TESTING FOR THE VERIFICATION OF COMPLIANCE OF PV INVERTER WITH:

EN 50549-1: 2019:

REQUIREMENTS FOR GENERATING PLANTS TO BE CONNECTED IN PARALLEL WITH DISTRIBUTION NETWORKS - PART 1: CONNECTION TO A LV DISTRIBUTION NETWORK - GENERATING PLANTS UP TO AND INCLUDING TYPE B

(REQUIREMENTS FOR PLANTS TYPE B)

Procedure: PE.T-LE-62

Test Report Number	:	**2222/0179**
Type	:	Solar Grid-tied Inverter
Tested Model	:	**SOFAR 255KTL-HV**
Trade Mark	:	
Variant Models	:	SOFAR 250KTL-HV

APPLICANT

Name	:	**SGS Tecnos, S.A. (Certification Body)**
Address	:	C/ Trespaderne, 29 - Edificio Barajas 1 28042 Madrid (Spain)

HIRED BY

Name	:	**Shenzhen SOFARSOLAR Co., Ltd.**
Address	:	11/F., Gaoxinqi Technology Building, No.67 Area, Xingdong Community, Xin'an Sub-district, Bao'an District, Shenzhen City, Guangdong Province, P.R. China

TESTING LABORATORY

Name	:	**SGS Tecnos, S.A. (Electrical Testing Laboratory)**
Address	:	C/ Trespaderne, 29 - Edificio Barajas 1 28042 Madrid (Spain)
Conducted (tested) by	:	Roger Hu (Project Engineer)
Approved by	:	Omar Kalim (Technical Reviewer)
Date of issue	:	2022/06/08
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Test Report Historical Revision:

Test Report Version	Date	Resume
2222/0179	2022/06/08	First issuance

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1. SCOPE

SGS Tecnos, S.A. (Electrical Testing Laboratory) has been contracted by SGS Tecnos, S.A. (Certification Body) to perform the testing according the EN 50549 – 1: 2019: Requirements for generating plants to be connected in parallel with distribution networks - part 1: connection to a LV distribution network - generating plants up to and including type B.

The tests offered at this test report evaluate the EUT compliance with the requirements of **Type B.**

2. GENERAL INFORMATION

2.1. TESTING PERIOD AND CLIMATIC CONDITIONS

The necessary testing has been performed between February 17th and April 09th of 2022.

All the tests and checks have been performed at climatic conditions:

Temperature	25 ± 5 ºC
Relative Humidity	50 ± 10 %
Pressure	96 ± 10 kPa

SITE TEST

Name ..... : **Dongguan BALUN Testing Technology Co., Ltd.**
Address ..... : Room 104, 204, 205, Building 1, No. 6, Industrial South Road, Songshan Lake District, Dongguan, Guangdong, China.

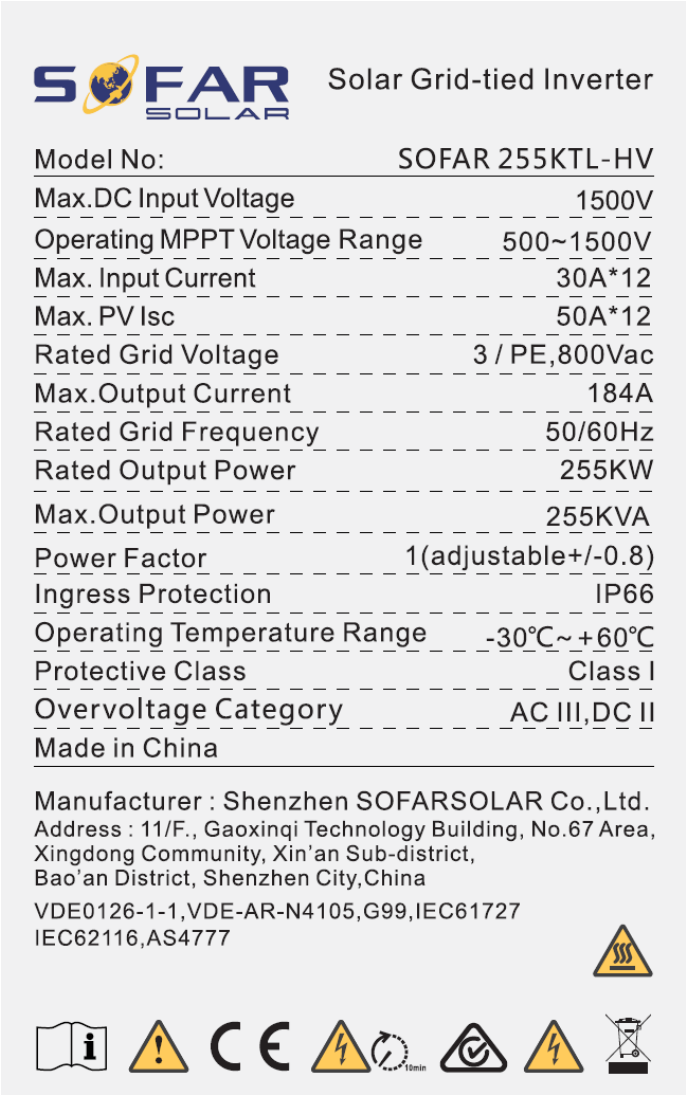
2.2. EQUIPMENT UNDER TESTING

Apparatus type ..... : Solar Grid-tied Inverter
Installation ..... : Fixed installation
Manufacturer ..... : **Shenzhen SOFARSOLAR Co., Ltd.**
Trade mark ..... : SOFAR SOLAR
Model / Type reference ..... : **SOFAR 255KTL-HV**
Serial Number ..... : SR1ES2R5MCG027
Software Version ..... : V000001
Rated Characteristics ..... : DC input: 500-1500 V_{MPPT} (Max.1500 V), 12*30 A
AC output: 3W/PE, 800 V_{ac}, 50 Hz, 184A (Max.184), 255 kW (Max.255 kVA)

Date of manufacturing: 2021

Test item particulars
Input..... : DC
Output..... AC,3W/PE
Class of protection against electric shock... : Class I
Degree of protection against moisture ..... : IP66
Type of connection to the main supply..... : Three Phase – Fixed installation
Cooling group ..... : Refer to page 8
Modular ..... : No
Internal Transformer..... : No

Copy of marking plate:



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 SOFAR 255KTL-HV's except the parameters of rating.

Equipment Under Testing:

- SOFAR 255KTL-HV

Variant models:

- SOFAR 250KTL-HV

The variant 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 of the EUT or Modular inverters.
- Same Firmware Version.

Equipment ratings and parameters have been provided by the manufacturer.

The models of SOFAR 250KTL-HV and SOFAR 255KTL-HV are identical on topological schematic circuit diagram and control solution codes except for the type designation, the input/output rating.

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.

Following table shows the full ratings of all the models referenced in this report, marked in **bold letters** the ones subjected to testing:

Model	SOFAR 250KTL-HV	**SOFAR 255KTL-HV**
DC Input		
Max. DC voltage	1500 V	
Rated input voltage	1160 V	
Start-up voltage	550 V	
MPPT operating voltage range	500 V~1500 V	
Full power MPPT voltage range	800 V~1300 V	
Max. input current	12*30 A	
Max. input short circuit current	12*50 A	
AC Output		
Rated AC Output power	250 kW	255 kW
Max. AC Output power	250 kVA@ 30 °C 235 kVA@ 40 °C 220 kVA@ 50 °C	255 kVA@ 30 °C 235 kVA@ 40 °C 220 kVA@ 50 °C
Rated current	180.5 A	184 A
Max. output current	180.5 A	184 A
Nominal grid voltage	3W/PE, 800 V	
Nominal output freqency	50 Hz	
Output power factor	1 default (adjustable +/-0.8)	
General Data		
Operating temperature range	-30 ºC ~ +60 ºC	
Ingress protection	IP66	
Protective class	Class I	
Cooling method	Smart forced air cooling (Fan)	
Topology	Transformerless	

2.3. REFERENCE VALUES

The values presented in the following table have been used for calculation of referenced values (p.u.; %) thougth the report.

Reference Values for the EUT	
Rated power, **Pn** in kW	255
Design active power, $\mathbf{P_D}$ in kW (1)	231
Maximun apparent power, **S max** in kVA	255
Rated wind speed (only WT), **vn** in m/s	N/A
Rated current (determined), **In** in A	184
Rated output voltage, (Line to Line) **Un** in Vac	800
Rated output voltage, (Line to Neutral) **Un** in Vac (2)	461.9
Note: In this report p.u. values are calculated as follows: -For Active & Reactive Power p.u values are reference to **Sn** -For Currents p.u values, the reference is always **In** -For Voltages p.u values, the reference is always **Un**	

(1) Manufacturer's declaration**:** P_D equals to 0.9 times of Rated AC Output power, according to measured $P_D \approx 0.9$ Pn (231.427 kW)

(2) Virtual neutral had been used to change 3W/PE wiring to 3W/N/PE wiring because of limitations of the test bench.

2.4. TEST EQUIPMENT LIST

From	No.	Equipment Name	Trademark / Model No.	Equipment No.	Calibration Period
Balun	1	Power analyzer	ZLG/ PA5000H	C8209090820211 0001	2021/12/21 to 2022/12/20
	2	Digital oscilloscope	Tektronix/ MD03024	C055210	2021/12/21 to 2022/12/20
	3	Voltage probe	SanHua/SI-9110	111539	2021/12/21 to 2022/12/20
	4	Voltage probe	SanHua/SI-9110	111541	2021/12/21 to 2022/12/20
	5	Voltage probe	SanHua/SI-9110	111134	2021/12/21 to 2022/12/20
	6	Current probe	Fluke/ CP1000A	C191000142	2021/12/21 to 2022/12/20
	7	Current probe	Fluke/ CP1000A	C191000127	2021/12/21 to 2022/12/20
	8	Current probe	Fluke/ CP1000A	C191000124	2021/12/21 to 2022/12/20
	9	Current probe	Fluke/ CP1000A	C181000929	2021/12/21 to 2022/12/20
	10	Temperature & Humidity meter	Anymeters/ TH101B	ZB-WSDJ-001	2021/12/21 to 2022/12/20
SGS	11	True RMS Multimeter	Fluke/187	GZE012-8	2021/11/19 to 2022/11/18

Note: Voltage direct measurement through power analyzer, the voltage probes were used with the digital oscilloscope. All measurement equipment was used inside their corresponding calibration period. Copy of all calibration certificates are available at the laboratory for reference.

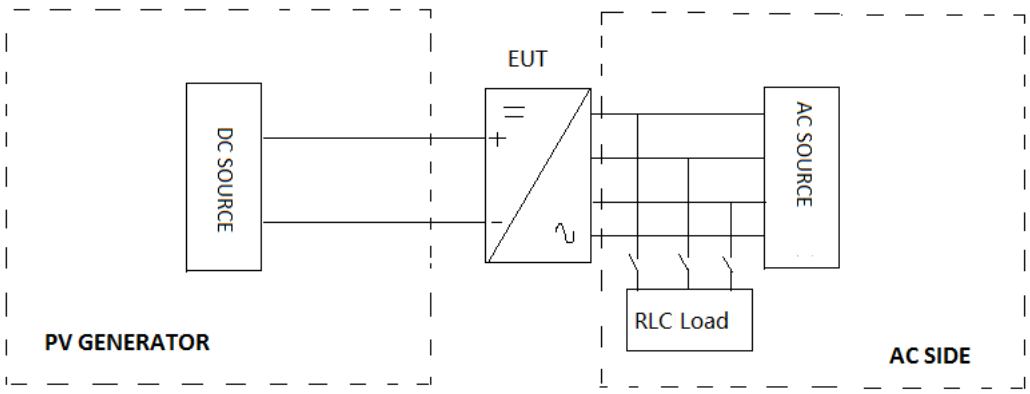
2.5. MEASUREMENT UNCERTAINTY

Associated uncertainties through measurements showed in 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.	

2.6. TEST SET UP OF THE DIFFERENT STANDARD

Below is the simplified construction of the test set up.



Different equipments have been used to take measures as shown in chapter 2.4. Current 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	Wogo / WLPA-33-1000kVA	1000 kVA 5-400 V_{rms} 44.5-65.5 Hz	BZ-DGD-L001
DC source	Wogo / WDGC-1000kW	0 – 1500 Vdc (0.01 V step) 0 – 1333 A (0.01 A step)	BZ-DGD-L002
RLC load	Qunlin / ACLT3816H	563.3kW, 563.3kVAr	BZ-DGD-L003

2.7. FACTORY INFORMATION

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

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

2.8. DEFINITIONS

EUT	Equipment Under Testing	Hz	Hertz
A	Ampere	V	Volt
Un	Nominal Voltage	p.u	Per unit
In	Nominal Current	Pn	Rated Active Power
Ia	Active Current	Qn	Rated Reactive Power
Ir	Reactive Current	Sn	Rated Apparent Power
MV	Medium Voltage	THC	Total Harmonic Current
LV	Low Voltage	TDD	Total Demand Distortion
UVRT	Under-Voltage Ride Through	I_h	Harmonic Current
OVRT	Over-Voltage Ride Through	Plt	Severity of Flicker Long-Term
Pst	Severity of Flicker Short-Term	ms	Millisecond
dc	Maximum Variation of Voltage	s	Second
d max	Maximum Absolute Value of	min	Minute
	Voltage Variation	P	Active Power
fn	Nominal frequency	Q	Reactive Power
IGBT	Insulated-Gate Bipolar Transistor	PF	Power Factor
RMS	Root Mean Square	Nr.	Number
$S_{k,fic}$	Short-circuit apparent power	POC	Point of Connection
AC	Alternating Current	Meas.	Measured
DC	Direct Current	Des.	Desired
DSO	Distribution System Operator	PGU	Power Generating Unit
EESS	Electrical energy storage system	P_D	Design active power
EES	Electrical energy storage	P_M	Momentary active power
Pmax	Maximum active power	Smax	Maximum apparent power
P_A	Available active power		

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

EN 50549-1:2019 – Requirements for plant category Type B have been considered.				
REPORT SECTION	**STANDARD SECTION**	**CHAPTER OF THE STANDARD**	**Plant category**	**Result**
4.1	4.4	Normal operating range	--	--
4.1.1	4.4.2	Operating frequency range	≥A	P
4.1.2	4.4.3	Minimal requirement for active power delivery at underfrequency	≥A	P
4.1.3	4.4.4	Continuous operating voltage range	≥A	P
4.2	4.5	Immunity to disturbances	≥A	P
4.2.1	4.5.2	Rate of change of frequency (ROCOF) immunity	≥A	P
4.2.2	4.5.3	Under-voltage ride through (UVRT)	B	P
4.2.3	4.5.4	Over-voltage ride through (OVRT)	≥A	P
4.3	4.6	Active response to frequency deviation	≥A	P
4.3.1	4.6.1	Power response to overfrequency	≥A	P
4.3.2	4.6.2	Power response to underfrequency	≥A	N/A
4.4	4.7	Power response to voltage changes	≥A	P
4.4.1 and 4.4.2	4.7.2	Voltage support by reactive power	≥A	P
4.4.3	4.7.3	Voltage related active power reduction	≥A	P
4.4.4	4.7.4	Short circuit current requirements on generating plants	B	N/A
4.5	4.8	EMC and power quality	≥A	N/R (1)
4.5.1	4.8	Harmonic emissions	≥A	P
4.5.2	4.8	Flicker and voltage fluctuations	≥A	P
4.6	4.9	Interface protection	≥A	P
4.6.1	4.9.3	Requirements on voltage and frequency protection	≥A	P
4.6.2	4.9.4	Means to detect island situation	≥A	N/R (2)
4.6.3	4.9.5	Digital input to the interface protection	≥A	P
4.7	4.10	Connection and starting to generate electrical power	≥A	P
4.7.1	4.10.2	Automatic reconnection after tripping	≥A	P
4.7.2	4.10.3	Starting to generate electrical power	≥A	P
4.7.3	4.10.4	Synchronization	≥A	P
4.8	4.11	Ceasing and reduction of active power on set point	≥A	P
4.8.1	4.11.1	Ceasing active power	≥A	P
4.8.2	4.11.2	Reduction of active power on set point	B	P
4.9	4.13 & 4.3	Requirements regarding single fault tolerance of interface protection system and interface switch	≥A	N/R (3)
Note: Decision rule of the declaration of conformity evaluated according to the ILAC G8: 09/2019 & IEC 115 Guidelines (Proc. 2 “Accuracy Method” based on OD-5014). Decision rule used: Binary with simple acceptance. (Safety Zone with respect to the limit w = 0). Specific risk: Probability of False Acceptance or Rejection less than 50%, (PFA / PFR <50%). For more information see ILAC Guide G8 / 09.				

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

(1) EN IEC 61000-6-2: 2019; EN IEC 61000-6-4: 2011: Test Report no.CTS20220059-E, issued by ShenZhen Chengxin Technology Service Co., Ltd. on 2022-05-13. CNAS L12944

(2) IEC 61727: 2004&IEC 62116:2014: Test Report no.64.290.21.30204.03, issued by TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch on 2022-05-24. CNAS L3584

(3) IEC 62109-1: 2010 and IEC 62109-2: 2011: Test Report no.64.290.21.30202.02 Part 1 of 2 and Test Report no. 64.290.21.30202.02 Part 2 of 2, issued by TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch on 2022-05-24. CNAS L3584

4. TEST RESULTS

4.1. NORMAL OPERATING RANGE

4.1.1. Operating frequency range

The test has been done according to the clause 4.4.2 of the standard, the requirement is as follows:

Table 1 — Minimum time periods for operation in underfrequency and overfrequency situations

Frequency Range	Time period for operation Minimum requirement	Time period for operation stringent requirement
47,0 Hz – 47,5 Hz	not required	20 s
47,5 Hz – 48,5 Hz	30 min [a]	90 min
48,5 Hz – 49,0 Hz	30 min [a]	90 min [a]
49,0 Hz – 51,0 Hz	Unlimited	Unlimited
51,0 Hz – 51,5 Hz	30 min [a]	90 min
51,5 Hz – 52,0 Hz	not required	15 min
[a] Respecting the legal framework, it is possible that longer time periods are required by the responsible party in some synchronous areas.		

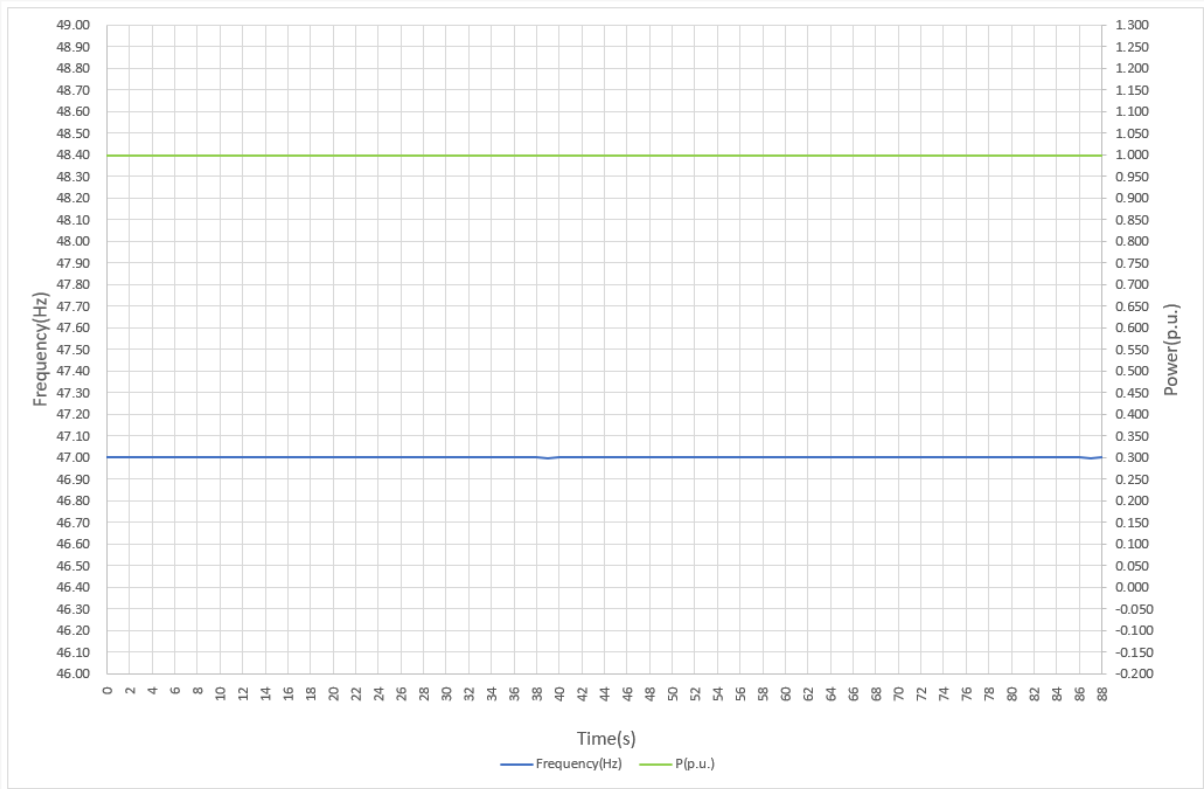
“Time period for operation, stringent requirement” (second column of the table) has been considered for this test.

In order to verify this function, parameter settings as in the following table have been considered to perform the test. Time requirements considered are the “stringent requirement” according to Table 1 of the standard:

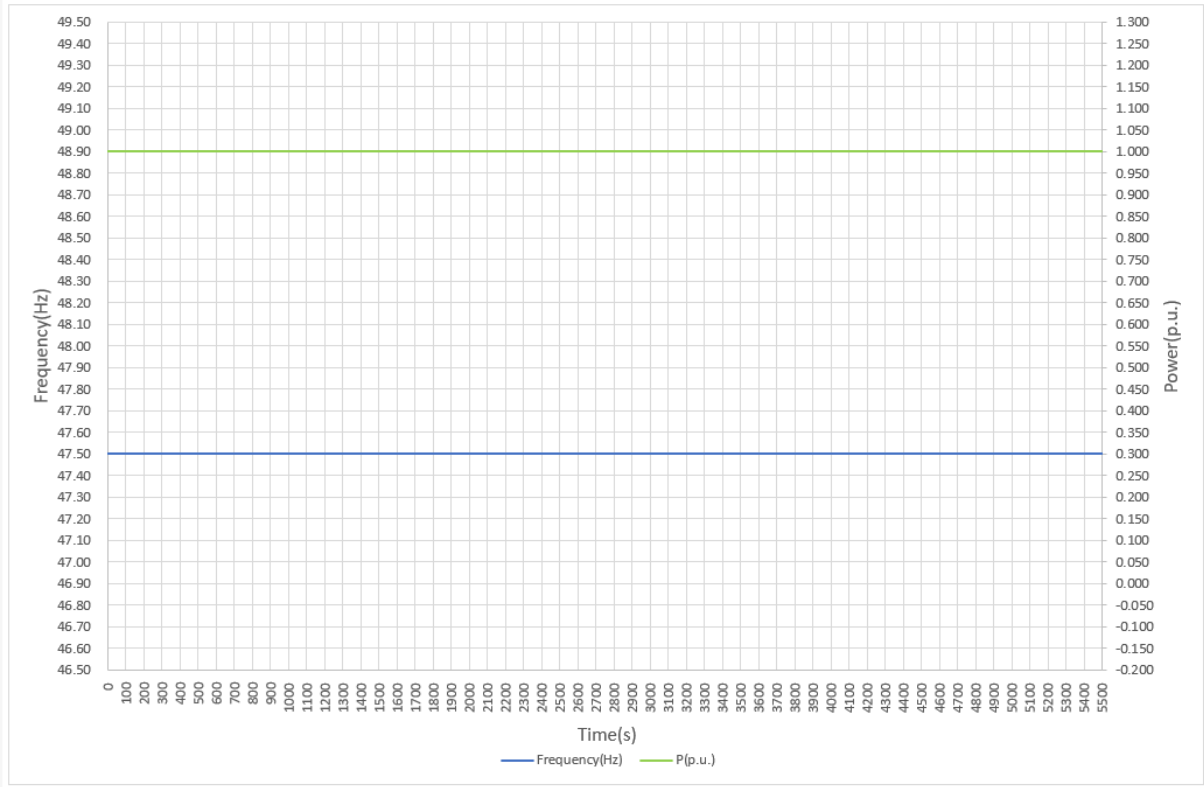
Steps	f (Hz) Setting	Time requirement	f Measured (Hz)	Time Measured (Min)	Power measured (p.u.)
1	47.00	>20 s	47.00	1.5	1.000
2	47.50	>90 min	47.50	91.7	1.000
3	48.50	>90 min	48.50	106.7	1.000
4	50.00	Unlimited	50.00	1.6	0.998
5	51.50	>90 min	51.50	200.0	0.999
6	52.00	>15 min	52.00	15.5	1.000

Test results are represented at diagrams below.

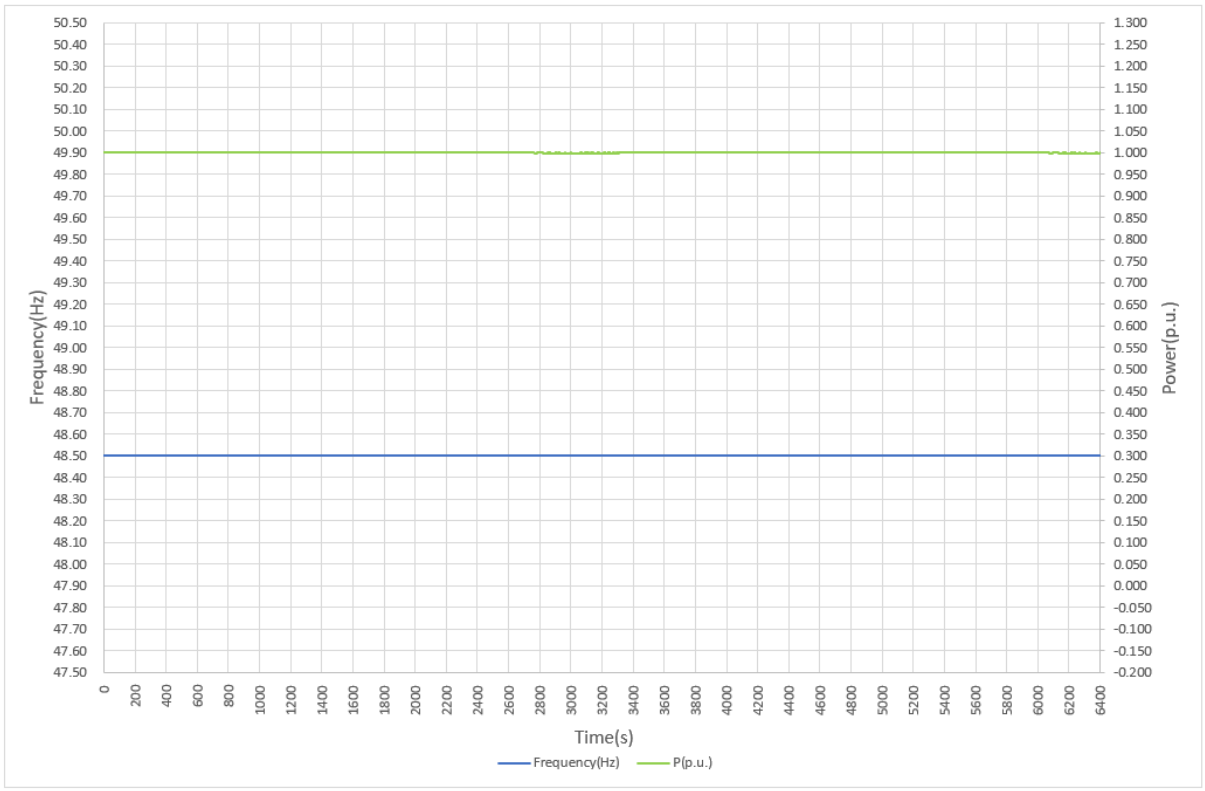
Test 1 - 47.0 Hz



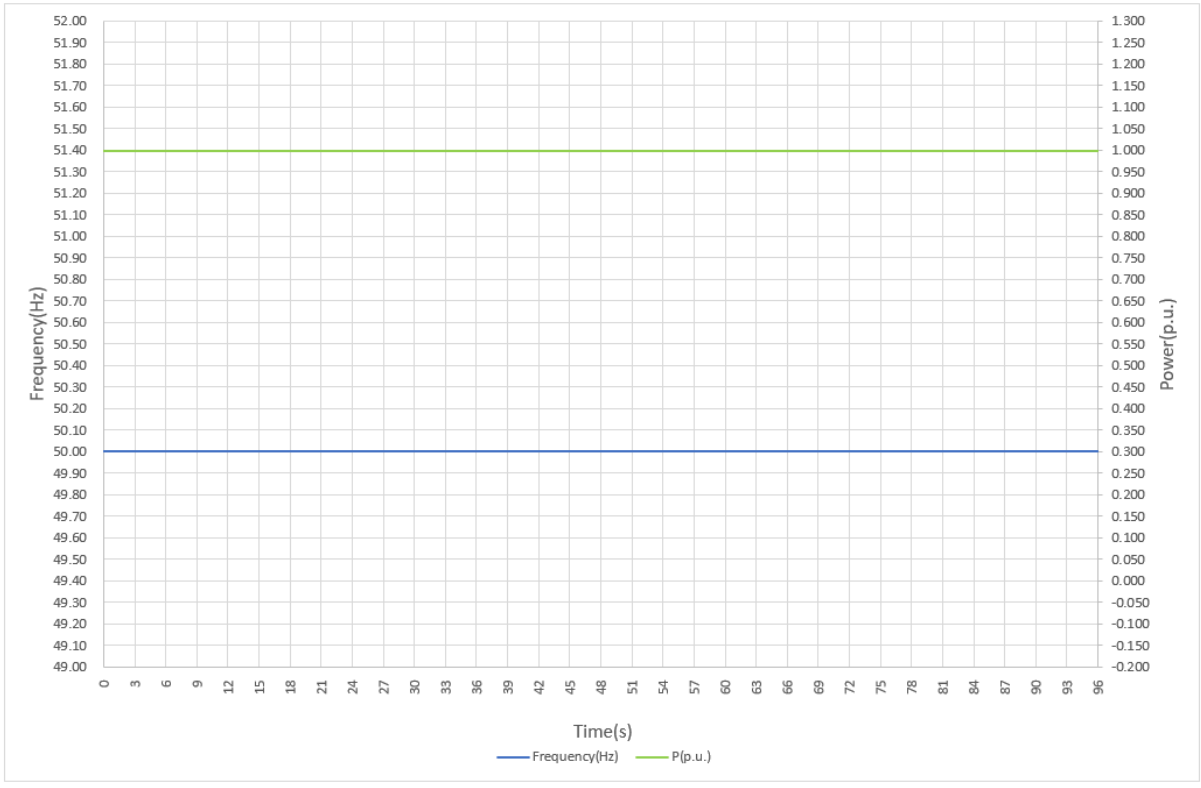
Test 2 - 47.5 Hz



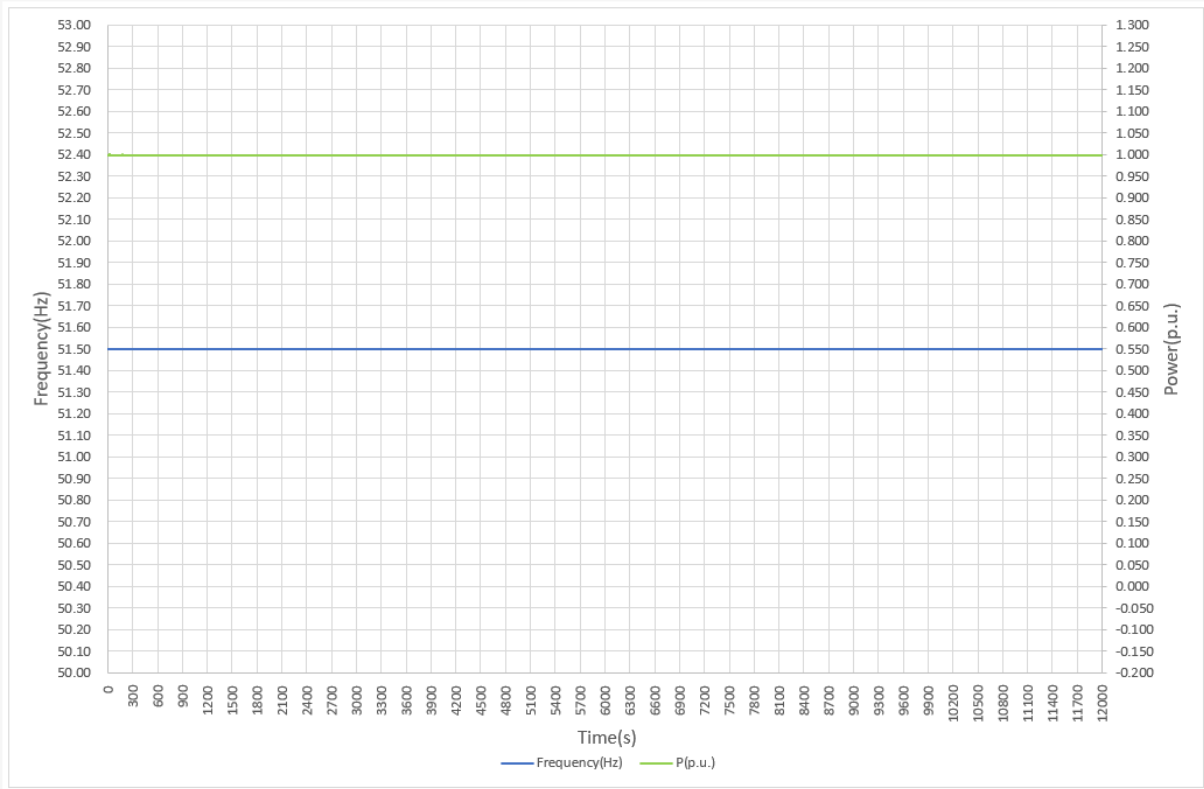
Test 3 - 48.5 Hz



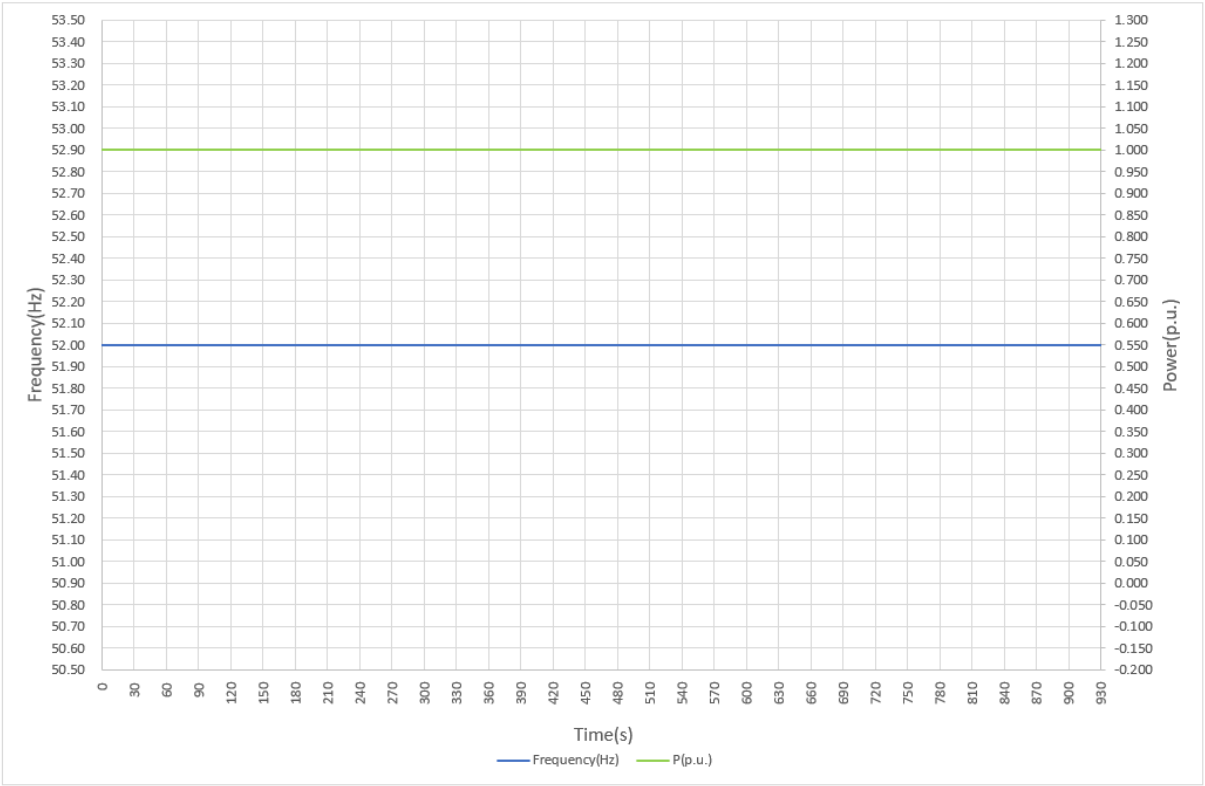
Test 4 - 50.0 Hz



Test 5 - 51.5 Hz



Test 6 - 52.0 Hz



4.1.2. Minimal requirement for active power delivery at underfrequency

The test has been done according to the clause 4.4.3 of the standard, the requirement is as follows:

A generating plant shall be resilient to the reduction of frequency at the point of connection while reducing the maximum active power as little as possible.

The admissible active power reduction due to underfrequency is limited by the full line in Figure 5 of the standard and is characterized by a maximum allowed reduction rate of 10 % of Pmax per 1 Hz for frequencies below 49.5 Hz.

It is possible that a more stringent power reduction characteristic is required by the responsible party. Nevertheless this requirement is expected to be limited to an admissible active power reduction represented by the dotted line in Figure 5 which is characterised by a reduction rate of 2 % of the maximum power Pmax per 1 Hz for frequencies below 49 Hz.

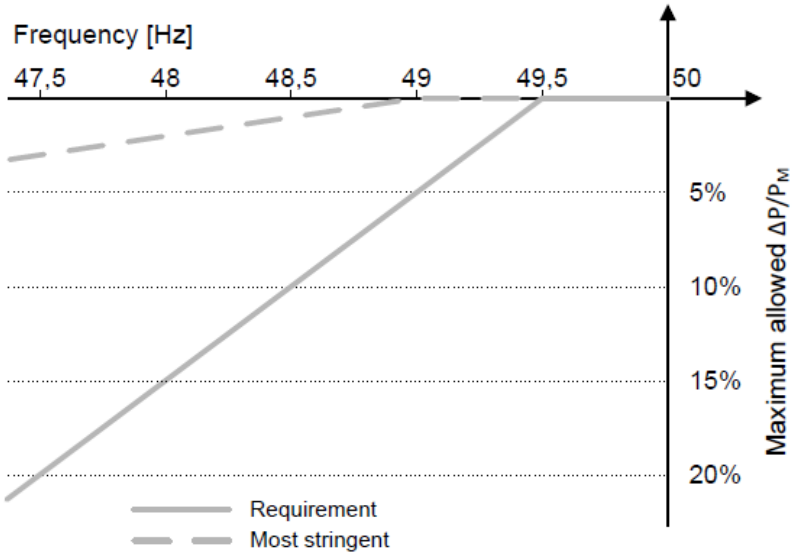


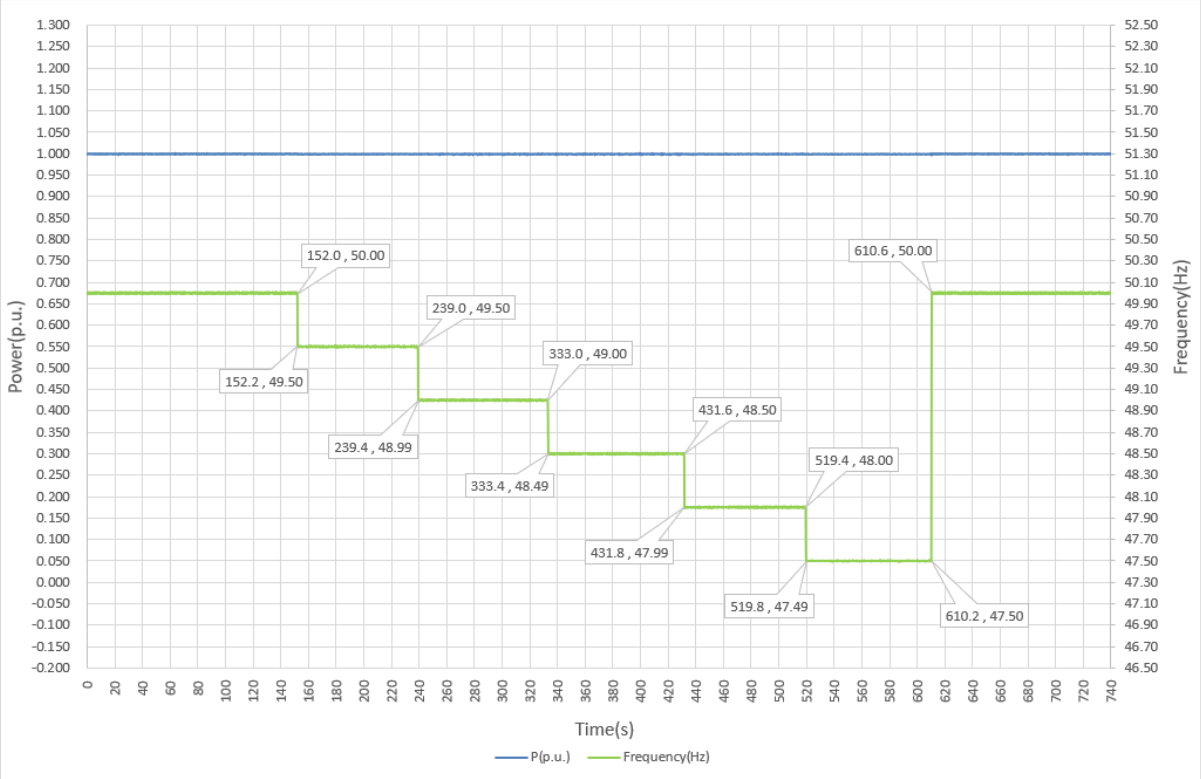
Figure 5 — Maximum allowable power reduction in case of underfrequency

As defined by manufacturer, the power will not reduce when the frequency is below 49.5 Hz.

Step	f (Hz) Setting	f meas. (Hz)	Time start (s)	Time end (s)	Time meas. (s)	Time (s)	P desired (p.u.)	P meas. (p.u.)	P deviation (p.u.)
1	50.00 ± 0.05	50.00	0.0	152.0	152.0	>60	1.000	0.999	-0.001
2	49.50 ± 0.05	49.50	152.2	239.0	86.8	>60	1.000	0.999	-0.001
3	49.00 ± 0.05	49.00	239.4	333.0	93.6	>60	1.000	0.999	-0.001
4	48.50 ± 0.05	48.50	333.4	431.6	98.2	>60	1.000	0.999	-0.001
5	48.00 ± 0.05	48.00	431.8	519.4	87.6	>60	1.000	0.999	-0.001
6	47.50 ± 0.05	47.50	519.8	610.2	90.4	>60	1.000	0.999	-0.001
7	50.00 ± 0.05	50.00	610.6	740.0	129.4	>60	1.000	0.999	-0.001

Test results are represented at diagrams below.

Active power delivery at underfrequency



4.1.3. Continuous operating voltage range

The test has been done according to the clause 4.4.4 of the standard, the requirement is as follows:

The generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85%Un to 110%Un.

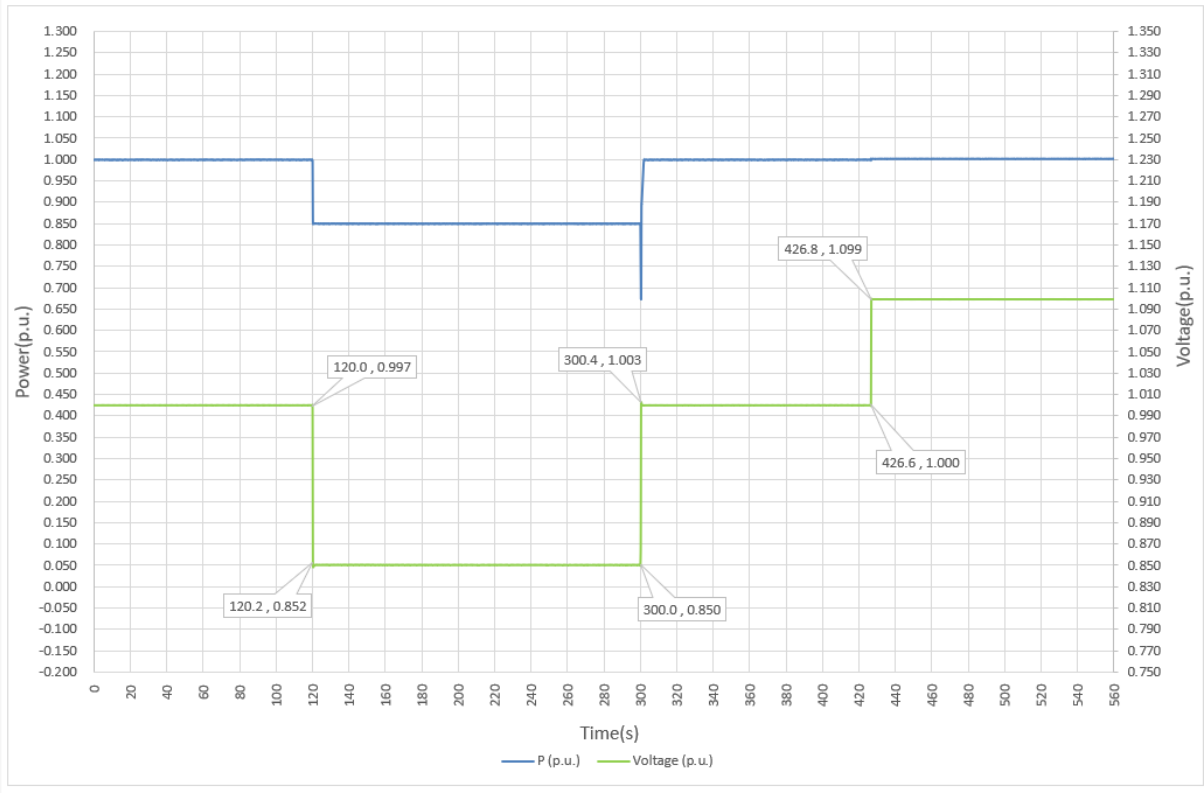
In order to verify this function, the parameter setting is as follows to perform the test:

Step	V desired (p.u.)	P desired (p.u.)	V meas. (p.u.)	P meas. (p.u.)	Time start (s)	Time end (s)	Time meas. (s)
1	1.000	1.000	1.000	0.999	0.0	120.0	120.0
2	0.850	1.000	0.850	0.849(1)	120.2	300.0	179.8
3	1.000	1.000	1.000	0.999	300.4	426.6	126.2
4	1.100	1.000	1.099	1.001	426.8	560.0	133.2

(1) Active power reduction is allowed due to current limitation.

Test results are represented at diagrams below.

Continuous operating voltage range



4.2. IMMUNITY TO DISTURBANCES

4.2.1. Rate of change of frequency (ROCOF) immunity

The test has been done according to the clause 4.5.2 of the standard, the requirement is as follows:

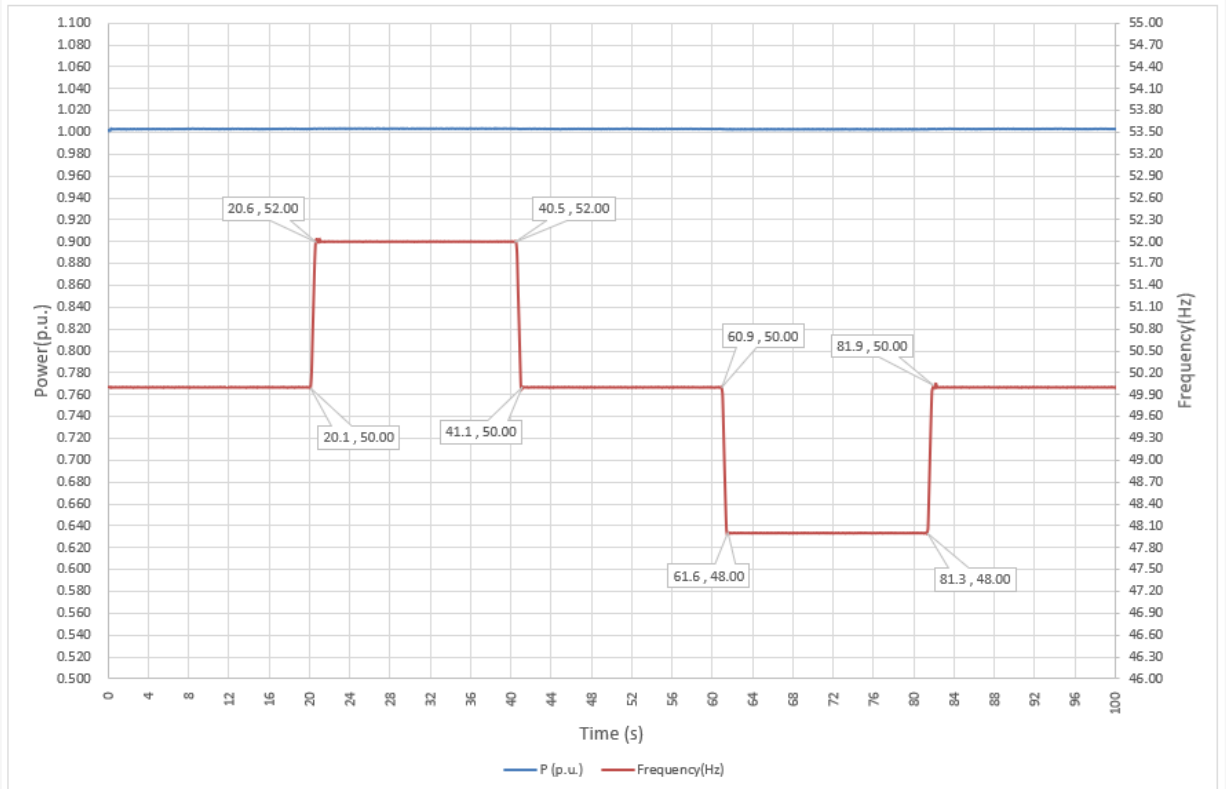
- **Non-synchronous generating technology: at least 2 Hz/s**

The ROCOF immunity is defined with a sliding measurement window of 500 ms as follows:

Steps	f (Hz)	ROCOF requirement (Hz/s)	Step time	Measured frequency (Hz)	Measured step change time (s)	ROCOF meas. (Hz/s)	Disconnection
1	50.00 ± 0.05	N/A	>10 s	50.00	--	--	No
2	52.00 ± 0.05	>2	>10 s	52.00	0.5	+4.0	No
3	50.00 ± 0.05	>2	>10 s	50.00	0.6	-3.3	No
4	48.00 ± 0.05	>2	>10 s	48.00	0.7	-2.9	No
5	50.00 ± 0.05	>2	>10 s	50.00	0.6	+3.3	No

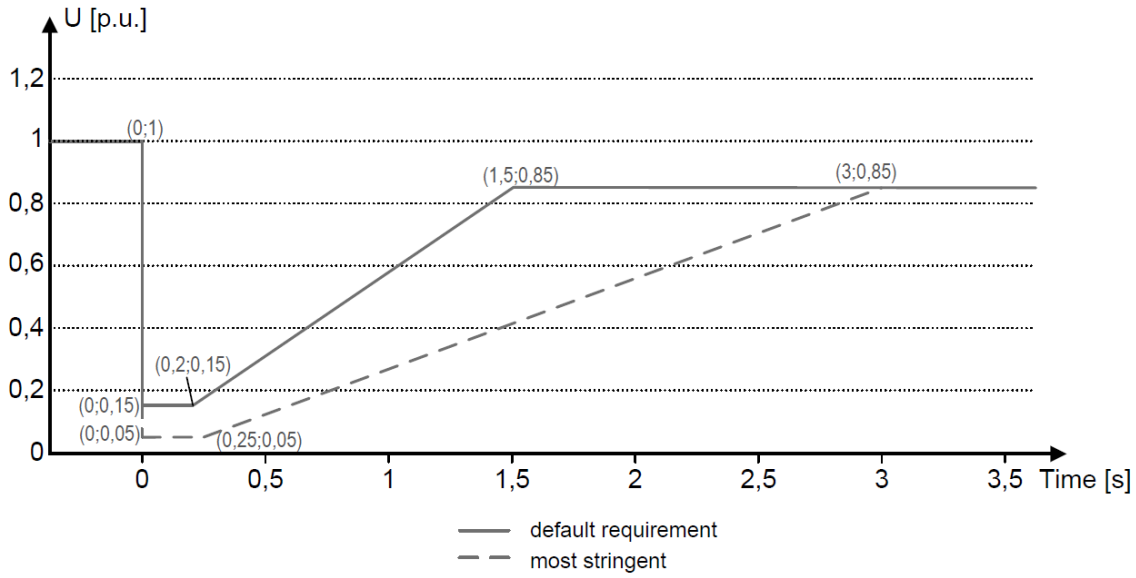
Test results are represented at diagrams below.

Rate of change of frequency (ROCOF) immunity



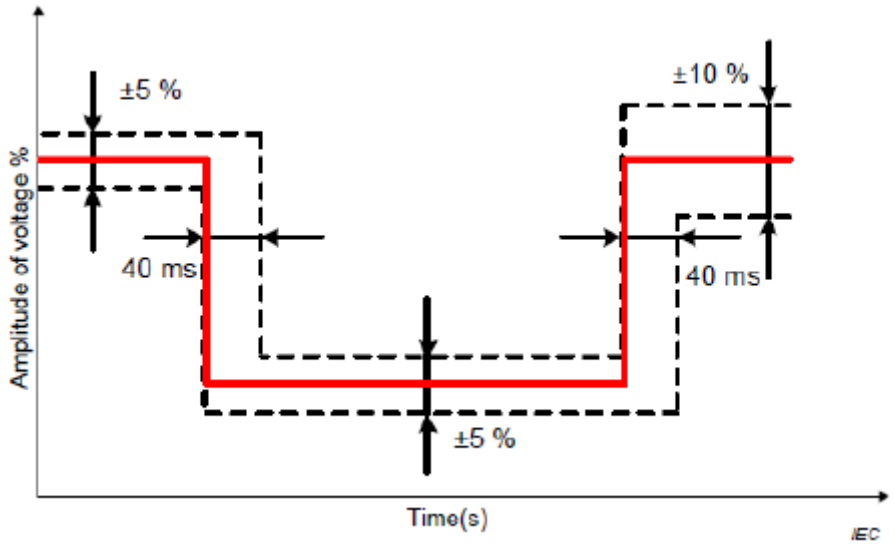
4.2.2. Under-voltage ride through (UVRT)

The requirements are defined in the clause 4.5.3 of the standard.
The test uses the most stringent line in the following figure.



4.2.1.1. No load Test

It is not specified in the reference standard, but following tolerances have been applied. Tolerances for drop depth and duration during no-load tests shall not exceed the values shown in the next figure:



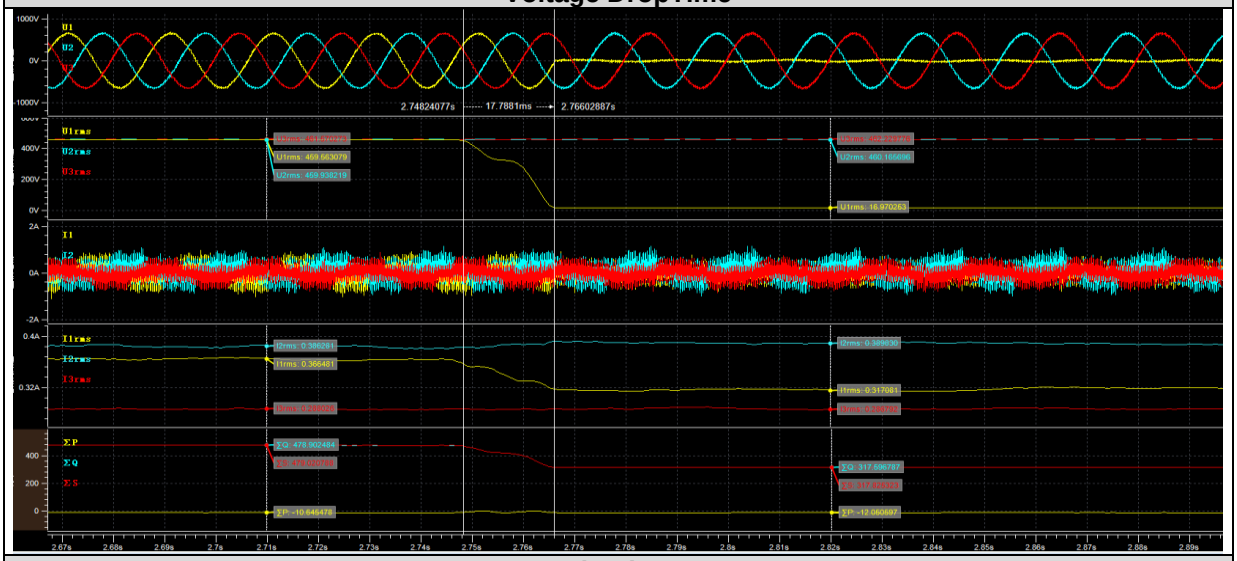
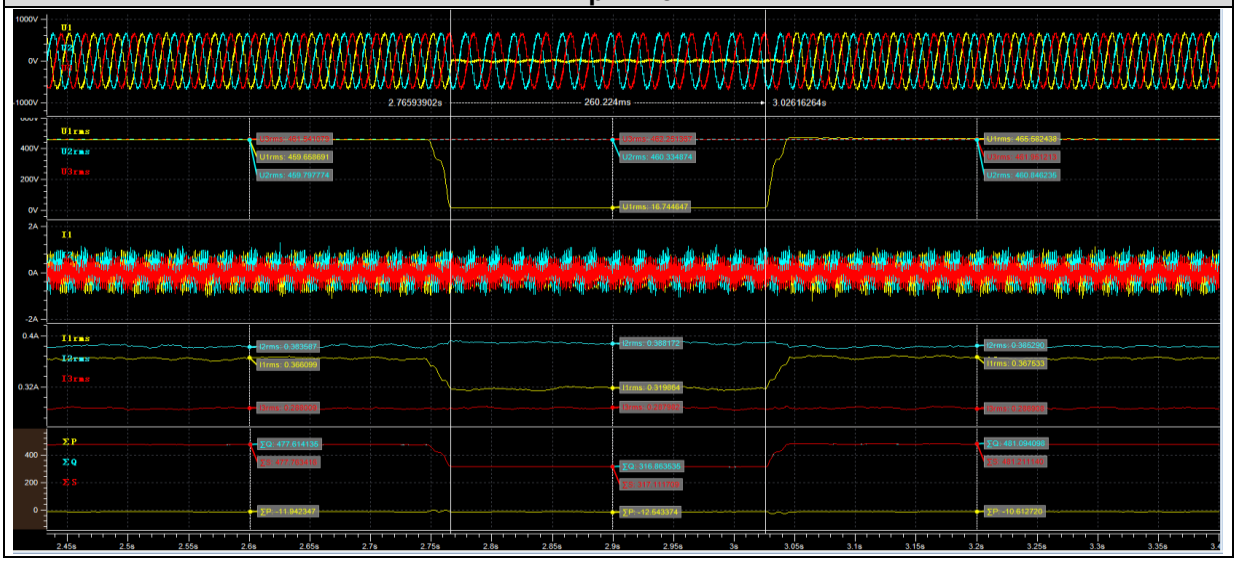
The tolerance for voltage magnitude is ±5%Un for the period before and during the voltage drop. The tolerance for voltage magnitude is ±10%Un during the period after voltage is recovered.
The tolerance range for both drop duration and rise time prefers 40 ms.

Test results of different no-load cases performed are offered below:

No Load								
Phase type	**Residual voltage desired (%Un)**	**Voltage before fault (%Un)**	**Voltage drop time (ms)**	**Residual voltage Measured (%Un)**	**Dip time desired (ms)**	**Dip time measured (ms)**	**Power recovery time (ms)**	**Voltage after recovery (%Un)**
1 ph	0.0-5.0	99.5	18	3.6	≥ 250	260	--	100.8
2 ph		99.5	20	3.7		259	--	101.0
3 ph		99.7	20	3.9		260	--	101.2
1 ph	25.0	99.4	18	24.9	≥ 938	980	--	100.0
2 ph		99.6	20	24.9		980	--	100.0
3 ph		99.7	20	24.9		979	--	99.9
1 ph	50.0	99.6	17	49.9	≥ 1797	1822	--	99.7
2 ph		99.6	20	49.9		1821	--	99.7
3 ph		99.7	20	49.9		1820	--	99.8
1 ph	75.0	99.4	17	75.1	≥ 2656	2762	--	99.6
2 ph		99.6	20	75.1		2760	--	99.7
3 ph		99.7	20	75.0		2760	--	99.7

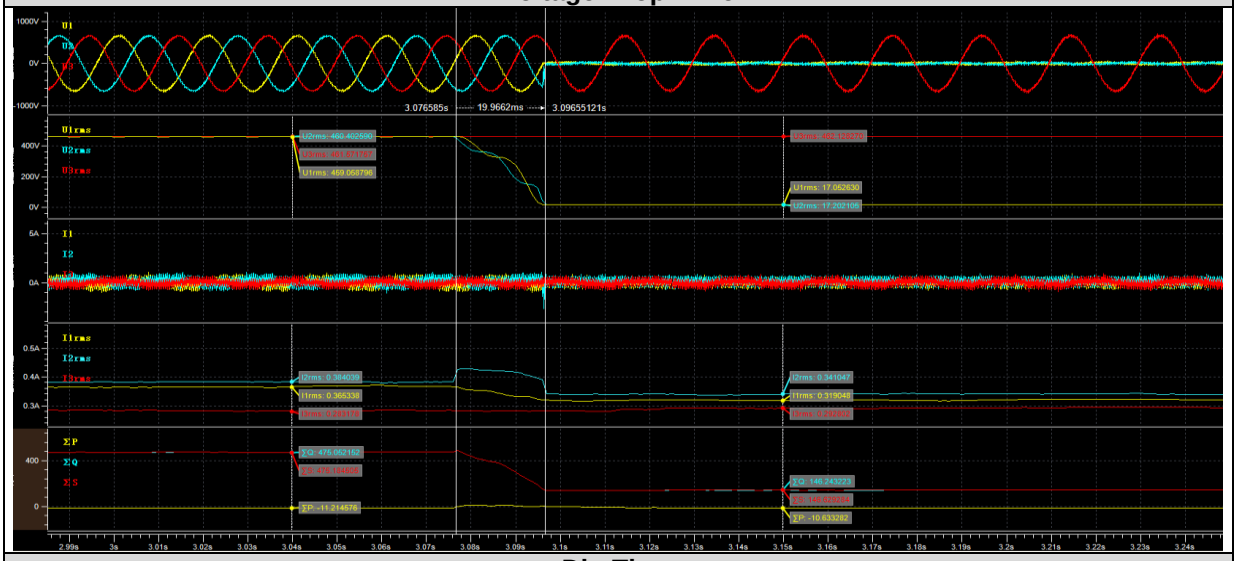
Note: The virtual neutral line was used in the test, Un ≈ 461.9 V.

Test results are graphically represented in the following pages.

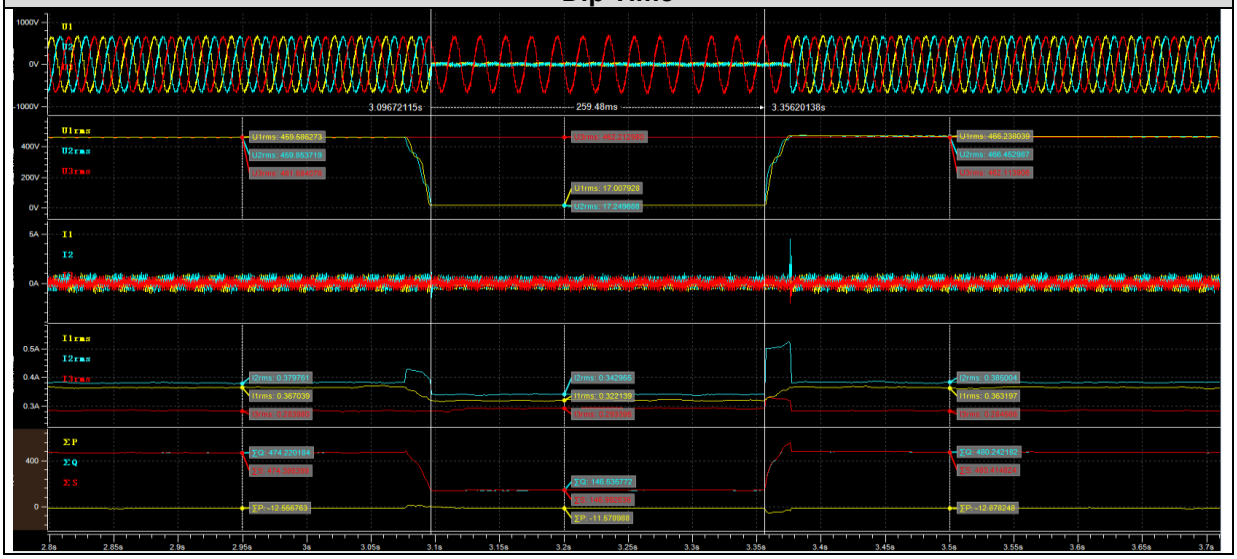
Single-Phase fault	
No Load	Residual voltage: 0~5 %Un
Voltage DropTime	
	
Dip Time	
	

Two-Phase fault	
No Load	Residual voltage: 0~5 %Un

Voltage Drop Time

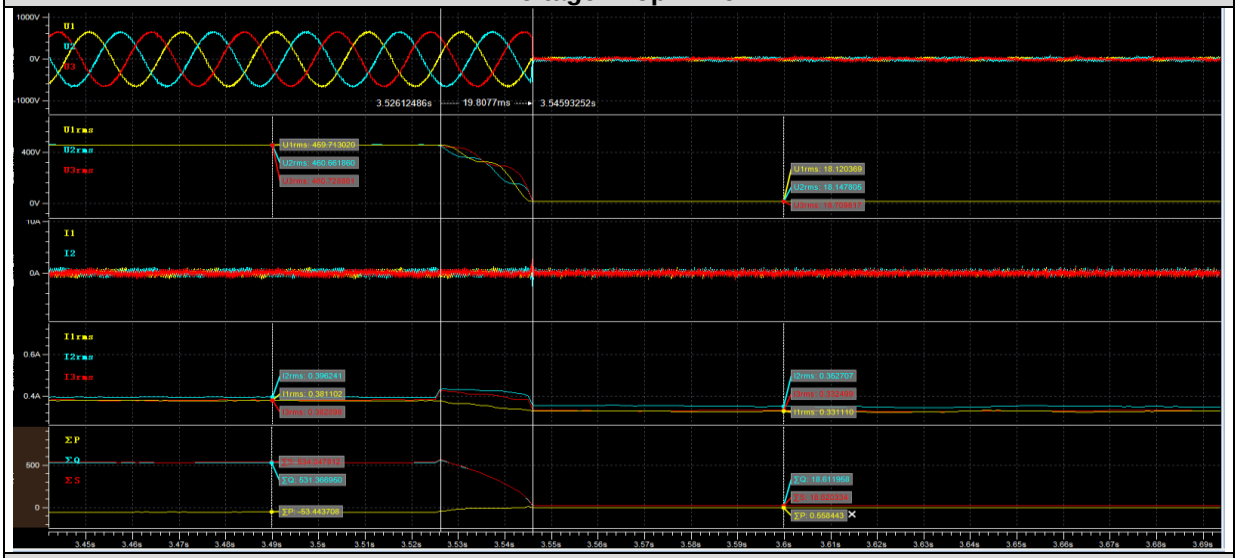


Dip Time

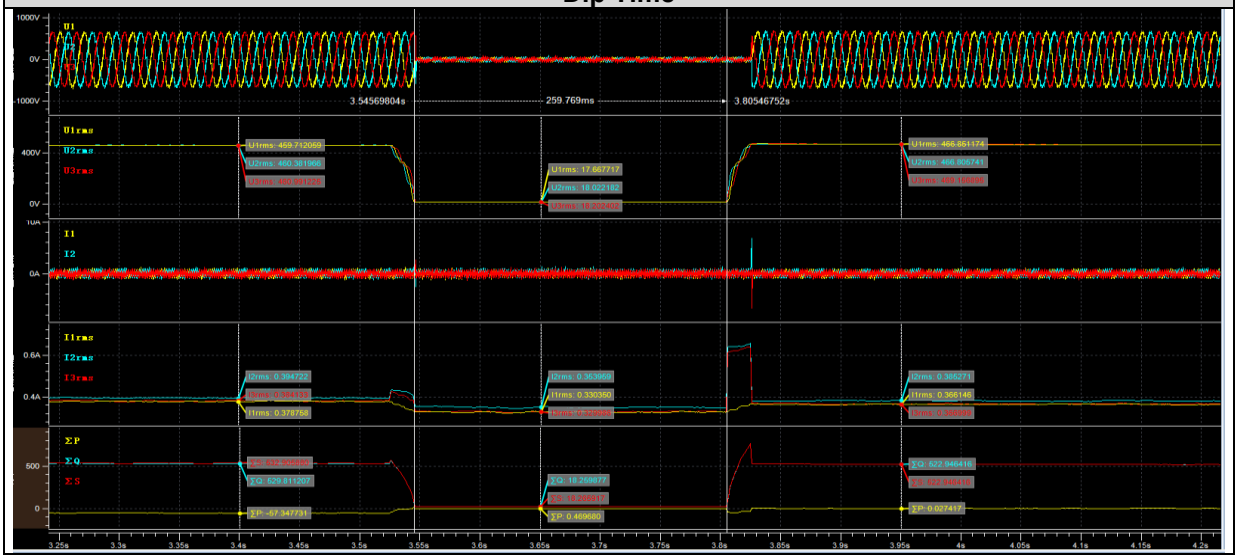


Three-Phase fault	
No Load	Residual voltage: 0~5 %Un

Voltage Drop Time

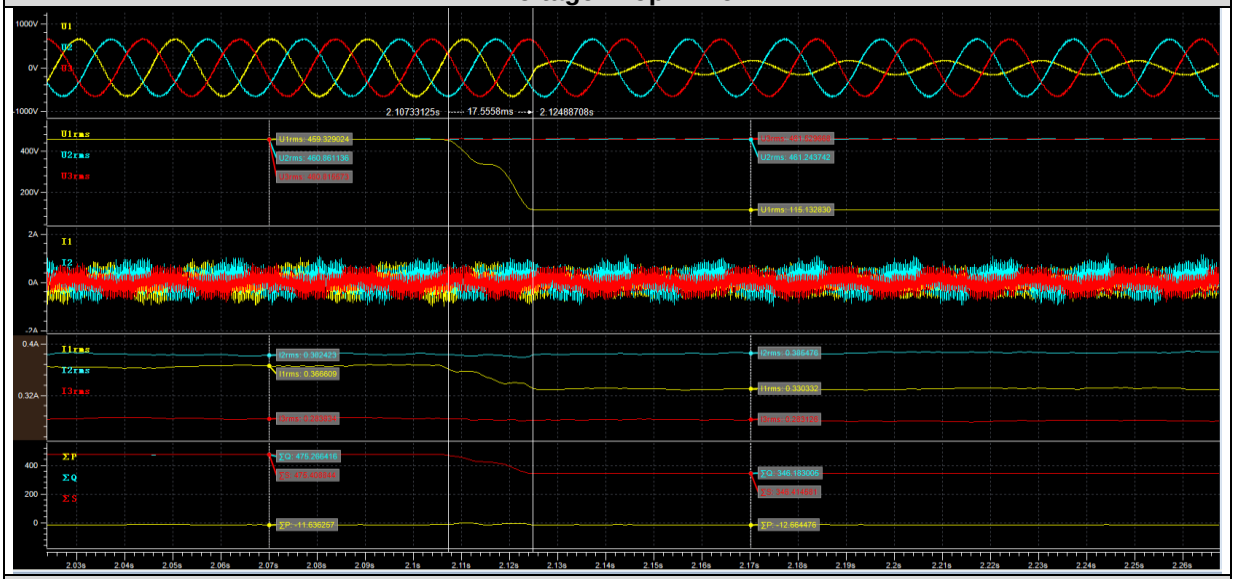


Dip Time

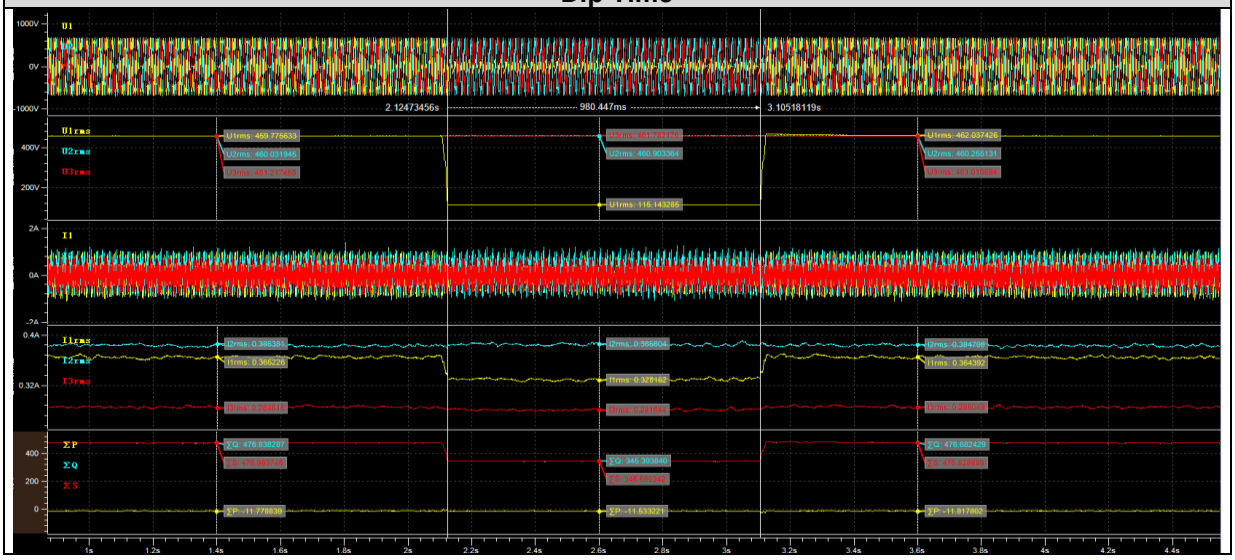


Single-Phase fault	
No Load	Residual voltage: 25 %Un

Voltage Drop Time

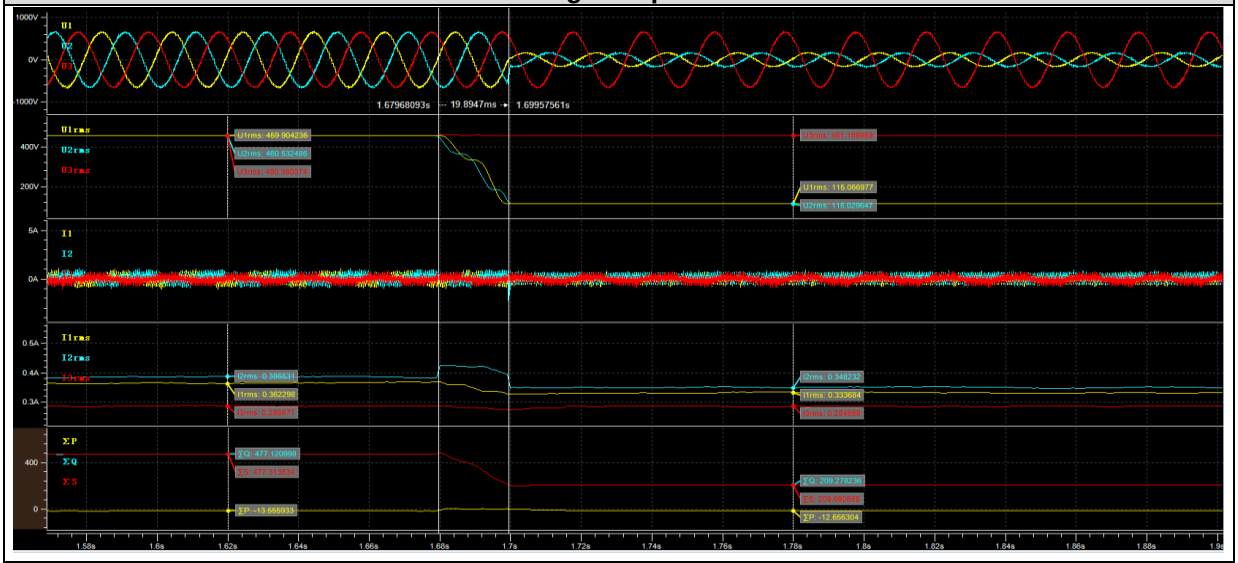


Dip Time

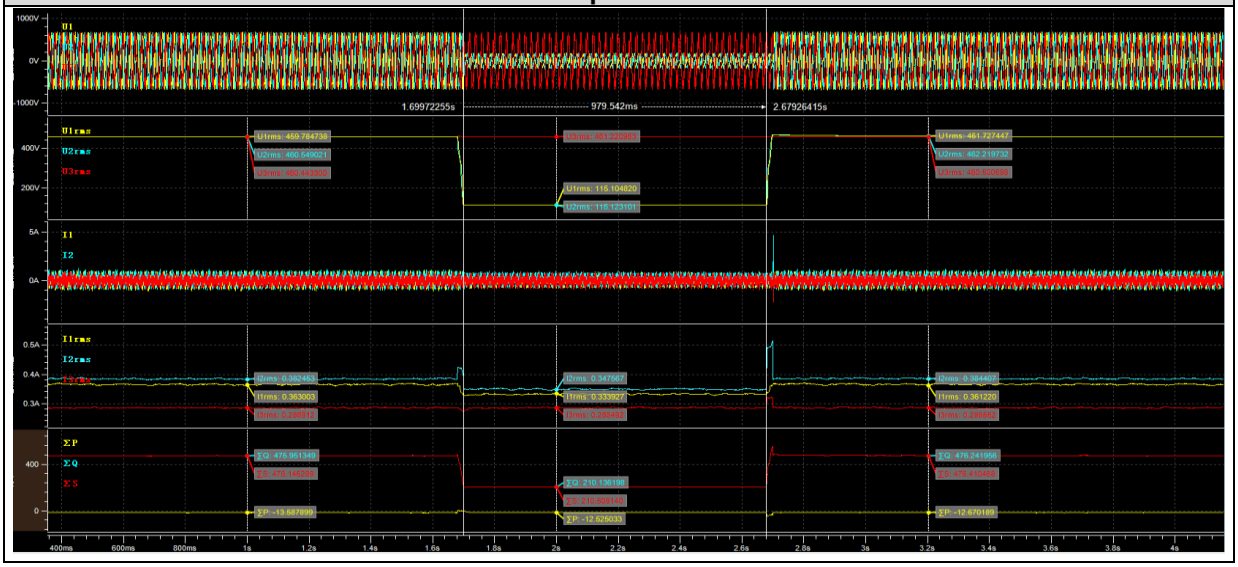


Two-Phase fault	
No Load	Residual voltage: 25 %Un

Voltage Drop Time

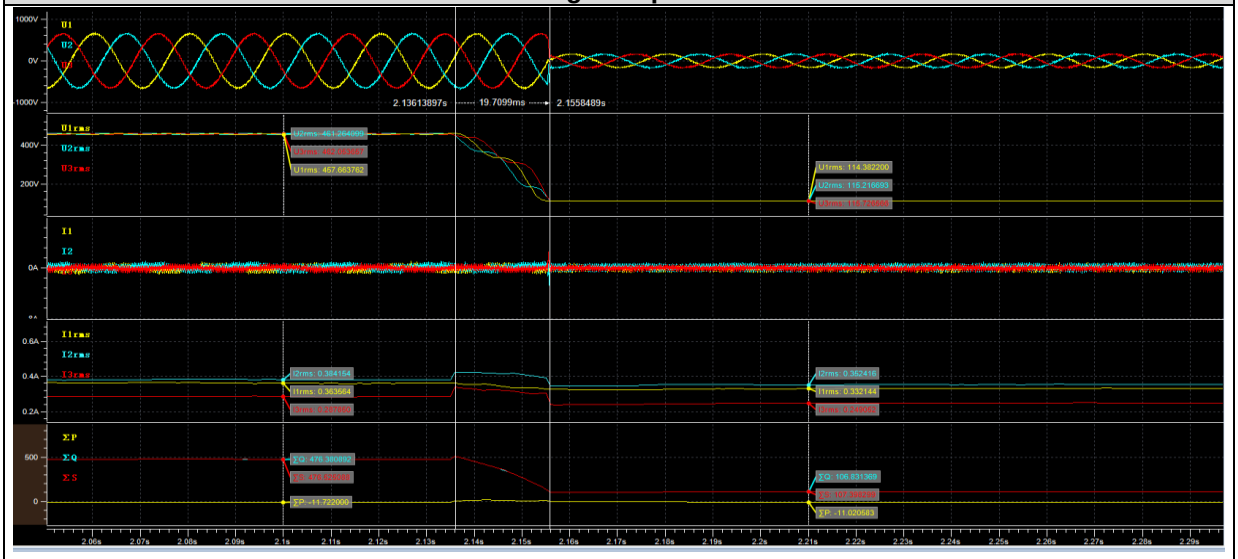


Dip Time

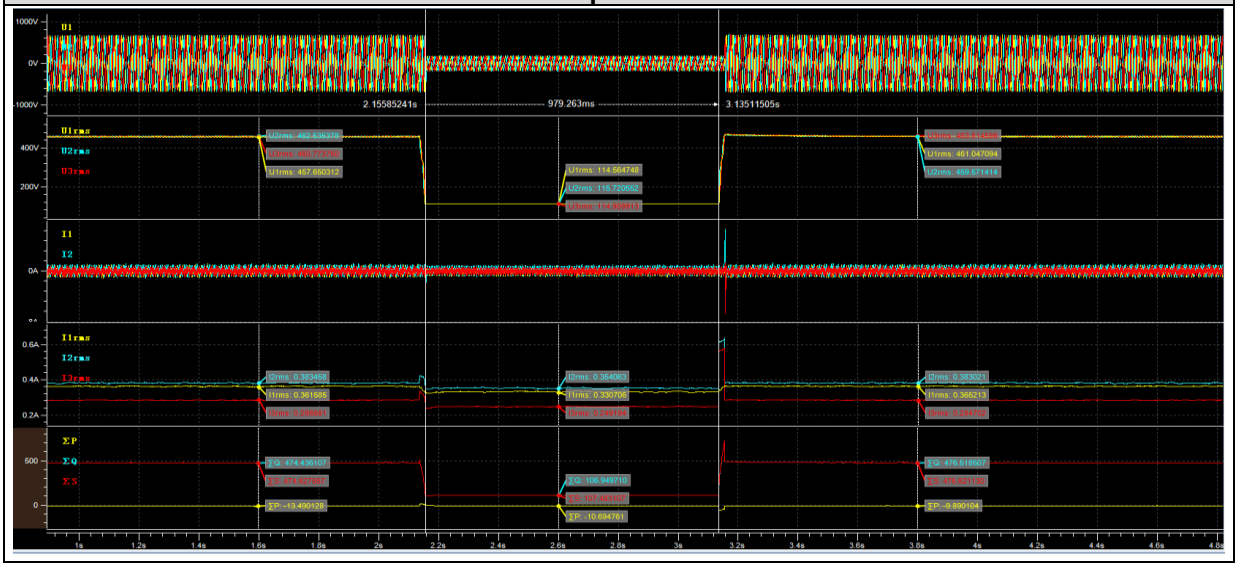


Three-Phase fault	
No Load	Residual voltage: 25 %Un

Voltage Drop Time

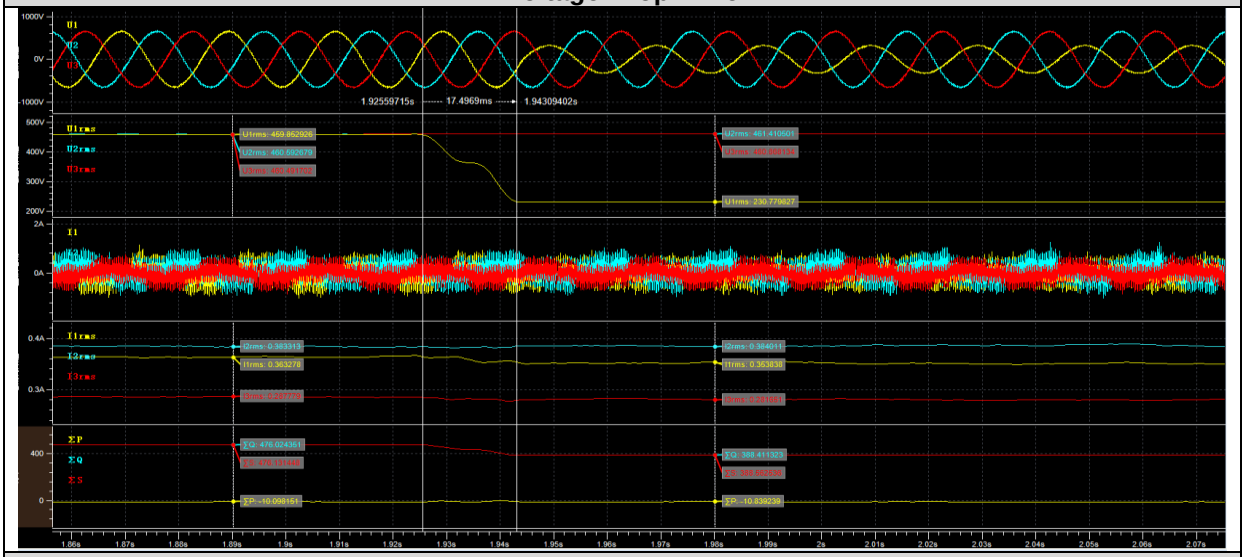


Dip Time

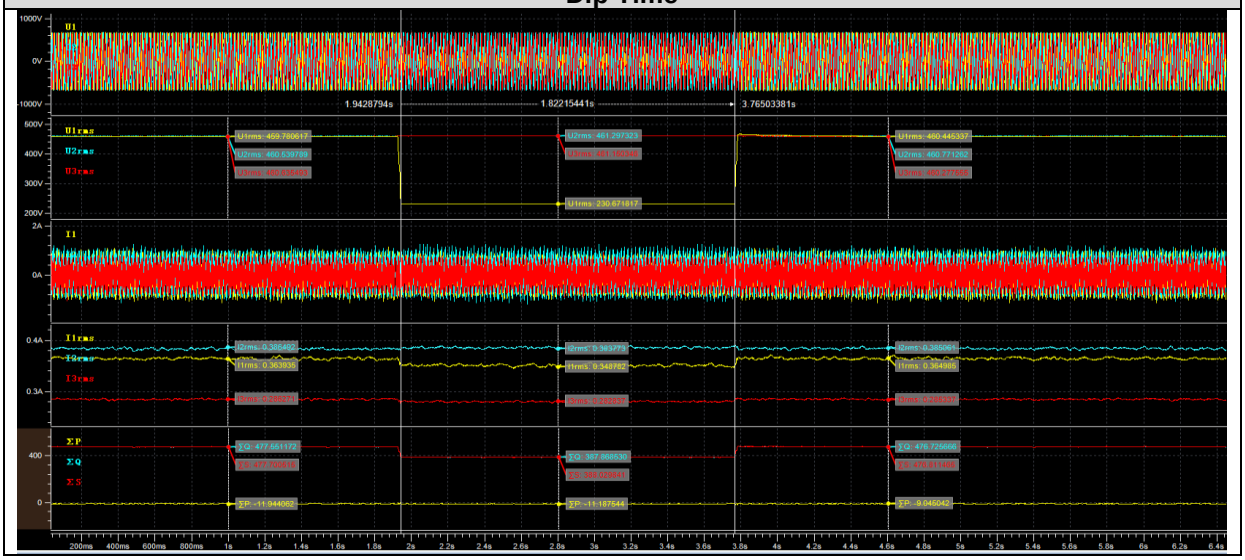


Single-Phase fault	
No Load	Residual voltage: 50 %Un

Voltage Drop Time

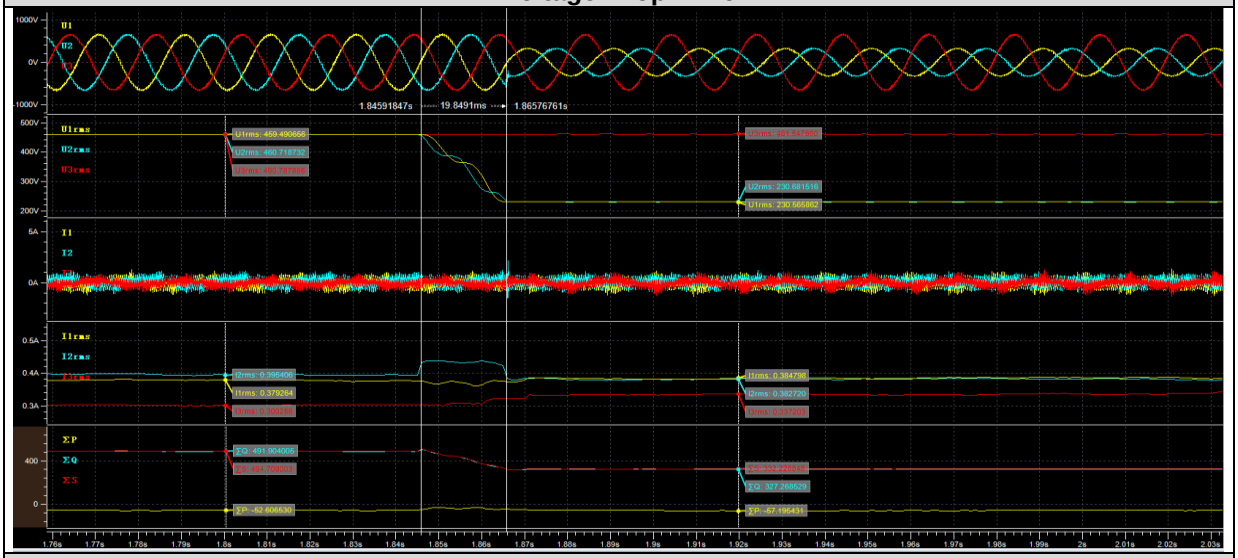


Dip Time

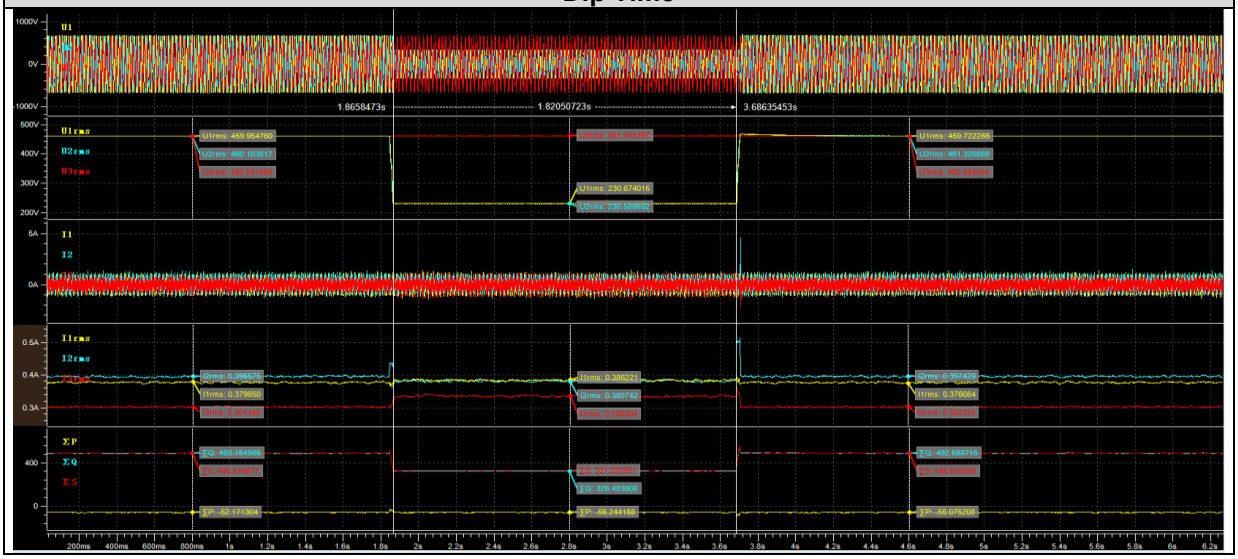


Two-Phase fault	
No Load	Residual voltage: 50 %Un

Voltage Drop Time

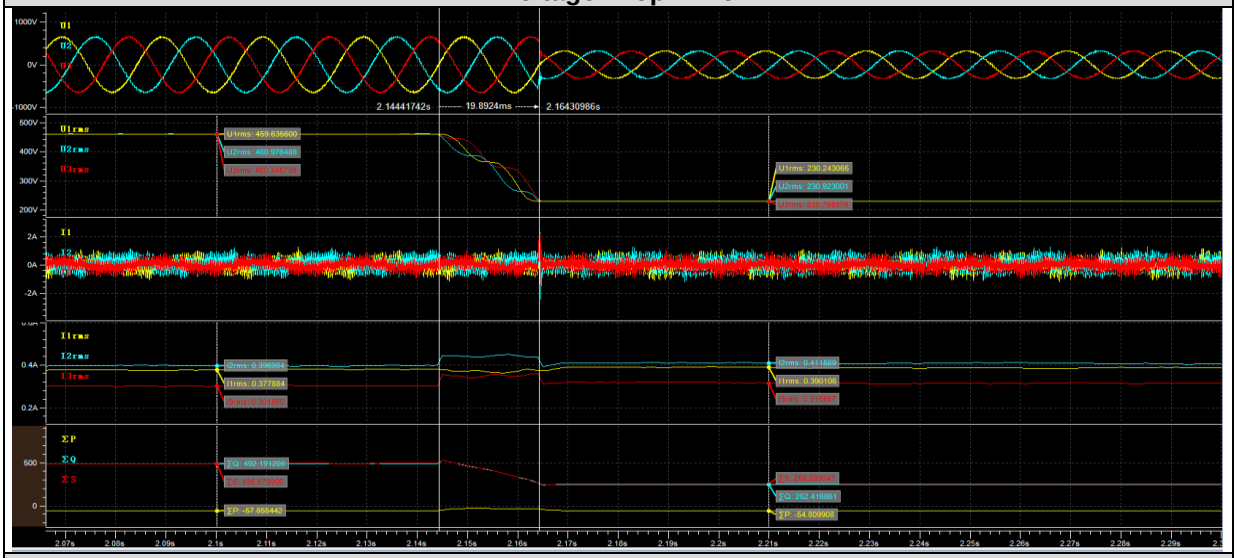


Dip Time

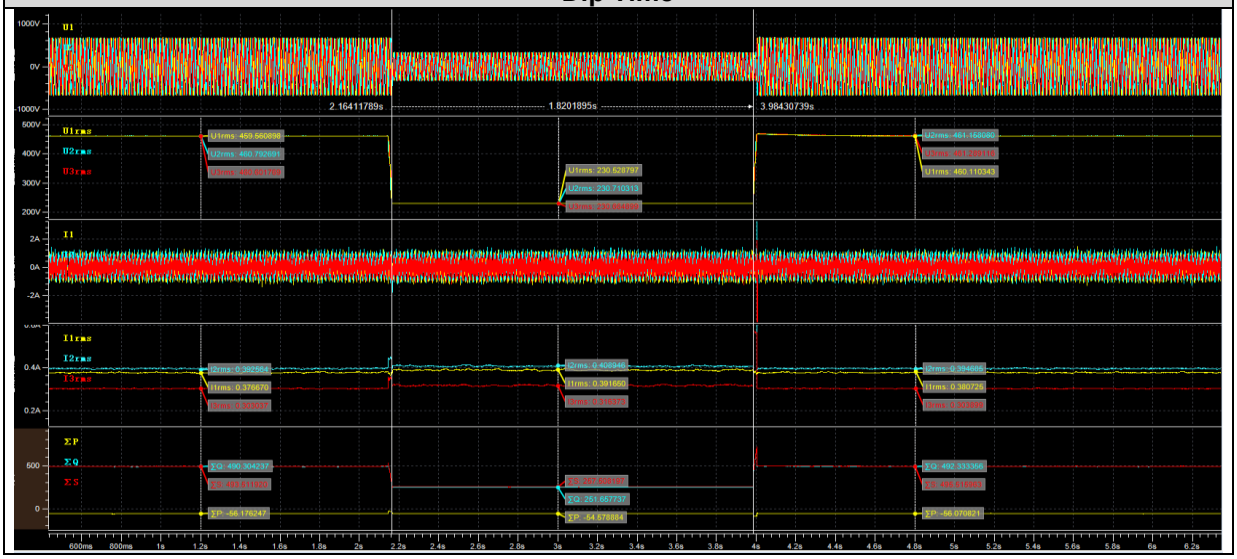


Three-Phase fault	
No Load	Residual voltage: 50 %Un

Voltage Drop Time

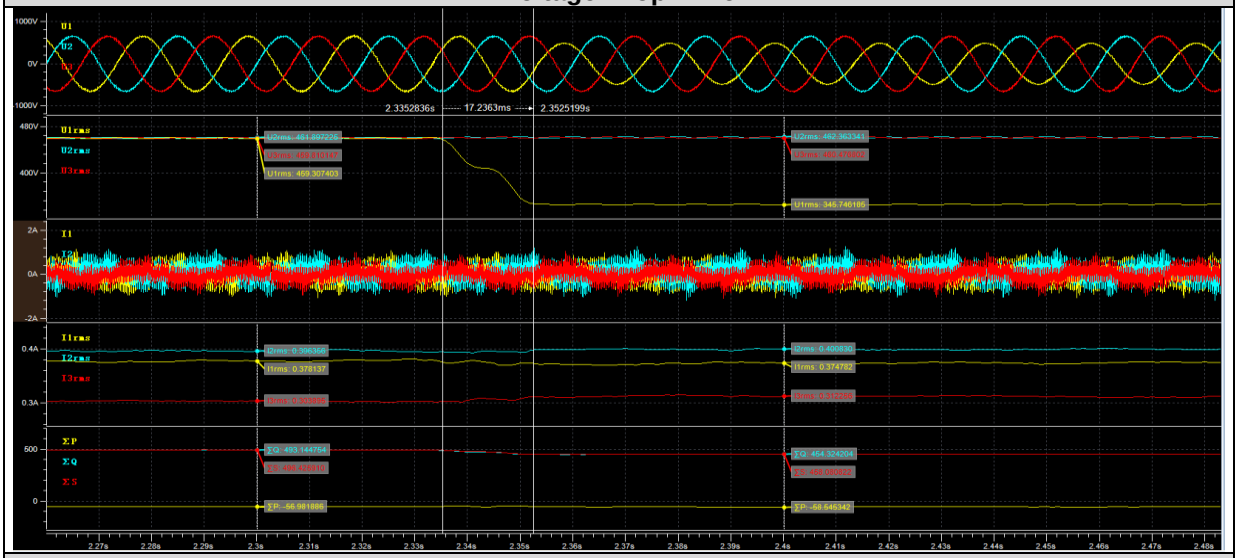


Dip Time

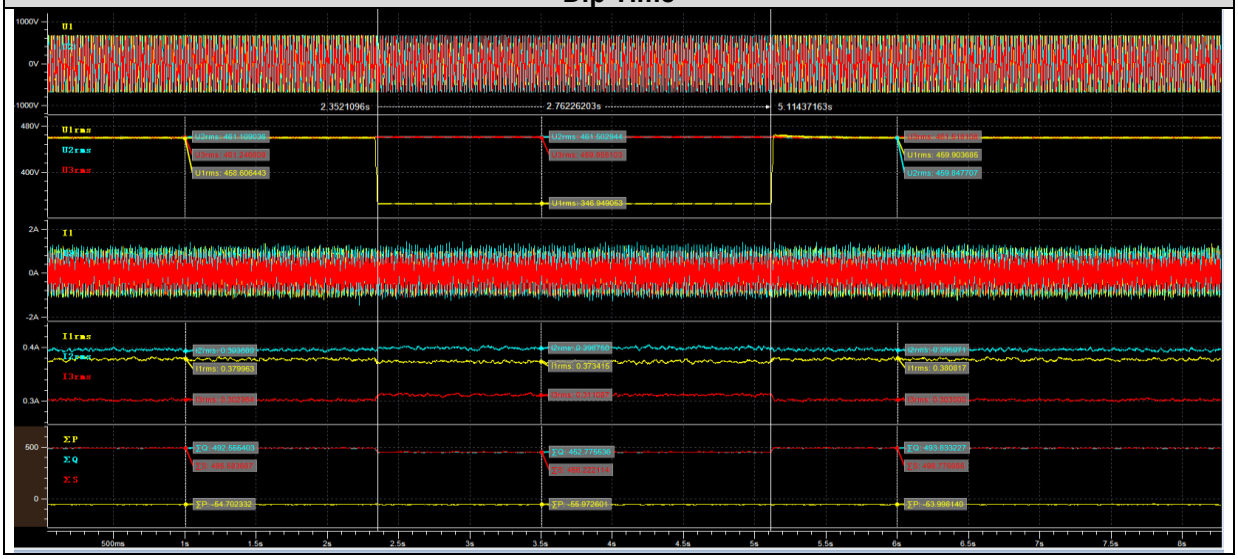


Single-Phase fault	
No Load	Residual voltage: 75 %Un

Voltage Drop Time

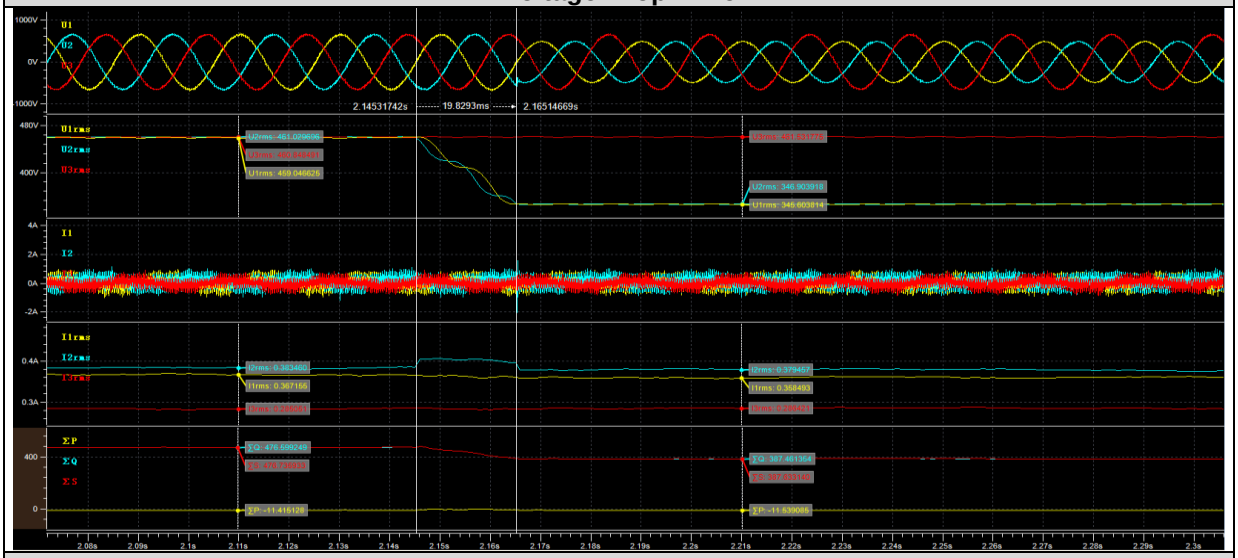


Dip Time

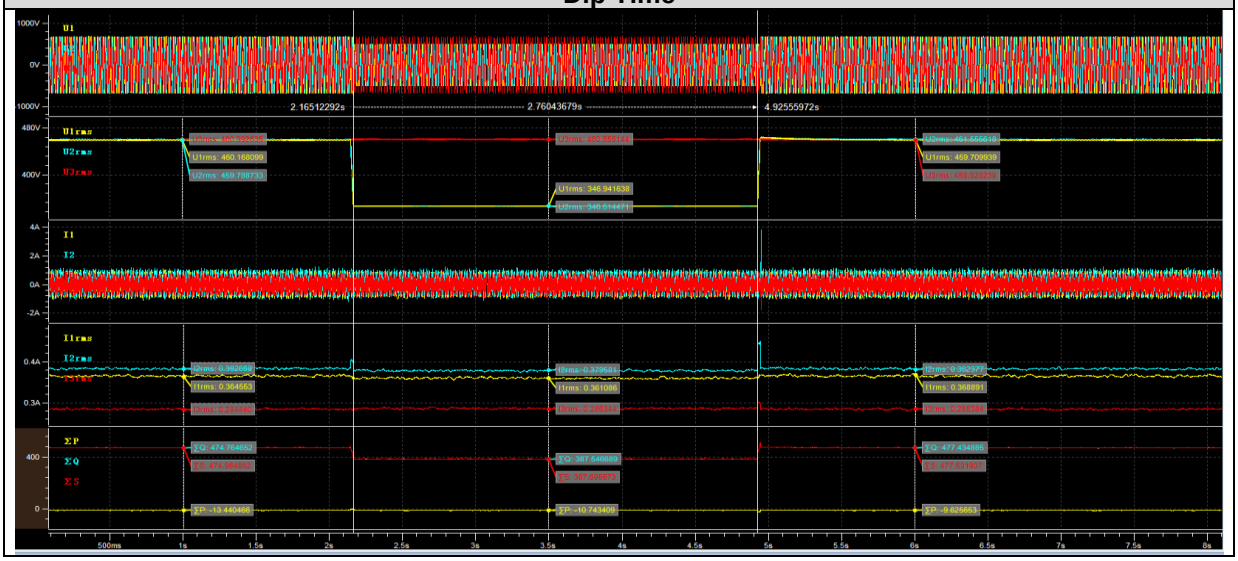


Two-Phase fault	
No Load	Residual voltage: 75 %Un

Voltage Drop Time

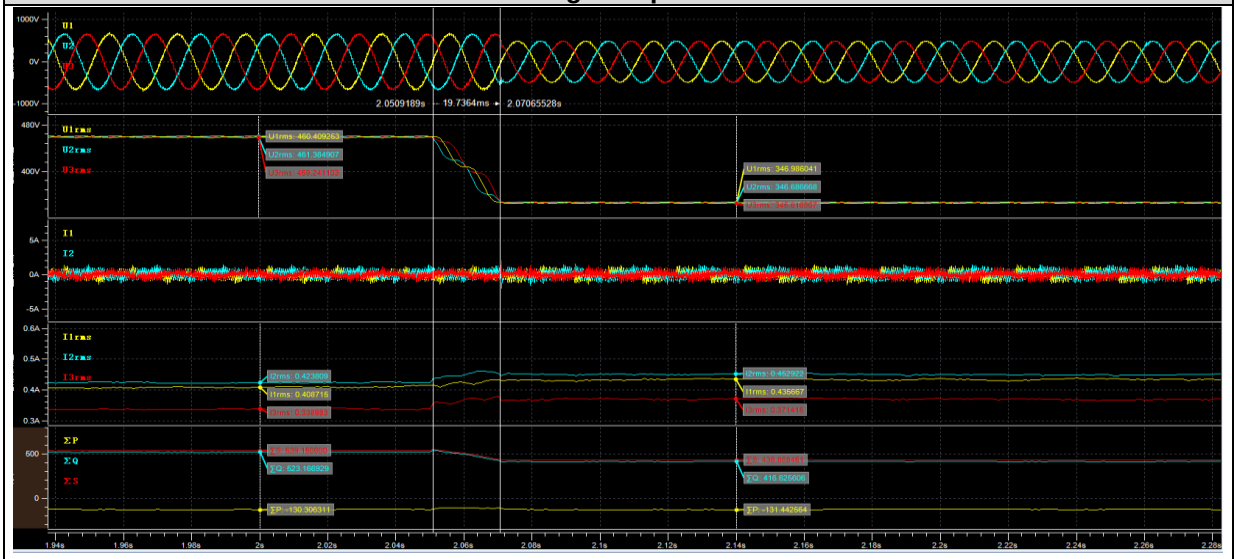


Dip Time

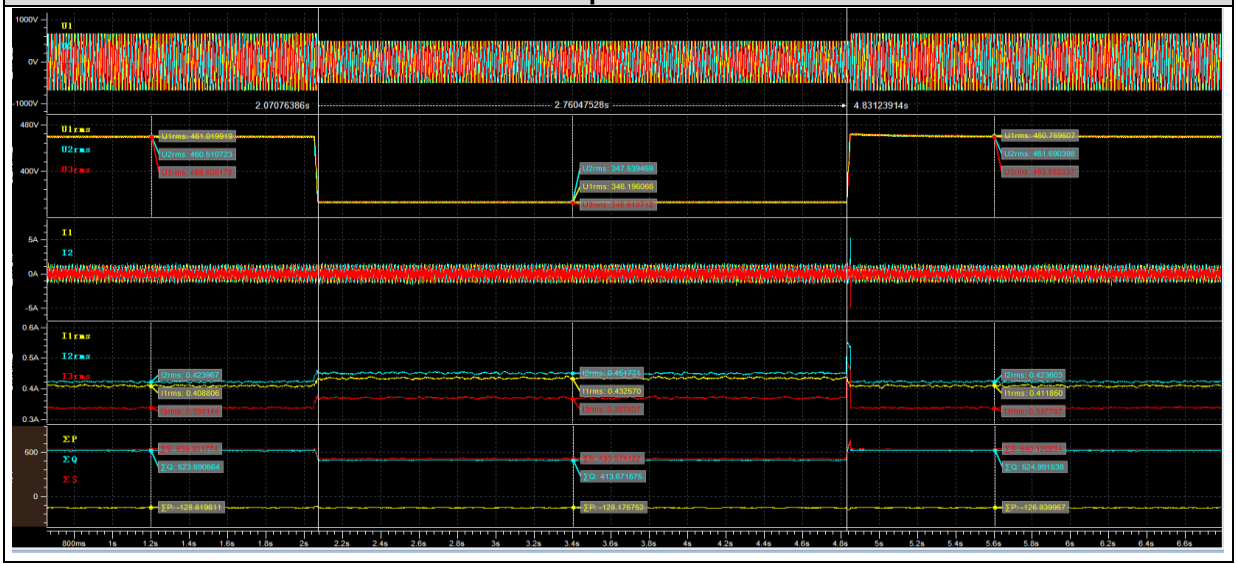


Three-Phase fault	
No Load	Residual voltage: 75 %Un

Voltage Drop Time



Dip Time



4.2.1.2. Load Tests: Partial load (20 %Pn)

Test results of different 20%Pn load cases performed are offered below:

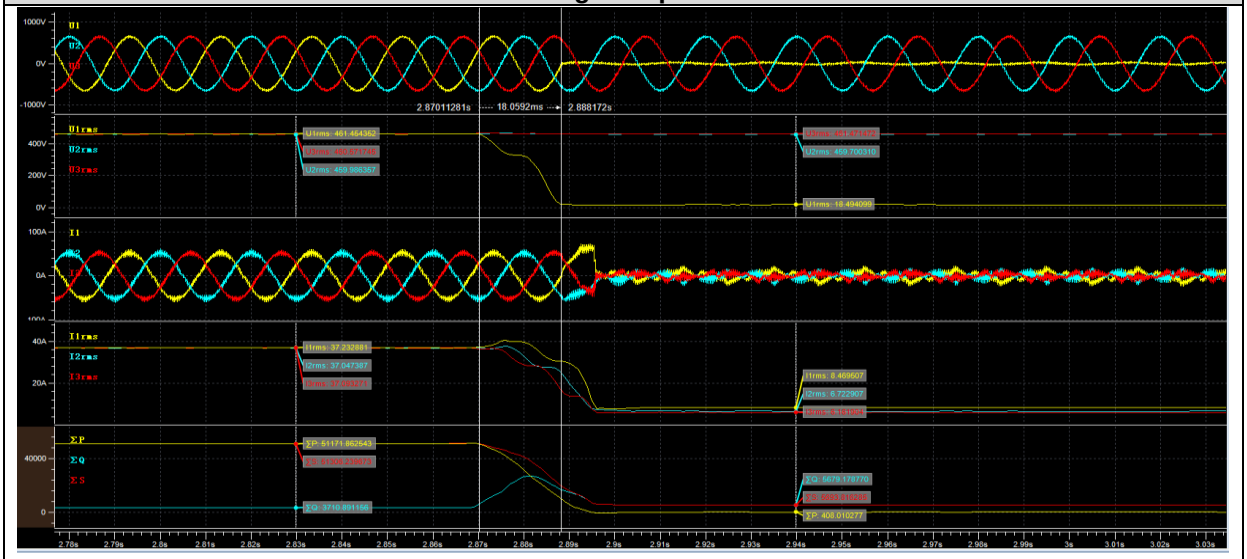
20 %Pn Load								
Phase type	**Residual voltage desired (%Un)**	**Voltage before fault (%Un)**	**Voltage drop time (ms)**	**Residual voltage Measured (%Un)**	**Dip time desired (ms)**	**Dip time measured (ms)**	**Power recovery time (ms)**	**Voltage after recovery (%Un)**
1 ph	0.0-5.0	99.9	18	4.0	≥ 250	260	279	100.7
2 ph		99.8	20	4.0		260	241	101.1
3 ph		99.7	20	4.1		260	229	101.1
1 ph	25.0	99.7	18	25.2	≥ 938	980	270	100.8
2 ph		99.8	20	25.0		979	245	100.8
3 ph		99.7	20	24.9		980	244	101.0
1 ph	50.0	99.5	19	50.1	≥ 1797	1822	267	100.3
2 ph		99.8	20	50.0		1820	258	100.7
3 ph		99.7	20	50.0		1820	245	100.7
1 ph	75.0	99.6	18	75.0	≥ 2656	2761	268	100.3
2 ph		99.6	20	75.1		2761	256	100.3
3 ph		99.7	20	75.0		2760	257	100.4

Note: The virtual neutral line was used in the test, Un ≈ 461.9 V.

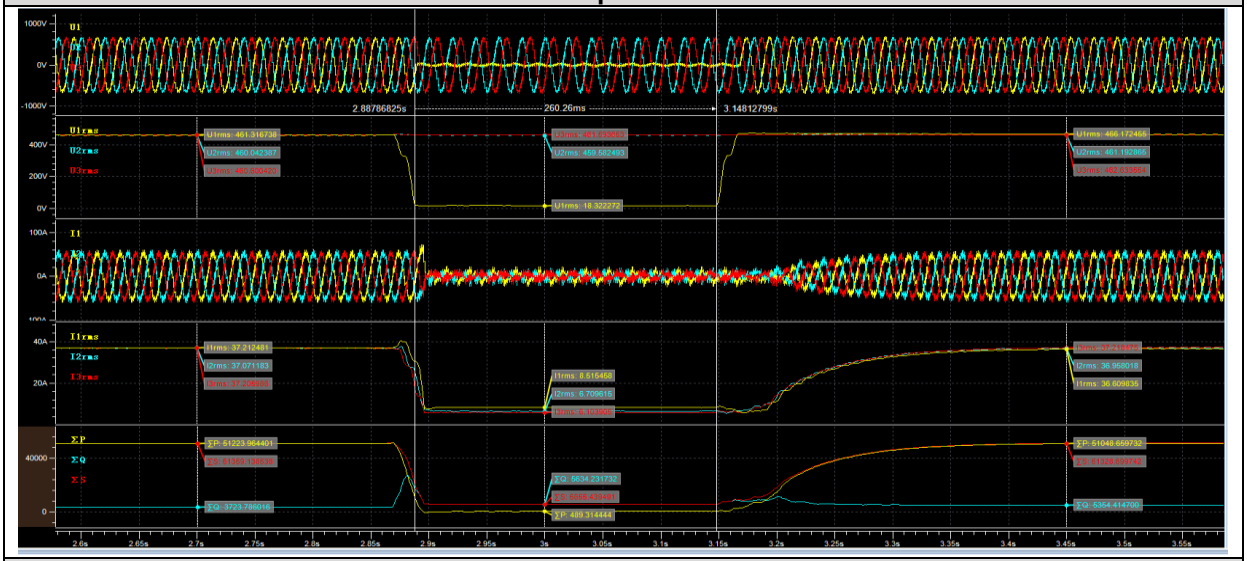
Test results are graphically represented at following pages.

Single-Phase fault	
20%Pn Load	Residual voltage: 0~5%Un

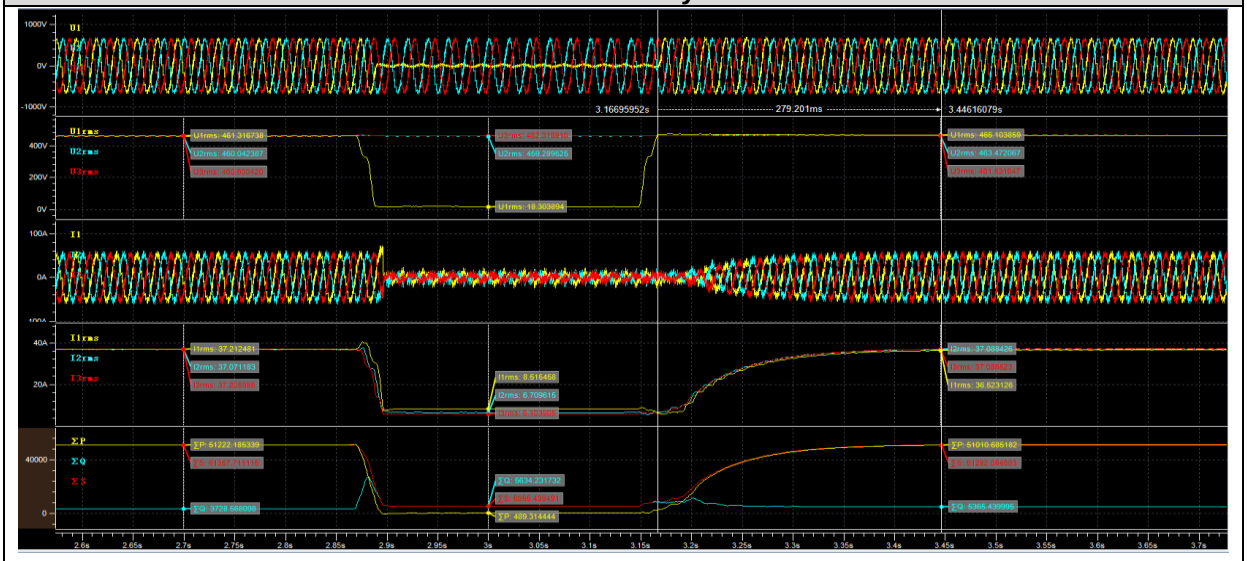
Voltage Drop time



Dip time

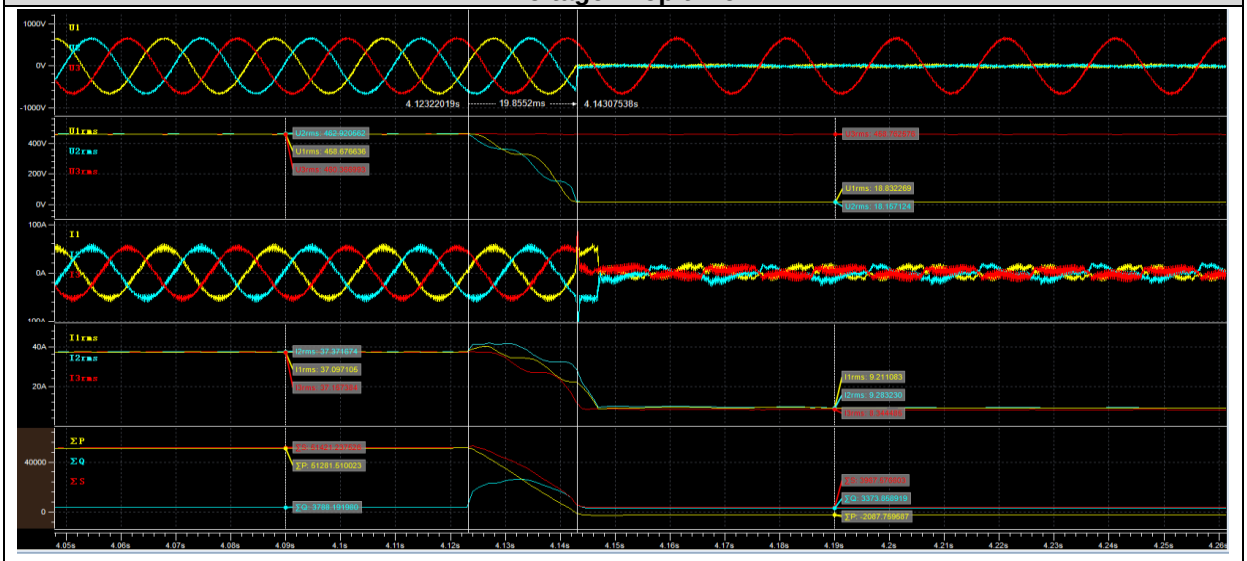


Power Recovery time

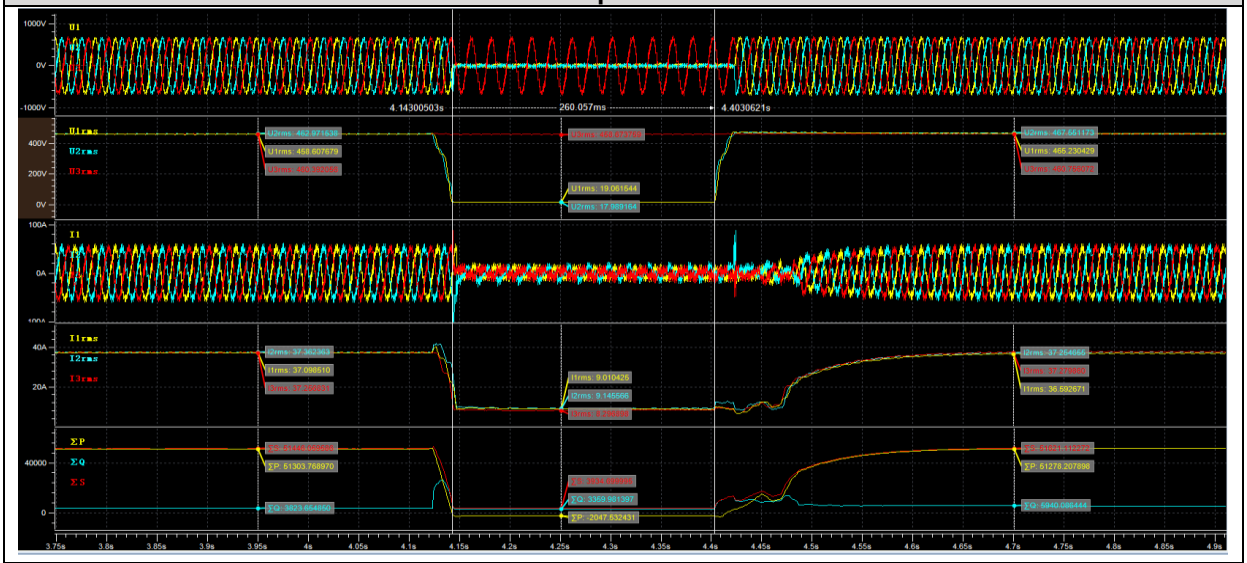


Two-Phase fault	
20%Pn Load	Residual voltage: 0~5%Un

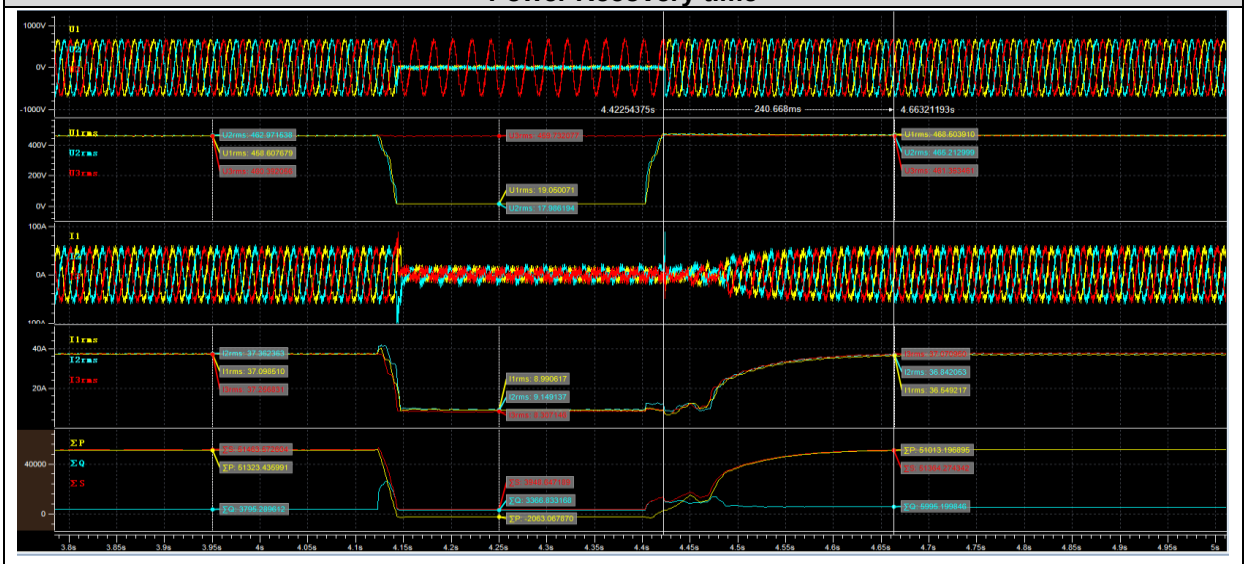
Voltage Drop time



DipTime

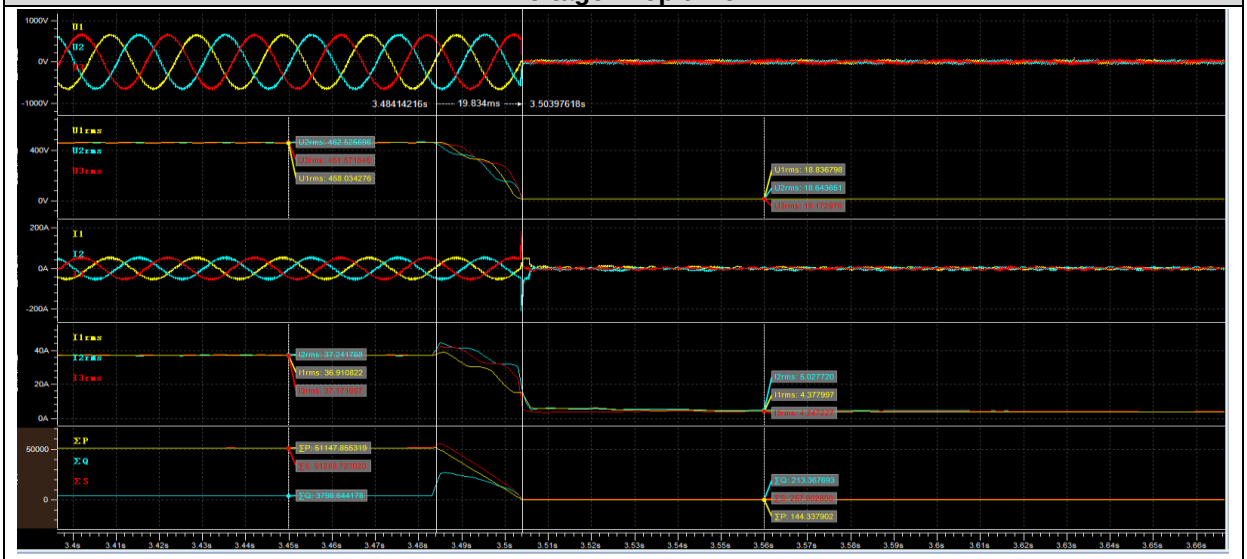


Power Recovery time

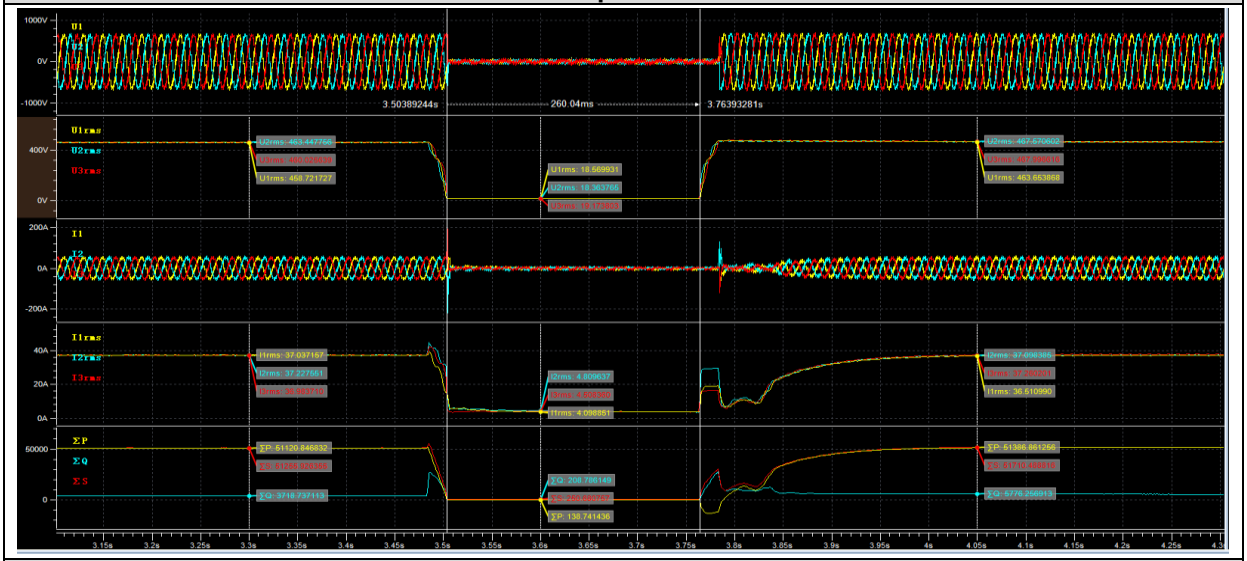


Three-Phase fault	
20%Pn Load	Residual voltage: 0~5%Un

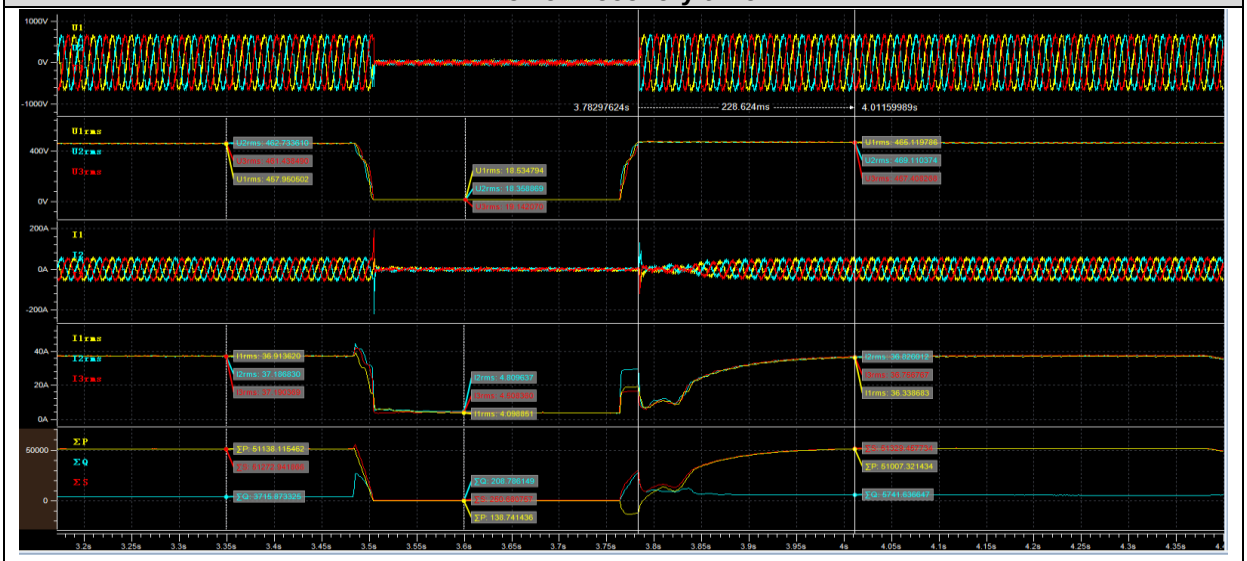
Voltage Drop time



DipTime

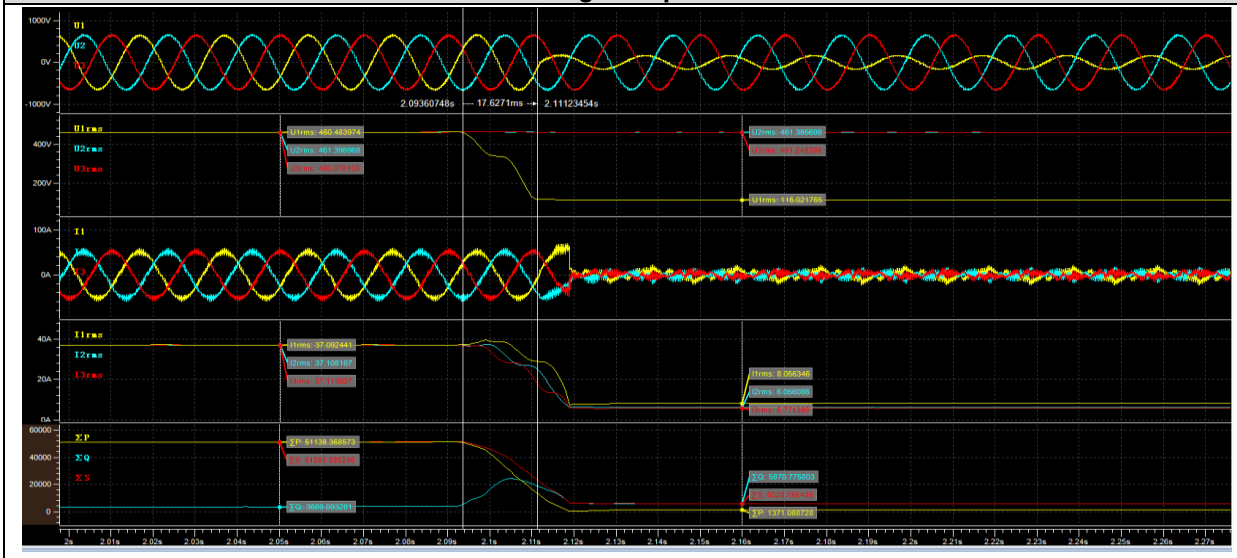


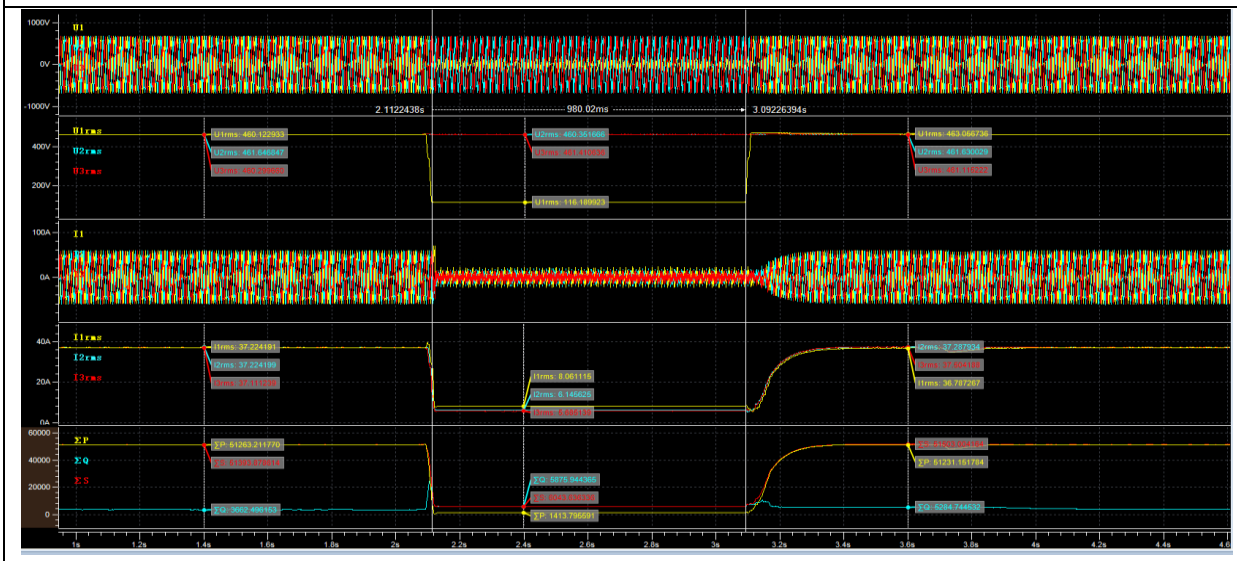
Power Recovery time



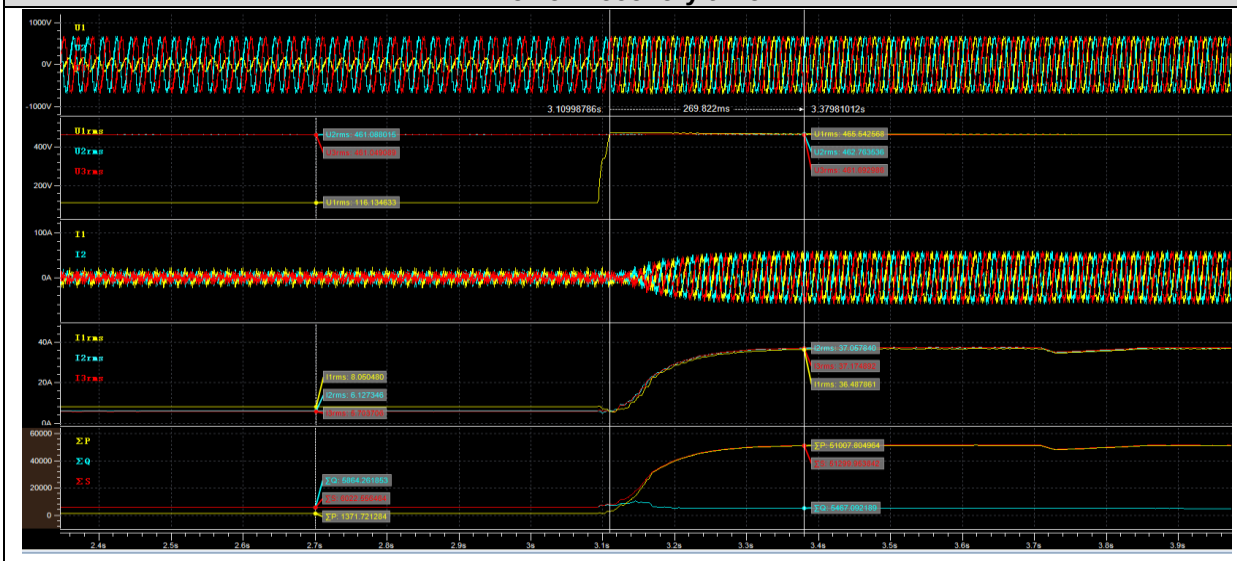
Single-Phase fault	
20%Pn Load	Residual voltage: 25%Un

Voltage Drop time



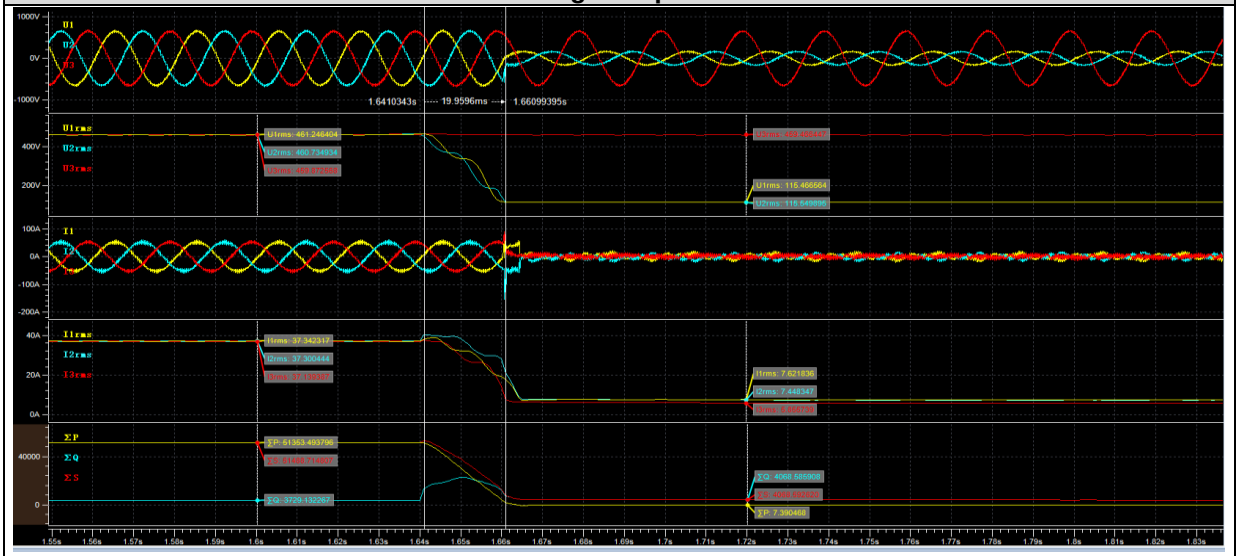


Power Recovery time

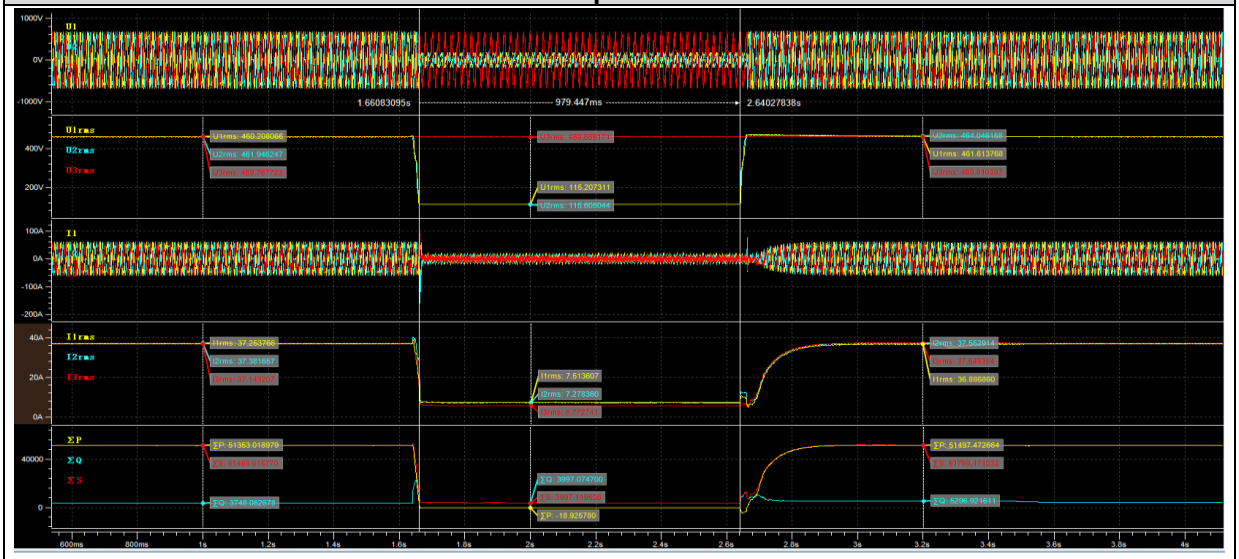


Two-Phase fault	
20%Pn Load	Residual voltage: 25%Un

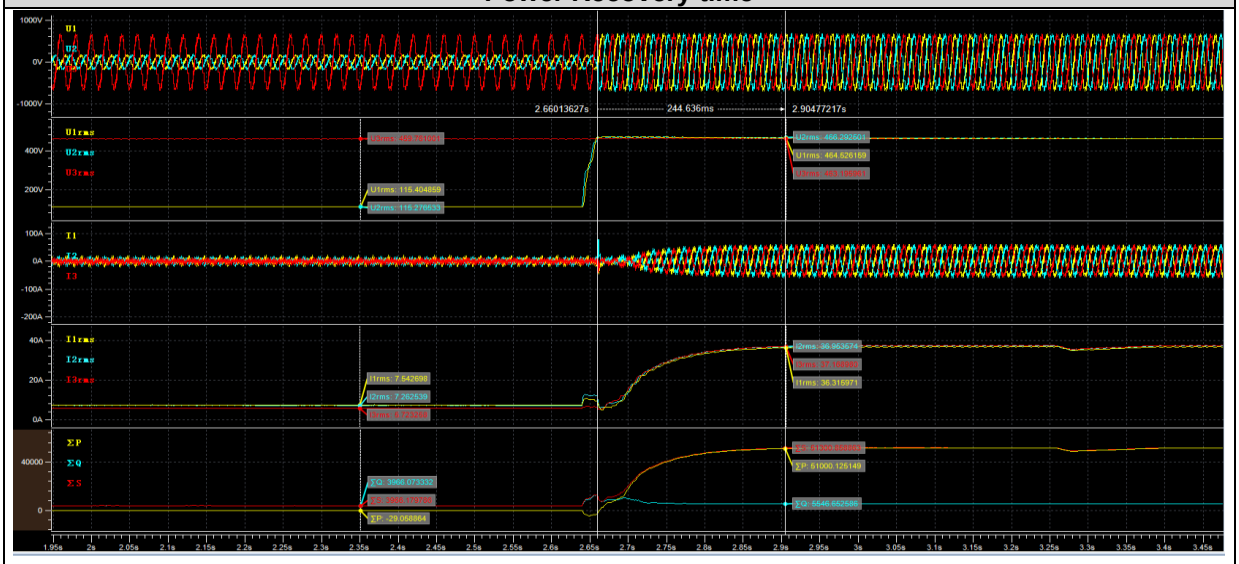
Voltage Drop time



DipTime

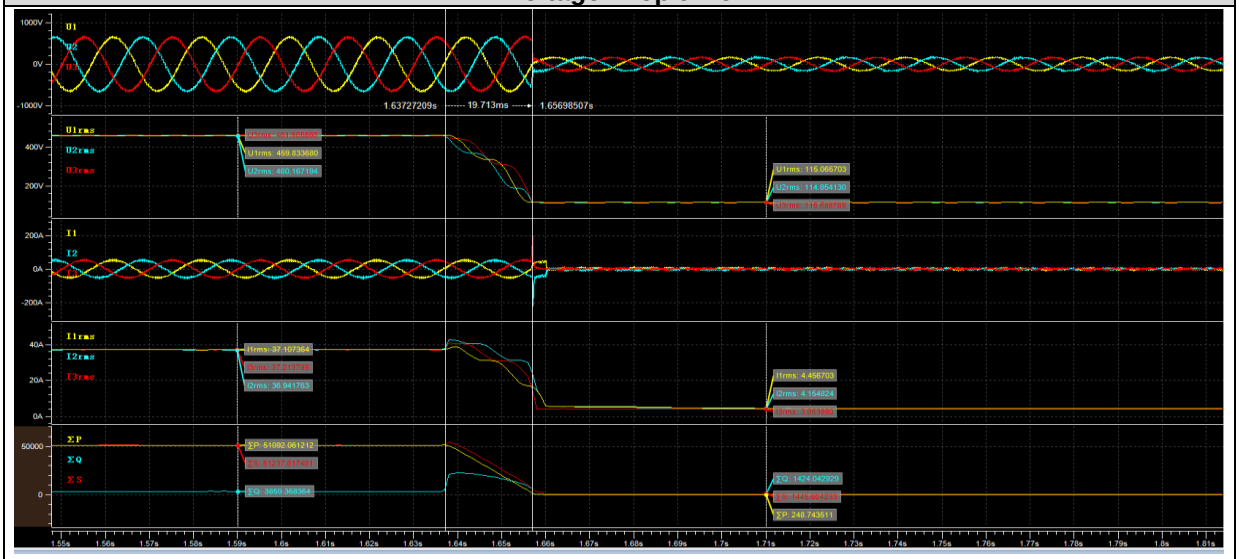


Power Recovery time

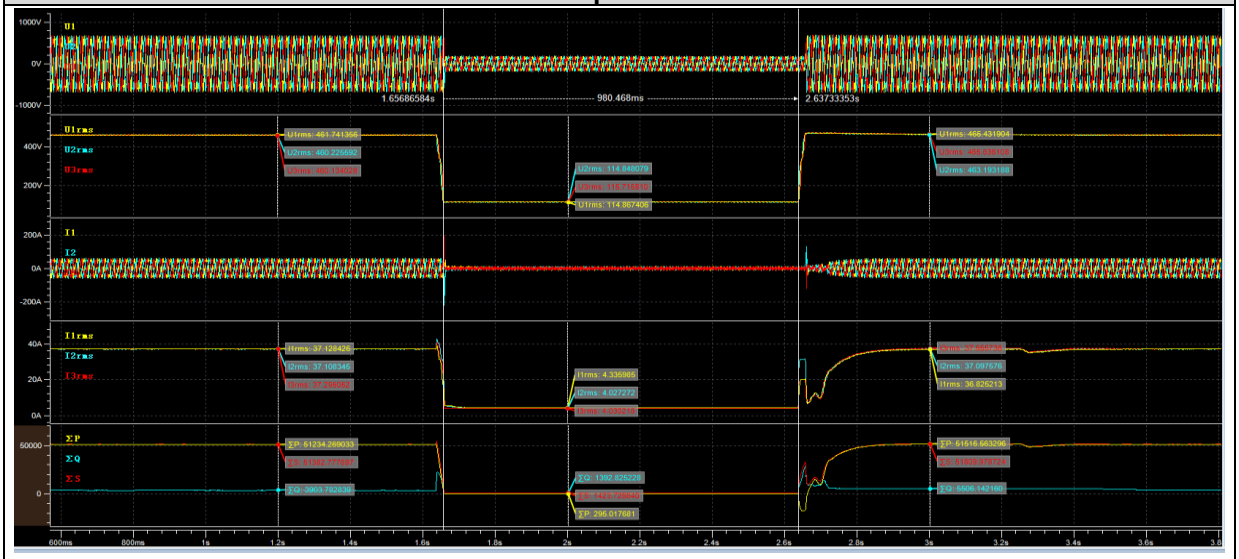


Three-Phase fault	
20%Pn Load	Residual voltage: 25%Un

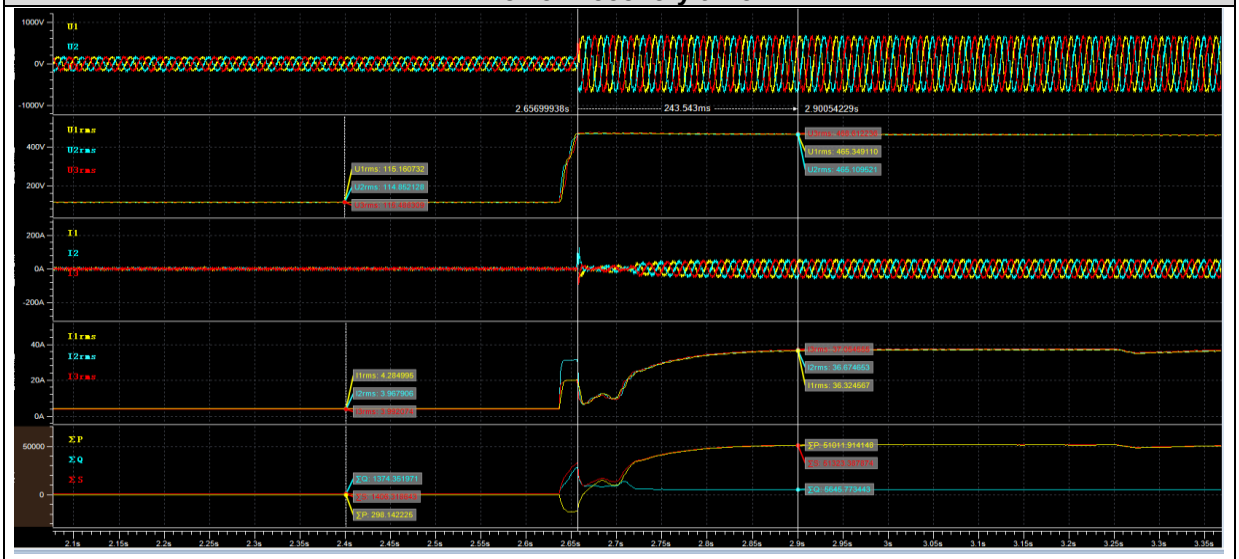
Voltage Drop time



DipTime

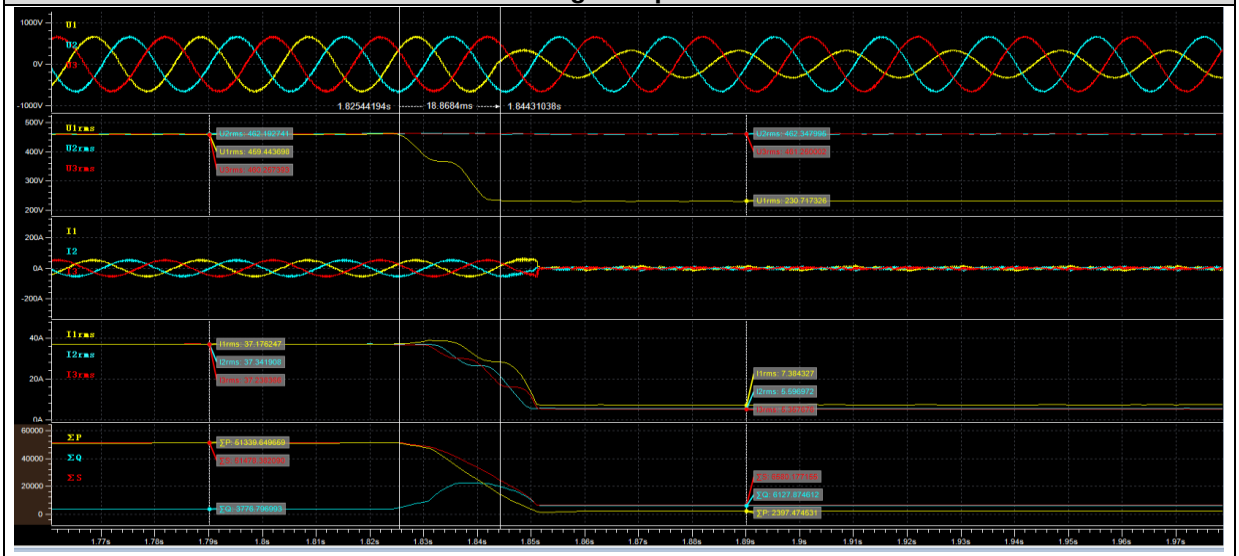


Power Recovery time

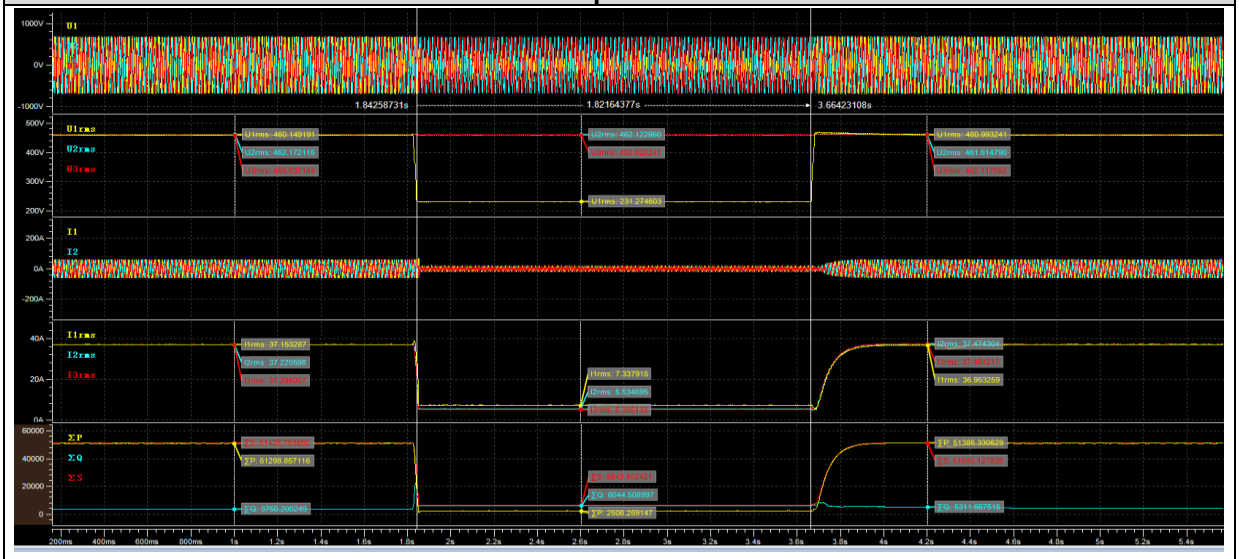


Single-Phase fault	
20%Pn Load	Residual voltage: 50%Un

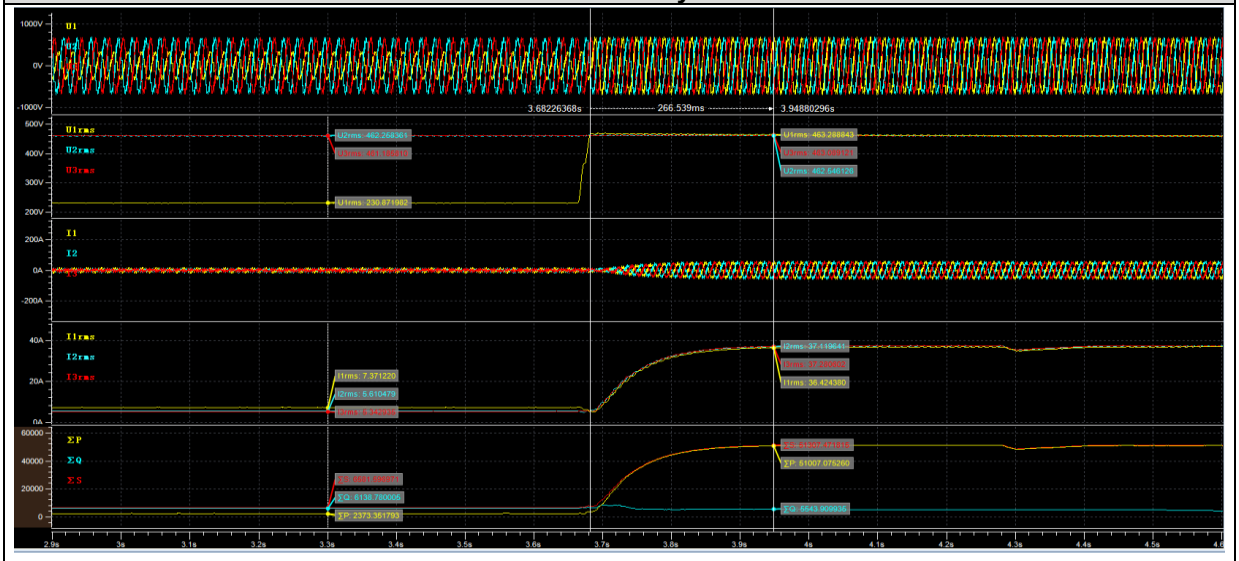
Voltage Drop time



DipTime

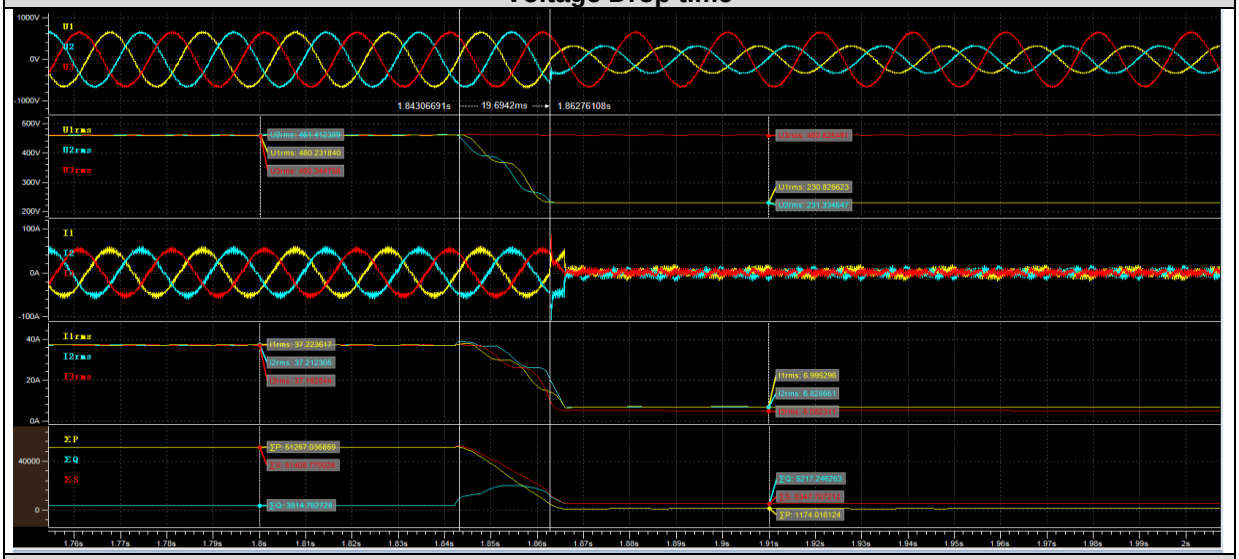


Power Recovery time

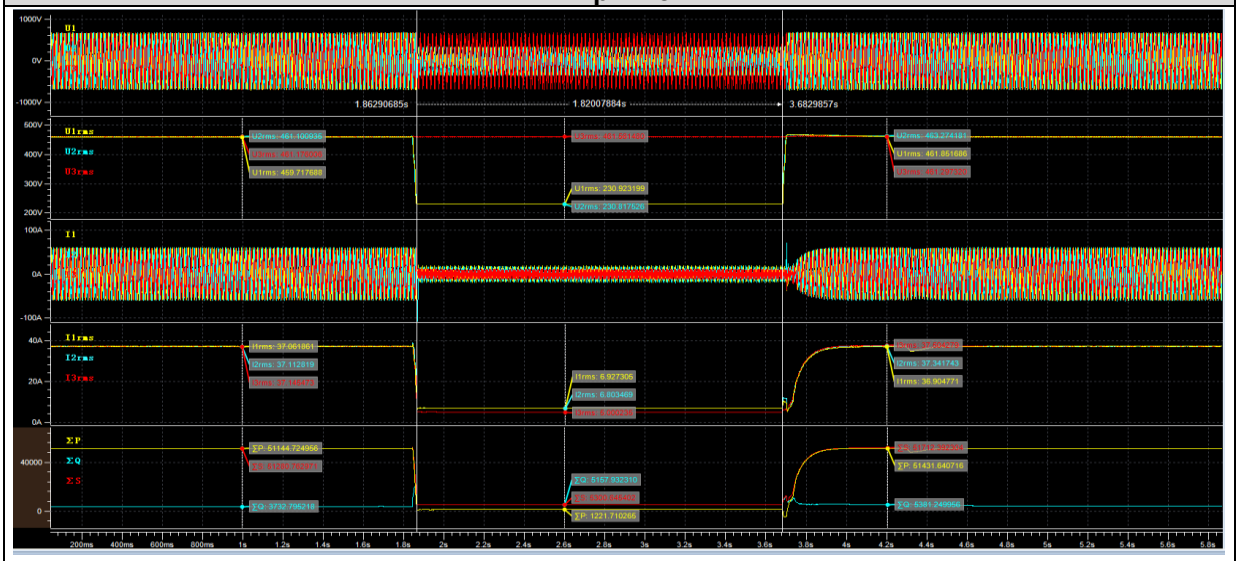


Two-Phase fault	
20%Pn Load	Residual voltage: 50%Un

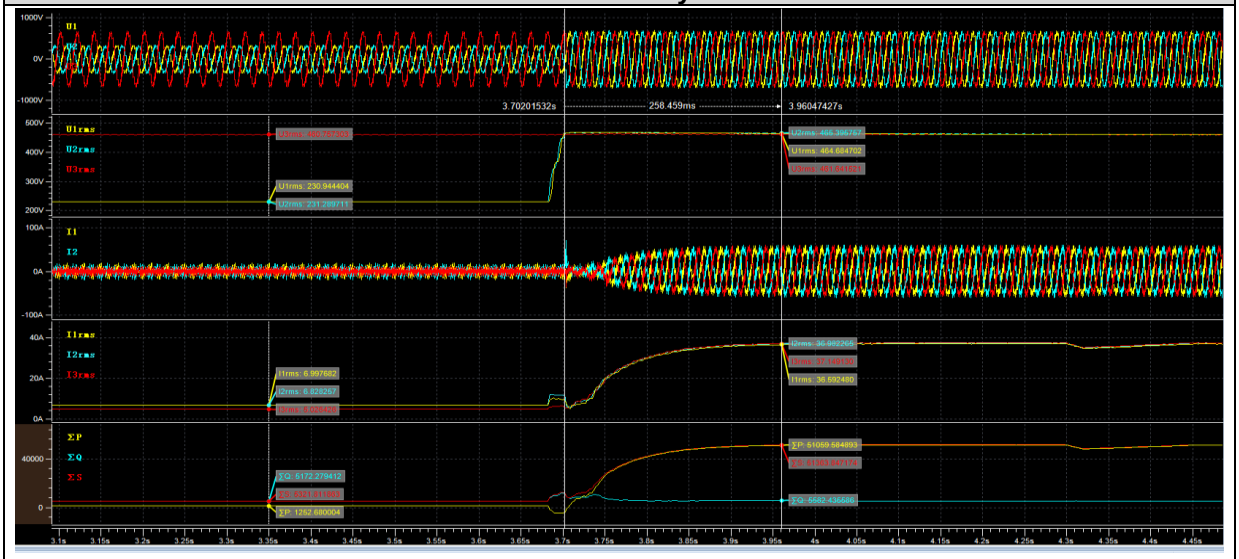
Voltage Drop time



DipTime

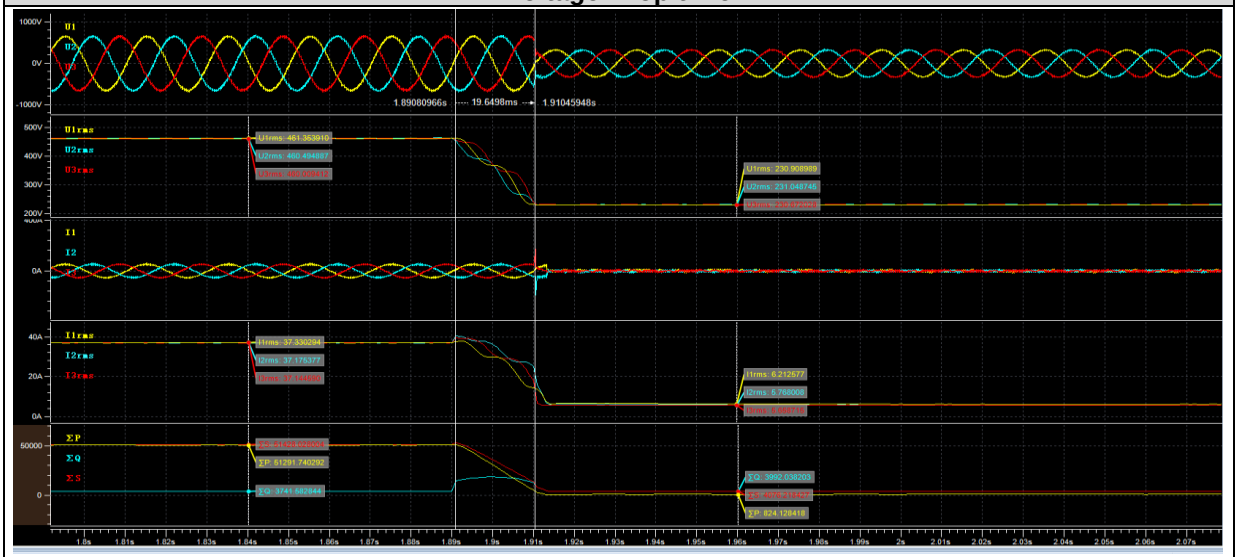


Power Recovery time

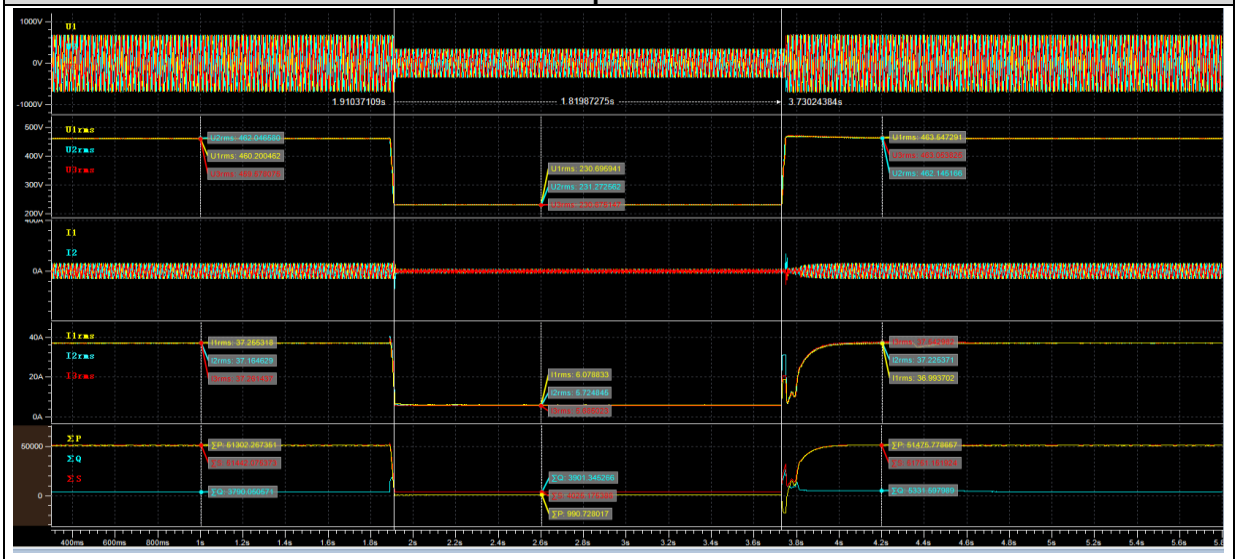


Three-Phase fault	
20%Pn Load	Residual voltage: 50%Un

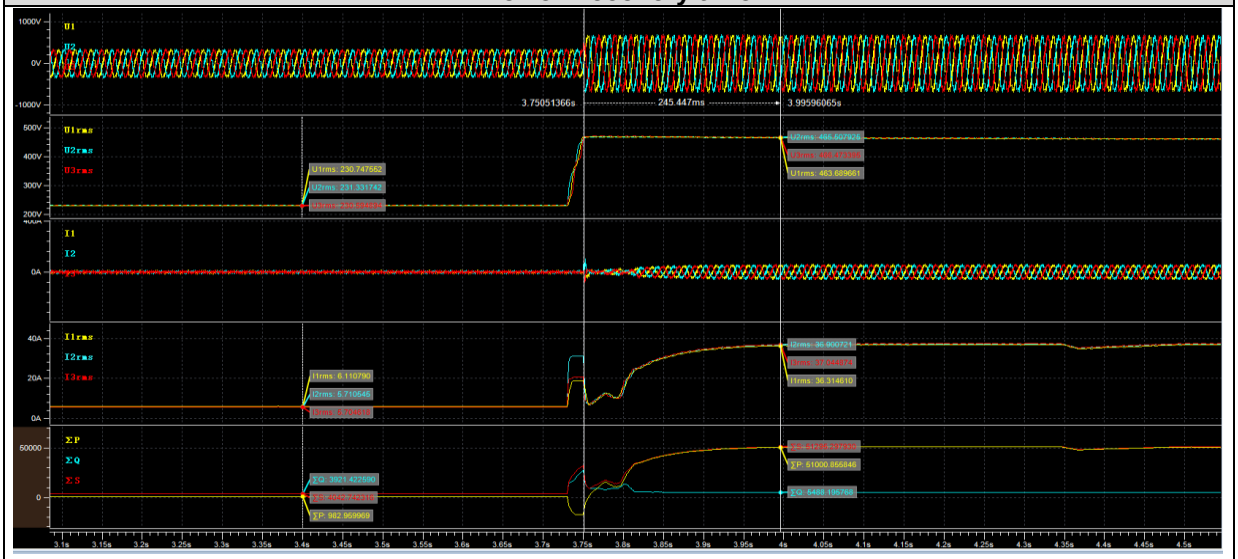
Voltage Drop time



DipTime

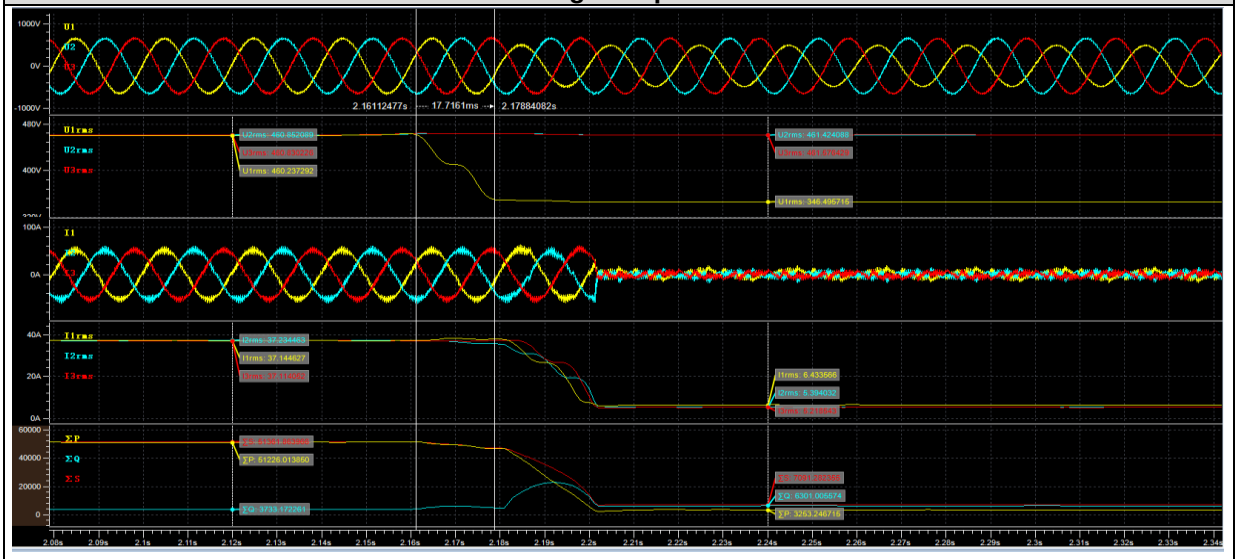


Power Recovery time

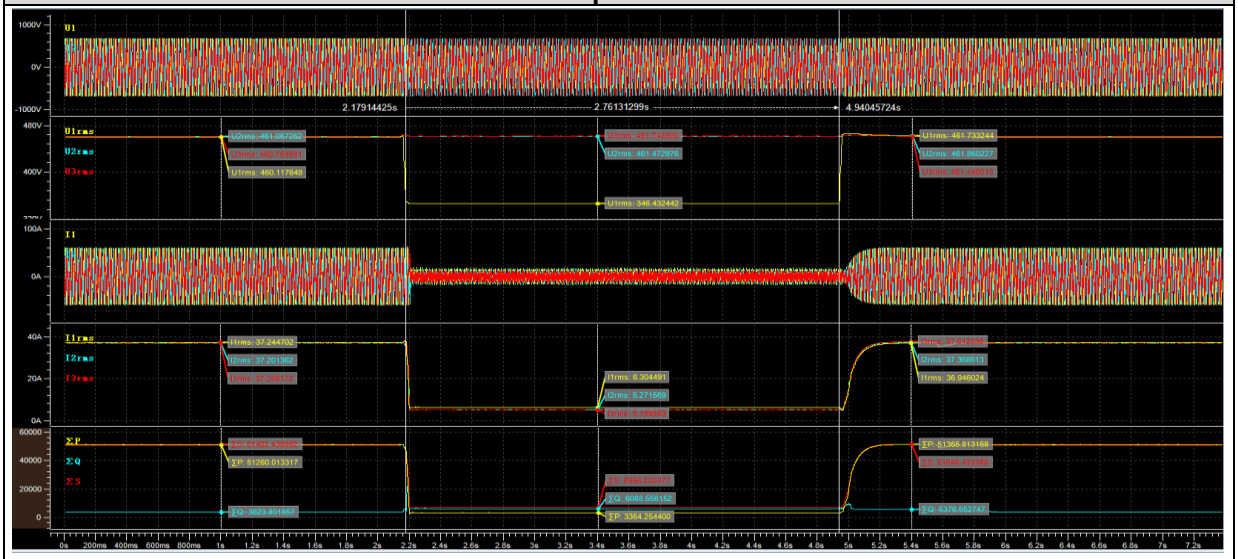


Single-Phase fault	
20%Pn Load	Residual voltage: 75%Un

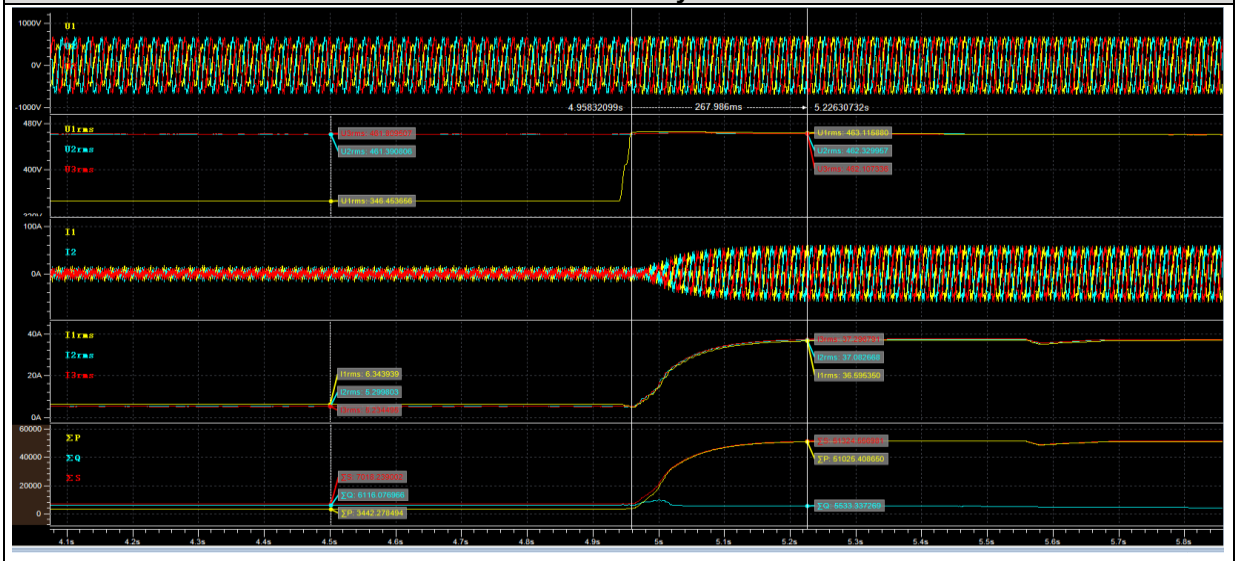
Voltage Drop time



DipTime

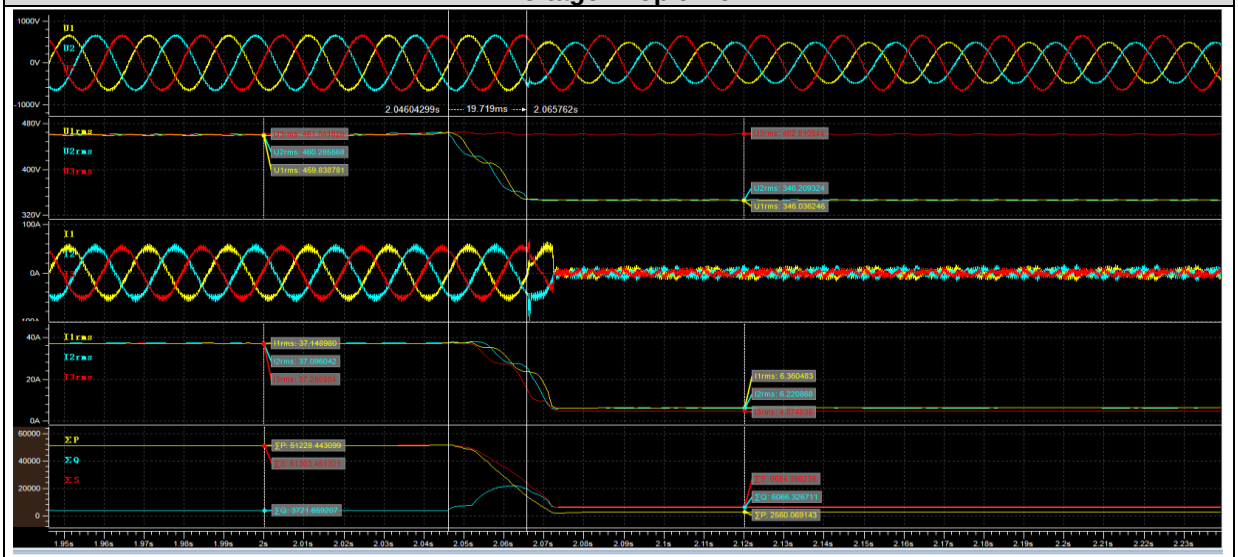


Power Recovery time

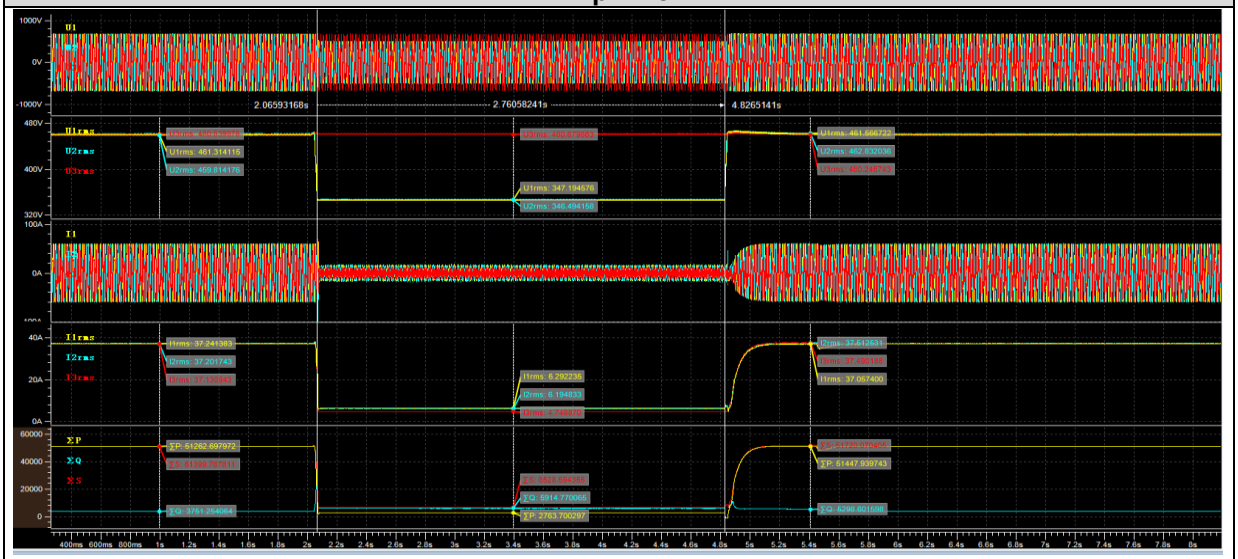


Two-Phase fault	
20%Pn Load	Residual voltage: 75%Un

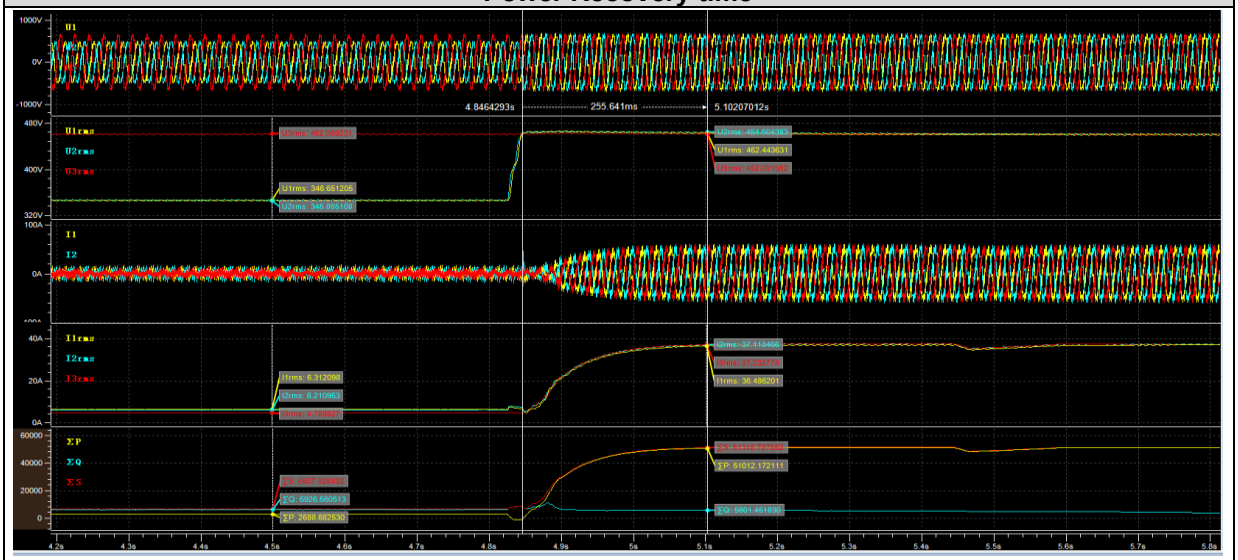
Voltage Drop time



DipTime

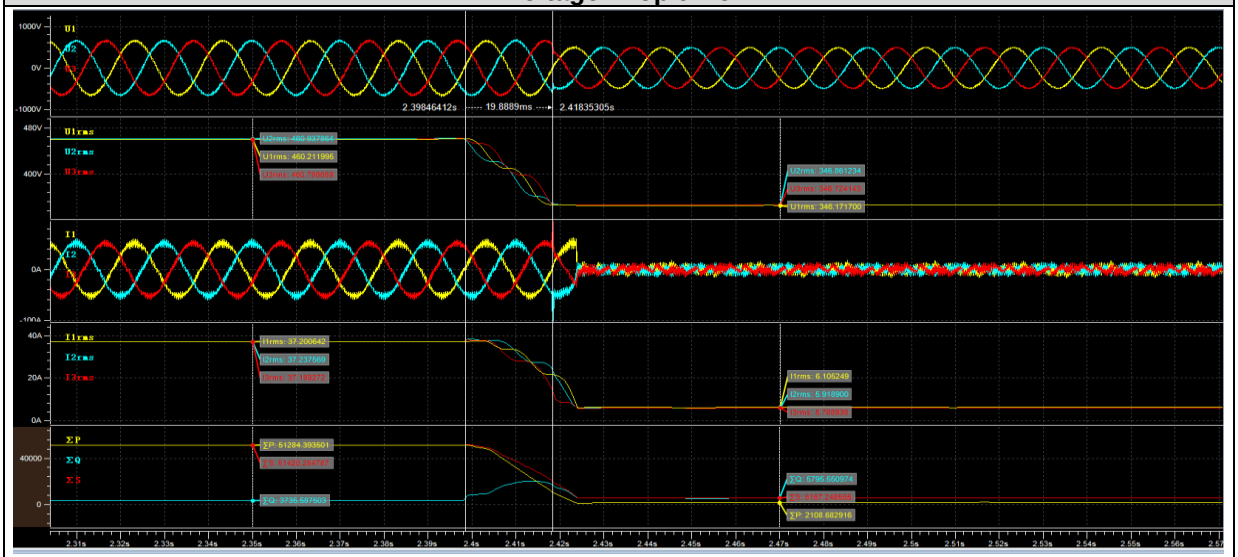


Power Recovery time

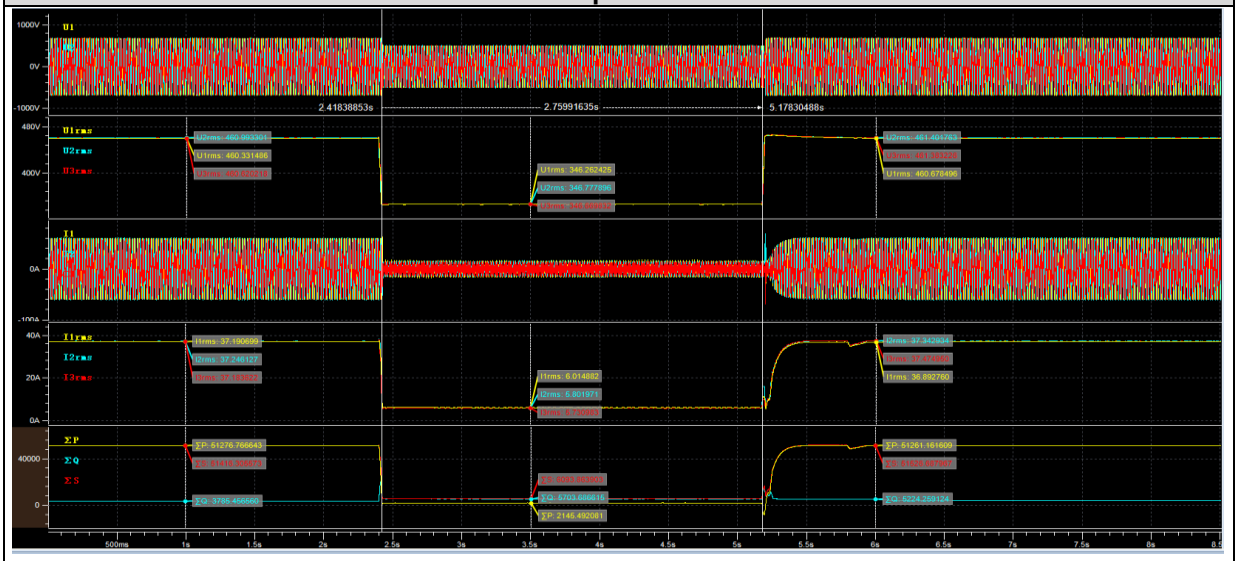


Three-Phase fault	
20%Pn Load	Residual voltage: 75%Un

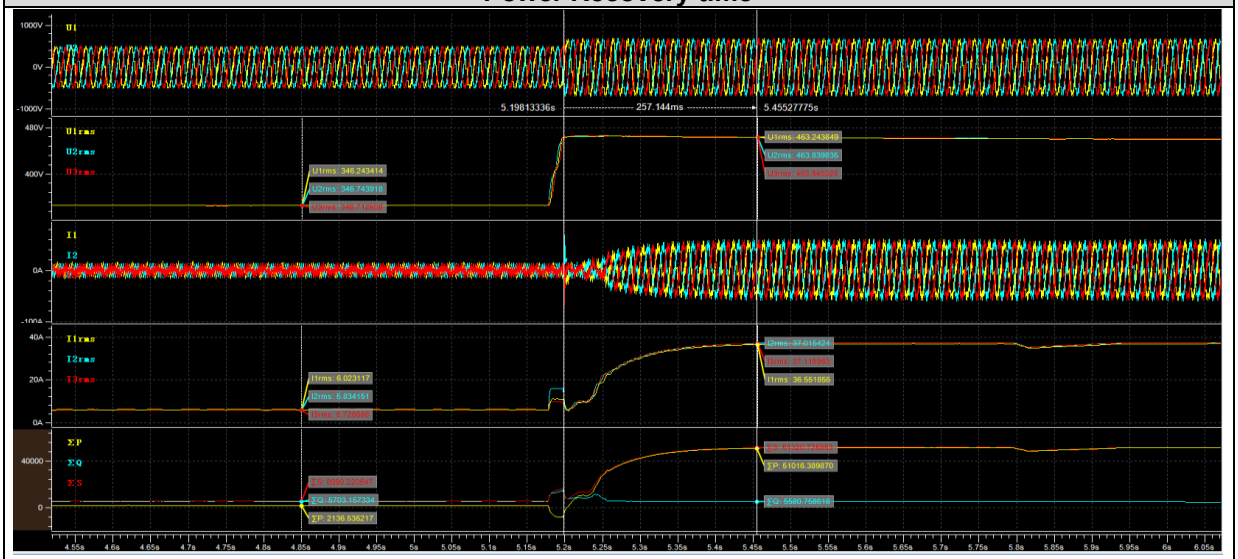
Voltage Drop time



DipTime



Power Recovery time



4.2.1.3. Load Tests: Partial load (> 90 %Pn)

Test results of different 100%Pn load cases performed are offered below:

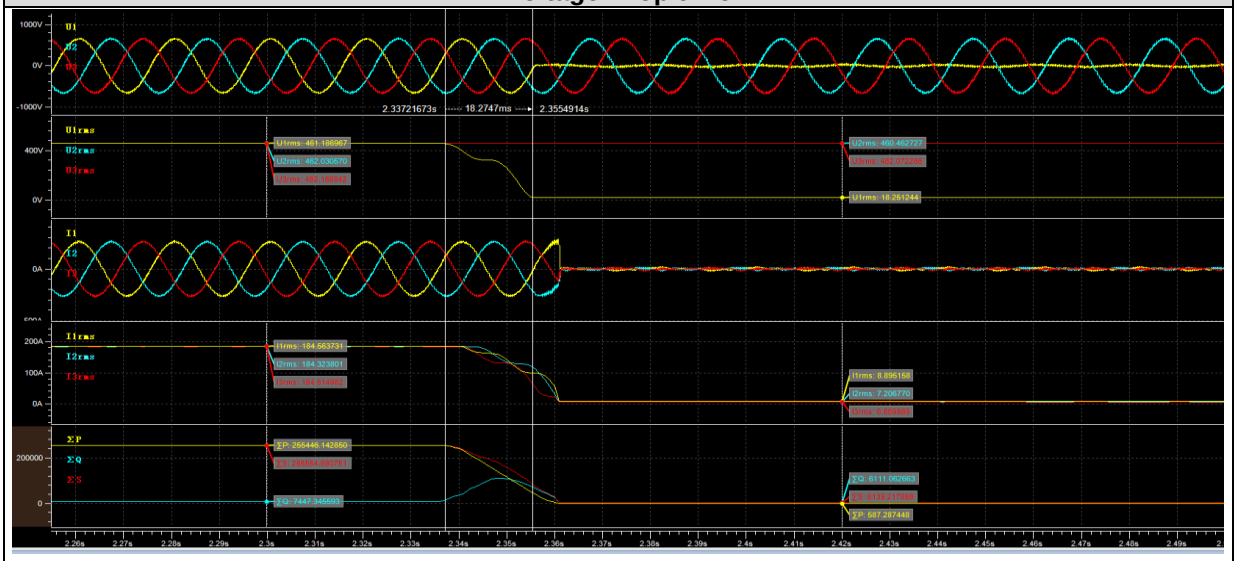
> 90 %Pn Load								
Phase type	**Residual voltage desired (%Un)**	**Voltage before fault (%Un)**	**Voltage drop time (ms)**	**Residual voltage Measured (%Un)**	**Dip time desired (ms)**	**Dip time measured (ms)**	**Power recovery time (ms)**	**Voltage after recovery (%Un)**
1 ph	0.0-5.0	99.8	18	4.0	≥ 250	260	202	101.3
2 ph		99.8	20	4.0		259	574	100.1
3 ph		100.0	20	4.1		260	547	100.4
1 ph	25.0	99.7	18	25.1	≥ 938	981	173	101.4
2 ph		99.9	20	25.0		979	186	101.2
3 ph		100.0	20	24.9		979	203	101.3
1 ph	50.0	100.0	17	50.1	≥ 1797	1821	288	100.4
2 ph		100.1	20	50.0		1820	187	101.0
3 ph		100.0	20	50.0		1820	136	101.1
1 ph	75.0	99.9	18	75.0	≥ 2656	2757	320	100.2
2 ph		99.9	20	75.1		2760	381	100.3
3 ph		100.0	20	75.0		2761	299	100.4

Note: The virtual neutral line was used in the test, Un ≈ 461.9 V.

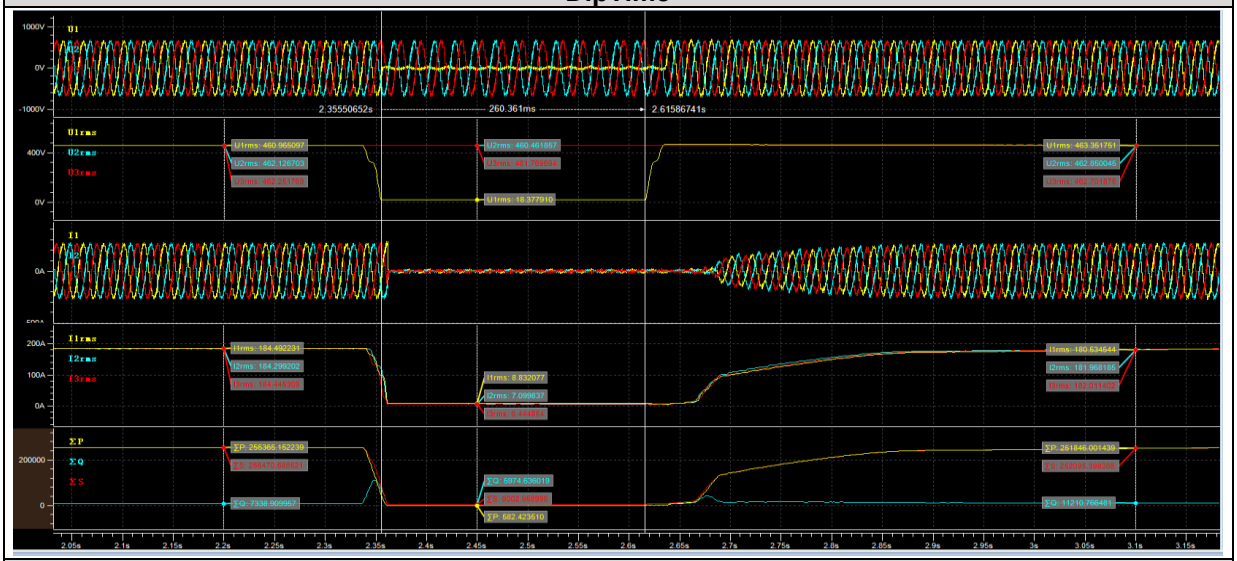
Test results are graphically represented at following pages.

Single-Phase fault	
100%Pn Load	Residual voltage: 0~5%Un

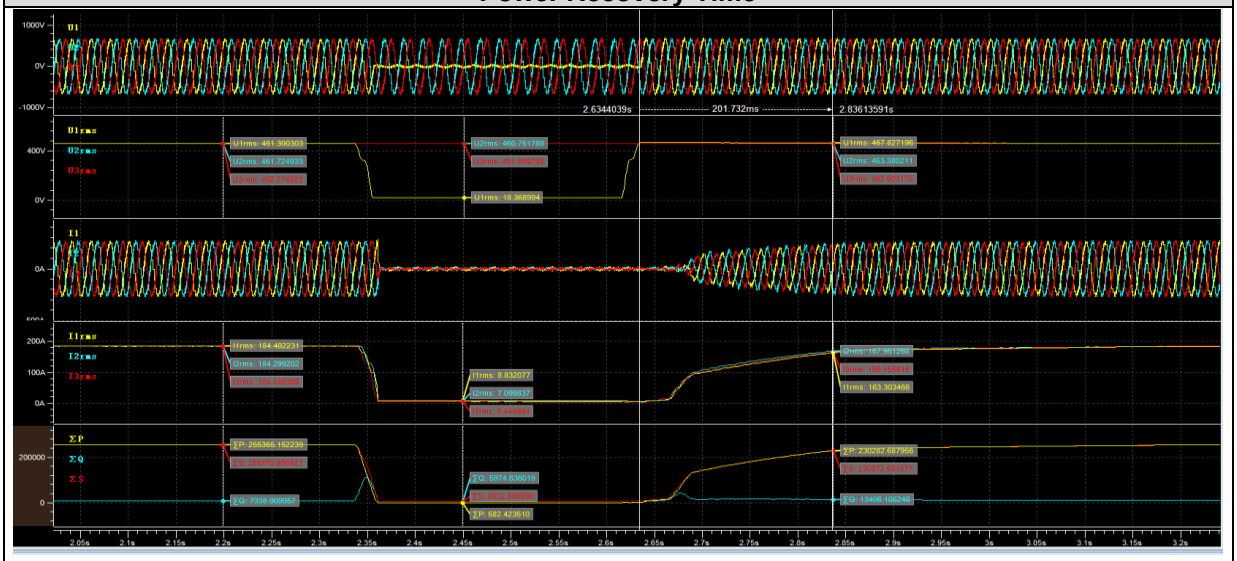
Voltage Drop time



DipTime

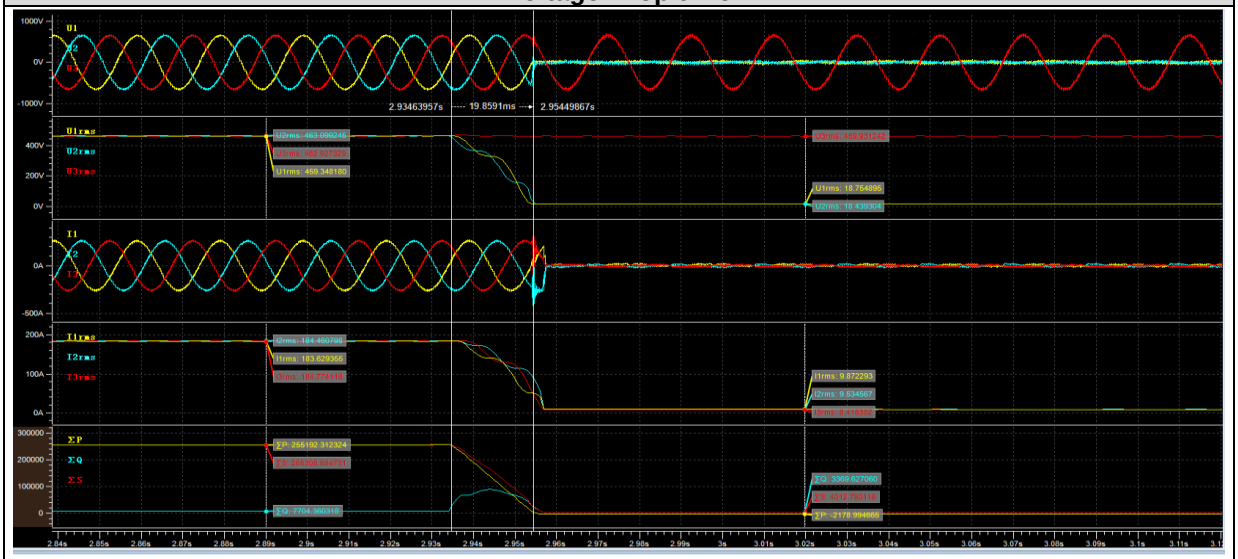


Power Recovery Time

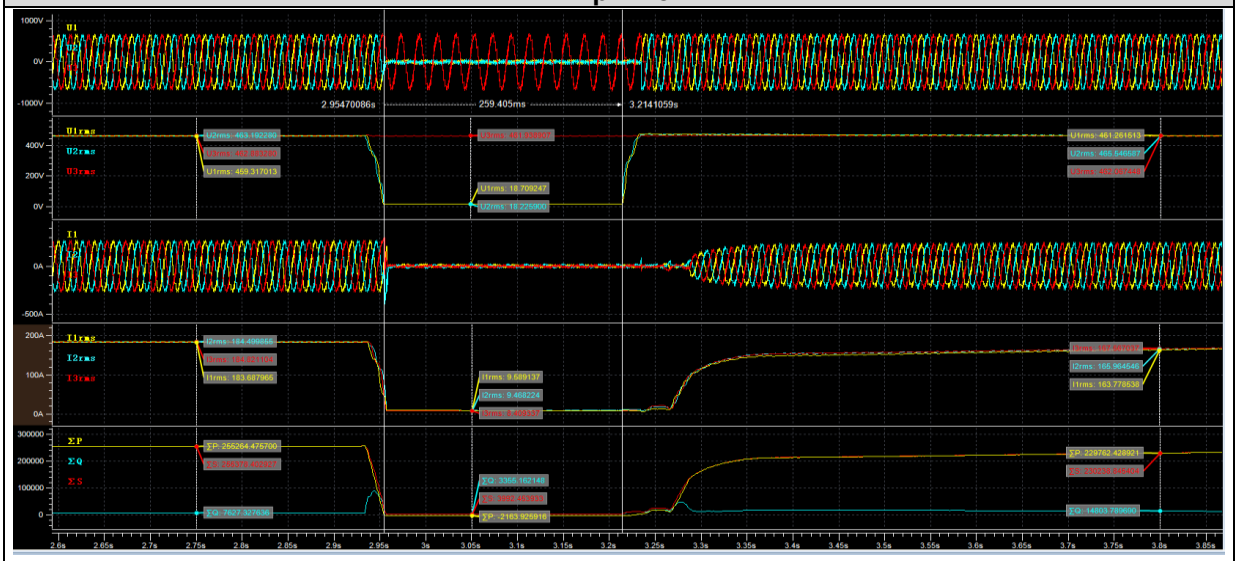


Two-Phase fault	
100%Pn Load	Residual voltage: 0~5%Un

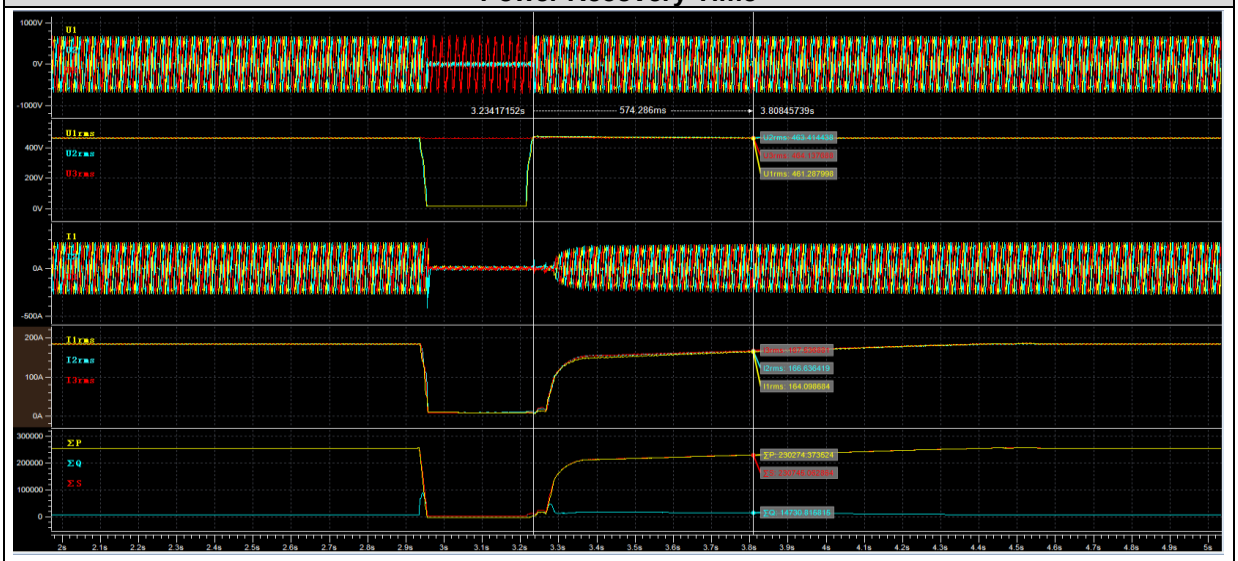
Voltage Drop time



DipTime

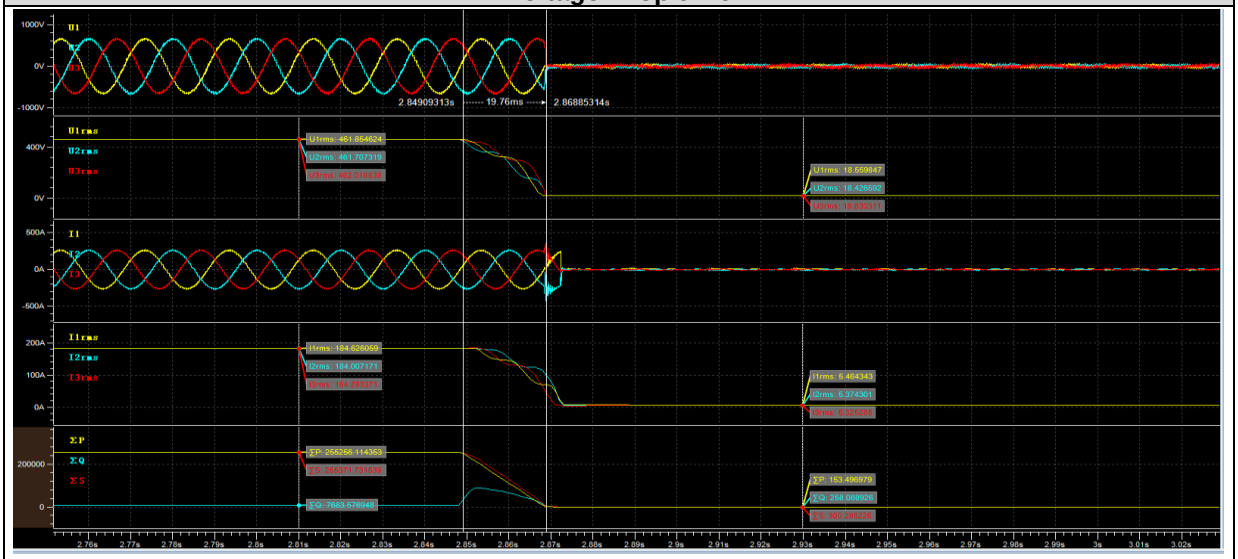


Power Recovery Time

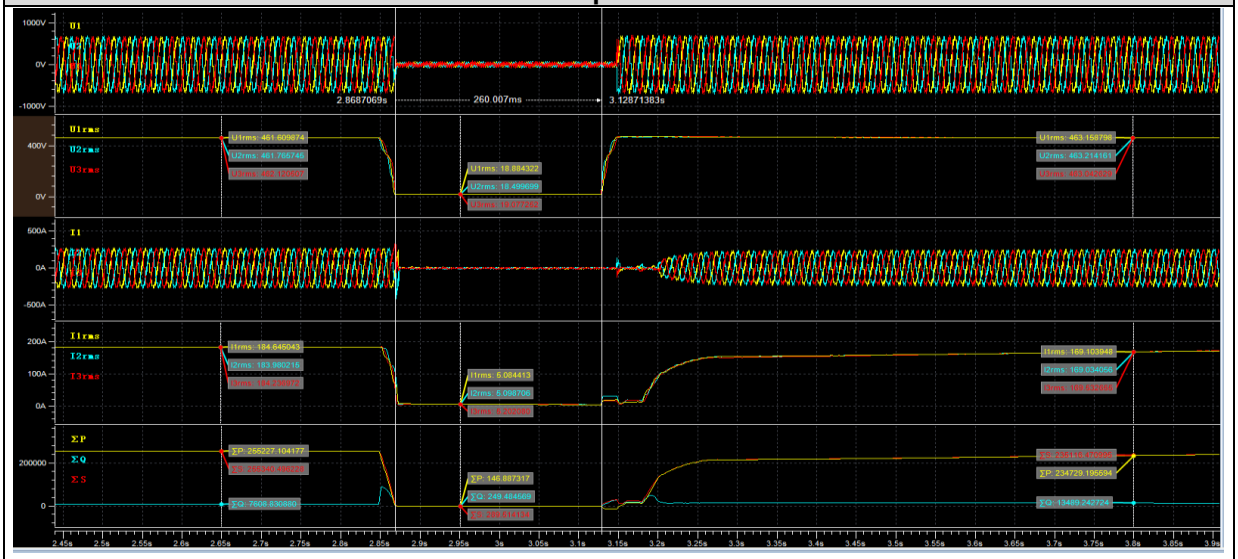


Three-Phase fault	
100%Pn Load	Residual voltage: 0~5%Un

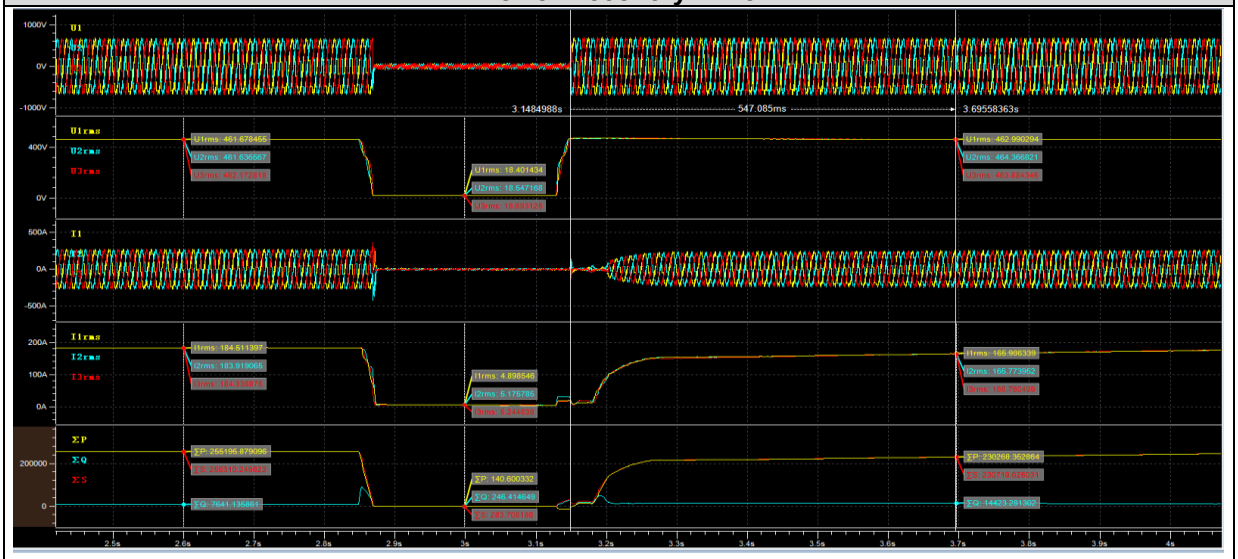
Voltage Drop time



DipTime

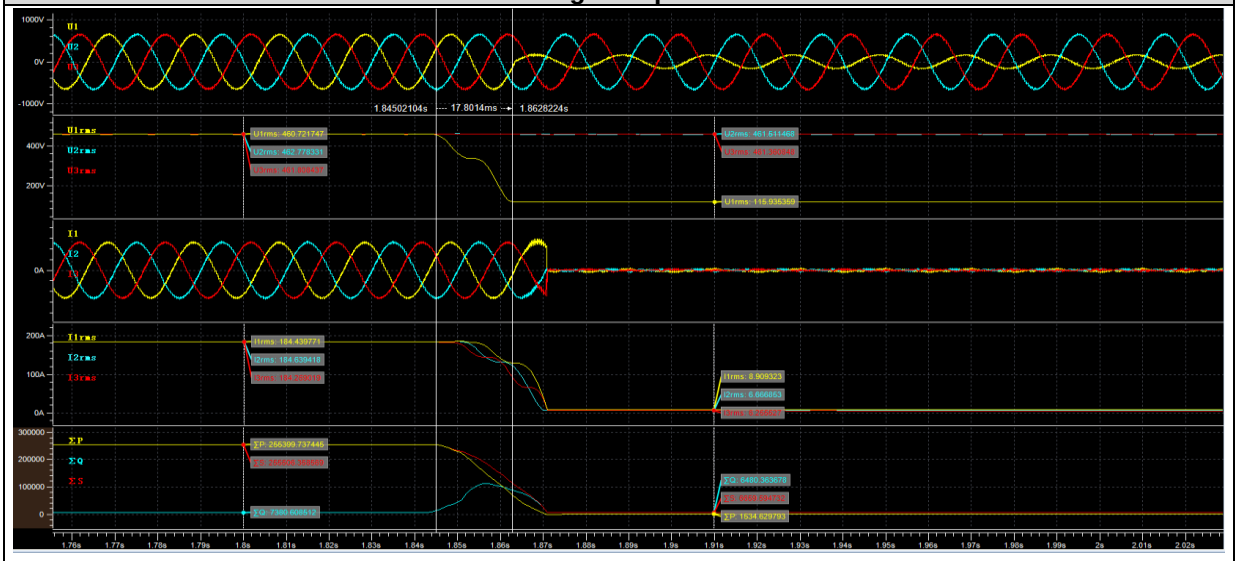


Power Recovery Time

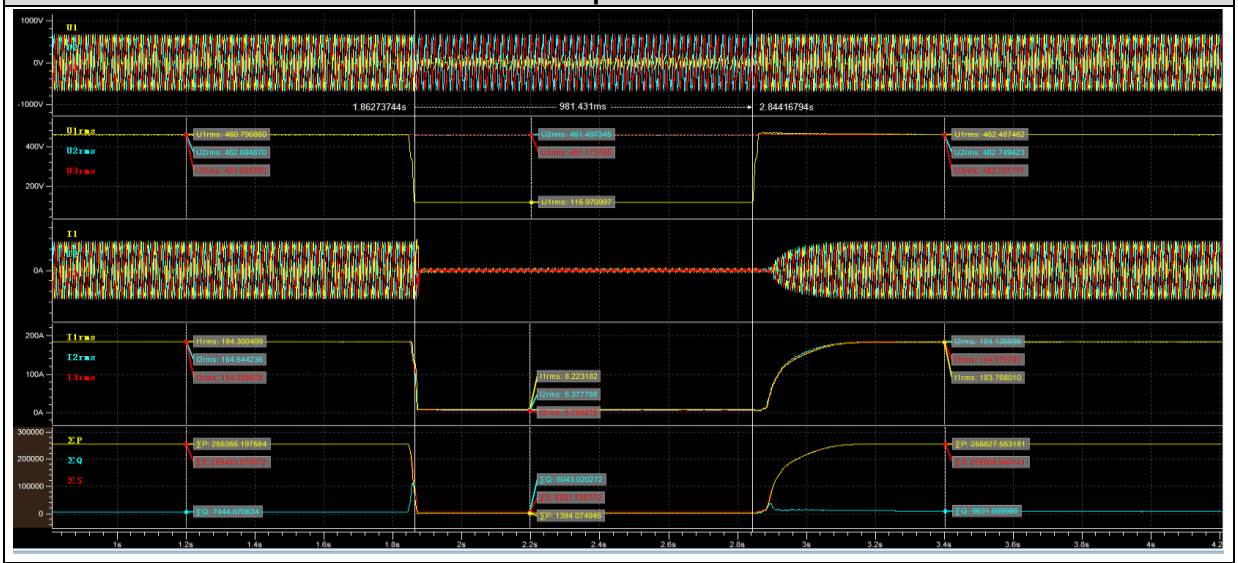


Single-Phase fault	
100%Pn Load	Residual voltage: 25%Un

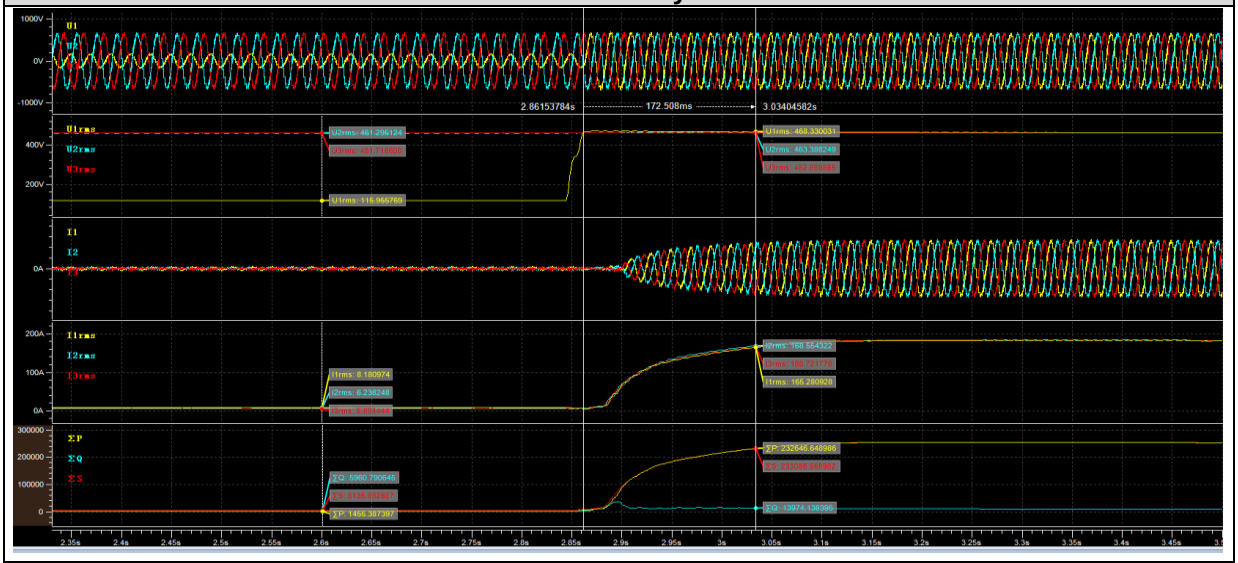
Voltage Drop time



DipTime

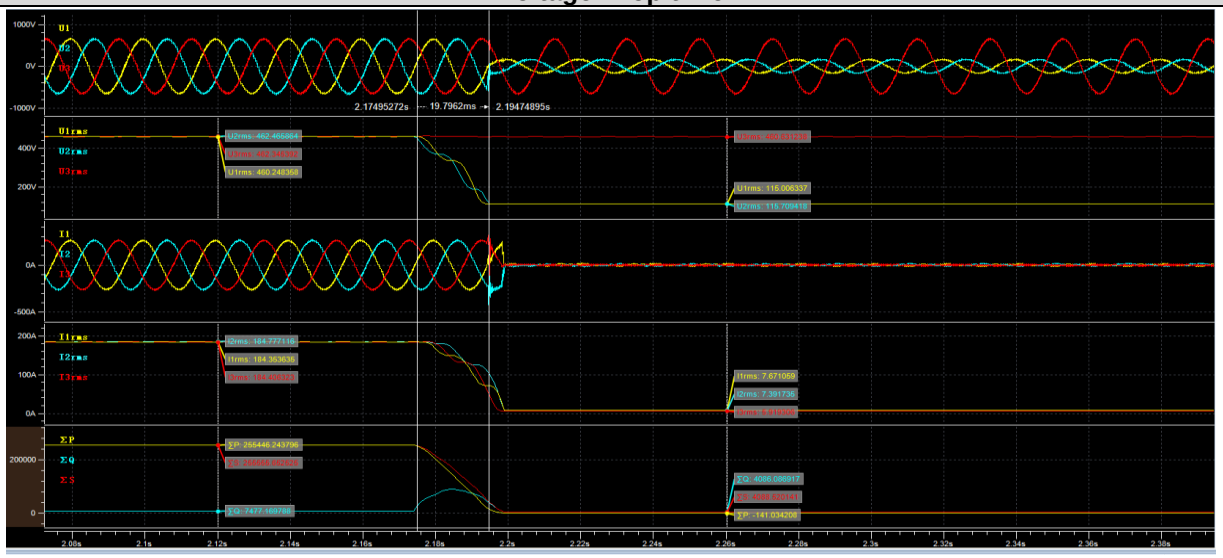


Power Recovery Time

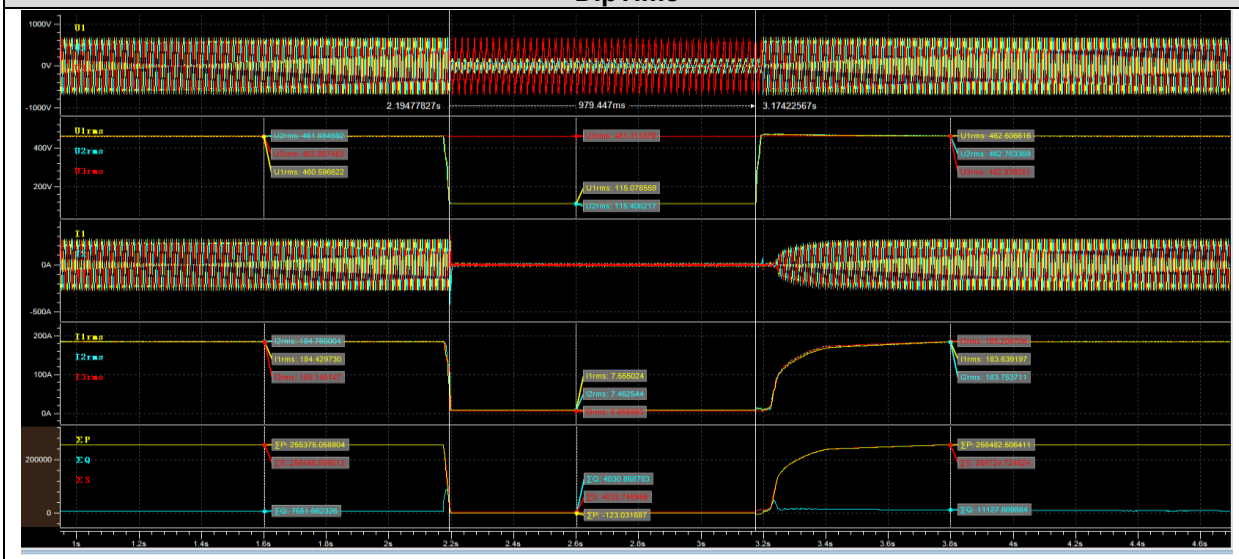


Two-Phase fault	
100%Pn Load	Residual voltage: 25%Un

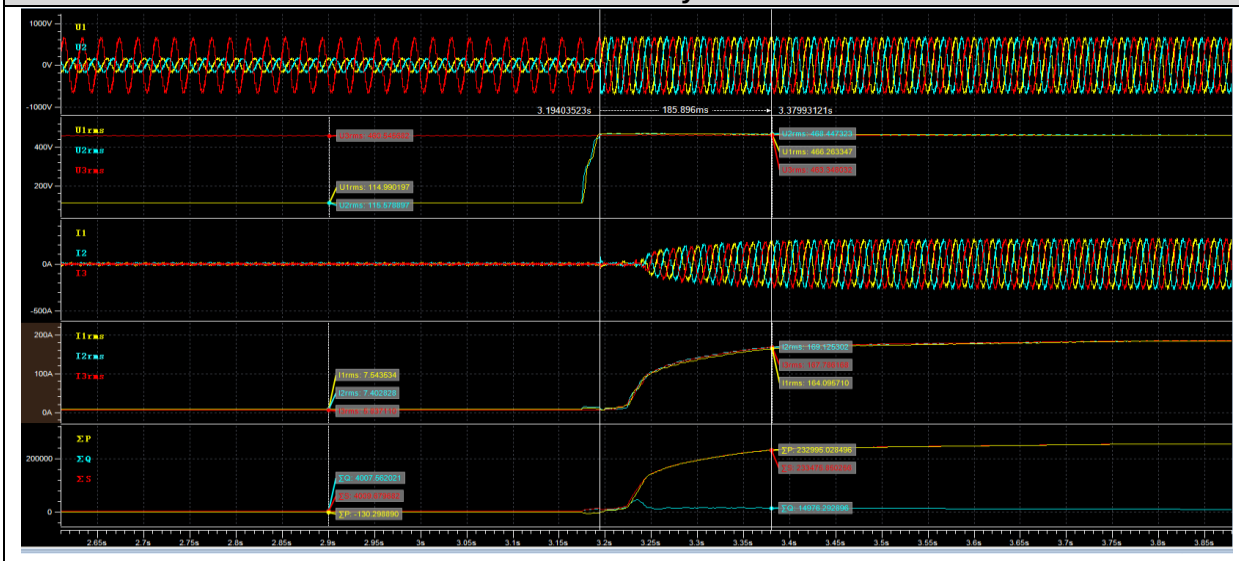
Voltage Drop time



DipTime

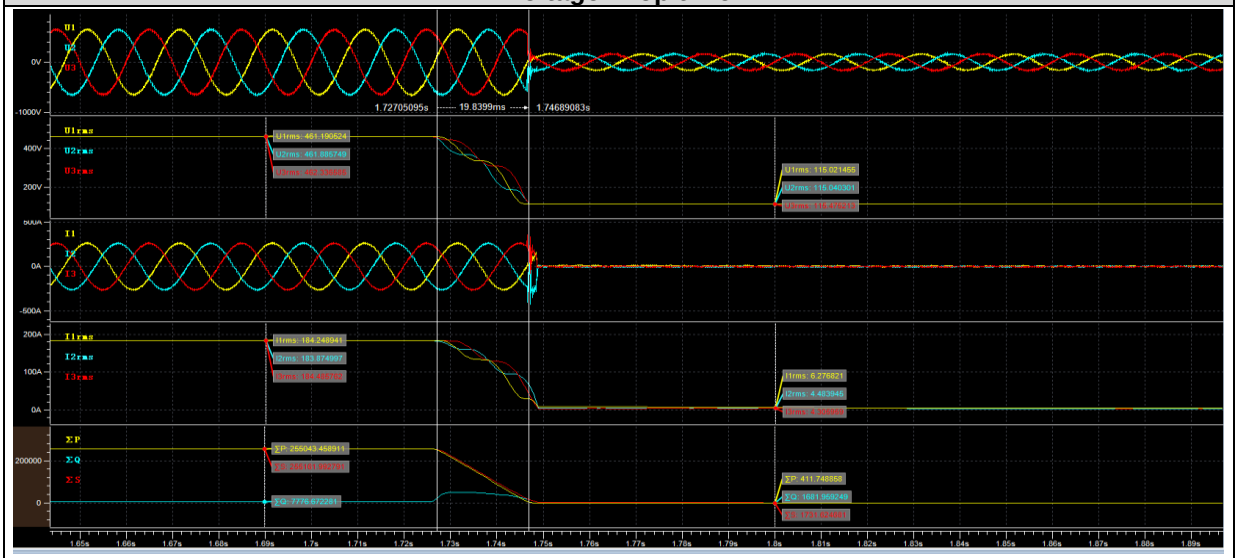


Power Recovery Time

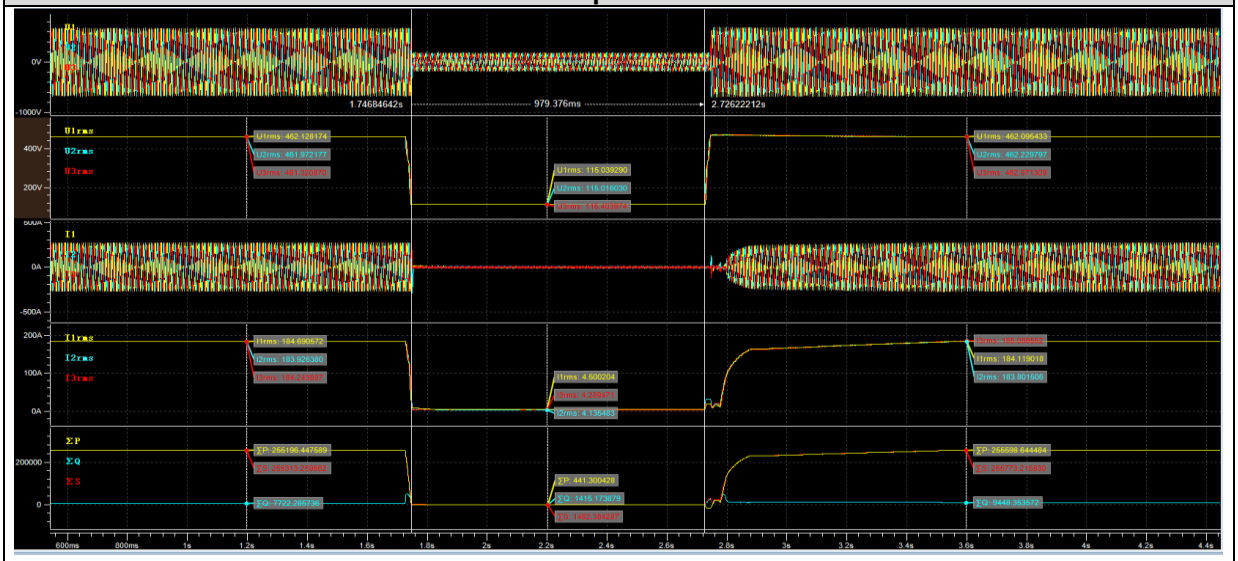


Three-Phase fault	
100%Pn Load	Residual voltage: 25%Un

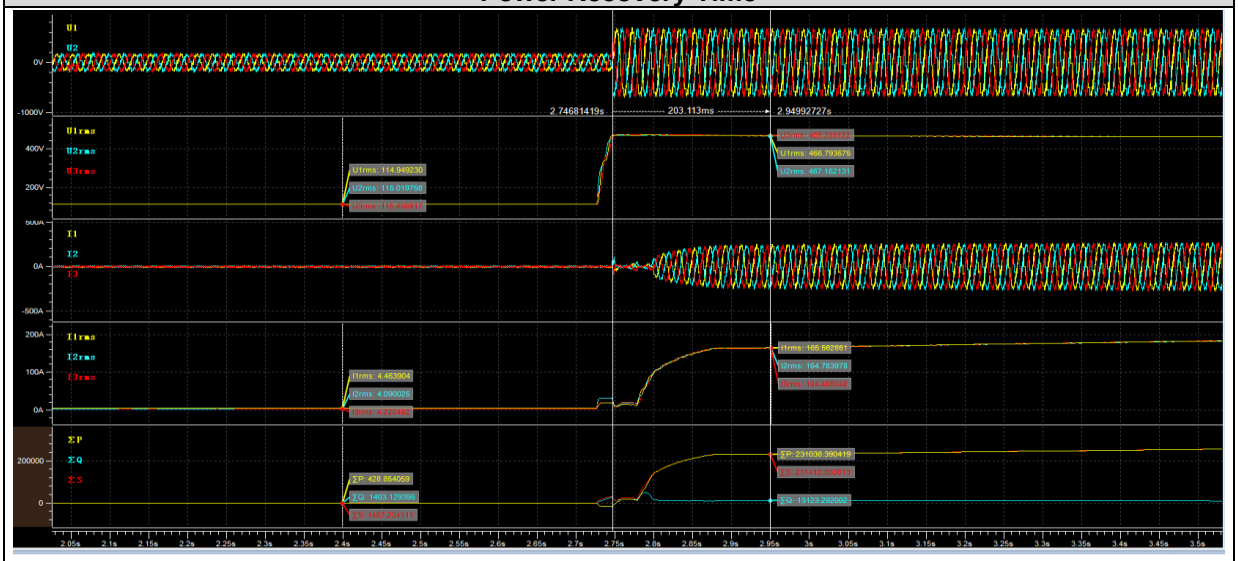
Voltage Drop time



DipTime

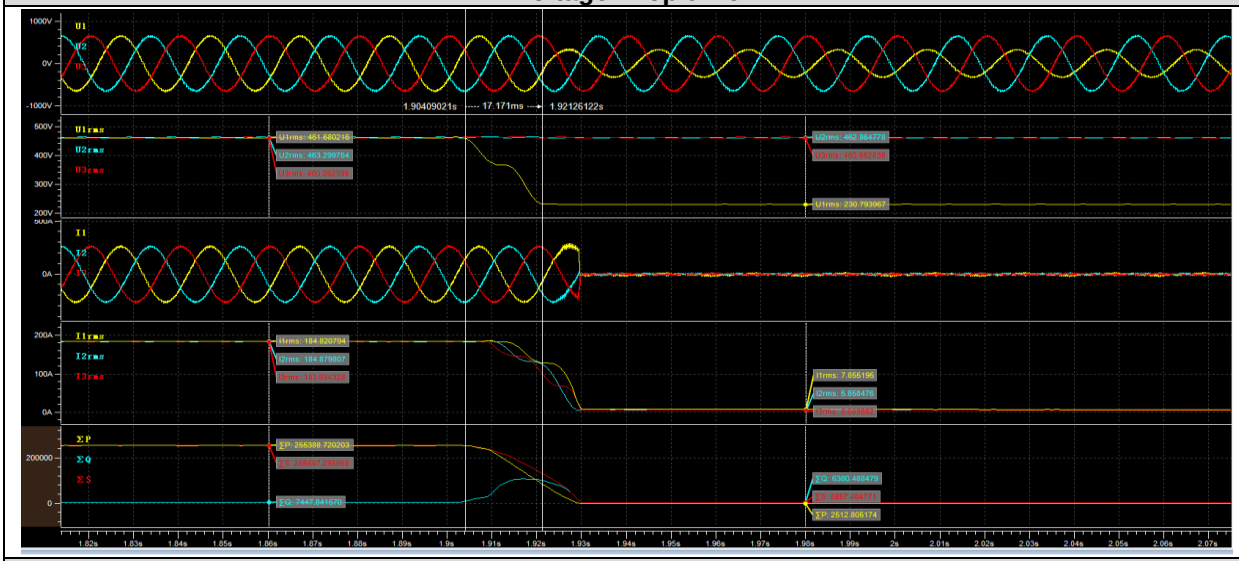


Power Recovery Time

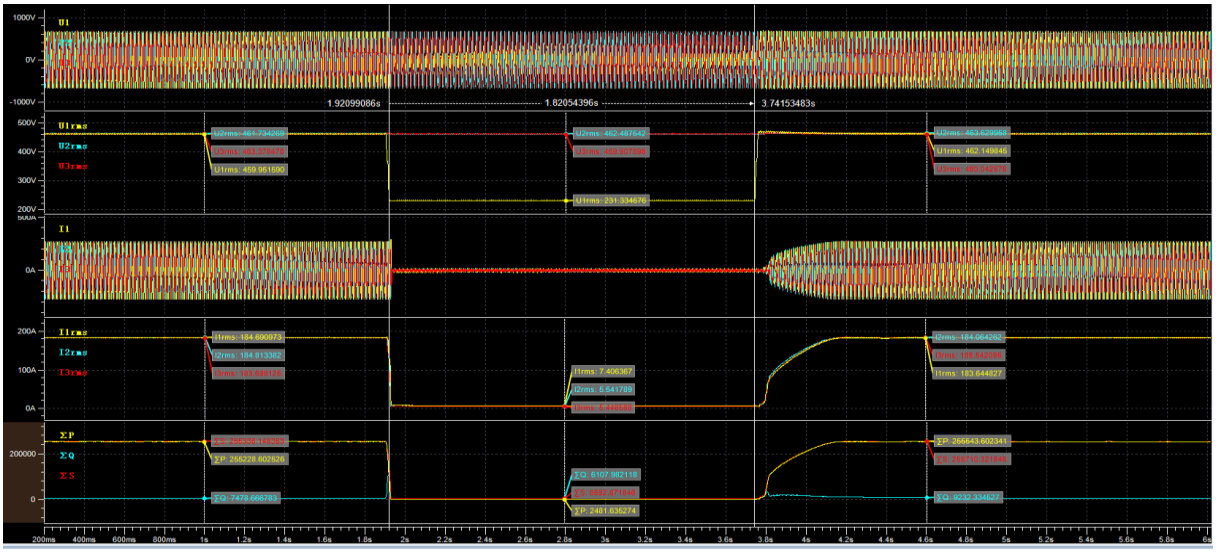


Single-Phase fault	
100%Pn Load	Residual voltage: 50%Un

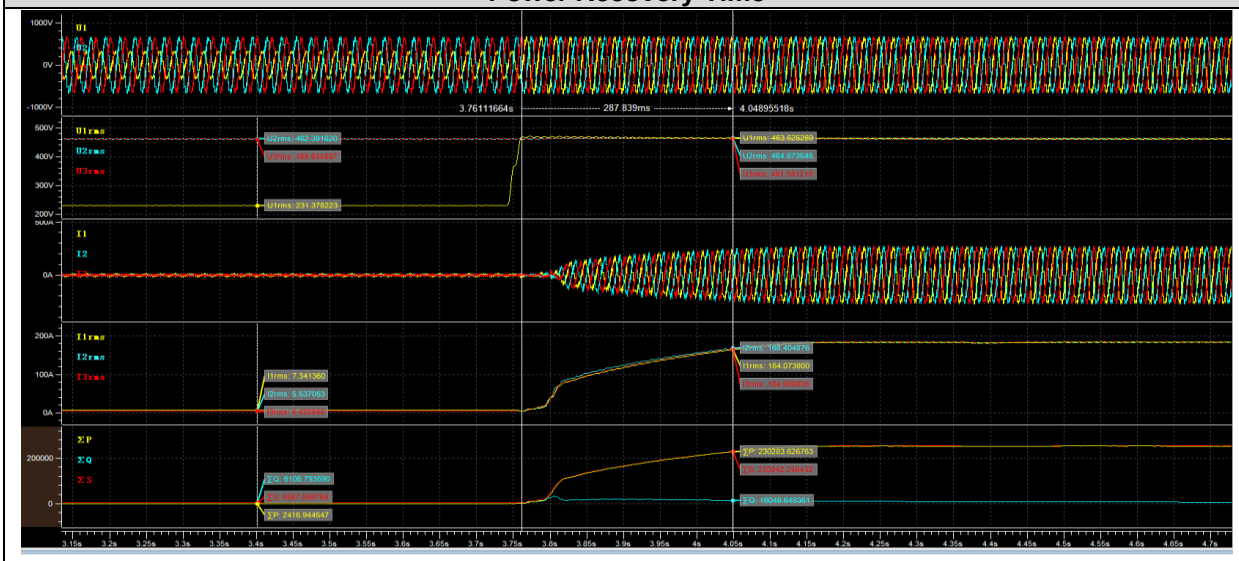
Voltage Drop time



DipTime

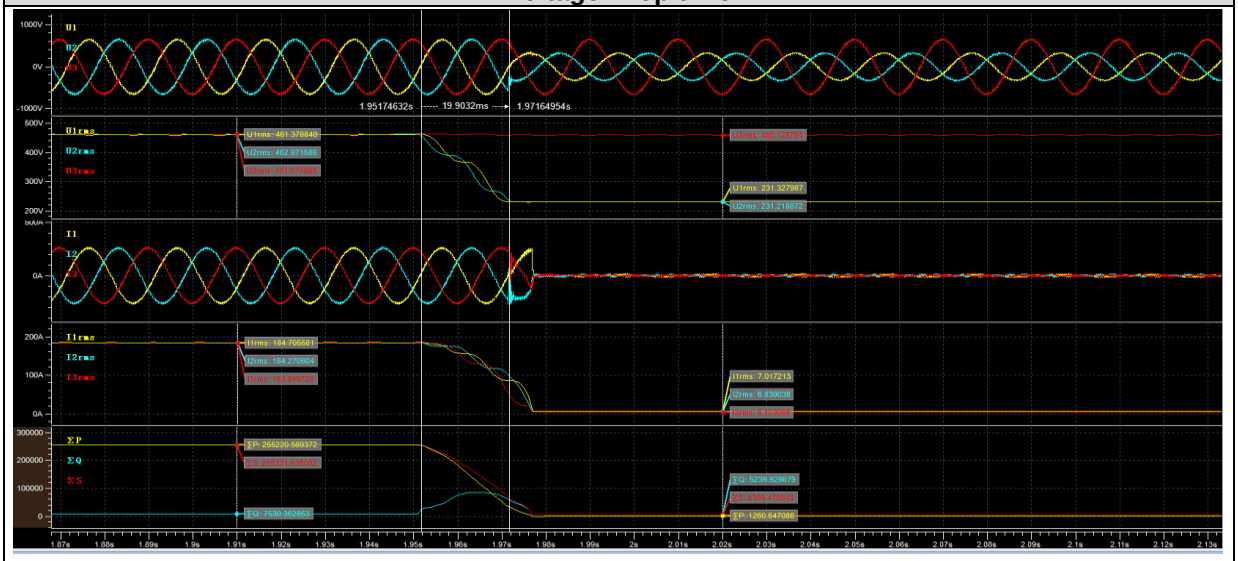


Power Recovery Time

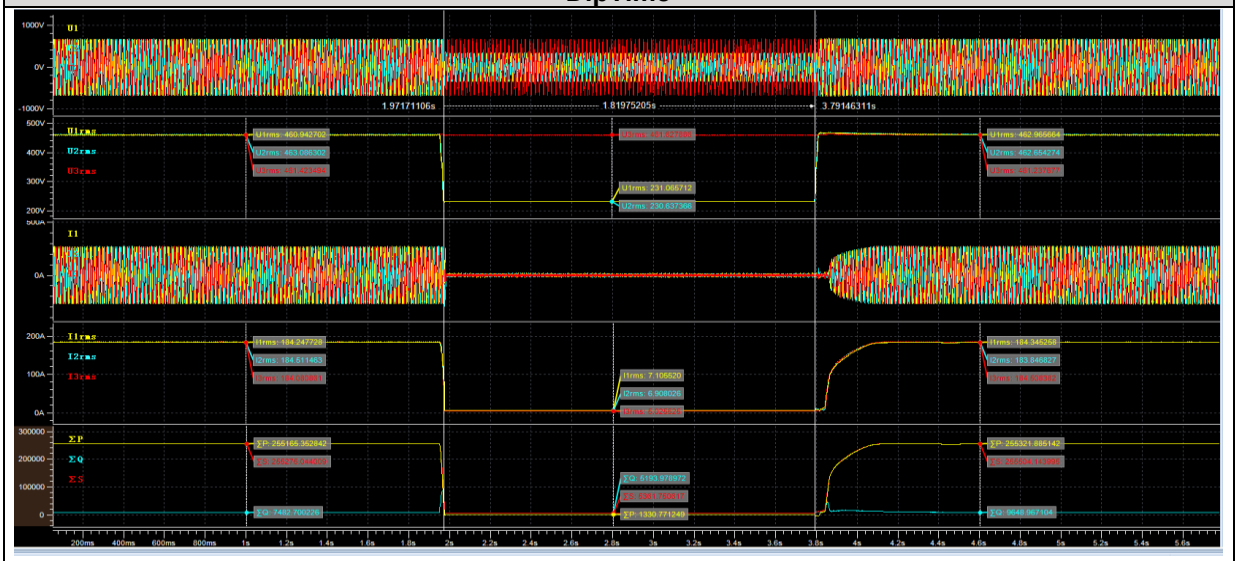


Two-Phase fault	
100%Pn Load	Residual voltage: 50%Un

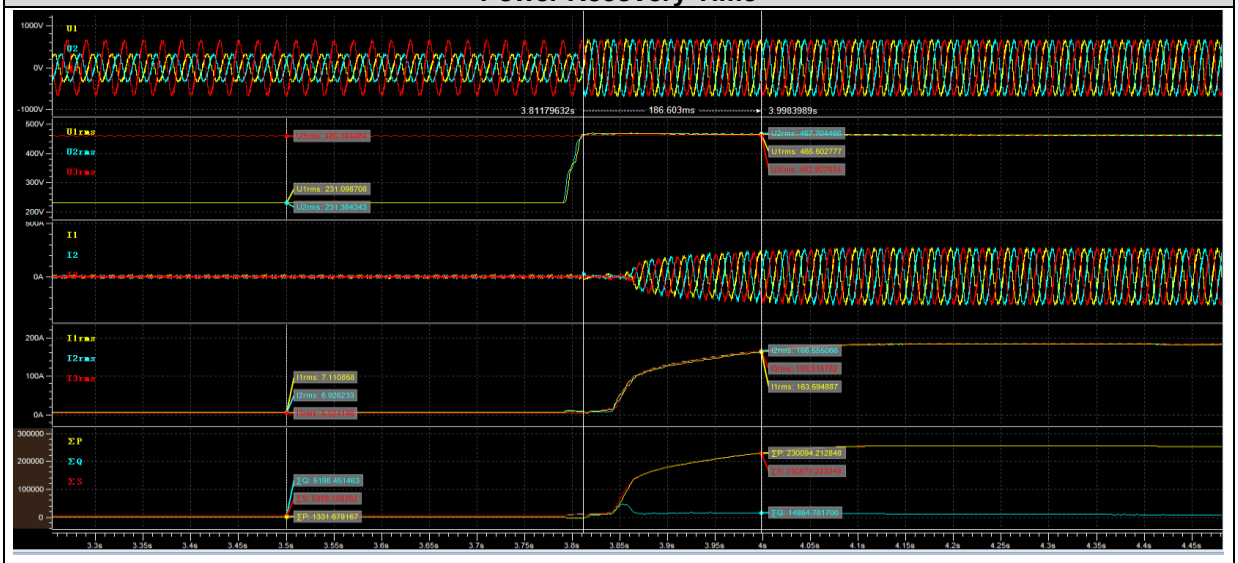
Voltage Drop time



DipTime

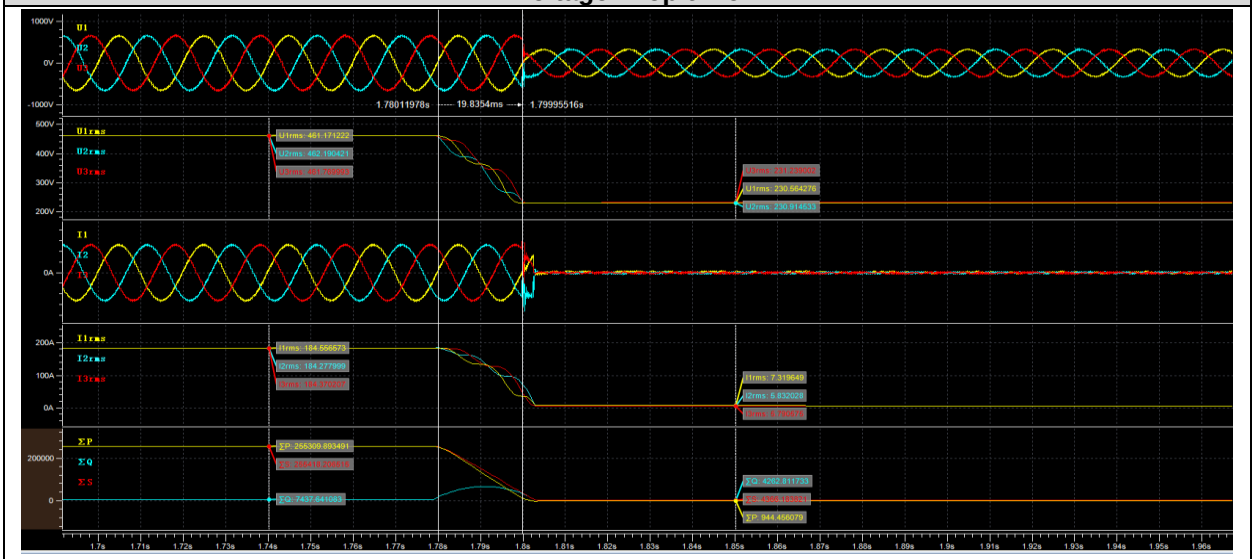


Power Recovery Time

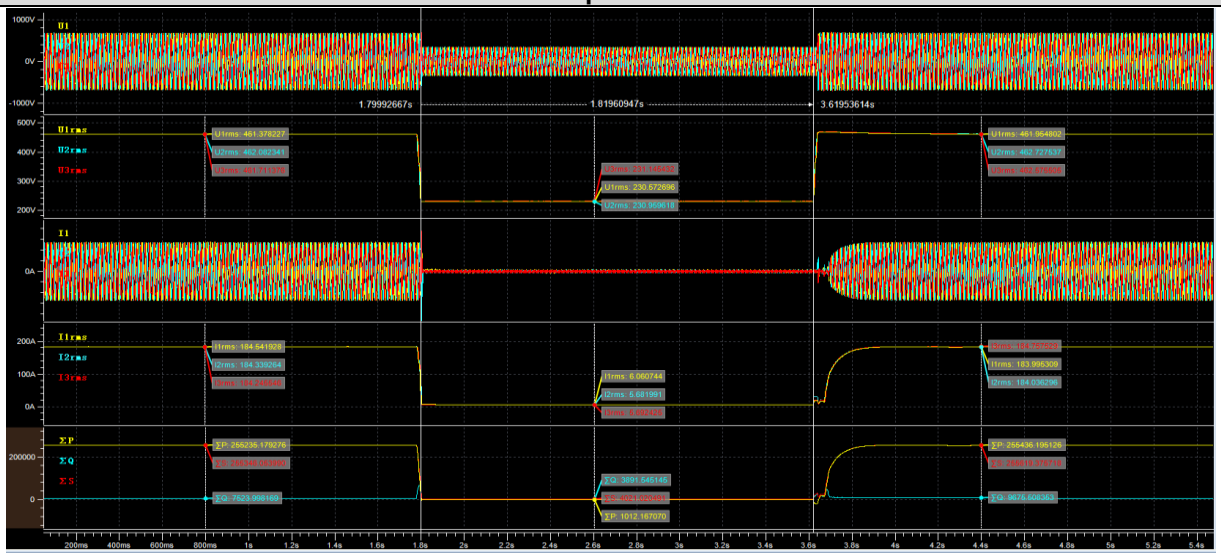


Three-Phase fault	
100%Pn Load	Residual voltage: 50%Un

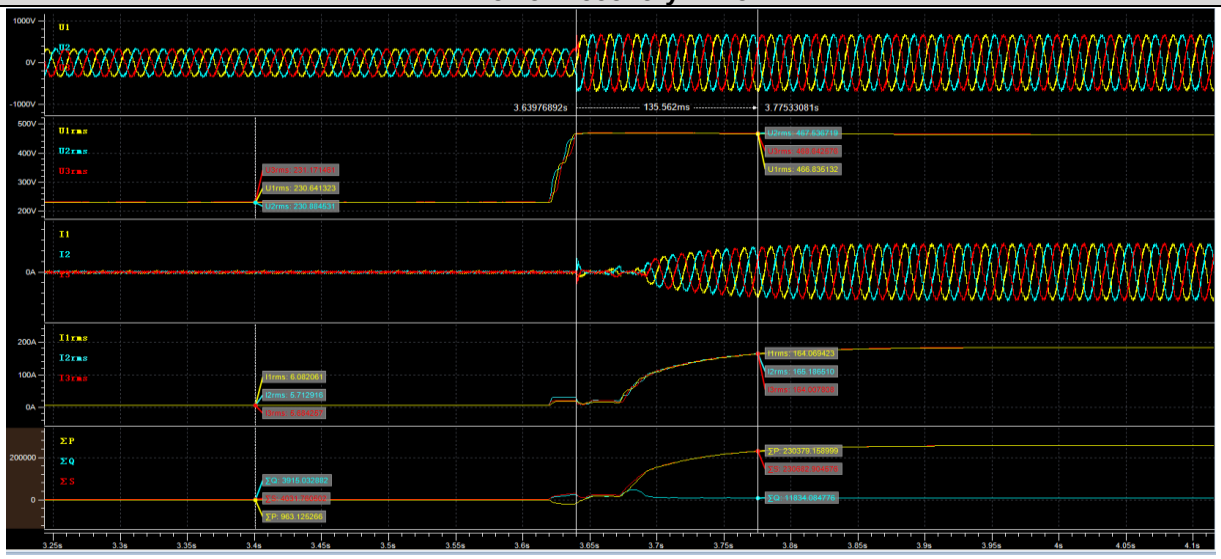
Voltage Drop time



DipTime

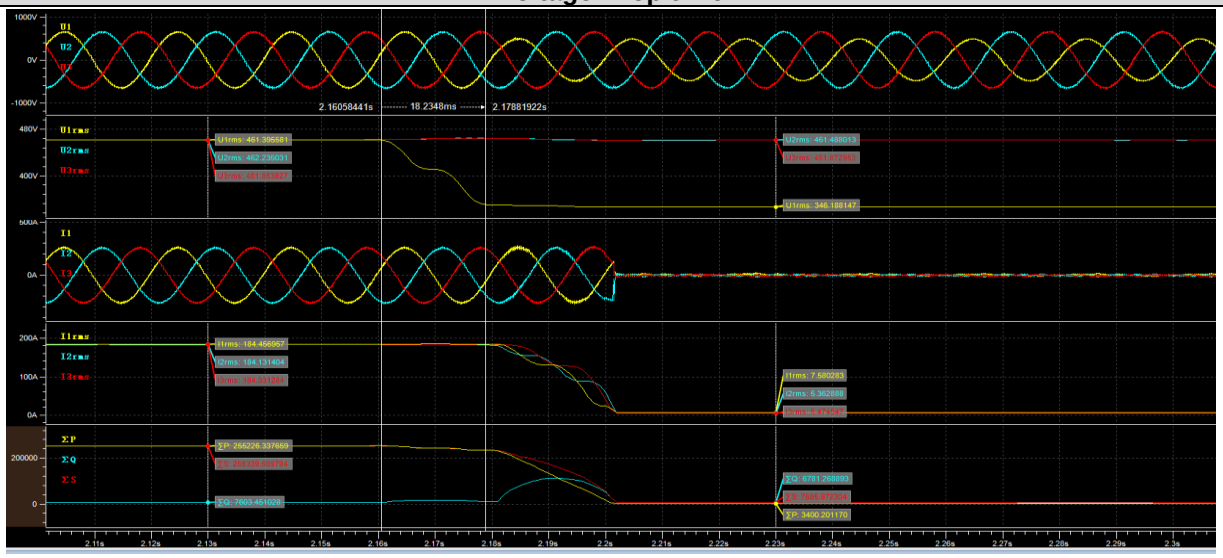


Power Recovery Time

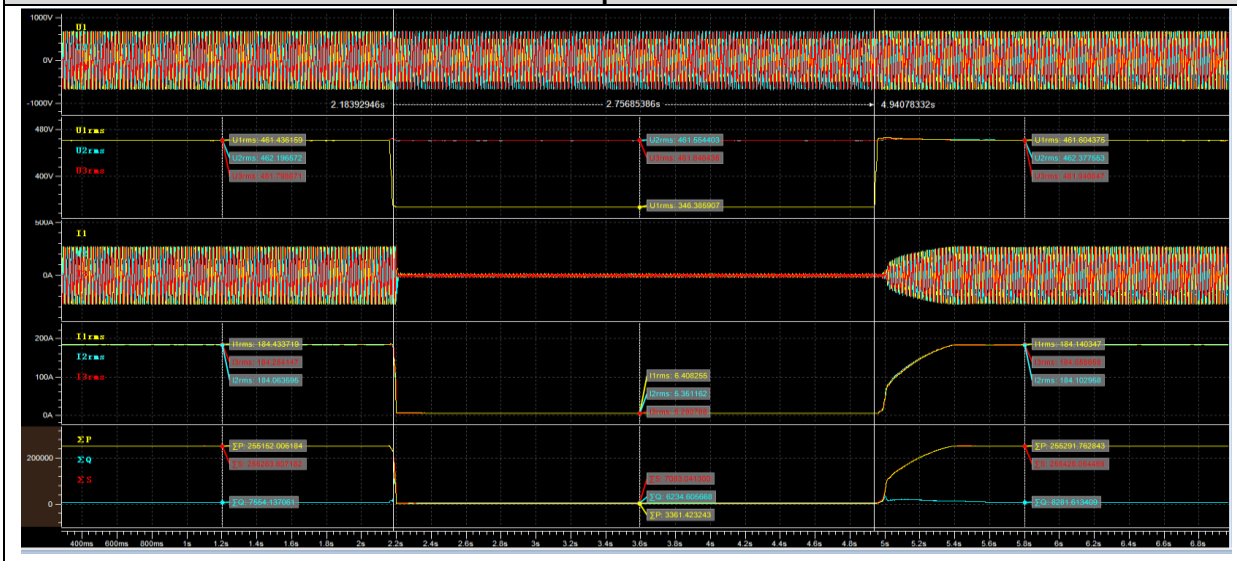


Single-Phase fault	
100%Pn Load	Residual voltage: 75%Un

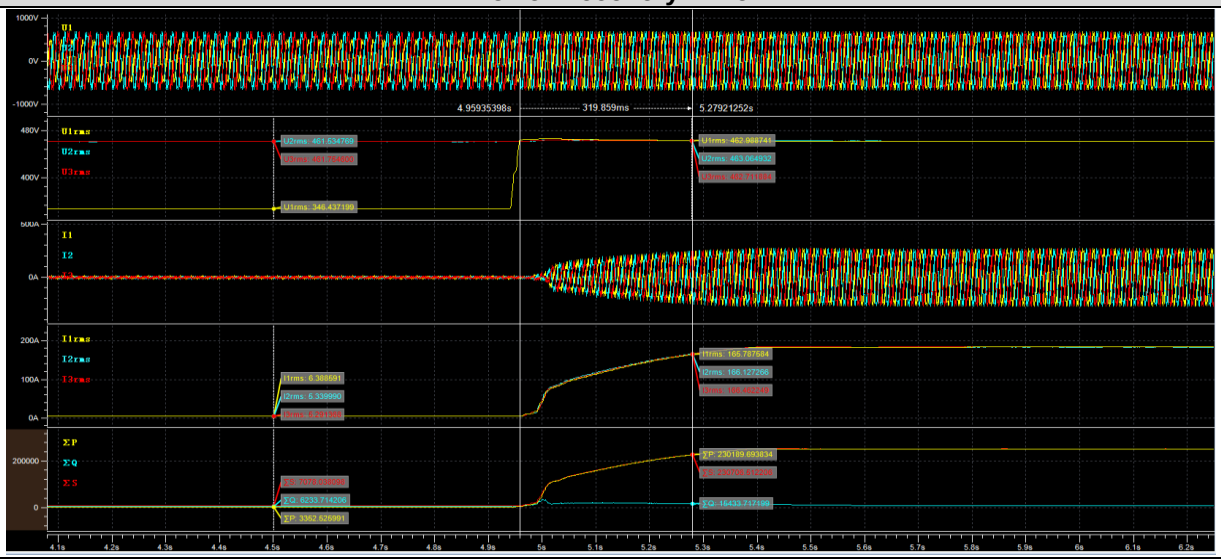
Voltage Drop time



DipTime

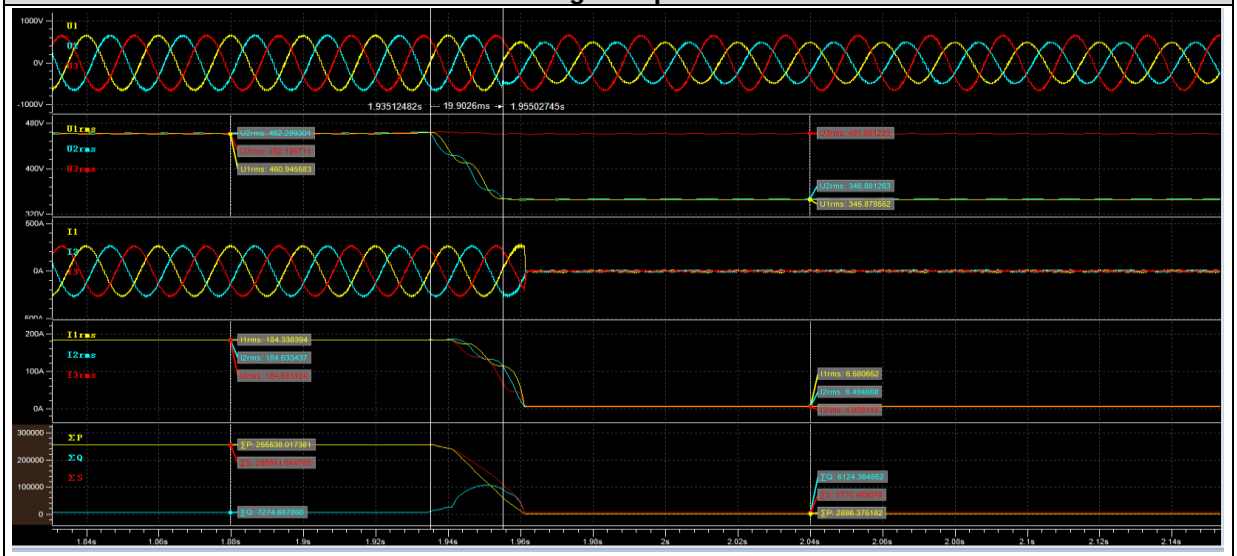


Power Recovery Time

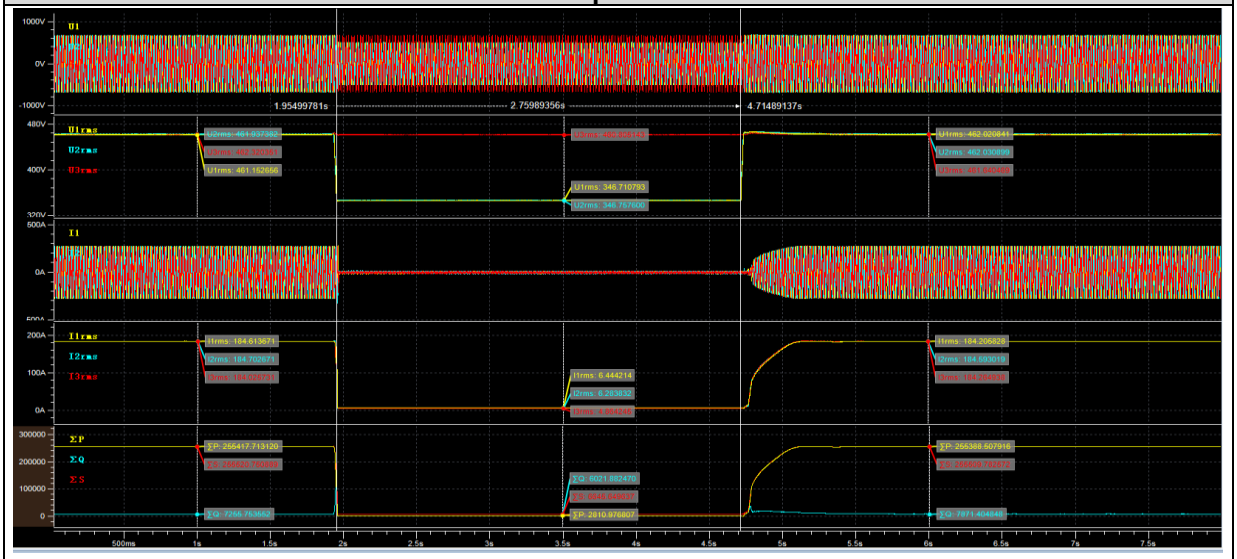


Two-Phase fault	
100%Pn Load	Residual voltage: 75%Un

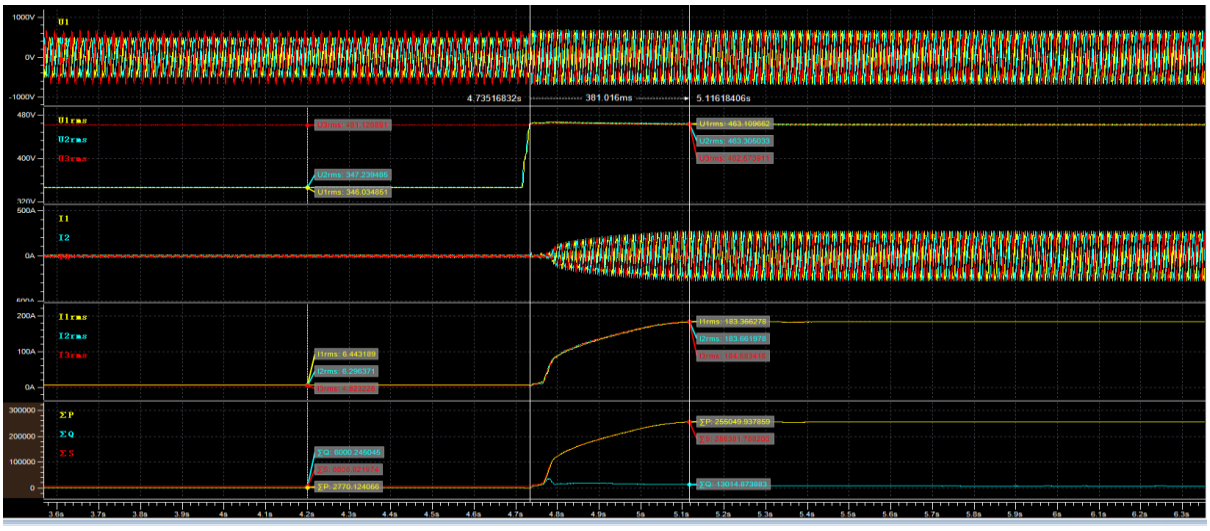
Voltage Drop time



DipTime

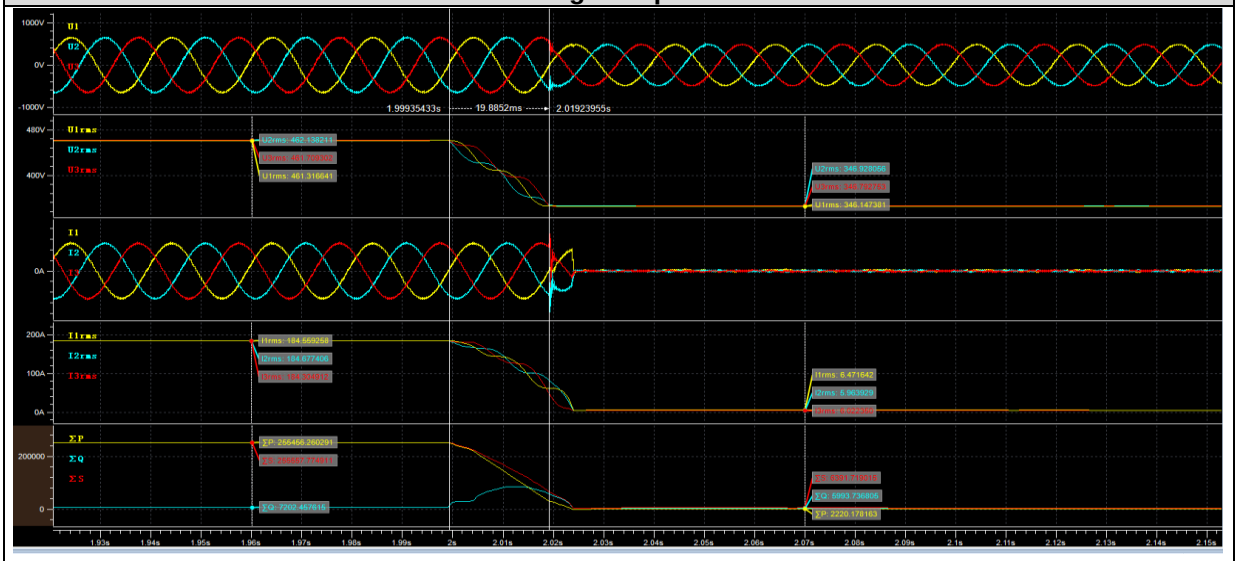


Power Recovery Time

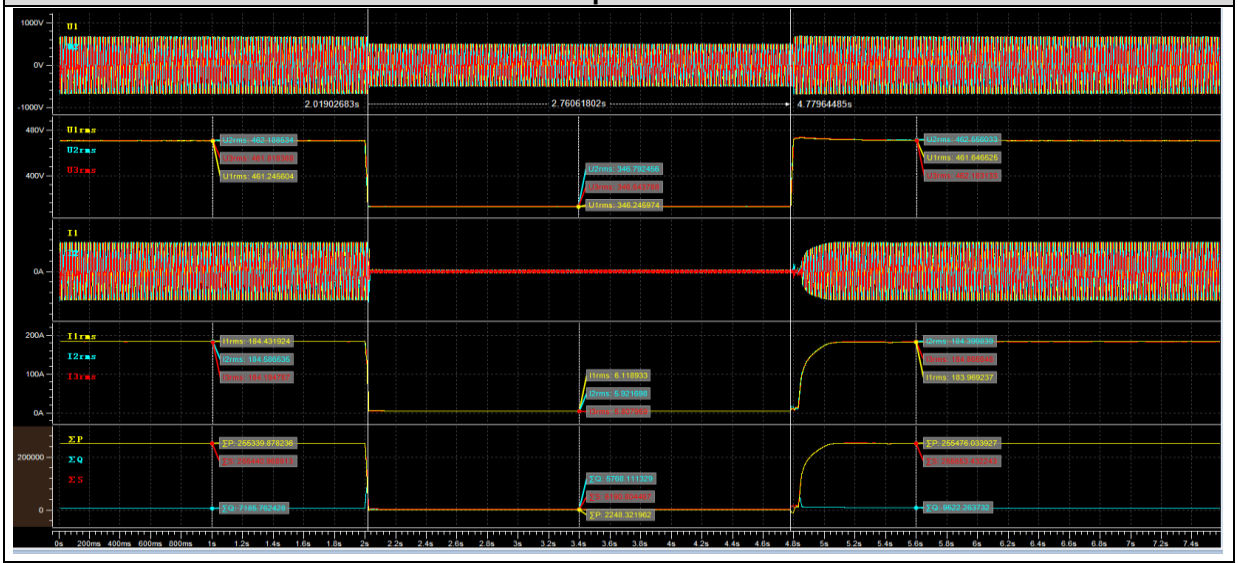


Three-Phase fault	
100%Pn Load	Residual voltage: 75%Un

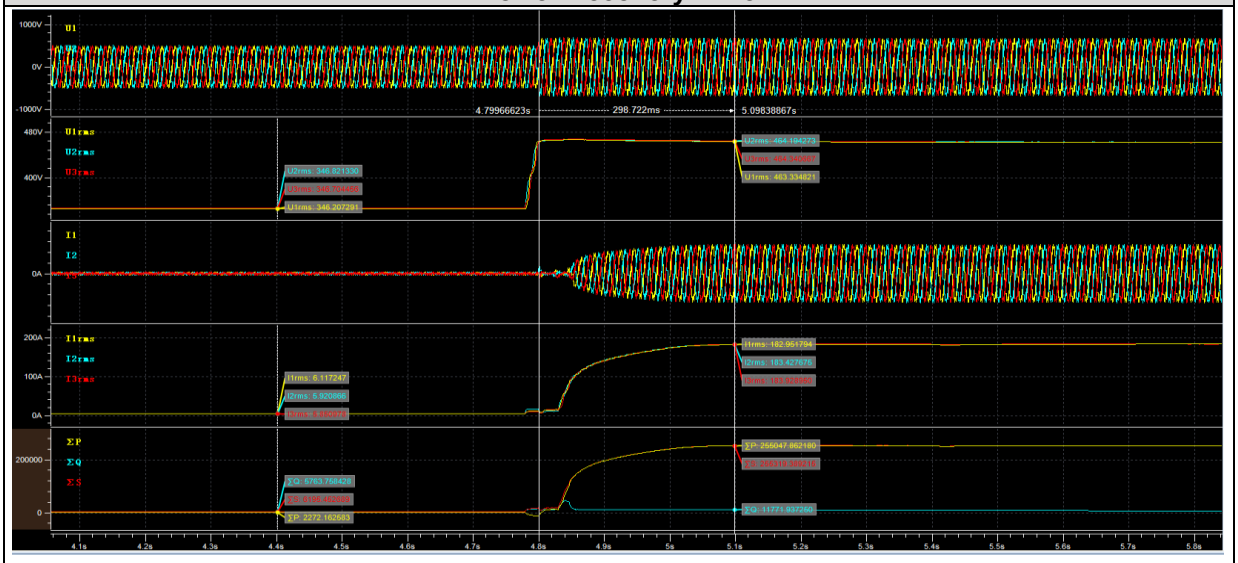
Voltage Drop time



DipTime



Power Recovery Time



4.2.3. Over-voltage ride through (OVRT)

The test has been done according to the clause 4.5.4 of the standard. The setting of over-voltage ride through capability is as follows:

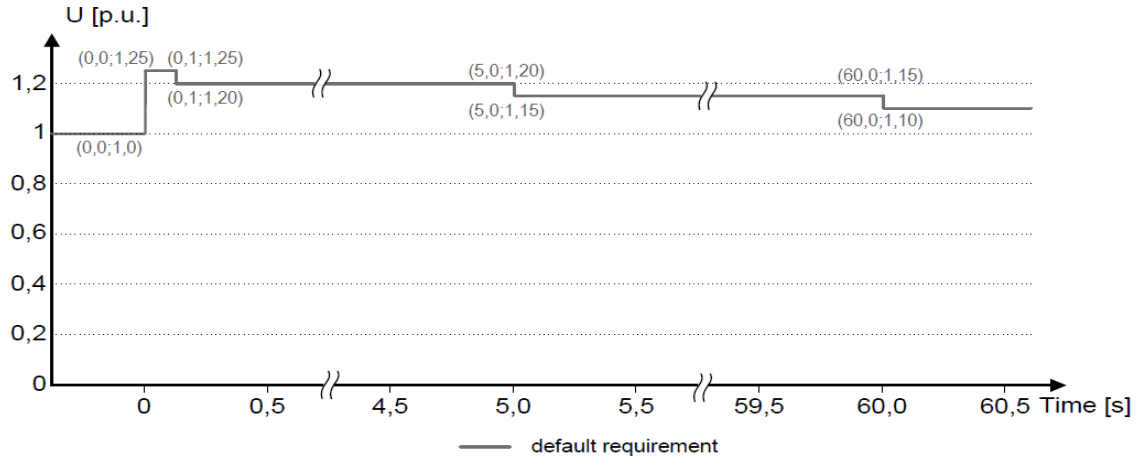
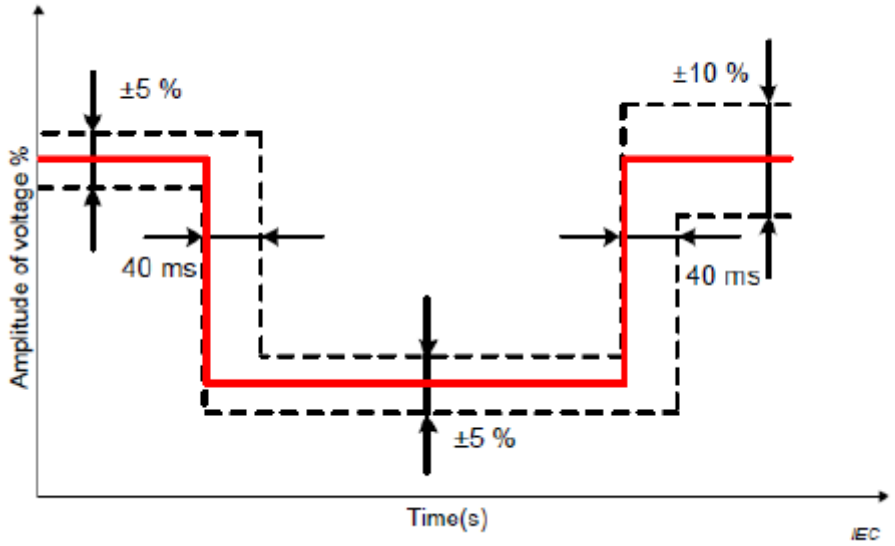


Figure 8 — Over-voltage ride through capability

4.2.3.1 *No load Test*

It is not specified in the reference standard, but following tolerances have been applied. Tolerances for drop depth and duration during no-load tests shall not exceed the values shown in the next figure:



The tolerance for voltage magnitude is ±5%Un for the period before and during the voltage drop. The tolerance for voltage magnitude is ±10%Un during the period after voltage is recovered.
The tolerance range for both drop duration and rise time prefers 40 ms.

Test results of different no-load cases performed are offered below:

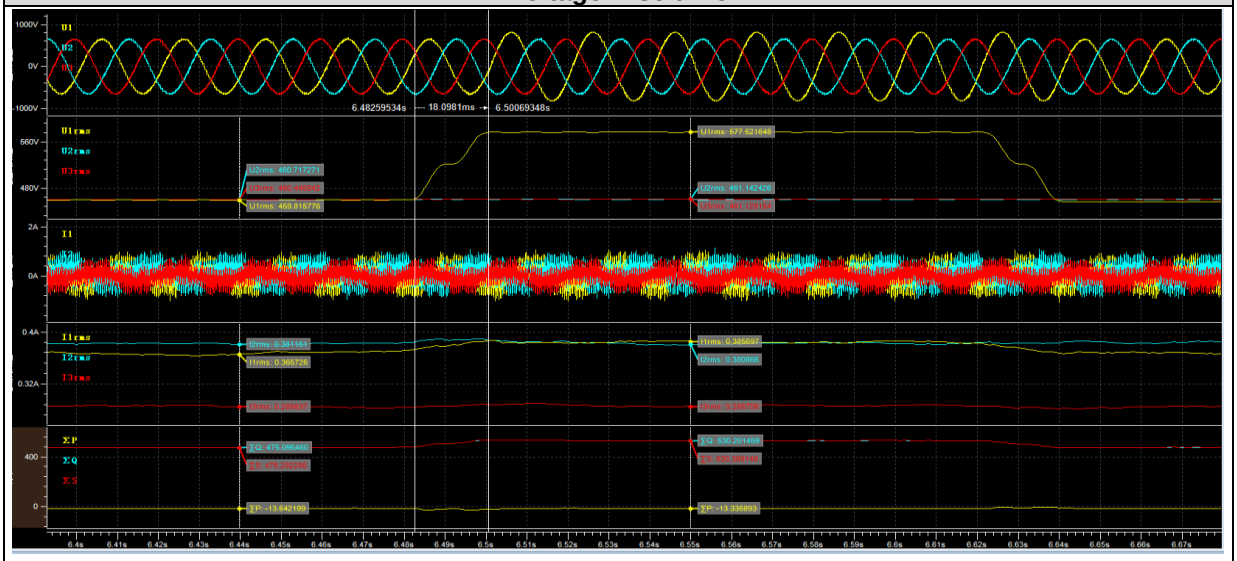
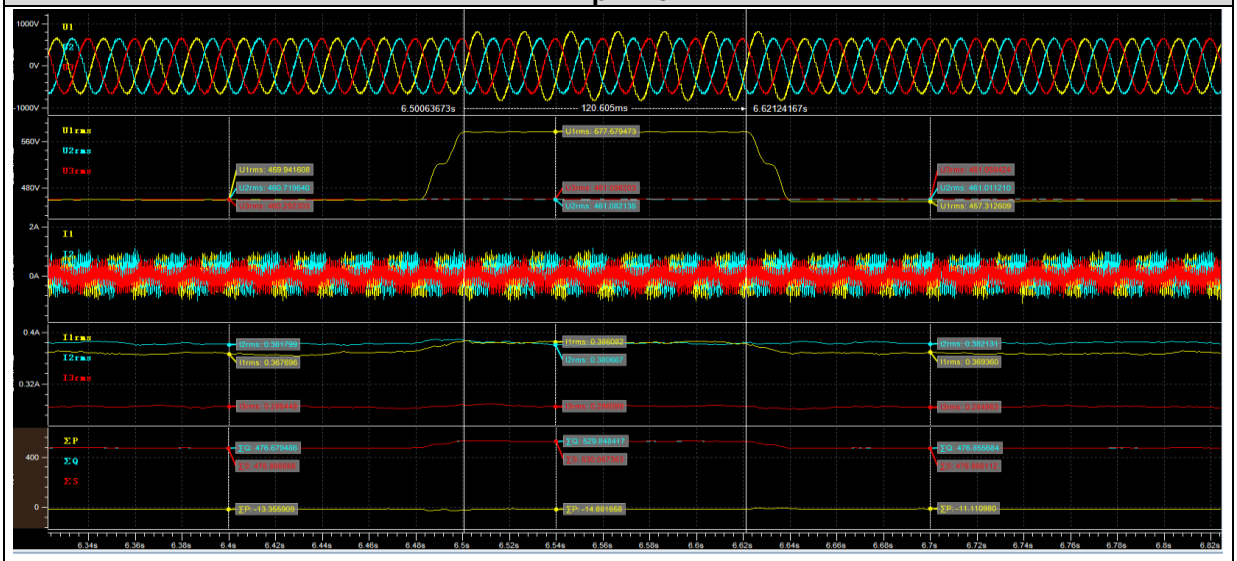
Single-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.5	18	125.0	> 100	121	--	99.0
120.0	99.6	18	120.0	> 5000	5033	--	99.6
115.0	100.0	20	114.9	> 60000	60060	--	99.5

Two-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.6	20	124.9	> 100	120	--	99.1
120.0	99.7	20	119.9	> 5000	5030	--	99.7
115.0	100.0	20	114.9	> 60000	60060	--	99.4

Three-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.7	20	125.7	> 100	120	--	99.0
120.0	99.7	20	119.9	> 5000	5030	--	99.7
115.0	100.0	20	114.8	> 60000	60060	--	99.6

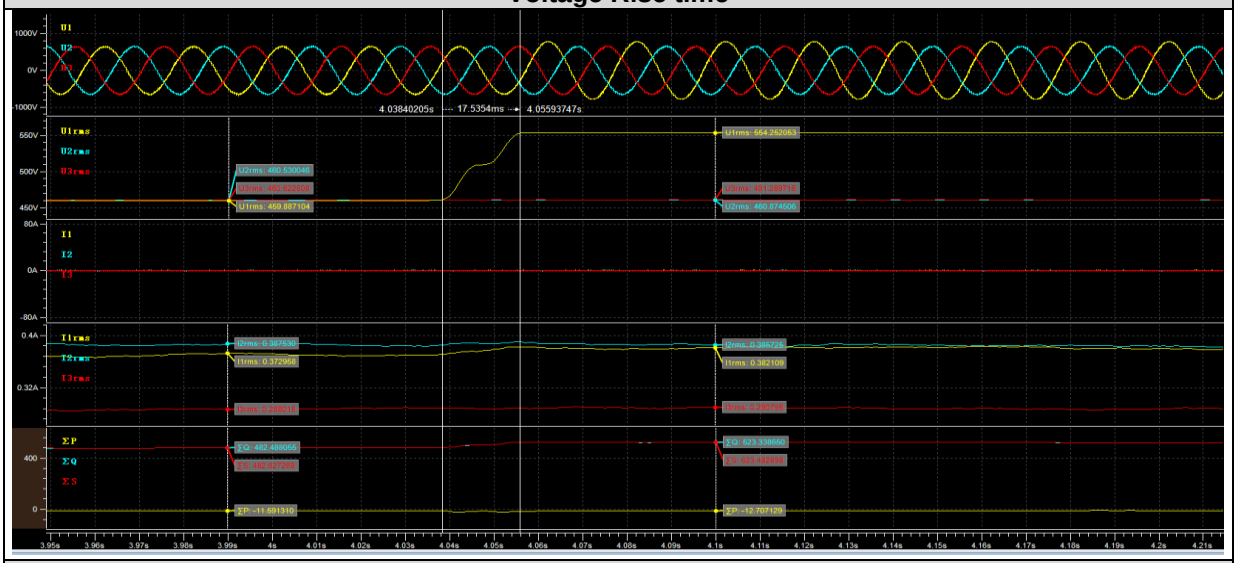
Note: The virtual neutral line was used in the test, Un ≈ 461.9 V.

Test results are graphically represented at following pages.

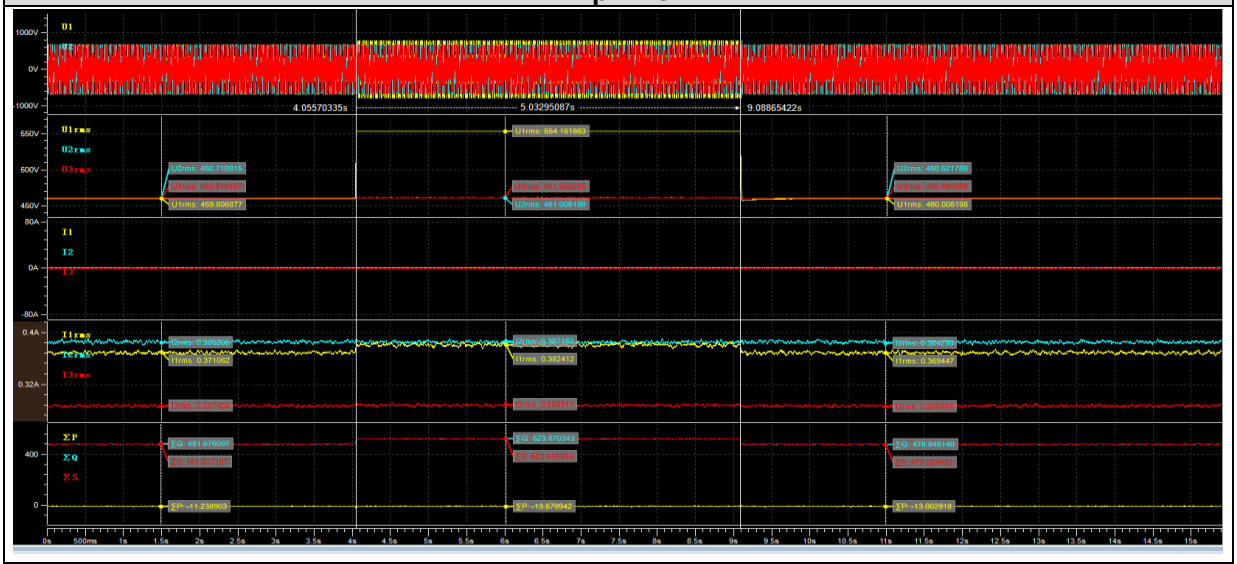
Single-Phase fault	
No Load	Residual voltage: 125.0%Un
Voltage Rise time	
	
DipTime	
	

Single-Phase fault	
No Load	Residual voltage: 120.0%Un

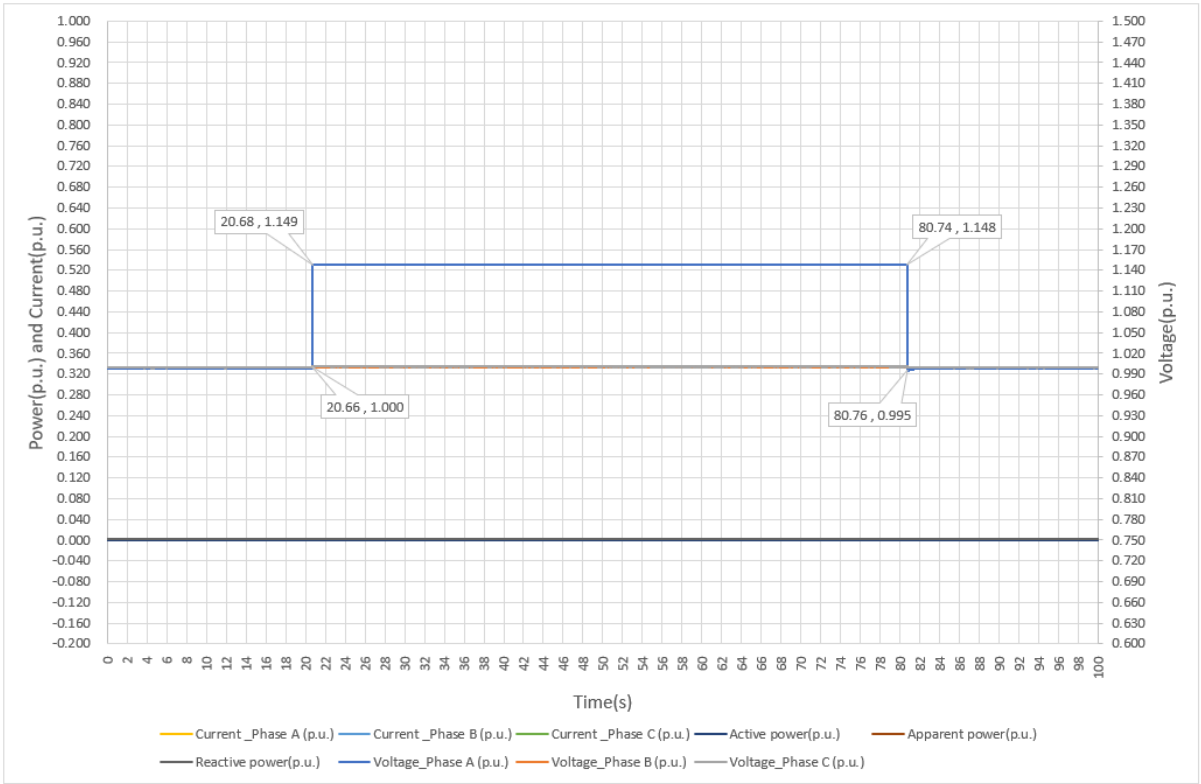
Voltage Rise time



DipTime

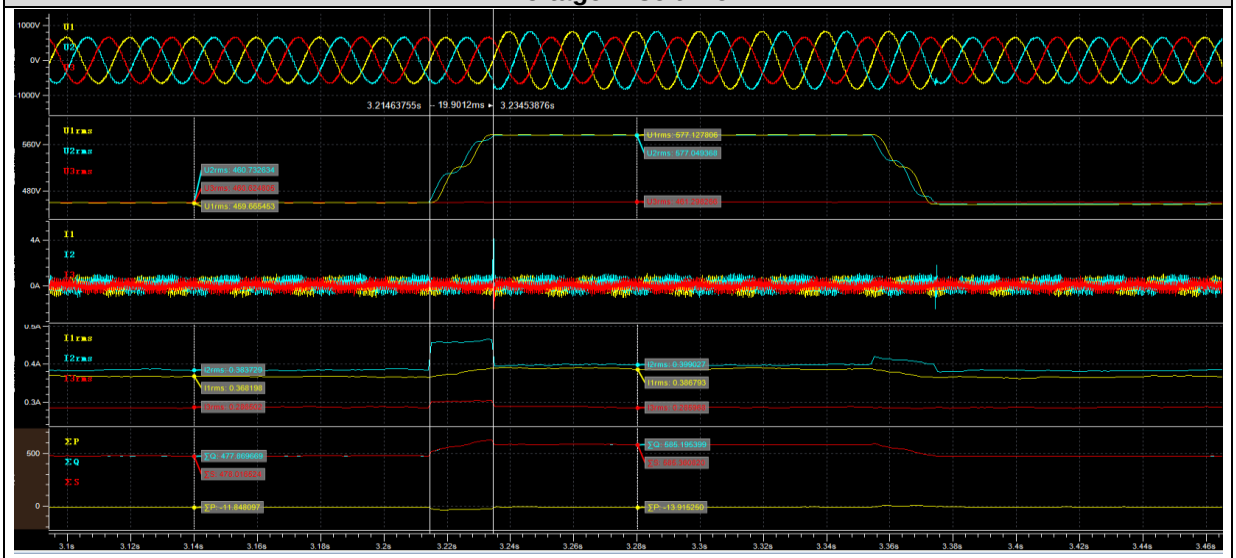


Single-Phase fault	
No Load	Residual voltage: 115.0%Un

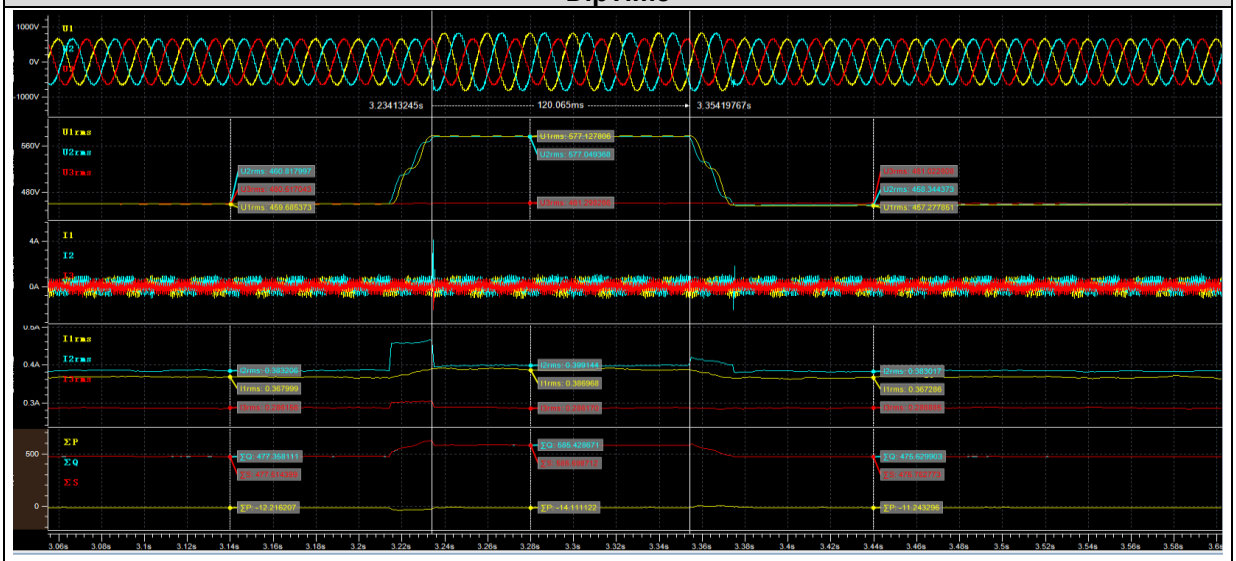


Two-Phase fault	
No Load	Residual voltage: 125.0%Un

Voltage Rise time

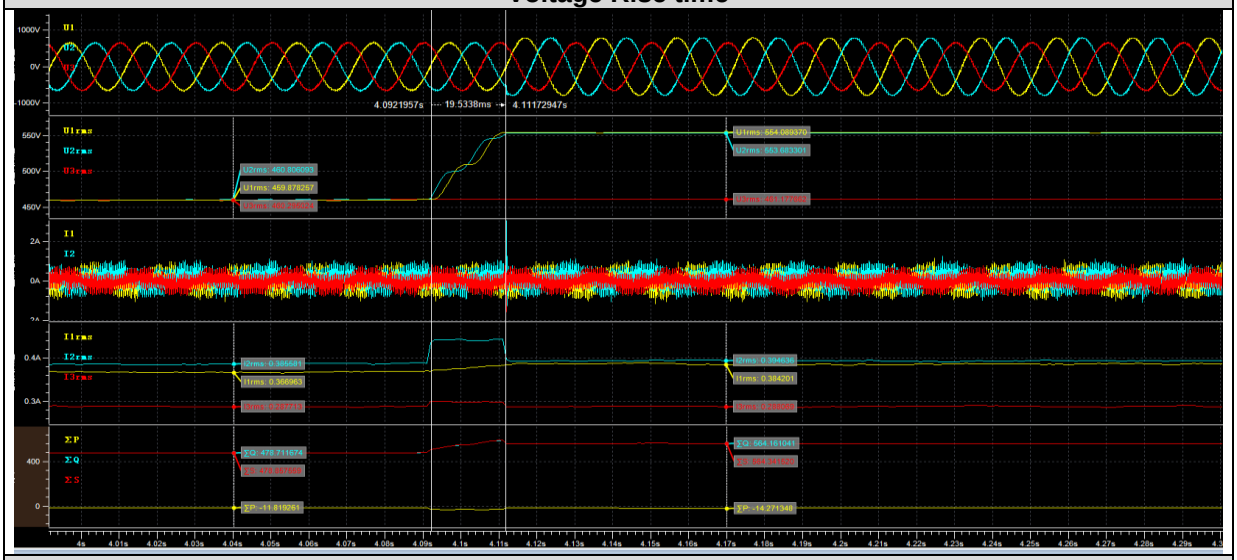


DipTime

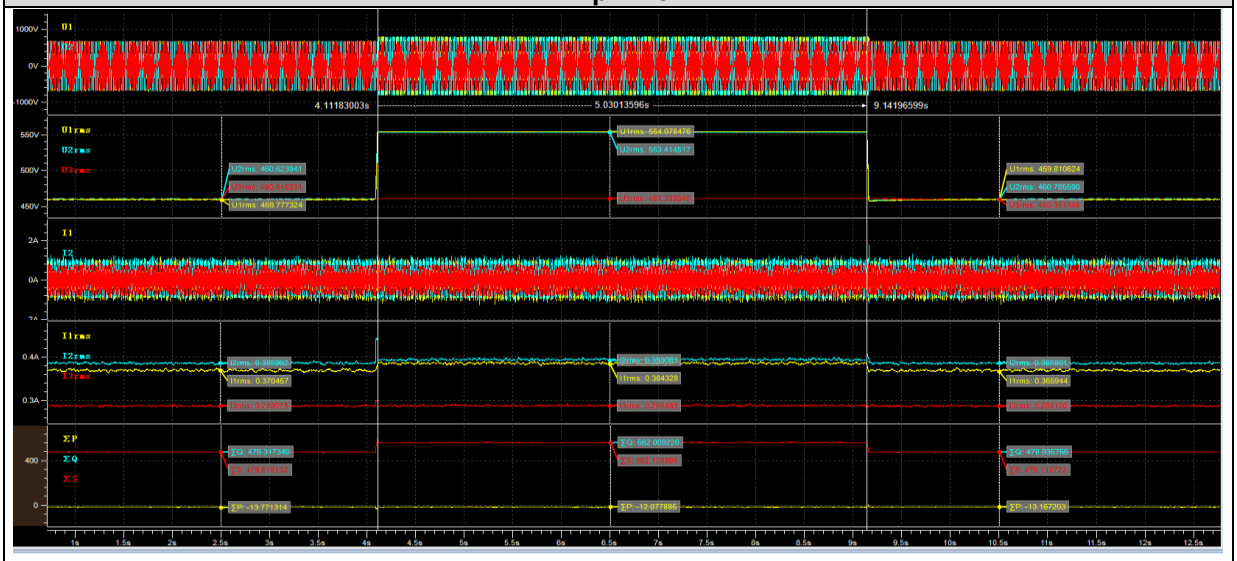


Two-Phase fault	
No Load	Residual voltage: 120.0%Un

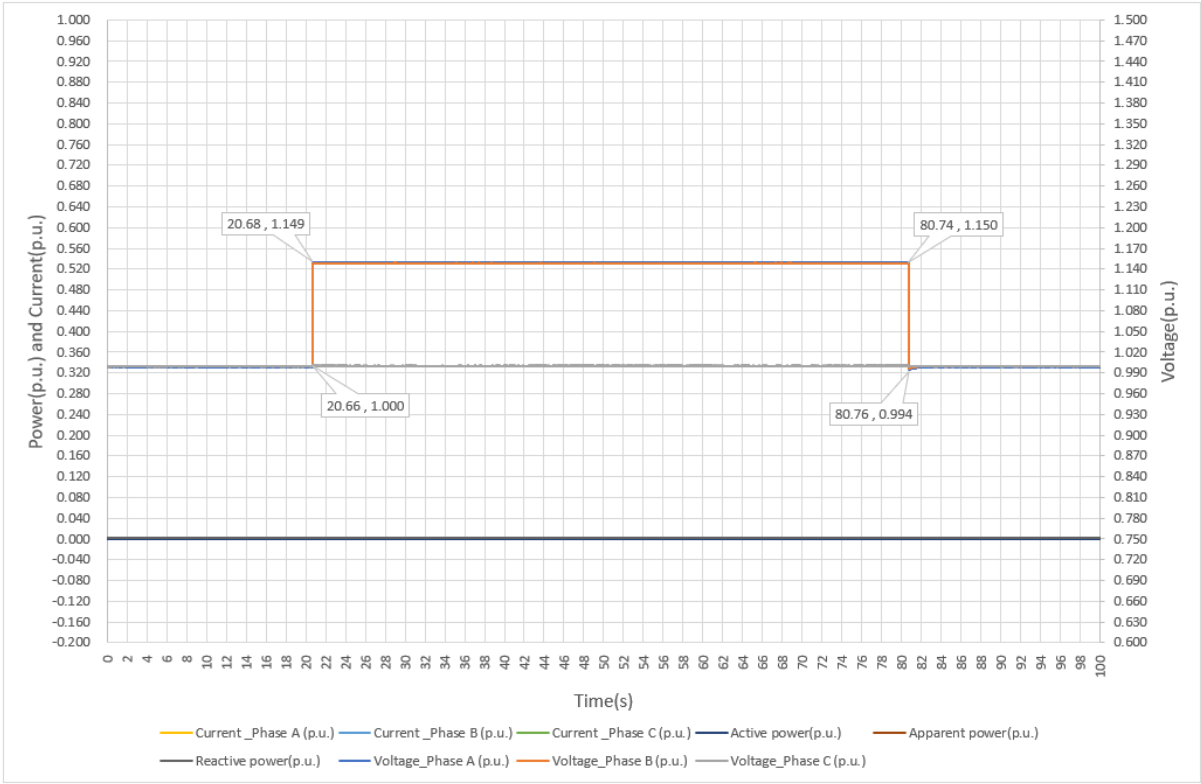
Voltage Rise time



DipTime

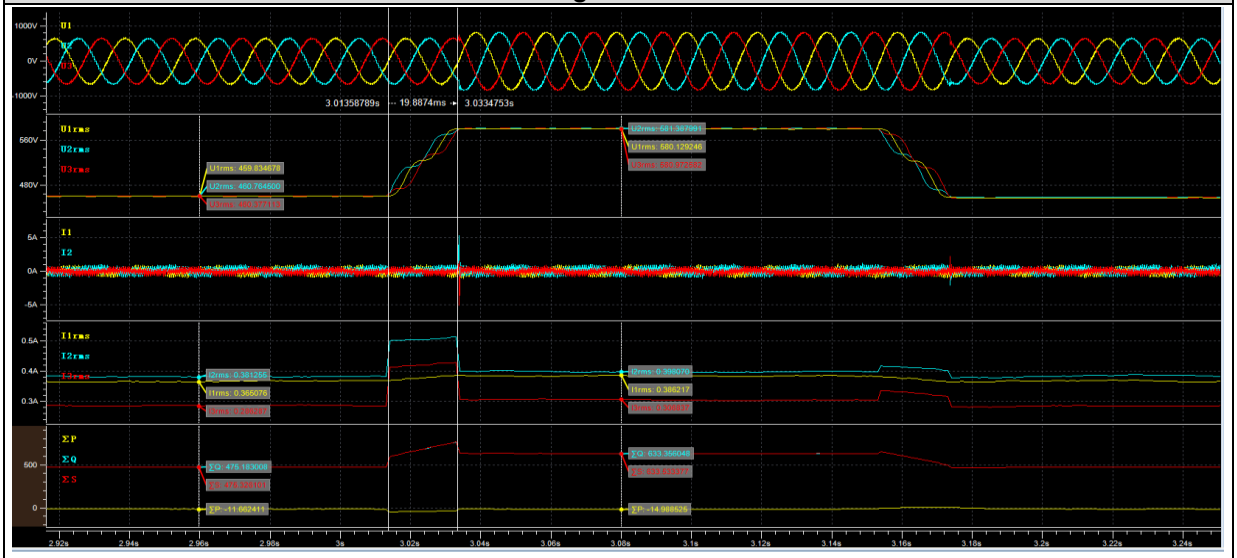


Two-Phase fault	
No Load	Residual voltage: 115.0%Un

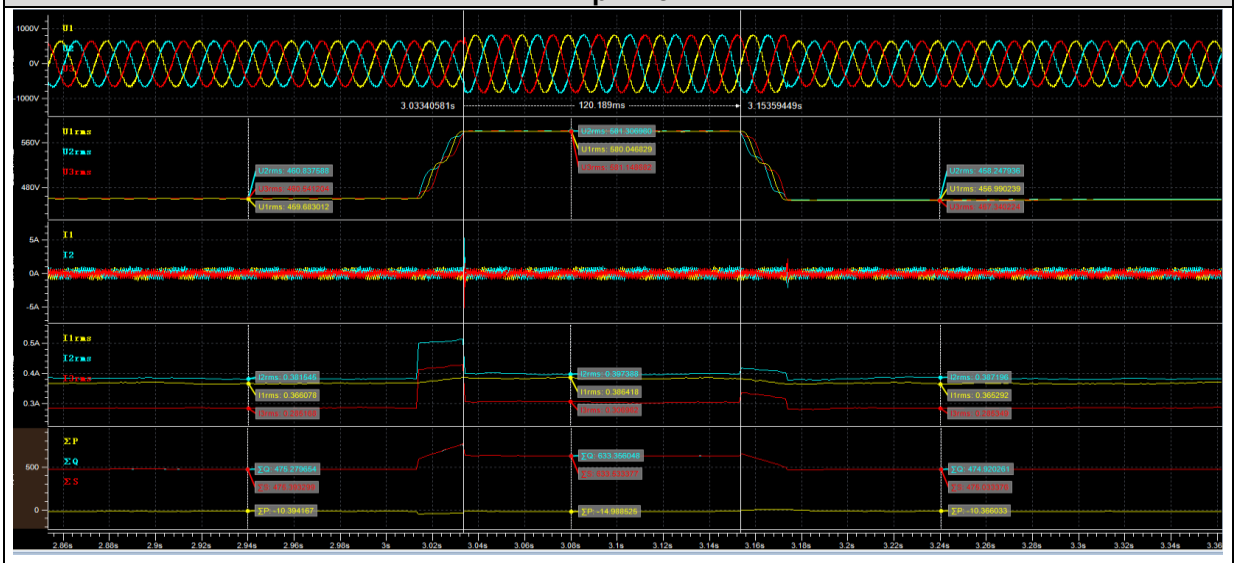


Three-Phase fault	
No Load	Residual voltage: 125.0%Un

Voltage Rise time

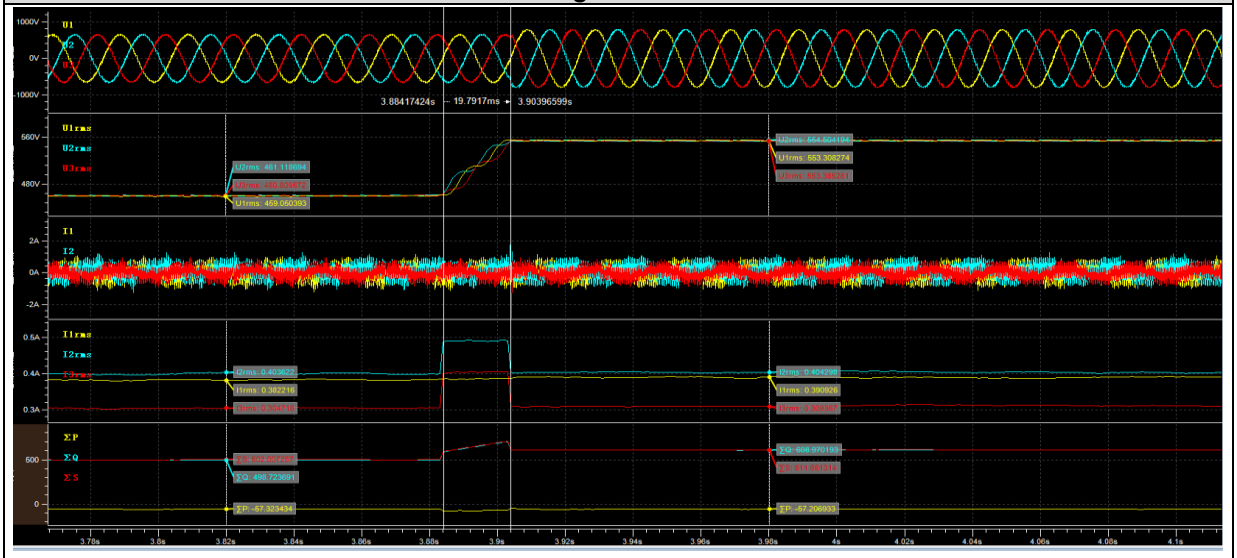


DipTime

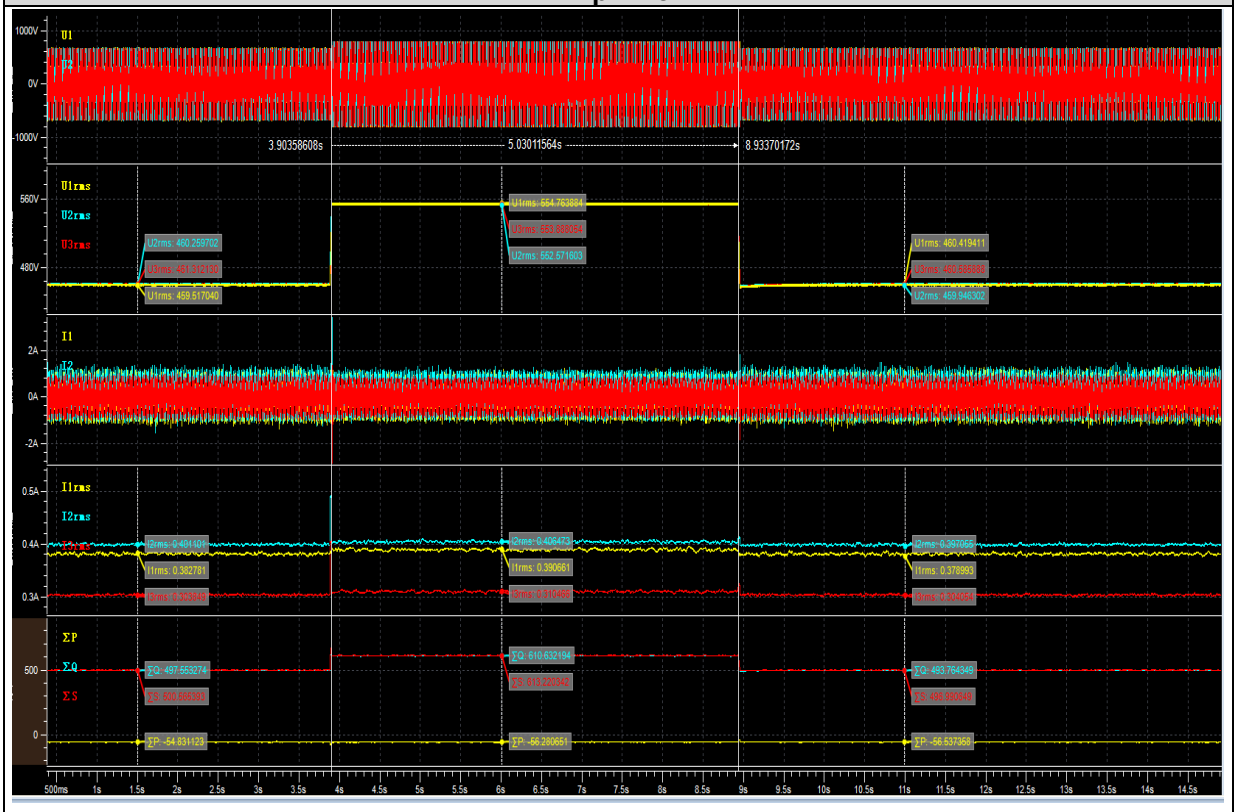


Three-Phase fault	
No Load	Residual voltage: 120.0%Un

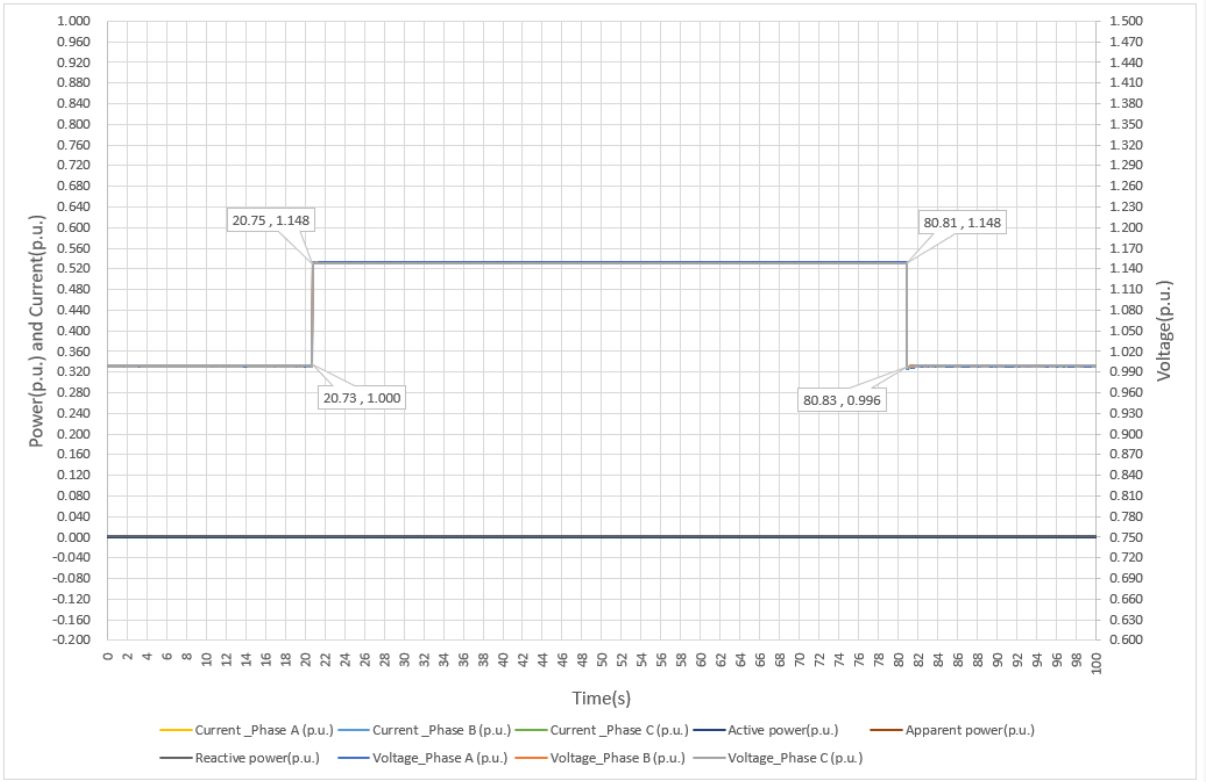
Voltage Rise time



DipTime



Three-Phase fault	
No Load	Residual voltage: 115.0%Un



4.2.3.2 Load Tests: Partial load (20%Pn)

Test results of 20%Pn power cases performed are offered below:

Single-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.5	18	124.9	> 100	122	397	99.5
120.0	99.9	17	119.7	> 5000	5031	298	99.4
115.0	99.8	10	114.8	> 60000	60070	130	99.4

Two-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.7	20	125.0	> 100	120	355	99.4
120.0	99.7	20	120.1	> 5000	5030	373	99.6
115.0	99.9	20	114.8	> 60000	60070	150	99.9

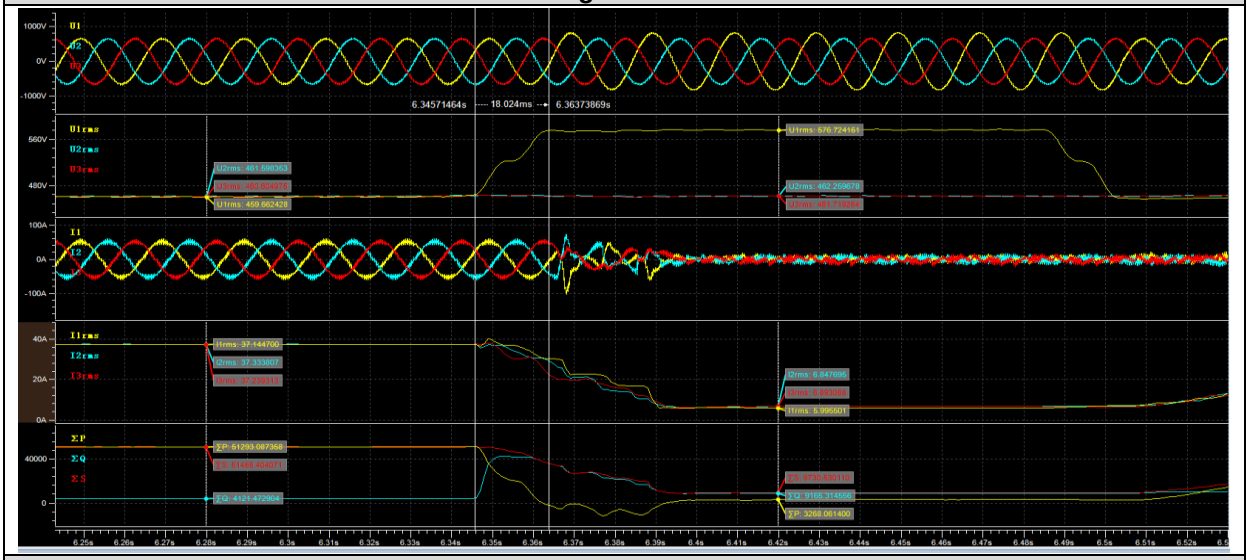
Three-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.7	20	124.9	> 100	120	392	99.7
120.0	99.7	20	120.0	> 5000	5030	333	99.8
115.0	100.6	20	114.7	> 60000	60060	140	99.6

Note: The virtual neutral line was used in the test, Un ≈ 461.9 V.

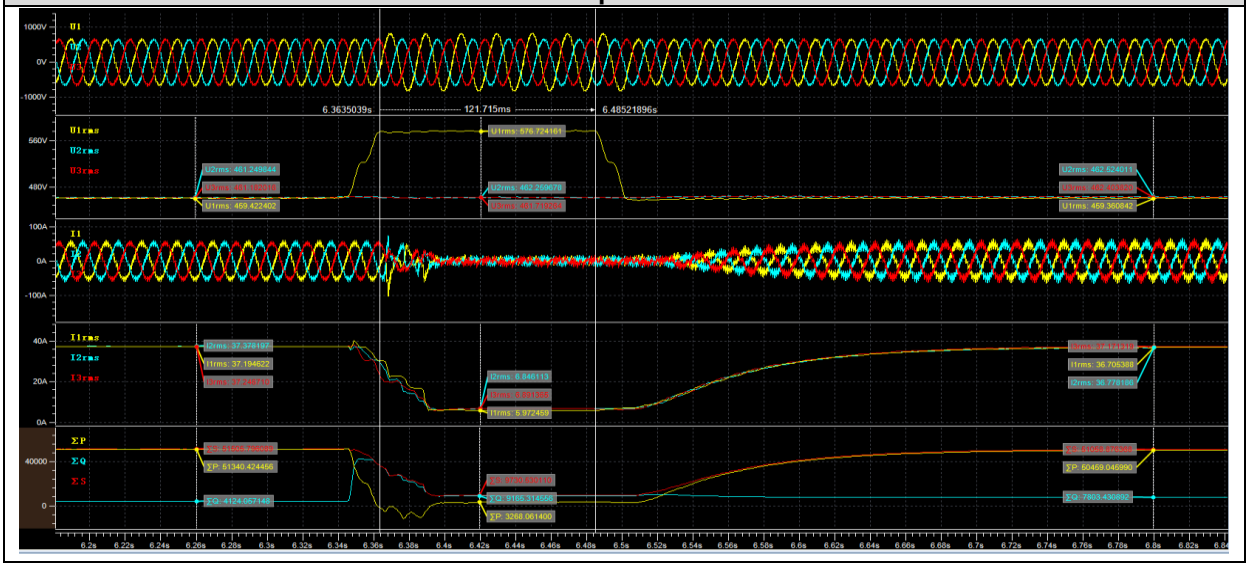
Test results are graphically represented at following pages.

Single-Phase fault	
Partial load (20%Pn)	Residual voltage: 125.0%Un

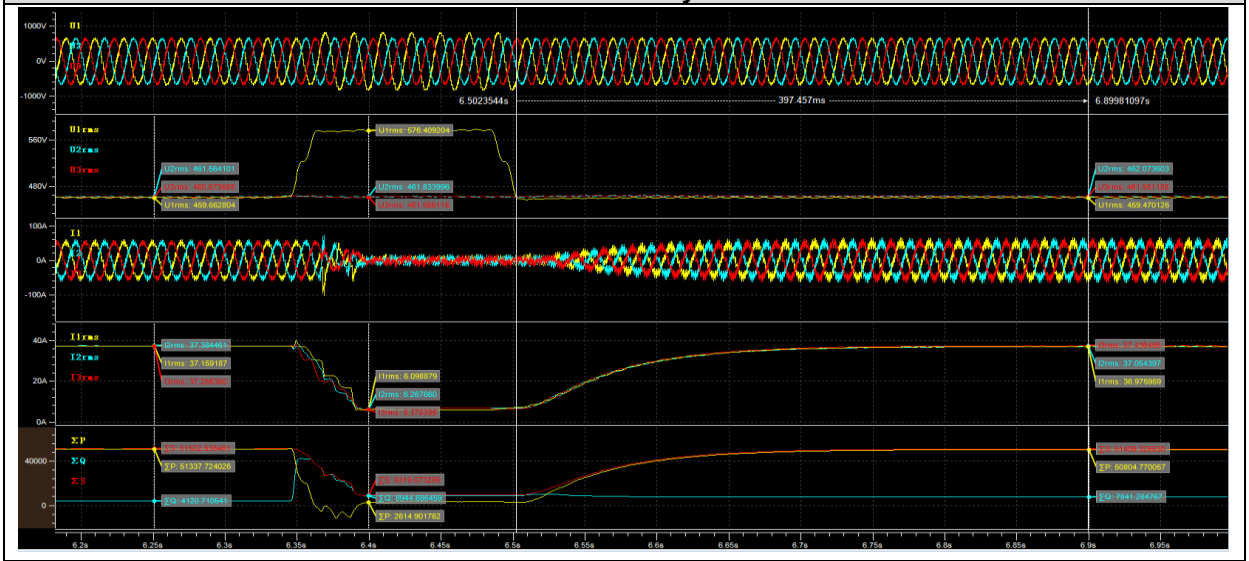
Voltage Rise time



DipTime

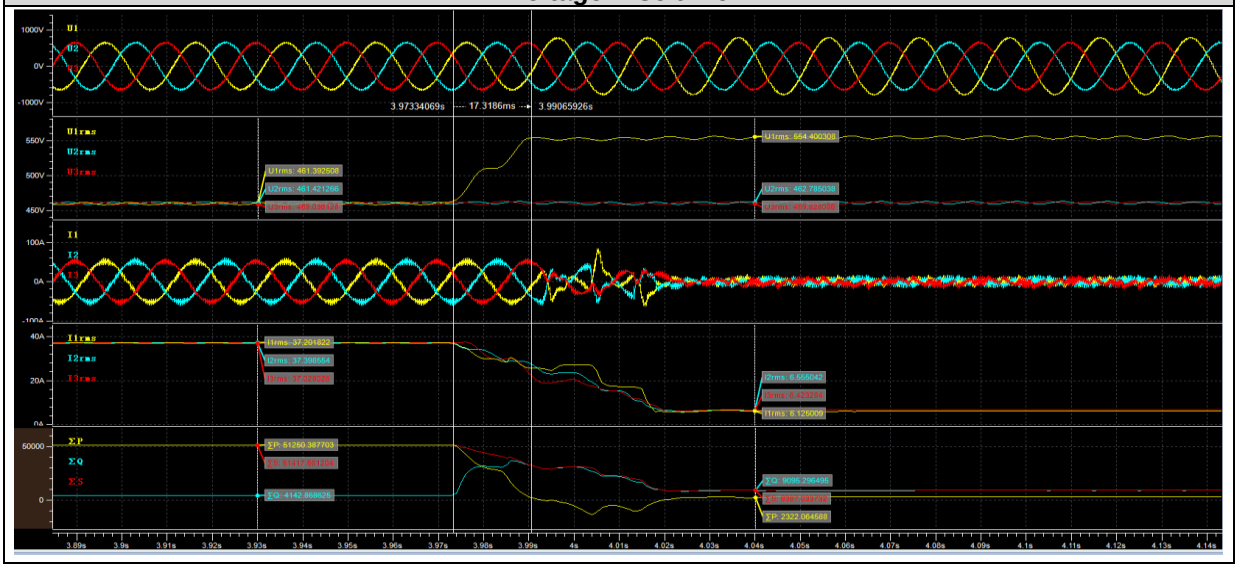


Power Recovery time

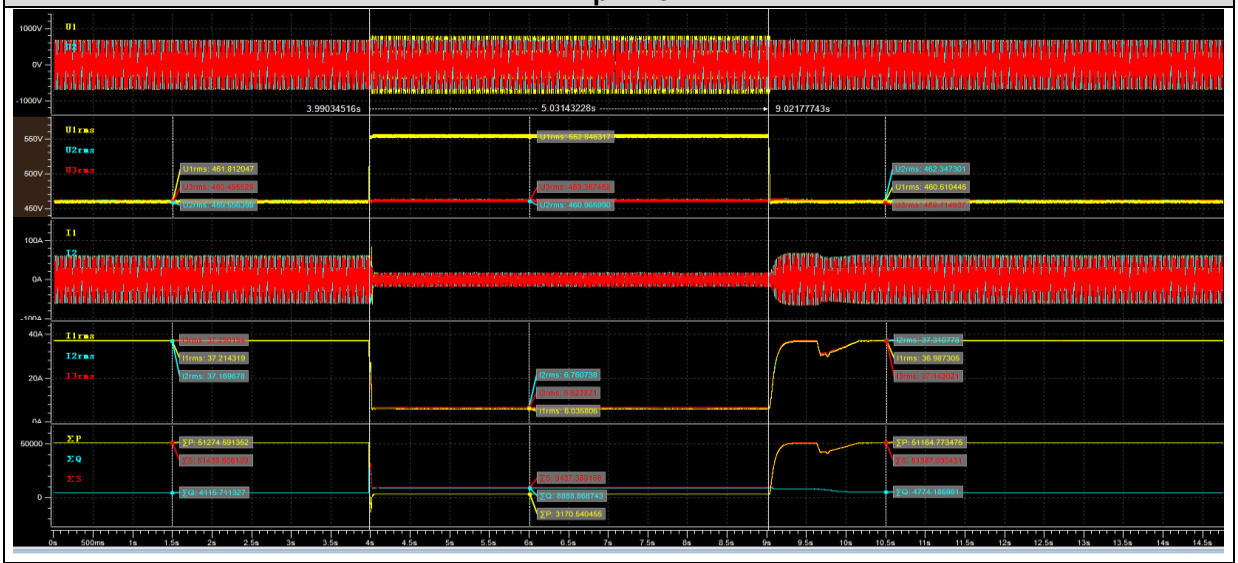


Single-Phase fault	
Partial load (20%Pn)	Residual voltage: 120.0%Un

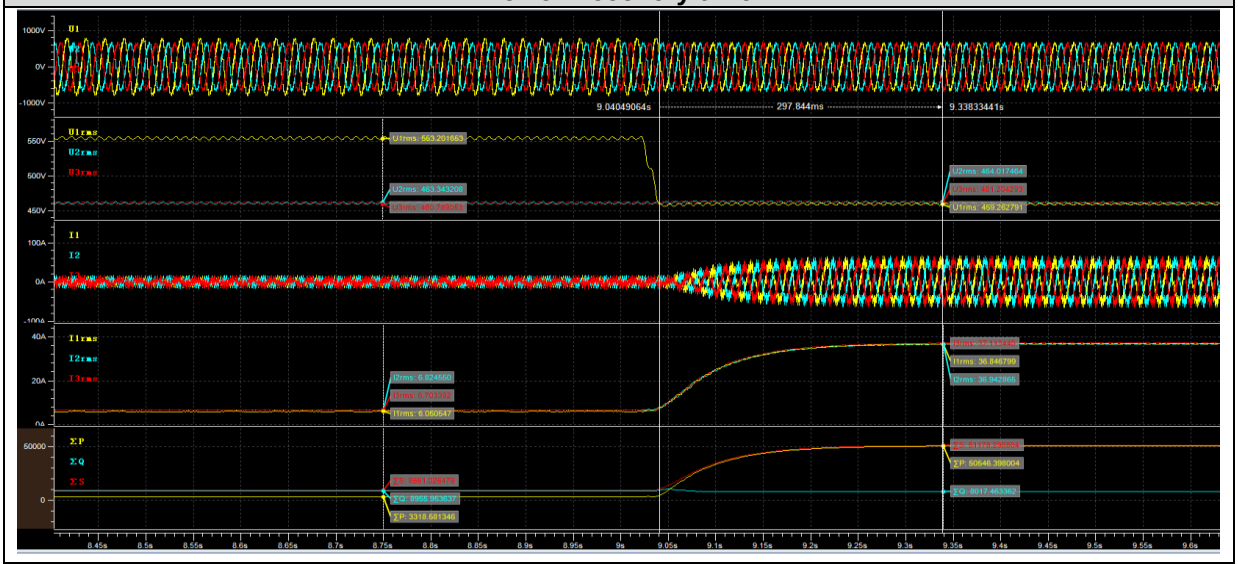
Voltage Rise time



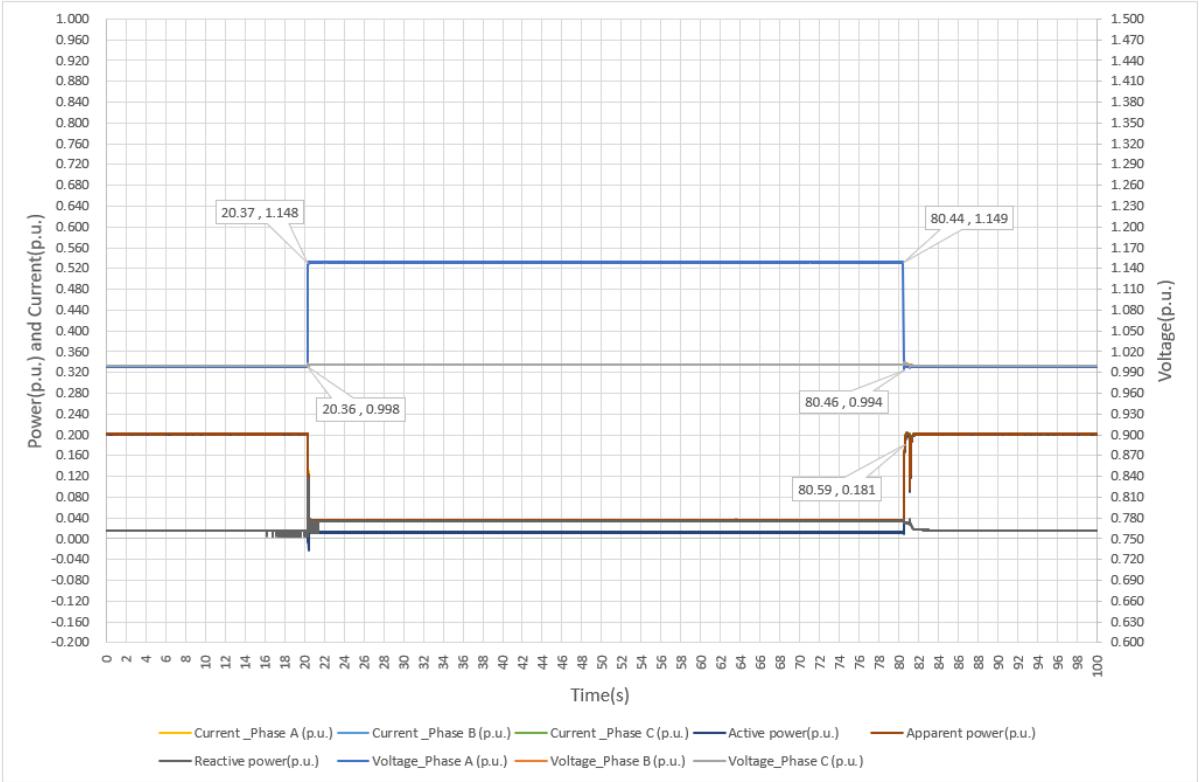
DipTime



Power Recovery time

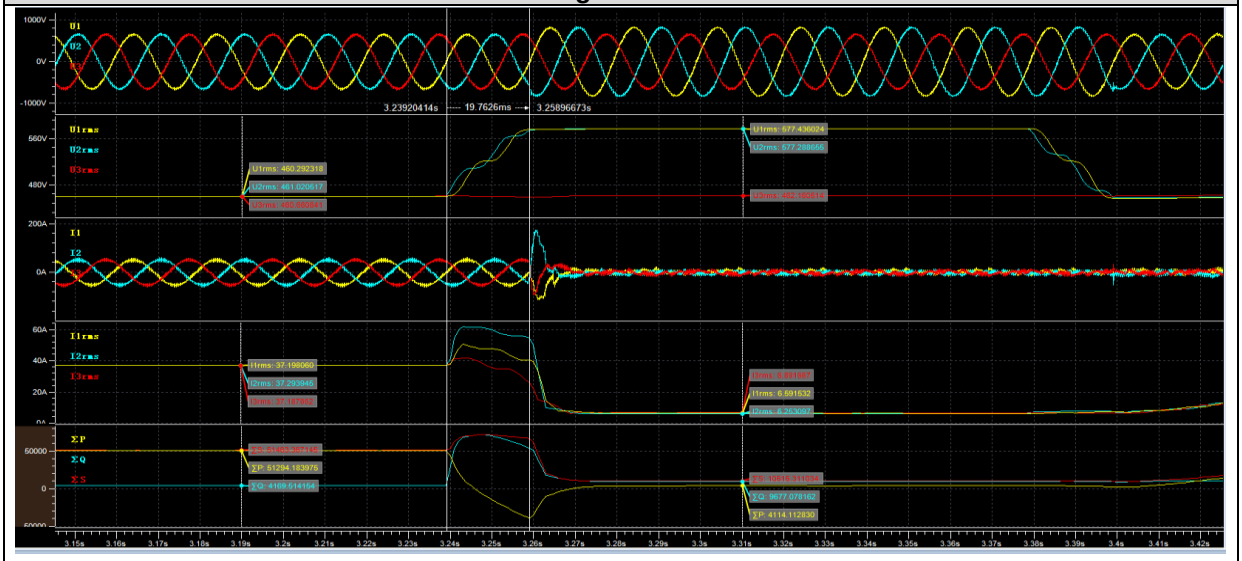


Single-Phase fault	
Partial load (20%Pn)	Residual voltage: 115.0%Un

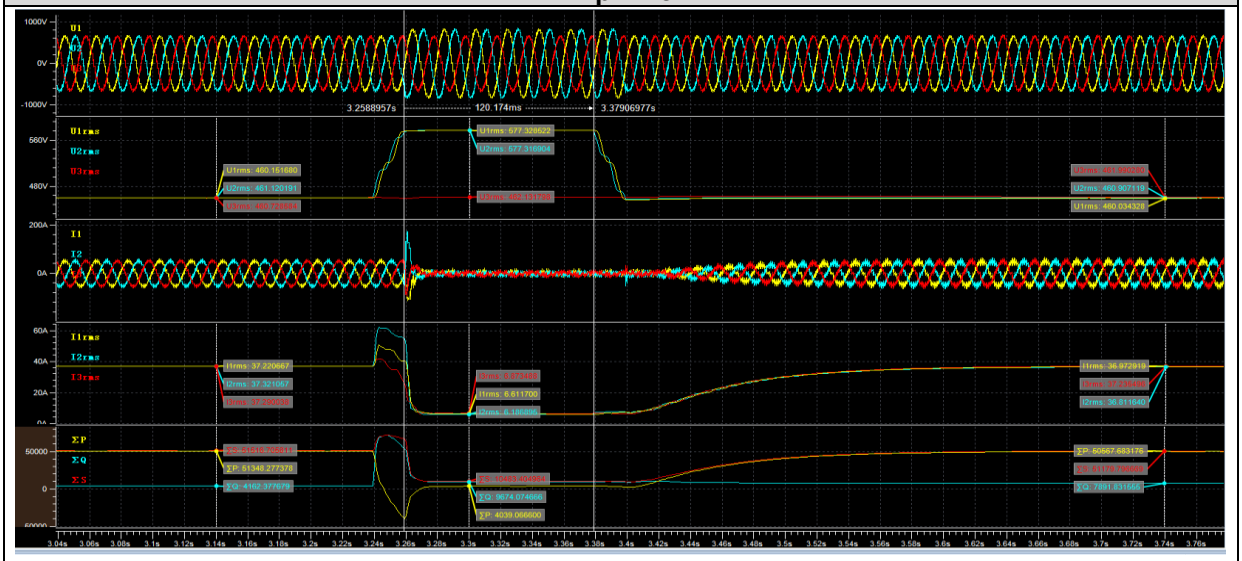


Two-Phase fault	
Partial load (20%Pn)	Residual voltage: 125.0%Un

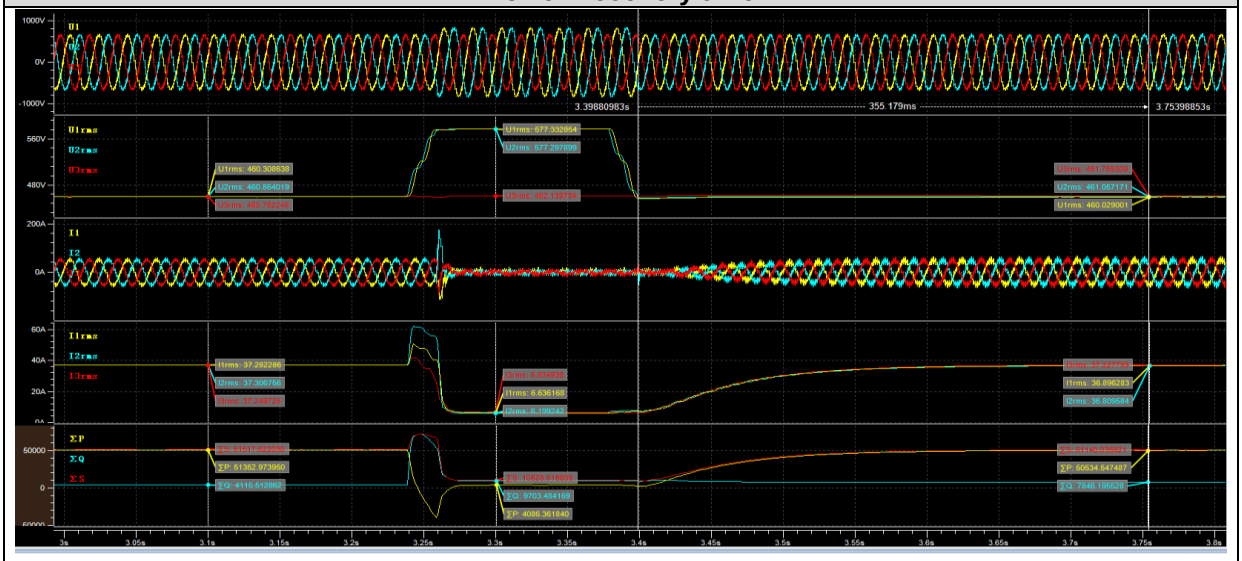
Voltage Rise time



DipTime

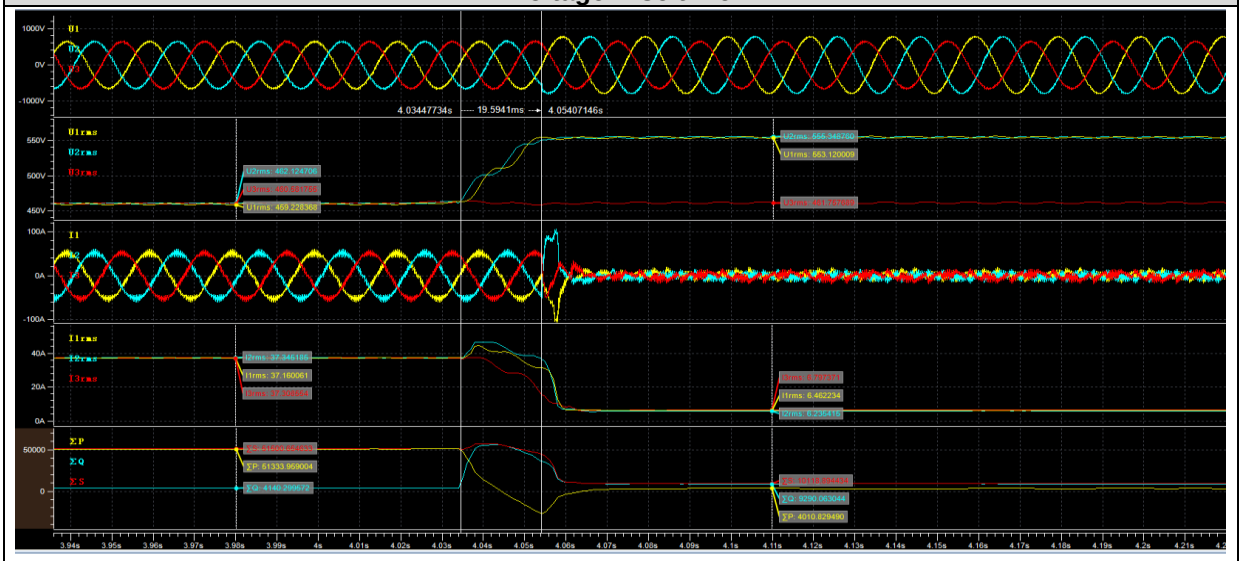


Power Recovery time

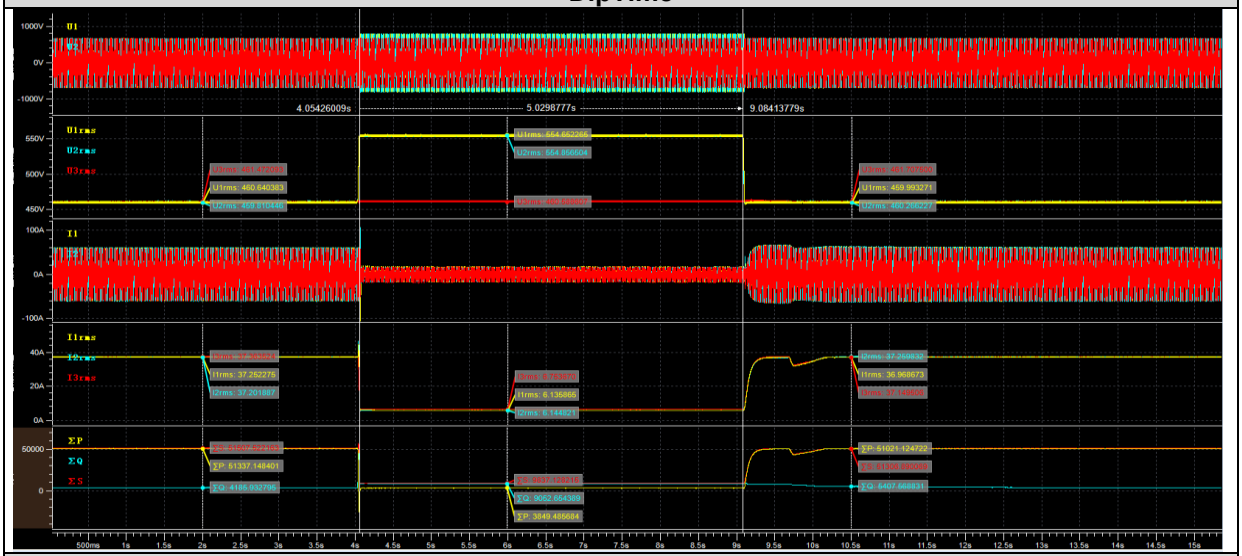


Two-Phase fault	
Partial load (20%Pn)	Residual voltage: 120.0%Un

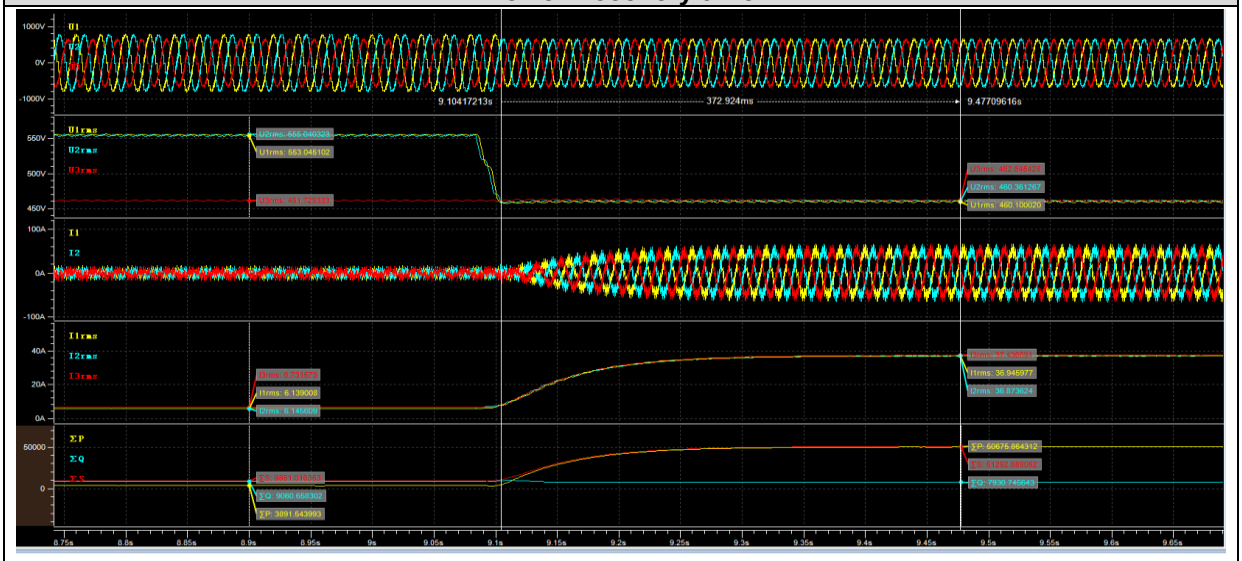
Voltage Rise time



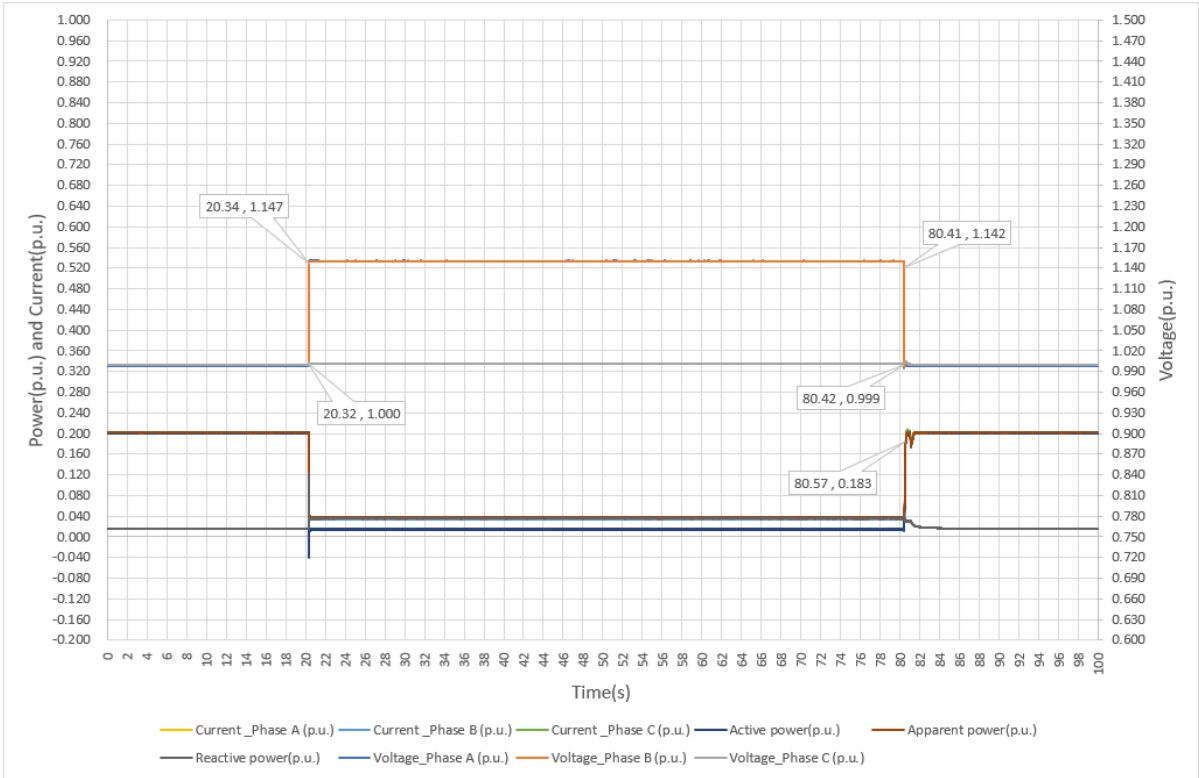
DipTime



Power Recovery time

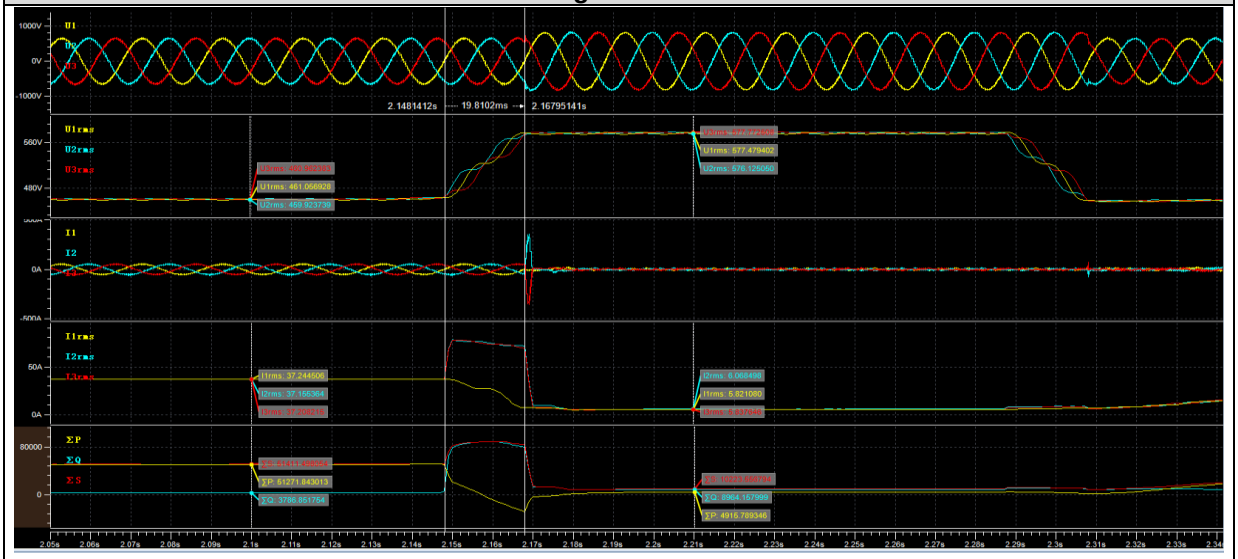


Two-Phase fault	
Partial load (20%Pn)	Residual voltage: 115.0%Un

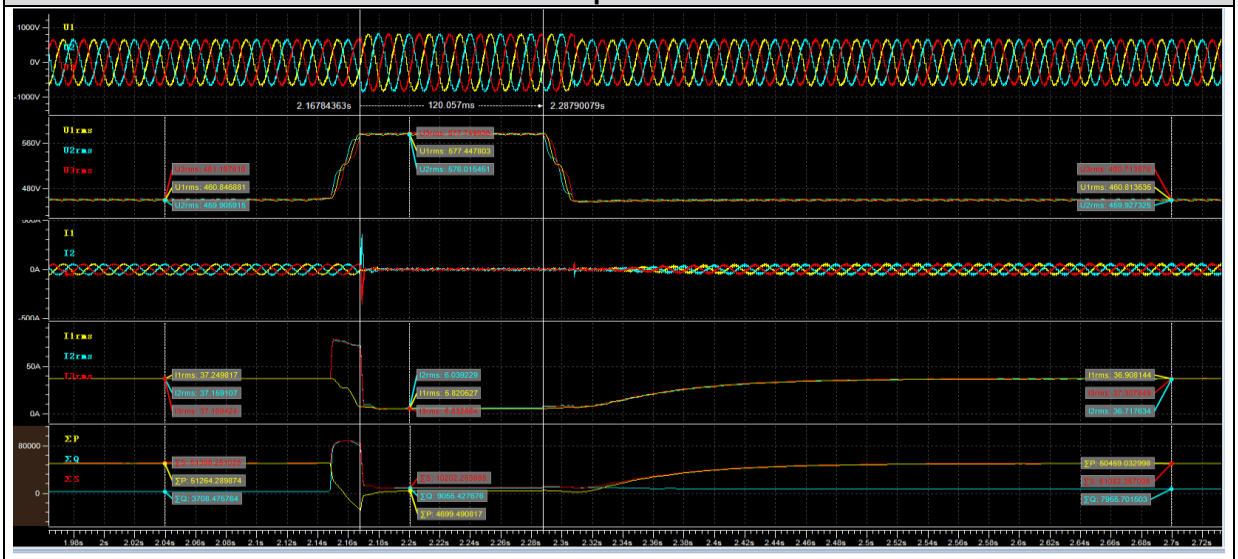


Three-Phase fault	
Partial load (20%Pn)	Residual voltage: 125.0%Un

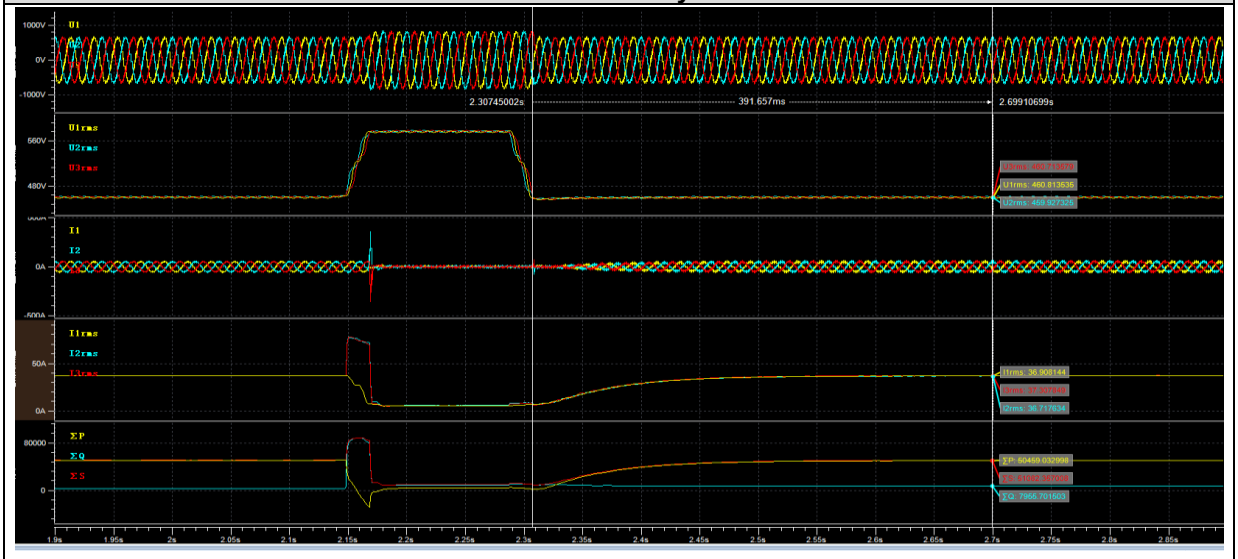
Voltage Rise time



DipTime

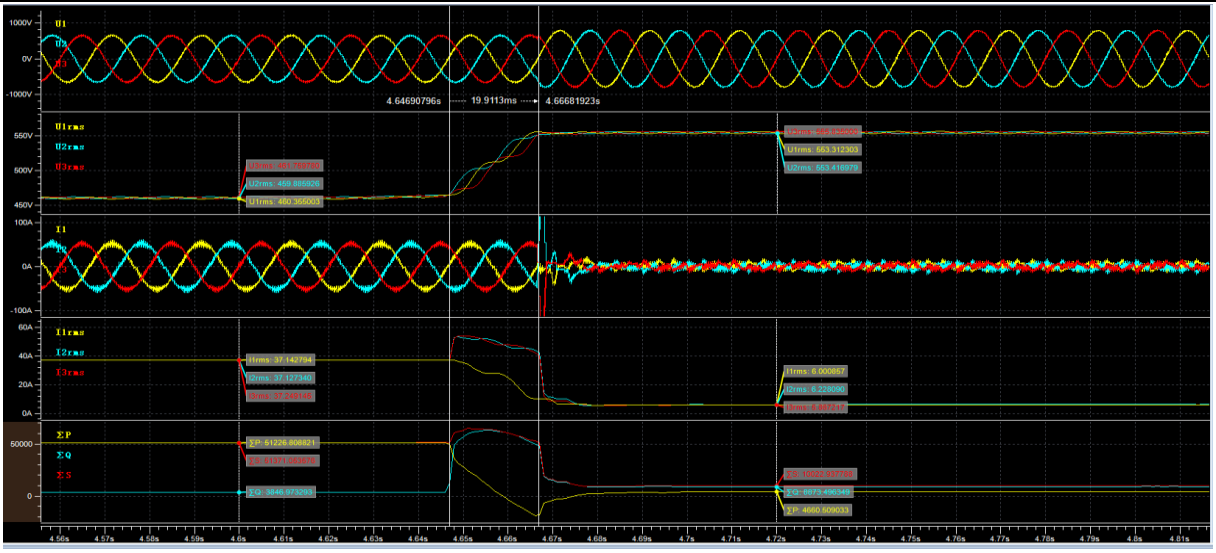


Power Recovery time

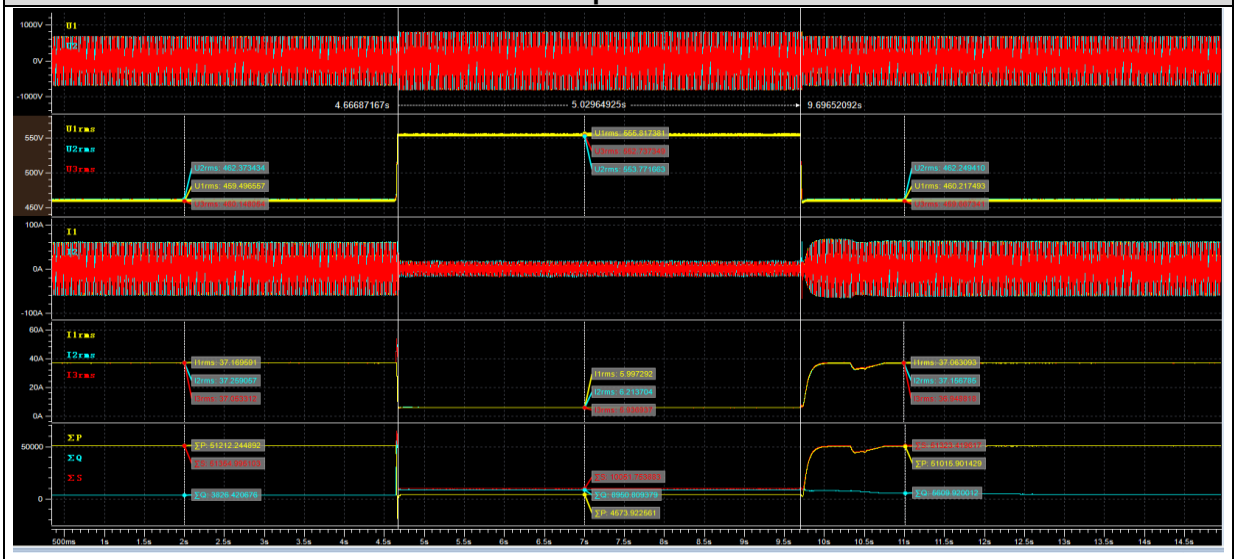


Three-Phase fault	
Partial load (20%Pn)	Residual voltage: 120.0%Un

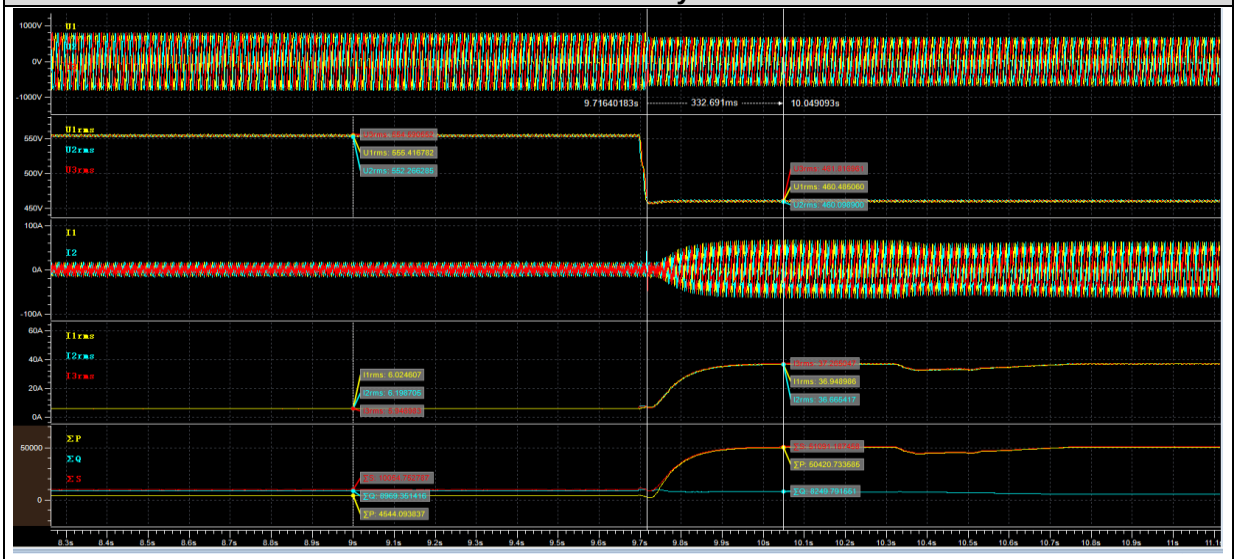
Voltage Rise time



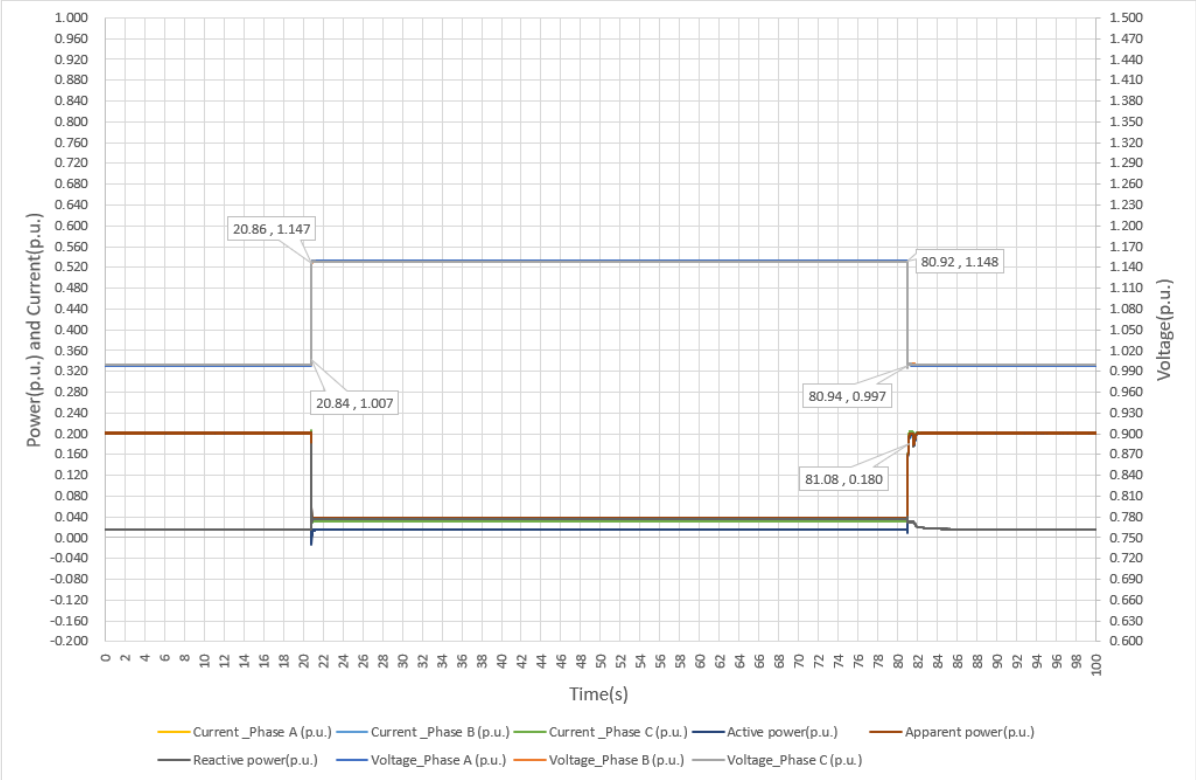
DipTime



Power Recovery time



Three-Phase fault	
Partial load (20%Pn)	Residual voltage: 115.0%Un



4.2.3.2 *Load Tests: Full Load (>* 90 %Pn*)*

Test results of full power cases performed are offered below:

Single-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.6	18	124.6	> 100	121	177	99.4
120.0	100.1	17	119.9	> 5000	5032	141	99.8
115.0	99.9	10	115.2	> 60000	60040	140	99.6

Two-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	99.9	20	124.9	> 100	120	145	99.7
120.0	100.0	20	120.0	> 5000	5030	131	99.9
115.0	100.2	20	114.3	> 60000	60030	130	99.5

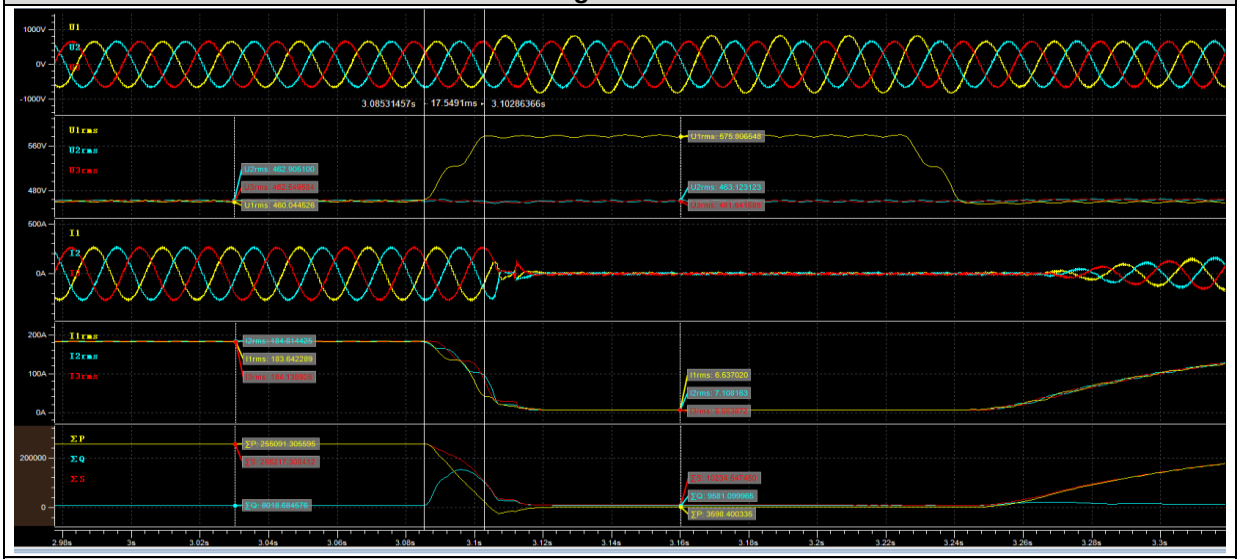
Three-Phase fault							
Residual voltage Desired (%Un)	Voltage before sag (%Un)	Voltage Rise time (ms)	Residual voltage Measured (%Un)	DipTime (ms)		Power Recovery time (ms)	Voltage after Recovery (%Un)
				Desired	Meas.		
125.0	100.0	20	124.9	> 100	120	140	99.7
120.0	100.0	20	119.9	> 5000	5029	150	99.9
115.0	100.2	20	114.7	> 60000	60030	130	99.5

Note: The virtual neutral line was used in the test, Un ≈ 461.9 V.

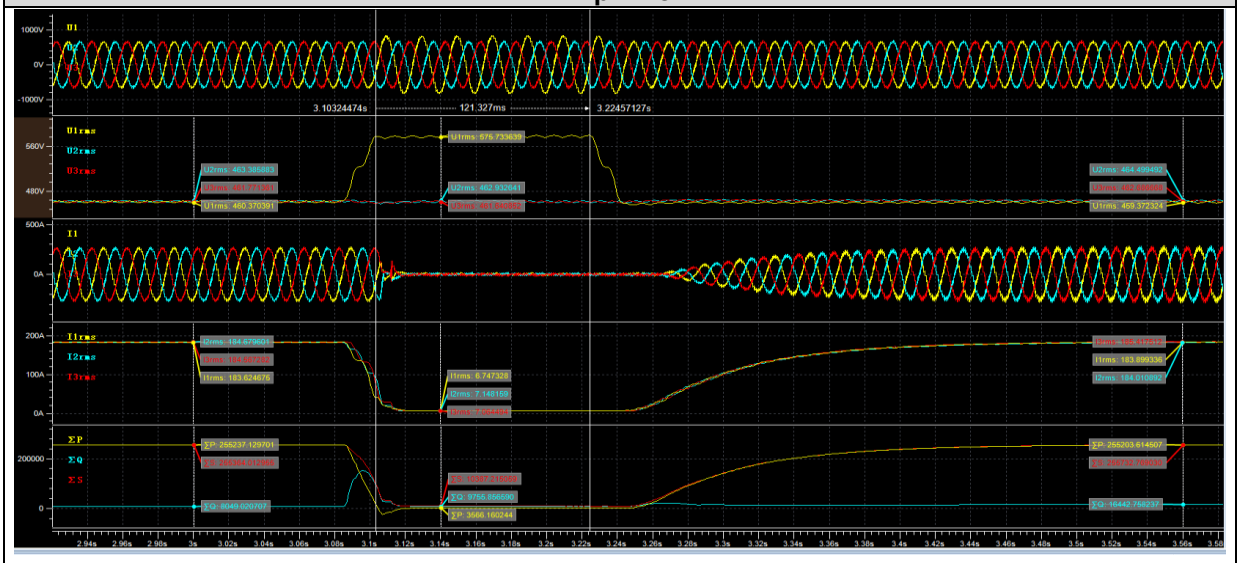
Test results are graphically represented at following pages.

Single-Phase fault	
Partial load (100%Pn)	Residual voltage: 125.0%Un

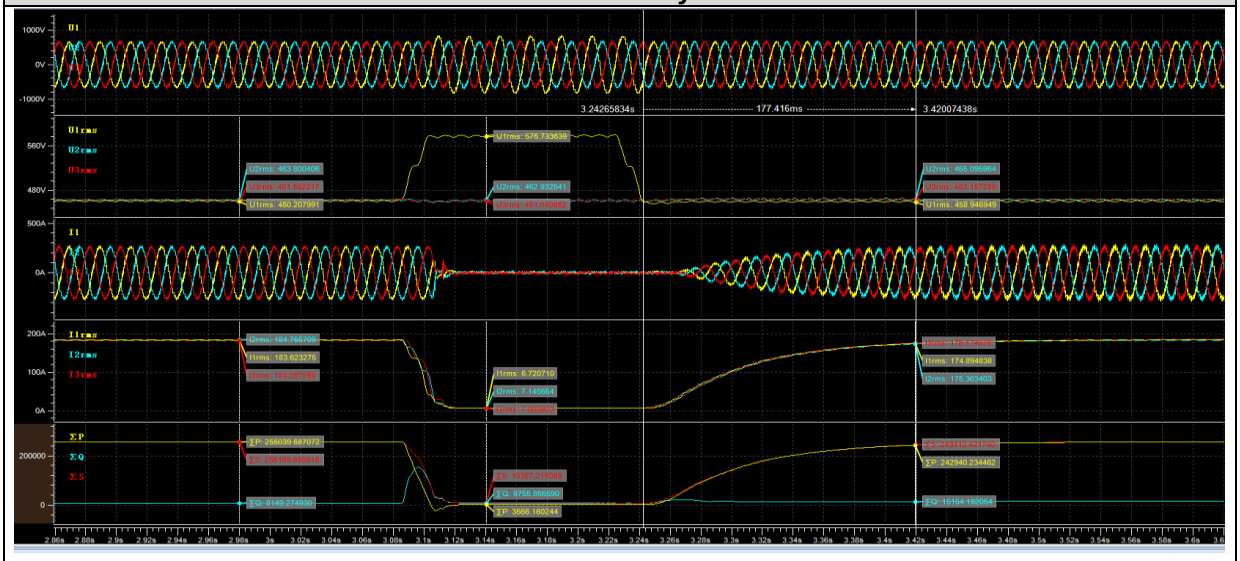
Voltage Rise time



DipTime

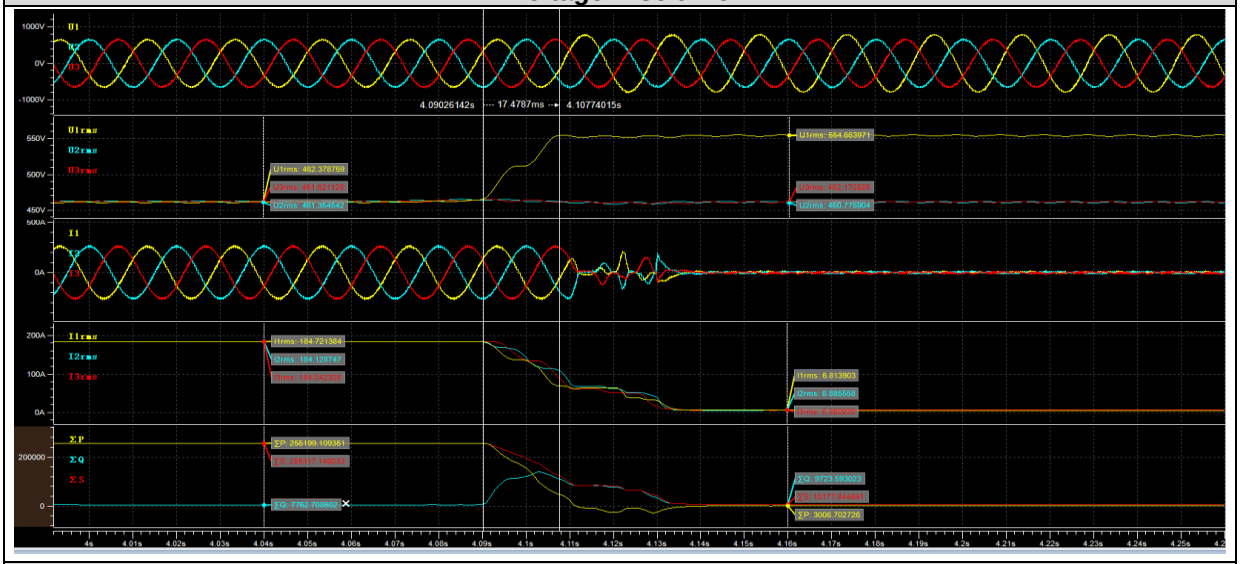


Power Recovery time

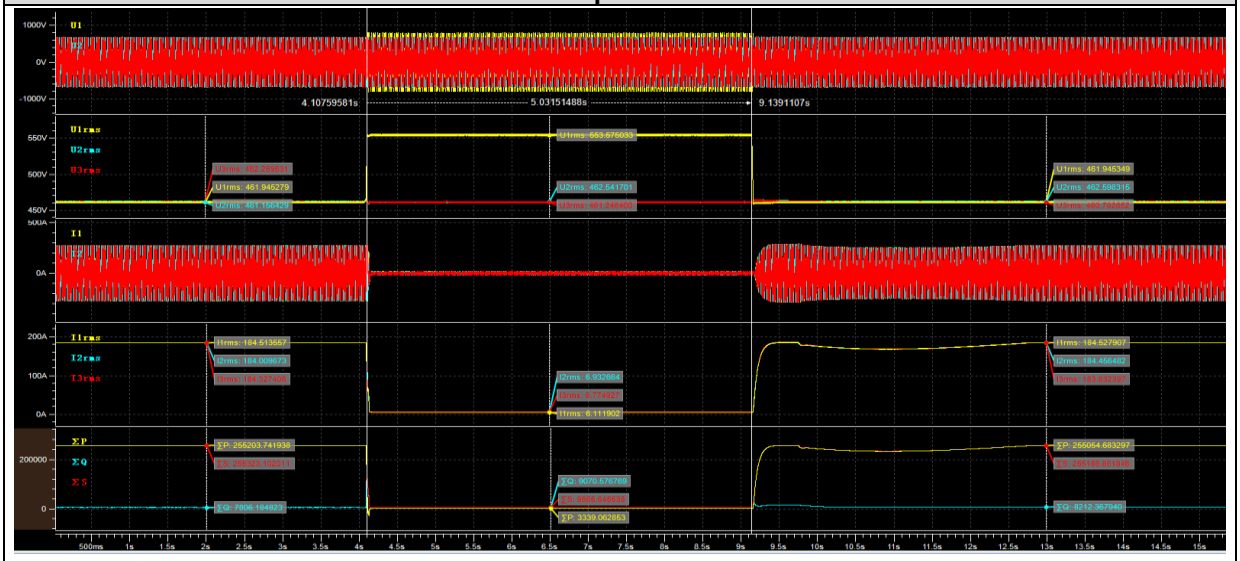


Single-Phase fault	
Partial load (100%Pn)	Residual voltage: 120.0%Un

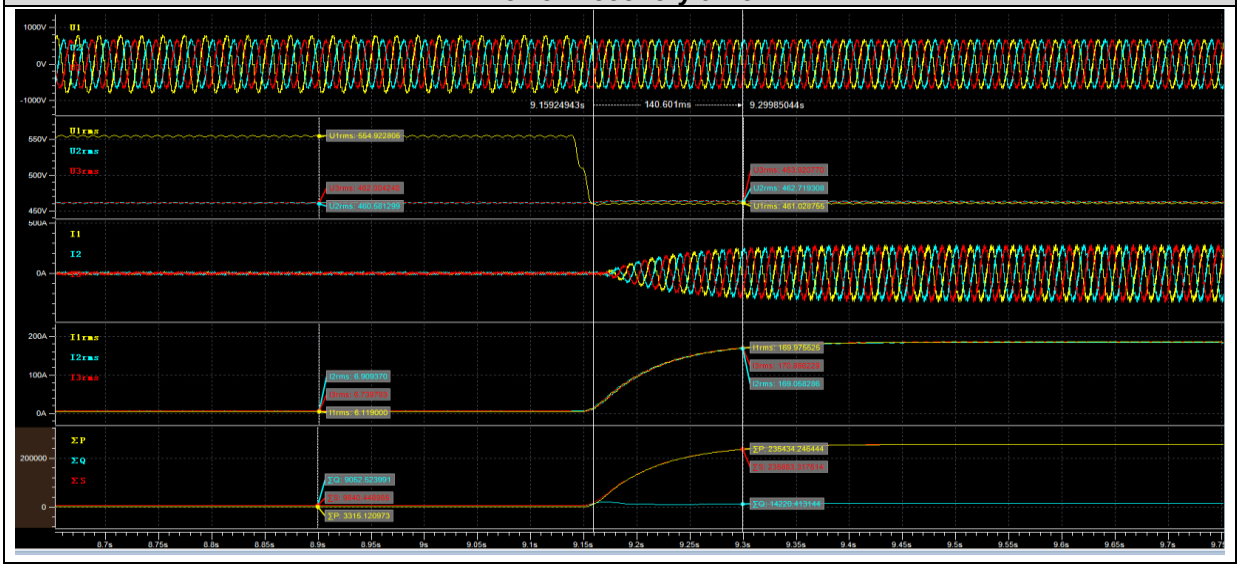
Voltage Rise time



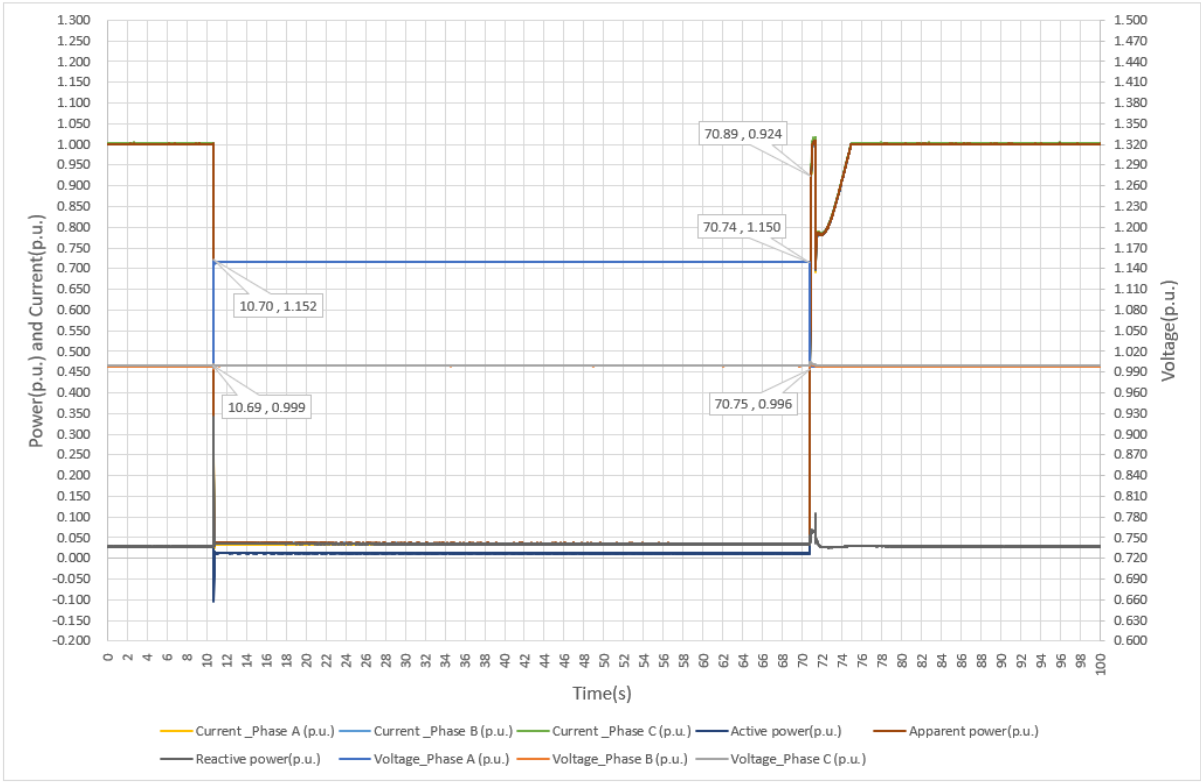
DipTime



Power Recovery time

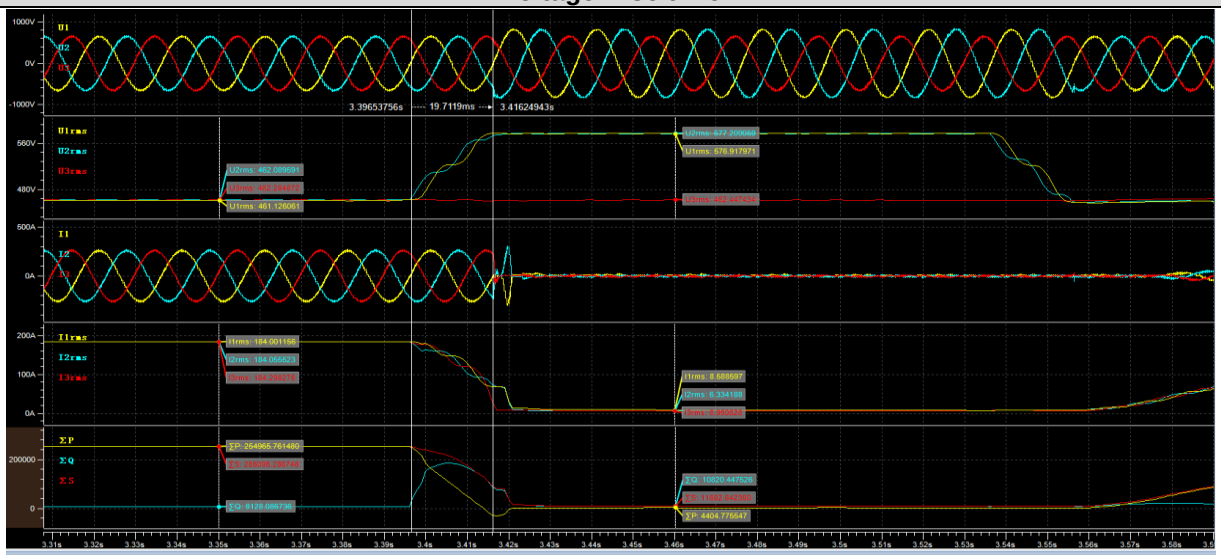


Single-Phase fault	
Partial load (100%Pn)	Residual voltage: 115.0%Un

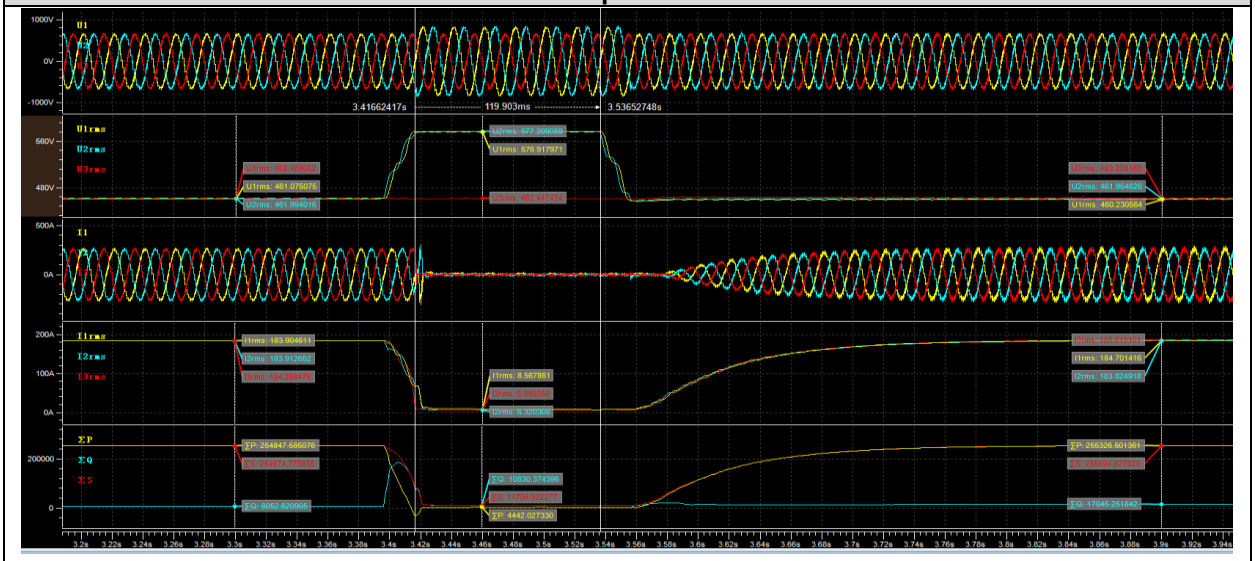


Two-Phase fault	
Partial load (100%Pn)	Residual voltage: 125.0%Un

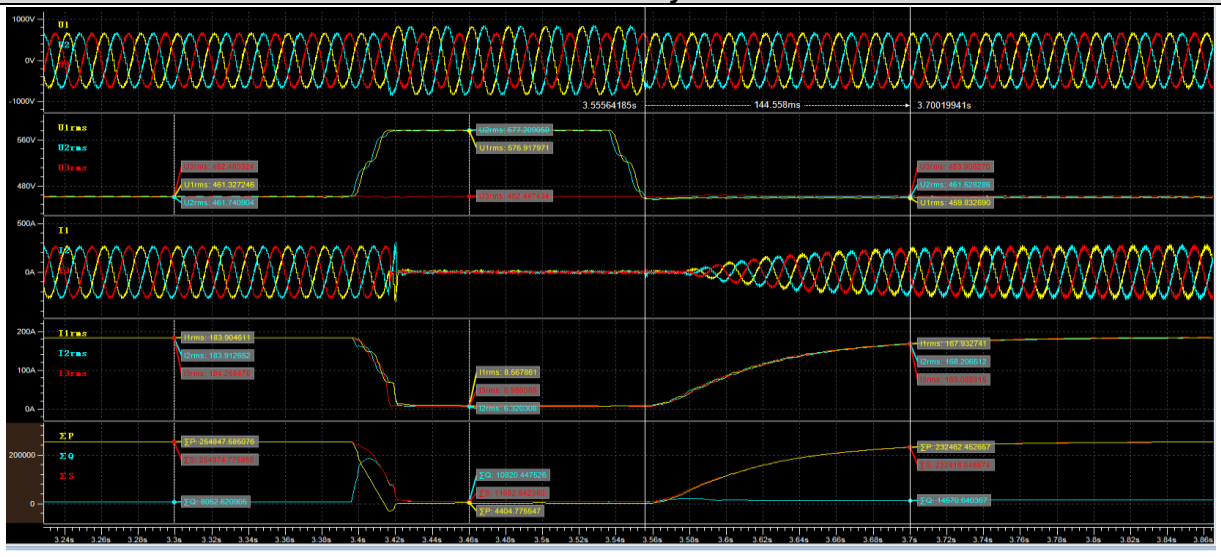
Voltage Rise time



DipTime

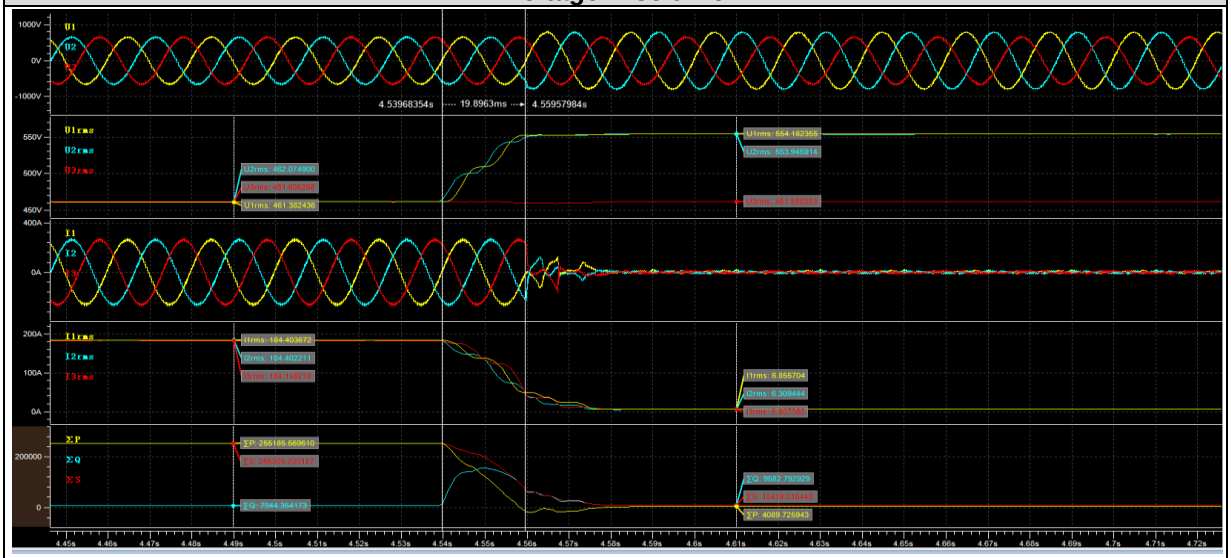


Power Recovery time

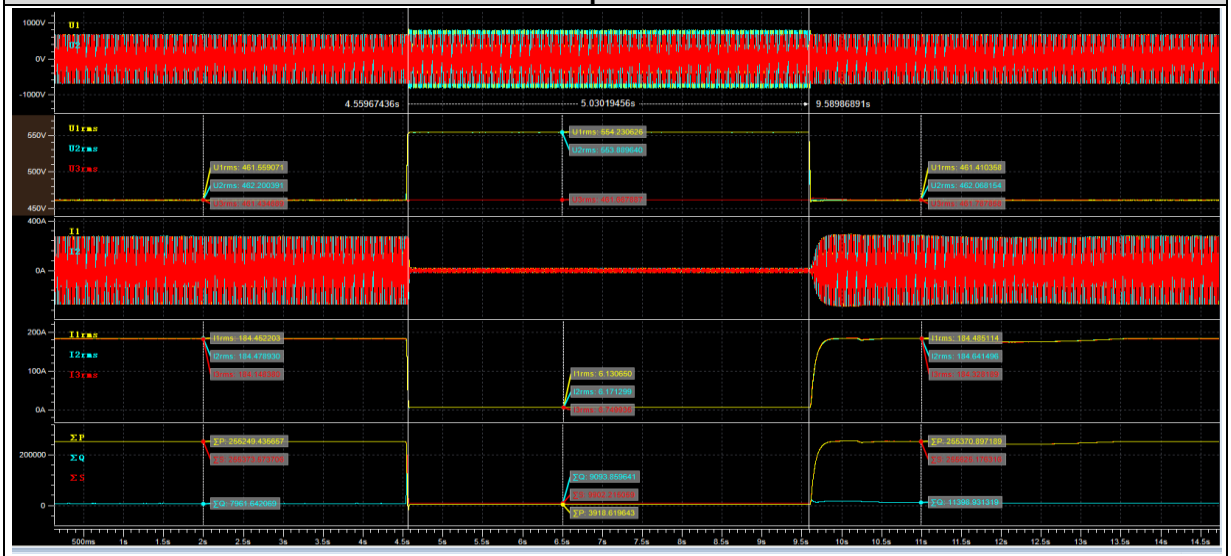


Two-Phase fault	
Partial load (100%Pn)	Residual voltage: 120.0%Un

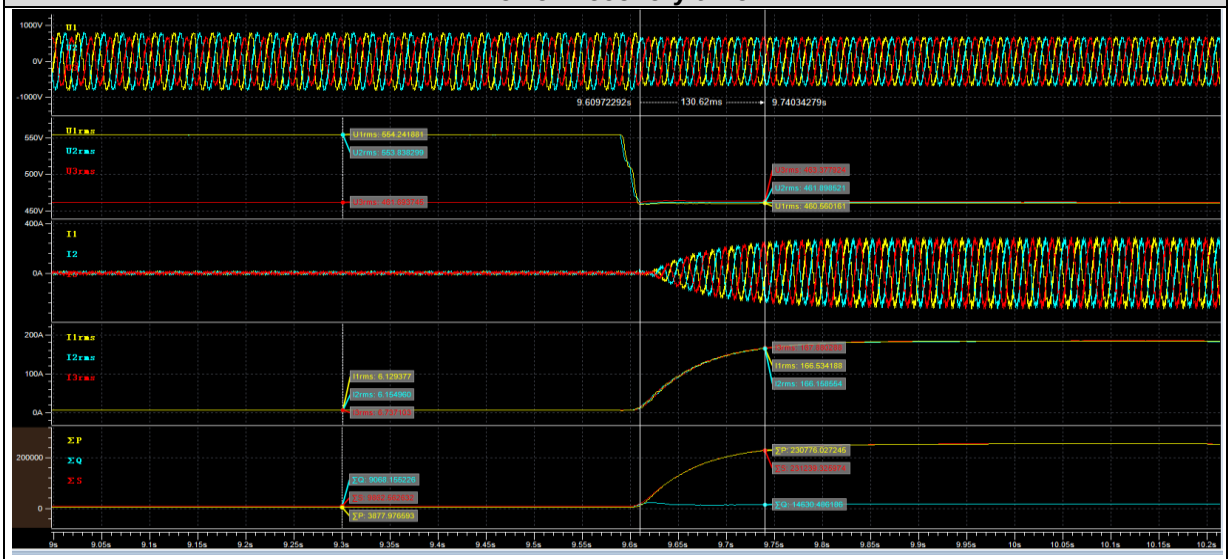
Voltage Rise time



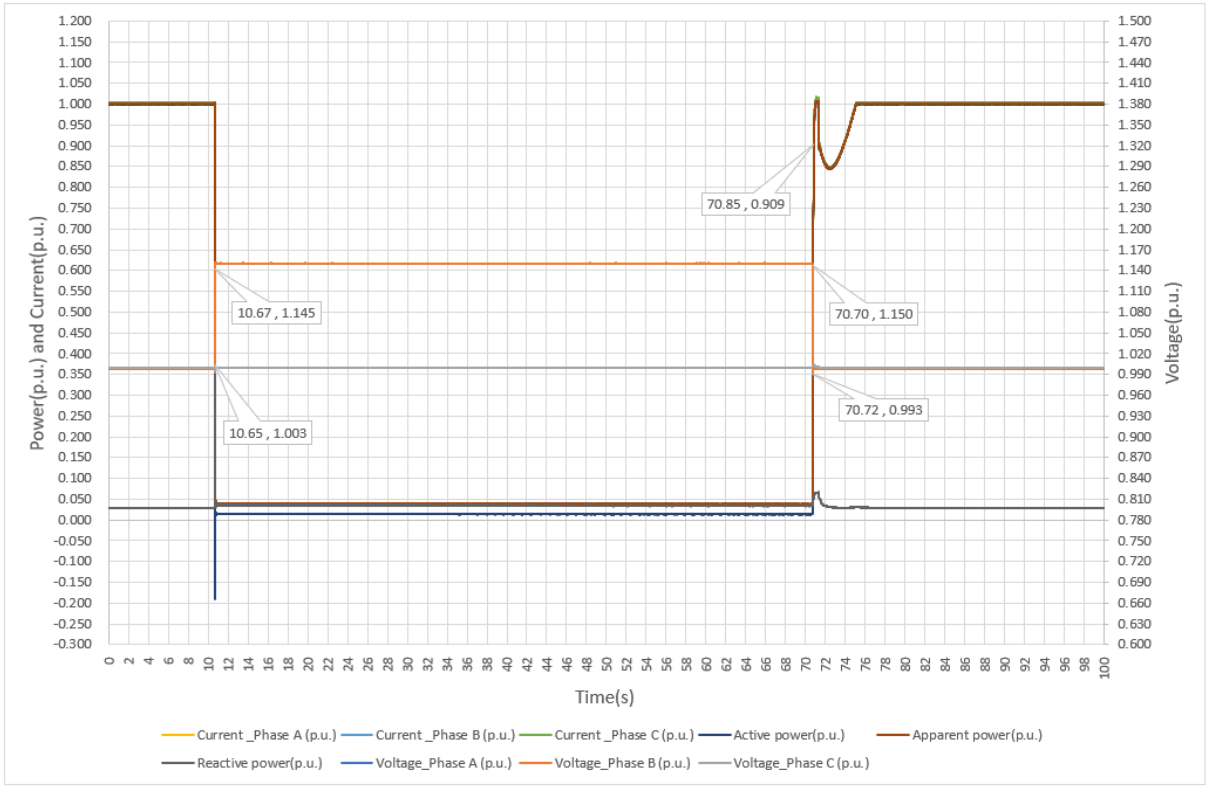
DipTime



Power Recovery time

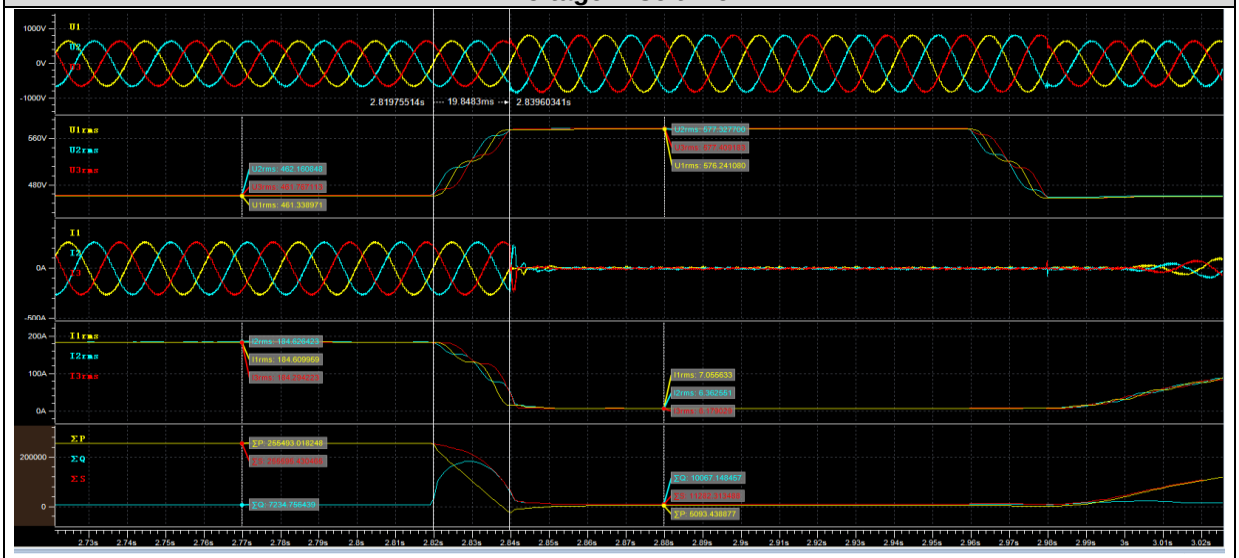


Two-Phase fault	
Partial load (100%Pn)	Residual voltage: 115.0%Un

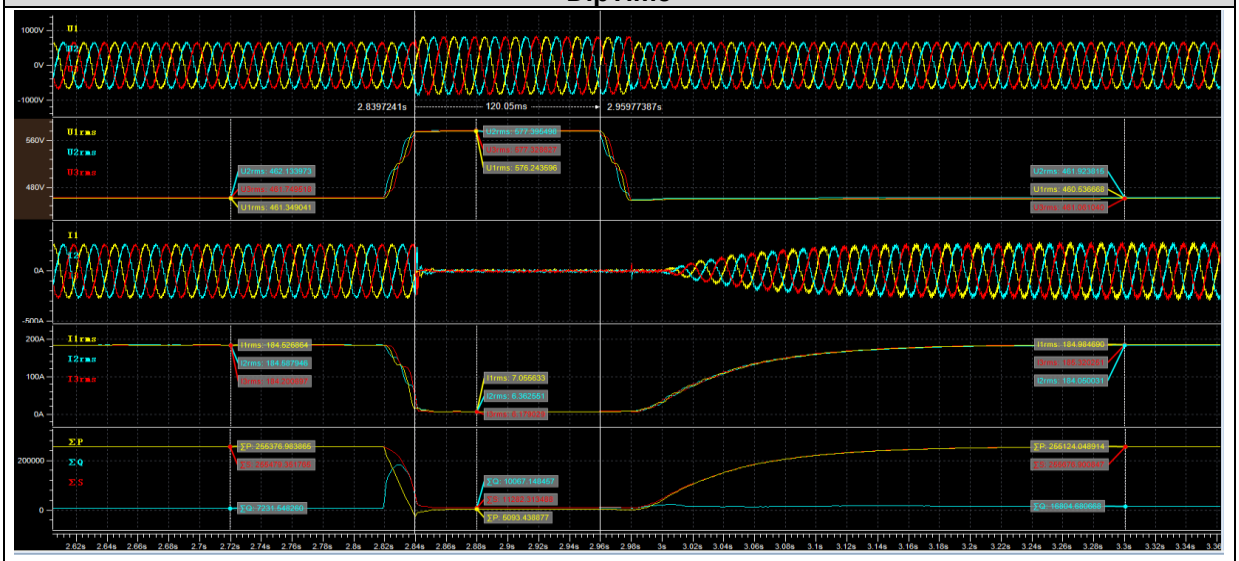


Three-Phase fault	
Partial load (100%Pn)	Residual voltage: 125.0%Un

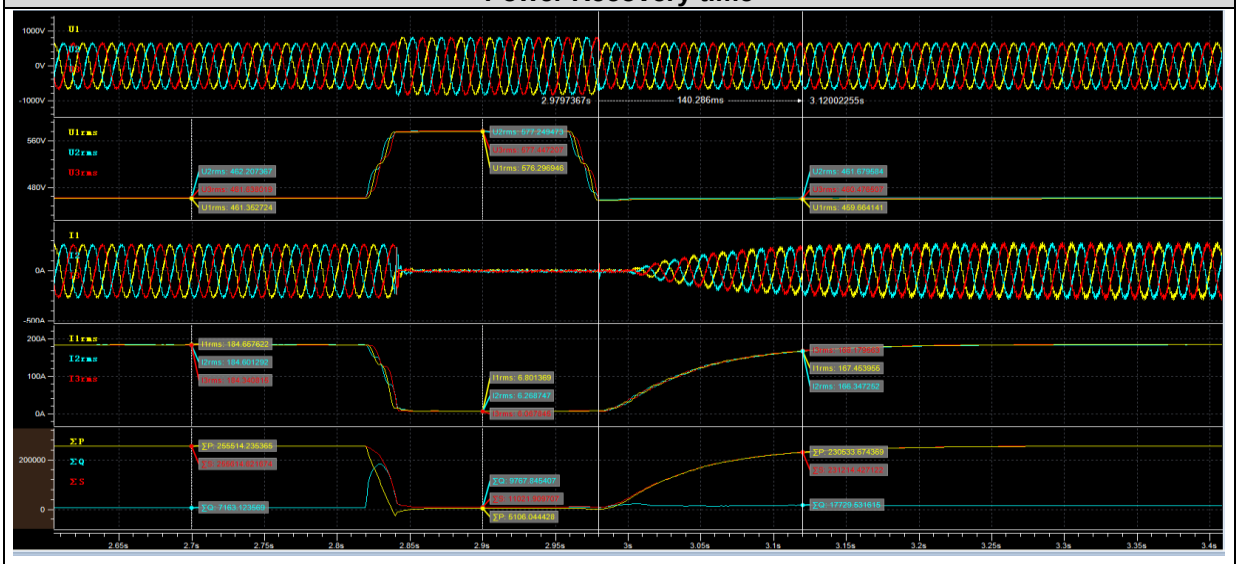
Voltage Rise time



DipTime

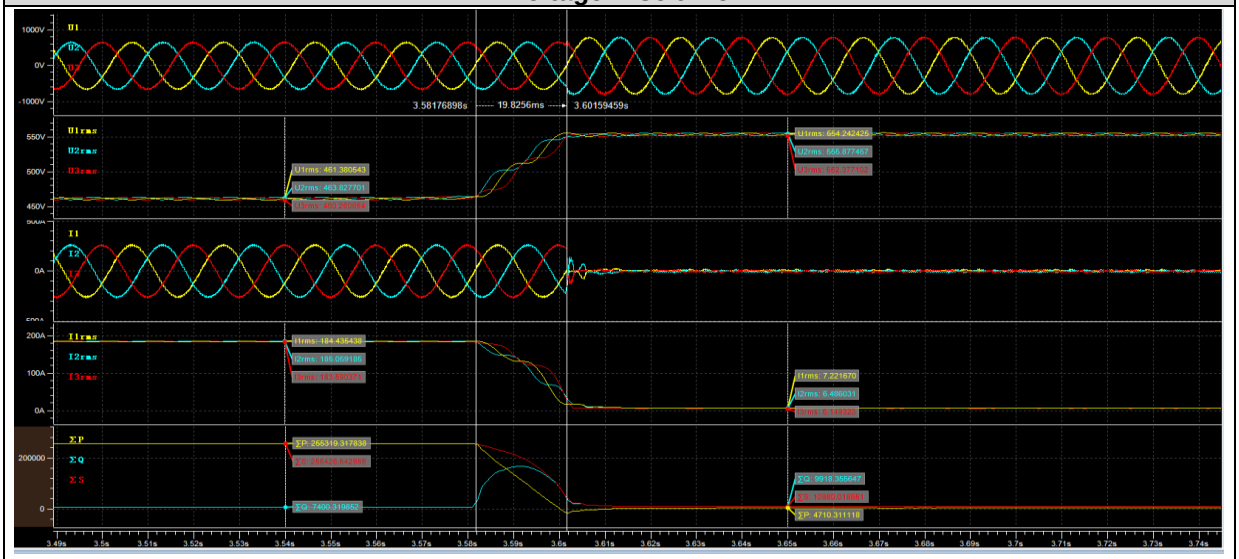


Power Recovery time

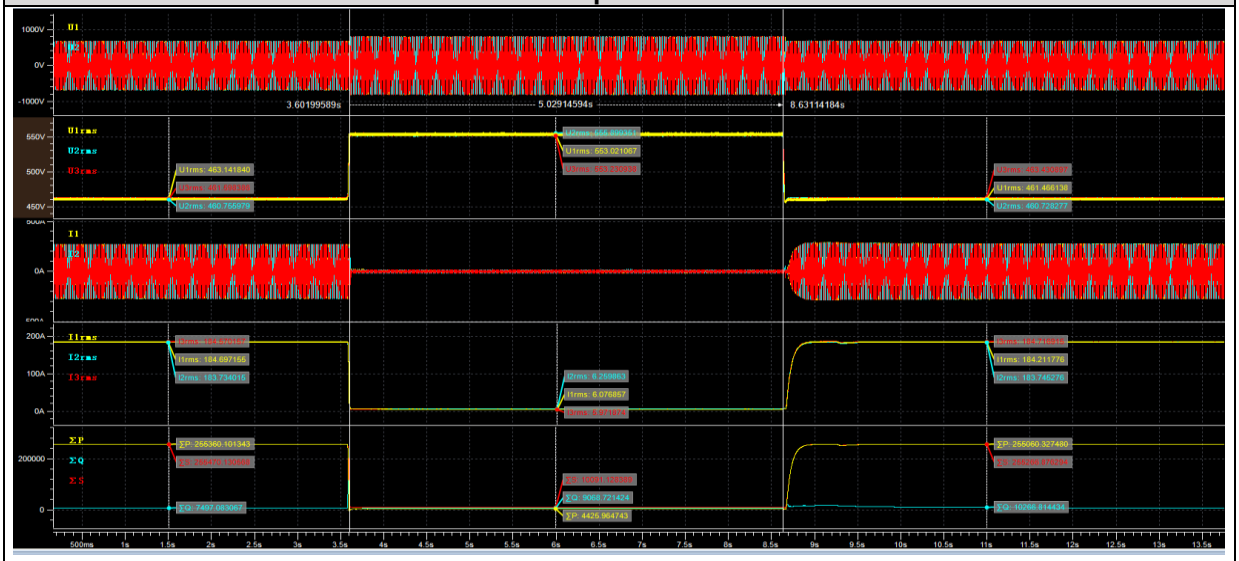


Three-Phase fault	
Partial load (100%Pn)	Residual voltage: 120.0%Un

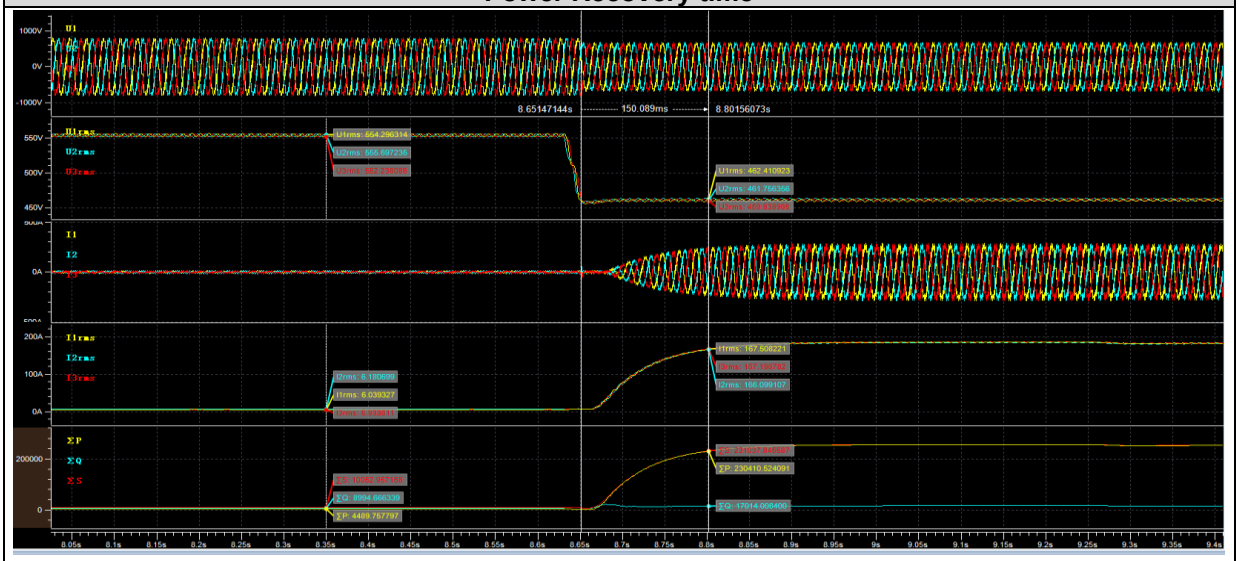
Voltage Rise time



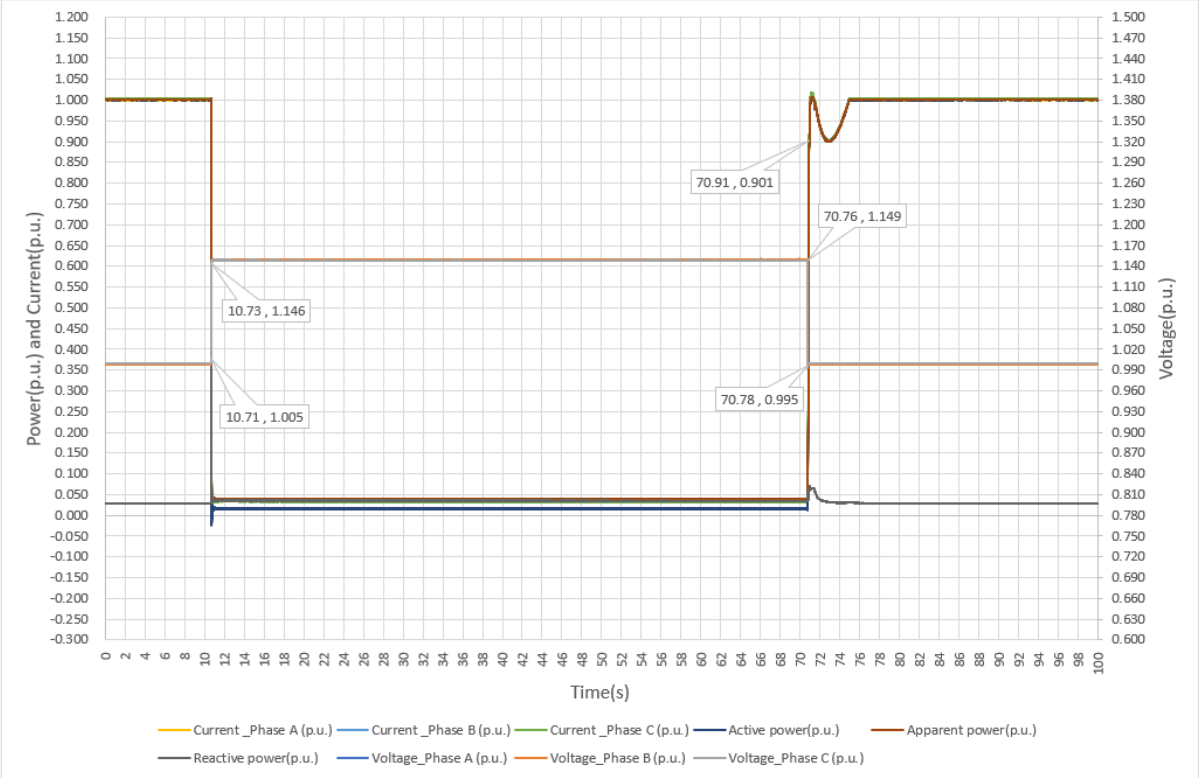
DipTime



Power Recovery time



Three-Phase fault	
Partial load (100%Pn)	Residual voltage: 115.0%Un



4.3. ACTIVE RESPONSE TO FREQUENCY DEVIATION

4.3.1. Power response to overfrequency

The test has been done according to the clause 4.6.1 of the standard. The following definitions apply to the test to verify the clause:

- Test 1: P = 100 %Pn; f1 = 50.2 Hz; droop = 12 %; f-stop deactivated, with delay of 2 s (1)
- Test 2: P = 100 %; f1 = 52.0 Hz; droop = 2 %; function deactivated
- Test 3: P = 50 %; f1 = 51.0 Hz; droop = 5 %; f-stop deactivated, no delay
- Test 4: P = 100 %, f1 = 50.2 Hz; droop = 5 %; f-stop = 50.1 Hz (hysteresis), no delay

(1) The intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.

Note:

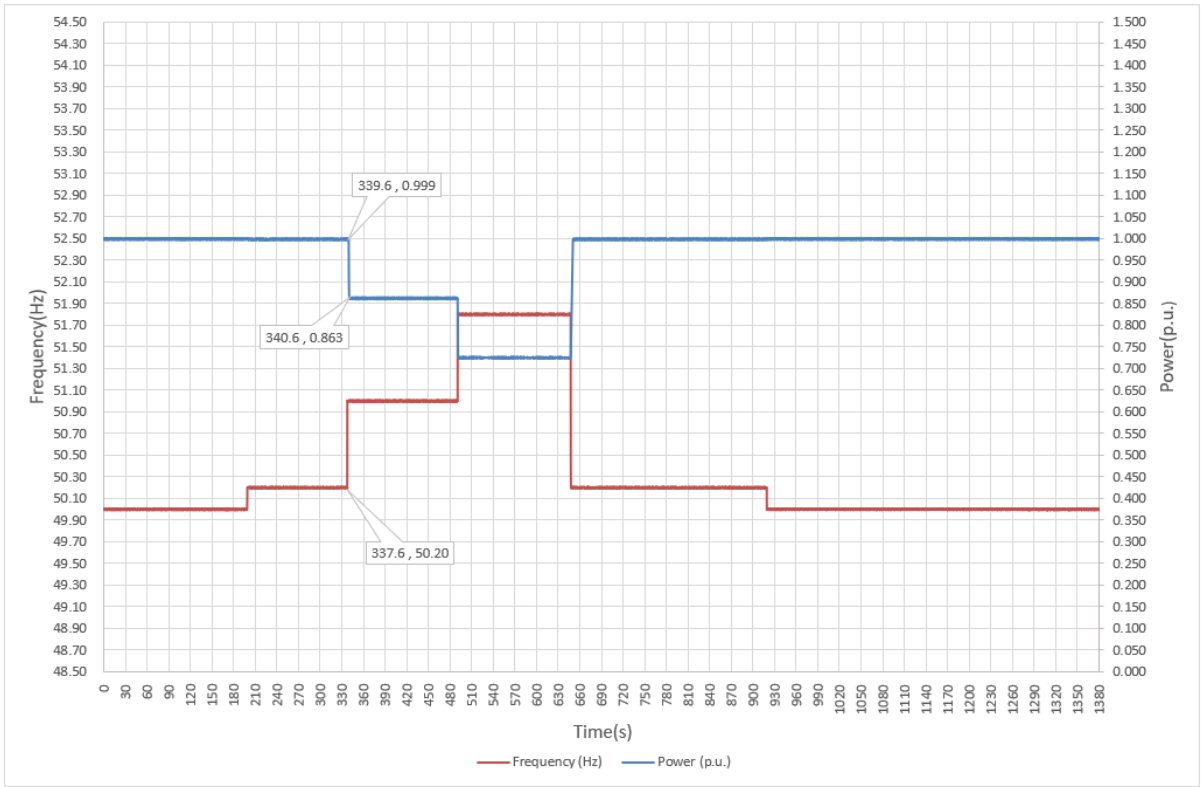
Threshold for discconnection overfrequency protection is set at 52.0 Hz at each test items.

Test results are offered at the table below.

Test 1					
Step	**Frequency (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	100.0	50.00	99.9	-0.1
2	50.20 ± 0.05 Hz	100.0	50.20	99.8	-0.2
3	51.00 ± 0.05 Hz	86.7	51.00	86.2	-0.5
4	51.80 ± 0.05 Hz	73.3	51.80	72.5	-0.8
5	50.20 ± 0.05 Hz	100.0	50.20	99.8	-0.2
6	50.00 ± 0.05 Hz	100.0	50.00	99.9	-0.1
Time delay setting from step 2 to step 3					
Time reference of change (s)			337.6		
End of delay (s)			339.6		
Delay time (s)			2.0		
End of change (s)			340.6		
Change time (s)			1.0		

Test results are represented at diagrams below.

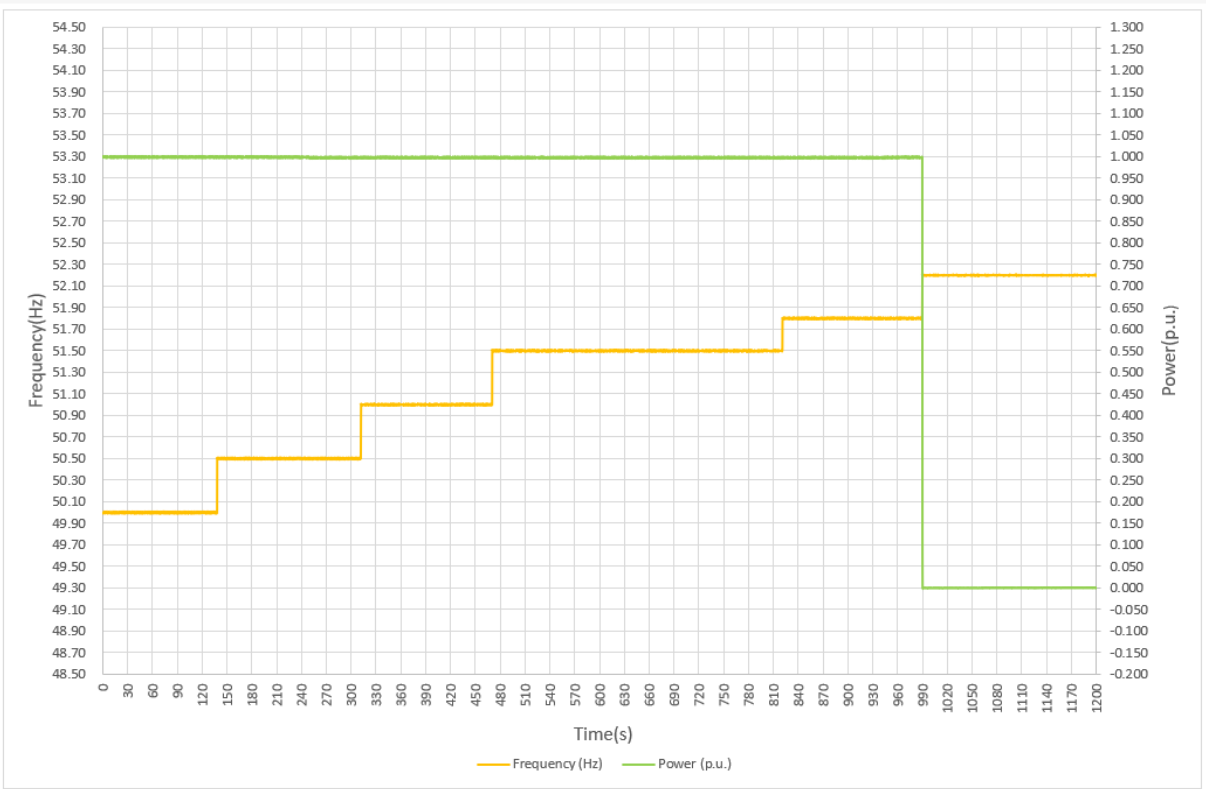
P vs F chart for Test 1



Test 2					
Step	**f (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	100.0	50.00	99.9	-0.1
2	50.50 ± 0.05 Hz	100.0	50.50	99.8	-0.2
3	51.00 ± 0.05 Hz	100.0	51.00	99.8	-0.2
4	51.50 ± 0.05 Hz	100.0	51.50	99.8	-0.2
5	51.80 ± 0.05 Hz	100.0	51.80	99.8	-0.2
6	52.20 ± 0.05 Hz	0.0	52.20	0.0	0.0

Test results are represented at diagrams below.

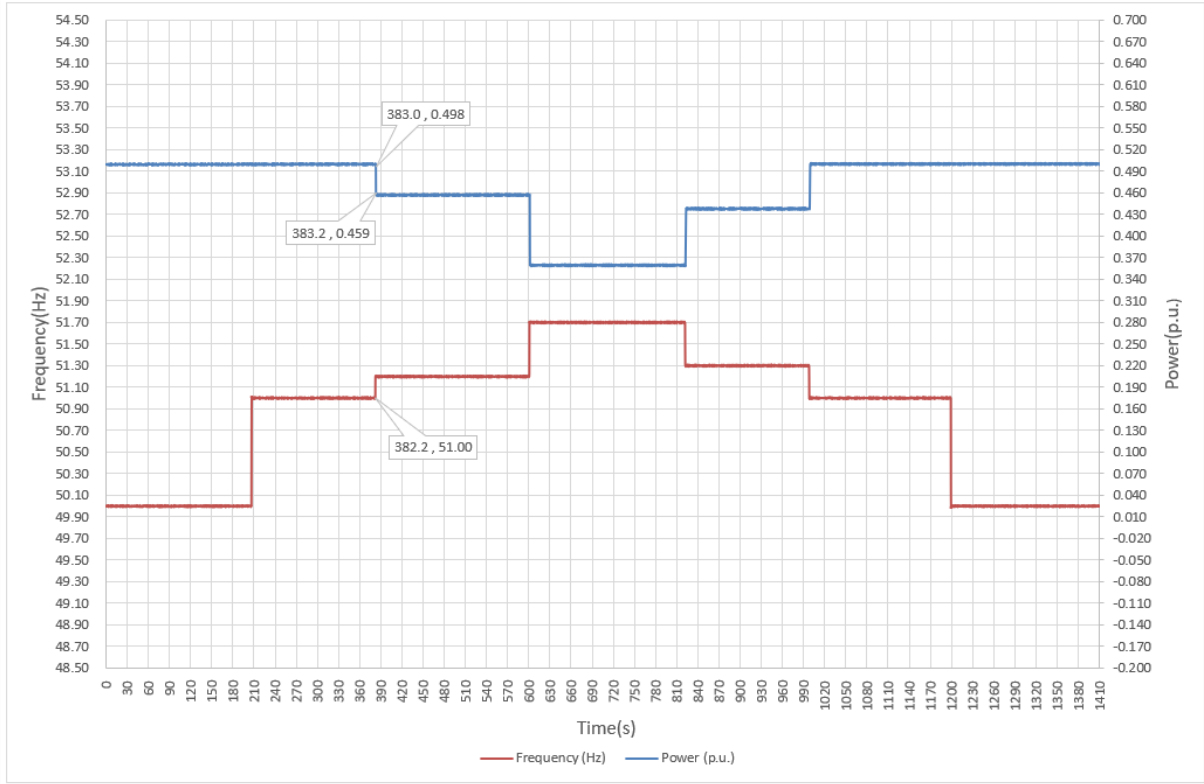
P vs F chart for Test 2



Test 3					
Step	**Frequency (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	50.0	50.00	50.0	-0.0
2	51.00 ± 0.05 Hz	50.0	51.00	50.0	-0.0
3	51.20 ± 0.05 Hz	46.0	51.20	45.7	-0.3
4	51.70 ± 0.05 Hz	36.0	51.70	35.9	-0.1
5	51.30 ± 0.05 Hz	44.0	51.30	43.8	-0.2
6	51.00 ± 0.05 Hz	50.0	51.00	50.0	0.0
7	50.00 ± 0.05 Hz	50.0	50.00	50.0	0.0
Time delay setting from step 2 to step 3					
Time reference of change (s)			382.2		
End of delay (s)			383		
Delay time (s)			0.8		
End of change (s)			383.2		
Change time (s)			0.2		

Test results are represented at diagrams below.

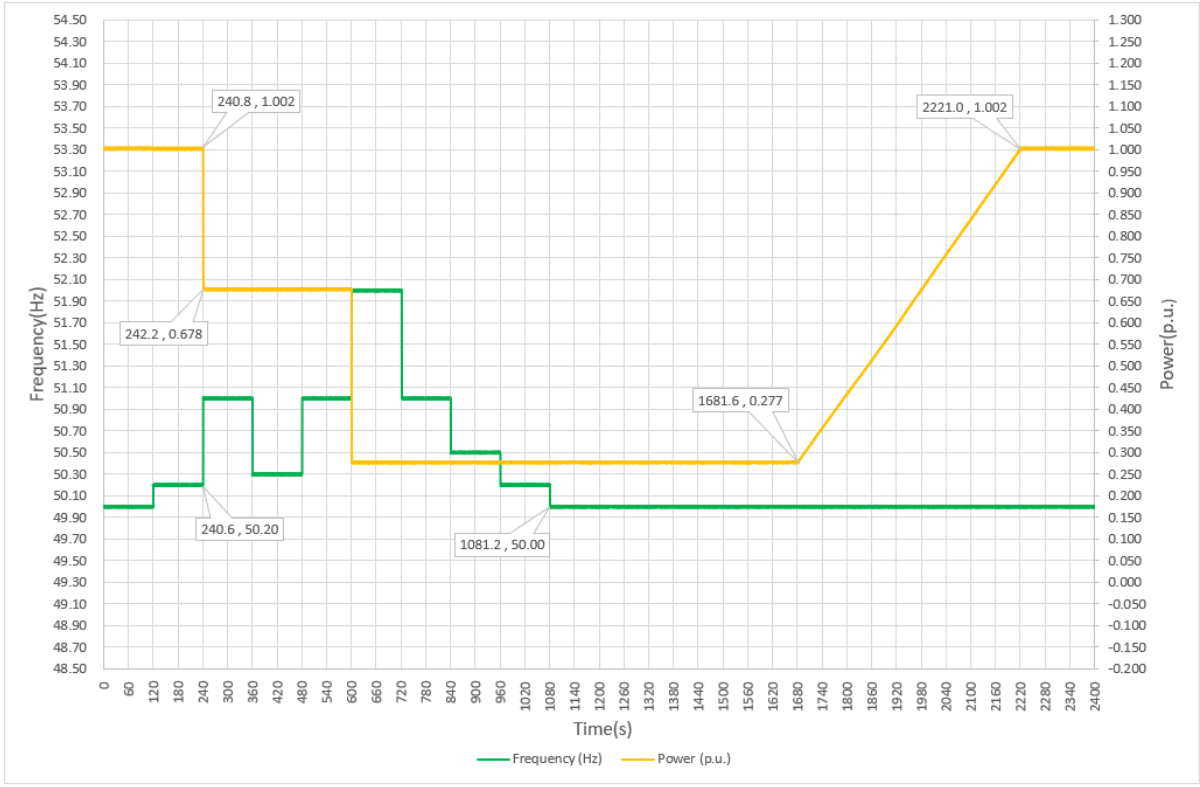
P vs F chart for Test 3



Test 4					
Step	**Frequency (Hz)**	**P desired (%Pn)**	**Frequency meas. (Hz)**	**P meas. (%Pn)**	**P deviation (%Pn) (within ±10 %)**
1	50.00 ± 0.05 Hz	100.0	50.00	100.3	+0.3
2	50.20 ± 0.05 Hz	100.0	50.20	100.2	+0.2
3	51.00 ± 0.05 Hz	68.0	51.00	67.8	-0.2
4	50.30 ± 0.05 Hz	68.0	50.30	67.8	-0.2
5	51.00 ± 0.05 Hz	68.0	51.00	67.8	-0.2
6	52.00 ± 0.05 Hz	28.0	52.00	27.7	-0.3
7	51.00 ± 0.05 Hz	28.0	51.00	27.7	-0.3
8	50.50 ± 0.05 Hz	28.0	50.50	27.7	-0.3
9	50.20 ± 0.05 Hz	28.0	50.20	27.7	-0.3
10	50.00 ± 0.05 Hz	100.0	50.00	100.3	+0.3
Time delay setting from step 2 to step 3					
Time reference of change (s)			240.6		
End of delay (s)			240.8		
Delay time (s)			0.2		
End of change (s)			242.2		
Change time (s)			1.4		
Recovery Time (s)			600.4		
Power ramp gradient (%Pn/min)			+8.1		

Test results are represented at diagrams below.

P vs F chart for Test 4



4.3.2. Power response to underfrequency

This test has not been performed to show the capability of the inverter, because it is only mandatory for Energy Storage Systems according to the clause 4.6.2 of the standard.

4.4. POWER RESPONSE TO VOLTAGE CHANGES

The generating unit shall be capable of operating in the control modes specified below within the limits specified in 4.7.2.2. The control modes are exclusive, only one mode may be active at a time.

- Q setpoint mode
- Q (U)
- Cos φ setpoint mode
- Cos φ (P)

4.4.1. Setpoint control modes

The test has been done according to the clause 4.7.2.3.2 of the standard. The following definitions apply to the test to verify the clause:

- Test 1: Q Zero (Q = 0 % P_D)
- Test 2: Rectangular Curve (Q = ±48.4 %Sn= ±48.4 %P_D)
- Test 3: Triangular Curve (PF = ±0.8)
- Test 4: Reactive power capability at active power P_D in the voltage range (0.85Un ~ 1.1Un)

4.4.1.1. Test 1: Q Zero (Q = 0 % P_D)

This test verifies the capability of the inverter to provide a fixed value of reactive power. In addition, it is verified the Q control mode.

When the measurement is equal to or greater than 10% Sn, the allowable tolerance of reactive power measurement should be within ±2% Smax or ±2.2% P_D.

Test results are offered at tables below.

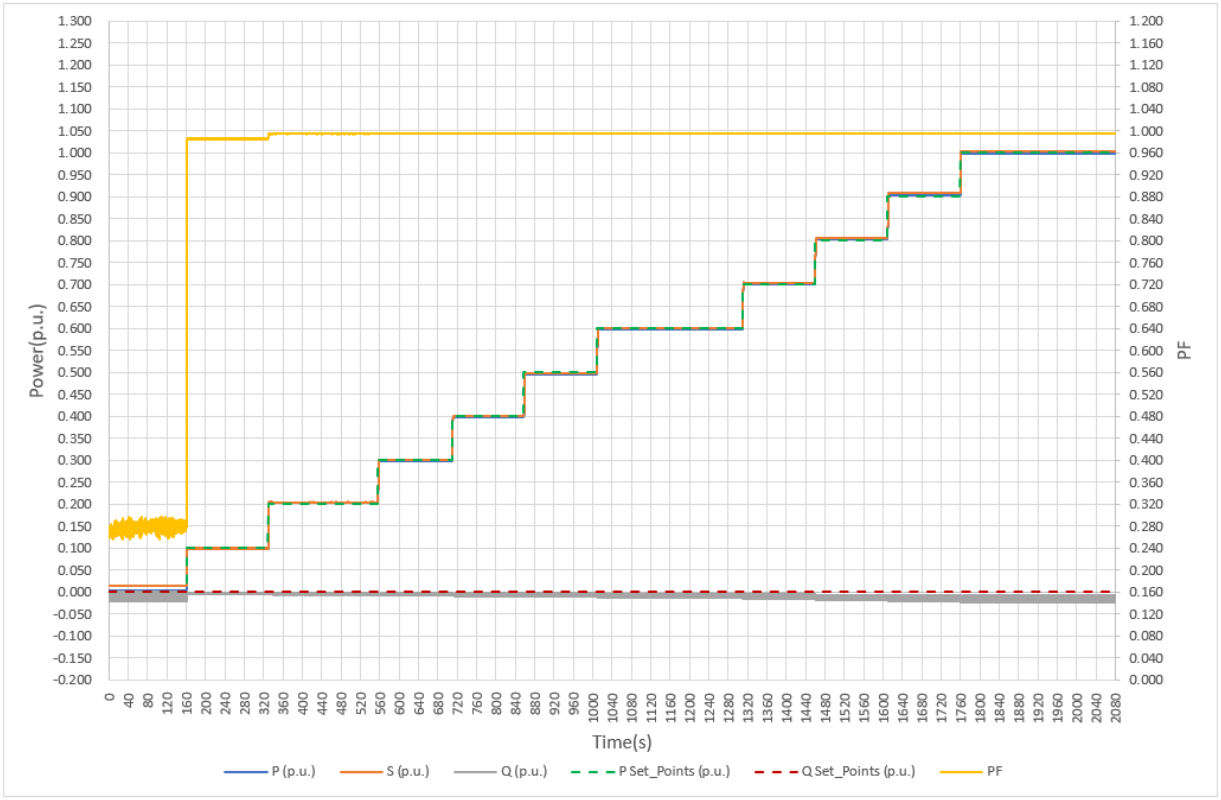
Rectangular Curve (Q=0% P_D)					
P Desired (%Sn)	**P measured (%Sn)**	**Q desired (%P_D)**	**Q measured (%P_D)**	**Q deviation (±2.2% P_D)**	**Power Factor (cos φ)**
0.0	1.5	--	-1.1	-- (1)	0.279
10.0	10.0	0.0	-0.3	-0.3	0.986
20.0	20.5	0.0	-0.4	-0.4	0.995
30.0	30.1	0.0	-0.5	-0.5	0.996
40.0	40.1	0.0	-0.6	-0.6	0.996
50.0	49.8	0.0	-0.6	-0.6	0.996
60.0	60.1	0.0	-0.8	-0.8	0.996
70.0	70.5	0.0	-1.0	-1.0	0.996
80.0	80.7	0.0	-1.2	-1.2	0.996
90.0	90.9	0.0	-1.4	-1.4	0.995
100.0	100.3	0.0	-1.6	-1.6	0.995

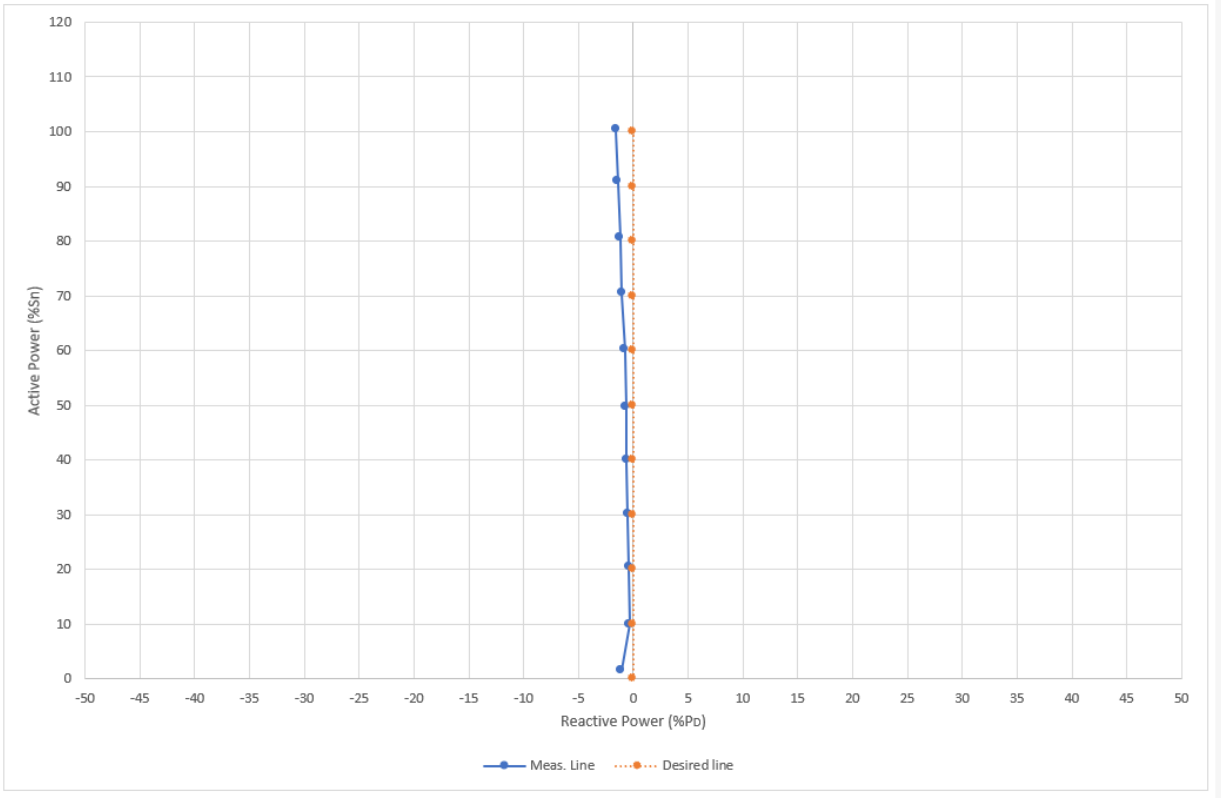
(1) The reactive power accuracy is ±2%Smax, which is not suitable for power below 10%Pn.

Note: P is with respect to Sn , Q is according to measured PD ≈ 0.9 Pn (231.427 kW)

Test results are represented at diagrams below.

Q = 0 %P_D





4.4.1.2. Test 2: Rectangular Curve (Q = ±43.6%Sn =±48.4%P_D)

This test verifies the capability of the inverter to provide a fixed value of reactive power. In addition, it is verified the Q control mode.

When the measurement is equal to or greater than 10% Sn, the allowable tolerance of reactive power measurement should be within ±2% Smax or ±2.2% P_D.

Test results are offered at tables below.

Rectangular Curve (Q=48.4 %P_D / Capacitive)					
P Desired (%Sn)	**P measured (%Sn)**	**Q desired (%P_D)**	**Q measured (%P_D)**	**Q Deviation (±2.2%P_D)**	**Power Factor (cos φ)**
0	0.4	--	-48.1	-- (1)	0.009
5	5.0	--	-48.2	-- (1)	0.114
10	10.1	-48.4	-48.2	+0.2	0.224
15	15.0	-48.4	-48.2	+0.2	0.325
20	19.9	-48.4	-48.2	+0.2	0.413
25	25.0	-48.4	-48.3	+0.1	0.494
30	30.1	-48.4	-48.3	+0.1	0.564
35	35.1	-48.4	-48.3	+0.1	0.623
40	40.1	-48.4	-48.3	+0.1	0.673
45	45.3	-48.4	-48.3	+0.1	0.716
50	50.4	-48.4	-48.3	+0.1	0.753
55	55.4	-48.4	-48.3	+0.1	0.782
60	60.3	-48.4	-48.3	+0.1	0.807
65	65.0	-48.4	-48.3	+0.1	0.828
70	70.2	-48.4	-48.3	+0.1	0.848
75	75.1	-48.4	-47.1	+1.3	0.860
80	80.2	-48.4	-48.3	+0.1	0.872
85	85.1	-48.4	-48.4	0.0	0.884
90	90.1	-48.4	-48.4	0.0	0.895
95	90.4 (2)	-48.4	-48.3	+0.1	0.896
100	90.4 (2)	-48.4	-48.2	+0.2	0.896

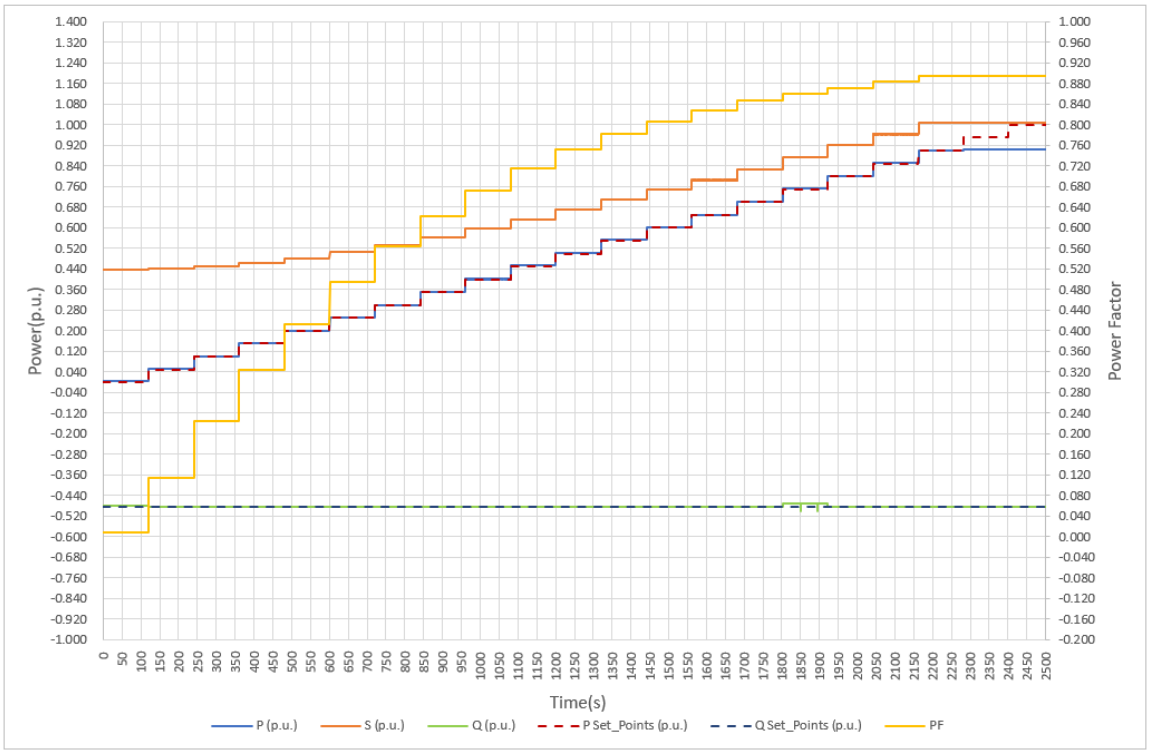
(1) The reactive power accuracy is ±2%Smax, which is not suitable for power below 10%Pn.
(2) Test performed in reactive power priority mode. Working in this mode, the inverter can't output the desired active power due to current limitation, so don't consider the deviation value.
Note: P is with respect to Sn , Q is according to measured PD ≈ 0.9 Pn (231.427 kW)

Rectangular Curve (Q=48.4 %P_D / Inductive)					
P Desired (%Sn)	**P measured (%P_D)**	**Q desired (%P_D)**	**Q measured (%P_D)**	**Q Deviation (±2.2%P_D)**	**Power Factor (cos φ)**
0	0.8	--	+32.1	-- (1)	0.028
5	5.0	--	+48.4	-- (1)	0.112
10	10.1	+48.4	+48.3	-0.1	0.225
15	15.1	+48.4	+48.2	-0.2	0.326
20	20.1	+48.4	+48.2	-0.2	0.417
25	25.1	+48.4	+48.1	-0.3	0.497
30	30.1	+48.4	+48.1	-0.3	0.566
35	35.1	+48.4	+48.1	-0.3	0.624
40	40.1	+48.4	+48.2	-0.2	0.674
45	45.3	+48.4	+48.2	-0.2	0.717
50	50.3	+48.4	+48.3	-0.1	0.752
55	55.4	+48.4	+48.3	-0.1	0.782
60	60.5	+48.4	+48.3	-0.1	0.808
65	65.5	+48.4	+48.4	0.0	0.829
70	70.6	+48.4	+48.7	+0.3	0.847
75	75.6	+48.4	+46.9	-1.5	0.863
80	80.6	+48.4	+47.4	-1.0	0.877
85	85.7	+48.4	+47.5	-0.9	0.889
90	90.4	+48.4	+47.5	-0.9	0.898
95	90.4 (2)	+48.4	+47.5	-0.9	0.898
100	90.4 (2)	+48.4	+47.5	-0.9	0.898

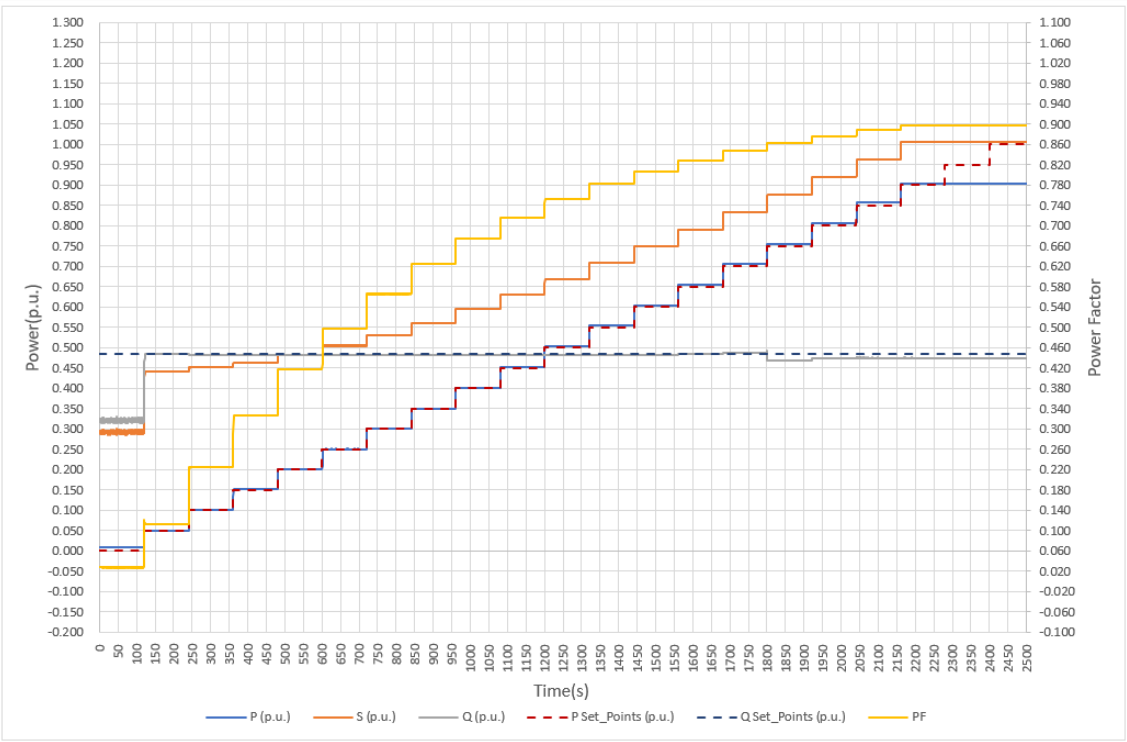
(1) The reactive power accuracy is ±2%Smax, which is not suitable for power below 10%Pn.
(2) Test performed in reactive power priority mode. Working in this mode, the inverter can't output the desired active power due to current limitation, so don't consider the deviation value.
Note: P is with respect to Sn , Q is according to measured PD ≈ 0.9 Pn (231.427 kW)

Test results are represented at diagrams below.
Supplementary information: p.u. values for P and S are given in reference to Sn, p.u. values for Q are given in reference to P_D.

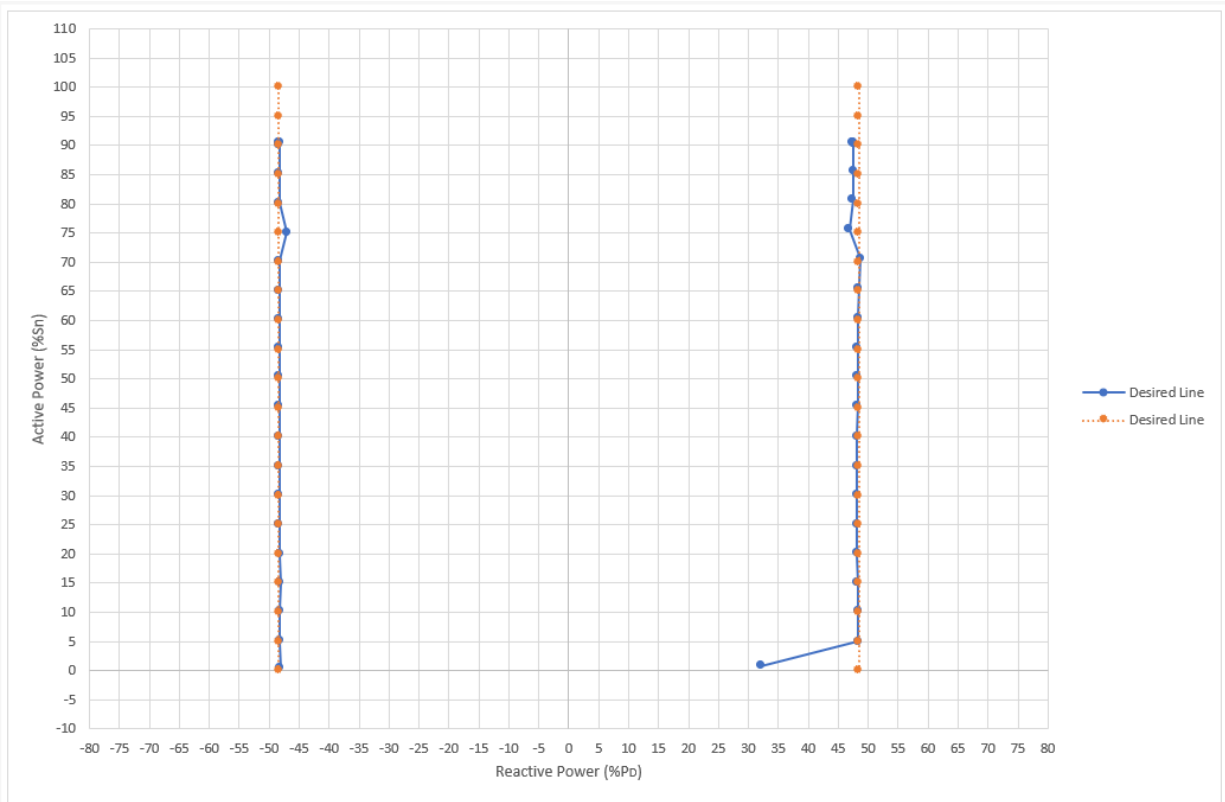
Rectangular Curve (Q = 48.4 %P_D / Capacitive)



Rectangular Curve (Q = 48.4 %P_D / Inductive)



Rectangular Curve (Capacitive vs Inductive)



4.4.1.3. Test 3: Triangular Curve (PF = ±0.8)

This test verifies the capability of the inverter to provide a fixed value of power factor. In addition, it is verified the PF control mode.

When the measurement is equal to or greater than 10% Sn, the allowable tolerance of reactive power measurement should be within ±2% Smax.

Test results are offered at the tables below.

Triangular Curve (PF = 0.8 / Capacitive)						
P desired (%Sn)	**P measured (%Sn)**	**Q measured (%Sn)**	**Q desired (%Sn) (3)**	**Q deviation (±2%Smax)**	**Power factor measured (cos φ)**	**Power factor deviation (cos φ)**
0	0.7	-2.1	0.0	-- (1)	0.350	-- (1)
5	5.1	-4.3	-3.8	-- (1)	0.799	-- (1)
10	10.0	-7.8	-7.5	-0.3	0.800	0.000
15	15.0	-11.4	-11.3	-0.1	0.800	0.000
20	20.1	-15.1	-15.0	-0.1	0.800	0.000
25	25.2	-18.8	-18.8	0.0	0.800	0.000
30	30.2	-22.5	-22.5	0.0	0.801	+0.001
35	35.0	-26.1	-26.3	+0.2	0.801	+0.001
40	40.1	-29.8	-30.0	+0.2	0.801	+0.001
45	45.2	-33.6	-33.8	+0.2	0.800	0.000
50	50.5	-37.5	-37.5	0.0	0.800	0.000
55	55.2	-40.9	-41.3	+0.4	0.801	+0.001
60	60.2	-44.6	-45.0	+0.4	0.801	+0.001
65	65.2	-48.2	-48.8	+0.6	0.801	+0.001
70	70.2	-52.0	-52.5	+0.5	0.800	0.000
75	75.1	-55.6	-56.3	+0.7	0.801	+0.001
80	80.2	-59.4	-60.0	+0.6	0.800	0.000
85	80.7 (2)	-59.6	-63.8	--	0.801	+0.001
90	80.7 (2)	-59.6	-67.5	--	0.801	+0.001
95	80.7 (2)	-59.6	-71.3	--	0.801	+0.001
100	80.7 (2)	-59.6	-75.0	--	0.801	+0.001

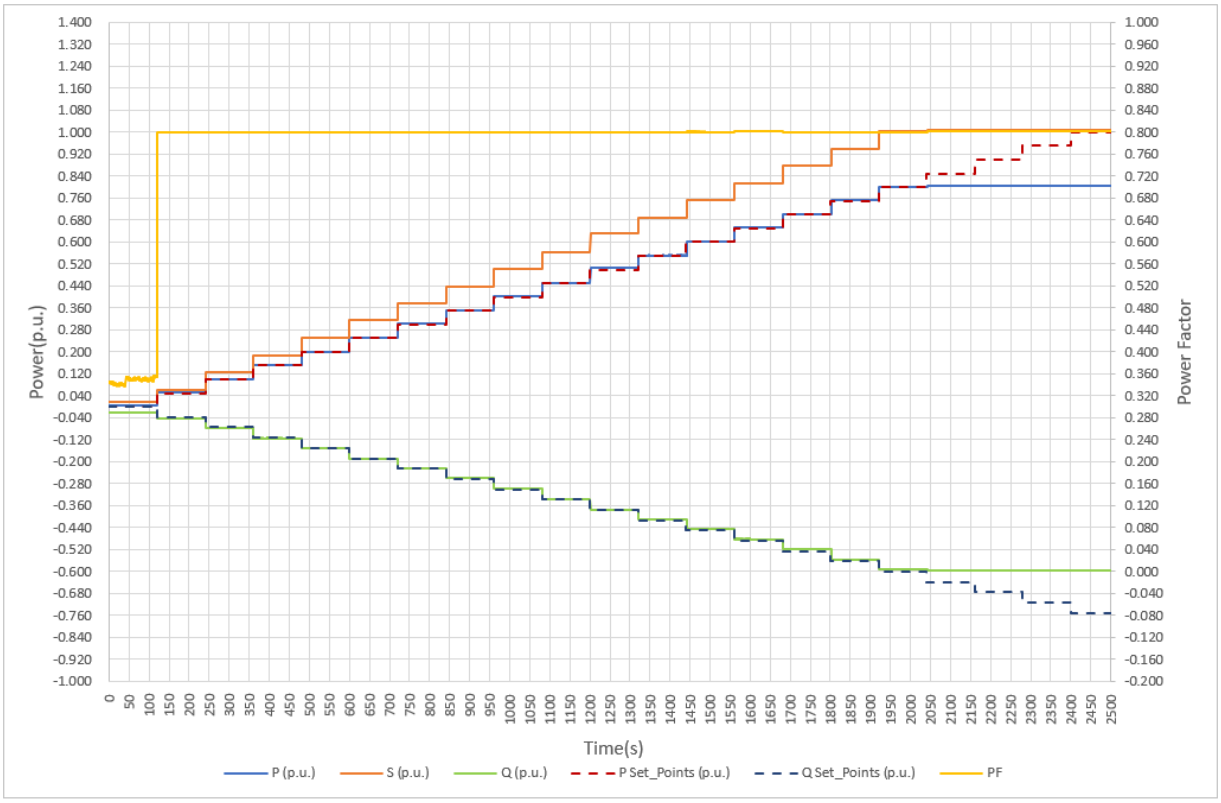
(1) The reactive power accuracy is ±2%Sn, which is not suitable for power below 10%Pn.
(2) Test performed in reactive power priority mode. Working in this mode, the inverter can't output the desired active power due to current limitation, so don't consider the deviation value.
(3) Q desired value is calculated from the desired power and fixed power factor (PF = 0.8).

Triangular Curve (PF = 0.8 / Inductive)						
P desired (%Sn)	**P measured (%Sn)**	**Q measured (%Sn)**	**Q desired (%Sn) (3)**	**Q deviation (±2%Sn)**	**Power factor measured (cos φ)**	**Power factor deviation (cos φ)**
0	0.7	1.9	0.0	--(1)	0.377	0.423
5	4.8	4.3	3.8	--(1)	0.774	0.026
10	9.9	7.8	7.5	+0.3	0.794	0.006
15	15.0	11.4	11.3	+0.1	0.799	0.001
20	20.0	15.1	15.0	+0.1	0.801	+0.001
25	25.1	18.7	18.8	-0.1	0.802	+0.002
30	30.1	22.4	22.5	-0.1	0.802	+0.002
35	35.1	26.0	26.3	-0.3	0.803	+0.003
40	40.0	29.6	30.0	-0.4	0.802	+0.002
45	45.0	33.3	33.8	-0.5	0.802	+0.002
50	50.3	37.2	37.5	-0.3	0.802	+0.002
55	55.4	41.0	41.3	-0.3	0.802	+0.002
60	60.6	44.9	45.0	-0.1	0.802	+0.002
65	65.7	48.7	48.8	-0.1	0.802	+0.002
70	70.4	52.1	52.5	-0.4	0.802	+0.002
75	75.4	55.7	56.3	-0.6	0.802	+0.002
80	80.5	59.4	60.0	-0.6	0.803	+0.003
85	80.8 (2)	59.7	63.8	--	0.803	+0.003
90	80.8 (2)	59.7	67.5	--	0.803	+0.003
95	80.8 (2)	59.6	71.3	--	0.803	+0.003
100	80.9 (2)	59.6	75.0	--	0.803	+0.003

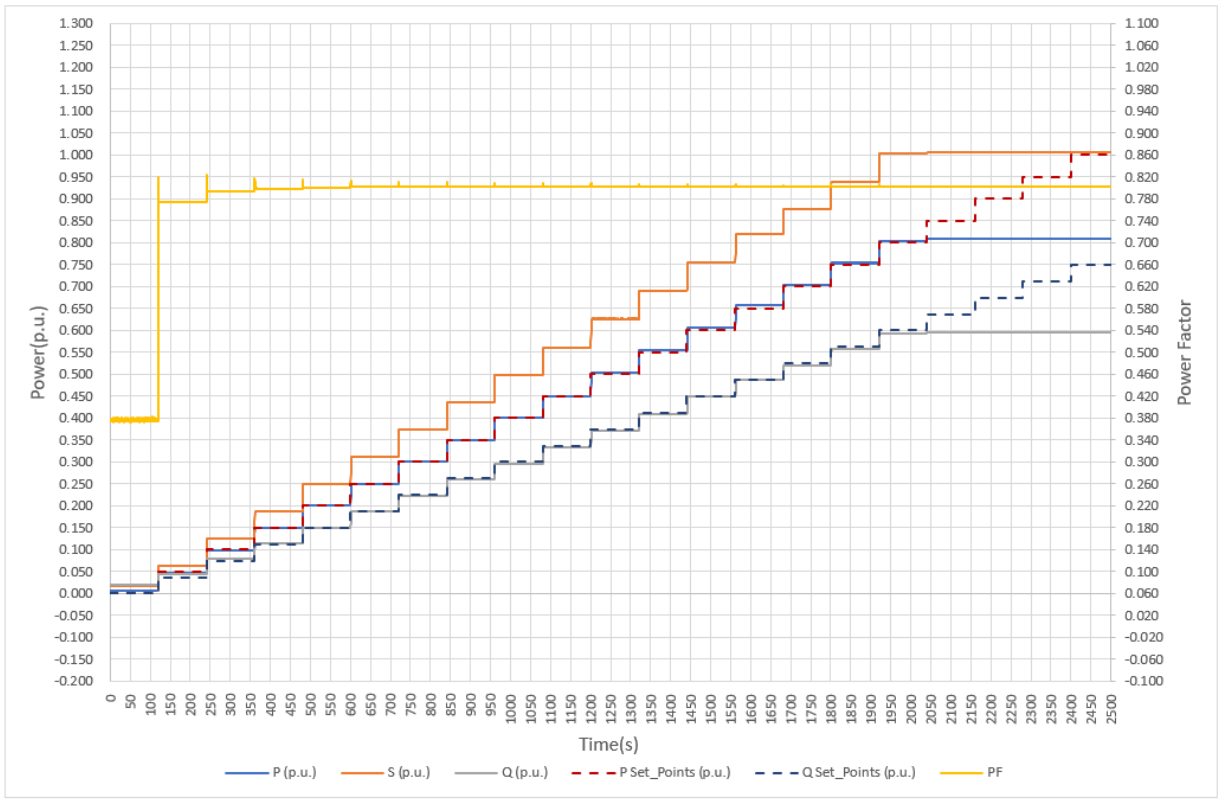
(1) The reactive power accuracy is ±2%Sn, which is not suitable for power below 10%Pn.
(2) Test performed in reactive power priority mode. Working in this mode, the inverter can't output the desired active power due to current limitation.
(3) Q desired value is calculated from the desired power and fixed power factor (PF = 0.8).

Test results are represented at the diagrams below.

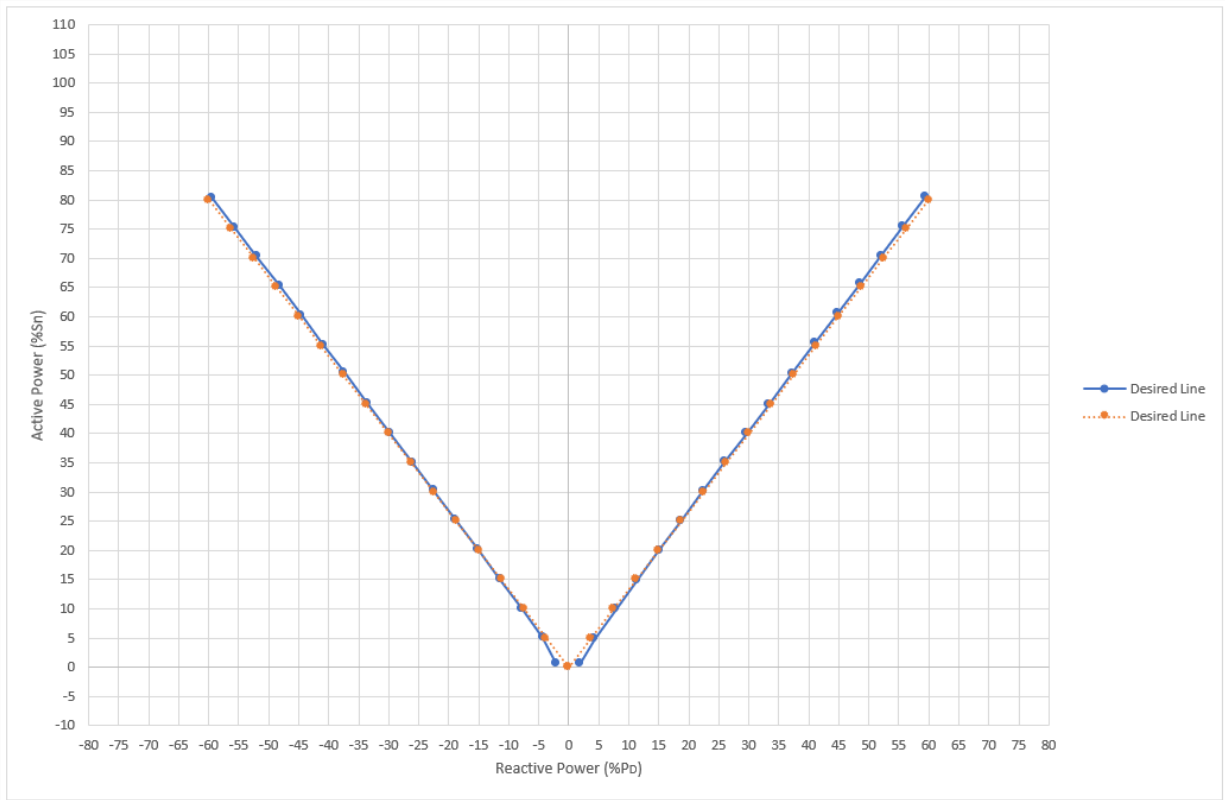
Triangular Curve (PF = 0.8 / Capacitive)



Triangular Curve (PF = 0.8 / inductive)



Triangular Curve (Inductive vs Capacitive)



4.4.1.4. Test 4: Reactive power capability at active power P_D in the voltage range (0.85Un~1.1Un)

This test verifies the capability of the inverter to provide reactive power capability at active power P_D in the voltage range, as the Figure 13 of standard:

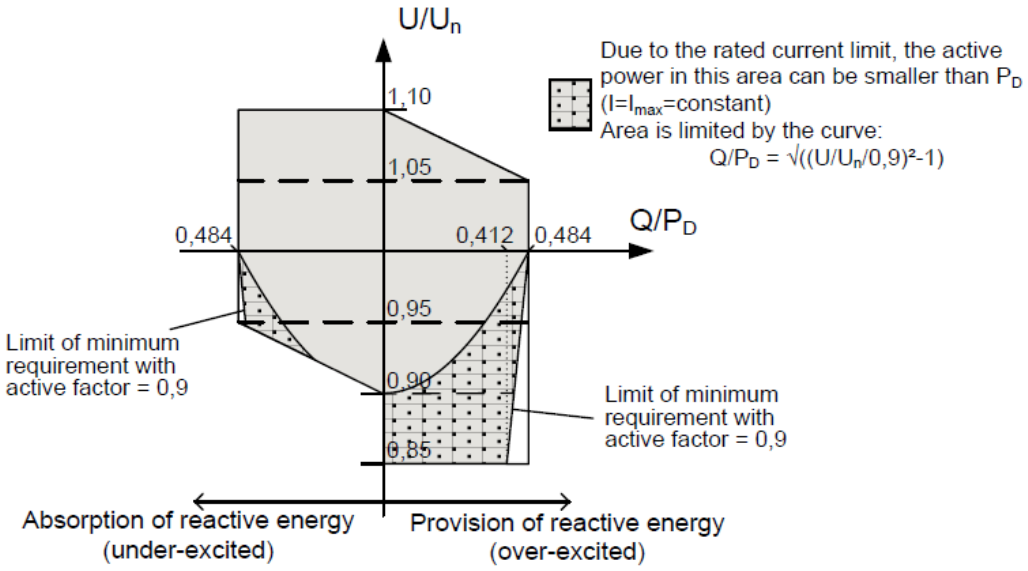


Figure 13 — Reactive power capability at active power P_D in the voltage range (positive sequence component of the fundamental)

Allowed tolerance for reactive power measurements is to be considered inside ±2% Sn or ±2.2 % P_D

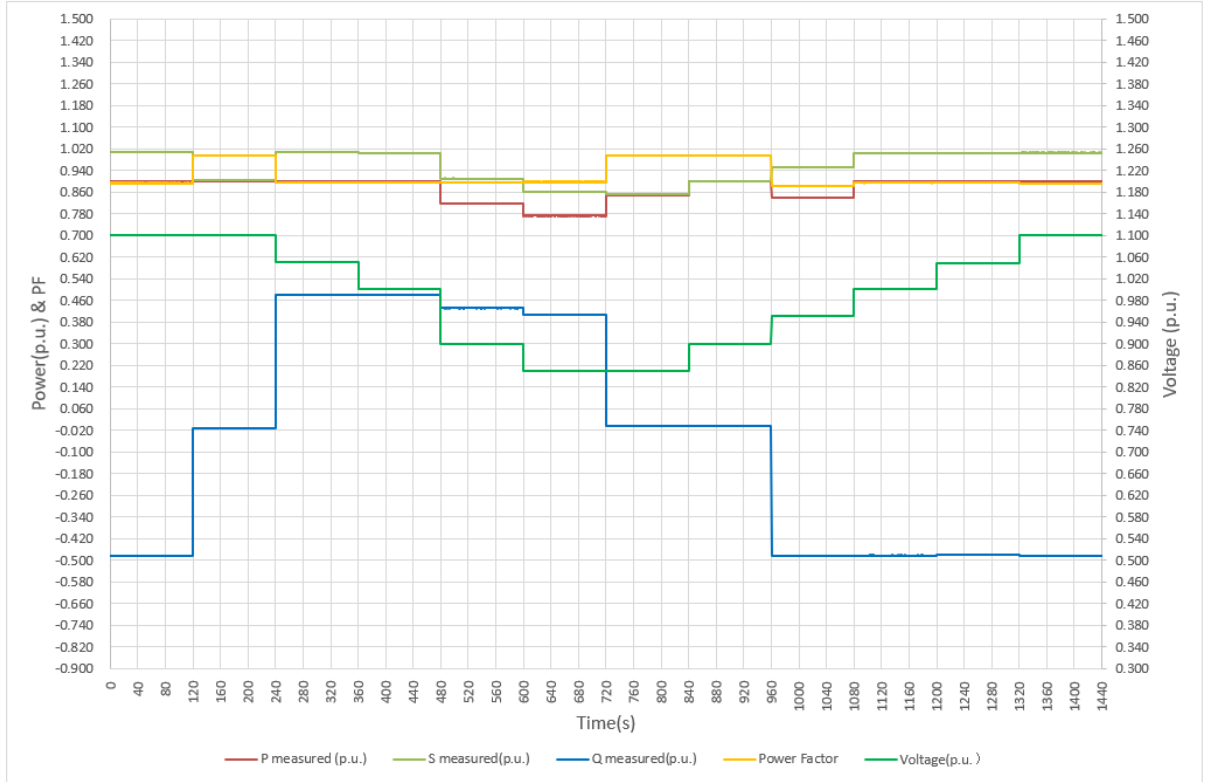
Test results are offered at the tables below.

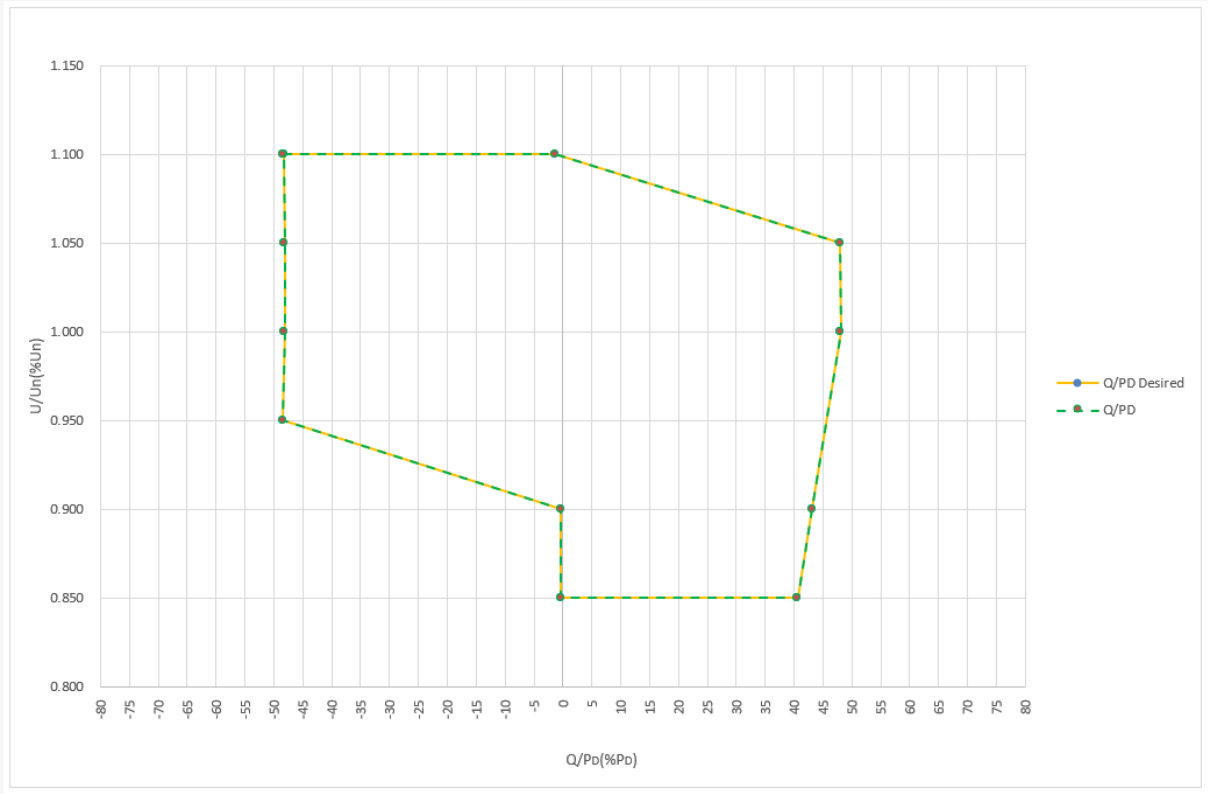
Reactive power capability at active power P_D in the voltage range								
Step	**Voltage desired (p.u.)**	**Voltage meas. (p.u.)**	**P desired (%Sn)**	**P meas. (%Sn)**	**Q meas. (%P_D)**	**Q desired (%P_D)**	**Q devation (±2.2%P_D)**	**Power Factor measured (cos φ)**
1	1.100	1.100	90.0	90.0	-48.2	-48.4	+0.2	0.894
2	1.100	1.101	90.0	90.1	-1.3	0.0	-1.3	0.995
3	1.050	1.051	90.0	90.1	48.0	+48.4	-0.4	0.895
4	1.000	1.001	90.0	90.0	48.1	+48.4	-0.3	0.894
5	0.900	0.901	90.0	81.8(1)	43.2	+43.6	-0.4	0.898
6	0.850	0.851	90.0	77.3(1)	40.7	+41.2	-0.5	0.898
7	0.850	0.850	90.0	84.9(1)	-0.3	0.0	-0.3	0.996
8	0.900	0.901	90.0	89.9	-0.3	0.0	-0.3	0.996
9	0.950	0.951	90.0	84.1(1)	-48.4	-48.4	0.0	0.883
10	1.000	1.000	90.0	90.0	-48.1	-48.4	+0.3	0.894
11	1.050	1.050	90.0	90.0	-48.1	-48.4	+0.3	0.895
12	1.100	1.100	90.0	90.0	-48.3	-48.4	+0.1	0.894

(1) Since the working mode is reactive power priority, the active power cannot reach the expected value due to current limitation.
Note: P is with respect to Sn , Q is according to measured $P_D \approx 0.9$ Pn (231.427 kW), while voltage operating range is at 0.85Un ~ 1.1Un.

Test results are represented at diagrams below.

Reactive power capability at active power P_D in the voltage range (0.85Un~1.00Un)





4.4.2. Voltage related control mode

4.4.2.1. Voltage related control mode Q(U)

The test has been done according to the clause 4.7.2.3.3 of the standard.

Note: This feature is optional, enabling and disabling the feature and its settings can be modified or adjusted through the manufacturer's guidelines.

Setting the characteristic as following to prove configurability of the inverter:

- U1 = 0.93, Qmax=43.6%Pn=48.4%P_D
- U2 = 0.96, Q= 9%Pn=10% P_D
- U3 = 1.04, Q= - 9%Pn=-10% P_D
- U4 = 1.07, -Qmax= - 43.6%Pn= - 48.4%P_D

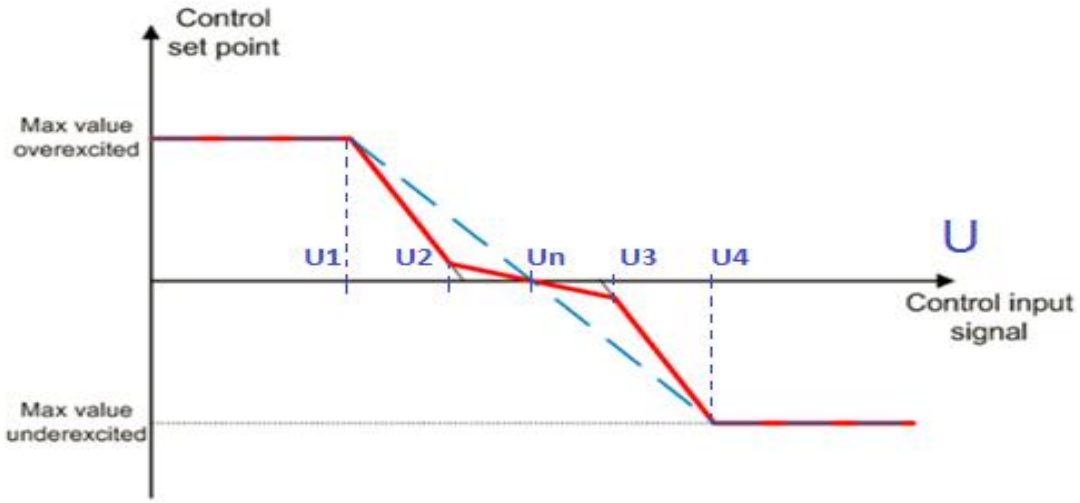


Figure 16 — Example characteristics for Q respectively cos φ control mode

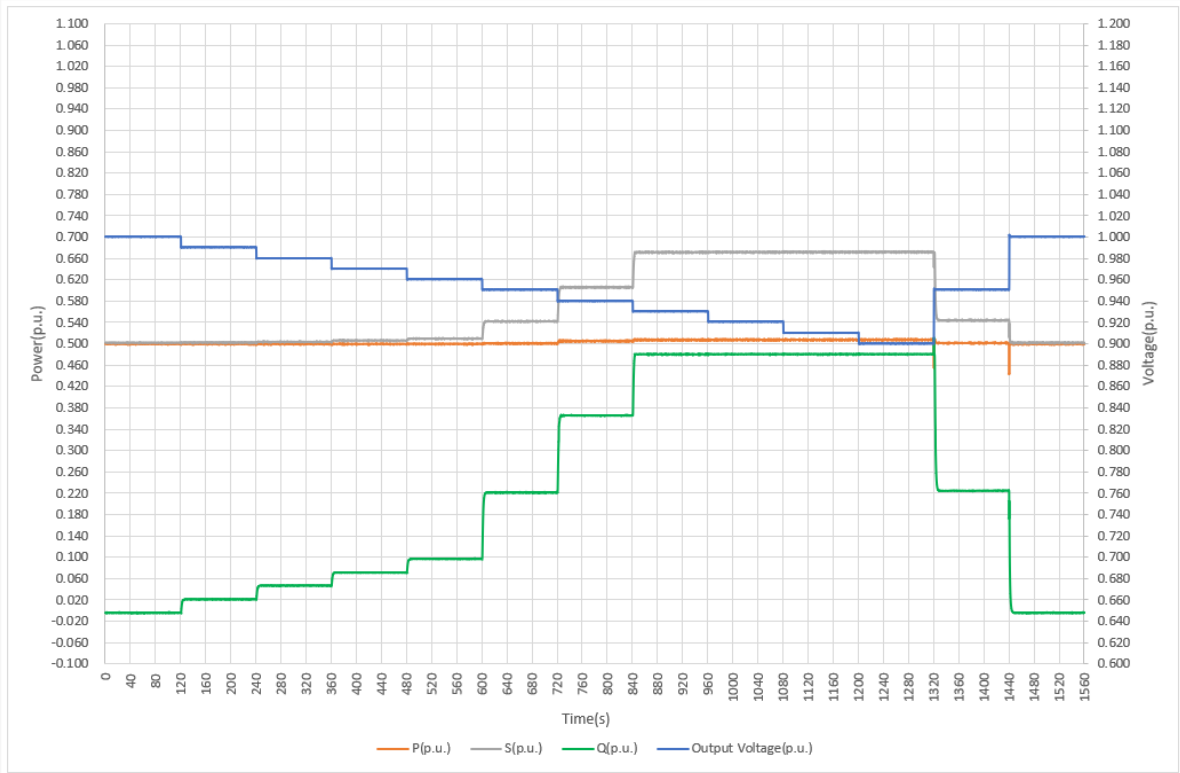
Test results are offered at the tables below.

Undervoltage Test						
P/Pn setpoint (%)	**U setpoint**	**P measured (%Sn)**	**V measured (p.u.)**	**Q measured (%P_D)**	**Q desired (%P_D)**	**ΔQ (p.u.) (±2.2%P_D)**
50	1.000 Un	50.0	1.000	+0.4	0.0	+0.4
50	0.990 Un	49.9	0.990	+2.1	+2.5	-0.4
50	0.980 Un	49.9	0.980	+4.7	+5.0	-0.3
50	0.970 Un	50.0	0.970	+7.1	+7.5	-0.4
50	0.960 Un	50.0	0.961	+9.7	+10.0	-0.3
50	0.950 Un	50.1	0.951	+22.1	+22.8	-0.7
50	0.940 Un	50.5	0.940	+36.6	+35.6	+1.0
50	0.930 Un	50.7	0.930	+48.0	+48.4	-0.4
50	0.920 Un	50.7	0.921	+48.0	+48.4	-0.4
50	0.910 Un	50.7	0.910	+48.0	+48.4	-0.4
50	0.900 Un	50.8	0.900	+48.0	+48.4	-0.4
50	0.950 Un	50.1	0.951	+22.4	+22.8	-0.4
50	1.000 Un	50.0	1.000	+0.4	0.0	+0.4

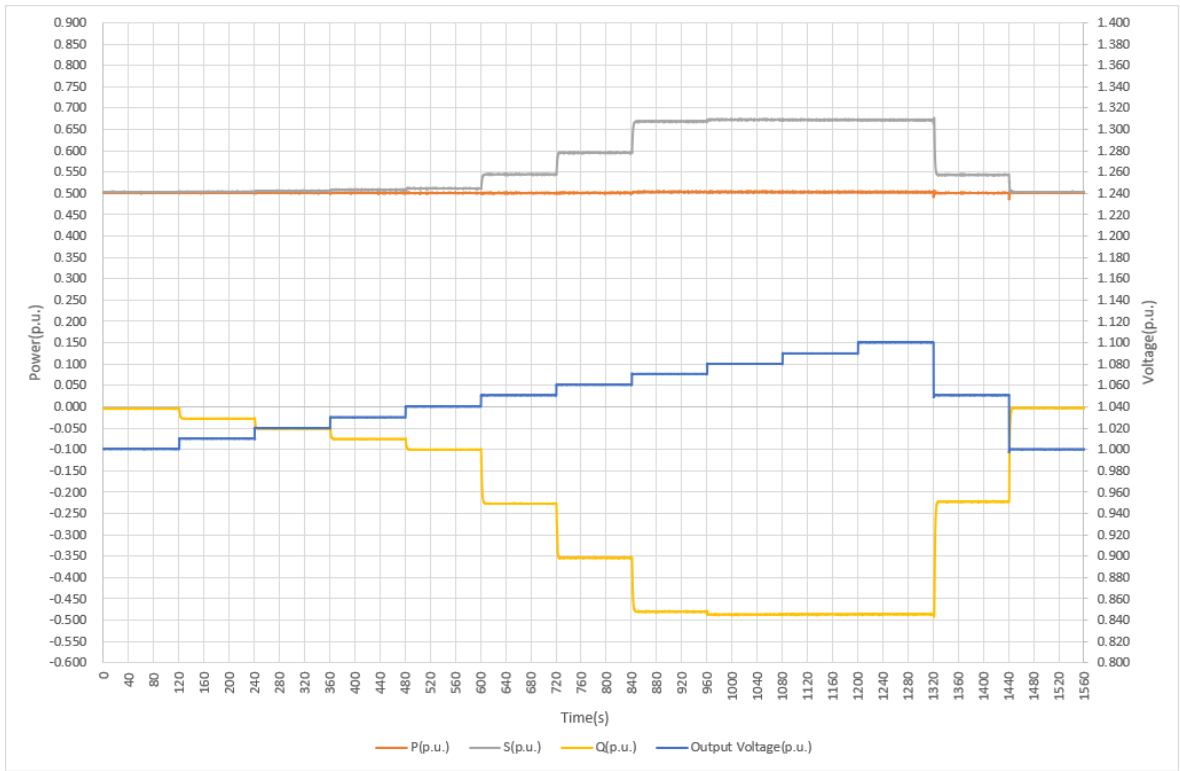
Overvoltage Test						
P/Pn setpoint (%)	**U setpoint**	**P measured (%Sn)**	**V measured (p.u.)**	**Q measured (%P_D)**	**Q desired (%P_D)**	**ΔQ (p.u.) (±2.2%P_D)**
50	1.000 Un	50.1	1.000	-0.4	0.0	-0.4
50	1.010 Un	50.1	1.010	-2.8	-2.5	-0.3
50	1.020 Un	50.1	1.020	-5.2	-5.0	-0.2
50	1.030 Un	50.1	1.030	-7.6	-7.5	-0.1
50	1.040 Un	50.1	1.040	-10.1	-10.0	-0.1
50	1.050 Un	50.1	1.051	-22.7	-22.8	+0.1
50	1.060 Un	50.1	1.061	-35.4	-35.6	+0.2
50	1.070 Un	50.3	1.071	-48.0	-48.4	+0.4
50	1.080 Un	50.3	1.080	-48.7	-48.4	-0.3
50	1.090 Un	50.3	1.090	-48.7	-48.4	-0.3
50	1.100 Un	50.3	1.100	-48.6	-48.4	-0.2
50	1.050 Un	50.1	1.051	-22.3	-22.8	+0.5
50	1.000 Un	50.1	1.000	-0.3	0.0	-0.3

Test results are represented at diagrams below.
Supplementary information: p.u. values for P and S are given in reference to Sn, p.u. values for Q are given in reference to P_D.

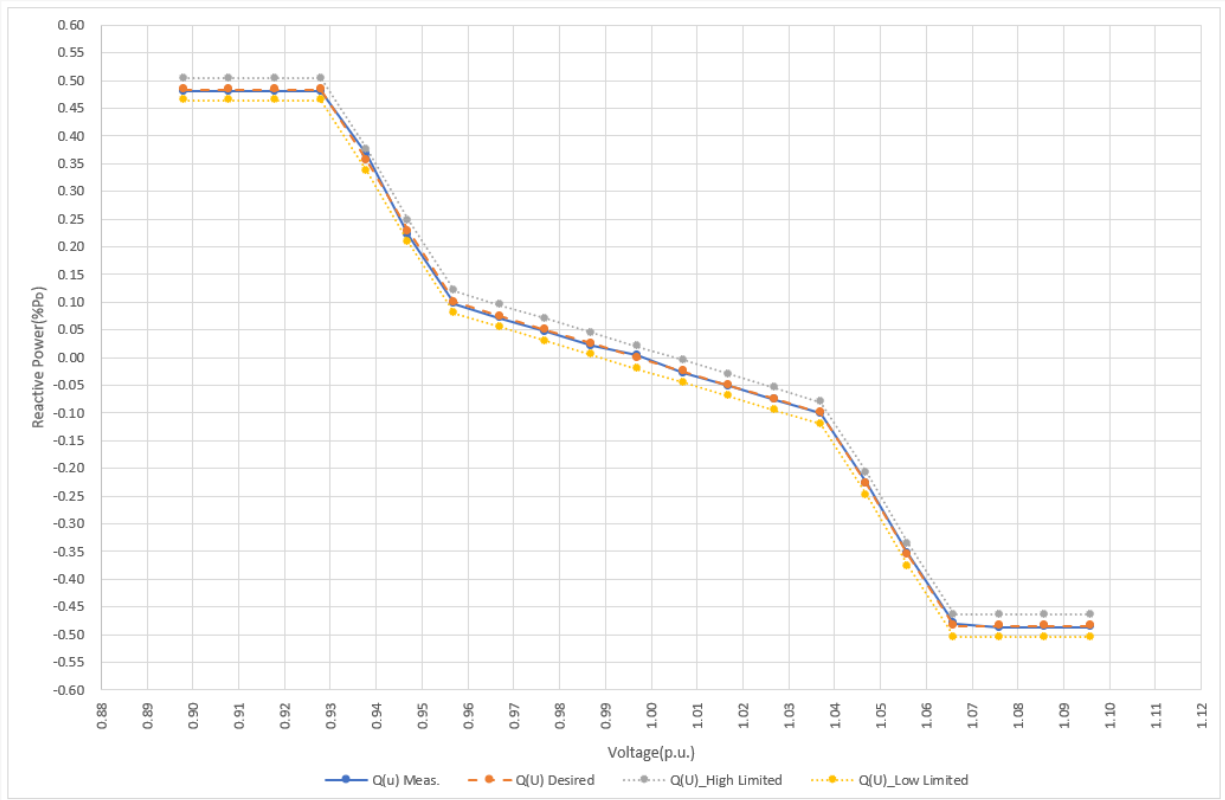
Voltage related control mode - Q(U) of Undervoltage Test



Voltage related control mode - Q(U) of Overvoltage Test



Voltage vs Reactive Power



4.4.2.2 Voltage related control mode Q(U) with lock-in/lock-out function

The test has been done according to the clause 4.7.2.3.3 of the standard.

Two active power levels shall be configurable both at least in the range of 0 % to 100 % of P_D. The lock-in value turns the Q(U) mode on, the lock-out value turns Q(U) off. If lock-in is larger than lock-out a hysteresis is given. See also Figure 14 in the standard.

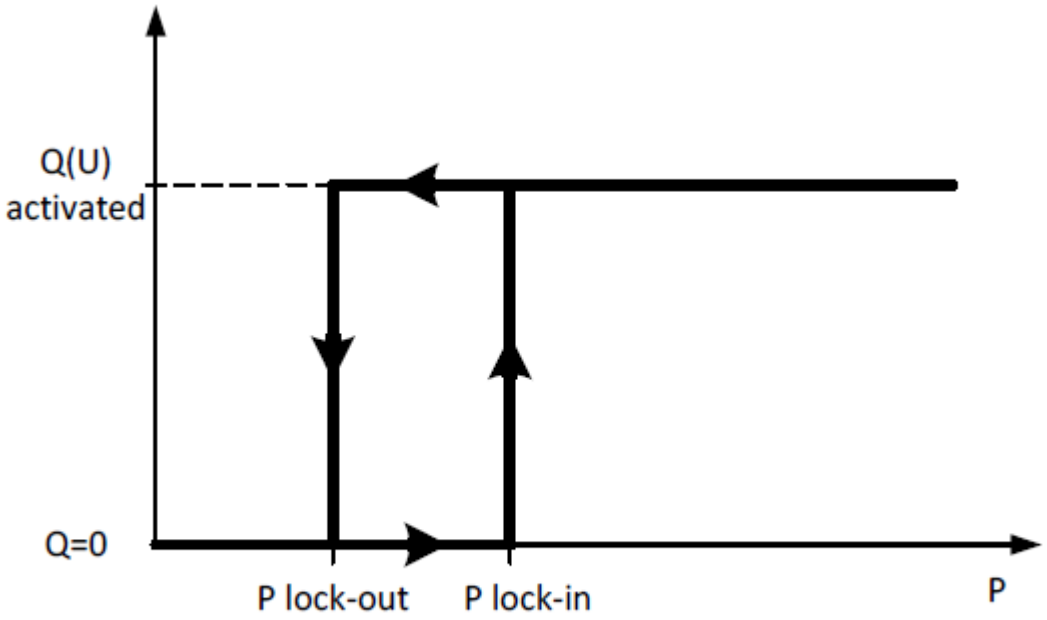


Figure 14 – Example of lock-in and lock-out values for Q(U) mode

Setting the characteristic as following to prove configurability of the inverter:

- U1 = 0.93, Qmax= 43.6%Pn= 48.4%P_D
- U2 = 0.96, Q= 9%Pn= 10% P_D
- U3 = 1.04, Q= - 9%Pn= -10% P_D
- U4 = 1.07, -Qmax= - 43.6%Pn=- 48.4%P_D

P lock-in = 30%Pn=33%P_D, P lock-out = 20%Pn=22%P_D

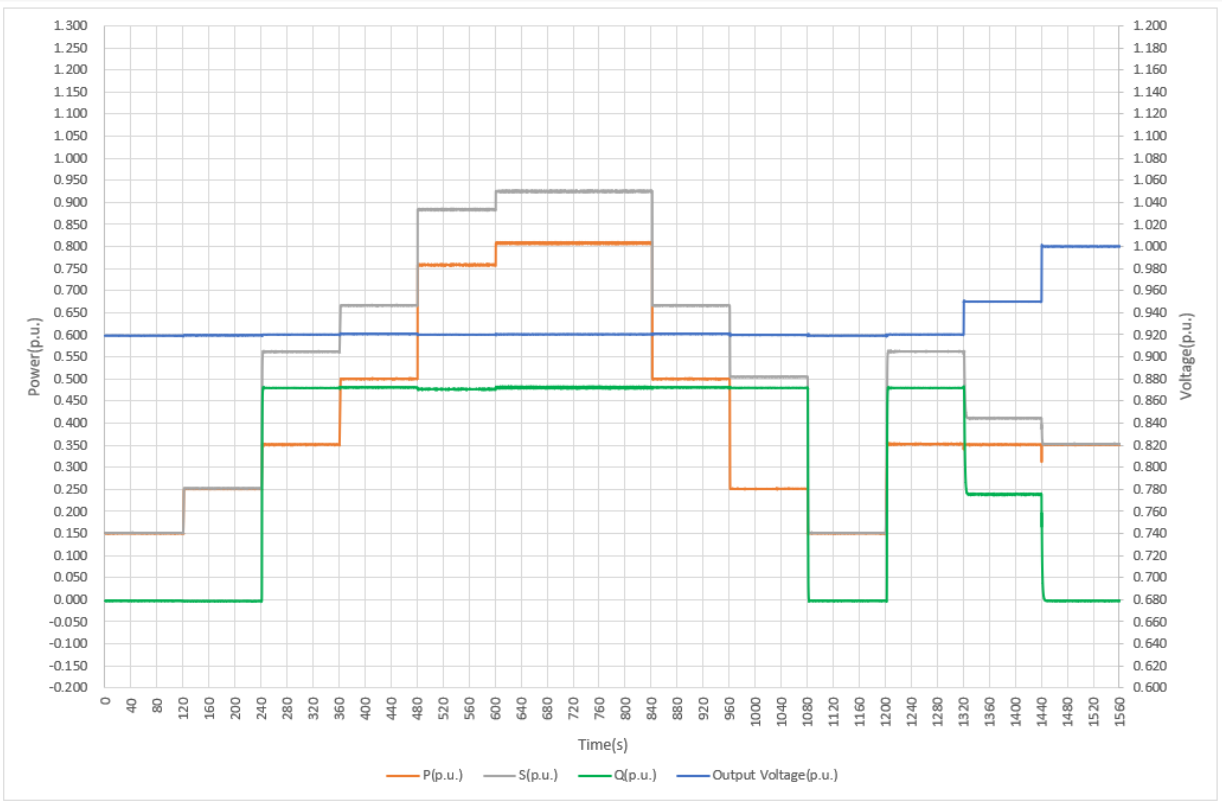
Test results are offered at the tables below.

Reactive power injection in relation with the Voltage (Inductive)						
P/Pn setpoint (%Pn)	**U setpoint (p.u.)**	**P measured (%Sn)**	**V measured (p.u.)**	**Q measured (%P_D)**	**Q desired (%P_D)**	**ΔQ (p.u.) (±2.2%P_D)**
<20.0	0.920	15.0	0.919	+0.3	0.0	+1.3
25.0	0.920	25.1	0.919	+0.4	0.0	+1.3
35.0	0.920	35.1	0.920	+47.9	+48.4	+0.1
50.0	0.920	50.0	0.921	+48.0	+48.4	+0.3
75.0	0.920	75.8	0.920	+47.7	+48.4	+0.4
90.0	0.920	80.8(1)	0.920	+48.1	+48.4	+0.4
100.0	0.920	80.8(1)	0.920	+48.0	+48.4	+0.4
50.0	0.920	50.0	0.921	+48.0	+48.4	+0.2
25.0	0.920	25.1	0.920	+48.0	+48.4	+0.1
<20.0	0.920	15.0	0.919	+0.3	0.0	+1.3
35.0	0.920	35.2	0.920	+47.9	+48.4	+0.2
35.0	0.950	35.1	0.950	+23.8	+24.2	-0.4
35.0	1.000	35.1	1.000	+0.3	0.0	+1.3

(1) Due to current limitation, the Active power cannot reach the expected value.

Test results are represented at diagrams below.
Supplementary information: p.u. values for P and S are given in reference to Sn, p.u. values for Q are given in reference to P_D.

Reactive power injection in relation with the Voltage (Inductive)

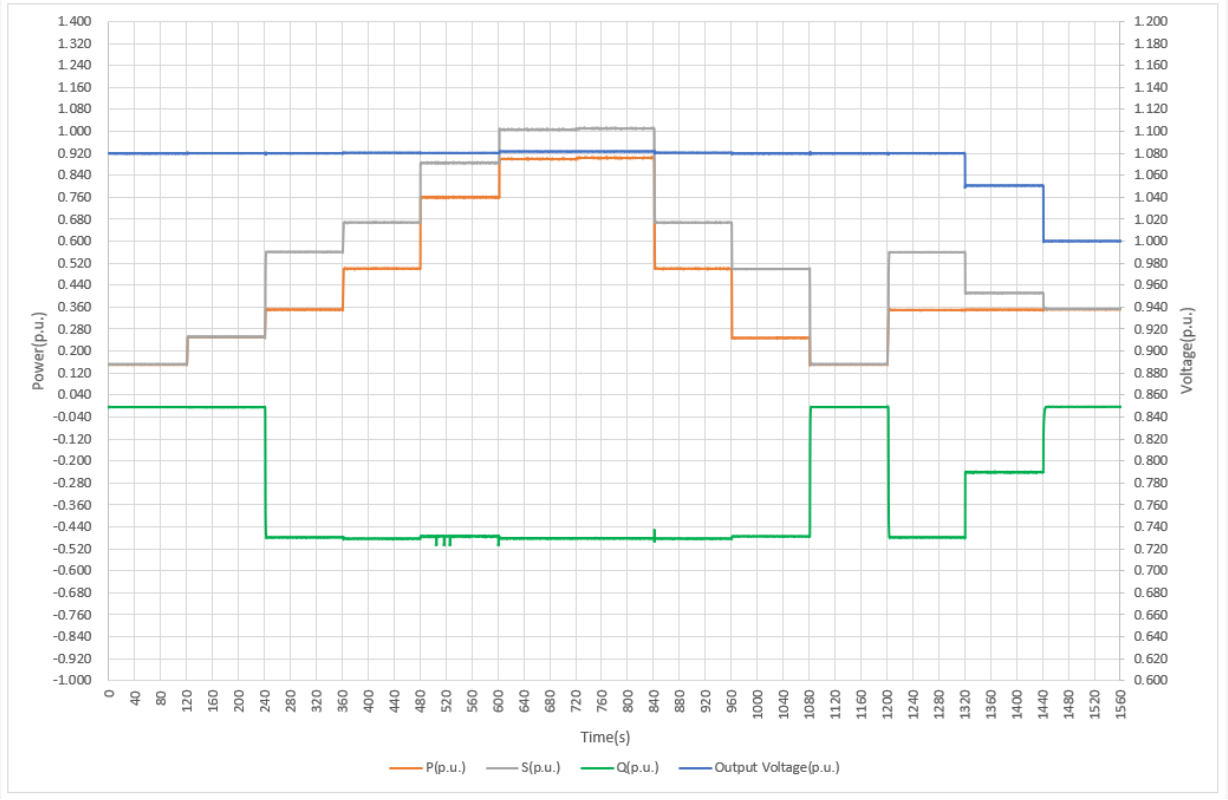


Reactive power injection in relation with the Voltage (Capacitive)						
P/Pn setpoint (%Pn)	U setpoint (p.u.)	P measured (%Sn)	V measured (p.u.)	Q measured (%P_D)	Q desired (%P_D)	ΔQ (p.u.) (±2.2%P_D)
<20.0	1.080	15.0	1.080	-0.4	0.0	-0.4
25.0	1.080	25.0	1.080	-0.5	0.0	-0.5
35.0	1.080	35.0	1.080	-47.9	-48.4	+0.5
50.0	1.080	50.0	1.080	-48.4	-48.4	0.0
75.0	1.080	75.9	1.080	-47.5	-48.4	+0.9
90.0	1.080	89.9	1.081	-48.2	-48.4	+0.2
100.0	1.080	90.3(1)	1.082	-48.3	-48.4	+0.1
50.0	1.080	50.0	1.080	-48.3	-48.4	+0.1
25.0	1.080	24.7	1.080	-47.5	-48.4	+0.9
<20.0	1.080	15.0	1.080	-0.4	0.0	-0.4
35.0	1.080	34.9	1.080	-47.9	-48.4	+0.5
35.0	1.050	35.0	1.050	-24.1	-24.2	+0.1
35.0	1.000	35.2	1.000	-0.3	0.0	-0.3

(1) Since the working mode is reactive power priority, the active power cannot reach the expected value due to current limitation.

Test results are represented at diagrams below.
Supplementary information: p.u. values for P and S are given in reference to Sn, p.u. values for Q are given in reference to P_D.

Reactive power injection in relation with the Voltage (Capacitive)



4.4.2.3 Static accuracy

The test has been done according to the clause 4.7.2.3.3 of the standard.

The dynamics of the control shall correspond with a first order filter having a time constant that is configurable in the range of 3 s to 60 s.

The dynamic accuracy shall be in accordance with Figure 15 in the standard with a maximum tolerance of ±5 $\%P_D$ plus a time delay of up to 3 seconds deviating from an ideal first order filter response.

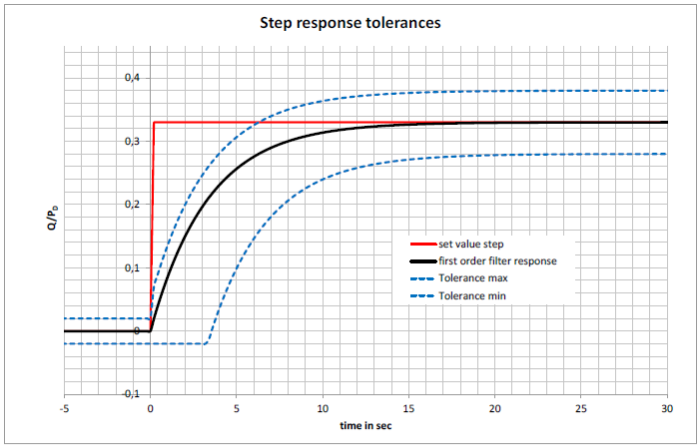


Figure 15 — Example of dynamic control response and tolerance band for a step from Q=0 to Q= 33%P_D with τ=3,33s

Note: Figure 15 – Is from Q=0 to Q= 33% P_D, but the actual measurement is from Q=0 to Q= 36% P_D. The response time is adjustable from 1s to 60s by settings, which is more stringent than the standard required from 3s to 60s.

Test results are offered at the tables below.

Settling time = 1 s				
%Pn	**Steps**	**Time measured (s)**	**Q Measured (%P_D)**	**Δ Q (%Sn) < ±2.2%P_D**
50	Q = 0 → Q = 32.4%Sn (36%P_D)(Inductive)	t = 0.8	+36.4	+0.4
	Q = 32.4%Sn (36%P_D) (Inductive) → Q = - 32.4%Sn (36%P_D) (Capacitive)	t = 0.8	-36.4	-0.4
	Q = -32.4%Sn (-36%P_D) (Capacitive) → Q = 0	t = 0.8	-0.5	-0.5

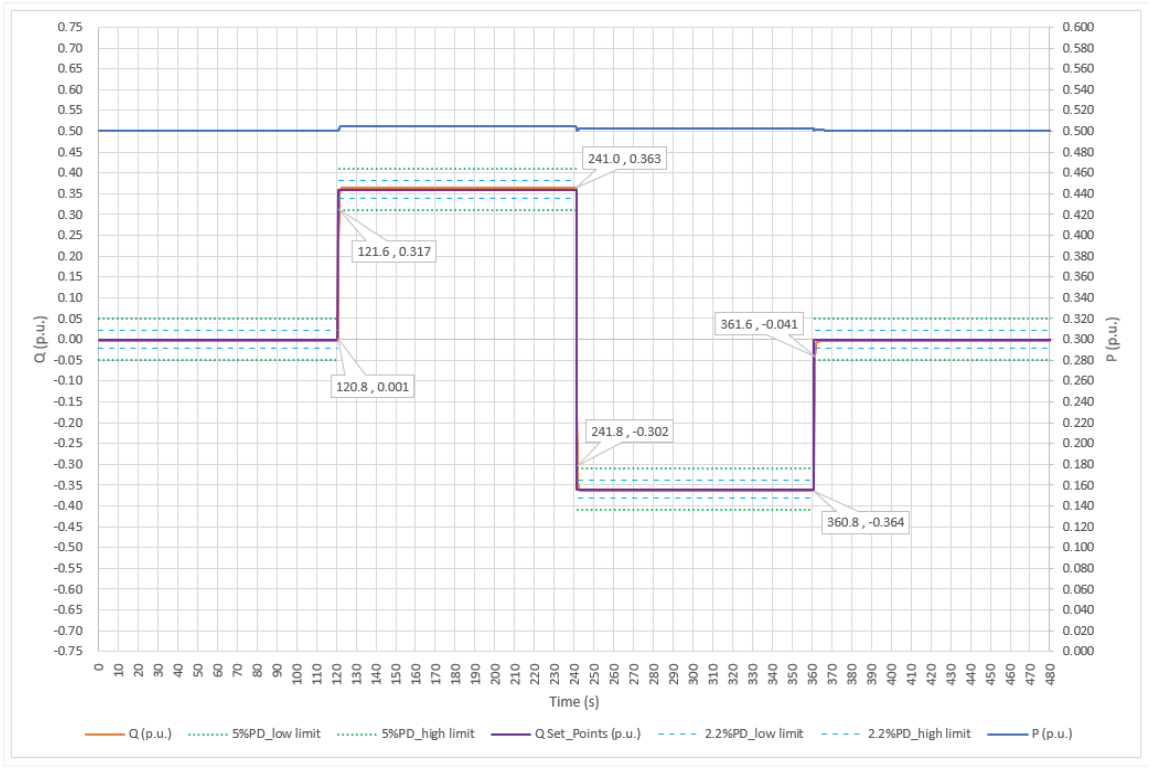
Settling time = 60 s				
%Pn	**Steps**	**Time measured (s)**	**Q Measured (%P_D)**	**Δ Q (%Sn) <±2.2%P_D**
50	Q = 0 → Q = 32.4%Sn (36%P_D)(Inductive)	t = 25.6	+36.4	+0.4
	Q = 32.4%Sn (36%P_D) (Inductive) → Q = - 32.4%Sn (36%P_D) (Capacitive)	t = 34.4	-36.4	-0.4
	Q = -32.4%Sn (-36%P_D) (Capacitive) → Q = 0	t =25.0	-0.5	-0.5

Note: P is with respect to Sn , Q is according to measured PD ≈ 0.9 Pn (231.427 kW)

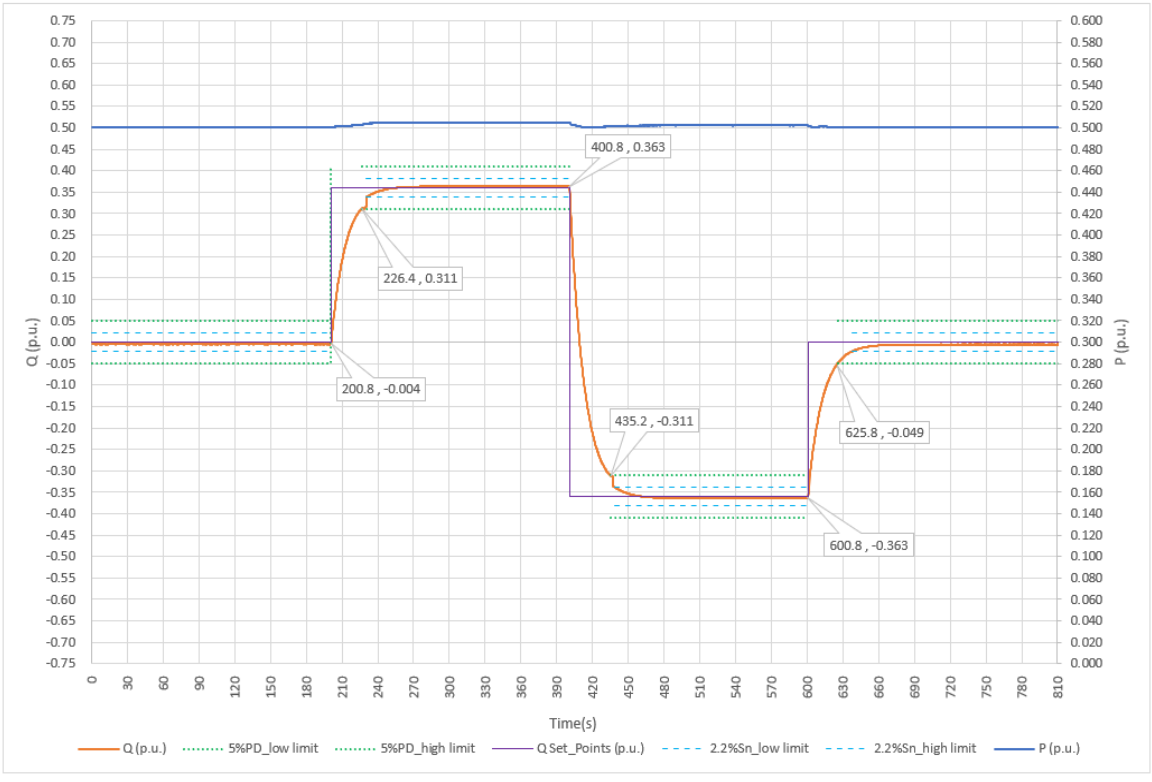
Test results are represented at diagrams below.

Supplementary information: p.u. values for P and S are given in reference to Sn, p.u. values for Q are given in reference to $P_{D.}$

Reactive power injection dynamic control response and tolerance band (Settling time = 1 s)



Reactive power injection dynamic control response and tolerance band (Settling time = 60 s)

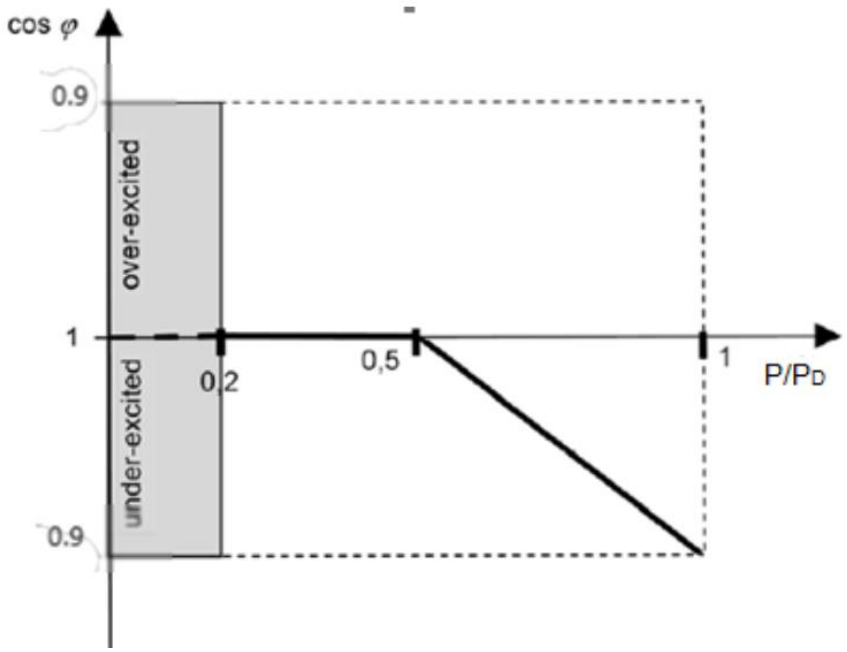


4.4.2.4 Power related control mode

The test has been done according to the clause 4.7.2.3.4 of the standard.

The power related control mode cos φ (P) controls the cos φ of the output as a function of the active power output.

For power related control modes, a characteristic defined by the manufacturer as follows:



Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic. The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power to be in synchrony with the change in active power. The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached. The static accuracy of each cos φ set point shall be according to 4.7.2.2.

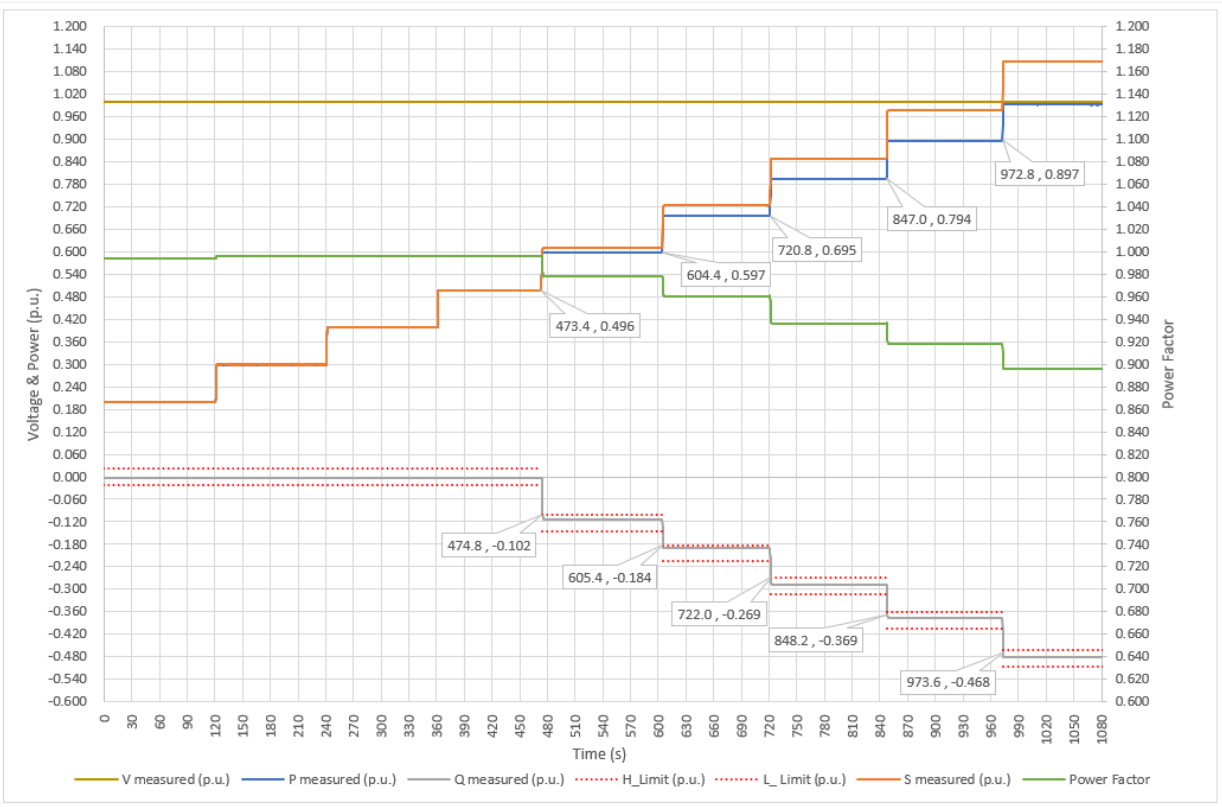
The results are offered in the table below (Note: 10 %Pn has not been measured in the following test):

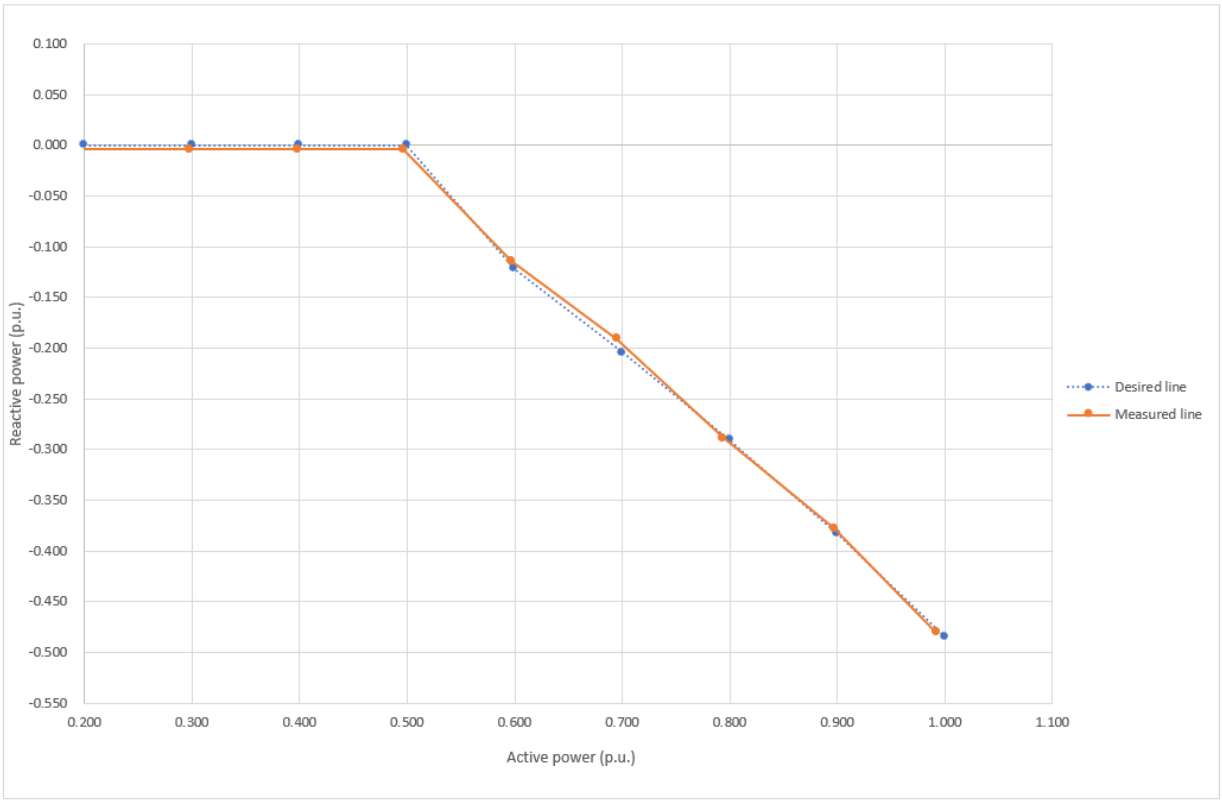
Setting cos φ(P) with the standard characteristic curve (20 %P_D to 100 %P_D)							
Active Power setting (%P_D)	**Active Power measured (p.u.)**	**Reactive Power measured (p.u.)**	**cos φ measured**	**Desired cos φ**	**Desired Q (p.u.)**	**Δ Q (p.u.) (±0.022)**	**Transient period (<10s)**
20	0.199	-0.004	1.000	1.000	0.000	-0.004	
30	0.298	-0.004	1.000	1.000	0.000	-0.004	--
40	0.398	-0.004	1.000	1.000	0.000	-0.004	--
50	0.496	-0.004	1.000	1.000	0.000	-0.004	--
60	0.597	-0.114	0.980	0.980	-0.122	+0.008	1.40
70	0.695	-0.191	0.960	0.960	-0.204	+0.013	1.00
80	0.794	-0.289	0.940	0.940	-0.290	+0.001	1.20
90	0.897	-0.378	0.920	0.920	-0.383	+0.005	1.20
100	0.992	-0.480	0.900	0.900	-0.484	+0.004	0.80

Supplementary information: p.u. values are given in reference to Pd, in this case $P_D \approx 0.9$ Pn (231.427 kW).
Note: The desired Q is calculated from $Q = -\sqrt{(S^2 - P^2)}$.

Test results are represented at diagrams below.

Setting cos φ(P) with standard characteristic curve (20 %P_D to 100 %P_D)



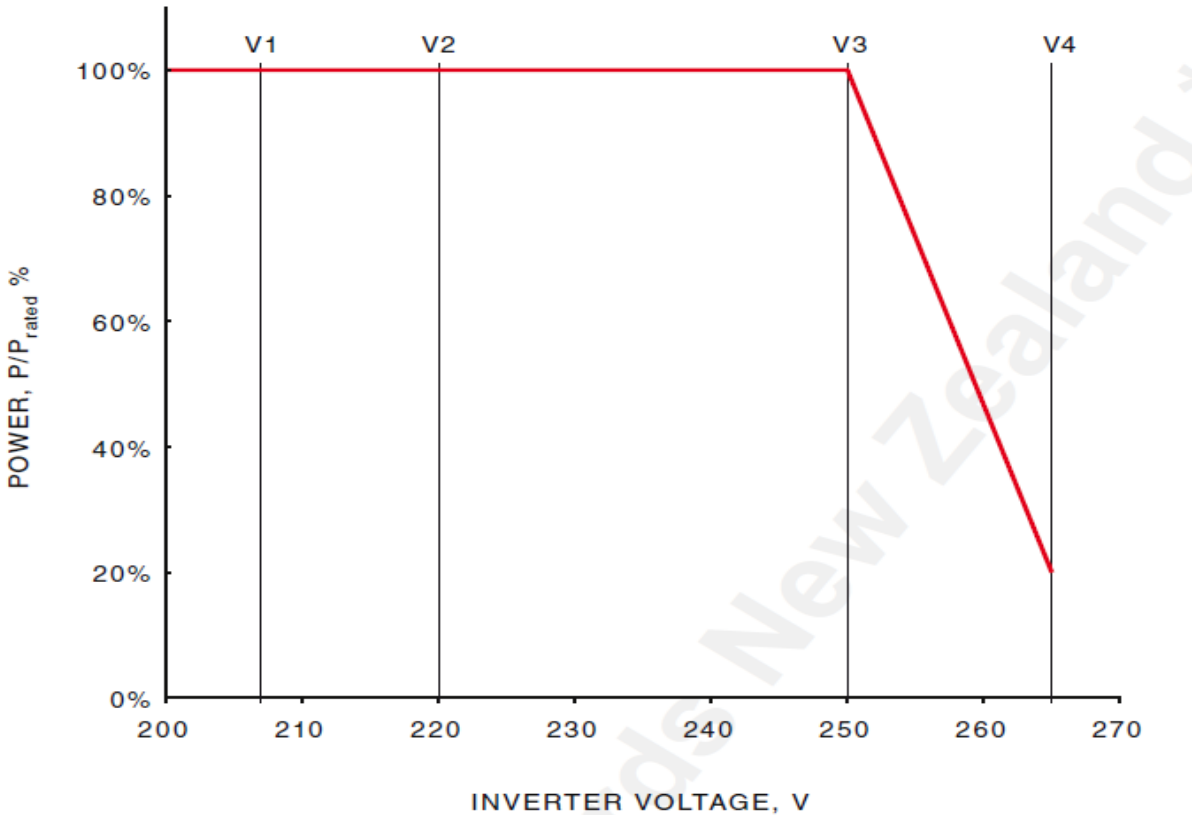


4.4.3. Voltage related active power reduction (Volt-Watt)

The test has been done according to the clause 4.7.3 of the standard.

The final implemented logic can be chosen by the manufacturer. Nevertheless, this logic shall not cause steps or oscillations in the output power. The power reduction caused by such a function may not be faster than an equivalent of a time constant tau = 3 s (= 33 %/s at a 100 % change).

The following paramaeters have been set by the manufacturer for this test:



Test 1 and Test 2 setpoint as following:

Reference	Test 1 Set points		Test 2 Set points	
	Volt. (%Un)	Power (%Pn)	Volt. (%Un)	Power (%Pn)
V1	90.0%	100%	90.0%	100%
V2	95.6%	100%	95.6%	100%
V3	104.0%	100%	108.7%	100%
V4	110.0%	20%	115.2%	20%

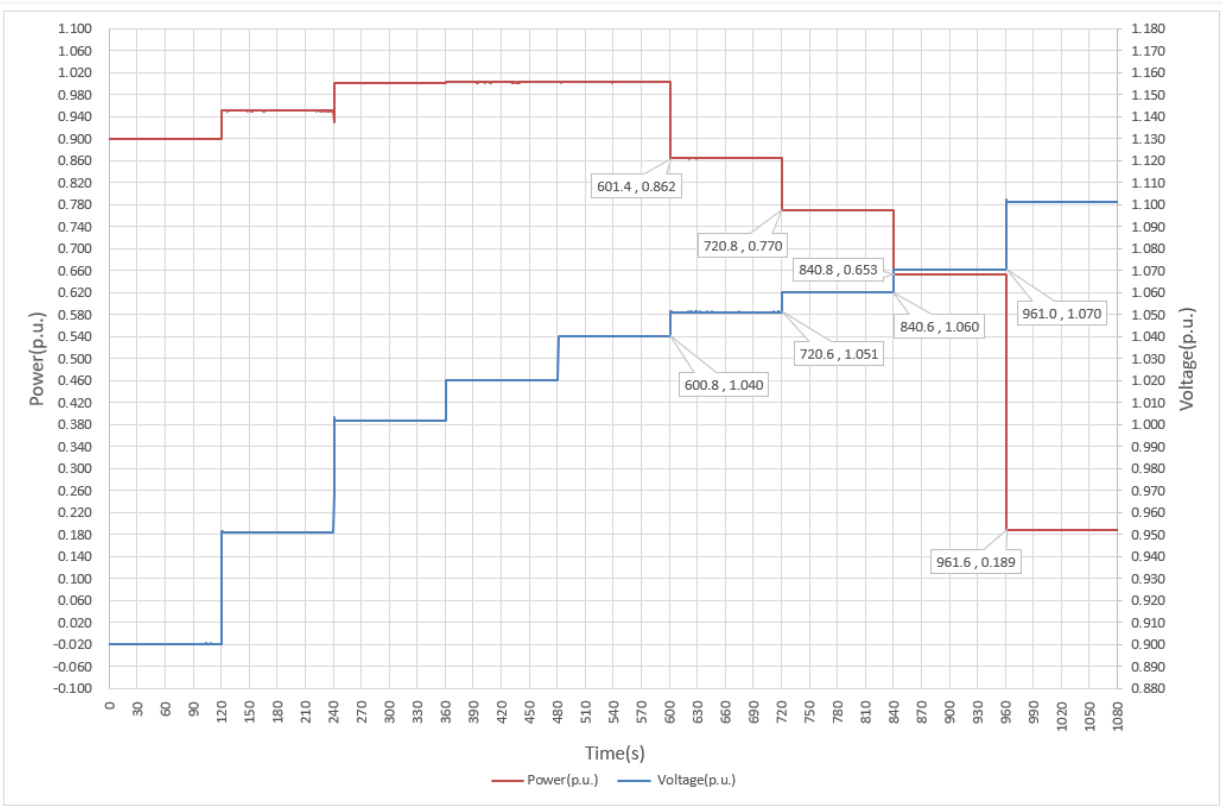
Test results are offered at tables below.

Volt-Watt TEST 1					
V setting (p.u.)	**V meas. (p.u.)**	**P desired (p.u.)**	**P meas. (p.u.)**	**P deviation (p.u.)**	**Response time (s)**
0.900	0.900	1.000	0.900(1)	-0.100	--
0.950	0.951	1.000	0.951(1)	-0.049	--
1.000	1.002	1.000	1.002	+0.002	--
1.020	1.020	1.000	1.003	+0.003	--
1.040	1.040	1.000	1.003	+0.003	--
1.050	1.051	0.867	0.865	-0.002	2.0
1.060	1.060	0.771	0.770	-0.001	1.0
1.070	1.070	0.657	0.653	-0.004	1.4
1.100	1.101	0.200	0.188	-0.012	2.0
Volt-Watt TEST 2					
V setting (p.u.)	**V meas. (p.u.)**	**P desired (p.u.)**	**P meas. (p.u.)**	**P deviation (p.u.)**	**Response time (s)**
0.900	0.900	1.000	0.900(1)	-0.100	--
0.950	0.951	1.000	0.951(1)	-0.049	--
1.000	1.002	1.000	1.002	+0.002	--
1.020	1.020	1.000	1.003	+0.003	--
1.040	1.040	1.000	1.003	+0.003	--
1.050	1.051	1.000	1.003	+0.003	--
1.060	1.060	1.000	1.003	+0.003	--
1.070	1.071	1.000	1.003	+0.003	--
1.100	1.102	0.840	0.841	+0.001	0.20
1.120	1.121	0.594	0.591	-0.003	0.60
1.152	1.152	0.200	0.188	-0.012	1.00

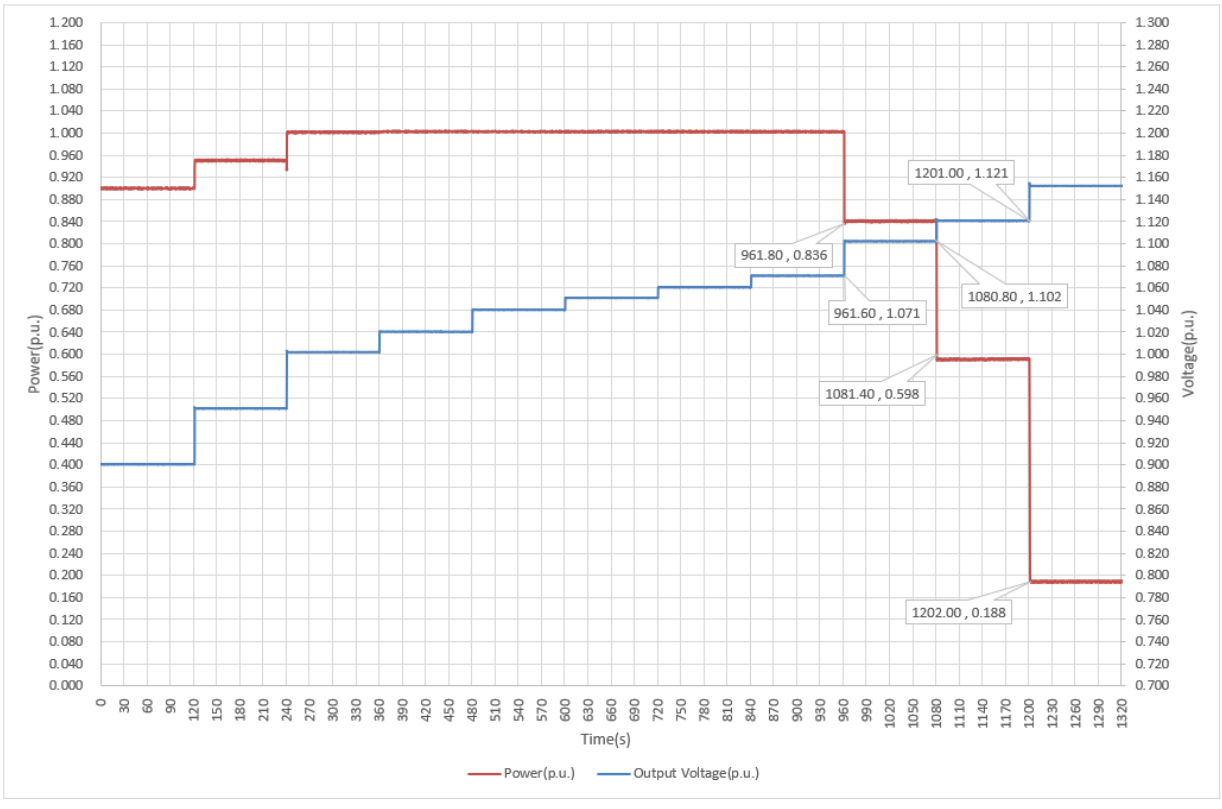
(1) Due to current limitation, the active power cannot reach the expected value.

Test results are represented at diagrams below.

Volt-Watt Test 1



Vatt-Watt Test 2



4.4.4. Short circuit current requirements on generating plants

The tests of the chapter 4.7.4 of the standard describe the required short circuit current contribution for generating plants taking into account the connection technology of the generating modules.

These tests are considered optional for Type A and Type B generating units connected to LV distribution grids, thus they have not been performed.

4.4.4.1 Generating plant with non-synchronous generating technology

4.4.4.1.1 Voltage support during faults and voltage steps

The requirements are stated in clause 4.7.4.2.1 of the standard.

The EUT is classified as Type A and B. This is no voltage support during faults and voltage steps.

4.4.4.1.2 Zero current mode for converter connected generating technology

The requirements are stated in clause 4.7.4.2.2 of the standard.

The EUT is classified as Type A and B. Refer to Section 4.2.2 and 4.2.3 of this report. During UVRT and OVRT, the EUT is always work at zero current mode.

4.4.4.1.3 Induction generator based units

The requirements are stated in clause 4.7.4.2.3 of the standard.

In general, no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. This clause is not applicable.

4.4.4.2 Generating plant with synchronous generating technology - Synchronous generator based units

The requirements are stated in clause 4.7.4.3 of the standard.

The EUT is with non-synchronous generating technology. This clause is not applicable.

4.5. EMC AND POWER QUALITY

As required in clause 4.8 of the standard, all electric and electronic equipment to be installed under the scope of this standard shall be in compliance with relative standards for Electromagnetic Compatibility.

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

EN IEC 61000-6-2: 2019; EN IEC 61000-6-4: 2011: Test Report no.CTS20220059-E, issued by ShenZhen Chengxin Technology Service Co., Ltd. on 2022-05-13. CNAS L12944

Note: Aside of EMC evidence of compliances, the harmonic and flicker content has been measured just to provide further information of the tested unit, and the results are stated in the following items 4.5.1 and 4.5.2 of the report.

4.5.1. Harmonic emissions

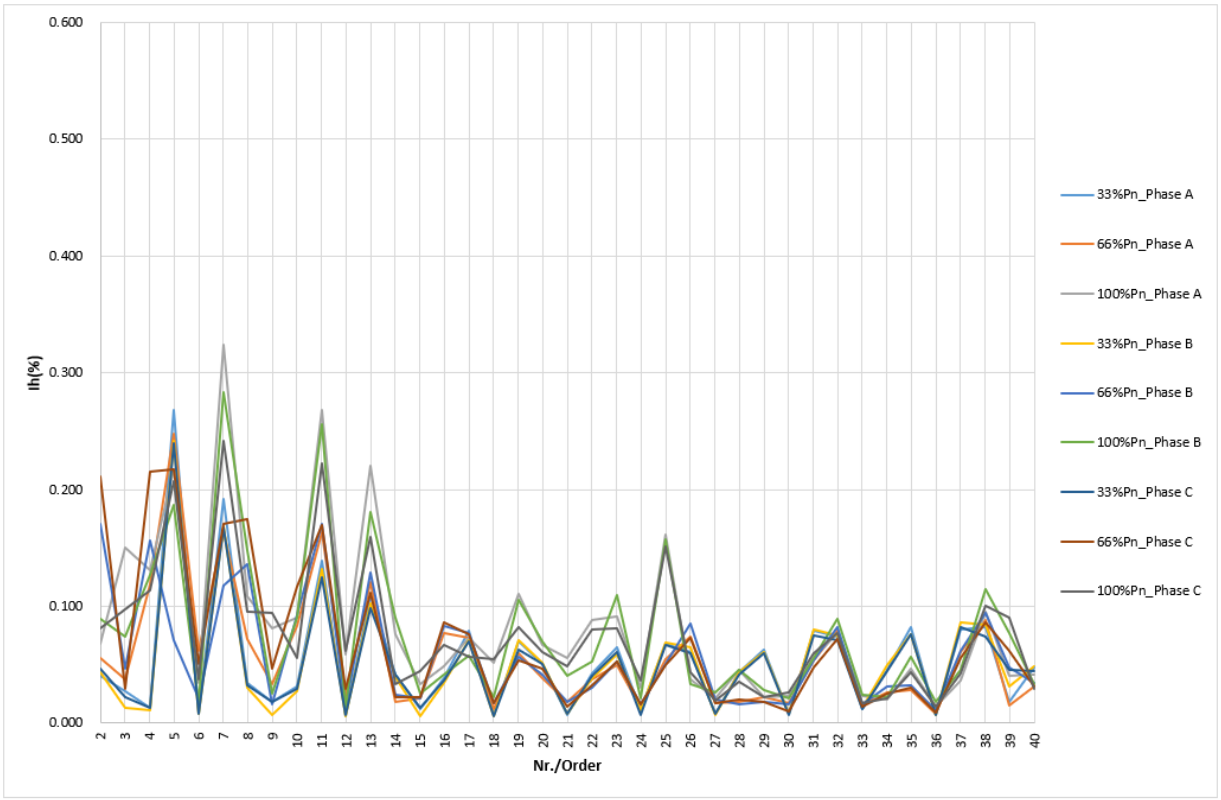
The test has been done according to the clause 4.8 of the standard EN 61000-3-12:2011-05

Below are the measured values of current harmonics.

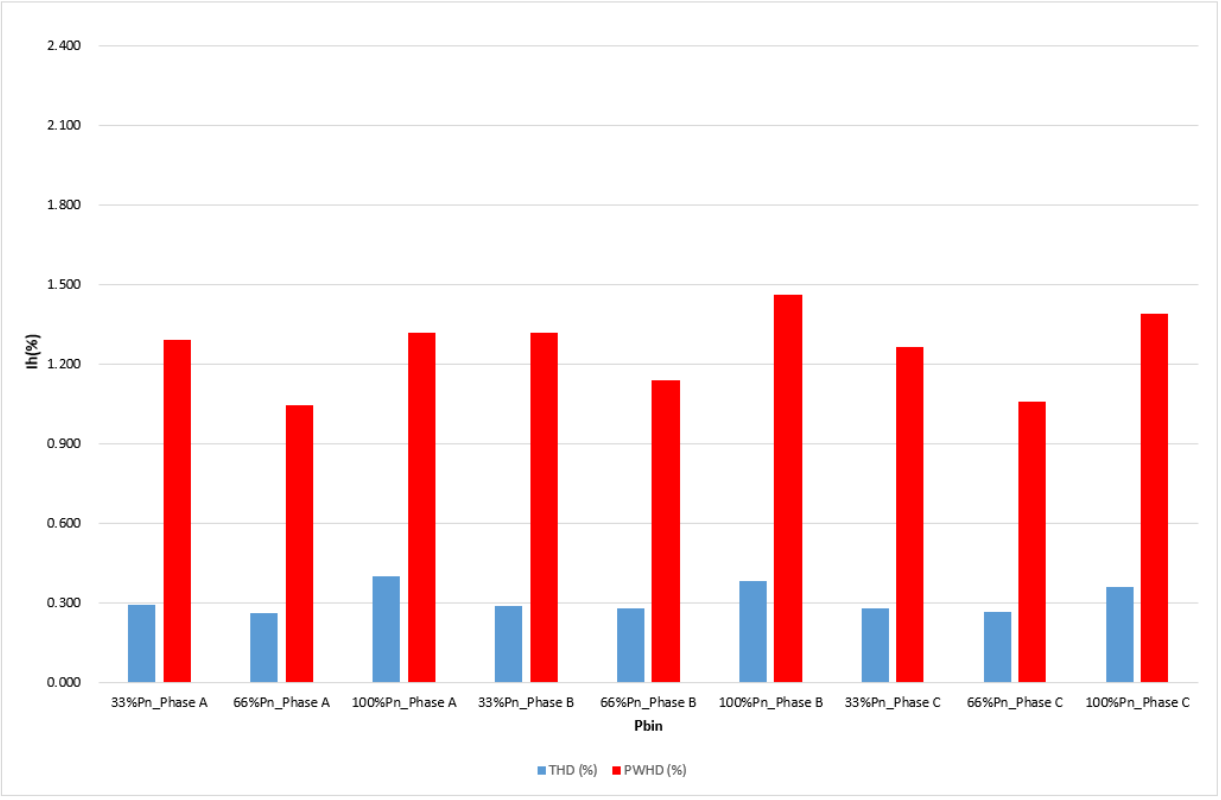
Pn (%)	Phase A			Phase B			Phase C			Limit (%)
	33	66	100	33	66	100	33	66	100	
Nr./Order	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	I_h (%)	
2	0.041	0.055	0.068	0.043	0.170	0.089	0.046	0.211	0.081	8.000
3	0.027	0.037	0.151	0.013	0.047	0.074	0.022	0.029	0.098	--
4	0.013	0.119	0.131	0.011	0.156	0.127	0.013	0.215	0.114	4.000
5	0.269	0.248	0.218	0.241	0.071	0.187	0.239	0.217	0.208	10.700
6	0.008	0.061	0.034	0.008	0.021	0.017	0.008	0.050	0.037	2.700
7	0.192	0.165	0.324	0.169	0.118	0.283	0.168	0.171	0.242	7.200
8	0.034	0.072	0.109	0.030	0.136	0.149	0.033	0.175	0.096	2.000
9	0.019	0.034	0.081	0.007	0.016	0.025	0.018	0.046	0.095	--
10	0.031	0.083	0.091	0.027	0.093	0.091	0.029	0.116	0.056	1.600
11	0.140	0.163	0.268	0.132	0.171	0.256	0.125	0.170	0.222	3.100
12	0.006	0.023	0.059	0.006	0.014	0.013	0.006	0.029	0.062	1.300
13	0.110	0.121	0.220	0.102	0.129	0.181	0.098	0.111	0.160	2.000
14	0.041	0.018	0.076	0.040	0.024	0.090	0.041	0.022	0.033	--
15	0.012	0.021	0.034	0.006	0.021	0.026	0.013	0.022	0.045	--
16	0.039	0.078	0.048	0.034	0.084	0.041	0.036	0.087	0.067	--
17	0.079	0.073	0.073	0.071	0.077	0.057	0.070	0.076	0.057	--
18	0.007	0.012	0.051	0.006	0.017	0.022	0.006	0.018	0.055	--
19	0.070	0.060	0.111	0.071	0.057	0.106	0.063	0.054	0.083	--
20	0.051	0.039	0.067	0.052	0.042	0.070	0.050	0.047	0.061	--
21	0.007	0.018	0.056	0.008	0.018	0.041	0.008	0.014	0.048	--
22	0.042	0.037	0.088	0.038	0.030	0.053	0.040	0.032	0.080	--
23	0.064	0.049	0.092	0.059	0.053	0.110	0.061	0.053	0.081	--
24	0.011	0.014	0.031	0.011	0.016	0.021	0.007	0.016	0.037	--
25	0.068	0.055	0.162	0.069	0.051	0.157	0.067	0.050	0.151	--
26	0.061	0.074	0.037	0.065	0.085	0.034	0.060	0.073	0.043	--
27	0.008	0.017	0.021	0.007	0.020	0.026	0.008	0.017	0.019	--
28	0.044	0.018	0.046	0.043	0.016	0.046	0.042	0.020	0.036	--
29	0.063	0.022	0.022	0.061	0.018	0.029	0.060	0.018	0.022	--
30	0.008	0.017	0.024	0.008	0.016	0.021	0.007	0.011	0.027	--
31	0.079	0.054	0.055	0.080	0.054	0.055	0.075	0.047	0.060	--
32	0.075	0.079	0.077	0.076	0.083	0.090	0.071	0.072	0.077	--
33	0.012	0.016	0.023	0.014	0.016	0.024	0.012	0.015	0.017	--
34	0.046	0.026	0.021	0.050	0.031	0.022	0.045	0.026	0.021	--
35	0.082	0.028	0.047	0.076	0.033	0.057	0.076	0.030	0.044	--
36	0.007	0.008	0.014	0.007	0.011	0.018	0.007	0.009	0.014	--
37	0.080	0.061	0.036	0.086	0.062	0.045	0.083	0.055	0.043	--
38	0.082	0.088	0.095	0.084	0.095	0.115	0.074	0.086	0.101	--
39	0.018	0.015	0.041	0.032	0.047	0.077	0.046	0.062	0.090	--
40	0.048	0.031	0.041	0.048	0.034	0.034	0.045	0.032	0.029	--
THD (%)	0.294	0.265	0.404	0.291	0.283	0.385	0.280	0.266	0.362	13.000
PWHD(%)	1.293	1.047	1.320	1.321	1.142	1.464	1.264	1.060	1.393	22.000

Test results are represented at diagrams below.

Current Harmonics



THD and PWHD



4.5.2. Flicker and voltage fluctuations

The test has been done according to the clause 4.8 of the standard.

The measurements of voltage fluctuations have been measured at 33%, 66% and 100% of the nominal power value of the inverter according to the standard IEC 61000-3-11:2017.

The flicker test result as following:

33 %Pn				
Item	**Limit**	**Phase A**	**Phase B**	**Phase C**
P_{ST}	≤ 1.000	0.013	0.015	0.015
P_{LT}	≤ 0.650	0.013	0.014	0.014
dc [%]	≤ 3.300	0.000	0.000	0.000
dmax [%]	4.000	0.000	0.000	0.000

66 %Pn				
Item	**Limit**	**Phase A**	**Phase B**	**Phase C**
P_{ST}	≤ 1.000	0.014	0.014	0.015
P_{LT}	≤ 0.650	0.014	0.014	0.015
dc [%]	≤ 3.300	0.000	0.000	0.000
dmax [%]	4.000	0.000	0.000	0.000

100%Pn				
Item	**Limit**	**Phase A**	**Phase B**	**Phase C**
P_{ST}	≤ 1.000	0.071	0.072	0.076
P_{LT}	≤ 0.650	0.069	0.070	0.074
dc [%]	≤ 3.300	0.006	0.008	0.007
dmax [%]	4.000	0.115	0.126	0.118

As it can be seen in the next screenshots, this test has 12 steps. The values took of Pst, Plt, dc and dmax are the most unfavorable of the 12 steps.

Test results are represented at diagrams below.

33 %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	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.013	Pass		
Result		Pass		Pass		Pass		Pass	0.013	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	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
Result		Pass		Pass		Pass		Pass	0.014	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	0.014	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
Result		Pass		Pass		Pass		Pass	0.014	Pass

66 %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	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
Result		Pass		Pass		Pass		Pass	0.014	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	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.014	Pass		
Result		Pass		Pass		Pass		Pass	0.014	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	0.015	Pass		
2	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
3	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
4	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
5	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
6	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
7	0.000	Pass	0.000	Pass	0.0	Pass	0.016	Pass		
8	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
9	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
10	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
11	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
12	0.000	Pass	0.000	Pass	0.0	Pass	0.015	Pass		
Result		Pass		Pass		Pass		Pass	0.015	Pass

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	0.004	Pass	0.114	Pass	0.0	Pass	0.069	Pass		
2	0.003	Pass	0.110	Pass	0.0	Pass	0.070	Pass		
3	0.004	Pass	0.113	Pass	0.0	Pass	0.070	Pass		
4	0.004	Pass	0.105	Pass	0.0	Pass	0.071	Pass		
5	0.004	Pass	0.107	Pass	0.0	Pass	0.071	Pass		
6	0.003	Pass	0.110	Pass	0.0	Pass	0.071	Pass		
7	0.004	Pass	0.104	Pass	0.0	Pass	0.068	Pass		
8	0.004	Pass	0.115	Pass	0.0	Pass	0.068	Pass		
9	0.006	Pass	0.110	Pass	0.0	Pass	0.068	Pass		
10	0.004	Pass	0.104	Pass	0.0	Pass	0.067	Pass		
11	0.003	Pass	0.106	Pass	0.0	Pass	0.068	Pass		
12	0.006	Pass	0.110	Pass	0.0	Pass	0.068	Pass		
Result		Pass		Pass		Pass		Pass	0.069	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	0.006	Pass	0.113	Pass	0.0	Pass	0.070	Pass		
2	0.008	Pass	0.126	Pass	0.0	Pass	0.070	Pass		
3	0.004	Pass	0.115	Pass	0.0	Pass	0.072	Pass		
4	0.007	Pass	0.122	Pass	0.0	Pass	0.072	Pass		
5	0.003	Pass	0.110	Pass	0.0	Pass	0.071	Pass		
6	0.004	Pass	0.102	Pass	0.0	Pass	0.072	Pass		
7	0.001	Pass	0.103	Pass	0.0	Pass	0.070	Pass		
8	0.005	Pass	0.104	Pass	0.0	Pass	0.070	Pass		
9	0.005	Pass	0.106	Pass	0.0	Pass	0.069	Pass		
10	0.007	Pass	0.108	Pass	0.0	Pass	0.069	Pass		
11	0.001	Pass	0.102	Pass	0.0	Pass	0.070	Pass		
12	0.005	Pass	0.114	Pass	0.0	Pass	0.069	Pass		
Result		Pass		Pass		Pass		Pass	0.070	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	0.005	Pass	0.102	Pass	0.0	Pass	0.075	Pass		
2	0.004	Pass	0.108	Pass	0.0	Pass	0.073	Pass		
3	0.002	Pass	0.114	Pass	0.0	Pass	0.076	Pass		
4	0.003	Pass	0.105	Pass	0.0	Pass	0.075	Pass		
5	0.002	Pass	0.107	Pass	0.0	Pass	0.076	Pass		
6	0.005	Pass	0.114	Pass	0.0	Pass	0.075	Pass		
7	0.004	Pass	0.112	Pass	0.0	Pass	0.074	Pass		
8	0.005	Pass	0.105	Pass	0.0	Pass	0.074	Pass		
9	0.006	Pass	0.109	Pass	0.0	Pass	0.074	Pass		
10	0.007	Pass	0.108	Pass	0.0	Pass	0.073	Pass		
11	0.006	Pass	0.111	Pass	0.0	Pass	0.073	Pass		
12	0.007	Pass	0.118	Pass	0.0	Pass	0.073	Pass		
Result		Pass		Pass		Pass		Pass	0.074	Pass

4.6. INTERFACE PROTECTION

4.6.1. Requirements on voltage and frequency protection

The test has been done according to the clause 4.9.3 of the standard. The minimum required accuracy for protection is:
- For frequency measurement ±0.05 Hz;
- For voltage measurement ±1 %Un.
- The reset time shall be ≤50 ms.
- The interface protection relay shall not conduct continuous starting and disengaging operations of the interface protection relay. Therefore, a reasonable reset ratio shall be implemented which shall not be zero but be below 2 % of nominal value for voltage and below 0.2 Hz for frequency.

4.6.1.1 Undervoltage protection

Undervoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Undervoltage threshold stage 1 [27 <]:
- Threshold (0.2 – 1.0) Un adjustable by steps of 0.01 Un
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Undervoltage threshold stage 2 [27 <<]:
- Threshold (0.2 – 1.0) Un adjustable by steps of 0.01 Un
- Operate time (0.1 – 5) s adjustable in steps of 0.05 s

The undervoltage threshold stage 2 is not applicable for micro-generating plants.

The following definitions apply to the test to verify the clause:

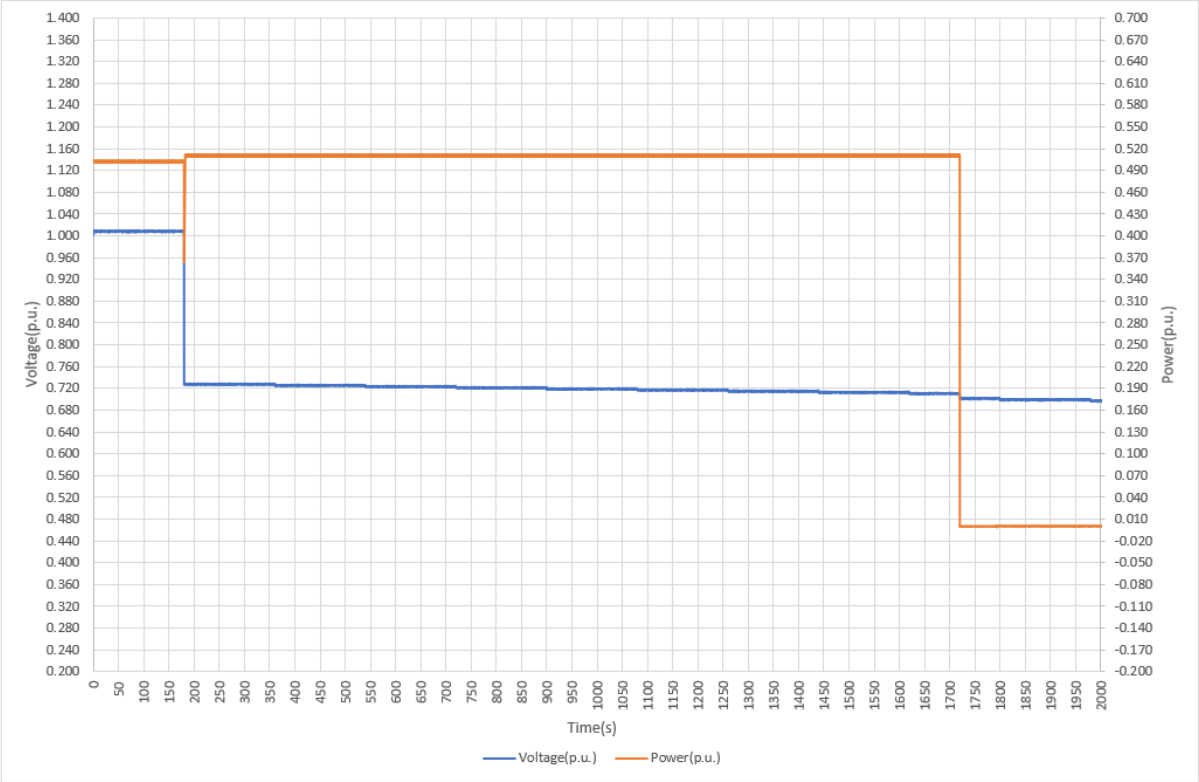
Undervoltage	Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [27 <]	1	0.700(1)	0.710	+0.010	100.000	99.970	-0.030
	2	1.000	1.003	+0.003	0.100	0.097	-0.032
Stage 2 [27 <<]	3	0.700(1)	0.710	+0.010	5.000	4.988	-0.012
	4	1.000	1.002	+0.002	0.100	0.092	-0.080

(1) As the manufacturer declared, the undervoltage stage 1 and stage 2 of this inverter is adjustable from 0.7Un to 1.0Un.

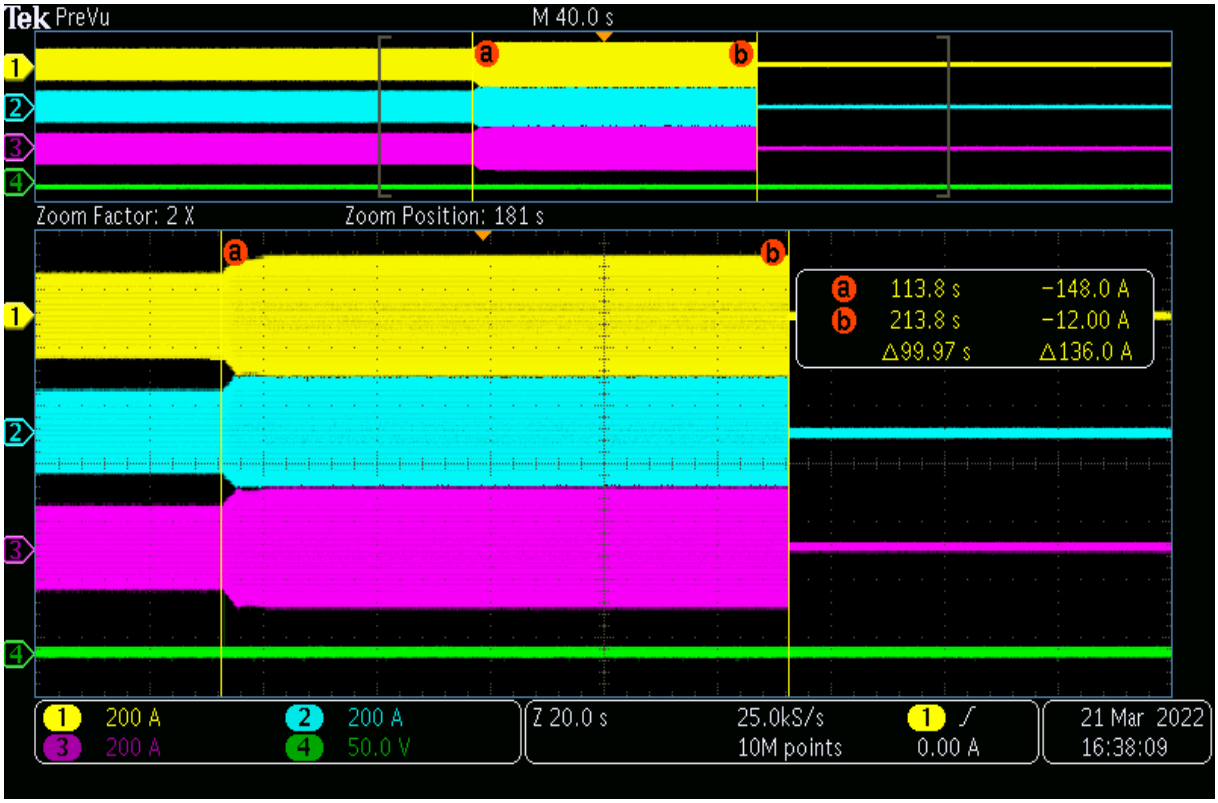
Remark: The virtual neutral line was used in the test.

Test results are represented at diagrams below.

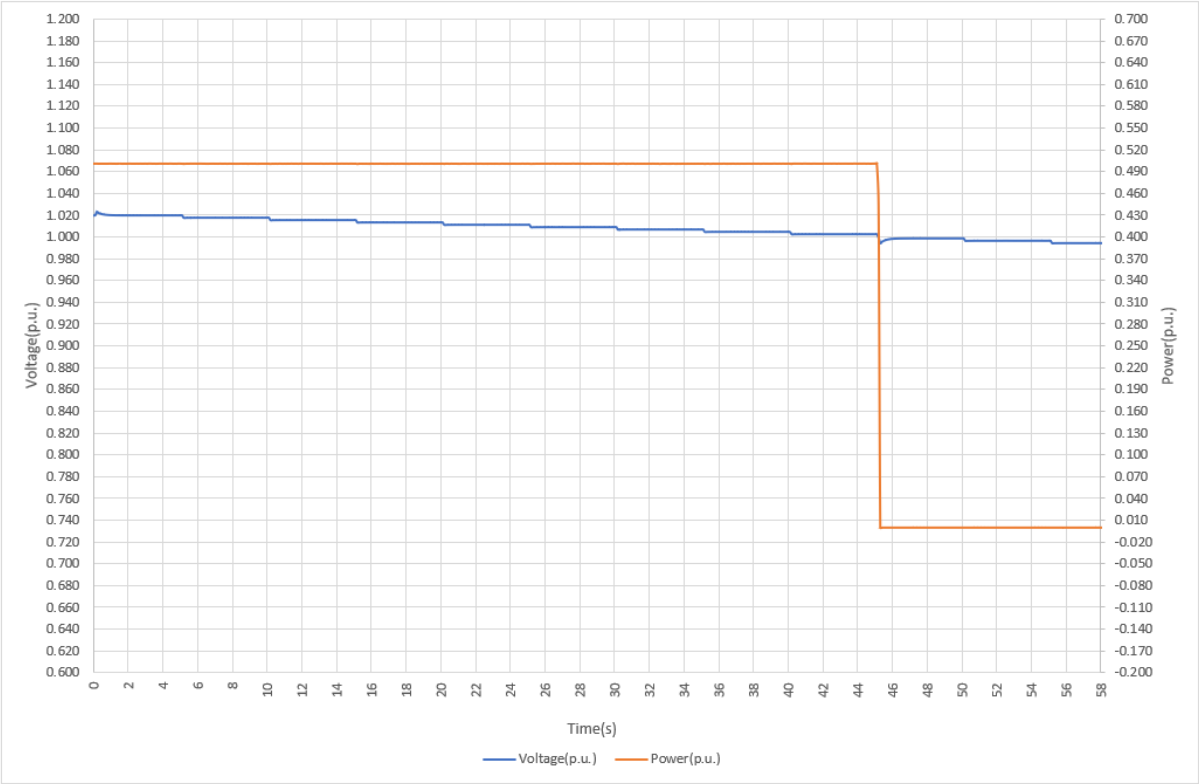
Undervoltage - Test 1: Trip value



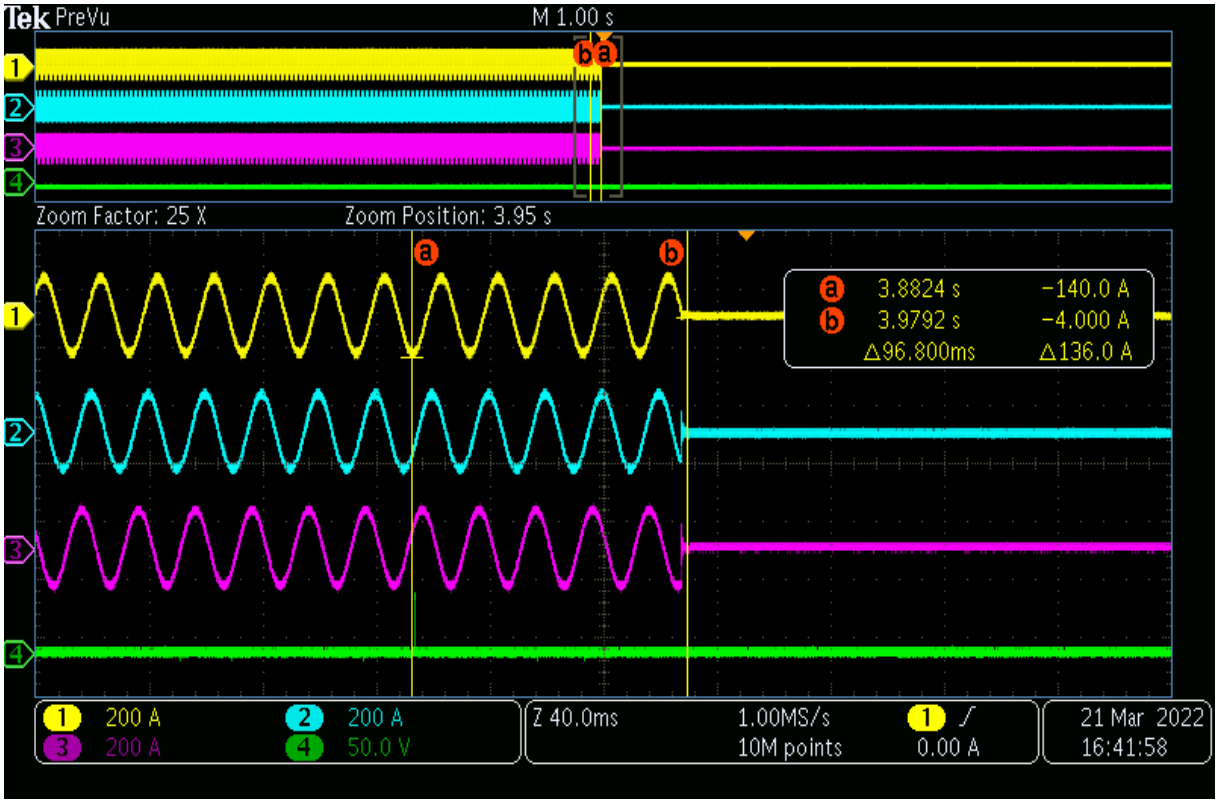
Undervoltage - Test 1: Trip time



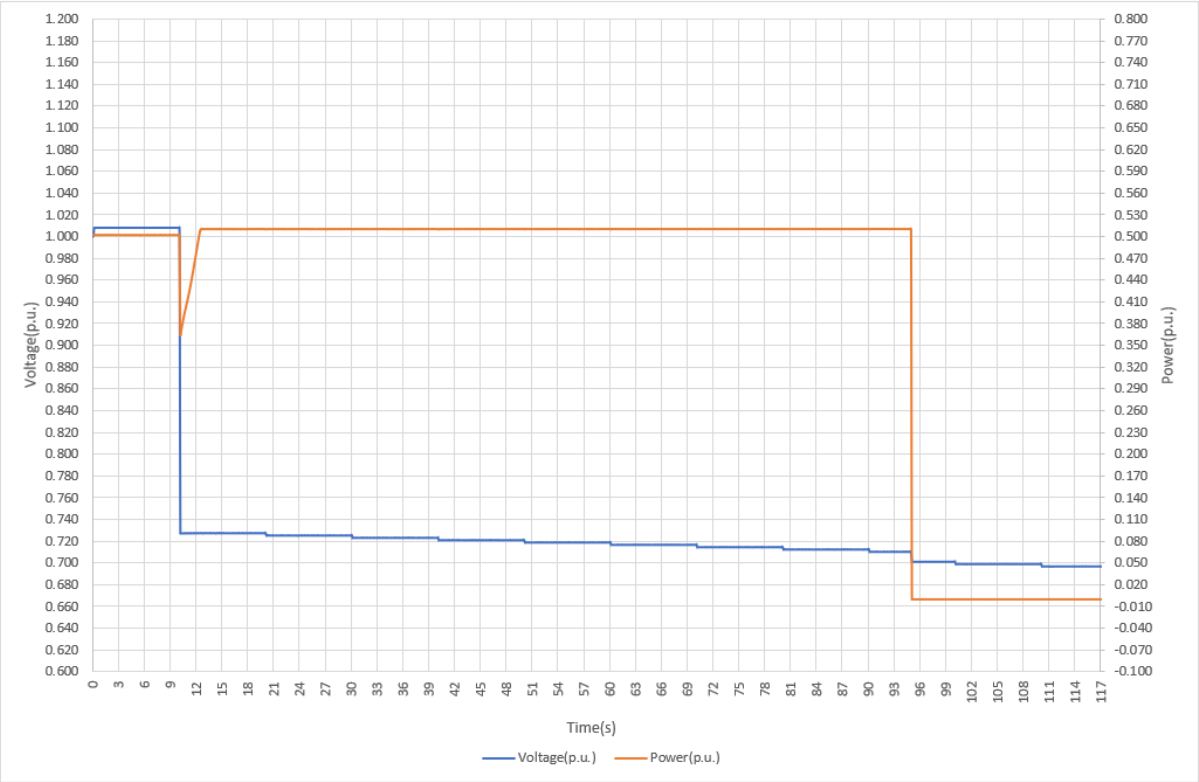
Under voltage - Test 2: Trip value



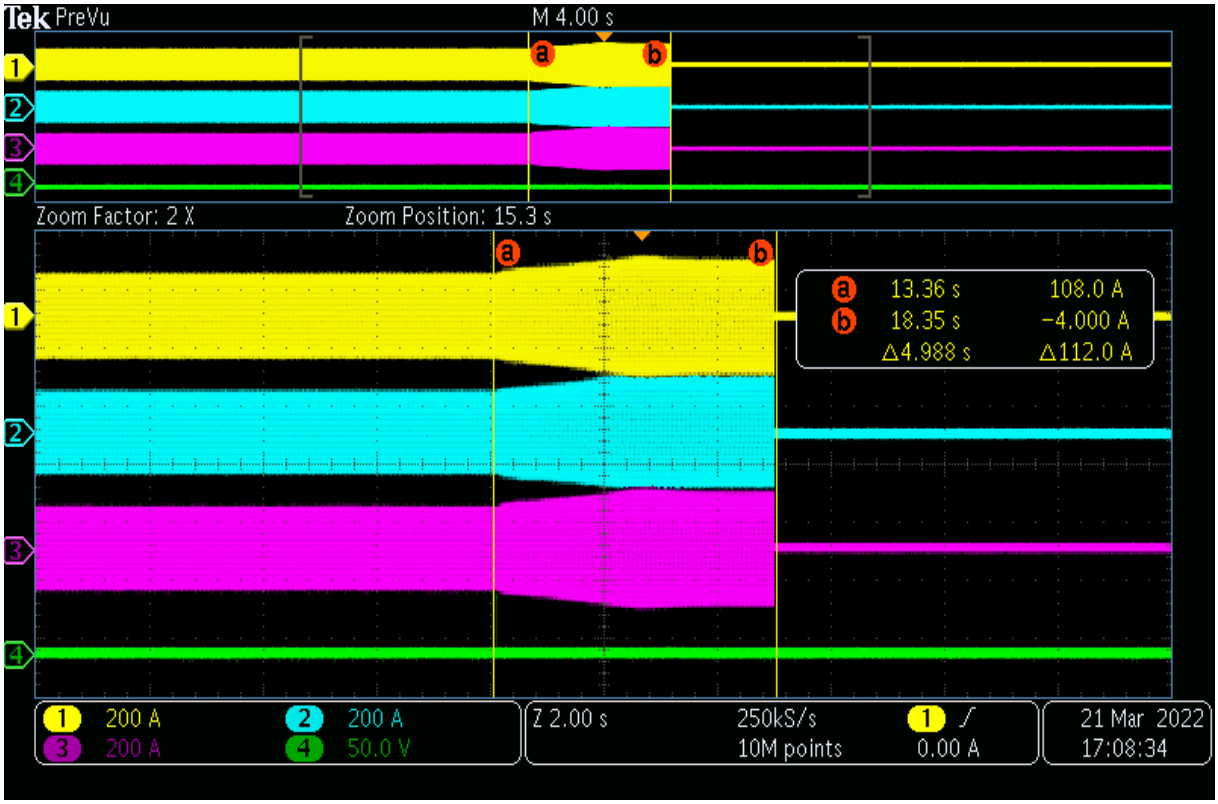
Under voltage - Test 2: Trip time



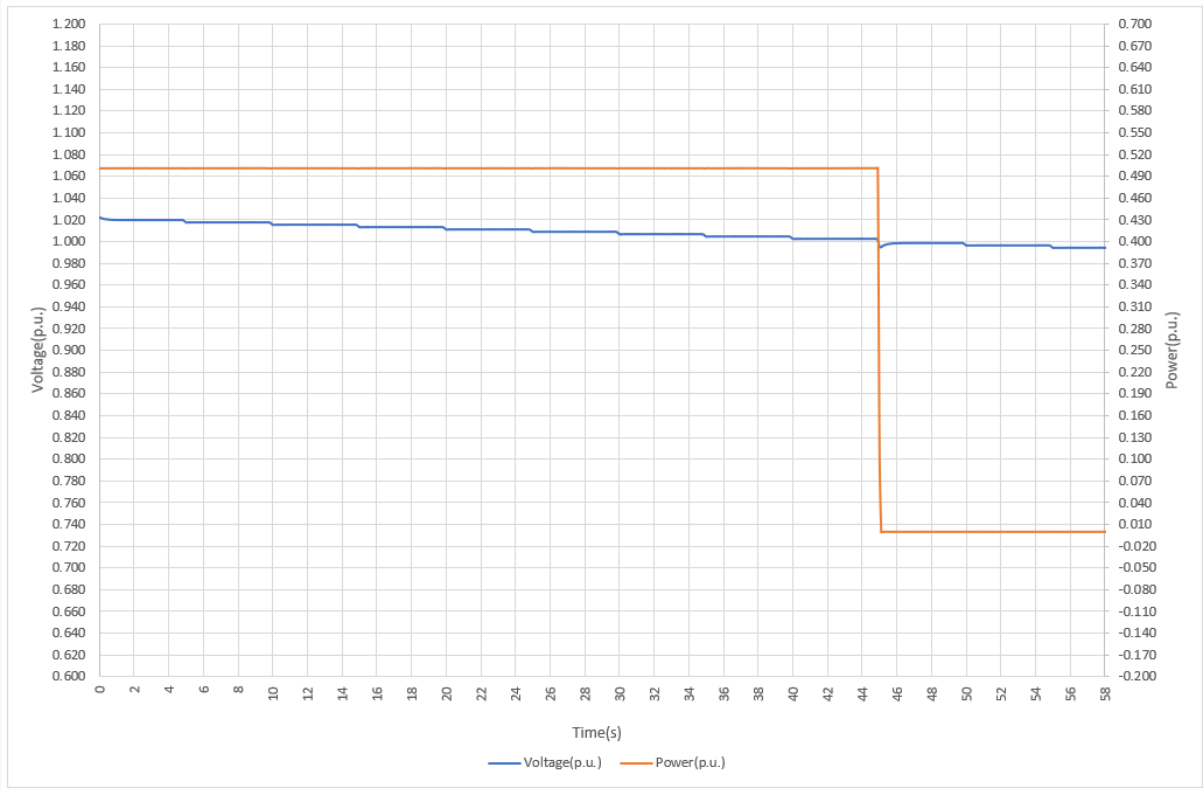
Undervoltage - Test 3: Trip value



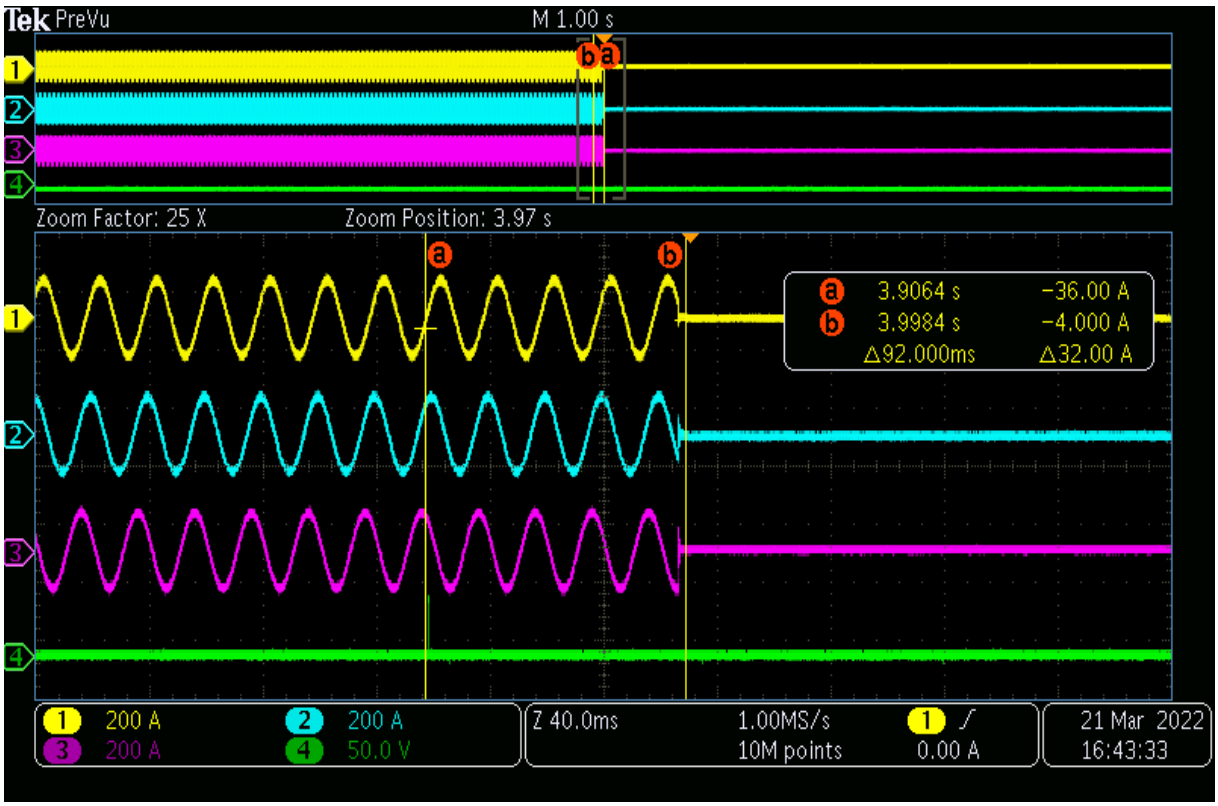
Undervoltage - Test 3: Trip time



Under voltage - Test 4: Trip value



Under voltage - Test 4: Trip time



4.6.1.2 Overvoltage protection

Overvoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Overvoltage threshold stage 1 [59 >]:
- Threshold (1.0 – 1.2) Un adjustable by steps of 0.01 *Un*
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Overvoltage threshold stage 2 [59 > >]:
- Threshold (1.0 – 1.3) Un adjustable by steps of 0.01 *Un*
- Operate time (0.1 – 5) s adjustable in steps of 0.05 s

The following definitions apply to the test to verify the clause:

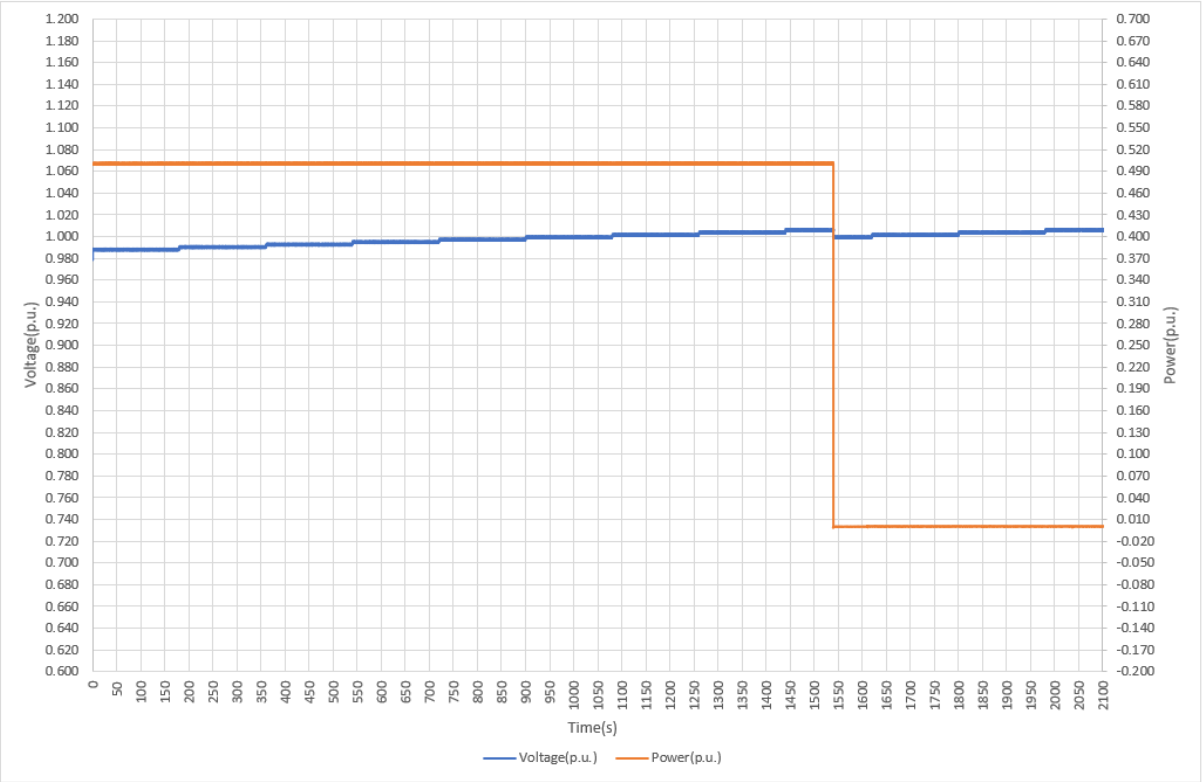
Overvoltage	Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [59 >]:	1	1.000	1.006	+0.006	100.000	99.940	-0.060
	2	1.150(1)	1.155	+0.005	0.100	0.087	-0.032
Stage 2 [59 > >]	3	1.000	1.006	+0.006	5.000	4.974	-0.026
	4	1.200(1)	1.204	+0.004	0.100	0.094	-0.062

(1) As the manufacturer declared, the overvoltage stage 1 and stage 2 of this inverter is adjustable from 1.0Un to 1.20Un.

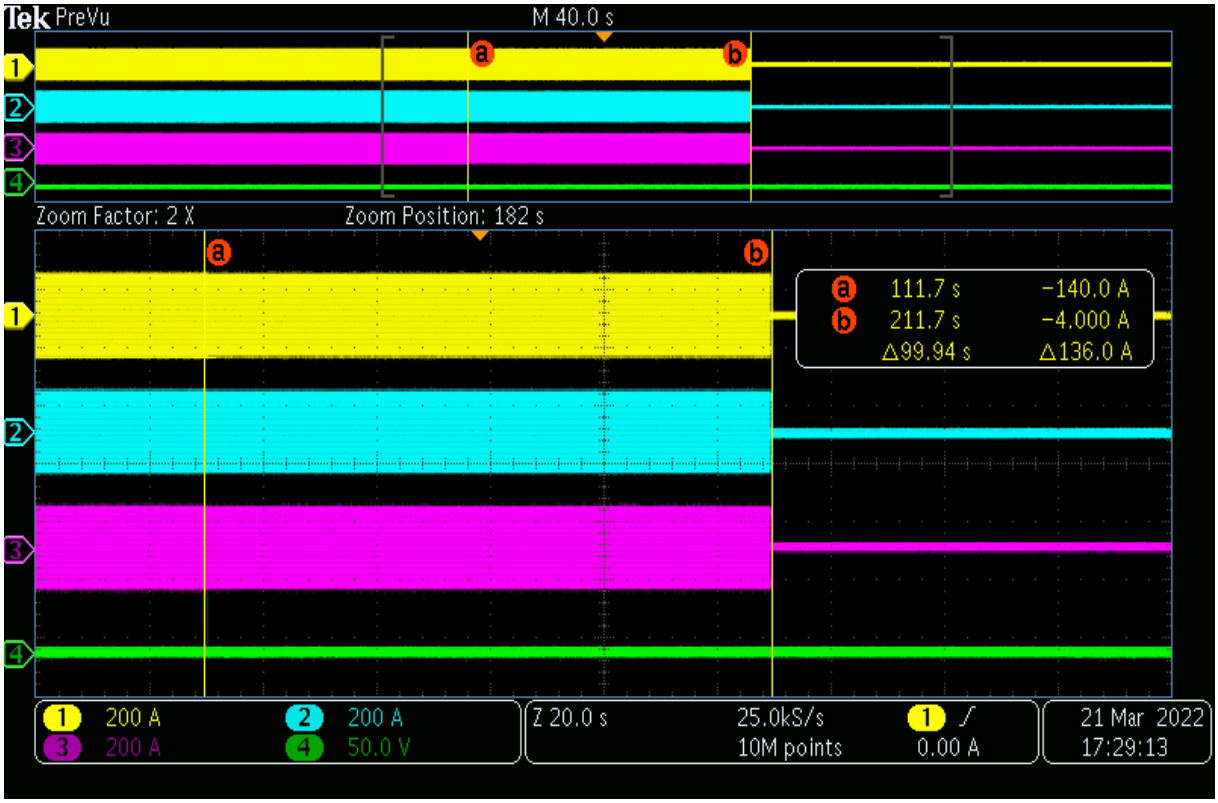
Remark: The virtual neutral line was used in the test.

Test results are represented at diagrams below.

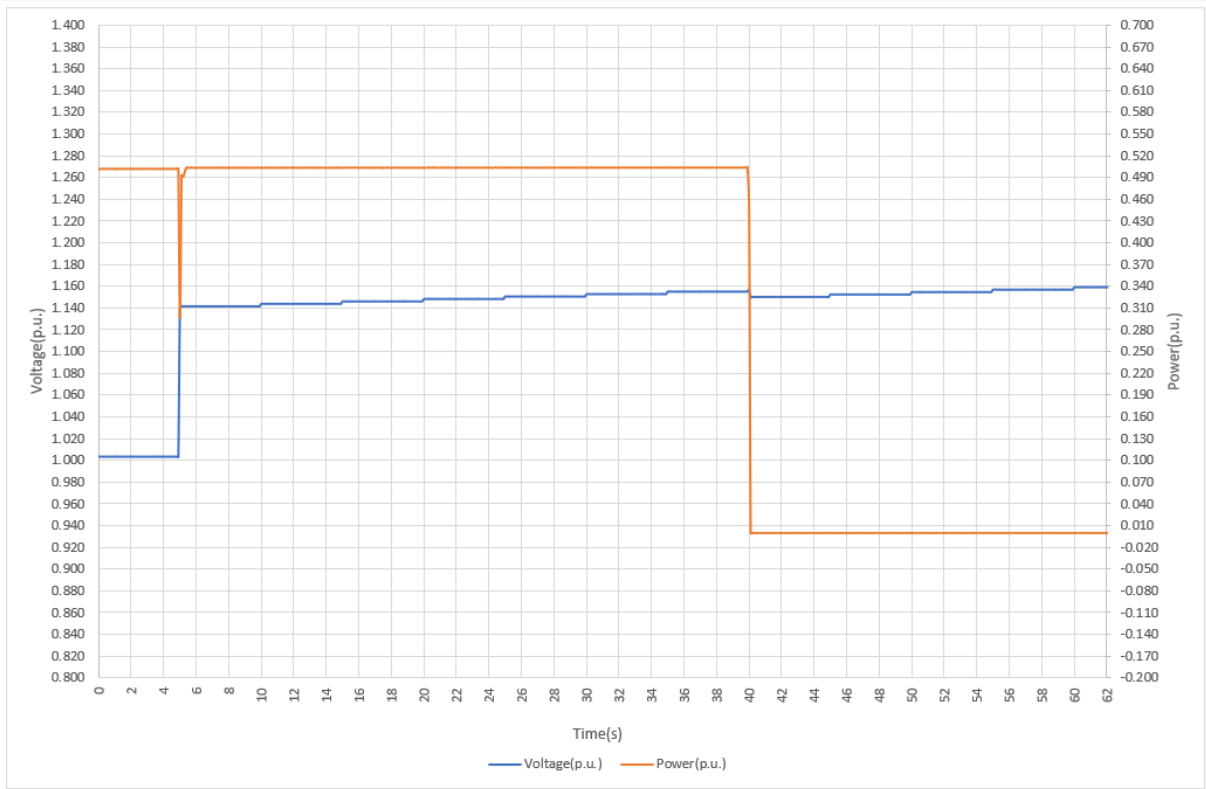
Overvoltage - Test 1: Trip value



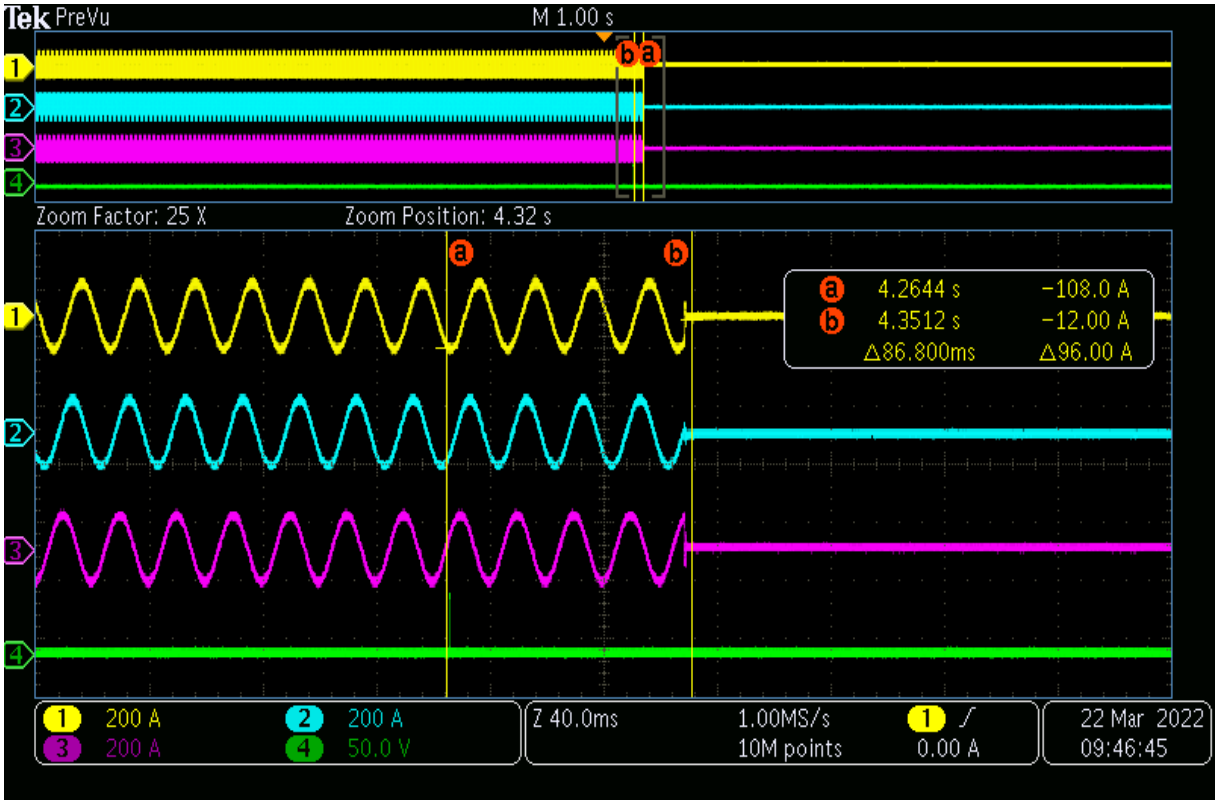
Overvoltage - Test 1: Trip time



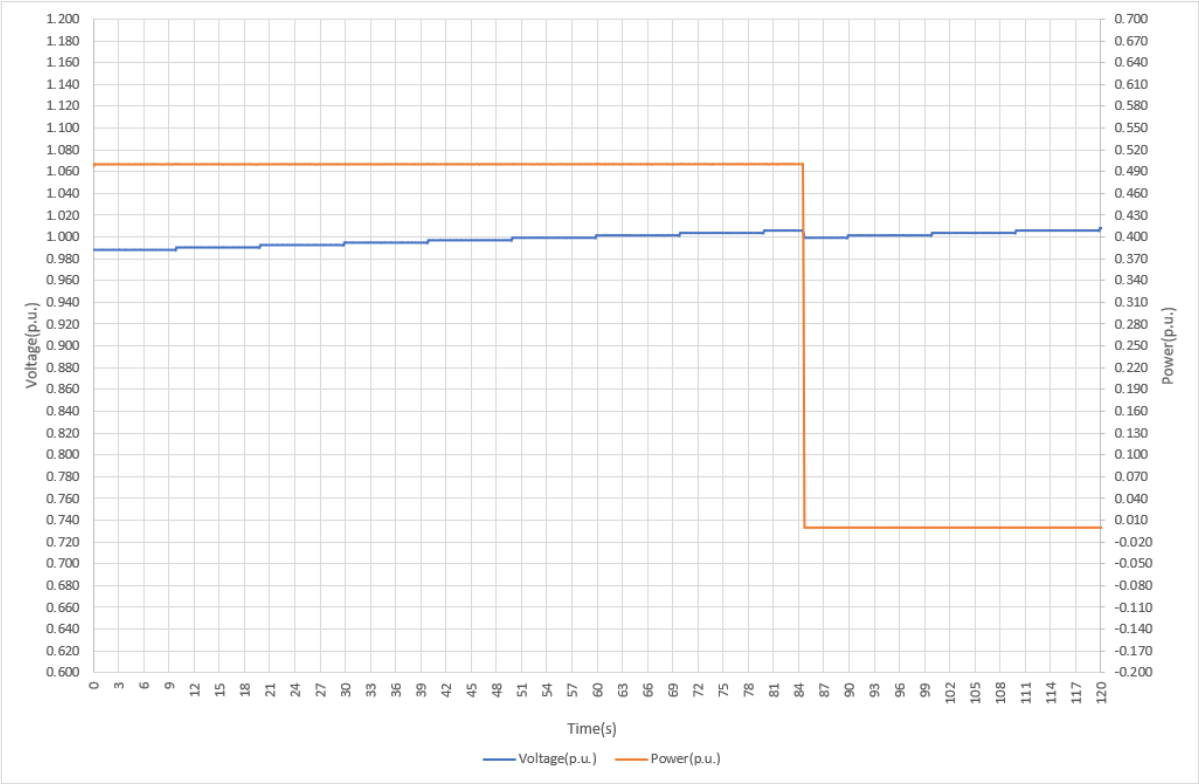
Overvoltage - Test 2: Trip value



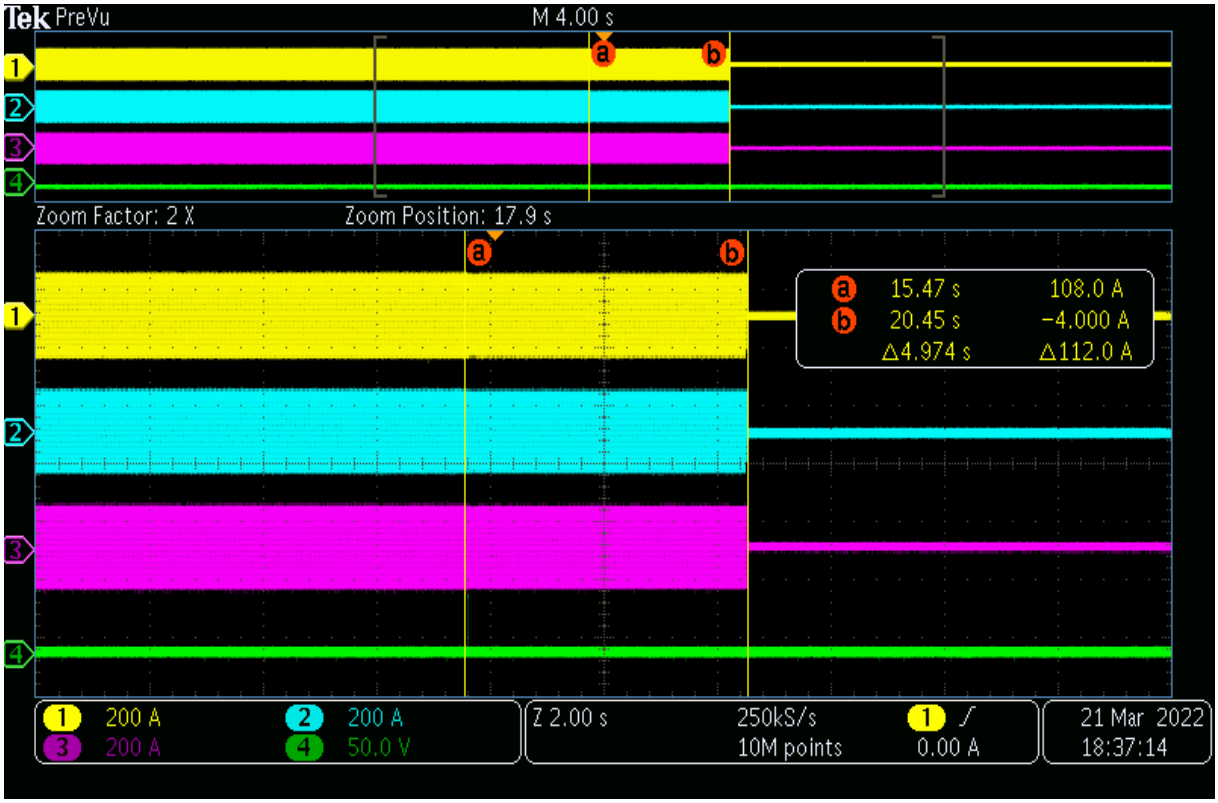
Overvoltage - Test 2: Trip time



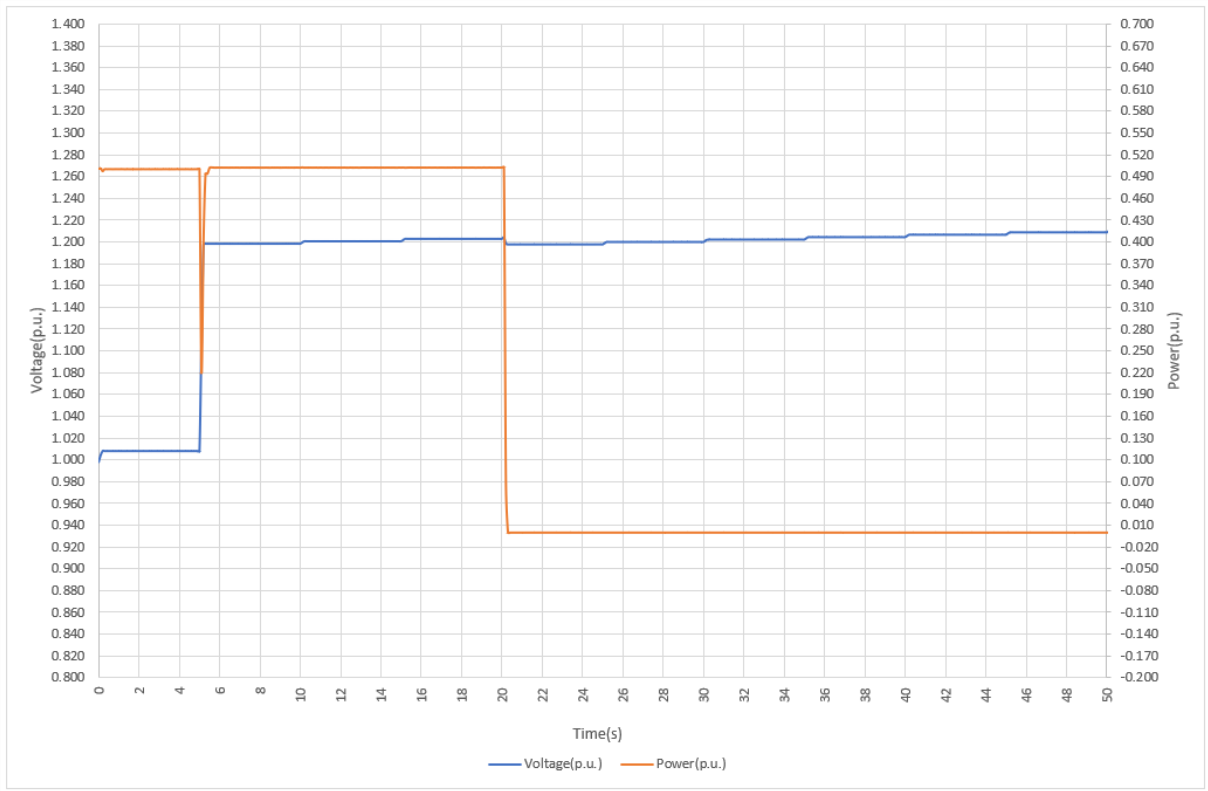
Overvoltage - Test 3: Trip value



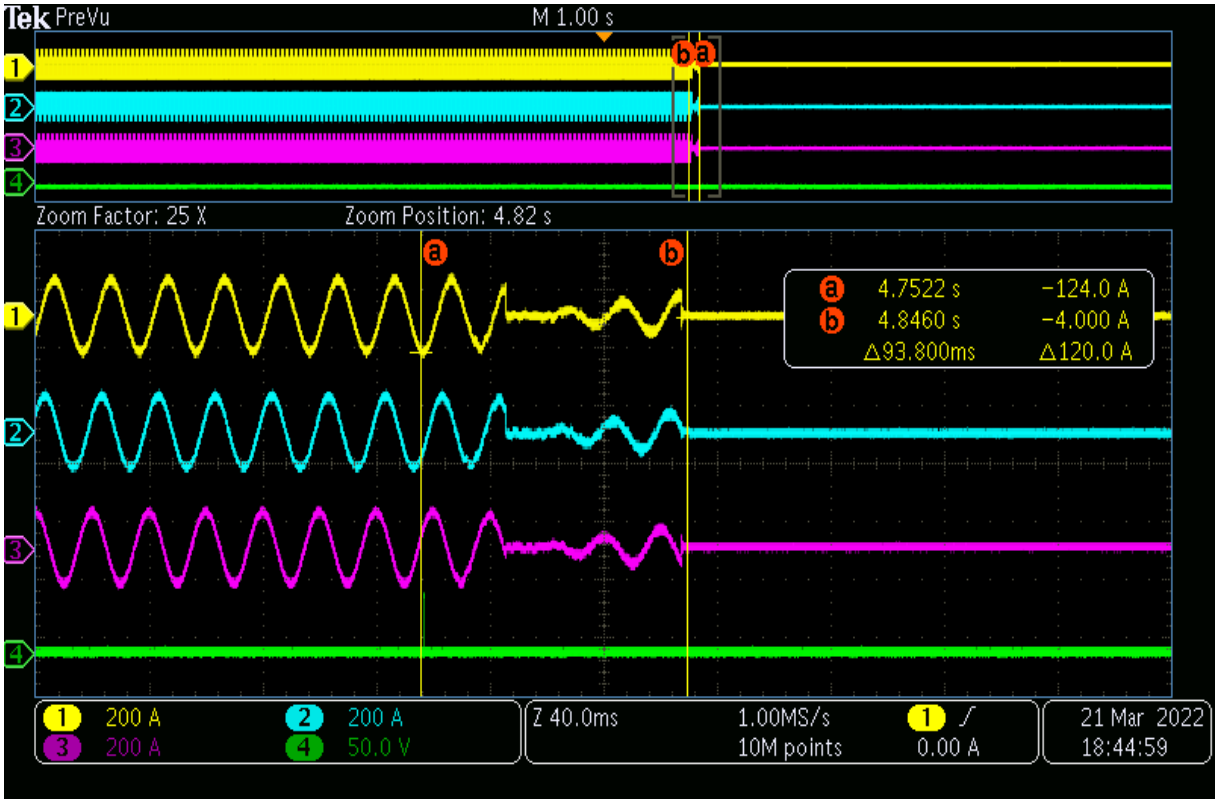
Overvoltage - Test 3: Trip time



Overvoltage - Test 4: Trip value



Overvoltage - Test 4: Trip time



4.6.1.3 Overvoltage 10 min mean protection

The function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. The calculation of a new 10 min value at least every 3 s is sufficient, which is then to be compared with the threshold value.

- Threshold (1.0 – 1.15) *Un* adjustable by steps of 0.01 *Un*
- Start time ≤ 3s not adjustable
- Time delay setting = 0 ms

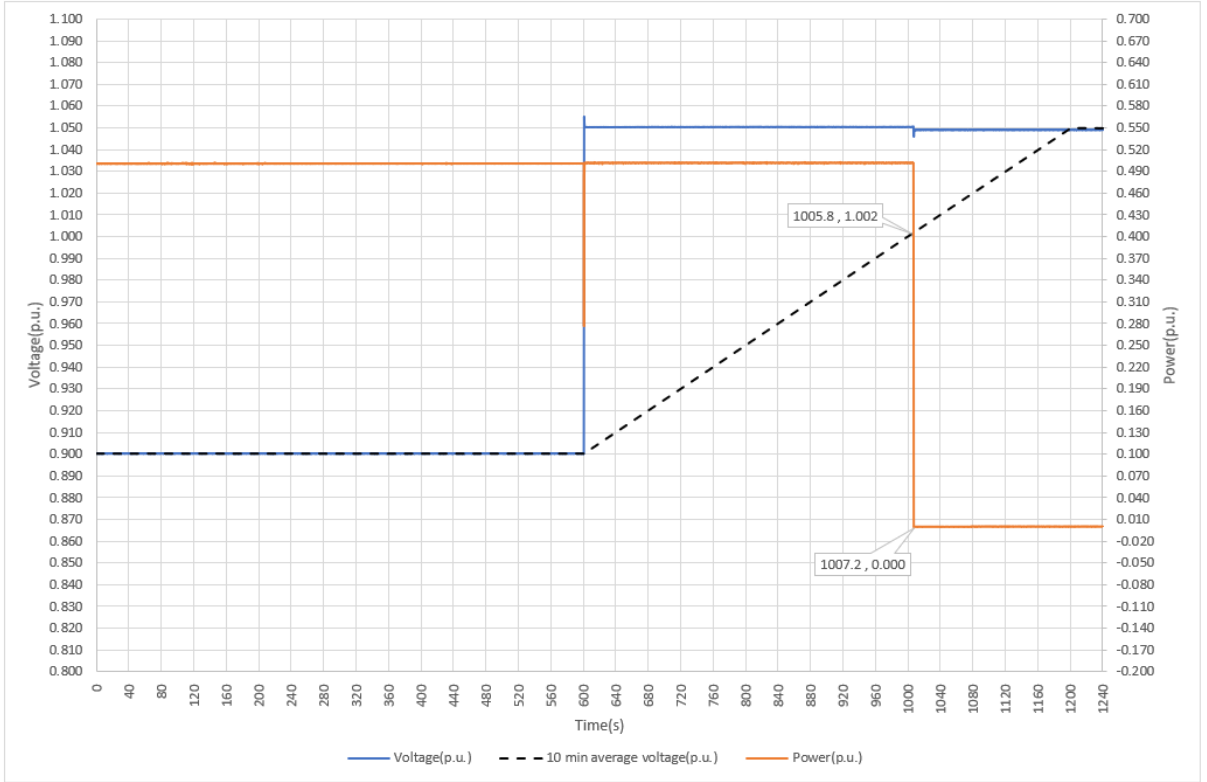
The following definitions apply to the test to verify the clause:

Test No.	Voltage setting (p.u.)	Voltage meas. (p.u.)	Voltage deviation (p.u.)	Trip time meas. (s)	Trip time limited
1	1.000	1.002	+0.002	1.4	≤ 3.0s
2	1.150	1.151	+0.001	1.4	≤ 3.0s

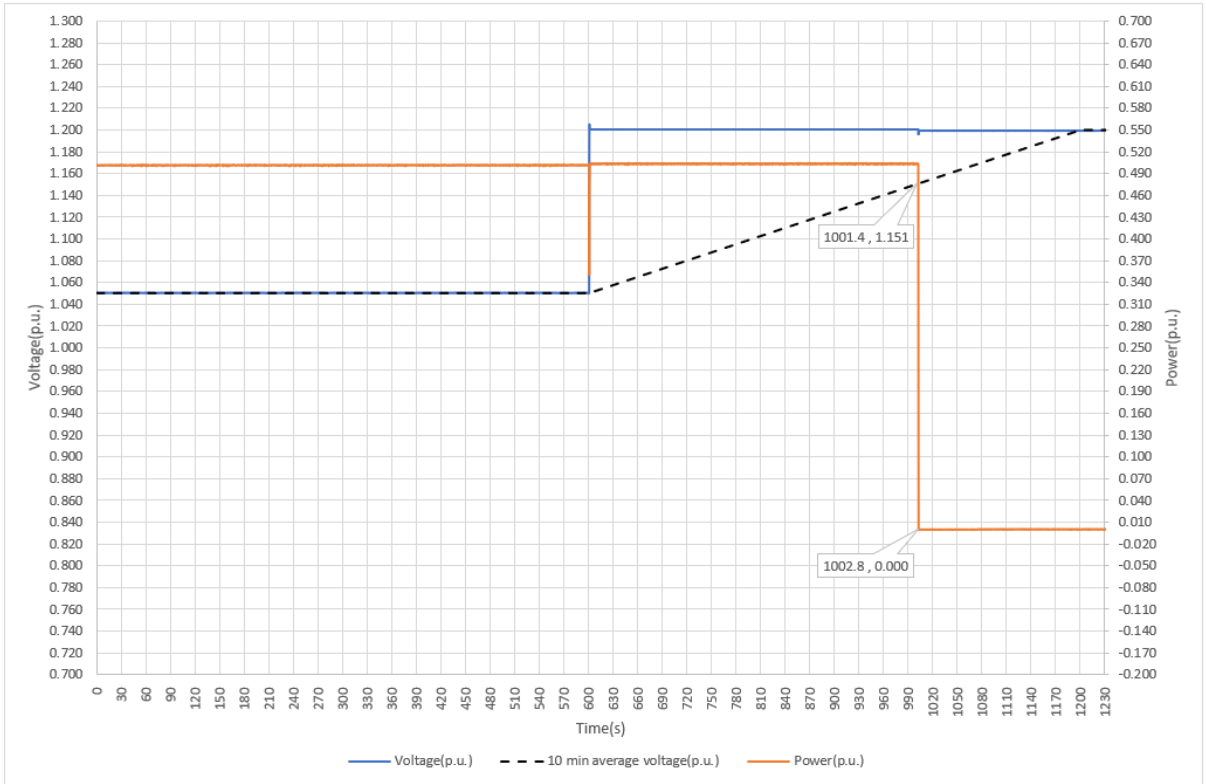
Remark: The trip voltage accuracy tolerance is ±0.01 Un.

Test results are represented at diagrams below.

Overvoltage 10 min mean protection - Test 1



Overvoltage 10 min mean protection - Test 2



4.6.1.4 Underfrequency protection

Underfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Underfrequency threshold stage 1 [81 <]:
- Threshold (47.0 – 50.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Underfrequency threshold stage 2 [81 <<]:
- Threshold (47.0 – 50.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 – 5) s adjustable in steps of 0.05 s

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.

The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.

Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen based on undervoltage protection.

The following definitions apply to the test to verify the clause:

Under frequency	Test No.	Frequency setting (Hz)	Frequency meas. (Hz)	Frequency deviation (Hz)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [81 <]	1	47.00	47.00	0.00	100.000	99.960	-0.040
	2	50.00	50.01	+0.01	0.100	0.094	-0.058
Stage 2 [81 < <]	3	47.00	47.00	0.00	5.000	4.886	-0.114
	4	50.00	50.01	+0.01	0.100	0.083	-0.017

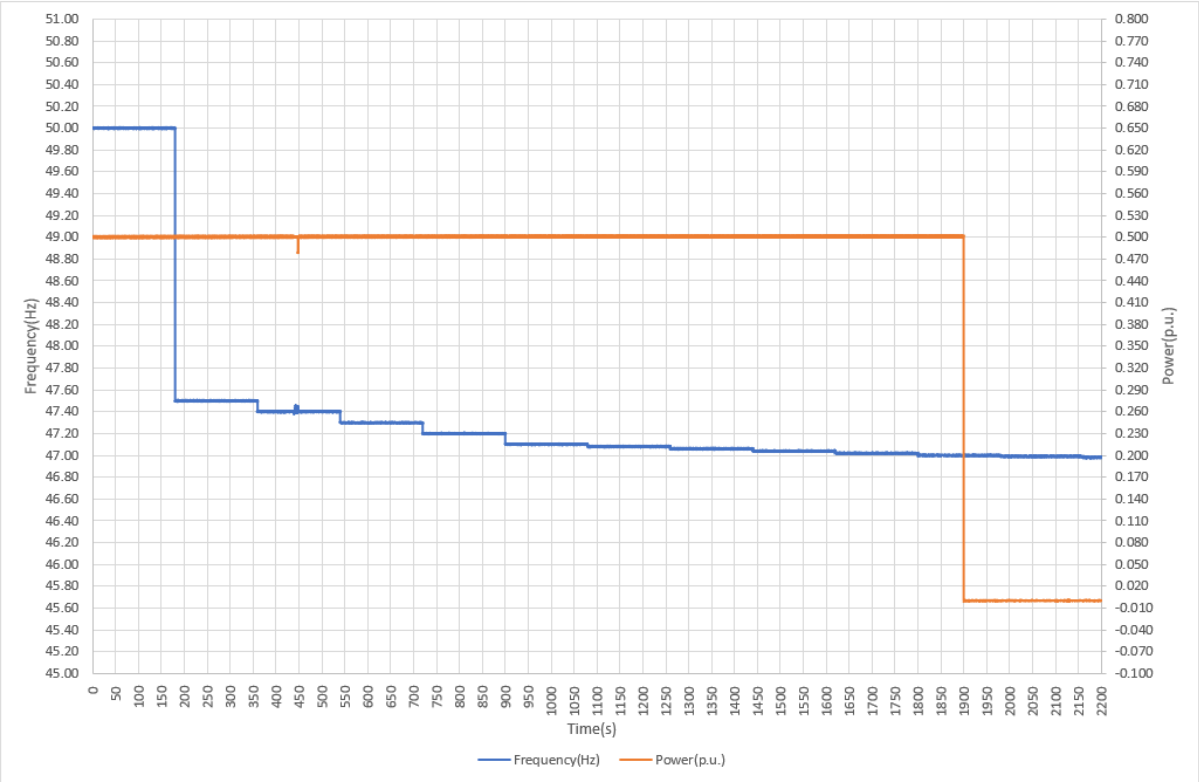
Voltage protection threshold setting (p.u.)	Test No.	Frequency setting (Hz)	Voltage setting (p.u.)	Trip value meas. (Hz)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
0.68 & 1.22	5	47.00	0.709[(1)]	46.97	5.000	4.920	-0.080
	6	47.00	1.189	46.98	5.000	4.923	-0.017
	7	47.00	0.691[(1)]	47.00	Not protected	--	--
		47.00	0.671[(1)]	47.00	5.000	4.903	-0.097
	8	47.00	1.210	47.00	Not protected	--	--
		47.00	1.233	47.00	5.000	4.943	-0.057

[(1)] As the manufacturer declared, the undervoltage stage 1 and stage 2 of this inverter is adjustable from 0.7Un to 1.0Un.

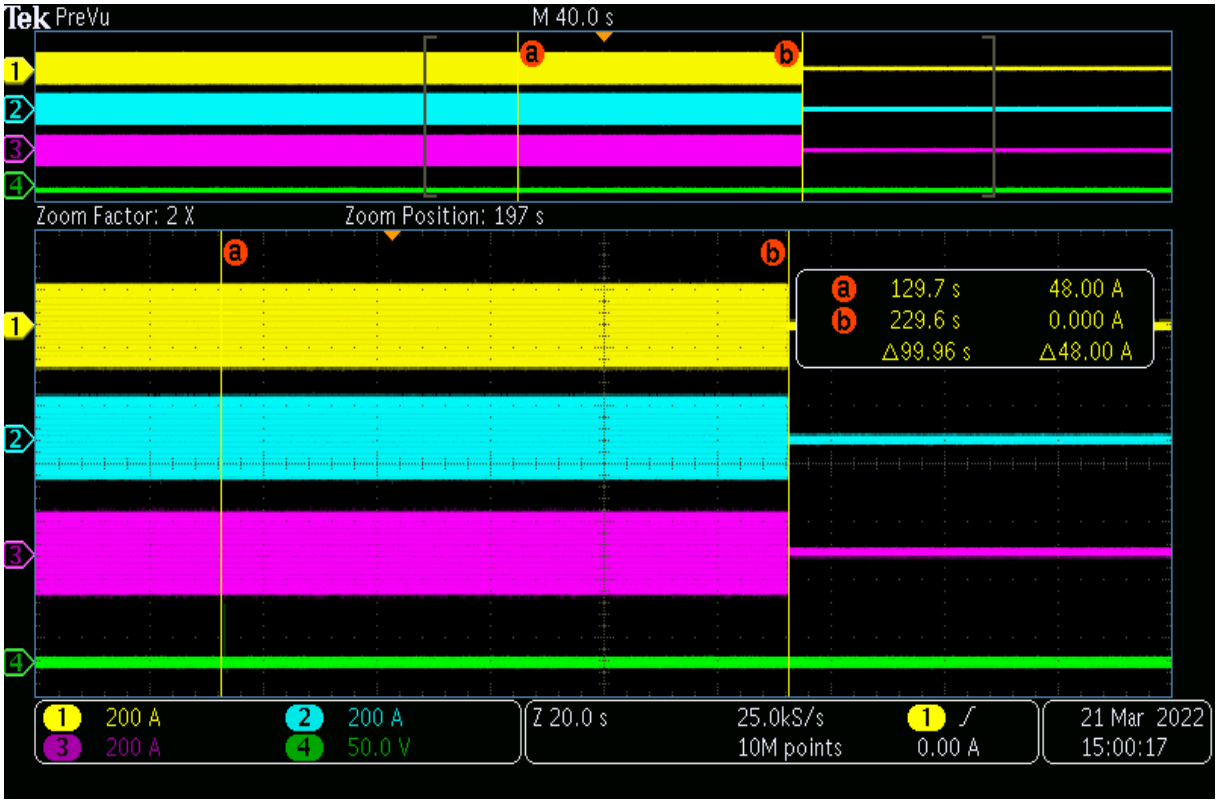
Note: Tests 7 and 8 are comprised by two different steps, the first was to verify the no trip value, and the second step was to verify the trip time.

Test results are represented at diagrams below.

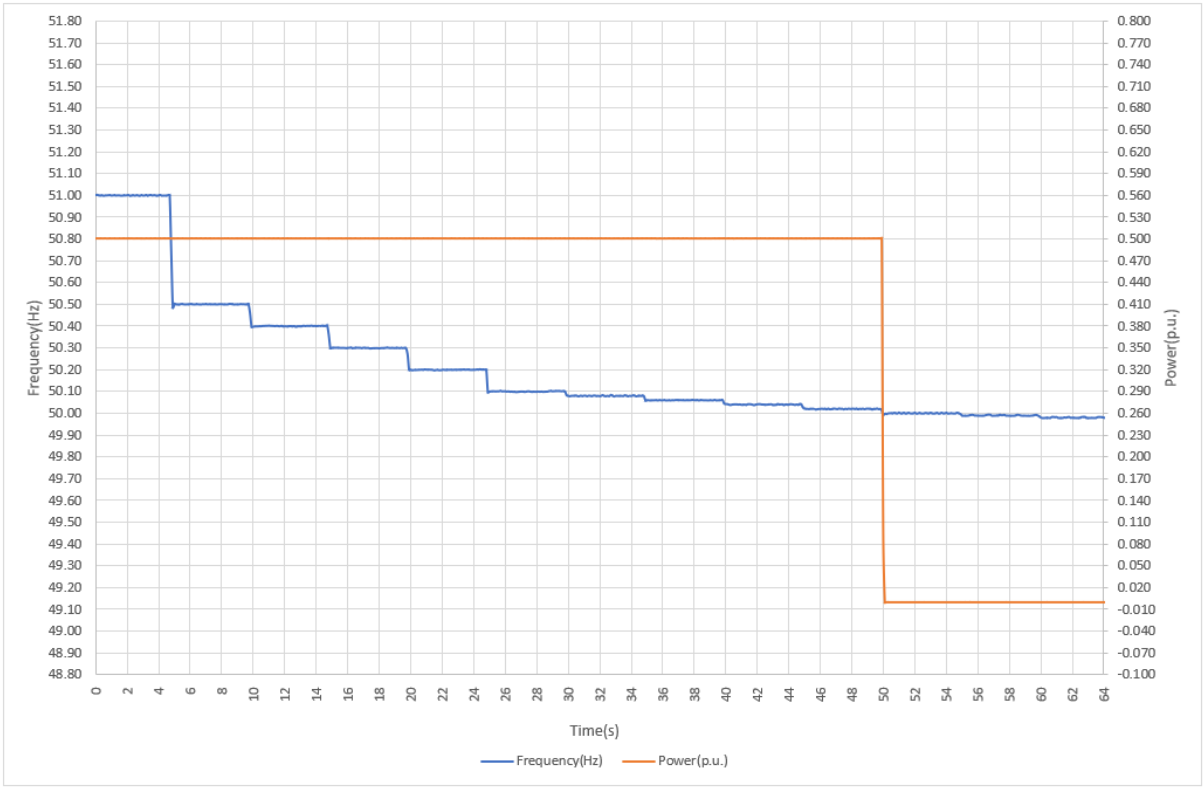
Underfrequency - Test 1: Trip value



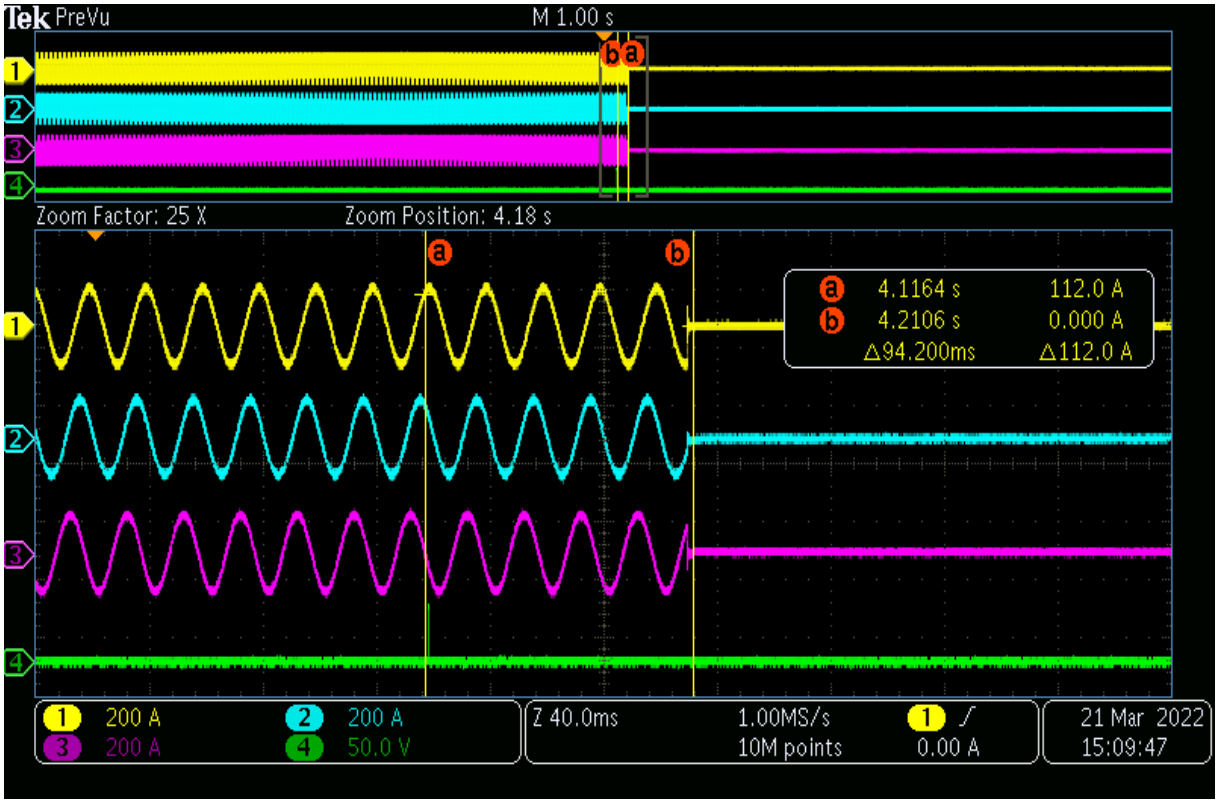
Underfrequency - Test 1: Trip time



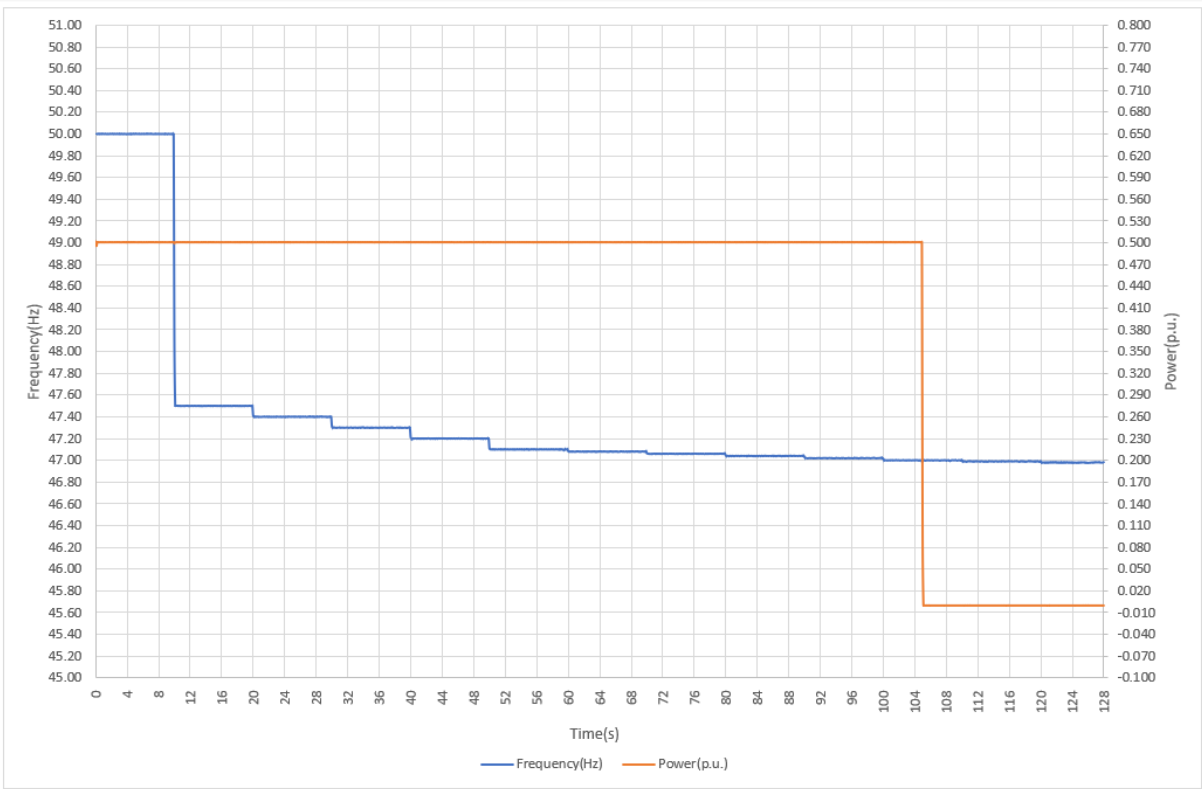
Underfrequency - Test 2: Trip value



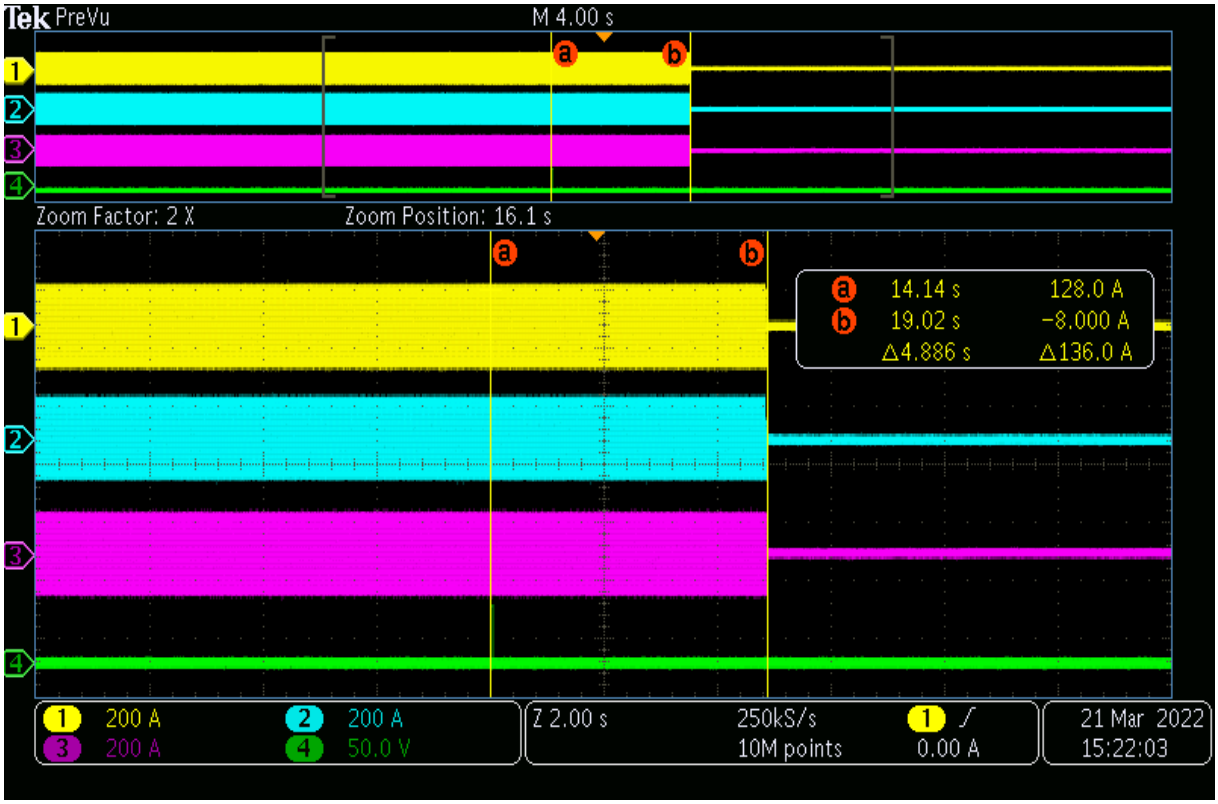
Underfrequency - Test 2: Trip time



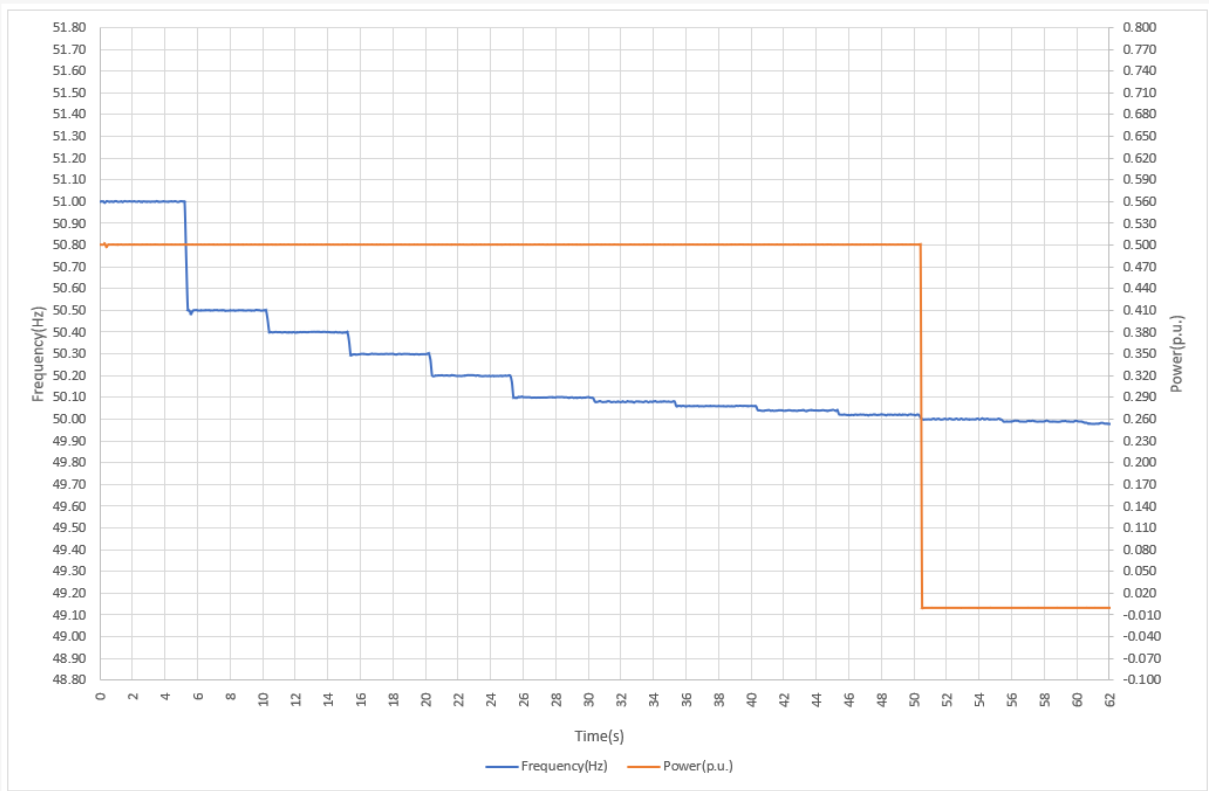
Underfrequency - Test 3: Trip value



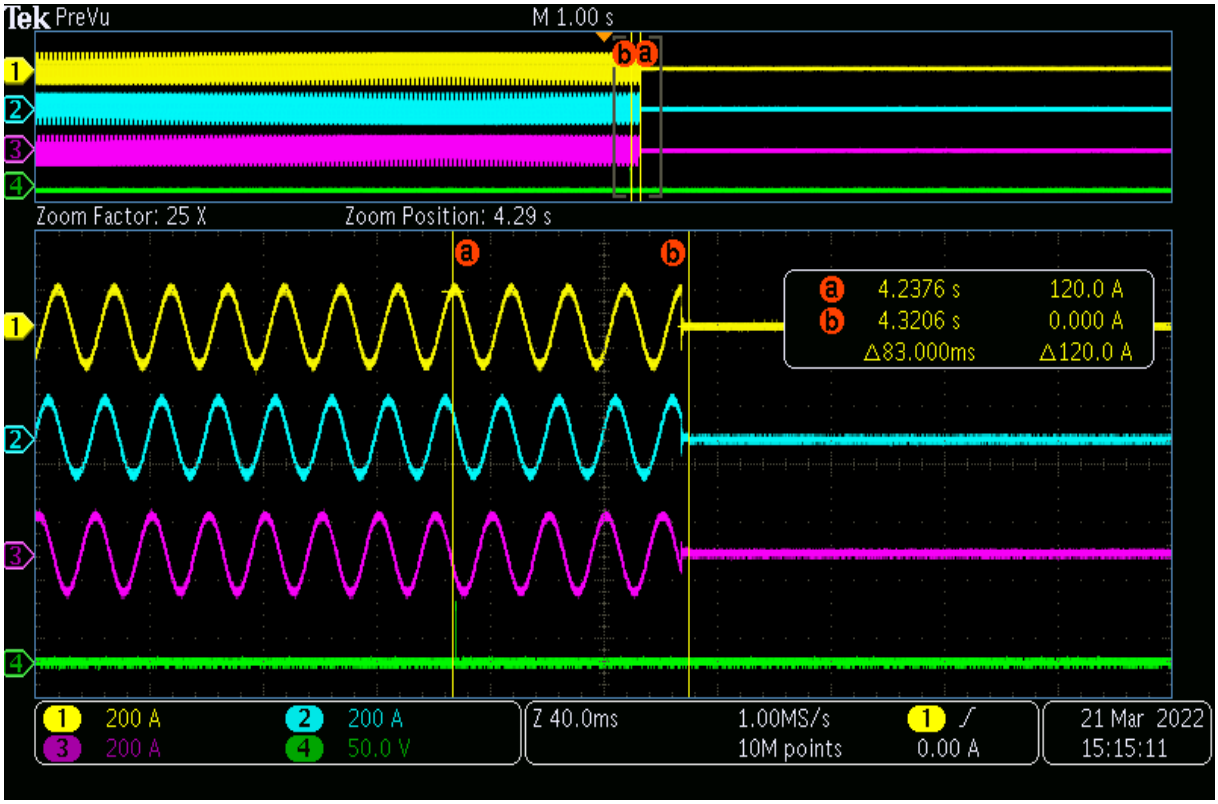
Underfrequency - Test 3: Trip time



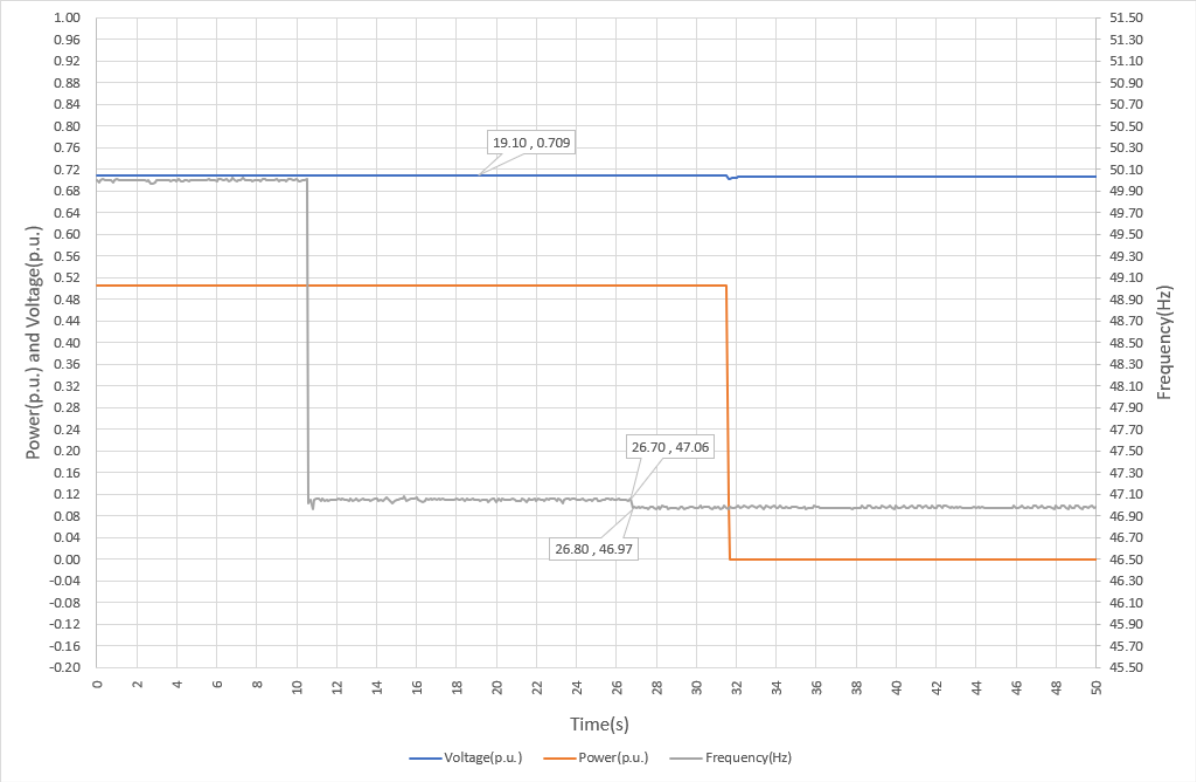
Underfrequency - Test 4: Trip value



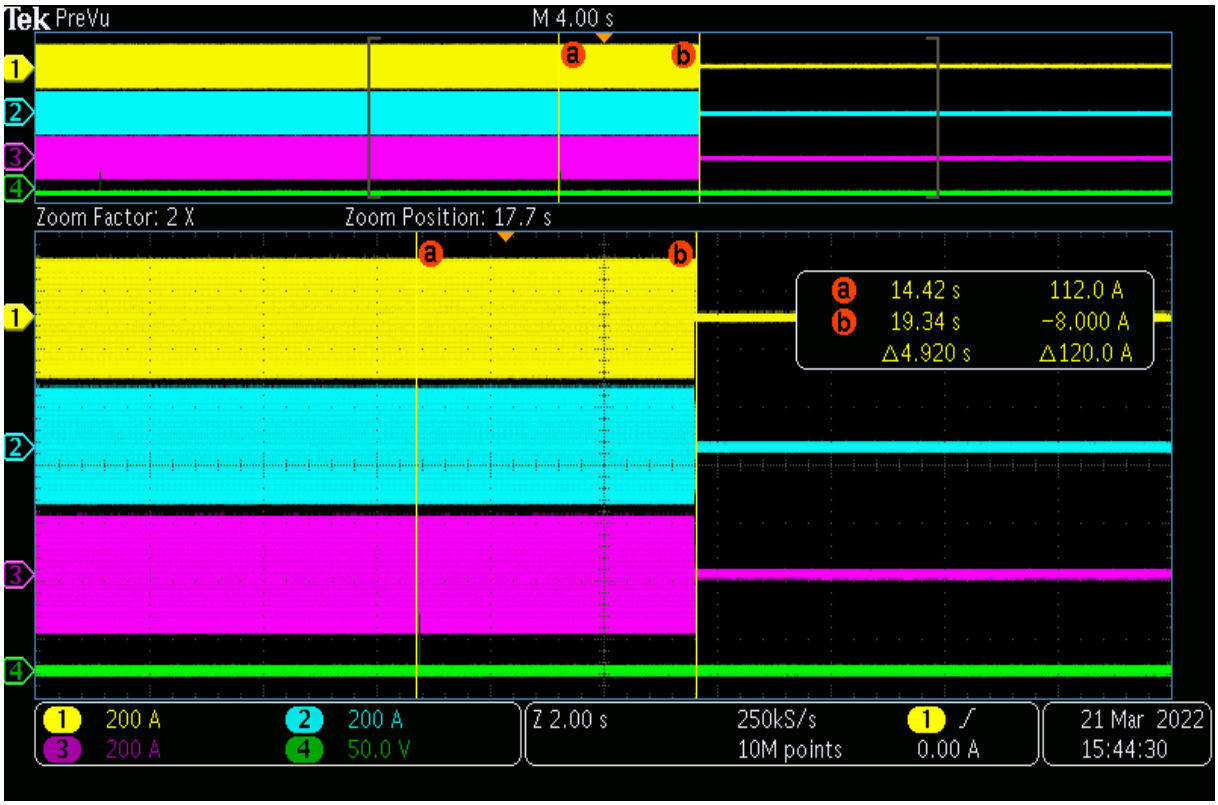
Underfrequency - Test 4: Trip time



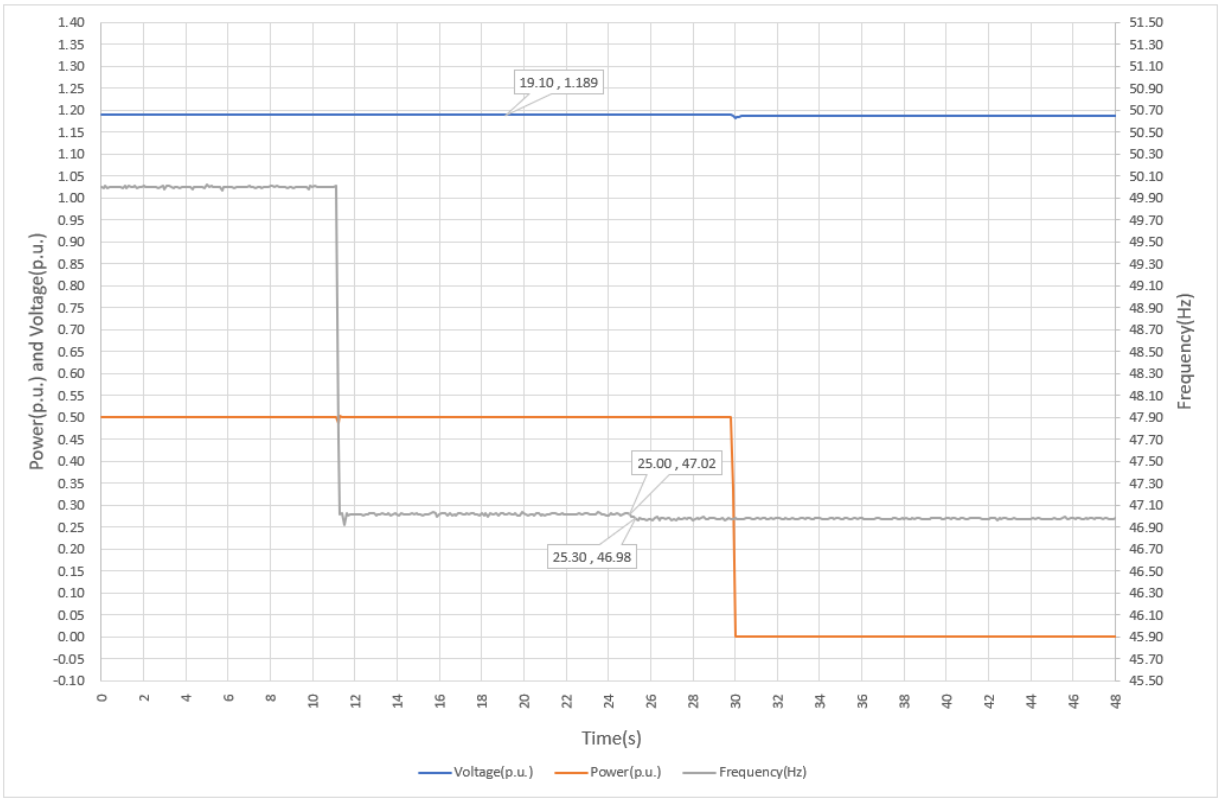
Underfrequency - Test 5: Trip value



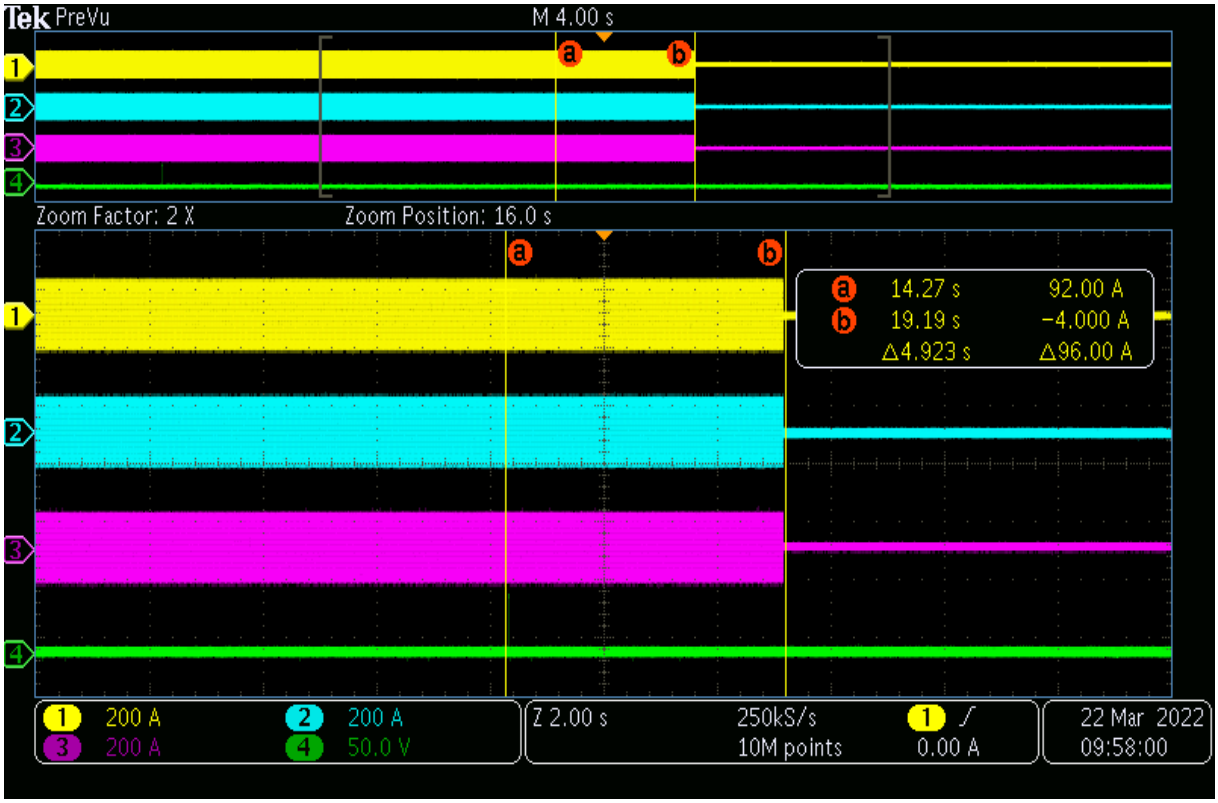
Underfrequency - Test 5: Trip time



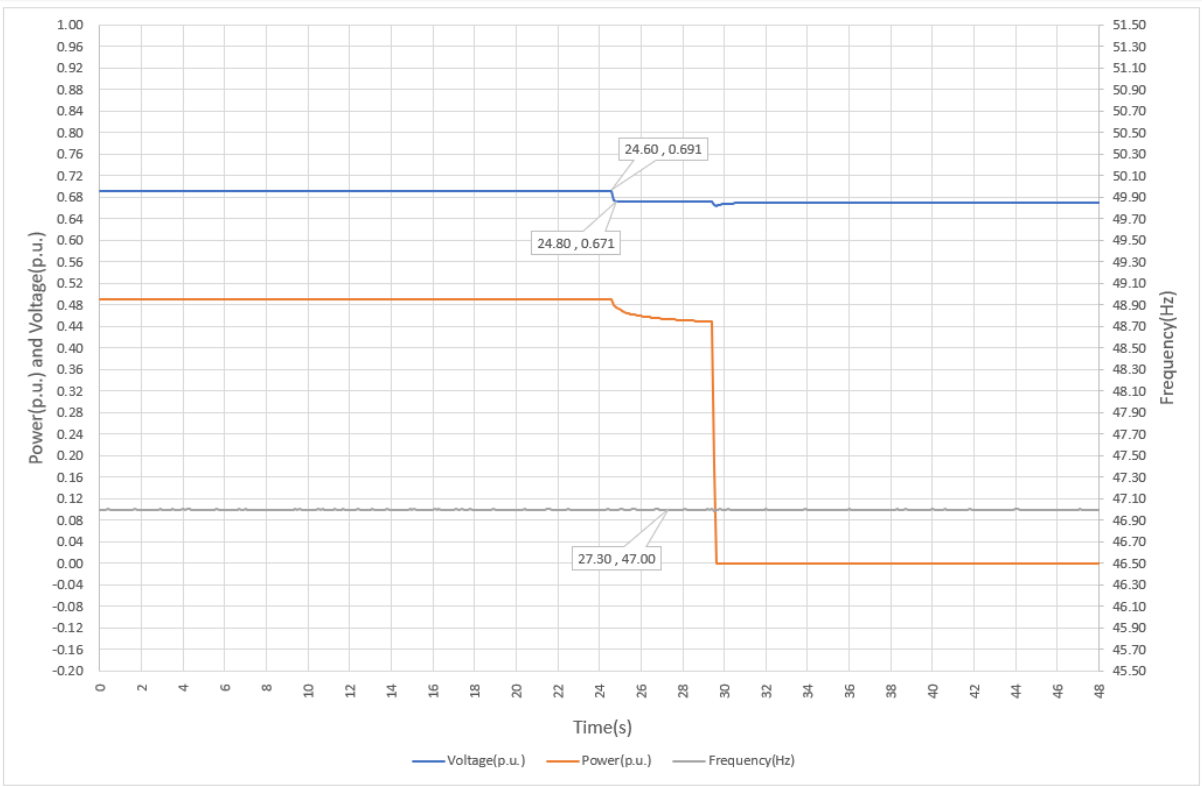
Underfrequency - Test 6: Trip value



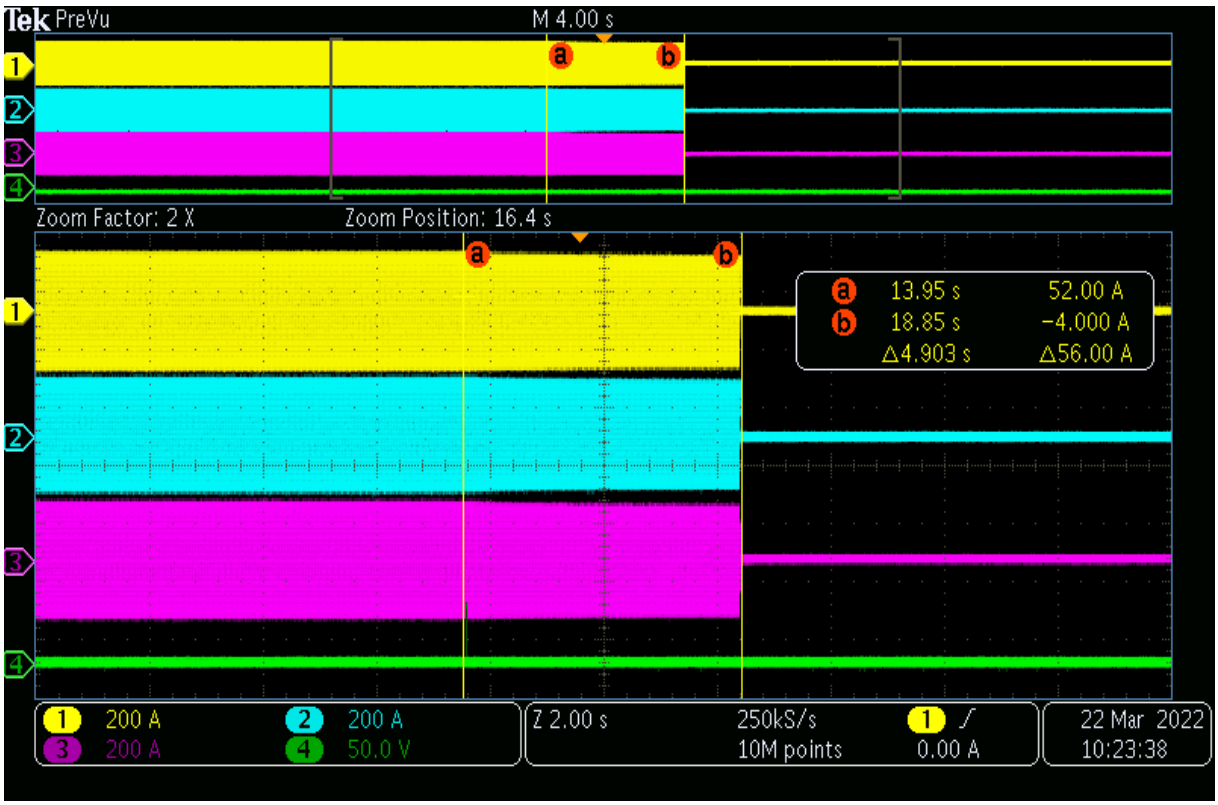
Underfrequency - Test 6: Trip time



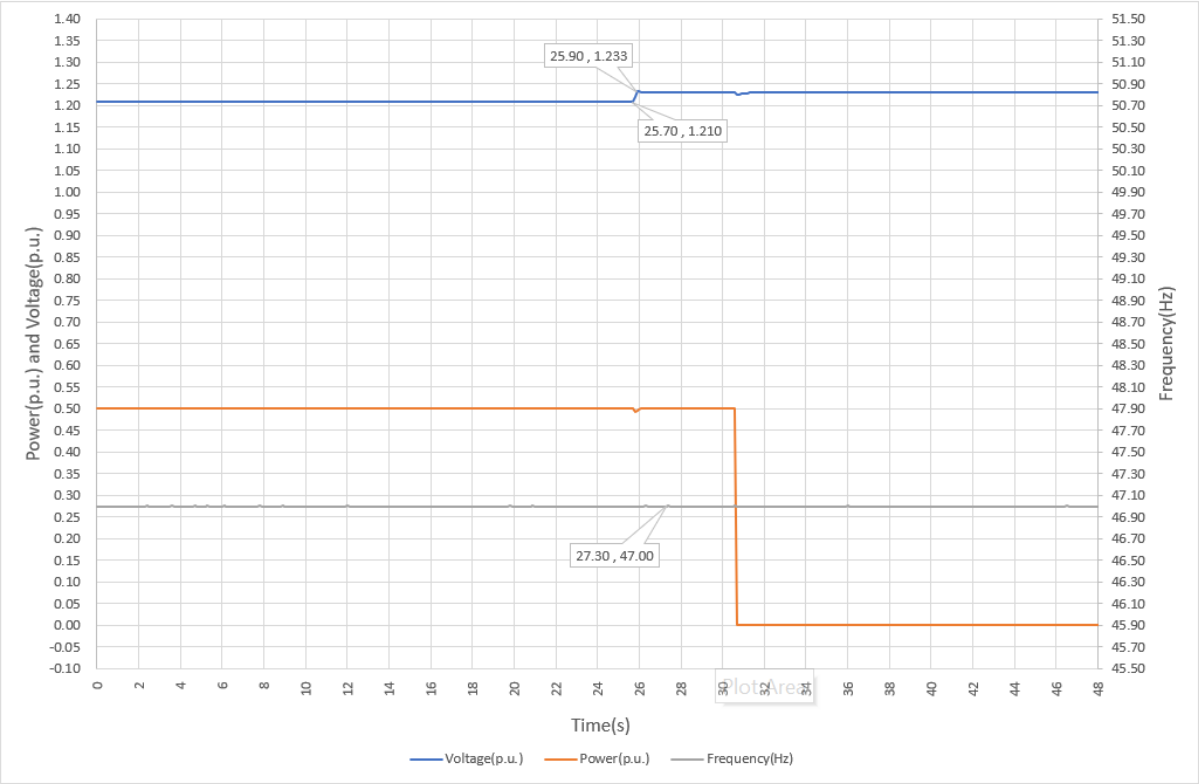
Underfrequency - Test 7: Trip value



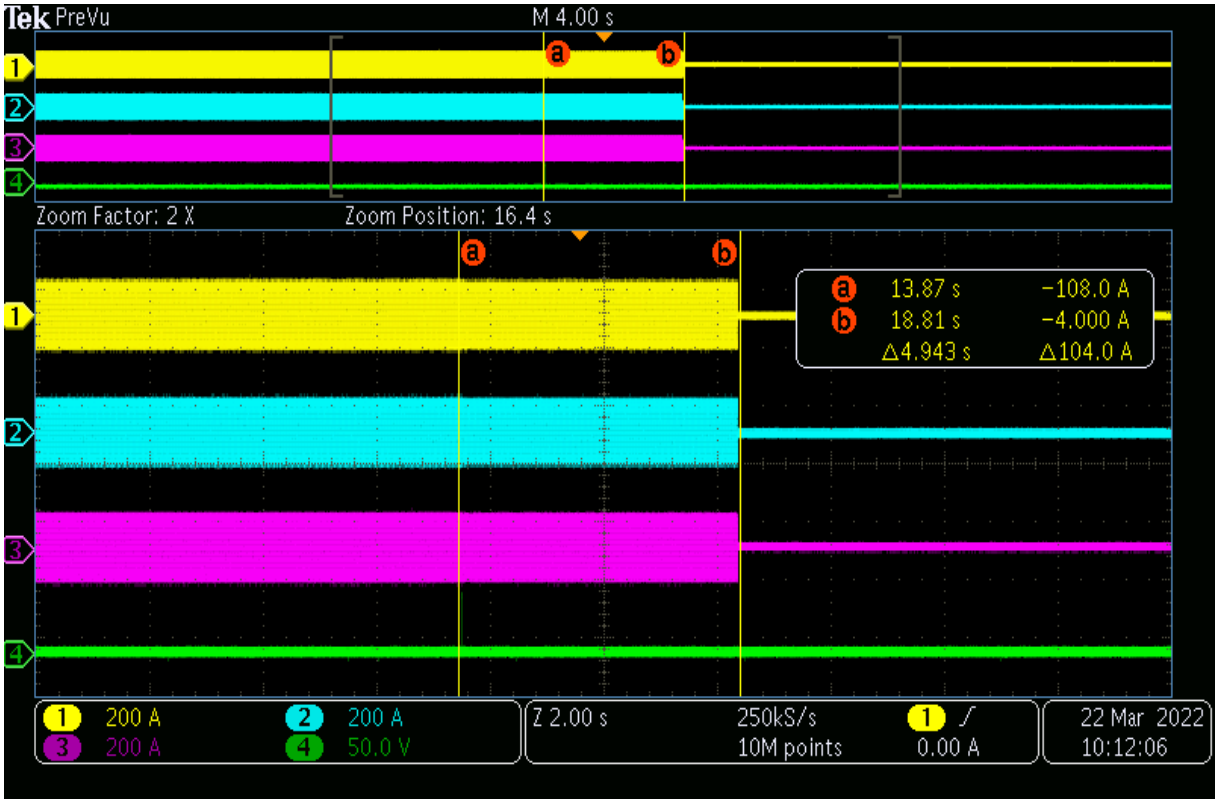
Underfrequency - Test 7: Trip time



Underfrequency - Test 8: Trip value



Underfrequency - Test 8: Trip time



4.6.1.5 Overfrequency protection

Overfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.

Overfrequency threshold stage 1 [81 >]:
- Threshold (50.0 – 52.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 – 100) s adjustable in steps of 0.1 s

Overfrequency threshold stage 2 [81 > >]:
- Threshold (50.0 – 52.0) Hz adjustment by steps of 0.1 Hz
- Operate time (0.1 - 5) s adjustable in steps of 0.05 s

In order to use narrow frequency thresholds for islanding detection (see4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.

The frequency protection shall function correctly in the input voltage range between 20 %Un and 120 %Un and shall be inhibited for input voltages of less than 20 %Un.

The following definitions apply to the test to verify the clause:

Over frequency	Test No.	Frequency setting (Hz)	Frequency meas. (Hz)	Frequency deviation (Hz)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
Stage 1 [81 >]	1	50.00	50.00	0.00	100.000	99.980	-0.020
	2	52.00	51.99	-0.01	0.100	0.087	-0.034
Stage 2 [81 > >]	3	50.00	50.00	0.00	5.000	4.949	-0.051
	4	52.00	51.99	-0.01	0.100	0.076	-0.042

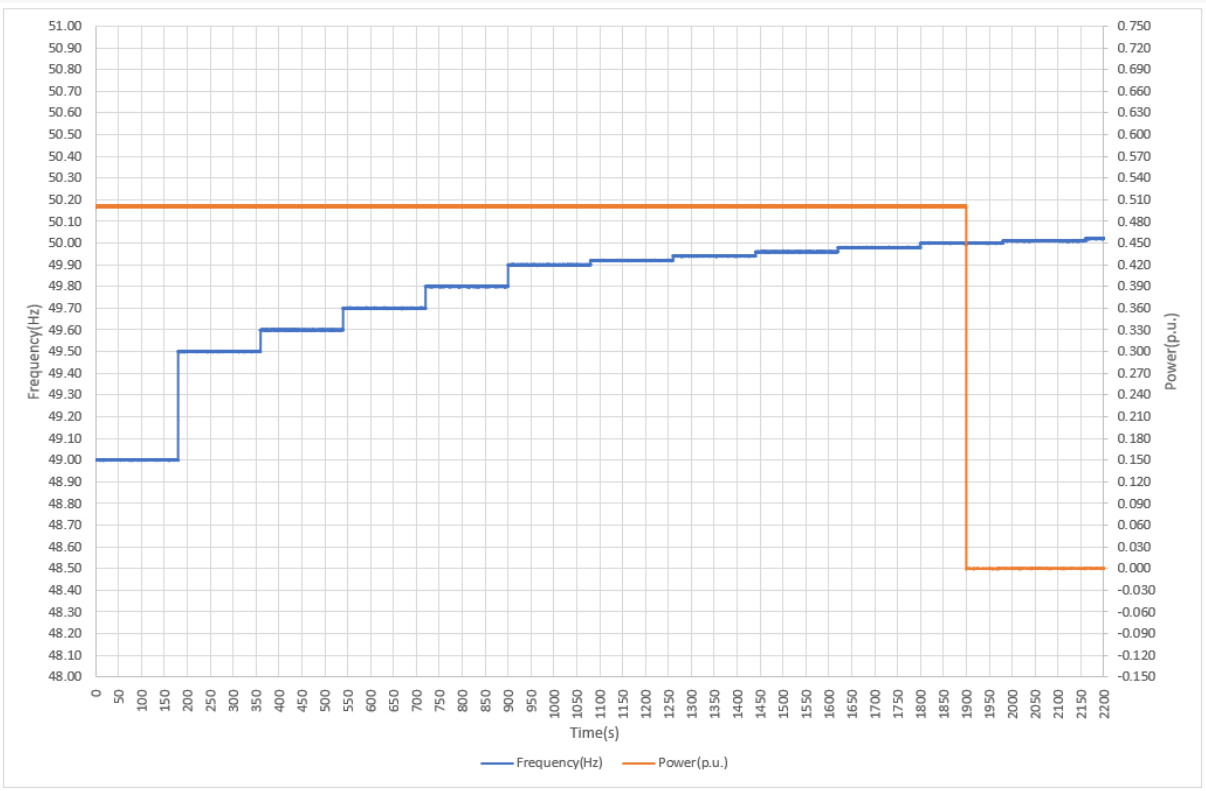
Voltage protection threshold setting (p.u.)	Test No.	Frequency setting (Hz)	Voltage setting (p.u.)	Trip value meas. (Hz)	Trip time setting (s)	Trip time meas. (s)	Trip time deviation (s)
0.68 & 1.22	5	52.00	0.711(1)	52.01	5.000	4.901	-0.099
	6	52.00	1.190	52.02	5.000	4.881	-0.119
	7	52.00	0.691(1)	52.00	Not protected	--	--
		52.00	0.671(1)	52.00	5.000	4.915	-0.085
	8	47.00	1.210	52.00	Not protected	--	--
		47.00	1.231	52.00	5.000	4.927	-0.073

(1) As the manufacturer declared, the undervoltage stage 1 and stage 2 of this inverter is adjustable from 0.7Un to 1.0Un.

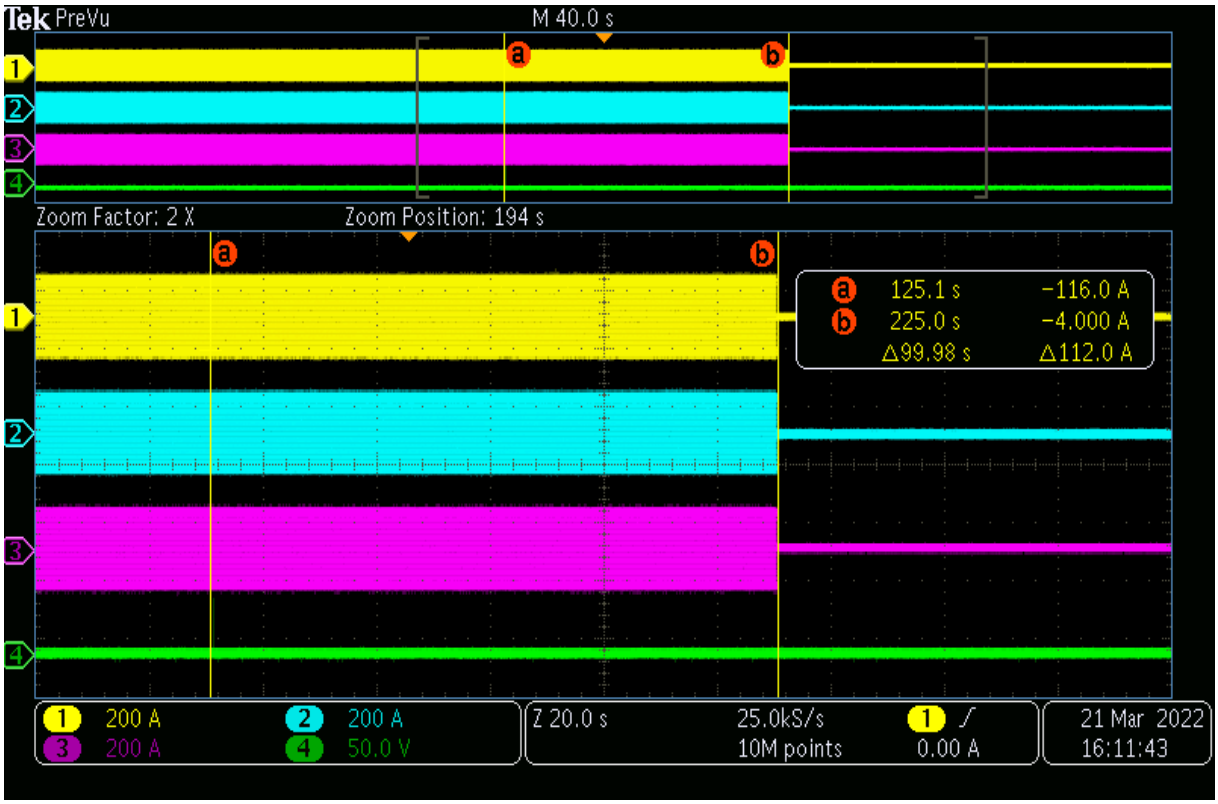
Note: Tests 7 and 8 are comprised by two different steps, the first was to verify the no trip value, and the second step was to verify the trip time.

Test results are represented at diagrams below.

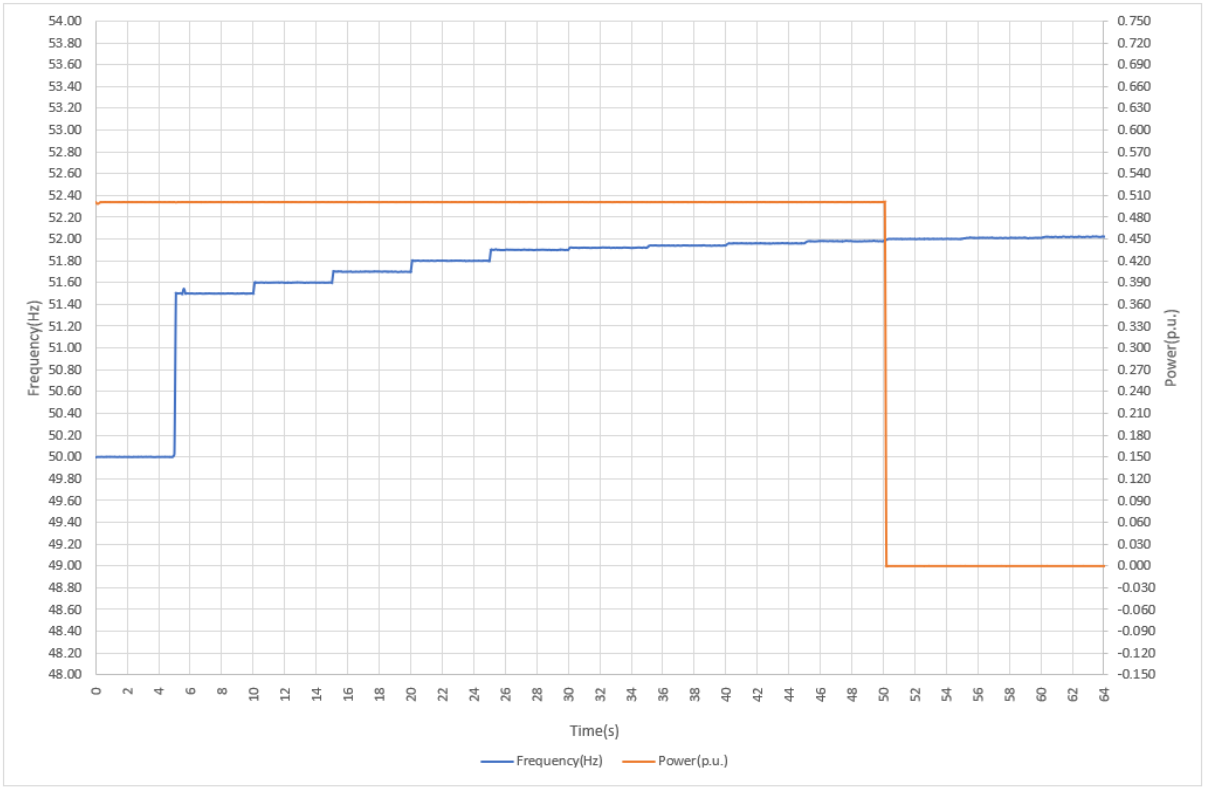
Over frequency - Test 1: Trip value



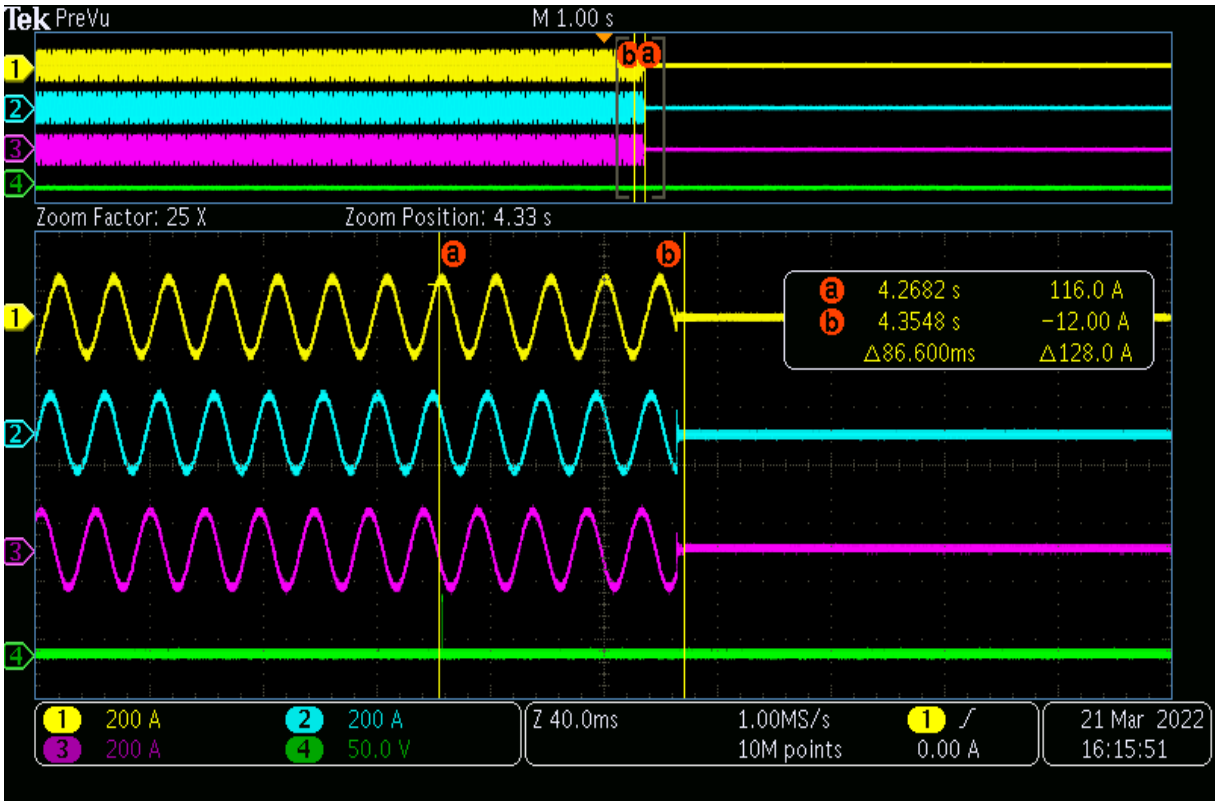
Over frequency - Test 1: Trip time



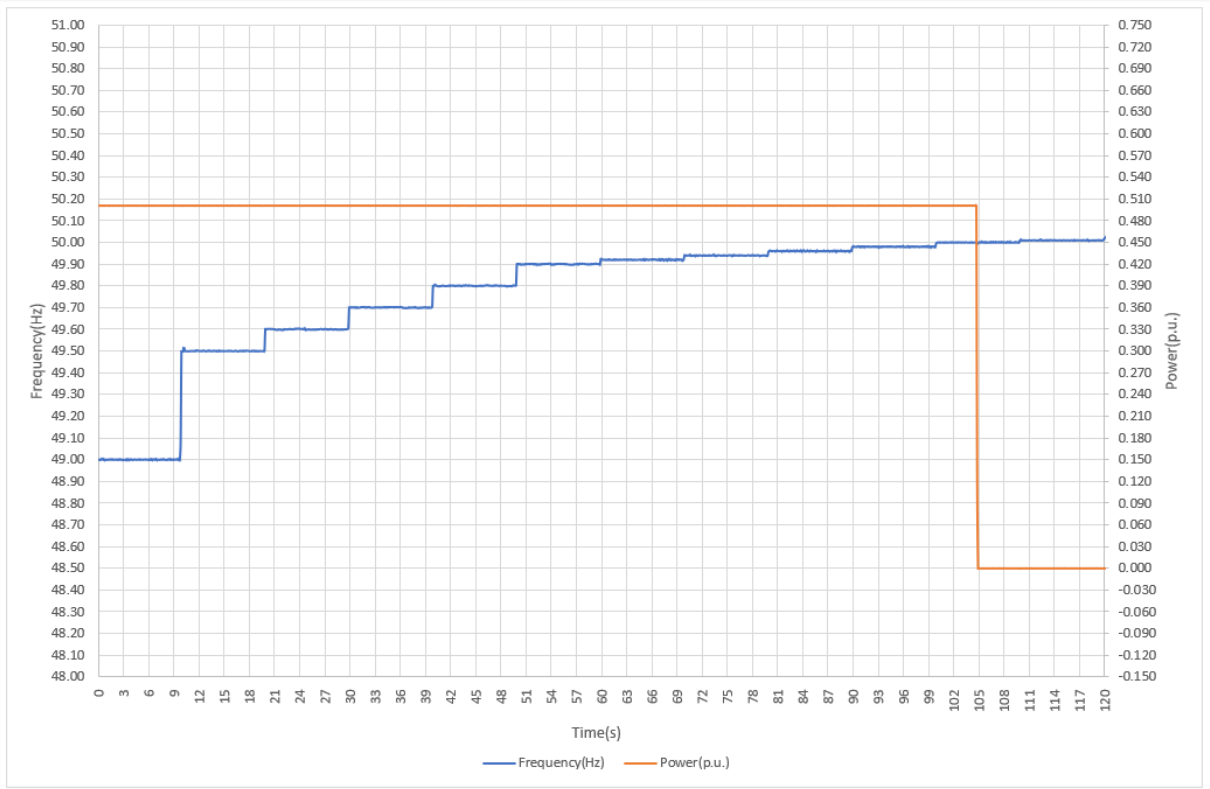
Over frequency - Test 2: Trip value



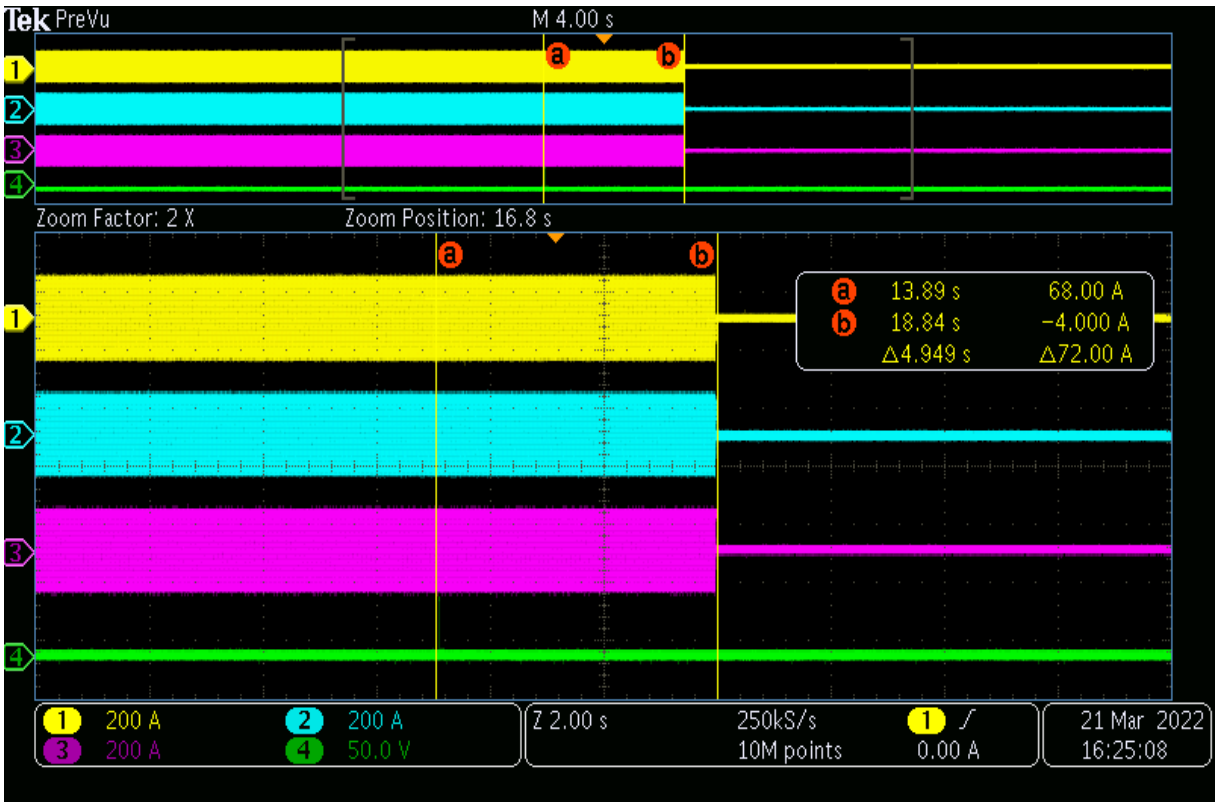
Over frequency - Test 2: Trip time



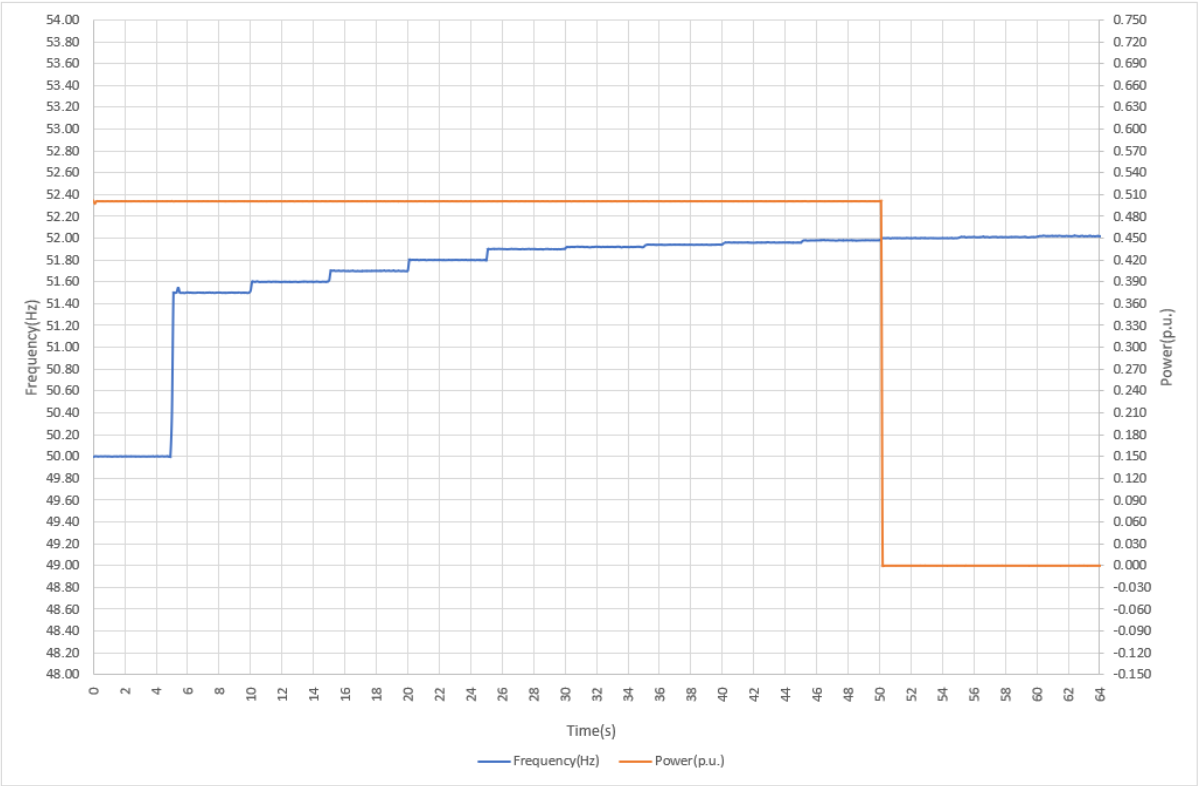
Over frequency - Test 3: Trip value



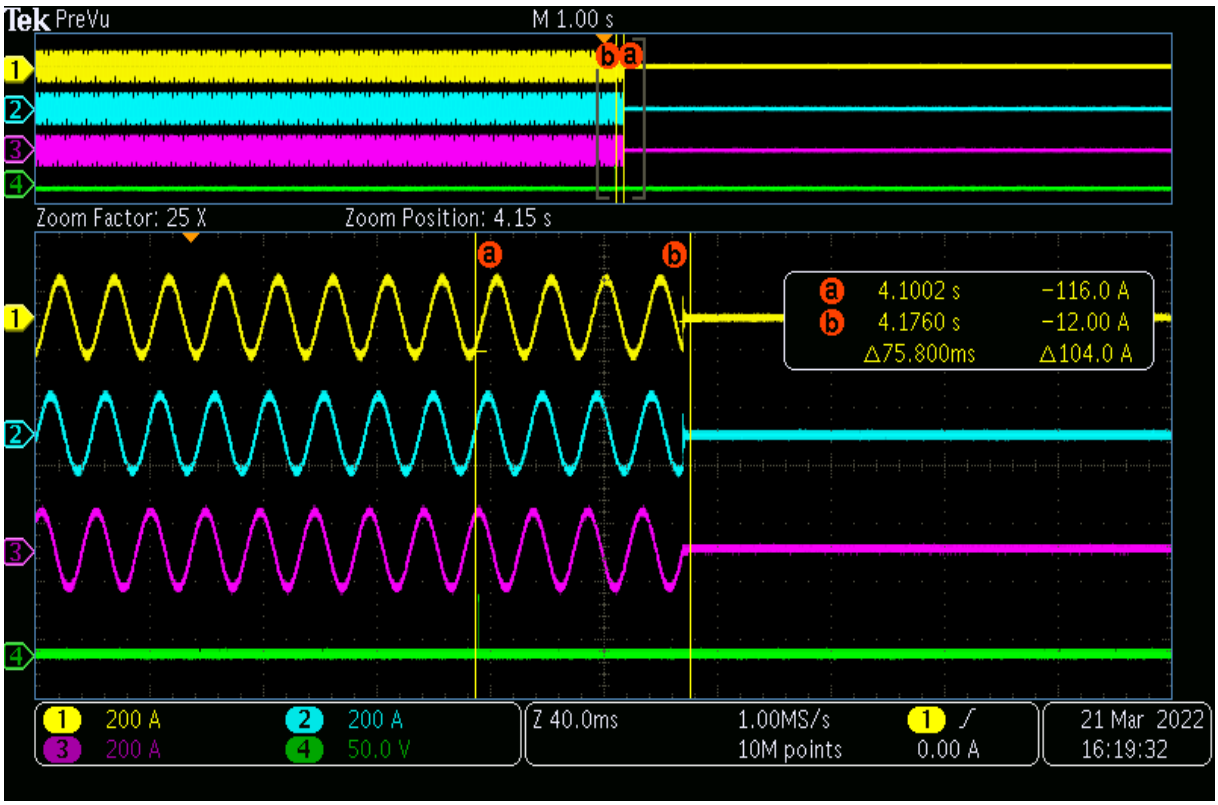
Over frequency - Test 3: Trip time



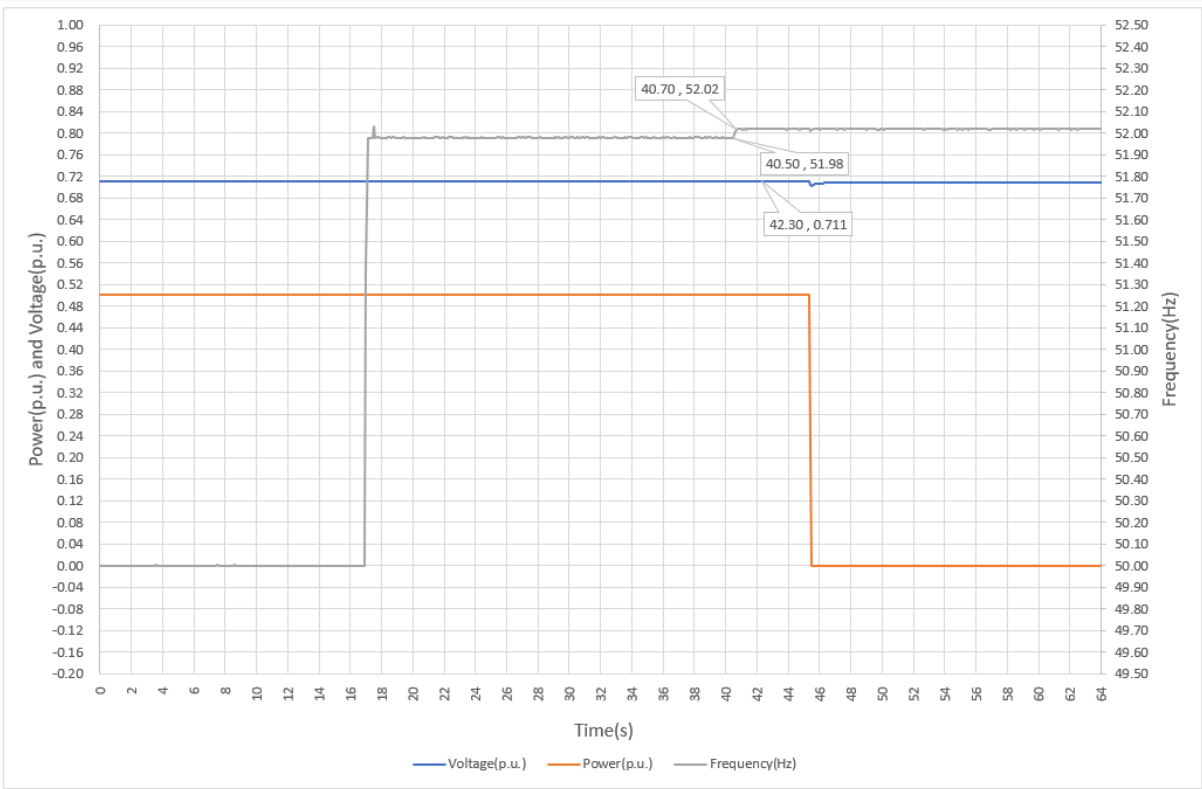
Over frequency - Test 4: Trip value



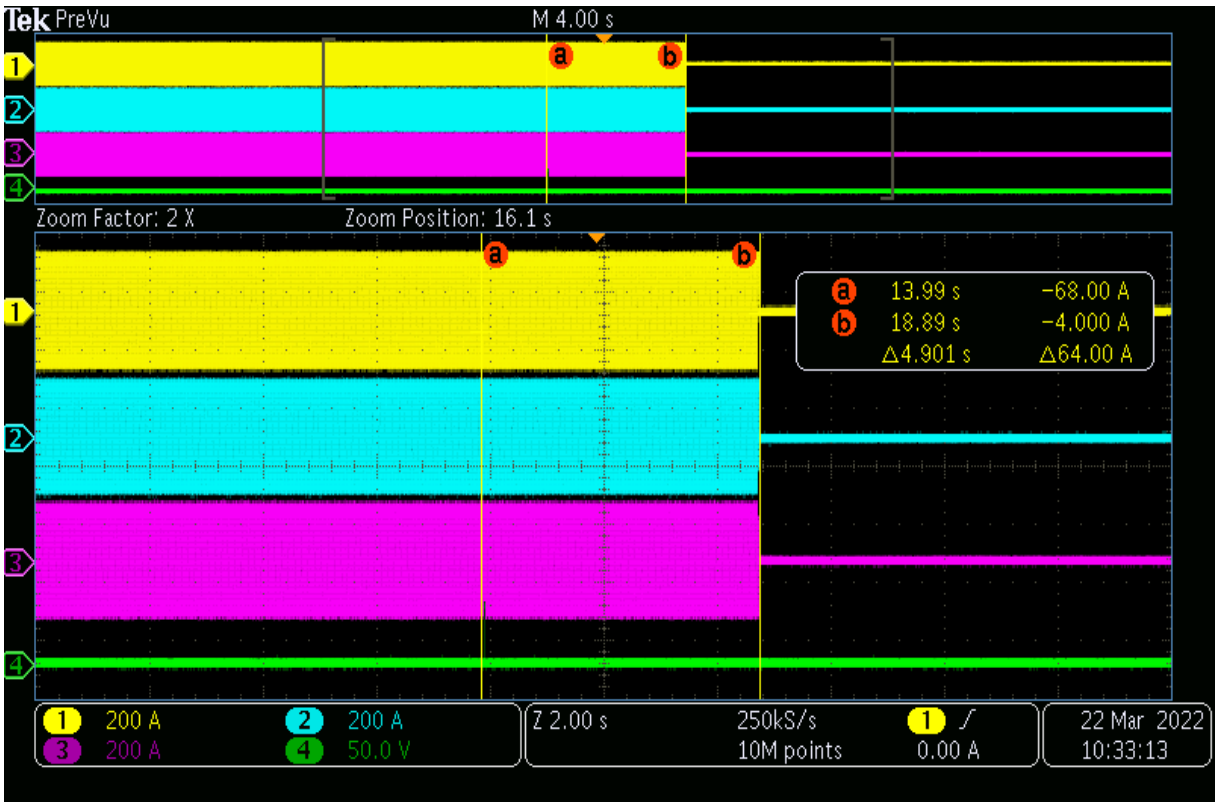
Over frequency - Test 4: Trip time



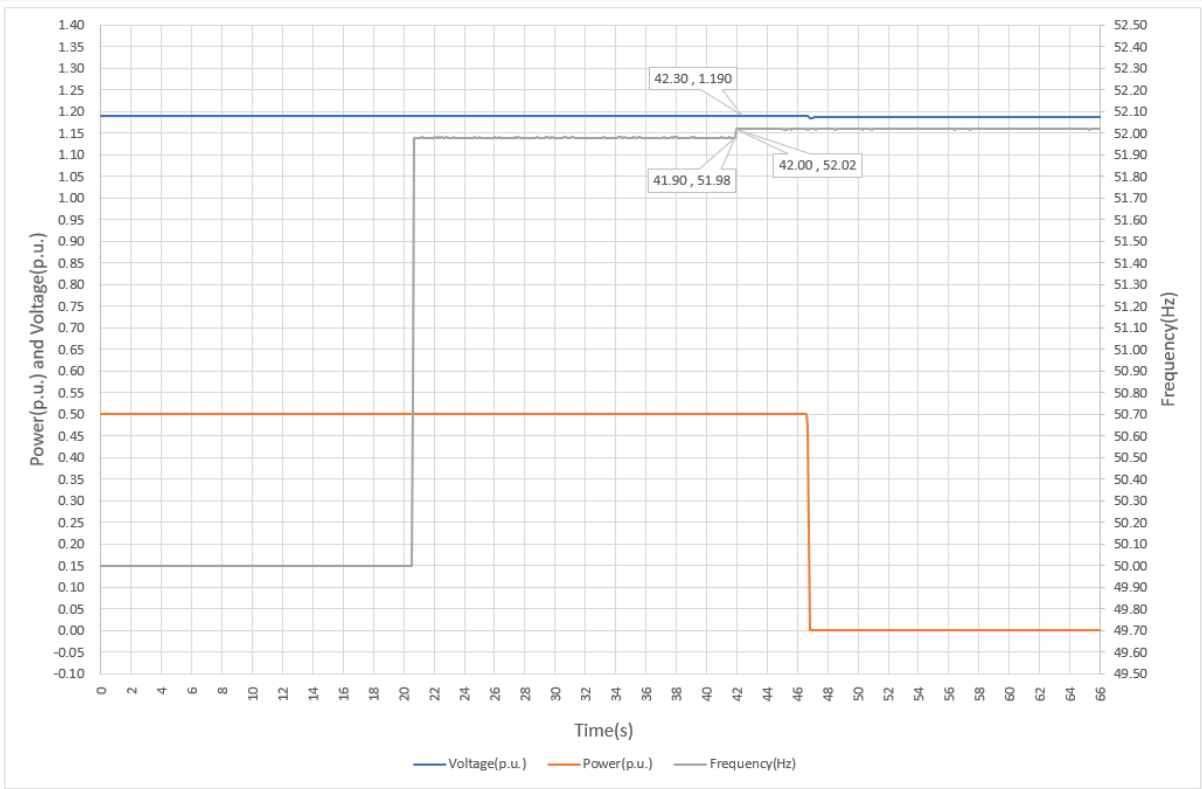
Over frequency - Test 5: Trip value



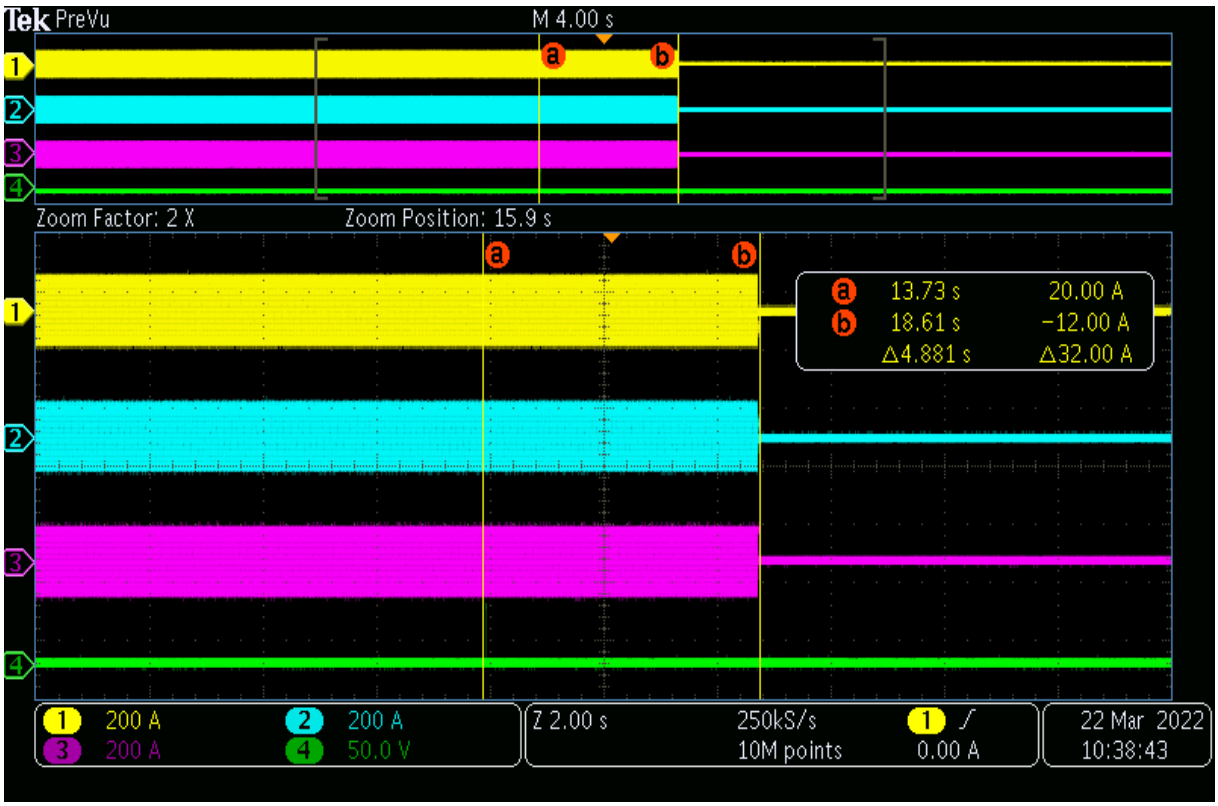
Over frequency - Test 5: Trip time



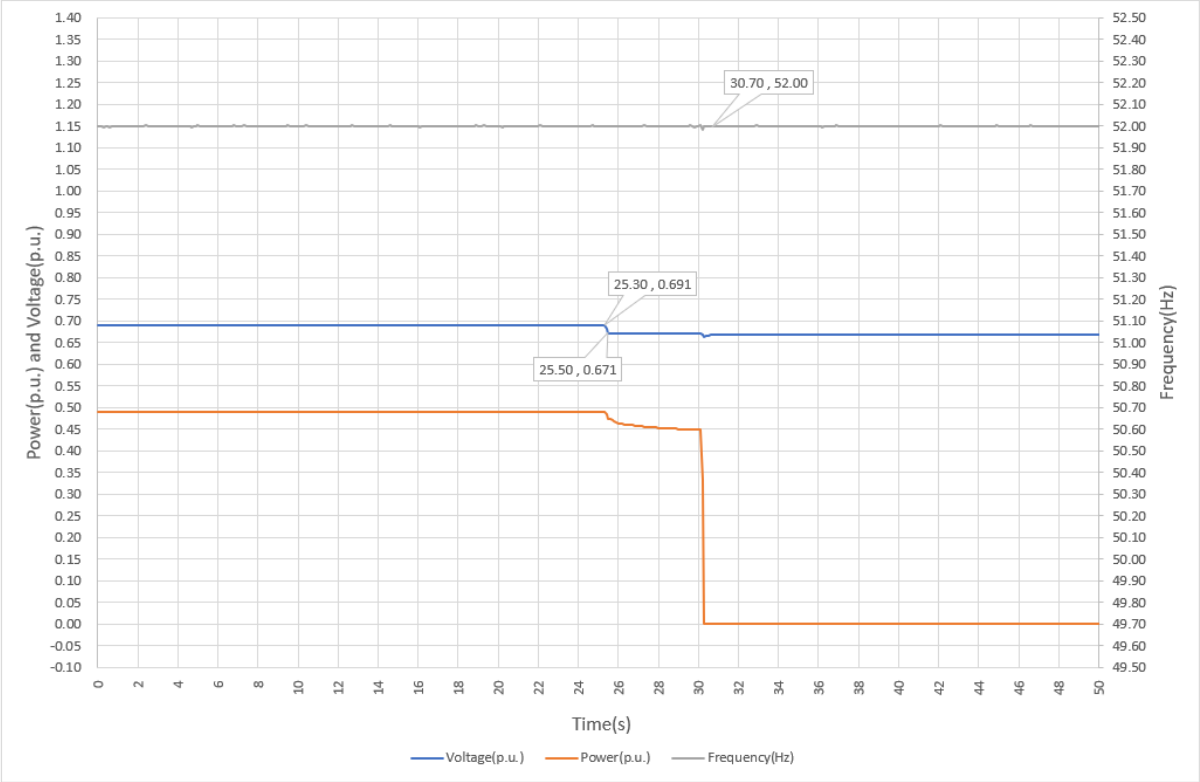
Over frequency - Test 6: Trip value



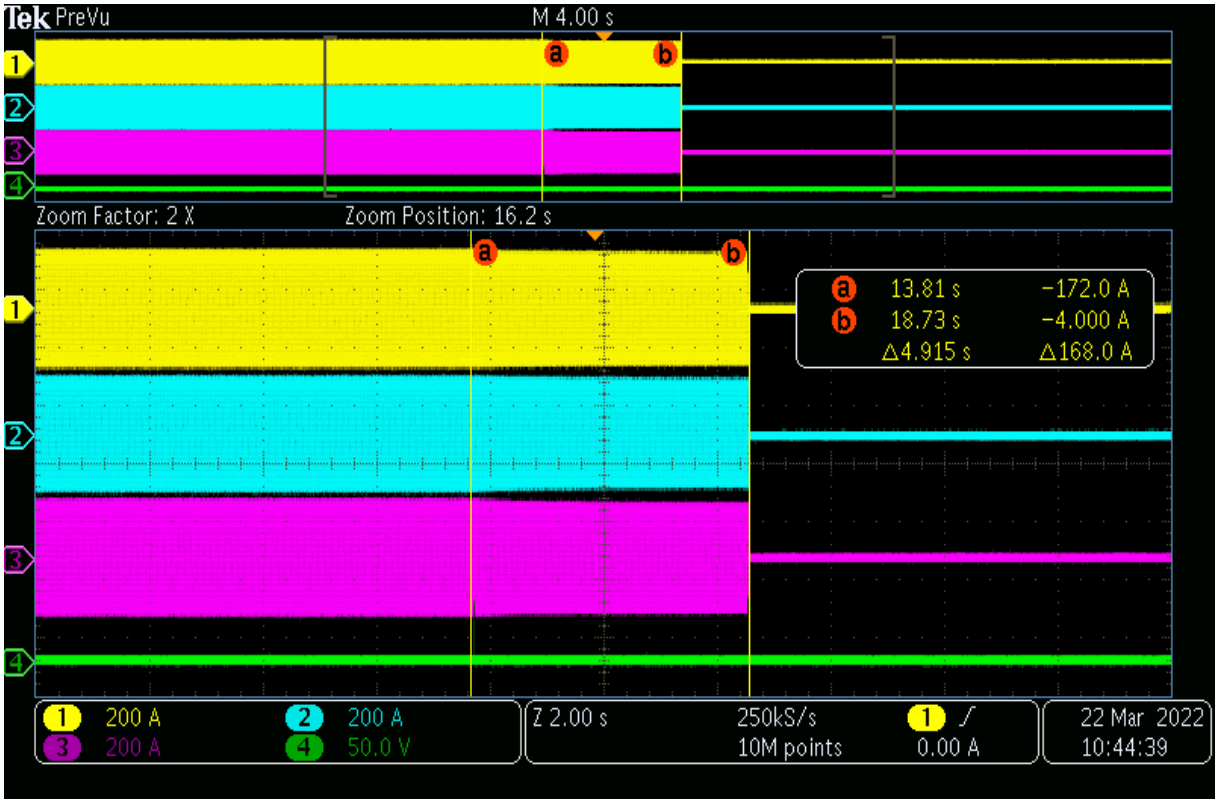
Over frequency - Test 6: Trip time



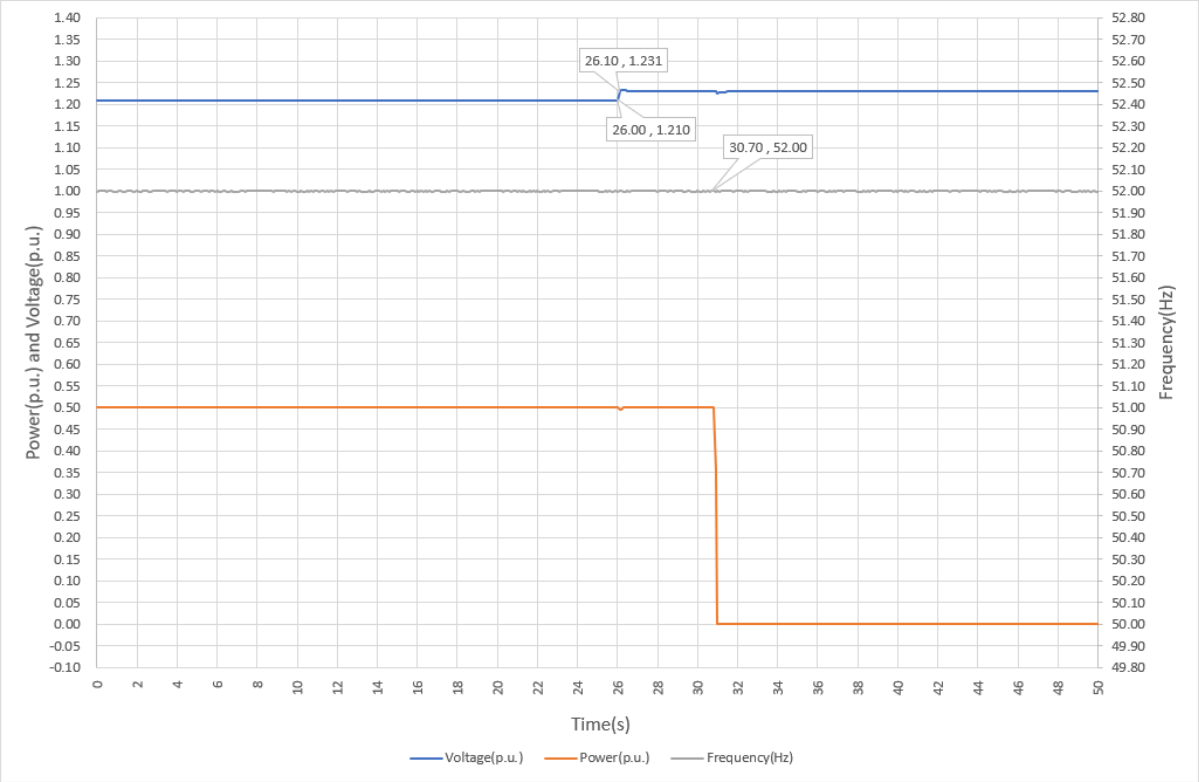
Over frequency - Test 7: Trip value



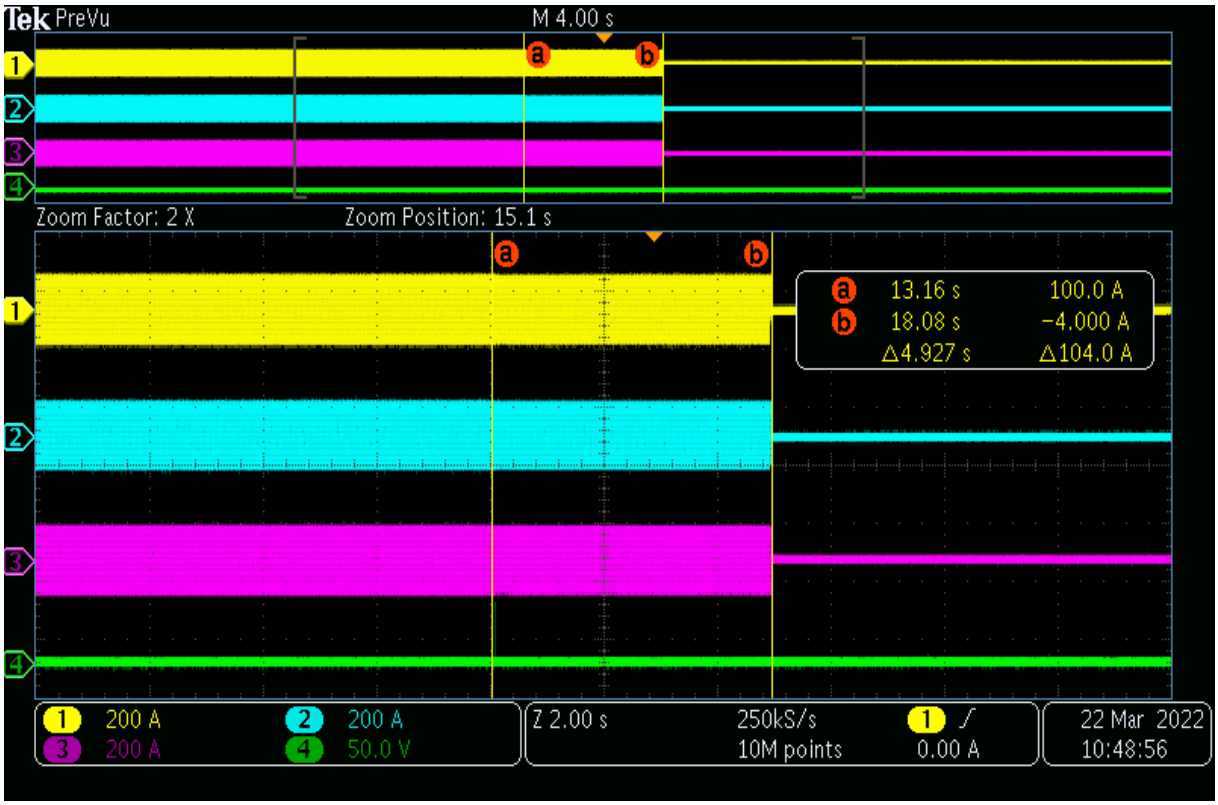
Over frequency - Test 7: Trip time



Over frequency - Test 8: Trip value



Over frequency - Test 8: Trip time



4.6.2. Means to detect island situation

The test has been done according to the clause 4.9.4 of the standard.

This protection device is also able to detect islanded situations and disconnect the equipment from the grid. Active methods tested with a resonant circuit used for detecting islanding situations.

The compliances with these requirements are stated in the according to EN 62116. An EUT is considered to comply with the requirements for islanding protection when each case of recorded run-on time is less than 2 s or meets the requirements of local codes.

The compliances with these requirements are stated in section 5.1 of the following test report:

IEC 61727: 2004&IEC 62116:2014: Test Report no.64.290.21.30204.03, issued by TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch on 2022-05-24. CNAS L3584

4.6.3. Digital input to the interface protection

The test has been done according to the clause 4.9.5 of the standard.

The interface protection shall have at least two configurable digital inputs, EUT used active methods tested with a resonant circuit and ROCOF to comply to the clause.

4.7. CONNECTION AND STARTING TO GENERATE ELECTRICAL POWER

The test has been done according to the clause 4.10 of the standard.

4.7.1. Automatic reconnection after tripping

The test has been done according to the clause 4.10.2 of the standard.

The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 3 column 2. If no settings are specified by the DSO and the responsible party, the default settings for the reconnection after tripping of the interface protection are according to Table 3 column 3.

Table 3 — Automatic reconnection after tripping

Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz
Upper frequency	50,0Hz – 52,0Hz	50,2Hz
Lower voltage	50% – 100%U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	10%/min

The following definitions apply to the test to verify the clause:

Disconnection Setting		Reconnection Setting		Setting Reconnection time (s)	Meas. Reconnection time (s)	Setting gradient (%Pn/min)	Meas. gradient (%Pn/min)
U= 115 %Un	Yes	U = 110 %Un	Yes	10.0	12.6	6.0	5.0
U = 84 %Un	Yes	U = 85 %Un	Yes	60.0	65.4	10.0	9.0
f = 52.00 Hz	Yes	f = 50.20 Hz	Yes	600.0	601.6	3000.0	536.3(1)
f = 47.50 Hz	Yes	f = 49.50 Hz	Yes	100.0	104.2	10.0	9.0

(1) This is the maximum gradient which can be measured for the setting of 3000.0 %Pn/min.

Note: See section 4.7.2 for the test result graph.

4.7.2. Starting to generate electrical power

The test has been done according to the clause 4.10.3 of the standard.

The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 4 column 2. If no settings are specified by the DSO and the responsible party, the default settings for connection or starting to generate electrical power due to normal operational startup or activity are according to Table 4 column 3.

Table 4 — Starting to generate electrical power

Parameter	Range	Default setting
Lower frequency	47,0Hz – 50,0Hz	49,5Hz
Upper frequency	50,0Hz – 52,0Hz	50,1Hz
Lower voltage	50% – 100% U_n	85 % U_n
Upper voltage	100% – 120% U_n	110 % U_n
Observation time	10s – 600s	60s
Active power increase gradient	6% – 3000%/min	disabled

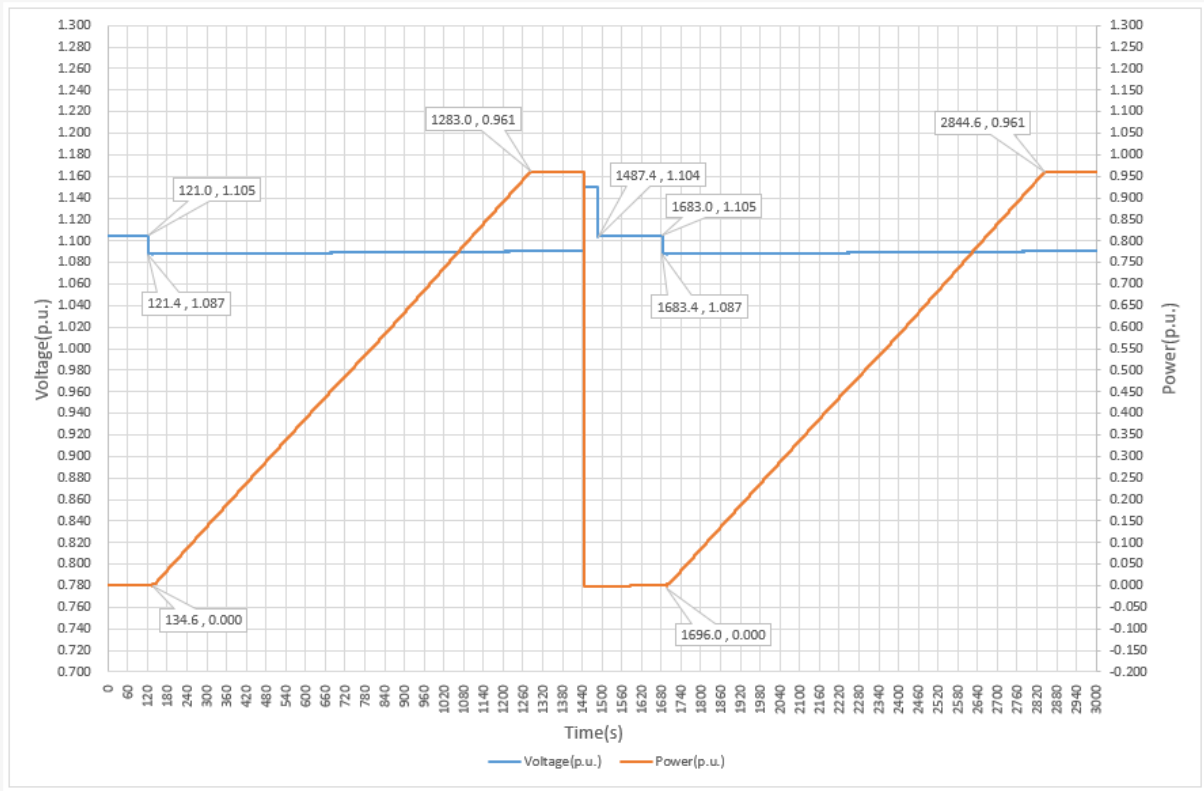
The following definitions apply to the test to verify the clause:

Connection		Setting Connection time (s)	Meas. Connection time (s)	Setting gradient (%Pn/min)	Meas. gradient (%Pn/min)
U < 110 %Un	Yes	10.0	13.2	6.0	5.0
85 % < U	Yes	60.0	65.6	10.0	9.0
f < 50.10 Hz	Yes	600.0	601.8	3000.0	546.3(1)
49.50 < f	Yes	100.0	104.2	10.0	9.0

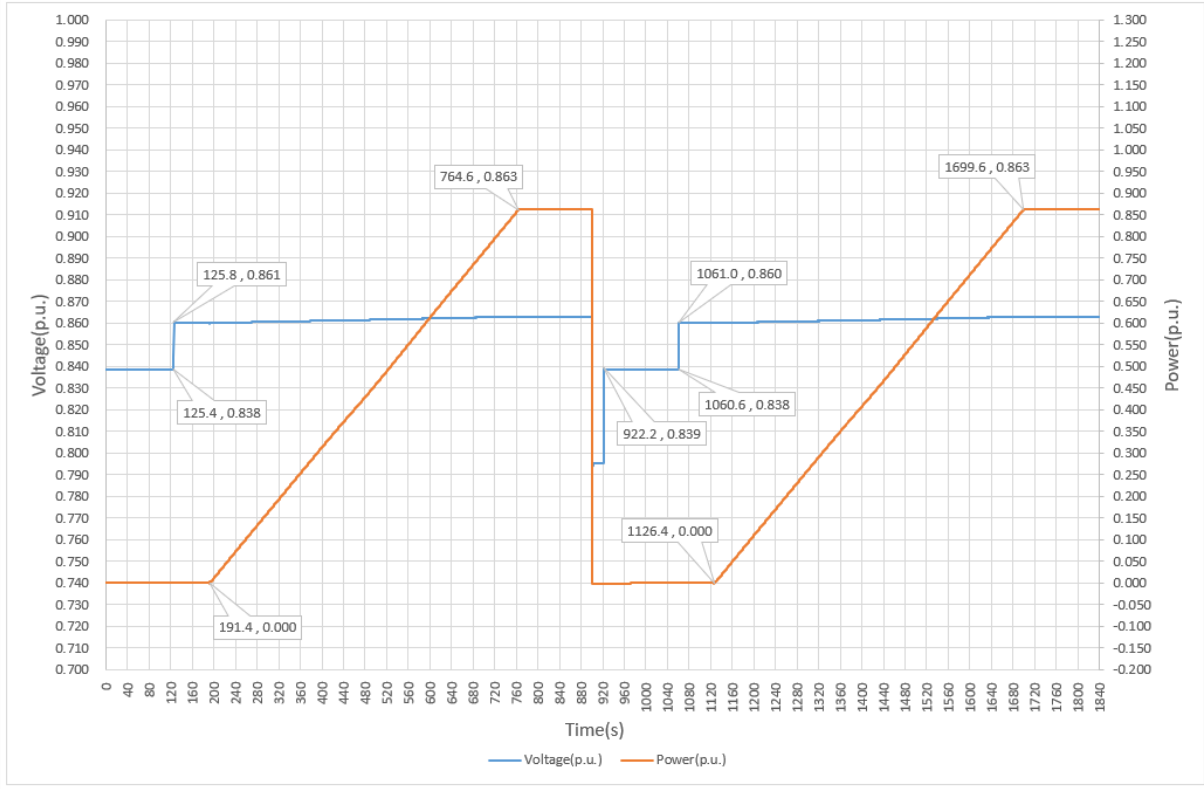
(1) This is the maximum gradient which can be measured for the setting of 3000.0 %Pn/min.

Test results are represented at diagrams below.

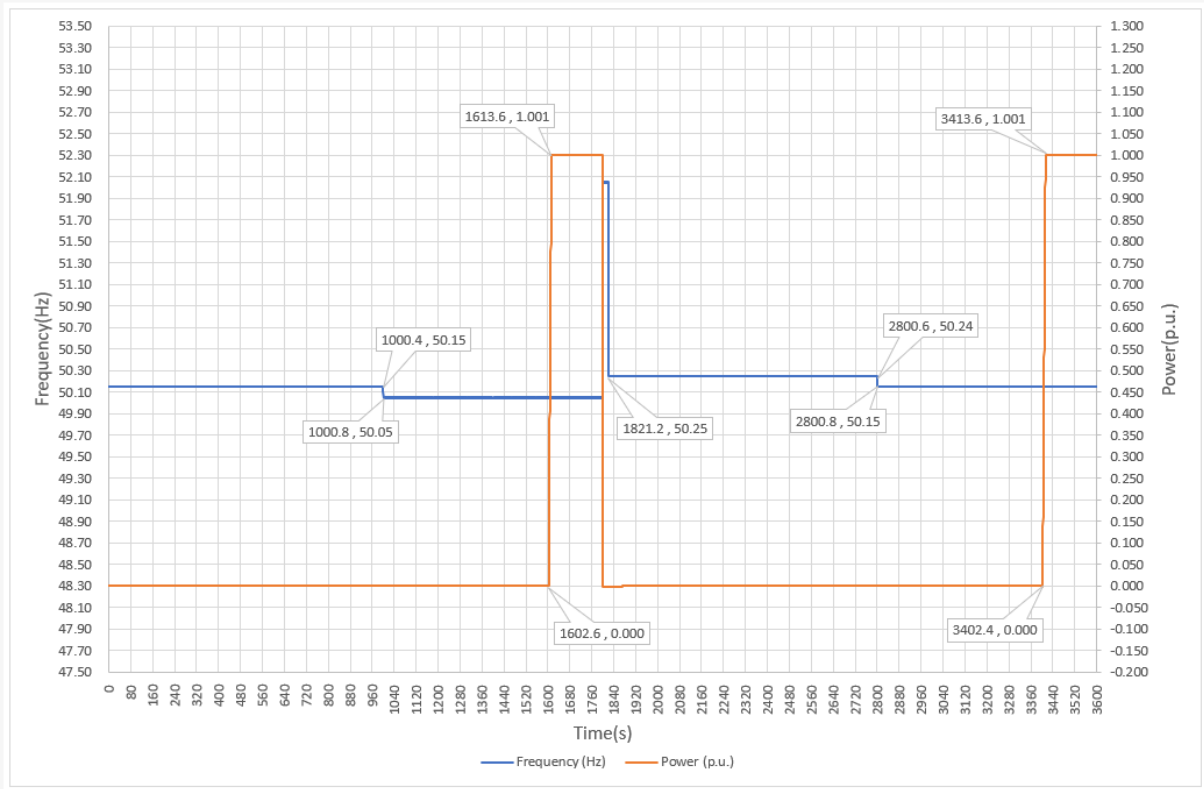
Overvoltage Connection and Reconnection



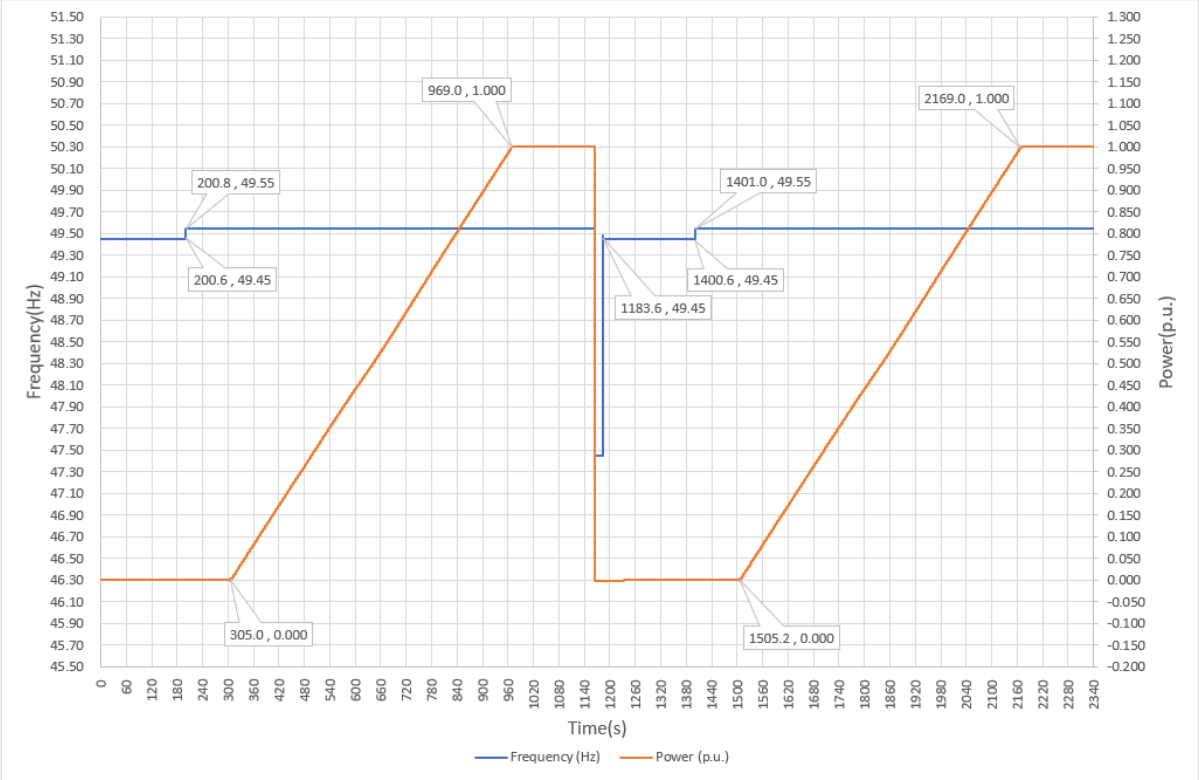
Undervoltage Connection and Reconnection



Overfrequency Connection and Reconnection



Underfrequency Connection and Reconnection



4.7.3. Synchronization

The requirements are from clause 4.10.4 of the standard. Synchronizing a generating plant/unit with the distribution network shall be fully automatic.

The EUT is fully automatic in the connection to the distribution network.

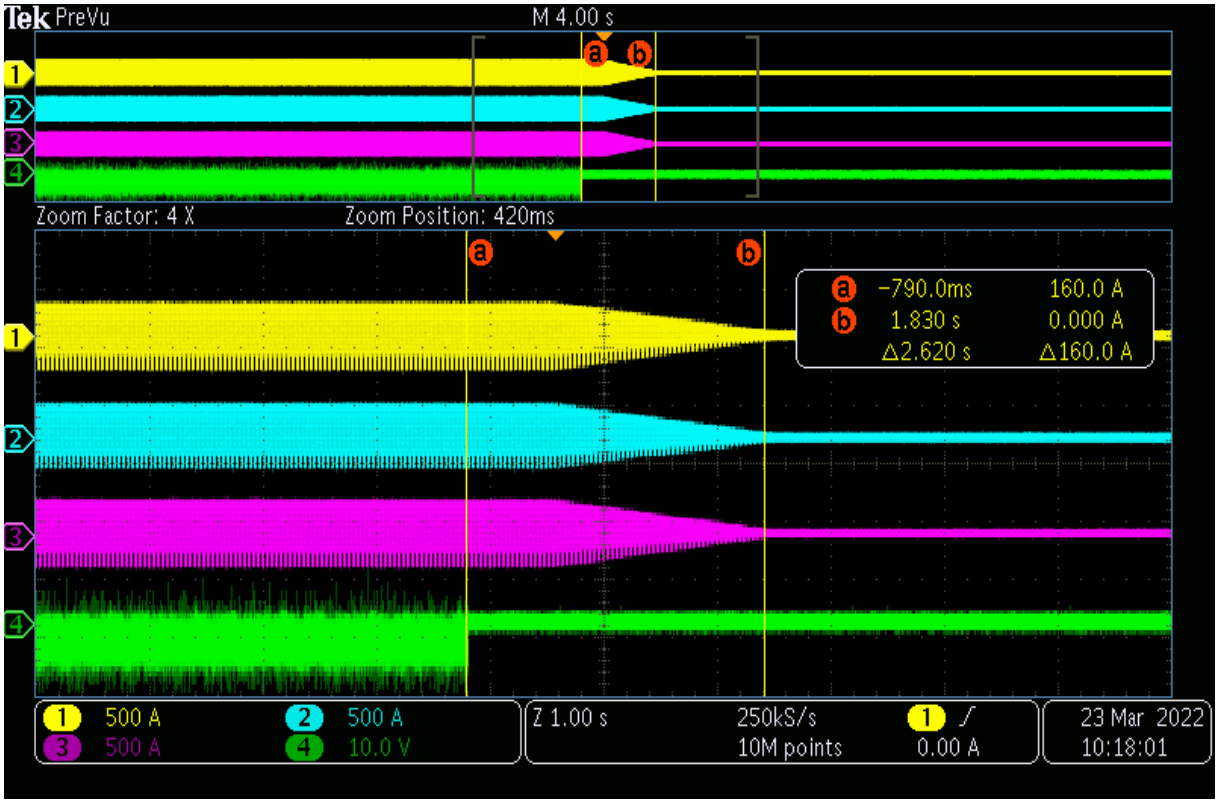
4.8. CEASING AND REDUCTION OF ACTIVE POWER ON SET POINT

4.8.1. Ceasing active power

The test has been done according to the clause 4.11.1 of the standard.

Generating plants with a maximum capacity of 0.8 kW or more shall be equipped with a logic interface (input port) in order to cease active power output within 5 seconds following an instruction being received at the input port. If required by the DSO and the responsible party, this includes remote operation.

Ceasing active power



Tested ceasing active power time: 2.620 s

Ch1: Output phase A current ; Output phase B current ;
Ch3: Output phase C current; Ch4: Signal line.

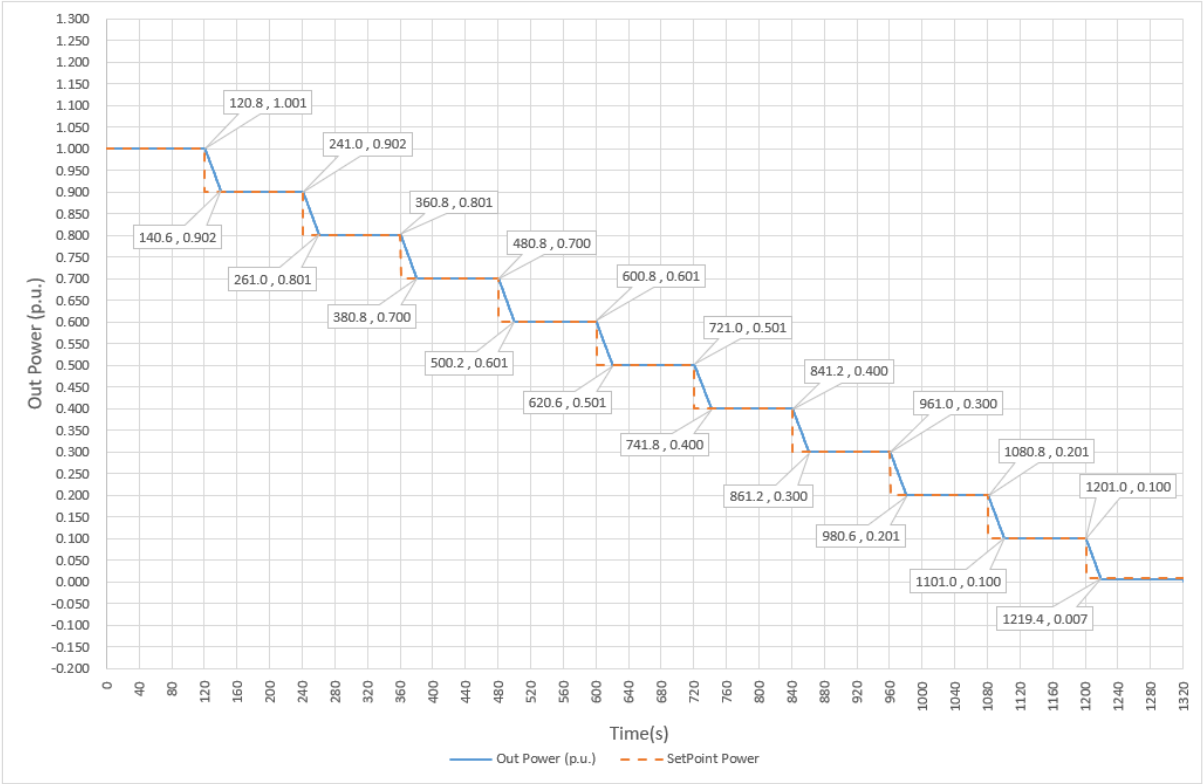
4.8.2. Reduction of active power on set point

Test requirements according to the clause 4.11.2 of the standard.

Active Power step ($\%P_n$)	Setpoint value		Actual value		Deviation <±5% P_n		Gradient 0.66%Pn/s to 0.33%Pn/s
	(kW)	(%Pn)	(kW)	($\%P_n$)	(kW)	($\%P_n$)	(%Pn/s)
100	255.000	100.0	255.250	100.1	+0.250	+0.1	--
90	229.500	90.0	230.070	90.2	+0.570	+0.2	0.50
80	204.000	80.0	204.302	80.1	+0.302	+0.1	0.51
70	178.500	70.0	178.600	70.0	+0.100	0.0	0.51
60	153.000	60.0	153.157	60.1	+0.157	+0.1	0.51
50	127.500	50.0	127.780	50.1	+0.280	+0.1	0.51
40	102.000	40.0	102.059	40.0	+0.059	0.0	0.49
30	76.500	30.0	76.586	30.0	+0.086	0.0	0.50
20	51.000	20.0	51.222	20.1	+0.222	+0.1	0.51
10	25.500	10.0	25.532	10.0	+0.032	0.0	0.50
0	0.000	0.0	1.722	0.7	+1.722	+0.7	0.51

Test results are represented at diagrams below.

Output power reduction by steps (100 %Pn to 0 %Pn)



4.9. REQUIREMENTS REGARDING SINGLE FAULT TOLERANCE OF INTERFACE PROTECTION SYSTEM AND INTERFACE SWITCH

The requeriments are from clause 4.3.2 and 4.13 of the standard.

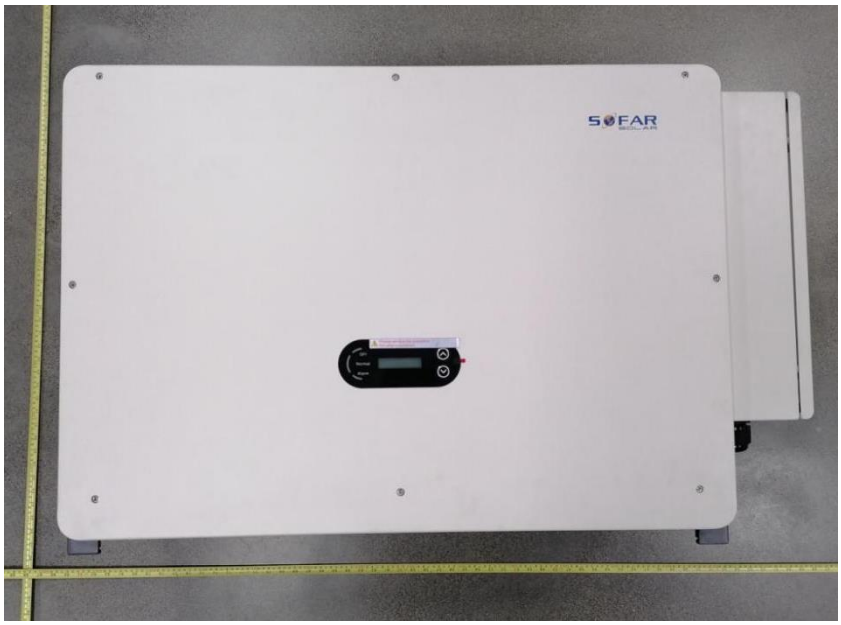
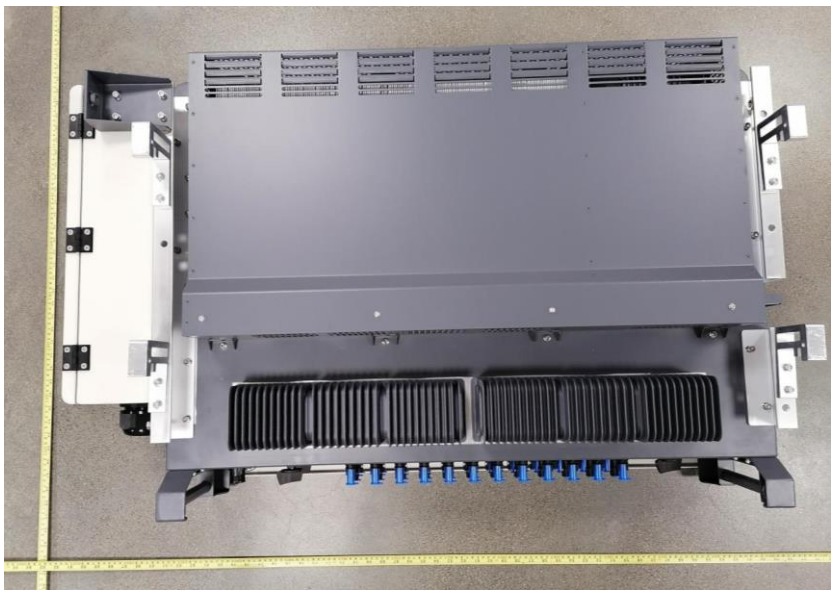
1) The compliances with the requirements of clause 4.3.2 are met with the following structure:

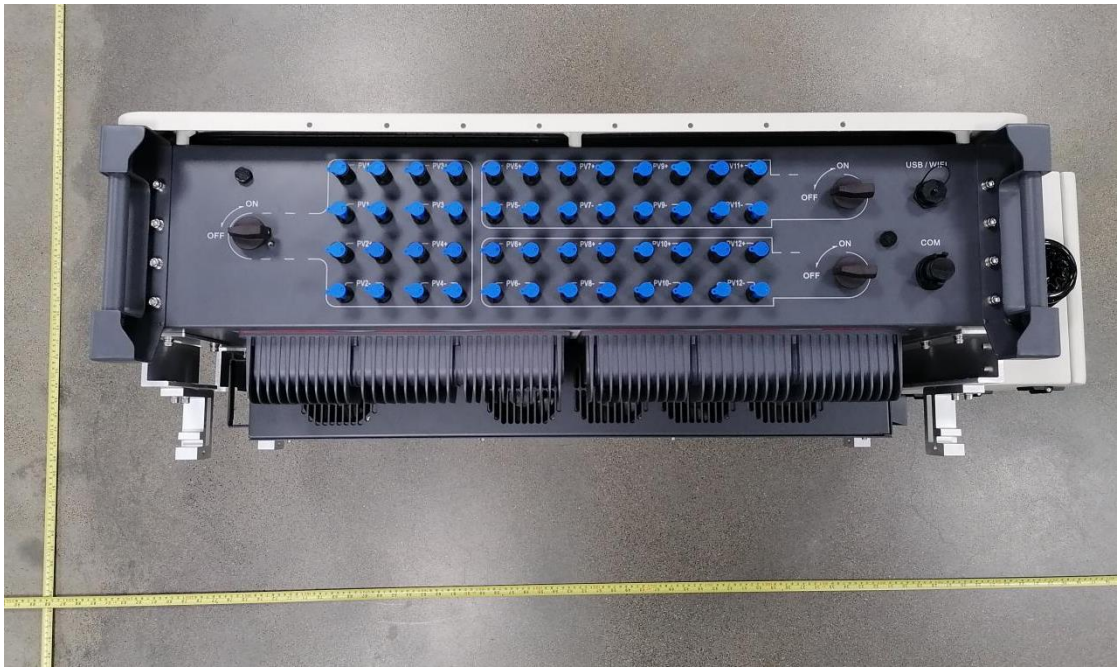
The output is switched off redundantly by the high-power switching bridge and relays, model:**HF167F-200**, rated: 200A/12Vdc.

2) The compliances with the requirements of clause 4.13 are stated in section 4.4 and 4.4.4 of the following test report:

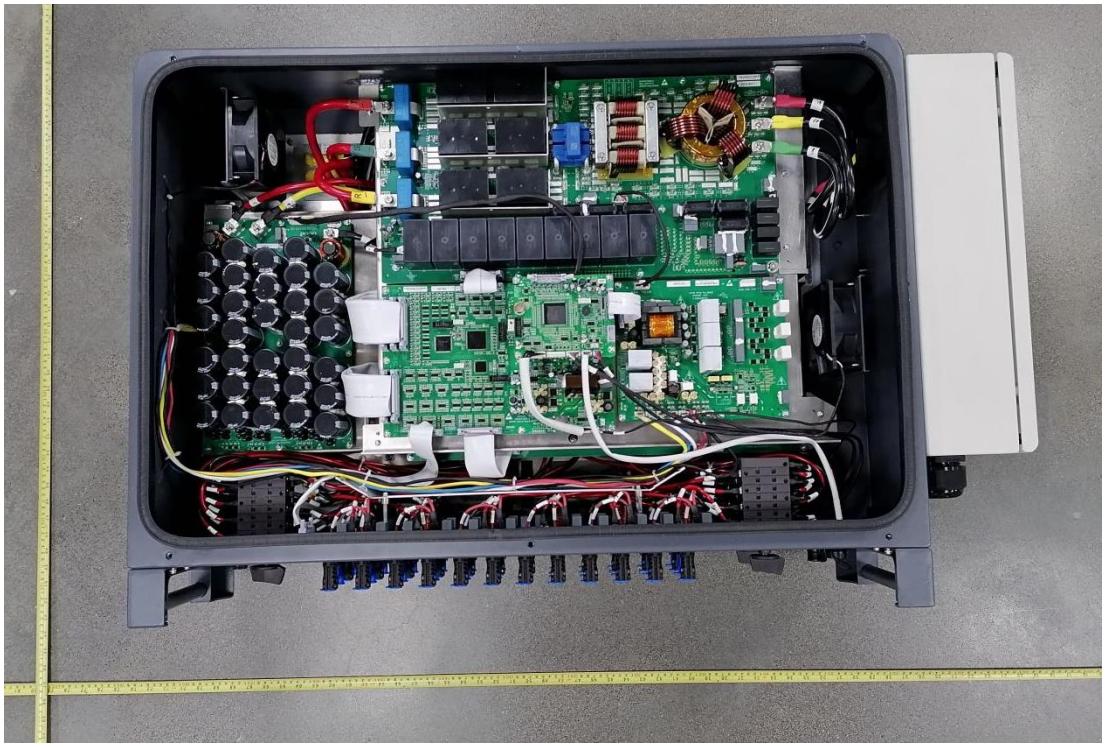
IEC 62109-1: 2010 and IEC 62109-2: 2011: Test Report no.64.290.21.30202.02 Part 1 of 2 and Test Report no. 64.290.21.30202.02 Part 2 of 2, issued by TÜV SÜD Certification and Testing (China) Co., Ltd. Guangzhou Branch on 2022-05-24. CNAS L3584

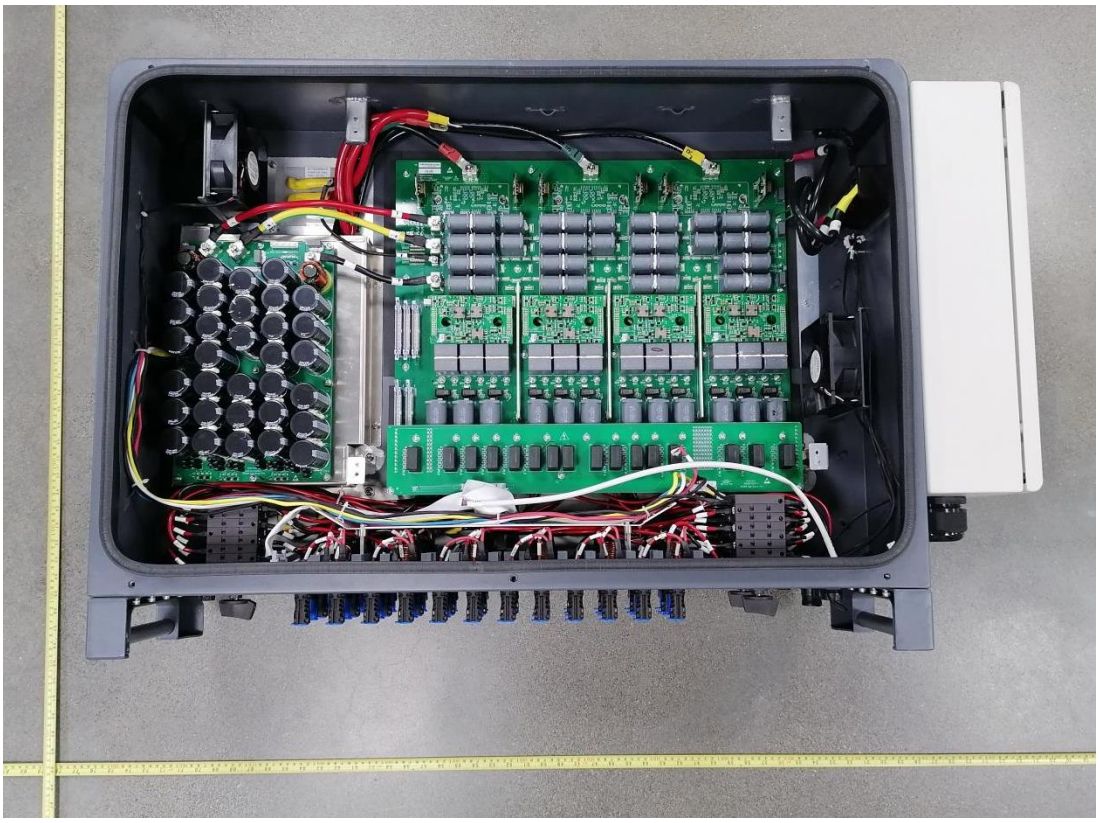
5. PICTURES

Front view

Back view


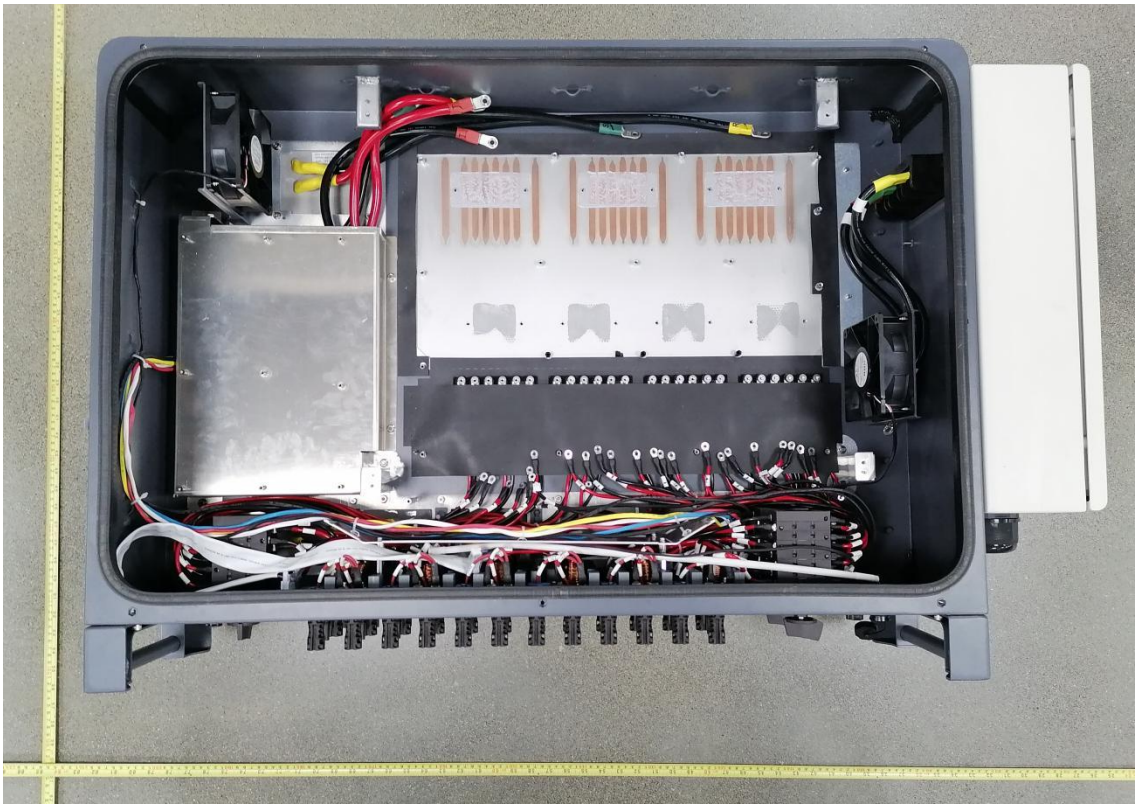
DC Connection interface


AC Connection interface


Internal View 1


Internal View 2


Internal View 3

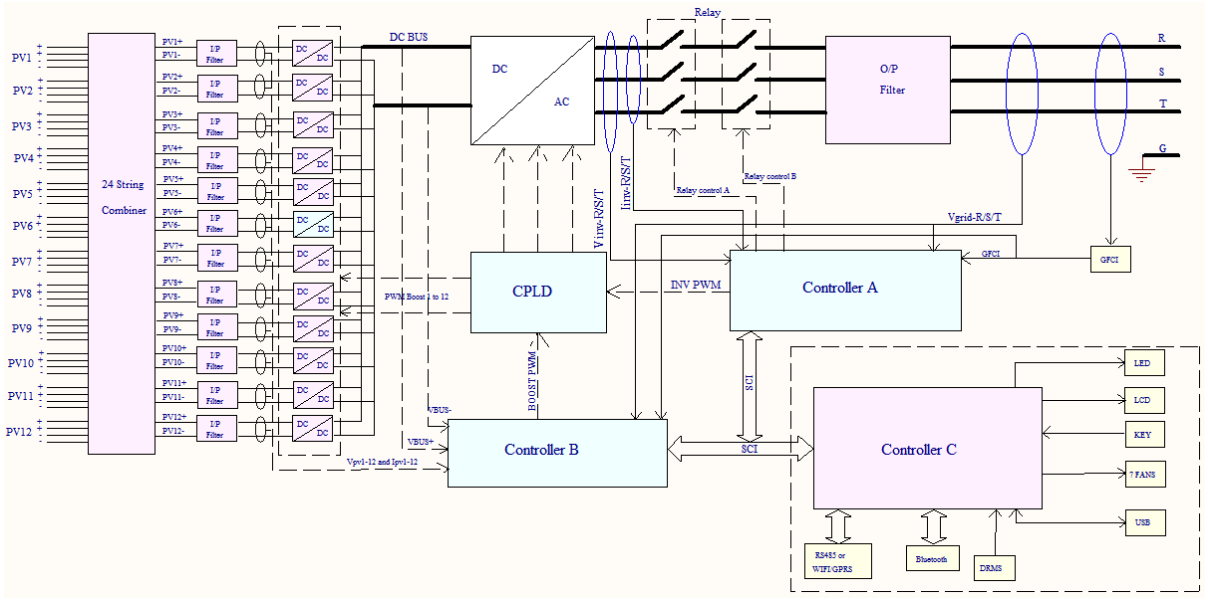


Ground terminal of shell

Serial number

Software Version


6. ELECTRICAL SCHEME



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