Test Report issued under the responsibility of:

TL-395

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 :2020-06

Report Reference No……………:	240415256GZU-001
Date of issue ………………………:	30 May 2024
Total number of pages……………:	159 pages
Testing Laboratory ....:	Intertek Testing Services Shenzhen Ltd. Guangzhou Branch
Address ....:	Room101/301/401/102/202/302/402/502/602/702/802, No. 7-2, Caipin Road, Huangpu District, Guangzhou, Guangdong, China
Testing location/ address ....:	Same as above
Tested by (name + signature)………:	Allen Feng Engineer
Approved by (+ signature) ....:	Gaison Li Reviewer
Applicant's name ....:	Zendure USA Inc.
Address ....:	1765 E BAYSHORE RD # 201 EAST PALO ALTO, CA 94303-5501 USA
Test specification:	
Standard...................................:	VDE-AR-N 4105:2018-11 DIN VDE V 0124-100 :2020-06
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

Test item description ....:	Hybrid Inverter
Trade Mark................................:	ZENDURE SuperCharged+-
Manufacturer ....:	ZENDURE TECHNOLOGY CO., LIMITED
Address	RM 517, NEW CITY ENTRE, 2 LEI YUE MUN ROAD, KWUN TONG, KOWLOON, HK, CHINA
Model/Type reference ....:	ZDHYP2000

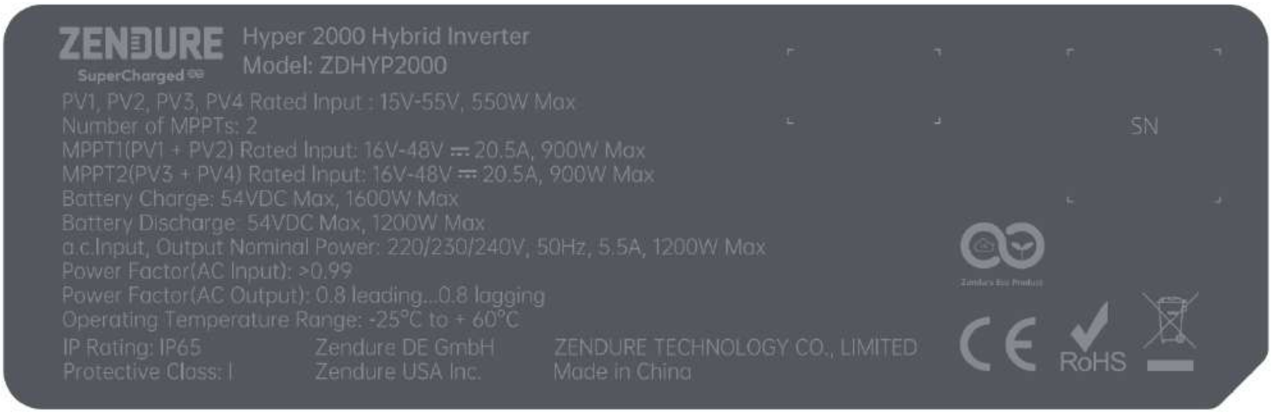
Ratings…..…….:	Model	ZDHYP2000
	PV input voltage Range	15 – 55 Vdc
	MPPT voltage Range	16 -48 Vdc
	Max.input current	2*20.5 A
	PV Isc	2*30A
	Nominal output voltage	230 Vac
	Nominal output Frequency	50 Hz
	Max. output current	5.5 A
	Max. output power	1200 W
	Max. apparent power	1200 VA
	Power factor range	0.8leading~0.8lagging
	Safety level	Class I
	Ingress Protection	IP 65
	Operation Ambient Temperature	-25℃ - +60℃
	Software version	V2

Summary of testing:

Tests performed (name of test and test clause):	**Testing location:**
(see table below)	Intertek Testing Services Shenzhen Ltd. Guangzhou Branch Room101/301/401/102/202/302/402/502/602/702/802, No. 7-2, Caipin Road, Huangpu District, Guangzhou, Guangdong, China

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
5.4.4.8 (5.2.6)	DC current feeding to network
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

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 +65℃
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 .... :	15 Apr 2024
Date (s) of performance of tests .... :	26 Apr 2024 – 20 May 2024

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.

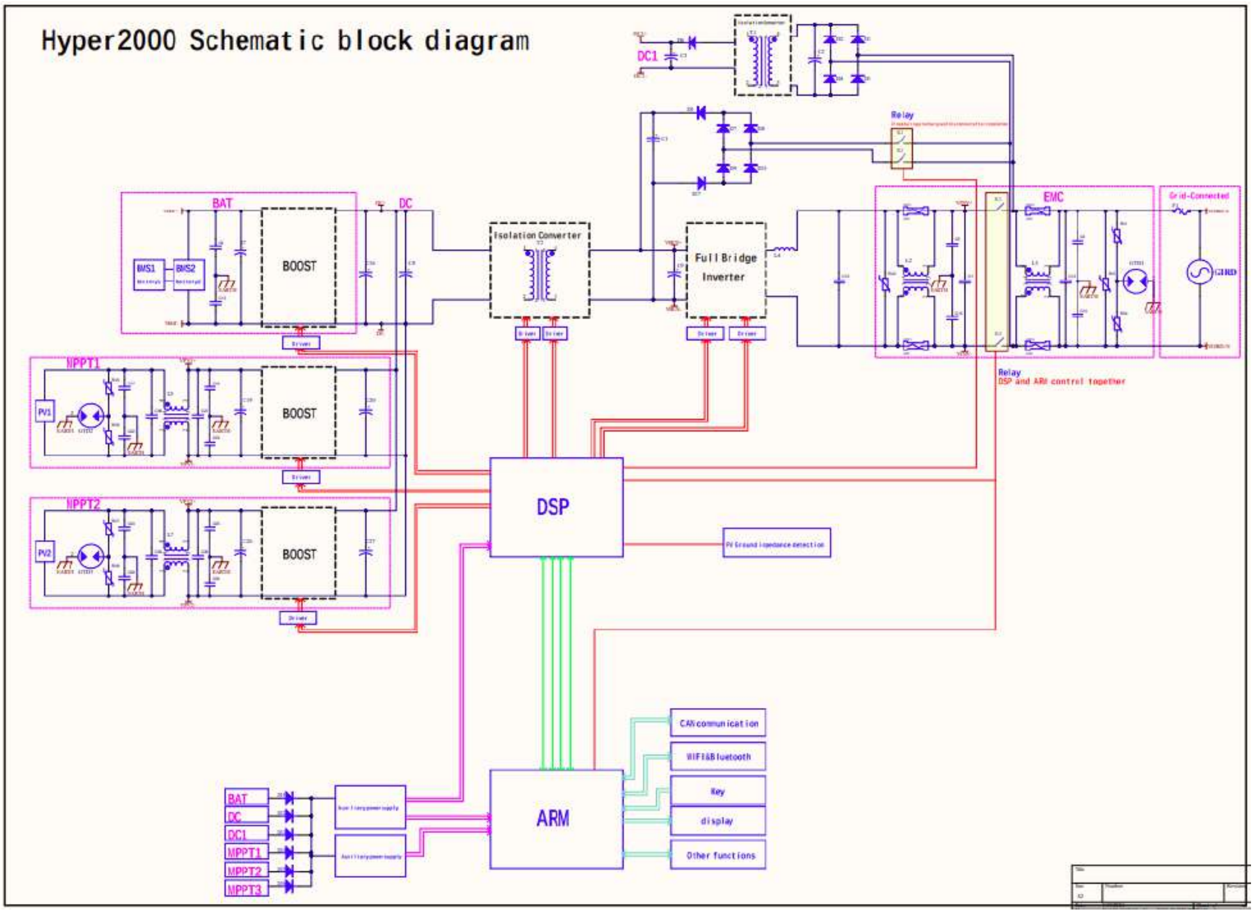
Throughout this report a point is used as the decimal separator.

General product information:

The unit is bidirectional which applies to the PV system with battery storage. Energy produced by the PV system is used to optimize self-consumption. Excess energy is used to charge the batteries, and then fed into the public grid when the PV energy is adequate.

When PV energy output is insufficient to support connected loads, the system automatically draws energy from the batteries if battery capacity is sufficient. If the battery capacity is insufficient to meet own consumption requirements, electricity will be drawn from the public grid.

The topology diagram as following:



The product was tested on:

The Software version: V2

The Hardware version: 19.12.00019 Hyper2000-PI-V1.2-20240421

Factory information:

Astec Energy Products (Dongguan)Company Limited

Address: Building 1, No. 215, Yuehai Avenue, Xiegang, Dongguan City, Guangdong Province, P.R. 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 ΣS_{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	P

VDE-AR-N 4105:2018-11			
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} ≤ 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
5.7	**Behaviour of the power generation system at the network**		P

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

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Clause	Requirement - Test	Result - Remark	Verdict
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 ϕ = 0,95under-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 ofΣSEmax ≤ 4,6 kVA , the network operator does not give any specifications. The value of cos ϕ lies within a range of cos ϕ = 0,95under-excited to 0,95over-excited. At its generator terminals, each power generation unit to be connected in systems ΣSEmax > 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 ≤ 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 ≤ 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 PGU S_{Emax}≤4.6 kVA characteristic curve provided by the network operator within cosφ= 0.95under-excited to 0.95 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 Phone and Server through WiFi module.	P

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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

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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 Phone and Server through WiFi module.	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

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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

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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

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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).	PV inverter units, a gradient of 40 % P_{Emax} per Hertz (s = 5 %) 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} ≤ 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

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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 $k_{imax} \leq 1,2$.		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	0.073	0.061	0.065
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	0.067	0.069	0.067
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	0.581	0.694	0.724
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 3) d_c and d_{Max} for voltage change refer to result of section 5.2.3 based on DIN EN 61000-3-3			

Switching actions	Ki
Marking operation without default (to primary energy carrier)	0.073
Worst case at switch over of generator sections	0.069
Marking operation at reference conditions (of primary energy carrier)	0.069
Breaking operation at nominal power	0.724
Worst case value of all switching operations Ki max	0.724

5.2.3	TABLE: Flicker					P
Test impedance	0.24Ω+0.15j					
Model: ZDHYP2000						
	Pst			cψk		
	L1	L2	L3	L1	L2	L3
1	0.078	--	--	1.56	--	--
2	0.078	--	--	1.56	--	--
3	0.078	--	--	1.56	--	--
4	0.078	--	--	1.56	--	--
5	0.078	--	--	1.56	--	--
6	0.078	--	--	1.56	--	--
7	0.078	--	--	1.56	--	--
8	0.078	--	--	1.56	--	--
9	0.078	--	--	1.56	--	--
10	0.078	--	--	1.56	--	--
11	0.077	--	--	1.54	--	--
12	0.077	--	--	1.54	--	--
Calculation						
Plt L1	0.078					
Plt L2	--					
Plt L3	--					
greatest ascertained cψk	1.56					

Note:
1) Sk,fic/Sn = 20

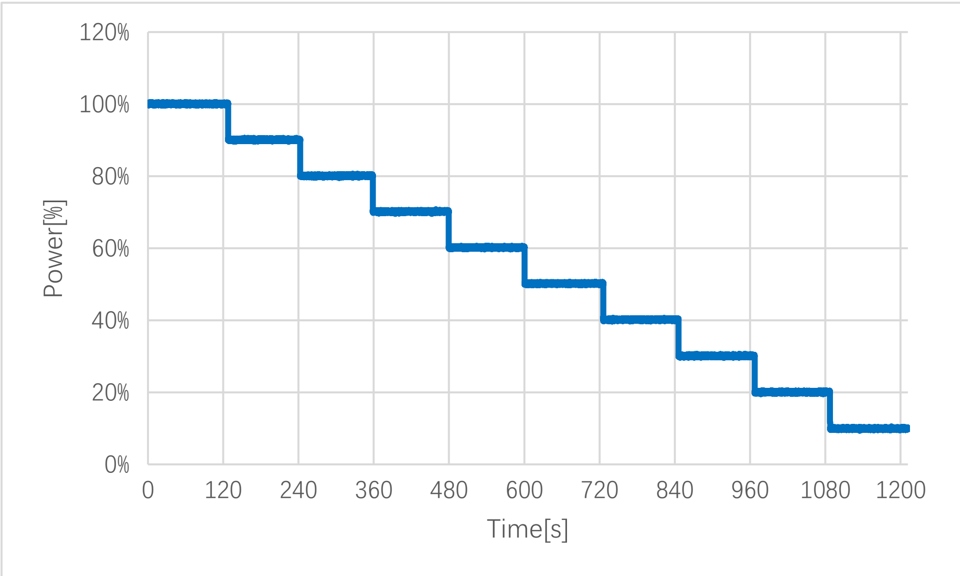
5.2.4	TABLE: Harmonics and inter-harmonics (according to DIN EN 61000-3-2) Model: ZDHYP2000										P
Active power P/P$_n$ [%]	10	20	30	40	50	60	70	80	90	100	Limit [A]
Harmonic number	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	I[A]	
2	0.0088	0.0120	0.0154	0.0188	0.0220	0.0257	0.0294	0.0324	0.0366	0.0399	1.080
3	0.0654	0.0580	0.0514	0.0465	0.0469	0.0537	0.0620	0.0733	0.0887	0.1092	2.3
4	0.0035	0.0039	0.0039	0.0040	0.0040	0.0039	0.0038	0.0040	0.0038	0.0036	0.43
5	0.0175	0.0202	0.0264	0.0307	0.0335	0.0360	0.0382	0.0399	0.0415	0.0408	1.14
6	0.0039	0.0038	0.0039	0.0040	0.0040	0.0039	0.0039	0.0038	0.0038	0.0036	0.3
7	0.0083	0.0061	0.0080	0.0105	0.0127	0.0140	0.0157	0.0174	0.0193	0.0200	0.77
8	0.0040	0.0041	0.0041	0.0040	0.0041	0.0039	0.0040	0.0039	0.0037	0.0038	0.23
9	0.0048	0.0048	0.0049	0.0051	0.0058	0.0058	0.0069	0.0081	0.0091	0.0108	0.4
10	0.0041	0.0042	0.0039	0.0041	0.0042	0.0042	0.0041	0.0041	0.0039	0.0037	0.184
11	0.0042	0.0045	0.0042	0.0044	0.0046	0.0041	0.0044	0.0050	0.0055	0.0063	0.33
12	0.0043	0.0043	0.0042	0.0042	0.0042	0.0041	0.0040	0.0041	0.0041	0.0038	0.153
13	0.0045	0.0046	0.0042	0.0044	0.0044	0.0040	0.0041	0.0043	0.0049	0.0052	0.21
14	0.0041	0.0043	0.0043	0.0042	0.0042	0.0042	0.0042	0.0042	0.0042	0.0043	0.131
15	0.0043	0.0045	0.0045	0.0046	0.0047	0.0043	0.0045	0.0046	0.0050	0.0052	0.15
16	0.0053	0.0044	0.0045	0.0045	0.0044	0.0044	0.0045	0.0043	0.0042	0.0043	0.115
17	0.0047	0.0046	0.0047	0.0046	0.0048	0.0044	0.0046	0.0047	0.0050	0.0052	0.132
18	0.0044	0.0059	0.0043	0.0045	0.0045	0.0045	0.0045	0.0045	0.0044	0.0043	0.102
19	0.0043	0.0045	0.0064	0.0048	0.0051	0.0046	0.0049	0.0051	0.0053	0.0053	0.118
20	0.0045	0.0047	0.0045	0.0048	0.0047	0.0047	0.0046	0.0046	0.0045	0.0043	0.092
21	0.0044	0.0048	0.0050	0.0062	0.0053	0.0046	0.0048	0.0049	0.0049	0.0047	0.107
22	0.0047	0.0046	0.0048	0.0047	0.0046	0.0047	0.0046	0.0045	0.0044	0.0044	0.084
23	0.0045	0.0047	0.0048	0.0050	0.0062	0.0045	0.0047	0.0048	0.0049	0.0049	0.098
24	0.0044	0.0047	0.0046	0.0047	0.0058	0.0048	0.0046	0.0046	0.0045	0.0045	0.077
25	0.0044	0.0047	0.0049	0.0052	0.0055	0.0048	0.0048	0.0049	0.0048	0.0049	0.09
26	0.0048	0.0047	0.0050	0.0048	0.0050	0.0059	0.0047	0.0046	0.0044	0.0046	0.071
27	0.0046	0.0048	0.0049	0.0051	0.0051	0.0056	0.0044	0.0043	0.0043	0.0042	0.083
28	0.0044	0.0046	0.0045	0.0045	0.0045	0.0044	0.0051	0.0044	0.0046	0.0048	0.066
29	0.0042	0.0043	0.0044	0.0046	0.0047	0.0042	0.0051	0.0042	0.0042	0.0044	0.078
30	0.0042	0.0043	0.0046	0.0046	0.0046	0.0047	0.0055	0.0048	0.0047	0.0047	0.061
31	0.0041	0.0042	0.0043	0.0045	0.0045	0.0041	0.0044	0.0041	0.0043	0.0042	0.073
32	0.0047	0.0049	0.0049	0.0048	0.0049	0.0049	0.0048	0.0048	0.0048	0.0046	0.058
33	0.0039	0.0041	0.0042	0.0043	0.0042	0.0041	0.0041	0.0048	0.0041	0.0040	0.068
34	0.0043	0.0046	0.0044	0.0045	0.0045	0.0047	0.0046	0.0056	0.0049	0.0047	0.054
35	0.0039	0.0040	0.0041	0.0042	0.0042	0.0041	0.0041	0.0049	0.0042	0.0041	0.064
36	0.0042	0.0043	0.0046	0.0048	0.0051	0.0051	0.0052	0.0058	0.0051	0.0049	0.051
37	0.0039	0.0041	0.0042	0.0043	0.0045	0.0043	0.0044	0.0046	0.0047	0.0047	0.061
38	0.0048	0.0054	0.0054	0.0056	0.0055	0.0054	0.0056	0.0054	0.0052	0.0054	0.048

39	0.0042	0.0047	0.0050	0.0052	0.0054	0.0048	0.0048	0.0049	0.0054	0.0049	0.058
40	0.0055	0.0055	0.0055	0.0054	0.0052	0.0051	0.0051	0.0052	0.0061	0.0055	0.046
41	0.0045	0.0047	0.0049	0.0050	0.0051	0.0046	0.0046	0.0045	0.0054	0.0046	--
42	0.0051	0.0051	0.0051	0.0052	0.0054	0.0055	0.0056	0.0058	0.0067	0.0063	--
43	0.0045	0.0047	0.0049	0.0051	0.0053	0.0048	0.0050	0.0051	0.0061	0.0057	--
44	0.0050	0.0053	0.0055	0.0060	0.0062	0.0063	0.0063	0.0063	0.0063	0.0061	--
45	0.0051	0.0056	0.0060	0.0066	0.0069	0.0063	0.0066	0.0068	0.0072	0.0073	--
46	0.0064	0.0067	0.0069	0.0070	0.0066	0.0062	0.0059	0.0057	0.0055	0.0053	--
47	0.0061	0.0066	0.0069	0.0073	0.0074	0.0063	0.0063	0.0064	0.0065	0.0064	--
48	0.0064	0.0063	0.0060	0.0055	0.0052	0.0049	0.0046	0.0047	0.0048	0.0053	--
49	0.0064	0.0063	0.0063	0.0063	0.0060	0.0050	0.0051	0.0051	0.0051	0.0057	--
50	0.0044	0.0043	0.0042	0.0042	0.0042	0.0042	0.0042	0.0043	0.0045	0.0053	--

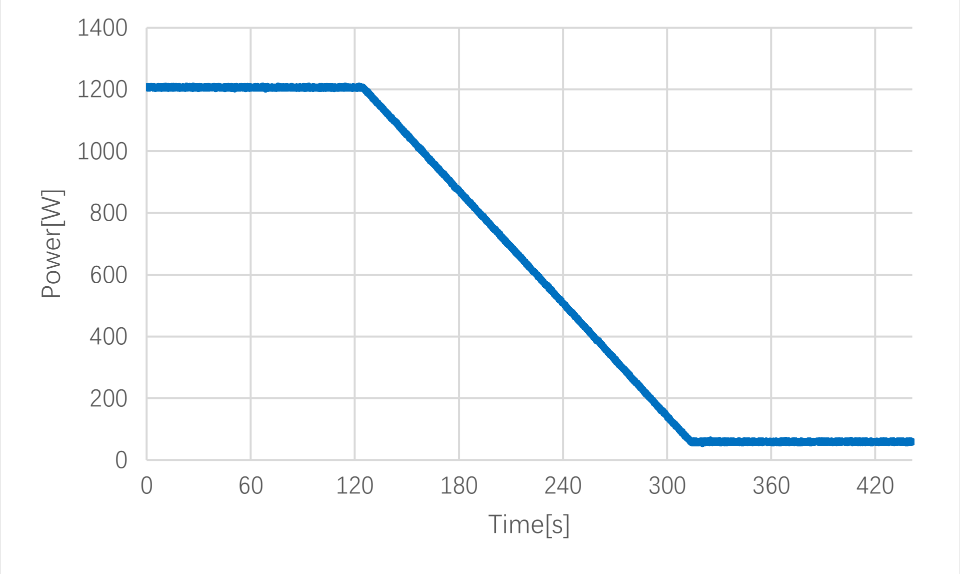
5.2.6	TABLE: DC Injection					P
Model: ZDHYP2000						
Rated output current: 5.22A						
Power P/Pn		100%				
Measurement						Limitation
Phase L1		Phase L2		Phase L3		
0.0213A	0.408%	--	--	--	--	0.5%
Power P/Pn [%]		60%				
Measurement						Limitation
Phase L1		Phase L2		Phase L3		
0.0012A	0.022%	--	--	--	--	0.5%
Power P/Pn [%]		30%				
Measurement						Limitation
Phase L1		Phase L2		Phase L3		
0.0164A	0.315%	--	--	--	--	0.5%

5.4.2	TABLE: Measurement of active- and reactive power ranges								P
Model: ZDHYP2000									
No.	Test condition		Measurement						
	Cosφ	U / Un	U [V]	I [A]	$P_{Emax600}$ *) [W]	$S_{emax600}$ *) [VA]	Q [Var]	Cosφ	
a1	1.00	90%	207.18	5.82	1204.70	1205.82	51.83	0.9999	
a3		100%	230.18	5.18	1191.83	1193.06	54.07	0.9999	
a5		109%	250.86	4.75	1190.37	1191.73	56.71	0.9999	
b1	max. under-excited	95%	219.31	5.71	1187.27	1252.36	-398.52	0.9501	
b3		100%	230.77	5.42	1186.31	1251.63	-399.06	0.9503	
B5		109%	251.41	4.96	1180.66	1246.29	-399.11	0.9509	
c1	max. over-excited	90%	207.89	6.16	1218.72	1281.35	395.69	0.9508	
c3		100%	230.80	5.54	1216.10	1279.21	396.84	0.9507	
c4		105%	242.27	5.27	1213.08	1276.26	396.58	0.9500	
$P_{Emax600}$ [W]			1218.72						
$S_{Emax600}$ [VA]			1281.35						

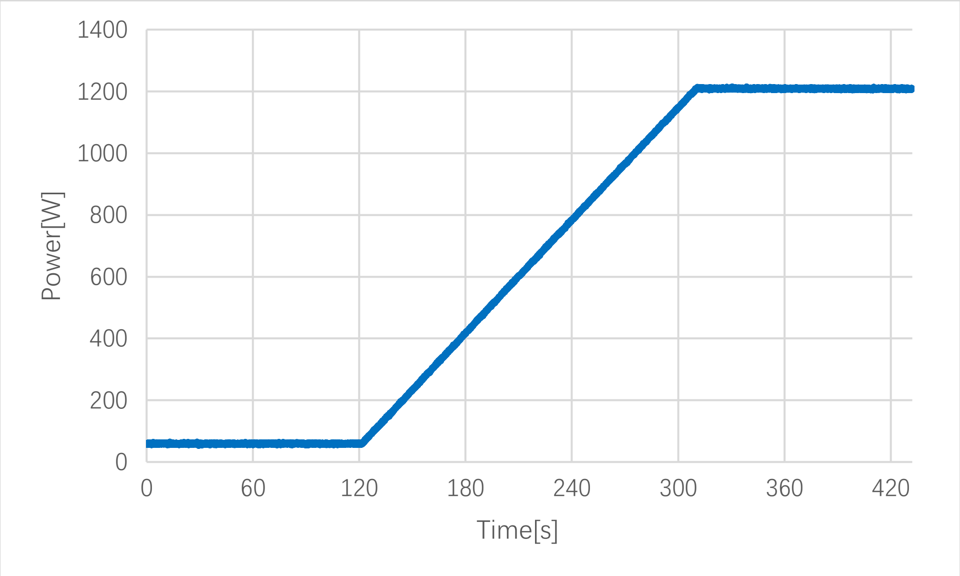
5.4.3	Active power reduction through setpoint specification			P
Measurement Item	Power Setting [W]	Actual Power [W]	Deviation of power [W]	∆ P/ Pn [%]
100%	1200	1201.36	1.36	0.11
90%	1080	1082.56	2.56	0.21
80%	960	961.05	1.05	0.09
70%	840	843.53	3.53	0.29
60%	720	723.37	3.37	0.28
50%	600	602.88	2.88	0.24
40%	480	482.56	2.56	0.21
30%	360	362.86	2.86	0.24
20%	240	242.69	2.69	0.22
10%	120	120.55	0.55	0.05
Limitation of ∆ P/ Pn	± 5%			



Power gradient (100%Pn ->5%Pn) [W/s]:	6.07W/s
Power gradient (5%Pn ->100%Pn) [W/s]:	6.11W/s
Limitation of gradient [W/s]	3.96W/s – 7.92W/s

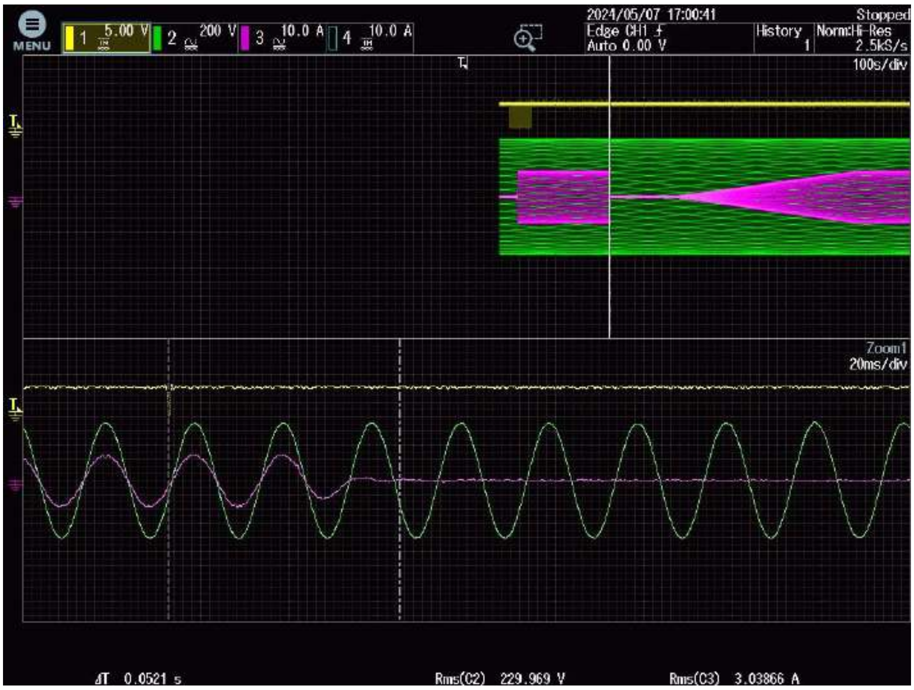


Power gradient from 100% to 5%



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%

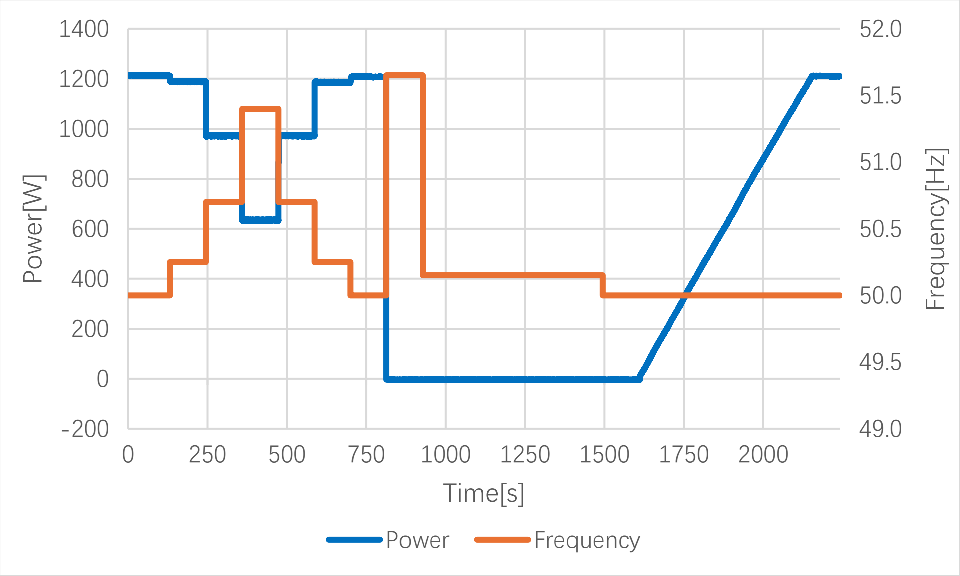


Response time: 0.052s

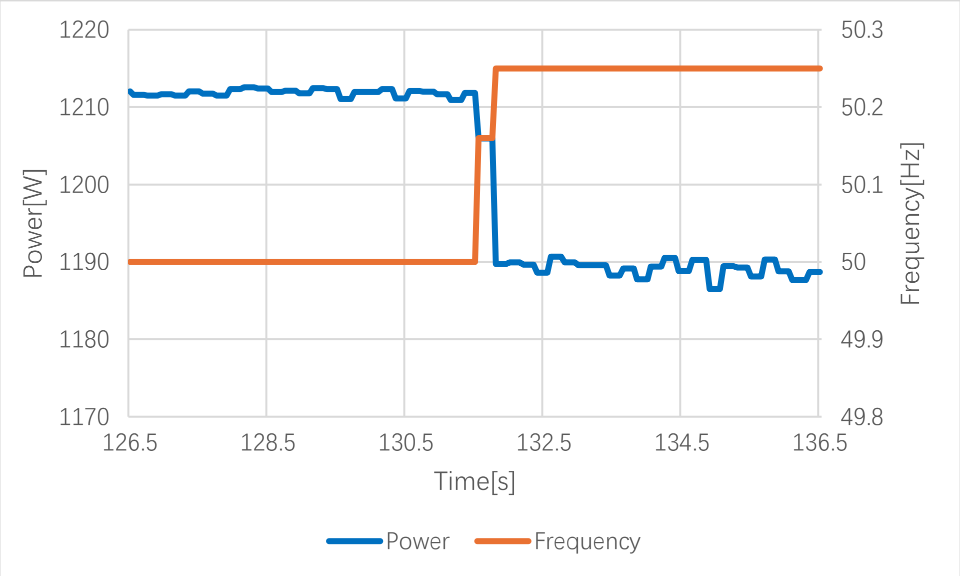
Noted: CH1 represents signal for activating logic interface, CH3: Current of EUT

5.4.4	Active power supply at overfrequency							P
Test 1	40%P_{Emax} (W)		480		10%P_{Emax} (W)		120	
Setting parameters of the EZE: P = 100% PEmax Start of power reduction at 50.2 Hz s = 5% (40% Pref / 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 $T_{an\_90\ \%}$ <2s	Time: The settling times <20s
a) 50Hz ± 0.01Hz	50.00	100	1213.82	1.15	< ± 5%	--	--	--
b)50.25Hz ± 0.01Hz	50.25	98	1190.77	1.23	< ± 10%	0.1	0.1	0.3
c)50.70Hz ± 0.01Hz	50.70	80	972.12	1.01	< ± 10%	--	0.1	0.2
d)51.40Hz ± 0.01Hz	51.40	52	633.82	0.82	< ± 10%	--	0.1	0.3
e)50.70Hz ± 0.01Hz	50.70	80	970.52	0.88	< ± 10%	--	0.5	0.9
f)50.25Hz ± 0.01Hz	50.25	98	1185.19	0.77	< ± 10%	--	0.2	0.5
g)50Hz ± 0.01Hz	50.00	100	1195.68	-0.36	< ± 10%	--	0.2	0.6
h)51.65Hz± 0.01Hz	51.65	0	0	Disconnection Time[ms]:100, Limitation[ms]: 200				
i)50.15Hz± 0.01Hz	50.15	0	0	Reconnection: ☐ Yes/ ☒ No, Limitation: No reconnection is allowed.				
j)50.00Hz± 0.01Hz	50.00	100	1210.67	Reconnection time: 117.1s Maximal Rising Gradient [%/min]:9.56 %, Limitation [%/min]: 10%				

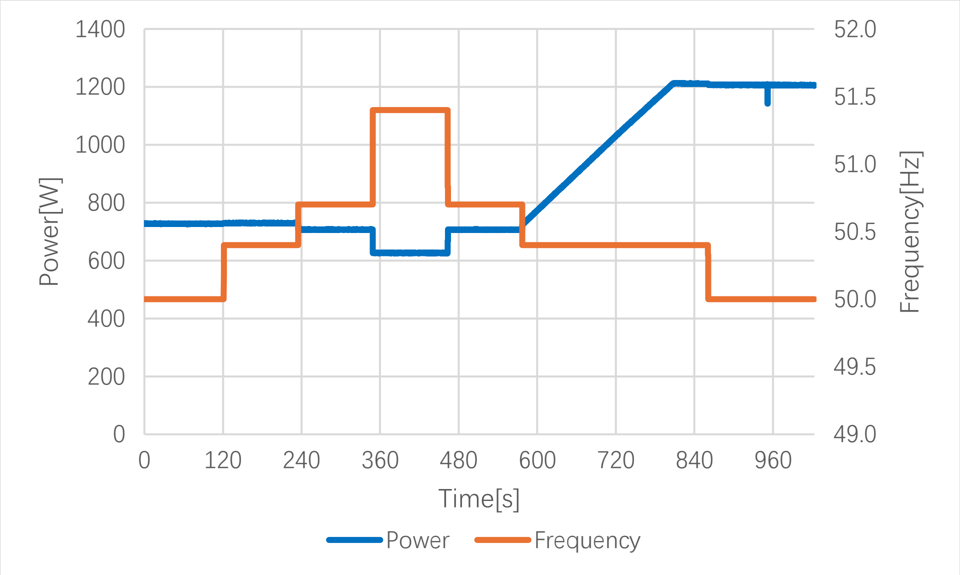
Test 2	16.67%P_{Emax} (W)		200		10%P_{Emax} (W)		120	
Setting parameters of the EZE: P = 60% PEmax (The reduction of the primary energy supply to limit the active power output, or the limiting setting of the active power output must be removed from measuring point c) Start of power reduction at 50.5 Hz s= 12% (16.67% 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 $T_{an\_90\ \%}$ <2s	The settling times <20s
a)50Hz ± 0.01Hz	50.00	60	727.75	0.65	< ± 5%	--	--	--
b)50.40Hz ± 0.01Hz	50,40	60	729.99	0.83	< ± 10%	--	--	--
c)50.70Hz ± 0.01Hz	50.70	58	707.66	0.97	< ± 10%	0.1	0.1	0.3
d)51.40Hz ± 0.01Hz	51.40	51	626.61	1.22	< ± 10%	--	0.1	0.2
e)50.70Hz ± 0.01Hz	50.70	58	706.35	0.86	< ± 10%	--	0.1	0.3
f)50.40Hz ± 0.01Hz	50.40	60-100	Maximal Rising Gradient [%/min]: 9.16, Limitation [%/min]: 10%					
g)50Hz ± 0.01Hz	50.00	100	--					



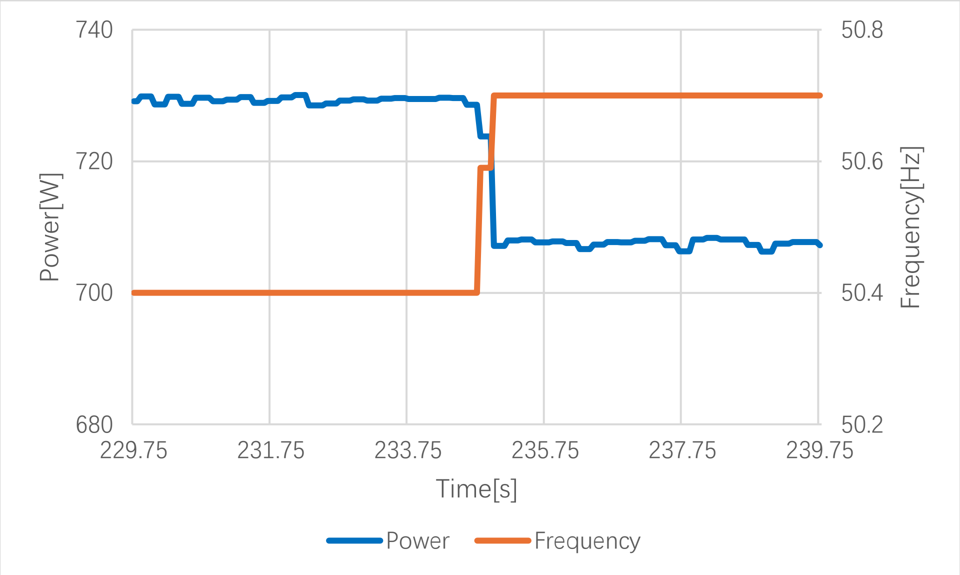
Test 1 P&F curve



Response time



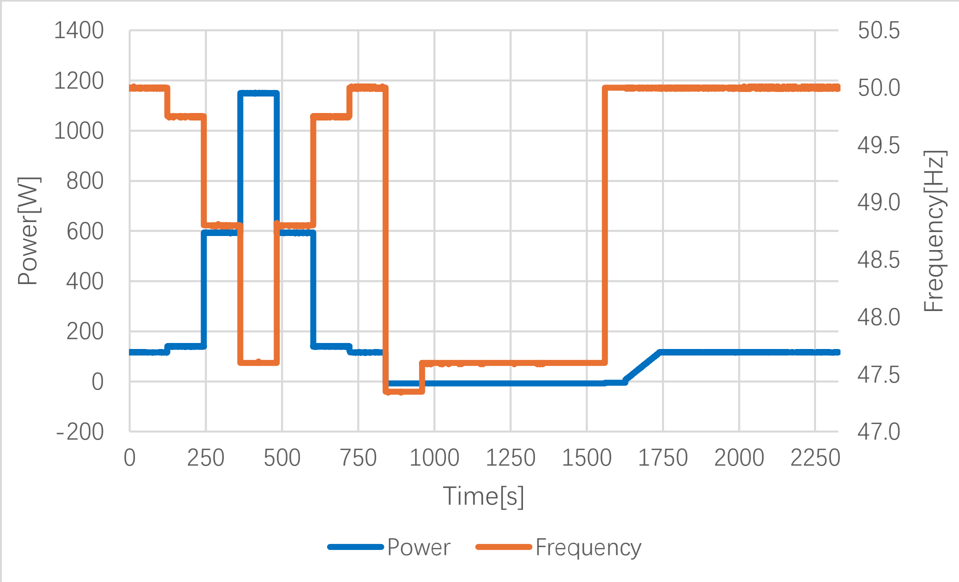
Test 2 P&F curve



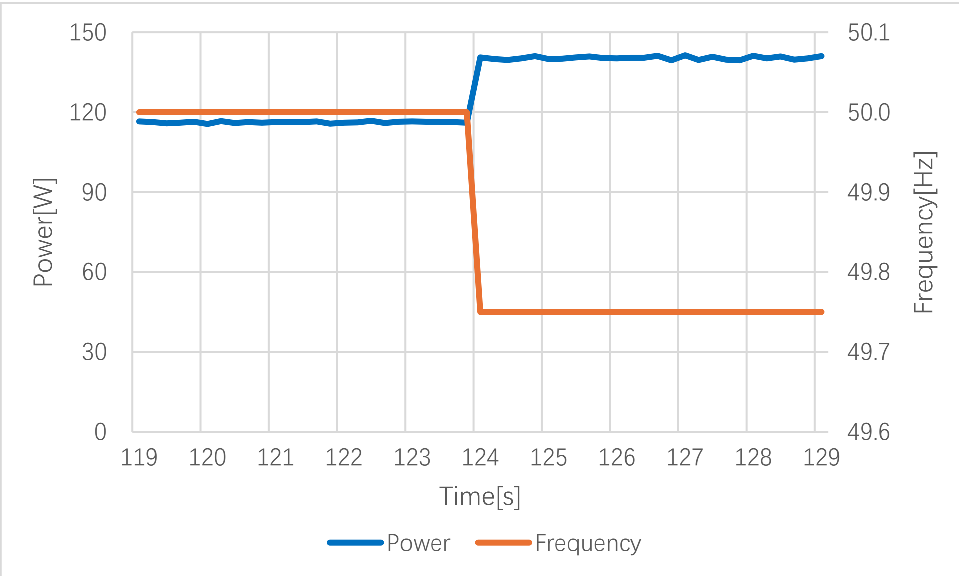
Response time

5.4.6	Active power supply at underfrequency							P
Test 1 Setting parameters of the EZE:P=10% Start of power reduction at 49.8 Hz	40%P_{Emax} (W)		480		10%P_{Emax} (W)		120	
	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 $T_{an\_90\ \%}$ <2s	The settling times <20s
a) 50Hz ± 0.01Hz	50.00	10.00	116.81	-0.27	< ± 5%	--	--	--
b)49.75Hz ± 0.01Hz	49.75	12.00	140.53	-0.29	< ± 10%	0.1	0.1	0.3
c)48.80Hz ± 0.01Hz	48.80	50.00	592.88	-0.59	< ± 10%	--	0.1	0.2
d)47.60Hz ± 0.01Hz	47.60	98.00	1149.52	-2.21	< ± 10%	--	0.1	0.2
e)48.80Hz ± 0.01Hz	48.80	50.00	592.65	-0.61	< ± 10%	--	0.1	0.3
f)49.75Hz ± 0.01Hz	49.75	12.00	140.31	-0.31	< ± 10%	--	0.1	0.2
g)50Hz ± 0.01Hz	50.00	10.00	116.23	-0.31	< ± 10%	--	0.1	0.2
h)47.35Hz± 0.01Hz	47.35	0	0	Disconnection Time[ms]:100ms, Limitation[ms]: _200_				
i)47.60Hz± 0.01Hz	47.60	0	0	Reconnection: ☐ Yes/ ☒ No, Limitation: No reconnection is allowed.				
j)50.00Hz± 0.01Hz	50.00	10	120.19	Reconnection time: 67.4s Maximal Rising Gradient [%/min]: 5.34%, Limitation [%/min]: 10%				

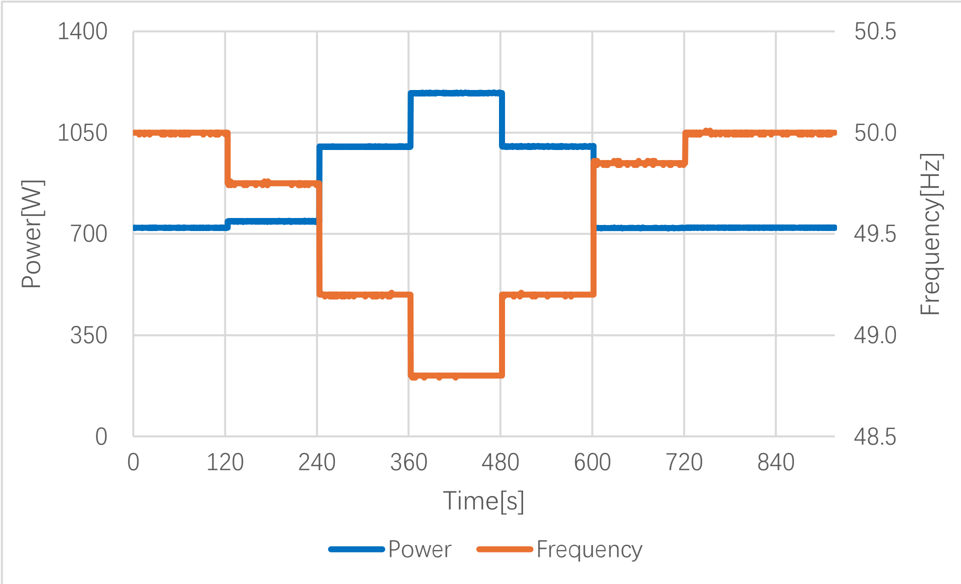
Test 2	40%P_{Emax} (W)		480			10%P_{Emax} (W)		120
Setting parameters of the EZE: P = 60% PEmax (The reduction of the primary energy supply to limit the active power output, or the limiting setting of the active power output must be removed from measuring point c) Start of power reduction at 49.8 Hz	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 $T_{an\_90\ \%}$ <2s	The settling times <20s
a)50Hz ± 0.01Hz	50.00	60.00	721.25	0.10	< ± 5%	--	--	--
b)49.75Hz ± 0.01Hz	49.75	62.00	742.82	-0.10	< ± 10%	0.1	0.1	0.2
c)49.20Hz ± 0.01Hz	49.20	84.00	1002.33	-0.47	< ± 10%	--	0.1	0.2
d)48.80Hz ± 0.01Hz	48.80	100.00	1186.35	-1.14	< ± 10%	--	0.1	0.3
e)49.20Hz ± 0.01Hz	49.20	84.00	1001.98	-0.50	< ± 10%	--	0.1	0.2
f)49.85Hz ± 0.01Hz	49.85	60.00	720.63	0.05	< ± 10%	--	0.1	0.2
g)50Hz ± 0.01Hz	50.00	60.00	721.99	0.17	< ± 10%	---	--	--



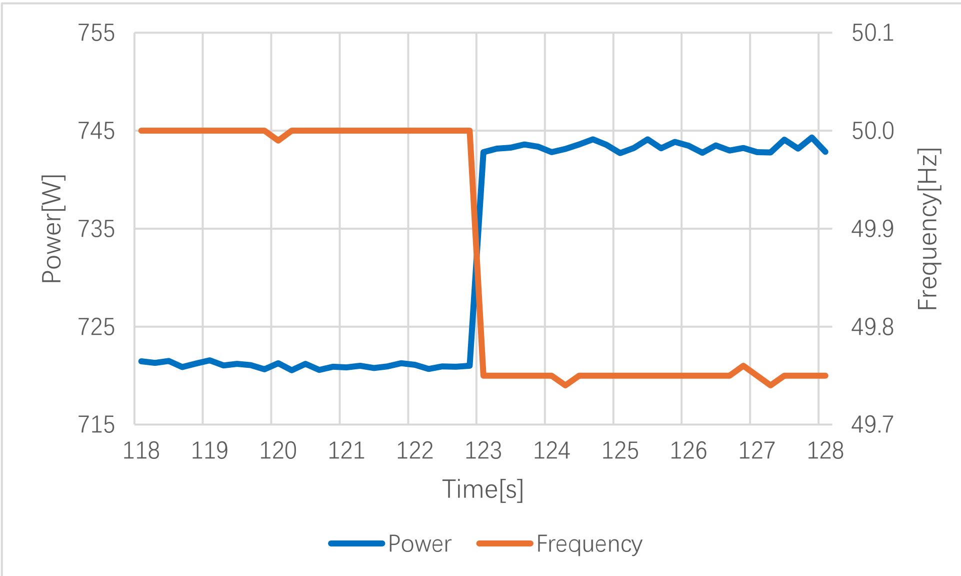
Test 1 P&F curve



Response time

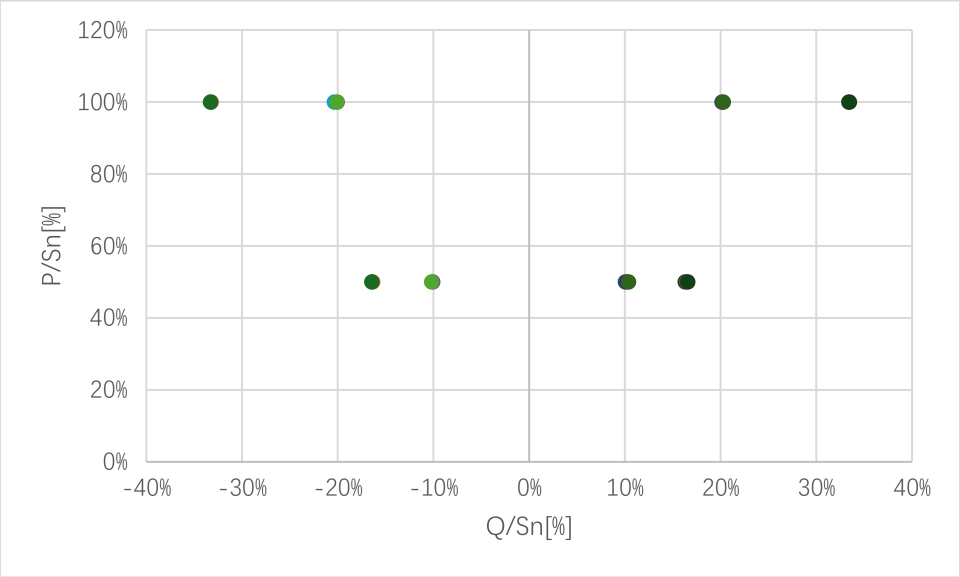


Test 2 P&F curve



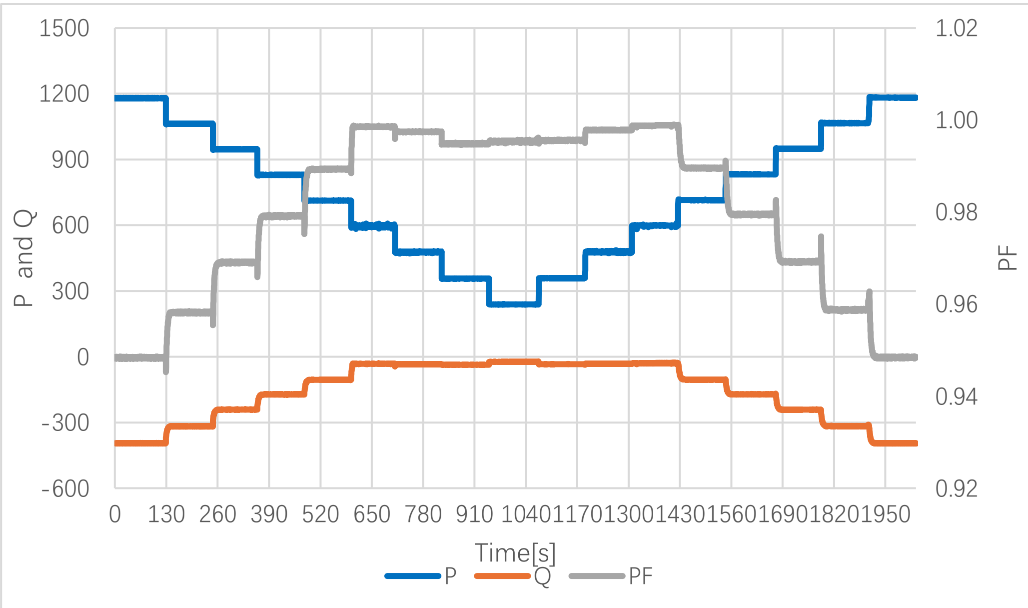
Response time

5.4.8.2	TABLE: Reactive power / displacement factor setting accuracy									P
No.	Test condition		Measurement							
	Cosφ	Power	U [V]	P [W]	Q [Var]	S [VA]	cos ϕ	∆ Q / P_{Emax}	Limit ∆ Q / P_{Emax}	
☒ ∑SEmax < 4.6kVA										
c)	0.95 under-excited	50%P_{Emax}	207.15	600.74	-196.53	632.07	0.9504	0.04	≤ ±4%	
			230.15	597.46	-196.07	628.81	0.9501	0.08	≤ ±4%	
			253.15	595.00	-196.96	626.76	0.9493	0.01	≤ ±4%	
		S_{Emax}	207.58	1186.29	-398.56	1251.45	0.9479	-0.37	≤ ±4%	
			230.53	1182.71	-398.69	1248.11	0.9476	-0.38	≤ ±4%	
			253.49	1177.86	-399.37	1243.73	0.9470	-0.43	≤ ±4%	
	0.98 under-excited	50%P_{Emax}	207.16	604.48	-120.99	616.47	0.9806	0.07	≤ ±4%	
			230.15	601.43	-120.89	613.46	0.9804	0.08	≤ ±4%	
			253.15	597.96	-122.09	610.30	0.9798	-0.02	≤ ±4%	
		S_{Emax}	207.58	1192.85	-244.13	1217.57	0.9796	-0.03	≤ ±4%	
			230.53	1189.82	-240.55	1213.89	0.9801	0.26	≤ ±4%	
			253.49	1185.00	-240.93	1209.25	0.9799	0.22	≤ ±4%	
d)	0.95 over-excited	50% P_{Emax}	207.16	614.28	195.94	644.77	0.9527	-0.09	≤ ±4%	
			230.16	611.19	197.83	642.41	0.9514	0.07	≤ ±4%	
			253.15	608.18	199.10	639.94	0.9504	0.17	≤ ±4%	
		S_{Emax}	207.60	1215.45	400.68	1279.79	0.9497	0.55	≤ ±4%	
			230.55	1211.95	401.18	1276.62	0.9493	0.59	≤ ±4%	
			253.51	1206.98	401.79	1272.10	0.9488	0.64	≤ ±4%	
	0.98 over-excited	50% P_{Emax}	207.16	612.84	120.90	624.65	0.9811	-0.08	≤ ±4%	
			230.15	610.10	123.17	622.41	0.9802	0.11	≤ ±4%	
			253.15	606.51	124.67	619.19	0.9795	0.24	≤ ±4%	
		S_{Emax}	207.59	1209.97	242.05	1233.94	0.9805	-0.13	≤ ±4%	
			230.54	1206.43	242.67	1230.60	0.9803	-0.08	≤ ±4%	
			253.50	1201.62	243.46	1226.04	0.9800	-0.02	≤ ±4%	

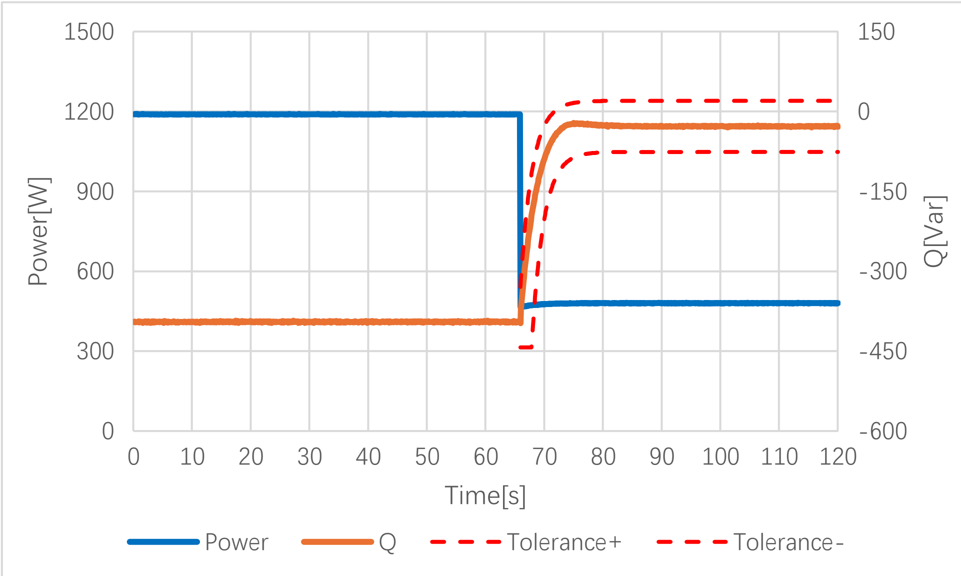

120%
100%
80%
60%
40%
20%
0%
P/Sn[%]
-40%
-30%
-20%
-10%
0%
10%
20%
30%
40%
Q/Sn[%]

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	∆ Q / P_{Emax}	Limitation
100%	1250.51	1179.70	-393.94	0.95	-394.10	0.01	± 4%
90%	1125.67	1063.06	-317.45	0.96	-315.00	-0.20	± 4%
80%	1001.92	946.11	-241.47	0.97	-240.50	-0.08	± 4%
70%	878.68	828.87	-171.93	0.98	-170.57	-0.11	± 4%
60%	756.99	712.44	-105.77	0.99	-102.55	-0.27	± 4%
50%	637.32	593.00	-32.32	1.00	0.0	-2.69	± 4%
40%	515.76	477.69	-34.25	1.00	0.0	-2.85	± 4%
30%	390.75	356.81	-36.39	1.00	0.0	-3.03	± 4%
20%	267.78	239.02	-23.55	1.00	0.0	-1.96	± 4%
30%	392.21	358.65	-33.82	1.00	0.0	-2.82	± 4%
40%	514.82	481.45	-31.80	1.00	0.0	-2.65	± 4%
50%	638.85	598.73	-28.76	1.00	0.0	-2.40	± 4%
60%	758.53	714.24	-104.62	0.99	-102.55	-0.17	± 4%
70%	881.80	831.99	-170.88	0.98	-170.57	-0.03	± 4%
80%	1004.98	949.42	-241.06	0.97	-240.50	-0.05	± 4%
90%	1128.34	1065.78	-316.23	0.96	-315.00	-0.10	± 4%
100%	1251.49	1181.25	-394.89	0.95	-394.10	-0.07	± 4%

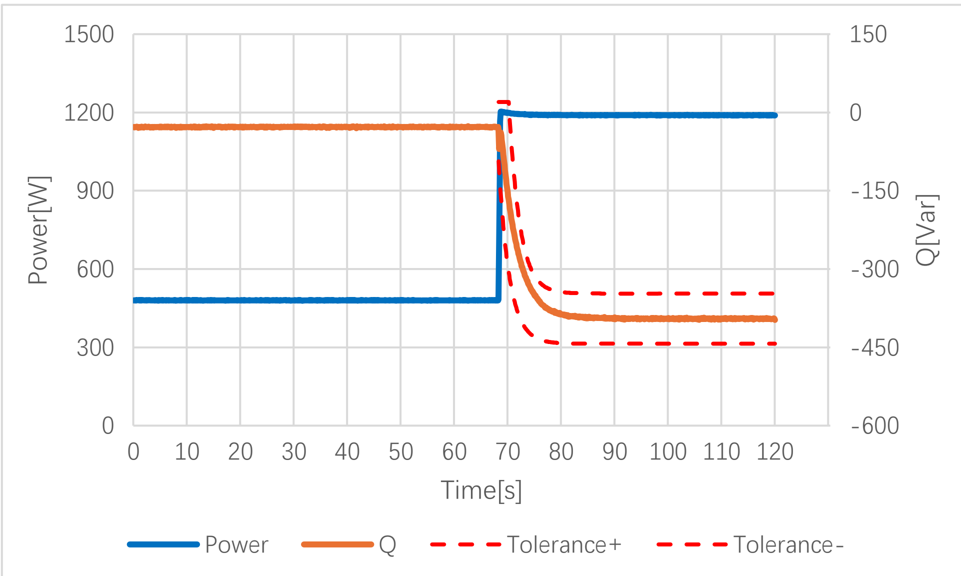
P(t), Q(t), Cos$_{\varphi}$(t), Diagram



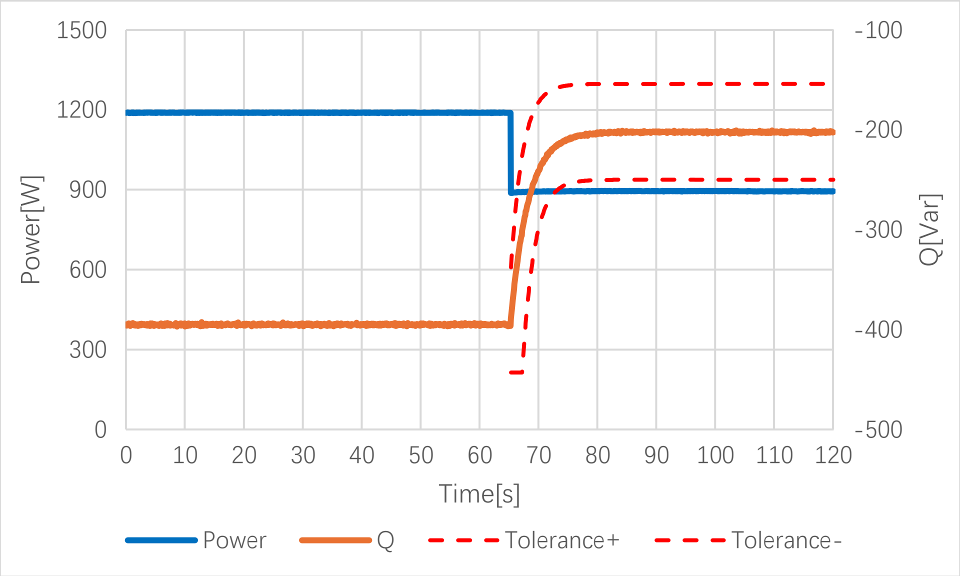
4) Test steps for supply-dependent EZE-dynamics		
Step	Duration [s]	Dynamic as PT1 character ?
100%	60s	--
40%	60s	☒ Pass ☐ Failed
100%	60s	☒ Pass ☐ Failed
75%	60s	☒ Pass ☐ Failed



Power from 100% to 40% with PT1 character



Power from 40% to 100% with PT1 character



Power from 100% to 75% 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: SONG CHUAN PRECISION CO., LTD, 215H-1AH-F-C.		
Response time of interface switch for integrated NS protection:15ms		
The max. initial short-circuited current of PGU Ik”: 17A		

No.	component No.	fault	test voltage (V)	test time	fuse No.	fuse current (A)	result
1.	PV input	Reverse before start up	45Vdc	10min	--	--	Reversed before start up, the Inverter could not operate, after fault removed, the inverter normal operation. No damage, No hazard.
2.	AC output	SC	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately, the breaker on the wall opened. F1 damage, No hazard.
3.	AC output	Reverse before start up	45Vdc	10min	--	--	Reversed before start up, the Inverter could tie to grid. No damage, No hazard.
4.	Realy1, Pin 2-4	SC	45Vdc	10min	--	--	The fault was applied before operation. After the fault, EUT disconnected from grid immediately. No damaged, No hazard.
5.	Realy2, Pin 2-4	SC	45Vdc	10min	--	--	The fault was applied before operation. After the fault, EUT disconnected from grid immediately. No damaged, No hazard.
6.	Realy1, Pin1-2	SC	45Vdc	10min	--	--	It applied during the unit operation.Afterthe fault, No hazard, No damage. Can resettable.
7.	Relay2, Pin1-2	SC	45Vdc	10min	--	--	It applied during the unit operation.Afterthe fault, No hazard. No damage. Can resettable.
8.	R 324	SC	45Vdc	10min	--	--	It applied during the unit operation. After the fault, No hazard, No damage. Can resettable.
9.	T5, Pin3-4	SC	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
10.	T2, Pin3-4	SC	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
11.	Fuse	SC	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. F1 damaged, No hazard.

12.	U4, Pin15-14	SC	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
13.	U15, Pin1-4	SC	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
14.	R94	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
15.	R110	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
16.	R126	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown after three seconds. No damage, No hazard.
17.	R142	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown after five seconds. No damage, No hazard.
18.	R174	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
19.	R191	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
20.	R212	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
21.	Filter capacitor, C185	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. C185 damaged, No hazard
22.	Q17, PinG-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. C184, C185 damaged, No hazard
23.	Q17, PinS-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
24.	Filter capacitor, C423	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
25.	Triode Q41, Pin1-3	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
26.	Triode Q41, Pin2-3	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
27.	Filter capacitor, C460	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
28.	Filter capacitor, C473	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
29.	Filter capacitor, C431	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard

30.	GDT2	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
31.	Diode Q21 Pin2-6	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
32.	Diode Q21 Pin4-6	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
33.	Resonant capacitor C91	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
34.	Q7, PinS-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
35.	Q7, PinG-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q7 damaged, No hazard.
36.	Q8, PinG-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q8 damaged, No hazard.
37.	Q8, PinS-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q8 damaged, No hazard.
38.	AC Relay K2B, Pin2-4	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard.
39.	Q2, Pin1-9	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q3, Q4 damaged, No hazard
40.	Q2, Pin6-9	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q3, Q4 damaged, No hazard
41.	Filter capacitor, C49	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
42.	Filter capacitor, C59	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. No damage, No hazard.
43.	Q3, pinG-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q3 damaged, No hazard.
44.	Q3, PinS-D	S-C	45Vdc	10min	--	--	After applying the fault, the unit shutdown immediately. Q3 damaged, No hazard.
45.	Filter capacitor, C14	S-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard.
46.	R95	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.
47.	R111	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.
48.	R127	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.

49.	R143	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.
50.	R175	O-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
51.	R192	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.
52.	R213	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.
53.	TP70	O-C	45Vdc	10min	--	--	After applying the fault, the unit normal operation. No damage, No hazard
54.	R7	O-C	45Vdc	10min	--	--	After applying the fault, the Inverter could not tie to grid. No damage, No hazard.
55.	Triode Q1, Pin 2-3	O-C	45Vdc	10min	--	--	After applying the fault,the Inverter could not tie to grid. No damage, No hazard.
Supplement: s-c: short-circuited, o-c: open-circuited, o-l: overload							

5.5.7.2 &5.5.7.4	TABLE: Protection device and settings			P
OV Stage 2 No.	Set value	Measured L1-N	Limitation	Test condition
1	1.25Un	287.47	+/-1%Un	1.2, UL1-N 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 2.2, UL1-N applying Leap 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	120	≤200ms	
2	1.25Un	287.84	+/-1%Un	
	100ms	140	≤200ms	
3	1.25Un	287.42	+/-1%Un	
	100ms	142	≤200ms	
4	1.25Un	287.42	+/-1%Un	
	100ms	139	≤200ms	
5	1.25Un	287.42	+/-1%Un	
	100ms	119	≤200ms	

OV Stage 1 No.		Trip time [s]	Limitation [s]	Test condition
1	Set value 1.10Un 100ms	485.2	450-550	3.1 Operation under nominal voltage for 10min, then jumped from Un to 1.12Un.
2		No disconnect	No disconnect	3.2 Operation under nominal voltage for 10min, then jumped from Un to 1.08Un.
3		281.2	225 - 375	3.3 Operation under 1.06 voltage for 10min, then jumped from 1.06Un to 1.14Un.

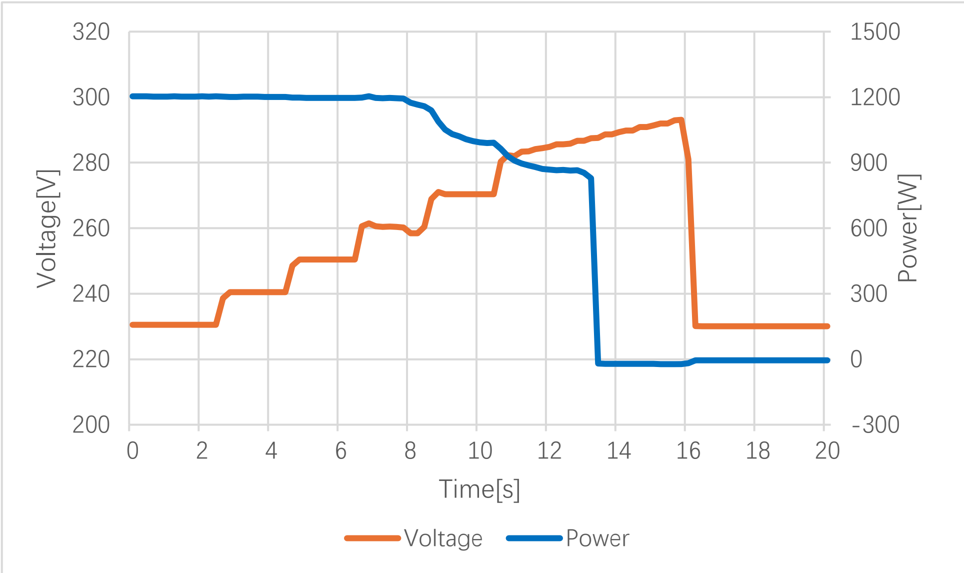
UV Stage 2 No.	Set value	Measured L1-N	Limitation [ms]	Test condition
1	0.45Un	104.10	+/-1%Un	6.2, UL1-N applying ramp test, start of >108.1 V, and ramp to <98.9V, step voltage length is <1.15 V, and step
	300ms	341	300-400ms	

UV Stage 2 No.	Set value	Measured L1-N	Limitation [ms]	Test condition
2	0.45Un	103.59	+/-1%Un	time is >500ms 7.2, UL1-N 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	322	300-400ms	
3	0.45Un	103.92	+/-1%Un	
	300ms	322	300-400ms	
4	0.45Un	103.67	+/-1%Un	
	300ms	340	300-400ms	
5	0.45Un	103.87	+/-1%Un	
	300ms	323	300-400ms	

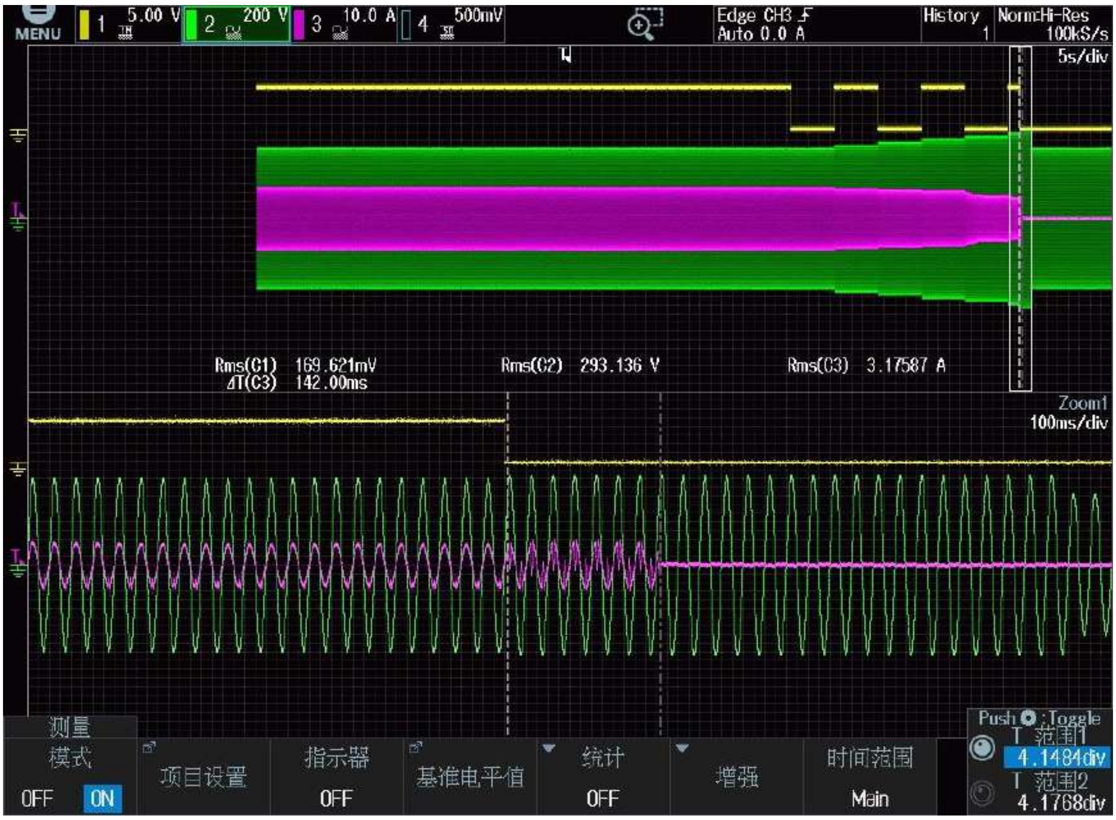
UV Stage 1 No.	Set value	Measured L1-N	Limitation [ms]	Test condition
1	0.8Un	184.37	+/-1%Un	4.2, UL1-N applying ramp test, start of >188.6 V, and ramp to <179.4V, step voltage length is <1.15 V, and step time is >3.2s 5.2, UL1-N applying Jump test, start of >200.1 V, and jump to <179.4V, step voltage length is >9.2 V, and step time is >3.2s
	3s	3.05	3-3.1s	
2	0.8Un	184.05	+/-1%Un	
	3s	3.05	3-3.1s	
3	0.8Un	184.11	+/-1%Un	
	3s	3.05	3-3.1s	
4	0.8Un	184.39	+/-1%Un	
	3s	3.05	3-3.1s	
5	0.8Un	184.13	+/-1%Un	
	3s	3.03	3-3.1s	

OF No.	Set value	Measured Trip value					Limitation	Remark
1	51.5Hz	51.50	51.50	51.49	51.50	51.49	+/-0.05Hz	8.1, 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	130	173	132	156	114	≤200	9.1, 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	47.48	47.48	47.48	47.48	47.48	+/-0.05Hz	10.1, 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	176	133	174	196	175	≤200	10.2, 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:

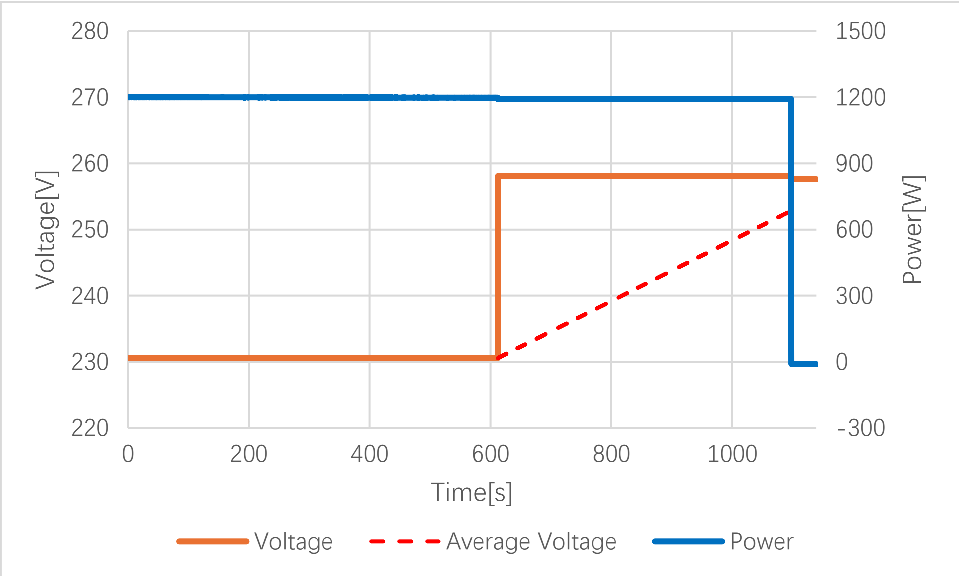


Ramp test

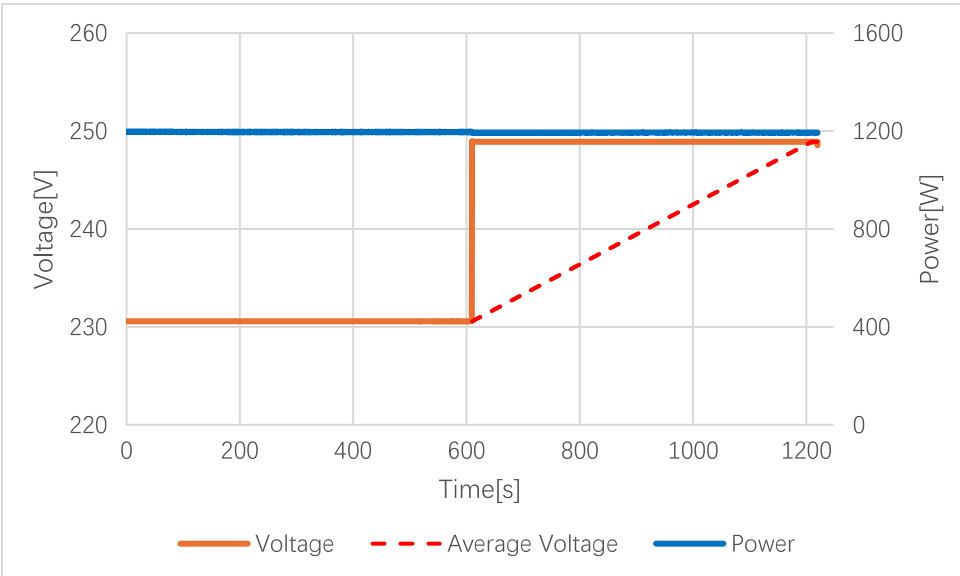


Leap test

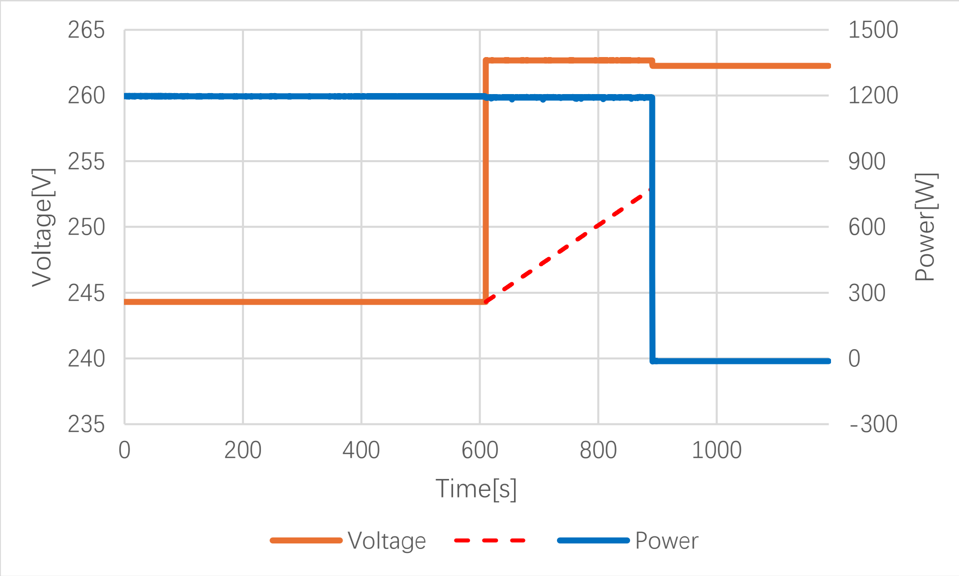
OV Stage 1:



112% Un

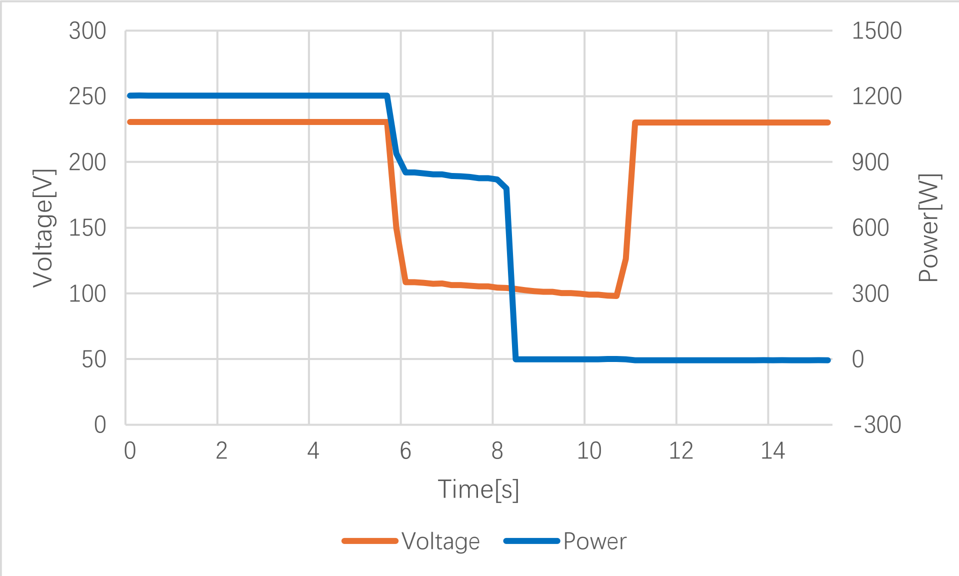


Un to 1.08Un



1.06 Un to 1.14Un

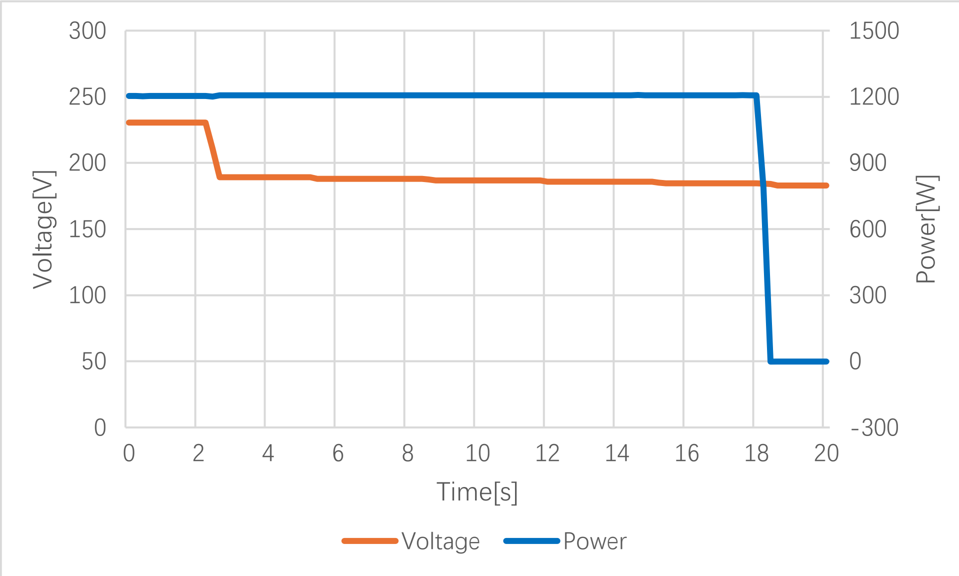
UV Stage 2



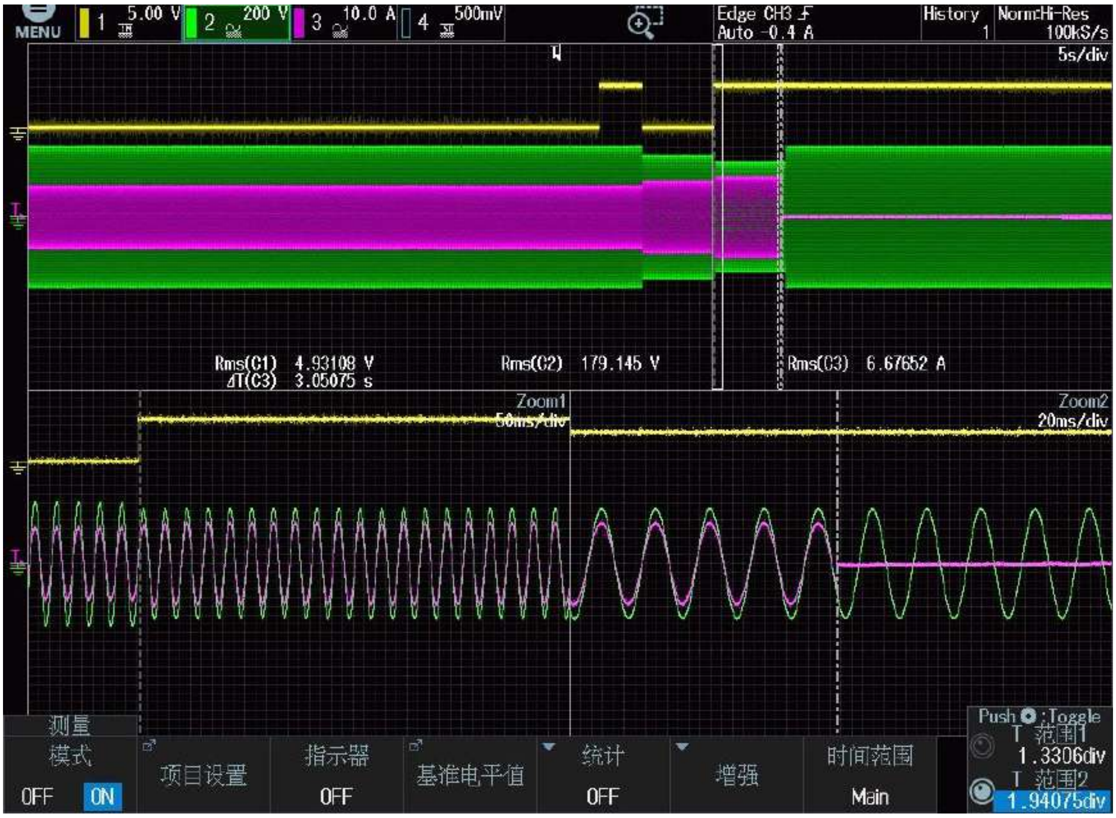
Ramp test

Leap Test

UV Stage 1

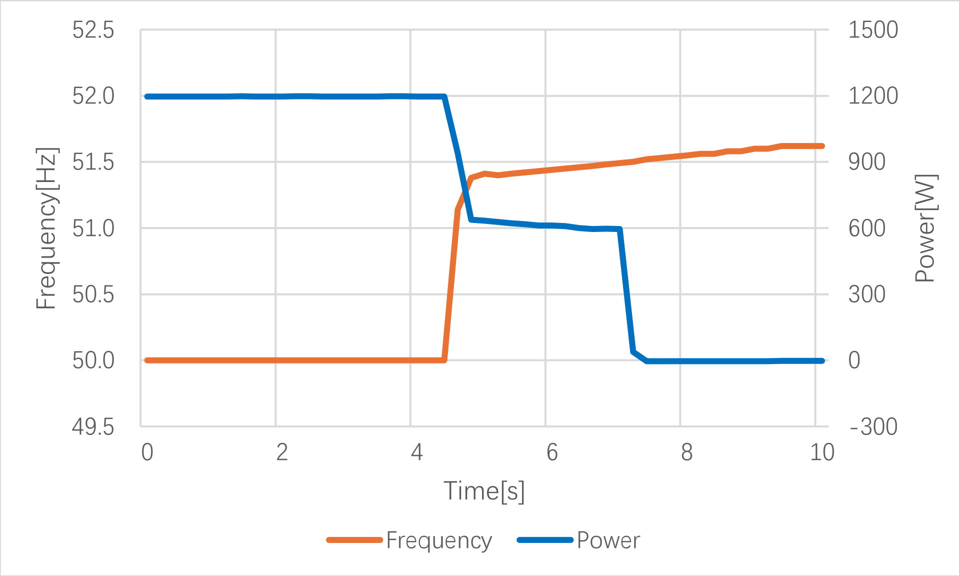


Ramp test



Leap test

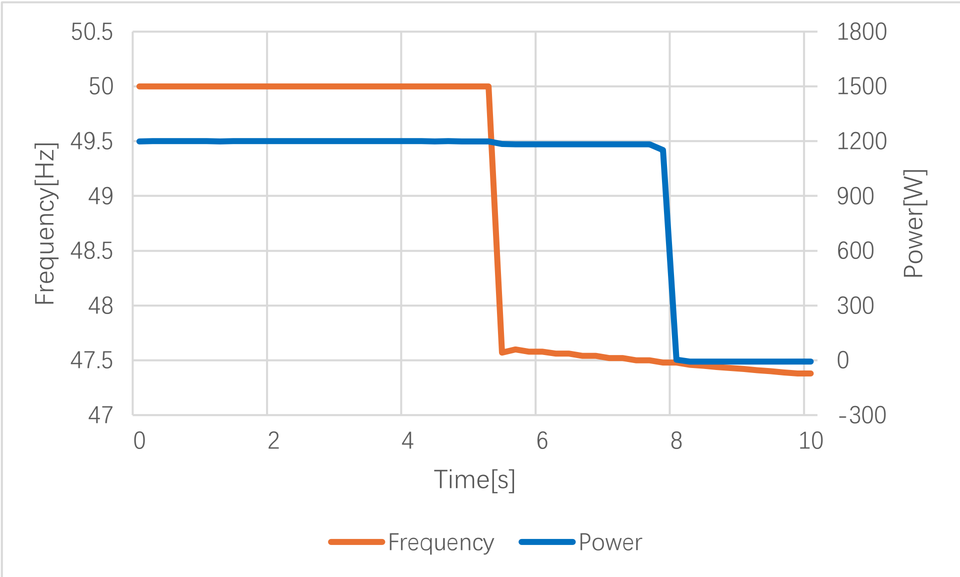
OF:



Ramp test

Leap test

UF:



Ramp test

Leap test

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	

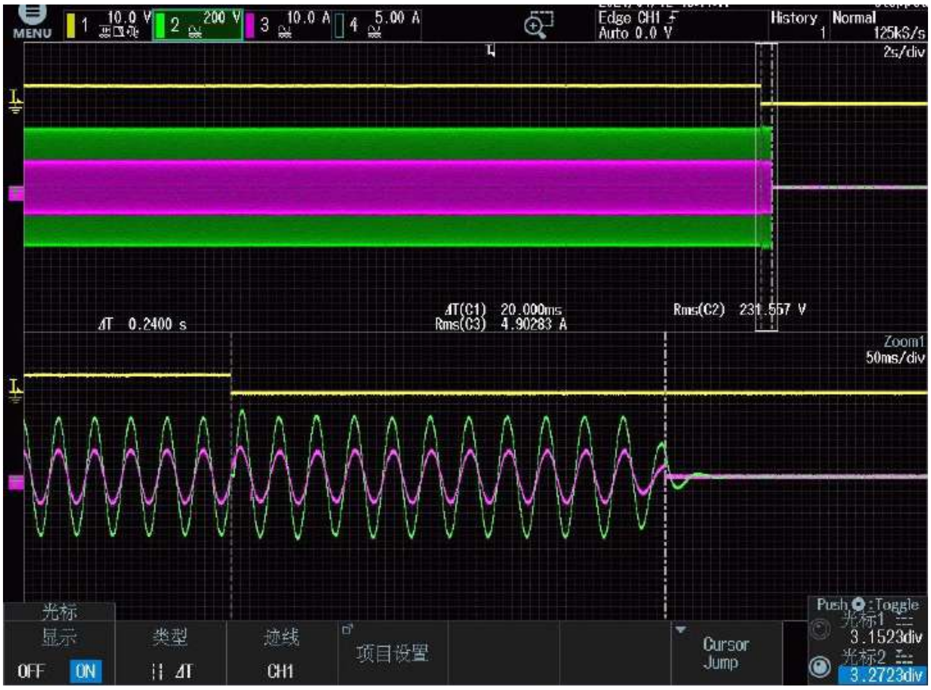
5.5.10	Island detection	P

No.	PEUT1) (% of EUT rating)	Reactive load (% of QL in 6.1.d)1)	PAC2) (% of nominal)	QAC3) (% of nominal)	Run on time (ms)	PEUT (KW)	Actual Qf	VDC	Remarks4)
1	100	100	0	0	198	1.20	1.01	40	Test A at BL
2	66	66	0	0	166	0.79	1.03	30	Test B at BL
3	33	33	0	0	157	0.40	1.01	20	Test C at BL
4	100	100	-5	-5	158	1.20	1.03	40	Test A at IB
5	100	100	-5	0	156	1.20	1.06	40	Test A at IB
6	100	100	-5	5	239	1.20	1.08	40	Test A at IB
7	100	100	0	-5	157	1.20	0.98	40	Test A at IB
8	100	100	0	5	219	1.20	1.03	40	Test A at IB
9	100	100	5	-5	157	1.20	0.94	40	Test A at IB
10	100	100	5	0	155	1.20	0.96	40	Test A at IB
11	100	100	5	5	217	1.20	0.98	40	Test A at IB
12	66	66	0	-5	164	0.79	1.00	30	Test B at IB
13	66	66	0	-4	167	0.79	1.01	30	Test B at IB
14	66	66	0	-3	166	0.79	1.01	30	Test B at IB
15	66	66	0	-2	165	0.79	1.02	30	Test B at IB
16	66	66	0	-1	165	0.79	1.02	30	Test B at IB
17	66	66	0	1	166	0.79	1.03	30	Test B at IB
18	66	66	0	2	165	0.79	1.04	30	Test B at IB
19	66	66	0	3	164	0.79	1.04	30	Test B at IB
20	66	66	0	4	163	0.79	1.04	30	Test B at IB
21	66	66	0	5	164	0.79	1.05	30	Test B at IB
22	66	66	0	6	152	0.79	1.05	30	Test B at IB
23	33	33	0	-5	145	0.40	0.98	20	Test C at IB
24	33	33	0	-4	146	0.40	0.98	20	Test C at IB
25	33	33	0	-3	160	0.40	0.99	20	Test C at IB
26	33	33	0	-2	145	0.40	1.00	20	Test C at IB
27	33	33	0	-1	158	0.40	1.00	20	Test C at IB
28	33	33	0	1	159	0.40	1.01	20	Test C at IB
29	33	33	0	2	160	0.40	1.02	20	Test C at IB
30	33	33	0	3	143	0.40	1.02	20	Test C at IB
31	33	33	0	4	145	0.40	1.02	20	Test C at IB
32	33	33	0	5	144	0.40	1.03	20	Test C at IB
33	100	100	-10	-10	158	1.20	1.03	40	Test A at IB
34	100	100	-10	-5	158	1.20	1.06	40	Test A at IB
35	100	100	-10	0	199	1.20	1.09	40	Test A at IB
36	100	100	-10	5	240	1.20	1.11	40	Test A at IB
37	100	100	-10	10	200	1.20	1,14	40	Test A at IB
38	100	100	-5	-10	158	1.20	1.00	40	Test A at IB
39	100	100	-5	10	201	1.20	1.11	40	Test A at IB

40	100	100	10	-10	156	1.20	0.87	40	Test A at IB
41	100	100	10	-5	156	1.20	0.89	40	Test A at IB
42	100	100	10	0	198	1.20	0.92	40	Test A at IB
43	100	100	10	5	218	1.20	0.94	40	Test A at IB
44	100	100	10	10	222	1.20	0.96	40	Test A at IB
45	100	100	0	-10	158	1.20	0.95	40	Test A at IB
46	100	100	0	10	208	1.20	1.05	40	Test A at IB
47	100	100	5	-10	157	1.20	0.91	40	Test A at IB
48	100	100	5	10	214	1.20	1.00	40	Test A 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.33~48) also require testing.



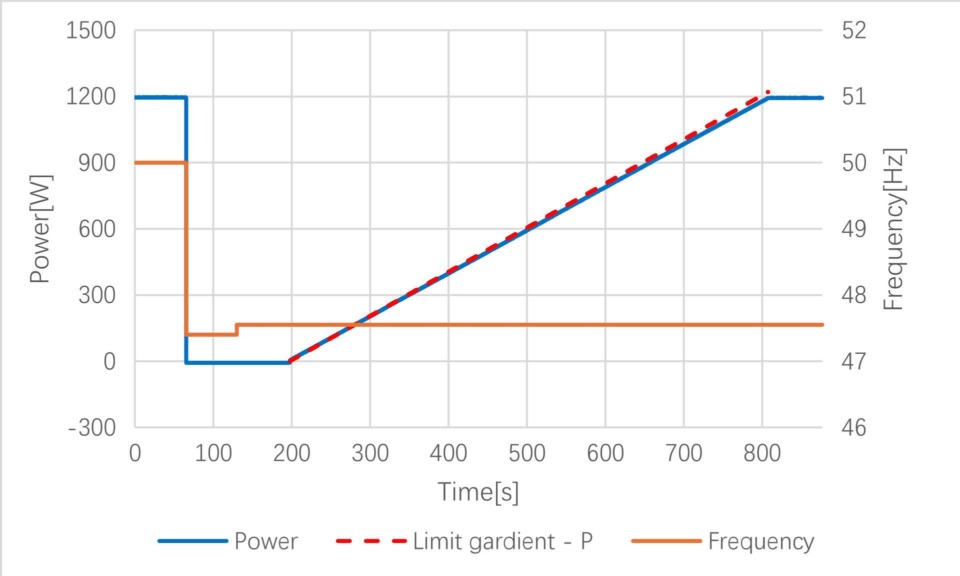
PEUT 100%, PAC -10%, QAC 5%, = 240ms

PEUT 66%, PAC 0%, QAC -4%, = 167ms

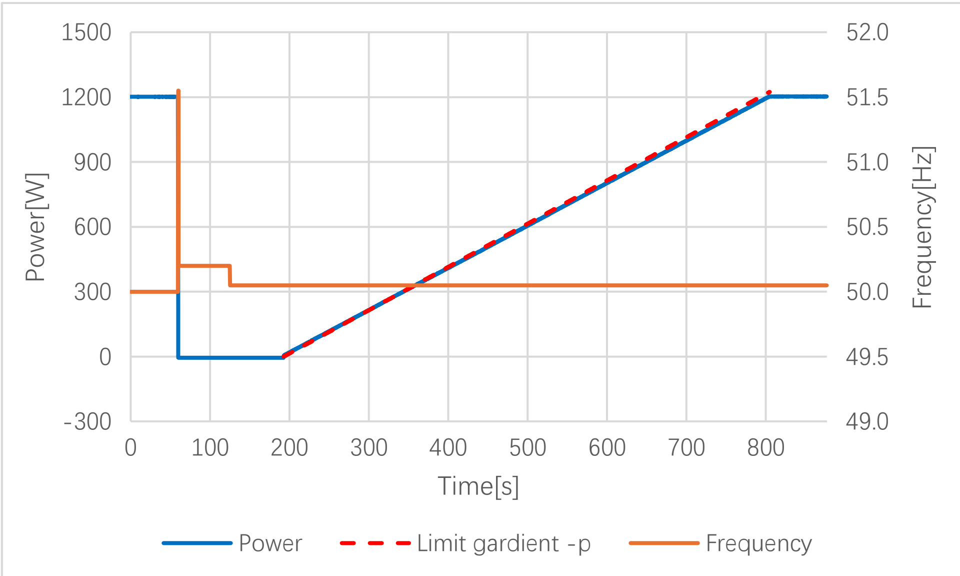
PEUT 33%, PAC 0%, QAC 2%, = 160ms

5.6	Connection conditions and synchronization				P
DC input:	AC output:		Rated Output Power		
40Vdc	230Vac; 50Hz		1.2kW		
Measure Item	Reconnection?		Measurement		
			Voltage [%Un]	Frequency [Hz]	Reconnection Time (>60s)
f_{ist} <47.45Hz	☐ Yes	☒ No	100	47.40	Cannot reconnection
f_{ist} ≥ 47.55Hz	☒ Yes	☐ No	100	47.55	67.8
f_{ist} > 50.15Hz	☐ Yes	☒ No	100	50.20	Cannot reconnection
f_{ist} ≤ 50.05Hz	☒ Yes	☐ No	100	50.05	67.6
U_{ist} < 84% U_n	☐ Yes	☒ No	83.93	50.00	Cannot reconnection
U_{ist} ≥ 86% U_n	☒ Yes	☐ No	86.11	50.00	67.6
U_{ist} > 111% U_n	☐ Yes	☒ No	111.36	50.00	Cannot reconnection
U_{ist} ≤ 109% U_n	☒ Yes	☐ No	108.73	50.00	67.8

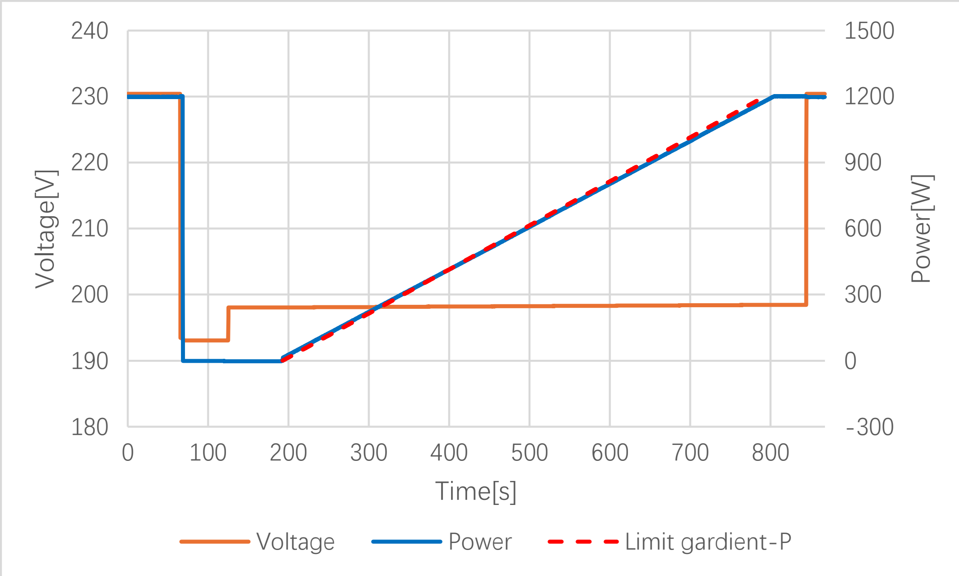
Graph of the gradual power supply and reconnection: for 47.55Hz



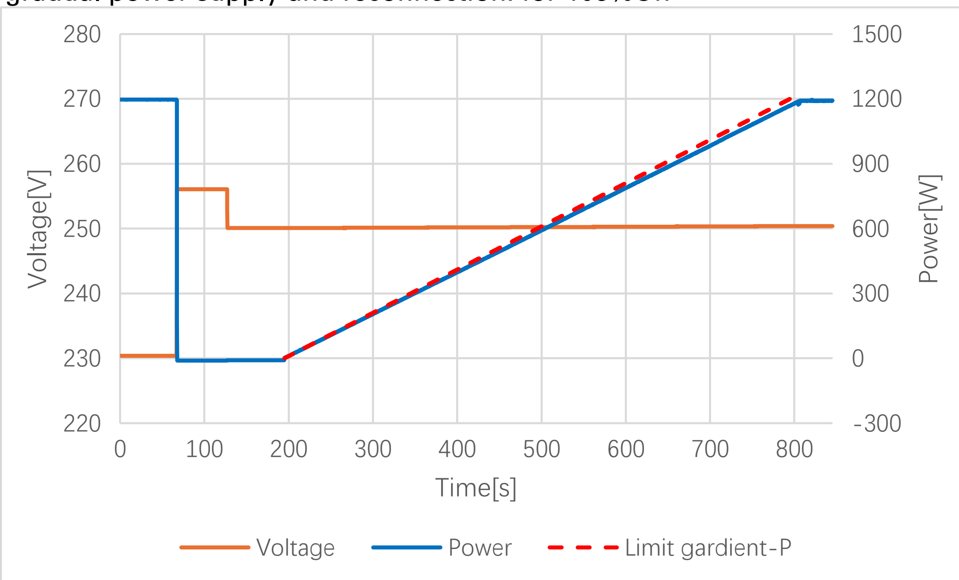
Graph of the gradual power supply and reconnection: for 50.05Hz



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

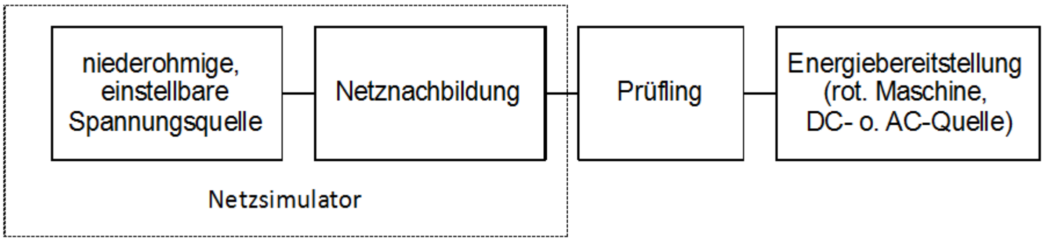


Graph of the gradual power supply and reconnection: for 109%Un



5.8	Dynamic Network support	P

Test equipment:

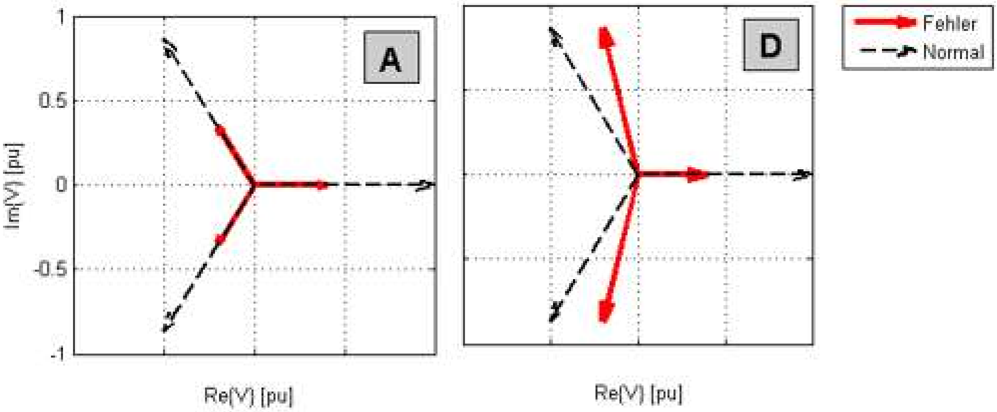


The effective network impedance from view of PGU must fulfill following criterion:
- short-circuited power at PGU before and after fault must be between 10xSn and 30xSn
- R/X 0.3-3 (for applied impedance in test equipment)

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:

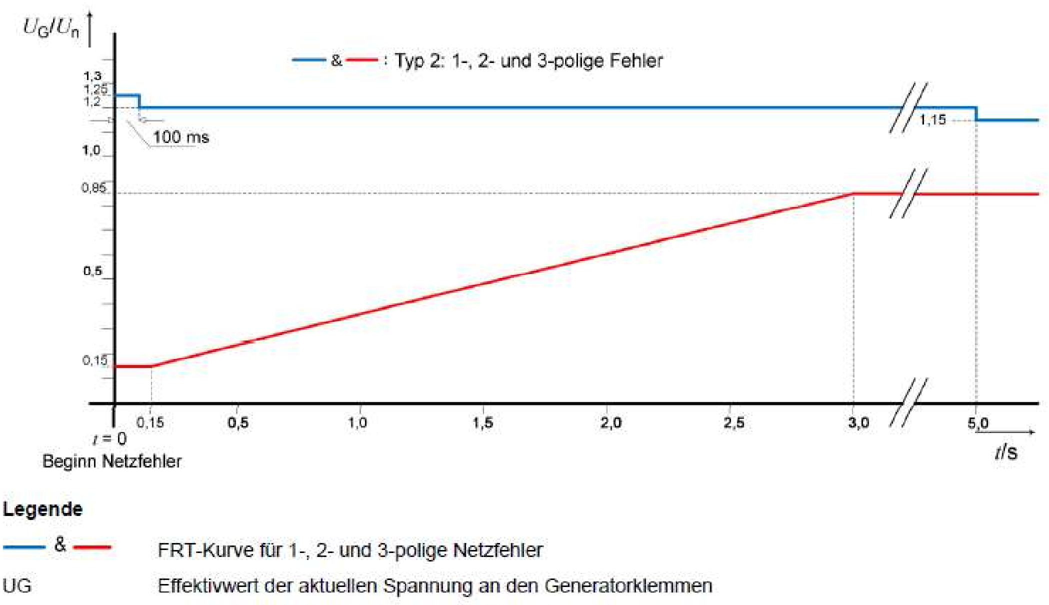
Empty load tests:

- 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:

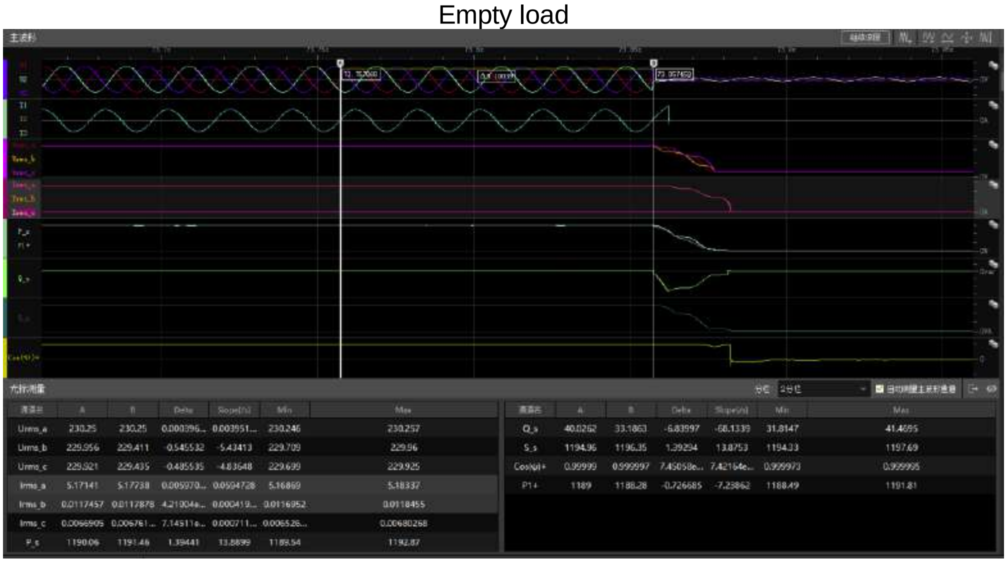
Notes on calculations:	Used formula	Remarks
General remarks: The average grid frequency over the measured interval is calculated from zero-crossings of the sine function. Only 10 cycles before the dip are used for this calculation. RMS-Calculations are performed with a moving window, which is determined 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]		4K						
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
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024		
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph		
	3	Fault type (phase)	--	--		A	A	A
	4	Setting voltage depth	Line to line	--	p.u.	0.15	0.5	0.5
	5	Setting dip duration		--	ms	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	150.0	1569.0	1571.8
	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
	10		Positive sequence		p.u.	0.15	0.5	0.5
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	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.	0.992	0.956	0.933
	14		Positive sequence			--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.033	0.318	-0.307
	16		Positive sequence			--	--	--
	17	Cos$_\varphi$	--	t1-10s to t1	--	0.9999	0.9501	0.9504
During dip t1 to	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.15	0.5	0.5

t2	19	Line current	Phase 1	t1+60ms	p.u.	0.009	0.019	0.019
	20		Phase 2			--	--	--
	21		Phase 3			--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	0.009	0.020	0.019
	23		Phase 2			--	--	--
	24		Phase 3			--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.001	0.001	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
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--
	29		Total			0.993	0.962	0.934
	39	Active power rising time	Positive sequence	--	s	0.550	0.496	0.563
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--
	32		Total			0.034	0.302	-0.303
	33	Reactive power rising time	Positive sequence	--	s	0.011	9.157	9.814
	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

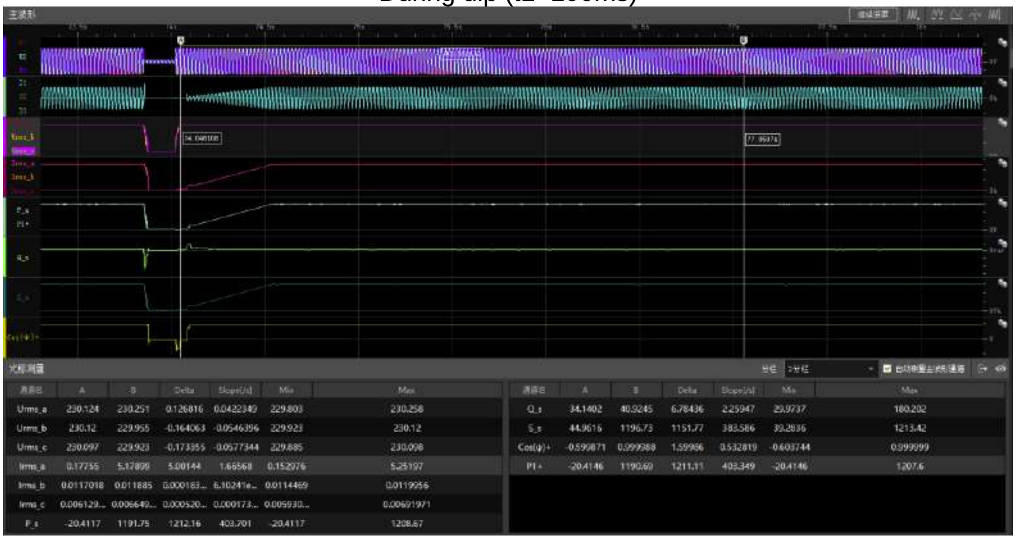
Empty load



Before dip (t1-100ms)

During dip (t1+60ms)

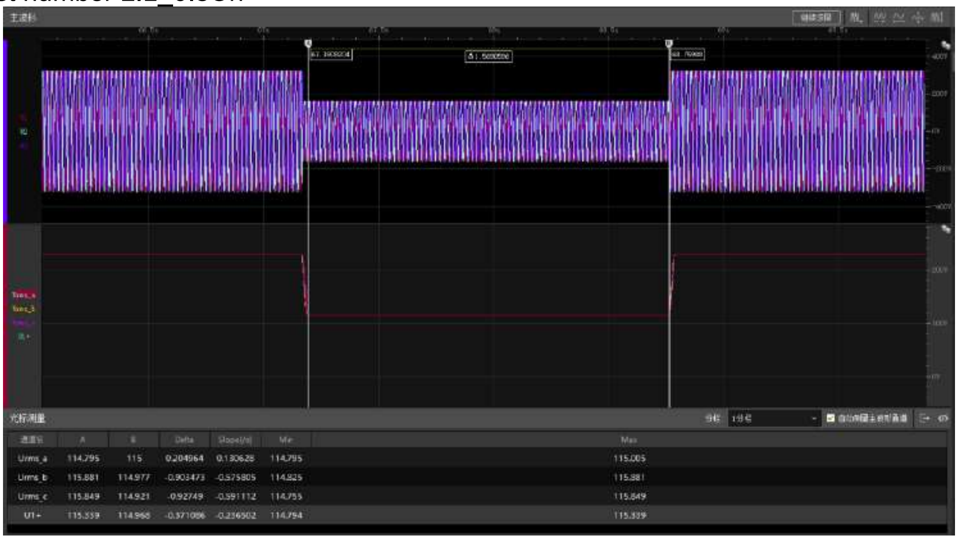
During dip (t1+100ms)



After dip (t2+3s)

Recovery time

Graph of Test number 2.1_0.5Un

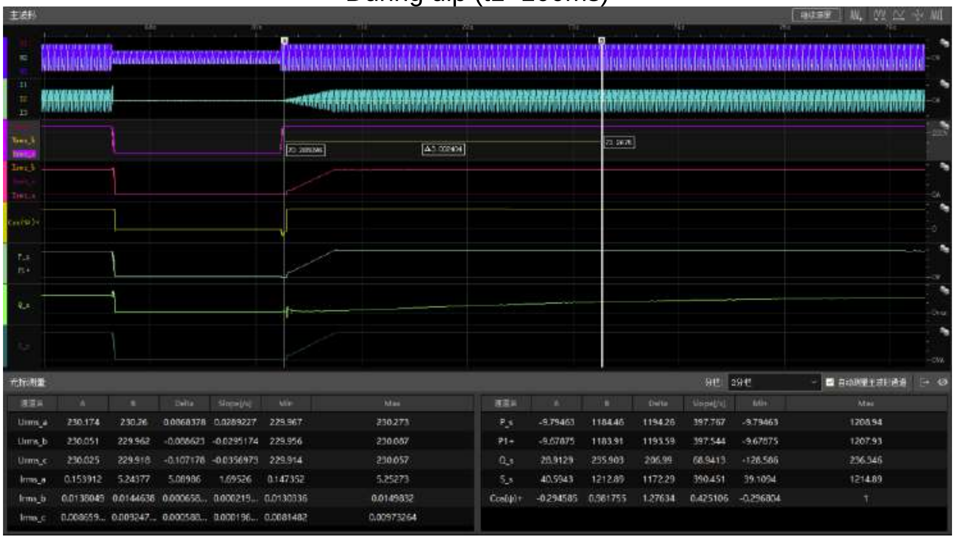


Empty load

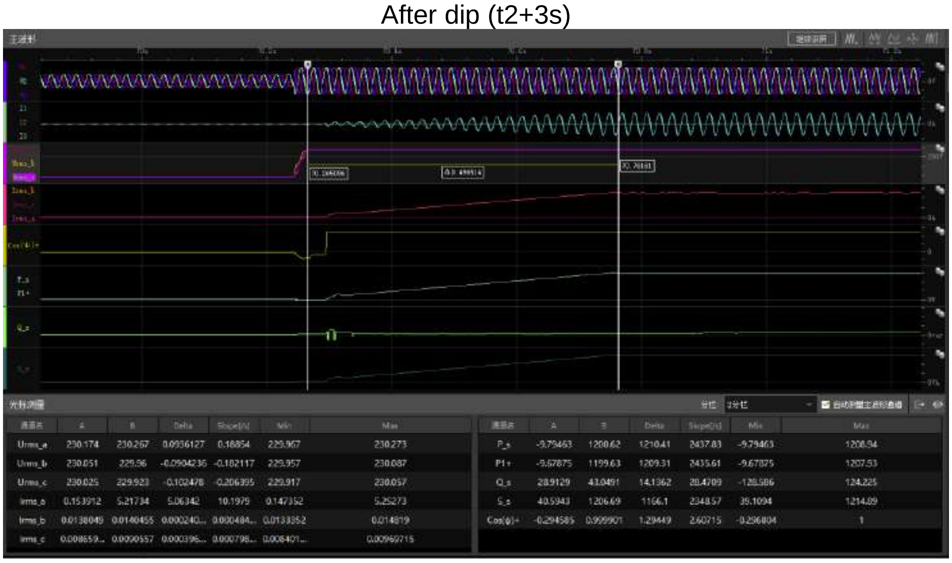
Before dip (t1-100ms)

During dip (t1+60ms)

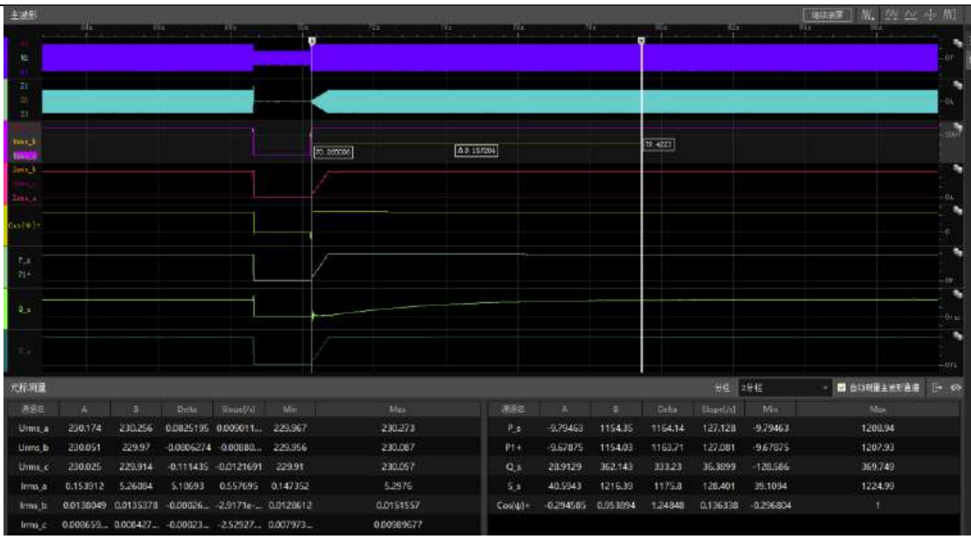
During dip (t1+100ms)



After dip (t2+3s)

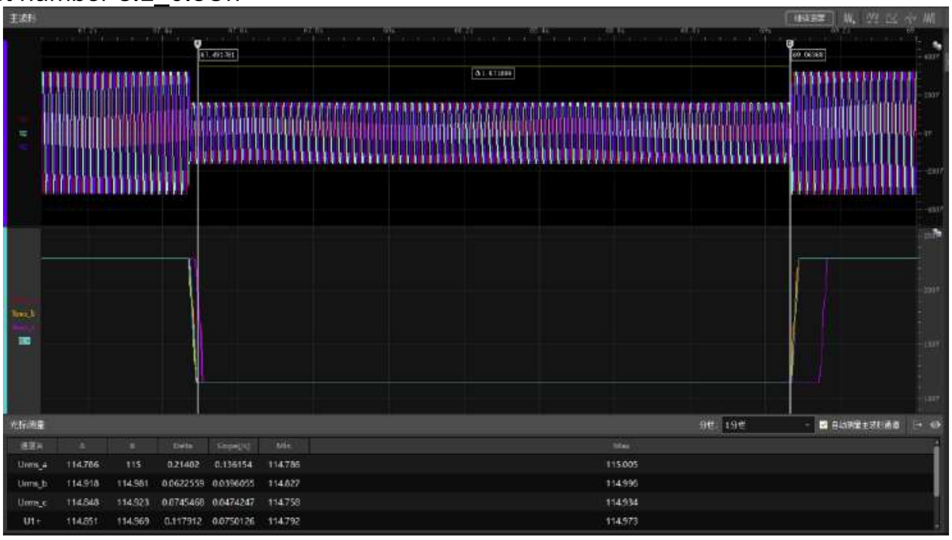


Recovery time-P

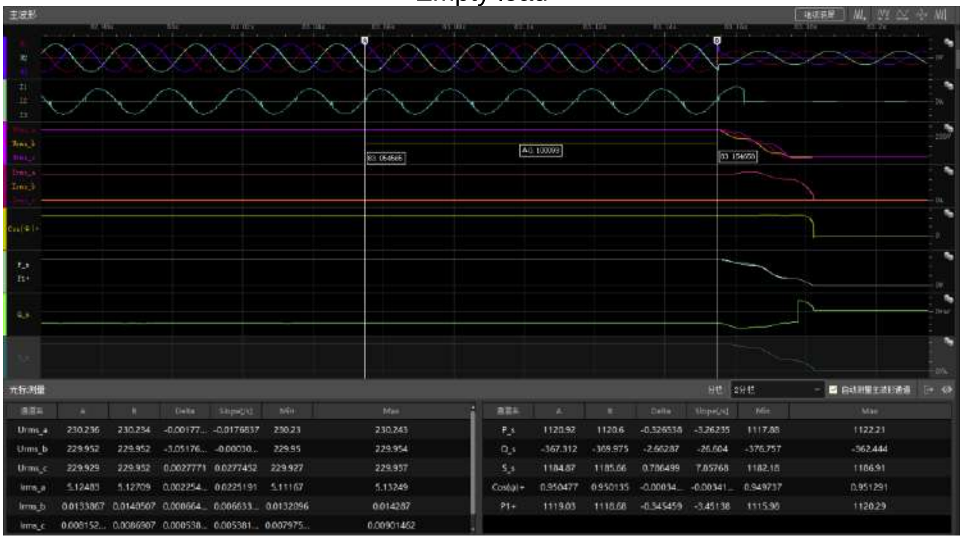


Recovery time-Q

Graph of Test number 3.1_0.5Un

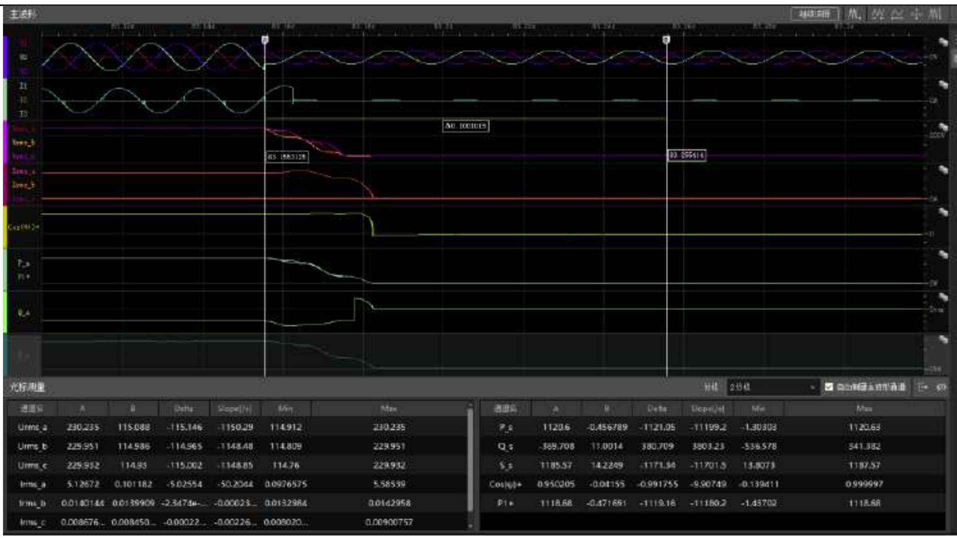


Empty load

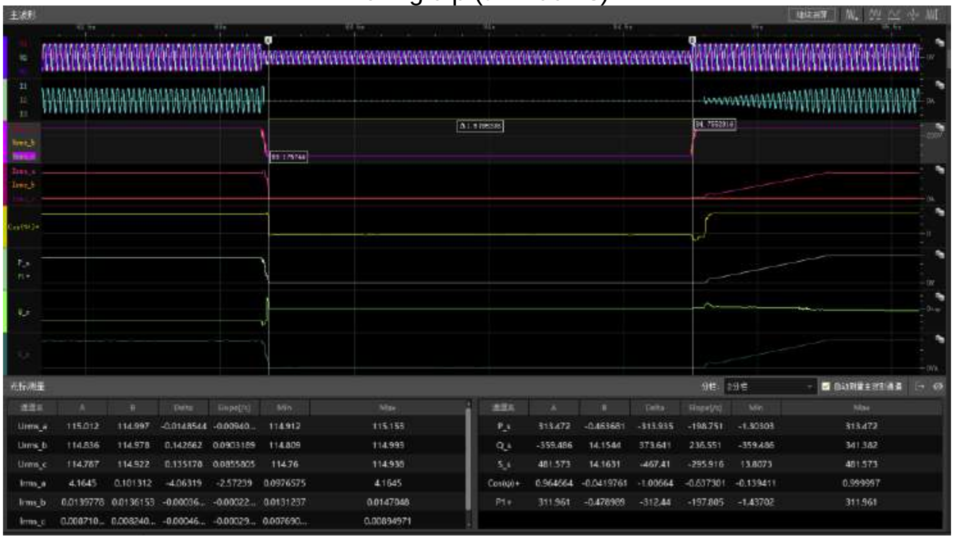


Before dip (t1-100ms)

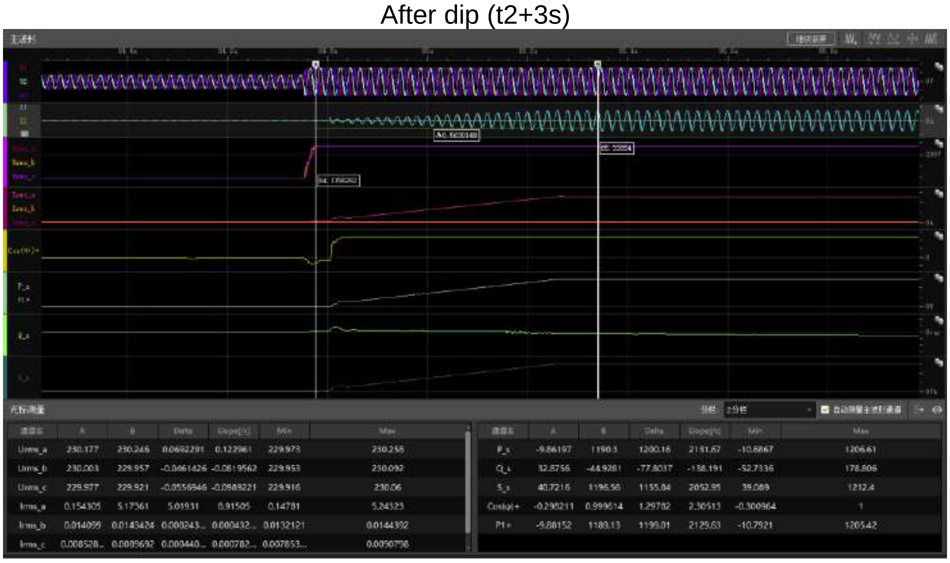
During dip (t1+60ms)



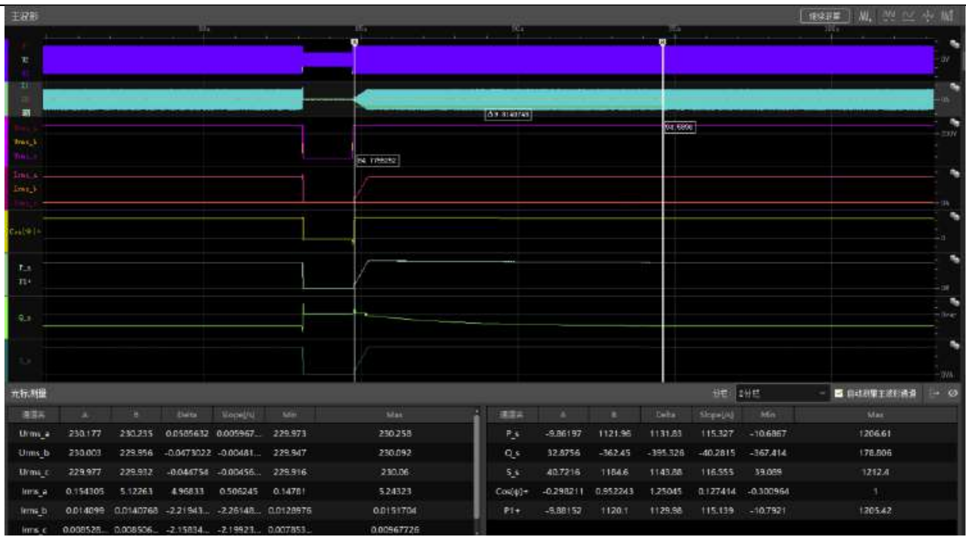
During dip (t1+100ms)



After dip (t2+3s)



Recovery time-P

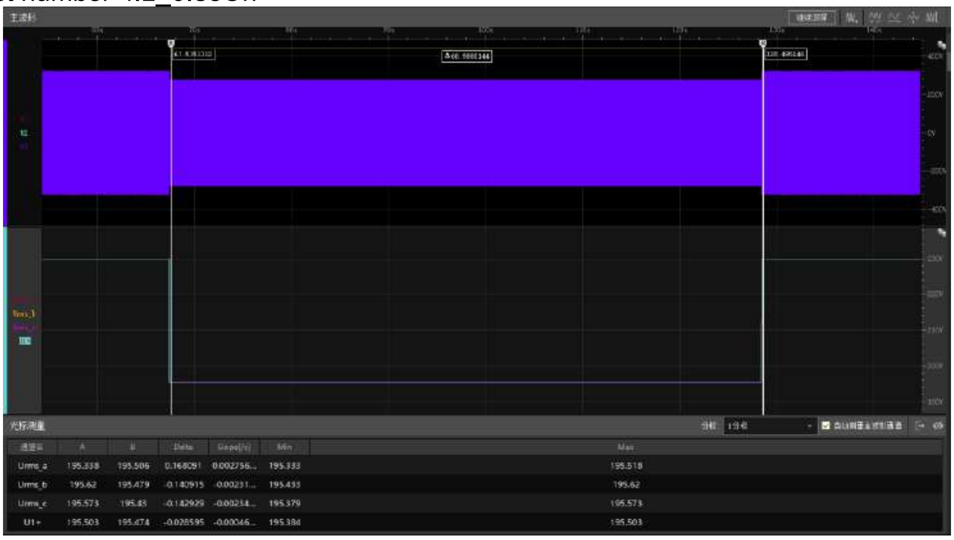


Recovery time-Q

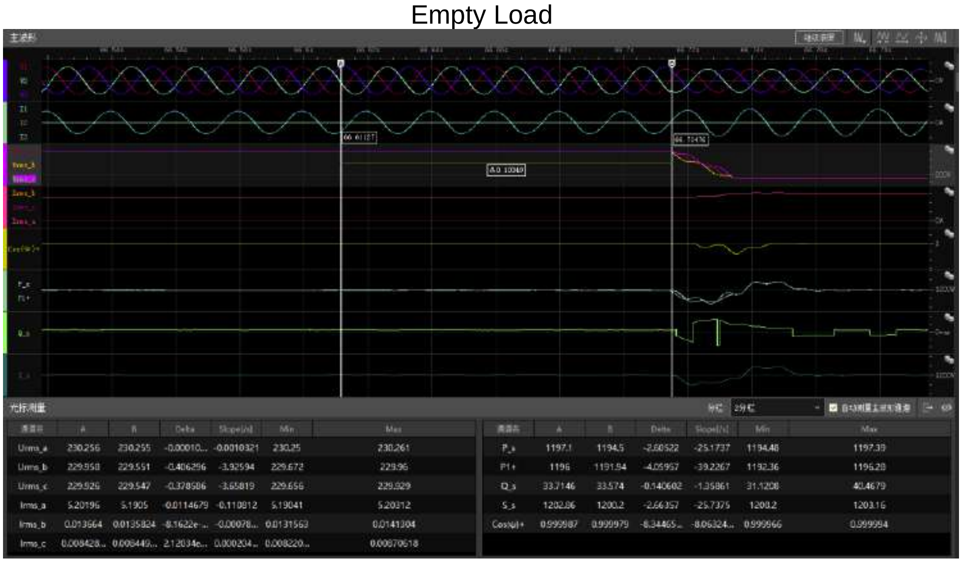
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			4K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	4.1	5.1	6.1	7.1
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024			
	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.	0.85	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	60980	100.0	5079.4	60079
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.85	1.25	1.20	1.15
	10		Positive sequence		p.u.	0.85	1.25	1.20	1.15
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.	0.998	0.998	0.994	0.994
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.028	0.032	0.033	0.034
	16		Positive sequence			--	--	--	--
	17	Cos$_{\varphi}$	--	t1-10s to t1	--	0.9999	0.9999	0.9999	0.9999
During dip t1 to	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.85	1.25	1.20	1.15

t2	19	Line current	Phase 1	t1+60ms	p.u.	1.172	0.034	0.033	0.857
	20		Phase 2			--	--	--	--
	21		Phase 3			--	--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	1.175	0.034	0.033	0.855
	23		Phase 2			--	--	--	--
	24		Phase 3			--	--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	1.000	0.001	0.001	0.985
	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			0.995	1.013	0.998	0.996
	39	Active power rising time	Positive sequence	--	s	0.016	0.492	0.499	0.012
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.033	0.032	0.040	0.028
	33	Reactive power rising time	Positive sequence	--	s	0.013	0.012	0.015	0.010
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

Graph of Test number 4.1_0.85Un

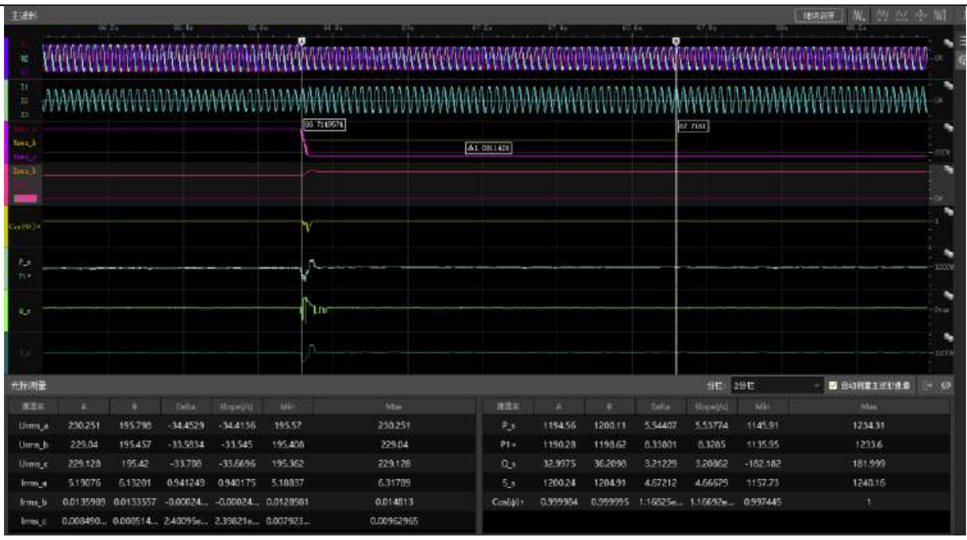


Empty Load

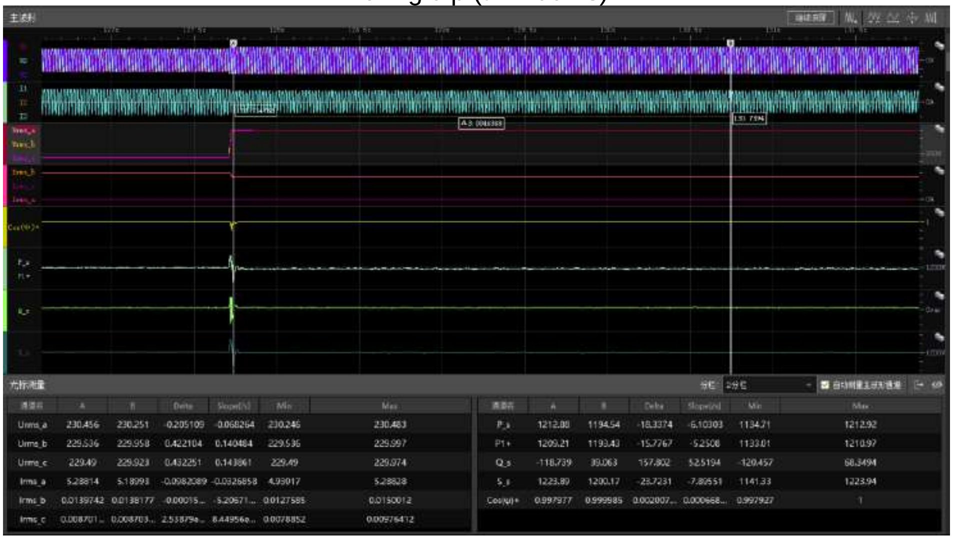


Before dip (t1-100ms)

During dip (t1+60ms)



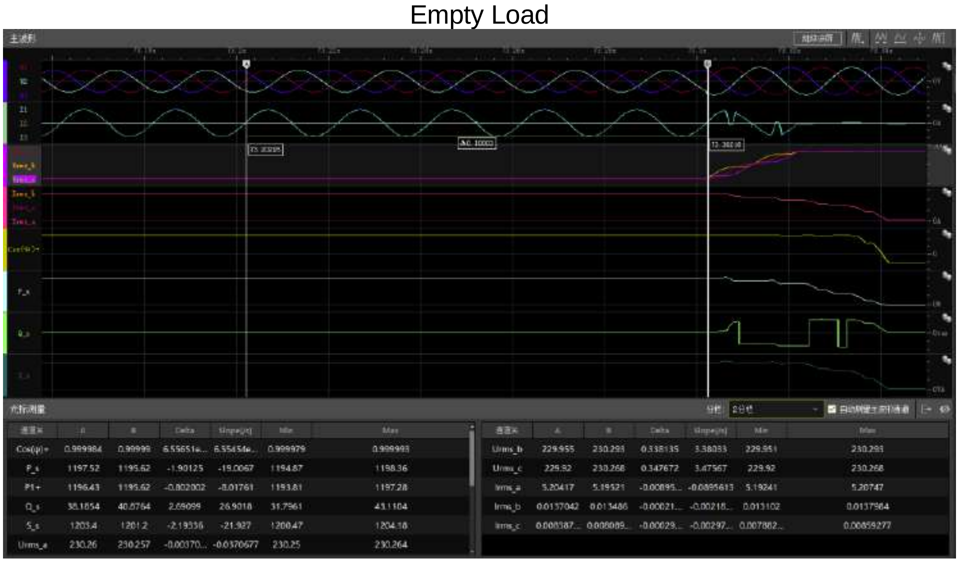
During dip (t1+100ms)



After dip(t2+3s)

Graph of Test number 5.1_1.25Un

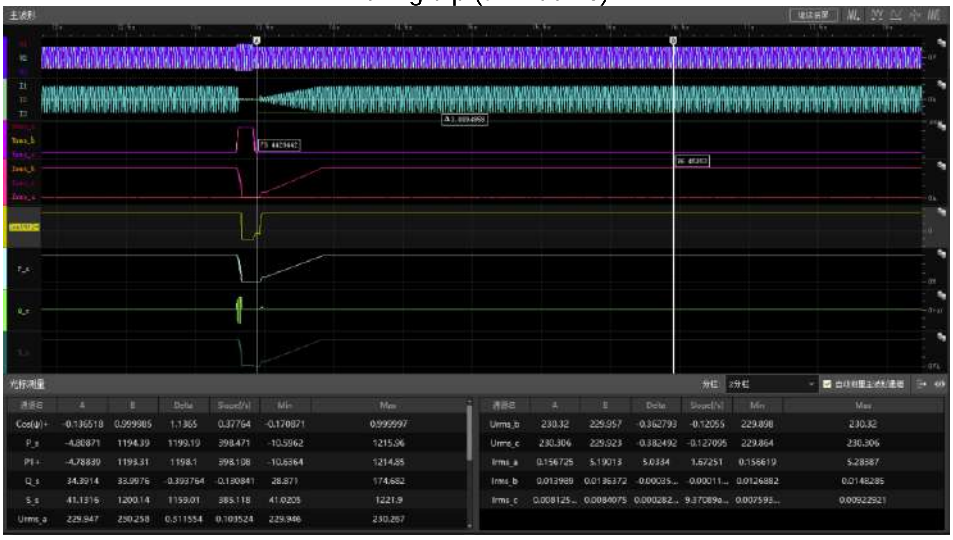
Empty Load



Before dip (t1-100ms)

During dip (t1+60ms)

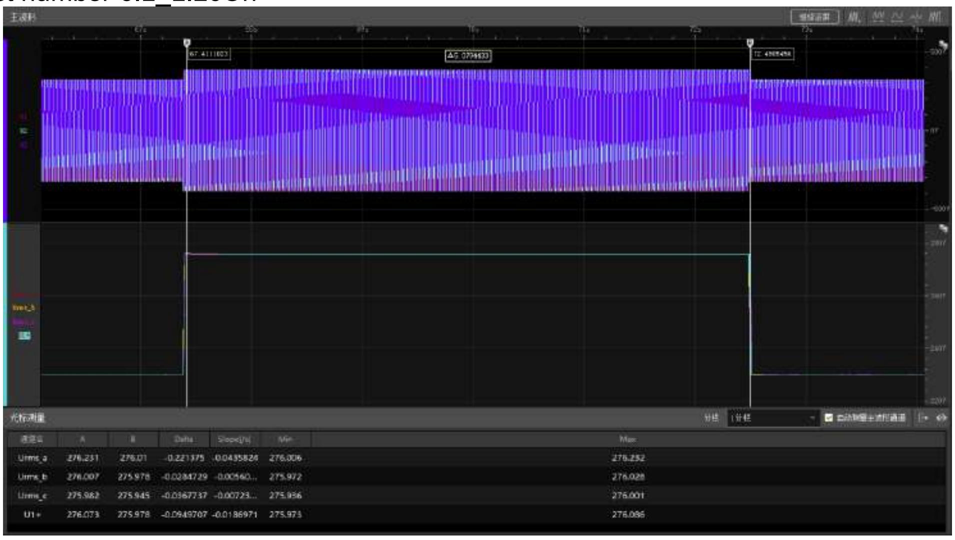
During dip (t1+100ms)



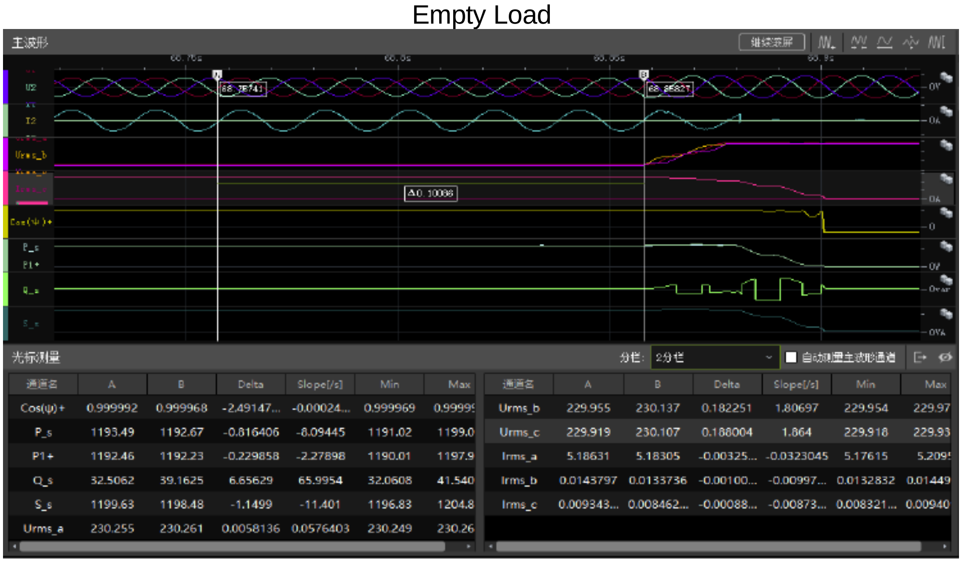
After dip(t2+3s)

Recovery time

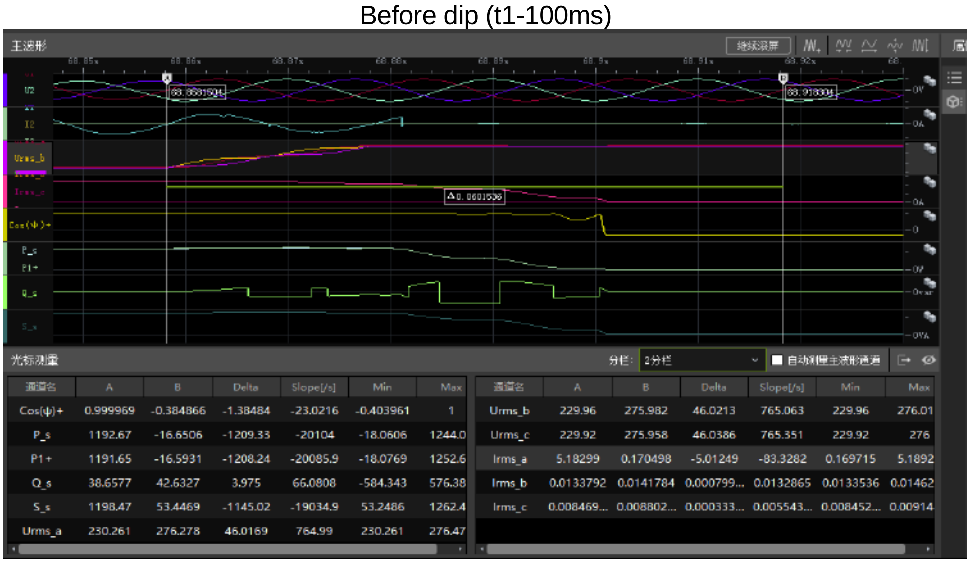
Graph of Test number 6.1_1.20Un



Empty Load



Before dip (t1-100ms)

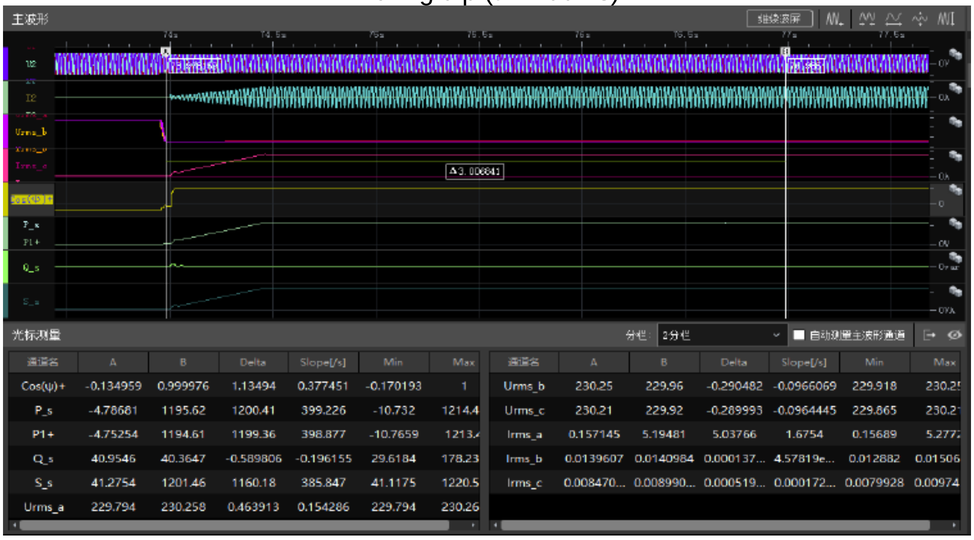


During dip (t1+60ms)

通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	0.999969	-0.383954	-1.38392	-13.8199	-0.403961	1
P_s	1192.67	-16.5968	-1209.27	-12075.8	-18.0606	1244.0
P1+	1191.65	-16.542	-1208.19	-12065	-18.0769	1252.6
Q_s	38.6577	45.4796	6.82183	68.123	-584.343	576.38
S_s	1198.47	52.9877	-1145.48	-11438.8	52.8055	1262.4
Urms_a	230.261	276.201	45.9393	458.751	230.261	276.47

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	229.96	275.984	46.0237	459.594	229.96	276.01
Urms_c	229.92	275.956	46.0363	459.72	229.92	276
Irms_a	5.18299	0.170412	-5.01258	-50.0557	0.169715	5.1892
Irms_b	0.0133792	0.0133789	-2.44938...	-2.44595...	0.0130731	0.01462
Irms_c	0.008469...	0.008071...	-0.00039...	-0.00396...	0.008039...	0.00914

During dip (t1+100ms)



通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	-0.134959	0.999976	1.13494	0.377451	-0.170193	1
P_s	-4.78681	1195.62	1200.41	399.226	-10.732	1214.4
P1+	-4.75254	1194.61	1199.36	398.877	-10.7659	1213.4
Q_s	40.9546	40.3647	-0.589806	-0.196155	29.6184	178.23
S_s	41.2754	1201.46	1160.18	385.847	41.1175	1220.5
Urms_a	229.794	230.258	0.463913	0.154286	229.794	230.26

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	230.25	229.96	-0.290482	-0.0966069	229.918	230.2
Urms_c	230.21	229.92	-0.289993	-0.0964445	229.865	230.2
Irms_a	0.157145	5.19481	5.03766	1.6754	0.15689	5.277
Irms_b	0.0139607	0.0140984	0.000137...	4.57819e...	0.012882	0.01506
Irms_c	0.008470...	0.008990...	0.000519...	0.000172...	0.0079928	0.00974

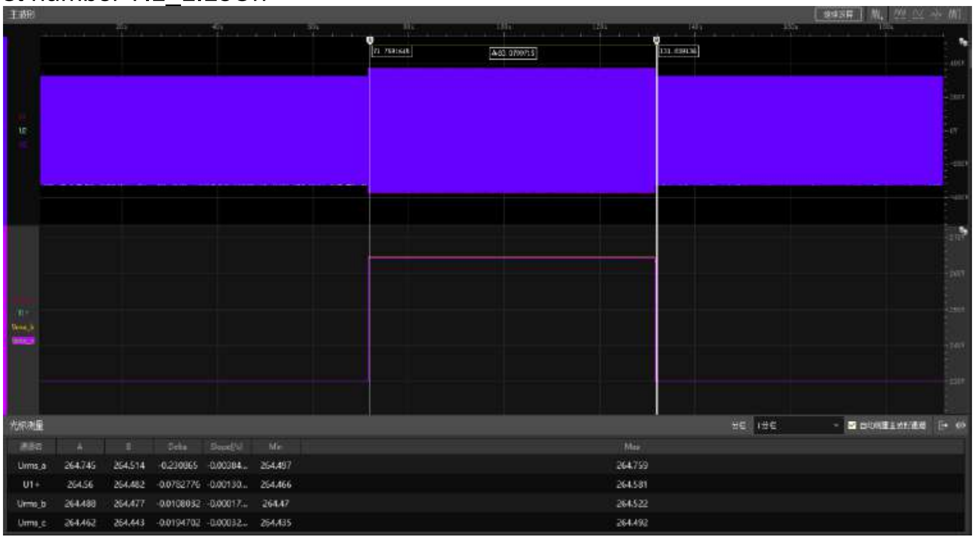
After dip(t2+3s)

通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	-0.134822	0.999995	1.13482	2.27368	-0.170193	0.9999
P_s	-4.79894	1192.85	1197.65	2399.57	-10.732	1214.4
P1+	-4.76204	1191.85	1196.61	2397.48	-10.7659	1213.4
Q_s	41.1265	47.8848	6.75828	13.5407	29.7035	178.23
S_s	41.4506	1199.4	1157.95	2320.03	41.1175	1220.5
Urms_a	229.795	230.252	0.457352	0.916334	229.794	230.26

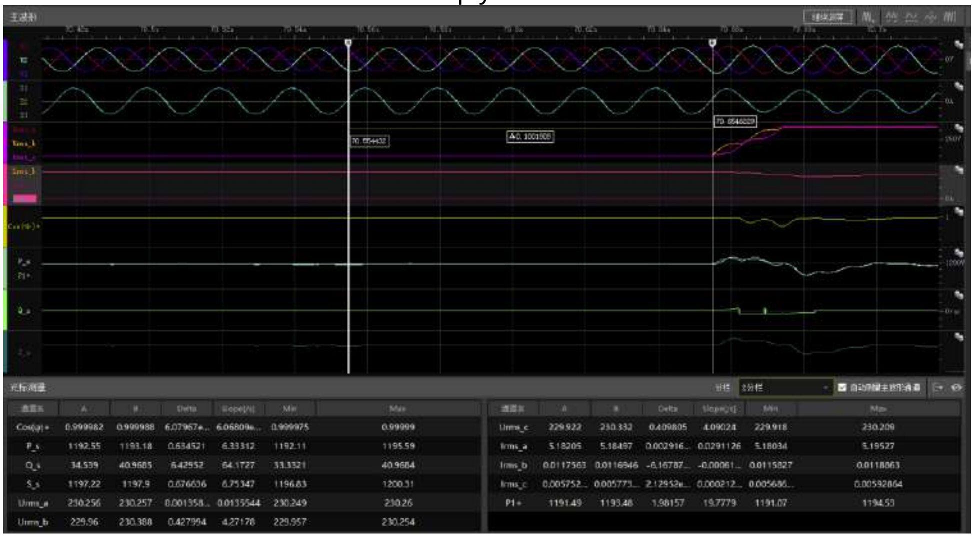
通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	229.921	229.961	0.0400696	0.0802821	229.918	229.98
Urms_c	229.867	229.921	0.0544891	0.109173	229.865	229.93
Irms_a	0.157727	5.18588	5.02815	10.0742	0.157532	5.277
Irms_b	0.0140719	0.0141859	0.000114...	0.000228...	0.0131762	0.01482
Irms_c	0.008571...	0.009039...	0.000468...	0.000937...	0.008016...	0.00952

Recovery time

Graph of Test number 7.1_1.15Un

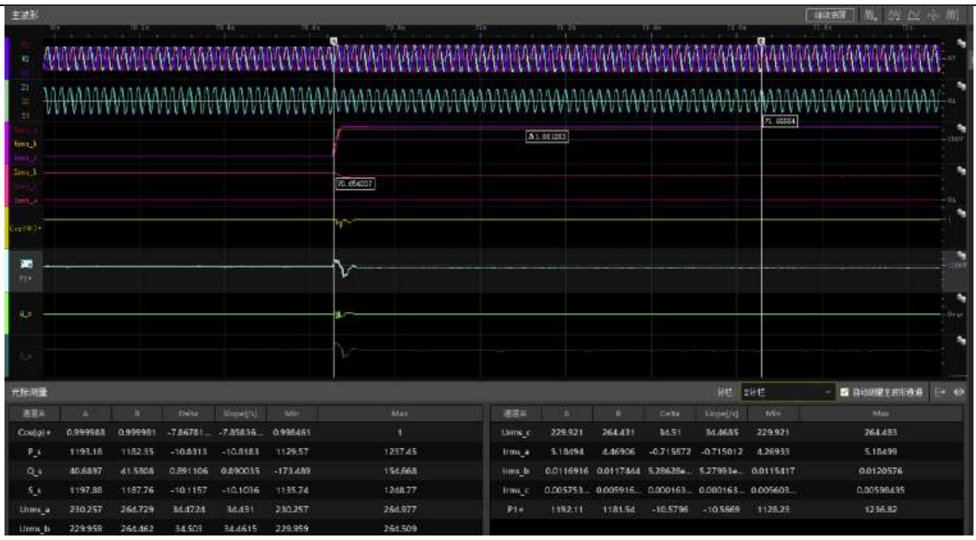


Empty Load

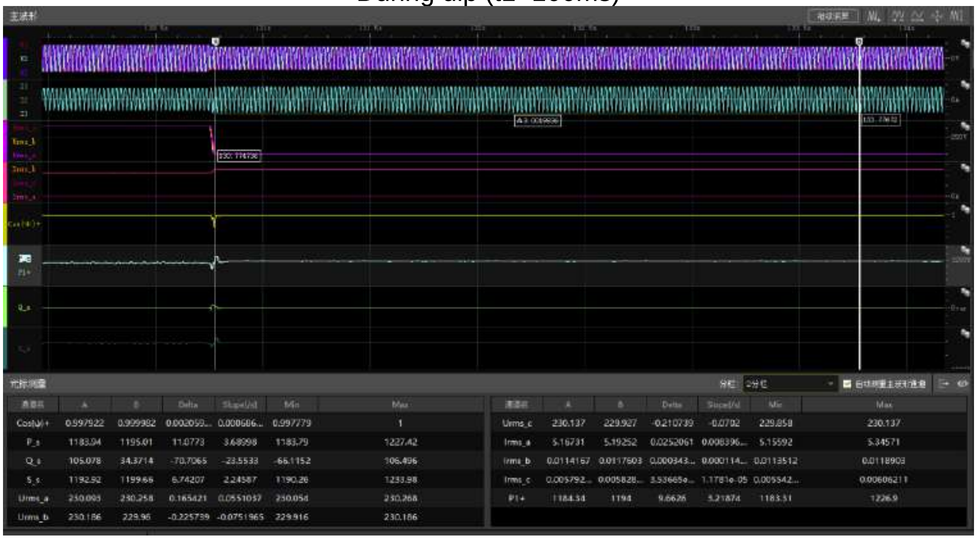


Before dip (t1-100ms)

During dip (t1+60ms)



During dip (t1+100ms)



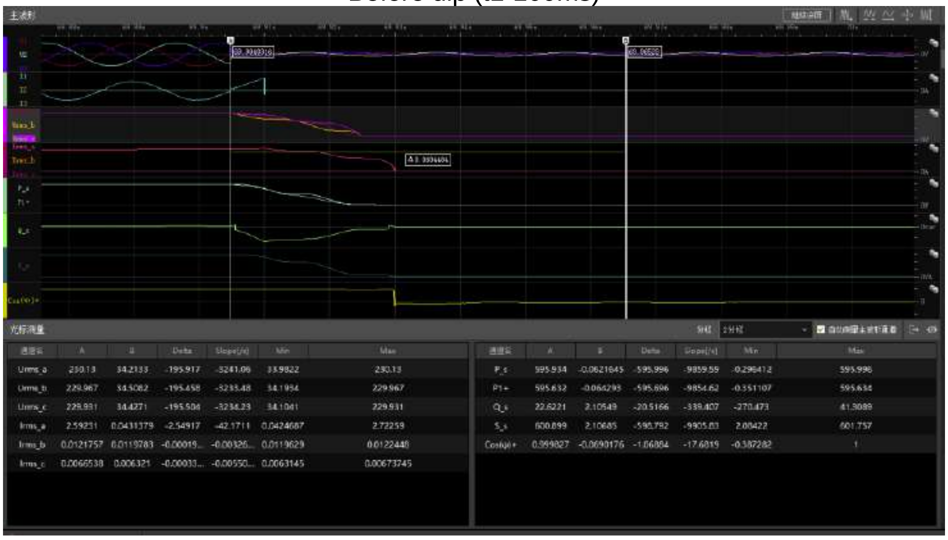
After dip(t2+3s)

Verification of dynamic network support								P
Short-circuited power at generator terminal [VA]			4K					
NS protection settings			See table 5.5 for detail.					
	No.	Parameter	Phase ref.	Time ref.	unit	Result		
General Info.	0	Test number	--	--	--	1.2	2.2	3.2
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024		
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph		
	3	Fault type (phase)	--	--		A	A	A
	4	Setting voltage depth	Line to line	--	p.u.	0.15	0.5	0.5
	5	Setting dip duration		--	ms	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	150.0	1569.0	1571.8
	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
	10		Positive sequence		p.u.	0.15	0.5	0.5
Before dip <t1	11	Voltage	Line to neutral	t1-10s to t1	p.u.	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.	0.497	0.511	0.496
	14		Positive sequence			--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.020	0.334	-0.331
	16		Positive sequence			--	--	--
	17	Cos_{φ}	--	t1-10s to t1	--	0.9999	0.9521	0.9479
During dip t1 to	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.15	0.50	0.50

t2	19	Line current	Phase 1	t1+60ms	p.u.	0.008	0.021	0.022
	20		Phase 2			--	--	--
	21		Phase 3			--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	0.009	0.022	0.022
	23		Phase 2			--	--	--
	24		Phase 3			--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.001	0.001	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
	28	Active power	Positive sequence.	t2+3s to t2+10s	p.u	--	--	--
	29		Total			0.498	0.501	0.500
	39	Active power rising time	Positive sequence	--	s	0.311	0.272	0.302
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--
	32		Total			0.020	0.322	-0.322
	33	Reactive power rising time	Positive sequence	--	s	0.008	9.452	9.619
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes		

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

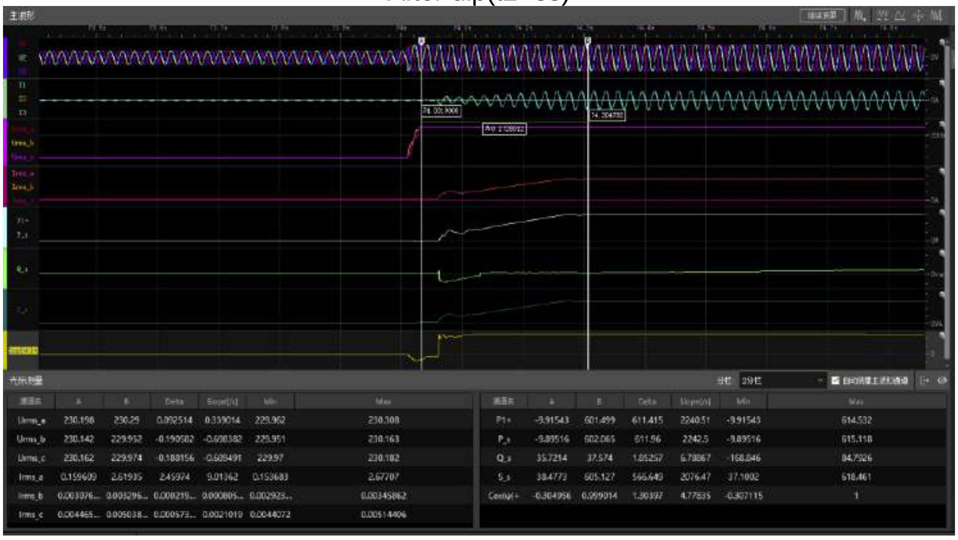
Graph of Test number 2.2_0.5Un

Before dip (t1-100ms)

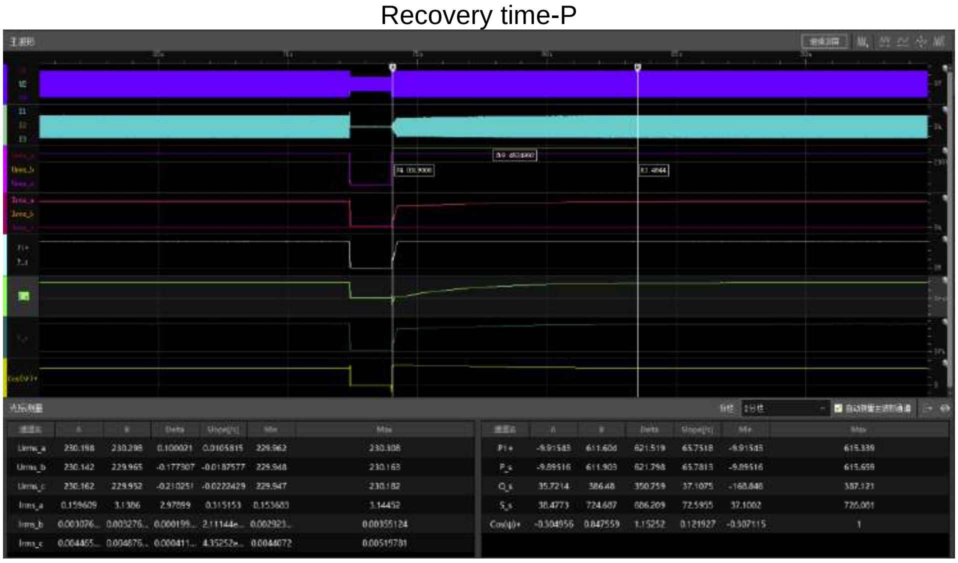
During dip (t1+60ms)

During dip (t1+100ms)

After dip(t2+3s)



Recovery time-P

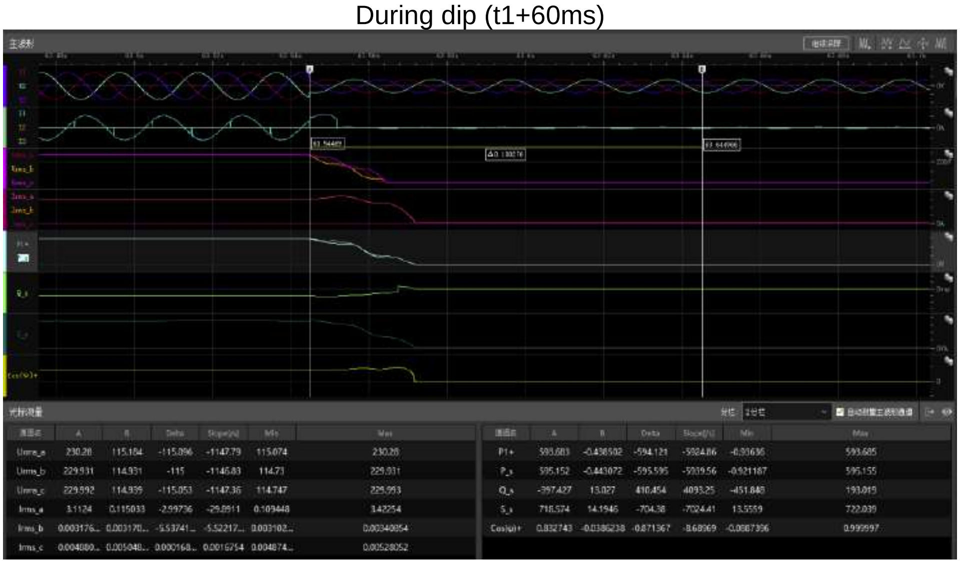


Recovery time-Q

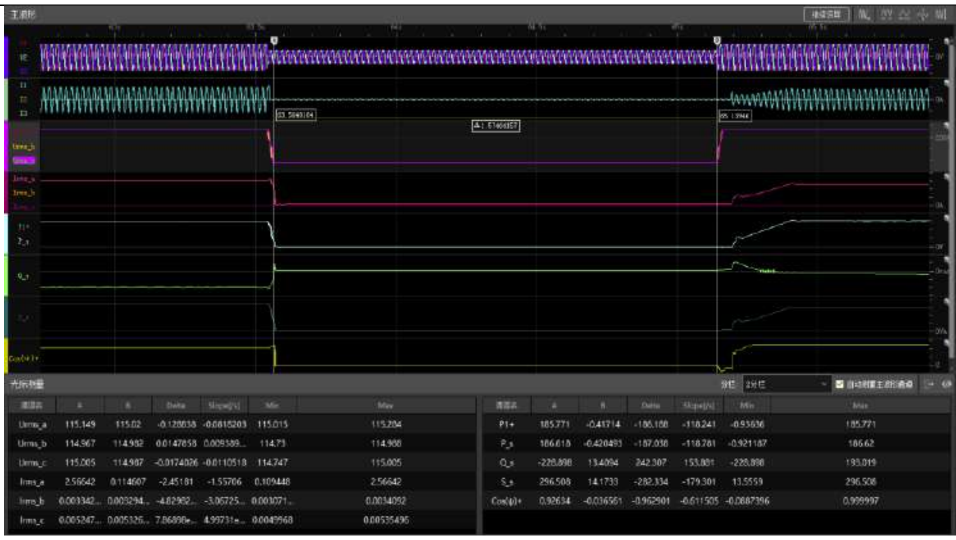
Graph of Test number 3.2_0.5Un

Before dip (t1-100ms)

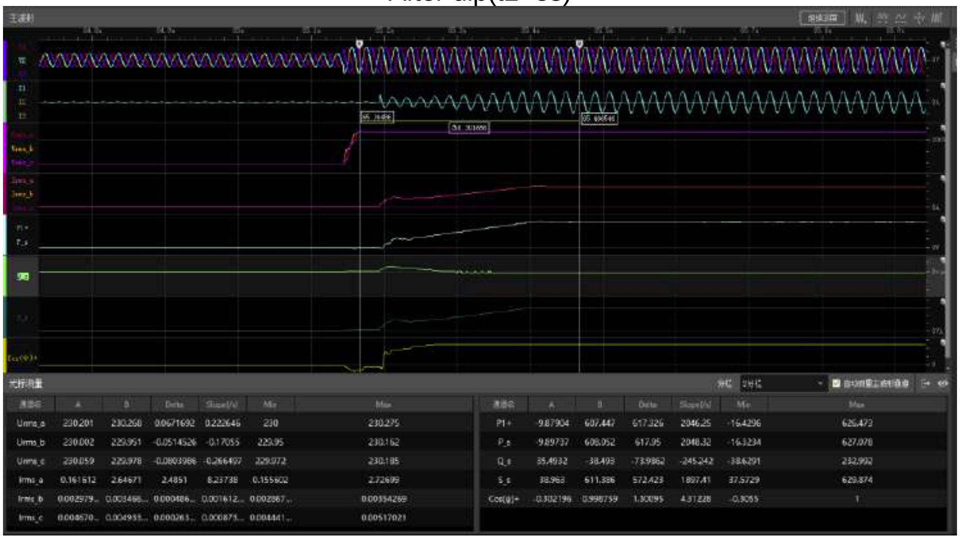
During dip (t1+60ms)



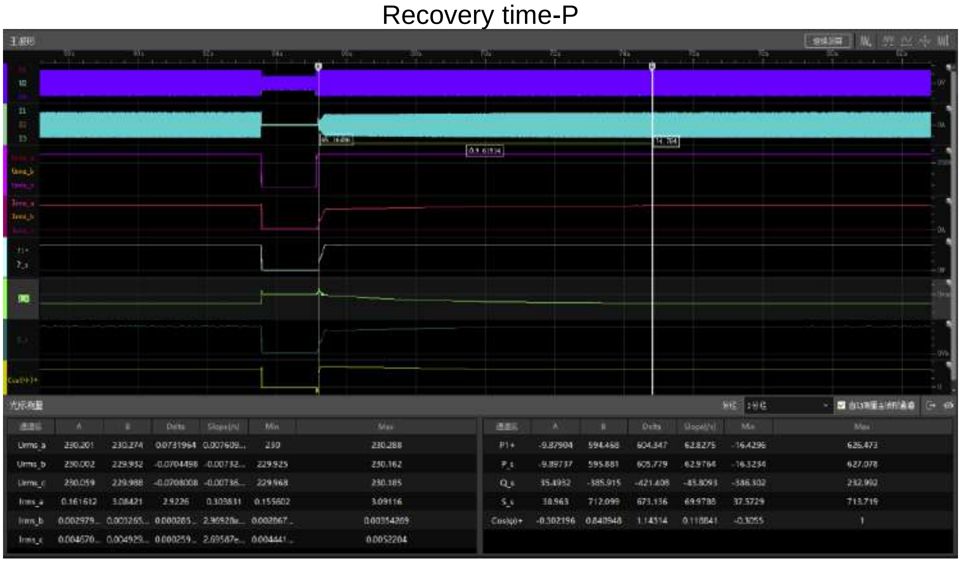
During dip (t1+100ms)



After dip(t2+3s)



Recovery time-P



Recovery time-Q

Verification of dynamic network support										P
Short-circuited power at generator terminal [VA]			4K							
NS protection settings			See table 5.5 for detail.							
	No.	Parameter	Phase ref.	Time ref.	unit	Result				
General Info.	0	Test number	--	--	--	4.2	5.2	6.2	7.2	
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024				
	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.	0.85	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	60980	100.0	5079.4	60079	
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.85	1.25	1.20	1.15	
	10		Positive sequence		p.u.	0.85	1.25	1.20	1.15	
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.	0.498	0.496	0.496	0.497	
	14		Positive sequence			--	--	--	--	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.017	0.021	0.023	0.020	
	16		Positive sequence			--	--	--	--	
	17	Cos_{φ}	--	t1-10s to t1	--	0.9998	0.9998	0.9998	0.9998	
During dip t1 to	18	Voltage	Line to neutral	t1+100ms to t2-20ms	p.u.	0.85	1.25	1.20	1.15	

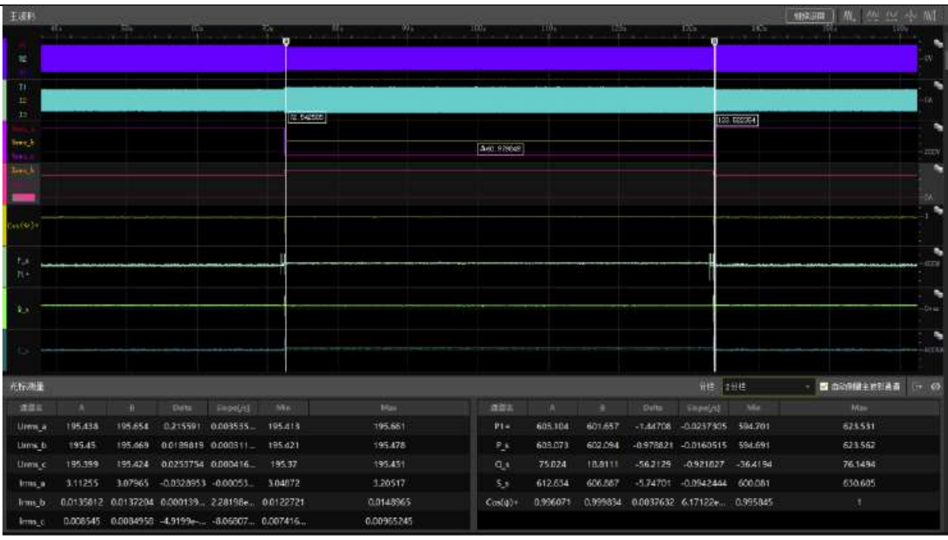
t2	19	Line current	Phase 1	t1+60ms	p.u.	0.587	0.034	0.033	0.426
	20		Phase 2			--	--	--	--
	21		Phase 3			--	--	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	0.588	0.034	0.033	0.424
	23		Phase 2			--	--	--	--
	24		Phase 3			--	--	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.500	0.001	0.001	0.486
	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			0.496	0.496	0.496	0.497
	39	Active power rising time	Positive sequence	--	s	0.011	0.271	0.241	0.021
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.018	0.018	0.017	0.020
	33	Reactive power rising time	Positive sequence	--	s	0.009	0.008	0.009	0.011
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

Graph of Test number 3.2_0.85Un

Before dip (t1-100ms)

During dip (t1+60ms)

During dip (t1+100ms)

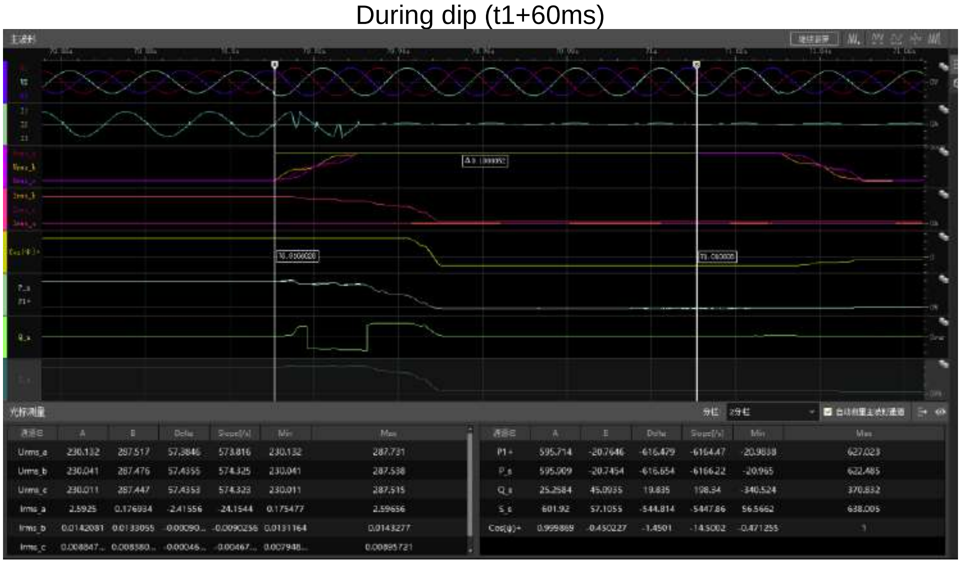


After dip(t2+3s)

Graph of Test number 5.2_1.25Un

Before dip (t1-100ms)

During dip (t1+60ms)

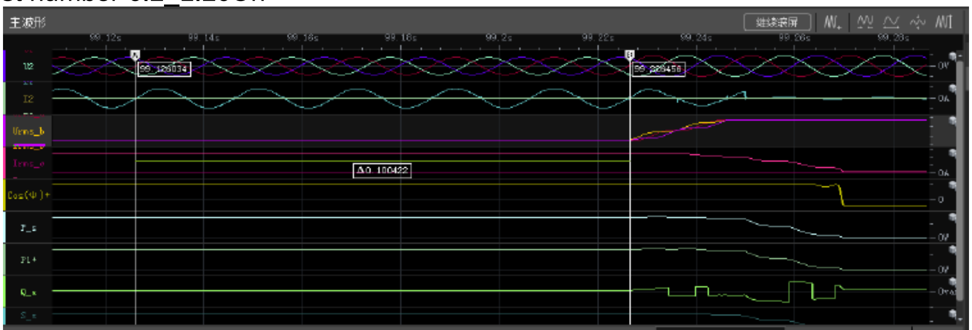


During dip (t1+100ms)

After dip(t2+3s)

Recovery time

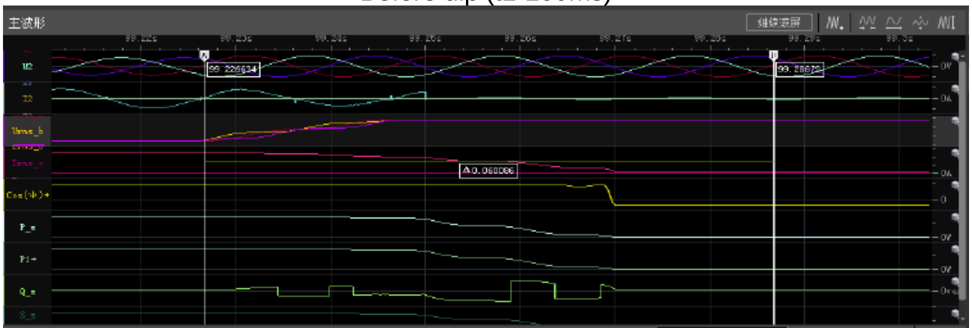
Graph of Test number 6.2_1.20Un



通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	0.999872	0.999748	-0.00012...	-0.0012316	0.999729	0.99990
P_s	594.154	595.31	1.15558	11.5072	593.285	597.57
P1+	593.817	595.872	2.05493	20.463	592.962	597.2
Q_s	20.8871	28.6656	7.77853	77.4584	20.0451	30.079
S_s	599.537	600.829	1.29187	12.8644	598.487	602.73
Urms_a	230.13	230.135	0.005523...	0.0550047	230.124	230.13

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	229.973	230.549	0.575821	5.73401	229.968	230.17
Urms_c	229.926	230.486	0.560028	5.57675	229.925	230.14
Irms_a	2.58447	2.58926	0.004787...	0.0476709	2.57999	2.5989
Irms_b	0.0131072	0.0133662	0.000258...	0.002578...	0.0126439	0.01339
Irms_c	0.007652...	0.008105...	0.000452...	0.004508...	0.0072417	0.00810

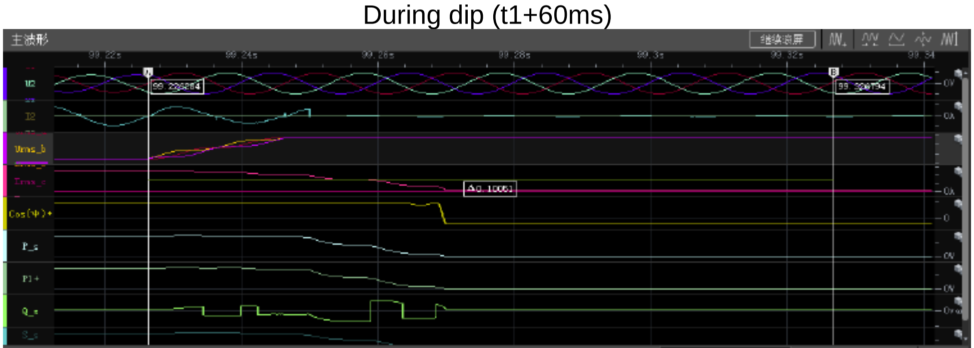
Before dip (t1-100ms)



通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	0.999731	-0.387689	-1.38742	-23.0906	-0.397537	1
P_s	595.276	-16.7049	-611.981	-10185.1	-17.3019	624.40
P1+	596.711	-16.7339	-613.444	-10209.4	-17.3509	622.48
Q_s	29.5331	42.5141	12.981	216.04	-272.384	279.19
S_s	600.857	52.5616	-548.295	-9125.17	52.4867	636.33
Urms_a	230.14	276.286	46.1458	767.996	230.14	276.37

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	231.145	275.986	44.841	746.281	231.145	276.03
Urms_c	230.987	275.958	44.9715	748.452	230.987	276.00
Irms_a	2.58924	0.170331	-2.41891	-40.2574	0.170083	2.5907
Irms_b	0.0133803	0.0127917	-0.00058...	-0.00979...	0.0127235	0.01386
Irms_c	0.008123...	0.007142...	-0.00098...	-0.0163175	0.007087...	0.00830

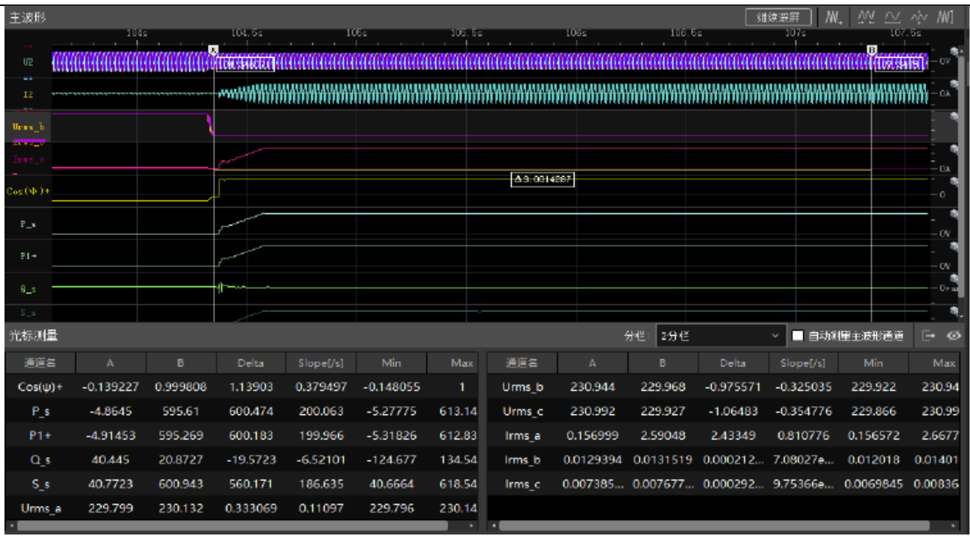
During dip (t1+60ms)



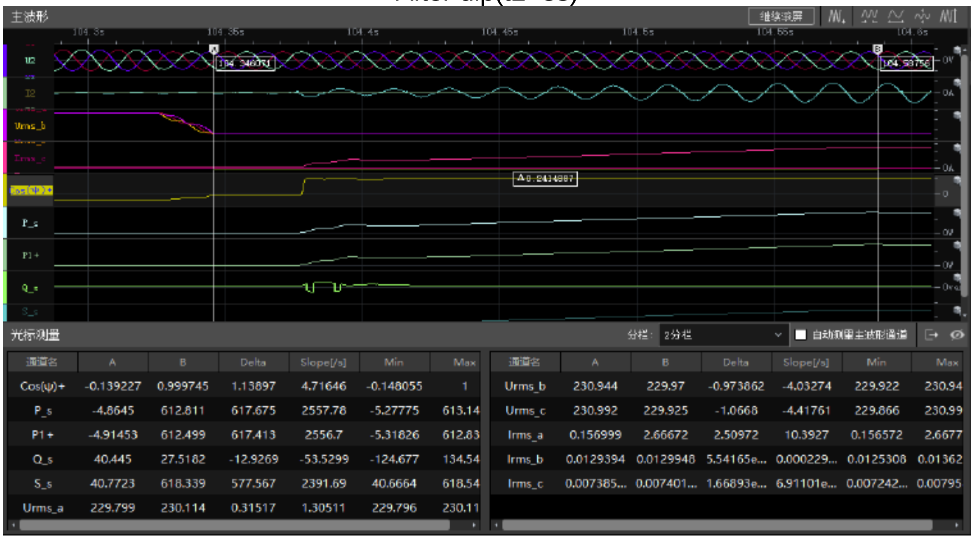
通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	0.999753	-0.386201	-1.38595	-13.7892	-0.397537	1
P_s	595.293	-16.6246	-611.917	-6088.12	-17.3019	624.40
P1+	594.959	-16.6565	-611.616	-6085.12	-17.3509	622.48
Q_s	27.8857	38.3734	10.4877	104.345	-272.384	279.19
S_s	600.746	52.7246	-548.022	-5452.41	52.3808	636.33
Urms_a	230.134	276.204	46.0695	458.357	230.134	276.37

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	229.971	275.987	46.0157	457.823	229.971	276.03
Urms_c	229.932	275.953	46.0205	457.87	229.932	276.00
Irms_a	2.58904	0.17036	-2.41868	-24.0641	0.170072	2.5907
Irms_b	0.0133227	0.0131457	-0.00017...	-0.0017611	0.012528	0.01386
Irms_c	0.008068...	0.007401...	-0.00066...	-0.00663...	0.006763...	0.00830

During dip (t1+100ms)



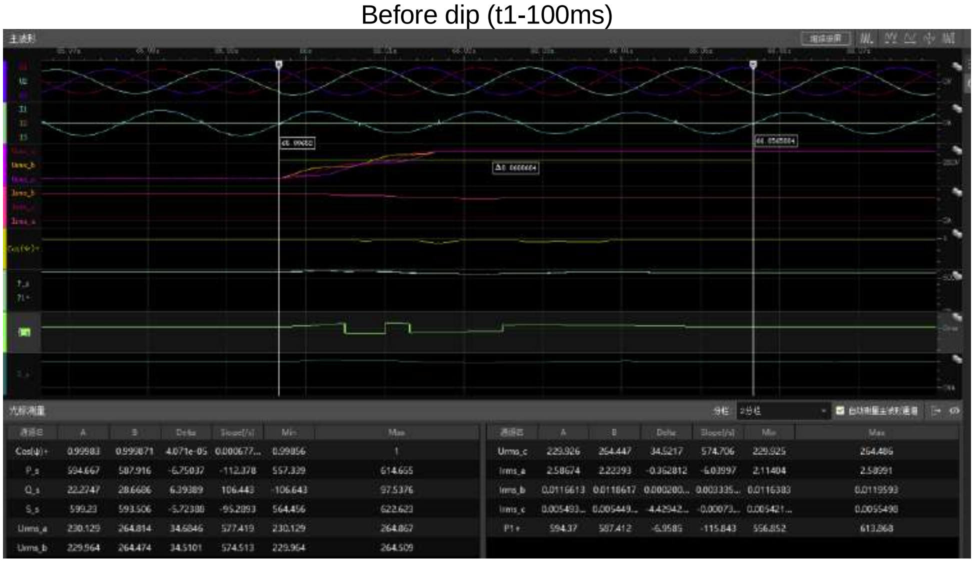
After dip(t2+3s)



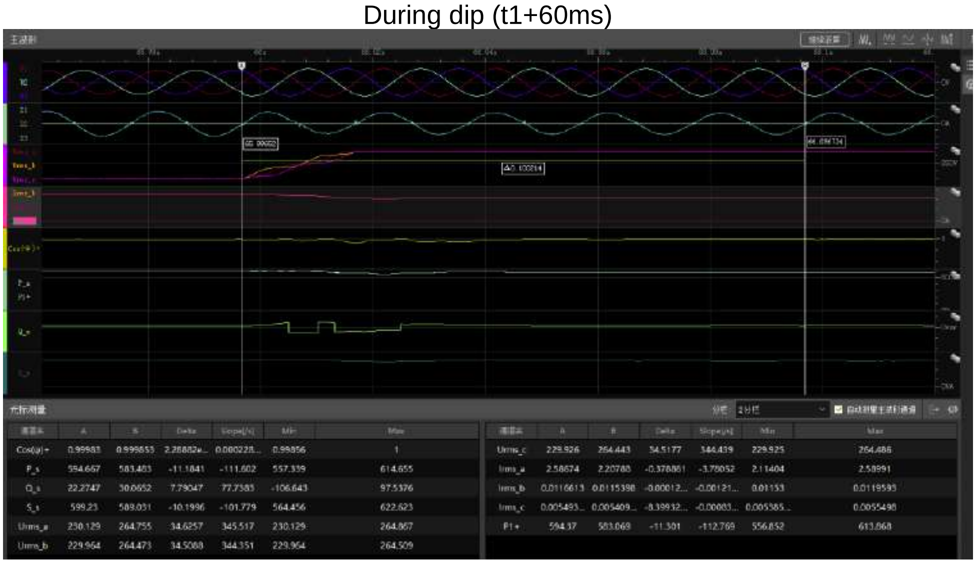
Recovery time

Graph of Test number 7.2_1.15Un

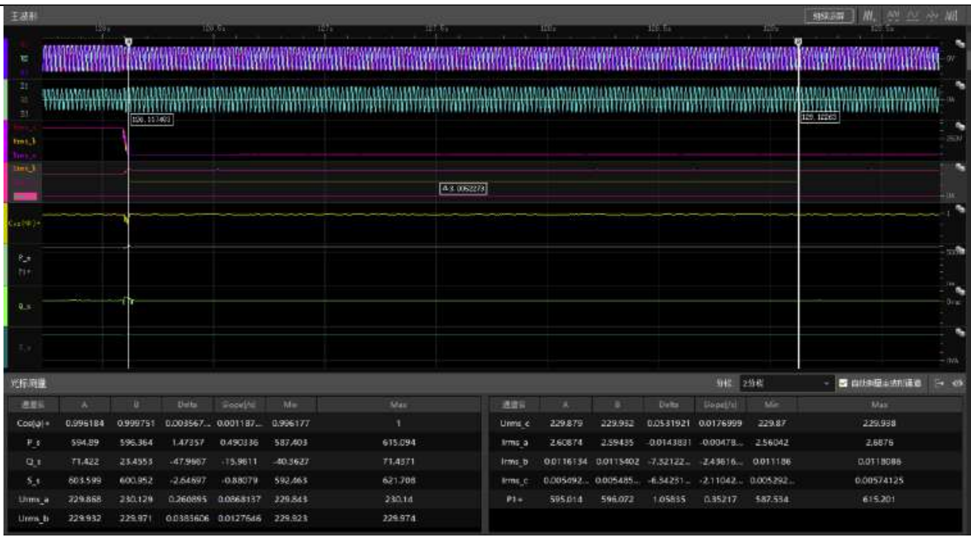
Before dip (t1-100ms)



During dip (t1+60ms)



During dip (t1+100ms)

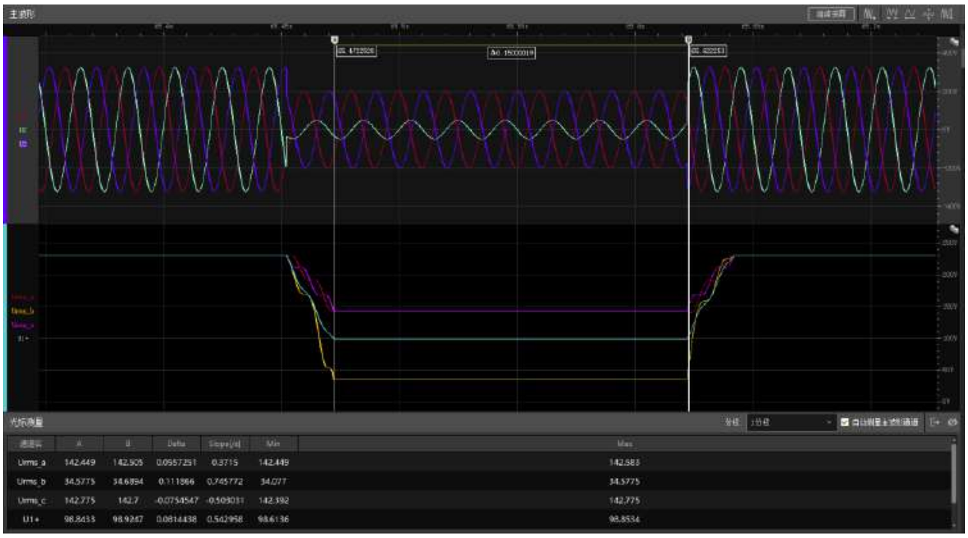


After dip(t2+3s)

<table>
<tr><td colspan="9">Verification of dynamic network support</td><td>P</td></tr>
<tr><td colspan="3">Short-circuited power at generator terminal [VA]</td><td colspan="7">4K</td></tr>
<tr><td colspan="3">NS protection settings</td><td colspan="7">See table 5.5 for detail.</td></tr>
<tr><td></td><td>No.</td><td>Parameter</td><td>Phase ref.</td><td>Time ref.</td><td>unit</td><td colspan="4">Result</td></tr>
<tr><td rowspan="11">General Info.</td><td>0</td><td>Test number</td><td>--</td><td>--</td><td>--</td><td>1.3</td><td>2.3</td><td>3.3</td><td>4.3</td></tr>
<tr><td>1</td><td>Date</td><td>--</td><td>--</td><td>dd.mm.yyyy</td><td colspan="4">15-Apr-2024 to 10-May-2024</td></tr>
<tr><td>2</td><td>Time (start of test)</td><td>--</td><td>--</td><td>hh:mm:ss.f</td><td colspan="4">See graph</td></tr>
<tr><td>3</td><td>Fault type (phase)</td><td>--</td><td>--</td><td></td><td>D1</td><td>D1</td><td>D1</td><td>D1</td></tr>
<tr><td>4</td><td>Setting voltage depth</td><td>Line to line</td><td>--</td><td>p.u.</td><td>0.15</td><td>0.50</td><td>0.50</td><td>0.85</td></tr>
<tr><td>5</td><td>Setting dip duration</td><td></td><td>--</td><td>ms</td><td>150</td><td>1500</td><td>1500</td><td>60000</td></tr>
<tr><td>6</td><td>Point of fault entry</td><td>Total</td><td>--</td><td>ms</td><td colspan="4">20ms</td></tr>
<tr><td>7</td><td>Point of fault clearance</td><td>Total</td><td>--</td><td>ms</td><td colspan="4">20ms</td></tr>
<tr><td>8</td><td>Fault duration in empty load test</td><td>Total</td><td>--</td><td>ms</td><td>150.0</td><td>1579.4</td><td>1579.4</td><td>60080</td></tr>
<tr><td>9</td><td rowspan="2">Voltage depth/height in empty load test</td><td>Total</td><td rowspan="2">t1+100ms to t2 and t1-10s to t1</td><td>p.u.</td><td>0.620</td><td>0.760</td><td>0.760</td><td>0.930</td></tr>
<tr><td>10</td><td>Positive sequence</td><td>p.u.</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td rowspan="7">Before dip <t1</td><td>11</td><td>Voltage</td><td>Line to neutral</td><td>t1-10s to t1</td><td>p.u.</td><td>1.00</td><td>1.00</td><td>1.00</td><td>1.00</td></tr>
<tr><td>12</td><td>Current</td><td>Positive sequence</td><td>t1-500ms to t1-100ms</td><td>p.u.</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>13</td><td rowspan="2">Active power</td><td>Total</td><td rowspan="2">t1-10s to t1</td><td rowspan="2">p.u.</td><td>0.999</td><td>0.956</td><td>0.932</td><td>0.994</td></tr>
<tr><td>14</td><td>Positive sequence</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>15</td><td rowspan="2">Reactive power</td><td>Total</td><td rowspan="2">t1-10s to t1</td><td rowspan="2">p.u.</td><td>0.031</td><td>0.317</td><td>0.308</td><td>0.021</td></tr>
<tr><td>16</td><td>Positive sequence</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
<tr><td>17</td><td>Cos_{φ}</td><td>--</td><td>t1-10s to t1</td><td>--</td><td>0.9999</td><td>0.9500</td><td>0.9506</td><td>0.9999</td></tr>
<tr><td>During</td><td>18</td><td>Voltage</td><td>Phase 1</td><td>t1+100ms</td><td>p.u.</td><td>--</td><td>--</td><td>--</td><td>--</td></tr>
</table>

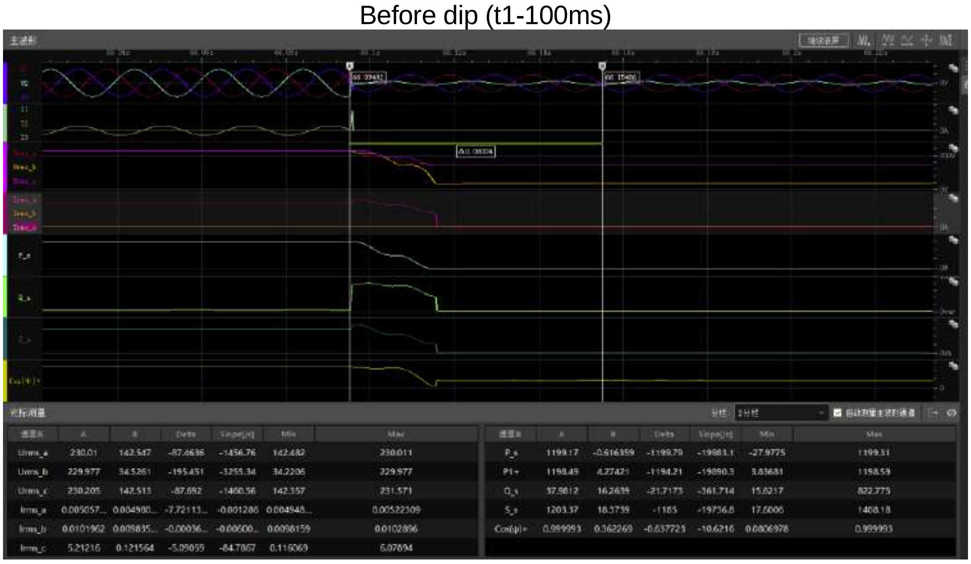
dip t1 to t2			Phase 2	to t2-20ms		--	--	--	--
			Phase 3			0.620	0.760	0.760	0.930
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			0.023	0.027	0.027	1.070
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			0.024	0.027	0.027	1.071
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.001	0.001	0.001	0.997
	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			0.999	0.957	0.937	0.995
	39	Active power rising time	Positive sequence	--	s	0.530	0.486	0.506	0.006
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.030	0.309	-0.301	0.031
	33	Reactive power rising time	Positive sequence	--	s	0.013	9.428	9.476	0.015
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

Graph of Test number 1.3



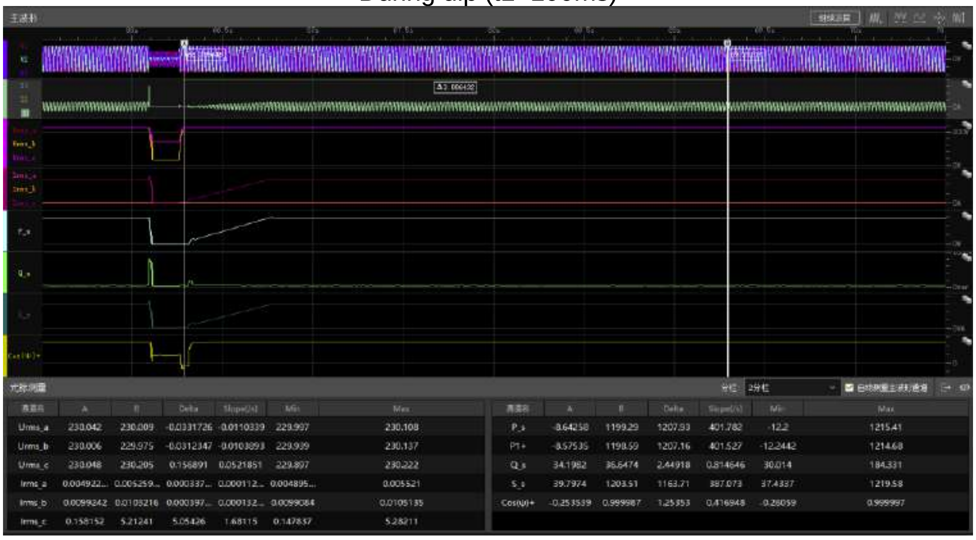
Empty load

Before dip (t1-100ms)

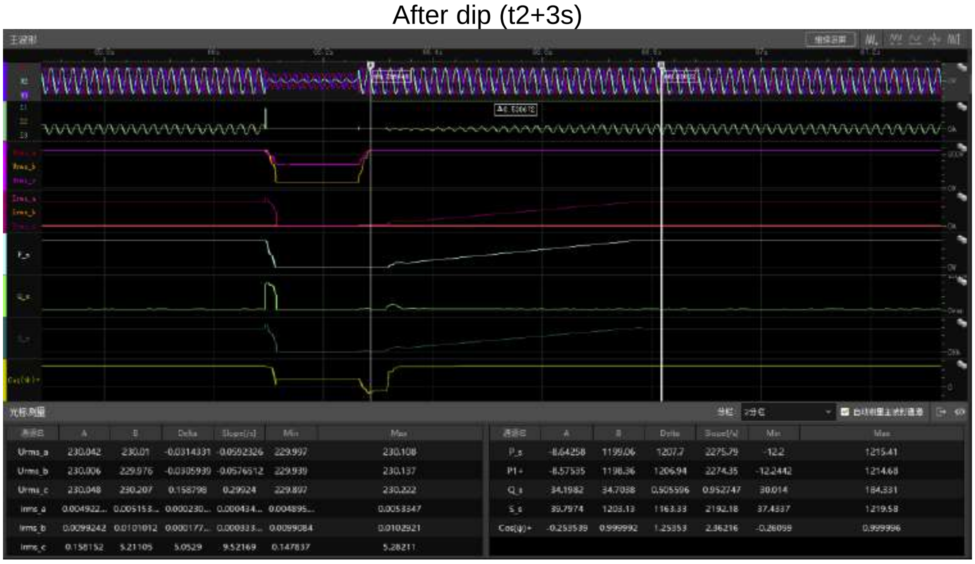


During dip (t1+60ms)

During dip (t1+100ms)

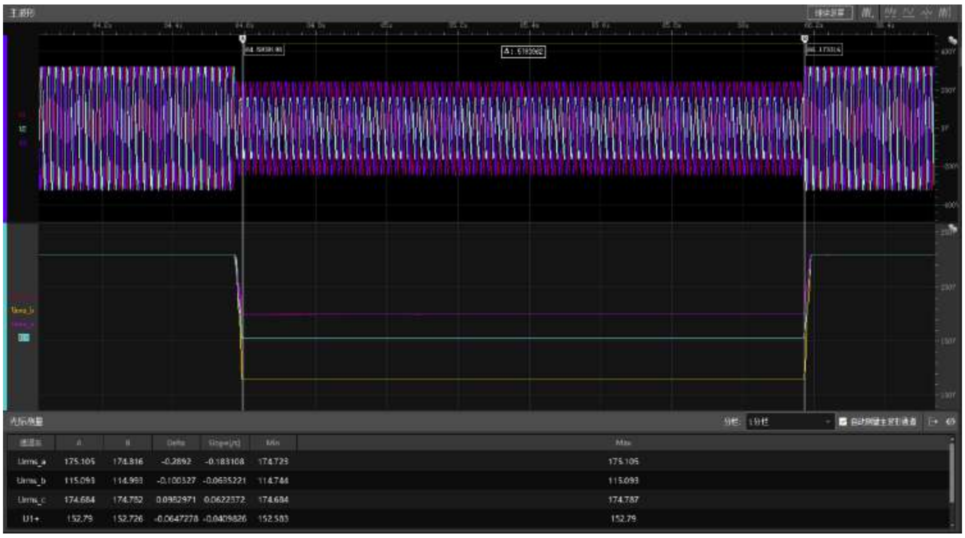


After dip (t2+3s)

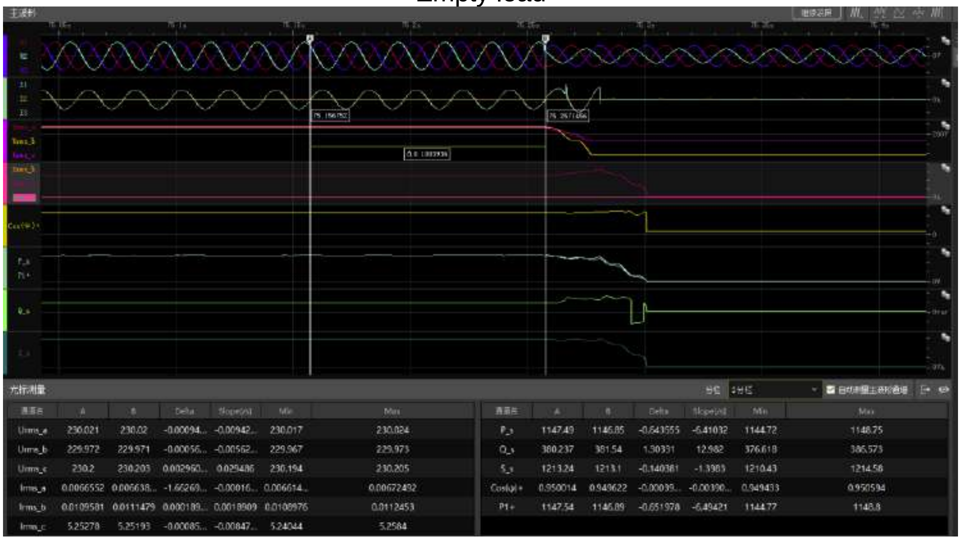


Recovery time

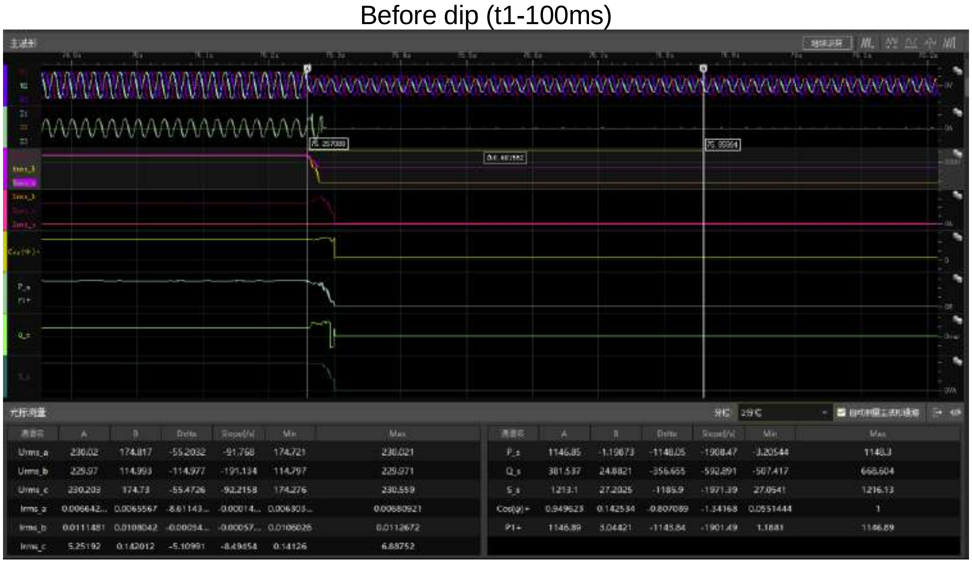
Graph of Test number 2.3



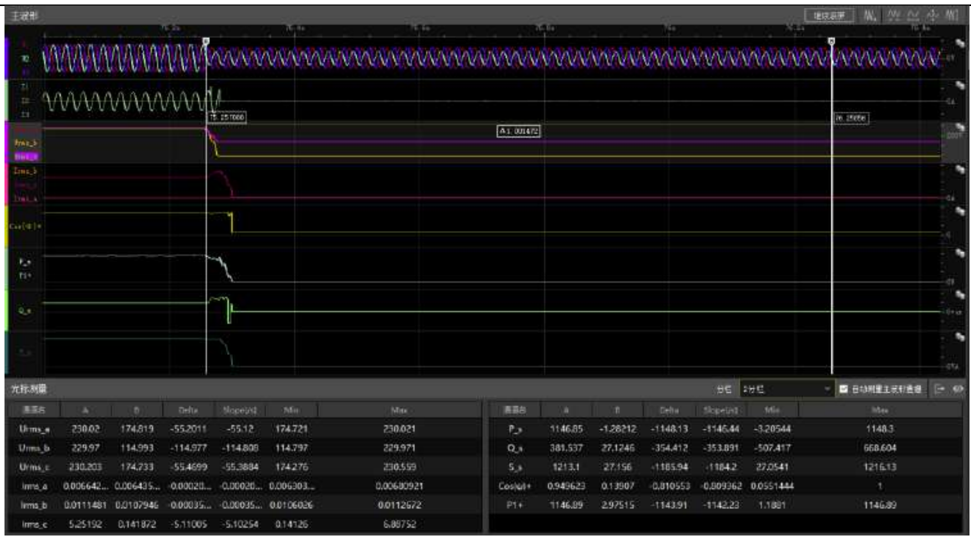
Empty load



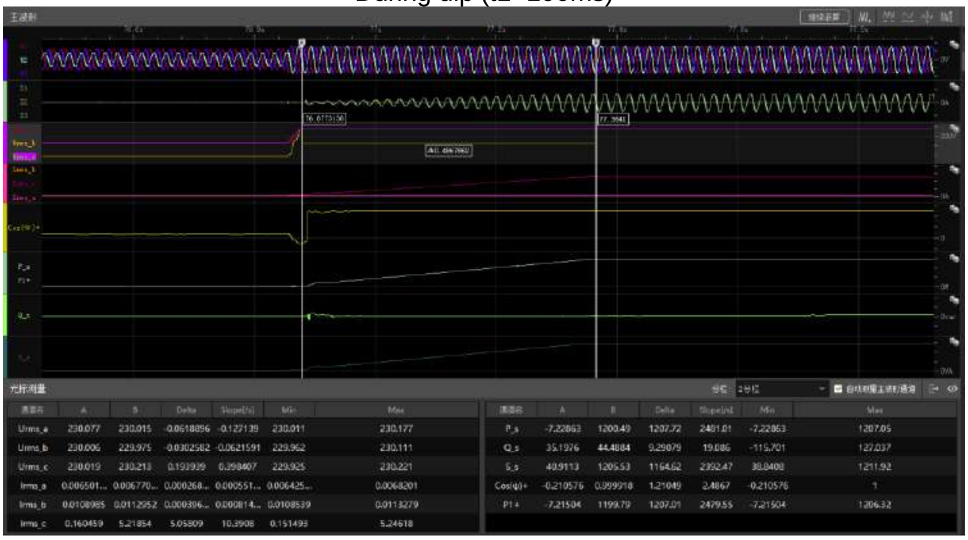
Before dip (t1-100ms)



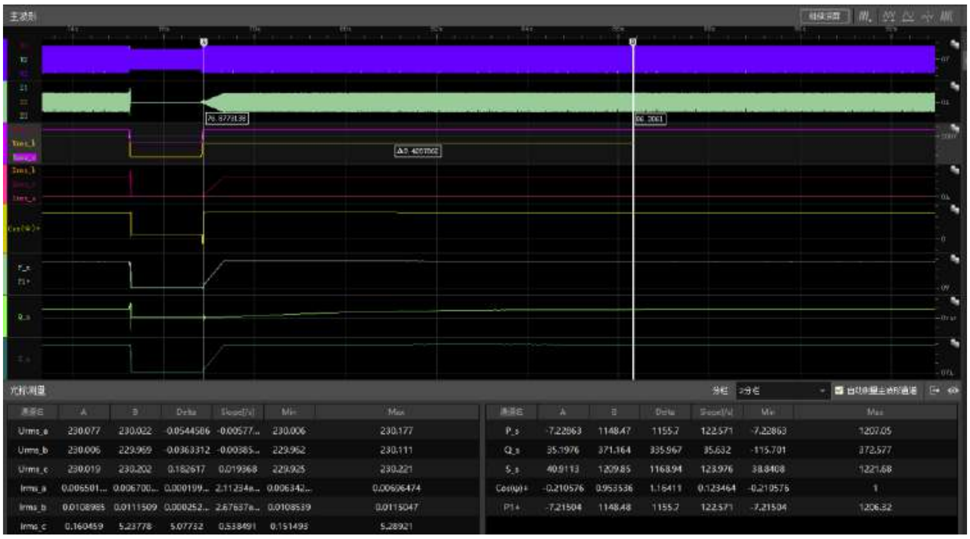
During dip (t1+60ms)



During dip (t1+100ms)

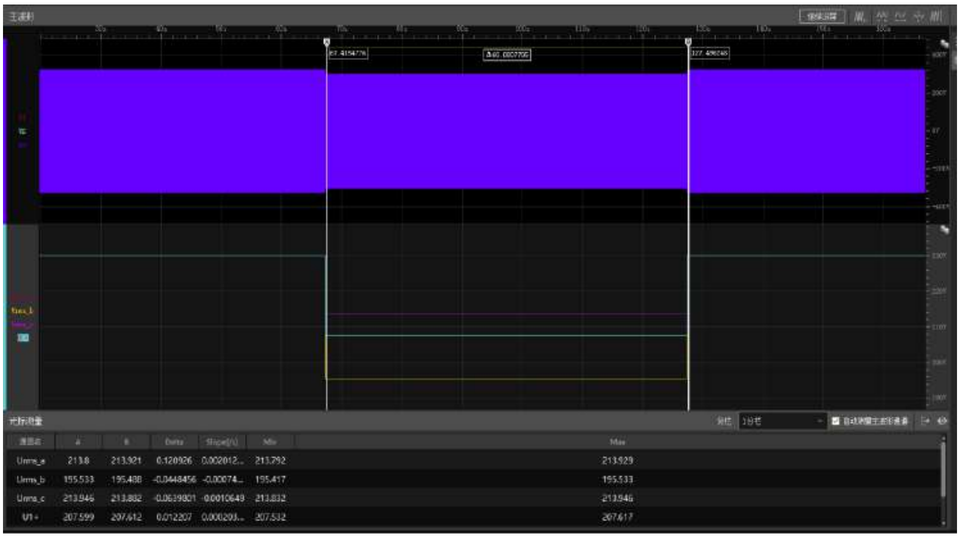


Recovery time-P

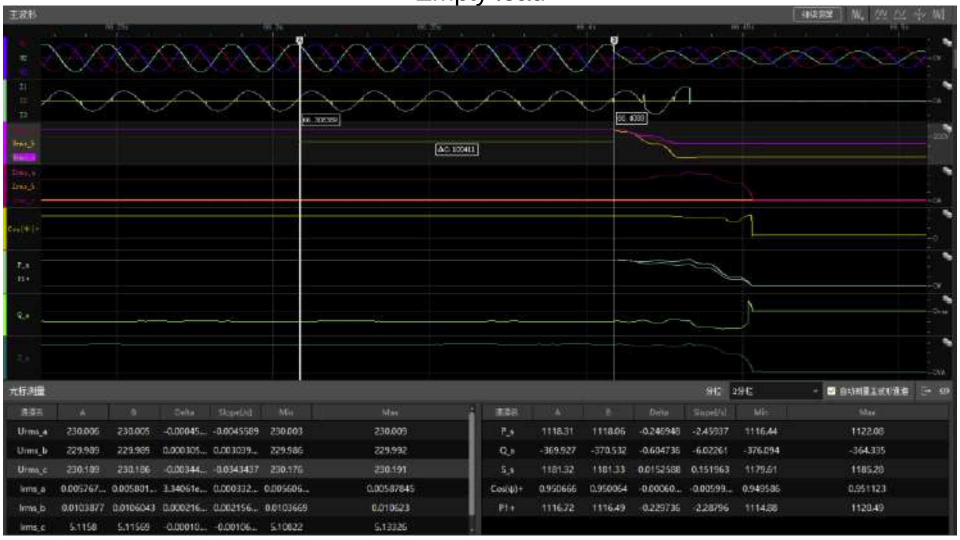


Recovery time-Q

Graph of Test number 3.3

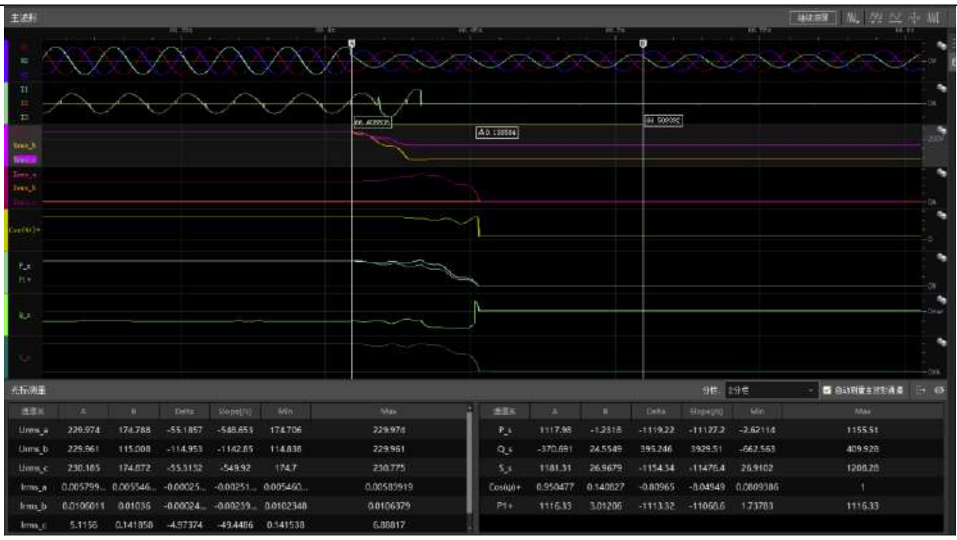


Empty load

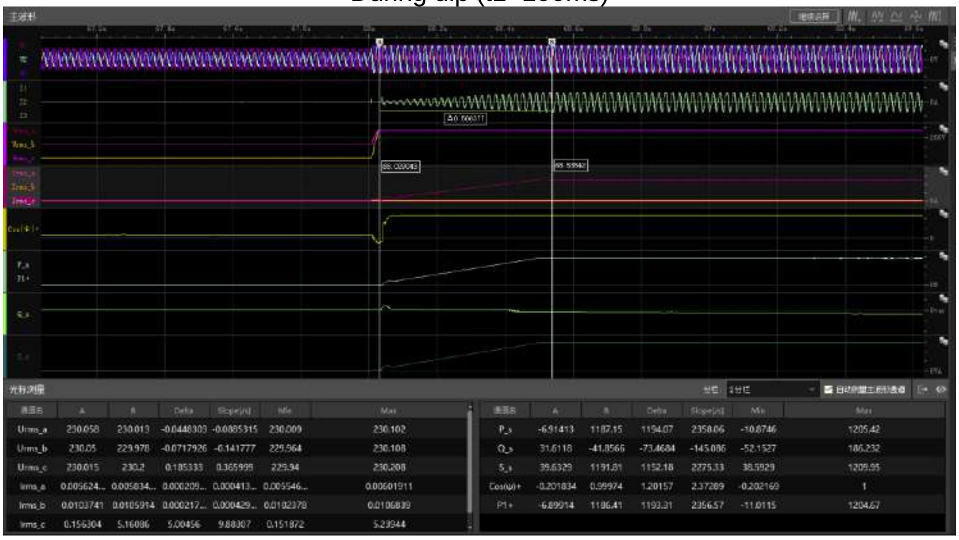


Before dip (t1-100ms)

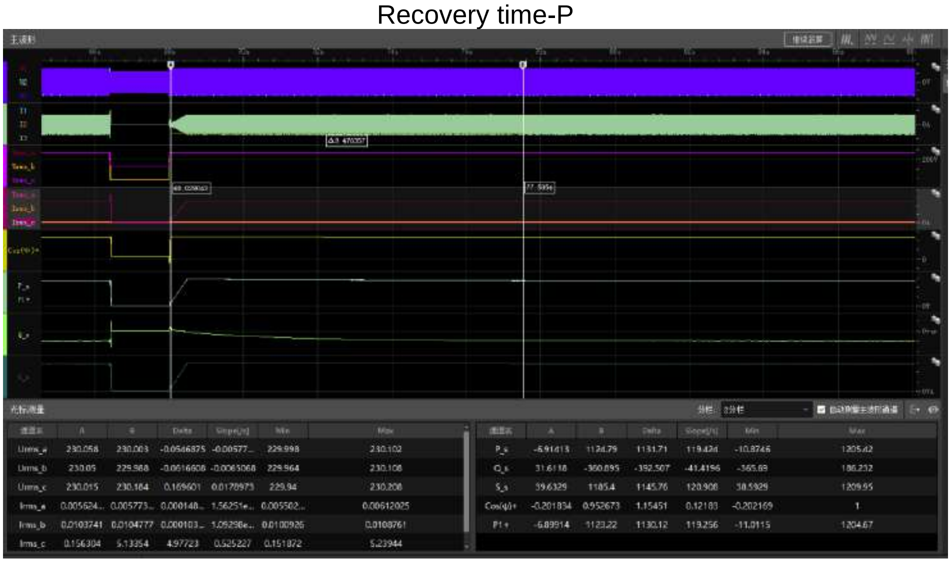
During dip (t1+60ms)



During dip (t1+100ms)

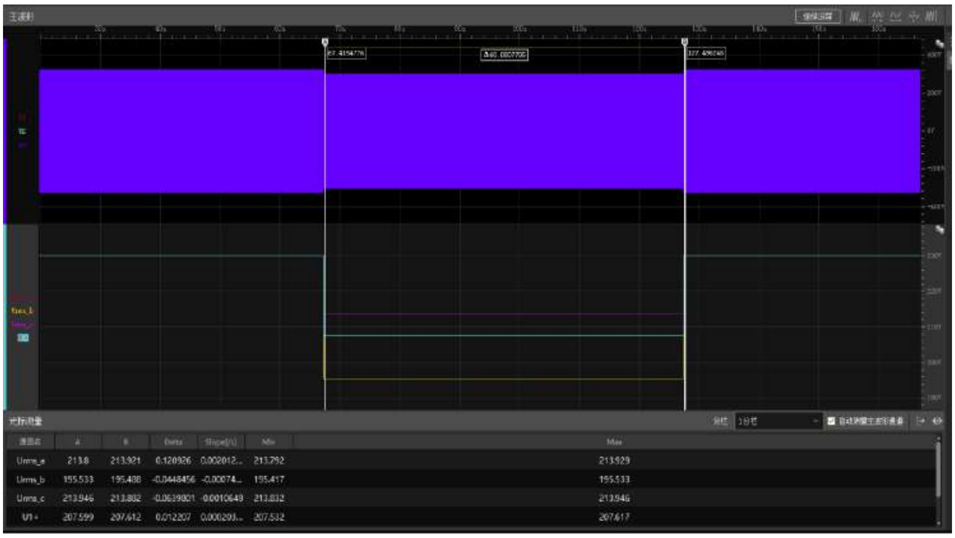


Recovery time-P



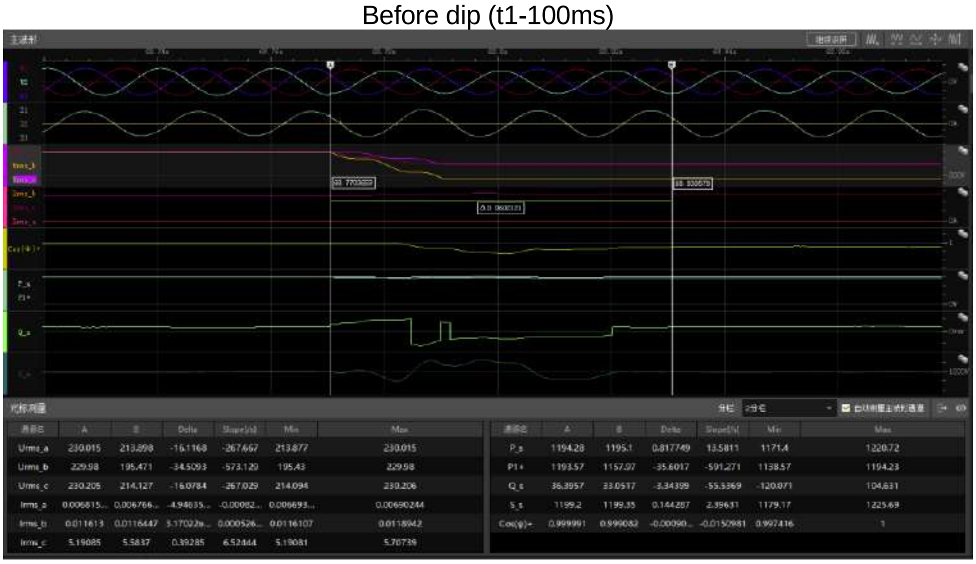
Recovery time-Q

Graph of Test number 4.3



Empty load

Before dip (t1-100ms)

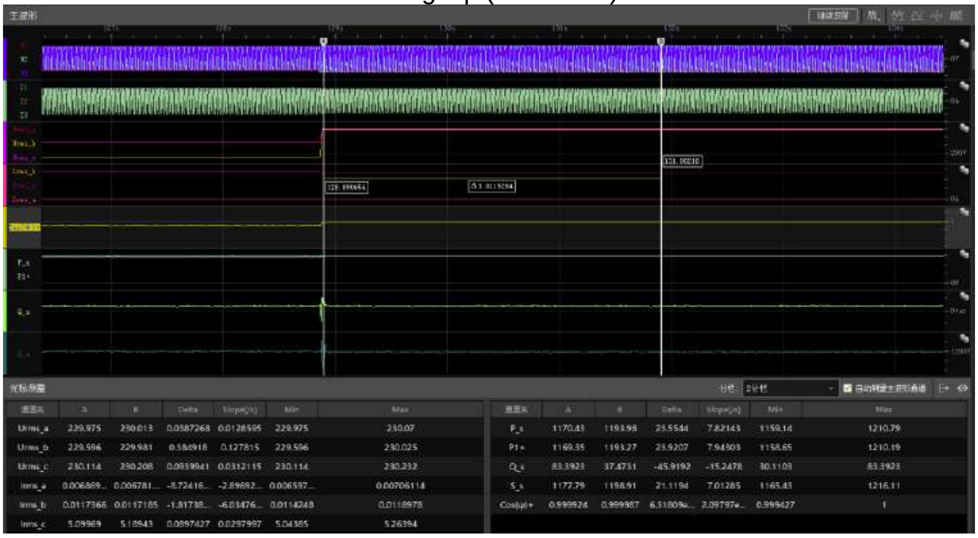


During dip (t1+60ms)

	A	B	Delta	Slope(/s)	Min	Max
Urms_a	230.015	213.901	-16.1143	-160.585	213.877	230.015
Urms_b	229.98	195.474	-34.506	-344.722	195.43	229.98
Urms_c	230.205	214.128	-16.0769	-160.611	214.094	230.206
Irms_a	0.006815...	0.006766...	-4.91296...	-0.00049...	0.006688...	0.00690244
Irms_b	0.011613	0.0117989	0.000185...	0.001857...	0.0116107	0.0118942
Irms_c	5.19085	5.58936	0.398502	3.98112	5.19081	5.70739

	A	B	Delta	Slope(/s)	Min	Max
P_s	1194.28	1196.22	1.93774	19.3585	1171.4	1220.72
P1+	1193.57	1159.1	-34.4707	-344.369	1138.57	1194.23
Q_s	36.3957	37.748	1.35238	13.5105	-120.071	104.631
S_s	1199.2	1200.59	1.39307	13.917	1179.17	1225.69
Cos(φ)+	0.999991	0.999114	-0.00087...	-0.00876...	0.997416	1

During dip (t1+100ms)



	A	B	Delta	Slope(/s)	Min	Max
Urms_a	229.975	230.013	0.0387268	0.0128595	229.975	230.07
Urms_b	229.596	229.981	0.384918	0.127815	229.596	230.025
Urms_c	230.114	230.208	0.0939941	0.0312115	230.114	230.232
Irms_a	0.006869...	0.006781...	-8.72416...	-2.89692...	0.006597...	0.00706114
Irms_b	0.0117366	0.0117185	-1.81738...	-6.03476...	0.0114248	0.0118978
Irms_c	5.09969	5.18943	0.0897427	0.0297997	5.04385	5.26394

	A	B	Delta	Slope(/s)	Min	Max
P_s	1170.43	1193.98	23.5544	7.82143	1159.14	1210.79
P1+	1169.35	1193.27	23.9207	7.94303	1158.65	1210.19
Q_s	83.3923	37.4731	-45.9192	-15.2478	30.1103	83.3923
S_s	1177.79	1198.91	21.1194	7.01285	1165.43	1216.11
Cos(φ)+	0.999924	0.999987	6.31809e...	2.09797e...	0.999427	1

After dip (t2+3s)

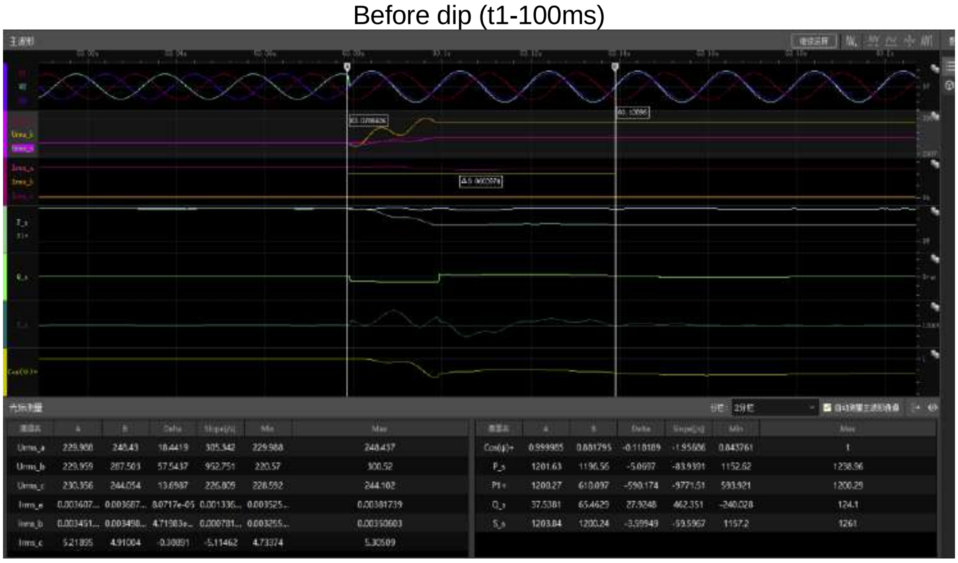
Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			4K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	5.3	6.3	7.3	1.4
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024			
	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.	1.25	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	100.0	5079.1	60081	1500.0
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.060	1.050	1.040	0.620
	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.	1.001	1.002	0.994	0.498
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.032	0.028	0.031	0.021
	16		Positive sequence			--	--	--	--
	17	Cos_{φ}	--	t1-10s to t1	--	0.9999	0.9999	0.9999	0.9999

During dip t1 to t2	18	Voltage	Phase 1	t1+100ms to t2-20ms	p.u.	--	--	--	--
			Phase 2			--	--	--	--
			Phase 3			1.060	1.050	1.040	0.620
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			0.941	0.961	0.953	0.023
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			0.942	0.950	0.954	0.023
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	1.000	0.999	0.993	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			1.000	1.001	0.972	0.497
	39	Active power rising time	Positive sequence	--	s	0.011	0.013	0.028	0.269
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.029	0.030	0.030	0.021
	33	Reactive power rising time	Positive sequence	--	s	0.013	0.012	0.013	0.010
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

Graph of Test number 5.3

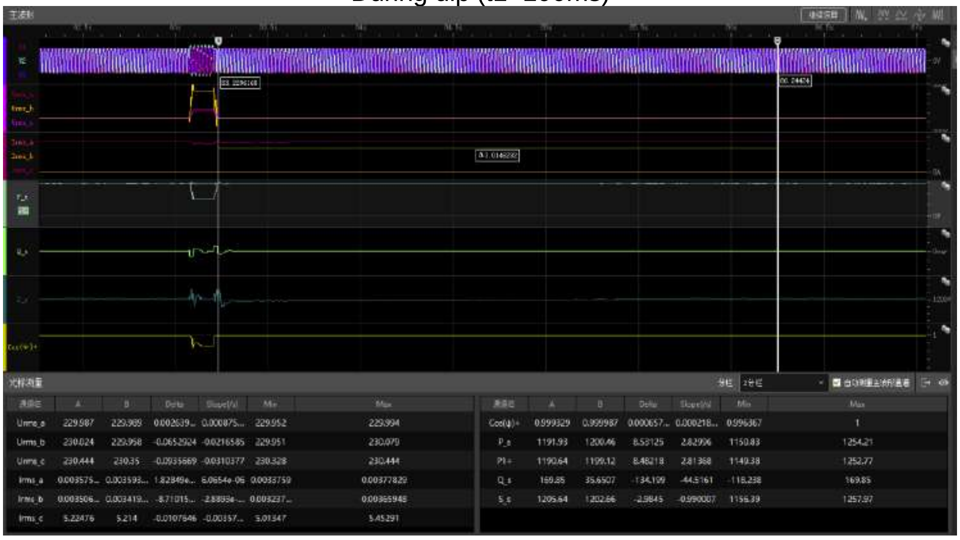
Empty load

Before dip (t1-100ms)



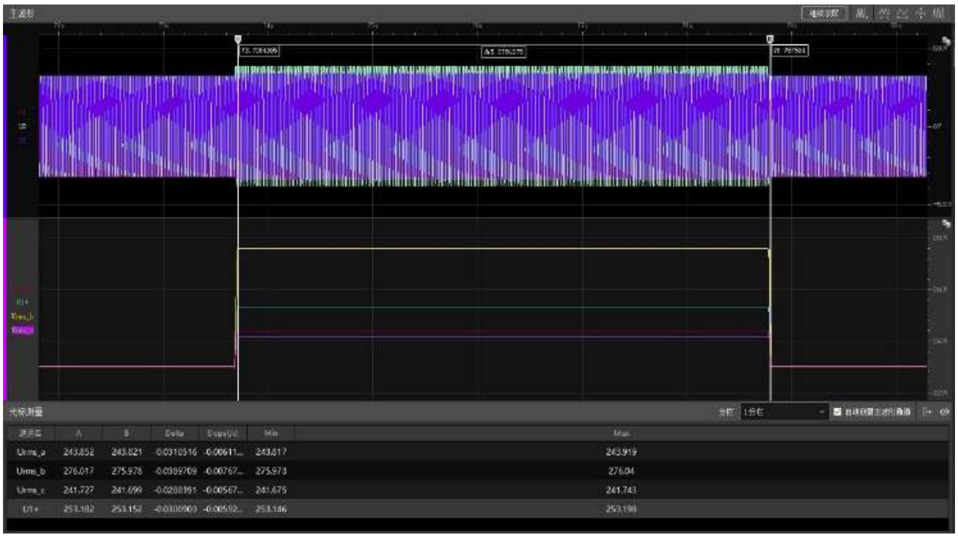
During dip (t1+60ms)

During dip (t1+100ms)



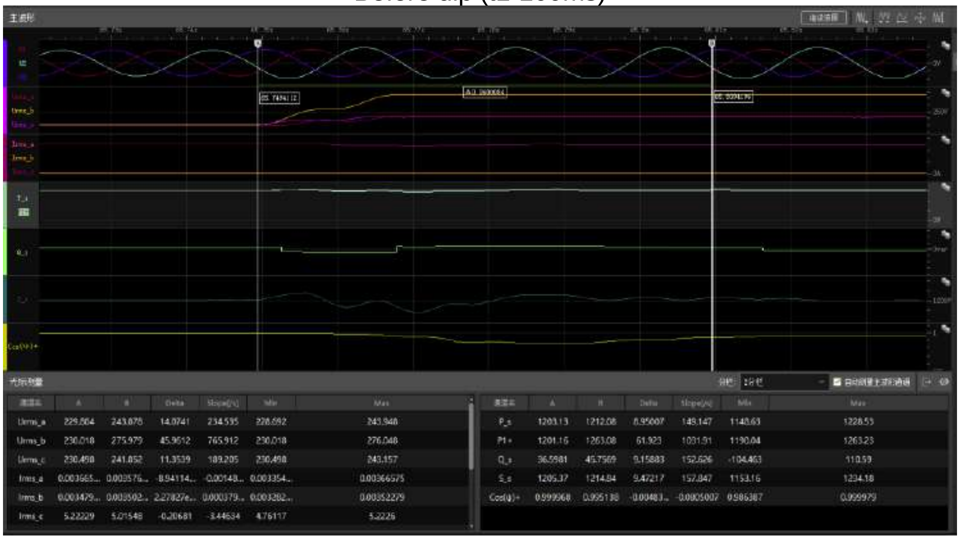
After dip (t2+3s)

Graph of Test number 6.3

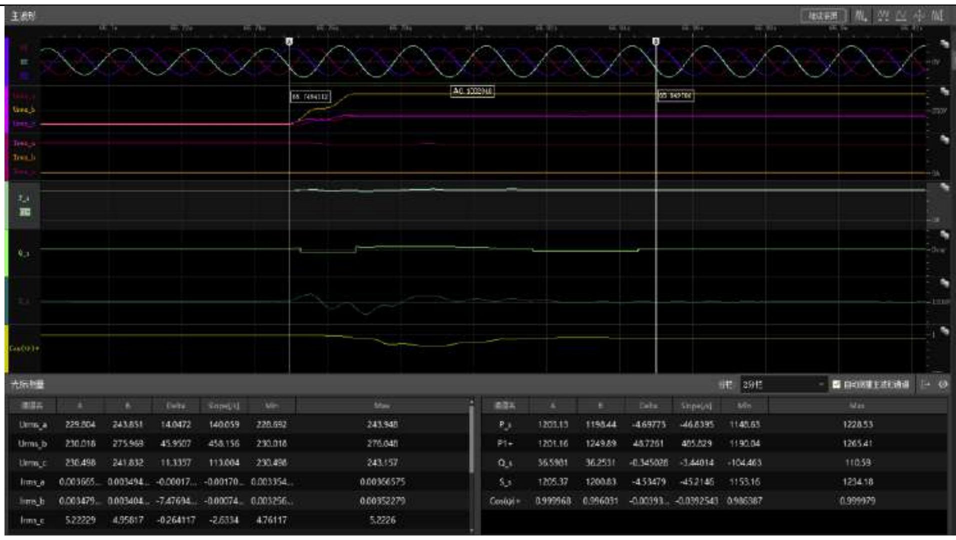


Empty load

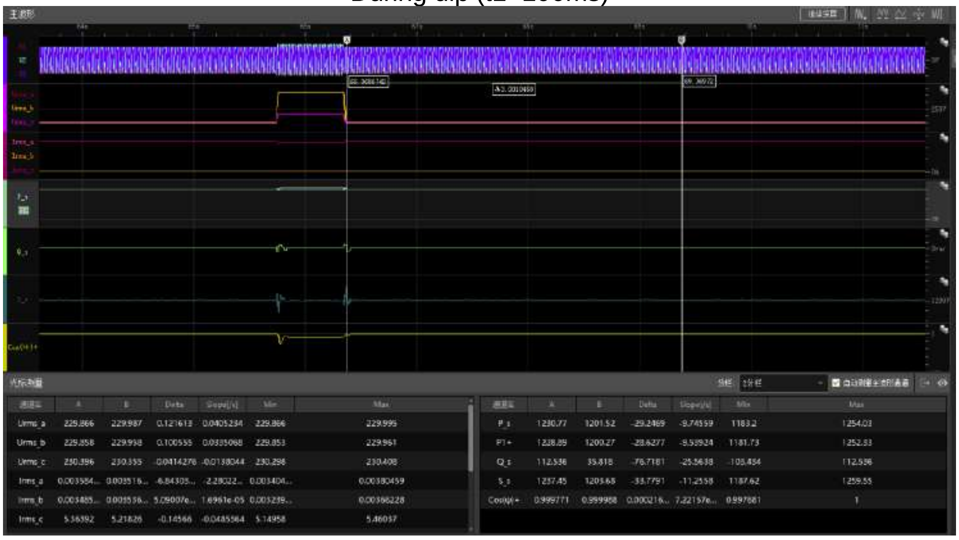
Before dip (t1-100ms)



During dip (t1+60ms)

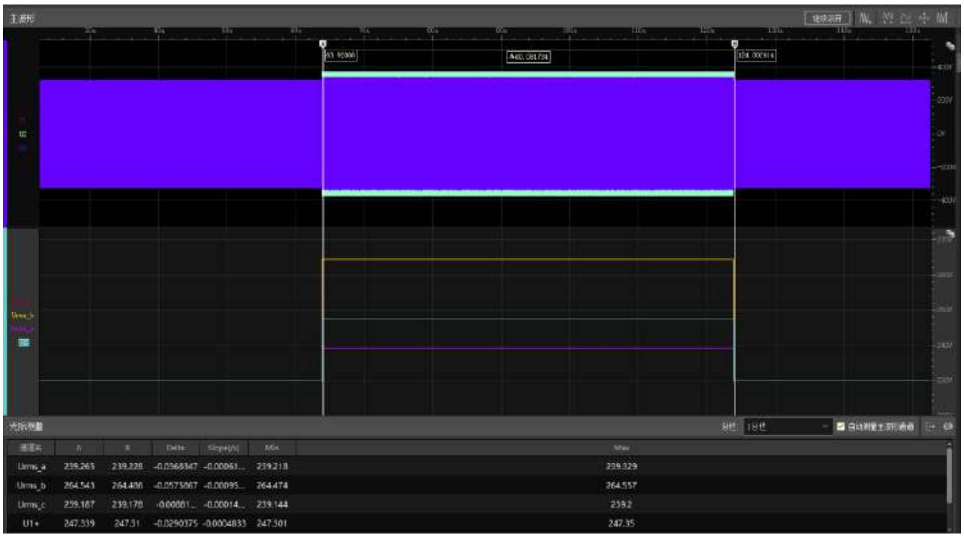


During dip (t1+100ms)

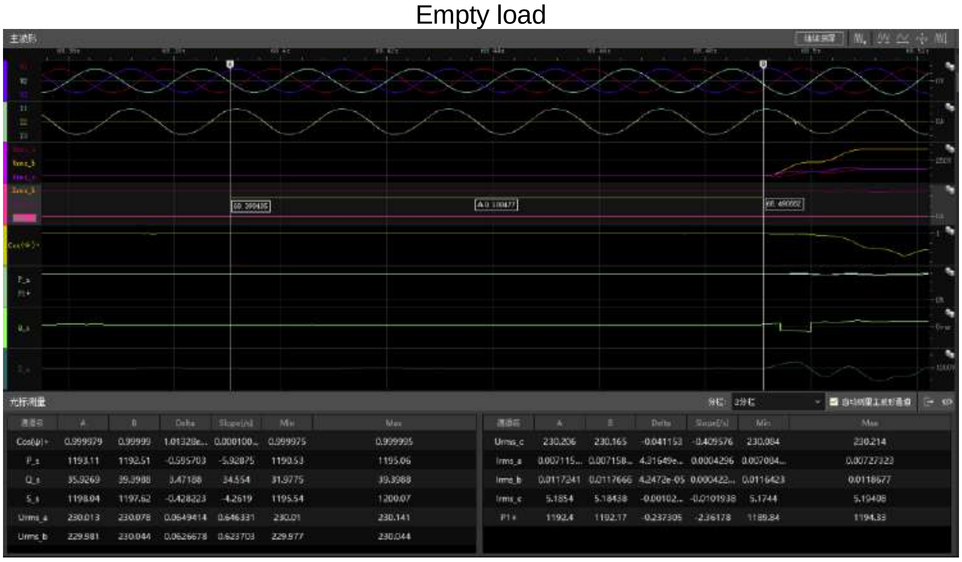


After dip (t2+3s)

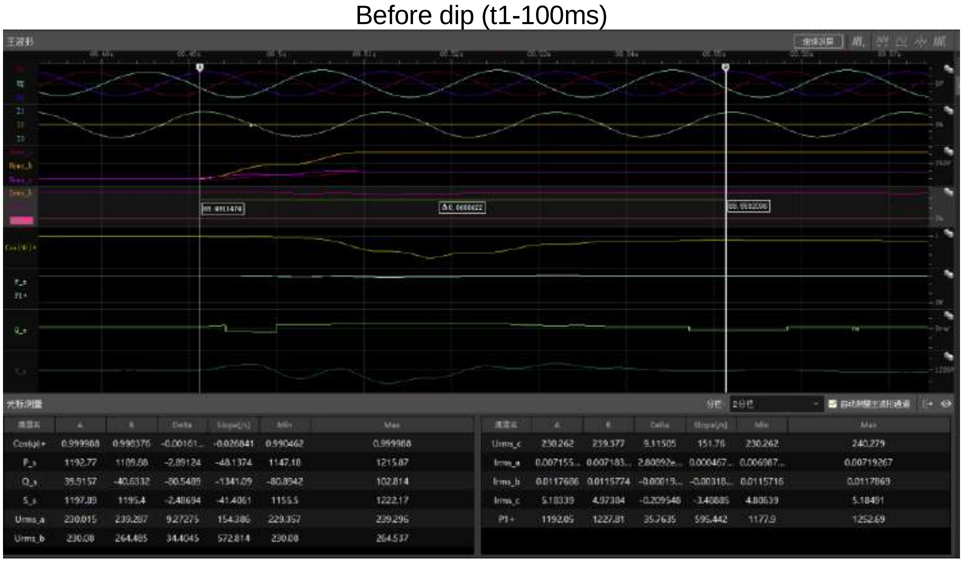
Graph of Test number 7.3



Empty load



Before dip (t1-100ms)



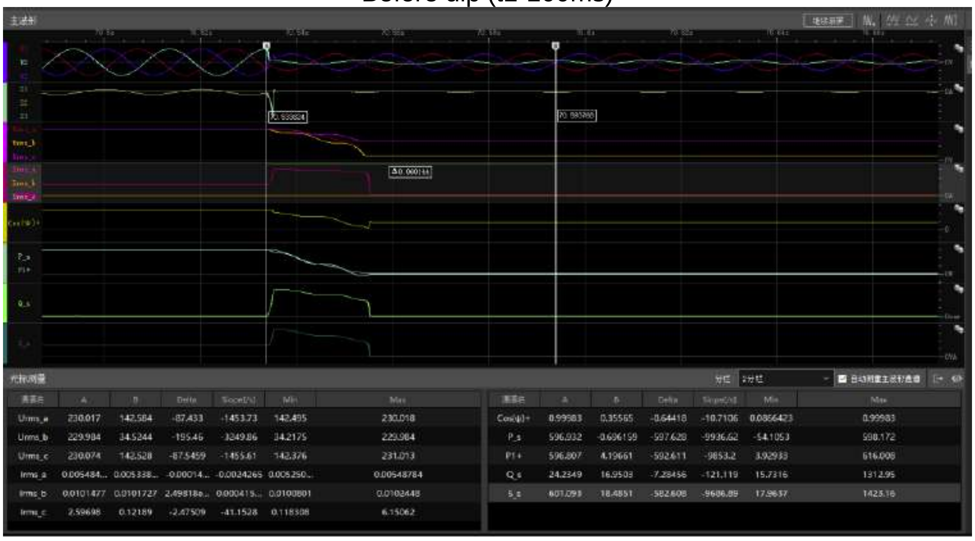
During dip (t1+60ms)

During dip (t1+100ms)

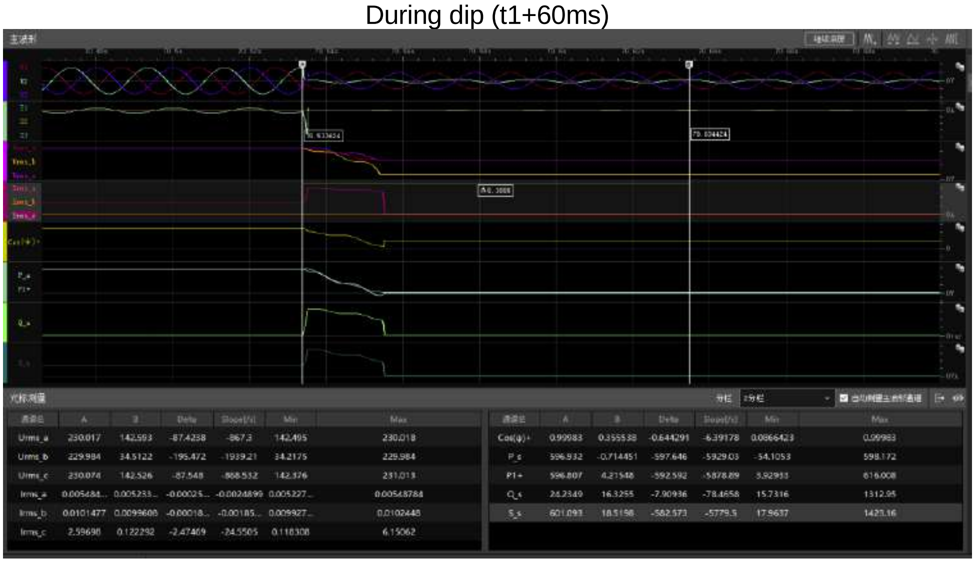
After dip (t2+3s)

Graph of Test number 1.4

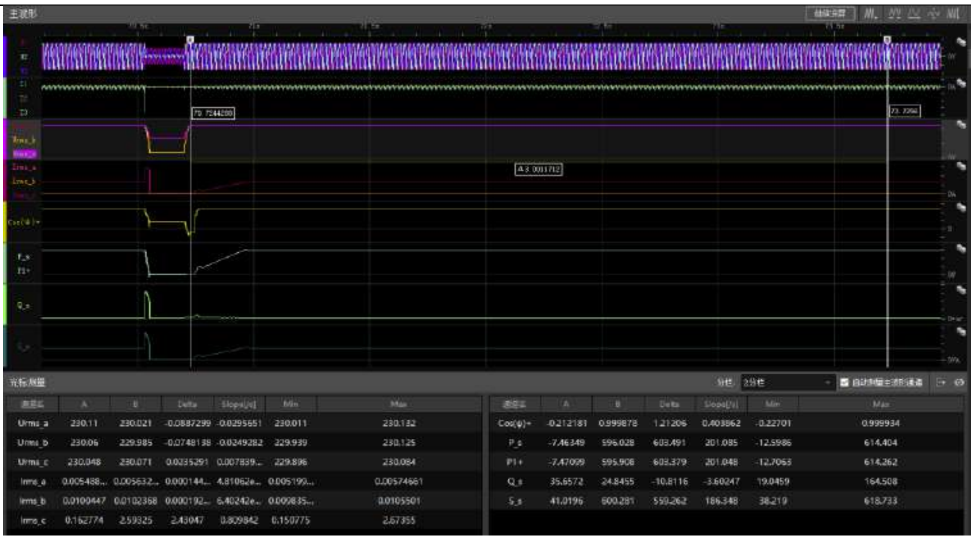
Before dip (t1-100ms)



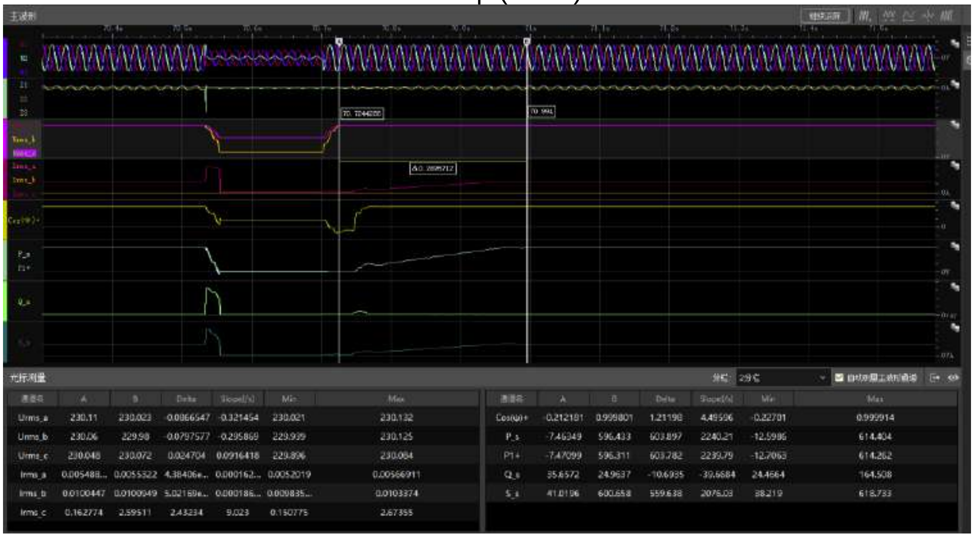
During dip (t1+60ms)



During dip (t1+100ms)



After dip (t2+3s)



Recovery time

Verification of dynamic network support									P
Short-circuited power at generator terminal [VA]			4K						
NS protection settings			See table 5.5 for detail.						
	No.	Parameter	Phase ref.	Time ref.	unit	Result			
General Info.	0	Test number	--	--	--	2.4	3.4	4.4	5.4
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024			
	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	0.50	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	1579.4	1579.4	60080	100.0
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	0.760	0.760	0.930	1.060
	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.	0.511	0.491	0.497	0.498
	14		Positive sequence			--	--	--	--
	15	Reactive power	Total	t1-10s to t1	p.u.	0.332	-0.335	0.021	0.022
	16		Positive sequence			--	--	--	--
	17	Cos_{φ}	--	t1-10s to t1	--	0.8396	0.8293	0.9998	0.9998
During	18	Voltage	Phase 1	t1+100ms	p.u.	--	--	--	--

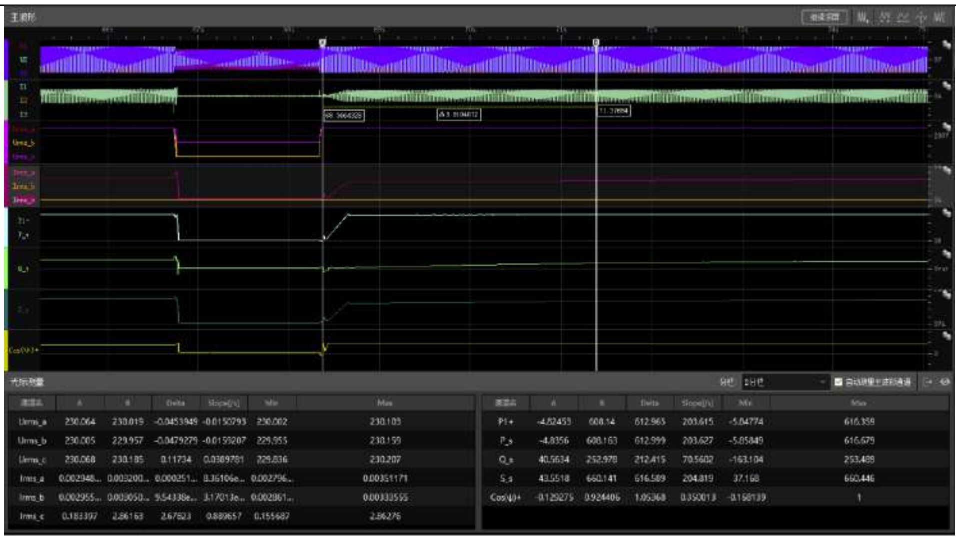
dip t1 to t2			Phase 2	to t2-20ms		--	--	--	--
			Phase 3			0.760	0.760	0.930	1.060
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	--	--
	21		Phase 3			0.028	0.028	0.535	0.468
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	--	--
	24		Phase 3			0.028	0.028	0.537	0.467
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.001	0.001	0.499	0.493
	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			0.511	0.494	0.497	0.449
	39	Active power rising time	Positive sequence	--	s	0.303	0.359	0.011	0.012
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.321	-0.326	0.023	0.022
	33	Reactive power rising time	Positive sequence	--	s	9.567	9.784	0.011	0.010
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

Graph of Test number 2.4

Before dip (t1-100ms)

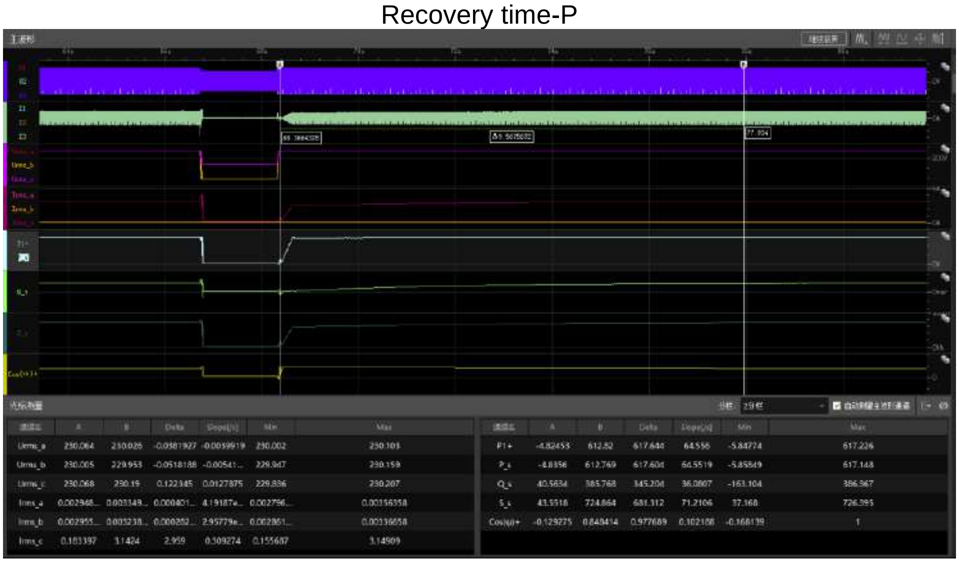
During dip (t1+60ms)

During dip (t1+100ms)



After dip (t2+3s)

Recovery time-P

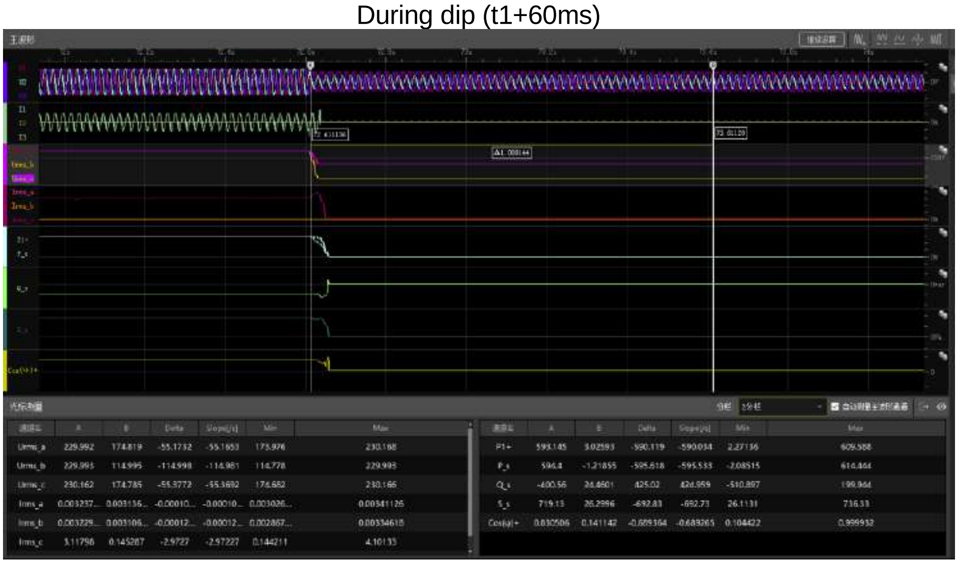


Recovery time-Q

Graph of Test number 3.4

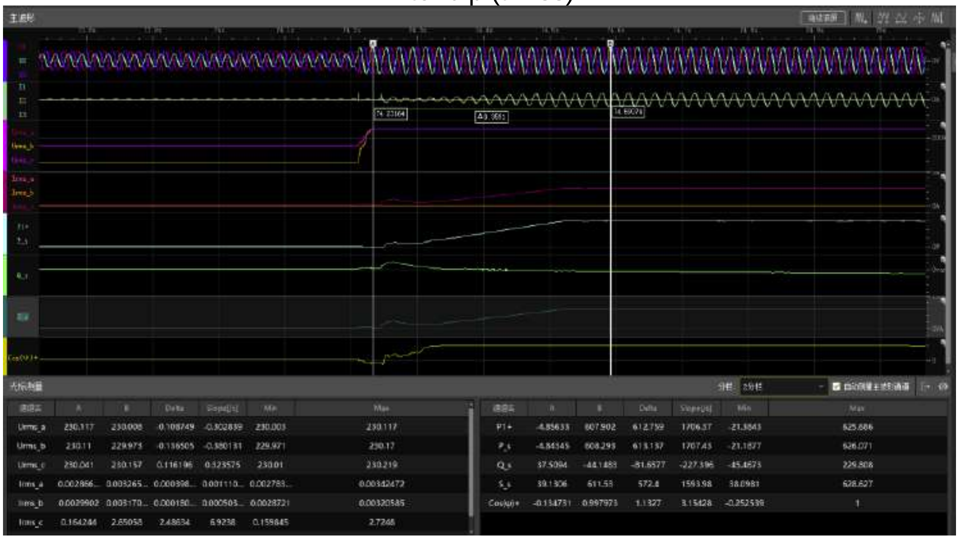
Before dip (t1-100ms)

During dip (t1+60ms)

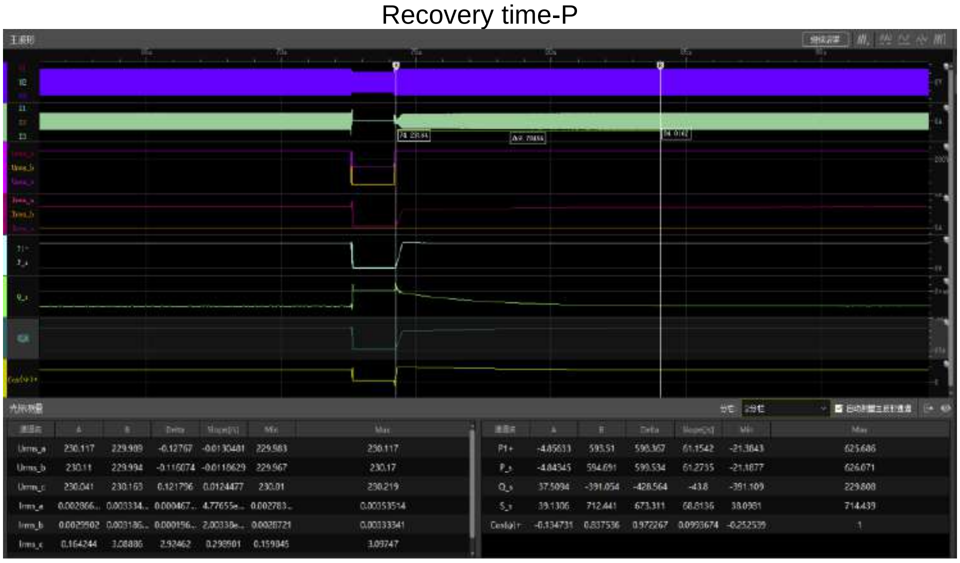


During dip (t1+100ms)

After dip (t2+3s)



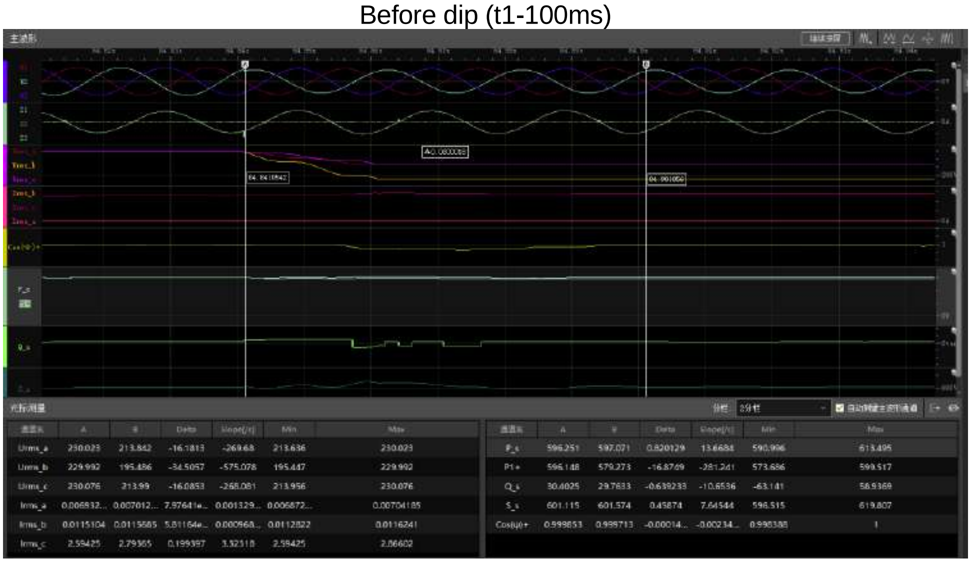
Recovery time-P



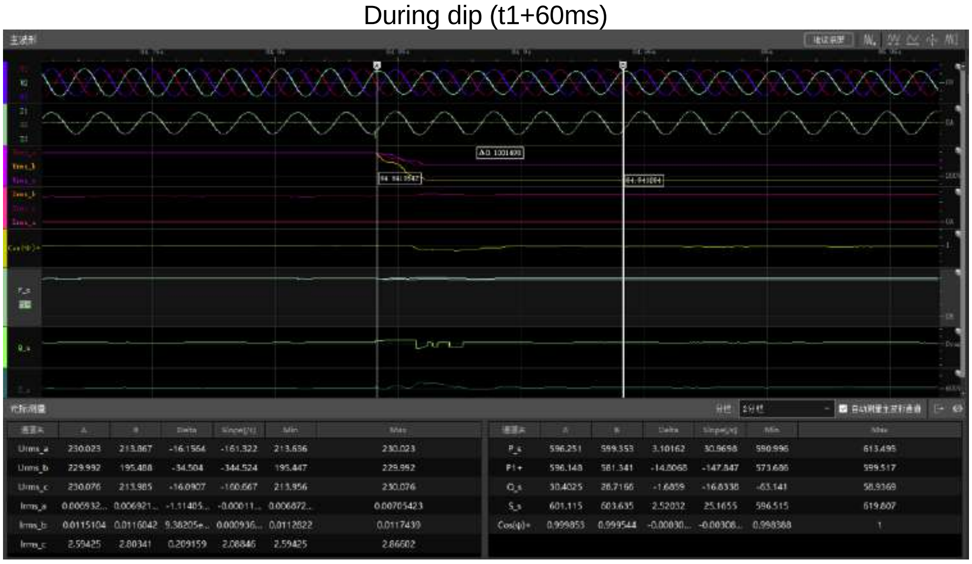
Recovery time-Q

Graph of Test number 4.4

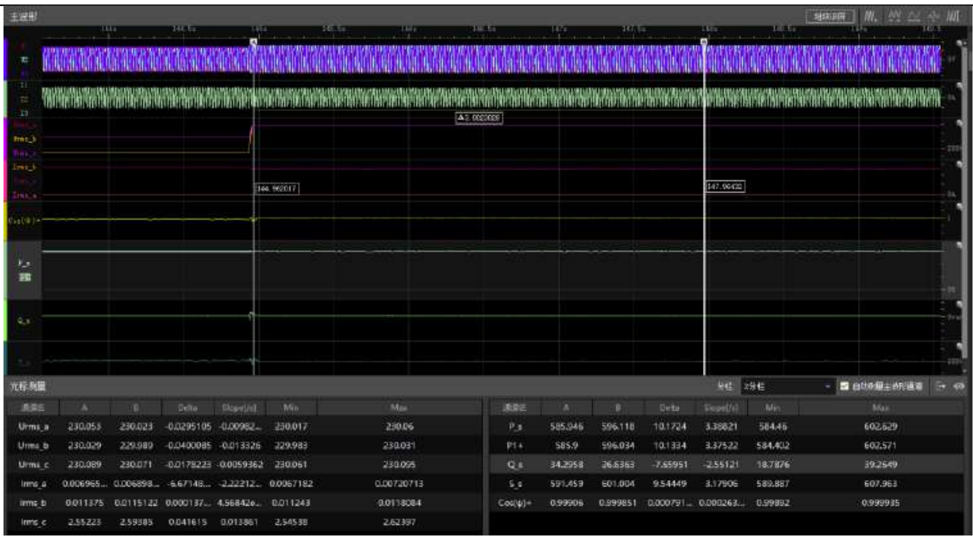
Before dip (t1-100ms)



During dip (t1+60ms)



During dip (t1+100ms)



After dip (t2+3s)

Graph of Test number 5.4

[illegible]	A	B	Delta	Slope(/s)	Min	Max
Urms_a	230.023	230.015	-0.0080719	-0.0805518	230.02	230.026
Urms_b	229.99	229.749	-0.241135	-2.40635	229.94	229.993
Urms_c	230.077	230.216	0.138794	1.38507	230.067	230.109
Irms_a	0.0065633	0.0067159	0.000152...	0.0015228	0.006538...	0.00673657
Irms_b	0.0112743	0.0114907	0.000216...	0.002158...	0.0111076	0.0114903
Irms_c	2.59812	2.59535	-0.00276...	-0.0276255	2.59086	2.60874

[illegible]	A	B	Delta	Slope(/s)	Min	Max
Cos(φ)+	0.999792	0.999886	9.38773e...	0.000936...	0.999791	0.999894
P_s	597.086	596.192	-0.894104	-8.92253	595.532	599.606
P1+	596.97	595.77	-1.19971	-11.9722	595.422	599.497
Q_s	26.3388	37.375	11.0362	110.134	20.9252	30.3094
S_s	601.871	601.676	-0.194702	-1.94299	600.196	604.34

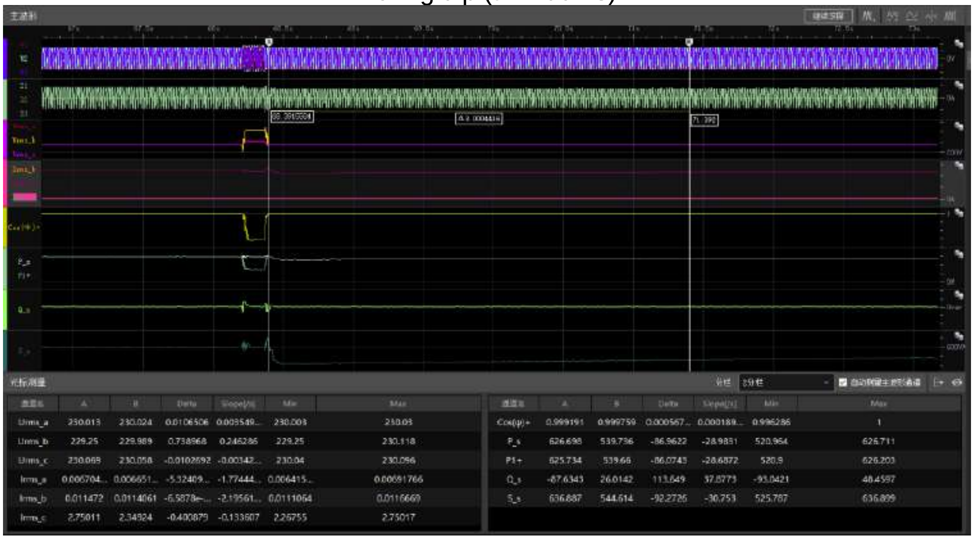
Before dip (t1-100ms)

[illegible]	A	B	Delta	Slope(/s)	Min	Max
Urms_a	230.025	248.494	18.4689	307.546	230.01	249.458
Urms_b	229.989	287.521	57.5312	958.016	199.521	287.577
Urms_c	230.075	243.85	13.7748	229.379	230.075	243.92
Irms_a	0.006711...	0.006642...	-6.83554...	-0.00113...	0.006580...	0.00675766
Irms_b	0.0114861	0.0113178	-0.00016...	-0.00280...	0.0112062	0.0115455
Irms_c	2.60335	2.44279	-0.160543	-2.67338	2.37365	2.62068

[illegible]	A	B	Delta	Slope(/s)	Min	Max
Cos(φ)+	0.999857	0.870439	-0.129418	-2.15508	0.869642	1
P_s	598.428	594.643	-3.78491	-63.0268	559.671	614.996
P1+	598.315	299.509	-298.807	-4975.76	298.496	598.315
Q_s	22.7619	38.7417	15.9798	266.098	-125.604	152.274
S_s	603.147	600.578	-2.56866	-42.7737	582.422	625.576

During dip (t1+60ms)

During dip (t1+100ms)

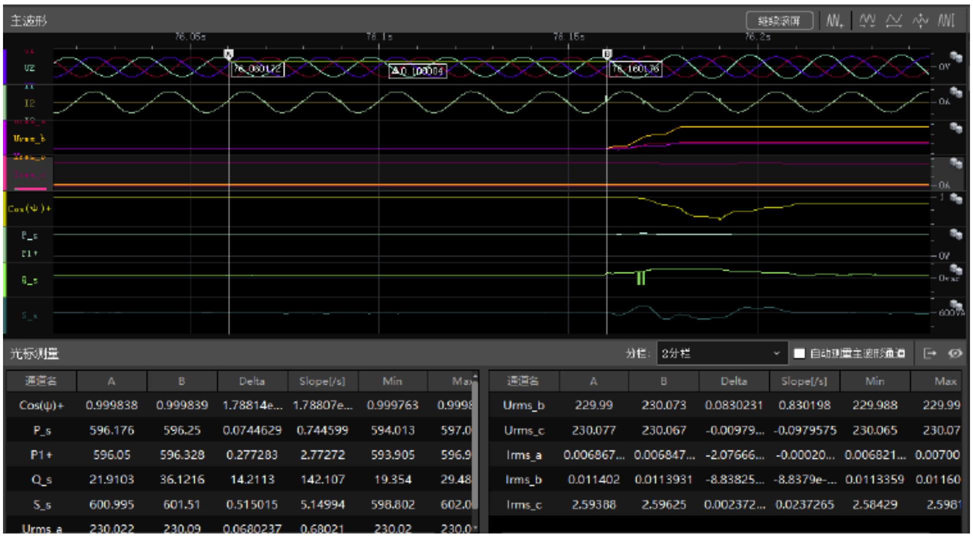


After dip (t2+3s)

Verification of dynamic network support										P
Short-circuited power at generator terminal [VA]			4K							
NS protection settings			See table 5.5 for detail.							
	No.	Parameter	Phase ref.	Time ref.	unit	Result				
General Info.	0	Test number	--	--	--	6.4	7.4	1.5	5.5	
	1	Date	--	--	dd.mm.yyyy	15-Apr-2024 to 10-May-2024				
	2	Time (start of test)	--	--	hh:mm:ss.f	See graph				
	3	Fault type (phase)	--	--		D1	D1	D2	D2	
	4	Setting voltage depth	Line to line	--	p.u.	1.20	1.15	0.15	1.25	
	5	Setting dip duration		--	ms	5000	60000	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	5079.1	60081	150.0	100.0	
	9	Voltage depth/height in empty load test	Total	t1+100ms to t2 and t1-10s to t1	p.u.	1.050	1.040	0.15	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.	0.497	0.495	0.994	1.002	
	14		Positive sequence			--	--	--	--	
	15	Reactive power	Total	t1-10s to t1	p.u.	0.018	0.021	0.032	0.030	
	16		Positive sequence			--	--	--	--	
	17	Cos_{φ}	--	t1-10s to t1	--	0.9998	0.9998	0.9999	0.9999	
During	18	Voltage	Phase 1	t1+100ms	p.u.	--	--	--	--	

dip t1 to t2			Phase 2	to t2-20ms		--	--	0.150	1.250
			Phase 3			1.050	1.040	--	--
	19	Line current	Phase 1	t1+60ms	p.u.	--	--	--	--
	20		Phase 2			--	--	0.023	0.034
	21		Phase 3			0.475	0.478	--	--
	22	Line current	Phase 1	t1+100ms	p.u.	--	--	--	--
	23		Phase 2			--	--	0.024	0.034
	24		Phase 3			0.472	0.478	--	--
	25	Active power	Total	t1+100ms to t2-20ms	p.u.	0.494	0.497	0.001	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			0.479	0.494	0.994	1.001
	39	Active power rising time	Positive sequence	--	s	0.011	0.012	0.620	0.569
	31	Reactive power	Positive sequence	t2+3s to t2+10s	p.u.	--	--	--	--
	32		Total			0.022	0.020	0.031	0.030
	33	Reactive power rising time	Positive sequence	--	s	0.008	0.009	0.011	0.009
	34	PGU does not disconnect from grid till 60s after fault	--	t2 to t2+60s	Yes / No	Yes			

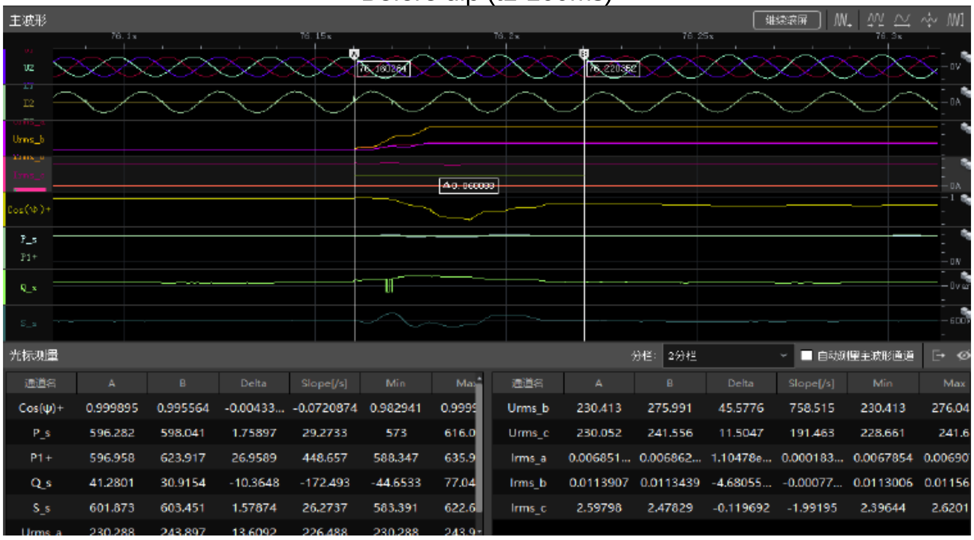
Graph of Test number 6.4



通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	0.999838	0.999839	1.78814e...	1.78807e...	0.999763	0.9998
P_s	596.176	596.25	0.0744629	0.744599	594.013	597.0
P1+	596.05	596.328	0.277283	2.77272	593.905	596.9
Q_s	21.9103	36.1216	14.2113	142.107	19.354	29.48
S_s	600.995	601.51	0.515015	5.14994	598.802	602.0
Urms_a	230.022	230.09	0.0680237	0.68021	230.02	230.0

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	229.99	230.073	0.0830231	0.830198	229.988	229.99
Urms_c	230.077	230.067	-0.00979...	-0.0979575	230.065	230.07
Irms_a	0.006867...	0.006847...	-2.07666...	-0.00020...	0.006821...	0.00700
Irms_b	0.011402	0.0113931	-8.83825...	-8.8379e-...	0.0113359	0.01160
Irms_c	2.59388	2.59625	0.002372...	0.0237265	2.58429	2.5981

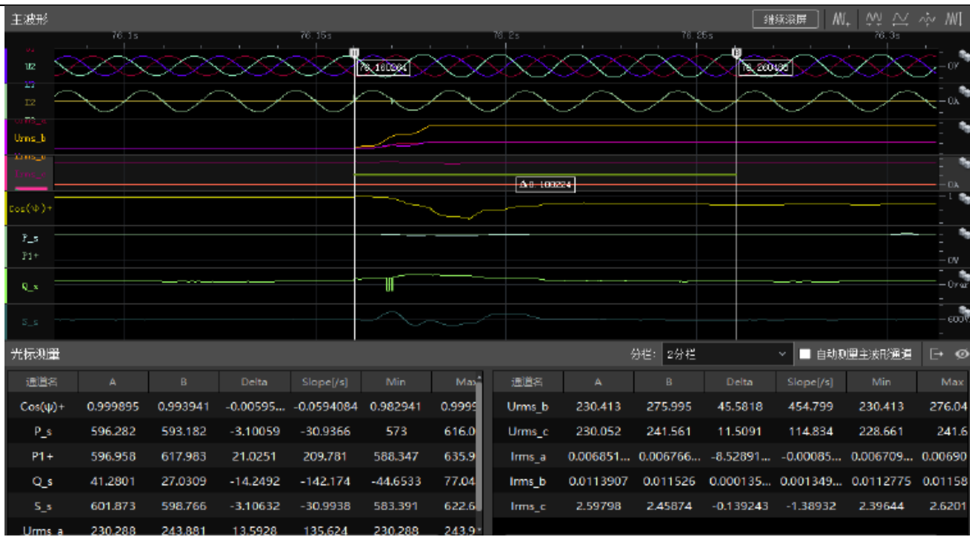
Before dip (t1-100ms)



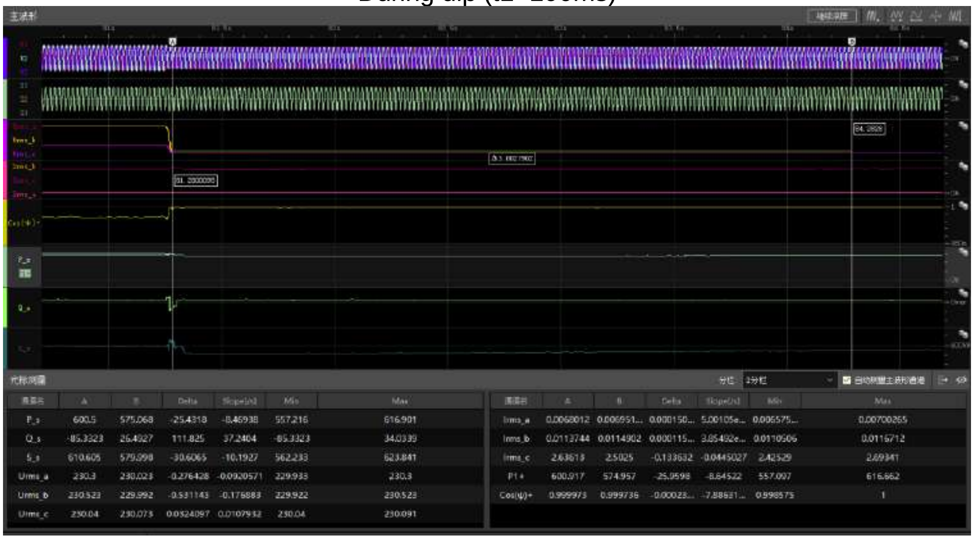
通道名	A	B	Delta	Slope[/s]	Min	Max
Cos(ψ)+	0.999895	0.995564	-0.00433...	-0.0720874	0.982941	0.9999
P_s	596.282	598.041	1.75897	29.2733	573	616.0
P1+	596.958	623.917	26.9589	448.657	588.347	635.9
Q_s	41.2801	30.9154	-10.3648	-172.493	-44.6533	77.04
S_s	601.873	603.451	1.57874	26.2737	583.391	622.6
Urms_a	230.288	243.897	13.6092	226.488	230.288	243.9

通道名	A	B	Delta	Slope[/s]	Min	Max
Urms_b	230.413	275.991	45.5776	758.515	230.413	276.04
Urms_c	230.052	241.556	11.5047	191.463	228.661	241.6
Irms_a	0.006851...	0.006862...	1.10478e...	0.000183...	0.0067854	0.00690
Irms_b	0.0113907	0.0113439	-4.68055...	-0.00077...	0.0113006	0.01156
Irms_c	2.59798	2.47829	-0.119692	-1.99195	2.39644	2.6201

During dip (t1+60ms)



During dip (t1+100ms)

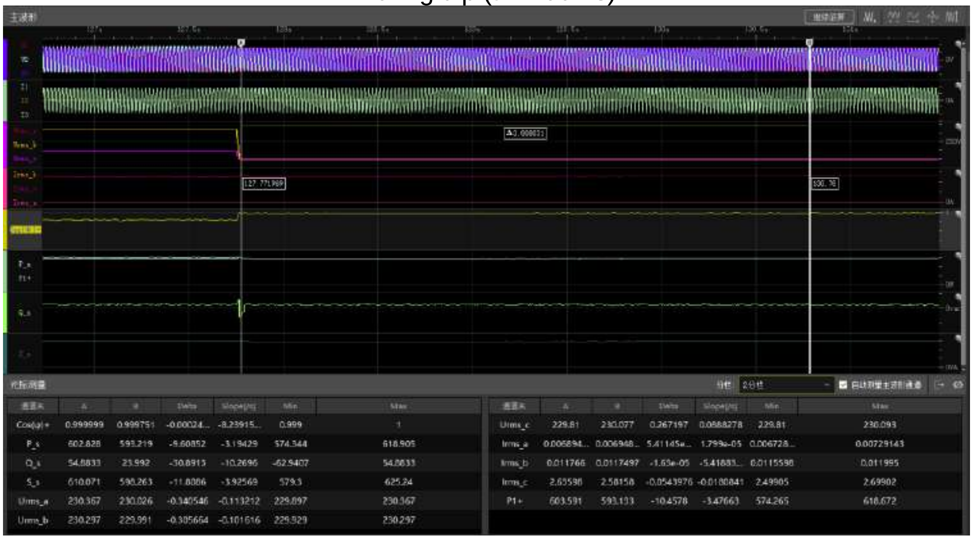

After dip (t2+3s)

Graph of Test number 7.4

Before dip (t1-100ms)

During dip (t1+60ms)

During dip (t1+100ms)



After dip (t2+3s)

Graph of Test number 1.5

光标测量

测量名	A	B	Delta	Slope(/s)	Min	Max
Urms_a	34.0927	34.3536	0.260929	1.73949	34.0915	34.3538
Urms_b	35.5125	35.1018	-0.410686	-2.73786	34.2024	35.5125
Urms_c	35.4394	35.0373	-0.402107	-2.68066	34.1047	35.4394
U1+	34.608	34.6456	0.03759	0.250595	34.1305	34.608
Urms_a_pu	0.148229	0.149363	0.001134...	0.007562...	0.148224	0.149364

Empty Load

光标测量

测量名	A	B	Delta	Slope(/s)	Min	Max
Urms_a	230.007	230.006	-0.00064...	-0.00639...	230	230.009
Urms_b	230.331	230.338	0.006576...	0.065642	230.326	230.338
Urms_c	229.918	229.92	0.001892...	0.0188854	229.913	229.92
Irms_a	0.007247...	0.007218...	-2.87578...	-0.00028...	0.007072...	0.00731383
Irms_b	5.18053	5.19764	0.017107	0.170749	5.17753	5.19704
Irms_c	0.005791...	0.005750...	-4.13163...	-0.00041...	0.005670...	0.00589445

测量名	A	B	Delta	Slope(/s)	Min	Max
P_s	1192.54	1196.54	4.00049	39.9298	1191.8	1196.39
Q_s	38.2548	38.1227	-0.132175	-1.31927	37.161	44.1973
S_s	1196.24	1200.2	3.9585	39.5107	1195.54	1200.05
Cos(φ)+	0.999982	0.999983	1.07288e...	1.07087e...	0.999971	0.99999
P1+	1191.3	1195.27	3.97473	39.6727	1190.55	1195.13

Before dip (t1-100ms)

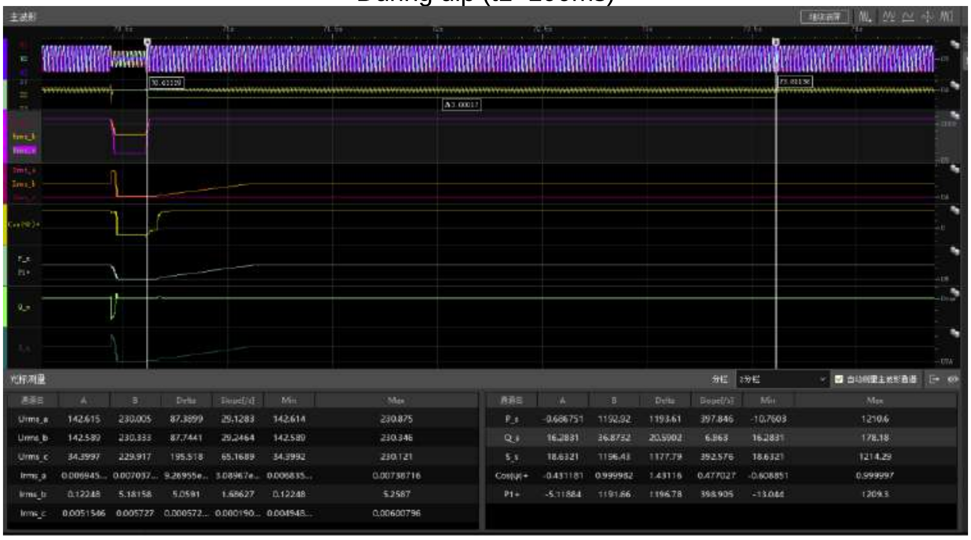
光标测量

测量名	A	B	Delta	Slope(/s)	Min	Max
Urms_a	230.006	142.621	-87.3849	-1455.68	141.268	230.007
Urms_b	230.335	142.571	-87.7637	-1461.99	142.198	230.338
Urms_c	229.919	34.3856	-195.534	-3257.24	34.0309	229.92
Irms_a	0.007225...	0.007072...	-0.00015...	-0.00253...	0.006907...	0.00727682
Irms_b	5.19638	0.12143	-5.07495	-84.5397	0.119725	10.486
Irms_c	0.005749...	0.005101...	-0.00064...	-0.0107976	0.005092...	0.00587067

测量名	A	B	Delta	Slope(/s)	Min	Max
P_s	1196.23	-0.741376	-1196.97	-19939.4	-1.19053	1200.6
Q_s	38.2492	16.113	-22.1362	-368.75	-1928.87	482.23
S_s	1199.89	18.4965	-1181.4	-19680	18.238	2213.77
Cos(φ)+	0.999983	-0.43412	-1.4341	-23.8896	-0.462768	1
P1+	1194.97	-5.11823	-1200.09	-19991.4	-5.23286	1207.88

During dip (t1+60ms)

During dip (t1+100ms)



After dip (t2+3s)

Recovery time

Graph of Test number 5.5

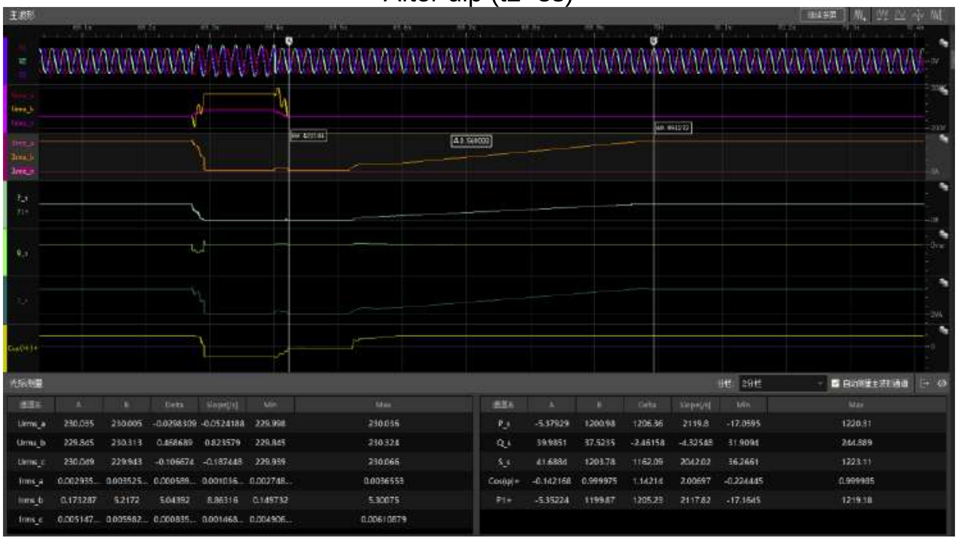
Empty Load

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: (Hersteller)	ZENDURE TECHNOLOGY CO., LIMITED. RM 517, NEW CITY ENTRE, 2 LEI YUE MUN ROAD, KWUN TONG, KOWLOON, HK, CHINA
Type of NS Protection: (Typ NA-Schutz)	**Integrierter NA-Schutz**
Software Version:	V2
Measurement Period: (Messzeitraum)	26 Apr 2024 – 20 May 2024

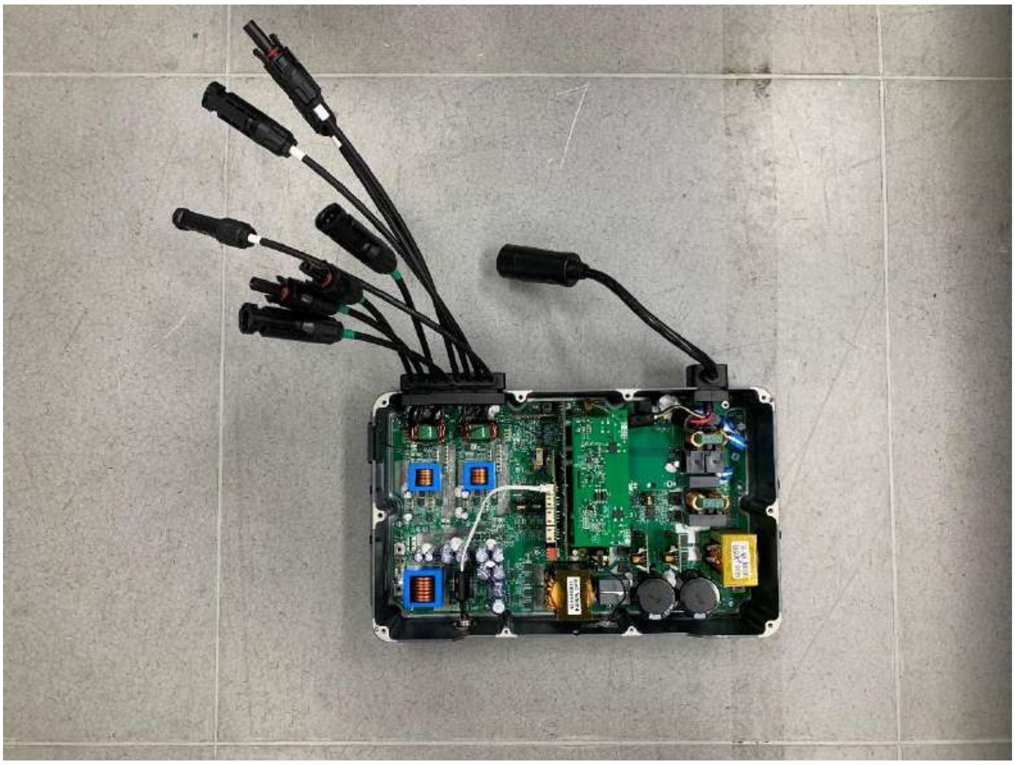
	Stirling generators, fuel cells (Stirlinggeneratoren, Brennstoffzellen)			Inverter(s) (Umrichter)		
	Synchronous and asynchronous generators with *P*n ≤ 50 kW coupled directly or via inverters (direkt oder über Umrichter gekoppelte Synchron- und Asynchrongeneratoren mit Pn ≤ 50 kW)			Directly coupled synchronous and asynchronous generators with *P*n > 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	1.251* Un	142.0ms
Rise-in-voltage protection (Spannungssteigerungsschutz) *U* >	--	--	--	1,10 * Un	1.101* Un	485.2s
Voltage drop protection (Spannungsrückgangsschutz) *U* <	--	--	--	0,8 * Un	0.801* Un	3.05s
Voltage drop protection (Spannungsrückgangsschutz) *U* <<	--			0,45* Un	0.452* Un	341.0ms
Frequency decrease protection (Frequenzrückgangsschutz) *f* <	--	--	--	47,5 Hz	47.48Hz	196ms
Frequency increase protection (Frequenzsteigerungsschutz) *f* >	--	--	--	51,5 Hz	51.50Hz	173ms

* 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	ZDHYP2000
Type integrated interface switch Typ integrierter Kuppelschalter	SONG CHUAN PRECISION CO., LTD. 215H-1AH-F-C.
Response time of interface switch for integrated NS protection Eigenzeit des Kuppelschalters bei integriertem NA-Schutz	15ms
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.	

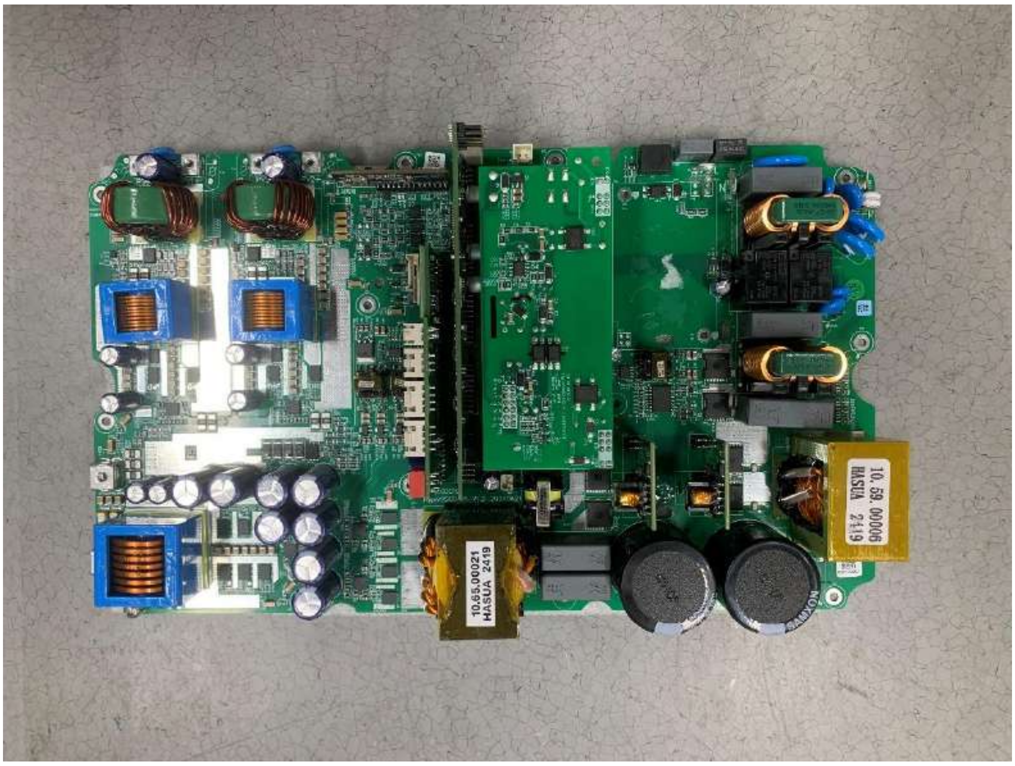
Appendix 1: photos

Overview

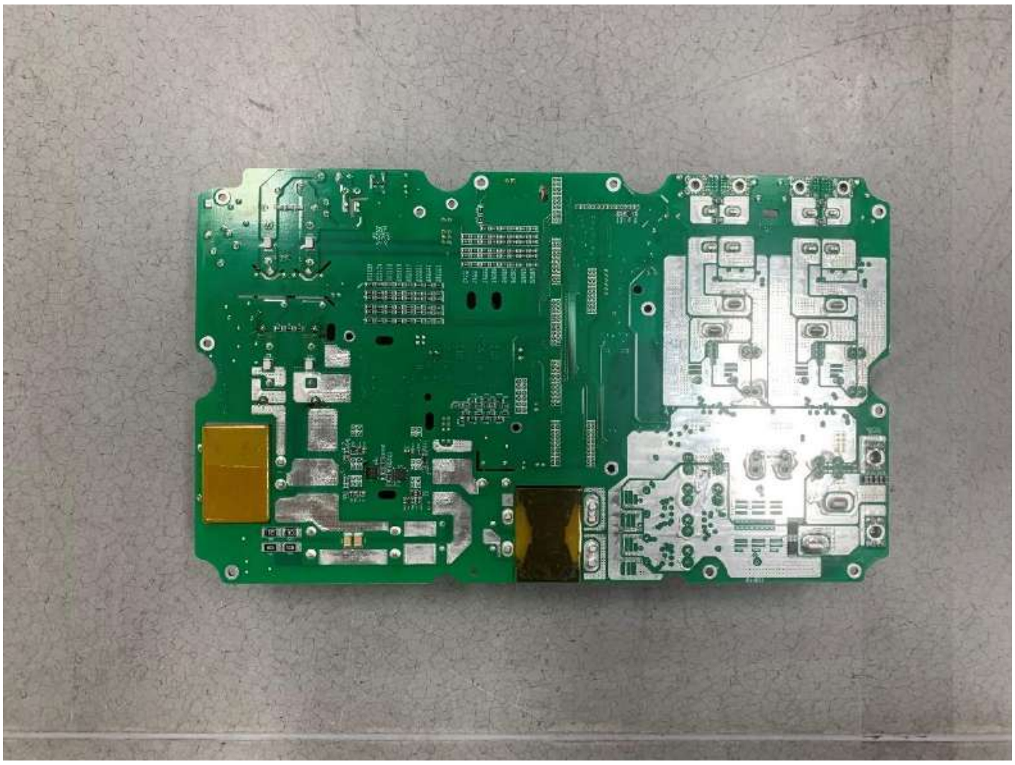
Bottom view



Internal view



Power board view (Components side)



Power board view (Soldered side)

Appendix 2: Equipment

Asset	Description	Manufacturer	Model	Cal Date	Cal Due
SA200-16	Precision Power Analyzer	YOKOGAWA	WT3000	21 Aug 2023	20 Aug 2024
SA200-02	RLC load	Qunling	ACLT-4830H	/	/
SA200-52	AC power source	Chroma	61860	/	/
SA050-33	Scope Corder	YOKOGAWA	DL 850E	05 Jan 2024	04 Jan 2025

(End of Report)