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REPORT
VDE-AR-N 4105:2018-11
Generators connected to the low-voltage distribution network – Technical requirements for the connection to and parallel operation with low-voltage distribution networks in junction with
DIN VDE V 0124-100 :2020

Report Reference No............... ...:	200320118GZU-001
Date of issue.............................:	25 Aug 2020
Total number of pages..................:	188 pages
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Testing location/ address..............	Same as above
Tested by (name + signature)………:	Max Gao Engineer Max
Approved by (+ signature)............	Jason Fu Technical Team Leader Jason Fu
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	VDE-AR-N 4105:2018-11 DIN VDE V 0124-100 :2020
Test procedure..............................	Type approval
Non-standard test method…………..:	N/A
Test Report Form No.	VDE-AR-N 4105d
Test Report Form(s) Originator	Intertek Guangzhou
Master TRF	Dated 2020-06

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Test item description	AC-coupled Storage Converter
Trade Mark....................................	SOFAR SOLAR
Manufacturer.................................	Same as Applicant
Model/Type reference	ME 3000SP

Rating…………………:	Battery Type: Lead-acid, Lithium-ion Battery Voltage Range: 42-58Vdc Max. Charging Current: 60A Max. Discharging Current: 60A Max. Charging & Discharging Power: 3000VA Nominal Grid Voltage: 230Vac Nominal output Voltage (stand-alone): 230Vac Max. output Current: 13A Nominal Grid frequency: 50Hz Power factor: 1 (adjustable +/-0.8) Nominal output power: 3000W Backup Max. output current: 13.0A Backup rated power: 3000W Ingress protection: IP65 Operating Temperature Range: -25℃ - 60℃ Protective Class: Class I Software version: V2.60

Summary of testing:

Tests performed (name of test and test clause):

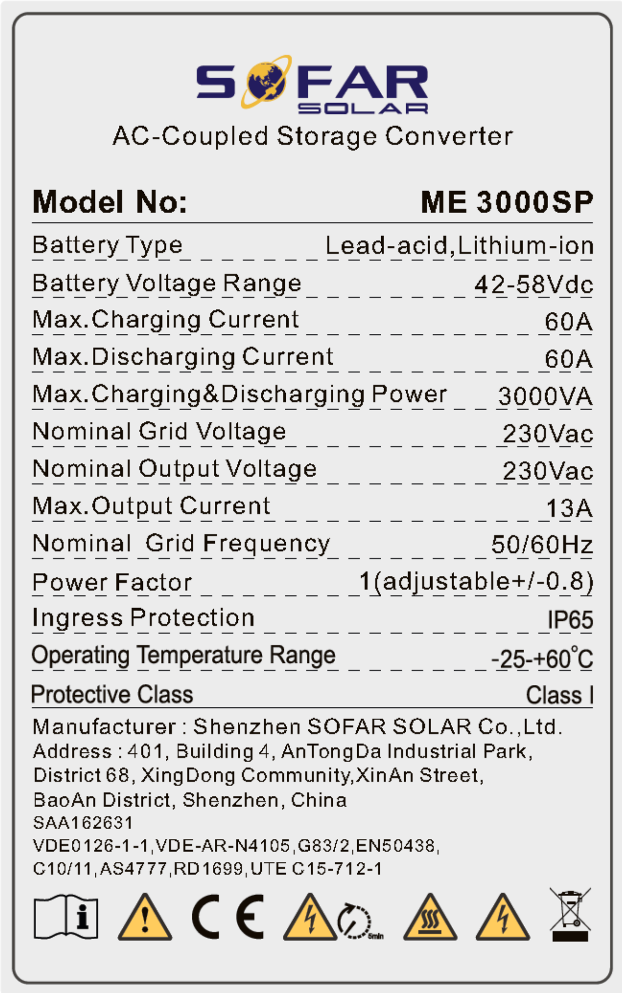
VDE4105 (VDE0124)	Test Description
5.4.4.1 (5.2.2)	Rapid voltage changes
5.4.4.2 (5.2.3)	Flicker
5.4.4.3 (5.2.4)	Harmonics and inter-harmonics
5.4.4.4 (5.2.5)	Commutation notches
5.4.4.8 (5.2.6)	DC current feeding to network
5.6 (5.3)	Asymmetry calculation for three-phase inverter
5.7.2.2.2 (5.4.2)	Measurement of active- and reactive power ranges
5.7.2.3 (5.4.8.1)	Reactive power provision below PEmax
5.7.2.4 (5.4.8.2 & 5.4.8.3)	Method of reactive power provision
5.7.3 (5.8)	Dynamic Network support
5.7.4.2 (5.4.3)	Network security management
5.7.4.3 (5.4.4 & 5.4.5 & 5.4.6 & 5.4.7)	Active power adjustment when over- and under frequency
6.4 (5.5.1 & 5.5.2 & 5.5.3 & 5.5.4 & 5.5.5 & 5.5.6)	Interface switch (Functional safety)
6.5.2 (5.5.7 & 5.5.8 & 5.5.9)	Protective function
6.5.3 (5.5.10)	Islanding detection
8.3 (5.6)	Connection conditions and synchronisation

Testing location:

Intertek Testing Services Shenzhen Ltd. Guangzhou Branch

Room 02, & 101/E201/E301/E401/E501/E601/E701/E801 of Room 01 1-8/F., No. 7-2. Caipin Road, Science City, GETDD, Guangzhou, Guangdong, 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.

Test item particulars...:	
Temperature range ....:	-25℃ to +60℃
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 ....:	IP65
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..:	27 April 2020
Date (s) of performance of tests..................................:	27 April 2020 – 17 Aug 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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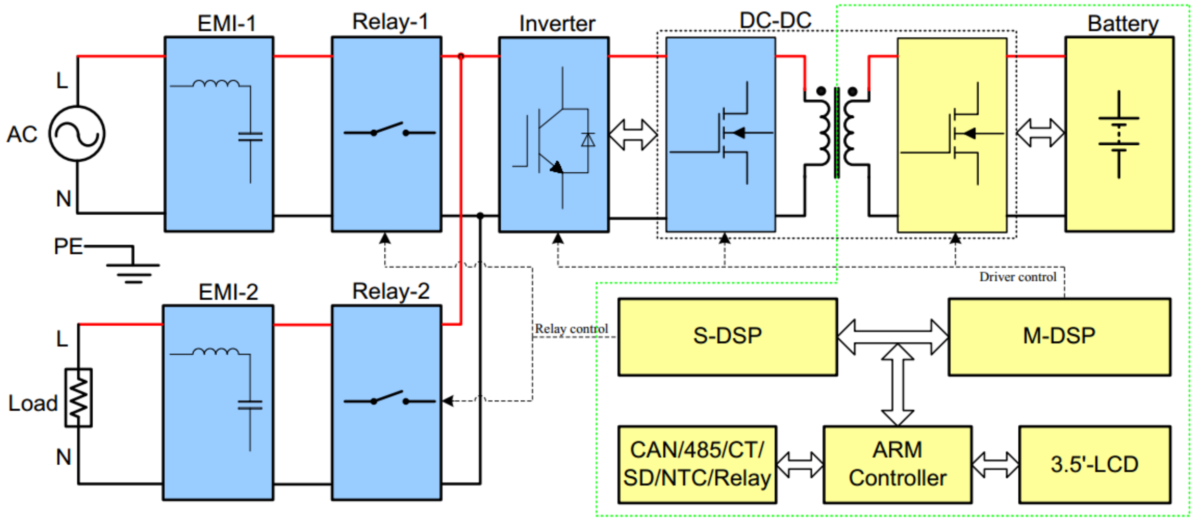
The test report only allows to be revised only within the report defined retention period unless standard or regulation was withdrawn or invalid.

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

General product information:

The equipment under test is single phase energy storage inverter. They are responsible for converting the direct current generated by battery into single-phase 230V, 50 Hz. It is basic insulation between grid and battery. Two mechanical disconnection device (relay) and high frequency isolated transformer are provided between grid and battery on line and neutral conductor

The topology diagram as following:



The inverters intended to operate at ambient temperature -25℃ - +60℃, which will be specified in the user manual, however, the inverters will output full power when operated at 45℃, if operated at higher than 45℃ temperature, the output power would be derated.

The equipment has three working mode. Charge mode, Discharge mode, Stand-alone mode:
Charge mode: The AC voltage from mains charges the battery provided in the final system.

Discharge mode: The inverter converters the energy from the battery to 230Va.c.,50 Hz voltage and connected to AC mains. In this mode the inverter works as grid connected inverter.

Stand-alone mode: The inverter converter the energy from the battery to 230Va.c,50 Hz voltage and feed the general load. In this mode the inverter worked as stand-alone inverter.

Factory information:

Dongguan SOFAR SOLAR Co., Ltd.

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

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
4	**General framework conditions**		N/A
4.1	**Provisions and regulations**	This report is only evaluated and tested for PGU; The PGS incorporated with the PGU shall further consider this clause and sub-clause.	N/A
4.2	**Application procedure and relevant document for connection**	Shall consider in final PGS	N/A
4.3	**Commissioning of the power generation system and/or the storage unit**	Shall consider in final PGS	N/A

5	**Network connection**		**P**
5.1	**Principles for determination of the network connection point** Power generation systems and storage units shall be connected at a suitable point of the network, i. e. the network connection point. Based on the documents listed in 4.2, the network operator determines the suitable network connection point which will ensure safe network operation while also taking into account the power generation system and the storage unit and at which the requested power can be drawn and transmitted. The essential aspect for a network connection evaluation is always the behaviour of the power generation system and the storage unit at the network connection point or at the PCC. This is intended to ensure that the power generation system or storage unit is operated without adverse interactions and impairment of the supply of other customers. Annex D shows an example of the connection evaluation of power generation systems..	Shall consider in final PGS	N/A
5.2	**Rating of the network equipment** Due to their operating mode, power generation systems and storage units may cause higher loading of lines, transformers and other network equipment. Therefore, the network operator verifies the transmission capacity of the network equipment with regard to the connected power generation systems and storage units in accordance with the relevant rating regulations. For calculation purposes, the maximum apparent power of the sum of all power generation systems and storage units $\sum S_{Amax}$ and usually the load factor m = 1 shall be used. This does not apply to buried cables for the connection of photovoltaic systems where a load factor m = 0,7 shall be used.	Shall consider in final PGS	N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.3	Permissible voltage change For undisturbed operation of the network, the amount of the voltage change caused by all power generation systems with a network connection point in a low-voltage network shall at none of the PCCs in this network may a value of 3 % as compared with the voltage without power generation systems. Deviations from the value of $\Delta u_a \leq 3$ % are permissible as specified by the network operator (e. g. when using a controllable local network transformer). When calculating the voltage change, the displacement factor shall be taken into account which is provided by the network operator for the maximum apparent connection power of the power generation system S_{Amax}.	Shall consider in final PGS	N/A
5.4	**Network interactions** For power generation systems and storage units, the permissible limits for network interactions are also described in VDE-AR-N 4100, 5.4. For the connection evaluation of power generation systems and storage units, the connection owner provides the completed forms E.2 to E.5 to the network operator.		N/A
5.5	**Connection criteria**		P
5.5.1	**General** When connecting a power generation system or a storage unit, the technical connection conditions of the network operator shall be observed.	Shall be considered full feed-in or excess feed-in that in accordance with VDE-AR-N 4100 in the power system, where also considered whether valid of PAV, E monitoring	P

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Clause	Requirement - Test	Result - Remark	Verdict

5.5.2	**$P_{AV, E}$ monitoring (feed-in limitation)** $P_{AV, E}$ monitoring allows a connection power $P_{AV, E}$ deviating from the installed power to be agreed with the network operator and to be set. The feed-in limit described in this sub-clause shall be measured at the central meter panel in accordance with VDE-AR-N 4100, 7.2. $P_{AV, E}$ monitoring can be an independent equipment mounted at the central meter panel in accordance with VDE-AR-N 4100 or in a suitable circuit distributor or may also be part of a power generation unit or a storage unit or a charging unit for electric vehicles. When $P_{AV, E}$ is exceeded, the power of the power generation system and/or the storage unit causing the event shall be reduced. $P_{AV, E}$ monitoring is to be used for monitoring the agreed active connection power $P_{AV, E}$ of power generation systems and/or storage units if thefeed-in power at the network connection point $P_{AV, E}$ agreed with the network operator is smaller than the sum of the installed maximum active connection power of all power generation systems and/or storage units at that network connection point.		N/A
5.5.3	**Power generation systems ready for connection** In addition to the requirements specified in this VDE application guide, DIN VDE V 0100-551-1 (VDE V 0100-551-1) applies to power generation systems ready for connection. Provided a connection-ready power generation system is connected via an existing specific energy socket (e. g. complying with VDE V 0628-1 (VDE V 0628-1)) and a bidirectional meter is mounted at the central meter panel, the signature and the details of the system installer on the commissioning protocol E.8 may be omitted. A site map is not required in this case. This only applies up to a value $S_{Amax} \leq 600$ VA per network user installation..		N/A
5.6	**Three-phase inverter systems** For three-phase power generation systems feeding into the network via inverters, the power feed-in into the three line conductors shall be three-phase balanced. The inverter circuit shall preferably be set up as a three phase current unit. The positive sequence system of the terminal voltages, even if they are unbalanced, is to be used as the reference quantity for the currents.		N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7	**Behaviour of the power generation system at the network**		P
5.7.1	**General** For frequencies between 47,5 Hz and 51,5 Hz, automatic disconnection from the network due to a frequency deviation is not permitted. The actual operating principle and the associated exceptions are detailed in 5.7.4.3. Frequency-dependent active power control is implemented in the open-loop control of the power generation units.. In the frequency range of 47,5 Hz to 51,5 Hz, power generation systems shall be capable of network parallel operation in compliance with the time-related minimum requirements given in Table 1. Power generation units shall be able to ride through rapid frequency changes without disconnection from the network. This requirement applies provided the following averaged rates of change of frequency (RoCoF) are not exceeded: – ± 2,0 Hz/s for a moving time slot of 0,5 s; or – ± 1,5 Hz/s for a moving time slot of 1 s; or – ± 1,25 Hz/s for a moving time slot of 2 s. In case of rapid frequency changes, frequency measurements shall not take more than 200 ms. The minimum accuracy of frequency measurements is ± 50 mHz.	(See appended table) The unit is verified with ROCOF (2.0Hz/s) without disconnection.	P
5.7.2	**Steady-state voltage stability/reactive power supply**		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.1	**General boundary conditions** Steady-state voltage stability means the reactive power supply provided by a power generation system and/or a storage unit when energy is supplied for the purpose of voltage stability in the distribution network. The steady-state voltage stability is intended to keep slow (steady-state) voltage changes in the distribution network within acceptable limits. In case of three-phase feed-in, the reactive power supply associated with all three methods described in 5.7.2.4 a) to c) refers to the positive sequence system components of the current and voltage fundamental component. In a passive sign convention system (see A.8), this means the operation of the power generation system in Quadrant II (under-excited) or Quadrant III (over-excited). If a storage unit consumes energy from the network, the reactive power exchange at the network connection point shall comply with the contractual agreements regarding the network connection for customer installations for consumption (see VDE-AR-N 4100). It shall be possible to approach each set-point resulting from the applied control method according to the required reactive power range given in 5.7.2.2 and to operate the power generation unit therein for any duration. Changes of the reactive power supply within the agreed reactive power range shall be possible at any time. Upon agreement with the network operator, the reactive power control range may be extended..		P
5.7.2.2	**Reactive power supply at ΣS_{Emax}**		P
5.7.2.2.1	**General** It is permissible in certain cases described in 5.7.2.2.2 and 5.7.3 to reduce the active power supply to the benefit of the reactive power supply. This is not considered a reduction of the active power supply in thecontext of network security management. Power generation systems shall comply with the reactive power supply irrespective of the number of feed-inphases under normal operating conditions in the voltage tolerance band $U_n \pm 10$ %.		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.2.2	**Type 2 systems – inverters only** At the generator terminals, each power generation unit to be connected shall meet the requirements according to Figure 2 and Figure 3.		P
5.7.2.2.3	**Type 2 systems – Asynchronous generators (directly connected to the network and principally not able to control any reactive power)** For power generation units with generators that are directly connected to the network and principally not able to control any reactive power and therefore use constant capacities, a constant displacement factor $\cos \phi = 0{,}95_{\text{under-excited}}$ with an accuracy of ± 0,02 at nominal voltage and rated power shall be observed.	Inverter	N/A
5.7.2.2.4	**Type 1 systems and type 2 systems – stirling generators and fuel cells** For power generation systems with a rated apparent power of$\Sigma S_{Emax} \leq 4{,}6$ kVA , the network operator does not give any specifications. The value of cos ϕ lies within a range of $\cos \phi = 0{,}95$under-excited to 0,95over-excited. At its generator terminals, each power generation unit to be connected in systems $\Sigma S_{Emax} > 4{,}6$ kVA shall meet the requirements according to Figure 4.		N/A
5.7.2.3	**Reactive power supply smaller than P_{Emax}** In addition to the requirements for reactive power supply at the operating point P_{Emax} of the power generation unit ($P_{mom} = P_{Emax}$), requirements also apply to operation with an instantaneous active power P_{mom} smaller than P_{Emax}. The minimum requirement for the reactive power supply in partial load operating mode at the generator terminals is indicated as a red triangle on the *P/Q* diagram. Within the ranges given in Figure 5 or Figure 6, the maximum residual deviation between the set-point and the actual value of the reactive power at the generator terminals shall not exceed ± 4,0 % in relation to P_{Emax}. Within the range of $0 \leq P_{mom}/P_{Emax} < 0{,}2$ (or 0,1, respectively), the power generation unit shall not exceed the reactive power value at the generator terminals of 10 % of the active power value P_{Emax} (reactive power supply and consumption respectively). Where a minimum technical power for a power generation unit has been agreed, the same conditions apply as for the range $0 \leq P_{mom}/P_{Emax} < 0{,}2$ (or 0,1, respectively) between 0 and the minimum technical power.	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.4	**Methods for reactive power supply** The reactive power supply for steady-state voltage stability shall not impair the dynamic network stability. The reactive power to be provided by the power generation system is limited to the range given in Figure 5 or Figure 6, respectively. In the context of network connection planning, the network operator prescribes to the connection owner one of the following methods for reactive power supply at the generator terminals of the power generation unit: a) reactive power voltage characteristic curve $Q(U)$; or b) displacement factor/active power characteristic curve cos ϕ (P); or c) fixed displacement factor cos ϕ. The $Q(U)$ rule applies only to three-phase power generation units connected to the three-phase current system. Here, too, the reactive power requirements are implemented at the generator terminals of the power generation units.	Method b and c are used for reactive power supply characteristic curve provided by the network operator within cosφ= 0.90under-excited to 0.90 over-excited.	P
	Re: a) reactive power voltage characteristic curve *Q*(*U*) The objective of this method is the reactive power exchange between power generation unit and network depending on the actual voltage at the generator terminals of the power generation unit ($Q= f(U)$). The reference voltage U_{Q0} is 400 V / 3. The arithmetic mean of the r.m.s. values (optionally of the positive sequence system) of the three measured line-to-neutral voltages at the generator terminals of the power generation unit is the target value for the reactive power to be fed in on all line conductors. Voltage measurement shall not exceed a maximum measurement error of 1 % in relation to the nominal value.		N/A
	Re: b) Displacement factor/active power characteristic curve cos ϕ (*P*) The objective of this method is the reactive power supply by the power generation unit depending on the actual active power output ($Q = f(P_{mom})$).	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Re: c) Displacement factor cos ϕ The objective of displacement factor control is the power feed-in by the power generation unit at a constant active power/apparent power ratio (cos ϕ = const). Thereby, the use of the reactive power control range given in Figure 5 and Figure 6 is restricted. For this purpose, the target value is defined with a minimum increment of Δ cos ϕ = 0,01. The maximum permissible error tolerance of the reactive power feed-in is calculated using the error tolerance given in 5.7.2.3 of ± 4 % in relation to P_{Emax}. The network operator predefines a displacement factor set-point.	(See appended table)	P
5.7.2.5	**Requirements for reactive power methods of type 2 systems (inverters only) and type 1 systems** In the delivery state, none of the three reactive power methods specified in 5.7.2.4 is set as default. During the commissioning of power generation units, the method specified by the network operator shall be set by the system installer. Without the setting of the method specified by the network operator, power generation units shall not feed in any power.		P
	The control behaviour of the reactive power (methods a), b) and c)) with respect to set-point offsets corresponds to the PT-1 behaviour shown in Figure 10. Method a) deals with a closed control circuit under consideration of the network impedance. Each reactive power value resulting from the control behavior predefined by the network operator shall be adjustable within a range of 6 s to 60 s (from 10 s to 60 s for type 1) when being provided by the power generation unit. The time specified by the network operator corresponds to 3 Tau of a PT-1 behaviour or to the time until reaching 95 % of the set-point. If no actual value is predefined by the network operator for this purpose, the applicable value is 10 s for 3 Tau or 95 % of the set-point, respectively. The envelop delay time includes the determination of the network voltage or the active and reactive powers.		P
5.7.2.6	**Special aspects regarding the extension of power generation systems** The requirements specified in 5.7.2.4 shall also be met by the newly added power generation units at their generator terminals. The reactive power supply by the added power generation units in accordance with 5.7.2.2 shall be determined based on the sum of the rated apparent powers of the existing power generation system and the newly added power generation units.		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict

5.7.3	**Dynamic network stability**		P
5.7.3.1	**General**	(See appended table)	P
5.7.3.2	**Dynamic network stability for type 1 units** **Transient stability – Reaction to network faults** Regarding the power generation unit remaining connected to the network, the following applies to type 1 units: Throughout the operating range of the power generation unit, voltage drops caused by single-phase, two phase or three-phase network faults and the subsequent voltage transient phenomena shall not cause the power generation unit to become unstable or to disconnect from the network if the voltage assumes values within the limit curves shown in Figure 11 (red for the under-voltage limit curve, blue for the over-voltage limit curve).		N/A
5.7.3.3	**Dynamic network stability for type 2 units and storage units** The following conditions apply to all type 2 power generation units and storage units: As long as the line-neutral-voltages at the generator terminals of the power generation unit or storage unit do not exceed the limit curves shown in Figure 12 (red for the under-voltage limit curve, blue for the over-voltage limit curve), both the power generation unit and the storage unit shall neither become unstable nor disconnect from the network throughout the operating range.		P
	For evaluating the curves, the smallest respective value of the line-neutral-voltages at the power generation unit or the storage unit shall be used in case of a voltage drop, and the highest respective value of the line-neutral- voltages at the power generation unit or the storage unit shall be used in case of a voltage rise. As far as the set values for the NS protection given in Table 2 (column “Inverter(s)”) anticipate the requirements given in Figure 12 in certain working points, merely the checking of the set values for NS protection is required for the verification procedure.		P
	If the voltage at the generator terminals falls below < 0,8 U_n or exceeds > 1,15 U_n (onset of fault), type 2 power generation units and storage units shall ride through voltage drops without feeding current into the network of the network operator (limited dynamic network stability).		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	This requirement is deemed to be met, if the current fed in by the power generation unit(s) and/or the storage unit in any line conductor does not exceed 20 % of the rated current I_r within 60 ms and 10 % of I_r within 100 ms upon a voltage drop below 0,8 U_n or a voltage rise above 1,15 U_n.		P
	Behaviour after the end of a fault If, after the end of a fault, the network voltage resumes a value within the voltage band from –15 % U_n to +10 % U_n and the active current of the power generation unit and/or the storage unit has been reduced during the network fault, it shall, immediately after the end of the fault, be increased to its pre-fault value as quickly as possible. The transient period shall not exceed a maximum of 1 s. The reactive power supply follows 5.7.2.5 in its time-related behaviour. In case of rotating machinery, the transient period shall not exceed a maximum of 6 s. At voltages of 1,15 U_n, the power generation units and storage units shall not disconnect from the network for a period of up to 60 s after the onset of the fault. If the tripping of the self-protection of the power generation units and/or the storage unit is imminent, these units can adjust their reactive power behaviour such as to prevent self-protection tripping.		P
5.7.4	**Active power output**		P
5.7.4.1	**General** In cases where set-points are specified by a third party (e. g. direct marketing) and of network security management in accordance with 5.7.4.2, the new set-point shall be approached with the customer installation's power gradients listed below in relation to the network connection point. Implementation of those power gradients directly at the power generation units or storage units is sufficient for meeting the requirement. The following power gradients shall be observed for increasing/reducing the active power output of power generation systems (minimum technical power or 5 % P_{Amax} ↔ 100 % P_{Amax}) as well as the energy supply and consumption by storage units (5 % P_{Amax} ↔ 100 % P_{Amax}): – at a maximum rate of 0,66 % P_{Amax} per s; – at a minimum rate of 0,33 % P_{Amax} per s. Power generation systems may react more slowly in case of set-points specified by third parties and of power increases. For this purpose, a minimum rate of 4 % P_{Amax} per minute should be observed.	The active power can be remote-controlled on the communication interface	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Other technically induced power gradients (e. g. for hydro power generation systems with level control depending on network demands) are permissible upon approval by the network operator. The power increase or reduction of the customer installation shall be realised in a uniform process, i. e. with a behaviour as linear as possible. The specification of set-points by third parties shall be realised on the level of the individual customer installation or by the sum of all systems accessed by a third party (e. g. by uniform distribution of the active powers to be connected or disconnected over a total period of ≥ 2,5 min).		N/A
	The power generation system or storage unit shall be provided with a logical interface (inlet port) which, irrespective of the power gradients listed above, allows to terminate the active power output within 5 s upon reception of a corresponding signal from the network operator. Additionally, the interface may be used for network security management.		P
5.7.4.2	**Network security management**		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.4.2.1	**Types of power generation systems and storage units** If not specified otherwise by legislation, the requirements described below apply. **Photovoltaic systems** PV systems shall contribute to the avoidance of network overload. For this purpose, PV system power is divided into three power groups: – For PV systems up to and including 30 kWp, the system operator may chose between two options: a) by means of a corresponding inverter design or a certified technical control, the active power feed-in of the PV system shall be permanently limited to a maximum value of 70 % of the installed module power at the network connection point with the power gradients given in 5.7.4.1; or b) the PV system shall be provided with a technical means for remote-controlled reduction of the feedin power by the network operator. – PV systems > 30 kWp up to and including 100 kWp shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator. – PV systems > 100 kWp shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power. If the installed total power increases to > 100 kWp due to the installation of a further PV system on the same plot or building within a period of 12 months, legal provisions require implementation of the feed-in management for systems > 100 kWp while providing the actual feed-in power for the total power..	The active power can be remote-controlled on the communication interface	P
	Cogeneration of power and heat (CHP) systems, wind, biogas, hydroelectric power as well as landfill and sewage gas systems Those PV systems with P_{Amax} > 100 kW shall be provided with a technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power.		N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Storage units buffering EEG or KWKG systems Those storage units with P_{Amax} > 100 kW shall be provided with a technical means enabling the remote controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power. These requirements do not apply if the feeding into the network of the network operator by a storage unit is prevented by technical control means. This shall be demonstrated by means of a manufacturer's declaration.		N/A
	Any EEG and KWKG systems with an intelligent measurement system If an intelligent measurement system is present, the network operator may demand the metering point operator to transmit network state data (i. e. also the actual feed-in power).		N/A
	Any power generation systems and storage units other than those indicated above All power generation systems and storage units shall be provided with technical means enabling the remote-controlled reduction of the feed-in power by the network operator and for the provision of the actual feed-in power.		P
5.7.4.2.2	**Implementation of network security management** Power generation systems and storage units shall be able to reduce their active power to a power value predetermined by the network operator at the network connection point without disconnecting from the network. The following values have proved effective: 100 %/60 %/30 %/0 % in relation to the installed active feed-in power P_{Amax}. Instead of reducing the generated active power, the consumed power of the customer installation can be increased, too. The sum of the reduced generated active power and/or the increased consumed active power at the network connection point shall not deviate by more than ± 5 % from the setpoint of active power limitation. Power reduction shall be possible for any operating state and from any operating point. In case of a redispatch, the power generation systems shall be technically capable of increasing the power to a maximum of P_{Amax} upon the network operator's request.	(See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.4.2.3	**Active power adjustment at over-frequency and under-frequency** A network frequency outside the tolerance band of ± 200 mHz around the nominal network frequency of 50,0 Hz indicates the presence of a critical system state in the integrated network where any power generation units and storage units shall contribute to the network frequency support. The accuracy of the frequency measurement in the steady state shall be ≤ ± 10 mHz. The requirements given in 5.7.4.3 do not apply to storage units in standby mode. Additionally, DC coupled storage units shall behave as type 2 units. In case of **over-frequency**, an excess of generated power is opposed by a deficit of consumed power. Therefore, all power generation units and storage units shall be able to adjust the active power working point at an over-frequency up to a maximum of 51,5 Hz (see Figure 14 and Figure 15). Power generation units shall enable the frequency for starting this frequency-dependent active power feed-in to be set to a value between 50,2 Hz and 50,5 Hz. Unless specified otherwise by the network operator, this start frequency shall be set to 50,2 Hz. The static value of the frequency-dependent active power feed-in shall be adjustable within a range of 2 % to 12 %. This corresponds to a power gradient within a range of 16,67 % of P_{ref} per Hertz (s = 12 %) to 100 % of P_{ref} per Hertz (s = 2 %). Unless specified otherwise by the network operator, a gradient of 40 % of P_{ref} per Hertz (s = 5 %) shall be set (see Figure 14). For storage units, the generated active power with a gradient of 40 % of P_{Emax} per Hertz (s = 5 %) shall be reduced or increased (see Figure 15). Consequently, the power generation unit or the storage unit will constantly move up and down along the frequency characteristic within the frequency range of 50,2 Hz (unless specified otherwise for power generation units by the network operator) to 51,5 Hz with regard to its maximum possible active power feed-in (“operation along the characteristic”).	(See appended table) The starting frequency can be set from 50.2 to 50.5Hz, And, power gradient 2%-12% adjustable Default 50.2 and power gradient 5% setting.	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	At frequencies below 49,8 Hz, all power generation units shall increase the instantaneous generated active power P_{mom} with a gradient of 40 % P_{Emax} per Hertz (s = 5 %) to its technically possible maximum value. For storage units, a gradient of 100 % P_{Emax} per Hertz (s = 2 %) applies. The maximum value is determined by the actual primary energy supply as well as the actually usable storage power. Power reductions for the protection of operating equipment are permitted even at under-frequency. For CHP systems, power reductions resulting from a heat-lead operating mode or a power drop due to the rotational speed are also permitted. Storage units dedicated to other purposes (e. g. gas storage units in biogas systems, DC buffer storage elements for self-consumption etc.) should be activated for this purpose. System-integrated storage units with an energy level below P_n × 30 s (e. g. smoothing chokes, indirect capacitors etc.) may be neglected for this application. Consequently, power generation units and storage units will constantly move up and down along the frequency characteristic also within the frequency range of 49,8 Hz to 47,5 Hz or 47,8 Hz with regard to their maximum possible active power feed-in (“operation along the characteristic”). At an under-frequency within the range of 49,8 Hz to 47,5 Hz, all storage units in charging mode shall reduce their instantaneous charging power according to the characteristic curve shown in Figure 15 to its technically possible minimum value (“operation along the characteristic”). In addition, storage units, as far as their charging state permits, shall change into the operating mode “energy supply” and increase their power according to the characteristic curve shown in Figure 15. In this case, system stability is of higher priority than a potential restraint for feeding storage energy into the network of the network operator based on technical/financial requirements. At network frequencies f < 47,5 Hz, power generation units and storage units shall disconnect from the network (see Figure 14 and Figure 15).	A gradient of 100 % P_{Emax} per Hertz (s = 2 %) applies (See appended table)	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Requirements for the control times for power generation units and storage units The initial time delay T_V of the frequency-dependent adjustment of the active power output at over-frequency and under-frequency is part of the transient period and shall preferably be ≤ 2 s. In case of a time delay > 2 s, the operator of the power generation system shall justify that delay by submitting technical proof to the transmission network operator. For type 2 power generation units and storage units, the necessary initial time delays T_V for reaching the required transient periods are significantly shorter than 2 s. For the time curve of the frequency-dependent active power adjustment, the following conditions regarding the initial time delay T_V and the transient period $T_{an\_90\ \%}$ shall be observed: – After $T_V + 0{,}1 \times (T_{an\_90\ \%} – T_V)$ has elapsed, a value of at least 9 % of the required power adjustment ΔP has been reached. – After the transient period $T_{an\_90\ \%}$ has elapsed, a value of 90 % of the power adjustment ΔP has been reached.		P
	During the control process ("operation along the characteristic"), the power generation unit and the storage unit shall respond as quickly as possible to sudden network frequency changes within a frequency range of 50,2 Hz to 51,5 Hz (subject to capability as declared by the manufacturer) with a transient period of 8 s for ΔP ≤ 45 % of P_{Emax} and ΔP for power changes beyond that in case of type 1 units and type 2 units with rotating machinery and 2 s in case of all other type 2 power generation units and 1 s in case of storage units. The settling period shall not exceed 30 s for type 1 units and type 2 units with rotating machinery or 20 s for all other type 2 power generation units and for storage units. After settling, the supplied active power should deviate by ≤ ± 10 % P_{Emax} from the set-point. The same requirements shall be applied to the active power increase at an under-frequency between 49,8 Hz and 47,5 Hz.		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Conditional requirements based on technical restrictions As an alternative to active power reduction at over-frequency, non-controllable power generation units may disconnect from the network within the frequency range of 50,2 Hz to 51,5 Hz; in that case, uniform distribution of the disconnection frequency in maximum increments of 0,1 Hz shall be ensured for each system type by the manufacturer. Power generation units of limited variability, e. g. only within the range of 70 % to 100 % P_{Emax}, can be curtailed within that range in accordance with the characteristic curve. Outside the controllable range, disconnection is then carried out according to the uniformly distributed shut-down limit curve. For power generation units with combustion engines or gas turbines, active power reduction occurs with a power gradient of at least 66 % P_{Emax} per minute (equals 1,11 % P_{Emax} per second). Thus, the transient period of 8 s can be observed up to a power reduction of 8,88 % P_{Emax}. In case of a greater change of frequency, the transient period is accordingly higher. Linear generators, such as stirling machines up to a maximum apparent power of $S_{Amax} \leq 4,6$ kVA, are exempt from the active power feed-in at over/under-frequency. They may remain connected to the network within a frequency range between 50,2 Hz and their maximum upper frequency limit and may disconnect from the network if this value is exceeded or, at the latest, when a frequency of 51,5 Hz is reached or exceeded. At an under-frequency between 49,8 Hz and their maximum lower frequency limit, linear generators should remain connected to the network but shall disconnect from it at the latest when a frequency of 47,5 Hz is reached or exceeded.		N/A

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
	End of critical network state and return to normal operation Even if the network frequency has resumed a value within the tolerance band of 50,0 Hz ± 200 mHz after a frequency deviation, a critical network state has still to be assumed initially. The time for transition from the critical network state to normal operation is limited by a maximum change of the active power set-point based on P_{mom}. This change of the active power set-point (except for providing the operating reserve) shall be limited to a maximum gradient of 10 % of the active power P_{Emax} per minute (under consideration of 5.7.1). Only after the network frequency has been within the tolerance band of 50,0 Hz ± 200 mHz for 10 min continuously, the normal operation of the network is deemed to be restored whereupon this requirement does no longer apply.		P
5.7.4.4	**Voltage-dependent active power reduction** In order to avoid disconnection of the power generation system due to over-voltage protection $U >$, it is permissible to reduce the active power feed-in as a function of the voltage of (a) power generation unit(s). Implementation is then chosen by the system manufacturer. This is not considered an active power reduction in the context of feed-in management in compliance with EEG. Surges or oscillations of the active power feed-in are not permitted for that purpose.		N/A
5.7.5	**Short-circuit contribution** Due to the operation of a power generation system, the short-circuit current of the low-voltage network is increased by the short-circuit current of the power generation system. Therefore, the short-circuit current of the power generation system to be expected at the network connection point shall be indicated in accordance with 4.2. For the determination of the initial short-circuit AC current contribution I_{kA} of a power generation system, the following roughly estimated values can be assumed: – for synchronous generators: 8 times the rated current; – for asynchronous generators: 6 times the rated current; – for generators and storage units with inverters: the rated current. If the power generation system causes a short-circuit current increase in the network operator’s network in excess of the rated value, then connection owner and network operator shall agree upon appropriate measures limiting the short-circuit current from the power generation system accordingly.		P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6	**Construction of the power generation system/network and system protection (NS protection)**		P
6.1	**General requirements** The network and system protection (NS protection) is a type-tested protective device with a NS protection certificate (see Form E.6) wherein all protective functions specified in 6.5 are installed. The NS protection acts on the interface switch in accordance with 6.4. Depending on the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point ΣS_{Amax} , the following conditions apply to the NS protection:		P
6.2	**Central NS protection** The central NS protection shall be accommodated, installed and connected as an independent equipment at the central meter panel in a suitable circuit distributor in accordance with VDE-AR-N 4100, Clause 8, Paragraph 1, and not in the upper connection compartment according to VDE-AR-N 4100, 7.2, Paragraph 11. Examples of the arrangement of the central NS protection and hence the connection of power generation systems to meter panels are shown in Annex C. For central NS protection, it is additionally required to carry out a trigger test for checking the tripping circuit “NS protection – interface switch”. For this purpose, the central NS protection is provided with a means for tripping the interface switch (e. g. by means of a test button) for testing purposes. Activation shall be visualised at the interface switch.	Integrated NS protection	N/A
6.3	**Integrated NS protection** In the case of integrated NS protection, the NS protection can be integrated in the programmable system control of the power generation units (e. g. in the inverter control). In this case, the means for testing the tripping circuit “NS protection – interface switch” by the system installer is not required. The integrated NS protection acts on an integrated interface switch (see 6.4.3).		P
6.4	**Interface switch**	The PSU include integrated interface switch and is type tested in the report	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6.4.1	**General** For the connection of the power generation system to the network operator's low-voltage network or to the remaining customer installation, an interface switch shall be used. The interface switch is controlled by the NS protection and automatically triggers if at least one protective function responds. As interface switches, the switching devices of the individual power generation units (integrated interface switch) can be used. The integrated interface switches can also be used in combination with the central NS protection. In any case, central NS protection from ΣS_{Amax}>30 kVA (sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point; for exceptions, see 6.1) shall be directly connected to the central meter panel. Where a signal is routed to a spatially separate switching device, it shall be ensured that the required disconnection periods given in Table 2 are observed and lead to the disconnection of the power generation system. During commissioning of the power generation system, a tripping test of the interface switch shall be conducted. The interface switch shall be designed for the rated conditional short-circuit current and under consideration of the protective devices required according to 6.5 and it shall enable instantaneous tripping. The switching capacity of the interface switch shall be rated according to the rated current of the upstream fuse or the maximum initial short-circuit AC current contribution of the power generation system, whichever is the higher. The functional check of the interface switch shall be carried out according to a) or b) or c): a) by using an interface switch which, in its active state, requires a control voltage to be applied continuously and which disconnects automatically when this voltage is no longer applied. The operational connection and disconnection processes shall be monitored; b) by connection and disconnection of the interface switch via the NS protection and monitoring its proper functioning (e. g. break contact of a monitoring contact) at least once daily; c) by using the integrated interface switch and the integrated NS protection for PV and battery inverters in compliance with DIN EN 62109 (VDE 0126-14). When a defect of the interface switch is detected, the power generation system shall neither feed in nor reconnect.	Integrated interface switch has been type tested in compliance with DIN EN 62109	P

VDE-AR-N 4105:2018-11			
Clause	Requirement - Test	Result - Remark	Verdict
6.4.2	**Central interface switch** The central interface switch shall be a galvanic break device (e. g. mechanical contactor, protective motor switch, mechanical circuit breaker). For a power generation system required to contribute to the dynamic network stability, an interface switch enabling compliance with the requirements specified in 5.7.3 (no malfunction at under-voltage in the context of the FRT requirements) shall be used. The interface switch shall be installed in the distribution field of or directly at the central meter panel in a circuit distributor. Examples of the arrangement of interface switches and hence the connection of power generation systems to meter panels are shown in Annex C.		N/A
6.4.3	**Integrated interface switch** For the construction of the interface switch, the requirements specified in 6.1 shall be considered. The interface switch (e. g. power relay, mechanical contactor, mechanical circuit-breaker, etc.) ensures galvanic breaking. For power generation systems with inverters, the interface switch shall be provided on the inverter's network side.	Integrated power relay in the PGU. Each live conductor is constructed with two relays	P
6.5	**Protective devices and protection settings**		P
6.5.1	**General** The purpose of NS protection is to disconnect the power generation system from the network in the event of inadmissible voltage and frequency values (also refer to DIN VDE 0100-551 (VDE 0100-551)). This is meant to prevent inadvertent feed-in from the power generation system into a partial network separated from the main distribution network.		P
6.5.2	**Protective functions** The NS protection shall be provided with a means for preventing unauthorised access (z. B. sealable, password protection). The rise-in-voltage protection $U >$ shall be designed such as to be adjustable in the NS protection (see Table 2, Footnote b). Additionally, the time delay of the voltage drop protection $U <$ and $U <<$ for directly coupled synchronous and asynchronous generators with $P_n > 50$ kW shall also be designed such as to be adjustable in the NS protection (see Table 2, Footnote d). Any other protective functions listed in 6.5.1 are either to be installed permanently, i. e. not adjustable, in the NS protection or to be provided with an additional separate protection against unauthorised access (e. g. password protection) for preventing modifications.	(See appended table)	P

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Clause	Requirement - Test	Result - Remark	Verdict
6.5.3	**Islanding detection**	(See appended table)	P
6.6	**Further requirements for power generation systems**	Shall be considered in PGS	N/A
7	**Metering for billing purposes**		N/A
8	**Operation of the system**		P
8.1	**General**		P
8.2	**Special aspects of the management of the network operator's network**		N/A
8.3	**Connection conditions and synchronisation**		P
8.3.1	**General** Power generation systems and storage units shall be connected to the network operator's network only if a suitable device determines that both the mains voltage and the mains frequency are within the tolerance range of 85 % U_n to 110 % U_n or 47,5 Hz to 50,1 Hz, respectively, for a period of at least 60 seconds. Additionally, the delay times for the reconnection of a generator and the staggered times applicable when connecting several generators shall be sufficient for safely finishing any control and adjustment processes within the power generation system and/or the storage unit caused by the connection. In case of power generation systems and storage units being reconnected to the network operator's network at the tripping of the NS protective device or the $P_{AV,\ E}$ monitoring, the active power of controllable power generation systems and storage units supplied to the network operator's network shall not exceed the gradient of 10 % of the active power P_{Amax} per minute. Non-controllable power generation systems and storage units can connect after 1 min to 10 min (random generator) or later.	(See appended table)	P
8.3.2	**Connection of synchronous generators**		N/A
8.3.3	**Connection of asynchronous generators**		N/A
8.3.4	**Connection of power generation units and storage units with inverters** Power generation units with inverters (such as photovoltaic systems) and storage units with inverters shall only be connected with $k_{imax} \le 1,2$.		P
8.4	**Special aspects regarding the planning, installation and operation of power generation systems and storage units each with PAmax ≥ 135 kW**		N/A
9	**Verification of electrical properties**		P

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Clause	Requirement - Test	Result - Remark	Verdict

	Annex A: Explanations (informative)	

	Annex B: Connection examples and measurement strategies (informative)	

	Annex C: Examples of meter panel configurations (informative)	

	Annex D: Examples for the connection evaluation of power generation systems - Connection of a 20 kW PV system (informative)	

	Annex E: Forms (mandatory)	**P**
E.1	Application procedure	N/A
E.2	Data sheet for power generation systems	N/A
E.3	Data sheet for storage units	N/A
E.4	Unit certificate	P
E.5	Test report “Network interactions” for power generation units with an input current > 75 A	N/A
E.6	Certificate of the network and system protection	P
E.7	Requirements for the test report for the NS protection	P
E.8	Commissioning protocol for power generation systems and/or storage units	N/A
E.9	Type approval procedure	N/A

Appended Table - Testing Result

5.2.2	TABLE: Rapid voltage change		P
Operation type: Switching on at any power level (without default to primary energy source)			
Condition	Test 1: cosφ=1	Test 2: cosφ=0.90over-excited	Test 3: cosφ=0.90under-excited
Ki	0.056	0.046	0.038
Kimax Limit	<1.2		
Operation type: start-up at Pn (reference condition) with circuit breaker reclosing			
Condition	Test 1: cosφ=1	Test 2: cosφ=0.90over-excited	Test 3: cosφ=0.90under-excited
Ki	0.035	0.038	0.051
Kimax Limit	<1.2		
Operation type: shut-down (breaking operation at nominal power)			
Condition	Test 1: cosφ=1	Test 2: cosφ=0.90over-excited	Test 3: cosφ=0.90under-excited
Ki	0.074	0.037	0.023
Kimax Limit	**<1.2**		
Note: 1) Sk,fic/Sn = 20 2) ki is the ratio of the highest current occurring during a switching operation to the normal generator current, the current is to be considered as an r.m.s. value over a period			

Switching actions	Ki
Marking operation without default (to primary energy carrier)	0.056
Worst case at switch over of generator sections	0.056
Marking operation at reference conditions (of primary energy carrier)	0.074
Breaking operation at nominal power	0.051
Worst case value of all switching operations Ki max	0.074

5.2.3	TABLE: Flick					P
Test impedance	0.4Ω +0.25j					
	Pst			$c_{\psi k}$		
	L1	L2	L3	L1	L2	L3
1	0.083	--	--	1.66	--	--
2	0.081	--	--	1.62	--	--
3	0.086	--	--	1.72	--	--
4	0.088	--	--	1.76	--	--
5	0.087	--	--	1.74	--	--
6	0.088	--	--	1.76	--	--
7	0.085	--	--	1.70	--	--
8	0.085	--	--	1.70	--	--
9	0.071	--	--	1.42	--	--
10	0.076	--	--	1.52	--	--
11	0.087	--	--	1.74	--	--
12	0.085	--	--	1.70	--	--
Calculation						
Plt L1	0.084					
Plt L2	--					
Plt L3	--					
greatest ascertained $c_{\psi k}$	1.76					
Note: 1) Sk,fic/Sn = 20						

Volt Range	300 V/50Hz	Element1	Judgement	Pass	
Un (U1)	230.065V	Total	Judgement	Pass	
Freq (U1)	50.000Hz	(Element1)			
Dmin	0.10%				

	dc[%]		dmax[%]		d(t)[ms]		Pst		Plt	
Limit	3.30		4.00		500 3.30%		1.00		0.65 N:12	
No. 1	0.270	Pass	0.314	Pass	0.0	Pass	0.083	Pass		
2	0.273	Pass	0.314	Pass	0.0	Pass	0.081	Pass		
3	0.273	Pass	0.322	Pass	0.0	Pass	0.086	Pass		
4	0.271	Pass	0.315	Pass	0.0	Pass	0.088	Pass		
5	0.269	Pass	0.302	Pass	0.0	Pass	0.087	Pass		
6	0.274	Pass	0.303	Pass	0.0	Pass	0.088	Pass		
7	0.270	Pass	0.310	Pass	0.0	Pass	0.085	Pass		
8	0.270	Pass	0.309	Pass	0.0	Pass	0.085	Pass		
9	0.168	Pass	0.208	Pass	0.0	Pass	0.071	Pass		
10	0.188	Pass	0.242	Pass	0.0	Pass	0.076	Pass		
11	0.266	Pass	0.289	Pass	0.0	Pass	0.087	Pass		
12	0.267	Pass	0.307	Pass	0.0	Pass	0.085	Pass		
Result		Pass		Pass		Pass		Pass	0.084	Pass

5.2.4	TABLE: Harmonics and inter-harmonics (according to DIN EN 61000-3-2) Model: ME3000SP	P

Active power P/P$_n$ [%]	10	20	30	40	50	60	70	80	90	100	Limit [A]
Harmonic number	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	
2	0.0048	0.0079	0.0016	0.0036	0.0044	0.0044	0.0062	0.0096	0.0098	0.0146	1.080
3	0.0596	0.0808	0.0873	0.0940	0.0898	0.0939	0.0909	0.0932	0.0907	0.0914	2.300
4	0.0087	0.0094	0.0053	0.0093	0.0042	0.0090	0.0070	0.0078	0.0074	0.0031	0.430
5	0.0355	0.0347	0.0434	0.0372	0.0431	0.0411	0.0437	0.0436	0.0459	0.0494	1.140
6	0.0015	0.0014	0.0017	0.0020	0.0026	0.0018	0.0017	0.0018	0.0016	0.0021	0.300
7	0.0248	0.0277	0.0252	0.0256	0.0260	0.0269	0.0307	0.0314	0.0358	0.0424	0.770
8	0.0011	0.0029	0.0028	0.0034	0.0027	0.0021	0.0029	0.0030	0.0021	0.0027	0.230
9	0.0130	0.0136	0.0111	0.0151	0.0229	0.0272	0.0291	0.0364	0.0362	0.0429	0.400
10	0.0009	0.0019	0.0019	0.0015	0.0015	0.0034	0.0025	0.0021	0.0031	0.0024	0.184
11	0.0092	0.0105	0.0094	0.0127	0.0164	0.0326	0.0311	0.0365	0.0411	0.0464	0.330
12	0.0025	0.0041	0.0036	0.0039	0.0034	0.0019	0.0025	0.0025	0.0018	0.0027	0.153
13	0.0049	0.0077	0.0087	0.0142	0.0196	0.0255	0.0363	0.0338	0.0436	0.0503	0.210
14	0.0015	0.0028	0.0024	0.0041	0.0040	0.0047	0.0044	0.0059	0.0038	0.0039	0.131
15	0.0030	0.0039	0.0055	0.0182	0.0235	0.0266	0.0362	0.0406	0.0387	0.0455	0.150
16	0.0023	0.0040	0.0033	0.0016	0.0033	0.0019	0.0018	0.0014	0.0016	0.0012	0.115
17	0.0013	0.0023	0.0047	0.0170	0.0236	0.0264	0.0288	0.0364	0.0379	0.0447	0.132
18	0.0012	0.0025	0.0035	0.0038	0.0025	0.0032	0.0025	0.0033	0.0039	0.0014	0.102
19	0.0032	0.0016	0.0037	0.0144	0.0194	0.0234	0.0263	0.0310	0.0369	0.0407	0.118
20	0.0007	0.0013	0.0017	0.0036	0.0036	0.0035	0.0026	0.0026	0.0026	0.0024	0.092
21	0.0019	0.0025	0.0042	0.0128	0.0176	0.0226	0.0244	0.0254	0.0307	0.0324	0.107
22	0.0014	0.0014	0.0011	0.0020	0.0020	0.0024	0.0013	0.0027	0.0013	0.0018	0.084
23	0.0035	0.0045	0.0017	0.0085	0.0137	0.0191	0.0217	0.0233	0.0254	0.0302	0.098
24	0.0011	0.0009	0.0023	0.0029	0.0025	0.0028	0.0023	0.0024	0.0016	0.0024	0.077
25	0.0013	0.0027	0.0019	0.0078	0.0127	0.0158	0.0191	0.0213	0.0229	0.0277	0.090
26	0.0019	0.0021	0.0024	0.0041	0.0040	0.0045	0.0038	0.0035	0.0040	0.0033	0.071
27	0.0017	0.0024	0.0018	0.0064	0.0095	0.0131	0.0150	0.0169	0.0178	0.0210	0.083
28	0.0012	0.0015	0.0013	0.0018	0.0032	0.0033	0.0038	0.0038	0.0033	0.0037	0.066
29	0.0012	0.0018	0.0014	0.0057	0.0088	0.0115	0.0138	0.0146	0.0159	0.0177	0.078
30	0.0006	0.0015	0.0016	0.0014	0.0012	0.0011	0.0014	0.0014	0.0020	0.0022	0.061
31	0.0036	0.0051	0.0026	0.0037	0.0049	0.0081	0.0111	0.0123	0.0137	0.0158	0.073
32	0.0019	0.0022	0.0033	0.0021	0.0022	0.0017	0.0017	0.0016	0.0016	0.0016	0.058
33	0.0052	0.0060	0.0039	0.0041	0.0049	0.0077	0.0099	0.0109	0.0125	0.0144	0.068
34	0.0024	0.0018	0.0018	0.0022	0.0023	0.0026	0.0015	0.0017	0.0015	0.0016	0.054
35	0.0022	0.0038	0.0035	0.0027	0.0035	0.0051	0.0061	0.0078	0.0093	0.0112	0.064
36	0.0008	0.0017	0.0019	0.0012	0.0015	0.0013	0.0015	0.0008	0.0014	0.0011	0.051
37	0.0044	0.0047	0.0044	0.0037	0.0029	0.0039	0.0053	0.0072	0.0084	0.0106	0.061
38	0.0016	0.0010	0.0018	0.0012	0.0019	0.0013	0.0009	0.0010	0.0012	0.0015	0.048
39	0.0037	0.0044	0.0029	0.0035	0.0019	0.0029	0.0039	0.0058	0.0063	0.0090	0.058
40	0.0006	0.0011	0.0010	0.0012	0.0014	0.0019	0.0025	0.0022	0.0025	0.0020	0.046

5.2.4	TABLE: Harmonics and inter-harmonics (According to DIN EN 61000-4-7)										
Model: ME3000SP											
Active power P/Pn [%]	0	10	20	30	40	50	60	70	80	90	100
Frequency [Hz]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]
75	0.4931	0.2382	0.1060	0.1048	0.0605	0.0479	0.0412	0.0447	0.0323	0.0408	0.0309
125	0.4321	0.1850	0.0942	0.0680	0.0474	0.0354	0.0299	0.0255	0.0208	0.0217	0.0219
175	0.4557	0.1985	0.1113	0.0843	0.0597	0.0443	0.0416	0.0280	0.0235	0.0219	0.0197
225	0.4213	0.1946	0.1160	0.0778	0.0551	0.0475	0.0428	0.0288	0.0233	0.0227	0.0196
275	0.3955	0.2115	0.1236	0.0880	0.0752	0.0476	0.0358	0.0292	0.0260	0.0230	0.0216
325	0.3673	0.2071	0.1250	0.0839	0.0694	0.0506	0.0403	0.0307	0.0283	0.0259	0.0217
375	0.3789	0.2431	0.1271	0.0760	0.0730	0.0489	0.0515	0.0354	0.0277	0.0255	0.0237
425	0.3716	0.2339	0.1362	0.0775	0.0843	0.0503	0.0580	0.0345	0.0295	0.0256	0.0257
475	0.3899	0.2212	0.1376	0.0762	0.0636	0.0525	0.0370	0.0319	0.0273	0.0233	0.0208
525	0.3888	0.2256	0.1304	0.0771	0.0784	0.0543	0.0413	0.0315	0.0295	0.0268	0.0214
575	0.3703	0.2092	0.1250	0.0747	0.0755	0.0533	0.0417	0.0313	0.0267	0.0248	0.0243
625	0.3865	0.2075	0.1226	0.0731	0.0685	0.0477	0.0461	0.0294	0.0267	0.0246	0.0229
675	0.3659	0.1886	0.1138	0.0834	0.0790	0.0484	0.0348	0.0313	0.0264	0.0247	0.0211
725	0.3717	0.1835	0.1216	0.0670	0.0895	0.0516	0.0324	0.0290	0.0234	0.0214	0.0214
775	0.3279	0.1742	0.1064	0.0679	0.0678	0.0730	0.0320	0.0358	0.0242	0.0246	0.0194
825	0.3516	0.1688	0.1008	0.0600	0.0546	0.0648	0.0310	0.0349	0.0228	0.0236	0.0183
875	0.3101	0.1754	0.0939	0.0627	0.0704	0.0480	0.0315	0.0306	0.0230	0.0202	0.0186
925	0.3451	0.1585	0.0904	0.0596	0.0876	0.0402	0.0289	0.0372	0.0226	0.0243	0.0182
975	0.3124	0.1503	0.0824	0.0580	0.0589	0.0351	0.0279	0.0290	0.0234	0.0200	0.0179
1025	0.3337	0.1452	0.0808	0.0538	0.0452	0.0332	0.0293	0.0319	0.0216	0.0190	0.0173
1075	0.3254	0.1341	0.0780	0.0534	0.0465	0.0329	0.0298	0.0246	0.0204	0.0205	0.0163
1125	0.3117	0.1325	0.0721	0.0559	0.0534	0.0329	0.0297	0.0230	0.0212	0.0214	0.0162
1175	0.3542	0.1209	0.0703	0.0461	0.0421	0.0322	0.0250	0.0271	0.0184	0.0192	0.0150
1225	0.3574	0.1281	0.0692	0.0478	0.0384	0.0366	0.0238	0.0272	0.0200	0.0185	0.0155
1275	0.3314	0.1286	0.0664	0.0513	0.0359	0.0330	0.0213	0.0221	0.0200	0.0172	0.0142
1325	0.2833	0.1245	0.0620	0.0466	0.0335	0.0284	0.0216	0.0200	0.0167	0.0158	0.0138
1375	0.3018	0.1230	0.0652	0.0430	0.0336	0.0299	0.0215	0.0226	0.0179	0.0191	0.0131
1425	0.2820	0.1145	0.0552	0.0415	0.0337	0.0273	0.0202	0.0205	0.0183	0.0156	0.0129
1475	0.2858	0.1091	0.0595	0.0416	0.0322	0.0302	0.0217	0.0238	0.0174	0.0158	0.0127
1525	0.2921	0.1056	0.0555	0.0403	0.0291	0.0259	0.0208	0.0207	0.0162	0.0162	0.0115
1575	0.2679	0.1049	0.0511	0.0410	0.0383	0.0285	0.0218	0.0236	0.0171	0.0149	0.0134
1625	0.2438	0.1006	0.0528	0.0404	0.0348	0.0263	0.0193	0.0236	0.0154	0.0147	0.0137
1675	0.2460	0.1106	0.0487	0.0374	0.0301	0.0301	0.0174	0.0174	0.0138	0.0150	0.0116
1725	0.2503	0.1056	0.0468	0.0349	0.0270	0.0292	0.0174	0.0155	0.0145	0.0153	0.0120
1775	0.2351	0.0898	0.0444	0.0314	0.0312	0.0226	0.0166	0.0149	0.0137	0.0128	0.0111
1825	0.2419	0.0929	0.0461	0.0360	0.0345	0.0218	0.0168	0.0158	0.0130	0.0123	0.0123
1875	0.2247	0.0864	0.0484	0.0300	0.0292	0.0216	0.0170	0.0164	0.0130	0.0131	0.0122
1925	0.2212	0.0818	0.0454	0.0331	0.0273	0.0240	0.0189	0.0161	0.0149	0.0135	0.0121
1975	0.2026	0.0899	0.0498	0.0310	0.0261	0.0230	0.0158	0.0156	0.0158	0.0129	0.0102

5.2.4	TABLE: Harmonics and inter-harmonics (According to DIN EN 61000-4-7)										
Model: ME3000SP											
Active power P/P$_n$ [%]	0	10	20	30	40	50	60	70	80	90	100
Frequency [kHz]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]	I[%]
2.1	0.0471	0.0549	0.0424	0.0446	0.0328	0.0405	0.0521	0.0665	0.0792	0.0862	0.1008
2.3	0.0530	0.0464	0.0446	0.0460	0.0311	0.0366	0.0436	0.0614	0.0713	0.0854	0.0943
2.5	0.0686	0.0607	0.0548	0.0505	0.0400	0.0303	0.0400	0.0539	0.0638	0.0767	0.0824
2.7	0.0637	0.0468	0.0542	0.0494	0.0412	0.0352	0.0406	0.0510	0.0624	0.0748	0.0824
2.9	0.0603	0.0441	0.0482	0.0435	0.0427	0.0346	0.0302	0.0392	0.0489	0.0589	0.0664
3.1	0.0555	0.0323	0.0388	0.0395	0.0410	0.0339	0.0295	0.0312	0.0397	0.0480	0.0577
3.3	0.0493	0.0247	0.0297	0.0358	0.0434	0.0350	0.0323	0.0286	0.0350	0.0450	0.0531
3.5	0.0415	0.0230	0.0236	0.0336	0.0350	0.0342	0.0277	0.0241	0.0323	0.0354	0.0412
3.7	0.0376	0.0191	0.0228	0.0267	0.0309	0.0310	0.0275	0.0227	0.0247	0.0307	0.0343
3.9	0.0365	0.0254	0.0226	0.0230	0.0282	0.0318	0.0248	0.0225	0.0233	0.0269	0.0302
4.1	0.0298	0.0197	0.0176	0.0194	0.0226	0.0258	0.0236	0.0193	0.0200	0.0258	0.0285
4.3	0.0335	0.0265	0.0200	0.0231	0.0246	0.0276	0.0253	0.0218	0.0194	0.0205	0.0259
4.5	0.0316	0.0279	0.0231	0.0198	0.0171	0.0200	0.0197	0.0173	0.0172	0.0190	0.0211
4.7	0.0288	0.0266	0.0211	0.0207	0.0212	0.0251	0.0243	0.0207	0.0199	0.0206	0.0216
4.9	0.0223	0.0204	0.0166	0.0149	0.0149	0.0179	0.0175	0.0148	0.0147	0.0166	0.0187
5.1	0.0225	0.0192	0.0172	0.0150	0.0132	0.0143	0.0141	0.0139	0.0156	0.0179	0.0198
5.3	0.0221	0.0225	0.0202	0.0166	0.0159	0.0179	0.0175	0.0158	0.0144	0.0150	0.0166
5.5	0.0223	0.0236	0.0225	0.0211	0.0201	0.0217	0.0224	0.0203	0.0192	0.0174	0.0174
5.7	0.0250	0.0279	0.0269	0.0242	0.0239	0.0220	0.0221	0.0216	0.0190	0.0168	0.0156
5.9	0.0176	0.0202	0.0204	0.0178	0.0176	0.0167	0.0178	0.0166	0.0159	0.0152	0.0138
6.1	0.0146	0.0136	0.0131	0.0129	0.0117	0.0119	0.0118	0.0121	0.0125	0.0138	0.0140
6.3	0.0126	0.0161	0.0160	0.0131	0.0131	0.0119	0.0130	0.0128	0.0130	0.0130	0.0126
6.5	0.0121	0.0162	0.0174	0.0142	0.0138	0.0127	0.0130	0.0129	0.0139	0.0136	0.0123
6.7	0.0120	0.0156	0.0144	0.0134	0.0135	0.0125	0.0120	0.0127	0.0139	0.0148	0.0151
6.9	0.0132	0.0196	0.0180	0.0164	0.0158	0.0147	0.0156	0.0155	0.0163	0.0172	0.0173
7.1	0.0132	0.0182	0.0157	0.0158	0.0147	0.0151	0.0140	0.0153	0.0159	0.0186	0.0188
7.3	0.0135	0.0124	0.0113	0.0119	0.0127	0.0130	0.0126	0.0140	0.0152	0.0168	0.0166
7.5	0.0123	0.0140	0.0132	0.0124	0.0116	0.0118	0.0116	0.0126	0.0143	0.0158	0.0160
7.7	0.0156	0.0206	0.0190	0.0192	0.0188	0.0183	0.0177	0.0188	0.0195	0.0209	0.0206
7.9	0.0187	0.0160	0.0153	0.0132	0.0131	0.0128	0.0124	0.0130	0.0132	0.0145	0.0142
8.1	0.0185	0.0201	0.0193	0.0200	0.0192	0.0192	0.0193	0.0198	0.0209	0.0218	0.0215
8.3	0.0162	0.0121	0.0121	0.0141	0.0140	0.0143	0.0149	0.0156	0.0162	0.0182	0.0184
8.5	0.0180	0.0099	0.0100	0.0109	0.0119	0.0125	0.0131	0.0139	0.0149	0.0153	0.0142
8.7	0.0134	0.0136	0.0138	0.0155	0.0153	0.0152	0.0157	0.0158	0.0176	0.0186	0.0194
8.9	0.0151	0.0112	0.0119	0.0131	0.0131	0.0133	0.0137	0.0140	0.0159	0.0169	0.0159

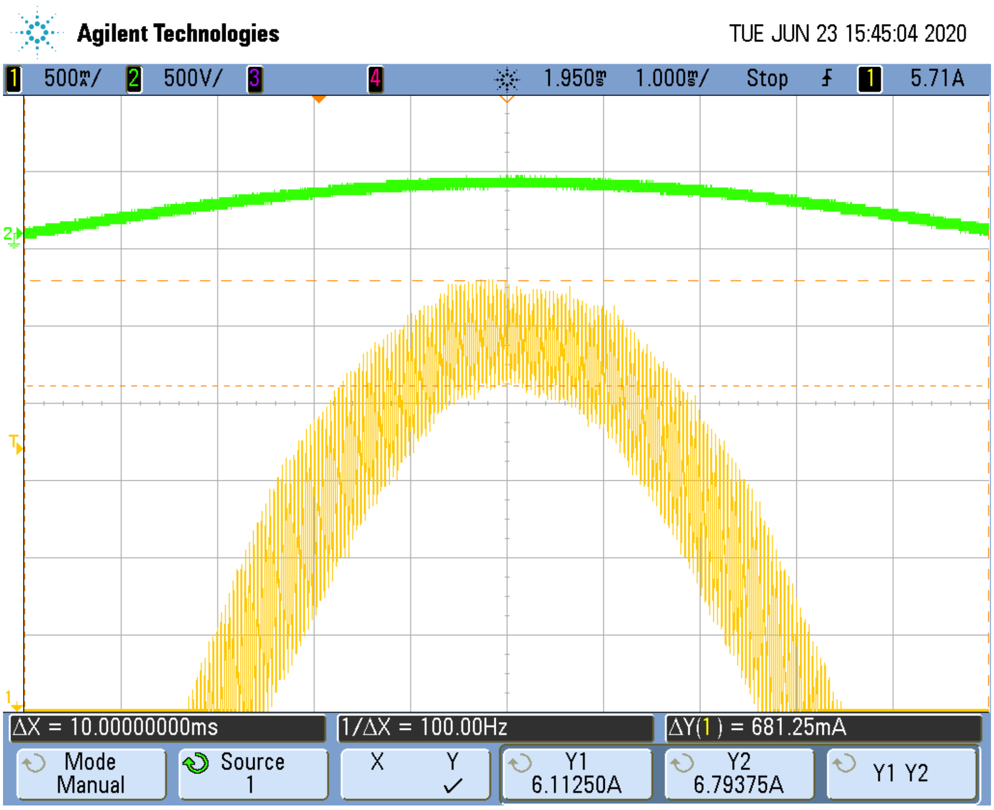
5.2.5	Commutation notches	P

$\hat{U}_n$ (The peak value of the nominal voltage U_n) = 325.22 V

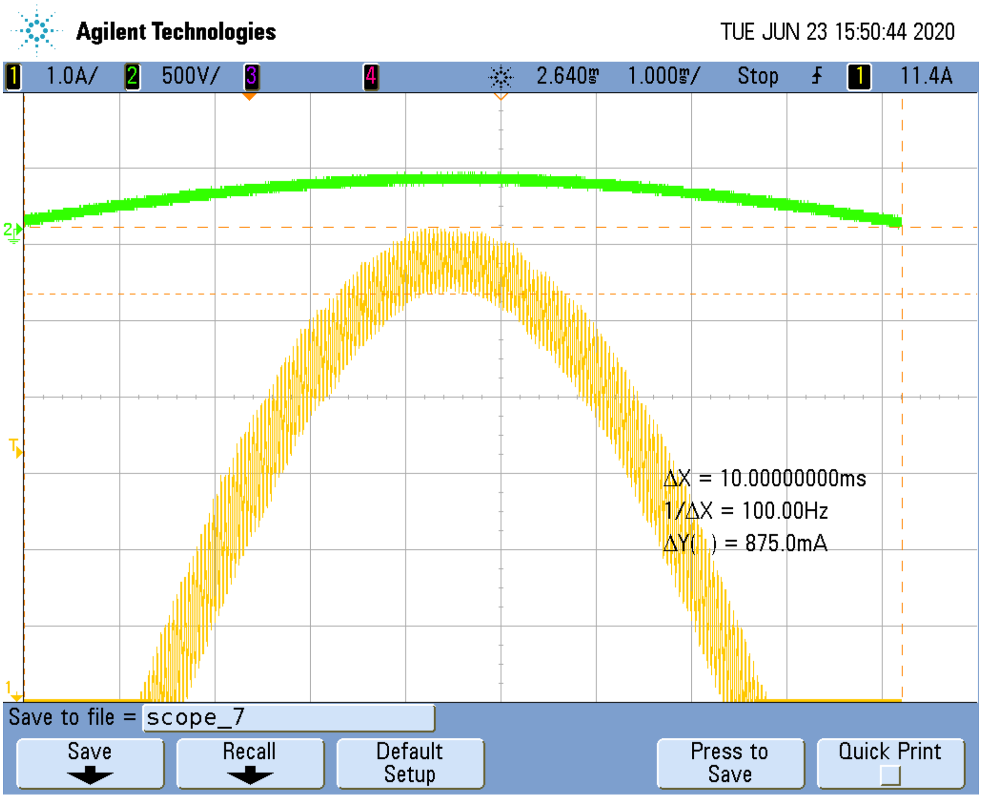
Test impedance: 0.4Ω +0.25j

Operating points	Maximum commutation current (A)	ΔU_{kom} (V)	d_{kom} (=ΔU_{kom}/ $\hat{U}_n$) (%)	d_{kom} limit (%)
25% P_{Emax} and 35 % P_{Emax}:	0.681	0.321	0.099	5
65%P_{Emax} and 75 % P_{Emax}:	0.875	0.413	0.127	5
>90 % P_{Emax}:	0.988	0.466	0.143	5

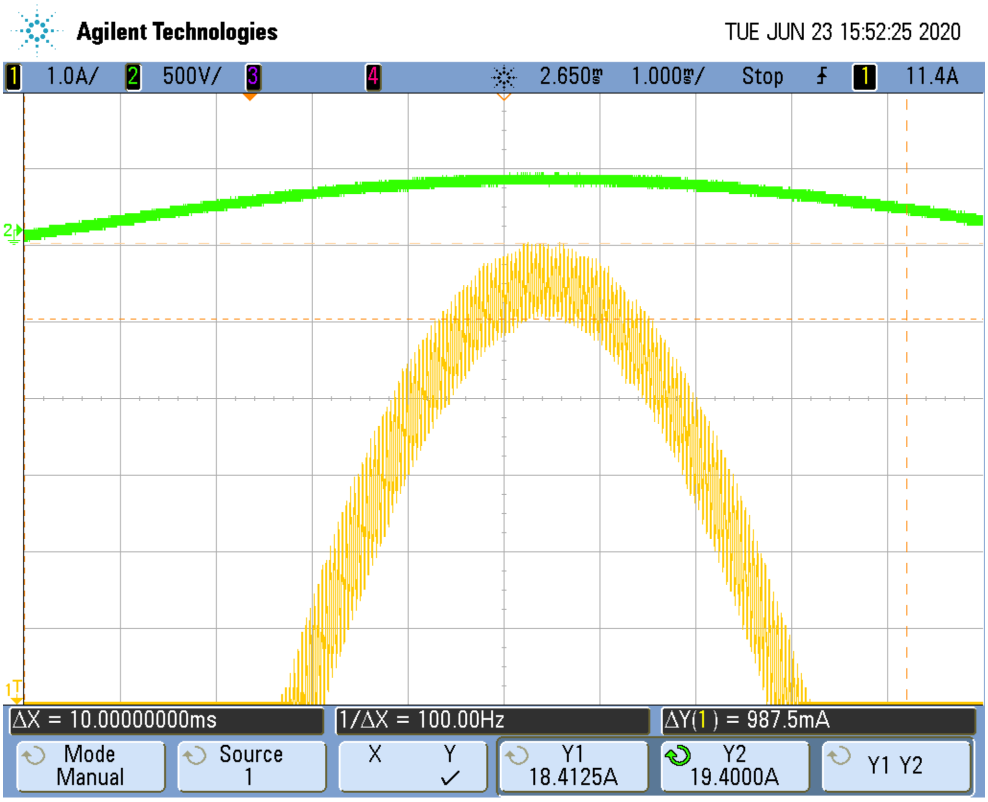
Between 25% P_{Emax} and 35 % P_{Emax}:



Between 65% P_{Emax} and 75 % P_{Emax}:



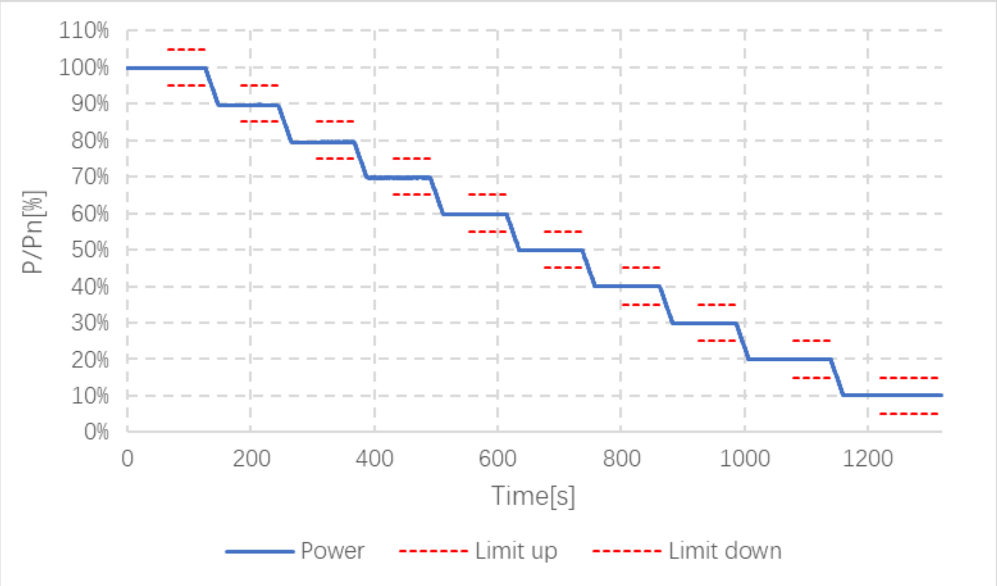
>90 % P_{Emax}:



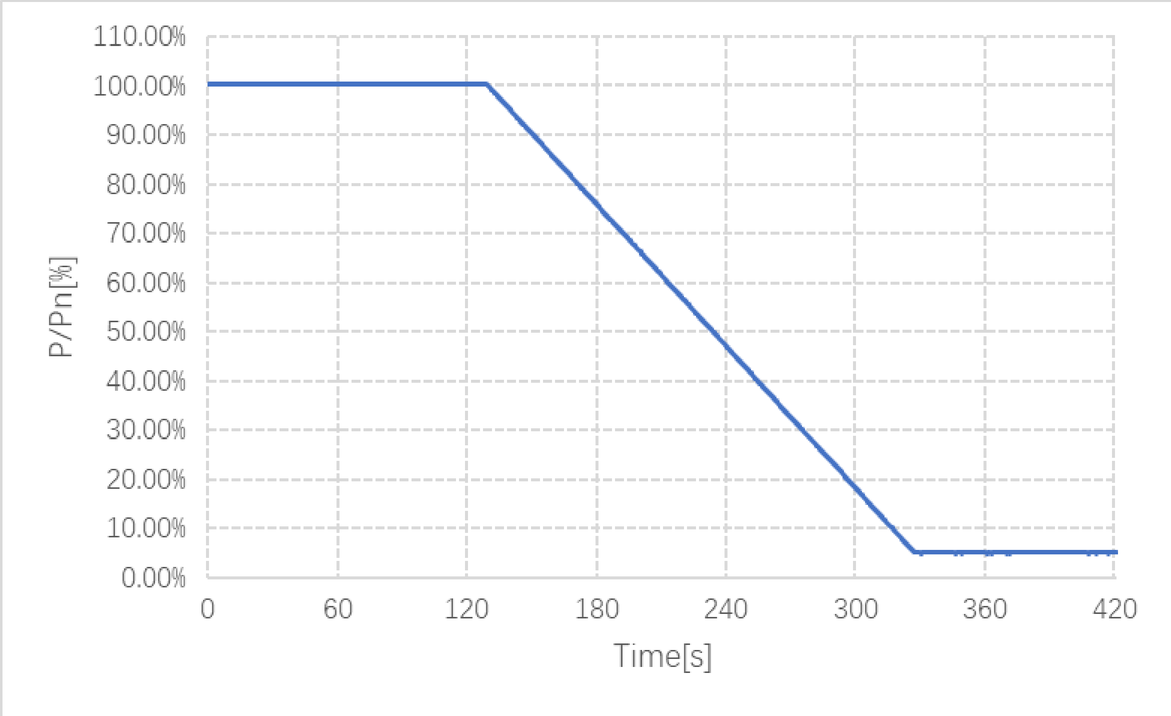
5.2.6	TABLE: DC Injection						P
Model: ME3000SP							
Mains voltage: 230V							
Power P/Pn		100%					
Measurement							Limitation
Phase L1		Phase L2		Phase L3			
0.061A	0.468%	--	--	--	--		0.5%
Power P/Pn [%]		66%					
Measurement							Limitation
Phase L1		Phase L2		Phase L3			
0.062A	0.472%	--	--	--	--		0.5%
Power P/Pn [%]		33%					
Measurement							Limitation
Phase L1		Phase L2		Phase L3			
0.063A	0.482%	--	--	--	--		0.5%
Remark: The absolute value of measurements have been taken.							

5.4.2	TABLE: Measurement of active- and reactive power ranges								P
Model: ME3000SP									
No.	Test condition		Measurement						
	Cosφ	U / Un	U [V]	I [A]	$P_{Emax600}$ *) [W]	$S_{emax600}$ *) [VA]	Q [Var]	Cosφ	
a1	1.00	90%	207.26	13.77	2852.55	2854.47	-104.42	0.9993	
a3		100%	230.12	13.08	3007.33	3009.23	-106.79	0.9994	
a5		109%	250.63	12.03	3012.81	3015.14	118.61	0.9992	
b1	max. under-excited	95%	218.53	13.61	2672.95	2975.02	-1306.18	0.8985	
b3		100%	230.00	13.21	2731.98	3037.81	-1328.37	0.8993	
B5		109%	250.52	12.11	2733.46	3033.27	-1314.88	0.9012	
c1	max. over-excited	90%	207.19	13.93	2612.86	2886.75	1227.31	0.9051	
c3		100%	230.07	13.52	2808.46	3110.66	1337.45	0.9028	
c4		105%	241.44	12.91	2810.40	3116.51	1346.95	0.9018	
$P_{Emax600}$ [W]			3012.81						
$S_{Emax600}$ [VA]			3116.51						

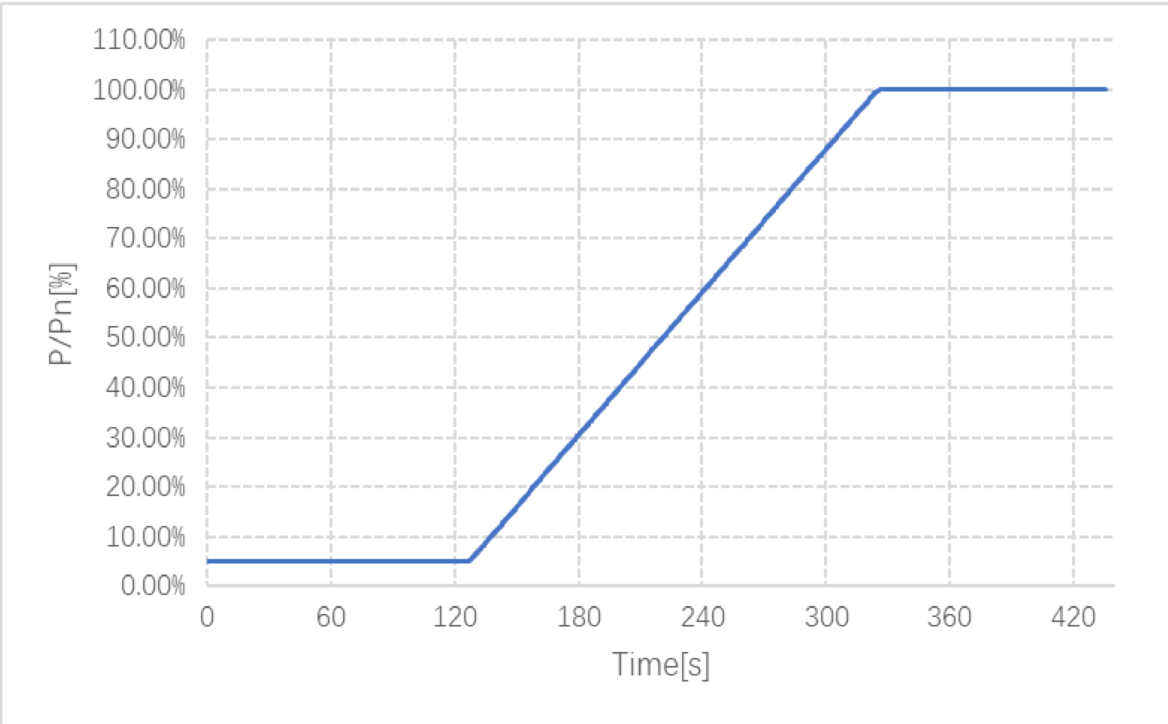
5.4.3	Active power reduction through setpoint specification				P
Measurement Item		Power Setting [W]	Actual Power [W]	Tolerance of power [W]	Δ P/ Pn [%]
100%		3000.00	3001.56	1.56	0.05%
90%		2700.00	2703.03	3.03	0.10%
80%		2400.00	2396.26	-3.74	-0.12%
70%		2100.00	2100.46	0.46	0.02%
60%		1800.00	1797.89	-2.11	-0.07%
50%		1500.00	1504.56	4.56	0.15%
40%		1200.00	1206.09	6.09	0.20%
30%		900.00	903.34	3.34	0.11%
20%		600.00	605.06	5.06	0.17%
10%		300.00	302.99	2.99	0.10%
Limitation of Δ P/ Pn		± 5%			



Power gradient (100%Pn ->5%Pn) [W/s]:	14.39W/s
Power gradient (5%Pn ->100%Pn) [W/s]:	14.39W/s
Limitation of gradient [W/s]	0.33%Pn – 0.66%Pn

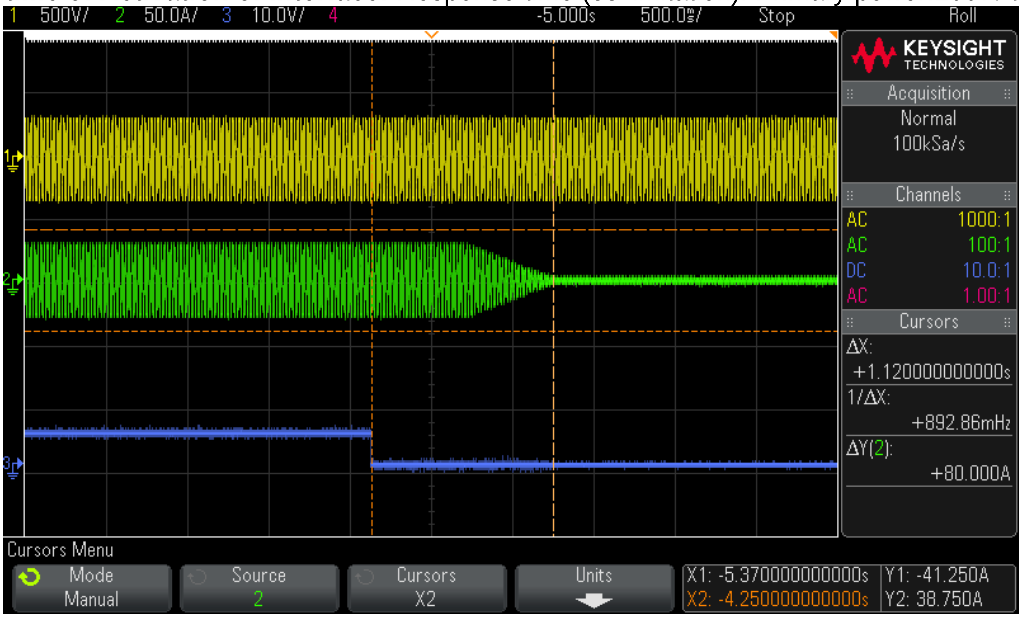


Power gradient from 100% to 5%



Power gradient from 5% to 100%

The exact name of interface: Logic interface
Information: if receiving the signal is low, the interface will change the state of power, which specified in the manual
Response time of Activation of interface: Response time (5s limitation): Primary power:100% to 0%



Noted: CH3 represents signal for activating logic interface, CH2: Current of EUT, CH1: Voltage of EUT
Logic interface will be specified in the manual

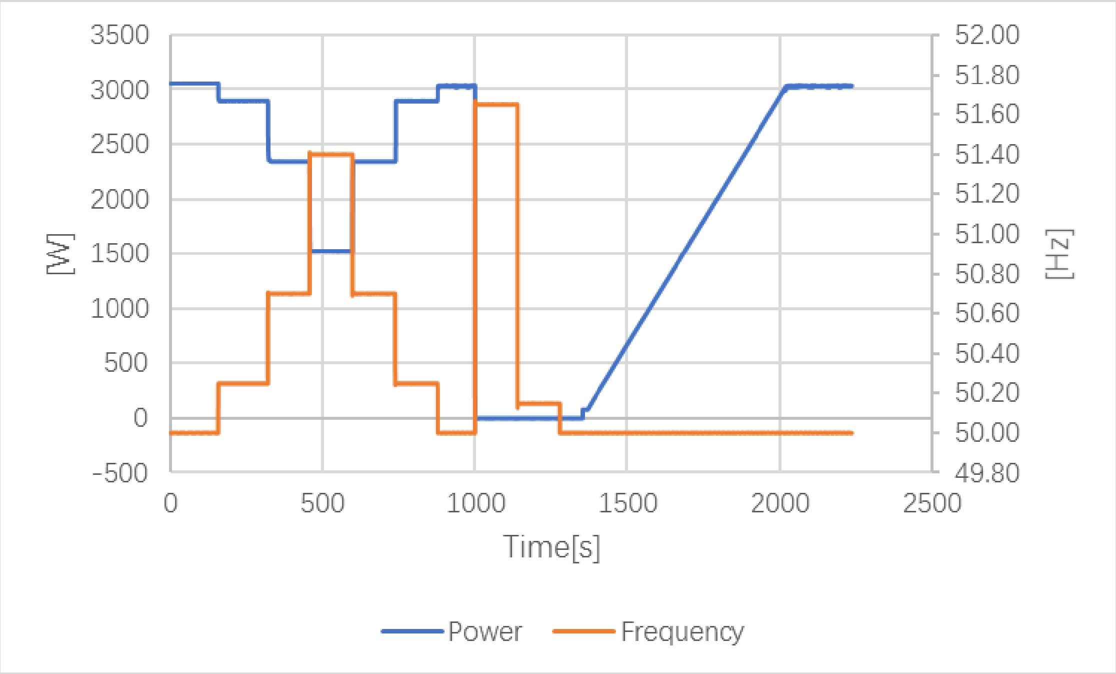
5.4.3.5 Measurement priority interfaces / energy management system

Interface	**1**	**2**	**3**	**4**
test 1: *P* in pu soll	0.6	1.0	0.3	0
test 2: *P* in pu soll	0.3	1.0	0	0.6
test 3: *P* in pu soll	1.0	0	0.6	0.3

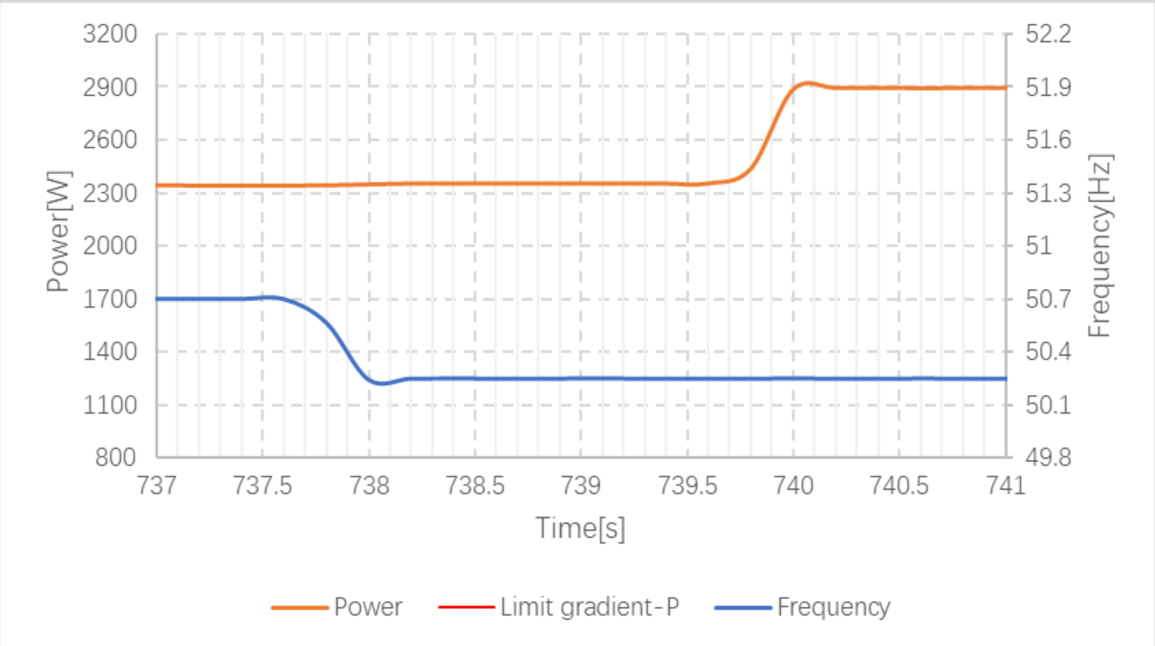
The PGU is always response at the lowest priority

5.4.4	Active power supply at overfrequency							P
Test 1	40%P_{Emax} (W)		1205.12		10%P_{Emax} (W)		301.28	
Setting parameters of the memory: P = 100% PEmax Start of power reduction at 50.2 Hz	f (Hz)	Expected Active power output [P/ PEmax] [%]	Measured output Power (W)	Tolerance between measured P and Expected [△P/ PEmax] [%]	Tolerance Limit [%]	Time The initial time delay TV <2s	Time The response times $T_{an\_90\ \%}$ <1s	Time The settling times <20s
a) 50Hz ± 0.01Hz	50.00	100	3057.19	1.47	< ± 5%	--	--	--
b)50.25Hz ± 0.01Hz	50.25	98	2895.17	-1.90	< ± 10%	0.40	0.40	1.00
c)50.70Hz ± 0.01Hz	50.70	80	2343.90	-2.20	< ± 10%	--	0.80	1.80
d)51.40Hz ± 0.01Hz	51.40	52	1524.66	-1.39	< ± 10%	--	0.80	2.20
e)50.70Hz ± 0.01Hz	50.70	80	2342.13	-2.26	< ± 10%	--	0.80	3.00
f)50.25Hz ± 0.01Hz	50.25	98	2891.20	-2.04	< ± 10%	--	0.35	2.40
g)50Hz ± 0.01Hz	50.00	100	3032.51	1.08	< ± 10%	--	0.20	0.40
h)51.65Hz± 0.01Hz	Disconnection Time[ms]:198, Limitation[ms]: 200							
i)50.15Hz± 0.01Hz	Reconnection: ☐ Yes/ ☒ No, Limitation: No reconnection is allowed.							
j)50.00Hz± 0.01Hz	Reconnection time: 76.6s Maximal Rising Gradient [%/min]:8.98%, Limitation [%/min]: 10%							

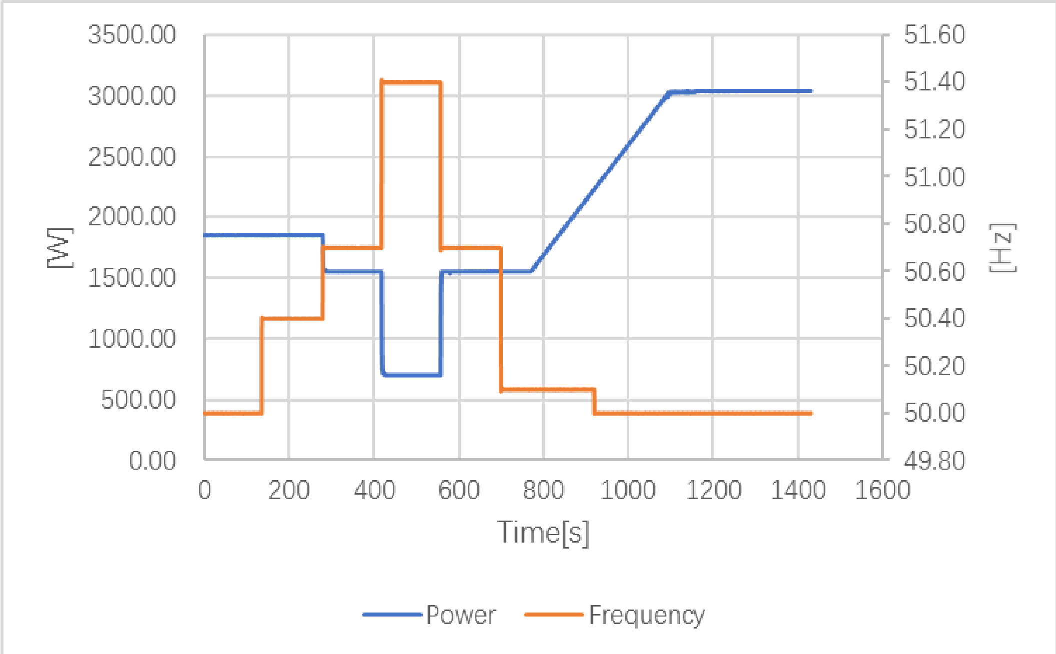
Test 2	40%P_{Emax} (W)		1205.12			10%P_{Emax} (W)		301.28
Setting parameters of the ESS: P = 60% PEmax (The reduction of the primary energy supply to limit the active power output, or the limiting setting of the active power output must be removed from measuring point c) Start of power reduction at 50.5 Hz s= 5% (40% P / Hz)	f (Hz)	Expected Active power output [P/ PEmax] [%]	Measured output Power (W)	Tolerance between measured P and Expected [△P/ PEmax] [%]	Tolerance Limit [%]	Time		
						The initial time delay TV <2s	The response times $T_{an\_90\,\%}$ <1s	The settling times <20s
a)50Hz ± 0.01Hz	50.00	60	1854.59	1.82	< ± 5%	--	--	--
b)50.40Hz ± 0.01Hz	50,40	60	1855.05	1.84	< ± 10%	--	--	--
c)50.70Hz ± 0.01Hz	50.70	52	1553.98	-0.20	< ± 10%	0.40	0.80	2.40
d)51.40Hz ± 0.01Hz	51.40	24	701.92	-0.60	< ± 10%	--	0.80	3.00
e)50.70Hz ± 0.01Hz	50.70	52	1555.00	-0.17	< ± 10%	--	0.80	4.00
f)50.10Hz ± 0.01Hz	50.10	60-100	Maximal Rising Gradient [%/min]: 9.05, Limitation [%/min]: 10%					
g)50Hz ± 0.01Hz	50.00	100	--					



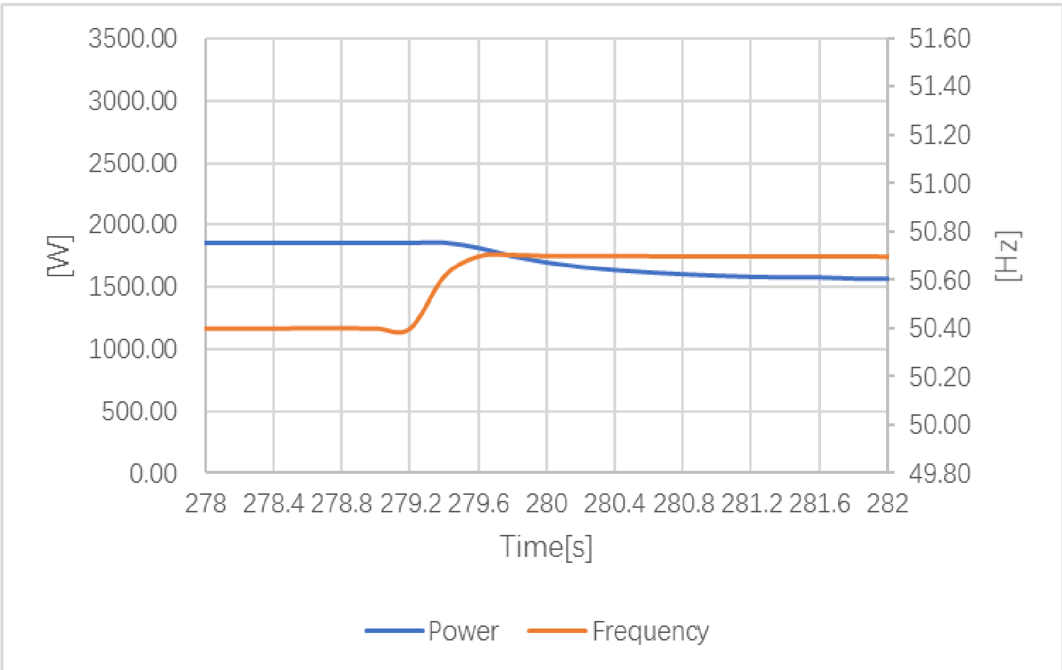
Test 1 P&F curve



Response time



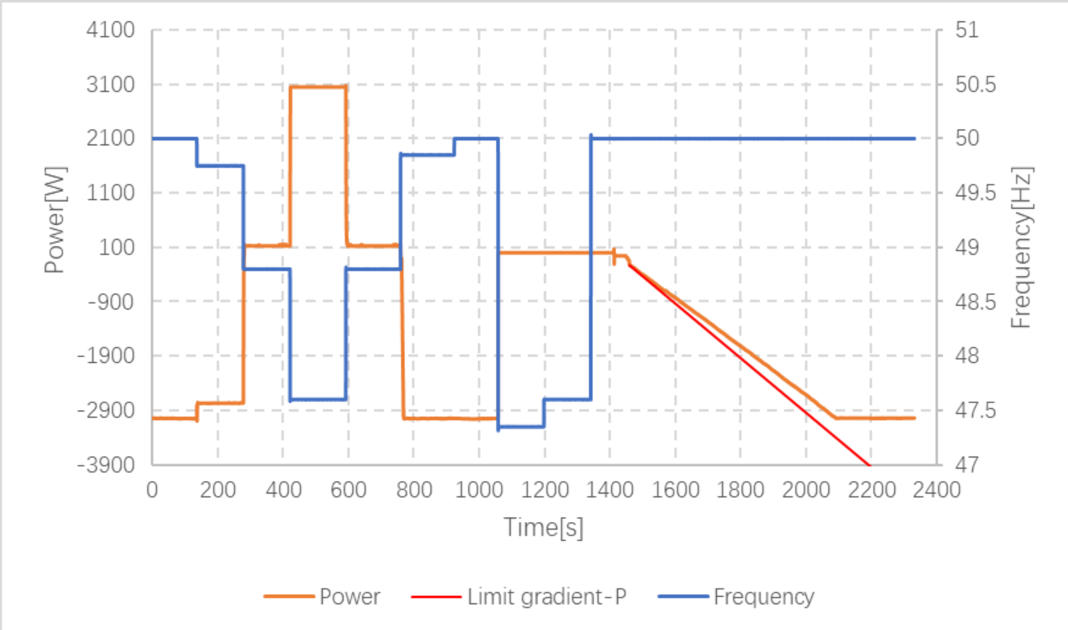
Test 2 P&F curve



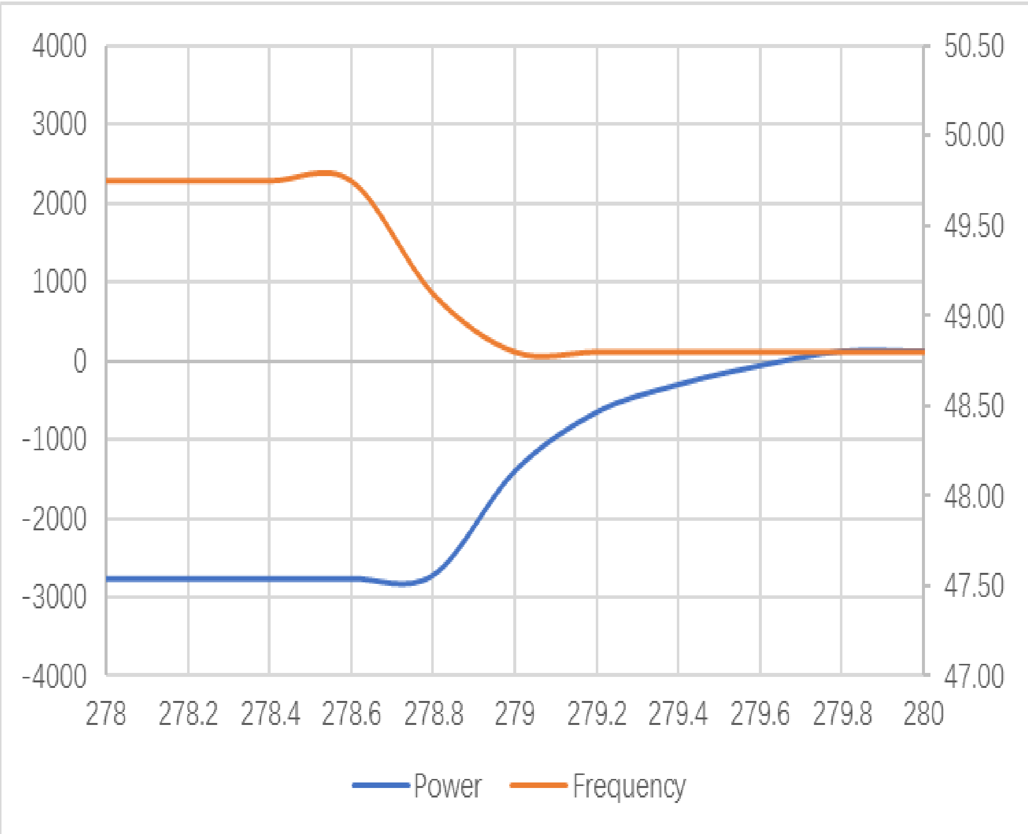
Response time

5.4.6	Active power supply at underfrequency							P
Test 1 Setting parameters of the ESS:P=-100% Start of power reduction at 49.8 Hz	100%P_{Emax} (W)		3012.80		10%P_{Emax} (W)		301.28	
	f (Hz)	Expected Active power output [P/ PEmax] [%]	Measured output Power (W)	Tolerance between measured P and Expected [△P/ PEmax] [%]	Tolerance Limit [%]	Time		
						The initial time delay TV <2s	The response times $T_{an\_90\ \%}$ <1s	The settling times <20s
a) 50Hz ± 0.01Hz	50.00	-100	-3048.02	-1.17	< ± 5%	--	--	--
b)49.75Hz ± 0.01Hz	49.75	-95	-2768.02	3.12	< ± 10%	0.20	0.50	2.60
c)48.80Hz ± 0.01Hz	48.80	0	124.29	4.13	< ± 10%	--	0.90	2.00
d)47.60Hz ± 0.01Hz	47.60	100	3049.15	1.21	< ± 10%	--	0.80	1.40
e)48.80Hz ± 0.01Hz	48.80	0	128.89	4.28	< ± 10%	--	0.80	2.80
f)49.85Hz ± 0.01Hz	49.85	-100	-2960.72	1.73	< ± 10%	--	0.80	9.40
g)50Hz ± 0.01Hz	50.00	-100	-3052.69	-1.32	< ± 10%	--	--	--
h)47.35Hz± 0.01Hz	Disconnection Time[ms]: 198, Limitation[ms]: _200__							
i)47.60Hz± 0.01Hz	Reconnection: ☐ Yes/ ☒ No, Limitation: No reconnection is allowed.							
j)50.00Hz± 0.01Hz	Reconnection time: 70.8s Maximal Rising Gradient [%/min]: 8.86%, Limitation [%/min]: 10%							

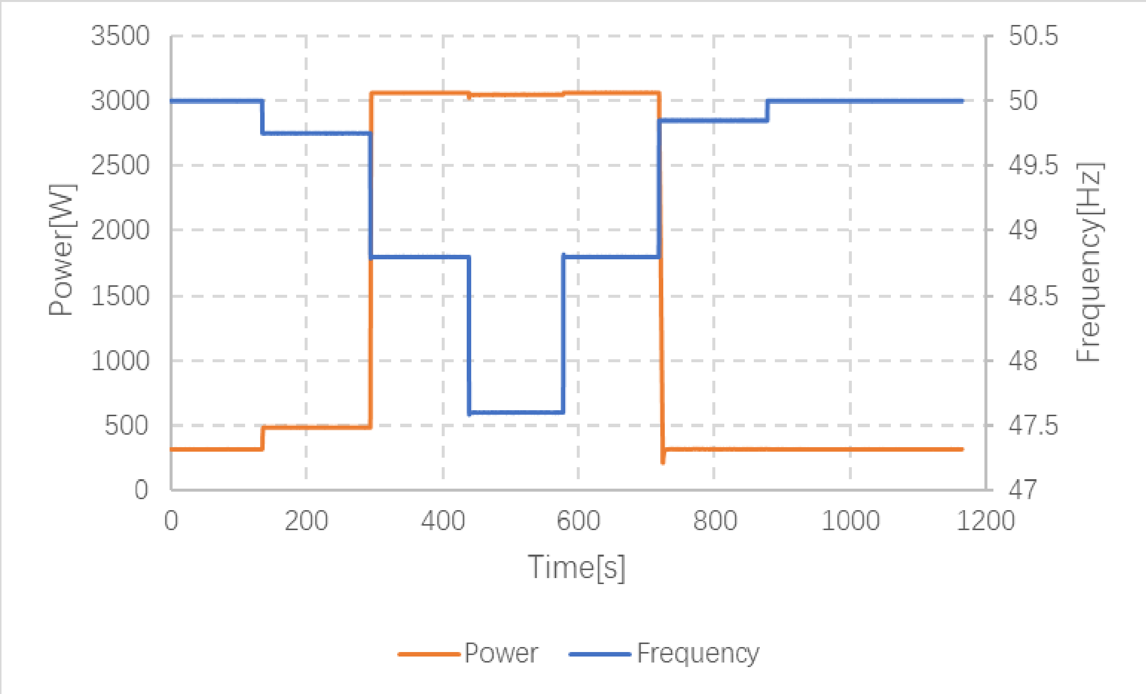
Test 2 Setting parameters of the ESS: P = 10% PEmax (The reduction of the primary energy supply to limit the active power output, or the limiting setting of the active power output must be removed from measuring point c) Start of power reduction at 49.8 Hz	100%P_{Emax} (W)		3012.80		10%P_{Emax} (W)		301.28	
	f (Hz)	Expected Active power output [P/ PEmax] [%]	Measured output Power (W)	Tolerance between measured P and Expected [△P/ PEmax] [%]	Tolerance Limit [%]	Time		
						The initial time delay TV <2s	The response times $T_{an\_90\ \%}$ <1s	The settling times <20s
a)50Hz ± 0.01Hz	50.00	10	316.90	0.52	< ± 5%	--	--	--
b)49.75Hz ± 0.01Hz	49.75	15	484.30	1.07	< ± 10%	0.20	0.90	1.20
c)49.80Hz ± 0.01Hz	48.80	100	3062.09	1.64	< ± 10%	--	0.80	1.60
d)47.60Hz ± 0.01Hz	47.60	100	3047.62	1.16	< ± 10%	--	--	--
e)48.80Hz ± 0.01Hz	48.80	100	3062.88	1.66	< ± 10%	--	--	--
f)49.85Hz ± 0.01Hz	49.85	10	346.31	1.49	< ± 10%	--	0.80	5.60
g)50Hz ± 0.01Hz	50.00	10	316.92	0.52	< ± 10%	---	--	--



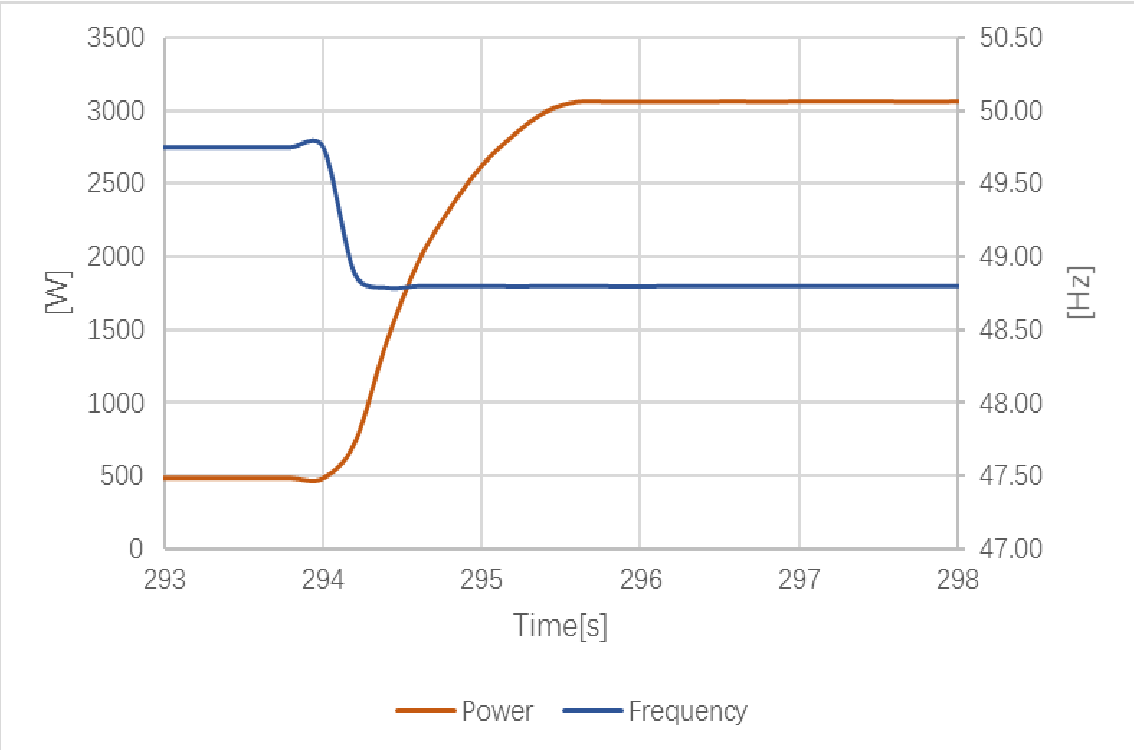
Test 1 P&F curve



Response time



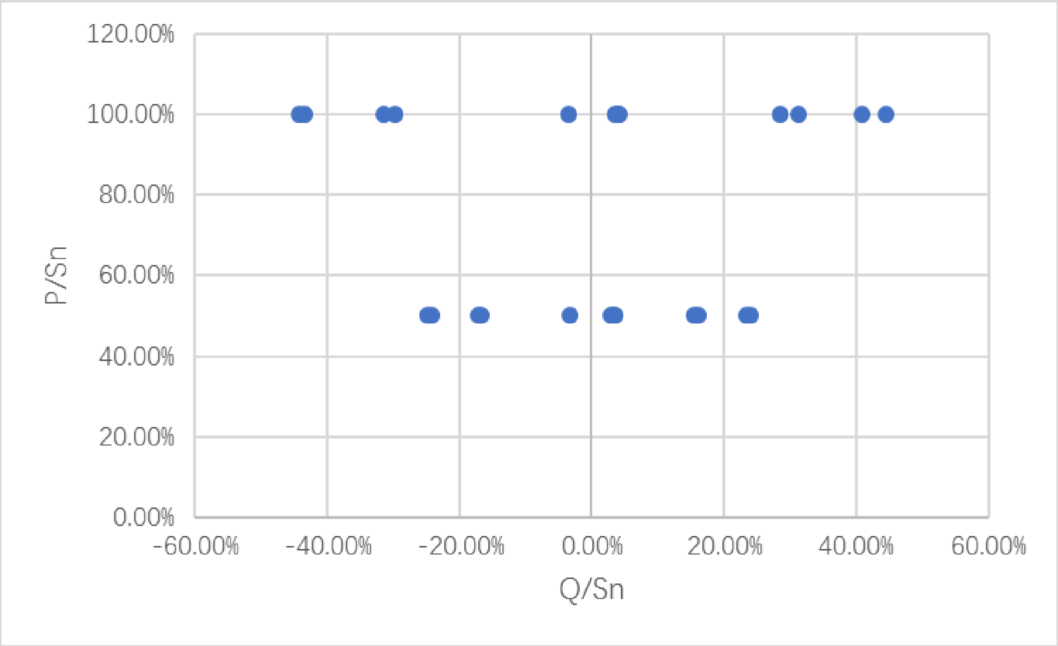
Test 2 P&F curve



Response time

5.4.8.2	TABLE: Reactive power / displacement factor setting accuracy								P
	Cosφ	Power	U [V]	P [W]	Q [Var]	S [VA]	cos φ	∆ Q / P_{Emax}	Limit ∆ Q / P_{Emax}
☒ ∑SEmax > 4.6kVA									
c)	0.90 under-excited	50%P_{Emax}	207.25	1511.14	-99.70	1518.08	0.9954	Pass for voltage-reactive restriction	
			229.53	1515.41	-742.40	1687.49	0.8980	-0.531	≤ ±4%
			253.21	1518.43	-727.84	1683.86	0.9018	-0.045	≤ ±4%
		S_{Emax}	207.43	2879.37	-107.77	2849.46	0.9965	Pass for voltage-reactive restriction	
			229.99	2732.63	-1328.71	3038.54	0.8993	-0.701	≤ ±4%
			253.35	2717.89	-1304.72	3014.84	0.9015	0.098	≤ ±4%
	0.95 under-excited	50%P_{Emax}	206.66	1509.05	89.54	1513.97	0.9968	Pass for voltage-reactive restriction	
			229.81	1515.67	-501.16	1596.38	0.9494	-0.271	≤ ±4%
			252.91	1519.30	-516.25	1604.62	0.9468	-0.774	≤ ±4%
		S_{Emax}	207.15	3026.51	116.35	3029.24	0.9991	Pass for voltage-reactive restriction	
			230.03	2898.68	-945.49	3048.98	0.9507	-0.291	≤ ±4%
			253.14	2890.99	-892.86	3025.73	0.9555	1.463	≤ ±4%
d)	0.90 over-excited	50% P_{Emax}	206.70	1516.71	704.00	1672.14	0.9071	-1.57%	≤ ±4%
			229.86	1512.77	720.34	1675.52	0.9029	-2.11%	≤ ±4%
			252.93	1507.67	104.42	1511.53	0.9975	Pass for voltage-reactive restriction	
		S_{Emax}	207.18	2614.30	1227.46	2888.12	0.9052	2.85%	≤ ±4%
			230.06	2810.15	1337.55	3112.23	0.9029	-0.81%	≤ ±4%
			253.16	3022.82	105.12	3025.27	0.9992	Pass for voltage-reactive restriction	
	0.95 over-excited	50% P_{Emax}	206.67	1521.21	467.52	1591.43	0.9559	0.09%	≤ ±4%
			229.52	1516.41	483.56	1591.64	0.9527	-0.44%	≤ ±4%
			252.60	1510.05	102.37	1513.51	0.9977	Pass for voltage-reactive restriction	
		S_{Emax}	207.23	2747.94	855.02	2877.89	0.9548	2.85%	≤ ±4%
			230.12	2958.09	938.67	3103.45	0.9532	0.07%	≤ ±4%
			253.16	3029.20	122.99	3031.86	0.9991	Pass for voltage-reactive restriction	

P-Q Diagram

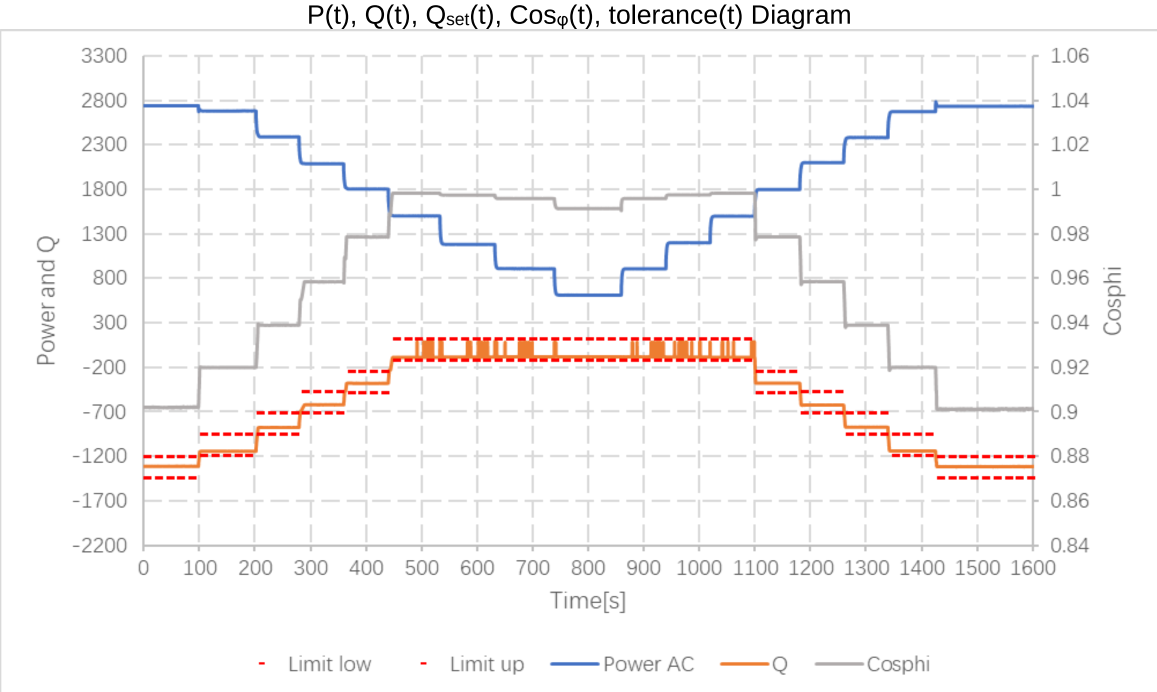

120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
P/Sn
-60.00%
-40.00%
-20.00%
0.00%
20.00%
40.00%
60.00%
Q/Sn

5.4.8.3	TABLE: Testing the displacement factor / active power characteristic curve Cos$_{\varphi}$(P)	P

3) Test steps for supply-dependent EZE accuracy (characteristic curve)

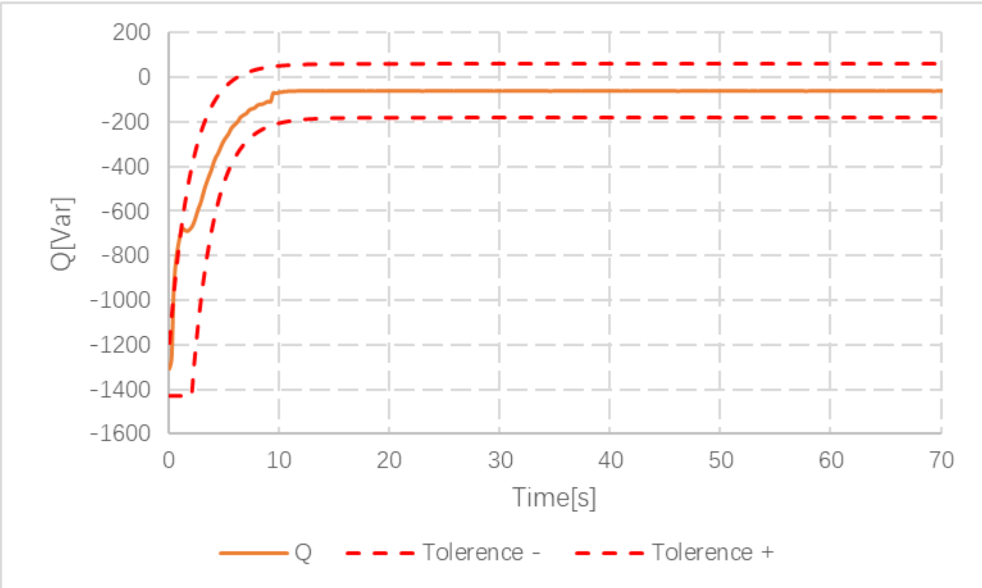
Step	Pdc[W]	P[W]	Q[Var]	Cosφ	Qdesired	Δ Q / P_{Emax}	Limitation
100%	2953.81	2740.87	-1311.65	0.9020	-1358.46	1.55%	± 4%
90%	2886.51	2681.89	-1143.15	0.9199	-1099.28	-1.46%	± 4%
80%	2563.64	2391.27	-876.43	0.9389	-850.62	-0.86%	± 4%
70%	2231.34	2088.40	-624.77	0.9580	-610.84	-0.46%	± 4%
60%	1922.96	1804.51	-381.14	0.9784	-372.11	-0.30%	± 4%
50%	1604.64	1507.34	-87.95	0.9956	0.00	-2.92%	± 4%
40%	1409.99	1324.59	-79.97	0.9978	0.00	-2.65%	± 4%
30%	971.97	909.31	-78.19	0.9959	0.00	-2.60%	± 4%
20%	662.96	612.82	-80.52	0.9914	0.00	-2.67%	± 4%
30%	970.03	907.53	-76.48	0.9959	0.00	-2.54%	± 4%
40%	1278.41	1201.04	-77.43	0.9975	0.00	-2.57%	± 4%
50%	1593.44	1498.16	-83.03	0.9983	0.00	-2.76%	± 4%
60%	1915.16	1798.38	-377.68	0.9787	-372.11	-0.19%	± 4%
70%	2242.36	2100.34	-624.42	0.9585	-610.84	-0.45%	± 4%
80%	2551.55	2382.36	-872.78	0.9390	-850.62	-0.74%	± 4%
90%	2875.13	2673.78	-1139.05	0.9200	-1099.28	-1.32%	± 4%
100%	2946.29	2734.90	-1314.88	0.9012	-1358.46	1.45%	± 4%

P(t), Q(t), Q_{set}(t), Cos$_{\varphi}$(t), tolerance(t) Diagram

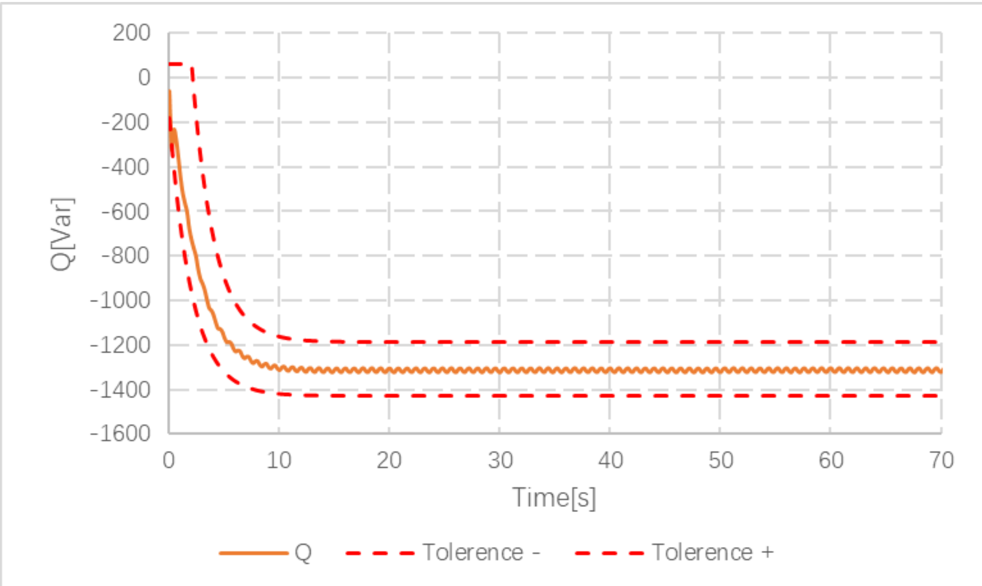


4) Test steps for supply-dependent EZE-dynamics

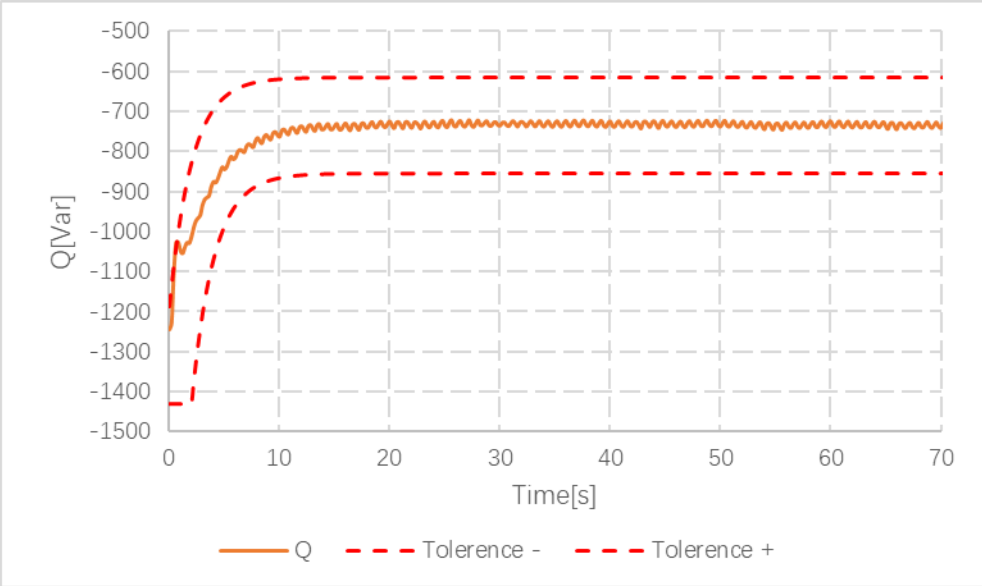
P/ Pn [%]	Duration [s]	Dynamic as PT1 character ?
100	60	--
40	60	☒ Pass ☐ Failed
100	60	☒ Pass ☐ Failed
75	60	☒ Pass ☐ Failed



Power from 100% to 40% with PT1 character



Power from 40% to 100% with PT1 character



Power from 40% to 100% with PT1 character

5.5.2, 5.5.3, 5.5.4	TABLE: Interface switch (Functional safety)	P

☒ Integrated interface switch

☒ Complied with DIN EN 62109-2

Switch manufacturer and type:
1, Hongfa HF161F-W
2, Panasonic, ALFG2PF12

Response time of interface switch for integrated NS protection: Max.10ms

The max. initial short-circuited current of PGU Ik”: 13A

String	1	U_{DC} = Un	50Vdc	Uac = Un	230Vac	P = (W)	3.0K

Component No.	Fault	Observation
EC2 in communication board	S/C	The PCE shutdown immediately, and disconnect from the grid. No hazards
C196	S/C	The PCE can operate normally, but the communication fails. No hazards
C197	S/C	The PCE switch off immediately, and disconnect from the grid, error code “ID17, ID18, ID19” display. No hazards
RY1	S/C	The PCE check relay fail before power on, error code “ID55, ID77” display. No hazards
HCT (12-13)	S/C)	The PCE switch off immediately, and disconnect from the grid, error code “ID10” display. No hazards
Q2 (C-G)	S/C	The PCE shutdown immediately, components Q2,Q8, R26,R27, Q4, Q24 damaged. No hazards
Q2 (C-E)	S/C	The PCE shutdown immediately, components Q8, C17, R44, Q3, C10, R25, Q7, R37 damaged. No hazards
Q3 (C-G)	S/C	The PCE shutdown immediately, components Q3, R28, R29, Q5, and U23 damaged. No hazards
Q3 (C-E)	S/C	The PCE shutdown immediately, components Q7, C16, R39, R37, R38, Q8, C17, and R44 damaged. No hazards
Q14	S/C	The PCE shutdown immediately, components Q14, R80, R73, and Q15 damaged. No hazards
QD2 (C-G)	S/C	The PCE shutdown immediately, components QD2, R76, R78, Q18, QD3 and U30 damaged. No hazards
QD2 (C-E)	S/C	The PCE shutdown immediately, components QD3, R96, R94, Q21, QD4 and U33 damaged. No hazards
QD1 (C-E)	S/C	The PCE shutdown immediately, components QD4, R93, R95, and QD2 damaged. No hazards
QD1 (C-G)	S/C	The PCE shutdown immediately, components QD1, Q18, R76, and R83 damaged. No hazards

EC2 in main board	S/C	The PCE shutdown immediately, components Q14, Q19, Q2, Q8, QD1 and QD3 damaged. No hazards
RD1	O/C	The PCE switch off immediately, and disconnect from the grid, error code “ID29, ID25” display. No hazards
RD5	O/C	The PCE switch off immediately, and disconnect from the grid, error code “ID29, ID25” display. No hazards
Q54 (D-S)	S/C	The PCE shutdown immediately, components Q62, Q63, R104, C63, R105 and Q64 damaged. No hazards
Q60 (D-S)	S/C	The PCE shutdown immediately, components Q64, Q65, R106, C65, R103 and Q66 damaged. No hazards
C39	S/C	The PCE shutdown immediately, components RT618, D5 and D8 damaged. No hazards
EC9	S/C	The PCE shutdown immediately, and disconnect from the grid. No hazards
EC11	S/C	The PCE shutdown immediately, and disconnect from the grid. No hazards
EC13	S/C	The PCE shutdown immediately, and disconnect from the grid. No hazards
EC18	S/C	The PCE shutdown immediately, and disconnect from the grid. No hazards
Q24 (G-D)	S/C	The PCE shutdown immediately, components Q24, R127 and U6 damaged. No hazards
Q24 (D-S)	S/C	The PCE shutdown immediately, components Q24, R137, R138, and R135 damaged. No hazards
ECF31	S/C	The PCE switch off immediately, and disconnect from the grid, error “communication fails” display. No hazards

Supplementary information:

SC: Short-circuited; OC: Open-circuited; O/L: Overloaded.

During the test:
Fire do not propagate beyond the EUT; Equipment do not emit molten metal;
Enclosures do not deform to cause non-compliance with the standard.

5.5.7.2 &5.5.7.4	TABLE: Protection device and settings					P
OV Stage 2 No.	Set value	Measured			Limitation	Test condition
		L1-N	L2-N	L3-N		
1	1.25Un	286.92V	--	--	+/-1%Un	1, applying ramp test, start of <282.9 V, and ramp to >292.1 V, step voltage length is <1.15 V, and step time is >400ms 2, applying Jump test, start of <282.9 V, and jump to >292.1 V, step voltage length is >9.2 V, and step time is >400ms
	100ms	81ms	--	--	≤200ms	
2	1.25Un	287.24V	--	--	+/-1%Un	
	100ms	76ms	--	--	≤200ms	
3	1.25Un	287.23V	--	--	+/-1%Un	
	100ms	75ms	--	--	≤200ms	
4	1.25Un	287.10V	--	--	+/-1%Un	
	100ms	77ms	--	--	≤200ms	
5	1.25Un	287.28V	--	--	+/-1%Un	
	100ms	77ms	--	--	≤200ms	

OV Stage 1 No.		Trip time [s]	Limitation [s]	Test condition
1	Set value 1.10Un 100ms	493.0s	450-550	Operation under nominal voltage for 10min, then jumped from Un to 1.12Un.
2		No disconnect	No disconnect	Operation under nominal voltage for 10min, then jumped from Un to 1.08Un.
3		313.4s	225 - 375	Operation under 1.06 voltage for 10min, then jumped from 1.06Un to 1.14Un.

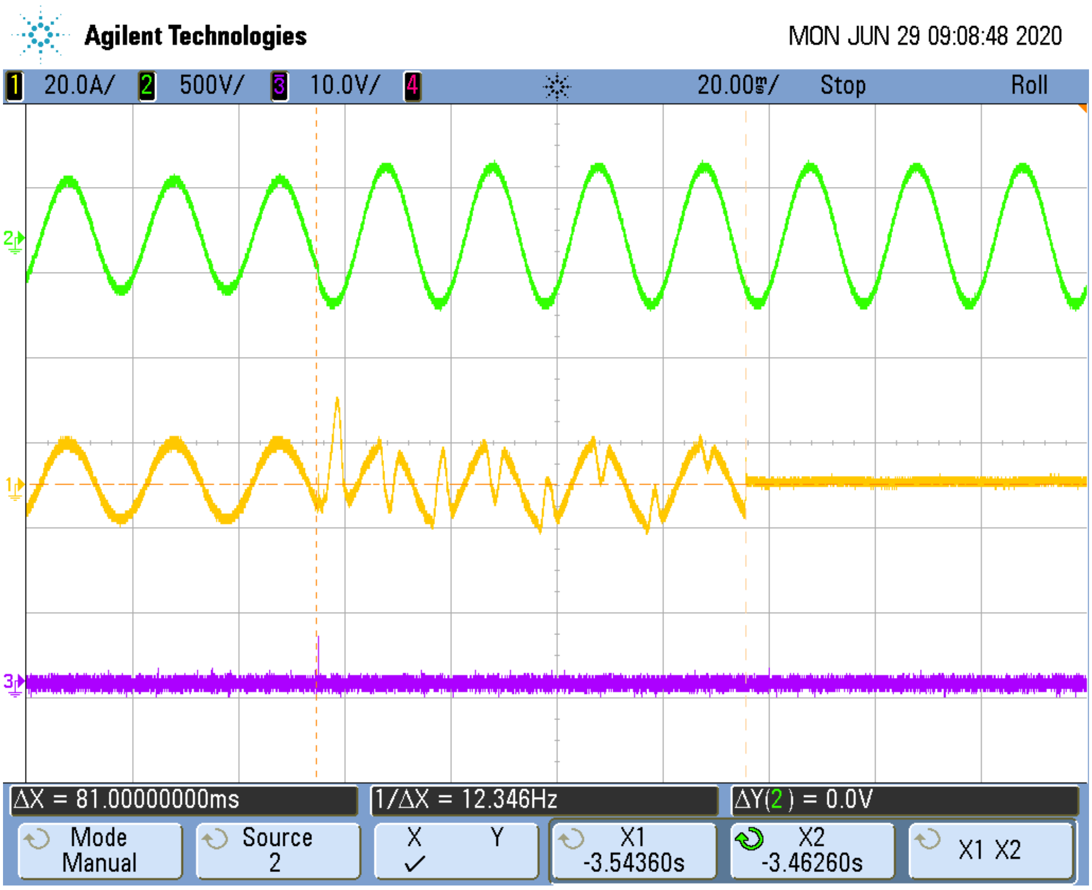
UV Stage 2 No.	Set value	Measured L1-N	Measured L2-N	Measured L3-N	Limitation [ms]	Test condition
1	0.45Un	104.13V	--	--	+/-1%Un	1, applying ramp test, start of >108.1 V, and ramp to <98.9V, step voltage length is <1.15 V, and step time is >500ms 2, applying Jump test, start of >108.1 V, and jump to <98.9V, step voltage length is >9.2 V, and step time is >500ms
	300ms	375ms	--	--	300-400ms	
2	0.45Un	104.13V	--	--	+/-1%Un	
	300ms	373ms	--	--	300-400ms	
3	0.45Un	104.15V	--	--	+/-1%Un	
	300ms	371ms	--	--	300-400ms	
4	0.45Un	104.12V	--	--	+/-1%Un	
	300ms	328ms	--	--	300-400ms	
5	0.45Un	104.12V	--	--	+/-1%Un	
	300ms	368ms	--	--	300-400ms	

UV Stage 1 No.	Set value	Measured L1-N	Measured L2-N	Measured L3-N	Limitation [ms]	Test condition
1	0.8Un	184.71V	--	--	+/-1%Un	1, applying ramp test, start of >188.6 V, and ramp to <179.4V, step voltage length is <1.15 V, and step time is >3.2s 2, applying Jump test, start of >200.1 V, and jump to <179.4V, step voltage length is >9.2 V, and step time is >3.2s
	3s	3.050s	--	--	3-3.1s	
2	0.8Un	184.71V	--	--	+/-1%Un	
	3s	3.040s	--	--	3-3.1s	
3	0.8Un	184.71V	--	--	+/-1%Un	
	3s	3.040s	--	--	3-3.1s	
4	0.8Un	184.70V	--	--	+/-1%Un	
	3s	3.050s	--	--	3-3.1s	
5	0.8Un	184.70V	--	--	+/-1%Un	
	3s	3.060s	--	--	3-3.1s	

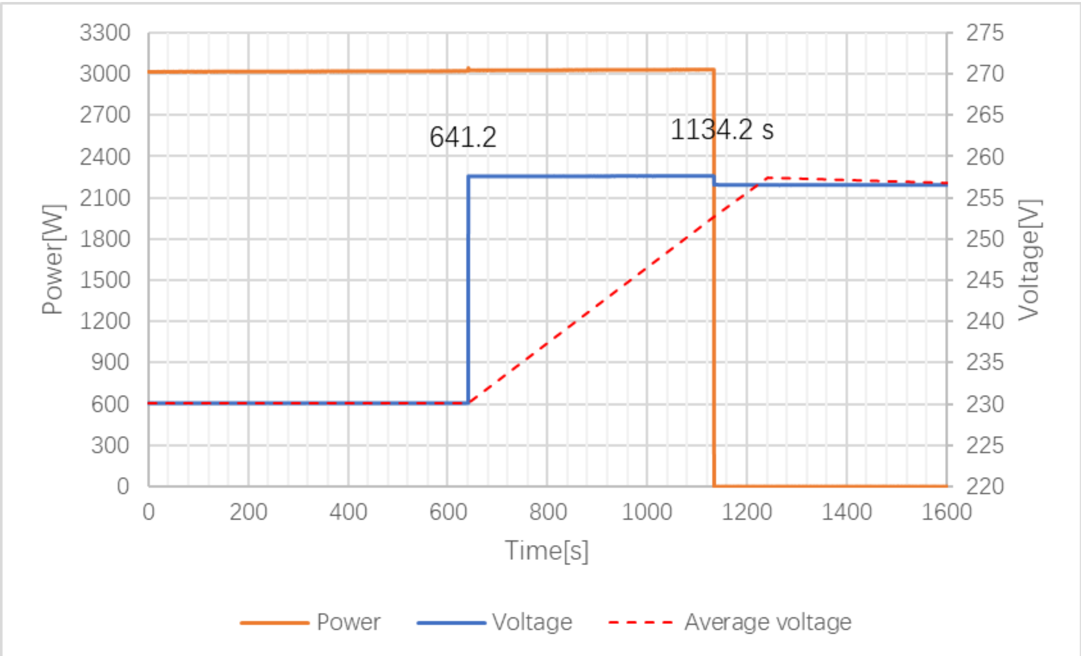
OF No.	Set value	Measured Trip value					Limitation	Remark
1	51.5Hz	51.50	51.50	51.49	51.50	51.50	+/-0.05Hz	1, applying ramp test, start of <51.4Hz, and ramp to >51.6Hz, step frequency length is <0.025 Hz, and step time is >400ms
2	100ms	44ms	80ms	82ms	56.8ms	55ms	≤ 200	2, applying Jump test, start of <51.4Hz, and jump to >51.6Hz, step frequency length is >0.2Hz, and step time is >400ms

UF No.	Set value	Measured Trip value					Limitation [ms]	Remark
1	47.5Hz	47.50	47.52	47.52	47.51	47.52	+/-0.05Hz	1, applying ramp test, start of >47.6Hz, and ramp to <47.4Hz, step frequency length is <0.025 Hz, and step time is >400ms
2	100ms	83ms	97ms	97ms	73ms	96ms	≤ 200	2, applying Jump test, start of >47.6Hz, and jump to <47.4Hz, step frequency length is >0.2Hz, and step time is >400ms

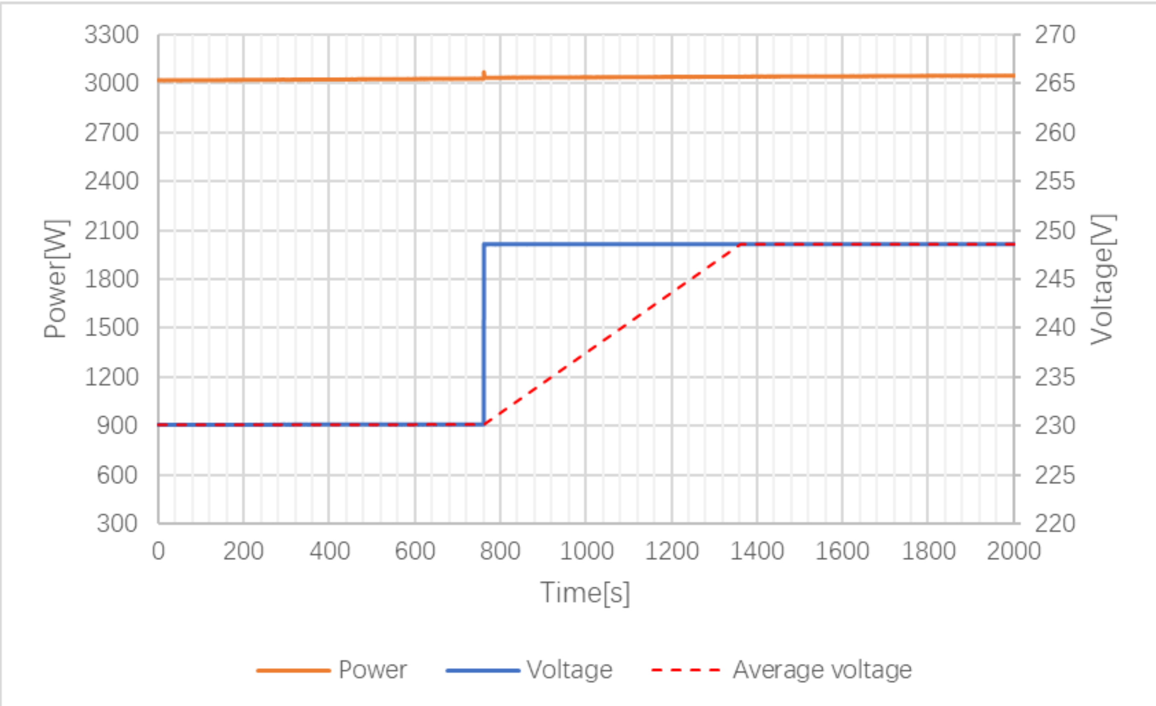
OV Stage 2:



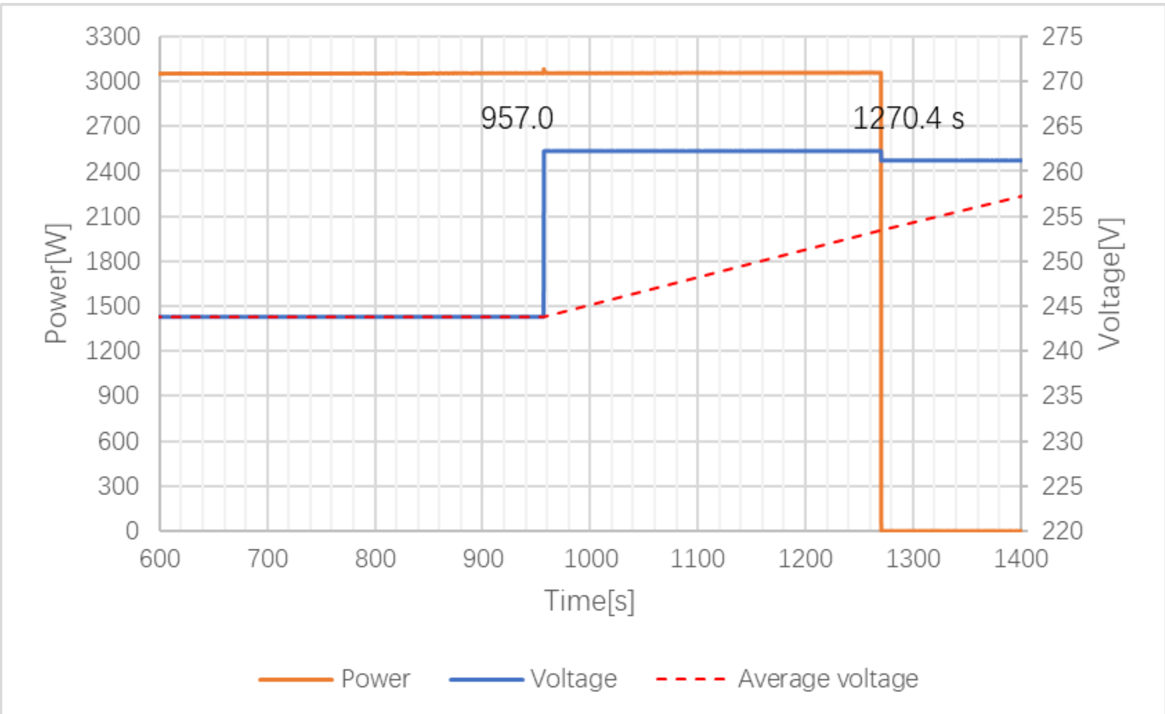
OV Stage 1:



112% Un

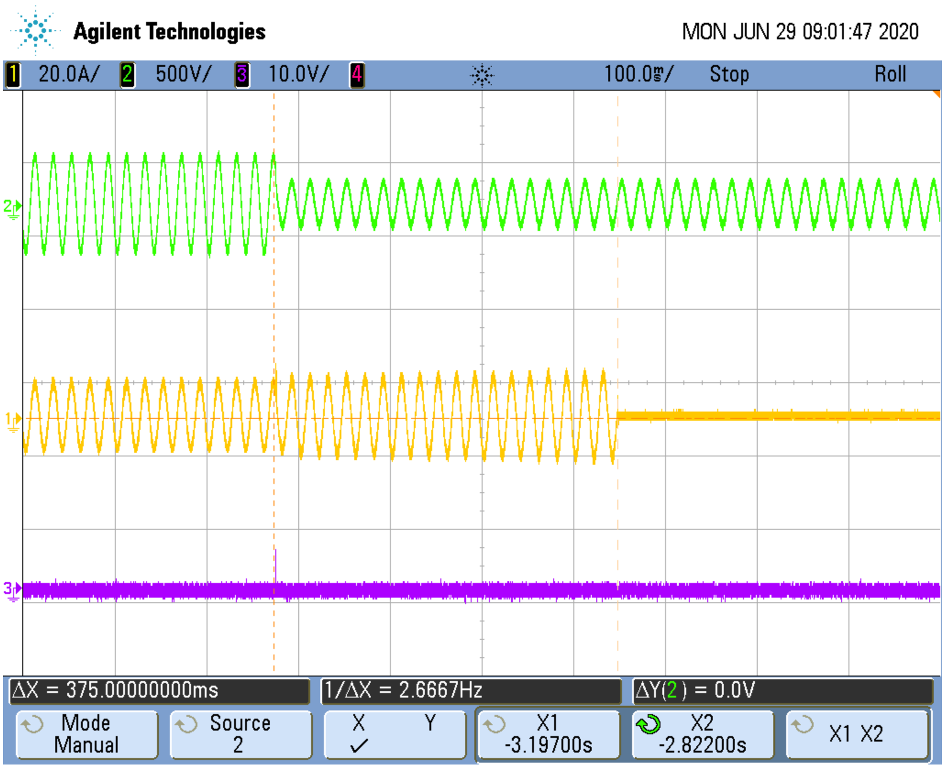


Un to 1.08Un



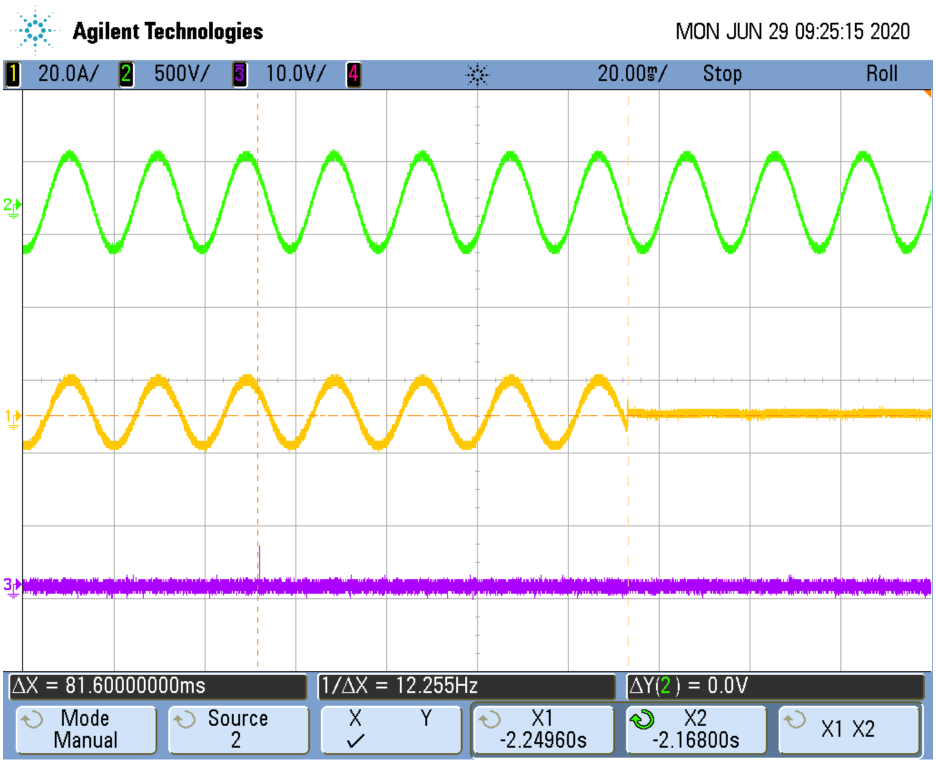
1.06 Un to 1.14Un

UV Stage 2

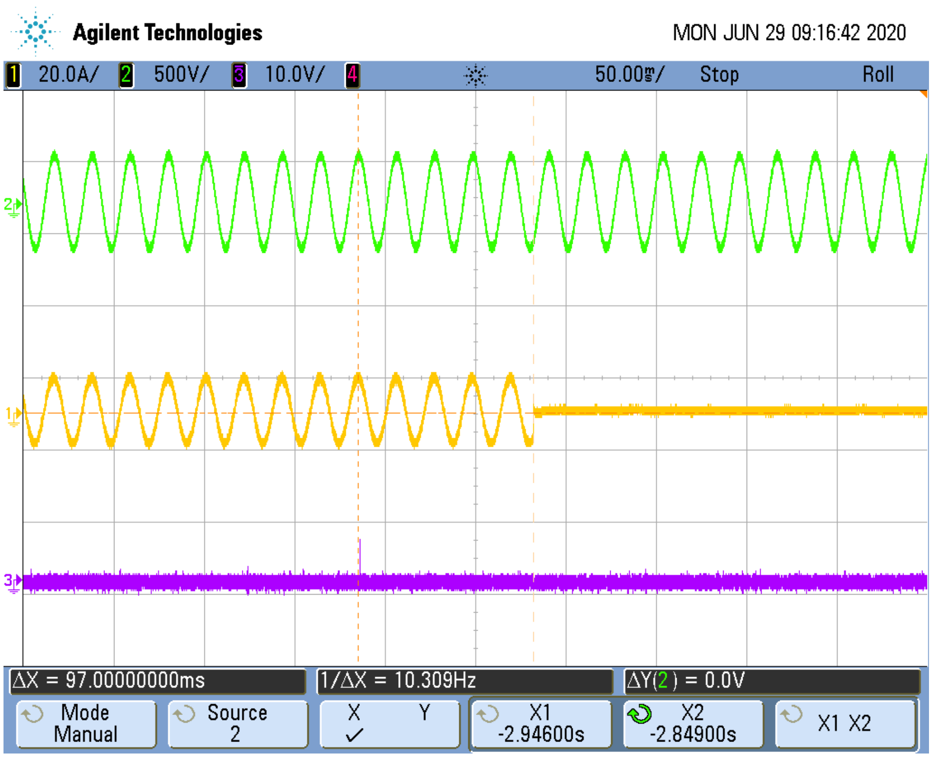


UV Stage 1

OF:


Agilent Technologies
MON JUN 29 09:25:15 2020
1 20.0A/ 2 500V/ 3 10.0V/ 4
20.00ms/ Stop Roll
ΔX = 81.60000000ms
1/ΔX = 12.255Hz
ΔY(2) = 0.0V
Mode
Manual
Source
2
X Y
X1
-2.24960s
X2
-2.16800s
X1 X2

UF:

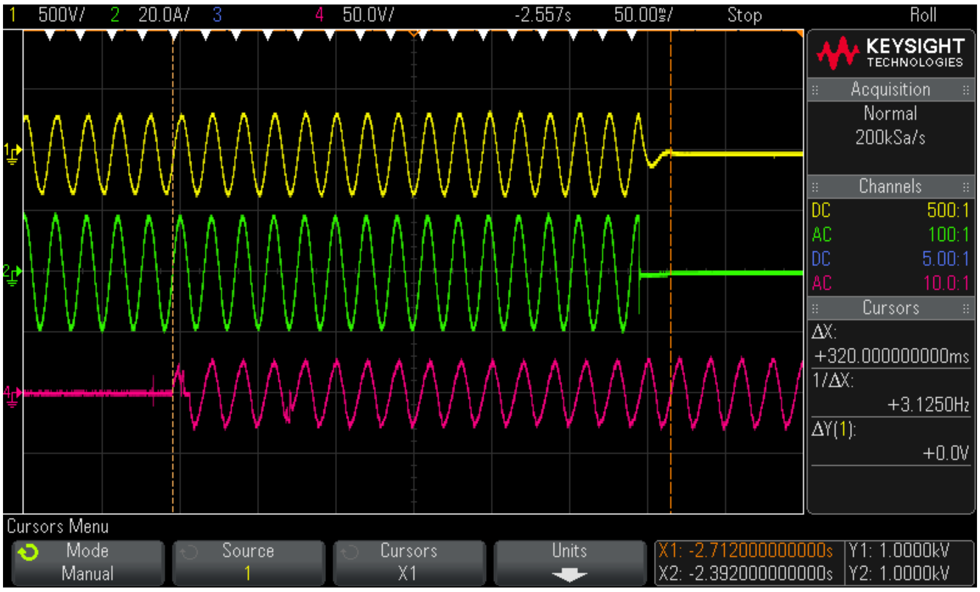

Agilent Technologies
MON JUN 29 09:16:42 2020
1 20.0A/ 2 500V/ 3 10.0V/ 4
50.00ms/ Stop Roll
ΔX = 97.00000000ms
1/ΔX = 10.309Hz
ΔY(2) = 0.0V
Mode
Manual
Source
2
X Y
X1
-2.94600s
X2
-2.84900s
X1 X2

5.5.8, 5.5.9	TABLE: Indication / protection of NS protection		P
1.	The last 5 fault indication can be read	☒ Pass ☐ Failed	
	Fault 1:	Error message display	
	Fault 2:	Error message display	
	Fault 3:	Error message display	
	Fault 4:	Error message display	
	Fault 5:	Error message display	
2.	Fault indication can be read after a supply interruption ≤ 3s	☒ Pass ☐ Failed	
	Fault 1:	Error message display	
	Fault 2:	Error message display	
	Fault 3:	Error message display	
	Fault 4:	Error message display	
	Fault 5:	Error message display	
3.	The protection settings can be read on PGU or data interface equipment	☒ Pass ☐ Failed	
		Interface equipment: remote monitor	
4.	The NS protection settings shall be protected.	☒ Pass ☐ Failed	
		Protection type: Integrated NS protection	
5.	If all protection settings are fixed	☒ Pass ☐ Failed	

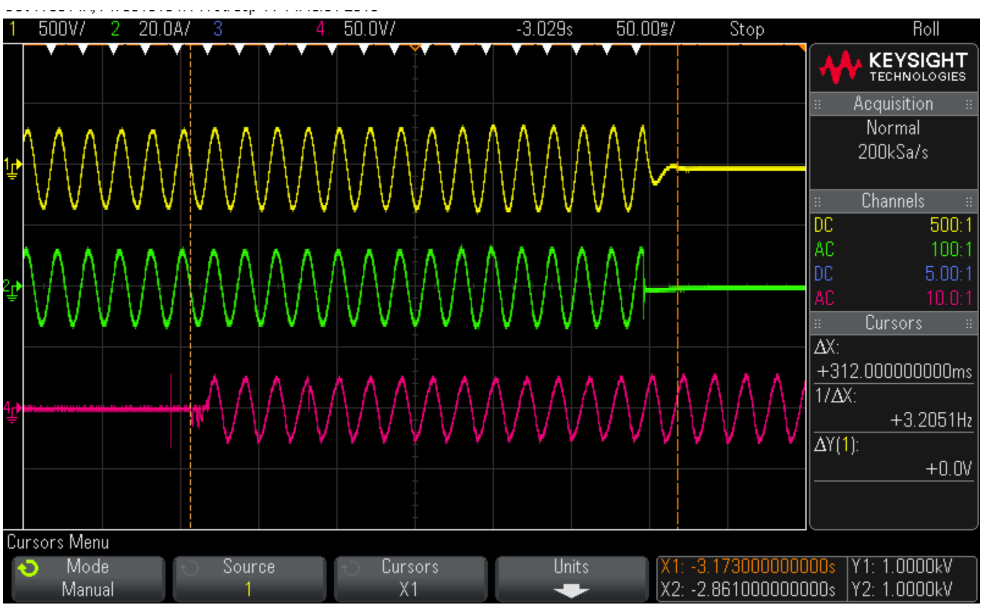
5.5.10	Island detection								P
No.	PEUT[1] (% of EUT rating)	Reactive load (% of QL in 6.1.d)1)	PAC[2] (% of nominal)	QAC[3] (% of nominal)	Run on time (s)	PEUT (W)	Actual Qf	VDC	Remarks[4]
1	100	100	0	0	320.00	3008.00	1.00	51	Test A at BL
2	66	66	0	0	312.00	1833.00	1.00	51	Test B at BL
3	33	33	0	0	285.00	991.00	1.00	51	Test C at BL
4	100	100	-5	-5	267.00	3008.00	0.97	51	Test A at IB
5	100	100	-5	0	300.00	3008.00	0.97	51	Test A at IB
6	100	100	-5	5	281.00	3008.00	0.93	51	Test A at IB
7	100	100	0	-5	200.00	3008.00	1.02	51	Test A at IB
8	100	100	0	5	282.00	3008.00	0.98	51	Test A at IB
9	100	100	5	-5	173.00	3008.00	1.07	51	Test A at IB
10	100	100	5	0	263.00	3008.00	1.05	51	Test A at IB
11	100	100	5	5	254.00	3008.00	1.02	51	Test A at IB
12	66	66	0	-5	182.00	1833.00	1.02	51	Test B at IB
13	66	66	0	-4	295.00	1833.00	1.03	51	Test B at IB
14	66	66	0	-3	270.00	1833.00	1.03	51	Test B at IB
15	66	66	0	-2	234.00	1833.00	1.01	51	Test B at IB
16	66	66	0	-1	229.00	1833.00	1.01	51	Test B at IB
17	66	66	0	1	277.00	1833.00	1.00	51	Test B at IB
18	66	66	0	2	253.00	1833.00	0.98	51	Test B at IB
19	66	66	0	3	223.00	1833.00	0.98	51	Test B at IB
20	66	66	0	4	267.00	1833.00	0.97	51	Test B at IB
21	66	66	0	5	215.00	1833.00	0.97	51	Test B at IB
22	33	33	0	-5	241.00	991.00	1.01	51	Test C at IB
23	33	33	0	-4	251.00	991.00	1.02	51	Test C at IB
24	33	33	0	-3	260.00	991.00	1.02	51	Test C at IB
25	33	33	0	-2	225.00	991.00	1.03	51	Test C at IB
26	33	33	0	-1	224.00	991.00	1.03	51	Test C at IB
27	33	33	0	1	260.00	991.00	0.99	51	Test C at IB
28	33	33	0	2	207.00	991.00	0.98	51	Test C at IB
29	33	33	0	3	203.00	991.00	0.98	51	Test C at IB
30	33	33	0	4	239.00	991.00	0.97	51	Test C at IB
31	33	33	0	5	196.00	991.00	0.97	51	Test C at IB

Remark:

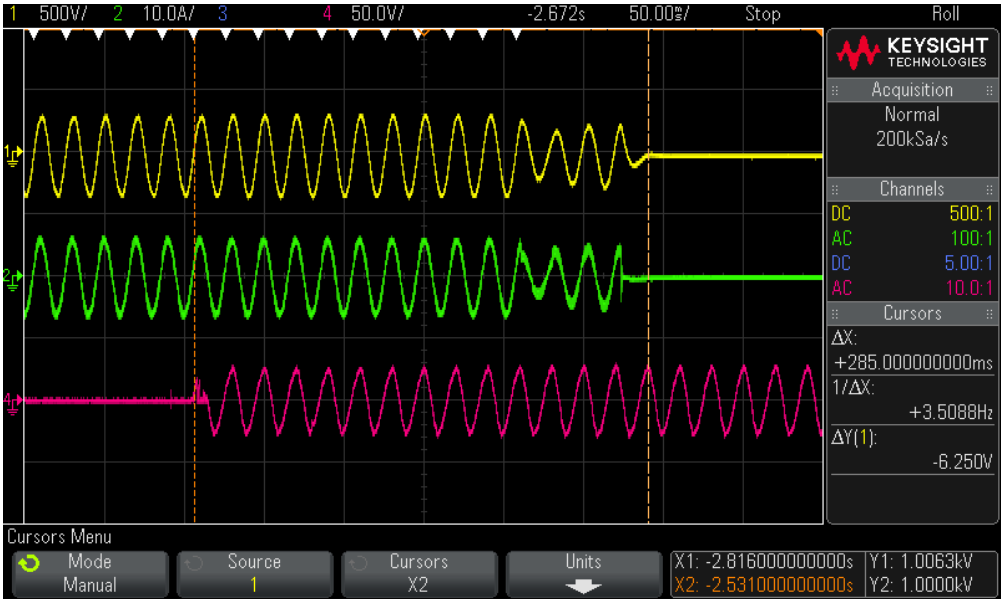
1) PEUT: EUT output power
2) PAC: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.
3) QAC: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.
4) BL: Balance condition, IB: Imbalance condition.
5) *Note: test condition A (100%): If any of the recorded run-on times are longer than the one recorded for the rated balance condition, i.e. test procedure 6.1 f), then the non-shaded parameter combinations (no.32~47) also require testing.



P_{EUT} 100, P_{AC} 0, Q_{AC} 0, =320.0ms



P_{EUT} 66, P_{AC} 0, Q_{AC} 0, =312.0m

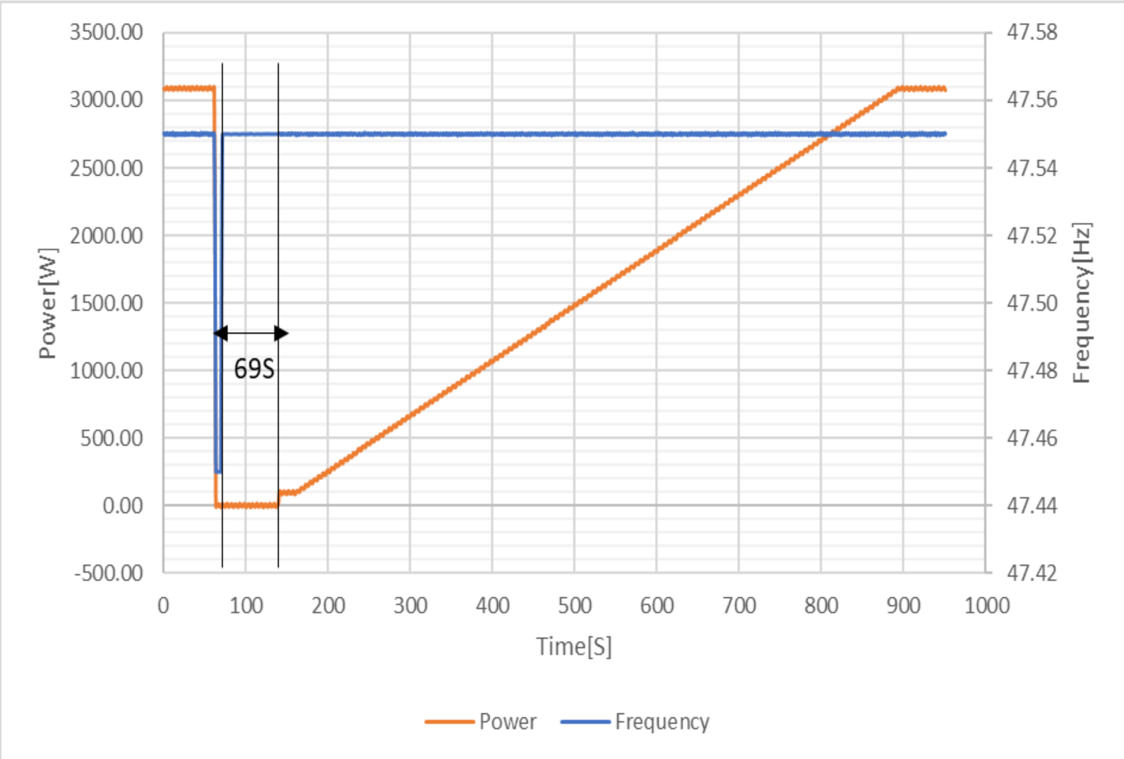


P_{EUT} 33, P_{AC} 0, Q_{AC} 0, = 285.0ms

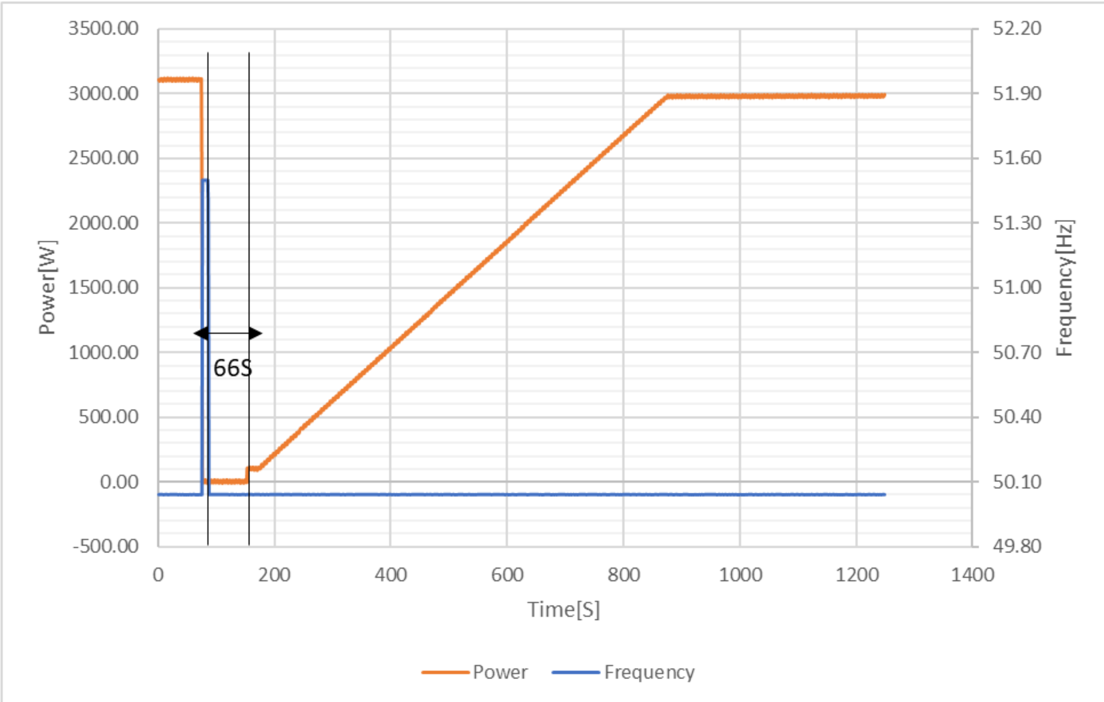
Note: CH1 input Voltage of EUT; CH4 Voltage of signal (the signal from Grid), CH2 Current of EUT

5.6	Connection conditions and synchronization		P
DC input:	AC output:		Rated Output Power
50Vdc	230Vac;	50Hz	3.0kW
Measure Item	Reconnection?		Reconnection Time (>60s)
f_{ist} <47.45Hz	☐ Yes	☒ No	Cannot reconnection
f_{ist} ≥ 47.55Hz	☒ Yes	☐ No	69s
f_{ist} > 50.15Hz	☐ Yes	☒ No	Cannot reconnection
f_{ist} ≤ 50.05Hz	☒ Yes	☐ No	66s
U_{ist} < 84% U_n	☐ Yes	☒ No	Cannot reconnection
U_{ist} ≥ 86% U_n	☒ Yes	☐ No	70s
U_{ist} > 111% U_n	☐ Yes	☒ No	Cannot reconnection
U_{ist} ≤ 109% U_n	☒ Yes	☐ No	66s

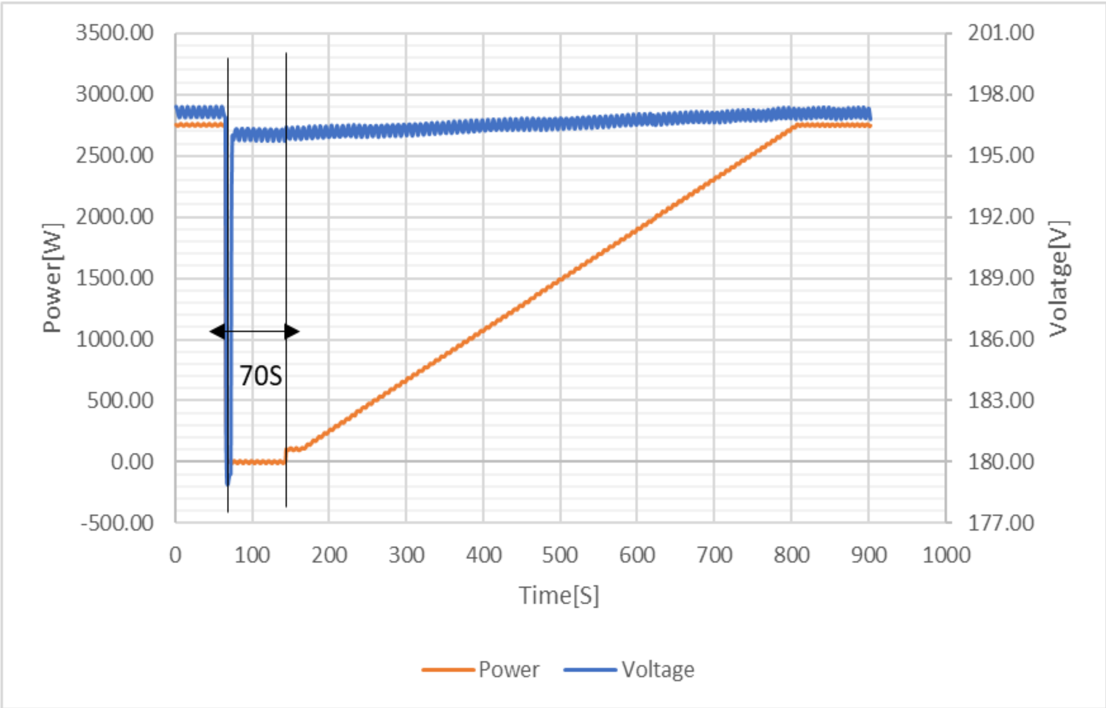
Graph of the gradual power supply and reconnection: for 47.55Hz



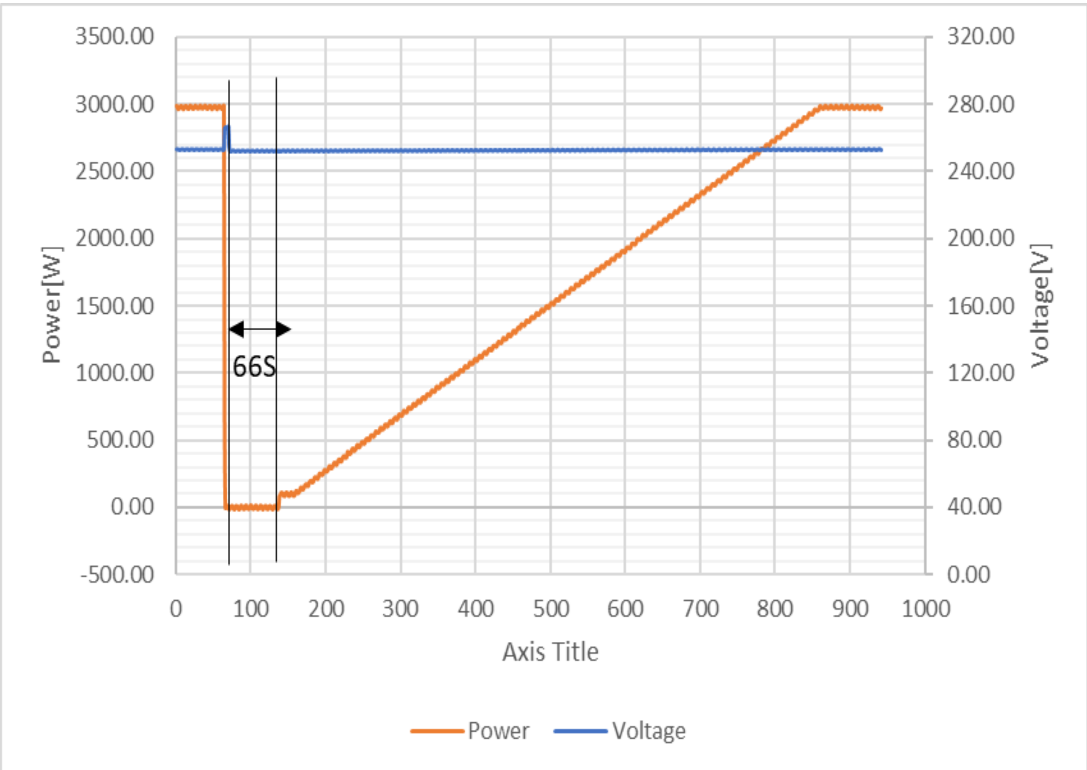
Graph of the gradual power supply and reconnection: for 50.05Hz



Graph of the gradual power supply and reconnection: for 86%Un

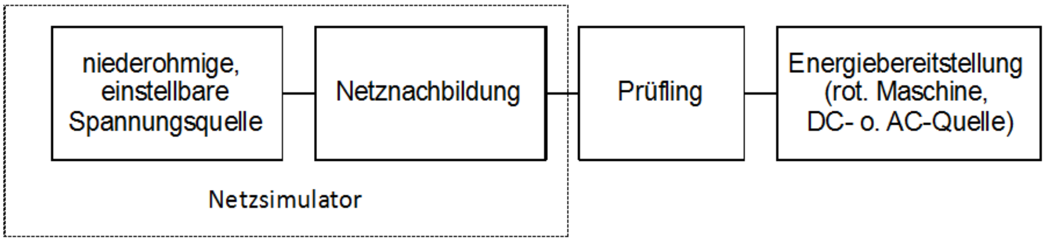


Graph of the gradual power supply and reconnection: for 109%Un



5.8	Dynamic Network support	P

Test equipment:

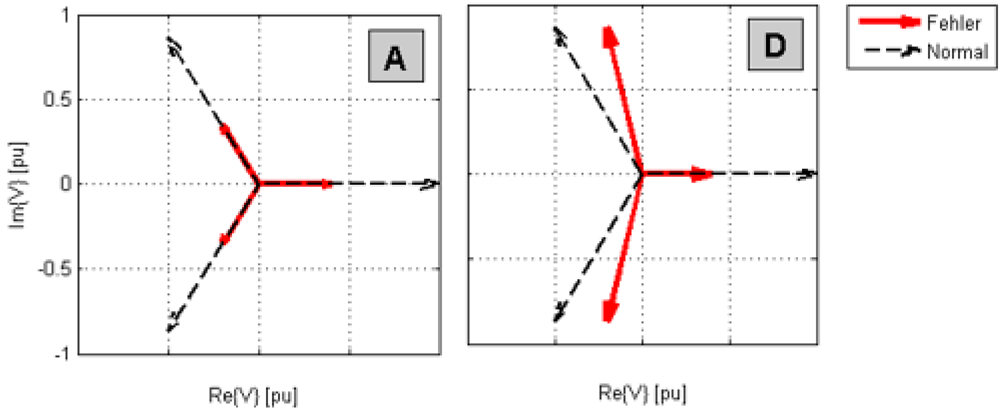


The effective network impedance from view of PGU must fulfill following criterion:
- short-circuited power at PGU before and after fault must be between 10xSn and 30xSn
- R/X 0.3-3 (for applied impedance in test equipment)

The test equipment and network simulator must be able to take the max. occurring PGU current, both in generating and motoring area. The energy absorb shall be designed for sudden short circuited current Ip (per IEC 60909). Ip is obvious different by the type of test sample, the correct value shall be:

- for inverter coupled system about 2.2In,
- for direct coupled Asynchronous or Synchronous machines about 7In.

Grid simulator settings for asymmetry grid fault:



D1	Test Equipment	Test Sample
Connection terminal	U	L1
	V	L2
	W	L3 (L for single phase)
D2	Test Equipment	Test Sample
Connection terminal	U	L3
	V	L1 (L for single phase)
	W	L2

VDE No.	U	V	W	Type	Remark
--	1.00, -150°	1.00, 90°	1.00, -30°	A	Initial status

1.3, 1.4	0.62, -173.3°	0.15, 90°	0.62, -6.9°	D	UVRT
2.3, 2.4, 3.3, 3.4	0.76, -161.1°	0.50, 90°	0.76, -19.1°	D	
4.3, 4.4	0.93, -152.8°	0.85, 89.9°	0.93, -27.4°	D	
5.3, 5.4	1.08, -144.5°	1.25, 89.1°	1.06, -36.3°	D	OVRT
6.3, 6.4	1.06, -145.5°	1.20, 89.3°	1.05, -35.1°	D	
7.3, 7.4	1.04, -146.6°	1.15, 89.4°	1.04, -33.9°	D	

Diagram:

For each test the following diagrams shall be figured since t1-1s (one second before fault entry) till t2+6s (six seconds after fault clear), zoomed if needed:

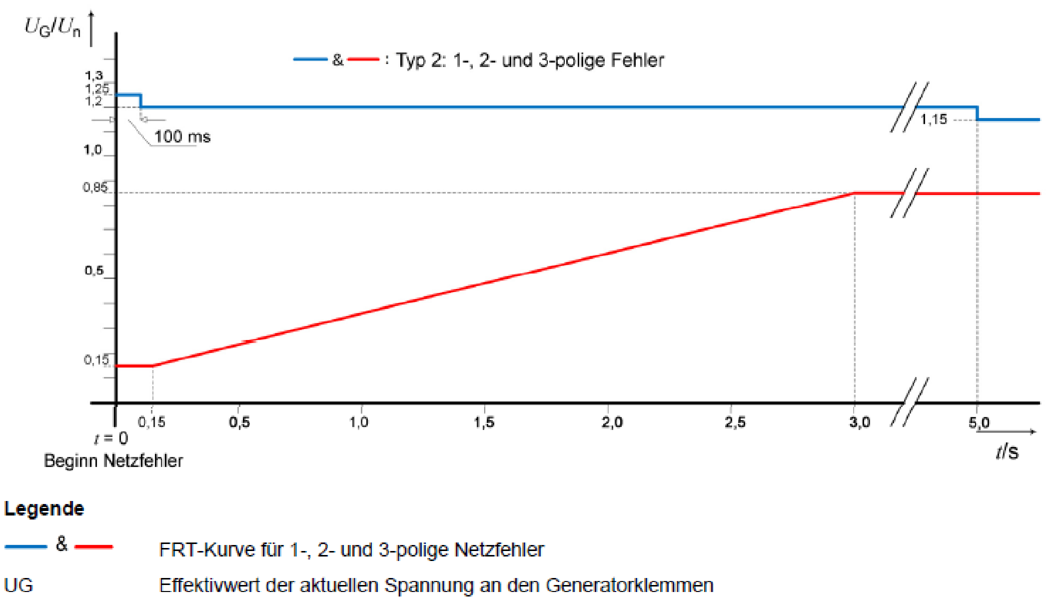
Empty load tests:

- line to line voltages and line to neutral voltages (signal)
- full period-RMS value of line to neutral voltages with updated rate of 1/ms.

Tests with sample:

- line to line voltage and line to neutral voltage (signal)
- line currents (signal)
- full period-RMS value of line to neutral voltage with updated rate of 1/ms
- full period-RMS value of line currents with updated rate of 1/ms (active and reactive part additionally)
- active power and reactive power in pos. sequence with updated rate of 1/ms
- voltage and current in pos. sequence with updated rate of 1/ms

Test condition:



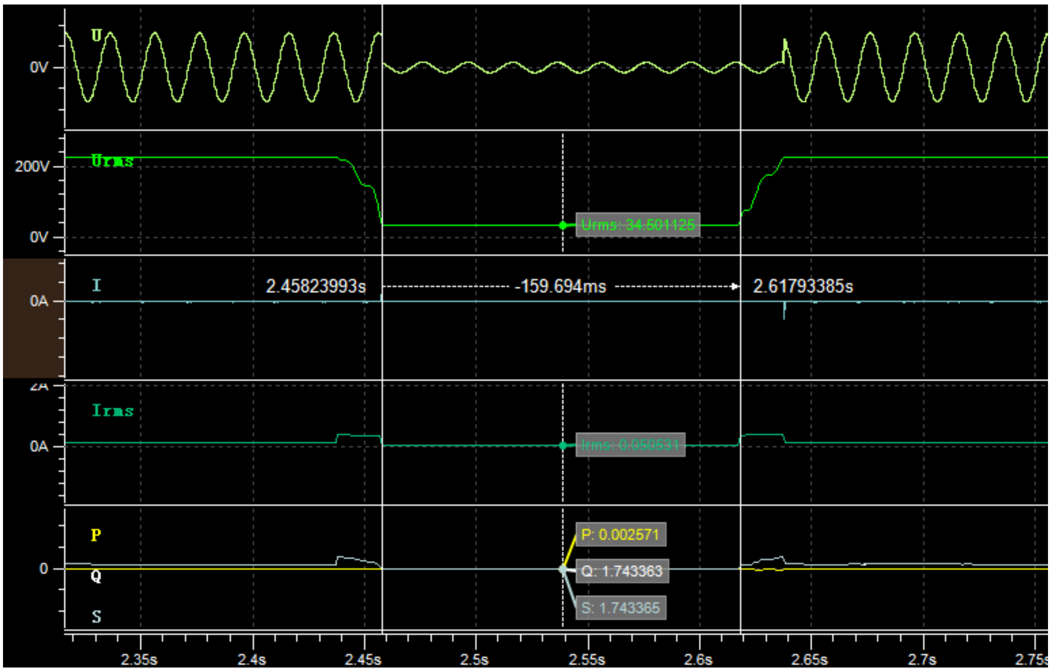
Method of calculations:

Notes on calculations:	Used formula	Remarks
General remarks: The average grid frequency over the measured interval is calculated from zero-crossings of the sine function. Only 10 cycles before the dip are used for this calculation. RMS-Calculations are performed with a moving window, which is determined by T = 1/f and must remain constant. The number of samples N per calculation window is determined by the sampling rate f_s. N has to be even and an integer number nearest to the product T*f_s.	$\underline{U}_1 = \frac{\sqrt{2}}{N} \cdot \sum_{n=0}^{N} u(n) \cdot e^{-j(\frac{2 \cdot \pi \cdot n}{N})}$ $\underline{I}_1 = \frac{\sqrt{2}}{N} \cdot \sum_{n=0}^{N} i(n) \cdot e^{-j(\frac{2 \cdot \pi \cdot n}{N})}$	- Calculated for each phase A,B,C - N: Amount of samples per window - n: number of sample
Performed Calculation	$\underline{U}^+ = \frac{1}{3} \cdot (\underline{U}_{1A} + \underline{U}_{1B} \cdot e^{+j\frac{2\pi}{3}} + \underline{U}_{1C} \cdot e^{-j\frac{2\pi}{3}})$ $\underline{I}^+ = \frac{1}{3} \cdot (\underline{I}_{1A} + \underline{I}_{1B} \cdot e^{+j\frac{2\pi}{3}} + \underline{I}_{1C} \cdot e^{-j\frac{2\pi}{3}})$	
Complex values for the fundamental harmonic	$P = 3 \cdot U^+ \cdot I^+ \cdot \cos(\varphi)$ $Q = 3 \cdot U^+ \cdot I^+ \cdot \sin(\varphi)$	Phase-angle : Angular difference between current and voltage $\varphi = (\varphi_U - \varphi_I)$
Positive sequence component of the voltage and current	$I_r = I^+ \cdot \sin(\varphi)$ $I_{tot} = I^+$	
Power:	$U_{rms} = \sqrt{\frac{1}{N} \cdot \sum_{n=0}^{N} (u(n) - \overline{u})^2}$ $\overline{u} = \frac{1}{N} \cdot \sum_{n=0}^{N} u(n)$	- Calculated for each phase A,B,C or L1, L2, L3

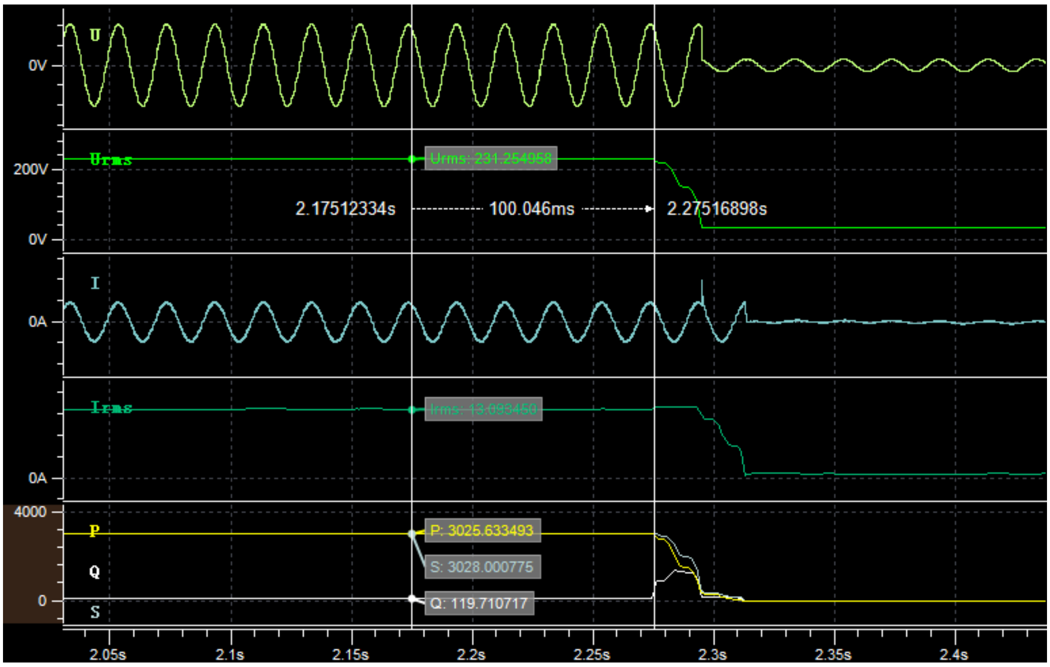
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			10K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	1.1	2.1	3.1	4.1
	1	Date	--	--	dd.mm.yyyy	16-June -2020 to 22-June-2020			
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph			
	3	Fault type (phase)	--	--		A	A	A	A
	4	Setting voltage depth	Line to line	--	p.u.	0.15	0.5	0.5	0.85
	5	Setting dip duration		--	ms	150	1500	1500	60000
	6	Point of fault entry	Total	--	ms	20ms			
	7	Point of fault clearance	Total	--	ms	20ms			
	8	Fault duration in empty load test	Total	--	ms	159.69	1516.88	1514.09	60015
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.15	0.5	0.5	0.85
	10		Positive sequence		p.u.	0.15	0.5	0.5	0.85
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.01	1.01	1.00	1.01
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--	--	--
	13	Active power	Total	t1-10s to t1	p.u.	1.009	0.915	0.887	1.008
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.040	0.488	-0.468	0.040
	16		Positive sequence			--	--	--	--
	17	Cos_{φ}	--	t1-10s to t1	--	0.9992	0.8826	0.8837	0.9992
During dip t1 to	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.15	0.50	0.50	0.85

t2	19	Line current	Phase 1	t1+60ms	p.u.	0.072	0.087	0.038	0.070
	20		Phase 2			--	--	--	--
	21		Phase 3			--	--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	0.062	0.083	0.052	0.073
	23		Phase 2			--	--	--	--
	24		Phase 3			--	--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.009	0.026	0.015	0.045
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.01	1.01	1.00	1.01
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			1.004	0.915	0.888	1.010
	39	Active power rising time	Positive sequence	--	s	0.187	0.128	0.187	0.116
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.040	0.487	-0.469	0.040
	33	Reactive power rising time	Positive sequence	--	s	0.187	0.128	0.187	0.116
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

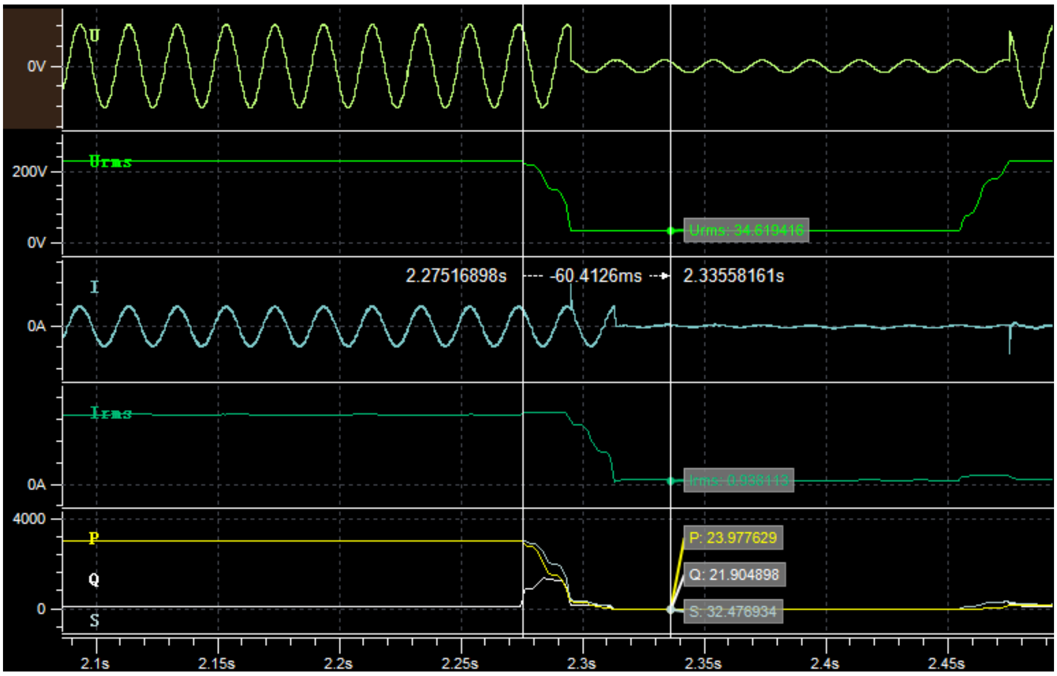
Graph of Test number 1.1_0.15Un



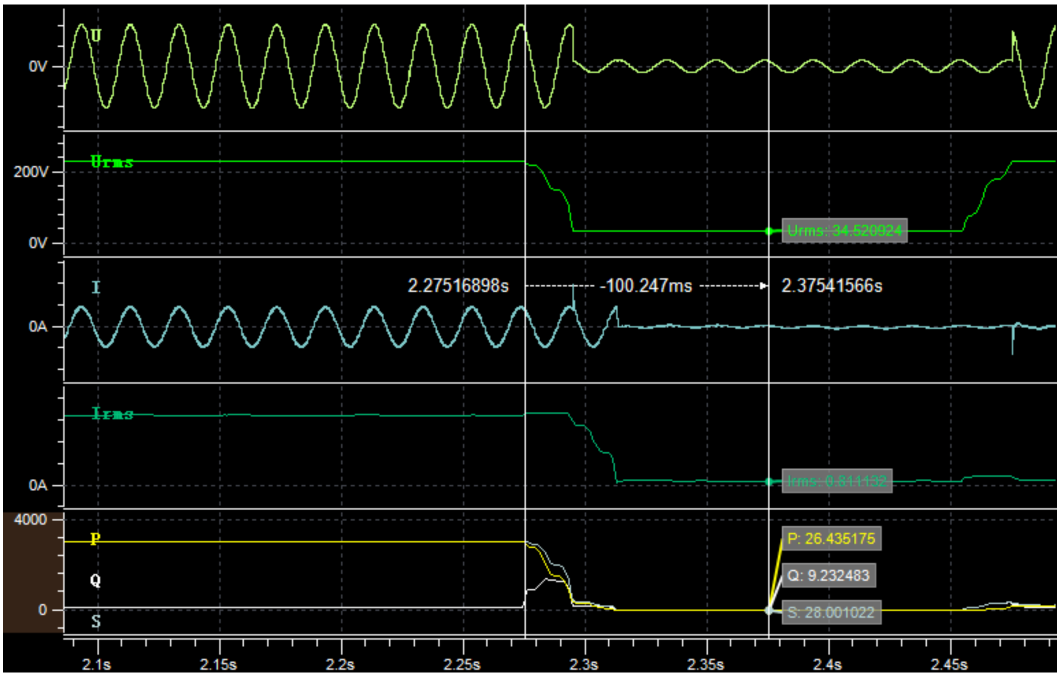
Empty load



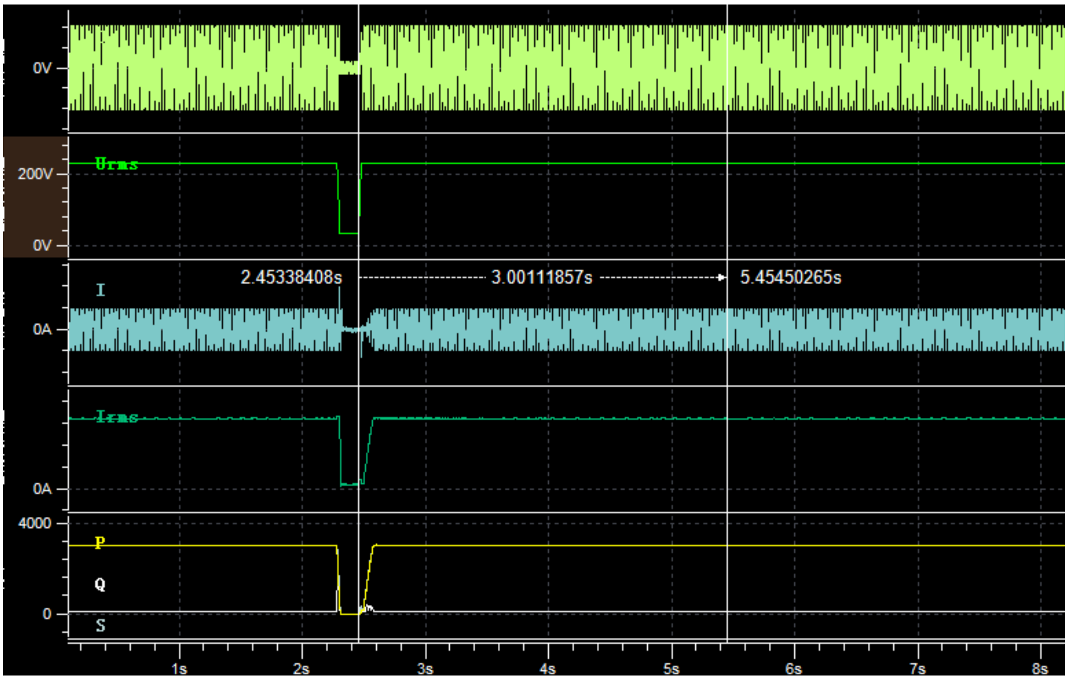
Before dip (t1-100ms)



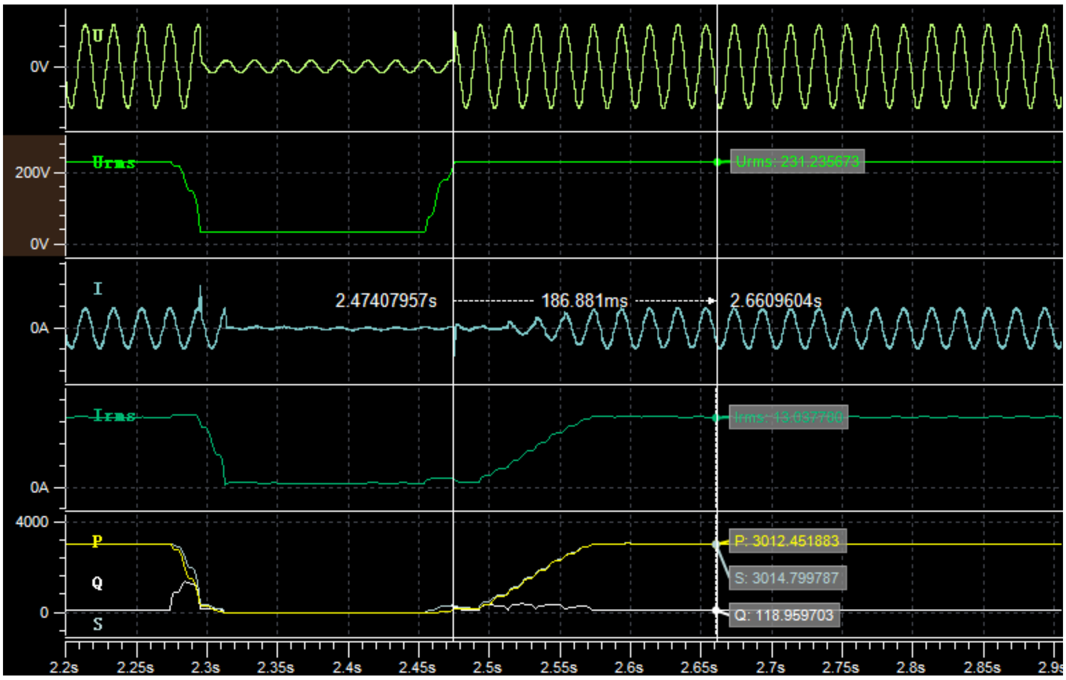
During dip (t1+60ms)



During dip (t1+100ms)

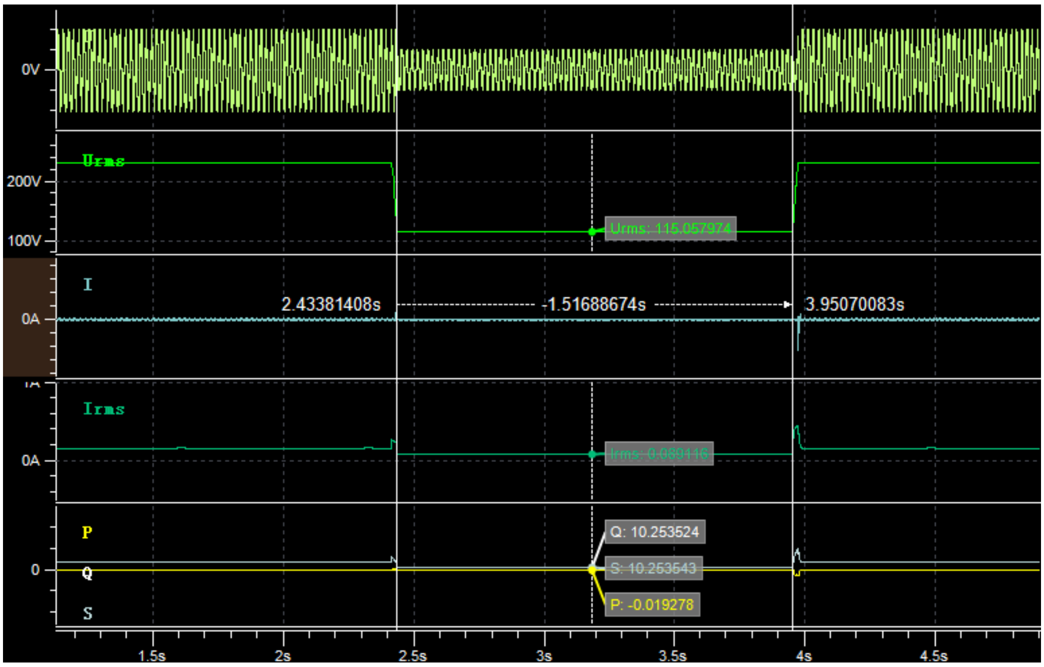


After dip (t2+3s)

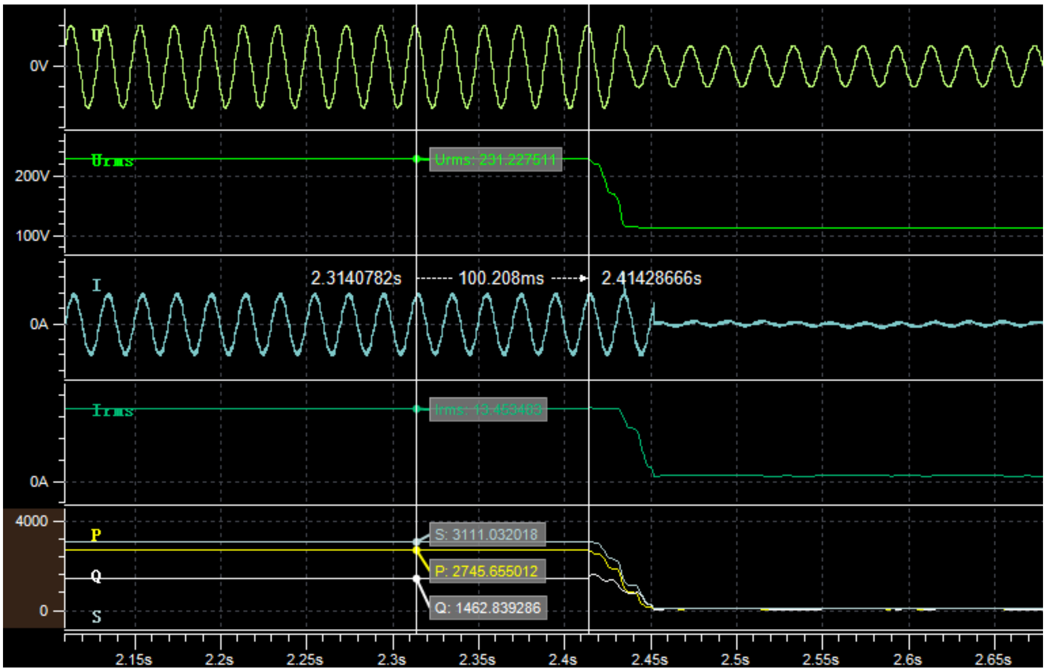


Recovery time

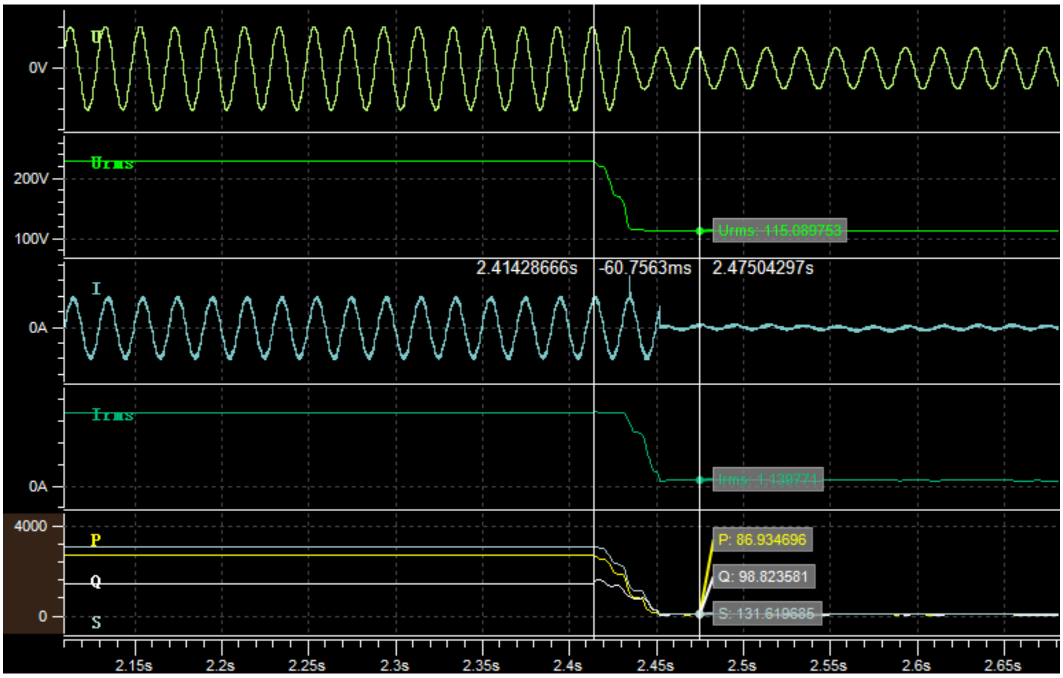
Graph of Test number 2.1_0.5Un



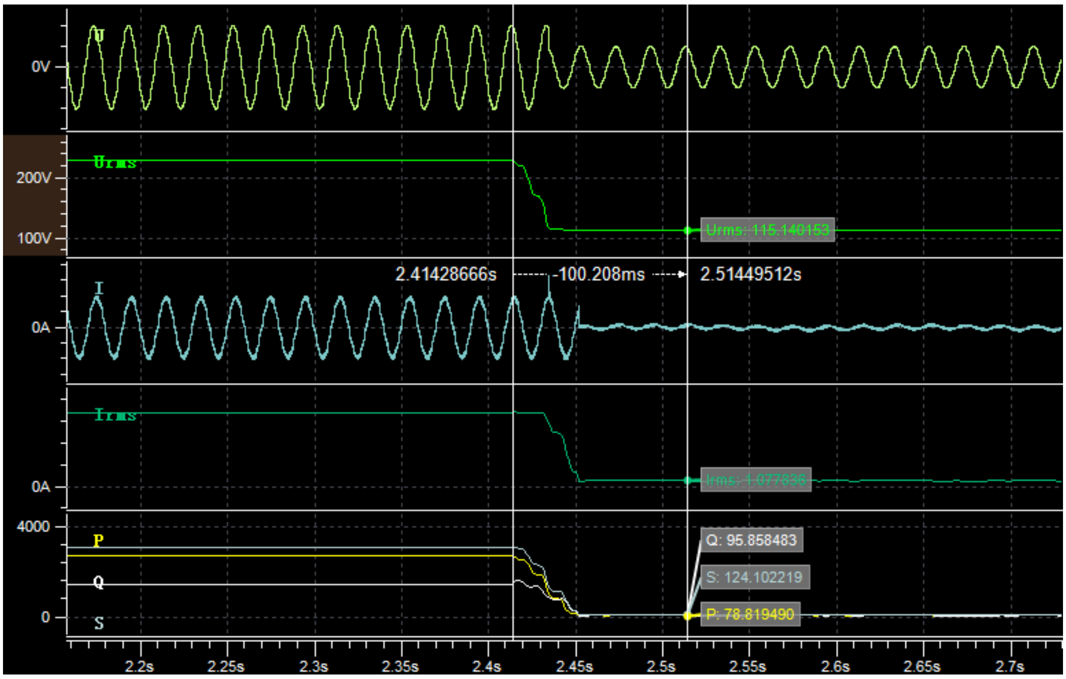
Empty load



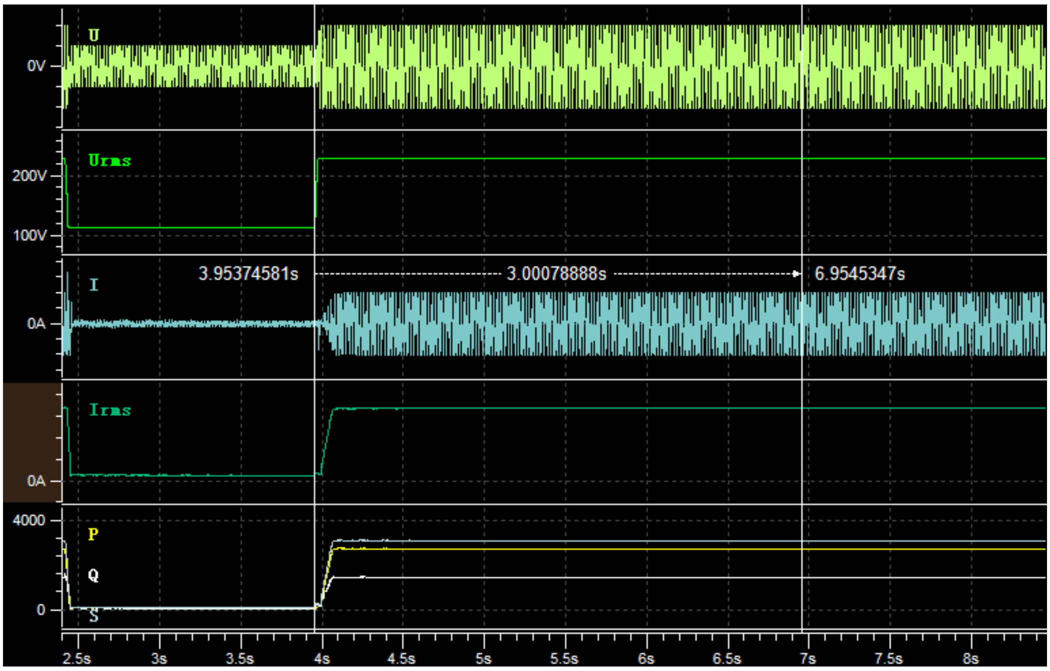
Before dip (t1-100ms)



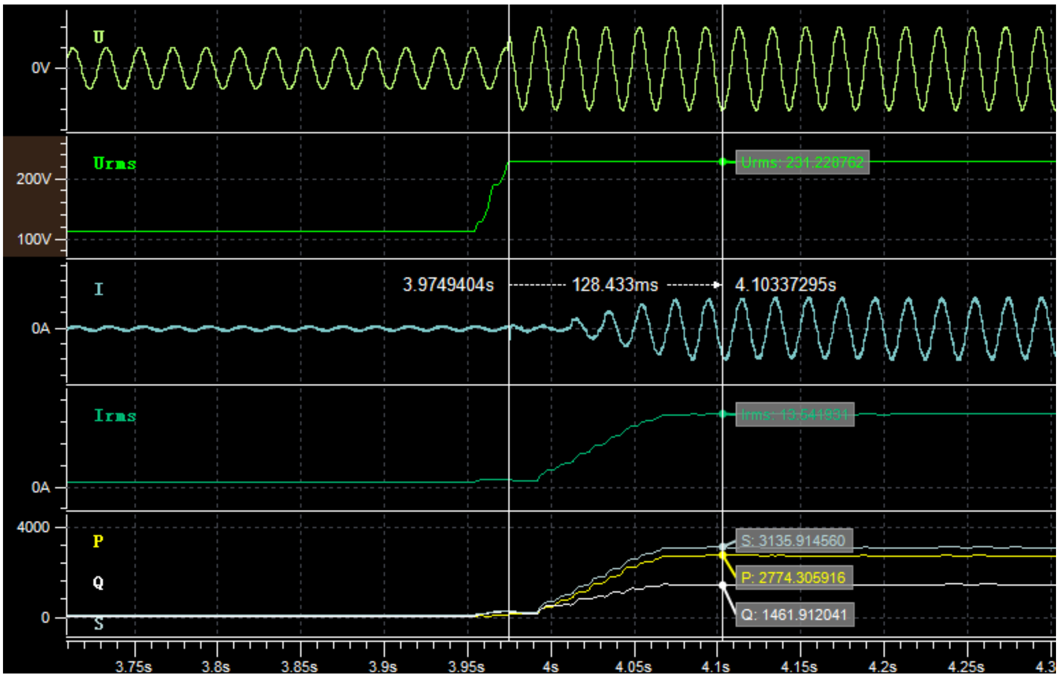
During dip (t1+60ms)



During dip (t1+100ms)

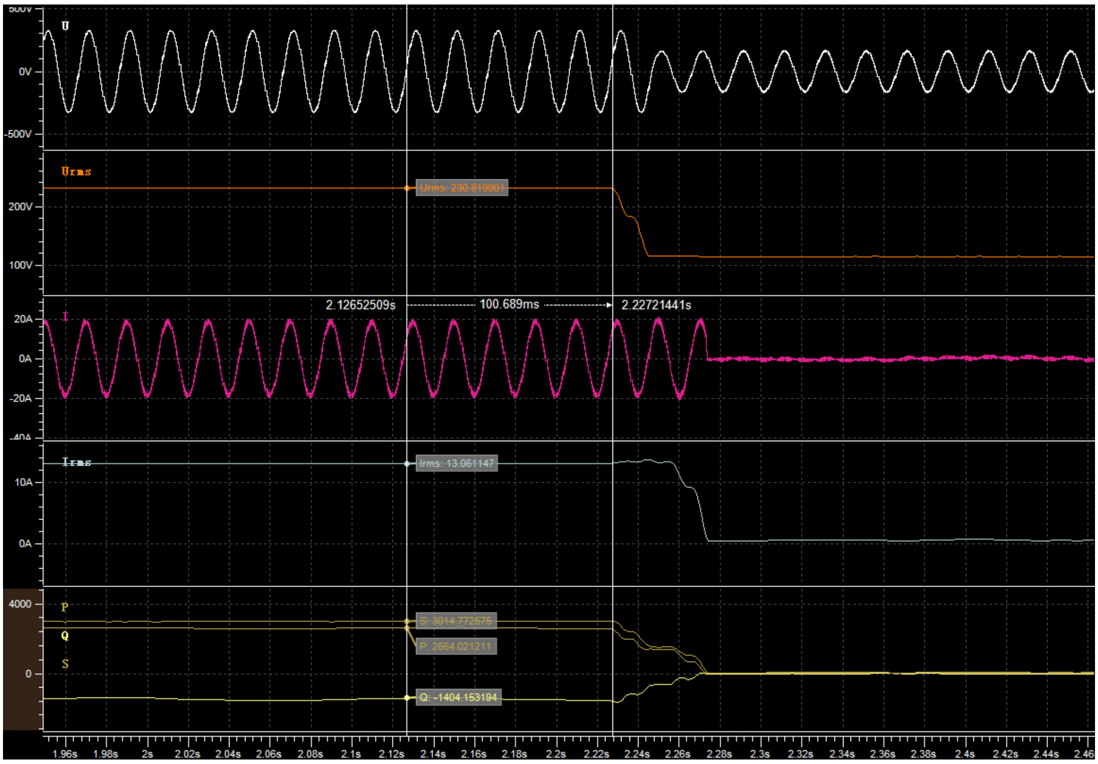


After dip(t2+3s)

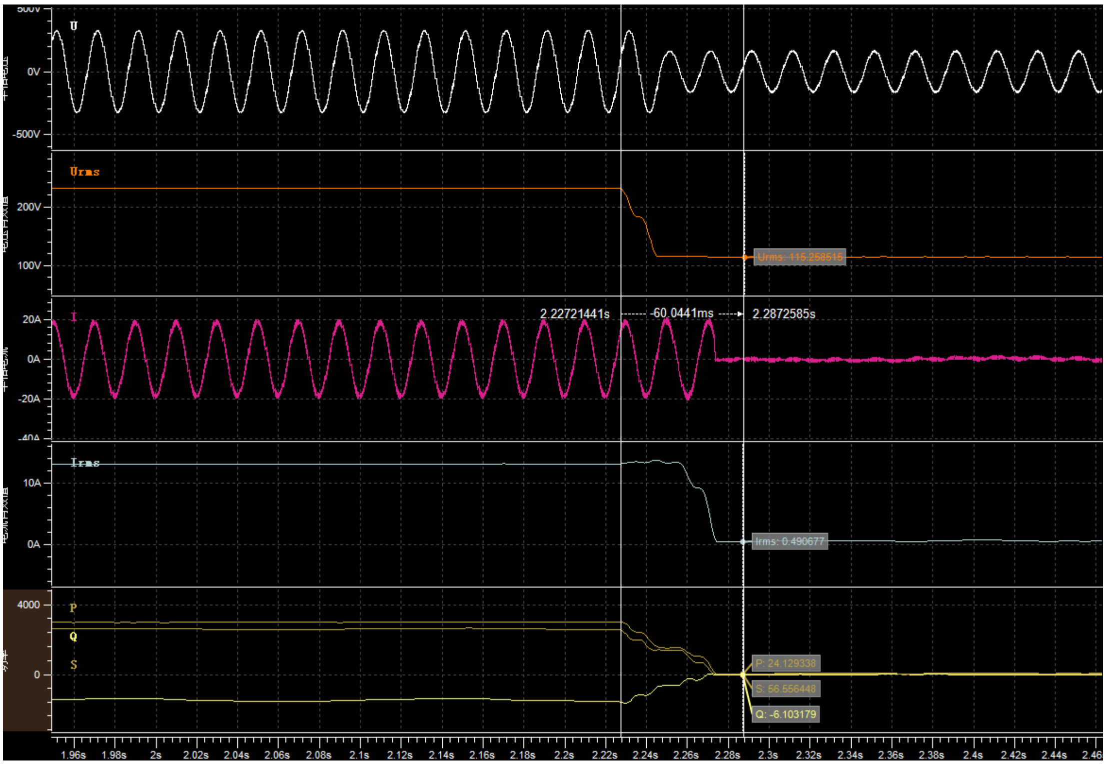


Recovery time

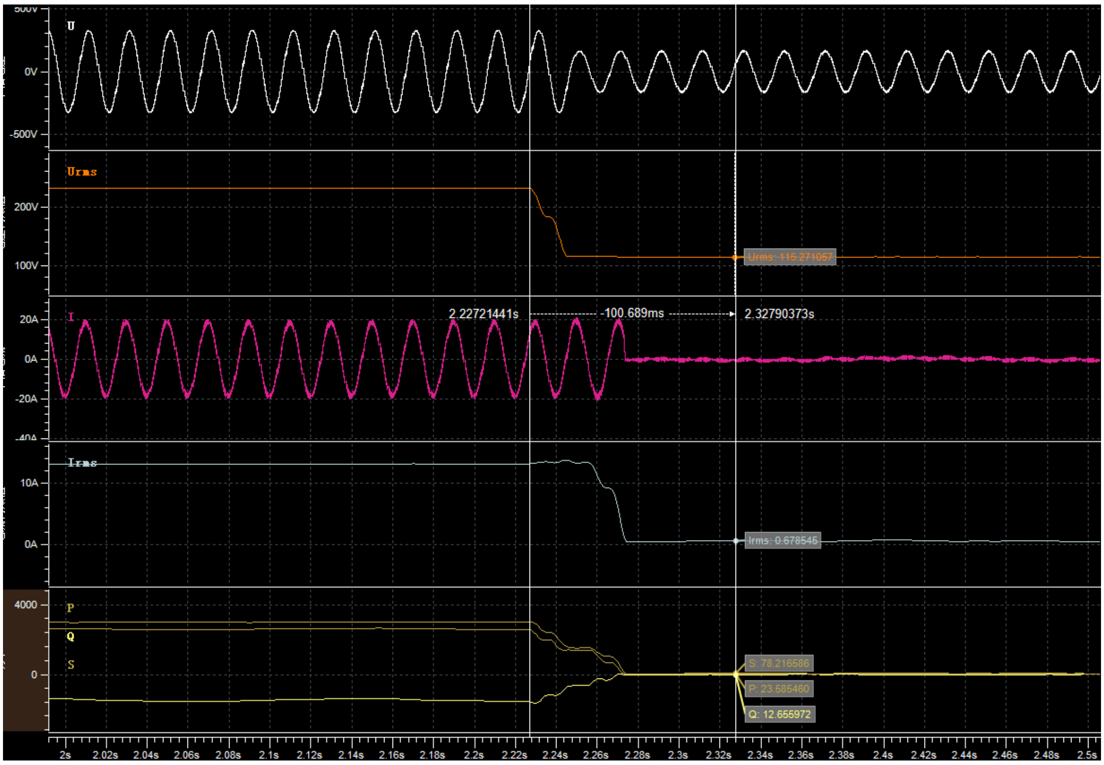
Graph of Test number 3.1_0.5Un



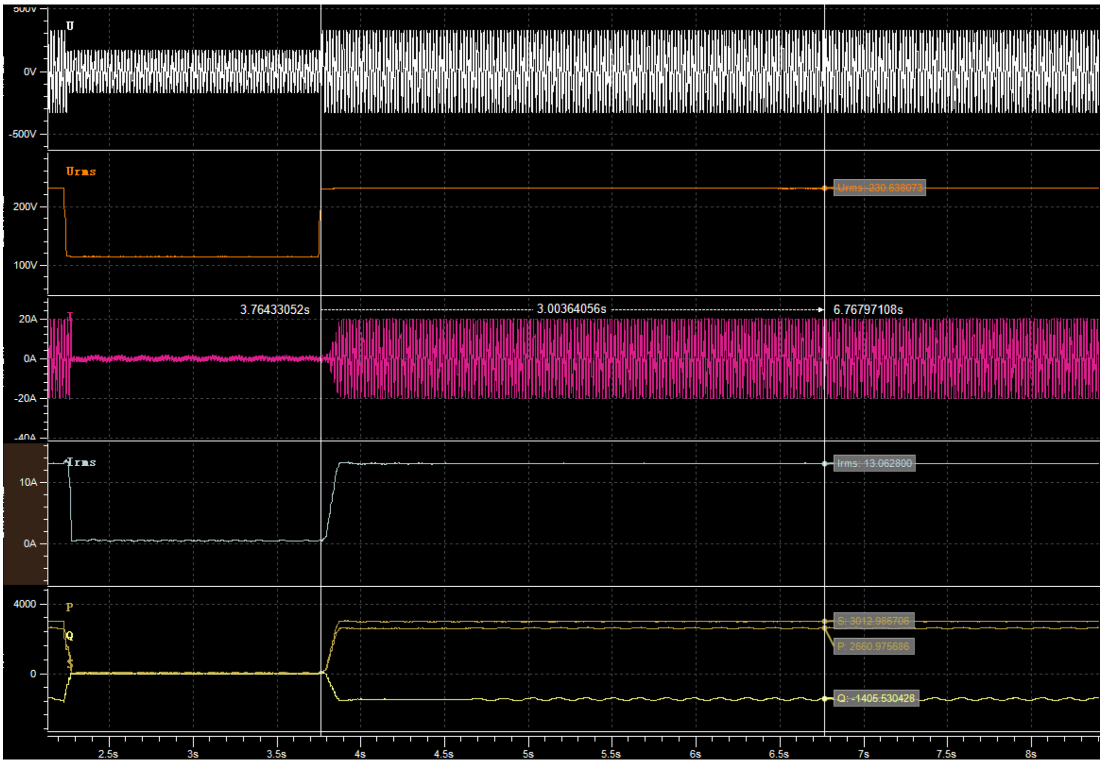
Before dip (t1-100ms)



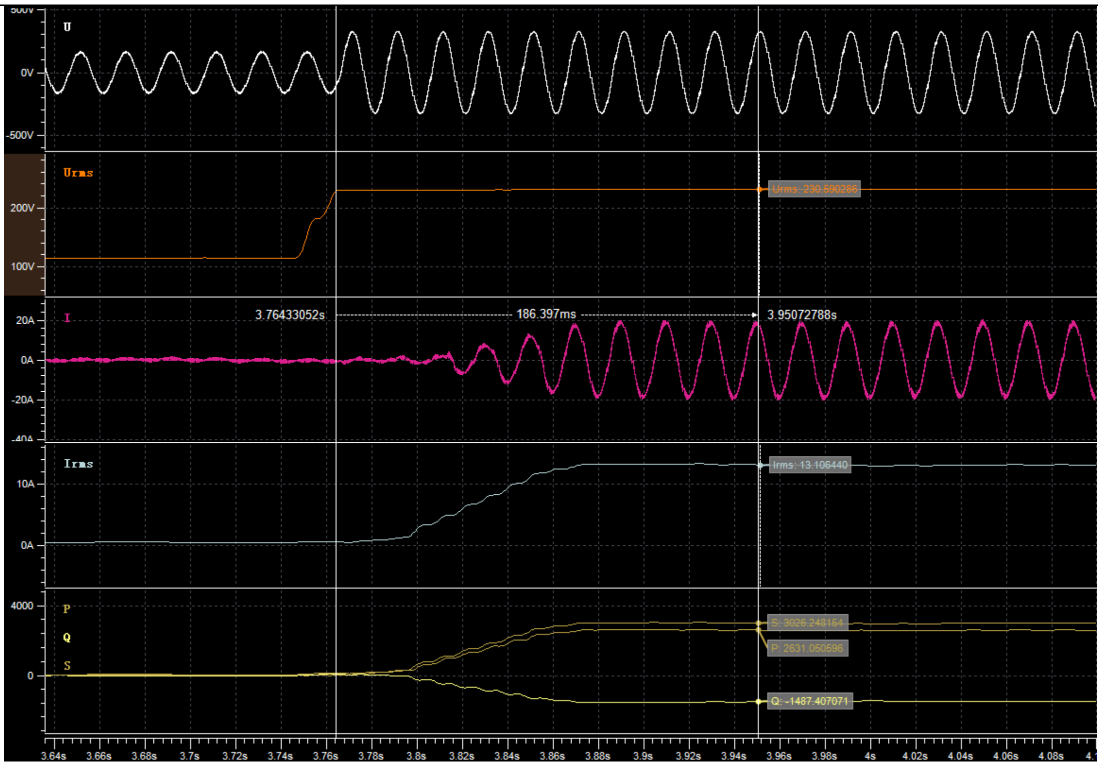
During dip (t1+60ms)



During dip (t1+100ms)

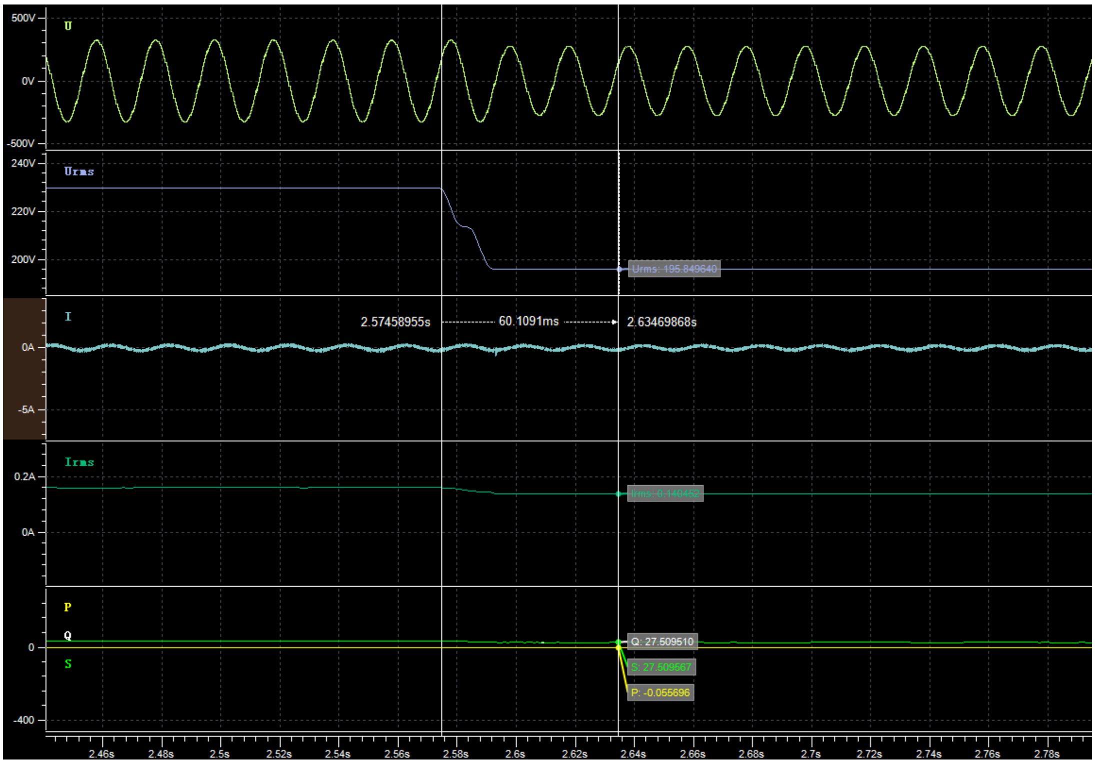


After dip(t2+3s)

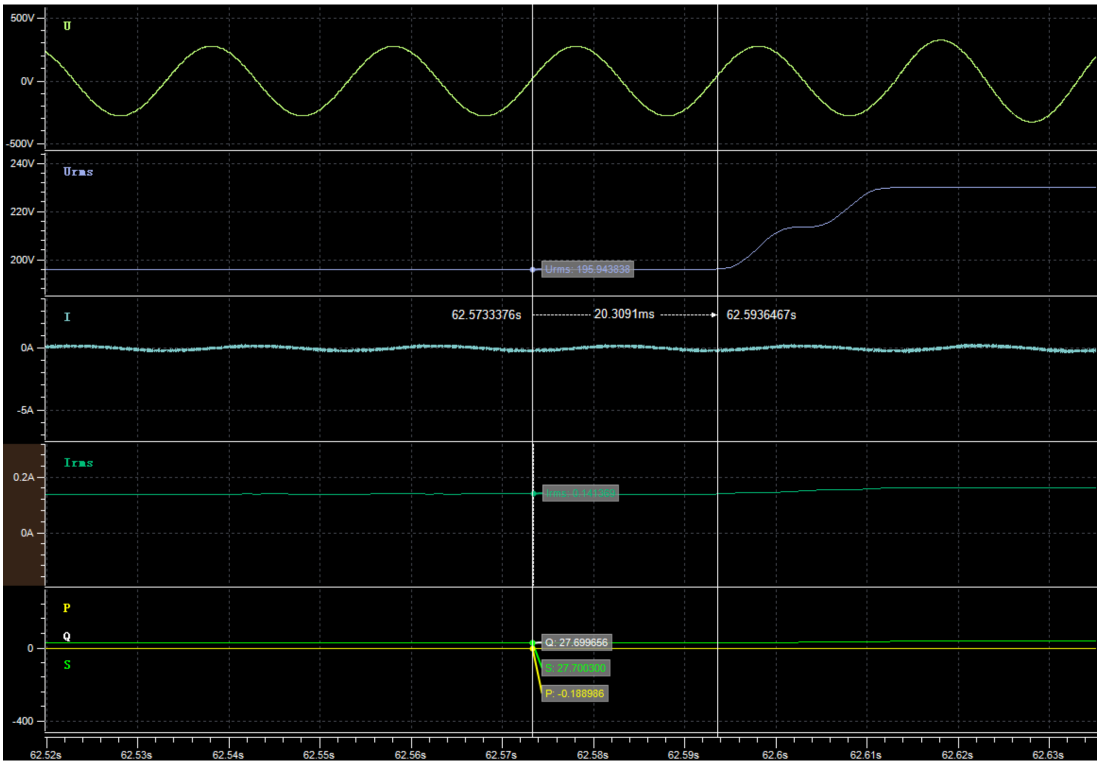


Recovery time

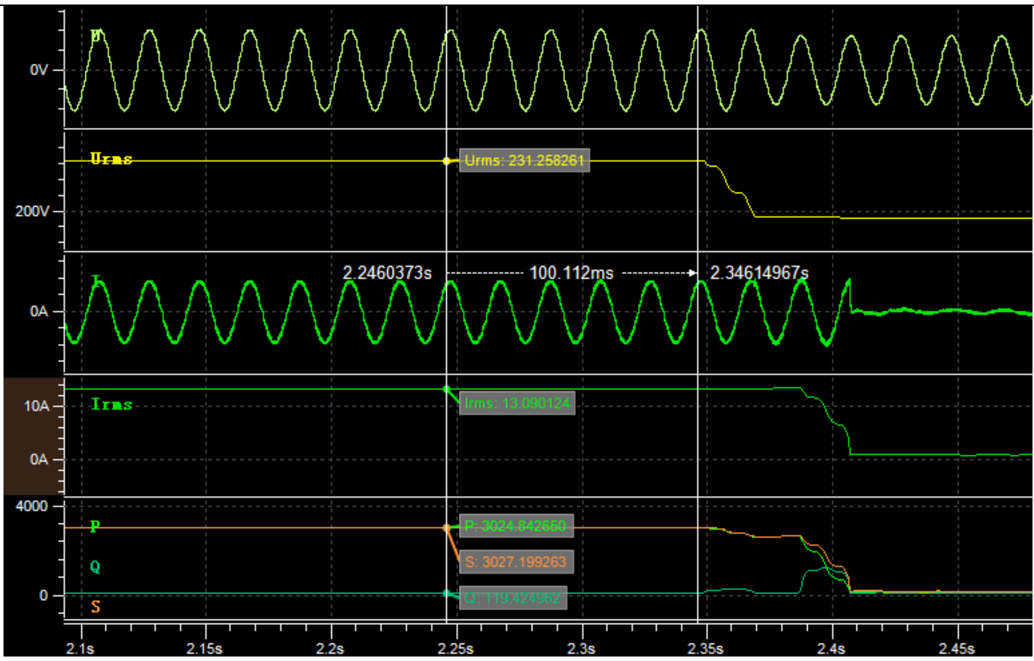
Graph of Test number 4.1_0.85Un



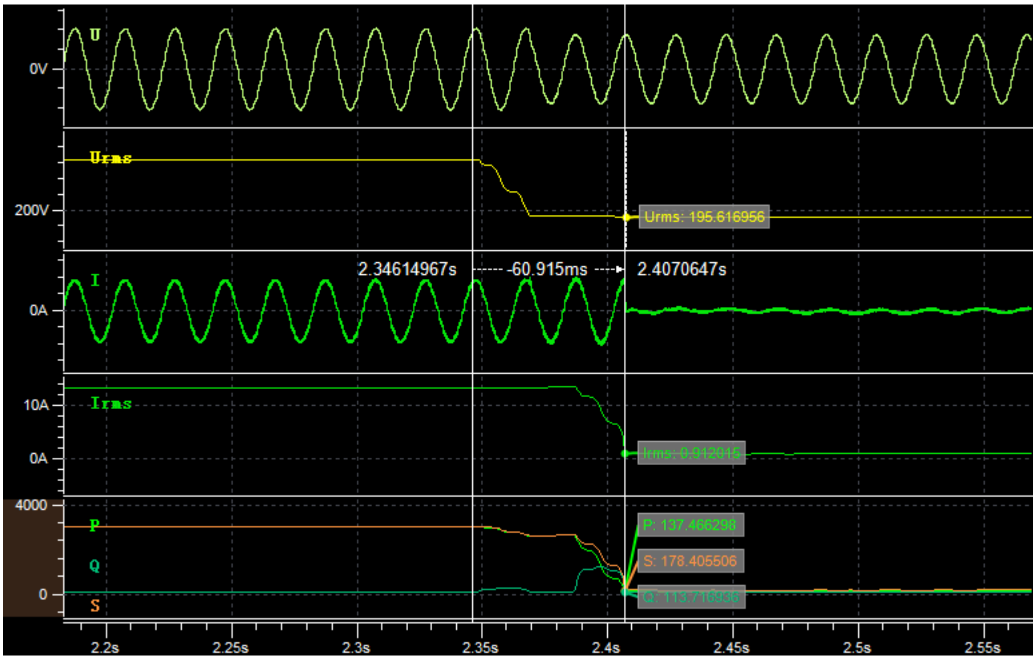
Empty load



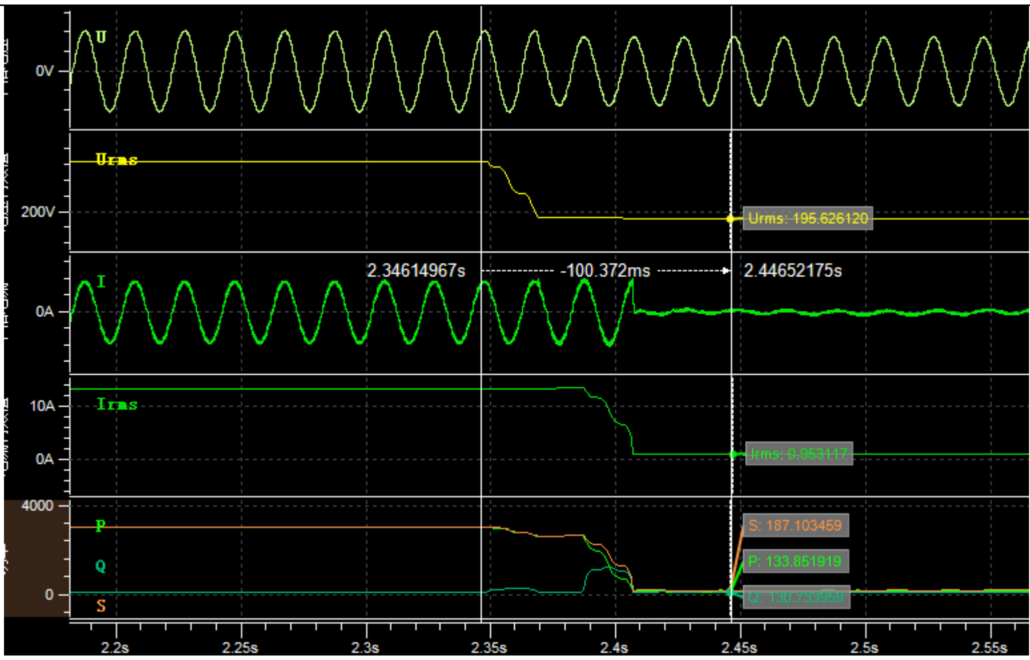
Empty load



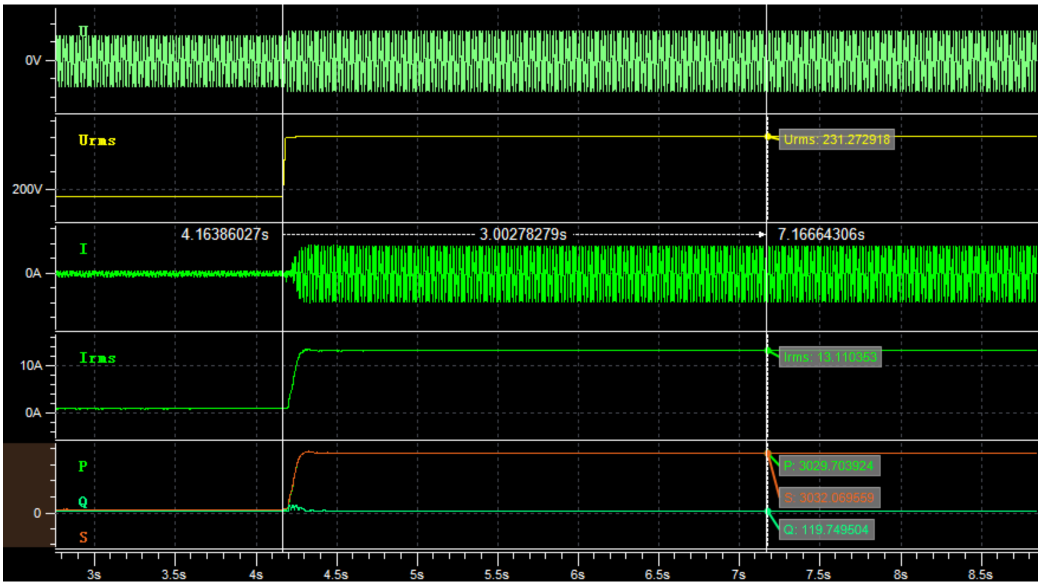
Before dip (t1-100ms)



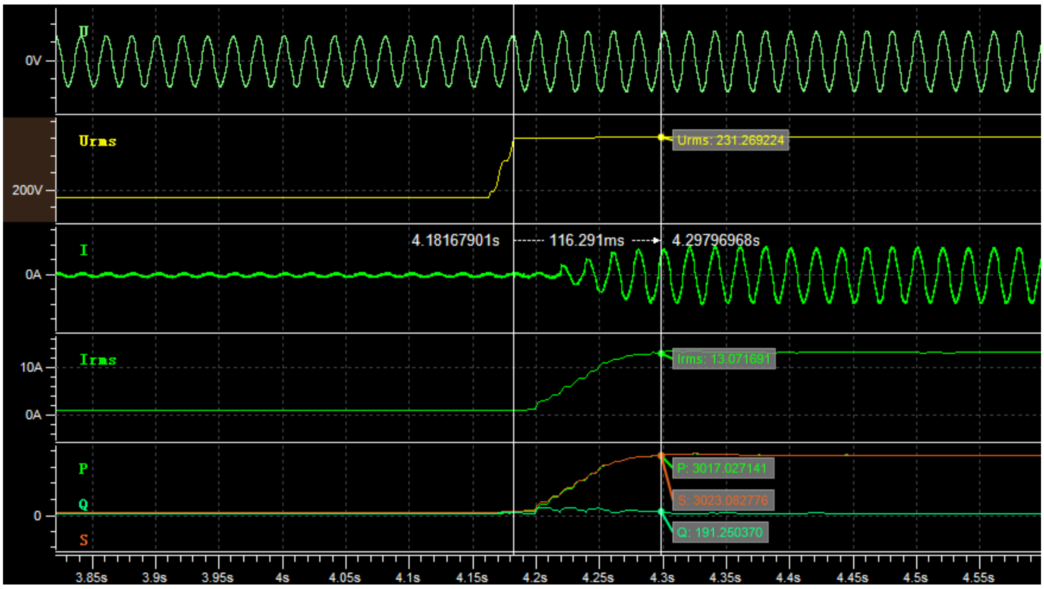
During dip (t1+60ms)



During dip (t1+100ms)



After dip(t2+3s)

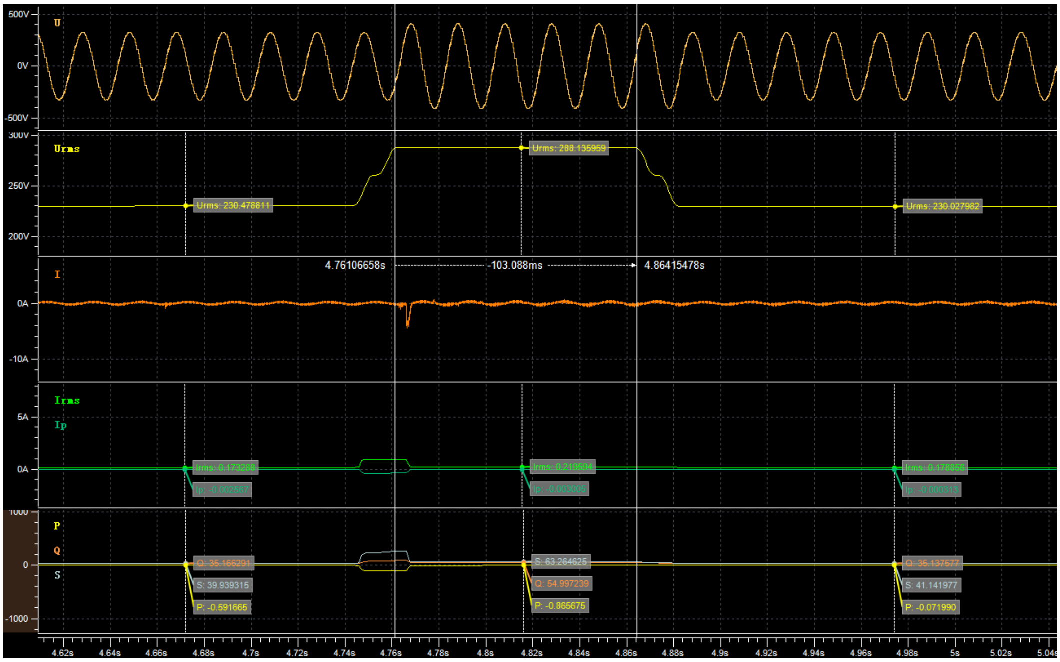


Recovery time

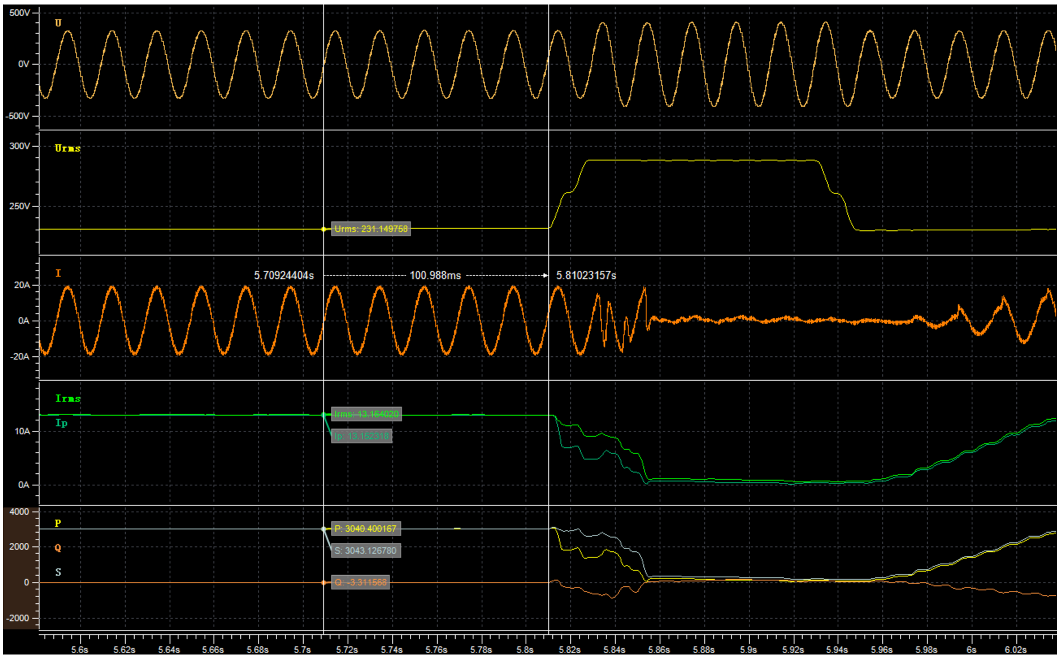
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			10K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	5.1	6.1	7.1	1.2
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020			
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph			
	3	Fault type (phase)	--	--		A	A	A	A
	4	Setting voltage depth	Line to line	--	p.u.	1.25	1.20	1.15	0.15
	5	Setting dip duration		--	ms	100	5000	60000	150
	6	Point of fault entry	Total	--	ms	20ms			
	7	Point of fault clearance	Total	--	ms	20ms			
	8	Fault duration in empty load test	Total	--	ms	103.09	5022.52	60021	159.19
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.25	1.20	1.15	0.15
	10		Positive sequence		p.u.	--	--	--	--
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.01	1.00	1.00	1.00
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	1.013	1.013	1.017	0.209
	13	Active power	Total	t1-10s to t1	p.u.	1.013	1.013	1.017	0.209
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	-0.001	-0.001	-0.001	0.027
	16		Positive sequence			--	--	--	--
	17	$\cos_{\varphi}$	--	t1-10s to t1	--	0.9991	0.9992	0.9992	0.9918
During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.25	1.20	1.15	0.15
	19	Line current	Phase 1	t1+60ms	p.u.	0.092	0.091	0.102	0.064

	20		Phase 2			--	--	--	--
	21		Phase 3			--	--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	0.074	0.063	0.082	0.061
	23		Phase 2			--	--	--	--
	24		Phase 3			--	--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.041	0.042	0.067	0.009
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			1.013	1.013	1.017	0.203
	39	Active power rising time	Positive sequence	--	s	0.110	0.107	0.103	0.041
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.004	-0.001	-0.001	0.030
	33	Reactive power rising time	Positive sequence	--	s	0.110	0.107	0.103	0.041
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

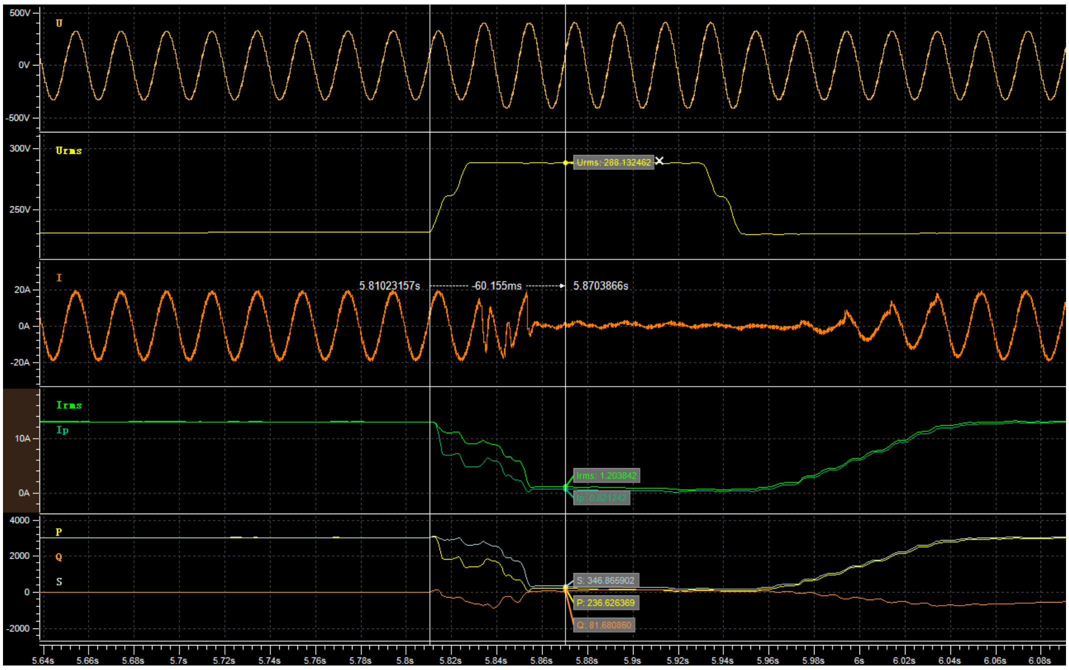
Graph of Test number 5.1_1.25Un



Empty Load

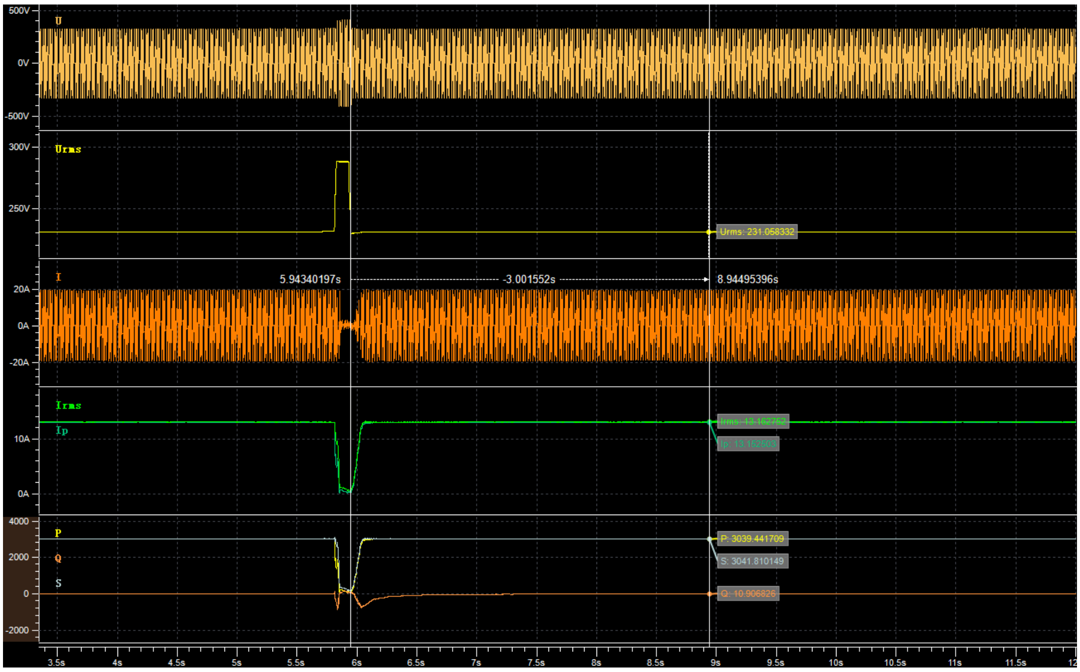


Before dip (t1-100ms)

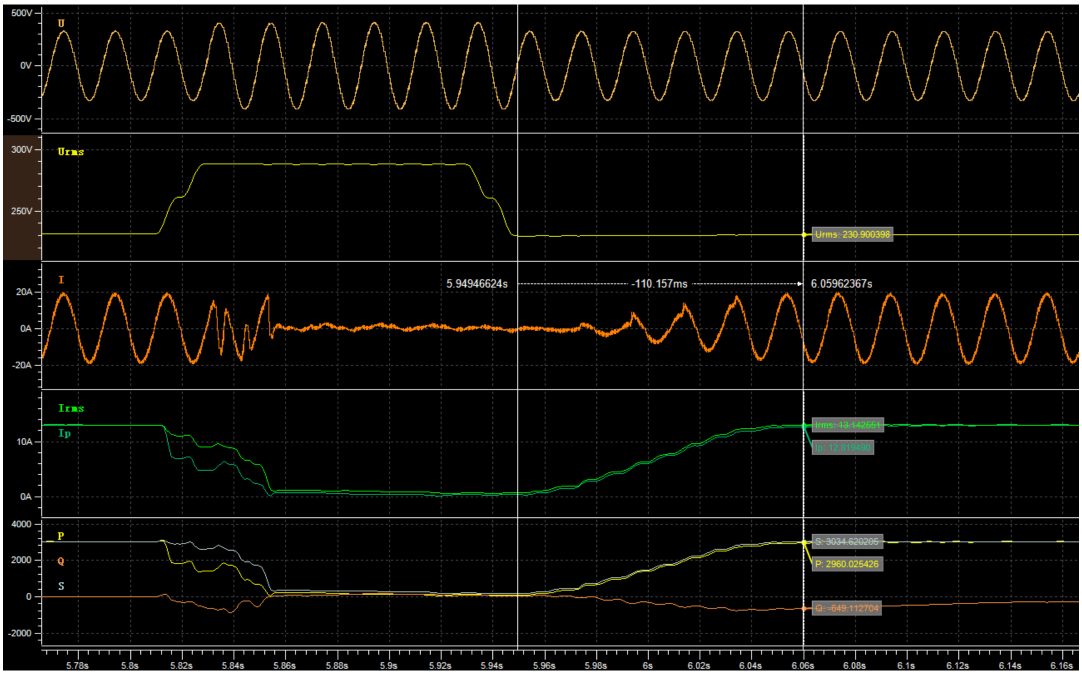


During dip (t1+60ms)

During dip (t1+100ms)

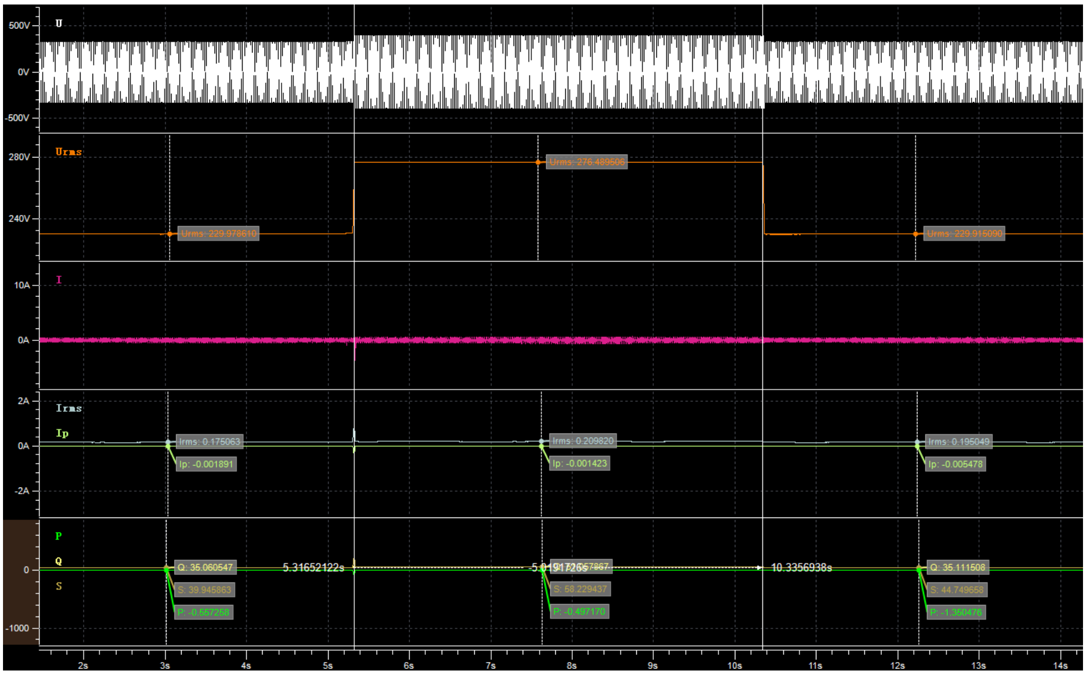


After dip(t2+3s)

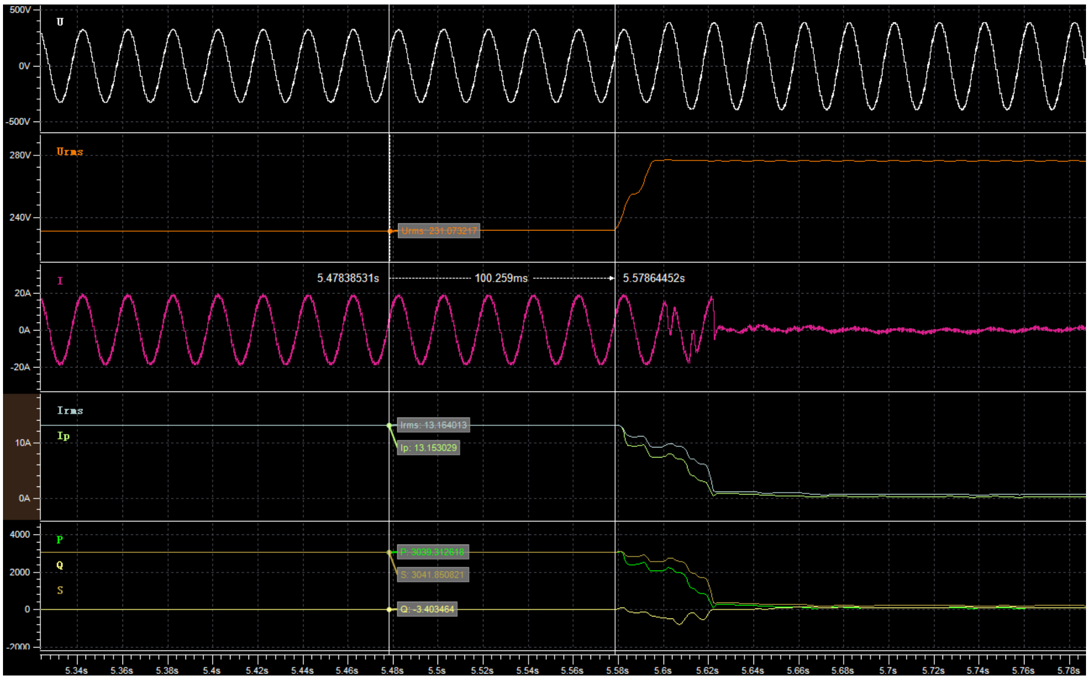


Recovery time

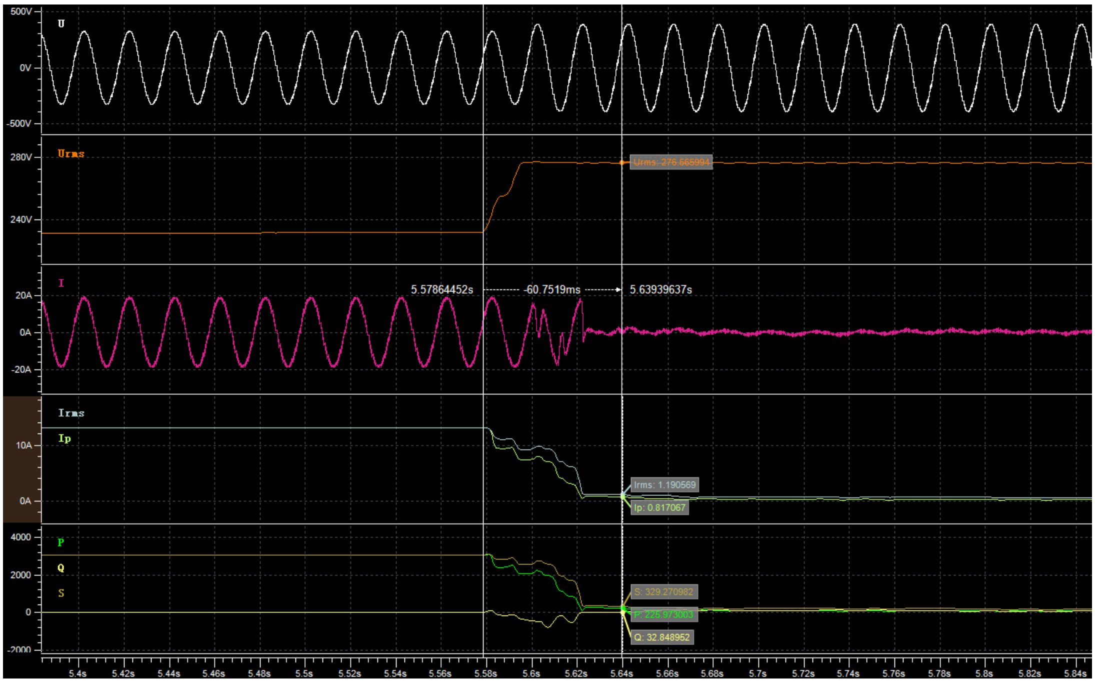
Graph of Test number 6.1_1.20Un



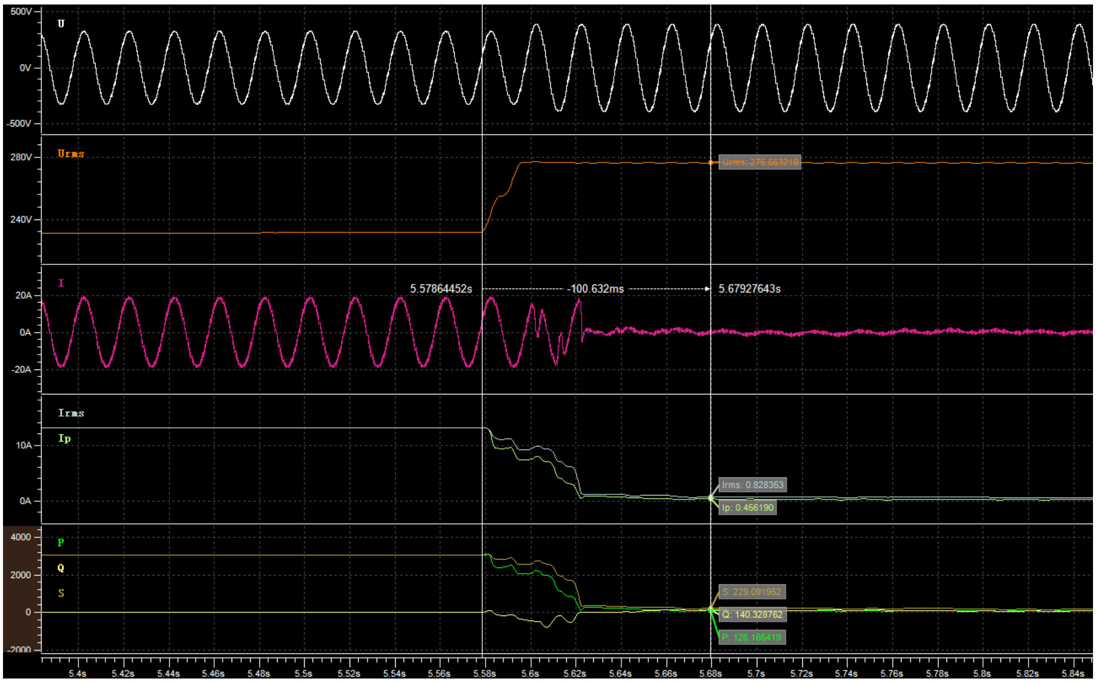
Empty Load



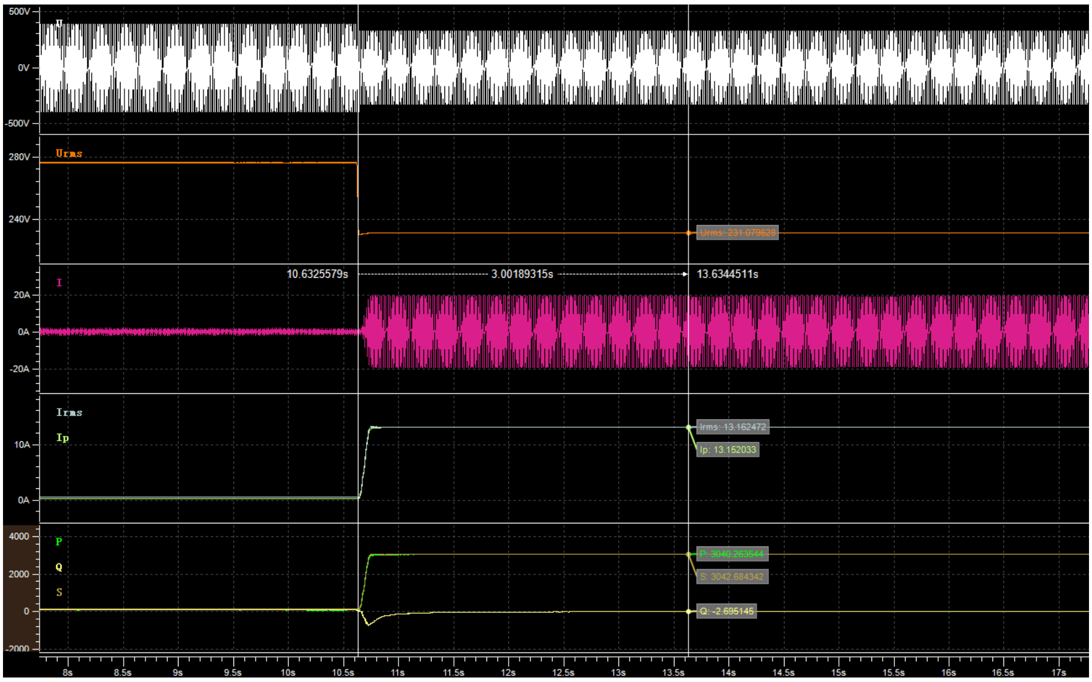
Before dip (t1-100ms)



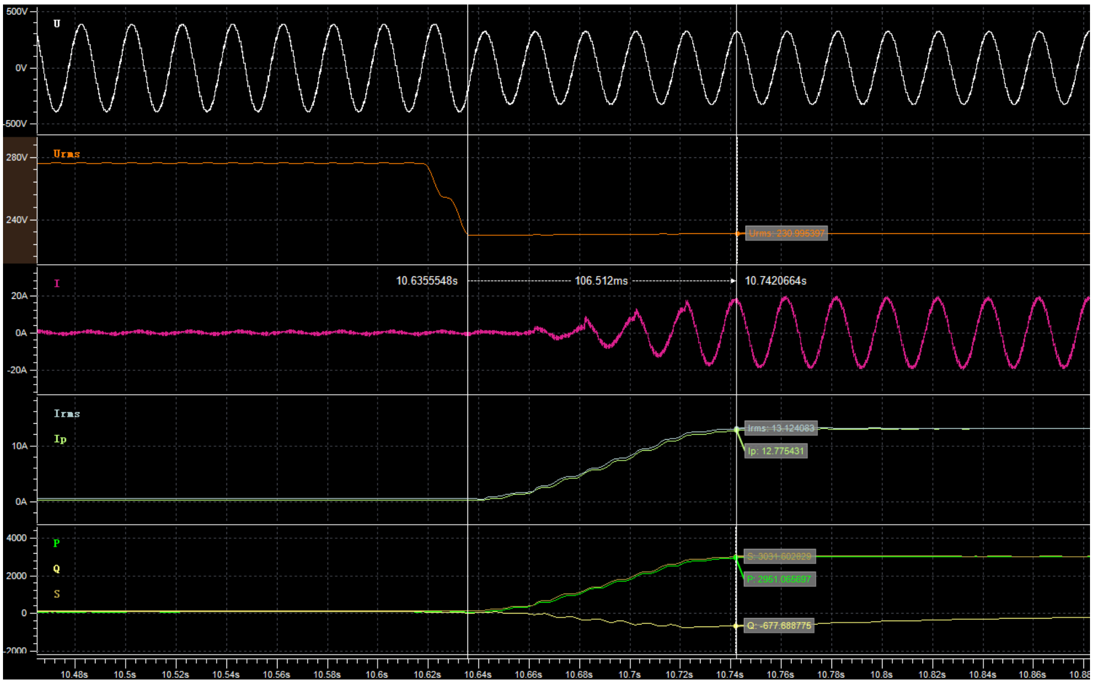
During dip (t1+60ms)



During dip (t1+100ms)

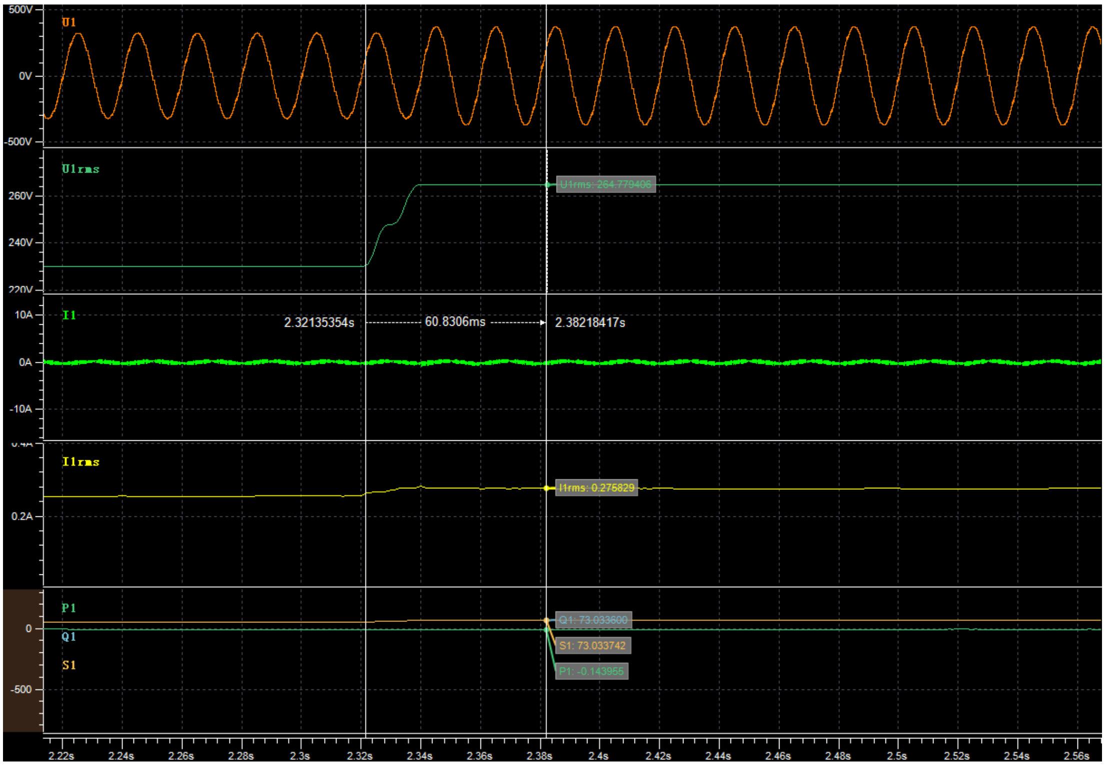


After dip(t2+3s)

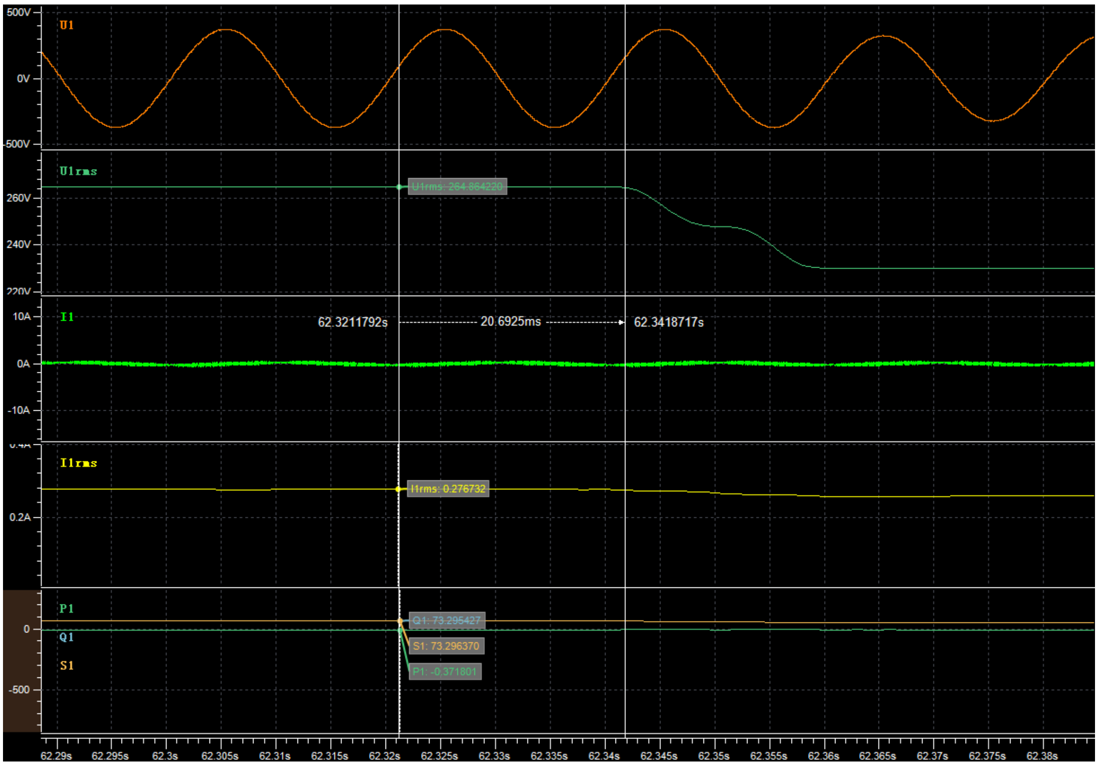


Recovery time

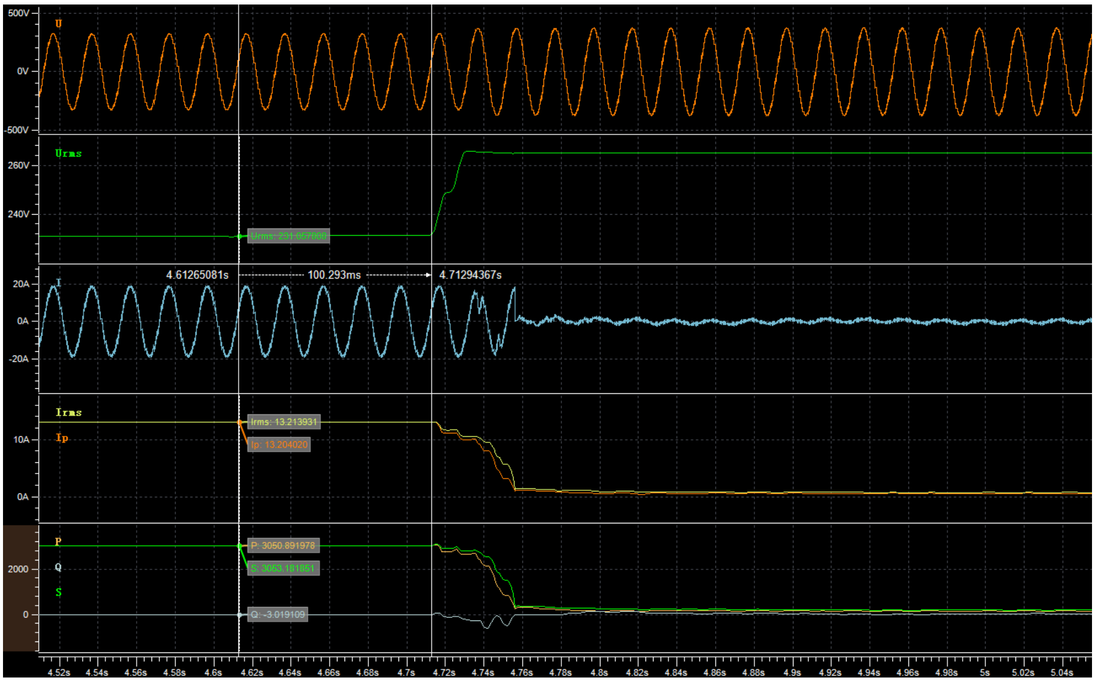
Graph of Test number 7.1_1.15Un



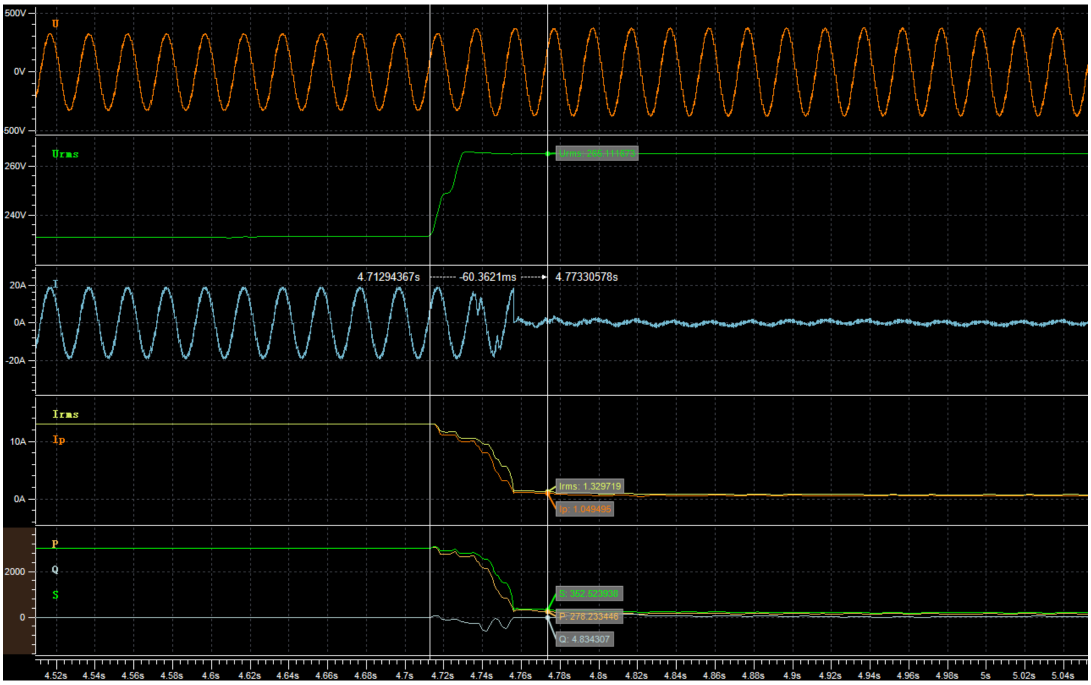
Empty load



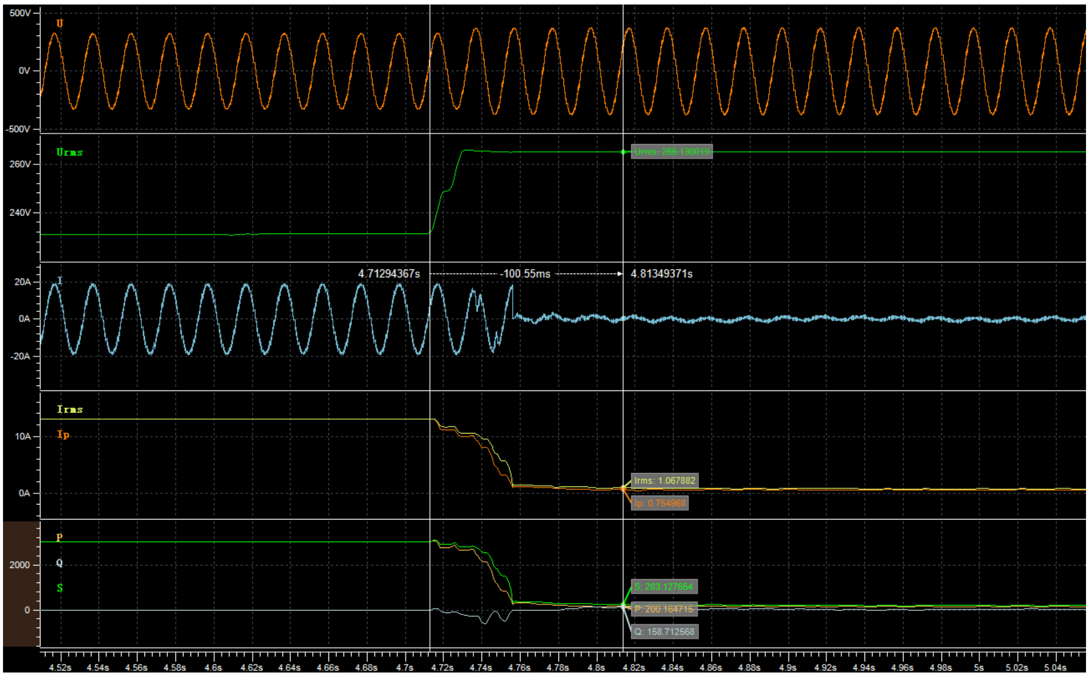
Empty load



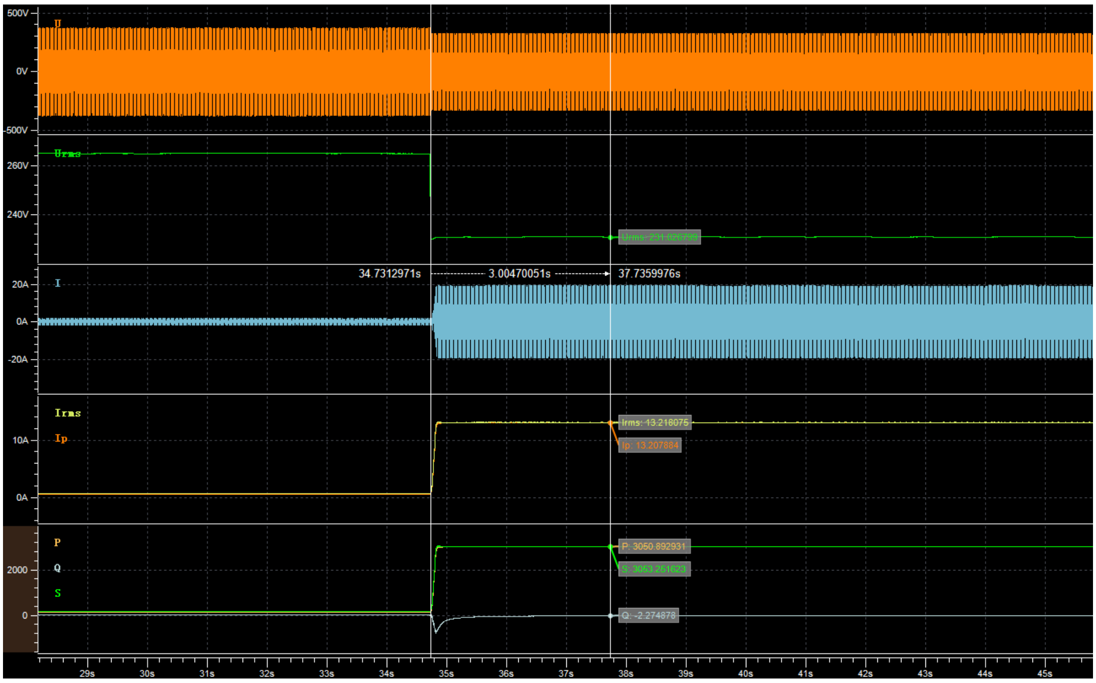
Before dip (t1-100ms)



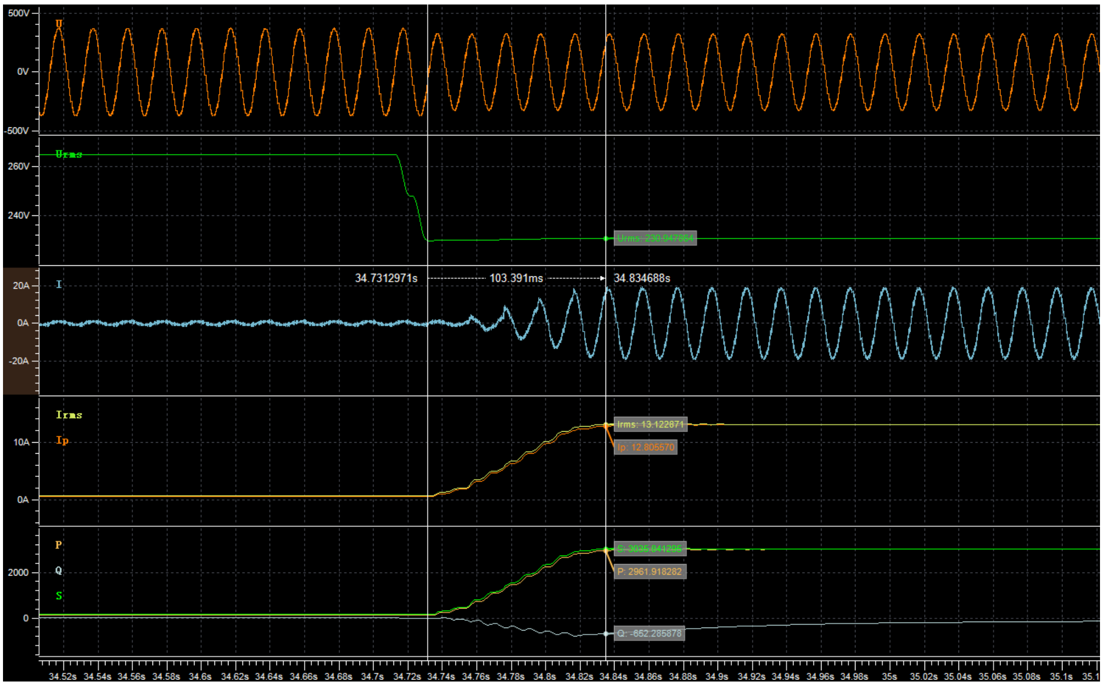
During dip (t1+60ms)



During dip (t1+100ms)

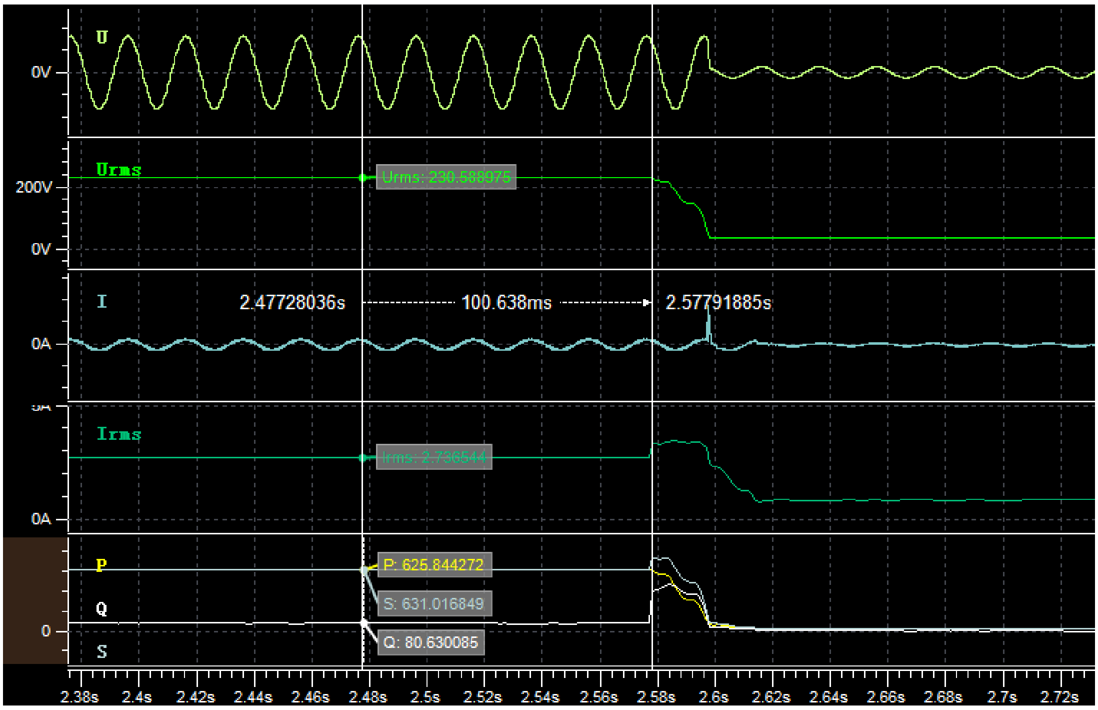


After dip(t2+3s)

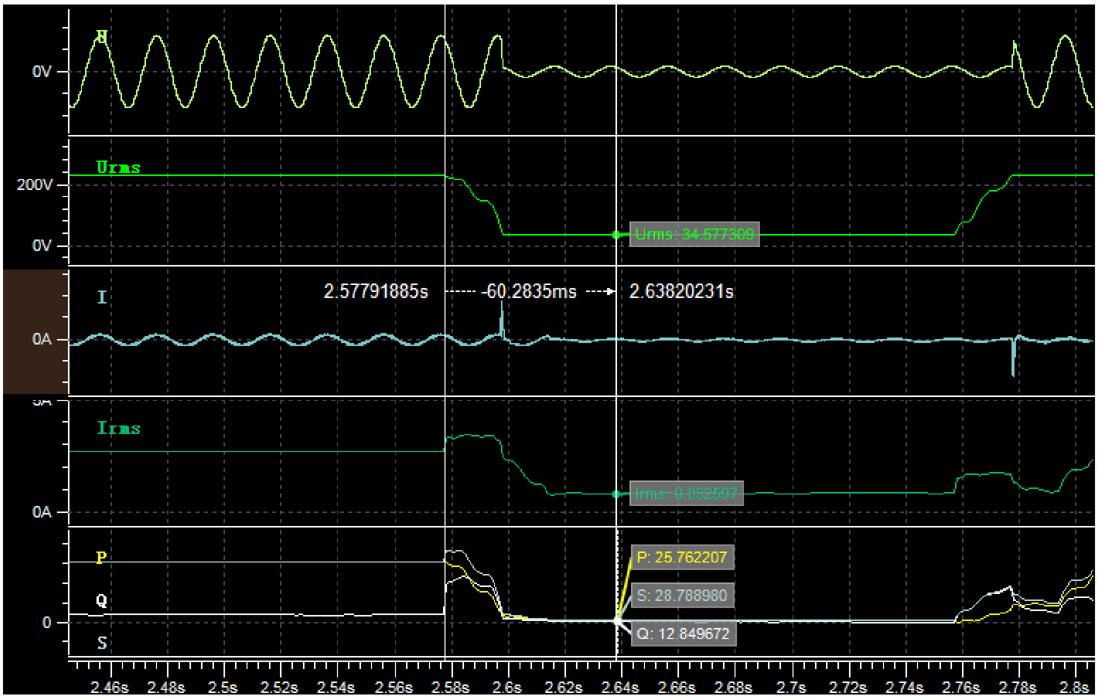


Recovery time

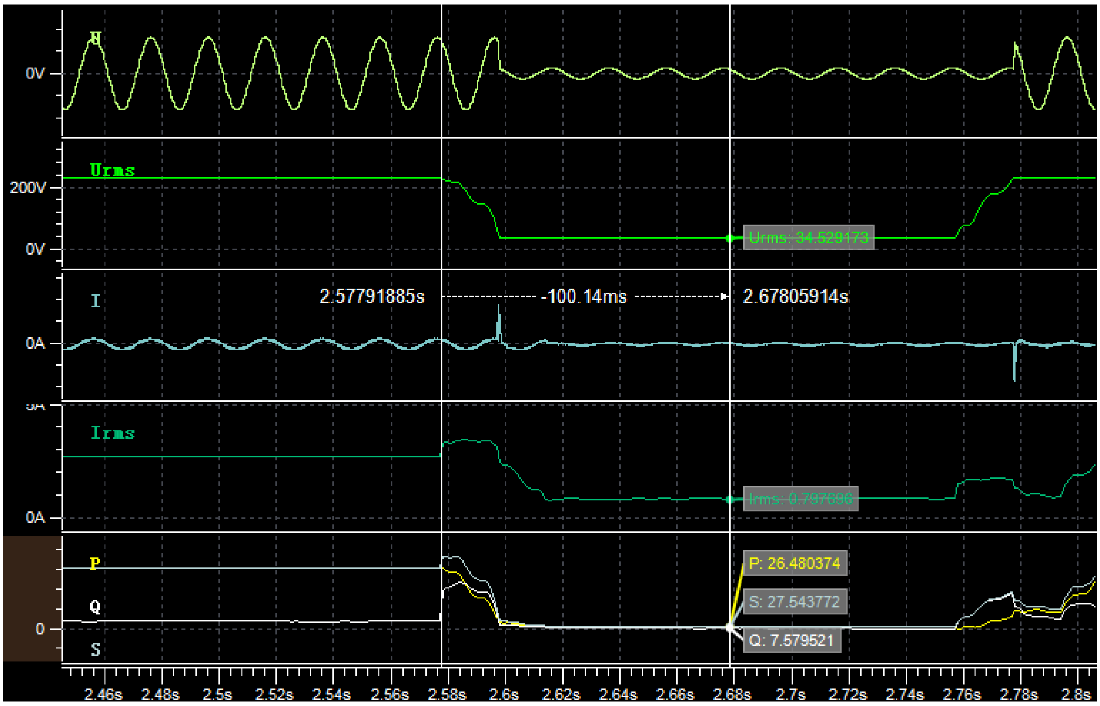
Graph of Test number 1.2_0.15Un



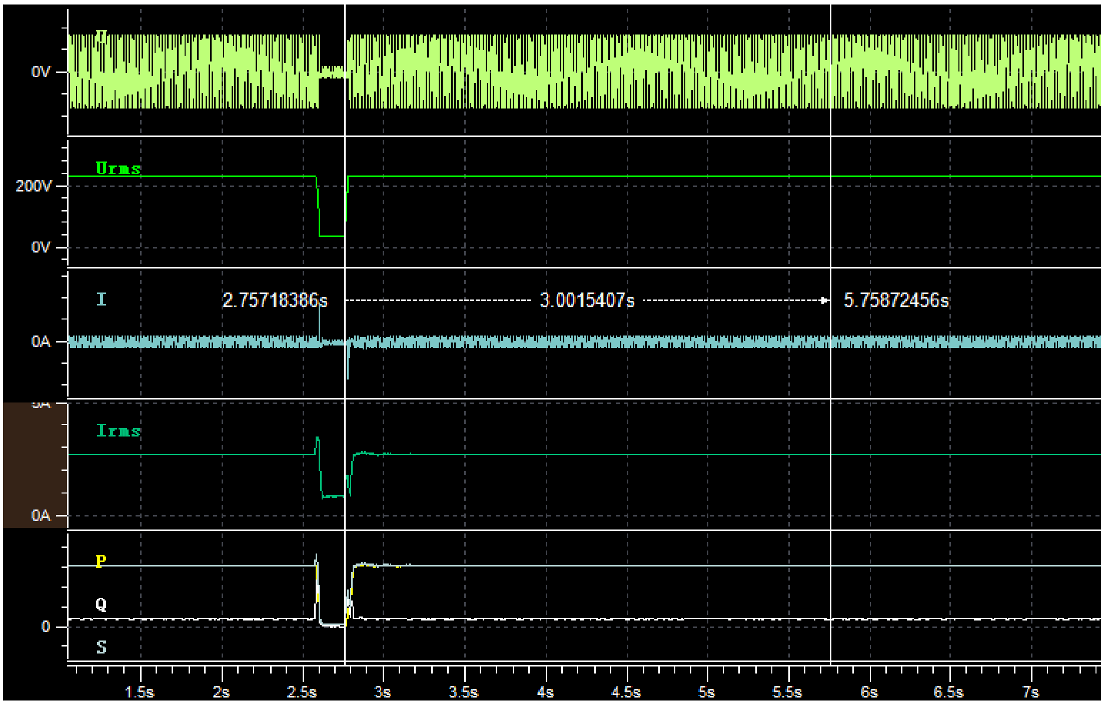
Before dip (t1-100ms)



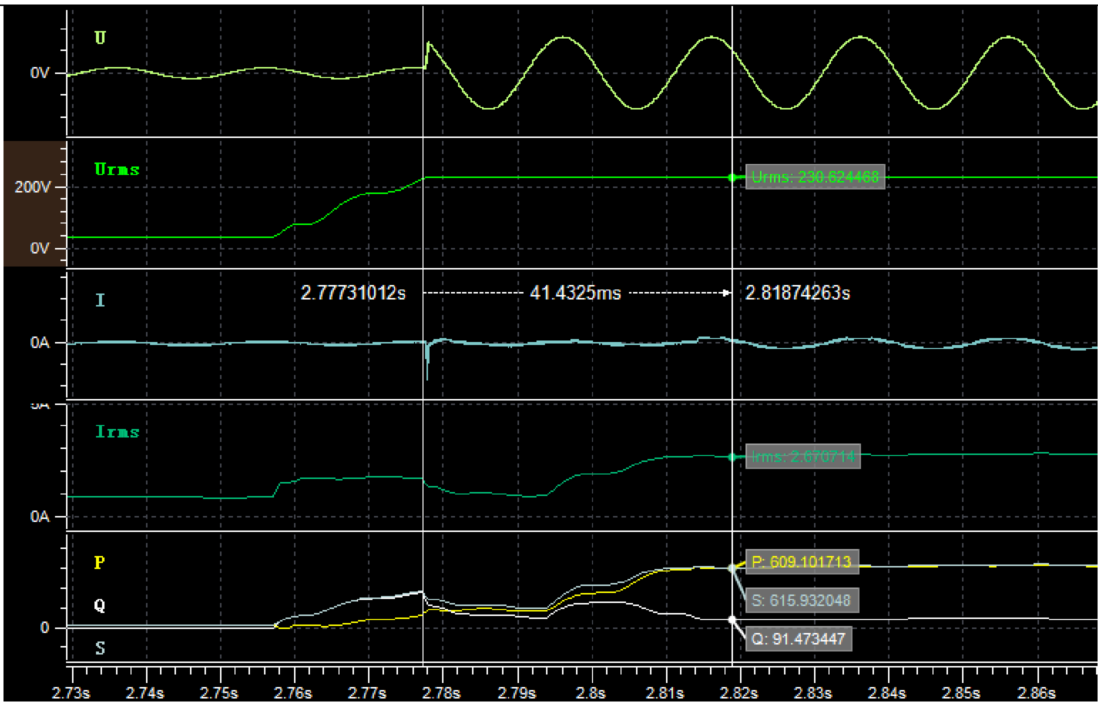
During dip (t1+60ms)



During dip (t1+100ms)



After dip(t2+3s)

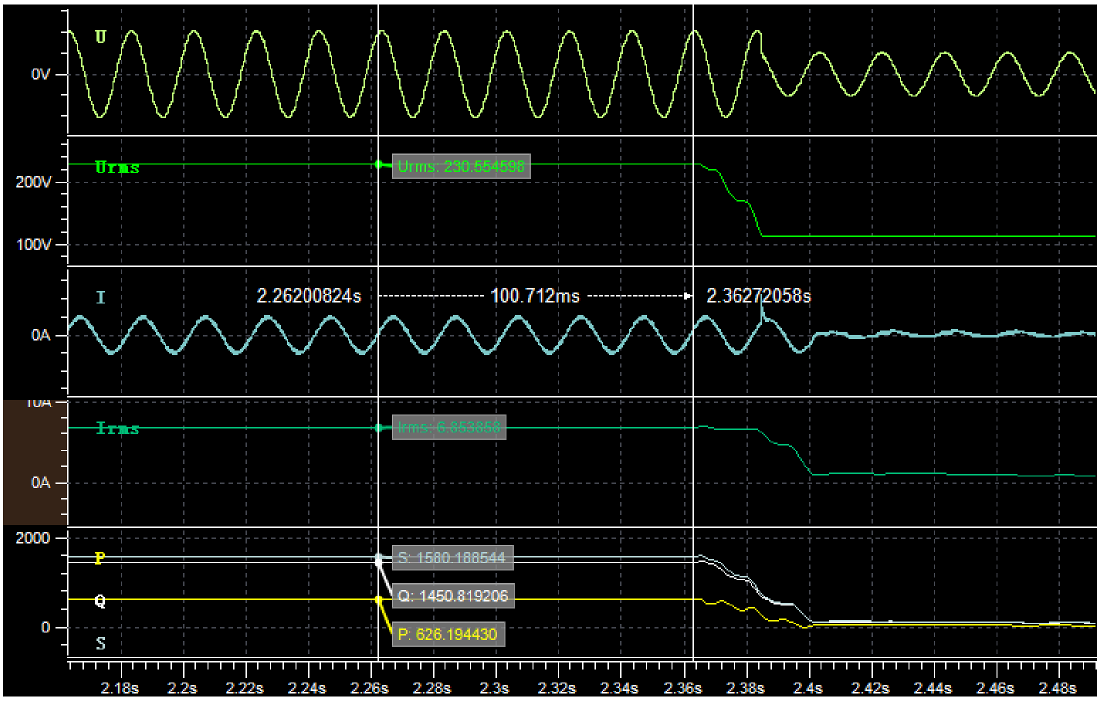


Recovery time

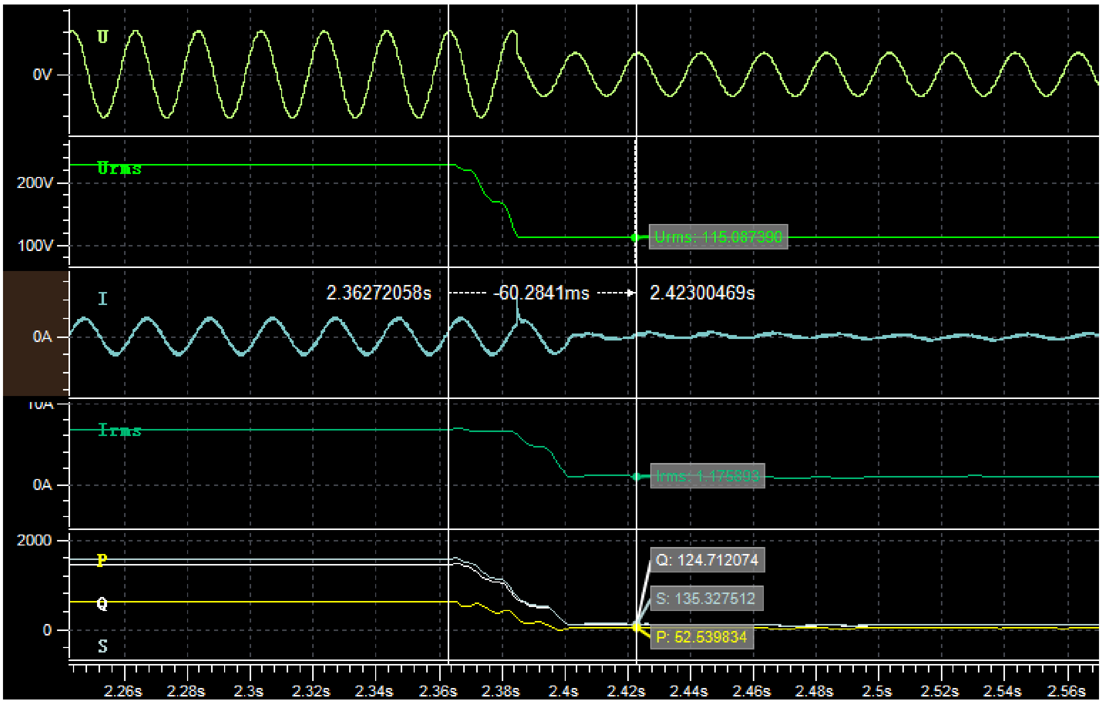
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			10K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	2.2	3.2	4.2	5.2
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020			
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph			
	3	Fault type (phase)	--	--		A	A	A	A
	4	Setting voltage depth	Line to line	--	p.u.	0.5	0.5	0.85	1.25
	5	Setting dip duration		--	ms	1500	1500	60000	100
	6	Point of fault entry	Total	--	ms	20ms			
	7	Point of fault clearance	Total	--	ms	20ms			
	8	Fault duration in empty load test	Total	--	ms	1516.89	1514.09	60015	103.09
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.50	0.50	0.85	1.25
	10		Positive sequence		p.u.	--	--	--	--
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.00	1.00	1.00	1.00
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--	--	--
	13	Active power	Total	t1-10s to t1	p.u.	0.209	0.208	0.208	0.210
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.484	-0.465	0.027	-0.001
	16		Positive sequence			--	--	--	--
	17	Cos_{φ}	--	t1-10s to t1	--	0.3958	0.4071	0.9917	0.9863
During dip t1 to	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.50	0.50	0.85	1.25

t2	19	Line current	Phase 1	t1+60ms	p.u.	0.090	0.029	0.068	0.076
	20		Phase 2			--	--	--	--
	21		Phase 3			--	--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	0.086	0.034	0.064	0.077
	23		Phase 2			--	--	--	--
	24		Phase 3			--	--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.016	0.016	0.046	0.061
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			0.208	0.224	0.208	0.210
	39	Active power rising time	Positive sequence	--	s	0.078	0.183	0.044	0.095
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.484	-0.479	0.027	-0.001
	33	Reactive power rising time	Positive sequence	--	s	0.078	8.37	0.044	0.095
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

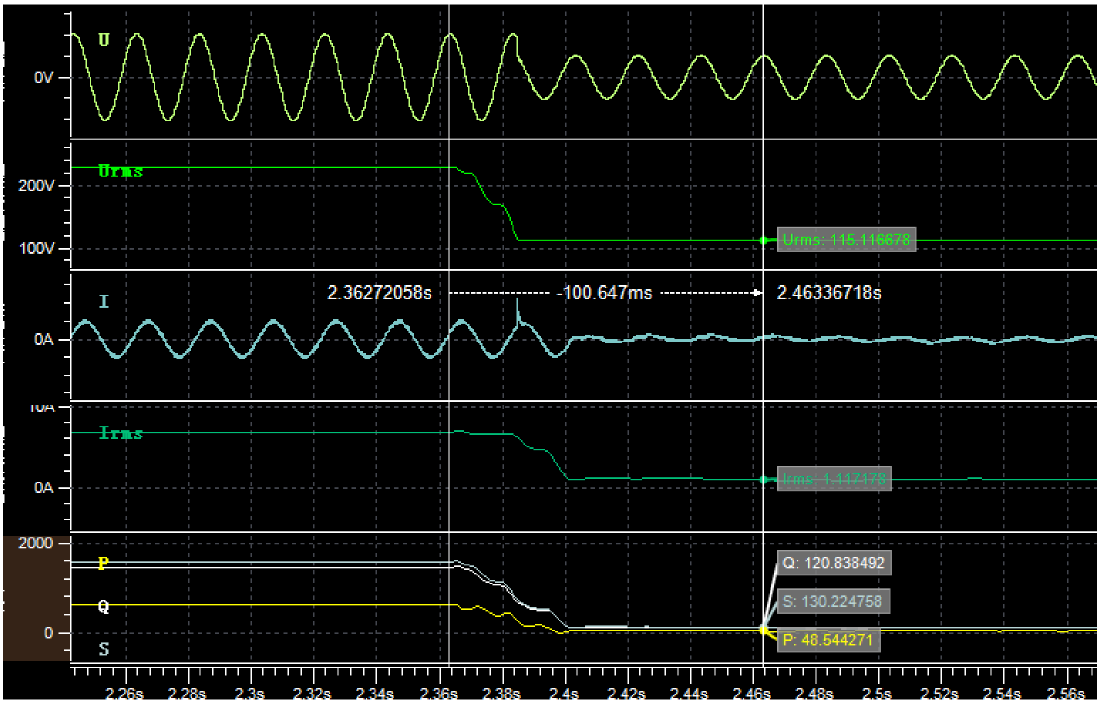
Graph of Test number 2.2_0.5Un



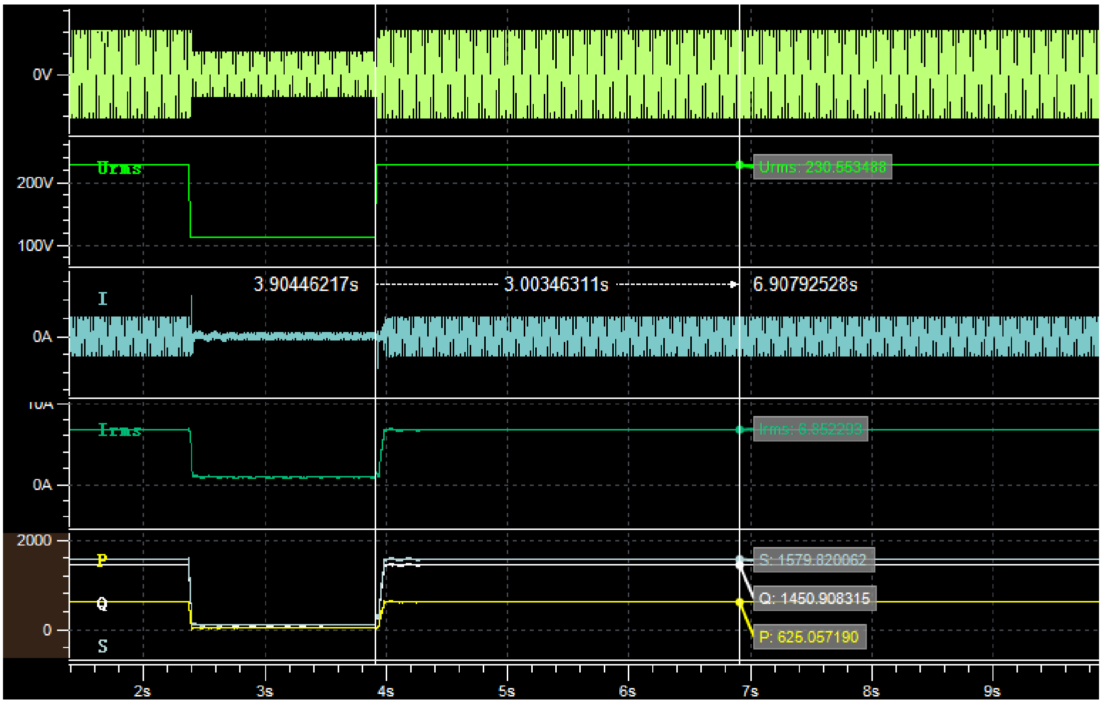
Before dip (t1-100ms)



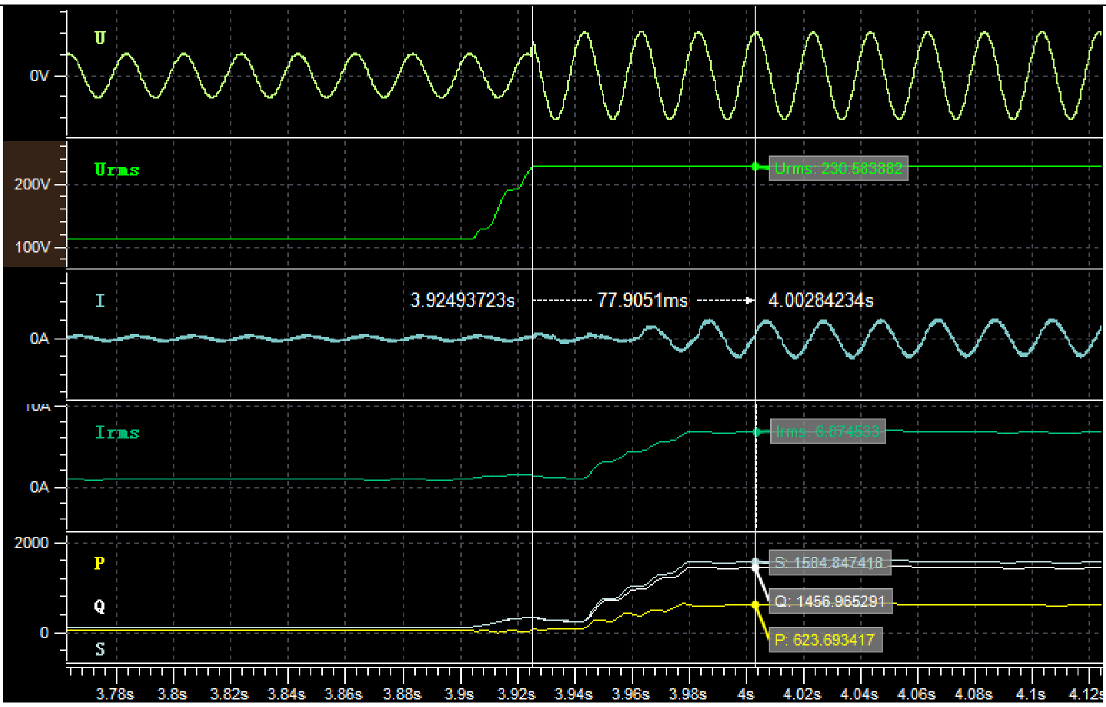
During dip (t1+60ms)



During dip (t1+100ms)

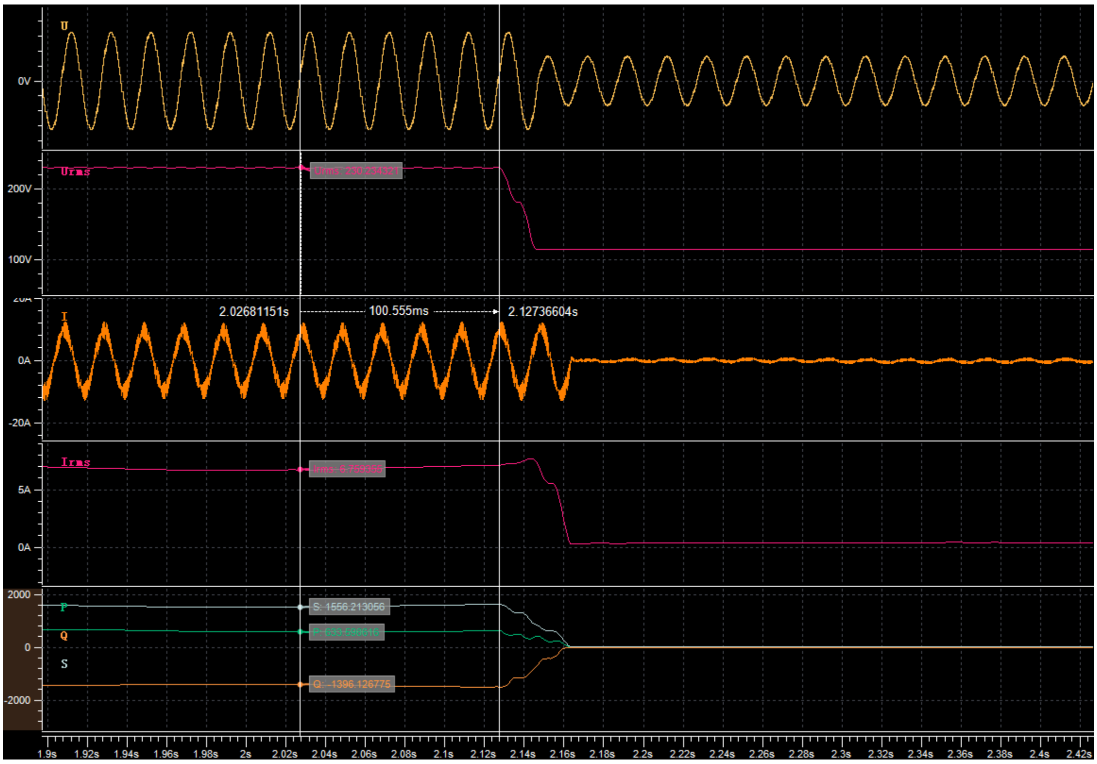


After dip(t2+3s)

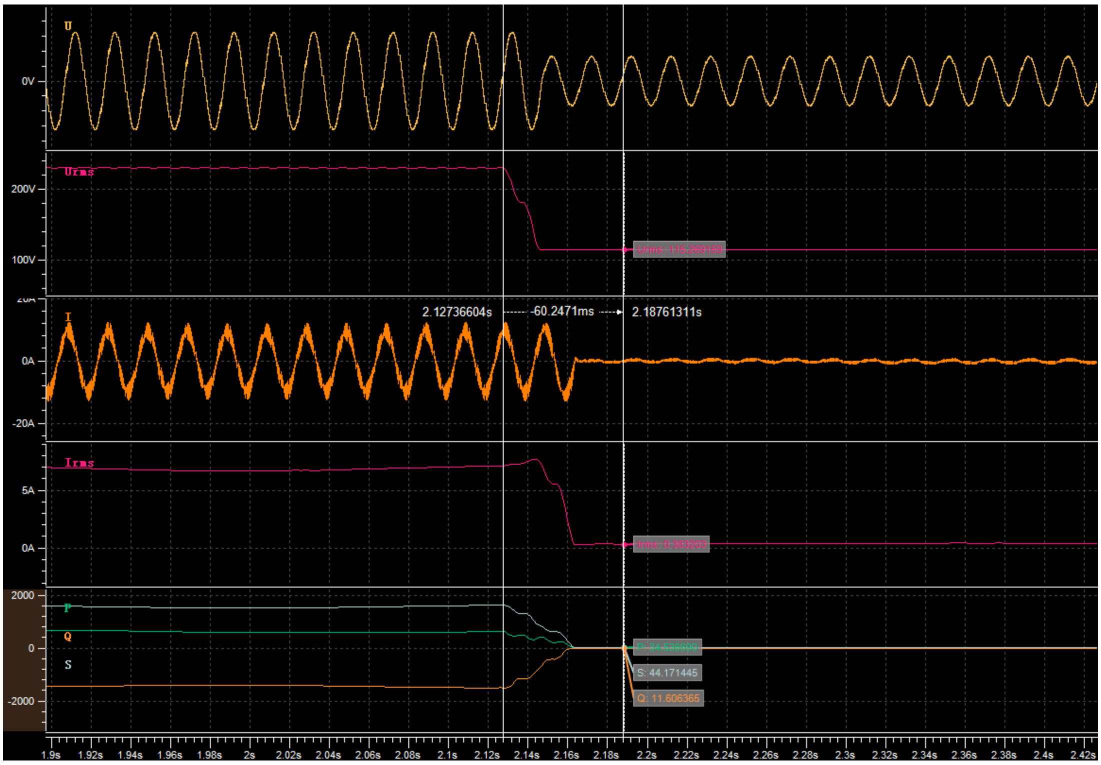


Recovery time

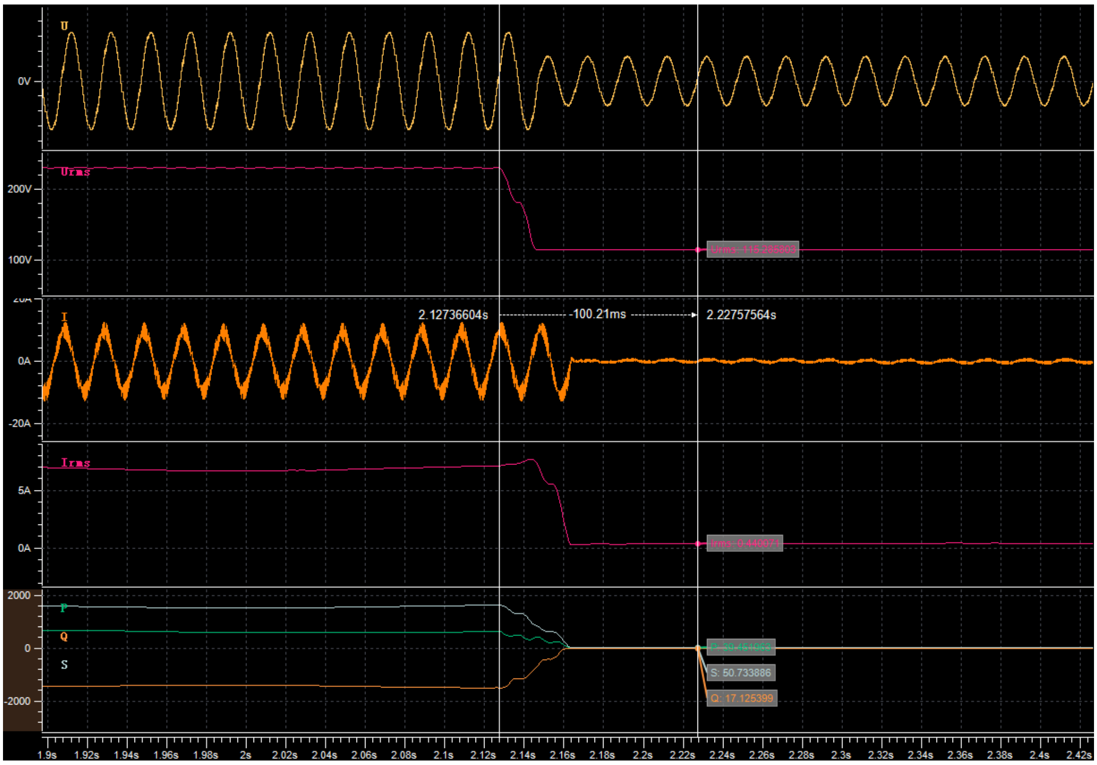
Graph of Test number 3.2_0.5Un



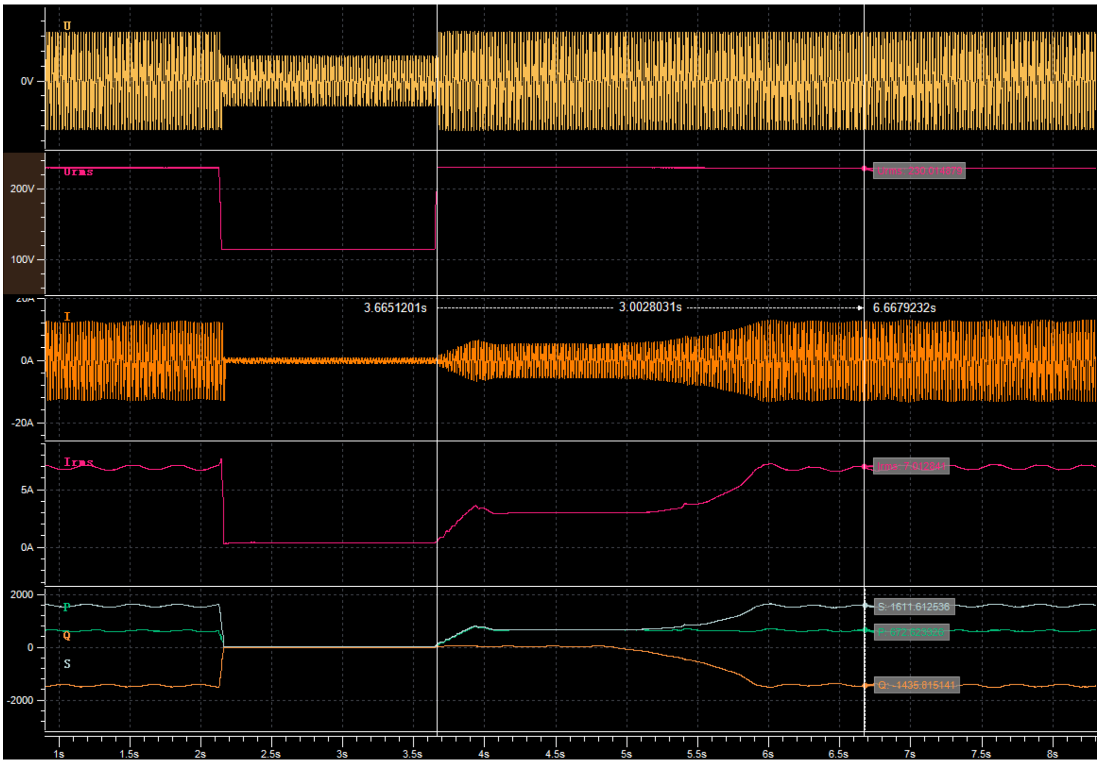
Before dip (t1-100ms)



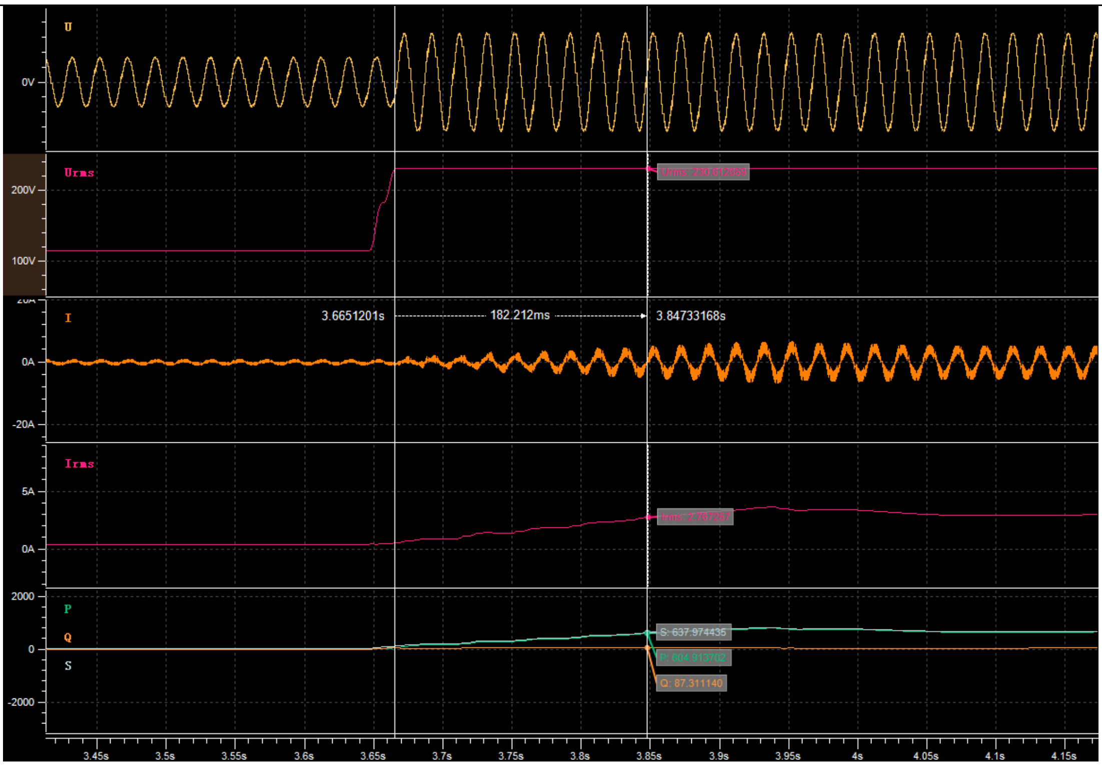
During dip (t1+60ms)



During dip (t1+100ms)



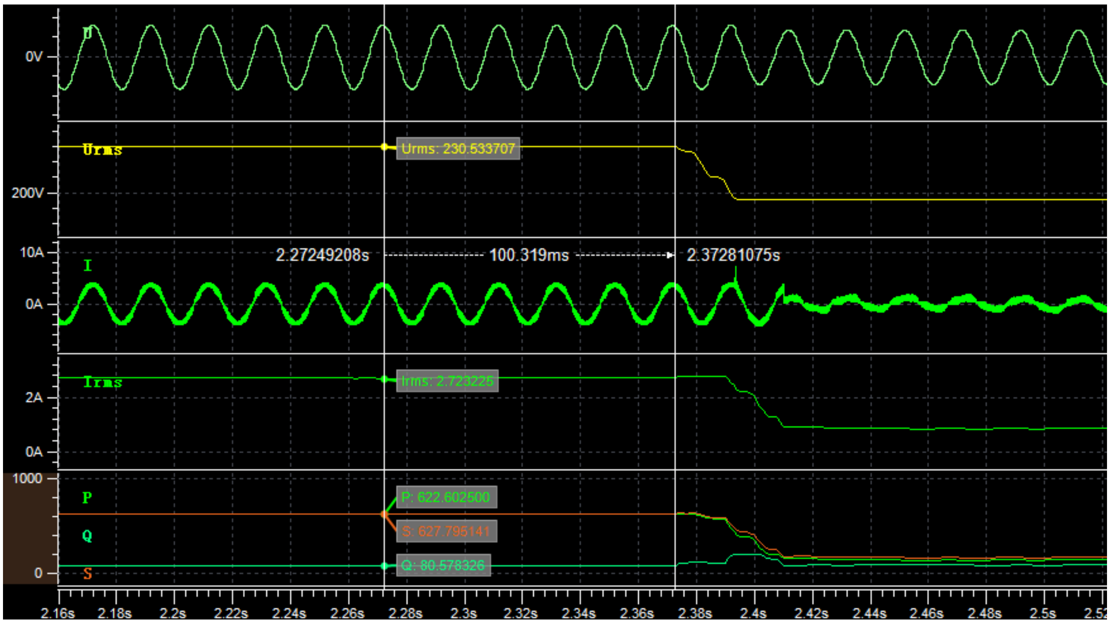
After dip(t2+3s)



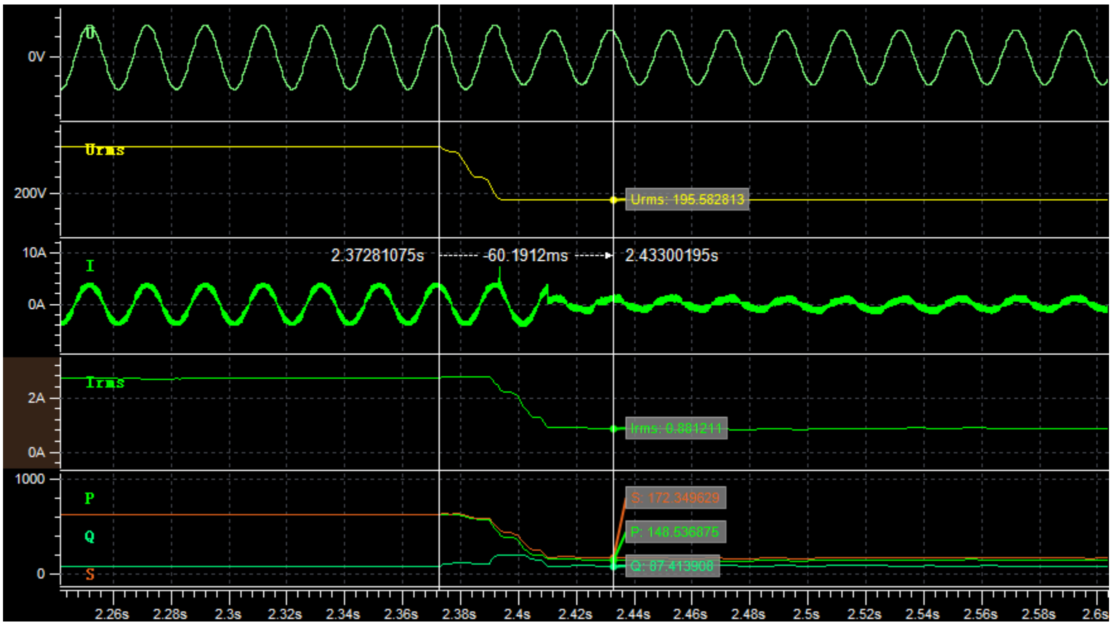
Recovery time

Wom wo

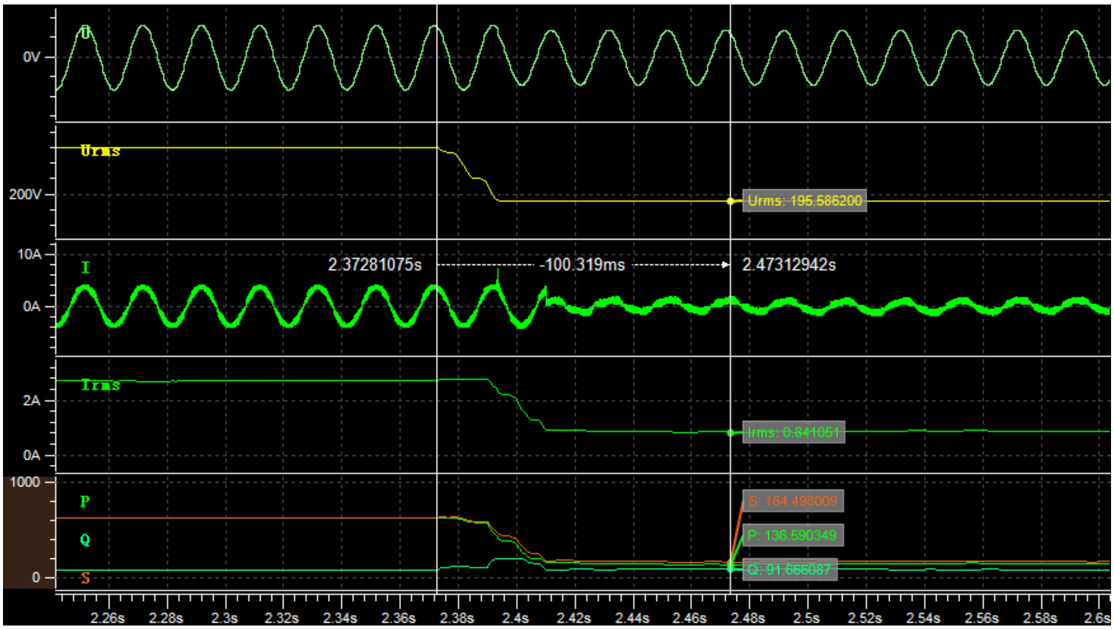
Graph of Test number 4.2_0.85Un



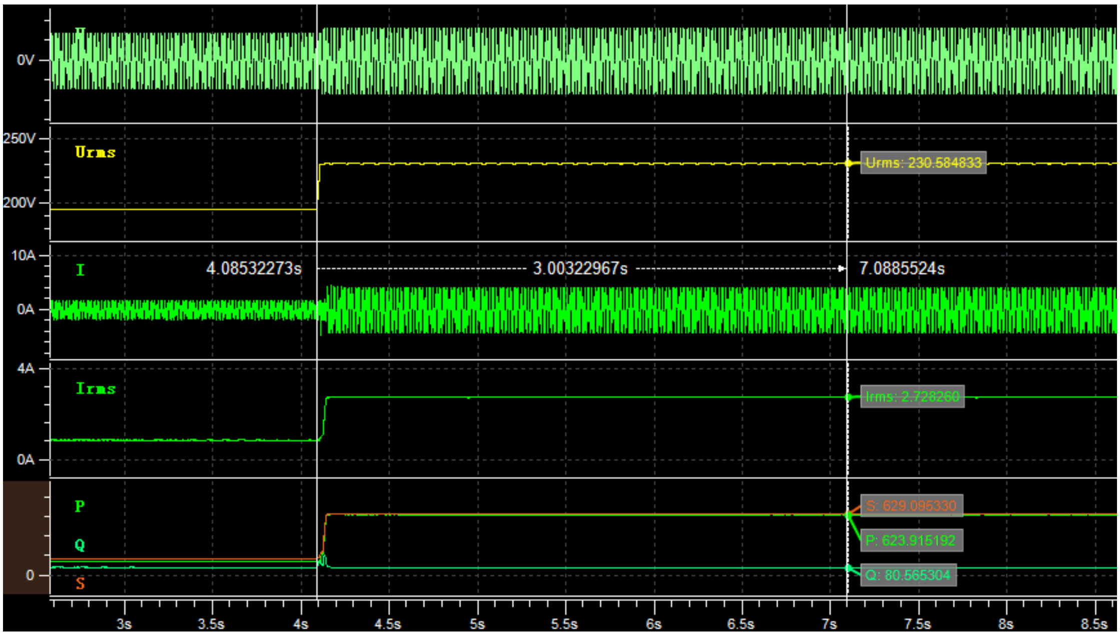
Before dip (t1-100ms)



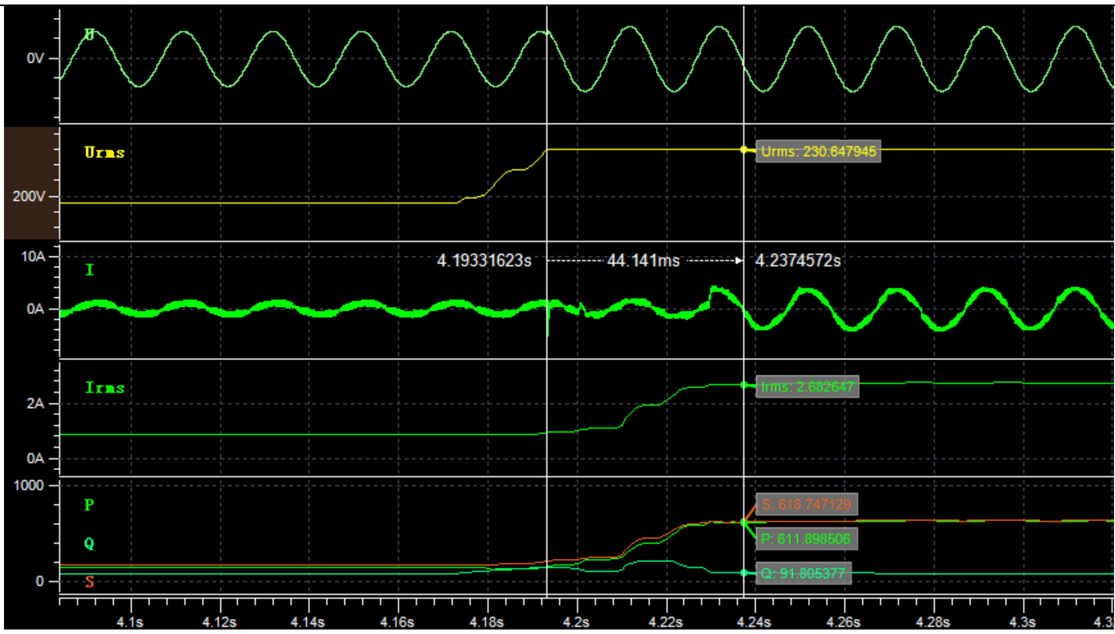
During dip (t1+60ms)



During dip (t1+100ms)

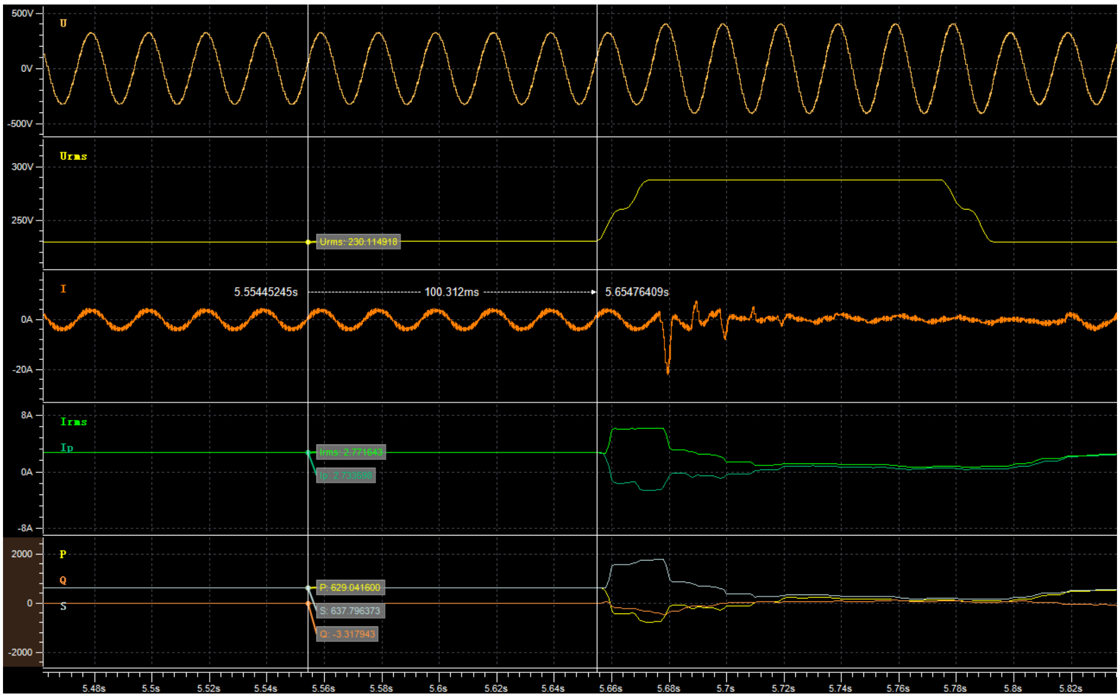


After dip(t2+3s)

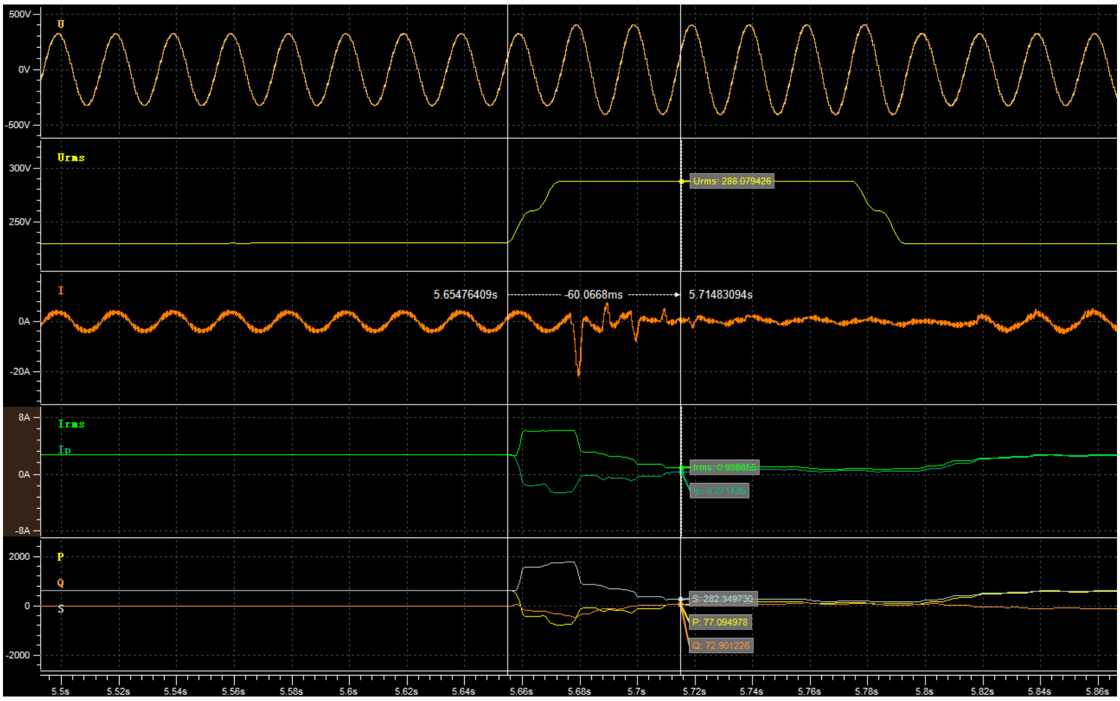


Recovery time

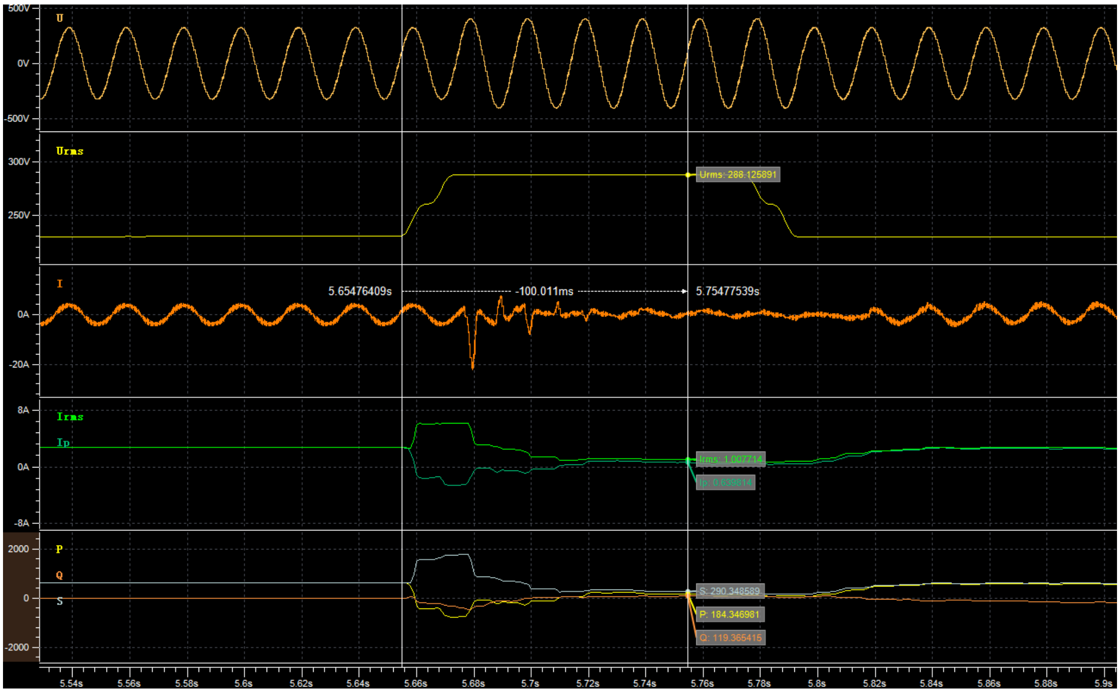
Graph of Test number 5.2_1.25Un



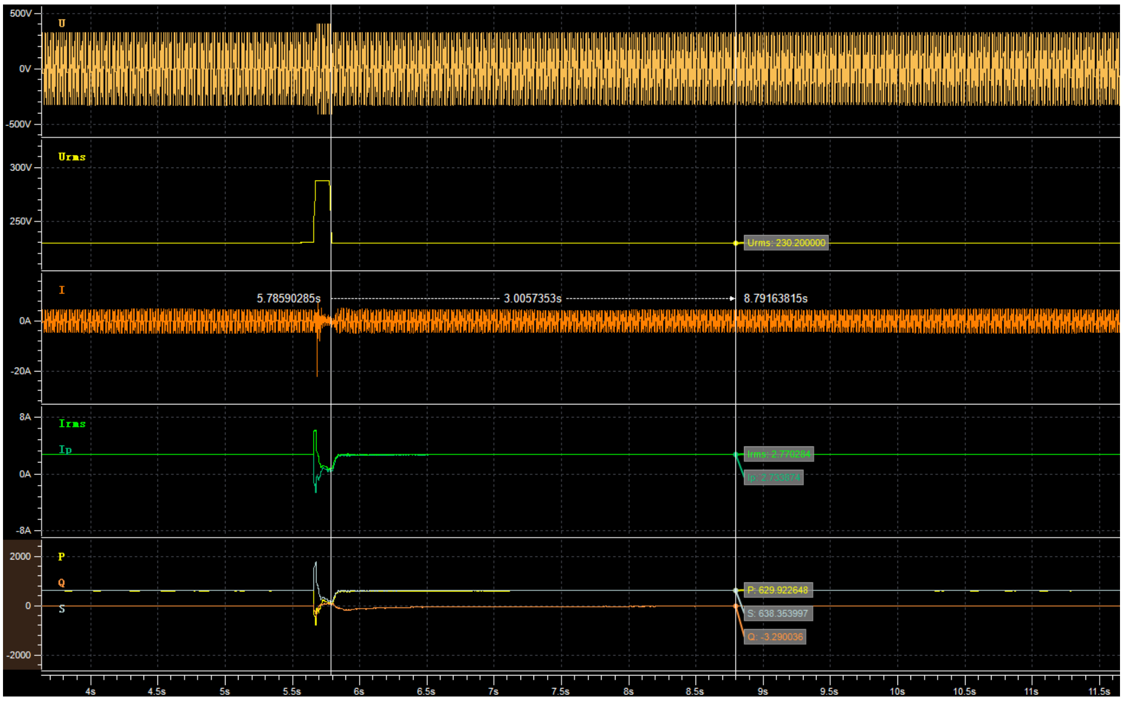
Before dip (t1-100ms)



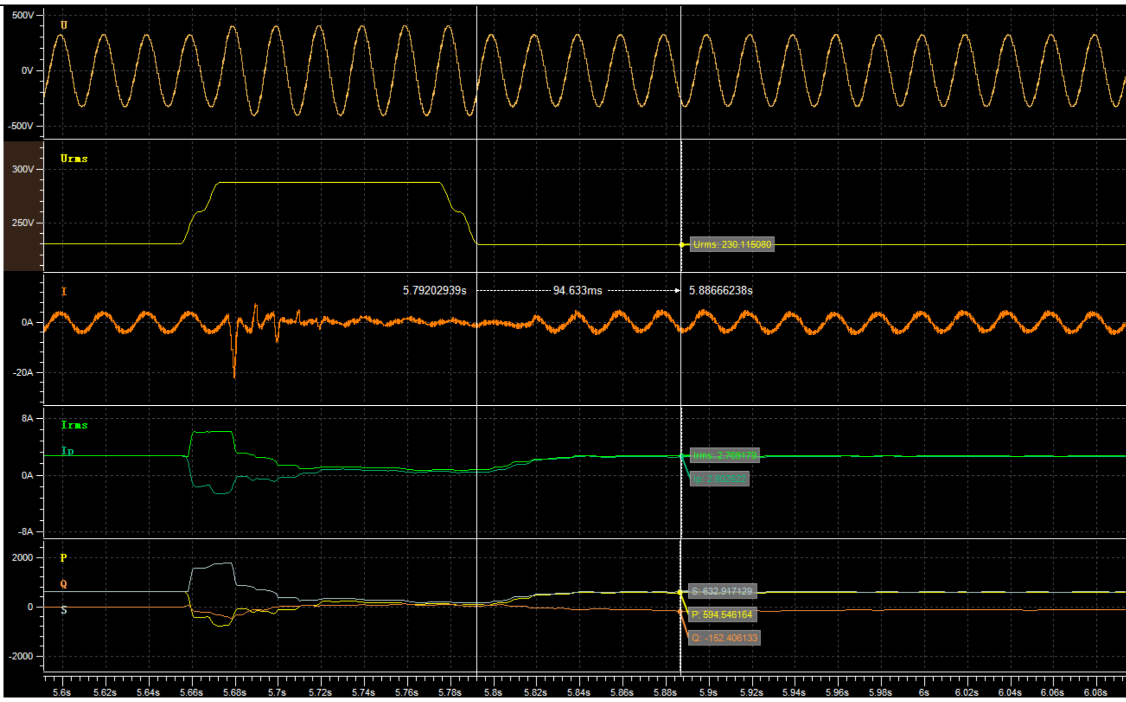
During dip (t1+60ms)



During dip (t1+100ms)



After dip(t2+3s)

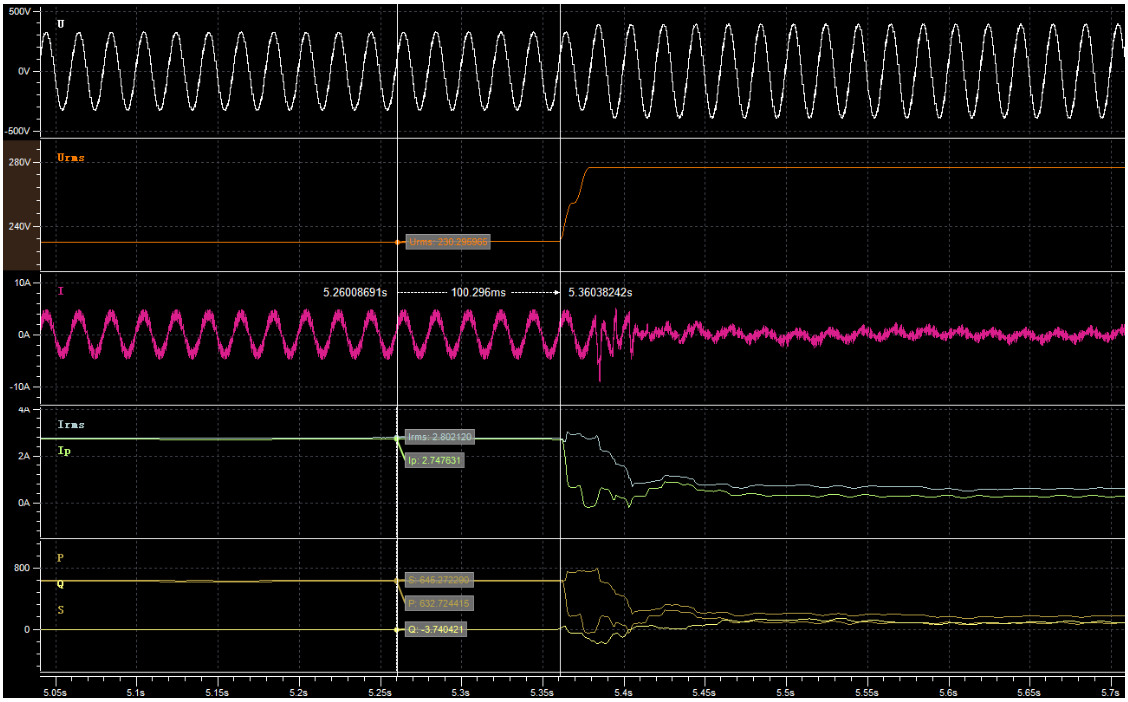


Recovery time

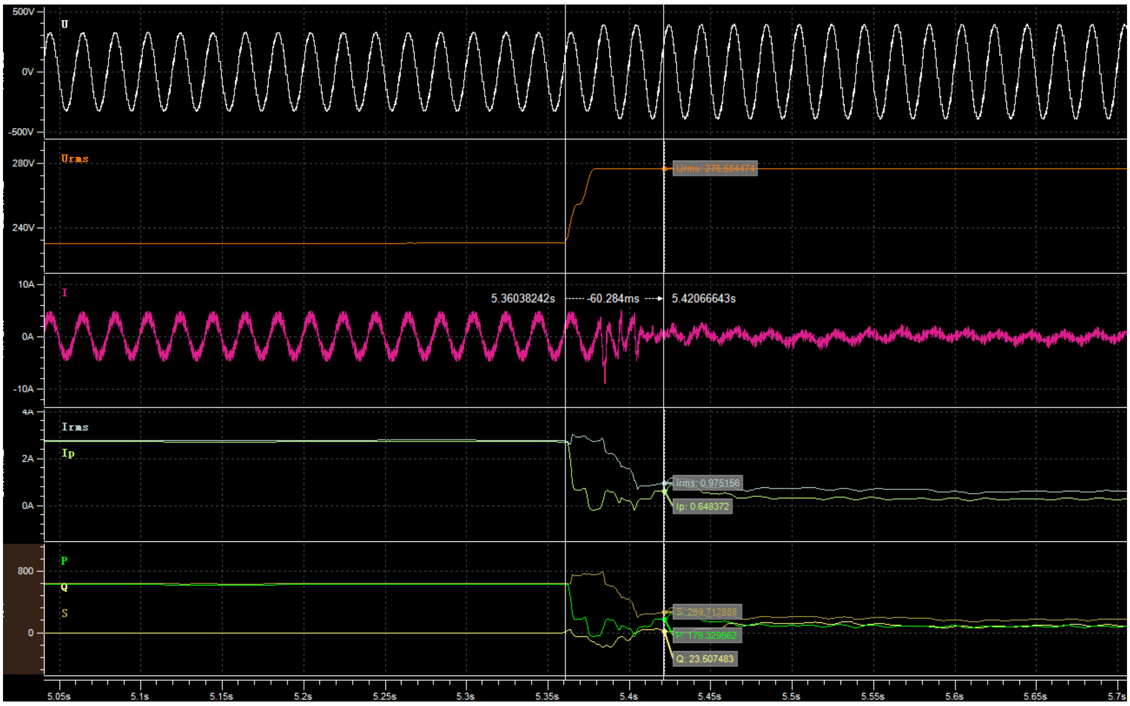
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			10K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	6.2	7.2	1.3	2.3
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020			
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph			
	3	Fault type (phase)	--	--		A	A	D1	D1
	4	Setting voltage depth	Line to line	--	p.u.	1.20	1.15	0.15	0.50
	5	Setting dip duration		--	ms	5000	60000	150	1500
	6	Point of fault entry	Total	--	ms	20ms			
	7	Point of fault clearance	Total	--	ms	20ms			
	8	Fault duration in empty load test	Total	--	ms	5022.52	60021	158.72	1512.84
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.20	1.15	0.62	0.76
								0.15	0.50
								0.62	0.76
	10		Positive sequence		p.u.	--	--	0.46	0.67
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.00	1.00	1.00	1.00
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--	--	--
	13	Active power	Total	t1-10s to t1	p.u.	0.211	0.210	1.013	0.913
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	-0.001	-0.001	0.000	0.484
	16		Positive sequence			--	--	--	--
	17	Cos$_{\varphi}$	--	t1-10s to t1	--	0.9806	0.9882	0.9993	0.8831

During dip t1 to t2	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	1.20	1.15	0.62	0.76
								0.15	0.50
								0.62	0.76
	19	Line current	Phase 1	t1+60ms	p.u.	0.075	0.077	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			--	--	0.078	0.064
	22	Line current	Phase 1	t1+100ms	p.u.	0.063	0.051	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			--	--	0.074	0.053
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.050	0.030	0.035	0.018
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			0.210	0.210	1.013	0.914
	39	Active power rising time	Positive sequence	--	s	0.099	0.070	0.123	0.126
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			-0.001	-0.001	-0.001	0.483
	33	Reactive power rising time	Positive sequence	--	s	0.099	0.070	0.123	0.126
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

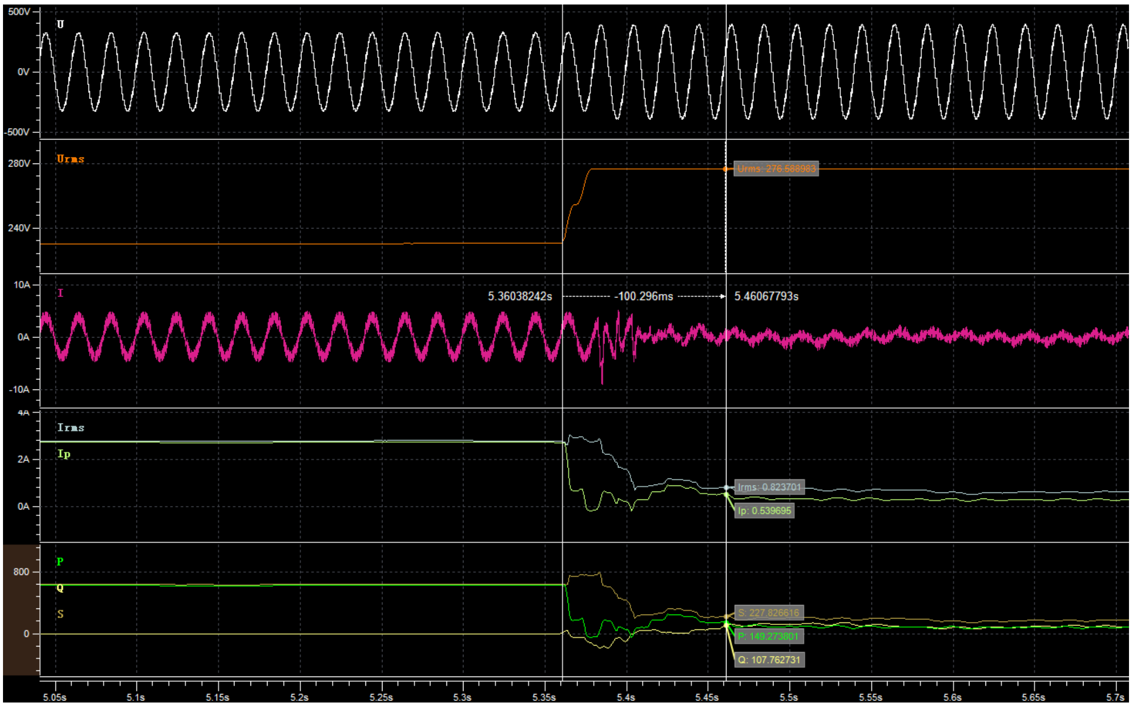
Graph of Test number 6.2_1.20Un



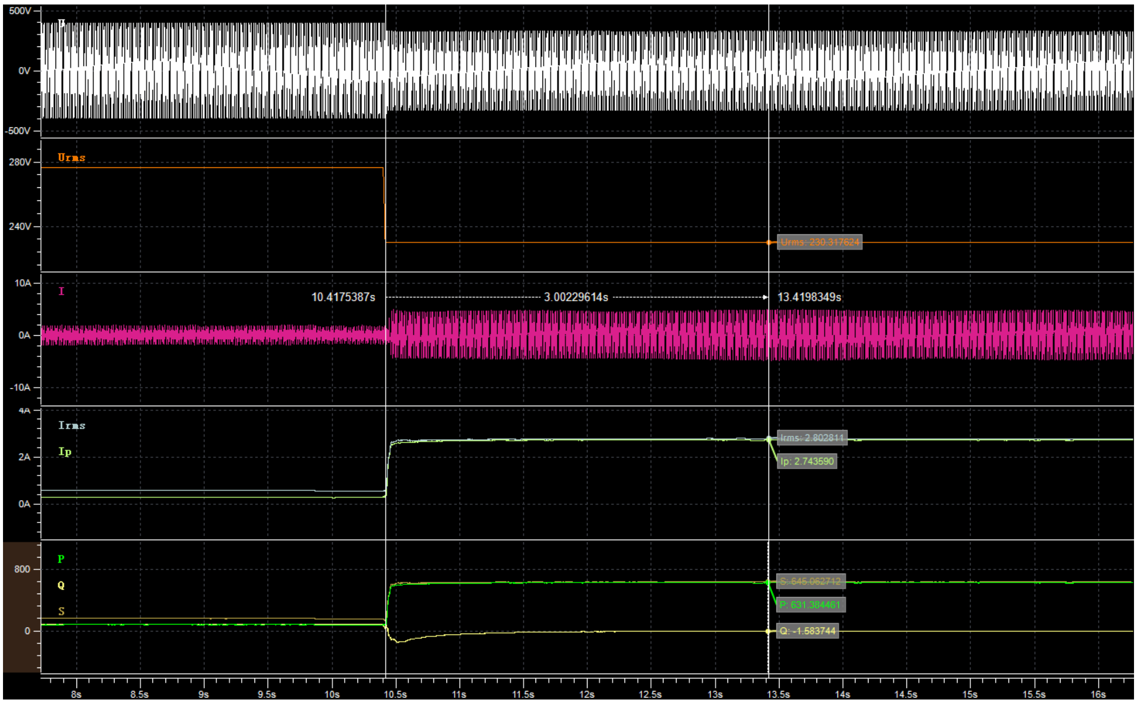
Before dip (t1-100ms)



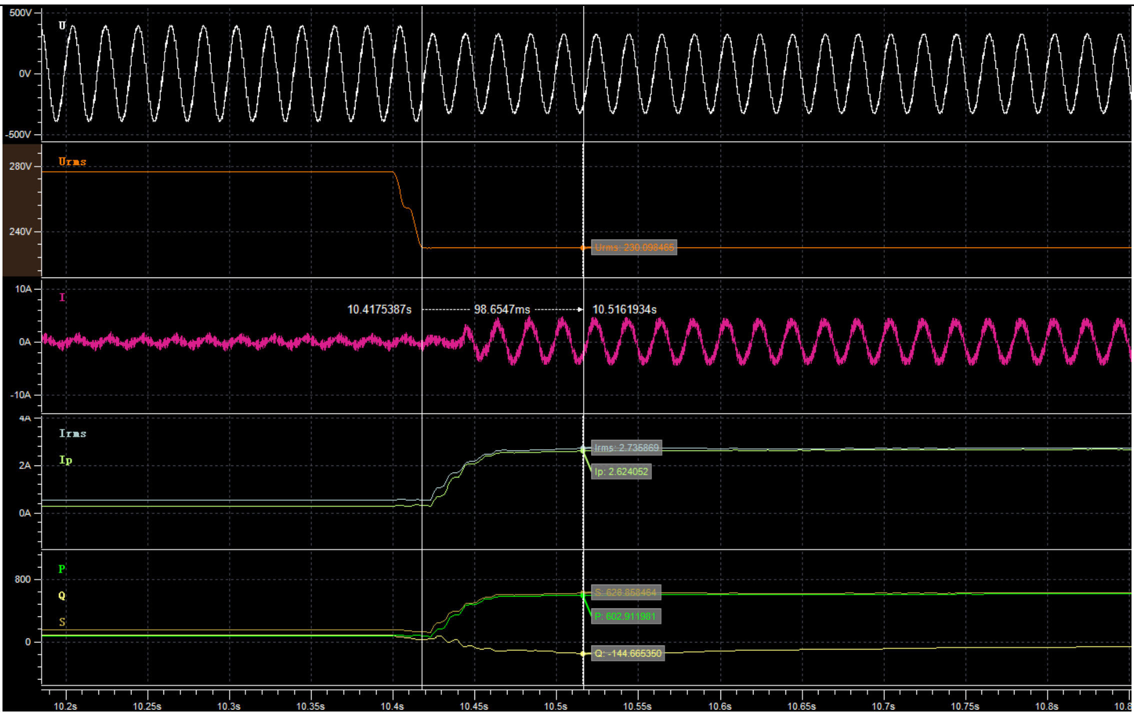
During dip (t1+60ms)



During dip (t1+100ms)

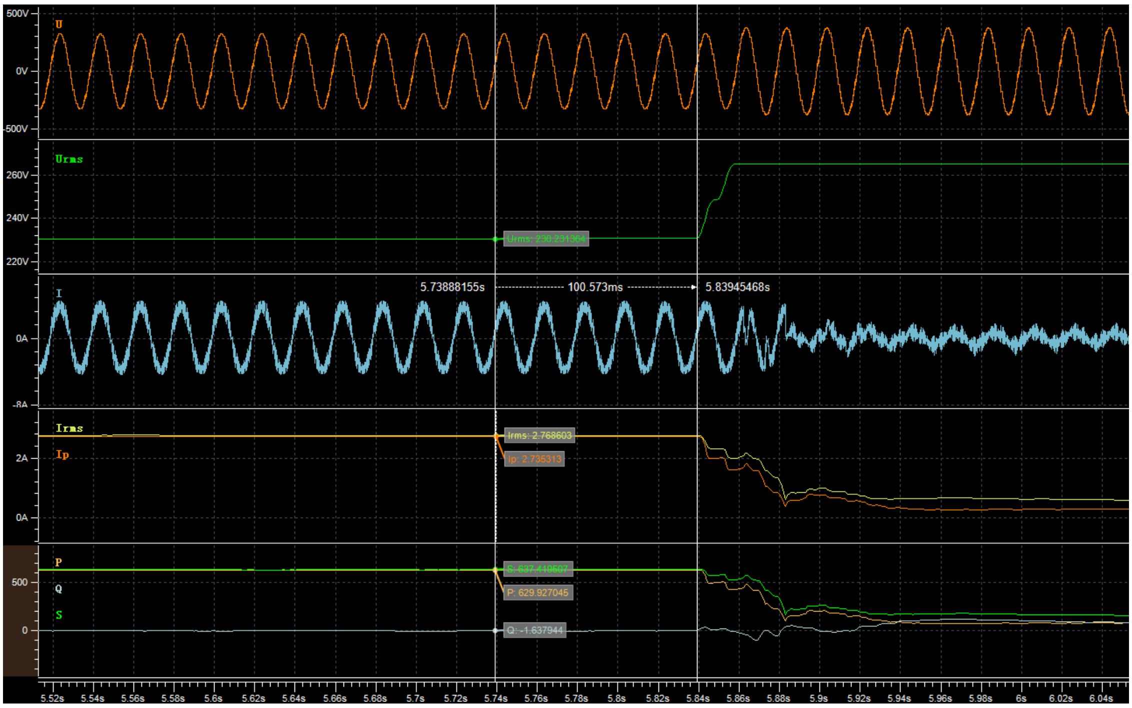


After dip(t2+3s)

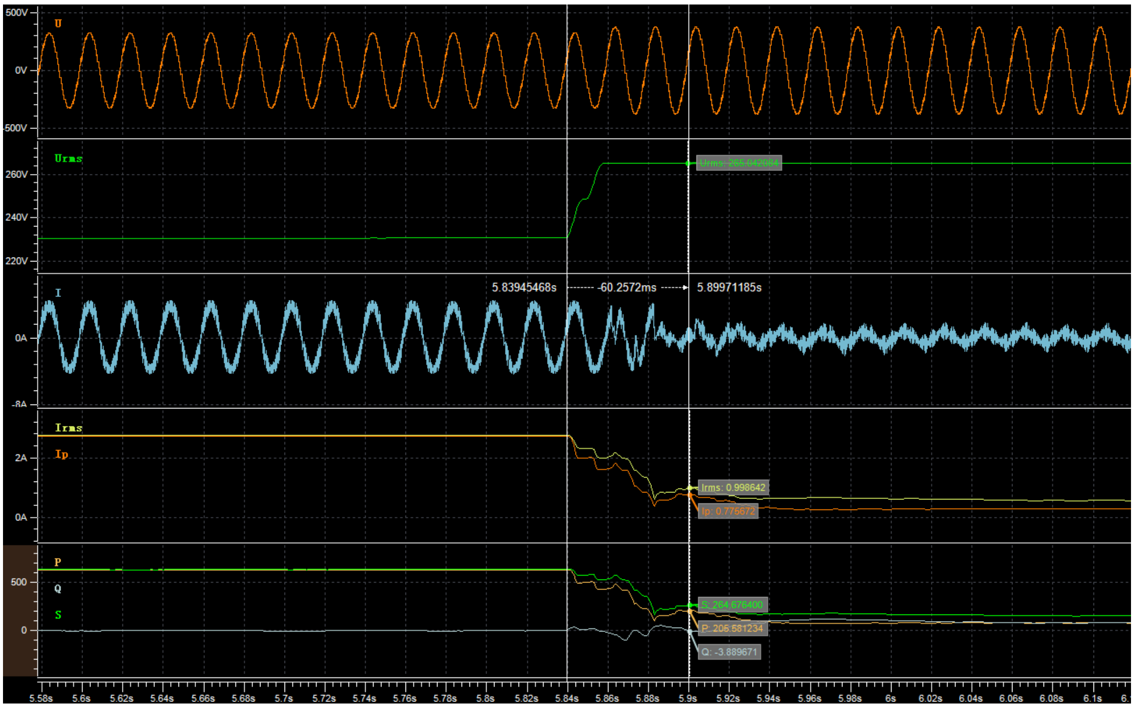


Recovery time

Graph of Test number 7.2_1.15Un

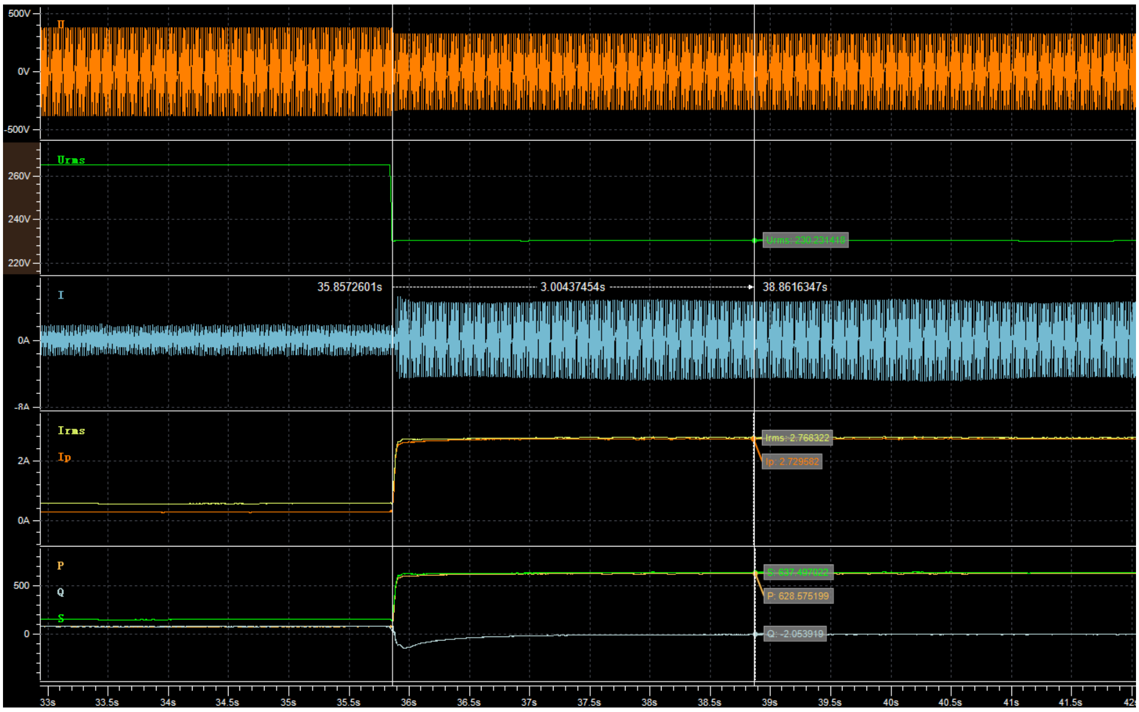


Before dip (t1-100ms)

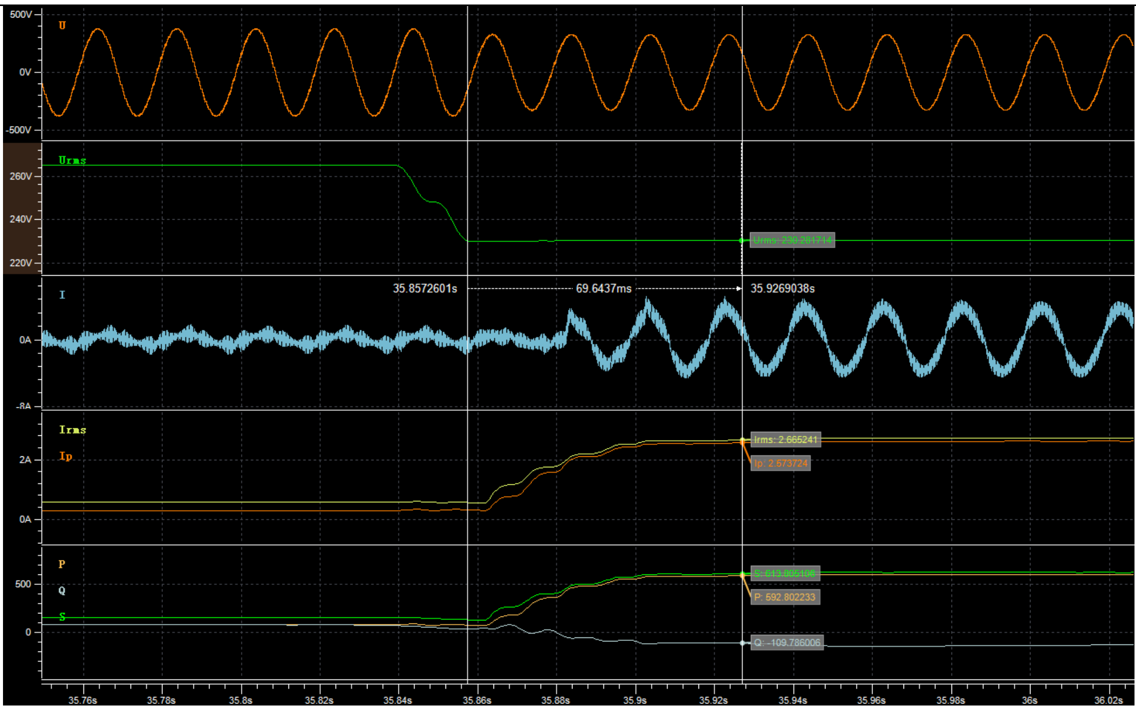


During dip (t1+60ms)

During dip (t1+100ms)

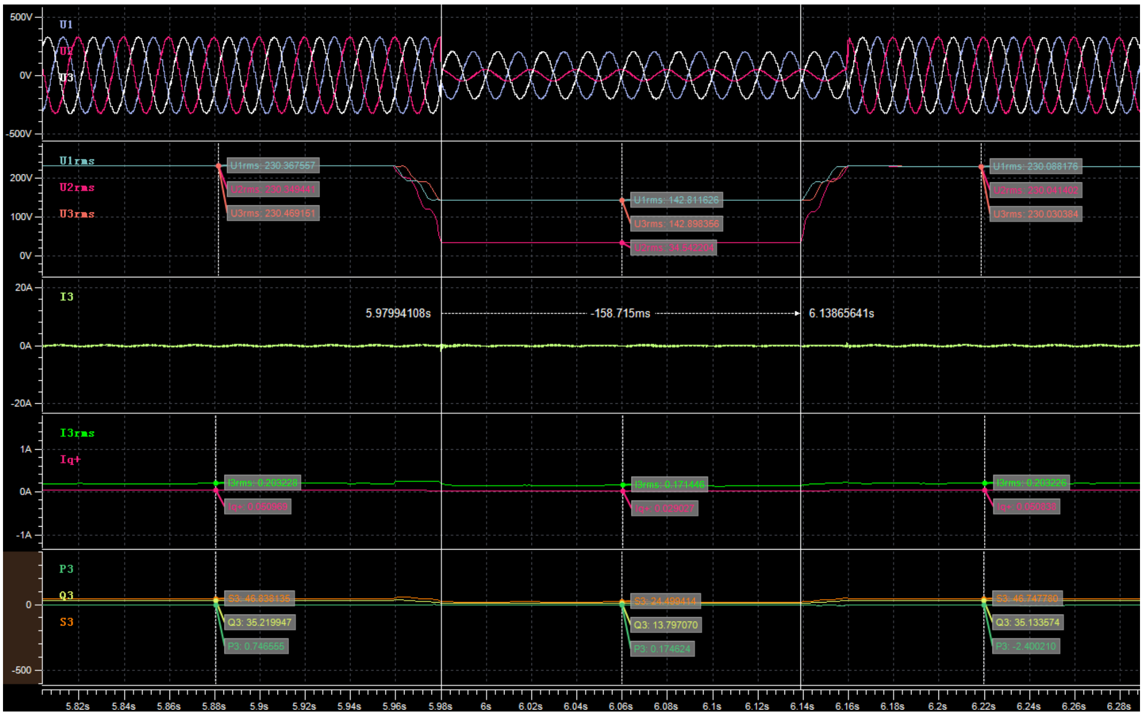


After dip(t2+3s)

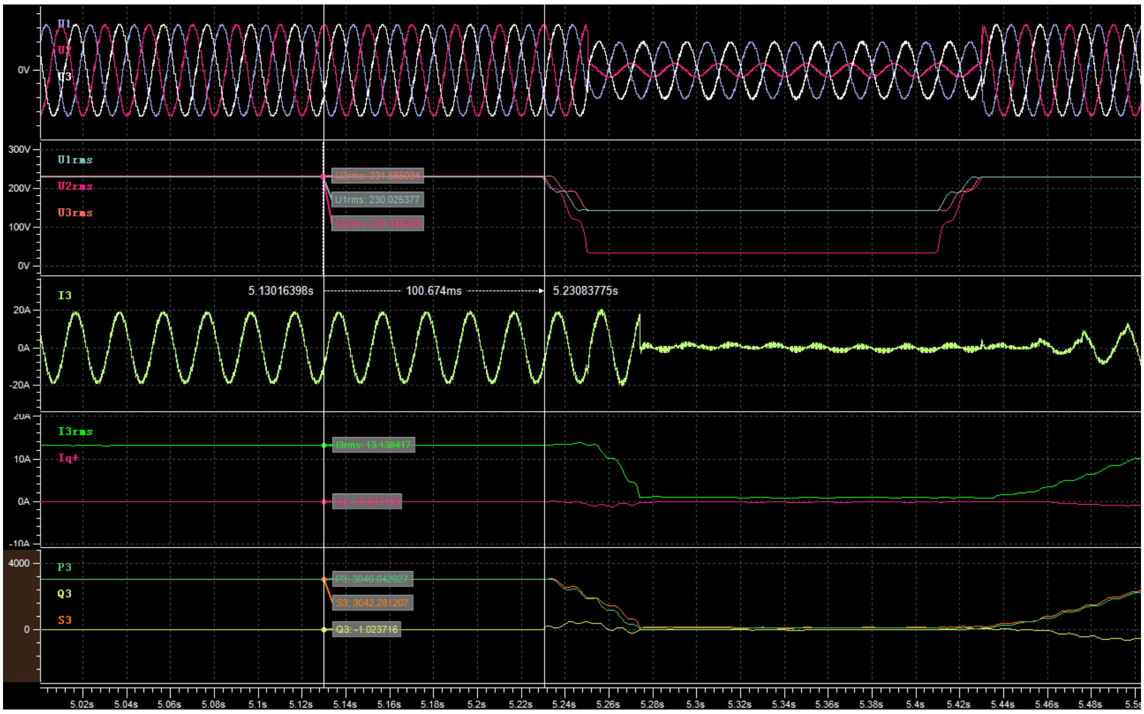


Recovery time

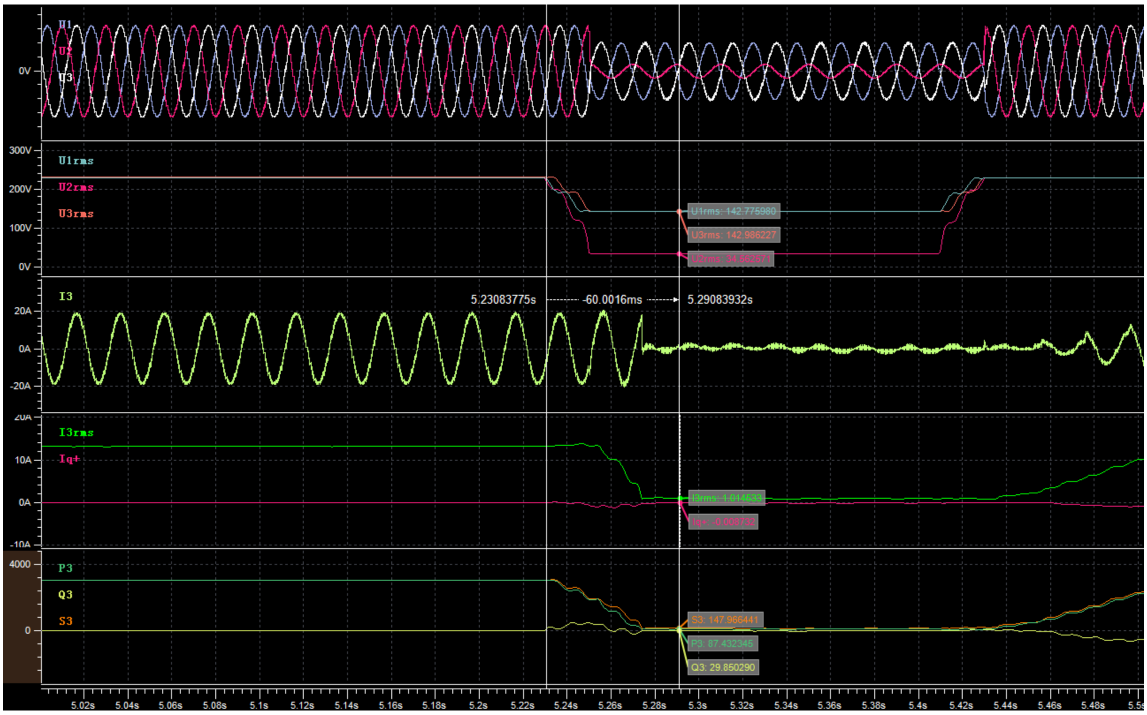
Graph of Test number 1.3_0.15Un



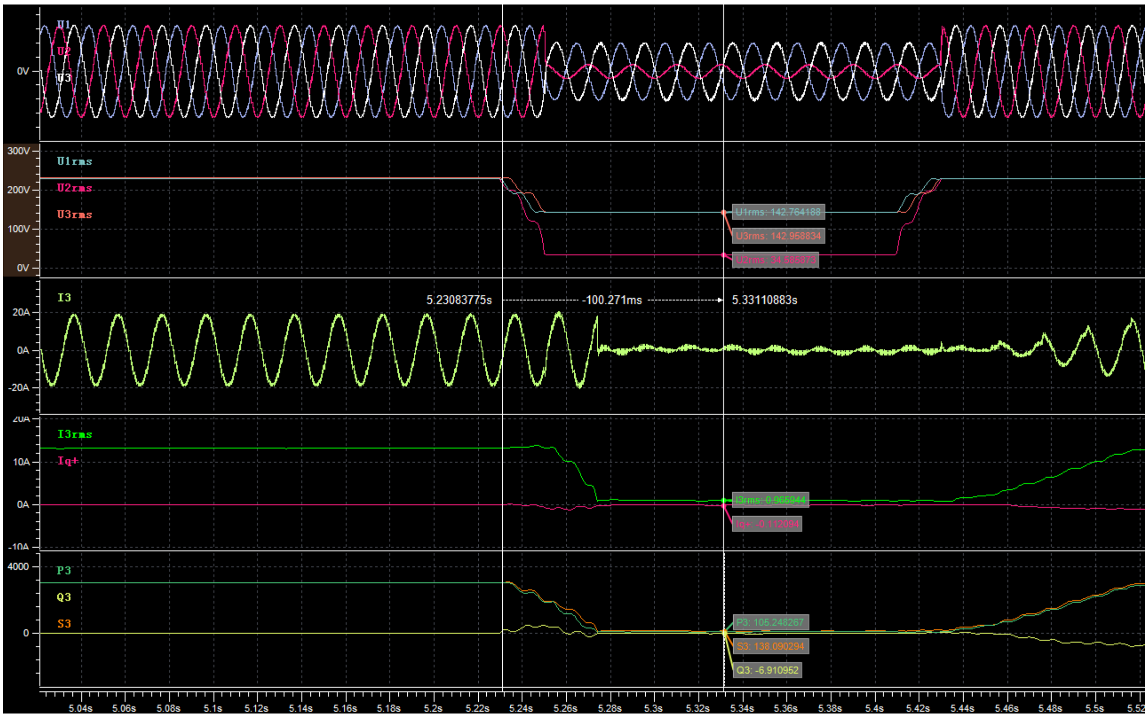
Empty Load



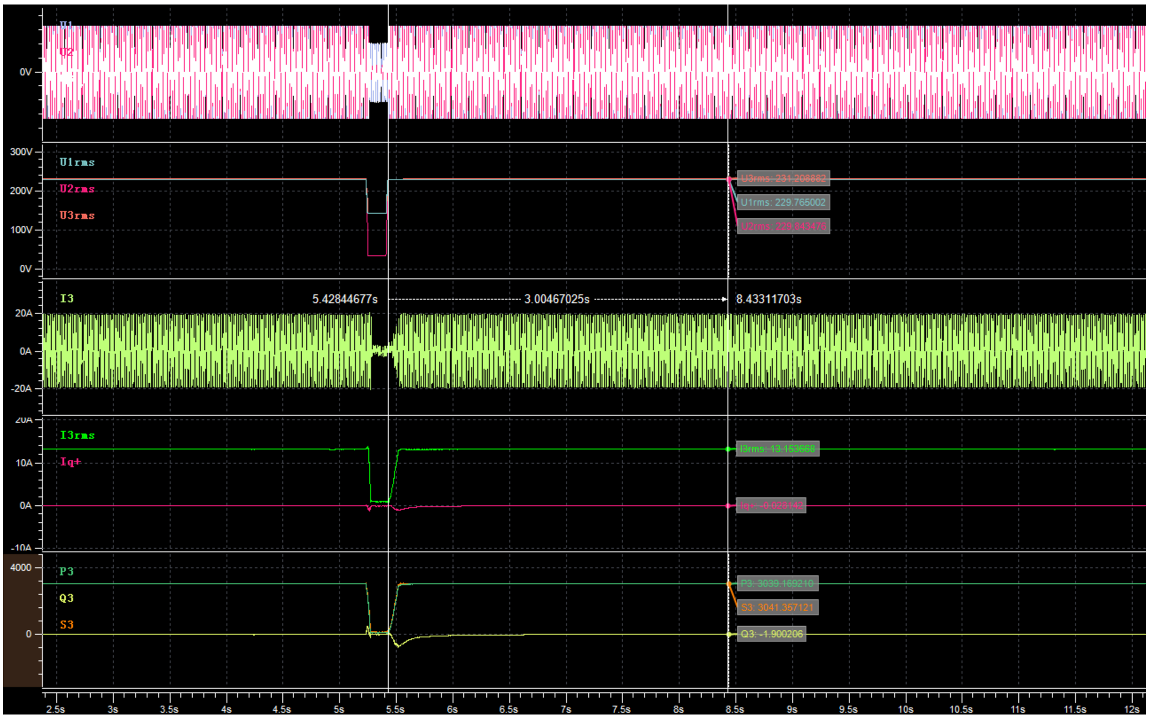
Before dip (t1-100ms)



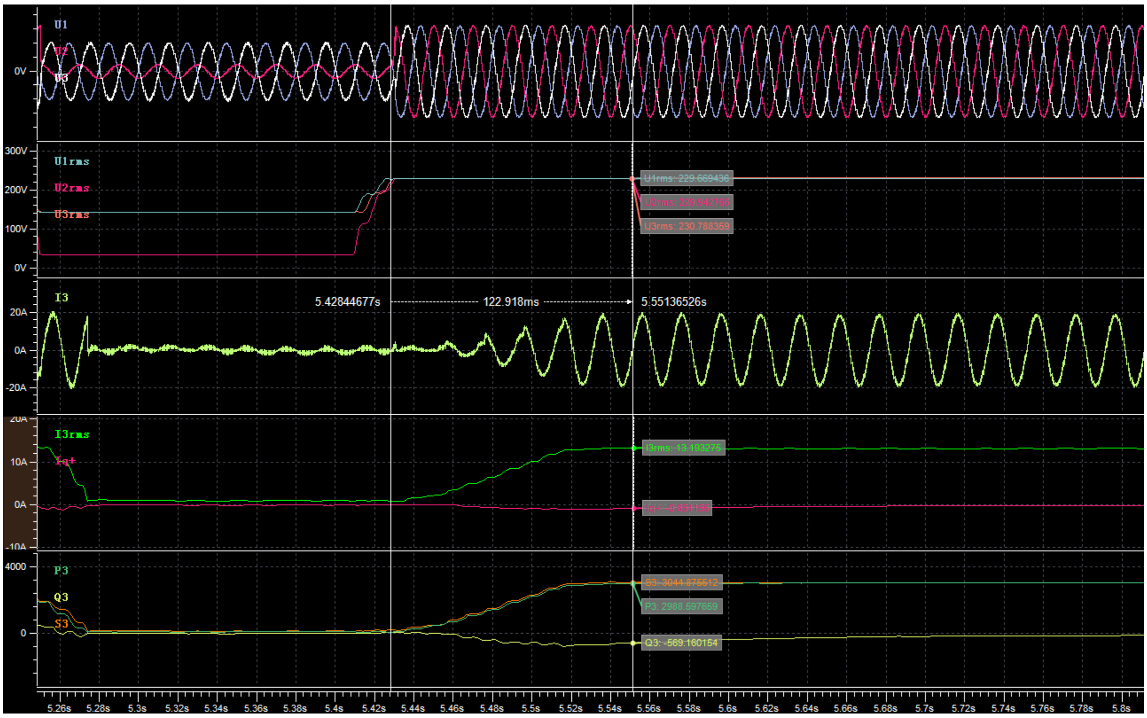
During dip (t1+60ms)



During dip (t1+100ms)

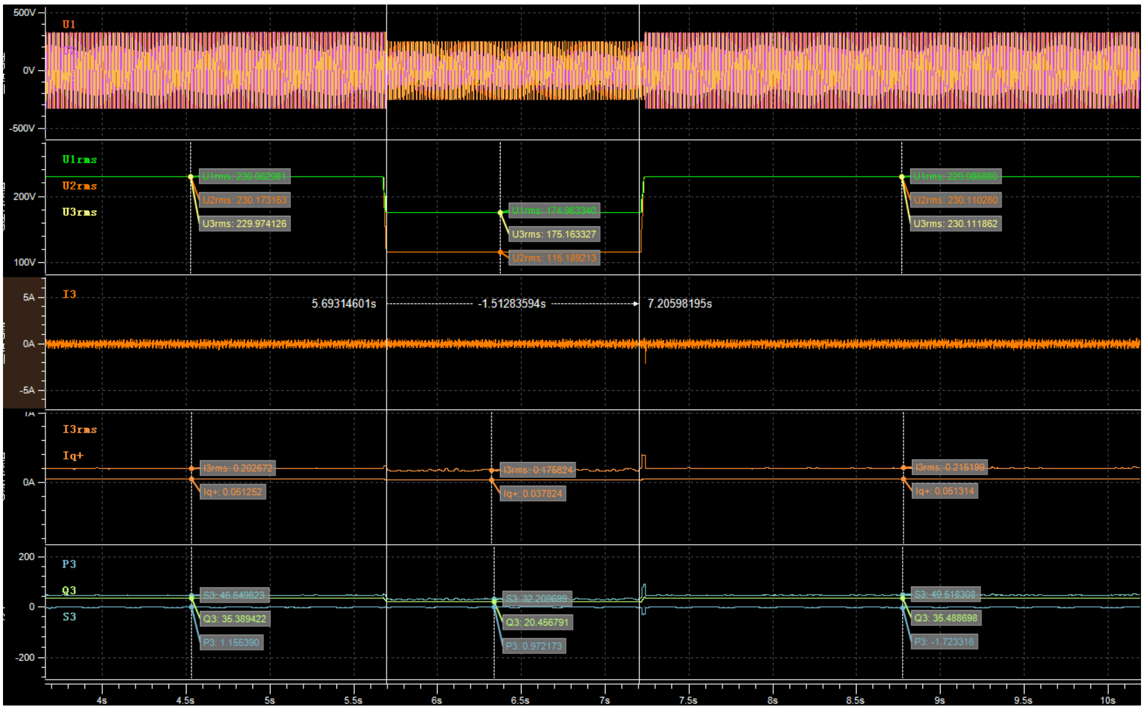


After dip(t2+3s)

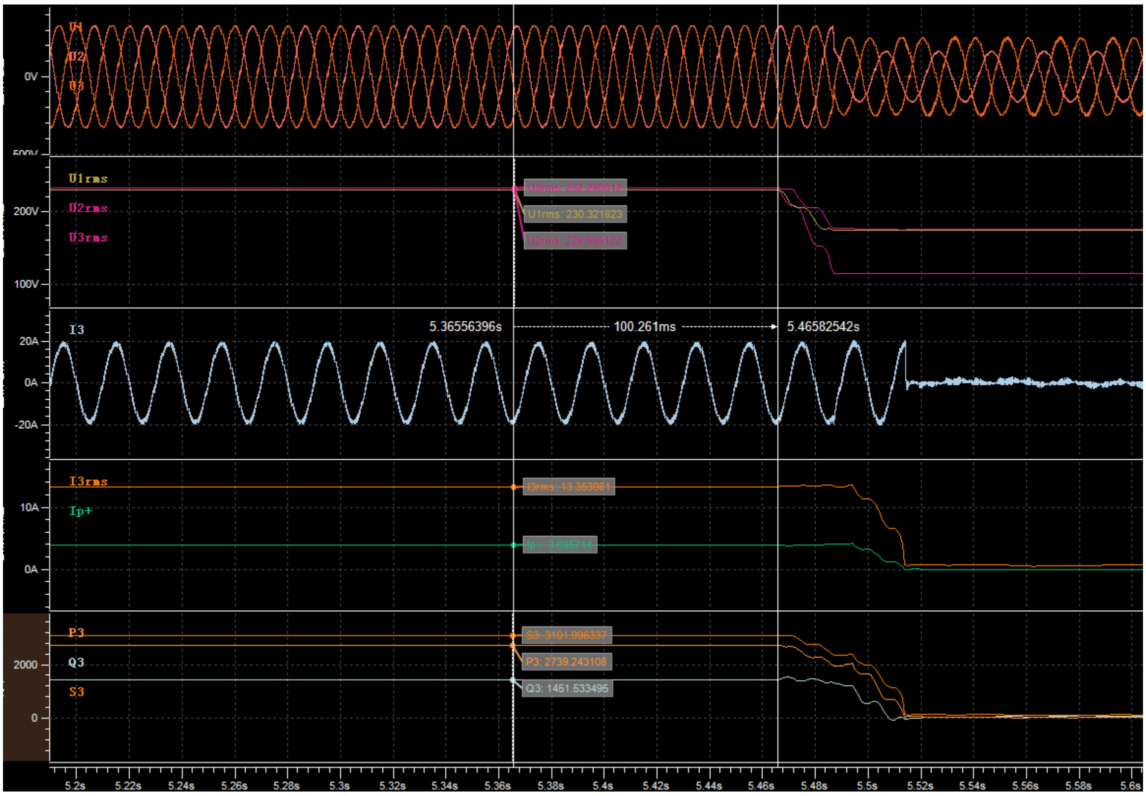


Recovery time

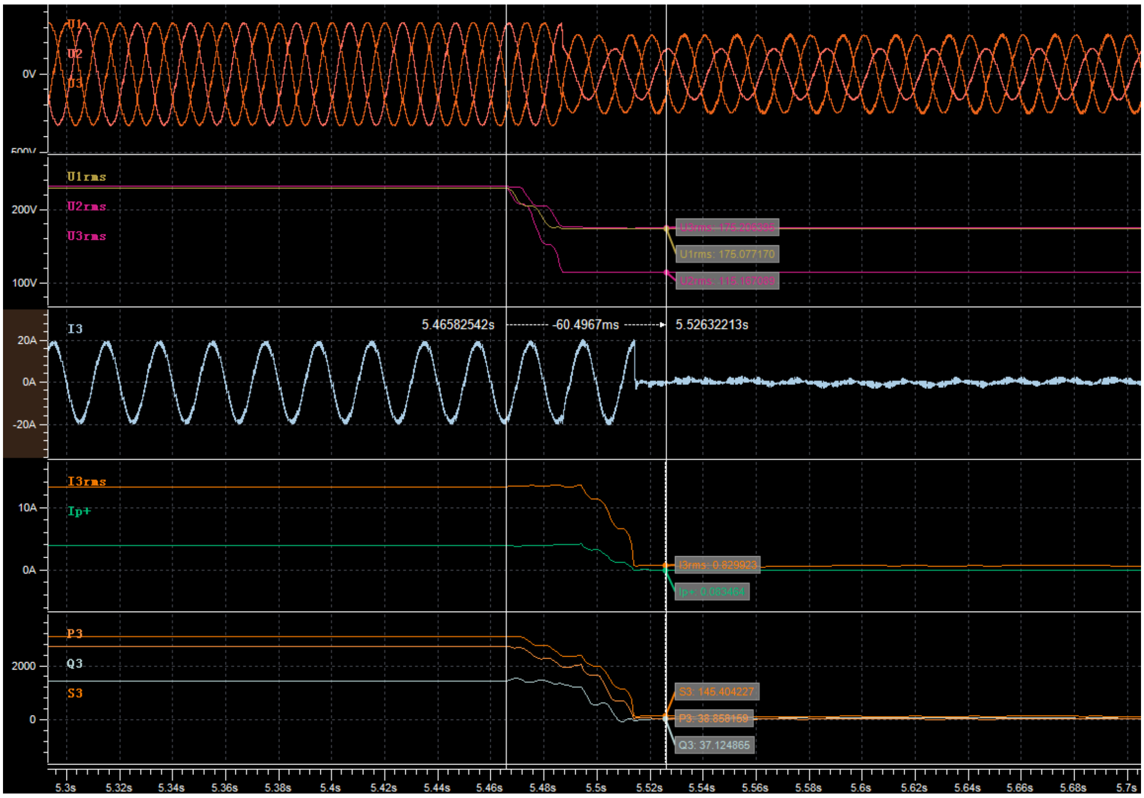
Graph of Test number 2.3_0.50Un



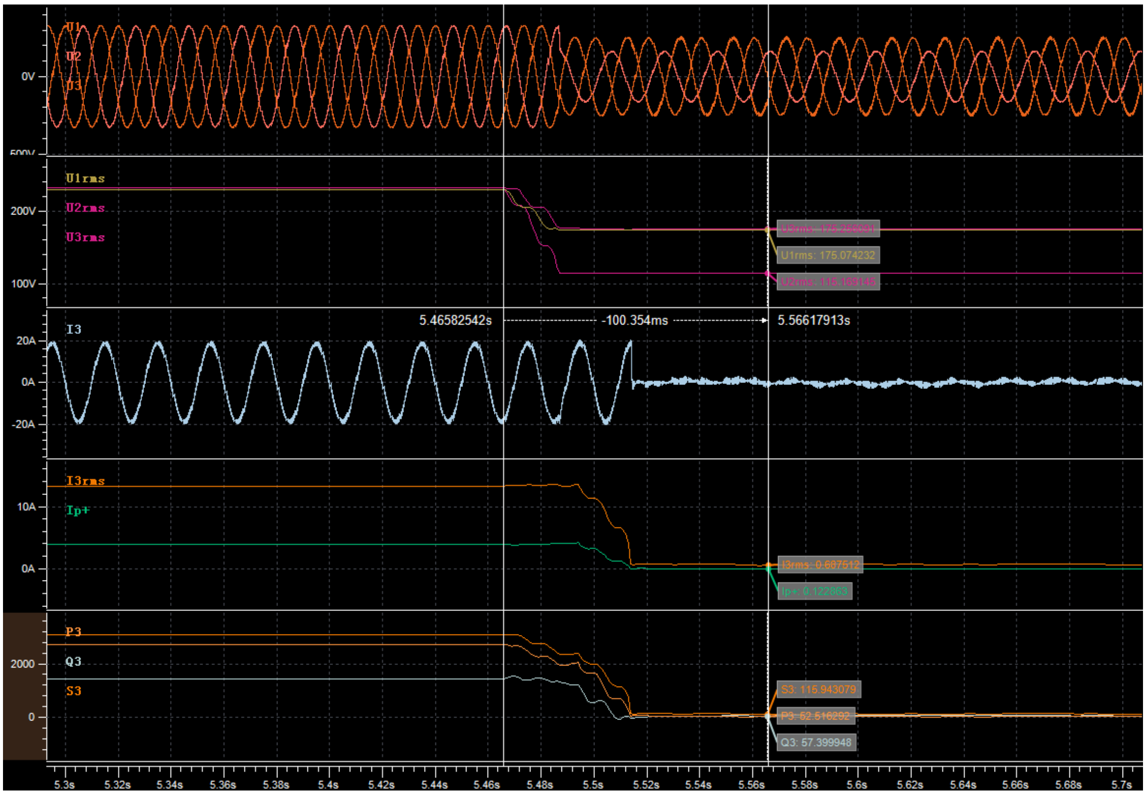
Empty Load



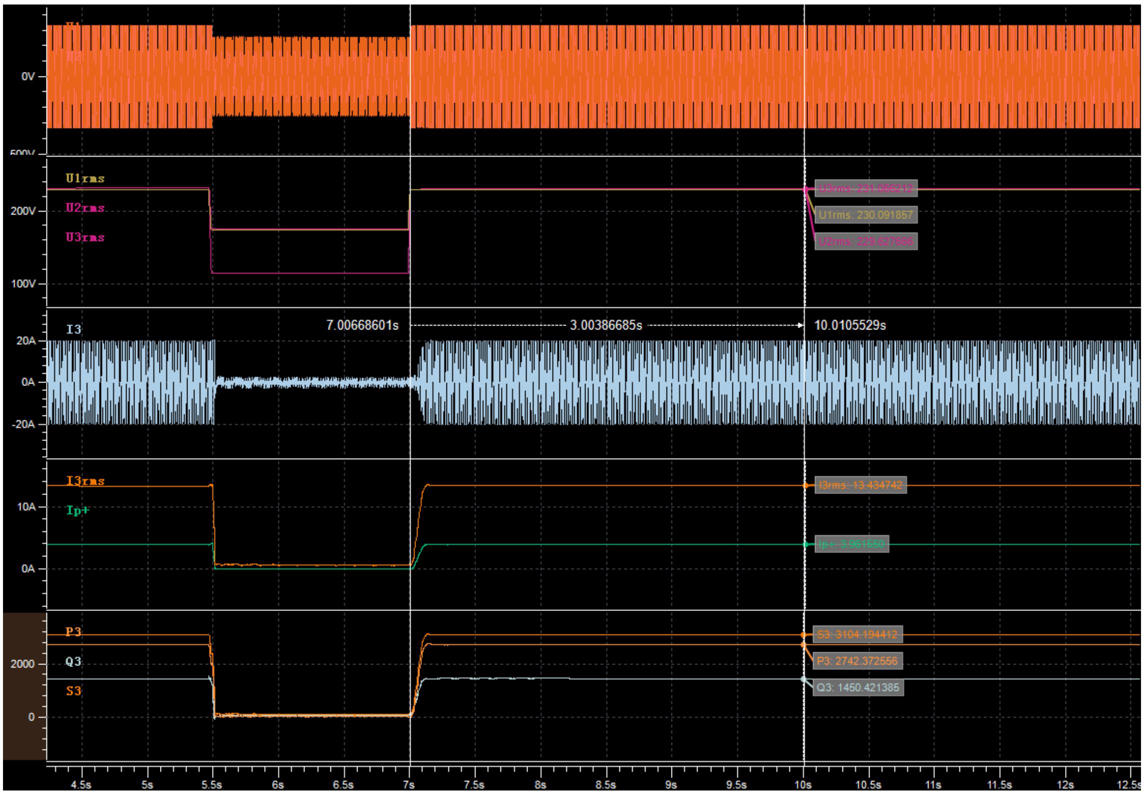
Before dip (t1-100ms)



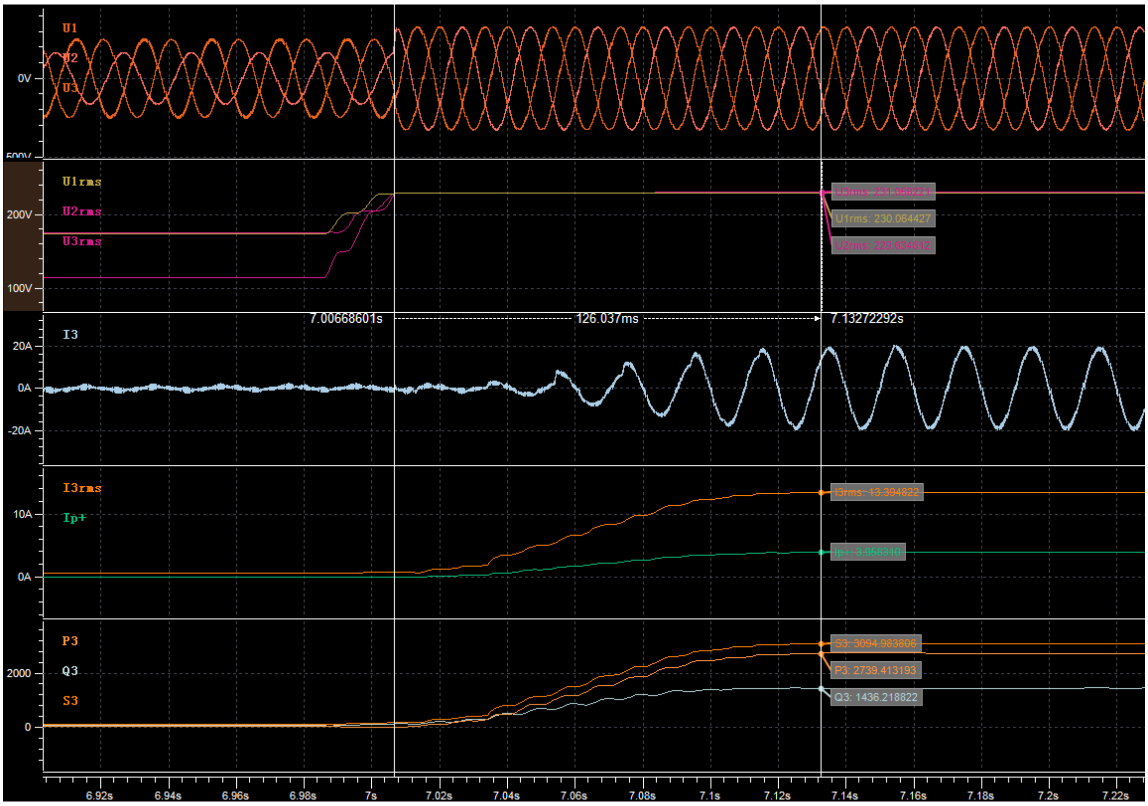
During dip (t1+60ms)



During dip (t1+100ms)



After dip(t2+3s)

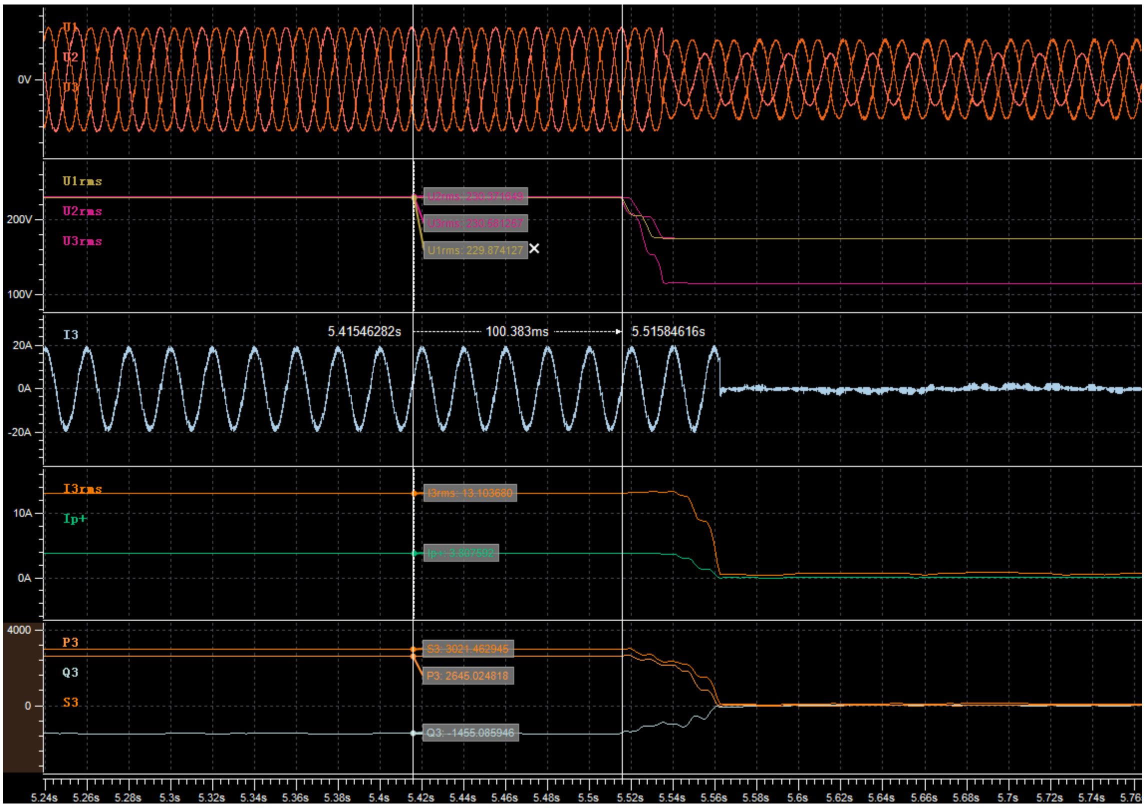


Recovery time

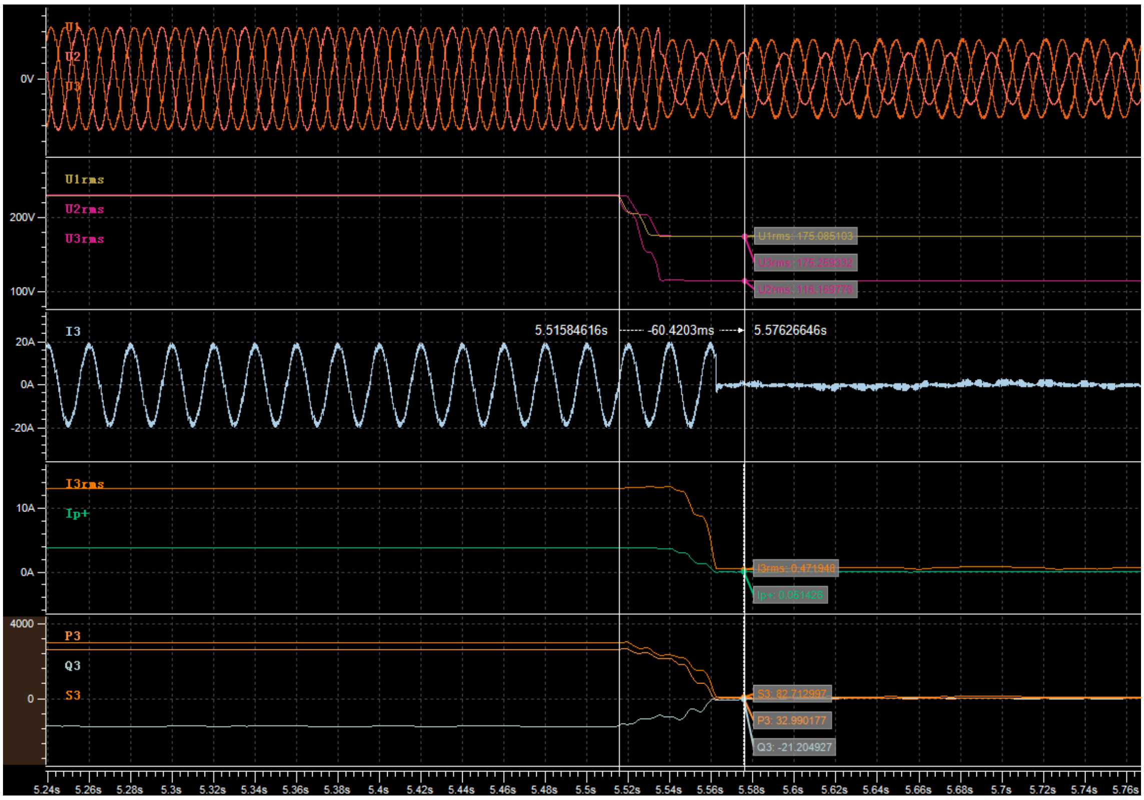
Verification of dynamic network support										P
Short-circuited power at generator terminal [VA]			10K							
NS protection settings			See table 5.5 for detail.							
	No.	Parameter	Phase ref.	Time ref.	unit	Result				
General Info.	0	Test number	--	--	--	3.3	4.3	5.3	6.3	
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020				
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph				
	3	Fault type (phase)	--	--		D1	D1	D1	D1	
	4	Setting voltage depth	Line to line	--	p.u.	0.50	0.85	1.25	1.20	
	5	Setting dip duration		--	ms	1500	60000	100	5000	
	6	Point of fault entry	Total	--	ms	20ms				
	7	Point of fault clearance	Total	--	ms	20ms				
	8	Fault duration in empty load test	Total	--	ms	1512.84	60020	100.11	5004.74	
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.76	0.93	1.08	1.06	
						0.50	0.85	1.25	1.20	
						0.76	0.93	1.06	1.05	
	10		Positive sequence		p.u.	0.67	0.90	1.13	1.11	
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.00	1.00	1.00	1.00	
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--	--	--	
	13	Active power	Total	t1-10s to t1	p.u.	0.882	1.014	1.013	1.015	
	14		Positive sequence			--	--	--	--	
	15	Reactive power	Total	t1-10s to t1	p.u.	-0.485	0.000	0.000	-0.001	
	16		Positive sequence			--	--	--	--	
	17	Cosφ	--	t1-10s to t1	--	0.8754	0.9993	0.9993	0.9993	

During dip t1 to t2	18	Voltage	Phase 1	t1+100ms to t2-20ms	p.u.	0.76	0.93	1.08	1.06
			Phase 2			0.50	0.85	1.25	1.20
			Phase 3			0.76	0.93	1.06	1.05
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			0.036	0.080	0.066	0.066
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			0.057	0.071	0.058	0.060
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.006	0.007	0.020	0.020
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			0.881	1.013	1.013	1.012
	39	Active power rising time	Positive sequence	--	s	0.149	0.120	0.120	0.126
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			-0.485	-0.001	-0.001	-0.001
	33	Reactive power rising time	Positive sequence	--	s	0.149	0.120	0.120	0.126
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

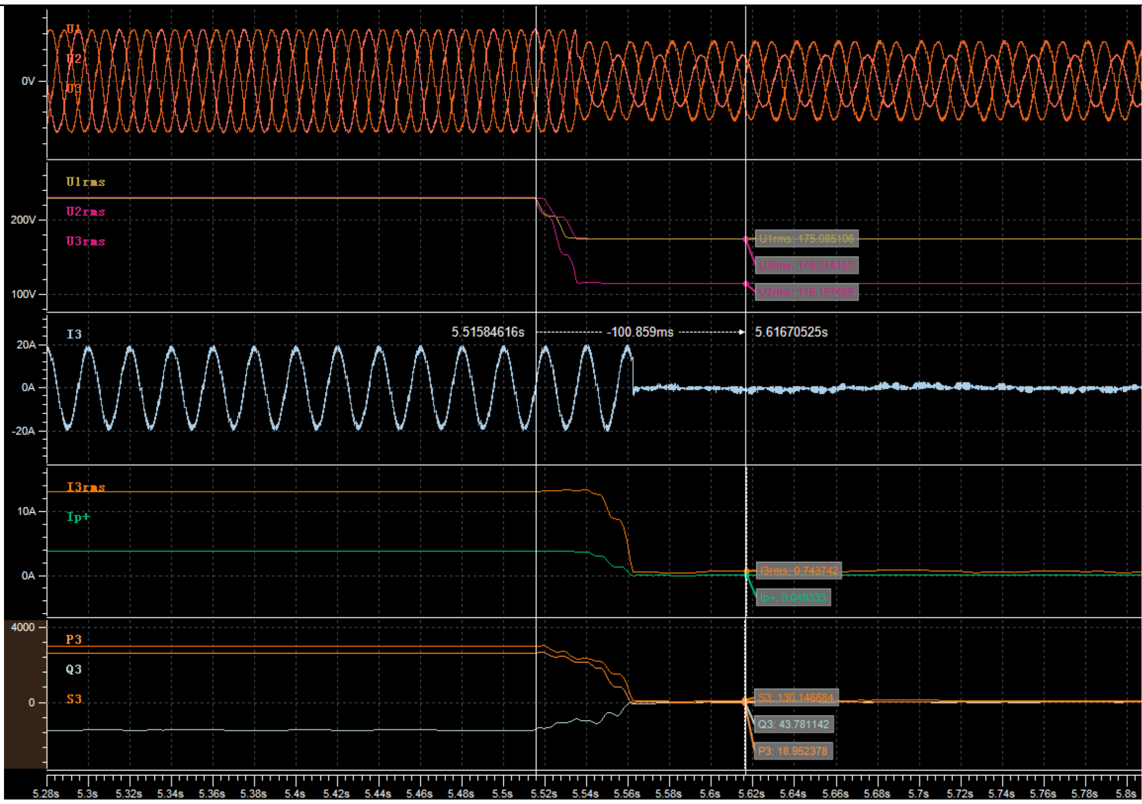
Graph of Test number 3.3_0.5Un



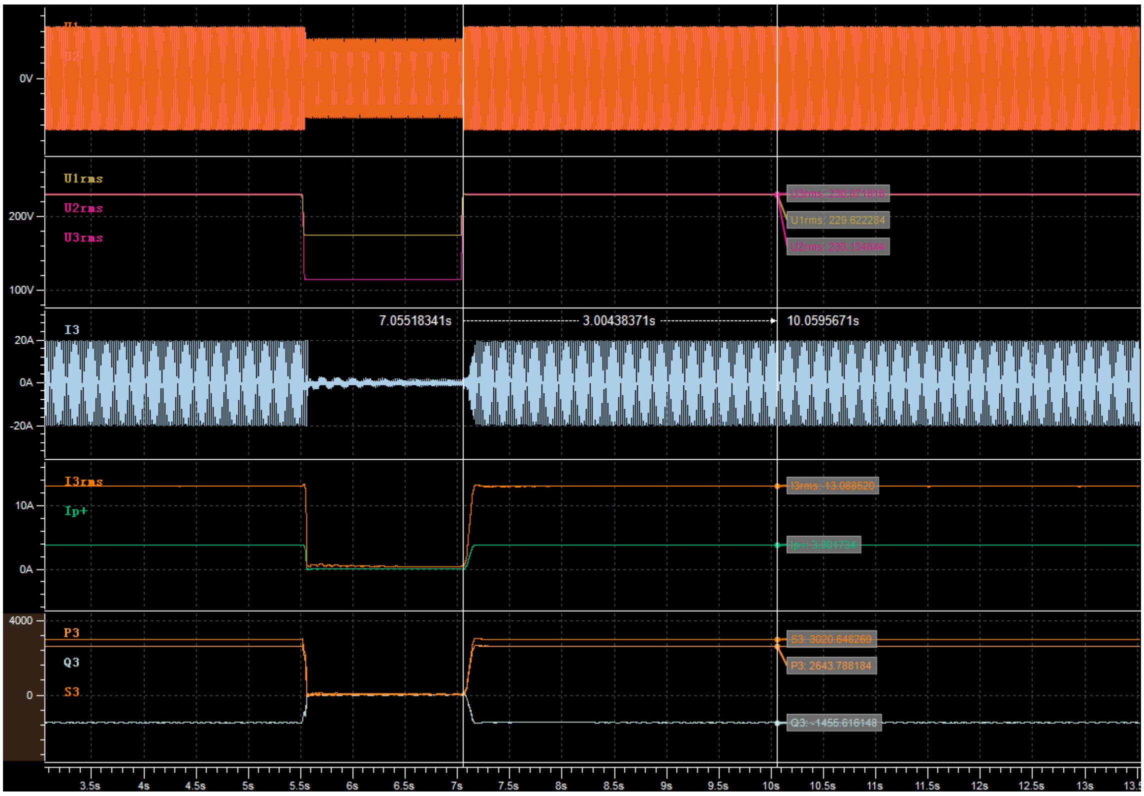
Before dip (t1-100ms)



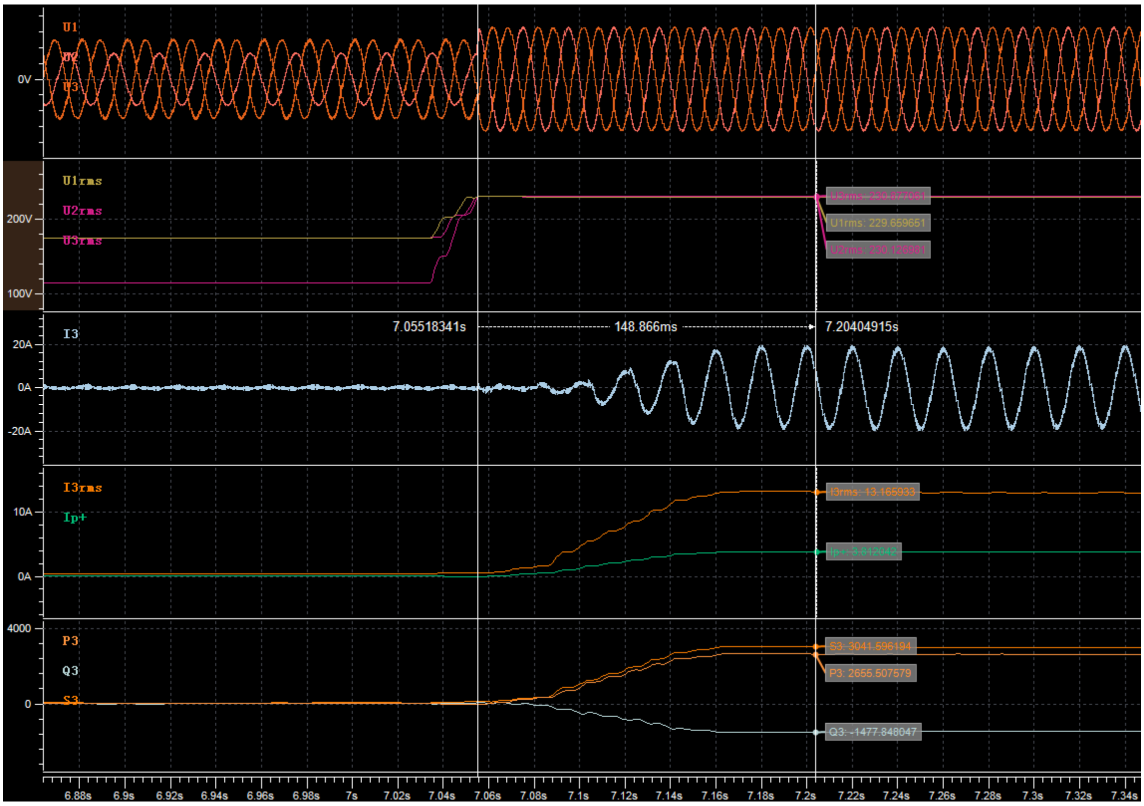
During dip (t1+60ms)



During dip (t1+100ms)

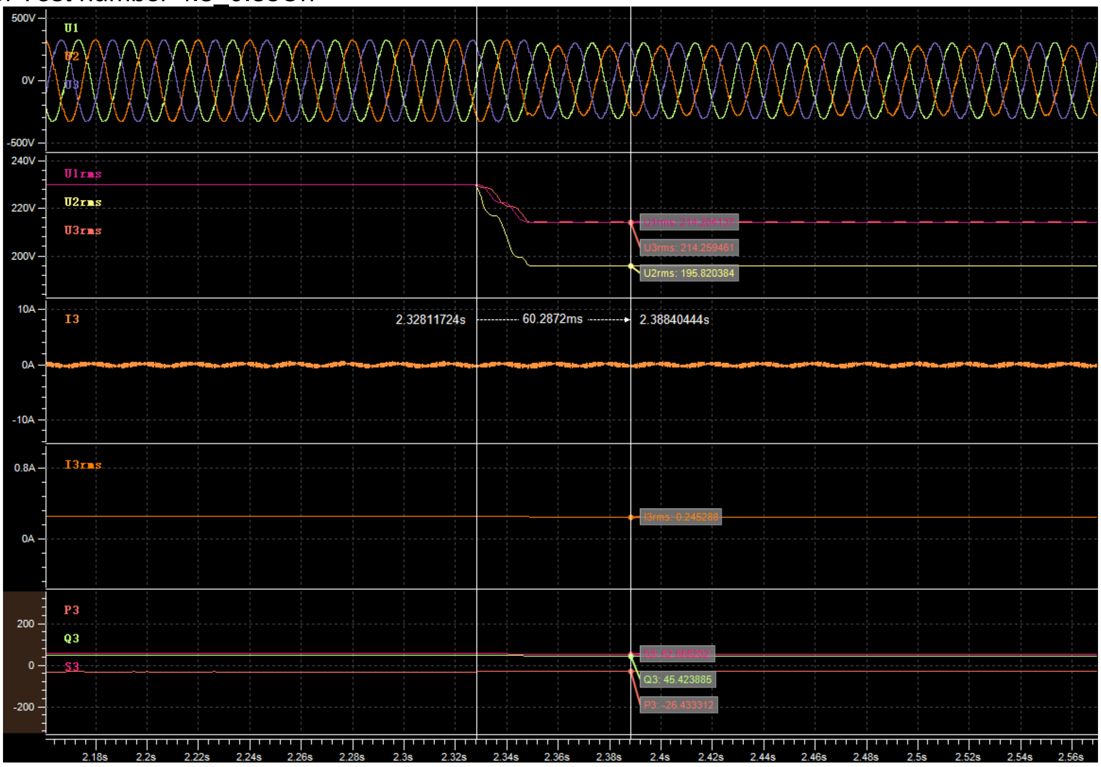


After dip (t2+3s)

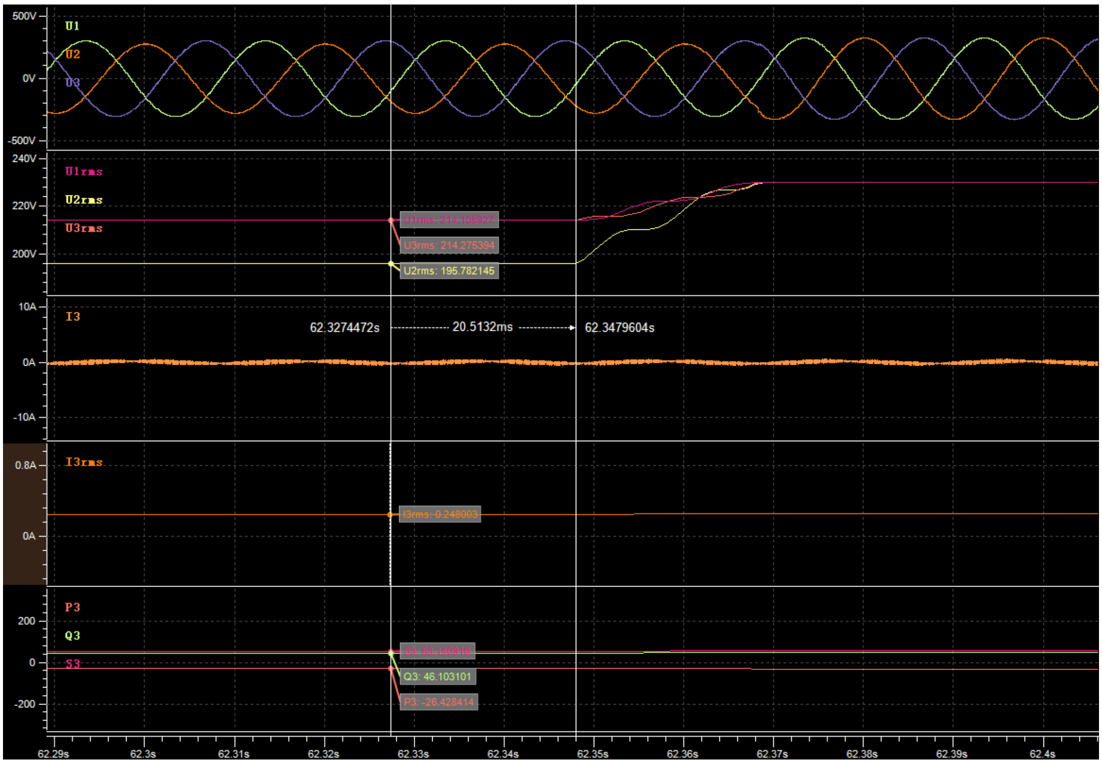


Recovery time

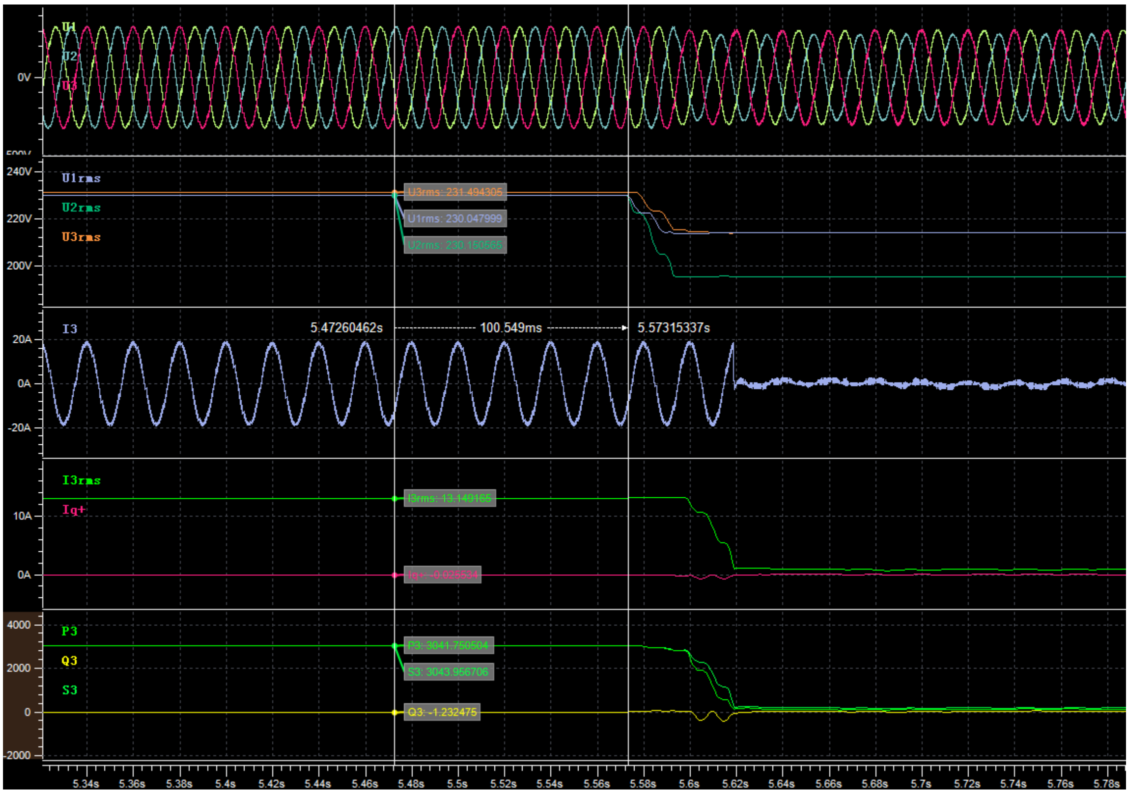
Graph of Test number 4.3_0.85Un



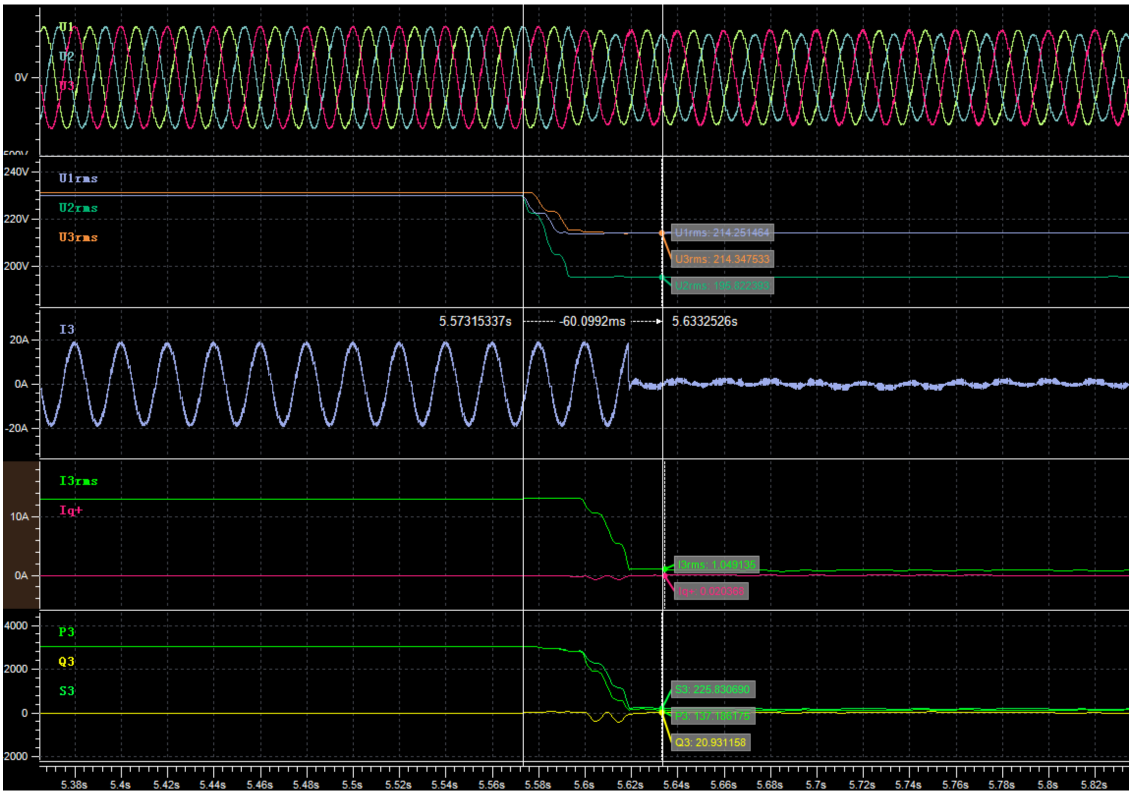
Empty load



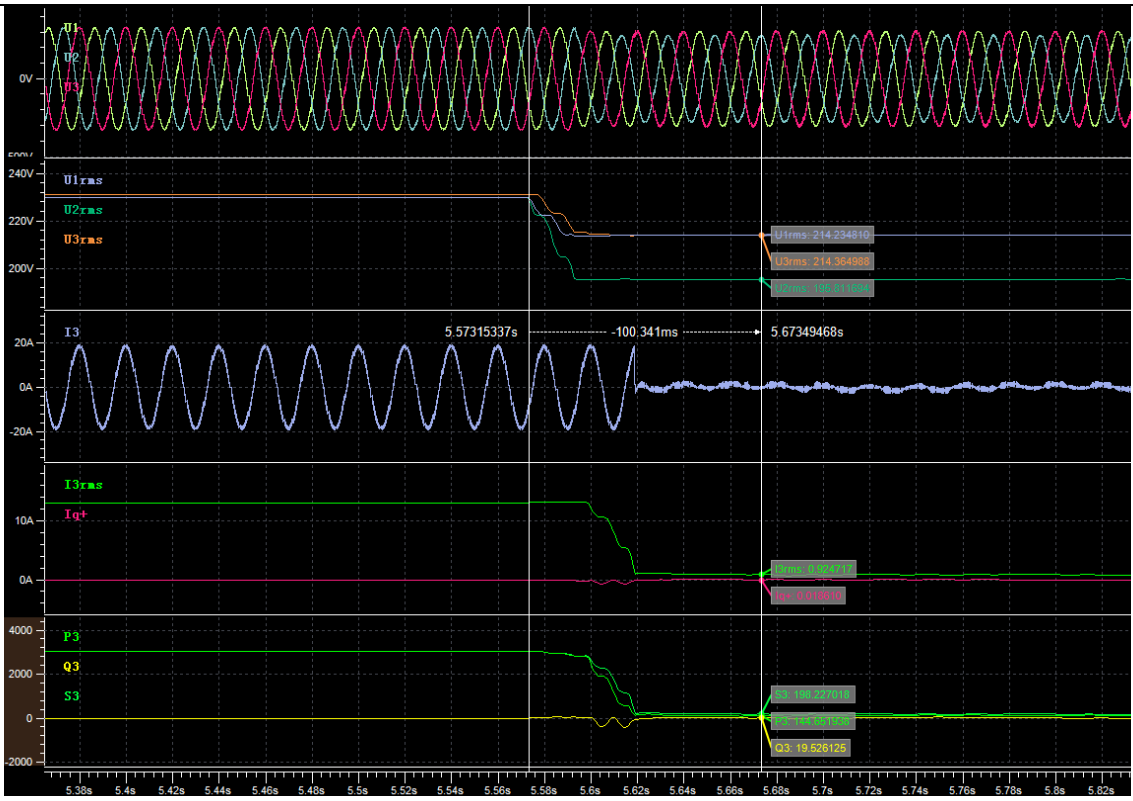
Empty load



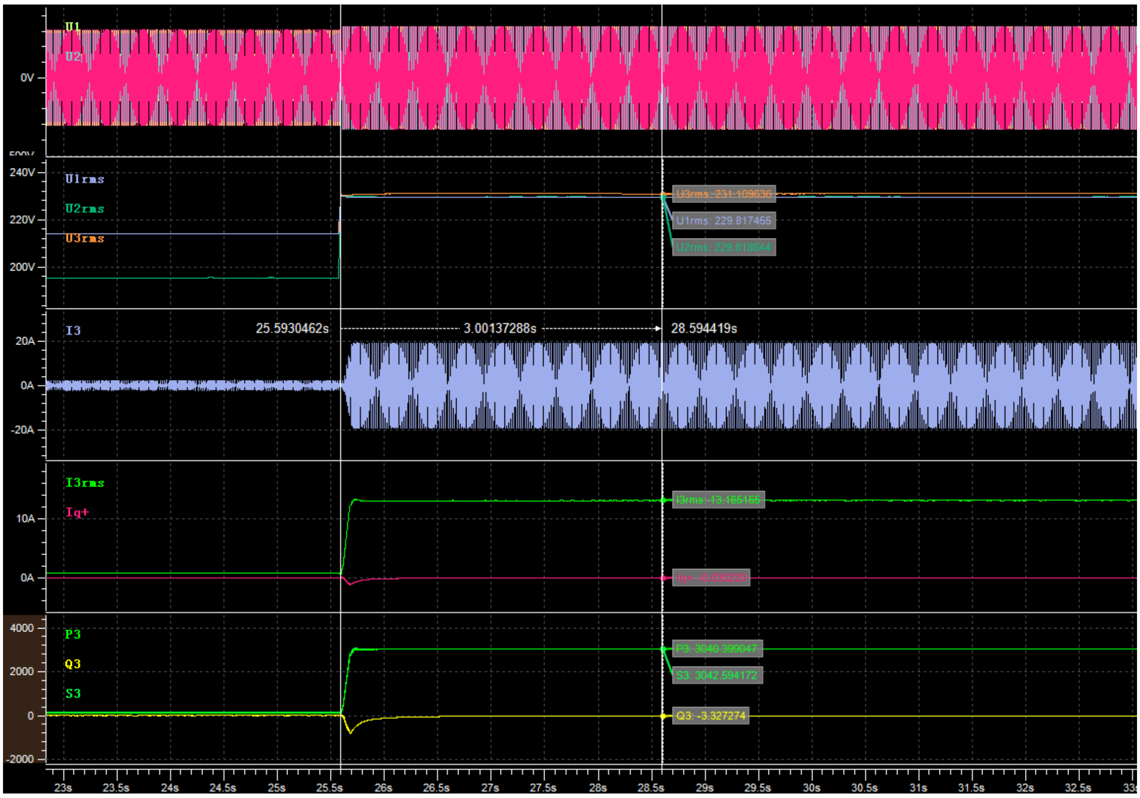
Before dip (t1-100ms)



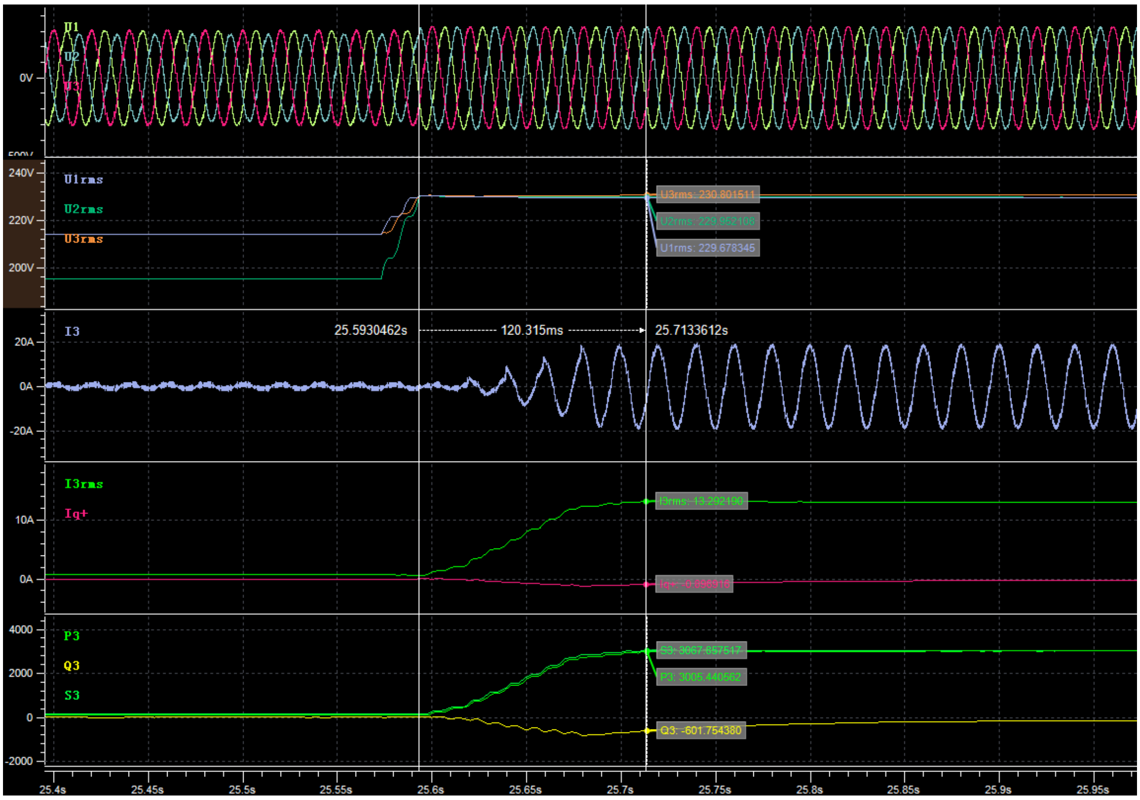
During dip (t1+60ms)



During dip (t1+100ms)

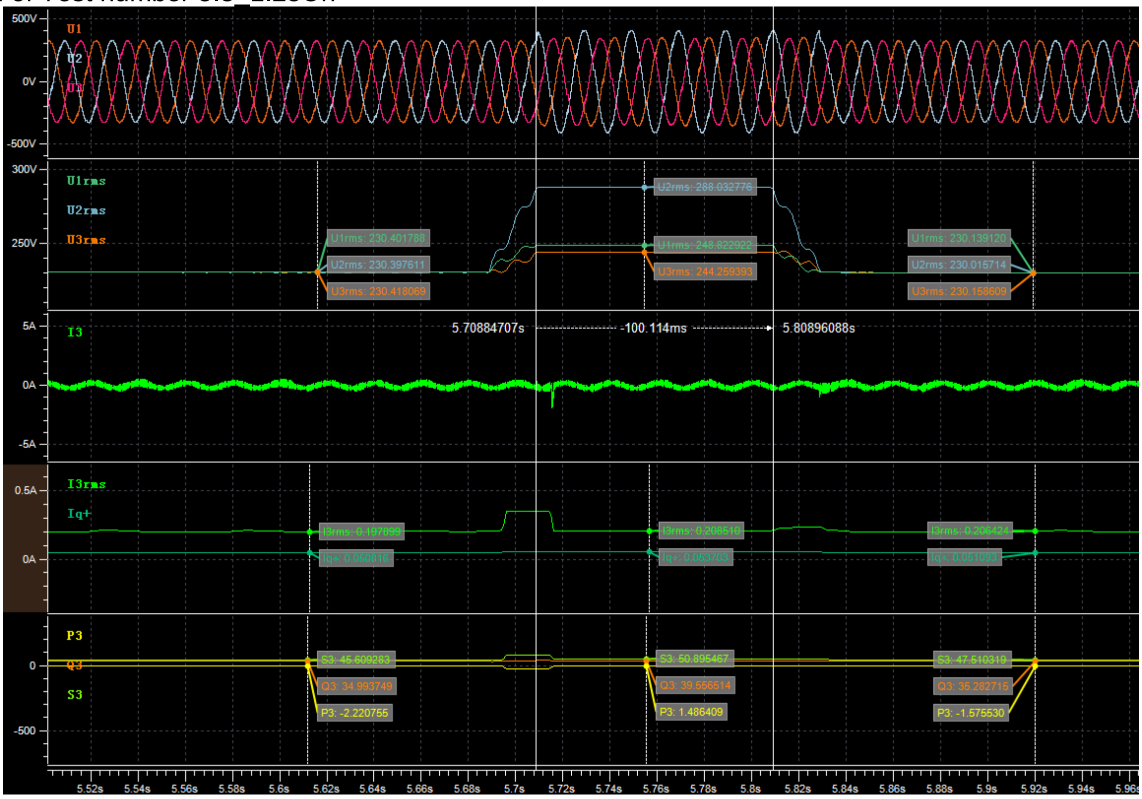


After dip (t2+3s)



Recovery time

Graph of Test number 5.3_1.25Un

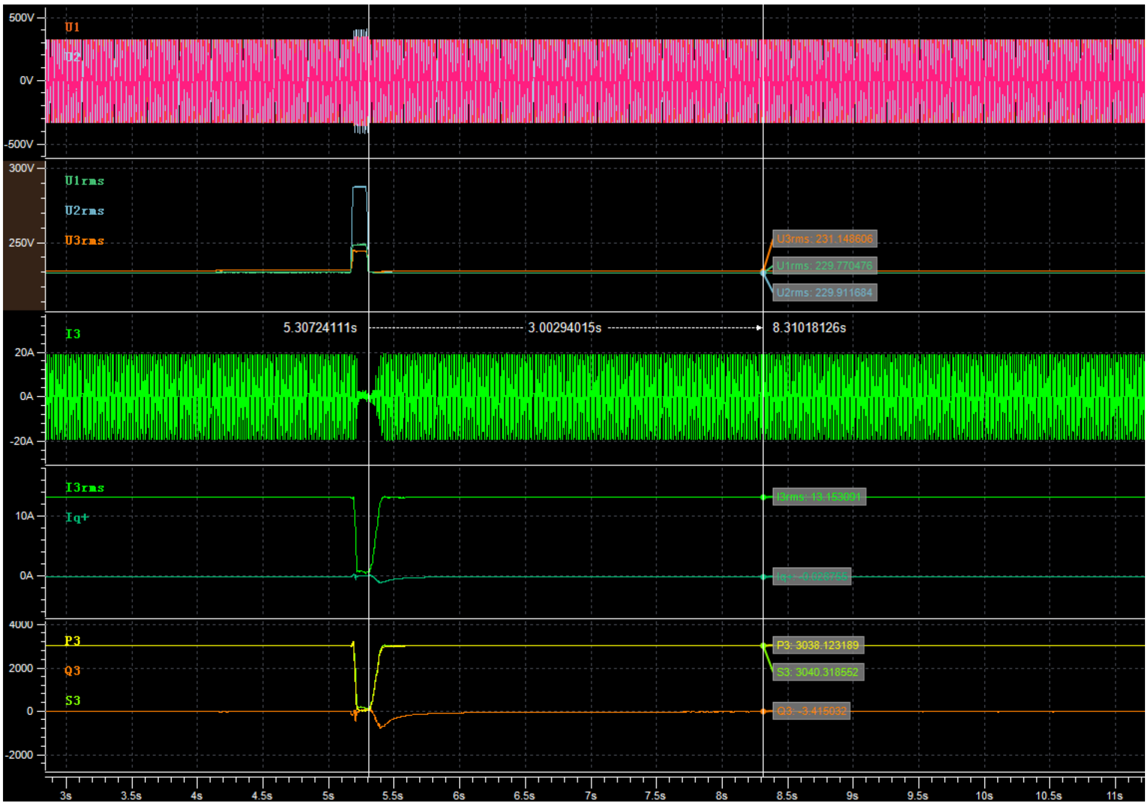


Empty load

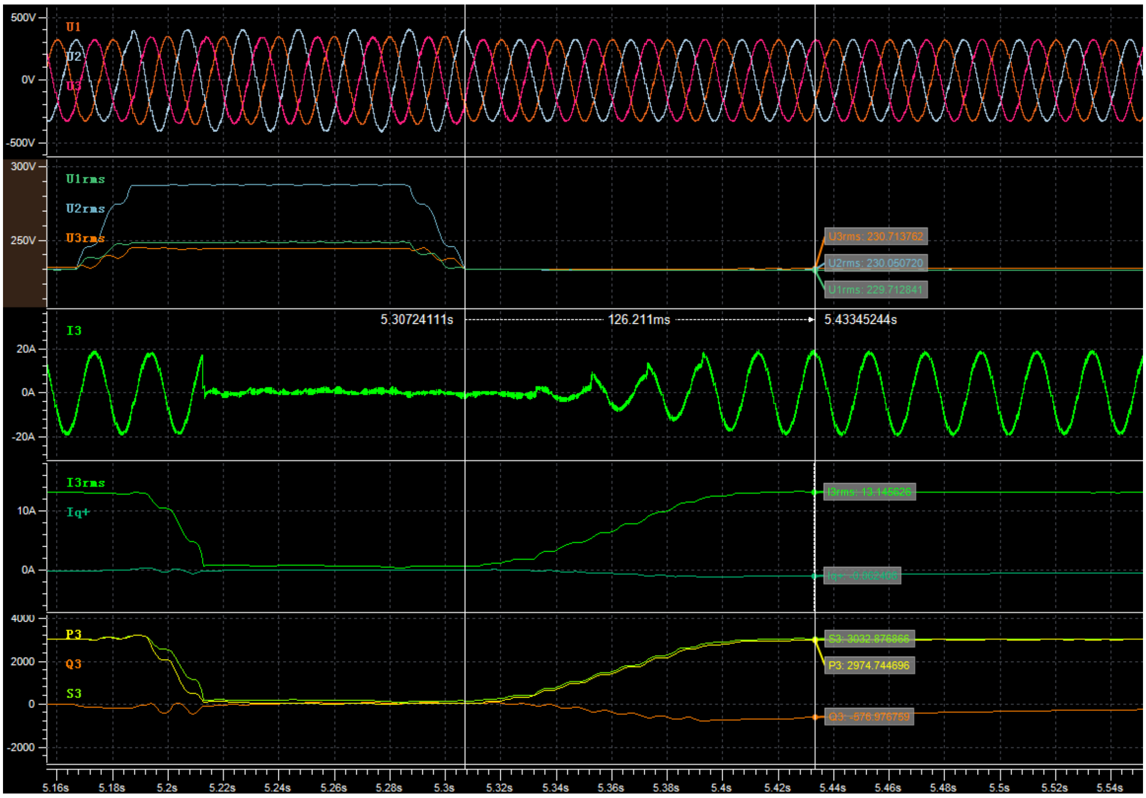
Before dip (t1-100ms)

During dip (t1+60ms)

During dip (t1+100ms)

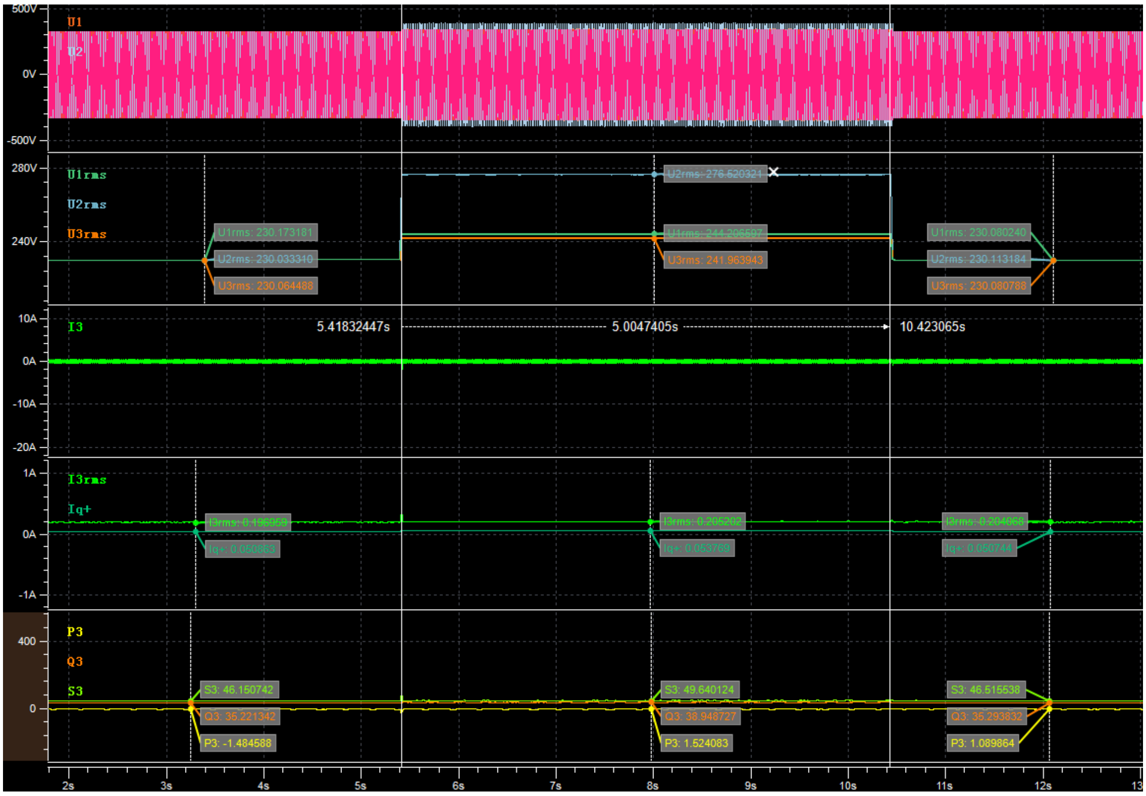


After dip (t2+3s)

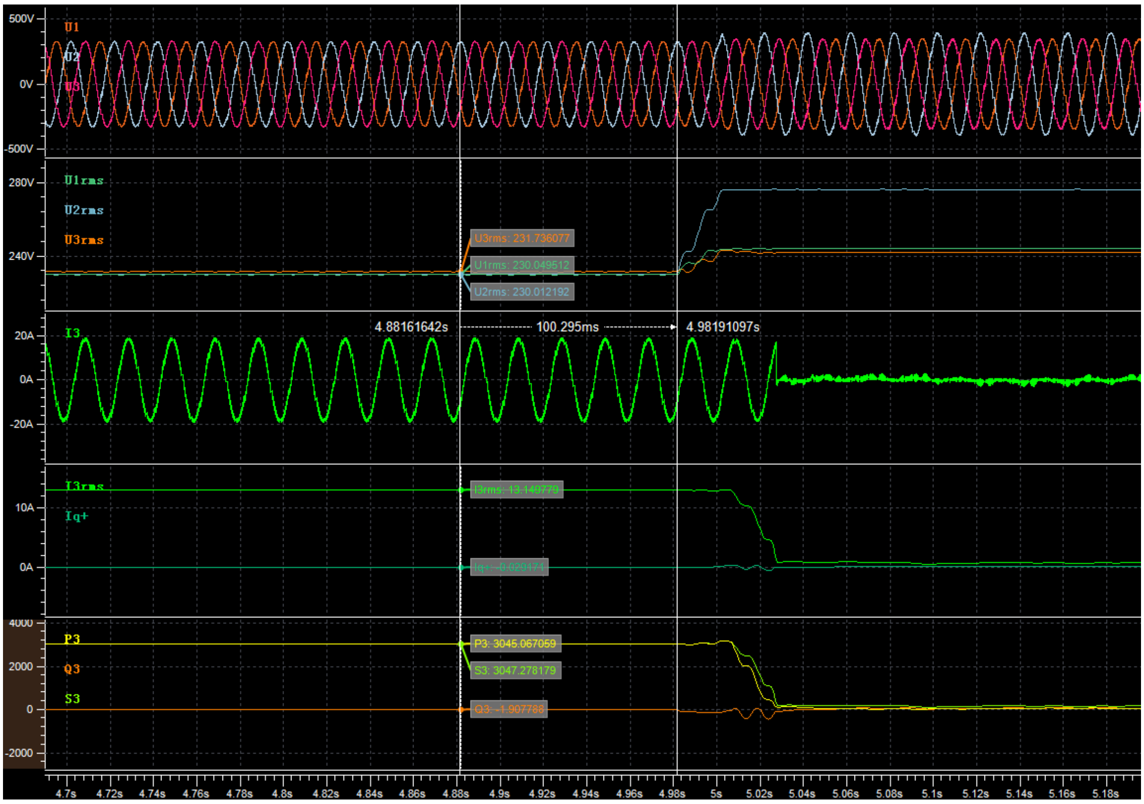


Recovery time

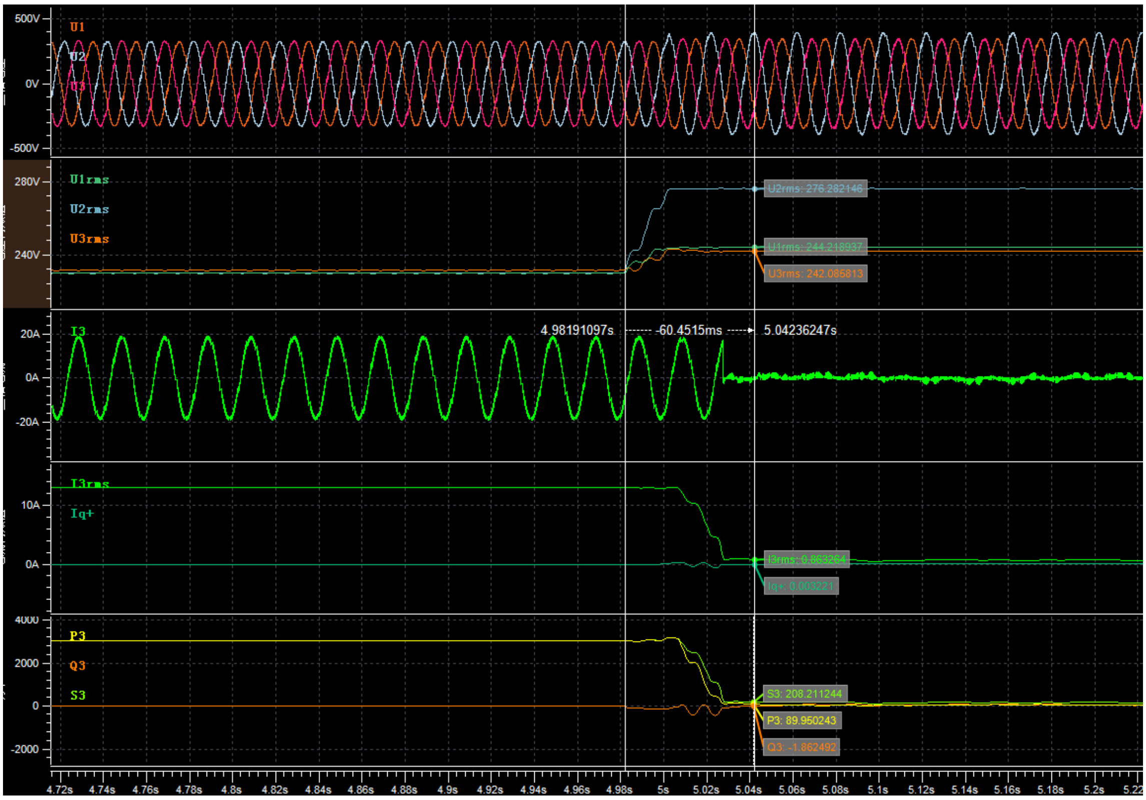
Graph of Test number 6.3_1.20Un



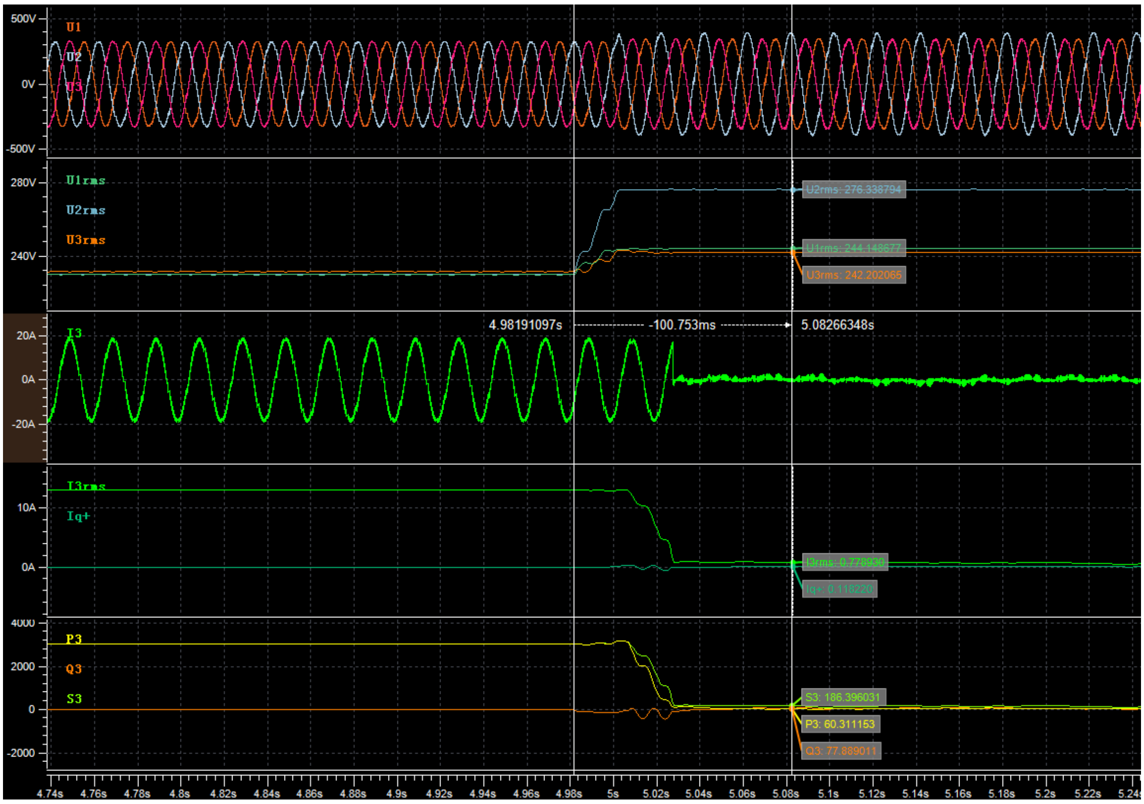
Empty Load



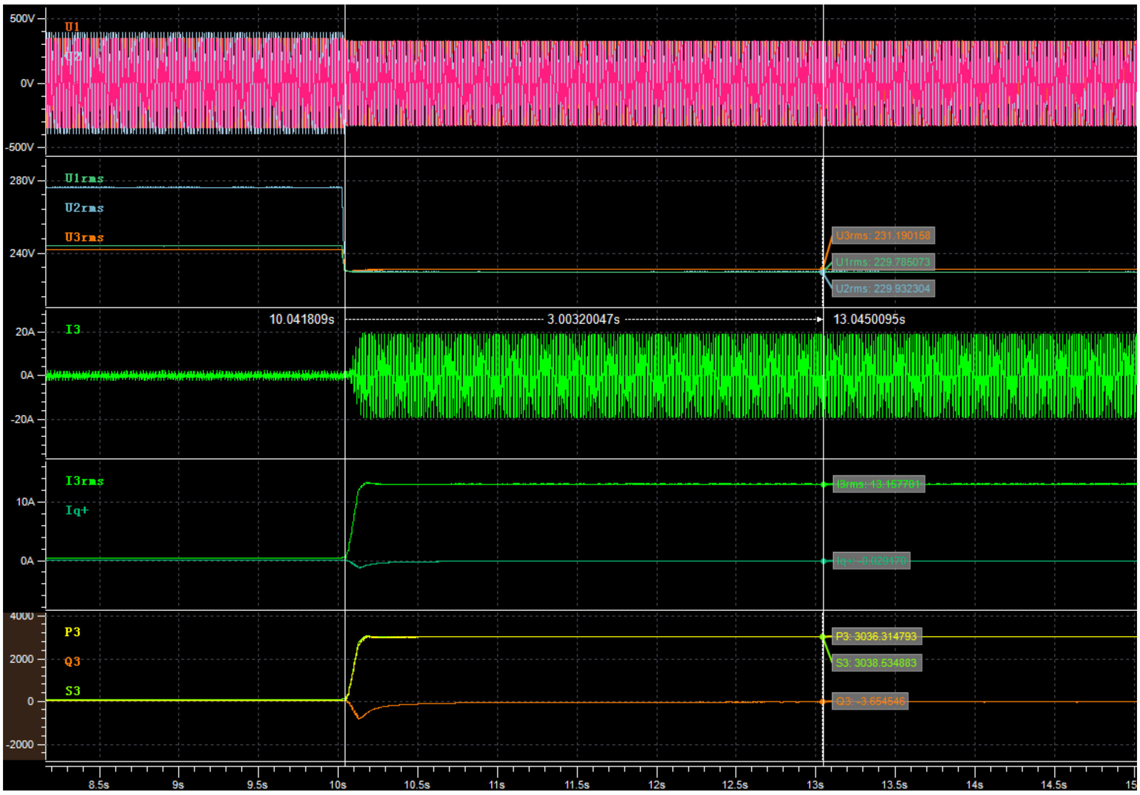
Before dip (t1-100ms)



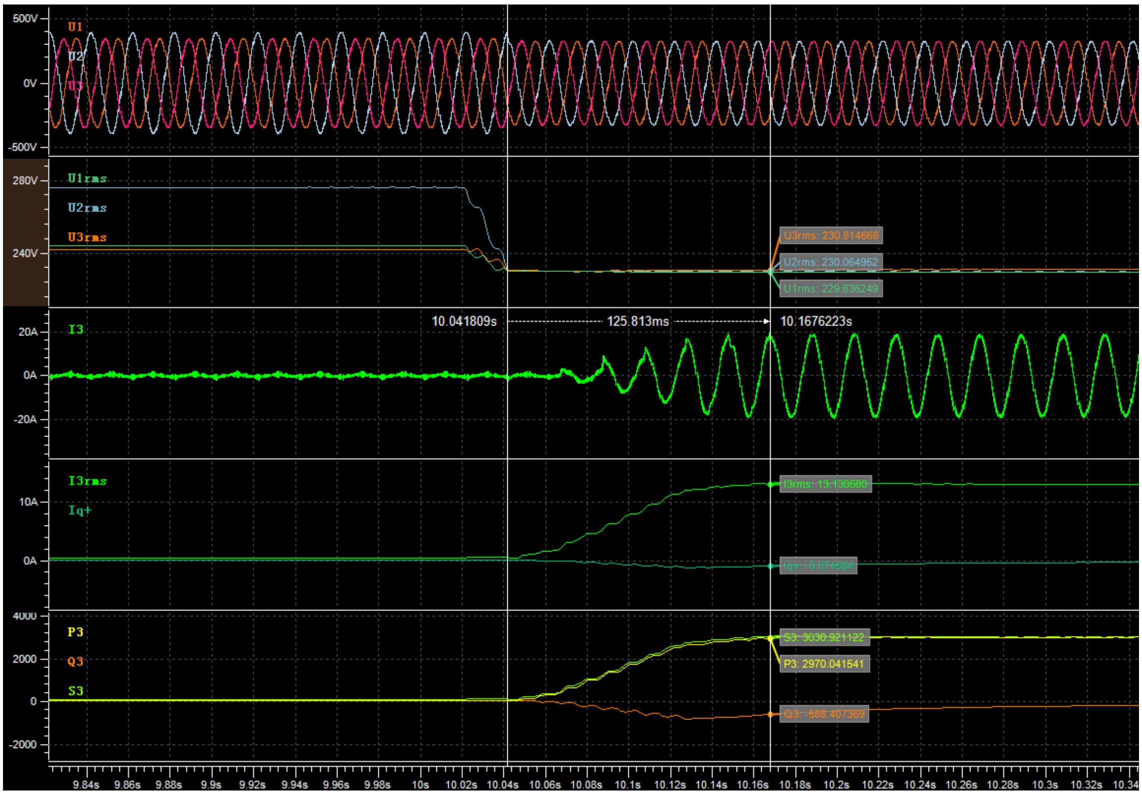
During dip (t1+60ms)



During dip (t1+100ms)



After dip (t2+3s)

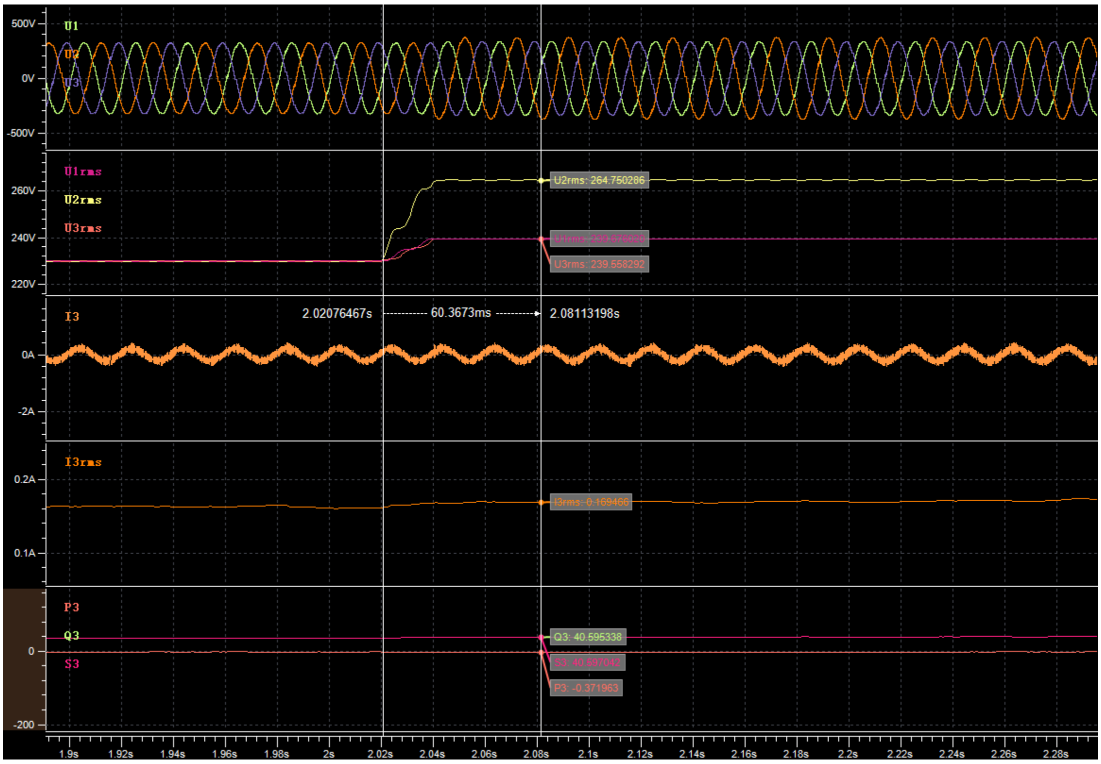


Recovery time

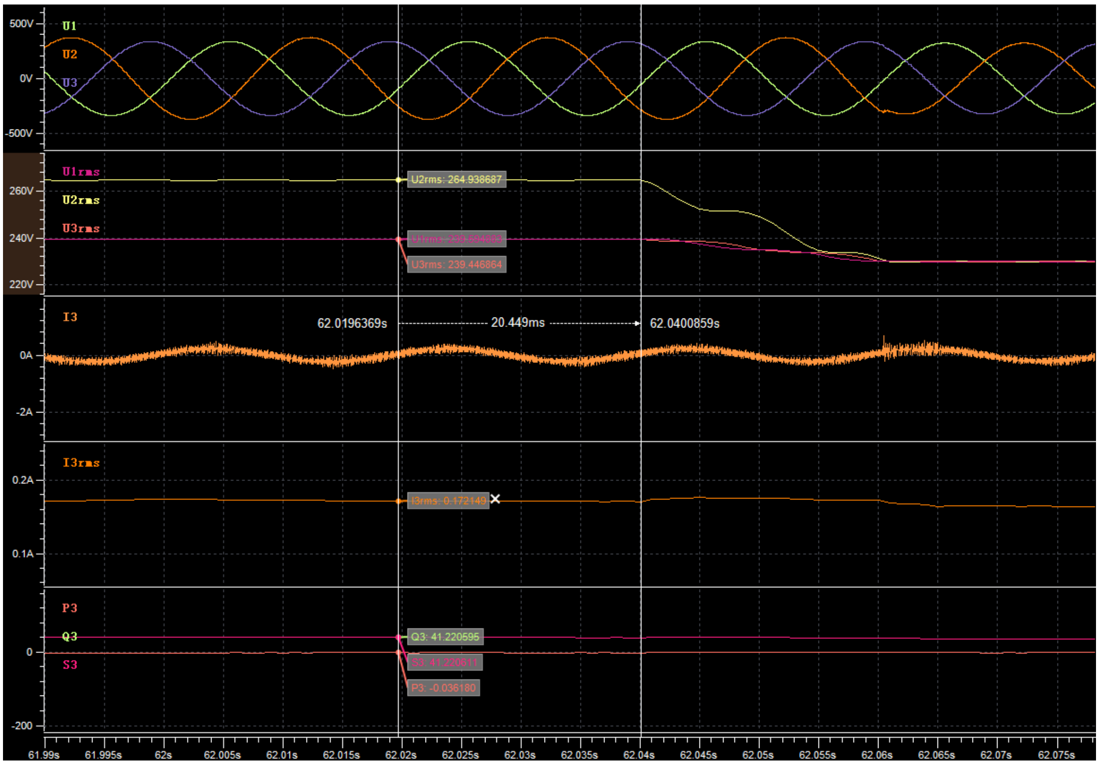
Verification of dynamic network support										P
Short-circuited power at generator terminal [VA]			10K							
NS protection settings			See table 5.5 for detail.							
	No.	Parameter	Phase ref.	Time ref.	unit	Result				
General Info.	0	Test number	--	--	--	7.3	1.4	2.4	3.4	
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020				
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph				
	3	Fault type (phase)	--	--		D1	D1	D1	D1	
	4	Setting voltage depth	Line to line	--	p.u.	1.15	0.15	0.50	0.50	
	5	Setting dip duration		--	ms	60000	150	1500	1500	
	6	Point of fault entry	Total	--	ms	20ms				
	7	Point of fault clearance	Total	--	ms	20ms				
	8	Fault duration in empty load test	Total	--	ms	60020	158.72	1512.84	1512.84	
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.04	0.62	0.76	0.76	
						1.15	0.15	0.5	0.5	
						1.04	0.62	0.76	0.76	
	10		Positive sequence		p.u.	1.08	0.46	0.67	0.67	
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.00	1.00	1.00	1.00	
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--	--	--	
	13	Active power	Total	t1-10s to t1	p.u.	1.014	0.210	0.207	0.207	
	14		Positive sequence			--	--	--	--	
	15	Reactive power	Total	t1-10s to t1	p.u.	-0.001	0.000	0.483	-0.483	
	16		Positive sequence			--	--	--	--	
	17	Cos$_{\varphi}$	--	t1-10s to t1	--	0.9993	0.9878	0.3935	0.3931	

During dip t1 to t2	18	Voltage	Phase 1	t1+100ms to t2-20ms	p.u.	1.04	0.62	0.76	0.76
			Phase 2			1.15	0.15	0.50	0.50
			Phase 3			1.04	0.62	0.76	0.76
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			0.067	0.065	0.064	0.037
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			0.057	0.066	0.068	0.052
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.022	0.032	0.011	-0.001
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			1.014	0.210	0.207	0.207
	39	Active power rising time	Positive sequence	--	s	0.129	0.089	0.095	0.089
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			-0.001	-0.001	0.483	-0.482
	33	Reactive power rising time	Positive sequence	--	s	0.129	0.089	0.095	0.089
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

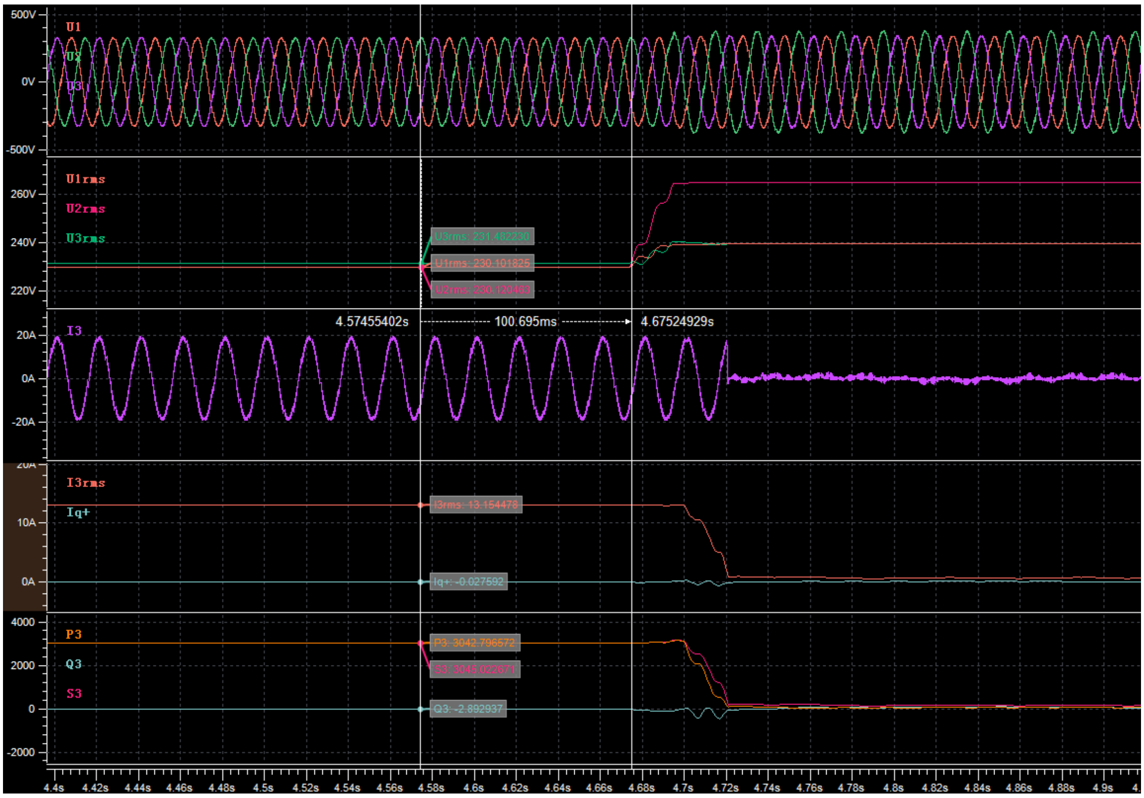
Graph of Test number7.3_1.15Un



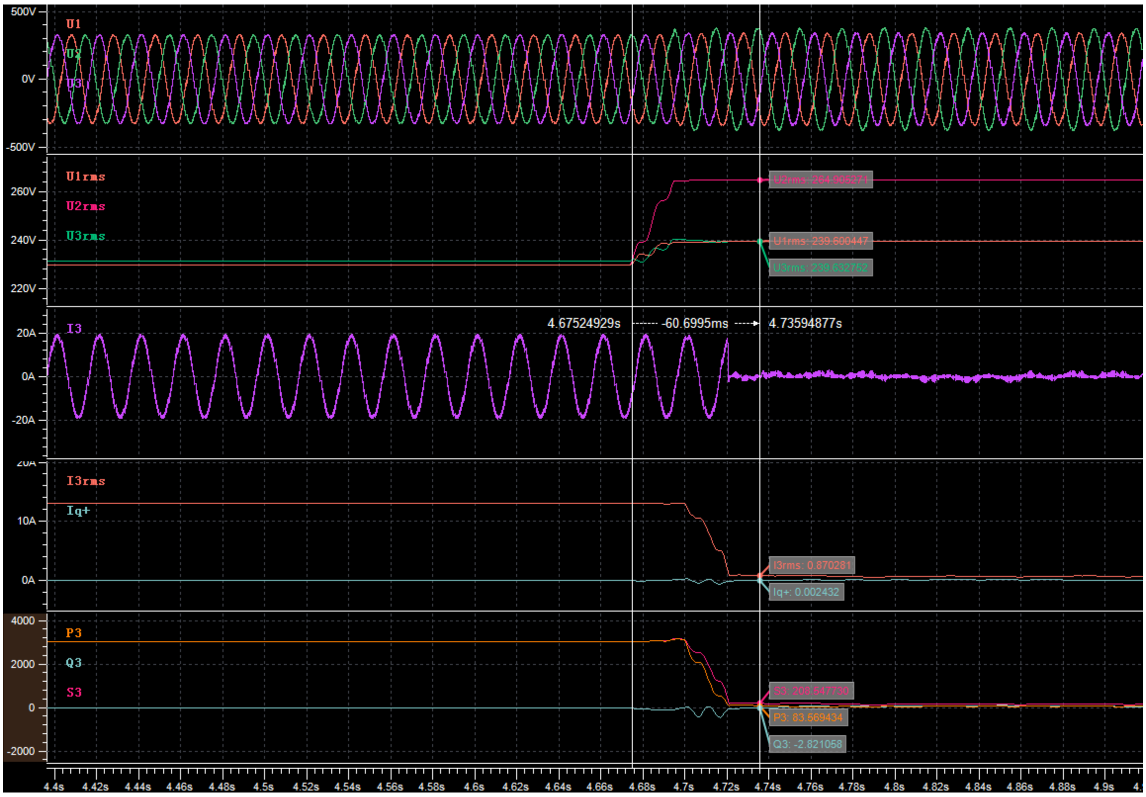
Empty load



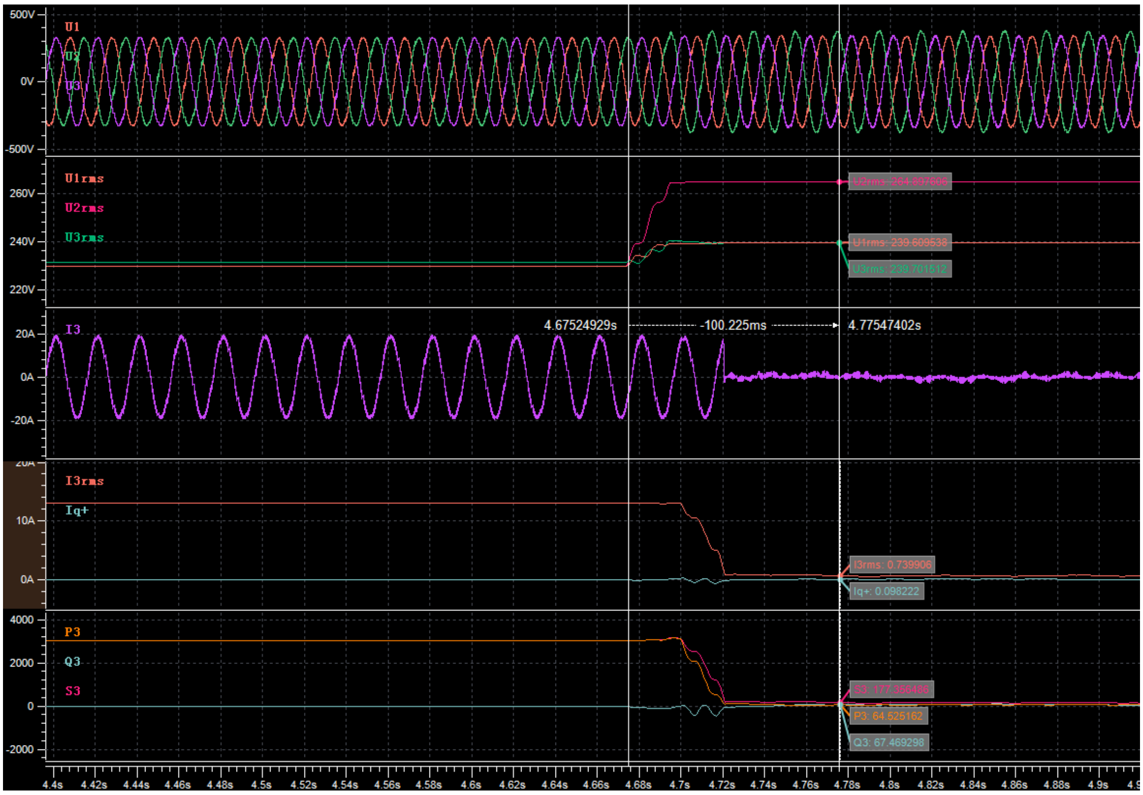
Empty load



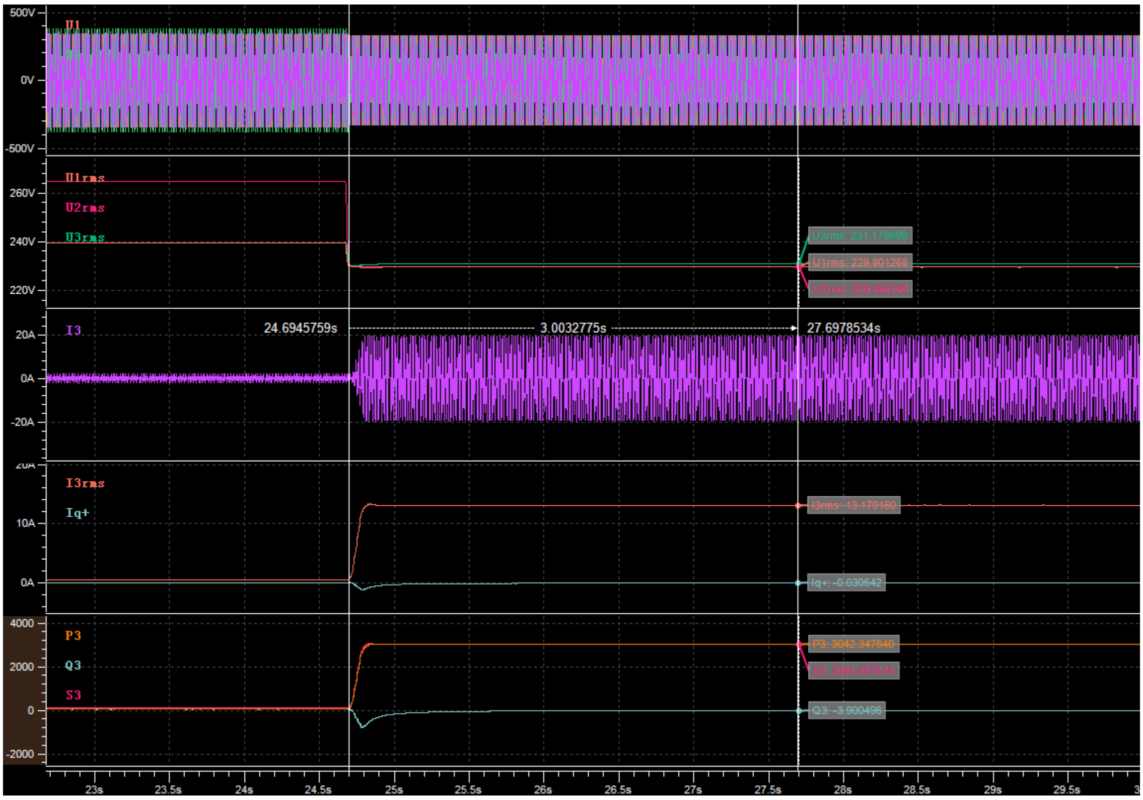
Before dip (t1-100ms)



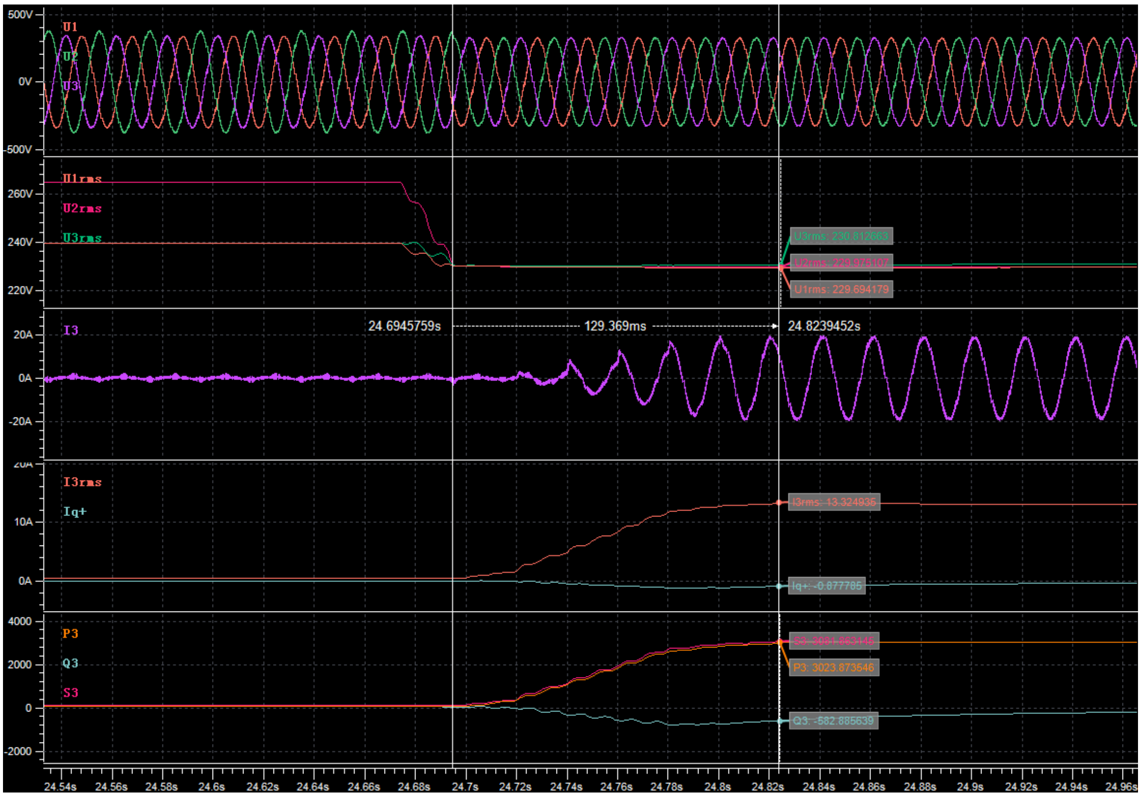
During dip (t1+60ms)



During dip (t1+100ms)

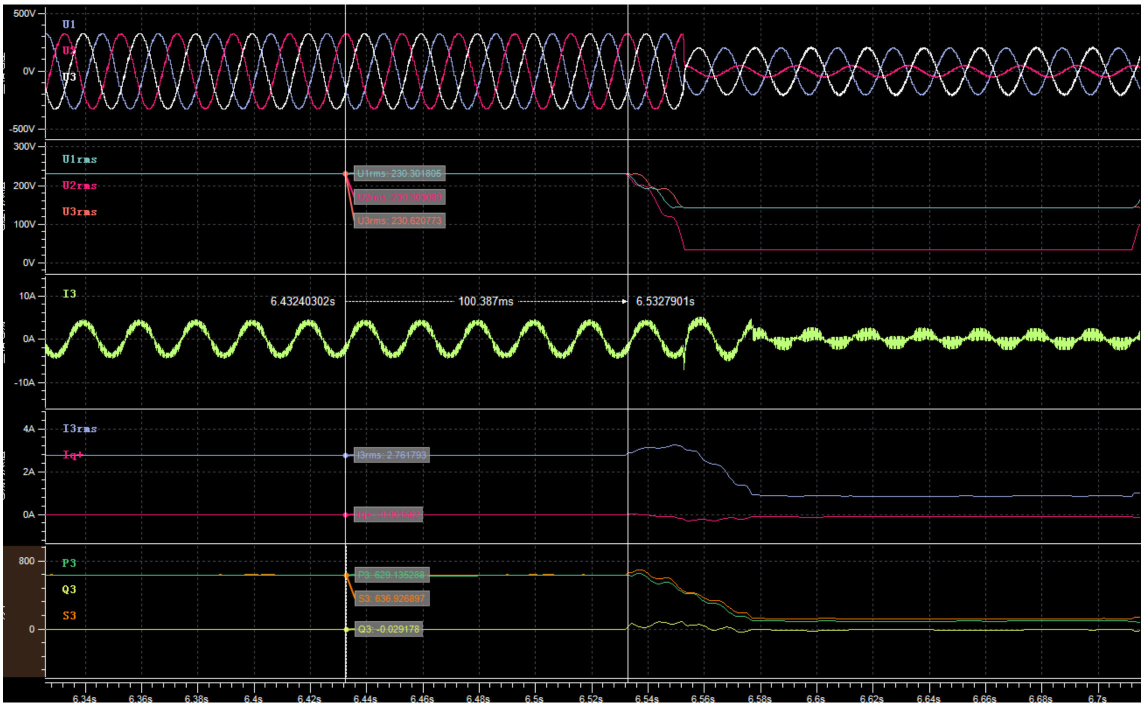


After dip (t2+3s)

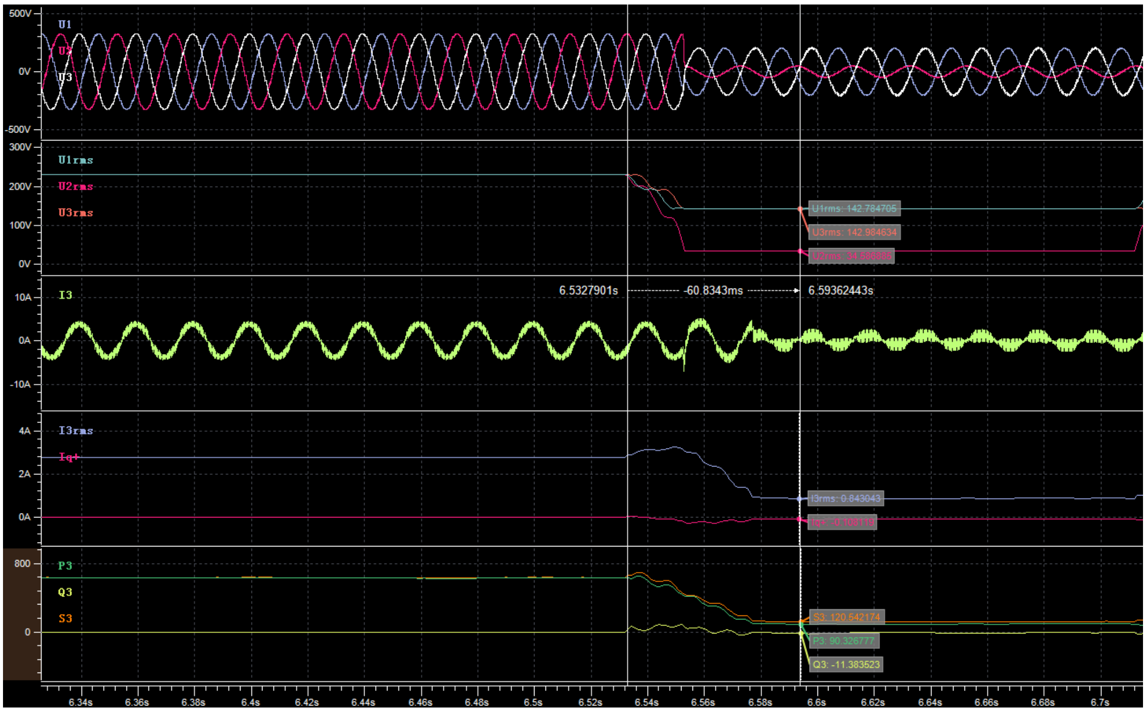


Recovery time

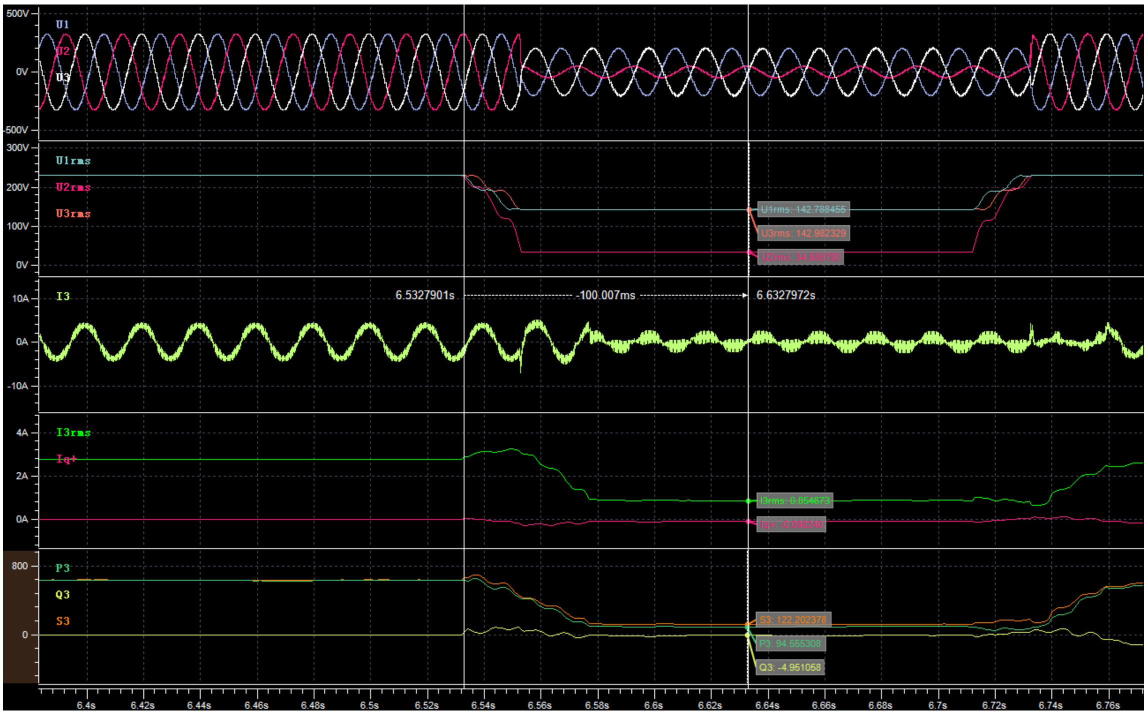
Graph of Test number 1.4_0.15Un



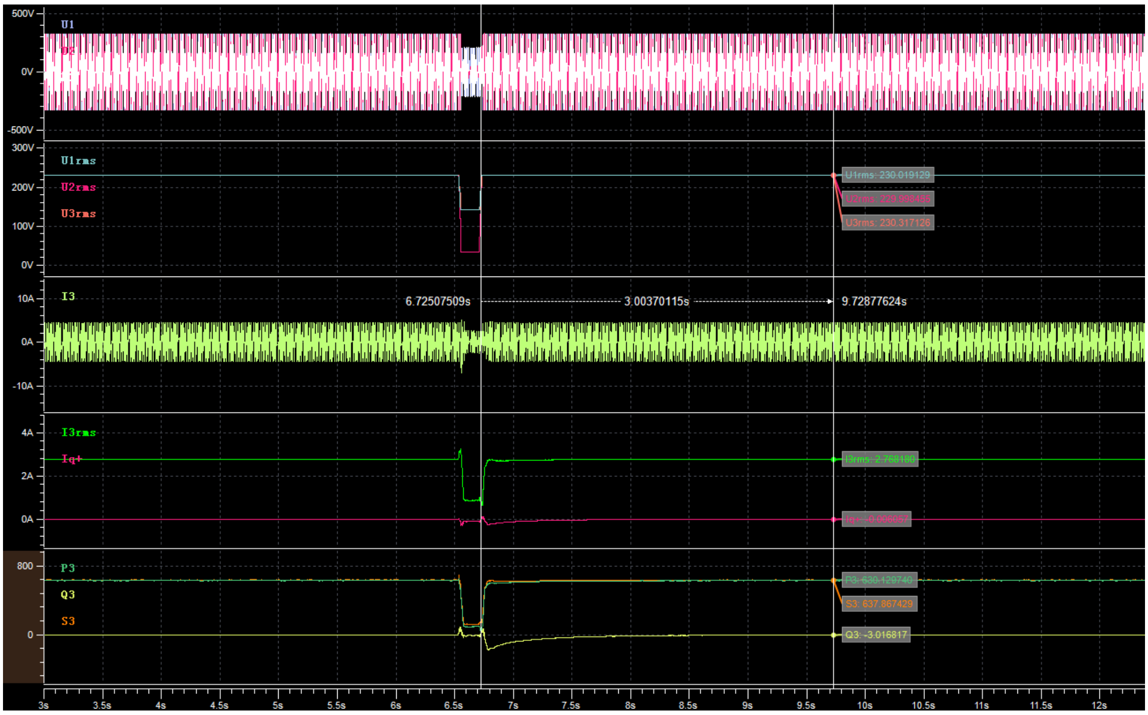
Before dip (t1-100ms)



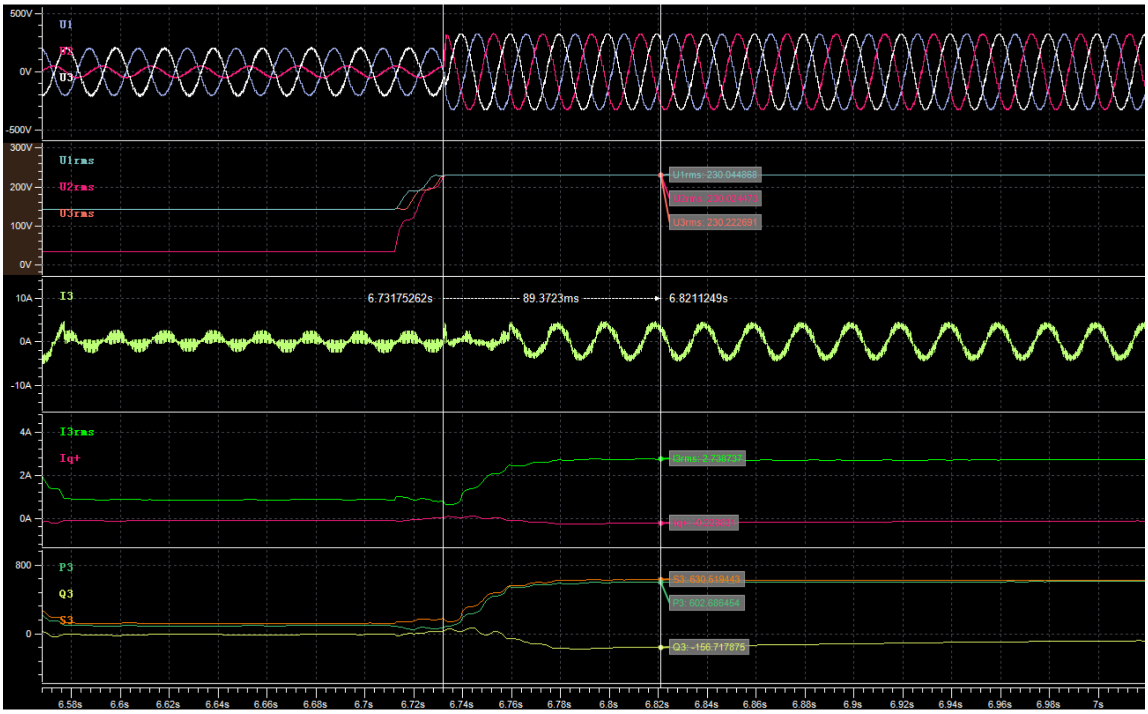
During dip (t1+60ms)



During dip (t1+100ms)

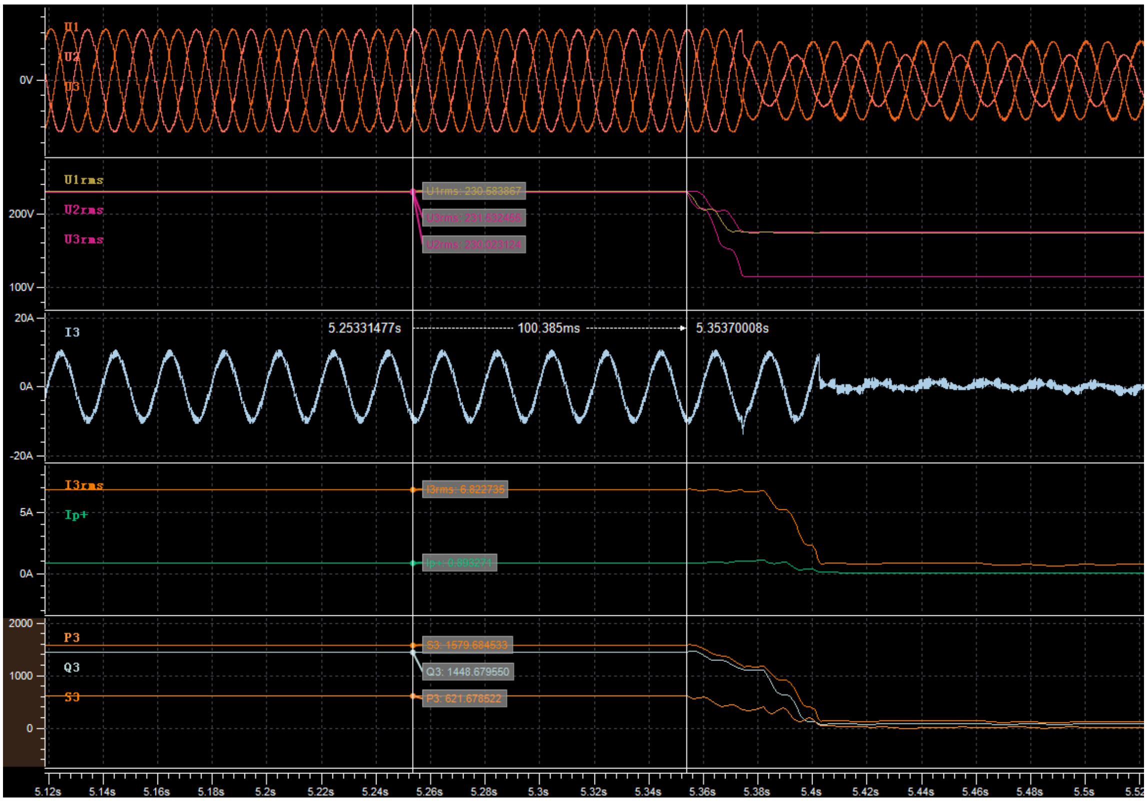


After dip (t2+3s)

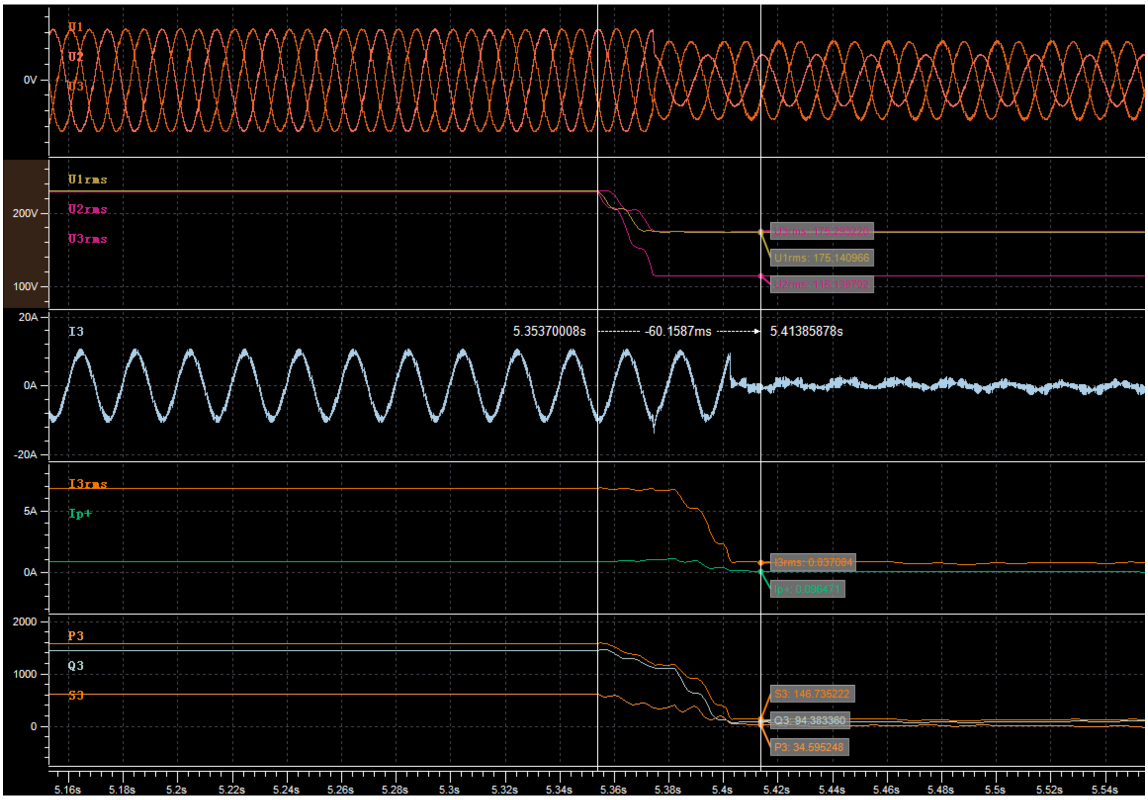


Recovery time

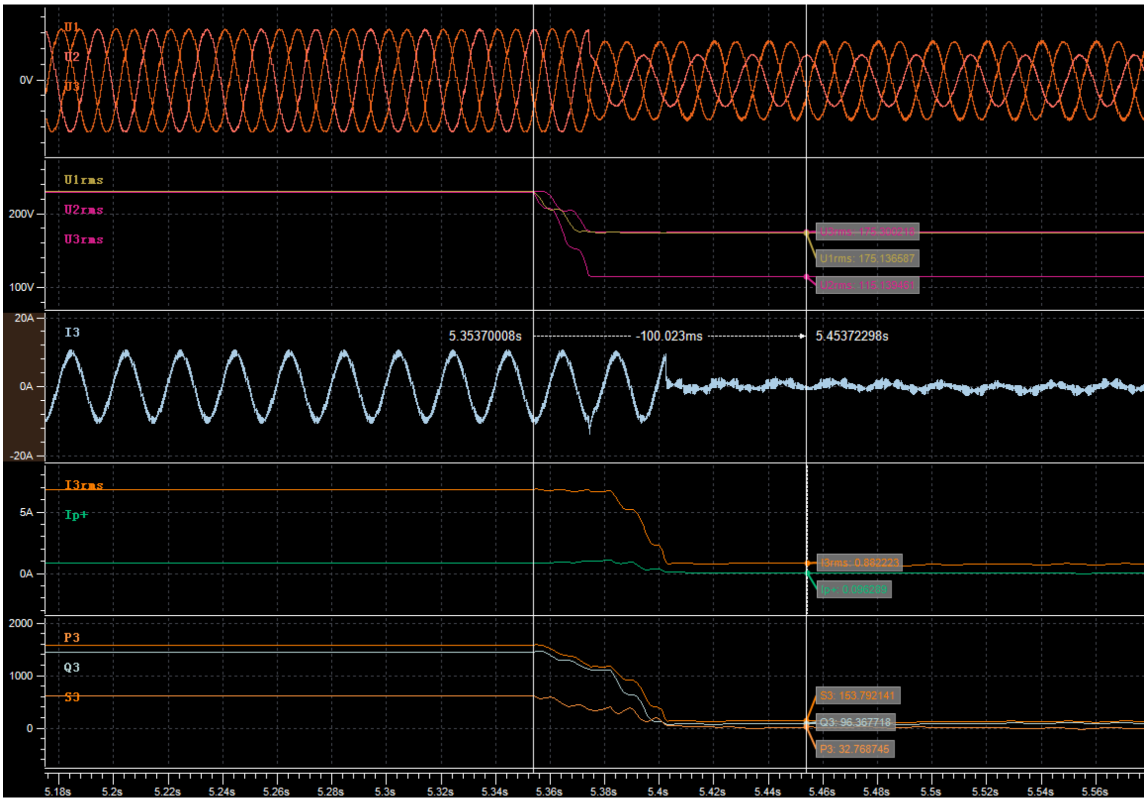
Graph of Test number 2.4_0.5Un



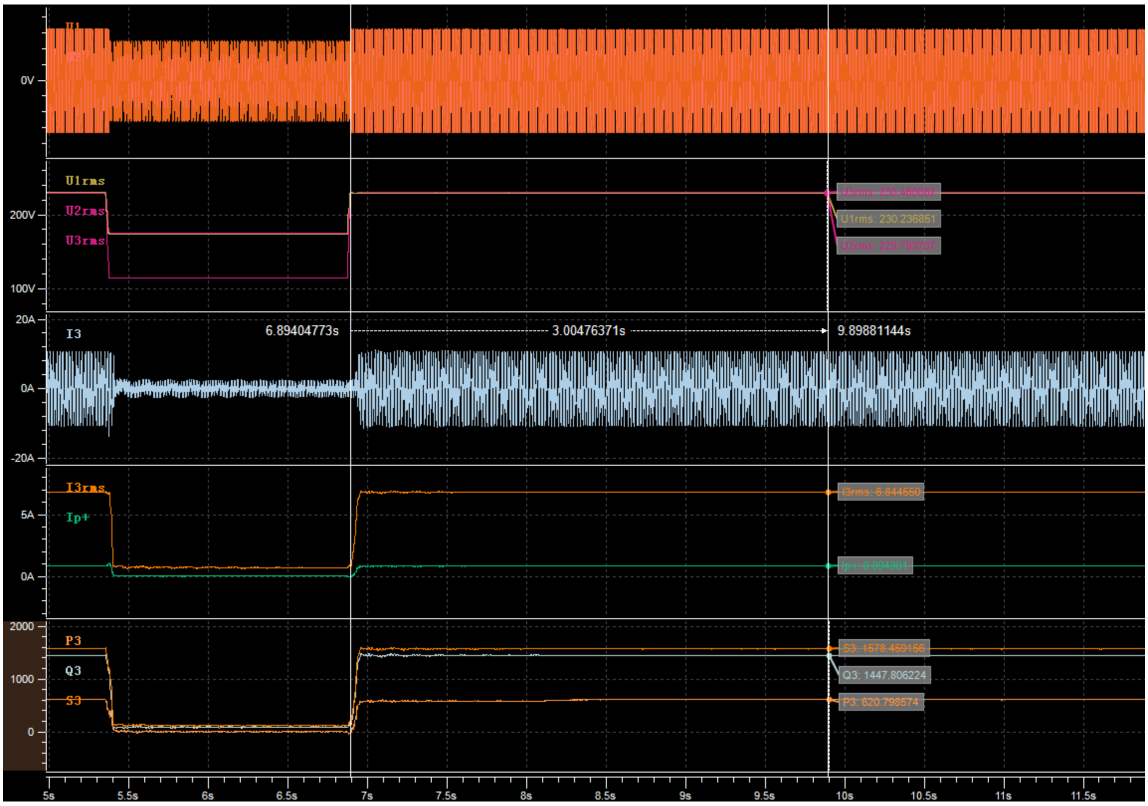
Before dip (t1-100ms)



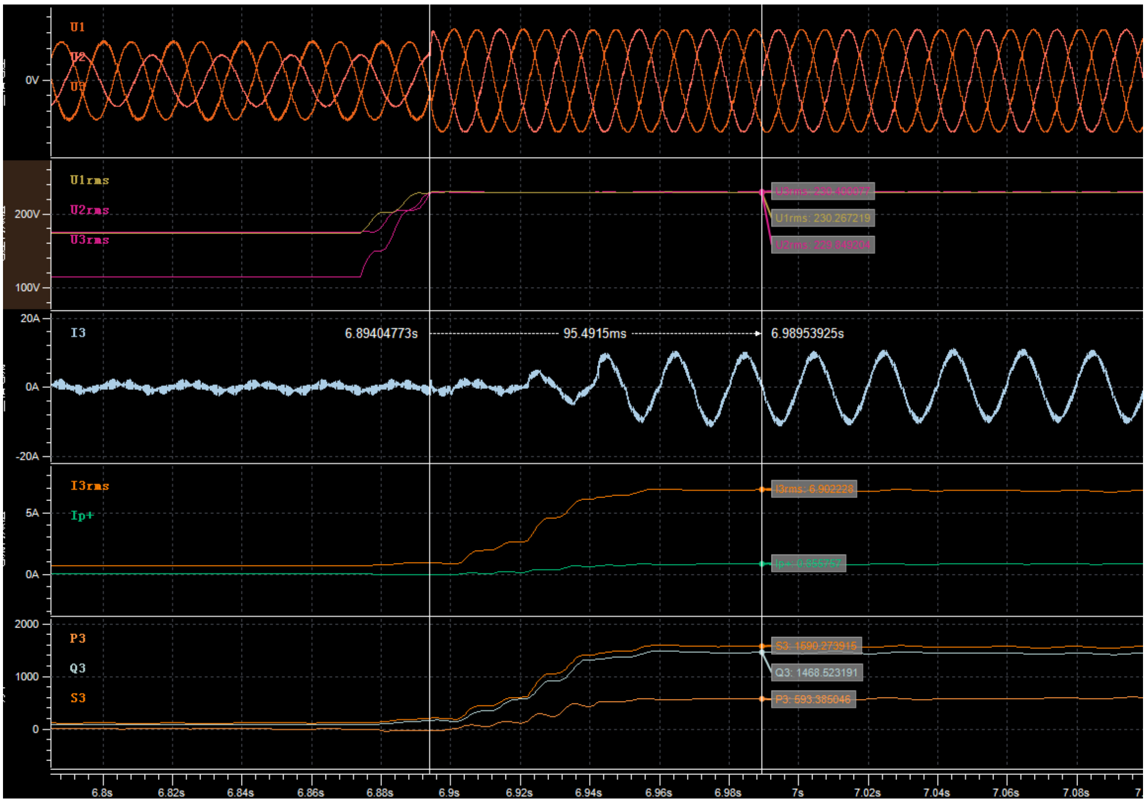
During dip (t1+60ms)



During dip (t1+100ms)

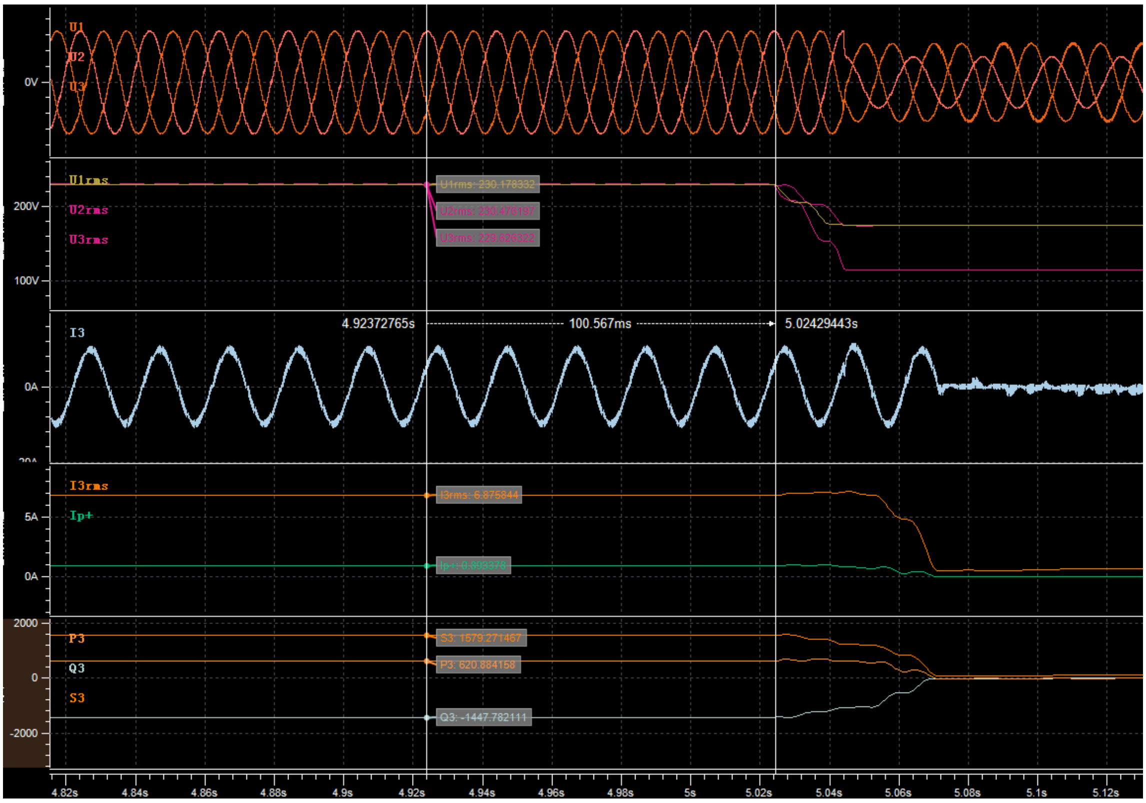


After dip (t2+3s)

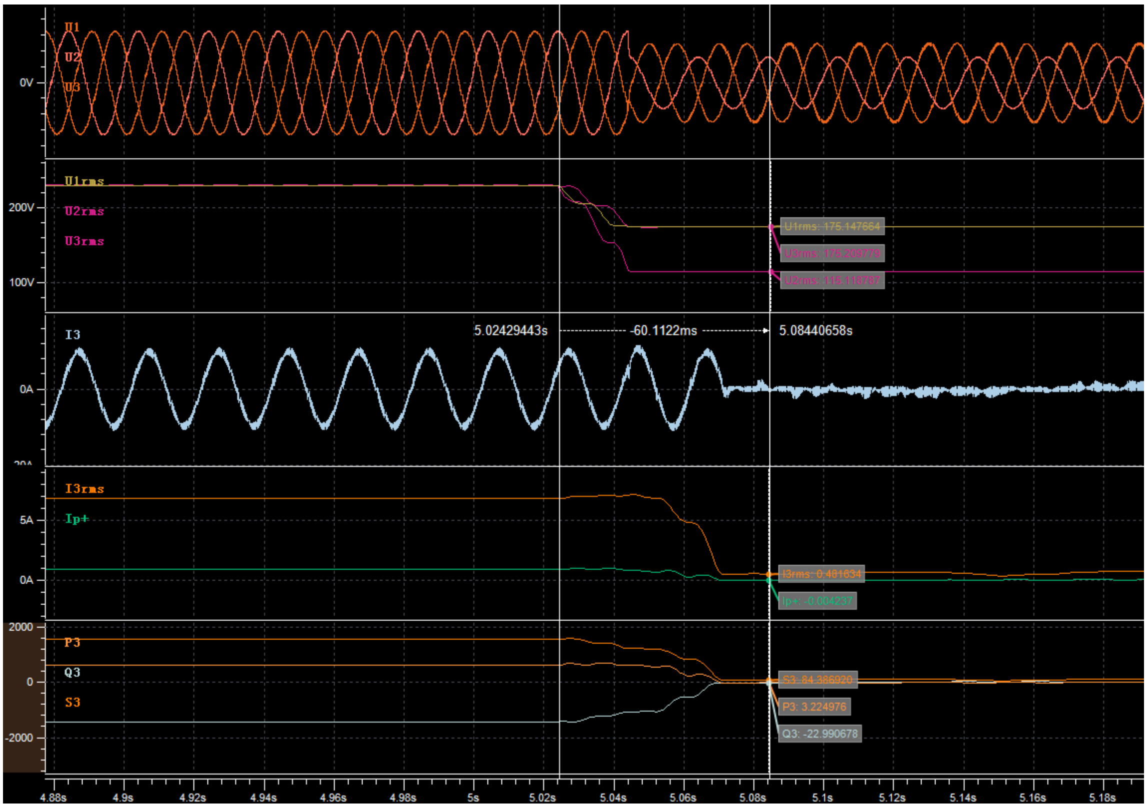


Recovery time

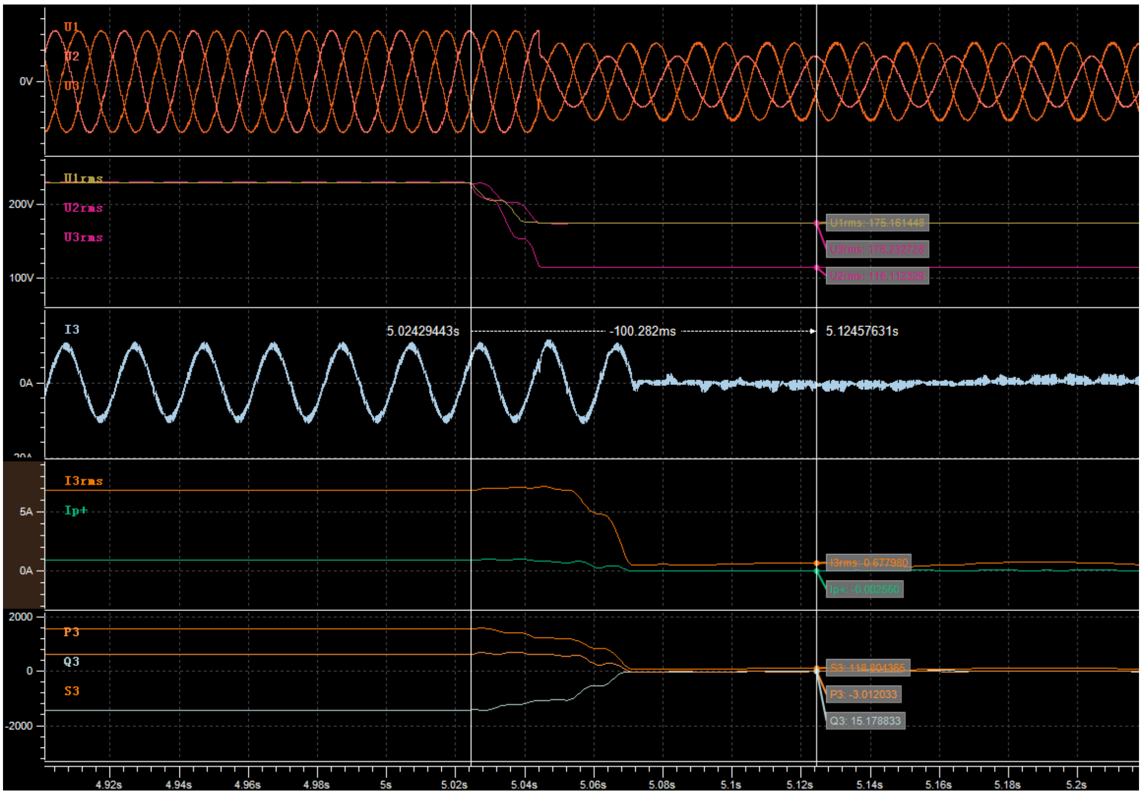
Graph of Test number 3.4_0.5Un



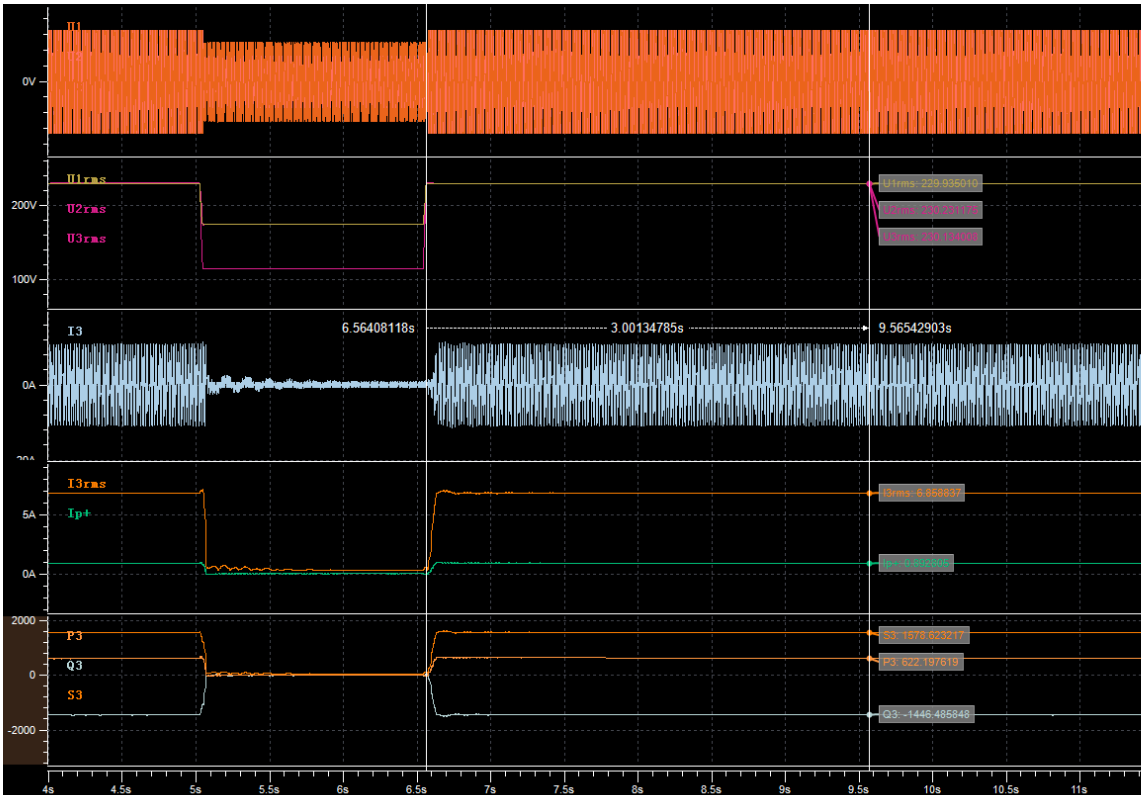
Before dip (t1-100ms)



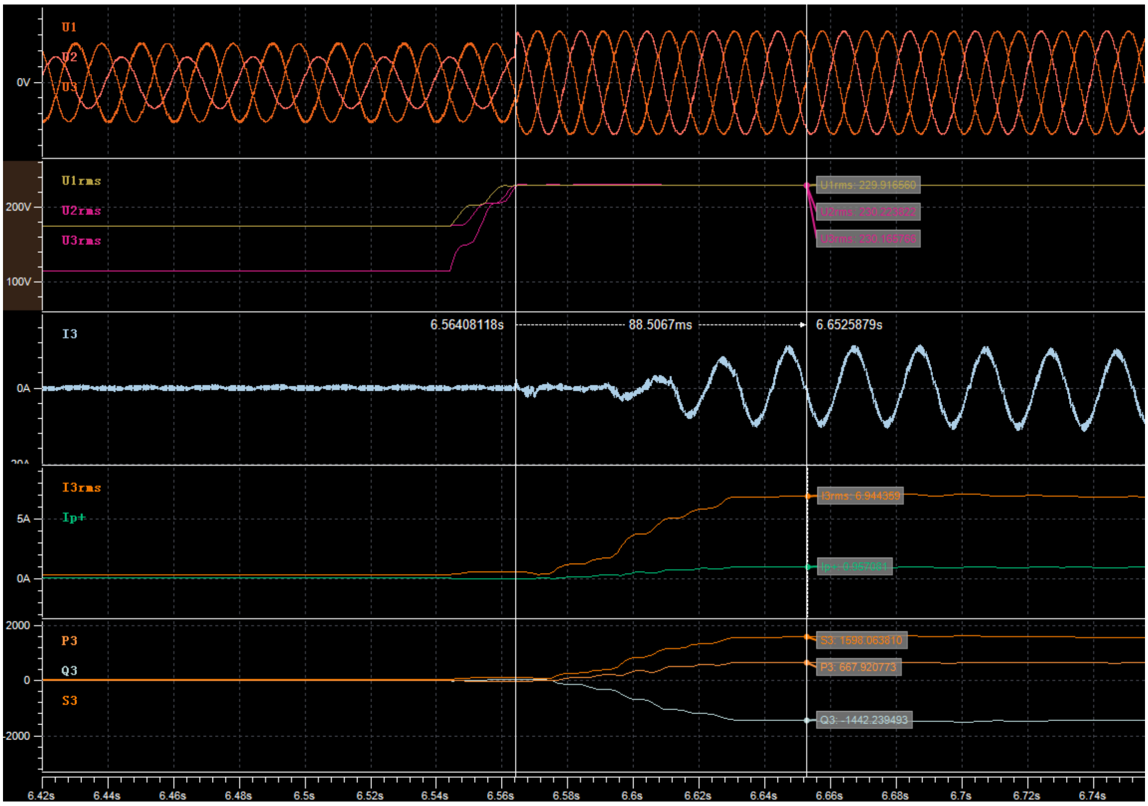
During dip (t1+60ms)



During dip (t1+100ms)



After dip (t2+3s)

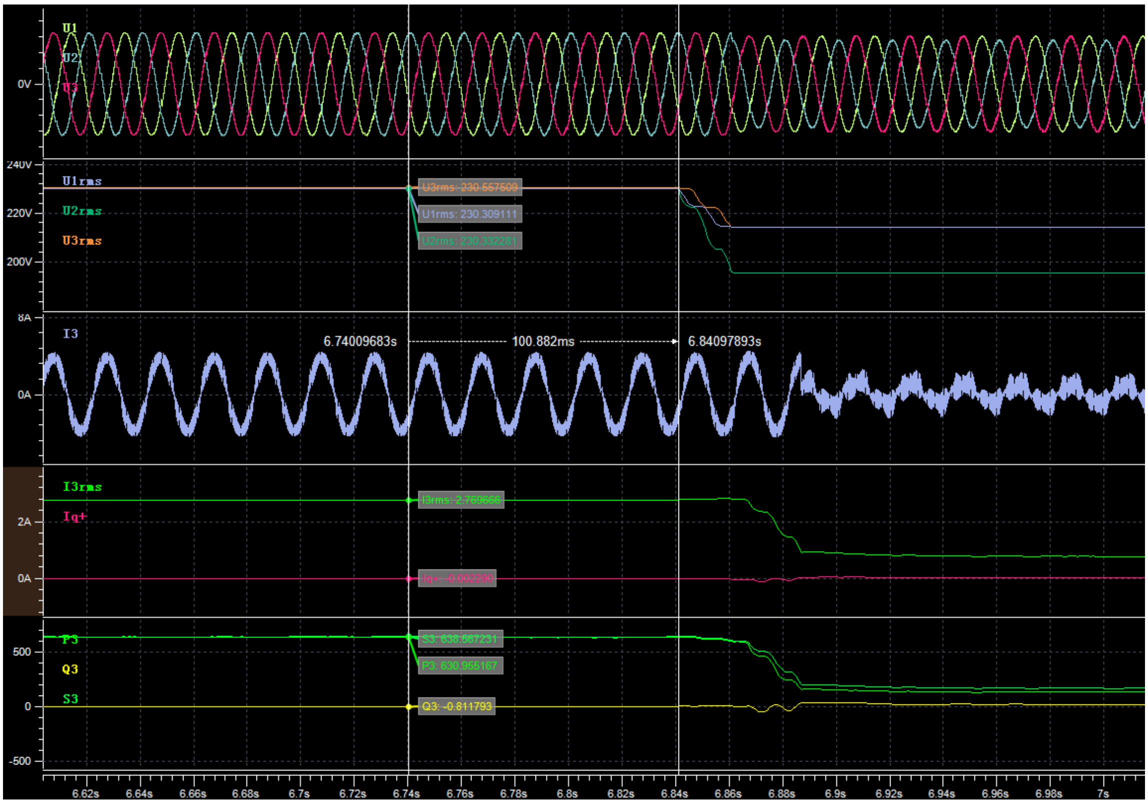


Recovery time

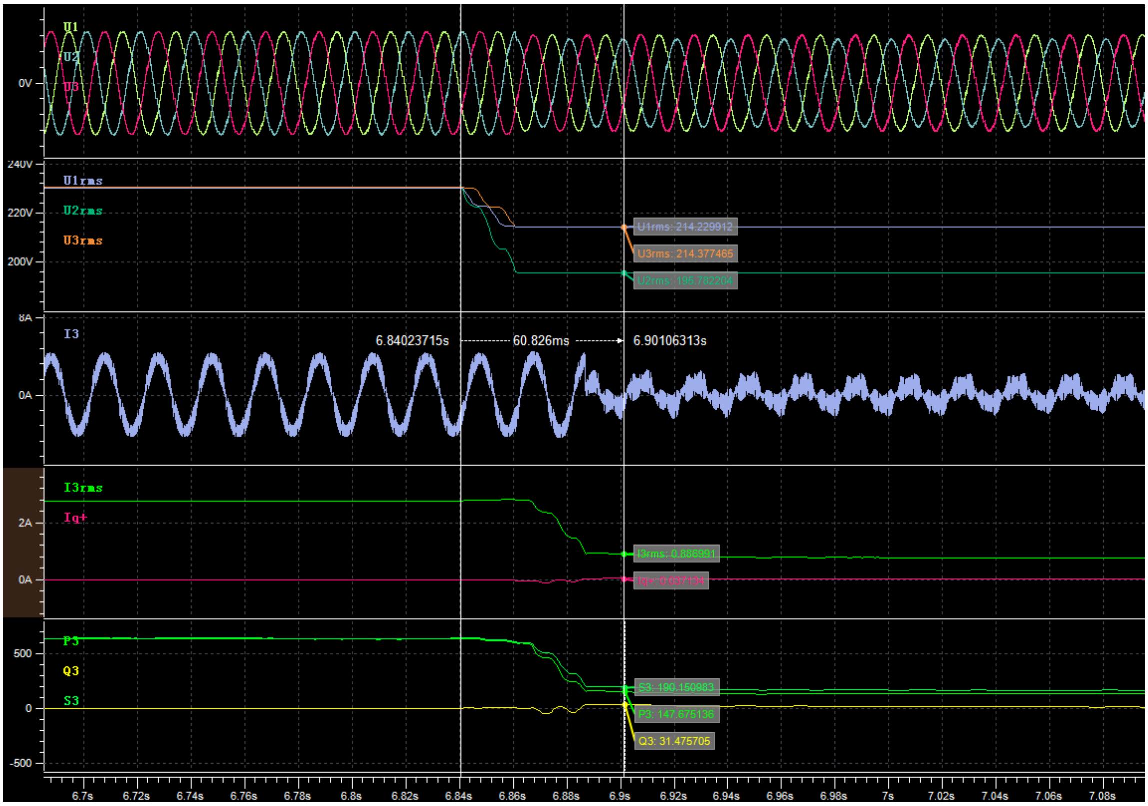
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			10K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	4.4	5.4	6.4	7.4
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020			
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph			
	3	Fault type (phase)	--	--		D1	D1	D1	D1
	4	Setting voltage depth	Line to line	--	p.u.	0.85	1.25	1.20	1.15
	5	Setting dip duration		--	ms	60000	100	5000	60000
	6	Point of fault entry	Total	--	ms	20ms			
	7	Point of fault clearance	Total	--	ms	20ms			
	8	Fault duration in empty load test	Total	--	ms	60020	100.11	5004.74	60020
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.93	1.08	1.06	1.04
						0.85	1.25	1.2	1.15
						0.93	1.06	1.05	1.04
	10		Positive sequence		p.u.	0.9	1.13	1.11	1.08
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.00	1.00	1.00	1.00
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--	--	--
	13	Active power	Total	t1-10s to t1	p.u.	0.210	0.210	0.210	0.210
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.000	-0.001	0.000	-0.001
	16		Positive sequence			--	--	--	--
	17	Cos_{φ}	--	t1-10s to t1	--	0.9881	0.9876	0.9879	0.9880

During dip t1 to t2	18	Voltage	Phase 1	t1+100ms to t2-20ms	p.u.	0.93	1.08	1.06	1.04
			Phase 2			0.85	1.25	1.20	1.15
			Phase 3			0.93	1.06	1.05	1.04
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			0.068	0.047	0.044	0.045
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			0.062	0.037	0.039	0.041
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.045	0.020	0.021	0.020
	26		Positive sequence			--	--	--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--	--
	29		Total			0.212	0.210	0.209	0.197
	39	Active power rising time	Positive sequence	--	s	0.099	0.083	0.091	0.100
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			-0.001	-0.001	-0.001	-0.001
	33	Reactive power rising time	Positive sequence	--	s	0.099	0.083	0.091	0.100
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

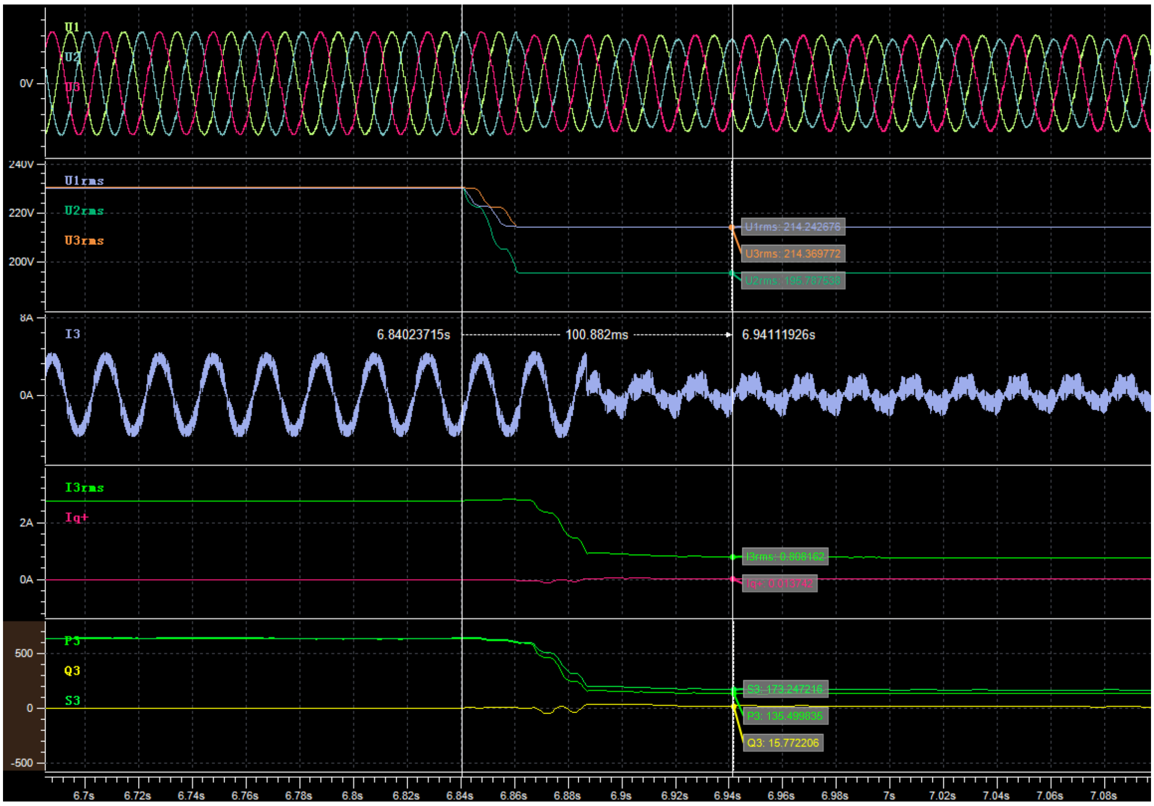
Graph of Test number 3.4



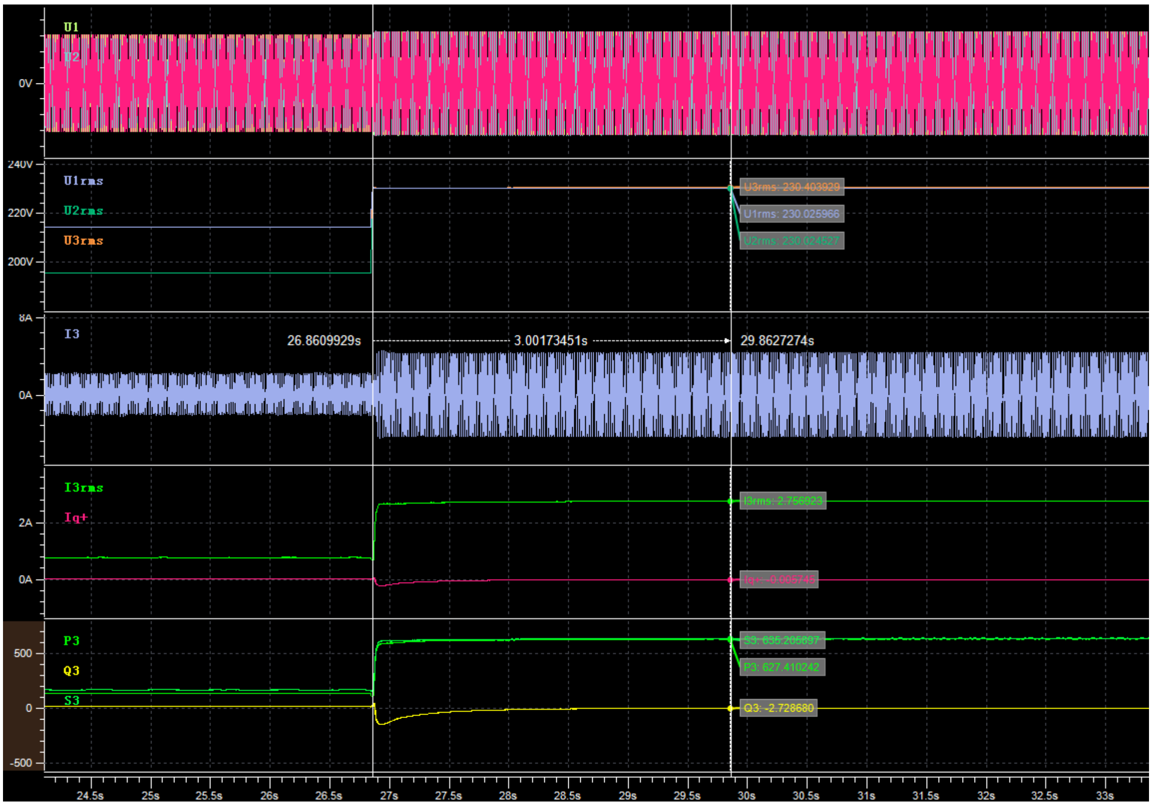
Before dip (t1-100ms)



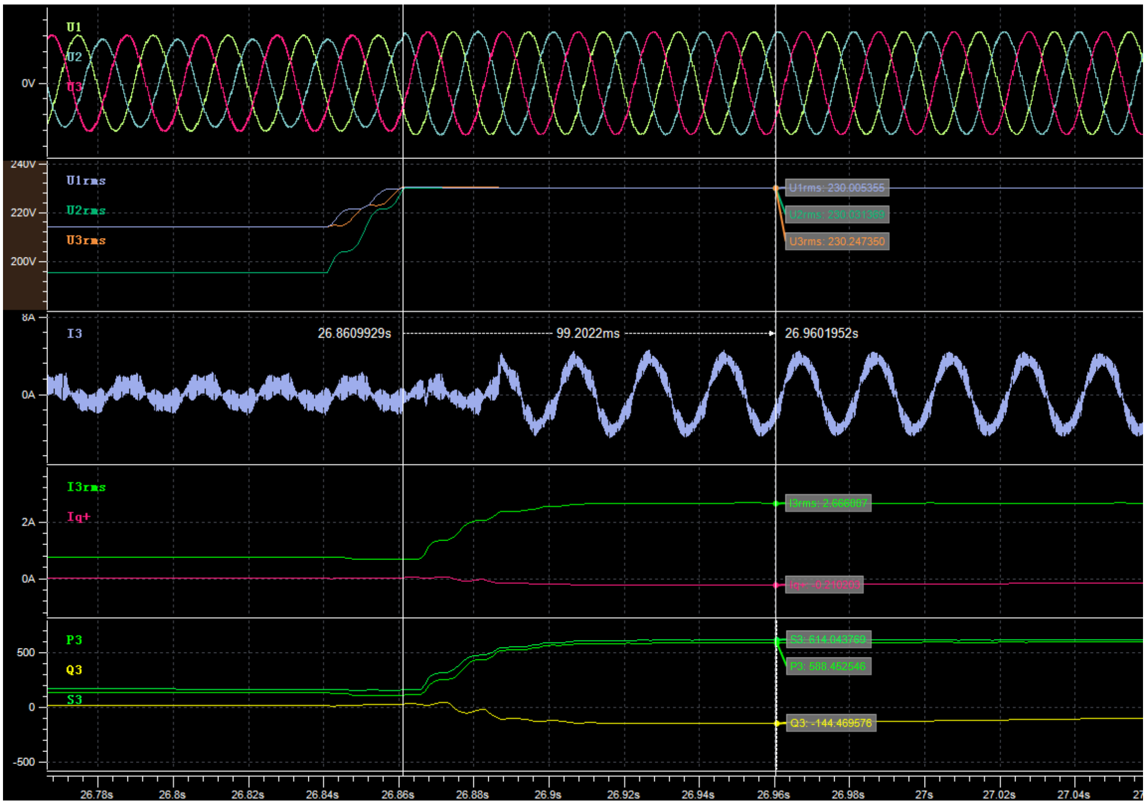
During dip (t1+60ms)



During dip (t1+100ms)



After dip (t2+3s)

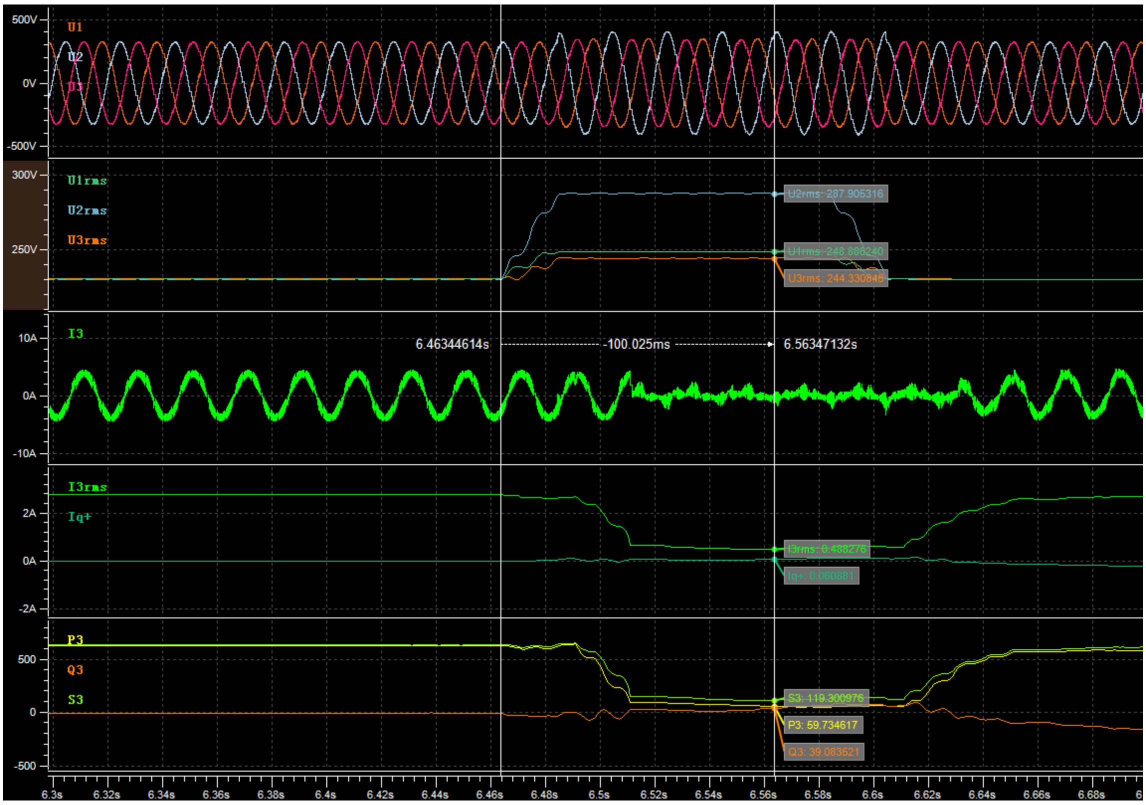


Recovery time

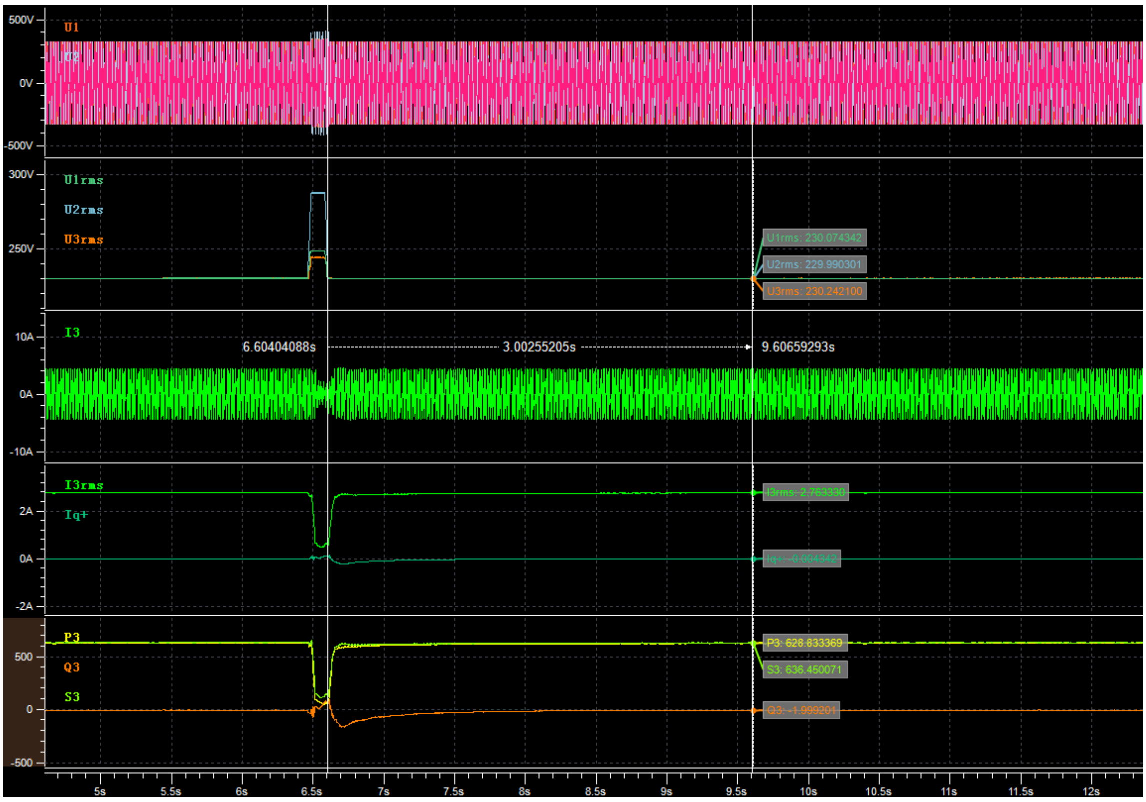
Graph of Test number 5.4_Un

Before dip (t1-100ms)

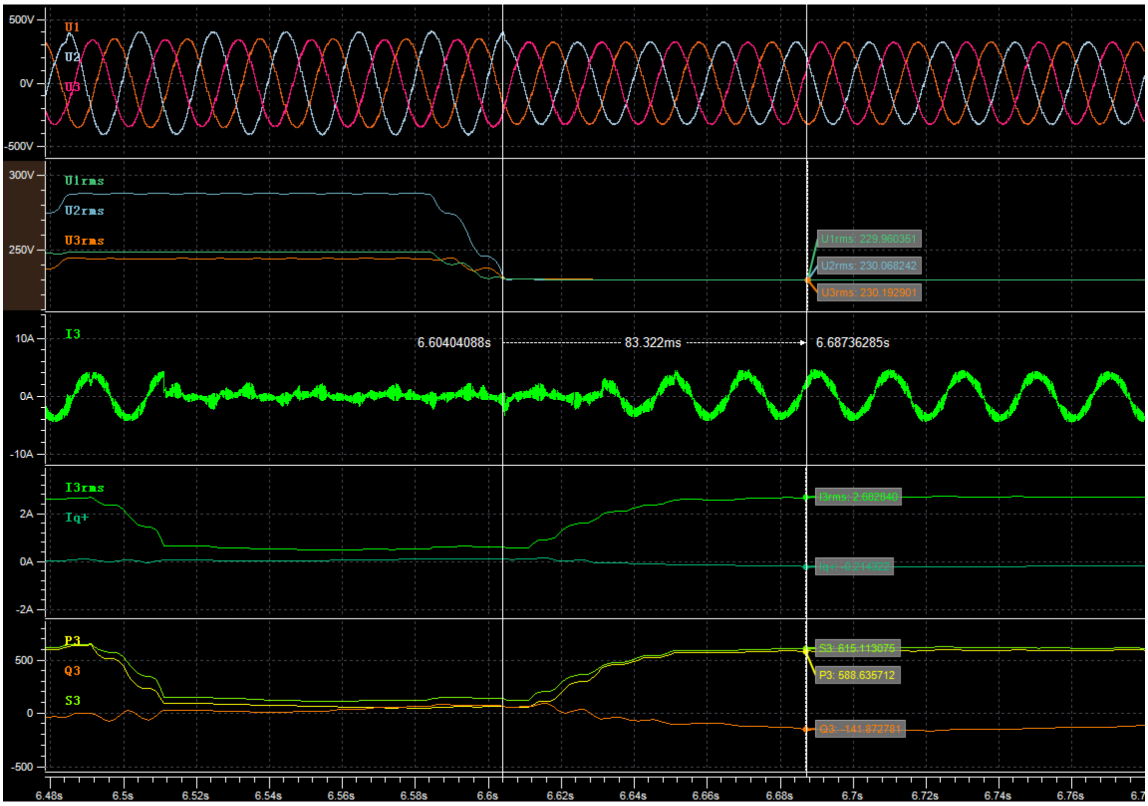
During dip (t1+60ms)



During dip (t1+100ms)

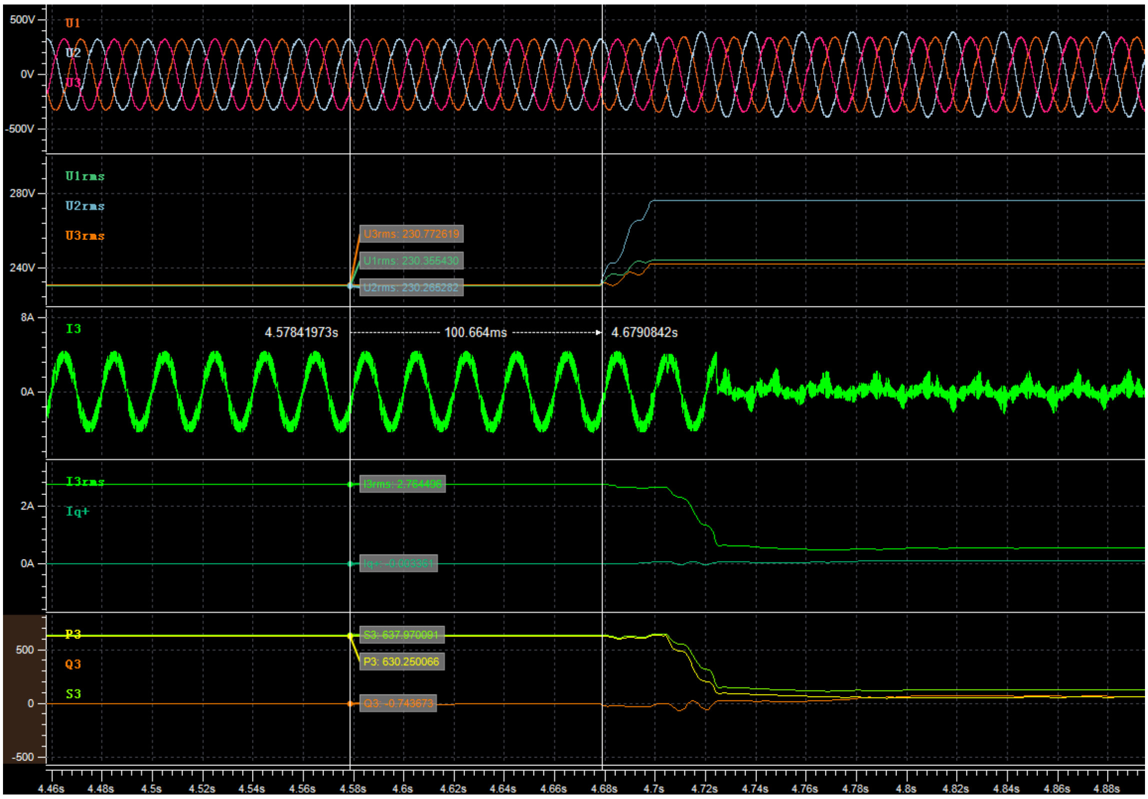


After dip (t2+3s)



Recovery time

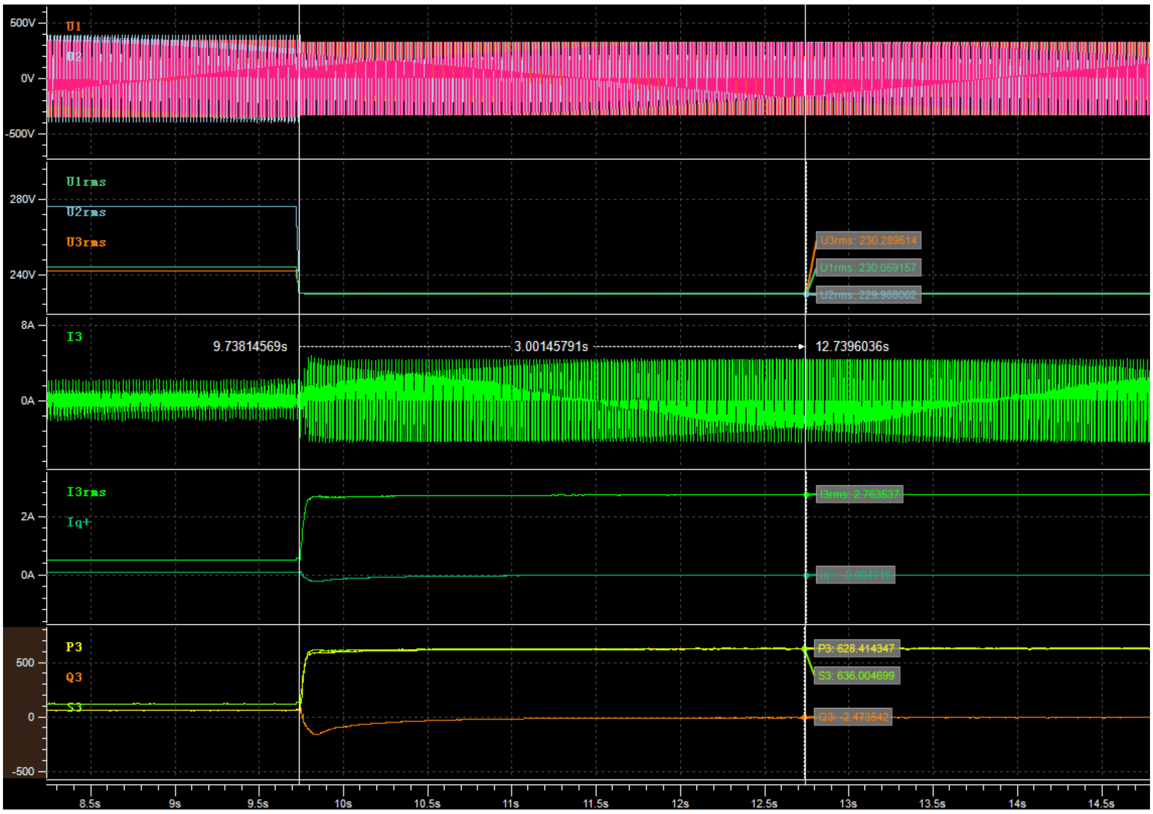
Graph of Test number 6.4_1.20Un



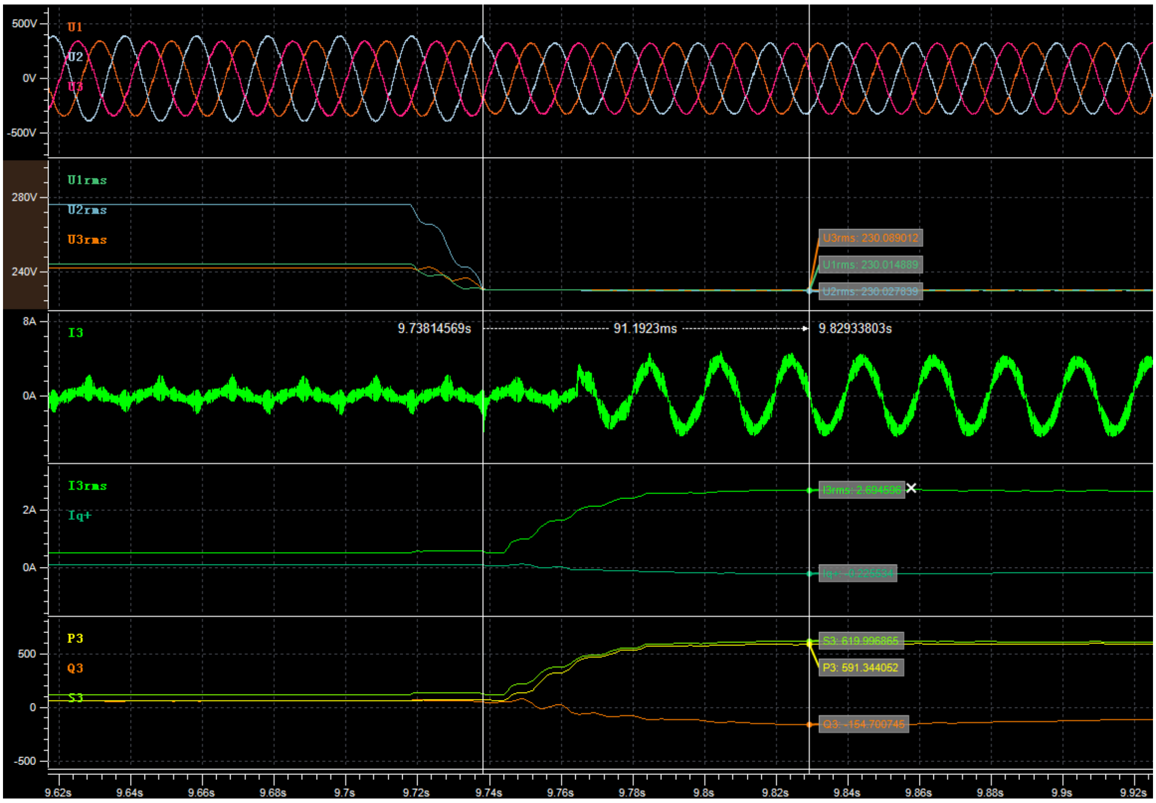
Before dip (t1-100ms)

During dip (t1+60ms)

During dip (t1+100ms)

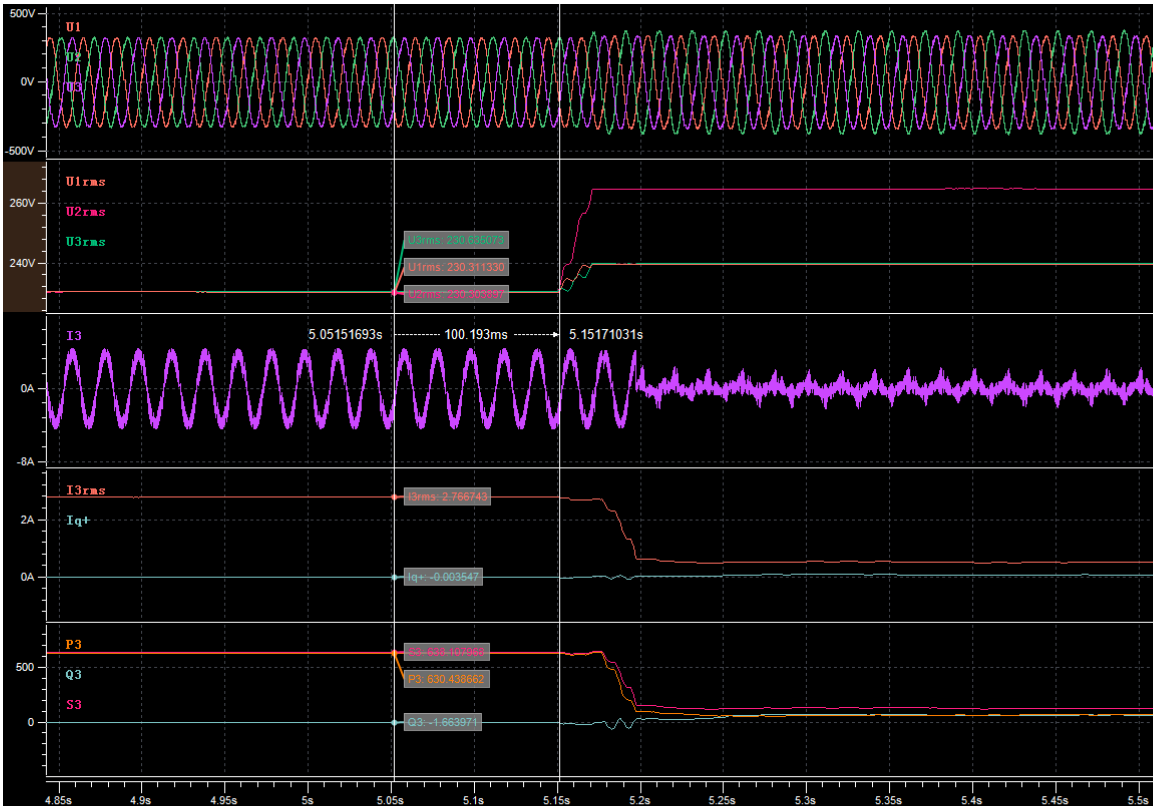


After dip (t2+3s)

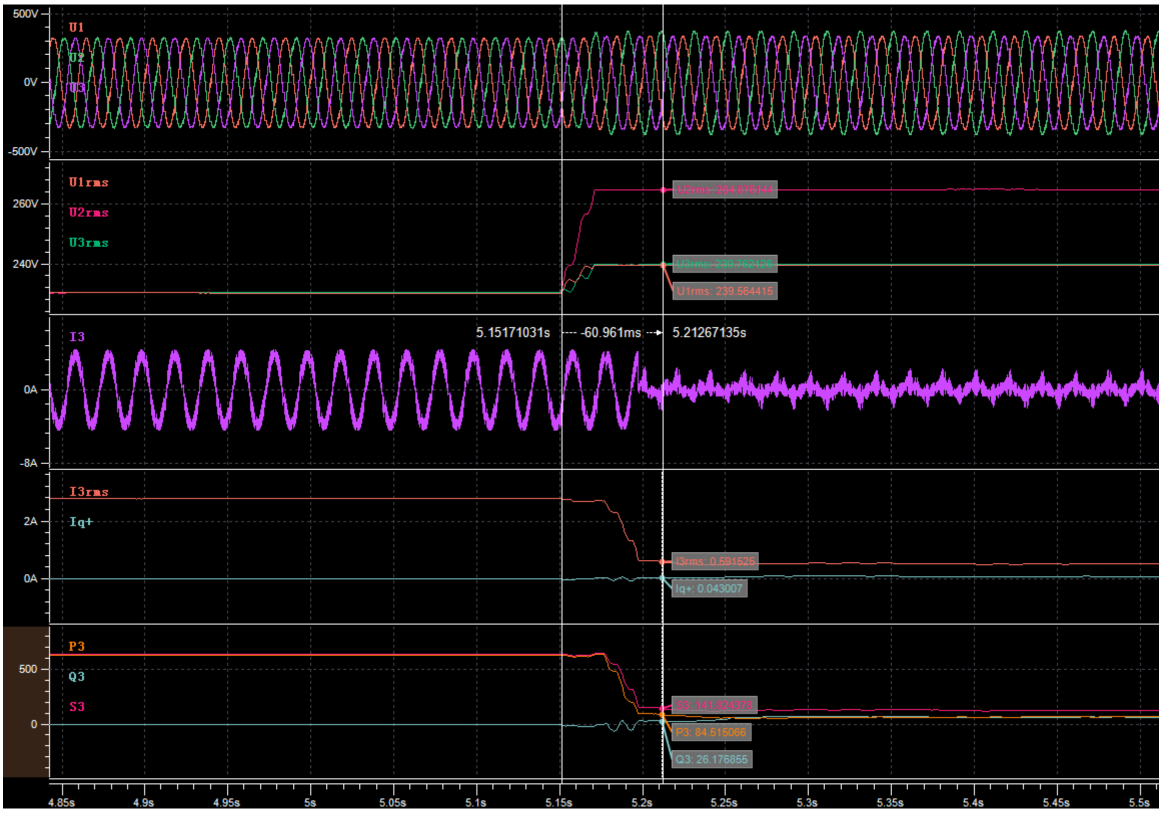


Recovery time

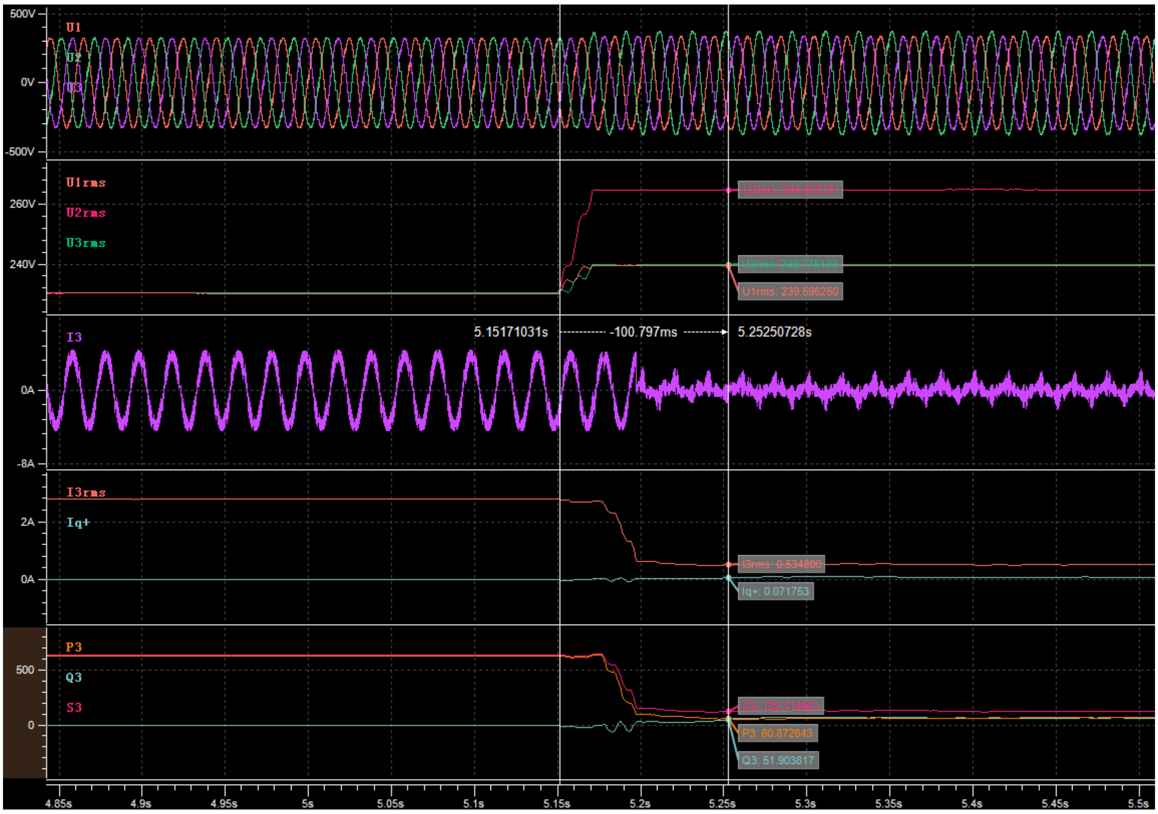
Graph of Test number 7.4_1.15Un

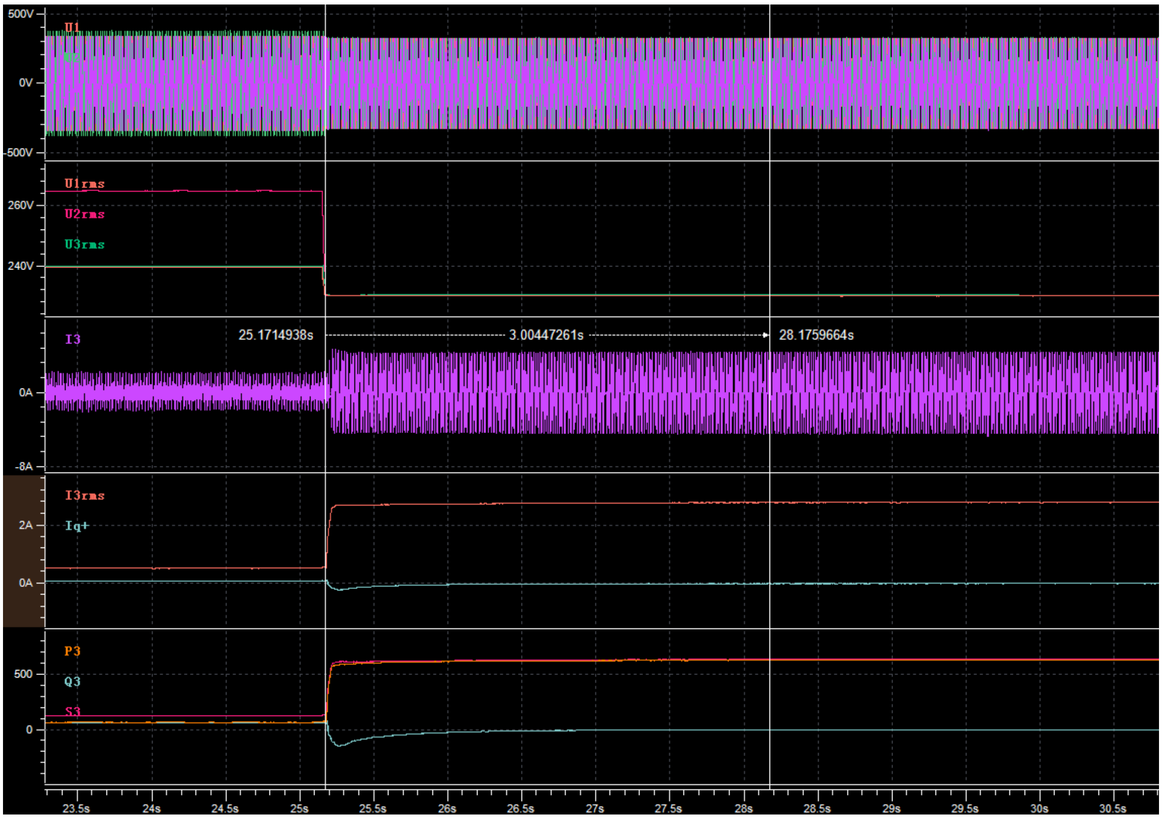


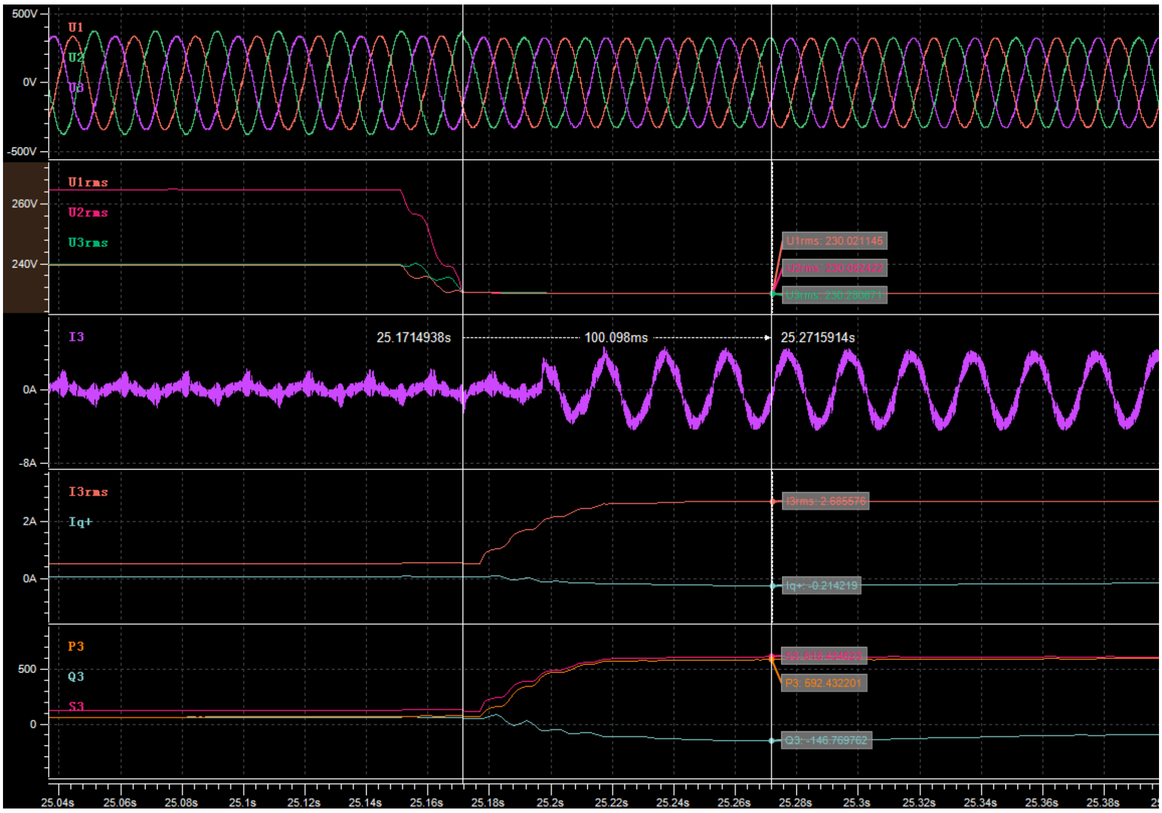
Before dip (t1-100ms)



During dip (t1+60ms)


During dip (t1+100ms)


After dip (t2+3s)

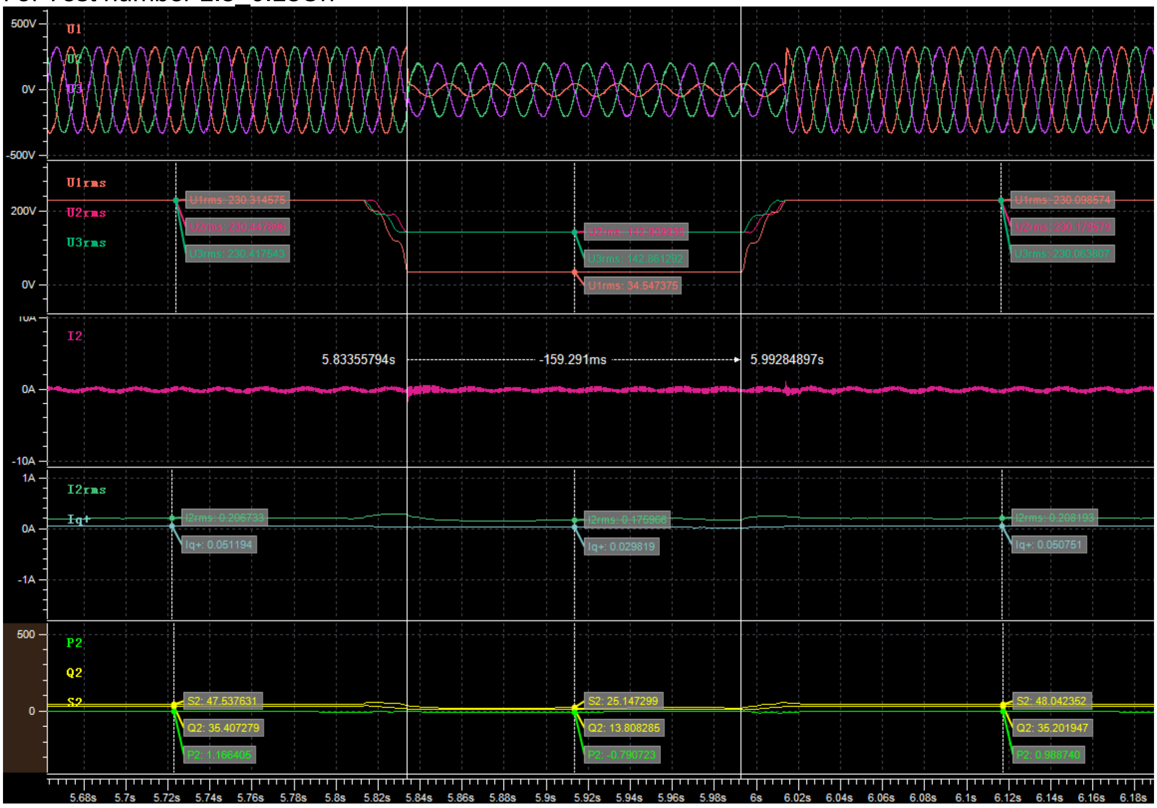


Recovery time

Verification of dynamic network support							P
Short-circuited power at generator terminal [VA]			3K				
NS protection settings			See table 5.5 for detail.				
	No.	Parameter	Phase ref.	Time ref.	unit	Result	
General Info.	0	Test number	--	--	--	1	5.5
	1	Date	--	--	dd.mm.yyyy	16-June-2020 to 22-June-2020	
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph	
	3	Fault type (phase)	--	--		D2	D2
	4	Setting voltage depth	Line to line	--	p.u.	0.15	1.25
	5	Setting dip duration		--	ms	150	100
	6	Point of fault entry	Total	--	ms	20ms	
	7	Point of fault clearance	Total	--	ms	20ms	
	8	Fault duration in empty load test	Total	--	ms	159.29	100.22
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.15	1.25
						0.62	1.06
						0.62	1.08
	10		Positive sequence		p.u.	0.46	1.13
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	1.00	1.00
	12	Current	Positive sequence	t1-500ms to t1-100ms	p.u.	--	--
	13	Active power	Total	t1-10s to t1	p.u.	1.013	1.014
	14		Positive sequence			--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	-0.001	-0.001
	16		Positive sequence			--	--
	17	$\cos_{\varphi}$	--	t1-10s to t1	--	0.9992	0.9992
During dip t1 to	18	Voltage	Phase 1	t1+100ms to t2-	p.u.	0.15	1.25
			Phase 2			0.62	1.06

t2			Phase 3	20ms		0.62	1.08
	19	Line current	Phase 1	t1+60ms	p.u.	--	--
	20		Phase 2			0.075	0.069
	21		Phase 3			--	--
	22	Line current	Phase 1	t1+100ms	p.u.	--	--
	23		Phase 2			0.075	0.043
	24		Phase 3			--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.036	0.025
	26		Positive sequence			--	--
After dip > t2	27	Voltage	Line to neutral	t2+3s to t2+10s	p.u.	1.00	1.00
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--
	29		Total			1.011	1.013
	39	Active power rising time	Positive sequence	--	s	0.122	0.112
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--
	32		Total			-0.001	-0.001
	33	Reactive power rising time	Positive sequence	--	s	0.122	0.112
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes	

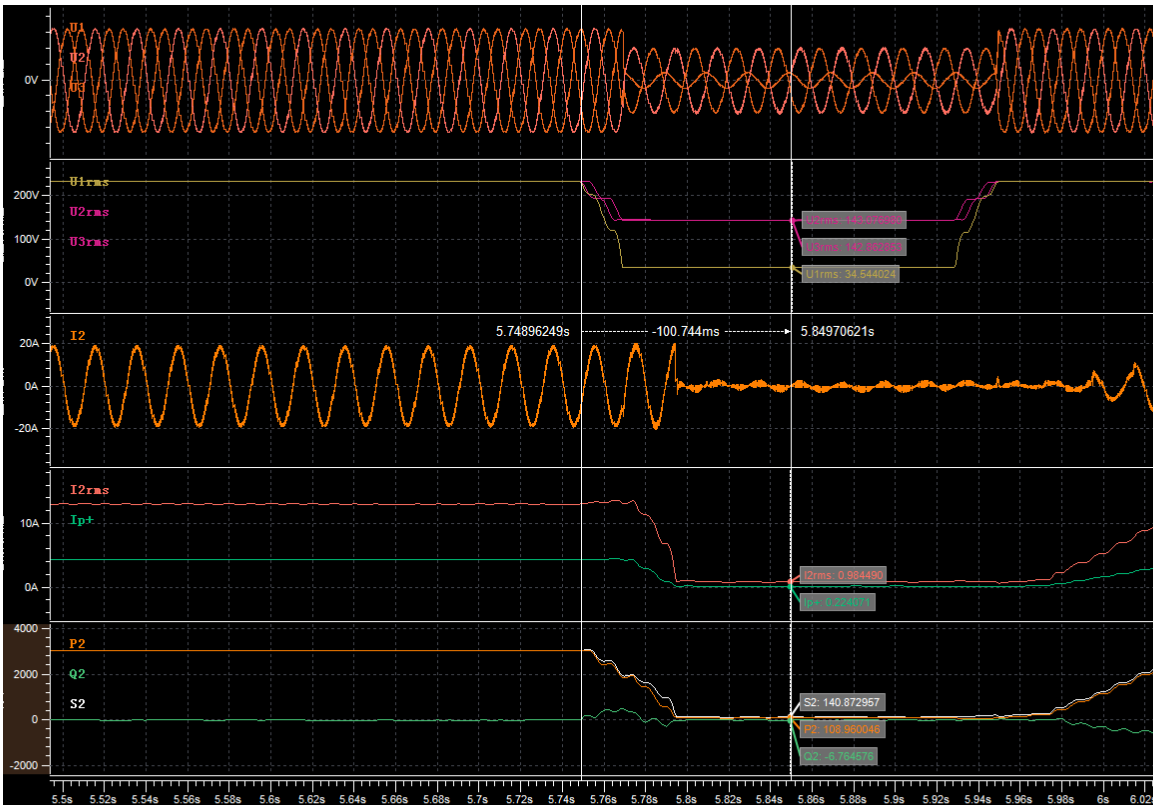
Graph of Test number 1.5_0.15Un



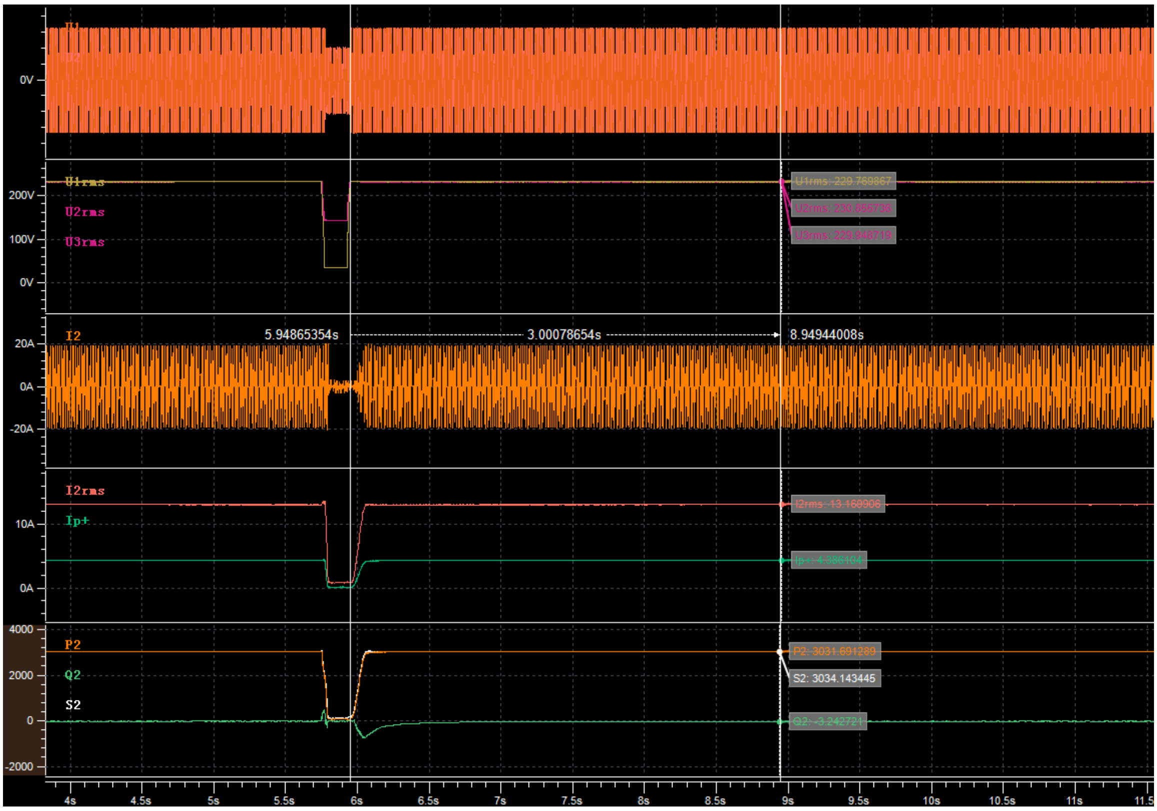
Empty load

Before dip (t1-100ms)

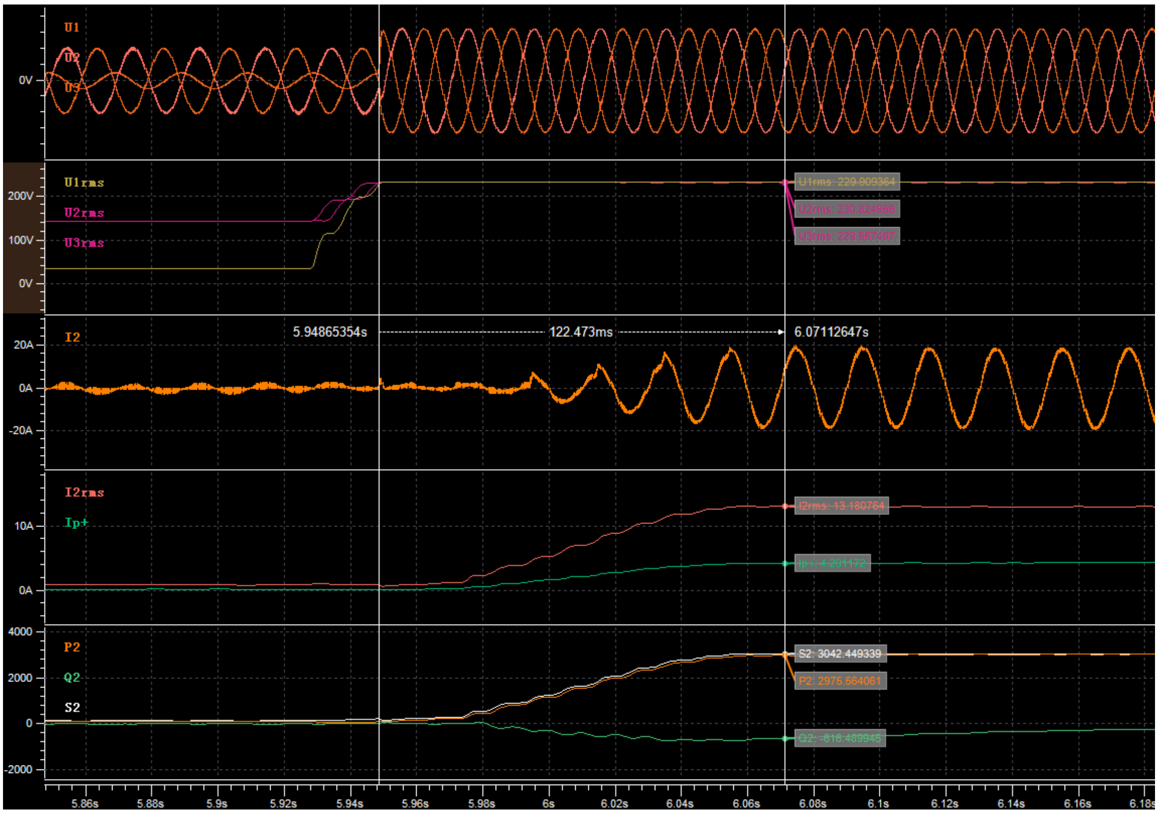
During dip (t1+60ms)



During dip (t1+100ms)

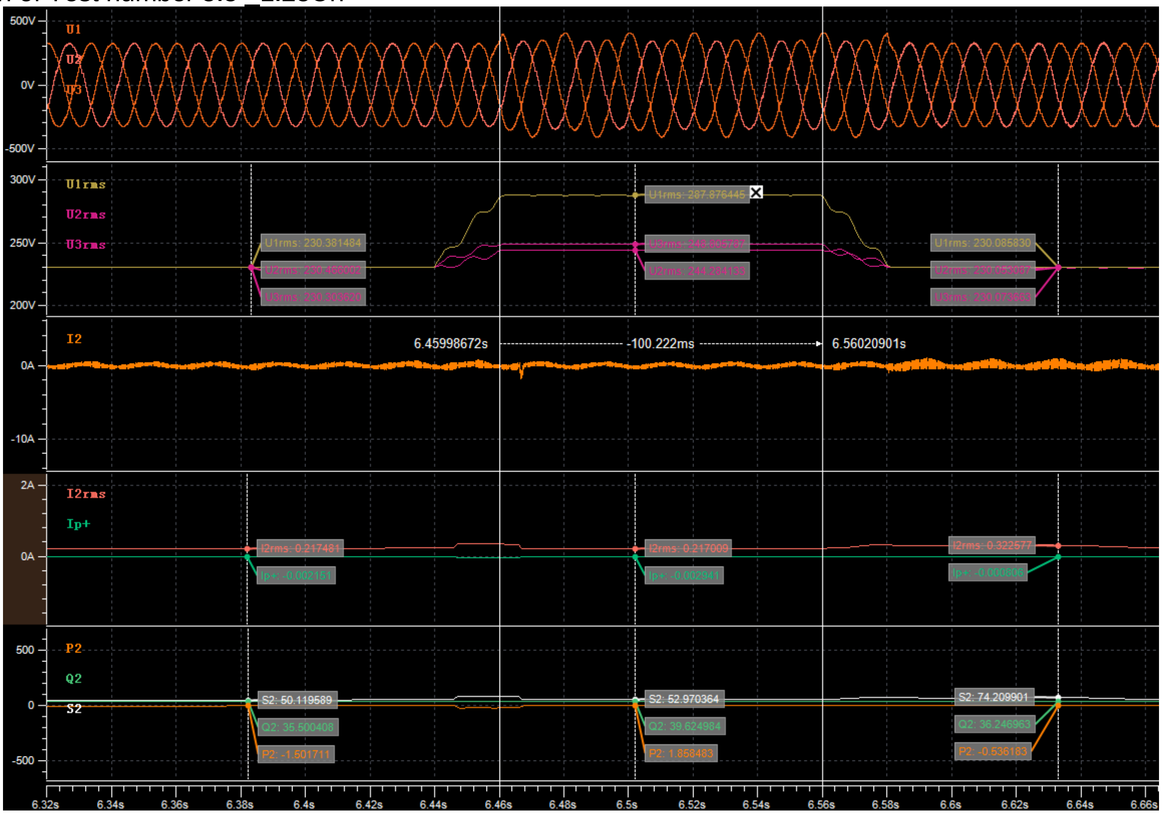


After dip (t2+3s)

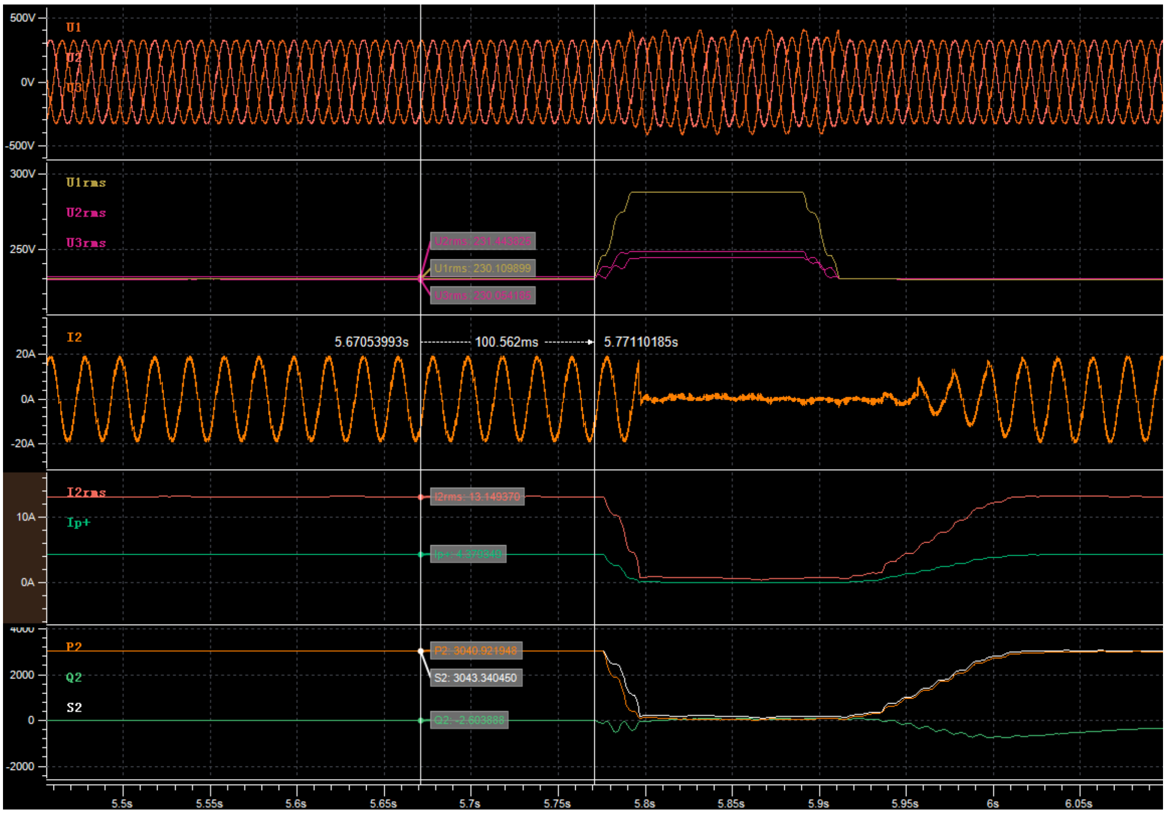


Recovery time

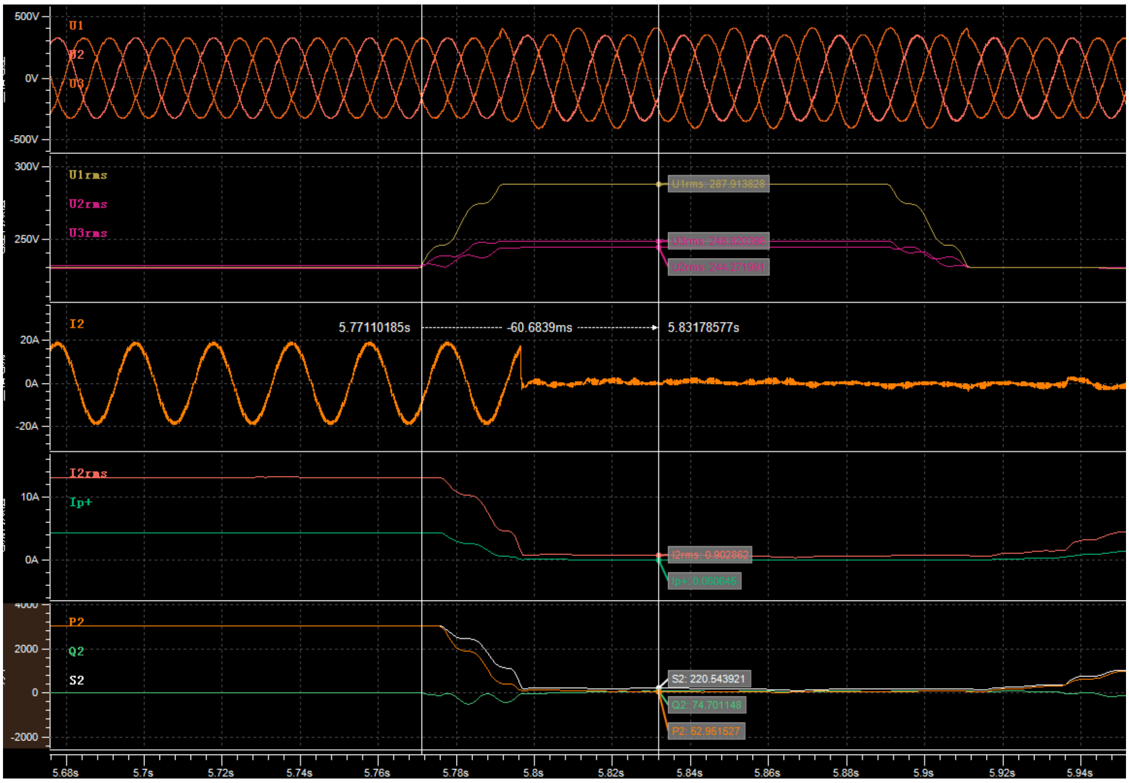
Graph of Test number 5.5 _1.25Un



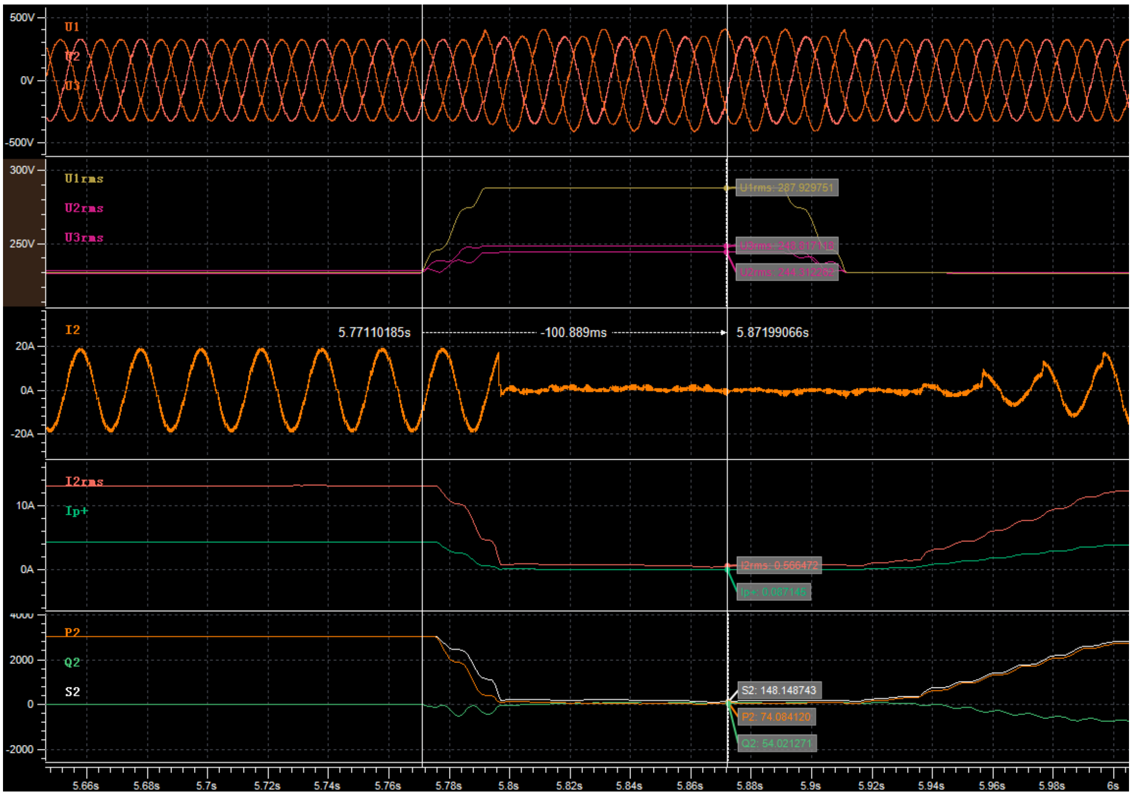
Empty load



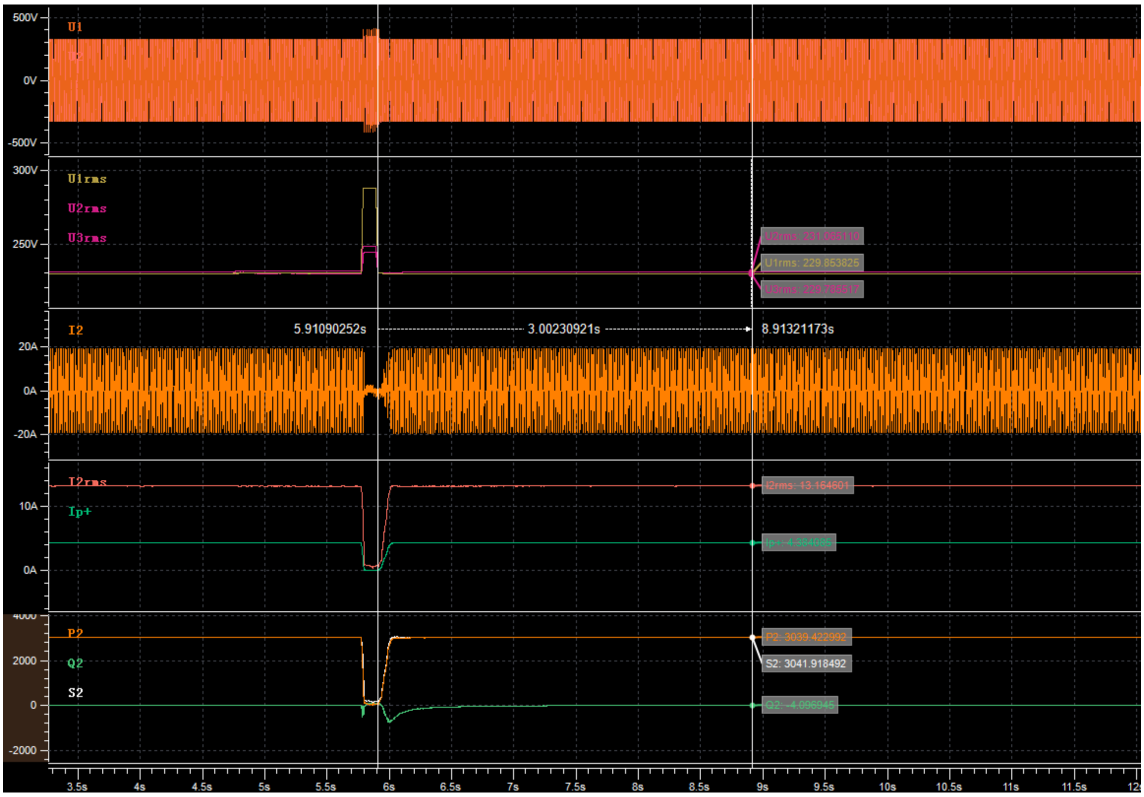
Before dip (t1-100ms)



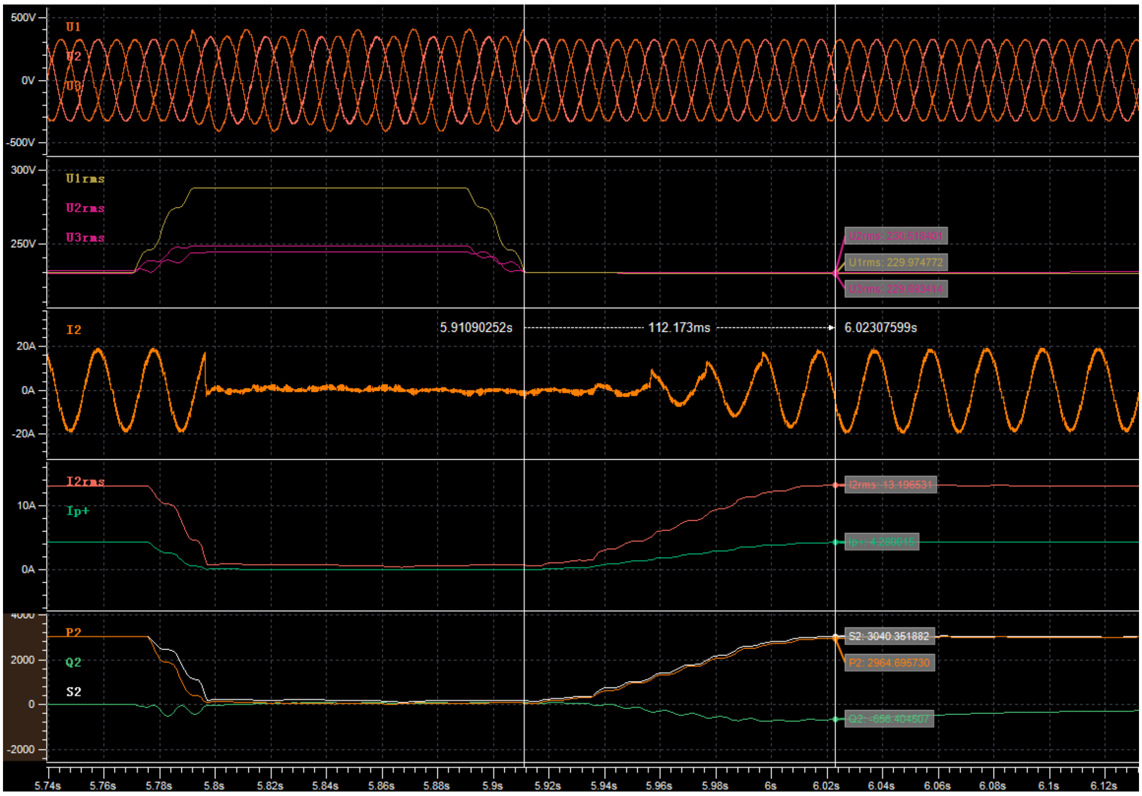
During dip (t1+60ms)



During dip (t1+100ms)



After dip (t2+3s)



Recovery time

E.7 Requirements for the test report for the NS protection

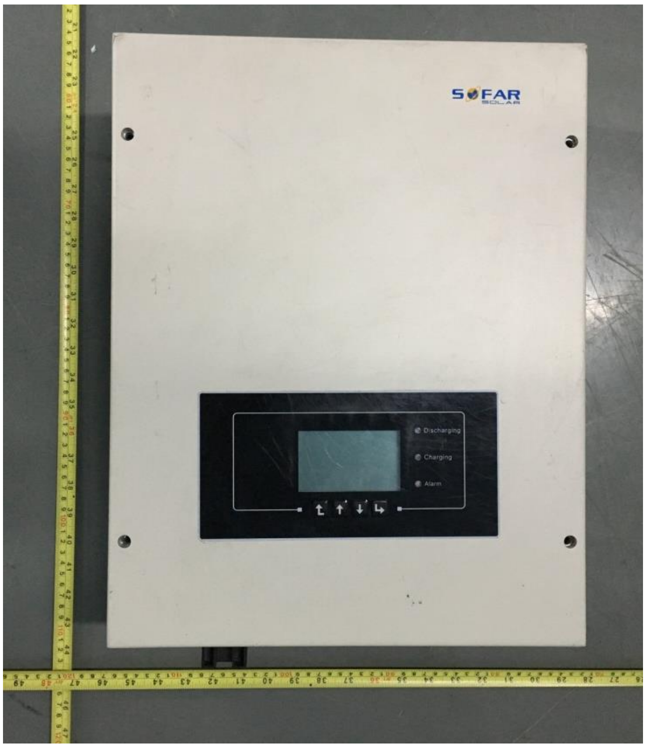
Requirements for the NS protection (Anforderungen an den NA-Schutz)						
Extract of the test report for NS protection (Auszug aus dem Prüfbericht für den NA-Schutz)						
NS protection as integrated NS protection (NA-Schutz als integrierter)						
Manufacturer: (Hergesteller)	**Shenzhen SOFAR SOLAR Co., Ltd.** 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China					
Type of NS Protection: (Typ NA-Schutz)	**Integrierter NA-Schutz**					
Software Version:	**V2.60**					
Measurement Period: (Messzeitraum)	2020-04-27 bis 2020-08-17					
	Stirling generators, fuel cells （Stirlinggeneratoren, Brennstoffzellen）			Inverter(s) （Umrichter）		
	Synchronous and asynchronous generators with $Pn \leq 50$ kW coupled directly or via inverters （direkt oder über Umrichter gekoppelte Synchron- und Asynchrongeneratoren mit Pn ≤ 50 kW）			Directly coupled synchronous and asynchronous generators with $Pn > 50$ kW （direkt gekoppelte Synchron- und Asynchrongeneratoren mit Pn > 50 kW）		
Protective function （Schutzfunktion）	Set value （Einstellwert）	Tripping value (Auslösewert)	Tripping time NS protection * (Auslösezeit NA-Schutz*)	Set value (Einstellwert)	Tripping value (Auslösewert)	Tripping time NS protection * (Auslösezeit NA-Schutz*)
Rise-in-voltage protection (Spannungssteigerungsschutz) $U >>$	--	--	--	1,25 * Un	1.249* Un	81.0ms
Rise-in-voltage protection (Spannungssteigerungsschutz) $U >$	--	--	--	1,10 * Un	1.10* Un	493s
Voltage drop protection (Spannungsrückgangsschutz) $U <$	--	--	--	0,8 * Un	0.803* Un	3.06s
Voltage drop protection (Spannungsrückgangsschutz) $U <<$	--			0,45* Un	0.453* Un	375ms
Frequency decrease protection (Frequenzrückgangsschutz) $f <$	--	--	--	47,5 Hz	47.52Hz	97.0ms
Frequency increase protection (Frequenzsteigerungsschutz) $f >$	--	--	--	51,5 Hz	51.49Hz	82.0ms

* The tripping time includes the period from the limit value violation U/f until the tripping signal to the interface switch. When planning the power generation system, the response time of the interface switch shall be added to the maximum time value obtained as indicated above. The disconnection time (sum of tripping time of the NS protection plus response time of the interface switch) shall not exceed 200 ms. * Die Auslösezeit umfasst den Zeitraum von der Grenzwertverletzung *U/f* bis zum Auslösesignal an den Kuppelschalter. Bei der Planung der Erzeugungsanlage ist die Eigenzeit des Kuppelschalters zum höchsten oben ermittelten Zeitwert zu addieren. Die Abschaltzeit (Summe der Auslösezeit NA-Schutz zzgl. Eigenzeit des Kuppelschalters) darf 200 ms nicht überschreiten.
☒ For integrated NS protection（Bei integriertem NA-Schutz)

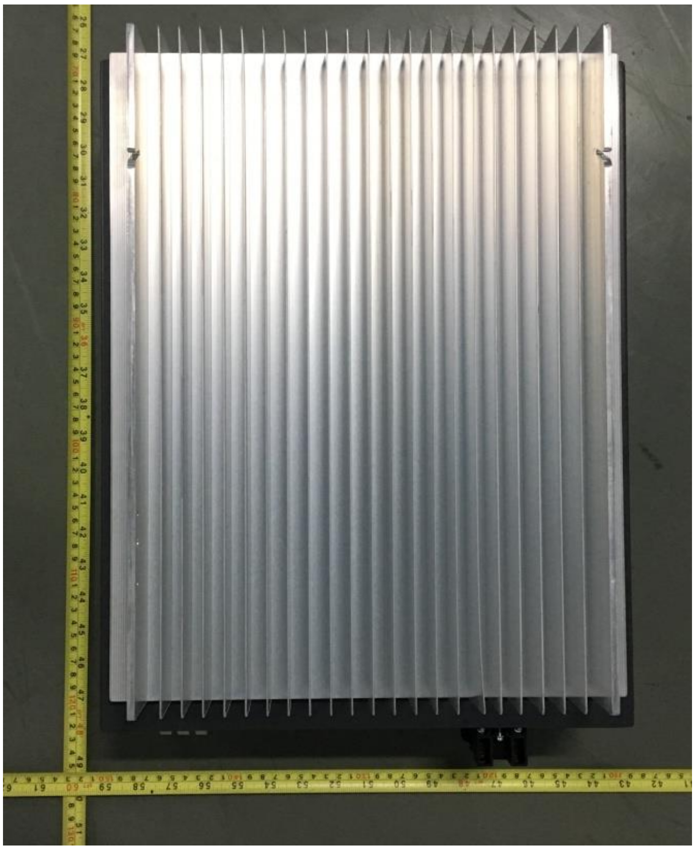
Assigned to power generation unit of type zugeordnet zu Erzeugungseinheit Typ	**ME 3000SP**
Type integrated interface switch Typ integrierter Kuppelschalter	**1, Hongfa HF161F-W** **2, Panasonic, ALFG2PF12**
Response time of interface switch for integrated NS protection Eigenzeit des Kuppelschalters bei integriertem NA-Schutz	**10ms**

Verification of the entire functional chain “integrated NS protection – interface switch” has resulted in successful disconnection. Die Überprüfung der Gesamtwirkungskette „integrierter NA-Schutz – Kuppelschalter“ führte zu einer erfolgreichen Abschaltung.

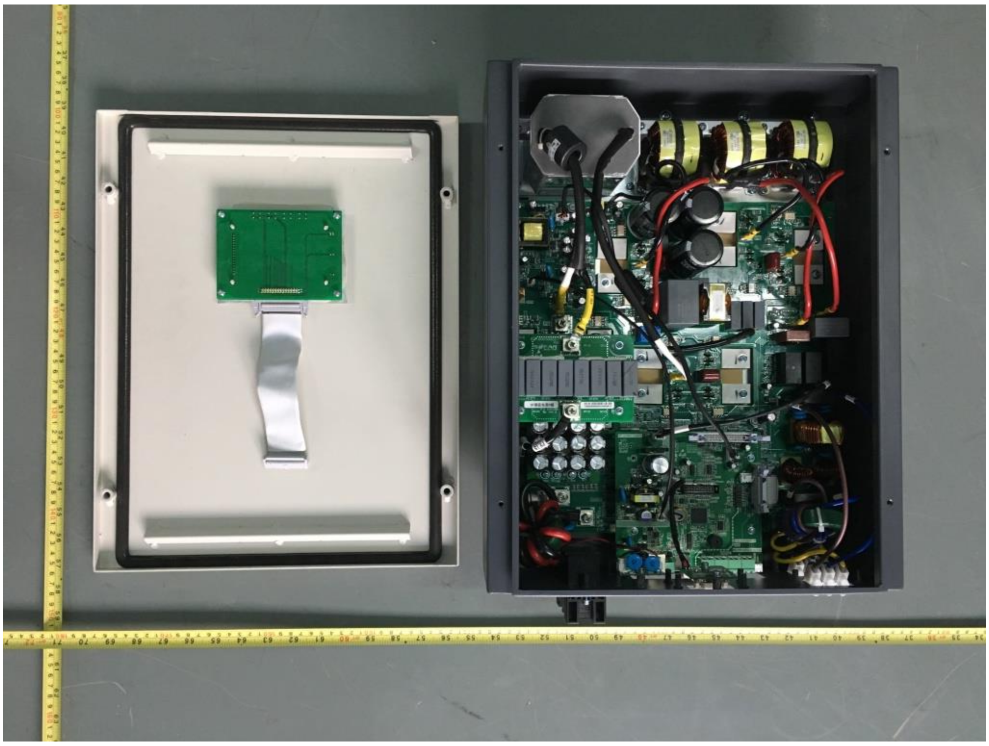
Appended photos



Top view

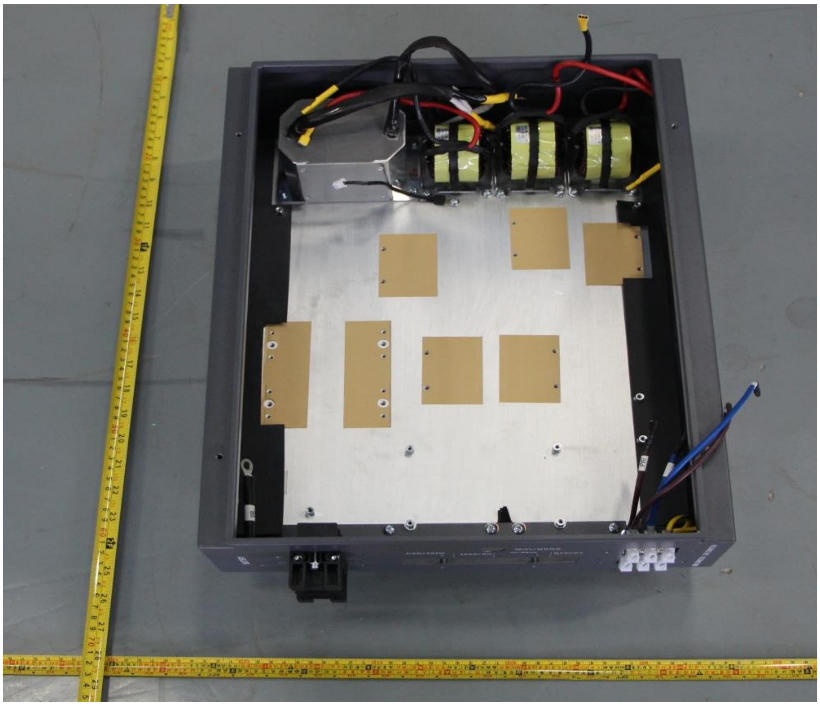

Heatsink view

Terminal view



Internal view

Internal view



Internal view

(End of Report)