TEST REPORT

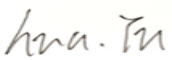
EN 50549-1:2019

Requirements for micro-generating plants to be connected in parallel with public low-voltage distribution networks

Part 1: Connection to a LV distribution network

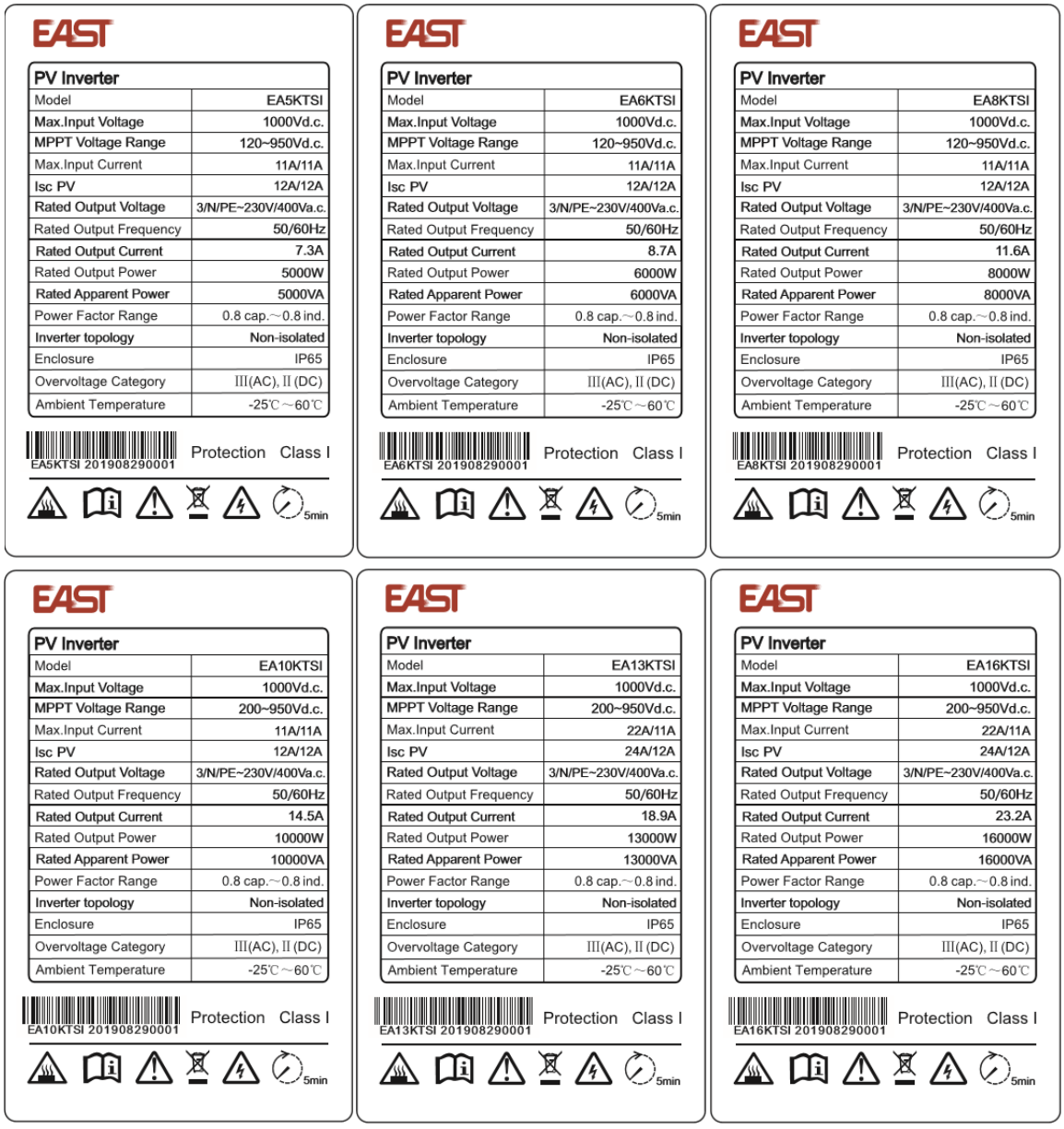
Report	
Report Number. ..... :	6052106.53
Date of issue..... :	2019-11-07
Total number of pages.....	188
Testing Laboratory ..... :	DEKRA Testing and Certification (Suzhou) Co., Ltd.
Address ..... :	No.99, Hongye Road, Suzhou Industrial Park, Suzhou, Jiangsu, P.R. China
Applicant's name ..... :	EAST Group Co., Ltd.
Address ..... :	No.6 Northern Industry Road, Songshan Lake Sci. & Tech. Industrial Park, Dongguan City, Guangdong Province, China
Test specification:	
Standard..... :	EN 50549-1:2019
Test procedure..... :	Type test
Non-standard test method..... :	N/A
Test Report Form No. ..... :	EN 50549-1_V1.0
Test Report Form(s) Originator ..... :	DEKRA Testing and Certification (Suzhou) Co., Ltd.
Master TRF..... :	Dated 2019-05-31
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 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 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 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 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 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 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, Jiangsu, 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: CTF Stage 1:~~		
~~Testing location/ address ..... :~~			
~~Tested by (name, function, signature) ..... :~~			
~~Approved by (name, function, signature)..... :~~			
☐	~~Testing procedure: CTF Stage 2:~~		
~~Testing location/ address ..... :~~			
~~Tested by (name + signature) ..... :~~			
~~Witnessed by (name, function, signature) ..... :~~			

~~Approved by (name, function, signature).....:~~			
☐	~~Testing procedure: CTF Stage 3:~~		
☐	~~Testing procedure: CTF Stage 4:~~		
~~Testing location/ address .....:~~			
~~Tested by (name, function, signature) .....:~~			
~~Witnessed by (name, function, signature) .....:~~			
~~Approved by (name, function, signature).....:~~			
~~Supervised by (name, function, signature) ....:~~			

Rating label:



PV Inverter	
Model	EA5KTSI
Max.Input Voltage	1000Vd.c.
MPPT Voltage Range	120~950Vd.c.
Max.Input Current	11A/11A
Isc PV	12A/12A
Rated Output Voltage	3/N/PE~230V/400Va.c.
Rated Output Frequency	50/60Hz
Rated Output Current	7.3A
Rated Output Power	5000W
Rated Apparent Power	5000VA
Power Factor Range	0.8 cap.~0.8 ind.
Inverter topology	Non-isolated
Enclosure	IP65
Overvoltage Category	III(AC), II (DC)
Ambient Temperature	-25℃~60℃

EA5KTSI 201908290001 Protection Class I

PV Inverter	
Model	EA6KTSI
Max.Input Voltage	1000Vd.c.
MPPT Voltage Range	120~950Vd.c.
Max.Input Current	11A/11A
Isc PV	12A/12A
Rated Output Voltage	3/N/PE~230V/400Va.c.
Rated Output Frequency	50/60Hz
Rated Output Current	8.7A
Rated Output Power	6000W
Rated Apparent Power	6000VA
Power Factor Range	0.8 cap.~0.8 ind.
Inverter topology	Non-isolated
Enclosure	IP65
Overvoltage Category	III(AC), II (DC)
Ambient Temperature	-25℃~60℃

EA6KTSI 201908290001 Protection Class I

PV Inverter	
Model	EA8KTSI
Max.Input Voltage	1000Vd.c.
MPPT Voltage Range	120~950Vd.c.
Max.Input Current	11A/11A
Isc PV	12A/12A
Rated Output Voltage	3/N/PE~230V/400Va.c.
Rated Output Frequency	50/60Hz
Rated Output Current	11.6A
Rated Output Power	8000W
Rated Apparent Power	8000VA
Power Factor Range	0.8 cap.~0.8 ind.
Inverter topology	Non-isolated
Enclosure	IP65
Overvoltage Category	III(AC), II (DC)
Ambient Temperature	-25℃~60℃

EA8KTSI 201908290001 Protection Class I

PV Inverter	
Model	EA10KTSI
Max.Input Voltage	1000Vd.c.
MPPT Voltage Range	200~950Vd.c.
Max.Input Current	11A/11A
Isc PV	12A/12A
Rated Output Voltage	3/N/PE~230V/400Va.c.
Rated Output Frequency	50/60Hz
Rated Output Current	14.5A
Rated Output Power	10000W
Rated Apparent Power	10000VA
Power Factor Range	0.8 cap.~0.8 ind.
Inverter topology	Non-isolated
Enclosure	IP65
Overvoltage Category	III(AC), II (DC)
Ambient Temperature	-25℃~60℃

EA10KTSI 201908290001 Protection Class I

PV Inverter	
Model	EA13KTSI
Max.Input Voltage	1000Vd.c.
MPPT Voltage Range	200~950Vd.c.
Max.Input Current	22A/11A
Isc PV	24A/12A
Rated Output Voltage	3/N/PE~230V/400Va.c.
Rated Output Frequency	50/60Hz
Rated Output Current	18.9A
Rated Output Power	13000W
Rated Apparent Power	13000VA
Power Factor Range	0.8 cap.~0.8 ind.
Inverter topology	Non-isolated
Enclosure	IP65
Overvoltage Category	III(AC), II (DC)
Ambient Temperature	-25℃~60℃

EA13KTSI 201908290001 Protection Class I

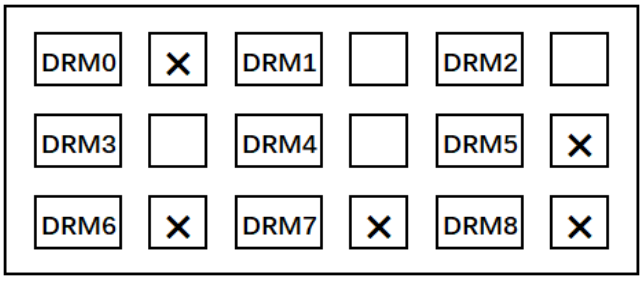
PV Inverter	
Model	EA16KTSI
Max.Input Voltage	1000Vd.c.
MPPT Voltage Range	200~950Vd.c.
Max.Input Current	22A/11A
Isc PV	24A/12A
Rated Output Voltage	3/N/PE~230V/400Va.c.
Rated Output Frequency	50/60Hz
Rated Output Current	23.2A
Rated Output Power	16000W
Rated Apparent Power	16000VA
Power Factor Range	0.8 cap.~0.8 ind.
Inverter topology	Non-isolated
Enclosure	IP65
Overvoltage Category	III(AC), II (DC)
Ambient Temperature	-25℃~60℃

EA16KTSI 201908290001 Protection Class I

Remark:

According to customer's requirement, these models were evaluated under the grid frequency of 50 Hz.

DRM label:



Test item particulars:				
Equipment mobility	movable fixed	hand-held transportable	stationary for building-in	
Connection to the mains	pluggable equipment permanent connection		direct plug-in for building-in	
Enviromental category	outdoor	indoor unconditional	indoor conditional	
Over voltage category Mains	OVC I	OVC II	OVC III	OVC IV
Over voltage category PV	OVC I	OVC II	OVC III	OVC IV
Mains supply tolerance (%)	-90 / +110 %			
Tested for power systems	TN			
IT testing, phase-phase voltage (V)	N/A			
Class of equipment	Class I Not classified	Class II	Class III	
Mass of equipment (kg)	25			
Pollution degree	Outside PD3; Inside PD2			
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	2019-08-04 (samples provided by applicant)			
Date (s) of performance of tests	2019-08-29 to 2019-10-30			

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.

Throughout this report a ☐ comma / ☒ point is used as the decimal separator.

Name and address of factory (ies):

EAST Group Co., Ltd.

No.6 Northern Industry Road, Songshan Lake Sci. & Tech. Industrial Park, Dongguan City, Guangdong Province, China

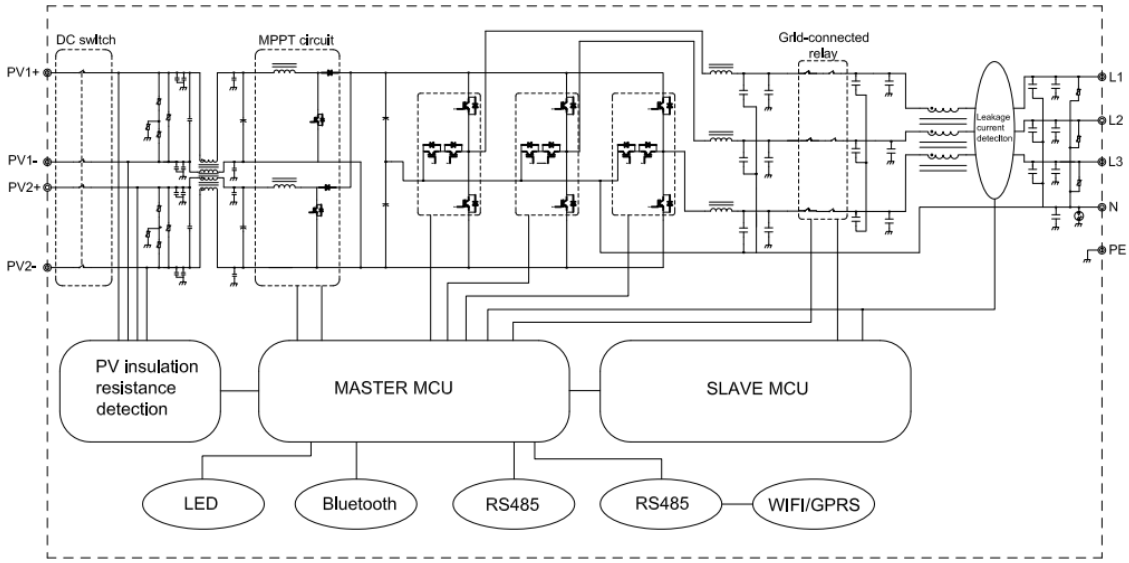
General product information:

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:

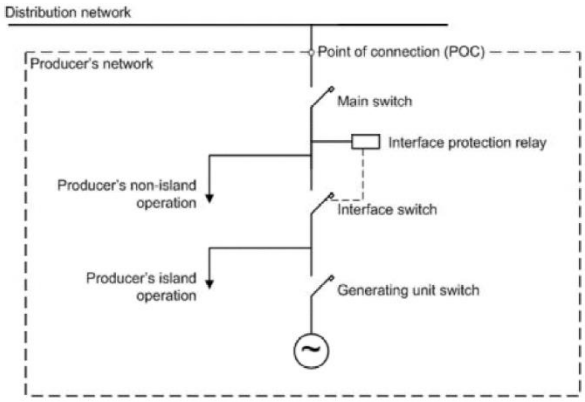
Hardware version: 00C

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.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
4	**Technical requirements**		P
4.1	General		P
	This clause defines the requirements on generating plants to be operated in parallel with the distribution network. Where settings or a range of configurability is provided and respecting the legal framework the configurations and settings may be provided by the DSO. Where no settings are provided by the DSO, the specified default settings shall be used; if no default settings are provided, the producer shall propose settings and inform the DSO.		P
	The requirements of Clause 4 apply during normal operation of the generating units and do not apply in case of maintenance or units out of operation. The provisions apply to EESS in generation mode. In charging mode EESS should have the same characteristics, unless stated otherwise in the clauses of this European Standard.	The generating units are grid-connected PV inverter and not EESS.	P
	The applicability is independent of the duration the generating unit operates in parallel with the distribution network. It is the responsibility of the DSO to relax, if deemed appropriate, the requirements for an individual generating unit or plant whose operation in parallel only lasts for a short time (temporary operation in parallel). The relaxed requirements shall be agreed between the DSO and the producer, along with the maximum allowable duration of the temporary operation in parallel.		P
	If different requirements on the generating plant interfere with each other, the following hierarchy in descending order shall be applied:		P
	1. Generating unit protection, including regarding the prime mover; 2. interface protection (see 4.9) and protection against faults within the generating plant; 3. voltage support during faults and voltage steps (see 4.7.4); 4. the lower value of: remote control command on active power limitation for distribution grid security (see 4.11) and local response to overfrequency (see 4.6.1); 5. local response to underfrequency if applicable (see 4.6.2); 6. reactive power (see 4.7.2) and active power (P(U) see 4.7.2) controls; 7. other control commands on active power set point for e.g. market, economic reasons, selfconsumption optimization.		P

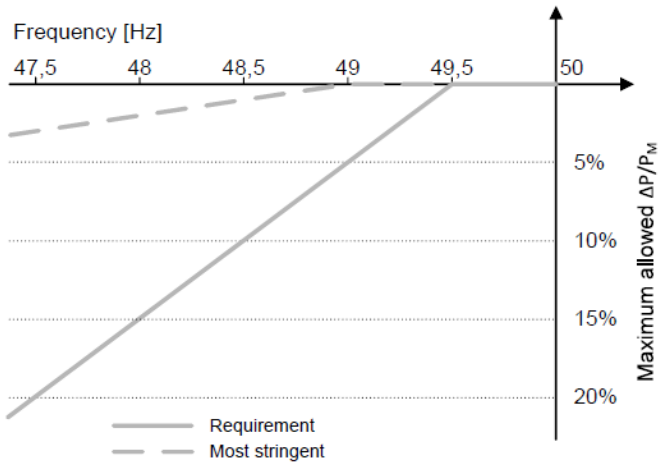
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	The system shall be so designed that under foreseeable conditions no self-protection trips prior to the fulfilment of the requirements of this European Standard and all settings provided by the DSO or responsible party.		P
	For cogeneration plants embedded in industrial sites, active power requirements shall be agreed between the responsible party and the producer. In such a case the priority list is adapted accordingly.		P
	Besides the requirements of Clause 4, additional requirements apply for connecting a generating plant to the distribution network, e.g. assessment of the point of connection. However, this is excluded from the scope of this European Standard but some guidance is provided in the informative Annex A.		P
4.2	Connection scheme		Info.
	The connection scheme of the generating plant shall be in compliance with the requirements of the DSO. Different requirements may be subject to agreement between the producer and the DSO depending on the power system needs.	It's depended on installer.	Info.
	Inter alia, the generating plant shall ensure the following:		Info.
	• synchronization, operation and disconnection under normal network operating conditions, i.e. in the absence of faults or malfunctions; • faults and malfunctions within the generating plant shall not impair the normal functioning of the distribution network; • coordinated operation of the interface switch with the generating unit switch, the main switch and switches in the distribution network, for faults or malfunctions within the generating plant or the DSO network during operation in parallel with the distribution network; and • disconnection of the generating plant from the distribution network by tripping the interface switch according to 4.9.		Info.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	In order to satisfy the above functions, coordinated but independent switches and protection equipment may be applied in the generating plant, as shown in the example in Figure 2.  Figure 2 — Example of an generating plant connected to a distribution network (schematic view of switches)	It's depended on installer.	Info.
4.3	Choice of switchgear		P
4.3.1	General		P
	Switches shall be chosen based on the characteristics of the power system in which they are intended to be installed. For this purpose, the short circuit current at the installation point shall be assessed, taking into account, inter alia, the short circuit current contribution of the generating plant.		P
4.3.2	Interface switch		P
	Switches shall be power relays, contactors or mechanical circuit breakers each having a breaking and making capacity corresponding to the rated current of the generating plant and corresponding to the short circuit contribution of the generating plant.	Two power relays in series installed each phase on the mains side of the unit to separate it from the grid.	P
	The short-time withstand current of the switching devices shall be coordinated with rated short circuit power at the point of connection.		P
	In case of loss of auxiliary supply power to the switchgear, a secure disconnection of the switch is required immediately.		P
	Where means of isolation (according to HD 60364-5-551) is not required to be accessible to the DSO at all times, automatic disconnection with single fault tolerance according to 4.13 shall be provided.		P
	NOTE 1 For PV-inverters, further requirements are stated in EN 62109–1 and EN 62109–2 with respect to the interface switch.	See separate IEC/EN 62109-1 and IEC/EN 62109-2 test report no. 6052106.50(A-B) issue by DEKRA for reference.	P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	The function of the interface switch might be combined with either the main switch or the generating unit switch in a single switching device. In case of a combination, the single switching device shall be compliant to the requirements of both, the interface switch and the combined main switch or generating unit switch. As a consequence, at least two switches in series shall be present between any generating unit and the POC.		P
	NOTE 2 This does not refer to the number of series-connected switches in order to ensure single fault tolerance as required in 4.13 but to the number of different switching devices itself.		P
4.4	Normal operating range		P
4.4.1	General		P
	Generating plants when generating power shall have the capability to operate in the operating ranges specified below regardless of the topology and the settings of the interface protection.		P
4.4.2	Operating frequency range		P
	The generating plant shall be capable of operating continuously when the frequency at the point of connection stays within the range of 49 Hz to 51 Hz. In the frequency range from 47 Hz to 52 Hz the generating plant should be capable of operating until the interface protection trips. Therefore, the generating plant shall at least be capable of operating in the frequency ranges, for the duration and for the minimum requirement as indicated in Table 1. **Table 1 — Minimum time periods for operation in underfrequency and overfrequency situations**	(See appended table)	P
	This permission does not affect the requirements for interface protection according to clause 4.9. In this case over and under frequency machine protection might trip prior to interface protection. If an integrated interface protection device is used, the reduction of the configuration range of the interface protection in clause 4.9 is acceptable.		P
4.4.3	Minimal requirement for active power delivery at underfrequency		P

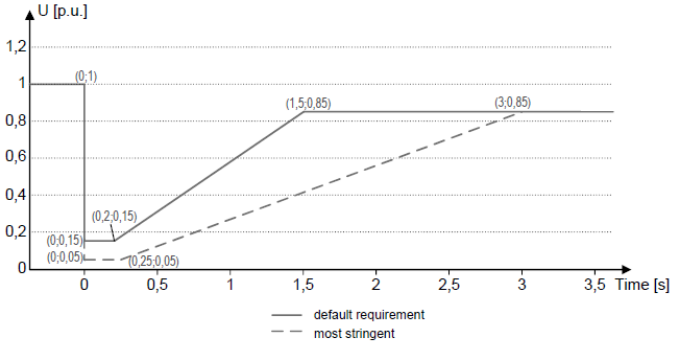
Frequency Range	Time period for operation Minimum requirement	Time period for operation stringent requirement
47,0 Hz – 47,5 Hz	not required	20 s
47,5 Hz – 48,5 Hz	30 min [a]	90 min
48,5 Hz – 49,0 Hz	30 min [a]	90 min [a]
49,0 Hz – 51,0 Hz	Unlimited	Unlimited
51,0 Hz – 51,5 Hz	30 min [a]	90 min
51,5 Hz – 52,0 Hz	not required	15 min

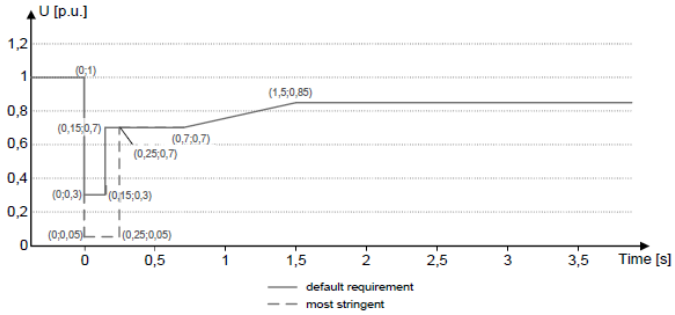
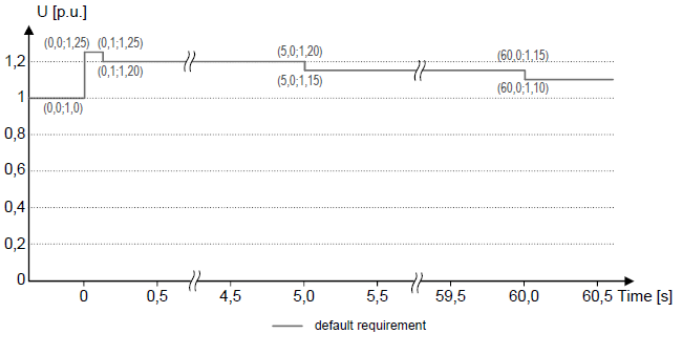
[a] Respecting the legal framework, it is possible that longer time periods are required by the responsible party in some synchronous areas.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	A generating plant shall be resilient to the reduction of frequency at the point of connection while reducing the maximum active power as little as possible. The admissible active power reduction due to underfrequency is limited by the full line in Figure 5 and is characterized by a maximum allowed reduction rate of 10 % of P_{max} per 1 Hz for frequencies below 49,5 Hz.  **Figure 5 — Maximum allowable power reduction in case of underfrequency**	(See appended table)	P
	It is possible that a more stringent power reduction characteristic is required by the responsible party. Nevertheless this requirement is expected to be limited to an admissible active power reduction represented by the dotted line in Figure 5 which is characterised by a reduction rate of 2 % of the maximum power P_{max} per 1 Hz for frequencies below 49 Hz.		P
	If any technologies intrinsic design or ambient conditions have influence on the power reduction behaviour of the system, the manufacturer shall specify at which ambient conditions the requirements can be fulfilled and eventual limitations. The information can be provided in the format of a graph showing the intrinsic behaviour of the generating unit for example at different ambient conditions. The power reduction and the ambient conditions shall comply with the specification given by the responsible party. If the generating unit does not meet the power reduction at the specified ambient conditions, the producer and the responsible party shall agree on acceptable ambient conditions.		P
4.4.4	Continuous operating voltage range		P
	When generating power, the generating plant shall be capable of operating continuously when the voltage at the point of connection stays within the range of 85 % U_n to 110 % U_n. Beyond these values the under and over voltage ride through immunity limits as specified in clause 4.5.3 and 4.5.4 shall apply.	(see appended table)	P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	In case of voltages below U_n, it is allowed to reduce the apparent power to maintain the current limits of the generating plant. The reduction shall be as small as technically feasible.		P
	For this requirement all phase to phase voltages and in case a neutral is connected, additionally all phase to neutral voltages shall be evaluated.		P
	The producer shall take into account the typical voltage rise and voltage drop within the generating plant.		Info.
4.5	Immunity to disturbances		P
4.5.1	In general, generating plants should contribute to overall power system stability by providing immunity towards dynamic voltage changes unless safety standards require a disconnection.		P
	The following clauses describe the required immunity for generating plants taking into account the connection technology of the generating modules.		P
	The following withstand capabilities shall be provided regardless of the settings of the interface protection.		P
4.5.2	Rate of change of frequency (ROCOF) immunity	(see appended table)	P
	ROCOF immunity of a power generating plant means that the generating modules in this plant stay connected with the distribution network and are able to operate when the frequency on the distribution network changes with a specified ROCOF. The generating units and all elements in the generating plant that might cause their disconnection or impact their behaviour shall have this same level of immunity.		P
	The generating modules in a generating plant shall have ROCOF immunity for a ROCOF equal or exceeding the value specified by the responsible party. If no ROCOF immunity value is specified, the following ROCOF immunity shall apply, making distinction between generating technologies:		P
	Non-synchronous generating technology: at least 2 Hz/s		P
	Synchronous generating technology: at least 1 Hz/s		P
	The ROCOF immunity is defined with a sliding measurement window of 500 ms.		P
	NOTE 1 For control action based on frequency measurement shorter measurement periods are expected to be necessary.		P
	NOTE 2 For small isolated distribution networks (typically on islands) higher ROCOF immunity values may be required.		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 3 ROCOF is used as a means to detect loss of mains situations in some countries. The ROCOF immunity requirement is independent of the interface protection settings. Disconnection settings of the interface protection relay always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings.		P
4.5.3	Under-voltage ride through (UVRT)		P
	Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.5.3.2 and 4.5.3.3.	Type A Generating modules.	N/A
	Generating modules classified as type A and smaller according to COMMISSION REGULATION 2016/631 should comply with these requirements.		P
	The actual behaviour of type A modules and smaller shall be specified in the connection agreement.		P
	NOTE 1 Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of under voltage.		P
	NOTE 2 A more distinctive differentiation for 1ph, 2ph and 3ph faults is under consideration.		Info.
	NOTE 3 These requirements are independent of the interface protection settings. Disconnection settings of the interface protection relay will always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings.		P
	NOTE 4 The FRT curves in Figure 6, Figure 7 and Figure 8 describe the minimum requirements for continued connection of the generating plant to the grid. They are not designed for parameterising the interface protection.		P
4.5.3.2	Generating plant with non-synchronous generating technology		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Generating modules shall be capable of remaining connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 6. The voltage is relative to U_n. The smallest phase to neutral voltage, or if no neutral is present, the smallest phase to phase voltage shall be evaluated.  **Figure 6 — Under-voltage ride through capability for non-synchronous generating technology**	(see appended table)	P
	The responsible party may define a different UVRT characteristic. Nevertheless, this requirement is expected to be limited to the most stringent curve as indicated in Figure 6.		P
	This means that the whole generating module has to comply with the UVRT requirement. This includes all elements in a generating plant: the generating units and all elements that might cause their disconnection.		P
	For the generating unit, this requirement is considered to be fulfilled if it stays connected to the distribution grid as long as the voltage at its terminals remains above the defined voltage-time diagram.		P
	After the voltage returns to continuous operating voltage range, 90 % of pre-fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 1 s unless the DSO and the responsible party requires another value.		P
4.5.3.3	Generating plant with synchronous generating technology		N/A

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Generating modules shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains above the voltage-time curve of Figure 7. The voltage is relative to Un. The smallest phase to neutral voltage or if no neutral is present the smallest phase to phase voltage shall be evaluated.  **Figure 7 — Under-voltage ride through capability for synchronous generating technology**		N/A
4.5.4	Over-voltage ride through (OVRT)		P
	Generating modules, except for micro-generating plants, shall be capable of staying connected to the distribution network as long as the voltage at the point of connection remains below the voltage-time curve of Figure 8.  **Figure 8 — Over-voltage ride through capability**	(see appended table)	P
	The highest phase to neutral voltage or if no neutral is present the highest phase to phase voltage shall be evaluated.		P
	This means that not only the generating units shall comply with this OVRT requirement but also all elements in a generating plant that might cause its disconnection.		P
	NOTE 1 Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of over voltage.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 2 These requirements are independent of the interface protection settings. Disconnection settings of the interface protection relay will always overrule technical capabilities. So, whether the generating plant will stay connected or not will also depend upon those settings.		P
	NOTE 3 This is a minimum requirement. Further power system stability aspects might be relevant. The technical discussion is still ongoing. A voltage jump of +10% of Un from any stable point of operation is considered. In case of steady state voltages near the maximum voltage before the event, this will result in an over voltage situation for many seconds. In later editions of this document, more stringent immunity might be required.		P
4.6	Active response to frequency deviation		P
4.6.1	Power response to over-frequency		P
	Generating plants shall be capable of activating active power response to over-frequency at a programmable frequency threshold f1 at least between and including 50,2 Hz and 52 Hz with a programmable droop in a range of at least s=2 % to s=12 %. The droop reference is P ref. Unless defined differently by the responsible party	The default droop is s=5%.	P
	• $P_{ref} = P_{max}$, in the case of synchronous generating technology and electrical energy storage systems	The PV inverter were not belong to synchronous generating technology and electrical energy storage systems	N/A
	• $P_{ref} = P_M$, the actual AC output power at the instant when the frequency reaches the threshold f_1, in the case of all other non-synchronous generating technology		P
	The power value calculated according to the droop is a maximum power limit. If e.g. the available primary power decreases during a high frequency period below the power defined by the droop function, lower power values are permitted.		P
	The maximum power limit is: $P_{max-limit} = P_M + \Delta P$ with $\Delta P = \frac{1}{s} \cdot \frac{(f_1 - f)}{f_n} \cdot P_{ref}$ with f the actual frequency		P
	NOTE 1 In other documents power response to overfrequency can also be described as frequency control or Limited Frequency Sensitive Mode - Overfrequency (LFSM-O).		Info.

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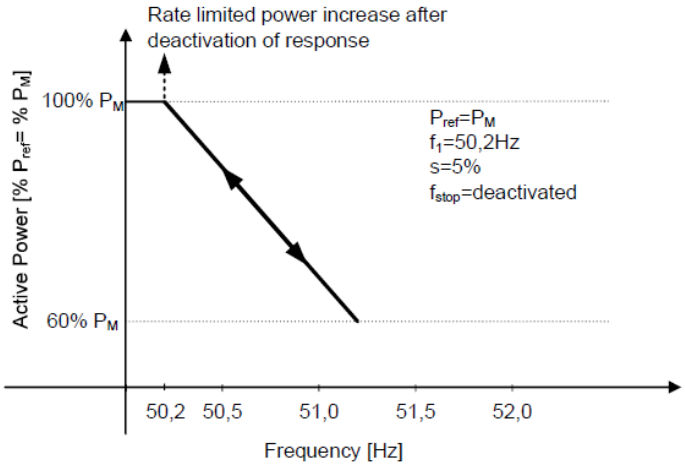
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 2 The active power droop relative to the reference power might also be defined as an active power gradient relative to the reference power. A droop in the range of 2 % to 12 % represents a gradient of 100 % to 16,7 % P_{ref} /Hz so with g defined by $g\left[\frac{P}{P_{ref}} / Hz\right] = \frac{1}{s \cdot f_n}$ we get $\Delta P = g \cdot P_{ref} \cdot (f_1 - f)$.	s=5% represents a gradient of 40% P_{ref} /Hz.	P
	The generating plant shall be capable of activating active power response to over-frequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s, unless another value is defined by the relevant party. An intentional delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.		P
	NOTE 3 The following response times are considered feasible, for PV and battery inverter below 1 s for P of 100% ∆ P_{max} and for wind turbines 2 s for ∆ P< 50%P_{max}		P
	After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power (see Figure 9). The resolution of the frequency measurement shall be ± 10 mHz or less. The accuracy is evaluated with a 1 min average value. At POC, loads if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.  **Figure 9 — Example of Active power frequency response to overfrequency**	(see appended table)	P
	NOTE 4 With the provision above, the intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.		P

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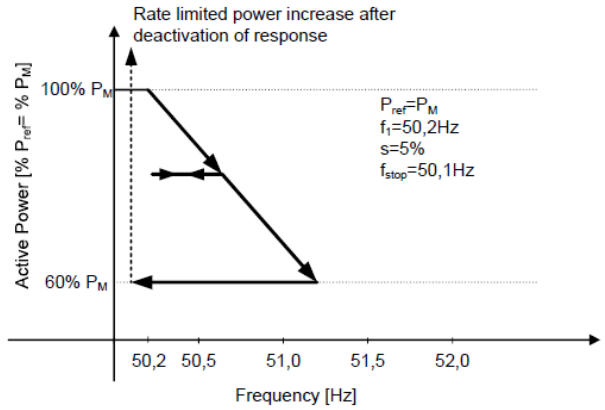
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 5 The option of an intentional delay is required since a very fast and undelayed active power frequency response in case of loss of mains would correct any excess of generation leading to a generation-consumption balance. In these circumstances, an unintended islanding situation with stable frequency would take place, in which the correct behaviour of any loss of mains detection based on frequency might be hindered.		P
	NOTE 6 The intentional delay is considered relevant for power system stability. For that reason, legal regulations might require a mutual agreement on the setting between DSO, responsible party and TSO.		P
	Generating plants reaching their minimum regulating level shall, in the event of further frequency increase, maintain this power level constant unless the DSO and the responsible party requires to disconnect the complete plant or if the plant consists of multiple units by disconnecting individual units.		P
	The active power frequency response is only deactivated if the frequency falls below the frequency threshold f_1.		P
	If required by the DSO and the responsible party an additional deactivation threshold frequency f_{stop} shall be programmable in the range of at least 50 Hz to f_1. If f_{stop} is configured to a frequency below f1 there shall be no response according to the droop in case of a frequency decrease (see Figure 10). The output power is kept constant until the frequency falls below f_{stop} for a configurable time t_{stop}.  Figure 10 — Example of active power frequency response to overfrequency with configured deactivation threshold	(see appended table)	P
	If at the time of deactivation of the active power frequency response the momentary active power PM is below the available active power PA, the active power increase of the generating plant shall not exceed the gradient defined in 4.10.2.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Settings for the threshold frequency f_1, the droop and the intentional delay are provided by the DSO and the responsible party. If no settings are provided, the default settings in Table 2 should be applied.		P
	NOTE 7 When applying active power response to overfrequency, the frequency threshold f_1 should be set to a value from 50,2 Hz up to 50,5 Hz. Setting the frequency threshold f_1 to 52 Hz is considered as deactivating this function.		P
	The enabling and disabling of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party.		P
	NOTE 8 PV generating units are considered to have the ability to reduce power over the full droop range.		P
	NOTE 9 Protection setting overrules this behaviour.		P
	Alternatively for the droop function described above, the following procedure is allowed for generating modules if permitted by the DSO and the responsible party:		P
	• the generating units shall disconnect at randomized frequencies, ideally uniformly distributed between the frequency threshold f_1 and 52 Hz;		P
	NOTE 10 The usage of a disconnection limit above 51,5Hz does not necessarily imply the requirement to operate at this frequency. Operating range is defined in clause 4.4.4. If the randomized disconnection value is above the operating range and interface protection setting, the unit is disconnected according to chapter 4.9 at the value set by the interface protection.		P
	• in case the frequency decreases again, the generating unit shall start its reconnection procedure once the frequency falls below the specific frequency that initiated the disconnection; for this procedure, the connection conditions described in 4.10 do not apply;		P
	• the randomization shall either be at unit level by changing the threshold over time, or on plant level by choosing different values for each unit within a plant, or on distribution system level if the DSO specifies a specific threshold for each plant or unit connected to its distribution system.		P

Table 2 — Standard settings for frequency response to overfrequency

Parameter	Range	Default setting
Threshold frequency f_1	50,2 Hz to 52 Hz	50,2 Hz
Deactivation threshold f_{stop}	50,0 Hz to f_1	Deactivated
Deactivation time t_{stop}	0 to 600 s	30s
Droop	2 % to 12 %	5 %
Intentional delay	0 s to 2 s	0 s

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Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 11 This procedure could be applied for generating modules for which it is technically not feasible to reduce power with the required accuracy in the required time or for reasons within the distribution network for example to prevent unintentional island operation.		P
	NOTE 12 The behaviour will, for a part of the network with many such units, result in a similar droop as specified above for controllable generating units and hence will provide for the necessary power system stability. Due to its fast reaction capability it contributes significantly to the avoidance of a frequency overshoot.		P
	EES units that are in charging mode at the time the frequency passes the threshold f1 shall not reduce the charging power below PM until frequency returns below f_1. Storage units should increase the charging power according to the configured droop. In case the maximum charging capacity is reached or to prevent any other risk of injury or damage of equipment, a reduction of charging power is permitted.		N/A
4.6.2	Power response to underfrequency		P
	EES units shall be capable of activating active power response to underfrequency. Other generating units/plants should be capable of activating active power response to underfrequency. If active power to underfrequency is provided by a generating plant/unit, the function shall comply with the requirements below.		P
	NOTE 1: In other documents power response to underfrequency is also described as frequency control or Limited Frequency Sensitive Mode - Underfrequency (LFSM-U).		P
	Active power response to under-frequency shall be provided when all of the following conditions are met:		P
	• when generating, the generating unit is operating at active power below its maximum active power P_{max};		P
	• when generating, the generating unit is operating at active power below the available active power P_A;		P
	NOTE 2 In case of EES units, the available power includes the state of charge of the storage.	Not EES unit.	N/A
	• the voltages at the point of connection of the generating plant are within the continuous operating voltage range; and		P
	• when generating, the generating unit is operating with currents lower than its current limit.		P
	NOTE 3 These conditions apply to each generating unit individually since the specified conditions need to be met by each generating unit individually to allow the unit to increase power.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	In the case of EES units, active power frequency response to under-frequency shall be provided in charging and generating mode.	Not EES unit.	N/A
	NOTE 4 In the case of EES units, the charging is regarded as a point of operation with negative active power. In charging mode the active power consumption is reduced according to the configured droop. Depending on the depth of the under-ferquency event a change to generating mode will happen. In this case the state of charge of the storage is part of the conditions above.	Not EES unit.	N/A
	NOTE 5 This clause provides additional detail to the network code on emergency and restoration (Regulation (EU) 2017/2196) and more precisely on its Article 15.3 (a).		P
	The active power response to underfrequency shall be delivered at a programmable frequency threshold f1 at least between and including 49,8 Hz and 46,0 Hz with a programmable droop in a range of at least 2 % to 12 %. The droop reference Pref is Pmax. If the available primary power or a local set value increases during an underfrequency period above the power defined by the droop function, higher power values are permitted. The power value calculated according to the droop is therefore a minimum limit. The minimum power limit is, $P_{min-limit} = P_M + \Delta P$ with $\Delta P = \frac{1}{s} \times \frac{(f1 - f)}{fn} \times Pref$ with f the actual frequency		P
	NOTE 6 In the case of active power response to underfrequency, P_{max} is used as P ref to allow for system support even in case of low power output in the moment the event begins.		P
	NOTE 7 The active power droop relative to the reference power might also be defined as an active power gradient relative to the reference power. A droop in the range of 2 % to 12 % represents a gradient of 100 % to 16,7 % P_{ref} /Hz so with g defined by $g\left[\frac{P}{P_{ref}} / Hz\right] = \frac{1}{s \cdot f_n}$ we get $\Delta P = g \cdot P_{ref} \cdot (f_1 - f)$.		P
	NOTE 8 In the case of an increase of active power generation, the hierarchy of requirements in clause 4.1 apply.		P

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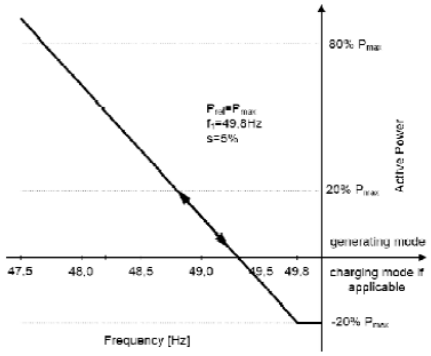
Clause	Requirement - Test	Result - Remark	Verdict
	The generating unit shall be capable of activating active power response to underfrequency as fast as technically feasible with an intrinsic dead time that shall be as short as possible with a maximum of 2 s and with a step response time of maximum 30 s unless another value is defined by the relevant party.		P
	An intentional initial delay shall be programmable to adjust the dead time to a value between the intrinsic dead time and 2 s.  Figure 11 — Example of active power frequency response to underfrequency in case of storage device with 20 % power charging at passing of threshold frequency f_1		P
	After activation, the active power frequency response shall use the actual frequency at any time, reacting to any frequency increase or decrease according to the programmed droop with an accuracy of ± 10 % of the nominal power. The accuracy is evaluated with a 1 min average value. The resolution of the frequency measurement shall be ± 10 mHz or less. At POC loads, if present in the producer's network, might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.		P
	NOTE 9 With the provision above, the intentional delay is only active for the activation of the function, once the function is operating, the established control loop is not intentionally delayed.		P
	NOTE 10 The option of an intentional delay is required since a very fast and undelayed active power frequency response in case of loss of mains would correct any shortage of generation leading to a generation-consumption balance. In these circumstances, an unintended islanding situation with stable frequency would take place, in which the correct behaviour of any loss of mains detection based on frequency might be hindered.		P
	NOTE 11 The intentional delay is considered relevant for power system stability. For that reason, legal regulations might require a mutual agreement on the setting between DSO, responsible party and TSO.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Generating modules reaching any of the conditions above during the provision of active power frequency response shall, in the event of further frequency decrease, maintain this power level constant.		P
	The active power frequency response is only deactivated if the frequency increases above the frequency threshold f_1.		P
	Settings for the threshold frequency f1, the droop and the intentional delay are defined by the DSO and the responsible party, if no settings are provided, the function shall be disabled.		P
	NOTE 12 When applying active power response to underfrequency, the frequency threshold f1 should be set to a value from 49,8 Hz up to 49,5 Hz. Setting the frequency threshold f_1 to 46 Hz is considered as deactivating this function.		P
	The activation and deactivation of the function and its settings shall be field adjustable and means shall be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO and the responsible party.		P
4.7	Power response to voltage changes		P
4.7.1	General		P
	When the contribution to voltage support is required by the DSO and the responsible party, the generating plant shall be designed to have the capability of managing reactive and/or active power generation according to the requirements of this clause.		P
4.7.2	Voltage support by reactive power		P
4.7.2.1	General		P
	Generating plants shall not lead to voltage changes out of acceptable limits. These limits should be defined by national regulation. Generating units and plants shall be able to contribute to meet this requirement during normal network operation.		P
	Throughout the continuous operating frequency (see 4.4.2) and voltage (see 4.4.4) range, the generating plant shall be capable to deliver the requirements stipulated below. Outside these ranges, the generating plant shall follow the requirements as good as technically feasible although there is no specified accuracy required.		P
4.7.2.2	Capabilities		P

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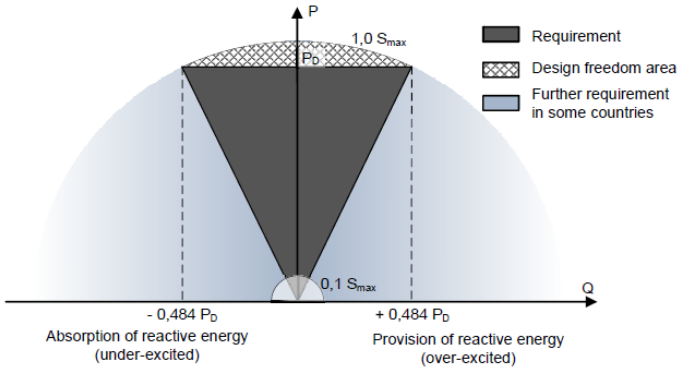
Clause	Requirement - Test	Result - Remark	Verdict
	 **Figure 12 — Reactive power capability at nominal voltage**	(see appended table)	P
	Figure 12 gives a graphical representation of the minimum and optional capabilities at nominal voltage.		P
	Unless specified differently below, for specific generating technologies, generating plants shall be able to operate with active factors as defined by the DSO and the responsible party from active factor = $0{,}90_{underexcited}$ to active factor= $0{,}90_{overexcited}$.		P
	The reactive power capability shall be evaluated at the terminals of the/each generating unit.		P
	CHP generating units with a capacity <150KVA shall be able to operate with active factors as defined by DSO from cos φ = $0{,}95_{underexcited}$ to cos φ = $0{,}95_{underexcited}$ to cos φ = $0{,}95_{overexcited}$	Not CHP generating units.	N/A
	Generating units with an induction generator coupled directly to the grid and used in generating plants above micro generating level, shall be able to operate with active factors as defined by the DSO from cos φ = $0{,}95_{underexcited}$ to cos = 1 at the terminals of the unit. Deviating from 4.7.2.3 point mode is required. Deviating from the accuracy requirements below, the accuracy is only required at active power P_D.	Not induction generator.	N/A
	Generating units with an induction generator coupled directly to the grid and used in micro generating plants shall operate with an active factor above 0,95 at the terminals of the generating unit. A controlled voltage support by reactive power is not required from this technology.	Not induction generator.	N/A
	Generating units with linear generators, coupled directly and synchronously to the grid shall operate with an active factor above 0,95 at the terminals of the generating unit, and therefore a controlled voltage support by reactive power is not required from this technology.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	In case of different generating technologies with different requirements in one generating plant, each unit shall provide voltage support by reactive power as required for its specific technology. A compensation of one technology to reach the general plant requirement is not expected.	The PV inverter under test provides voltage support by reactive power, for other generating technologies in one generating plant, it's depended on installer and plant owner.	Info.
	The DSO and the responsible party may relax the above requirements. This relaxation might be general or specific for a certain generating plant or generating technology.		P
	NOTE 1 The generating unit manufacturer has a certain freedom in the sizing of the output side of the generating unit considering the advantages and drawbacks in the practical use of the generating unit when evaluating the need to reduce active output power (e.g. due to voltage changes or reactive power exchange) in order to respond to the requirements of this European Standard. This is indicated by the Design freedom area in Figure 12.		P
	All involved parties can expect to have access to information documenting the actual choices regarding active power capabilities relative to reactive power requirements and related to the power rating in the operating voltage range (see further in this clause). A P-Q Diagram shall be included in the product documentation of a generating unit.		P
	NOTE 2 For additional network support an optional extended reactive power capability according to Figure 12 might be provided by the generating plant, if agreed on between the DSO and the producer and is generally required in some countries for some technologies by legal regulations.		P
	NOTE 3 Additional requirements (e.g. continuous Var compensation or continuous reactive power operation disregarding the availability of the primary energy) might be provided by the generating plant, if agreed between the DSO and the producer.		P
	NOTE 4 In case of overvoltage, additional reactive power might be exchanged up to the rated current (increasing the apparent power as a consequence), if agreed on between the DSO and the producer.		P

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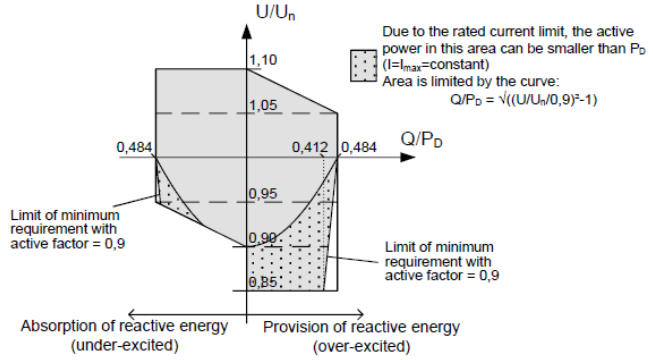
Clause	Requirement - Test	Result - Remark	Verdict
	When operating above the apparent power threshold S_{min} equal to 10 % of the maximum apparent power S_{max} or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % S_{max}. Up to this apparent power threshold S_{min}, deviations above 2 % are permissible; nevertheless the accuracy shall always be as good as technically feasible and the exchange of uncontrolled reactive power in this low-power operation mode shall not exceed 10 % of the maximum apparent power S_{max}. At POC loads, if present in the producer's network might interfere with the response of the generating plant. The effect of loads is not considered for the evaluation of the accuracy, only the behaviour of the generating plant is relevant.		P
	For generating units with a reactive power capability according Figure 12 the reactive power capability at active power P_D shall be at least according Figure 13. For generating units with a reduced reactive power capability Figure 13 is only applicable up to the maximum reactive power capability.  **Figure 13 — Reactive power capability at active power P_D in the voltage range (positive sequence component of the fundamental)**		P
	NOTE 5 Depending on the P-Q characteristic of the generating plant/unit, the reactive power at active powers below P_D might be lower respecting the requirements above. If no or less than 0,484 Q/P_D reactive power is required, the active power might increase above P_D as indicated in Figure 12		P
	For voltages below Un it is allowed to reduce apparent power according to 4.4.4		P
	NOTE 6 Whether there is a priority given to P or Q or the active factor when reaching the maximum apparent power this is not defined in this European Standard. Risks and benefits of different priority approaches are under consideration.		P
4.7.2.3	Control modes		P
4.7.2.3.1	General		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The control shall refer to the terminals of the generating units The generating plant/unit shall be capable of operating in the control modes specified below within the limits specified in 4.7.2.2. The control modes are exclusive; only one mode may be active at a time.		P
	• Q setpoint mode	(see appended table)	P
	• Q (U)	(see appended table)	P
	• Cos setpoint mode	(see appended table)	P
	• Cos (P)	(see appended table)	P
	For mass market products, it is recommended to implement all control modes. In case of site specific generating plant design, only the control modes required by the DSO need to be implemented.		P
	The configuration, activation and deactivation of the control modes shall be field adjustable. For field adjustable configurations and activation of the active control mode, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO. Which control modes are available in a product and how they are configured shall be stated in the product documentation.		P
4.7.2.3.2	Setpoint control modes	(see appended table)	P
	Q setpoint mode and cos φ setpoint mode control the reactive power output and the cos φ of the output respectively, according to a set point set in the control of the generating plant/unit. In the case of change of the set point local or by remote control the settling time for the new set point shall be less than one minute.		P
4.7.2.3.3	Voltage related control mode	(see appended table)	P
	It is the responsibility of the generating plant designer to choose a method. One of the following methods should be used:		P
	• the positive sequence component of the fundamental;		P
	• the average of the voltages measured independently for each phase to neutral or phase to phase;		P
	• phase independently the voltage of every phase to determine the reactive power for every phase.		P

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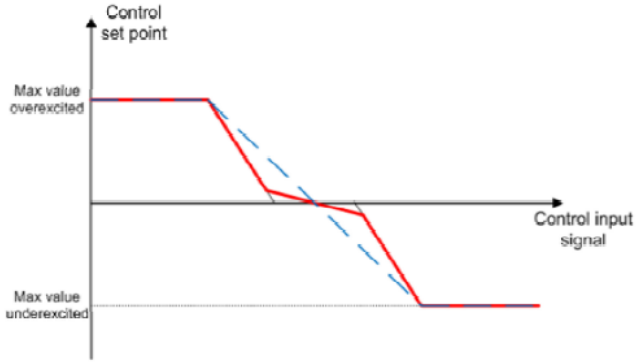
Clause	Requirement - Test	Result - Remark	Verdict
	For voltage related control modes, a characteristic with a minimum and maximum value and three connected lines according to Figure 16 shall be configurable.  **Figure 16 — Example characteristics for Q respectively cos φ control mode**		P
	In addition to the characteristic, further parameters shall be configurable:		P
	• The dynamics of the control shall correspond with a first order filter having a time constant that is configurable in the range of 3 s to 60 s		P
	NOTE 1 The time to perform 95 % of the changed set point due to a change in voltage will be 3 times the time constant.		P
	NOTE 2 The dynamic response of the generating units to voltage changes is not considered here. The response to disturbances as in 4.5 and short circuit current requirements as in 4.7.4 is not included in this clause.		P
	NOTE 3 An intentional delay is under consideration.		P
	To limit the reactive power at low active power two methods shall be configurable:		P
	• a minimal cos shall be configurable in the range of 0-0.95;		P

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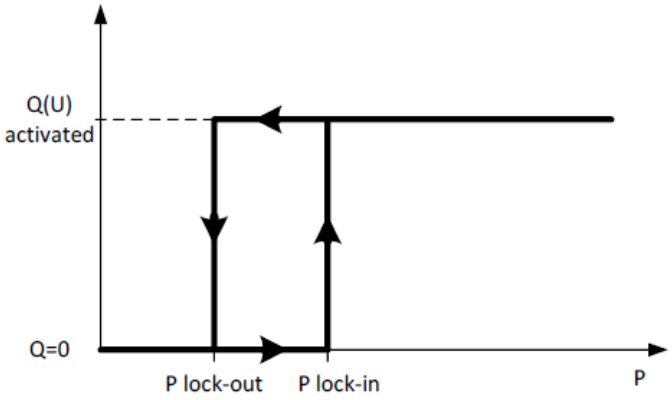
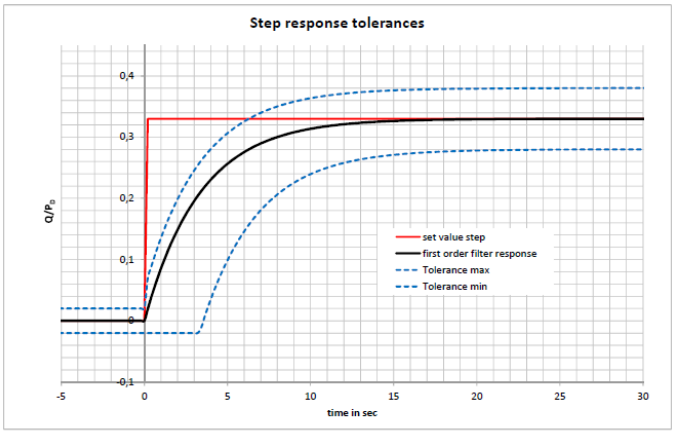
Clause	Requirement - Test	Result - Remark	Verdict
	• two active power levels shall be configurable both at least in the range of 0 % to 100 % of P_D. The lock-in value turns the Q(U) mode on, the lock-out value turns Q(U) off. If lock-in is larger than lock-out a hysteresis is given. See also Figure 14.  **Figure 14 – Example of lock-in and lock-out values for Q(U) mode**		P
	The static accuracy shall be in accordance with 4.7.2.2. The dynamic accuracy shall be in accordance with Figure 15 - 5% of PD plus a time delay of up to 3 seconds deviating from an ideal first order filter response.  **Figure 15 — Example of dynamic control response and tolerance band for a step from Q=0 to Q= 33%P_D with τ=3,33s**		P
4.7.2.3.4	Power related control mode	(see appended table)	P
	The power related control mode cos φ (P) controls the output as a function of the active power output.		P
	For power related control modes, a characteristic with a minimum and maximum value and three connected lines shall be configurable in accordance with Figure 16.		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Resulting from a change in active power output a new cos φ set point is defined according to the set characteristic .The response to a new cos φ set value shall be as fast as technically feasible to allow the change in reactive power, The new reactive power set value shall be reached at the latest within 10 s after the end value of the active power is reached, the static accuracy of each cos set point shall be according to 4.7.2.2		P
4.7.3	Voltage related active power reduction		P
	In order to avoid disconnection due to overvoltage protection (see 4.9.3.3 and 4.9.3.4), generating plants/units are allowed to reduce active power output as a function of this rising voltage. The final implemented logic can be chosen by the manufacturer. Nevertheless, this logic shall not cause steps or oscillations in the output power. The power reduction caused by such a function may not be faster than an equivalent of a time constant tau = 3 s (= 33%/s at a 100% change). The enabling and disabling of the function shall be field adjustable and means have to be provided to protect the setting from unpermitted interference (e.g. password or seal) if required by the DSO.	(see appended table)	P
4.7.4	Short circuit current requirements on generating plants		P
4.7.4.1	General		P
	The following clauses describe the required short circuit current contribution for generating plants taking into account the connection technology of the generating modules.		P
	Generating modules classified as type B modules according to COMMISSION REGULATION 2016/631 shall comply with the requirements of 4.7.4.2 and 4.7.4.3.	Type A generating modules.	N/A
	Generating modules classified as type A according to COMMISSION REGULATION 2016/631 should comply with these requirements. The actual behaviour of type A modules shall be specified in the connection agreement.		P
	NOTE Based on the chosen banding threshold it is considered necessary to include generating modules classified as type A if connected to medium voltage distribution grids. Exemption is only acceptable for CHP and generating units based on rotating machinery below 50 kW as EN 50465 for gas appliance requests disconnection in case of under voltage.		P
4.7.4.2.1	Voltage support during faults and voltage steps		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN 50549-2 applies		P
4.7.4.2.2	Zero current mode for converter connected generating technology		P
	If UVRT capability (see 4.5.3) is provided additional to the requirements of 4.5, generating units connected to the grid by a converter shall have the capability to reduce their current as fast as technically feasible down to or below 10 % of the rated current when the voltage is outside of a static voltage range. Generating units based on a doubly fed induction machine can only reduce the positive sequence current below 10 % of the rated current. Negative sequence current shall be tolerated during unbalanced faults. In case this current reduction is not sufficient, the DSO should choose suitable interface protection settings.		P
	The static voltage range shall be adjustable from 20 % to 100 % of Un for the under-voltage boundary and from 100 % to 130 % of Un for the overvoltage boundary. The default setting shall be 50% of Un for the under-voltage boundary and 120% of Un for the overvoltage boundary. Each phase to neutral voltage or if no neutral is present each phase to phase voltage shall be evaluated. At voltage re-entry into the voltage range, 90% of pre-fault power or available power, whichever is the smallest, shall be resumed as fast as possible, but at the latest according to 4.5.3 and 4.5.4.		P
	All described settings are defined by the DSO and the responsible party. If no settings are provided, the function shall be disabled. The enabling and disabling and the settings shall be field adjustable and means have to be provided to protect these from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.7.4.2.3	Induction generator based units	The unit was not induction generator.	N/A
	In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.		N/A

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
4.7.4.3	Generating plant with synchronous generating technology - Synchronous generator based units	The inverter is the not synchronous generating technology.	N/A
	In general no voltage support during faults and voltage steps is required from generating plants connected in LV distribution networks as the additional reactive current is expected to interfere with grid protection equipment. If the responsible party requires voltage support during faults and voltage steps for generating plants of type B connected to LV distribution grids, the clause 4.7.4 of EN50549-2 applies.		N/A
4.8	EMC and power quality		P
	Similar to any other apparatus or fixed installation, generating units shall comply with the requirements on electromagnetic compatibility established in Directive 2014/30/EU or 2014/53/EU, whichever applies.	See separate EMC test report No.1942106E-IT-CE-P05V01 prepared by DEKRA for reference.	P
	EMC limits and tests, described in EN 61000 series, have been traditionally developed for loads, without taking into account the particularities of generating units, such as their capability to create overvoltages or high frequency disturbances due to the presence of power converters, which were either impossible or less frequent in case of loads.		Info.
	NOTE 1 Currently, IEC SC 77A are reviewing all their existing standards to include, where necessary, specific requirements for generating units/plants. For dispersed generating units in LV networks, the Technical Report IEC/TR 61000–3-15 is addressing gaps in the existing EMC standards making recommendations on the following aspects: • Harmonic emissions; • Flicker and voltage fluctuations; • DC injection; • Short and long duration overvoltages emission; • Switching frequency emission; • Immunity to voltage dips and short interruptions; • Immunity to frequency variation; • Immunity to harmonics and inter-harmonics; • Unbalance.		Info.
	As long as specific tests for generating units are not available for immunity and/or emission, generic EMC standards and/or any relevant EU harmonized EMC standard should be applied.	See separate EMC test report No.1942106E-IT-CE-P05V01 prepared by DEKRA for reference.	P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 2 Besides the compliance with EN61000 Series, in most countries power quality characteristic according to standards such as for example EN 61400‑21 or VDE V 0124‑100 are required as part of the connection agreement.		P
	Additional phenomena need to be addressed specifically to generating plants and their integration in the power system.		P
	• ROCOF: See 4.5.2	(see appended table)	P
	• UVRT: See 4.5.3	(see appended table)	P
	• OVRT: See 4.5.4	(see appended table)	P
	• DC injection: Generating plants shall not inject direct currents.	(see appended table)	P
	NOTE 3 The DC injection clause is considered to be passed when for all generating units within the generating plant the measured DC injection of a type-tested unit is below the testing threshold.		P
	Generating plants can also disturb mains signalling (ripple control or power line carrier systems). EMC requirements on inter-harmonics and on conducted disturbances in the frequency range between 2 kHz and 150 kHz are under development. In case of electromagnetic interferences to mains signalling systems due to the connection of a generating plant, mitigation measures should be taken and national requirements may apply.		P
	Generating units are also expected to be compatible with voltage characteristics at the point of connection, as described in EN 50160 or in national regulations; however no compliance test is required due to the scope of EN 50160.		P
4.9	Interface protection		P
4.9.1	General		P
	According to HD 60364-5-551:2010, 551.7.4, means of automatic switching shall be provided to disconnect the generating plant from the distribution network in the event of loss of that supply or deviation of the voltage or frequency at the supply terminals from values declared for normal supply.		P
	This automatic means of disconnection has following main objectives:		P
	• prevent the power production of the generating plant to cause an overvoltage situation in the distribution network it is connected to. Such over-voltages could result in damages to the equipment connected to the distribution network as well as the distribution network itself;		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	• detect unintentional island situations and disconnect the generating plant in this case. This is contributing to prevent damage to other equipment, both in the producers' installations and the distribution network due to out of phase re-closing and to allow for maintenance work after an intentional disconnection of a section of the distribution network;		P
	NOTE 1 It is pointed out that checking the absence of voltage on all the live conductors is anyway mandatory before accessing a site for (maintenance) work.		P
	• assist in bringing the distribution network to a controlled state in case of voltage or frequency deviations beyond corresponding regulation values.		P
	It is not the purpose of the interface protection system to:		P
	• disconnect the generating plant from the distribution network in case of faults internal to the power generating plant. Protection against internal faults (short-circuits) shall be coordinated with network protection, according to DSO protection criteria. Protection against e.g. overload, electric shock and against fire hazards shall be implemented additionally according to HD 60364-1 and local requirements;		P
	• prevent damages to the generating unit due to incidents (e.g. short circuits) on the distribution network		P
	Interface protections may contribute to preventing damage to the generating units due to out-of-phase reclosing of automatic reclosing which may happen after some hundreds of ms. However, in some countries some technologies of generating units are explicitly required to have an appropriate immunity level against the consequences of out-of-phase reclosing.		P
	The type of protection and the sensitivity and operating times depend upon the protection and the characteristics of the distribution network.		P
	A wide variety of approaches to achieve the above mentioned objectives is used throughout Europe. Besides the passive observation of voltage and frequency other active and passive methods are available and used to detect island situations. The requirements given in this clause are intended to provide the necessary functions for all known approaches as well as to give guidance in their use. Which functions are available in a product shall be stated in the product documentation.		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	The interface protection system shall comply with the requirements of this European Standard, the available functions and configured settings shall comply with the requirements of the DSO and the responsible party. In any case, the settings defined shall be understood as the values for the interface protection system, i.e. where there is a wider technical capability of the generation module, it shall not be withheld by the settings of the protections (other than the interface protection).		P
	For micro generating plants, the interface protection system and the point of measurement might be integrated into the generating units. For generating plants with nominal current above 16 A the DSO may define a threshold above which the interface protection system shall be realized as a dedicated device and not integrated into the generating units.		P
	NOTE 2 Example thresholds are 11,08 kW per generating plant (Italy), 30 kVA per generating plant (Germany, Austria) and 50 kW per generating unit (GB)		Info.
	NOTE 3 Integrated interface protection systems might not be possible for two different reasons:		P
	• to place the protection system as close to the point of connection as possible, to avoid tripping due to overvoltages resulting from the voltage rise within the producer's network;		P
	• to allow for periodic field tests. In some countries periodic field tests are not required if the protection system meets the requirements of single fault safety.		P
	The interface protection relay acts on the interface switch. The DSO may require that the interface protection relay acts additionally on another switch with a proper delay in case the interface switch fails to operate.		P
	In case of failure of the power supply of the interface protection, the interface protection shall trigger the interface switch without delay. An uninterruptible power supply may be required by the DSO, for instance in case of UVRT capability, delay in protection etc.		P
	In case of field adjustable settings of threshold and operation time, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.9.2	Void		N/A
4.9.3	Requirements on voltage and frequency protection		P
4.9.3.1	General		P
	Part or all of the following described functions may be required by the DSO and the responsible party.		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE 1 In the following the headings of the clause sections contain ANSI device numbers according to IEEE/ANSI C37.2 in square brackets e.g. [27].		P
	The protection functions shall evaluate at least all phases where generating units, covered by this protection system, are connected to.		P
	In case of three phase generating units/plants and in all cases when the protection system is implemented as an external protection system in a three phase power supply system, all phase to phase voltages and, if a neutral conductor is present, all phase to neutral voltages shall be evaluated.		P
	NOTE 2 It is possible to calculate the phase to phase voltages based on phase-neutral measurements.		P
	The frequency shall be evaluated on at least one of the voltages.		P
	If multiple signals (e.g. 3 phase to phase voltages) are to be evaluated by one protection function, this function shall evaluate all of the signals separately. The output of each evaluation shall be OR connected, so that if one signal passes the threshold of a function, the function shall trip the protection in the specified time.		P
	The minimum required accuracy for protection is:		P
	• for frequency measurement ± 0,05 Hz;		P
	• for voltage measurement ± 1 % of Un.		P
	• The reset time shall be ≤ 50 ms		P
	• The interface protection relay shall not conduct continuous starting and disengaging operations of the interface protection relay. Therefore a reasonable reset ratio shall be implemented which shall not be zero but be below 2% of nominal value for voltage and below 0,2Hz for frequency.		P
	NOTE 3 If the interface protection system is external to the generating unit, it is preferably located as close as possible to the point of connection. The voltage rise between the point of connection and the measurement input of the interface protection system is then kept as small as possible to avoid nuisance tripping of the overvoltage protection.		P
4.9.3.2	Under-voltage protection [27]	(see appended table)	P
	The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed.		P
	Undervoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Undervoltage threshold stage 1 [27 <]:		P
	• Threshold (0,2 – 1) Un adjustable by steps of 0,01 Un		P
	• Operate time (0,1 – 100) s adjustable in steps of 0,1 s		P
	Undervoltage threshold stage 2 [27 < <]:		P
	• Threshold (0,2 – 1) Un adjustable by steps of 0,01 Un		P
	• Operate time (0,1 – 5) s adjustable in steps of 0,05 s		P
	The undervoltage threshold stage 2 is not applicable for micro-generating plants		P
4.9.3.3	Overvoltage protection	(see appended table)	P
	The protection shall comply with EN 60255-127. The evaluation of the r.m.s. or the fundamental value is allowed.		P
	Overvoltage protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P
	Overvoltage threshold stage 1 [59 >]:		P
	• Threshold (1,0 – 1,2) Un adjustable by steps of 0,01 Un		P
	• Operate time (0,1 – 100) s adjustable in steps of 0,1 s		P
	Overvoltage threshold stage 2 [59 > >]:		P
	• Threshold (1,0 – 1,30) Un adjustable by steps of 0,01 Un		P
	• Operate time (0,1 – 5) s adjustable in steps of 0,05 s		P
4.9.3.4	Overvoltage 10 min mean protection	(see appended table)	P
	The calculation of the 10 min value shall comply with the 10 min aggregation of EN 61000-4-30 Class S, but deviating from EN 61000-4-30 as a moving window is used. Therefore the function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. The calculation of a new 10 min value at least every 3 s is sufficient, which is then to be compared with the threshold value.		P
	• Threshold (1,0 – 1,15) Un adjustable by steps of 0,01 Un		P
	• Start time 3s not adjustable		P
	• Time delay setting = 0 ms		P
	NOTE 1 This function evaluates the r.m.s value.		P
	NOTE 2 More information can be found in EN 50160.		P
4.9.3.5	Under-frequency protection [81 <]	(see appended table)	P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Under frequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P
	Under-frequency threshold stage 1 [81 <]:		P
	• Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz		P
	• Operate time (0,1 – 100) s adjustable in steps of 0,1 s		P
	Under-frequency threshold stage 2 [81 < <]:		P
	• Threshold (47,0 – 50,0) Hz adjustment by steps of 0,1 Hz		P
	• Operate time (0,1 – 5) s adjustable in steps of 0,05 s		P
	In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.		P
	The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un. Under 0,2 Un the frequency protection is inhibited. Disconnection may only happen based on under-voltage protection.		P
4.9.3.6	Over-frequency protection [81 >]	(see appended table)	P
	Overfrequency protection may be implemented with two completely independent protection thresholds, each one able to be activated or not. The standard adjustment ranges are as follows.		P
	Overfrequency threshold stage 1 [81 >]:		P
	• Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz		P
	• Operate time (0,1 – 100) s adjustable in steps of 0,1 s		P
	Overfrequency threshold stage 2 [81 > >]:		P
	• Threshold (50,0 - 52,0) Hz adjustment by steps of 0,1 Hz		P
	• Operate time (0,1 - 5) s adjustable in steps of 0,05 s		P
	In order to use narrow frequency thresholds for islanding detection (see4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal.		P
	The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.		P
4.9.4	Means to detect island situation		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
4.9.4.1	General		P
	Besides the passive observation of voltage and frequency further means to detect an island may be required by the DSO. Detecting islanding situations shall not be contradictory to the immunity requirements of 4.5.	Vector shift	P
	Commonly used functions include: • Active methods tested with a resonant circuit; • ROCOF tripping; • Switch to narrow frequency band; • Vector shift • Transfer trip.		P
	Only some of the methods above rely on standards. Namely for ROCOF tripping and for the detection of a vector shift, also called a vector jump, currently no European Standard is available.		P
4.9.4.2	Active methods tested with a resonant circuit		P
	These are methods which pass the resonant circuit test for PV inverters according to EN 62116.		P
4.9.4.3	Switch to narrow frequency band (see Annex E and Annex F)		P
	In case of local phenomena (e.g. a fault or the opening of circuit breaker along the line) the DSO in coordination with the responsible party may require a switch to a narrow frequency band to increase the interface protection relay sensitivity. In the event of a local fault it is possible to enable activation of the restrictive frequency window (using the two under-frequency/over-frequency thresholds described in 4.9.2.5 and 4.9.2.6) correlating its activation with another additional protection function.		P
	If required by the DSO, a digital input according to 4.9.4 shall be available to allow the DSO the activation of a restrictive frequency window by communication. NOTE An additional gateway to ensure communication with the DSO communication system might be required.		P
4.9.5	Digital input to the interface protection		P
	If required by the DSO, the interface protection shall have at least two configurable digital inputs. These inputs can for example be used to allow transfer trip or the switching to the narrow frequency band.		P
4.10	Connection and starting to generate electrical power		P
4.10.1	General		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Connection and starting to generate electrical power is only allowed after voltage and frequency are within the allowed voltage and frequency ranges for at least the specified observation time. It shall not be possible to overrule these conditions.		P
	Within these voltage and frequency ranges, the generating plant shall be capable of connecting and starting to generate electrical power.		P
	The setting of the conditions depends on whether the connection is due to a normal operational startup or an automatic reconnection after tripping of the interface protection. In case the settings for automatic reconnection after tripping and starting to generate power are not distinct in a generating plant, the tighter range and the start-up gradient shall be used.		P
	The frequency range, the voltage range, the observation time and the power gradient shall be field adjustable.		P
	For field adjustable settings, means shall be provided to protect the settings from unpermitted interference (e.g. password or seal) if required by the DSO.		P
4.10.2	Automatic reconnection after tripping		P
	The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 3 column 2. If no settings are specified by the DSO and the responsible party, the default settings for the reconnection after tripping of the interface protection are according to Table 3 column 3. **Table 3 — Automatic reconnection after tripping** Parameter / Range / Default setting Lower frequency / 47,0Hz – 50,0Hz / 49,5Hz Upper frequency / 50,0Hz – 52,0Hz / 50,2Hz Lower voltage / 50% – 100%U_n / 85 % U_n Upper voltage / 100% – 120% U_n / 110 % U_n Observation time / 10s – 600s / 60s Active power increase gradient / 6% – 3000%/min / 10%/min	(see appended table)	P
	After reconnection, the active power generated by the generating plant shall not exceed a specified gradient expressed as a percentage of the active nominal power of the unit per minute. If no gradient is specified by the DSO and the responsible party, the default setting is 10 % Pn /min. Generating modules for which it is technically not feasible to increase the power respecting the specified gradient over the full power range may connect after 1 min to 10 min (randomized value, uniformly distributed) or later.		P
4.10.3	Starting to generate electrical power		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	The frequency range, the voltage range, the observation time shall be adjustable in the range according to Table 4 column 2. If no settings are specified by the DSO and the responsible party, the default settings for connection or starting to generate electrical power due to normal operational startup or activity are according to Table 4 column 3.	(see appended table)	P
	If applicable, the power gradient shall not exceed the maximum gradient specified by the DSO and the responsible party. Heat driven CHP generating units do not need to keep a maximum gradient, since the start up is randomized by the nature of the heat demand.		P
	For manual operations performed on site (e.g. for the purpose of initial start-up or maintenance) it is permitted to deviate from the observation time and ramp rate.		P
4.10.4	Synchronization		P
	Synchronizing a generating plant/unit with the distribution network shall be fully automatic i.e. it shall not be possible to manually close the switch between the two systems to carry out synchronization.		P
4.11.1	Ceasing active power		P
	Generating plants with a maximum capacity of 0,8 kW or more shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port. If required by the DSO and the responsible party, this includes remote operation.	(see appended table)	P
4.11.2	Reduction of active power on set point		P
	For generating modules of type B, a generating plant shall be capable of reducing its active power to a limit value provided remotely by the DSO. The limit value shall be adjustable in the complete operating range from the maximum active power to minimum regulating level.		P
	The adjustment of the limit value shall be possible with a maximum increment of 10% of nominal power.		P

Table 4 — Starting to generate electrical power

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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	A generation unit/plant shall be capable of carrying out the power output reduction to the respective limit within an envelope of not faster than 0,66 % Pn/ s and not slower than 0,33 % Pn / s with an accuracy of 5 % of nominal power. Generating plants are permitted to disconnect from the network at a limit value below it minimum regulating level. If required by the DSO, this includes remote operation.	(see appended table)	P
	NOTE Besides the requirements of this clause there might be other systems in place to control active power for reasons of market participation or local optimisation.		P
4.12	Remote information exchange		P
	Generating plants whose power is above a threshold to be determined by the DSO and the responsible party shall have the capacity to be monitored by the DSO or TSO control centre or control centres as well as receive operation parameter settings for the functions specified in this European Standard from the DSO or TSO control centre or control centres.		P
	It should not interact directly with the power generation equipment and the switching devices of the generating plant. It should interact with the operation and control system of the generating plant.		P
	In principle, standardized communication should be used. It is recommended that in case of using protocols for signal transmission used between the DSO or TSO control centre or control centres and the generating plant, relevant technical standards (e.g. EN 60870-5-101, EN 60870-5-104, EN 61850 and in particular EN 61850-7-4, EN 61850-7-420, IEC/TR 61850-90-7, as well as EN 61400-25 for wind turbines and relevant parts of IEC 62351 for relevant security measures) are recognized.		P
	Alternative protocols can be agreed between the DSO and the producer. These protocols include hardwired digital input/output and analogue input/output provided locally by DSO. The information needed for remote monitoring and the setting of configurable parameters are specific to each distribution network and to the way it is operated.		P
4.13	Requirements regarding single fault tolerance of interface protection system and interface switch	(see appended table)	P
	If required in 4.3.2, the interface protection system and the interface switch shall meet the requirements of single fault tolerance.		P
	A single fault shall not lead to a loss of the safety functions.		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict
	NOTE This requirement for the detection of individual faults does not mean that all faults are detected. Accumulation of undetected faults can therefore lead to an unintentional output signal and result in a hazardous condition.		P
	Series-connected switches shall each have a independent breaking capacity corresponding to the rated current of the generating unit and corresponding to the short circuit contribution of the generating unit.		P
	The short-time withstand current of the switching devices shall be coordinated with maximum short circuit power at the connection point.		P
	At least one of the switches shall be a switch-disconnector suitable for overvoltage category 2. For single-phase generating units, the switch shall have one contact of this overvoltage category for both the neutral conductor and the line conductor. For poly-phase generating units, it is required to have one contact of this overvoltage category for all active conductors. The second switch may be formed of electronic switching components from an inverter bridge or another circuit provided that the electronic switching components can be switched off by control signals and that it is ensured that a failure is detected and leads to prevention of the operation at the latest at the next reconnection.		P
	For PV-inverters without simple separation between the network and the PV generating unit (e.g. PV Inverter without transformer) both switches mentioned in the paragraph above shall be switch disconnectors with the requirements described therein, although one switching device is permitted to be located between PV array and PV inverter.		P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Annex A	Interconnection guidance		P
Annex B	Void		Info.
Annex C	Parameter Table		P
Annex D	List of national requirements applicable for generating plants		Info.
Annex E	Loss of Mains and overall power system security		P
Annex F	Examples of protection strategies		Info.
Annex G	Abbreviations		Info.
Annex H	Relationship between this European standard and the COMMISSION REGULATION (EU) 2016/631		P
	Generating plants compliant with the clauses of this European Standard are considered to be compliant with the relevant Article of COMMISSION REGULATION (EU) 2016/631, provided, that all settings as provided by the DSO and the responsible party are complied with.		P
	Table H.1 – Correspondence between this European standard and the COMMISSION REGULATION (EU) 2016/631		P

Article	Clause(s) / subclause(s) of this EN
13.1(a)	4.4.2 Operating frequency range
13.1(b)	4.5.2 Rate of change of frequency (ROCOF) immunity
13.2	4.6.1 Power response to overfrequency
13.3	4.4.3 Minimal requirement for active power delivery at underfrequency
13.4	4.4.3 Minimal requirement for active power delivery at underfrequency
13.5	4.4.3 Minimal requirement for active power delivery at underfrequency
13.6	4.11.1 Ceasing active power
13.7	4.10 Connection and starting to generate electrical power
14.1	4.4.2, 4.5.2, 4.6.1, 4.4.3, 4.11.1 and 4.10
14.2(a)	4.11.2 Reduction of active power on set point
14.2(b)	4.12 Remote information exchange
14.3	4.5.3 Under-voltage ride through (UVRT)
14.4.	4.10 Connection and starting to generate electrical power
14.5(a)	4.6, 4.7, 4.9, 4.10, 4.11, 4.12
14.5(b)	4.9 Interface protection,
14.5(c)	4.1 General
14.5(d)	4.12 Remote information exchange
17.1	4. as applicable above
17.2	4.7.2 Voltage support by reactive power
17.3	4.5.3 Under-voltage ride through (UVRT)
20.1	4. as applicable above
20.2 (a)	4.7.2 Voltage support by reactive power
20.2 (b) (c)	4.7.4.2 Short circuit current requirements on generating plants
20.3	4.5.3 Under-voltage ride through (UVRT)

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test overview:		
EN 50549-1:2019		
4.4.2	Operating frequency range	P
4.4.3	Minimal requirement for active power delivery at under-frequency	P
4.4.4	Continuous operating voltage range	P
4.5.2	Rate of change of frequency (ROCOF) immunity	P
4.5.3	Under-voltage ride through (UVRT)	P
4.5.4	Over-voltage ride through (OVRT)	P
4.6.1	Power response to under-frequency	P
4.6.2	Power response to over-frequency	P
4.7.2	Voltage support by reactive power	P
4.7.2.3.2	Setpoint control modes – Q setpoint mode	P
4.7.2.3.2	Setpoint control modes – Cos φ setpoint mode	P
4.7.2.3.3	Voltage related control mode – Q(U)	P
4.7.2.3.4	Power related control mode – cos φ (P)	P
4.7.3	Voltage related active power reduction	P
4.7.4	Short circuit current requirements on generating plants	P
4.8	EMC and power quality	P
4.9.3	Requirements on voltage and frequency protection	P
4.9.3.2	Under-voltage protection	P
4.9.3.3	Overvoltage protection	P
4.9.3.4	Overvoltage 10 min mean protection	P
4.9.3.5	Underfrequency protection	P
4.9.3.6	Overfrequency protection	P
4.9.4	Means to detect island situation	P
4.9.5	Digital input to the interface protection	P
4.10.2	Automatic reconnection after tripping	P
4.10.3	Starting to generate electrical power	P
4.11.1	Ceasing active power	P
4.11.2	Reduction of active power on set point	P
4.13	Requirements regarding single fault tolerance of interface protection system	P

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.4.2	**TABLE: Operating frequency range – B: Stringent requirement**				**P**
Model	SG20KTL-M				
Test sequence	Frequency [Hz]	Voltage [V]	Output power [W]	Time period measured [min]	Time period Required
Test 1	47.1	232	15900	4.17	> 20 s
Test 2	47.6	231	15841	91.6	> 90 min
Test 3	48.6	231	15824	91.6	> 90 min
Test 4	49.1	231	15198	4.17	Unlimited
Test 5	50.9	231	15400	4.17	Unlimited
Test 6	51.4	231	15841	91.6	> 90 min
Test 7	51.9	232	15833	16.67	> 15 min
Note: Respecting the legal framework, it is possible that longer time periods are required by the responsible party in some synchronous areas.					

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.4.3	**TABLE: Minimal requirement for active power delivery at under-frequency**			**P**
Model	EA16KTSI			
Voltage	Un=230Vac			
Test sequence	Frequency [Hz]	Output power [W]	$\Delta P/P_M$ per 1 Hz	Reduction rate limits
Test a)	50.0Hz	15933.98	0	0%
Test b)	49.6Hz	15932.58	0	0%
Test c)	47.6Hz	12802.57	9.8%	10%

Test:

The test must be carried out at 100% P_n,
Measurements are carried out at the following operating points:
a) nominal frequency$\pm$0.01 Hz;
b) a point between the nominal frequency -0.4 Hz to -0.5 Hz;
c) a point between the nominal frequency -2.4 Hz to -2.5 Hz.
The operating point b) and c) shall be maintained for at least 5 min, sample rate: 1 s.

Assessment criterion:

The test is regarded as passed if:

- the inverter does not disconnect from the network at the operating Points a) to c) when the network frequency is changed and
- the inverter does not reduce output energy at Point b) and
- the power reduction in point c) is less or equal to the allowed power reduction according to 4.4.3.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.4.4	TABLE: Continuous operating voltage range				P
Model	EA16KTSI				
Test 1	1.10Un				
Test sequence	Voltage [V]	Frequency [Hz]	Output power [W]	Time period measured	Time period Limited
Phase L1	253.39	50Hz	5307.15	> 30 min	Unlimited
Phase L2	252.88	50Hz	5282.09		
Phase L3	253.49	50Hz	5316.34		
Test 2	0.85Un				
Test sequence	Voltage [V]	Frequency [Hz]	Output power [W]	Time period measured	Time period Limited
Phase L1	196.02	50Hz	4604.06	> 30 min	Unlimited
Phase L2	195.75	50Hz	4592.75		
Phase L3	196.29	50Hz	4621.63		
Note: The specified accepted reduction of output power is an absolute minimum requirement. Further power system aspects might require maintained output power in the entire continuous operation voltage range.					

4.5.2	TABLE: Rate of change of frequency (ROCOF) immunity			P
Model	EA16KTSI			
Test sequence	Ramp Range	Test frequency ramp	Test Duration	Confirm no trip
Test 1	47.50 Hz to 51.50 Hz	2 Hz/s	2.0 s	No trip
Test 2	51.50 Hz to 47.50 Hz	2 Hz/s	2.0 s	No trip
Note: The ROCOF immunity is defined with a sliding measurement window of 500 ms.				

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

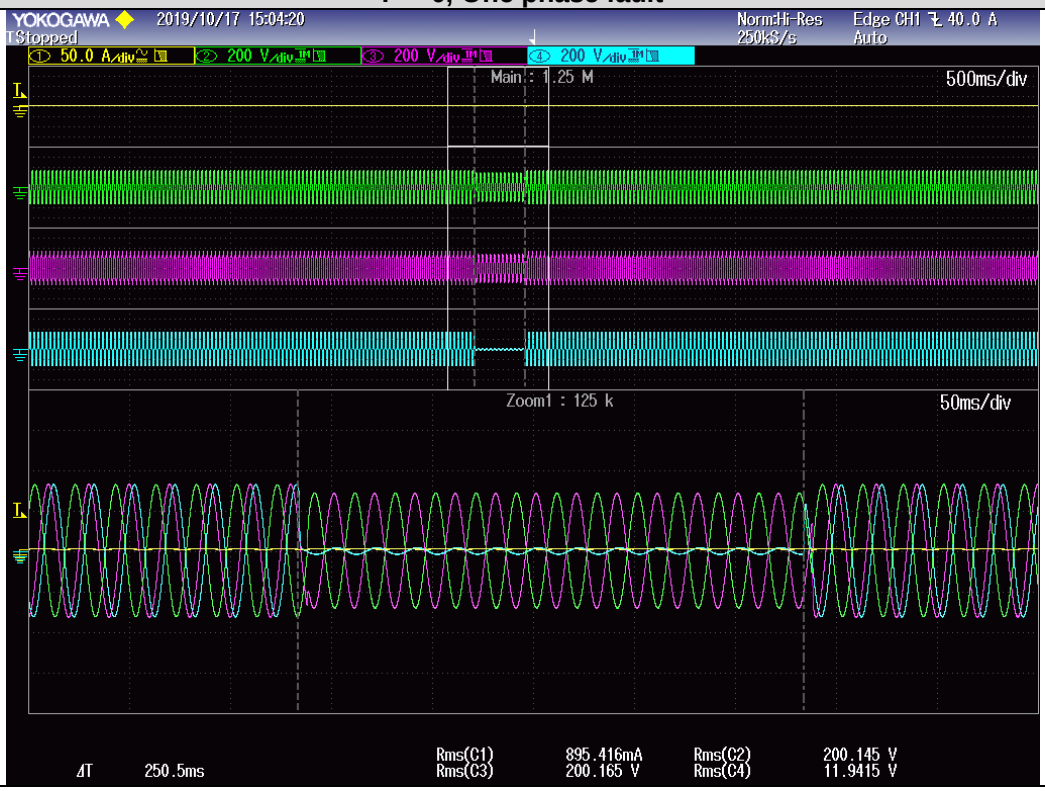
4.5.3 4.7.4.2.2	**TABLE:Under – voltage ride through (UVRT) – most stringent Zero current mode for converter connected generating technology**						**P**
Test number	U/U_n [pu]	No. of phases fault	Output power level P set point (%P_n)	Required fault duration [ms]	Q set point (%Pn)	Average remaining voltage [%]	Duration of restoring network [ms]
1	0.05	One phase asymetric fault	P = 0	250	0%	5%	N/A
2			P = 20% ± 5% Pn	250	20%	5%	638.5
3			P = 100% ± 5% Pn	250	20%	5%	365.9
4		Two phase asymetric fault	P = 0	250	0%	5%	N/A
5			P = 20% ± 5% Pn	250	20%	5%	218.7
6			P = 100% ± 5% Pn	250	20%	5%	392.1
7		Three phase symetric fault	P = 0	250	0%	5%	N/A
8			P = 20% ± 5% Pn	250	20%	5%	610.5
9			P = 100% ± 5% Pn	250	20%	5%	485.9
10	0.50	One phase asymetric fault	P = 0	1797	0%	50%	N/A
11			P = 20% ± 5% Pn	1797	20%	50%	607.7
12			P = 100% ± 5% Pn	1797	20%	50%	651.1
13		Two phase asymetric fault	P = 0	1797	0%	50%	N/A
14			P = 20% ± 5% Pn	1797	20%	50%	342.7
15			P = 100% ± 5% Pn	1797	20%	50%	437.1
16		Three phase symetric fault	P = 0	1797	0%	50%	N/A
17			P = 20% ± 5% Pn	1797	20%	50%	243.9
18			P = 100% ± 5% Pn	1797	20%	50%	318.0
19	0.84	One phase asymetric fault	P = 0	2966	0%	84%	N/A
20			P = 20% ± 5% Pn	2966	20%	84%	538.3
21			P = 100% ± 5% Pn	2966	20%	84%	811.2
22		Two phase asymetric fault	P = 0	2966	0%	84%	N/A
23			P = 20% ± 5% Pn	2966	20%	84%	337.5
24			P = 100% ± 5% Pn	2966	20%	84%	381.2
25		Three phase symetric fault	P = 0	2966	0%	84%	N/A
26			P = 20% ± 5% Pn	2966	20%	84%	429.2
27			P = 100% ± 5% Pn	2966	20%	84%	385.2

Note:

The converters will go into zero current mode and reduce their current within 0.1s down to or below 10 % of the rated current when the voltage is outside of static voltage range.

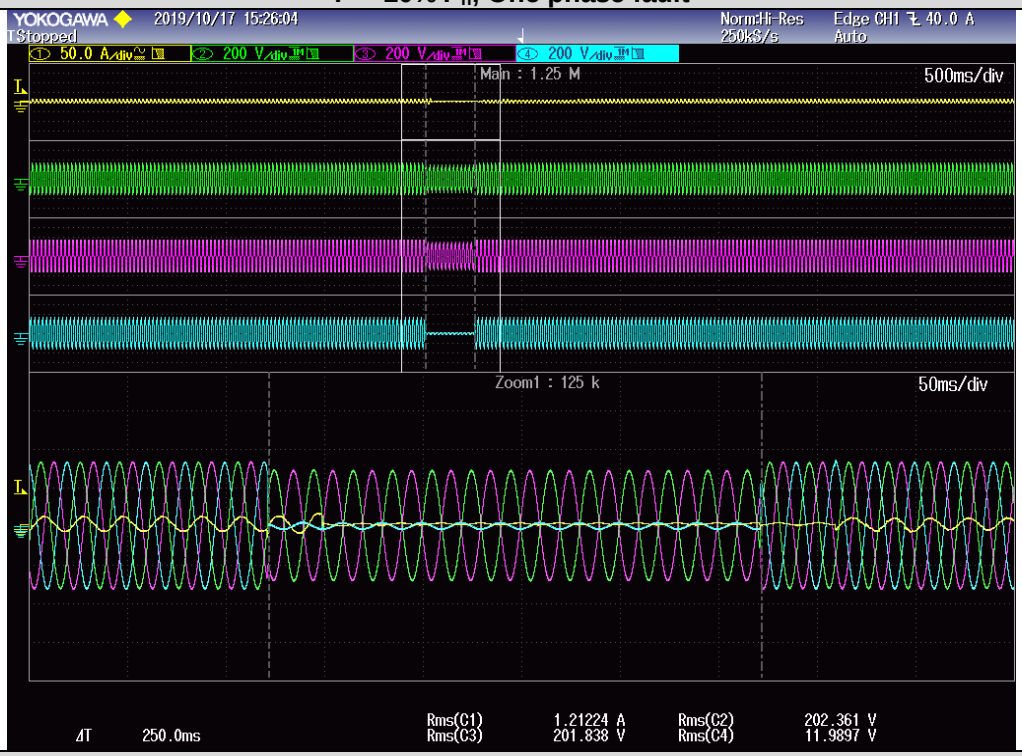
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 1–One-phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure P = 0, One phase fault

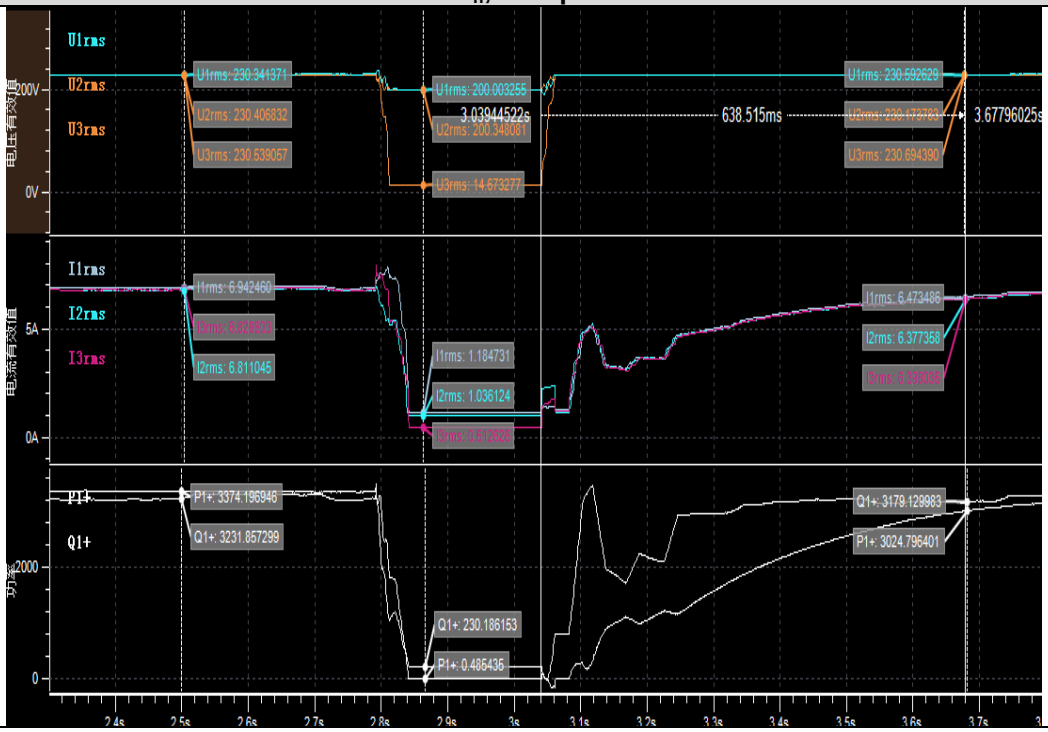


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 2–One-phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 20% P_n, One phase fault

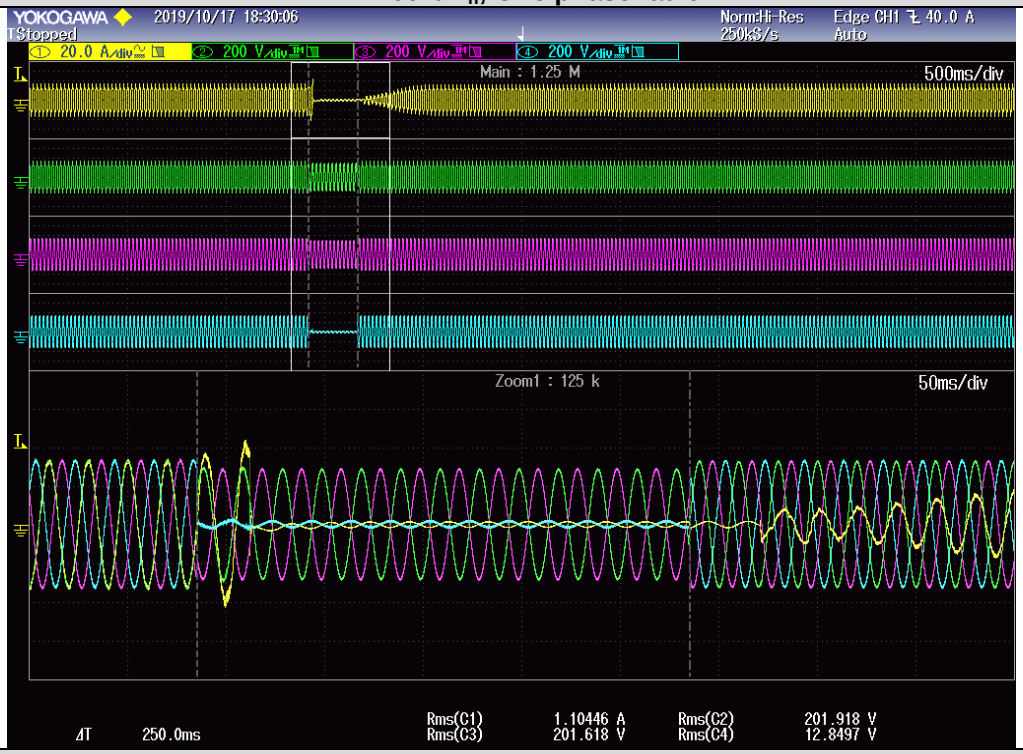


Test 2–One-phase asymmetrical fault (U/U_n = 0.05): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, One phase fault

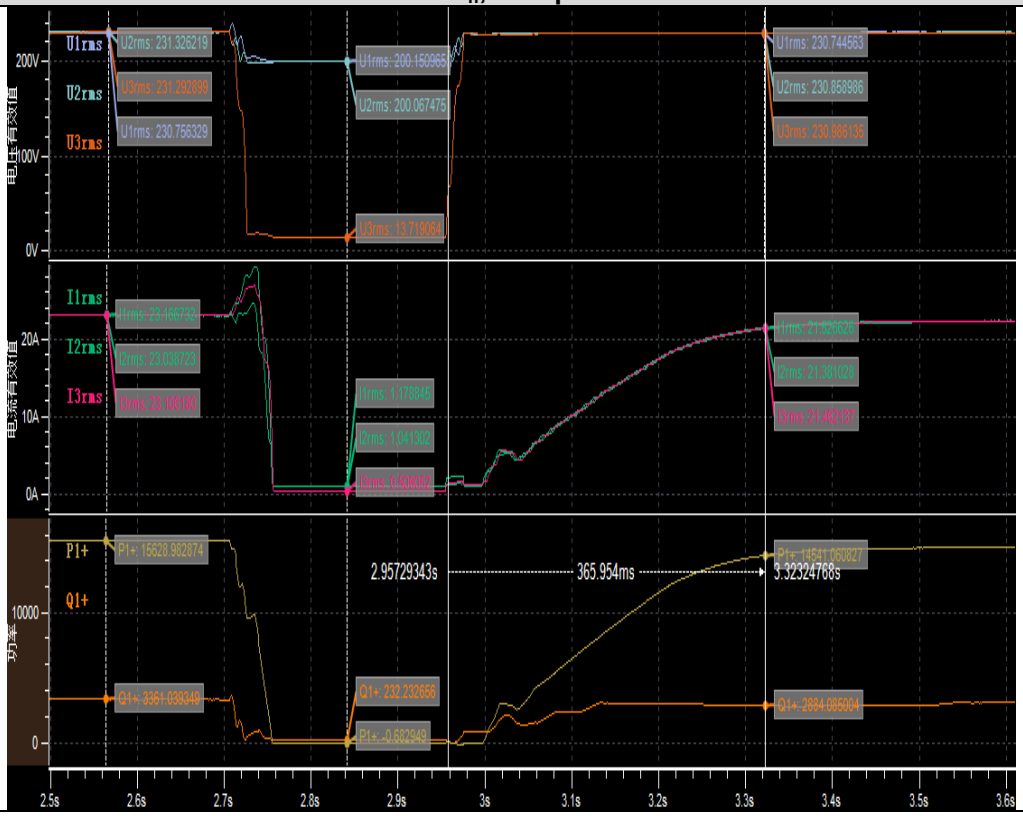


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 3–One-phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 100% P_n, One phase fault

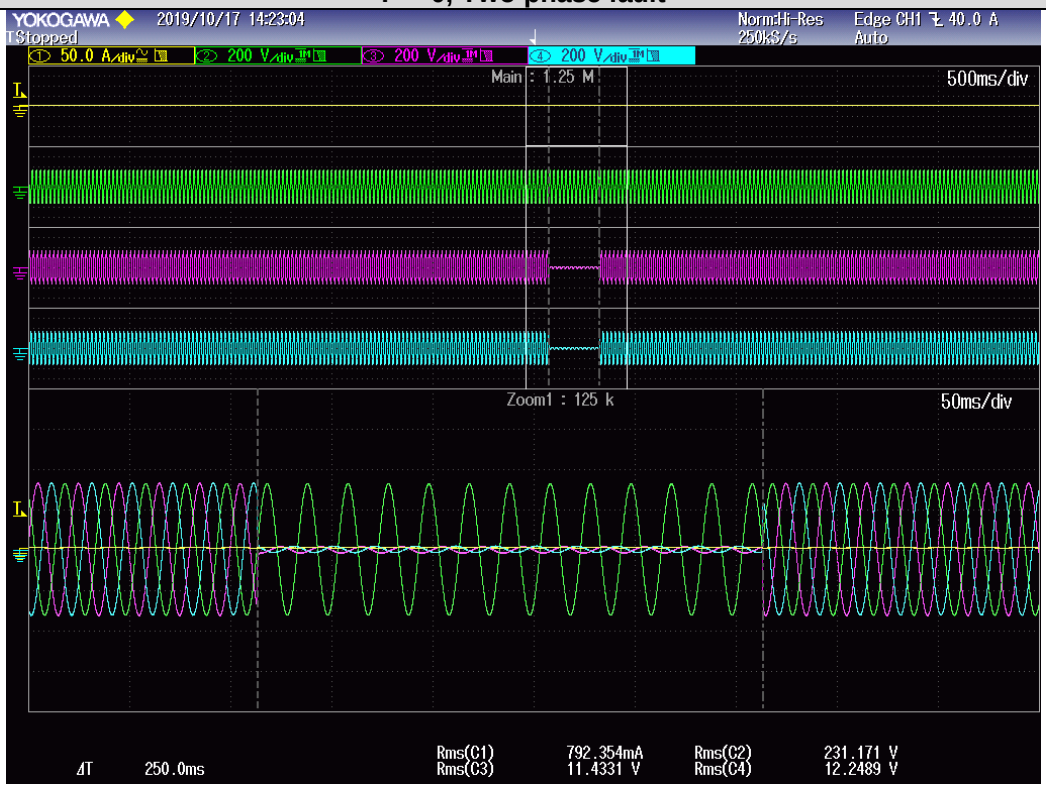


Test 3 – One -phase asymmetrical fault (U/U_n = 0.05): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, One phase fault



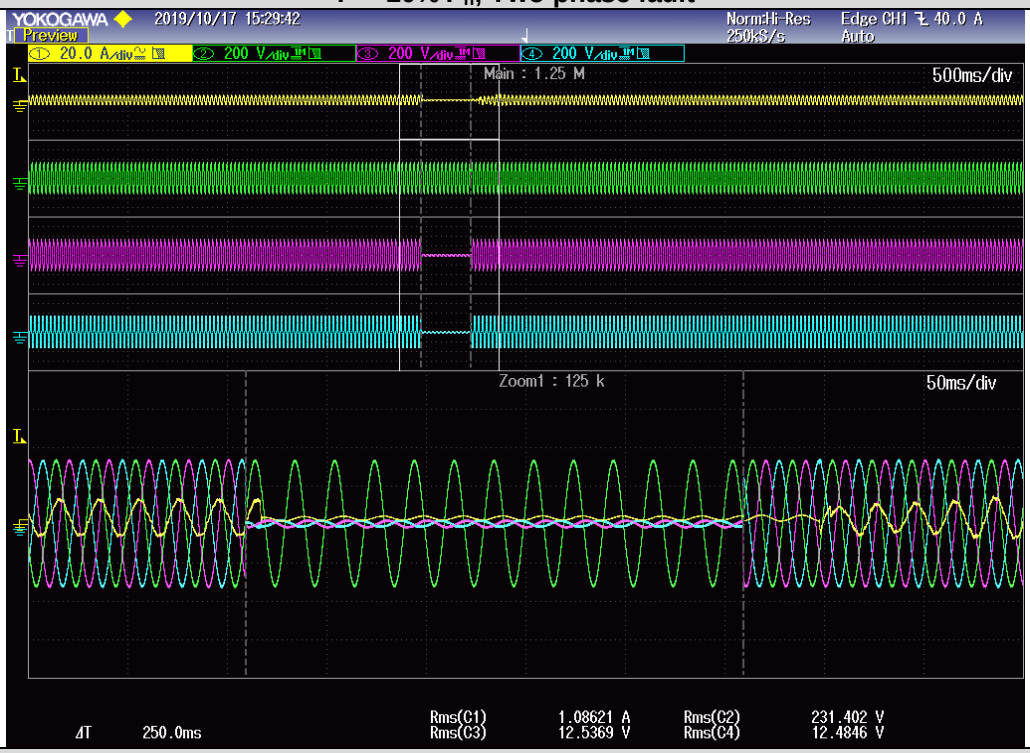
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 4 – Two-phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure P = 0, Two phase fault

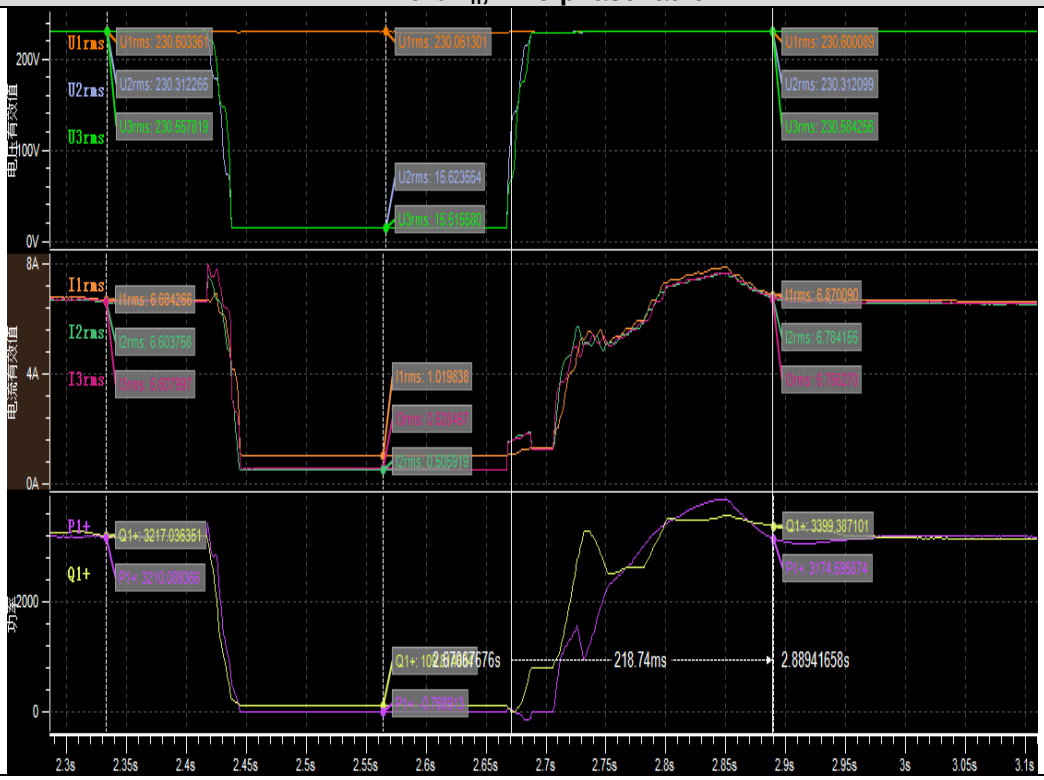


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 5 –Two -phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 20% P_n, Two phase fault

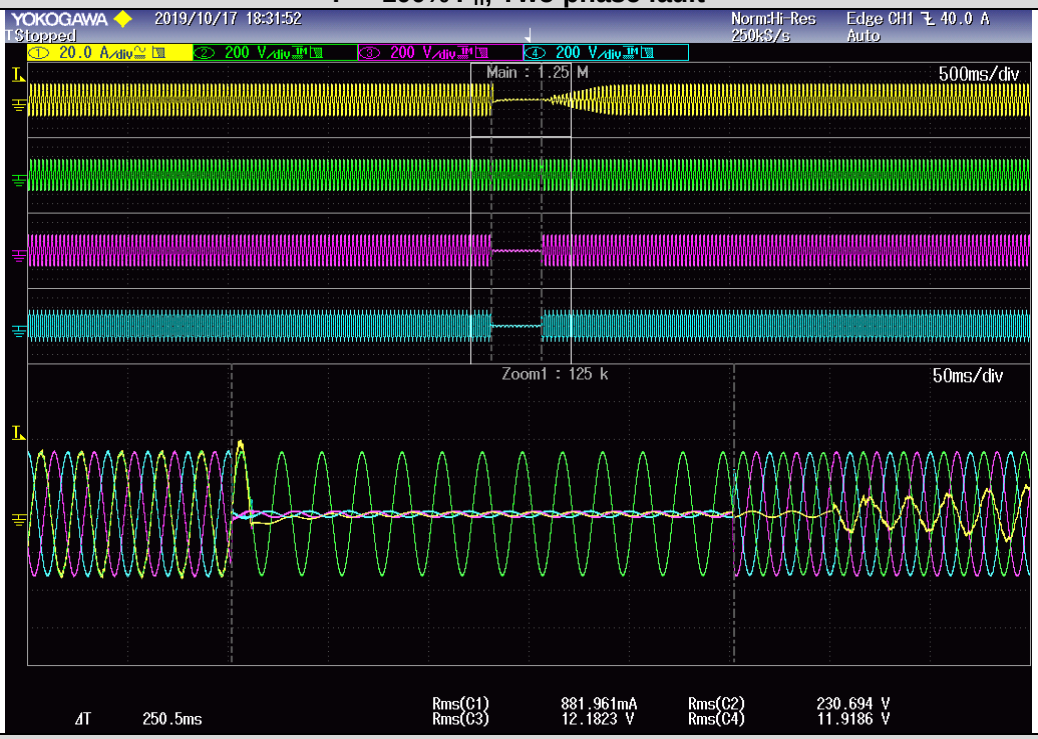


Test 5 –Two-phase asymmetrical fault (U/U_n = 0.05): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Two phase fault

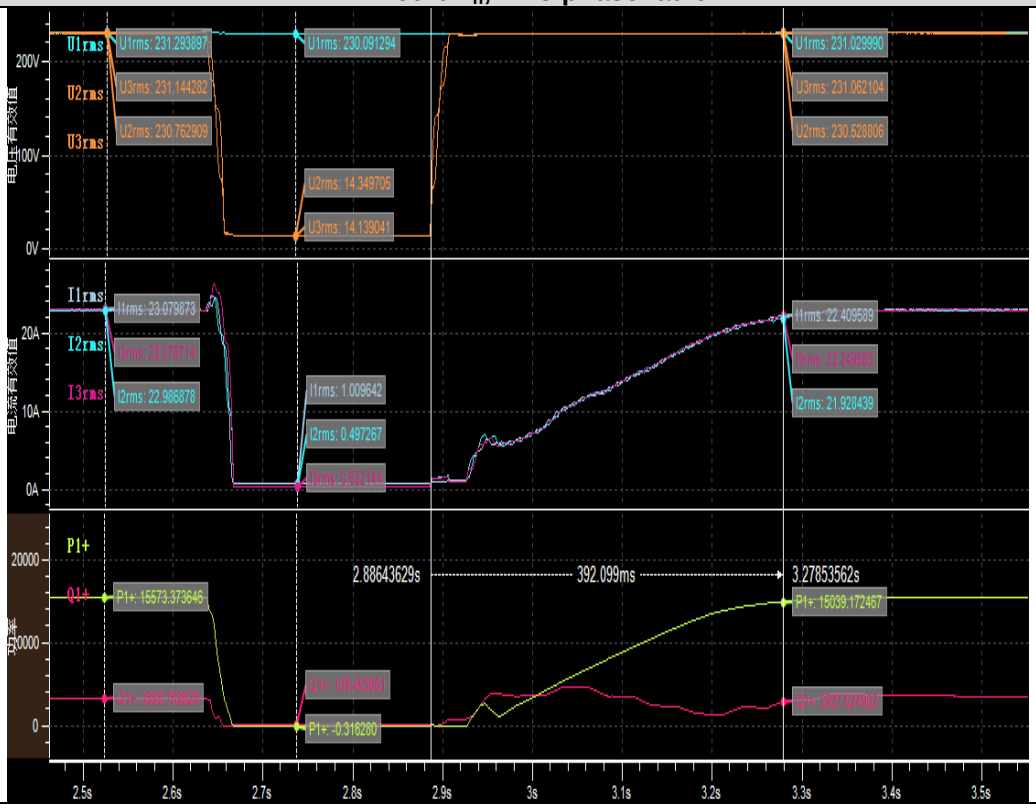


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 6 –Two-phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 100% P_n, Two phase fault



Test 6 –Two -phase asymmetrical fault (U/U_n = 0.05): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Two phase fault

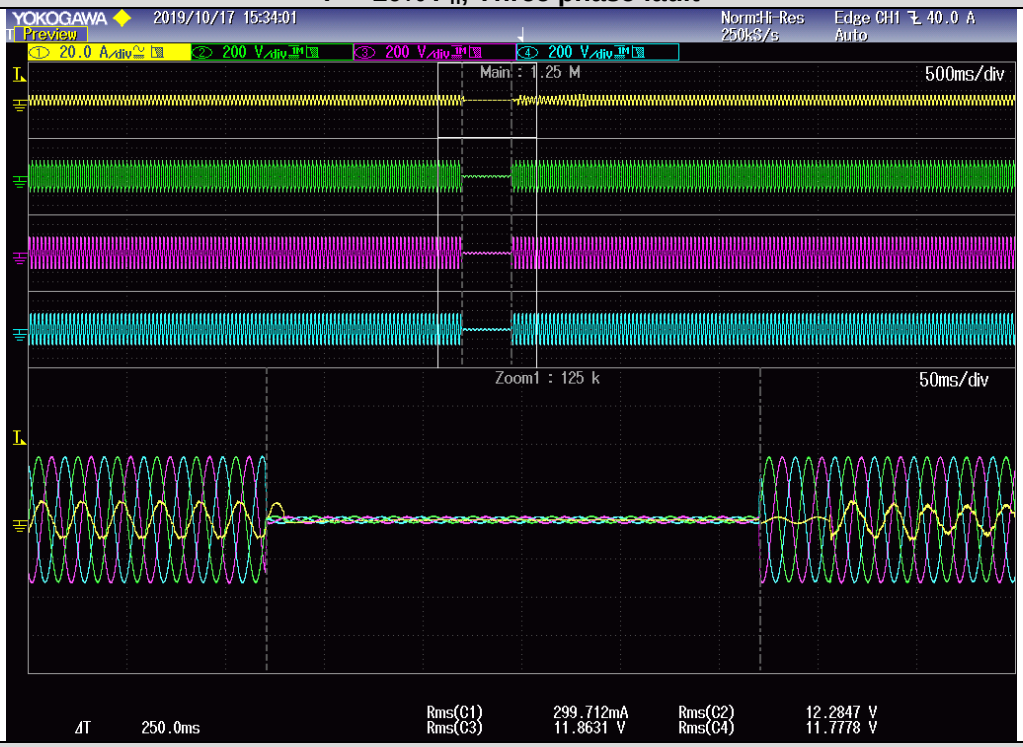


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

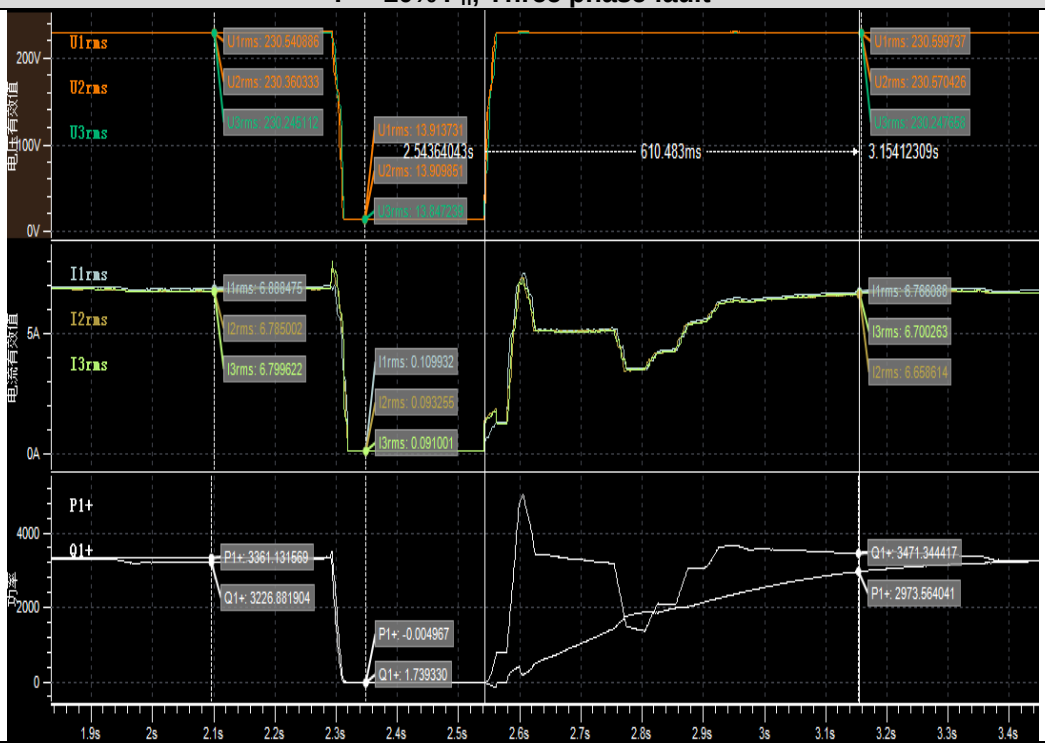
Test 7–Three-phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 0, Three phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 8 –Three -phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 20% P_n, Three phase fault

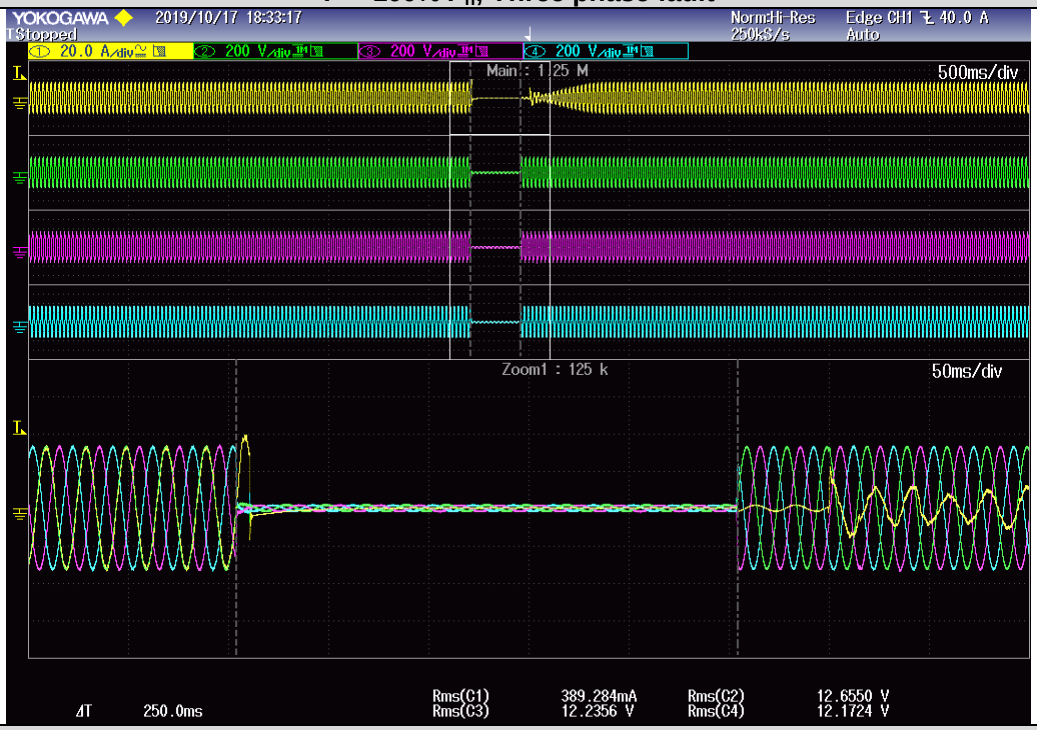


Test 8 –Three -phase asymmetrical fault (U/U_n = 0.05): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Three phase fault

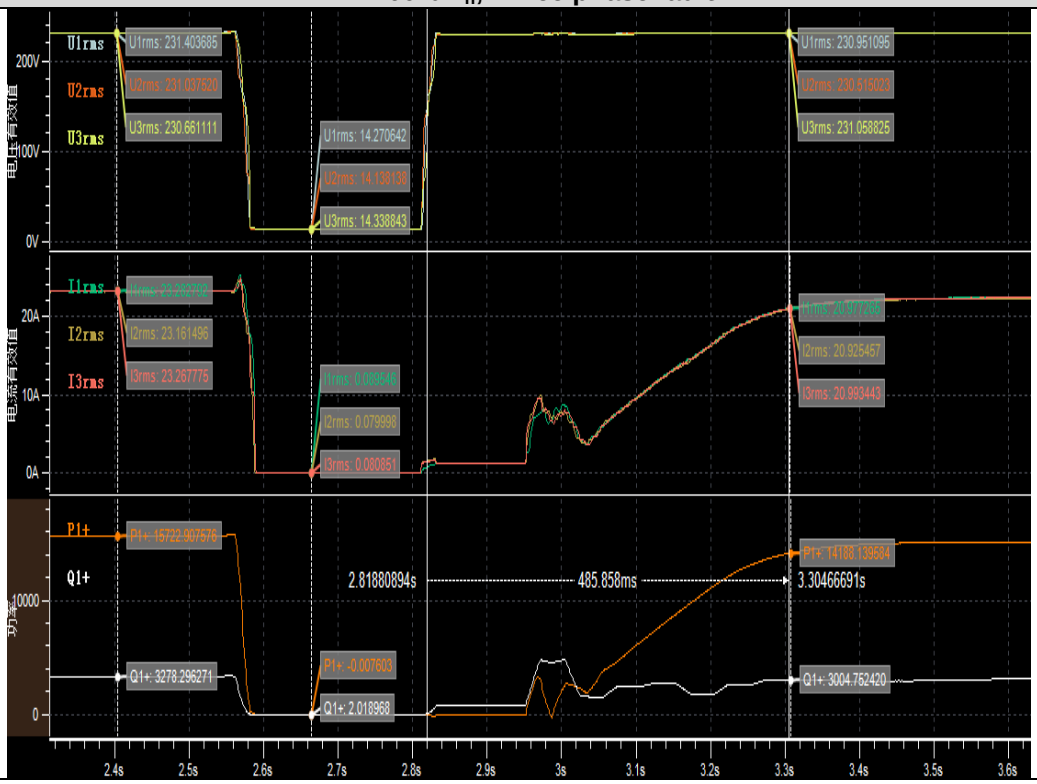


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 9 –Three -phase asymmetrical fault (U/U_n = 0.05): Phase current and voltage of the whole failure
P = 100% P_n, Three phase fault

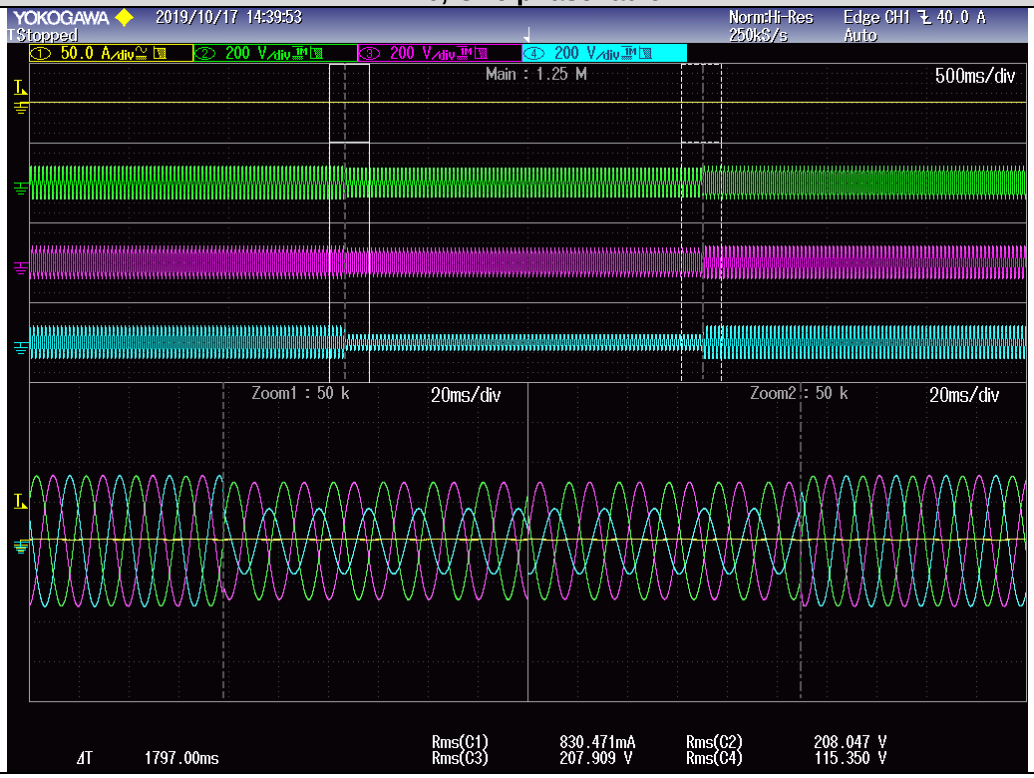


Test 9–Three -phase asymmetrical fault (U/U_n = 0.05): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Three phase fault



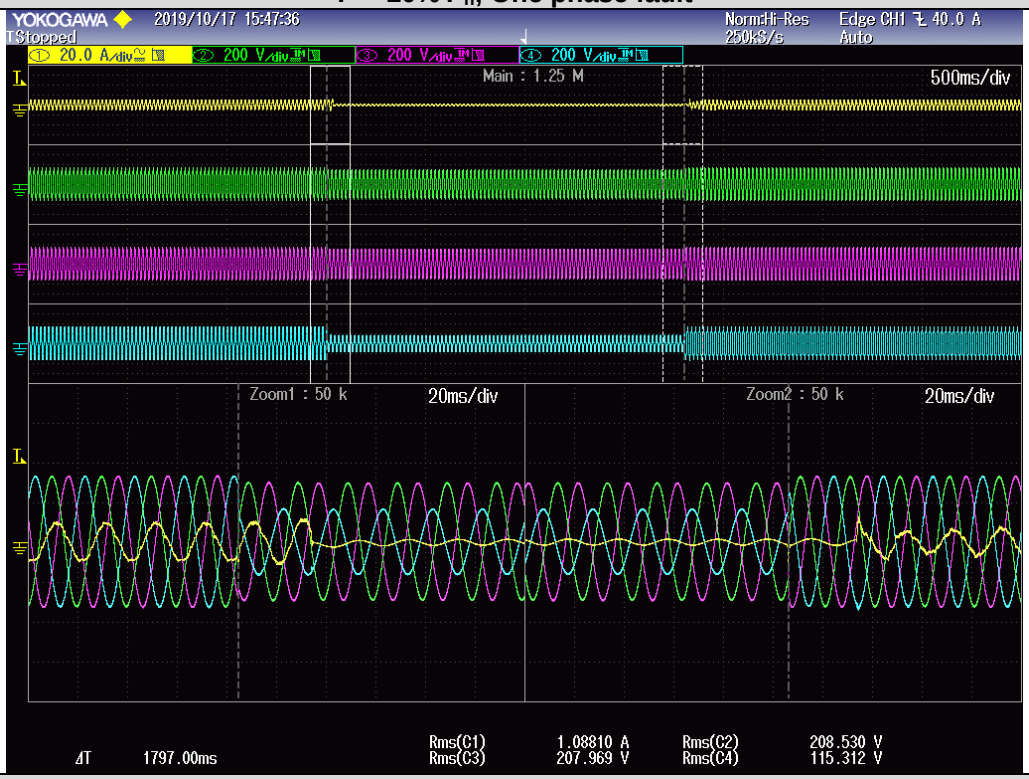
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 10–One-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure P = 0, One phase fault

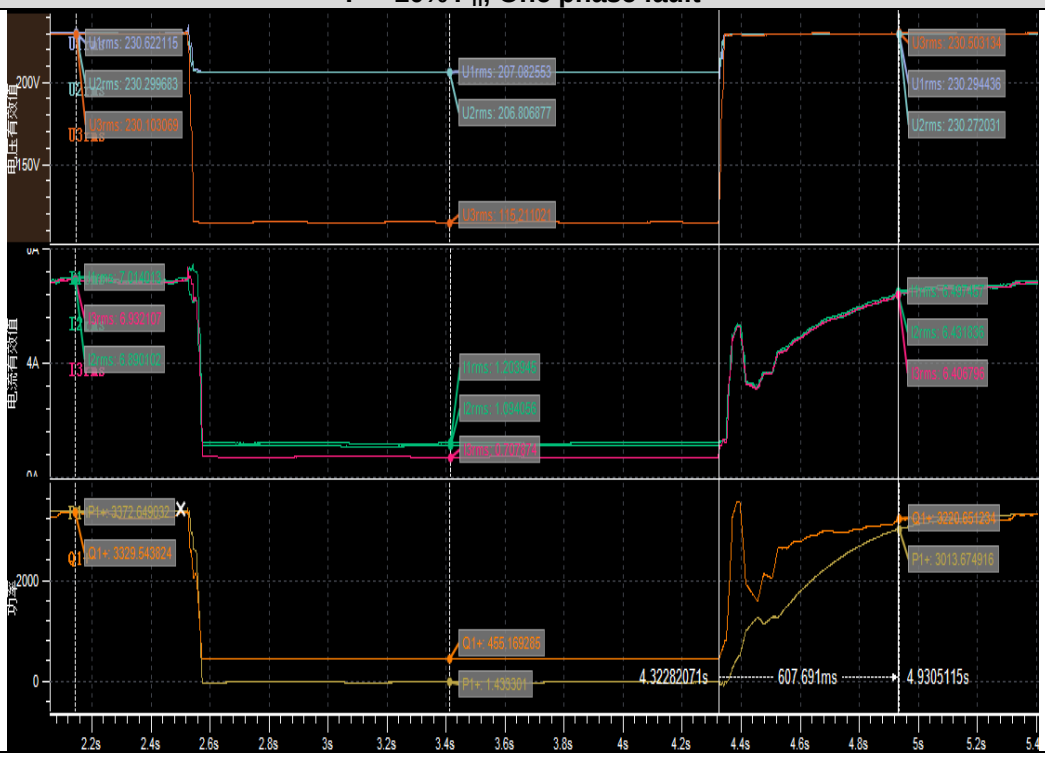


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 11–One-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 20% P_n, One phase fault

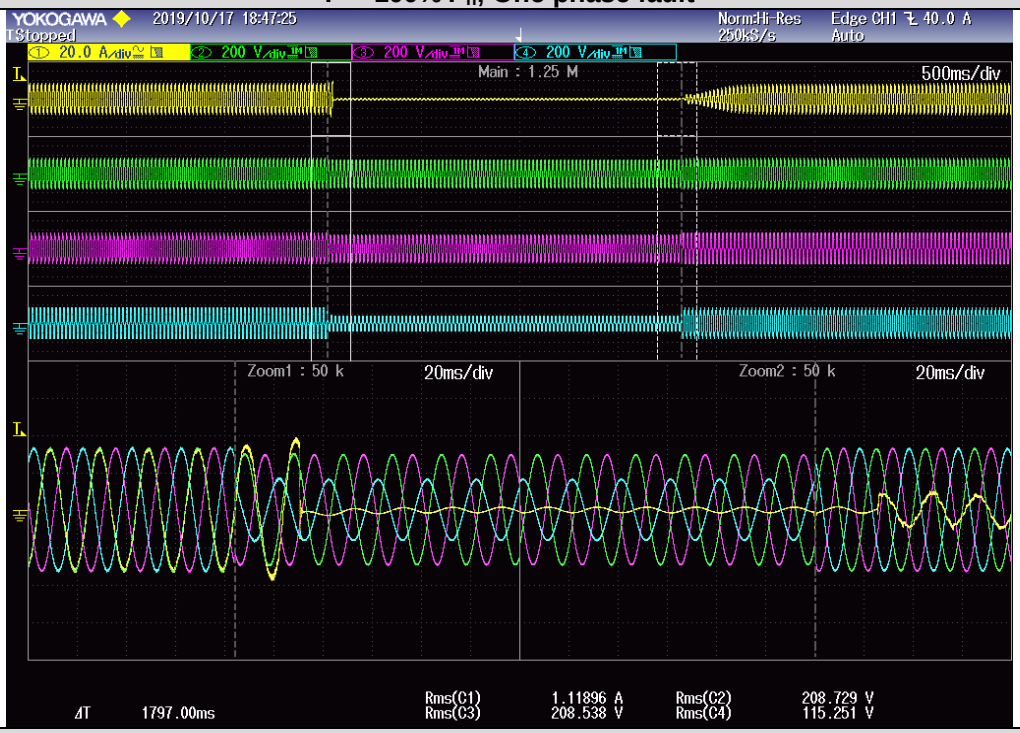


Test 11–One-phase asymmetrical fault (U/U_n = 0.5): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, One phase fault

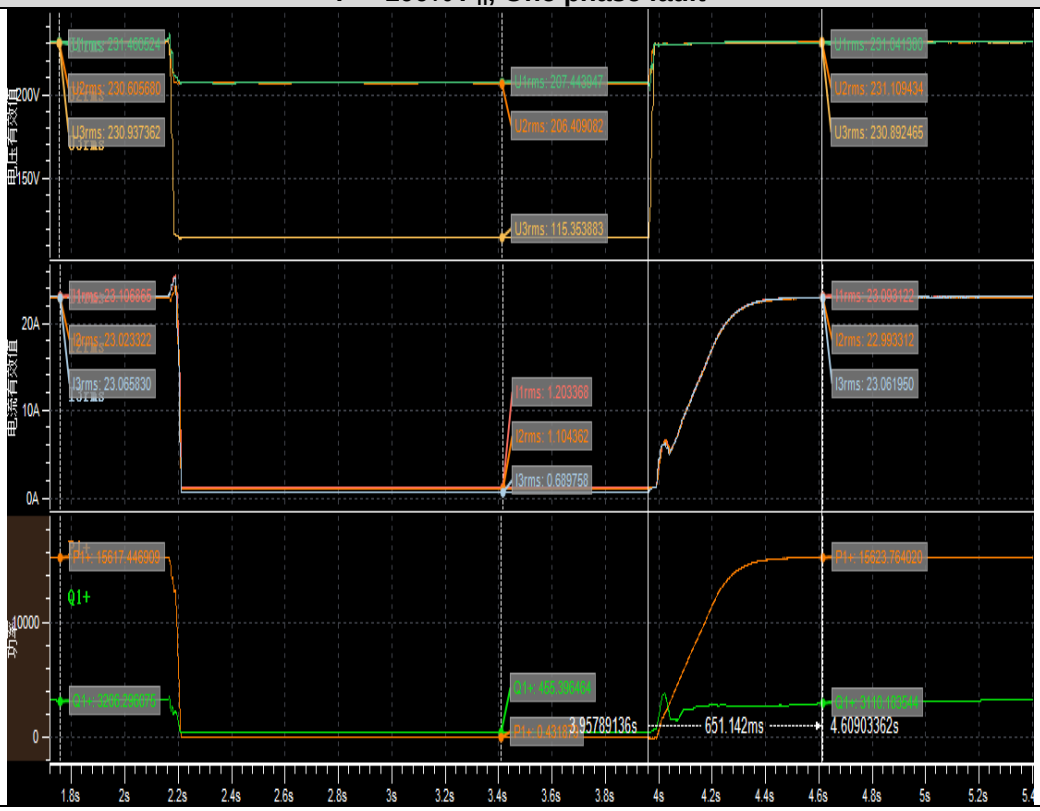


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 12–One-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 100% P_n, One phase fault

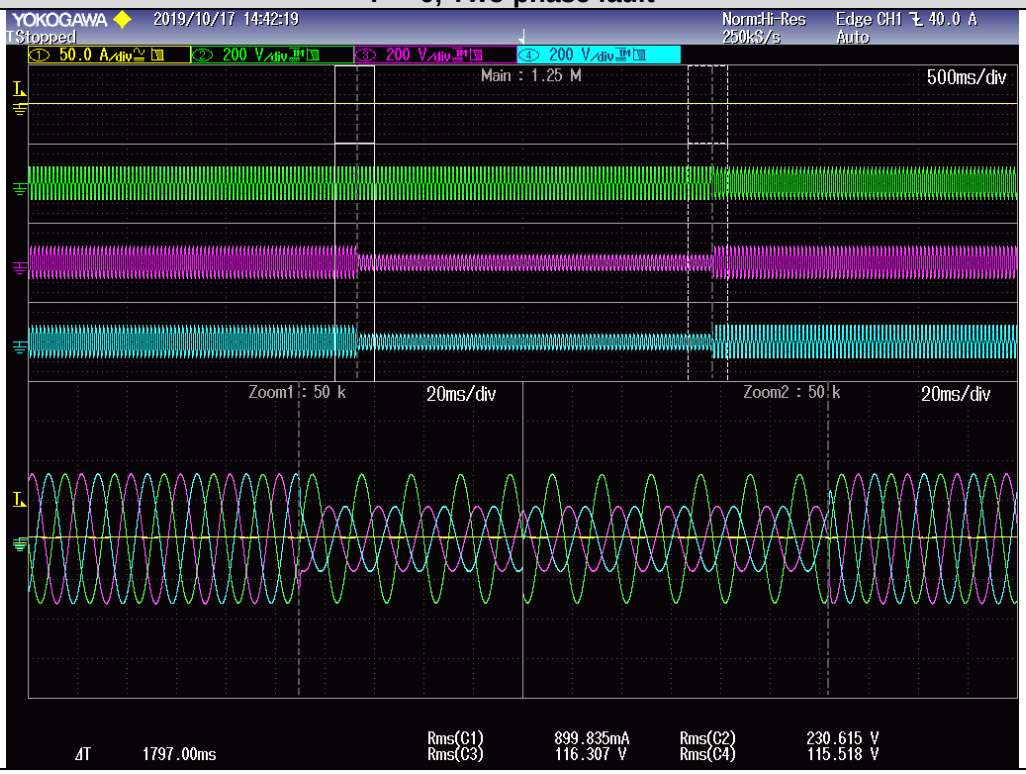


Test 12–One-phase asymmetrical fault (U/U_n = 0.5): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, One phase fault



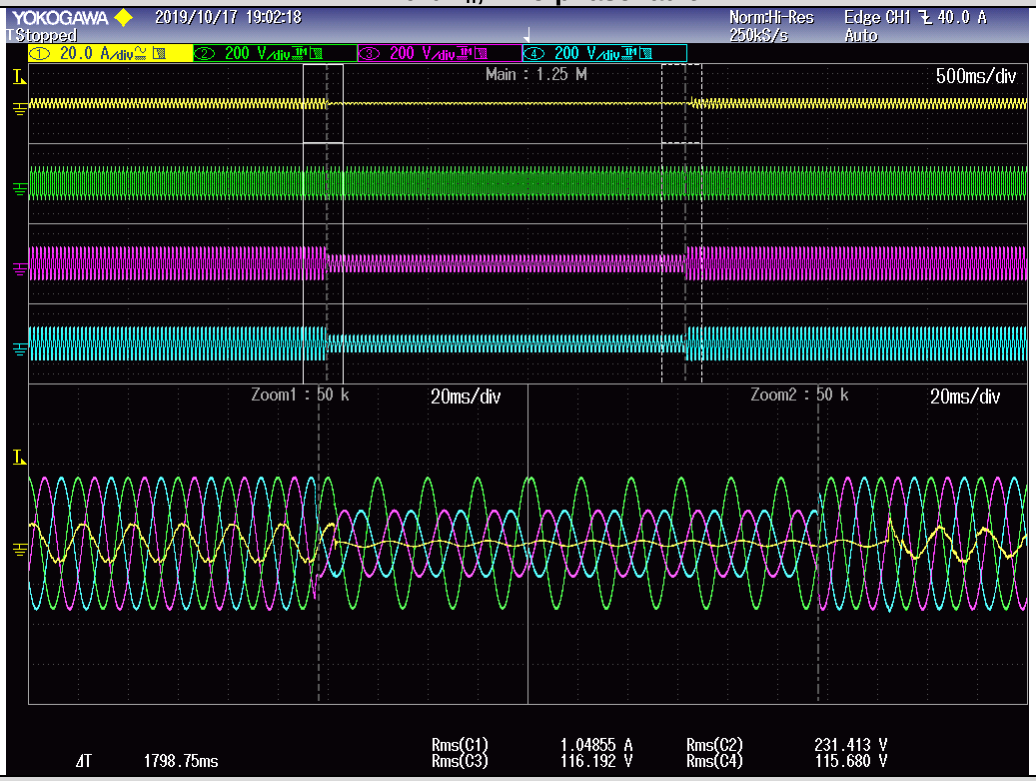
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 13– Two-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure P = 0, Two phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 14– Two-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 20% P_n, Two phase fault

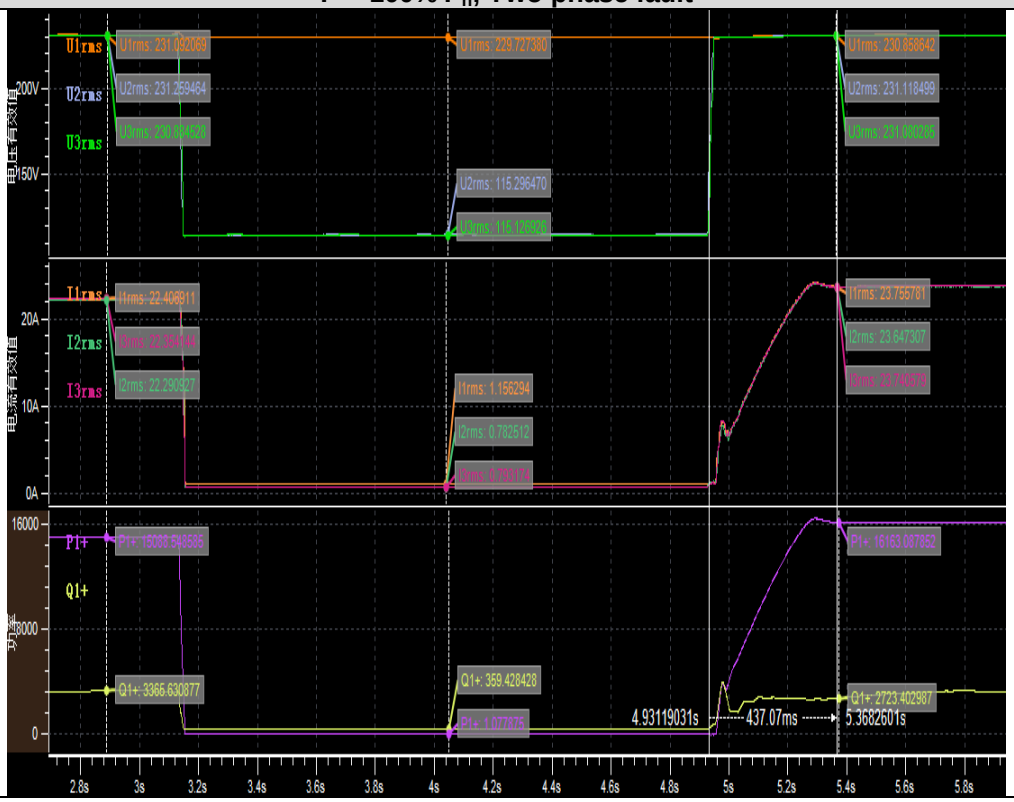


Test 14– Two-phase asymmetrical fault (U/U_n = 0.5): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Two phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 15– Two-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 100% P_n, Two phase fault

Test 15– Two-phase asymmetrical fault (U/U_n = 0.5): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Two phase fault

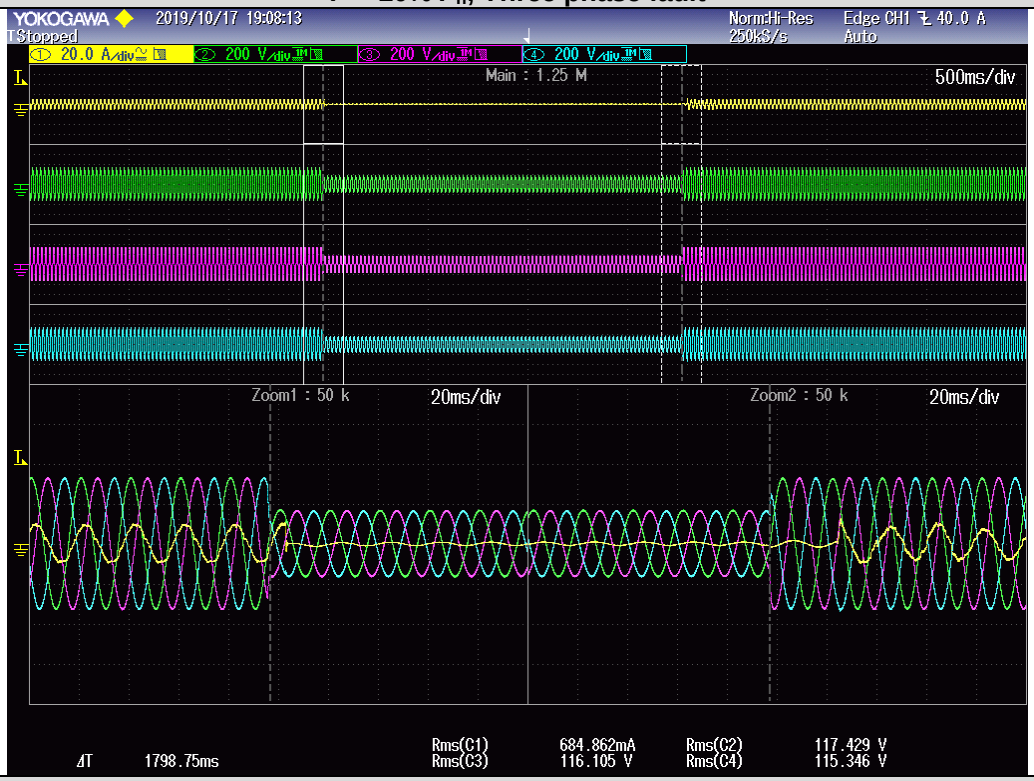


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

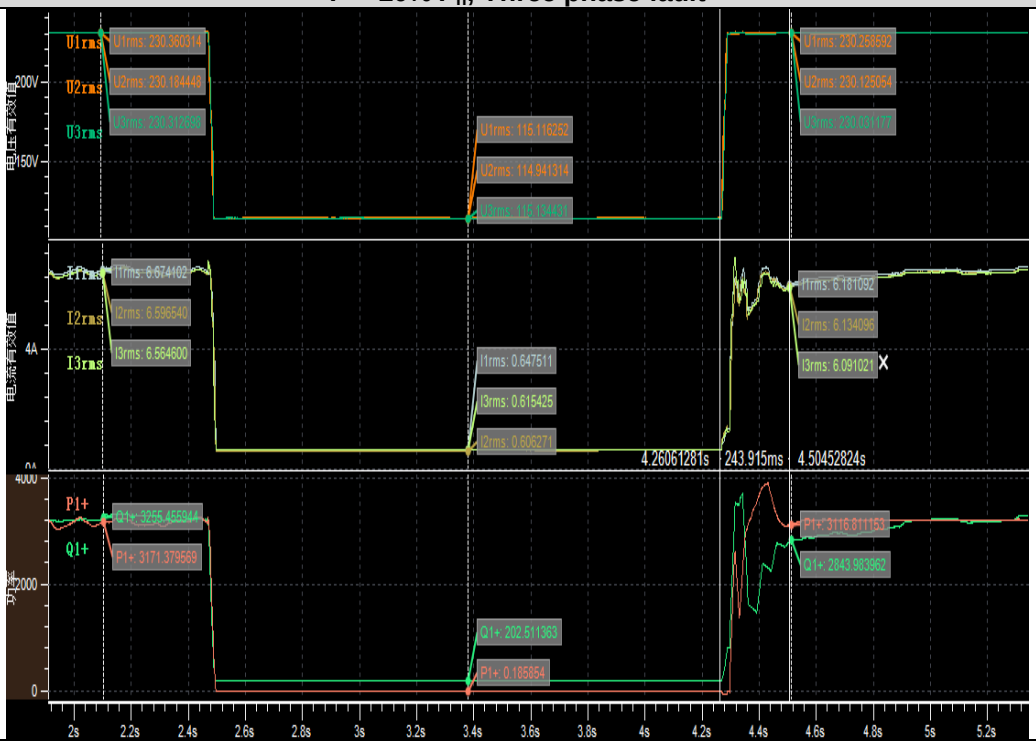
Test 16– Three-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 0, Three phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 17– Three-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 20% P_n, Three phase fault

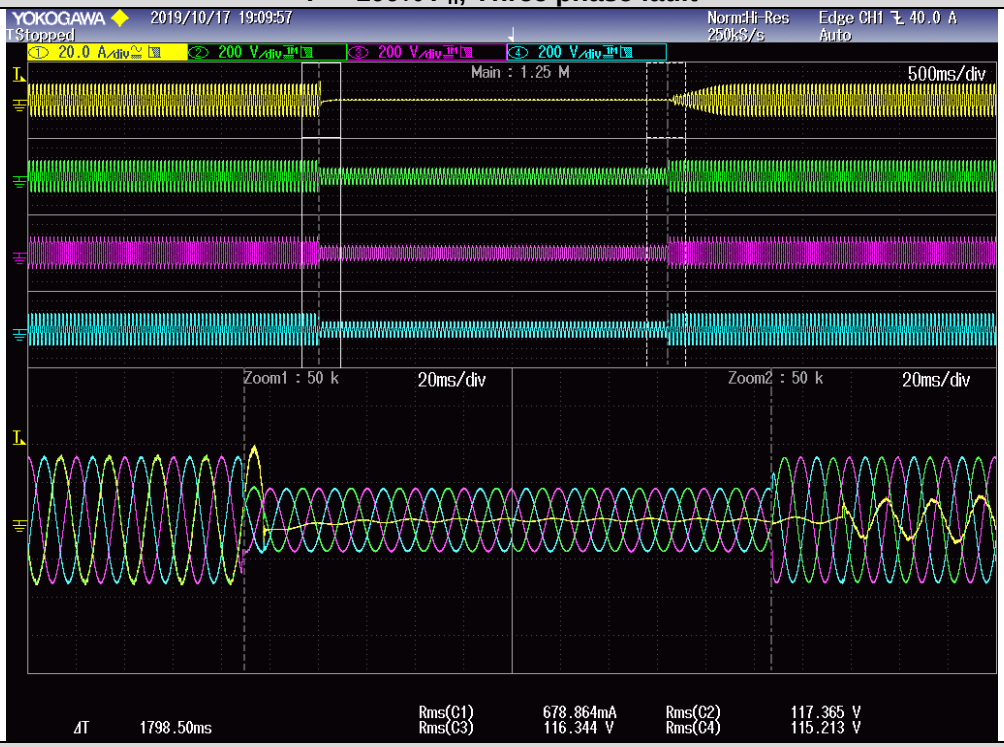


Test 17–Three -phase asymmetrical fault (U/U_n = 0.5): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Three phase fault

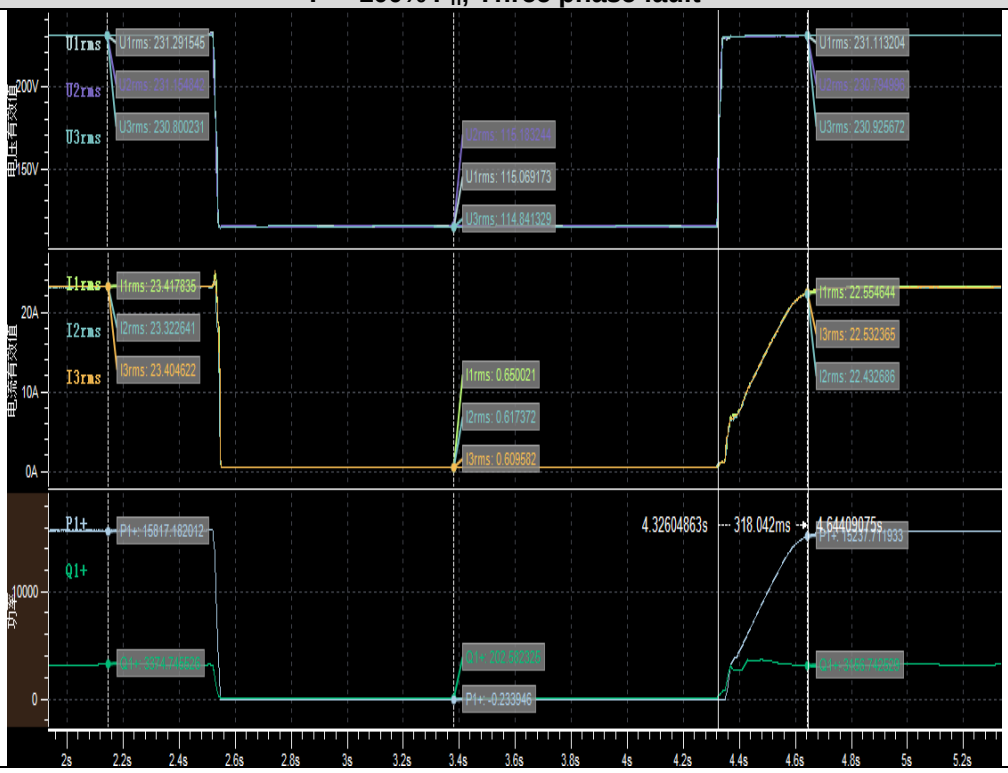


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 18– Three-phase asymmetrical fault (U/U_n = 0.5): Phase current and voltage of the whole failure
P = 100% P_n, Three phase fault

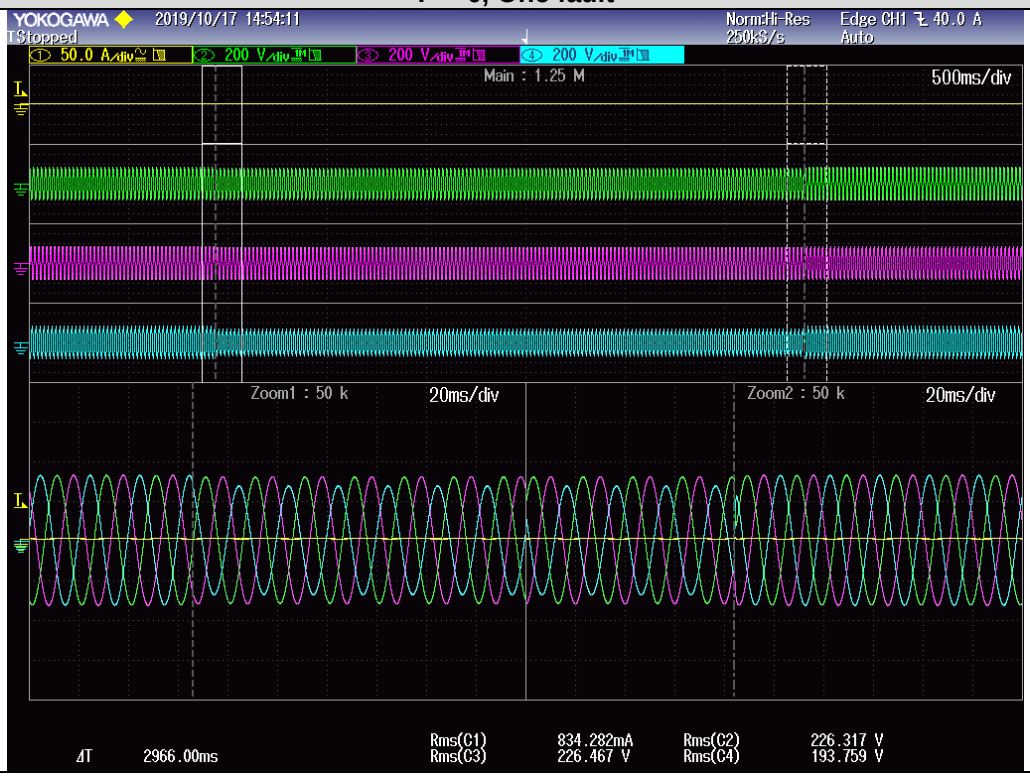


Test 18 –Three asymmetrical fault (U/U_n = 0.5): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Three phase fault



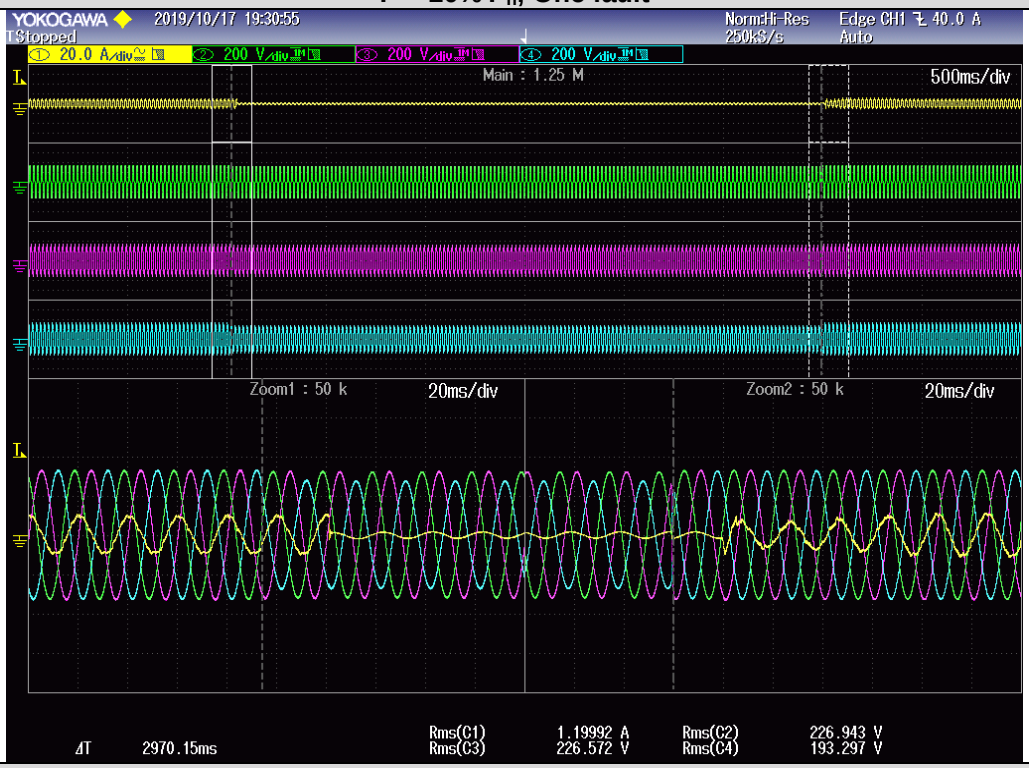
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 19– One-phase symmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure P = 0, One fault

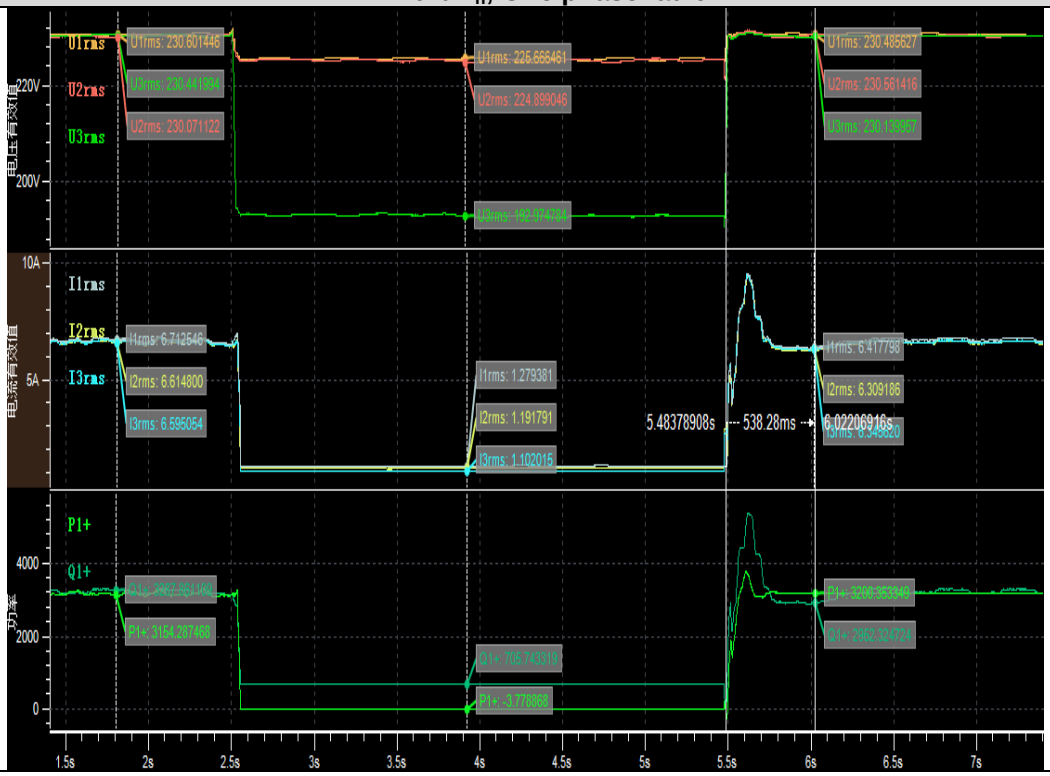


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 20– One-phase symmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure P = 20% P_n, One fault

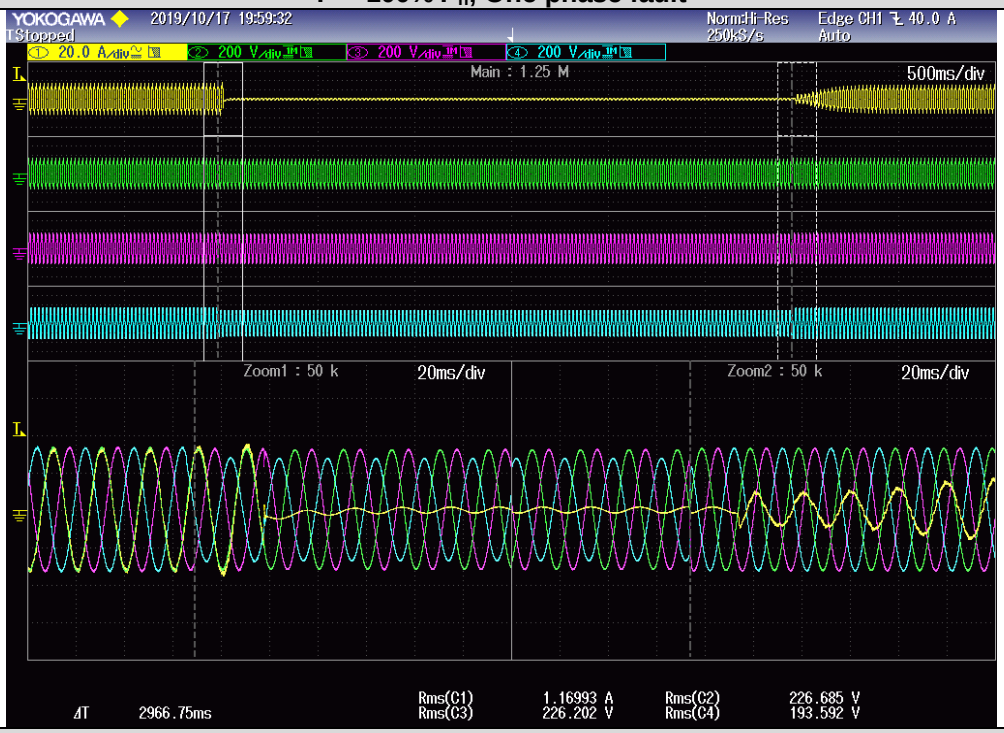


Test 20–One-phase symmetrical fault (U/U_n = 0.84): Phase currents after the voltage returns to continuous operating voltage range P = 20% P_n, One phase fault

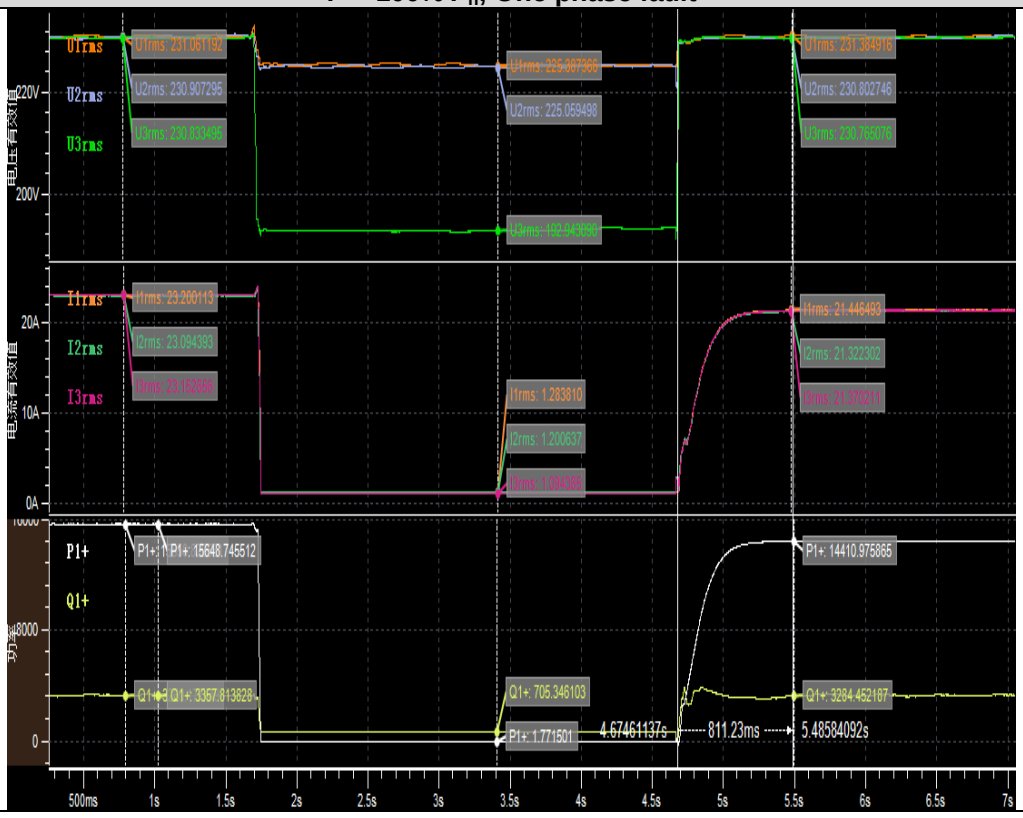


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 21–One-phase symmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure
P = 100% P_n, One phase fault

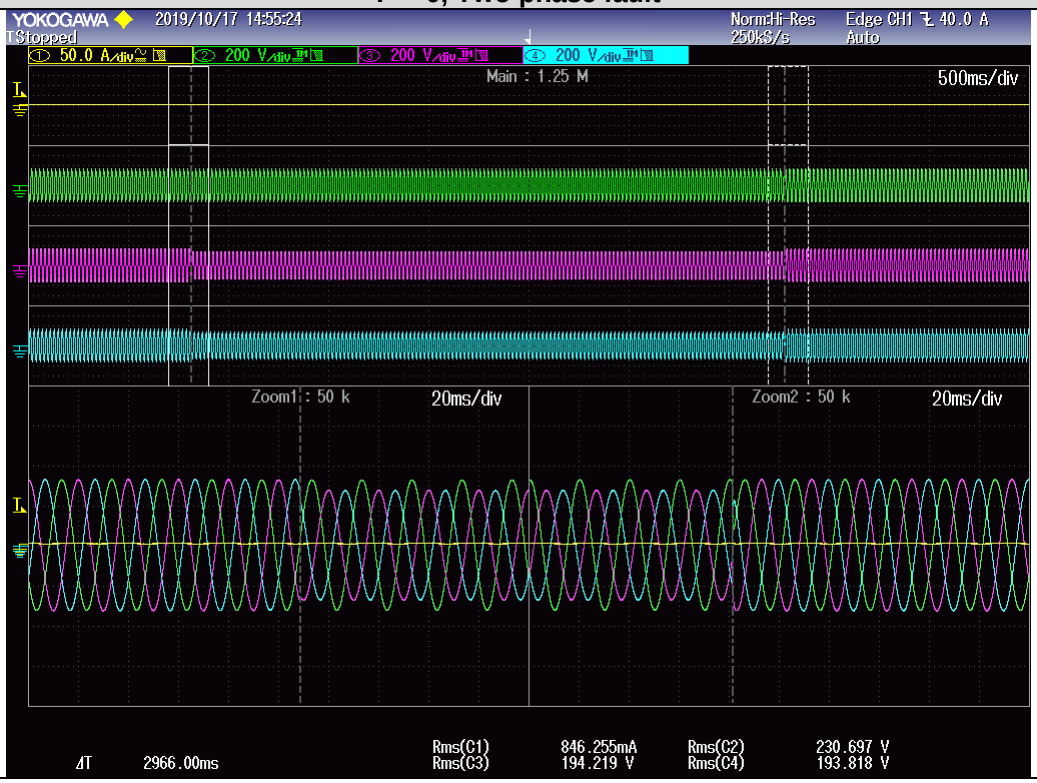


Test 21–One-phase symmetrical fault (U/U_n = 0.84): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, One phase fault



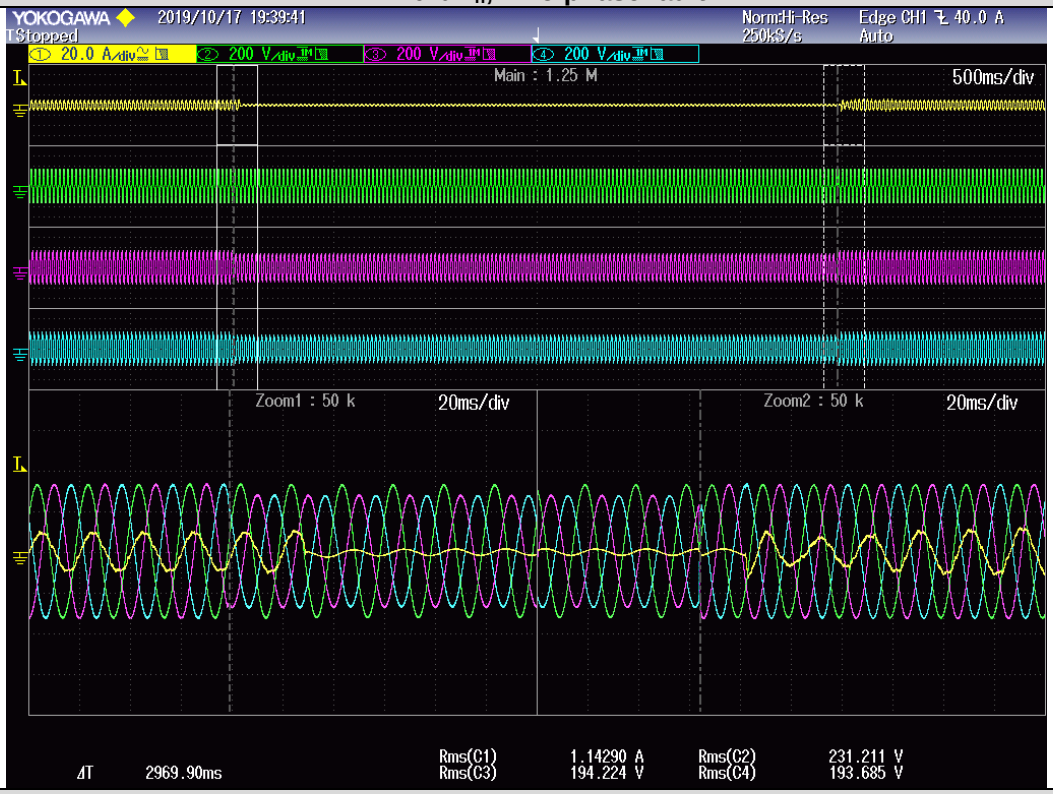
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 22–Two-phase asymmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure P = 0, Two phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

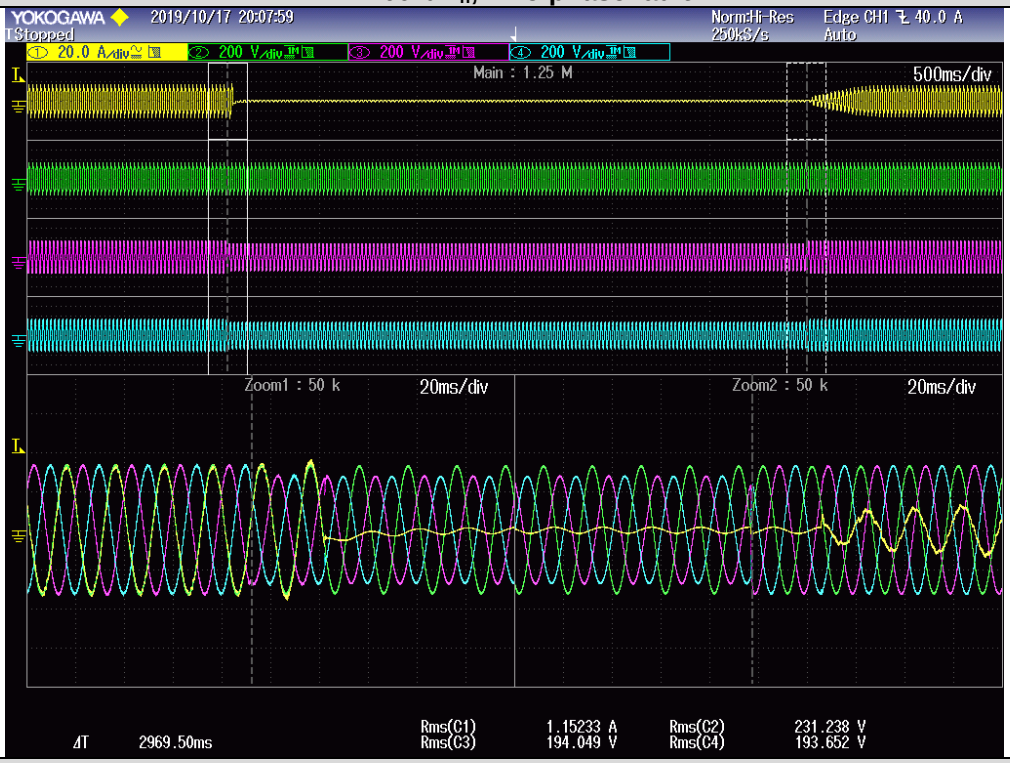
Test 23–Two-phase asymmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure
P = 20% P_n, Two phase fault



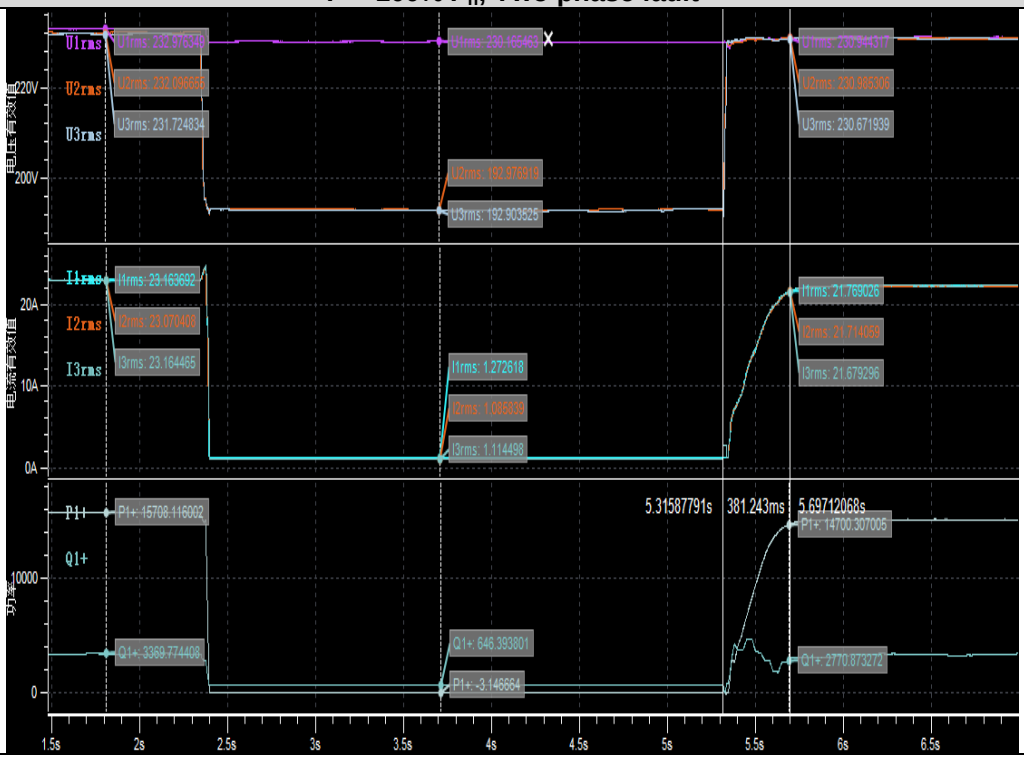
Test 23–Two-phase asymmetrical fault (U/U_n = 0.84): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Two phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 24–Two-phase asymmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure
P = 100% P_n, Two phase fault

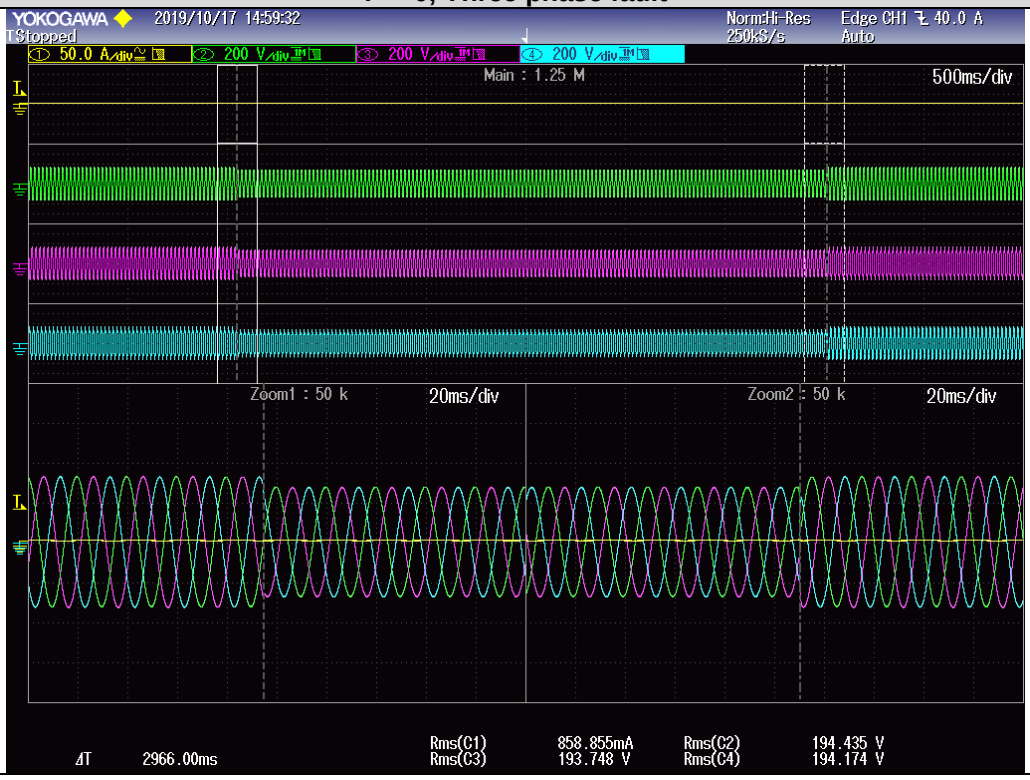


Test 24–Two-phase asymmetrical fault (U/U_n = 0.84): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Two phase fault



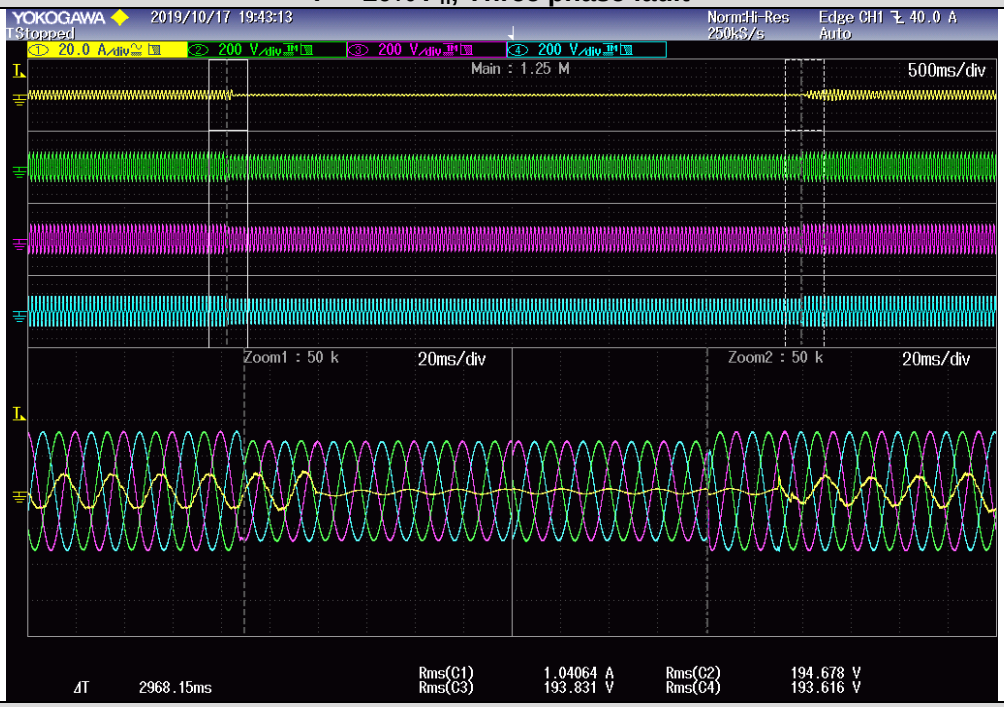
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 25–Three-phase asymmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure
P = 0, Three phase fault

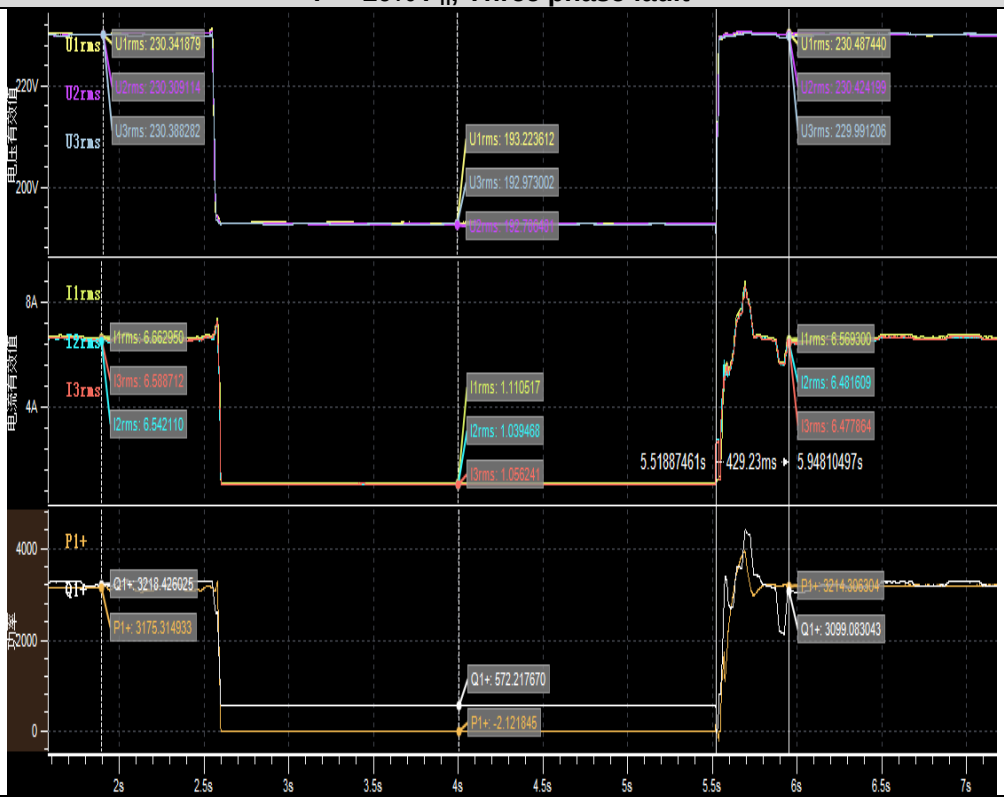


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 26–Three-phase asymmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure
P = 20% P_n, Three phase fault

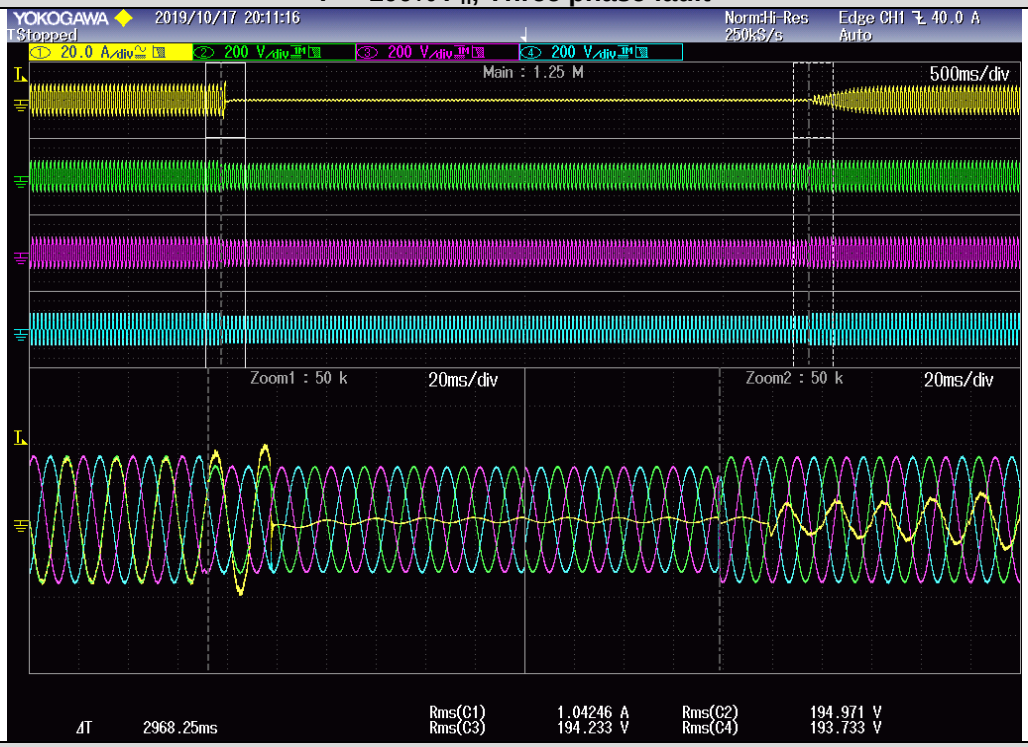


Test 26–Three-phase asymmetrical fault (U/U_n = 0.84): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Three phase fault

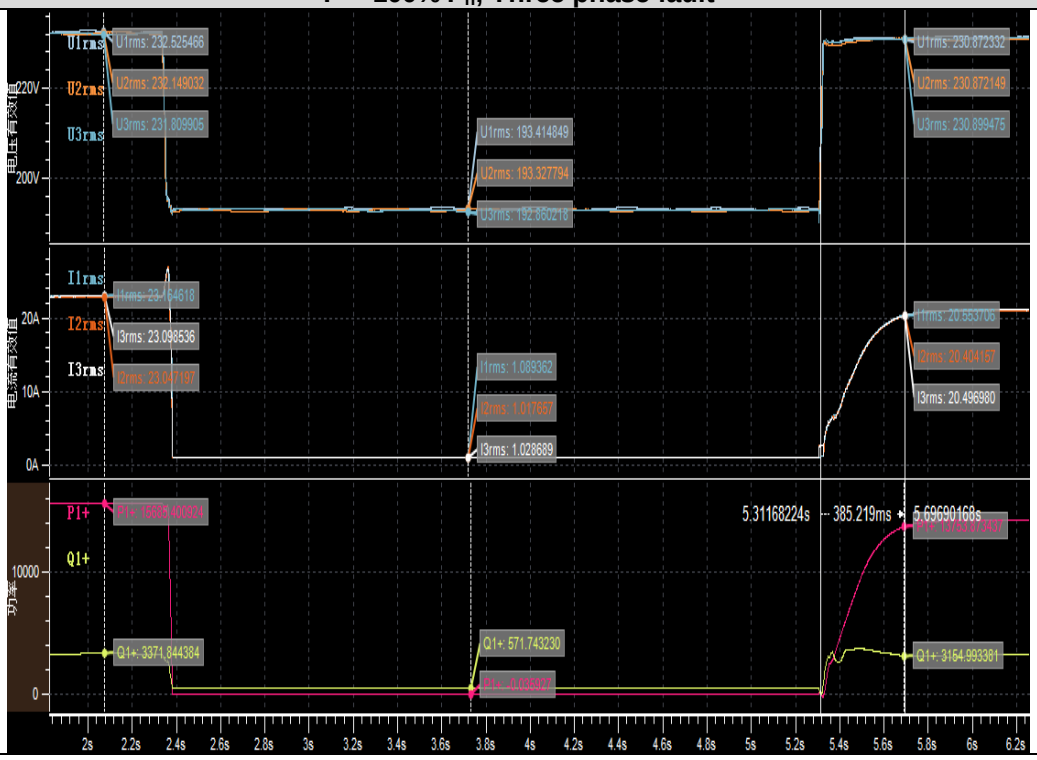


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 27–Three-phase asymmetrical fault (U/U_n = 0.84): Phase current and voltage of the whole failure
P = 100% P_n, Three phase fault



Test 27–Three-phase asymmetrical fault (U/U_n = 0.84): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Three phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.5.4 4.7.4.2.2	**TABLE: Over - voltage ride through (OVRT) Zero current mode for converter connected generating technology**						**P**
Test number	U/U_n [pu]	No. of phases fault	Output power level P set point (%P_n)	Required fault duration [ms]	Q set point (%Pn)	Average remaining voltage [%]	Duration of restoring network [ms]
1	1.25	One phase asymetric fault	P = 0	100	0	125%	N/A
2			P = 20% ± 5% Pn	100	20%	125%	589.2
3			P = 100% ± 5% Pn	100	20%	125%	330.6
4		Two phase asymetric fault	P = 0	100	0	125%	N/A
5			P = 20% ± 5% Pn	100	20%	125%	208.4
6			P = 100% ± 5% Pn	100	20%	125%	307.8
7		Three phase symetric fault	P = 0	100	0	125%	N/A
8			P = 20% ± 5% Pn	100	20%	125%	196.4
9			P = 100% ± 5% Pn	100	20%	125%	318.6
10	1.20	One phase asymetric fault	P = 0	5000	0	120%	N/A
11			P = 20% ± 5% Pn	5000	20%	120%	562.3
12			P = 100% ± 5% Pn	5000	20%	120%	600.9
13		Two phase asymetric fault	P = 0	5000	0	120%	N/A
14			P = 20% ± 5% Pn	5000	20%	120%	516.9
15			P = 100% ± 5% Pn	5000	20%	120%	704.4
16		Three phase symetric fault	P = 0	5000	0	120%	N/A
17			P = 20% ± 5% Pn	5000	20%	120%	576.2
18			P = 100% ± 5% Pn	5000	20%	120%	723.9
19	1.15	One phase asymetric fault	P = 0	60000	0	115%	N/A
20			P = 20% ± 5% Pn	60000	20%	115%	607.3
21			P = 100% ± 5% Pn	60000	20%	115%	563.4
22		Two phase asymetric fault	P = 0	60000	0	115%	N/A
23			P = 20% ± 5% Pn	60000	20%	115%	615.3
24			P = 100% ± 5% Pn	60000	20%	115%	645.9
25		Three phase symetric fault	P = 0	60000	0	115%	N/A
26			P = 20% ± 5% Pn	60000	20%	115%	770.6
27			P = 100% ± 5% Pn	60000	20%	115%	789.7

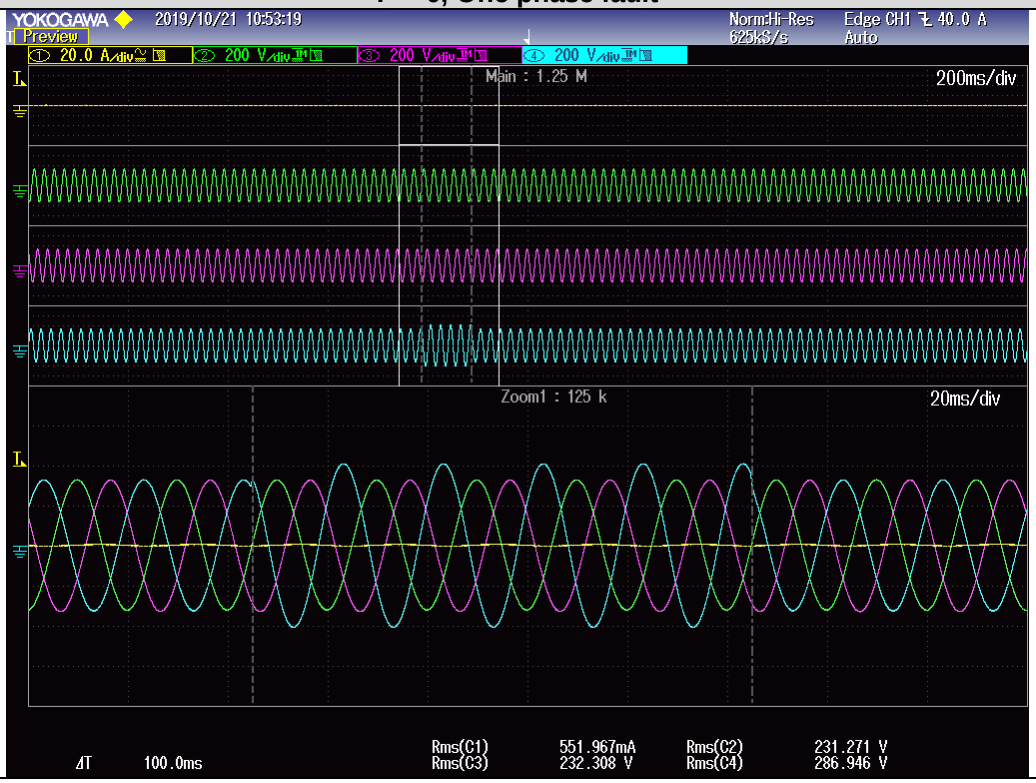
Note:

The converters will go into zero current mode and reduce their current within 0.1s down to or below 10 % of the rated current when the voltage is outside of static voltage range.

After the voltage returns to continuous operating voltage range of 85%U_n to 110%U_n, 90 % of pre-fault power or available power whichever is the smallest shall be resumed as fast as possible, but at the latest within 1 s unless the DSO and the responsible party requires another value.

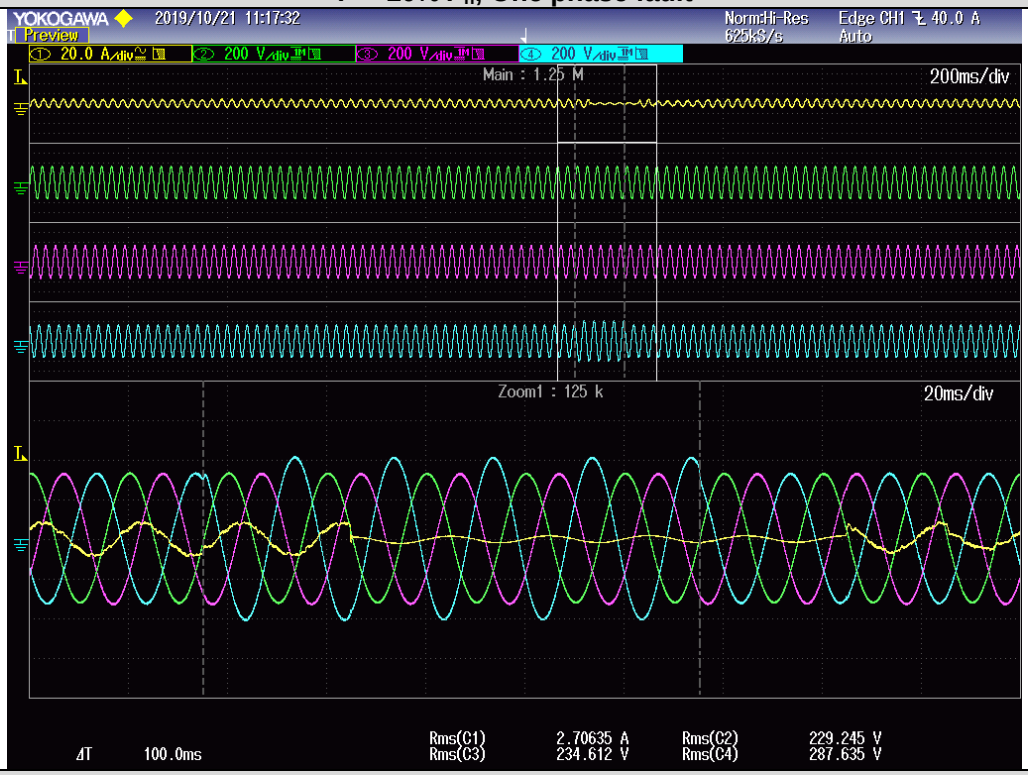
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 1 – One-phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure P = 0, One phase fault

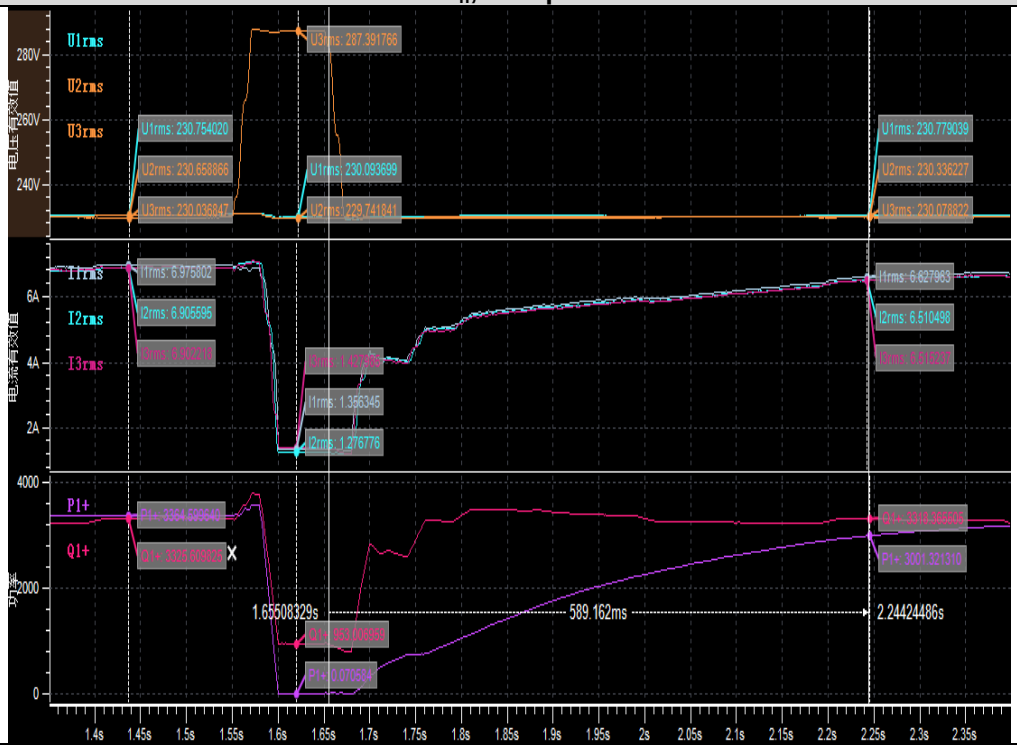


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 2 – One -phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 20% P_n, One phase fault

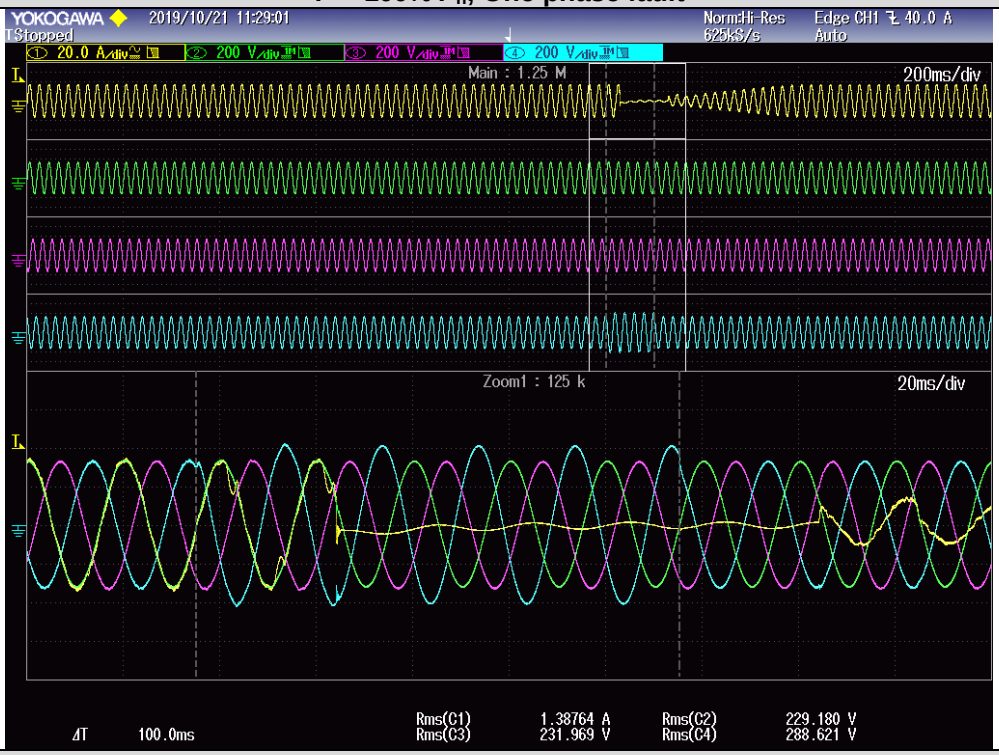


Test 2 – One -phase asymmetrical fault (U/U_n = 1.25): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, One phase fault

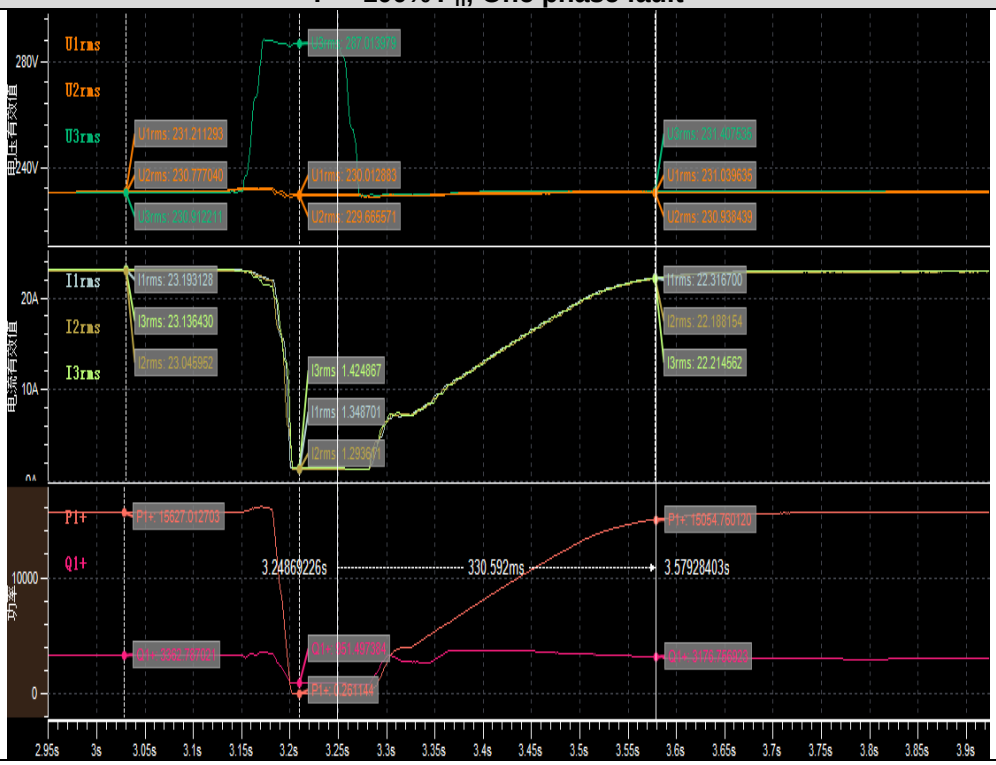


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 3 – One -phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 100% P_n, One phase fault

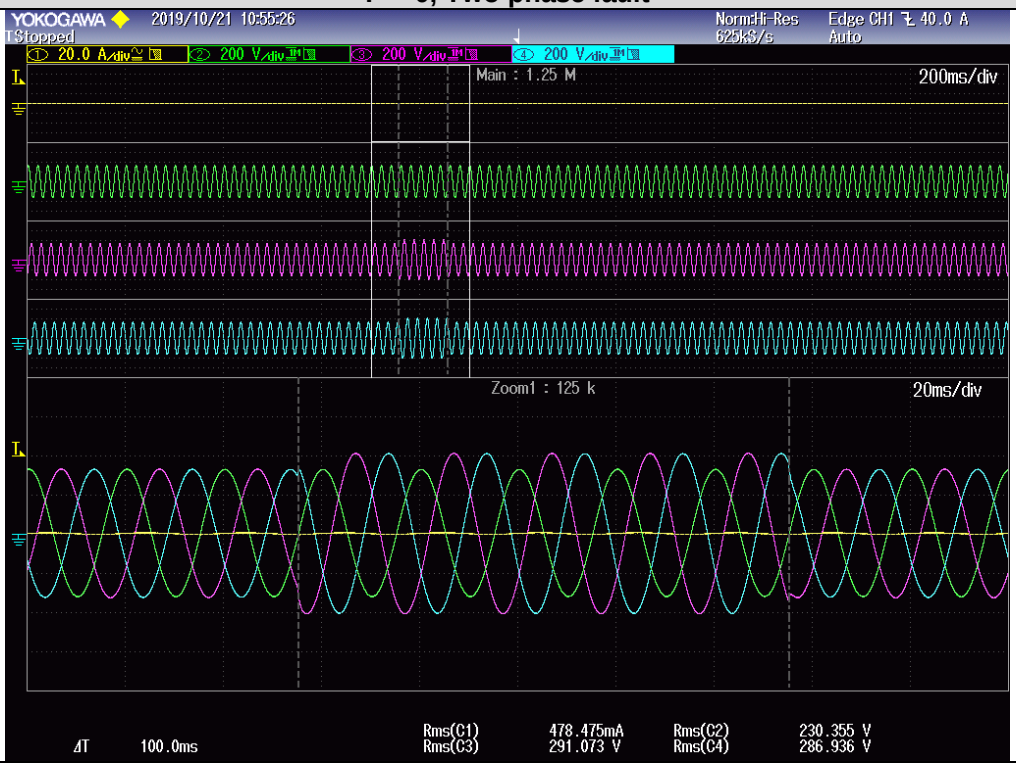


Test 3 – One -phase asymmetrical fault (U/U_n = 1.25): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, One phase fault



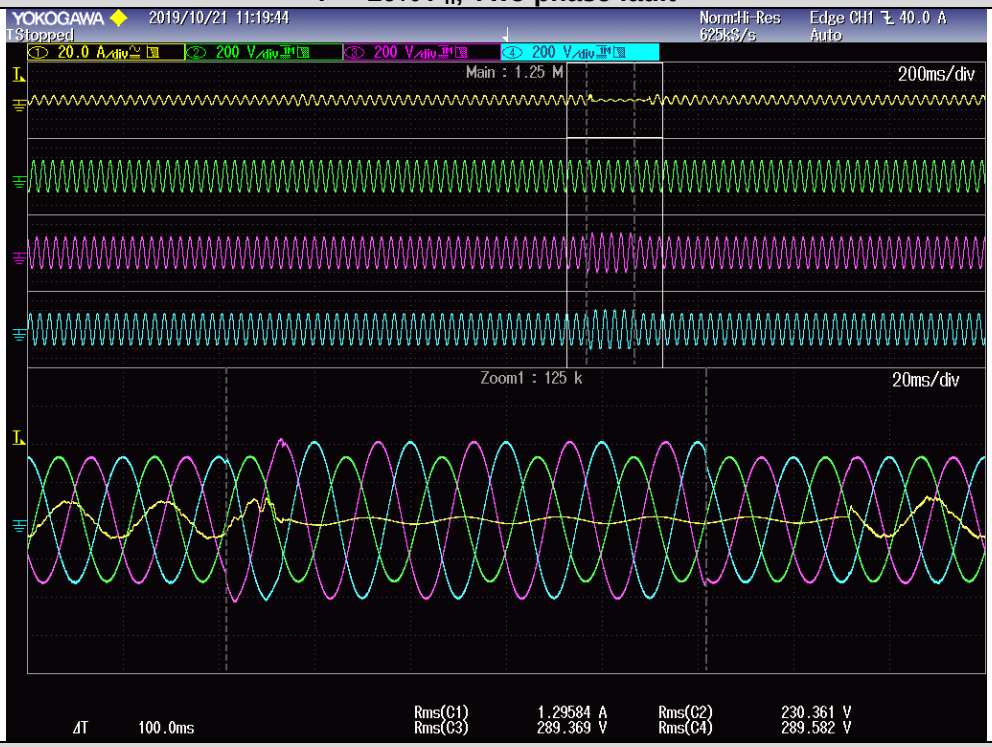
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 4 – Two-phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure P = 0, Two phase fault

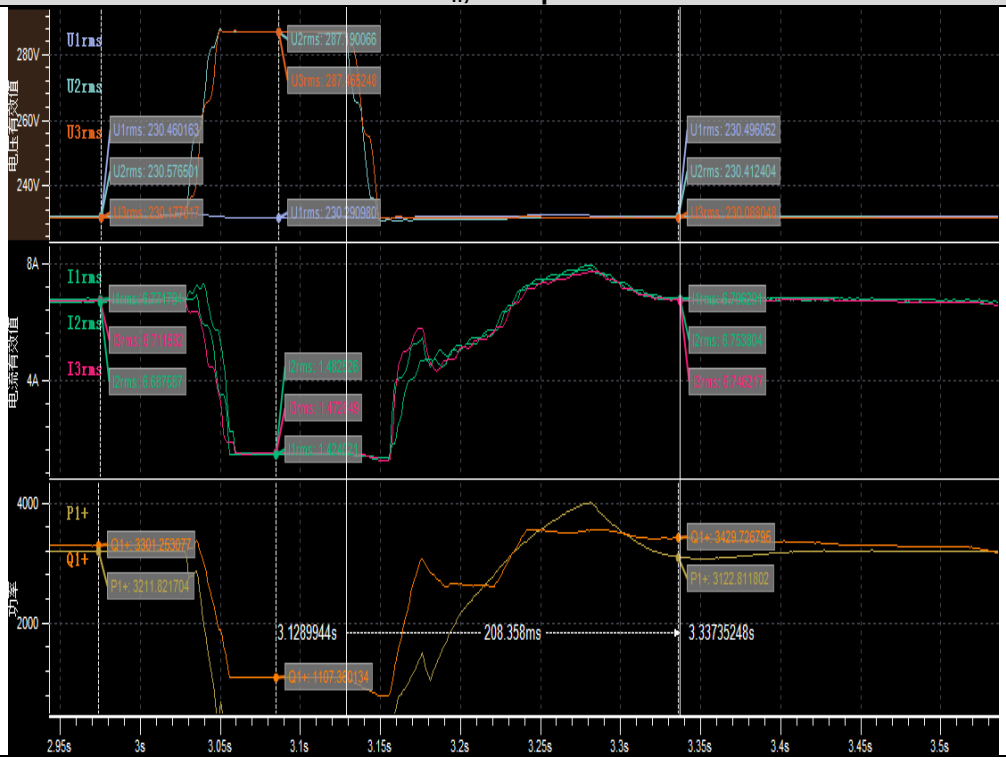


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 5 – Two -phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 20% P_n, Two phase fault

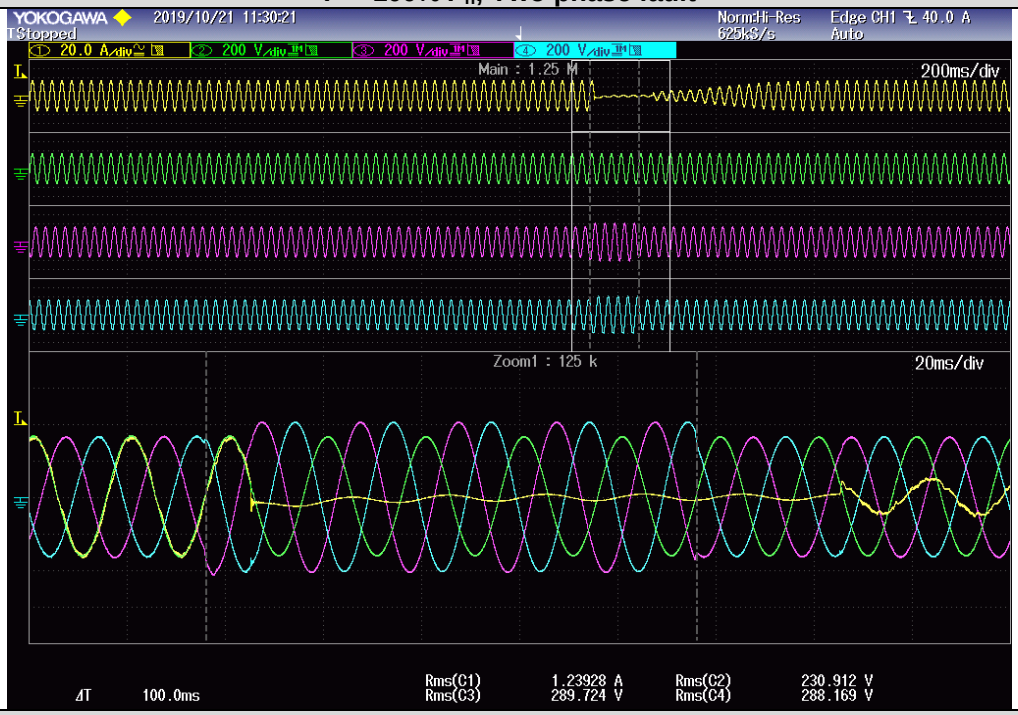


Test 5 – Two -phase asymmetrical fault (U/U_n = 1.25): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Two phase fault

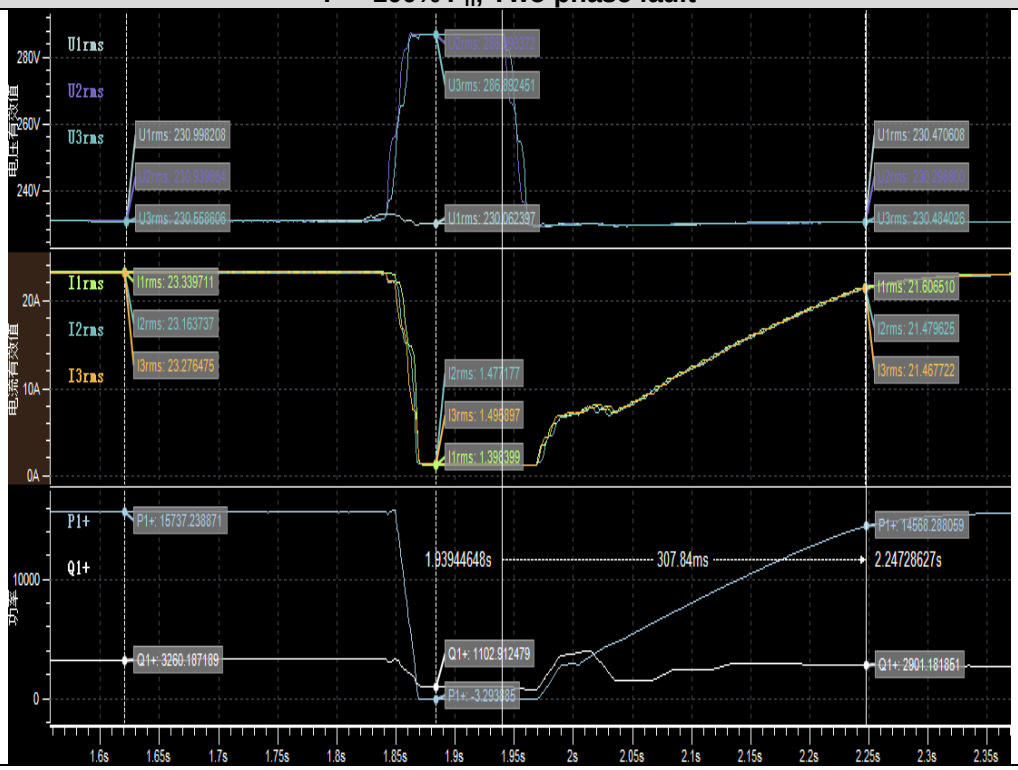


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 6 – Two -phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 100% P_n, Two phase fault



Test 6 –Two-phase asymmetrical fault (U/U_n = 1.25): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Two phase fault



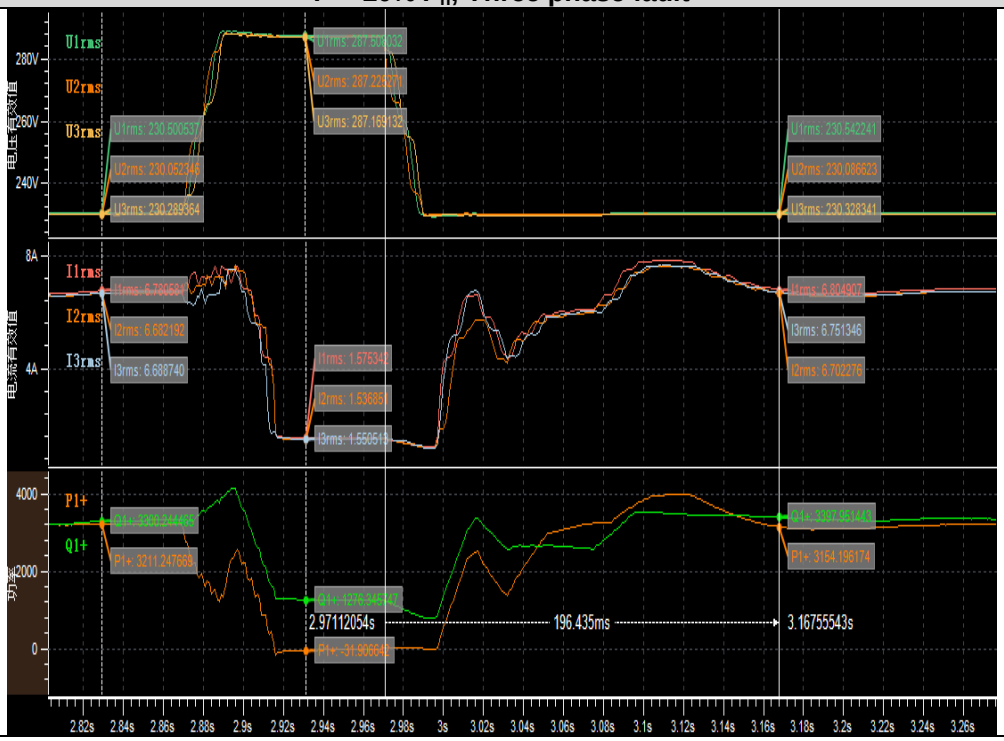
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 7 – Three-phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 0, Three phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

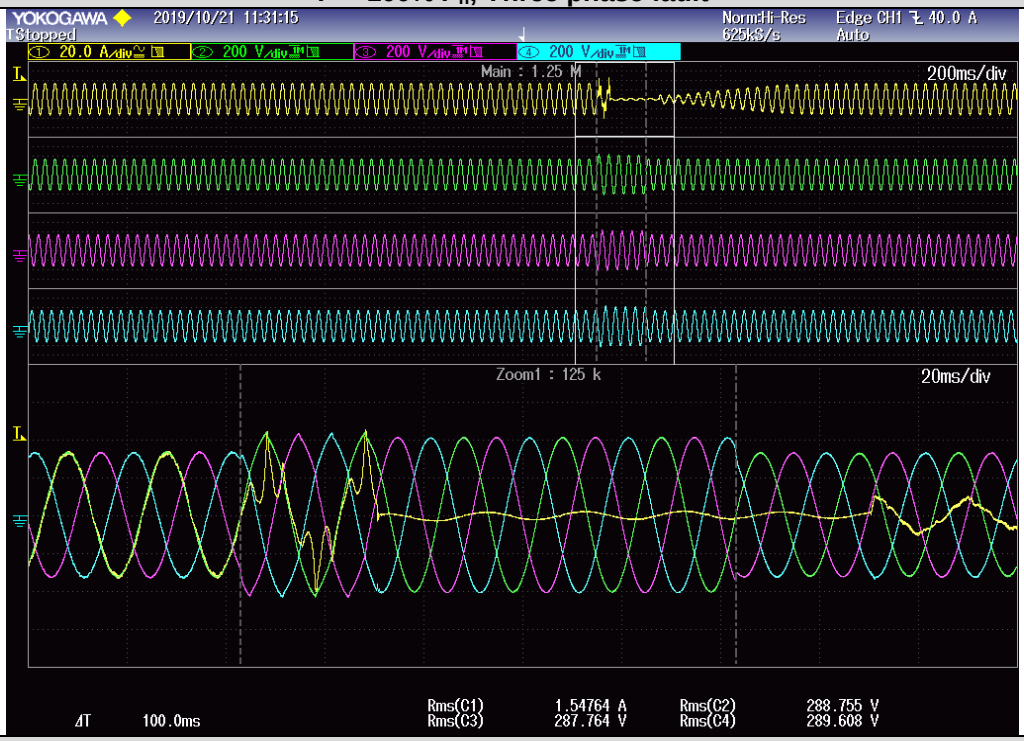
Test 8 – Three-phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 20% P_n, Three phase fault

Test 8– Three-phase asymmetrical fault (U/U_n = 1.25): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Three phase fault

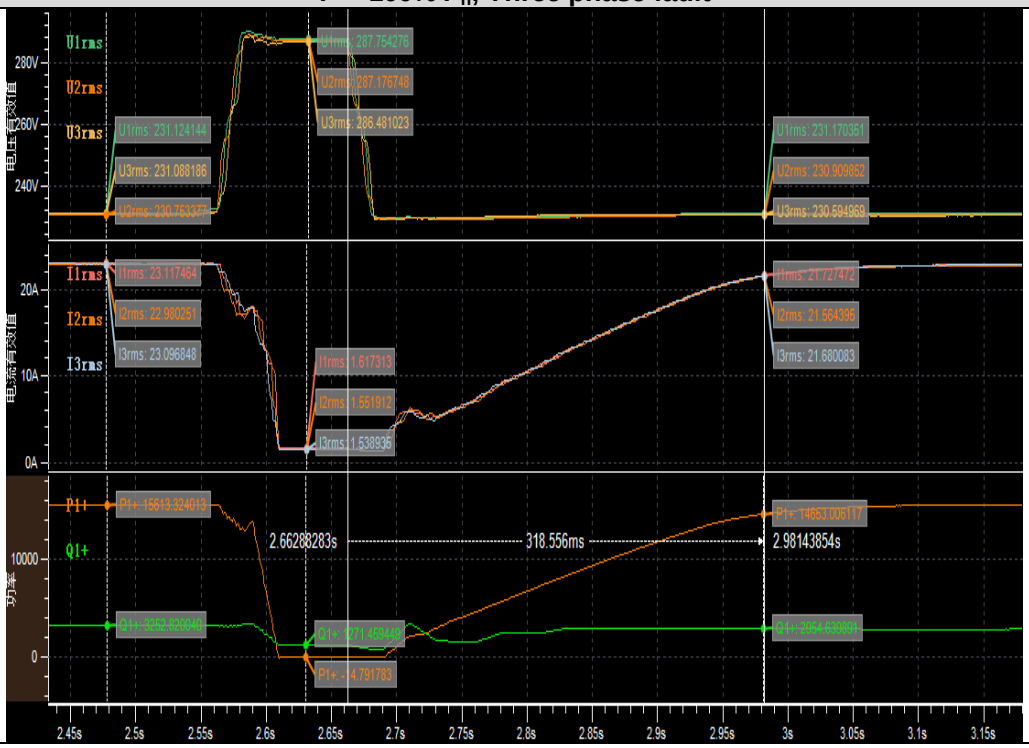


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 9 – Three -phase asymmetrical fault (U/U_n = 1.25): Phase current and voltage of the whole failure
P = 100% P_n, Three phase fault



Test 9 – Three -phase asymmetrical fault (U/U_n = 1.25): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Three phase fault



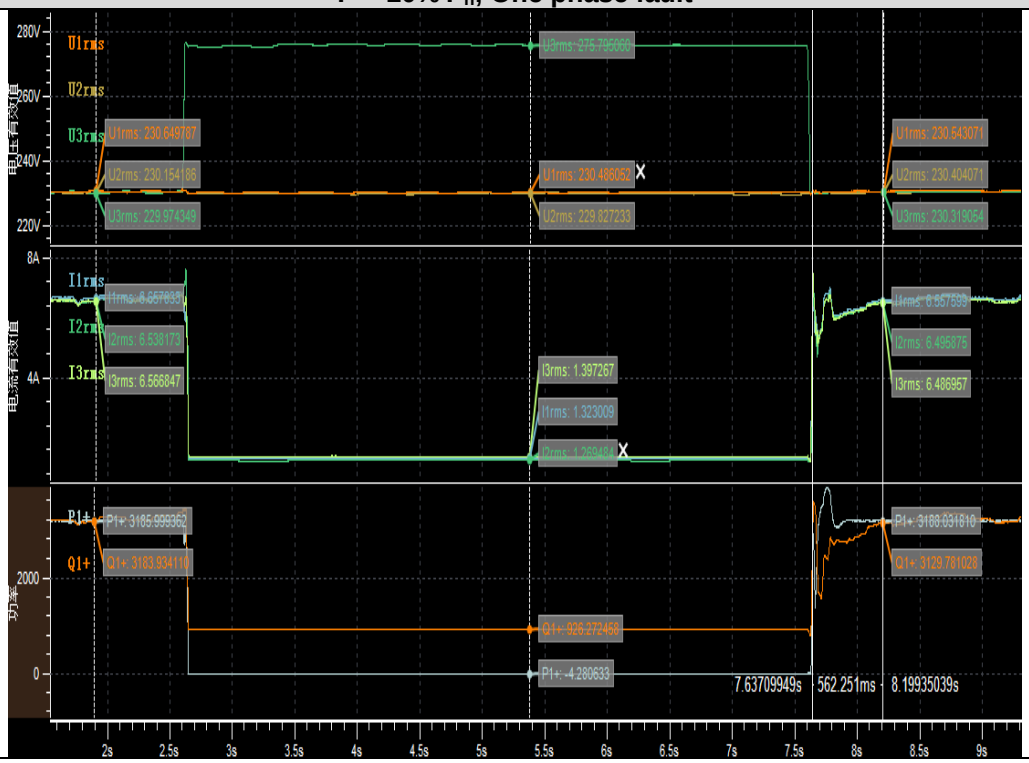
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 10 – One-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 0, One phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 11 – One-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 20% P_n, One phase fault

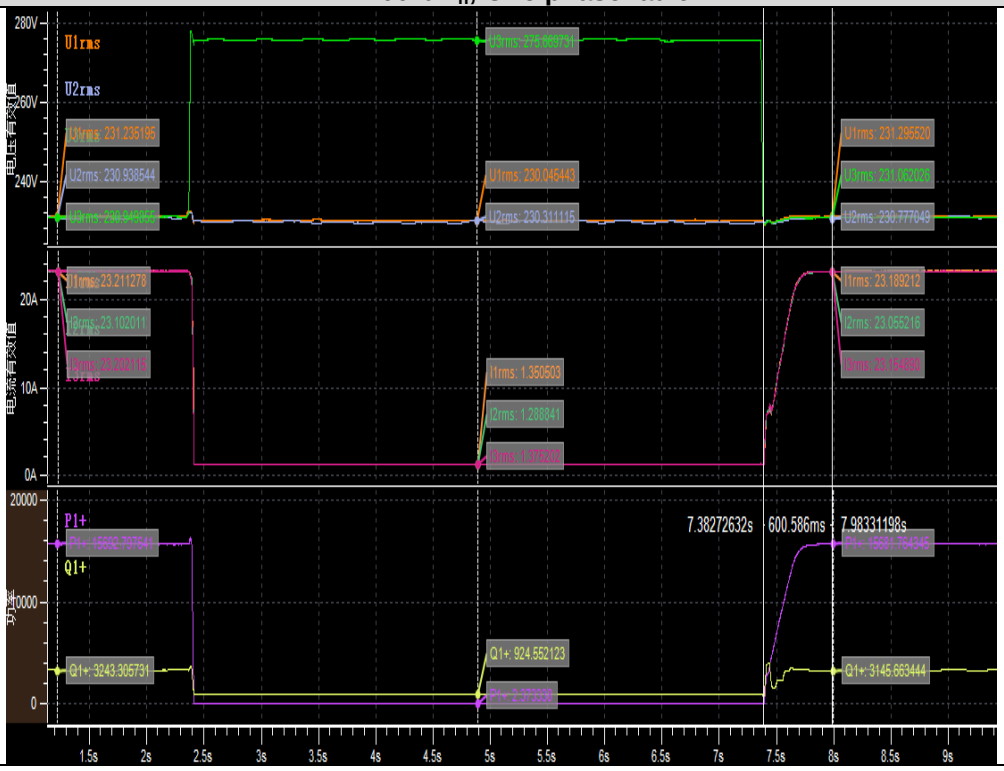
Test 11– One-phase asymmetrical fault (U/U_n = 1.20): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, One phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

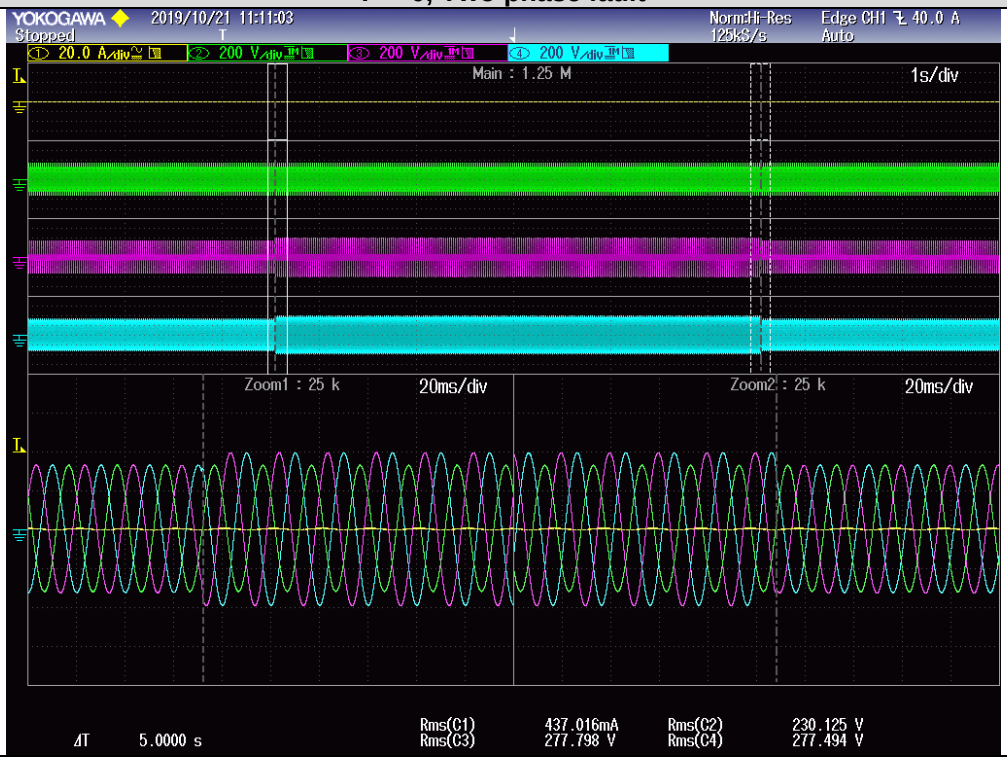
Test 12– One-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 100% P_n, One phase fault

Test 12– One-phase asymmetrical fault (U/U_n = 1.20): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, One phase fault



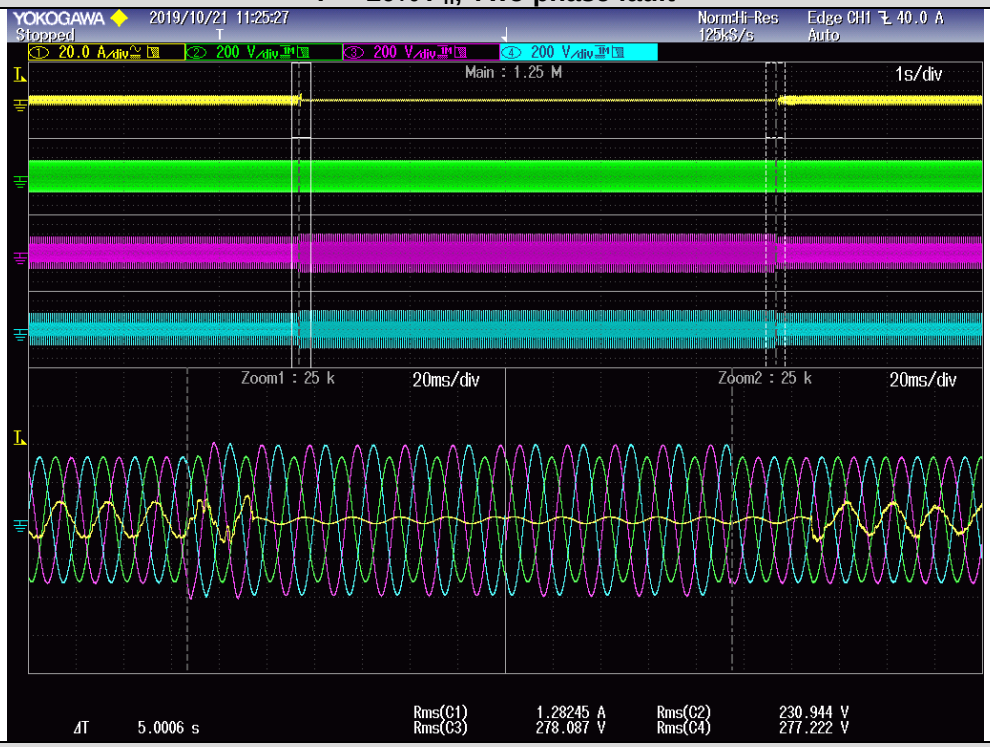
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 13 – Two-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 0, Two phase fault

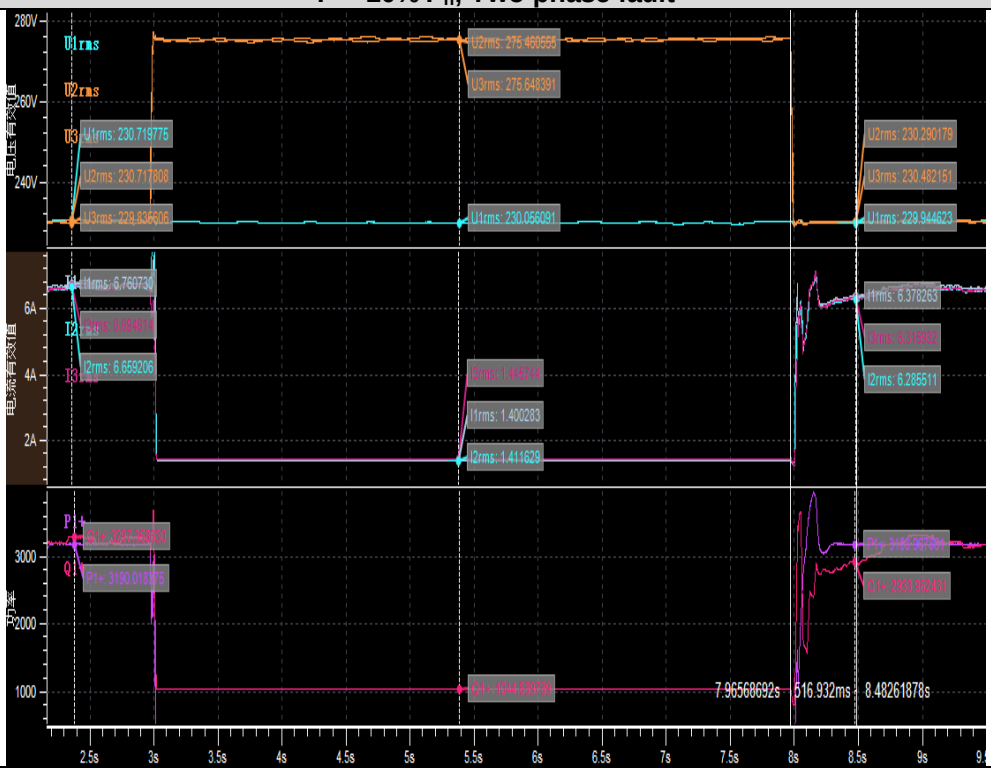


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 14 – Two-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 20% P_n, Two phase fault



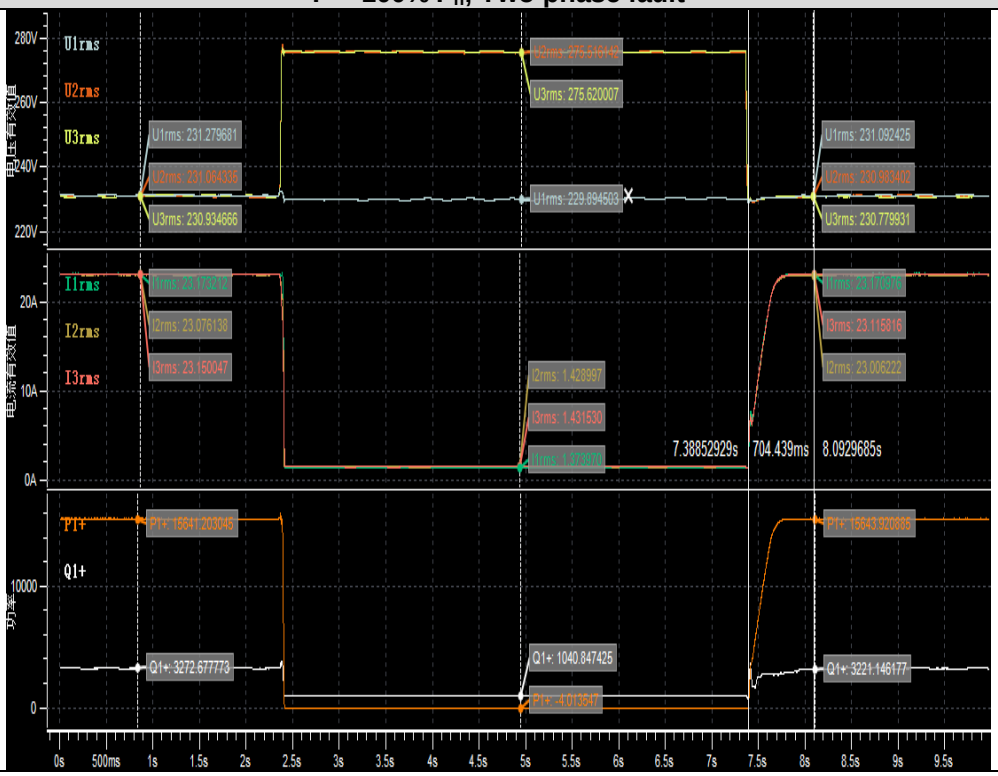
Test 14 – Two-phase asymmetrical fault (U/U_n = 1.20): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Two phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 15 – Two-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 100% P_n, Two phase fault

Test 15 – Two-phase asymmetrical fault (U/U_n = 1.20): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Two phase fault

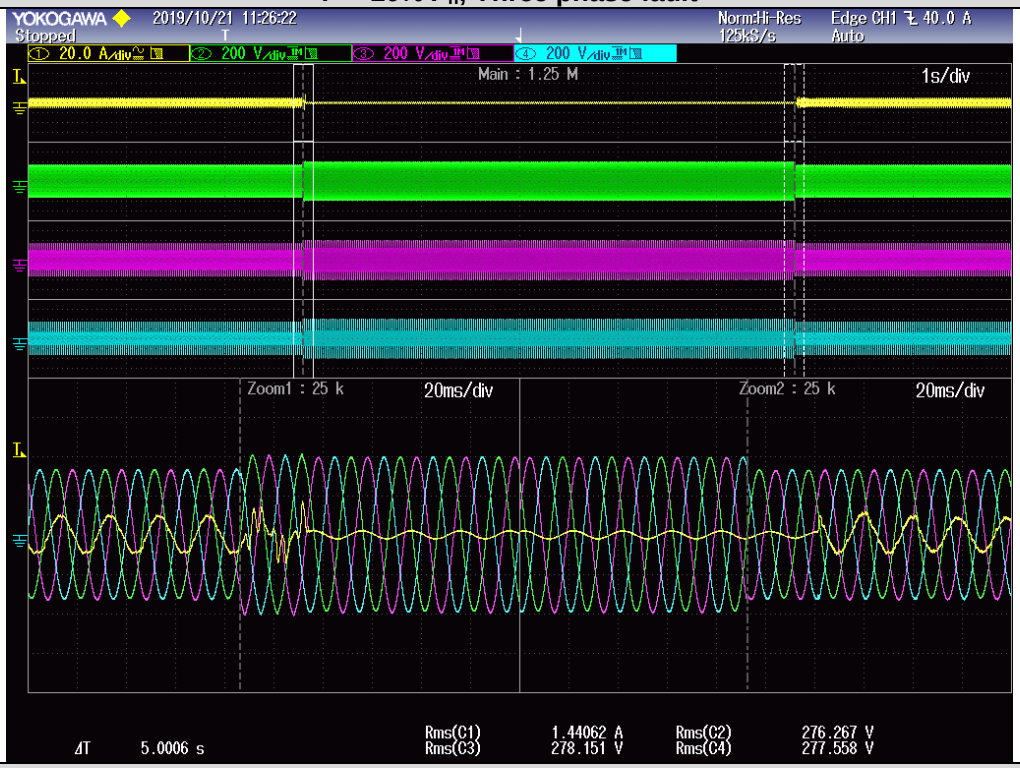


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

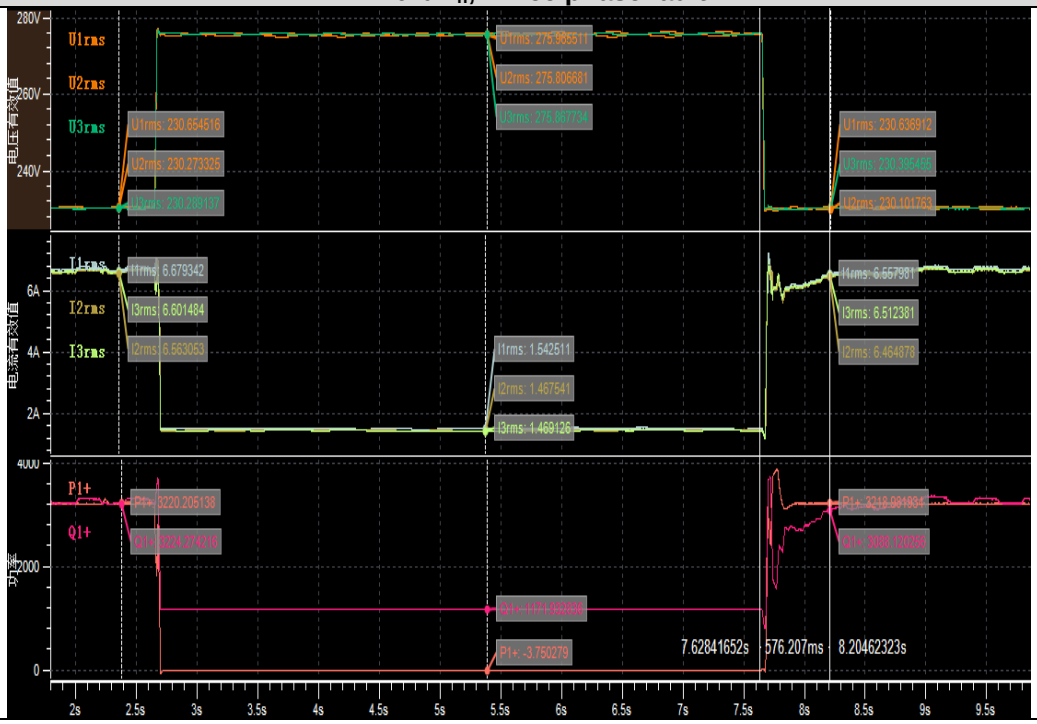
Test 16 – Three-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 0, Three phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 17 – Three-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 20% P_n, Three phase fault

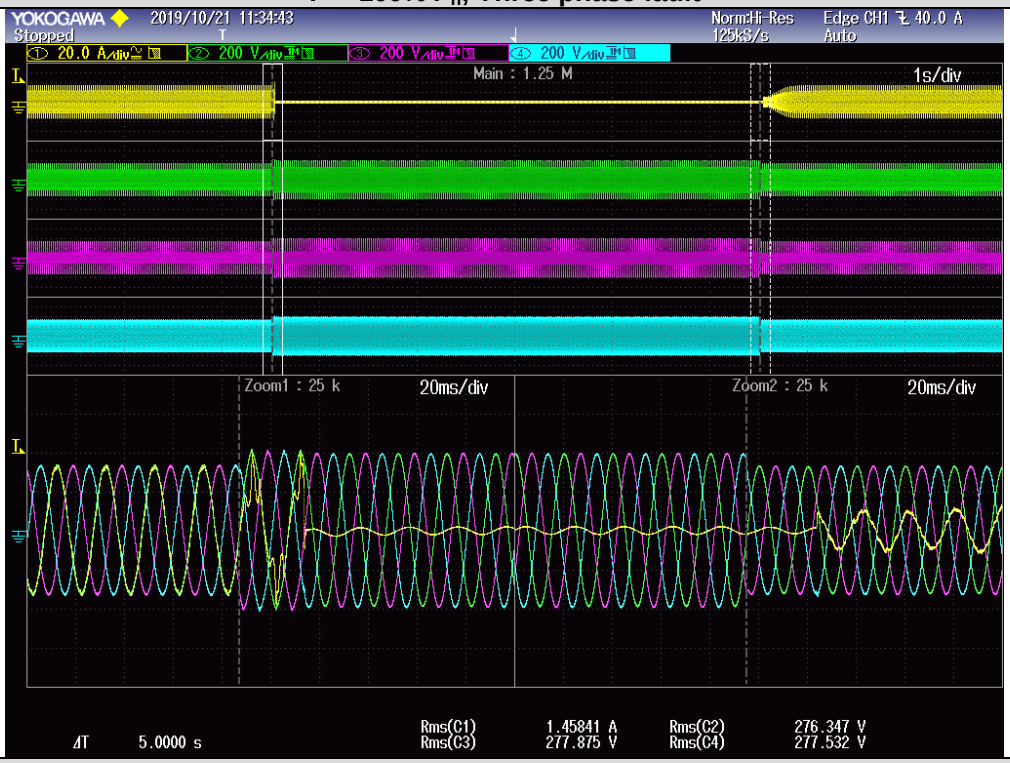


Test 17–Three-phase asymmetrical fault (U/U_n = 1.20): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Three phase fault

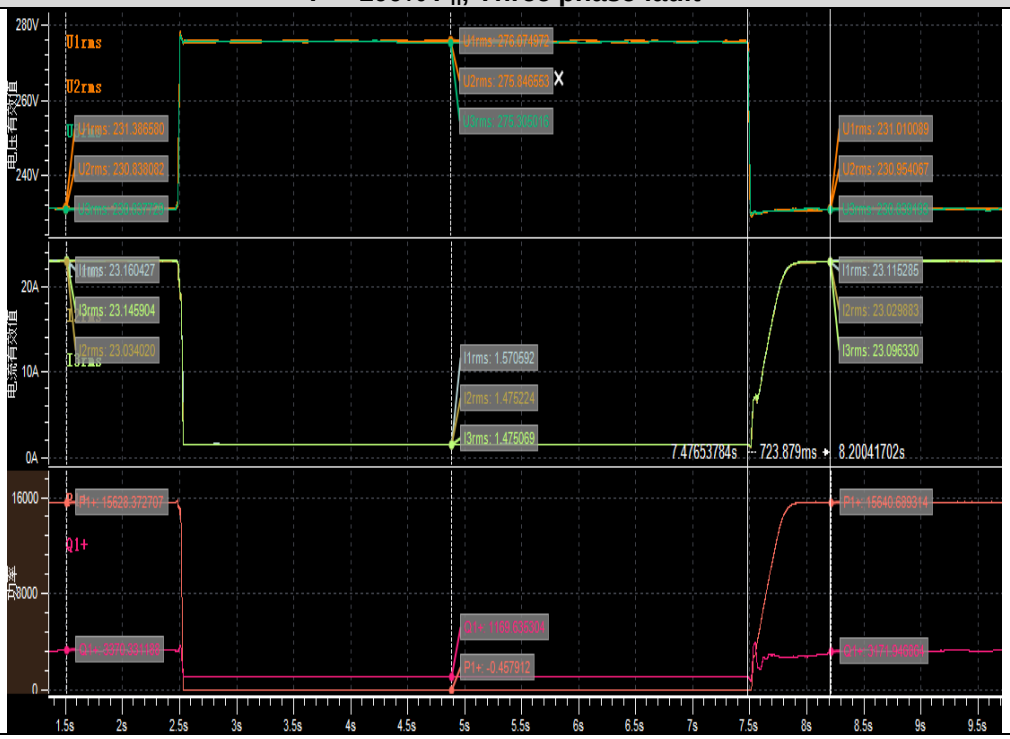


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 18 – Three-phase asymmetrical fault (U/U_n = 1.20): Phase current and voltage of the whole failure
P = 100% P_n, Three phase fault



Test 18 – Three-phase asymmetrical fault (U/U_n = 1.20): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Three phase fault

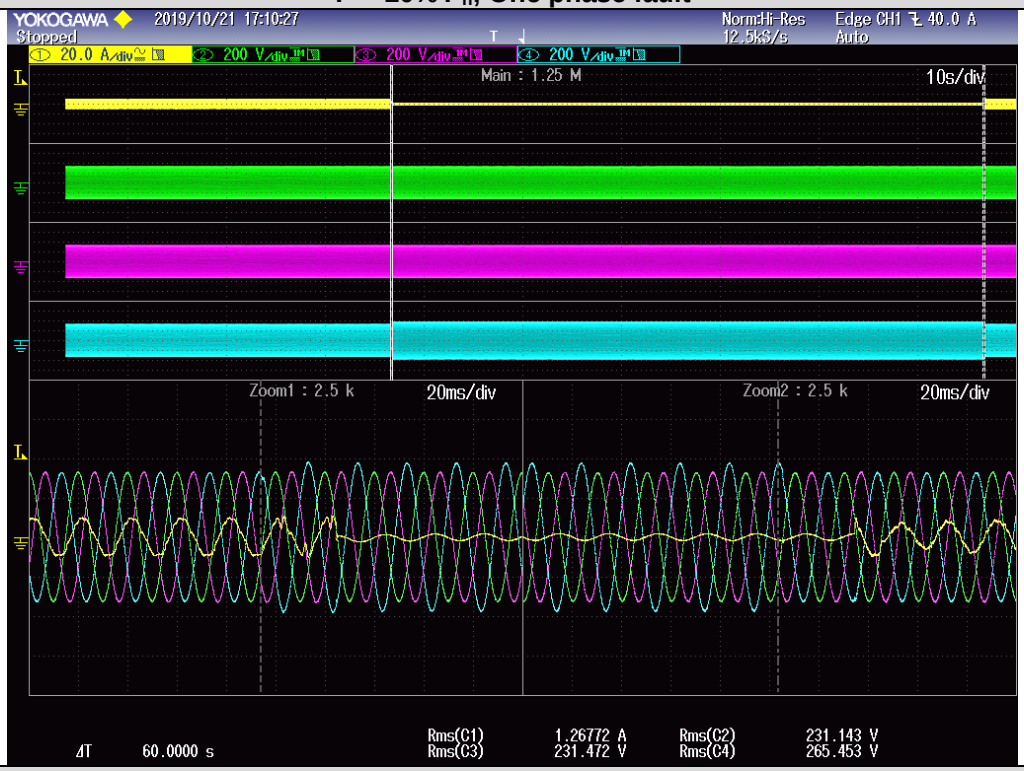


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

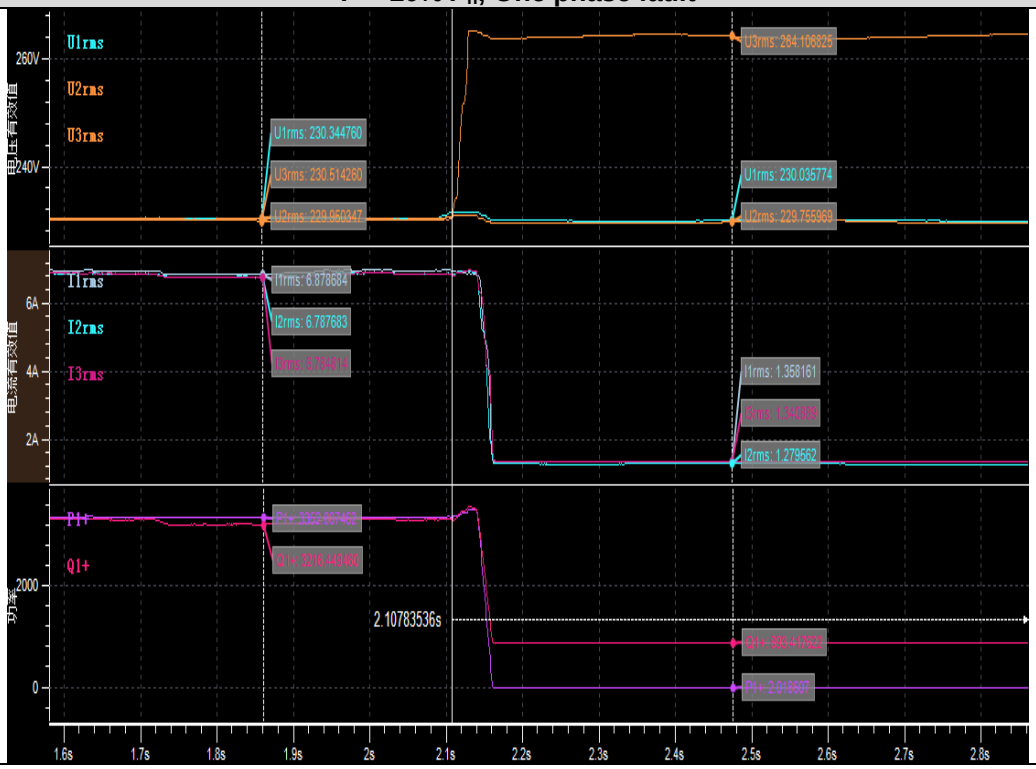
Test 19 – One-phase symmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure P = 0, One phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

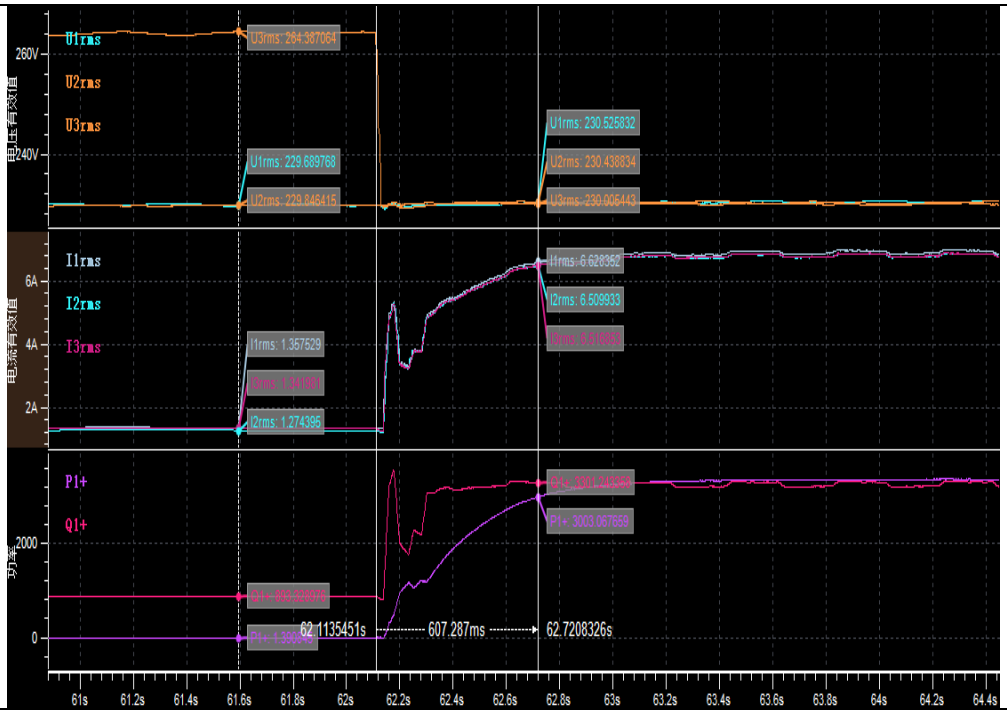
Test 20 – One-phase symmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 20% P_n, One phase fault



Test 20 – One-phase symmetrical fault (U/U_n = 1.15): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, One phase fault



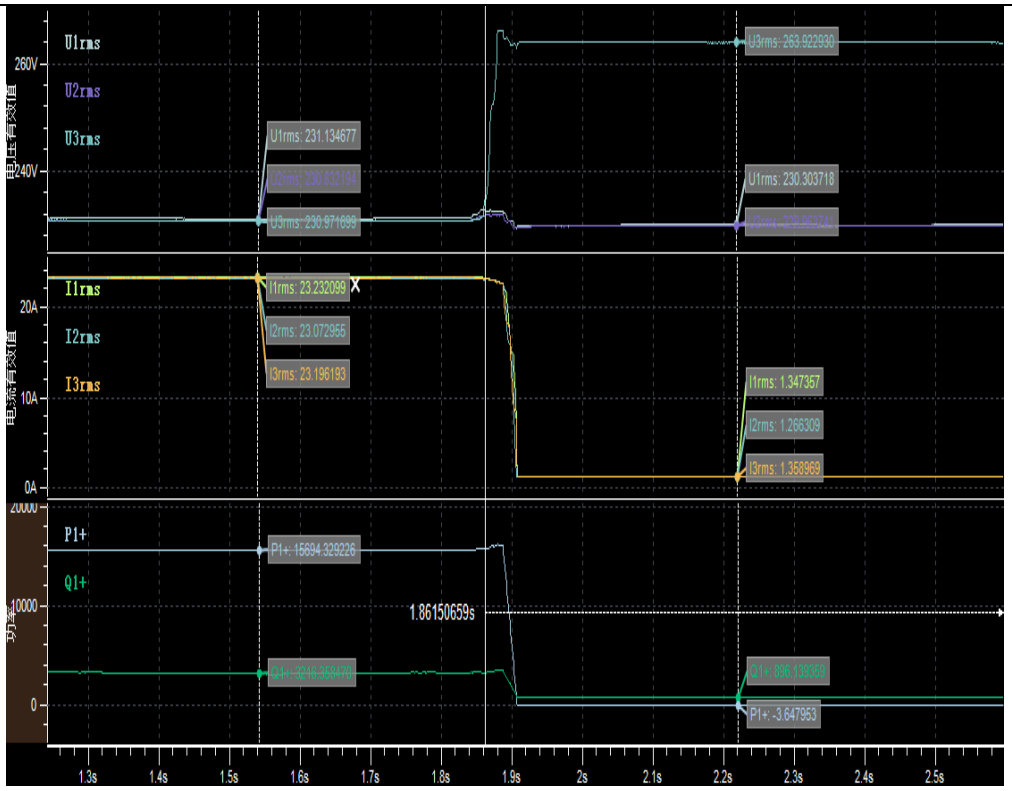
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

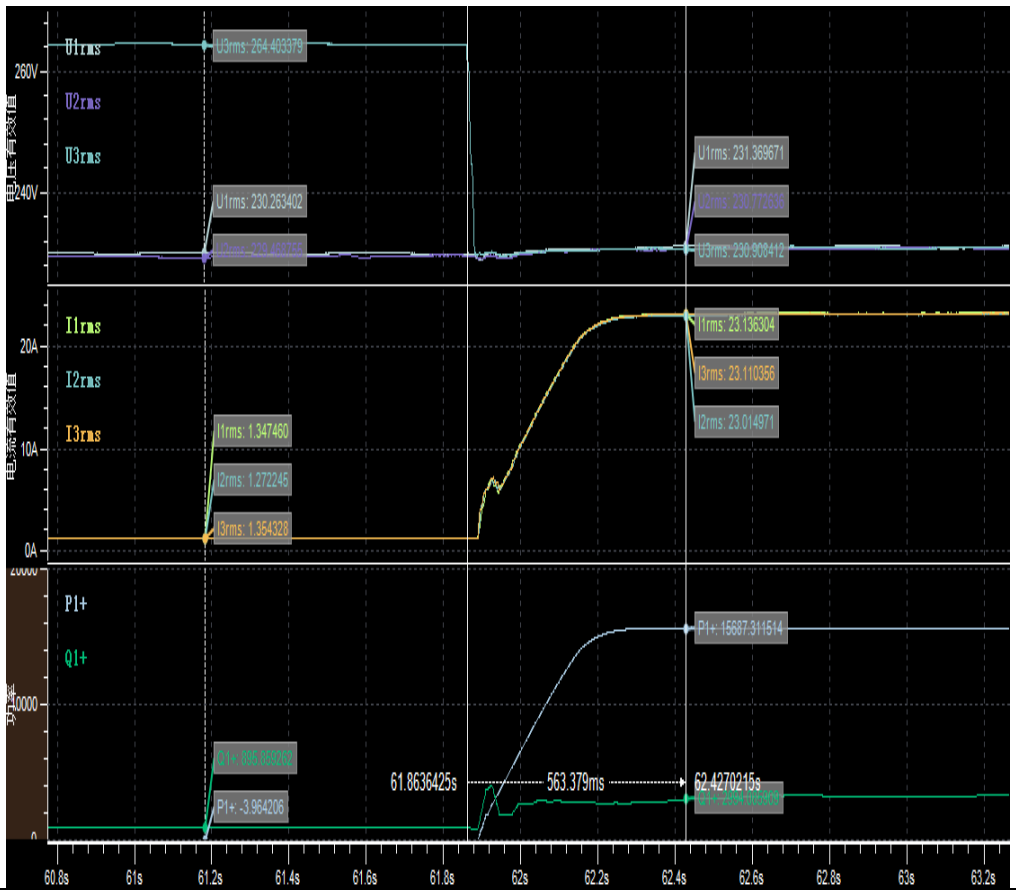


Test 21 – One-phase symmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 100% P_n, One phase fault

Test 21–One-phase symmetrical fault (U/U_n = 1.15): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, One phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict



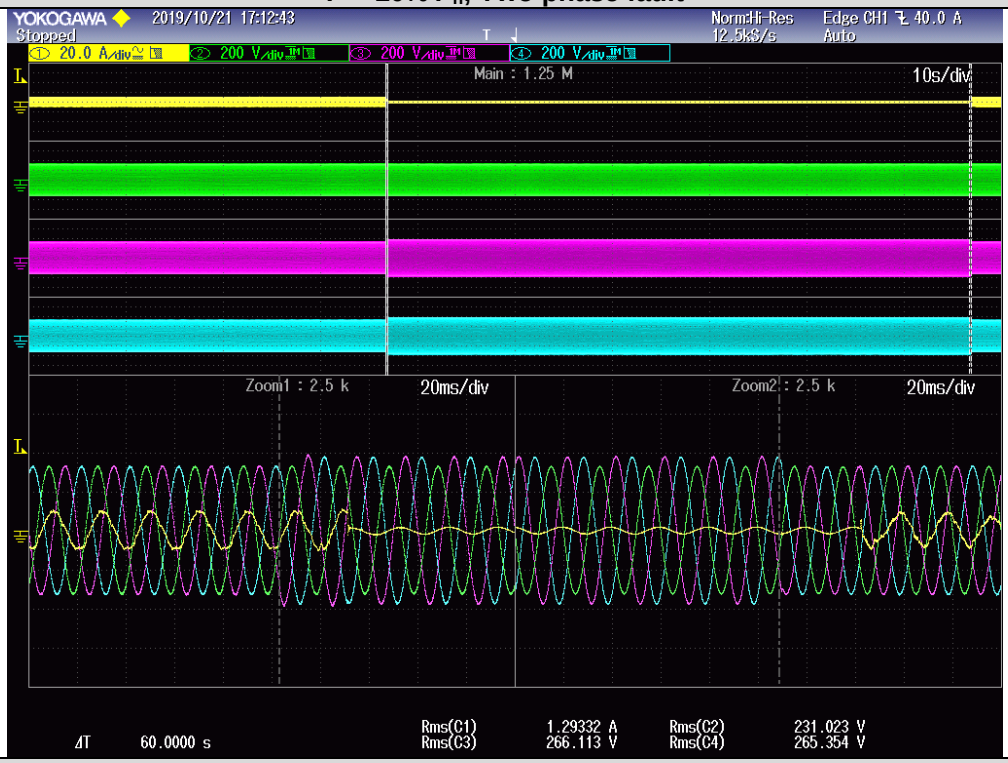


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

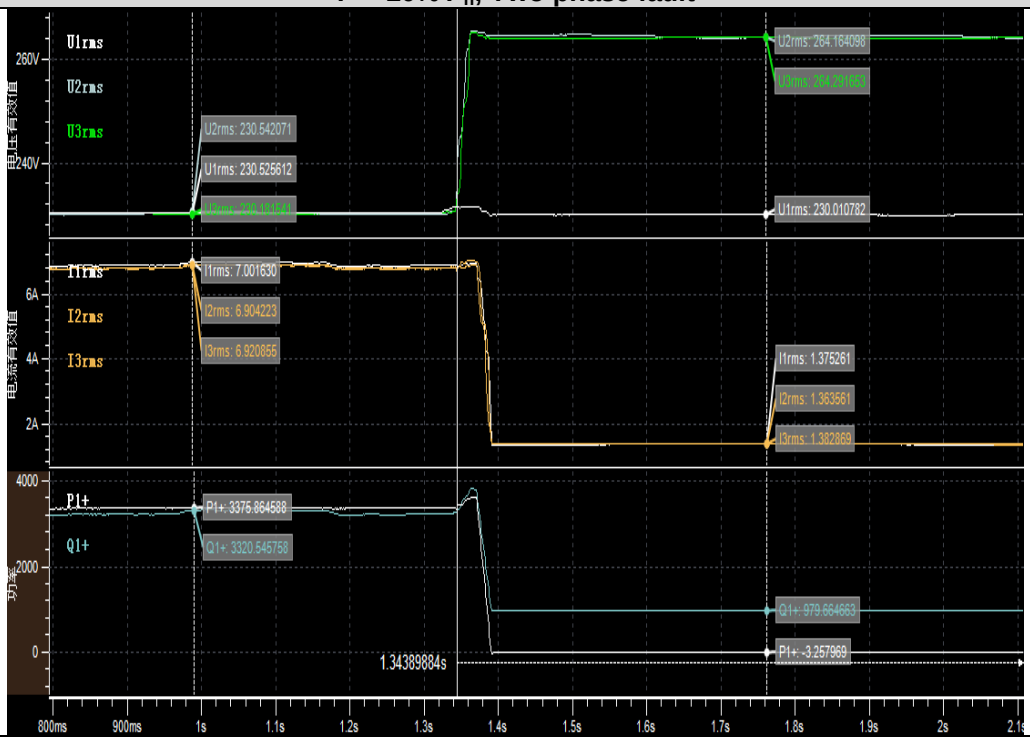
Test 22 – Two-phase asymmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 0, Two phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

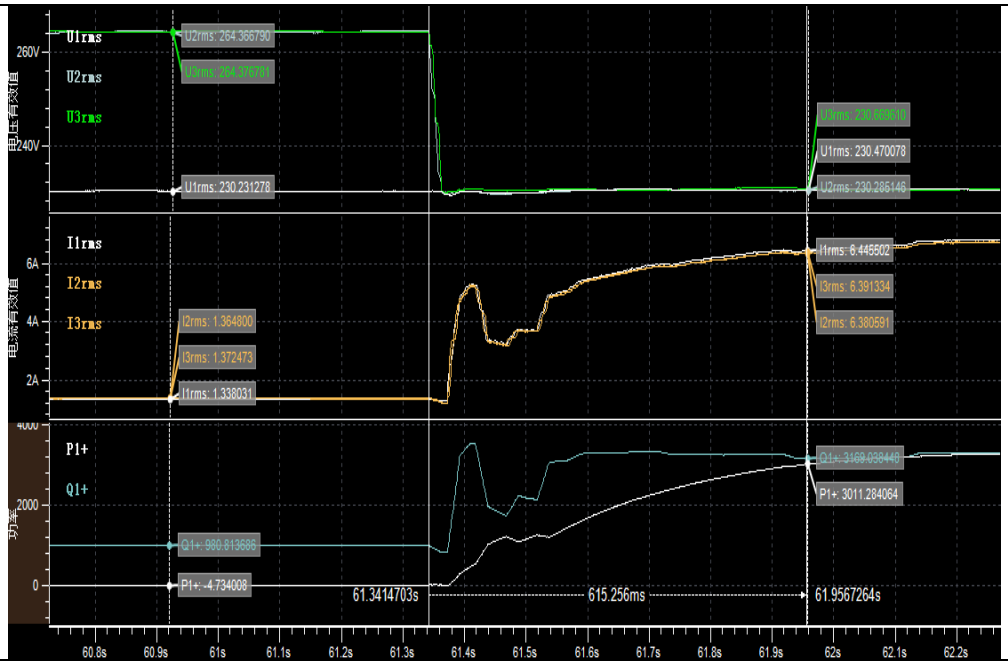
Test 23 – Two-phase asymmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 20% P_n, Two phase fault



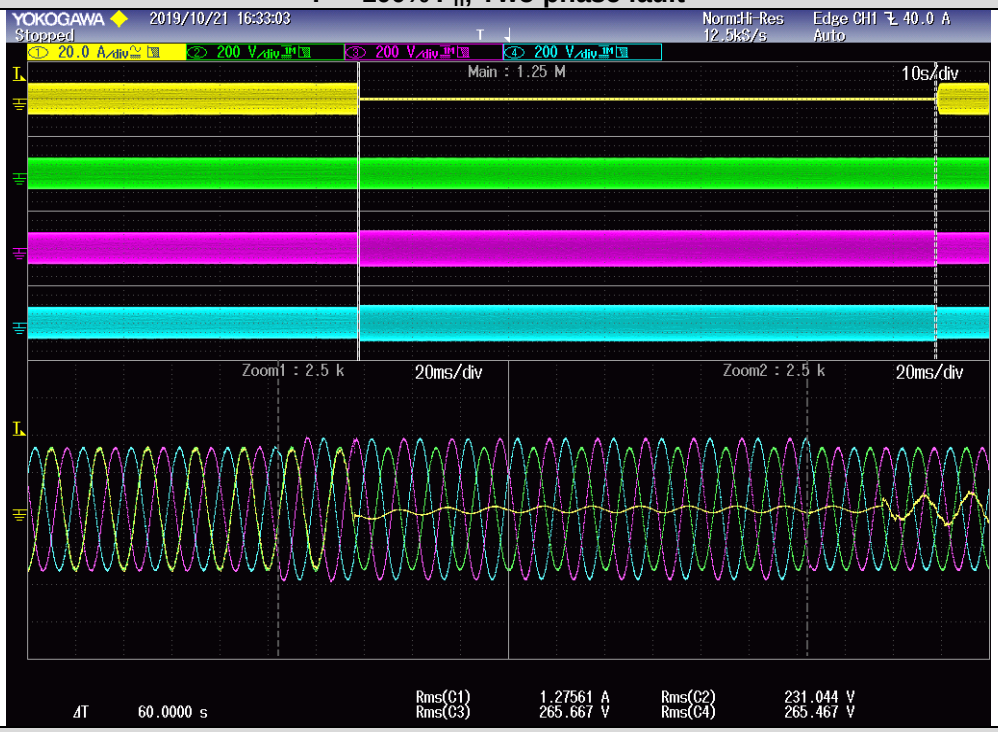
Test 23 – Two-phase asymmetrical fault (U/U_n = 1.15): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Two phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

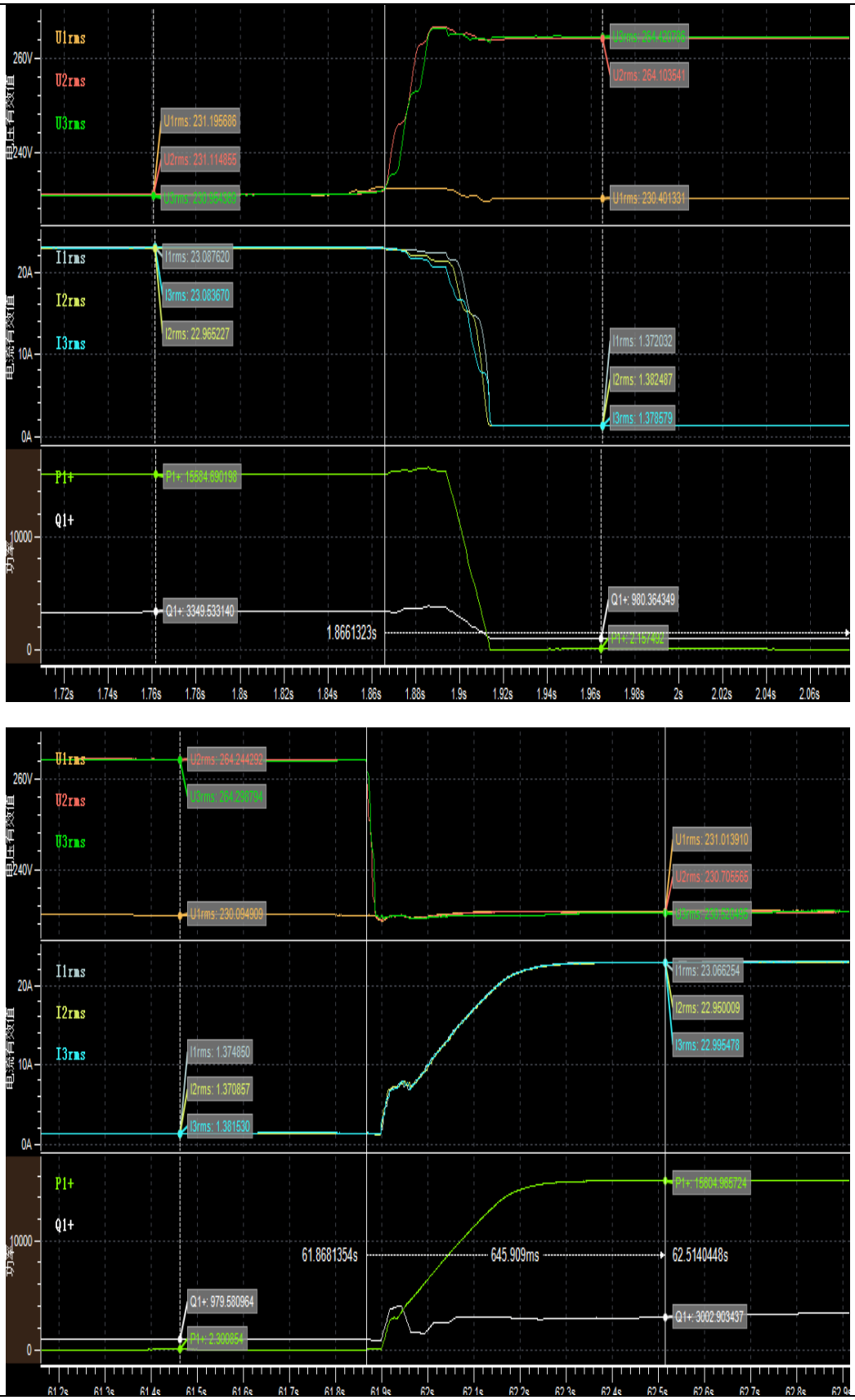


Test 24 – Two-phase asymmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 100% P_n, Two phase fault



Test 24 – Two-phase asymmetrical fault (U/U_n = 1.15): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Two phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

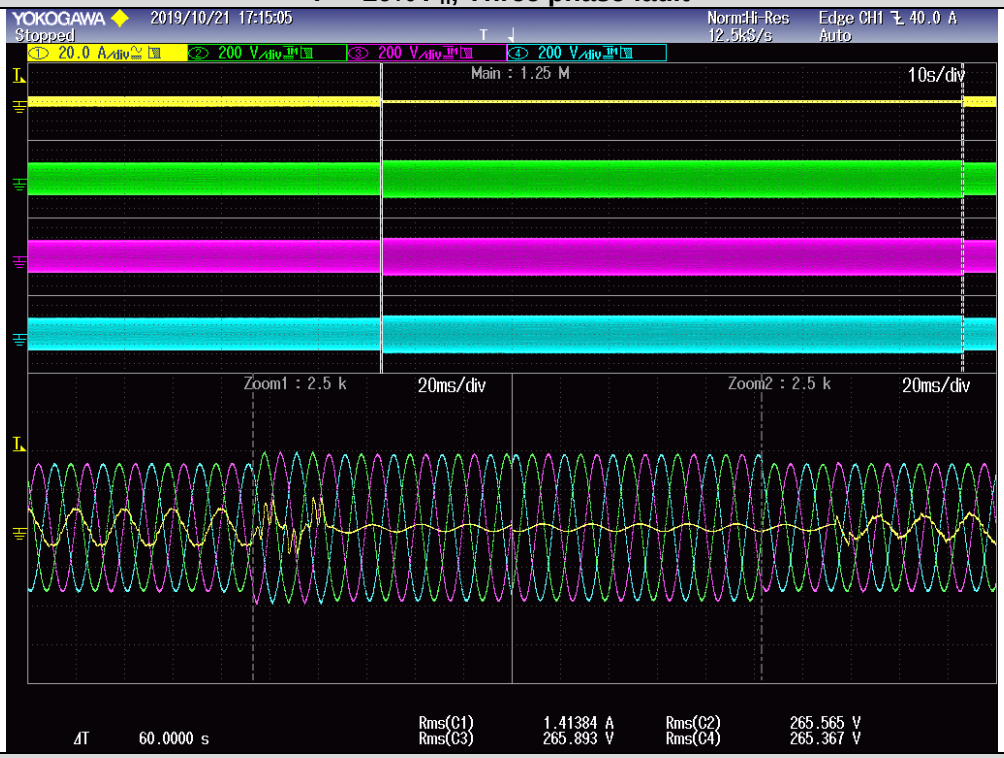


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

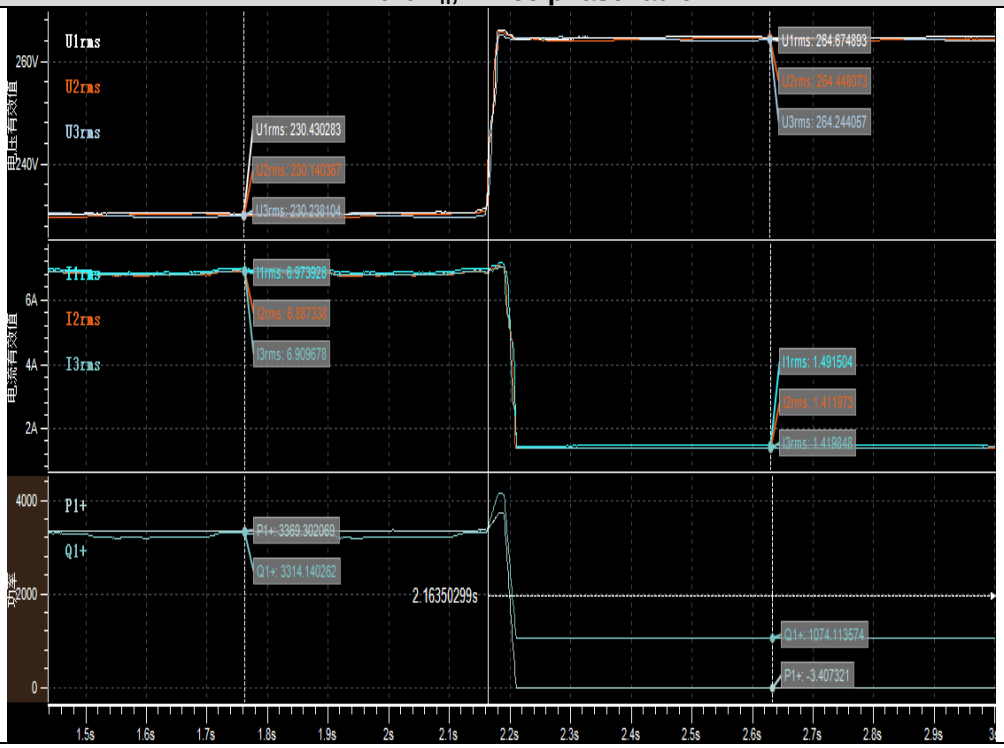
Test 25 – Three-phase asymmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 0, Three phase fault

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

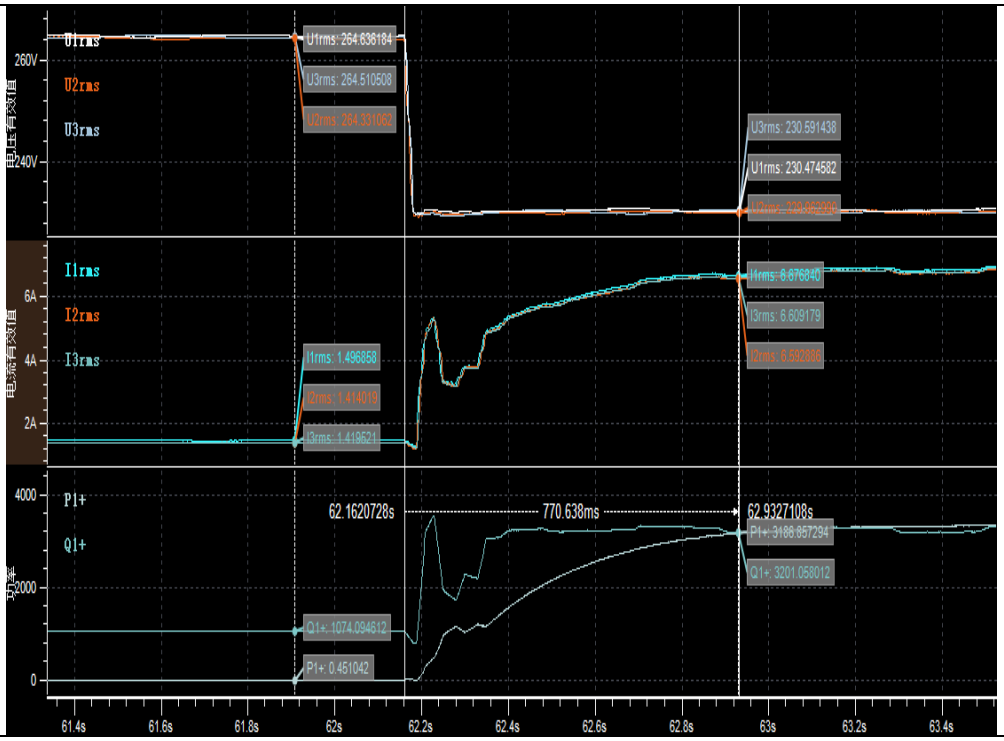
Test 26 – Three-phase asymmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 20% P_n, Three phase fault



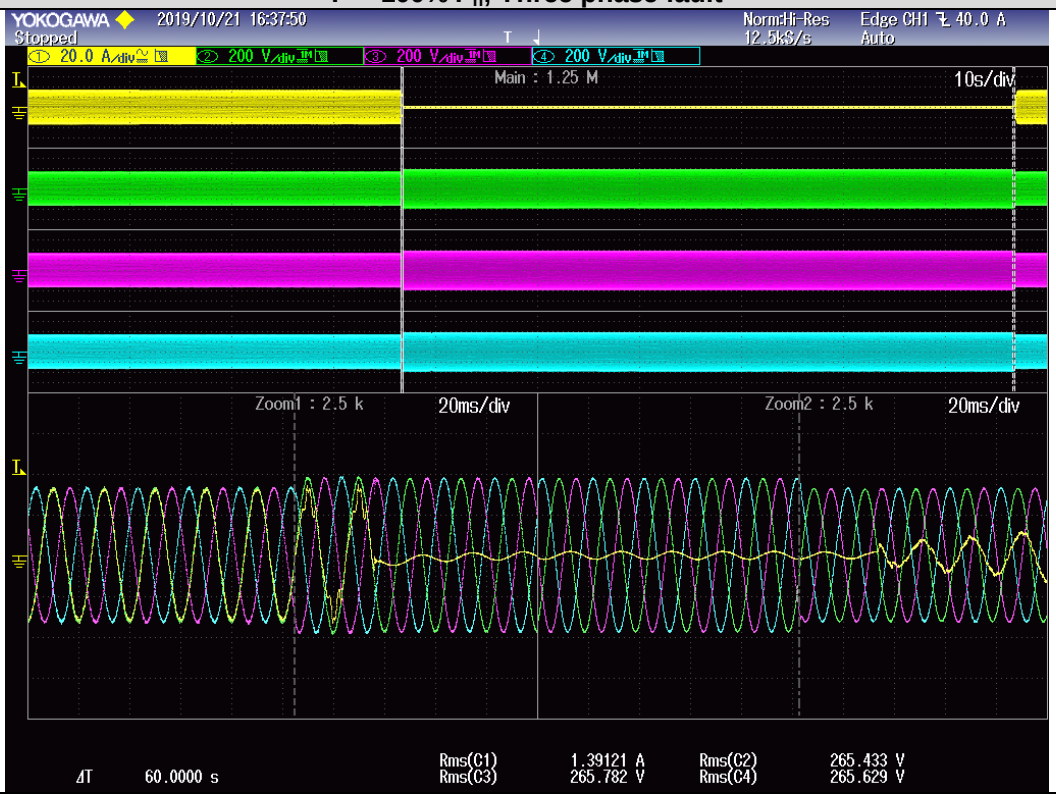
Test 26 – Three-phase asymmetrical fault (U/U_n = 1.15): Phase currents after the voltage returns to continuous operating voltage range
P = 20% P_n, Three phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

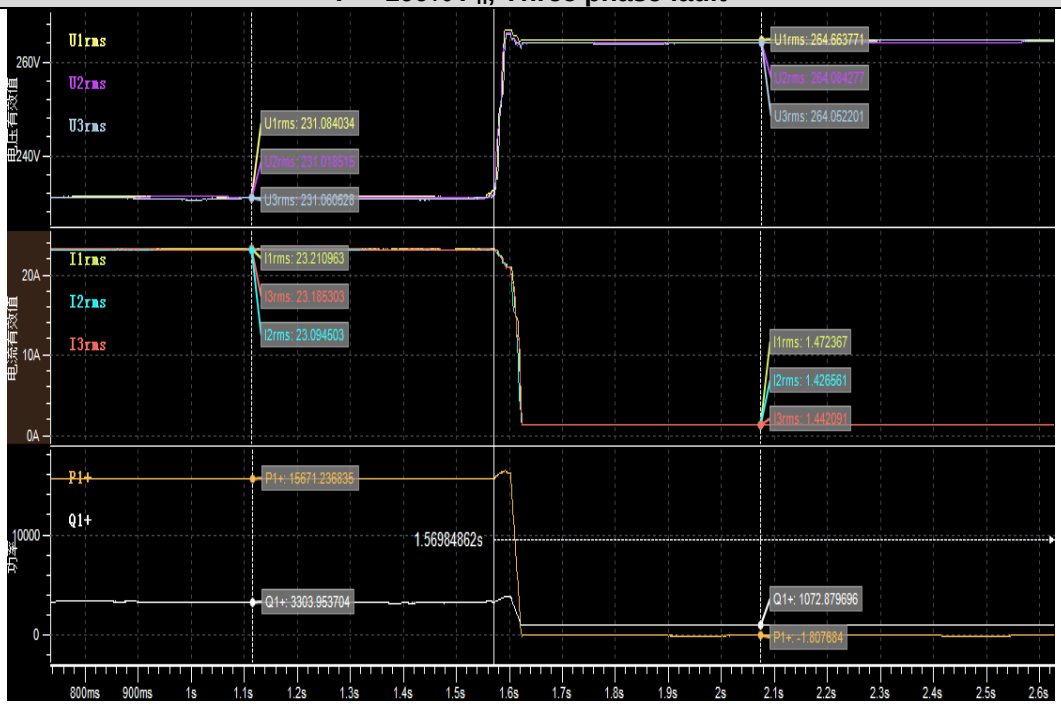


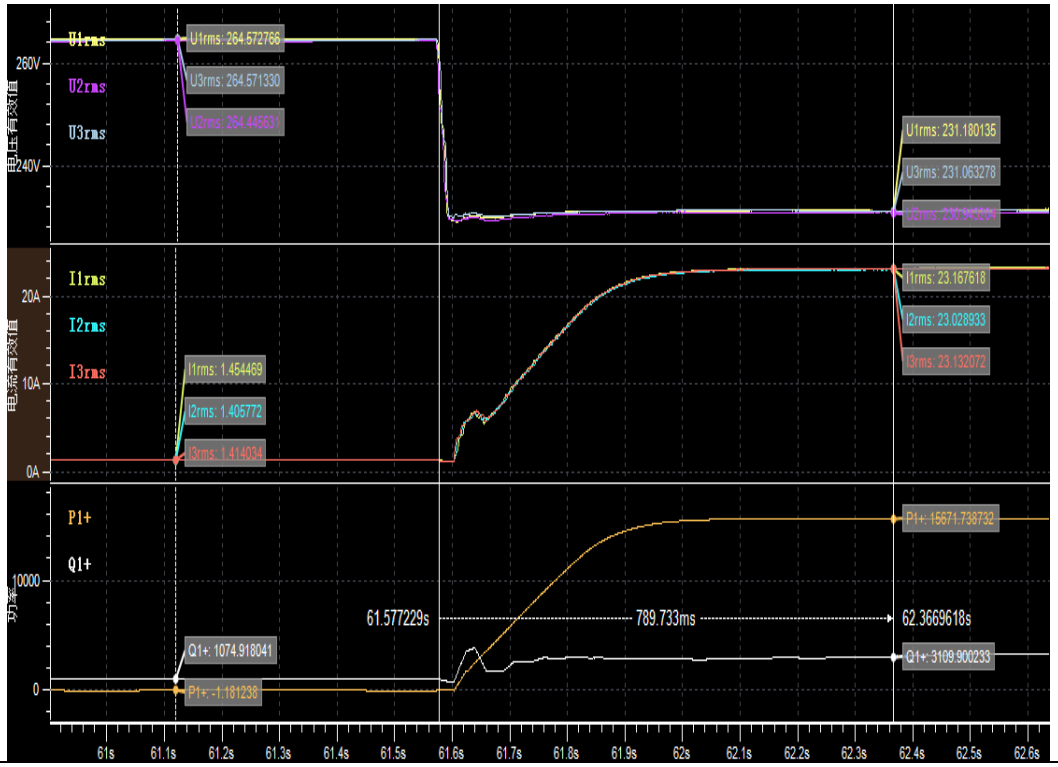
Test 27 – Three-phase asymmetrical fault (U/U_n = 1.15): Phase current and voltage of the whole failure
P = 100% P_n, Three phase fault



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Test 27 – Three-phase asymmetrical fault (U/U_n = 1.15): Phase currents after the voltage returns to continuous operating voltage range
P = 100% P_n, Three phase fault

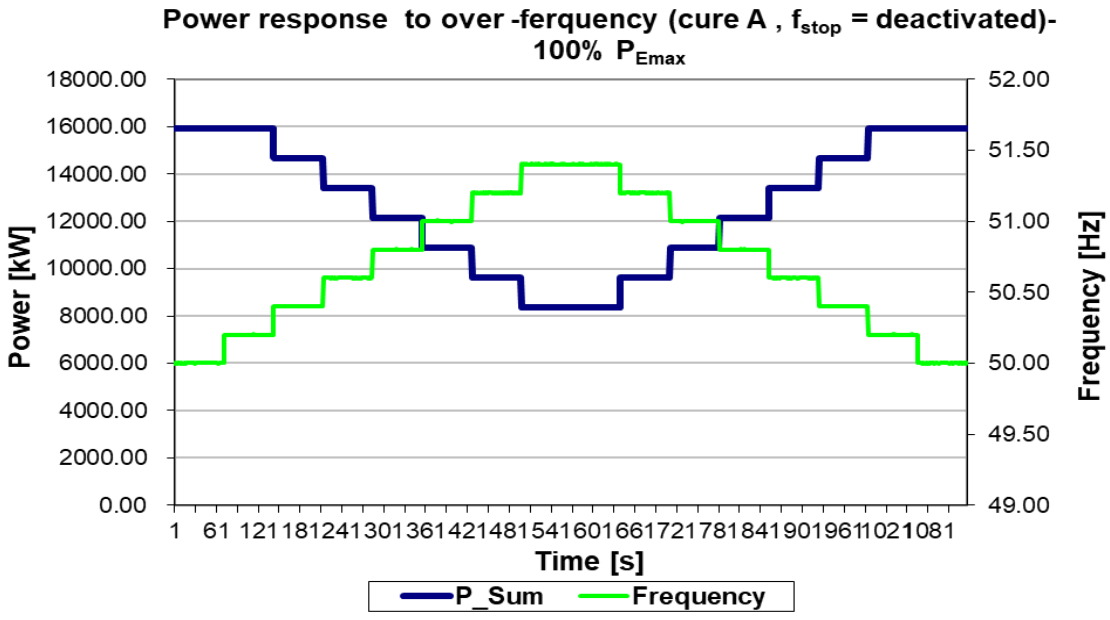




EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.6.1	TABLE: Power response to over-frequency (curve A, f_{stop} = deactivated)				P
Model	EA16KTSI				
1.Starting active power = 100% P_{Emax}			P_M [W]	15909.83	
s = 5%		f_1 = 50.2 Hz	P_{ref} = P_M		

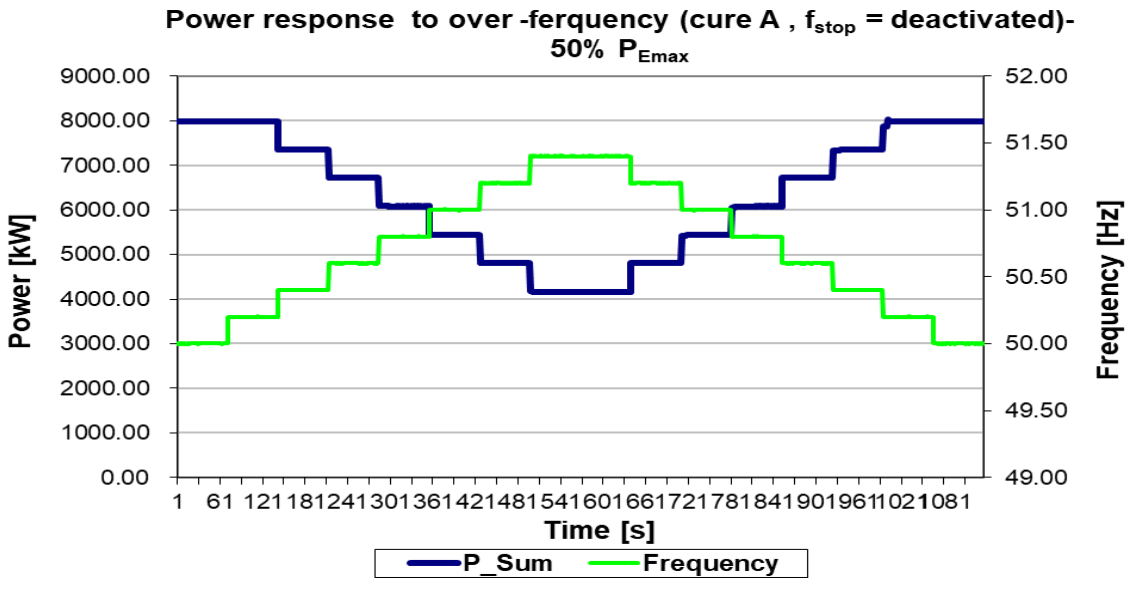
Frequency set point [Hz]		Measured frequency [Hz]	Power output [W]	Measured $\Delta P/P_{ref}$ [%]	Target $\Delta P/P_{ref}$ [%]
Frequency increase step	50.00	50.00	15910.97	-	-
	50.20	50.20	15909.83	-	-
	50.40	50.40	14661.84	-7.85	-8
	50.60	50.60	13402.70	-15.76	-16
	50.80	50.80	12145.57	-23.67	-24
	51.00	51.00	10885.87	-31.58	-32
	51.20	51.20	9621.58	-39.53	-40
	51.40	51.40	8351.95	-47.51	-48
Frequency restore step	51.40	51.40	8351.87	-47.51	-48
	51.20	51.20	9621.23	-39.53	-40
	51.00	51.00	10885.20	-31.59	-32
	50.80	50.80	12144.44	-23.67	-24
	50.60	50.60	13400.87	-15.78	-16
	50.40	50.40	14657.29	-7.88	-8
	50.20	50.20	15908.06	-	-
	50.00	50.00	15908.89	-	-



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.6.1	TABLE: Power response to over-frequency (curve A, f_{stop} = deactivated)				P
Model	EA16KTSI				
2.Starting active power between 40% P_{Emax} and 60% P_{Emax}			P_M [W]	7992.23	
s = 5%		f_1 = 50.2 Hz	$P_{ref} = P_M$		

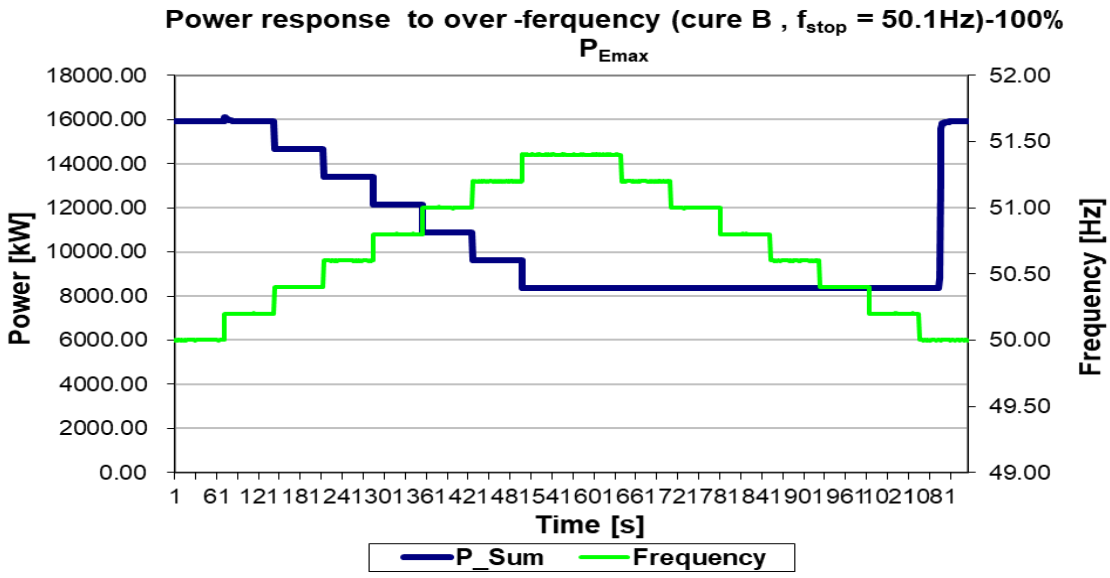
Frequency set point [Hz]		Measured frequency [Hz]	Power output [W]	Measured $\Delta P/P_{ref}$ [%]	Target $\Delta P/P_{ref}$ [%]
Frequency increase step	50.00	50.00	7992.85	-	-
	50.20	50.20	7992.23	-	-
	50.40	50.40	7359.76	-7.92	-8
	50.60	50.60	6721.82	-15.90	-16
	50.80	50.80	6082.42	-23.90	-24
	51.00	51.00	5444.17	-31.89	-32
	51.20	51.20	4805.01	-39.88	-40
	51.40	51.40	4163.15	-47.91	-48
Frequency restore step	51.40	51.40	4162.12	-47.93	-48
	51.20	51.20	4803.25	-39.91	-40
	51.00	51.00	5440.36	-31.93	-32
	50.80	50.80	6078.33	-23.95	-24
	50.60	50.60	6719.33	-15.93	-16
	50.40	50.40	7353.28	-8.00	-8
	50.20	50.20	7981.73	-	-
	50.00	50.00	7992.60	-	-



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.6.1	TABLE: Power response to over-frequency (curve B, f_{stop} = 50.1Hz)				P
Model	EA16KTSI				
3.Starting active power = 100% P_{Emax}			P_M [W]	15933.64	
s = 5%		f_1 = 50.2 Hz	t_{stop} = 30 s		

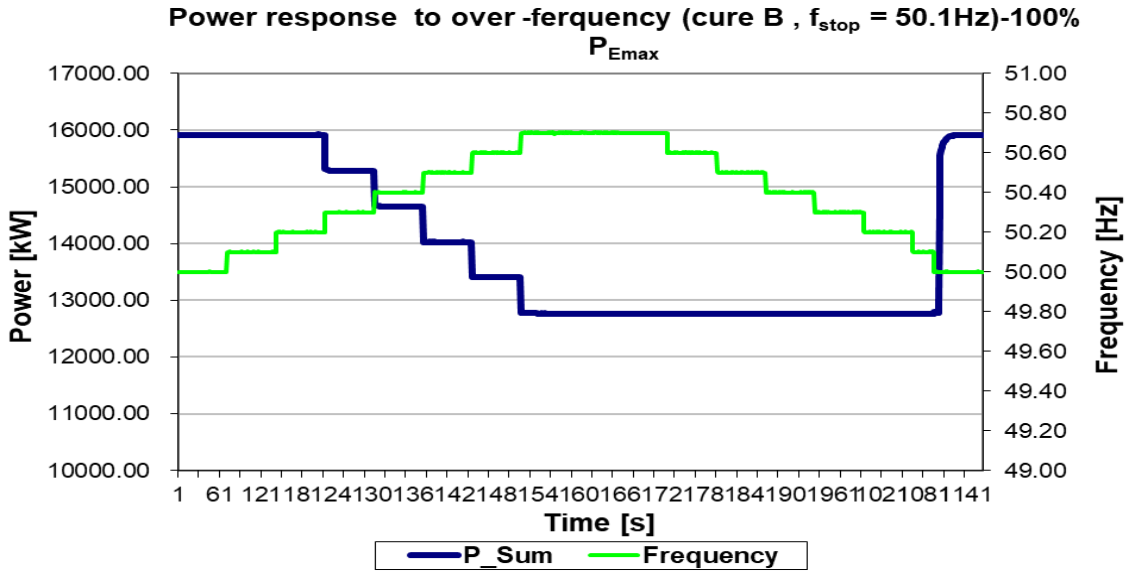
Frequency set point [Hz]		Measured frequency [Hz]	Power output [W]	Measured $\Delta P/P_{ref}$ [%]	Target $\Delta P/P_{ref}$ [%]
Frequency increase step	50.00	50.00	15916.39	-	-
	50.20	50.20	15933.64	-	-
	50.40	50.40	14665.31	-7.96	-8
	50.60	50.60	13408.33	-15.85	-16
	50.80	50.80	12151.31	-23.74	-24
	51.00	51.00	10892.93	-31.64	-32
	51.20	51.20	9627.75	-39.58	-40
	51.40	51.40	8357.15	-47.55	-48
Frequency restore step	51.40	51.40	8356.64	-47.55	-48
	51.20	51.20	8348.11	-47.61	-48
	51.00	51.00	8348.34	-47.61	-48
	50.80	50.80	8348.53	-47.60	-48
	50.60	50.60	8348.57	-47.60	-48
	50.40	50.40	8348.37	-47.61	-48
	50.20	50.20	8348.33	-47.61	-48
	50.00	50.00	15917.00	-0.10	0



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.6.1	TABLE: Power response to over-frequency (curve B, f_{stop} = 50.1Hz)				P
Model	EA16KTSI				
4.Starting active power = 100% P_{Emax}			P_M [W]	15918.04	
s = 5%		f_1 = 50.2 Hz		t_{stop} = 30 s	

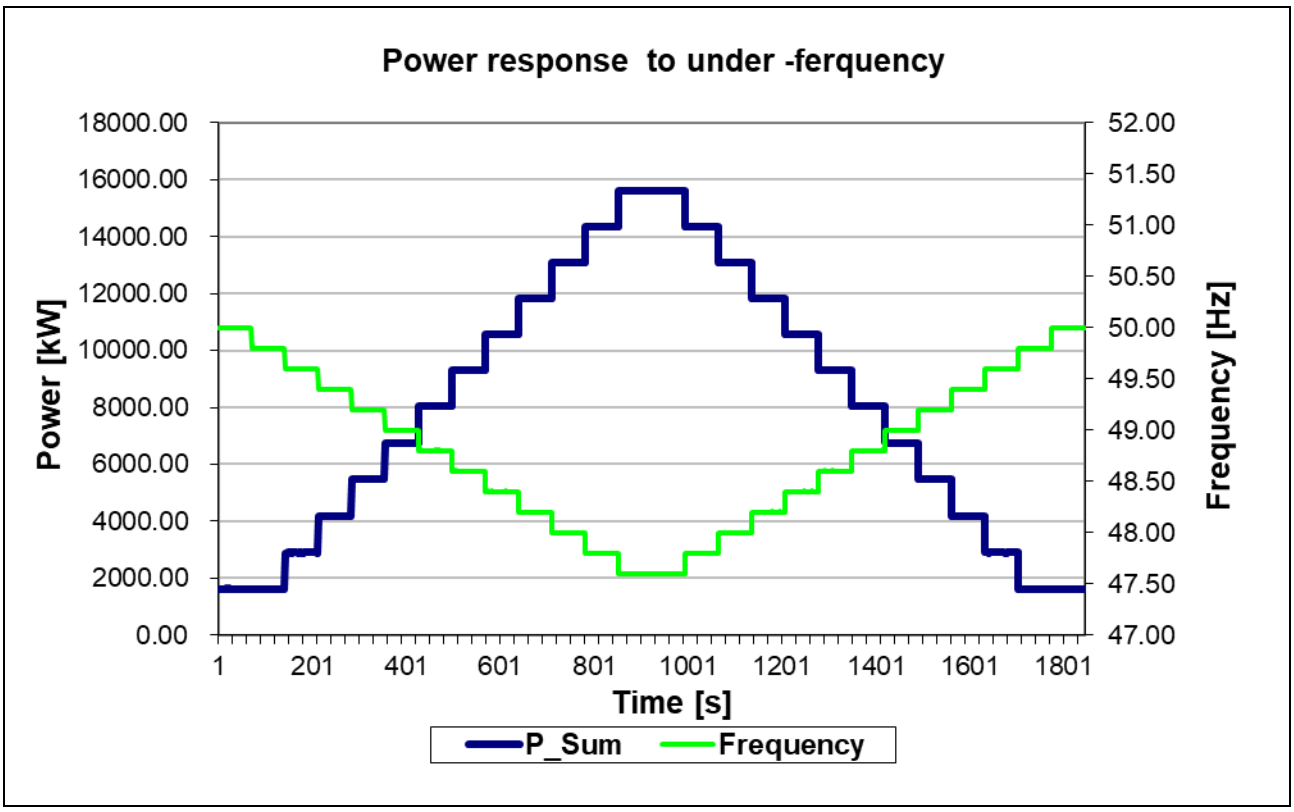
Frequency set point [Hz]		Measured frequency [Hz]	Power output [W]	Measured $\Delta P/P_{ref}$ [%]	Target $\Delta P/P_{ref}$ [%]
Frequency increase step	50.00	50.00	15918.04	-	-
	50.10	50.10	15918.34	-	-
	50.20	50.20	15918.26	-	-
	50.30	50.30	15287.54	-3.96	-4
	50.40	50.40	14658.49	-7.91	-8
	50.50	50.50	14029.19	-11.87	-12
	50.60	50.60	13402.89	-15.80	-16
	50.70	50.70	12769.00	-19.78	-20
Frequency restore step	50.70	50.70	12763.44	-19.82	-20
	50.60	50.60	12763.87	-19.82	-20
	50.50	50.50	12763.70	-19.82	-20
	50.40	50.40	12763.69	-19.82	-20
	50.30	50.30	12764.01	-19.82	-20
	50.20	50.20	12763.67	-19.82	-20
	50.10	50.10	12761.43	-19.83	-20*
	50.00	50.00	15912.91	-0.03	0



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.6.2	**TABLE: Power response to under-frequency**					**P**
Model	EA16KTSI					
Measurement: Starting active power output = 10% P_{max} for inverter						
s = 5 %		f_1 = 49.8 Hz		P_{ref} [W]: 16000		
Frequency set point [Hz]		Measured frequency [Hz]	Power output [W]	Measured $\Delta P/_{Pref}$ [%]	Target $\Delta P/P_{ref}$ [%]	Disconnect or not
Frequency decrease step	50.00	50.00	1623.04	0	0	No
	49.80	49.80	1605.54	0	0	No
	49.60	49.60	2891.92	8.0	8	No
	49.40	49.40	4181.40	16.1	16	No
	49.20	49.20	5472.79	24.2	24	No
	49.00	49.00	6756.94	32.2	32	No
	48.80	48.80	8038.36	40.2	40	No
	48.60	48.60	9310.65	48.2	48	No
	48.40	48.40	10576.31	56.1	56	No
	48.20	48.20	11835.99	64.0	64	No
	48.00	48.00	13093.39	71.8	72	No
	47.80	47.80	14349.29	79.7	80	No
	47.60	47.60	15605.27	87.5	88	No
Frequency restore step	47.60	47.60	15605.67	87.5	88	No
	47.80	47.80	14351.03	79.7	80	No
	48.00	48.00	13094.57	71.8	72	No
	48.20	48.20	11837.17	64.0	64	No
	48.40	48.40	10577.10	56.1	56	No
	48.60	48.60	9310.44	48.2	48	No
	48.80	48.80	8039.18	40.2	40	No
	49.00	49.00	6757.38	32.2	32	No
	49.20	49.20	5472.04	24.2	24	No
	49.40	49.40	4181.02	16.1	16	No
	49.60	49.60	2892.53	8.1	8	No
	49.80	49.80	1604.89	0	0	No
	50.00	50.00	1605.37	0	0	No
Limit $\Delta P_{E60}/P_{ref}$:		± 10% of P_{ref}				

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.7.2.2 4.7.2.3.2	**TABLE: Setpoint control modes – Q setpoint mode**	**P**
Model	EA16KTSI	

Inductive supply reactive power

Rating power [%]	Active power [W]	Reactive Power [Var]	Q/P_D [%]	Power factor [cos φ]	Voltage [V]
0% - 10%	1373.972	7883.25	49.27	0.17	229.1
	1208.924	7883.40	49.27	0.15	229.0
	1208.37	7883.79	49.27	0.15	229.0
10% - 20%	2338.65	7882.53	49.26	0.28	229.0
	2338.49	7883.24	49.27	0.28	229.0
	2338.57	7882.40	49.27	0.28	229.0
20% - 30%	3949.50	7878.72	49.24	0.45	229.0
	3949.42	7878.58	49.24	0.45	229.0
	3949.07	7878.10	49.24	0.45	229.0
30% - 40%	5554.72	7873.48	49.21	0.58	229.0
	5554.96	7872.02	49.20	0.58	229.0
	5554.00	7837.40	48.98	0.58	229.0
40% - 50%	7151.63	7876.07	49.23	0.67	229.0
	7153.88	7877.13	49.23	0.67	229.0
	7154.22	7875.90	49.22	0.67	230.0
50% - 60%	8739.28	7874.00	49.21	0.74	230.0
	8740.06	7872.23	49.20	0.74	230.0
	8738.31	7873.57	49.21	0.74	230.0
60% - 70%	10316.26	7870.58	49.19	0.80	230.0
	10316.39	7873.51	49.21	0.79	230.0
	10317.18	7869.81	49.19	0.80	230.0
70% - 80%	11885.44	7867.52	49.17	0.83	230.0
	11885.43	7867.54	49.17	0.83	230.0
	11885.65	7867.53	49.17	0.83	230.0
80% - 90%	13454.26	7867.74	49.17	0.86	230.0
	13455.14	7867.80	49.17	0.86	230.0
	13454.17	7868.94	49.18	0.86	230.0
90% - 100%	13846.52	7871.93	49.19	0.87	230.0
	13848.41	7870.83	49.19	0.87	230.0
	13849.52	7870.30	49.19	0.87	230.0

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Capacitive supply reactive power					
Rating power [%]	Active power [W]	Reactive Power [Var]	Q/P_D [%]	Power factor [cos φ]	Voltage [V]
0% - 10%	1272.62	-7886.64	-49.29	0.16	229.0
	1270.00	-7890.00	-49.31	0.16	229.0
	1272.47	- 7886.45	-49.29	0.16	229.0
10% - 20%	2404.85	- 7874.38	-49.22	0.29	229.0
	2405.71	- 7874.15	-49.21	0.29	229.0
	2406.24	- 7873.90	-49.21	0.29	229.0
20% - 30%	4017.07	- 7859.59	-49.12	0.46	229.0
	4017.25	- 7859.06	-49.12	0.46	229.0
	4017.05	- 7859.92	-49.13	0.46	229.0
30% - 40%	5618.98	- 7837.82	-48.98	0.58	230.0
	5619.03	- 7837.96	-48.98	0.58	230.0
	5619.18	- 7838.44	-48.99	0.58	230.0
40% - 50%	7214.88	- 7818.50	-48.86	0.68	230.0
	7215.30	- 7816.85	-48.86	0.68	230.0
	7215.32	- 7816.38	-48.85	0.68	230.0
50% - 60%	8802.31	- 7792.19	-48.70	0.75	230.0
	8801.89	-7792.44	-48.70	0.75	230.0
	8801.82	-7793.09	-48.70	0.75	230.0
60% - 70%	10402.47	-7760.74	-48.51	0.80	230.0
	10388.83	-7761.33	-48.51	0.80	230.0
	10388.60	-7761.97	-48.51	0.80	230.0
70% - 80%	11957.68	-7739.03	-48.37	0.84	230.0
	11957.27	-7741.39	-48.38	0.84	230.0
	11955.84	-7741.22	-48.38	0.84	230.0
80% - 90%	13522.57	-7723.99	-48.28	0.87	230.0
	13522.93	-7724.47	-48.28	0.87	230.0
	13523.03	-7726.04	-48.29	0.87	230.0
90% - 100%	13915.90	-7724.06	-48.28	0.87	231.0
	13915.66	-7724.20	-48.28	0.87	231.0
	13914.77	-7723.93	-48.28	0.87	231.0

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Clause	Requirement - Test	Result - Remark	Verdict

Cos phi = 1 no reactive power supply					
Rating power [%]	Active power [W]	Reactive Power [Var]	Q/P_D [%]	Power factor [cos φ]	Voltage [V]
0% - 10%	1176.34	-383.86	-2.39	-0.95	230.19
	976.72	-376.72	-2.35	-0.93	230.16
	679.66	-334.20	-2.09	-0.86	230.13
10% - 20%	2074.77	-389.42	-2.43	-0.98	230.29
	2478.75	-389.56	-2.44	-0.99	230.29
	2774.18	-389.48	-2.43	-0.99	230.36
20% - 30%	3359.17	-395.30	-2.47	-0.99	230.45
	3955.02	-397.38	-2.48	-0.99	230.48
	4353.02	-398.61	-2.49	-0.99	230.53
30% - 40%	4947.31	-400.82	-2.51	-0.99	230.56
	5543.04	-401.04	-2.51	-0.99	230.63
	5841.95	-404.56	-2.53	-0.99	230.65
40% - 50%	6631.50	-385.46	-2.41	-0.99	230.73
	7123.43	-431.77	-2.69	-0.99	230.74
	7715.19	-430.85	-2.69	-0.99	230.78
50% - 60%	8115.46	-427.84	-2.67	-0.99	230.84
	8708.68	-379.31	-2.37	-0.99	230.91
	9006.87	-359.96	-2.25	-0.98	230.94
60% - 70%	9600.22	-299.93	-1.87	-0.97	231.07
	9875.78	-290.02	-1.81	-0.94	231.10
	10577.62	-256.75	-1.61	-0.99	231.21
70% - 80%	11165.88	-209.85	-1.31	-0.99	231.27
	11556.87	-188.38	-1.18	-0.99	231.32
	12036.18	-167.57	-1.04	-0.99	231.38
80% - 90%	12630.42	-124.66	-0.78	-0.99	231.45
	13018.51	-72.80	-0.46	-0.99	231.50
	13503.50	-21.90	-0.13	-0.99	231.55
90% - 100%	13992.93	9.72	0.06	-0.99	231.62
	14574.29	18.39	0.11	-0.99	231.67
	15321.71	94.78	0.59	-0.99	231.77

Note:
When operating above the apparent power threshold S_{min} equal to 10 % of the maximum apparent power S_{max} or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % S_{max}. Up to this apparent power threshold S_{min}, deviations above 2 % are permissible.

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Clause	Requirement - Test	Result - Remark	Verdict

4.7.2.2 4.7.2.3.2	**TABLE: Setpoint control modes – Cos φ setpoint mode**									**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
30 s mean value	cos φ over-excited (c) @ U_n									
U [V]:	230.2	230.48	230.58	230.50	230.53	230.41	230.29	230.29	230.27	230.27
P_{E30} [W]:	1572.01	3173.60	4782.88	6389.50	7984.98	9569.04	11144.30	12792.23	14282.53	14369.90
Q_{E30} [VAr]:	740.84	1507.49	2241.35	3162.56	3949.81	4726.81	5501.52	6312.95	7042.50	7076.64
cos $\varphi_{E30\text{-over-excited}}$:	0.900	0.903	0.906	0.896	0.896	0.897	0.897	0.897	0.897	0.897
30 s mean value	cos φ over-excited (c) @ 1.09 U_n									
U [V]:	250.47	250.64	250.85	250.91	250.87	250.85	250.83	250.77	250.70	250.71
P_{E30} [W]:	1563.75	3163.31	4769.76	6378.84	7981.25	9574.31	11156.03	12729.80	14289.53	14389.77
Q_{E30} [VAr].	758.43	1511.74	2236.38	2976.10	3839.37	4596.78	5349.92	6103.15	6894.88	6894.69
cos $\varphi_{E30\text{-over-excited}}$:	0.900	0.902	0.905	0.906	0.901	0.902	0.902	0.902	0.902	0.902
30 s mean value	cos φ under-excited (i) @ U_n									
U [V]:	230.05	230.14	230.07	230.14	230.13	230.18	230.13	230.17	230.27	230.61
P_{E30} [kW]:	1614.65	3223.64	4838.78	6448.79	8048.53	9639.93	11218.40	12789.40	14358.47	14436.70
Q_{E30} [kVAr]:	-796.85	-1568.91	-2321.00	-3073.33	-3825.51	-4574.88	-5319.88	-6059.83	-6796.84	-6833.53
cos $\varphi_{E30\text{-under-excited}}$:	0.904	0.899	0.902	0.903	0.903	0.903	0.904	0.904	0.904	0.904
30 s mean value	cos φ under-excited (i) @ 1.09 U_n									
U [V]:	250.36	250.42	250.42	250.53	250.62	250.53	250.65	250.63	250.72	250.70
P_{E30} [kW]:	1569.15	3174.61	4784.29	6393.31	7996.25	9590.56	11175.53	12753.00	14329.87	14409.60
Q_{E30} [kVAr]:	-778.54	-1528.55	-2254.13	-3074.62	-3826.37	-4573.68	-5320.78	-6062.00	-6798.54	-6835.54
cos $\varphi_{E30\text{-under-excited}}$:	0.896	0.901	0.905	0.901	0.902	0.903	0.903	0.903	0.903	0.903
Limit cos φ_{E30}:	cos φ= 0.89 to 0.91 (c) and cos φ= 0.89 to 0.91 (i)									

Note:
When operating above the apparent power threshold S_{min} equal to 10 % of the maximum apparent power S_{max} or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % S_{max}. Up to this apparent power threshold S_{min}, deviations above 2 % are permissible.
The tests were performed on model EA16KTSI also applicable for all other models stated in this report.

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Clause	Requirement - Test	Result - Remark	Verdict

4.7.2.2 **4.7.2.3.3**	**TABLE: Voltage related control mode – Q(U)**	**P**
Model	EA16KTSI	
Setting of the PCE		
Time constant range	3 s ~ 60 s	
Lock-in value setting	20% P_D	
Lock-out value setting	5% P_D	

Inductive reactive power absorption

P/P_n Set-point	Vac [V] Set point	P/P_n [%] measured	Vac [V] measured	Q [Var] measured	Q [Var] expected	ΔQ [Var] [≤±2% P_n]
< 20%	1.07Vn	15.57	246.55	-394.00	≈0(<±2%P_n)	394.00
< 20%	1.09Vn	15.56	249.13	-377.07	≈0(<±2%P_n)	377.07
< 20%->30%	1.09Vn	31.37	250.65	-3870.59	-0.5 Q_{max} (within 10s)	3.81
40%	1.09Vn	42.20	250.67	-3804.24	-0.5 Q_{max}	70.06
50%	1.09Vn	51.78	250.77	-3889.27	-0.5 Q_{max}	14.87
60%	1.09Vn	61.91	250.81	-3850.77	-0.5 Q_{max}	23.63
70%	1.09Vn	71.98	250.86	-3870.90	-0.5 Q_{max}	3.50
80%	1.09Vn	82.02	250.92	-3867.71	-0.5 Q_{max}	6.69
90%	1.09Vn	91.98	251.01	-3876.75	-0.5 Q_{max}	2.35
100%	1.09Vn	96.38	251.05	-3868.24	-0.5 Q_{max}	6.16
100%	1.1 Vn	99.86	253.38	-7806.81	- Q_{max}	58.01
100%->10%	1.1 Vn	10	253.00	-7350.63	- Q_{max}	398.17
10%->≤5%	1.1 Vn	5	252.40	-375.29	≈0(<±2%P_n)	375.29

Capacitive reactive power supply

P/P_n Set-point	Vac [V] Set point	P/P_n [%] measured	Vac [V] measured	Q [Var] measured	Q [Var] expected	ΔQ [Var] [≤±2%P_n]
< 20%	0,93 V_n	16.0	213.93	-360.23	≈0 (<±2%P_n)	360.23
< 20%	0,91 V_n	15.8	209.306	-351.368	≈0 (<±2%P_n)	351.37
< 20%->30%	0,91 V_n	28.0	209.03	3715.75	0.5 Q_{max} (within 10s)	158.65
40%	0,91 V_n	41.0	209.32	3841.17	0.5 Q_{max}	33.23
50%	0,91 V_n	51.2	209.42	3878.90	0.5 Q_{max}	4.50
60%	0,91 V_n	61.0	209.45	3834.04	0.5 Q_{max}	44.36
70%	0,91 V_n	71.5	209.53	3774.09	0.5 Q_{max}	100.31
80%	0,91 V_n	81.6	209.73	3850.34	0.5 Q_{max}	24.06

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Clause	Requirement - Test				Result - Remark	Verdict

90%	0,91 V_n	91.6	209.57	3972.65	0.5 Q_{max}	98.25
100%	0,91 V_n	93	209.69	3910.18	0.5 Q_{max}	35.78
100%	0,90 V_n	90	207.04	7919.31	Q_{max}	170.51
100%-10%	0,90 V_n	10	207.13	7939.40	Q_{max}	190.60
10%-5%	0,90 V_n	5	207.13	-365.20	≈0(<±2%P_n)	365.20

Note:
The test method reference CEI 0-21:2019-04, Annex B1.2.6 as below:
The parameters V_{1i}, V_{2i}, V_{1s} and V_{1s} should be set in the range between 0.9 V_n and 1.1 V_n with 0.01 V_n steps. In order to facilitate execution of the type tests, the characterizing parameters are conventionally set as follows:
V_{1s} = 1,08 V_n; V_{2s} = 1,1 V_n
V_{1i} = 0,92 V_n; V_{2i} = 0,9 V_n
and the active power lock-in value (default value P = 0.2 P_n).

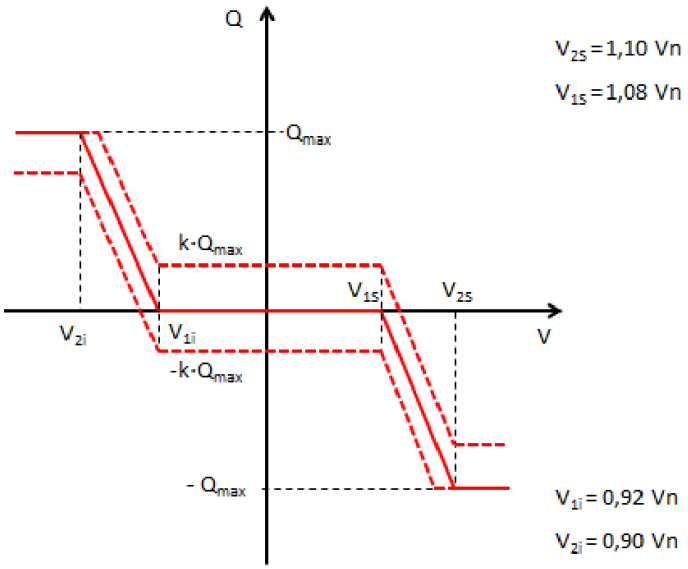

Figure 5 – Standard characteristic curve Q= f(V)

When operating above the apparent power threshold S_{min} equal to 10 % of the maximum apparent power S_{max} or the minimum regulating level of the generating plant, whichever is the higher value, the reactive power capability shall be provided with an accuracy of ± 2 % S_{max}. Up to this apparent power threshold S_{min}, deviations above 2 % are permissible.

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Clause	Requirement - Test	Result - Remark	Verdict

4.7.2.2 4.7.2.3.4	**TABLE: Power related control mode – cos φ (P)**									**P**
Model	EA16KTSI									
Test a): displacement factor active power characteristic curve cos φ (P)										
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	230.34
P_{E30} [kW]:	14.303	14.263	12.707	11.145	9.574	7.997	6.398	4.790	3.182	1.579
P_{E30} of P_{Emax} [%]:	89.39	89.14	79.42	69.66	59.83	49.98	39.98	29.94	19.89	9.87
Q_{E30} [kVAr]:	6.976	6.099	4.603	3.218	1.879	0.326	0.317	0.320	0.321	0.179
cos φ_{E30}:	0.899	0.919	0.940	0.961	0.981	0.999	0.999	0.998	0.995	0.991
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:										

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Clause	Requirement - Test	Result - Remark	Verdict

Test b): Response time-hold on			
30 s mean value	10% → 50% → 100% P_{Emax}		
P/P_n [%]	10	50	100
U [V]:	230.00	231.00	230.00
P_{E30} [kW]:	1.640	8.259	14.833
P_{E30} of P_{Emax} [%]:	10.25	51.62	92.71
Q_{E30} [kVAr]:	0.040	-0.506	-6.566
cos φ_{E30}:	0.999	0.995	0.913
cos $\varphi_{setpoint}$:	1.000	1.000	0.900
ΔT [s]:	10% → 50% P_{Emax}:	3	
	50% → 100% P_{Emax}:	3	
30 s mean value	100% → 50% → 10% P_{Emax}		
P/P_n [%]	100	50	10
U [V]:	230.00	230.93	230.00
P_{E30} [kW]:	14.700	8.383	1.720
P_{E30} [%]:	91.88	52.39	10.75
Q_{E30} [kVAr]:	-6.443	-0.652	0.114
cos φ_{E30}:	0.914	0.995	0.999
cos $\varphi_{setpoint}$:	0.900	1.000	1.000
ΔT [s]:	100% → 50% P_{Emax}:	8	
	50% → 10% P_{Emax}:	4	
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.			

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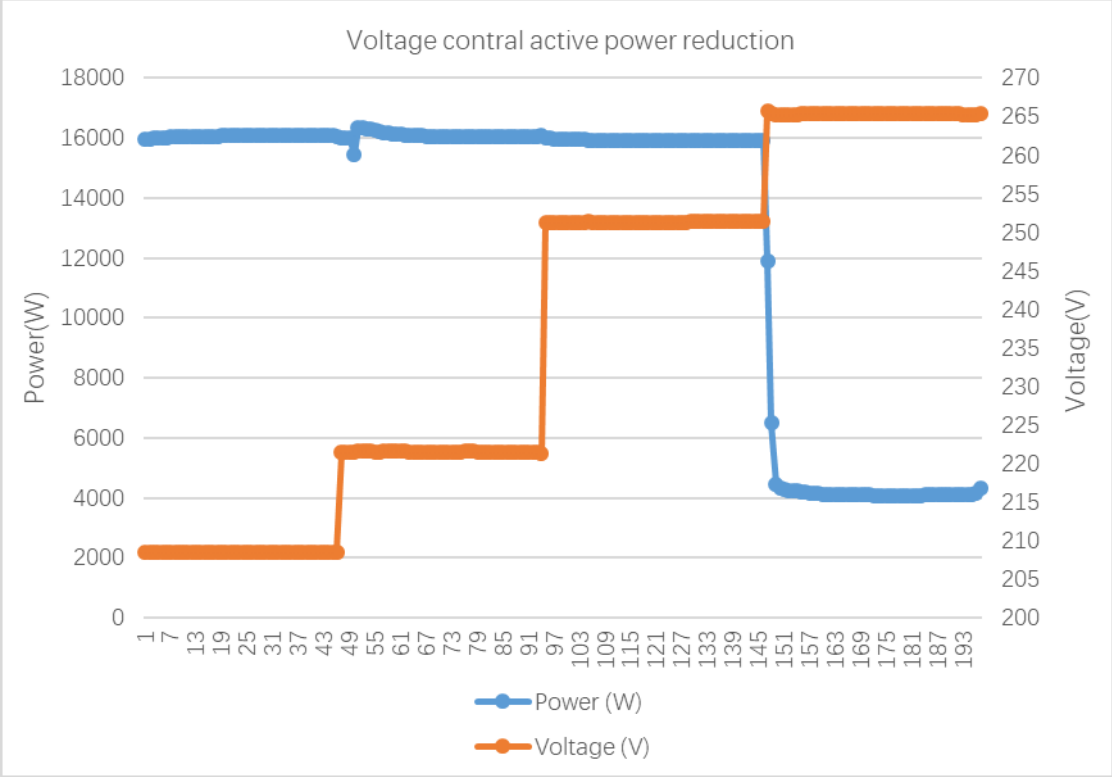
Clause	Requirement - Test	Result - Remark	Verdict

4.7.3	**Voltage related active power reduction (Optional)**		**P**
Model	EA16KTSI		
Setting of the PCE			
Threshold of reduction	1.15%U_n		
Reduction method	Δ P%/ Δ U:	2.06%	
Primary power	100% Available power		
Fault (Threshold + 10%)			

Test condition	Voltage level (%Un)	Measured voltage (V)	Measured active power (W)	Measured time [s]	Limit / a time constant Tau
1	90	208.52	16059.84	/	> 3 s
2	96	221.60	16073.52	/	> 3 s
3	109	251.35	15937.76	/	> 3 s
4	115	265.39	4336	4	> 3 s



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Clause	Requirement - Test	Result - Remark	Verdict

4.8	TABLE: Power quality - Harmonic and inter-harmonics									P
The currents of the interharmonics to 2 kHz must be measured in accordance with DIN EN 61000-4-7 (VDE 0817-4-7), Annex A. The measurements of higher-frequency harmonic currents between 2 kHz and 9 kHz must be conducted in line with DIN EN 61000-4-7 (VDE 0847-4-7), Annex B.										
Harmonics										
Model	EA16KTSI									
P/P_n [%]	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2nd	0.36	1.69	1.09	0.79	0.61	0.46	0.59	0.49	0.88	0.42
3rd	0.37	0.75	0.50	0.37	0.28	0.20	0.29	0.24	0.33	0.13
4th	0.22	1.70	0.76	0.57	0.44	0.32	0.41	0.30	0.33	0.18
5th	1.25	8.12	2.35	2.62	1.88	1.18	2.13	1.88	1.77	1.45
6th	0.56	1.07	0.31	0.23	0.20	0.12	0.27	0.18	0.19	0.11
7th	1.59	8.46	1.73	1.14	0.88	0.58	0.74	0.90	1.18	1.17
8th	0.26	0.21	0.46	0.11	0.08	0.09	0.14	0.11	0.19	0.09
9th	0.66	1.57	0.96	0.49	0.41	0.37	0.50	0.50	0.43	0.27
10th	0.30	0.46	0.21	0.21	0.10	0.10	0.06	0.05	0.20	0.14
11th	0.81	5.44	4.68	1.48	0.39	0.34	0.38	0.42	0.83	0.55
12th	0.63	0.58	0.39	0.35	0.21	0.14	0.07	0.04	0.10	0.12
13th	1.07	3.24	3.38	1.60	0.32	0.27	0.26	0.45	0.53	0.41
14th	0.15	0.53	0.08	0.16	0.09	0.09	0.05	0.05	0.08	0.02
15th	0.49	1.02	0.45	0.33	0.25	0.13	0.15	0.11	0.14	0.07
16th	0.26	0.68	0.27	0.12	0.09	0.07	0.06	0.05	0.10	0.06
17th	0.34	3.04	2.52	1.95	1.16	0.52	0.36	0.07	0.16	0.24
18th	0.56	0.61	0.30	0.29	0.11	0.20	0.11	0.10	0.16	0.08
19th	0.59	2.46	1.85	1.09	0.91	0.57	0.37	0.23	0.26	0.22
20th	0.19	0.13	0.09	0.07	0.04	0.08	0.03	0.02	0.06	0.04
21th	0.39	0.98	0.78	0.57	0.47	0.37	0.18	0.16	0.19	0.18
22th	0.22	0.26	0.14	0.03	0.07	0.03	0.04	0.04	0.27	0.02
23th	0.51	1.34	0.75	0.47	0.44	0.44	0.30	0.24	0.23	0.06
24th	0.35	0.51	0.28	0.10	0.10	0.08	0.03	0.02	0.05	0.02
25th	0.21	0.79	0.24	0.58	0.25	0.38	0.21	0.21	0.16	0.06
26th	0.04	0.34	0.21	0.08	0.05	0.05	0.03	0.03	0.08	0.03
27th	0.27	0.37	0.24	0.15	0.11	0.11	0.02	0.05	0.10	0.06
28th	0.14	0.11	0.07	0.04	0.03	0.03	0.04	0.03	0.05	0.03
29th	0.07	0.67	0.13	0.52	0.28	0.21	0.13	0.17	0.18	0.09
30th	0.23	0.10	0.11	0.05	0.03	0.02	0.01	0.01	0.03	0.01
31th	0.11	0.61	0.18	0.33	0.27	0.12	0.09	0.13	0.14	0.10
32th	0.07	0.09	0.09	0.02	0.02	0.02	0.01	0.01	0.04	0.01
33th	0.17	0.22	0.10	0.05	0.07	0.05	0.02	0.02	0.07	0.01
34th	0.14	0.13	0.06	0.03	0.02	0.03	0.01	0.01	0.04	0.01
35th	0.08	0.47	0.26	0.13	0.20	0.16	0.11	0.08	0.13	0.11
36th	0.13	0.12	0.04	0.04	0.02	0.02	0.01	0.01	0.03	0.01

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Clause	Requirement - Test	Result - Remark	Verdict

37th	0.03	0.15	0.06	0.03	0.02	0.01	0.01	0.01	0.02	0.01
38th	0.08	0.34	0.25	0.20	0.17	0.15	0.07	0.07	0.09	0.07
39th	0.07	0.07	0.06	0.03	0.02	0.03	0.01	0.01	0.07	0.01
40th	0.36	1.69	1.09	0.79	0.61	0.46	0.59	0.49	0.88	0.42

Inter-harmonics											**P**
Model	EA16KTSI										
P/P_n [%]	Frequency	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Order	[Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
1st	75	0.080	1.131	0.578	0.474	0.313	0.256	0.205	0.184	0.162	0.140
2nd	125	0.061	0.388	0.182	0.125	0.102	0.086	0.071	0.053	0.051	0.050
3rd	175	0.064	0.338	0.155	0.108	0.085	0.070	0.063	0.045	0.041	0.046
4th	225	0.064	0.397	0.145	0.105	0.080	0.066	0.061	0.041	0.039	0.043
5th	275	0.061	0.328	0.153	0.099	0.076	0.068	0.060	0.045	0.038	0.044
6th	325	0.065	0.329	0.160	0.102	0.080	0.068	0.061	0.045	0.040	0.046
7th	375	0.066	0.334	0.158	0.106	0.081	0.068	0.063	0.045	0.041	0.047
8th	425	0.066	0.293	0.151	0.111	0.083	0.069	0.067	0.044	0.039	0.046
9th	475	0.065	0.308	0.157	0.112	0.086	0.072	0.068	0.048	0.042	0.049
10th	525	0.065	0.377	0.167	0.119	0.090	0.073	0.071	0.047	0.044	0.048
11th	575	0.067	0.363	0.182	0.119	0.095	0.078	0.075	0.053	0.048	0.053
12th	625	0.066	0.391	0.183	0.127	0.095	0.078	0.076	0.054	0.049	0.052
13th	675	0.070	0.400	0.194	0.131	0.100	0.083	0.081	0.061	0.055	0.058
14th	725	0.071	0.363	0.188	0.132	0.101	0.087	0.080	0.063	0.058	0.058
15th	775	0.075	0.385	0.201	0.138	0.108	0.090	0.086	0.071	0.065	0.067
16th	825	0.073	0.426	0.228	0.149	0.123	0.103	0.086	0.070	0.065	0.063
17th	875	0.076	0.462	0.228	0.175	0.124	0.100	0.088	0.072	0.065	0.066
18th	925	0.083	0.452	0.236	0.164	0.124	0.104	0.085	0.071	0.067	0.067
19th	975	0.078	0.488	0.243	0.173	0.130	0.110	0.084	0.070	0.064	0.067
20th	1025	0.082	0.474	0.251	0.177	0.134	0.114	0.083	0.070	0.067	0.070
21th	1075	0.085	0.475	0.262	0.184	0.142	0.119	0.081	0.071	0.070	0.070
22th	1125	0.086	0.513	0.288	0.196	0.149	0.131	0.079	0.071	0.071	0.072
23th	1175	0.102	0.632	0.396	0.262	0.204	0.173	0.078	0.076	0.076	0.072
24th	1225	0.092	0.510	0.315	0.208	0.164	0.149	0.070	0.068	0.071	0.069
25th	1275	0.102	1.031	0.638	0.454	0.370	0.320	0.136	0.127	0.127	0.121
26th	1325	0.115	0.548	0.318	0.247	0.191	0.173	0.071	0.067	0.070	0.070
27th	1375	0.106	0.533	0.314	0.231	0.196	0.185	0.065	0.058	0.065	0.063
28th	1425	0.175	0.513	0.275	0.203	0.158	0.152	0.054	0.045	0.048	0.052
29th	1475	0.119	0.555	0.307	0.232	0.185	0.168	0.051	0.043	0.046	0.048
30th	1525	0.155	0.429	0.242	0.199	0.154	0.148	0.056	0.050	0.050	0.052
31th	1575	0.108	0.412	0.214	0.167	0.128	0.124	0.043	0.036	0.036	0.041
32th	1625	0.170	0.392	0.206	0.155	0.134	0.128	0.053	0.049	0.049	0.050
33th	1675	0.117	0.336	0.177	0.125	0.109	0.102	0.039	0.029	0.029	0.032
34th	1725	0.190	0.400	0.176	0.122	0.103	0.094	0.036	0.028	0.028	0.031

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Clause	Requirement - Test	Result - Remark	Verdict

35th	1775	0.119	0.335	0.164	0.115	0.096	0.084	0.033	0.025	0.025	0.029
36th	1825	0.119	0.338	0.150	0.105	0.087	0.078	0.033	0.026	0.026	0.028
37th	1875	0.138	0.311	0.144	0.097	0.082	0.072	0.031	0.026	0.026	0.028
38th	1925	0.131	0.250	0.133	0.088	0.074	0.065	0.030	0.024	0.023	0.025
39th	1975	0.141	0.250	0.128	0.087	0.070	0.062	0.030	0.022	0.021	0.024
40th	2025	0.136	0.250	0.121	0.079	0.068	0.057	0.028	0.022	0.021	0.019

Higher Frequencies										
Model	EA16KTSI									
P/P_n [%]	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
f [kHz]	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
2.3	0.05	0.09	0.03	0.03	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
2.7	0.05	0.09	0.02	0.03	0.02	0.02	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
3.1	0.03	0.09	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.02
3.3	0.02	0.06	0.03	0.04	0.02	0.02	0.03	0.02	0.02	0.02
3.5	0.02	0.17	0.07	0.05	0.03	0.03	0.03	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
3.9	0.02	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.02
4.1	0.02	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
4.3	0.02	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.5	0.02	0.04	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
4.9	0.02	0.05	0.02	0.02	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
5.3	0.02	0.06	0.02	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
5.7	0.02	0.04	0.02	0.02	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
6.1	0.01	0.05	0.01	0.01	0.01	0.01	0.00	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
6.5	0.02	0.07	0.02	0.02	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
6.9	0.01	0.10	0.02	0.04	0.01	0.01	0.01	0.01	0.02	0.01
7.1	0.02	0.22	0.03	0.07	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
7.5	0.02	0.09	0.03	0.04	0.01	0.01	0.01	0.01	0.03	0.01
7.7	0.02	0.18	0.04	0.06	0.01	0.01	0.01	0.01	0.02	0.01
7.9	0.02	0.11	0.03	0.05	0.01	0.01	0.01	0.01	0.02	0.01
8.1	0.02	0.06	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.01
8.3	0.02	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.01

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Clause	Requirement - Test						Result - Remark			Verdict
8.5	0.02	0.08	0.02	0.02	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
8.9	0.02	0.08	0.02	0.09	0.01	0.01	0.01	0.01	0.01	0.01

4.8	**TABLE: Power quality - Harmonic and inter-harmonics**									**P**
The currents of the interharmonics to 2 kHz must be measured in accordance with DIN EN 61000-4-7 (VDE 0817-4-7), Annex A. The measurements of higher-frequency harmonic currents between 2 kHz and 9 kHz must be conducted in line with DIN EN 61000-4-7 (VDE 0847-4-7), Annex B.										
Harmonics										
Model	EA5KTSI									
P/P_n [%]	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Order	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
2nd	0.34	4.29	2.16	1.44	1.12	0.89	1.15	0.96	1.03	0.78
3rd	0.44	1.95	0.50	0.29	0.24	0.20	0.30	0.24	0.27	0.20
4th	0.21	3.92	1.92	1.24	1.00	0.80	1.01	0.83	0.77	0.56
5th	1.13	7.25	2.04	2.62	2.16	1.70	1.73	1.34	1.10	0.89
6th	0.67	1.91	0.80	0.50	0.39	0.31	0.30	0.26	0.28	0.22
7th	1.30	7.26	1.30	1.25	1.39	1.14	0.86	0.40	0.25	0.19
8th	0.31	1.34	1.02	0.61	0.36	0.29	0.33	0.27	0.32	0.24
9th	0.66	1.82	1.30	1.02	0.65	0.47	0.41	0.33	0.32	0.25
10th	0.33	1.21	0.22	0.43	0.28	0.17	0.13	0.11	0.17	0.10
11th	0.83	3.12	4.33	2.17	0.58	0.29	0.67	0.58	0.93	0.39
12th	0.85	2.23	0.97	0.76	0.58	0.47	0.42	0.35	0.34	0.25
13th	1.01	5.17	2.21	2.95	1.34	0.56	0.17	0.42	0.69	0.63
14th	0.25	0.51	0.72	0.18	0.27	0.19	0.15	0.11	0.16	0.07
15th	0.64	1.77	0.84	0.60	0.50	0.38	0.30	0.26	0.25	0.18
16th	0.37	1.35	0.59	0.24	0.22	0.19	0.22	0.19	0.17	0.12
17th	0.24	2.00	1.35	0.96	1.57	1.31	0.76	0.38	0.19	0.05
18th	0.73	1.28	0.63	0.51	0.38	0.29	0.18	0.13	0.15	0.11
19th	0.56	2.85	0.69	0.42	1.03	0.93	0.48	0.33	0.25	0.14
20th	0.23	0.66	0.24	0.16	0.13	0.06	0.06	0.06	0.12	0.05
21th	0.47	0.56	0.28	0.09	0.13	0.14	0.09	0.08	0.11	0.07
22th	0.32	0.76	0.32	0.15	0.09	0.07	0.02	0.03	0.24	0.03
23th	0.57	0.80	0.16	0.44	0.39	0.40	0.21	0.20	0.22	0.14
24th	0.42	0.65	0.29	0.19	0.12	0.08	0.05	0.05	0.07	0.04
25th	0.20	0.69	0.84	0.58	0.28	0.10	0.10	0.20	0.23	0.18
26th	0.05	0.25	0.20	0.14	0.14	0.07	0.04	0.04	0.05	0.04
27th	0.28	0.84	0.67	0.42	0.32	0.15	0.10	0.10	0.10	0.09
28th	0.15	0.55	0.17	0.07	0.08	0.05	0.02	0.03	0.04	0.04
29th	0.12	0.65	1.01	0.30	0.25	0.09	0.06	0.10	0.13	0.12
30th	0.19	0.23	0.16	0.08	0.08	0.05	0.03	0.03	0.04	0.02
31th	0.09	1.02	0.46	0.13	0.15	0.07	0.03	0.05	0.06	0.03
32th	0.06	0.32	0.11	0.05	0.07	0.05	0.04	0.04	0.04	0.01
33th	0.16	0.74	0.39	0.20	0.18	0.10	0.15	0.16	0.20	0.10

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Clause	Requirement - Test	Result - Remark	Verdict

34th	0.14	0.16	0.09	0.05	0.04	0.02	0.02	0.03	0.04	0.02
35th	0.18	0.58	0.20	0.25	0.15	0.23	0.13	0.09	0.08	0.04
36th	0.11	0.17	0.08	0.06	0.04	0.04	0.02	0.02	0.02	0.01
37th	0.53	0.93	0.31	0.26	0.12	0.20	0.04	0.03	0.05	0.06
38th	0.09	0.27	0.15	0.11	0.08	0.06	0.03	0.01	0.02	0.02
39th	0.07	0.40	0.23	0.30	0.24	0.19	0.13	0.07	0.03	0.02
40th	0.05	0.16	0.13	0.13	0.07	0.06	0.03	0.03	0.04	0.02

Inter-harmonics											**P**
Model	EA5KTSI										
P/P_n [%]	Frequency	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Order	[Hz]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]	I [%]
1st	75	0.020	0.025	0.025	0.022	0.021	0.024	0.028	0.021	0.021	0.027
2nd	125	0.004	0.009	0.008	0.006	0.005	0.008	0.009	0.005	0.005	0.008
3rd	175	0.003	0.006	0.006	0.005	0.004	0.006	0.007	0.004	0.004	0.006
4th	225	0.003	0.005	0.005	0.004	0.004	0.005	0.006	0.004	0.004	0.005
5th	275	0.003	0.005	0.006	0.005	0.005	0.005	0.006	0.004	0.004	0.005
6th	325	0.004	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
7th	375	0.003	0.005	0.005	0.006	0.006	0.006	0.006	0.005	0.005	0.005
8th	425	0.004	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
9th	475	0.003	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
10th	525	0.003	0.006	0.006	0.006	0.006	0.007	0.007	0.006	0.006	0.006
11th	575	0.004	0.006	0.008	0.008	0.008	0.007	0.007	0.007	0.007	0.007
12th	625	0.004	0.006	0.008	0.011	0.012	0.014	0.014	0.014	0.014	0.014
13th	675	0.004	0.008	0.008	0.009	0.008	0.008	0.007	0.007	0.007	0.007
14th	725	0.004	0.006	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
15th	775	0.004	0.007	0.008	0.008	0.008	0.008	0.007	0.007	0.007	0.007
16th	825	0.004	0.006	0.007	0.007	0.007	0.008	0.007	0.007	0.007	0.007
17th	875	0.003	0.007	0.009	0.009	0.009	0.009	0.008	0.008	0.008	0.008
18th	925	0.004	0.007	0.008	0.008	0.009	0.009	0.008	0.008	0.008	0.008
19th	975	0.004	0.009	0.011	0.009	0.009	0.010	0.009	0.009	0.009	0.009
20th	1025	0.005	0.007	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.009
21th	1075	0.004	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
22th	1125	0.004	0.008	0.010	0.009	0.009	0.010	0.010	0.009	0.009	0.010
23th	1175	0.004	0.009	0.012	0.011	0.011	0.012	0.012	0.012	0.012	0.012
24th	1225	0.004	0.008	0.009	0.009	0.009	0.010	0.010	0.010	0.010	0.010
25th	1275	0.004	0.010	0.011	0.011	0.011	0.013	0.012	0.012	0.012	0.013
26th	1325	0.005	0.009	0.011	0.010	0.011	0.012	0.012	0.012	0.012	0.012
27th	1375	0.004	0.009	0.010	0.010	0.011	0.010	0.010	0.011	0.011	0.011
28th	1425	0.009	0.011	0.012	0.011	0.012	0.012	0.011	0.011	0.011	0.011
29th	1475	0.004	0.009	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.011
30th	1525	0.007	0.009	0.009	0.010	0.010	0.011	0.010	0.011	0.011	0.011
31th	1575	0.004	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.009	0.009

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Clause	Requirement - Test	Result - Remark	Verdict

32th	1625	0.008	0.009	0.009	0.009	0.009	0.010	0.010	0.010	0.011	0.011
33th	1675	0.004	0.008	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.008
34th	1725	0.008	0.009	0.009	0.009	0.009	0.008	0.008	0.008	0.008	0.008
35th	1775	0.004	0.007	0.007	0.007	0.007	0.006	0.006	0.006	0.007	0.007
36th	1825	0.004	0.007	0.006	0.006	0.006	0.006	0.006	0.007	0.006	0.006
37th	1875	0.004	0.008	0.007	0.007	0.006	0.006	0.006	0.007	0.007	0.007
38th	1925	0.005	0.007	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
39th	1975	0.004	0.007	0.006	0.006	0.006	0.006	0.005	0.005	0.005	0.006
40th	2025	0.005	0.007	0.006	0.006	0.006	0.006	0.005	0.006	0.006	0.006

Higher Frequencies										
Model	EA5KTSI									
P/P_n [%]	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
f [kHz]	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
2.3	0.05	0.09	0.03	0.03	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
2.7	0.05	0.09	0.02	0.03	0.02	0.02	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
3.1	0.03	0.09	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.02
3.3	0.02	0.06	0.03	0.04	0.02	0.02	0.03	0.02	0.02	0.02
3.5	0.02	0.17	0.07	0.05	0.03	0.03	0.03	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
3.9	0.02	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.02
4.1	0.02	0.07	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
4.3	0.02	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
4.5	0.02	0.04	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
4.9	0.02	0.05	0.02	0.02	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
5.3	0.02	0.06	0.02	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
5.7	0.02	0.04	0.02	0.02	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
6.1	0.01	0.05	0.01	0.01	0.01	0.01	0.00	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
6.5	0.02	0.07	0.02	0.02	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
6.9	0.01	0.10	0.02	0.04	0.01	0.01	0.01	0.01	0.02	0.01
7.1	0.02	0.22	0.03	0.07	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
7.5	0.02	0.09	0.03	0.04	0.01	0.01	0.01	0.01	0.03	0.01
7.7	0.02	0.18	0.04	0.06	0.01	0.01	0.01	0.01	0.02	0.01

EN 50549-1										
Clause	Requirement - Test						Result - Remark			Verdict
7.9	0.02	0.11	0.03	0.05	0.01	0.01	0.01	0.01	0.02	0.01
8.1	0.02	0.06	0.03	0.03	0.01	0.01	0.01	0.01	0.03	0.01
8.3	0.02	0.10	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0.01
8.5	0.02	0.08	0.02	0.02	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
8.9	0.02	0.08	0.02	0.09	0.01	0.01	0.01	0.01	0.01	0.01

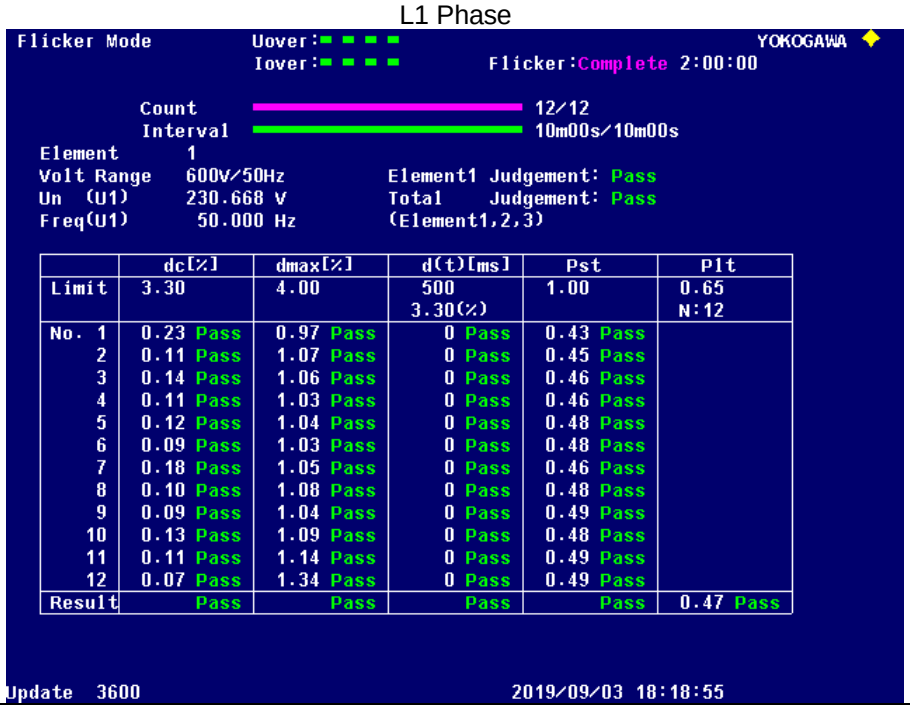
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.8	**Power quality - Voltage fluctuations and flicker**	**P**
Model	EA16KTSI	

Parameter	Limits	Test Value
P_{st}	1.0	See below
P_{lt}	0.65	See below
d(t) – 500ms	3.3%	See below
dc%	3.3%	See below
d_{max}	4%	See below

Note:
Maximum permissible flicker and voltage fluctuation as per EN 61000-3-11(>16A)

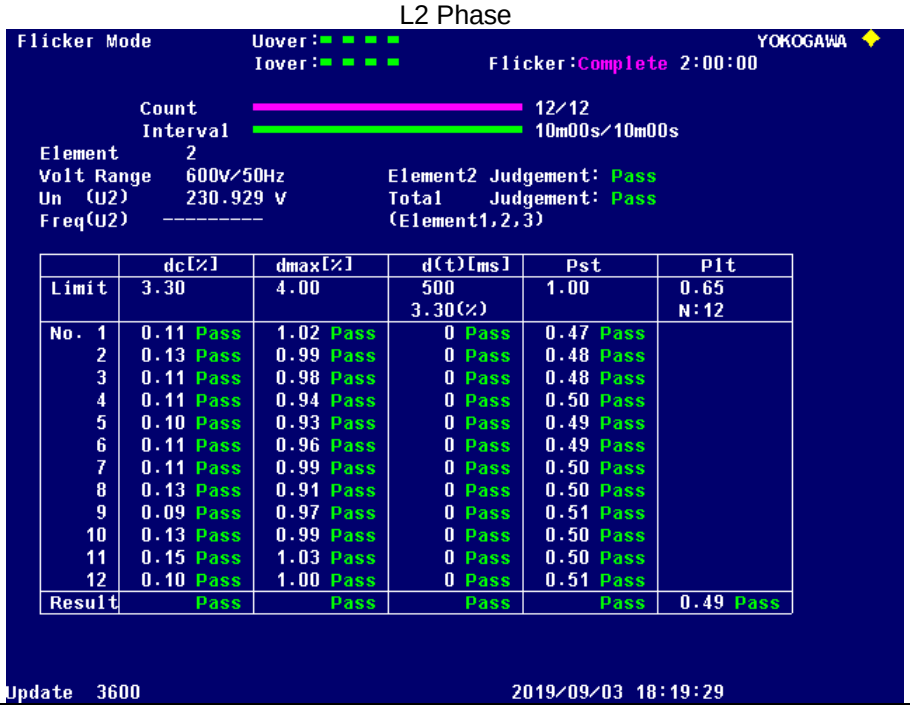
L1 Phase



	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.23 Pass	0.97 Pass	0 Pass	0.43 Pass	
2	0.11 Pass	1.07 Pass	0 Pass	0.45 Pass	
3	0.14 Pass	1.06 Pass	0 Pass	0.46 Pass	
4	0.11 Pass	1.03 Pass	0 Pass	0.46 Pass	
5	0.12 Pass	1.04 Pass	0 Pass	0.48 Pass	
6	0.09 Pass	1.03 Pass	0 Pass	0.48 Pass	
7	0.18 Pass	1.05 Pass	0 Pass	0.46 Pass	
8	0.10 Pass	1.08 Pass	0 Pass	0.48 Pass	
9	0.09 Pass	1.04 Pass	0 Pass	0.49 Pass	
10	0.13 Pass	1.09 Pass	0 Pass	0.48 Pass	
11	0.11 Pass	1.14 Pass	0 Pass	0.49 Pass	
12	0.07 Pass	1.34 Pass	0 Pass	0.49 Pass	
Result	Pass	Pass	Pass	Pass	0.47 Pass

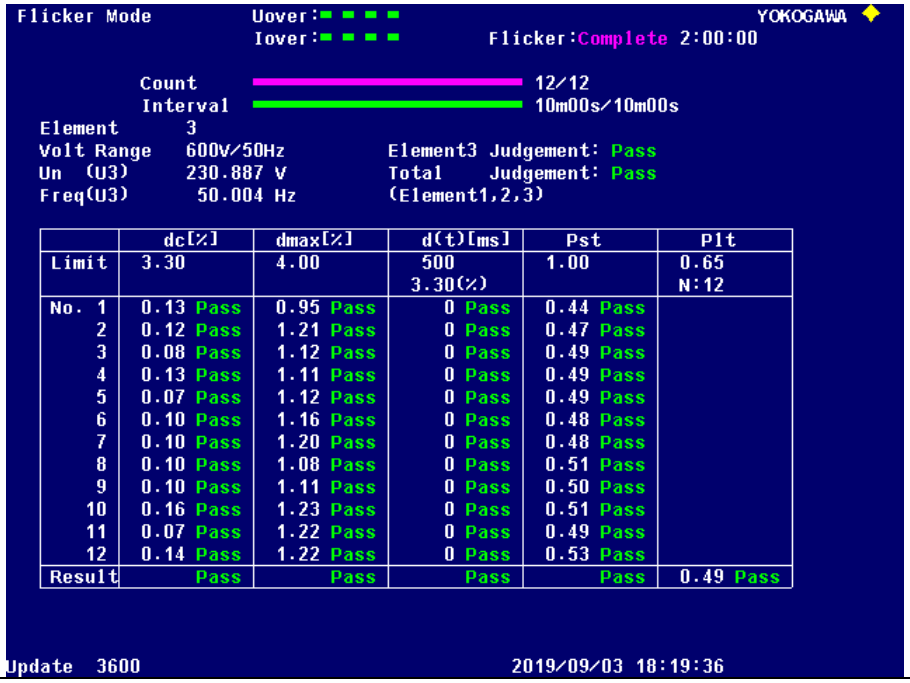
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

L2 Phase



	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.11 Pass	1.02 Pass	0 Pass	0.47 Pass	
2	0.13 Pass	0.99 Pass	0 Pass	0.48 Pass	
3	0.11 Pass	0.98 Pass	0 Pass	0.48 Pass	
4	0.11 Pass	0.94 Pass	0 Pass	0.50 Pass	
5	0.10 Pass	0.93 Pass	0 Pass	0.49 Pass	
6	0.11 Pass	0.96 Pass	0 Pass	0.49 Pass	
7	0.11 Pass	0.99 Pass	0 Pass	0.50 Pass	
8	0.13 Pass	0.91 Pass	0 Pass	0.50 Pass	
9	0.09 Pass	0.97 Pass	0 Pass	0.51 Pass	
10	0.13 Pass	0.99 Pass	0 Pass	0.50 Pass	
11	0.15 Pass	1.03 Pass	0 Pass	0.50 Pass	
12	0.10 Pass	1.00 Pass	0 Pass	0.51 Pass	
Result	Pass	Pass	Pass	Pass	0.49 Pass

L3 Phase



	dc[%]	dmax[%]	d(t)[ms]	Pst	Plt
Limit	3.30	4.00	500 3.30(%)	1.00	0.65 N:12
No. 1	0.13 Pass	0.95 Pass	0 Pass	0.44 Pass	
2	0.12 Pass	1.21 Pass	0 Pass	0.47 Pass	
3	0.08 Pass	1.12 Pass	0 Pass	0.49 Pass	
4	0.13 Pass	1.11 Pass	0 Pass	0.49 Pass	
5	0.07 Pass	1.12 Pass	0 Pass	0.49 Pass	
6	0.10 Pass	1.16 Pass	0 Pass	0.48 Pass	
7	0.10 Pass	1.20 Pass	0 Pass	0.48 Pass	
8	0.10 Pass	1.08 Pass	0 Pass	0.51 Pass	
9	0.10 Pass	1.11 Pass	0 Pass	0.50 Pass	
10	0.16 Pass	1.23 Pass	0 Pass	0.51 Pass	
11	0.07 Pass	1.22 Pass	0 Pass	0.49 Pass	
12	0.14 Pass	1.22 Pass	0 Pass	0.53 Pass	
Result	Pass	Pass	Pass	Pass	0.49 Pass

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.8	**TABLE: Power quality - DC injection**		**P**
Model	EA16KTSI		
EN 50549 Limit:	0.5 % of I_{nom} (116 mA)		
Power level	20%	60%	100%
Output power (VA)	3300	9663.83	16050
DC inject current L1 (mA)	6.77	8.97	62.79
DC inject current L2 (mA)	8.66	22.10	81.83
DC inject current L3 (mA)	2.85	20.80	18.33
Note:			

4.8	**TABLE: Power quality - DC injection**		**P**
Model	EA5KTSI		
EN 50549 Limit:	0.5 % of I_{nom} (36.5 mA)		
Power level	20%	60%	100%
Output power (VA)	1020	3013.83	5030
DC inject current L1 (mA)	4.49	17.50	5.39
DC inject current L2 (mA)	3.89	15.80	3.36
DC inject current L3 (mA)	2.64	12.80	2.97
Note:			

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.8	**TABLE: Power quality - Voltage unbalance**				**P**
Model	EA16KTSI				
Measurement No.	1	2	3	4	5
Test at rated power @ cos φ = 1					
U_{E60} [V]: L1	230.85	230.91	230.96	230.96	230.96
U_{E60} [V]: L2	230.63	230.59	230.57	230.56	230.56
U_{E60} [V]: L3	230.72	230.76	230.76	230.74	230.77
U_{E60} [V]: |L1 - L2|	0.22	0.32	0.39	0.4	0.4
U_{E60} [V]: |L2 - L3|	0.09	0.17	0.19	0.18	0.21
U_{E60} [V]: |L3 - L1|	0.13	0.15	0.2	0.22	0.19
cos φ_{E60} max.:	1.0				
max voltage unbalance [V]:	0.4				
Limit, 1%U_{Rated} [V]:	2.3				
Note: Three-phase generators may not contribute more than 1 % voltage unbalance when connected to a network with impedance equal to the reference impedance.					

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

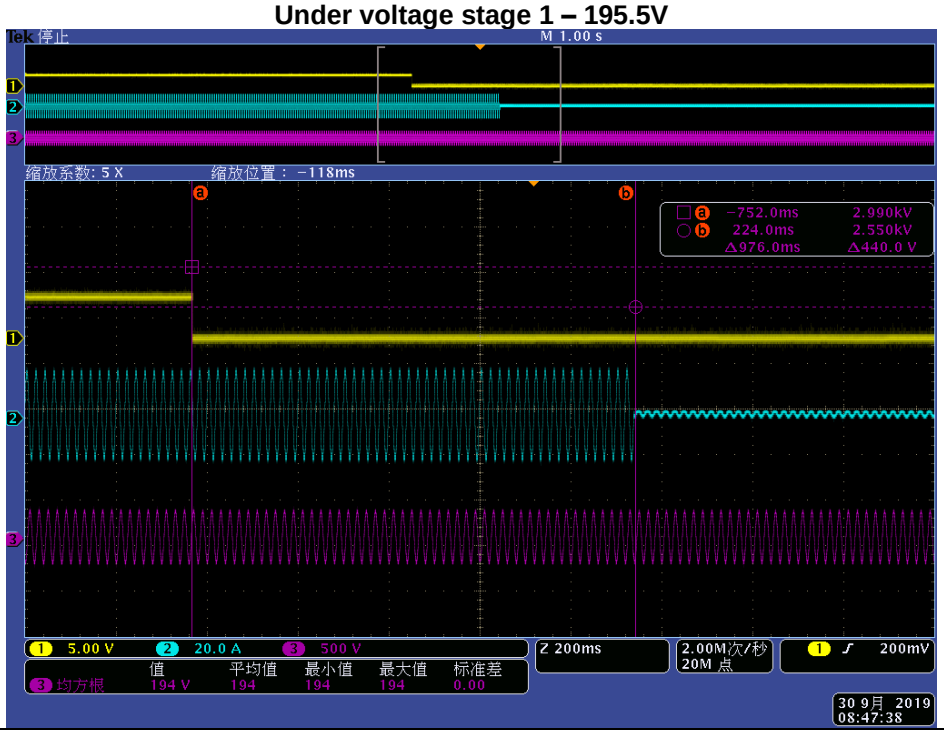
4.9.3.2	**TABLE: Under-voltage protection – Default setting**	**P**
Model	EA16KTSI	
Test condition:	Output level: 50 ± 5% of its rated current output Frequency: 50 Hz	

Phase	Adjustment thresholds ranges [V]	Actual thresholds setting [V]	Measured trip value [V]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
L1 Phase	0.2-1.0U_n (stage 1)	195	194	0.1-100s	1	0.976
		195	193		1	0.958
		195	193		1	0.964
	0.2-1.0U_n (stage 2)	115	115	0.1-5s	0.1	0.0597
		115	116		0.1	0.0953
		115	116		0.1	0.0717
L2 Phase	0.2-1.0U_n (stage 1)	195	193	0.1-100s	1	0.972
		195	195		1	0.962
		195	194		1	0.954
	0.2-1.0U_n (stage 2)	115	114	0.1-5s	0.1	0.0593
		115	114		0.1	0.0749
		115	113		0.1	0.0763
L3 Phase	0.2-1.0U_n (stage 1)	195	194	0.1-100s	1	0.958
		195	194		1	0.970
		195	194		1	0.974
	0.2-1.0U_n (stage 2)	115	115	0.1-5s	0.1	0.0845
		115	114		0.1	0.0817
		115	115		0.1	0.0801

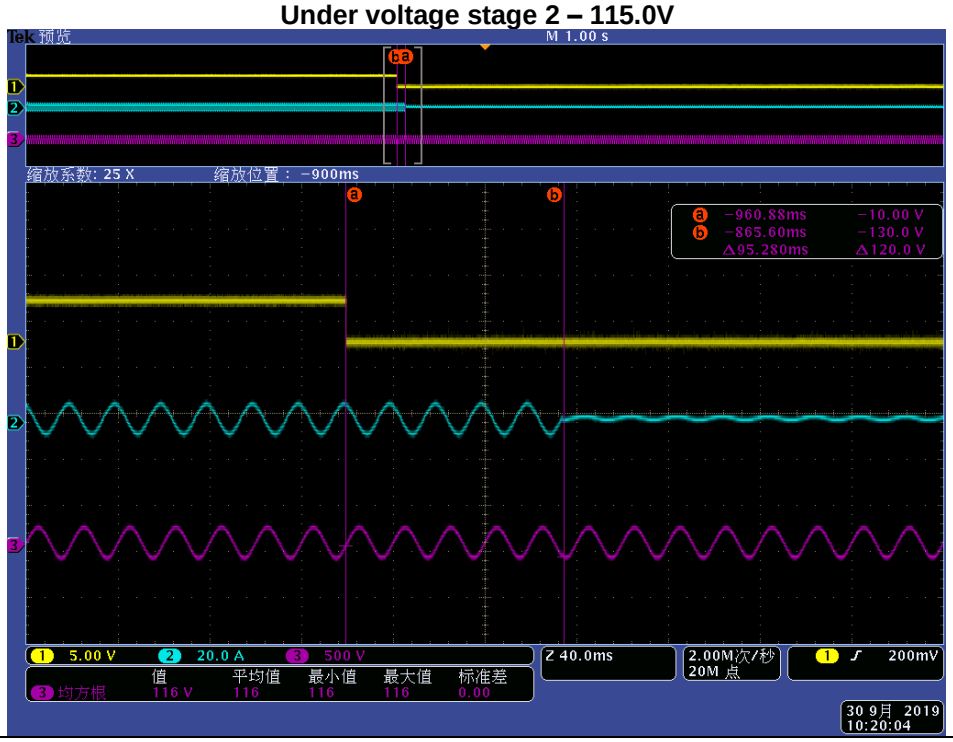
Note:
The minimum required accuracy for protection is:
for frequency measurement ± 0,05 Hz;
for voltage measurement ± 1 % of U_n;
The reset time shall be ≤ 50 ms.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under voltage stage 1 – 195.5V



Under voltage stage 2 – 115.0V



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

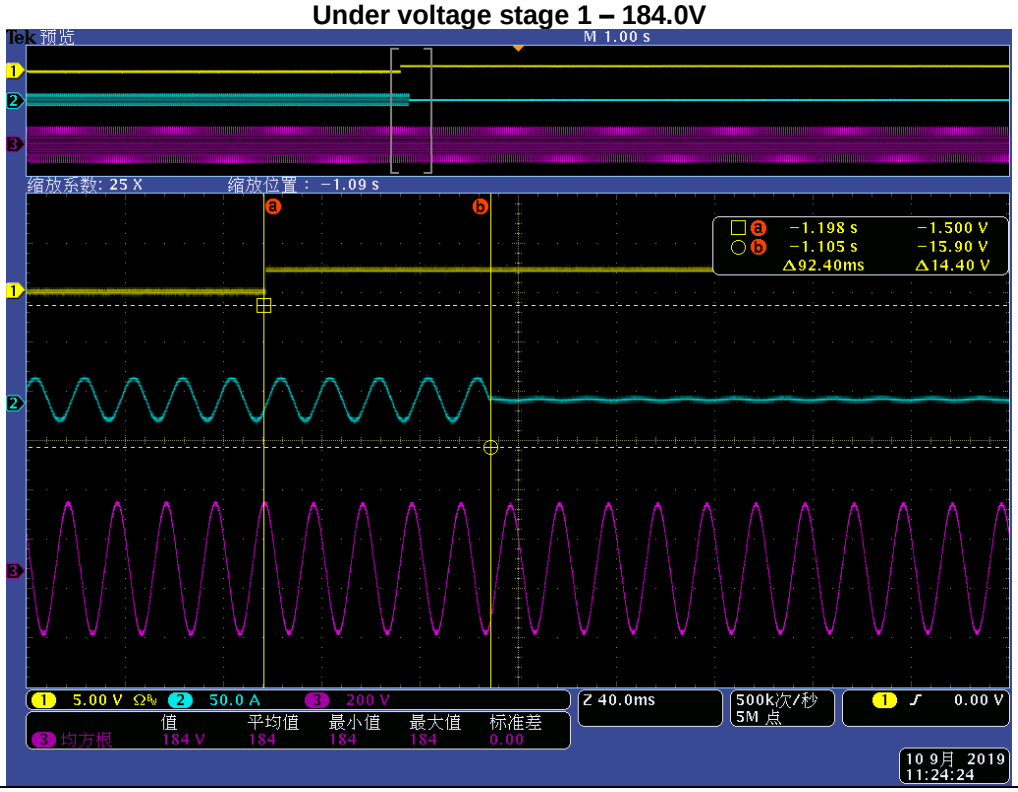
4.9.3.2	**TABLE: Under-voltage protection – Adjustable setting**	**P**
Model	EA16KTSI	
Test condition:	Output level: 50 ± 5% of its rated current output Frequency: 50 Hz	

Phase	Adjustment thresholds ranges [V]	Actual thresholds setting [V]	Measured trip value [V]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
L1 Phase	0.2-1.0U_n (stage 1)	0.80U_n=184.0	184	0.1-100s	0.1	0.0924
		0.85U_n=195.5	195		10	9.980
		0.90U_n=203.0	204		100	99.80
	0.2-1.0U_n (stage 2)	0.20U_n=46.0	46.7	0.1-5s	0.1	0.0960
		0.50U_n=115.0	114		1	1.0
		0.80U_n=195.5	195		5	4.970
L2 Phase	0.2-1.0U_n (stage 1)	0.80U_n=184.0	184	0.1-100s	0.1	0.0912
		0.85U_n=195.5	194		10	10.0
		0.90U_n=203.0	202		100	100.0
	0.2-1.0U_n (stage 2)	0.20U_n=46.0	44	0.1-5s	0.1	0.01
		0.50U_n=115.0	114		1	0.996
		0.80U_n=195.5	195		5	4.980
L3 Phase	0.2-1.0U_n (stage 1)	0.80U_n=184.0	184	0.1-100s	0.1	0.0868
		0.85U_n=195.5	195		10	10.0
		0.90U_n=203.0	202		100	100.0
	0.2-1.0U_n (stage 2)	0.20U_n=46.0	46.3	0.1-5s	0.1	0.094
		0.50U_n=115.0	114		1	1.0
		0.80U_n=195.5	195		5	4.970

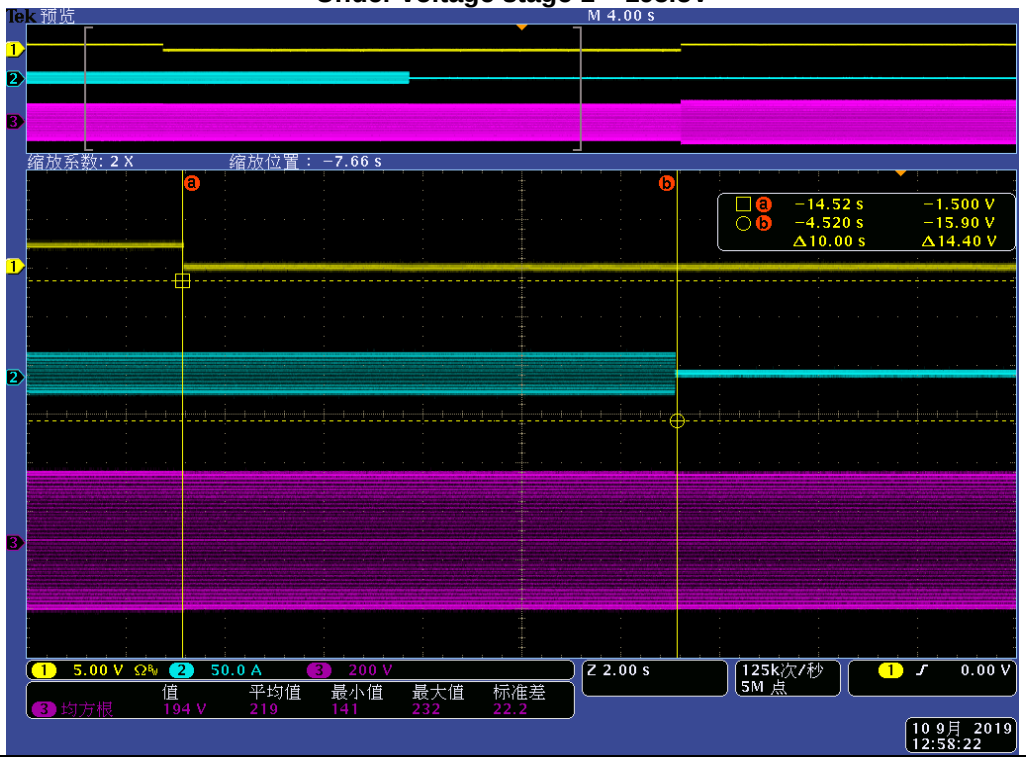
Note:
The minimum required accuracy for protection is:
for frequency measurement ± 0,05 Hz;
for voltage measurement ± 1 % of U_n;
The reset time shall be ≤ 50 ms.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under voltage stage 1 – 184.0V

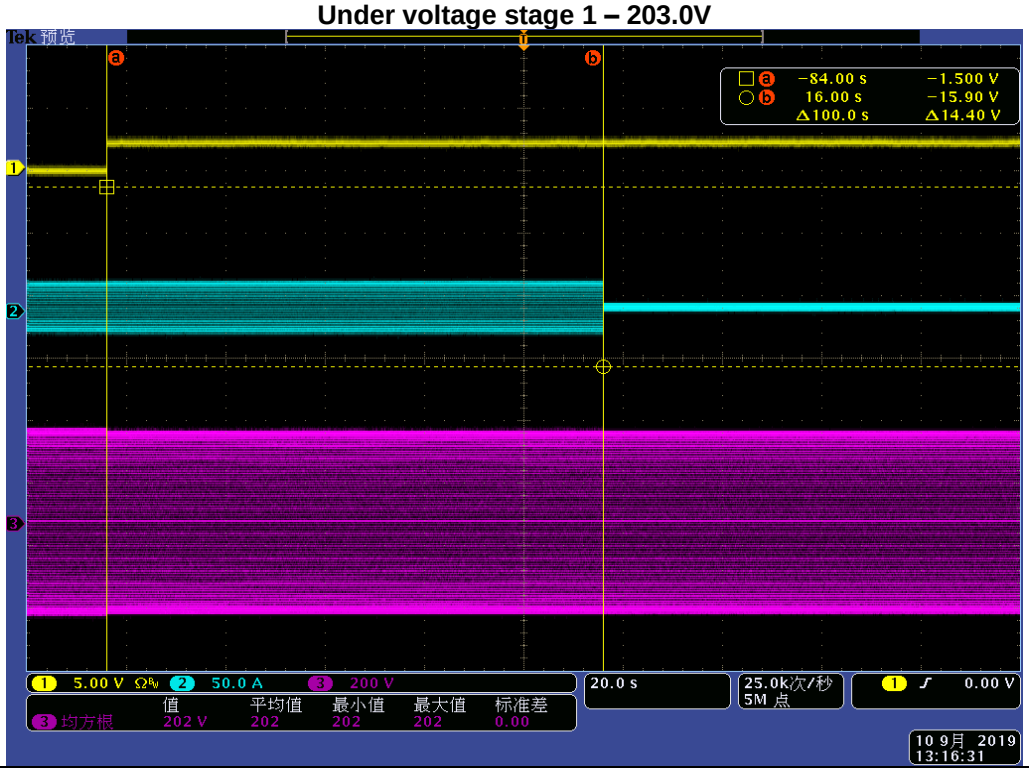


Under voltage stage 1 – 195.5V

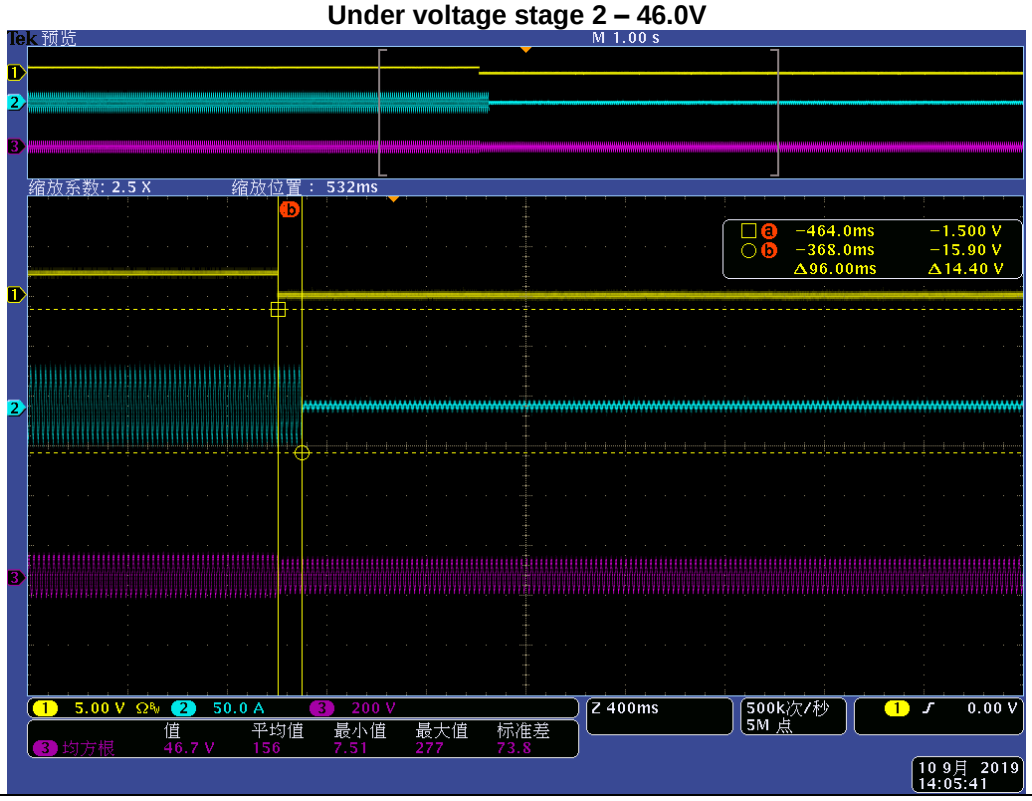


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under voltage stage 1 – 203.0V

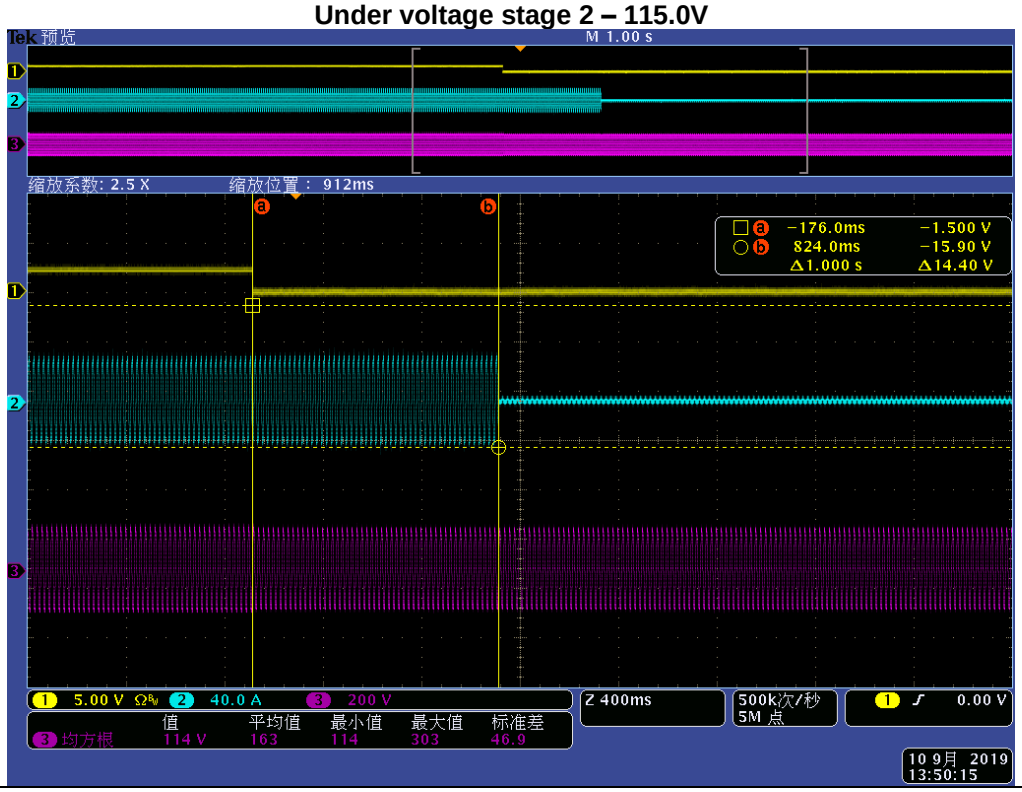


Under voltage stage 2 – 46.0V

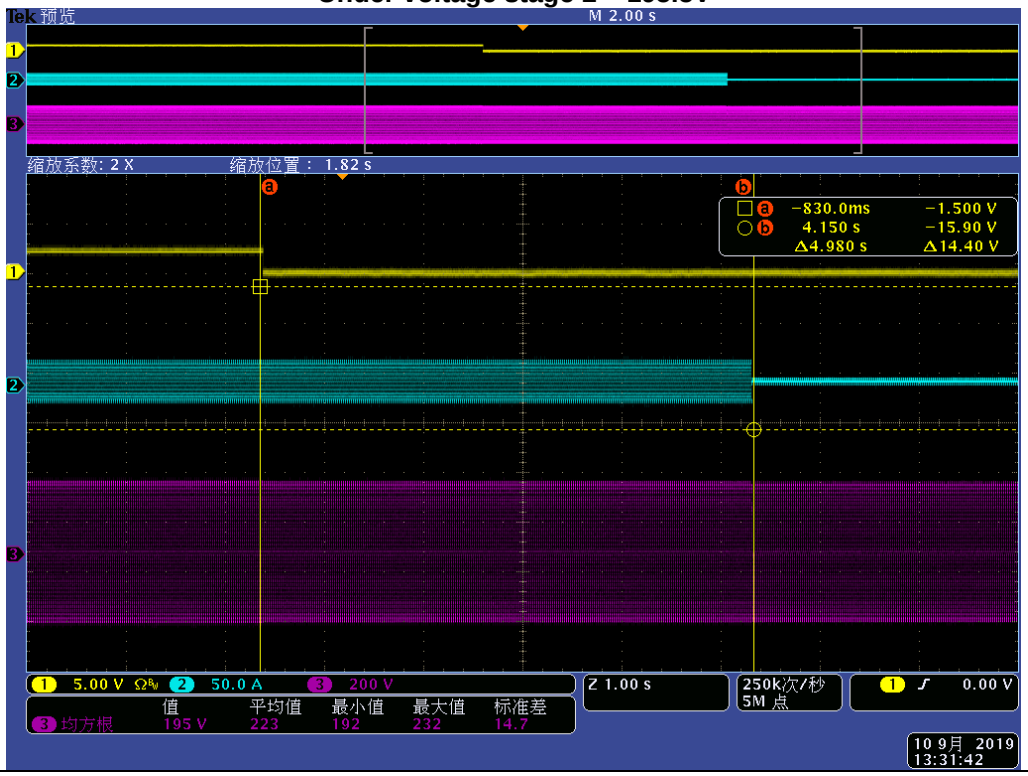


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under voltage stage 2 – 115.0V



Under voltage stage 2 – 195.5V



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.3.3	**TABLE: Overvoltage protection – Default setting**	**P**
Model	EA16KTSI	
Test condition:	Output level: 50 ± 5% of its rated current output Frequency: 50 Hz	

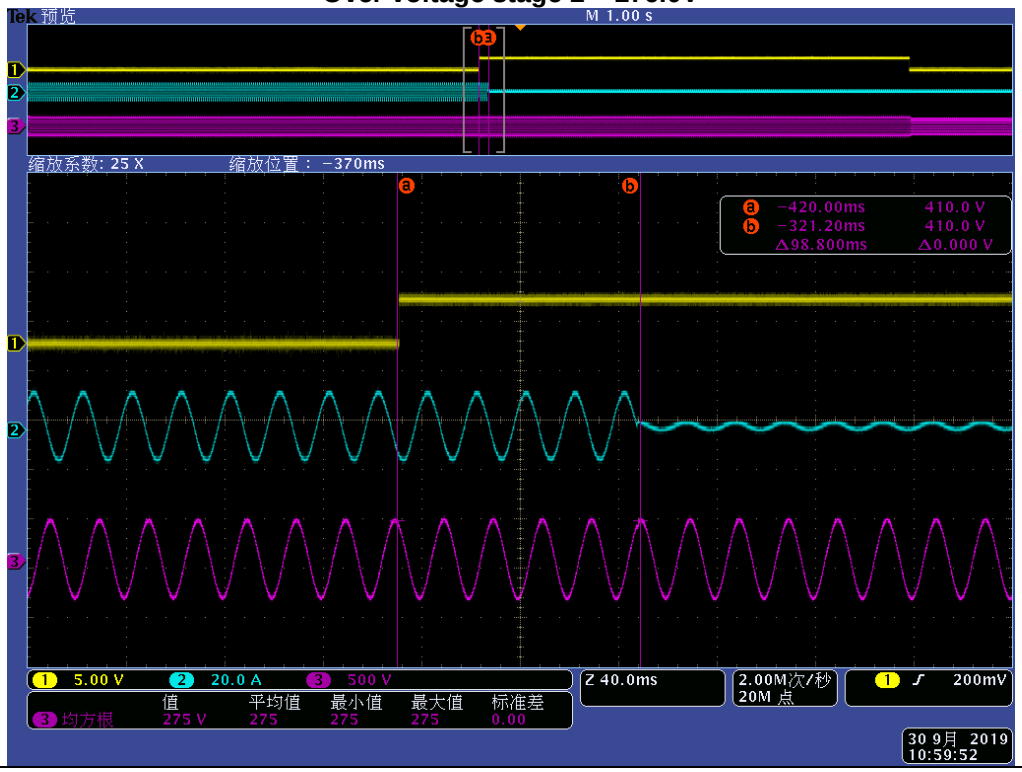
Phase	Adjustment thresholds ranges [V]	Actual thresholds setting [V]	Measured trip value [V]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
L1 Phase	1.0-1.2U_n (stage 1)	253	253	0.1-100s	1	0.960
		253	253		1	0.958
		253	252		1	0.978
	1.0-1.3U_n (stage 2)	276	275	0.1-5s	0.1	0.0988
		276	277		0.1	0.0764
		276	276		0.1	0.0736
L2 Phase	1.0-1.2U_n (stage 1)	253	253	0.1-100s	1	0.974
		253	253		1	0.970
		253	253		1	0.956
	1.0-1.3U_n (stage 2)	276	276	0.1-5s	0.1	0.0964
		276	276		0.1	0.0808
		276	276		0.1	0.0996
L3 Phase	1.0-1.2U_n (stage 1)	253	253	0.1-100s	1	0.964
		253	253		1	0.974
		253	253		1	0.966
	1.0-1.3U_n (stage 2)	276	276	0.1-5s	0.1	0.0892
		276	276		0.1	0.960
		276	276		0.1	0.958

Note:
The minimum required accuracy for protection is:
for frequency measurement ± 0,05 Hz;
for voltage measurement ± 1 % of U_n;
The reset time shall be ≤ 50 ms.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over voltage stage 1 – 253.0V

Over voltage stage 2 – 276.0V



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

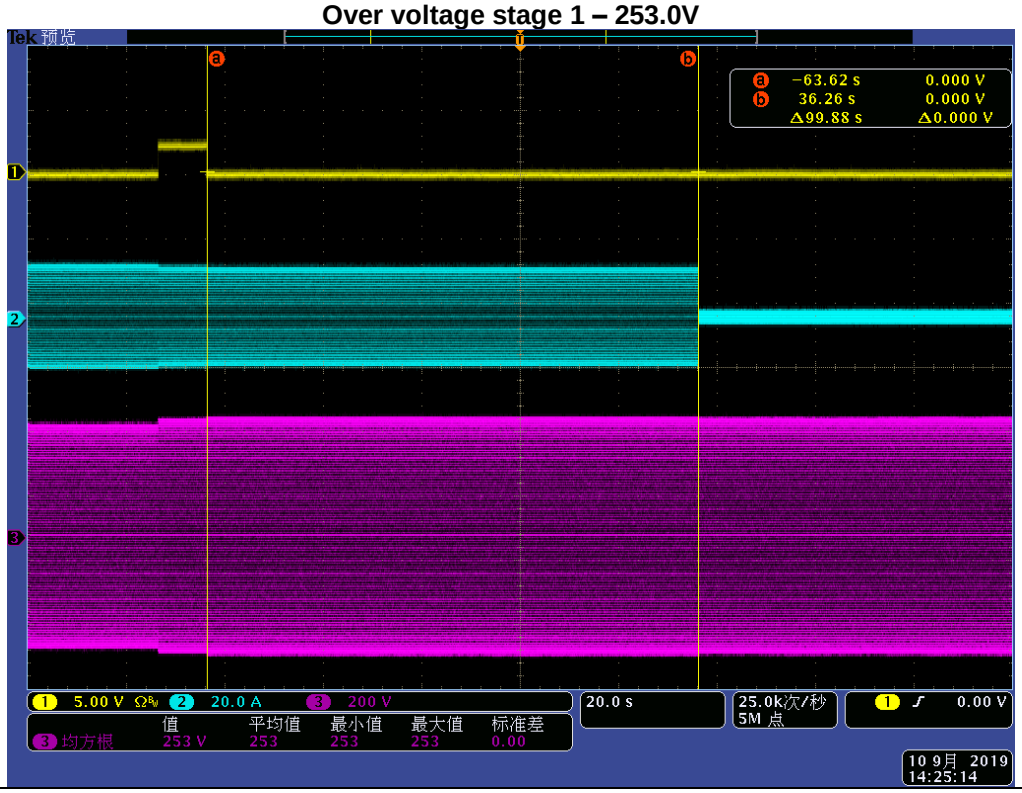
4.9.3.3	TABLE: Overvoltage protection – Adjustable setting	P
Model	EA16KTSI	
Test condition:	Output level: 50 ± 5% of its rated current output Frequency: 50 Hz	

Phase	Adjustment thresholds ranges [V]	Actual thresholds setting [V]	Measured trip value [V]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
L1 Phase	1.0-1.2U_n (stage 1)	1.10U_n=253.0	253	0.1-100s	100	99.88
		1.15U_n=264.5	264		10	9.968
		1.20U_n=276.0	277		0.1	0.0862
	1.0-1.3U_n (stage 2)	1.20U_n=276.0	278	0.1-5s	5	4.968
		1.25U_n=287.5	288		1	0.978
		1.30U_n=299.0	299		0.1	0.087
L2 Phase	1.0-1.2U_n (stage 1)	1.10U_n=253.0	255	0.1-100s	100	99.88
		1.15U_n=264.5	265		10	9.984
		1.20U_n=276.0	277		0.1	0.079
	1.0-1.3U_n (stage 2)	1.20U_n=276.0	277	0.1-5s	5	4.968
		1.25U_n=287.5	288		1	0.980
		1.30U_n=299.0	299		0.1	0.092
L3 Phase	1.0-1.2U_n (stage 1)	1.10U_n=253.0	254	0.1-100s	100	99.88
		1.15U_n=264.5	264		10	10.0
		1.20U_n=276.0	276		0.1	0.0738
	1.0-1.3U_n (stage 2)	1.20U_n=276.0	277	0.1-5s	5	4.988
		1.25U_n=287.5	288		1	0.99
		1.30U_n=299.0	299		0.1	0.0806

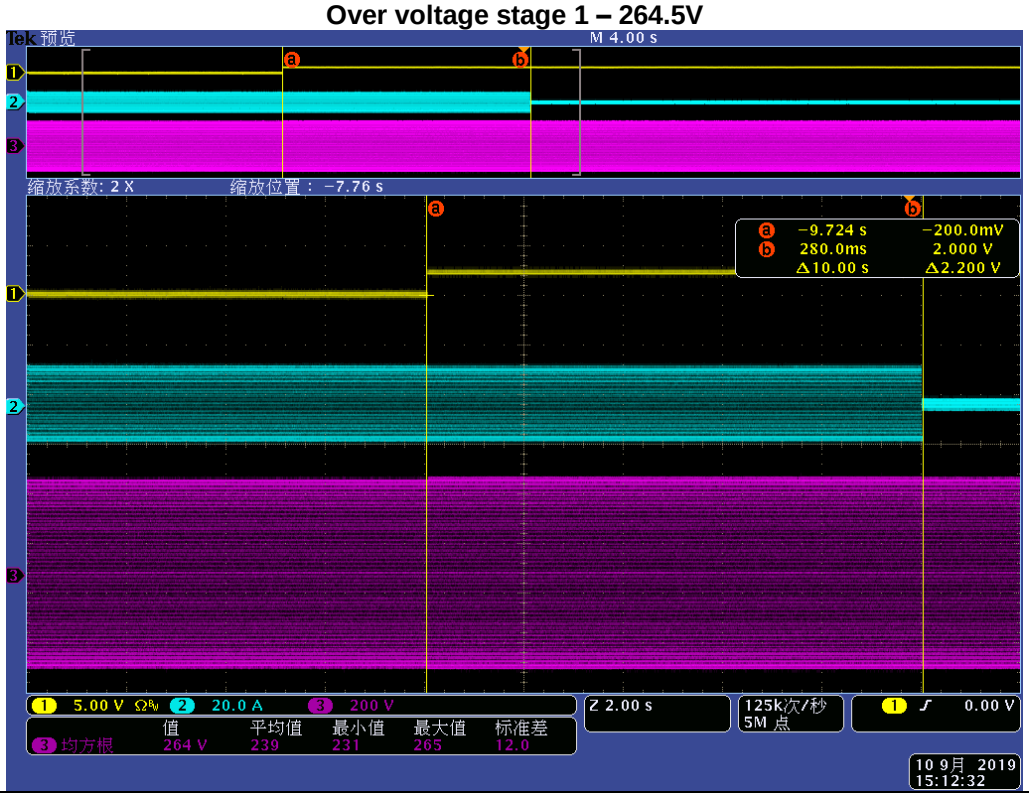
Note:
The minimum required accuracy for protection is:
for frequency measurement ± 0,05 Hz;
for voltage measurement ± 1 % of U_n;
The reset time shall be ≤ 50 ms.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over voltage stage 1 – 253.0V

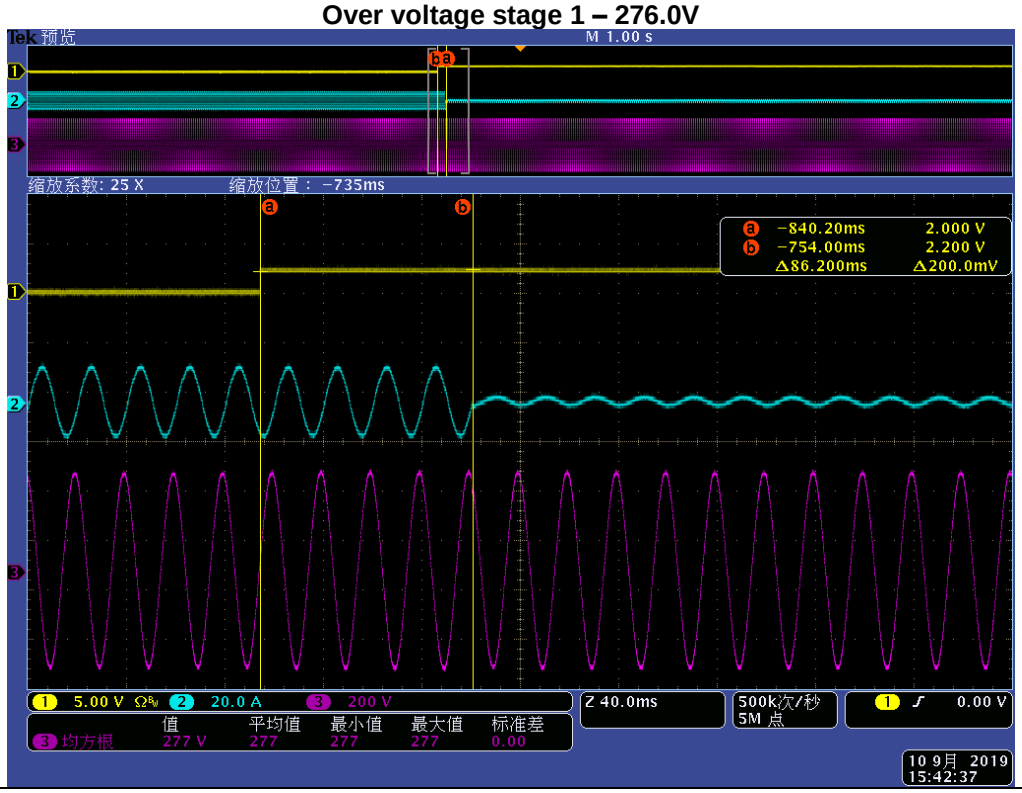


Over voltage stage 1 – 264.5V

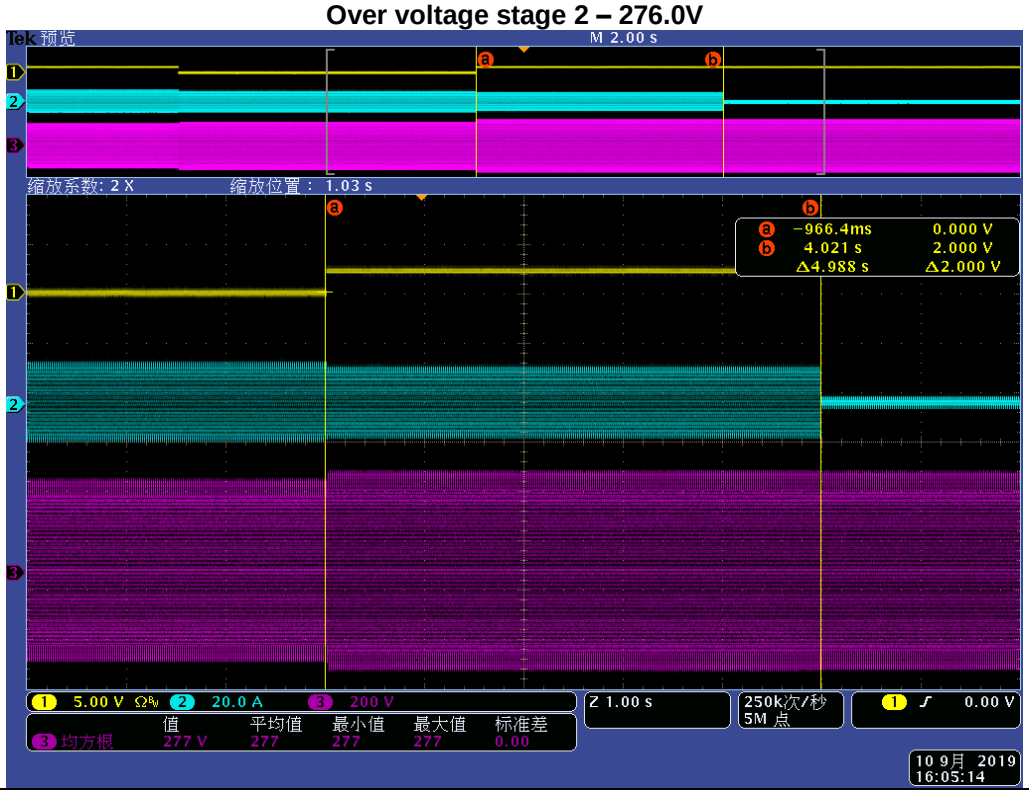


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over voltage stage 1 – 276.0V

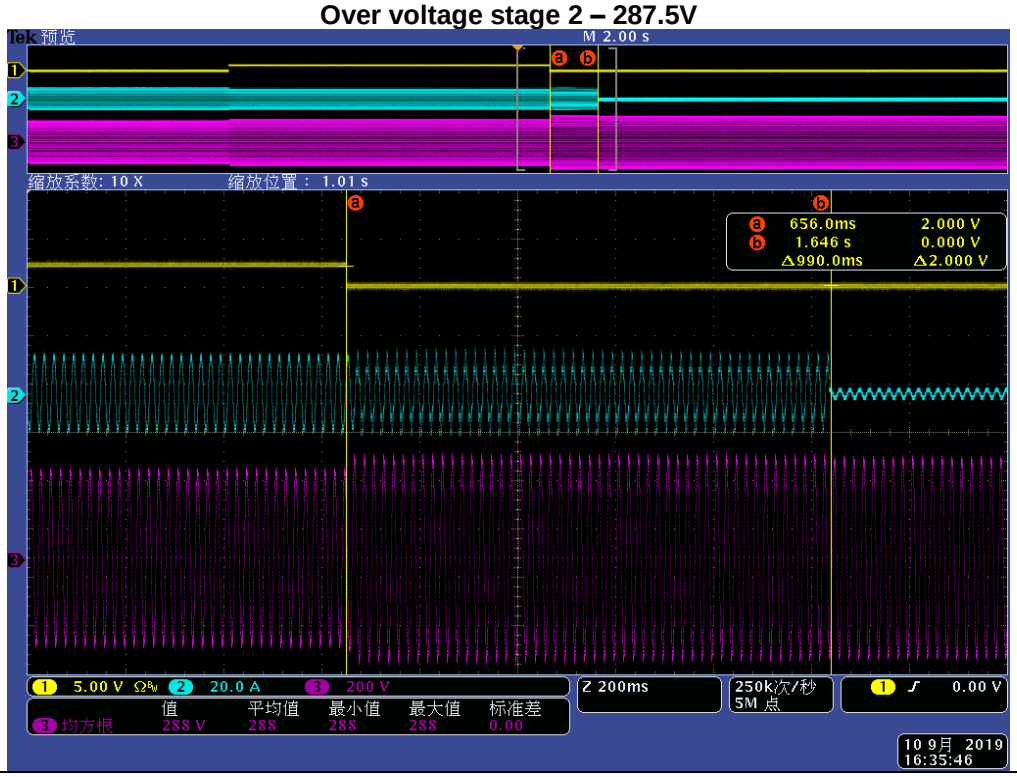


Over voltage stage 2 – 276.0V

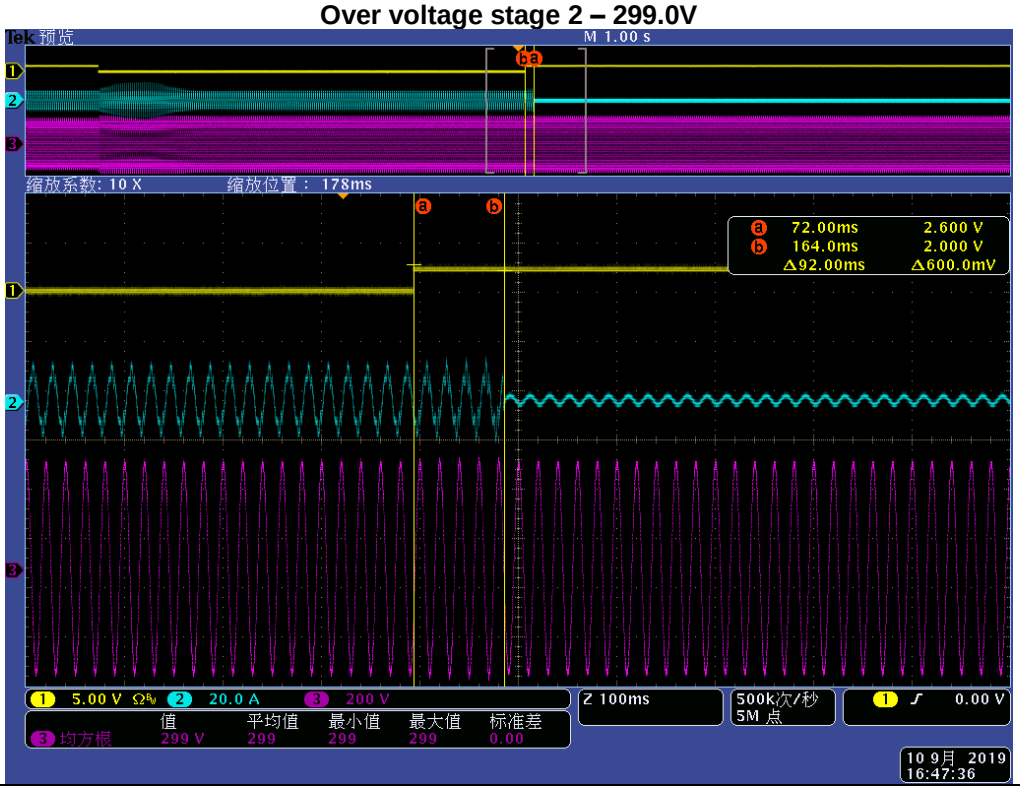


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over voltage stage 2 – 287.5V



Over voltage stage 2 – 299.0V



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.3.4	**TABLE: Overvoltage 10 min mean protection**		**P**
Model	EA16KTSI		

Parameter:	Test voltage:(V)	Disconnection time:(s)	Limit:(min)
L1 Phase	252.91	600	10
L2 Phase	253.85	600	10
L3 Phase	252.57	600	10

Note:
Over-voltage – stage 1 Un (100% - 115 %): 10-min-value corresponding to EN 50160.

The calculation of the 10 min value shall comply with the 10 min aggregation of EN 61000-4-30, class S. The function shall be based on the calculation of the square root of the arithmetic mean of the squared input values over 10 min. In deviation from EN 61000-4-30, a moving window shall be used. The calculation of a new 10-min value at least every 3 s is sufficient, which is then to be compared with the trip value.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.3.5	**TABLE: Underfrequency protection – Default setting**					**P**
Model	EA16KTSI					
Test condition:	Output level: 100 ± 5% of its rated current output					
Adjustment thresholds ranges [Hz]	Actual thresholds setting [Hz]	Test voltage [V]	Measured trip value [Hz]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
47.0-50.0Hz (Stage 1)	49.0	$0.2U_n$	48.98	0.1-100s	1	0.997
	49.0	$1.0U_n$	48.99		1	0.999
	49.0	$1.2U_n$	48.98		1	0.989
47.0-50.0Hz (Stage 2)	47.5	$0.2U_n$	47.48	0.1-5s	0.1	0.0924
	47.5	$1.0U_n$	47.48		0.1	0.0928
	47.5	$1.2U_n$	47.50		0.1	0.0904

Note:

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal. The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.

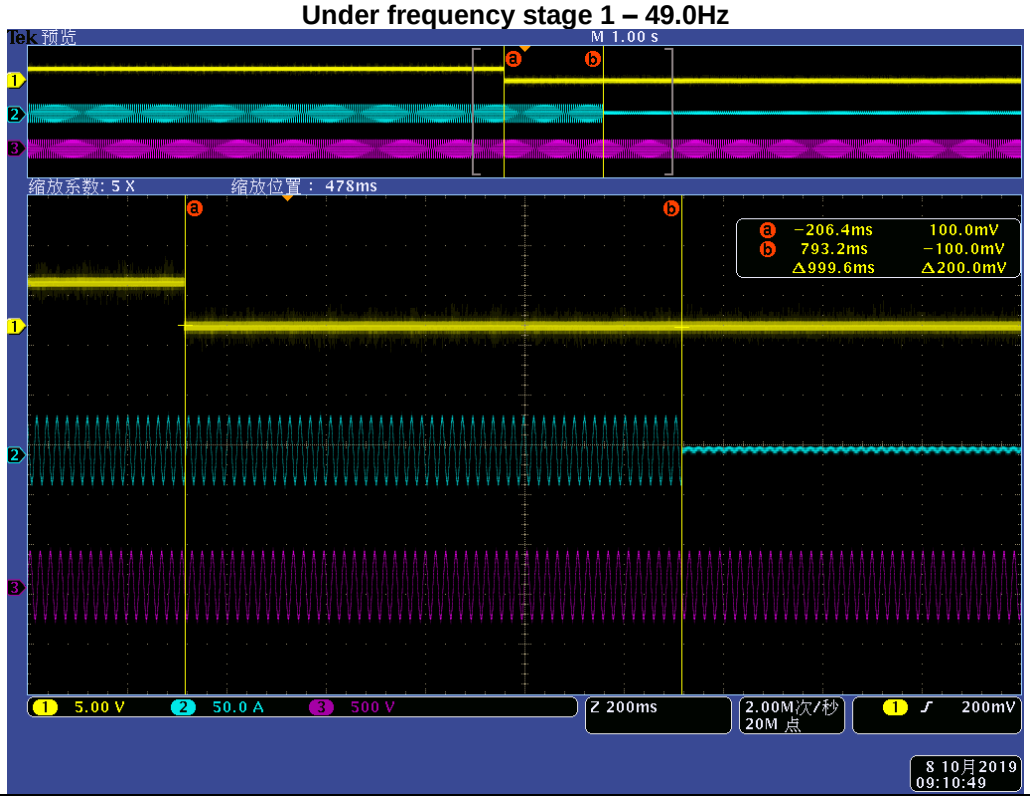
Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen base on under voltage protection.

* the limit actual stage 1 frequency limits and stage 2 frequency limits are required of the standard, the interface protection of the product maybe required by the DSO.

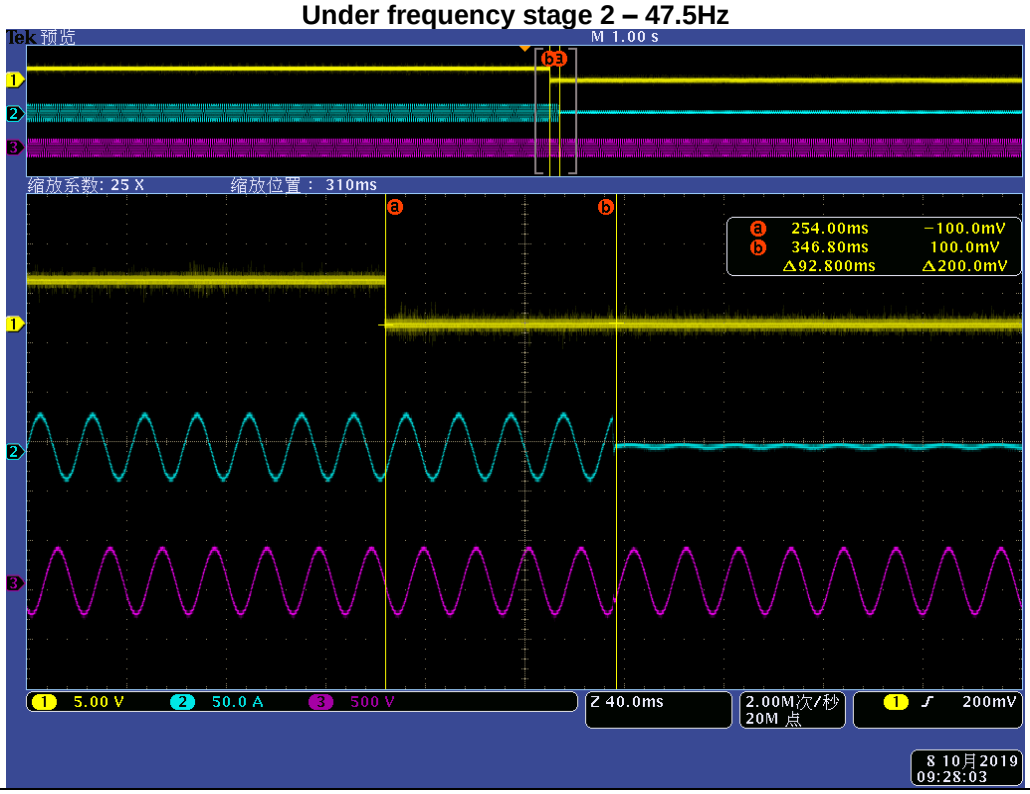
** the limit time is the upper limit and the under limits of the underfrequency protect are required of the standard, the interface protection of the product maybe required by the DSO .

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under frequency stage 1 – 49.0Hz



Under frequency stage 2 – 47.5Hz



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.3.5	**TABLE: Underfrequency protection – Adjustable setting**					**P**
Model	EA16KTSI					
Test condition:	Output level: 100 ± 5% of its rated current output					
Adjustment thresholds ranges [Hz]	Actual thresholds setting [Hz]	Test voltage [V]	Measured trip value [Hz]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
47.0-50.0Hz (Stage 1)	49.5	$0.2U_n$	49.51	0.1-100	100	100.2
	48.5	$1.0U_n$	48.48		10	10.02
	47.5	$1.2U_n$	47.48		0.1	0.0838
47.0-50.0Hz (Stage 2)	48.0	$0.2U_n$	47.99	0.1-5	5	5.028
	47.5	$1.0U_n$	47.48		1	0.981
	47.0	$1.2U_n$	46.98		0.1	0.0984

Note:

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal. The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.

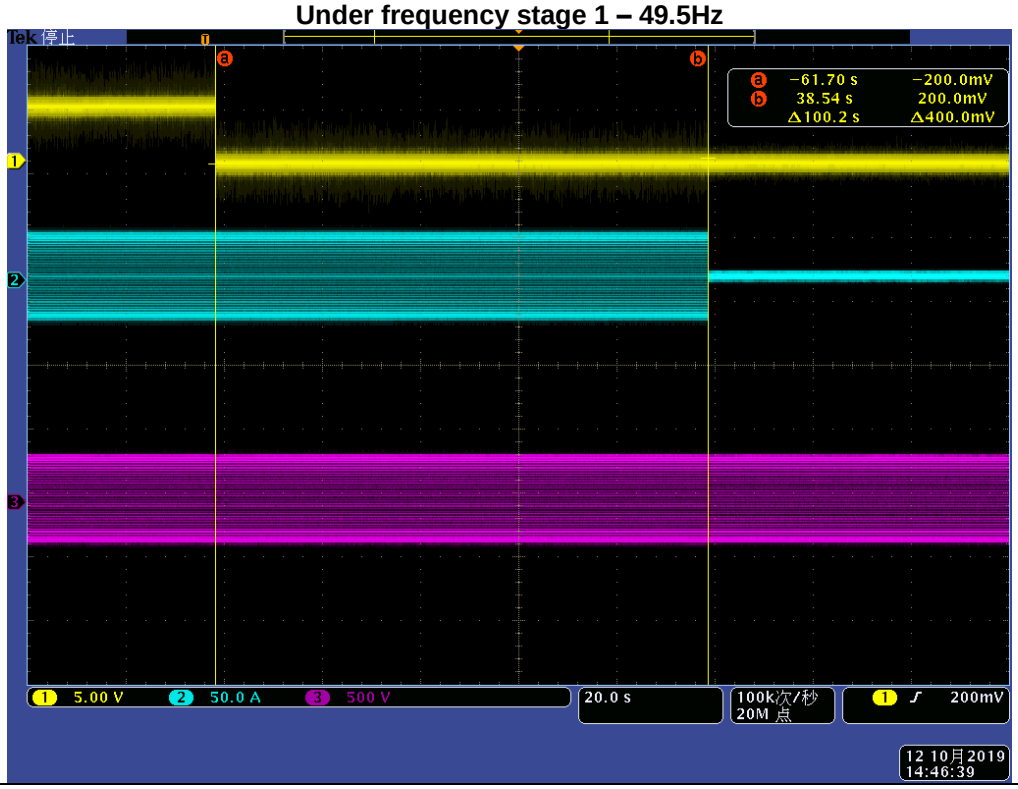
Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen base on under voltage protection.

* the limit actual stage 1 frequency limits and stage 2 frequency limits are required of the standard, the interface protection of the product maybe required by the DSO.

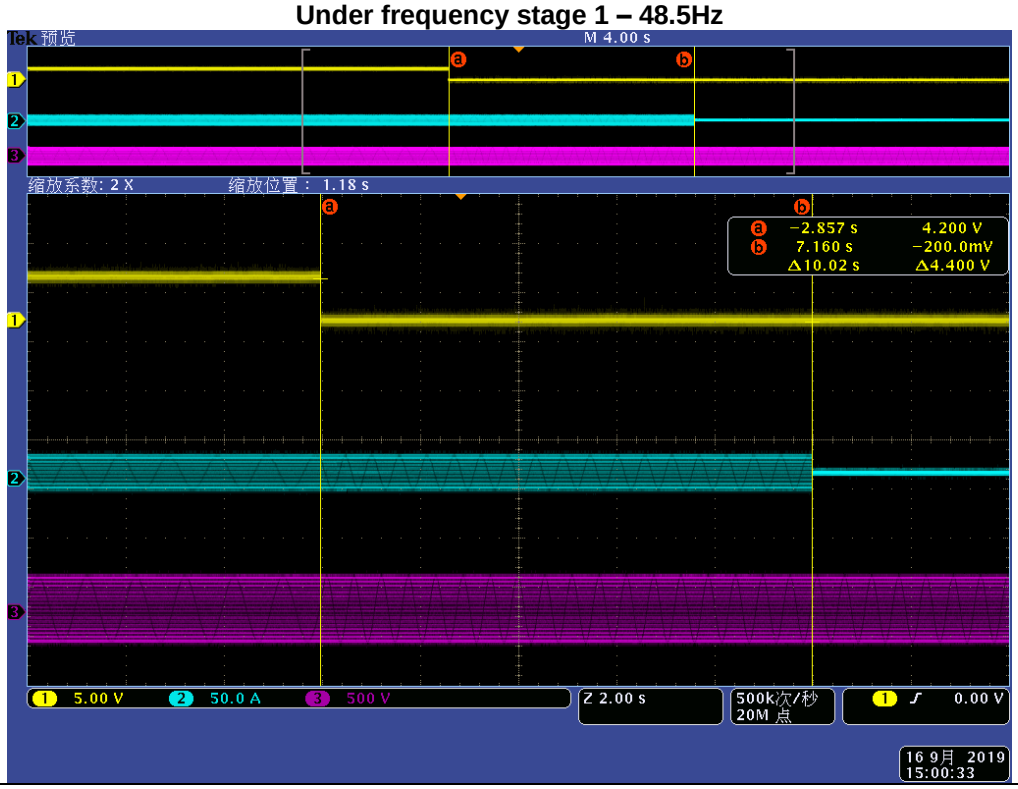
** the limit time is the upper limit and the under limits of the underfrequency protect are required of the standard, the interface protection of the product maybe required by the DSO.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under frequency stage 1 – 49.5Hz

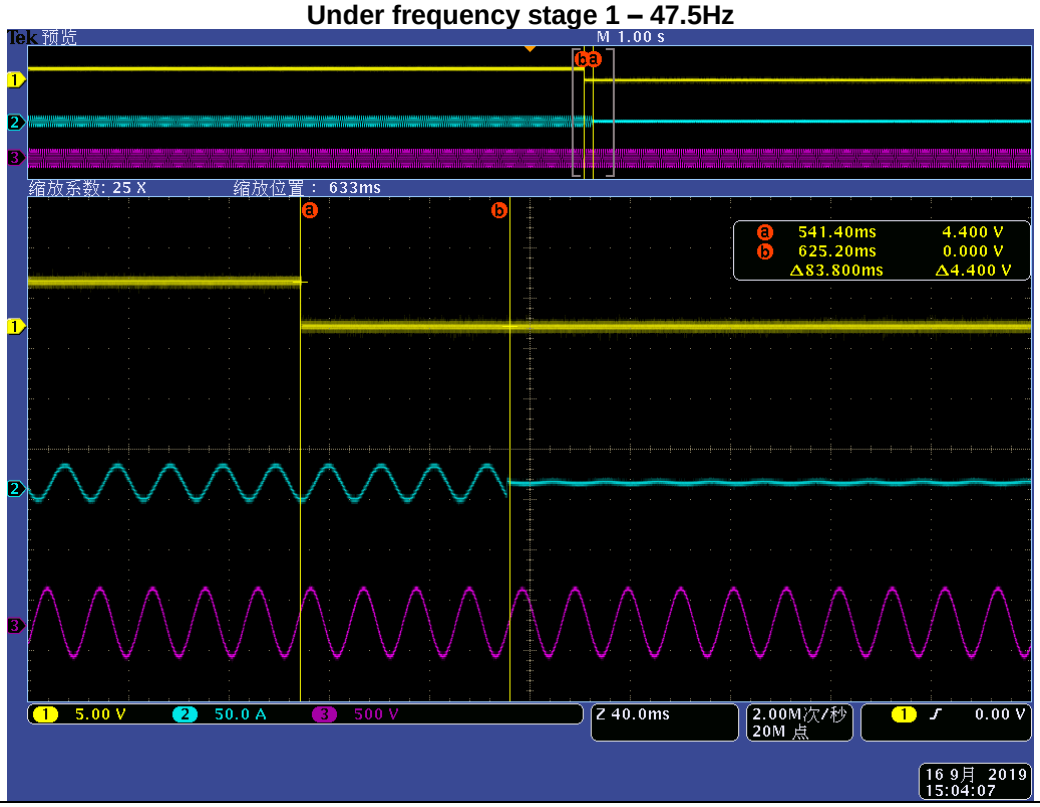


Under frequency stage 1 – 48.5Hz

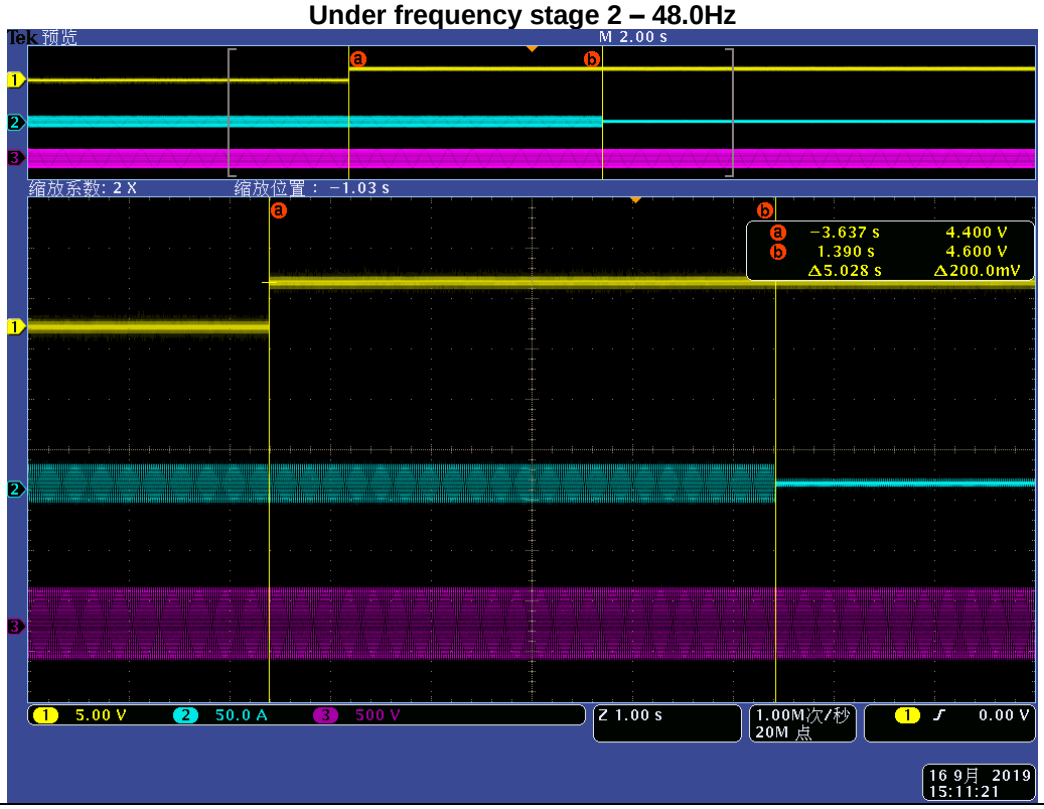


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under frequency stage 1 – 47.5Hz

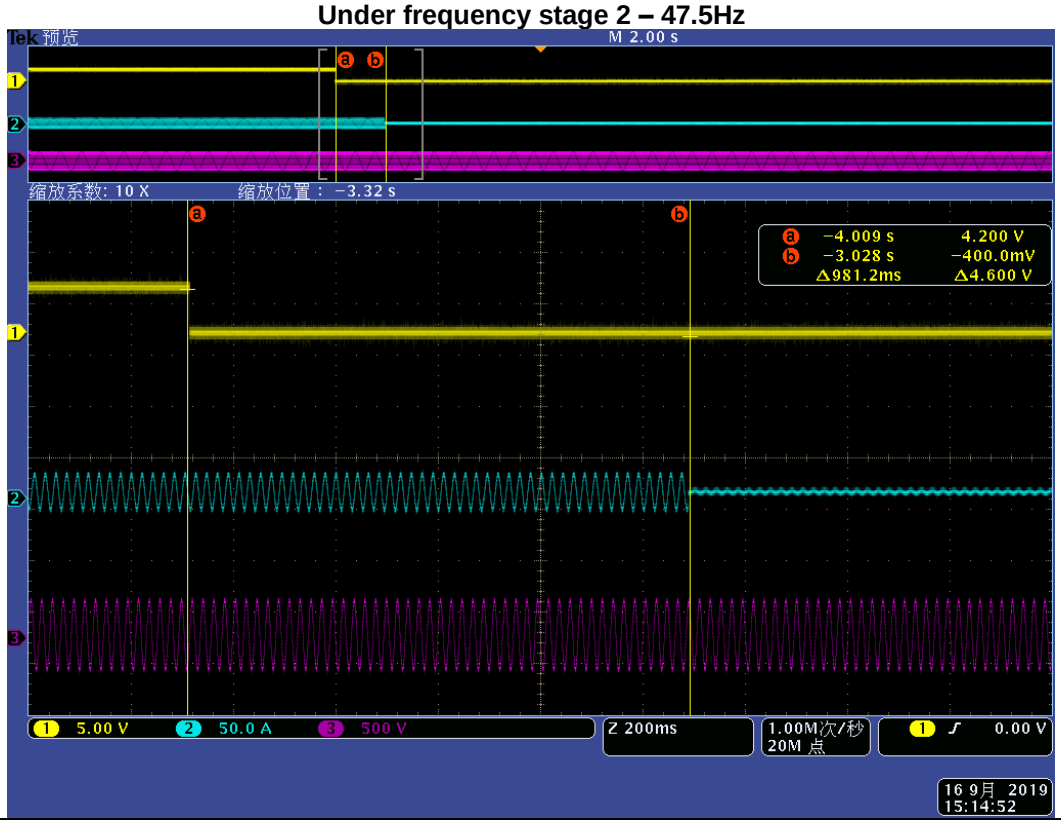


Under frequency stage 2 – 48.0Hz

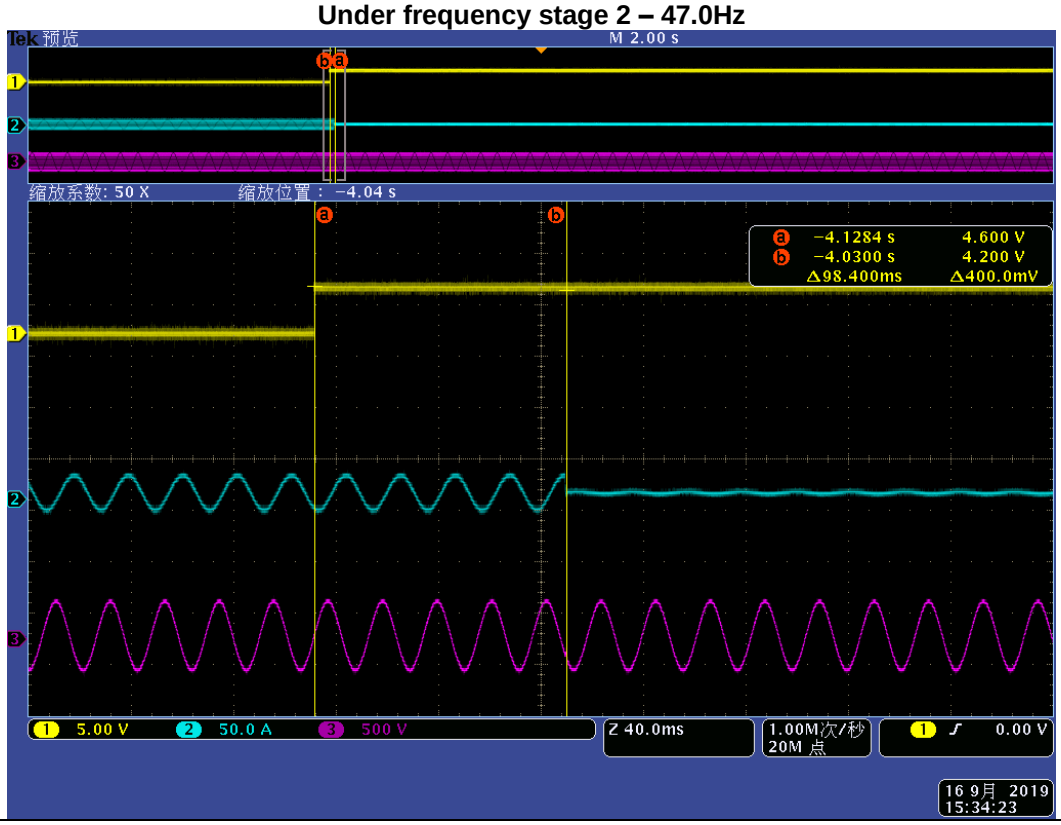


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Under frequency stage 2 – 47.5Hz



Under frequency stage 2 – 47.0Hz



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.3.6	**TABLE: Overfrequency protection – Default setting**					**P**
Model	EA16KTSI					
Test condition:	Output level: 50 ± 5% of its rated current output					
Adjustment thresholds ranges [Hz]	Actual thresholds setting [Hz]	Test voltage [V]	Measured trip value [Hz]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
50.0-52.0Hz (Stage 1)	51	$0.2U_n$	50.98	0.1-100s	1	0.994
	51	$1.0U_n$	51.00		1	1.006
	51	$1.2U_n$	50.99		1	0.996
50.0-52.0Hz (Stage 2)	51.5	$0.2U_n$	51.48	0.1-5s	0.1	0.0888
	51.5	$1.0U_n$	51.49		0.1	0.094
	51.5	$1.2U_n$	51.49		0.1	0.0772

Note:

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal. The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.

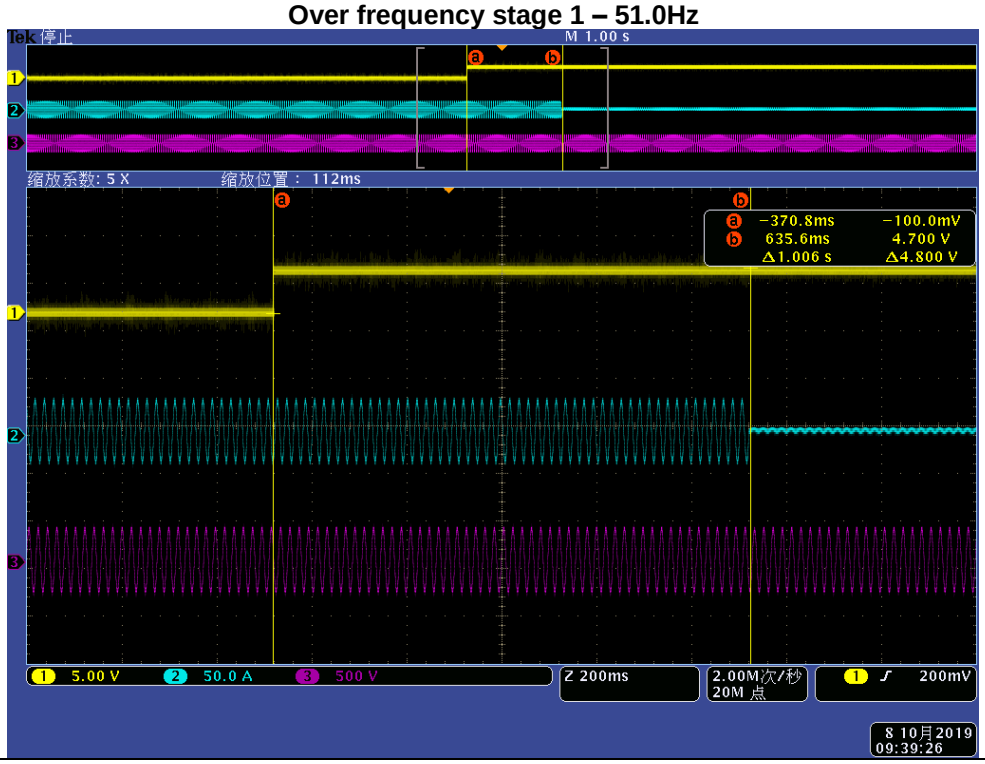
Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen base on under voltage protection.

* the limit actual stage 1 frequency limits and stage 2 frequency limits are required of the standard, the interface protection of the product maybe required by the DSO.

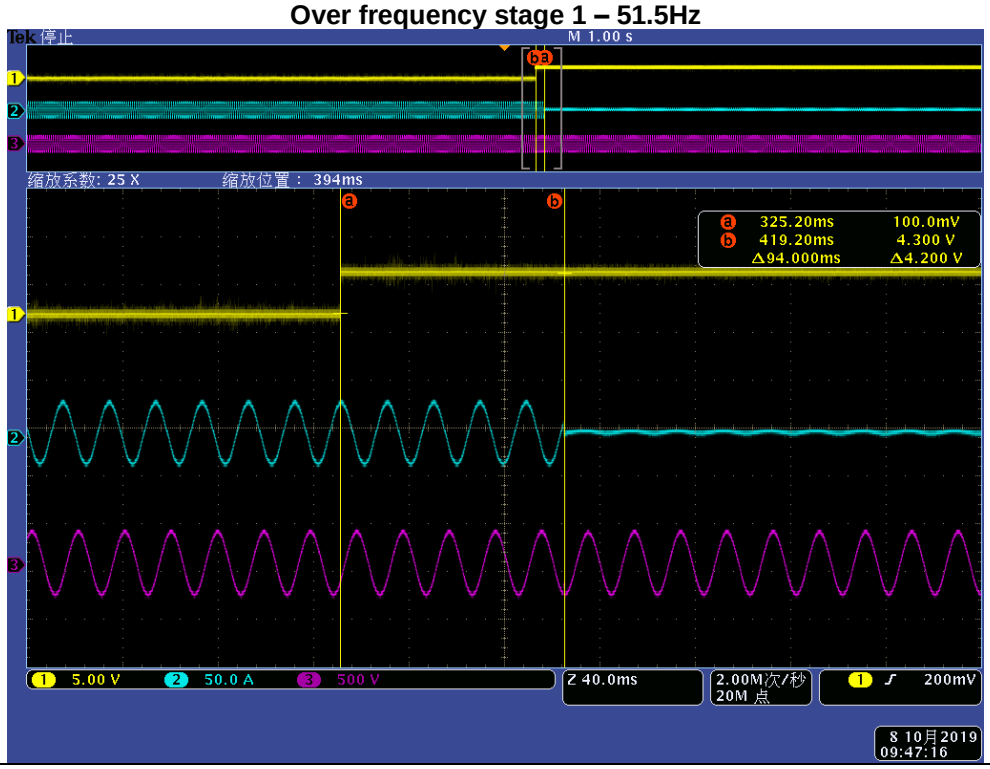
** the limit time is the upper limit and the under limits of the underfrequency protect are required of the standard, the interface protection of the product maybe required by the DSO.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over frequency stage 1 – 51.0Hz



Over frequency stage 1 – 51.5Hz



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.3.6	**TABLE: Overfrequency protection – Adjustable setting**					**P**
Model	EA16KTSI					
Test condition:	Output level: 50 ± 5% of its rated current output					
Adjustment thresholds ranges [Hz]	Actual thresholds setting [Hz]	Test voltage [V]	Measured trip value [Hz]	Adjustment disconnection time range [s]	Actual disconnection time setting [s]	Measured disconnection time [s]
50.0-52.0Hz (Stage 1)	50.5	$0.2U_n$	50.51	0.1-100s	100	104.0
	51.0	$1.0U_n$	51.01		10	10.04
	51.5	$1.2U_n$	51.52		0.1	0.0776
50.0-52.0Hz (Stage 2)	51.0	$0.2U_n$	51.02	0.1-5s	5	5.018
	51.5	$1.0U_n$	51.51		1	1.003
	52.0	$1.2U_n$	52.01		0.1	0.0887

Note:

In order to use narrow frequency thresholds for islanding detection (see 4.9.3.3) it may be required to have the ability to activate and deactivate a stage by an external signal. The frequency protection shall function correctly in the input voltage range between 20 % Un and 120 % Un and shall be inhibited for input voltages of less than 20 % Un.

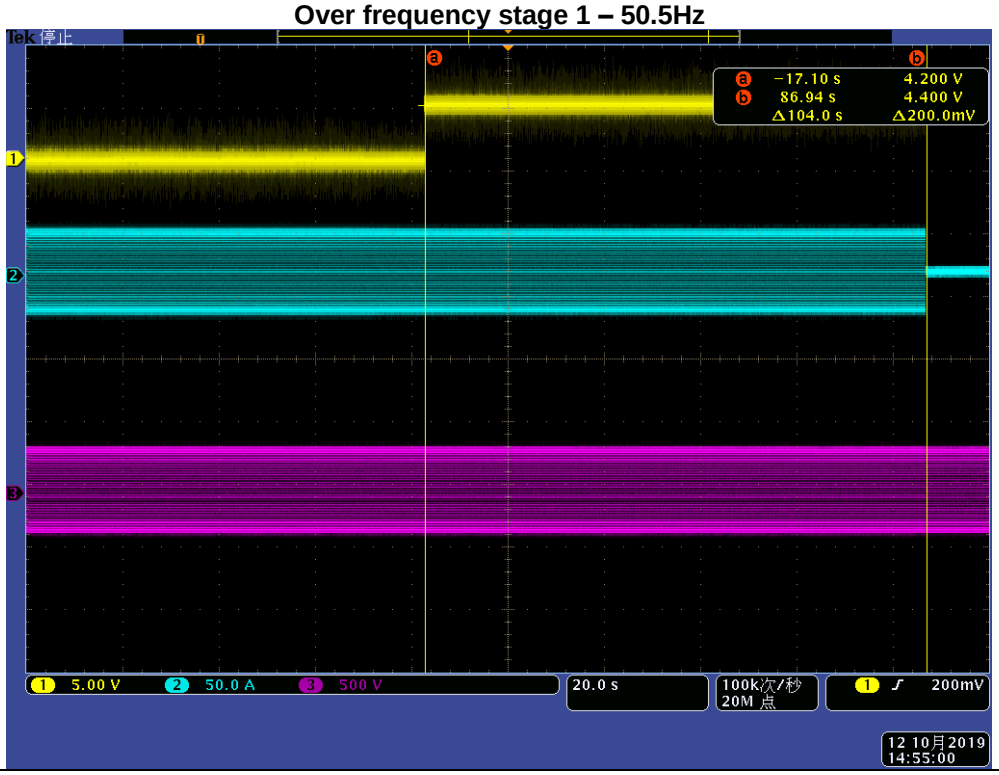
Under 0.2 Un the frequency protection is inhibited. Disconnection may only happen base on under voltage protection.

* the limit actual stage 1 frequency limits and stage 2 frequency limits are required of the standard, the interface protection of the product maybe required by the DSO.

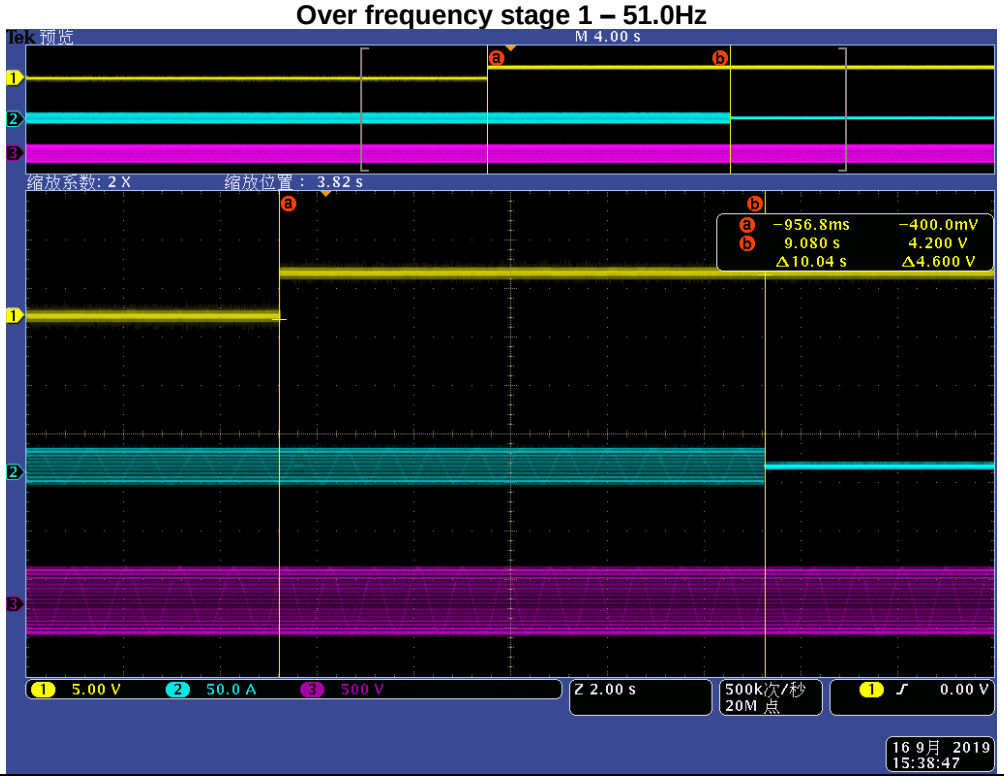
** the limit time is the upper limit and the under limits of the underfrequency protect are required of the standard, the interface protection of the product maybe required by the DSO.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over frequency stage 1 – 50.5Hz

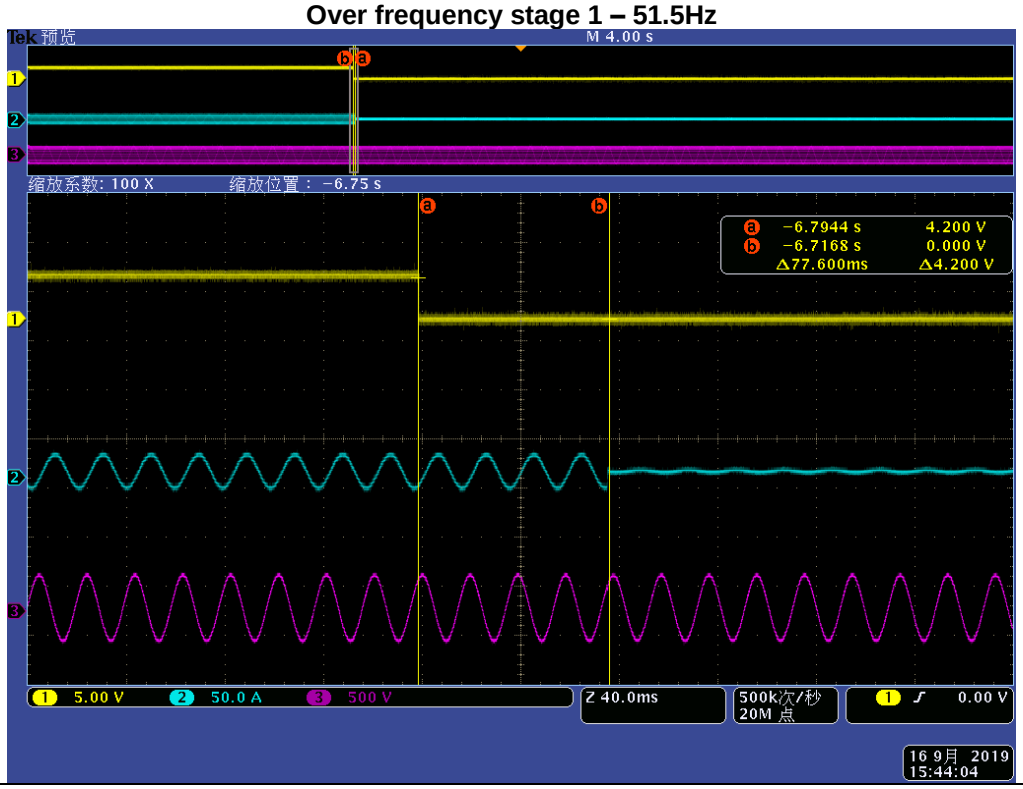


Over frequency stage 1 – 51.0Hz

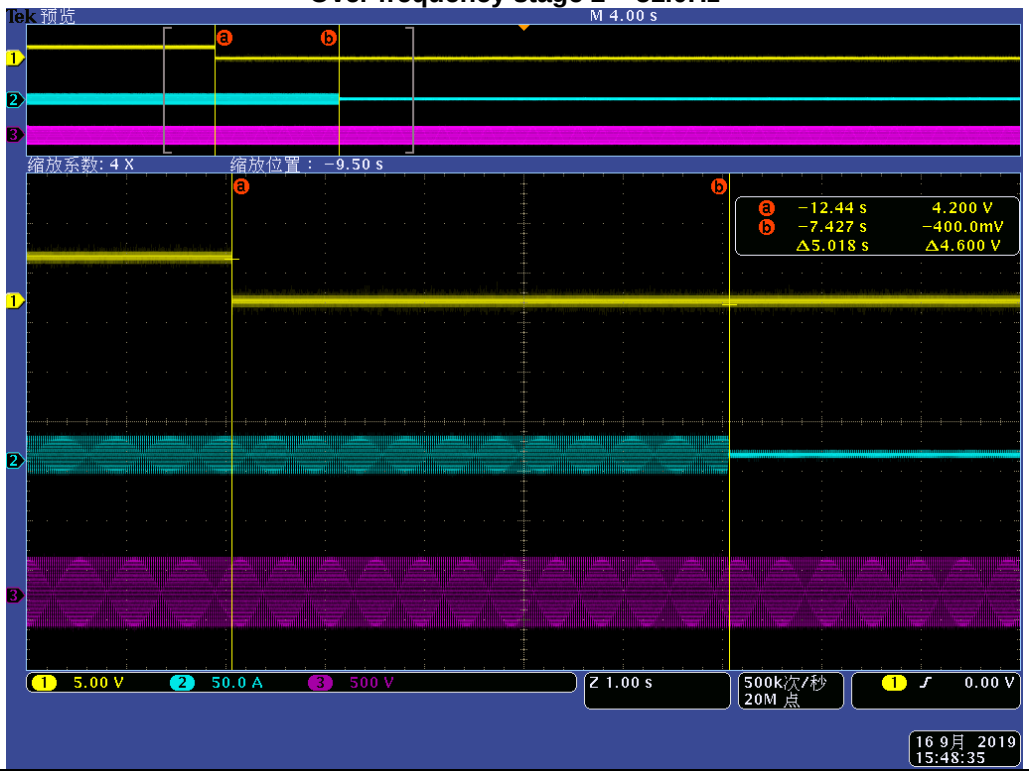


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over frequency stage 1 – 51.5Hz

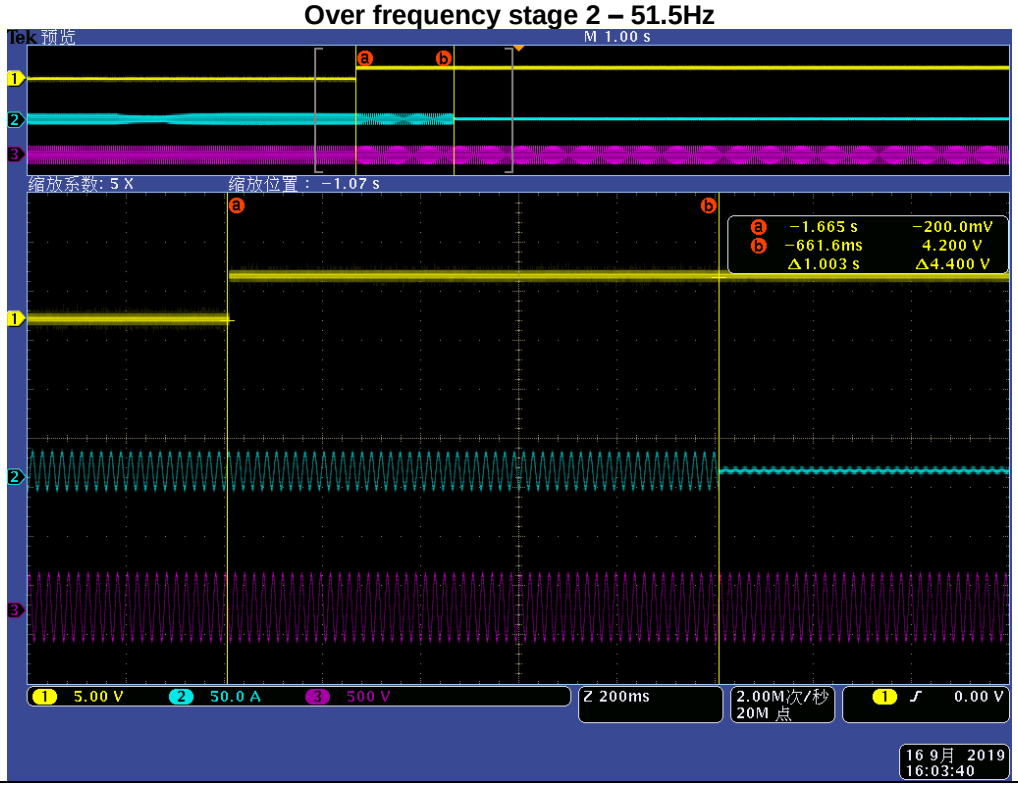


Over frequency stage 2 – 51.0Hz

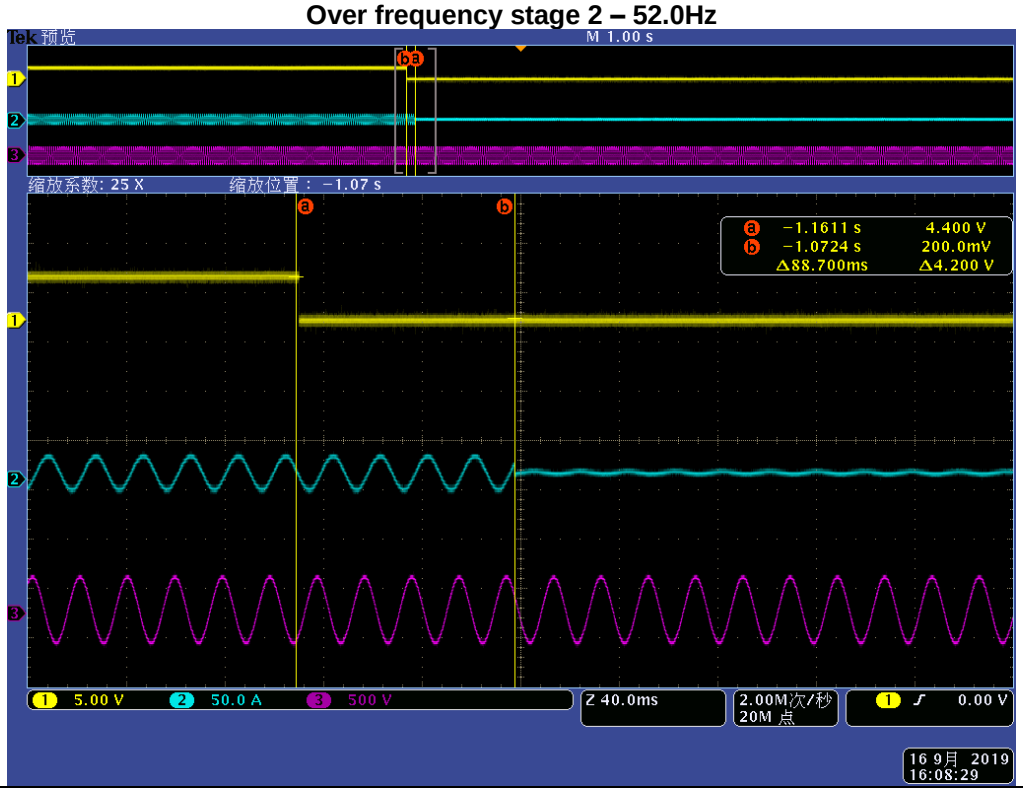


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

Over frequency stage 2 – 51.5Hz



Over frequency stage 2 – 52.0Hz



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.4.2	TABLE: Active methods tested with a resonant circuit for PV inverters according to EN 62116 – 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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

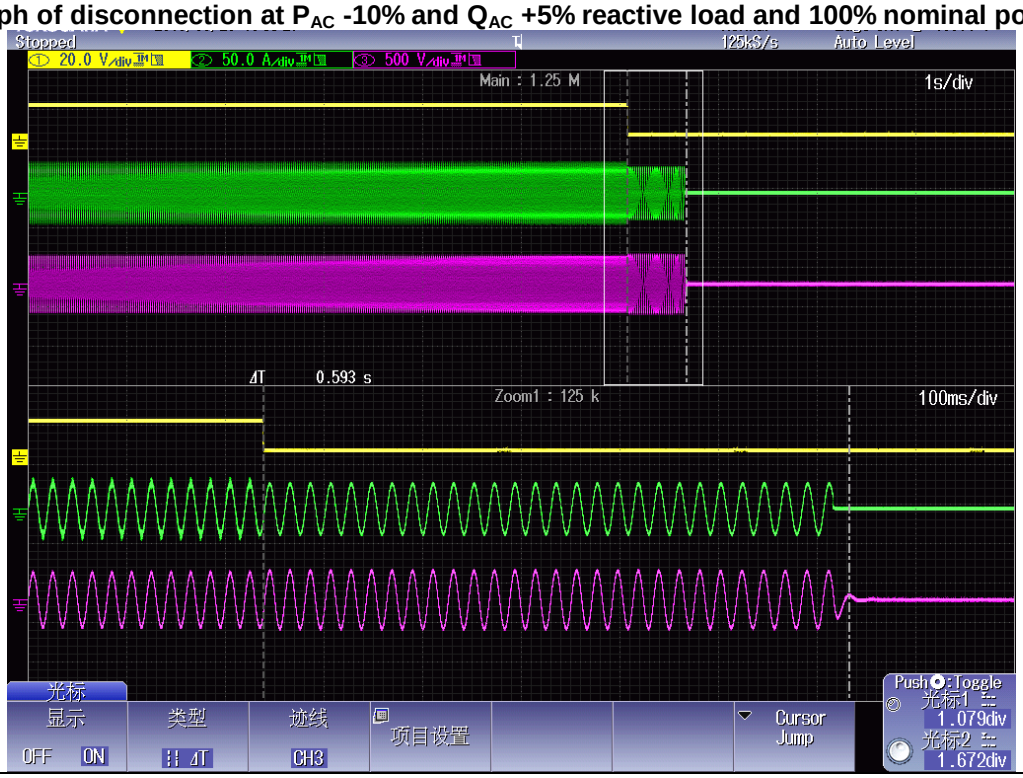
23	100	100	+ 10	0	214	5322	0.93	818	Test A at IB
24	100	100	+ 10	+ 5	370	5355	0.94	818	Test A at IB
25	100	100	+ 10	+ 10	177	5341	0.98	818	Test A at IB
Test condition B									
1	66	66	0	- 5	382	3441	0.95	673	Test B at IB
2	66	66	0	- 4	341	3451	0.96	674	Test B at IB
3	66	66	0	- 3	553	3455	0.96	673	Test 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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

11	33	33	0	+ 5	162	1794	1.07	448	Test C at IB

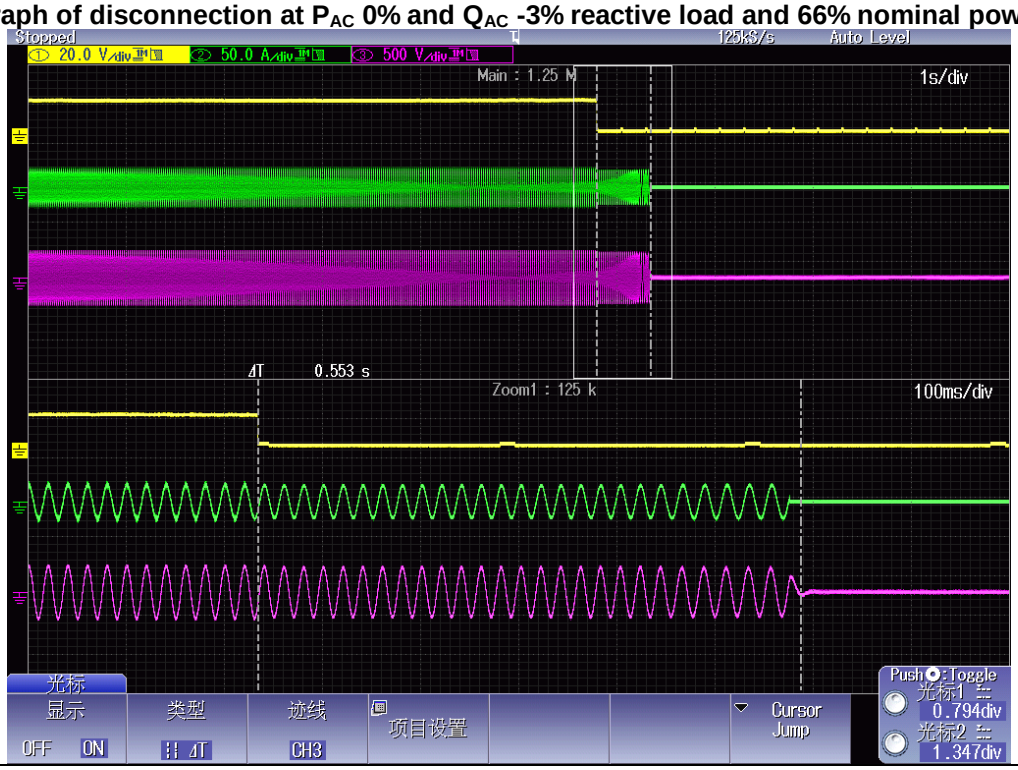
Remark:
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional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

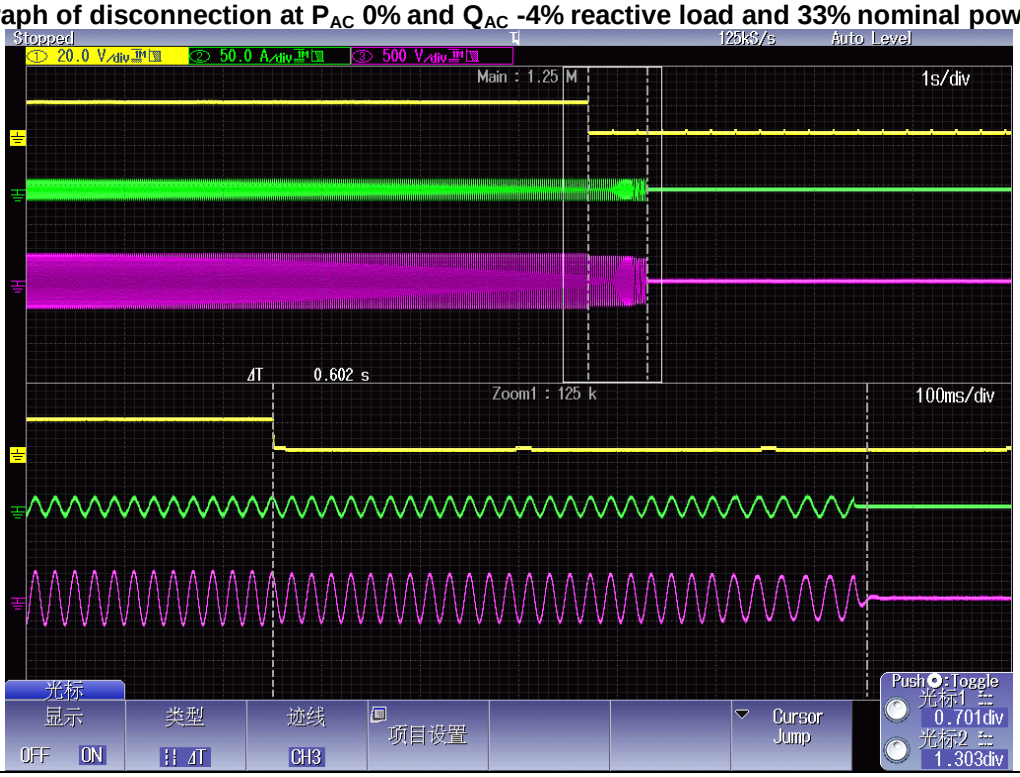


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

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



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.4.2	TABLE: Active methods tested with a resonant circuit for PV inverters according to EN 62116 – 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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

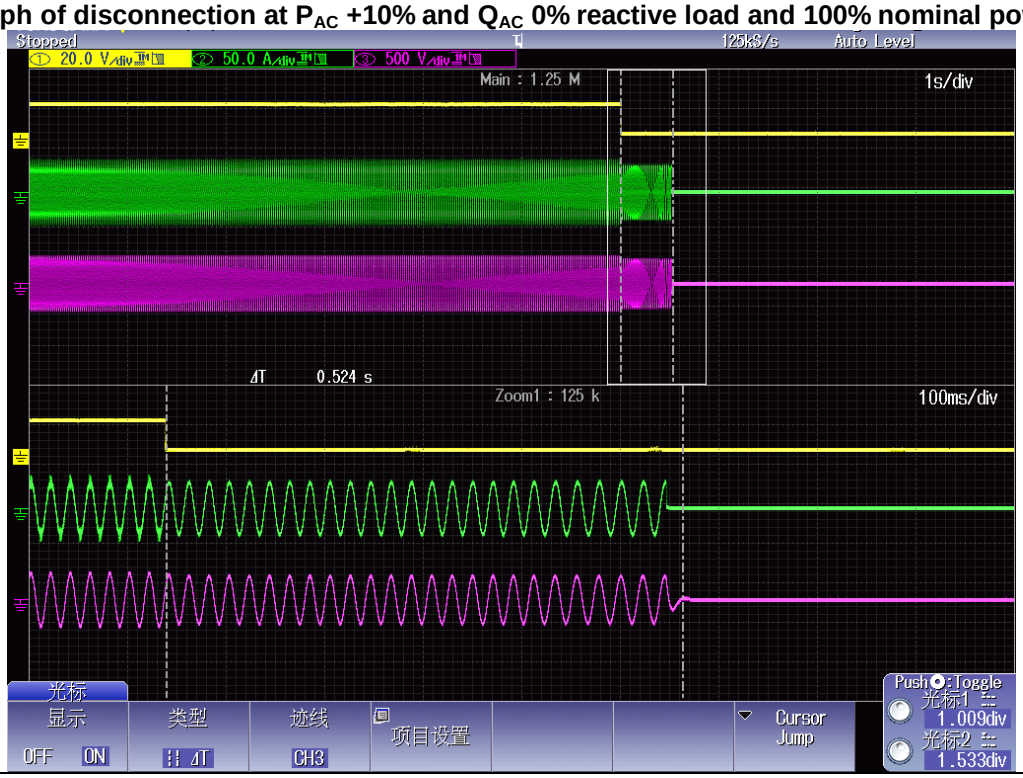
23	100	100	+ 10	0	524	5240	0.93	818	Test A at IB
24	100	100	+ 10	+ 5	264	5255	0.95	817	Test A at IB
25	100	100	+ 10	+ 10	177	5257	0.98	817	Test A at IB
Test condition B									
1	66	66	0	- 5	358	3529	0.98	673	Test B at IB
2	66	66	0	- 4	365	3549	0.98	674	Test B at IB
3	66	66	0	- 3	242	3546	0.99	673	Test 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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

11	33	33	0	+ 5	164	1777	1.03	448	Test C at IB

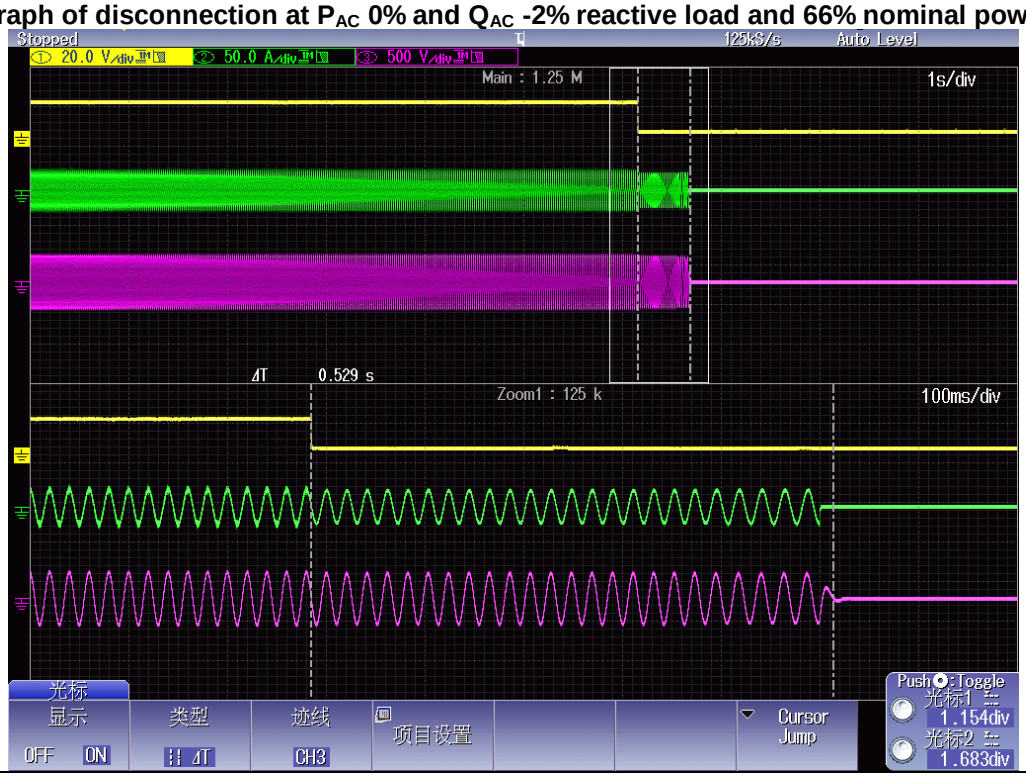
Remark:
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional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

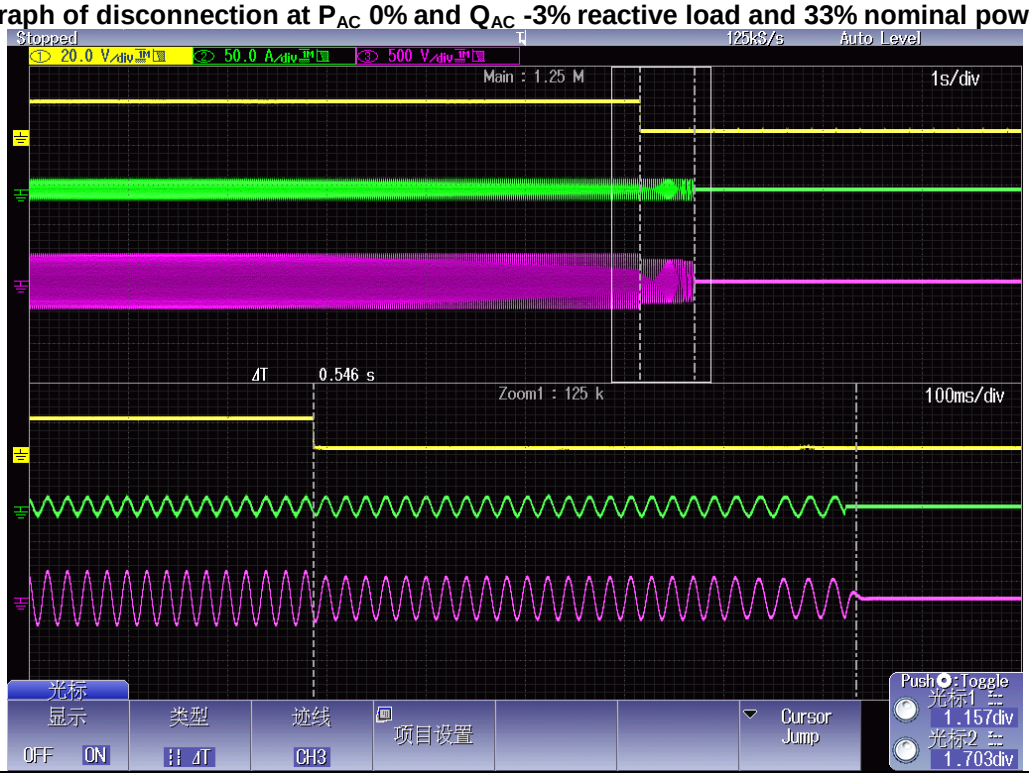


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

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



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.9.4.2	TABLE: Active methods tested with a resonant circuit for PV inverters according to EN 62116 – 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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

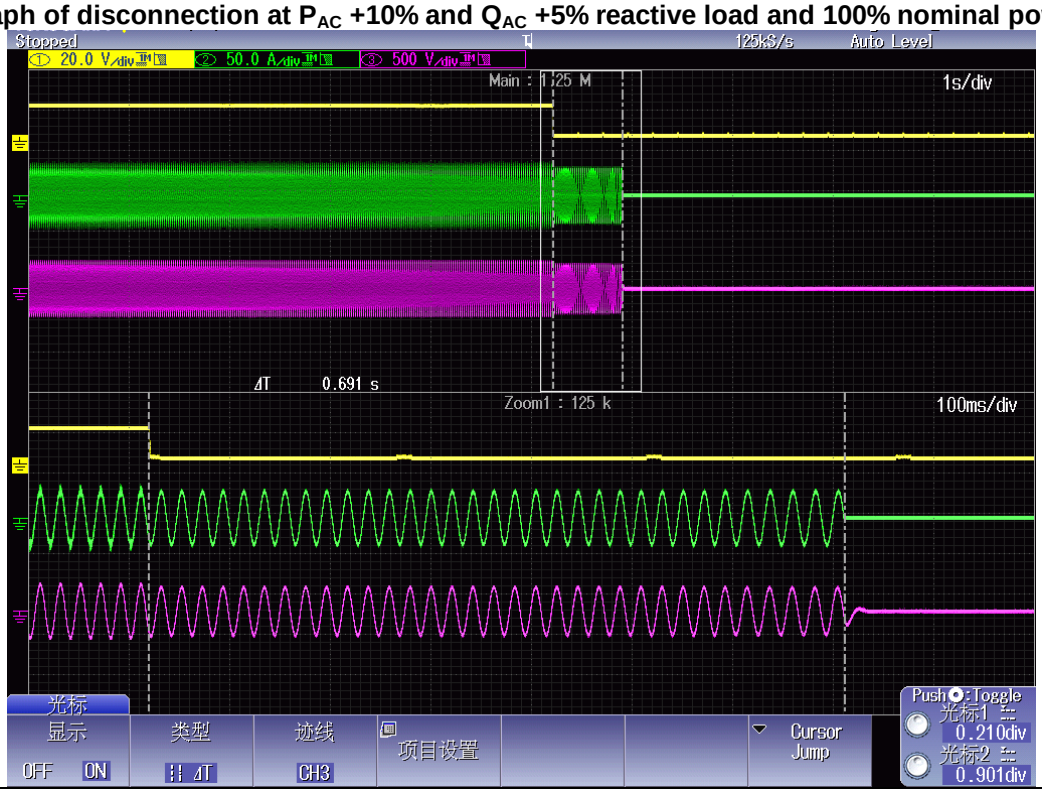
22	100	100	+ 10	- 5	145	5225	0.87	817	Test A at IB
23	100	100	+ 10	0	496	5255	0.90	818	Test A at IB
24	100	100	+ 10	+ 5	691	5239	0.91	817	Test A at IB
25	100	100	+ 10	+ 10	151	5245	0.95	817	Test A at IB
Test condition B									
1	66	66	0	- 5	303	3515	0.95	673	Test B at IB
2	66	66	0	- 4	327	3526	0.95	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

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

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

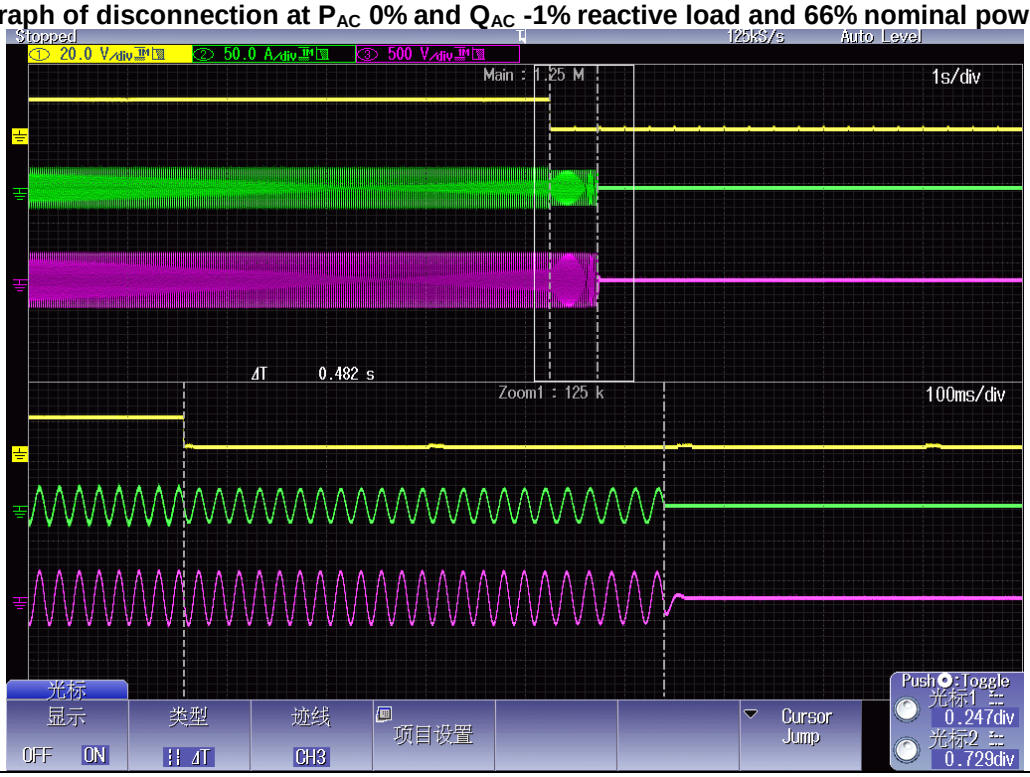
Remark:
For test condition A:
If any of the recorded run-on times are longer than the one recorded for the rated balance condition, then the non-shaded parameter combinations also require testing.
For test condition B and C:
If run-on times are still increasing at the 95 % or 105 % points, additional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

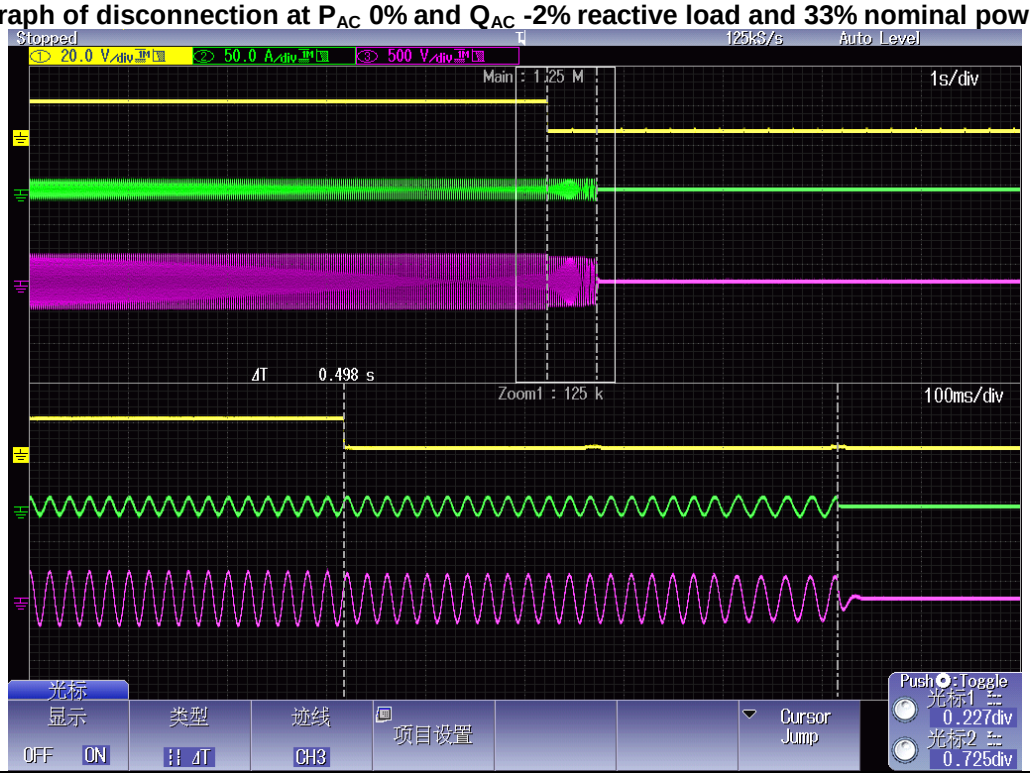


EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

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



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.10.2	**TABLE: Automatic reconnection after tripping**			**P**
Model	EA16KTSI			
Setting values	Parameter	Range	Default setting	
	Lower frequency [Hz]:	47.0 – 50.0	49.5	
	Upper frequency [Hz]:	50.0 – 50.2	50.2	
	Lower voltage [V]:	115.0 – 230.0	195.5	
	Upper voltage [V]:	230.0 – 276.0	253.0	
	Observation time [s]:	10 – 600	60	
	Active power increase gradient:	6% – 3000%/min	10%/min	

Connecting conditions for frequencies:			
	f_{act}	Reconnection time:	Limit:
a)	< 49.50 Hz	Not reconnect	No reconnection permitted
	Switch to:		
b)	≥ 49.50 Hz	108.4s	≥ 60 s(0~600s)
c)	> 50.20 Hz	Not reconnect	No reconnection permitted
	Switch to:		
d)	≤ 50.20 Hz	110.6s	≥ 60 s

Connecting conditions for voltages:				
	U_{act}			Limit:
e)	< 0.85 U_n	Not reconnect		No reconnection permitted
	Switch to:			
f)	≥ 0.85 U_n	116.8s		≥ 60 s
g)	> 1.10 U_n	Not reconnect		No reconnection permitted
	Switch to:			
h)	≤ 1.10 U_n	115s		≥ 60 s
After reconnection:		Active power gradient [%]	10	≤10 %

Note:
After reconnection the active power generated by the generating plant shall not exceed a specified gradient expressed as a percentage of the active nominal power of the unit per minute. If no gradient is specified by the DSO, the default setting is 10 % Pn/min. Non-adjustable or partly adjustable generating units may connect after 1 min to 10 min (randomised value) or later

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.10.3	**TABLE: Start of generating electrical power**			**P**
Setting values	Parameter	Range	Default setting	
	Lower frequency [Hz]:	47.0 – 50.0	49.5	
	Upper frequency [Hz]:	50.0 – 50.2	50.1	
	Lower voltage [V]:	115.0 – 230.0	195.5	
	Upper voltage [V]:	230.0 – 276.0	253.0	
	Observation time [s]:	10 – 600	60	
	Active power increase gradient:	6% – 3000%/min	10%/min	

Start conditions for frequencies:

	f_{act}	Reconnection time:	Limit:
a)	< 49.50 Hz	No starting	No starting permitted
	Switch to:		
b)	≥ 49.50 Hz	117.8s	≥ 60 s
c)	> 50,10 Hz	No starting	No starting permitted
	Switch to:		
d)	≤ 50,10 Hz	114.6s	≥ 60 s

Start conditions for voltages:

	U_{act}	Reconnection time:	Limit:
e)	< 0,85 U_n	No starting	No starting permitted
	Switch to:		
f)	≥ 0,85 U_n	114.3s	≥ 60 s
g)	> 1,10 U_n	No starting	No starting permitted
	Switch to:		
h)	≤ 1,10 U_n	111.9s	≥ 60 s

After reconnection:	Active power gradient [%]	10	≤10 %

Note:
If applicable, the power gradient shall not exceed the maximum gradient specified by the DSO and the responsible party.

For manual operations performed on site (e.g. for the purpose of initial start-up or maintenance) it is permitted to deviate from the observation time and ramp rate.

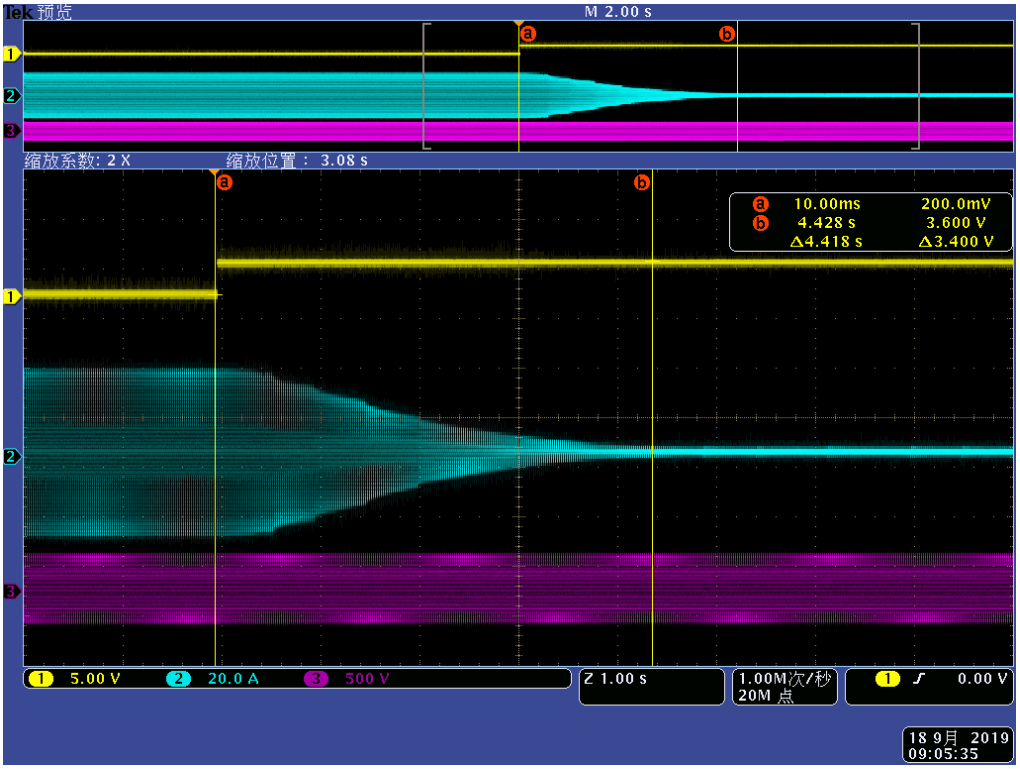
EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.11.1	**TABLE: Ceasing active power**	**P**

Reducing the active power from 100% P_n to 0

Measured max power [kW]	Ceasing time [s]	Limit [s]
16	4.418	5

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



EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.11.2	**TABLE: Reduction of active power on set point**	**P**

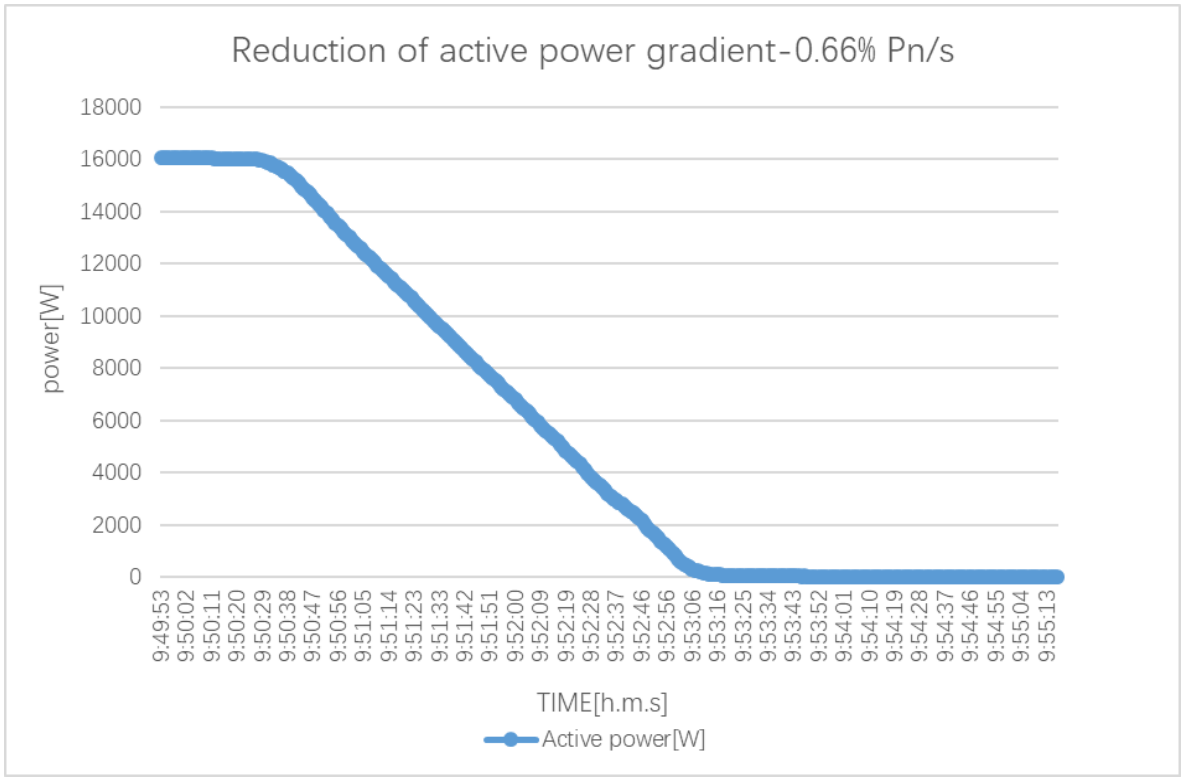
Reducing the active power from 100% P_n to 0

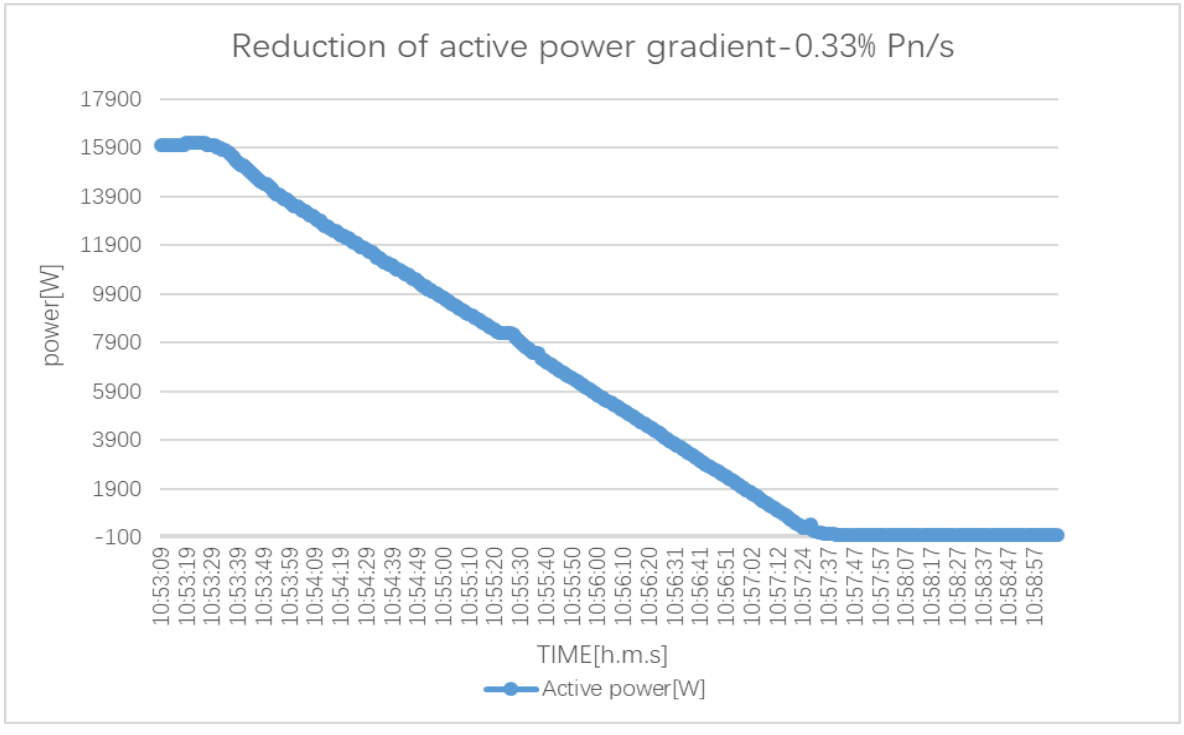
Actual gradient setting [%]	Measured during time [s]	Measured Gradient [%]	Gradient limit [%]
0.66% P_n / s	180	0.55	0.66% P_{Amax} / s
0.33% P_n / s	272	0.37	0.33% P_{Amax} / s

Note:
A generation unit/plant shall be capable of carrying out the power output reduction to the respective limit within an envelope of not faster than 0,66 % P_n/s and not slower than 0,33 % P_n/ s with an accuracy of 5 % of nominal power. Generating plants are permitted to disconnect from the network at a limit value below it minimum regulating level. If required by the DSO, this includes remote operation.

With a programmable AC source, the PGU is operated at 100% P_n and 50±0,01 Hz, set power factor equal to 1.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict





EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

4.13	TABLE: Requirements regarding single fault tolerance of interface protection system	P

No.	component No.	fault	test voltage [V]	test time	fuse No.	fuse current [A]	Test result
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.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

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.	Off grid 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.

EN 50549-1			
Clause	Requirement - Test	Result - Remark	Verdict

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.

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Clause	Requirement - Test					Result - Remark		Verdict
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.	
Note:								

Appendix: Pictures

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

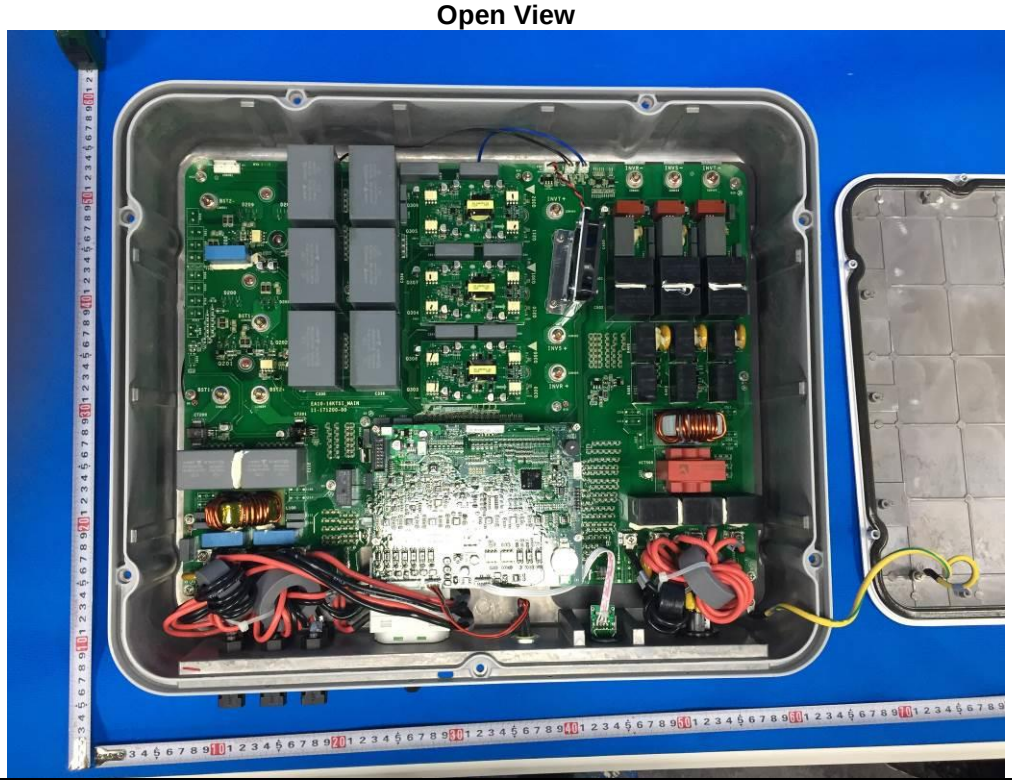
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Enclosure – Rear View

EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI
Enclosure – Bottom View

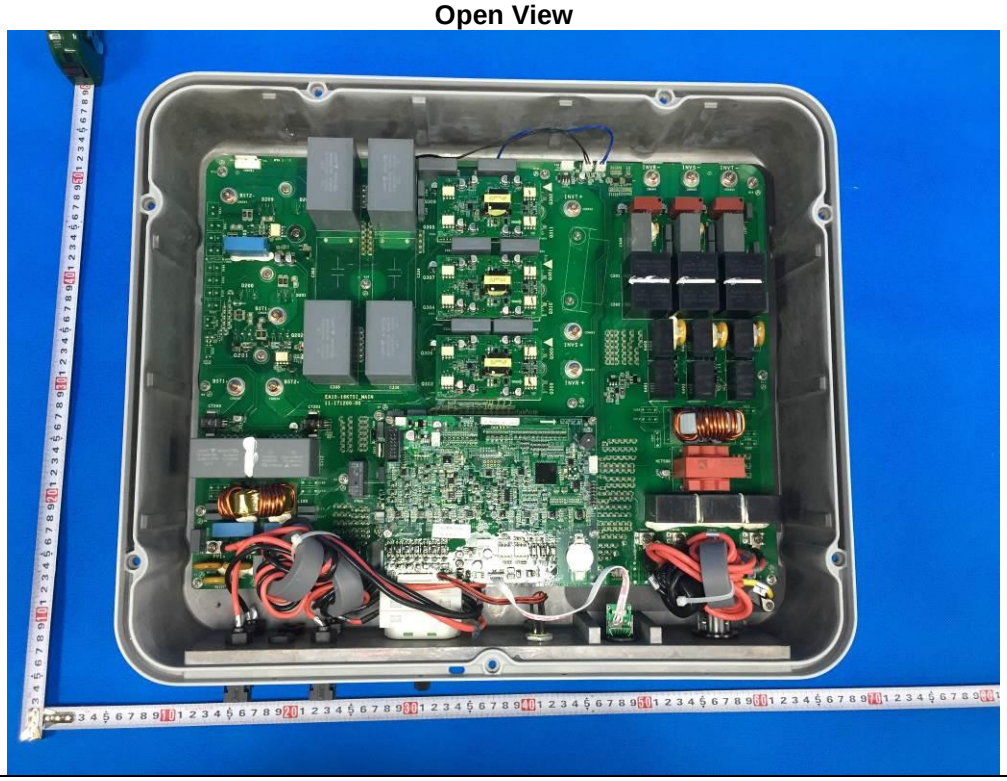
EA13KTSI / EA16KTSI
Enclosure – Bottom View

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

EA13KTSI / EA16KTSI
Open View

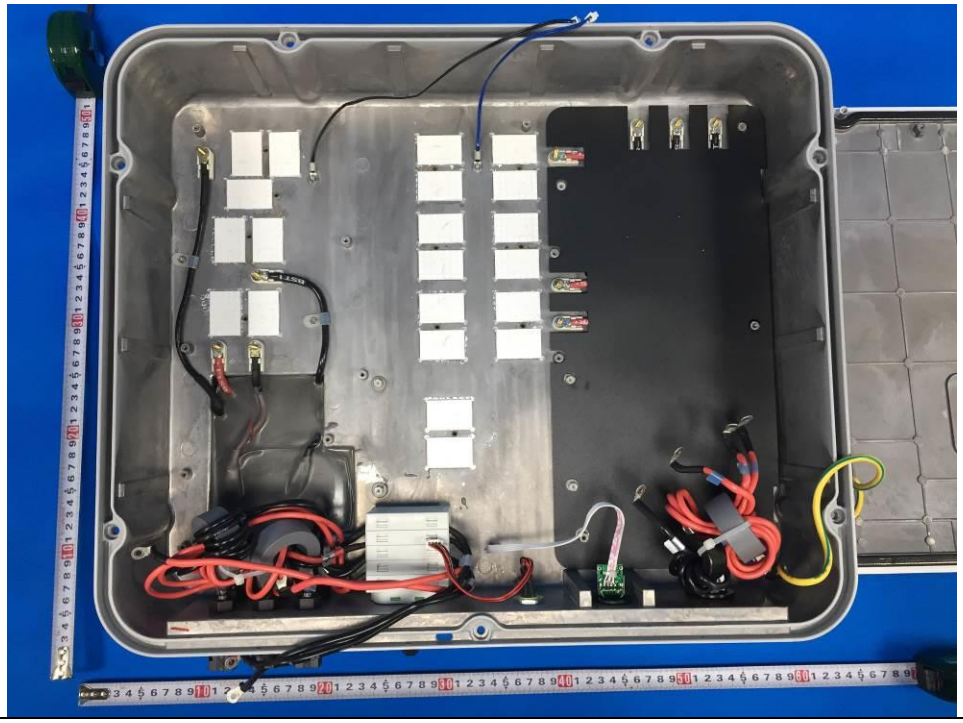


EA8KTSI / EA10KTSI
Open View

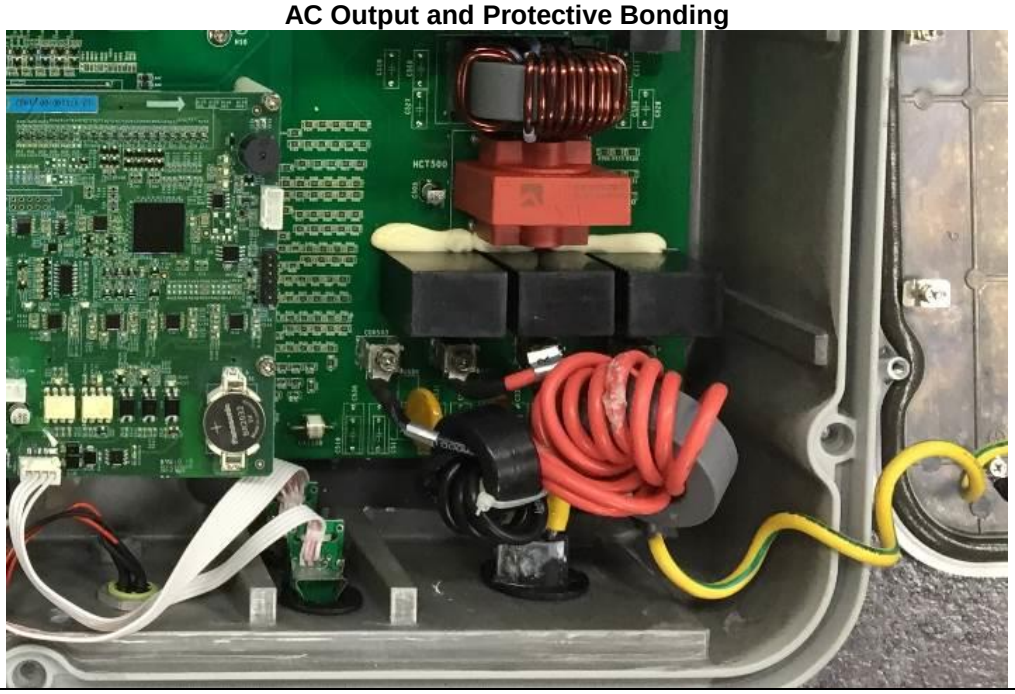


EA5KTSI / EA6KTSI
Open View

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

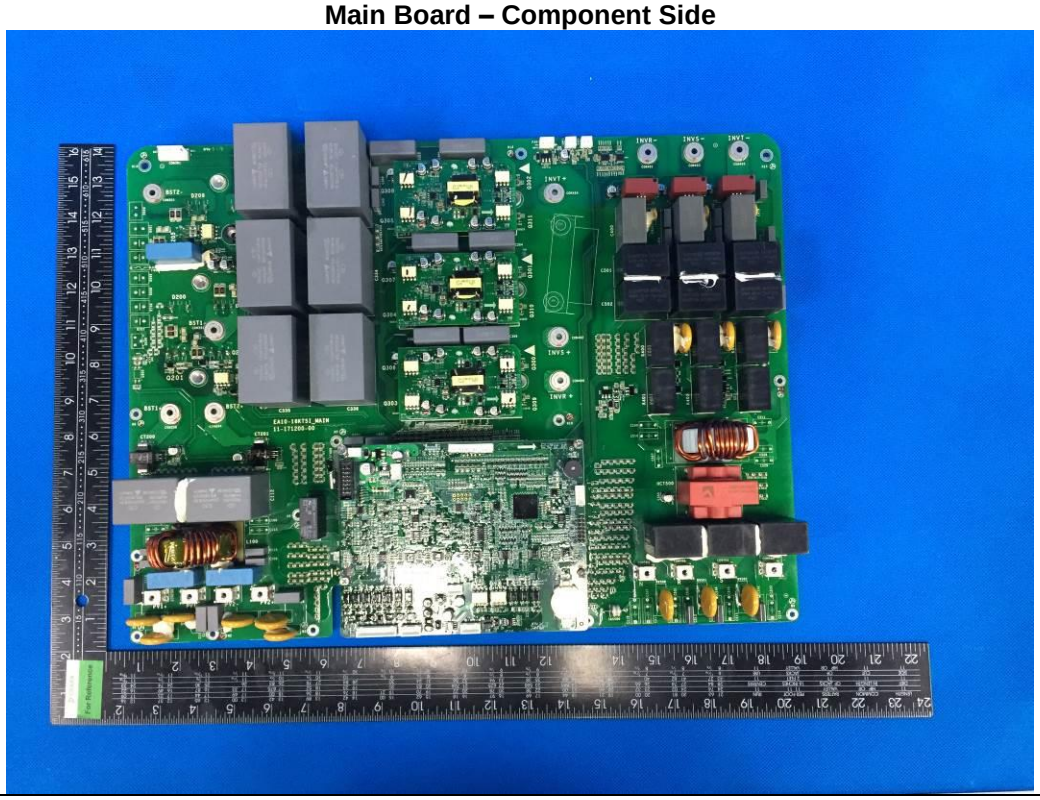


EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
AC Output and Protective Bonding

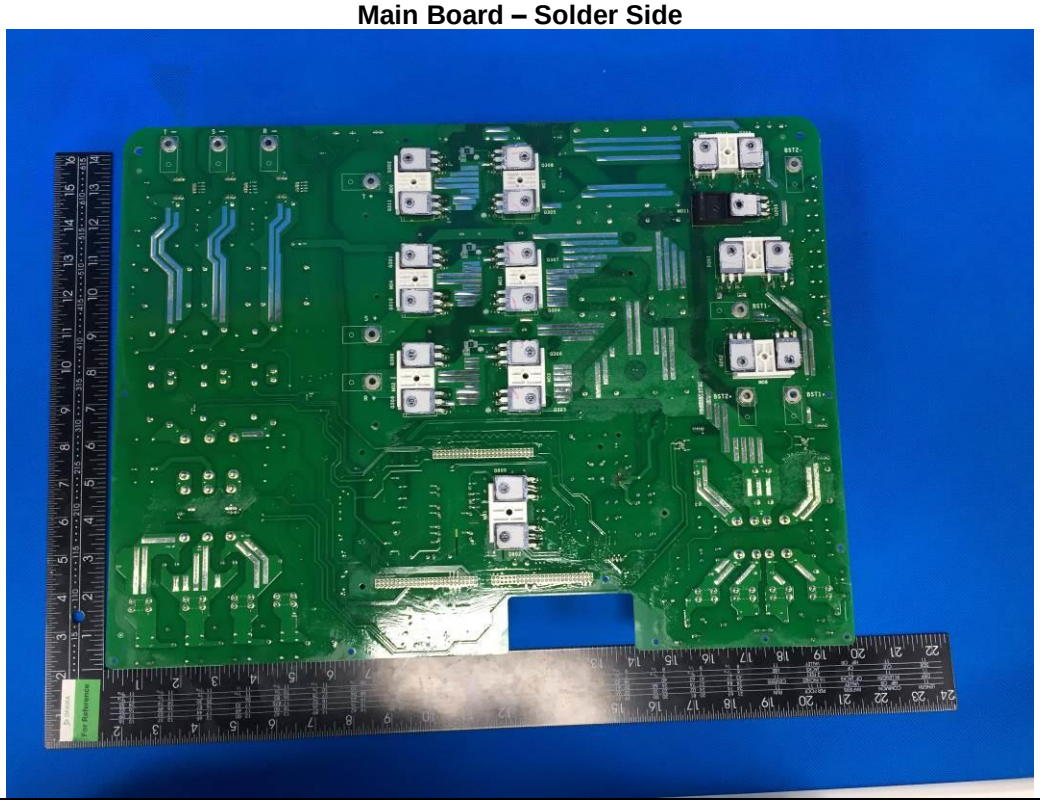


EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
AC Output and Protective Earthing

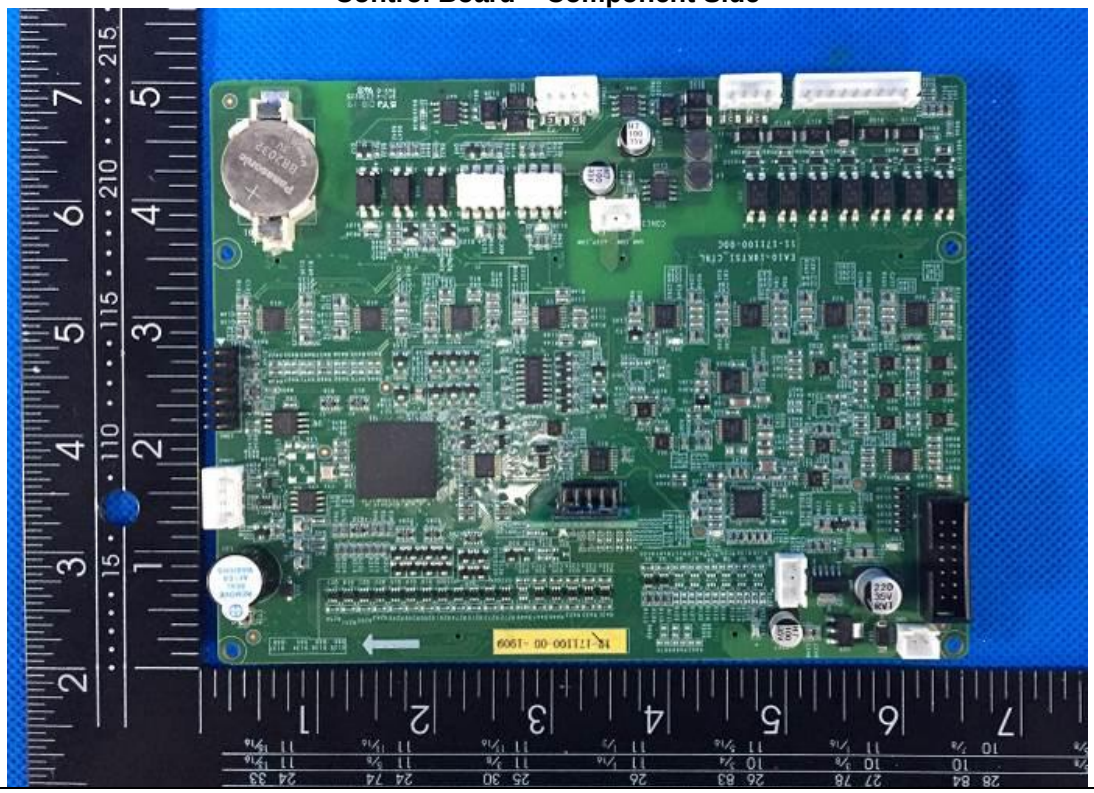
Main Board – Component Side



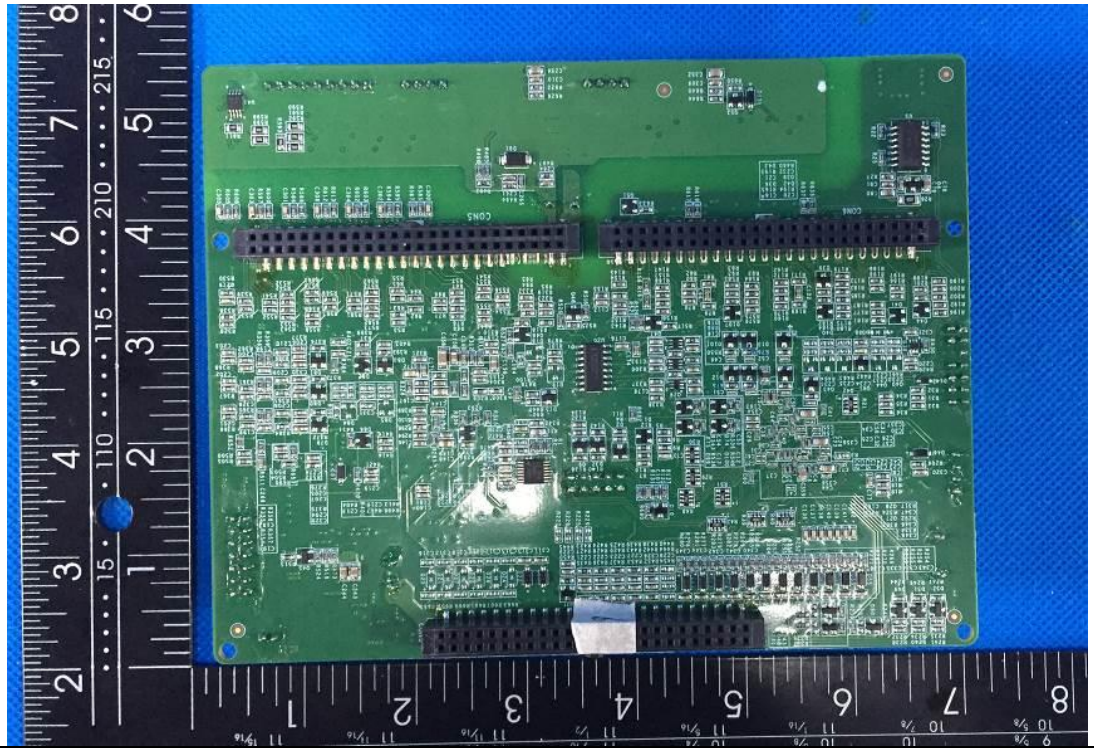
Main Board – Solder Side



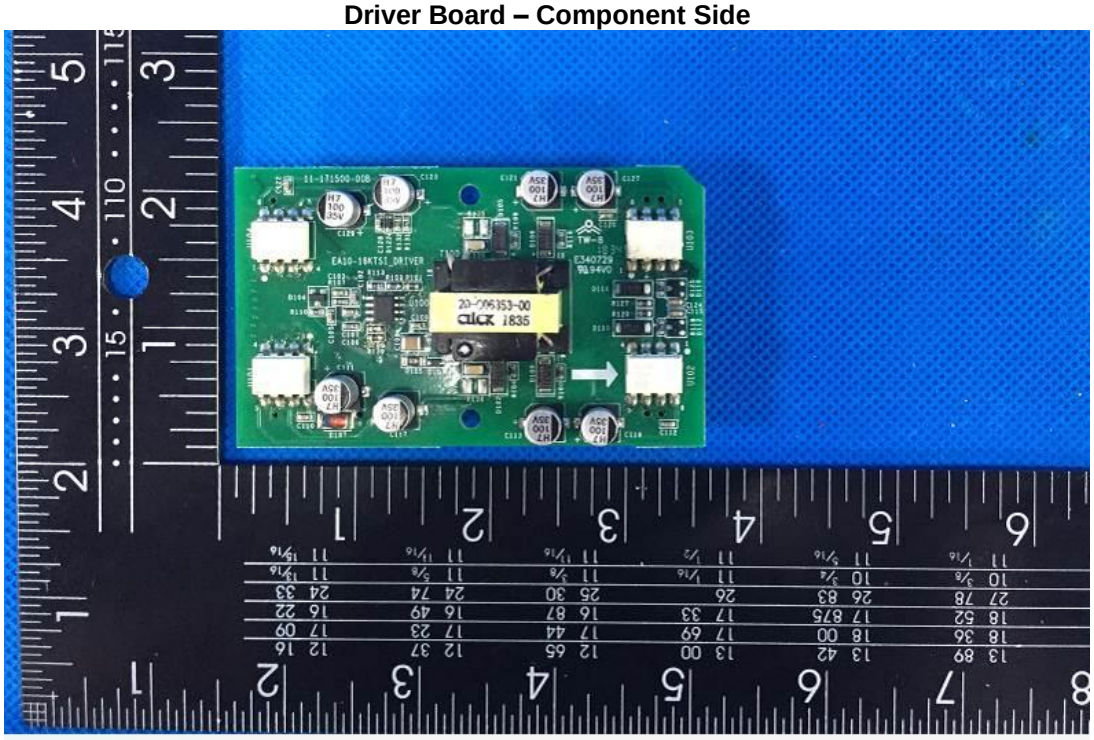
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Control Board – Component Side



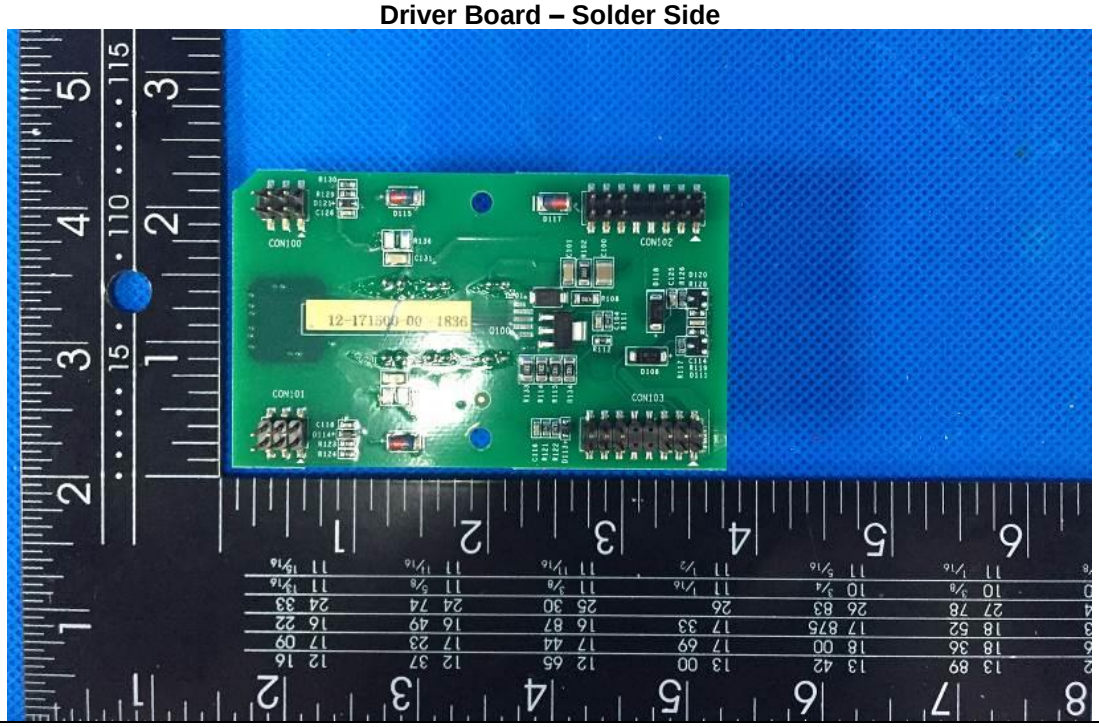
EA5KTSI / EA6KTSI / EA8KTSI / EA10KTSI / EA13KTSI / EA16KTSI
Control Board – Solder Side



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



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



--- End of test report---