DEKRA

TEST REPORT
VDE-AR-N 4105
Generators connected to the low-voltage distribution network — Technical requirements for the connection to and parallel operation with low-voltage distribution networks

Report Number. .... :	6052106.54
Date of issue.................................. :	2019-12-20
Total number of pages .... :	172 pages
Testing Laboratory .... :	
Address .... :	DEKRA Testing and Certification (Suzhou) Co., Ltd.
Applicant's name .... :	EAST Group Co., Ltd.
Address .... :	No.6 Northern Industry Road, Songshan Lake Sci. & Tech. Industrial Park, Dongguan City, Guangdong Province, China
Test specification:	
Standard.. :	VDE-AR-N 4105:2018-11
Test procedure .... :	Type test
Non-standard test method…………..:	N/A
Test Report Form No. .... :	VDE-AR-N 4105_V2.0
Test Report Form(s) Originator .... :	DEKRA Testing and Certification (Suzhou) Ltd.
Master TRF .... :	Dated 2019-09
Test item description....................... :	Grid-connected PV Inverter
Trade Mark .... :	EAST
Manufacturer .... :	EAST Group Co., Ltd. No.6 Northern Industry Road, Songshan Lake Sci. & Tech. Industrial Park, Dongguan City, Guangdong Province, China
Model/Type reference .... :	EA5KTSI, EA6KTSI, EA8KTSI, EA10KTSI, EA13KTSI, EA16KTSI

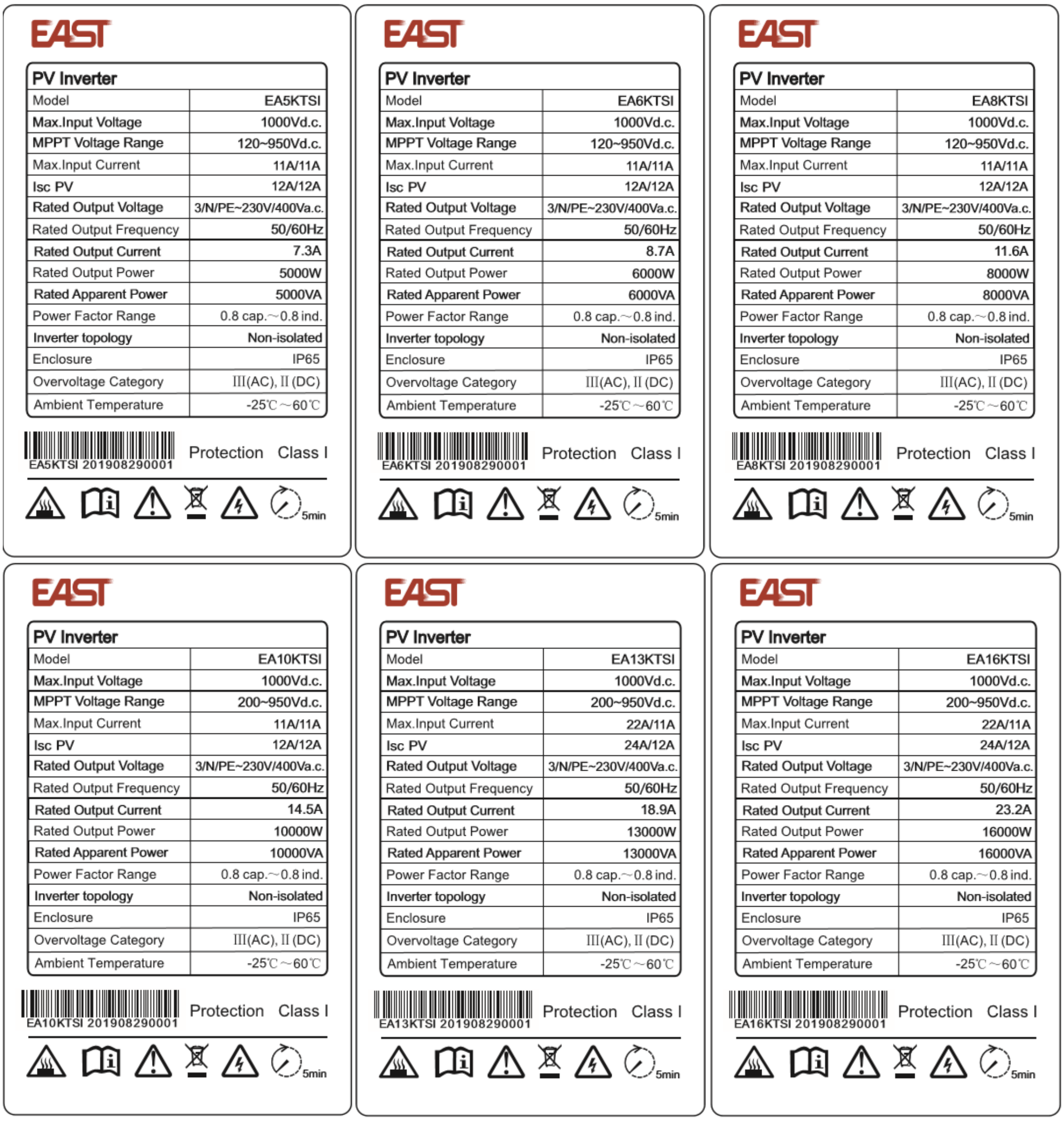
Ratings……………………………..:	EA5KTSI: PV input: Max. 1000 Vdc, MPPT voltage range: 120-950 Vdc, max 11A /11 A, Isc PV: 12 A/12 A Output: 230/400 Vac, 3/N/PE, 50/60 Hz, 5000 VA, max 7.3 A EA6KTSI: PV input: Max. 1000 Vdc, MPPT voltage range: 120-950 Vdc, max 11 A/11 A, Isc PV: 12 A/12 A Output: 230/400 Vac, 3/N/PE, 50/60 Hz, 6000 VA, max 8.7 A EA8KTSI: PV input: Max. 1000 Vdc, MPPT voltage range: 120-950 Vdc, max 11 A/11 A, Isc PV: 12 A/12 A Output: 230/400 Vac, 3/N/PE, 50/60 Hz, 8000 VA, max 11.6 A EA10KTSI: PV input: Max. 1000 Vdc, MPPT voltage range: 200-950 Vdc, max 11 A/11 A, Isc PV: 12 A/12 A Output: 230/400 Vac, 3/N/PE, 50/60 Hz, 10000 VA, max 14.5 A EA13KTSI: PV input: Max. 1000 Vdc, MPPT voltage range: 200-950 Vdc, max 22 A/11 A, Isc PV: 24 A/12 A Output: 230/400 Vac, 3/N/PE, 50/60 Hz, 13000 VA, max 18.9 A EA16KTSI: PV input: Max. 1000 Vdc, MPPT voltage range: 200-950 Vdc, max 22 A/11 A, Isc PV: 24 A/12 A Output: 230/400 Vac, 3/N/PE, 50/60 Hz, 16000 VA, max 23.2 A

Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):		
☒ Testing Laboratory:	DEKRA Testing and Certification (Suzhou) Co., Ltd.	
Testing location/ address .... :	No. 99, Hongye Road, Suzhou Industrial Park Suzhou, 215006, P.R. China	
☐ ~~Associated Testing Laboratory:~~		
~~Testing location/ address .... :~~		
Tested by (name, function, signature) .... :	Hua Yu	
Approved by (name, function, signature) .... :	Jason Guo	
☐ ~~Testing procedure: TMP/CTF Stage 1:~~		
~~Testing location/ address .... :~~		
~~Tested by (name, function, signature) .... :~~		
~~Approved by (name, function, signature) .... :~~		
☐ ~~Testing procedure: WMT/CTF Stage 2:~~		
~~Testing location/ address .... :~~		
~~Tested by (name + signature) .... :~~		
~~Witnessed by (name, function, signature)...... :~~		
~~Approved by (name, function, signature) .... :~~		
☐ ~~Testing procedure: SMT/CTF Stage 3 or 4:~~		
~~Testing location/ address .... :~~		
~~Tested by (name, function, signature) .... :~~		
~~Witnessed by (name, function, signature)...... :~~		
~~Approved by (name, function, signature) .... :~~		
~~Supervised by (name, function, signature)..... :~~		

Copy of marking plate:

"The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective NCB' s that own these marks"

Rating label



Remark:

According to customer's requirement and Germany low-voltage distribution networks code, these models were only evaluated under the grid frequency of 50 Hz.

Test item particulars .... :	Grid-connected PV Inverter
Class of equipment .... :	Class I
Connection to the mains .... :	Permanent connection
IP protection class .... :	IP65
Possible test case verdicts:	
- test case does not apply to the test object ....:	N/A
- test object does meet the requirement.....................:	P (Pass)
- test object does not meet the requirement ....:	F (Fail)
- this clause is information reference for installation...:	Info.
Testing...:	
Date of receipt of test item(s) ....:	2019-09-04 (samples provided by applicant)
Dates tests performed...:	2019-09-04 to 2019-12-10

General remarks:

The test results presented in this report relate only to the object tested.
This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
The measurement result is considered in conformance with the requirement if it is within the prescribed limit, It is not necessary to account the uncertainty associated with the measurement result.
This report is only for reference and is not used for legal proof function in China market.
The information provided by the customer in this report may affect the validity of the results, the test lab is not responsible for it.

"(See Enclosure #)" refers to additional information appended to the report.
"(See appended table)" refers to a table appended to the report. The table clause no. including one standard VDE-AR-N 4105:2018-11.
In case of doubt the German version standard will be valid.
Throughout this report a ☐comma / ☒ point is used as the decimal separator.
The following suffixes are used for variables in tables and figures:

- "P_N" for the nominal active power.
  $P_n = U_n \times I_n \times \cos \varphi_n$ (single-Phase); $P_n = \sqrt{3}\, U_n \times I_n \times \cos \varphi_n$ (three-Phase).
- "_E0,2" for gliding average values over 200 milliseconds.
- "_E60" for gliding average values over 60 seconds.
- "_E600" for gliding average values over 10 minutes.
- "(c)" for over-excited.
- "(i)" for under-excited.
- If the inverter consumes inductive reactive power the reactive power is marked "inductive" or has a positive sign.
- If the inverter consumes capacitive reactive power the reactive power is marked "capacitive" or has a negative sign.

Acronyms:

PGUs: power generating units.
PGSs: power generating systems.

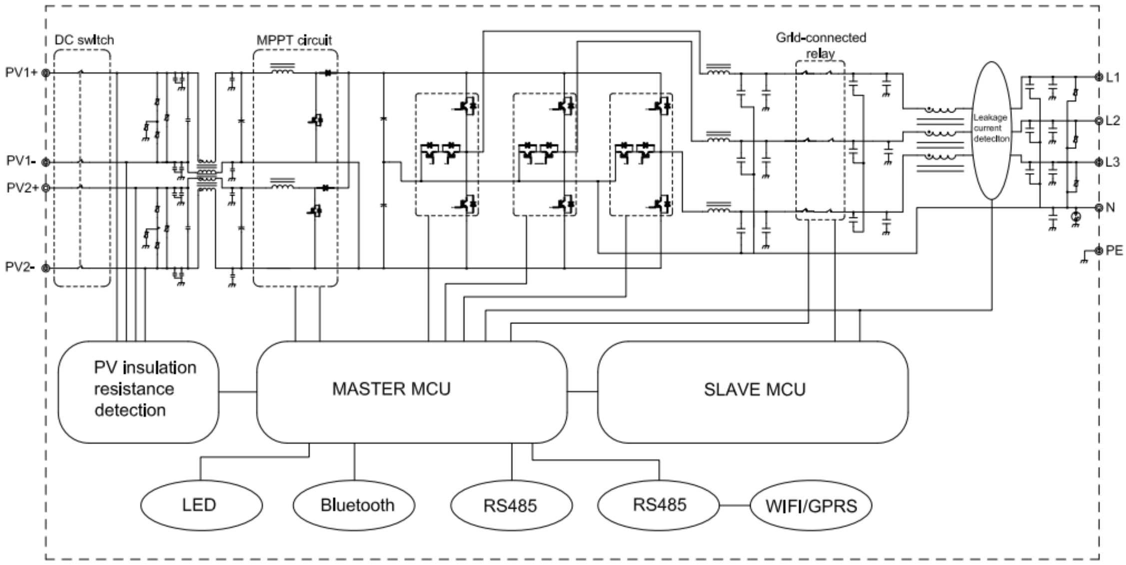
General product information:

The products are grid-connected photovoltaic inverter converts DC voltage into AC voltage, the unit is providing EMC filtering at the input and output towards mains.

The output was switched off redundant by the high power switching bridge and relay in series. This designation assures that the disconnection of the output circuit from the grid will also operate in case of one error.

The internal control is redundant built. It consists of two Microcontrollers (master DSP U1, slave DSP U22). The master DSP can control the relays; detect the PV voltage, PV current and BUS voltage, measures grid voltage, frequency, AC current with injected DC, insulation resistance to ground and residual current. The slave CPU (U22) were also detected grid voltage, injected DC current and residual current. Both microcontrollers communicate with each other. Any abnormal of those electrical parameter will trigger the disconnection of the inverter from the grid.

Block Diagram:



Model difference:

1) The model EA5KTSI is identical with EA6KTSI; EA8KTSI is identical with EA10KTSI; EA13KTSI is identical with EA16KTSI in hardware and just power derating according to setting variations parameter in software.
2) The models EA5KTSI, EA6KTSI, EA8KTSI, EA10KTSI and EA13KTSI are identical with EA16KTSI in topological schematic circuit diagram of hardware except for the bus capacitors number (EA5KTSI and EA6KTSI with 2 bus capacitors, EA8KTSI and EA10KTSI with 4 bus capacitors, EA13KTSI and EA16KTSI with 6 bus capacitors); boost current sensor rating; inductive reactance of INV inductors and Boost inductors; Boost diode rating; Internal fan (Only model EA13KTSI and EA16KTSI designed with internal fan); the type designation and the input/output electrical rating.

The product was tested on:

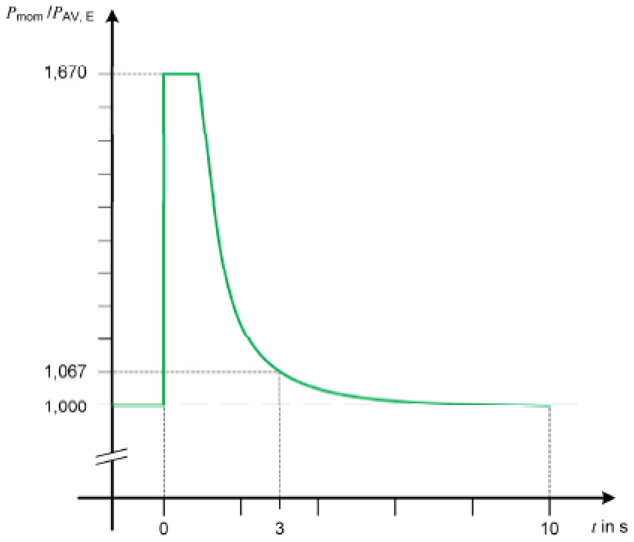
Hardware version: 00C
Software version: HornetV008
Unless otherwise specified, all the tests were performed on model EA16KTSI and also applicable for all other models stated in this report. According to the user manual and testing, the product was evaluated for maximum ambient temperature of 60°C and will derating the output power above 45°C.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
5	Network connection		P
5.1	Principles for determination of the network connection point		Info.
	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		Info.
	As a rule, power generation systems and storage units are connected to the supply point of or within the consumption system.		Info.
	Multiple connections within one building are permissible only if the connection and operation of the power generation system or storage unit cannot be ensured by means of a network connection. Deviations from this principle shall be agreed with the network operator. It shall be ensured that the power generation system or storage unit is clearly separated electrically from any other power consuming equipment of the customer. Each of the two supply points shall be labelled with an indication of the location of the other supply point. Each separate supply point for the power generation system or of a storage unit shall be permanently labelled with “Sectioning point: power generation system – supply network” or “Sectioning point: storage unit – supply network” by the connection owner.		Info.
	As a rule, power generation systems and storage units which are installed on different plots with their own respective network connections shall not be connected to the network operator’s network together at the same network connection point. The same applies to power generation systems and storage units which are installed on different buildings each having their own network connection. PV systems installed on a building with continuous roofing (e. g. apartment block or terraced houses) and with several network connections may be connected to the network operator’s network together at the same network connection point (supply point marking as described above).		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For the purpose of evaluating the connectivity with regard to the network interactions, the impedance of the network at the PCC (network short-circuit power, resonances), the maximum apparent connection power as well as the type and operating mode of the power generation system or the storage unit are considered. The evaluation is made assuming the normal switching state and undisturbed operation of the network. If more than one power generation system or storage unit is connected within the same low-voltage network, their total effect shall be considered. For circuit modifications due to maintenance or forced outage reasons, the determined network connection point may require temporary reduction of the output power of the power generation system or the storage unit or the system's/unit's disconnection from the network. For connection examples, see Annex B (Figure B.1 to Figure B.10).		Info.
	For type 1 systems, a specific minimum short-circuit power at the network connection point S_{kV} is required for the purpose of system stability and compliance with the requirements for dynamic network stability and steady-state voltage stability. This minimum short-circuit power shall be verified by the network operator during the connection evaluation of type 1 systems using the following simplified procedure:		Info.
	– the network short-circuit power at the low-voltage busbar of the supplying local network transformer $S_{K\ NS\text{-}SS}$ shall be equal to at least 10 times the total apparent power of all type 1 systems connected to this low-voltage network ($S_{K\ NS\text{-}SS} \geqslant 10 * \Sigma S_{Amax}$) (type 1 systems throughout the NS network of the local network transformer); and		Info.
	– at the network connection point, the network short-circuit power S_{kV} shall be at least equal to 10 times the total apparent power of all type 1 systems to be connected to this network connection point. For this purpose, is shall be noted that the apparent power values of all type 1 systems at this network connection point itself and at the downstream low-voltage network to the standard sectioning point or the line end have to be added.		Info.
	In case of non-compliance with the limit values, the power generation system shall not be connected.		Info.
5.2	Rating of the network equipment		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		P
	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.		P
5.3	Permissible voltage change		P
	For the undisturbed operation of the network, the level of slow voltage change caused by all power generation systems and storage units with a network connection point in a low-voltage network shall at none of the PCCs in this network exceed a value of 3 % as compared with the voltage without power generation systems and storage units: $\Delta u_a \leq 3$ % 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).	(See appended table)	P
	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}.		P
5.4	Network interactions		P
	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.	(See appended table)	P
5.5	Connection criteria		P
5.5.1	General		Info.
	When connecting a power generation system or a storage unit, the technical connection conditions of the network operator shall be observed.		Info.
	Full feed-in		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	In case of a full feed-in into the network of the network operator, the connection line of the power generation system shall be permanently connected to the meter panel; the meter panel shall be designed in accordance with VDE-AR-N 4100 and the TAB of the network operator. For this purpose, supply to the meter panel is always carried out via the connection compartment on the system side.		Info.
	Excess feed-in		Info.
	In case of self-supply with excess feed-in (e. g. according to EEG [2] or KWKG [3]), the connection line of the power generation system can be connected centrally at the meter panel or decentralised in a sub-distribution. The meter panels for generation meters (see Clause 7 and connection examples in Annex B) shall then be designed as follows:		Info.
	a) for a central position, in accordance with VDE-AR-N 4100;		Info.
	b) for a decentralised position beside the power generation system, in accordance with VDE-AR-N 4100 or – in case of KWKG systems – in the small distributor in accordance with DIN EN 60670-24 (VDE 0606-24), also with a top hat rail meter meeting the requirements of § 29 MsbG for a modern measurement device or an intelligent measuring system;		Info.
	c) in case of KWKG systems and when being in a decentralised position in the power generation unit under consideration of the specifications of the chosen meter construction and the product standard of the power generation unit.		Info.
	In case of KWKG systems, the system operators themselves may operate the net current meter, provided they comply with the legal requirements of MsbG for a third party operating a metering point. The net current is derived from the gross current (at the generator terminal) minus the own consumption. Only internal current metering allows the allocation of consumers to the gross or the net current.		Info
	The operation of the net current meter listed under c) may also be realised by a third-party operator of a metering point.		Info.
	Examples of meter panel configurations are shown in Annex C (see Figure C.1 to Figure C.5).		Info.
5.5.2	$P_{AV, E}$ monitoring (feed-in limitation)		P

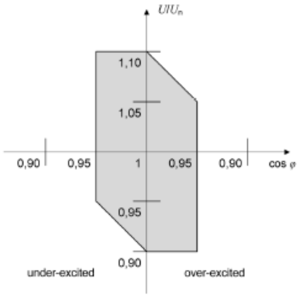
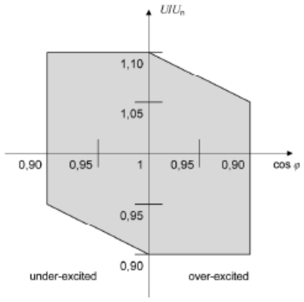
VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	$P_{AV,E}$ monitoring allows a connection power $P_{AV,E}$ deviating from the installed power to be agreed with the network operator and to be set.		P
	The feed-in limit described in this sub-clause shall be measured at the central meter panel in accordance with VDE-AR-N 4100, 7.2.		P
	$P_{AV,E}$ 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 the feed-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.		P
	$P_{AV,E}$ monitoring shall cover all line conductors. The active power fed into the low-voltage network and measured at the central meter panel represents the reference value for the active connection power $P_{AV,E}$ agreed with the network operator. If the r.m.s. value of the active power measured at the central meter panel exceeds the active power $P_{AV,E}$, the active power fed in by the power generation system and/or storage unit shall be reduced. Power generation systems shall not exceed the active power limit curve shown in Figure 1.  **Figure 1 – Active power limit curve for power generation systems**	(See appended table)	P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 1 In its exponential course, the active power limit curve follows the function below: $P_{AV, E}$ (t) = 0,67 × e $^{-1,05 \times (t-0,8)}$ + 1.		P
	Here, the active connection power $P_{AV, E}$, as agreed with the network operator, shall be at least 60 % of the installed active power P_{inst} of all power generation systems operated within the customer installation and all storage units feeding simultaneously into the network of the network operator. Therefore $P_{AV, E} \geq 0,6\ P_{inst}$		P
	Load drop or cloud drift can cause a short-term feed-in of the entire installed active power at the network connection point into the network of the network operator. The surplus power, i. e. the difference between P_{inst} and $_{PAV, E}$, shall be reduced to merely 10 % of the initial value within 3 s according to Figure 1. After a maximum of 10 s, the agreed active connection power $P_{AV, E}$ shall be fully resumed.		P
	Usually, power generation units with a relatively low power gradient such as BHKW, are not able to adjust the exceeding of power limit values according to Figure 1, as may occur during the disconnection of high loads, within the permissible times according to Figure 1. Nevertheless, installation of and operation with a connection power $_{PAV, E}$ deviating from the installed power is possible. For this purpose, the power generation system(s) and the storage units feeding into the network, adjusted to the consumption load profile of the customer installation, shall be dimensioned and operated such as to prevent power limit values from being exceeded even at the disconnection at high loads.		P
	When the active power limit curve is exceeded, the power generation systems and/or storage units operated in the customer installation shall be disconnected automatically within 200 ms. Automatic reconnection complies with the connection conditions in accordance with 8.3.		P
	For the determination of the maximum connection power, storage units exclusively feeding into the customer installation need not to be taken into account. The functions for the feed-in limitation of $P_{AV, E}$ monitoring can be taken on by the energy flow direction sensor (see VDE-AR-N 4100), provided it has the technical properties of the $P_{AV, E}$ monitoring.		P
5.5.3	Power generation systems ready for connection		Info.
	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.		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		Info.
5.6	Three-phase inverter systems		P
	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.		P
5.7	Behaviour of the power generation system at the network		P
5.7.1	General		P
	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.		P
	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. **Table 1 – Frequency/time ranges for the proper operation of power generation systems** Frequency range: Operating period 47,5 Hz to 49,0 Hz: ≥ 30 min 49,0 Hz to 51,0 Hz: unlimited 51,0 Hz to 51,5 Hz: ≥ 30 min		P
	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)	P
5.7.2	Steady-state voltage stability / reactive power supply		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.1	General boundary conditions		P
	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.		P
	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).	(See appended table)	P
	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).	Not storage unit.	N/A
	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.		P
	Upon agreement with the network operator, the reactive power control range may be extended.		P
	When switching compensation systems that are part of a power generation system, a maximum voltage increment of 0,5 % Un shall not be exceeded.		P
	In addition, the minimum requirements specified in the clauses below shall apply to the power generation system.		P
5.7.2.2	Reactive power supply at ΣS_{Emax}		P
5.7.2.2.1	General		P
	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 the context of network security management.		P
	Power generation systems shall comply with the reactive power supply irrespective of the number of feed-in phases under normal operating conditions in the voltage tolerance band $U_n \pm 10$ %.		P

VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.2.2	Type 2 systems - inverters only		P
	At the generator terminals, each power generation unit to be connected shall meet the requirements according to Figure 2 and Figure 3.  **Figure 2 – Requirements for power generation units regarding the reactive power supply at the generator terminals ($\sum S_{Emax} \leq 4{,}6$ kVA)**  **Figure 3 – Requirements for power generation units regarding the reactive power supply at the generator terminals ($\sum S_{Emax} > 4{,}6$ kVA)**		P
5.7.2.2.3	Type 2 systems – Asynchronous generators (directly connected to the network and principally not able to control any reactive power)	The PGU is PV inverter.	N/A
	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= $0{,}95_{under\text{-}excited}$ with an accuracy of ± 0,02 at nominal voltage and rated power shall be observed.		N/A
5.7.2.2.4	Type 1 systems and Type 2 systems - Stirling generators and fuel cells	The PGU is PV inverter.	N/A
	For power generation systems with a rated apparent power of $\Sigma S_{Emax} \leqslant 4{,}6$ kVA , the network operator does not give any specifications. The value of cos φ lies within a range of cos φ= $0{,}95_{under\text{-}excited}$ to $0{,}95_{over\text{-}excited}$.		N/A
	At its generator terminals, each power generation unit to be connected in systems $\Sigma S_{Emax} > 4{,}6$ kVA shall meet the requirements according to Figure 4.  **Figure 4 – Reactive power supply at power generation units of types 1 and 2, stirling generators, fuel cells with $\sum S_{Emax} > 4{,}6$ kVA**		N/A
5.7.2.3	Reactive power supply smaller than P_{Emax}		P

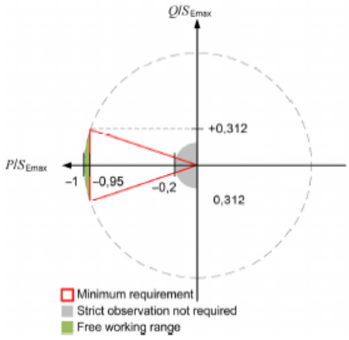
<table>
<tr><th colspan="4">VDE-AR-N 4105</th></tr>
<tr><th>Clause</th><th>Requirement - Test</th><th>Result - Remark</th><th>Verdict</th></tr>
<tr><td></td><td>In addition to the requirements for reactive power supply at the operating point P_{Emax} of the power generation unit (P_{mom} = P_{Emax}), requirements also apply to operation with an instantaneous active power P_{mom} smaller than P_{Emax}.</td><td></td><td>P</td></tr>
<tr><td></td><td>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.


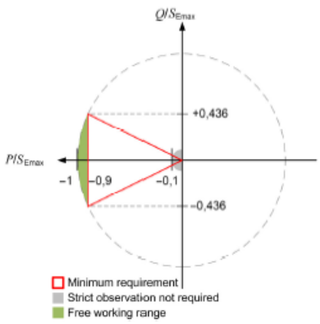
Figure 5 – P/Q diagram for type 2 $\sum S_{Emax} \leq$ 4,6 kVA and type 1, stirling generator, fuel cell $\sum S_{Emax} >$ 4,6 kVA at the generator terminals in the passive sign convention system


Figure 6 – P/Q diagram for type 2 (inverters only) $\sum S_{Emax} >$ 4,6 kVA at the generator terminals in the passive sign convention system</td><td>(See appended table)</td><td>P</td></tr>
<tr><td></td><td>On the P/Q diagram, the ordinate indicates the reactive power Q_{vb} to be provided in relation to the apparent power S_{Emax}. The abscissa indicates the instantaneous active power P_{mom} (negative value in a passive sign convention system) in relation to the apparent power S_{Emax}.</td><td></td><td>P</td></tr>
<tr><td></td><td>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}.</td><td></td><td>P</td></tr>
<tr><td></td><td>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 PEmax (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.</td><td></td><td>P</td></tr>
<tr><td></td><td>For type 2 systems with generators directly connected to the network (asynchronous generators) that are principally not able to control any reactive power, the conditions given in 5.7.2.2 result in a combination of a generator and associated compensation devices. This combination shall not be changed for power values < S_{Emax}. When disconnecting the asynchronous generator, the associated compensation device shall also be disconnected from the network.</td><td>Not asynchronous generators.</td><td>N/A</td></tr>
</table>

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.2.4	Methods for reactive power supply		P
	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:		P
	a) reactive power voltage characteristic curve Q(U); or		P
	b) displacement factor/active power characteristic curve cos φ (P); or		P
	c) fixed displacement factor cos φ.		P
	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.		P
	The reactive power voltage characteristic Q(U) is to be preferred for its reactive power supply depending on the load case and the resulting efficiency. If, in the considered low-voltage network, the cumulative generation power operated with the reactive power voltage characteristic curve Q(U) exceeds 50 % of the rated power of the local network transformer used, either a stability analysis should be carried out or method b) or c) should be chosen for power generation systems yet to be connected.		P
	In network areas where a operating voltage range of -10 % Un to -15 % Un occurs more frequently, the following is recommended to network operators:		P
	– three-phase power generation units and storage units connected to the three-phase current system should be operated with a reactive power voltage characteristic curve Q(U); – any other power generation units should be operated with a permanent cos φ = 1.		P
	Re: a) Reactive power voltage characteristic curve Q (U)		P
	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)).		P
	The reference voltage U_{Q0} is 400 V /√3.		P

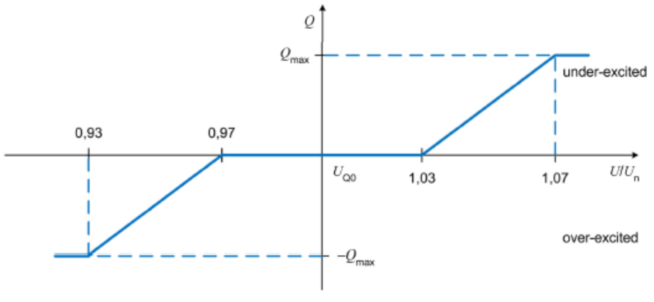
<table>
<tr><th colspan="4">VDE-AR-N 4105</th></tr>
<tr><th>Clause</th><th>Requirement - Test</th><th>Result - Remark</th><th>Verdict</th></tr>
<tr><td></td><td>The arithmetic mean of the r.m.s. values (optionally of the positive sequence system) of the three measured line-to-neutral voltages at the 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.


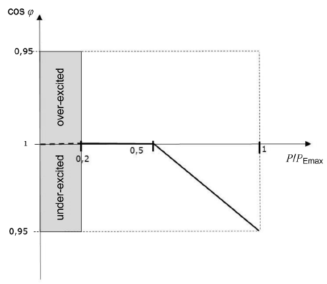
Figure 7 – Standard $Q(U)$ characteristic curve</td><td>(See appended table)</td><td>P</td></tr>
<tr><td></td><td>Re: b) Displacement factor/active power characteristic curve cos φ (P)</td><td></td><td>P</td></tr>
<tr><td></td><td>The objective of this method is the reactive power supply by the power generation unit depending on the actual active power output ($Q = f(P_{mom})$).


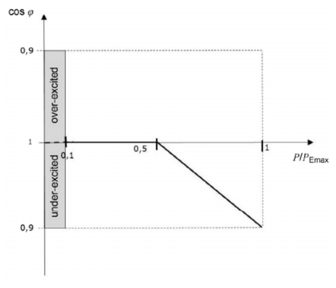
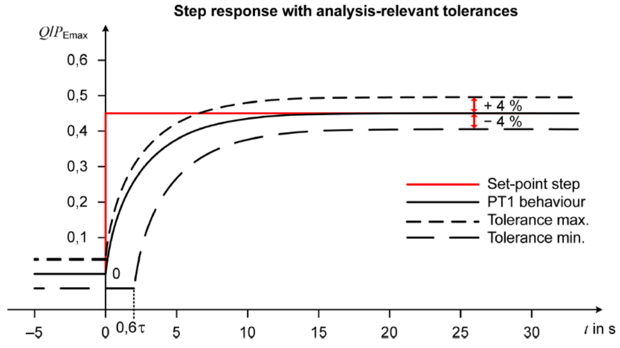
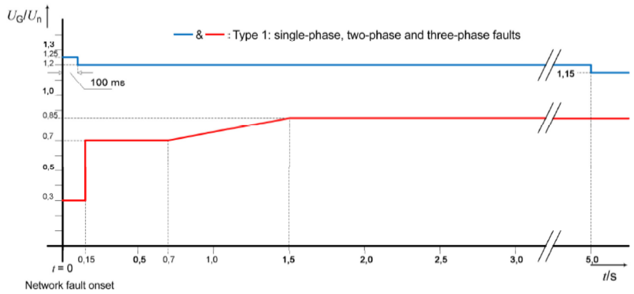
Figure 8 – Characteristic curve for type 2 $\sum S_{Emax} \leq 4{,}6$ kVA and type 1, stirling generator, fuel cell $\sum S_{Emax} > 4{,}6$ kVA


Figure 9 – Standard characteristic curve for type 2 (inverters only) $\sum S_{Emax} > 4{,}6$ kVA</td><td>(See appended table)</td><td>P</td></tr>
<tr><td></td><td>Re: c) Displacement factor cos φ</td><td></td><td>P</td></tr>
<tr><td></td><td>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.</td><td>(See appended table)</td><td>P</td></tr>
<tr><td></td><td>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}.</td><td></td><td>P</td></tr>
<tr><td></td><td>The network operator predefines a displacement factor set-point.</td><td></td><td>P</td></tr>
<tr><td>5.7.2.5</td><td>Requirements for reactive power methods of type 2 systems (inverters only) and type 1systems</td><td></td><td>P</td></tr>
</table>

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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
	For type 2 systems with a rated apparent power of S_{Amax} ≤ 4,6 kVA, the network operator predefines either – a reactive current feed-in with the characteristic curve cos φ (P) as shown in Figure 8; or – a fixed cos φ between cos φ = $0,95_{under-excited}$ and cos φ = $0,95_{over-excited}$.	The power generator with a rated apparent power more than 4.6kVA.	N/A
	For type 1 systems with a rated apparent power of S_{Amax} ≤ 4,6 kVA, the network operator does not predefine a value for the reactive power behaviour. Such type 1 systems may also feed in power without setting the method specified by the network operator.	Not type 1 systems.	N/A
	For type 2 systems with a rated apparent power of S_{Amax} > 4,6 kVA, the network operator predefines either – a reactive current feed-in with the characteristic curve Q(U) as shown in Figure 7 with a control range between cos φ = $0,90_{under-excited}$ and cos φ = $0,90_{over-excited}$; or – a reactive current feed-in with the characteristic curve cos φ (P) as shown in Figure 8; or – a fixed cos φ between cos φ = $0,90_{under-excited}$ and cos φ = $0,90_{over-excited}$.	Comply with Figure 9.	N/A
	For type 2 systems with a rated apparent power of S_{Amax} > 4,6 kVA, the network operator predefines either – a reactive current feed-in with the characteristic curve Q(U) as shown in Figure 7 with a control range between cos φ = $0,95_{under-excited}$ and cos φ = $0,95_{over-excited}$; or – a reactive current feed-in with the characteristic curve cos φ (P) as shown in Figure 9; or – a fixed cos φ between cos φ = $0,95_{under-excited}$ and cos φ = $0,95_{over-excited}$.	Comply with Figure 7 and Figure 9.	P
	When storing with a rated apparent power of S_{Amax} ≤ 4,6 kVA, the network operator predefines a fixed value for cos φ between cos φ = $0,95_{under-excited}$ and cos φ = $0,95_{over-excited}$.	Not storage system.	N/A
	When storing with a rated apparent power of S_{Amax} > 4,6 kVA, the network operator predefines either – a reactive current feed-in with the characteristic curve Q(U) as shown in Figure 7 with a control range between cos φ = $0,90_{under-excited}$ and cos φ = $0,90_{over-excited}$; or – a fixed cos φ between cos φ = $0,90_{under-excited}$ and cos φ = $0,90_{over-excited}$. All storage units shall be delivered with a fixed cos φ = 1.	Not storage system.	N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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 behaviour 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.  Figure 10 – Illustration of 3 Tau = 10 s		P
5.7.2.6	Special aspects regarding the extension of power generation systems		P
	The requirements specified in 5.7.2.4 shall also be met by the newly added power generation units at their generator terminals.		P
	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
5.7.3	Dynamic network support		P
5.7.3.1	General		P
	The objective of dynamic network stability is to prevent any unintentional disconnection of the generation power in case of short-term voltage drops/rises thereby avoiding to jeopardise the network stability.		P
	A network fault is present if the voltage at the generator terminals of the power generation unit is below 0,85 Un or exceeds 1,15 Un.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The criterion for the end of a fault is defined as the earlier of the following two events: – the line-neutral-voltage at the power generation unit and/or the storage unit resumes a value within the range of –15 % Un to +10 % Un; – 5 s after the onset of the fault.		P
5.7.3.2	Dynamic network support for Type 1 units(Transient stability - performance in case of network faults)	The PGU were Type 2 units.	N/A
	Regarding the power generation unit remaining connected to the network, the following applies to type 1 units:		N/A
	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



Key

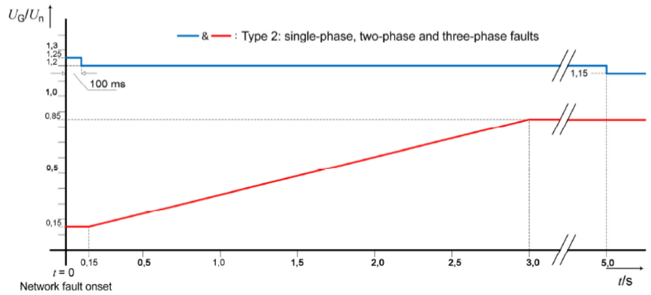
& FRT curve for single-phase, two-phase and three-phase network faults

U_G r.m.s. value of the actual voltage at the generator terminals

Figure 11 – Fault Ride-Through (FRT) limit curve for the voltage curve at the generator terminals for a type 1 power generation unit

	Voltage controllers are recommended which take into account all applied line-neutral voltages.		N/A
	The voltage controller may change the exciting current during a network fault (additional exciting current) in order to reduce the synchronous generated angle and thereby improve the stability of the power generation unit. During and after a network fault, the voltage rise due to the reactive power feed-in shall not lead to a violation of the over-voltage limit curve.		N/A
	Behaviour after the end of a fault		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	If, after the end of a fault, the network voltage resumes a value within the voltage band from －15 % Un to +10 % Un and the active power of the power generation unit has been reduced during the network fault, it shall be increased to its pre-fault value immediately after the end of the fault. The transient period shall not exceed a maximum of 6 s. The reactive power supply succeeds the active power supply as soon as possible.		N/A
	At voltages of 1,15 Un, the power generation unit 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 power generation unit's self-protection is imminent, the unit can adjust its reactive power behaviour such as to prevent the self-protection tripping.		N/A
5.7.3.3	Dynamic network stability for type 2 units and storage units		P
	The following conditions apply to all type 2 power generation units and storage units:		P
	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.	(See appended table)	P



Key

& FRT curve for single-phase, two-phase and three-phase network faults

UG r.m.s. value of the actual voltage at the generator terminals

Figure 12 – Fault Ride-Through (FRT) limit curve for the voltage curve at the generator terminals for a type 2 power generation unit and for storage units

	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.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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 Un or exceeds > 1,15 Un (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).	(See appended table)	P
	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 Ir within 60 ms and 10 % of Ir within 100 ms upon a voltage drop below 0,8 Un or a voltage rise above 1,15 Un.	(See appended table)	P
	Behaviour after the end of a fault		P
	If, after the end of a fault, the network voltage resumes a value within the voltage band from -15 % Un to +10 % Un 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.	(See appended table)	P
	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		P
	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.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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}):		P
	– 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.		P
	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.		P
	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).		P
	The specifications are based on the active power. For this purpose, the reactive power shall comply with the specifications in 5.7.2 of this VDE application guide.		P
	For power generation systems with combustion engines, the maximum permissible operating durations of the combustion engine shall be taken into account when reducing the active power output at set-points below the engine's technical minimum continuous power. If the power value is below the combustion engine's minimum technical power output and the permissible operating duration is exceeded, the combustion engine may disconnect from the network.		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
	According to EnWG [4], the network operator is entitled to request and apply a temporary limitation of the active power output or a system shut-down at any time.		P
5.7.4.2	Network security management		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
5.7.4.2.1	Types of power generation systems and storage units		P
	If not specified otherwise by legislation, the requirements described below apply.		P
	Photovoltaic systems		P
	PV systems shall contribute to the avoidance of network overload. For this purpose, PV system power is divided into three power groups:		P
	− 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 feed-in power by the network operator.		P
	− 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.		N/A
	− 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.		N/A
	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.		N/A
5.7.4.2.2	Implementation of network security management		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		P
	It shall be noted for combined systems that the total effect at the network connection point is resulting from the power of the power generation system and the power of the consumption system. The power reduction requirement relates to the installed active feed-in power P_{Amax} irrespective of the actual power flow or its direction at the network connection point. Power reduction implemented directly at the power generation units and/or by connection of electric equipment in combined systems is sufficient for meeting the requirement. Self-consumption strategies involving storage units shall not be in conflict with these requirements. Each network operator's reduction request shall be justifiable based on the metering strategy or a remote controlled connection for the network operator.		P
	The power generation system may be disconnected from the network below the minimum technical power (also refer to the exceptions for combustion engines given in 5.7.4.1). In case of a predefined power value of 0 % P_{Amax}, disconnection from the network is not strictly necessary.		P
	The active power value is specified separately for each primary energy carrier (where multiple primary energy carriers are connected to the customer installation).		P
	Requirements of the network security management invariably take precedence over market-relevant requirements.		P
5.7.4.3	Active power adjustment at over-frequency and under-frequency		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		P
	The accuracy of the frequency measurement in the steady state shall be ≤ ± 10 mHz.		P
	Storage systems in standby mode are exempted from the requirements of 5.7.4.3. In addition, DC-coupled storage systems shall perform as Type 2 units.		Info.
	In case of over-frequency, an excess of generated power is opposed by a deficit of consumed power.		P
	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).		P
	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 $s = \frac{\Delta f}{f_{\mathrm{n}}} / \frac{\Delta P}{P_{\mathrm{ref}}}$ 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).	(See appended table)	P
	For storage units, the generated active power with a gradient of 40 % of PEmax per Hertz (s = 5 %) shall be reduced or increased (see Figure 15).	Not storage units.	N/A
	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”).		P
	At network frequencies f > 51,5 Hz, power generation units and storage units shall disconnect from the network if energy is supplied (see Figure 14 and Figure 15).		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Reduction of the active power output shall be continued at least until the minimum technical power is reached. Further reduction below the minimum technical power is permitted. During this, stable operation of the power generation unit shall be ensured.		P
	If the value of 50,2 Hz has been exceeded, controllable storage units in charging mode shall not reduce their charging power until the frequency has dropped below 50,2 Hz with a gradient of 10 % P_{ref} per minute. During the over-frequency, storage units in charging mode should adjust their charging power according to Figure 15 (i. e. an increase of the charging power according to the characteristic curve is explicitly desired). This does not apply to the reduction of the charging power in order to prevent overcharge or harm to persons or damages to property.	Not storage units.	N/A
	In case of under-frequency, a deficit of generated power is opposed by an excess of consumed power.		P
	Figure 13 shows the requirement for the output power of the power generation units in the dynamic short-time range. At frequency curves between 50 Hz and the blue curve, the power generation unit shall not reduce its specified active power output.		P

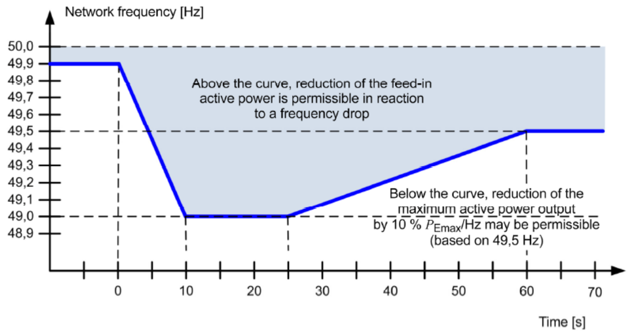
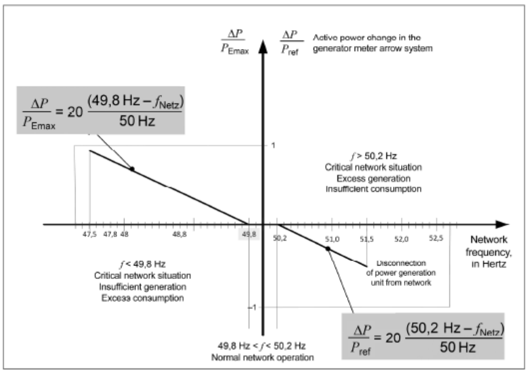


Figure 13 – Requirement for the output power of the power generation units in the dynamic short-time range

	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.		P

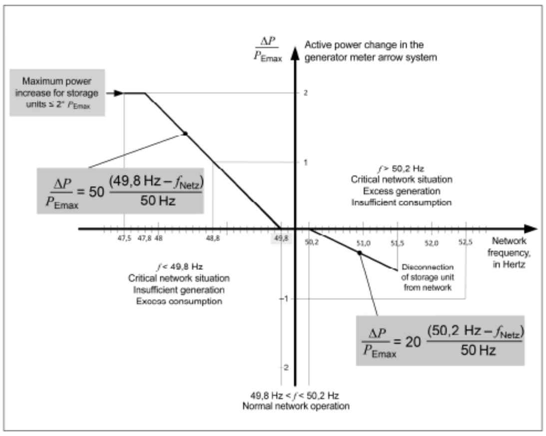
<table>
<tr><th>Clause</th><th>Requirement - Test</th><th>Result - Remark</th><th>Verdict</th></tr>
<tr><td></td><td>Consequently, power generation units and storage units will constantly move up and down along the frequency characteristic also within the frequency range of 49,8 Hz to 47,5 Hz or 47,8 Hz with regard to their maximum possible active power feed-in (“operation along the characteristic”).</td><td></td><td>P</td></tr>
<tr><td></td><td>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.</td><td>Not storage units.</td><td>N/A</td></tr>
<tr><td></td><td>At network frequencies f < 47,5 Hz, power generation units and storage units shall disconnect from the network (see Figure 14 and Figure 15).



Key

P_{Emax} highest active power of a power generation unit (10 min mean value)
P_{ref} equals P_{Emax} for type 1 power generation units or P_{mom} for type 2 power generation units at the moment when 50,2 Hz is exceeded.
ΔP power change
f network frequency

Figure 14 – Active power adjustment for type 1 and type 2 power generation units at over-frequency and under-frequency with a static value of 5 % and frequency limit values of 49,8 Hz and 50,2 Hz for starting the adjustment</td><td>Comply with Figure 14.</td><td>P</td></tr>
</table>

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	 Key P_{Emax} highest active power of a power generation unit (10 min mean value) ΔP power change f network frequency **Figure 15 – Active power adjustment for storage units at an over-frequency with a static value of 5 % and an under-frequency with a static value of 2 % and frequency limit values of 49,8 Hz and 50,2 Hz for starting the adjustment**	Not storage units.	N/A
	Requirements for the control times for power generation units and storage units		P
	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.		P
	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 the expiration of T_V + 0.1 x ($T_{an\_90\%}$ - T_V) at least 9% of the required power adjustment ΔP is achieved. − 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 PEmax 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.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		P
	After settling, the supplied active power should deviate by ≤ ± 10 % PEmax from the set-point.		P
	The same requirements shall be applied to the active power increase at an under-frequency between 49,8 Hz and 47,5 Hz.		P
	Conditional requirements based on technical restrictions		P
	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.		P
	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.		P
	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.	The power generation units not with combustion engines or gas turbines.	N/A
	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.	Not linear generators.	N/A
	End of critical network status and return to normal operation		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		P
	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}.		P
	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		P
	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.		P
	Surges or oscillations of the active power feed-in are not permitted for that purpose.		P
5.7.5	Short-circuit current contribution		P
	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.		P
6	Construction of the power generation system/network and system protection (NS protection)		P
6.1	General requirements		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The network and system protection (NS protection) is a type-tested protective device with certificate for the NS protection (see form E.6), in which all protection functions according to 6.5 are implemented. NS protection acts on the interface switch according to 6.4.		P
	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: – $\sum S_{Amax} > 30$ kVA : • Central NS protection at the central meter panel. Exception 1: In the case of combined heat and power units, integrated NS protection is also permitted for power generation systems of > 30 kVA, if, at the network connection point, a disconnection device is provided that is accessible for the network operator's staff at all times. Exception 2: For storage units not feeding into the low-voltage network of the network operator, integrated NS protection is also permitted at > 30 kVA. – $\sum S_{Amax} \leq 30$ kVA : • Central NS protection at the central meter panel or decentralised in a sub-distribution; or • integrated NS protection.	$\Sigma S_{Amax} \leq 30$ kVA, integrated NS protection used.	P
	When determining the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point ΣS_{Amax}, it is necessary to consider both any existing as well as any new systems. Storage units not feeding into the low-voltage network of the network operator at this network connection point and combined heat and power units connected via a disconnection device that is accessible at all times shall not be taken into account when determining ΣS_{Amax}.		Info.
	Where the sum of the maximum apparent powers of all power generation systems and storage units connected to the same network connection point whereat they feed into the low-voltage network of the network operator is a value $\Sigma S_{Amax} > 30$ kVA, a central NS protection shall be installed or, if applicable, retrofitted. This also applies if the limit value of 30 kVA is exceeded due to later measures. This includes e. g.: − addition of new power generation units; − the operating mode of the storage unit(s) is modified such that it/they feed(s) into the low-voltage network of the network operator; − combined heat and power units no longer connected and operated via a disconnection device that is accessible at all times.		Info.
	The loss of the auxiliary voltage of the central NS protection or the control of the integrated NS protection shall lead to an instantaneous tripping of the interface switch. Protective tripping of the integrated protection shall not be inadmissibly delayed by other control functions in order to observe the required disconnection periods. The protective functions shall be maintained even in the event of a malfunction in the system control.		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The central NS protection, the integrated NS protection, the central and the integrated interface switch as well as the associated tripping circuits shall meet the following requirements:		Info.
	− such equipment shall be designed, constructed, chosen, assembled and combined at least such as to be able to withstand the operating conditions (e. g. reliability with regard to their breaking capacity and switching frequency) and external influences (e. g. mechanical vibration, external fields, interruptions or disturbances of the energy supply) to be expected. − A single fault shall not lead to a loss of the protective function of the NS protection. Faults of common cause shall be taken into account if the probability of their occurrence is of any significance. Each single fault should be indicated and lead to shut-down of the respective power generation unit or system.		Info.
6.2	Central NS protection		N/A
	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.		N/A
	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.		N/A
6.3	Integrated NS protection		P
	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.		P
	The integrated NS protection acts on an integrated interface switch (see 6.4.3).		P
6.4	Interface switch		P
6.4.1	General		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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		P
	As interface switches, the switching devices of the individual power generation units (integrated interface switch) can be used.		P
	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.		P
	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) The use of an interface switch, where a control voltage must always be present when the unit is switched on, and which switches off automatically if this voltage is not present. The operational switch-on or switch-off procedures must be monitored. b) At least once daily switching on or off of the interface switch by the NS protection and monitoring of the proper function of the interface switch (e.g. normally closed contact of a feedback contact). c) Use of the integrated interface switch and the integrated NS protection for PV and battery inverters according to DIN EN 62109 (VDE 0126-14).		P
	When a defect of the interface switch is detected, the power generation system shall neither feed in nor reconnect.		P
6.4.2	Central interface switch		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	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.		N/A
	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		P
	For the construction of the interface switch, the requirements specified in 6.1 shall be considered		P
	The interface switch (e.g. power relay, contactor, mechanical circuit breaker, etc.) ensures galvanic shutdown.		P
	For power generation systems with inverters, the interface switch must be provided on the network side of the inverter.		P
6.5	Protective devices and protection settings		P
6.5.1	General		P
	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
	The specifications given in 6.5.2 do not refer to the protective functions of short-circuit protection, overload protection, protection against electric shock and all-phase separator of the circuit to the power generation system (e. g. by means of line circuit breakers, residual current operated circuit-breakers (RCD)) which shall be carried out in accordance with the applicable VDE regulations and for which the connection owners are themselves responsible (to ensure self-protection). In this respect, the protection function described in this VDE application guide may have to be extended accordingly by the connection owner of the power generation system. However, the self-protection shall not undermine the requirements described in this VDE application guide.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	System operators shall themselves take precautions to prevent damages to their systems and installations due to switching actions, voltage fluctuations and automatic reclosings in the upstream network or other processes in the network of the network operator. The following functions of the NS protection shall be implemented: – rise-in-voltage protection *U* >>; – rise-in-voltage protection *U* >; – voltage drop protection *U* <; – voltage drop protection *U* <<; – frequency decrease protection *f* <; – frequency increase protection *f* >; – islanding detection.		P
	Voltage protection devices should evaluate the r.m.s. value. Evaluation of the 50 Hz fundamental component is sufficient.		P
	Rise-in-voltage protection U > must be designed as a sliding 10-minute mean value protection which prevents the upper voltage limit according to DIN EN 50160 from being exceeded (monitoring of the voltage quality). It is sufficient if a new 10-minute mean value is formed every 3 s at the latest, which must be compared with the setting value for U > from Table 2.		P
	Voltage protection devices must be designed in such a way that they monitor the feeding external conductors. With power generation systems ≤ 30 kVA, the voltage(s) (per individual line to which power is fed) between the individual lines and the neutral conductor must be measured		P
	For power generation systems > 30 kVA, the voltage protection devices must be three-phase. For this purpose, the three voltages between the individual lines and the neutral conductor must be measured; the three interlinked individual line voltages must either be calculated from the three line-to-neutral voltages or measured separately. This means that 2 x 3 voltages are to be recorded here.	Power generation systems ≤ 30 kVA.	N/A
	The voltages are to be logically OR linked. Logic OR linking here means: − For rise-in-voltage protection relays, exceeding the threshold value leads to an excitation for at least one measuring voltage; − For voltage-drop protection relays, a drop below the threshold value leads to an excitation for at least one measuring voltage.		P
	Frequency protection devices can be single-phase equipment		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The setting values of the protective functions and the last five dated error messages (relative time stamp is sufficient, i.e. no real-time clock required) must be readable on the NS protection. Supply interruptions ≤ 3 s must not lead to any loss of the error messages. At central NS protection, readout must be possible independently of the operating status of the power generation system and without additional aids (e.g. on a display). With the integrated NS protection, the readout can be affected via a data interface.		P
	Where systems are provided with functions such as unbalance protection (see VDE-AR-N 4100, 5.5.3) or $P_{AV, E}$ monitoring (see 5.5.2), those functions may be implemented within a device in combination with the NS protection.		P
6.5.2	Protective functions		P
	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 Pn > 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.		P
	The setting values for protection purposes are considered to be functionally dependent on the technical capabilities of the power generation units.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The protection functions according to Table 2 must be set in NS protection. The protection relay settings, which can be changed by the network operator or the system operator according to specifications, are listed below Table 2.		P

Table 2 - Setting values for NS protection

Protective function	Protection relay setting values[a]					
	Stirling generators, fuel cells Synchronous and asynchronous generators coupled directly or via inverter with $P_n \leq 50$ kW		Directly coupled synchronous and asynchronous generators with $P_n > 50$ kW		Inverters	
Rise-in-voltage protection $U»$	1.15 U_n	≤ 100 ms	1.25 U_n	≤ 100 ms	1.25 U_n	≤ 100 ms
Rise-in-voltage protection $U >$	1.10 U_n[b]	≤ 100 ms	1.10 U_n[b]	≤ 100 ms	1.10 U_n[b]	≤ 100 ms
Voltage drop protection $U <$	0.8 U_n[c]	≤ 100 ms	0.8 U_n	1.0 s[d]	0.8 U_n	3.0 s
Voltage drop protection $U <<$	not applicable		0.45 U_n	300 ms[d]	0.45 U_n	300 ms
Frequency decrease protection $f <$	47.5 Hz	≤ 100 ms	47.5 Hz	≤ 100 ms	47.5 Hz	≤ 100 ms
Frequency increase protection $f >$	51.5 Hz	≤ 100 ms	51.5 Hz	≤ 100 ms	51.5 Hz	≤ 100 ms

a The time specification "< 100 ms" for the protection relay setting value assumes a maximum inherent time for NS protection + interface switch of also 100 ms. This results in the maximum 200 ms "total shutdown time". If the inherent time of the components is < 100 ms (e.g. 50 ms),t then correspondingly more time can be used for the measurement and evaluation of the protective function (e.g. then up to 150 ms). This would result in a higher protection relay initial value than "< 100 ms", namely "< 150 ms". In this case, however, only the 100 ms at NS protection can be visualized as the setting value. However, the shutdown time of 200 ms must not be exceeded under any circumstances.

b It must be ensured that the voltage 1.10 U_n is not exceeded at the network connection point. If this requirement is ensured by central NS protection, it is permissible to set the rise-in-voltage protection on the decentralized power generation unit/system to up to 1.15 U_n. In this case the system erector should consider possible effects on the customer installation. The combination of central NS protection ($U >$: 1.1 U_n) and integrated NS protection ($U >$: 1.1 U_n to 1.15 U_n) is to be recommended if the voltage drop in the house installation is not negligible. This is typically the case with longer connecting cables.

c To protect the power generation unit, an additional self-protection setting value (e.g. 0.83 U_n) may be used to switch off the power generation unit before it reaches the setting value of 0.8 U_n.

d The following protection settings are recommended if the network operator's medium voltage network upstream of the generation system is operated with automatic reclosing (AR): $U <<$ relay: 0.45 U_{NS} undelayed (i.e. smallest possible time delay) and $U <$ relay: 0.8 U_{NS}, 300 ms. The specification is made by the network operator.

	If only integrated NS protection is used for power generation systems ≤ 30 kVA, the value of the rise-in-voltage protection U > of 1.1 Un must not be changed.		P
	The permissible tolerance between setting value and trigger value is for the voltage maximum ±1% Un and for the frequency maximum ±0.1%fn.		P
	The conditions for connection/re-connection of the power generation system are described in 8.3.		P
6.5.3	Islanding detection		P
	For power generation systems, islanding detection shall be carried out using one of the following methods: a) Active method, e.g. by means of a frequency shift method (generally for PV systems); or a combination of active and passive methods, whereby for instance the RoCoF method can be used as the passive method; NOTE 1 For the RoCoF method, a setting value of 2 Hz/s with a minimum measurement period of 0,5 s is recommended in order to avoid jeopardising the system stability. b) Passive method by means of the three-phase voltage monitoring (possible only for power generation units without inverters or for single-phase power generation units with inverters). NOTE 2 Three-phase voltage monitoring is also permissible for structural integration of several single-phase power generation units feeding into different line conductors provided the currents of those power generation units are regulated independently of each other such as to allow the development of arbitrary phase relationships.		P

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Method a) shall be verified by means of a resonant circuit test in accordance with DIN EN 62116 (VDE 0126-2), whereas method b) is already implemented by means of the rise-in-voltage protection and the voltage drop protection of the NS protection.	(See appended table)	P
	The islanding detection is implemented in either the central or the integrated NS protection of the power generation unit. If an islanding detection system acting on the integrated interface switch is integrated in all power generation units of a power generation system, then the islanding detection in the central NS protection may be omitted irrespective of the system power.		P
	Detection of an island network and disconnection of the power generation system by means of the interface switch shall be completed within 2 s. Since the execution of dynamic network stability and the subsequent increase of the active power feed-in has a higher priority that the islanding detection, the latter may be deactivated for the duration of dynamic network stability. If the islanding detection remains active, it shall not undermine the dynamic network stability and the subsequent increase of the active power feed-in.		P
	Islanding detection and the resulting disconnection of the power generation system shall be completed within 9 s.		P
6.6	Further requirements for generation systems		Info.
6.6.1	Ability to provide primary control power		Info.
	Power generation systems connected to low-voltage networks are not subject to any requirements regarding the provision of primary control power. Where it is intended that power generation systems connected to low voltage networks contribute to the primary control, they shall meet the requirements specified in VDE-AR-N 4120, 10.5.3.		Info.
6.6.2	Ability to provide the secondary control power and tertiary control		Info.
	The power generation systems connected to low-voltage networks are not required to provide secondary control power and minute reserve. If power generation systems with connection to low-voltage networks wish to participate in the secondary control power and/or the minute reserve, they must meet the requirements of VDE-AR-N 4120, 10.5.4.		Info.
7	Metering for billing purposes		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Installation and operation of the measuring device required in business transactions with an energy supplier or the network operator for the billing of purchased or generated energy is affected in accordance with MsbG, VDE-AR-N 4400, VDE-AR-N 4100 and the technical connection conditions of the network operator.	It's depended on energy supplier or the network operator.	N/A
	Installation and operation of the metering devices shall be agreed in due time between the system installer and the network operator or metering point operator, respectively. According to the German Measurement and Calibration Act (MessEG, de: Gesetz über das Mess- und Eichwesen), meters and transformers approved and calibrated for commercial purposes as well as metering devices with a certificate of conformity in accordance with the MID (Measuring Instruments Directive) shall be used		N/A
	As the meter Z1 for consumption from the network operator's network and for feed-in into the network operator's network, a bidirectional meter shall be used. Its design shall be agreed between the metering point operator and the network operator. The metering devices (Z1) used for consumption and feed-in in conjunction with power generation systems shall be designed such as to ensure a measurement procedure balancing over all phases separately for the two current flow directions.		N/A
	In order to ensure correct metering of the generation quantities supplied to the customer installation in accordance with EEG [2] or of the CHP net current generation in accordance with KWKG [3], only backstop meters shall be installed as meter Z2 (see C.4). Separate meters Z2 shall be installed for each type of system (e. g. PV or CHP system). A separator shall be installed between the meter Z2 and the customer installation. It is not permitted to allocate the three line conductors of a power generation unit feeding into the three-phase system to different metering devices (e. g. for full feed-in and excess feed-in). At the discretion of the network operator, the metering device Z2 may be installed at a central metering panel in accordance with VDE-AR-N 4100 or next to or, in case of CHP systems, also in the power generation unit (see 5.5).		N/A
	In addition, the metrological framework conditions depending on the respective meter type (e. g. temperature, humidity, operating position, mechanical influences) shall be met.		N/A
	The building of data transmission paths for the transmission of billing data is subject to the regulations of MsbG [5].		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	For a metering device directly connected to a meter panel in accordance with VDE-AR-N 4100, the colours for the line conductors specified in DIN VDE 0603-2-1 (VDE 0603-2-1) shall be selected as follows: – lines “lower connection compartment → metering device”: black – lines “metering device → lower connection compartment”: brown		N/A
	The meter section shall be marked permanently and legibly with the label “power generation system”.		N/A
8	Operation of the system		P
8.1	General		P
	The systems and settings for the protection of a customer installation against internal electrical faults (self-protection), network protection, as well as regulations for system operation are to be designed in such way that the ability of the system to meet the requirements described in this application guide is not conceptually restricted.		P
	During operation of the customer installation, network situations may occur in which the requirements of this application guide cannot be fulfilled simultaneously without contradiction. In these situations, the following prioritisation applies to the tasks and modes of operation of self-protection, network protection and operational control functions (in descending order): 1) Avoidance or limitation of possible damage to systems and equipment, especially in the event of overload and short-circuit protection; 2) Compliance with the requirements for dynamic network support according to 5.7.3; 3) Specifications by the network operator’s network security management according to 5.7.4.2; 4) Compliance with the requirements for $P_{AV,E}$ monitoring according to 5.5.2; 5) Compliance with the requirements for performance in case of over- and under-frequency according to 5.7.4.3; 6) Compliance with the requirements for reactive power operation for static voltage stability according to 5.7.2.2; 7) Frequency control (control energy) according to 6.6.1 and 6.6.2.		P
	The prioritisation does not restrict the requirements for the design of the system and its protective devices.		Info
	The requirements of lower priority are to be implemented unless in conflict with the requirements of higher priority.		Info
	The requirements by the network security management of the distribution network operator in accordance with 5.7.4.2 take precedence over the requirements for power increase in the event of under-frequency in accordance with 5.7.4.3 (blocking of power increase in accordance with 5.7.4.3). The distribution network operators shall comply with the following conditions: − The network bottlenecks must be monitored promptly by the distribution network operator and must not have been forecast based on projections − the precedence shall apply to the bottleneck area only.		Info

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The operation of electrical installations shall include all technical and organisational activities necessary to ensure that installations are functional and safe. The activities include all operating actions as well as electro-technical and non-electrical work as described in the relevant regulations and rules. Special reference is made to DIN VDE 0105-100 (VDE 105-100).		Info
	The system operator is responsible for the operation of the power generation system and/or storage system. If required by the network operator, the system operator will name an electrician for the network operator who may carry out the necessary work on the electrical system of the system operator.		Info
	For the connection of the power generation system as well as the storage system the conditions according to 8.3 have to be observed. During operation, the conditions according to Section 5, on which the decisions regarding the connection of the power generation system and/or the storage system are based, may only be changed with the consent of the network operator.		Info
	The system operator must always keep the equipment required for parallel operation with the low-voltage network in a technically flawless condition. The switches and protective devices must also be checked at regular intervals by a qualified electrician to ensure that they are in proper working order. This requirement is fulfilled under normal operating and environmental conditions if the inspection intervals specified in DGUV regulation 3 or TRBS 1201 are observed. Retesting must additionally include the following scope: − Environmental conditions (contamination, mechanical or insulation damage) and, if necessary, correction of inadequacies; − Tripping test of the interface switch.		Info
	The result shall be recorded in a test protocol which shall be provided on request to the network operator		P
	When using certified NS protective devices, regular maintenance testing of the NS protection, the interface switch and the functional chain “NS protection − interface switch” is not required.		N/A
	In justified cases, the network operator may demand a test of the NS protection and the interface switch to prove their functionality.		N/A
	Power reduction or disconnection required due to network conditions		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Upon request of the network operator, the system operator is obliged to switch off the power generation system and/or the storage unit and to disconnect it from the network if required for conducting works in the network operator's network that are necessary for operational purposes. Scheduled disconnections shall be announced to the system operator in a timely and suitable manner.		N/A
	In case of danger, breakdown or imminent loss of network security, the network operator is entitled to immediately disconnect the power generation system and/or the storage unit from the network or to reduce its active power output, respectively.		N/A
	If the agreed maximum connection power is exceeded, the network operator is entitled to disconnect the power generation system and/or the storage system from the network. For this purpose, the network operator may require the system operator to install appropriate technical equipment that disconnects the power generation system and/or the storage system from the network operator's network if certain limit values (e.g. maximum apparent connection power) are exceeded (see 5.5.2).		N/A
	If the network operator detects serious defects in the power generation system or the storage system with regard to personal and system safety, he is entitled to disconnect these system components from the network or to demand disconnection from the network by the system operator until the defects have been rectified.		N/A
	Access		P
	Upon co-ordination with the system operator, the network operator shall be granted access to all components of the power generation system and/or storage system (meter panel, central NS protection (if available), interface switch, facilities of the power generation/network security management (if available), and the power generation units).		P
	Exchange of information		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	The network operator will inform the system operator about substantial modifications in his network which will have an impact on the current parallel operation. The system operator shall, in due time, co-ordinate with the network operator any scheduled modifications to his power generation system as well to his storage system which will have an impact on the parallel operation or the decoupling protection or NS protection, such as increase or decrease of the system power, replacement of protective devices or modifications to the compensation equipment.		Info.
	Coupling of network connection points		Info.
	Different network connection points on the network of the network operator(s) shall not be operated by systems of one or more system operator(s).		Info.
	Reaction to disturbances		Info.
	The reconnection conditions given in 8.3 shall be satisfied.		Info.
	The system operator shall immediately inform the network operator about any incidents detected as far as they are of importance to the network operator.		Info.
	Due to the possibility of voltage recovery at any time after an interruption of supply, the network connection point is to be considered to be constantly energised. Reconnection is usually carried out by the network operator without prior consultation with the system operator.		Info.
	Fault clearance may require unscheduled investigations and measurements which the network operator and the system operator shall carry out on their respective operating equipment. For fault clearance and remedy, the network operator and the system operator shall provide mutual support. All information required for fault clearance shall be exchanged between them.		Info.
8.2	Special aspects of the management of the network operator’s network		Info.
	Earthing and short-circuiting for works on the network		Info.
	After isolation, a prerequisite for the safety of works on the network is to prevent any voltage sources and - as working methods in accordance with DIN VDE 0105-100 (VDE 0105-100) - from reconnecting unintentionally. Earthing and short-circuiting are required upstream as well as downstream of the point where the work is done. For this, sufficiently dimensioned house connection boxes should also be used.		Info.

Clause	Requirement - Test	Result - Remark	Verdict
	This means that network operators are required to consistently apply all five of the safety rules when works are carried out on the low-voltage network (with the exception of live working). It is therefore required also to provide earthing and short-circuiting downstream of a disconnected line in the network operator’s low-voltage network (when viewed from the local network transformer, i.e. on the customer side of the sectioning point). If earthing and short-circuiting are not provided on the customer side of the sectioning point, then third-party feed-in (e.g. via an emergency power generator as used in farming) shall be prevented by other means.		Info.
	It should also be noted that an NA protective device integrated in the power generation unit or in a storage system can obtain its supply voltage from the network. Connection to the network is also required for voltage and frequency measurement. Furthermore, passive elements (e.g. EMC filters) can be mounted unconnected on the network side of the interface switch. When determining zero potential within the scope of the five safety regulations (according to DIN VDE 0105-100 (VDE 0105-100)), it must be noted that in systems with capacitors, the discharge must be waited for before determining the zero potential. For stationary capacitors, the discharge times can be taken from the relevant standards (10 min to < 75 V residual voltage or separate labelling of the discharge time on the system).		Info.
	Operation of network stand-by systems		Info.
	For certain works on the network (e.g. replacement of a local network transformer), the network operator has to disconnect sub-networks from the remaining network. In order to ensure continuous supply to the customers during this time, the network operator may use network stand-by systems. Normally, the network operator will not inform the customers concerned about the use and operation of network stand-by systems		Info.

VDE-AR-N 4105

Clause	Requirement - Test	Result - Remark	Verdict
	However, if the feed-in power of the power generation systems and storage systems exceeds the load extraction in this separated sub-network, it is possible for the network stand-by system to be disconnected by the protection system. Stable operation of the network stand-by system would then no longer be possible. In order to prevent this from happening, care shall be taken that the power generation systems and storage systems (regardless of extraction or feed-in) are and remain disconnected in the event of such an operating state or that in case of an emergency power operation of the customer installation it is disconnected from the public network at the network connection point. To this end, the network stand-by system is connected and started in parallel to the low-voltage network. Afterwards, the local network transformer is switched off and the network stand-by system takes over the supply of the “network island”. The network stand-by system shall be set to 51.7 Hz to 52.0 Hz, so that all power generation systems and storage systems can safely disconnect from the network. Given that operating mode, all power generation systems and storage systems will remain separated from the network operator’s network (prior to this VDE application guide VDE-AR-N 4105:2011-08 between 50.05 Hz and 51.5 Hz, starting with the application of this VDE application guide VDE-AR-N 4105:2011-08 between 50.05 Hz and 50.1 Hz/60 s; see 8.3).		Info.
	In order to enable uninterrupted resynchronisation of the sub-network with the rest of the network, the frequency is realigned to the current mains frequency once operation of the network stand-by system is ended and the local network transformer is returned to service. In order to prevent the power generation systems and storage systems from immediately switching on again as soon as the frequency returns to within the tolerance range specified by the connection and reconnection conditions given in 8.3, which would, at that time, put the stability of the network operation at risk, it is required to ensure a waiting period of at least 60 seconds after a shutdown time of the power generation systems and storage systems of more than 3 s.		Info.
	For uninterrupted supply of the network – in particular, when the network stand-by system connects at a moment of a power surplus in the low-voltage network – it is recommended to use network stand-by systems that are able to reverse power on a short-term basis.		Info
8.3	Connection conditions and synchronisation		P
8.3.1	General		P

Clause	Requirement - Test	Result - Remark	Verdict
	Power generation systems and storage systems may only be connected to the network of the network operator if a suitable device determines that both the network voltage is within the tolerance range of 85% Un to 110% Un and the mains frequency is within the tolerance range of 47.5 Hz to 50.1 Hz for a duration of at least 60 s. In addition, the delay times when a generator is switched on again and the staggered times when several generators are switched on must be long enough to ensure that all control and compensation processes within the power generation system and/or the storage systems are safely completed due to the switch-on.		P
	In case of reconnection of power generation systems and storage systems to the network of the network operator when the NA protective device or the PAV,E monitoring is triggered, the active power of controllable power generation systems and storage systems delivered to the network of the network operator must not exceed the gradient of 10% of the active power Amax per minute. Non-controllable power generation systems and storage systems can be switched on after 1 min to 10 min (random generator) or later. Therefore, after 10 min the power can be fed in with Amax. In the case of manual operation on site (e.g. for reasons of commissioning or maintenance), the reconnection conditions described in this paragraph may be deviated from.		P
	In the event of manual disconnection of the power generation system and/or storage system by the network operator, the system operator shall coordinate the reconnection with the network operator's unit responsible for network operation.		P
8.3.2	Connection of synchronous generators		N/A
	At an adequate point, a synchronisation device shall be provided for synchronous generators coupled directly to the network. While the synchronisation equipment for power generation systems that are not capable of island operation is expediently assigned to the generator switch, power generation systems capable of island operation should additionally be provided with synchronisation equipment at the interface switch. An automatic parallel connection device shall be provided. The setting values shall be coordinated with the network operator.	Not synchronous generators.	N/A
	The following common maximum values can be assumed: − $\Delta\varphi = \pm 10°$; − $\Delta f = \pm 500$ mHz; − $\Delta U = \pm 10\% \ U_n$.		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Depending on the ratio of network short-circuit power to generator power it may be necessary to establish narrower limits to avoid inadmissible system reactions at the moment of connection.		N/A
8.3.3	Connection of asynchronous generators		N/A
	For asynchronous generators started by a prime mover and connected at a rotational speed between 95% and 105% of the synchronous rotational speed, k_{imax} is expected to be = 4.	Not asynchronous generators.	N/A
	For asynchronous generators, which are not connected dead, the connection conditions specified for synchronous generators shall be satisfied		N/A
8.3.4	Connection of power generation units with inverters		P
	Power generation units with inverters (e.g. photovoltaic systems) shall only be connected with k_{imax} ≤ 1.2.		P
8.4	Special features in the planning, installation and operation of power generation systems and storages systems with P_{Amax} ≥ 135 kW each		N/A
	For power generation systems and storage units with an active power each of P_{Amax} ⩾ 135 kW, compliance with the requirements of VDE-AR-N 4110 shall be demonstrated. For the planning, installation and operation of such power generation systems and storage units certified in accordance with VDE-AR-N 4110 and connected to a low-voltage network of the network operator, the following requirements shall be met:		N/A
	− Network interactions: The test report for the unit certificate according to VDE-AR-N 4110 shows the network interactions with their measured values. These must be evaluated by the network operator according to VDE-AR-N 4100, 5.4.		N/A
	− Protection settings: The central NS protection must be parameterised according to the specifications in Table 2 in 6.5.2 of this VDE application guide. If integrated NS protection is still present in the power generation units, it must not compromise the requirements regarding static voltage stability and dynamic network support from this application guide. A setting of the rise-in-voltage protection U > to values > 1.10 Un is only permissible to the extent that it corresponds to the capability of the power generation system and/or storage system. The exceptions according to 6.1 remain valid.		N/A

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	– Steady-state voltage stability: • When selecting the operating mode “reactive power characteristic curve Q(U)”, it shall be parametrised as specified in Figure 7 in 5.7.2.4 of this VDE application guide (e. g. by applying the method “reactive power with voltage limiting function” according to VDE-AR-N 4110). For this purpose, $Q_{max} = P_{Emax} \times 0{,}33$ (equal to cos φ = 0,95) shall be set. • When selecting the operating mode “displacement factor/active power characteristic curve cos φ (P)” according to this application guide, the method “reactive power/active power characteristic curve Q(P)” according to VDE-AR-N 4110 shall be selected. For this purpose, the following support points shall be parametrised in accordance with VDE-AR-N 4110, Figure 9: P1 (0,0/0,0), P2 (– 0,5/0,0), P3 (– 1,0/0,33). NOTE 1 The first value within the brackets represents the ratio P/P_{Emax}, the second represents the ratio Q/P_{Emax}.		N/A
	– For the dynamic network stability, type 2 power generation systems shall be set to the operating mode “limited dynamic network stability” in accordance with VDE-AR-N 4110, 10.2.3.3.2. NOTE 2 From 01/01/2021 onwards at the latest, type 2 power generation units in the operating mode “limited dynamic network stability” will also conduct full dynamic network stability at voltages higher than 0,7 Un.		N/A
	– Connection condition: The connection of a power generation system or storage unit in accordance with VDE-AR-N 4110 is conducted at an operating voltage between 90 % Un and 110 % Un at the generator terminals of the power generation unit with the permissible power gradients as specified in VDE-AR-N 4110.		N/A
9	Verification of the electrical properties		Info.
	This VDE application guide does not itself require certificates and/or proofs of conformity, but only provides the proofs required in NC RfG and NELEV [8] (see Preface, Section 4).		Info.

VDE-AR-N 4105			
Clause	Requirement - Test	Result - Remark	Verdict
	Together with the registration for the network connection, the connection owner hands over the cover pages of the following certificates to the network operator: − Certificate for each planned type of power generation unit and storage system (unit certificate(s), see form E.4); − Certificate for network and system protection (integrated or central) (certificate for NS protection, see form E.6); − If required in the respective connection case: Certificate for power flow monitoring at the network connection point (PAV,E monitoring, 70% limitation according to 5.7.4.2, symmetry device according to VDE-AR-N 4100, 5.5).		Info.
	In the test reports for the certificates, the electrical properties of the power generation unit, the storage system and/or the NS protection are shown. In an excerpt from the test reports (according to E.5 and E.7) the data relevant for the connection evaluation by the network operator shall be summarized.		Info.
	The certificates themselves prove that the planned power generation unit, storage system and/or NS protection meets all the requirements of this VDE application guide.		Info.
	The basis for the preparation of a unit certificate is the measurement by a test laboratory accredited according to DIN EN ISO/IEC 17025 for this area of application.		Info.
	The certification of power generation units, storage systems and NS protection must be carried out by a certification body accredited according to DIN EN ISO/IEC 17065 for this area of application.		Info.
	Details regarding the design of the metrological verification and the documentation of the measurement results are described in DIN VDE-V 0124-100 (VDE V 0124-100). The requirements of this VDE application guide must neither be compromised nor toughened.		Info.

Summary of Test

Clause	Test	Summary (P/F/N/Retest)	Checked
5.4, E.5	Rapid voltage changes	P	☒
5.4, E.5	Flicker	P	☒
5.4, E.5	Harmonics and Interharmonics	P	☒
5.5.2	$P_{AV,E}$ monitoring (feed-in limitation)	P	☒
5.7	Behaviour of the power generation system at the network	P	☒
5.7.2.2	Reactive power provision at $\sum S_{\mathrm{Emax}}$	P	☒
5.7.2.4	Procedure for reactive power provision – method a) Reactive power voltage characteristic curve Q (U)	P	☒
5.7.2.4	Procedure for reactive power provision – method b) Displacement factor/active power characteristic curve cos φ (P)	P	☒
5.7.2.4	Procedure for reactive power provision – method c) Displacement factor cos φ	P	☒
5.7.3	Dynamic network stability	P	☒
5.7.4.1	Active power output	P	☒
5.7.4.2	Network security management	P	☒
5.7.4.2.3	Active power adjustment in case of over- and under-frequency	P	☒
6.2 & 6.3	Network security (NS) protection	P	☒
6.5.1	Reporting NS protection	P	☒
6.5.1	Measuring the rise-in voltage protection as a running 10-minute mean value	P	☒
6.5.2	Protective functions	P	☒
6.5.2	Frequency Monitoring	P	☒
6.5.3	Islanding detection	P	☒
8.3.1	Connection conditions and synchronisation	P	☒
8.3.1	Reconnection after interruption	P	☒

Annex 1

Test data record

5.4, E.5	TABLE: Rapid voltage changes					P
Model	EA16KTSI					
Test cases:	Switching on without specification (10% rated output power)			Most unfavourable case when switching the generator (10% → 100% rated output power)		
Phase	A	B	C	A	B	C
Single period effective values of the voltage [V]	233.0	232.0	232.0	233.0	233.0	233.0
Single period effective values of the current [A]	2.59	2.61	2.59	4.67	4.65	4.65
k_i	0.11	0.11	0.11	0.20	0.20	0.20
Test cases:	Switching on at rated power			Switch off at rated power		
Phase	A	B	C	A	B	C
Single period effective values of the voltage [V]	21.2	21.4	21.4	232.0	233.0	233.0
Single period effective values of the current [A]	3.91	4.04	3.89	3.98	3.97	4.11
k_i	0.17	0.17	0.17	0.17	0.17	0.18
k_{imax}	0.2					
Test conditions: Frequency: 50 Hz ± 0,5% THD of the voltage supply: ≤ 3% Voltage rise of the PGU at 100% P_{Emax}: ≤ 3%						
Note: Power generation units with inverters (such as photovoltaic systems) and storage units with inverters shall only be connected with k_{imax} ≤1.2. The tests were performed on model EA16KTSI also applicable for all other models stated in this report.						

5.4, E.5	**TABLE: Flicker**				**P**
Model	EA16KTSI				
Flicker to DIN EN 61000-3-3 (VDE 0838-3) or DIN EN 61000-3-11 (VDE 0838-11) for PGUs ≤ 75 A					
Parameter:	dc%	dmax	d(t)	*P_{st}	*P_{lt}
Limit:	3.3%	4.00%	500ms	0.5	0.5
DIN EN 61000-3-11 (> 16 A)					
Phase A	0.12	1.00	0	0.47	0.47
Phase B	0.12	0.98	0	0.49	0.49
Phase C	0.11	1.14	0	0.49	0.49

Note:

* VDE-AR-N 4105:2011-08, clause 5.4.3 require all power generation systems in the low-voltage network shall not exceed the following flicker strength at the most unfavourable PCC:
Long-term flicker strength: P_{lt} = 0.5, the maximum for all P_{st} values must be selected as the value for long-term flicker value P_{lt}.

Flicker to DIN EN 61400-21 (VDE 0127-21) (or FGW TR3)		P
Grid impedance angle ψ_k	32°	
Short-term flicker P_{st}	0.49	
Flicker coefficient $c(\psi_k)$	5.72	

Assessment criterion:

Determination of the flicker coefficient:

$$c_{\psi k} = P_{st} \times (S_k / P_n)$$

Where
P_{st} is the short-term flicker value measured at the grid substitute element;
S_k is the short-circuit power of the network standby element (during the determination of the appropriate P_{st} values).

Test conditions:

Voltage: 86% U_n to 109% U_n
Frequency: 50 Hz ± 0.5%
THD of the voltage supply: ≤ 3%
Voltage rise of the PGU at 100% P_{Emax}: ≤ 3%

Note:

The tests were performed on model EA16KTSI and EA5KTSI also applicable for all other models stated in this report.

5.4, E.5	TABLE: Harmonics Test										P
Model	EA16KTSI										
Maximum permissible harmonic current as per EN 61000-3-12											Phase A
Harmonic	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Limit [%] 3-phase	8.00	N/A	4.00	10.70	2.67	7.20	2.00	N/A	1.60	3.10	1.33	2.00
Limit [%] single phase	8.00	21.60	4.00	10.70	2.67	7.20	2.00	3.80	1.60	3.10	1.33	2.00
Test value [%]	0.45	0.14	0.18	1.19	0.21	1.24	0.09	0.23	0.11	0.59	0.17	0.39
	THD						PWHD					
Limit [%] 3-phase	13						22					
Limit [%] single-phase	23						23					
Test value [%]	2.02						2.15					
Maximum permissible harmonic current as per EN 61000-3-12											Phase B
Harmonic	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Limit [%] 3-phase	8.00	N/A	4.00	10.70	2.67	7.20	2.00	N/A	1.60	3.10	1.33	2.00
Limit [%] single phase	8.00	21.60	4.00	10.70	2.67	7.20	2.00	3.80	1.60	3.10	1.33	2.00
Test value [%]	0.23	0.09	0.14	1.24	0.26	1.20	0.11	0.19	0.09	0.50	0.03	0.49
	THD						PWHD					
Limit [%] 3-phase	13						22					
Limit [%] single-phase	23						23					
Test value [%]	1.96						2.00					
Maximum permissible harmonic current as per EN 61000-3-12											Phase C
Harmonic	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th
Limit [%] 3-phase	8.00	N/A	4.00	10.70	2.67	7.20	2.00	N/A	1.60	3.10	1.33	2.00
Limit [%] single phase	8.00	21.60	4.00	10.70	2.67	7.20	2.00	3.80	1.60	3.10	1.33	2.00
Test value [%]	0.63	0.18	0.30	1.15	0.08	1.05	0.05	0.06	0.17	0.56	0.17	0.39
	THD						PWHD					
Limit [%] 3-phase	13						22					
Limit [%] single-phase	23						23					
Test value [%]	1.93						4.49					
Note: The tests should be based on the limits of the EN 61000-3-12 for more than 16 A.												

<table>
<tr><td>5.4, E.5</td><td colspan="7">TABLE: Harmonics Test</td><td>P</td></tr>
<tr><td>Model</td><td colspan="8">EA5KTSI</td></tr>
<tr><td colspan="8">Maximum permissible harmonic current as per EN 61000-3-2 Class A</td><td>Phase A</td></tr>
<tr><td>Harmonics</td><td>2nd</td><td>3rd</td><td>5th</td><td>7th</td><td>9th</td><td>11th</td><td>13th</td><td>15 th ≤n≤ 39 th</td></tr>
<tr><td>Limit [A]</td><td>1.08</td><td>2.3</td><td>1.14</td><td>0.77</td><td>0.4</td><td>0.33</td><td>0.21</td><td>0.15 * (15/n)</td></tr>
<tr><td>Test value [A]:</td><td>0.048</td><td>0.015</td><td>0.063</td><td>0.030</td><td>0.019</td><td>0.021</td><td>0.045</td><td>0.011</td></tr>
<tr><td></td><td colspan="4">THD</td><td colspan="4">PWHD</td></tr>
<tr><td>Limit [%] 3-phase</td><td colspan="4">13</td><td colspan="4">22</td></tr>
<tr><td>Limit [%] single-phase</td><td colspan="4">23</td><td colspan="4">23</td></tr>
<tr><td>Test value [%]</td><td colspan="4">1.56</td><td colspan="4">1.61</td></tr>
<tr><td colspan="8">Maximum permissible harmonic current as per EN 61000-3-2 Class A</td><td>Phase B</td></tr>
<tr><td>Harmonics</td><td>2nd</td><td>3rd</td><td>5th</td><td>7th</td><td>9th</td><td>11th</td><td>13th</td><td>15 th ≤n≤ 39 th</td></tr>
<tr><td>Limit [A]</td><td>1.08</td><td>2.3</td><td>1.14</td><td>0.77</td><td>0.4</td><td>0.33</td><td>0.21</td><td>0.15 * (15/n)</td></tr>
<tr><td>Test value [A]:</td><td>0.016</td><td>0.008</td><td>0.069</td><td>0.026</td><td>0.009</td><td>0.027</td><td>0.051</td><td>0.014</td></tr>
<tr><td></td><td colspan="4">THD</td><td colspan="4">PWHD</td></tr>
<tr><td>Limit [%] 3-phase</td><td colspan="4">13</td><td colspan="4">22</td></tr>
<tr><td>Limit [%] single-phase</td><td colspan="4">23</td><td colspan="4">23</td></tr>
<tr><td>Test value [%]</td><td colspan="4">1.47</td><td colspan="4">1.70</td></tr>
<tr><td colspan="8">Maximum permissible harmonic current as per EN 61000-3-2 Class A</td><td>Phase C</td></tr>
<tr><td>Harmonics</td><td>2nd</td><td>3rd</td><td>5th</td><td>7th</td><td>9th</td><td>11th</td><td>13th</td><td>15 th ≤n≤ 39 th</td></tr>
<tr><td>Limit [A]</td><td>1.08</td><td>2.3</td><td>1.14</td><td>0.77</td><td>0.4</td><td>0.33</td><td>0.21</td><td>0.15 * (15/n)</td></tr>
<tr><td>Test value [A]:</td><td>0.033</td><td>0.019</td><td>0.062</td><td>0.030</td><td>0.013</td><td>0.035</td><td>0.046</td><td>0.016</td></tr>
<tr><td></td><td colspan="4">THD</td><td colspan="4">PWHD</td></tr>
<tr><td>Limit [%] 3-phase</td><td colspan="4">13</td><td colspan="4">22</td></tr>
<tr><td>Limit [%] single-phase</td><td colspan="4">23</td><td colspan="4">23</td></tr>
<tr><td>Test value [%]</td><td colspan="4">1.59</td><td colspan="4">1.75</td></tr>
<tr><td colspan="9">Note:
The tests should be based on the limits of the EN 61000-3-2 for less than 16 A.
The tests were performed on model EA16KTSI and EA5KTSI also applicable for all other models stated in this report.</td></tr>
</table>

5.4, E.5	**Additional Measurements for PGU provided for PGS having Nominal Currents > 75 A**									**P**
Model	EA16KTSI									
Harmonics										
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2	0.36	1.69	1.09	0.79	0.61	0.46	0.59	0.49	0.88	0.42	0.45
3	0.37	0.75	0.50	0.37	0.28	0.20	0.29	0.24	0.33	0.13	0.14
4	0.22	1.70	0.76	0.57	0.44	0.32	0.41	0.30	0.33	0.18	0.18
5	1.25	8.12	2.35	2.62	1.88	1.18	2.13	1.88	1.77	1.45	1.19
6	0.56	1.07	0.31	0.23	0.20	0.12	0.27	0.18	0.19	0.11	0.21
7	1.59	8.46	1.73	1.14	0.88	0.58	0.74	0.90	1.18	1.17	1.24
8	0.26	0.21	0.46	0.11	0.08	0.09	0.14	0.11	0.19	0.09	0.09
9	0.66	1.57	0.96	0.49	0.41	0.37	0.50	0.50	0.43	0.27	0.23
10	0.30	0.46	0.21	0.21	0.10	0.10	0.06	0.05	0.20	0.14	0.11
11	0.81	5.44	4.68	1.48	0.39	0.34	0.38	0.42	0.83	0.55	0.59
12	0.63	0.58	0.39	0.35	0.21	0.14	0.07	0.04	0.10	0.12	0.17
13	1.07	3.24	3.38	1.60	0.32	0.27	0.26	0.45	0.53	0.41	0.39
14	0.15	0.53	0.08	0.16	0.09	0.09	0.05	0.05	0.08	0.02	0.05
15	0.49	1.02	0.45	0.33	0.25	0.13	0.15	0.11	0.14	0.07	0.06
16	0.26	0.68	0.27	0.12	0.09	0.07	0.06	0.05	0.10	0.06	0.06
17	0.34	3.04	2.52	1.95	1.16	0.52	0.36	0.07	0.16	0.24	0.29
18	0.56	0.61	0.30	0.29	0.11	0.20	0.11	0.10	0.16	0.08	0.03
19	0.59	2.46	1.85	1.09	0.91	0.57	0.37	0.23	0.26	0.22	0.26
20	0.19	0.13	0.09	0.07	0.04	0.08	0.03	0.02	0.06	0.04	0.03
21	0.39	0.98	0.78	0.57	0.47	0.37	0.18	0.16	0.19	0.18	0.20
22	0.22	0.26	0.14	0.03	0.07	0.03	0.04	0.04	0.27	0.02	0.02
23	0.51	1.34	0.75	0.47	0.44	0.44	0.30	0.24	0.23	0.06	0.04
24	0.35	0.51	0.28	0.10	0.10	0.08	0.03	0.02	0.05	0.02	0.02
25	0.21	0.79	0.24	0.58	0.25	0.38	0.21	0.21	0.16	0.06	0.02
26	0.04	0.34	0.21	0.08	0.05	0.05	0.03	0.03	0.08	0.03	0.02
27	0.27	0.37	0.24	0.15	0.11	0.11	0.02	0.05	0.10	0.06	0.02
28	0.14	0.11	0.07	0.04	0.03	0.03	0.04	0.03	0.05	0.03	0.02
29	0.07	0.67	0.13	0.52	0.28	0.21	0.13	0.17	0.18	0.09	0.05
30	0.23	0.10	0.11	0.05	0.03	0.02	0.01	0.01	0.03	0.01	0.02
31	0.11	0.61	0.18	0.33	0.27	0.12	0.09	0.13	0.14	0.10	0.06
32	0.07	0.09	0.09	0.02	0.02	0.02	0.01	0.01	0.04	0.01	0.01
33	0.17	0.22	0.10	0.05	0.07	0.05	0.02	0.02	0.07	0.01	0.02
34	0.14	0.13	0.06	0.03	0.02	0.03	0.01	0.01	0.04	0.01	0.01
35	0.08	0.47	0.26	0.13	0.20	0.16	0.11	0.08	0.13	0.11	0.08
36	0.13	0.12	0.04	0.04	0.02	0.02	0.01	0.01	0.03	0.01	0.01
37	0.40	0.26	0.10	0.07	0.17	0.13	0.09	0.05	0.12	0.08	0.05
38	0.03	0.15	0.06	0.03	0.02	0.01	0.01	0.01	0.02	0.01	0.01
39	0.08	0.34	0.25	0.20	0.17	0.15	0.07	0.07	0.09	0.07	0.08
40	0.07	0.07	0.06	0.03	0.02	0.03	0.01	0.01	0.07	0.01	0.01

5.4, E.5	**Additional Measurements for PGU provided for PGS having Nominal Currents > 75 A**									**P**
Model	EA5KTSI									
Harmonics										
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2	0.34	4.29	2.16	1.44	1.12	0.89	1.15	0.96	1.03	0.78	0.67
3	0.44	1.95	0.50	0.29	0.24	0.20	0.30	0.24	0.27	0.20	0.22
4	0.21	3.92	1.92	1.24	1.00	0.80	1.01	0.83	0.77	0.56	0.38
5	1.13	7.25	2.04	2.62	2.16	1.70	1.73	1.34	1.10	0.89	0.88
6	0.67	1.91	0.80	0.50	0.39	0.31	0.30	0.26	0.28	0.22	0.22
7	1.30	7.26	1.30	1.25	1.39	1.14	0.86	0.40	0.25	0.19	0.42
8	0.31	1.34	1.02	0.61	0.36	0.29	0.33	0.27	0.32	0.24	0.17
9	0.66	1.82	1.30	1.02	0.65	0.47	0.41	0.33	0.32	0.25	0.27
10	0.33	1.21	0.22	0.43	0.28	0.17	0.13	0.11	0.17	0.10	0.10
11	0.83	3.12	4.33	2.17	0.58	0.29	0.67	0.58	0.93	0.39	0.30
12	0.85	2.23	0.97	0.76	0.58	0.47	0.42	0.35	0.34	0.25	0.24
13	1.01	5.17	2.21	2.95	1.34	0.56	0.17	0.42	0.69	0.63	0.63
14	0.25	0.51	0.72	0.18	0.27	0.19	0.15	0.11	0.16	0.07	0.05
15	0.64	1.77	0.84	0.60	0.50	0.38	0.30	0.26	0.25	0.18	0.16
16	0.37	1.35	0.59	0.24	0.22	0.19	0.22	0.19	0.17	0.12	0.11
17	0.24	2.00	1.35	0.96	1.57	1.31	0.76	0.38	0.19	0.05	0.11
18	0.73	1.28	0.63	0.51	0.38	0.29	0.18	0.13	0.15	0.11	0.07
19	0.56	2.85	0.69	0.42	1.03	0.93	0.48	0.33	0.25	0.14	0.05
20	0.23	0.66	0.24	0.16	0.13	0.06	0.06	0.06	0.12	0.05	0.06
21	0.47	0.56	0.28	0.09	0.13	0.14	0.09	0.08	0.11	0.07	0.06
22	0.32	0.76	0.32	0.15	0.09	0.07	0.02	0.03	0.24	0.03	0.04
23	0.57	0.80	0.16	0.44	0.39	0.40	0.21	0.20	0.22	0.14	0.08
24	0.42	0.65	0.29	0.19	0.12	0.08	0.05	0.05	0.07	0.04	0.03
25	0.20	0.69	0.84	0.58	0.28	0.10	0.10	0.20	0.23	0.18	0.10
26	0.05	0.25	0.20	0.14	0.14	0.07	0.04	0.04	0.05	0.04	0.04
27	0.28	0.84	0.67	0.42	0.32	0.15	0.10	0.10	0.10	0.09	0.07
28	0.15	0.55	0.17	0.07	0.08	0.05	0.02	0.03	0.04	0.04	0.03
29	0.12	0.65	1.01	0.30	0.25	0.09	0.06	0.10	0.13	0.12	0.10
30	0.19	0.23	0.16	0.08	0.08	0.05	0.03	0.03	0.04	0.02	0.02
31	0.09	1.02	0.46	0.13	0.15	0.07	0.03	0.05	0.06	0.03	0.05
32	0.06	0.32	0.11	0.05	0.07	0.05	0.04	0.04	0.04	0.01	0.01
33	0.16	0.74	0.39	0.20	0.18	0.10	0.15	0.16	0.20	0.10	0.05
34	0.14	0.16	0.09	0.05	0.04	0.02	0.02	0.03	0.04	0.02	0.01
35	0.18	0.58	0.20	0.25	0.15	0.23	0.13	0.09	0.08	0.04	0.04
36	0.11	0.17	0.08	0.06	0.04	0.04	0.02	0.02	0.02	0.01	0.01
37	0.53	0.93	0.31	0.26	0.12	0.20	0.04	0.03	0.05	0.06	0.08
38	0.09	0.27	0.15	0.11	0.08	0.06	0.03	0.01	0.02	0.02	0.02
39	0.07	0.40	0.23	0.30	0.24	0.19	0.13	0.07	0.03	0.02	0.04
40	0.05	0.16	0.13	0.13	0.07	0.06	0.03	0.03	0.04	0.02	0.01

5.4, E.5	**Additional Measurements for PGU provided for PGS having Nominal Currents > 75 A**										**P**
Model	EA16KTSI										
Interharmonics											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
75	0.080	1.131	0.578	0.474	0.313	0.256	0.205	0.184	0.162	0.140	0.110
125	0.061	0.388	0.182	0.125	0.102	0.086	0.071	0.053	0.051	0.050	0.038
175	0.064	0.338	0.155	0.108	0.085	0.070	0.063	0.045	0.041	0.046	0.035
225	0.064	0.397	0.145	0.105	0.080	0.066	0.061	0.041	0.039	0.043	0.034
275	0.061	0.328	0.153	0.099	0.076	0.068	0.060	0.045	0.038	0.044	0.035
325	0.065	0.329	0.160	0.102	0.080	0.068	0.061	0.045	0.040	0.046	0.037
375	0.066	0.334	0.158	0.106	0.081	0.068	0.063	0.045	0.041	0.047	0.039
425	0.066	0.293	0.151	0.111	0.083	0.069	0.067	0.044	0.039	0.046	0.037
475	0.065	0.308	0.157	0.112	0.086	0.072	0.068	0.048	0.042	0.049	0.039
525	0.065	0.377	0.167	0.119	0.090	0.073	0.071	0.047	0.044	0.048	0.039
575	0.067	0.363	0.182	0.119	0.095	0.078	0.075	0.053	0.048	0.053	0.045
625	0.066	0.391	0.183	0.127	0.095	0.078	0.076	0.054	0.049	0.052	0.042
675	0.070	0.400	0.194	0.131	0.100	0.083	0.081	0.061	0.055	0.058	0.049
725	0.071	0.363	0.188	0.132	0.101	0.087	0.080	0.063	0.058	0.058	0.050
775	0.075	0.385	0.201	0.138	0.108	0.090	0.086	0.071	0.065	0.067	0.054
825	0.073	0.426	0.228	0.149	0.123	0.103	0.086	0.070	0.065	0.063	0.054
875	0.076	0.462	0.228	0.175	0.124	0.100	0.088	0.072	0.065	0.066	0.059
925	0.083	0.452	0.236	0.164	0.124	0.104	0.085	0.071	0.067	0.067	0.058
975	0.078	0.488	0.243	0.173	0.130	0.110	0.084	0.070	0.064	0.067	0.058
1025	0.082	0.474	0.251	0.177	0.134	0.114	0.083	0.070	0.067	0.070	0.059
1075	0.085	0.475	0.262	0.184	0.142	0.119	0.081	0.071	0.070	0.070	0.060
1125	0.086	0.513	0.288	0.196	0.149	0.131	0.079	0.071	0.071	0.072	0.062
1175	0.102	0.632	0.396	0.262	0.204	0.173	0.078	0.076	0.076	0.072	0.067
1225	0.092	0.510	0.315	0.208	0.164	0.149	0.070	0.068	0.071	0.069	0.062
1275	0.102	1.031	0.638	0.454	0.370	0.320	0.136	0.127	0.127	0.121	0.120
1325	0.115	0.548	0.318	0.247	0.191	0.173	0.071	0.067	0.070	0.070	0.067
1375	0.106	0.533	0.314	0.231	0.196	0.185	0.065	0.058	0.065	0.063	0.061
1425	0.175	0.513	0.275	0.203	0.158	0.152	0.054	0.045	0.048	0.052	0.047
1475	0.119	0.555	0.307	0.232	0.185	0.168	0.051	0.043	0.046	0.048	0.044
1525	0.155	0.429	0.242	0.199	0.154	0.148	0.056	0.050	0.050	0.052	0.049
1575	0.108	0.412	0.214	0.167	0.128	0.124	0.043	0.036	0.036	0.041	0.035
1625	0.170	0.392	0.206	0.155	0.134	0.128	0.053	0.049	0.049	0.050	0.046
1675	0.117	0.336	0.177	0.125	0.109	0.102	0.039	0.029	0.029	0.032	0.027
1725	0.190	0.400	0.176	0.122	0.103	0.094	0.036	0.028	0.028	0.031	0.026
1775	0.119	0.335	0.164	0.115	0.096	0.084	0.033	0.025	0.025	0.029	0.023
1825	0.119	0.338	0.150	0.105	0.087	0.078	0.033	0.026	0.026	0.028	0.023
1875	0.138	0.311	0.144	0.097	0.082	0.072	0.031	0.026	0.026	0.028	0.023
1925	0.131	0.250	0.133	0.088	0.074	0.065	0.030	0.024	0.023	0.025	0.021
1975	0.141	0.250	0.128	0.087	0.070	0.062	0.030	0.022	0.021	0.024	0.019

5.4, E.5	**Additional Measurements for PGU provided for PGS having Nominal Currents > 75 A**										**P**
Model	EA5KTSI										
Interharmonics											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
75	0.020	0.025	0.025	0.022	0.021	0.024	0.028	0.021	0.021	0.027	0.020
125	0.004	0.009	0.008	0.006	0.005	0.008	0.009	0.005	0.005	0.008	0.026
175	0.003	0.006	0.006	0.005	0.004	0.006	0.007	0.004	0.004	0.006	0.009
225	0.003	0.005	0.005	0.004	0.004	0.005	0.006	0.004	0.004	0.005	0.006
275	0.003	0.005	0.006	0.005	0.005	0.005	0.006	0.004	0.004	0.005	0.005
325	0.004	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005
375	0.003	0.005	0.005	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.006
425	0.004	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.005
475	0.003	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
525	0.003	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.006	0.006	0.006
575	0.004	0.006	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007	0.006
625	0.004	0.006	0.008	0.011	0.012	0.014	0.014	0.014	0.014	0.014	0.008
675	0.004	0.008	0.008	0.009	0.008	0.008	0.007	0.007	0.007	0.007	0.015
725	0.004	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008
775	0.004	0.007	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007
825	0.004	0.006	0.007	0.007	0.007	0.008	0.007	0.007	0.007	0.007	0.008
875	0.003	0.007	0.009	0.009	0.009	0.009	0.008	0.008	0.008	0.008	0.008
925	0.004	0.007	0.008	0.008	0.009	0.009	0.008	0.008	0.008	0.008	0.008
975	0.004	0.009	0.011	0.009	0.009	0.010	0.009	0.009	0.009	0.009	0.010
1025	0.005	0.007	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
1075	0.004	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
1125	0.004	0.008	0.010	0.009	0.009	0.010	0.010	0.009	0.009	0.010	0.010
1175	0.004	0.009	0.012	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.010
1225	0.004	0.008	0.009	0.009	0.009	0.010	0.010	0.010	0.010	0.010	0.012
1275	0.004	0.010	0.011	0.011	0.011	0.013	0.012	0.012	0.012	0.013	0.011
1325	0.005	0.009	0.011	0.010	0.011	0.012	0.012	0.012	0.012	0.012	0.013
1375	0.004	0.009	0.010	0.010	0.011	0.010	0.010	0.011	0.011	0.011	0.013
1425	0.009	0.011	0.012	0.011	0.012	0.012	0.011	0.011	0.011	0.011	0.012
1475	0.004	0.009	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.012
1525	0.007	0.009	0.009	0.010	0.010	0.011	0.010	0.011	0.011	0.011	0.011
1575	0.004	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.012
1625	0.008	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.011	0.011	0.009
1675	0.004	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008	0.011
1725	0.008	0.009	0.009	0.009	0.009	0.008	0.008	0.008	0.008	0.008	0.008
1775	0.004	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.008
1825	0.004	0.007	0.006	0.006	0.006	0.006	0.006	0.007	0.006	0.006	0.007
1875	0.004	0.008	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.007	0.007
1925	0.005	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.007
1975	0.004	0.007	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.006	0.006

5.4, E.5	**Additional Measurements for PGU provided for PGS having Nominal Currents > 75 A**										**P**
Model	EA16KTSI										
Higher Frequencies											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [kHz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2.1	0.02	0.12	0.03	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01
2.3	0.05	0.09	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2.5	0.06	0.10	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
2.7	0.05	0.09	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01
2.9	0.03	0.15	0.06	0.05	0.02	0.03	0.02	0.02	0.01	0.01	0.01
3.1	0.03	0.09	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.02	0.03
3.3	0.02	0.06	0.03	0.04	0.02	0.02	0.03	0.02	0.02	0.02	0.03
3.5	0.02	0.17	0.07	0.05	0.03	0.03	0.03	0.02	0.02	0.02	0.02
3.7	0.02	0.07	0.03	0.02	0.01	0.01	0.02	0.02	0.03	0.02	0.01
3.9	0.02	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.02	0.03
4.1	0.02	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02
4.3	0.02	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
4.5	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.7	0.01	0.06	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.9	0.02	0.05	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.1	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.3	0.02	0.06	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.5	0.01	0.05	0.02	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.7	0.02	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.9	0.02	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.1	0.01	0.05	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01
6.3	0.02	0.09	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.5	0.02	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.7	0.01	0.12	0.02	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.9	0.01	0.10	0.02	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01
7.1	0.02	0.22	0.03	0.07	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7.3	0.01	0.18	0.03	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7.5	0.02	0.09	0.03	0.04	0.01	0.01	0.01	0.01	0.03	0.01	0.01
7.7	0.02	0.18	0.04	0.06	0.01	0.01	0.01	0.01	0.02	0.01	0.01
7.9	0.02	0.11	0.03	0.05	0.01	0.01	0.01	0.01	0.02	0.01	0.01
8.1	0.02	0.06	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.01	0.01
8.3	0.02	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.01	0.01
8.5	0.02	0.08	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8.7	0.02	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
8.9	0.02	0.08	0.02	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.01

5.4, E.5	**Additional Measurements for PGU provided for PGS having Nominal Currents > 75 A**										**P**
Model	EA5KTSI										
Higher Frequencies											
P/P_n [%]	0	10	20	30	40	50	60	70	80	90	100
f [kHz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2.1	0.05	0.14	0.08	0.04	0.02	0.02	0.02	0.02	0.02	0.02	0.02
2.3	0.05	0.10	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.02
2.5	0.08	0.08	0.04	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01
2.7	0.04	0.11	0.08	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.01
2.9	0.04	0.16	0.04	0.04	0.03	0.02	0.01	0.01	0.02	0.01	0.01
3.1	0.07	0.10	0.04	0.04	0.03	0.03	0.02	0.02	0.03	0.02	0.02
3.3	0.04	0.10	0.08	0.03	0.03	0.03	0.02	0.02	0.03	0.02	0.01
3.5	0.04	0.17	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.01	0.01
3.7	0.05	0.09	0.04	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01
3.9	0.04	0.09	0.08	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.1	0.04	0.08	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.3	0.04	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.5	0.04	0.07	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.7	0.04	0.07	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.9	0.04	0.08	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.1	0.04	0.07	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.3	0.04	0.08	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.5	0.04	0.09	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
5.7	0.04	0.08	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5.9	0.04	0.09	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.1	0.04	0.10	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01
6.3	0.03	0.10	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.5	0.04	0.12	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
6,7	0.04	0.14	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
6.9	0.04	0.14	0.08	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7.1	0.04	0.18	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7.3	0.04	0.20	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
7.5	0.04	0.22	0.08	0.03	0.03	0.01	0.02	0.01	0.01	0.01	0.01
7.7	0.04	0.24	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01
7.9	0.04	0.17	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8.1	0.04	0.19	0.08	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
8.3	0.04	0.14	0.04	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
8.5	0.04	0.09	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8.7	0.04	0.12	0.08	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
8.9	0.04	0.06	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

Note:

The stated harmonics are max values of three phases.

The tests were performed on model EA5KTSI/ EA16KTSI also applicable for all other models stated in this report.

5.5.2	TABLE: $P_{AV,E}$ monitoring (feed-in limitation)		P
Model	EA16KTSI		
Time after adjustment	Actual P_{mom}	P_{mom} limit	
3 s	9660.70	10176	
5 s	9617.20	9696.45	

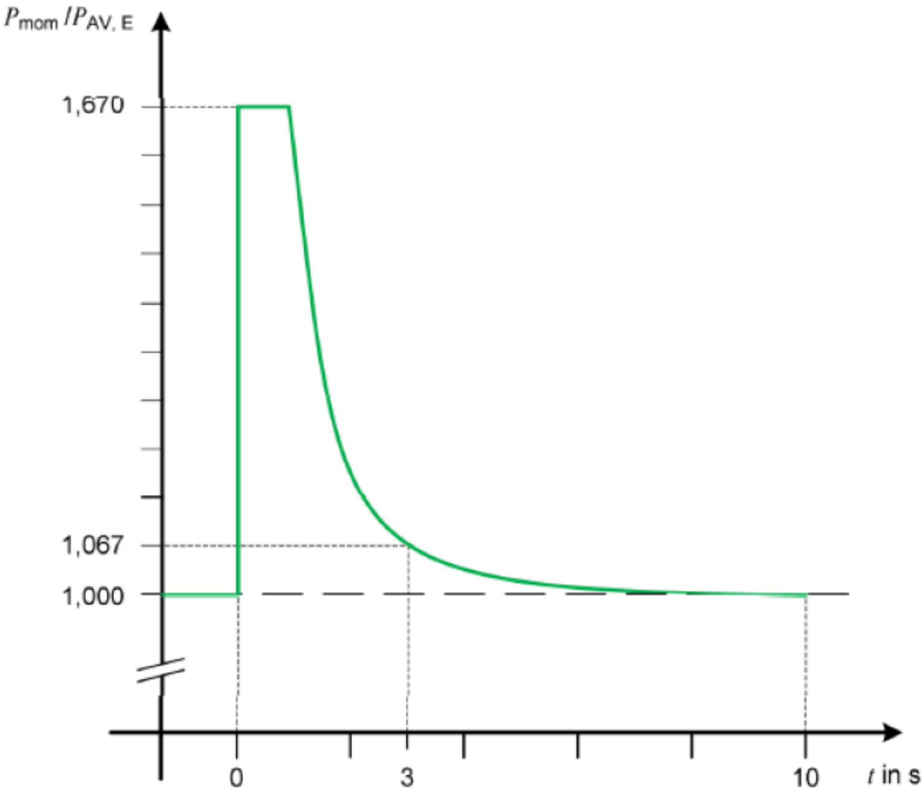


Figure 1 - Active power limit curve for power generation systems

- Calculate $P_{AV,E}$ by $P_{AV,E}$ = 0,6 P_{Emax}
- Ensure power generation unit is working at maximum active power P_{Emax}
- Adjust power generation unit power to $P_{AV,E}$
- Record P_{mom} at 3 s after the action of adjustment. P_{mom} shall be no more than 1,067 $P_{AV,E}$
- Record P_{mom} at 10 s after the action of adjustment. P_{mom} shall be no more than $P_{AV,E}$
- The active power limit curve follows in the exponential course of the following function: $PAV,E(t)= 0.67 \times e^{-1,05\times(t-0,8)}+1$

The tests were performed on model EA5KTSI/ EA16KTSI also applicable for all other models stated in this report.

5.7	TABLE: Behaviour of the power generation system at the network				P
Model	EA16KTSI				
Test sequence	Frequency	Output power	cos φ	Time period measured	Time period Required
Test 1	47.5 Hz	15920	0.99	33.33	≥ 30 min
Test 2	49.0 Hz	15856	0.92	33.33	≥ 30 min
Test 3	51.0 Hz	15853	0.88	33.33	≥ 30 min
Test 4	51.5 Hz	15851	0.96	33.33	≥ 30 min

Power generation units must be able to withstand rapid frequency changes without being disconnected from the network. This requirement applies as long as the following mean frequency change rates (RoCoF) are not exceeded:

Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+ 2.0 Hz/s	0.5 s	No trip
51.0 Hz to 49.0 Hz	- 2.0 Hz/s	0.5 s	No trip
49.0 Hz to 51.0 Hz	+1.5 Hz/s	1.0 s	No trip
51.0 Hz to 49.0 Hz	-1.5 Hz/s	1.0 s	No trip
49.0 Hz to 51.0 Hz	+1.25 Hz/s	2.0 s	No trip
51.0 Hz to 49.0 Hz	-1.25 Hz/s	2.0 s	No trip

Note:

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

5.7.2.2.	**TABLE: Reactive power provision at $\sum S_{\mathrm{Emax}}$**							**P**
Model	EA16KTSI							
Setting values	cos φ max over-excited:				+0.90			
	cos φ max under-excited:				-0.90			
Overexcited: U/U_n	0.90	1.00	1.05	1.06	1.07	1.08	1.09	1.10
U [V]	205.9	230.8	241.4	243.6	245.9	248.2	250.6	252.9
$P_{Emax\ 600}$ [kW]	14.544	14.736	14.696	14.687	14.680	14.676	14.673	14.671
$S_{Emax600}$ [kVA]	16.077	16.284	16.243	16.233	16.266	16.219	16.215	16.212
file: cos φ (c)	0.905	0.905	0.905	0.905	0.905	0.905	0.905	0.905
Underexcited: U/U_n	0.90	0.91	0.92	0.93	0.94	0.95	1.00	1.10
U [V]	206.9	209.1	211.5	213.7	216.0	218.3	230.3	252.8
$P_{Emax\ 600}$ [kW]	14.586	14.739	14.820	14.807	14.795	14.785	14.738	14.668
$S_{Emax600}$ [kVA]	16.126	16.291	16.379	16.365	16.351	16.340	16.285	16.206
file: cos φ (i)	0.905	0.905	0.905	0.905	0.905	0.905	0.905	0.905
$P_{Emax\ 600}$ [kW]					14.820			
$S_{Emax600}$ [kVA]					16.379			

Assessment criterion:

For generator units (PGU) used in generator plants (PGS) ≤ 4,6 kVA, *cos φ* shall meet figure 2 as following:

For generator units (PGU) used in generator plants (PGS) > 4,6 kVA, *cos φ* shall meet figure 3 as following:

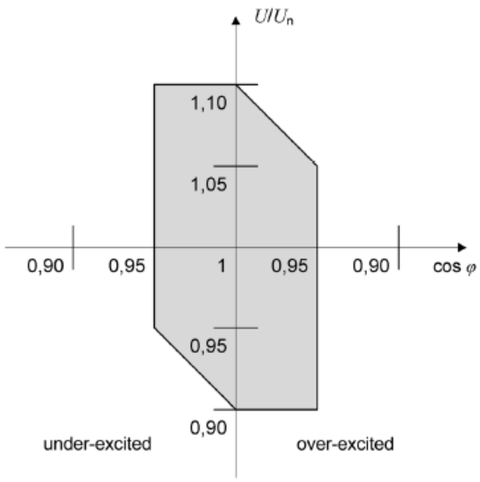


Figure 2

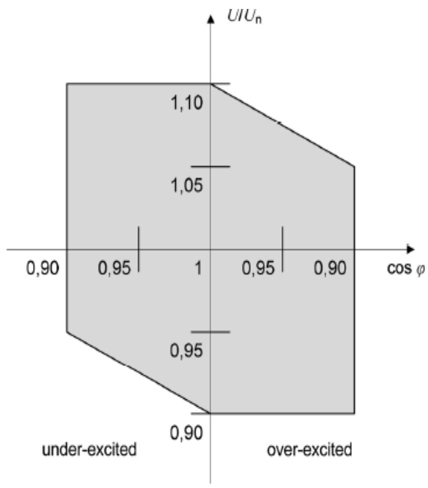


Figure 3

Note:
The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

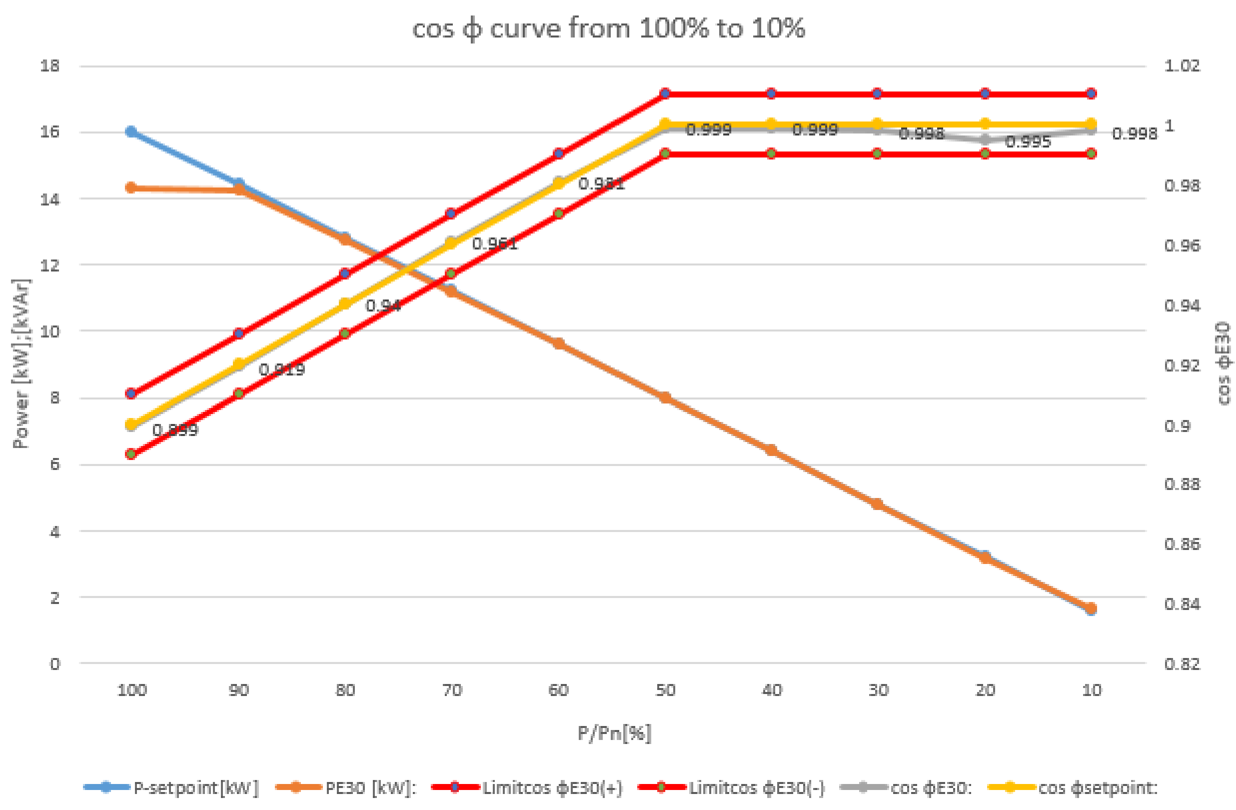
5.7.2.4	TABLE: Procedure for reactive power provision – method a) Reactive power voltage characteristic curve Q (U)					P
Model	EA16KTSI					
Test a)						
P/P_n [%] Set-point	Vac [V] Set-point	P/P_n [%] Actual	Vac [V] Actual	Q [Var] Actual	Q [Var] Limit	∆Q (≤ ± 4% P_n)
< 20%	0.93 Vn	18	212.68	-6983.08	-6976	7.08
< 20%	0.97Vn	18	223.98	172.73	0	172.73
< 20%	1.03 Vn	18	236.76	288.43	0	288.43
< 20%	1.07 Vn	18	245.59	6840.59	6976	135.41
< 20% → 30%	0.93 Vn	25	213.26	-7008.45	-6976	32.45
< 20% → 30%	0.97 Vn	25	223.75	322.59	0	322.59
< 20% → 30%	1.03 Vn	25	237.45	214.74	0	214.74
< 20% → 30%	1.07 Vn	25	245.65	6993.74	6976	17.74
40%	0.93 Vn	40	213.73	6991.58	-6976	15.58
40%	0.97 Vn	40	223.95	321.40	0	321.40
40%	1.03 Vn	40	237.77	333.48	0	333.48
40%	1.07 Vn	40	245.78	6997.42	6976	23.42
50%	0.93 Vn	50	213.74	-6977.72	-6976	1.72
50%	0.97 Vn	50	224.21	316.67	0	316.67
50%	1.03 Vn	50	236.96	319.78	0	319.78
50%	1.07 Vn	50	245.22	6995.46	6976	19.46
60%	0.93 Vn	60	213.91	-6964.83	-6976	32.83
60%	0.97 Vn	60	224.36	276.63	0	276.63
60%	1.03 Vn	60	237.13	307.01	0	307.01
60%	1.07 Vn	60	245.96	6989.23	6976	13.23
70%	0.93 Vn	70	214.00	-6949.10	-6976	27.10
70%	0.97 Vn	70	223.50	63.62	0	63.62
70%	1.03 Vn	70	236.83	288.52	0	288.52
70%	1.07 Vn	70	246.14	6981.40	6976	5.14
80%	0.93 Vn	80	214.14	-6933.44	-6976	43.44
80%	0.97 Vn	80	223.84	361.08	0	361.08
80%	1.03 Vn	80	237.51	346.01	0	346.01
80%	1.07 Vn	80	246.38	6976.63	6976	0.63
90%	0.93 Vn	90	213.89	-6924.39	-6976	54.39
90%	0.97 Vn	90	223.94	376.19	0	376.19
90%	1.03 Vn	90	236.79	352.62	0	352.62

90%	1.07 Vn	90	246.46	6973.73	6976	2.27
100%	0.93 Vn	100	212.46	-6924.49	-6976	51.15
100%	0.97 Vn	100	223.04	384.43	0	384.43
100%	1.03 Vn	100	236.83	357.29	0	357.29
100%	1.07 Vn	100	246.51	6968.73	6976	7.27
Note: The tests were performed on model EA16KTSI also applicable for all other models stated in this report.						

5.7.2.4	TABLE: Procedure for reactive power provision – method b) Displacement factor/active power characteristic curve cos φ (P)									P
Model	EA16KTSI									
Test a):										
30 s mean value	10% → 100% P_{Emax}									
P/P_n [%]	10	20	30	40	50	60	70	80	90	100
U [V]:	230.00	230.61	230.72	231.01	231.13	231.40	230.73	230.46	230.50	230.51
P_{E30} [kW]:	1.600	3.181	4.790	6.396	7.997	9.574	11.145	12.706	14.263	14.304
P_{E30} of P_{Emax} [%]:	10.00	19.88	29.94	39.97	49.98	59.83	69.65	79.41	89.14	89.63
Q_{E30} [kVAr]:	0.194	0.147	0.271	0.170	0.318	1.880	3.218	4.603	6.009	6.977
cos φ_{E30}:	0.994	0.995	0.998	0.999	0.999	0.981	0.960	0.940	0.919	0.898
cos $\varphi_{setpoint}$:	1.000	1.000	1.000	1.000	1.000	0.980	0.960	0.940	0.920	0.900
30 s mean value	100% → 10% P_{Emax}									
P/P_n [%]	100	90	80	70	60	50	40	30	20	10
U [V]:	230.56	230.58	230.54	230.88	231.45	231.19	231.03	230.87	230.62	230.00
P_{E30} [kW]:	14.303	14.263	12.707	11.145	9.574	7.997	6.398	4.790	3.182	1.649
P_{E30} of P_{Emax} [%]:	89.39	89.14	79.42	69.66	59.83	49.98	39.98	29.94	19.89	10.31
Q_{E30} [kVAr]:	6.976	6.099	4.603	3.218	1.879	0.326	0.317	0.320	0.321	0.104
cos φ_{E30}:	0.899	0.919	0.940	0.961	0.981	0.999	0.999	0.998	0.995	0.998
cos $\varphi_{setpoint}$:	0.900	0.920	0.940	0.960	0.980	1.000	1.000	1.000	1.000	1.000
Limit cos φ_{E30}:	cos $\varphi_{setpoint}$ ± 0.01									
Note: The tests were performed on model EA16KTSI also applicable for all other models stated in this report.										

Graph of cos φ over-excited (c) and under-excited (i) from 10% to 100% P_{Emax}

Graph of cos φ over-excited (c) and under-excited (i) from 100% to 10% P_{Emax}



Test b):			
30 s mean value	10% → 50% → 100% P_{Emax}		
P/P_n [%]	10	50	100
U [V]:	230.00	230.77	230.54
P_{E30} [kW]:	1.645	8.305	14.304
P_{E30} of P_{Emax} [%]:	10.29	51.90	89.4
Q_{E30} [kVAr]:	0.104	0.800	6.975
cos φ_{E30}:	0.998	0.991	0.899
cos $\varphi_{setpoint}$:	1.000	1.000	0.900
ΔT [s]:	10% → 50% P_{Emax}:	5	
	50% → 100% P_{Emax}:	4	
30 s mean value	100% → 50% → 10% P_{Emax}		
P/P_n [%]	100	50	10
U [V]:	230.54	231.14	230.22
P_{E30} [kW]:	14.600	7.997	1.682
P_{E30} of P_{Emax} [%]:	91.25	49.98	10.51
Q_{E30} [kVAr]:	6.683	0.327	0.460
cos φ_{E30}:	0.912	0.999	0.996
cos $\varphi_{setpoint}$:	0.900	1.000	1.000
ΔT [s]:	100% → 50% P_{Emax}:	6	
	50% → 10% P_{Emax}:	6	
Limit T_0 [s]:	10		
Limit cos φ_{E30}:	cos $\varphi_{setpoint}$ ± 0.02		

Note:

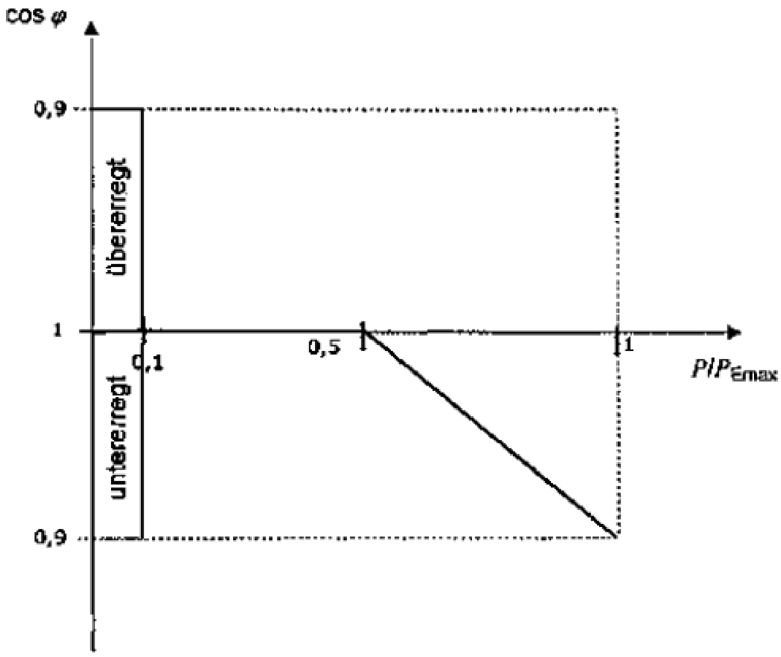
When cos φ noise is superimposed due to island grid detection, and the cos φ tolerance band ±0.02 is violated for the nominal value after transient due to this noise, then this parasitic induction caused by island grid detection can be neglected.

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

Test:

Test a): Using the standard characteristic curve increases the active power from 10% P_{Emax} in increments of 10% P_{Emax} to 100% P_{Emax}. The test is carried out in reverse.

Test b): Using the standard characteristic curve increases the active power from 10% P_{Emax} to 50% P_{Emax} and to 100% P_{Emax}. The test is carried out in reverse.



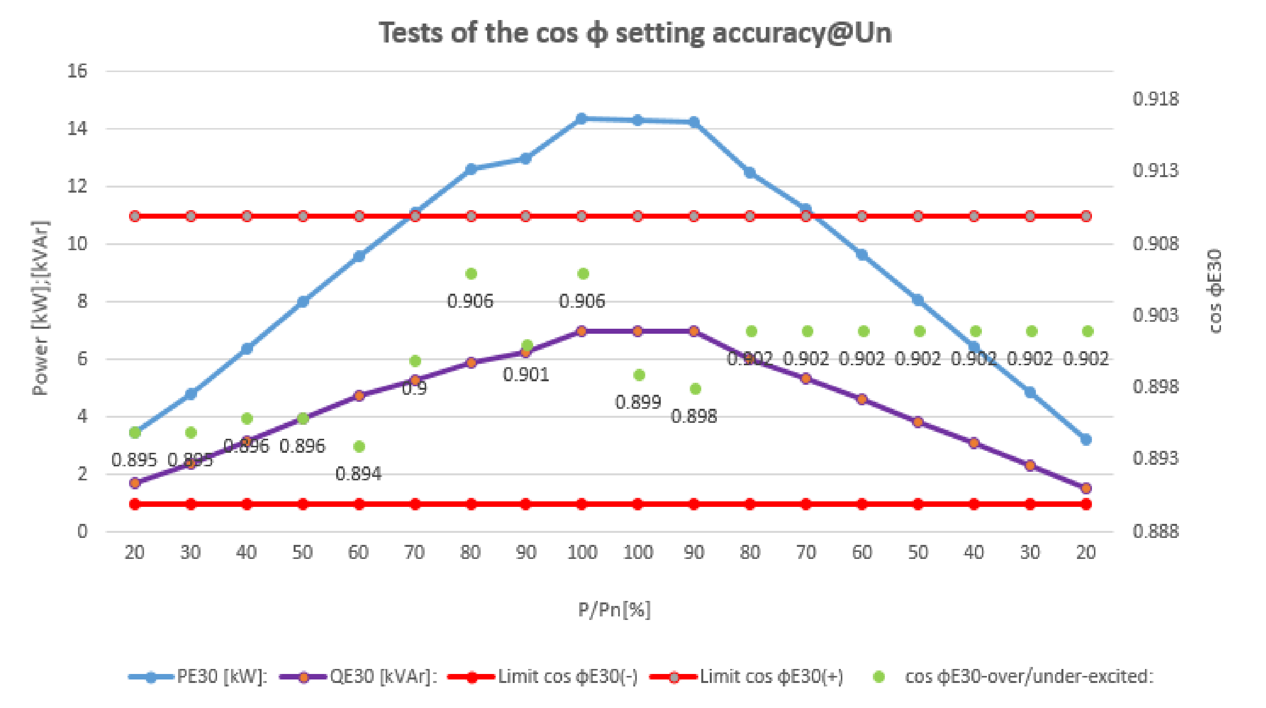
Assessment criterion:

Test a): cos φ accuracy: cos $φ_{setpoint}$ ± 0.01
Test b): cos φ accuracy: cos $φ_{setpoint}$ ± 0.02

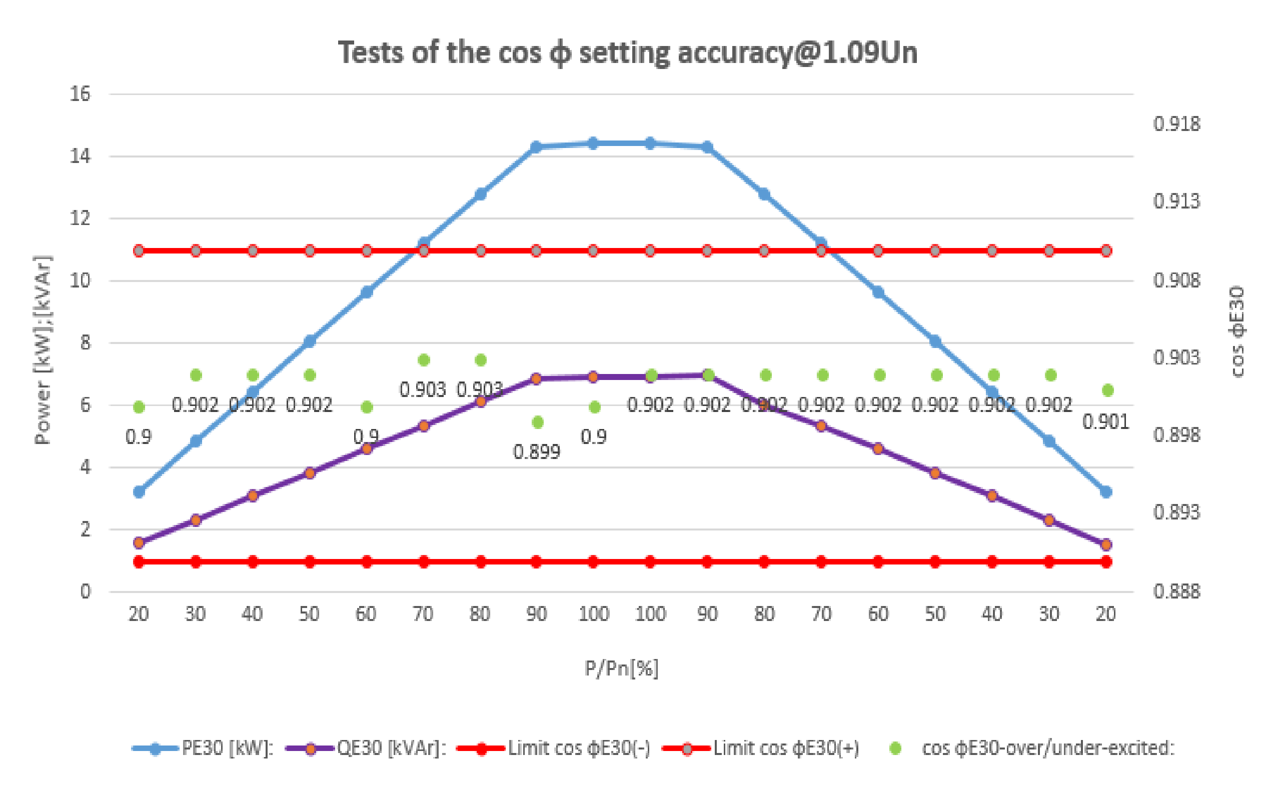
For the test b) to be passed, the cos φ setpoint from the active power must be measured at the terminals of the PGU within a settling time of 10 s.

5.7.2.4	**TABLE: Procedure for reactive power provision – method c) Displacement factor cos φ**								**P**
Model	EA16KTSI								
Setting values		cos φ over-excited:			+0.90				
		cos φ under-excited:			-0.90				
P/P_n [%]	10	20	30	40	50	60	70	80	90	100
a) PGUs used in PGSs < 3,68 kVA b) and c) PGUs used in PGSs > 3,68 kVA and ≤ 13,8 kVA d) and e) PGUs used in PGSs > 13,8 kVA									
30 s mean value	cos φ over-excited (c) @ U_n								
U [V]:	N/A	230.8	231.0	231.0	231.0	231.0	230.9	230.7	232.0	230.9
P_{E30} [kW]:	N/A	3.473	4.780	6.380	7.979	9.559	11.100	12.590	12.950	14.388
Q_{E30} [kVAr]:	N/A	1.728	2.380	3.167	3.962	4.742	5.285	5.876	6.266	6.950
cos $\varphi_{E30\text{-over-excited}}$:	N/A	0.895	0.895	0.896	0.896	0.894	0.900	0.906	0.901	0.906
30 s mean value	cos φ over-excited (c) @ 1.09 U_n								
U [V]:	N/A	249.0	249.0	249.1	249.0	249.0	249.0	249.0	249.0	249.0
P_{E30} [kW]:	N/A	3.230	4.836	6.442	8.039	9.626	11.200	12.800	14.300	14.400
Q_{E30} [kVAr].	N/A	1.556	2.312	3.077	3.846	4.606	5.365	6.121	6.875	6.914
cos $\varphi_{E30\text{-over-excited}}$:	N/A	0.900	0.902	0.902	0.902	0.900	0.903	0.903	0.899	0.900
30 s mean value	cos φ under-excited (i) @ U_n								
U [V]:	N/A	230.6	230.7	230.6	230.5	230.2	230.2	230.2	230.5	230.5
P_{E30} [kW]:	N/A	3.233	4.843	6.447	8.042	9.627	11.199	12.504	14.257	14.303
Q_{E30} [kVAr]:	N/A	1.549	2.314	3.079	3.844	4.594	5.358	5.993	6.952	6.975
cos $\varphi_{E30\text{-under-excited}}$:	N/A	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.898	0.899
30 s mean value	cos φ under-excited (i) @ 1.09 U_n								
U [V]:	N/A	249.3	249.3	249.5	249.4	249.2	249.1	249.0	249.1	249.1
P_{E30} [kW]:	N/A	3.229	4.835	6.442	8.041	9.629	11.205	12.771	14.333	14.411
Q_{E30} [kVAr]:	N/A	1.556	2.313	3.077	3.848	4.608	5.365	6.122	6.878	6.917
cos $\varphi_{E30\text{-under-excited}}$:	N/A	0.901	0.902	0.902	0.902	0.902	0.902	0.902	0.902	0.902
Limit cos φ_{E30}:	a): cos φ= 0.90 (c) to cos φ= 0.90 (i) b) and c): cos φ= 0.89 to 0.91 (c) and cos φ= 0.89 to 0.91 (i) d) and e): cos φ= 0.89 to 0.91 (c) and cos φ= 0.89 to 0.91 (i)								
Note: The tests were performed on model EA16KTSI also applicable for all other models stated in this report.									

Graph of cos φ over-excited (c) and under-excited (i) @ U_n



Graph of cos φ over-excited (c) and under-excited (i) @ 1,09 U_n



5.7.3	TABLE: Dynamic network stability					P
Model	EA16KTSI					
Three phase						
Test	Voltage Depth [p.u.]	Fault type	Fault duration [ms]	P set point [P_{rE}]	Q set point [Q/P_{rE}]	Test number
1	0.15	A	≥150	100%	0~10%	1.1
				20%		1.2
		D	≥150	100%		1.3
				20%		1.4
2	0.5	A	≥1500	100%	max (c)	2.1
				20%		2.2
		D	≥1500	100%		2.3
				20%		2.4
3	0.5	A	≥1500	100%	max (i)	3.1
				20%		3.2
		D	≥1500	100%		3.3
				20%		3.4
4	0.85	A	≥60000	100%	0~10%	4.1
				20%		4.2
		D	≥60000	100%		4.3
				20%		4.4
5	1.25	A	≥100	100%	0~10%	5.1
				20%		5.2
		D	≥100	100%		5.3
				20%		5.4
6	1.20	A	≥5000	100%	0~10%	6.1
				20%		6.2
		D	≥5000	100%		6.3
				20%		6.4
7	1.15	A	≥60000	100%	0~10%	7.1
				20%		7.2
		D	≥60000	100%		7.3
				20%		7.4

Setting:

Test number	Voltage Depth [p.u.]	U_1/U_{1nom}	U_2/U_{2nom}	U_3/U_{3nom}	φ1	φ2	φ3
1.1; 1.2	0.15	0.15	0.15	0.15	-150.0°	90°	-30.0°
1.3; 1.4		0.62	0.15	0.62	-173.3°	90°	-6.9°
2.1; 2.2	0.50	0.50	0.50	0.50	-150.0°	90°	-30.0°
2.3; 2.4		0.76	0.50	0.76	-161.1°	90°	-19.1°
3.1; 3.2	0.50	0.50	0.50	0.50	-150.0°	90°	-30.0°
3.3; 3.4		0.76	0.50	0.76	-161.1°	90°	-19.1°
4.1; 4.2	0.85	0.85	0.85	0.85	-150.0°	90°	-30.0°
4.3; 4.4		0.93	0.85	0.93	-152.8°	89.9°	-27.4°
5.1; 5.2	1.25	1.25	1.25	1.25	-150.0°	90°	-30.0°
5.3; 5.4		1.08	1.25	1.06	-144.5°	89.1°	-36.3°
6.1; 6.2	1.20	1.20	1.20	1.20	-150.0°	90°	-30.0°
6.3; 6.4		1.06	1.20	1.05	-145.5°	89.3°	-35.1°
7.1; 7.2	1.15	1.15	1.15	1.15	-150.0°	90°	-30.0°
7.3; 7.4		1.04	1.15	1.04	-146.6°	89.4°	-33.9°

Note:

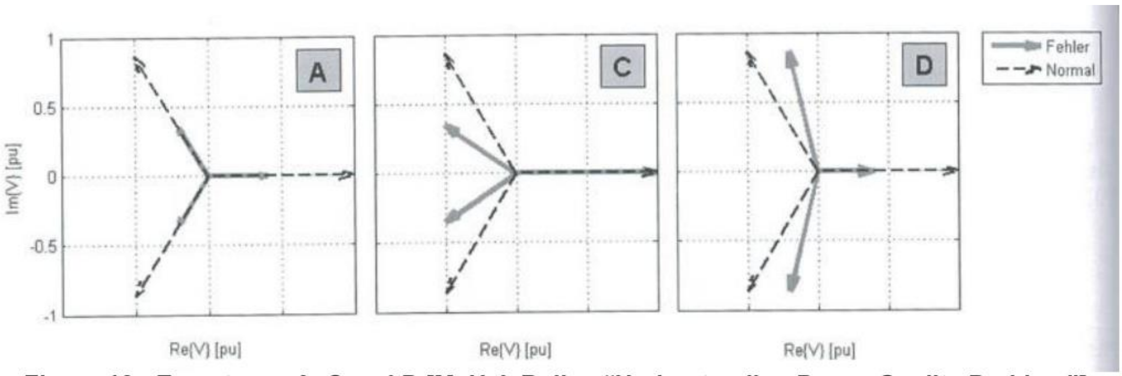


Figure 10 - Error types A, C and D [M. H.J. Bollen "Understanding Power Quality Problem"]

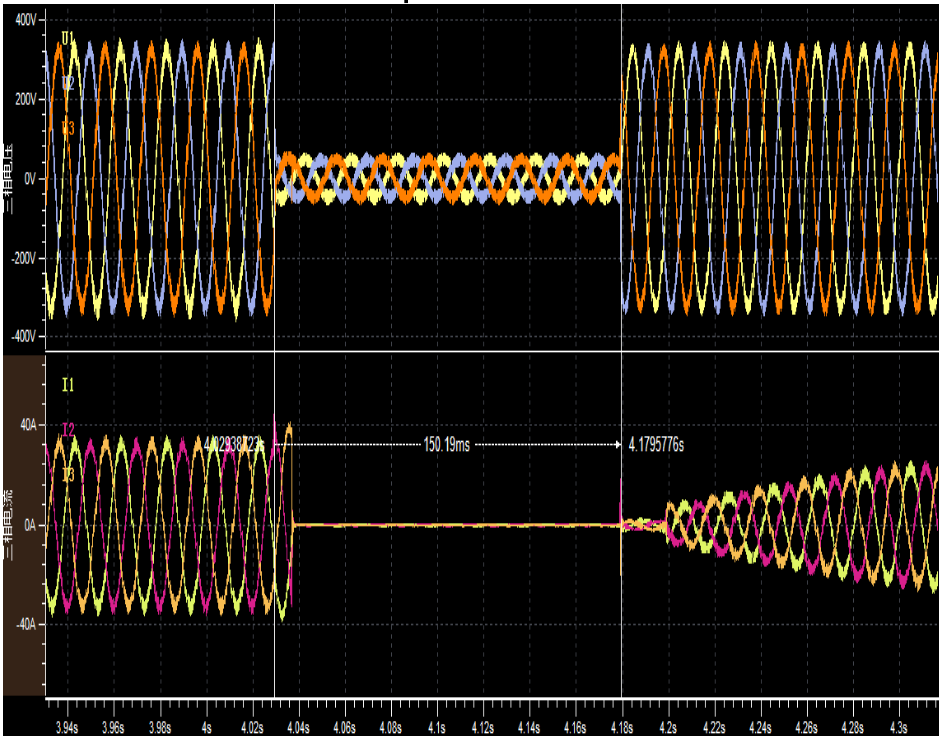
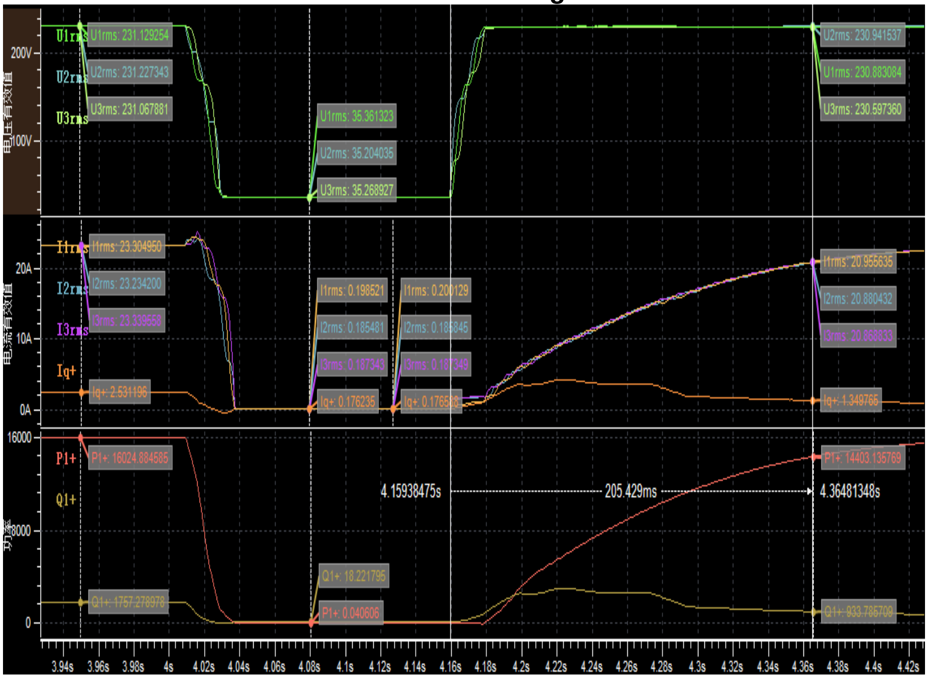
5.7.3	TABLE: Dynamic network stability						P
Test number	Phase no.	Required fault depth /duration [p.u.], [ms]	Measured fault duration [ms]	Average remaining voltage [p.u.]	Percent of current after fault 60 ms [%Ir]	Percent of current after fault 100 ms [%Ir]	Duration of restoring [ms]
1.1	L1	0.15 / 150	150.190	35.092	0.199	0.200	205.429
	L2		150.190	34.947	0.185	0.186	205.429
	L3		150.190	34.230	0.187	0.187	205.429
1.2	L1	0.15 / 150	150.214	35.092	0.194	0.192	626.897
	L2		150.214	34.947	0.187	0.185	626.897
	L3		150.214	34.230	0.184	0.185	626.897
1.3	L1	0.15 / 150	150.040	144.351	0.825	0.818	202.416
	L2		150.040	34.893	0.277	0.274	202.416
	L3		150.040	143.386	0.759	0.758	202.416
1.4	L1	0.15 / 150	150.870	144.150	0.825	0.815	626.506
	L2		150.870	34.981	0.262	0.247	626.506
	L3		150.870	143.054	0.763	0.759	626.506
2.1	L1	0.50 / 1500	1500.158	116.463	0.649	0.636	789.773
	L2		1500.158	115.392	0.608	0.603	789.773
	L3		1500.158	114.637	0.610	0.609	789.773
2.2	L1	0.50 / 1500	1501.730	116.425	0.652	0.641	793.799
	L2		1501.730	115.363	0.615	0.605	793.799
	L3		1501.730	114.681	0.606	0.604	793.799
2.3	L1	0.50 / 1500	1502.333	174.672	1.031	1.040	491.697
	L2		1502.333	115.001	0.641	0.654	491.697
	L3		1502.333	174.584	0.950	0.949	491.697
2.4	L1	0.50 / 1500	1500.017	175.010	1.008	1.000	816.605
	L2		1500.017	115.157	0.656	0.657	816.605
	L3		1500.017	174.652	0.927	0.926	816.605
3.1	L1	0.50 / 1500	1501.103	115.319	0.640	0.648	756.018
	L2		1501.103	114.953	0.607	0.612	756.018
	L3		1501.103	115.161	0.603	0.606	756.018
3.2	L1	0.50 / 1500	1501.103	115.185	0.637	0.637	800.61
	L2		1501.103	114.962	0.608	0.610	800.61
	L3		1501.103	115.240	0.608	0.606	800.61
3.3	L1	0.50 / 1500	1500.621	174.839	1.019	1.006	556.474
	L2		1500.621	115.089	0.657	0.653	556.474
	L3		1500.621	174.740	0.927	0.926	556.474
3.4	L1	0.50 / 1500	1500.545	174.762	1.036	1.045	740.083
	L2		1500.545	115.018	0.664	0.659	740.083

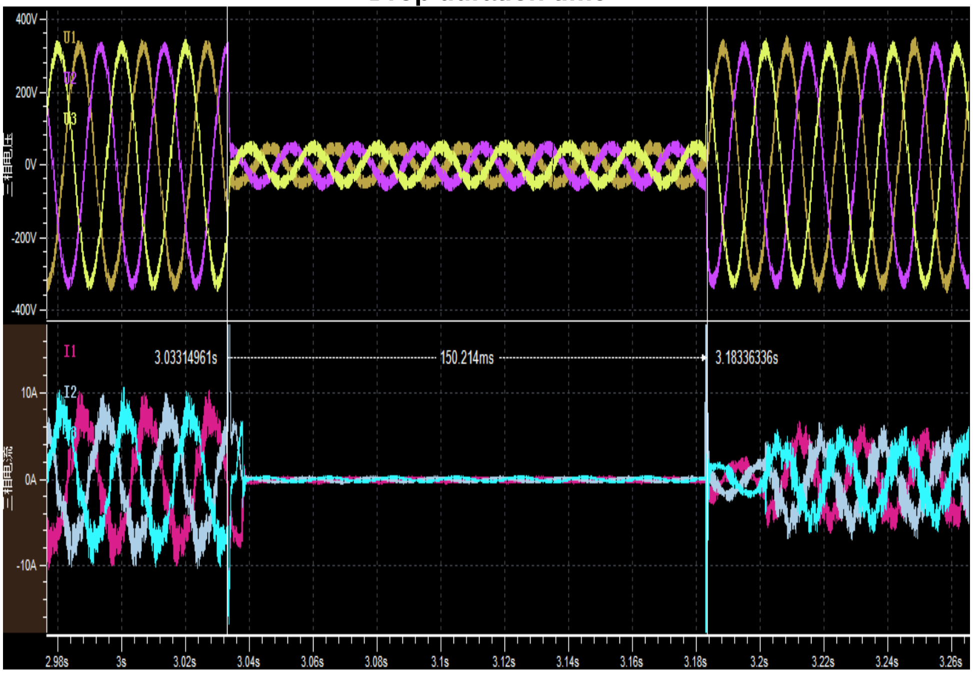
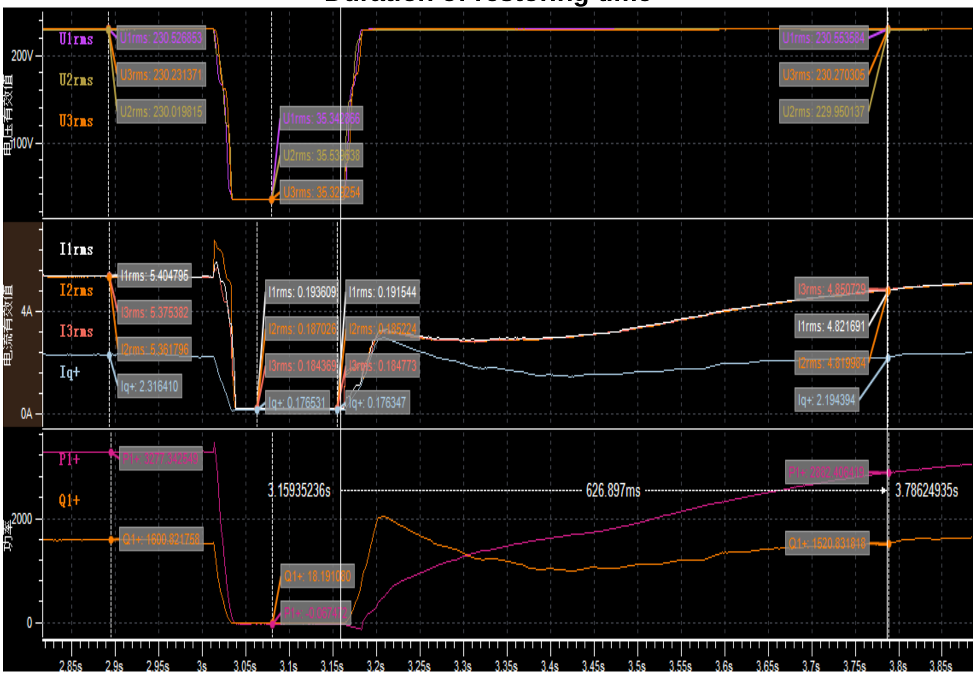
5.7.3	TABLE: Dynamic network stability						P
	L3		1500.545	174.551	0.942	0.942	740.083
4.1	L1	0.85 / 60000	60010.627	197.891	26.966	26.981	991.577
	L2		60010.627	197.330	26.941	26.950	991.577
	L3		60010.627	197.359	27.028	27.018	991.577
4.2	L1	0.85 / 60000	60005.482	196.032	1.113	1.131	877.644
	L2		60005.482	196.037	1.057	1.049	877.644
	L3		60005.482	195.683	1.052	1.061	877.644
4.3	L1	0.85 / 60000	60011.183	215.146	3.023	24.178	920.683
	L2		60011.183	197.056	3.161	24.347	920.683
	L3		60011.183	214.774	3.153	24.275	920.683
4.4	L1	0.85 / 60000	60005.760	214.267	1.790	1.695	862.787
	L2		60005.760	195.987	1.939	1.808	862.787
	L3		60005.760	213.549	1.618	1.539	862.787
5.1	L1	1.25 / 100	100.236	288.459	1.621	1.610	520.425
	L2		100.236	290.405	1.523	1.527	520.425
	L3		100.236	287.964	1.551	1.532	520.425
5.2	L1	1.25 / 100	100.029	287.286	1.602	1.725	643.562
	L2		100.029	291.727	1.523	1.459	643.562
	L3		100.029	288.622	1.511	1.478	643.562
5.3	L1	1.25 / 100	100.150	250.581	1.419	1.420	246.687
	L2		100.150	288.607	1.547	1.532	246.687
	L3		100.150	244.814	1.286	1.282	246.687
5.4	L1	1.25 / 100	100.144	250.590	1.441	1.427	648.916
	L2		100.144	288.888	1.546	1.534	648.916
	L3		100.144	244.058	1.307	1.309	648.916
6.1	L1	1.20 / 5000	5002.657	277.567	1.547	1.534	962.949
	L2		5002.657	276.813	1.457	1.474	962.949
	L3		5002.657	276.004	1.455	1.474	962.949
6.2	L1	1.20 / 5000	5008.147	276.063	1.544	1.541	841.663
	L2		5008.147	276.509	1.454	1.477	841.663
	L3		5008.147	277.324	1.462	1.455	841.663
6.3	L1	1.20 / 5000	5002.904	245.607	1.376	1.393	699.584
	L2		5002.904	277.296	1.480	1.477	699.584
	L3		5002.904	241.941	1.279	1.302	699.584
6.4	L1	1.20 / 5000	5008.924	245.705	1.396	1.397	864.655
	L2		5008.924	277.055	1.470	1.467	864.655
	L3		5008.924	242.106	1.292	1.292	864.655
7.1	L1	1.15 / 60000	60005.196	265.896	1.487	1.503	610.851

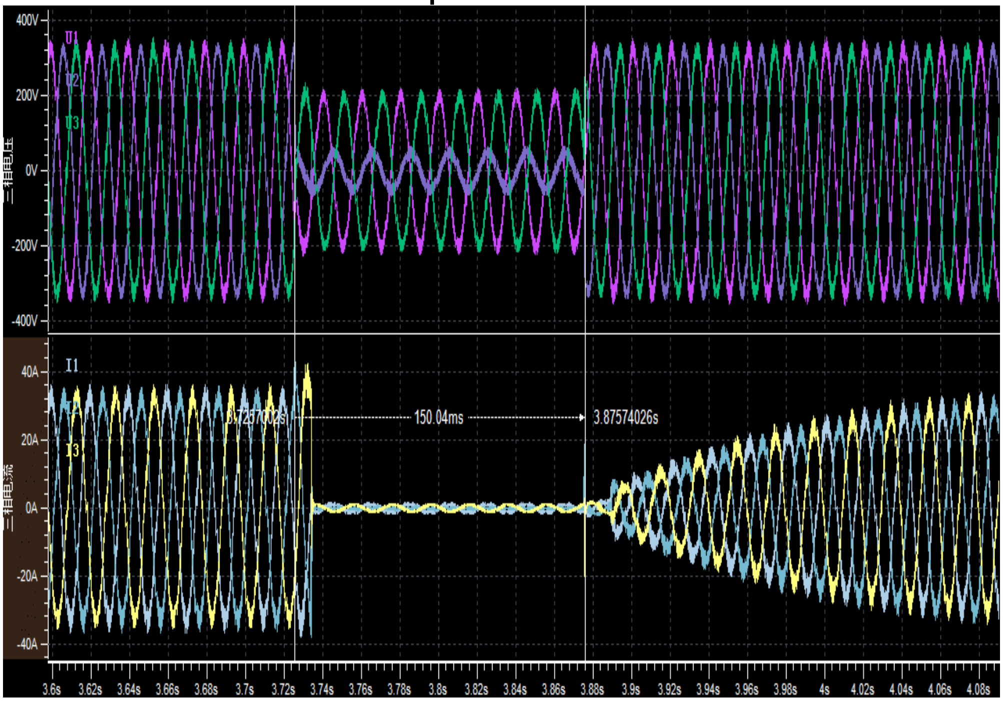
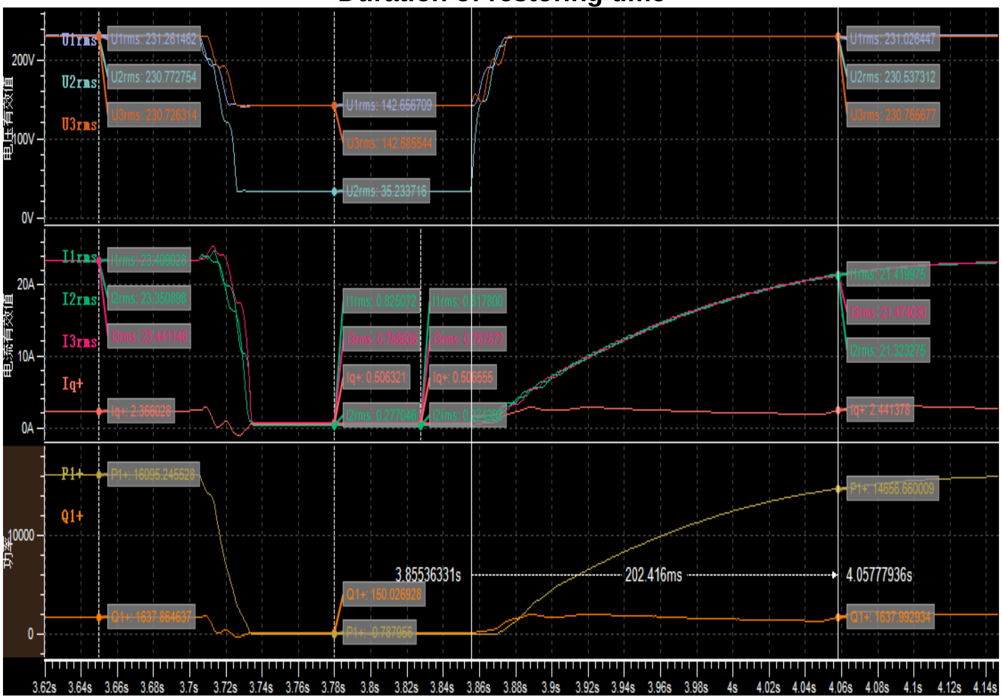
5.7.3	**TABLE: Dynamic network stability**						**P**
	L2		60005.196	264.656	1.402	1.422	610.851
	L3		60005.196	264.372	1.412	1.404	610.851
7.2	L1	1.15 / 60000	60000.635	266.520	1.495	1.471	777.244
	L2		60000.635	265.156	1.403	1.409	777.244
	L3		60000.635	264.941	1.437	1.424	777.244
7.3	L1	1.15 / 60000	60001.850	240.919	1.365	1.375	661.058
	L2		60001.850	265.425	1.409	1.409	661.058
	L3		60001.850	240.325	1.277	1.288	661.058
7.4	L1	1.15 / 60000	60000.056	240.975	1.400	1.356	657.417
	L2		60000.056	265.222	1.349	1.398	657.417
	L3		60000.056	239.994	1.263	1.267	657.417

Note:

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

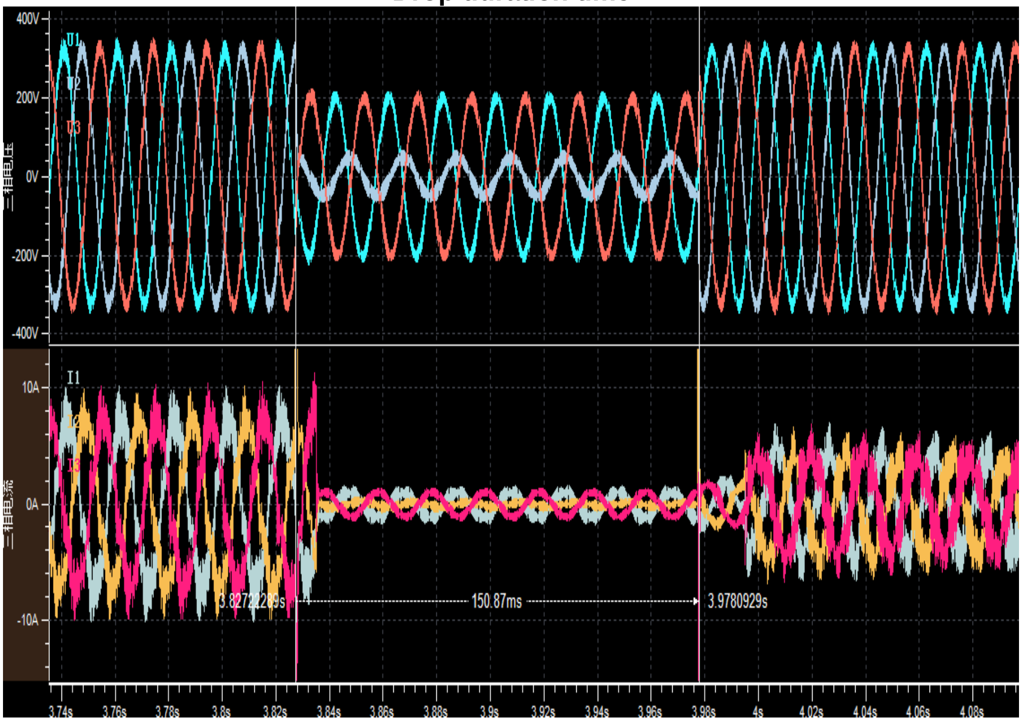
Test 1.1
Drop duration time

Duration of restoring time


Test 1.2
Drop duration time 
Duration of restoring time 

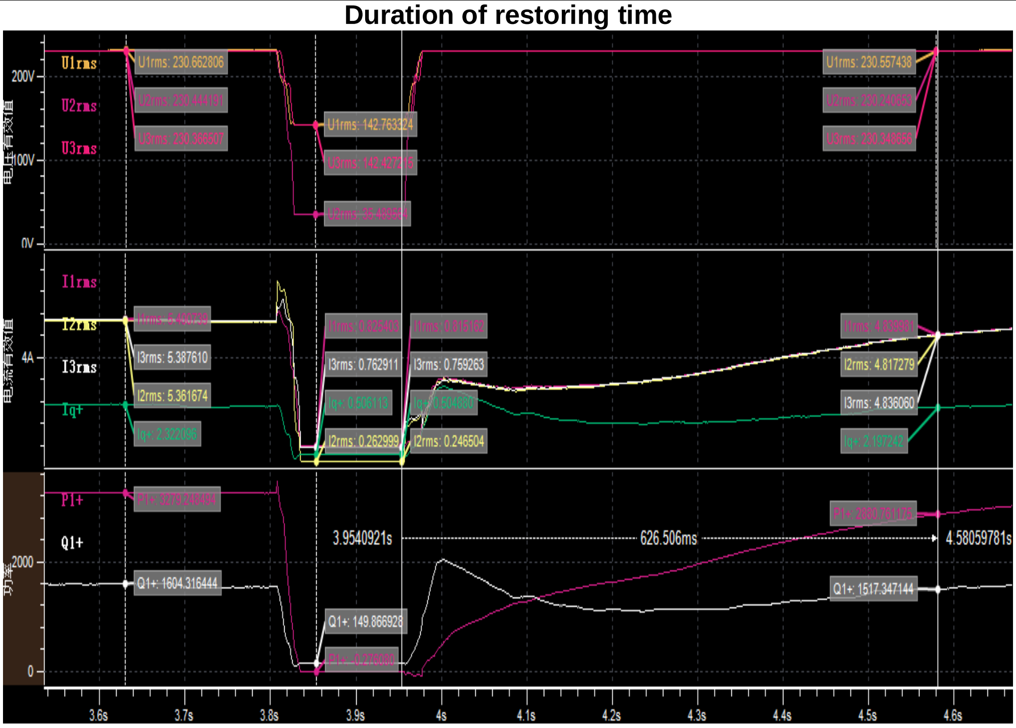
Test 1.3
Drop duration time

Duration of restoring time


Test 1.4

Drop duration time

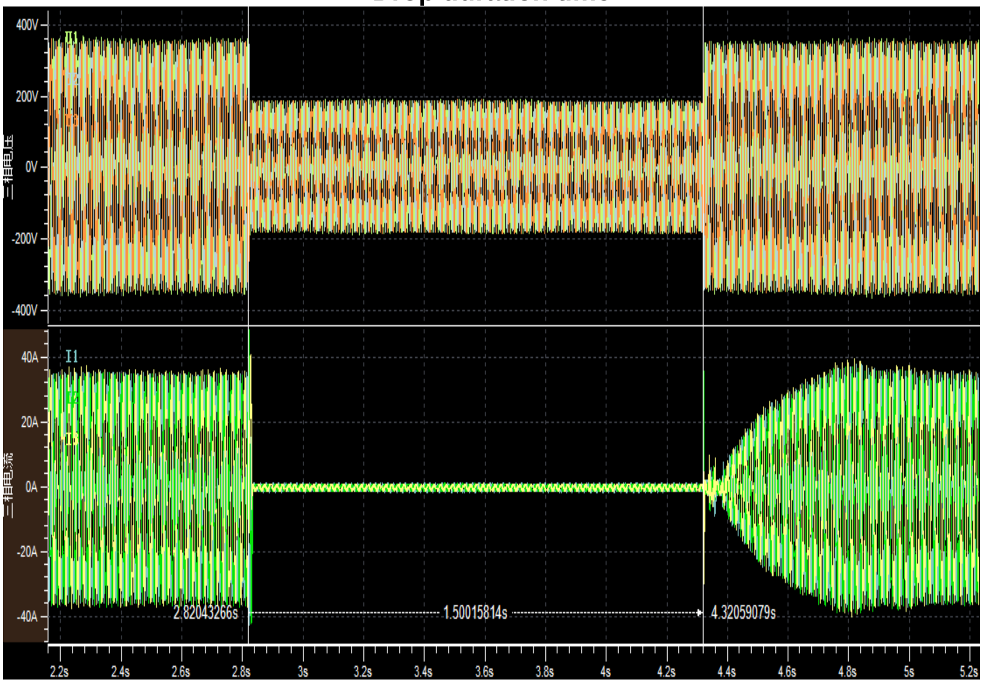


Duration of restoring time

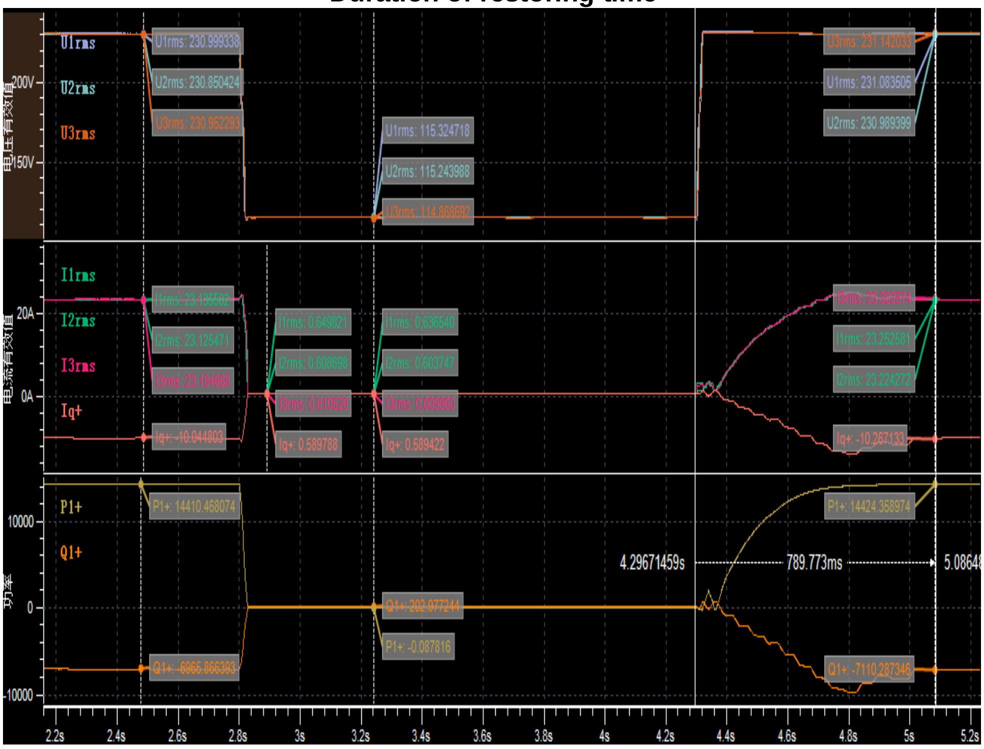


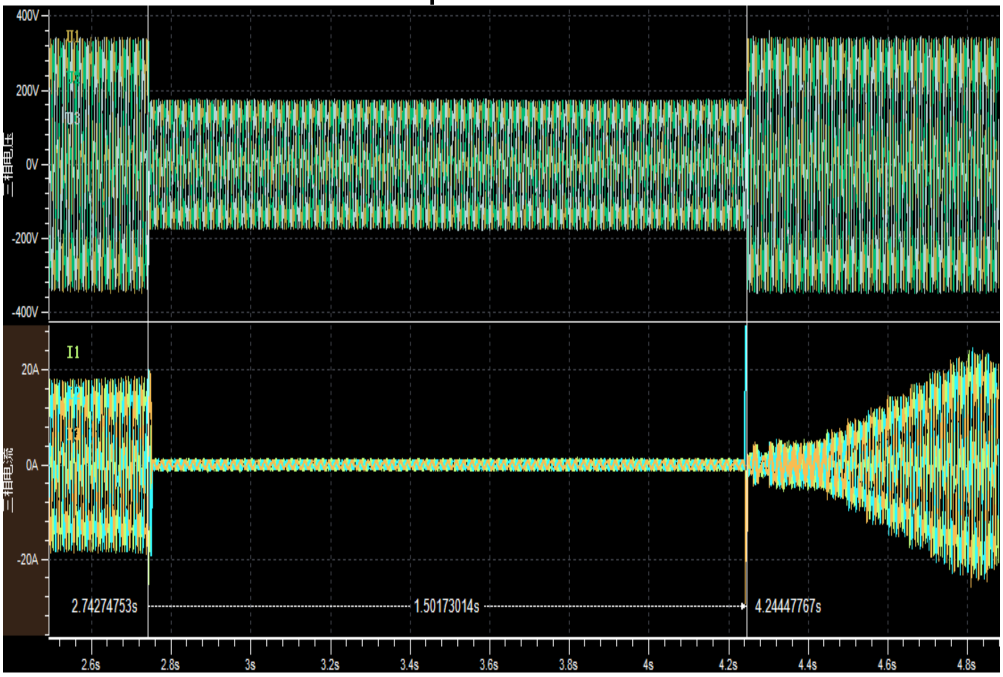
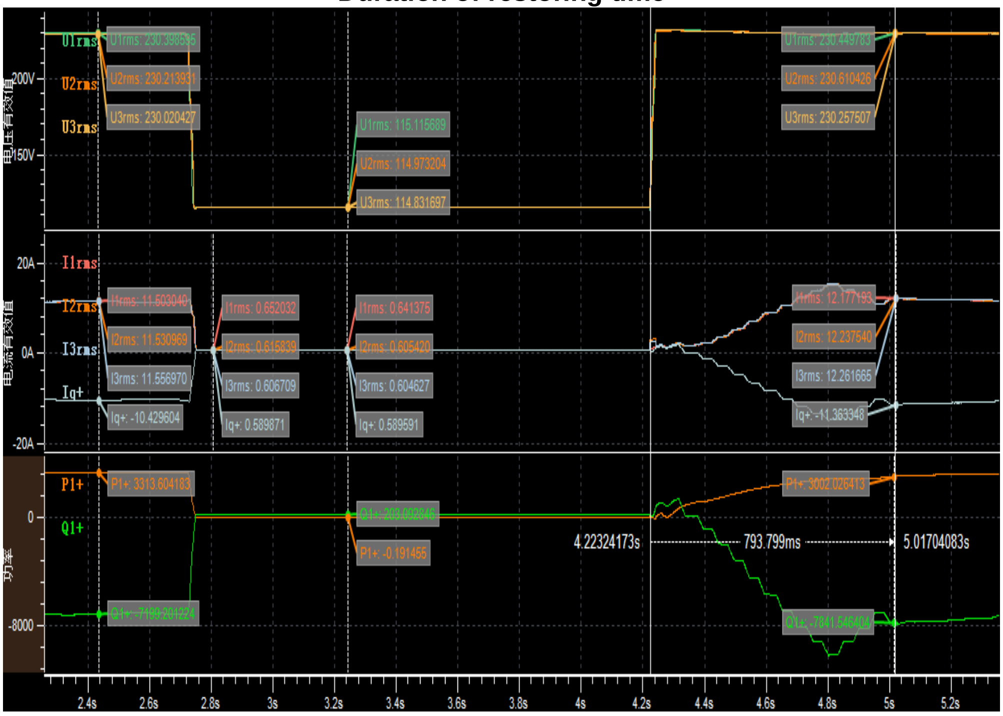
Test 2.1

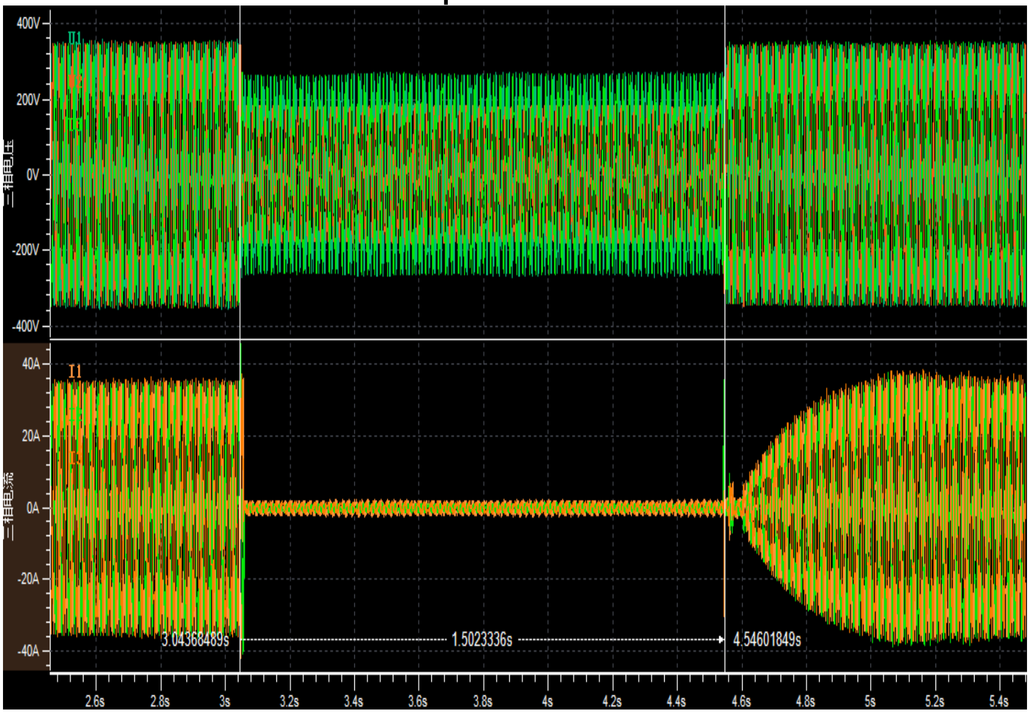
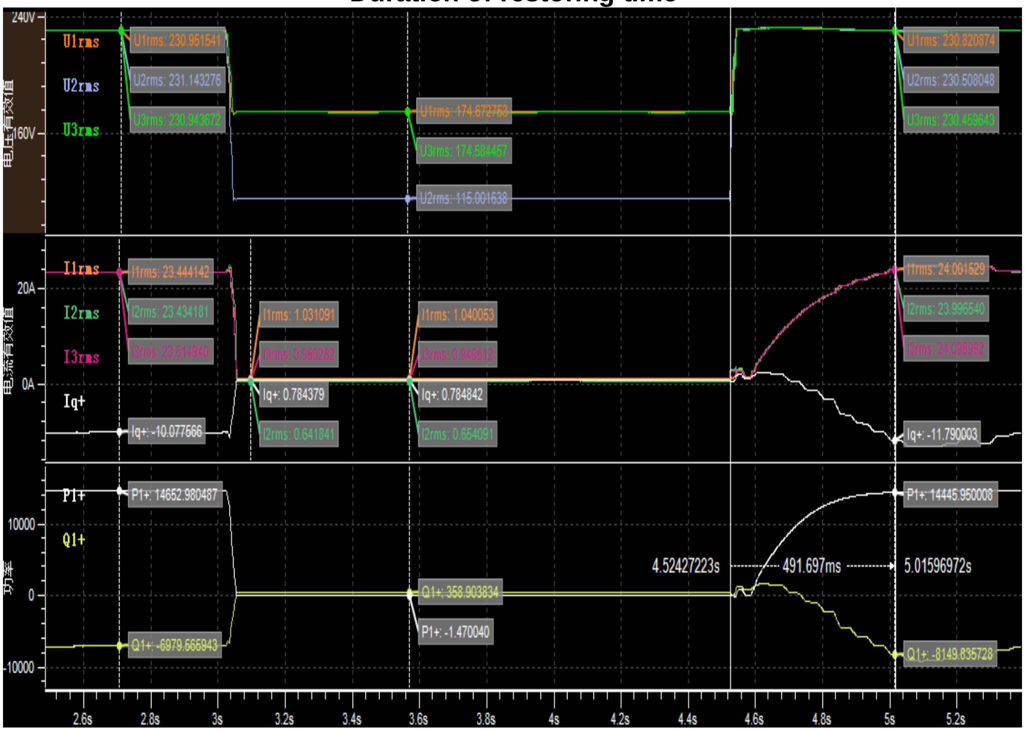
Drop duration time

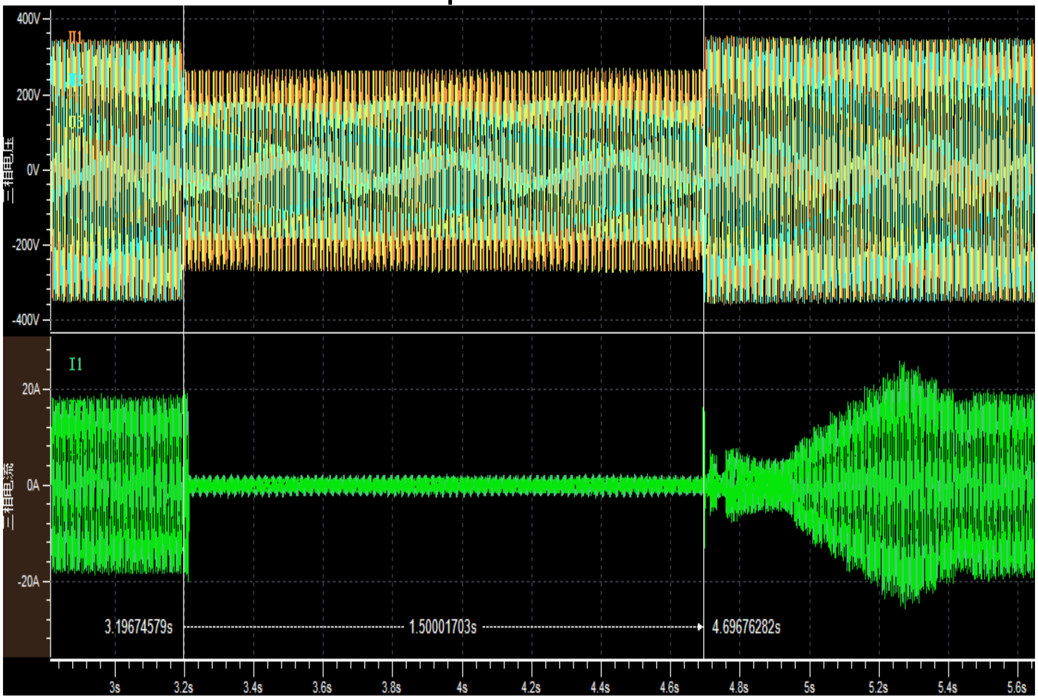
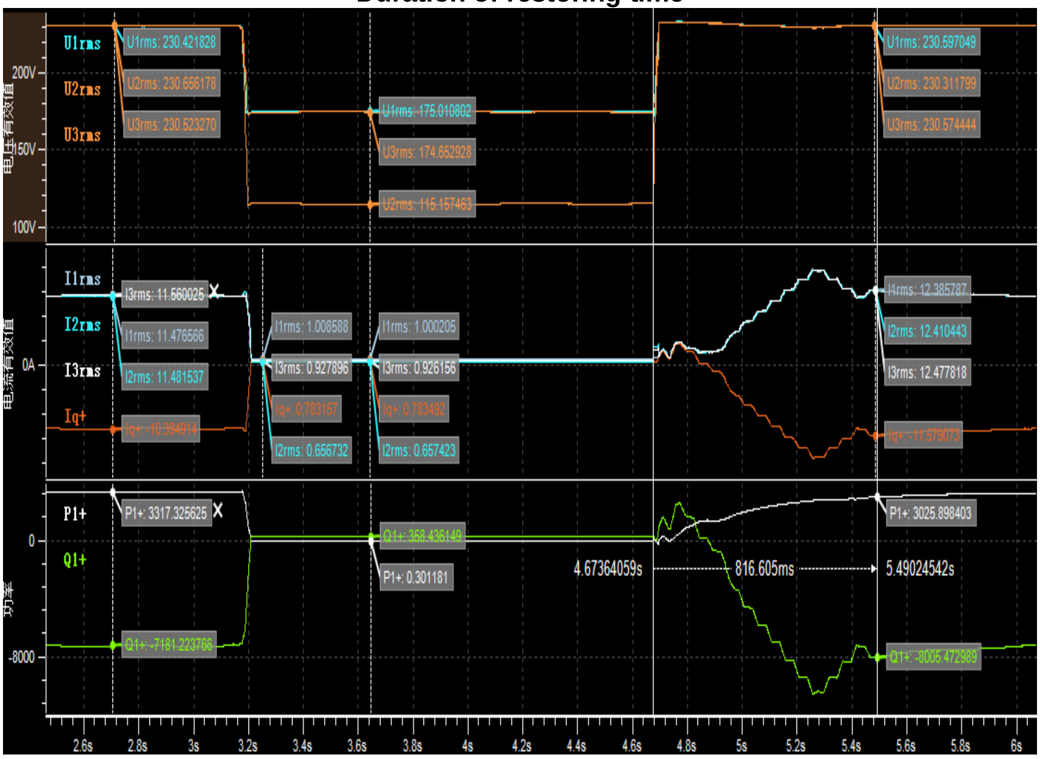


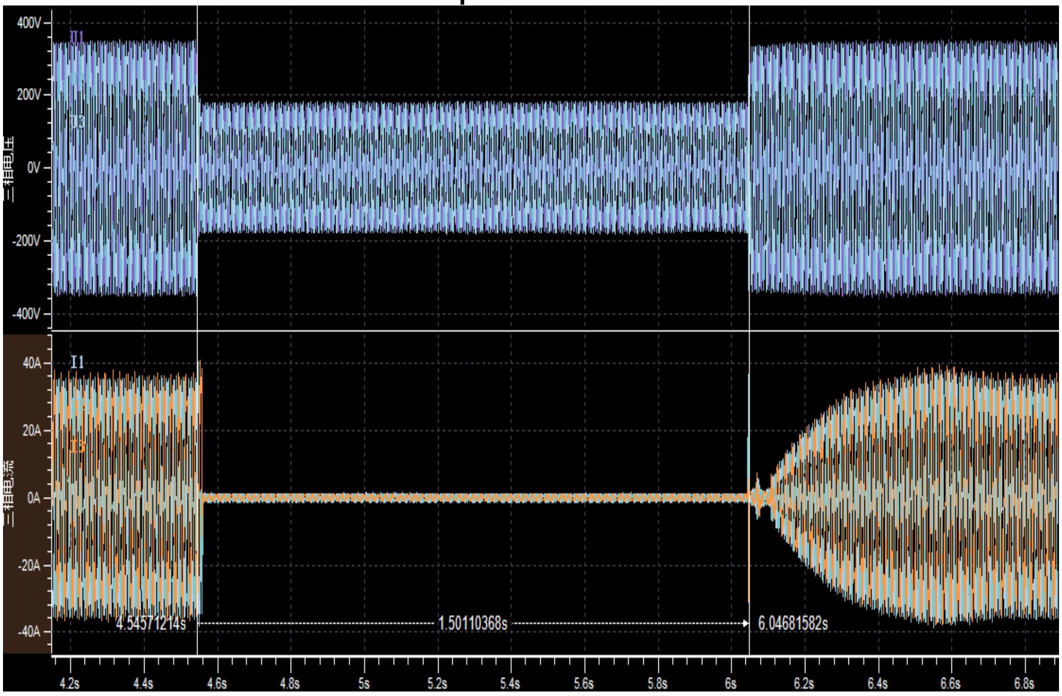
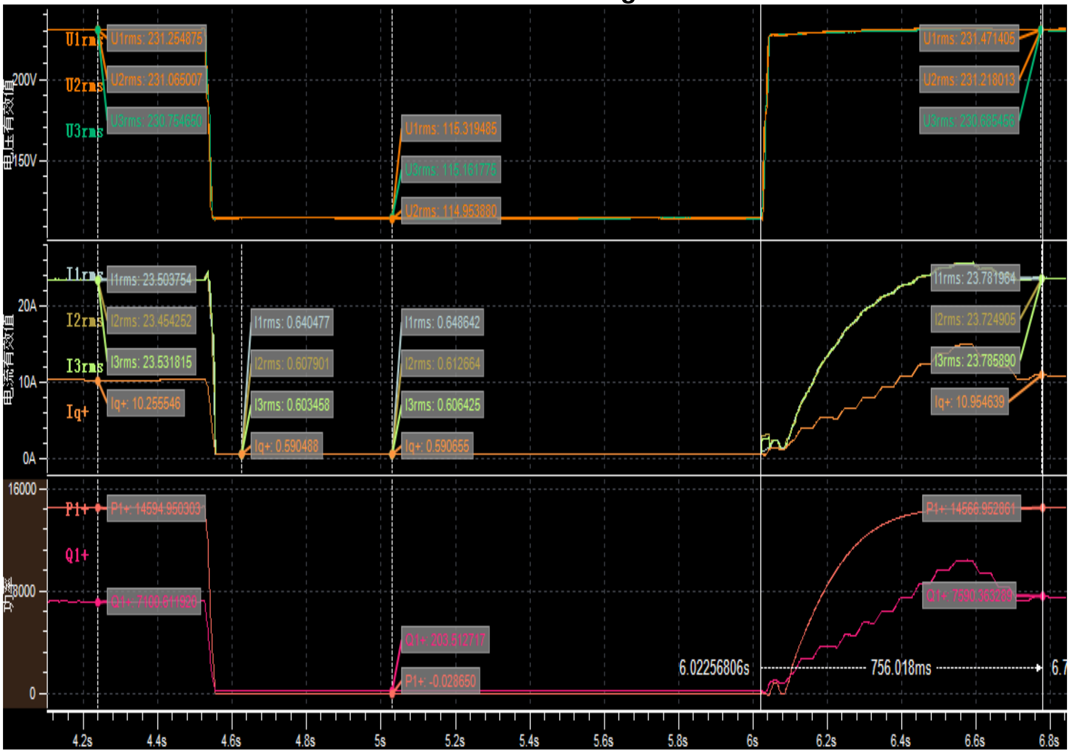
Duration of restoring time

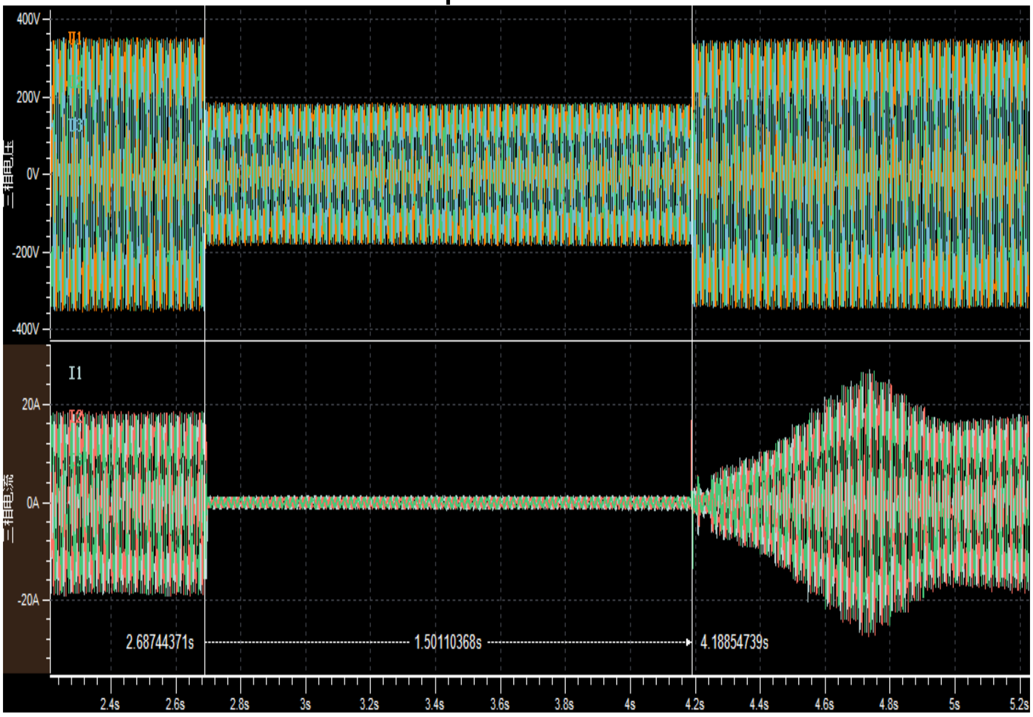
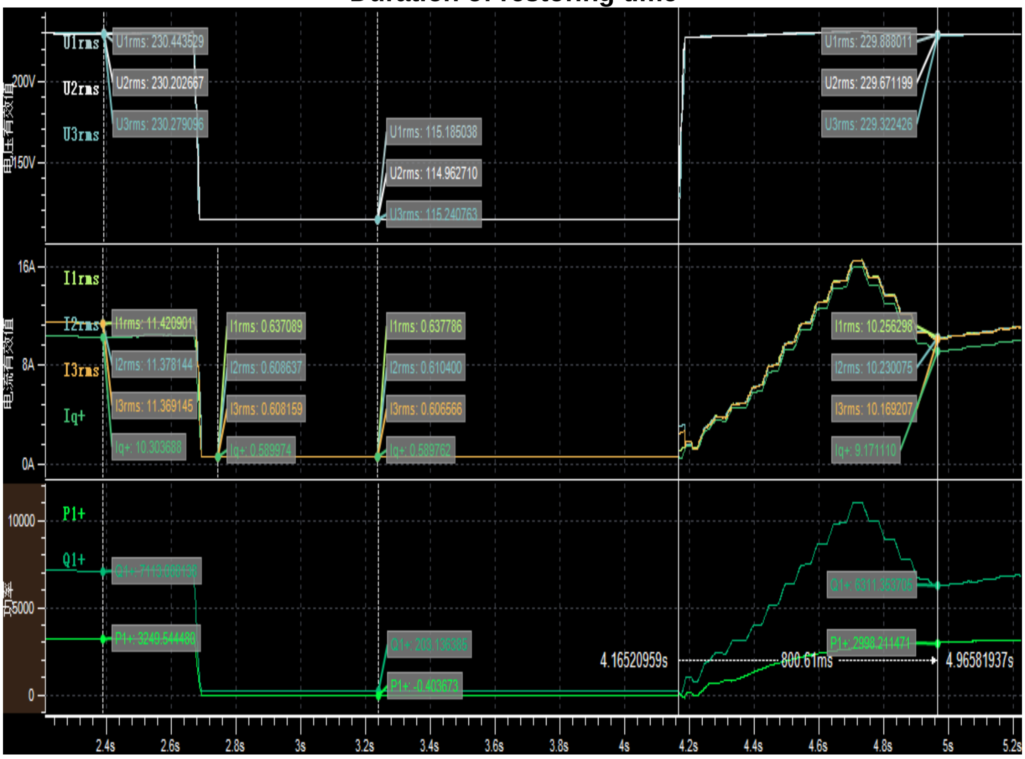


Test 2.2
Drop duration time

Duration of restoring time


Test 2.3
Drop duration time 
Duration of restoring time 

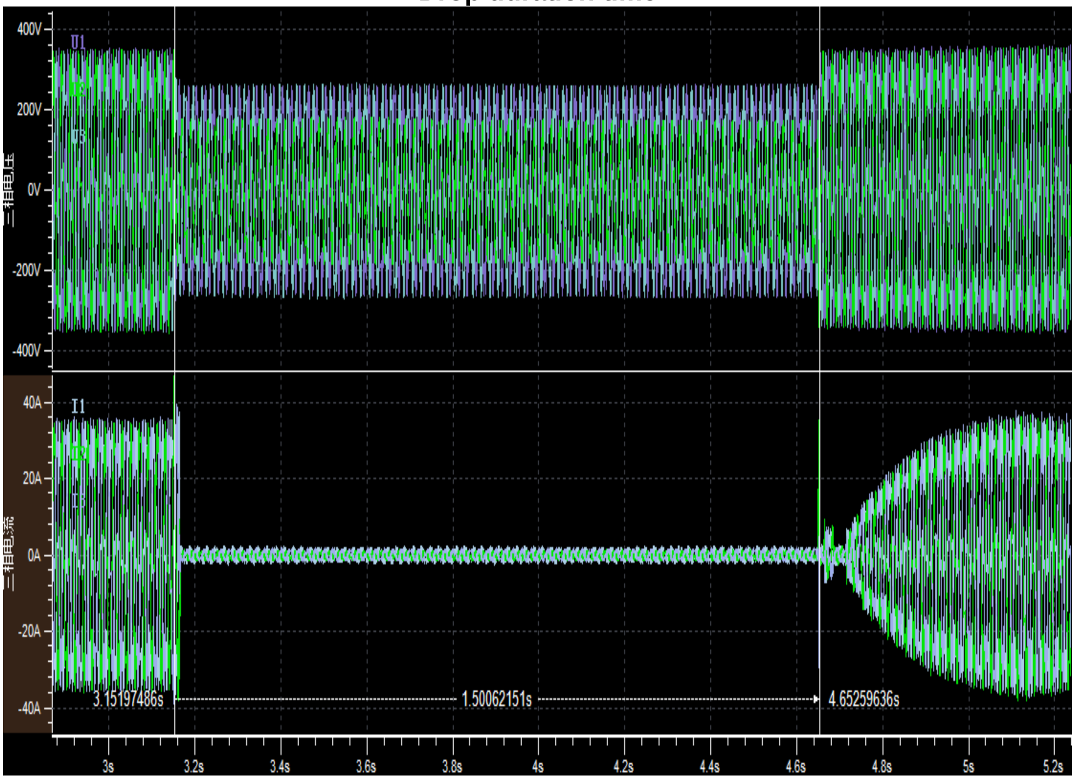
Test 2.4
Drop duration time

Duration of restoring time


Test 3.1
Drop duration time 
Duration of restoring time 

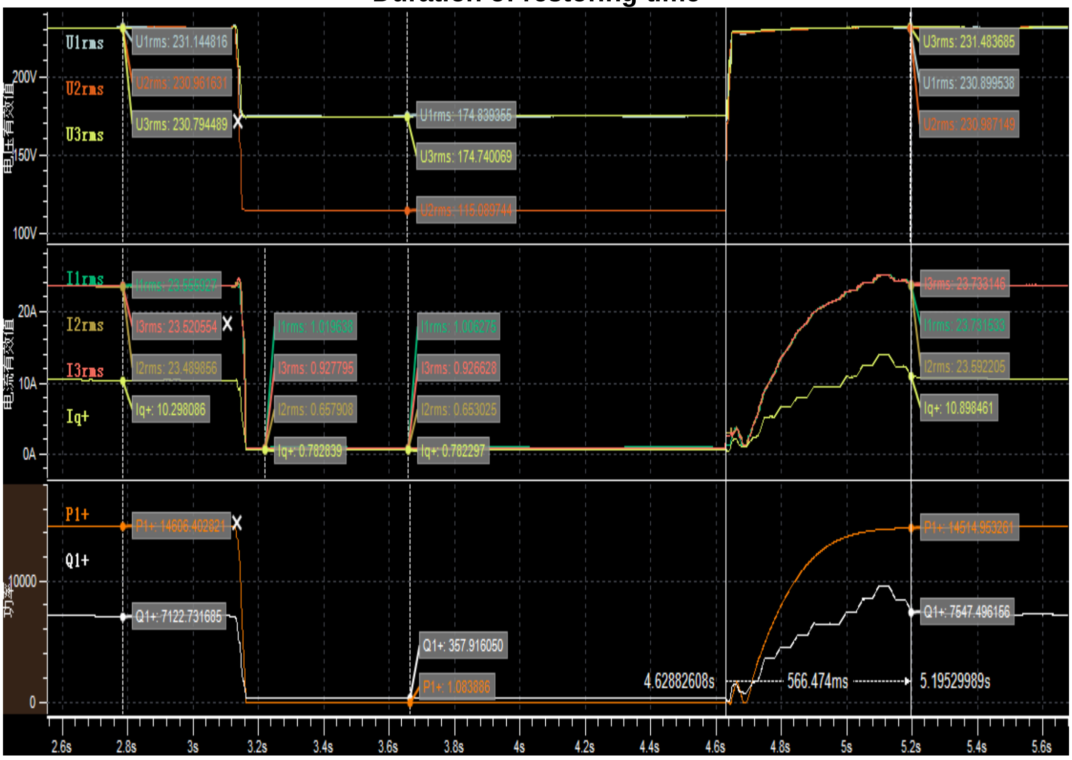
Test 3.2
Drop duration time 
Duration of restoring time 

Test 3.3

Drop duration time

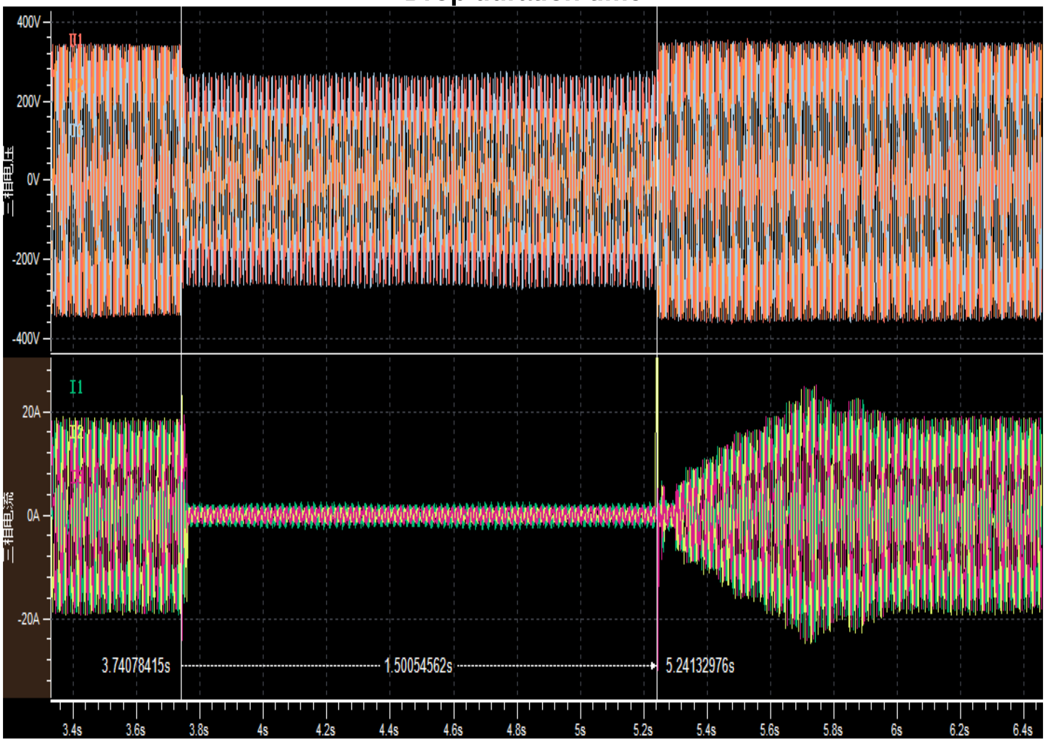


Duration of restoring time

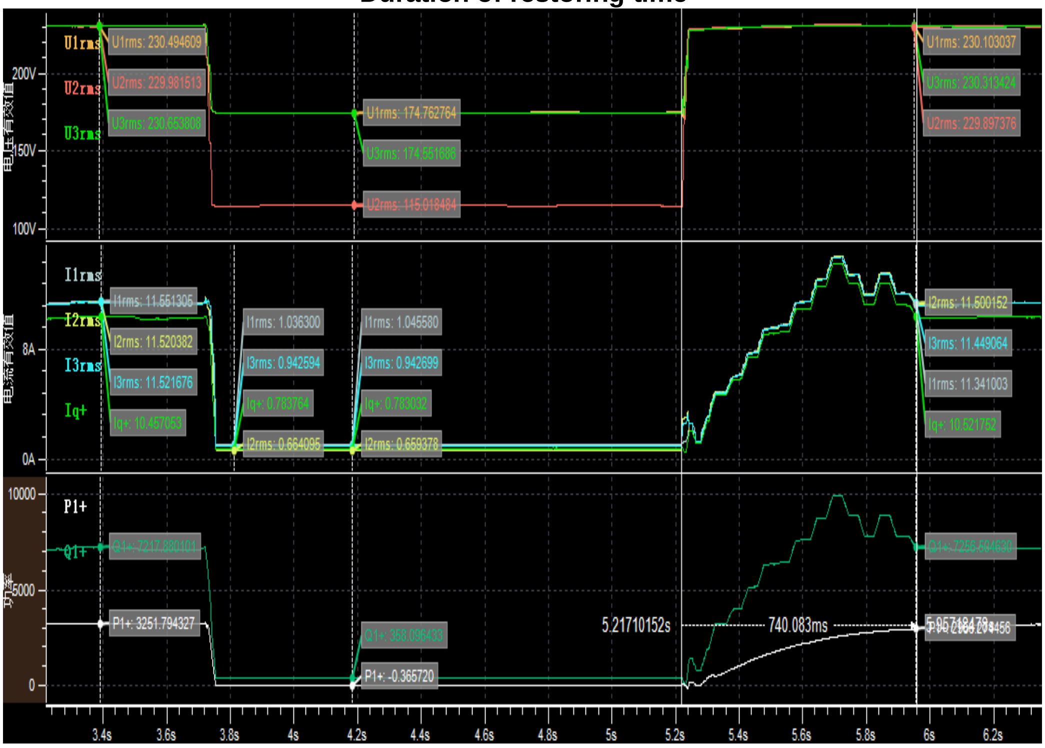


Test 3.4

Drop duration time

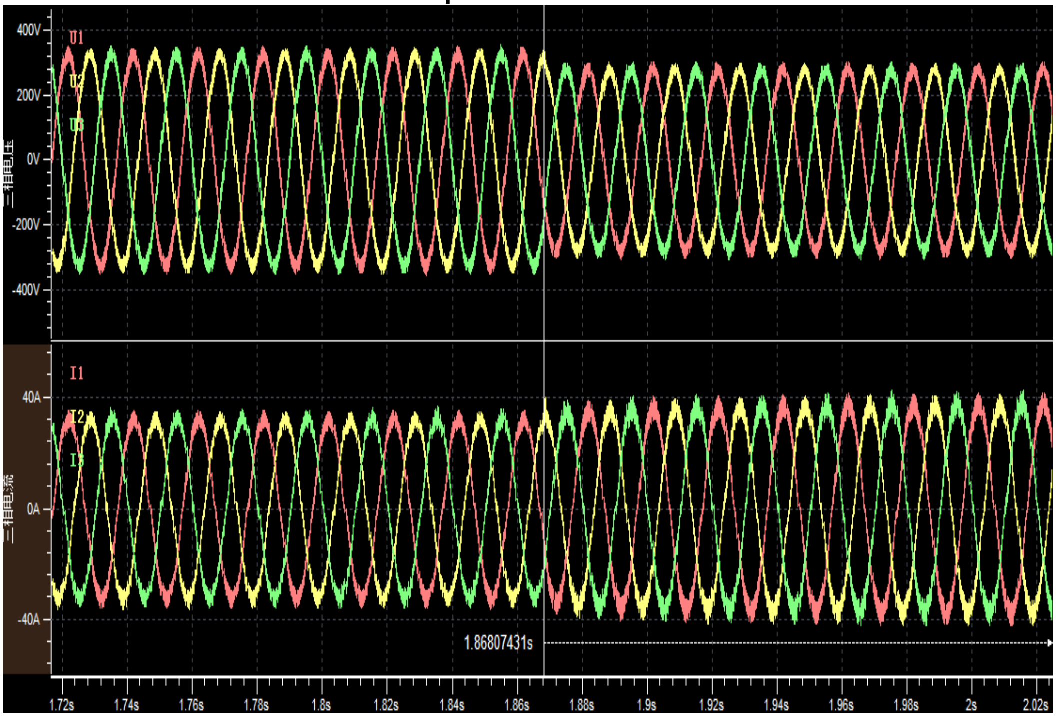


Duration of restoring time

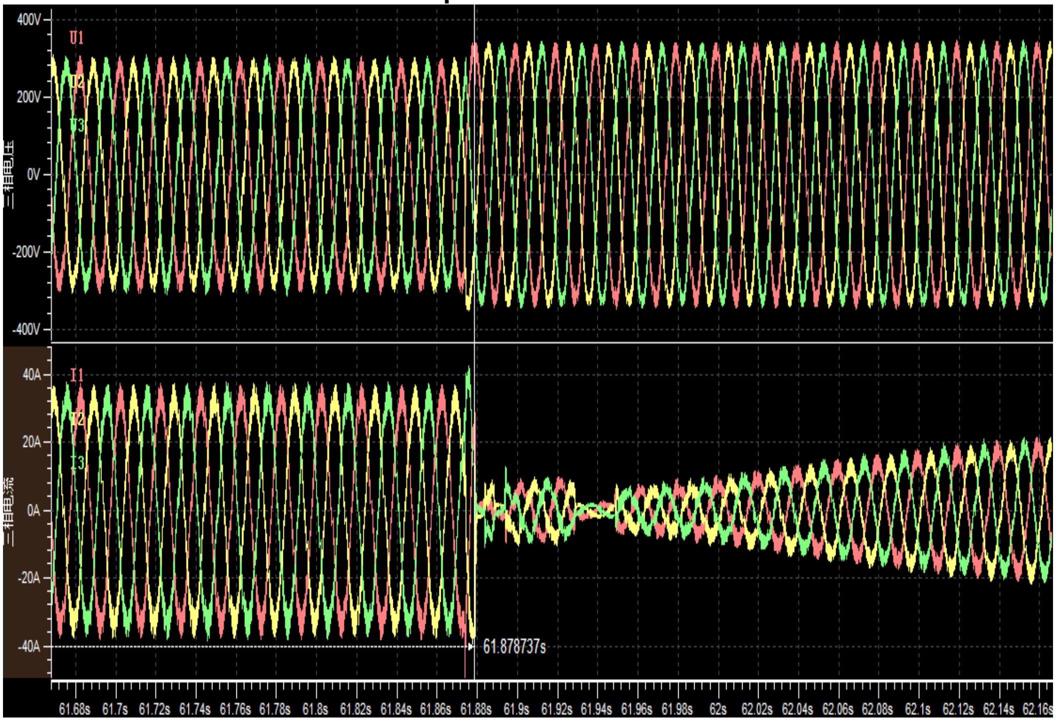


Test 4.1

Drop duration time-1

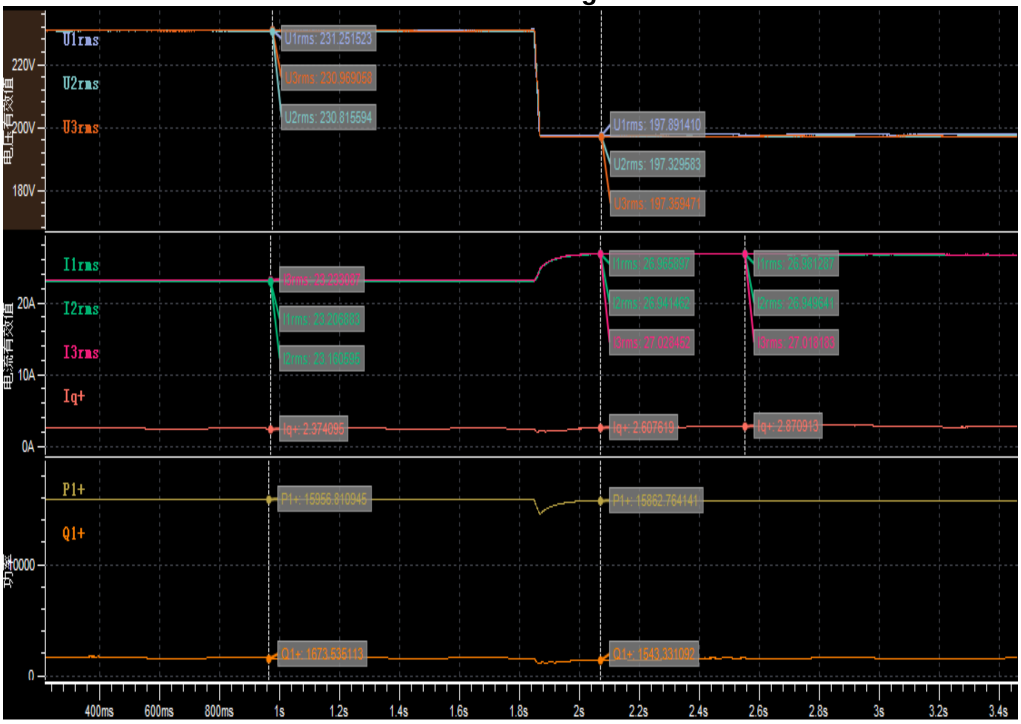


Drop duration time-2

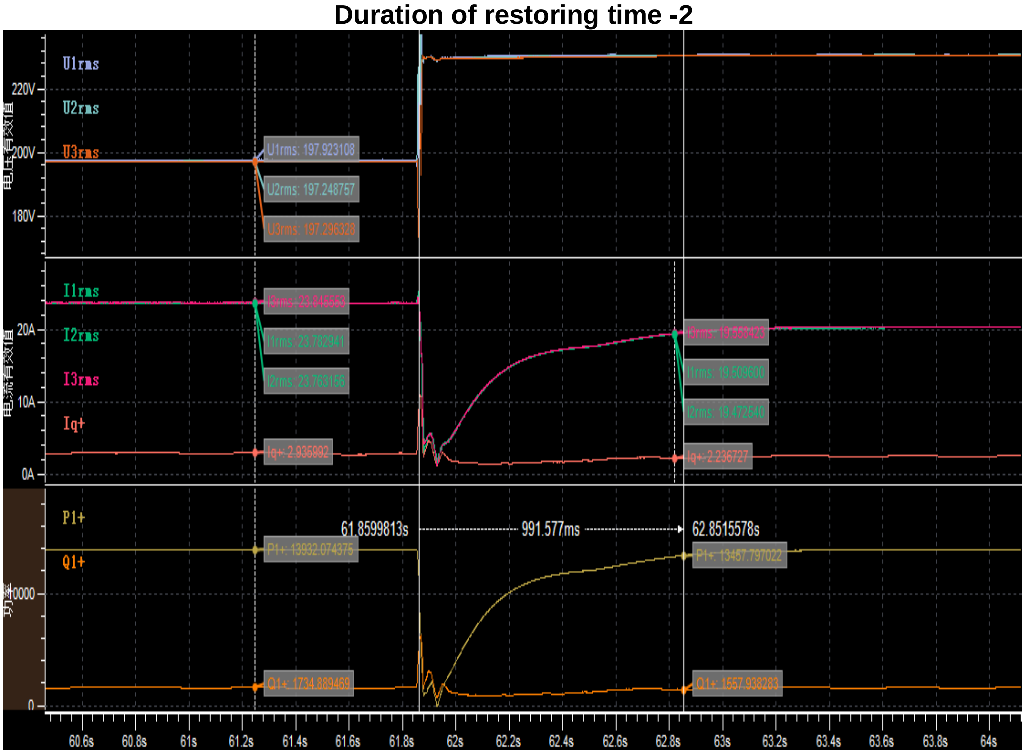


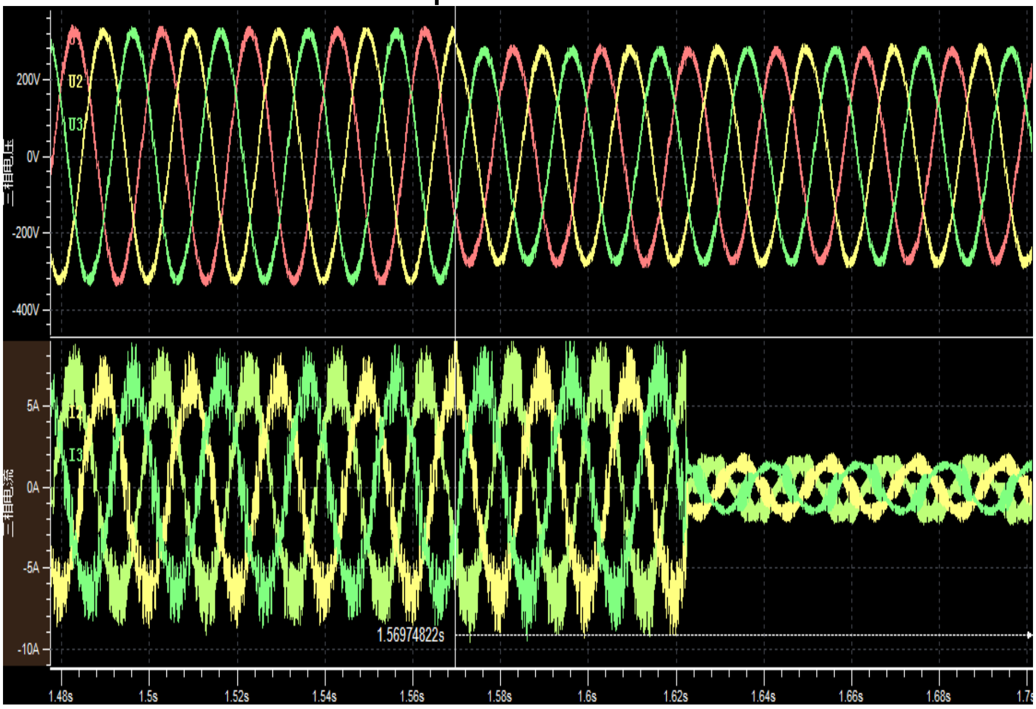
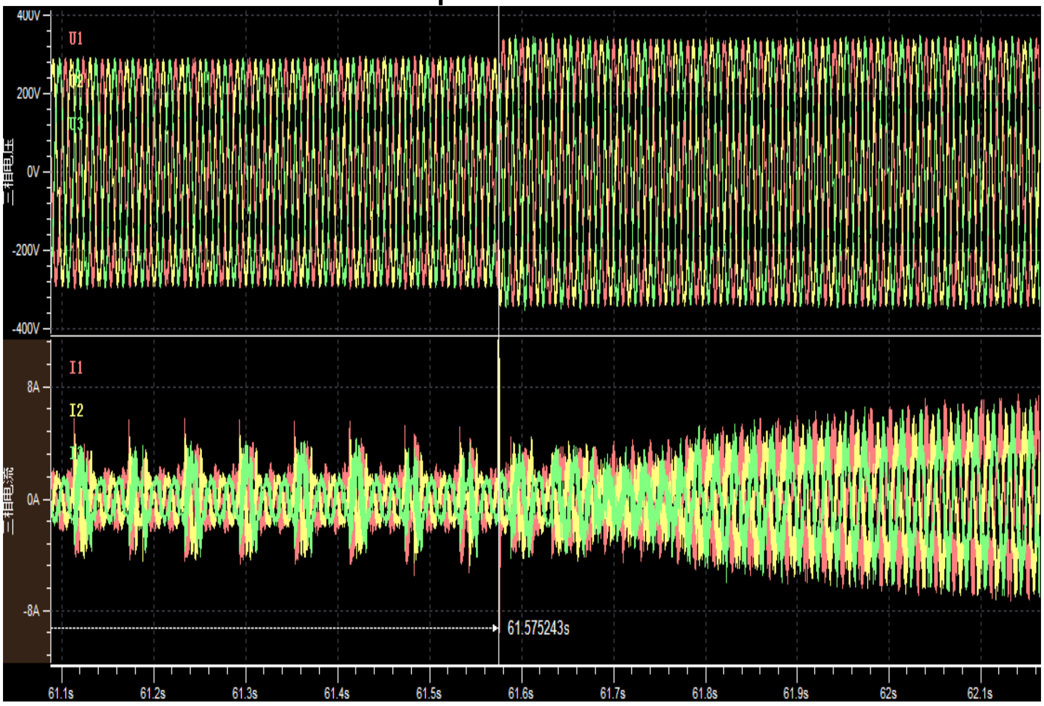
Test 4.1

Duration of restoring time -1



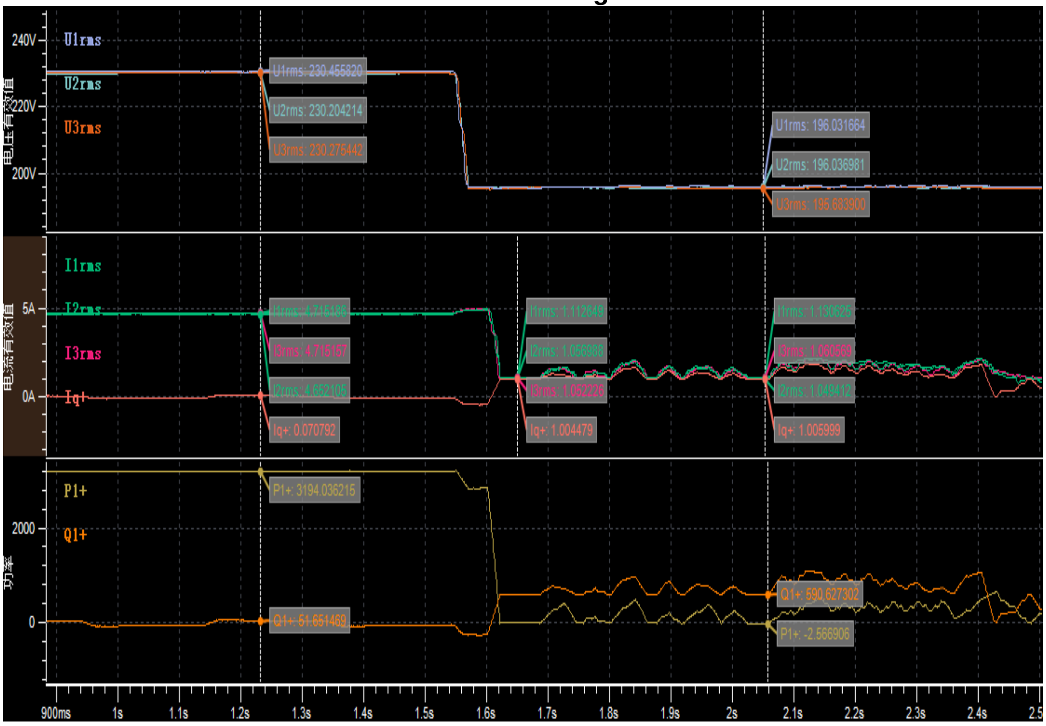
Duration of restoring time -2



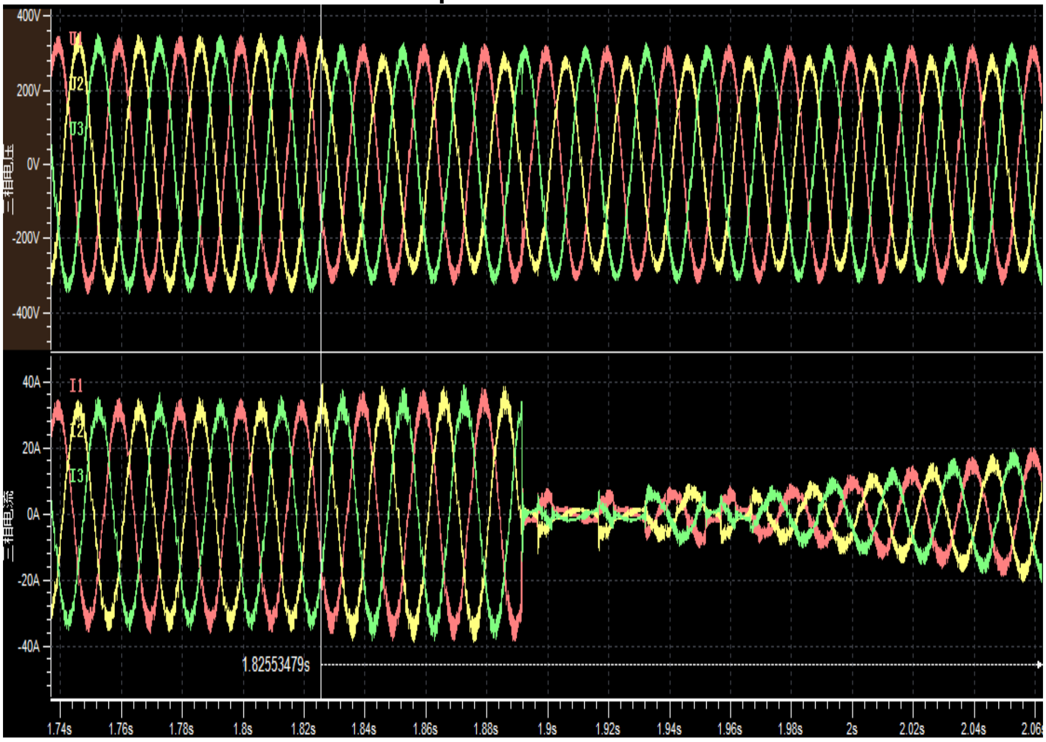
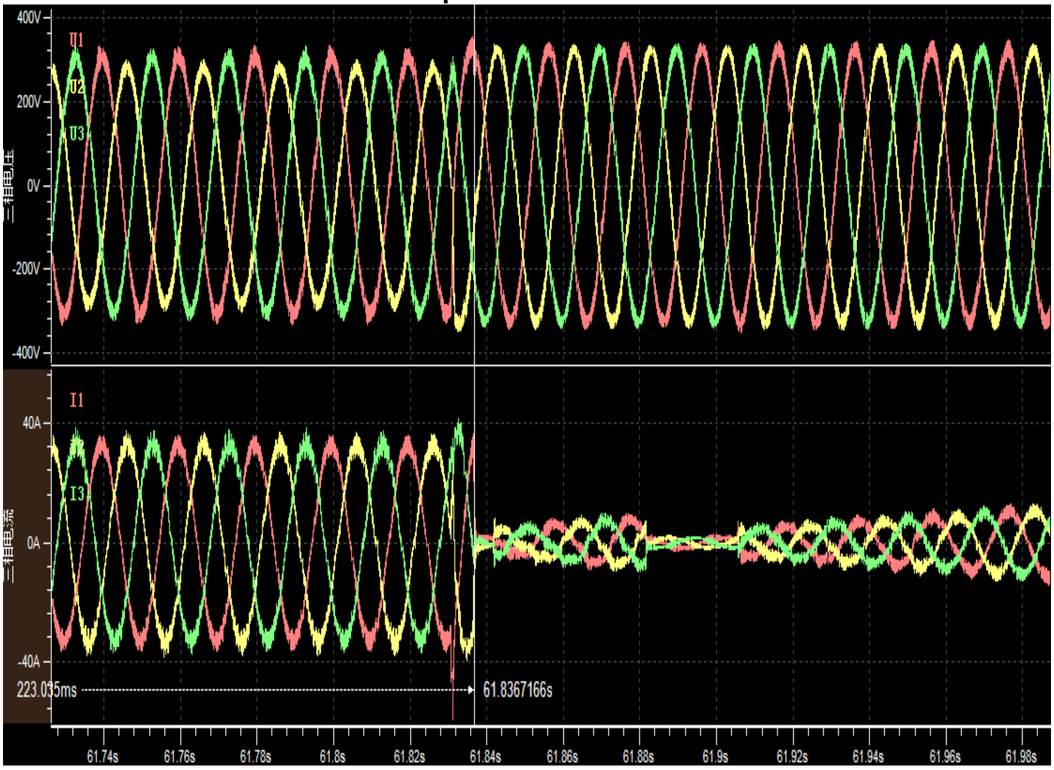
Test 4.2
Drop duration time-1

Drop duration time-2


Test 4.2

Duration of restoring time -1

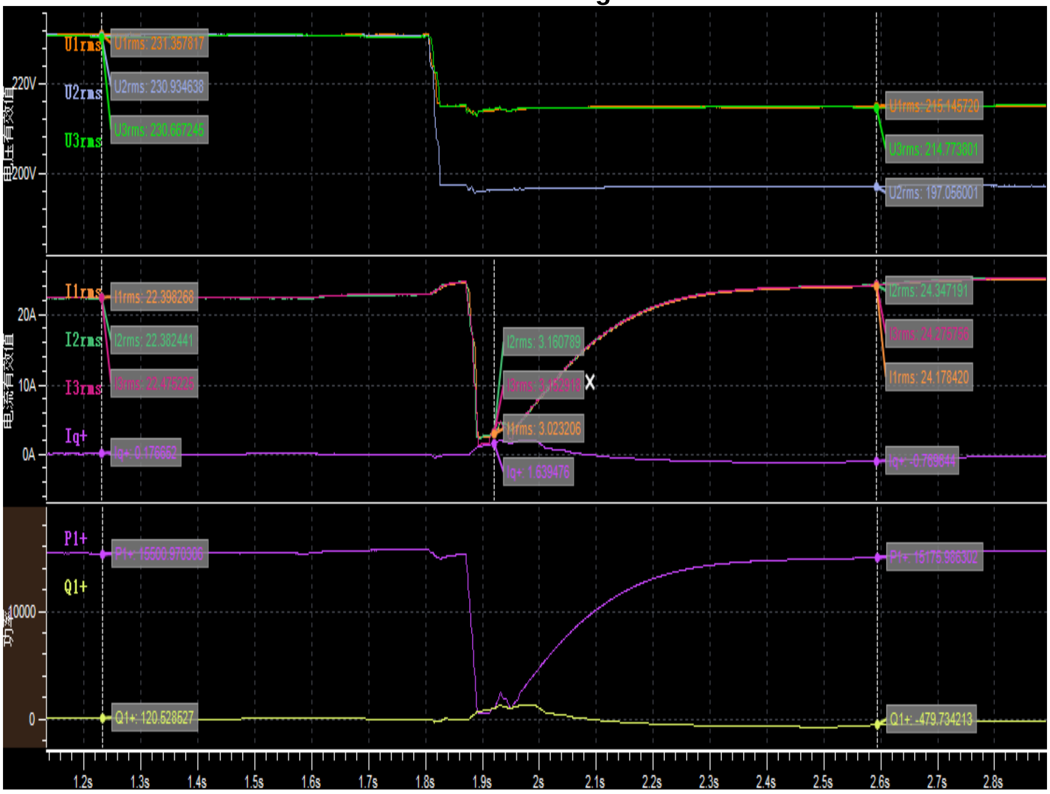


Duration of restoring time -2

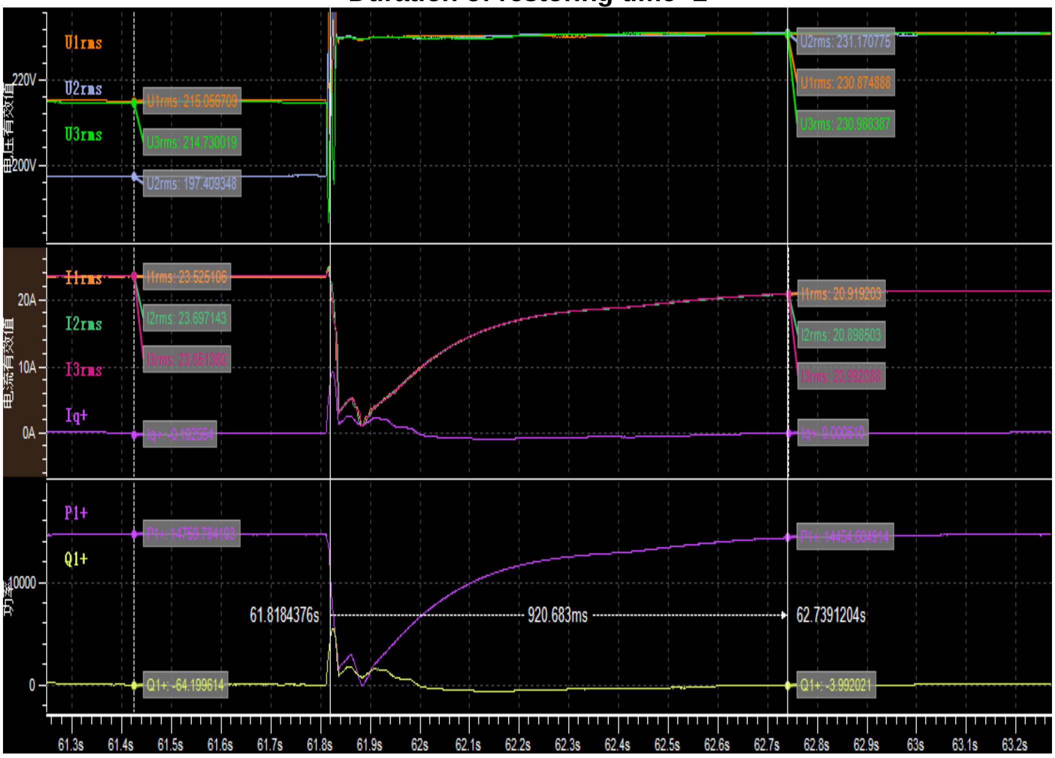
Test 4.3
Drop duration time-1

Drop duration time-2


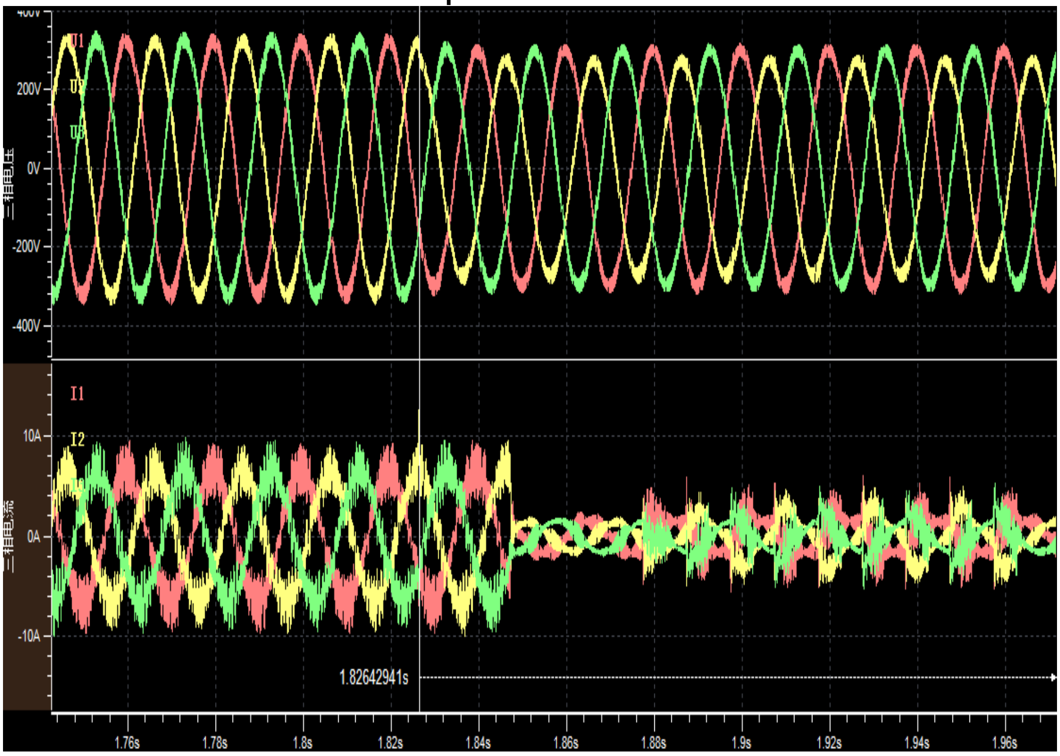
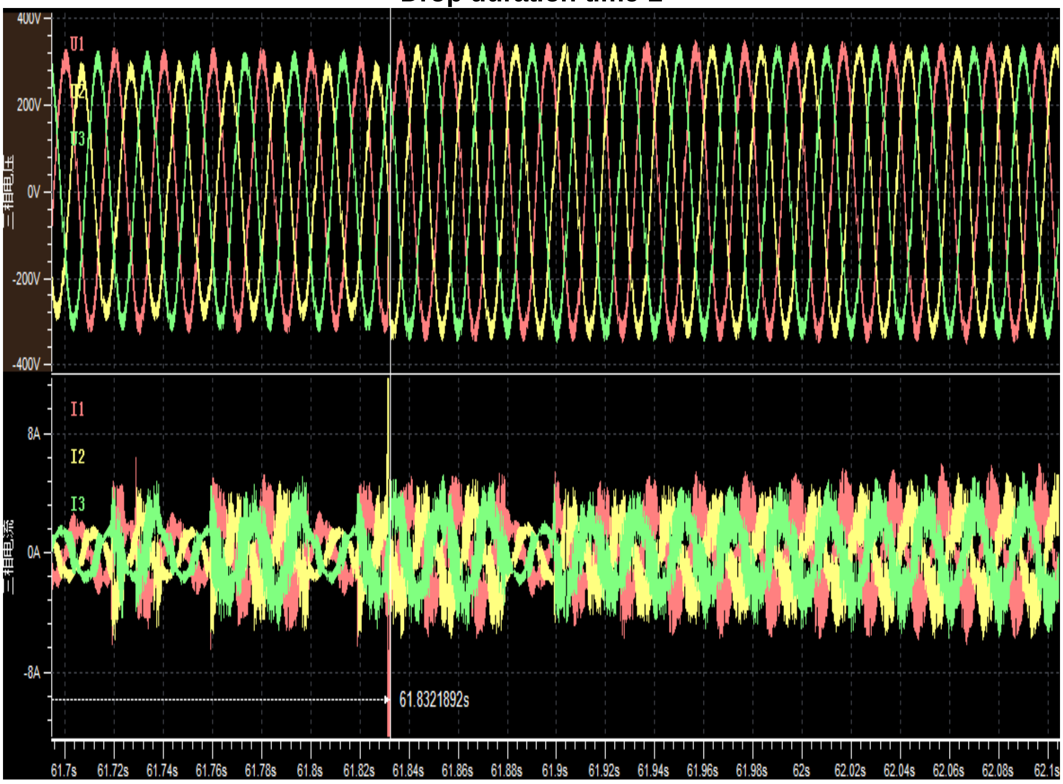
Test 4.3

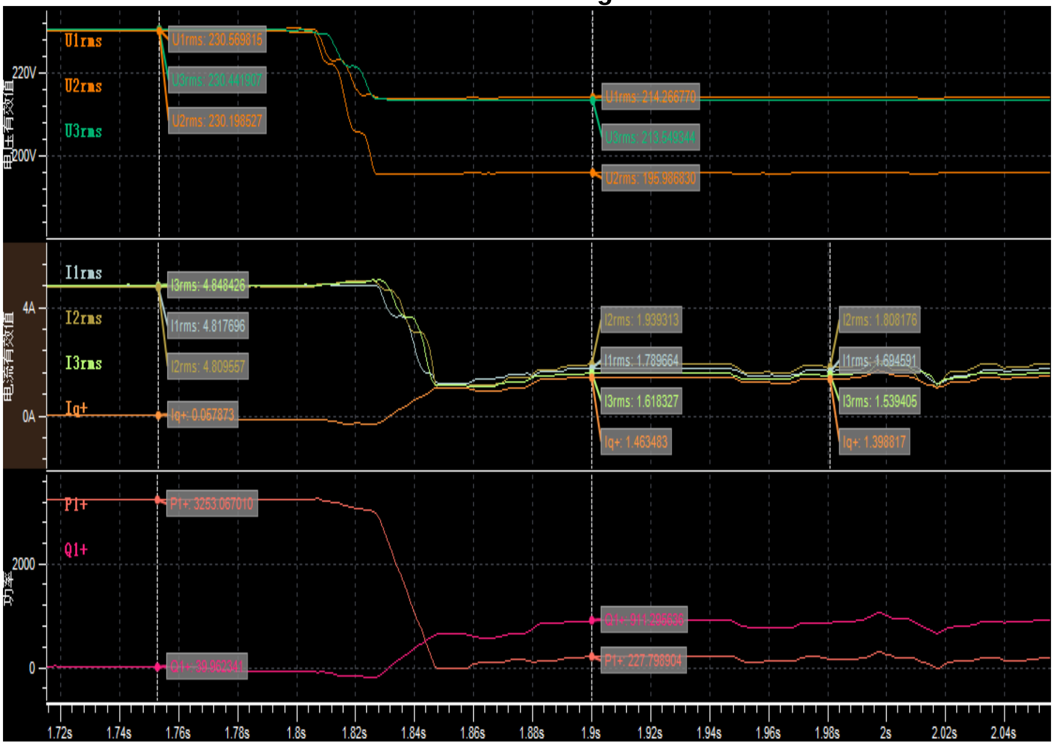
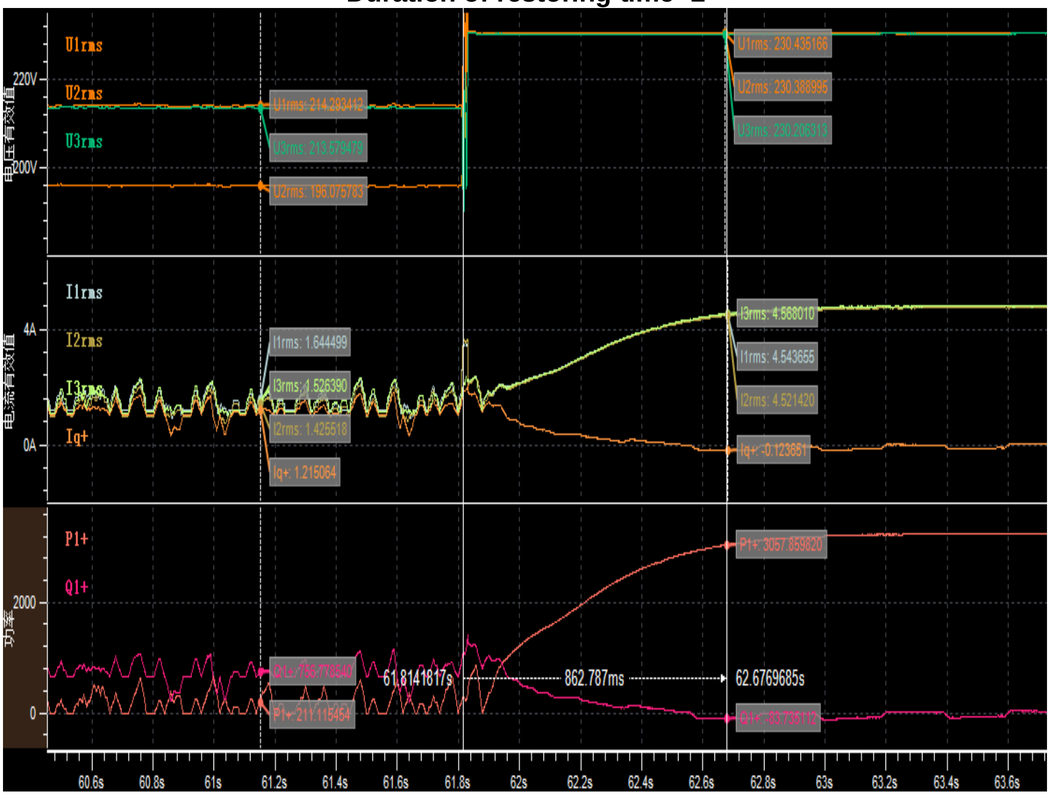
Duration of restoring time -1



Duration of restoring time -2

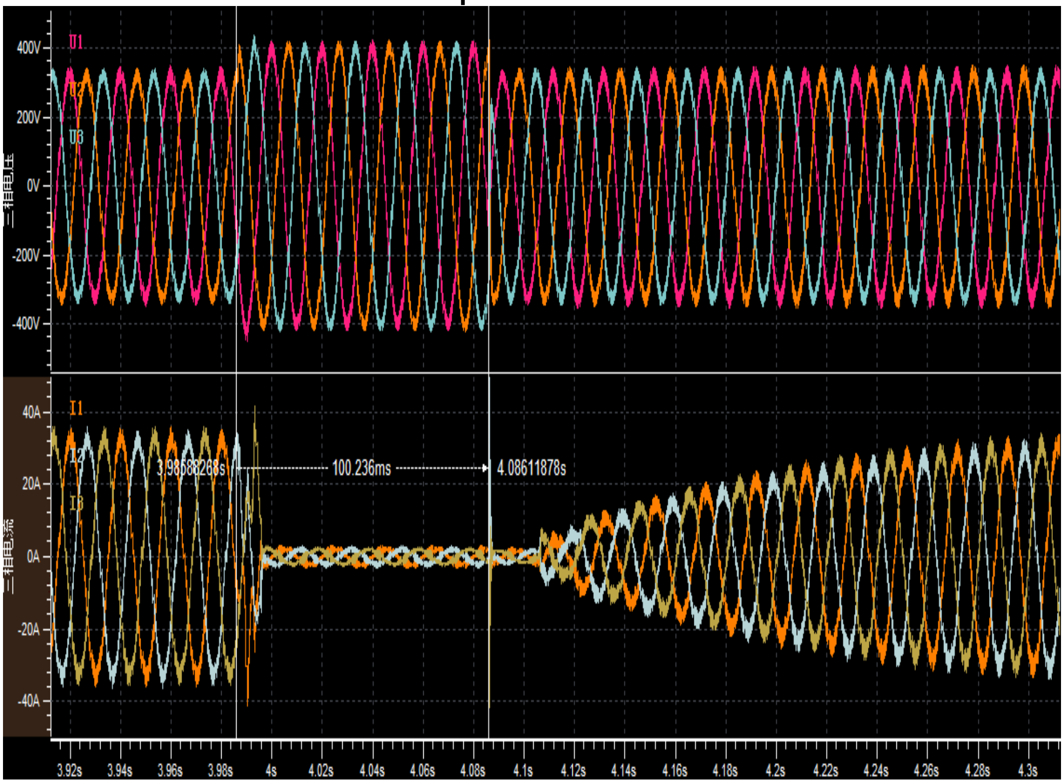


Test 4.4
Drop duration time-1

Drop duration time-2


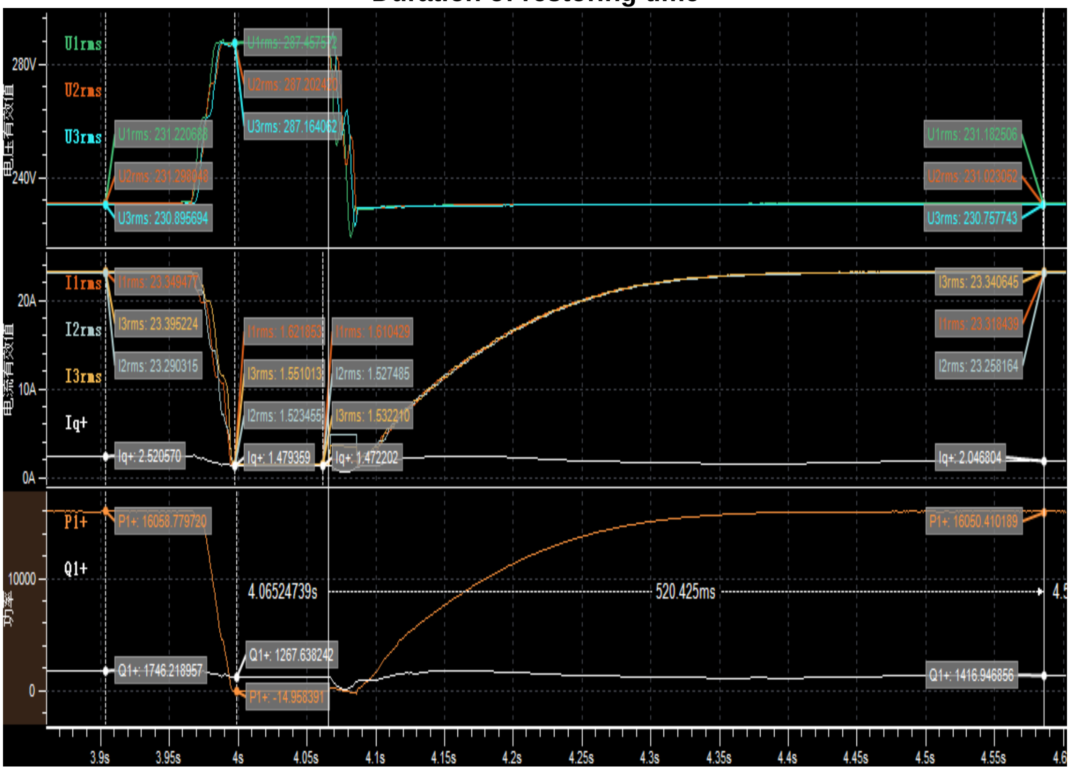
Test 4.4
Duration of restoring time -1

Duration of restoring time -2


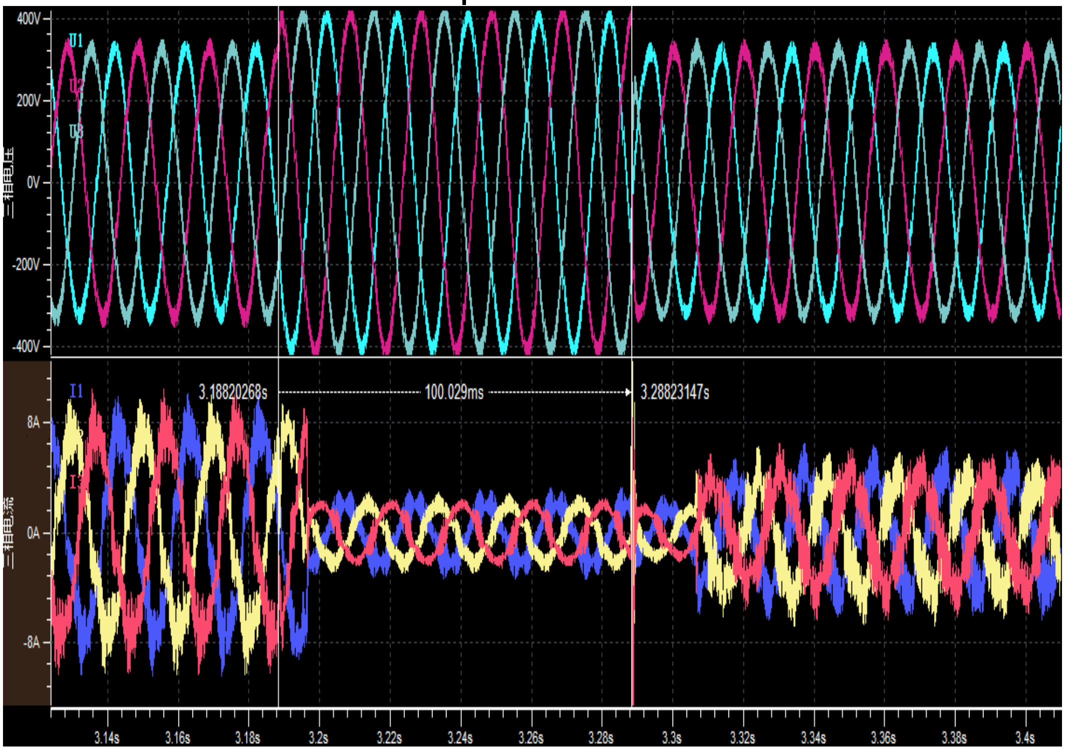
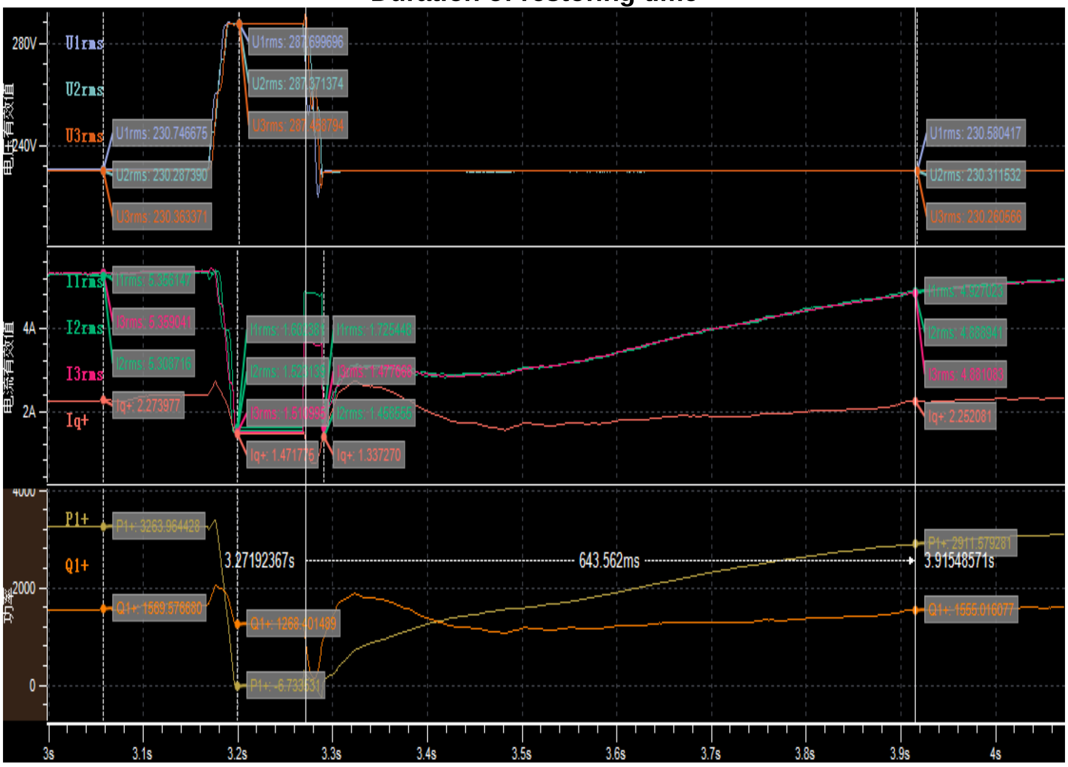
Test 5.1

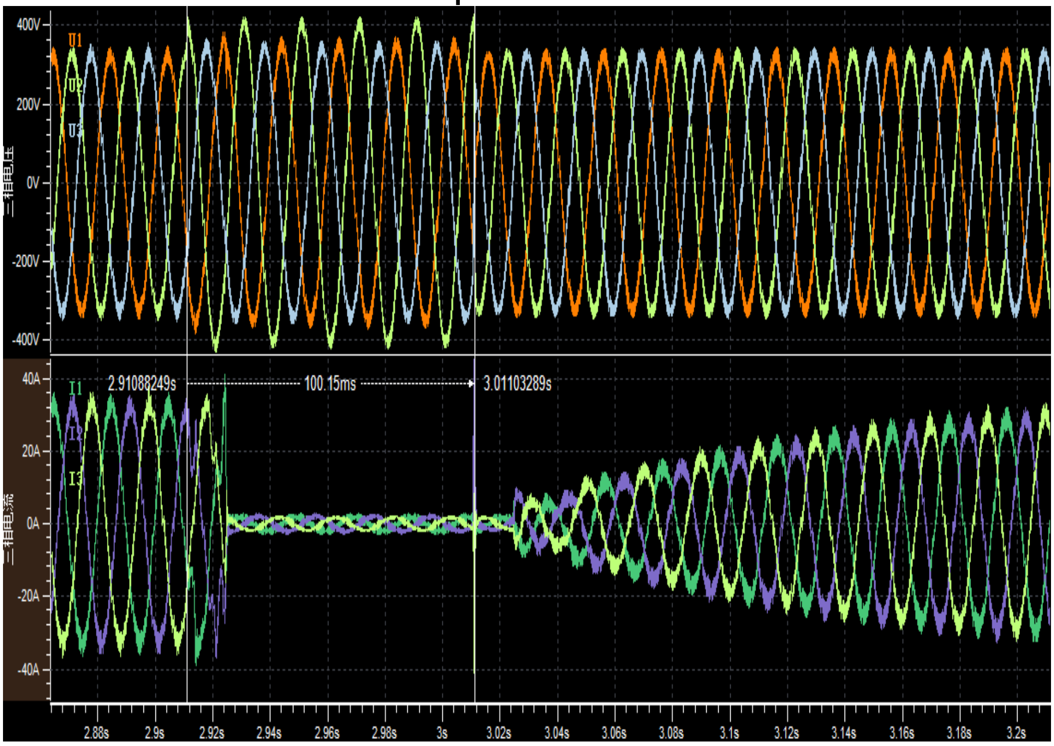
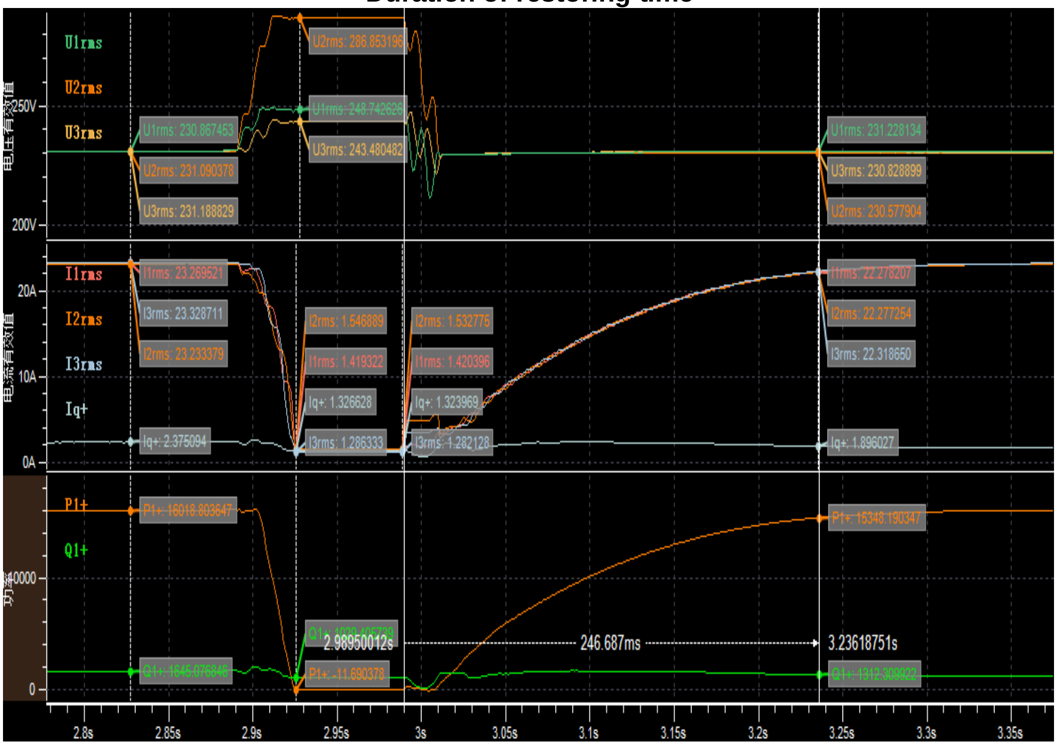
Drop duration time



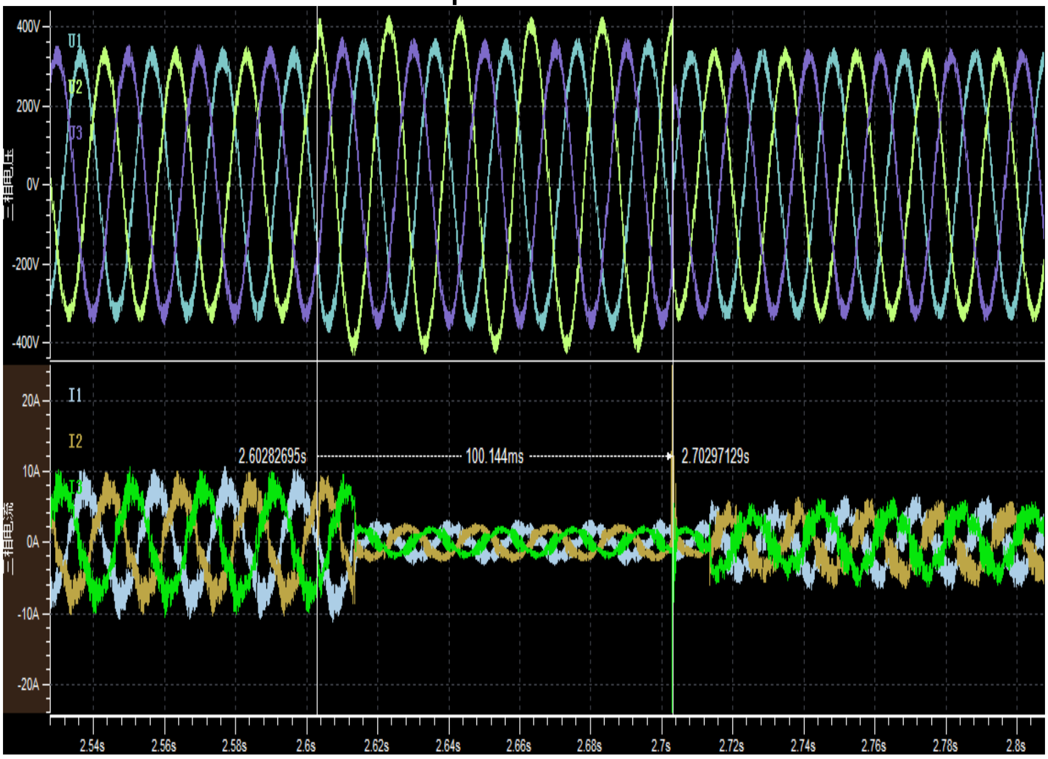
Duration of restoring time



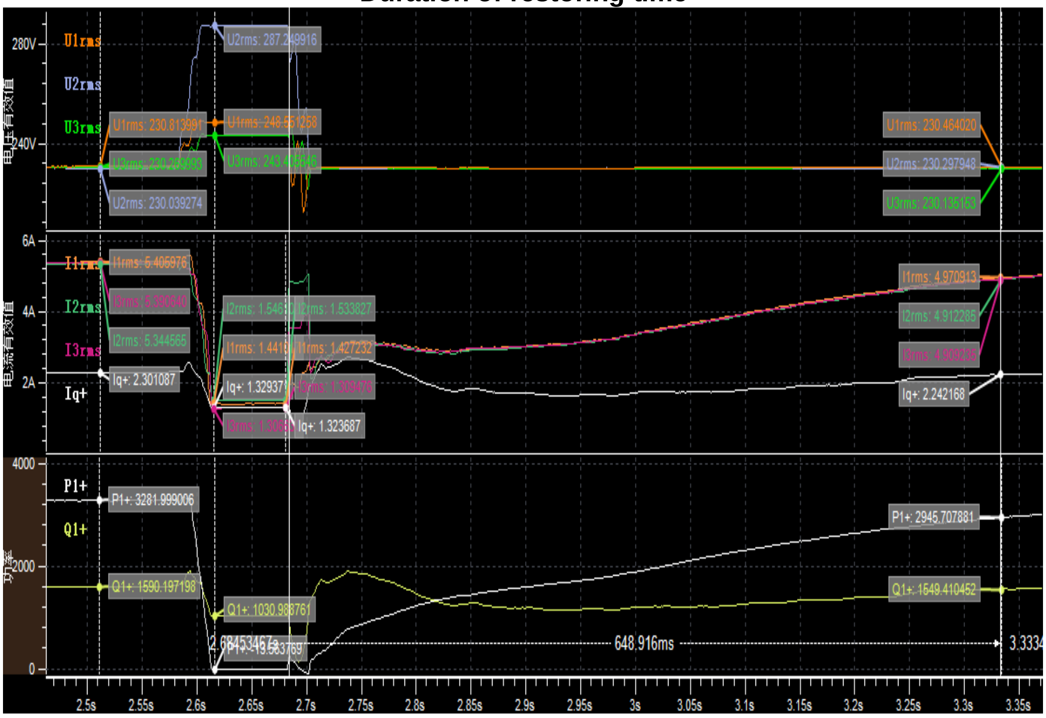
Test 5.2
Drop duration time 
Duration of restoring time 

Test 5.3
Drop duration time

Duration of restoring time


Test 5.4
Drop duration time

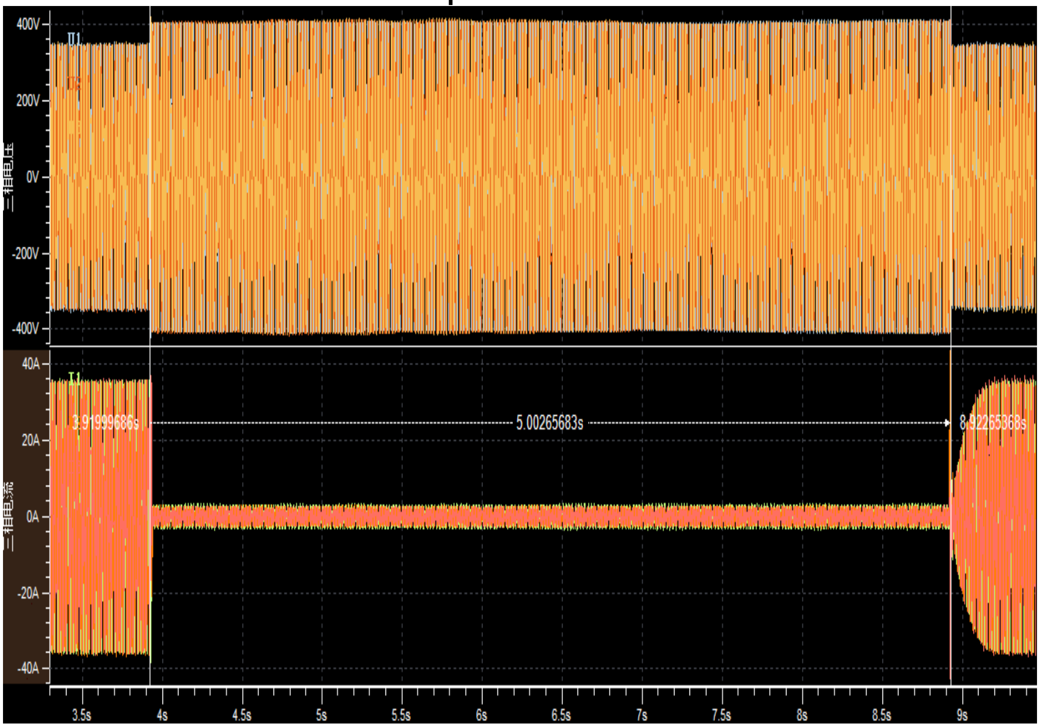


Duration of restoring time

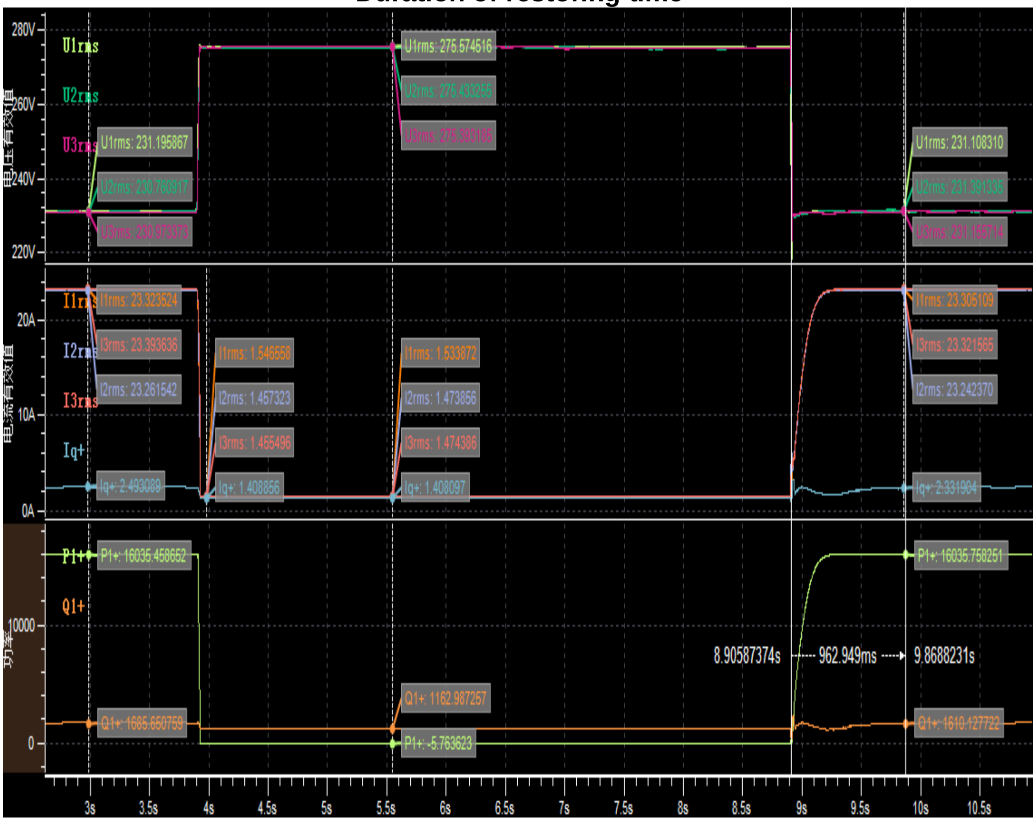


Test 6.1

Drop duration time

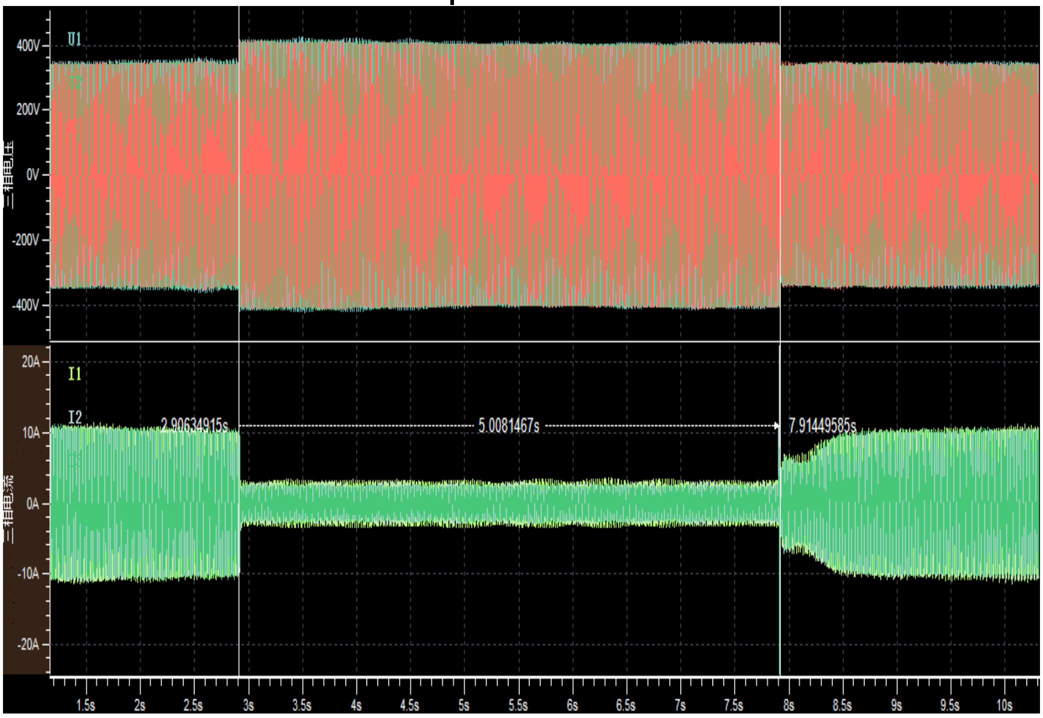


Duration of restoring time

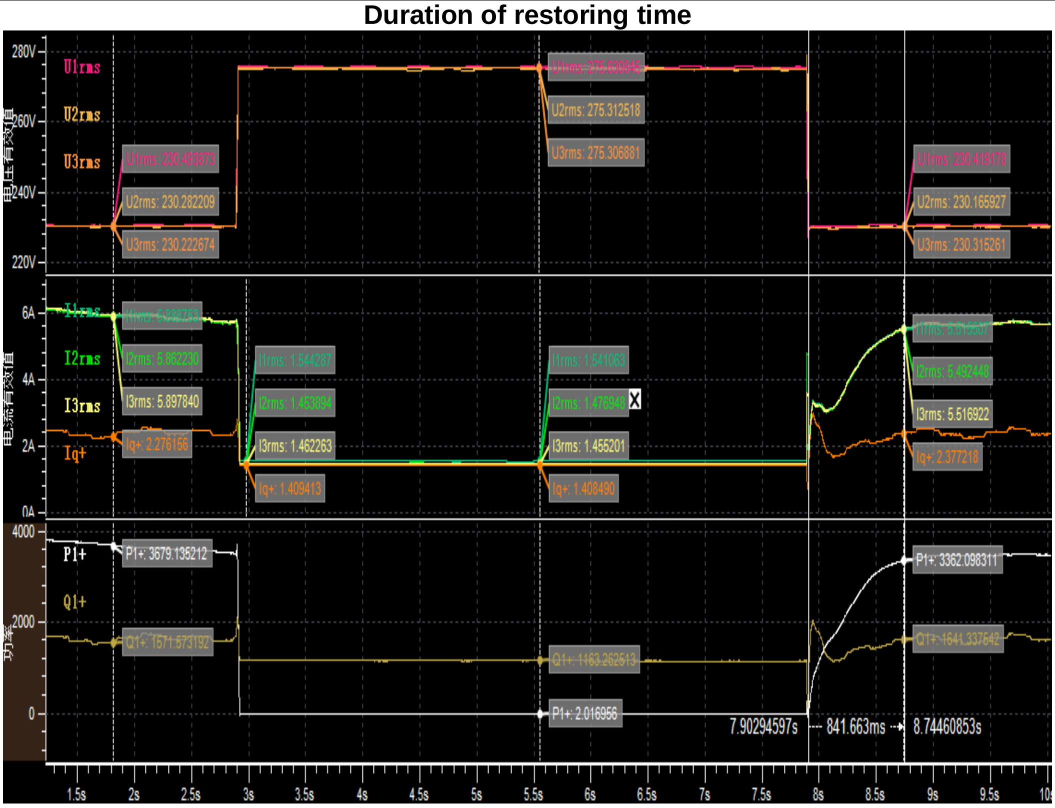


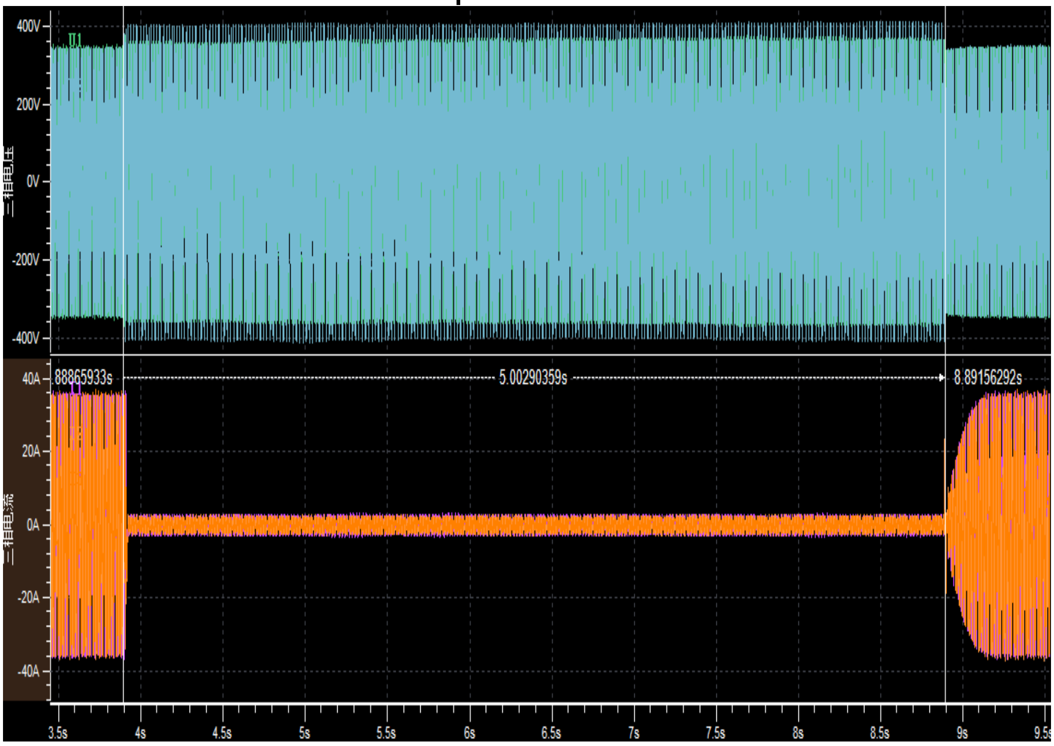
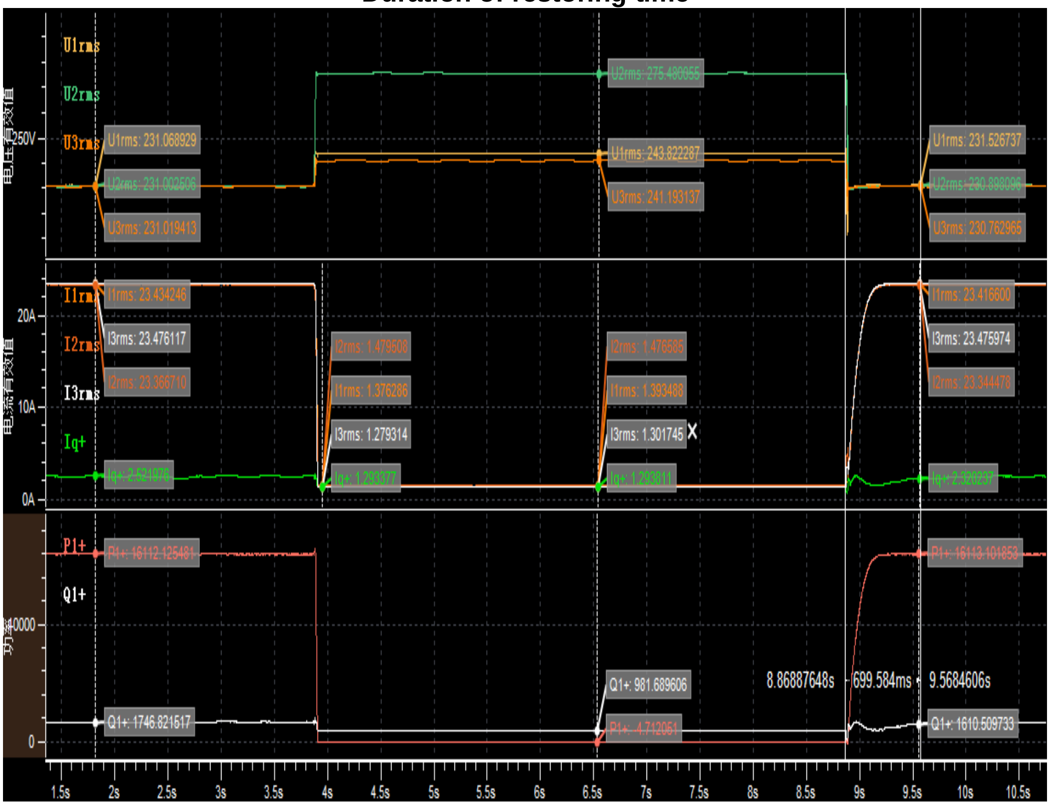
Test 6.2

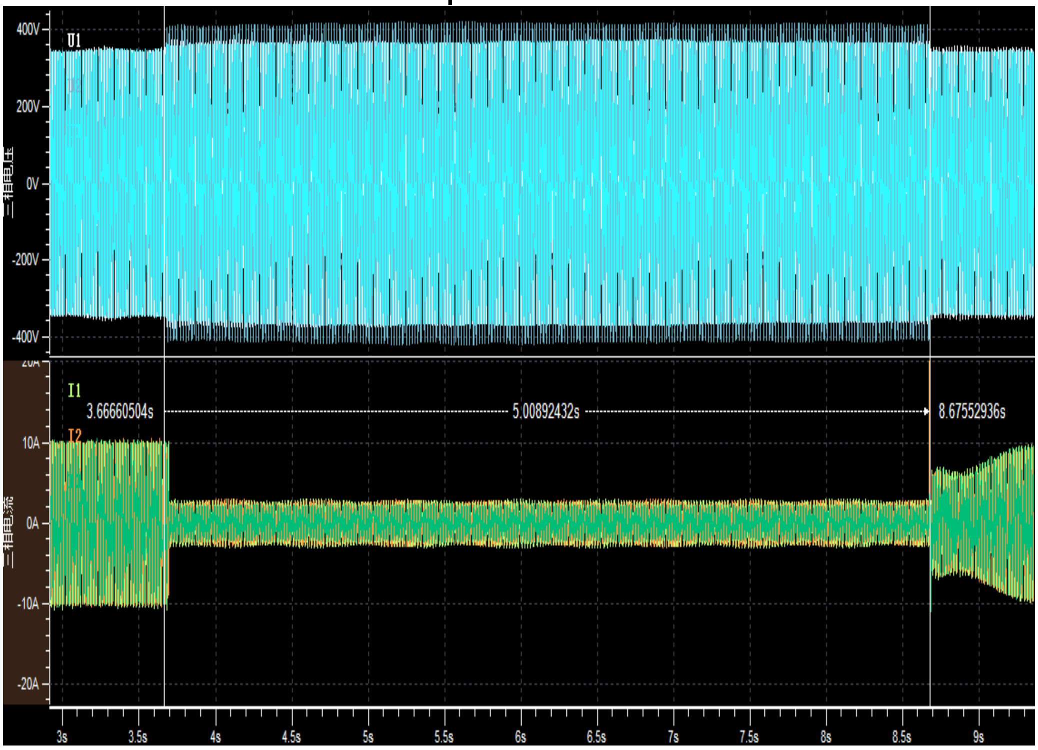
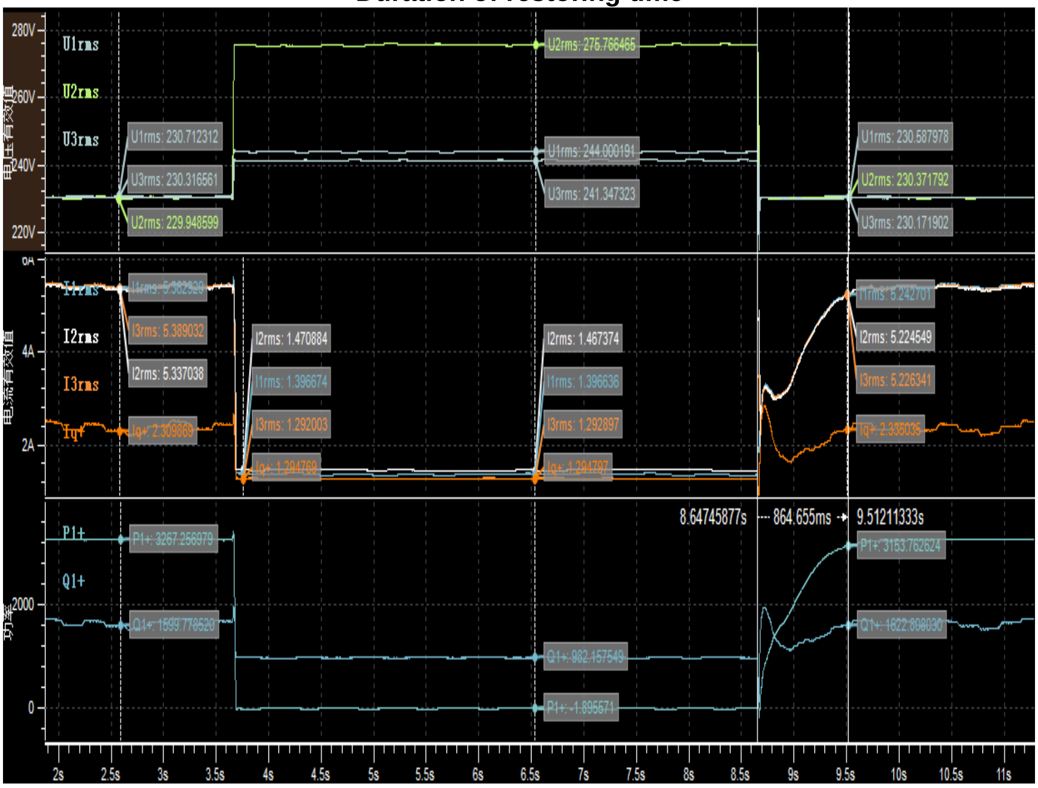
Drop duration time

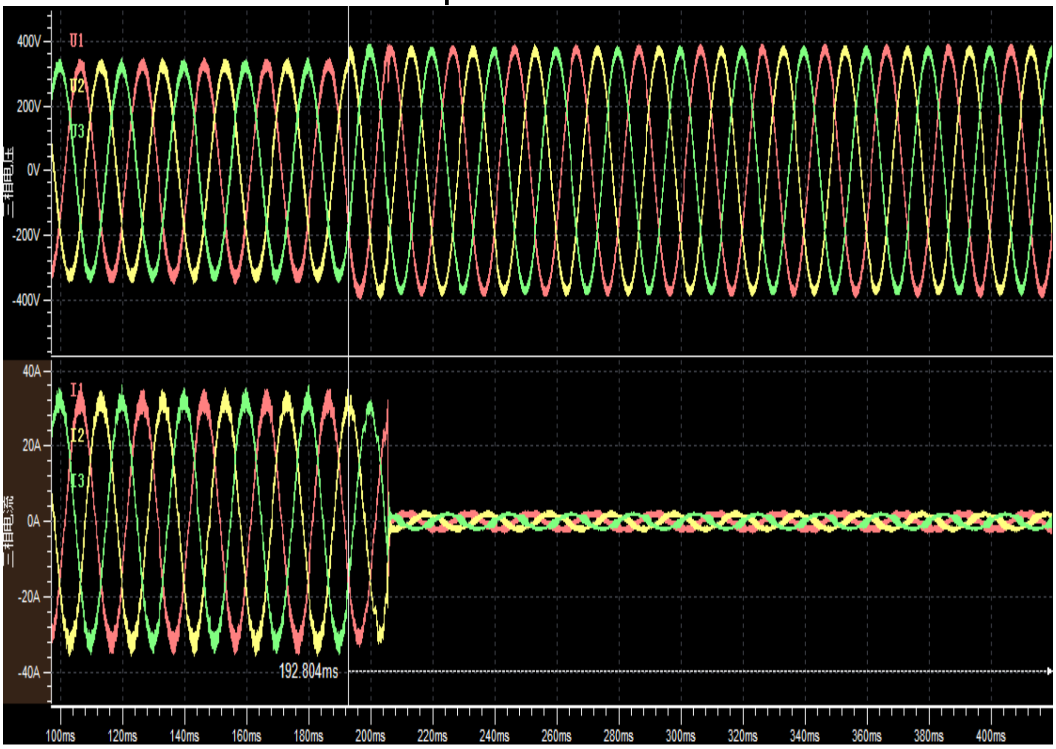
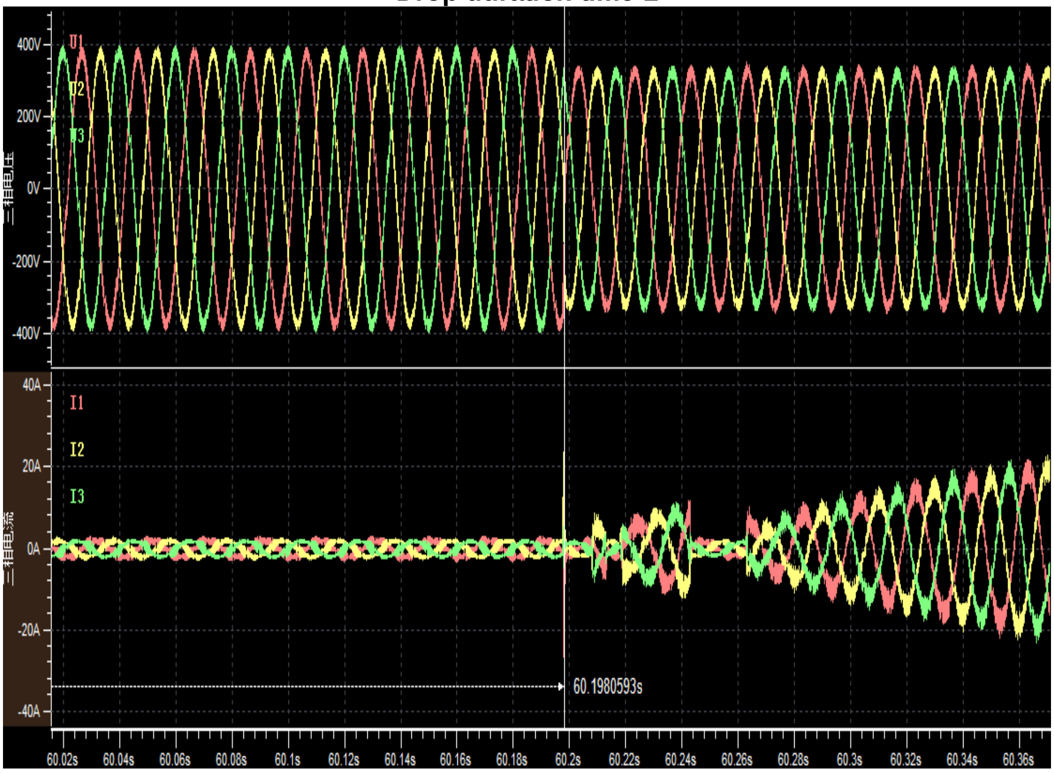


Duration of restoring time



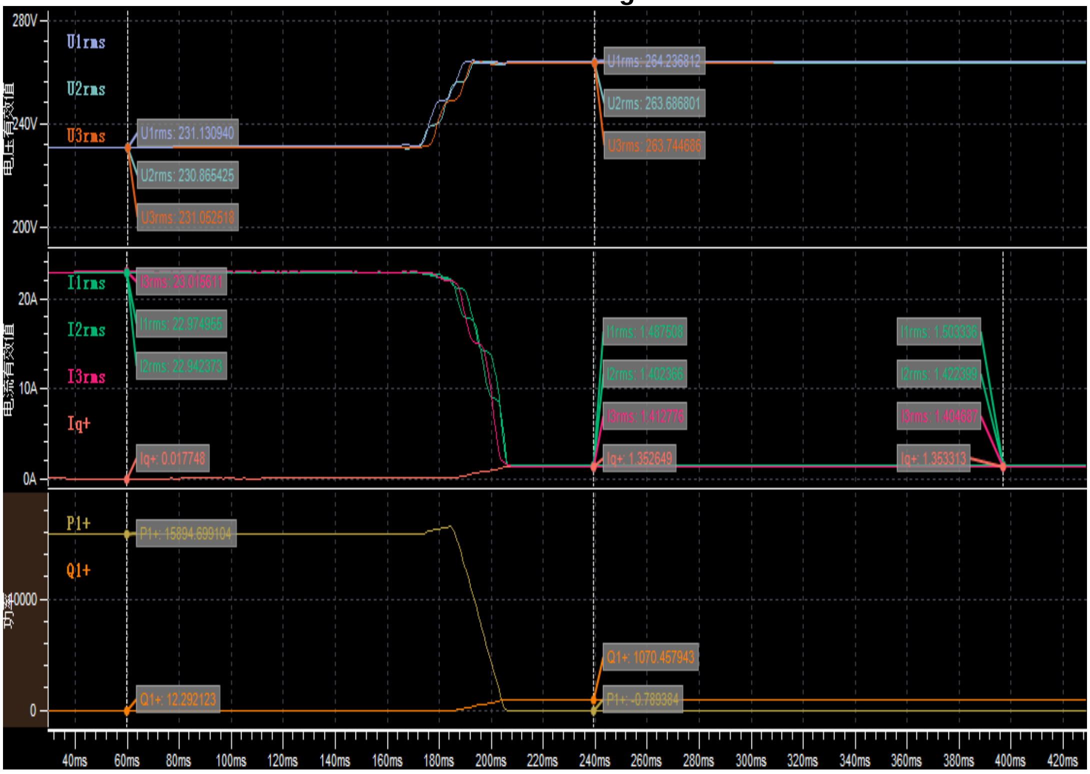
Test 6.3
Drop duration time

Duration of restoring time


Test 6.4
Drop duration time 
Duration of restoring time 

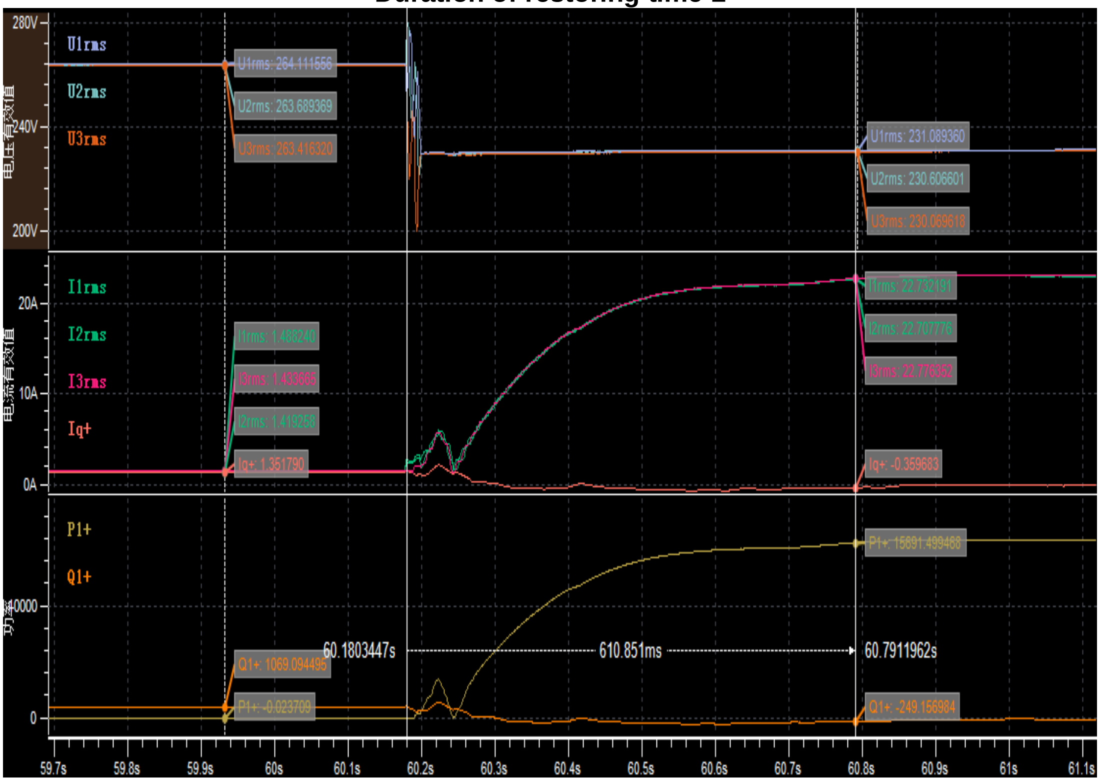
Test 7.1
Drop duration time-1

Drop duration time-2


Test 7.1

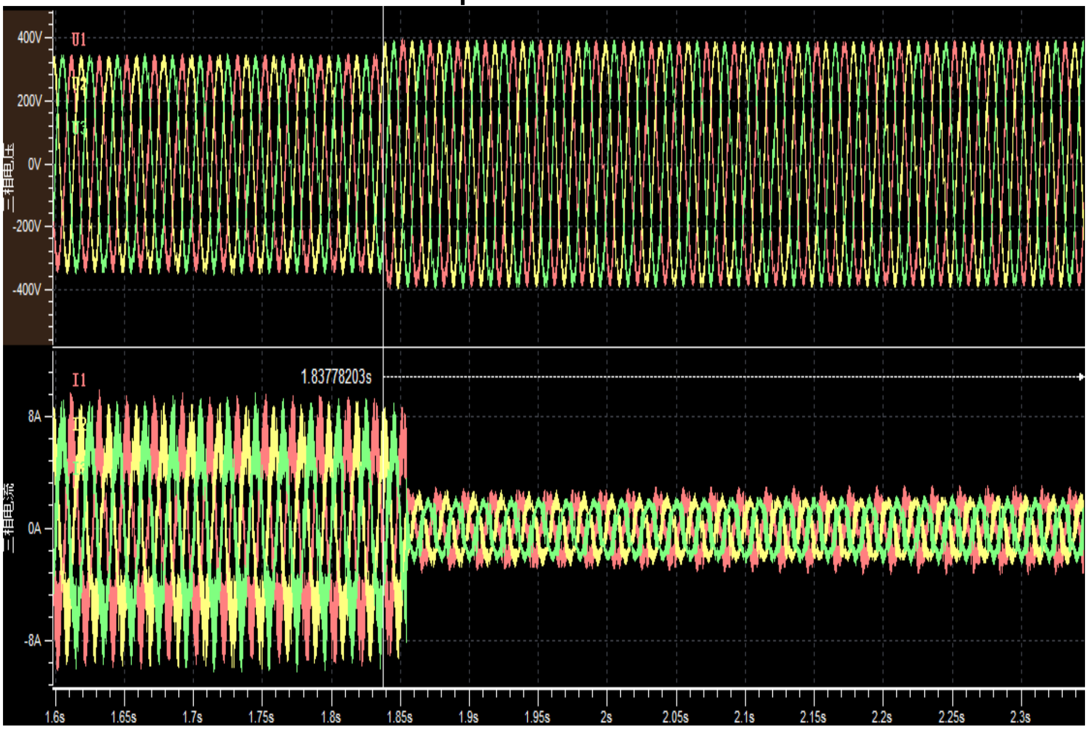
Duration of restoring time-1



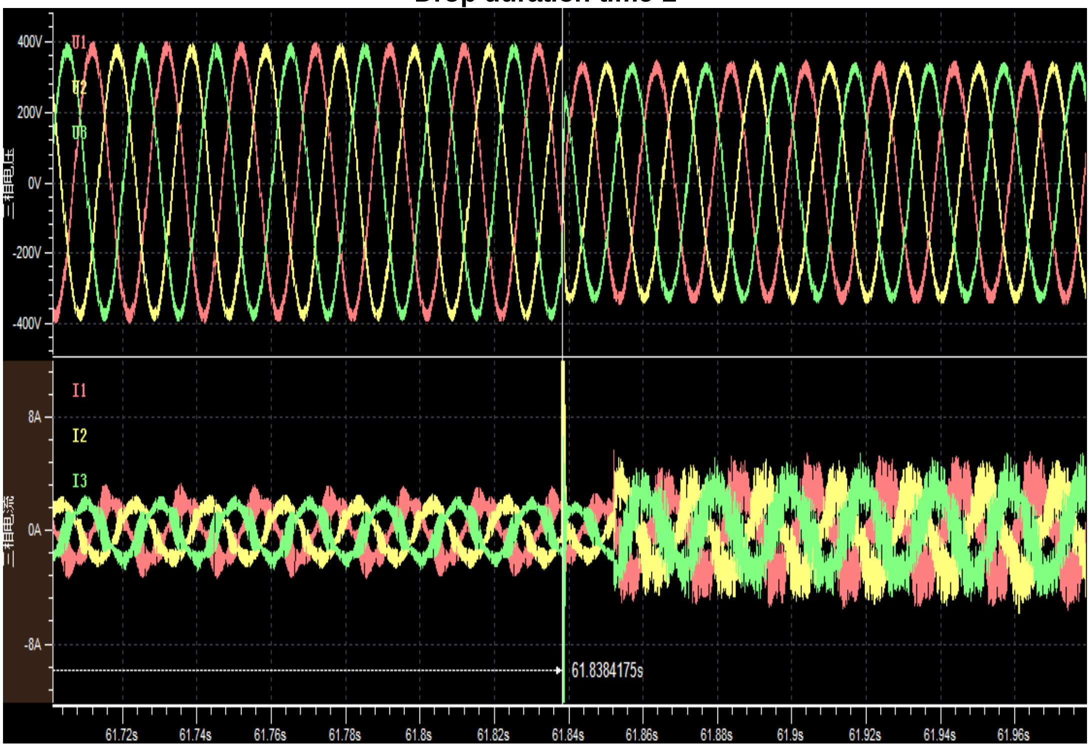
Duration of restoring time-2



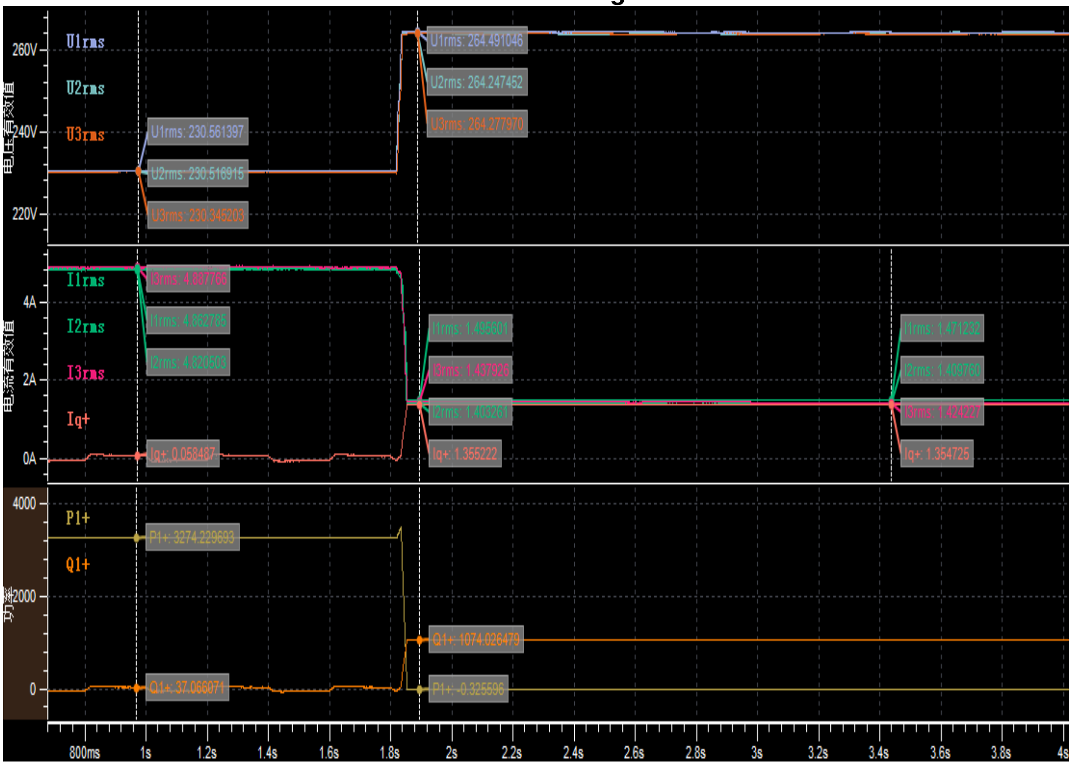
Test 7.2
Drop duration time-1



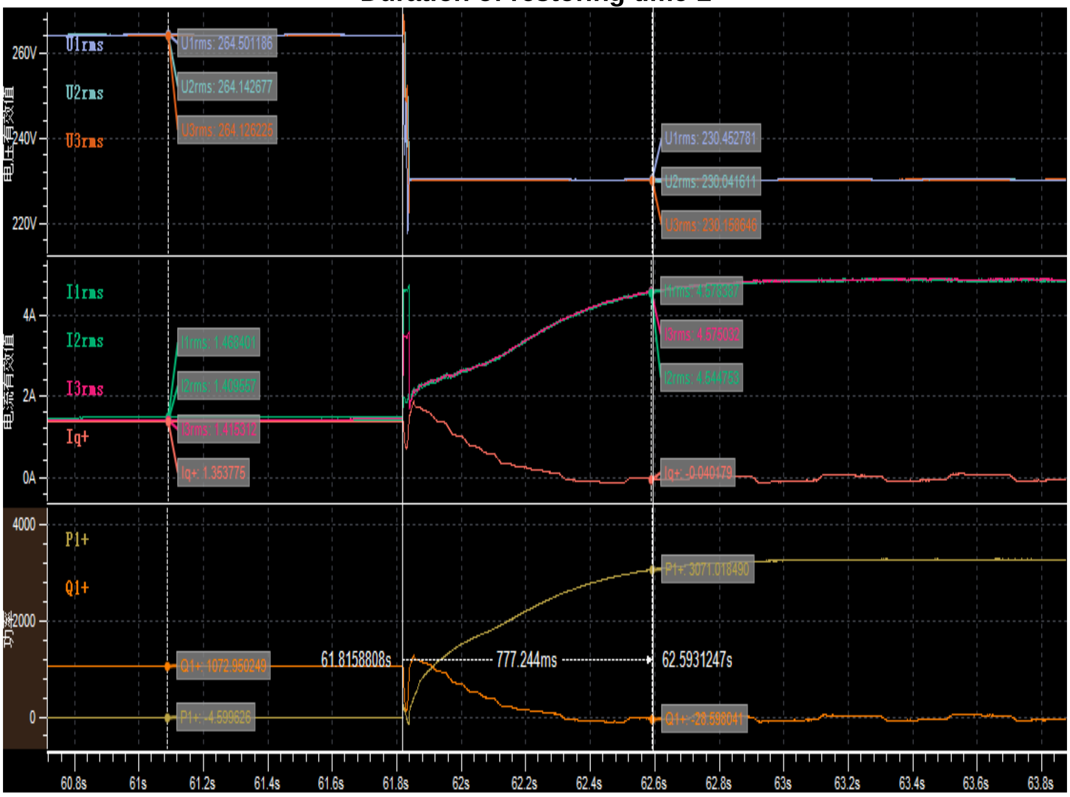
Drop duration time-2

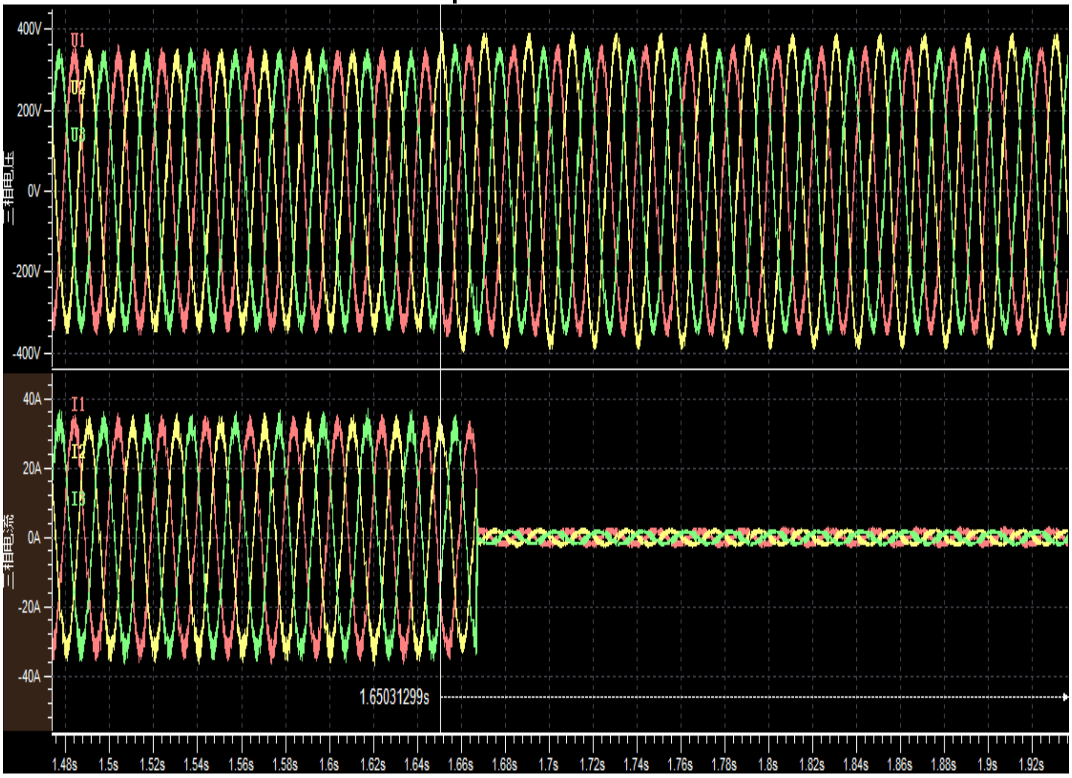
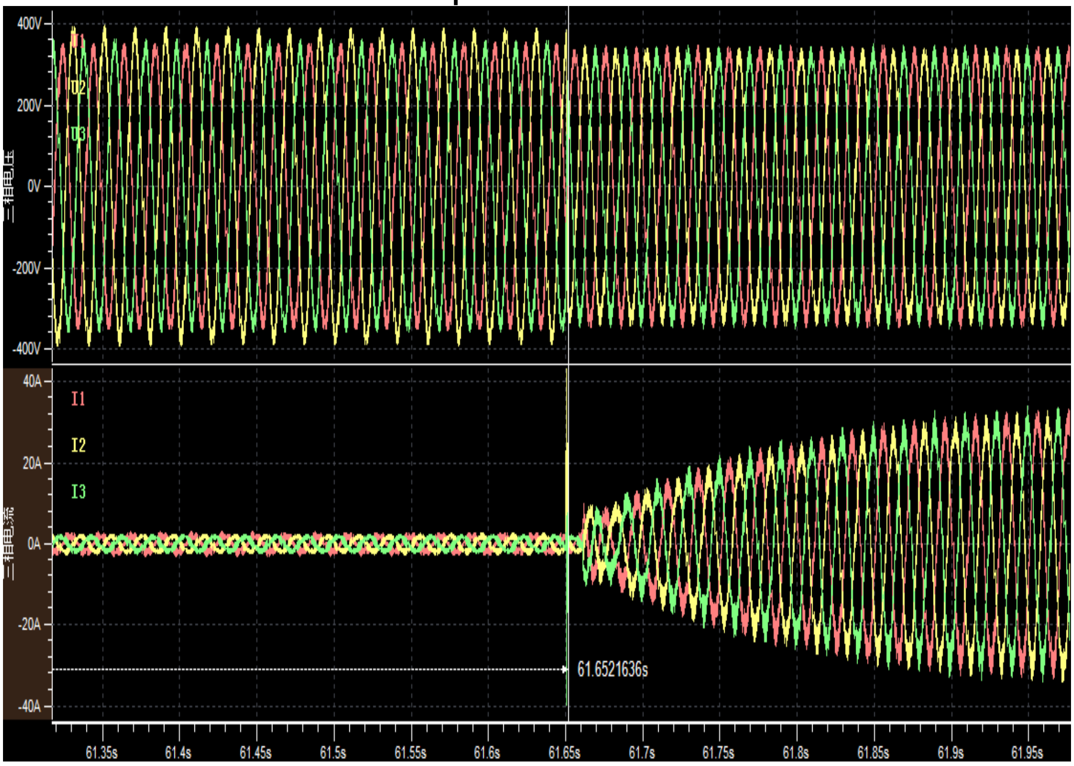


Test 7.2
Duration of restoring time-1



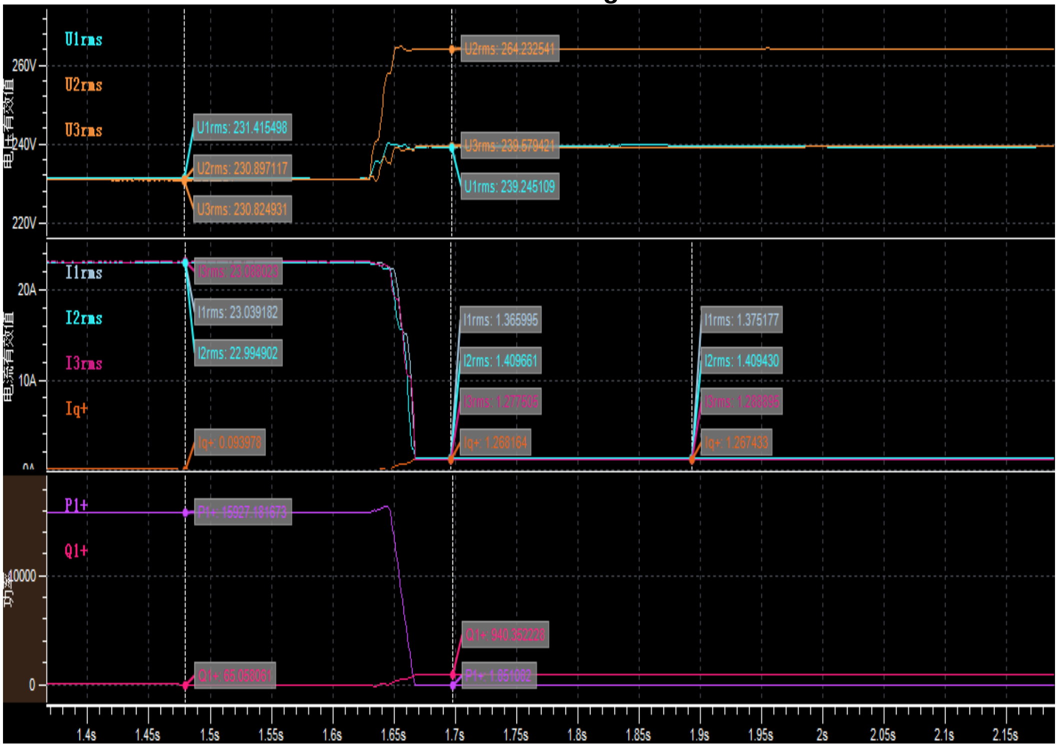
Duration of restoring time-2



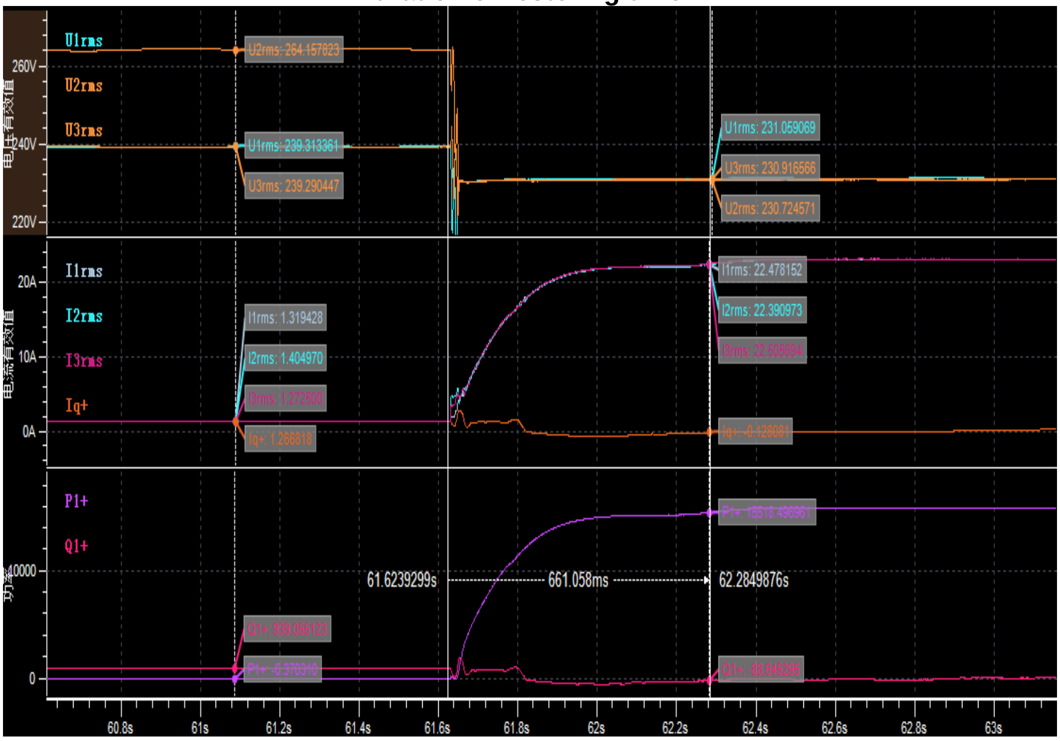
Test 7.3
Drop duration time-1

Drop duration time-2


Test 7.3

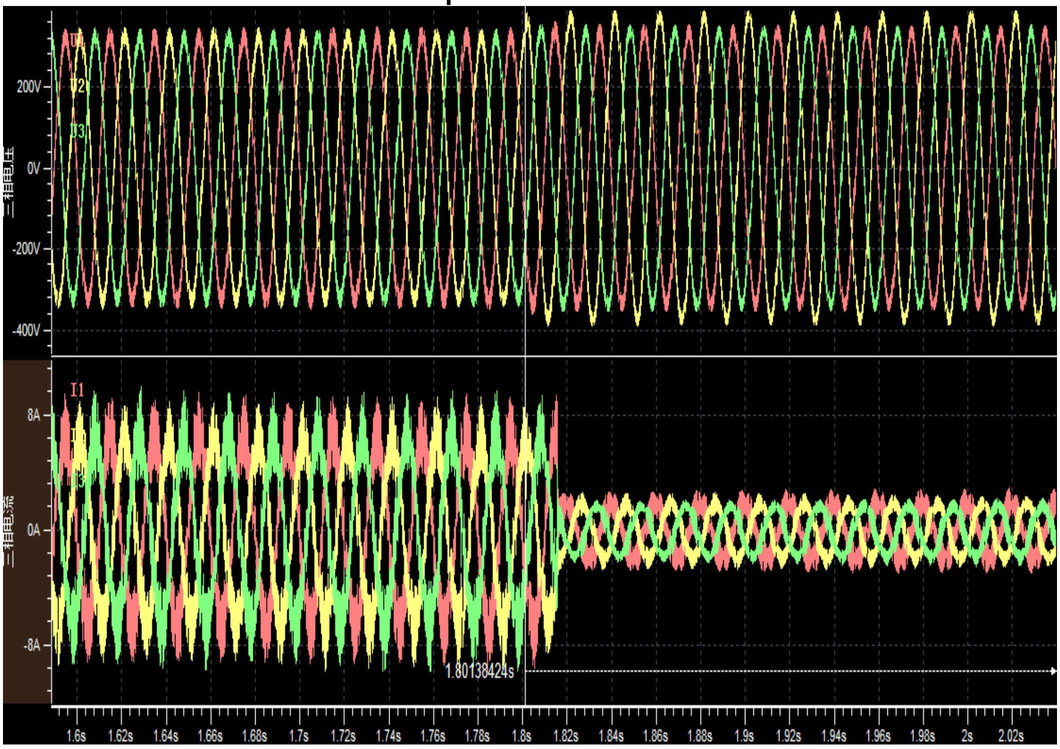
Duration of restoring time-1



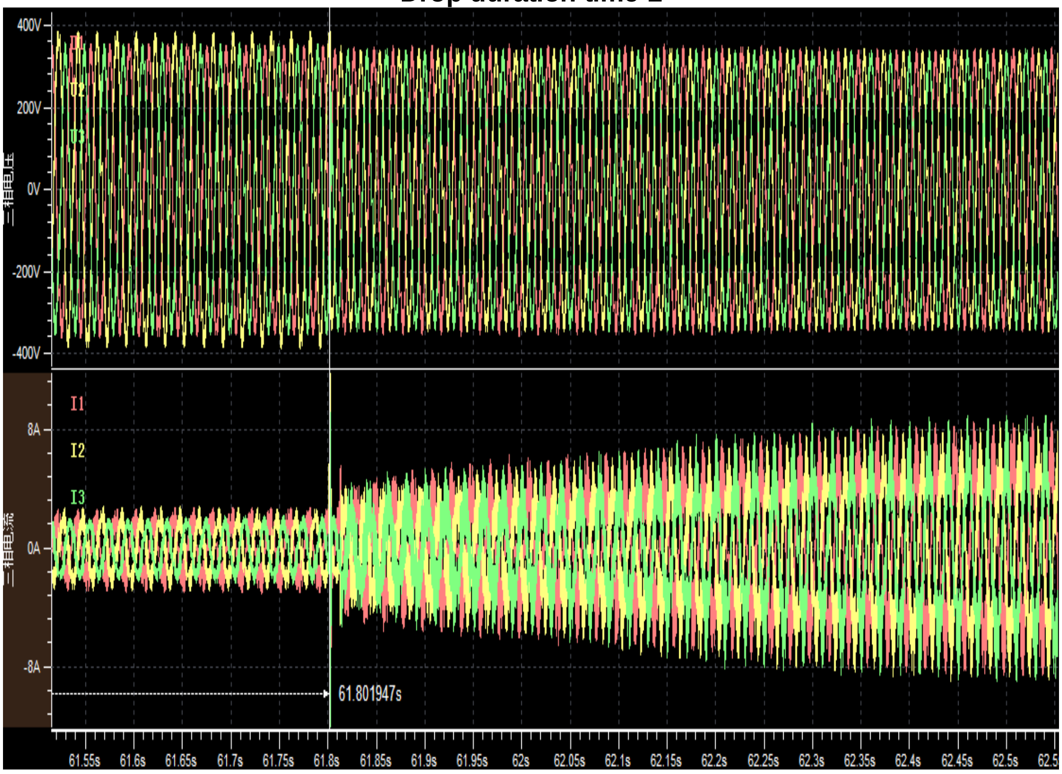
Duration of restoring time-2



Test 7.4
Drop duration time-1

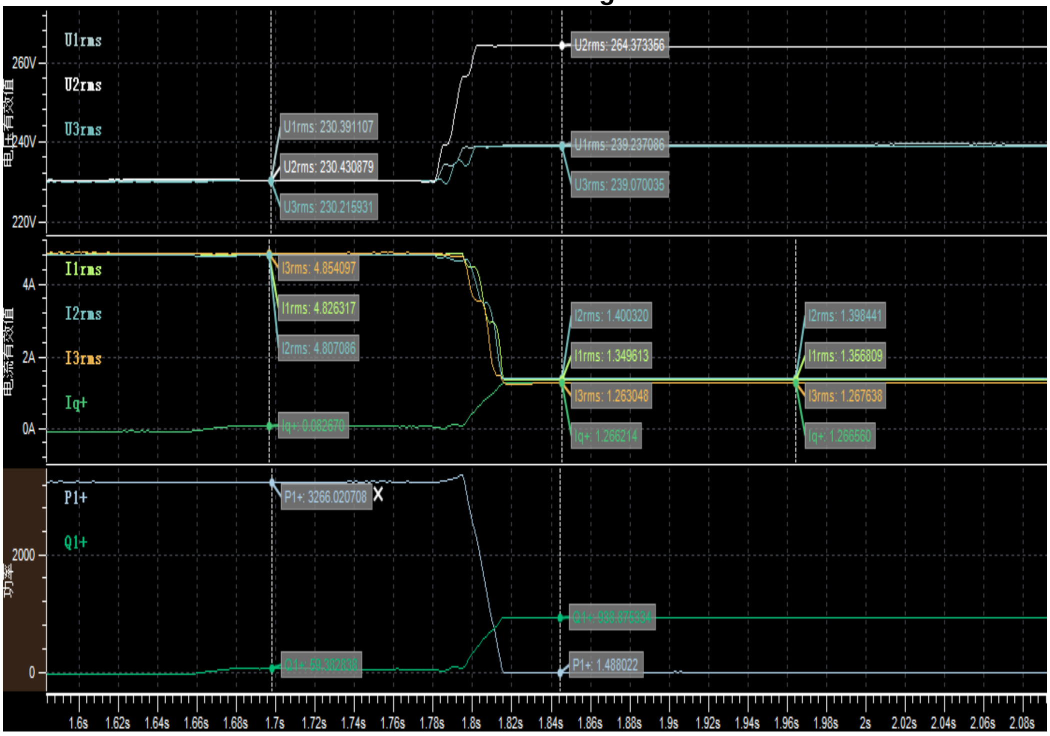


Drop duration time-2

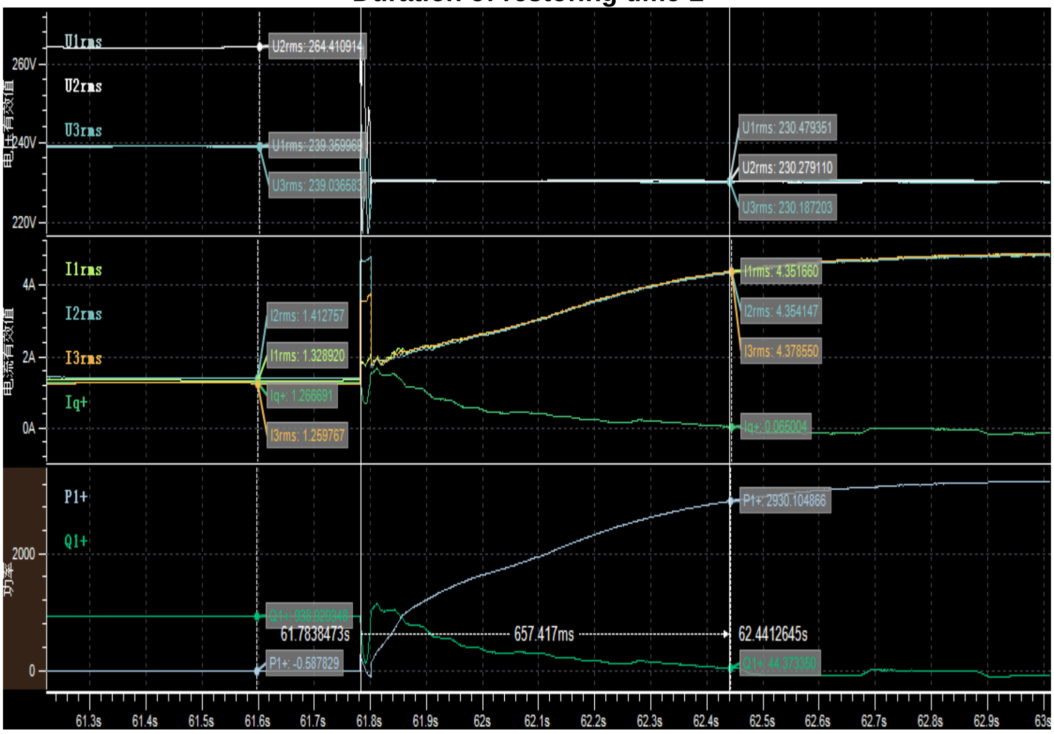


Test 7.4

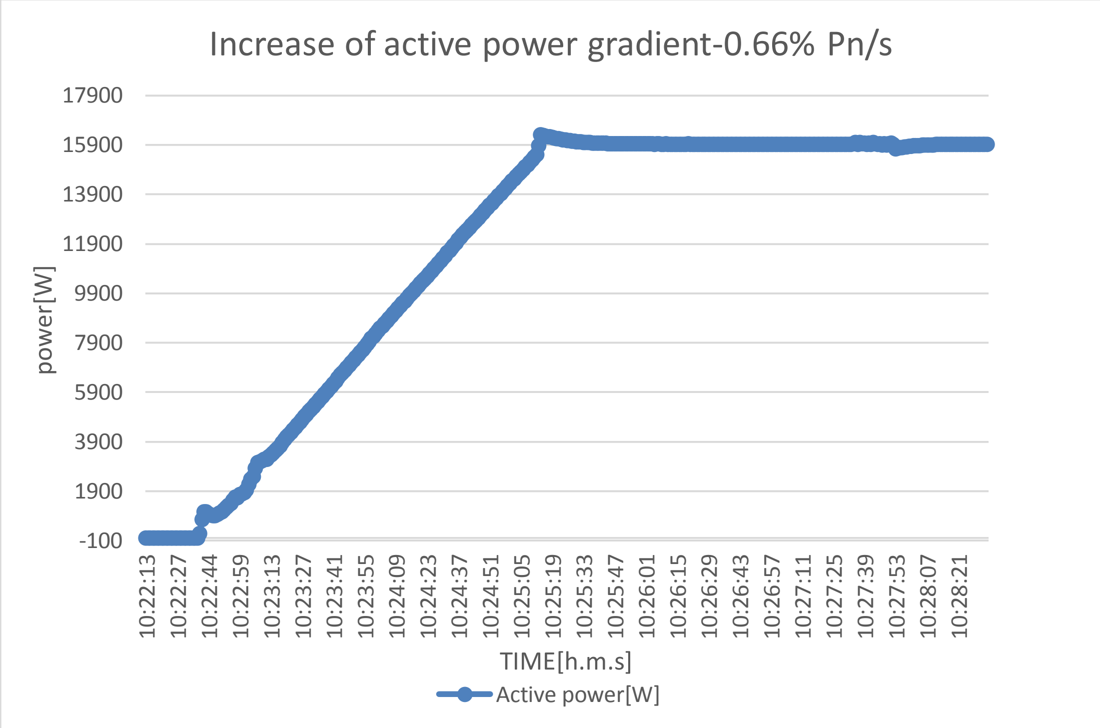
Duration of restoring time-1

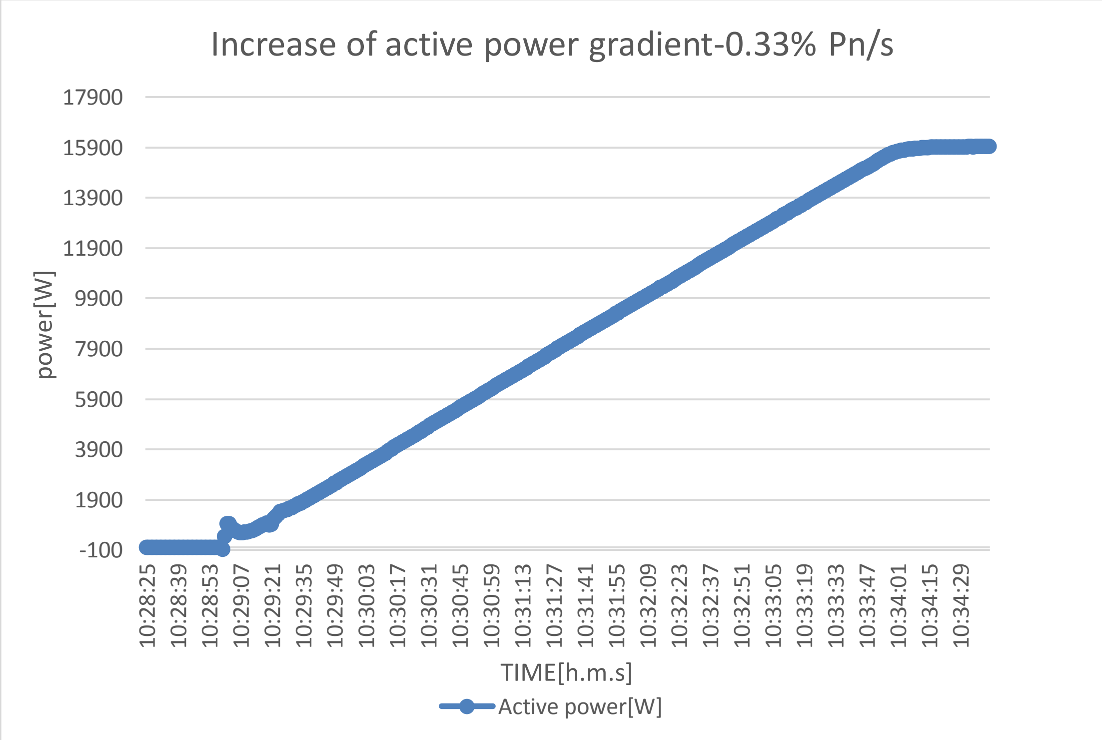


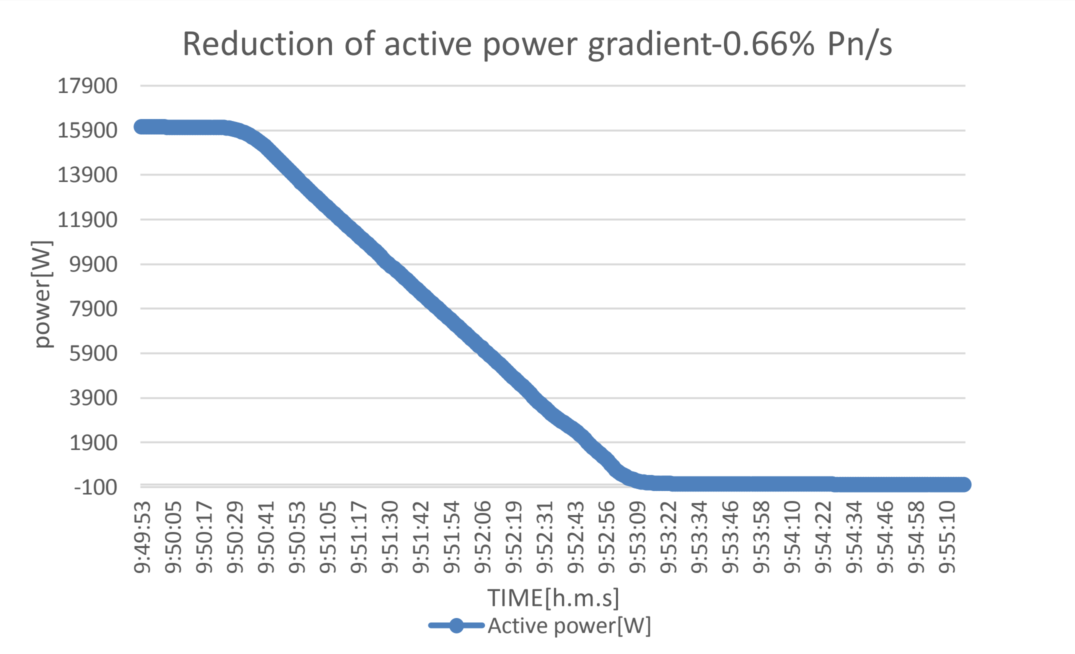
Duration of restoring time-2

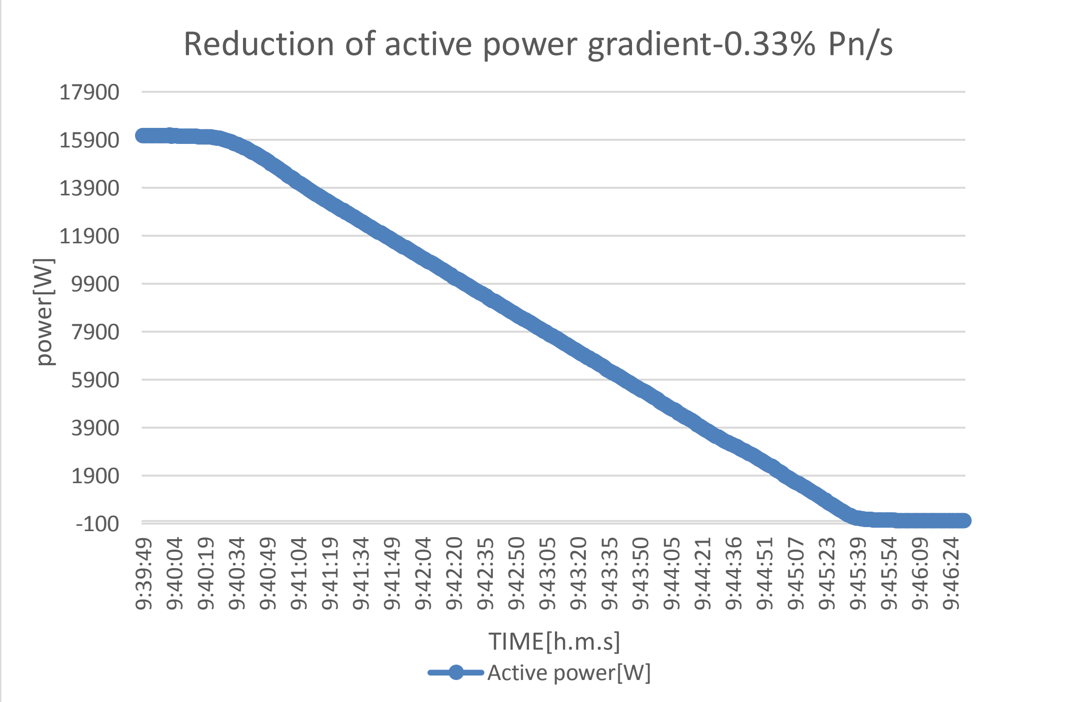


5.7.4.1	TABLE: Active power output		P
Model	EA16KTSI		
Test condition a): Increasing active power form 0 P_{Amax} to 100% P_{Amax}			
Measured during time [s]	Measured Gradient [%]	Gradient limit [%]	
195	0.51	0.66% P_{Amax} / s	
302	0.33	0.33% P_{Amax} / s	
Test condition b): Reducing the active power form 100% P_{Amax} P_{Amax} to 0			
Measured during time [s]	Measured Gradient [%]	Gradient limit [%]	
208	0.48	0.66% P_{Amax} / s	
301	0.33	0.33% P_{Amax} / s	
Note: With a programmable AC source, the PGU is operated at 100% P_{Amax} and 50±0,01 Hz, set power factor equal to 1. The tests were performed on model EA16KTSI also applicable for all other models stated in this report.			


Increase of active power gradient-0.66% Pn/s
power[W]
17900
15900
13900
11900
9900
7900
5900
3900
1900
-100
10:22:13
10:22:27
10:22:44
10:22:59
10:23:13
10:23:27
10:23:41
10:23:55
10:24:09
10:24:23
10:24:37
10:24:51
10:25:05
10:25:19
10:25:33
10:25:47
10:26:01
10:26:15
10:26:29
10:26:43
10:26:57
10:27:11
10:27:25
10:27:39
10:27:53
10:28:07
10:28:21
TIME[h.m.s]
Active power[W]


Increase of active power gradient-0.33% Pn/s
power[W]
17900
15900
13900
11900
9900
7900
5900
3900
1900
-100
10:28:25
10:28:39
10:28:53
10:29:07
10:29:21
10:29:35
10:29:49
10:30:03
10:30:17
10:30:31
10:30:45
10:30:59
10:31:13
10:31:27
10:31:41
10:31:55
10:32:09
10:32:23
10:32:37
10:32:51
10:33:05
10:33:19
10:33:33
10:33:47
10:34:01
10:34:15
10:34:29
TIME[h.m.s]
Active power[W]


Reduction of active power gradient-0.66% Pn/s
17900
15900
13900
11900
9900
7900
5900
3900
1900
-100
power[W]
9:49:53
9:50:05
9:50:17
9:50:29
9:50:41
9:50:53
9:51:05
9:51:17
9:51:30
9:51:42
9:51:54
9:52:06
9:52:19
9:52:31
9:52:43
9:52:56
9:53:09
9:53:22
9:53:34
9:53:46
9:53:58
9:54:10
9:54:22
9:54:34
9:54:46
9:54:58
9:55:10
TIME[h.m.s]
Active power[W]


Reduction of active power gradient-0.33% Pn/s
17900
15900
13900
11900
9900
7900
5900
3900
1900
-100
power[W]
9:39:49
9:40:04
9:40:19
9:40:34
9:40:49
9:41:04
9:41:19
9:41:34
9:41:49
9:42:04
9:42:20
9:42:35
9:42:50
9:43:05
9:43:20
9:43:35
9:43:50
9:44:05
9:44:21
9:44:36
9:44:51
9:45:07
9:45:23
9:45:39
9:45:54
9:46:09
9:46:24
TIME[h.m.s]
Active power[W]

5.7.4.2	TABLE: Network security management			P
1-min mean value	100% P_{Amax}	60% P_{Amax}	30% P_{Amax}	0% P_{Amax}
$P_{Setpoint}$ [kW]:	16000	9600	4800	0
P_{A60} [kW]:	16004.38	9685.40	4852.22	7.19
$\Delta P_{A60}/P_{Amax}$ [%]:	0.027	0.889	1.088	0
Limit $\Delta P_{A60}/P_{Amax}$ [%]:	± 5 % P_{Amax}			

Note:

The following values have proved effective: 100 %/60 %/30 %/0 % in relation to the installed active feed-in power P_{Amax}.

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.
The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

5.7.4.2.3	**TABLE: Active power feed-in for over-frequency**									**P**
Model	EA16KTSI									
Test:										
1. Measurement a) to j): Active power output 100%										
Frequency [Hz]:	50.00	50.25	50.70	51.40	50.70	50.25	50.00	51.65	50.15	50.00
Expected active power output [% P_{Emax}]	100	98	80	52	80	98	100	0	0	100
$P_{setpoint}$ [kW]:	16.00	15.68	12.80	8.32	12.80	15.68	16.00	0	0	16.00
P_{E60} [kW]:	16.03	15.63	12.88	8.40	12.88	15.70	16.01	0	0	16.03
$\Delta P_{E60}/P_{Setpoint}$ [%]:	0.212	0.299	0.687	0.985	0.679	0.165	0.106	0	0	0.156

2. Measurement a) to g): Active power output 60%							
Frequency [Hz]:	50.00	50.40	50.70	51.40	50.70	50.40	50.00
Expected active power output [% P_{Emax}	60	60	58	51	58	60	100
$P_{setpoint}$ [kW]:	9.60	9.60	9.28	8.16	9.28	9.60	16.00
P_{E60} [kW]:	9.70	9.70	9.36	8.23	9.36	9.68	16.01
$\Delta P_{E60}/P_{Setpoint}$ [%]:	1.083	1.063	0.862	0.857	0.841	0.833	0.037
Limit $\Delta P_{E60}/P_{Setpoint}$:	± 10% of P_{Emax}						

Test:

The test is carried out in two test runs, with the respective setting parameters of the EZE:
In the two tests, the following measuring points a) to j) must be approached with an accuracy of ±10 mHz. The measuring points a) to h) and j) shall be started at least 60 s or until the maximum power is reached after a shutdown. The measuring point i) must be approached for at least 10 min. The predetermined initial output must be adhered to with a tolerance of ±5% P_{Emax}.
a) for adjustable EZE if:

- in the above-mentioned measuring points 5.4.4.1 a) to g) and j) the expected active power output, after swinging in, with a deviation of +0% P_{Emax}.
in the measuring points h) and i) dart no action power is output.
- the initial time delay TV of the frequency-dependent adjustment of the active power output is 2 s

- the tuning time of the adjustment of the active power output is a maximum of 8 s (type 1 units and type 2 units with rotating machines) or 2 s (all other type 2 units) and

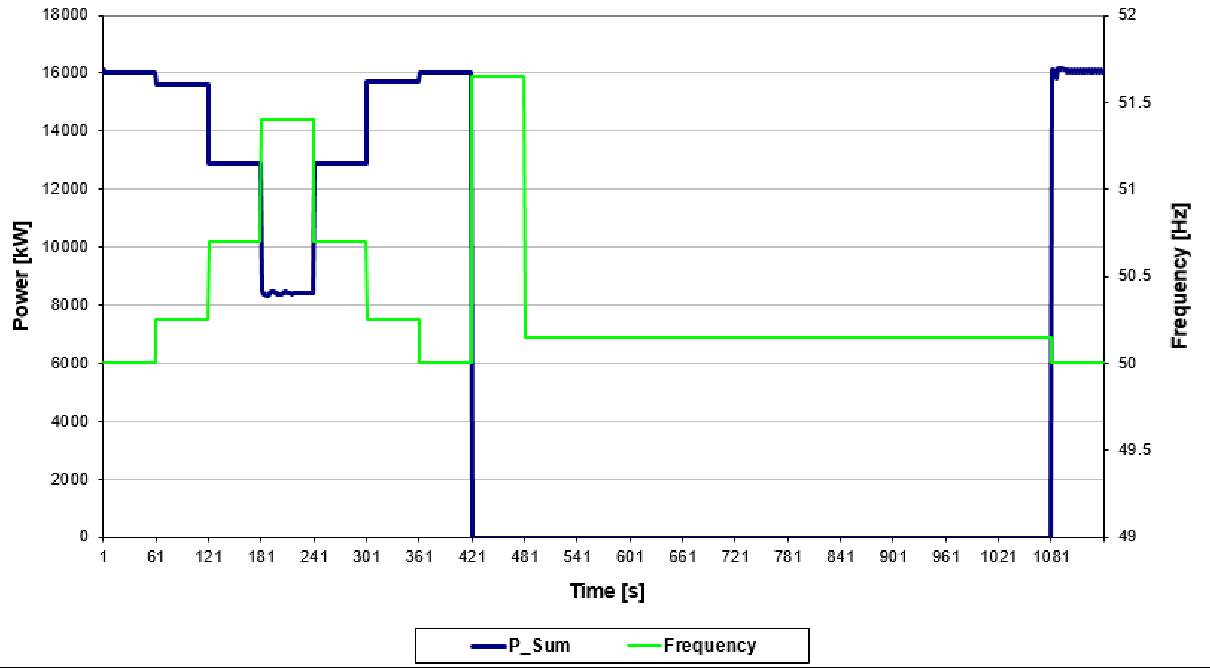
- the settling time of the adjustment of the active power output is a maximum of 30 s (for type 1 units and for type 2 units with rotating machines) or a maximum of 20 s (for all other generation units type 2) and

- the switching time in j) is at least 60 s and the power is then increased with a gradient of 10% P_{Emax}/min.

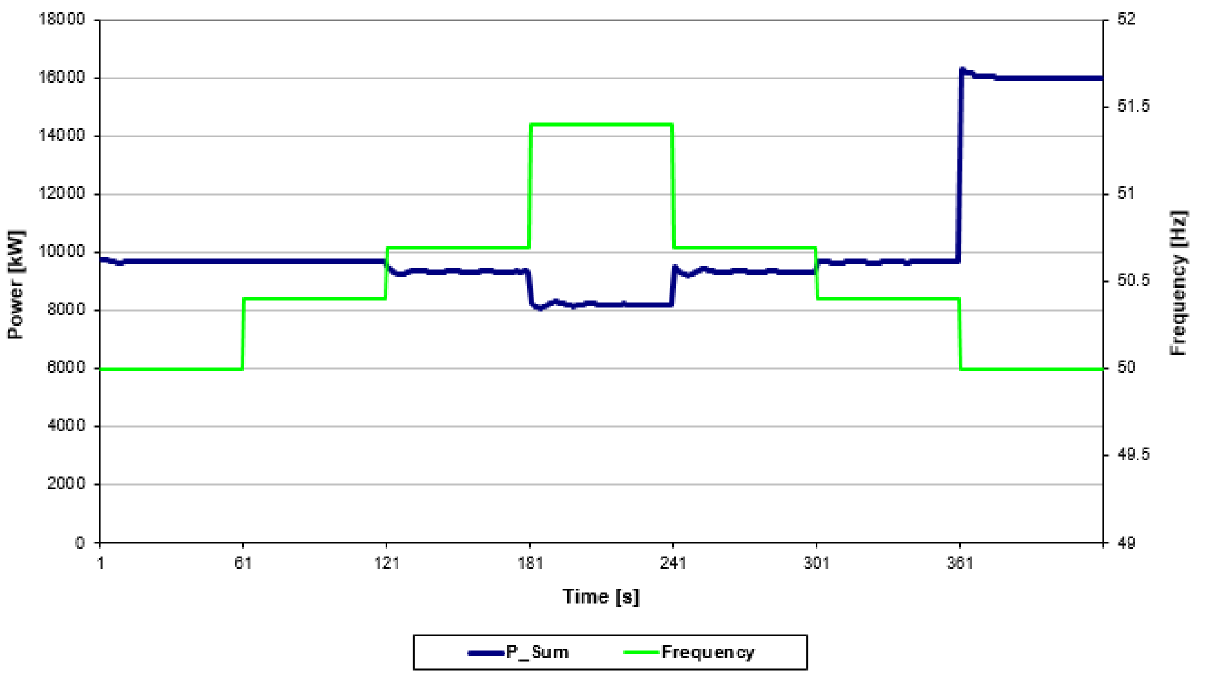
- In the case of production units with combustion engines or gas turbines, the test shall be carried out even if the effect output is adjusted with a power gradient of at least 66 % P_{Emax} per min (equivalent to 1.11% P_{Emax} per s);

Note:
The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

Graph of Measurement 1.: Active power output 100% P_{Emax}



Graph of Measurement 2.: Active power output 60% P_{Emax}



5.7.4.2.3	TABLE: Active power feed-in for under-frequency	P
Model	EA16KTSI	

Test:

1. Measurement a) to j): Active power output 100% P_{Emax}

Frequency [Hz]:	50.00	49.75	48.80	47.60	48.80	49.75	50.00	47.35	47.60	50.00
Expected active power output [% P_{Emax}]	10	12	50	98	50	12	10	0	0	10
$P_{setpoint}$ [kW]:	1.60	1.92	8.00	15.68	8.00	1.92	1.60	0	0	1.60
P_{E60} [kW]:	1.62	1.94	8.11	15.71	8.10	1.94	1.62	0	0	1.62
$\Delta P_{E60}/P_{Setpoint}$ [%]:	1.250	0.885	1.425	0.178	1.250	1.042	1.500	0	0	1.375

2. Measurement a) to g): Active power output 60% P_{Emax}

Frequency [Hz]:	50.00	49.75	48.80	47.60	48.80	49.85	50.00
Expected active power output [% P_{Emax}]	60	62	100	100	100	60	60
$P_{setpoint}$ [kW]:	9.60	9.92	16.00	16.00	16.00	9.60	9.60
P_{E60} [kW]:	9.72	10.04	16.02	16.02	16.02	9.69	9.69
$\Delta P_{E60}/P_{Setpoint}$ [%]:	1.229	1.169	0.131	0.131	0.131	0.958	0.958
Limit $\Delta P_{E60}/P_{Set point}$:	± 10% of P_{Emax}						

Test:

The test is carried out in 2 test runs, with the respective active power output (before the frequency change) of the EZE.
NOTE: The start of the active power increase is predetermined with 49.8 Hz and the statics with s=5% (40 P_{Emax}/Hz).
In the two tests, the following measuring points a) to j) must be approached with an accuracy of ±10 mHz. The measuring points a) to h) and j) shall be started at least 60 s or until the maximum power is reached after a shutdown. The measuring point i) must be approached for at least 10 min. The predetermined initial output must be adhered to with a tolerance of ±5% P_{Emax}.
a) for adjustable EZE if:

- in the above-mentioned measuring points 5.4.4.1 a) to g) and j) the expected active power output, after swinging in, with a deviation of +0% P_{Emax}.
in the measuring points h) and i) dart no action power is output.
- the initial time delay TV of the frequency-dependent adjustment of the active power output is 2 s

- the tuning time of the adjustment of the active power output is a maximum of 8 s (type 1 units and type 2 units with rotating machines) or 2 s (all other type 2 units) and

- the settling time of the adjustment of the active power output is a maximum of 30 s (for type 1 units and for type 2 units with rotating machines) or a maximum of 20 s (for all other generation units type 2) and

- the switching time in j) is at least 60 s and the power is then increased with a gradient of 10% P_{Emax}/min.

- In the case of production units with combustion engines or gas turbines, the test shall be carried out even if the effect output is adjusted with a power gradient of at least 66 % P_{Emax} per min (equivalent to 1.11% P_{Emax} per s);

b) for conditionally adjustable EZE, if

- they behave within their control range as in (a) and

- outside the controllable range, the power fed in when leaving the control range remains constant until the shutdown

- the switch-on time in j) and possibly in g) corresponds to the manufacturer's information on the random generator

c) for non-adjustable EZE, if

- there is no shutdown between 49.8 Hz and 47.5 Hz;

- the switch-on time in j) corresponds to the manufacturer's information on the random generator

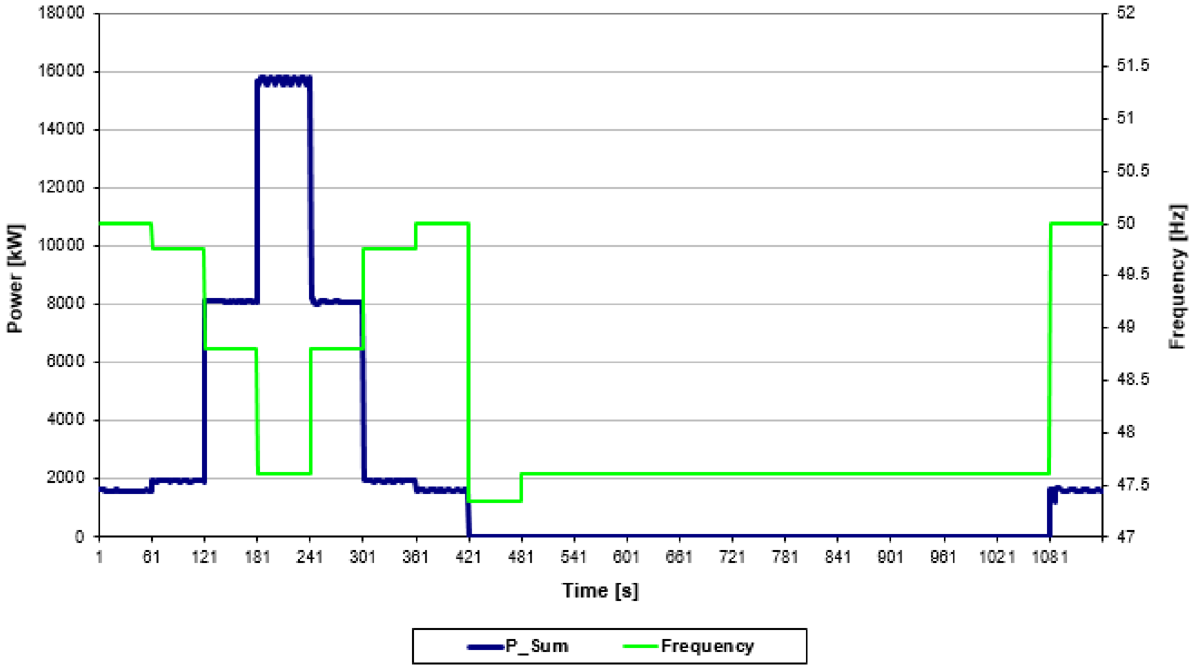
d) for linear generators with $S_{Emax} \leq 4.6$ kVA,

- if they disconnect from the network at a frequency ≤ 49.8 Hz and their maximum frequency limit (according to the manufacturer's specification), but at the latest at a rate of less than 47.5 Hz,

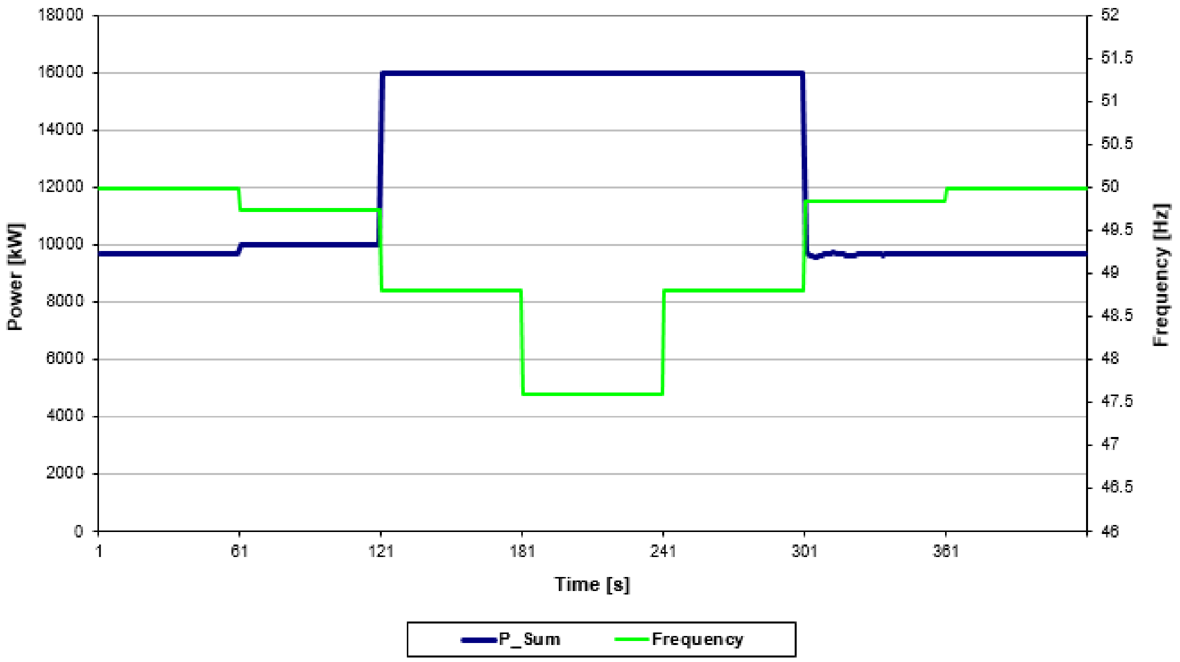
- the switch-on time in j) corresponds to the manufacturer's information on the random generator:

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

Graph of Measurement 1.: Active power output 100% P_{Emax}



Graph of Measurement 2.: Active power output 60% P_{Emax}



6.2 & 6.3	TABLE: Network security (NS) protection						P
Ambient temperature (°C) ……………………………………….:						25	—
No.	component No.	fault	test voltage (V)	test time	fuse No.	fuse current (A)	result
4.4.4.1 Component fault test							
1	BUS Voltage detection (R374)	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected immediately. Error message: “Bus Over Volt Trans Err”. No damage, no hazard.
2	BUS Voltage detection (R374)	short circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “Bus Volt Plus-Minus Unbalance Err”. No damage, no hazard.
3	Inv voltage detection R(R423)	short circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start up. Error message: “Inv soft Start Fail Err”. No damage, no hazard.
4	Inv voltage detection R (R423)	Open Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start up. Error message: “Inv soft Start Fail Err”. No damage, no hazard.
5	Inv voltage detection N(R144)	Open Circuit before start up	620Vdc 230Vac	10min	--	--	The PCE can’t start up. Error message: “Output Relay Err”. No damage, no hazard.
6	Power supply +12V (T612-T614)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected immediately. No error massage. No damage, no hazard.
7	Power supply +7V (T616-T619)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected immediately. No error massage. No damage, no hazard.
8	Power supply +15V (T609-T610)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected immediately. No error massage. No damage, no hazard
9	Power supply +15V2 (T604-T606)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected immediately. Error message: “Inv soft Start Fail Err”. No damage, no hazard.
10	ISO detection relay (RY900)	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start up. Error message: “ISO Fail Err”. No damage, no hazard.

11	BUS Capacitor (C301)	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start up. Error message: "Bus Over Volt Trans Err". No damage, no hazard.
12	Output L1-N	shorted	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "Inv Short Circuit Err". No damage, no hazard.
13	Output L1-PE	shorted	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "Inv Short Circuit Err". No damage, no hazard.
14	Output L1-L2	shorted	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "Inv Short Circuit Err". No damage, no hazard.
15	Output Phase line	Mis-wiring with incorrect phase sequence	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "Inv Short Circuit Err". No damage, no hazard.
16	PV+ to PV-	Shorted	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. No error massage. No damage, no hazard.
17	PV+ to PV-	Reversed	620Vdc 230Vac	10min	--	--	PCE shutdown No error massage. No damage, no hazard.
18	Leakage current detection (R579)	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "GFCI Sensor Err". No damage, no hazard.
19	Leakage current detection (R580)	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "GFCI Sensor Err". No damage, no hazard
20	Offgrid voltage detection (R164)	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: "Grid Over Volt Err". No damage, no hazard.
21	INV Current detection (R75)	Open Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start up. Error message: "Inv Over Curr Trans Err". No damage, no hazard.

22	Grid frequency detection (R408)	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “Grid Under Freq Err”. No damage, no hazard.
23	Output Relay (K400)	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start-up, Error message: “Relay check fail”, No damage, no hazard.
24	Output Relay (K401	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start-up, Error message: “Relay check fail. No damage, no hazard.
25	Output Relay (K402)-	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start-up, Error message: “Relay check fail”. No damage, no hazard.
26	Output Relay (K403)-	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start-up, Error message: “Relay check fail”. No damage, no hazard.
27	Output Relay (K404)	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start-up, Error message: “Relay check fail”. No damage, no hazard.
28	Output Relay (K405)	Short Circuit before start up	620Vdc 230Vac	10min	--	--	PCE cannot start-up, Error message: “Relay check fail”. No damage, no hazard.
29	DSP power supply loss 3.3V (C240)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. No error massage, No damage, no hazard.
30	Crystal Oscillator defect (C183)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “SMCU Grid Freq Err”. No damage, no hazard.
31	BUS Voltage detection (R550)	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “PV above BUS volt Err”. No damage, no hazard.
32	Grid voltage detection R540	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “Grid Under Volt Err1”. No damage, no hazard.
33	Grid voltage detection R540	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “Grid Over Volt Err1”. No damage, no hazard.

34	N-PE voltage detection R678	Open Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “Ground Connection Err”. No damage, no hazard.
35	N-PE voltage detection R678	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “Ground Connection Err”. No damage, no hazard.
36	Crystal Oscillator defect (C182)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “SMCU Grid Freq Err”. No damage, no hazard.
37	Communication defect between DSP (R28 pin 2 to pin 7)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “SPI Comm Fail Err”. no damage, no hazard.
38	Communication defect between DSP (R28 pin 4 to pin 5)	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Error message: “SPI Comm Fail Err”. No damage, no hazard.
39	Internal cooling Fan	Locked	620Vdc 230Vac	60min	--	--	PCE working normally. No damage, no hazard.
40	Bus capacitor, C334	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Q303 damaged, no hazard.
41	IGBT, Q300 C to E	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Q309 damaged, no hazard.
42	IGBT, Q300 C to G	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. Q300, D314 and drive board damaged, no hazard.
43	IGBT, Q300 E to G	Short Circuit	620Vdc 230Vac	10min	--	--	PCE shutdown and disconnected from grid immediately. R32 and drive board damaged, no hazard.

Supplementary information:

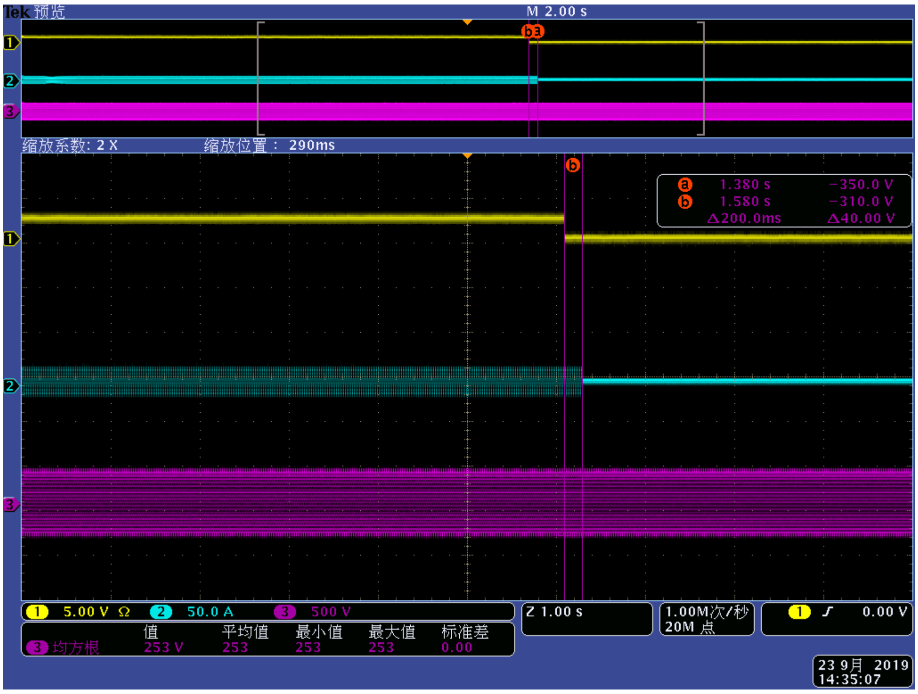
Tests performed under abnormal or fault conditions shall be tested with a source capable of 1.25 to 1.5 times the PCE rated maximum input current (Isc PV) for that input.

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

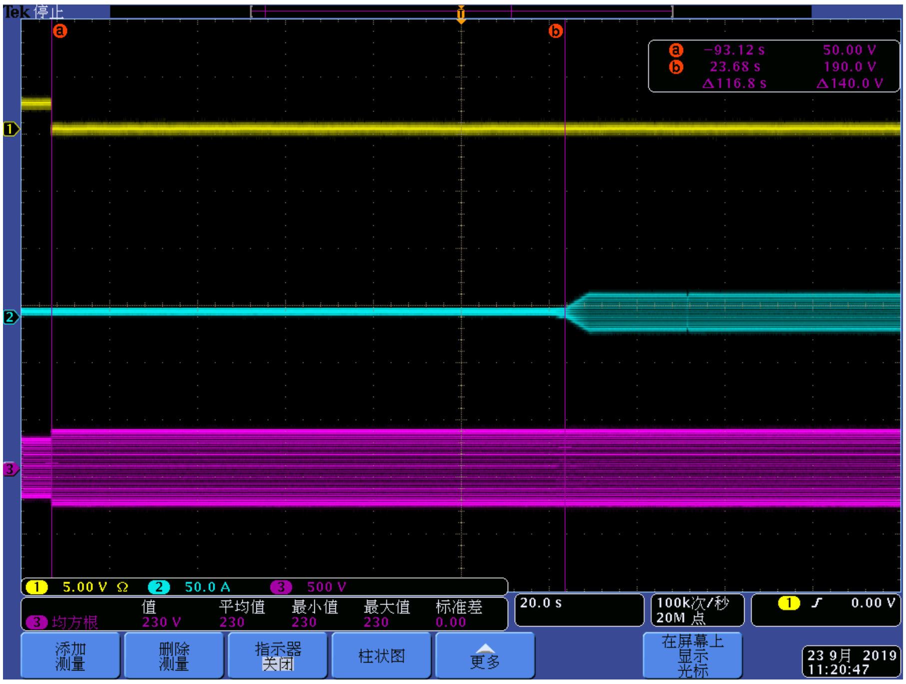
6.5.2	TABLE: Integrated NS protection single / three phase ≤ 30kVA (phase to neutral) (Voltage Monitoring)					P
Setting values of the NS protection:	Setting U < [V]:			184.0		
	Setting U >> [V]:			253.0		
	Setting $T_{disconnection}$ [ms]			100		
	Under Voltage Stage 1			Over Voltage Stage 1		
L1 to N:						
Step	230.0 V → 177.1 V			230.0 V → 257.6 V		
Setting [V]	184.0			253.0		
Measurement Voltage [V]	183	183	183	254	252	253
Disconnection time [ms]	2999.0	2999.0	2999.0	190.0	170.0	177.2
Limit [ms]	3000			200		
Reconnection time [s]	116.8			111.2		
Limit [s]	> 60			> 60		
L2 to N:						
Step	230.0 V → 177.1 V			230.0 V → 257.6 V		
Setting [V]	184.0			253.0		
Measurement Voltage [V]	185	185	182	254	253	252
Disconnection time [ms]	2997.0	2977.0	2997.0	189.2	176.4	187.6
Limit [ms]	3000			200		
Reconnection time [s]	115			122.4		
Limit [s]	> 60			> 60		
L3 to N:						
Step	230.0 V → 177.1 V			230.0 V → 257.6 V		
Setting [V]	184.0			253.0		
Measurement Voltage [V]	185	185	182	253	254	252
Disconnection time [ms]	2976.0	2986.0	2986.0	182.0	182.4	191.6
Limit [ms]	3000			200		
Reconnection time [s]	114.2			116.0		
Limit [s]	> 60			> 60		
Assessment criterion: The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1% of U_n. The tests were performed on model EA16KTSI and are also applicable for all other models stated in this report.						

Under Voltage Stage 1- disconnection time:

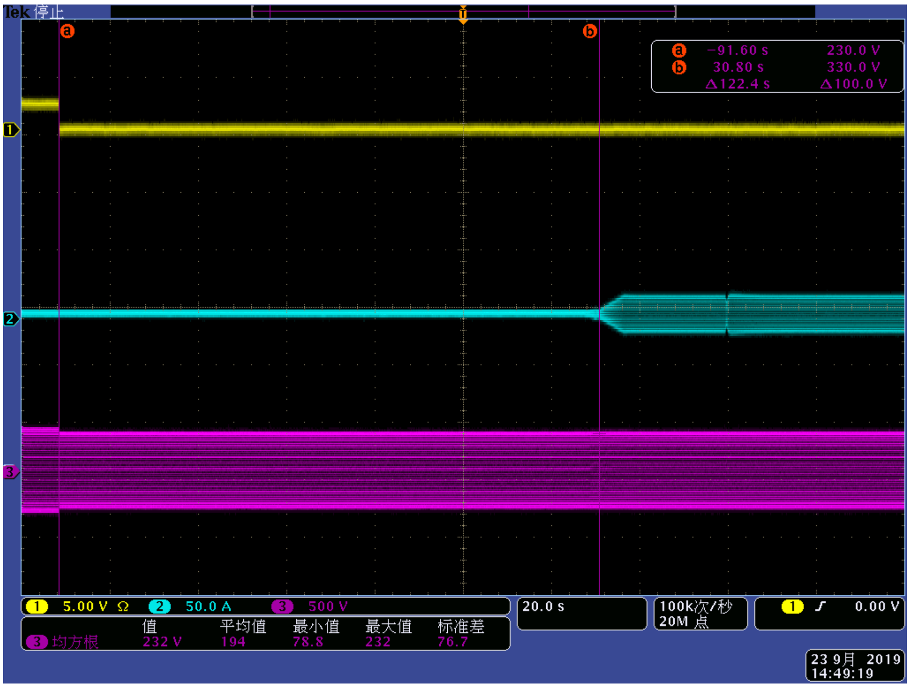
Over Voltage Stage 1- disconnection time:



Under Voltage Stage 1 - Reconnection time:

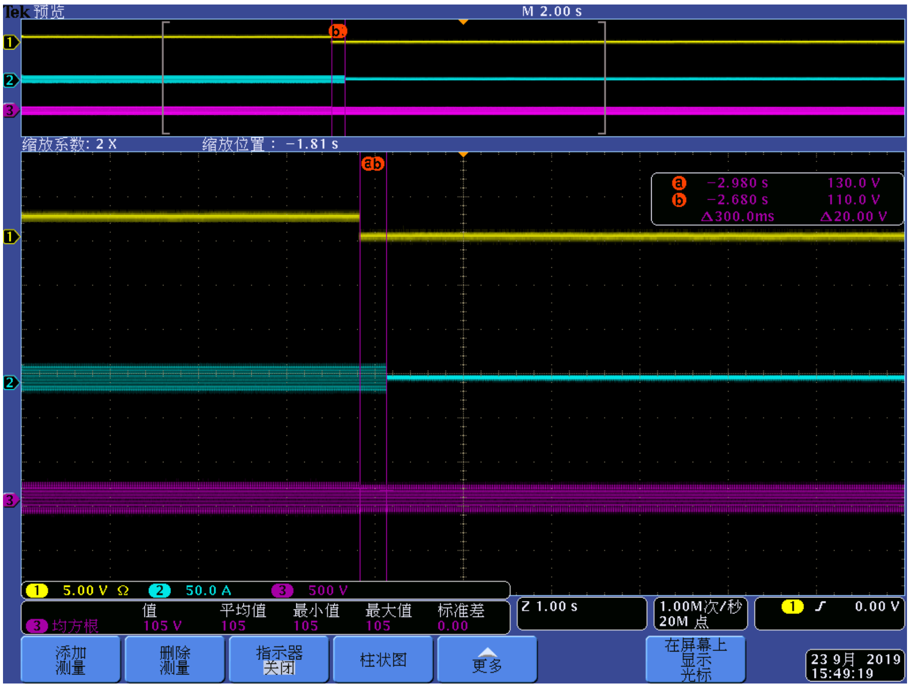


Over Voltage Stage 1- Reconnection time:

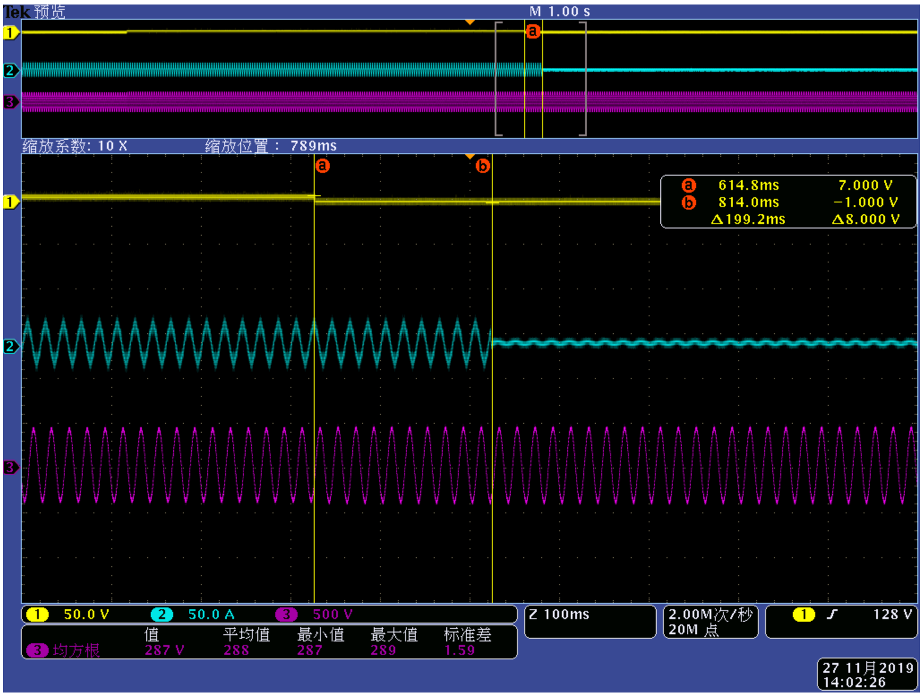


6.5.2	TABLE: Integrated NS protection single / three phase ≤ 30kVA (phase to neutral) (Voltage Monitoring)					P
Setting values of the NS protection:	Setting U < [V]:			103.5		
	Setting U >> [V]:			287.5		
	Setting $T_{disconnection}$ [ms]			100		
	Under Voltage Stage 2			Over Voltage Stage 2		
L1 to N:						
Step	230.0 V → 98.9 V			230.0 V → 292.1 V		
Setting [V]	103.5			287.5		
Measurement Voltage [V]	102	102	102	289	287	288
Disconnection time [ms]	254.8	259.2	245.6	164.2	199.2	188.4
Limit [ms]	300			200		
Reconnection time [s]	116.2			105.4		
Limit [s]	> 60			> 60		
L2 to N:						
Step	230.0 V → 98.9 V			230.0 V → 292.1 V		
Setting [V]	103.5			287.5		
Measurement Voltage [V]	102	103	103	286	287	286
Disconnection time [ms]	236.4	255.2	254.8	180.0	182.0	192.2
Limit [ms]	300			200		
Reconnection time [s]	118.4			116		
Limit [s]	> 60			> 60		
L3 to N:						
Step	230.0 V → 98.9 V			230.0 V → 292.1 V		
Setting [V]	103.5 V			287.5 V		
Measurement Voltage [V]	102	102	102	286	286	287
Disconnection time [ms]	257.2	262.0	252.0	189.6	162.0	177.2
Limit [ms]	300			200		
Reconnection time [s]	110.4			108.4		
Limit [s]	> 60			> 60		
Assessment criterion: The permitted tolerance between setting value and trip value of the voltage may not exceed ± 1% of U_n. The tests were performed on model EA16KTSI and are also applicable for all other models stated in this report.						

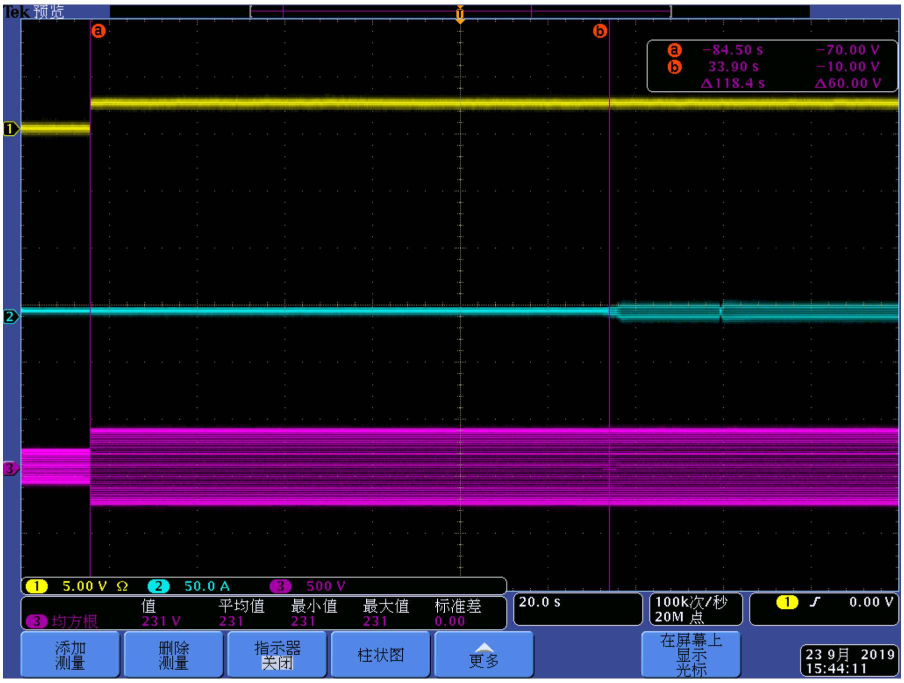
Under Voltage Stage 2- disconnection time:



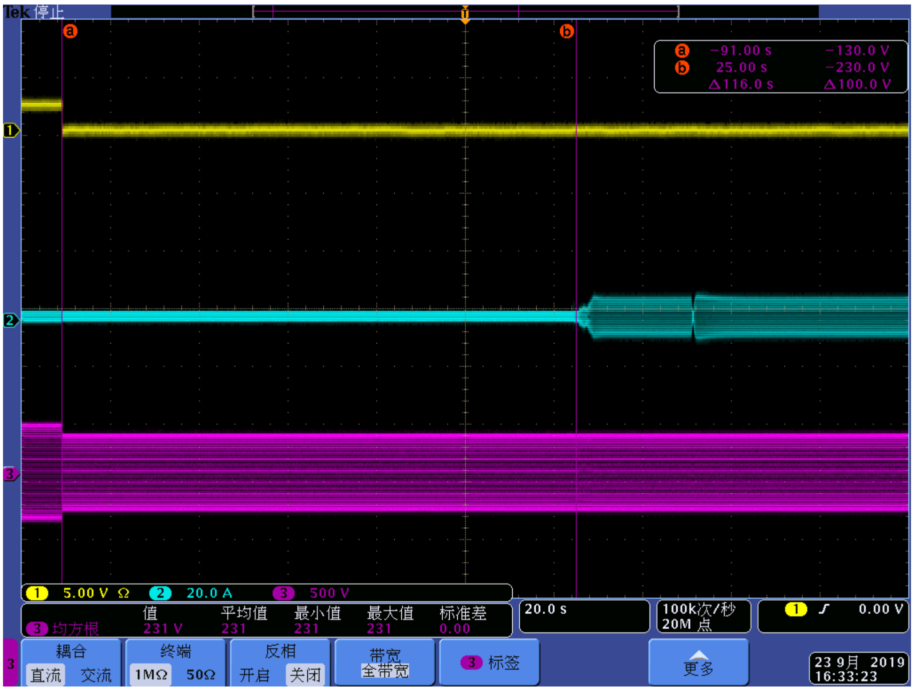
Over Voltage Stage 2- disconnection time:



Under Voltage Stage 2- Reconnection time:

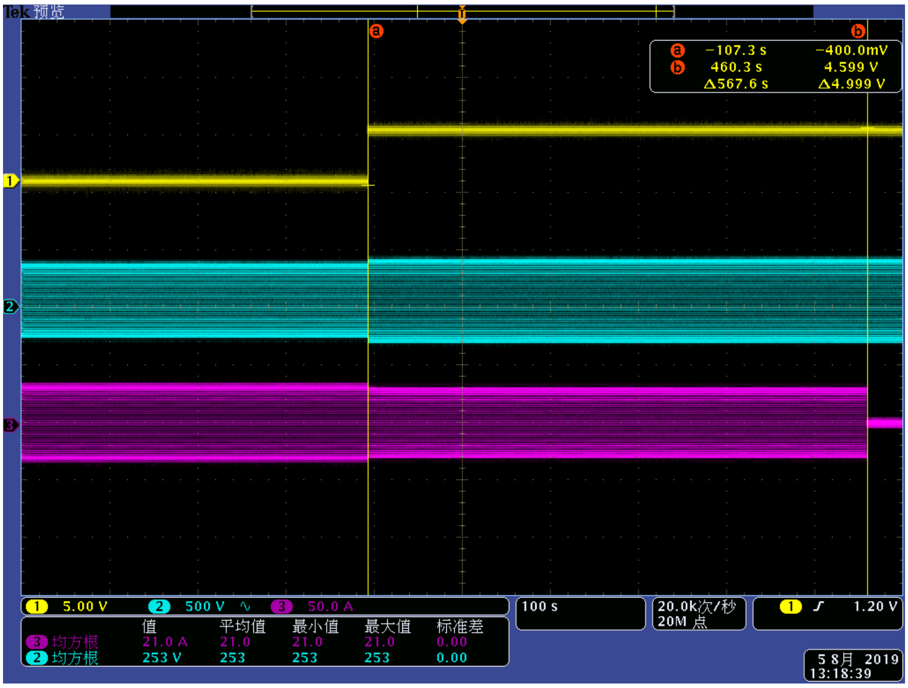


Over Voltage Stage 2- Reconnection time:

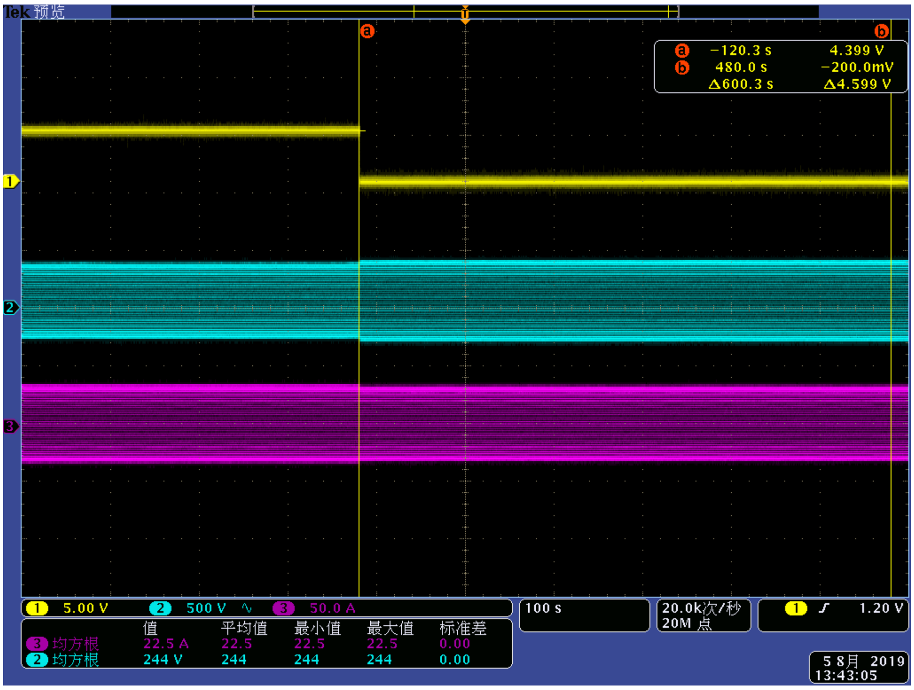


<table>
<tr><th>6.5.1</th><th colspan="3">TABLE: Measuring the rise-in voltage protection as a running 10-minute mean value</th><th>P</th></tr>
<tr><td>Model</td><td colspan="4">EA16KTSI</td></tr>
<tr><td colspan="2">Test:</td><td>Disconnection time [s]:</td><td colspan="2">Limit [s]:</td></tr>
<tr><td rowspan="4">a)</td><td colspan="4">The voltage is set to 100% U_n and held for 600 s. Thereafter the voltage is set to 112% U_n. Disconnection must take place within 600 s.</td></tr>
<tr><td>Phase 1</td><td>478.3</td><td colspan="2" rowspan="3">≤ 600</td></tr>
<tr><td>Phase 2</td><td>486.3</td></tr>
<tr><td>Phase 3</td><td>567.6</td></tr>
<tr><td rowspan="4">b)</td><td colspan="4">The voltage is set to U_n for 600 s and then to 108% U_n for 600 s. No disconnection should take place.</td></tr>
<tr><td>Phase 1</td><td>No disconnection</td><td colspan="2" rowspan="3">Disconnection should not take place.</td></tr>
<tr><td>Phase 2</td><td>No disconnection</td></tr>
<tr><td>Phase 3</td><td>No disconnection</td></tr>
<tr><td rowspan="4">c)</td><td colspan="4">The voltage is set to 106 % U_n and held for 600 s. Thereafter the voltage is set to 114 % U_n. Disconnection must take place within 300 s or about 50 % of the disconnection time measured in point a).*</td></tr>
<tr><td>Phase 1</td><td>262.3</td><td colspan="2" rowspan="3">The disconnection time should be about 50 % of the value measured in a). *</td></tr>
<tr><td>Phase 2</td><td>265.3</td></tr>
<tr><td>Phase 3</td><td>247.3</td></tr>
<tr><td colspan="5">Note:
*If the setting value is set to 600 s, then the disconnection time can be in the range between 225 s and 375 s.
The tests were performed on model EA16KTSI and are also applicable for all other models stated in this report.</td></tr>
</table>

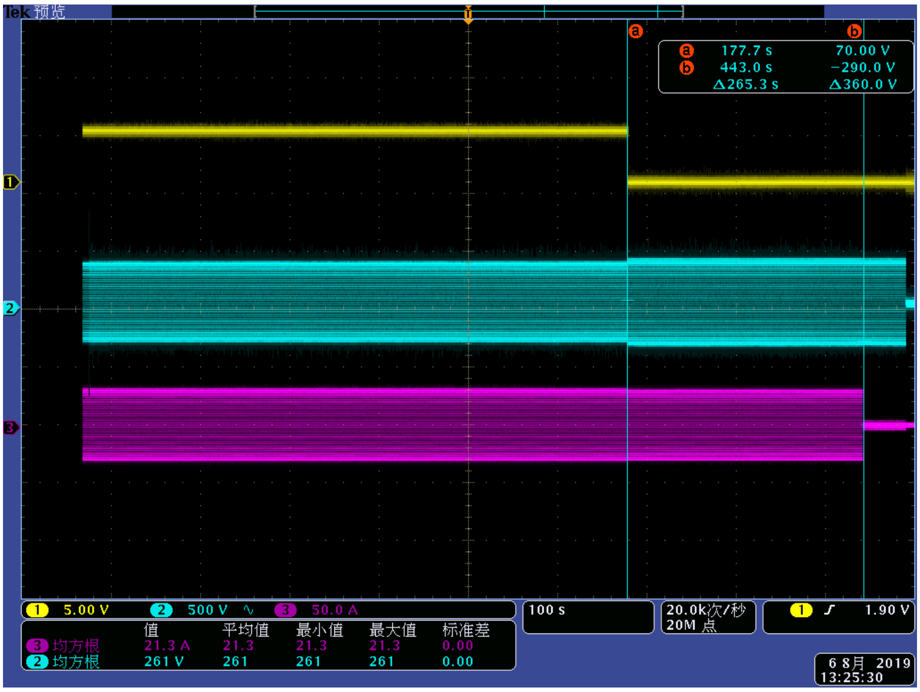
a) Voltage set to 112 % U_n:



b) Voltage set to 108% U_n:

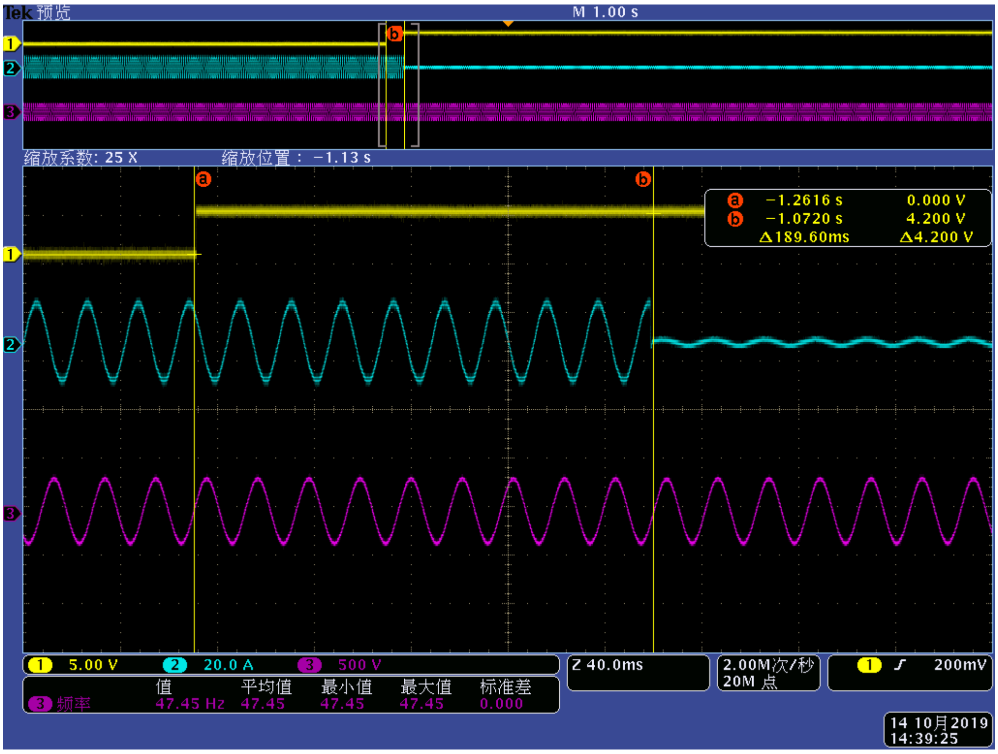


c) Voltage set to 106 % Un, thereafter 114% Un:

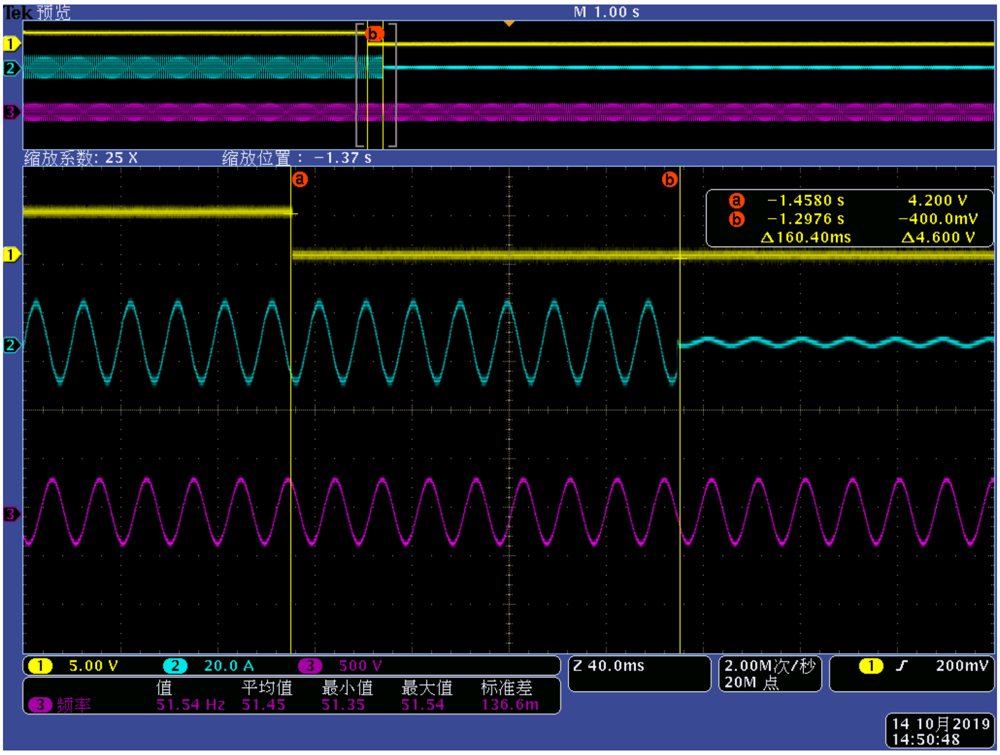


6.5.2	TABLE: Frequency Monitoring					P
Model	EA16KTSI					
Setting values of the NS protection:	Setting f < [Hz]:			47.5		
	Setting f > [Hz]:			51.5		
	Setting $T_{disconnection}$ [ms]			100		
	Under-Frequency			Over-Frequency		
Step	48.00 Hz → 47.00 Hz			51.00 Hz → 52.00 Hz		
Setting (Hz)	47.50			51.50		
Measurement Frequency(Hz)	47.47	47.45	47.46	51.54	51.55	51.55
Disconnection time (ms)	172.4	189.6	179.2	160.4	158.4	160.4
Limit (ms)	200			200		
Reconnection time (s)	116.2			108.1		
Limit (s)	> 60			> 60		
Assessment criterion: The setting value and the trip value of the frequency may not vary by more than ±0.1% fn .						
Note: The tests were performed on model EA16KTSI and are also applicable for all other models stated in this report.						

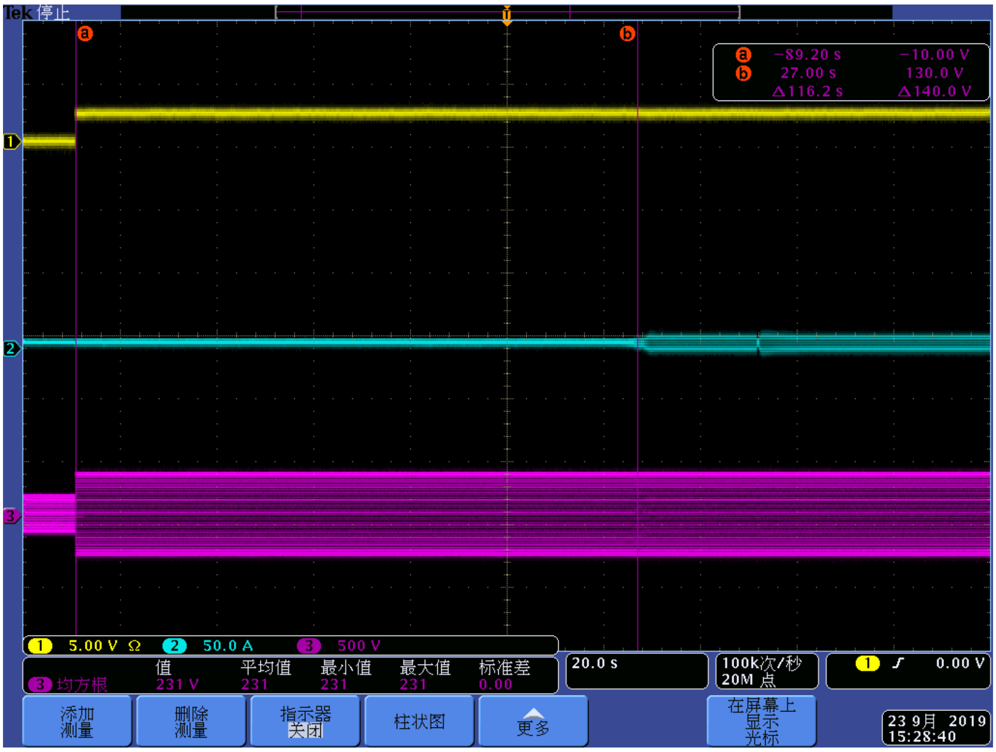
Under Frequency- Disconnection Time



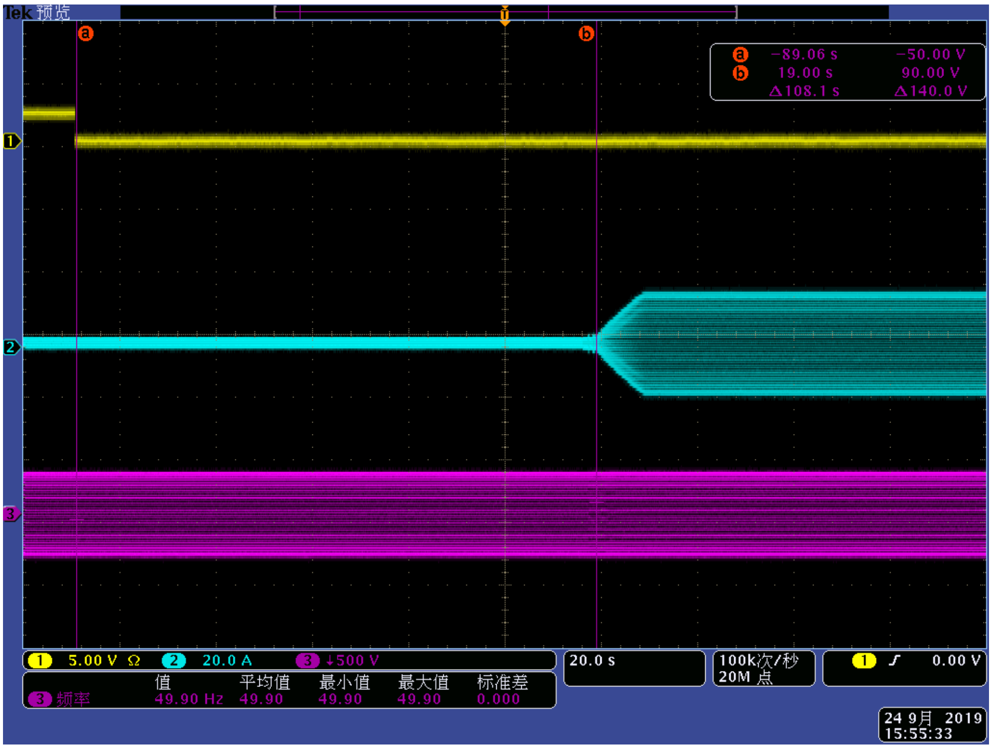
Over Frequency- Disconnection Time



Under Frequency- Reconnection Time



Over Frequency- Reconnection Time



6.5.1	TABLE: Reporting NS protection	P
It must be determined by visual inspection that the last 5 dated failure reports can be read on the NS protection. An interruption of the supply voltage ≤ 3 s does not result in any loss of failure reports. Integrated NS protection: It is possible to read out the values of the NS protection via the data interface, unless values can be read directly.		
Note:		

6.5.3	TABLE: Islanding protection - tested condition and run-on time – L1 phase								P
No.	P_{EUT} (% of EUT rating)	Reactive load (% of normial)	P_{AC}	Q_{AC}	Run-on time (ms)	P_{EUT} (W)	Actual Q_f (kVar)	V_{DC}	Remark
Test condition A									
1	100	100	0	0	263	5305	1.01	818	Test A at BL
2	100	100	0	- 5	224	5317	0.97	818	Test A at IB
3	100	100	0	+ 5	285	5250	1.04	817	Test A at IB
4	100	100	- 5	- 5	133	5216	1.04	817	Test A at IB
5	100	100	- 5	0	210	5305	1.08	818	Test A at IB
6	100	100	- 5	+ 5	239	5351	1.11	817	Test A at IB
7	100	100	+ 5	- 5	124	5335	0.93	817	Test A at IB
8	100	100	+ 5	0	494	5323	0.97	817	Test A at IB
9	100	100	+ 5	+ 5	253	5342	0.99	818	Test A at IB
10	100	100	- 5	- 10	110	5337	1.00	817	Test A at IB
11	100	100	- 5	+ 10	170	5326	1.14	817	Test A at IB
12	100	100	0	- 10	126	5310	0.94	817	Test A at IB
13	100	100	0	+ 10	176	5321	1.07	818	Test A at IB
14	100	100	+ 5	- 10	105	5330	0.90	817	Test A at IB
15	100	100	+ 5	+ 10	138	5319	1.02	818	Test A at IB
16	100	100	- 10	- 10	129	5318	1.06	818	Test A at IB
17	100	100	- 10	- 5	137	5343	1.10	818	Test A at IB
18	100	100	- 10	0	442	5337	1.14	818	Test A at IB
19	100	100	- 10	+ 5	593	5339	1.16	817	Test A at IB
20	100	100	- 10	+10	209	5350	1.20	817	Test A at IB
21	100	100	+ 10	- 10	134	5344	0.85	817	Test A at IB
22	100	100	+ 10	- 5	175	5364	0.88	817	Test A at IB
23	100	100	+ 10	0	214	5322	0.93	818	Test A at IB
24	100	100	+ 10	+ 5	370	5355	0.94	818	Test A at IB
25	100	100	+ 10	+ 10	177	5341	0.98	818	Test A at IB

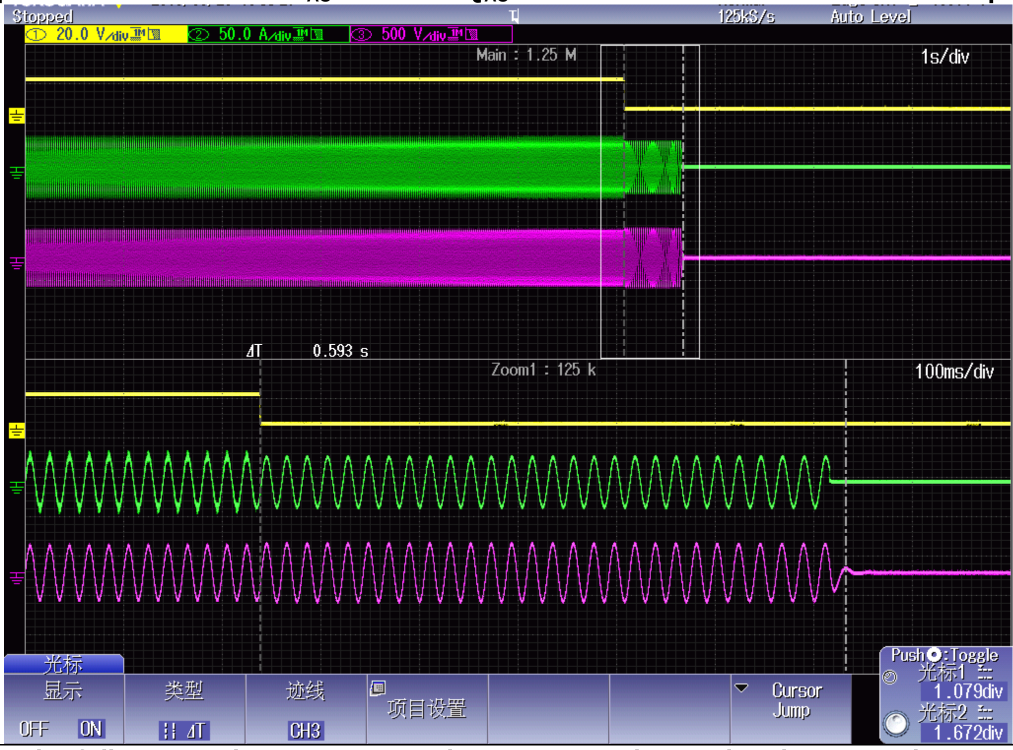
Test condition B									
1	66	66	0	- 5	382	3441	0.95	673	Test B at IB
2	66	66	0	- 4	341	3451	0.96	674	Test B at IB
3	66	66	0	- 3	553	3455	0.96	673	Test B at IB
4	66	66	0	- 2	247	3464	0.98	673	Test B at IB
5	66	66	0	- 1	353	3468	0.99	673	Test B at IB
6	66	66	0	0	549	3470	1.00	673	Test B at BL
7	66	66	0	+ 1	312	3477	1.00	673	Test B at IB
8	66	66	0	+ 2	233	3465	1.00	673	Test B at IB
9	66	66	0	+ 3	473	3448	1.00	673	Test B at IB
10	66	66	0	+ 4	214	3473	1.01	674	Test B at IB
11	66	66	0	+ 5	174	3455	1,02	674	Test B at IB
Test condition C									
1	33	33	0	- 5	420	1791	0.98	447	Test C at IB
2	33	33	0	- 4	602	1789	0.96	448	Test C at IB
3	33	33	0	- 3	382	1796	0.97	448	Test C at IB
4	33	33	0	- 2	443	1787	0.97	448	Test C at IB
5	33	33	0	- 1	503	1794	0.98	448	Test C at IB
6	33	33	0	0	220	1791	1.00	448	Test C at BL
7	33	33	0	+ 1	203	1792	1.02	449	Test C at IB
8	33	33	0	+ 2	239	1795	1.02	448	Test C at IB
9	33	33	0	+ 3	322	1793	1.03	448	Test C at IB
10	33	33	0	+ 4	187	1794	1.04	448	Test C at IB
11	33	33	0	+ 5	162	1794	1.07	448	Test C at IB

Remark:

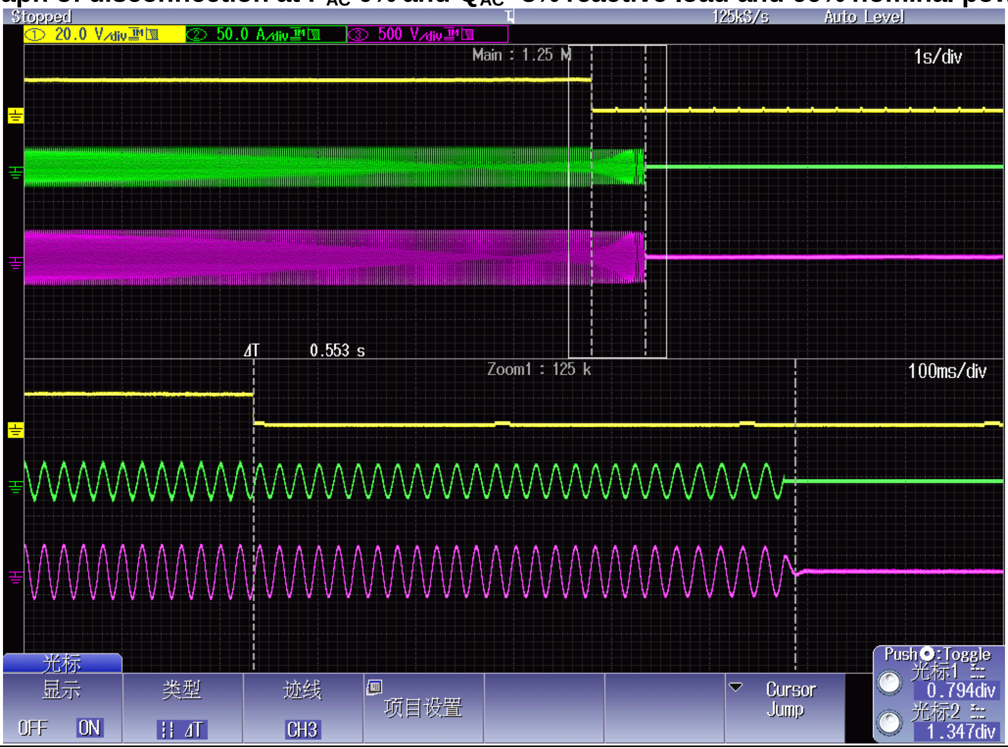
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional 1 % increments is taken until run-on times begin decreasing.

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

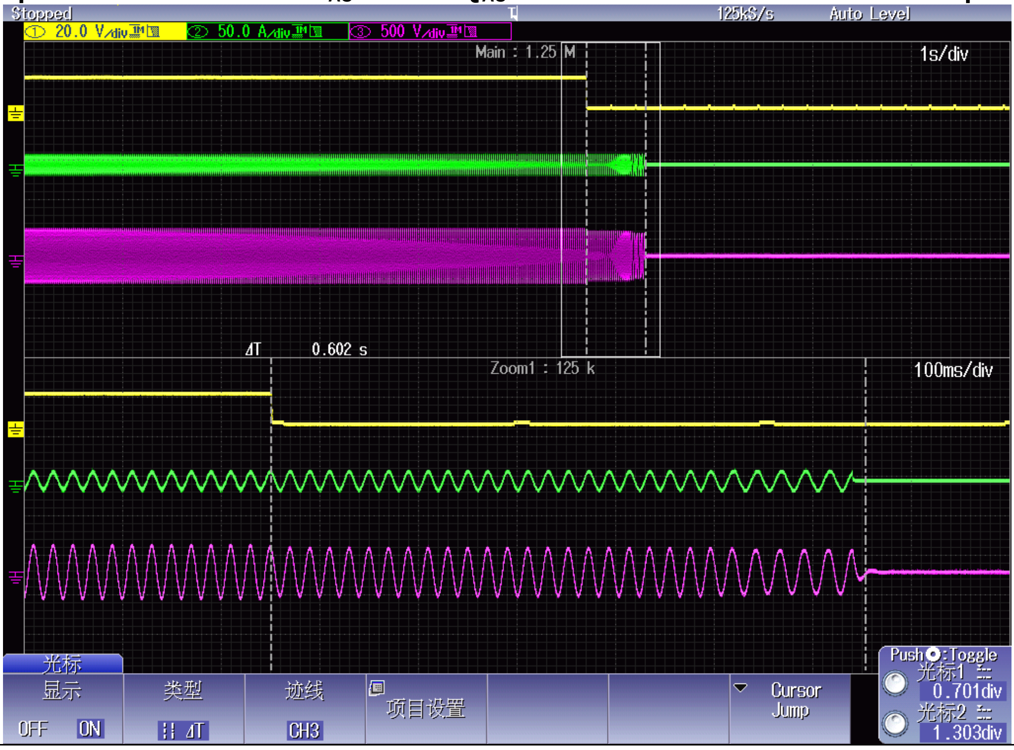
Graph of disconnection at P_{AC} -10% and Q_{AC} +5% reactive load and 100% nominal power



Graph of disconnection at P_{AC} 0% and Q_{AC} -3% reactive load and 66% nominal power



Graph of disconnection at P_{AC} 0% and Q_{AC} -4% reactive load and 33% nominal power



6.5.3	TABLE: Islanding protection - tested condition and run-on time – L2 phase								P
No.	P_{EUT} (% of EUT rating)	Reactive load (% of normial)	P_{AC}	Q_{AC}	Run-on time (ms)	P_{EUT} (W)	Actual Q_f (kVar)	V_{DC}	Remark
Test condition A									
1	100	100	0	0	219	5326	1.01	818	Test A at BL
2	100	100	0	- 5	312	5303	0.99	817	Test A at IB
3	100	100	0	+ 5	155	5266	1.04	818	Test A at IB
4	100	100	- 5	- 5	233	5284	1.05	818	Test A at IB
5	100	100	- 5	0	369	5288	1.08	818	Test A at IB
6	100	100	- 5	+ 5	206	5270	1.10	818	Test A at IB
7	100	100	+ 5	- 5	183	5276	0.95	818	Test A at IB
8	100	100	+ 5	0	444	5268	0.97	817	Test A at IB
9	100	100	+ 5	+ 5	393	5294	1.00	818	Test A at IB
10	100	100	- 5	- 10	143	5289	1.03	818	Test A at IB
11	100	100	- 5	+ 10	161	5281	1.13	817	Test A at IB
12	100	100	0	- 10	140	5285	0.97	818	Test A at IB
13	100	100	0	+ 10	148	5291	1.08	818	Test A at IB
14	100	100	+ 5	- 10	152	5277	0.93	817	Test A at IB
15	100	100	+ 5	+ 10	156	5277	1.02	818	Test A at IB
16	100	100	- 10	- 10	160	5279	1.08	818	Test A at IB
17	100	100	- 10	- 5	280	5279	1.11	818	Test A at IB
18	100	100	- 10	0	380	5254	1.12	818	Test A at IB
19	100	100	- 10	+ 5	470	5260	1.16	818	Test A at IB
20	100	100	- 10	+10	201	5267	1.20	817	Test A at IB
21	100	100	+ 10	- 10	137	5238	0.89	818	Test A at IB
22	100	100	+ 10	- 5	218	5257	0.91	818	Test A at IB
23	100	100	+ 10	0	524	5240	0.93	818	Test A at IB
24	100	100	+ 10	+ 5	264	5255	0.95	817	Test A at IB
25	100	100	+ 10	+ 10	177	5257	0.98	817	Test A at IB

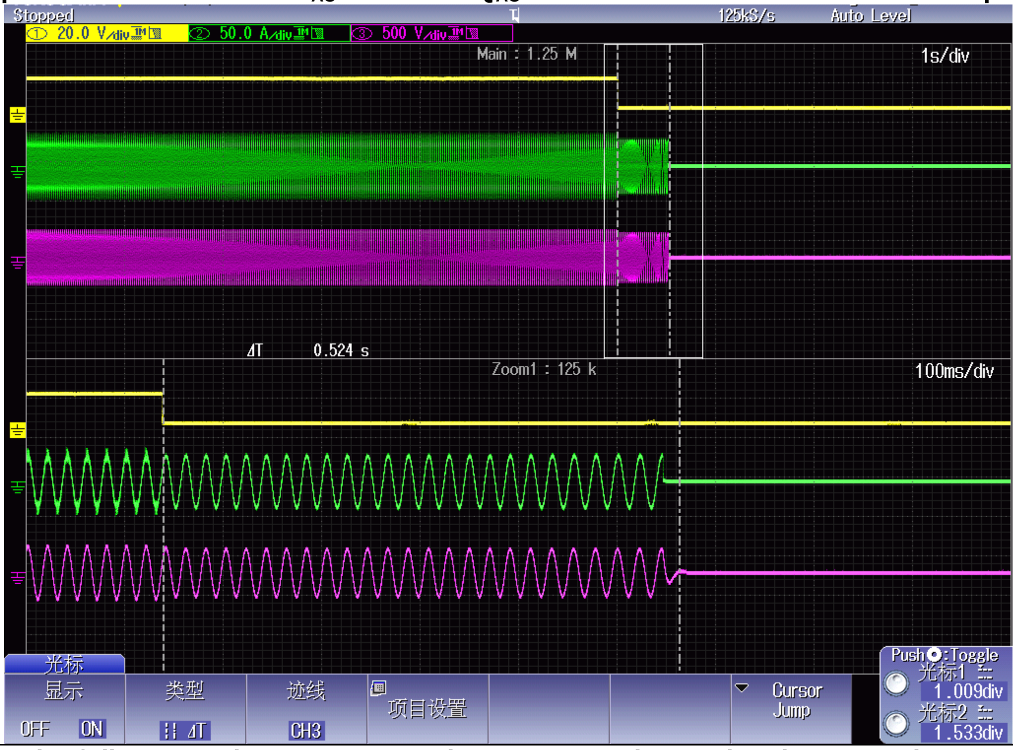
Test condition B									
1	66	66	0	- 5	358	3529	0.98	673	Test B at IB
2	66	66	0	- 4	365	3549	0.98	674	Test B at IB
3	66	66	0	- 3	242	3546	0.99	673	Test B at IB
4	66	66	0	- 2	529	3537	0.99	673	Test B at IB
5	66	66	0	- 1	363	3555	1.00	673	Test B at IB
6	66	66	0	0	467	3543	1.00	674	Test B at BL
7	66	66	0	+ 1	293	3534	1.01	673	Test B at IB
8	66	66	0	+ 2	273	3549	1.01	673	Test B at IB
9	66	66	0	+ 3	224	3537	1.01	673	Test B at IB
10	66	66	0	+ 4	278	3553	1.02	673	Test B at IB
11	66	66	0	+ 5	272	3553	1.02	673	Test B at IB
Test condition C									
1	33	33	0	- 5	509	1770	0.98	448	Test C at IB
2	33	33	0	- 4	425	1772	0.98	449	Test C at IB
3	33	33	0	- 3	546	1773	0.99	448	Test C at IB
4	33	33	0	- 2	409	1776	1.00	448	Test C at IB
5	33	33	0	- 1	396	1775	1.00	449	Test C at IB
6	33	33	0	0	374	1773	1.00	448	Test C at BL
7	33	33	0	+ 1	364	1777	1.01	448	Test C at IB
8	33	33	0	+ 2	292	1776	1.02	448	Test C at IB
9	33	33	0	+ 3	258	1776	1.02	449	Test C at IB
10	33	33	0	+ 4	258	1779	1.02	448	Test C at IB
11	33	33	0	+ 5	164	1777	1.03	448	Test C at IB

Remark:

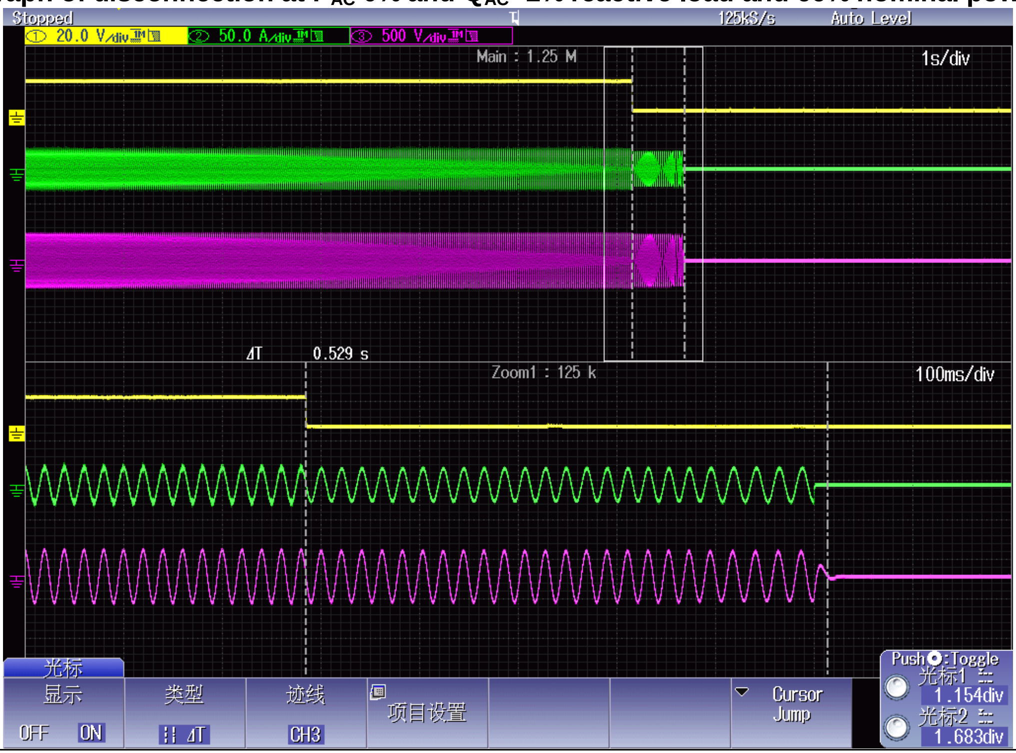
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional 1 % increments is taken until run-on times begin decreasing.

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

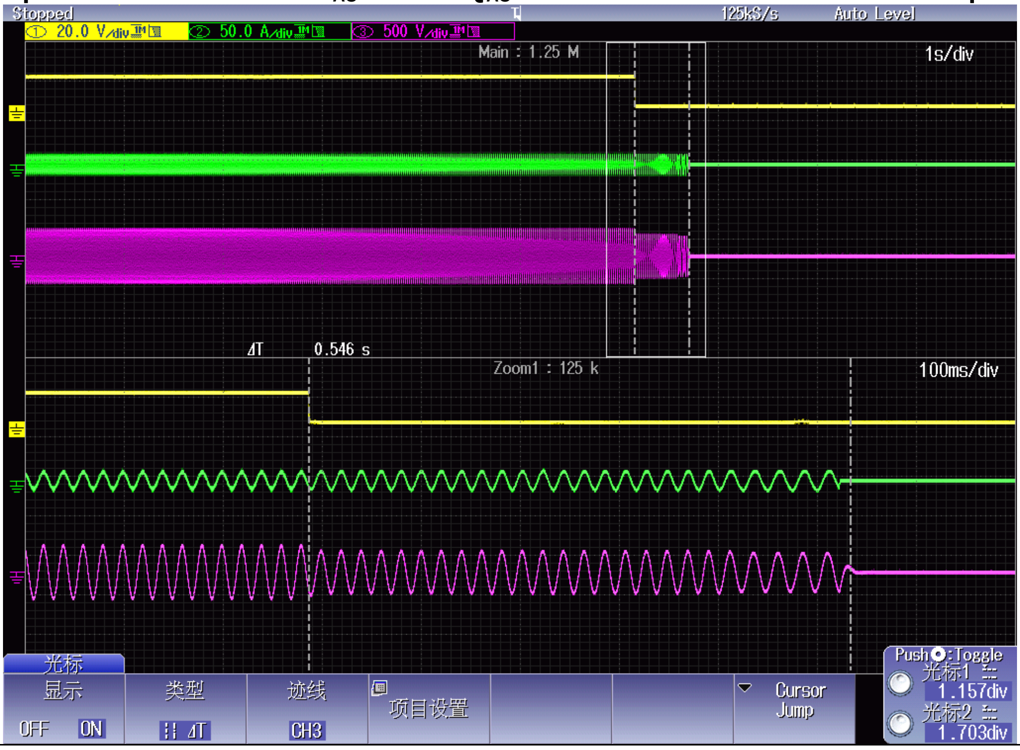
Graph of disconnection at P_{AC} +10% and Q_{AC} 0% reactive load and 100% nominal power



Graph of disconnection at P_{AC} 0% and Q_{AC} -2% reactive load and 66% nominal power



Graph of disconnection at P_{AC} 0% and Q_{AC} -3% reactive load and 33% nominal power



6.5.3	TABLE: Islanding protection - tested condition and run-on time – L3 phase								P
No.	P_{EUT} (% of EUT rating)	Reactive load (% of normial)	P_{AC}	Q_{AC}	Run-on time (ms)	P_{EUT} (W)	Actual Q_f (kVar)	V_{DC}	Remark
Test condition A									
1	100	100	0	0	213	5248	1.00	818	Test A at BL
2	100	100	0	- 5	172	5218	0.95	818	Test A at IB
3	100	100	0	+ 5	502	5231	1.01	818	Test A at IB
4	100	100	- 5	- 5	170	5244	1.01	817	Test A at IB
5	100	100	- 5	0	415	5249	1.05	818	Test A at IB
6	100	100	- 5	+ 5	241	5254	1.06	818	Test A at IB
7	100	100	+ 5	- 5	159	5264	0.91	818	Test A at IB
8	100	100	+ 5	0	454	5243	0.94	818	Test A at IB
9	100	100	+ 5	+ 5	217	5234	0.95	817	Test A at IB
10	100	100	- 5	- 10	132	5237	0.99	817	Test A at IB
11	100	100	- 5	+ 10	198	5248	1.09	818	Test A at IB
12	100	100	0	- 10	143	5223	0.94	817	Test A at IB
13	100	100	0	+ 10	189	5246	1.03	817	Test A at IB
14	100	100	+ 5	- 10	149	5228	0.90	817	Test A at IB
15	100	100	+ 5	+ 10	160	5244	0.99	817	Test A at IB
16	100	100	- 10	- 10	149	5239	1.04	818	Test A at IB
17	100	100	- 10	- 5	160	5234	1.05	817	Test A at IB
18	100	100	- 10	0	376	5230	1.11	817	Test A at IB
19	100	100	- 10	+ 5	573	5207	1,11	817	Test A at IB
20	100	100	- 10	+10	218	5243	1.15	817	Test A at IB
21	100	100	+ 10	- 10	137	5234	0.86	817	Test A at IB
22	100	100	+ 10	- 5	145	5225	0.87	817	Test A at IB
23	100	100	+ 10	0	496	5255	0.90	818	Test A at IB
24	100	100	+ 10	+ 5	691	5239	0.91	817	Test A at IB
25	100	100	+ 10	+ 10	151	5245	0.95	817	Test A at IB
Test condition B									

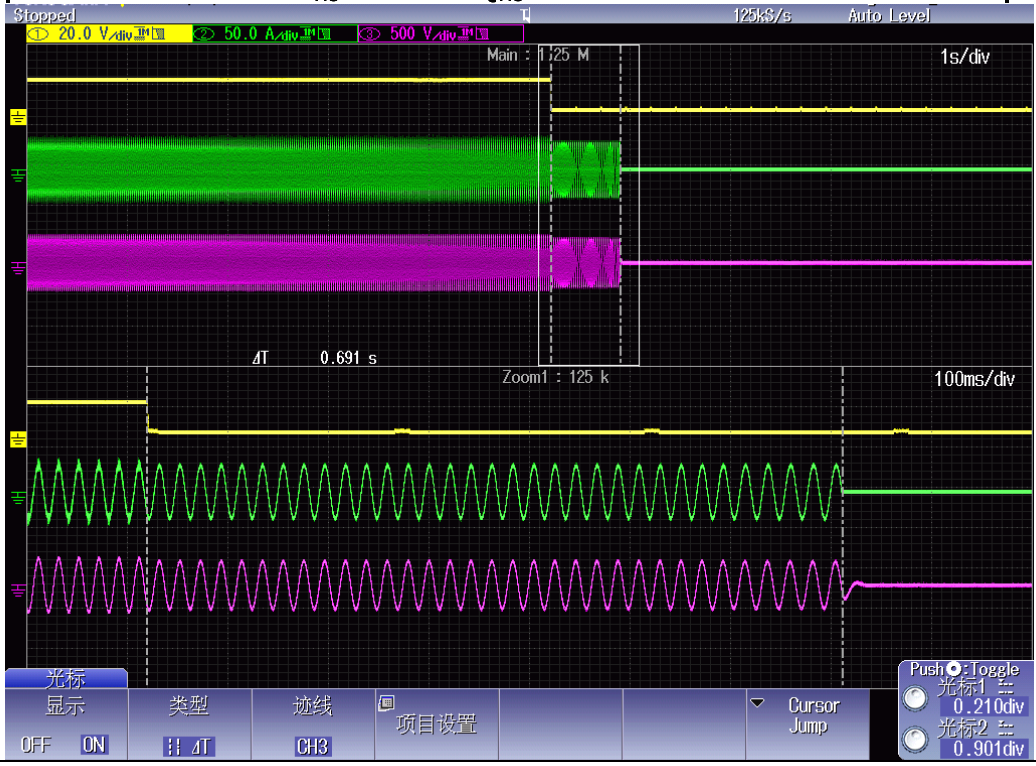
1	66	66	0	- 5	303	3515	0.95	673	Test B at IB
2	66	66	0	- 4	327	3526	0.95	673	Test B at IB
3	66	66	0	- 3	347	3532	0.96	673	Test B at IB
4	66	66	0	- 2	216	3519	0.97	674	Test B at IB
5	66	66	0	- 1	482	3549	0.98	673	Test B at IB
6	66	66	0	0	165	3523	1.01	673	Test B at BL
7	66	66	0	+ 1	220	3546	1.01	673	Test B at IB
8	66	66	0	+ 2	324	3531	1.01	673	Test B at IB
9	66	66	0	+ 3	311	3540	1.01	673	Test B at IB
10	66	66	0	+ 4	169	3543	1.01	673	Test B at IB
11	66	66	0	+ 5	180	3545	1.02	673	Test B at IB
Test condition C									
1	33	33	0	- 5	170	1756	0.99	448	Test C at IB
2	33	33	0	- 4	217	1767	0.99	448	Test C at IB
3	33	33	0	- 3	230	1768	0.99	448	Test C at IB
4	33	33	0	- 2	498	1771	0.99	448	Test C at IB
5	33	33	0	- 1	490	1749	0.99	448	Test C at IB
6	33	33	0	0	394	1771	1.01	448	Test C at BL
7	33	33	0	+ 1	307	1765	1.02	448	Test C at IB
8	33	33	0	+ 2	188	1776	1,03	448	Test C at IB
9	33	33	0	+ 3	253	1770	1.04	448	Test C at IB
10	33	33	0	+ 4	157	1758	1.07	448	Test C at IB
11	33	33	0	+ 5	165	1770	1.08	448	Test C at IB

Remark:

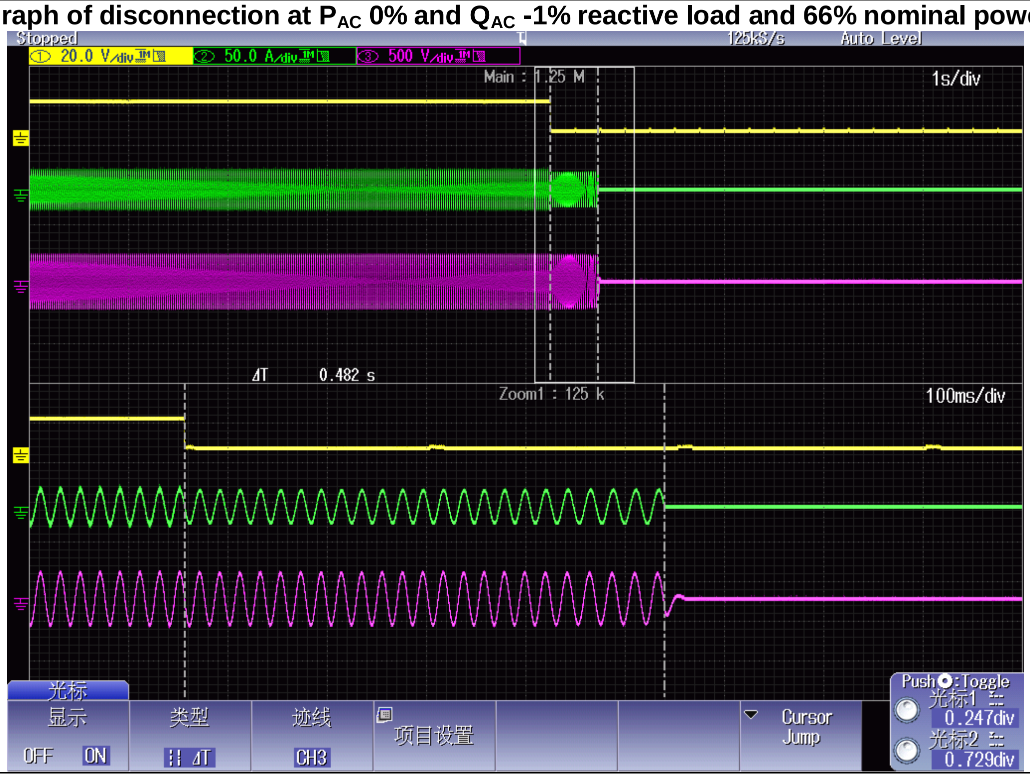
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional 1 % increments is taken until run-on times begin decreasing.

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

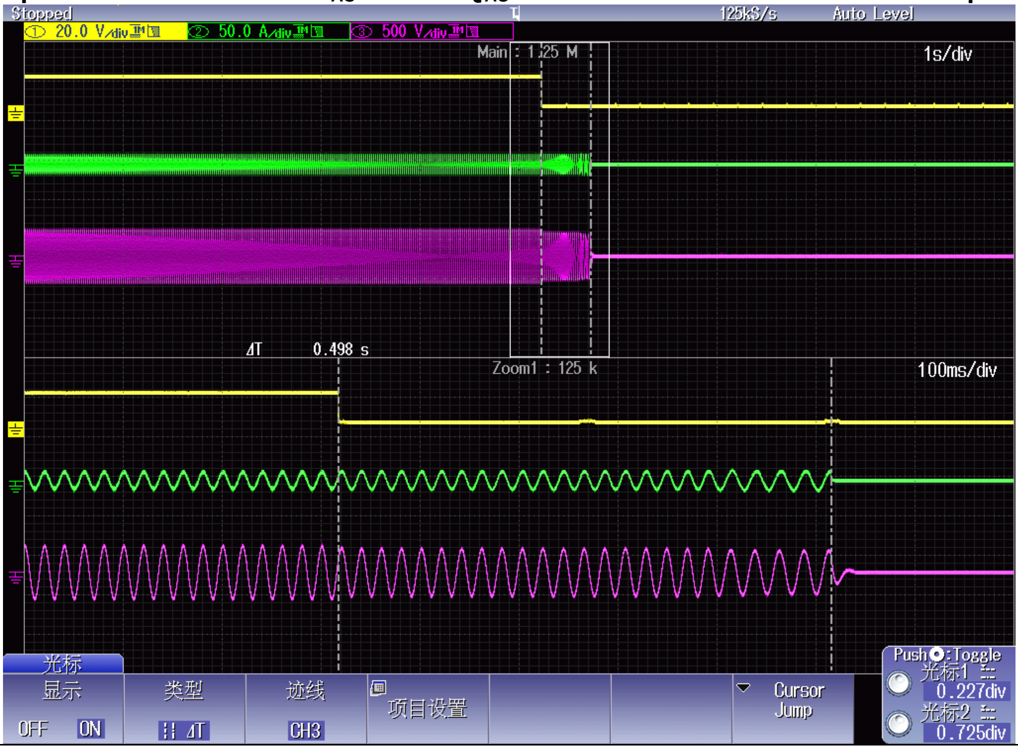
Graph of disconnection at P_{AC} +10% and Q_{AC} +5% reactive load and 100% nominal power



Graph of disconnection at P_{AC} 0% and Q_{AC} -1% reactive load and 66% nominal power



Graph of disconnection at P_{AC} 0% and Q_{AC} -2% reactive load and 33% nominal power



<table>
<tr><th>8.3.1</th><th colspan="3">TABLE: Connecting conditions and synchronisation</th><th>P</th></tr>
<tr><td colspan="2" rowspan="5">Setting values:</td><td>Setting $T_{reconnection}$ [s]:</td><td colspan="2">60</td></tr>
<tr><td>Setting f< [Hz]:</td><td colspan="2">47.5</td></tr>
<tr><td>Setting f> [Hz]:</td><td colspan="2">50.1</td></tr>
<tr><td>Setting V< [V]:</td><td colspan="2">195.5</td></tr>
<tr><td>Setting V>> [V]:</td><td colspan="2">253</td></tr>
<tr><td colspan="5">Test:</td></tr>
<tr><th></th><th>Test condition</th><th>Reconnection time [s]:</th><th colspan="2">Limit [s]:</th></tr>
<tr><td colspan="5">Connecting conditions for frequencies:</td></tr>
<tr><td>a)</td><td>47.45 Hz</td><td>No reconnection</td><td colspan="2">No resetting allowed</td></tr>
<tr><td></td><td colspan="4">Switch to:</td></tr>
<tr><td>b)</td><td>47.55 Hz</td><td>117</td><td colspan="2">≥ 60 s</td></tr>
<tr><td>c)</td><td>50.15 Hz</td><td>No reconnection</td><td colspan="2">No resetting allowed</td></tr>
<tr><td></td><td colspan="4">Switch to:</td></tr>
<tr><td>d)</td><td>50.00 Hz</td><td>117</td><td colspan="2">≥ 60 s</td></tr>
<tr><td colspan="5">Connecting conditions for voltages:</td></tr>
<tr><td>e)</td><td>84%</td><td>No reconnection</td><td colspan="2">No resetting allowed</td></tr>
<tr><td></td><td colspan="4">Switch to:</td></tr>
<tr><td>f)</td><td>86%</td><td>118</td><td colspan="2">≥ 60 s</td></tr>
<tr><td>g)</td><td>111%</td><td>No reconnection</td><td colspan="2">No resetting allowed</td></tr>
<tr><td></td><td colspan="4">Switch to:</td></tr>
<tr><td>h)</td><td>109%</td><td>123</td><td colspan="2">≥ 60 s</td></tr>
<tr><td colspan="5">Note:
The conditions and testing is performed according to V VDE 0124-100, clause 5.5.1
The tests were performed on model EA16KTSI also applicable for all other models stated in this report.</td></tr>
</table>

8.3.1	TABLE: Reconnection after interruption	P
Setting values:	Setting $T_{reconnection\ 5s}$ [s]:	60
	Setting $T_{reconnection\ 60s}$ [s]:	60
	Setting V< [V]:	184
	Step 1:	**Step 2:**
Step [V to V]	230 to 177.1	230 to 177.1
Jump Duration [s]:	2	4
Limit [s]:	≥ 5	≥ 60
Reconnection Time [s]:	65.45	73.05

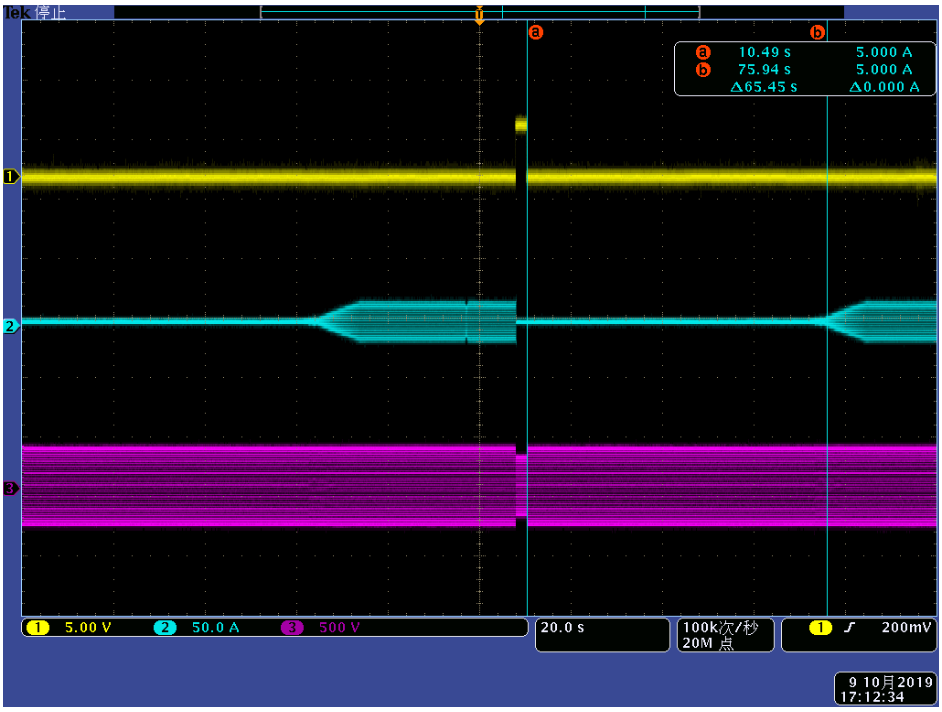
Note:

The grid voltage is reduced from nominal voltage to 77% U_n by a jump. A jump to nominal voltage is carried out after 2 s. Reconnection time must be longer than 5 s.
The grid voltage is reduced from nominal voltage to 77% U_n by a jump. A jump to nominal voltage is carried out after 4 s. Reconnection time must be longer than 60 s.

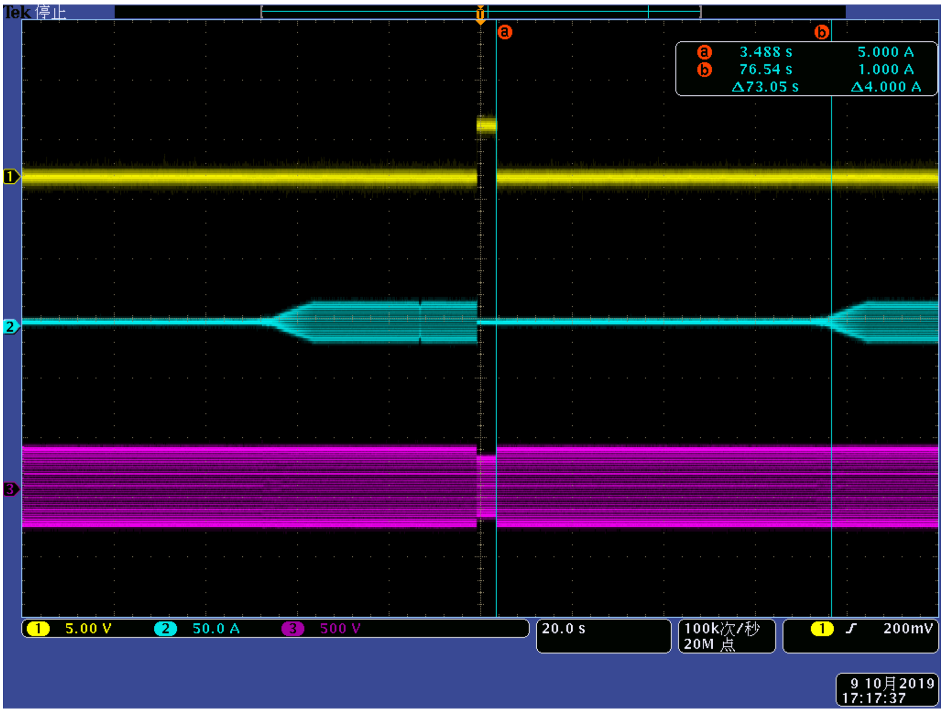
A ramp of 10% P_n is not necessary after short interruptions.

The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

Test 1: 230 V to 177.1 V in 2 s



Test 2: 230 V to 177.1 V in 4 s



Annex 2

Datasheet of the relay

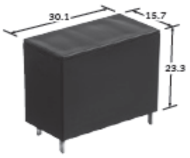
Panasonic Automation Controls Catalog

cULus VDE RoHS

Load for solar inverter, Compact size, 1 Form A 22A/33A power relays

LF-G RELAYS(ALFG)

Protective construction : Flux-resistant type



(Unit : mm)

FEATURES

1. High capacity
High capacity control possible at 22A/ 33A (High capacity type) 250V AC rating in compact size (L: 15.7 × W: 30.1 × H: 23.3 mm L: .618 × W: 1.185 × H: .917 inch)

2. Contact gap: 1.5 mm .059 inch and 1.8 mm* .071 inch**
Compliant with European photovoltaic standard (IEC62109* and VDE0126**).
* Safety standard of PV power inverter
**German safety standard of PV power inverter
***Due to addition of altitude stipulation (2,000 m 6,561.68 ft or more) to IEC62109.
EN61810-1 certified: 2.5 kV surge breakdown voltage (between contacts)

3. Long insulation distance
Creepage distance between contact and coil terminal: Min. 9.5 mm .354 inch
Clearance distance between contact and coil terminal: Min. 6.5 mm .256 inch
Surge breakdown voltage: 6 kV

4. Coil holding voltage contributes to saving energy of equipment
The coil holding voltage can be reduced up to 35%V of the nominal coil voltage (Ambient temperature: 20°C 68°F).
Power consumption at the lowest coil holding voltage: 170 mW equivalent
*Coil holding voltage is the coil voltage after 100 ms from the applied nominal coil voltage.
*When the ambient temperature during use is 85°C 185°F, make the coil holding voltage between 45% and 80%V of the nominal coil voltage.

5. Conforms to various safety standards
UL/C-UL and VDE approved

TYPICAL APPLICATIONS

1. **Photovoltaic power generation systems (Solar inverter)**
2. **Uninterruptible Power Supplies (UPS)**
3. **Home appliances**
4. **Office equipment**

ORDERING INFORMATION

ALFG _ P F _ _

- Contact arrangement
  - 1 : 1 Form A Standard type
  - 2 : 1 Form A High capacity type
- Terminal shape
  - P : PCB type
- Coil insulation class
  - F : UL Class F
- Nominal coil voltage (DC)
  - 09 : 9V, 12 : 12V
  - 18 : 18V, 24 : 24V
- Contact gap
  - Nil : 1.5mm
  - 1 : 1.8mm

Note : Certified by UL/C-UL and VDE

TYPES

Contact arrangement	Nominal coil voltage	Part No.			
		Contact Gap 1.5 mm .059 inch type		Contact Gap 1.8 mm .071 inch type	
		Standard type	High capacity type	Standard type	High capacity type
1 Form A	9V DC	ALFG1PF09	ALFG2PF09	ALFG1PF091	ALFG2PF091
	12V DC	ALFG1PF12	ALFG2PF12	ALFG1PF121	ALFG2PF121
	18V DC	ALFG1PF18	ALFG2PF18	ALFG1PF181	ALFG2PF181
	24V DC	ALFG1PF24	ALFG2PF24	ALFG1PF241	ALFG2PF241

Standard packing: Carton: 50 pcs.; Case: 200 pcs.

LF-G (ALFG)

RATING

1.Coil data

• Operating characteristics such as 'Operate voltage' and 'Release voltage' are influenced by mounting conditions, ambient temperature, etc. Therefore, please use the relay within ± 5% of rated coil voltage.
• 'Initial' means the condition of products at the time of delivery.

Nominal coil voltage	Pick-up voltage (at 20°C 68°F) (Initial)	Drop-out voltage (at 20°C 68°F) (Initial)	Nominal operating current [±10%] (at 20°C 68°F)	Coil resistance [±10%] (at 20°C 68°F)	Nominal operating power	Max. applied voltage (at 20°C 68°F)
9V DC	70%V or less of nominal voltage	10%V or more of nominal voltage	155mA	58Ω	1,400mW	120%V of nominal voltage
12V DC			117mA	103Ω		
18V DC			78mA	230Ω		
24V DC			59mA	410Ω		

2. Specifications

Characteristics	Item		Specifications		
			Standard type	High capacity type	
			Contact Gap 1.5 mm .059 inch type Contact Gap 1.8 mm .071 inch type	Contact Gap 1.5 mm .059 inch type	Contact Gap 1.8 mm .071 inch type
Contact	Arrangement		1 Form A		
	Contact resistance (Initial)		Max. 100 mΩ (By voltage drop 6 V DC 1A)		
	Contact material		$AgSnO_2$ type		
Rating	Nominal switching capacity		22A 250V AC	31A 250V AC	33A 250V AC
	Max. switching power		5,500VA	7,750VA	8,250VA
	Max. switching voltage		250V AC		
	Max. switching current		22A (AC)	31A (AC)	33A (AC)
	Nominal operating power		1,400mW		
	Min. switching capacity (Reference value)*1		100mA 5V DC		
Electrical characteristics	Insulation resistance (Initial)		Min. 1,000MΩ (at 500V DC) Measurement at same location as "Breakdown voltage" section.		
	Breakdown voltage (Initial)	Between open contacts	2,500 Vrms for 1 min. (Detection current: 10 mA)		
		Between contact and coil	4,000 Vrms for 1 min. (Detection current: 10 mA)		
	Surge breakdown voltage*2 (Between contact and coil) (Initial)		6,000 V		
	Coil holding voltage*3		35 to 120%V (contact carrying current: 22A, at 20°C 68°F) 45 to 80%V (contact carrying current: 22A, at 85°C 185°F)	35 to 120%V (contact carrying current: 31A, at 20°C 68°F) 45 to 80%V (contact carrying current: 31A, at 85°C 185°F)	35 to 120%V (contact carrying current: 33A, at 20°C 68°F) 45 to 80%V (contact carrying current: 33A, at 85°C 185°F)
	Operate time (at 20°C 68°F) (Initial)		Max. 20 ms (at nominal coil voltage excluding contact bounce time.)		
	Release time (at 20°C 68°F) (Initial)		Max. 10 ms (at nominal coil voltage excluding contact bounce time, without diode)		
Mechanical characteristics	Shock resistance	Functional	Min. 100 m/s^2 (Half-wave pulse of sine wave: 11 ms; detection time: 10μs.)		
		Destructive	Min. 1,000 m/s^2 (Half-wave pulse of sine wave: 6 ms.)		
	Vibration resistance	Functional	10 to 55 Hz at double amplitude of 1.5 mm (Detection time: 10μs.)		
		Destructive	10 to 55 Hz at double amplitude of 1.5 mm		
Expected life	Mechanical		Contact Gap 1.5 mm .059 inch type: Min. 10^6 (at 180 times/min.) Contact Gap 1.8 mm .071 inch type: Min. 5×10^5 (at 180 times/min.)		
	Electrical	Resistive load	22A 250V AC, Min. 3×10^4 (at 20 times/min.)	—	—
		Inductive load	Destructive: 22A 250V AC (cosφ = 0.8), Min. 3×10^4 (on:off = 0.1s:10s) Over load: 35A 250V AC (cosφ = 0.8), Min. 50 (on:off = 0.1s:10s)	Destructive: 31A 250V AC (cosφ = 0.8), Min. 3×10^4 (on:off = 0.1s:10s) Over load: 47A 250V AC (cosφ = 0.8), Min. 50 (on:off = 0.1s:10s)	Destructive: 33A 250V AC (cosφ = 0.8), Min. 3×10^4 (on:off = 0.1s:10s) Over load: 50A 250V AC (cosφ = 0.8), Min. 50 (on:off = 0.1s:10s)
Conditions	Conditions for operation, transport and storage*4		Ambient temperature: –40°C to +60°C –40°F to +140°F (When nominal coil voltage applied) –40°C to +85°C –40°F to +185°F (Coil holding voltage is when 45 to 80%V of nominal coil voltage is applied.) Humidity: 5 to 85% R.H. (Not freezing and condensing at low temperature) Air pressure: 86 to 106 kPa		
Unit weight			Approx. 23 g .81 oz		

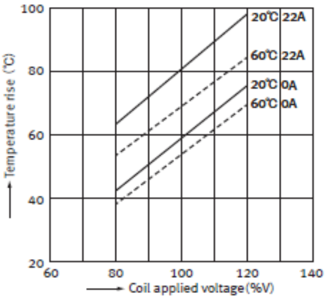
Notes: *1. This value can change due to the switching frequency, environmental conditions, and desired reliability level, therefore it is recommended to check this with the actual load.
*2. Wave is standard shock voltage of ±1.2×50μs according to JEC-212-1981
*3. Coil holding voltage is the coil voltage after 100 ms from the applied nominal coil voltage.
*4. The upper limit of the ambient temperature is the maximum temperature that can satisfy the coil temperature rise value. Refer to Usage, transport and storage conditions in NOTES.

REFERENCE DATA

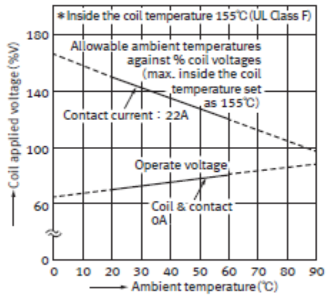
1. Standard type (Contact Gap 1.5 mm .059 inch type) (Contact Gap 1.8 mm .071 inch type)

1. Coil temperature rise

Tested sample : ALFG1PF09, ALFG1PF091, 6 pcs.
Measured portion : Coil inside
Contact current : 22A
Ambient temperature : 20℃, 60℃

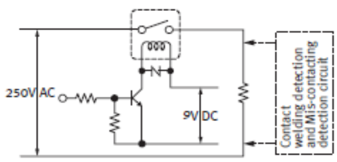


2. Ambient temperature characteristics and coil

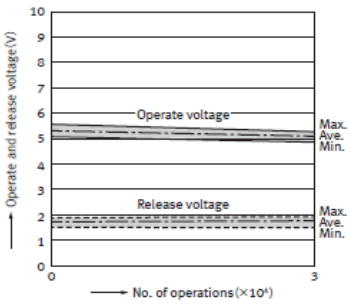


3. Electrical life test
(22A 250V AC Resistive load)

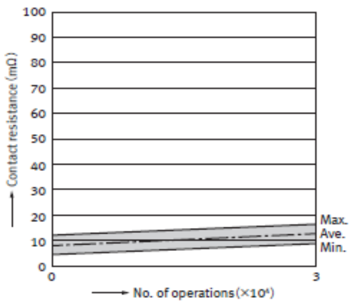
Tested sample : ALFG1PF09, ALFG1PF091, 6 pcs.
Operation frequency : ON : OFF = 1.5s : 1.5s
Ambient temperature : 85°C
Circuit :



Change of operate and release voltage

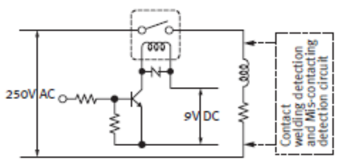


Change of contact resistance

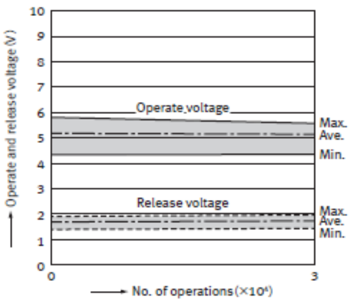


4. Electrical life test
(22A 250V AC cosφ = 0.8 Inductive load)

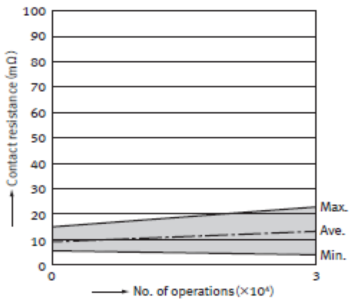
Tested sample : ALFG1PF09, ALFG1PF091, 6 pcs.
Operation frequency : ON : OFF = 0.1s : 10s
Ambient temperature : 85°C
Circuit :



Change of operate and release voltage



Change of contact resistance

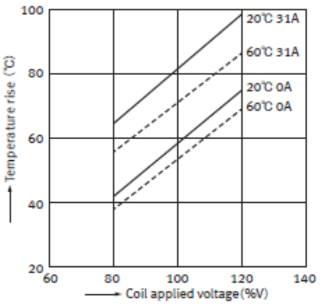


LF-G (ALFG)

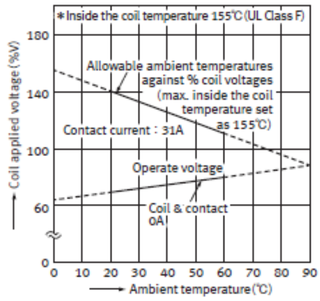
2. High capacity type (Contact Gap 1.5 mm .059 inch type)

1. Coil temperature rise

Tested sample : ALFG2PF09, 6 pcs.
Measured portion : Coil inside
Contact current : 31A
Ambient temperature : 20℃, 60℃

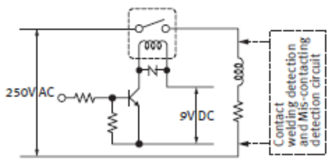


2. Ambient temperature characteristics and coil applied voltage

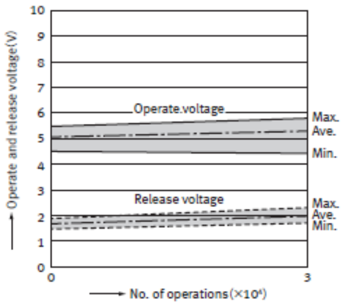


3. Electrical life test
(31A 250V AC cosφ = 0.8 Inductive load)

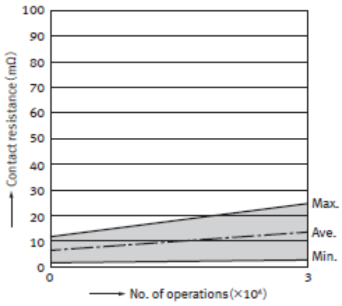
Tested sample : ALFG2PF09, 6 pcs.
Operation frequency : ON : OFF = 0.1s : 10s
Ambient temperature : 85℃
Circuit :



Change of operate and release voltage



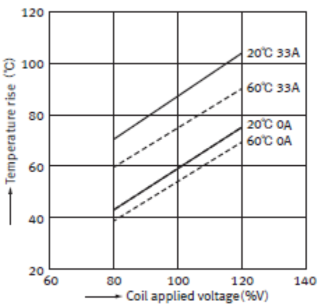
Change of contact resistance



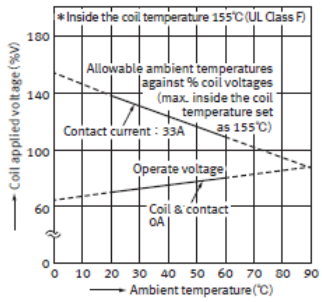
3. High capacity type (Contact Gap 1.8 mm .071 inch type)

1. Coil temperature rise

Tested sample : ALFG2PF091, 6 pcs.
Measured portion : Coil inside
Contact current : 33A
Ambient temperature : 20℃, 60℃

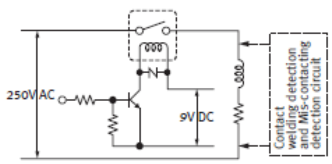


2. Ambient temperature characteristics and coil applied voltage

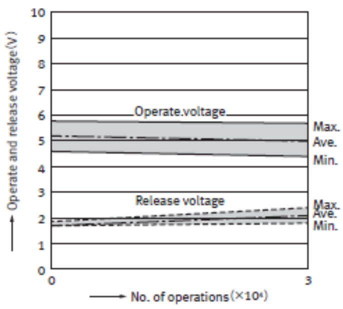


3. Electrical life test
(33A 250V AC cosφ = 0.8 Inductive load)

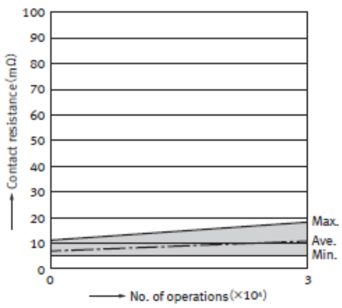
Tested sample : ALFG2PF091, 6 pcs.
Operation frequency : ON : OFF = 0.1s : 10s
Ambient temperature : 85℃
Circuit :



Change of operate and release voltage



Change of contact resistance

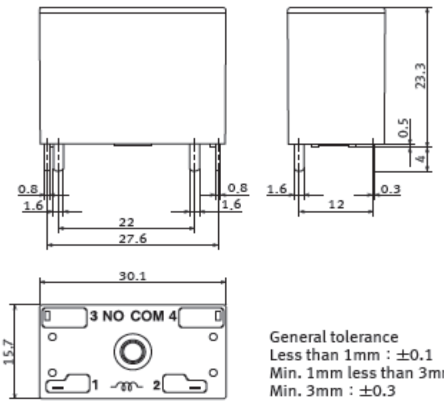


DIMENSIONS (mm)

CAD The CAD data of the products with a "CAD" mark can be downloaded from our Website.

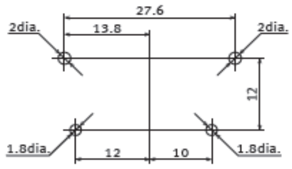
CAD

External dimensions



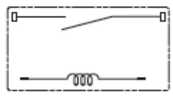
General tolerance
Less than 1mm : ±0.1
Min. 1mm less than 3mm : ±0.2
Min. 3mm : ±0.3

PC board pattern (Bottom view)



Tolerance ±0.1

Schematic (Bottom view)



SAFETY STANDARDS

Item		UL/C-UL (Recognized)				VDE (VDE0435) (Certified)			
		File No.	Contact rating	Temp.	Cycles	File No.	Contact rating	Temp.	Cycles
Standard type (Contact GAP 1.5 mm/1.8 mm .059 inch/.071 inch)		E43028	22A 277V AC General Use	85°C 185°F	3 × 10^4	40023067	22A 250V AC (cosφ=0.8)	85°C 185°F	3 × 10^4
			22A 277V AC Resistive	85°C 185°F	3 × 10^4	—	—	—	—
			22A 30V DC Resistive	40°C 104°F	3 × 10^4	—	—	—	—
High capacity type	1.5 mm .059 inch	E43028	31A 277V AC General Use	85°C 185°F	3 × 10^4	40023067	31A 250V AC (cosφ=0.8)	85°C 185°F	3 × 10^4
	1.8 mm .071 inch	E43028	33A 277V AC General Use 33A 30V DC Resistive	85°C 185°F 40°C 104°F	3 × 10^4 3 × 10^4	40023067	33A 250V AC (cosφ=0.8)	85°C 185°F	3 × 10^4

EN/IEC VDE Certified
INSULATION CHARACTERISTIC (IEC61810-1)

Item	Characteristic
Clearance/Creepage distance (IEC61810-1)	Min. 5.5mm/5.5mm
Category of protection (IEC61810-1)	RT II
Tracking resistance (IEC60112)	PTI 175
Insulation material group	III a
Over voltage category	III
Rated voltage	250V
Pollution degree	2
Type of insulation (Between contact and coil)	Reinforced insulation
Type of insulation (Between open contacts)	Full disconnection

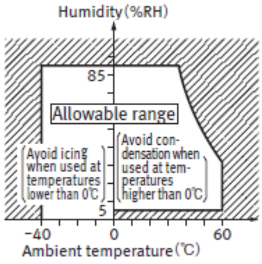
NOTES

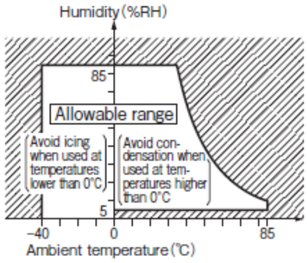
1. **For cautions for use, please read "GENERAL APPLICATION GUIDELINES".**
2. **Usage, transport and storage conditions**

   1) Temperature:
   –40 to +60°C –40 to +140°F (When nominal coil voltage applied)
   –40 to +85°C –40 to +185°F (When coil holding voltage is 45% to 80% of the nominal coil voltage)
   2) Humidity: 5 to 85% RH
   (Avoid freezing and condensation.)
   The humidity range varies with the temperature. Use within the range indicated in the graph below.
   3) Atmospheric pressure: 86 to 106 kPa

Please refer to **"the latest product specifications"** when designing your product.
• Requests to customers :
https://industrial.panasonic.com/ac/e/salespolicies/

Temperature and humidity range for usage, transport, and storage





* –40 to +85°C –40 to +185°F (When 45% to 80%V of coil holding voltage)

GUIDELINES FOR POWER RELAYS AND HIGH-CAPACITY DC CUT OFF RELAYS USAGE

For cautions for use, please read “GUIDELINES FOR RELAY USAGE”.
https://industrial.panasonic.com/ac/e/control/relay/cautions_use/index.jsp

Precautions for Coil Input

■Long term current carrying

A circuit that will be carrying a current continuously for long periods without relay switching operation. (circuits for emergency lamps, alarm devices and error inspection that, for example, revert only during malfunction and output warnings with form B contacts) Continuous, long-term current to the coil will facilitate deterioration of coil insulation and characteristics due to heating of the coil itself.
For circuits such as these, please use a magnetic-hold type latching relay. If you need to use a single stable relay, use a sealed type relay that is not easily affected by ambient conditions and make a failsafe circuit design that considers the possibility of contact failure or disconnection.

■DC Coil operating power

Steady state DC current should be applied to the coil. The wave form should be rectangular. If it includes ripple, the ripple factor should be less than 5%.
However, please check with the actual circuit since the electrical characteristics may vary. The rated coil voltage should be applied to the coil and the set/reset pulse time of latching type relay differs for each relays, please refer to the relay's individual specifications.

■Coil connection

When connecting coils of polarized relays, please check coil polarity (+,-) at the internal connection diagram (Schematic). If any wrong connection is made, it may cause unexpected malfunction, like abnormal heat, fire and so on, and circuit do not work. Avoid impressing voltages to the set coil and reset coil at the same time.

■Maximum allowable voltage and temperature rise

Proper usage requires that the rated coil voltage be impressed on the coil. Note, however, that if a voltage greater than or equal to the maximum continuous voltage is impressed on the coil, the coil may burn or its layers short due to the temperature rise. Furthermore, do not exceed the usable ambient temperature range listed in the catalog.

■Operate voltage change due to coil temperature rise

(Hot start)

In DC relays, after continuous passage of current in the coil, if the current is turned OFF, then immediately turned ON again, due to the temperature rise in the coil, the pick-up voltage will become somewhat higher. Also, it will be the same as using it in a higher temperature atmosphere. The resistance/temperature relationship for copper wire is about 0.4% for 1°C, and with this ratio the coil resistance increases. That is, in order to operate of the relay, it is necessary that the voltage be higher than the pick-up voltage and the pick-up voltage rises in accordance with the increase in the resistance value. However, for some polarized relays, this rate of change is considerably smaller.

Ambient Environment

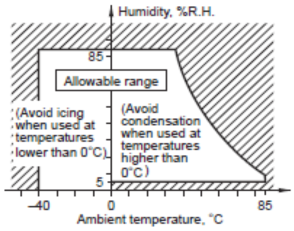
■Usage, Transport, and Storage Conditions

During usage, storage, or transportation, avoid locations subjected to direct sunlight and maintain normal temperature, humidity and pressure conditions.

●Temperature/Humidity/Pressure

When transporting or storing relays while they are tube packaged, there are cases the temperature may differ from the allowable range. In this case be sure to check the individual specifications. Also allowable humidity level is influenced by temperature, please check charts shown below and use relays within mentioned conditions. (Allowable temperature values differ for each relays, please refer to the relay's individual specifications.)

1) Temperature:
The tolerance temperature range differs for each relays, please refer to the relay's individual specifications
2) Humidity:
5 to 85 % RH
3) Pressure:
86 to 106 kPa



■Dew condensation

Condensation occurs when the ambient temperature drops suddenly from a high temperature and humidity, or the relay is suddenly transferred from a low ambient temperature to a high temperature and humidity. Condensation causes the failures like insulation deterioration, wire disconnection and rust etc.
Panasonic Corporation does not guarantee the failures caused by condensation.
The heat conduction by the equipment may accelerate the cooling of device itself, and the condensation may occur.
Please conduct product evaluations in the worst condition of the actual usage. (Special attention should be paid when high temperature heating parts are close to the device. Also please consider the condensation may occur inside of the device.)

●Icing

Condensation or other moisture may freeze on relays when the temperature become lower than 0°C.This icing causes the sticking of movable portion, the operation delay and the contact conduction failure etc. Panasonic Corporation does not guarantee the failures caused by the icing.
The heat conduction by the equipment may accelerate the cooling of relay itself and the icing may occur. Please conduct product evaluations in the worst condition of the actual usage.

■Low temperature and low humidity

The plastic becomes brittle if the switch is exposed to a low temperature, low humidity environment for long periods of time.

■High temperature and high humidity

Storage for extended periods of time (including transportation periods) at high temperature or high humidity levels or in atmospheres with organic gases or sulfide gases may cause a sulfide film or oxide film to form on the surfaces of the contacts and/or it may interfere with the functions. Check out the atmosphere in which the units are to be stored and transported.

GUIDELINES FOR POWER RELAYS AND HIGH-CAPACITY DC CUT OFF RELAYS USAGE

●**Package**
In terms of the packing format used, make every effort to keep the effects of moisture, organic gases and sulfide gases to the absolute minimum.

●**Silicon**
When a source of silicone substances (silicone rubber, silicone oil, silicone coating materials and silicone filling materials etc.) is used around the relay, the silicone gas (low molecular siloxane etc.) may be produced.
This silicone gas may penetrate into the inside of the relay. When the relay is kept and used in this condition, silicone compound may adhere to the relay contacts which may cause the contact failure. Do not use any sources of silicone gas around the relay (Including plastic seal types).

●**NOx Generation**
When relay is used in an atmosphere high in humidity to switch a load which easily produces an arc, the NOx created by the arc and the water absorbed from outside the relay combine to produce nitric acid. This corrodes the internal metal parts and adversely affects operation. Avoid use at an ambient humidity of 85%RH or higher (at 20°C). If use at high humidity is unavoidable, please contact our sales representative.

Others

■**Cleaning**

1) Although the environmentally sealed type relay (plastic sealed type, etc.) can be cleaned, avoid immersing the relay into cold liquid (such as cleaning solvent) immediately after soldering. Doing so may deteriorate the sealing performance.
2) Cleaning with the boiling method is recommended(The temperature of cleaning liquid should be 40°C or lower).
   Avoid ultrasonic cleaning on relays. Use of ultrasonic cleaning may cause breaks in the coil or slight sticking of the contacts due to ultrasonic energy.

Please refer to **"the latest product specifications"** when designing your product.
•Requests to customers:
https://industrial.panasonic.com/ac/e/salespolicies/

Annex 3

Pictures of the unit

EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI Enclosure – Front View

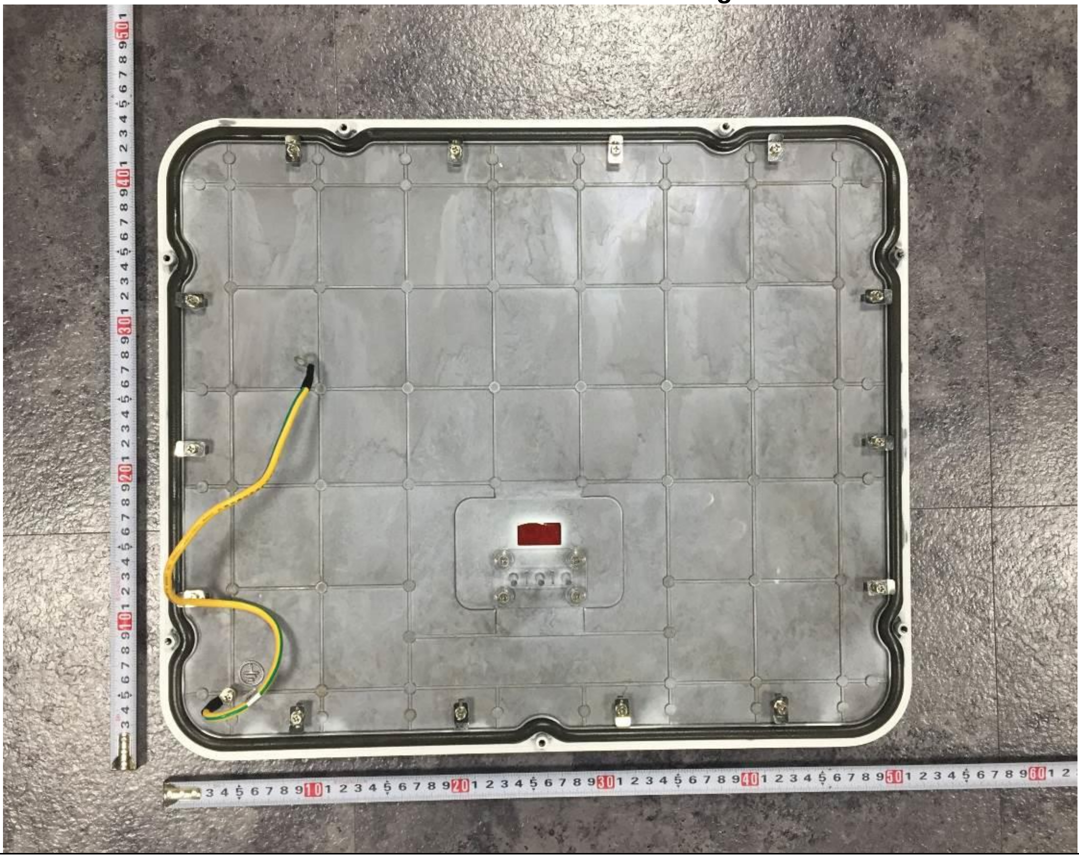
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI **Enclosure – Rear View**

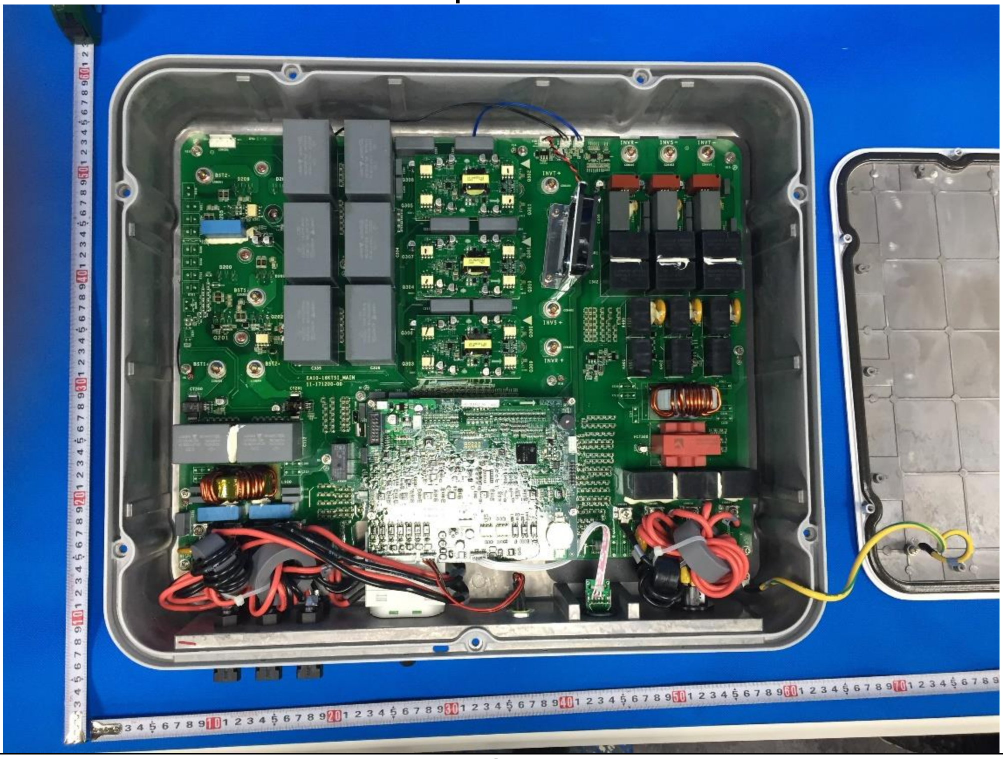
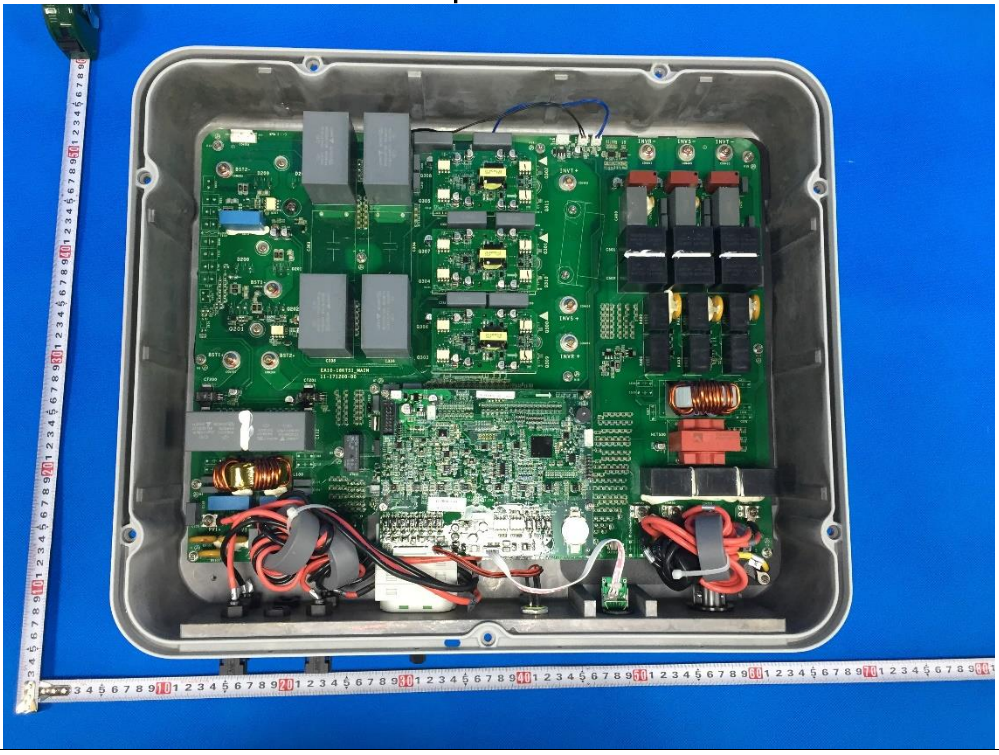

EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Enclosure – Front View

EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Enclosure – Rear View

EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI **Enclosure – Bottom View**	**EA13KTSI / EA16KTSI** **Enclosure – Bottom View**
	

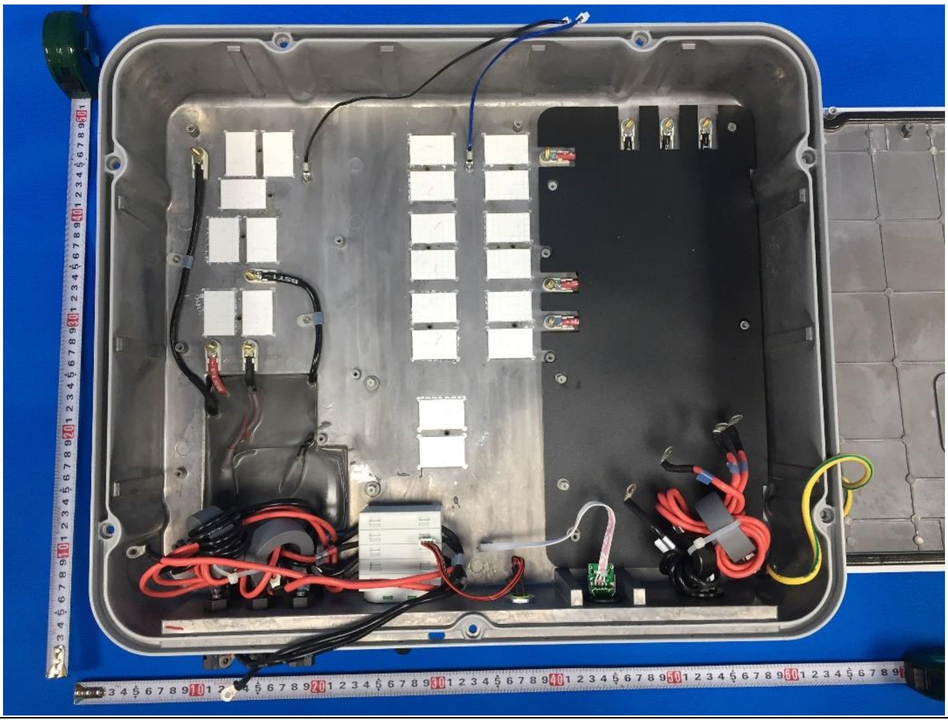
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Cover and Protective Bonding



EA13KTSI / EA16KTSI **Open View** 
EA8KTSI / EA10KTSI **Open View** 

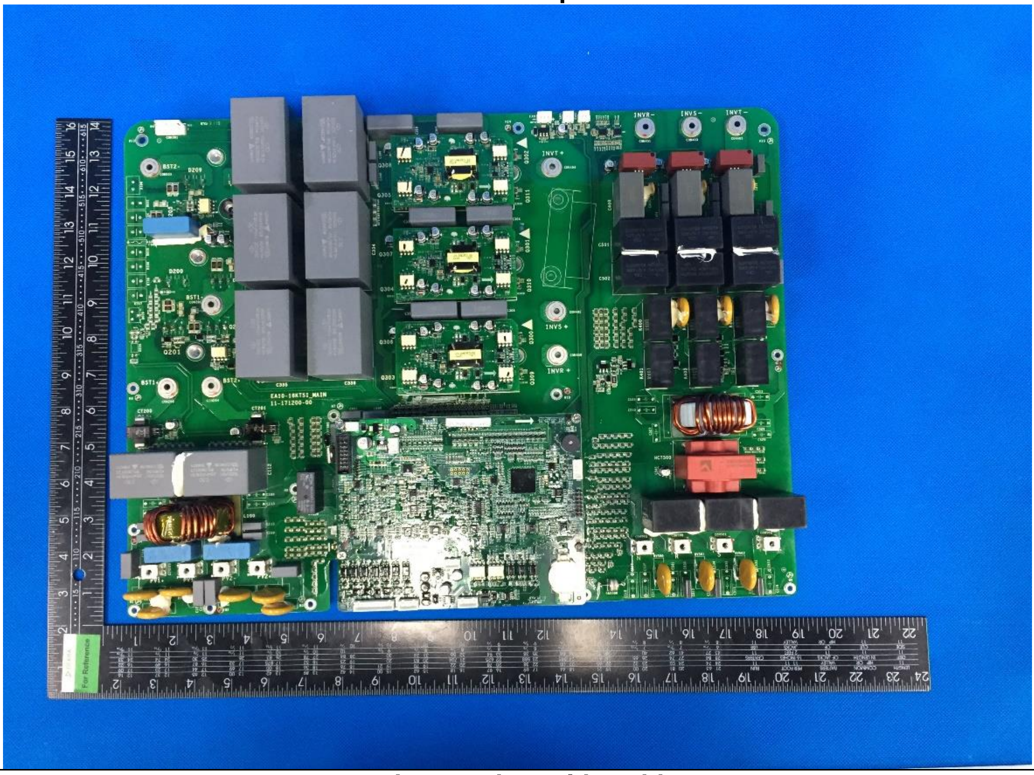
EA5KTSI / EA6KTSI
Open View

EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Internal Enclosure

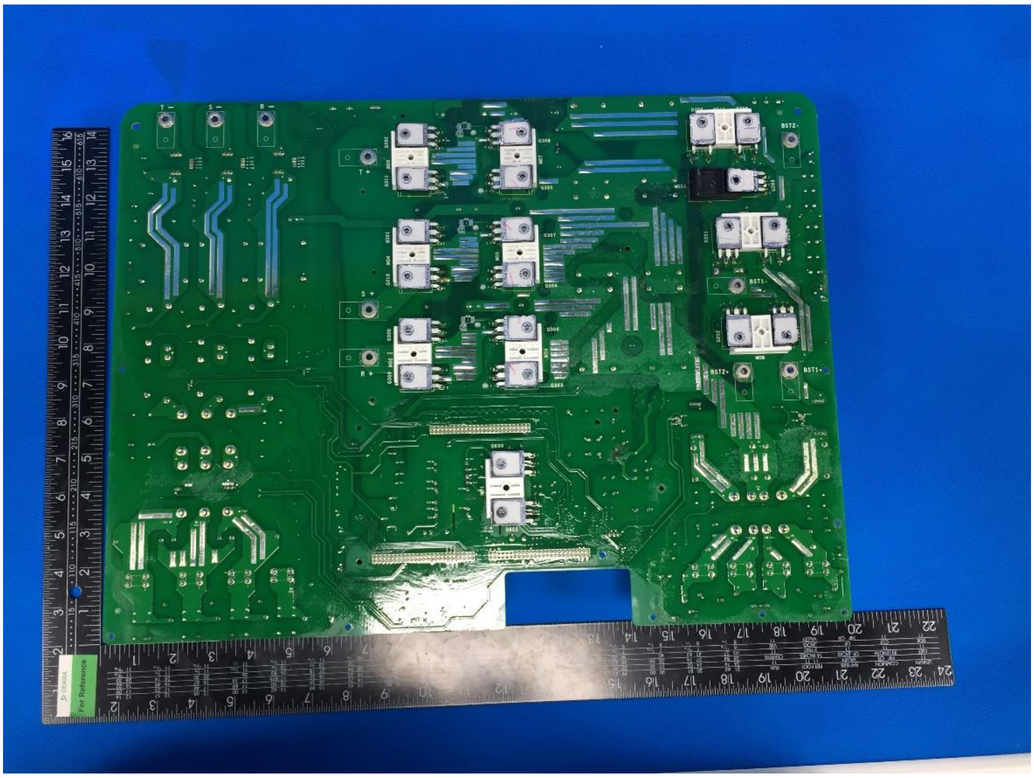


EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI **AC Output and Protective Bonding** 
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI **AC Output and Protective Earthing** 

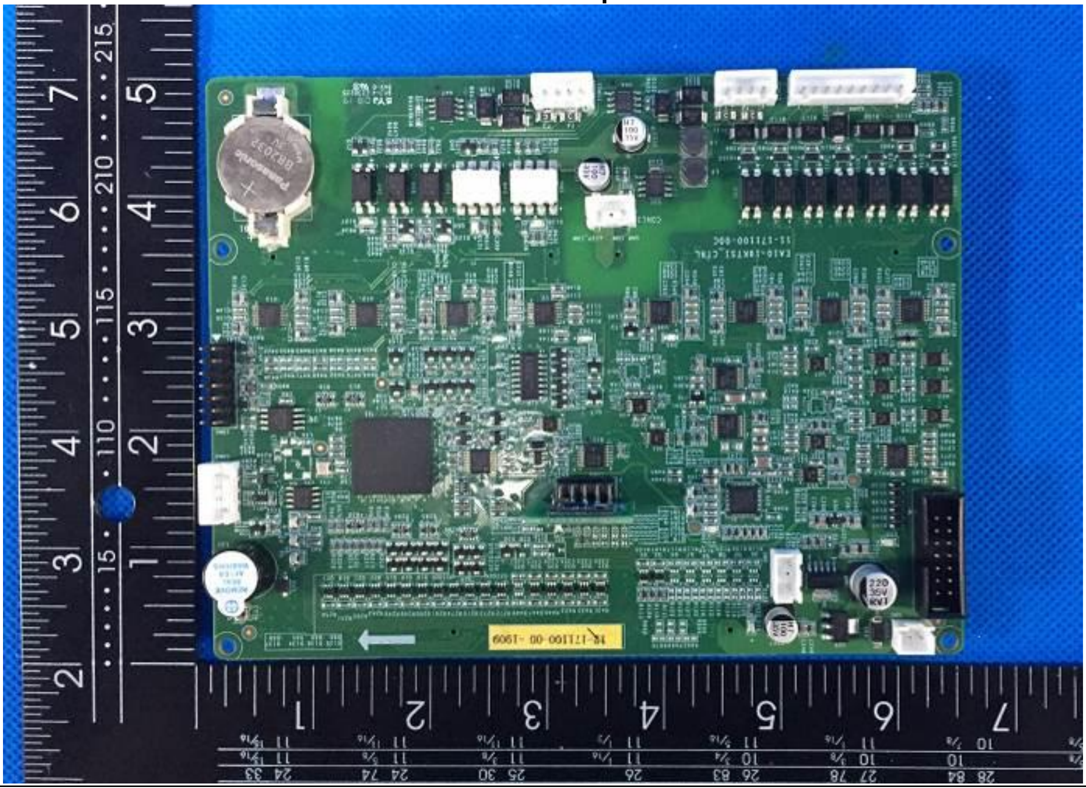
Main Board – Component Side



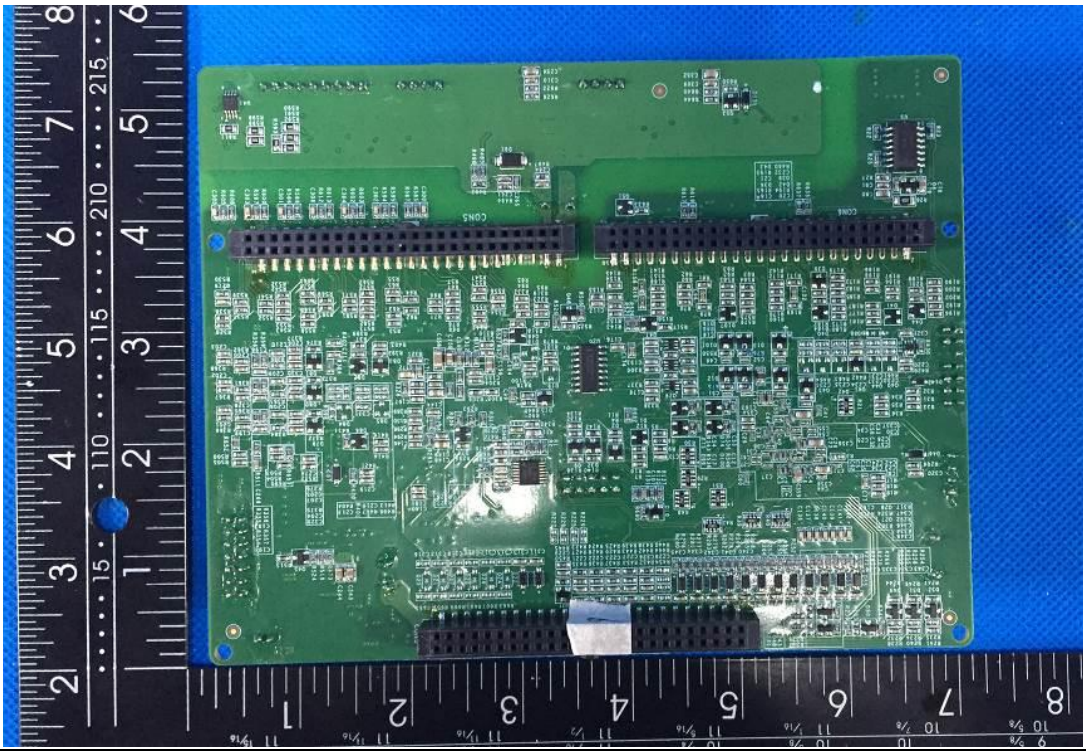
Main Board – Solder Side



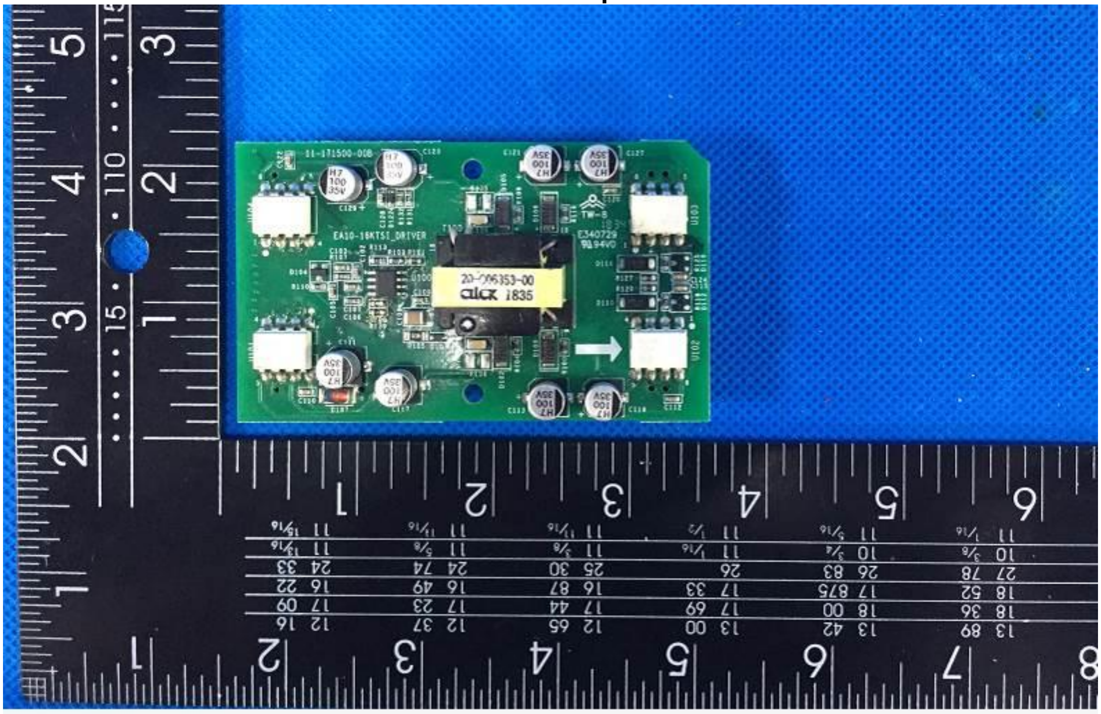
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Control Board – Component Side



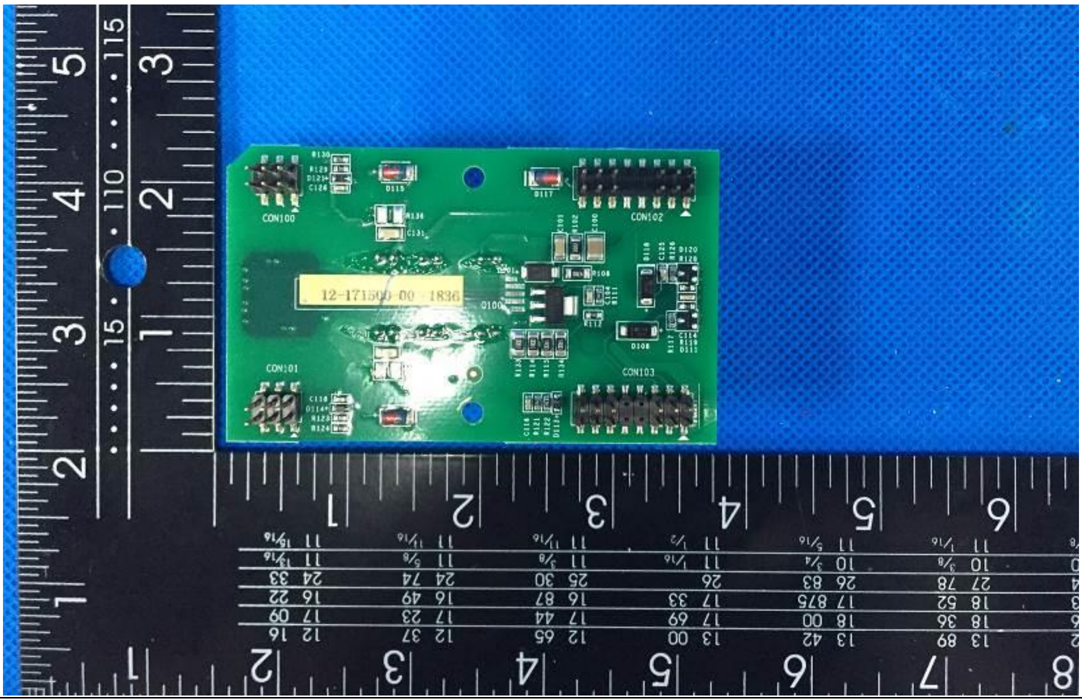
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Control Board – Solder Side



EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Driver Board – Component Side



EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Driver Board – Solder Side



--END--