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TEST REPORT
P.O.12.3 Testing of LVRT behaviour
Requirements for response to voltage dips in wind installations

Report Reference No…… ...:	191024045GZU-001
Date of issue ……:	15 Jan 2020
Total number of pages……..:	43 pages

Testing Laboratory	Intertek Testing Services Shenzhen Ltd. Guangzhou Branch
Address.....	Block E, No.7-2 Guang Dong Software Science Park, Caipin Road, Guangzhou Science City, GETDD, Guangzhou, China
Testing location/ address.....	Same as above
Tested by (name + signature)……:	Jason Fu Technical Team Leader
Approved by (+ signature)	Tommy Zhong Technical Manager

Applicant's name	Shenzhen SOFAR SOLAR Co., Ltd.
Address.....	401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China

Test specification:

Standard	BOE 254:2006 ANNEX P.O.12.3
Test procedure.....	Type approval
Non-standard test method……..:	N/A

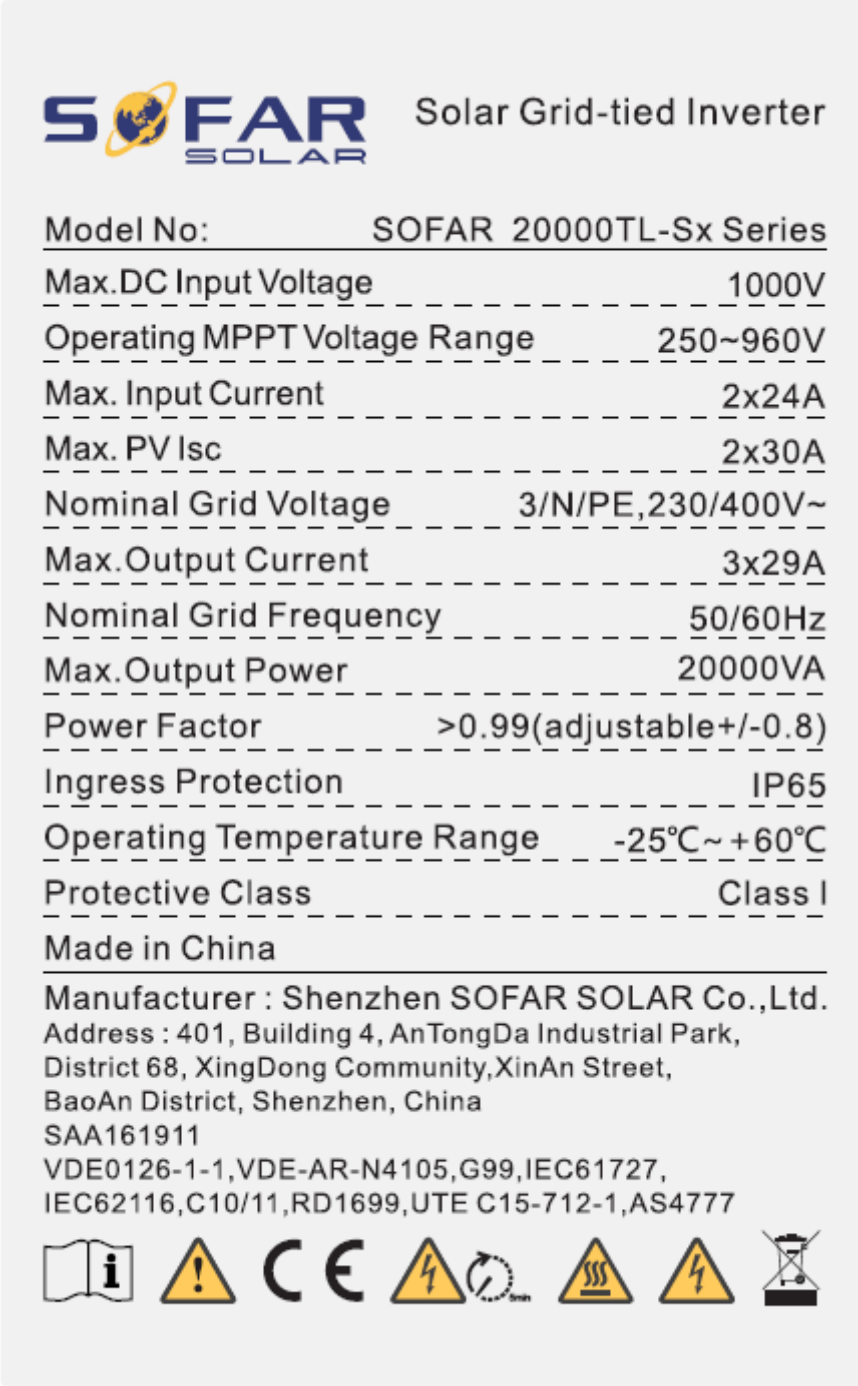
Test Report Form No.	P.O.12.3a
Test Report Form(s) Originator.....	Intertek Guangzhou
Master TRF.....	Dated 2019-11

Test item description	Solar Grid-tied Inverter
Trade Mark	SOFAR SOLAR, ZCS
Manufacturer.....	Same as Applicant
Model/Type reference.....	SOFAR 20000TL-Sx Series, SOFAR 17000TL-Sx Series, SOFAR 15000TL-Sx Series, SOFAR 10000TL-Sx Series (x=0-6)

Ratings	Maximum d.c. input voltage: 1000 V Input voltage rang: 250-960 V Max. input current: 2×24 A (for SOFAR 20000TL-Sx Series); 2×21 A (for SOFAR 17000TL-Sx Series, SOFAR 15000TL-Sx Series); 2×15 A (for SOFAR 10000TL-Sx Series) Max. PV Isc: 2×30 A (for SOFAR 20000TL-Sx Series); 2×27 A (for SOFAR 17000TL-Sx Series, SOFAR 15000TL-Sx Series); 2×20 A (for SOFAR 10000TL-Sx Series) Nominal output voltage: 3/N/PE230V/400V Max. output current: 3×29 A (for SOFAR 20000TL-Sx Series); 3×25 A (for SOFAR 17000TL-Sx Series); 3×22 A (for SOFAR 15000TL-Sx Series); 3×15 A (for SOFAR 10000TL-Sx Series) Nominal frequency: 50 Hz Max. output power: 20000 VA (for 20000TL-Sx Serie); 17000 VA (for SOFAR 17000TL-Sx Serie); 15000 VA (for SOFAR 15000TL-Sx Serie); 10000 VA (for SOFAR 10000TL-Sx Serie) Ingress protection: IP65 Operating temperature range: -25～60℃ Software Version: V4.90

Summary of testing:	
Tests performed (name of test and test clause): All applicable tests The model SOFAR 20000TL-Sx is type tested.	**Testing location:** Intertek Testing Services Shenzhen Ltd. Guangzhou Branch Block E, No.7-2 Guang Dong Software Science Park, Caipin Road, Guangzhou Science City, GETDD, Guangzhou, China

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. The other model labels are identical with label above, except the model name and rating.

Test item particulars.....:	
Temperature range .....:	
AC Overvoltage category.....:	☐ OVC I ☐ OVC II ☒ OVC III ☐ OVC IV
DC Overvoltage category.....:	☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV
IP protection class .....:	
Possible test case verdicts:	
- test case does not apply to the test object ..... :	N/A (Not applicable)
- test object does meet the requirement..... :	P (Pass)
- test object does not meet the requirement..... :	F (Fail)
Testing.....:	
Date of receipt of test item ..... :	01 Dec 2019
Date (s) of performance of tests ..... :	01 Dec 2019 – 14 Jan 2020

General remarks:

The test results presented in this report relate only to the object tested.
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"(see Enclosure #)" refers to additional information appended to the report.
"(see appended table)" refers to a table appended to the report.

When determining for test conclusion, measurement uncertainty of tests has been considered.
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The test report only allows to be revised only within the report defined retention period unless standard or regulation was withdrawn or invalid.

Throughout this report a point is used as the decimal separator.

Description of the vector system to depict test result:

The regarded system of the voltage and current vectors is the generator reference system:

- If the inverter feeds to the grid the active power is measured with positive sign
- If the inverter generates inductive reactive power the reactive power has a positive sign
- If the inverter generates capacitive reactive power the reactive power has a negative sign

Factory information:

Dongguan SOFAR SOLAR Co., Ltd

1F-6F, Building E, No.1 JinQi Road, Bihu Industrial Park, Wulian Village, Fenggang Town, Dongguan City

General product information:

The unit is a three-phase solar inverter, it can convert the high PV voltage to AC output.

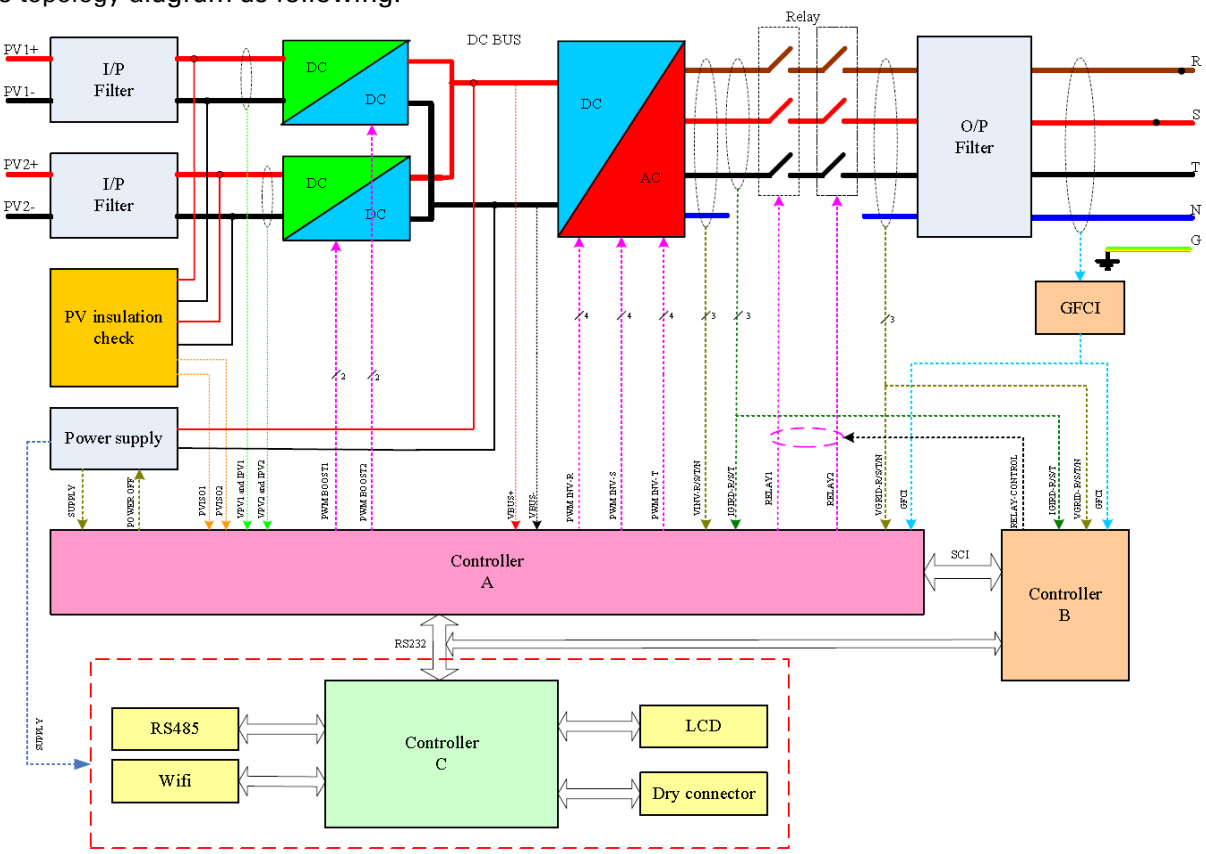
The unit is providing EMI filtering at the PV. It does not provide basic insulation separate from PV side to Grid (transformerless).

The unit has two controllers. the master controller A monitor the PV statue; measure the PV voltage and current, bus voltage, AC voltage, current, GFCI and frequency.

The slave controller B monitor AC voltage, GFCI and communicate with the master controller A

The master controller A and controller B are used together to control relay open or close, if the single fault on one MCU, the other one MUC can be capable to open the relay, so that still providing safety means

The topology diagram as following:



Model differences:

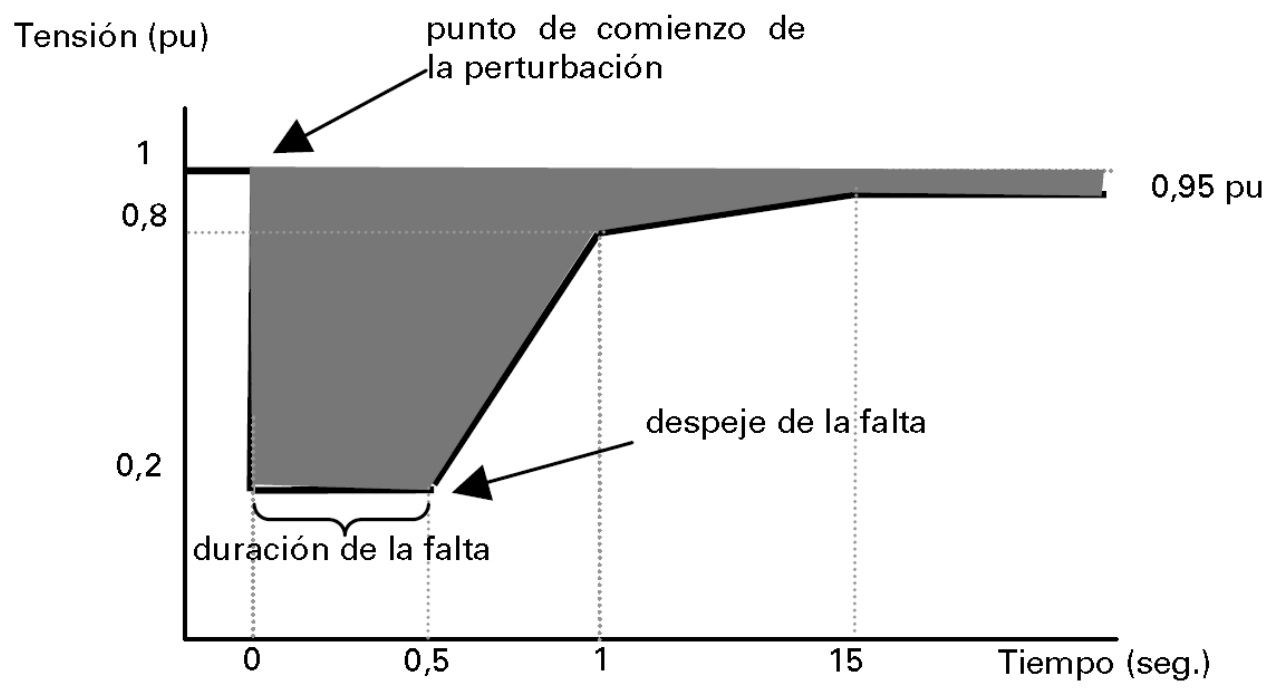
All models have identical mechanical and electrical construction except some parameter of the software architecture to control the max output power. The detailed difference as following:

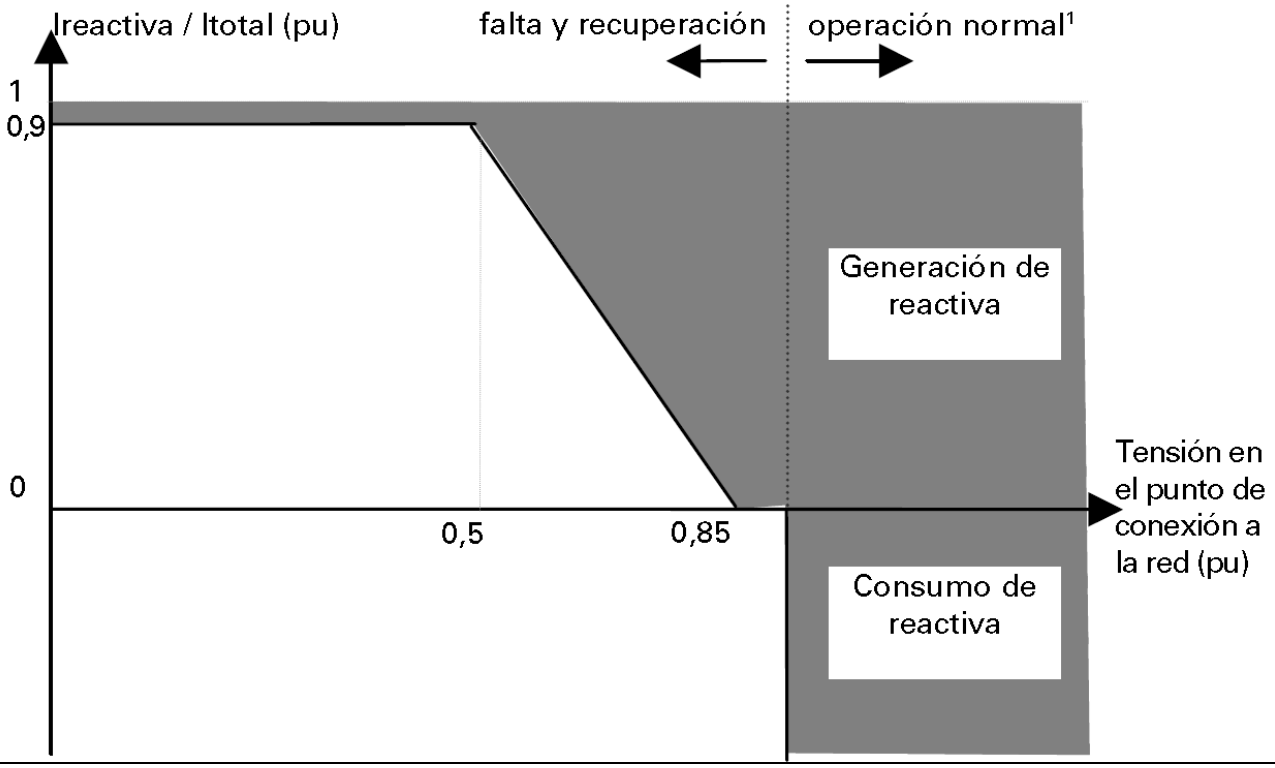
Model	DC Cable Gland	PV connector	DC inside connector	Fuse PCB+ String detection board	DC surge arrester	DC switch	AC switch	AC surge arrester
Sofar 20000TL-S0 Sofar 17000TL-S0 Sofar 15000TL-S0 Sofar 10000TL-S0	√		√					

Sofar 20000TL-S1 Sofar 17000TL-S1 Sofar 15000TL-S1 Sofar 10000TL-S1	√		√			√		
Sofar 20000TL-S2 Sofar 17000TL-S2 Sofar 15000TL-S2 Sofar 10000TL-S2		√	√			√		
Sofar 20000TL-S3 Sofar 17000TL-S3 Sofar 15000TL-S3 Sofar 10000TL-S3		√		√		√		
Sofar 20000TL-S4 Sofar 17000TL-S4 Sofar 15000TL-S4 Sofar 10000TL-S4		√		√	√	√		
Sofar 20000TL-S5 Sofar 17000TL-S5 Sofar 15000TL-S5 Sofar 10000TL-S5		√		√	√	√		√
Sofar 20000TL-S6 Sofar 17000TL-S6 Sofar 15000TL-S6 Sofar 10000TL-S6		√		√	√	√	√	√
√ denote incorporating this component								

Appended Table - Testing Result:

P.O.12.3 on LVRT	P

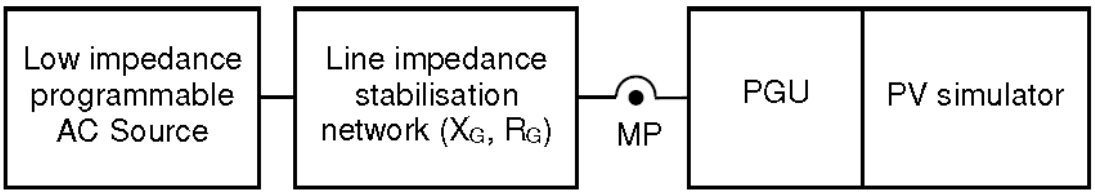




Behaviour during grid disturbance							
No. load Test	No. of phase					Test number	
1	Three					1.1	
	Two					1.2A (for test A) 1.2B (for test B) 1.2C (for test C)	
	One					1.3A(for test A) 1.3B(for test B) 1.3C(for test A)	
No. load Test	No. of phase	Output power level			Duration of voltage dip	Test number	Verdict
Three-phase system							
2	Three	P>0.8Pn	100%	Ures<20%Un	t>500ms	2.1	P
		0.1Pn<P<0.3Pn	20%			2.2	P
	Two	P>0.8Pn	100%	Ures<60%Un	t>750ms	2.3	P
		0.1Pn<P<0.3Pn	20%			2.4	P
	One	P>0.8Pn	100%	Ures<60%Un	t>750ms	2.5	P
		0.1Pn<P<0.3Pn	20%			2.6	P
Single-phase system							
3	One	P>0.8Pn	100%	Ures<20%Un	t>500ms	3.1	N/A
		0.1Pn<P<0.3Pn	20%			3.2	N/A
		P>0.8Pn	100%	Ures<60%Un	t>750ms	3.3	N/A
		0.1Pn<P<0.3Pn	20%			3.4	N/A

Behaviour during grid disturbance

Schematic of test setup:



Note on test setup:

A programmable AC source used.

Note:

Measurement points used: MP

Evaluation of data measured at MP

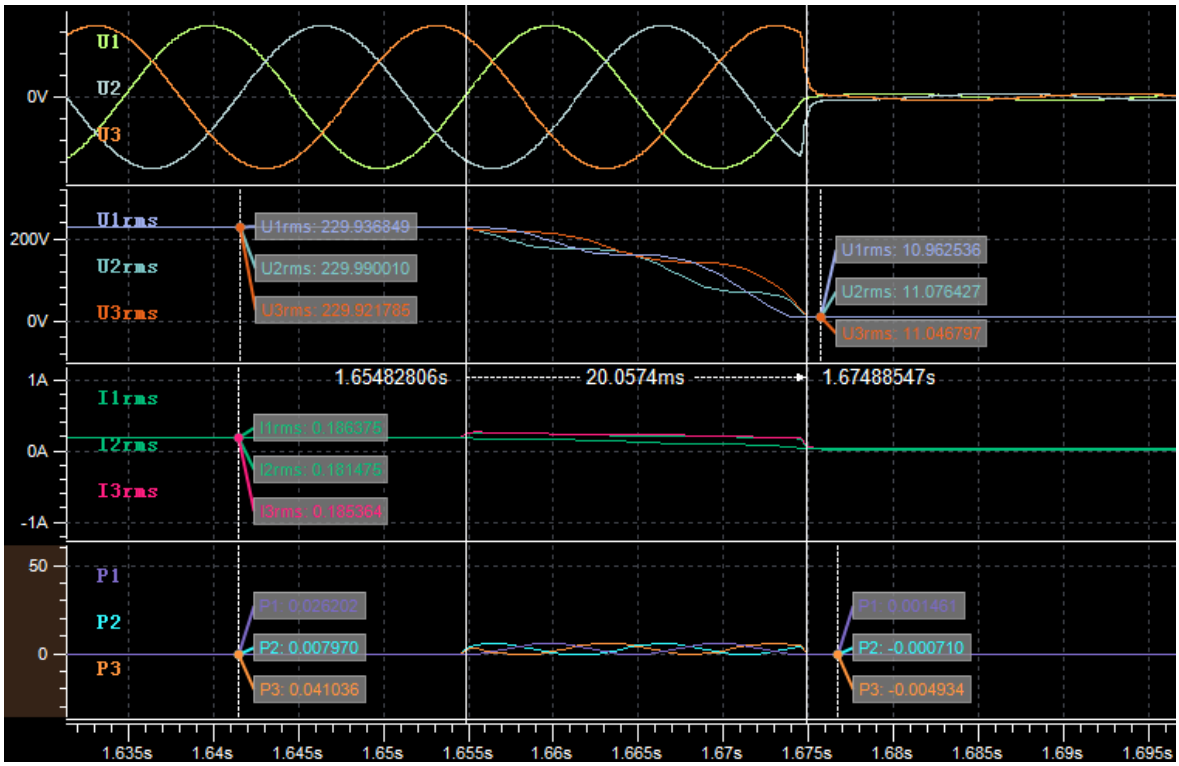
Used sample rate: 10KHz

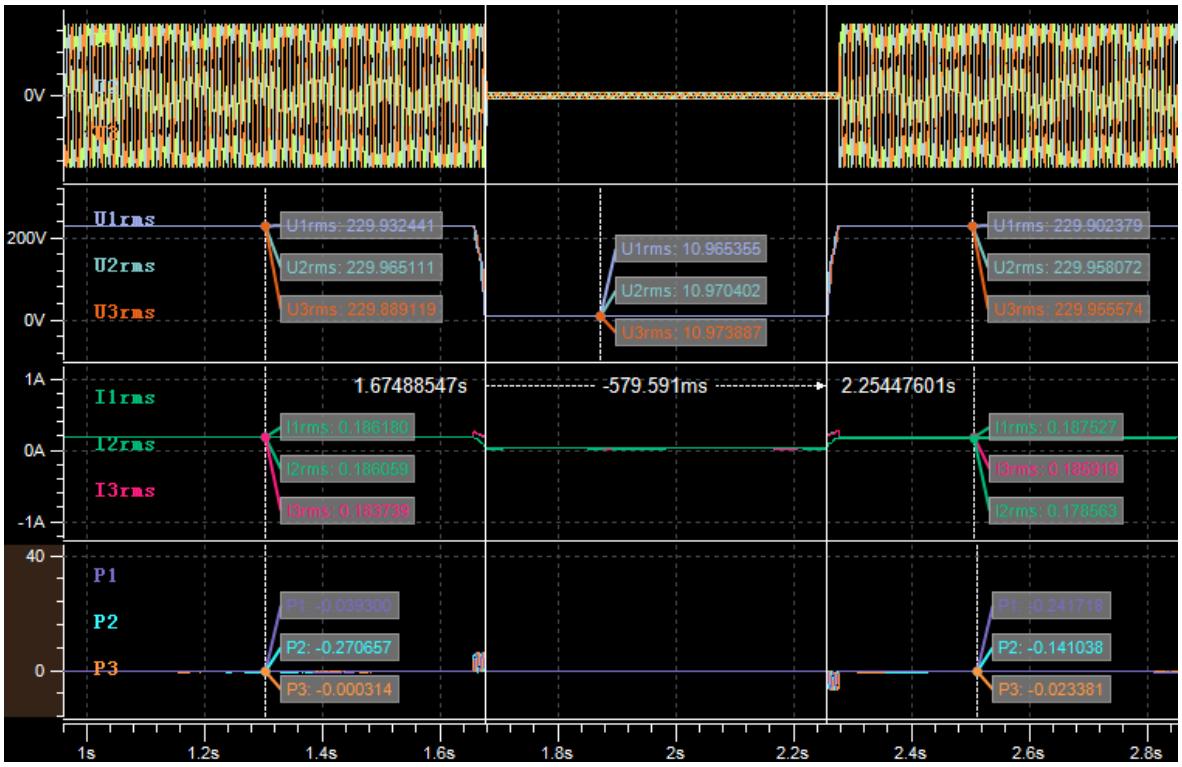
Description of the type of voltage dips:

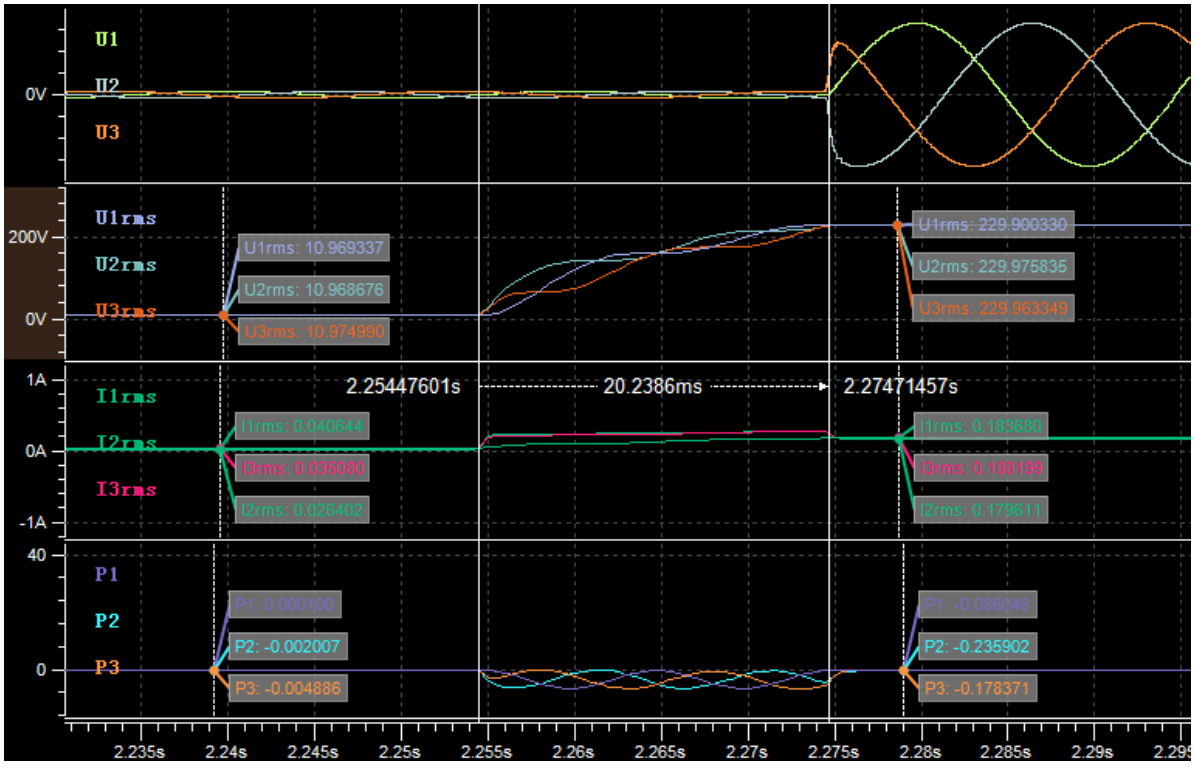
Asymmetric voltage dips were simulated to mirror the behavior during phase to phase faults (isolated) on a medium voltage grid separated by DY5 transformer. Symmetric dips were simulated as three-phase faults (isolated) based on the same setup.

Grid parameters at MP	
Nominal voltage PCC // U[V]	230Vac (L-N)
Minimal short circuit power // S_K [KVA]	60
Grid impedance R [mΩ]	1.81
Grid reactance X [mΩ]	5.56

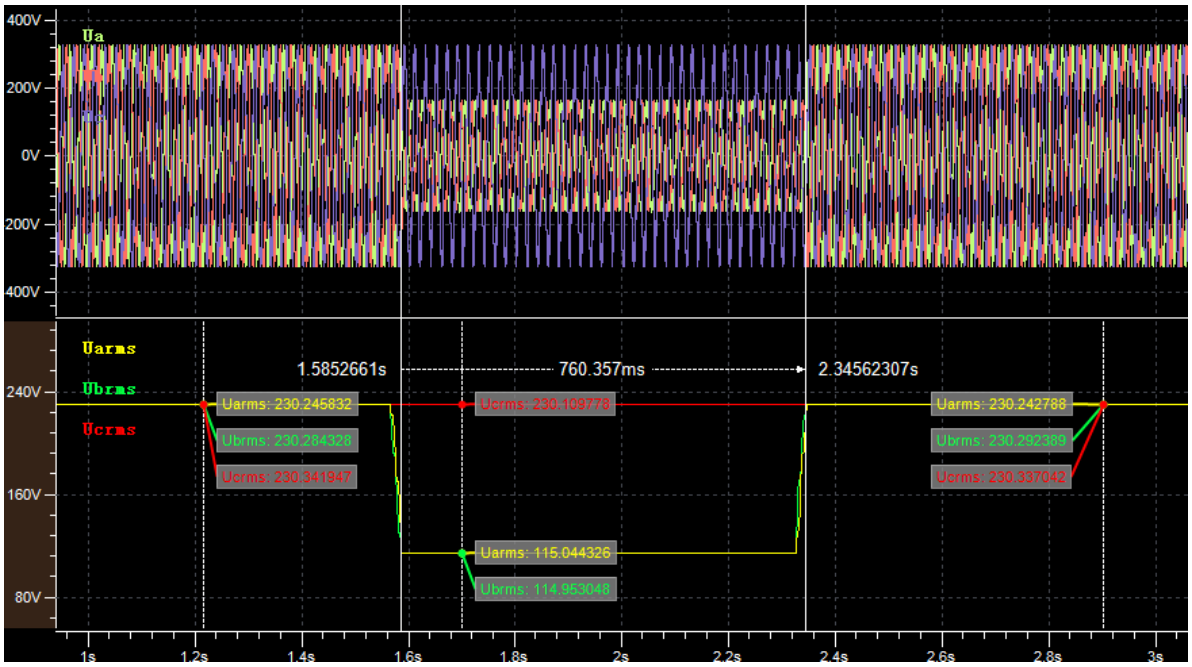
Behaviour during grid disturbance			
Test			
Test No.	1.1		
Phase No.	1	2	3
Fault duration [ms]	>500	>500	>500
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	229.93		
Residual voltage [V] (Average of all phase)	10.97		
Fault duration [ms]	579.59		



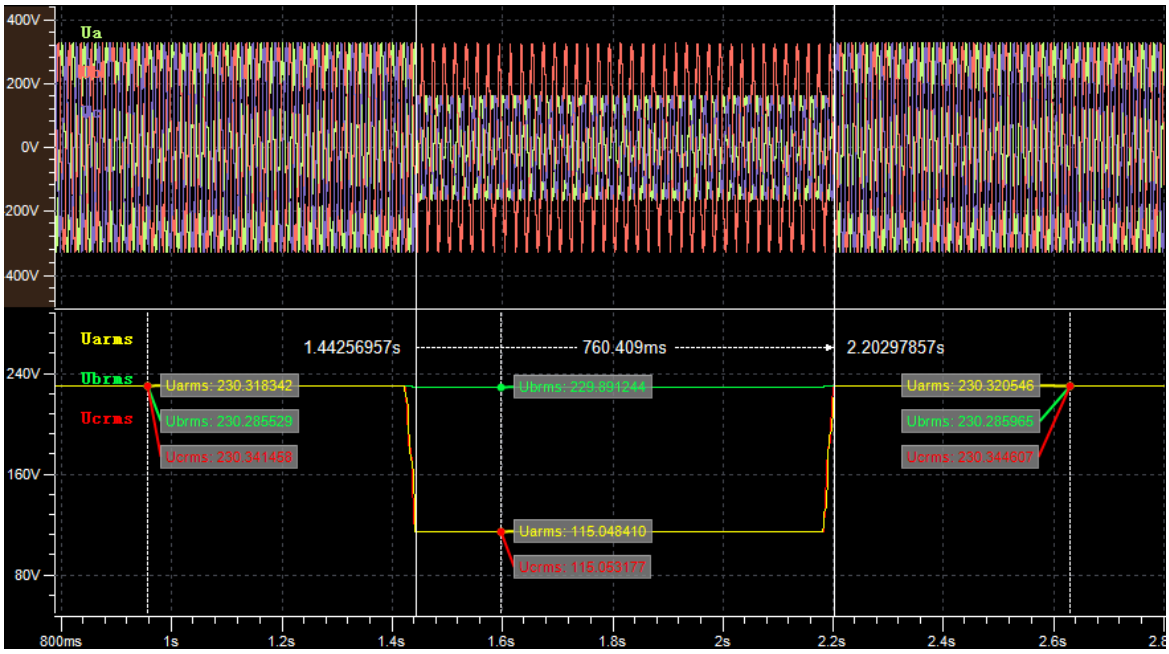

0V
U1rms
U2rms
U3rms
200V
0V
U1rms: 229.932441
U2rms: 229.965111
U3rms: 229.889119
U1rms: 10.965355
U2rms: 10.970402
U3rms: 10.973887
U1rms: 229.902379
U2rms: 229.958072
U3rms: 229.955574
1A
I1rms
I2rms
I3rms
0A
-1A
1.67488547s
-579.591ms
2.25447601s
I1rms: 0.186180
I2rms: 0.186059
I3rms: 0.183739
I1rms: 0.187527
I3rms: 0.186919
I2rms: 0.178563
40
P1
P2
P3
0
P1: -0.039300
P2: -0.270657
P3: -0.000314
P1: -0.241718
P2: -0.141038
P3: -0.023381
1s
1.2s
1.4s
1.6s
1.8s
2s
2.2s
2.4s
2.6s
2.8s


U1
U2
U3
0V
U1rms
U2rms
U3rms
200V
0V
U1rms: 10.969337
U2rms: 10.968676
U3rms: 10.974990
U1rms: 229.900330
U2rms: 229.975835
U3rms: 229.963349
1A
I1rms
I2rms
I3rms
0A
-1A
2.25447601s
20.2386ms
2.27471457s
I1rms: 0.040644
I3rms: 0.035080
I2rms: 0.026402
I1rms: 0.183680
I3rms: 0.188199
I2rms: 0.179611
40
P1
P2
P3
0
P1: 0.000100
P2: -0.002007
P3: -0.004886
P1: -0.086046
P2: -0.235902
P3: -0.178371
2.235s
2.24s
2.245s
2.25s
2.255s
2.26s
2.265s
2.27s
2.275s
2.28s
2.285s
2.29s

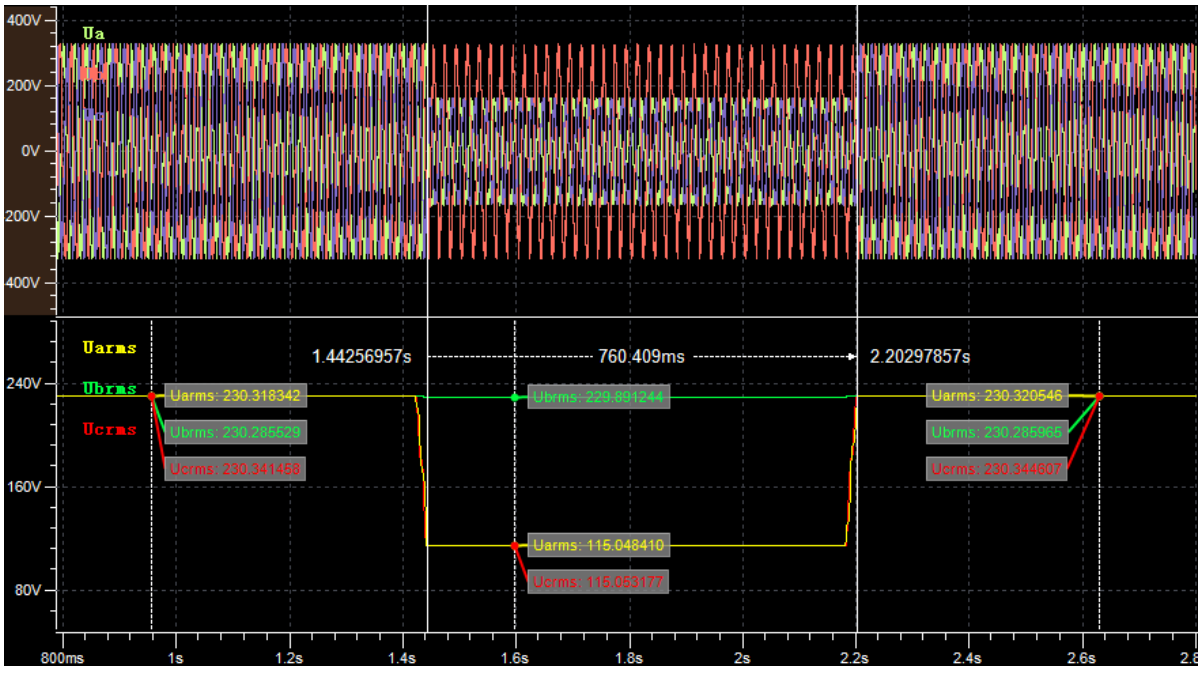
Behaviour during grid disturbance			
Test			
Test No.	1.2A		
Phase No.	1	2	3
Fault duration [ms]	>750	>750	>750
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	229.93		
Residual voltage [V]	114.79	114.82	229.54
Fault duration [ms]	739		



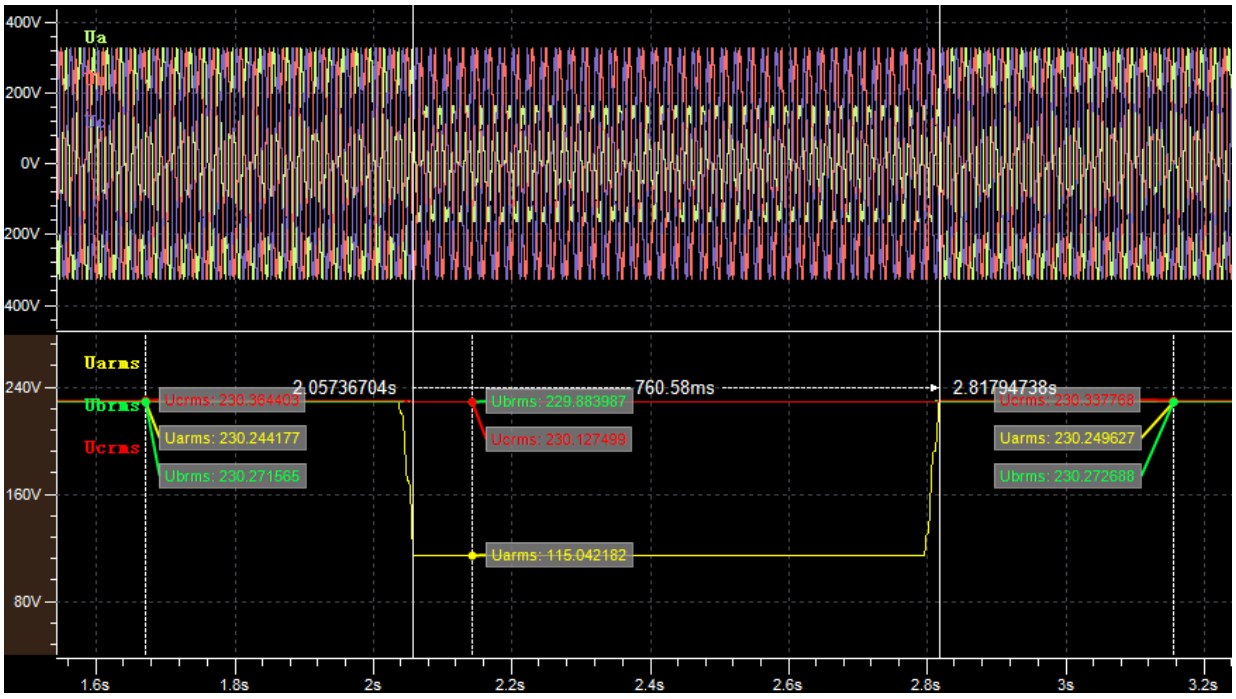
Behaviour during grid disturbance			
Test			
Test No.	1.2B		
Phase No.	1	2	3
Fault duration [ms]	>750	>750	>750
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	230.31		
Residual voltage [V]	115.04	229.89	115.05
Fault duration [ms]	760.41		



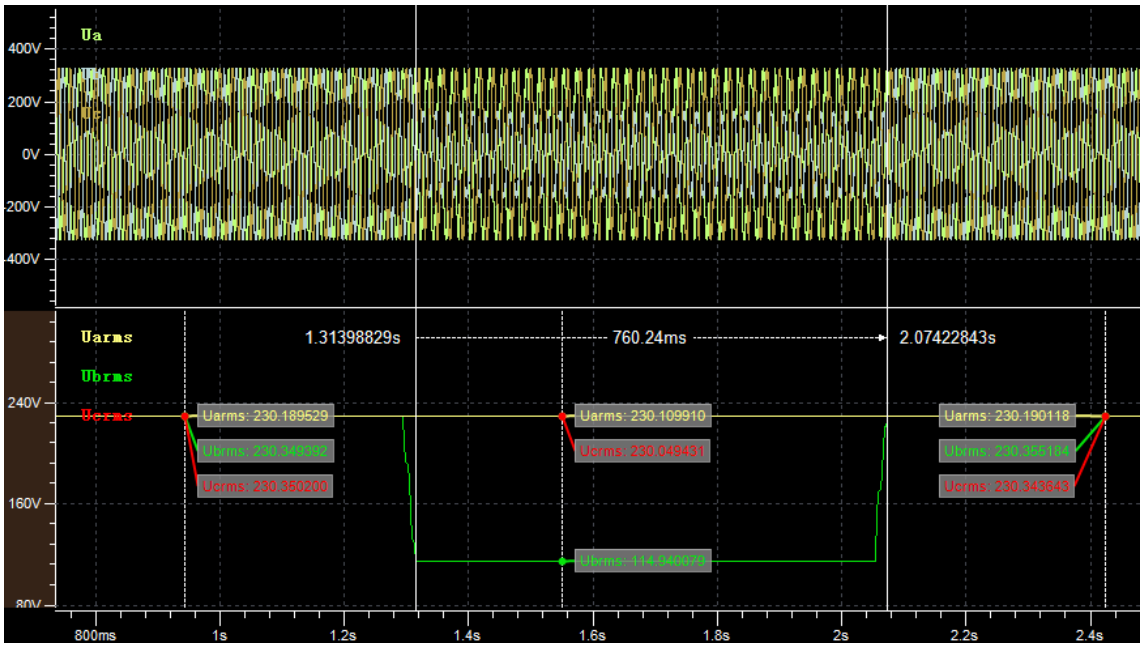
Behaviour during grid disturbance			
Test			
Test No.	1.2C		
Phase No.	1	2	3
Fault duration [ms]	>750	>750	>750
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	230.22		
Residual voltage [V]	230.04	114.97	115.05
Fault duration [ms]	759.86		



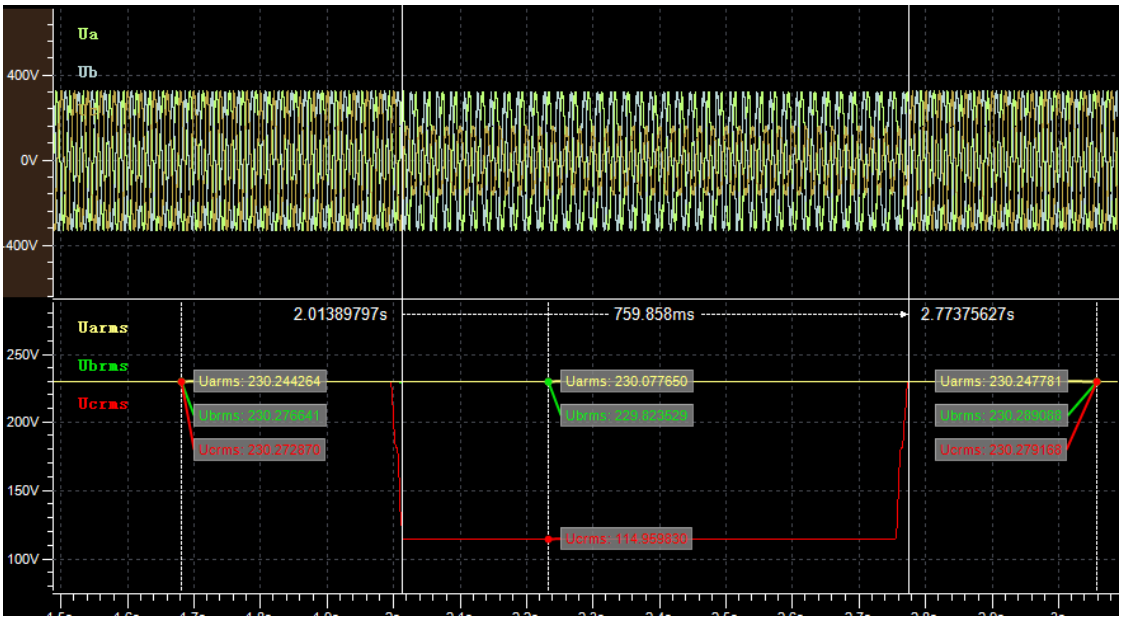
Behaviour during grid disturbance			
Test			
Test No.	1.3A		
Phase No.	1	2	3
Fault duration [ms]	>750	>750	>750
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	230.24		
Residual voltage [V]	115.04	229.88	230.13
Fault duration [ms]	760.58		



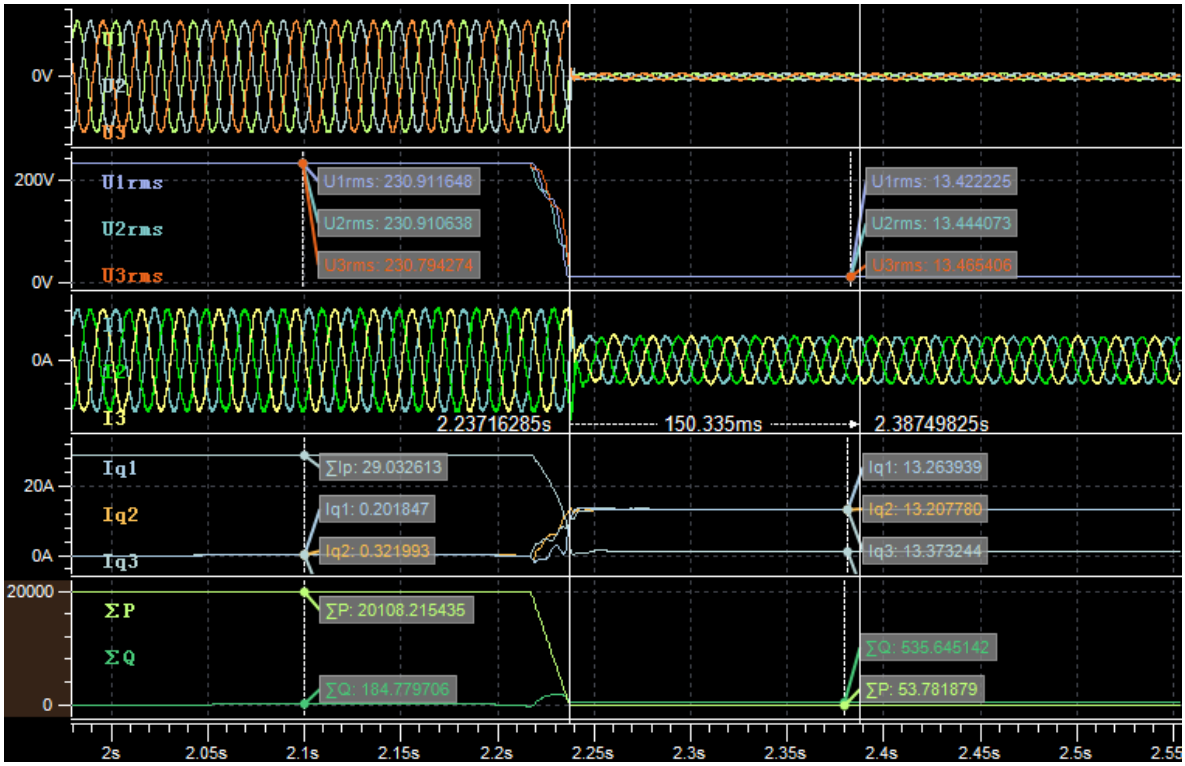
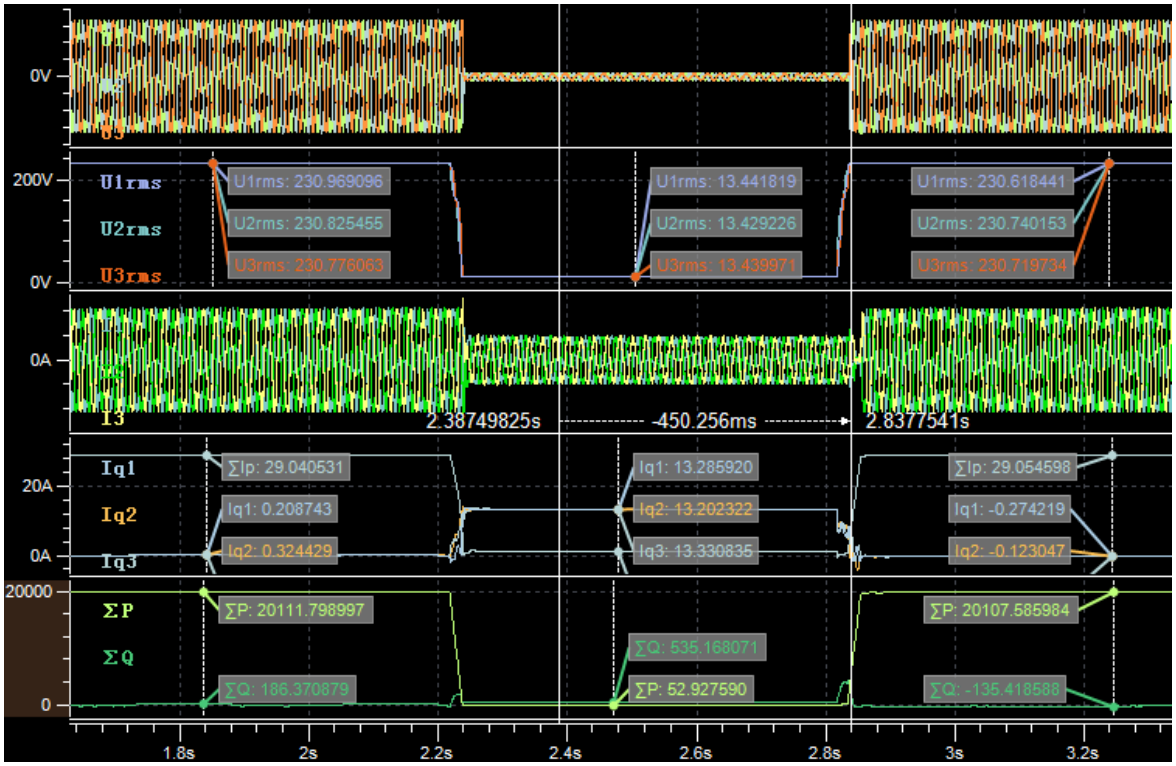
Behaviour during grid disturbance			
Test			
Test No.	1.3B		
Phase No.	1	2	3
Fault duration [ms]	>750	>750	>750
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	230.29		
Residual voltage [V]	230.11	114.94	230.05
Fault duration [ms]	760.24		

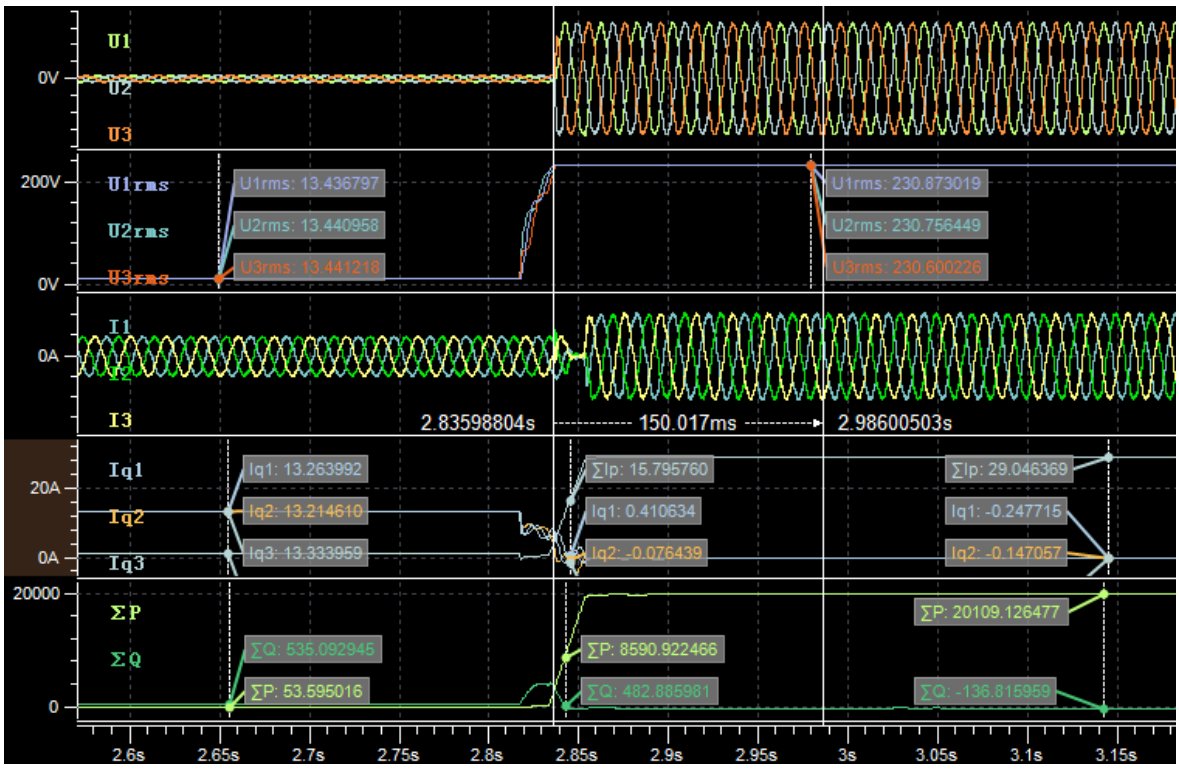


Behaviour during grid disturbance			
Test			
Test No.	1.3C		
Phase No.	1	2	3
Fault duration [ms]	>750	>750	>750
Voltage $U_{pre\text{-}fault}$ [V](Average of all phase)	230.26		
Residual voltage [V]	230.08	229.82	114.96
Fault duration [ms]	758.86		

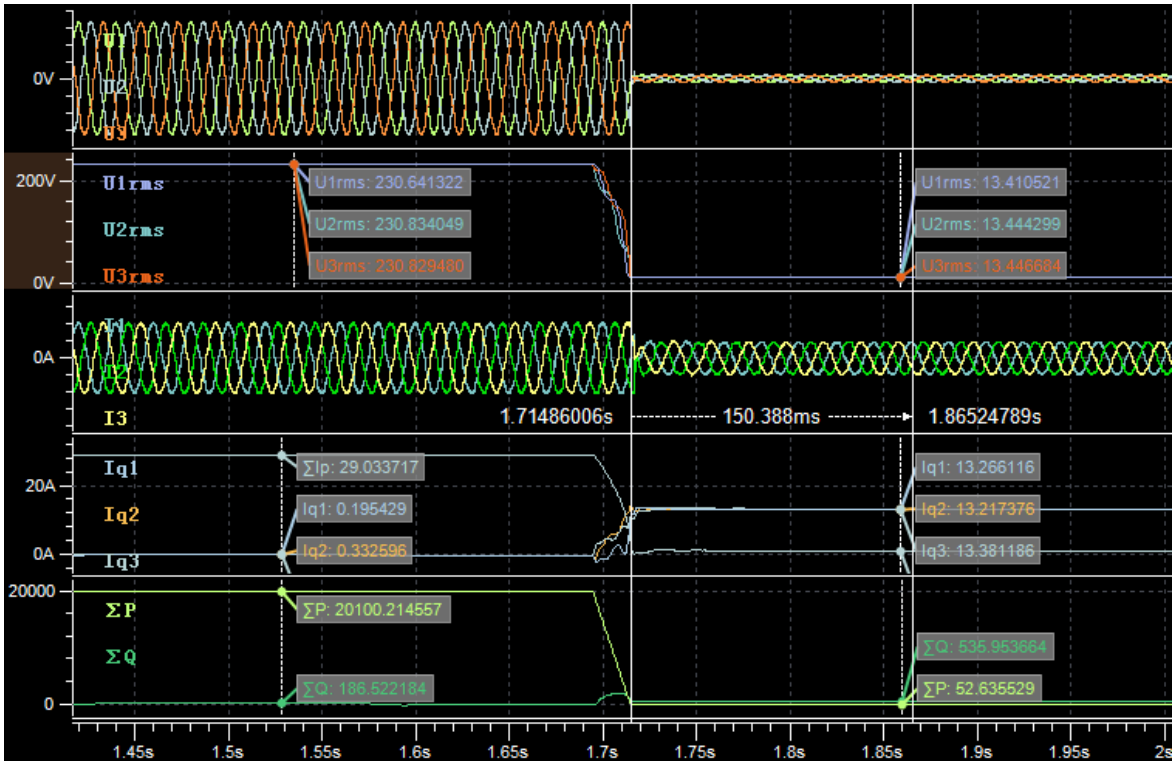
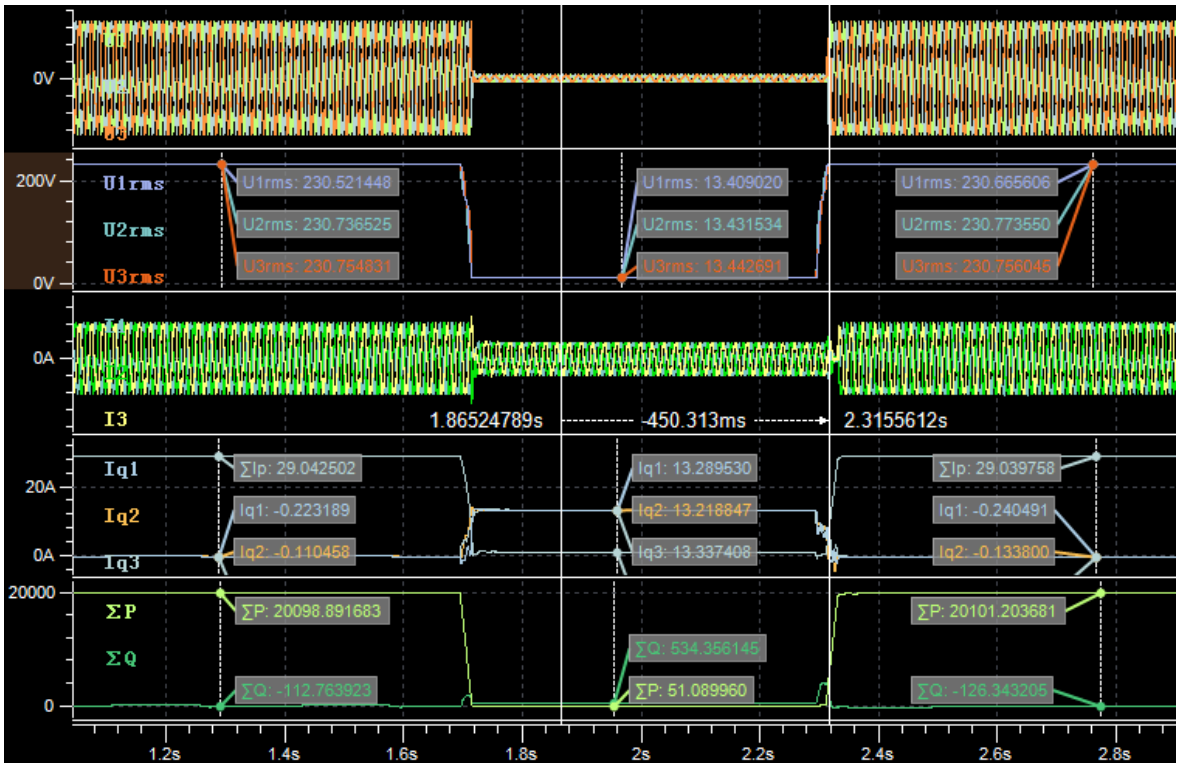


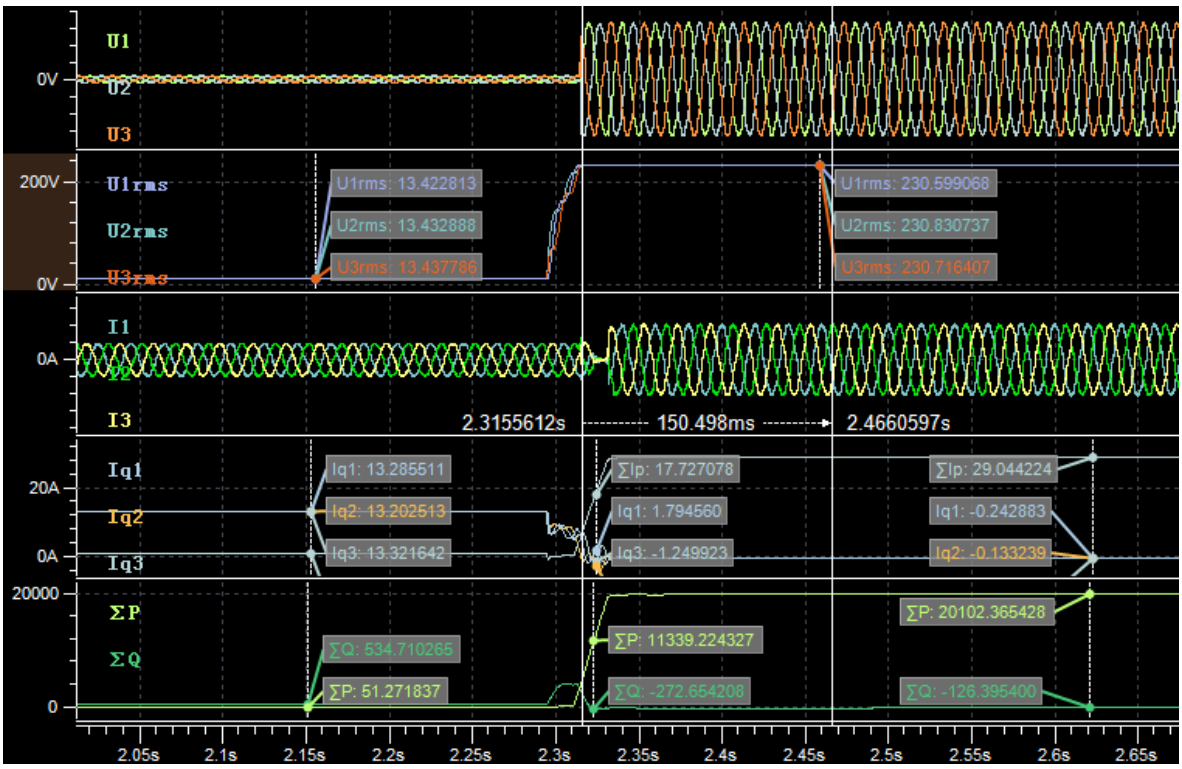
Behaviour during grid disturbance **Balanced faults**				
Test No.2.1				
Voltage dip	**Measurement**			**Limit**
	Phase A	**Phase B**	**Phase C**	
Voltage dip and during 150ms				
Net comsumption Q<60%Pn (20ms)	0.027 p.u	0.027 p.u	0.027 p.u	-0.6p.u
Voltage dip after 150ms until recovery				
Net comsumption P<10%Pn (20ms)	0.0026p.u	0.0026p.u	0.0026p.u	-0.1p,u
Reactive current ratio: Ireactive/Itotal	0.946 p.u	0.942p.u	0.959p.u	>0.9p.u
Voltage recovery during 150ms				
Net reactive consumption energy Er<60%Pn*150ms	-1.026 ms*p.u	-2.045 ms*p.u	-5.367 ms*p.u	-90ms*p.u
Net reactive consumption Ir<1.5In (20ms)	-0.009 p.u	-0.005 p.u	-0.036 p.u	-1.5 p.u

Graph_Phase A

Voltage dip and during 150ms

Voltage dip after 150ms until recovery

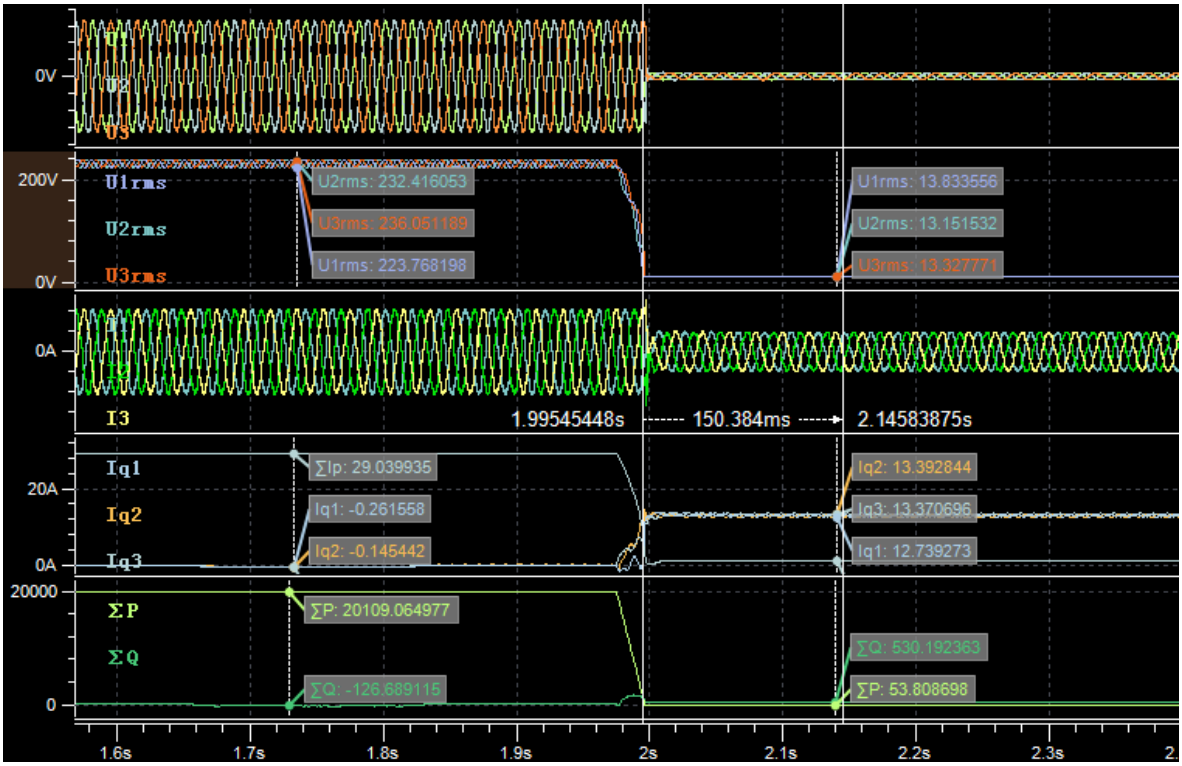
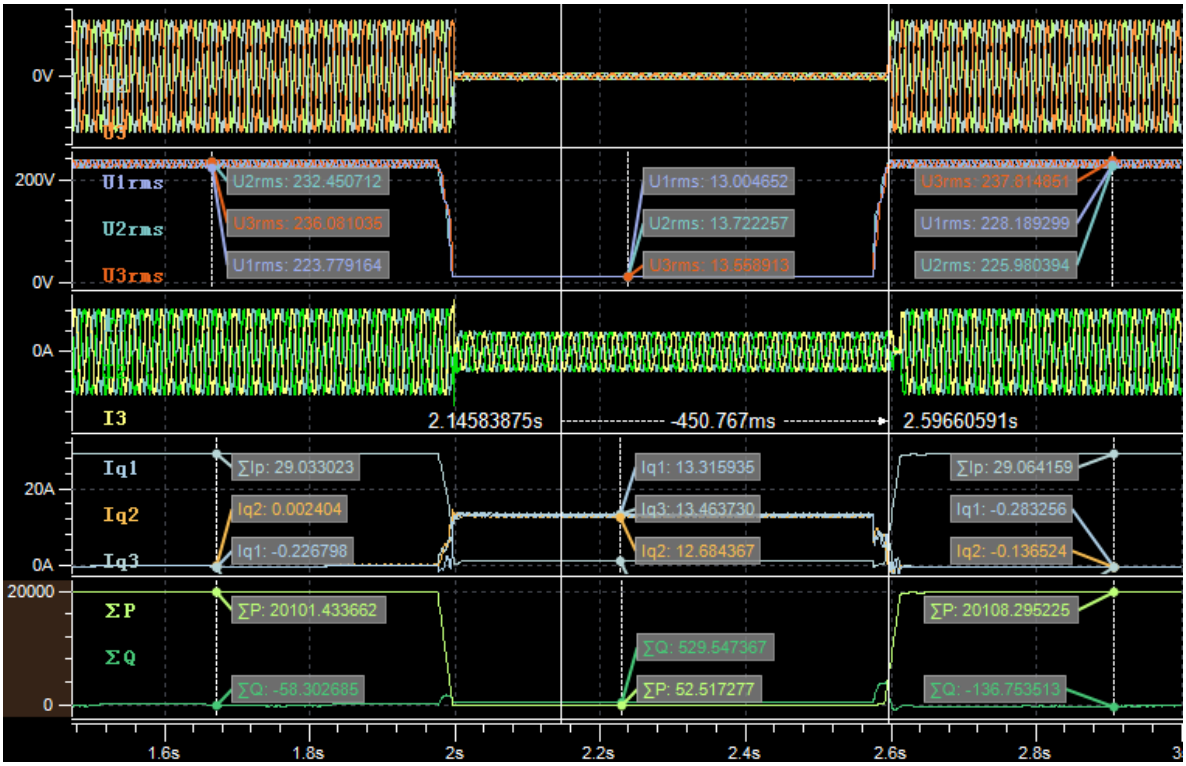


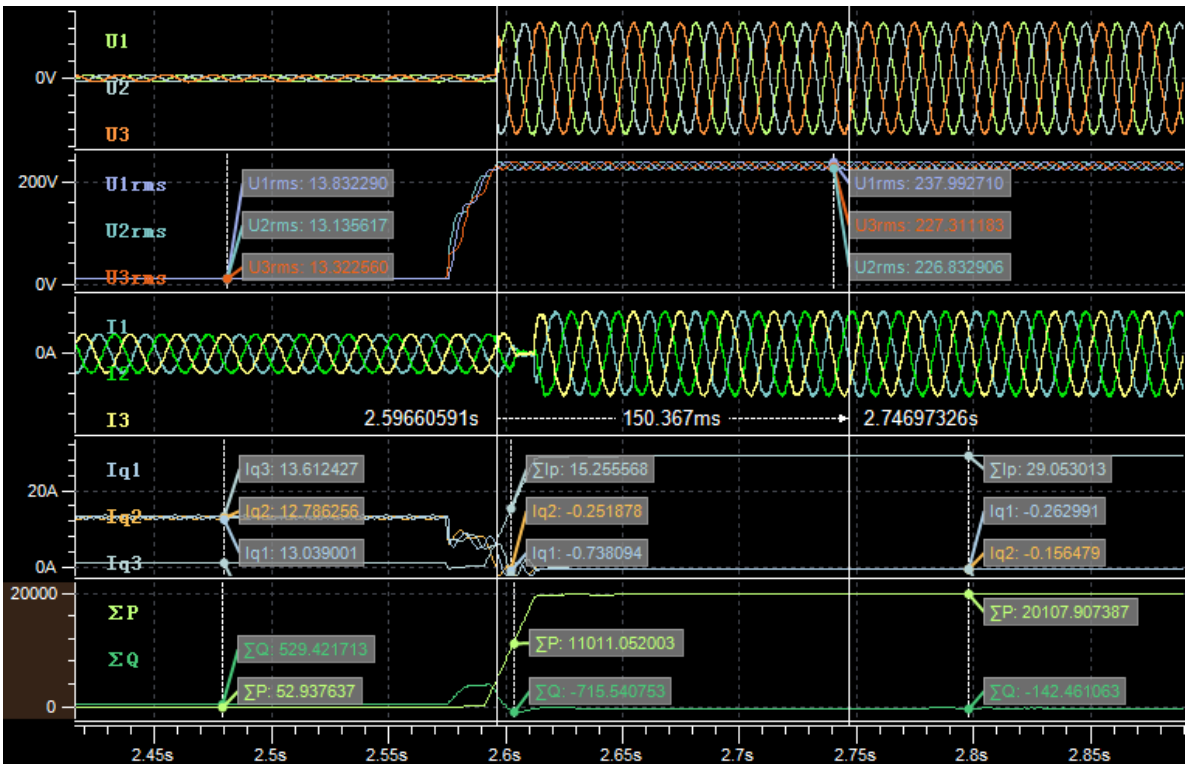
Voltage recovery during 150ms

Graph_Phase B

Voltage dip and during 150ms

Voltage dip after 150ms until recovery



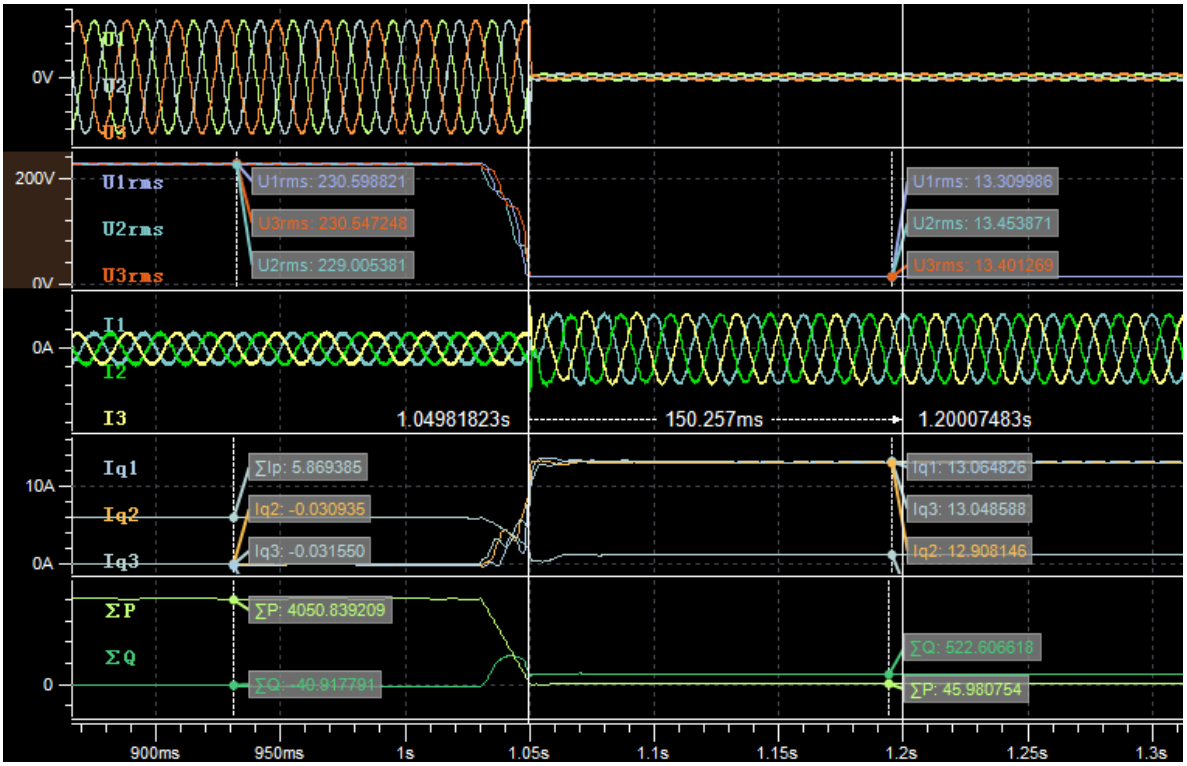
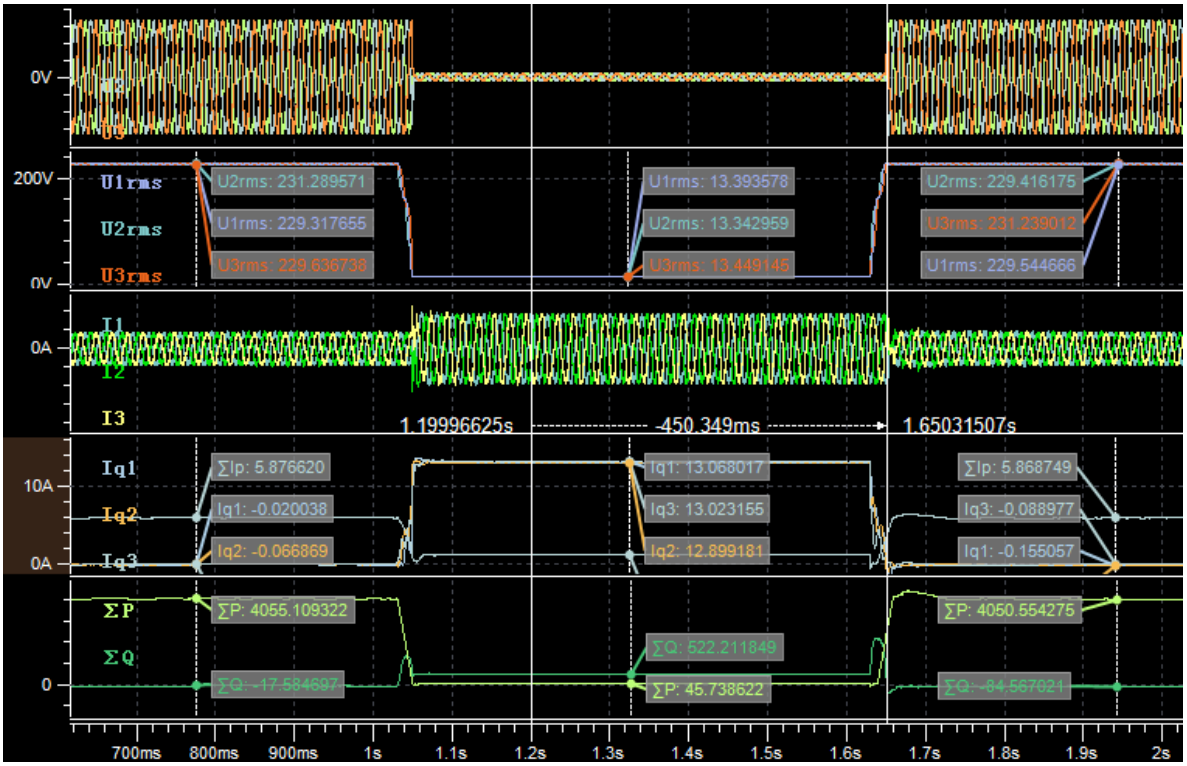
Voltage recovery during 150ms

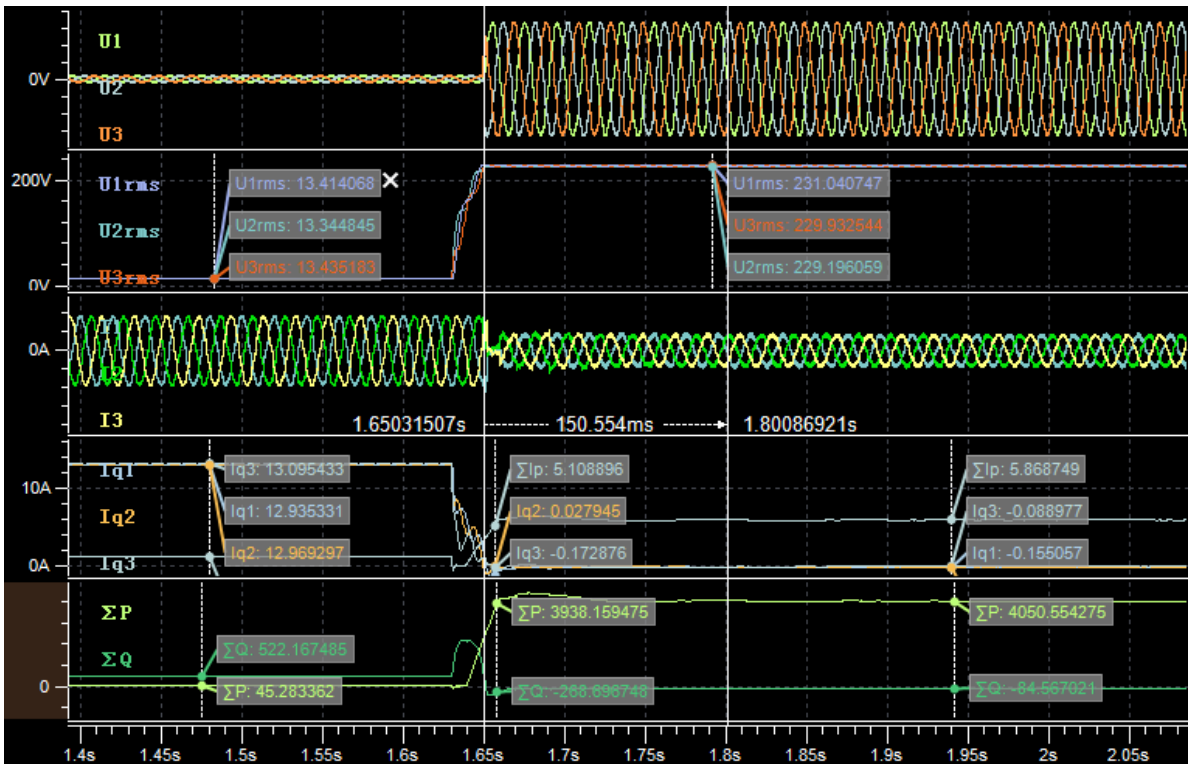
Graph_Phase C

Voltage dip and during 150ms

Voltage dip after 150ms until recovery



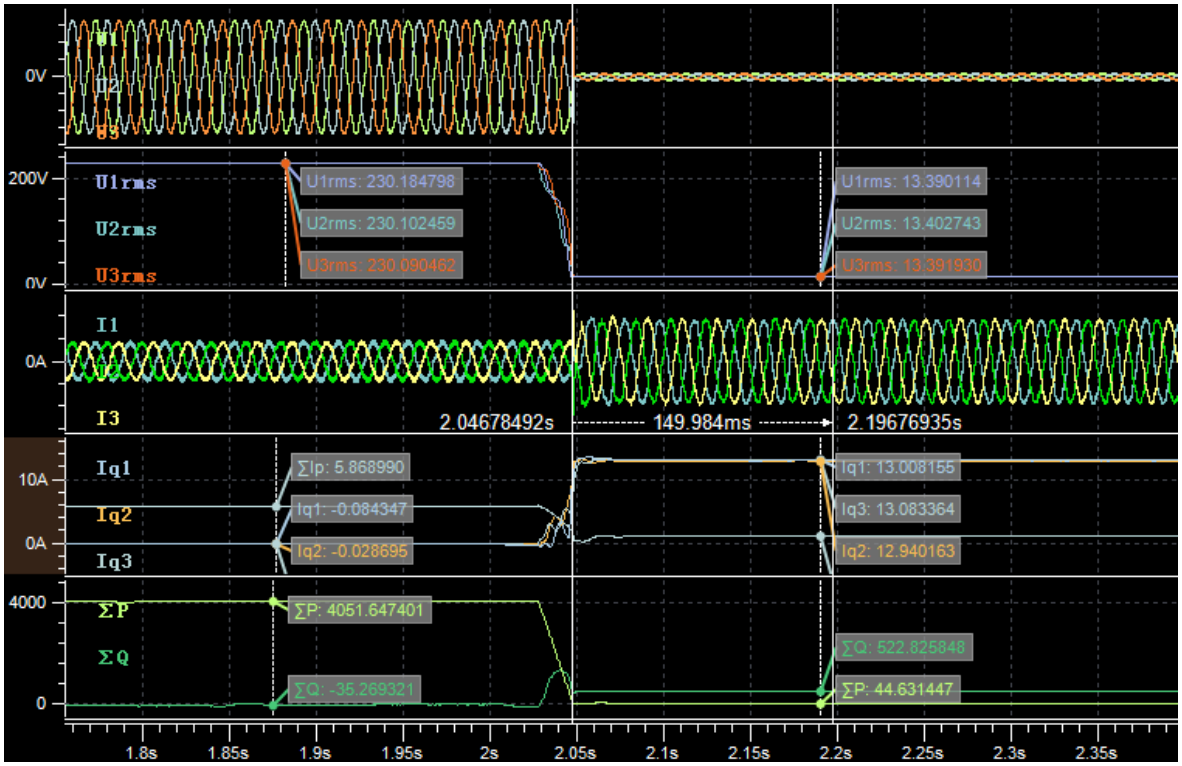
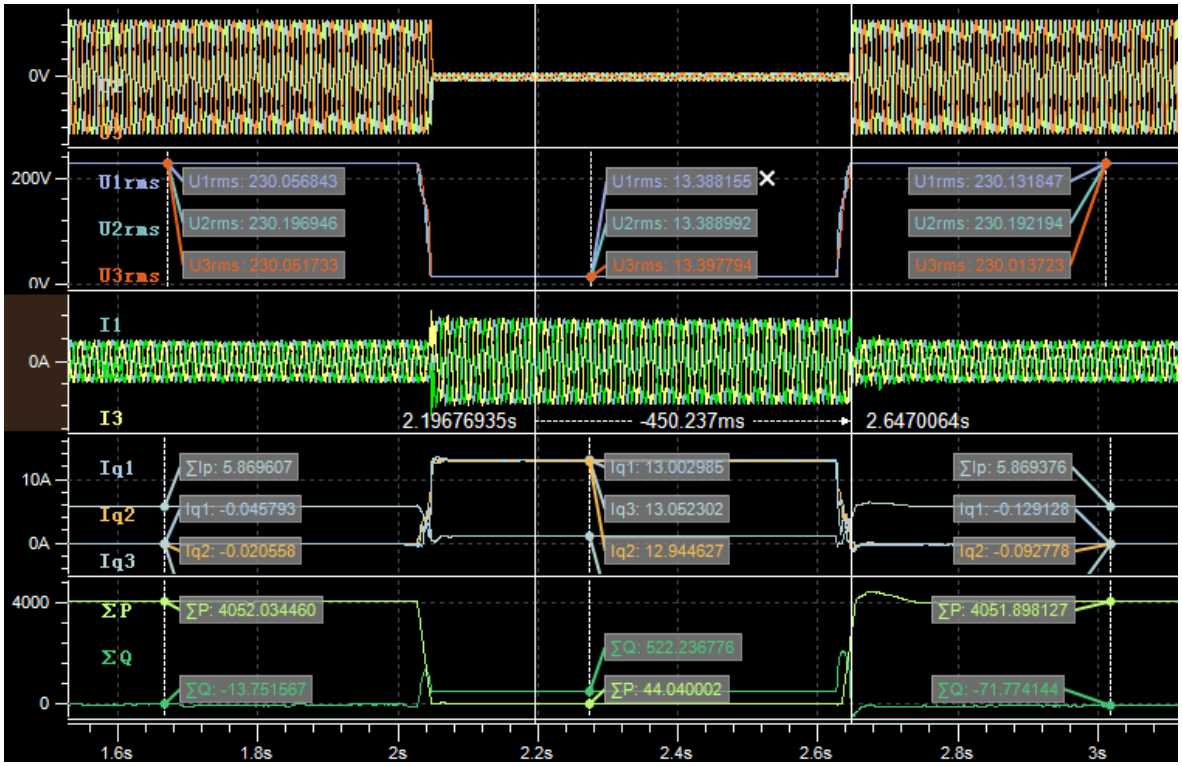
Voltage recovery during 150ms

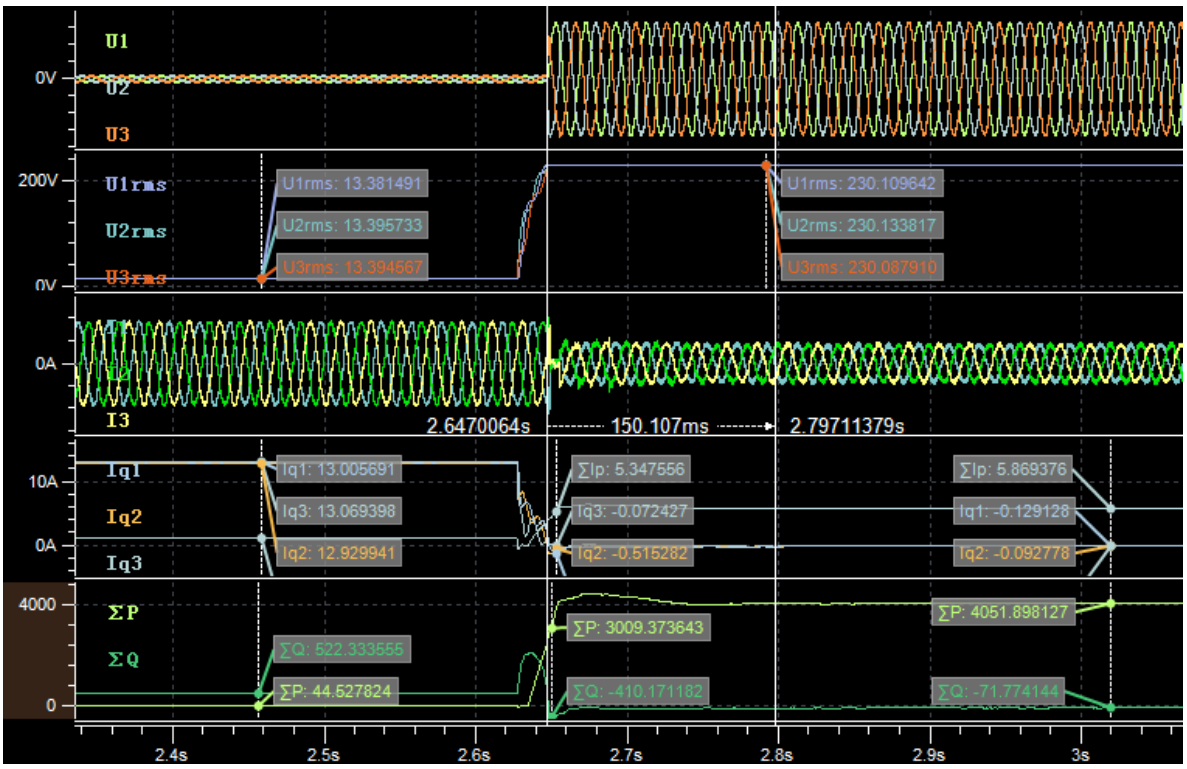
Behaviour during grid disturbance **Balanced faults**				
Test No.2.2				
Voltage dip	**Measurement**			**Limit**
	Phase A	**Phase B**	**Phase C**	
Voltage dip and during 150ms				
Net comsumption Q<60%Pn (20ms)	0.026 p.u	0.026 p.u	0.027 p.u	-0.6p.u
Voltage dip after 150ms until recovery				
Net comsumption P<10%Pn (20ms)	0.0023p.u	0.0022p.u	0.0024p.u	-0.1p,u
Reactive current ratio: Ireactive/Itotal	0.931 p.u	0.922p.u	0.950p.u	>0.9p.u
Voltage recovery during 150ms				
Net reactive consumption energy Er<60%Pn*150ms	-2.015 ms*p.u	-3.076 ms*p.u	-0.601 ms*p.u	-90ms*p.u
Net reactive consumption Ir<1.5In (20ms)	-0.013 p.u	-0.018 p.u	-0.003 p.u	-1.5 p.u

Graph_Phase A

Voltage dip and during 150ms

Voltage dip after 150ms until recovery

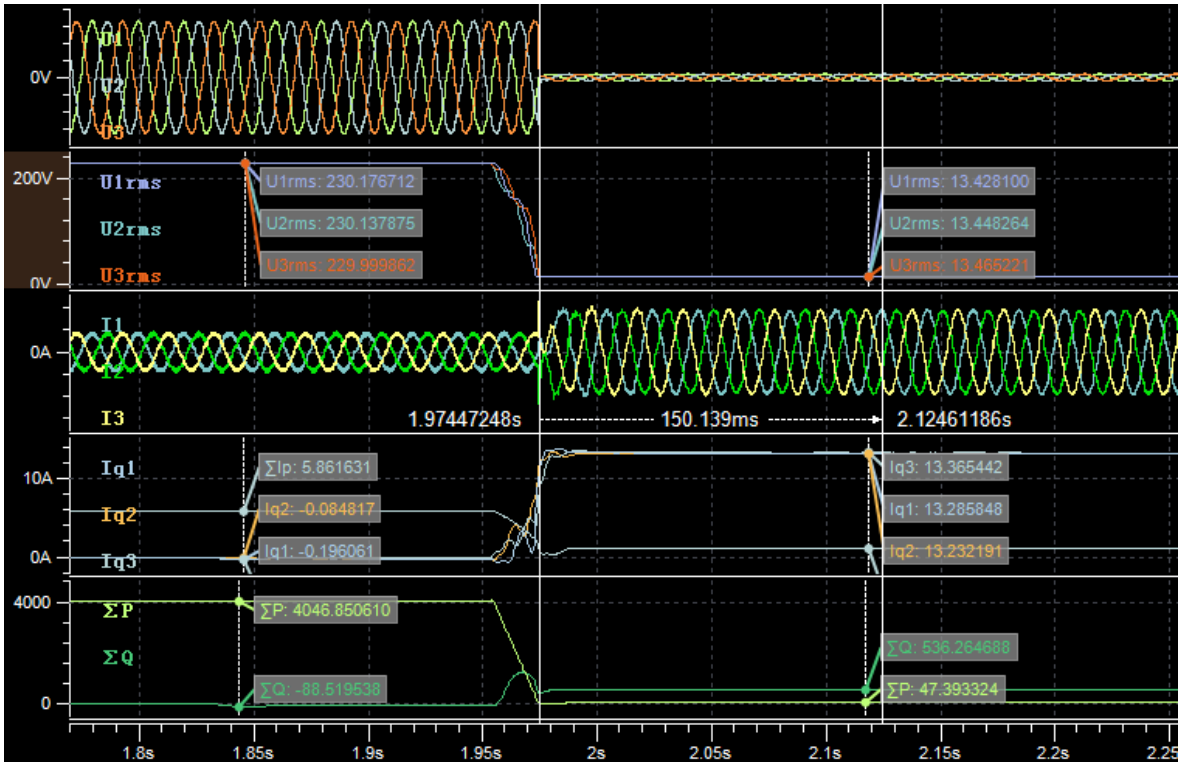
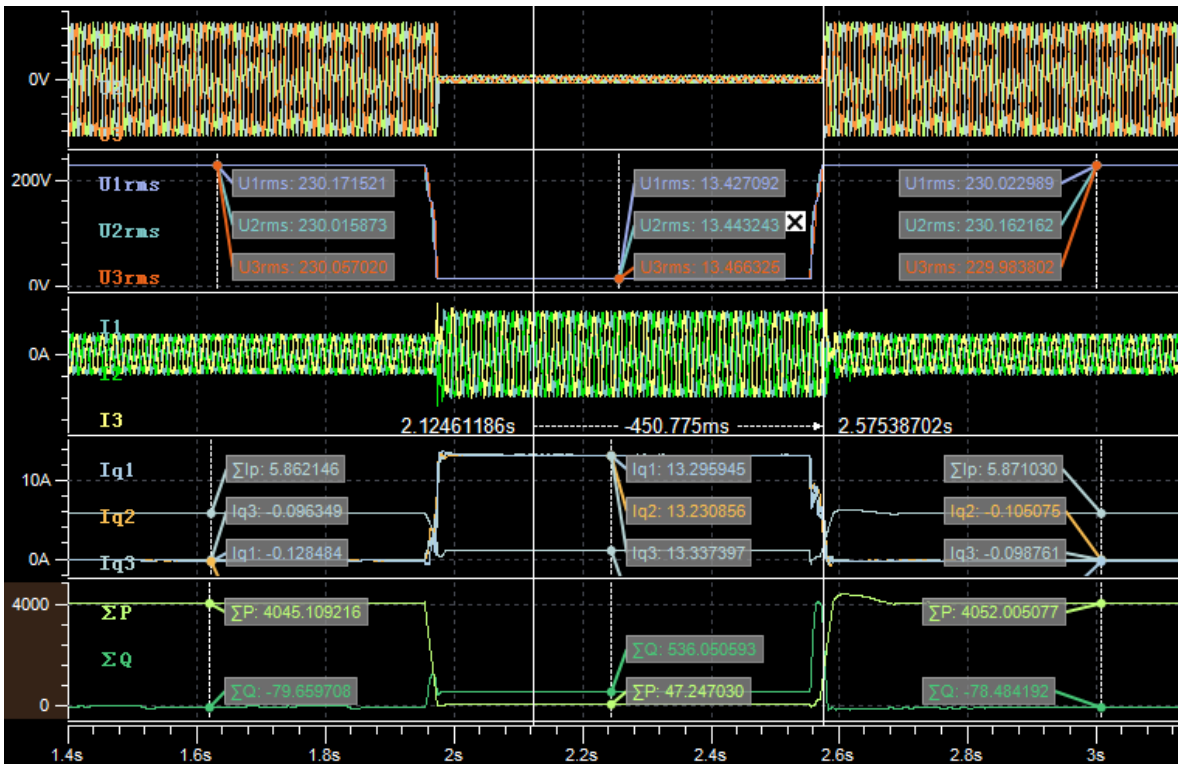


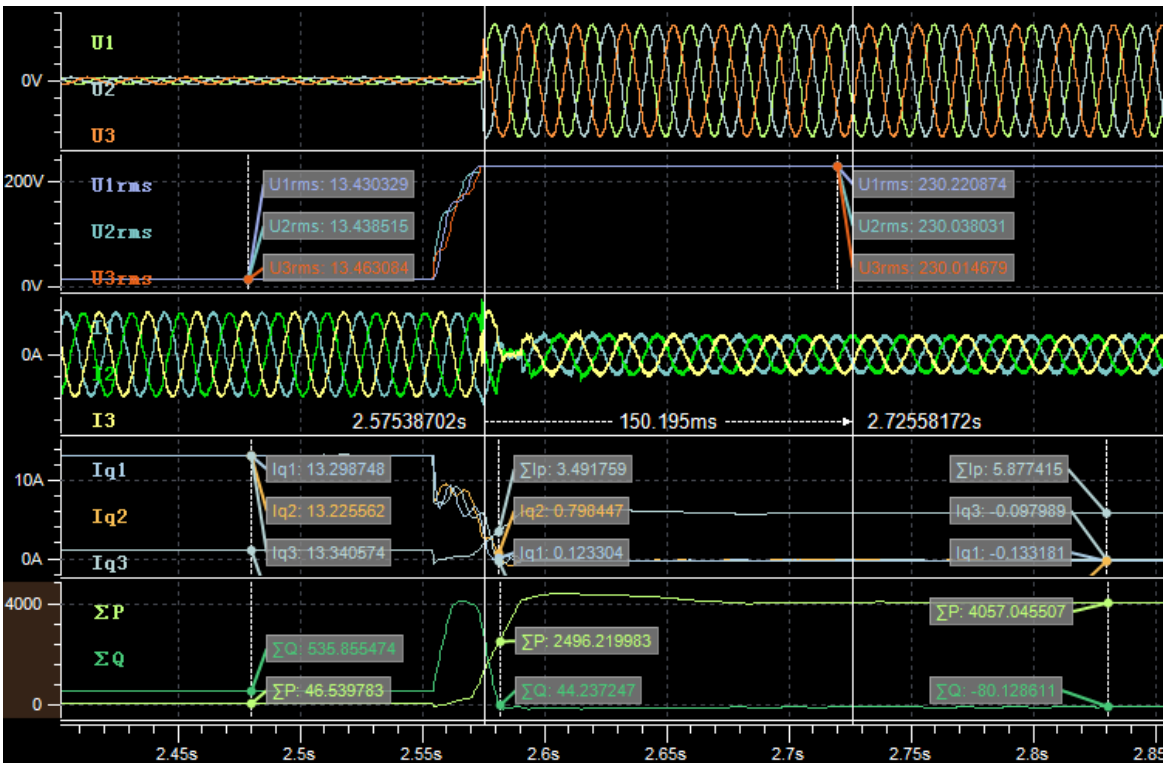
Voltage recovery during 150ms

Graph_Phase B

Voltage dip and during 150ms

Voltage dip after 150ms until recovery



Voltage recovery during 150ms

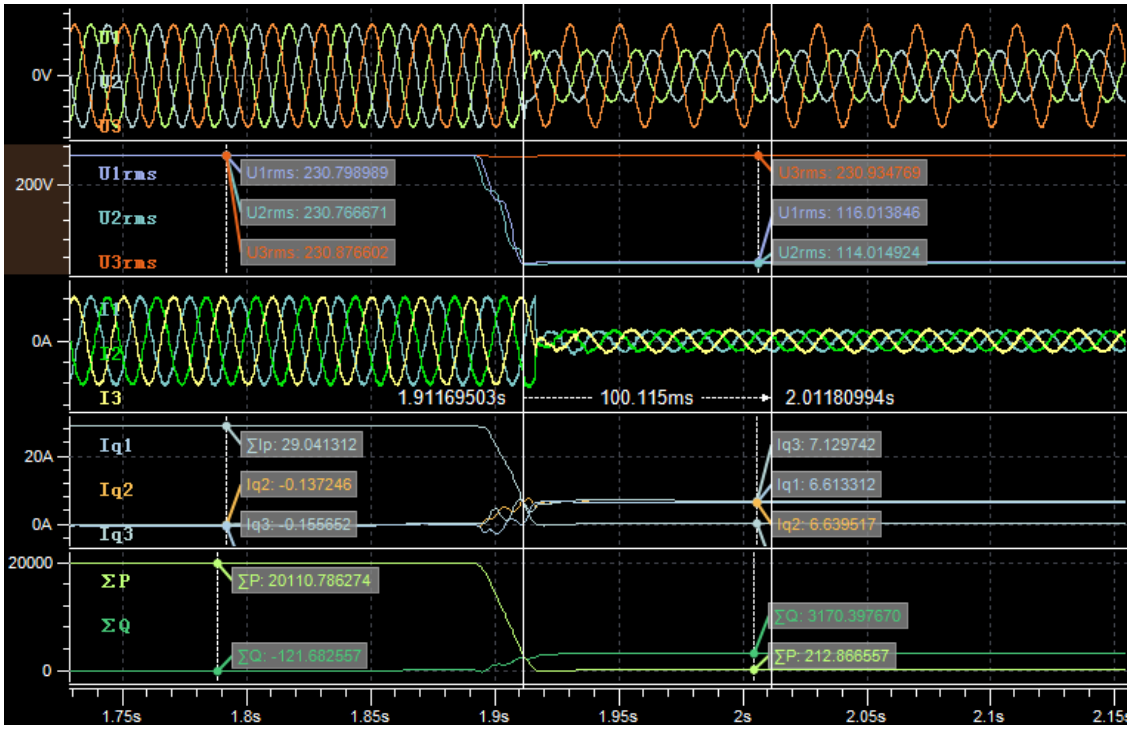
Graph_Phase C

Voltage dip and during 150ms

Voltage dip after 150ms until recovery



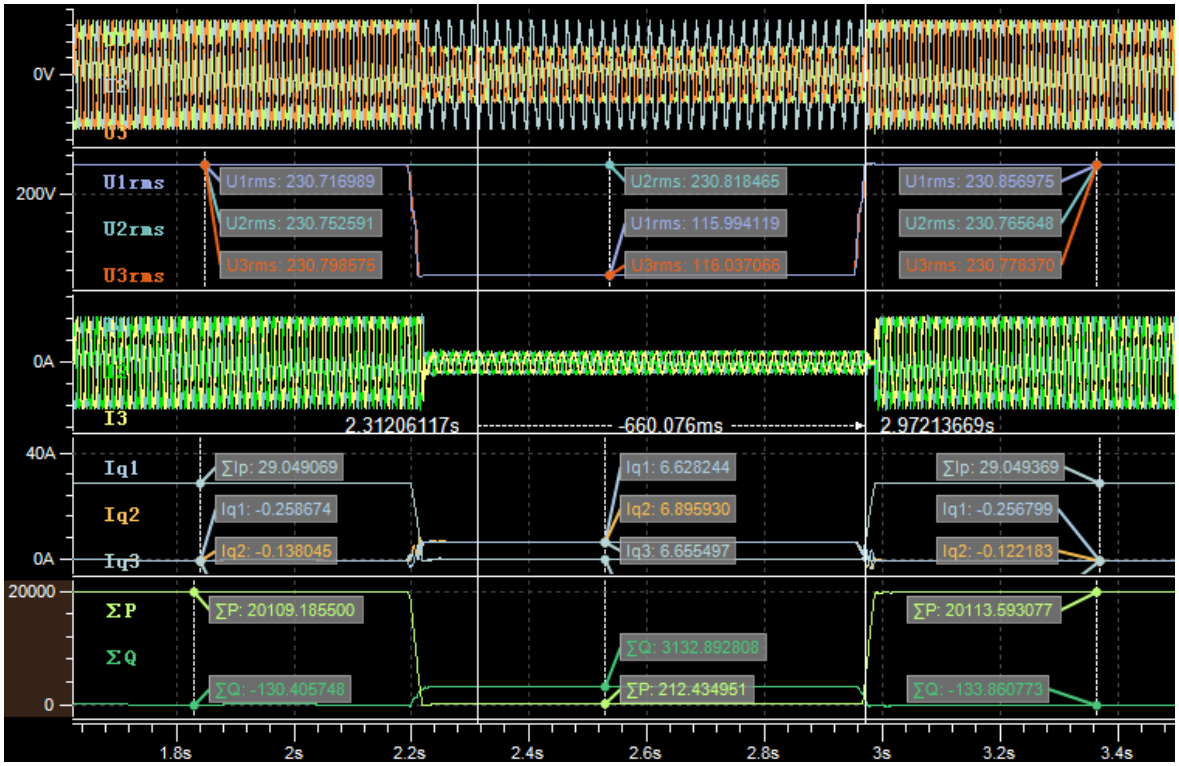
Voltage recovery during 150ms

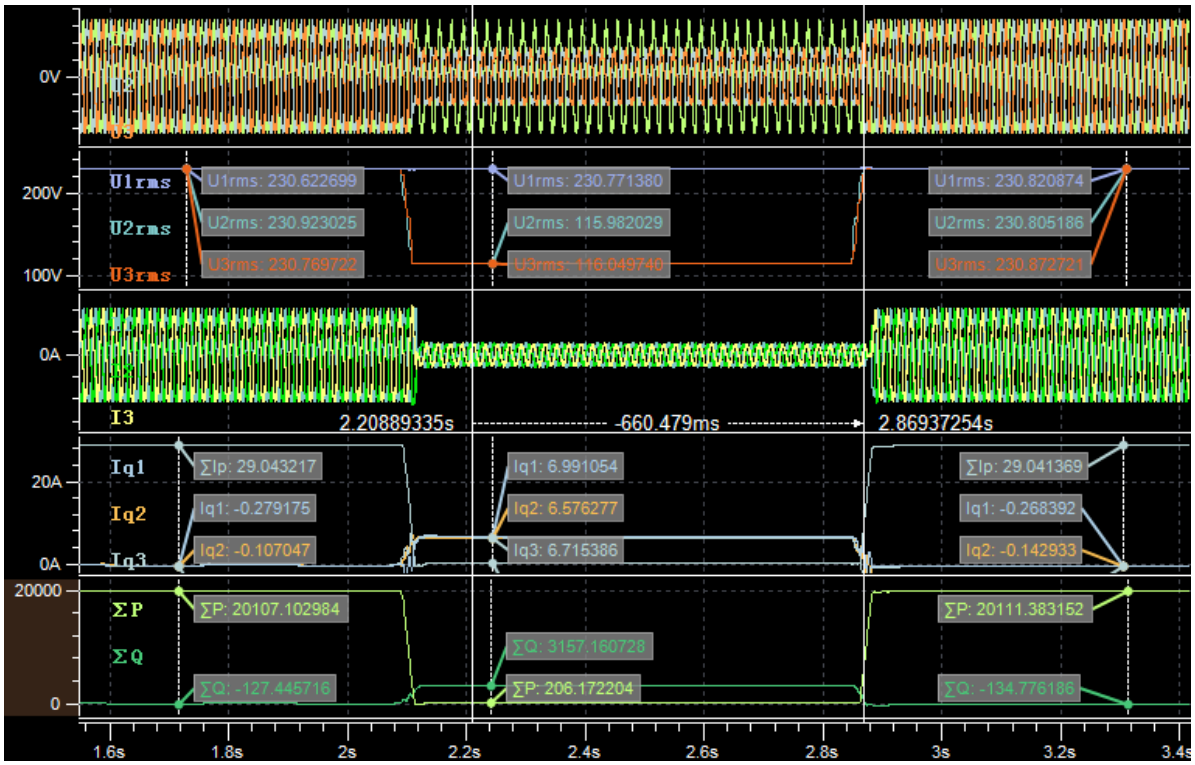
Behaviour during grid disturbance **Unbalanced faults**				
Test No.2.3				
Voltage dip	**Measurement**			**Limit**
	Phase A-B	**Phase A-C**	**Phase B-C**	
Voltage dip after 150ms until recovery				
Net reactive comsumption energy Er<40%Pn*100ms	15.83 ms*p.u	15.66 ms*p.u	15.79 ms*p.u	-40ms*p.u
Net reactive comsumption Q<40%Pn(20ms)	0.1583p.u	0.1566p.u	0.1579p.u	-0.4 p.u
Net active power comsumption energy Ep<45%Pn*100ms	1.050 ms*p.u	1.062 ms*p.u	1.031 ms*p.u	-45ms*p.u
Net active power comsumption P<30%Pn(20ms)	0.0105p.u	0.0106p.u	0.0103p.u	-0.3 p.u

Graph_Phase A-B



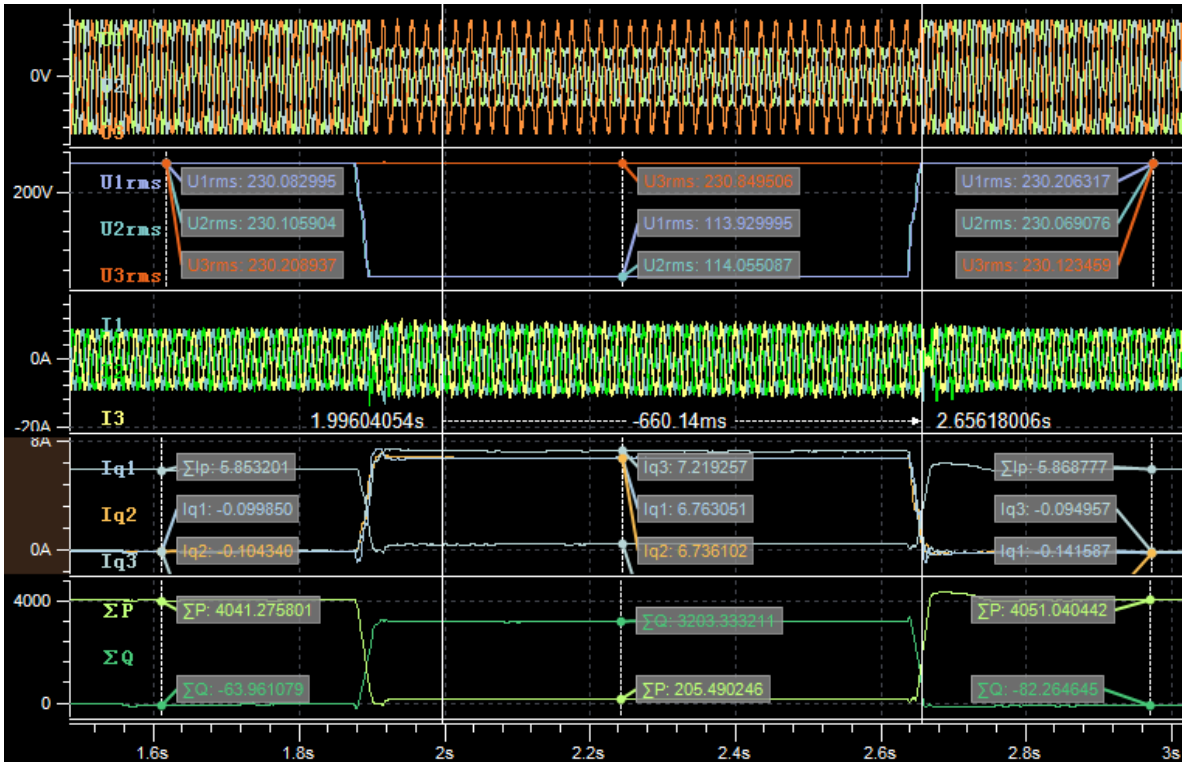
Voltage dip after 150ms until recovery

Graph_Phase A-C

Voltage dip after 150ms until recovery

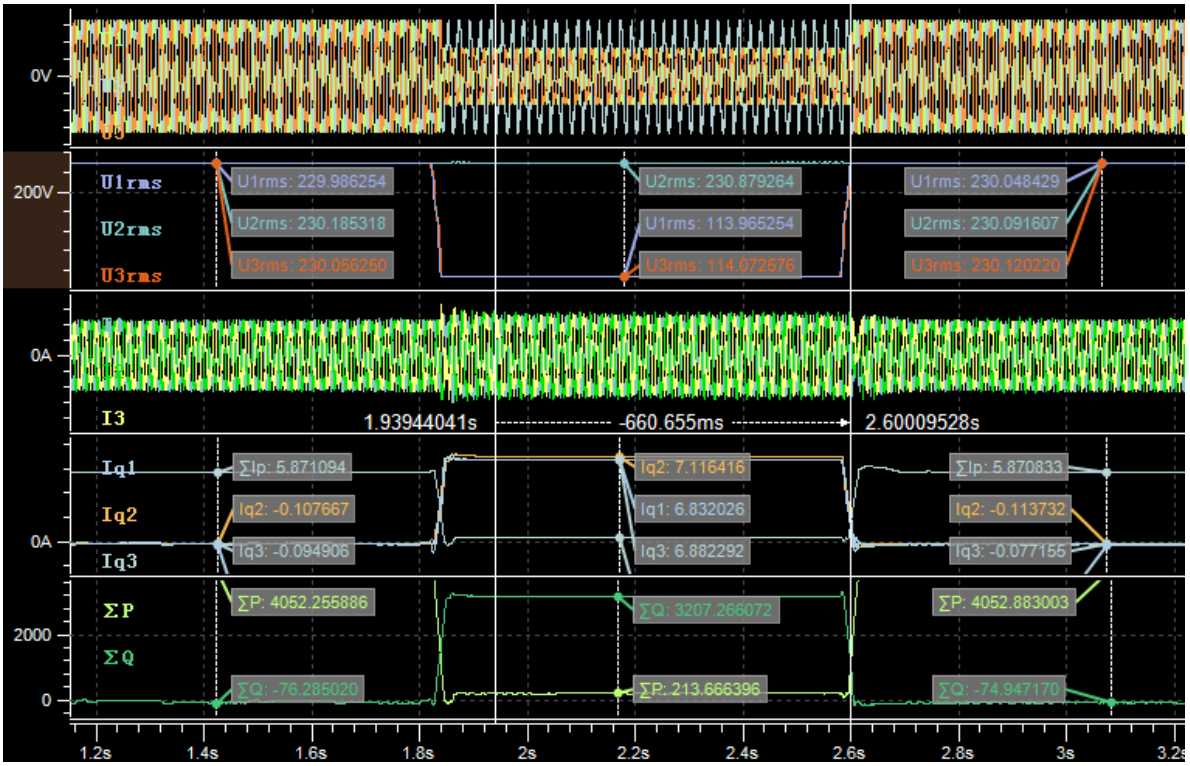
Graph_Phase B-C

Voltage dip after 150ms until recovery

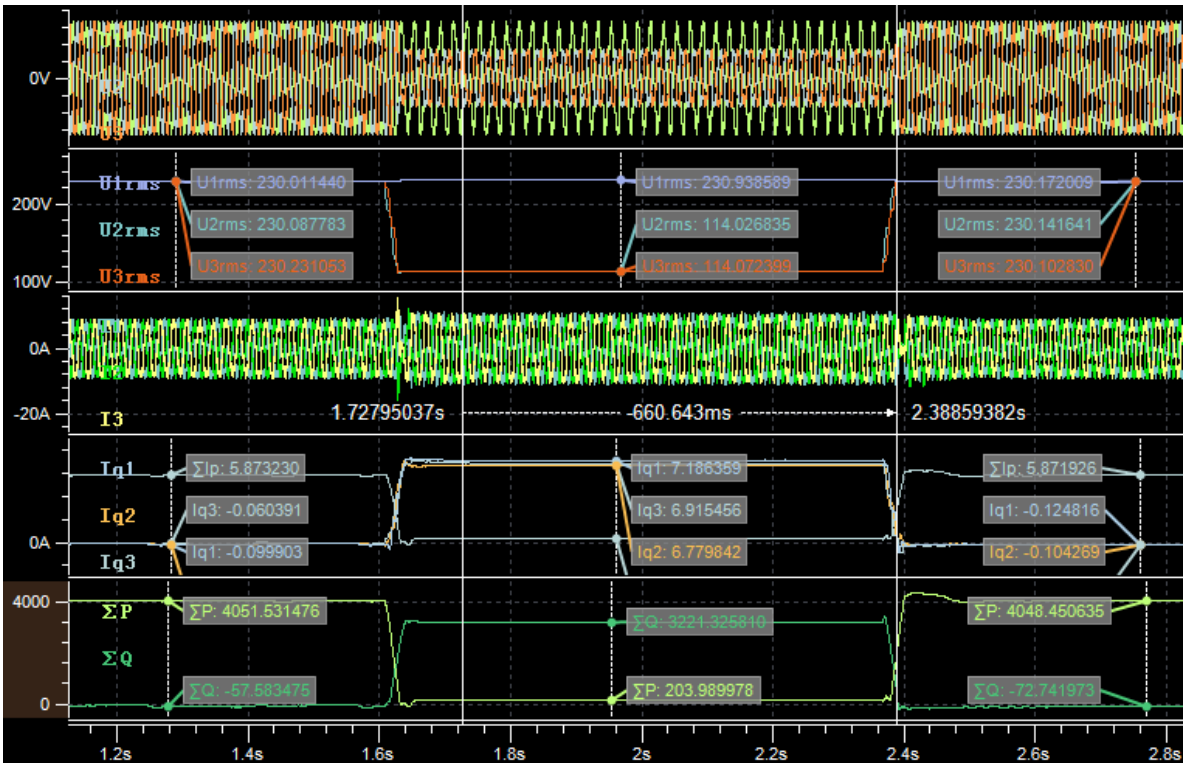
Behaviour during grid disturbance **Unbalanced faults**				
Test No.2.4				
Voltage dip	**Measurement**			**Limit**
	Phase A-B	**Phase A-C**	**Phase B-C**	
Voltage dip after 150ms until recovery				
Net comsumption energy Er<40%Pn*100ms	16.017 ms*p.u	16.036 ms*p.u	16.107 ms*p.u	-40ms*p.u
Net comsumption Q<40%Pn(20ms)	0.1602p.u	0.1604p.u	0.1611p.u	-0.4 p.u
Net comsumption energy Ep<45%Pn*100ms	1.030 ms*p.u	1.068 ms*p.u	1.020 ms*p.u	-45ms*p.u
Net comsumption P<30%Pn(20ms)	0.0103p.u	0.0107p.u	0.0102p.u	-0.3 p.u

Graph_Phase A-B



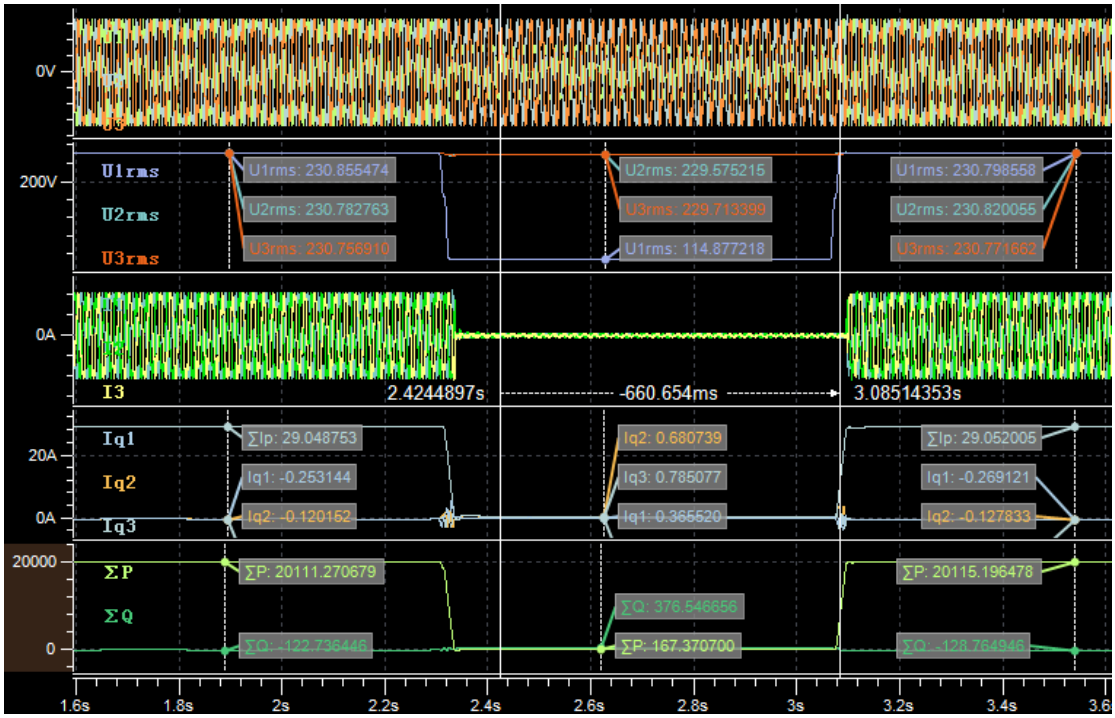
Voltage dip after 150ms until recovery

Graph_Phase A-C

Voltage dip after 150ms until recovery

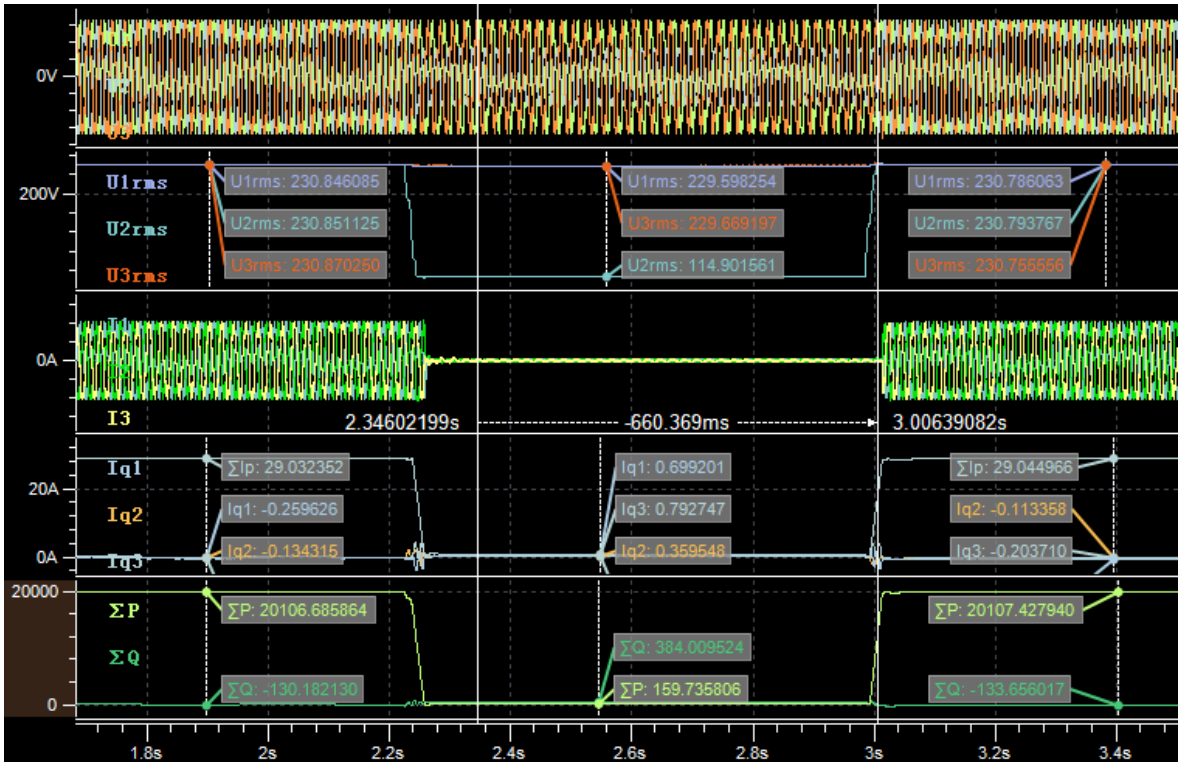
Graph_Phase B-C

Voltage dip after 150ms until recovery

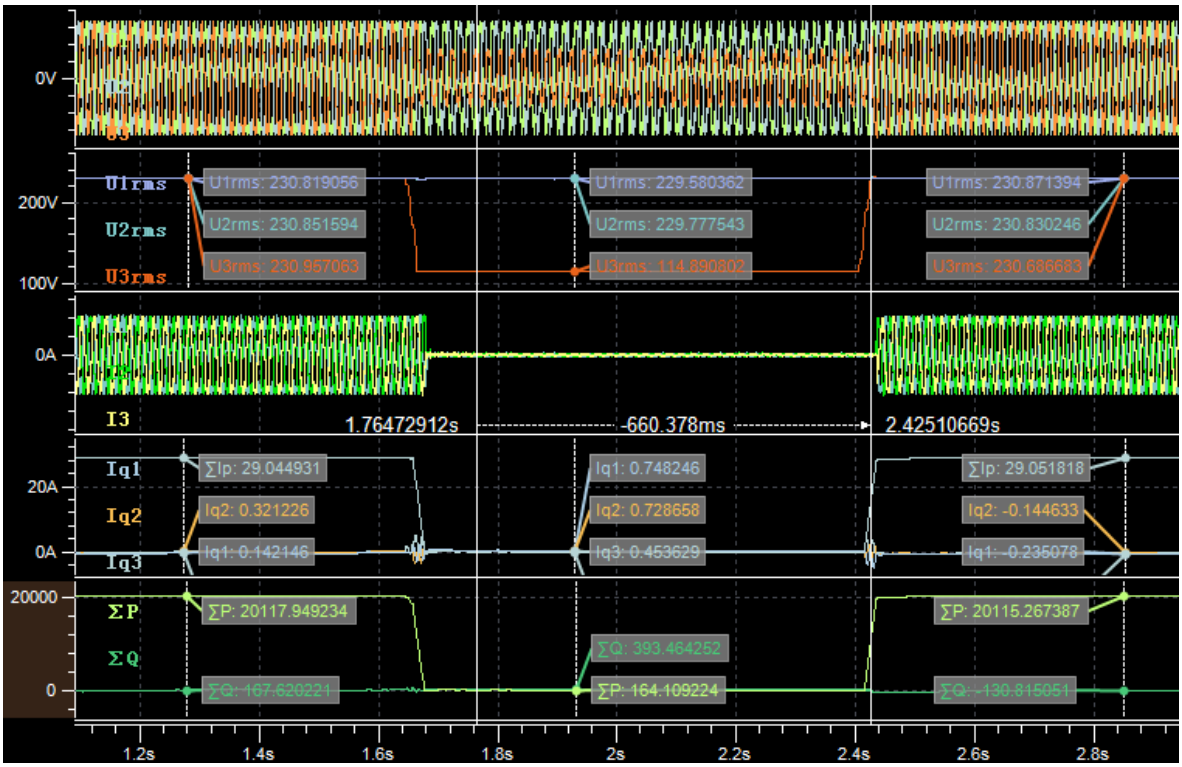
Behaviour during grid disturbance **Unbalanced faults**				
Test No.2.5				
Voltage dip	**Measurement**			**Limit**
	Phase A	**Phase B**	**Phase C**	
Voltage dip after 150ms until recovery				
Net ractive comsumption energy Er<40%Pn*100ms	1.883 ms*p.u	1.920 ms*p.u	1.967 ms*p.u	-40ms*p.u
Net ractive comsumption Q<40%Pn(20ms)	0.0188p.u	0.0192p.u	0.0197p.u	-0.4 p.u
Net actiove power comsumption energy Ep<45%Pn*100ms	0.837 ms*p.u	0.799 ms*p.u	0.821 ms*p.u	-45ms*p.u
Net active powe comsumption P<30%Pn(20ms)	0.0084p.u	0.0080p.u	0.0082p.u	-0.3 p.u

Graph_Phase A



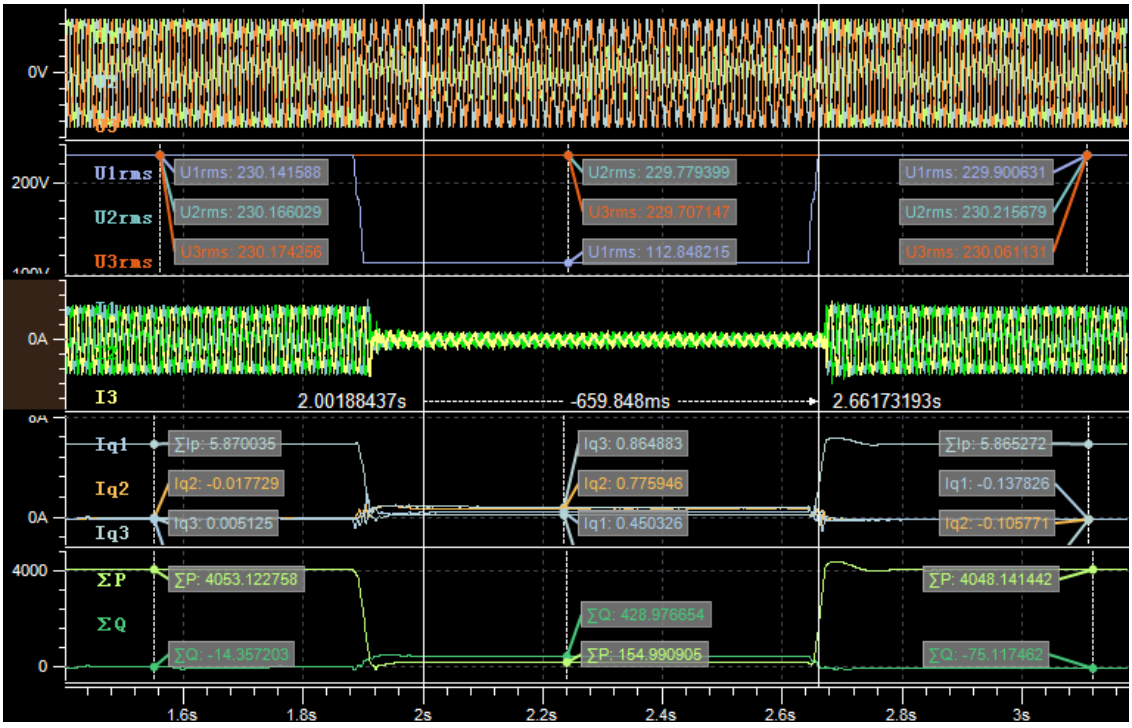
Voltage dip after 150ms until recovery

Graph_Phase B

Voltage dip after 150ms until recovery

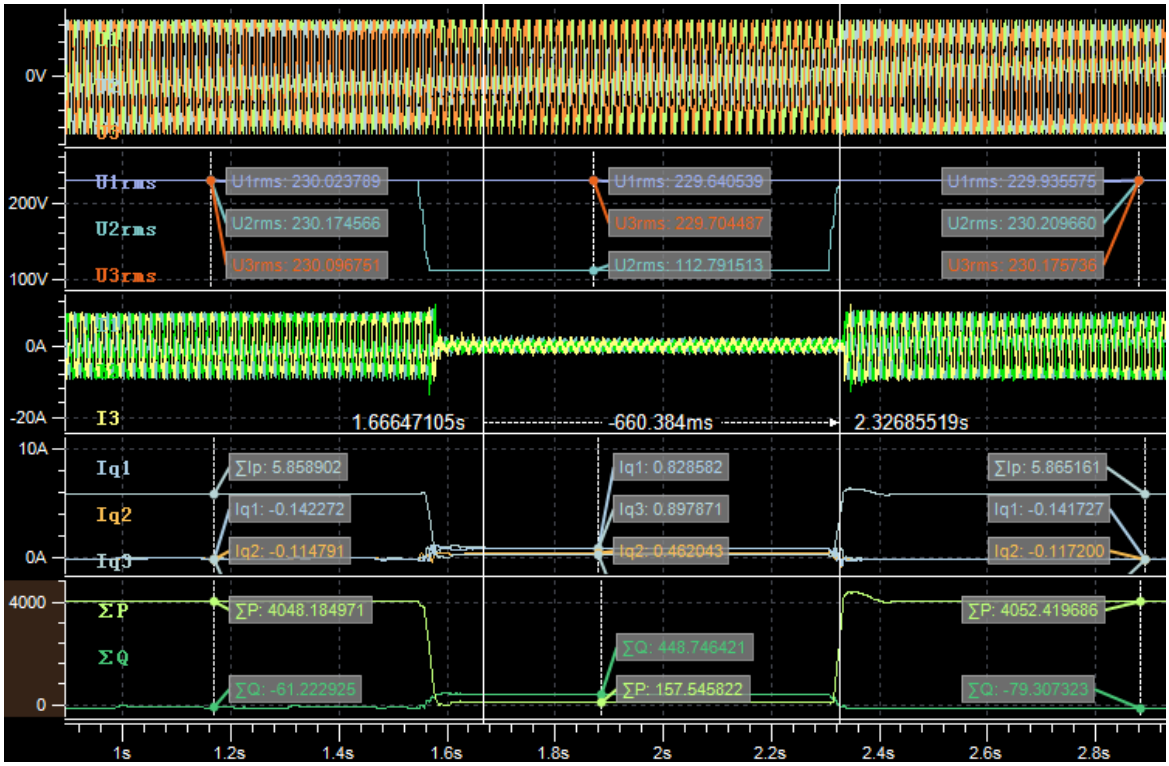
Graph_Phase C

Voltage dip after 150ms until recovery

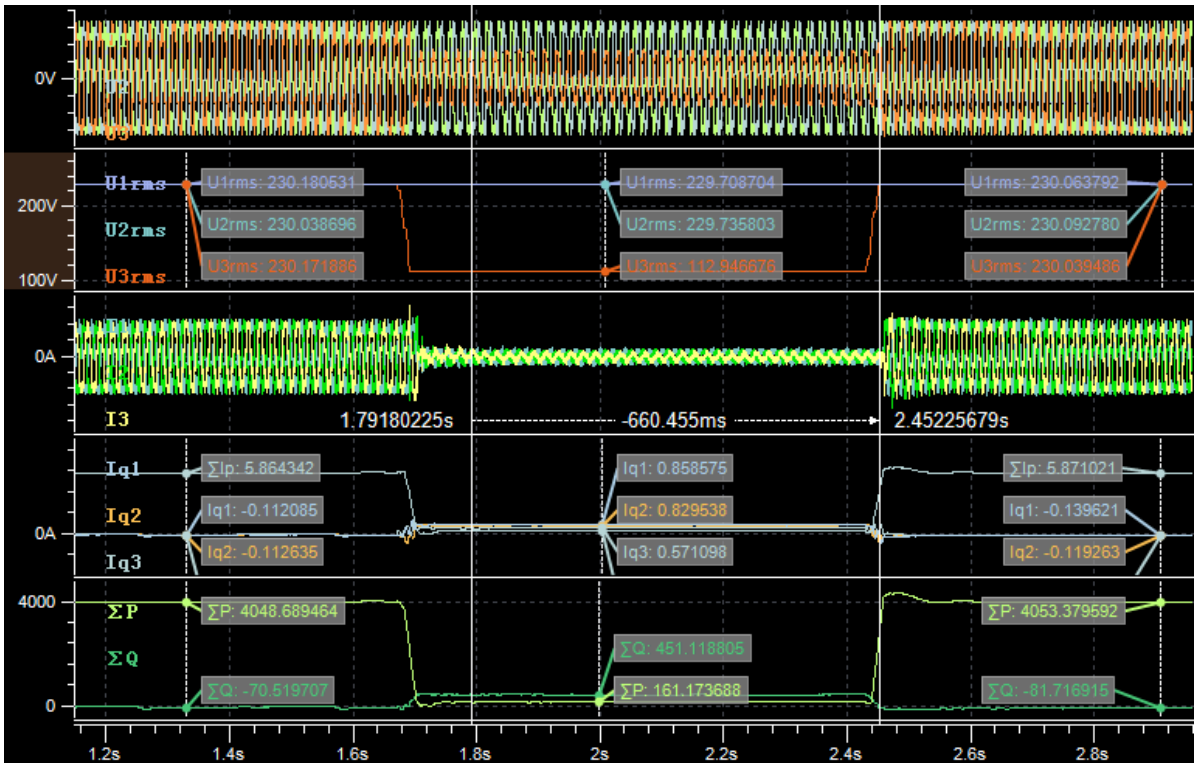
Behaviour during grid disturbance **Unbalanced faults**				
Test No.2.6				
Voltage dip	**Measurement**			**Limit**
	Phase A	**Phase B**	**Phase C**	
Voltage dip after 150ms until recovery				
Net reactive comsumption energy Er<40%Pn*100ms	2.145 ms*p.u	2.244 ms*p.u	2.256 ms*p.u	-40ms*p.u
Net reactive comsumption Q<40%Pn(20ms)	0.0215p.u	0.0224p.u	0.0226p.u	-0.4 p.u
Net active power comsumption energy Ep<45%Pn*100ms	0.775 ms*p.u	0.788 ms*p.u	0.806 ms*p.u	-45ms*p.u
Net active power comsumption P<30%Pn(20ms)	0.0077p.u	0.0079p.u	0.0081p.u	-0.3 p.u

Graph_Phase A

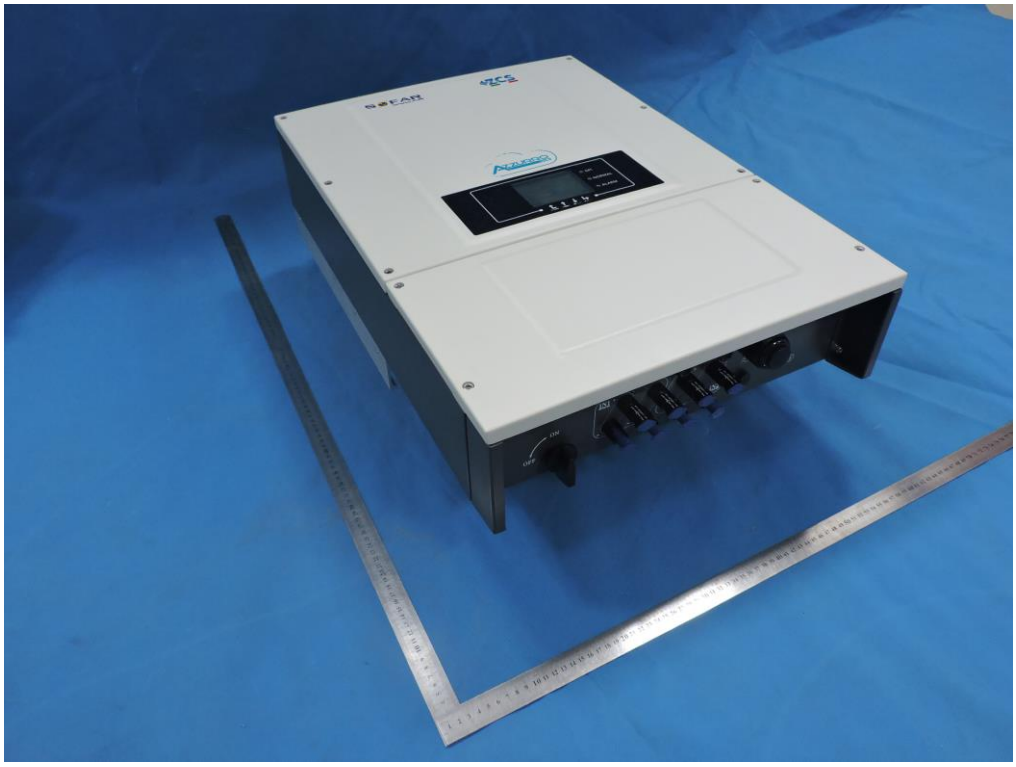


Voltage dip after 150ms until recovery

Graph_Phase B

Voltage dip after 150ms until recovery

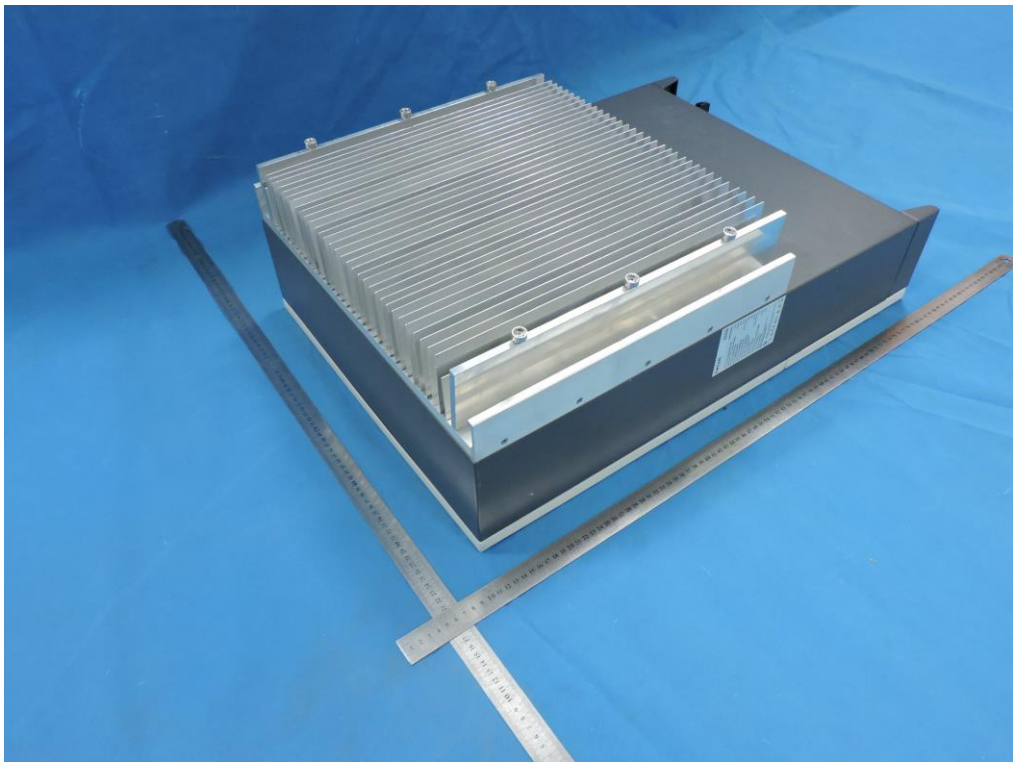
Graph_Phase C

Voltage dip after 150ms until recovery

Appended photos



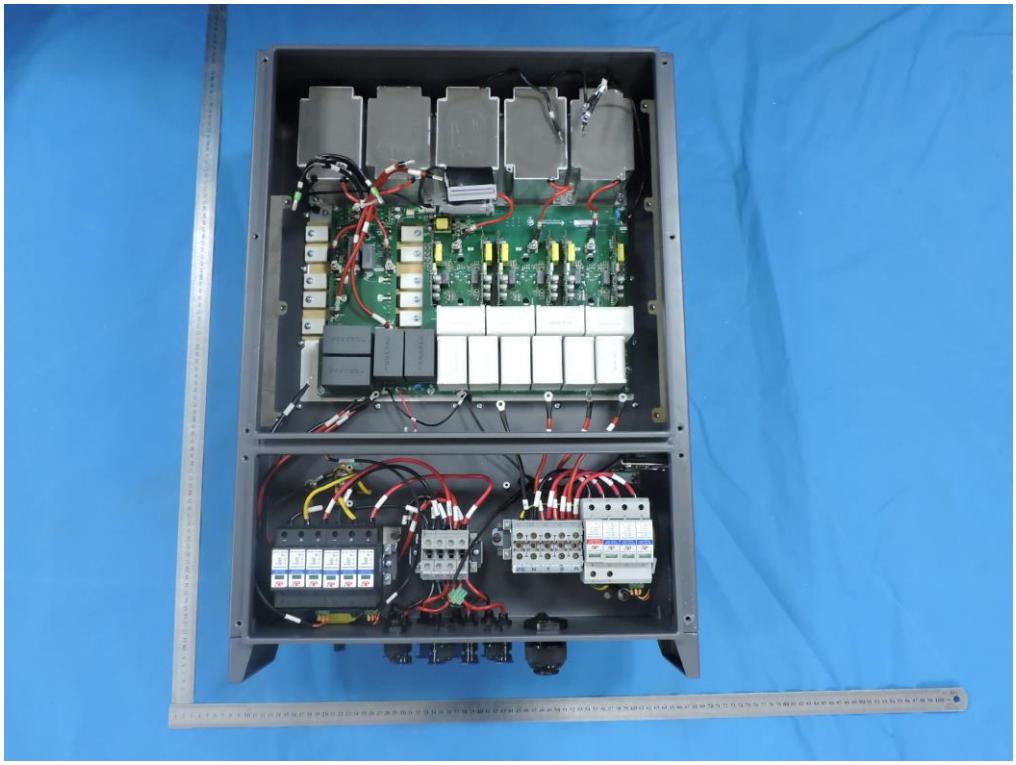
Overview

View of terminal



Rear view

Internal view



Internal view

(End of Report)