TESTING FOR THE VERIFICATION OF COMPLIANCE OF PV INVERTER WITH :

ENGINEERING RECOMMENDATION G99 ISSUE 1-AMENDMENT 3, 16 MAY 2018,

REQUIREMENTS FOR THE CONNECTION OF GENERATION EQUIPMENT IN PARALLEL WITH PUBLIC DISTRIBUTION NETWORKS ON OR AFTER 27 APRIL 2019

Test Report Number	:	GZES200702291202
Type	:	SOFAR SOLAR
Tested Model	:	HYD 15KTL-3PH
Variant Models	:	HYD 5KTL-3PH, HYD 6KTL-3PH; HYD 8KTL-3PH, HYD 10KTL-3PH, HYD 20KTL-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	:	129

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Test Report Historical Revision:

Test Report Version	Date	Resume
GZES200702291202	26 / 08 / 2020	First issuance

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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 G99 ISSUE 1-AMENDMENT 3, 16 MAY 2018, REQUIREMENTS FOR THE CONNECTION OF GENERATION EQUIPMENT IN PARALLEL WITH PUBLIC DISTRIBUTION NETWORKS ON OR AFTER 27 APRIL 2019”.

Note: This standard details connection process, technical and compliance requirements for Type A, Type B, Type C and Type D Power Generating Modules. The tests offered at this test report evaluate the EUT compliance with the requirements of **Type A** defined as below:

Type A
A Power Generating Module with a Connection Point below 110 kV and a Registered Capacity of 0.8 kW or greater but less than 1 MW.

Type B
A Power Generating Module with a Connection Point below 110 kV and Registered Capacity of 1 MW or greater but less than 10 MW.

Type C
A Power Generating Module with a Connection Point below 110 kV and a Registered Capacity of 10 MW or greater but less than 50 MW.

Type D
A Power Generating Module with a Connection Point at or greater than 110 kV, and/or with a Registered Capacity of 50 MW or greater.

2 GENERAL INFORMATION

2.1 TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed along between the 08rd of July to 20th 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 15KTL-3PH

Serial Number ..... : SP1ES020H71002

Software Version..... : V2.00

Rated Characteristics..... : DC input: 180-960 V, Max. 2× 25 A
AC output: 3~/N/PE 230, 50 Hz, 3× 21.7A
(max. 3× 24A), 15000 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

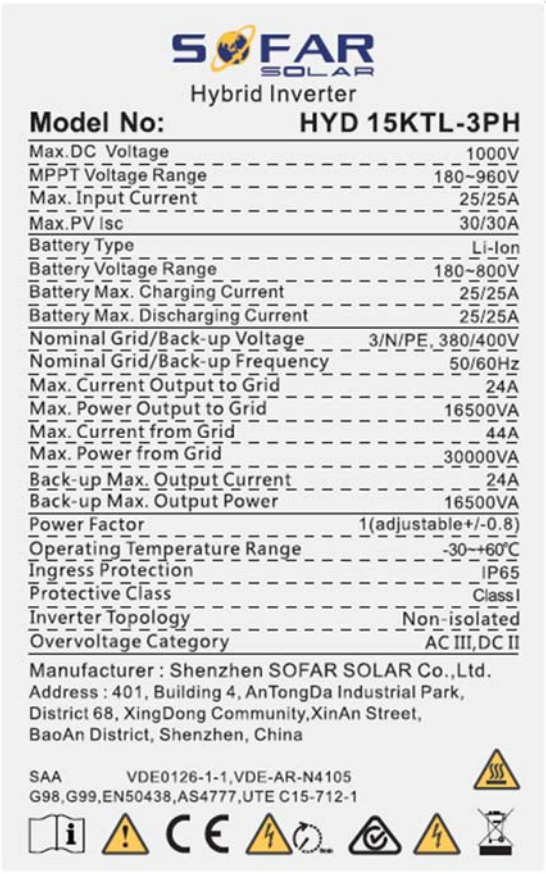
Type of connection to the main supply ..... : TN

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 **HYD15KTL-3PH**'s except the parameters of rating.

Equipment Under Testing:

- HYD 15KTL-3PH;

The variants models are:

- HYD 5KTL-3PH;
- HYD 6KTL-3PH;
- HYD 8KTL-3PH;
- HYD 10KTL-3PH;
- HYD 20KTL-3PH;

Model	HYD 5KTL-3PH	HYD 6KTL-3PH	HYD 8KTL-3PH	HYD 10KTL-3PH	HYD 15KTL-3PH	HYD 20KTL-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	350V~850V	450V~850V
Max. input current	12.5A/12.5A	12.5A/12.5A	12.5A/12.5A	25A/25A	25A/25A	25A/25A
Max. short current	15A/15A	15A/15A	15A/15A	30A/30A	30A/30A	30A/30A
Battery Input Data						
Battery voltage range	180V~800V					
Battery voltage range for full load	200V~800V	240V~800V	320V~800V	200V~800V	300V~800V	400V~800V
No. of battery input	1			2		
Nominal charging/discharging power	5000W	6000W	8000W	10000W	15000W	20000W
Max. charging/discharging current	25A	25A	25A	50A (25A/25A)	50A (25A/25A)	50A (25A/25A)
AC Output Data (On-grid)						
Nominal AC power	5000W	6000W	8000W	10000W	15000W	20000W
Max. AC power output to utility grid	5500VA	6600VA	8800VA	11000VA	16500VA	22000VA
Max. AC power from utility grid	10000VA	12000VA	16000VA	20000VA	30000VA	40000VA
Max. AC current output to utility grid	8A	10A	13A	16A	24A	32A
Rated AC current output to utility grid	7.2A	8.7A	11.6A	14.5A	21.7A	29A

Max. AC Current from utility grid	15A	17A	24A	29A	44A	58A
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	15000W	20000W
Max. output power	5500VA	6600VA	8800VA	11000VA	16500VA	22000VA
Rated. output current	7.2A	8.7A	11.6A	14.5A	21.7A	29A
Max. output current	8A	10A	13A	16A	24A	32A
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	Fan	Fan

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	C8202909082002110001	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	C8202909082002110002	2020/03/02	2021/03/01
SGS	13	True RMS Multimeter	Fluke / 187	GZE012-8	2019/12/05	2020/12/04

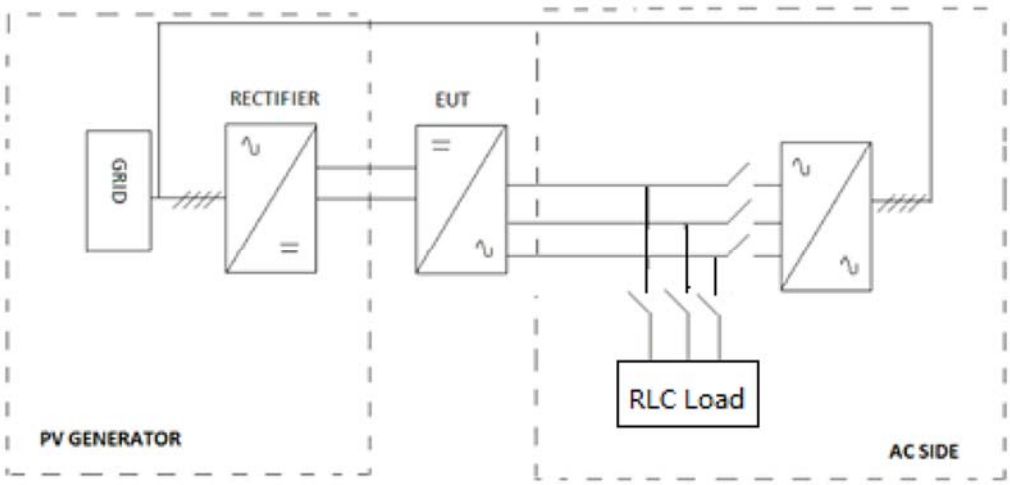
2.4 MEASUREMENT UNCERTAINTY

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

Magnitude	Uncertainty
Voltage measurement	±1.5 %
Current measurement	±2.0 %
Frequency measurement	±0.2 %
Time measurement	±0.2 %
Power measurement	±2.5 %
Phase Angle	±1 º
Temperature	±3 ºC
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 petitioner. 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	
Annex A 2-3 (1)	Operating Range		P
A.7.1.5	Harmonics		P
A.7.1.4.3	Voltage fluctuations and Flicker		P
A.7.1.4.4	DC injection		P
A.7.1.4.2	Power Factor		P
A.7.1.2.3	Frequency tests		P
A.7.1.2.2	Voltage tests:		P
A.7.1.2.4	Loss of Mains test		P
A.7.1.2.6	Loss of Mains Protection, Vector Shift Stability test.		P
	Loss of Mains Protection, RoCoF Stability test		P
A.7.1.3	Limited Frequency Sensitive Mode – Over frequency test		P
Annex A 2-3 (10)	Re-connection timer.		P
A.7.1.5	Fault level contribution		P
A.7.1.7	Self-Monitoring solid state switching	No solid state switching devices	N/A
Para 15.2.1	Wiring functional tests		N/A
Annex A 2-3 (14)	Logic Interface (input port)		P

4 TEST RESULTS

4.1 OPERATING RANGE

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

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

The Interface Protection shall be disabled during the tests.

The evaluation of this point has been made according to Annex A.7.2.2.

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

Test 1:

Voltage = 85% of nominal (195.5 V)

Frequency = 47 Hz

Power factor = 1

Period of test 20 s

Test 2:

Voltage = 85% of nominal (195.5 V)

Frequency = 47.5 Hz

Power factor = 1

Period of test 90 minutes

Test 3:

Voltage = 110% of nominal (253 V).

Frequency = 51.5 Hz

Power factor = 1

Period of test 90 minutes

Test 4:

Voltage = 110% of nominal (253 V).

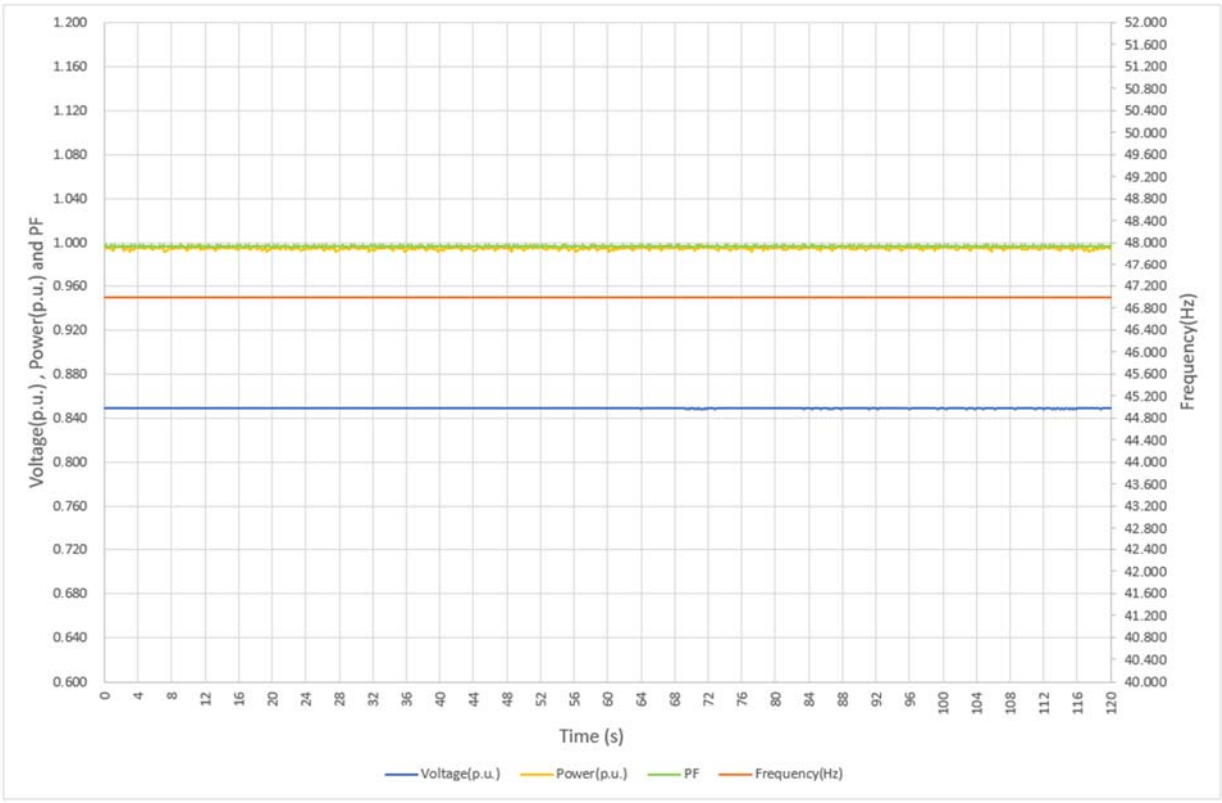
Frequency = 52.0 Hz

Power factor = 1

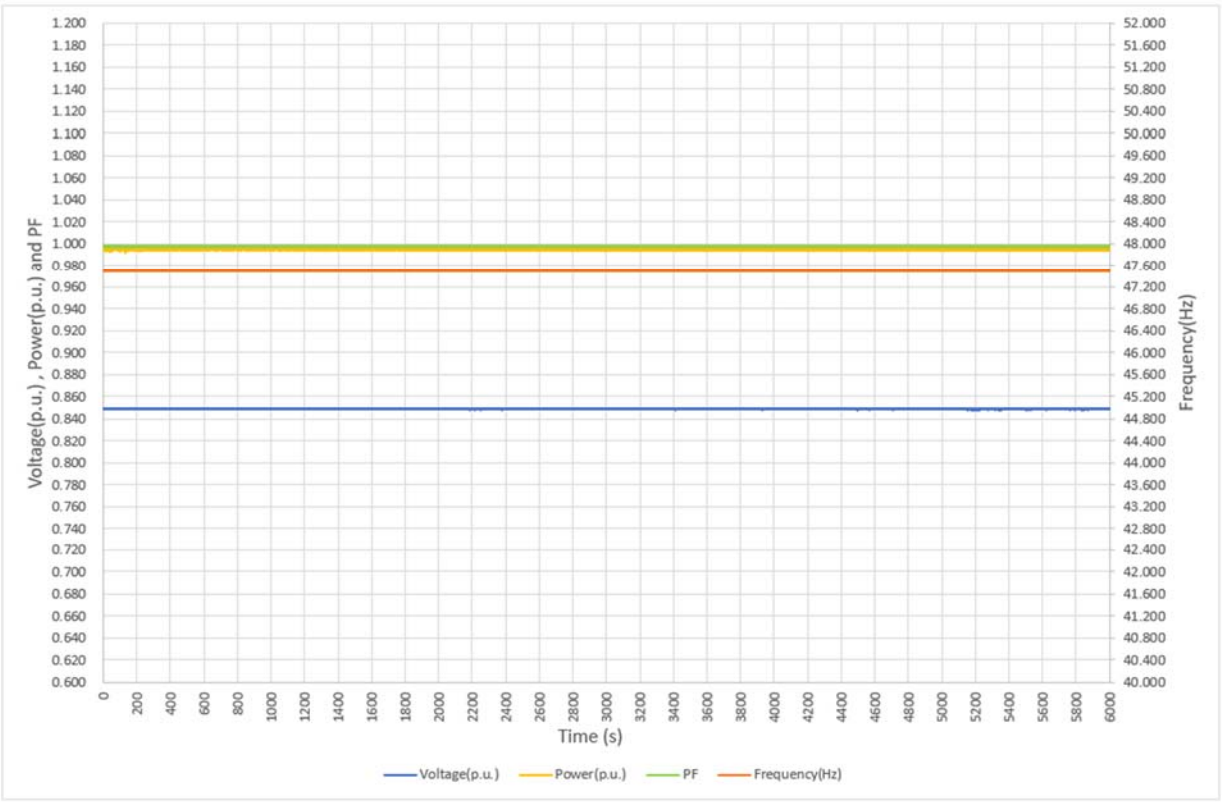
Period of test 15 minutes

Test results are graphically shown in following pages.

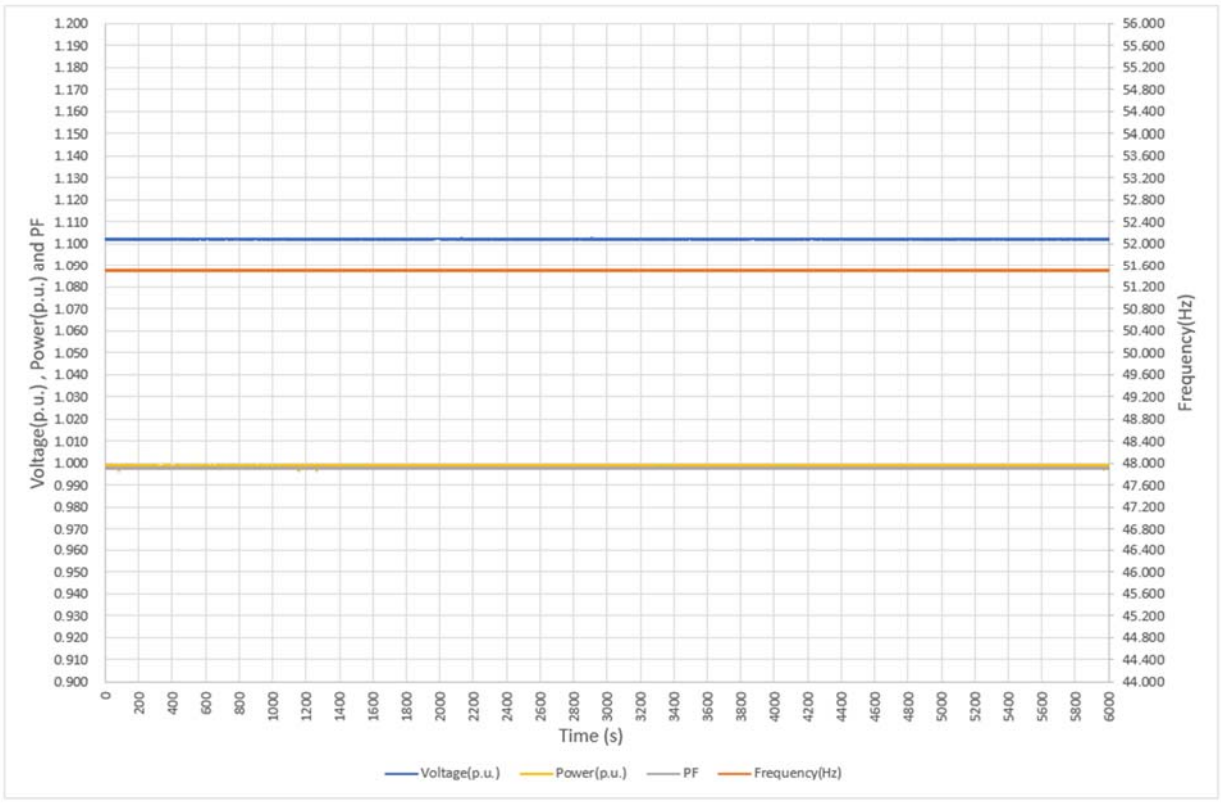
Test 1


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

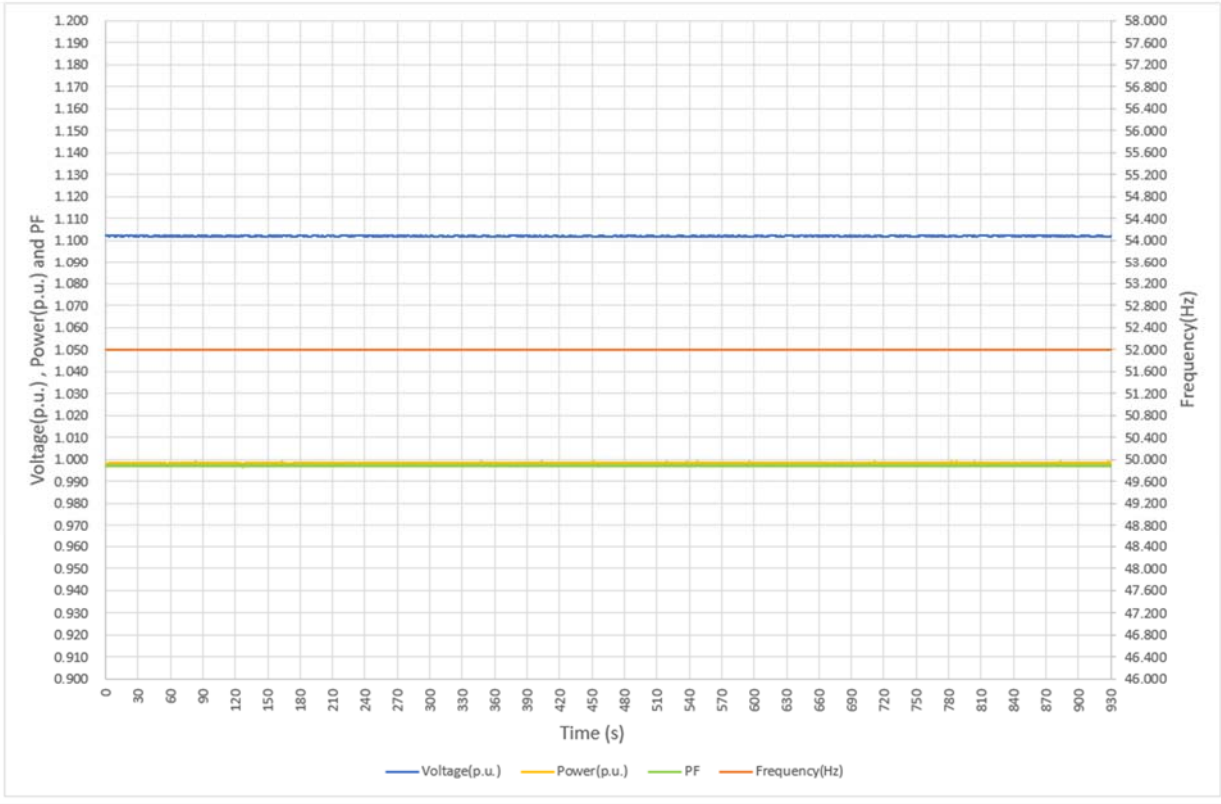
Test 2


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)

Test 4


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 Harmonics

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

Power Generating Modules with emissions close to the limits laid down in BS EN 61000-3-12 may require the installation of a transformer between 2 and 4 times the rating of the Power Generating Module in order to accept the connection to a Distribution Network.

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

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

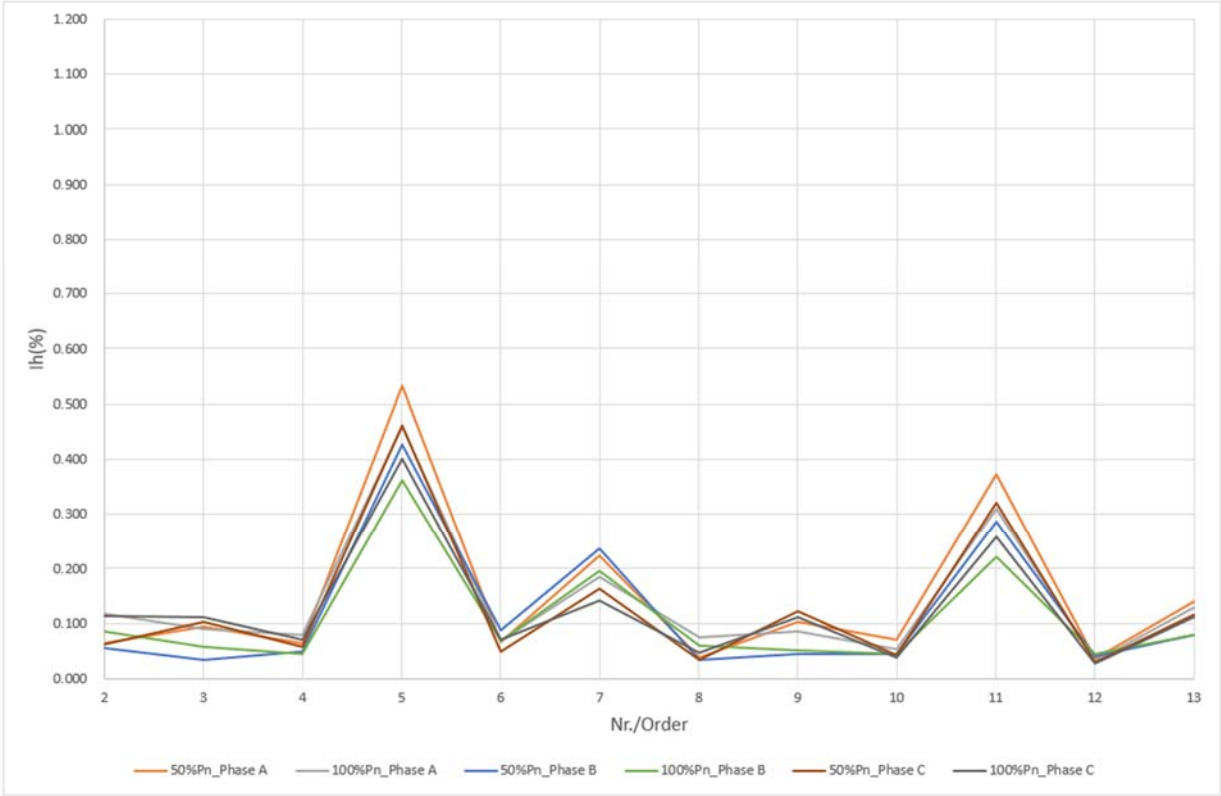
Following tables show the test results:

Power Generating Module rating per phase (rpp)			15	kVA	Harmonic % = Measured Value (A) x 23/rating per phase (kVA)	
Phase A						
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	(%)	Measured Value MV in Amps	(%)	1 Phase	3 Phase
2	0.014	0.063	0.025	0.117	8%	8%
3	0.020	0.093	0.019	0.089	21.6%	Not stated
4	0.014	0.063	0.017	0.078	4%	4%
5	0.116	0.534	0.100	0.458	10.7%	10.7%
6	0.014	0.065	0.015	0.068	2.67%	2.67%
7	0.049	0.223	0.040	0.185	7.2%	7.2%
8	0.008	0.038	0.016	0.075	2%	2%
9	0.022	0.103	0.019	0.086	3.8%	Not stated
10	0.015	0.070	0.012	0.054	1.6%	1.6%
11	0.081	0.372	0.067	0.309	3.1%	3.1%
12	0.008	0.036	0.007	0.030	1.33%	1.33%
13	0.030	0.140	0.028	0.129	2%	2%
THD	--	0.291	--	0.264	23%	13%
PWHD	--	0.771	--	0.769	23%	22%

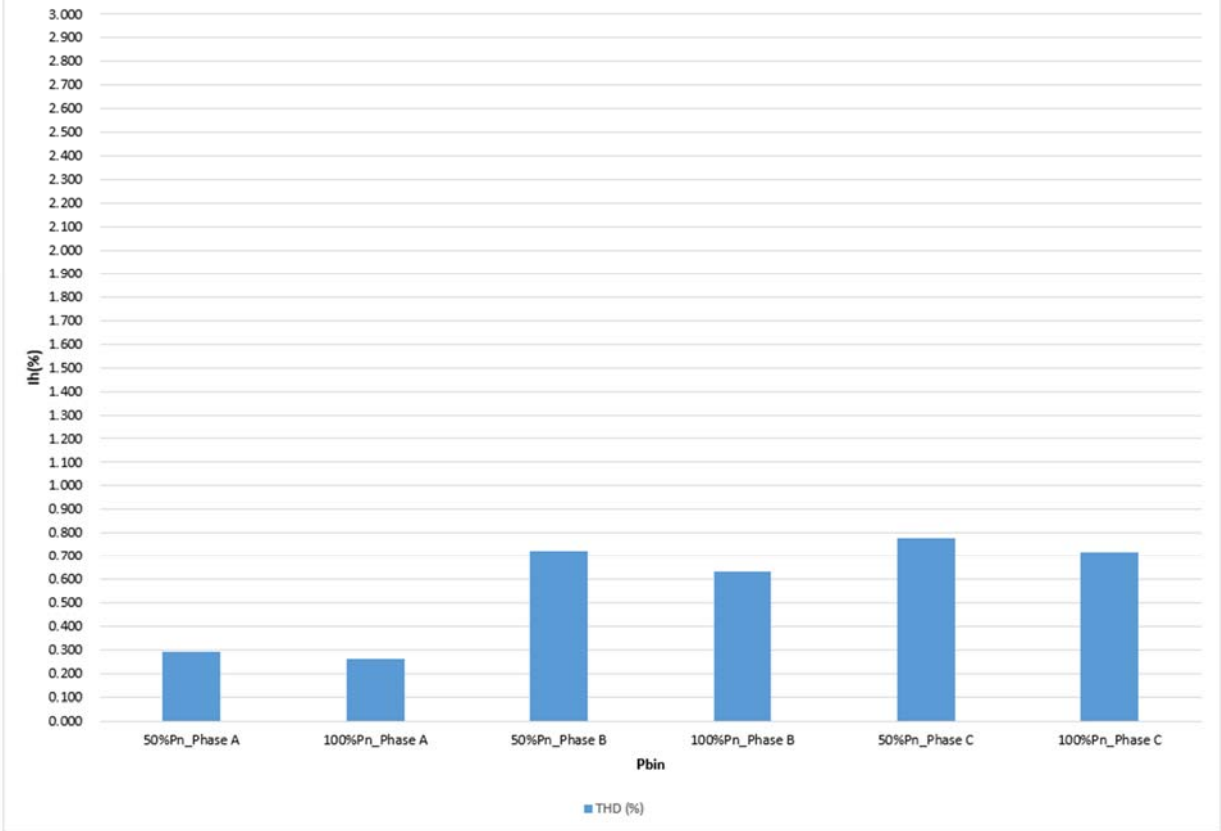
Phase B						
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	(%)	Measured Value MV in Amps	(%)	1 Phase	3 Phase
2	0.012	0.055	0.019	0.086	8%	8%
3	0.007	0.033	0.012	0.056	21.6%	Not stated
4	0.010	0.048	0.010	0.044	4%	4%
5	0.093	0.427	0.079	0.361	10.7%	10.7%
6	0.019	0.088	0.015	0.068	2.67%	2.67%
7	0.052	0.237	0.042	0.194	7.2%	7.2%
8	0.007	0.033	0.013	0.058	2%	2%
9	0.009	0.043	0.011	0.051	3.8%	Not stated
10	0.010	0.044	0.009	0.043	1.6%	1.6%
11	0.062	0.287	0.048	0.222	3.1%	3.1%
12	0.009	0.040	0.009	0.044	1.33%	1.33%
13	0.017	0.079	0.017	0.078	2%	2%
THD	--	0.721	--	0.634	23%	13%
PWHD	--	2.052	--	1.958	23%	22%

Phase C						
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	(%)	Measured Value MV in Amps	(%)	1 Phase	3 Phase
2	0.013	0.061	0.025	0.114	8%	8%
3	0.022	0.102	0.024	0.110	21.6%	Not stated
4	0.013	0.058	0.015	0.069	4%	4%
5	0.100	0.461	0.087	0.401	10.7%	10.7%
6	0.010	0.048	0.015	0.071	2.67%	2.67%
7	0.036	0.164	0.031	0.142	7.2%	7.2%
8	0.007	0.034	0.010	0.046	2%	2%
9	0.026	0.121	0.024	0.110	3.8%	Not stated
10	0.009	0.041	0.008	0.038	1.6%	1.6%
11	0.070	0.321	0.056	0.258	3.1%	3.1%
12	0.006	0.029	0.006	0.027	1.33%	1.33%
13	0.025	0.114	0.024	0.111	2%	2%
THD	--	0.781	--	0.719	23%	13%
PWHD	--	2.261	--	2.228	23%	22%

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	0.131	0.034
PLT	≤ 0.65	0.105	0.105
dc	≤ 3.30%	0.25%	0.0%
d(t)	≤ 3.30%	0	0
dmax	4%	0.35%	0.0%
Phase B			
	Limit	**Starting measured values**	**Stopping measured values**
PST	≤ 1	0.187	0.187
PLT	≤ 0.65	0.153	0.153
dc	≤ 3.30%	0.29%	0.02%
d(t)	≤ 3.30%	0	0.
dmax	4%	0.44%	0.11%
Phase C			
	Limit	**Starting measured values**	**Stopping measured values**
PST	≤ 1	0.133	0.048
PLT	≤ 0.65	0.107	0.107
dc	≤ 3.30%	0.26%	0.00%
d(t)	≤ 3.30%	0	0
dmax	4%	0.74%	0.00%

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

Phase B

Phase C


Flicker Mode
Flicker
Range Over
U1 U2 U3 U4 U5 U6 U7
I1 I2 I3 I4 I5 I6 I7
SCL Line Filter
AVG Freq Filter
PA_00001.tif
CH: 1 2 3 4 5 6 7
ΣA(3P4W)
U1 300 V
I1 50 A
Sync Src: U1
Integral: Reset
U2 300 V
I2 50 A
Sync Src: U1
Integral: Reset
U3 300 V
I3 50 A
Sync Src: U1
Integral: Reset
Element 4
U4 1000 V
I4 50 A
Sync Src: U1
Integral: Reset
Element 5
U5 1000 V
I5 5 A
Sync Src: U1
Integral: Reset
Count 2/2 Complete
Interval 00:00s/10:00s
Element 3
Volt Range 300 V/50Hz
Un (U3) 230.584V
Freq (U3) 50.000Hz
Dmin 0.10%
Element3 Judgement Pass
Total Judgement Pass
(Element1,2,3)
dc[%] dmax[%] d(t)[ms] Pst Plt
Limit 3.30 4.00 500 3.00% 1.00 0.65 N:2
No. 1 0.257 Pass 0.744 Pass 0.0 Pass 0.133 Pass
2 0.000 Pass 0.000 Pass 0.0 Pass 0.048 Pass
Result Pass Pass Pass Pass 0.107 Pass
Update: 659
Runtime: 6:51:31
2020-08-03
15:14:51

Running operation 2 hours				
Pbin (%)	100%			
	Limit	Phase A	Phase B	Phase C
		Measured values	Measured values	Measured values
PST	≤ 1	0.078	0.154	0.067
PLT	≤ 0.65	0.068	0.148	0.059
dc	≤ 3.30%	0.13%	0.03%	0.03%
d(t)	≤ 3.30%	0	0	0
dmax	4%	0.20%	0.14%	0.10%

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	0.110	Pass	0.187	Pass	0.0	Pass	0.075	Pass		
2	0.110	Pass	0.185	Pass	0.0	Pass	0.076	Pass		
3	0.107	Pass	0.180	Pass	0.0	Pass	0.078	Pass		
4	0.108	Pass	0.170	Pass	0.0	Pass	0.078	Pass		
5	0.101	Pass	0.165	Pass	0.0	Pass	0.070	Pass		
6	0.104	Pass	0.166	Pass	0.0	Pass	0.064	Pass		
7	0.104	Pass	0.162	Pass	0.0	Pass	0.065	Pass		
8	0.101	Pass	0.203	Pass	0.0	Pass	0.059	Pass		
9	0.127	Pass	0.186	Pass	0.0	Pass	0.059	Pass		
10	0.115	Pass	0.168	Pass	0.0	Pass	0.058	Pass		
11	0.115	Pass	0.182	Pass	0.0	Pass	0.060	Pass		
12	0.107	Pass	0.168	Pass	0.0	Pass	0.065	Pass		
Result		Pass		Pass		Pass		Pass	0.068	Pass

Phase B

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.027	Pass	0.140	Pass	0.0	Pass	0.154	Pass		
2	0.022	Pass	0.132	Pass	0.0	Pass	0.154	Pass		
3	0.029	Pass	0.146	Pass	0.0	Pass	0.153	Pass		
4	0.029	Pass	0.132	Pass	0.0	Pass	0.153	Pass		
5	0.008	Pass	0.129	Pass	0.0	Pass	0.150	Pass		
6	0.029	Pass	0.130	Pass	0.0	Pass	0.145	Pass		
7	0.027	Pass	0.136	Pass	0.0	Pass	0.147	Pass		
8	0.032	Pass	0.130	Pass	0.0	Pass	0.143	Pass		
9	0.030	Pass	0.137	Pass	0.0	Pass	0.143	Pass		
10	0.014	Pass	0.134	Pass	0.0	Pass	0.141	Pass		
11	0.013	Pass	0.128	Pass	0.0	Pass	0.143	Pass		
12	0.025	Pass	0.133	Pass	0.0	Pass	0.148	Pass		
Result		Pass		Pass		Pass		Pass	0.148	Pass

Phase C

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.000	Pass	0.000	Pass	0.0	Pass	0.064	Pass		
2	0.018	Pass	0.105	Pass	0.0	Pass	0.065	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.066	Pass		
4	0.028	Pass	0.103	Pass	0.0	Pass	0.067	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.061	Pass		
6	0.012	Pass	0.101	Pass	0.0	Pass	0.054	Pass		
7	0.009	Pass	0.104	Pass	0.0	Pass	0.057	Pass		
8	0.014	Pass	0.101	Pass	0.0	Pass	0.052	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.051	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.050	Pass		
11	0.020	Pass	0.105	Pass	0.0	Pass	0.052	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.058	Pass		
Result		Pass		Pass		Pass		Pass	0.059	Pass

4.2.3 DC Injection

The tests should be carried out on a single Generating Unit. Tests are to be carried out at three defined power levels ±5%. At 230 V a 15 kW three phase Inverter has a current output of 65A so DC limit is 163 mA. These tests should be undertaken in accordance with Annex A.7.1.4.4.

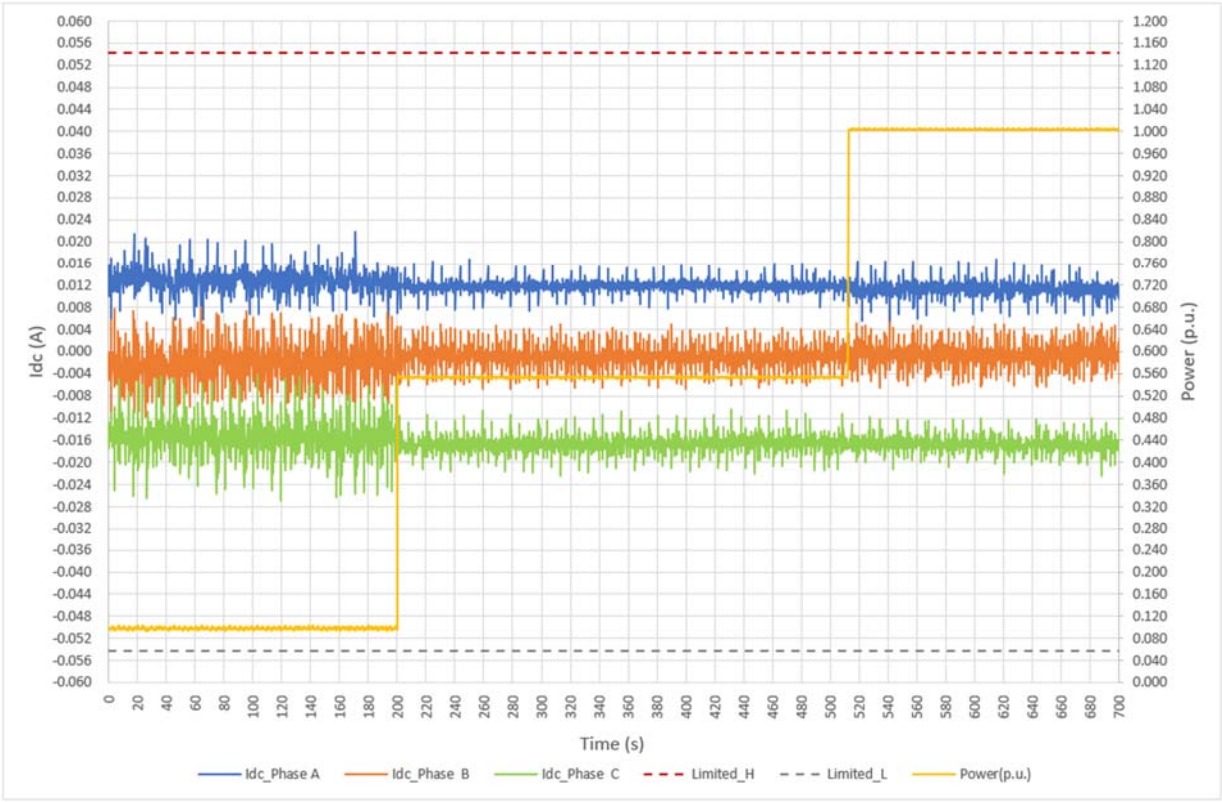
Following tables show the test results:

DC injection			
Phase A			
Test power level	10%	55%	100%
Recorded value in Amps	0.013	0.012	0.011
as % of rated AC current	0.06%	0.05%	0.05%
Limit	0.25%	0.25%	0.25%

Phase B			
Test power level	10%	55%	100%
Recorded value in Amps	0.003	0.001	0.001
as % of rated AC current	0.01%	0.01%	0.01%
Limit	0.25%	0.25%	0.25%

Phase C			
Test power level	10%	55%	100%
Recorded value in Amps	0.015	0.017	0.017
as % of rated AC current	0.07%	0.08%	0.08%
Limit	0.25%	0.25%	0.25%

DC injection test result



4.2.4 Power Factor

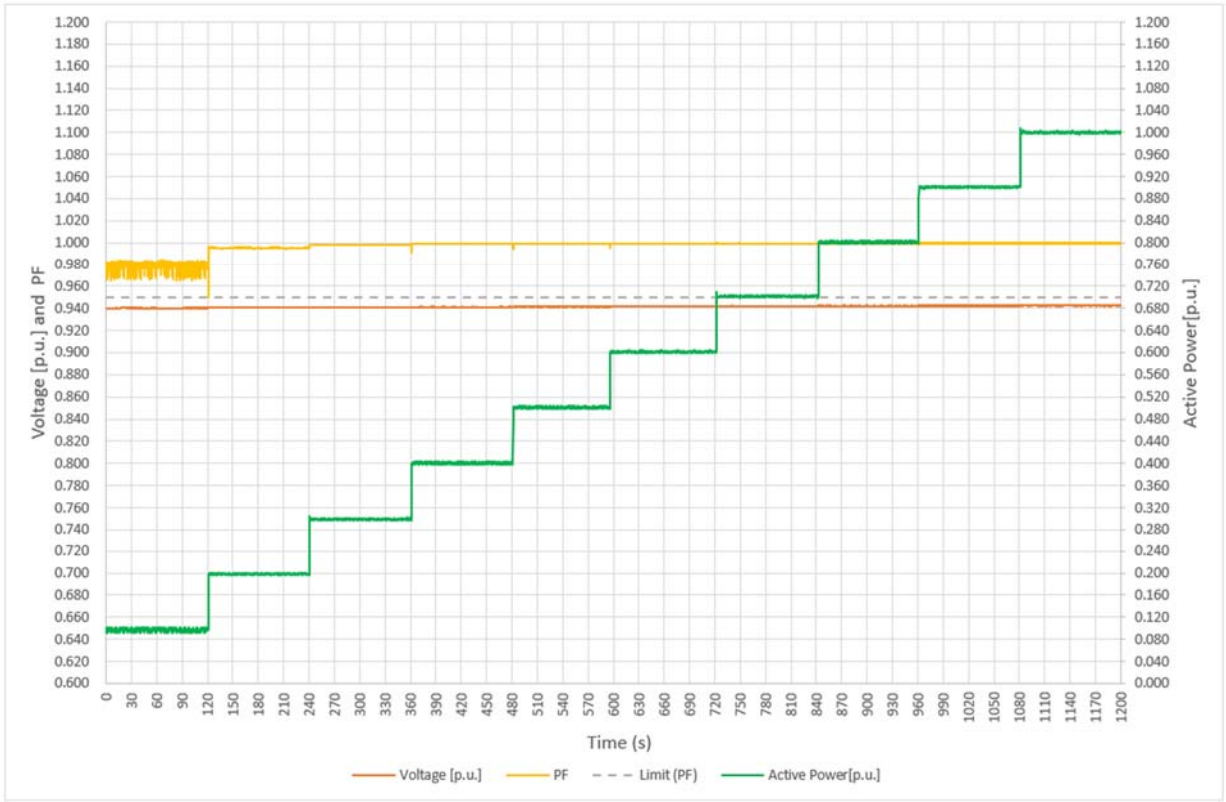
The tests should be carried out on a single Power Generating Module. Tests are to be carried out at three voltage levels and at Registered Capacity. Voltage to be maintained within ±1.5% of the stated level during the test. These tests should be undertaken in accordance with Annex A.7.1.4.2.

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

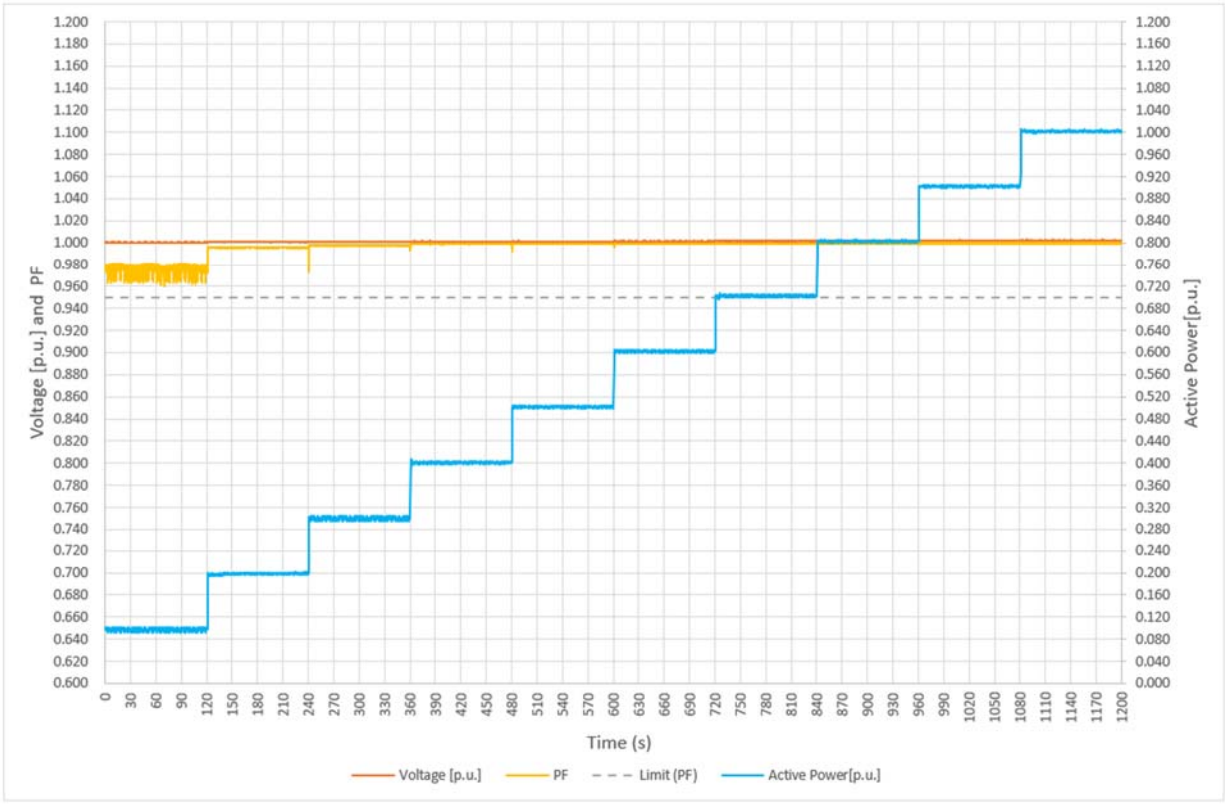
Volatge	0.94 pu (216.2 V)	1 pu (230 V)	1.1 pu (253 V)
Measured value	1.00	1.00	1.00
Power Factor Limit	>0.95	>0.95	>0.95

Test results are graphically shown below.

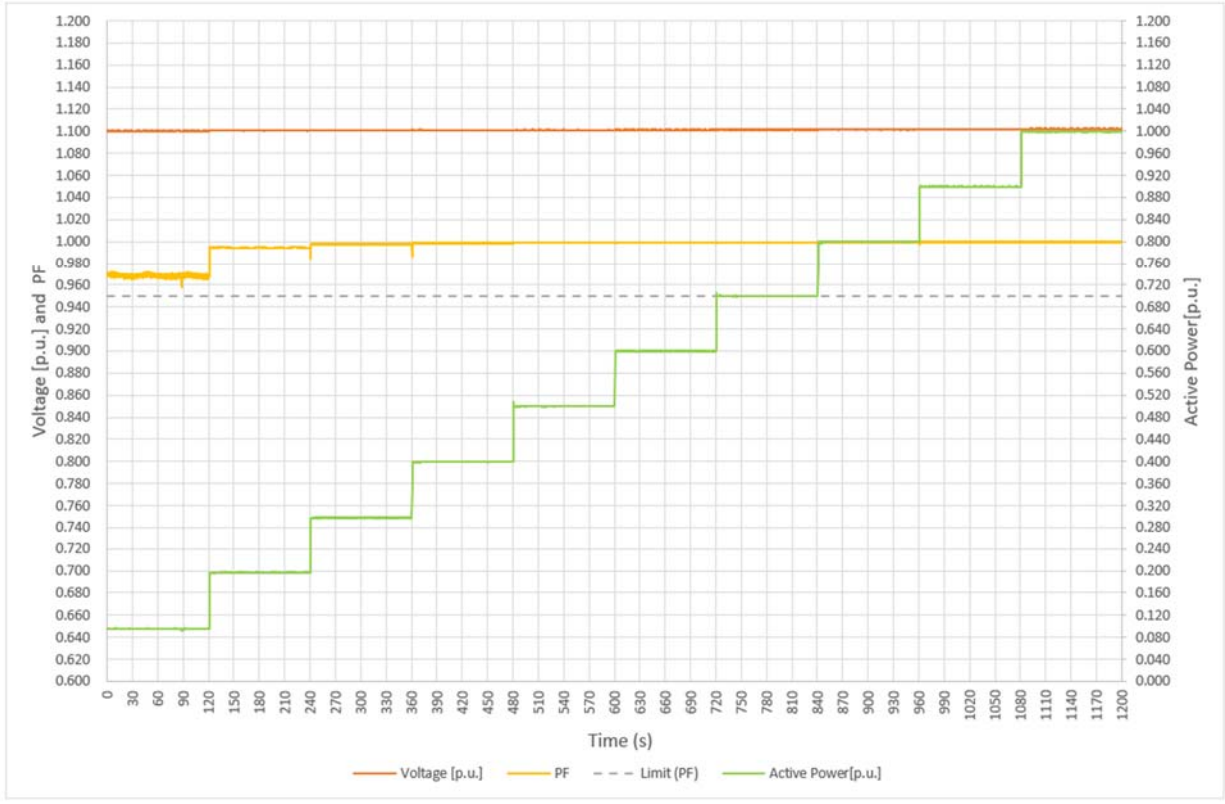
Power Factor 216.2V



Power Factor 230V



Power Factor 253V



4.3 PROTECTION

4.3.1 Frequency tests

These tests should be carried out in accordance with Annex A.7.1.2.3.

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.

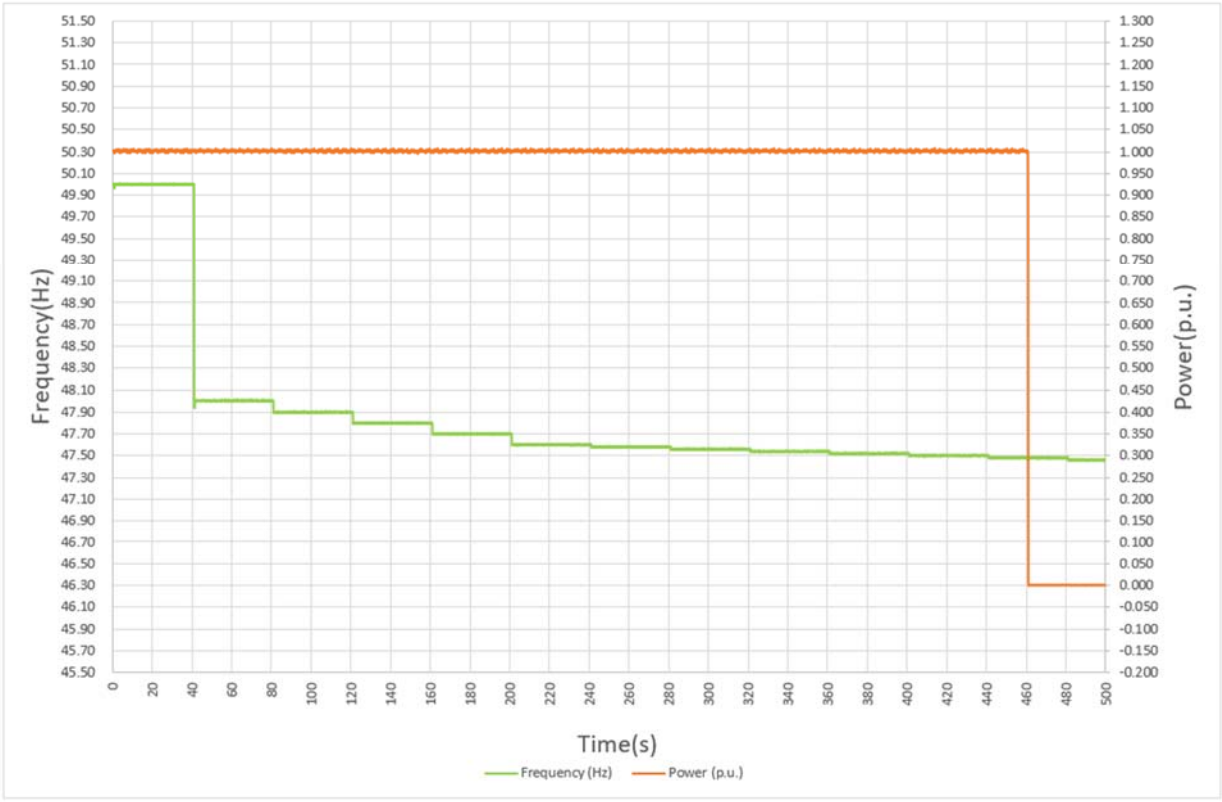
To establish the trip time, the test frequency should be applied starting from 0.3 Hz below or above the recorded trip frequency and should be changed to 0.3 Hz above or below the recorded trip frequency in a single step. For each trip setting five tests shall be carried out.

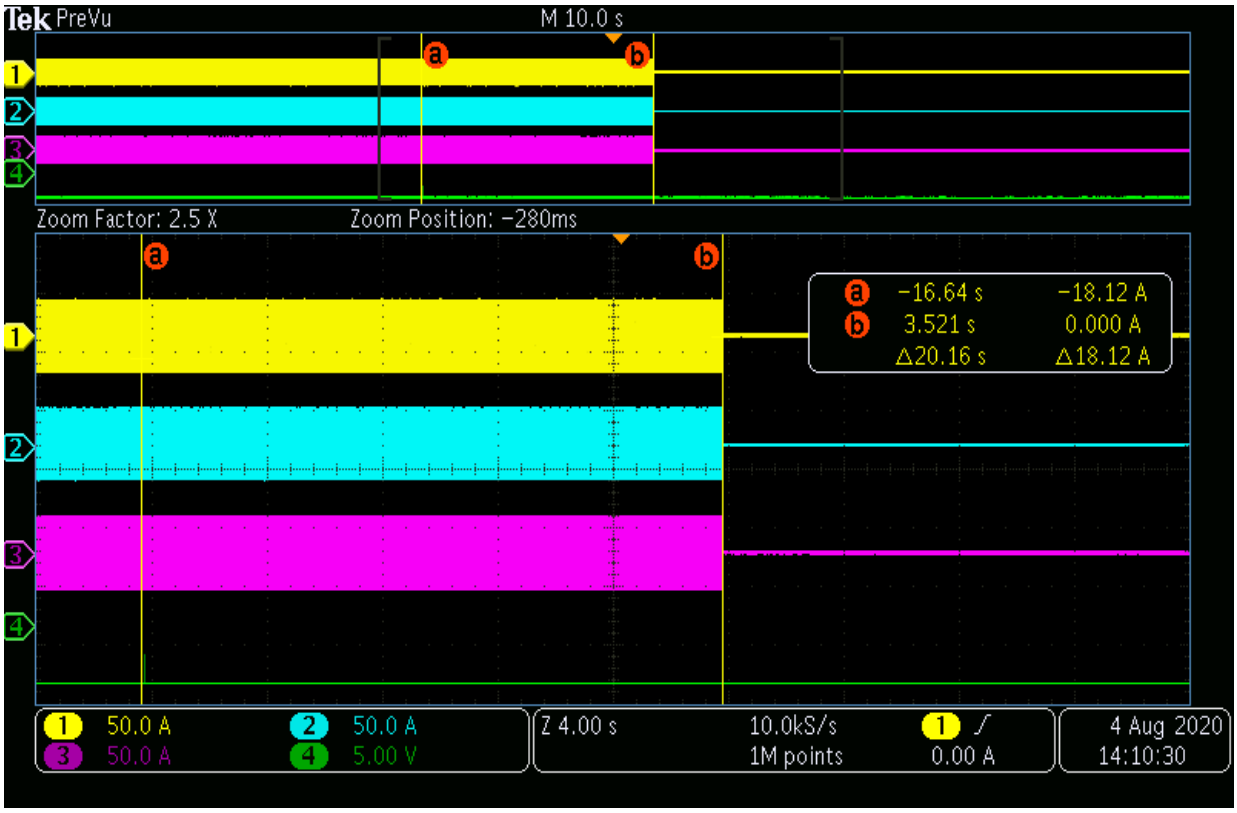
Following tables show the test results:

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	47.5	20.160	47.7 Hz / 25 s	Pass
			47.5	20.090		
			47.5	20.060		
			47.5	20.050		
			47.5	20.040		
U/F stage 2	47 Hz	0.5 s	47.0	0.513	47.2 Hz / 19.98 s	Pass
			47.0	0.503		
			47.0	0.505		
			47.0	0.517		
			47.0	0.501		
					46.8 Hz / 0.48 s	Pass
O/F stage 1	52 Hz	0.5 s	52.0	0.536	51.8 Hz / 89.98 s	Pass
			52.0	0.514		
			52.0	0.526		
			52.0	0.522		
			52.0	0.532		
					52.2 Hz / 0.48 s	Pass

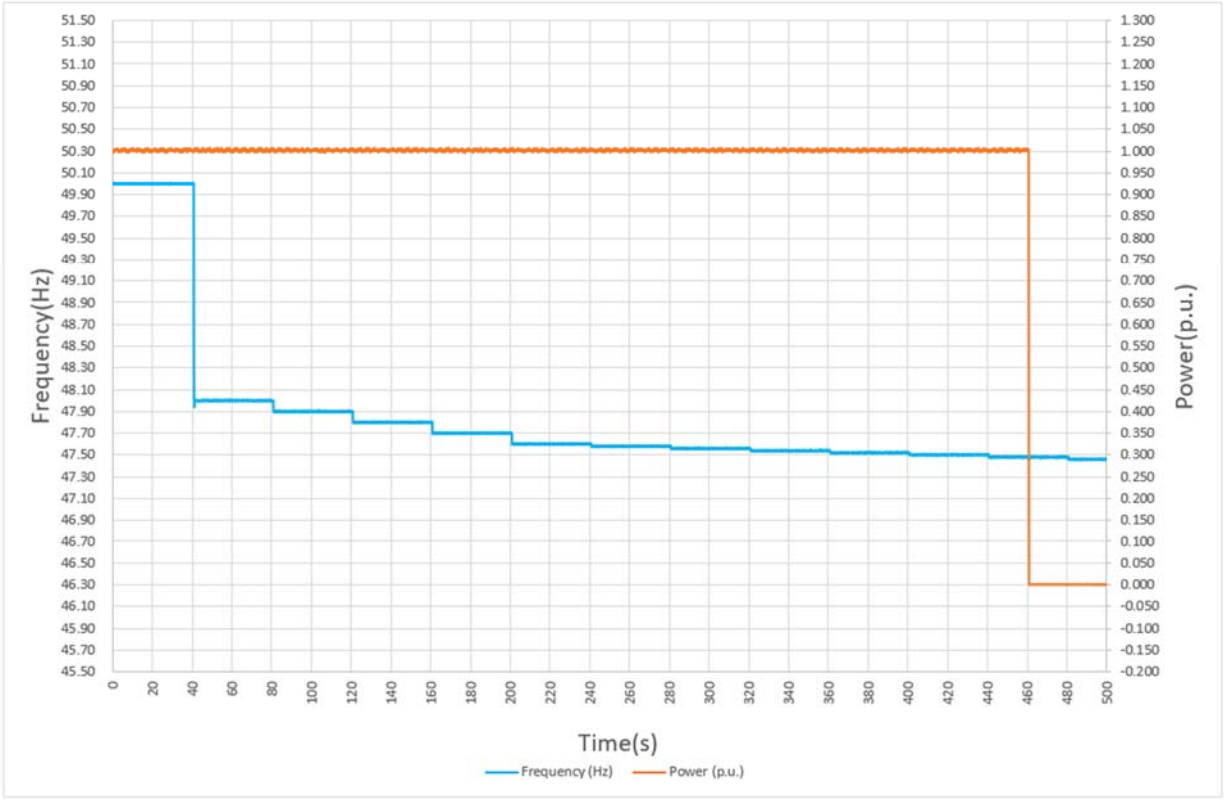
Test results are graphically shown below.

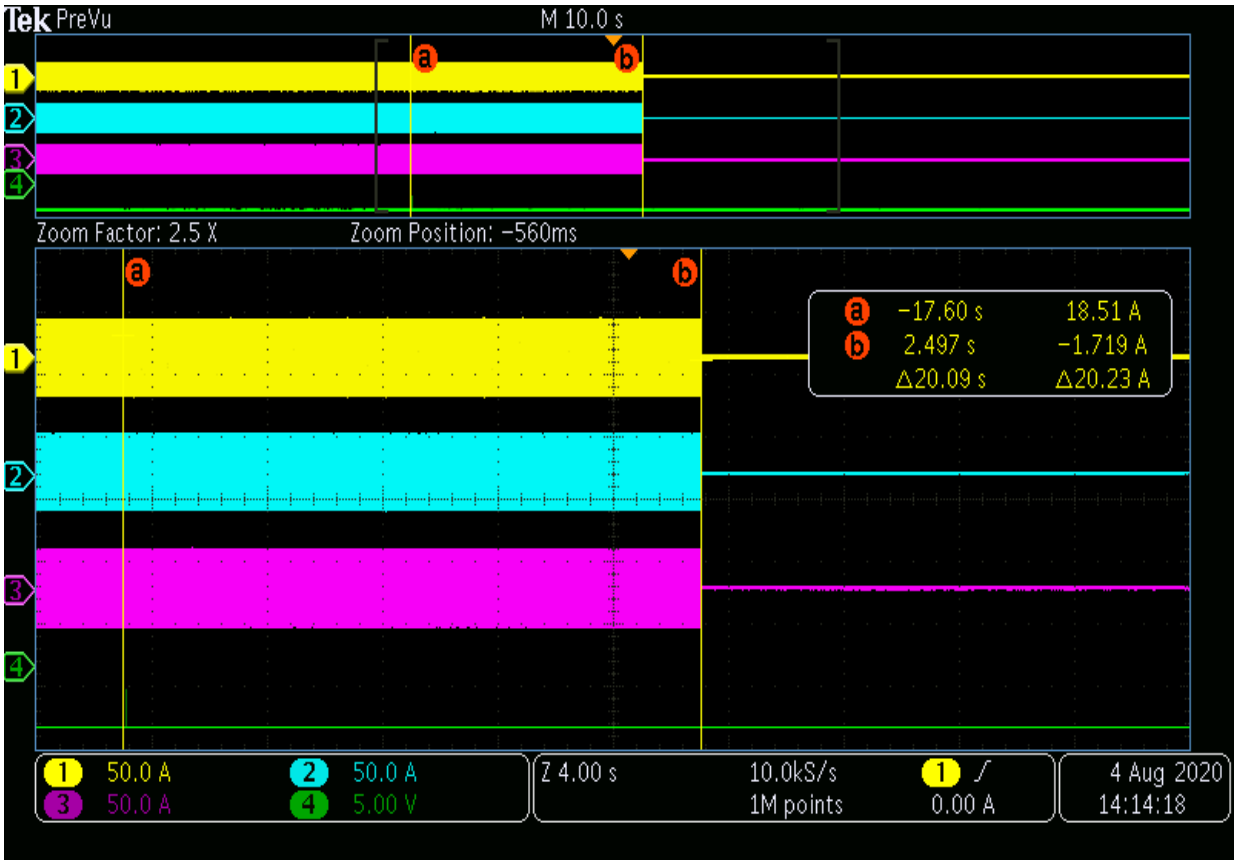
U/F stage 1-1



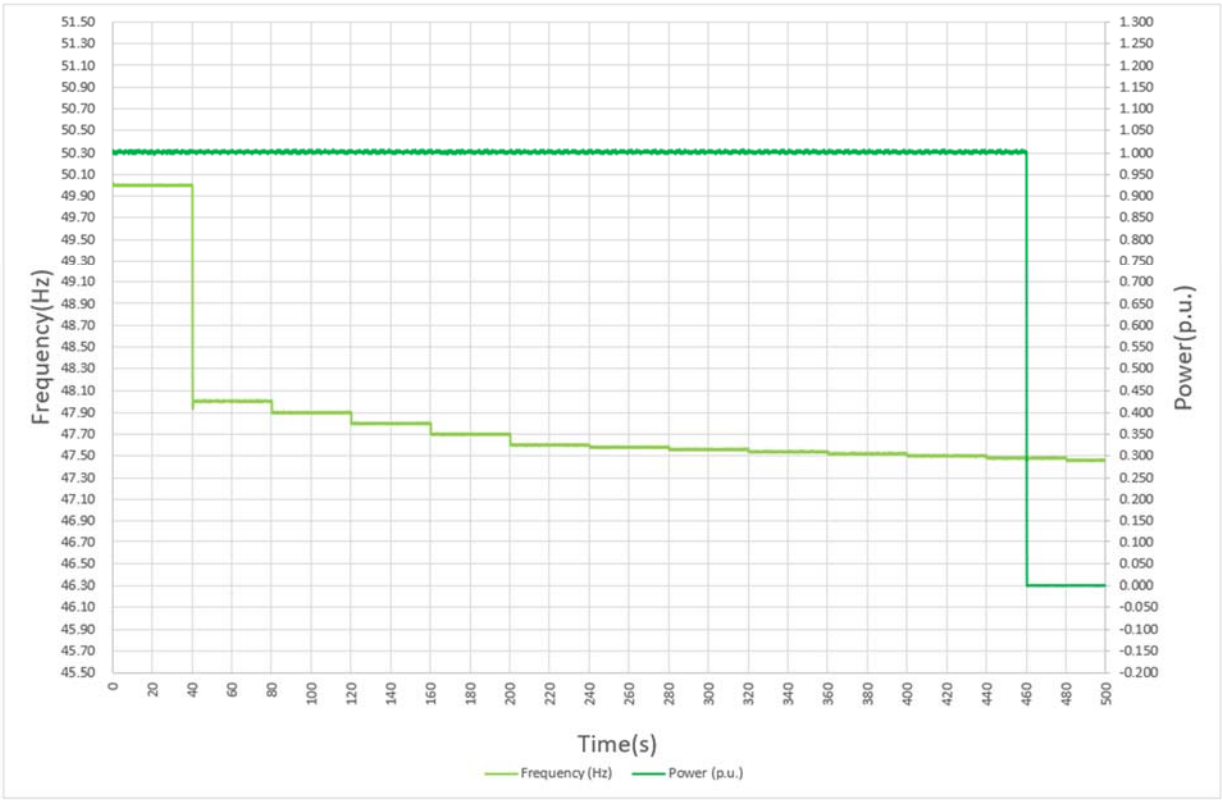


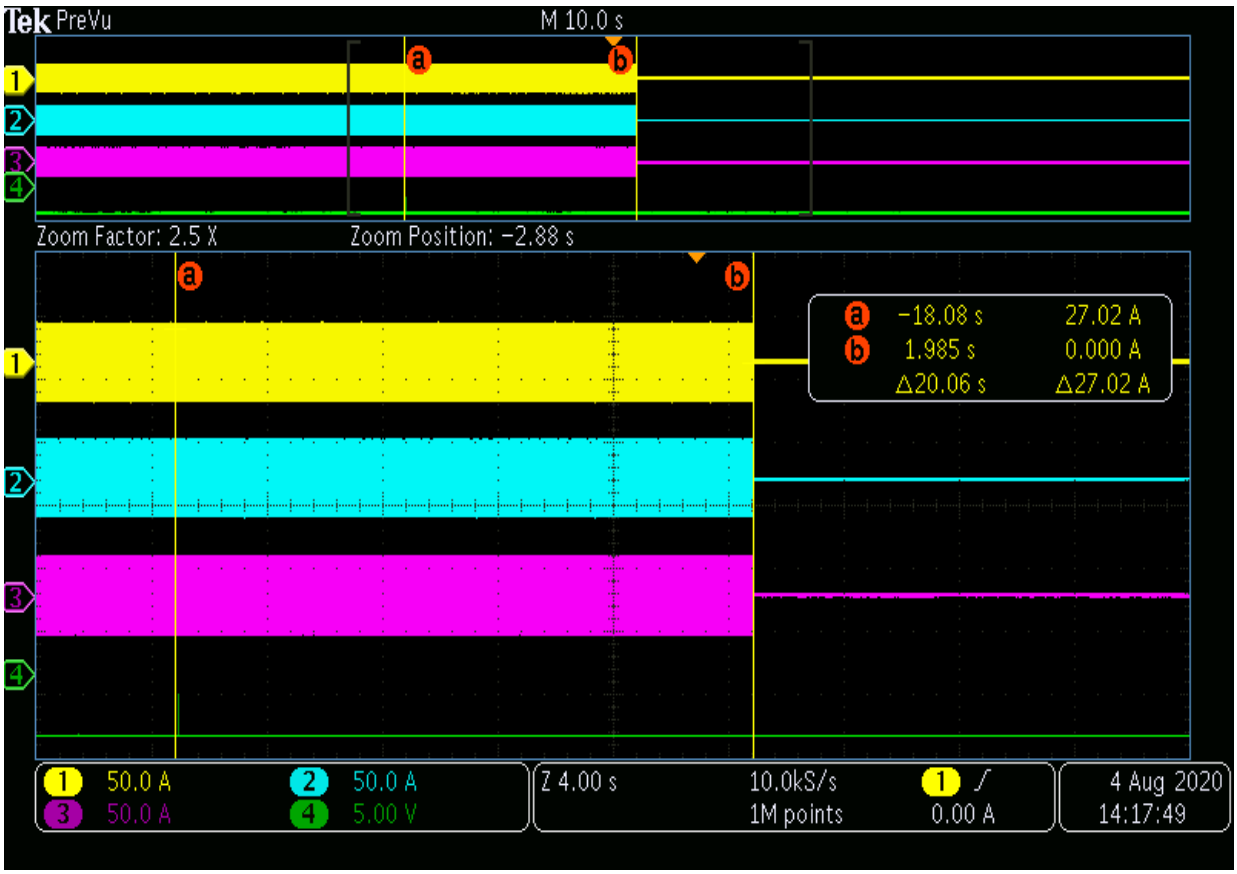
U/F stage 1-2


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

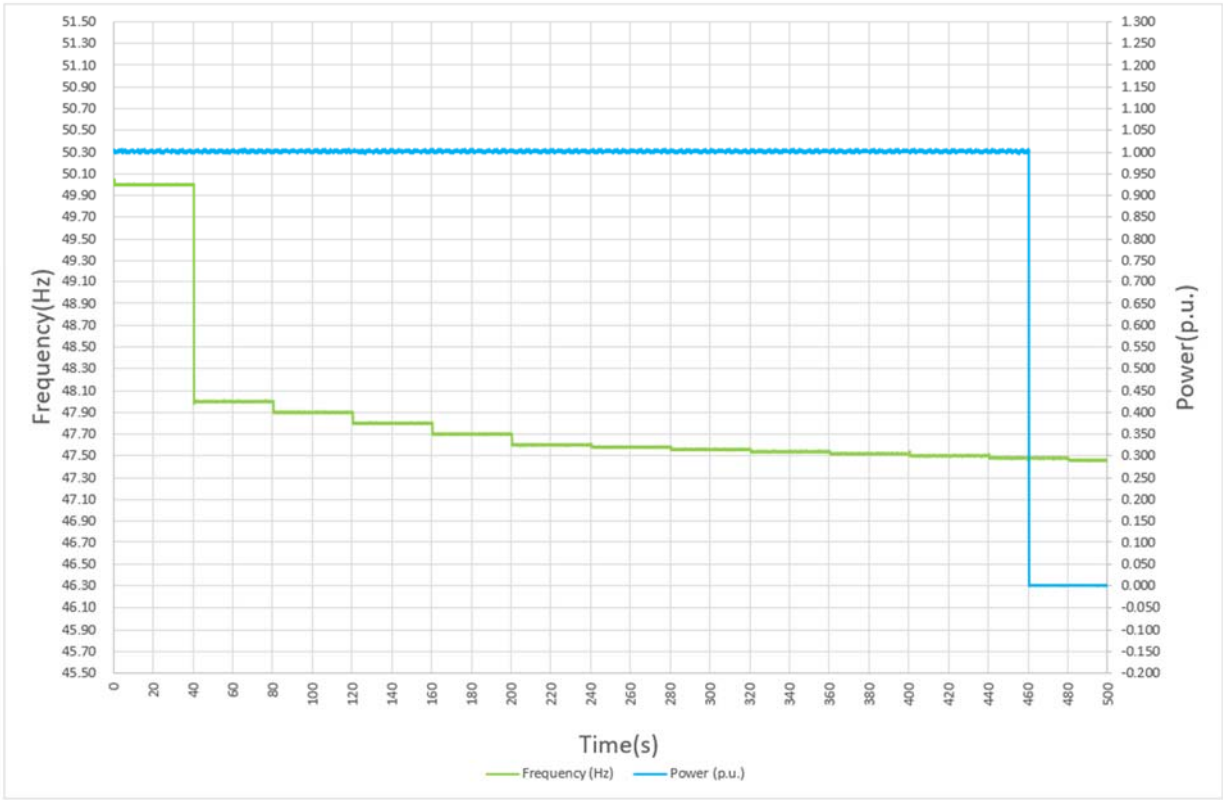

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -560ms
a -17.60 s 18.51 A
b 2.497 s -1.719 A
Δ20.09 s Δ20.23 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
4 Aug 2020
14:14:18

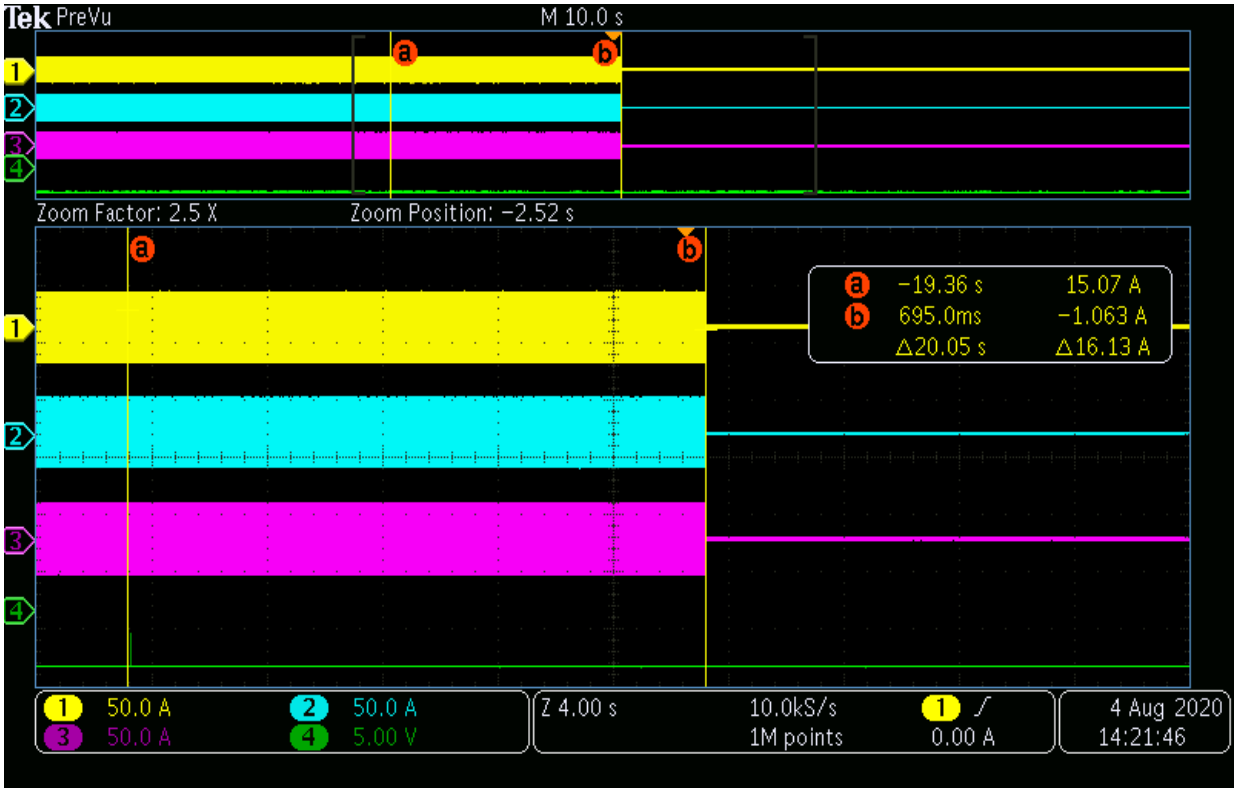
U/F stage 1-3


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

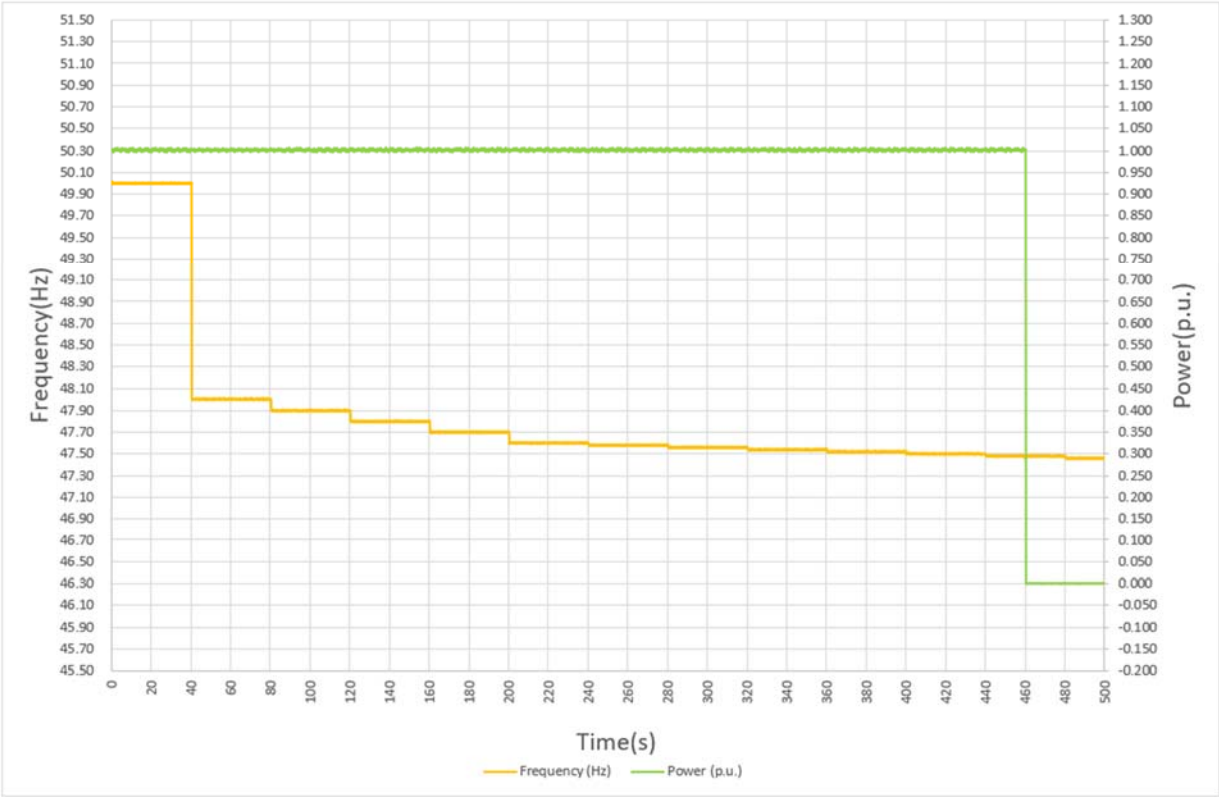

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -2.88 s
a -18.08 s 27.02 A
b 1.985 s 0.000 A
Δ20.06 s Δ27.02 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
4 Aug 2020
14:17:49

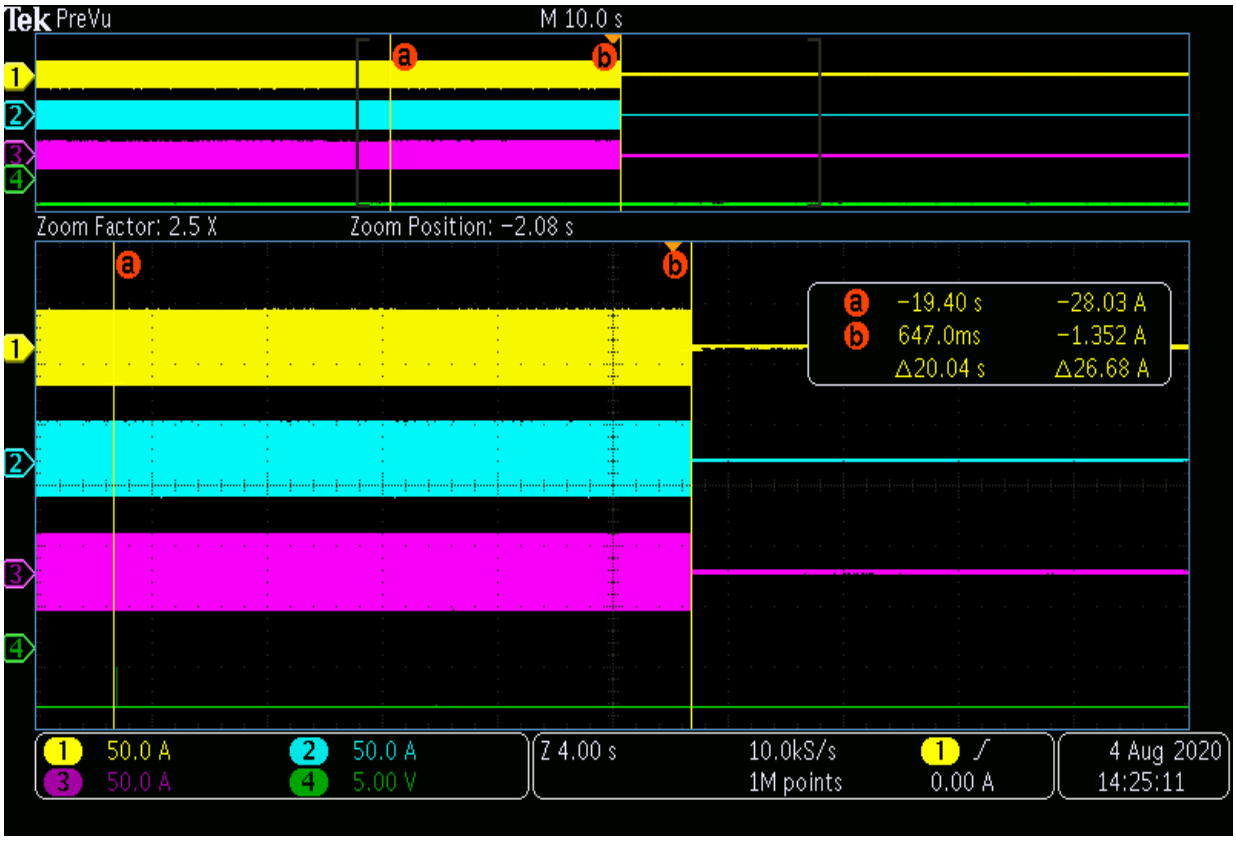
U/F stage 1-4


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

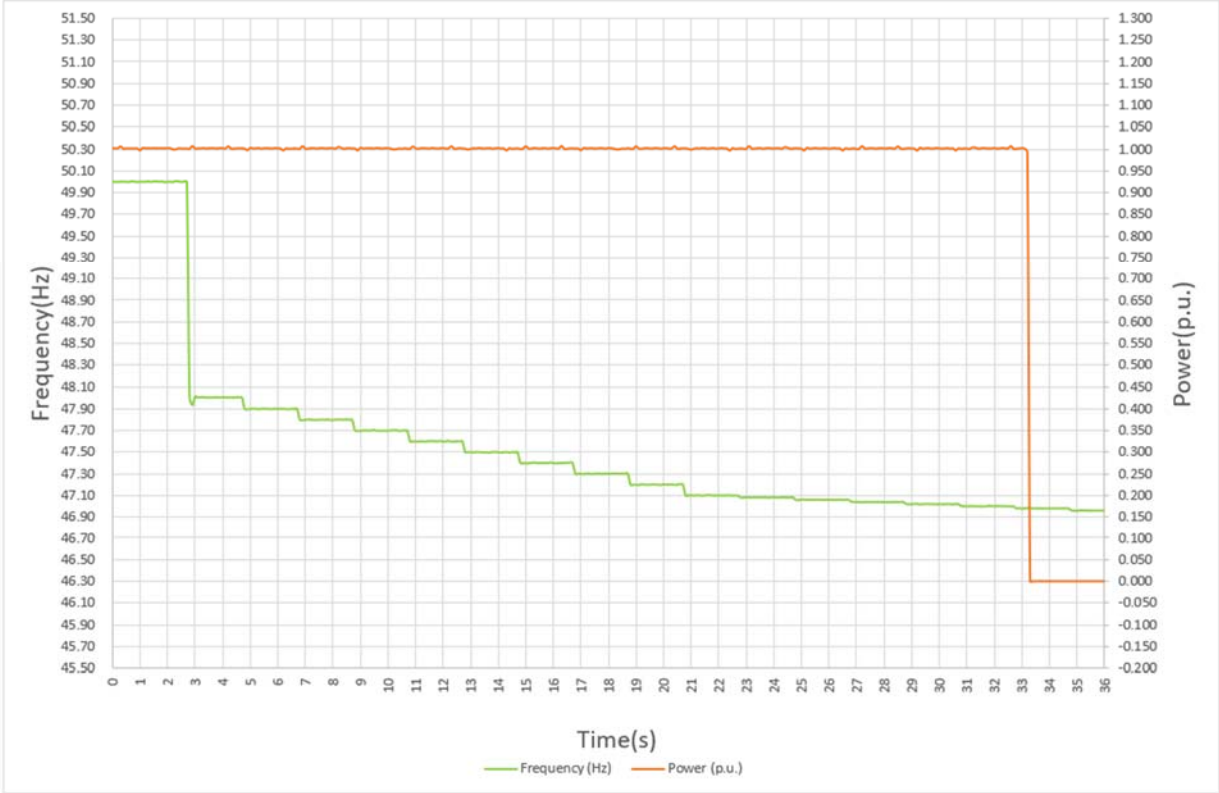

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -2.52 s
a -19.36 s 15.07 A
b 695.0ms -1.063 A
Δ20.05 s Δ16.13 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
1 ⎍ 0.00 A
4 Aug 2020
14:21:46

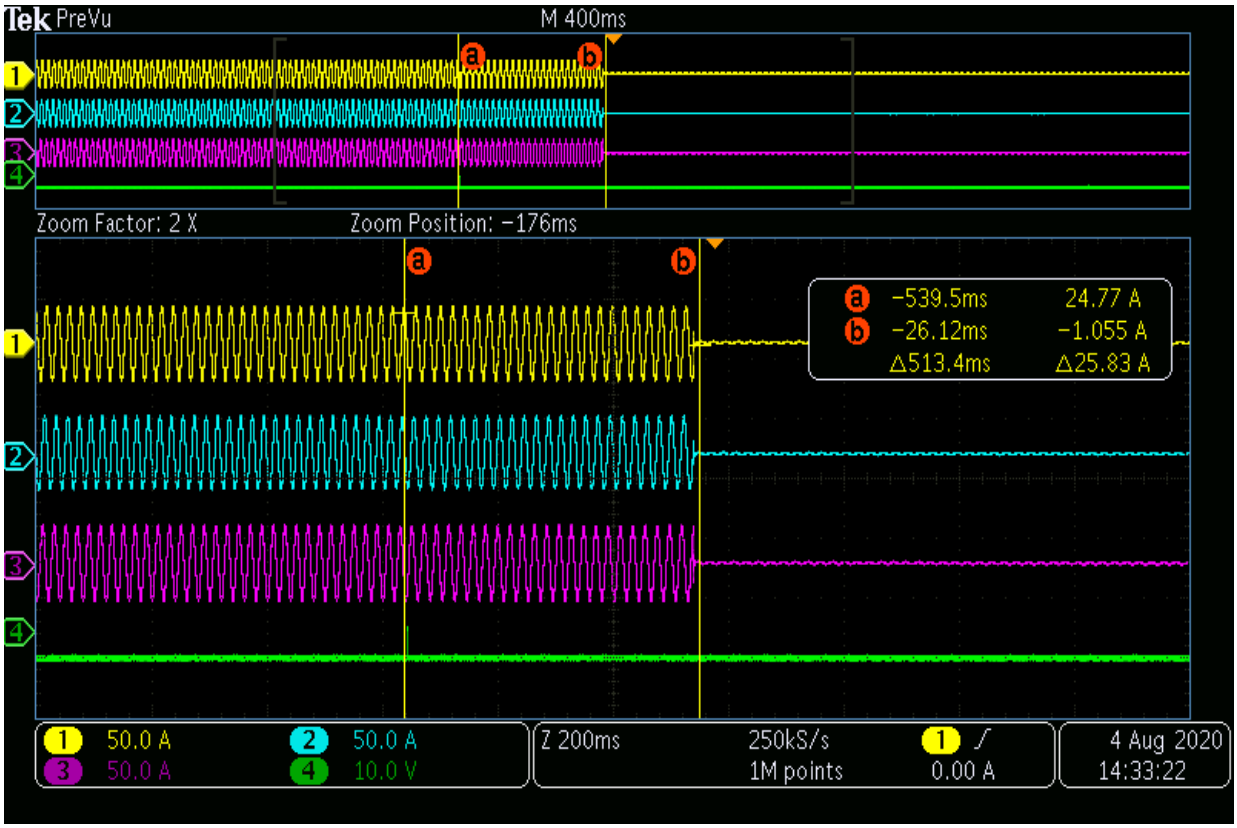
U/F stage 1-5


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

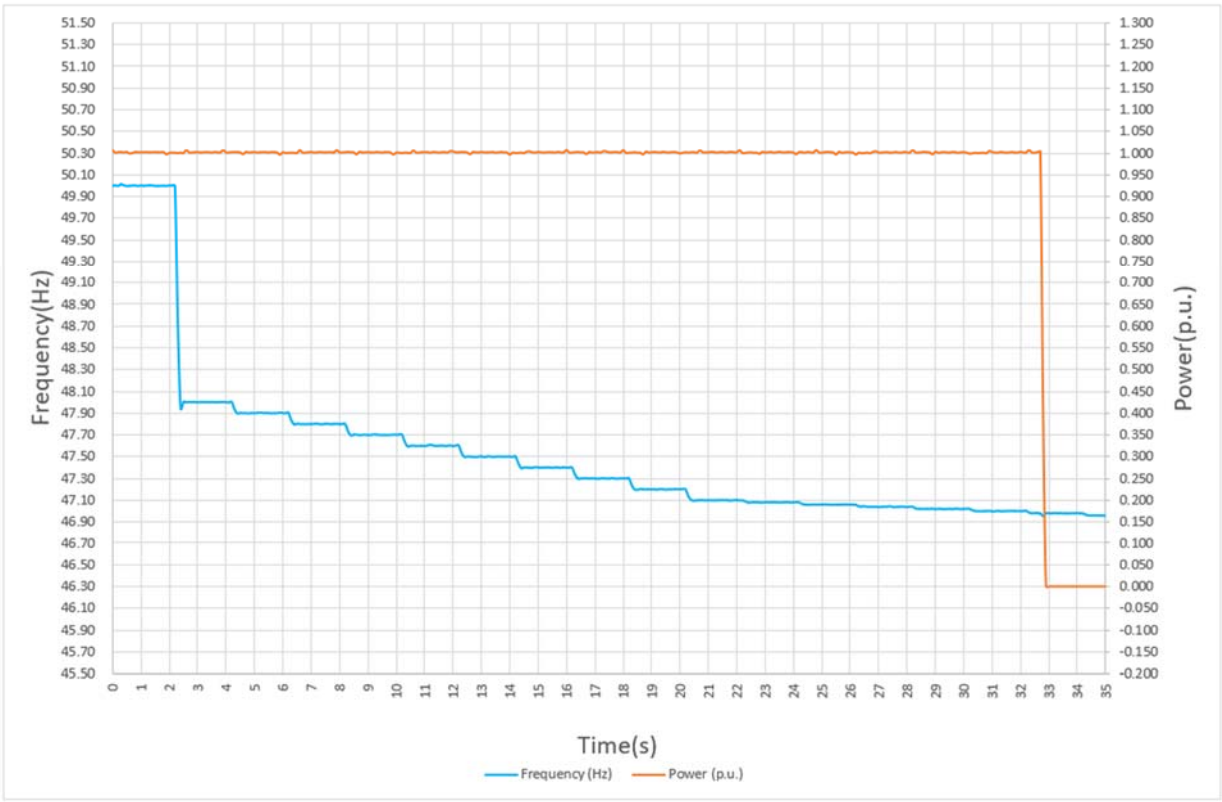

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -2.08 s
a -19.40 s -28.03 A
b 647.0ms -1.352 A
Δ20.04 s Δ26.68 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
4 Aug 2020
14:25:11

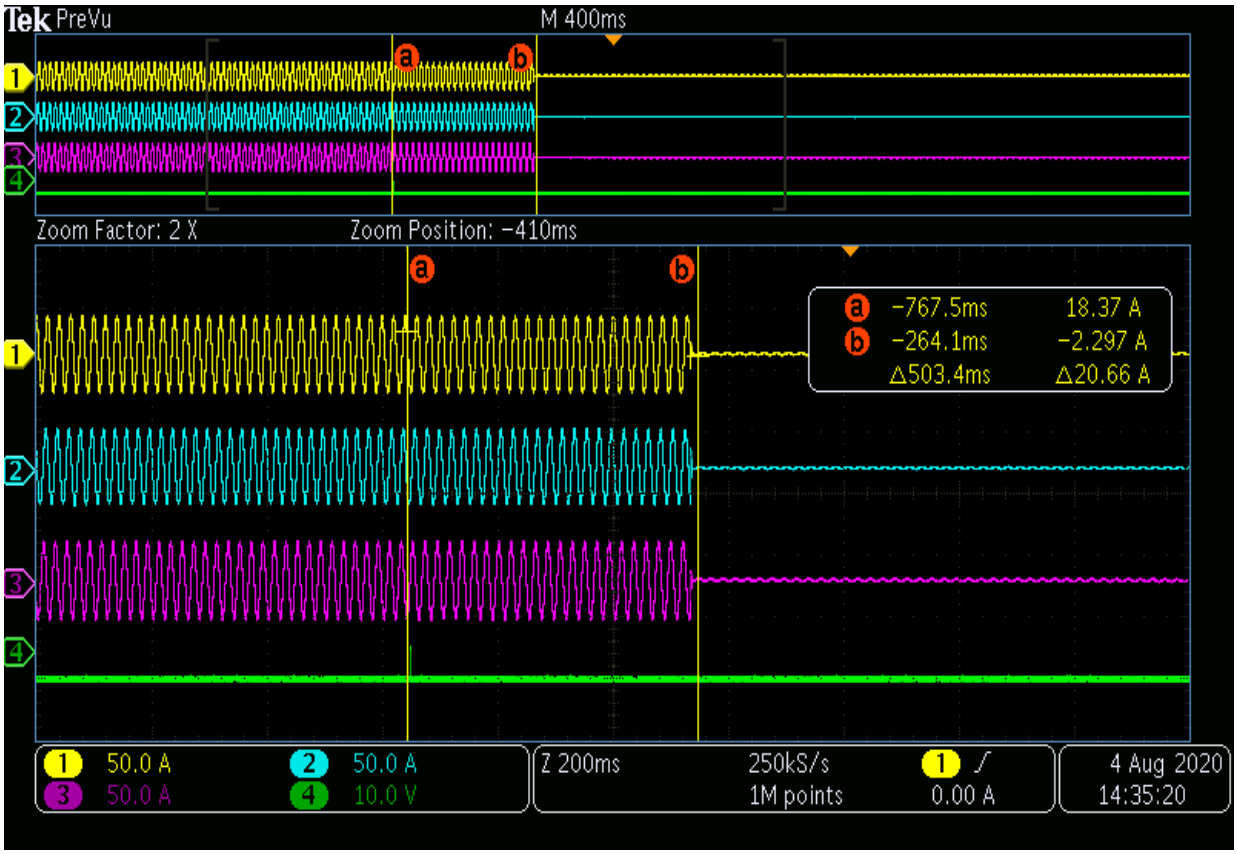
U/F stage 2-1


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

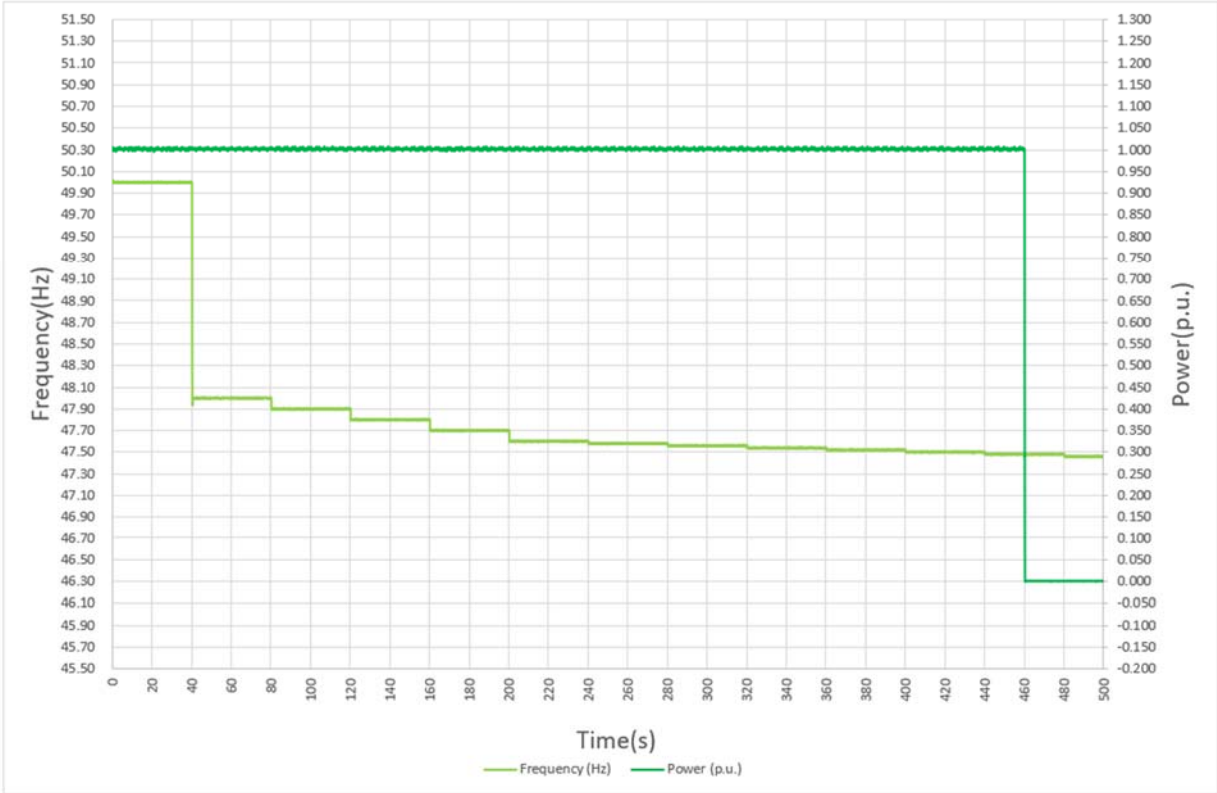

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: -176ms
a -539.5ms 24.77 A
b -26.12ms -1.055 A
Δ513.4ms Δ25.83 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
1 ⨍
0.00 A
4 Aug 2020
14:33:22

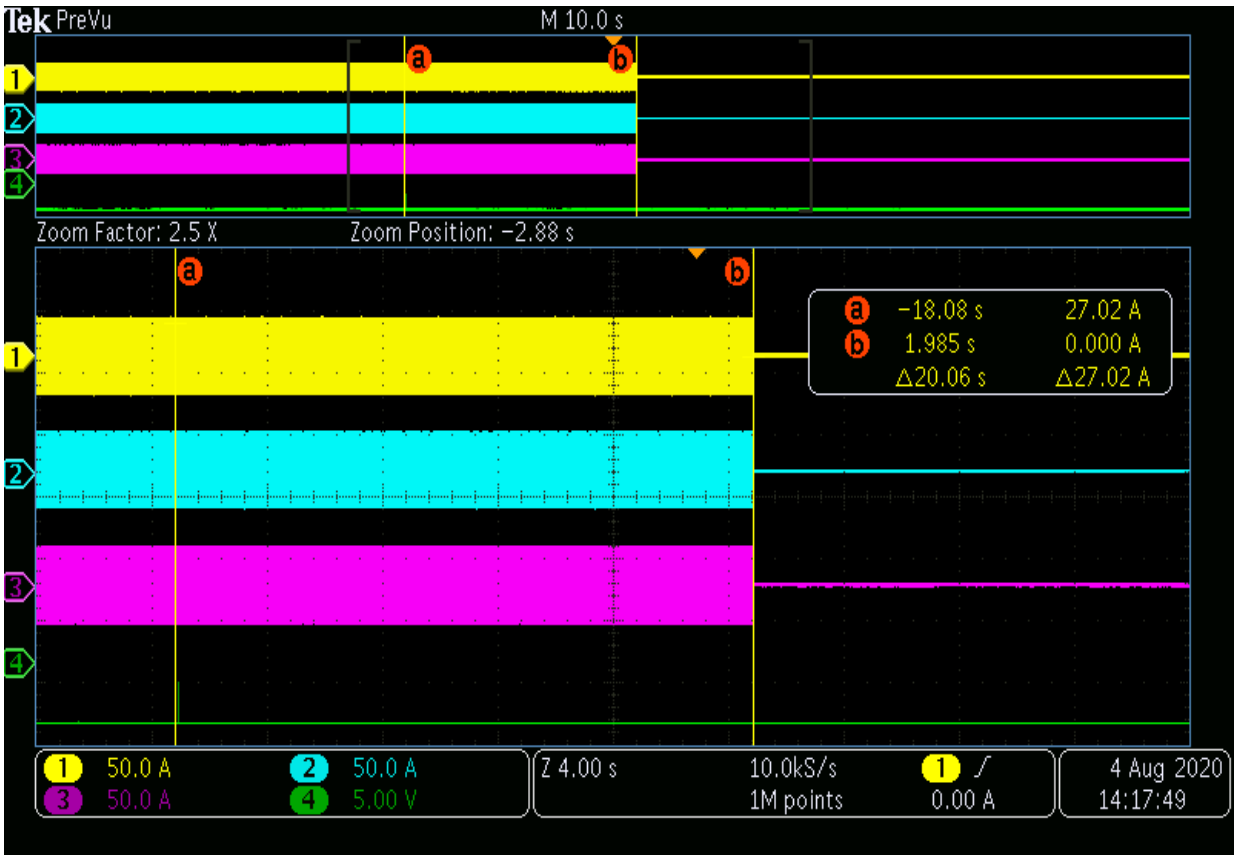
U/F stage 2-2


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

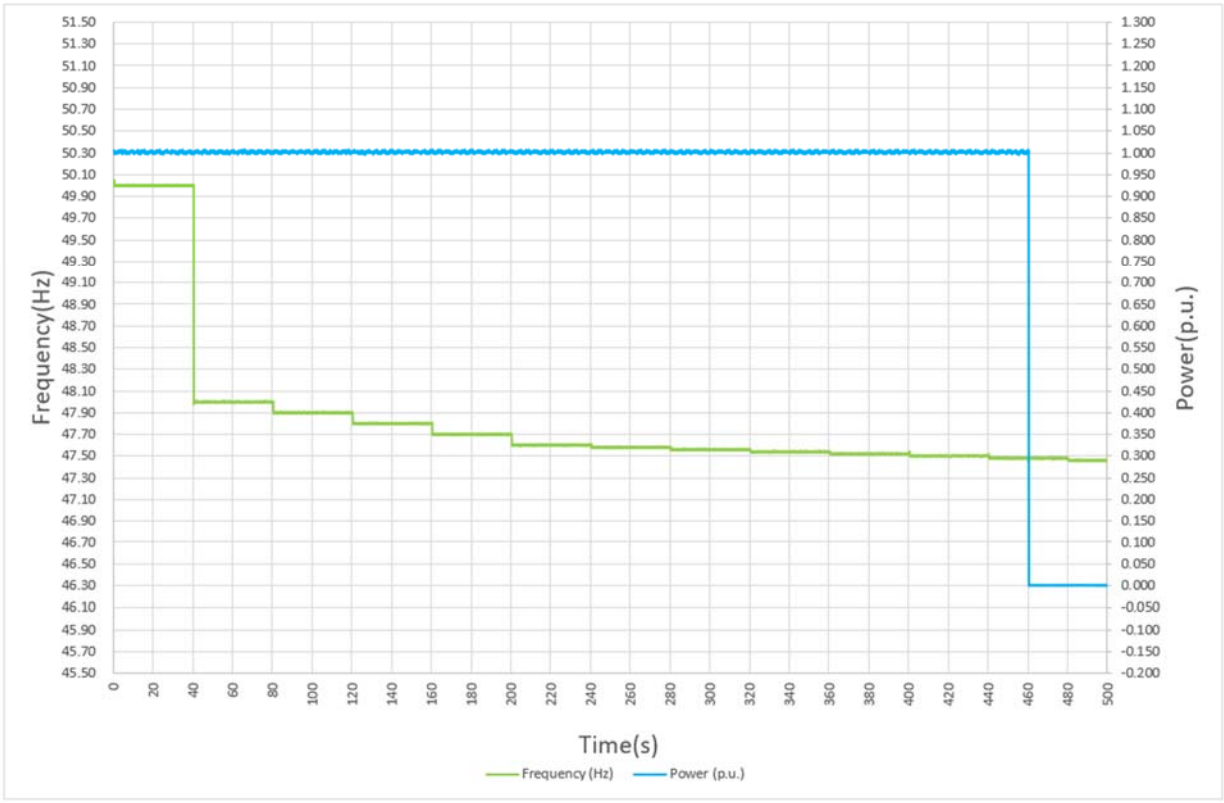

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: -410ms
a -767.5ms 18.37 A
b -264.1ms -2.297 A
Δ503.4ms Δ20.66 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
1 ⨍
0.00 A
4 Aug 2020
14:35:20

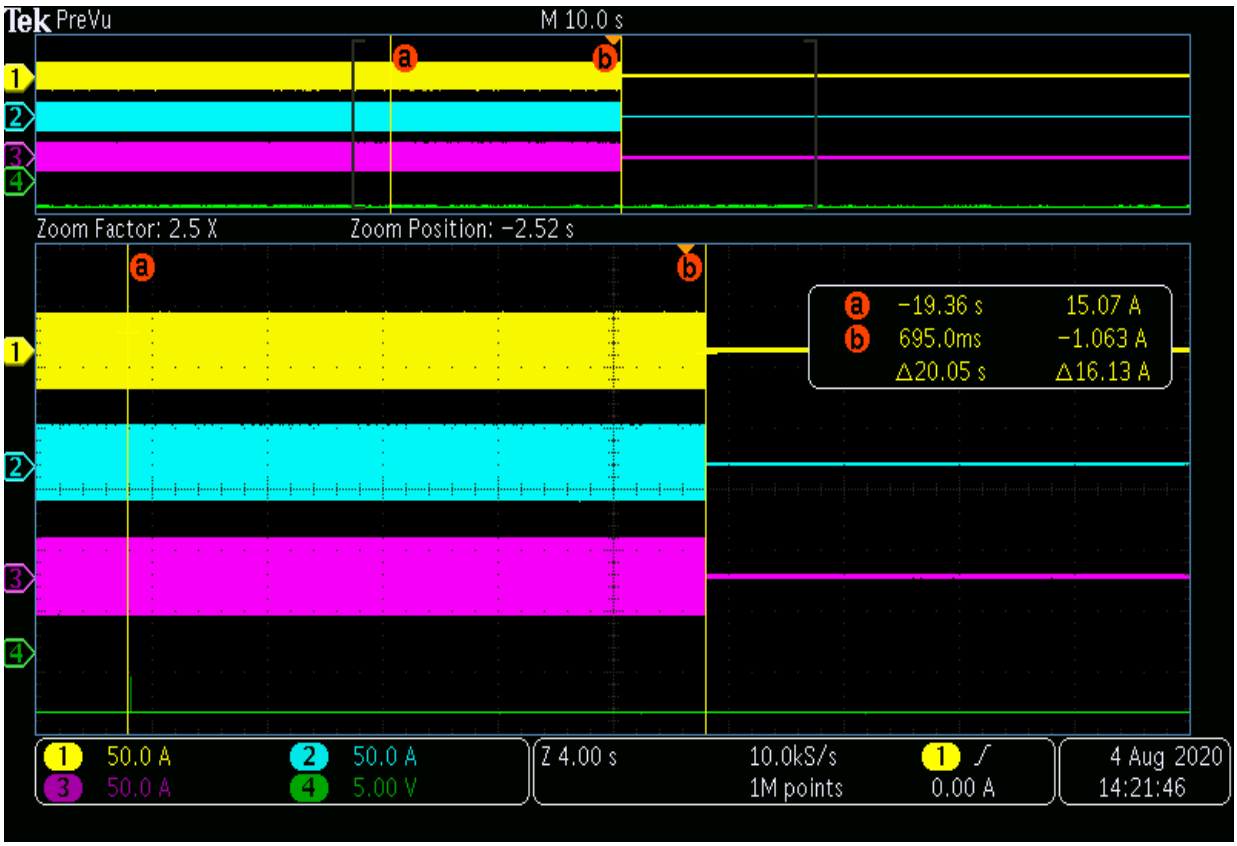
U/F stage 2-3


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

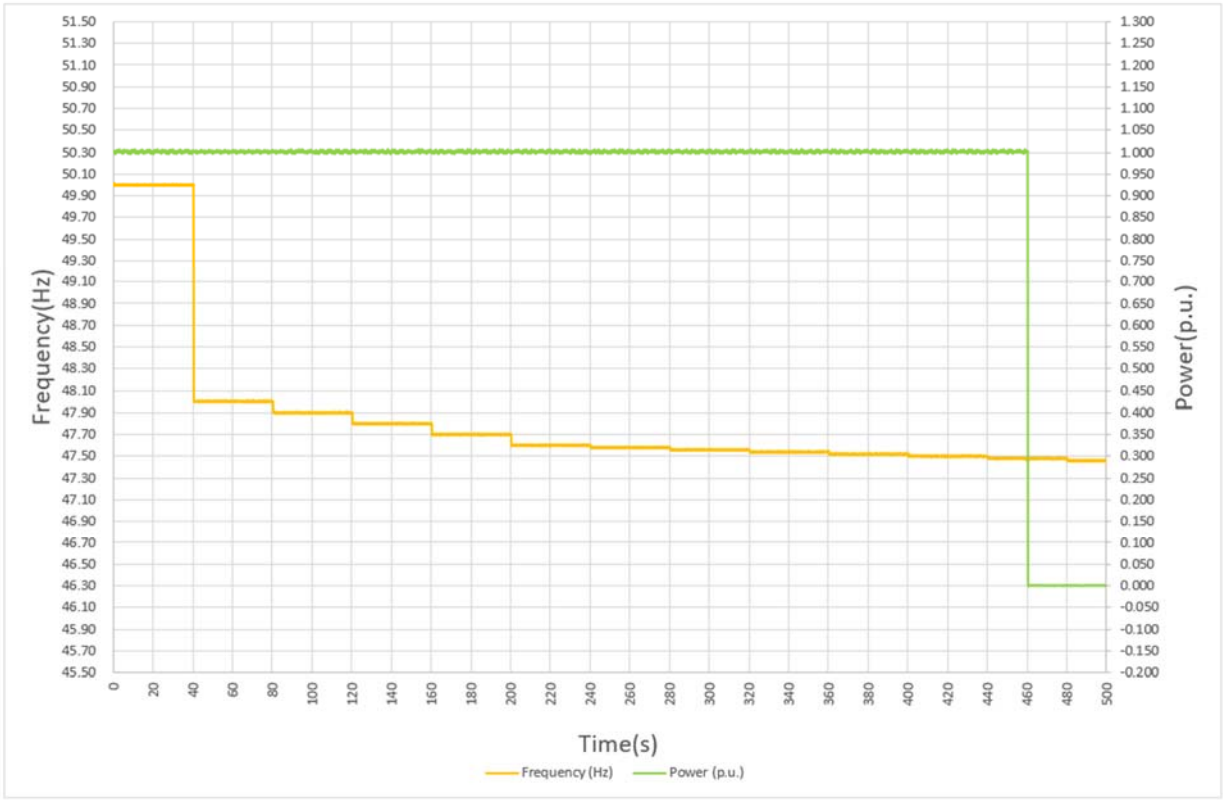

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -2.88 s
a -18.08 s 27.02 A
b 1.985 s 0.000 A
Δ20.06 s Δ27.02 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
4 Aug 2020
14:17:49

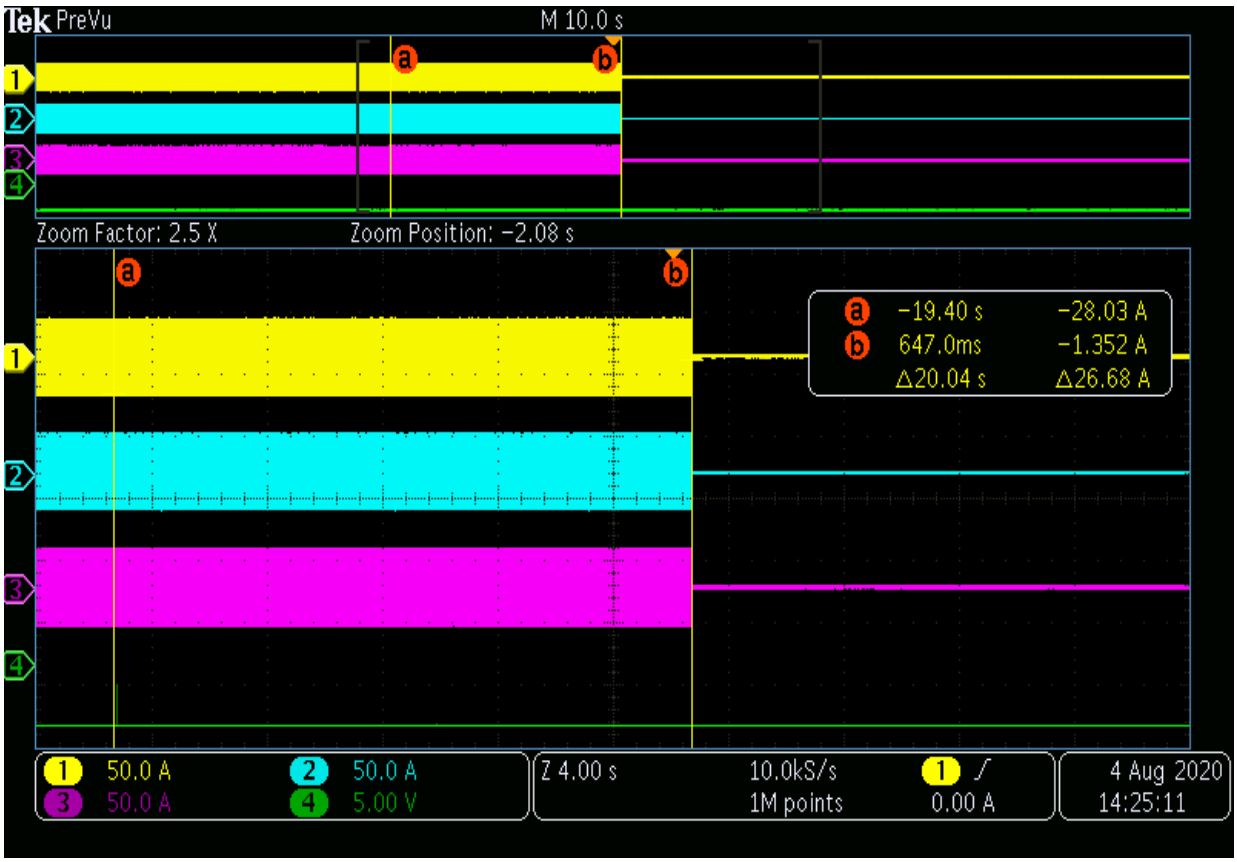
U/F stage 2-4


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

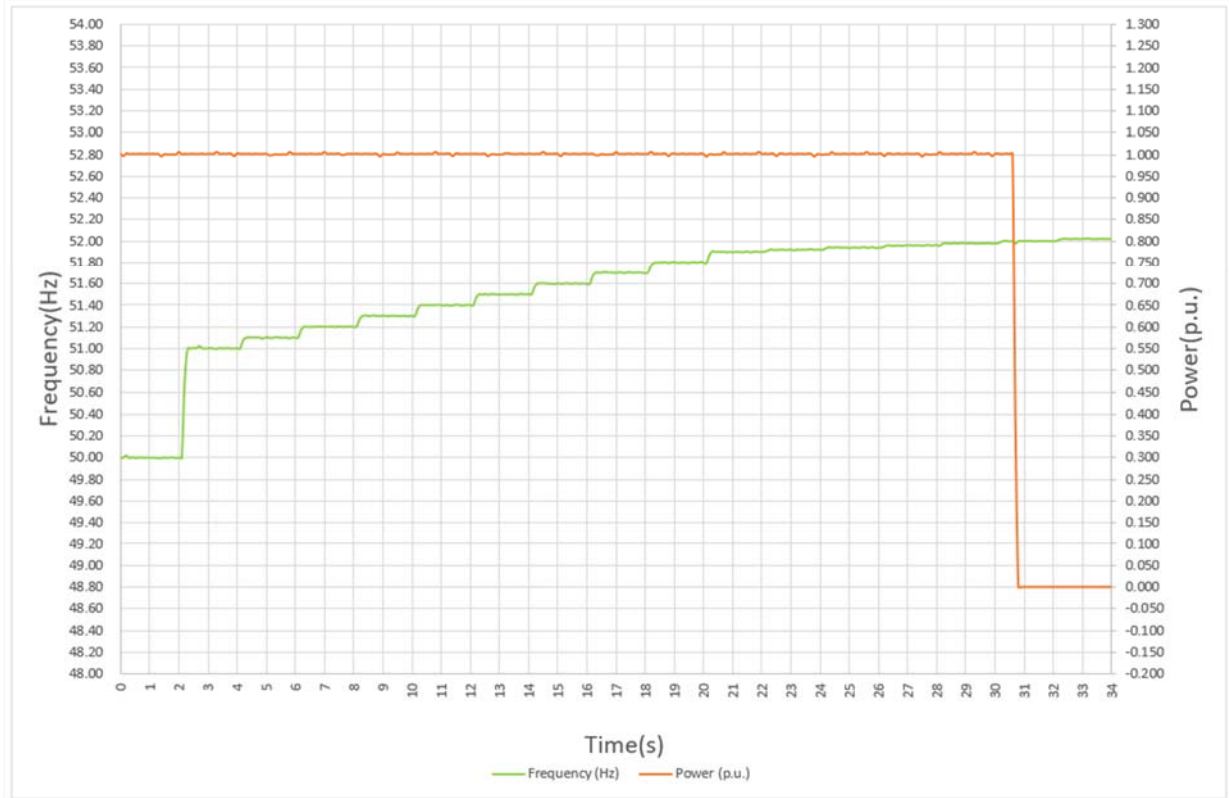

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -2.52 s
a -19.36 s 15.07 A
b 695.0ms -1.063 A
Δ20.05 s Δ16.13 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
4 Aug 2020
14:21:46

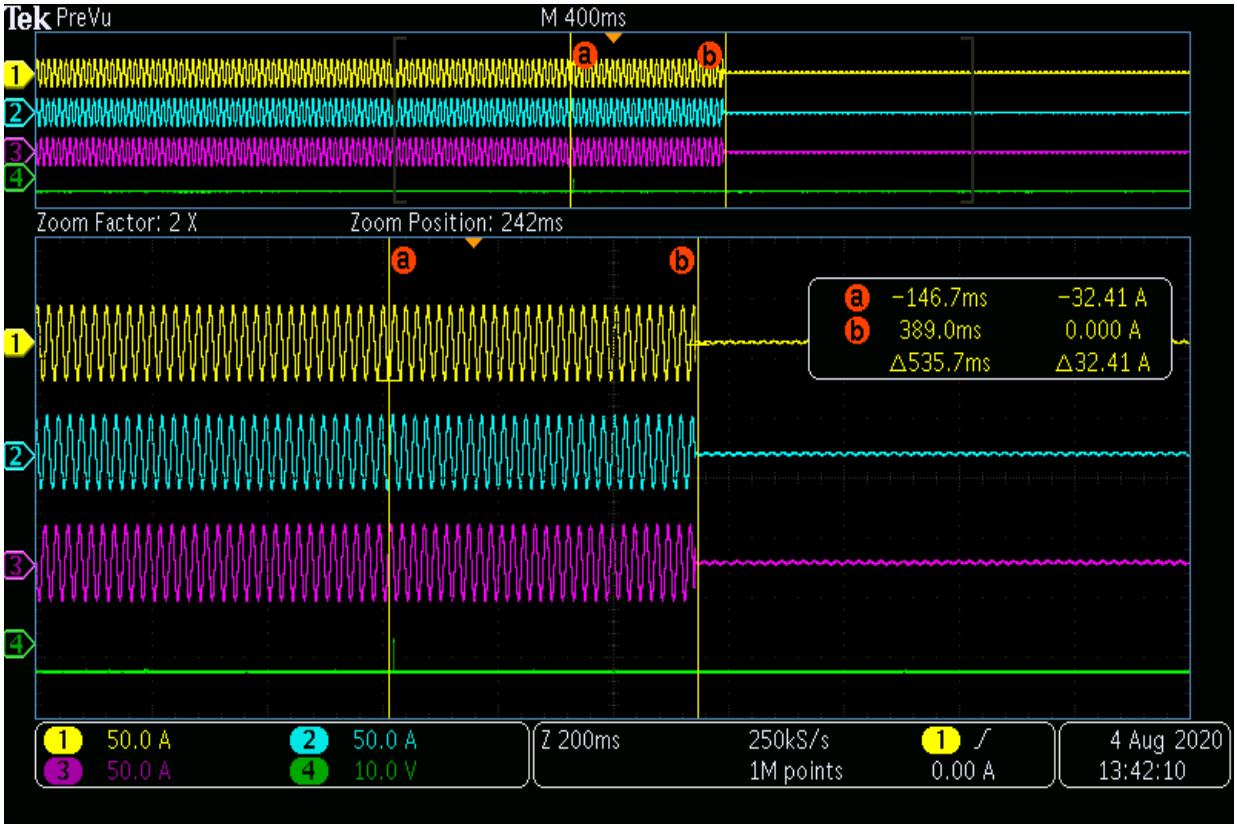
U/F stage 2-5


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

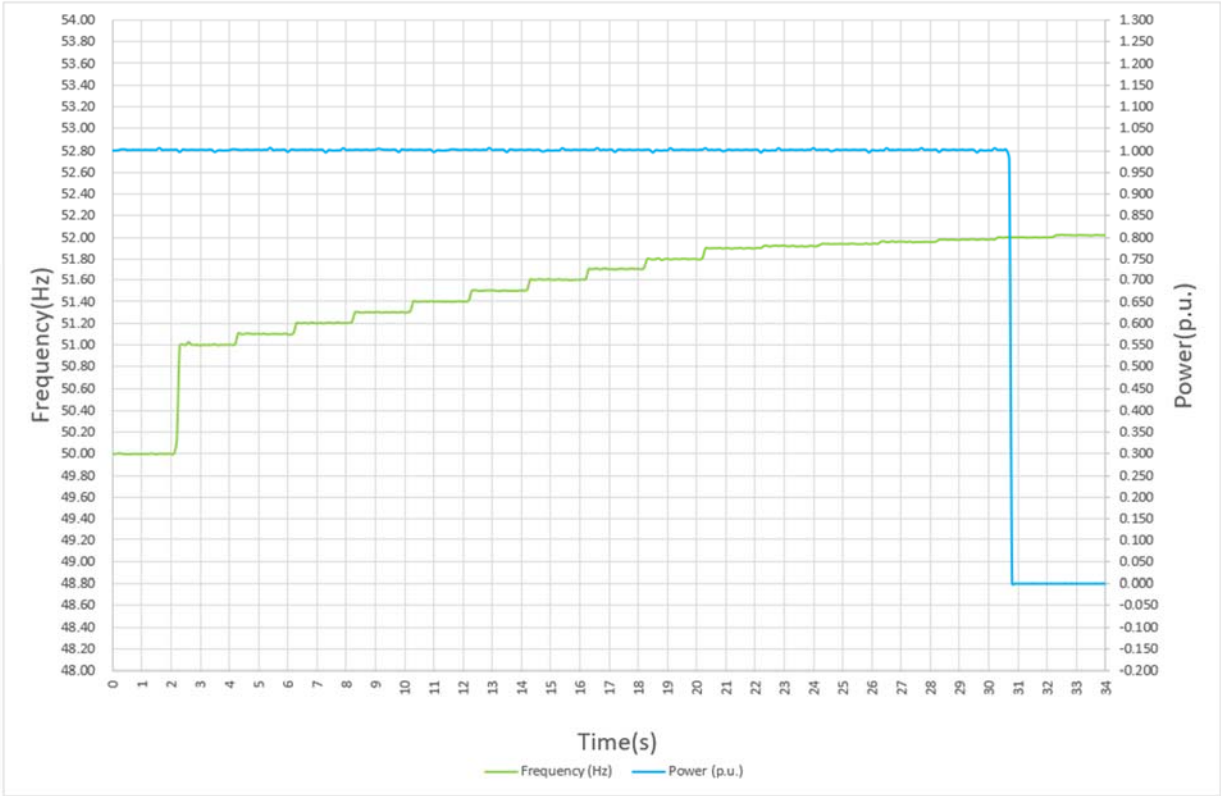

Tek PreVu
M 10.0 s
Zoom Factor: 2.5 X
Zoom Position: -2.08 s
a -19.40 s -28.03 A
b 647.0ms -1.352 A
Δ20.04 s Δ26.68 A
1 50.0 A
2 50.0 A
3 50.0 A
4 5.00 V
Z 4.00 s
10.0kS/s
1M points
0.00 A
4 Aug 2020
14:25:11

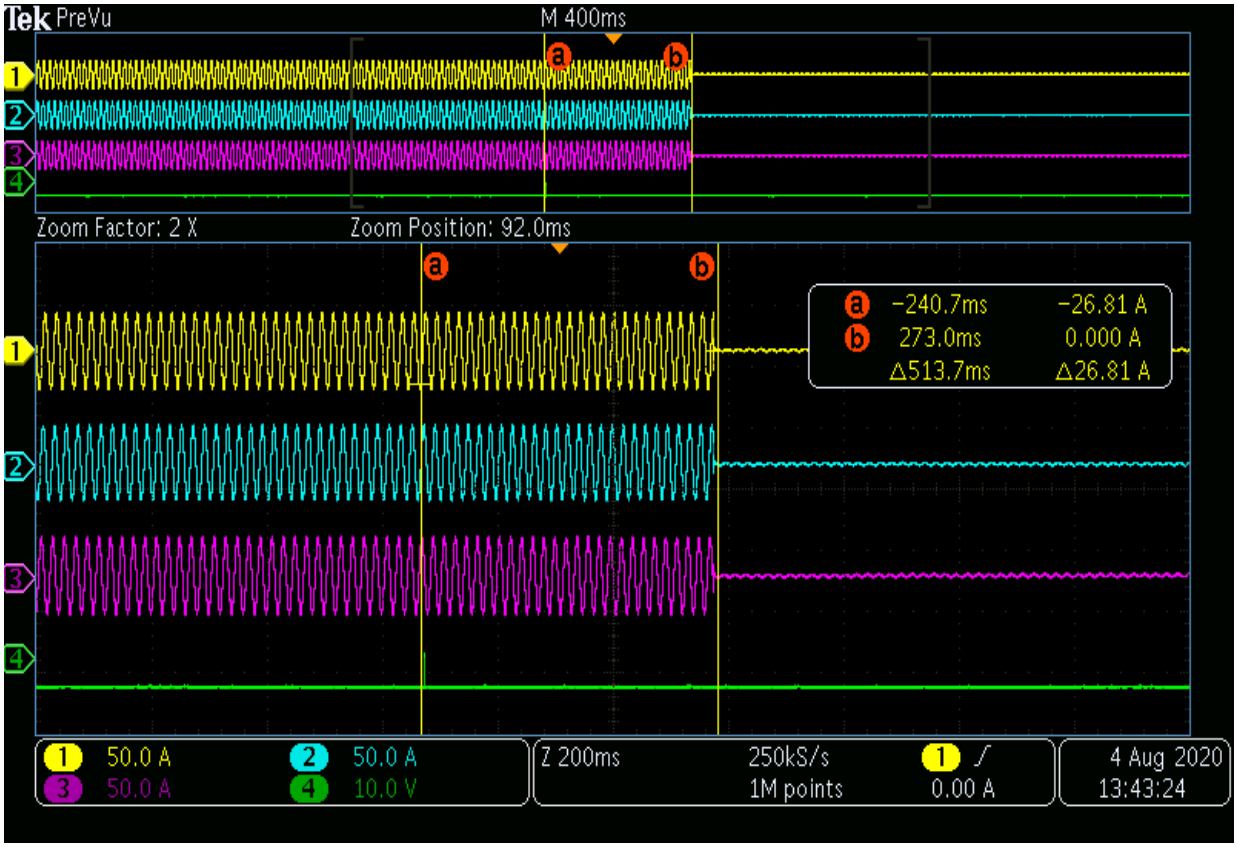
O/F stage 1-1


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

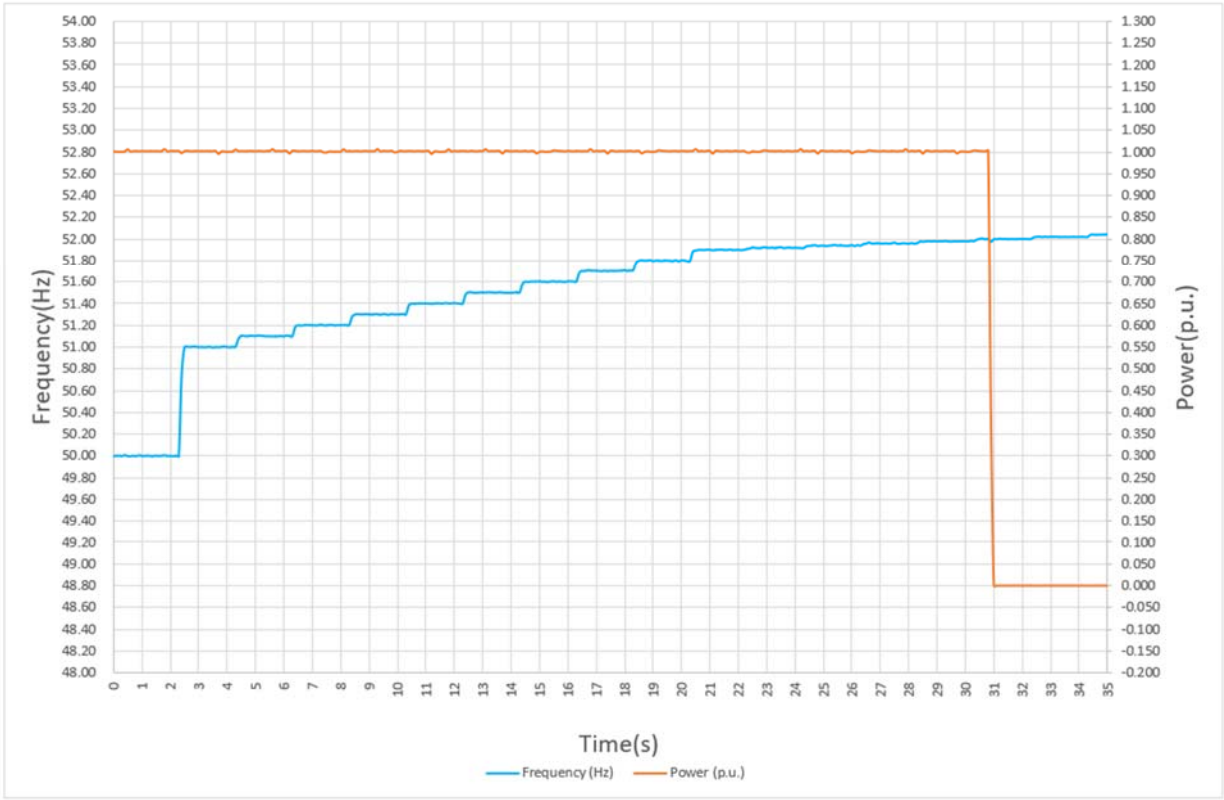

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 242ms
a -146.7ms -32.41 A
b 389.0ms 0.000 A
Δ535.7ms Δ32.41 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
1 ⎍ 0.00 A
4 Aug 2020
13:42:10

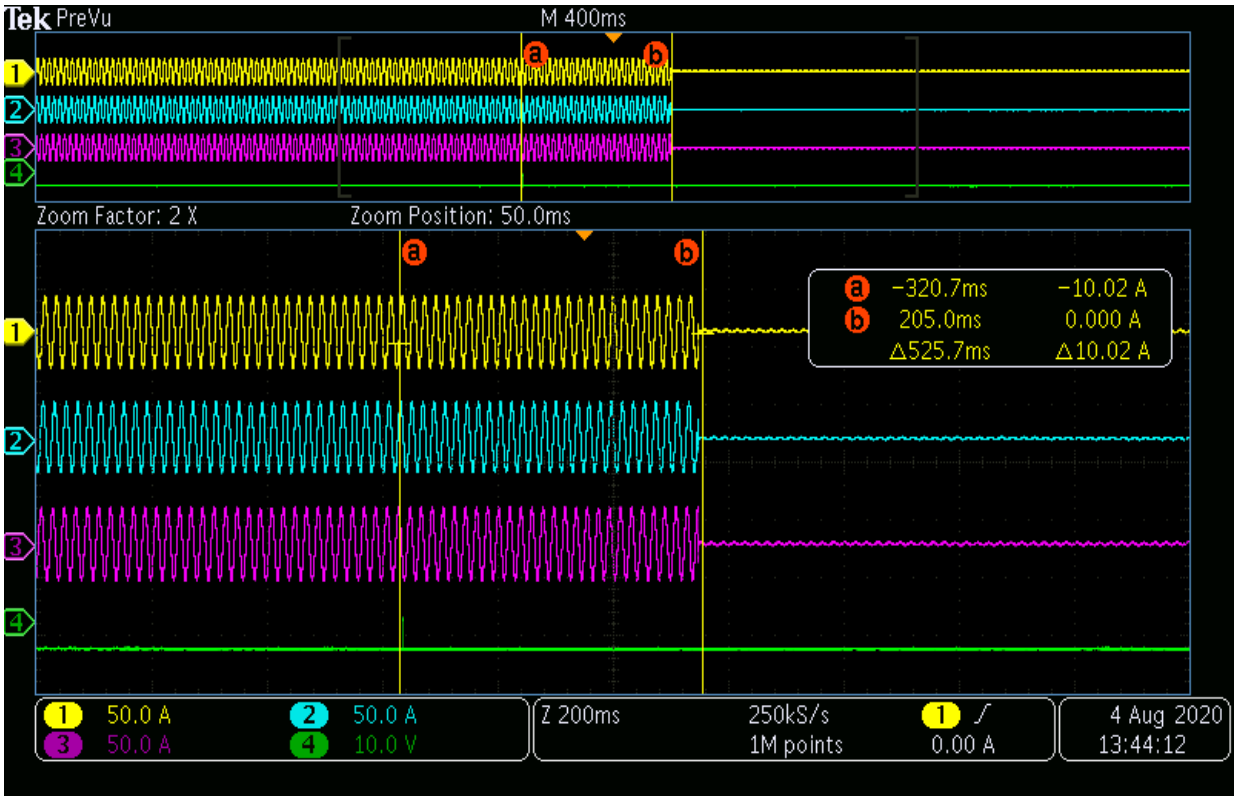
O/F stage 1-2


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

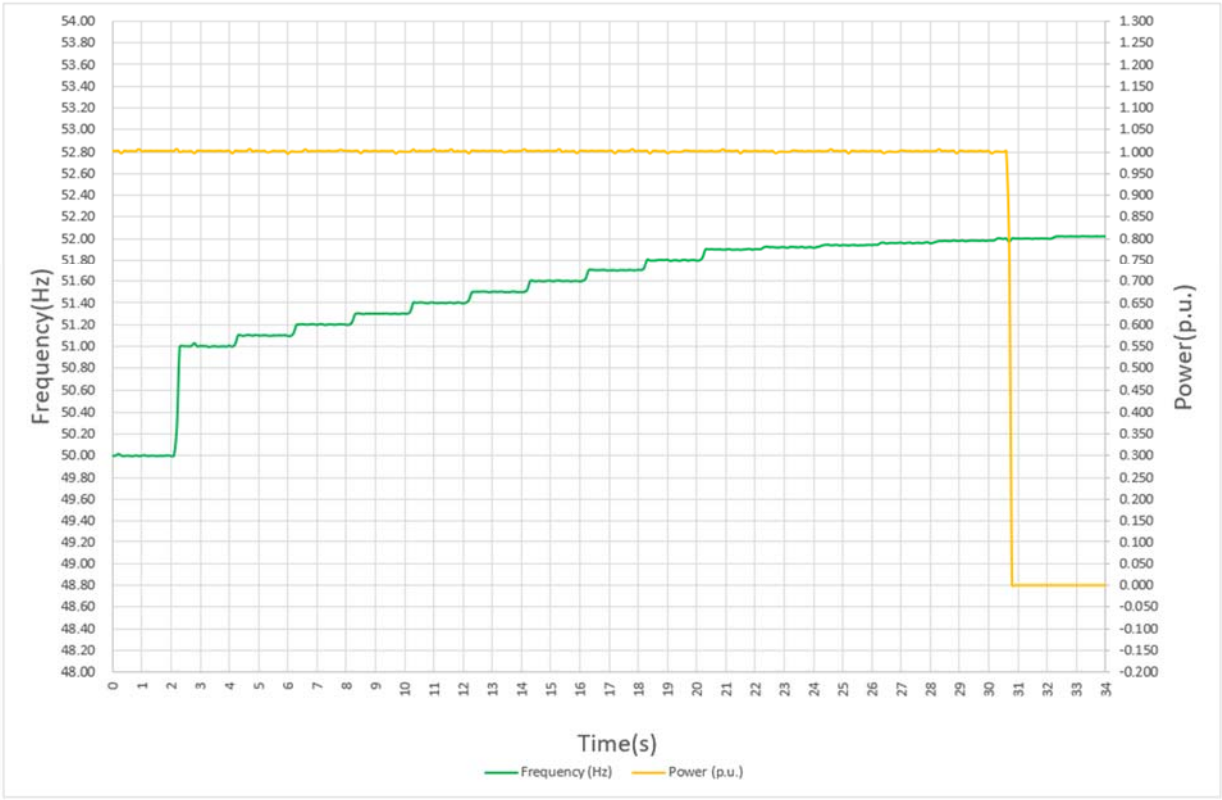

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 92.0ms
a -240.7ms -26.81 A
b 273.0ms 0.000 A
Δ513.7ms Δ26.81 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
1 ⨍
0.00 A
4 Aug 2020
13:43:24

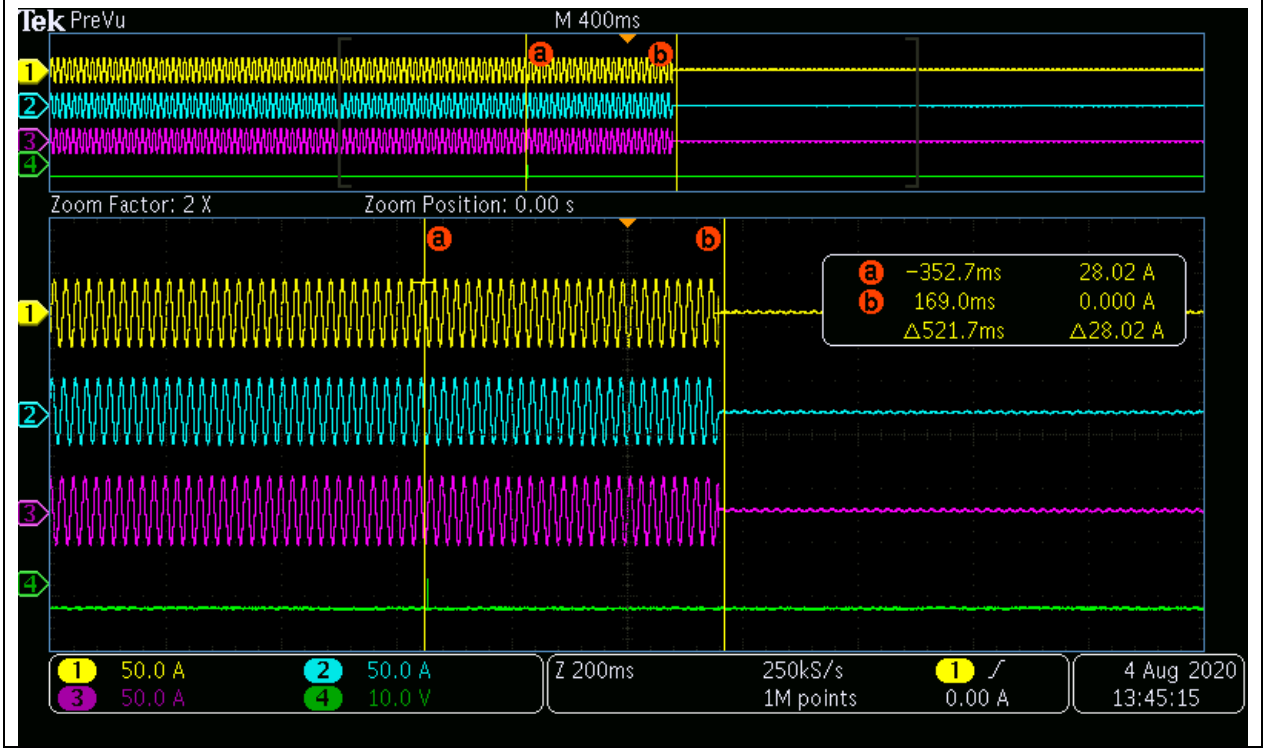
O/F stage 1-3


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

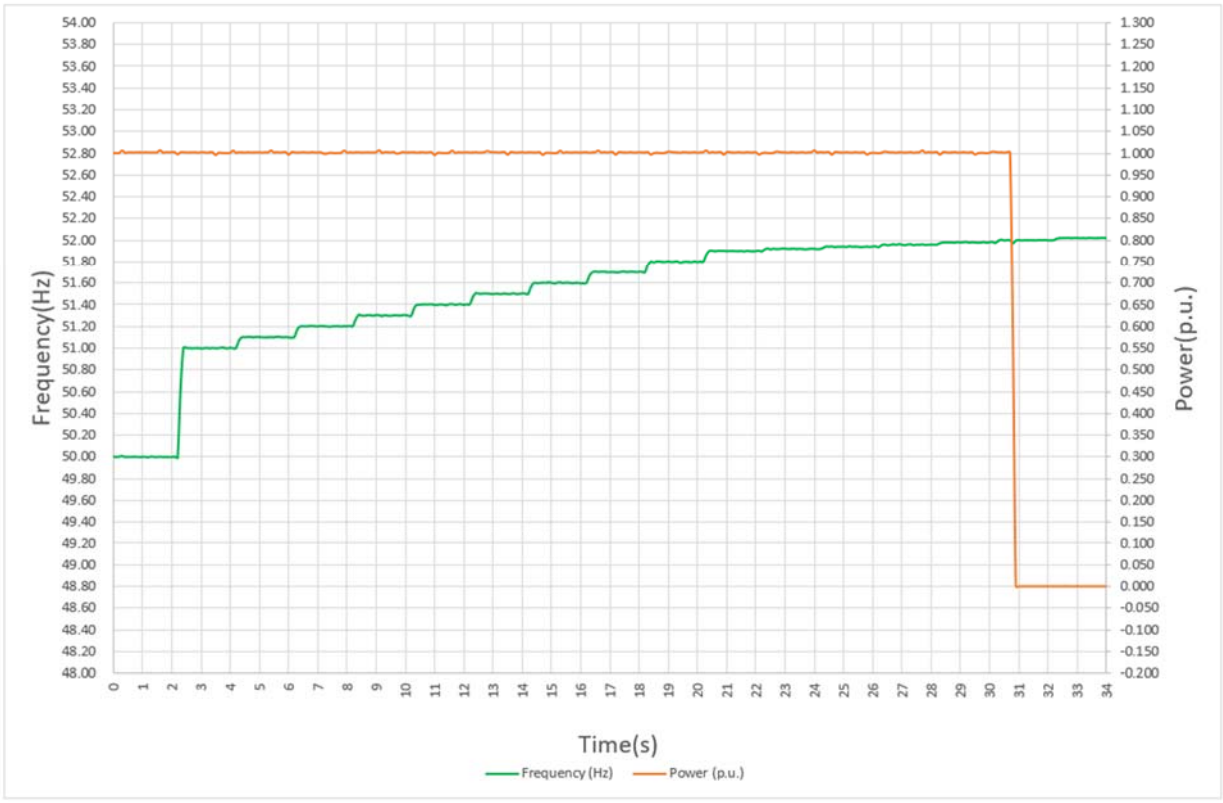

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 50.0ms
a -320.7ms -10.02 A
b 205.0ms 0.000 A
Δ525.7ms Δ10.02 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
1 ⁄
0.00 A
4 Aug 2020
13:44:12

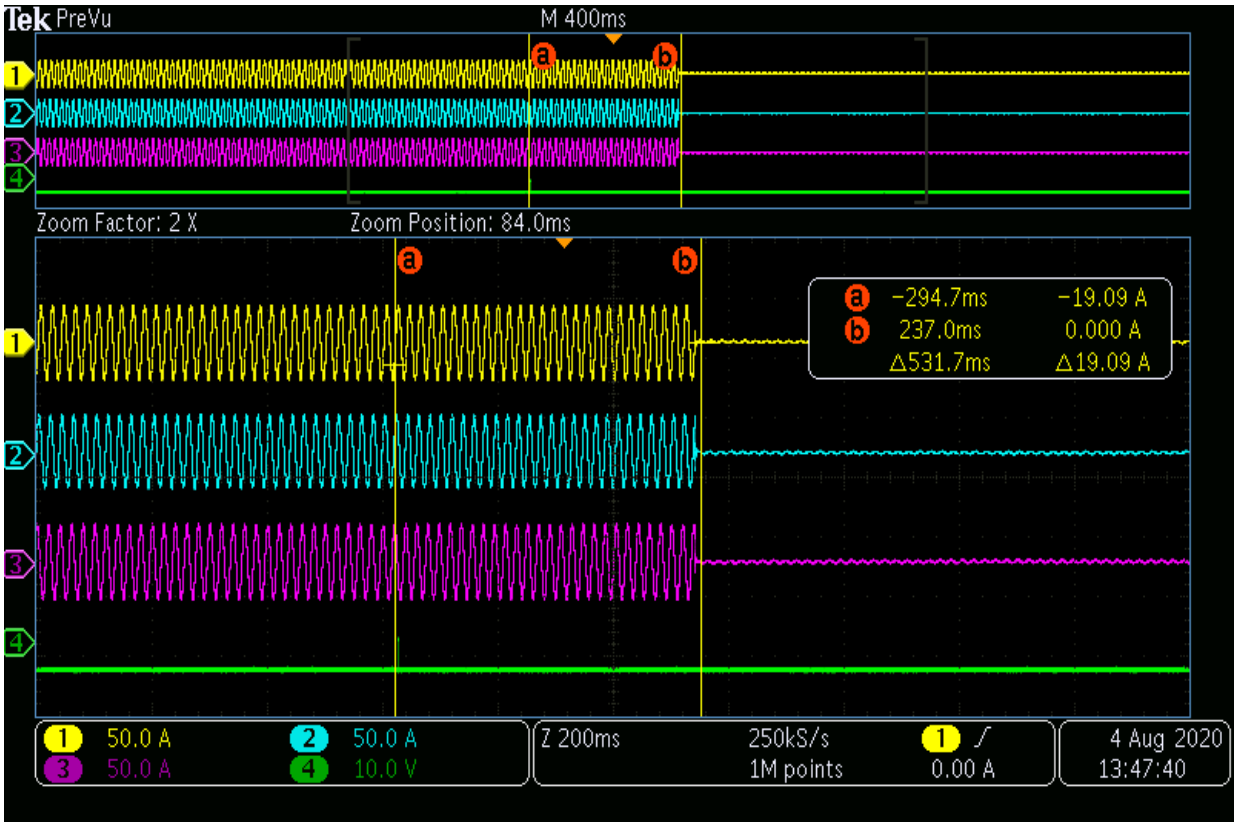
O/F stage 1-4


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

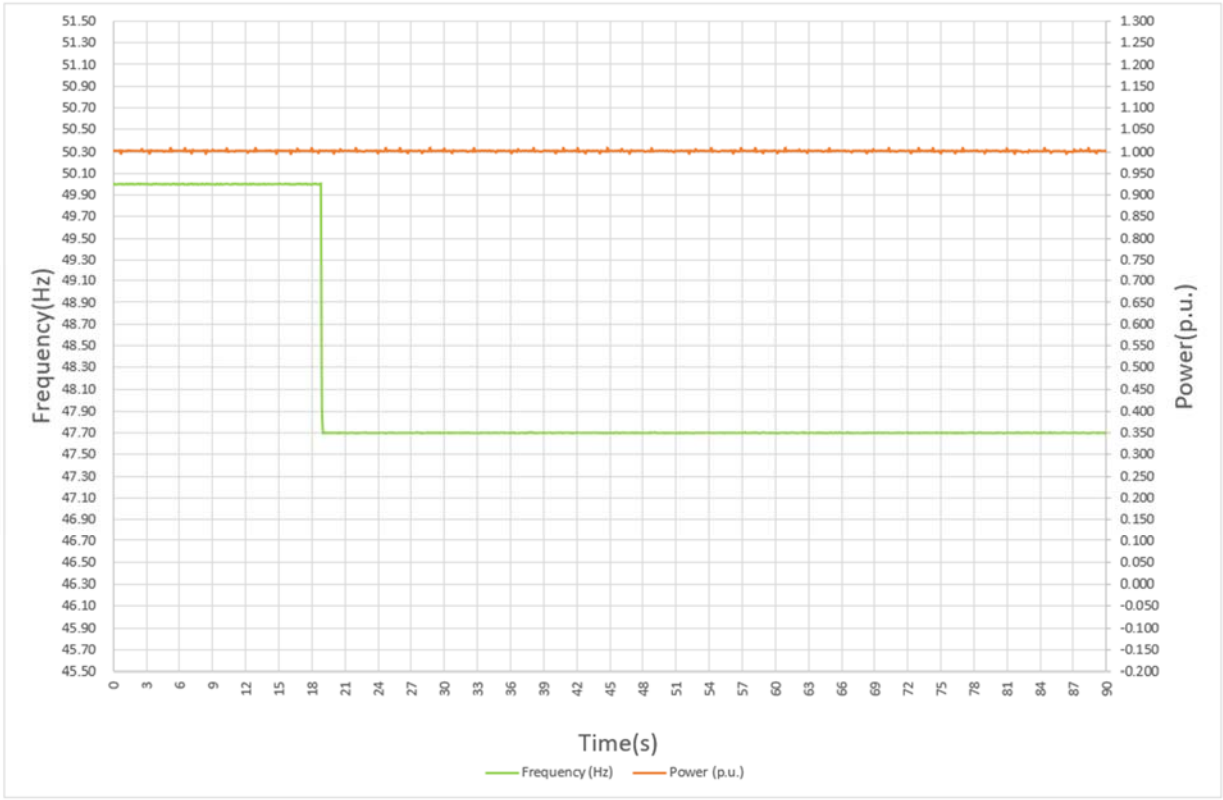

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 0.00 s
a -352.7ms 28.02 A
b 169.0ms 0.000 A
Δ521.7ms Δ28.02 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
0.00 A
4 Aug 2020
13:45:15

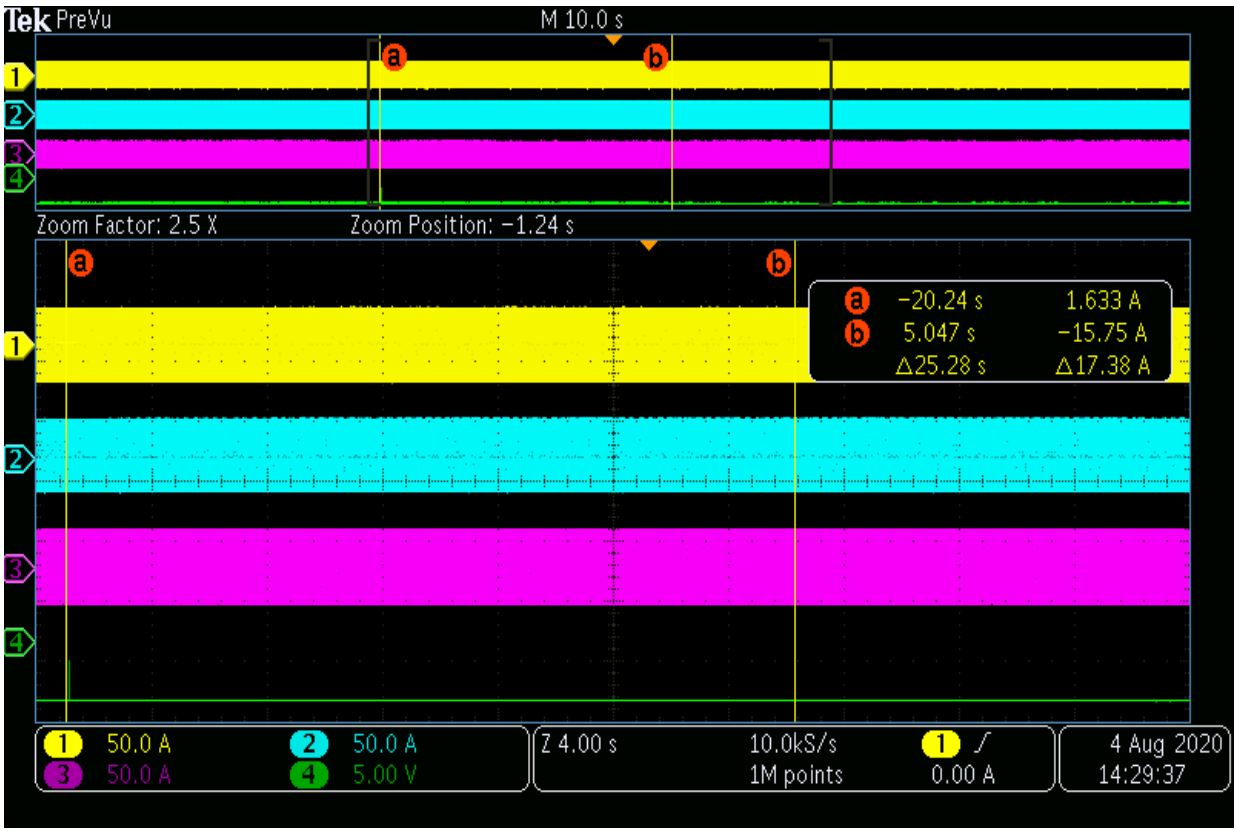
O/F stage 1-5


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

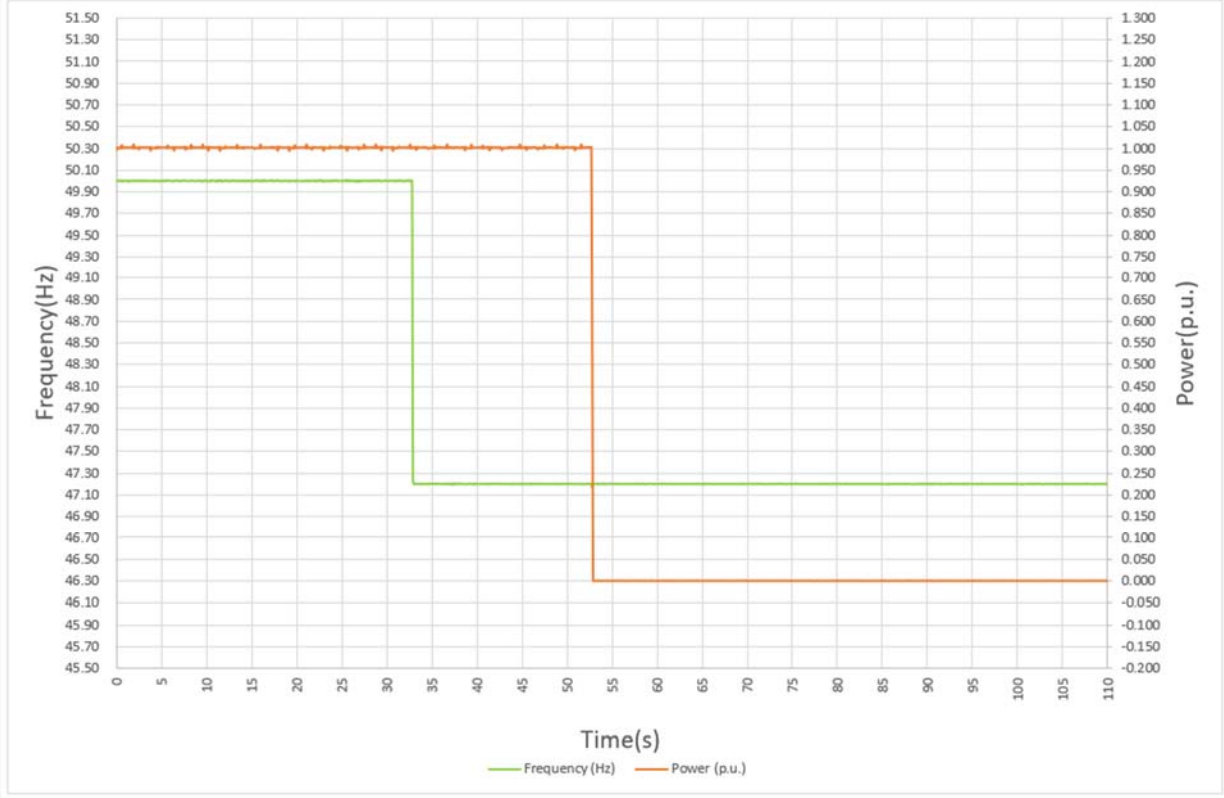

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 84.0ms
a -294.7ms -19.09 A
b 237.0ms 0.000 A
Δ531.7ms Δ19.09 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
0.00 A
4 Aug 2020
13:47:40

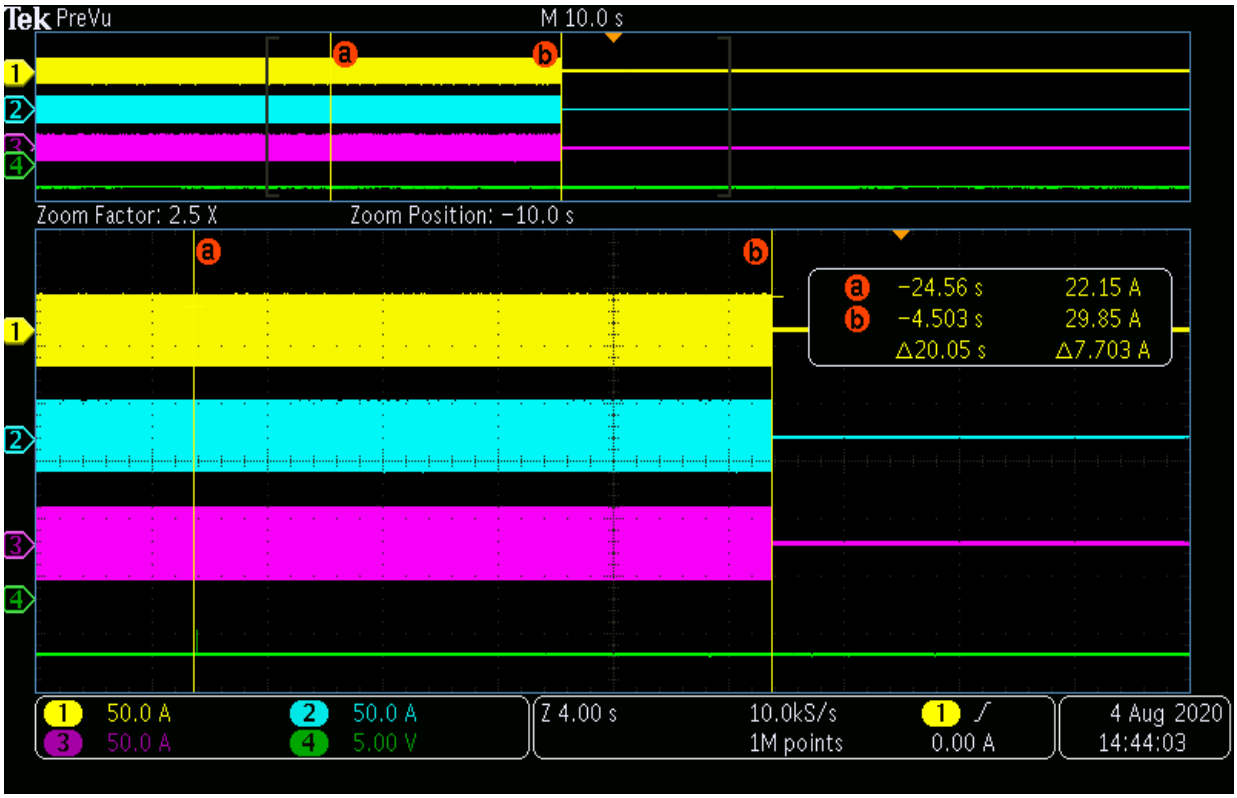
No trip tests - 47.7Hz



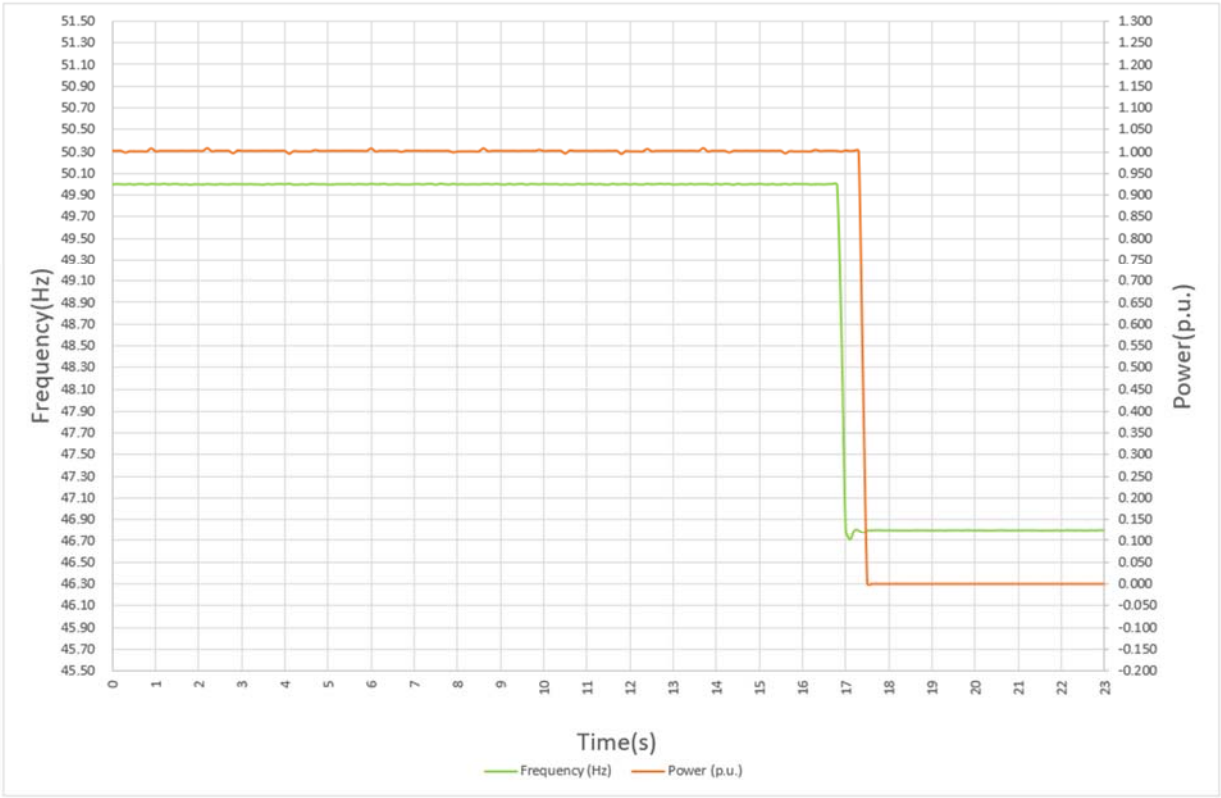


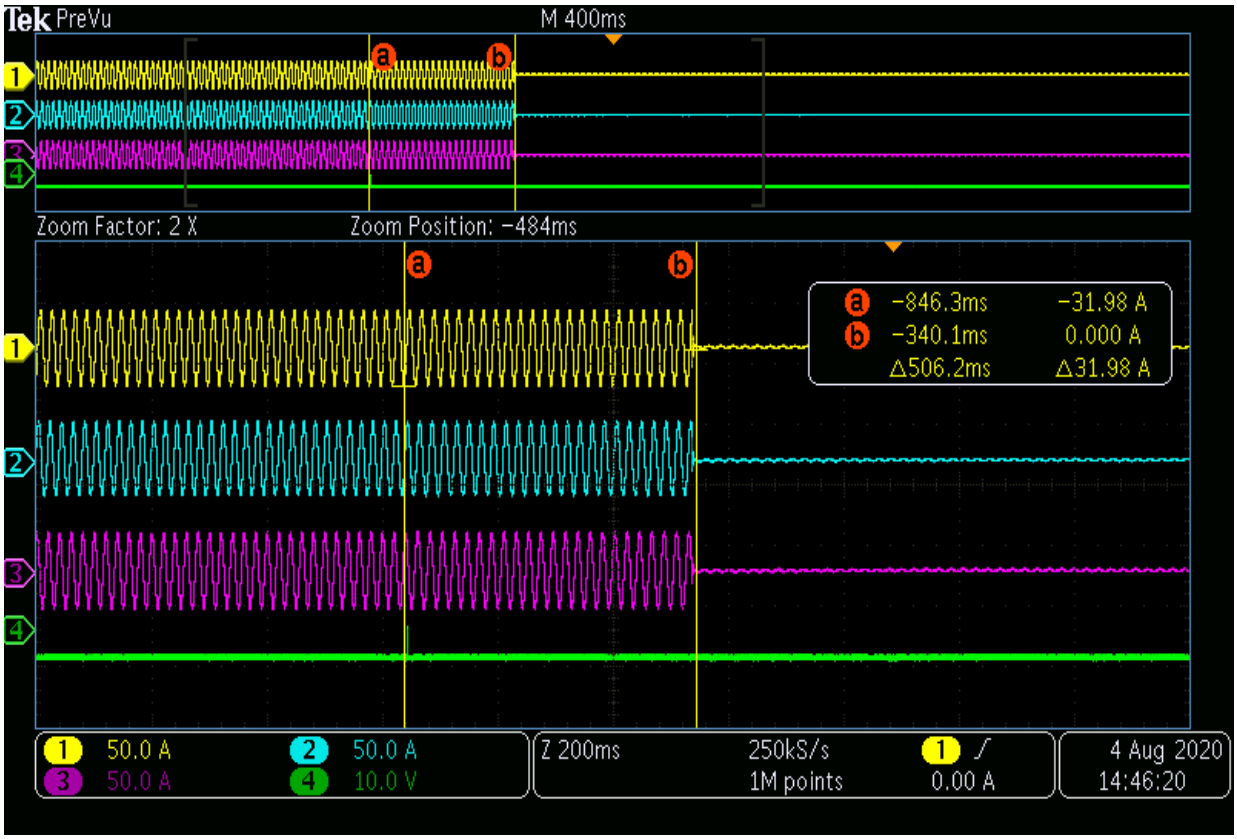
No trip tests – 47.2Hz



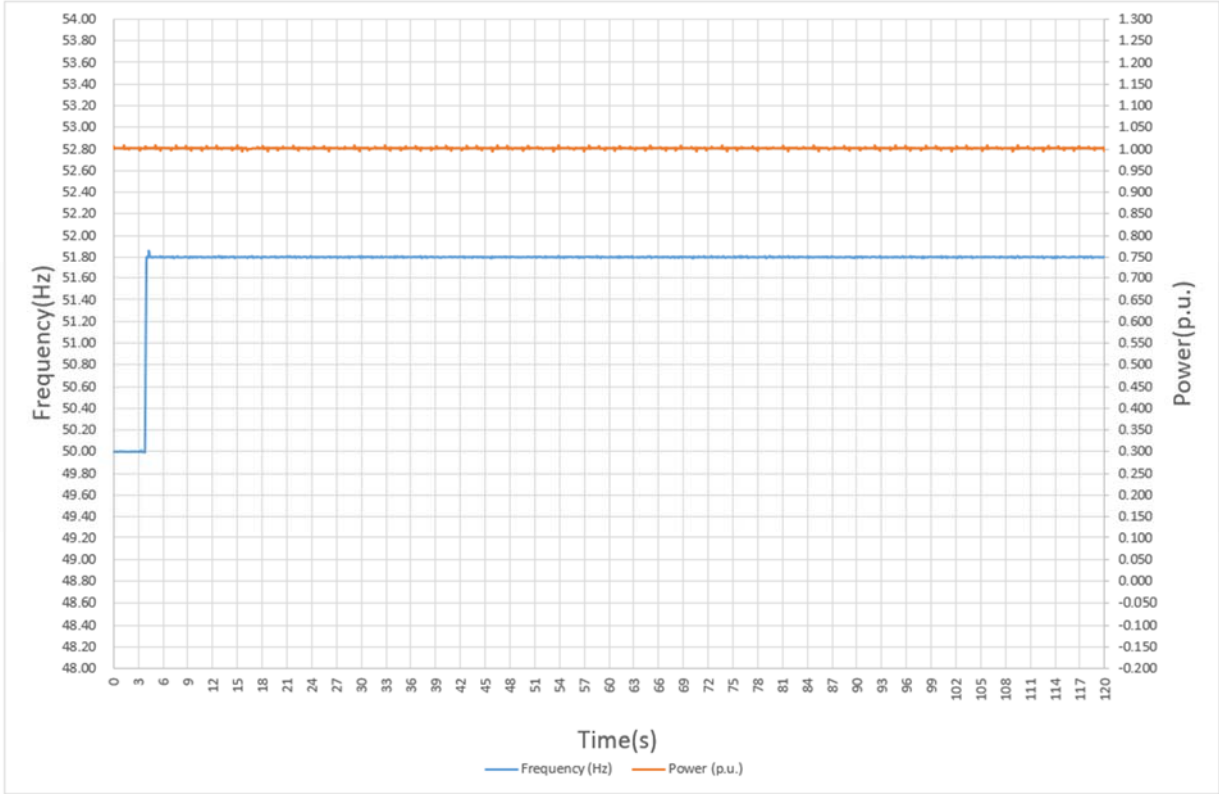


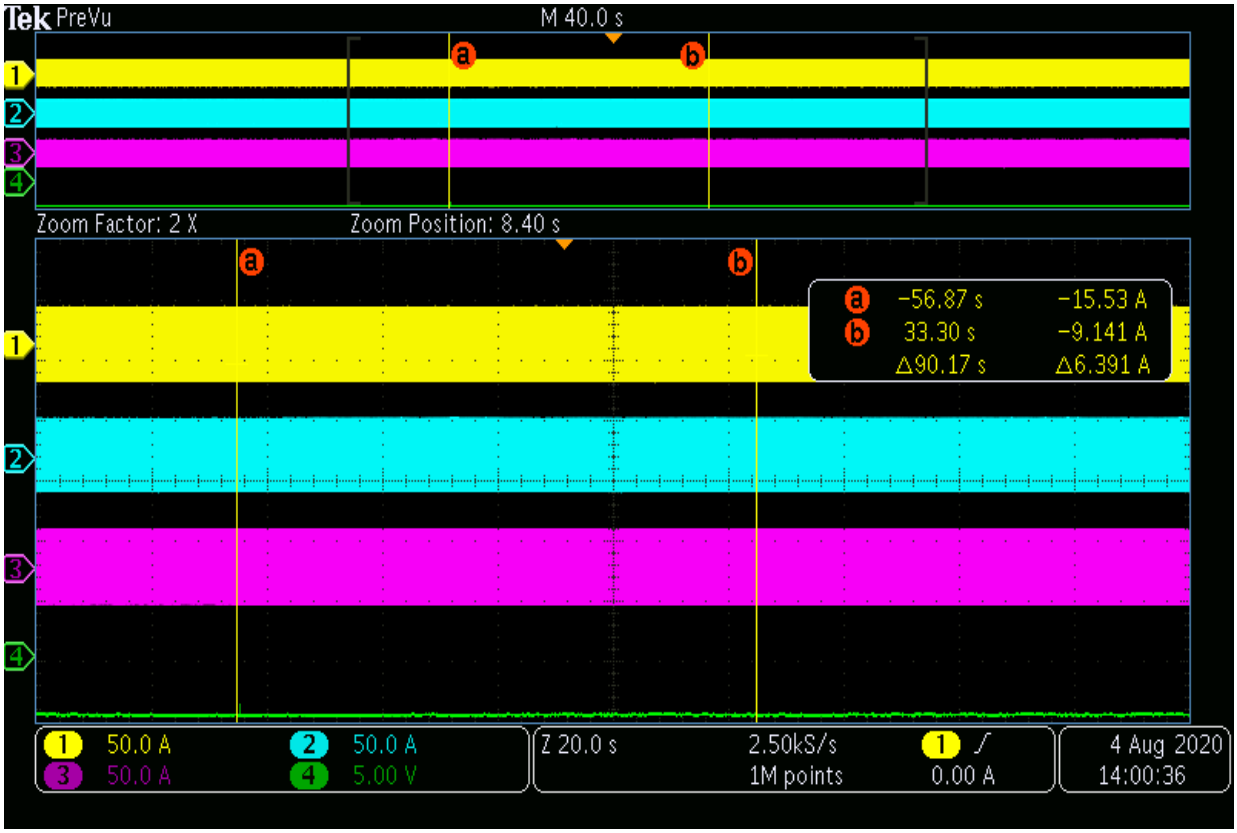
No trip tests – 46.8Hz



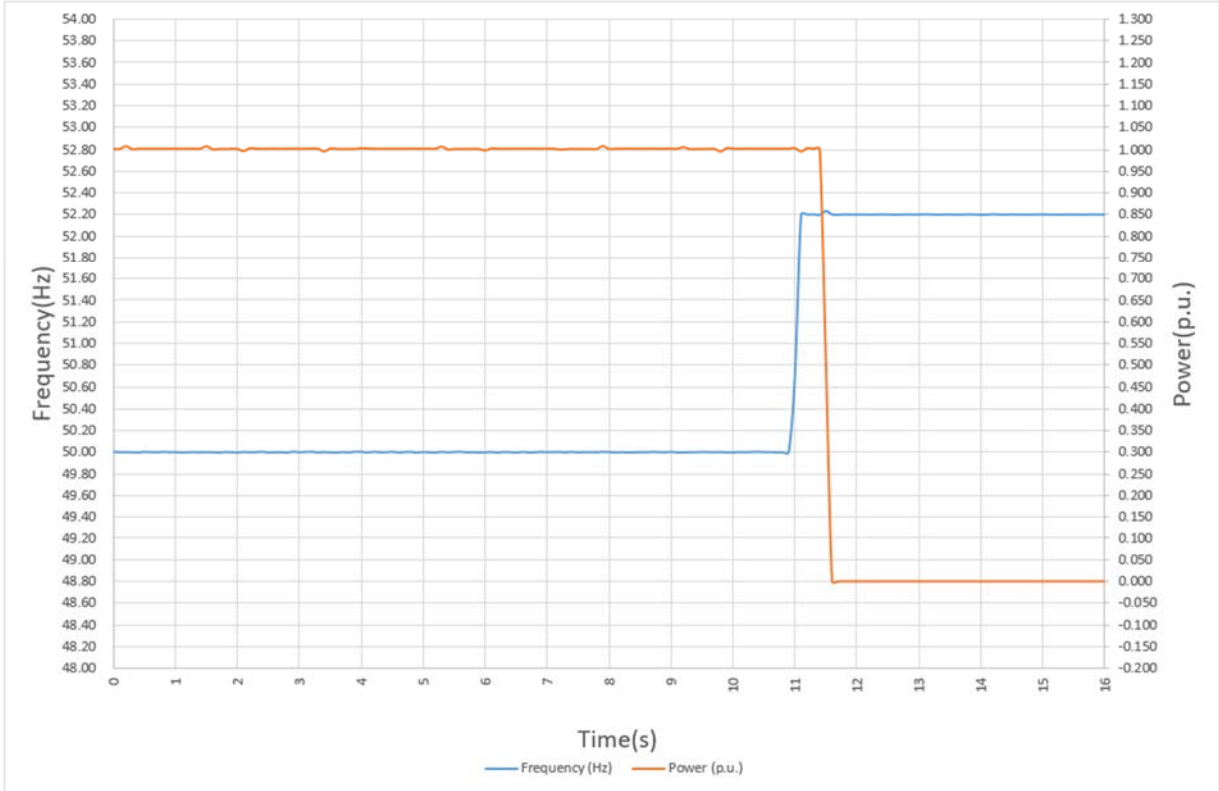


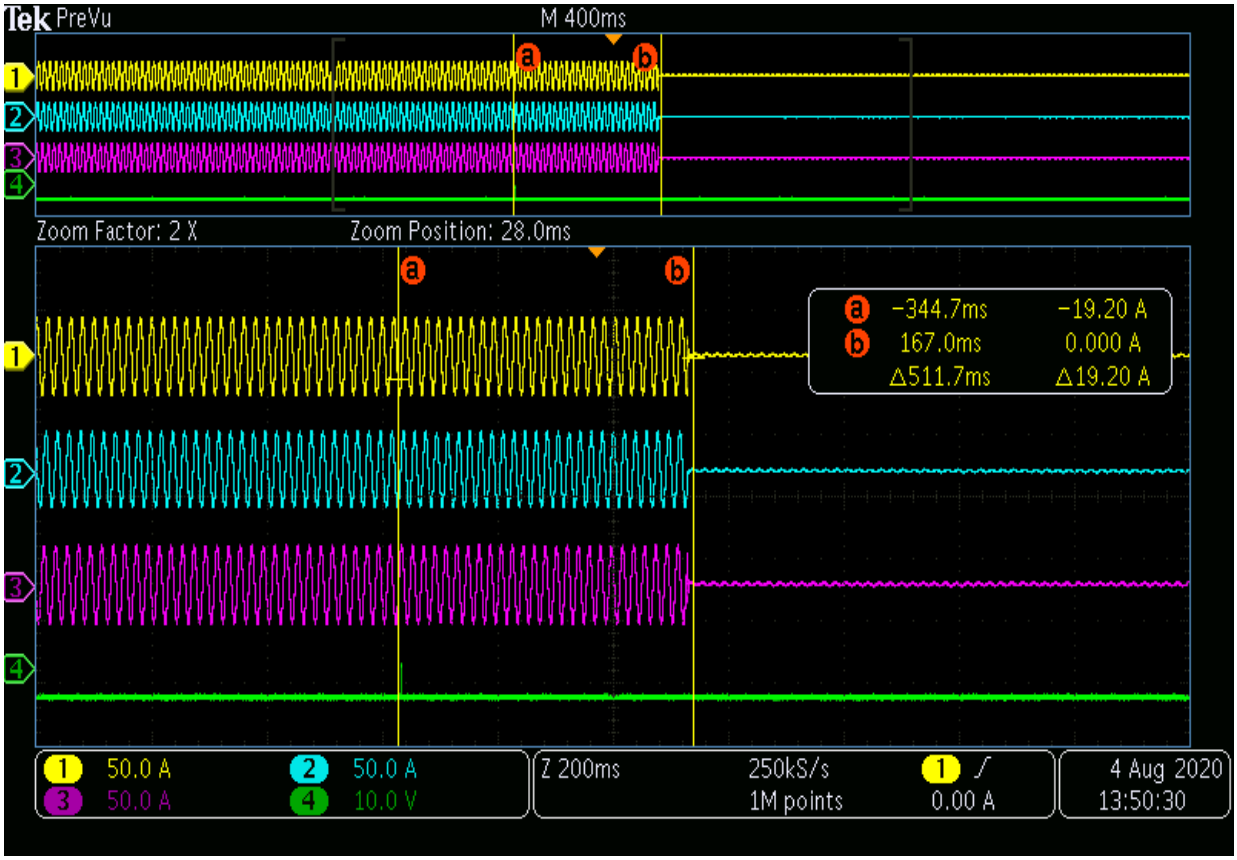
No trip tests - 51.8Hz





No trip tests – 52.2Hz





4.3.2 Voltage tests

These tests should be carried out in accordance with Annex A.7.1.2.2.

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.

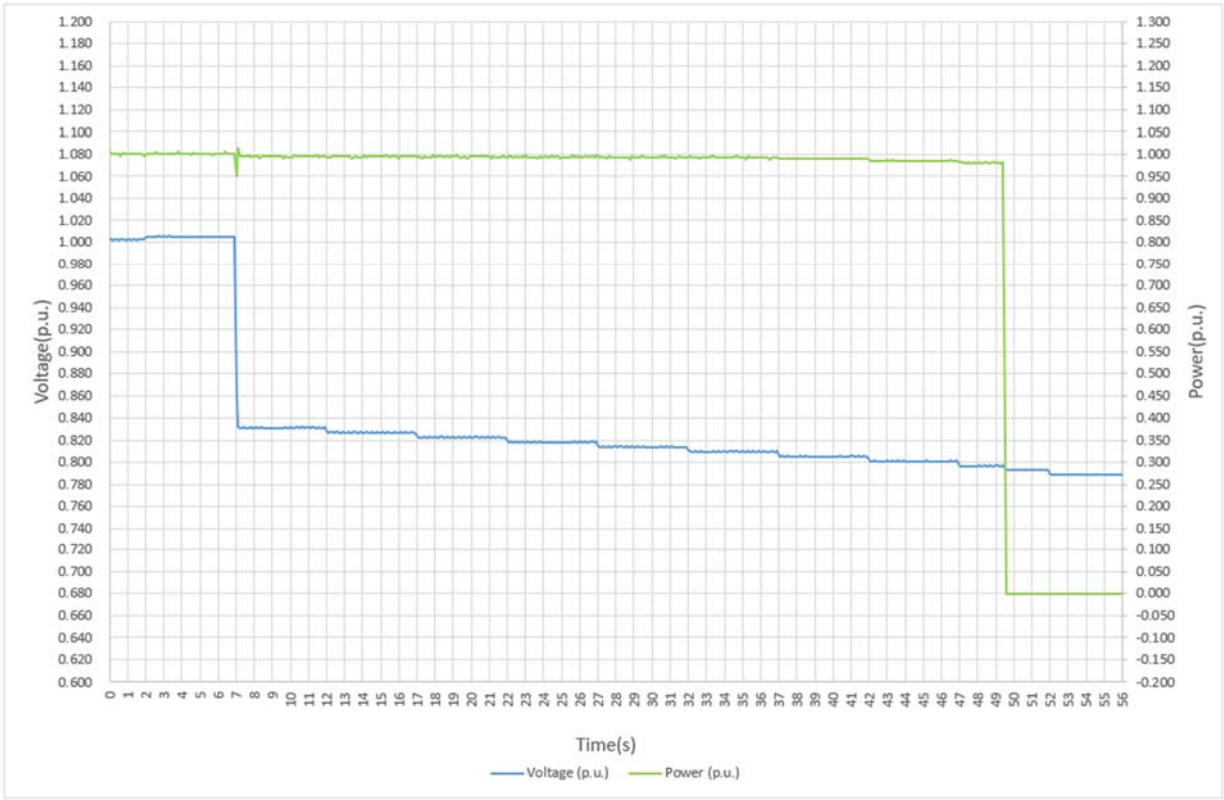
To establish the certified trip time, the test voltage should be applied starting from ± 1.8% below the certified trip voltage in a step of at least ± 0.5% of setting for a duration that is longer than the trip time delay. For each trip setting five tests shall be carried out.

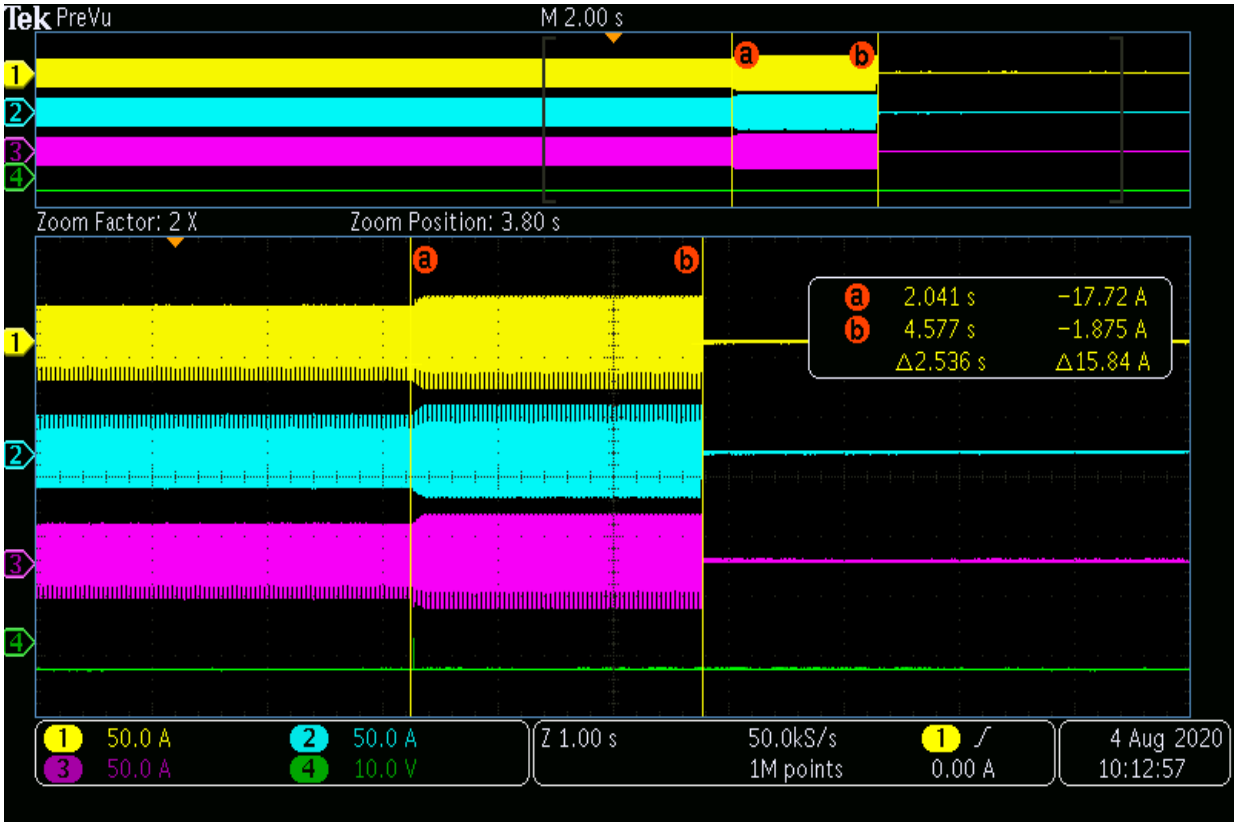
Following tables show the test results:

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	182.4	2.536	188 V / 3.50 s	Pass
			182.4	2.526		
			182.4	2.530		
			182.4	2.518		
			182.4	2.528		
					180 V / 2.48 s	Pass
O/V stage 1	262.2 V	1.0 s	261.7	1.003	258.2 V / 2.0 s	Pass
			261.6	1.019		
			261.5	1.011		
			261.5	1.009		
			261.5	1.012		
O/V stage 2	273.7 V	0.5 s	273.5	0.523	269.7 V / 0.98 s	Pass
			273.5	0.525		
			273.6	0.515		
			273.5	0.521		
			273.5	0.521		
					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.						

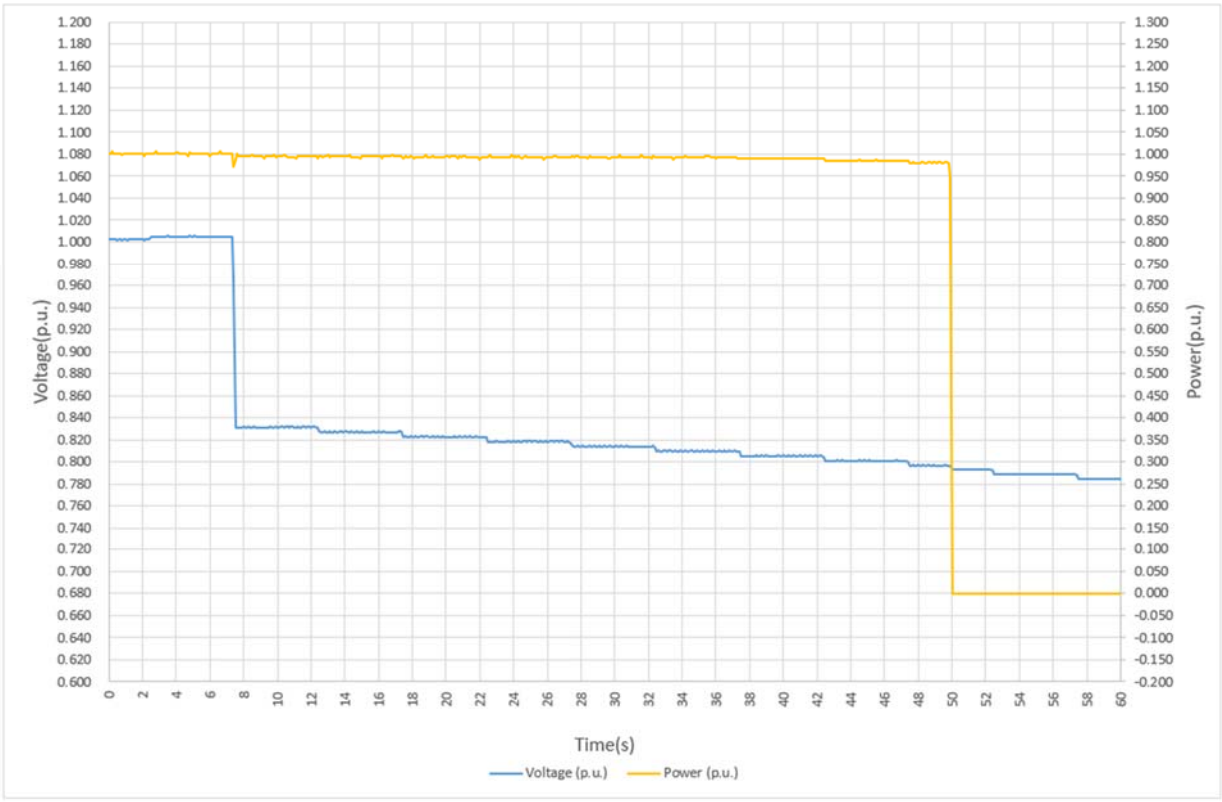
Test results are graphically shown in following pages.

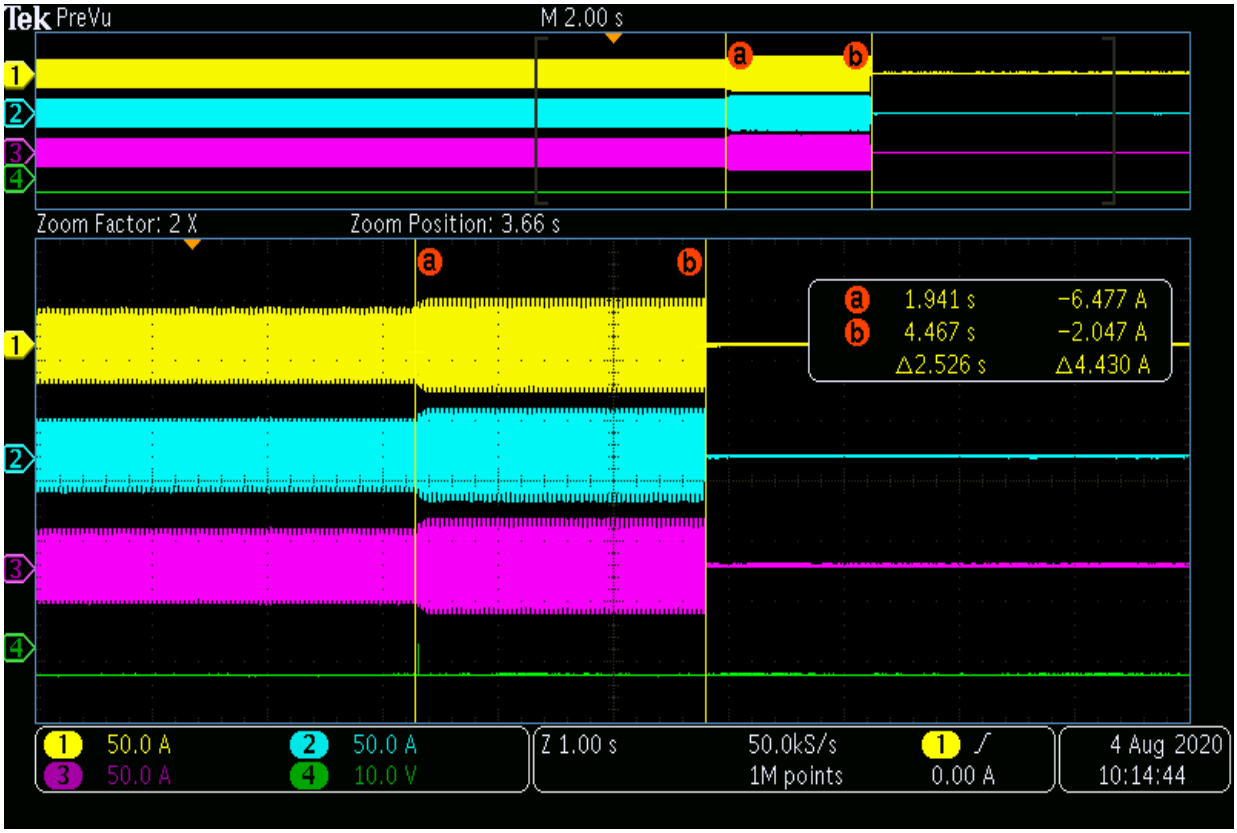
U/V -1



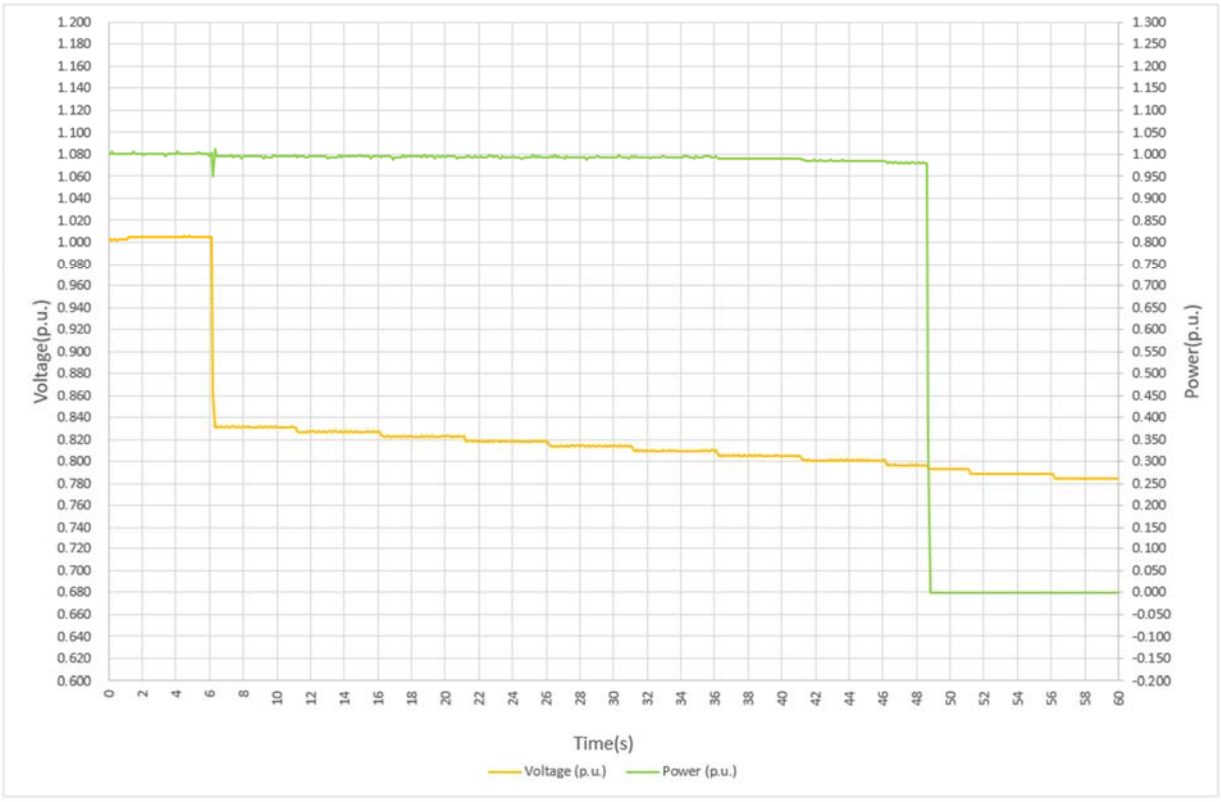


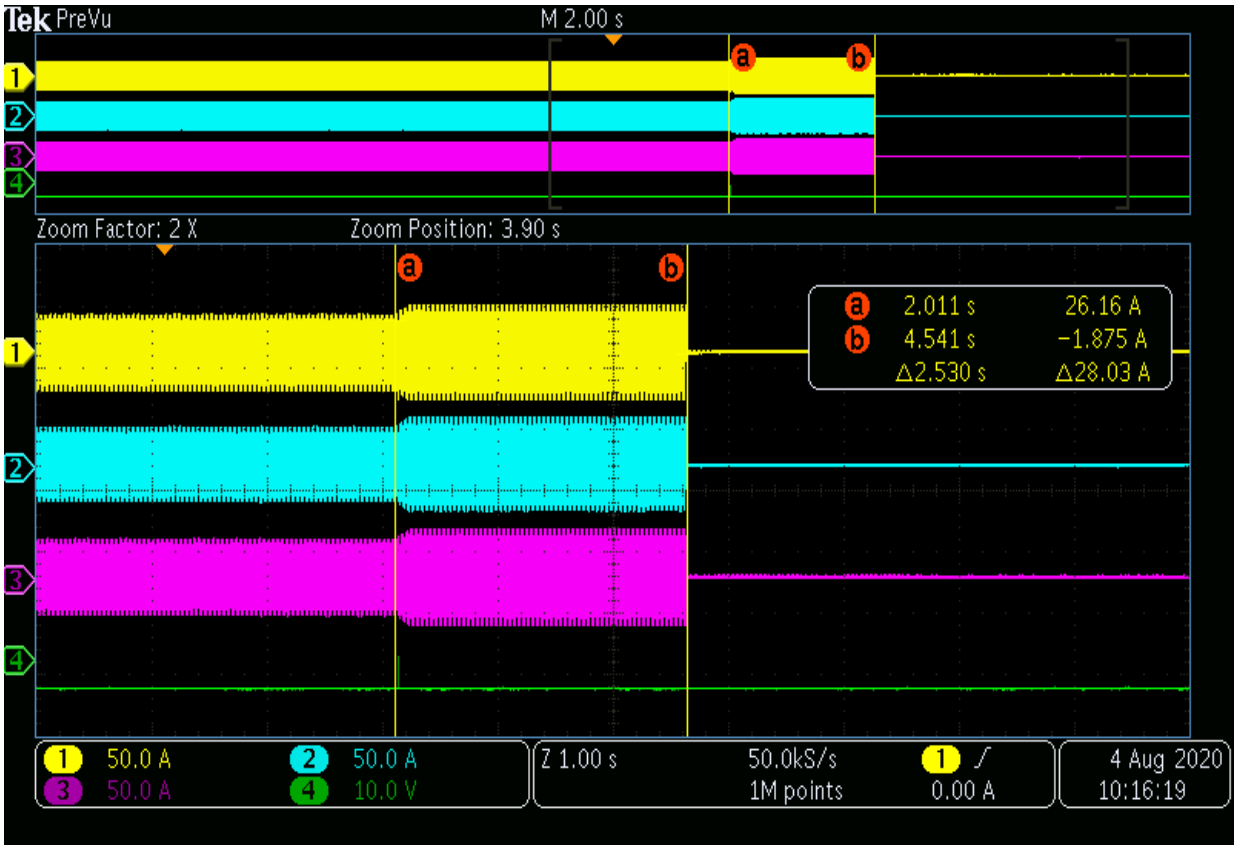
U/V -2


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

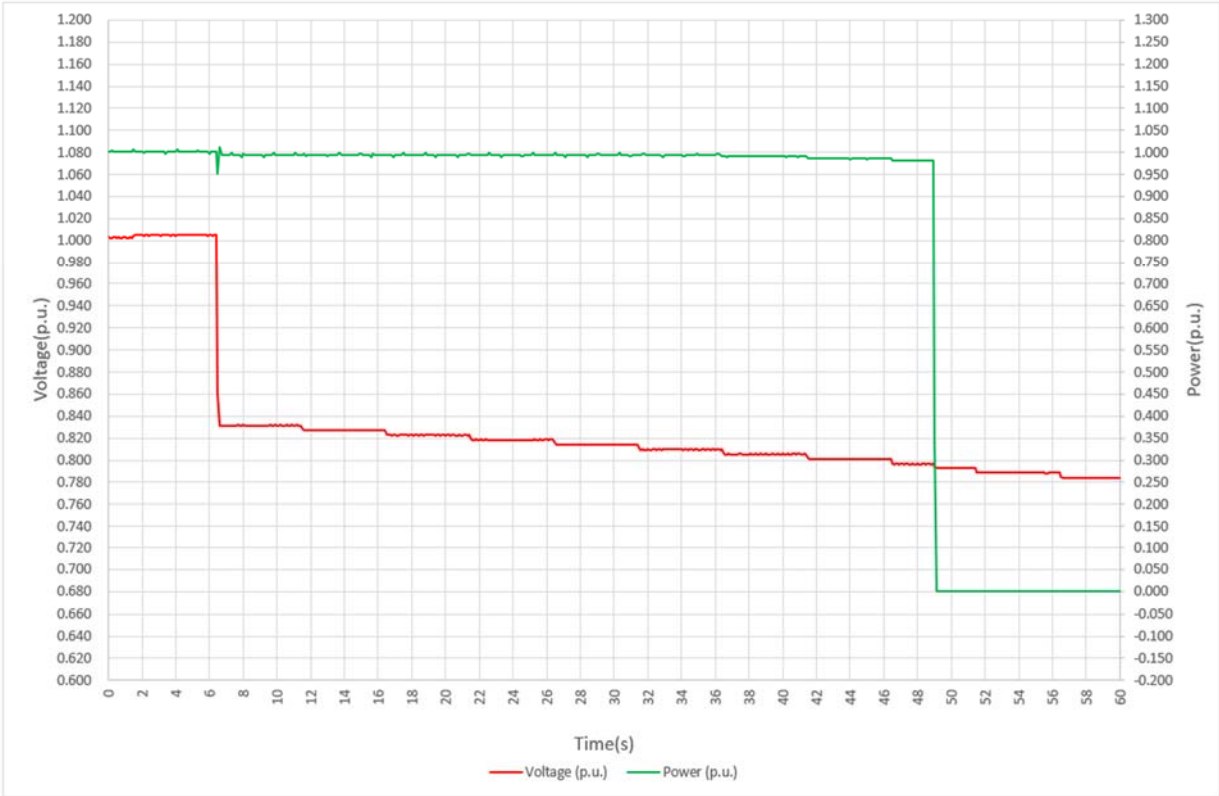

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 3.66 s
a 1.941 s -6.477 A
b 4.467 s -2.047 A
Δ2.526 s Δ4.430 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 1.00 s
50.0kS/s
1M points
0.00 A
4 Aug 2020
10:14:44

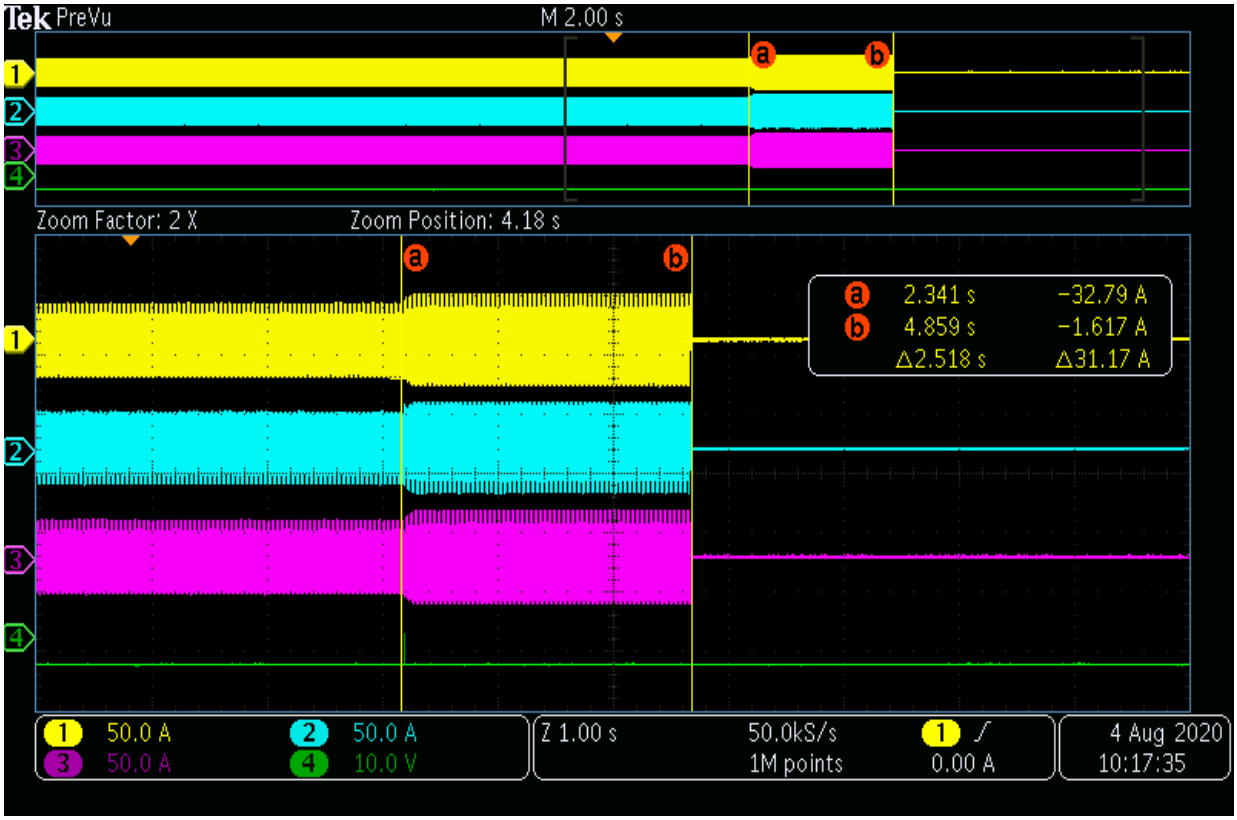
U/V -3


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

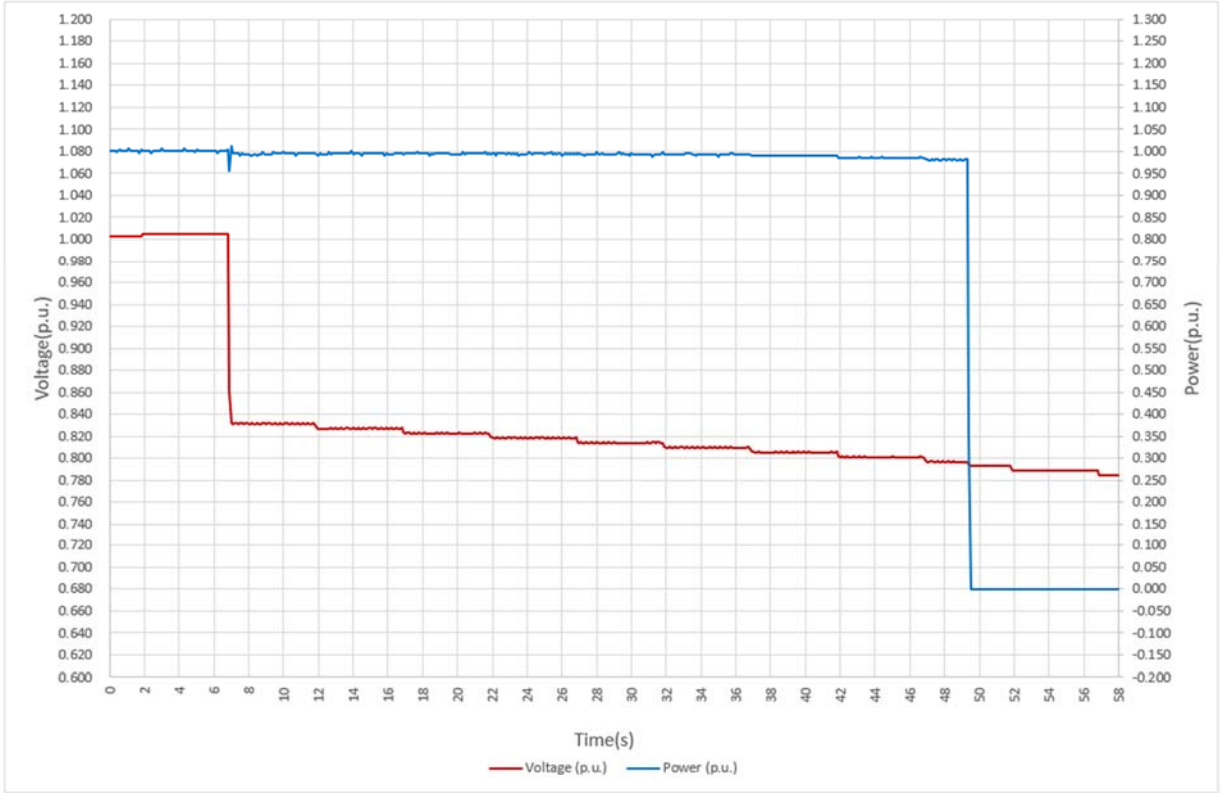

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 3.90 s
a 2.011 s 26.16 A
b 4.541 s -1.875 A
Δ2.530 s Δ28.03 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 1.00 s
50.0kS/s
1M points
0.00 A
4 Aug 2020
10:16:19

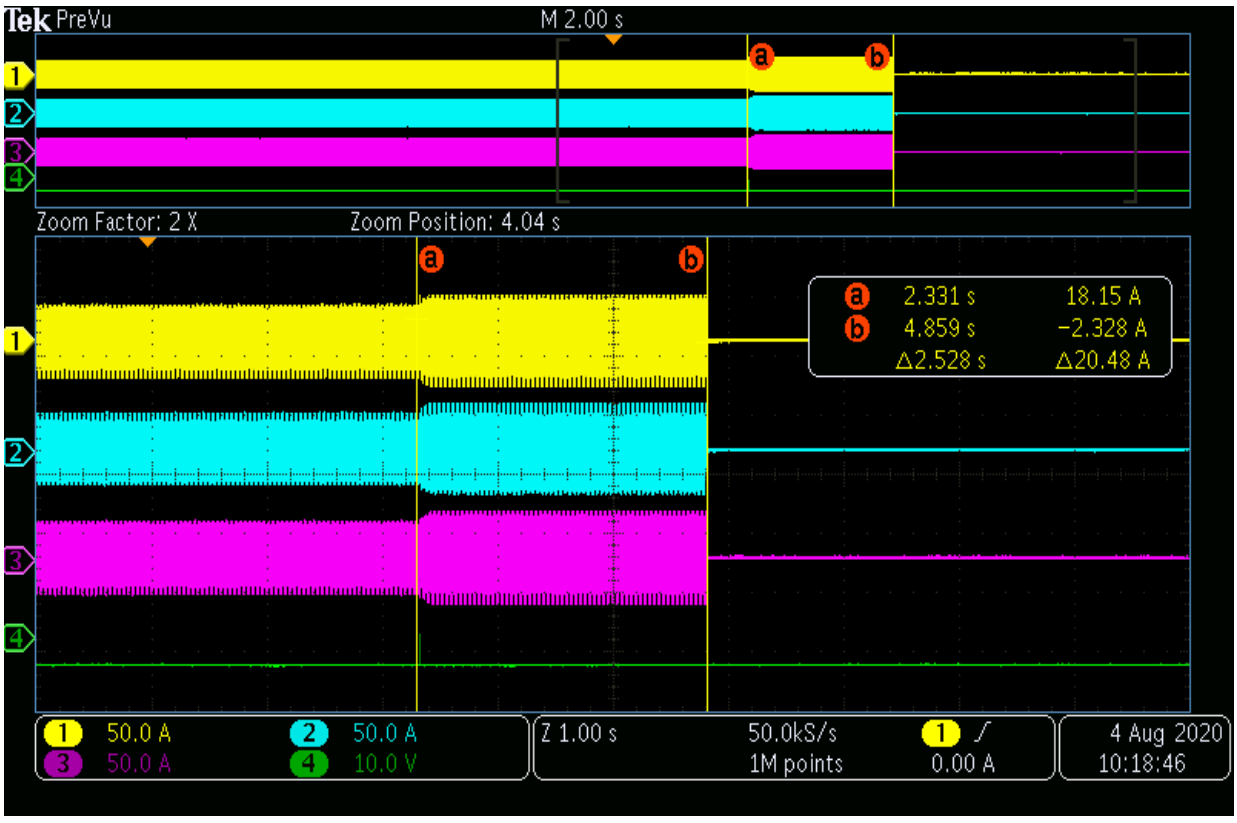
U/V -4


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

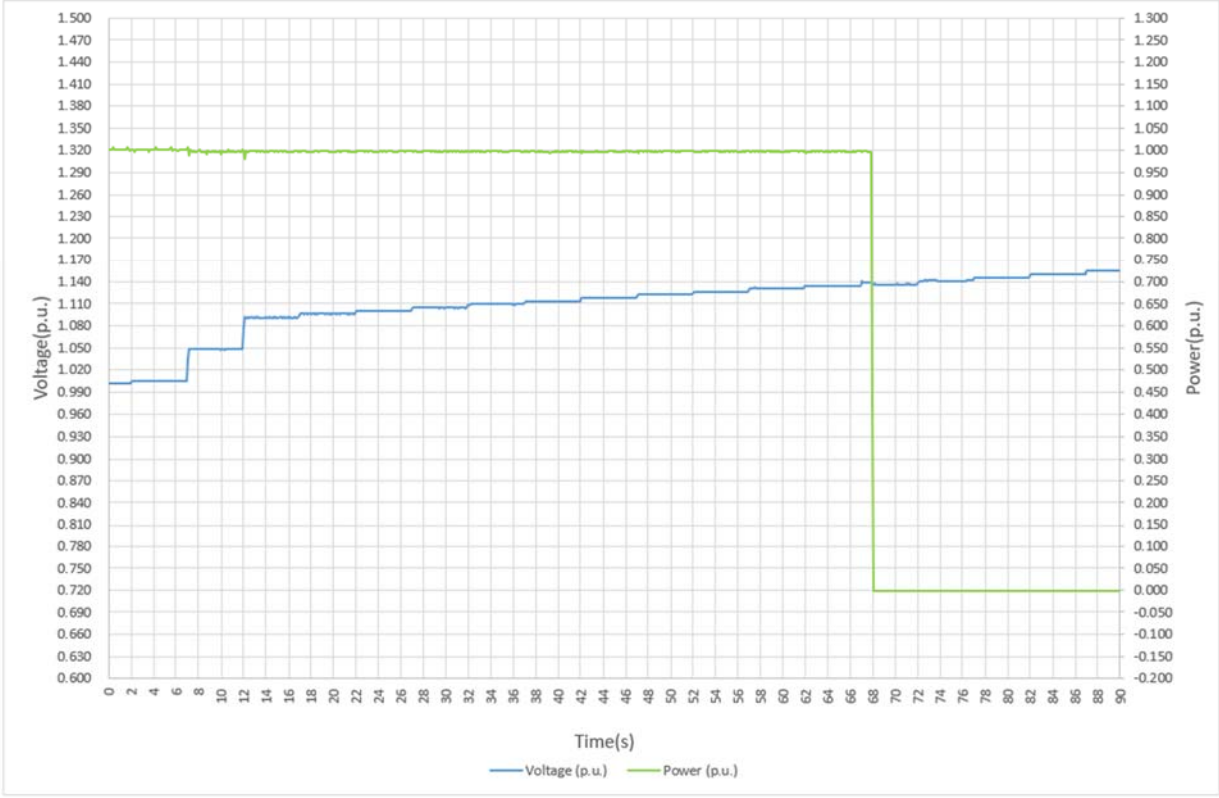

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 4.18 s
a 2.341 s -32.79 A
b 4.859 s -1.617 A
Δ2.518 s Δ31.17 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 1.00 s
50.0kS/s
1M points
0.00 A
4 Aug 2020
10:17:35

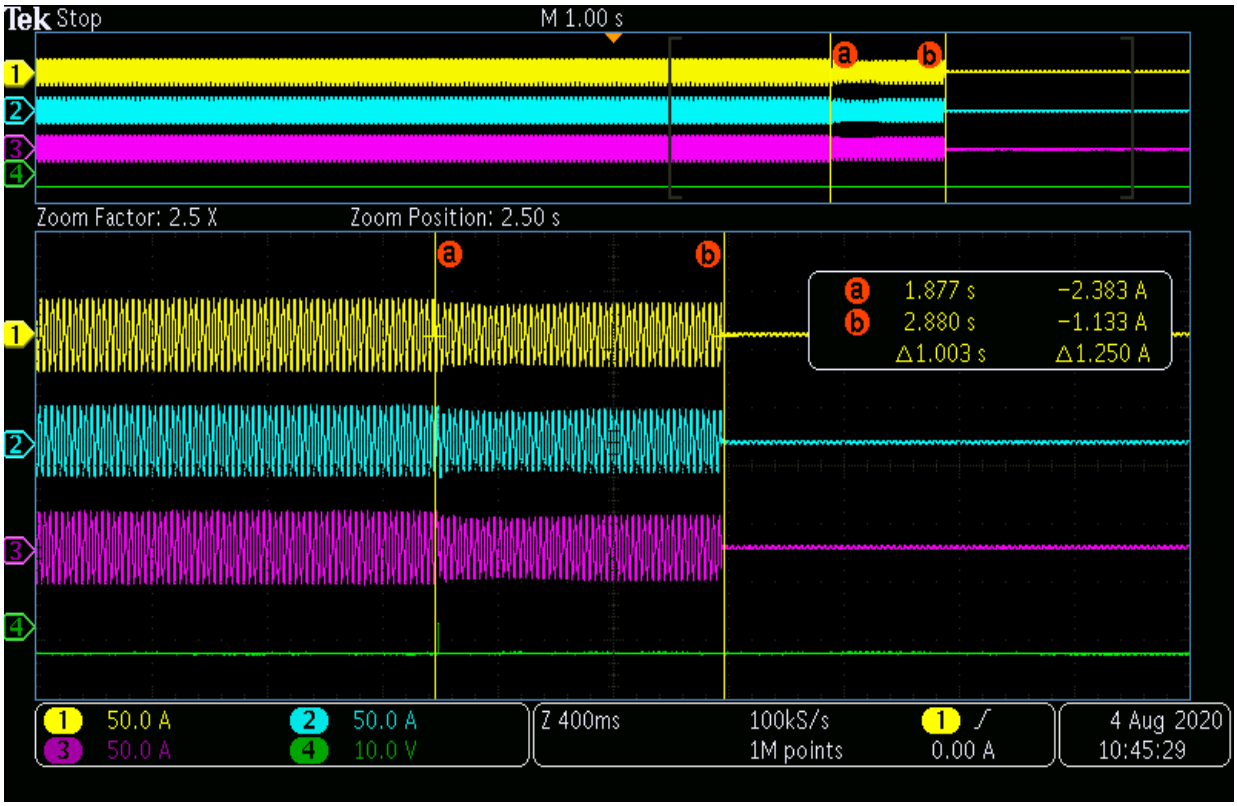
U/V -5


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

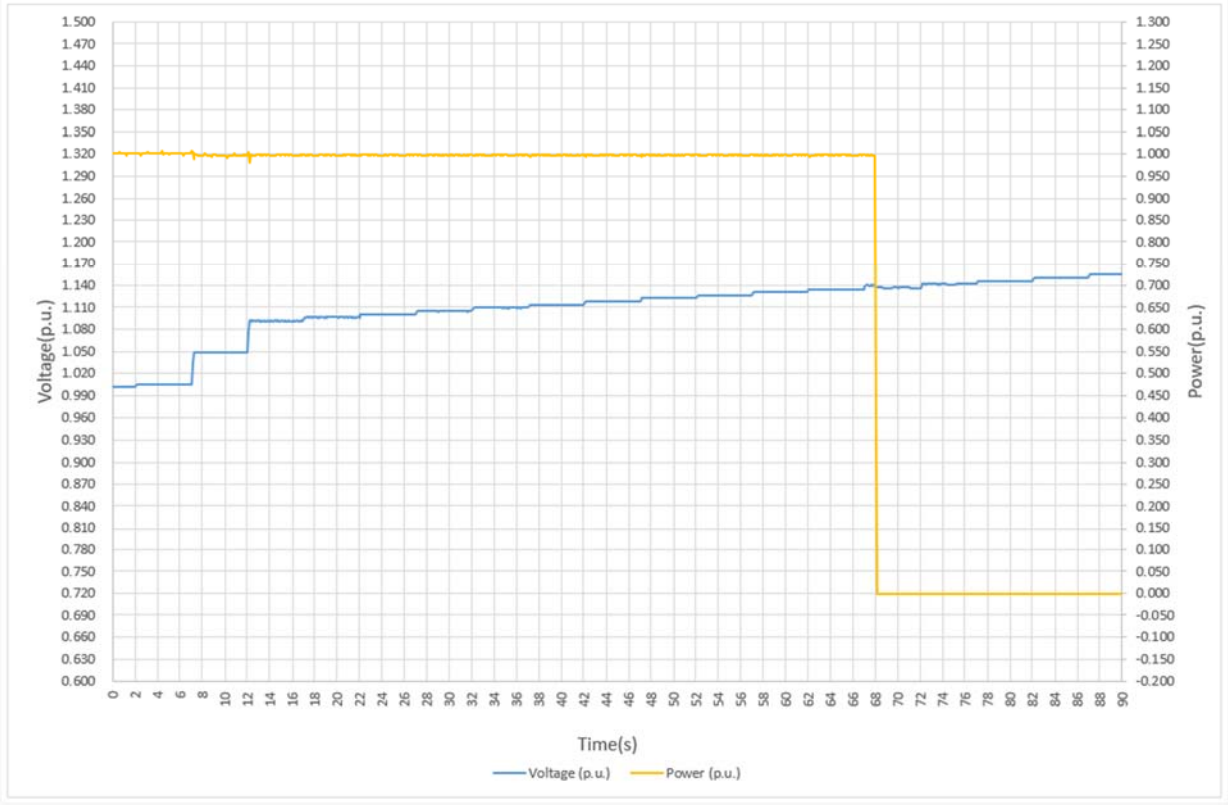

Tek PreVu
M 2.00 s
Zoom Factor: 2 X
Zoom Position: 4.04 s
a 2.331 s 18.15 A
b 4.859 s -2.328 A
Δ2.528 s Δ20.48 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 1.00 s
50.0kS/s
1M points
0.00 A
4 Aug 2020
10:18:46

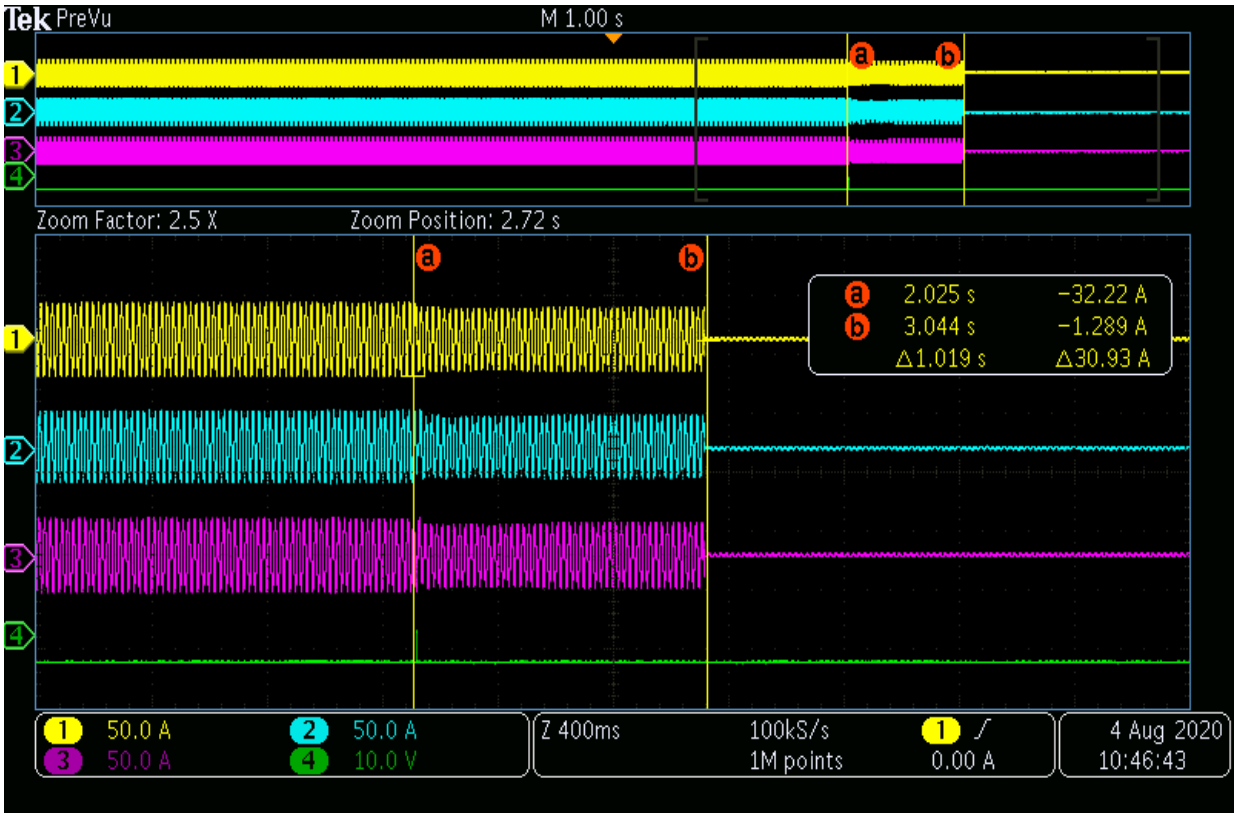
O/V stage 1-1


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


Tek Stop
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 2.50 s
a 1.877 s -2.383 A
b 2.880 s -1.133 A
Δ1.003 s Δ1.250 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 400ms
100kS/s
1M points
1 ⁄
0.00 A
4 Aug 2020
10:45:29

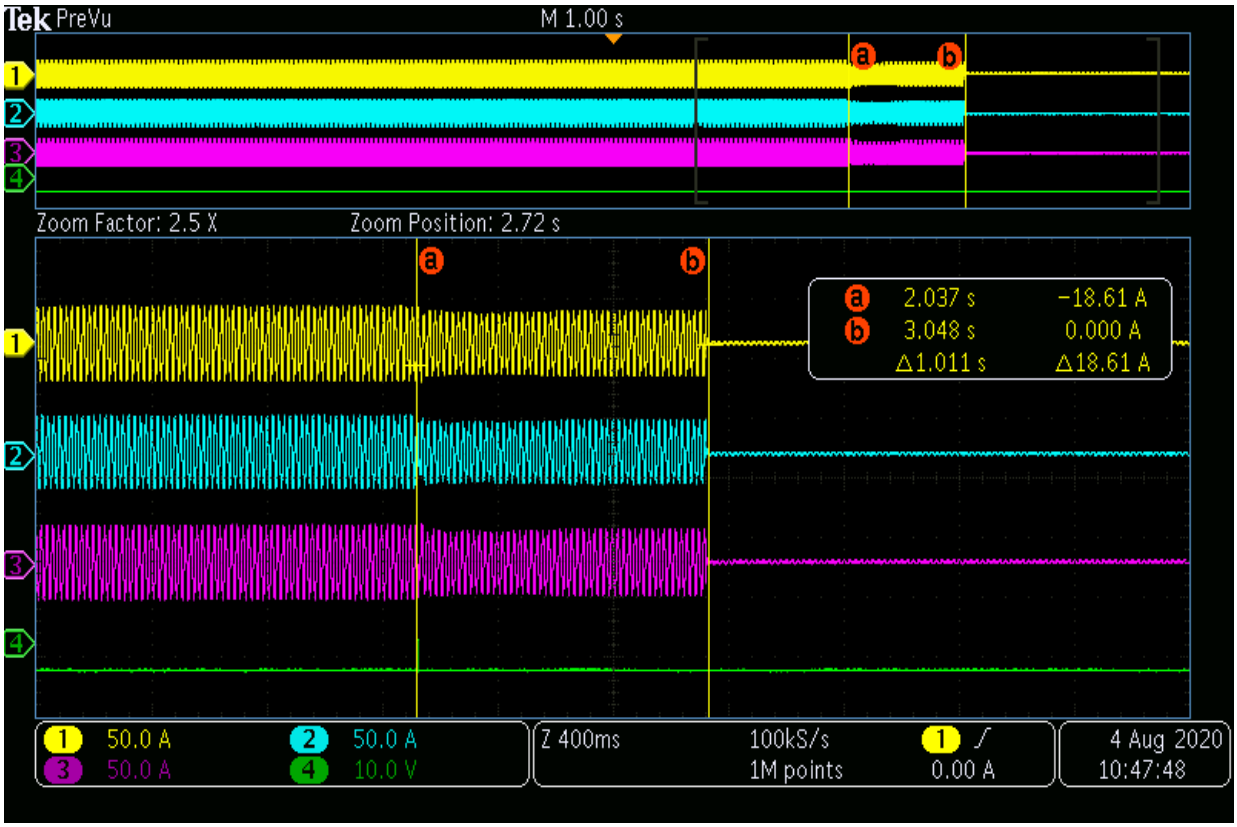
O/V stage 1-2


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

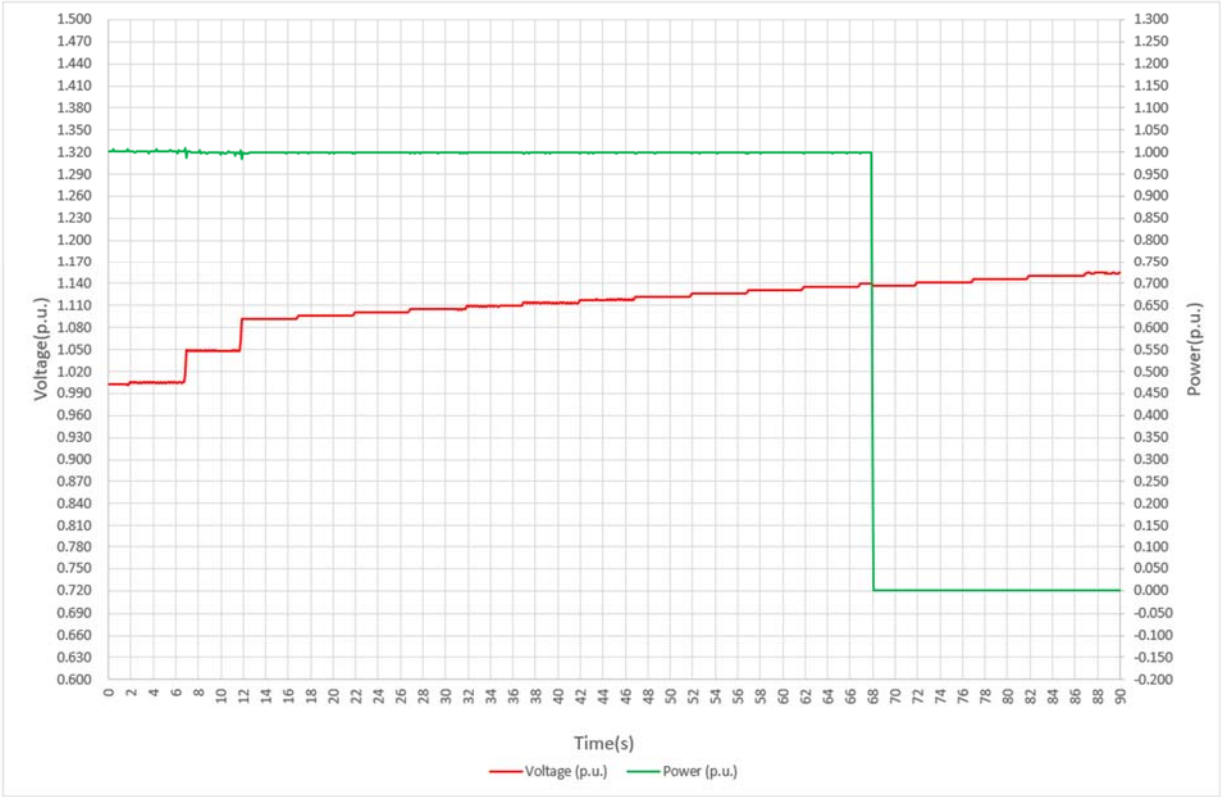

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 2.72 s
a 2.025 s -32.22 A
b 3.044 s -1.289 A
Δ1.019 s Δ30.93 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 400ms
100kS/s
1M points
0.00 A
4 Aug 2020
10:46:43

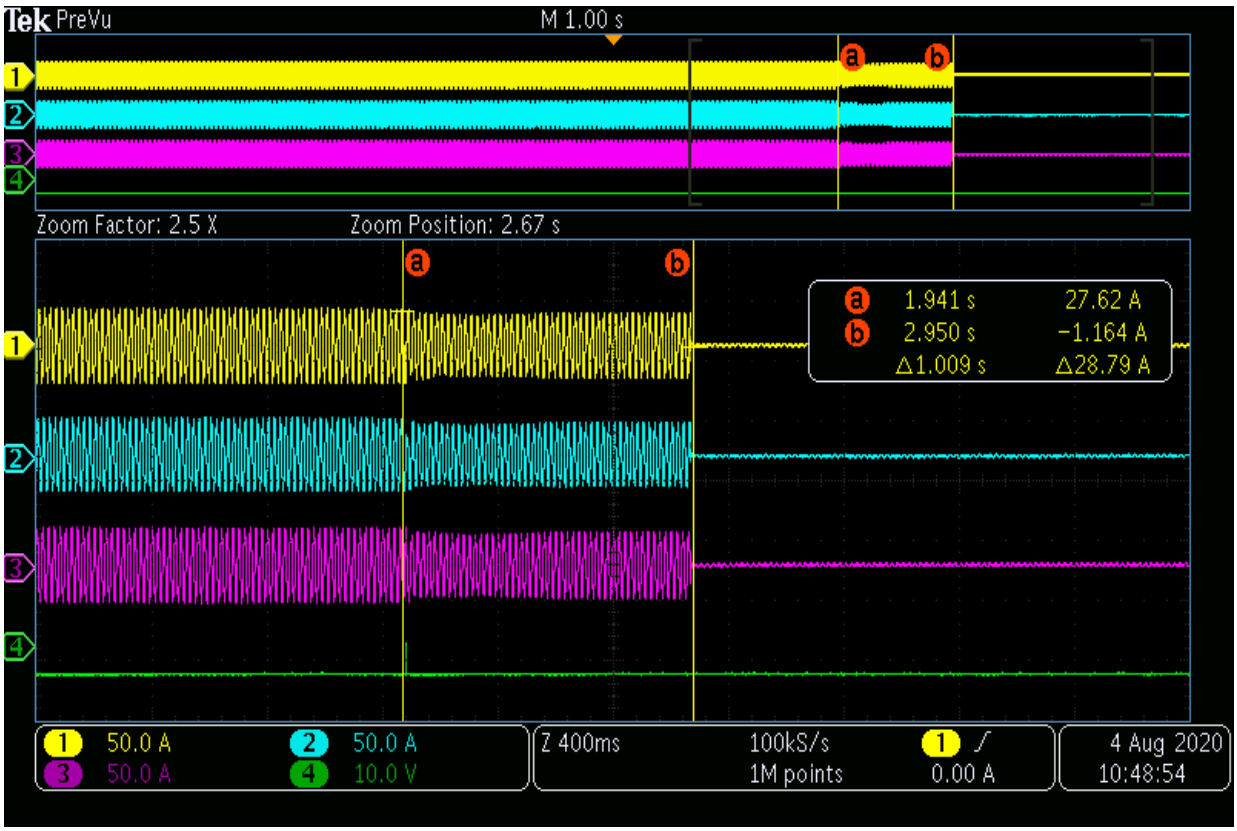
O/V stage 1-3


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

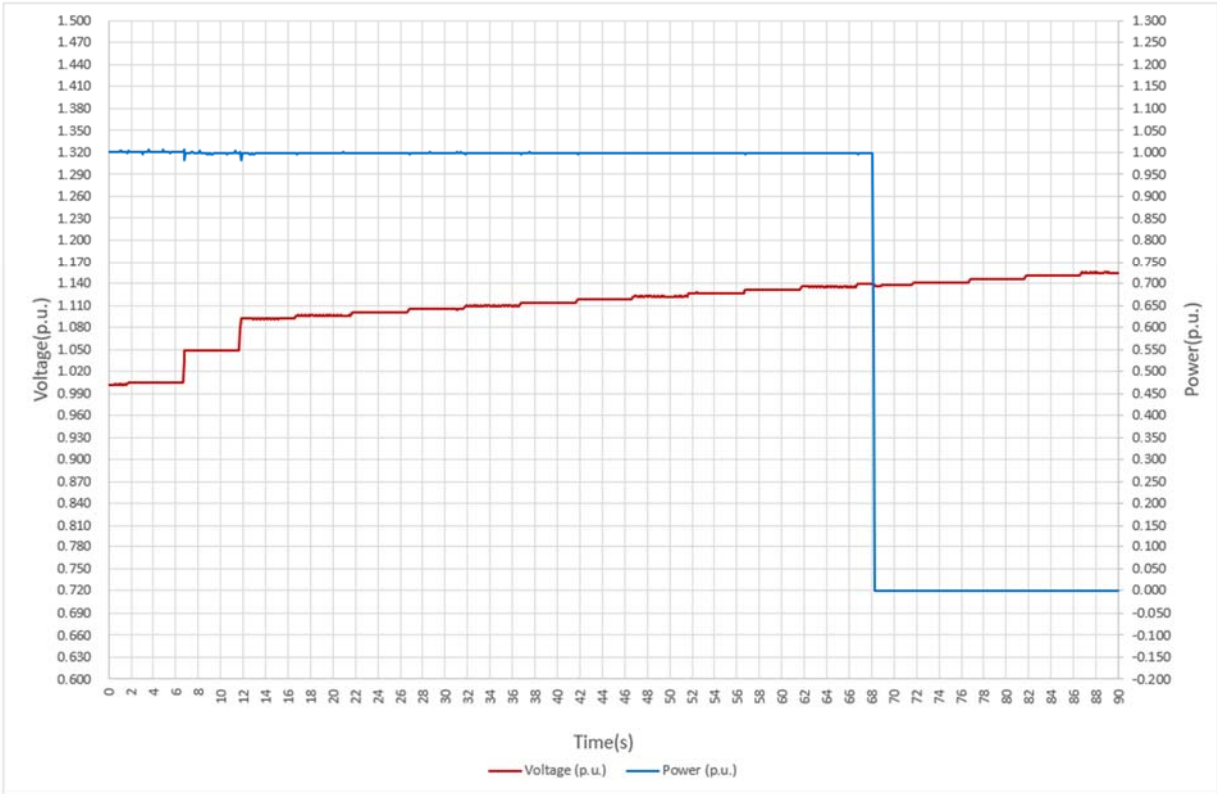

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 2.72 s
a 2.037 s -18.61 A
b 3.048 s 0.000 A
Δ1.011 s Δ18.61 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 400ms
100kS/s
1M points
1 ⨍
0.00 A
4 Aug 2020
10:47:48

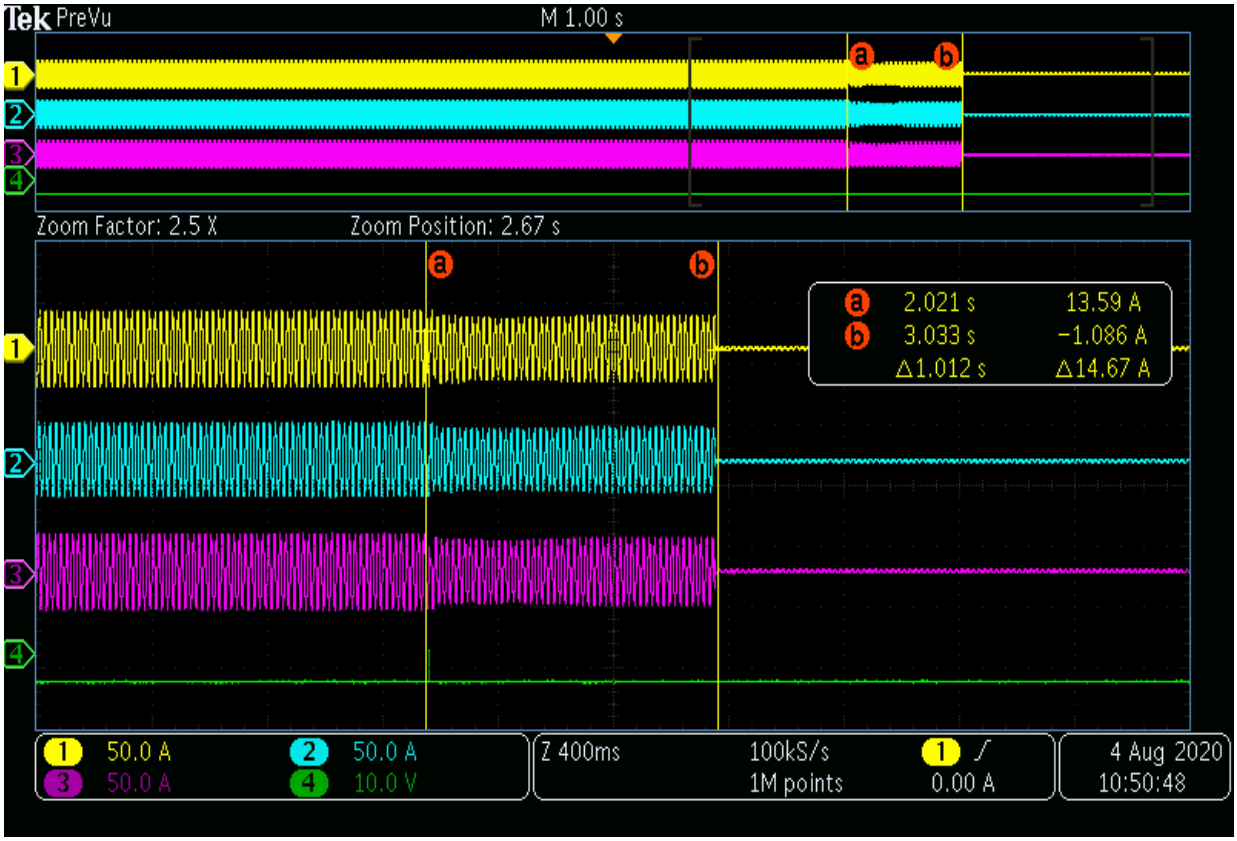
O/V stage 1-4


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

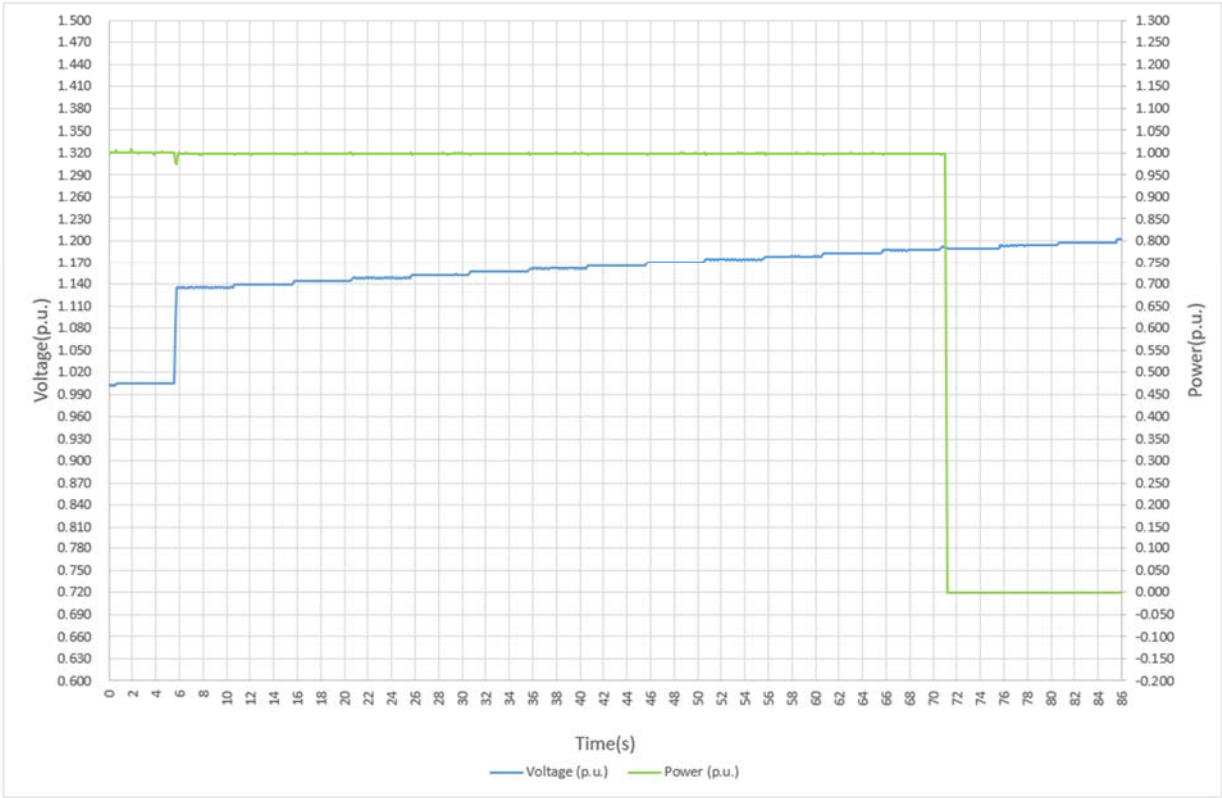

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 2.67 s
a 1.941 s 27.62 A
b 2.950 s -1.164 A
Δ1.009 s Δ28.79 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 400ms
100kS/s
1M points
1 ⎍
0.00 A
4 Aug 2020
10:48:54

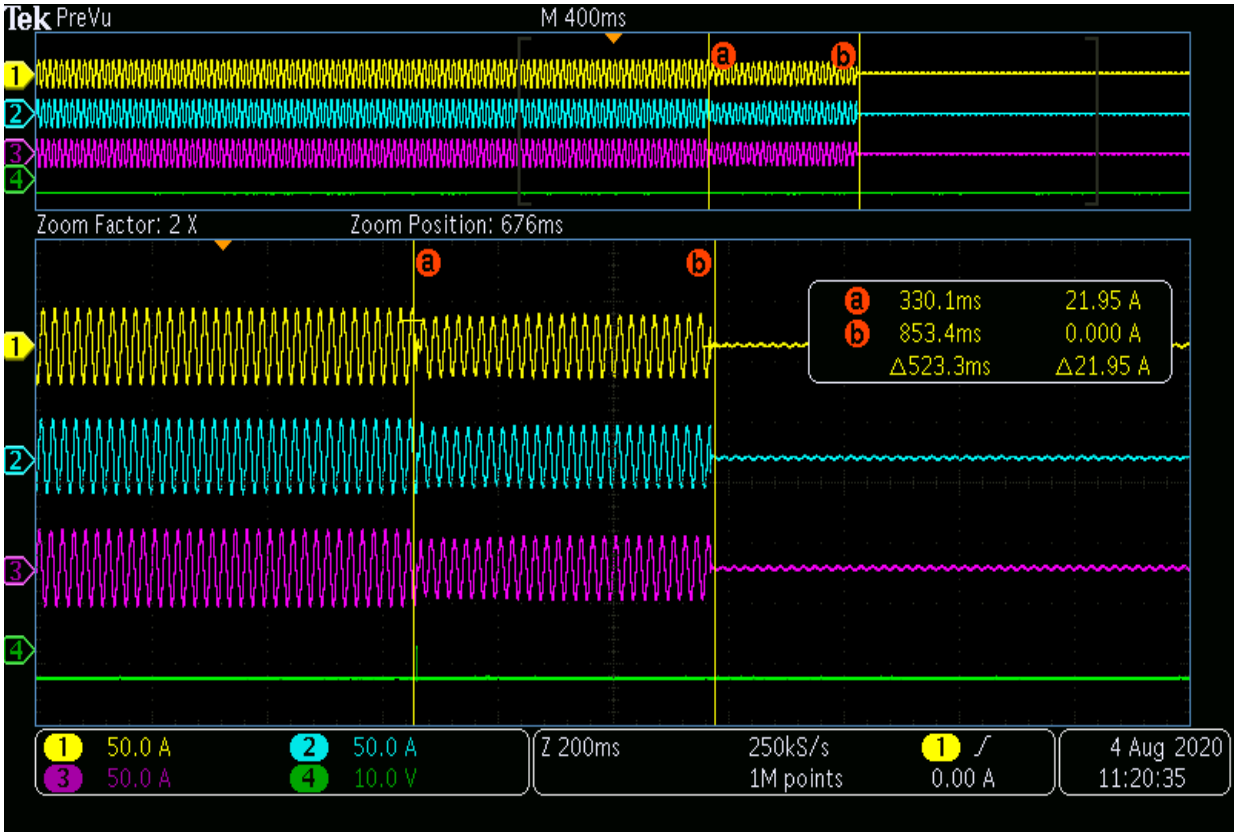
O/V stage 1-5


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

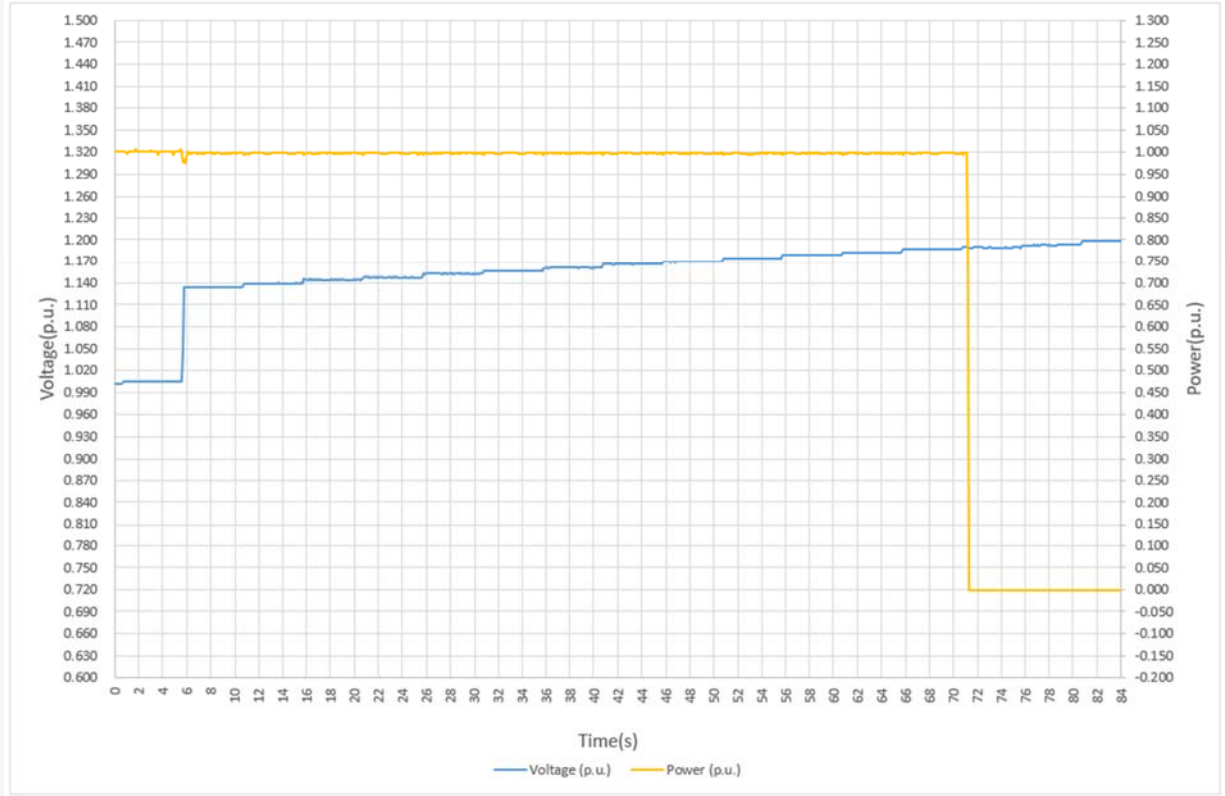

Tek PreVu
M 1.00 s
Zoom Factor: 2.5 X
Zoom Position: 2.67 s
a 2.021 s 13.59 A
b 3.033 s −1.086 A
Δ1.012 s Δ14.67 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 400ms
100kS/s
1M points
1 ⎍
0.00 A
4 Aug 2020
10:50:48

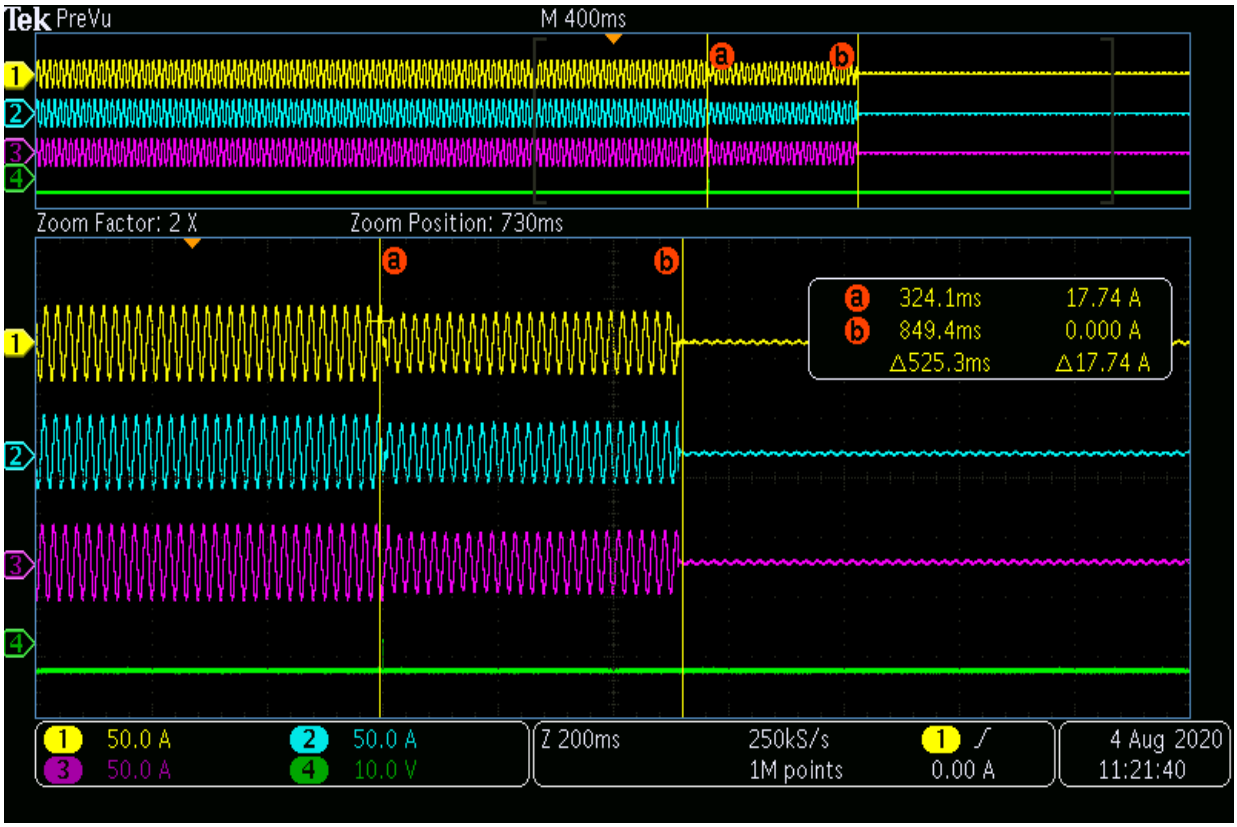
O/V stage 2-1


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


Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 676ms
a 330.1ms 21.95 A
b 853.4ms 0.000 A
Δ523.3ms Δ21.95 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
0.00 A
4 Aug 2020
11:20:35

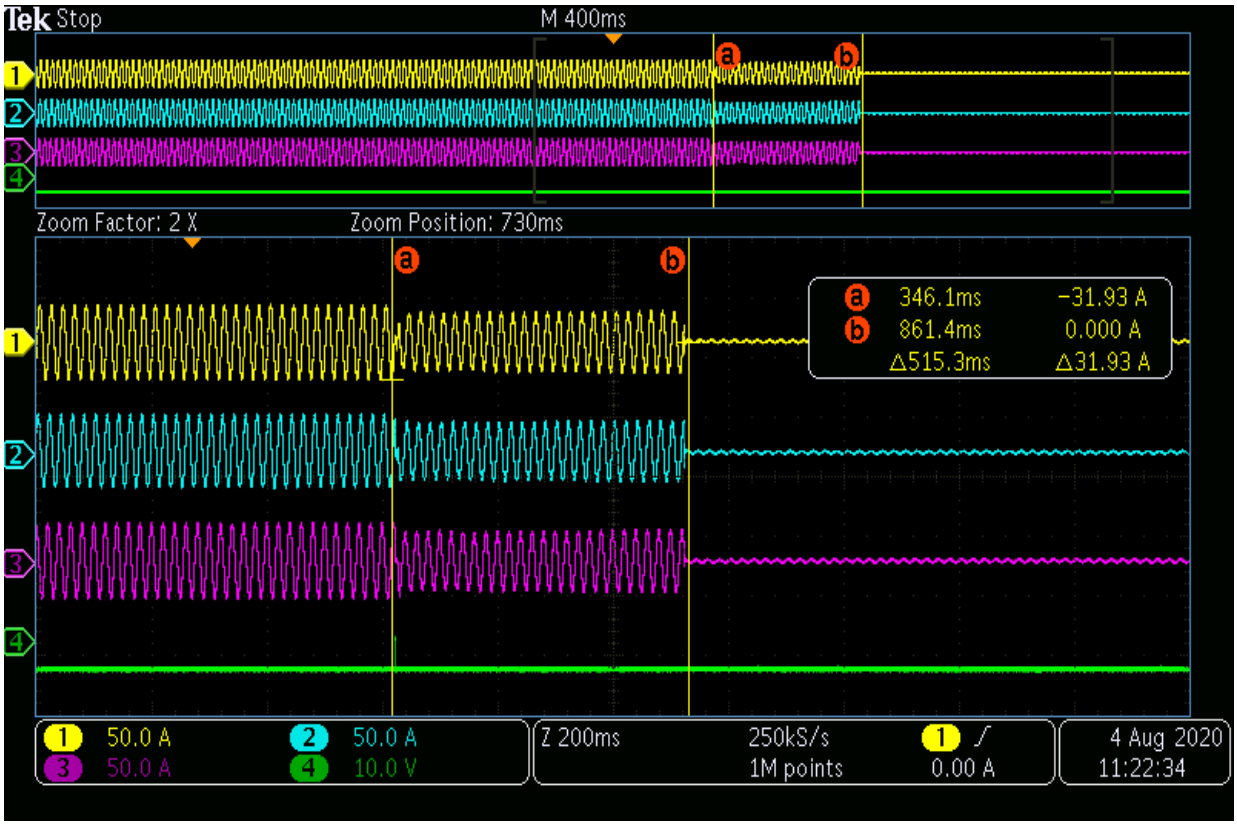
O/V stage 2


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

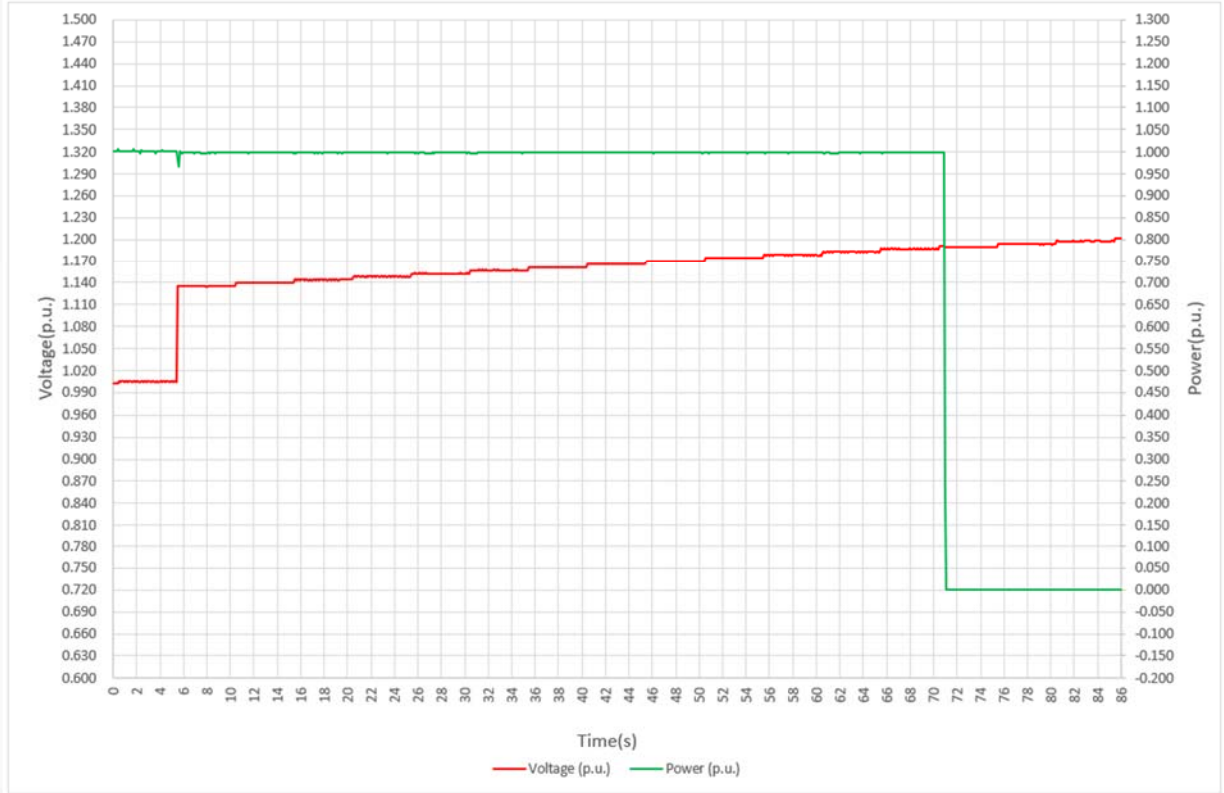

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 730ms
a 324.1ms 17.74 A
b 849.4ms 0.000 A
Δ525.3ms Δ17.74 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
0.00 A
4 Aug 2020
11:21:40

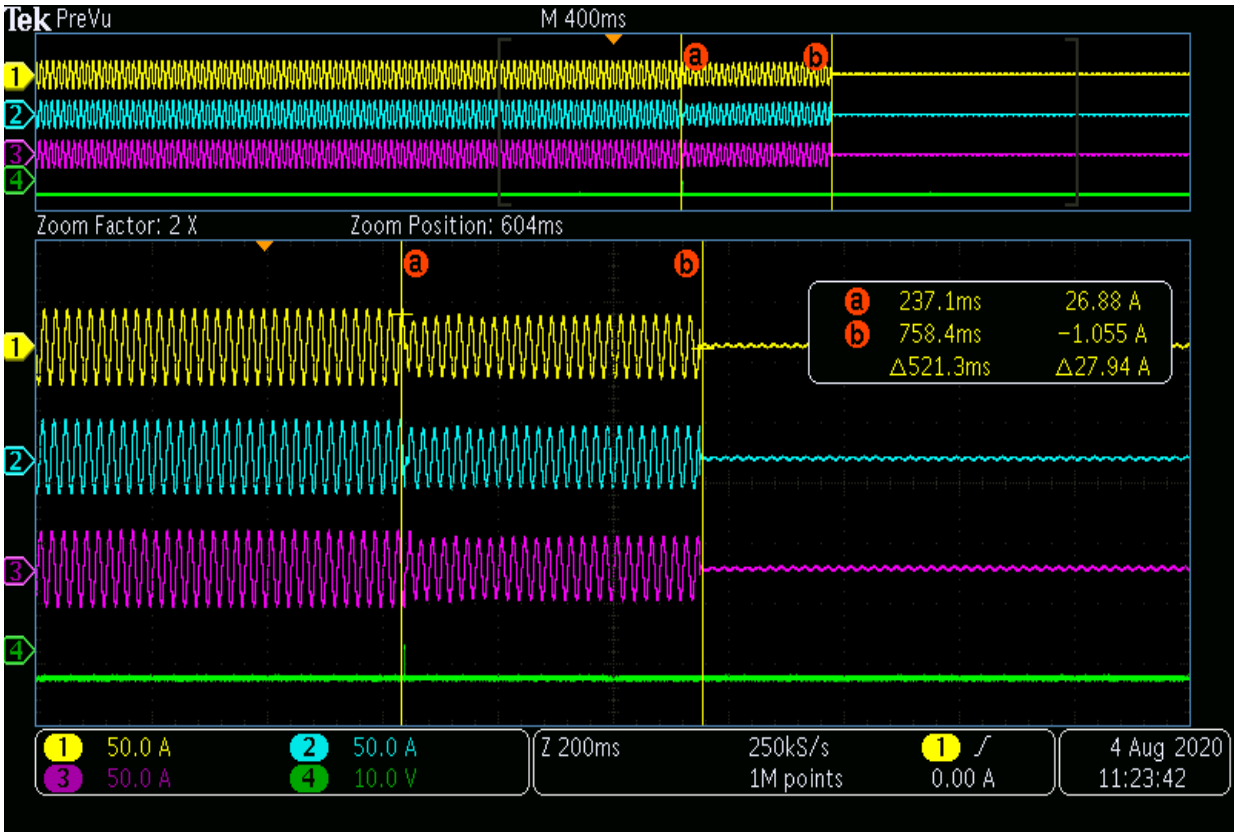
O/V stage 2


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

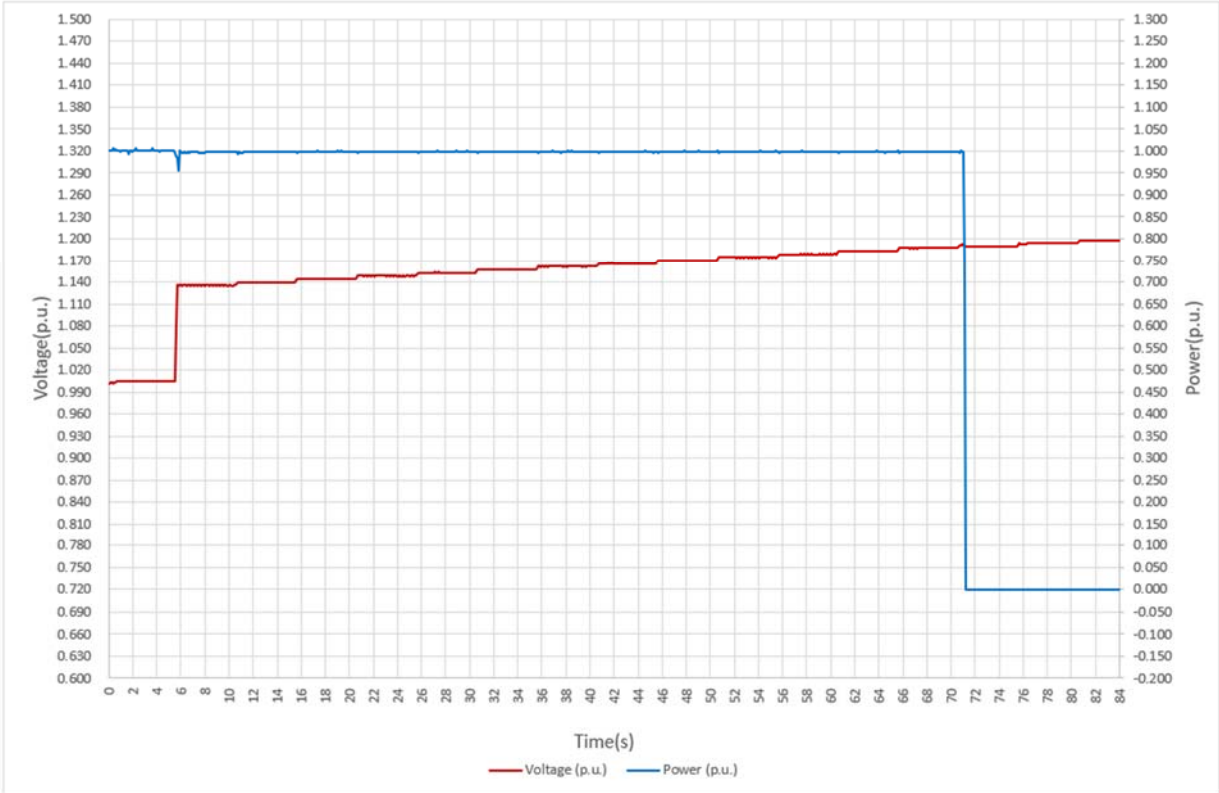

Tek Stop
M 400ms
Zoom Factor: 2 X
Zoom Position: 730ms
a 346.1ms -31.93 A
b 861.4ms 0.000 A
Δ515.3ms Δ31.93 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
1 ⎍ 0.00 A
4 Aug 2020
11:22:34

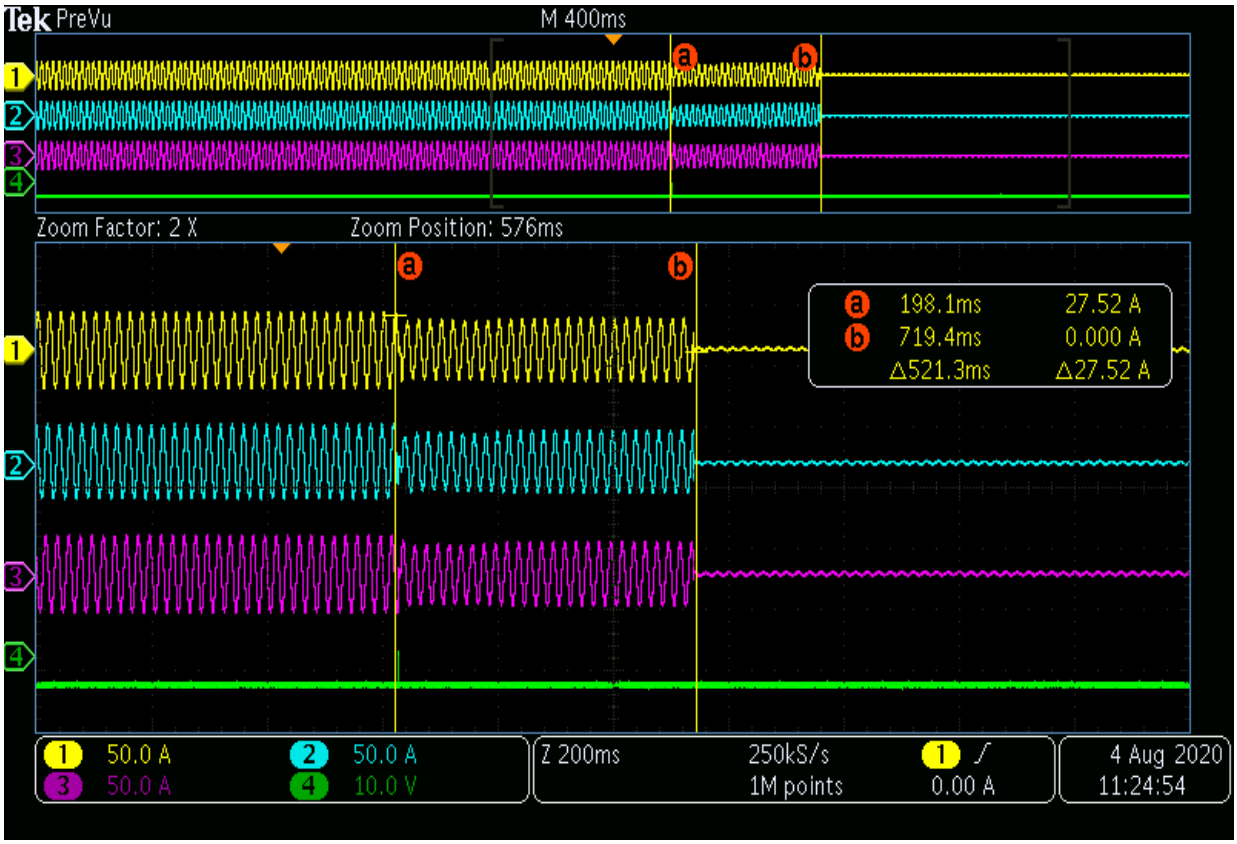
O/V stage 2-4


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

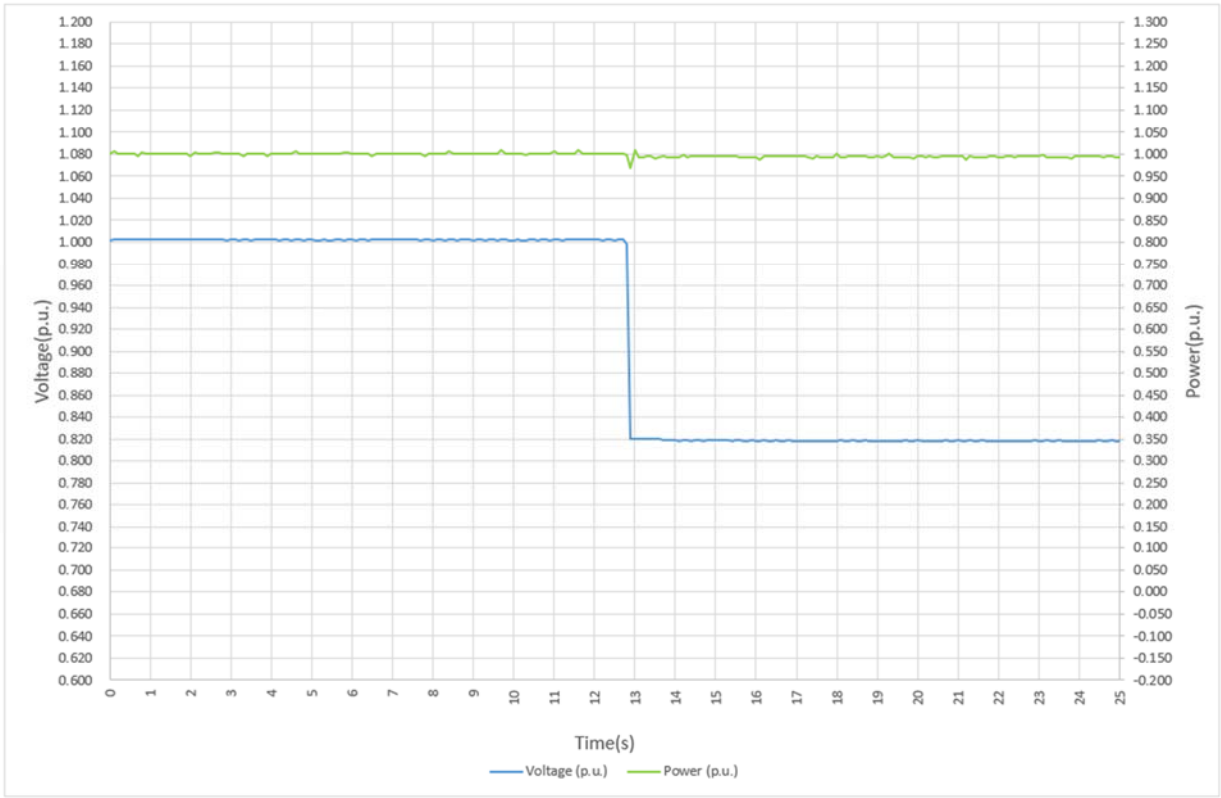

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 604ms
a 237.1ms 26.88 A
b 758.4ms -1.055 A
Δ521.3ms Δ27.94 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
0.00 A
4 Aug 2020
11:23:42

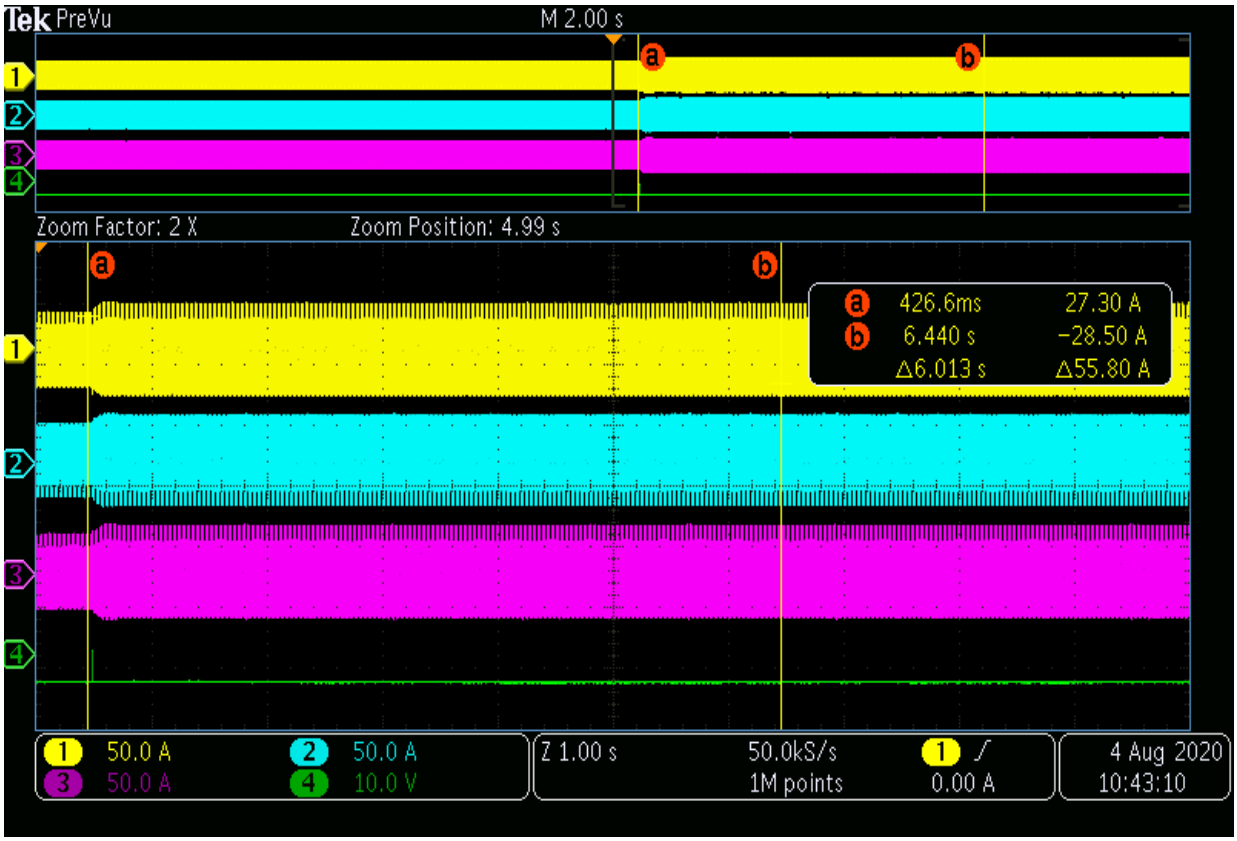
O/V stage 2-5


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

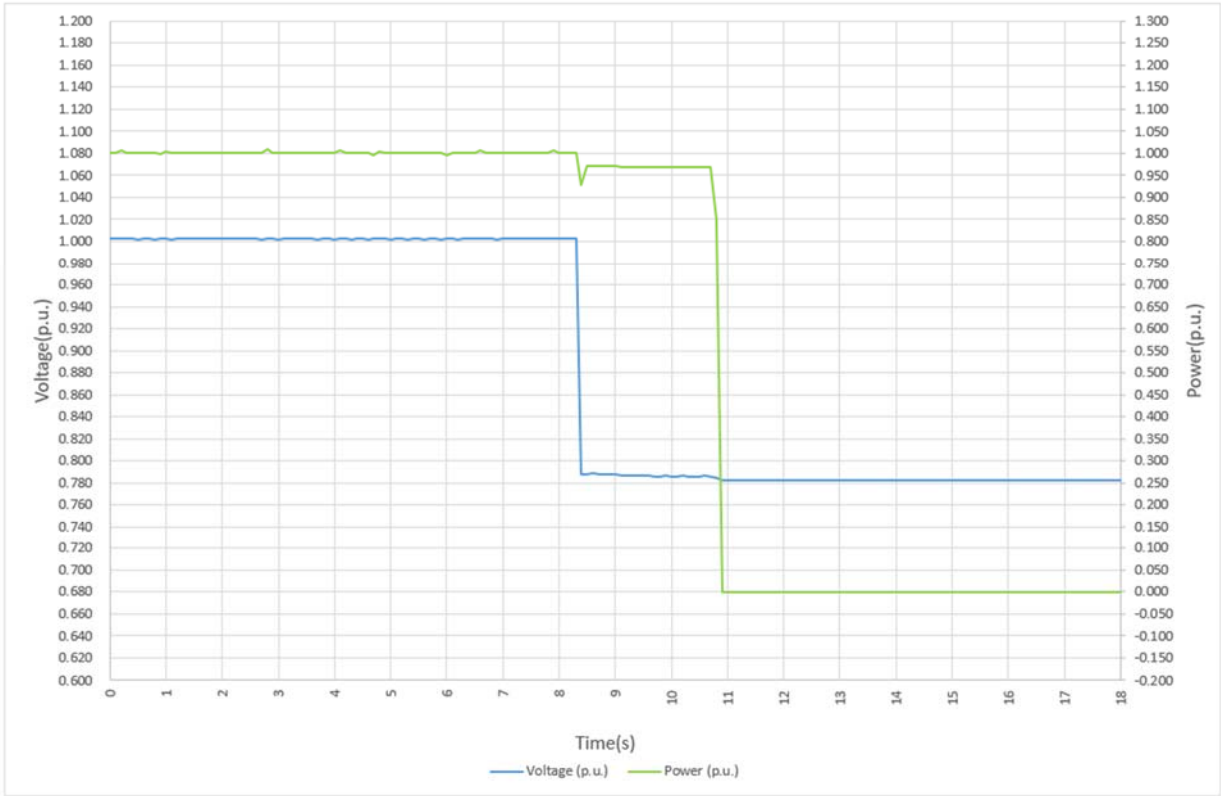

Tek PreVu
M 400ms
Zoom Factor: 2 X
Zoom Position: 576ms
a 198.1ms 27.52 A
b 719.4ms 0.000 A
Δ521.3ms Δ27.52 A
1 50.0 A
2 50.0 A
3 50.0 A
4 10.0 V
Z 200ms
250kS/s
1M points
0.00 A
4 Aug 2020
11:24:54

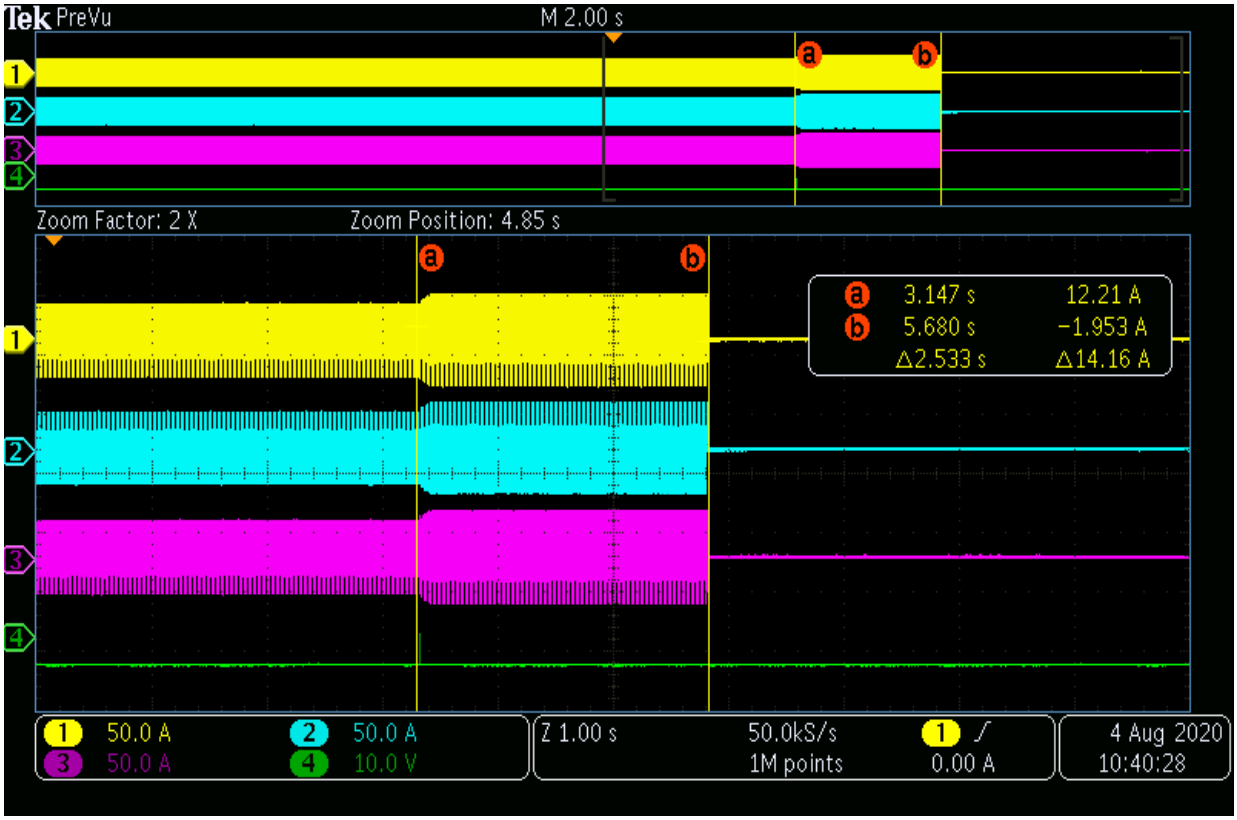
No trip tests – 188V



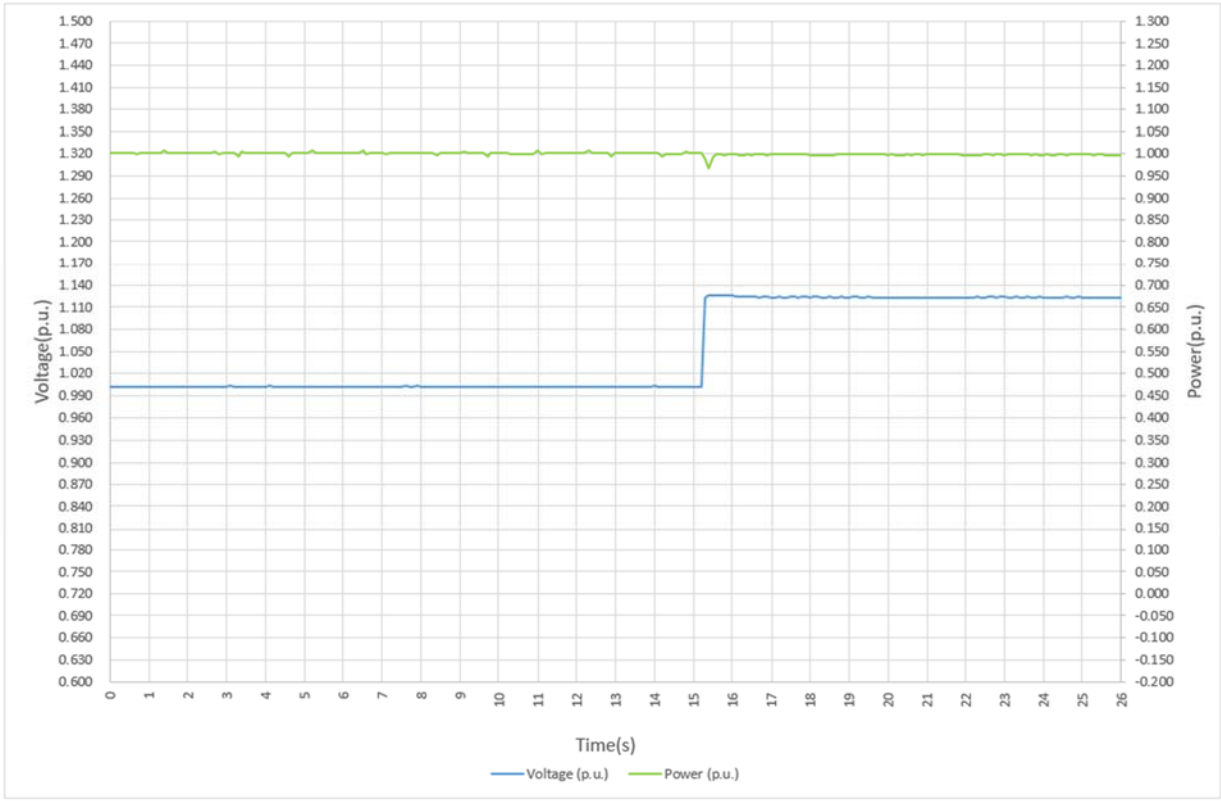


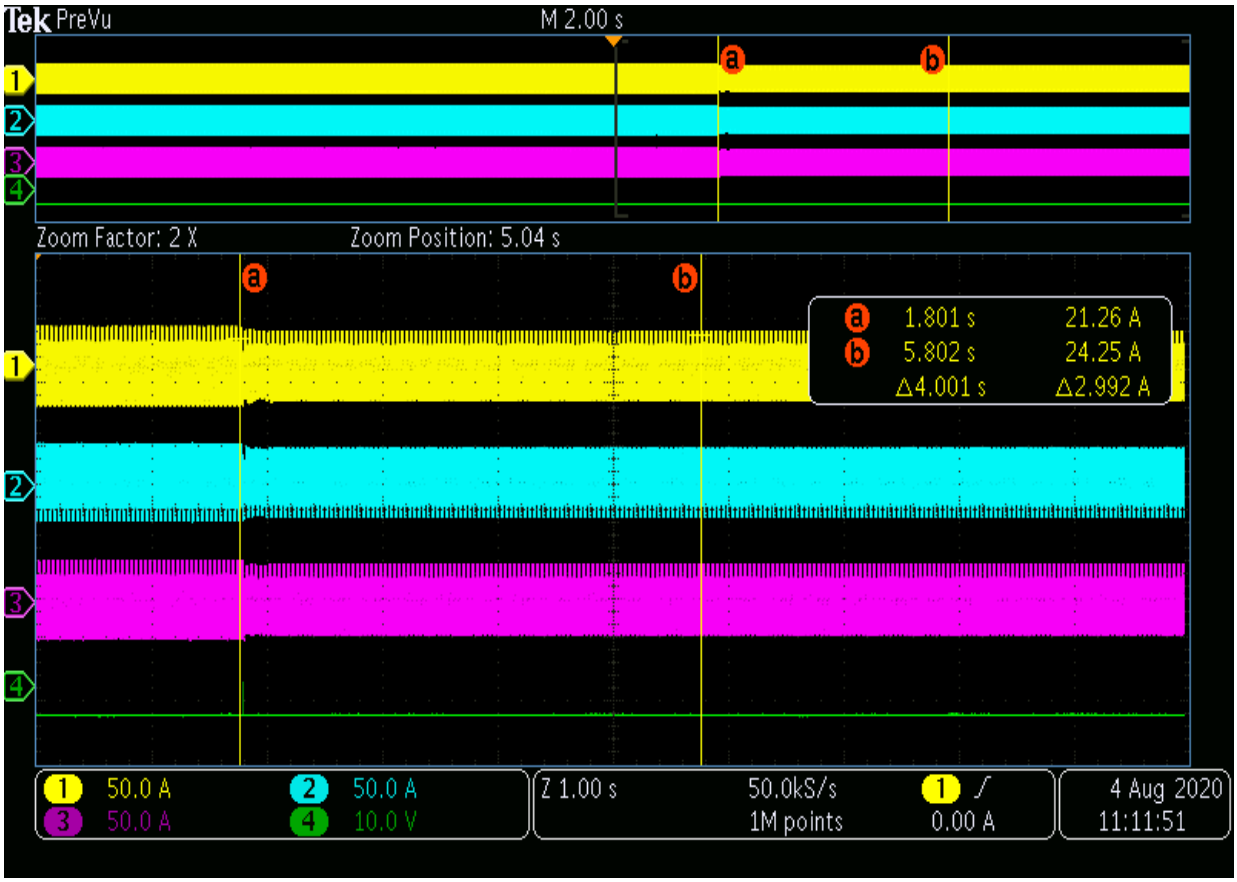
No trip tests – 180V



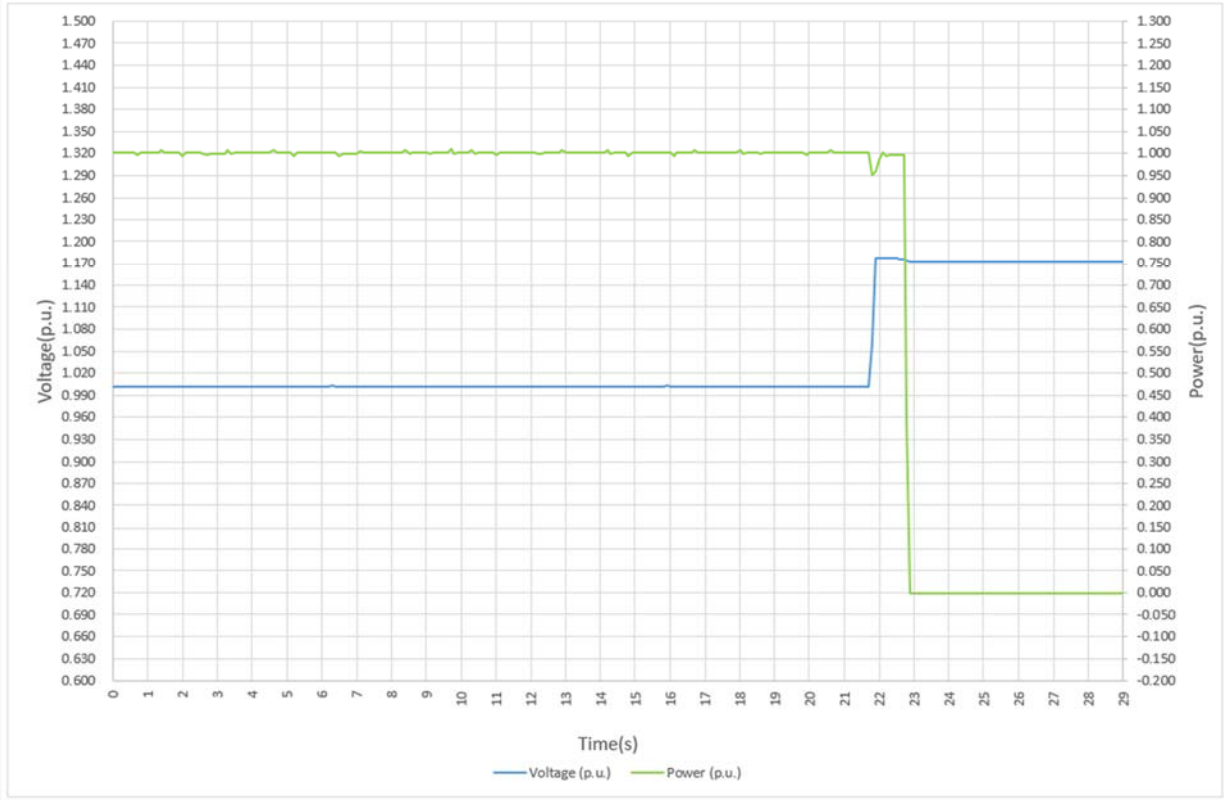


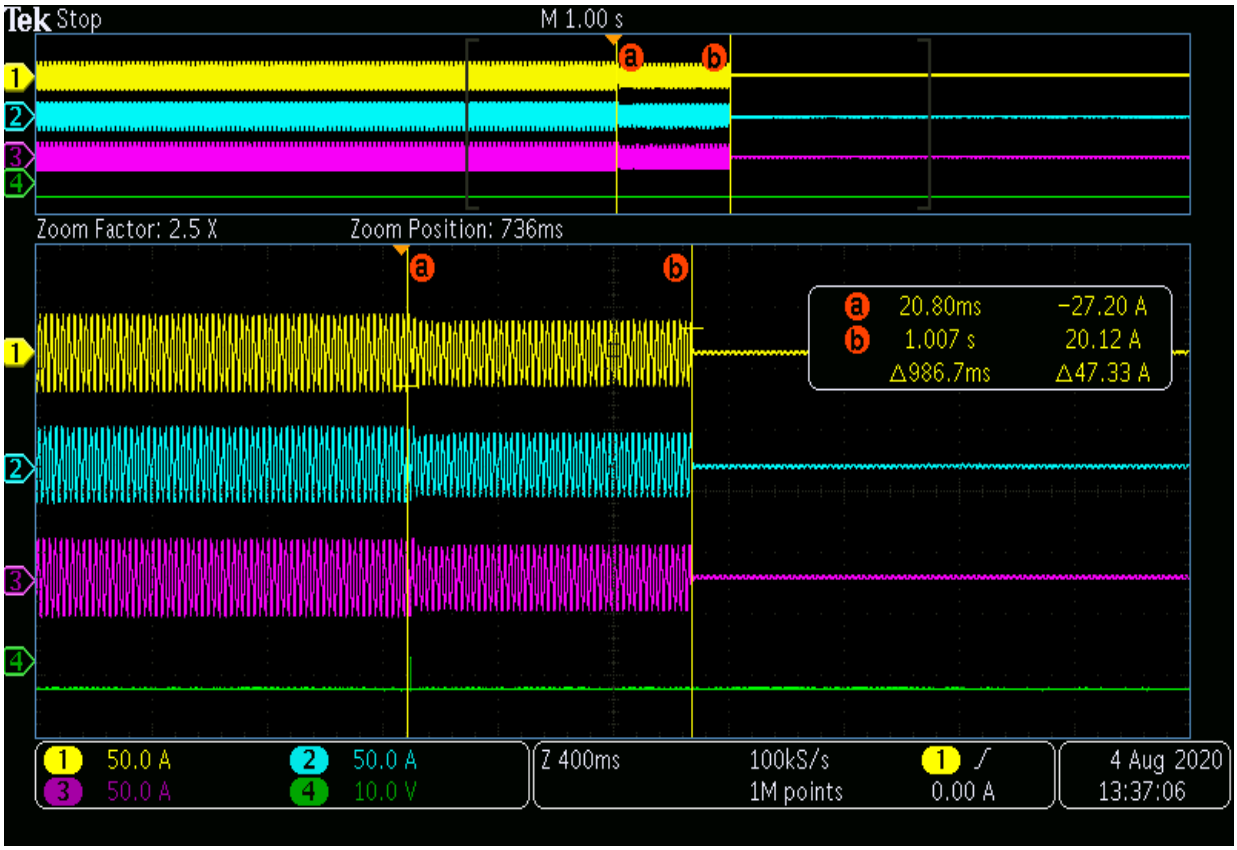
No trip tests – 258.2V



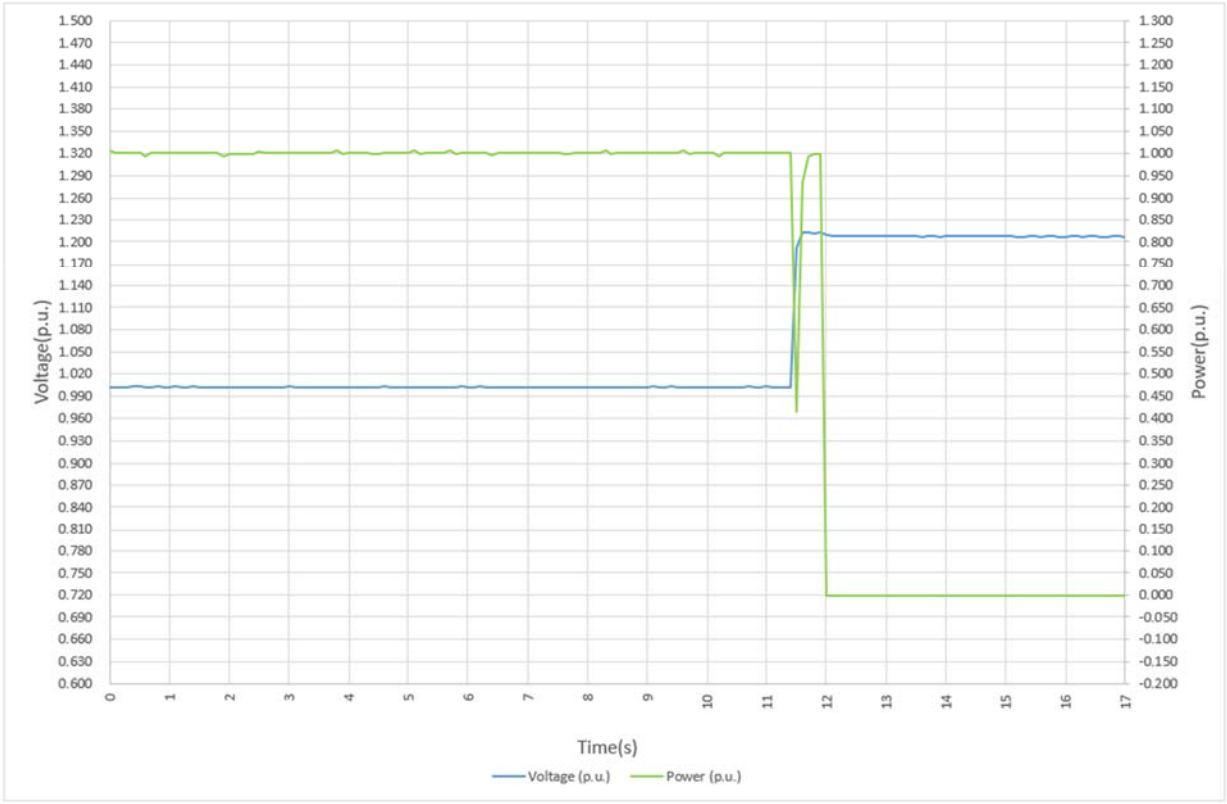


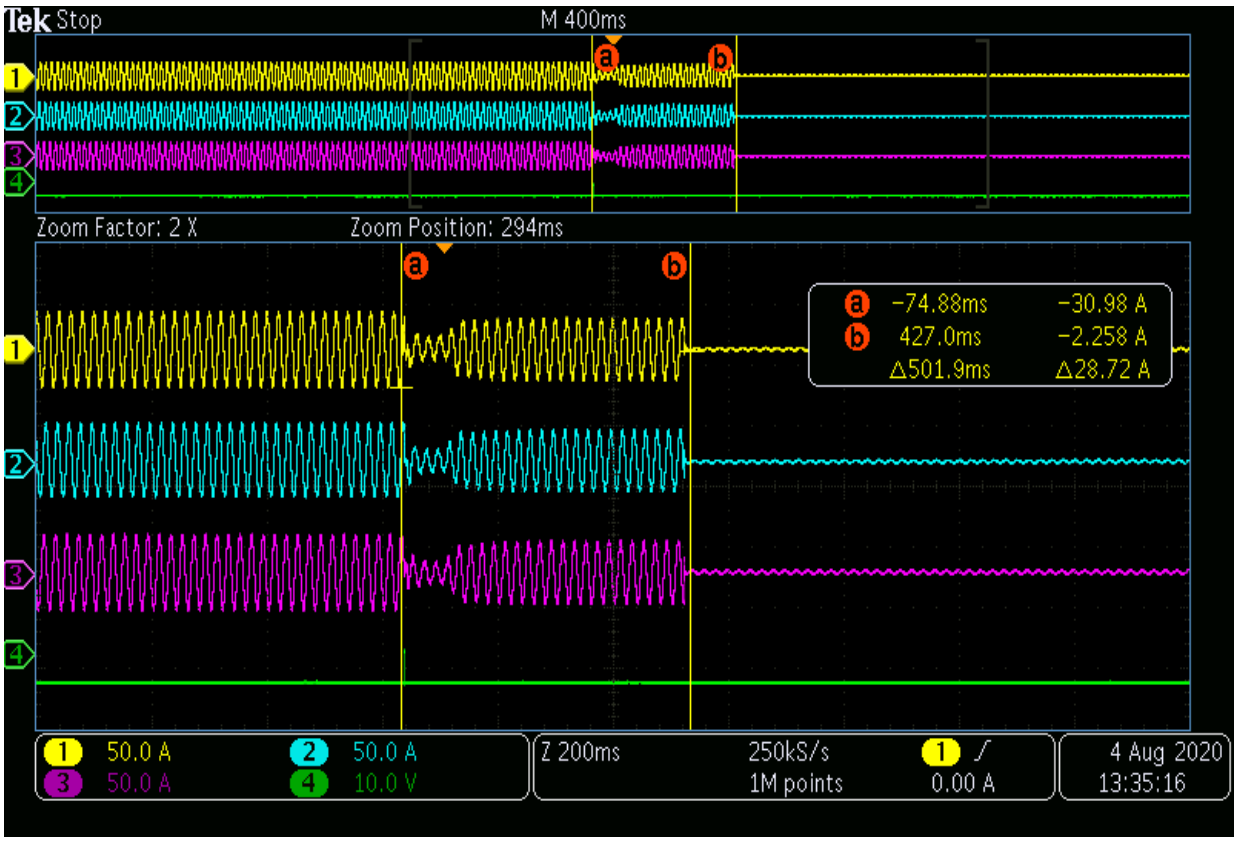
No trip tests – 269.7V





No trip tests – 277.7V





4.3.3 Loss of Mains test

These tests should be carried out in accordance with BS EN 62116. Annex A.7.1.2.4.

The maximum trip time is 0.5 s.

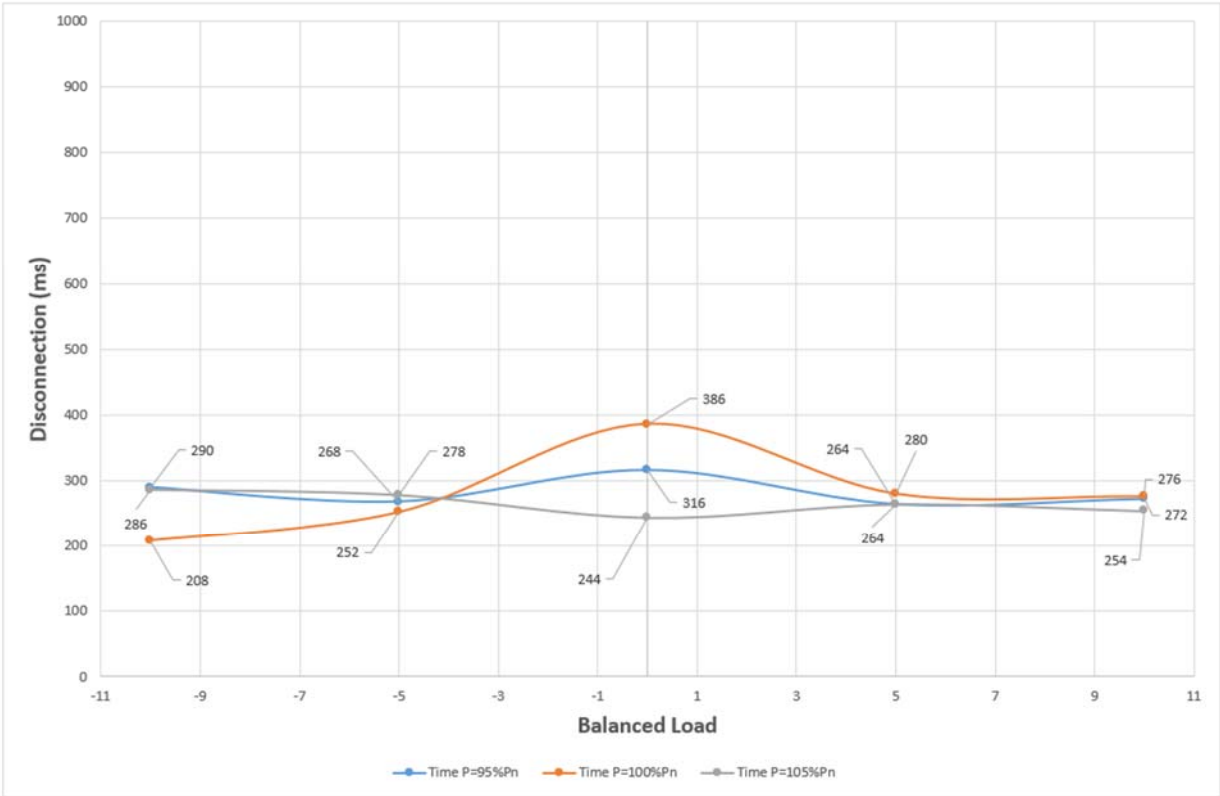
Note for technologies which have a substantial shut down time this can be added to the 0.5 s in establishing that the trip occurred in less than 0.5 s. Maximum shut down time could therefore be up to 1.0 s for these technologies.

Following tables show the test results:

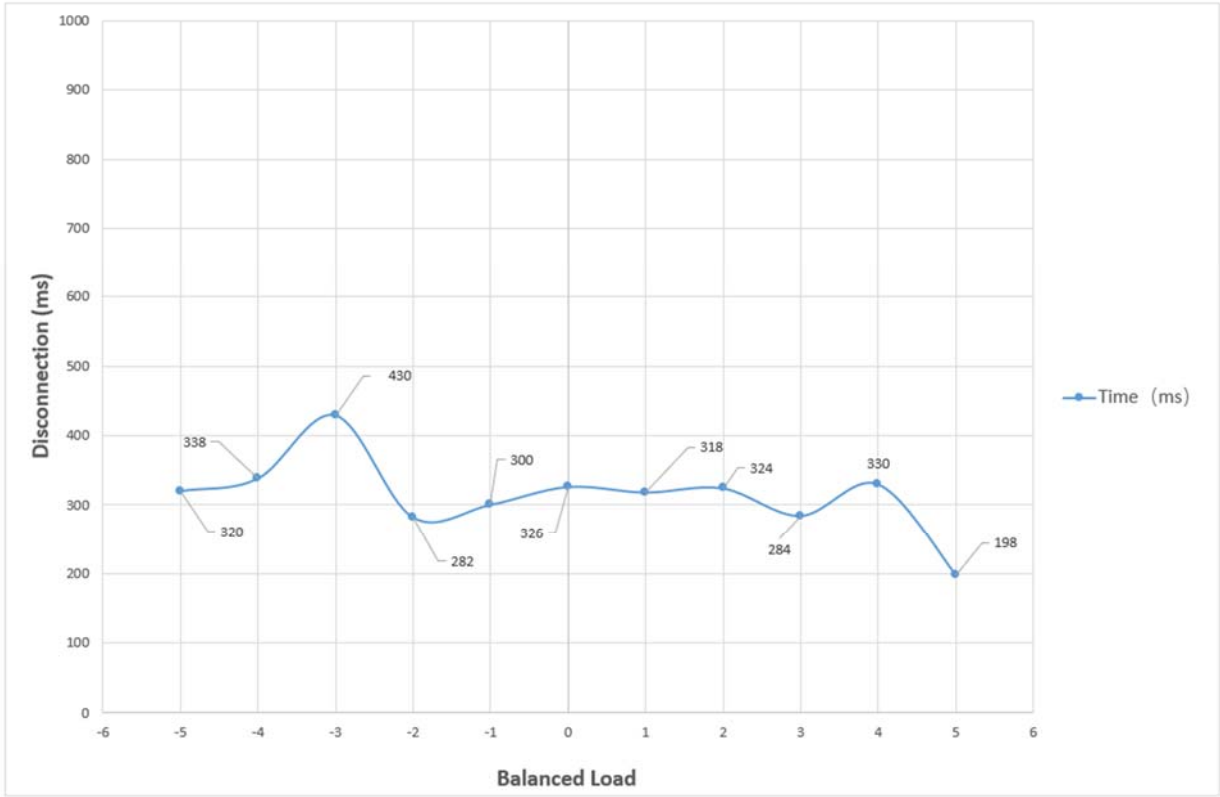
	Table: tested condition and trip time					P
No.	P_{EUT} (% of EUT rating)	Reactive load (% of normial)	P_{AC}	Q_{AC}	Trip time(s)	Which load is selected to be adjusted (R or L)
Test condition A						
1	100	100	0	0	386	--
2	100	100	-5	-5	268	R/L
3	100	100	-5	0	316	R
4	100	100	-5	+5	264	R/L
5	100	100	0	-5	252	L
6	100	100	0	+5	280	L
7	100	100	+5	-5	278	R/L
8	100	100	+5	0	244	R
9	100	100	+5	+5	264	R/L
10	100	100	-10	+10	214	R/L
11	100	100	-5	+10	272	R/L
12	100	100	0	+10	276	L
13	100	100	+10	+10	216	R/L
14	100	100	+10	+5	236	R/L
15	100	100	+10	0	432	R
16	100	100	+10	-5	236	R/L
17	100	100	+10	-10	196	R/L
18	100	100	+5	-10	286	R/L
19	100	100	+5	+10	254	R/L
20	100	100	0	-10	208	L
21	100	100	-5	-10	290	R/L
22	100	100	-10	-10	274	R/L
23	100	100	-10	-5	260	R/L
24	100	100	-10	0	256	R
25	100	100	-10	+5	258	R/L
Test condition B						
1	66	66	0	0	326	--
2	66	66	0	-5	320	L
3	66	66	0	-4	338	L
4	66	66	0	-3	430	L
5	66	66	0	-2	282	L
6	66	66	0	-1	300	L
7	66	66	0	1	318	L
8	66	66	0	2	324	L
9	66	66	0	3	284	L
10	66	66	0	4	330	L
11	66	66	0	5	198	L
Test condition C						
1	33	33	0	0	278	--
2	33	33	0	-5	364	L
3	33	33	0	-4	414	L
4	33	33	0	-3	354	L
5	33	33	0	-2	326	L
6	33	33	0	-1	326	L
7	33	33	0	1	318	L
8	33	33	0	2	296	L
9	33	33	0	3	232	L
10	33	33	0	4	300	L
11	33	33	0	5	274	L

Test results are graphically shown in following pages.

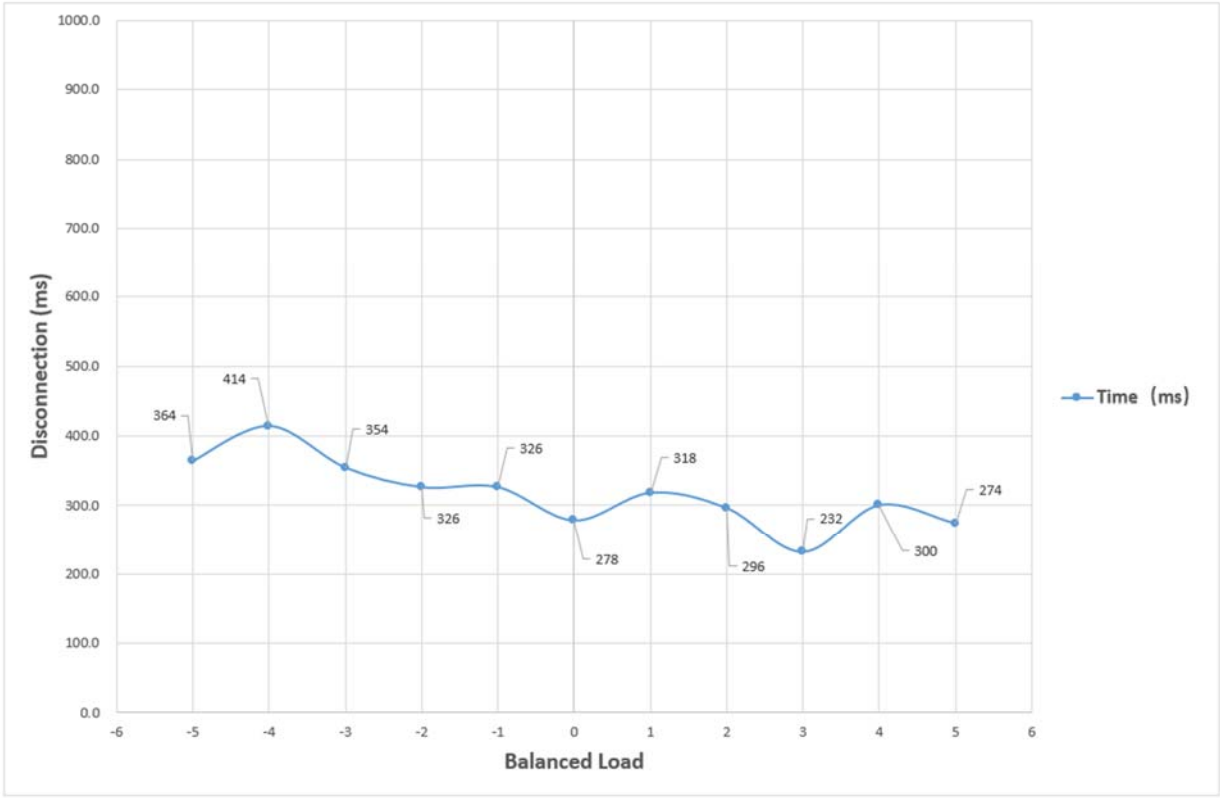
Test Condition A



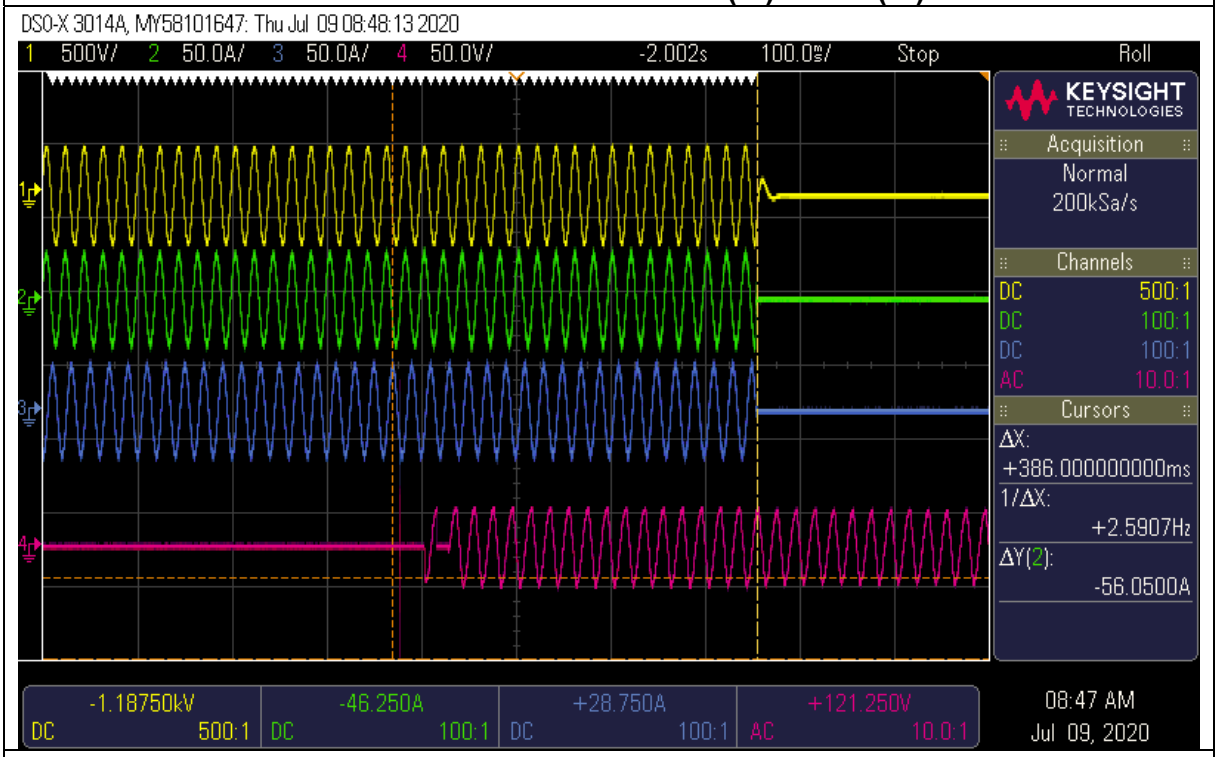
Test Condition B



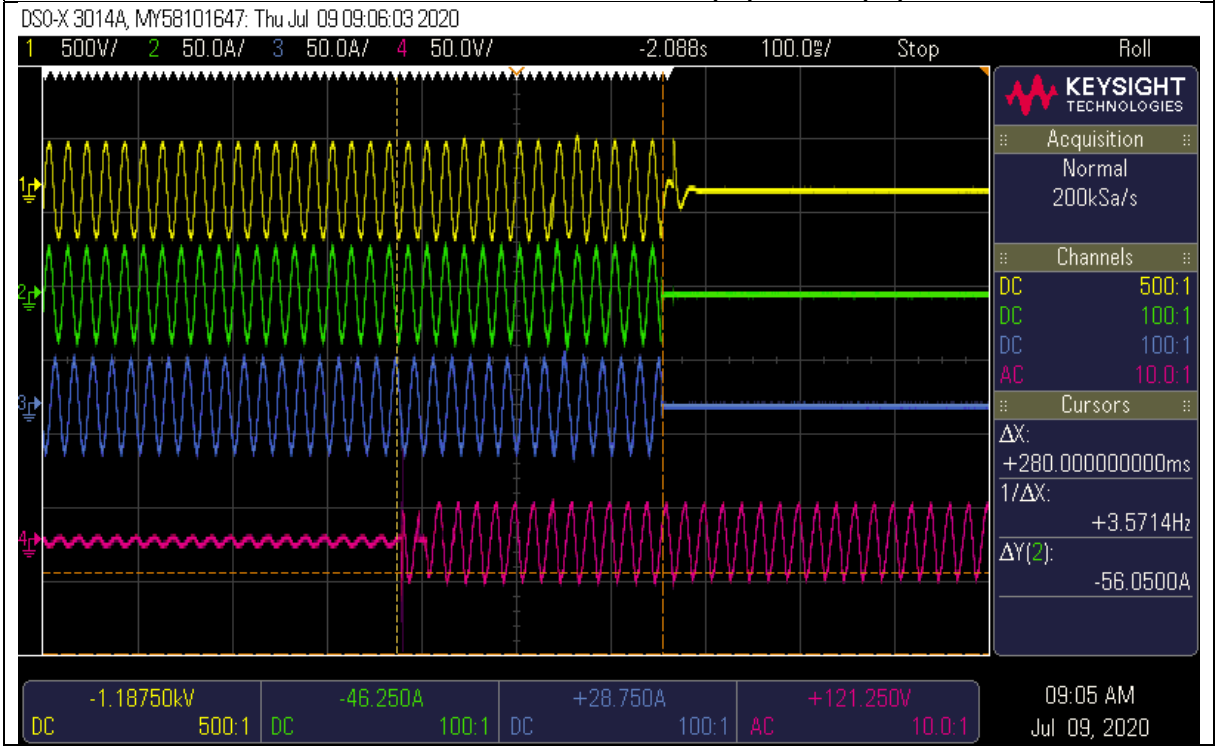
Test Condition C



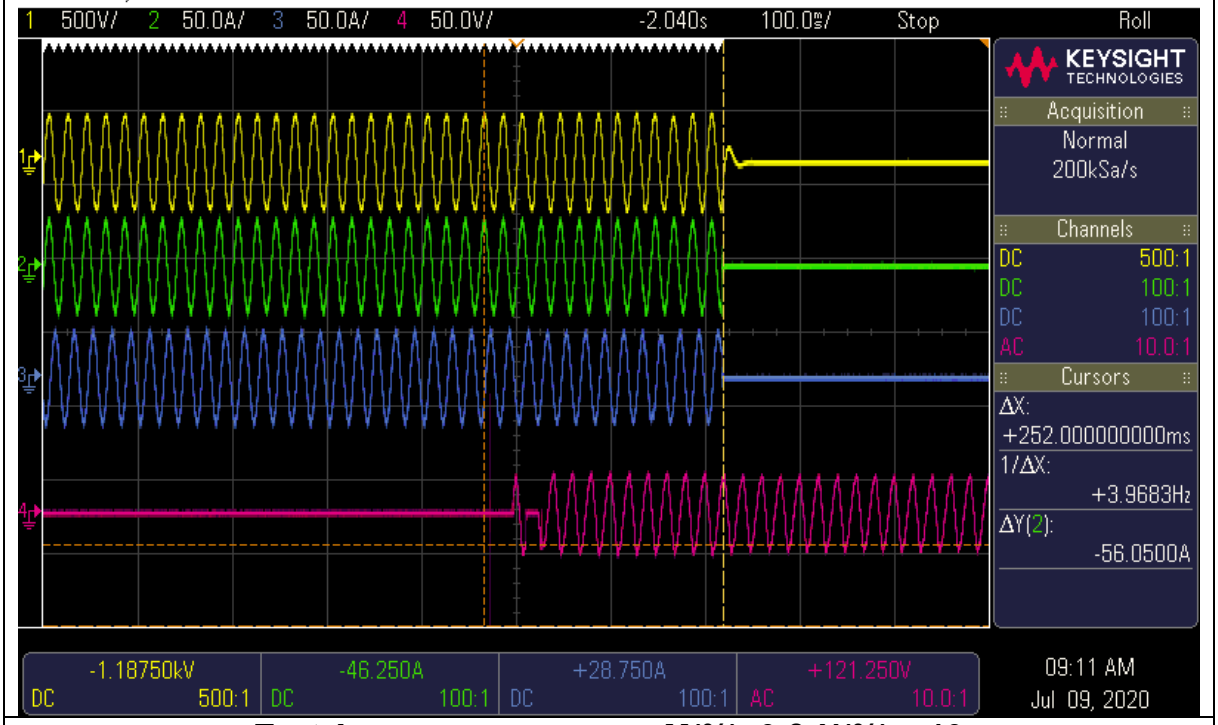
Test A	M(%)=0 & N(%)=0



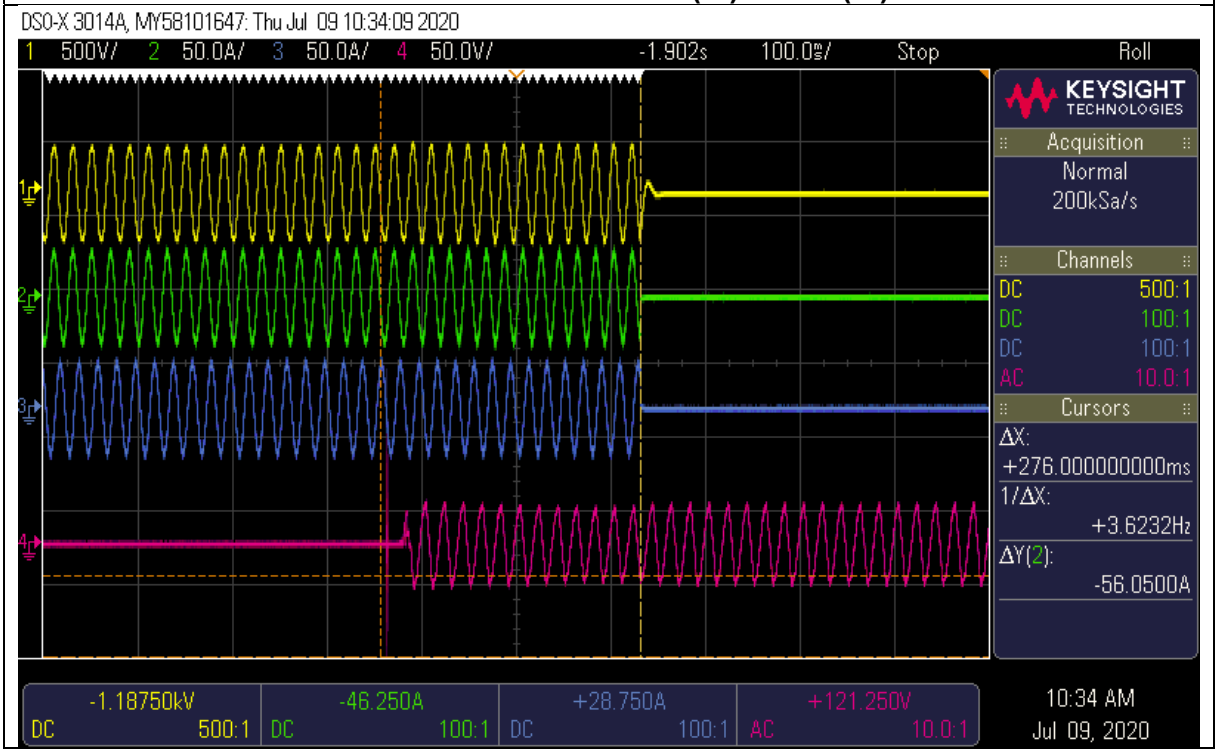
Test A	M(%)=0 & N(%)=+5



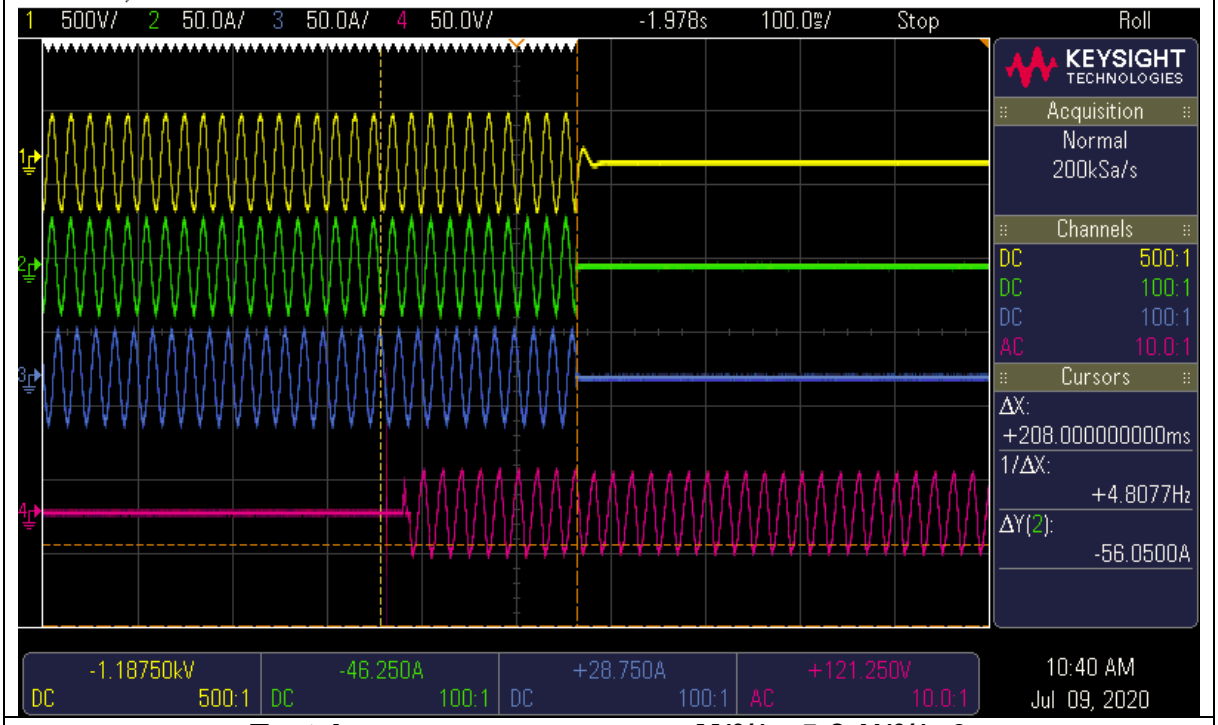
Test A **M(%)=0 & N(%)=-5**



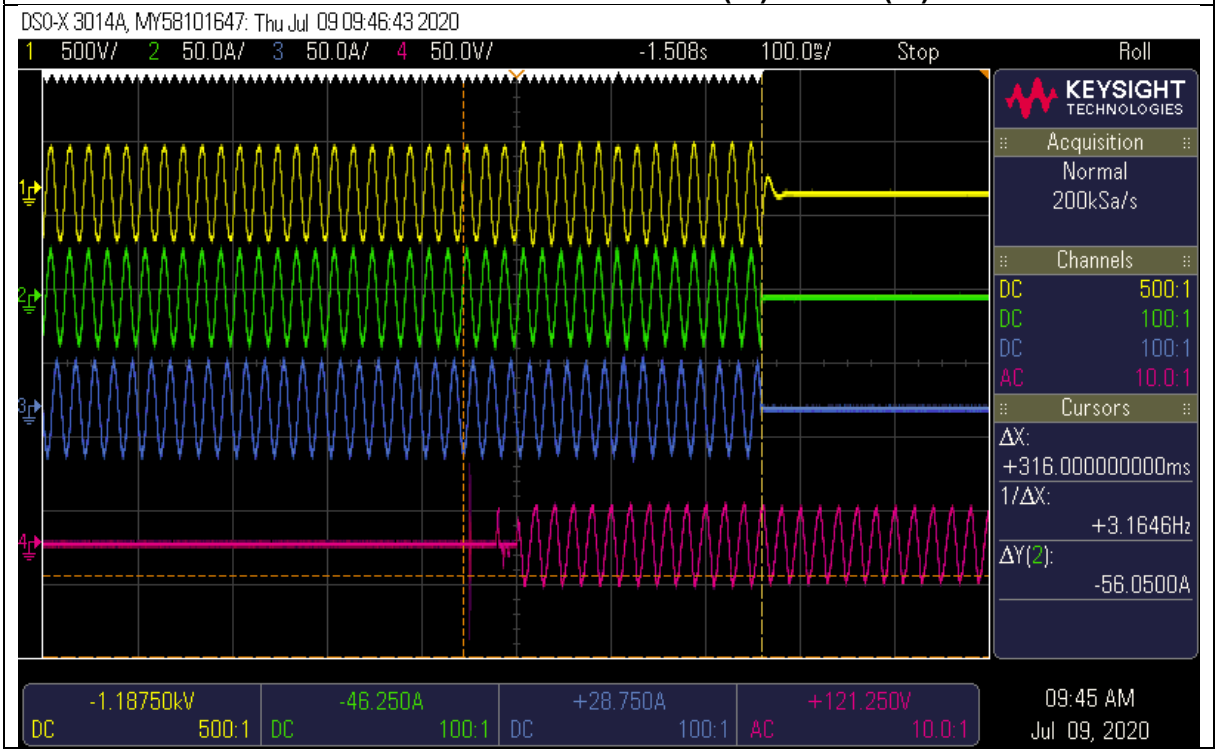
Test A **M(%)=0 & N(%)=+10**



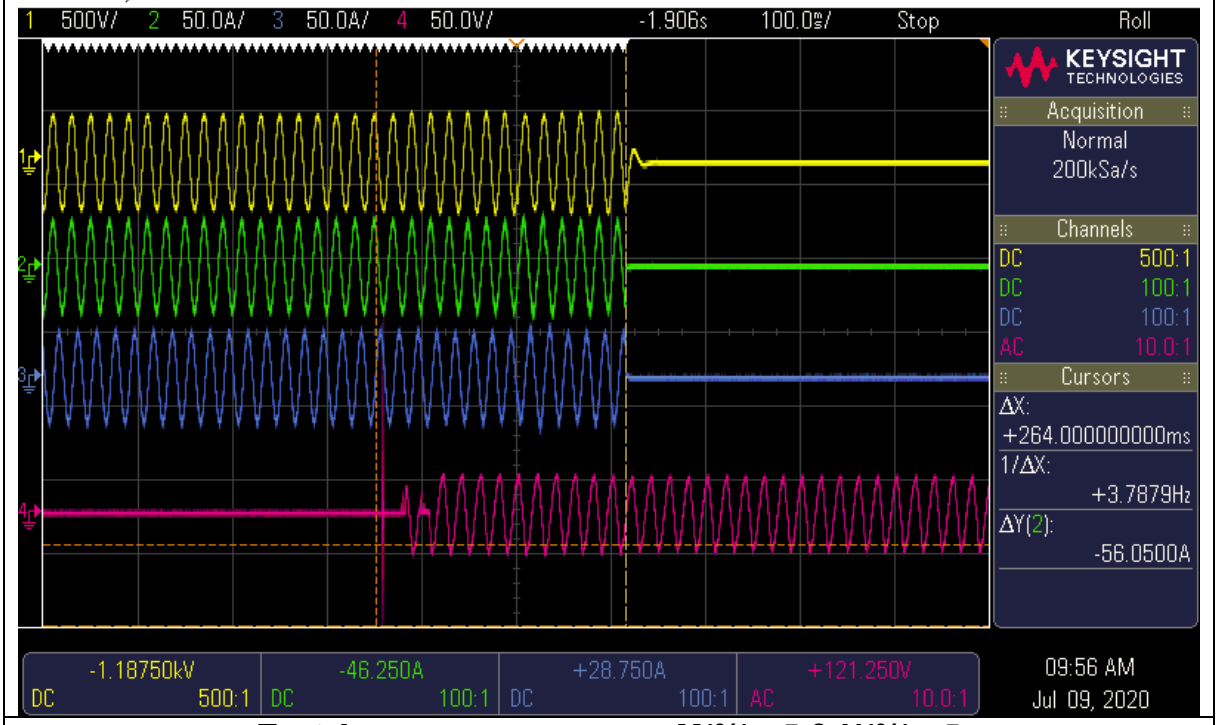
Test A	M(%)=0 & N(%)=-10



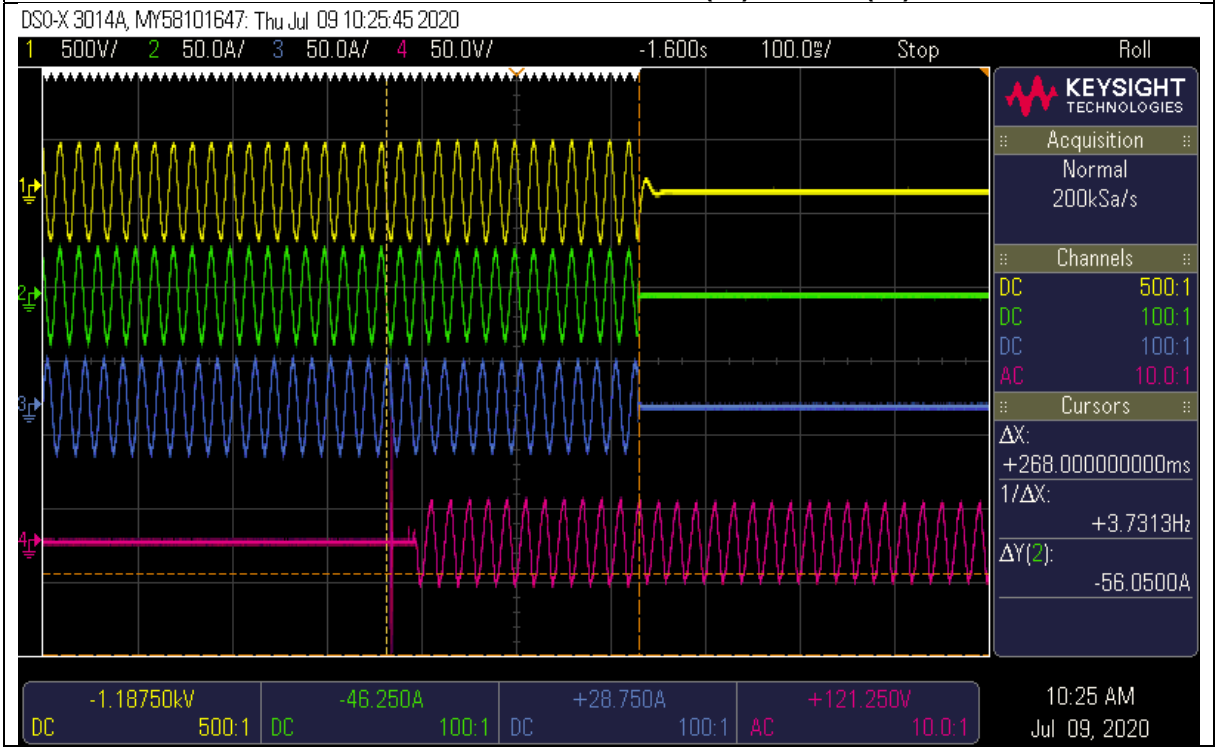
Test A	M(%)=-5 & N(%)=0



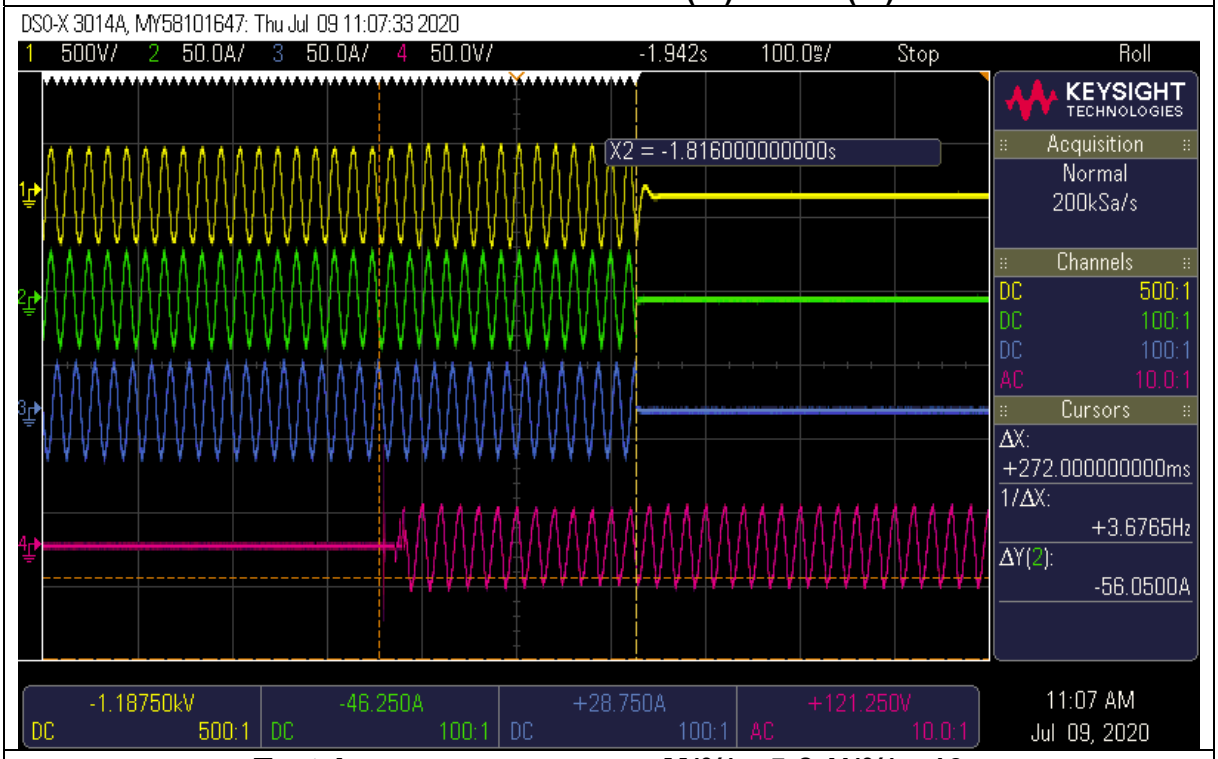
Test A **M(%)=-5 & N(%)=+5**



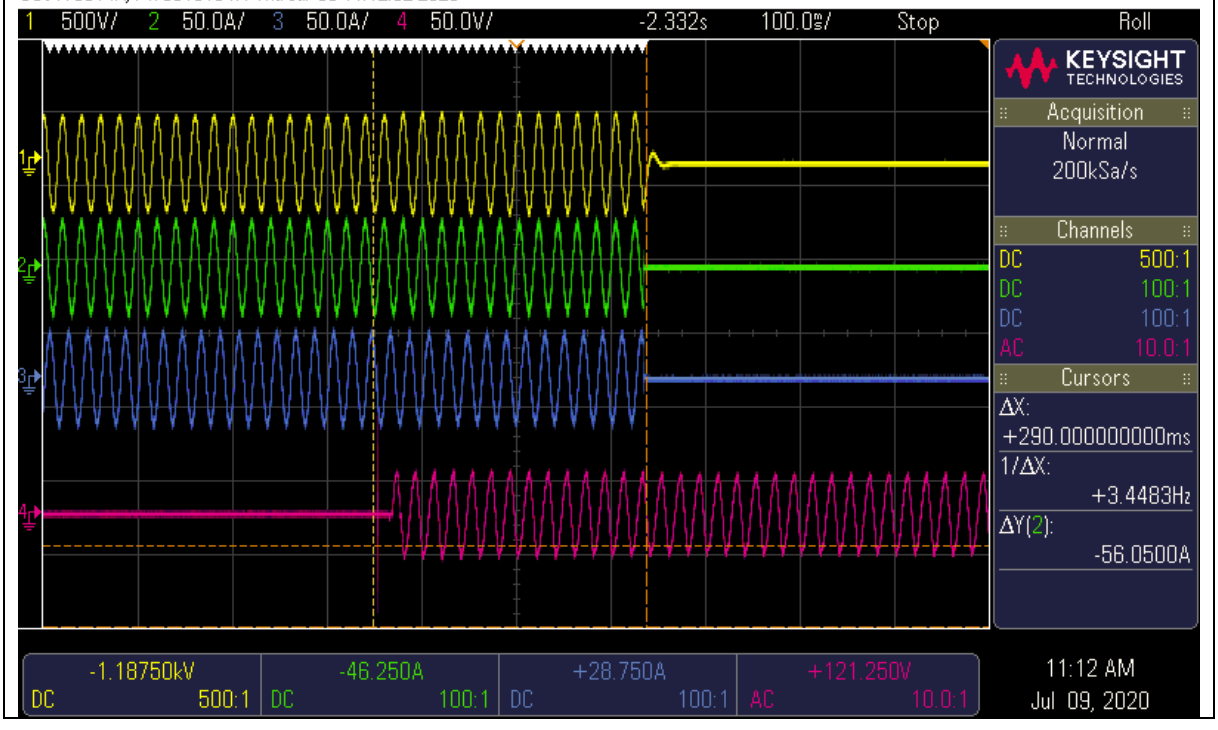
Test A **M(%)=-5 & N(%)=-5**



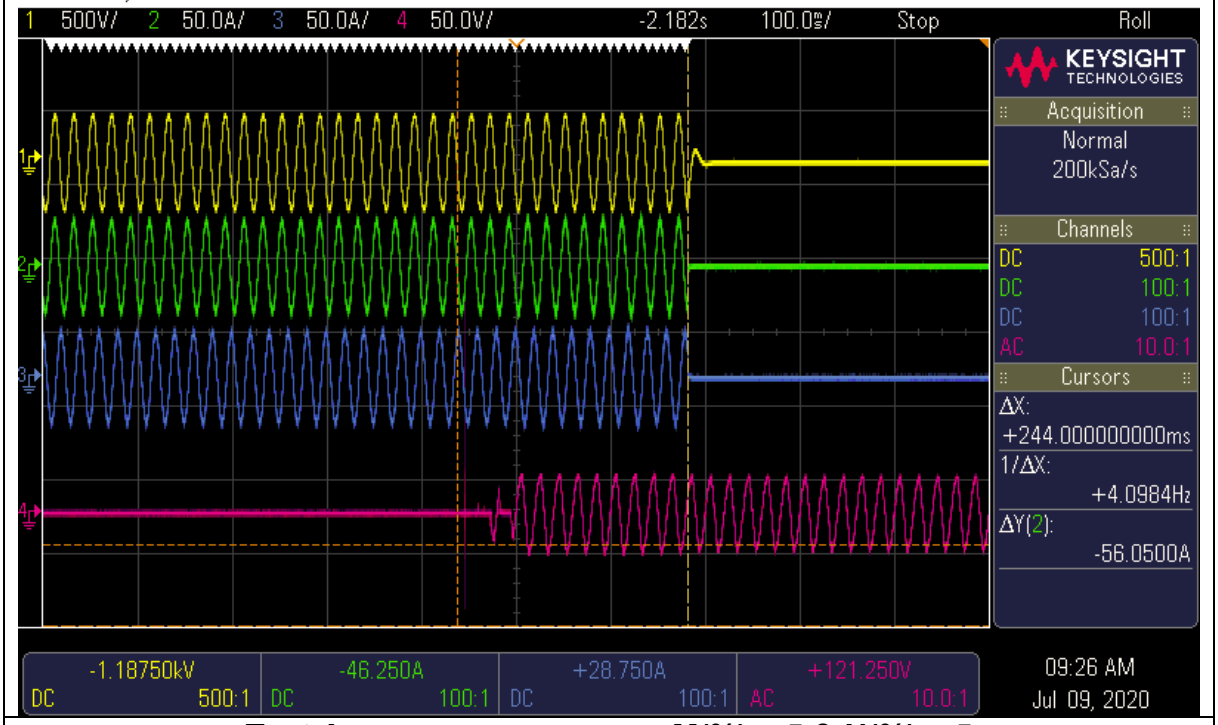
Test A **M(%)=-5 & N(%)=+10**



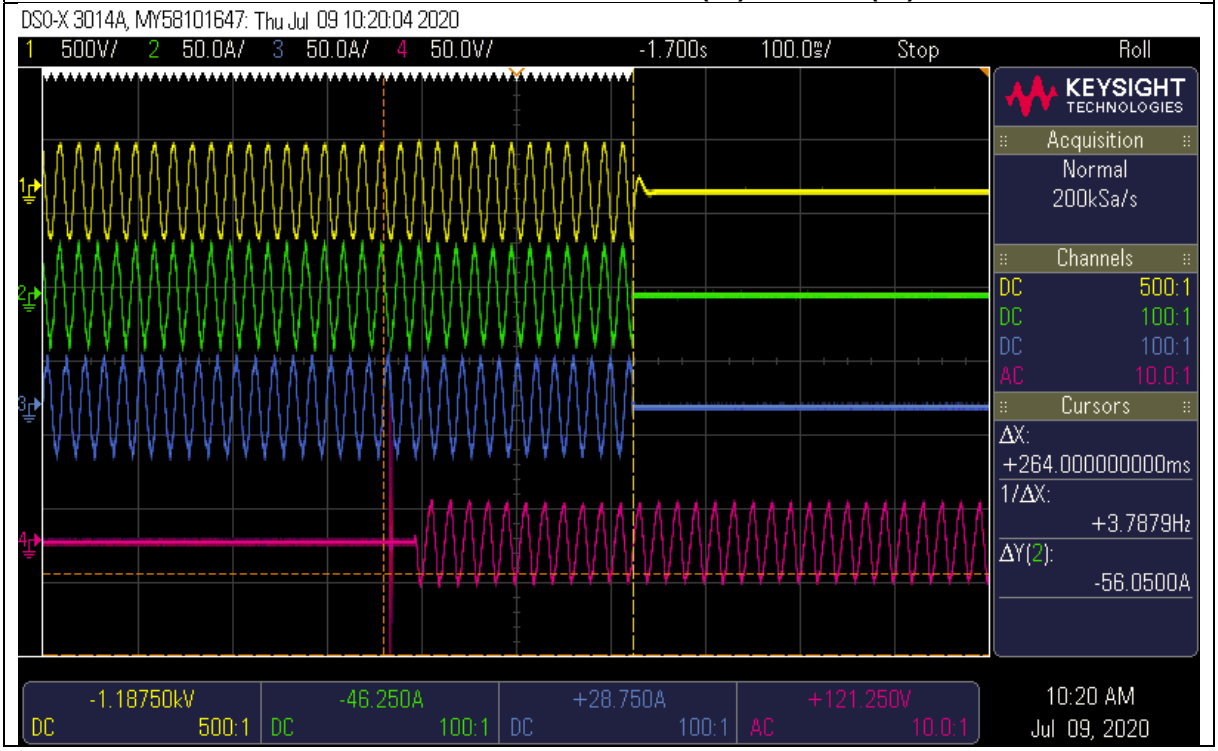
Test A **M(%)=-5 & N(%)=-10**



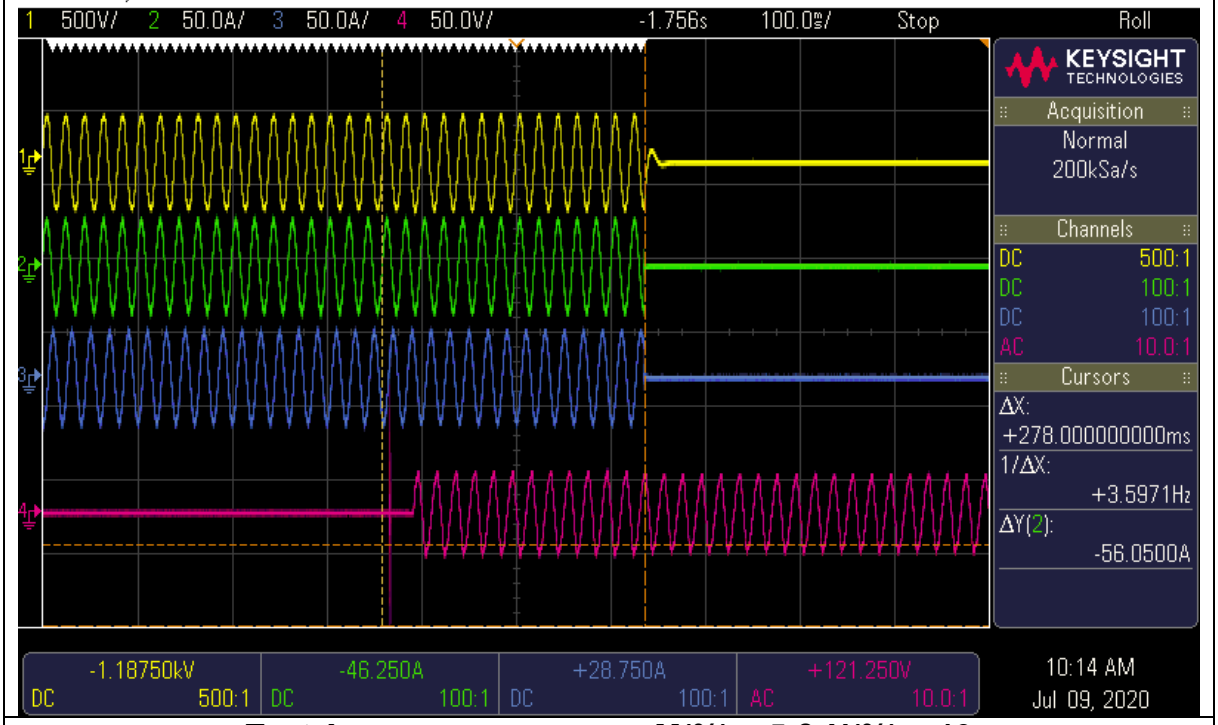
Test A **M(%)=+5 & N(%)=0**



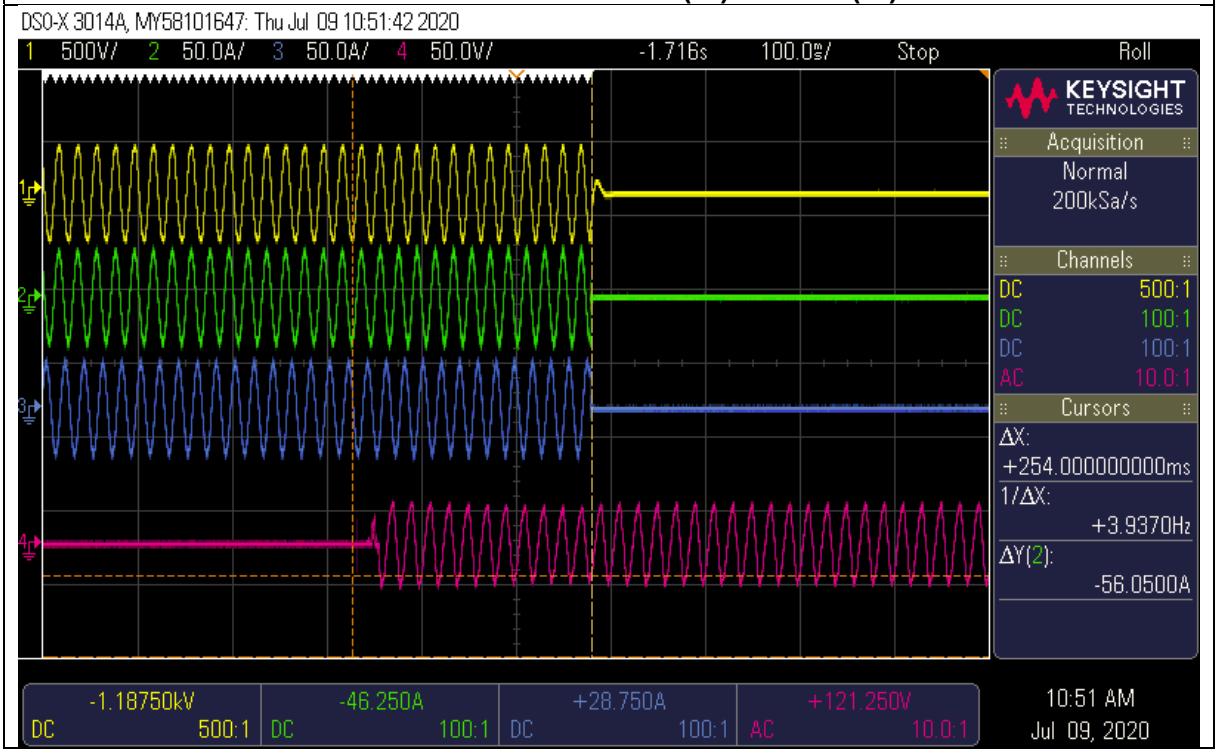
Test A **M(%)=+5 & N(%)=+5**



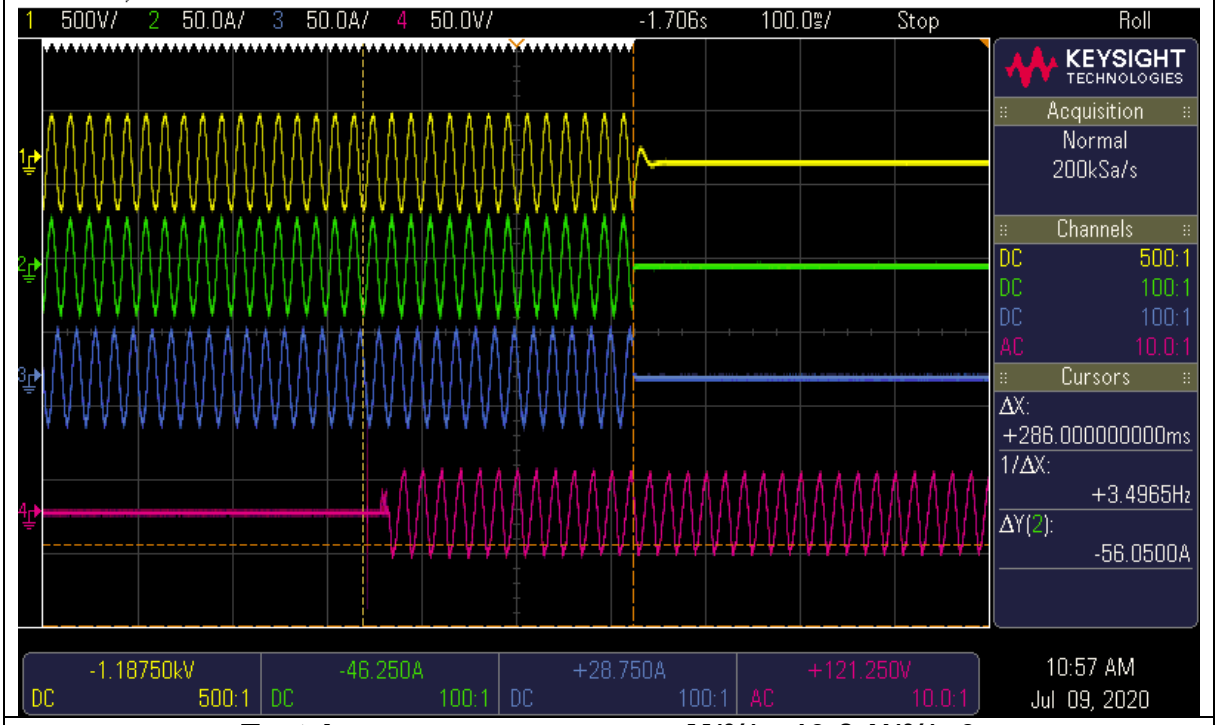
Test A **M(%)=+5 & N(%)=-5**



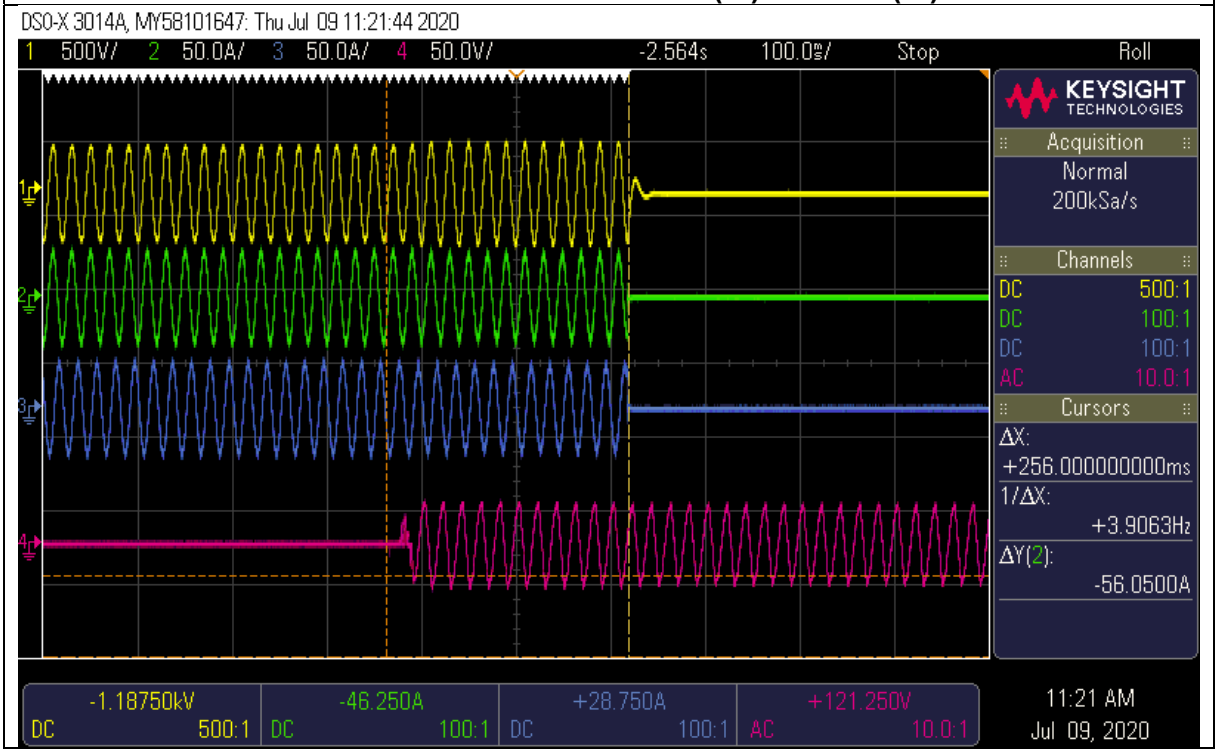
Test A **M(%)=+5 & N(%)=+10**



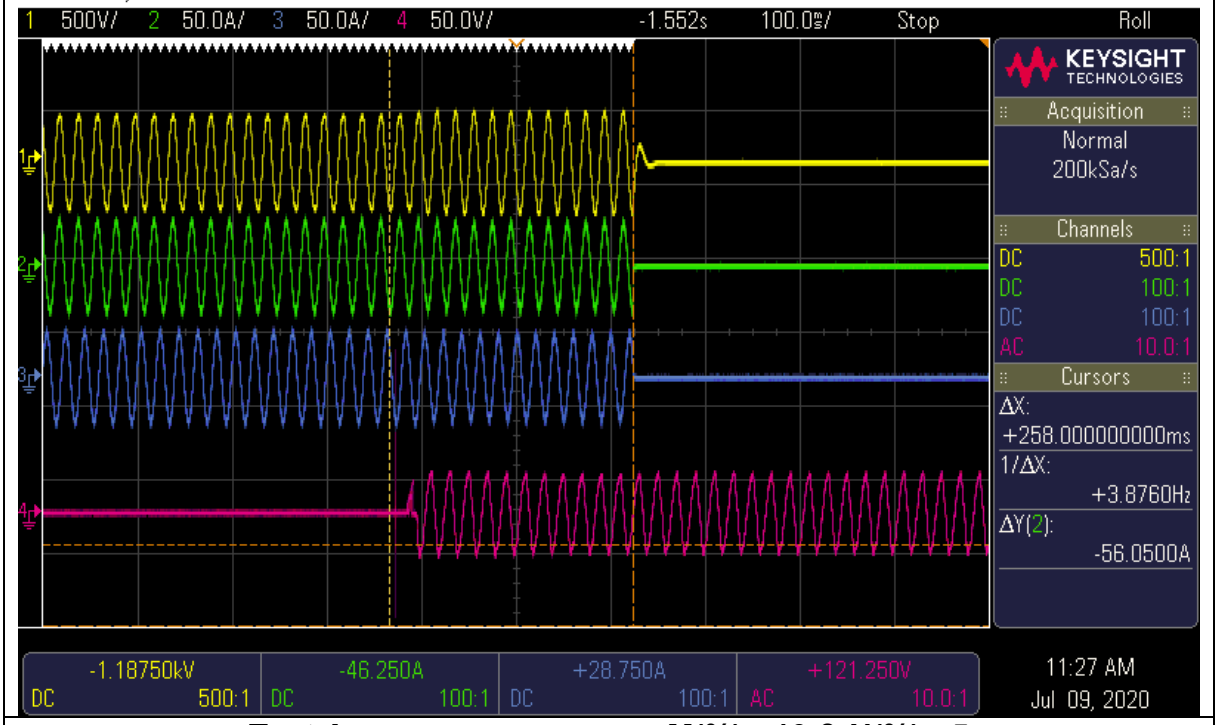
Test A **M(%)=+5 & N(%)=-10**



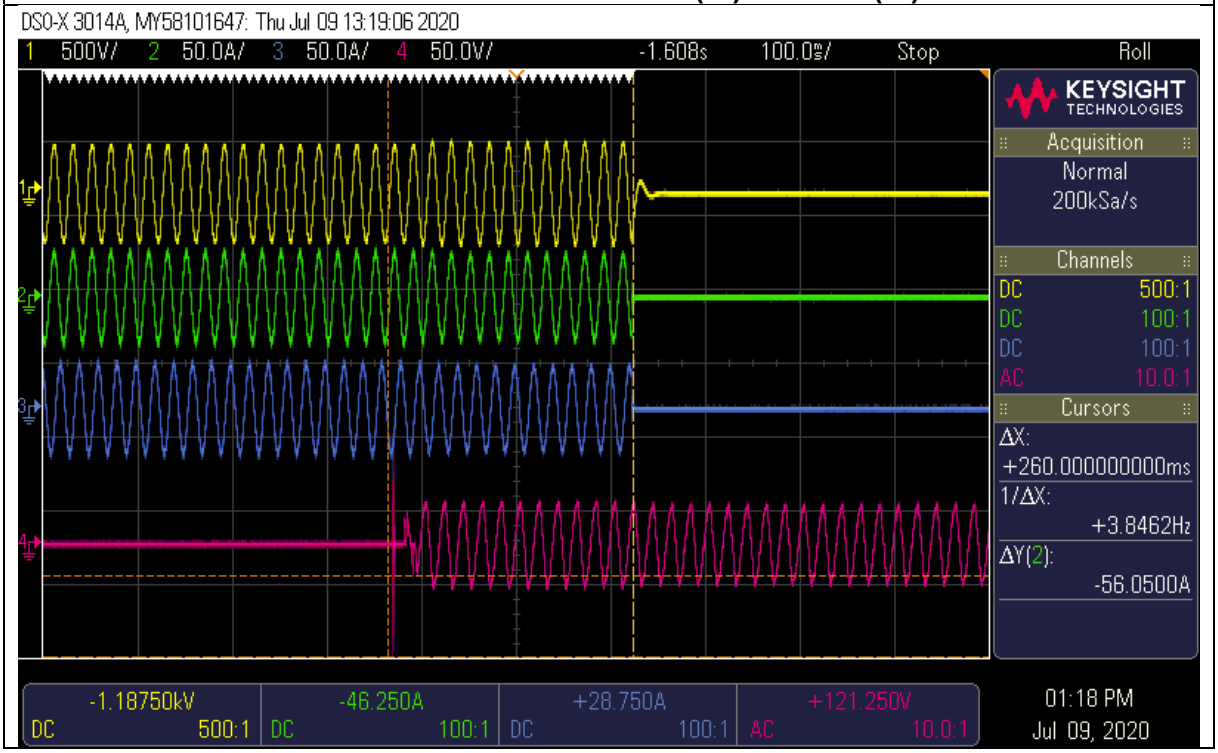
Test A **M(%)=-10 & N(%)=0**



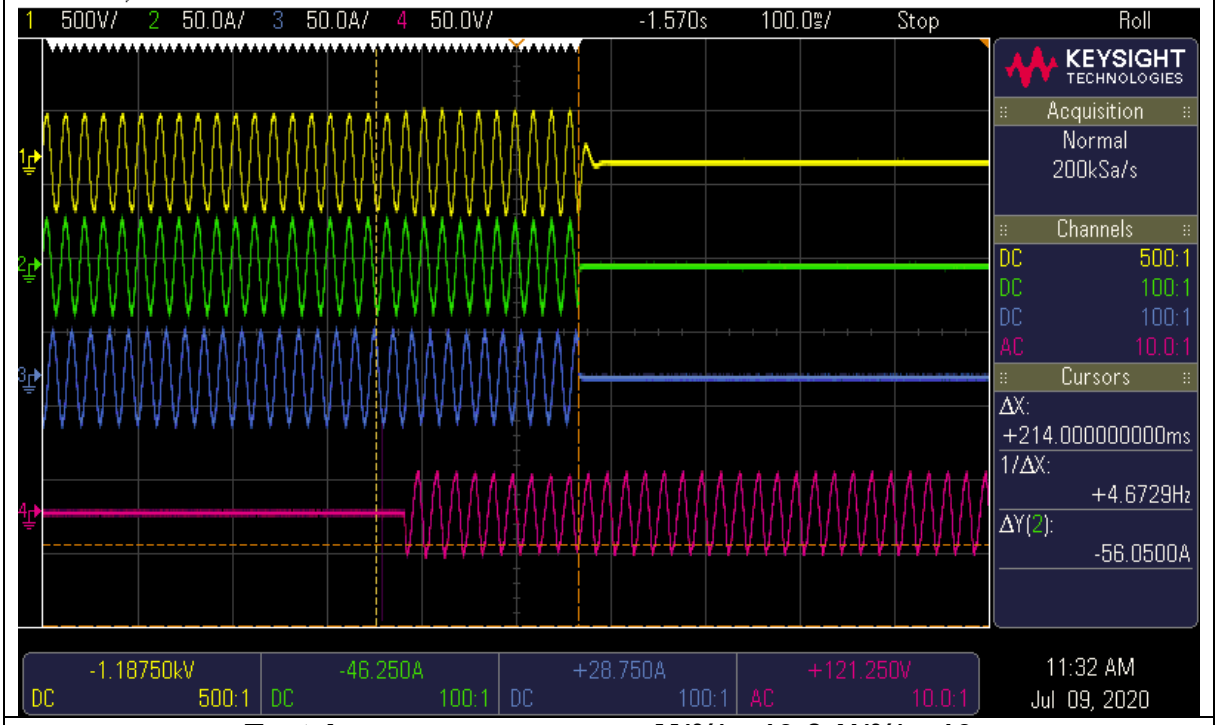
Test A	M(%)=-10 & N(%)=+5



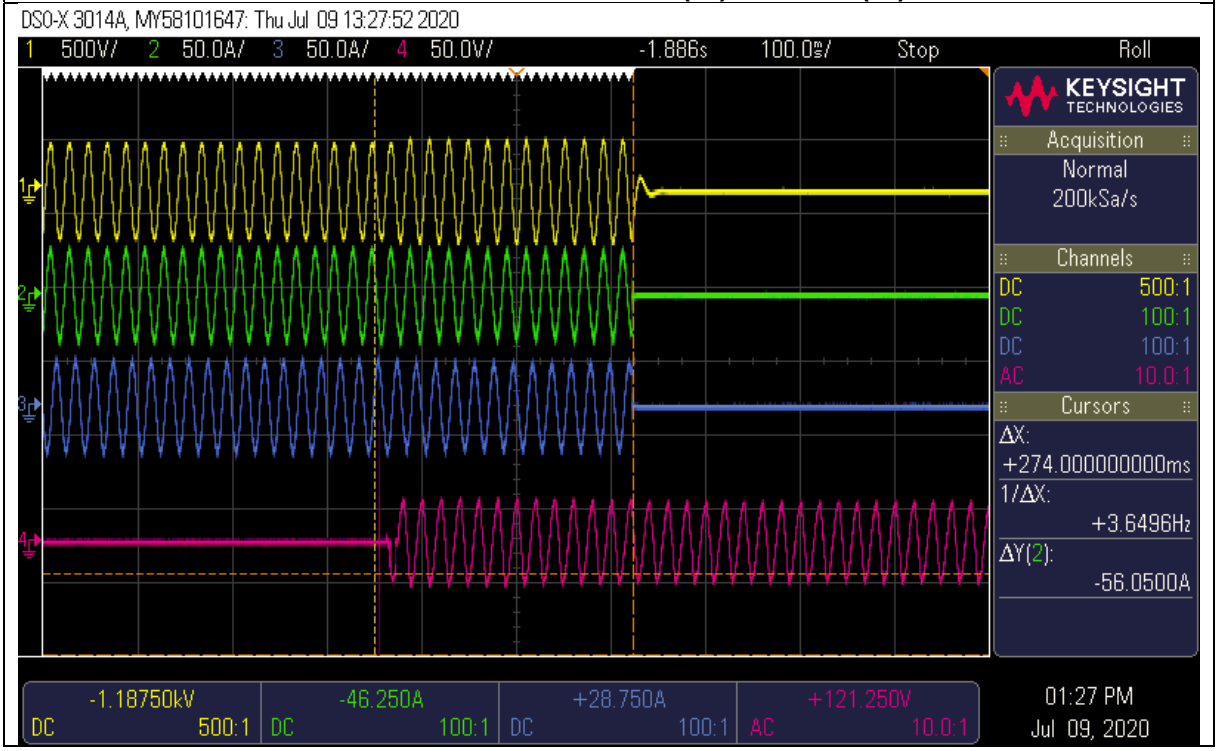
Test A	M(%)=-10 & N(%)=-5



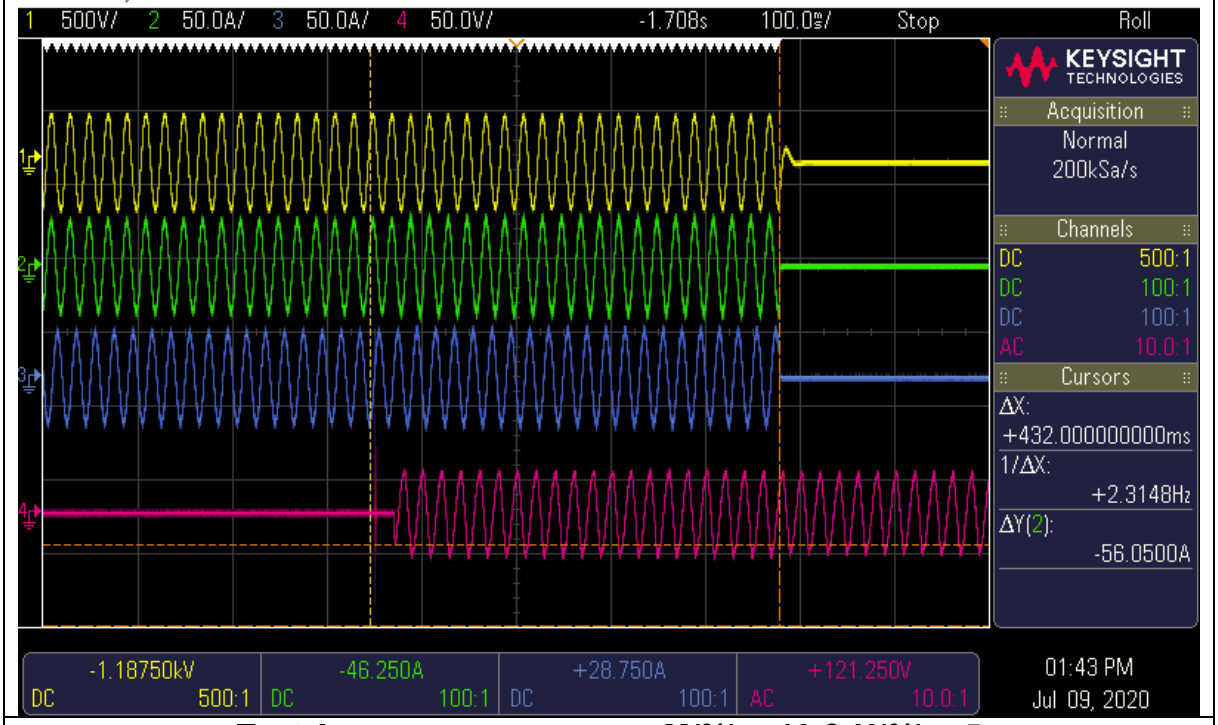
Test A **M(%)=-10 & N(%)=+10**



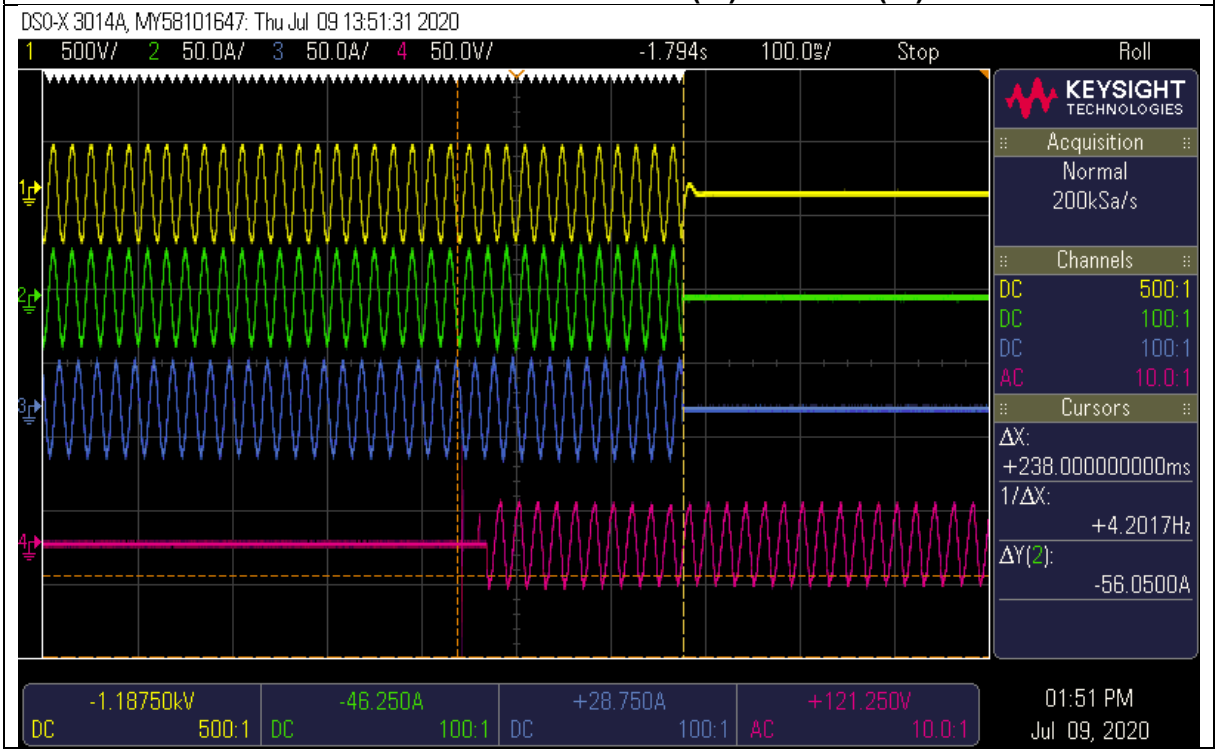
Test A **M(%)=-10 & N(%)=-10**



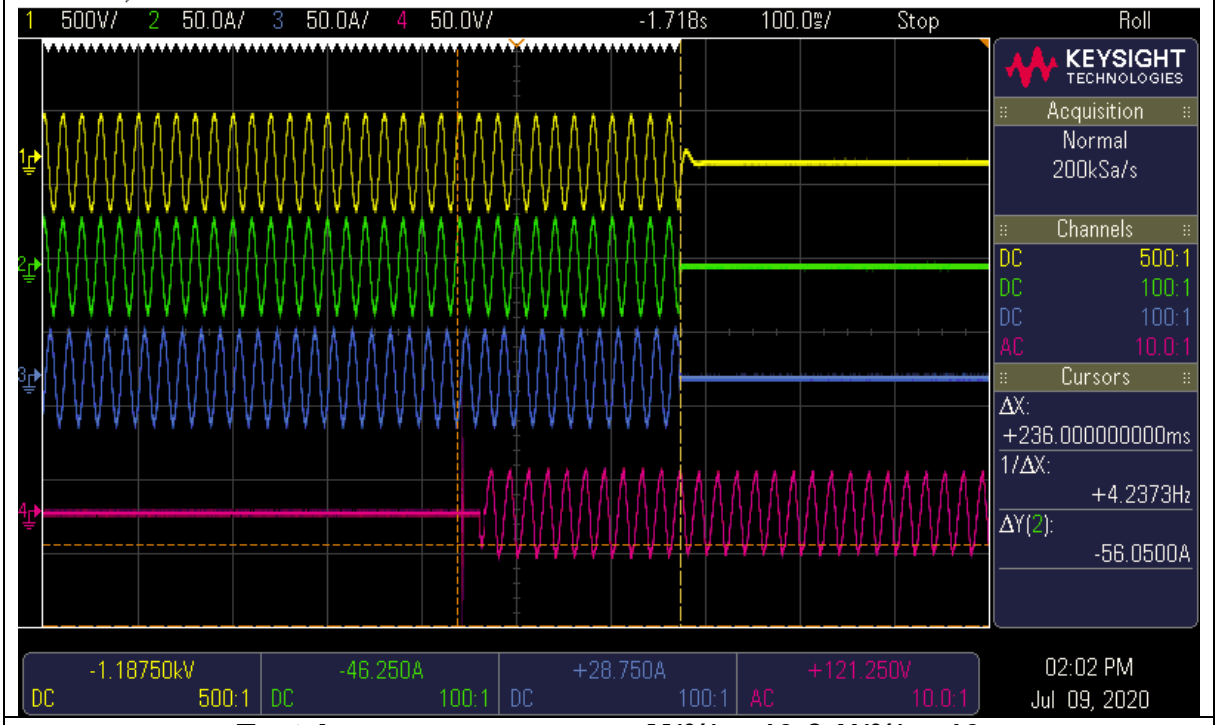
Test A	M(%)=+10 & N(%)=0



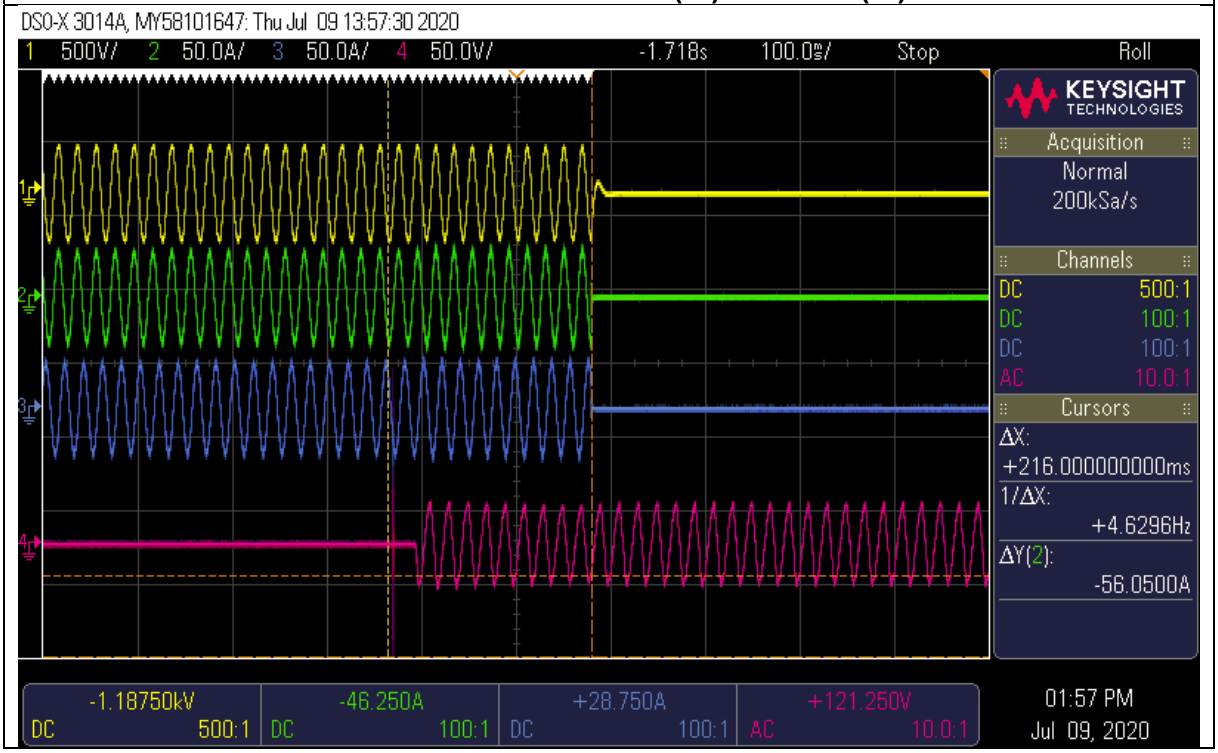
Test A	M(%)=+10 & N(%)=+5



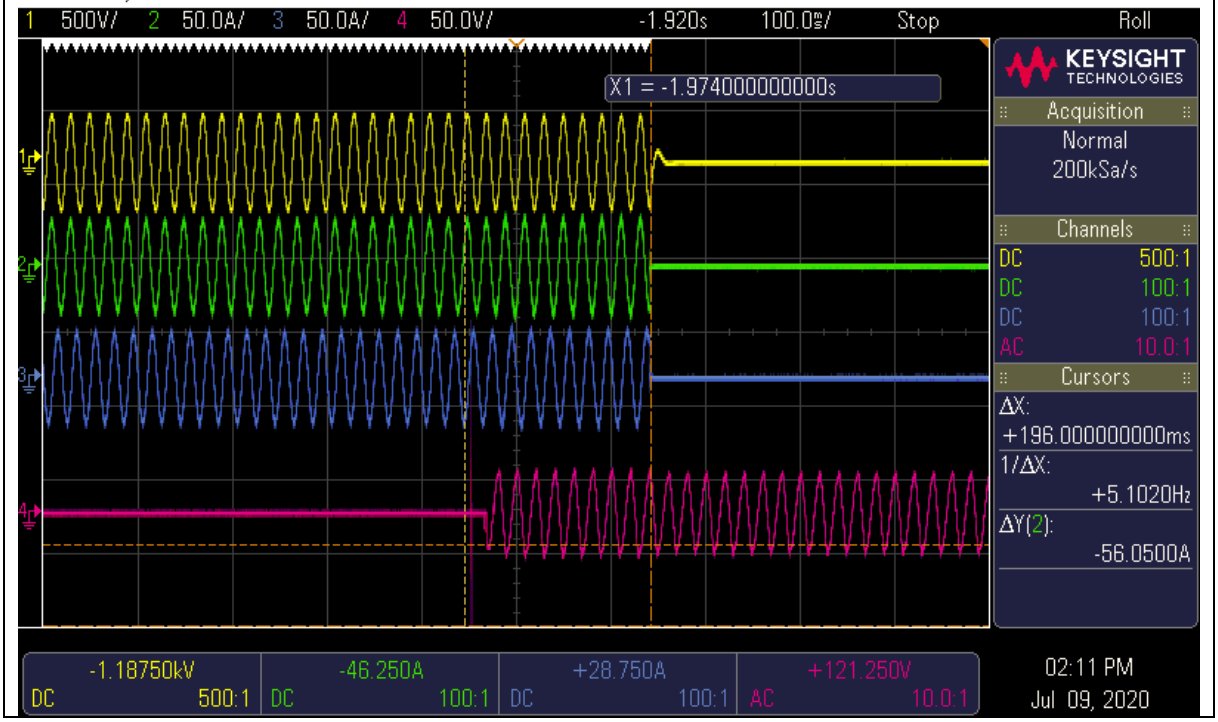
Test A **M(%)=+10 & N(%)=-5**



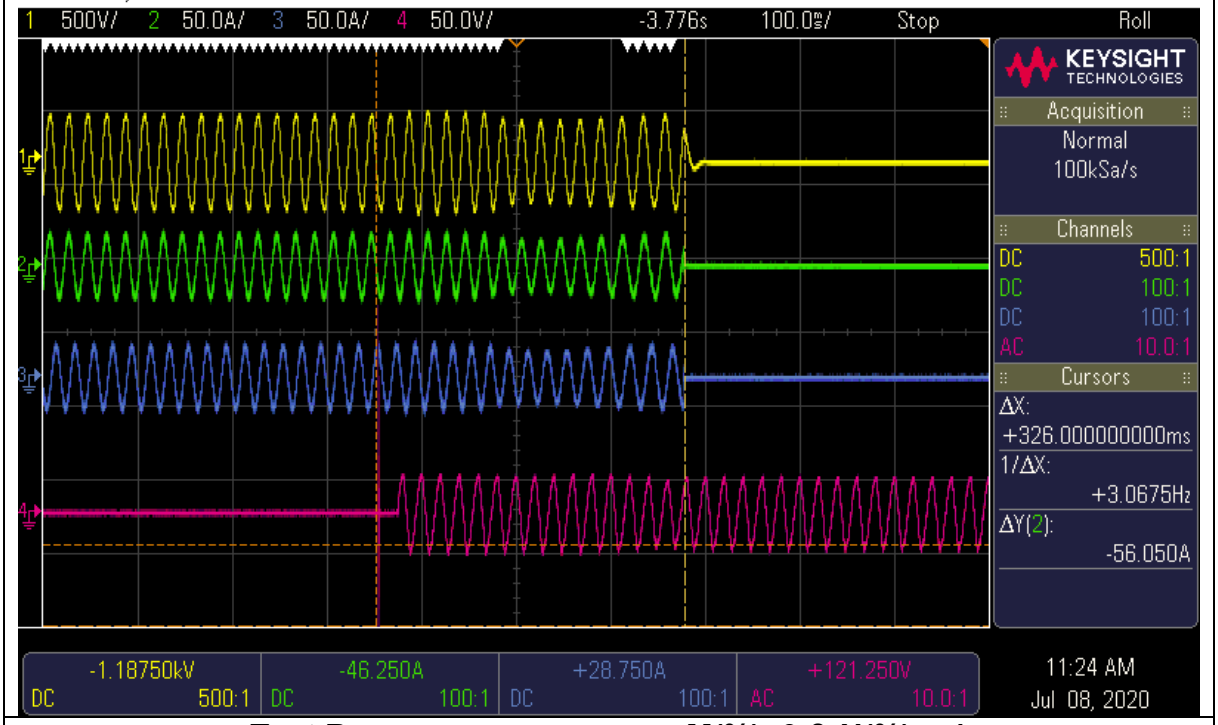
Test A **M(%)=+10 & N(%)=+10**



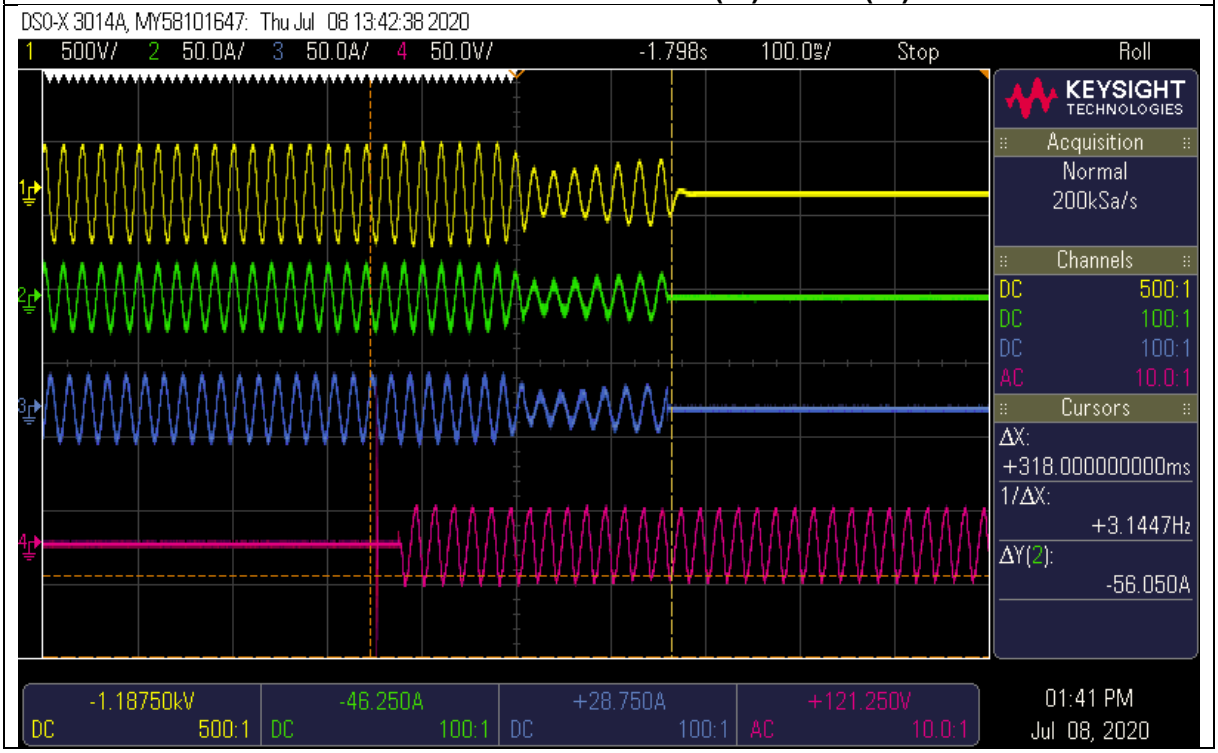
Test A	M(%)=+10 & N(%)=-10



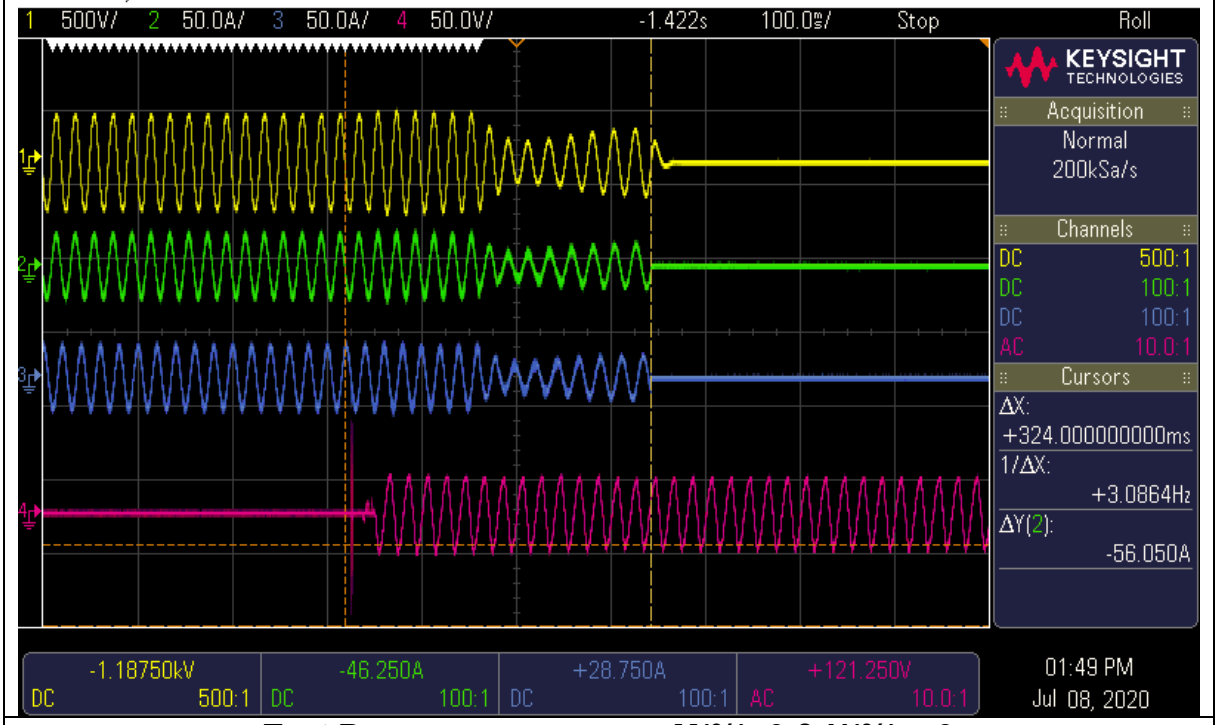
Test B **M(%)=0 & N(%)=0**



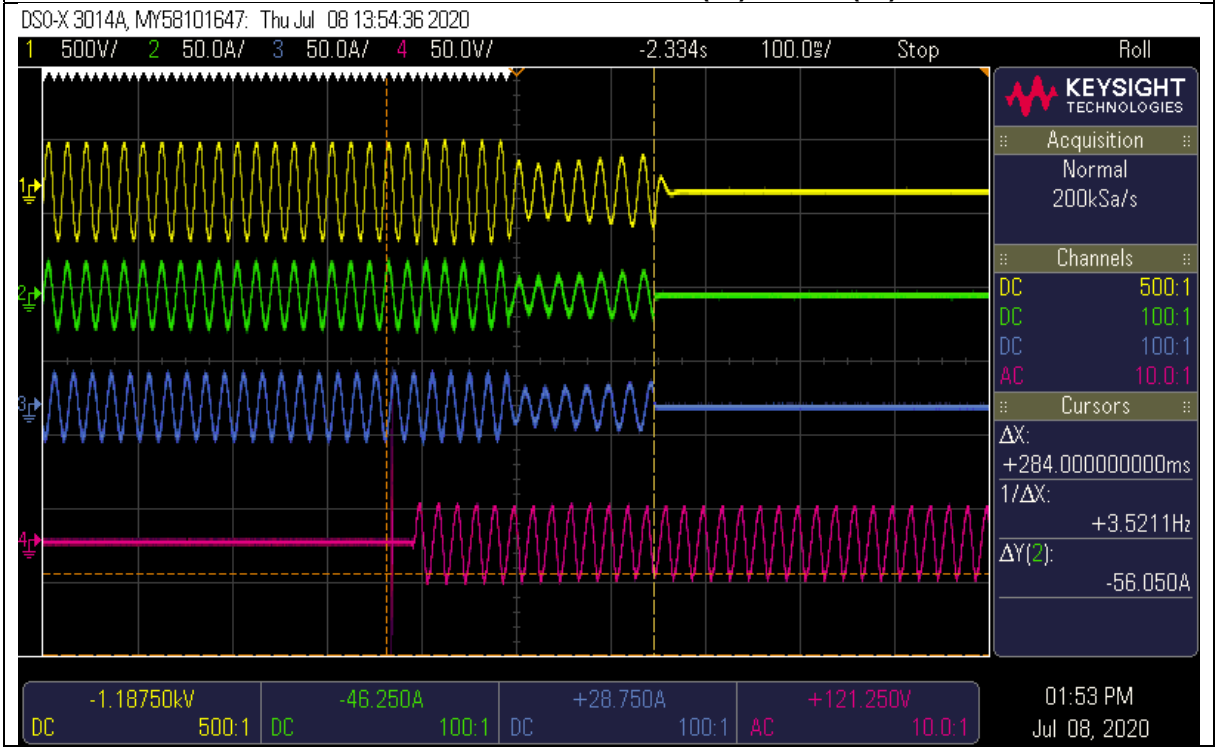
Test B **M(%)=0 & N(%)=+1**



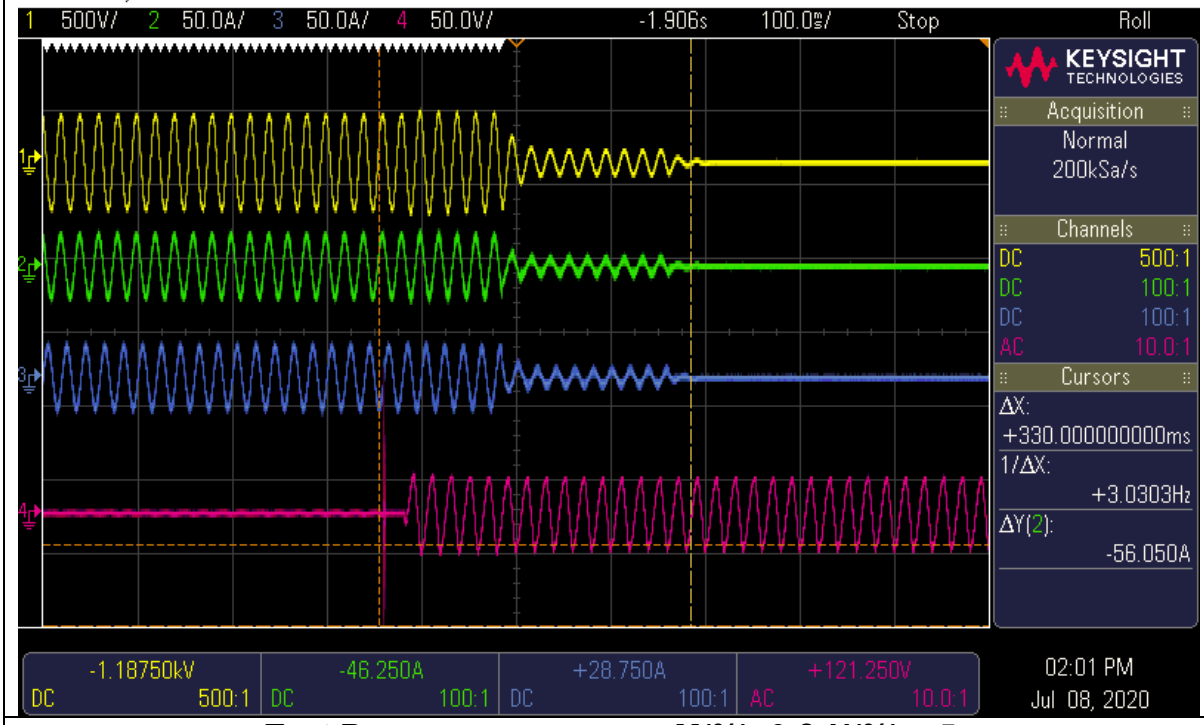
Test B **M(%)=0 & N(%)=+2**



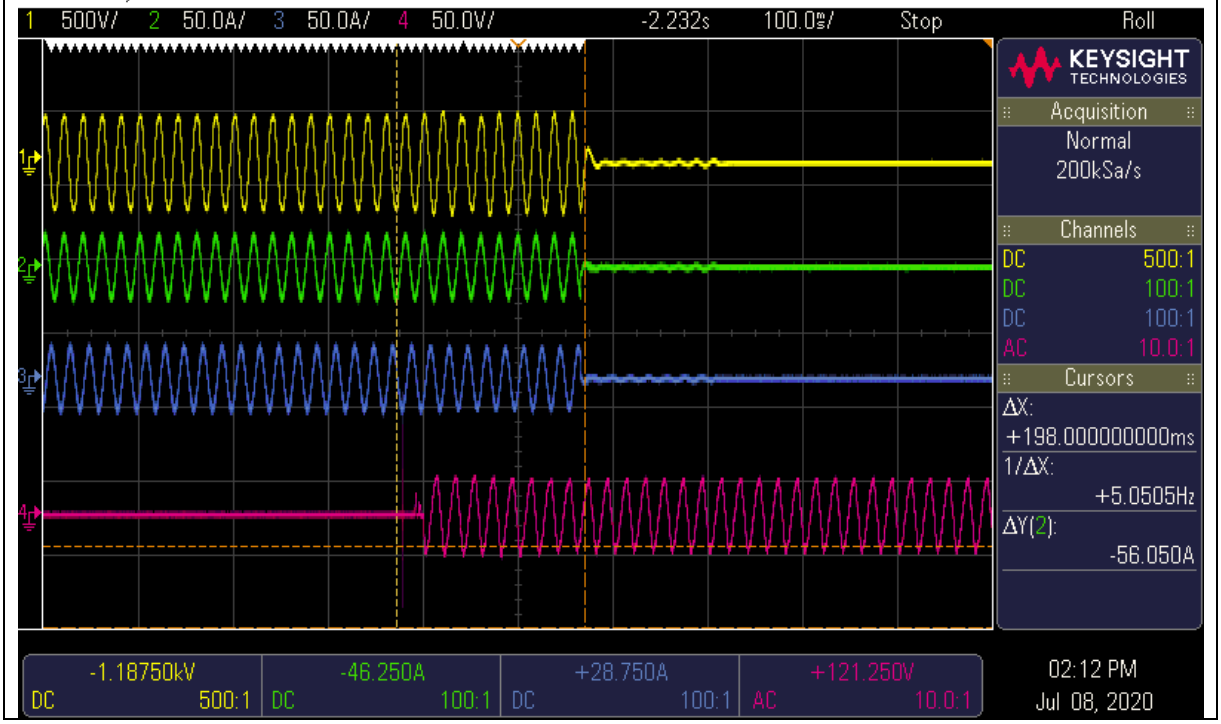
Test B **M(%)=0 & N(%)=+3**



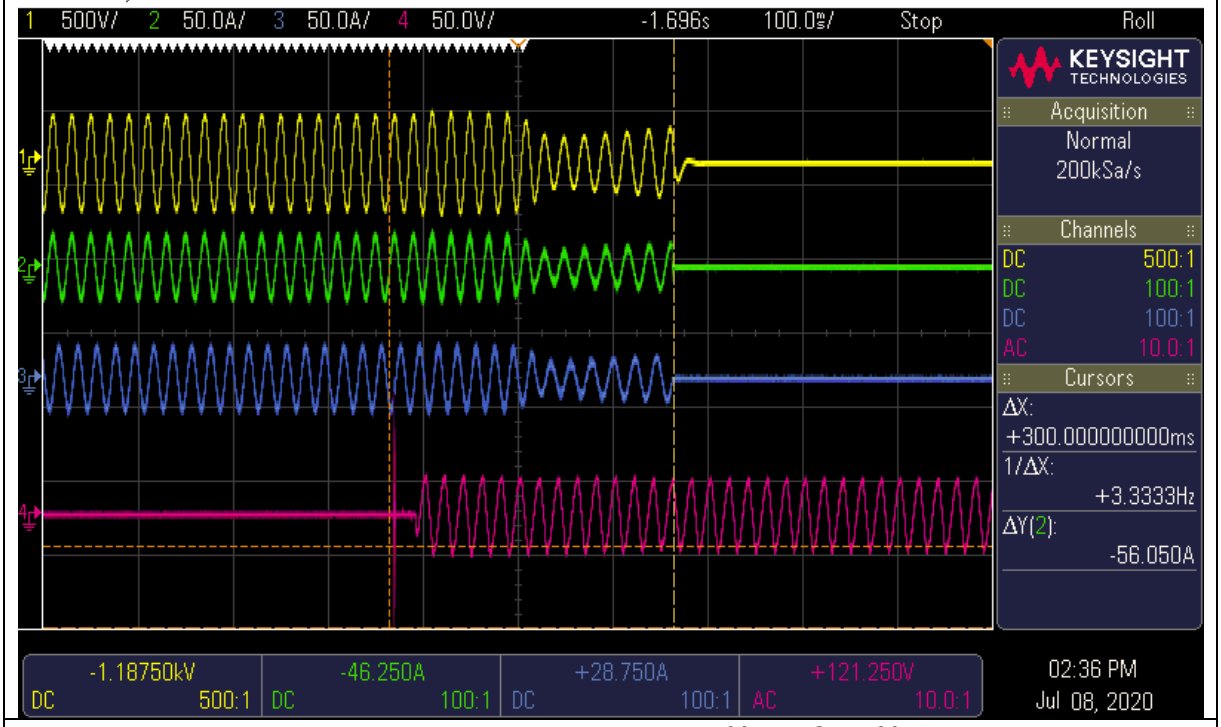
Test B **M(%)=0 & N(%)=+4**



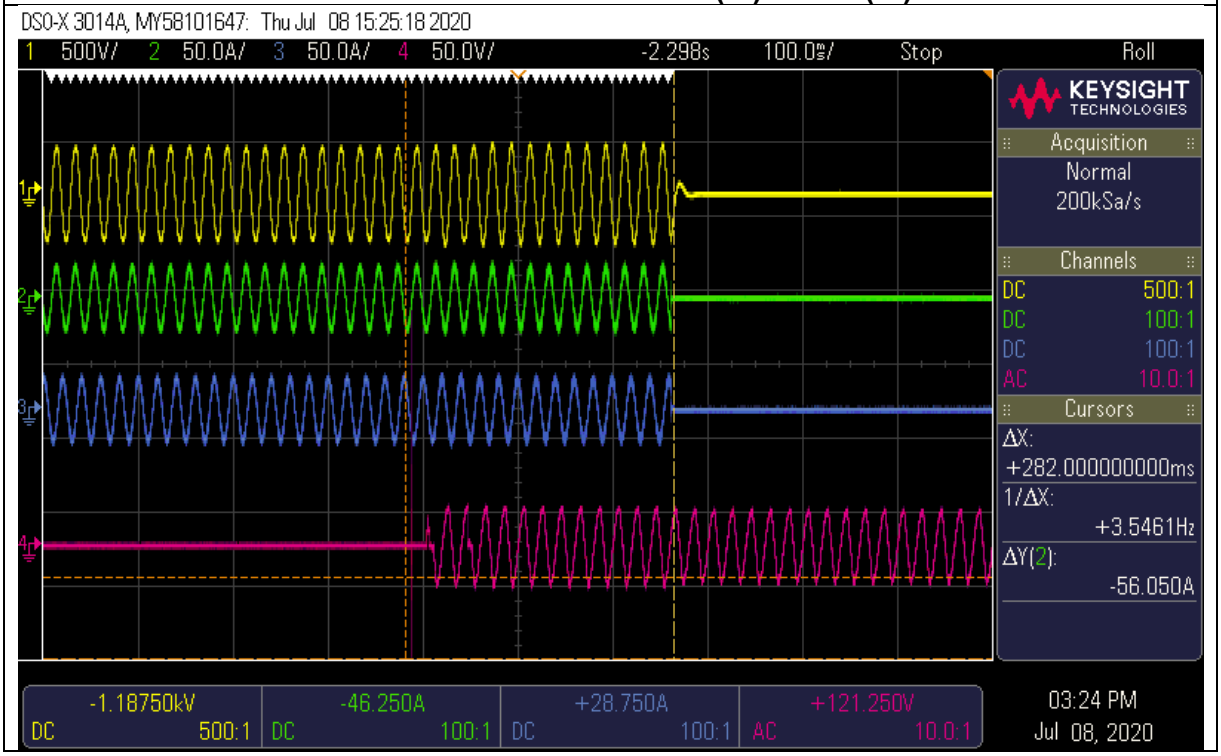
Test B **M(%)=0 & N(%)=+5**



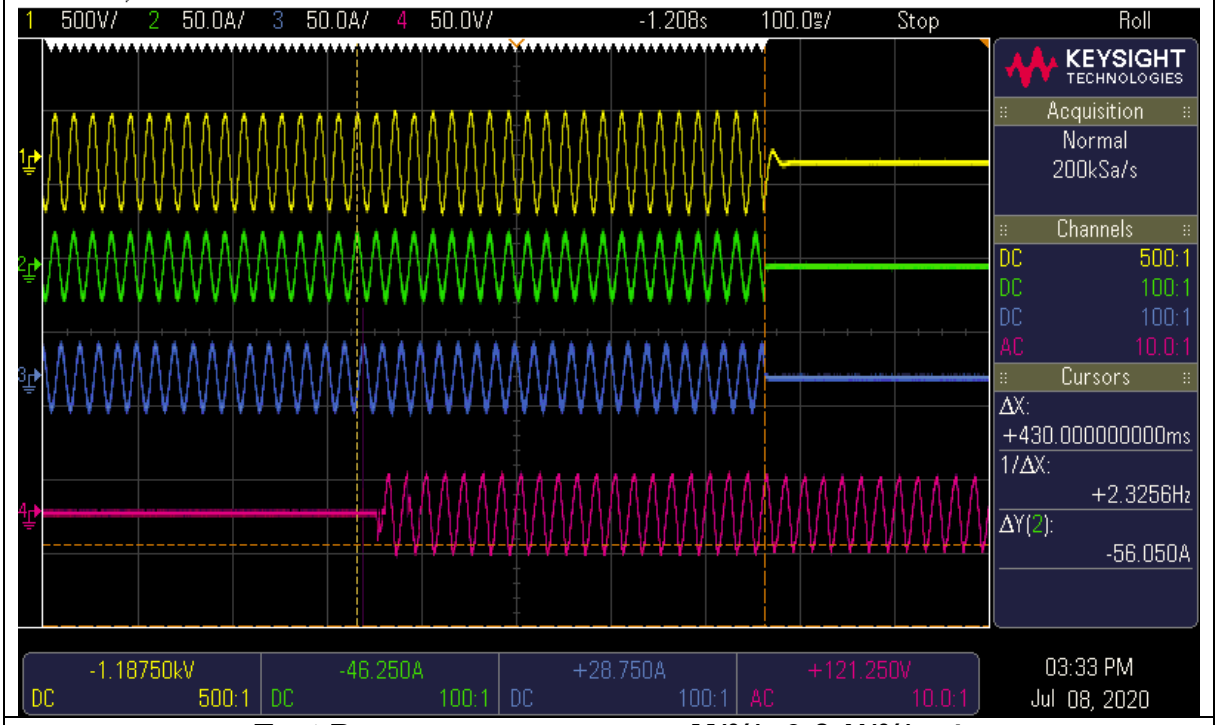
Test B **M(%)=0 & N(%)=-1**



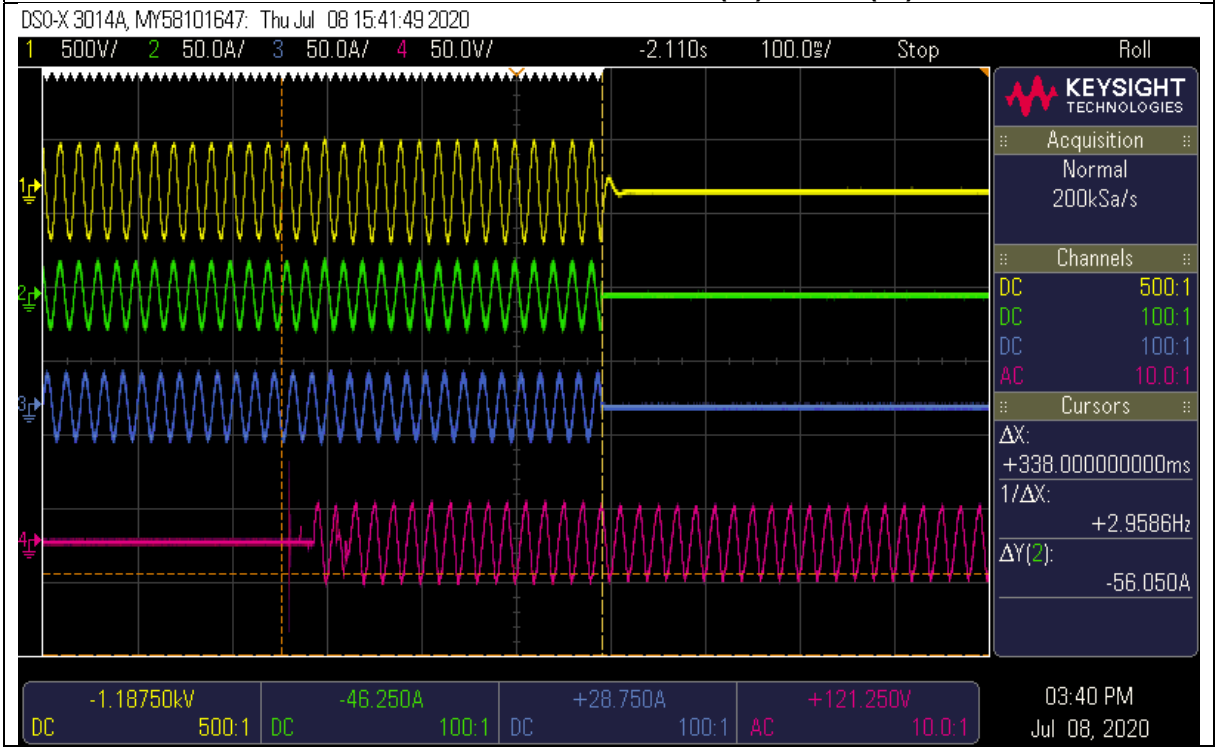
Test B **M(%)=0 & N(%)=-2**



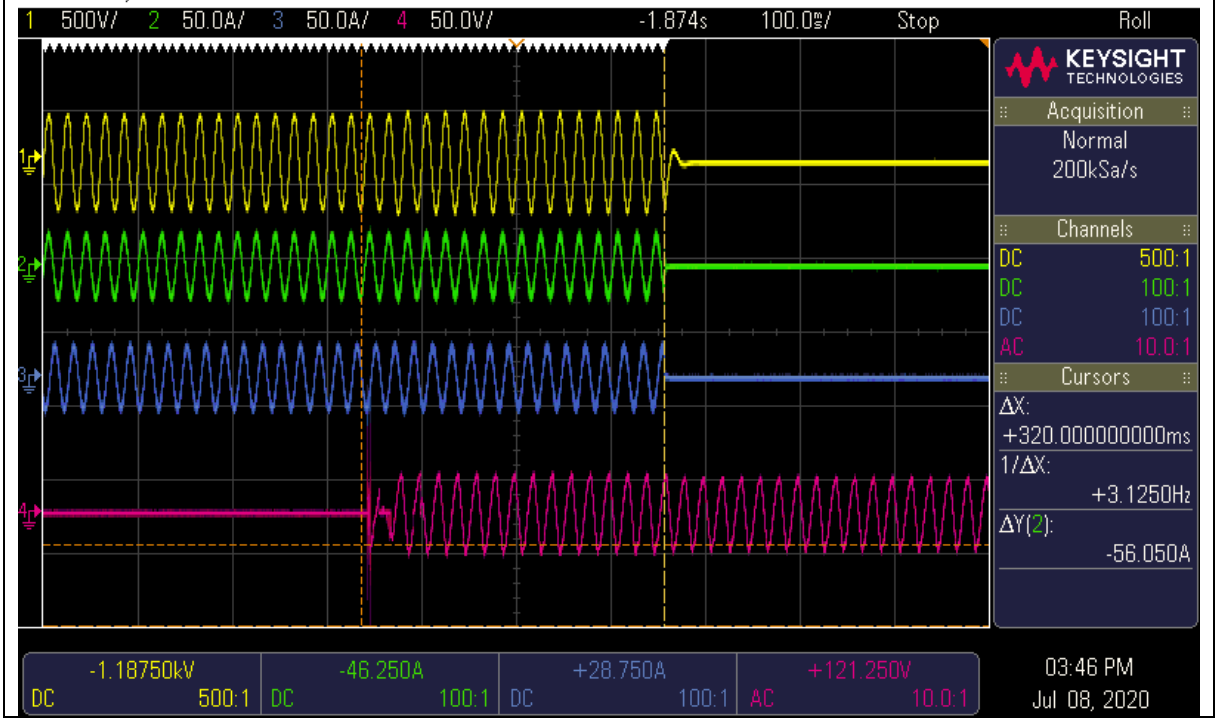
Test B **M(%)=0 & N(%)=-3**



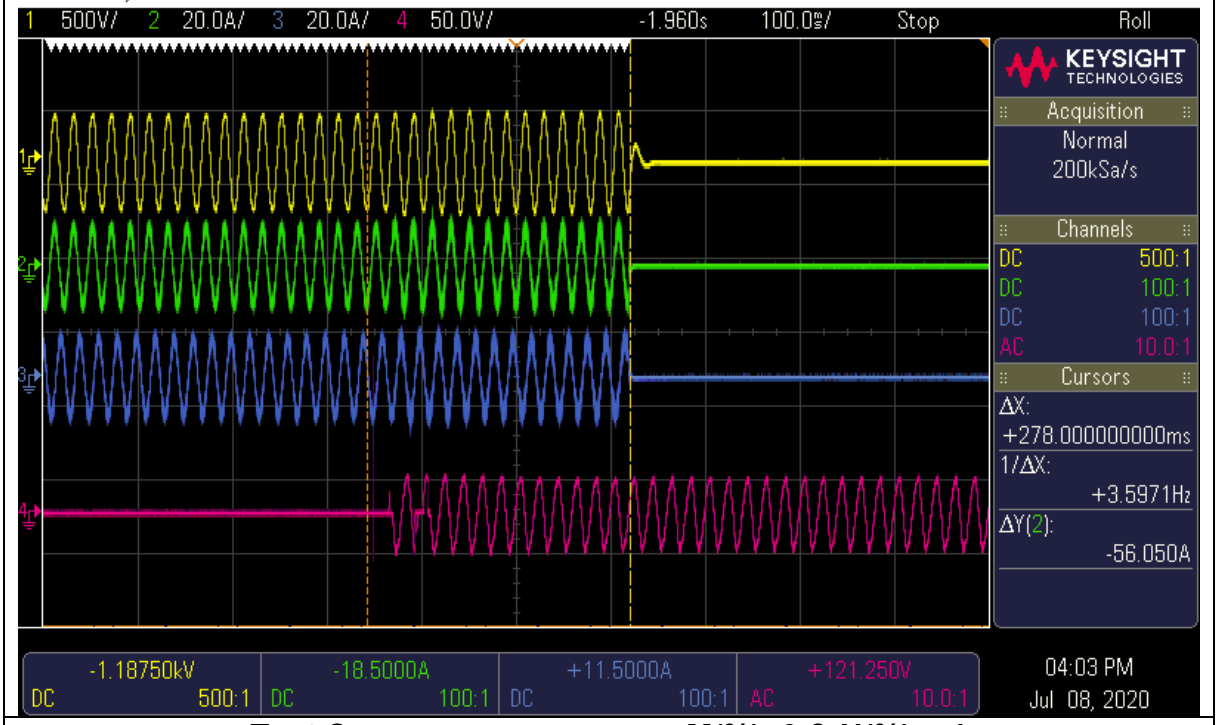
Test B **M(%)=0 & N(%)=-4**



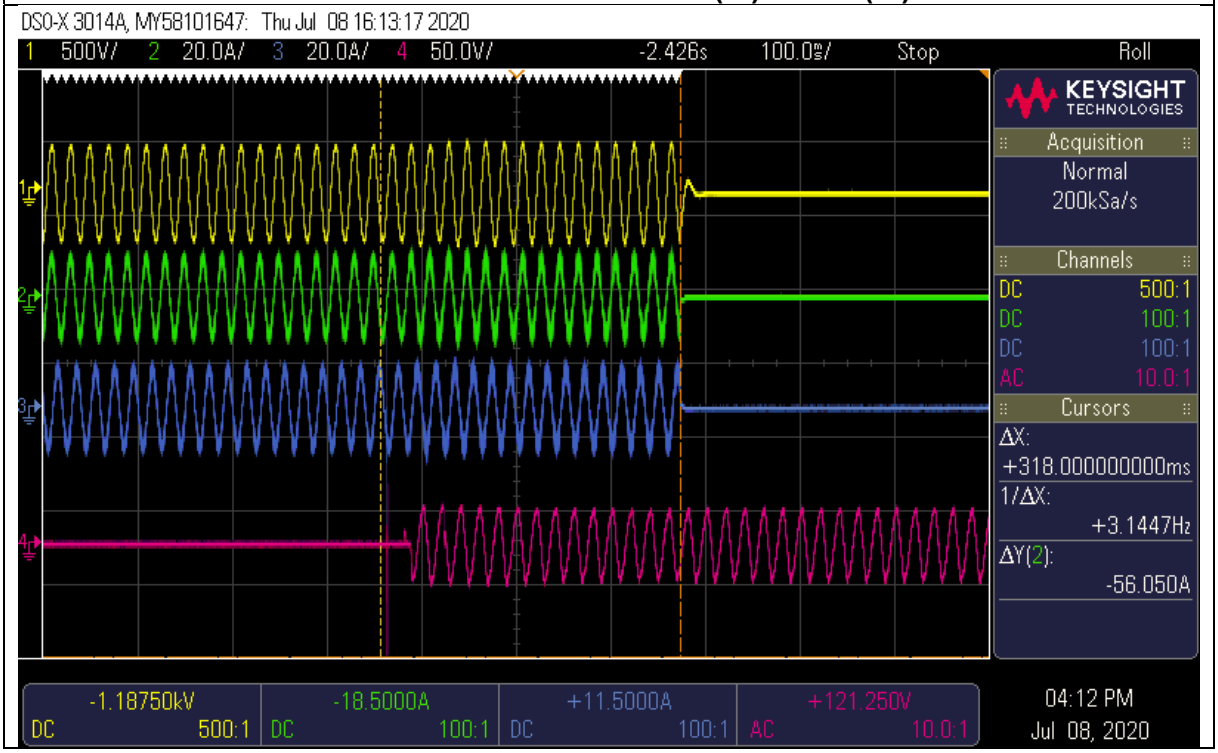
Test B	M(%)=0 & N(%)=-5


DSO-X 3014A, MY58101647: Thu Jul 08 15:47:08 2020
1 500V/ 2 50.0A/ 3 50.0A/ 4 50.0V/
-1.874s
100.0s/
Stop
Roll
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
200kSa/s
Channels
DC 500:1
DC 100:1
DC 100:1
AC 10.0:1
Cursors
ΔX:
+320.000000000ms
1/ΔX:
+3.1250Hz
ΔY(2):
-56.050A
-1.18750kV
DC 500:1
-46.250A
DC 100:1
+28.750A
DC 100:1
+121.250V
AC 10.0:1
03:46 PM
Jul 08, 2020

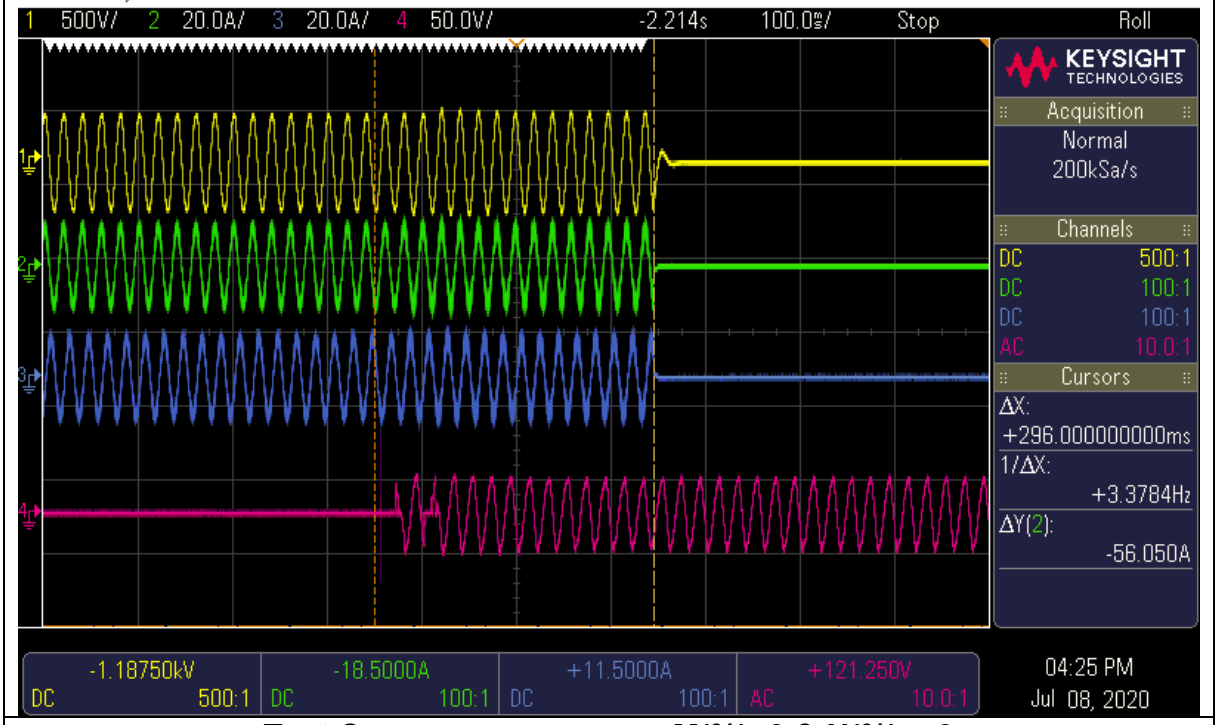
Test C **M(%)=0 & N(%)=0**



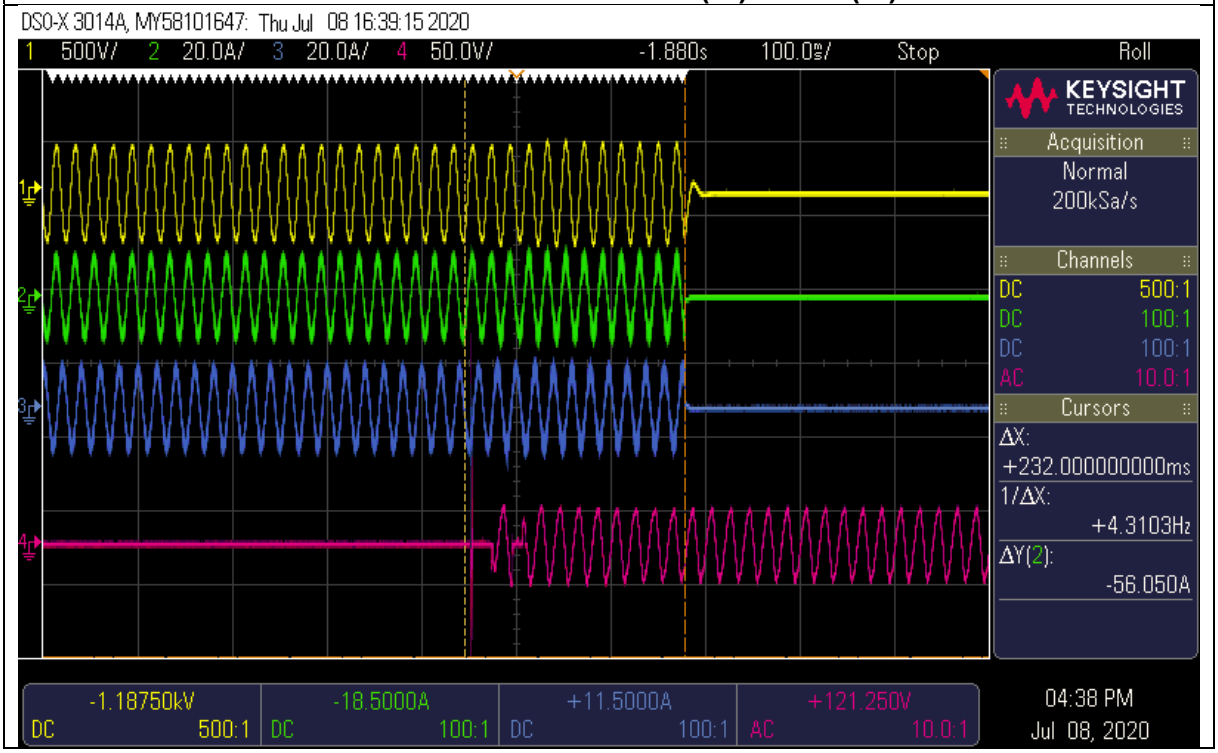
Test C **M(%)=0 & N(%)=+1**



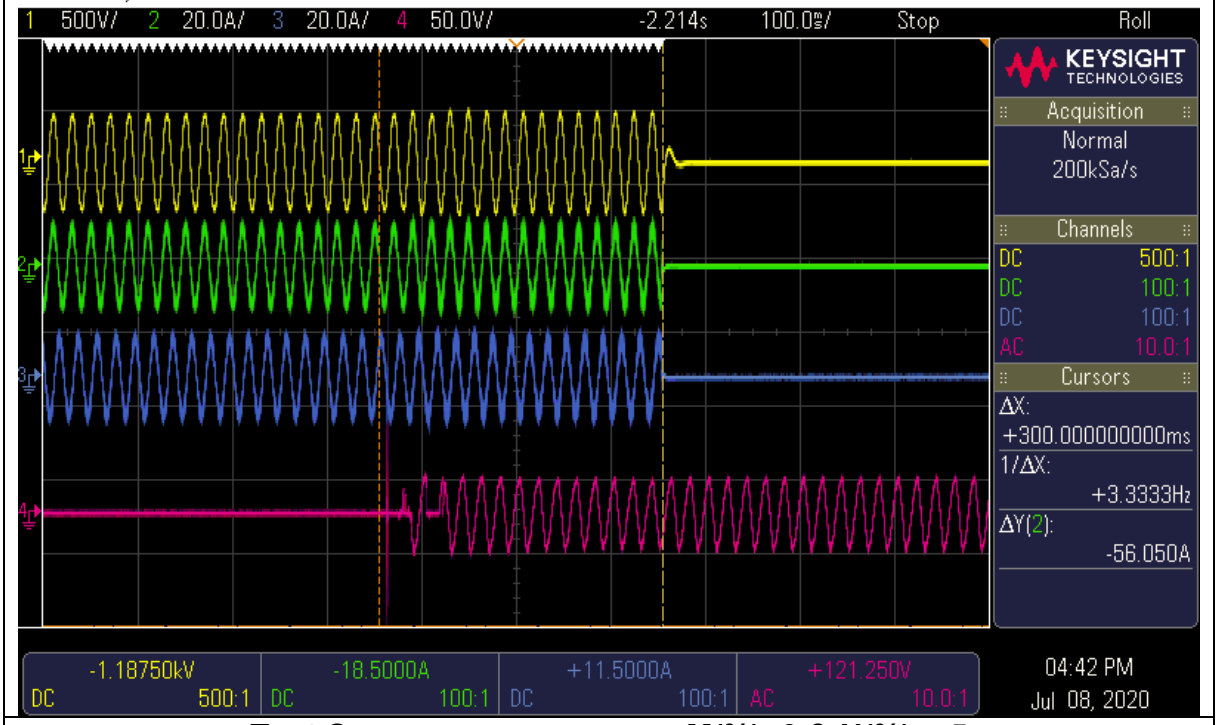
Test C **M(%)=0 & N(%)=+2**



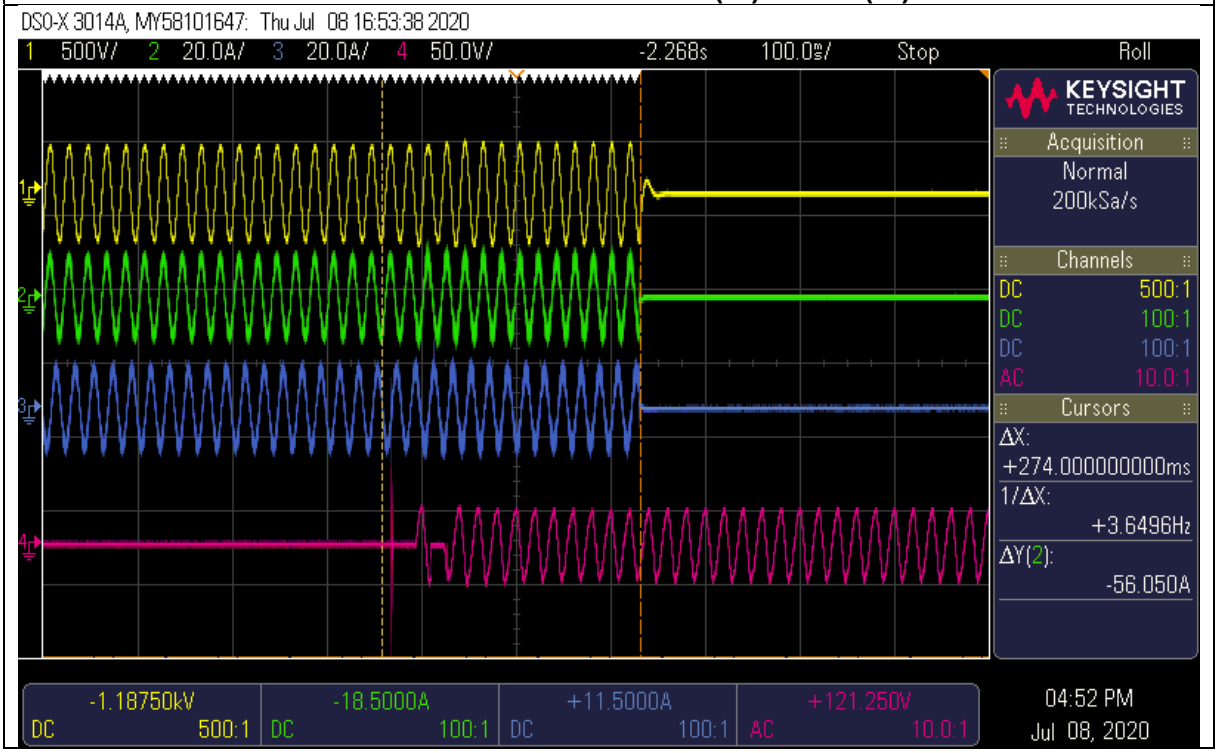
Test C **M(%)=0 & N(%)=+3**



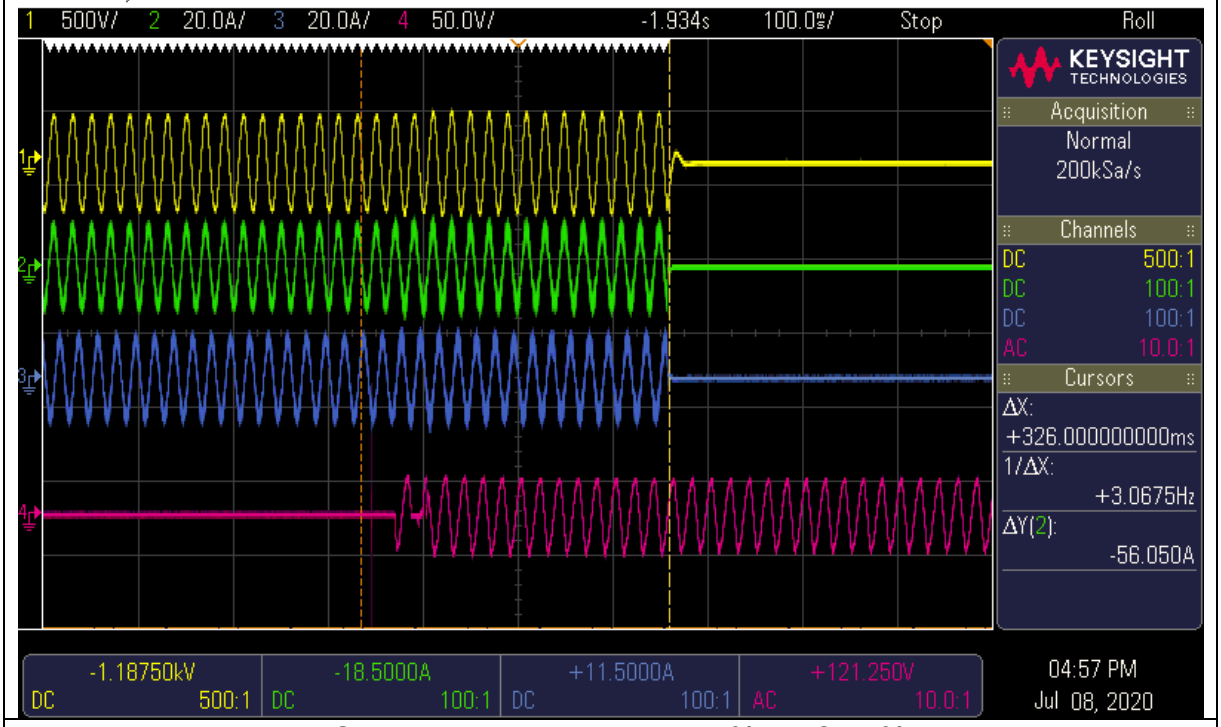
Test C **M(%)=0 & N(%)=+4**



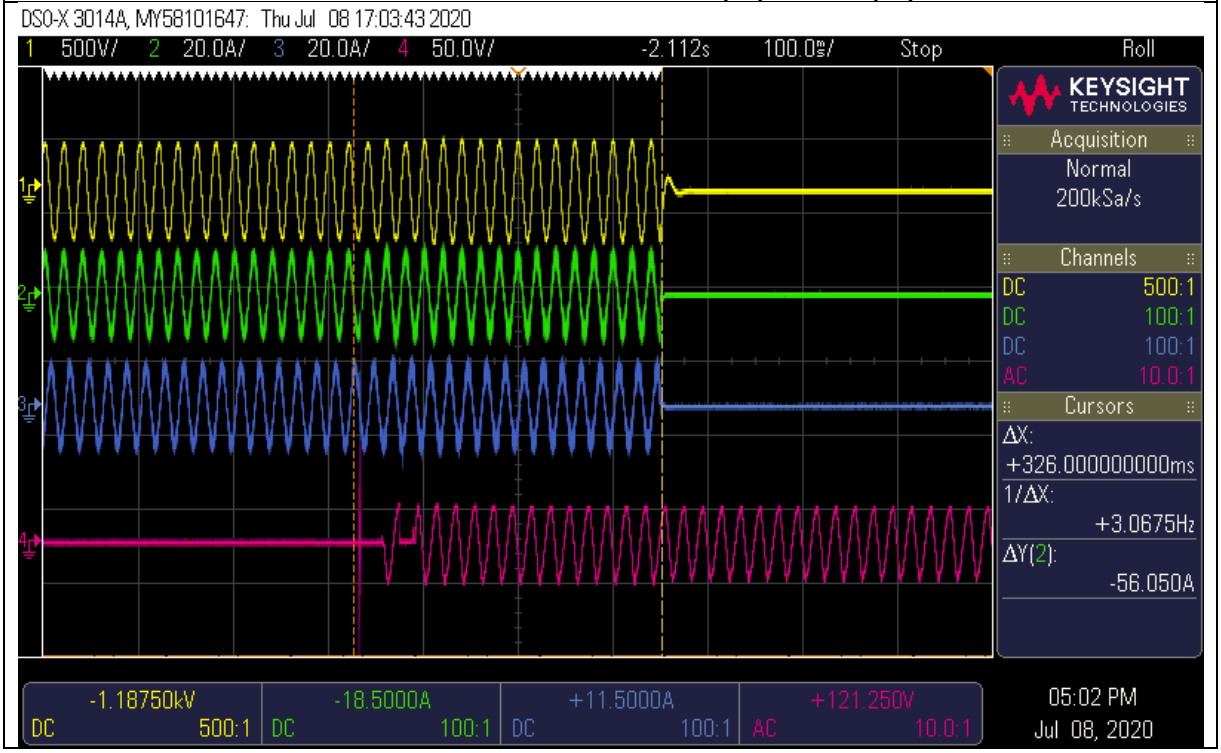
Test C **M(%)=0 & N(%)=+5**



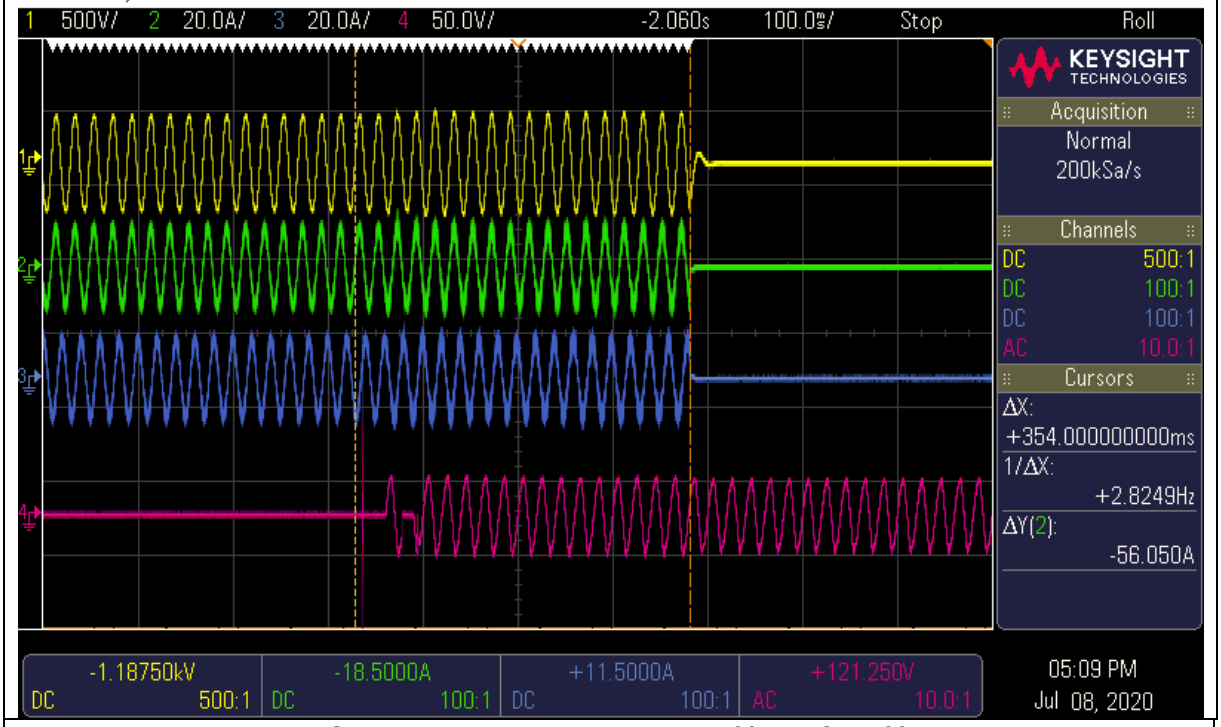
Test C **M(%)=0 & N(%)=-1**



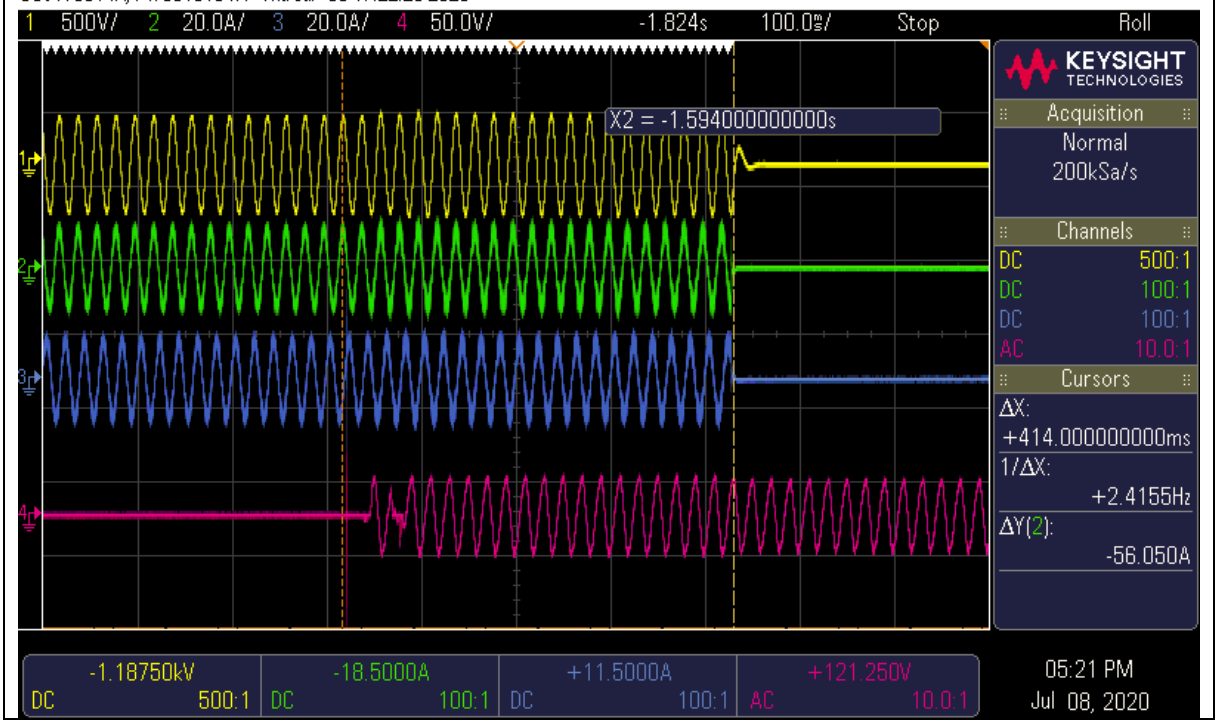
Test C **M(%)=0 & N(%)=-2**



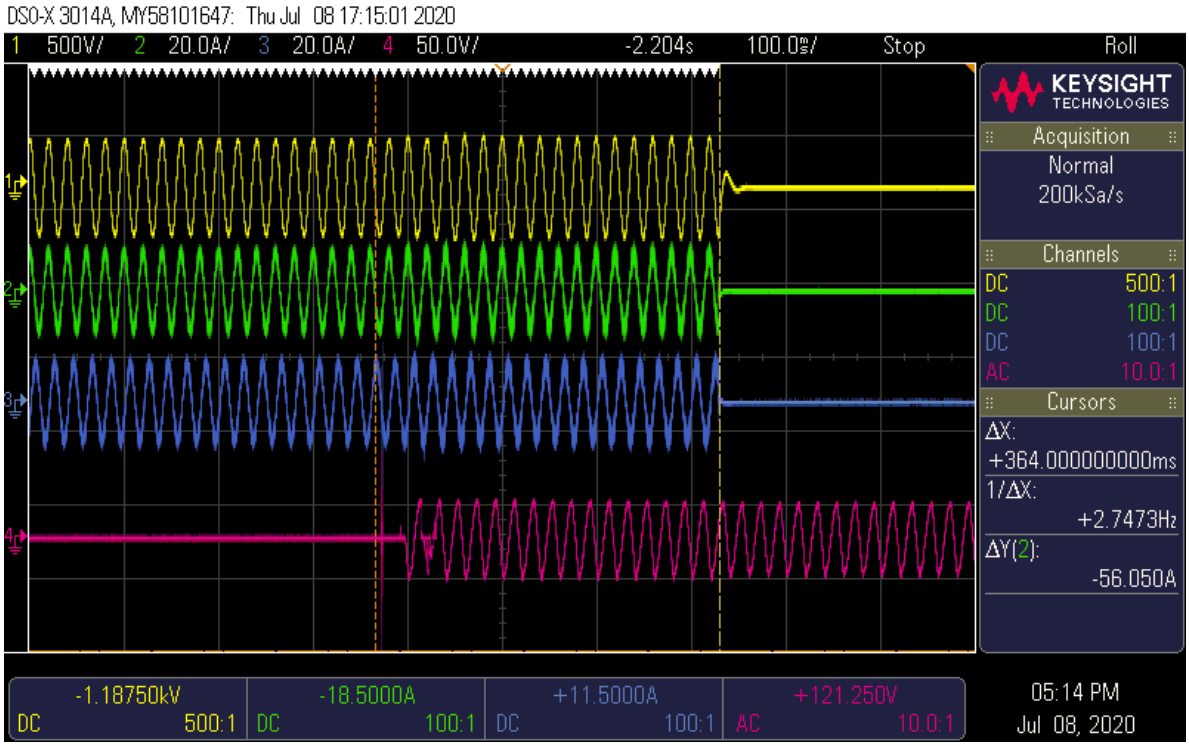
Test C **M(%)=0 & N(%)=-3**



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



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


DSO-X 3014A, MY58101647: Thu Jul 08 17:15:01 2020
1 500V/ 2 20.0A/ 3 20.0A/ 4 50.0V/
-2.204s
100.0ks/
Stop
Roll
KEYSIGHT TECHNOLOGIES
Acquisition
Normal
200kSa/s
Channels
DC 500:1
DC 100:1
DC 100:1
AC 10.0:1
Cursors
ΔX:
+364.000000000ms
1/ΔX:
+2.7473Hz
ΔY(2):
-56.050A
-1.18750kV DC 500:1
-18.5000A DC 100:1
+11.5000A DC 100:1
+121.250V AC 10.0:1
05:14 PM
Jul 08, 2020

4.3.4 Loss of Mains Protection, Vector Shift Stability test and *RoCoF Stability test*

This test should be carried out in accordance with Annex A.7.1.2.6.

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 Power Generating Module 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 Power Generating Module should not trip during this test.

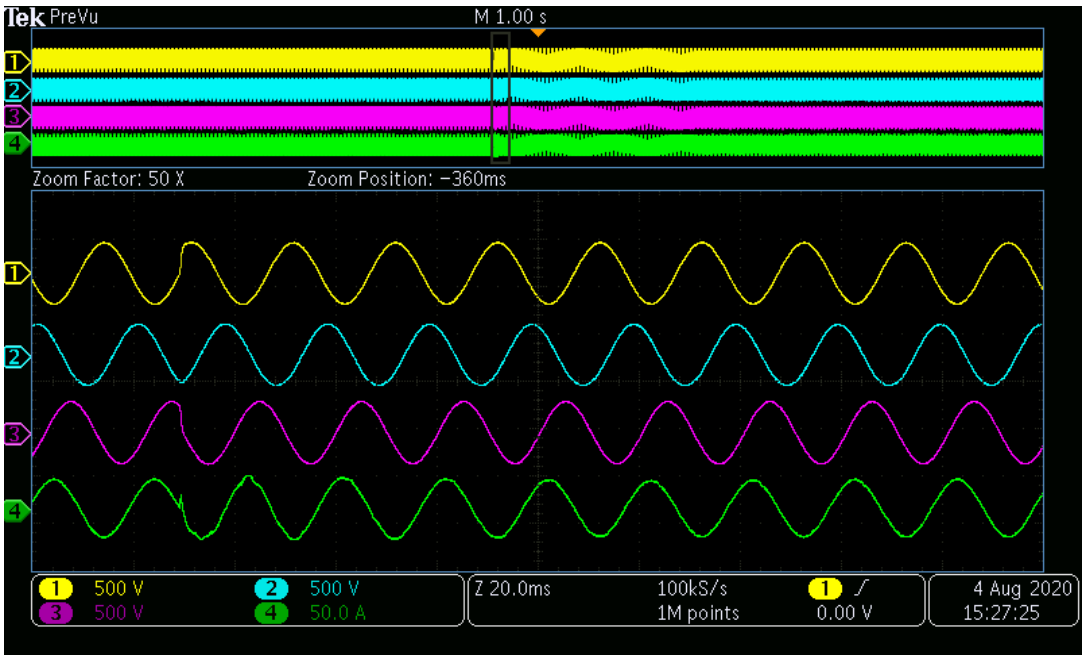
For frequency drift tests the Power Generating Module should be operated with a measurable output at the start frequency and then the frequency changed in a ramp function at 0.95 Hz/s to the end frequency. On reaching the end frequency it should be maintained for a period of at least 10s. The Power Generating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

Test results are graphically shown in following pages.

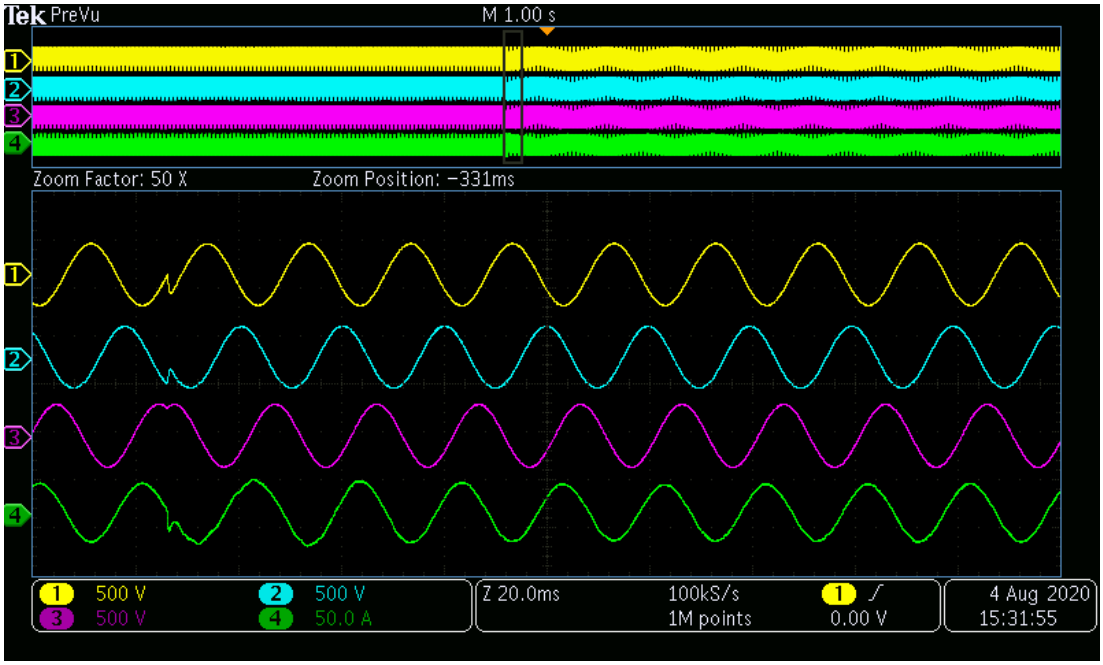
Protection –Loss of Mains Protection, Vector Shift Stability test: This test should be carried out in accordance with Annex A.7.1.2.6.

	Start Frequency	Change	Confirm no trip
Positive Vector Shift	49.5 Hz	+50 degrees	Pass
Negative Vector Shift	50.5 Hz	- 50 degrees	Pass

Positive Vector Shift:

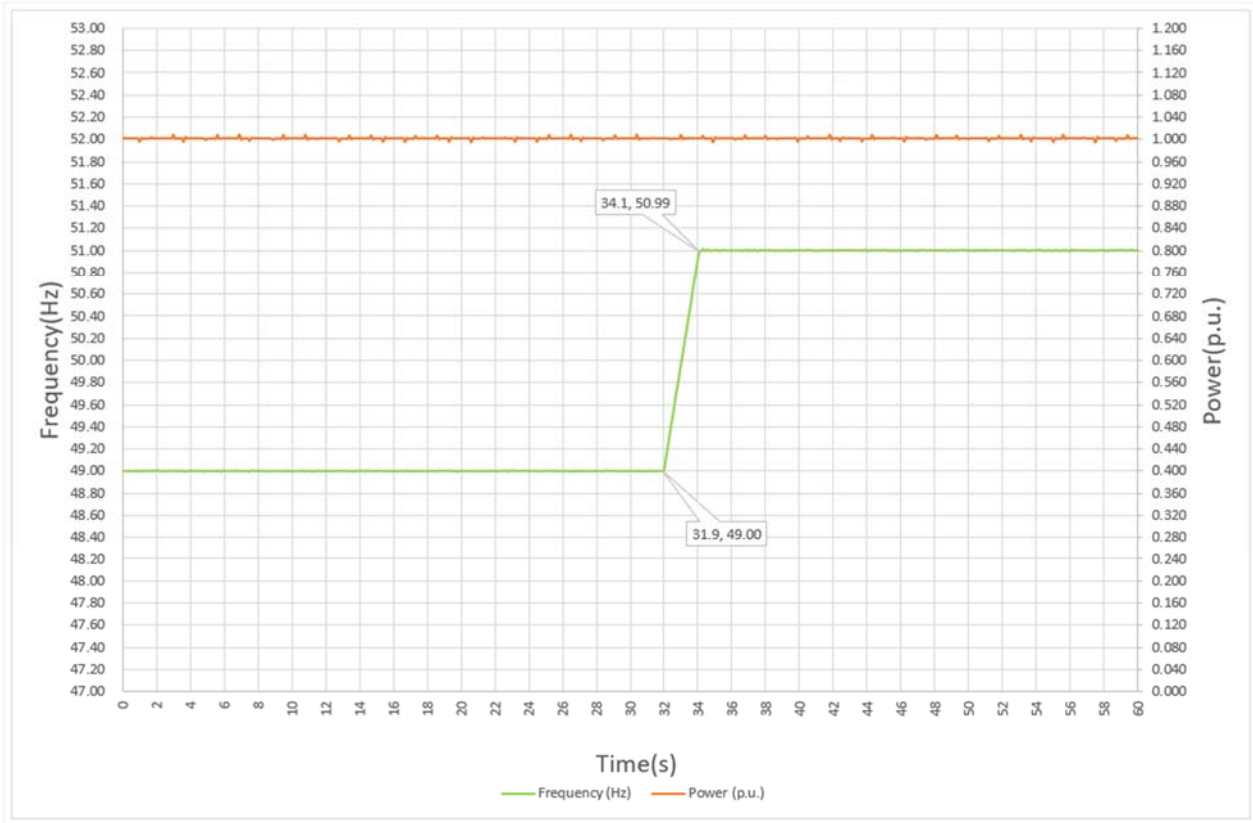


Negative Vector Shift:

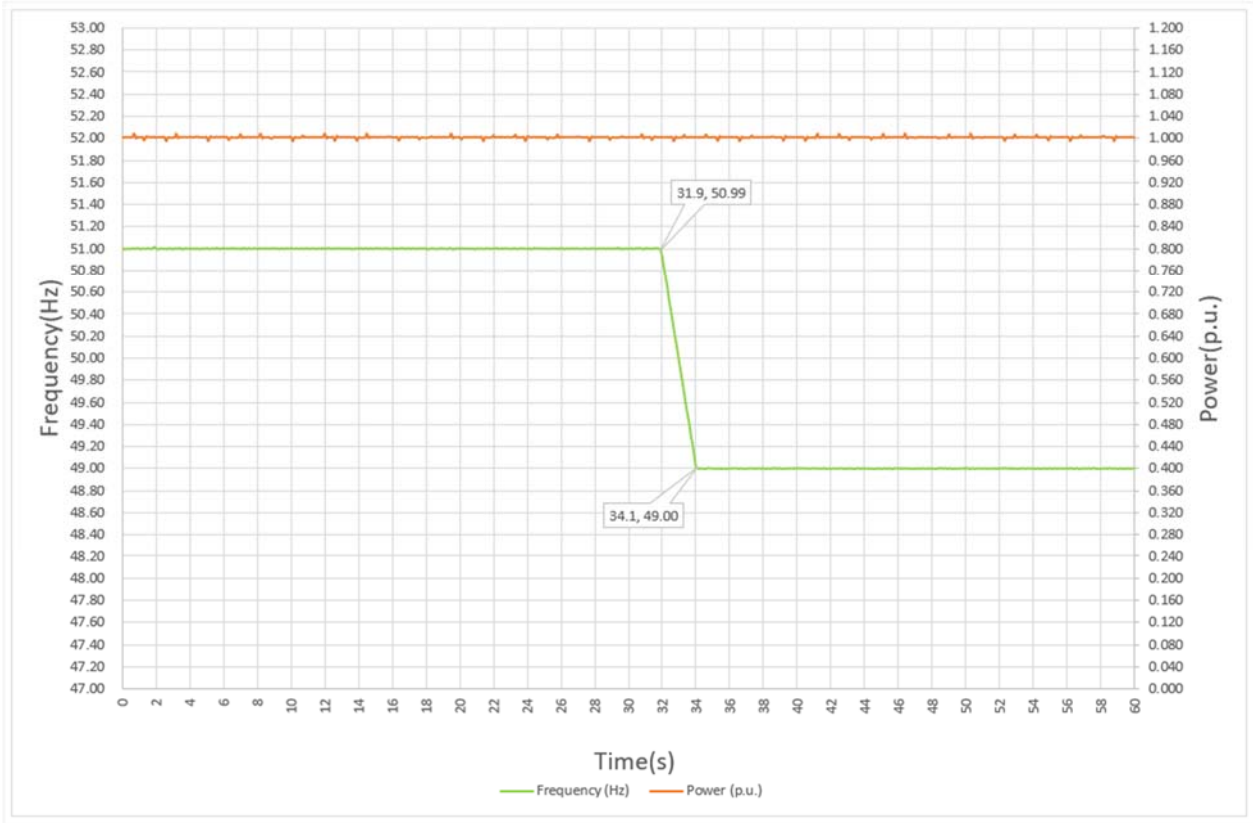


Protection –Loss of Mains Protection, RoCoF Stability test: This test should be carried out in accordance with Annex A.7.1.2.6.			
Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+0.95 Hzs^{-1}	2.2 s	Pass
51.0 Hz to 49.0 Hz	-0.95 Hzs^{-1}	2.2 s	Pass

+0.95 Hz/s:



-0.95 Hz/s:



4.4 Limited Frequency Sensitive Mode - Overfrequency test

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

The test should be carried out above 80% Registered Capacity and repeated at 40-60% Registered Capacity using the specific threshold frequency of 50.4 Hz and Droop of 10%.

The Power Park Module should be tested at the following frequencies:
Step a) 50.00 Hz ±0.01 Hz
Step b) 50.45 Hz ±0.05 Hz
Step c) 50.70 Hz ±0.10 Hz
Step d) 51.15 Hz ±0.05 Hz
Step e) 50.70 Hz ±0.10 Hz
Step f) 50.45 Hz ±0.05 Hz
Step g) 50.00 Hz ±0.01 Hz

The frequency at each step should be maintained for at least one minute and the Active Power reduction in the form of a gradient determined and assessed for compliance with paragraph 11.2.3.

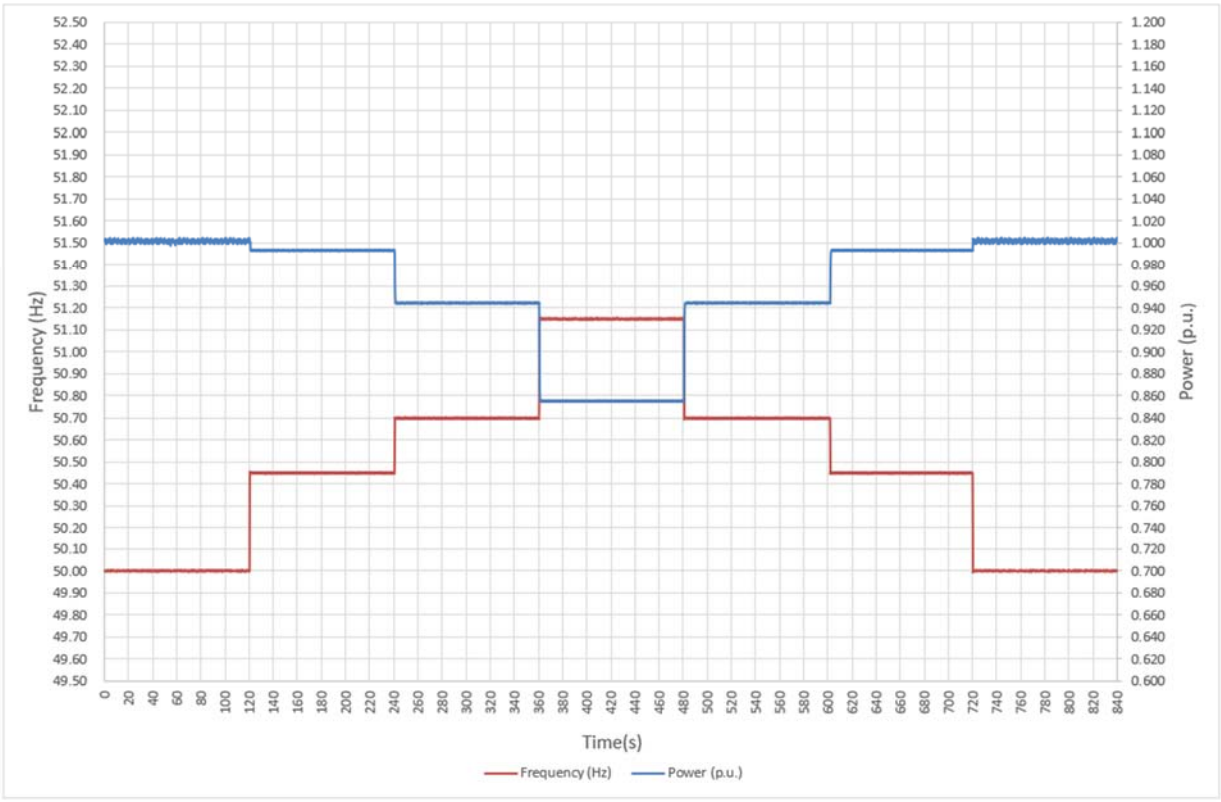
Following tables show the test results:

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	15027.6	50.00	DC Souce	N/A
Step b) 50.45 Hz ±0.05 Hz	14897.2	50.45		11.5%
Step c) 50.70 Hz ±0.10 Hz	14166.4	50.70		10.5%
Step d) 51.15 Hz ±0.05 Hz	12829.5	51.15		10.3%
Step e) 50.70 Hz ±0.10 Hz	14164.8	50.70		10.4%
Step f) 50.45 Hz ±0.05 Hz	14896.9	50.45		11.5%
Step g) 50.00 Hz ±0.01 Hz	15029.4	50.00		N/A

Test sequence at Registered Capacity 40% - 60%	Measured Active Power Output (W)	Frequency (Hz)	Primary Power Source	Active Power Gradient
Step a) 50.00 Hz ±0.01 Hz	7516.2	50.00	DC Souce	N/A
Step b) 50.45 Hz ±0.05 Hz	7451.4	50.45		11.6%
Step c) 50.70 Hz ±0.10 Hz	7089.3	50.70		10.6%
Step d) 51.15 Hz ±0.05 Hz	6430.1	51.15		10.4%
Step e) 50.70 Hz ±0.10 Hz	7089.1	50.70		10.6%
Step f) 50.45 Hz ±0.05 Hz	7451.5	50.45		11.6%
Step g) 50.00 Hz ±0.01 Hz	7515.9	50.00		N/A

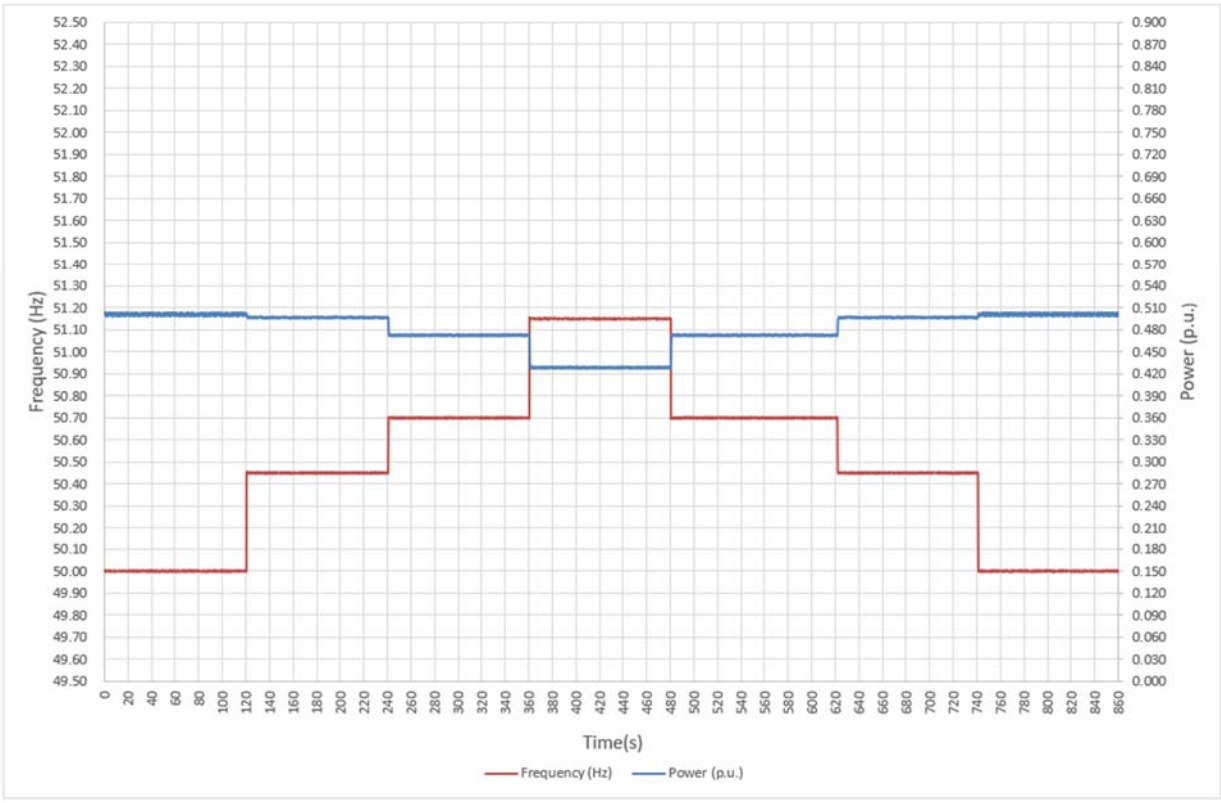
Test results are graphically shown in following pages.

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 Re-connection timer

Test should prove that the reconnection sequence starts after a minimum delay of 20 s for restoration of voltage and frequency to within the stage 1 settings of Table 10.1.

The evaluation of this point has been made according to Annex A.7.2.2.5.

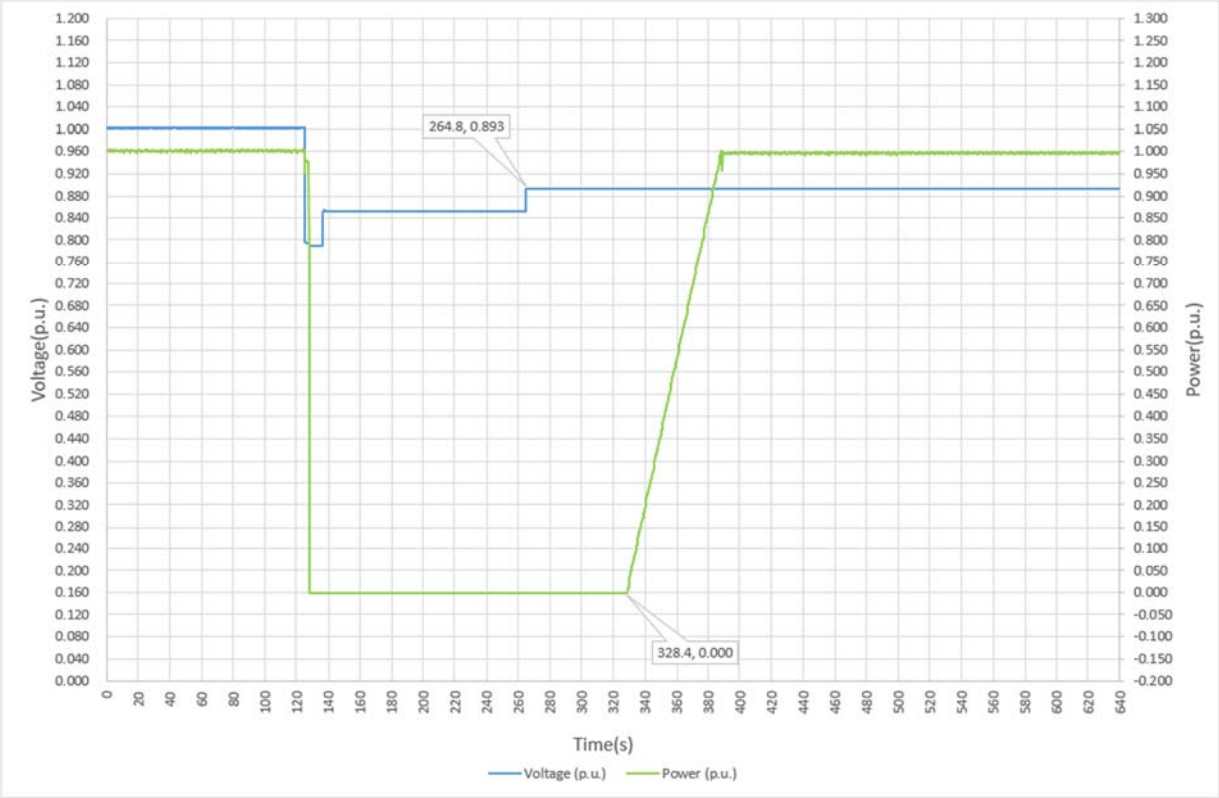
4.5.1 Voltage Reconnection Conditions

The following table detail tests performed.

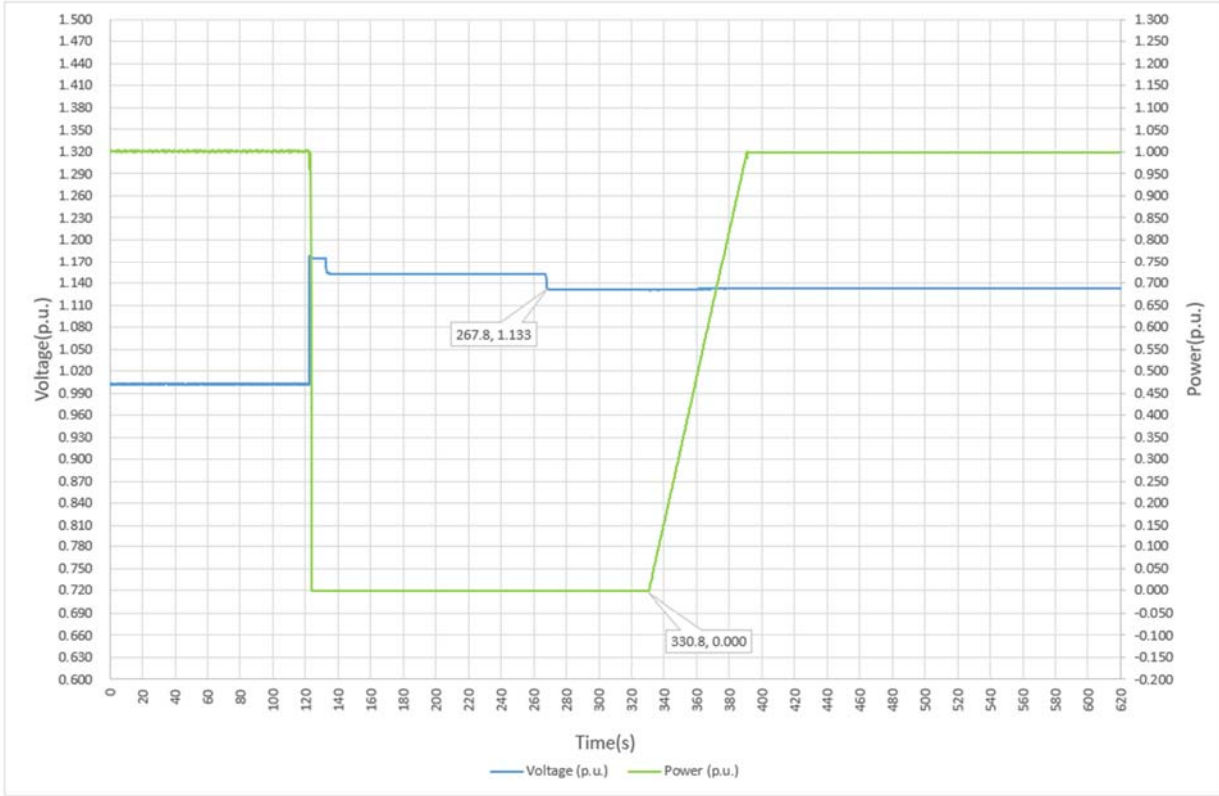
Test at	Time delay setting(s)	Measured delay(s)	Checks on no reconnection when voltage is brought to just outside stage 1 limits of table 1.	
UV	60	63.6	At 266.2V	At 196.1V
OV	60	63.0		
Confirmation that the Micro-generator does not re-connect.			Not reconnection	Not reconnection

Test results are graphically shown below.

Under voltage reconnection



Over voltage reconnection



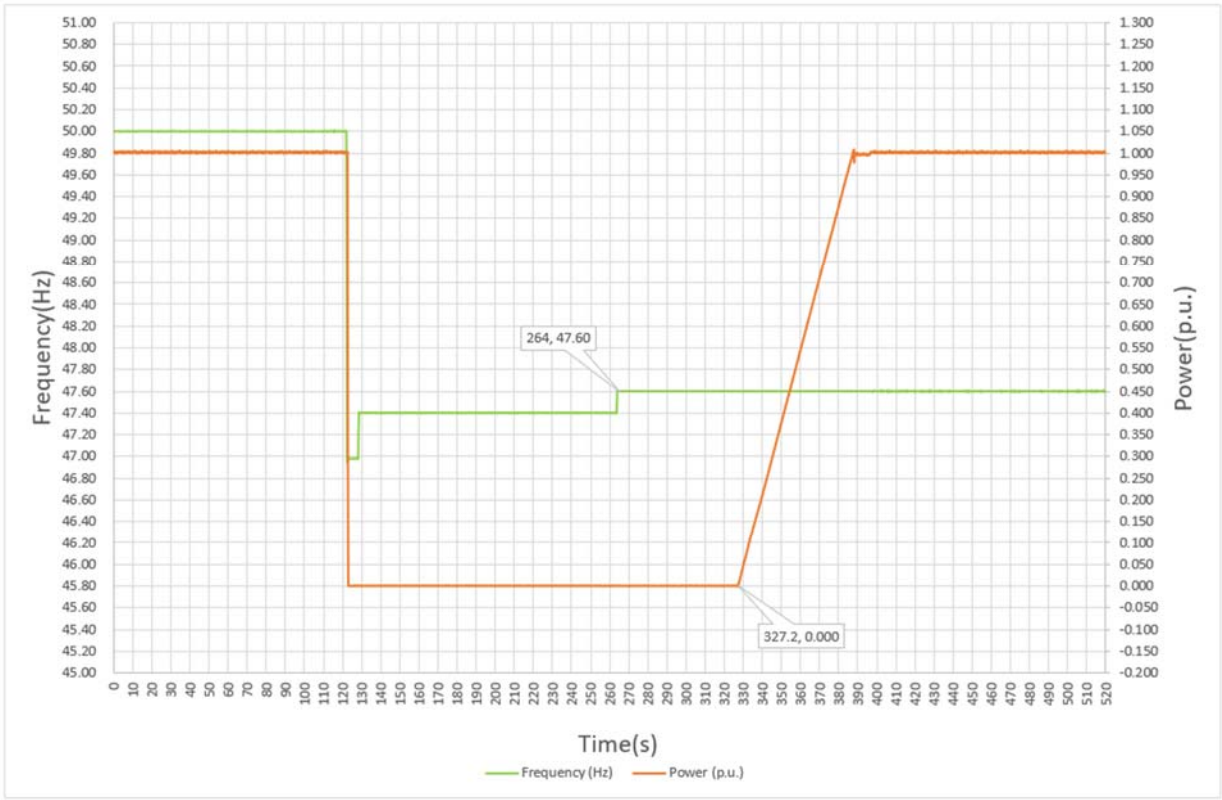
4.5.2 Frequency Reconnection Conditions

The following table detail tests performed.

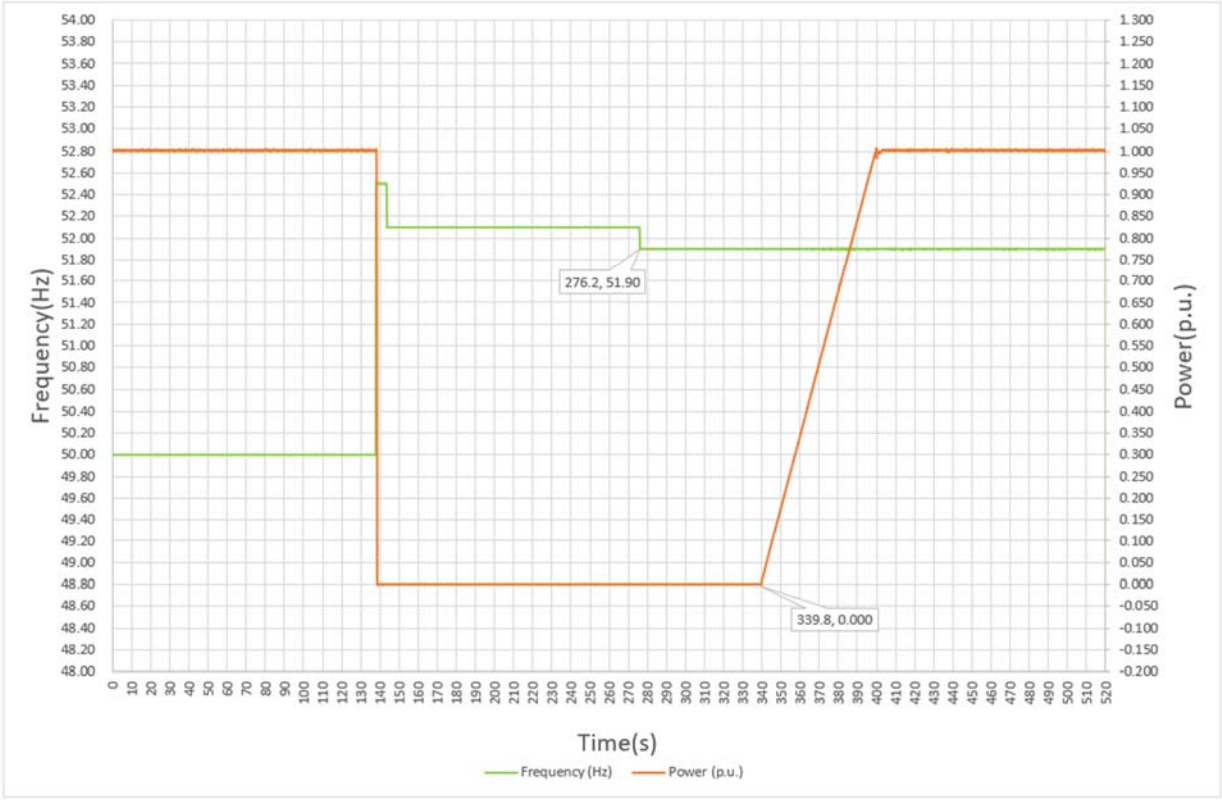
Test at	Time delay setting(s)	Measured delay(s)	Checks on no reconnection when frequency is brought to just outside stage 1 limits of table 1.	
UF	60	63.2	At 47.4Hz	At 52.1Hz
OF	60	63.6		
Confirmation that the Micro-generator does not re-connect.			Not reconnection	Not reconnection

Test results are graphically shown below.

Under frequency reconnection



Over frequency reconnection



4.6 Fault level contribution

These tests shall be carried out in accordance with EREC G99 Annex A.7.1.5.

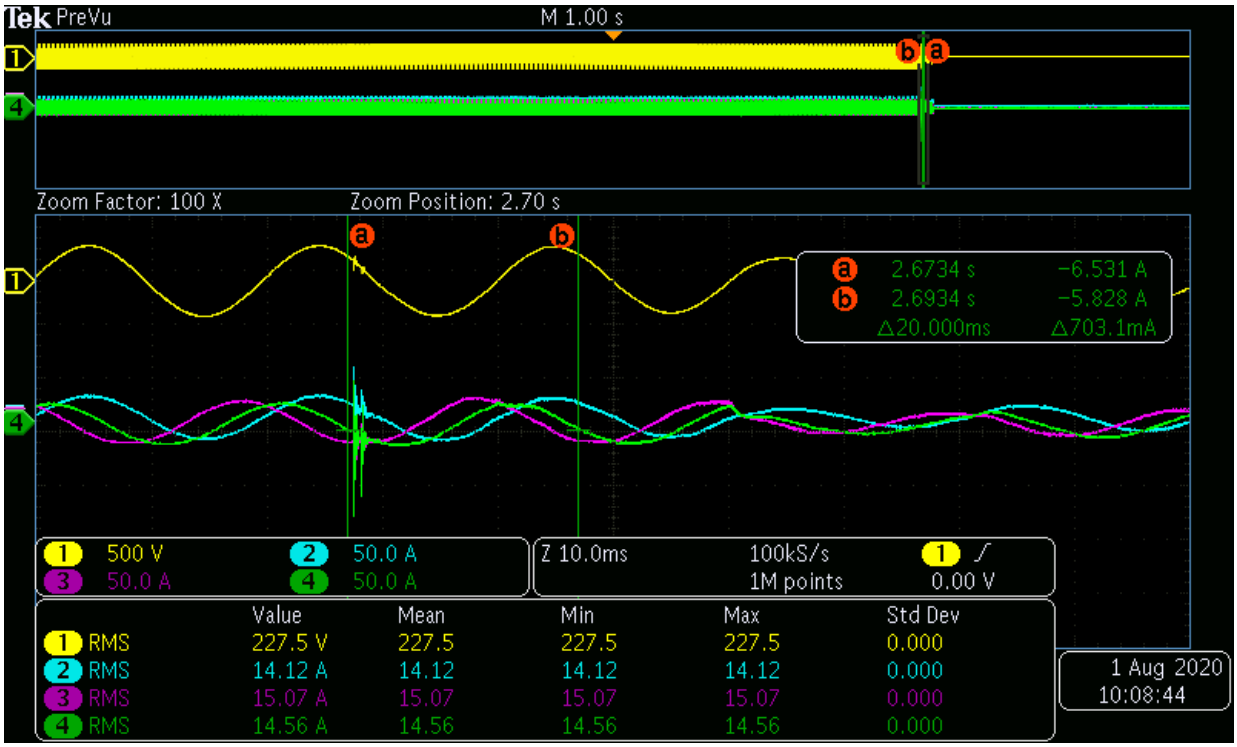
They have been performed different short circuit tests that are detailed in the table and pictures below.

Short circuit current		
L3-LN		
Time after fault	**Volts(V)**	**Amps(A)**
20ms	227.5	15.07
100ms	166.6	11.3
250ms	0.0	0.0
500ms	0.0	0.0
Time to trip	0.0	In seconds

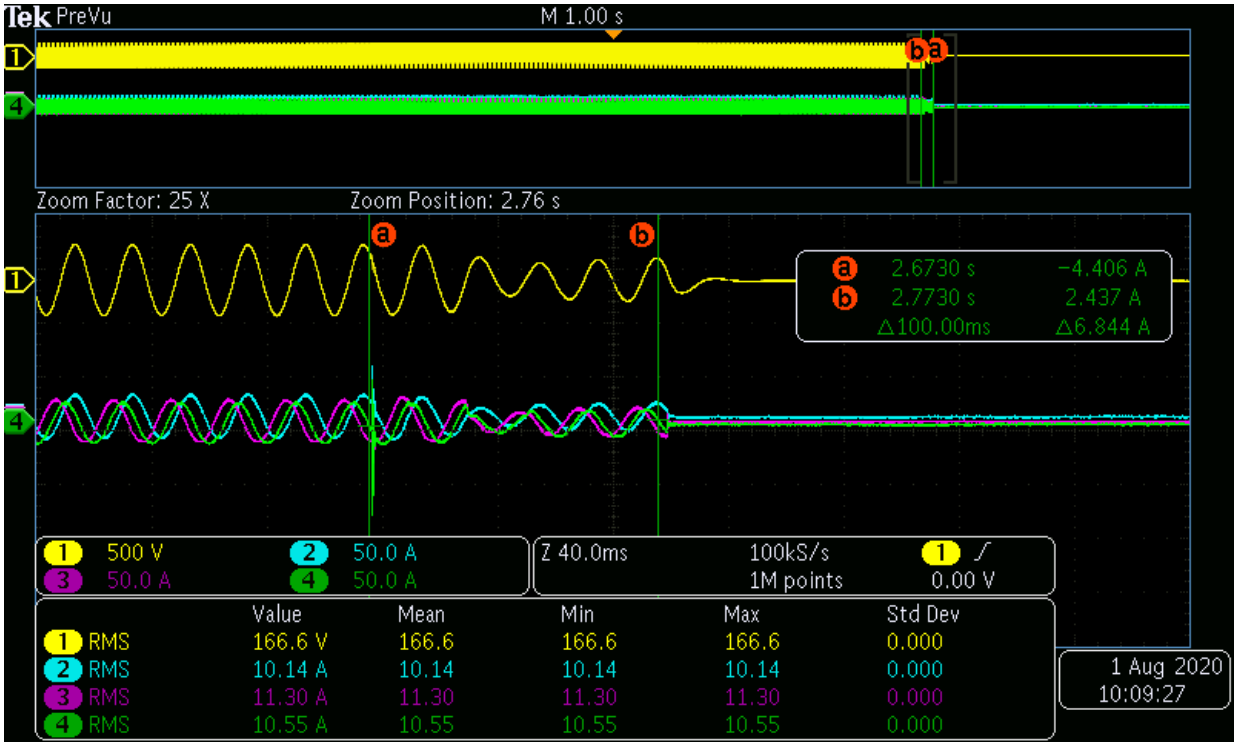
Short circuit current		
L3-L2		
Time after fault	**Volts(V)**	**Amps(A)**
20ms	231.0	18.6
100ms	223.8	16.4
250ms	0.0	0.0
500ms	0.0	0.0
Time to trip	0.0	In seconds

L3-LN

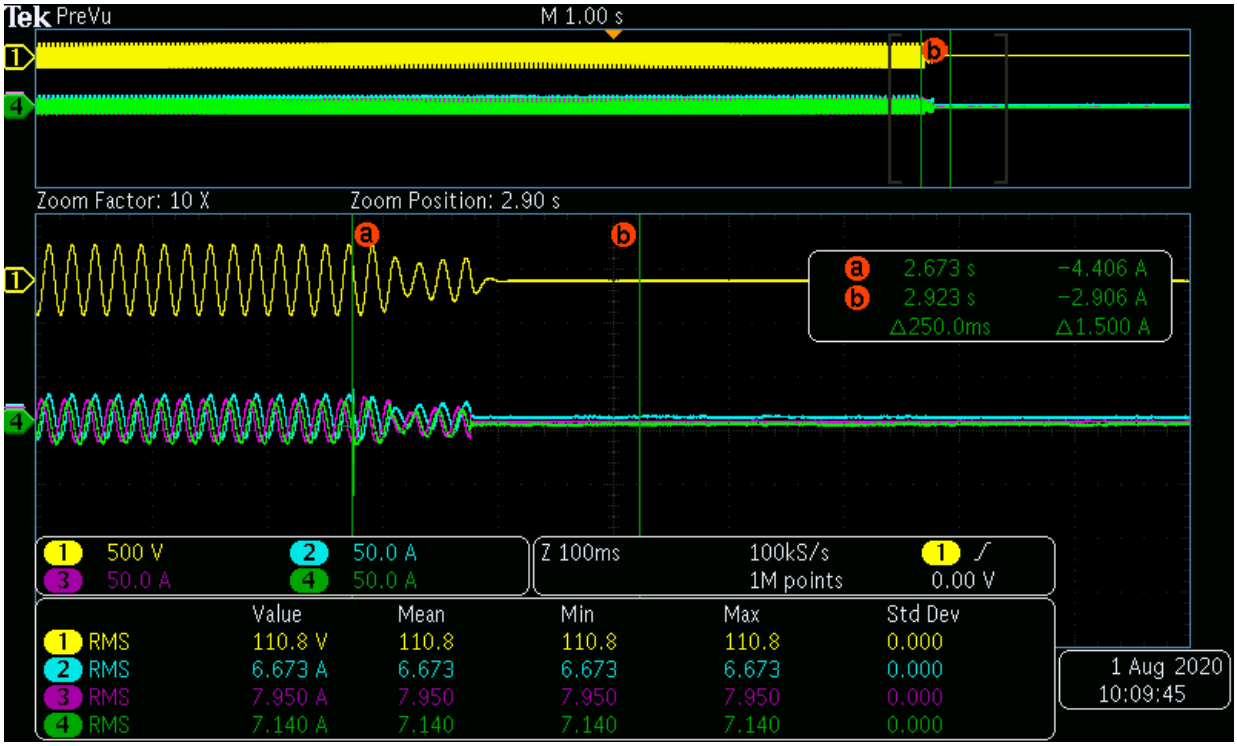
Time after 20ms fault



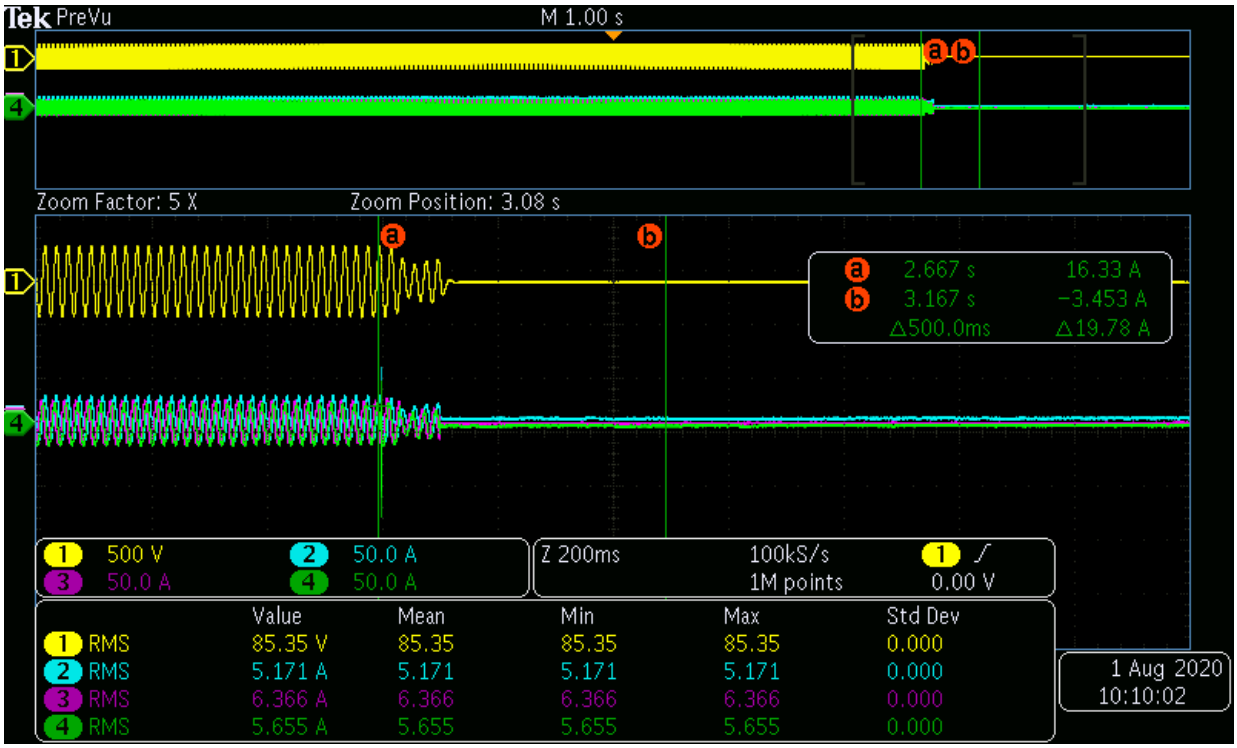
Time after 100ms fault



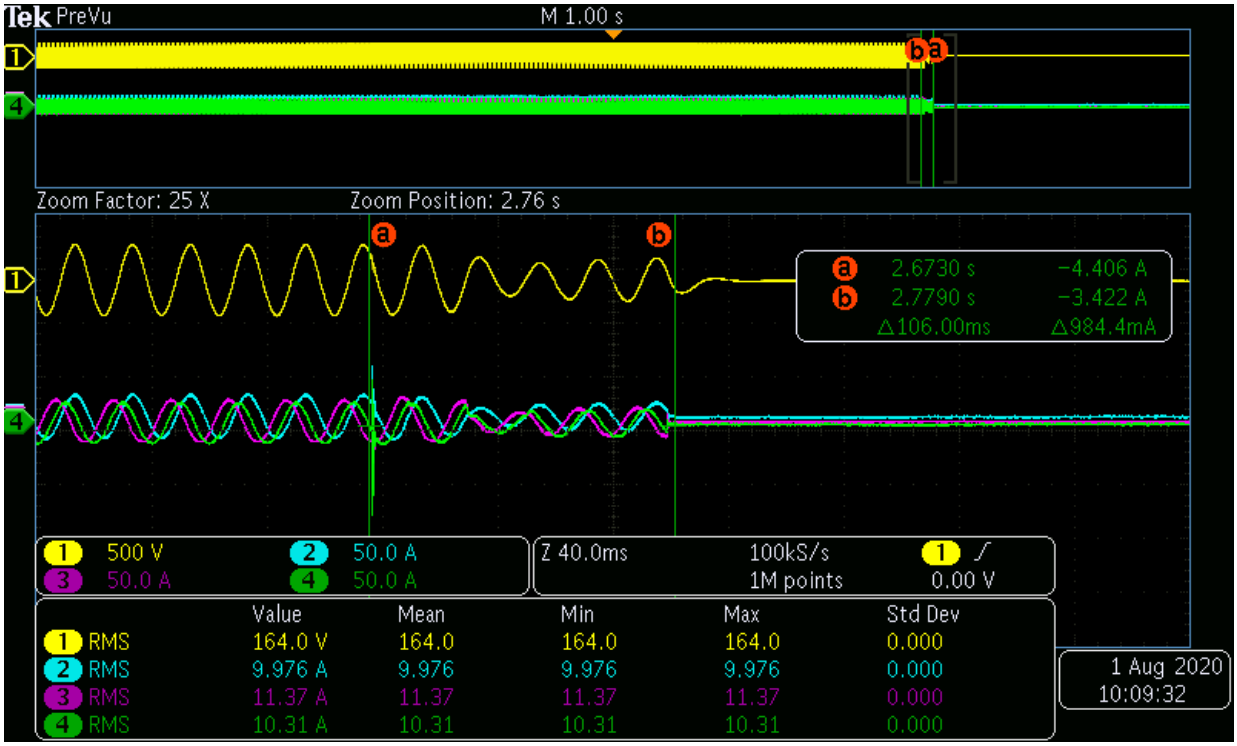
Time after 250ms fault



Time after 500ms fault

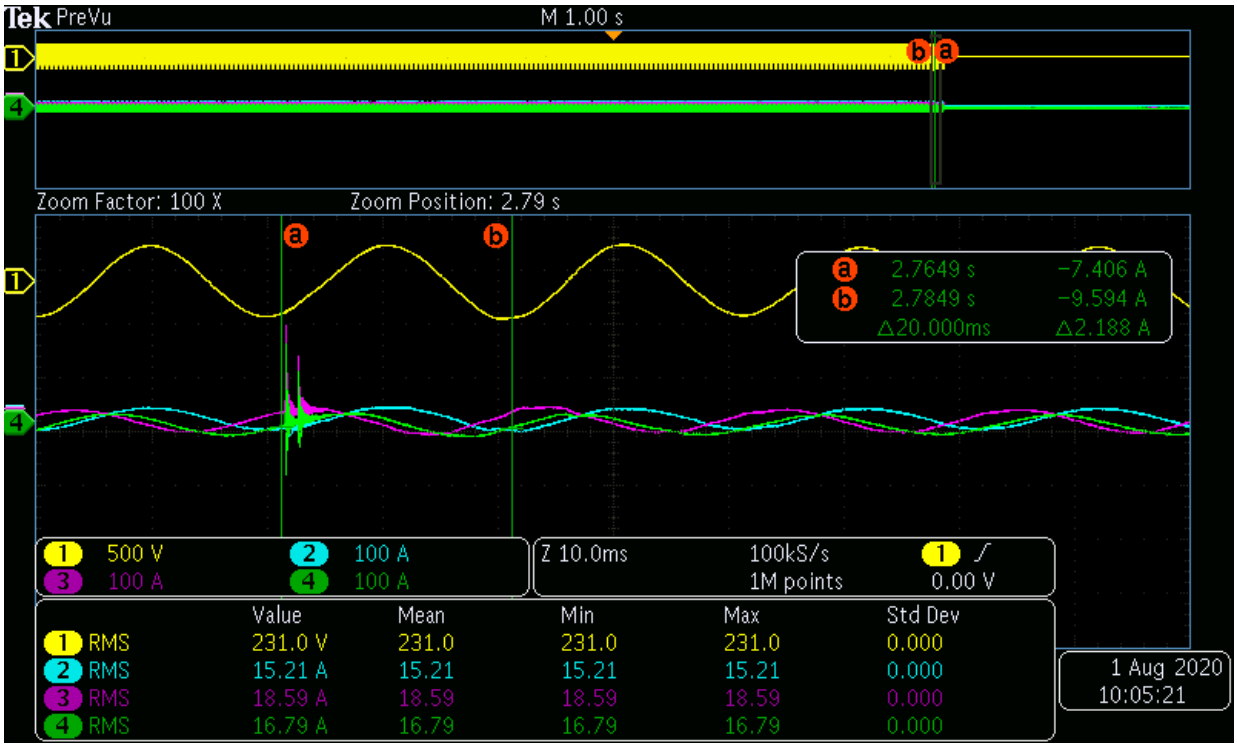


Time to trip

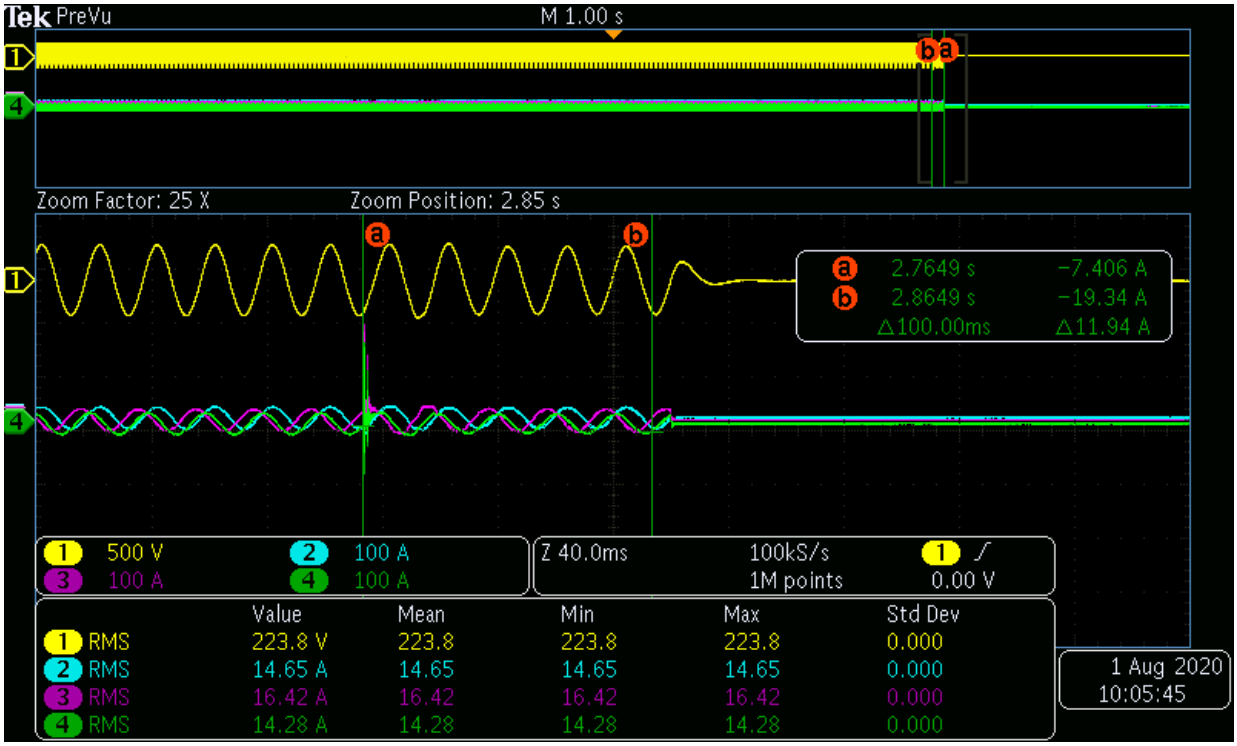


L3-L2

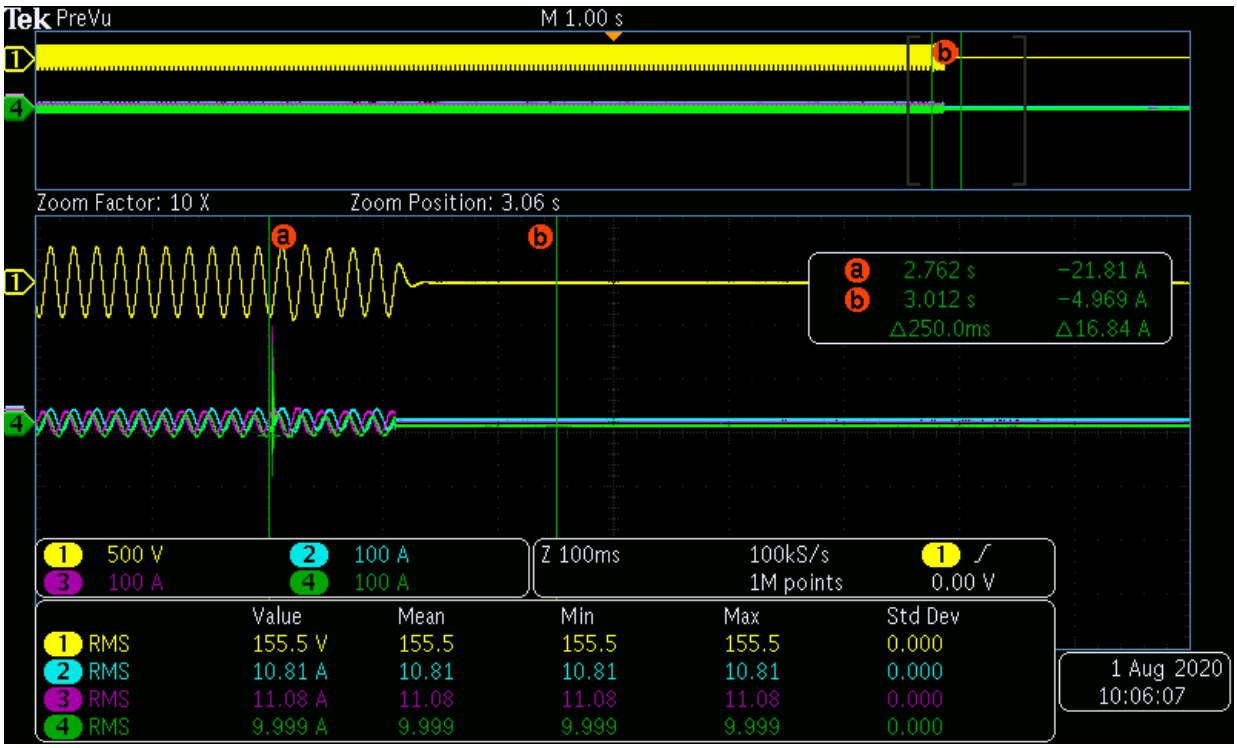
Time after 20ms fault



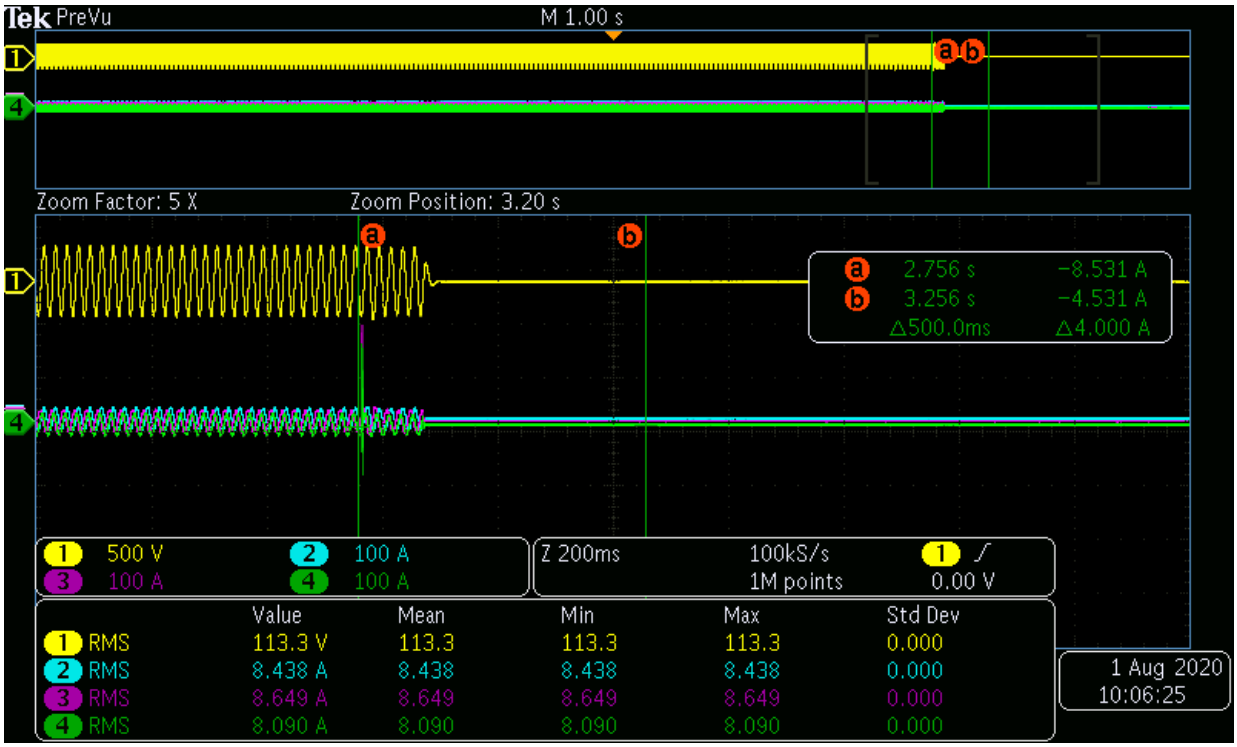
Time after 100ms fault



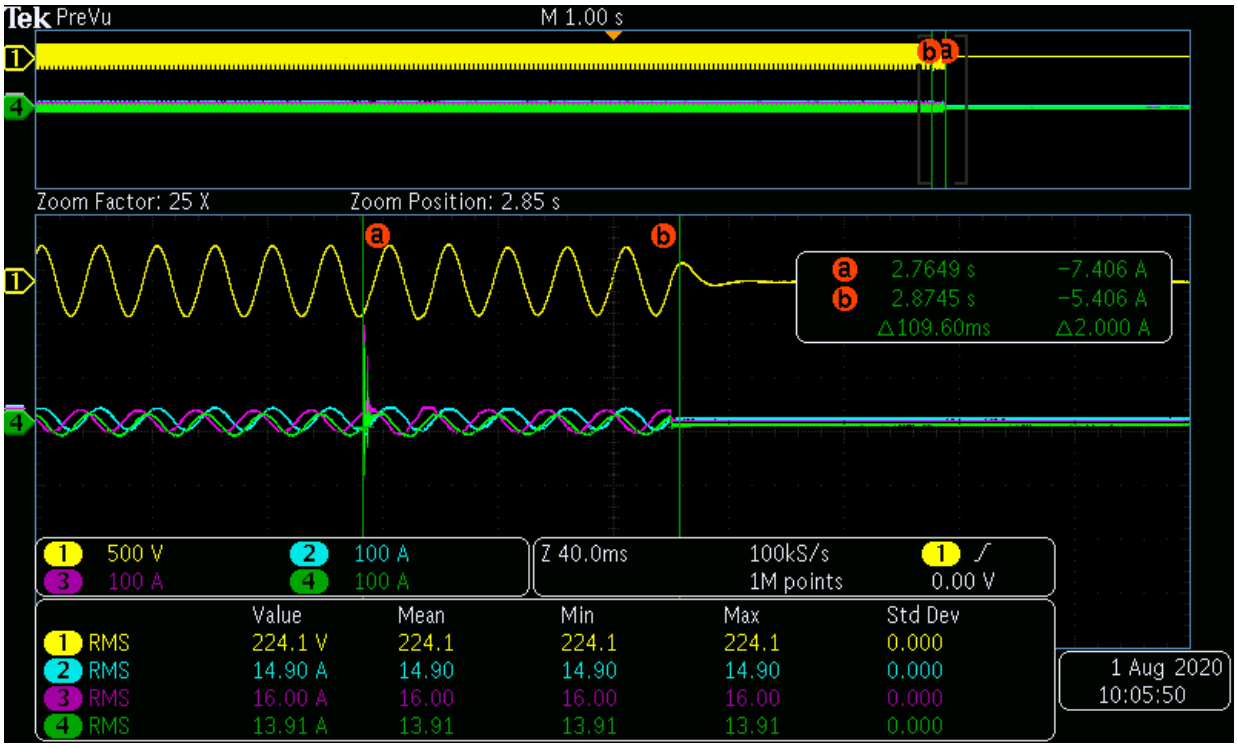
Time after 250ms fault



Time after 500ms fault



Time to trip



4.7 SELF-MONITORING SOLID STATE SWITCHING

It has been verified that in the event of the solid state switching device failing to disconnect the Power Park Module, the voltage on the output side of the switching device is reduced to a value below 50 volts within 0.5 s.

The evaluation of this point has been made according to Annex A.7.1.7.

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

4.8 WIRING FUNCTIONAL TESTS:

Where Type Tested components are wired together on site, ie not using specifically designed plugs and sockets for the purpose, it will be necessary to prove that all wiring has been correctly terminated by proving the functions which rely on the wiring. The Generator will submit to the DNO for agreement a schedule of the wiring connections to be made, the functions that they enable, and the tests to prove them. Satisfactory completion of the agreed tests will enable the Power Generating Modules to attain or retain Type Tested status.

This test does not apply because connectors were designed error-proof connectors.

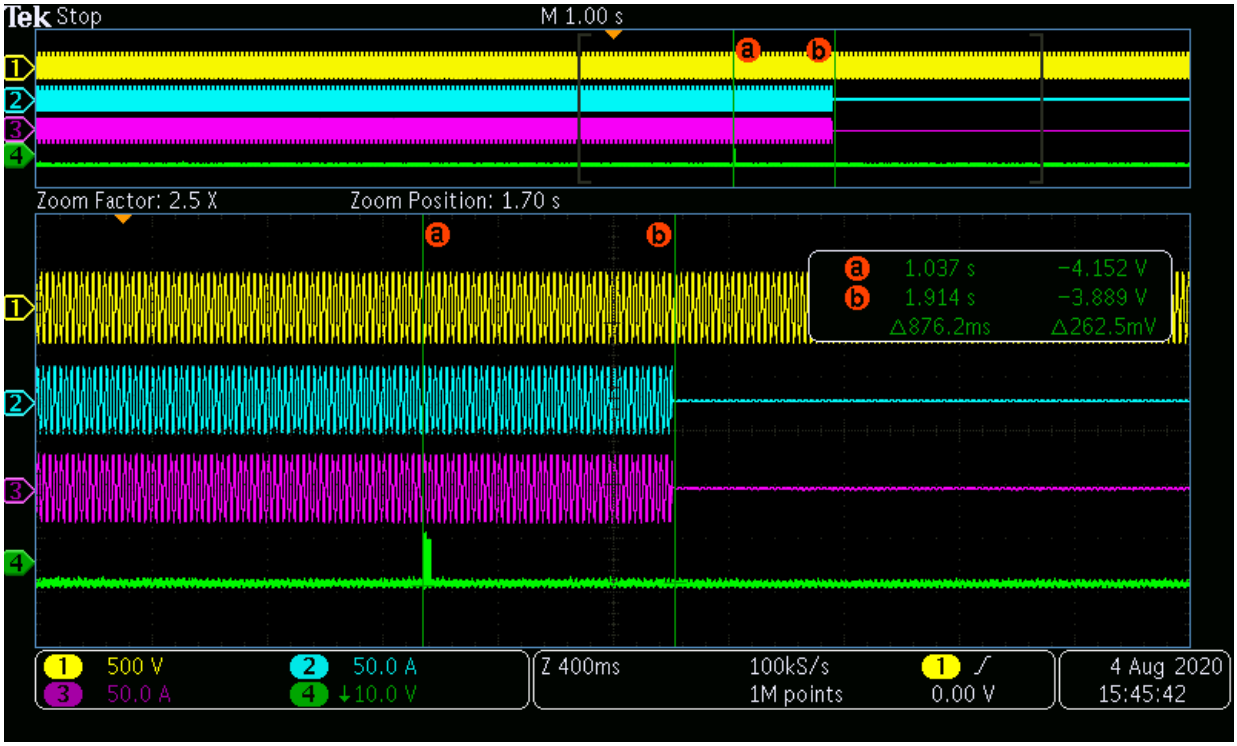
4.9 LOGIC INTERFACE (INPUT PORT).

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 11.1.3 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

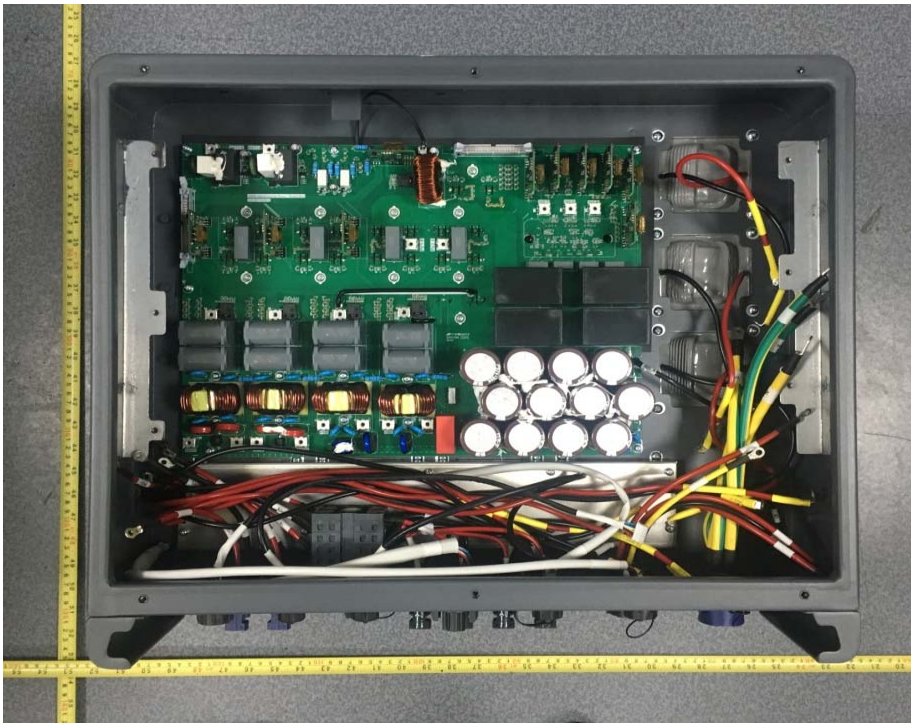
Ch4: Signal of logic interface.

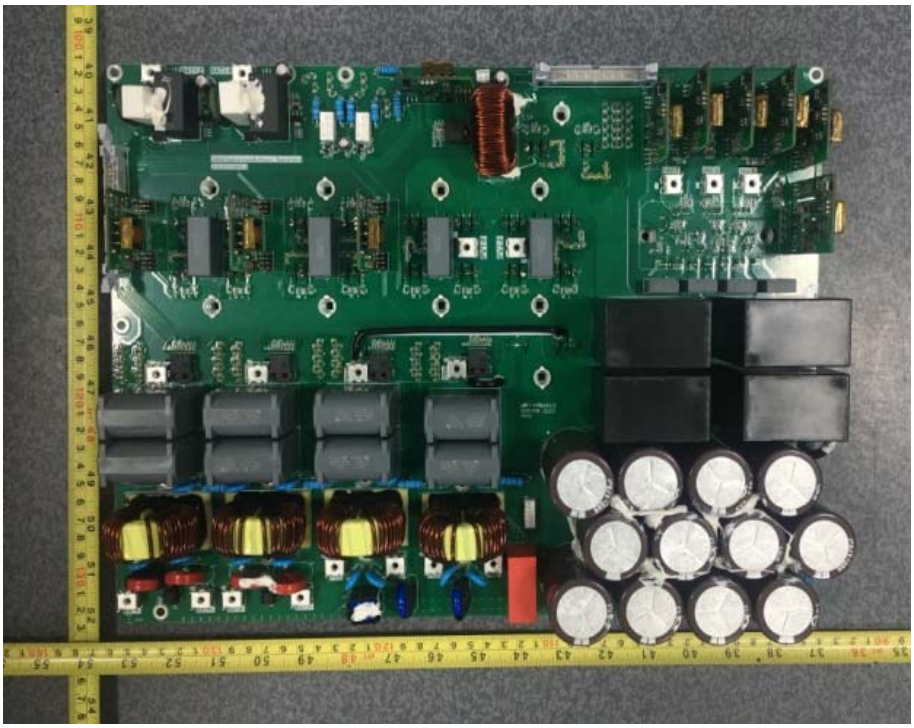
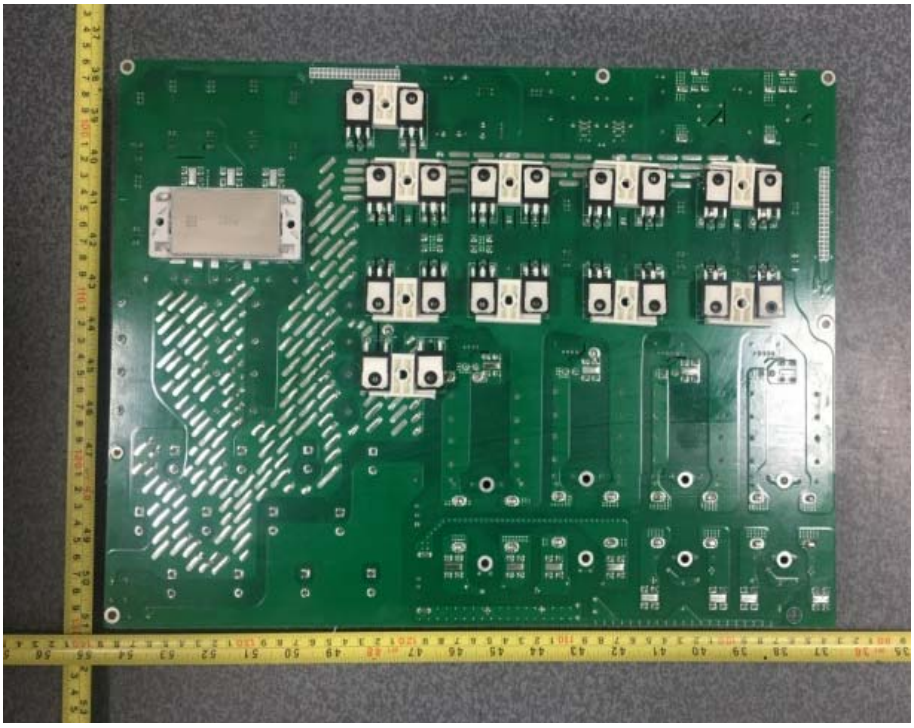
5 PICTURES

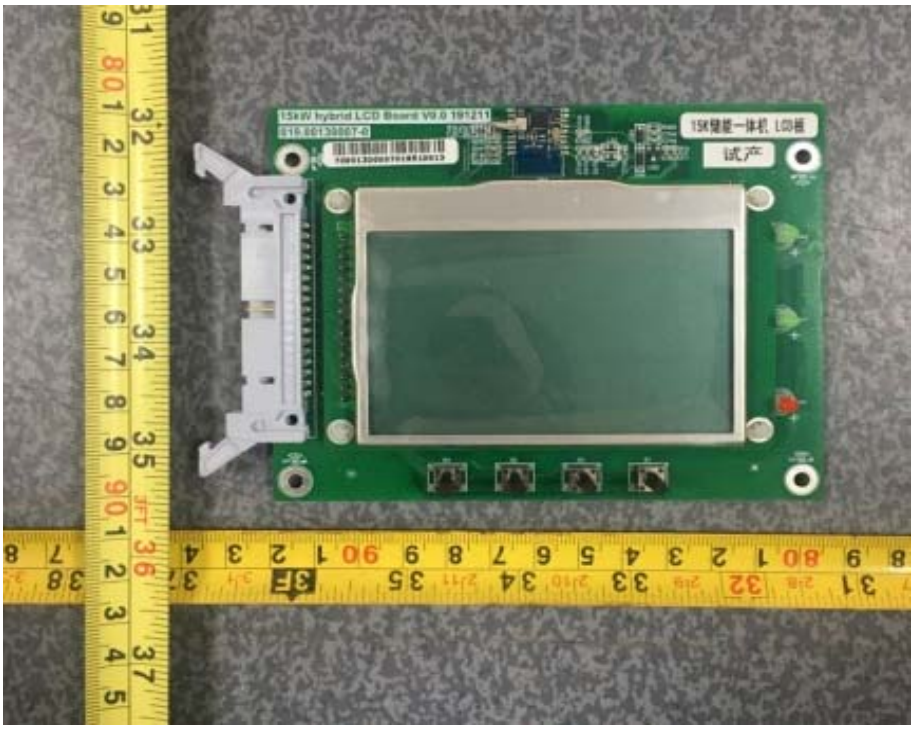
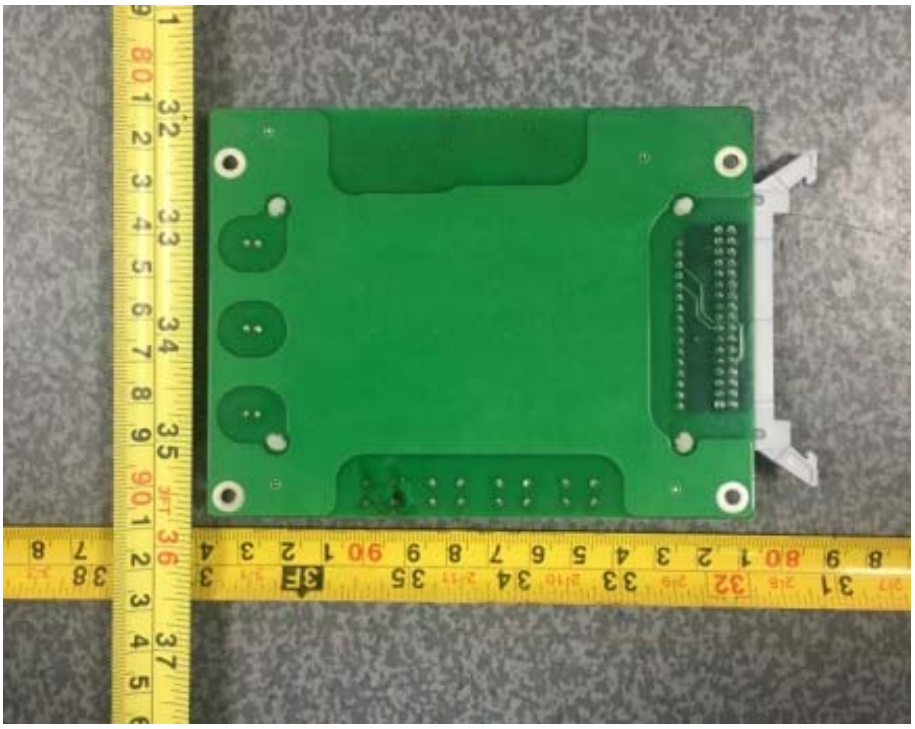
Front view

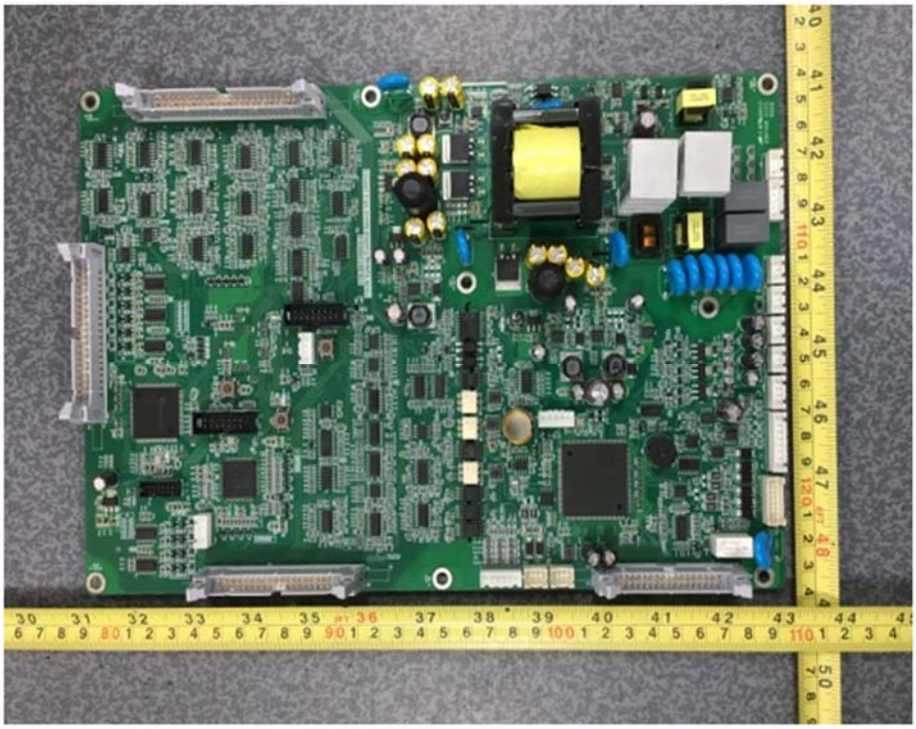
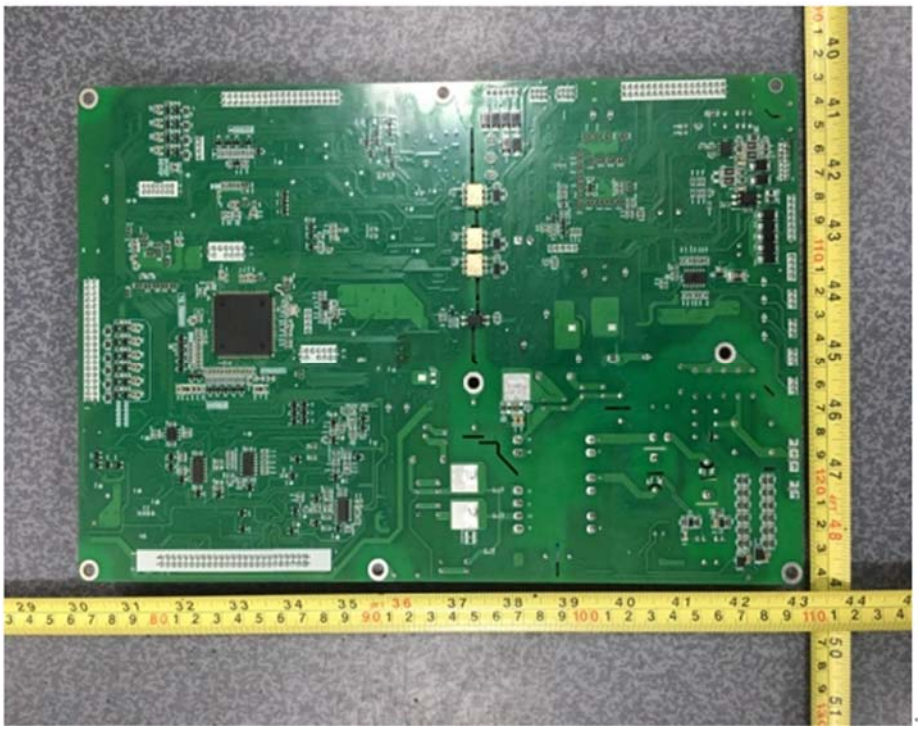
Back view

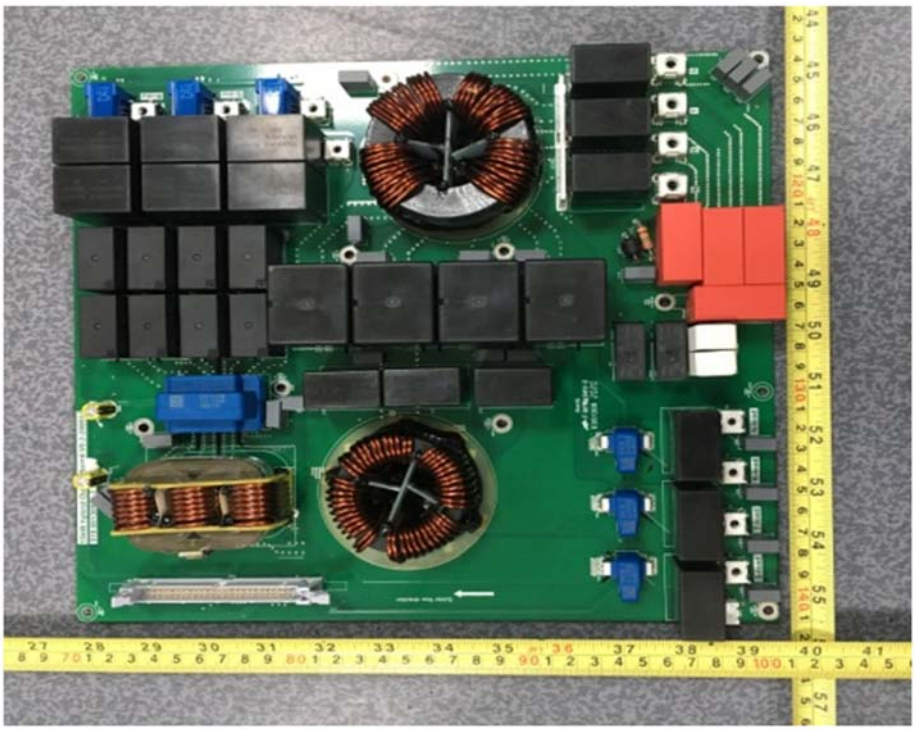
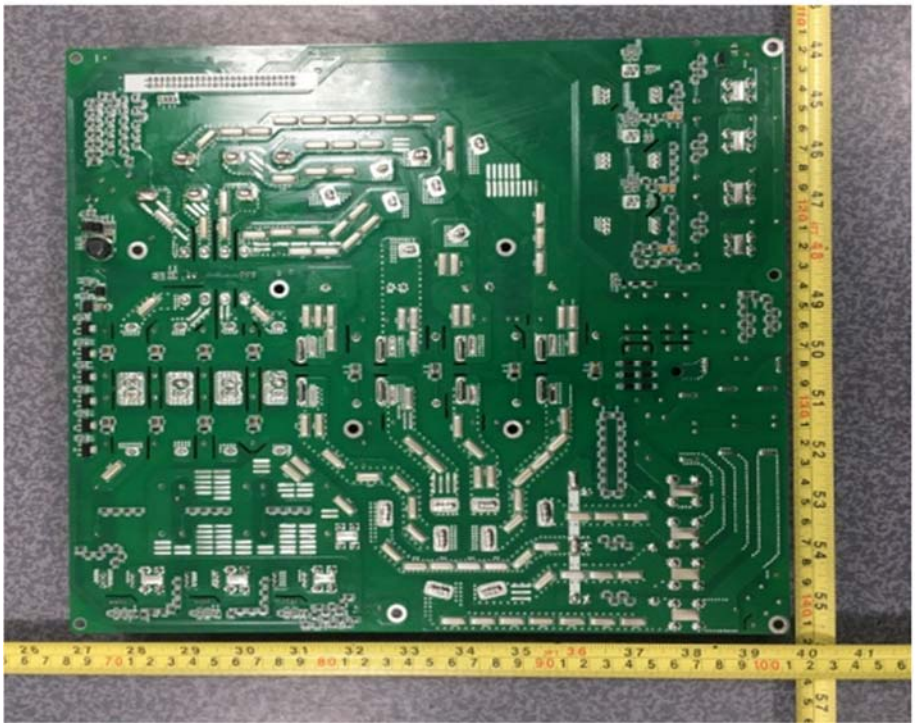

Internal View 1


Internal View 2


Front side of Power board

Back side of Power board


Front side of Display board

Back side of Display board


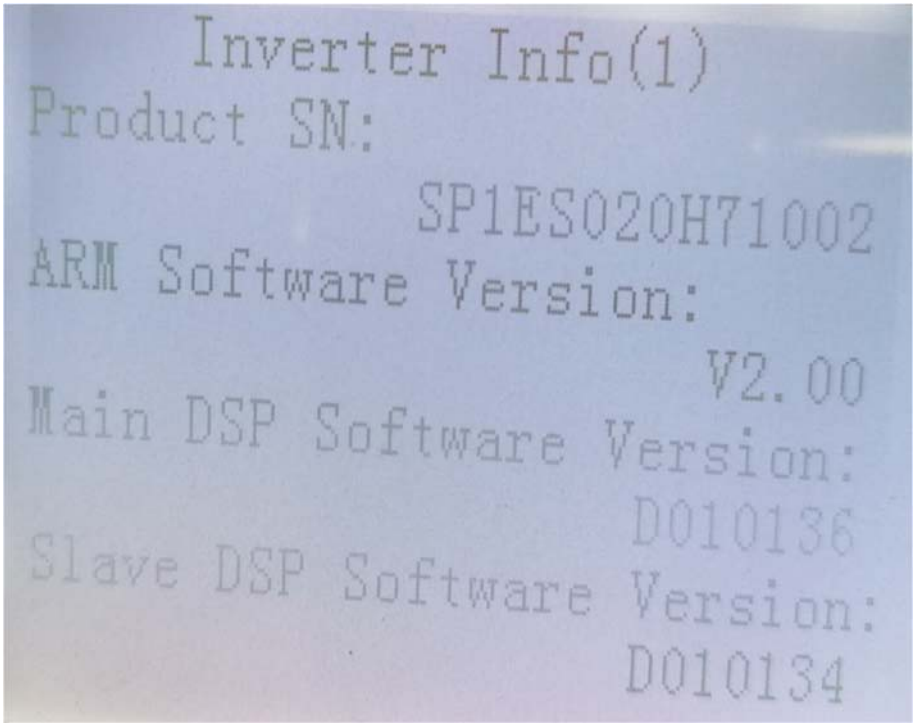
Front side of Control board

Back side of Control board


Front side of Output board front

Back side of Output board front


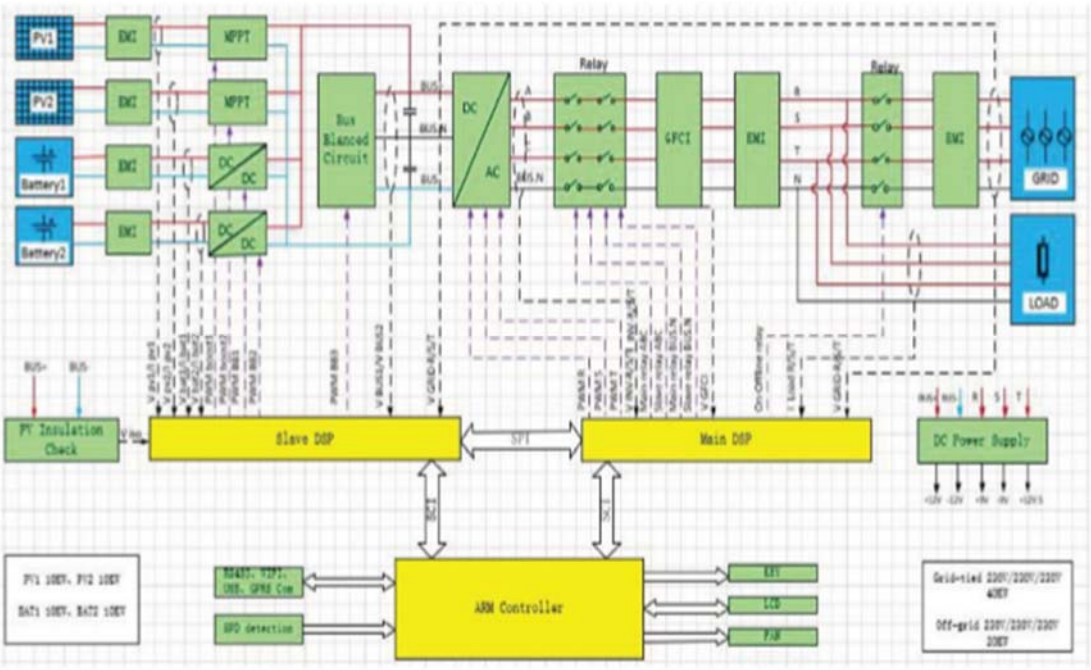
Grounding

Connection interface


Serial Number and Software Version



6 ELECTRICAL SCHEMES

Equipment under testing


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