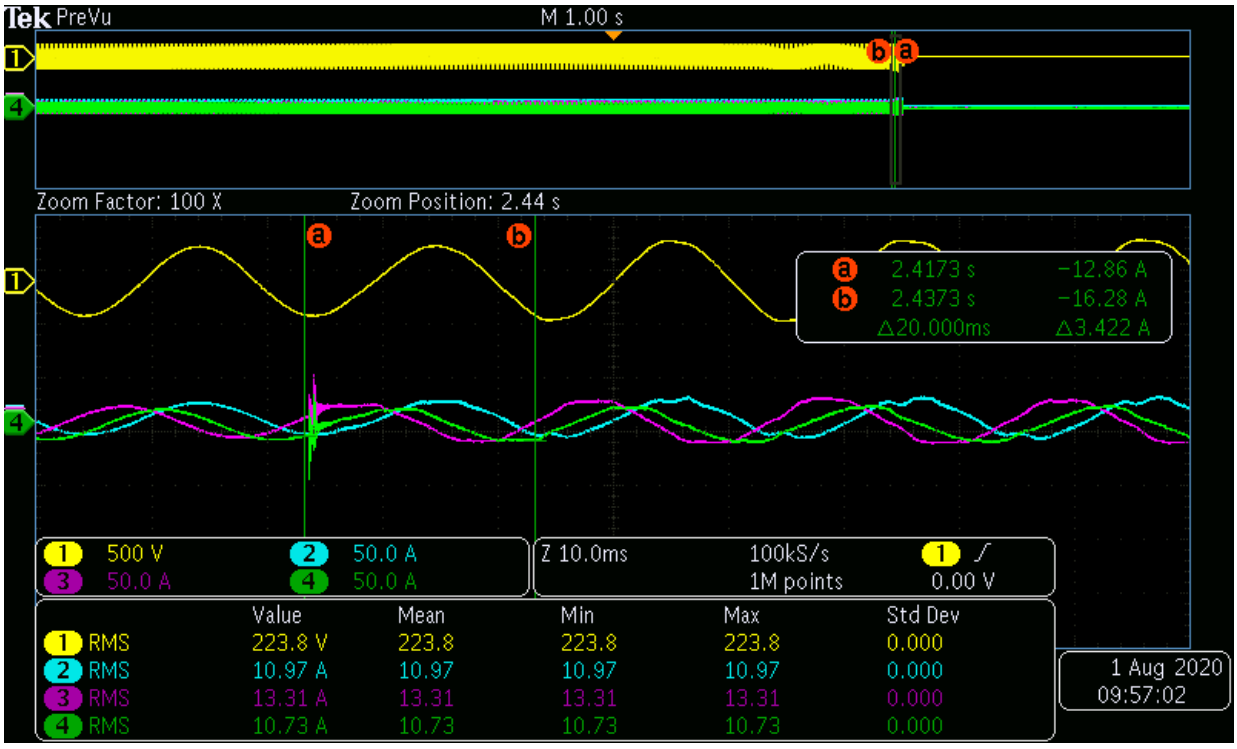


Time to trip

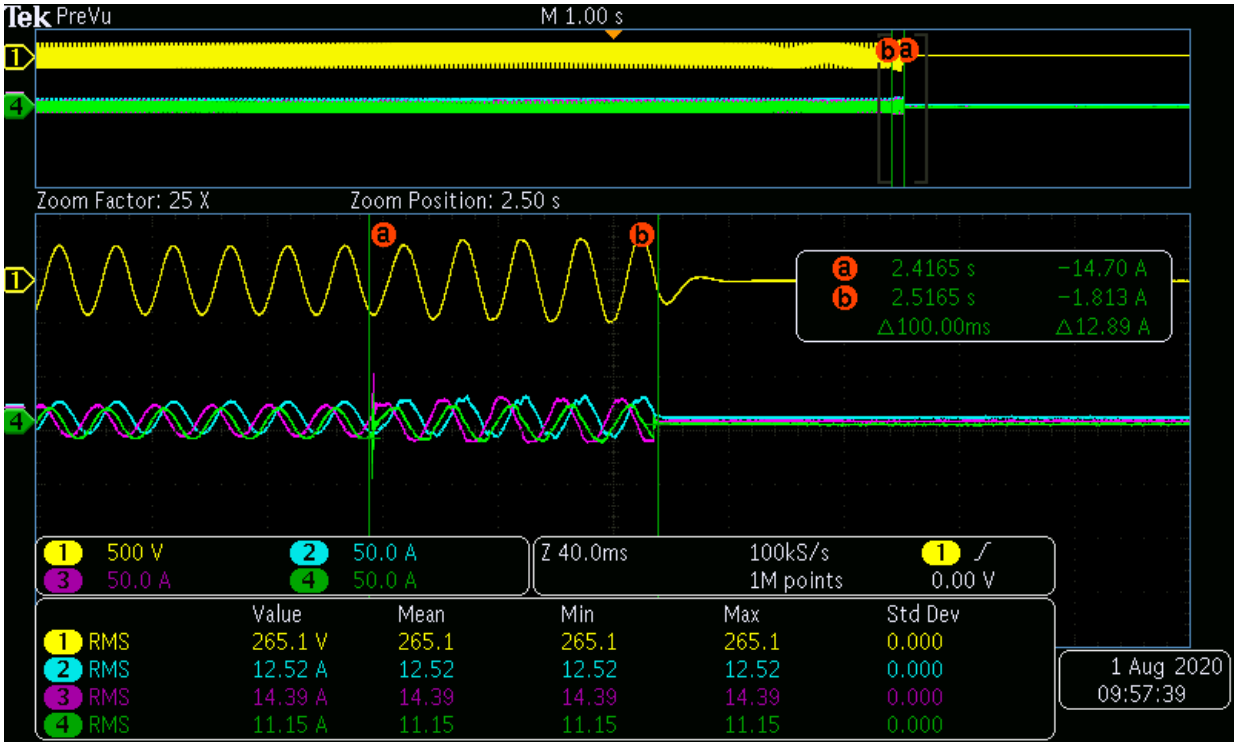


L2-L3

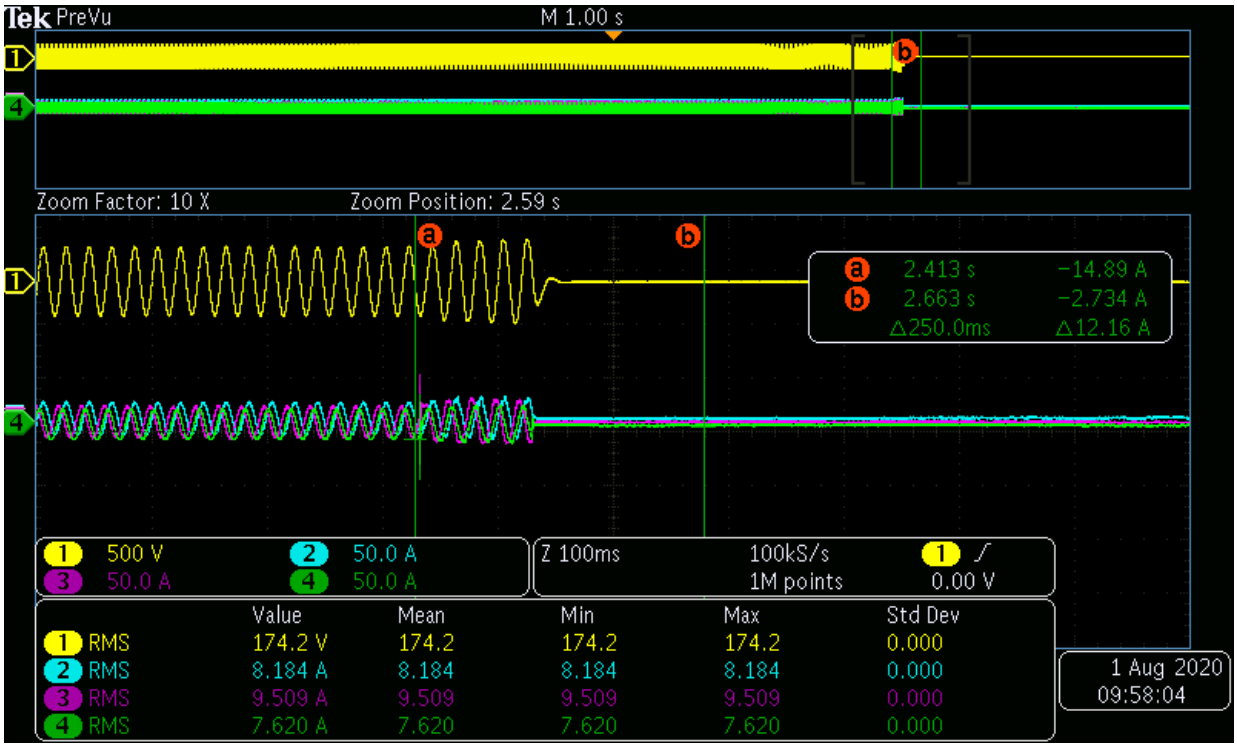
Time after 20ms fault



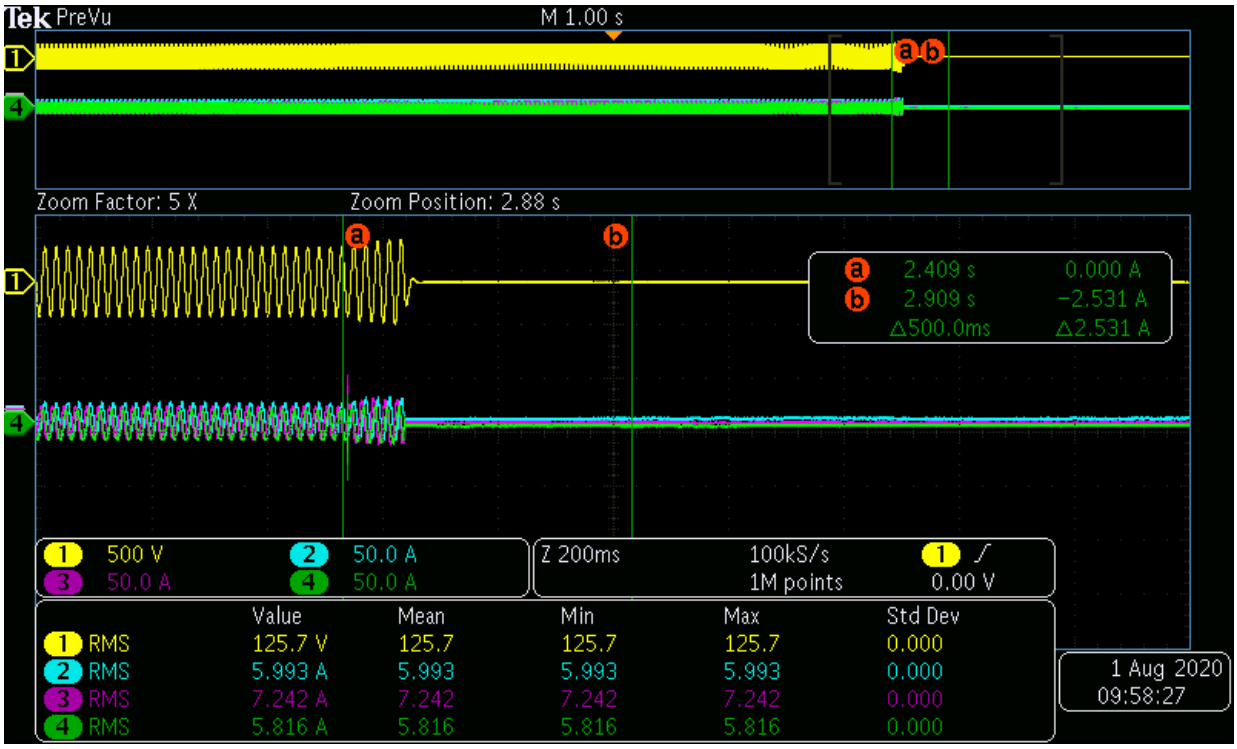
Time after 100ms fault



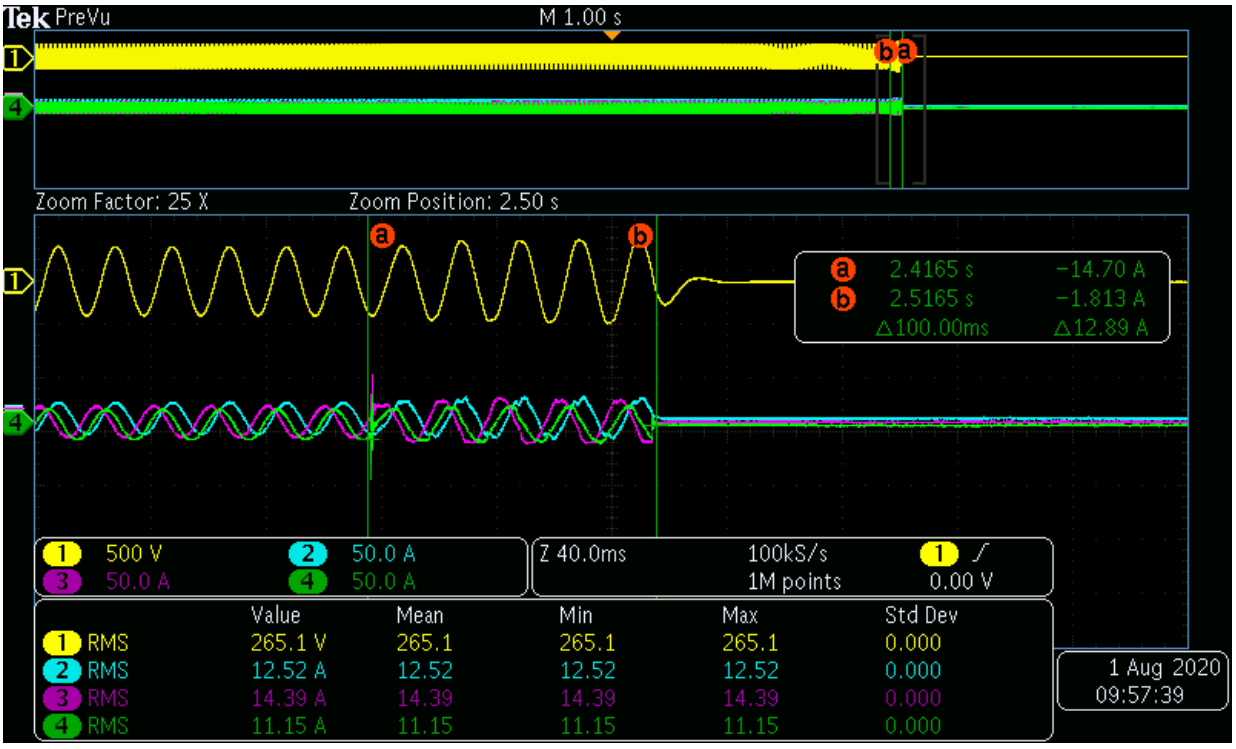
Time after 250ms fault



Time after 500ms fault



Time to trip



4.8 SELF-MONITORING SOLID STATE SWITCHING

The evaluation of this point has been made according to EREC G98 Annex A1 A.1.3.6.

This test does not apply because in the inverter there are not solid-state switching devices.

4.9 ELECTROMAGNETIC COMPATIBILITY (EMC)

All equipment shall conform to the generic EMC standards: BS EN61000-6-3: Electromagnetic Compatibility, Generic Emission Standard; and BS EN61000-6-1: Electromagnetic Compatibility, Generic Immunity Standard.

The compliances with these requirements are stated in the following test report:

- EMC Test Report: Test Report no CE200608N033 on 2020/06/17 which issued by Shenzhen BALUN Technology Co,. Ltd.

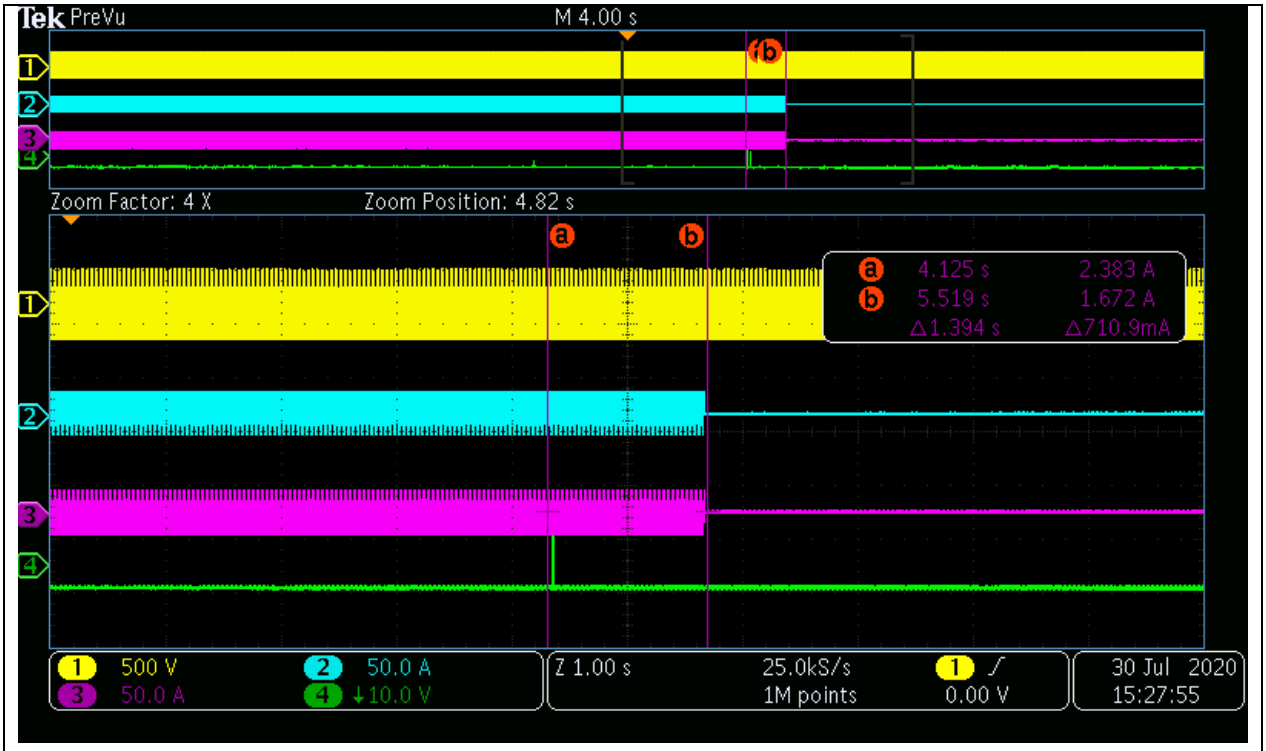
4.10 LOGIC INTERFACE.

Confirm that an input port is provided and can be used to shut down the module.

The evaluation of this point has been made according to Clause 9.4.3 of the standard.

Power Generating Modules connected to the DNO's Distribution Network shall be equipped with a logic interface (input port) in order to cease Active Power output within 5 s following an instruction being received at the input port.

Test results are graphically shown as below.



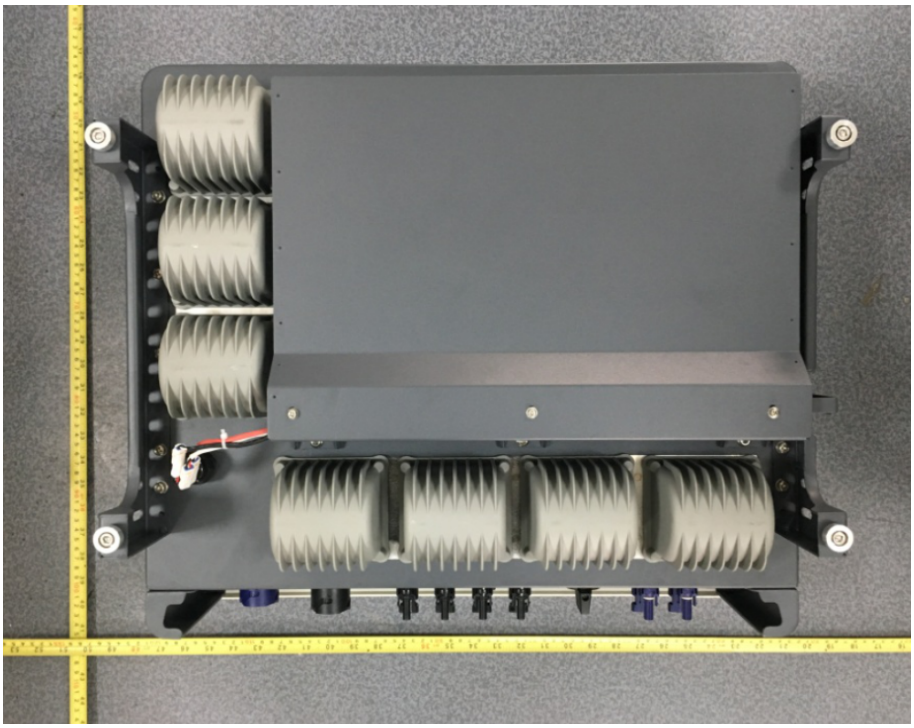
Ch1: AC Voltage

Ch2 and Ch3: Output Current

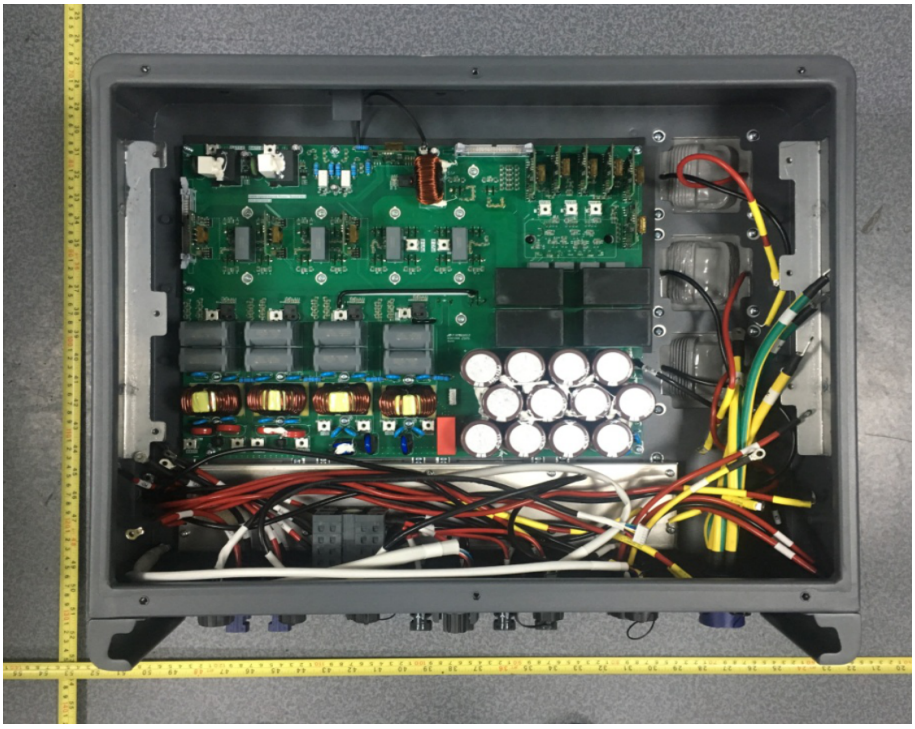
Ch4: Signal of logic interface.

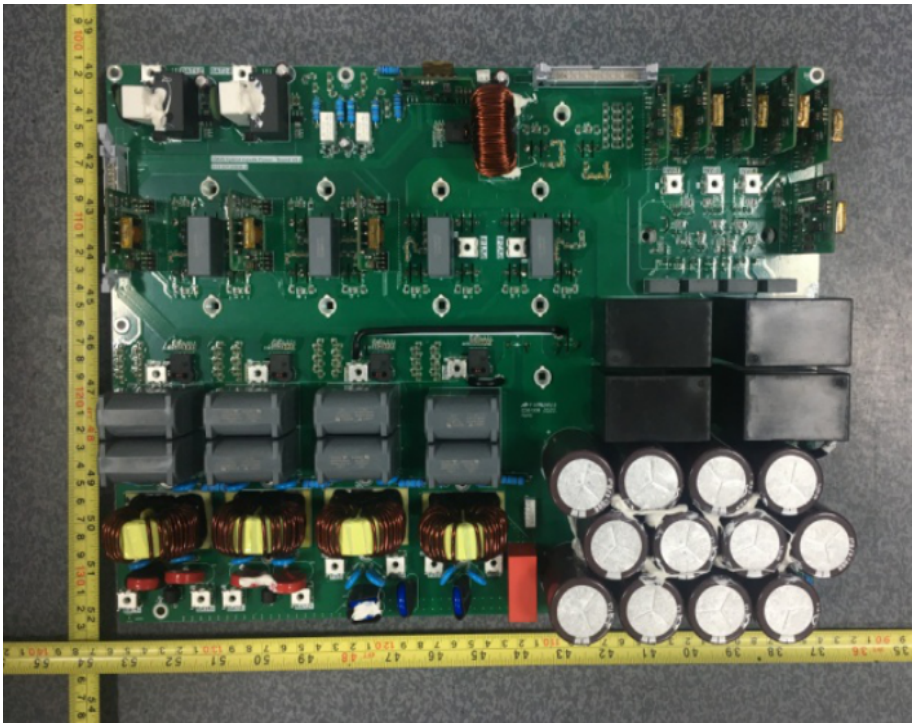
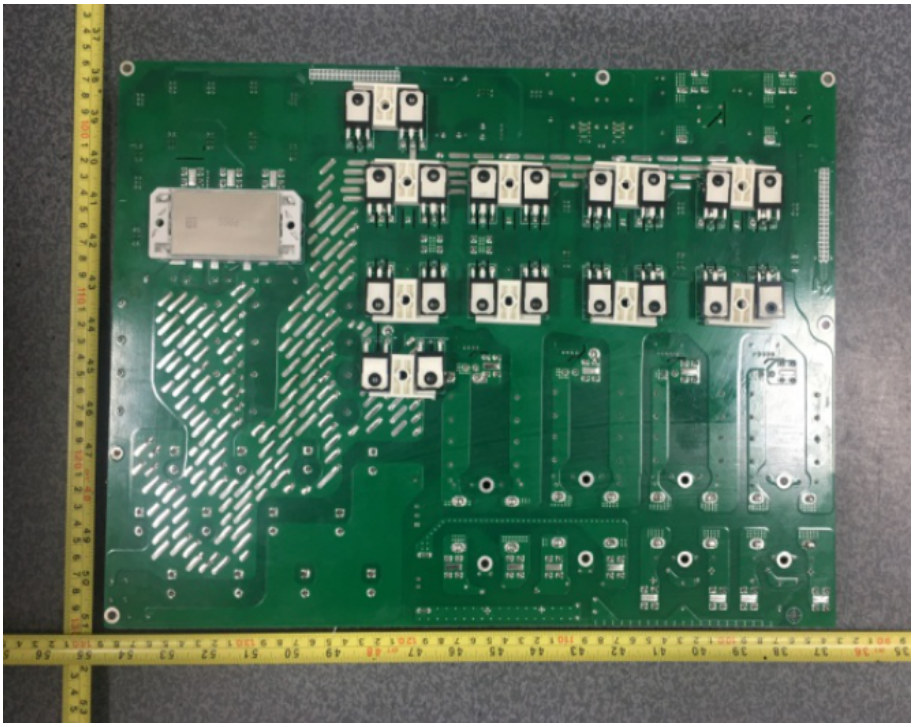
5 PICTURES

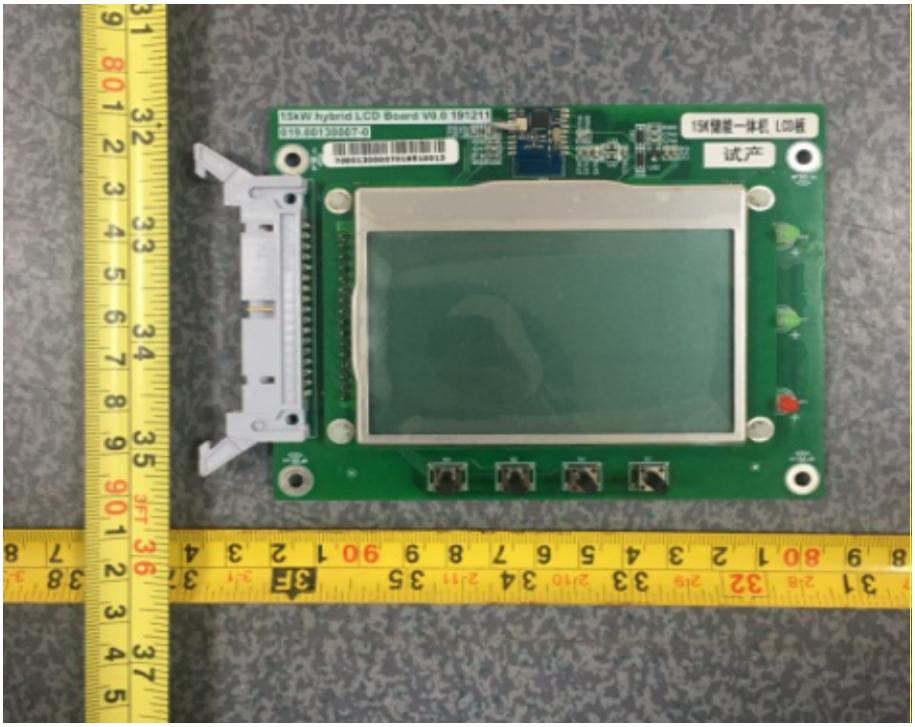
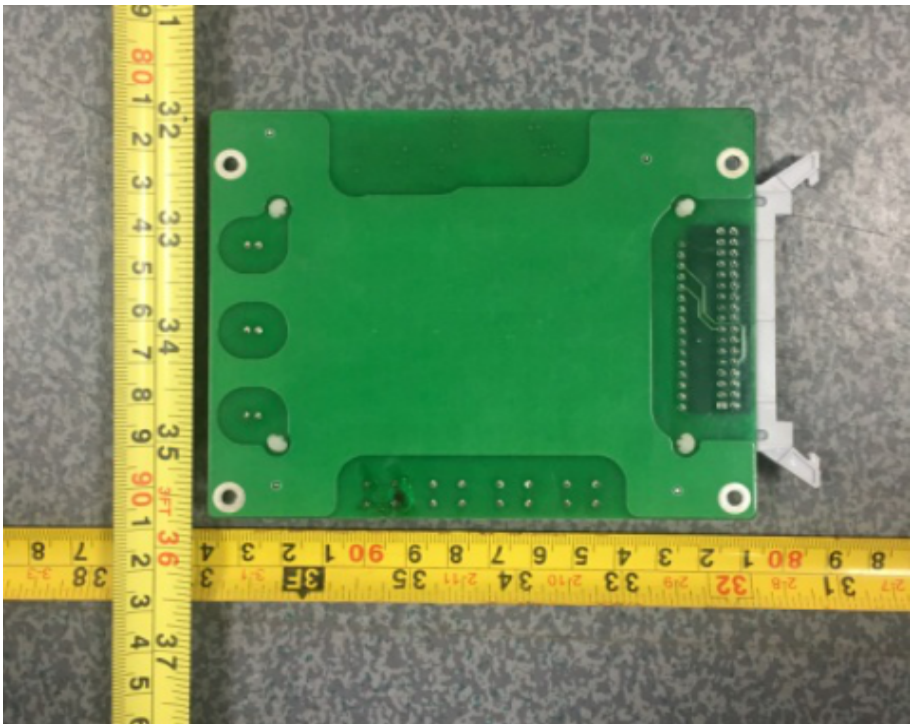
Front view

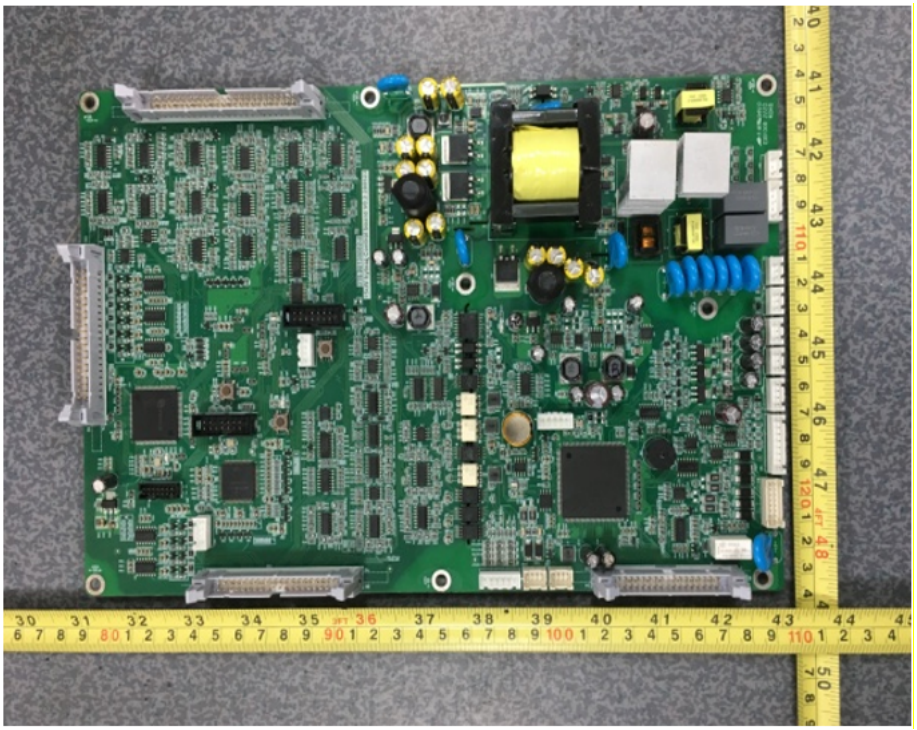
Back view


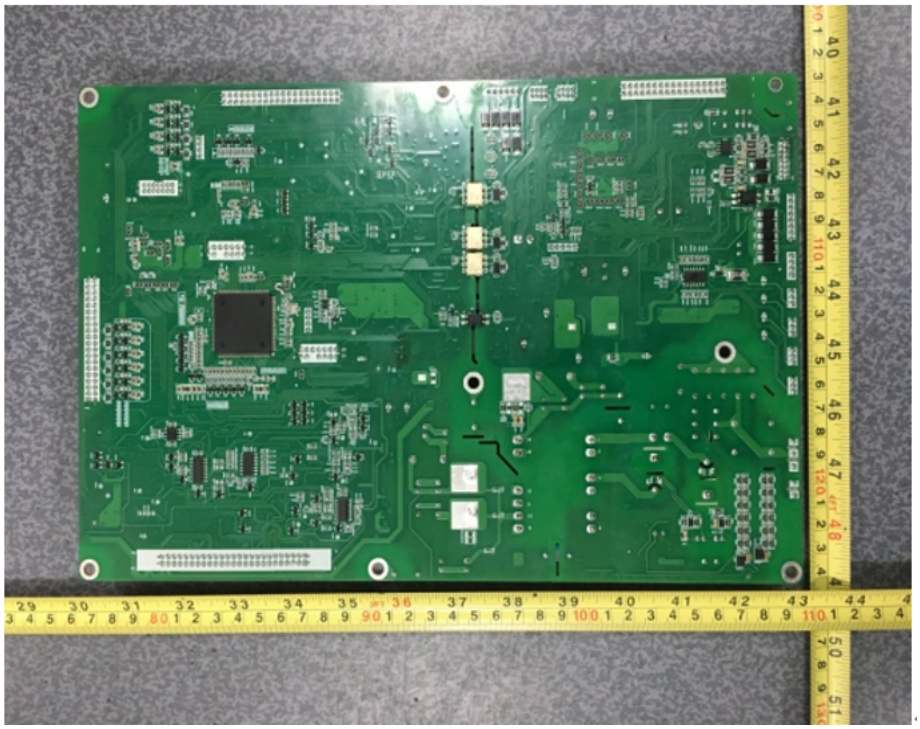
Internal View 1

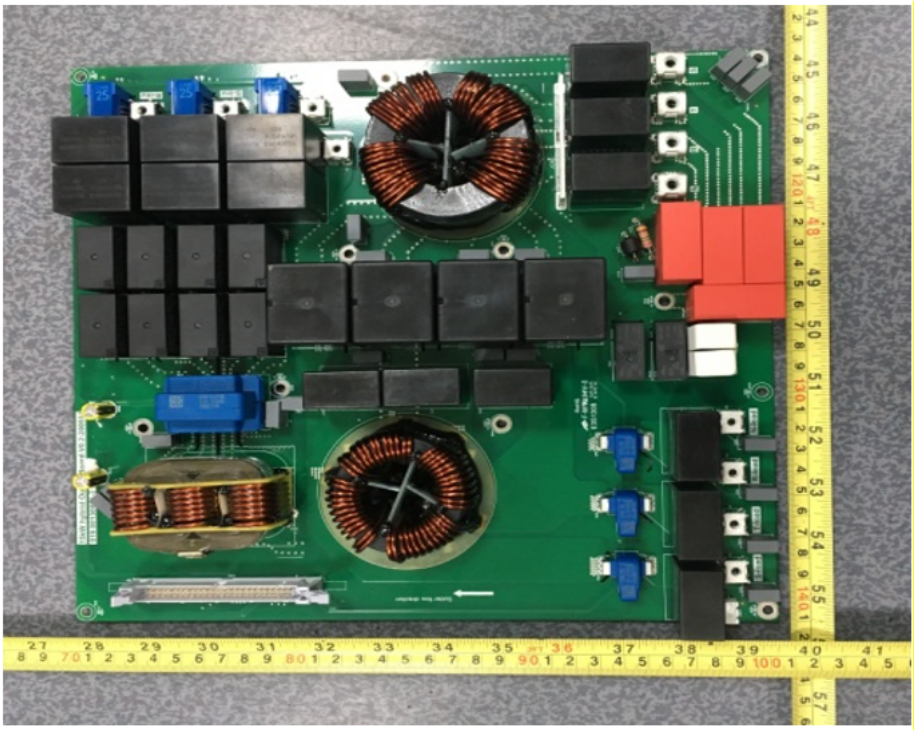
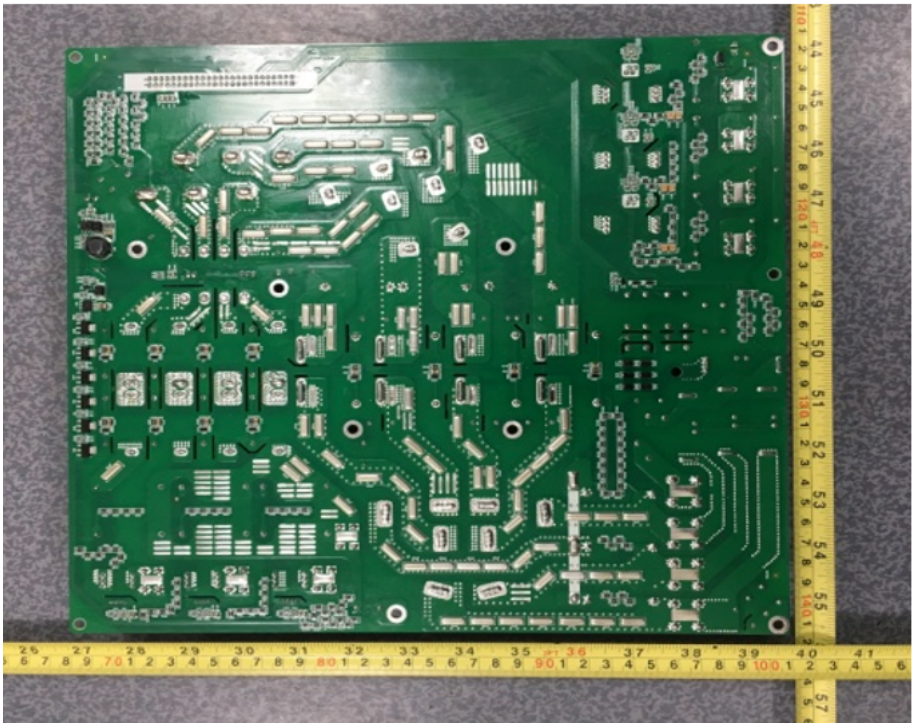

Internal View 2


Front side of Power board

Back side of Power board


Front side of Display board

Back side of Display board


Front side of Control board


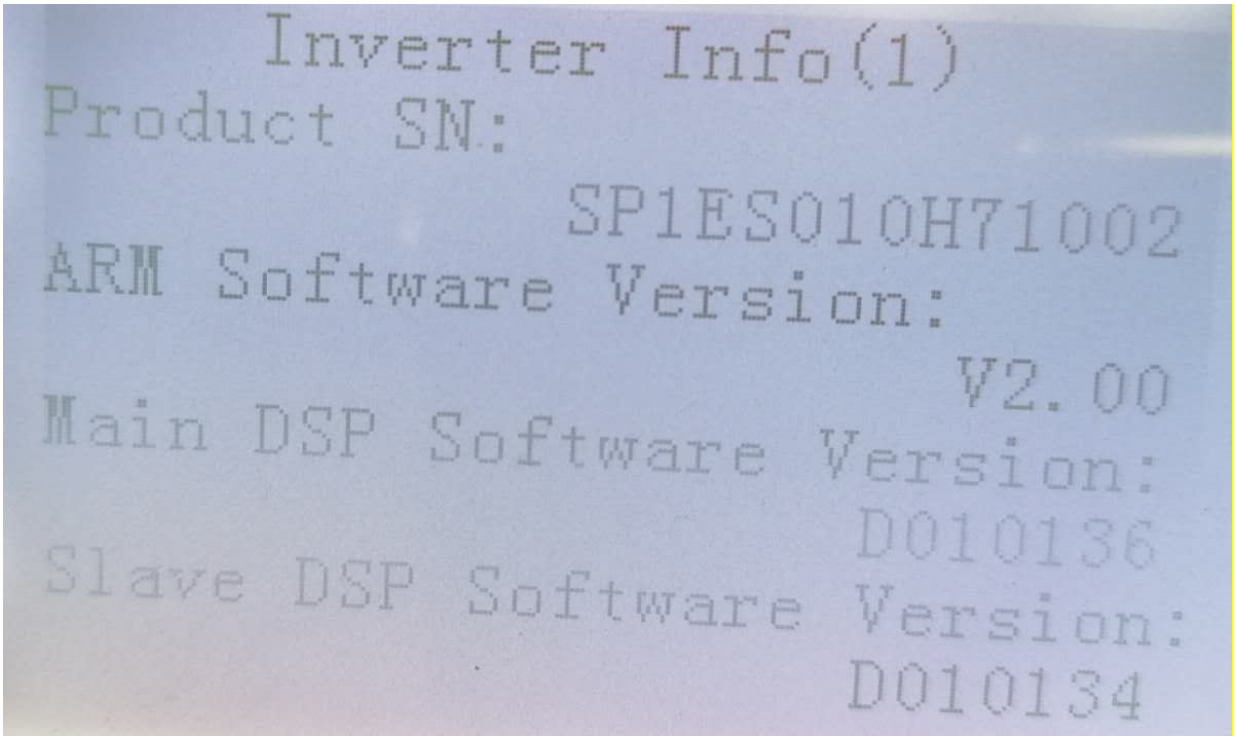
Back side of Control board


Front side of Output board front

Back side of Output board front


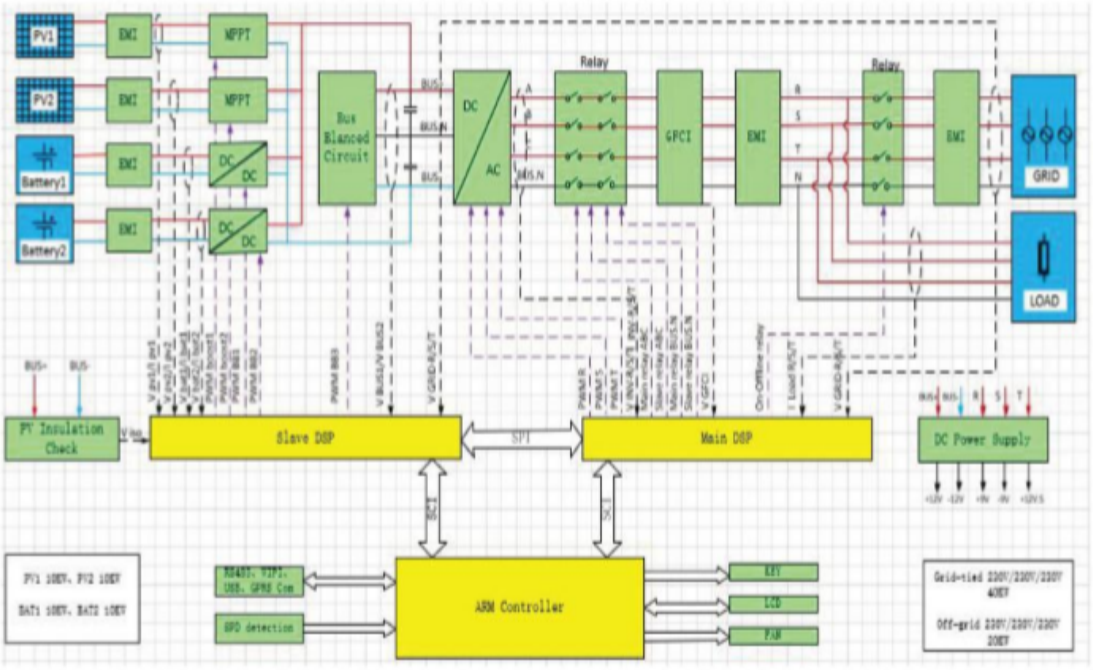
Grounding

Connection interface

Serial Number and Software Version



6 ELECTRICAL SCHEMES

Equipment under testing


----------END OF REPORT----------