TEST REPORT
Engineering Recommendation G59
RECOMMENDATIONS FOR THE CONNECTION OF GENERATING PLANT TO THE DISTRIBUTION SYSTEMS OF LICENSED DISTRIBUTION NETWORK OPERATORS

Report Reference No. ....:	140327083GZU-001
Tested by (name + signature)..........:	Jason Fu Jason Fu
Approved by (name + signature) .....:	Tommy Zhong Tommy
Date of issue ....:	30 May 2014
Contents ....:	44 Pages
Testing Laboratory ....:	Intertek Testing Services Shenzhen Ltd. Guangzhou Branch
Address ....:	Block E, No.7-2 Guang Dong Software Science Park, Caipin Road, Guangzhou Science City, GETDD, Guangzhou, China
Testing location / procedure.............:	TL ☒ SMT ☐ TMP ☐
Testing location / address ....:	Same as above
Applicant's name.............................:	Shenzhen SOFARSOLAR Co., Ltd.
Address ....:	3A-1, Huake Building, East Technology Park, Qiaoxiang Road, Nanshan District, Shenzhen, China
Test specification:	
Standard..:	ER G59_3_2013
Test procedure ....:	Type test
Non-standard test method..............:	N/A
Test Report Form/blank test report	
Test Report Form No. ....:	TTRF_G59_3_2013_V1.0_2013-12
TRF Originator ....:	Intertek
Master TRF ....:	2013-12

Test item description .... :	Grid-connected PV inverter
Trade Mark .... :	SOFAR SOLAR
Manufacturer .... :	Same as applicant
Model/Type reference............. :	Sofar 20000TL-Sx, Sofar 17000TL-Sx, Sofar 15000TL-Sx (x=0-6)
Rating…………………………..:	Maximum d.c. input voltage: 1000 V Input voltage rang: 250-960 V Max. input current: 2×24 A (for Sofar 20000TL-Sx); 2×21 A (for Sofar 17000TL-Sx, Sofar 15000TL-Sx); Max. PV Isc: 2×30 A (for Sofar 20000TL-Sx); 2×27 A (for Sofar 17000TL-Sx, Sofar 15000TL-Sx); Nominal output voltage: 3/N/PE230V/400V Max. output current: 3×29 A (for Sofar 20000TL-Sx); 3×25 A (for Sofar 17000TL-Sx); 3×22 A (for Sofar 15000TL-Sx); Nominal frequency: 50 Hz Max. output power: 20000 W (for Sofar 20000TL-Sx); 17000 W (for Sofar 17000TL-Sx); 15000 W (for Sofar 15000TL-Sx) Ingress protection: IP65 Operating temperature range: -25～60℃

Test item particulars... :	
Temperature range ....:	-25°C ~60°C
IP protection class ....:	IP 65
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)
Testing.. :	
Date of receipt of test item.. :	27 Mar 2014
Date (s) of performance of tests................................... :	27 Mar 2014 – 09 May 2014

General remarks:

The test results presented in this report relate only to the object (single PV inverter unit) tested and base on Low Voltage connected on small power station. The information about Generating Plant is not consider and tesing.

Installer and relevant persons shall comply with G59 and relevant standard and Grid Code in G59

This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
"(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 point is used as the decimal separator.

Determination of the test result includes consideration of measurement uncertainty from the test equipment and methods.

The test results presented in this report relate only to the item tested. The results indicate that the specimen partially complies with standard"ER G59/3:2013". See general product information next for details information.

General product information:

1. Product covered by this report is non-isolated grid-connected PV inverter for connection with low voltage grid in terms of ER G59_3_2013
2. The inverters intended to operate at ambient temperature -25℃ - +60℃ and 250-960 Vdc input, which will be specified in the user manual; The inverters will output full power when operated at 45℃. If operated at higher than 45℃ temperature, the output power derating.

For all models, if the DC input voltage is higher than 850 Vdc the output power will be derating.
For model Sofar 20000TL-Sx, if the DC input voltage is lower than 430 Vdc, the output power will be derating.
For model Sofar 17000TL-Sx, if the DC input voltage is lower than 420 Vdc, the output power will be derating.
For model Sofar 15000TL-Sx, if the DC input voltage is lower than 370 Vdc, the output power will be derating.
For all models, if the AC output voltage is lower than 230 Vac the output current will be limited to not higher than rated output current.

Model difference:
All the models have identical mechanical and electrical construction except some componnents and some parameter of the software architecture in order to control the max output power. And refer to the following table for detail.

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

Sofar 15000TL-S0								
Sofar 20000TL-S1 Sofar 17000TL-S1 Sofar 15000TL-S1	√		√			√		
Sofar 20000TL-S2 Sofar 17000TL-S2 Sofar 15000TL-S2		√	√			√		
Sofar 20000TL-S3 Sofar 17000TL-S3 Sofar 15000TL-S3		√		√		√		
Sofar 20000TL-S4 Sofar 17000TL-S4 Sofar 15000TL-S4		√		√	√	√		
Sofar 20000TL-S5 Sofar 17000TL-S5 Sofar 15000TL-S5		√		√	√	√		√
Sofar 20000TL-S6 Sofar 17000TL-S6 Sofar 15000TL-S6		√		√	√	√	√	√
√ denote incorporating this component								

Model Sofar 17000TL-Sx similar to Sofar 20000TL-Sx except amount of the DC-link capacitors, different of input and output sampling resistors and different inductance of Boost, invert inductor.

Model Sofar 15000TL-Sx similar to Sofar 17000TL-Sx except amount of the DC-link capacitors, different inductance of Boost, invert inductor and less PV input circuits (including PV terminal, fuse and sampling circuits of fuse).

Model Sofar 20000TL-Sx and Sofar 17000TL-Sx have two external fans.

Model Sofar 15000TL-Sx has one external fan

Unless other special note, the model Sofar 20000TL-S6 selected as representative sample for testing in this report.
The product was tested on
hardware version: Prototype

software version: V1.00

Factory information:

Factory: Dongguan dingqiang Machinery & Electric Co., Ltd.

Address: No. 8, Fulong road, Qingxi town, Dongguan city, Guangdong, China

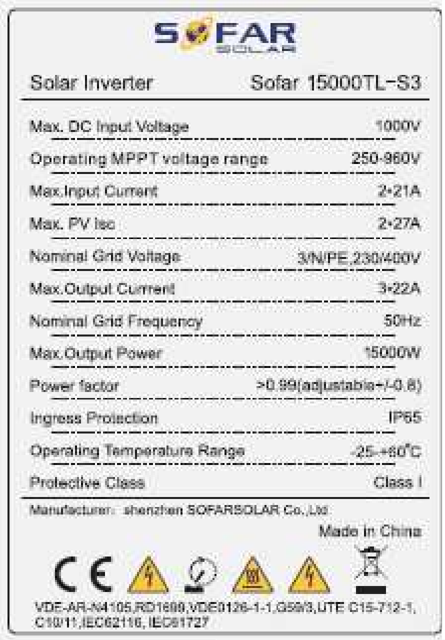
Software setting as following:

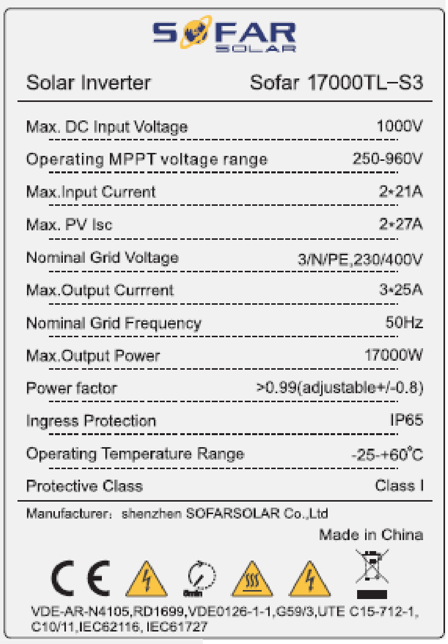
Different country can be set on switch SWT3 on communication board, digit “0” represents OFF, digit “1” represents ON

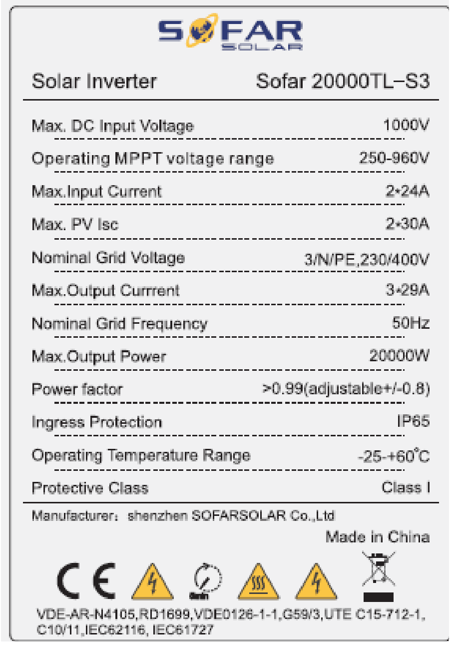
SWITCH 5	SWITCH 4	SWITCH 3	SWITCH 2	SWITCH 1	Country
0	1	0	0	1	UK_G59

Copy of marking plate:

The artwork below may be only a draft. The use of certification marks on a product must be authorized by the respective certification body that owns these marks.







SC1ES320E39001

ER G59			
Clause	Requirement - Test	Result - Remark	Verdict
5	LEGAL ASPECTS	NA on generating unit-PV inverter tesing	N/A
6	CONNECTION APPLICATION		N/A
7	CONNECTION ARRANGEMENTS		N/A
7.1	Operating Modes		N/A
7.2	Long-Term Parallel Operation		N/A
7.3	Infrequent Short-Term Parallel Operation		N/A
7.4	Switched Alternative-Only Operation		N/A
8	EARTHING		N/A
9	GENERATING PLANT CONNECTION DESIGN AND OPERATION		P
9.1	General Criteria		N/A
9.1.1	As outlined in Section 5, DNOs have to meet certain statutory and Distribution Licence obligations when designing and operating their Distribution Systems. These obligations will influence the options for connecting Generating Plant		N/A
9.1.2	The technical and design criteria to be applied in the design of the Distribution System and Generating Plant connection are detailed within the Distribution Planning and Connection Code (DPC) and the standards listed in Annex 1 of the Distribution Code		N/A
	The criteria are based upon the performance requirements of the Distribution System necessary to meet the above obligations		N/A
9.1.3	The Distribution System, and any Generating Plant connection to that System, shall be designed		N/A
	a. to comply with the obligations (to include security, frequency and voltage; voltage disturbances and harmonic distortion; auto reclosing and single phase protection operation).		N/A
	b. according to design principles in relation to Distribution System‟s plant and equipment, earthing, voltage regulation and control, and protection as outlined in DPC4, subject to any modification to which the DNO may reasonably consent	NA on generating unit-PV inverter	N/A
9.1.4	Generating Plant should meet a set of technical requirements in relation to its performance with respect to frequency and voltage, control capabilities, protection coordination requirements, phase voltage unbalance requirements, neutral earthing provisions, islanding and black start capability. These requirements are listed in DPC7.4 of the Distribution Code	Only parts requirements comply with and test.	N/A
9.1.5	There are additional performance requirements that are specified in the Grid Code for all embedded Medium and Large Power Stations. The requirements for Medium Power Stations are referenced in DPC7.5 of the Distribution Code, and are all listed in CC3.3 to CC3.5 of the Grid Code		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
9.2	Generating Plant Connection Designs	NA on generating unit-PV inverter	N/A
9.3	Generating Plant Performance and Control Requirements		P
9.3.1	In accordance with DPC7.4.1 of the Distribution Code, the rated power output of a Generating Unit should not be affected by voltage changes within the statutory limits declared by the DNO in accordance with the ESQCR unless otherwise agreed with the DNO.	NA on generating unit-PV inverter	N/A
9.3.2	Under abnormal conditions automatic low-frequency load-shedding provides for load reduction down to 47Hz.		P
	In exceptional circumstances, the frequency of the DNO's Distribution System could rise above 50.5 Hz		P
	Therefore all embedded Small Power Stations should be capable of continuing to operate in parallel with the Distribution System in accordance with the following:		P
	a. 47 Hz – 47.5 Hz Operation for a period of at least 20 seconds is required each time the frequency is within this range		P
	b. 47.5 Hz – 51.5 Hz Disconnection by overfrequency or underfrequency protection is not permitted in this range		P
	c. 51.5 Hz – 52 Hz Operation for a period of at least 90 seconds is required each time the frequency is within this range		P
9.3.3	The operational characteristics of the control systems of Generating Plant control systems (e.g. excitation, speed governor, voltage and frequency controls if applicable) must be co-ordinated with other voltage control systems influencing the voltage profile on the Distribution System. The DNO will provide information on performance requirements in accordance with DPC7.4.2.	NA on generating unit-PV inverter	N/A
9.3.4	Following consultation with the Generator and dependent on Distribution System voltage studies, a DNO will agree the reactive power and voltage control requirements for all Generating Units that are connected to their Distribution Systems.		N/A
9.3.5	Each item of Generating Plant and its associated control equipment must be designed for stable operation in parallel with the Distribution System	Only consider the single unit	P
9.3.6	Load flow and System Stability studies may be necessary to determine any output constraints or post fault actions necessary for n-1 fault conditions and credible n-2 conditions (where n-1 and n-2 conditions are the first and second outage conditions as, for example, specified in ER P2/6) involving a mixture of fault and planned outages.	NA on generating unit-PV inverter	N/A
	The Connection Agreement should include details of the relevant outage conditions. It may be necessary under these fault conditions, where the combination of Generating Plant output, load and through flow levels leads to circuit overloading, to rapidly disconnect or constrain the Generating Plant	NA on generating unit-PV inverter	N/A

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Clause	Requirement - Test	Result - Remark	Verdict
9.3.7	Type Tested Generating Units Performance Requriements		P
	Type Tested Generating Units should be capable of continuing to operate in parallel with the Distribution System as per section 9.2 for non-type tested Generating Units. However allowing for tolerances and measurement errors the following test voltages and frequencies at which the tests should be carried out with no trips have been defined. These are shown on the Generating Unit Type test sheet in section 13.1 and described in section 13.8		P
	a. Voltage range: Maximum Voltage of 258.2V with no time limit, 269.7V for 0.98s and of 277.7V for 0.48s. Minimum Voltage of 204.1V with no time limit, 188V for 2.48s and 180V for 0.48s		P
	b. Frequency range: Maximum Frequency 51.3Hz with no time limit, 51.8Hz for 89.98s and 52.2Hz for 0.48s Minimum frequency 47.7Hz with no time limit, 47.2 Hz for 19.98s and 46.8Hz for 0.48s		P
	c. Rates of Change of Frequency range:		P
	d. Voltage Vector shift rangeof:		P
	e. And when operating at rated power shall operate at a power factor within the range 0.95 lagging to 0.95 leading relative to the voltage waveform unless otherwise agreed with the DNO eg for power factor improvement. The test to be carried out at three voltage levels.		P
9.4	Fault Contributions and Switchgear Considerations		P
9.4.1	Under the ESQCR 2002 and the EaWR 1989 the Generator and the DNO have legal duties to ensure that their respective systems are capable of withstanding the short circuit currents associated with their own equipment and any infeed from any other connected system.		N/A
9.4.2	The Generator may accept that protection installed on the Distribution System can help discharge some of his legal obligations relating to fault clearance and, if requested, the DNO should consider allowing such faults on the Generator's system to be detected by DNO protection systems and cleared by the DNO's circuit breaker		N/A
	The DNO will not allow the Generator to close the DNO's circuit breaker nor to synchronise using the DNO's circuit breaker. In all such cases the exact nature of the protection afforded by the DNO's equipment should be agreed and documented. The DNO may make a charge for the provision of this service		N/A
9.4.3	The design and safe operation of the Generator's and the DNO's installation's depend upon accurate assessment of the contribution to the short circuit current made by all the Generating Plant operating in parallel with the Distribution System at the instant of fault and the Generator should discuss this with the DNO at the earliest possible stage		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
9.4.4	Short circuit current calculations should take account of the contributions from all synchronous and asynchronous infeeds including induction motors		N/A
	The prospective short circuit „make' and „break' duties on switchgear should be calculated to ensure that plant is not potentially over-stressed.		N/A
9.4.5	The connection of Generating Plant can raise the Distribution System reactance/resistance (X/R) ratio. In some cases, this will place a more onerous duty on switchgear by prolonging the duration of the DC component of fault current from fault inception.		N/A
	The performance of connected switchgear must be assessed to ensure safe operation of the Distribution System. The performance of protection may also be impaired by partial or complete saturation of current transformers resulting from an increase in Distribution System X/R ratio		N/A
9.4.6	Newly installed protection systems and circuit breakers for Generating Unit connections should be designed, specified and operated to account for the possibility of out-of-phase operation. It is expected that the DNO's metering/interface circuit beaker will be specified for this duty, but in the case of existing circuit breakers on the Distribution System, the DNO will need to establish the possibility or otherwise of the DNOs protection (or the Generator's protection if arranged to trip the DNO's circuit breaker) initiating a circuit breaker trip during a period when one of more Generating Units might have lost Synchronism with the Total System. Where necessary, switchgear replacement, improved security arrangements and other control measures should be considered to mitigate this risk.		N/A
9.4.7	When connection of Generating Plant is likely to increase short circuit currents above Distribution System design ratings, consideration should be given to the installation of reactors, sectionalising networks, connecting the Generating Plant to part of the Distribution System operating at a higher voltage, changing the Generating Unit specification or other means of limiting short circuit current infeed.		N/A
9.4.8	For busbars with three or more direct connections to the rest of the Total System, consideration may be given to reducing fault levels by having one of the connections 'open' and on automatic standby		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
9.4.9	Disconnection of Generating Plant must be achieved by the separation of mechanical contacts unless the disconnection is at Low Voltage and the equipment at the point of disconnection contains appropriate self monitoring of the point of disconnection, in which case an appropriate electronic means such as a suitably rated semiconductor switching device would be acceptable. The self monitoring facility shall incorporate fail safe monitoring to check the voltage level at the output stage. In the event that the solid state switching device fails to disconnect the Generating Unit, the voltage on the output side of the switching device shall be reduced to a value below 50 volts within 0.5s. For the avoidance of doubt this disconnection is a means of providing LoM disconnection and not as a point of isolation to provide a safe system of work.		P
9.5	Voltage Limits and Control		N/A
9.6	Power Quality		P
9.6.1	The connection of Generating Plant may cause a distortion of the Distribution System voltage waveform resulting in voltage fluctuations, harmonics or phase voltage unbalance.		P
	DPC4.2.3 of the Distribution Code outlines the limits on voltage disturbances and harmonic distortion		N/A
	DPC7.4.4 sets phase voltage unbalance requirement that any Generating Plant connected to the Distribution System would need to comply with		N/A
9.6.2	Flicker		P
	Where the input motive power of the Generating Plant may vary rapidly, causing corresponding changes in the output power, flicker may result. Any run up or synchronizing effects on voltage waveform that give risk to flicker must not breach the limits for flicker in ER P28.		P
	The fault level of the Distribution System needs to be considered to ensure that the emissions produced by the Generating Plant do not cause a problem on the Distribution System. For Type Tested Generating Units of up to 17kW per phase or 50kW three phase voltage step change and flicker measurements as required by BS EN 61000-3-11 shall be made and recorded in the type test declaration for the Generating Unit.		P
9.6.2.1	For wind turbines, flicker testing should be carried out during the performance tests specified in IEC 61400-21.		N/A
9.6.2.2	For technologies other than wind, the controls or automatic programs used shall produce the most unfavourable sequence of voltage changes for the purposes of the test.		P
9.6.3	Harmonic		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Harmonic voltages and currents produced within the Generator‟s system may cause excessive harmonic voltage distortion in the Distribution System. The Generator s installation must be designed and operated to comply with the planning criteria for harmonic voltage distortion as specified in ER G5/4-1. like all planning standards referenced in this recommendation, is applicable at the time of connection of additional equipment to a Customer‟s Installation.		P
	For Type Tested Generating Units of up to 17kW per phase or 50kW three phase harmonic measurements as required by BS EN 61000-3-12 shall be made and recorded in the type test declaration for the Generating Unit.		P
	Alternatively, if the harmonic emissions are low and they are shown to meet the requirements of BS EN 61000-3-2 then there will be no need to carry out fault level to Generating Unit size ratio check. Generating Units meeting the requirements of BS EN 61000-3-2 will need no further assessment with regards to harmonics.		P
9.6.4	Where the Generating Plant is connected via a long cable circuit the likelihood of a resonant condition is greatly increased, especially at 132kV. This arises from the reaction of the transformer inductance with the cable capacitance. Resonance is likely in the low multiples of the fundamental frequency (8th-11th harmonic). The resonant frequency is also a function of the Total System fault level. If there is the possibility that this can change significantly eg by the connection of another Generating Plant, then a full harmonic study should be carried out.		N/A
9.6.5	Voltage imbalance		N/A
	ER P29 is a planning standard which sets the Distribution System compatibility levels for voltage unbalance caused by uneven loading of three phase supply systems. Generating Units should be capable of performing satisfactorily under the conditions it defines		N/A
9.6.6	The level of voltage unbalance at the Point of Common Coupling should be no greater than 1.3% for systems with a nominal voltage below 33kV, or 1% for other systems with a nominal voltage no greater than 132kV. Overall, voltage unbalance should not exceed 2% when assessed over any one minute period. ER P29, like all planning standards, is applicable at the time of connection.		N/A
9.6.6.1	For Power Stations of 50kW or less section 7.5 of this document specifies maximum unbalance of Generating Units. Where these requirements are met then no further action is required by the Generator.		N/A
9.6.7	Power factor correction equipment is sometimes used with asynchronous Generating Units to decrease reactive power flows on the Distribution System. Where the power factor correction equipment is of a fixed output, stable operating conditions in the event of loss of the DNO supply are extremely unlikely to be maintained, and therefore no special protective actions are required in addition to the standard protection specified in this document		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
9.6.8	DC Injection		P
	The effects of, and therefore limits for, DC currents injected into the Distribution System is an area currently under investigation by DNOs. Until these investigations are concluded the limit for DC injection is less than 0.25% of the AC rating per Generating Unit.		P
9.7	System Stability		N/A
9.8	Island Mode		N/A
9.8.1	The principles discussed in this section generally also apply where Generation Plant on a Customer's site is designed to maintain supplies to that site in the event of a failure of the DNO supply		N/A
9.8.2	When considering whether Generating Plant can be permitted to operate in island mode, detailed studies need to be undertaken to ensure that the islanded system will remain stable and comply with all statutory obligations and relevant planning standards when separated from the remainder of the Total System.		N/A
	Before operation in island mode can be allowed, a contractual agreement between the DNO and Generator must be in place and the legal liabilities associated with such operation must be carefully considered by the DNO and the Generator		N/A
	Consideration should be given to the following areas: a. load flows, voltage regulation, frequency regulation, voltage unbalance, voltage flicker and harmonic voltage distortion b. earthing arrangements c. short circuit currents and the adequacy of protection arrangements d. System Stability e. resynchronisation to the Total System f. safety of personnel		N/A
9.8.3	Suitable equipment will need to be installed to detect that an island situation has occurred and an intertripping scheme is preferred to provide absolute discrimination at the time of the event. Confirmation that a section of Distribution System is operating in island mode, and has been disconnected from the Total System, will need to be transmitted to the Generating Unit(s) protection and control schemes.		N/A
9.8.4	The ESQCR requires that supplies to Customers are maintained within statutory limits at all times		N/A
9.8.5	The ESQCR also require that Distribution Systems are earthed at all times. Generators, who are not permitted to operate their installations and plant with an earthed star-point when in parallel with the Distribution System, must provide an earthing transformer or switched star-point earth for the purpose of maintaining an earth on the system when islanding occurs.		N/A

ER G59			
Clause	Requirement - Test	Result - Remark	Verdict
	The ESQCR also require that Distribution Systems are earthed at all times. Generators, who are not permitted to operate their installations and plant with an earthed star-point when in parallel with the Distribution System, must provide an earthing transformer or switched star-point earth for the purpose of maintaining an earth on the system when islanding occurs.		N/A
9.8.6	Detailed consideration must be given to ensure that protection arrangements are adequate to satisfactorily clear the full range of potential faults within the islanded system taking into account the reduced fault currents and potential longer clearance times that are likely to be associated with an islanded system.		N/A
9.8.7	Switchgear shall be rated to withstand the voltages which may exist across open contacts under islanded conditions. The DNO may require interlocking and isolation of its circuit breaker(s) to prevent out of phase voltages occurring across the open contacts of its switchgear. Intertripping or interlocking should be agreed between the DNO and the Generator where appropriate.		N/A
9.8.8	It will generally not be permissible to interrupt supplies to DNO Customers for the purposes of resynchronisation. The design of the islanded system must ensure that synchronising facilities are provided at the point of isolation between the islanded network and the DNO supply. Specific arrangements for this should be agreed and recorded in the Connection Agreement with the DNO.		N/A
10	PROTECTION		P
10.1	General		P
10.1.1	The main function of the protection systems and settings described in this document is to prevent the Generating Plant supporting an islanded section of the Distribution System when it would or could pose a hazard to the Distribution System or customers connected to it.		P
	The settings recognize the need to avoid nuisance tripping and therefore require a two stage approach where practicable		P
10.1.2	practice it is for the Generator to install, own and maintain this protection. The Generator can therefore determine the approach, i.e. per Generating Unit or per installation, and where in the installation the protection is sited.		P
10.1.3	In exceptional circumstance additional protection may be required by the DNO to protect the Distribution System from the Generating Plant.		N/A
10.2	Protection Requirements		P
10.2.1	The basic requirements for protection are laid out in DPC7.4 of the Distribution Code. The requirements of EREC G59 are as follows:-		P

ER G59			
Clause	Requirement - Test	Result - Remark	Verdict
	• UnderVoltage (2 stage); • OverVoltage (2 stage); • UnderFrequency (2 stage); • OverFrequency (2 stage); • Loss of Mains (LoM).		P
	. This LoM protection will depend for its operation on the detection of some suitable parameter, for example, rate of change of frequency (RoCoF), phase angle change or unbalanced voltages. More details on LoM protection are given in Section 10.3		P
	It is in the interest of Generators, DNOs and NETSO that Generating Plant remains synchronised to the Distribution System during system disturbances,		N/A
	conversely to disconnect reliably for true LoM situations. As some forms of LoM protection might not readily achieve the required level of performance (e.g. under balanced load conditions), the preferred method for Medium Power Stations and Large Power Stations is by means of intertripping. This does not preclude consideration of other methods that may be more appropriate for a particular connection		P
10.2.2	The protective equipment, provided by the Generator, to meet the requirements of this section must be installed in a suitable location that affords immediate visual inspection of the relays but is secure from interference by unauthorised personnel.		N/A
10.2.3	If automatic resetting of the protective equipment is used, there must be a time delay to ensure that healthy supply conditions exist for a minimum continuous period of 20s. Reset times may need to be co-ordinated where more than one Generating Plant is connected to the same feeder. The automatic reset must be inhibited for faults on the Generator's installation.		P
10.2.4	Protection equipment is required to function correctly within the environment in which it is placed and shall satisfy the following standards:		P
	BS EN 61000 (Electromagnetic Standards)		P
	BS EN 60255 (Electrical Relays);		N/A
	BS EN 61810 (Electrical Elementary Relays);		P
	BS EN 60947 (Low Voltage Switchgear and Control gear);		N/A
	BS EN 60044 (Instrument Transformers).		N/A
	Where these standards have more than one part, the requirements of all such parts shall be satisfied, so far as they are applicable.		P
10.2.5	Protection equipment and protection functions may be installed within, or form part of the generator control equipment as long as:		P
	a. the control equipment satisfies all the requirements of Section 10 including the relevant standards specified in 10.2.5		P

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Clause	Requirement - Test	Result - Remark	Verdict
	b. the Generating Plant shuts down in a controlled and safe manner should there be an equipment failure that affects both the protection and control functionality, for example a power supply failure or microprocessor failure		P
	c. the equipment is designed and installed so that protection calibration and functional tests can be carried out easily and safely using secondary injection techniques (i.e. using separate low voltage test equipment).		N/A
	d. a Type Tested Generating Unit's Interface Protection must not rely on interconnection using cables which could be terminated incorrectly on site ie the interconnections must be made by plug and socket		P
10.3	Loss of Mains (LoM)		P
10.3.1	To achieve the objectives of Section 10.1.1, in addition to protection installed by the Generator for his own purposes, the Generator must install protection to achieve (amongst other things) disconnection of the Generating Plant from the Distribution System in the event of loss of one or more phases of the DNOs supply.		P
	This LoM protection is required to ensure that the Generating Plant is disconnected, to ensure that the requirements for Distribution System earthing, and out-of-Synchronism closure are complied with		P
	and that Customers are not supplied with voltage and frequencies outside statutory limits.		P
10.3.2	LoM is mandatory for all Small Power Stations. For Medium and Large Power Stations the DNO will advise if LoM is required. The requirements of 10.5.2 apply to LoM protection for all power stations.		P
10.3.3	A problem can arise for Generators who operate Generating Plant in parallel with the Distribution System prior to a failure of the network supply because if their Generating Plant continues to operate in some manner, even for a relatively short period of time, there is a risk that when the network supply is restored the Generating Plant will be out of Synchronism with the Total System and suffer damage. LoM protection can be employed to disconnect the Generating Plant immediately after the supply is lost, thereby avoiding damage to the Generating Plant.		P
10.3.4	Many Customers are connected to parts of Distribution Systems which will be automatically re-energised within a relatively short period following a fault; with dead times typically between 1s and 180s. The use of such schemes is likely to increase in future as DNOs seek to improve supply availability by installing automatic switching equipment on their Distribution Systems.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
10.3.5	Where the amount of Distribution System load that the Generating Plant will attempt to pick up following a fault on the Distribution System is significantly more than its capability the Generating Plant will rapidly disconnect, or stall. However depending on the exact conditions at the time of the Distribution System failure, there may or may not be a sufficient change of load on the Generating Plant to be able to reliably detect the failure. The Distribution System failure may result in one of the following load conditions being experienced by the Generating Plant		P
	a. The load may slightly increase or reduce, but remain within the capability of the Generating Plant. There may even be no change of load;		P
	b. The load may increase above the capability of the prime mover, in which case the Generating Plant will slow down, even though the alternator may maintain voltage and current within its capacity. This condition of speed/frequency reduction can be easily detected; or		P
	c. The load may increase to several times the capability of the Generating Plant, in which case the following easily detectable conditions will occur: Overload and accompanying speed/frequency reduction Over current and under voltage on the alternator		P
10.3.6	LoM protection is designed to detect these conditions.		P
	LoM protection is designed to detect these conditions, In some particularly critical circumstances it may be necessary to improve the dependability of LoM detection by using at least two LoM techniques operating with different principles or by employing a LoM relay using active methods.		P
10.3.7	LoM signals can also be provided by means of intertripping signals from circuit breakers that have operated in response to the Distribution System fault.		N/A
10.3.8	The LoM protection can utilise one or a combination of the passive protection principles such as reverse power flow, reverse reactive power, rate of change of frequency (RoCoF) and voltage vector phase shift.		P
	Alternatively, active methods such as reactive export error detection or frequency shifting may be employed		N/A
	These may be arranged to trip the interface circuit breaker at the DNO Generator interface, thus, leaving the Generating Plant available to satisfy the load requirements of the site		N/A
	or the Generating Plant circuit breaker can be tripped, leaving the breaker at the interface closed and ready to resume supply when the Distribution System supply is restored.		P
	The most appropriate arrangement is subject to agreement between the DNO and Generator.		N/A
10.3.9	Protection based on measurement of reverse flow of real or reactive power can be used when circumstances permit and must be set to suit the Generating Plant rating, the site load conditions and requirements for reactive power.		P

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Clause	Requirement - Test	Result - Remark	Verdict
10.3.10	Where the Generating Plant capacity is such that the site will always import power from the Distribution System, a reverse power relay may be used to detect failure of the supply. It will usually be appropriate to monitor all three phases for reverse power.		N/A
10.3.11	However, where the Generating Plants normal mode of operation is to export power, it is not possible to use a reverse power relay and consequently failure of the supply cannot be detected by measurement of reverse power flow		N/A
	The protection should then be specifically designed to detect loss of the mains connection using techniques to detect the rate of change of frequency or sudden phase shifts of voltage vector and/or power factor		P
	All these techniques are susceptible to Distribution System conditions and the changes that occur without islanding taking place. These relays must be set to prevent islanding but with the best possible immunity to unwanted nuisance operation.		P
10.3.12	Both RoCoF and vector phase shift relays use a measurement of the period of the mains voltage cycle		N/A
	The RoCoF technique measures the rate of change in frequency caused by any difference between prime mover power and electrical output power of the embedded Generating Plant over a number of cycles.		N/A
	RoCoF relays should normally ignore the slow changes but respond to relatively rapid changes of frequency which occur when the Generation Plant becomes disconnected from the Total System		N/A
	The voltage vector shift technique tries to detect the shift in the voltage vector caused by a sudden change in the output of Generating Plant or load over one or two cycles (or half cycles).		N/A
	The main advantage of a vector shift relays is its speed and response to transient disturbances which are common to the onset of islanding but often difficult to quantify. Speed of response is also very important where high speed auto reclosing schemes are present		N/A
10.3.13	Observations of frequency disturbances on the GB system indicate that the rates of change of frequency that typically occur are within the range of 0.04 to 0.16 Hz/s. Experience to date suggests that settings which correspond to a rate of change of frequency of up to 0.1Hz/s are suitable for the detection of an islanded situation but may result in some nuisance tripping. Use of a constant rate of change of frequency of 0.125 Hz/s reduces nuisance tripping. Section 10.5.7.1 includes setting factors to increase resilience against nuisance tripping when connected to weak networks.		N/A
10.3.14	The LoM relay that operates on the principle of voltage vector shift can achieve fast disconnection for close up Distribution System faults and power surges, and under appropriate conditions can also detect islanding when normally a large step change in generation occurs.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	The relay measures the period for each half cycle in degrees and compares it with the previous one to determine if this exceeds its setting.		N/A
	A typical setting is 6 degrees, which is normally appropriate to avoid operation for most normal vector changes in low impedance Distribution Systems. This equates to a constant rate of change of frequency of about 1.67 Hz/s and hence the relay is insensitive to slow rates of change of frequency		N/A
	Hz/s and hence the relay is insensitive to slow rates of change of frequency. When vector shift relays are used in higher impedance Distribution Systems, and especially on rural Distribution Systems where auto-reclosing systems are used, a higher setting may be required to prevent nuisance tripping. Typically this is between 10 and 12 degrees		N/A
10.3.15	RoCoF protection is generally only applicable for Small Power Stations. DPC7.4 in the Distribution Code details where RoCoF may be used, and what the differences are between Scotland and England and Wales		N/A
10.3.16	Raising settings on any relay to avoid spurious operation may reduce a relay's capability to detect islanding and it is important to evaluate fully such changes. Appendix A13.6 provides some guidance for assessments, which assume that during a short period of islanding the trapped load is unchanged.		N/A
	In some circumstances it may be necessary to employ a different technique, or a combination of techniques to satisfy the conflicting requirements of safety and avoidance of nuisance tripping. In those cases where the DNO requires LoM protection this must be provided by a means not susceptible to spurious or nuisance tripping, e.g. intertripping.		P
10.3.17	For a radial or simple Distribution System controlled by circuit breakers that would clearly disconnect the entire circuit and associated Generating Plant, for a LoM event an intertripping scheme can be easy to design and install. For meshed or ring Distribution Systems, it can be difficult to define which circuit breakers may need to be incorporated in an intertripping scheme to detect a LoM event and the inherent risks associated with a complex system should be considered alongside those associated with a using simple, but potentially less discriminatory LoM relay.		N/A
10.3.18	It is the responsibility of the Generator to incorporate the most appropriate technique or combination of techniques to detect a LoM event in his protection systems. This will be based on knowledge of the Generating Unit, site and network load conditions.		P
	The DNO will assist in the decision making process by providing information on the Distribution System and its loads. The settings applied must be biased to ensure detection of islanding under all practical operating conditions		N/A
10.4	Additional DNO Protection		N/A
10.5	Protection Settings		P

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Clause	Requirement - Test	Result - Remark	Verdict
	The following notes aim to explain the settings requirements as given in Section 10.5.7.1 below.		P
10.5.1	The protection systems and settings can have an impact on the behaviour of Generating Plant when the Total System is in distress. Where Generating Plant has the capability to operate at the extremes of the possible operating range of the Total System, it would be inappropriate to artificially impose protection settings that would cause Generating Plant to be disconnected where it would otherwise be capable of remaining connected and help to maintain the integrity of the Total System.		P
	It is not the intention that this Section specifies the performance requirements of Generating Plant connected to Distribution Systems, only that protection settings do not aggravate the stress on the Total System by tripping before there is a definite need in those circumstances. (For Medium Power Stations and Large Power Stations, performance requirements are specified in the Grid Code). For Type Tested Generating Units there are performance requirements and these are specified in section 9.3.7		P
10.5.2	A LoM protection of RoCoF or vector shift type will generally be appropriate for Small Power Stations, but this type of LoM protection must not be installed for power stations at or above 50 MW.		P
	In those cases where the DNO requires LoM protection this must be provided by a means not susceptible to spurious or nuisance tripping, e.g. intertripping.		N/A
10.5.3	Under Voltage		P
	To that end, for all LV and HV connected Generating Plant a 2-Stage under voltage protection should be applied as follows:		P
	Stage 1 should have a setting of -13% (i.e. 10% to cater for a future LV statutory voltage limit and an additional 3% to provide immunity from 3% Step Voltage Changes permitted under ER P28) and a time delay of 2.5s.		P
	Stage 2 should have a setting of –20% (ie to detect a major Distribution System disturbance), with a time delay of 0.5s.		P
	The Grid Code calls for fault-ride through capability for Medium Power Stations and Large Power Stations6 as there is a more material requirement for such Generating Units to remain connected to the Distribution System save in exceptional circumstances. In this case a single stage with a permitted time delay of 2.5s and a setting of –20% should be applied.		N/A
10.5.4	Over Voltage		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Stage 1 (LV) should have a setting of +14% (ie the LV statutory upper voltage limit of +10%,with a further 4% permitted for voltage rise internal to the Customer's installation and measurement errors),with a time delay of 1.0s (to avoid nuisance tripping for short duration excursions); • Stage 2 (LV) should have a setting of +19% with a time delay of 0.5s (ie recognising the need to disconnect quickly for a material excursion);		P
	Stage 1 (HV) should have a setting of +10% with a time delay of 1.0s (ie the HV statutory upper voltage limit of +6%,with a further 4% permitted for voltage rise internal to the Customers Installation and measurement errors),, with a time delay of 1.0s to avoid nuisance tripping for short duration excursions); • Stage 2 (HV) should have a setting of +13% with a time delay of 0.5s (ie recognising the need to disconnect quickly for a material excursion).		N/A
	To achieve high utilisation and Distribution System efficiency, it is common for the HV Distribution System to be normally operated near to the upper statutory voltage limits. The presence of Generating Plant within such Distribution Systems may increase the risk of the statutory limit being exceeded, e.g. when the Distribution System is operating abnormally. In such cases the DNO may specify additional over voltage protection at the Generating Plant connection point. This protection will typically have an operating time delay long enough to permit the correction of transient over voltages by automatic tap-changers.		N/A
10.5.5	Over Frequency		P
	The Grid Code incorporates a requirement for Medium Power Stations and Large Power Stations to stay connected for Total System frequencies up to 52 Hz so as to provide the necessary regulation to control the Total System frequency to a satisfactory level.		N/A
	Similarly, in order to prevent the unnecessary disconnection of a large volume of smaller Generating Plant for all LV and HV connected Generating Plant, a 2-stage protection is to be applied as follows:		P
	Stage 1 should have a time delay of 90s and a setting of 51.5 Hz. The 90s setting should provide sufficient time for the NETSO to bring the Total System frequency below this level. Should the frequency rise be the result of a genuine islanding condition which the LoM protection fails to detect, this setting will help to limit the duration of the islanding period		P

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Clause	Requirement - Test	Result - Remark	Verdict
	Stage 2 should have a time delay of 0.5s and a setting of 52 Hz (ie to co-ordinate with the Grid Code and Distribution Code requirements with a practical time delay that can be tolerated by most Generating Plant). If the frequency rise to and above 52 Hz is the result of an undetected islanding condition, the Generating Plant will be disconnected with a delay of 0.5s plus circuit breaker operating time.		P
10.5.6	Under Frequency		P
	The Grid Code requires Medium Power Stations and Large Power Stations to maintain connection unless the Total System frequency falls below 47.5 Hz for 20s or below 47 Hz		P
	For all LV and HV connected Generating Plant, the following 2-stage under frequency protection should be applied:		P
	• Stage 1 should have a setting of 47.5 Hz with a time delay of 20s;		P
	• Stage 2 should have a setting of 47.0 Hz with a time delay of 0.5s;		
	• These settings are in line with the Distribution Code requirements.		P
10.5.7	Loss of Mains (LoM)		P
	In order to avoid unnecessary disconnection of Generating Plant during Distribution System faults or switching events and the consequent disruption to Generators and customers, as well as take into account the aggregate effect caused by multiple LoM operations on Total System Stability, consideration should be given to use of the appropriately sensitive settings which can be adjusted to take into account Generating Plant type & rating and Distribution System fault level. Example setting formulae are indicated in the notes below the Table 10.5.7.1.		P
10.5.7.1	Settings for Long-Term Parallel Operation		P
10.5.7.2	Settings for Infrequent Short-Term Parallel Operation		N/A
10.5.8	Over and Under voltage protection must operate independently for all three phases in all cases.		N/A
10.5.9	The settings in 10.5.7.1 should generally be applied to all Generating Plant		N/A
	In exceptional circumstances Generators have the option to agree alternative settings with the DNO if there are valid justifications in that the Generating Plant may become unstable or suffer damage with the settings specified in 10.5.7.1. The agreed settings should be recorded in the Connection Agreement		N/A
10.5.10	Once the settings of relays have been agreed between the Generator and the DNO they must not be altered without the written agreement of the DNO. Any revised settings should be recorded again in the amended Connection Agreement		N/A
10.5.11	Once the settings of relays have been agreed between the Generator and the DNO they must not be altered without the written agreement of the DNO. Any revised settings should be recorded again in the amended Connection Agreement		P

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Clause	Requirement - Test	Result - Remark	Verdict
10.5.12	OFor LV connected Generating Plant, the voltage settings will be based on the 230V nominal System voltage. In some cases Generating Plant may be connected to LV Systems with non-standard operating voltages. Section 10.5.16 details how suitable settings can be calculated based upon the HV connected settings in table 10.5.7.1. Note that Generating Units with non-standard LV protection settings cannot be Type Tested and these will need to be agreed by the DNO on a case by case basis.		N/A
10.5.13	Co-ordination with existing protection equipment and auto-reclose scheme is also required, as stated in DPC7.4.3 of the Distribution Code.		N/A
	In particular the Generator's protection should detect a LoM situation and disconnect the Generating Plant in a time shorter than any auto reclose dead time. This should include an allowance for circuit breaker operation and generally a minimum of 0.5s should be allowed for this. For auto-reclosers set with a dead time of 3s, this implies a LoM response time of 2.5s. A similar response time is expected from under and over voltage relays		P
	Where auto-reclosers have a dead time of less than 3s, there may be a need to reduce the operating time of under and over voltage relays		N/A
	For Type Tested Generating Units no changes are required to the operating times irrespective of the auto reclose times.		P
10.5.14	If automatic resetting of the protective equipment is used, as part of an auto-restore scheme for the Generating Plant, there must be a time delay to ensure that healthy supply conditions exist for a continuous period of at least 20 s. The automatic reset must be inhibited for faults on the Generator's installation. Staged timing may be required where more than one Generating Plant is connected to the same feeder. For Type Tested Generating Units the time delay is set at 20s.		P
10.5.15	Where an installation contains power factor correction equipment which has a variable susceptance controlled to meet the reactive power demands, the probability of sustained generation is increased. For LV installations, additional protective equipment provided by the Generator, is required as in the case of self-excited asynchronous machines		N/A
10.5.16	Non-Standard private LV networks calculation of appropriate protection settings		N/A
10.5.17	The Generator shall provide a means of displaying the protection settings so that they can be inspected if required by the DNO to confirm that the correct settings have been applied. The Manufacturer needs to establish a secure way of displaying the settings in one of the following ways:		P

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Clause	Requirement - Test	Result - Remark	Verdict
	a. A display on a screen which can be read; b. A display on an electronic device which can communicate with the Generating Unit and confirm that it is the correct device by means of a Identification number / name permanently fixed to the device and visible on the electronic device screen at the same time as the settings; c. Display of all settings including nominal voltage and current outputs, alongside the identification number / name of the device, permanently fixed to the Generating Unit.		P
10.6	Typical Protection Application Diagrams		N/A
11	INSTALLATION, OPERATION AND CONTROL INTERFACE		P
11.1	General		N/A
11.1.1	Installations should be carried out by competent persons, who have sufficient skills and training to apply safe methods of work to install the Generating Plant in compliance with this Engineering Recommendation. Ideally they should have recognised and approved qualifications relating to the fuel / energy sources and general electrical installations.		N/A
11.1.2	Notwithstanding the requirements of this Engineering Recommendation, the installation should be carried out to the standards required in the Manufacturer's installation instructions		N/A
11.1.3	The Generator and DNO must give due regard to these requirements and ensure that all personnel are competent in that they have adequate knowledge and sufficient judgement to take the correct action when dealing with an emergency. Failure to take correct action may jeopardise the Generator's equipment or the Distribution System and give rise to danger		N/A
11.1.4	No parameter relating to the electrical connection or setting that is subject to type verification certification shall be modified as part of or after the installation process unless previously agreed in writing between the DNO and the Generator. User access to change such parameters shall be prevented by the use of sealing plugs / paper seals etc where possible		N/A
11.1.5	The DNO and the Generator must agree in writing the salient technical requirements of the interface between their two systems. These requirements will generally be contained in the Site Responsibility Schedule and/or the Connection Agreement		N/A
11.1.6	The Generators should be aware that many DNOs apply auto-reclose systems to High Voltage overhead line circuits. This may affect the operations of directly connected HV Generating Plants and also Generating Plants connected to LV Distribution Systems supplied indirectly by HV overhead lines		N/A
11.2	Isolation and Safety Labelling		P

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Clause	Requirement - Test	Result - Remark	Verdict
11.2.1	Every installation or system which includes Generating Plant operating in parallel with the Distribution System must include a means of isolation capable of disconnecting the whole of the Generating Plant8 infeed to the Distribution System. This equipment will normally be owned by the Generator, but may by agreement be owned by the DNO		P
11.2.2	The Generator must grant the DNO rights of access to the means of isolation In accordance with DPC7.2 of the Distribution Code		N/A
11.2.3	To ensure that DNO staff and that of the User and their contractors are aware of the presence of Generating Plant, appropriate warning labels should be used		N/A
11.2.4	Where the installation is connected to the Low Voltage Distribution System the Generator should generally provide labelling at the Point of Supply (Fused Cut-Out), meter position, consumer unit and at all points of isolation within the customer's premises to indicate the presence of Generating Plant		N/A
	The labelling should be sufficiently robust and if necessary fixed in place to ensure that it remains legible and secure for the lifetime of the installation. The Health and Safety (Safety Signs & Signals) Regulations 1996 stipulates that labels should display the prescribed triangular shape, and size, using black on yellow colouring. A typical label, for both size and content, is shown below in figure 11.1		N/A
11.2.5	Where the installation is connected to the DNO HV Distribution System the Generator should give consideration to the labelling requirements. In some installations e.g. a complex CHP installation, extensive labelling may be required, but in others e.g. a wind farm connection, it is likely to be clear that Generating Units are installed on site and labelling may not be required. Any labels should comply with The Health and Safety (Safety Signs & Signals) Regulations 1996 which stipulates that labels should display the prescribed triangular shape, and size, using black on yellow colouring		N/A
11.3	Site Responsibility Schedule		N/A
11.4	Operational and Safety Aspects		N/A
11.5	Synchronizing and Operational Control		P
11.5.1	Before connecting two energised electrical systems, for example a Distribution System and Generating Plant, it is necessary to synchronise them by minimising their voltage, frequency and phase differences		P
11.5.2	Operational switching, for example synchronising, needs to take account of Step Voltage Changes as detailed in Section 9.5		N/A
11.5.3	Automatic synchronising equipment will be the norm which, by control of the Generating Unit's field system (Automatic Voltage Regulator) and governor, brings the incoming unit within the acceptable operating conditions of voltage and speed (frequency), and closes the synchronising circuit breaker		P

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Clause	Requirement - Test	Result - Remark	Verdict
11.5.4	The facility to use the DNOs circuit breaker manually for synchronizing can only be used with the specific agreement of the DNO		N/A
11.5.6	The synchronising voltage supply may, with DNO agreement, be provided from a DNO owned voltage transformer. Where so provided, the voltage supplies should be separately fused at the voltage transformer		N/A
11.5.7	Where the Generator's system comprises ring connections with normal open points, it may not be economic to provide synchronising at all such locations. In such cases mechanical key interlocking may be applied to prevent closure unless one side of the ring is electrically dead. A circuit breaker or breakers will still, however, require synchronising facilities to achieve paralleling between the Generator and the DNO supply		N/A
11.5.8	The conditions to be met in order to allow automatic reconnection when the DNO supply is restored are defined in Section 10. Where a Generator requires his Generating Plant to continue to supply a temporarily disconnected section of the Distribution System in island mode, the special arrangements necessary will need to be discussed with the DNO		N/A
12	TESTING AND COMMISSIONING		N/A
12.1	General		N/A
12.2	Procedures and Witnessing Requirements		N/A
12.3	Commissioning Tests / Checks required at all Power Stations		N/A
12.4	Additional Commissioning requirements for Non Type Tested Generating Units		N/A
12.5	Periodic Testing		N/A
12.6	Changes at the Installation		N/A
13	APPENDICES		P
13.1	Generating Plant Type Verification Test Sheet Type Approved Generating Plant (>16A per phase but ≤ 50 kW 3 phase or 17 kW 1 phase)		P
13.2	Generating Plant Installation and Commissioning Tests (1)Type approved generating plant (>16A per phase but < 50 kW 3 phase or 17 kW 1 phase)		N/A
13.3	Generating Plant Installation and Commissioning Tests (2) Non type approved generating plant and generating plant >50kW 3 phase or 17kW 1 phase.		N/A
13.4	Generating Plant Decommissioning Confirmation		N/A
13.5	Application for connection of Type Tested Generating Units with total aggregate Power Station capacity <50kW 3 phase or 17kW single phase.		N/A
13.6	Additional Information Relating to System Stability Studies		N/A
13.7	Loss of Mains (LoM) Protection Analysis		N/A
13.8	Type Testing of Generation Units of 50kW three phase, or 17kW per phase or less. Guidance for Manufacturers.		P

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Clause	Requirement - Test	Result - Remark	Verdict
13.8.1	General Arrangements		P
	This annex describes a methodology for obtaining type certification or type test for the interface equipment between a non ER G83/1-1 compliant, or >16A per phase but ≤ 50kW 3 phase (or 17kW 1 phase) Generating Unit and the Distribution System		P
	Typically, all interface functions are contained within the separate protection and control systems of the Generating Unit and in such cases it is only necessary to type test these. Alternatively, a package of specific separate parts of equivalent function may also be type tested.		P
13.8.2	CE Marking and Certification		P
	The type verification procedure requires that the Generating Unit interface be certified to the relevant requirements of the applicable Directives before the Generating Unit can be labelled with a CE mark		P
	Where the protection control is to be provided as a separate device, this must also be type tested and certified to the relevant requirements of the applicable Directives before it can be labeled with a CE mark.		N/A
	The Generating Unit's Interface Protection shall satisfy the requirements of all of the following standards. Where these standards have more than one part, the requirements of all such parts shall be satisfied, so far as they are applicable		P
	BS EN 61000 (Electromagnetic Standards)		P
	BS EN 60255 (Electrical Relays)		N/A
	BS EN 61810 (Electrical Elementary Relays)		P
	BS EN 60947 (Low Voltage Switchgear and Control gear)		N/A
	BS EN 60044 (Instrument Transformers)		N/A
	Currently there are no harmonised functional standards that apply to the Generating Unit's Interface Protection. Consequently, in cases where power electronics is used for energy conversion along with any separate Interface Protection unit both will require functional type verification as described in this Annex, and recorded in format similar to that shown in Appendix A13.1.		N/A
	Where the Interface Protection is physically integrated within the overall Generating Unit control system, the functionality of the Interface Protection unit should not be compromised by any failure of other elements of the control system (fail safe)		P
13.8.3	Type Verification Functional Testing of the Interface Protection		P
13.8.3.1	Disconnection times		P
13.8.3.2	Over / Under Voltage		P
13.8.3.3	Over / Under Frequency		P
13.8.3.4	Loss of Mains (LoM) Protection		P
13.8.3.5	Re-connection		P

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Clause	Requirement - Test	Result - Remark	Verdict
13.8.4	Power Quality		P
13.8.4.1	Harmonics		P
13.8.4.2	Power Factor		P
13.8.4.3	Voltage Flicker		P
13.8.4.4	DC Injection		P
13.8.4.5	Over Current Protection		N/A
13.8.4.6	Short Circuit Current Contribution		P
13.8.4.7	Self Monitoring - Solid State Disconnection		N/A
13.8.4.8	Electromagnetic Compatibility (EMC)		P
13.8.4.9	Generating Unit Electrical Installation		N/A
13.8.5	Separate Specific Technology Requirements		P
13.9	Main Statutory and other Obligations		N/A
13.10	Example calculations to determine if unequal generation across different phases is acceptable or not.		N/A

Appendices:
13.1

Power Quality. Harmonics. These tests should be carried out as specified in 61000-3-12 or 61000-3-2. Only one set of tests is required and the **Manufacturer** should decide which one to use and complete the relevant table. The chosen test should be undertaken with a fixed source of energy at two power levels a) between 45 and 55% and b) at 100% of maximum export capacity.

The test should be carried out on a single **Generating Unit.** The results need to comply with the limits of table 2 of BS EN 61000-3-12 for single phase equipment, to table 3 of BS EN 61000-3-12 for three phase equipment or to table 1 of BS EN 61000-3-2 if that standard is used.

Note that Generating Units meeting the requirements of BS EN 61000-3-2 will need no further assesment with regards to harmonics. Generating Units with emissions close to the limits laid down in BS EN 61000-3-12 may require the installation of a transformer between 2 and 4 times the rating of the **Generating Unit** in order to accept the connection to a **DNO**'s network.

Generating Unit tested to BS EN 61000-3-2						
SSEG rating per phase R (rpp)			6.7kW		NV=MV*3.68/rpp	
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value (MV) (A)	Normalised Value (NV) (A)	Measured Value (MV) (A)	Normalised Value (NV) (A)	Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.0227	0.0125	0.0613	0.0338	1.080	
3	0.0137	0.0075	0.0203	0.0112	2.300	
4	0.0140	0.0077	0.0125	0.0069	0.430	
5	0.1908	0.1048	0.2188	0.1205	1.140	
6	0.0048	0.0026	0.0048	0.0026	0.300	
7	0.1015	0.0557	0.1318	0.0726	0.770	
8	0.0067	0.0037	0.0384	0.0211	0.230	
9	0.0199	0.0109	0.0133	0.0073	0.400	
10	0.0068	0.0038	0.0378	0.0208	0.184	
11	0.0391	0.0215	0.0328	0.0181	0.330	
12	0.0035	0.0019	0.0050	0.0027	0.153	
13	0.0333	0.0183	0.0632	0.0348	0.210	
14	0.0060	0.0033	0.0026	0.0014	0.131	
15	0.0044	0.0024	0.0081	0.0044	0.150	
16	0.0054	0.0030	0.0230	0.0127	0.115	
17	0.0114	0.0063	0.0251	0.0138	0.132	
18	0.0026	0.0014	0.0037	0.0020	0.102	
19	0.0071	0.0039	0.0627	0.0346	0.118	
20	0.0042	0.0023	0.0229	0.0126	0.092	
21	0.0070	0.0039	0.0094	0.0052	0.107	0.160
22	0.0039	0.0022	0.0117	0.0064	0.084	
23	0.0099	0.0055	0.0268	0.0148	0.098	0.147
24	0.0026	0.0014	0.0082	0.0045	0.077	
25	0.0126	0.0069	0.0370	0.0204	0.090	0.135
26	0.0018	0.0010	0.0133	0.0073	0.071	
27	0.0031	0.0017	0.0088	0.0049	0.083	0.124
28	0.0018	0.0010	0.0124	0.0068	0.066	
29	0.0141	0.0078	0.0326	0.0179	0.078	0.117
30	0.0016	0.0009	0.0044	0.0024	0.061	
31	0.0151	0.0083	0.0126	0.0069	0.073	0.109
32	0.0013	0.0007	0.0076	0.0042	0.058	
33	0.0030	0.0017	0.0036	0.0020	0.068	0.102
34	0.0015	0.0009	0.0042	0.0023	0.054	
35	0.0125	0.0069	0.0153	0.0084	0.064	0.096
36	0.0017	0.0009	0.0056	0.0031	0.051	
37	0.0112	0.0062	0.0068	0.0037	0.061	0.091

38	0.0014	0.0008	0.0068	0.0037	0.048	
39	0.0025	0.0013	0.0032	0.0018	0.058	0.087
40	0.0016	0.0009	0.0092	0.0051	0.046	
Generating Unit tested to BS EN 61000-3-2						
SSEG rating per phase S (rpp)			6.7kW		NV=MV*3.68/rpp	
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value (MV) (A)	Normalised Value (NV) (A)	Measured Value (MV) (A)	Normalised Value (NV) (A)	Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.0233	0.0128	0.0513	0.0282	1.080	
3	0.0285	0.0156	0.0178	0.0098	2.300	
4	0.0173	0.0095	0.0150	0.0082	0.430	
5	0.2056	0.1129	0.1991	0.1094	1.140	
6	0.0026	0.0015	0.0014	0.0007	0.300	
7	0.0917	0.0504	0.1265	0.0695	0.770	
8	0.0025	0.0014	0.0350	0.0192	0.230	
9	0.0085	0.0046	0.0140	0.0077	0.400	
10	0.0050	0.0028	0.0323	0.0177	0.184	
11	0.0483	0.0266	0.0452	0.0248	0.330	
12	0.0015	0.0008	0.0028	0.0015	0.153	
13	0.0263	0.0144	0.0615	0.0338	0.210	
14	0.0033	0.0018	0.0076	0.0042	0.131	
15	0.0061	0.0033	0.0071	0.0039	0.150	
16	0.0046	0.0025	0.0211	0.0116	0.115	
17	0.0153	0.0084	0.0331	0.0182	0.132	
18	0.0019	0.0010	0.0041	0.0023	0.102	
19	0.0038	0.0021	0.0609	0.0334	0.118	
20	0.0026	0.0014	0.0193	0.0106	0.092	
21	0.0063	0.0034	0.0043	0.0023	0.107	0.160
22	0.0031	0.0017	0.0058	0.0032	0.084	
23	0.0109	0.0060	0.0301	0.0165	0.098	0.147
24	0.0019	0.0010	0.0034	0.0019	0.077	
25	0.0121	0.0066	0.0352	0.0194	0.090	0.135
26	0.0028	0.0016	0.0154	0.0085	0.071	
27	0.0024	0.0013	0.0048	0.0026	0.083	0.124
28	0.0015	0.0008	0.0110	0.0061	0.066	
29	0.0146	0.0080	0.0355	0.0195	0.078	0.117
30	0.0017	0.0010	0.0032	0.0018	0.061	
31	0.0138	0.0076	0.0173	0.0095	0.073	0.109
32	0.0011	0.0006	0.0084	0.0046	0.058	
33	0.0045	0.0025	0.0029	0.0016	0.068	0.102
34	0.0012	0.0006	0.0034	0.0019	0.054	
35	0.0130	0.0072	0.0247	0.0136	0.064	0.096
36	0.0016	0.0009	0.0025	0.0014	0.051	
37	0.0099	0.0054	0.0144	0.0079	0.061	0.091
38	0.0008	0.0004	0.0072	0.0040	0.048	
39	0.0017	0.0009	0.0041	0.0023	0.058	0.087
40	0.0009	0.0005	0.0076	0.0042	0.046	
Generating Unit tested to BS EN 61000-3-2						
SSEG rating per phase T (rpp)			6.7kW		NV=MV*3.68/rpp	
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value (MV) (A)	Normalised Value (NV) (A)	Measured Value (MV) (A)	Normalised Value (NV) (A)	Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2	0.0229	0.0126	0.0549	0.0301	1.080	
3	0.0352	0.0193	0.0309	0.0170	2.300	
4	0.0162	0.0089	0.0186	0.0102	0.430	
5	0.2147	0.1179	0.2286	0.1256	1.140	

6	0.0035	0.0019	0.0058	0.0032	0.300	
7	0.1150	0.0632	0.1414	0.0777	0.770	
8	0.0062	0.0034	0.0383	0.0211	0.230	
9	0.0224	0.0123	0.0257	0.0141	0.400	
10	0.0037	0.0020	0.0341	0.0188	0.184	
11	0.0421	0.0231	0.0523	0.0287	0.330	
12	0.0026	0.0014	0.0031	0.0017	0.153	
13	0.0317	0.0174	0.0616	0.0338	0.210	
14	0.0040	0.0022	0.0070	0.0038	0.131	
15	0.0095	0.0052	0.0112	0.0062	0.150	
16	0.0034	0.0019	0.0243	0.0133	0.115	
17	0.0091	0.0050	0.0355	0.0195	0.132	
18	0.0021	0.0011	0.0035	0.0019	0.102	
19	0.0067	0.0037	0.0653	0.0359	0.118	
20	0.0040	0.0022	0.0149	0.0082	0.092	
21	0.0054	0.0030	0.0126	0.0069	0.107	0.160
22	0.0025	0.0014	0.0050	0.0027	0.084	
23	0.0123	0.0067	0.0342	0.0188	0.098	0.147
24	0.0023	0.0012	0.0094	0.0051	0.077	
25	0.0150	0.0082	0.0432	0.0237	0.090	0.135
26	0.0037	0.0021	0.0131	0.0072	0.071	
27	0.0034	0.0019	0.0068	0.0037	0.083	0.124
28	0.0012	0.0007	0.0137	0.0075	0.066	
29	0.0154	0.0085	0.0341	0.0188	0.078	0.117
30	0.0015	0.0008	0.0020	0.0011	0.061	
31	0.0165	0.0091	0.0194	0.0107	0.073	0.109
32	0.0014	0.0008	0.0056	0.0031	0.058	
33	0.0047	0.0026	0.0026	0.0014	0.068	0.102
34	0.0018	0.0010	0.0022	0.0012	0.054	
35	0.0133	0.0073	0.0208	0.0114	0.064	0.096
36	0.0011	0.0006	0.0040	0.0022	0.051	
37	0.0115	0.0063	0.0141	0.0078	0.061	0.091
38	0.0013	0.0007	0.0080	0.0044	0.048	
39	0.0027	0.0015	0.0005	0.0003	0.058	0.087
40	0.0012	0.0006	0.0084	0.0046	0.046	

Power Quality. Voltage fluctuations and Flicker. The tests should be carried out on a single **Generating Unit.** Results should be normalised to a standard source impedance or if this results in figures above the limits set in BS EN 61000-3-11 to a suitable Maximum Impedance.

	Starting			Stopping			Running	
	d max	d c	d(t)	d max	d c	d(t)	P st	P lt 2 hours
Measured Values at test impedance(%)	1.30	1.18	--	1.30	1.18	--	0.068	0.196
Normalised to standard impedance (%)	1.30	1.18	--	1.30	1.18	--	0.068	0.196
Normalised to required maximum impedance	--	--	--	--	--	--	--	--
Limits set under BS EN 61000-3-11	4%	3.3%	3.3%	4%	3.3%	3.3%	1.0	0.65

Test Impedance	R		Ω	Xl		Ω
Standard Impedance	R	0.24 * 0.4 ^	Ω	Xl	0.15 * 0.25 ^	Ω

Maximum Impedance	R		Ω	Xl		Ω

* Applies to three phase and split single phase **Generating Unit**s
^ Applies to single phase **Generating Unit**s and **Generating Unit**s using two phases on a three phase system
For voltage change and flicker measurements the following formula is to be used to convert the measured values to the normalised values where the power factor of the generation output is 0.98 or above.
Normalised value = Measured value*reference source resistance/measured source resistance at test point
Single phase units reference source resistance is 0.4 Ω
Two phase units in a three phase system reference source resistance is 0.4 Ω
Two phase units in a split phase system reference source resistance is 0.24 Ω
Three phase units reference source resistance is 0.24 Ω
Where the power factor of the output is under 0.98 then the Xl to R ratio of the test impedance should be close to that of the Standard Impedance.
The stopping test should be a trip from full load operation.
The duration of these tests need to comply with the particular requirements set out in the testing notes for the technology under test.

Power quality. DC injection. The tests should be carried out on a single **Generating Unit** Tests are to be carried out three power defined levels ±5%. At 230V a 2kW single phase inverter has a current output of 8.7A so DC limit is 21.75mA, a 10kW three phase inverter has a current output of 43.5A at 230V so DC limit is 108.75mA

Test power level	10%	55%	100%	
Recorded value in Amps (Phase R)	0.0132	0.0093	0.0093	
as % of rated AC current	0.046%	0.032%	0.032%	
Recorded value in Amps (Phase S)	0.0035	0.0096	0.0106	
as % of rated AC current	0.012%	0.033%	0.037%	
Recorded value in Amps (Phase T)	0.0076	0.0168	0.0179	
as % of rated AC current	0.026%	0.058%	0.062%	
Limit	0.25%	0.25%	0.25%	

Power Quality. Power factor. The tests should be carried out on a single Generating Unit. Testa are to be carried out at three voltage levels and at full output. Voltage to be maintained within + or – 1.5% of the stated level during the test.

	216.2V	230V	253V	Measured at three voltage levels and at full output. Voltage to be maintained within + or – 1.5% of the stated level during the test.
Measured value	0.9998	0.9998	0.9999	
Limit	>0.95	>0.95	>0.95	

Protection. Frequency tests						
Function	Setting		Trip test		"No-trip tests"	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
O/F stage 1	51.5Hz	90s	51.51Hz	90.20s	51.3Hz 95s	No trip
O/F stage 2	52Hz	0.5s	52.10Hz	0.56s	51.8Hz 89.98s	No trip
					52.2Hz 0.48s	No trip
U/F stage 1	47.5Hz	20s	47.49Hz	20.10s	47.7Hz 25s	No trip
U/F stage 2	47Hz	0.5s	46.95Hz	0.52s	47.2Hz 19.98s	No trip
					46.8 Hz 0.48s	No trip
Note. For frequency Trip tests the Frequency required to trip is the setting ± 0.1Hz. In order to measure the time delay a larger deviation than the minimum required to operate the projection can be used.. The "No-trip tests" need to be carried out at the setting ± 0.2Hz and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						

Protection. Voltage tests						
Function	Setting		Trip test		"No trip-tests" All phases at same voltage	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
O/V stage 1	262.2V	1.0s	261.5V	1.015s	258.2V 2.0 sec	No trip
O/V stage 2	273.7V	0.5s	274.0V	0.528s	269.7V 0.98s	No trip
					277.7V 0.48s	No trip
U/V stage 1	200.1V	2.5s	199.9V	2.510s	204.1V 3.5s	No trip
U/V stage 2	184V	0.5s	183.5V	0.522s	188V 2.48s	No trip
					180v 0.48 sec	No trip
Note. For voltage tests the voltage required to trip is the setting plus or minus 3.45V. The time delay can be measured at a larger deviation than the minimum required to operate the projection. The No-trip tests need to be carried out at the setting ±4V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						
Remark: for three phases R, S,T						

Protection. Voltage tests						
Function	Setting		Trip test		"No trip-tests" All phases at same voltage	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
O/V stage 1	262.2V	1.0s	262.0V	1.020s	258.2V 2.0s	No trip
O/V stage 2	273.7V	0.5s	273.3V	0.530s	269.7V 0.98s	No trip
					277.7V 0.48s	No trip
U/V stage 1	200.1V	2.5s	199.6V	2.540s	204.1V 3.5s	No trip
U/V stage 2	184V	0.5s	183.8V	0.528s	188V 2.48s	No trip
					180v 0.48s	No trip
Note. For voltage tests the voltage required to trip is the setting plus or minus 3.45V. The time delay can be measured at a larger deviation than the minimum required to operate the projection. The No-trip tests need						

to be carried out at the setting ±4V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.
Remark: for phase R

Protection. Voltage tests						
Function	Setting		Trip test		"No trip-tests" All phases at same voltage	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
O/V stage 1	262.2V	1.0s	262.1V	1.020s	258.2V 2.0s	No trip
O/V stage 2	273.7V	0.5s	273.2V	0.524s	269.7V 0.98s	No trip
					277.7V 0.48s	No trip
U/V stage 1	200.1V	2.5s	199.5V	2.530s	204.1V 3.5s	No trip
U/V stage 2	184V	0.5s	183.8V	0.528s	188V 2.48s	No trip
					180v 0.48s	No trip
Note. For voltage tests the voltage required to trip is the setting plus or minus 3.45V. The time delay can be measured at a larger deviation than the minimum required to operate the projection. The No-trip tests need to be carried out at the setting ±4V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						
Remark: for Phase S						

Protection. Voltage tests						
Function	Setting		Trip test		"No trip-tests" All phases at same voltage	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
O/V stage 1	262.2V	1.0s	262.1V	1.014s	258.2V 2.0s	No trip
O/V stage 2	273.7V	0.5s	273.3V	0.526s	269.7V 0.98s	No trip
					277.7V 0.48s	No trip
U/V stage 1	200.1V	2.5s	199.6V	2.530s	204.1V 3.5s	No trip
U/V stage 2	184V	0.5s	183.7V	0.509s	188V 2.48s	No trip
					180v 0.48s	No trip
Note. For voltage tests the voltage required to trip is the setting plus or minus 3.45V. The time delay can be measured at a larger deviation than the minimum required to operate the projection. The No-trip tests need to be carried out at the setting ±4V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.						
Remark: for Phase T						

Protection. Loss of Mains test and single phase test. The tests are to be To be carried out at three output power levels plus or minus 5%, an alternative for inverter connected Generating Units can be used instead.

To be carried out at three output power levels plus or minus 5%, an alternative for inverter connected Generating Units can be used instead.

Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded network	95% of Generating Unit output	95% of Generating Unit output	95% of Generating Unit output	105% of Generating Unit output	105% of Generating Unit output	105% of Generating Unit output
Trip time. Limit is 0.5s	---	---	---	---	---	---

Note. For technologies which have a substantial shut down time this can be added to the 0.5s in establishing that the trip occurred in less than 0.5s maximum. Shut down time could therefore be up to 1.0s for these technologies.

Indicate additional shut down time included in above results	s

Note as an alternative, inverters can be tested to BS EN 62116. The following sub set of tests should be recorded in the following table.

Test Power and imbalance	33% -5% Q Test 22	66% -5% Q Test 12	100% -5% P Test 5	33% +5% Q Test 31	66% +5% Q Test 21	100% +5% P Test 10
Trip time. Limit is 0.5s	108ms	190ms	137ms	104ms	273ms	154ms

Single phase test for multi phase Generating Units. Confirm that when generating in parallel with a network operating at around 50Hz with no network disturbance, that the removal of a single phase connection to the Generating Unit, with the remaining phases connected causes a disconnection of the generating unit within a maximum of 1s.

	Ph1 removed	Confirm Trip	Ph2 removed	Confirm Trip	Ph3 removed	Confirm Trip

Detail test results see result of Protection. Loss of Mains test.-BS EN 62116

Protection. Frequency change, Stability test				
	Start Frequency	Change	End Frequency	Confirm no trip
Positive Vector Shift	49.5Hz	+9 degrees		No trip
Negative Vector Shift	50.5Hz	- 9 degrees		No trip
Positive Frequency drift	49.5Hz	+0.19Hz	51.5Hz	No trip
Negative Frequency drift	50.5Hz	-0.19Hz	47.5Hz	No trip

Protection. Re-connection timer. The tests should prove that the reconnection sequence starts in no less than 20s for restoration of voltage and frequency to within the stage 1 settings of table 10.5.7.1					
Test should prove that the reconnection sequence starts in no less than 20s for restoration of voltage and frequency to within the stage 1 settings of table 10.5.7.1					
Time delay setting (s)	Measured delay (s)	Checks on no reconnection when voltage or frequency is brought to just outside stage 1 limits of table 10.5.7.1.			
20	33.35	At 266.2V	At 196.1V	At 47.4Hz	At 51.6Hz
Confirmation that the **Generating Unit** does not re-connect		Not re-connect	Not re-connect	Not re-connect	Not re-connect

Fault level contribution.					
For machines with electro-magnetic output			For Inverter output		
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	i_p	---	20ms	31.5V	R: 42.5Apeak S: 43.5Apeak T: 42.0Apeak
Initial Value of aperiodic current	A	---	100ms	30.9V	R: 43.0Apeak S: 43.0Apeak T: 42.5Apeak
Initial symmetrical short-circuit current*	I_k	---	250ms	23.0V	R: 43.5Apeak S: 42.5Apeak T: 43.0Apeak
Decaying (aperiodic) component of short circuit current*	i_{DC}	---	500ms	23.0V	R: 0 S: 0 T: 0
Reactance/Resistance Ratio of source*	$^X/_R$	---	Time to trip	0.28	In seconds
For rotating machines and linear piston machines the test should produce a 0s – 2s plot of the short circuit current as seen at the **Generating Unit** terminals. * Values for these parameters should be provided where the short circuit duration is sufficiently long to enable interpolation of the plot					

Self Monitoring solid state switching	N/A
It has been verified that in the event of the solid state switching device failing to disconnect the **Generating Unit**, the voltage on the output side of the switching device is reduced to a value below 50 Volts within 0.5 seconds	N/A

Protection. Loss of Mains test.-BS EN 62116

Table 9 – List of tested condition and run on time

No.	PEUT[1] (% of EUT rating)	Reactive load (% of QL in 6.1.d)1)	PAC[2] (% of nominal)	QAC[3] (% of nominal)	Run on time (ms)	PEUT (W)	Actual Qf	VDC	Remarks[4]
1	100	100	0	0	306	20000	1.00	800	Test A at BL
2	66	66	0	0	272	13200	1.00	600	Test B at BL
3	33	33	0	0	436	6600	1.00	300	Test C at BL
4	100	100	-5	-5	128	20000	1.00	800	Test A at IB
5	100	100	-5	0	137	20000	1.05	800	Test A at IB
6	100	100	-5	5	145	20000	1.10	800	Test A at IB
7	100	100	0	-5	171	20000	0.95	800	Test A at IB
8	100	100	0	5	136	20000	1.05	800	Test A at IB
9	100	100	5	-5	144	20000	0.90	800	Test A at IB
10	100	100	5	0	154	20000	0.95	800	Test A at IB
11	100	100	5	5	148	20000	1.00	800	Test A at IB
12	66	66	0	-5	190	13200	0.95	600	Test B at IB
13	66	66	0	-4	194	13200	0.96	600	Test B at IB
14	66	66	0	-3	205	13200	0.97	600	Test B at IB
15	66	66	0	-2	189	13200	0.98	600	Test B at IB
16	66	66	0	-1	192	13200	0.99	600	Test B at IB
17	66	66	0	1	285	13200	1.01	600	Test B at IB
18	66	66	0	2	286	13200	1.02	600	Test B at IB
19	66	66	0	3	284	13200	1.03	600	Test B at IB
20	66	66	0	4	282	13200	1.04	600	Test B at IB
21	66	66	0	5	273	13200	1.05	600	Test B at IB
22	33	33	0	-5	108	6600	0.95	300	Test C at IB
23	33	33	0	-4	120	6600	0.96	300	Test C at IB
24	33	33	0	-3	110	6600	0.97	300	Test C at IB
25	33	33	0	-2	99	6600	0.98	300	Test C at IB
26	33	33	0	-1	230	6600	0.99	300	Test C at IB
27	33	33	0	1	144	6600	1.01	300	Test C at IB
28	33	33	0	2	115	6600	1.02	300	Test C at IB
29	33	33	0	3	122	6600	1.03	300	Test C at IB
30	33	33	0	4	114	6600	1.04	300	Test C at IB
31	33	33	0	5	104	6600	1.05	300	Test C at IB

Remark:

1) PEUT: EUT output power

2) PAC: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.

3) QAC: Reactive power flow at S1 in Figure 1. Positive means power form EUT to utility. Nominal is the 0% test condition value.

4) BL: Balance condition, IB: Imbalance condition.

Annex B Photos

Overall view of the unit

Bottom view of the unit

PV connector (Sofar 20000TL-Sx and Sofar 17000TL-Sx has 3×2 pairs)
(Sofar 15000TL-Sx and Sofar 10000TL-Sx has 2×2 pairs)

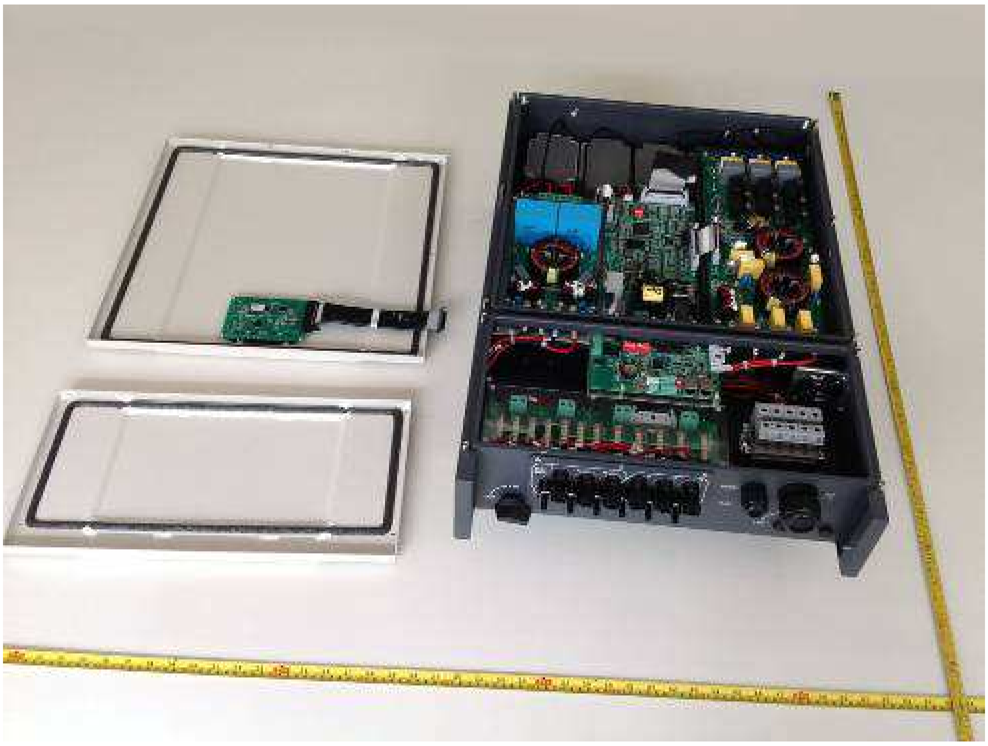
Terminals view of the unit (for models “-S2” to “-S6”)

Terminals view of the unit (without AC switch)

Terminals view of the unit for model Sofar 10000TL-Sx

DC Cable Gland

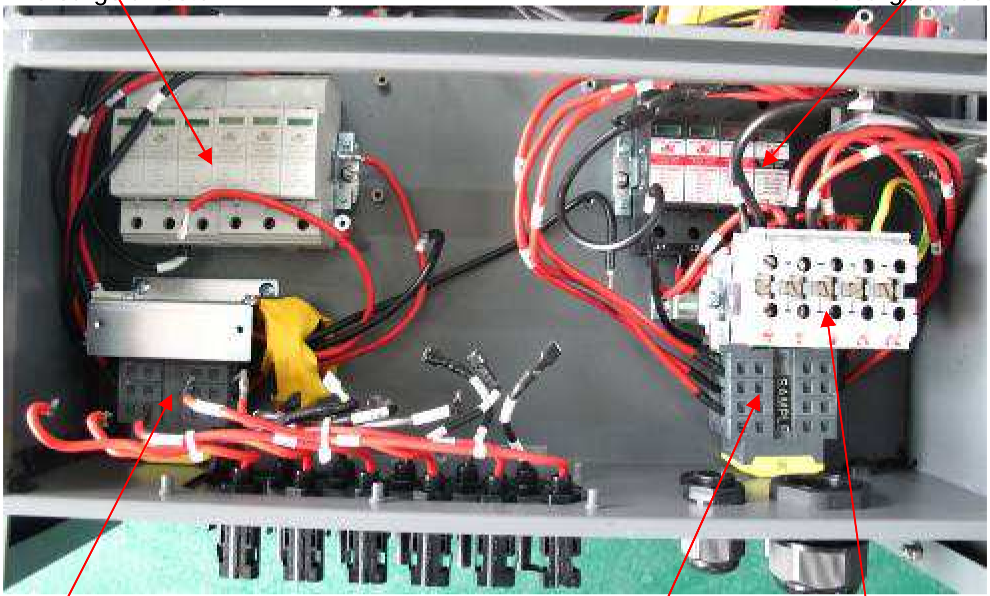
Terminals view of the unit (for models “-S0” to “-S1”)



Internal view of the unit

Internal view of the unit

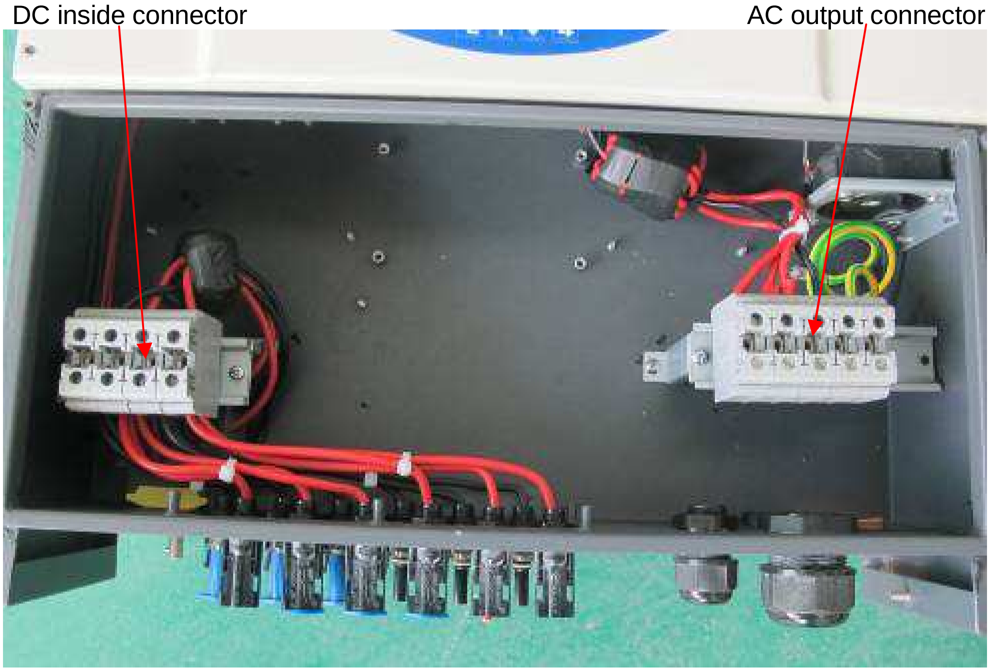
DC surge arrester AC surge arrester



DC switch AC switch, AC output connector

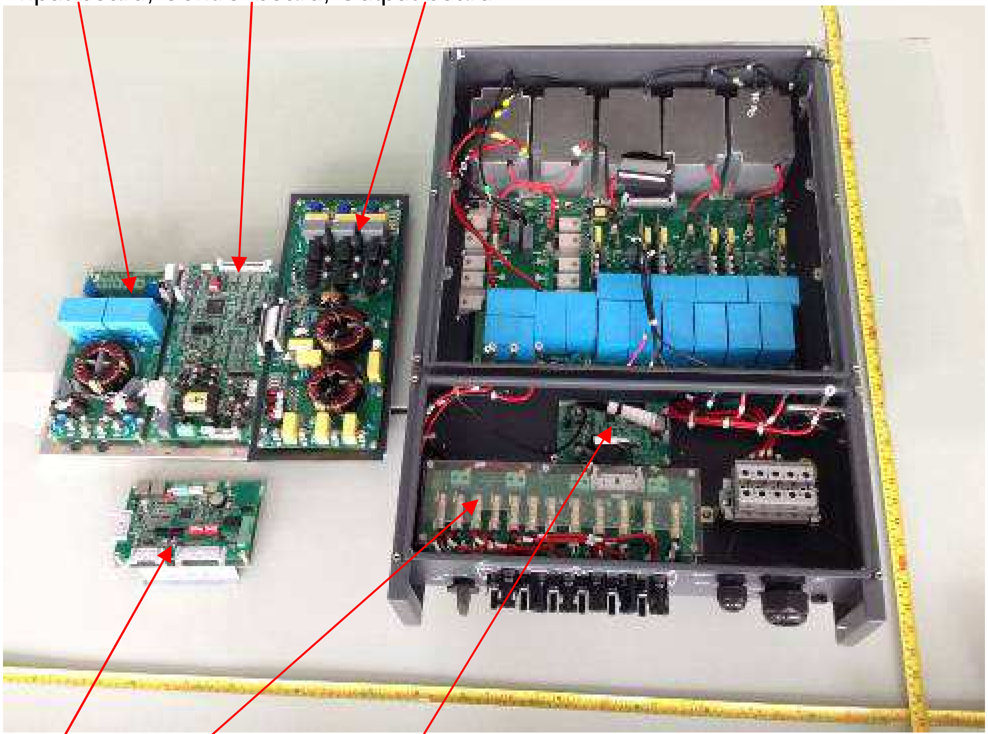
Internal view of the unit

DC inside connector AC output connector



Internal view of the unit

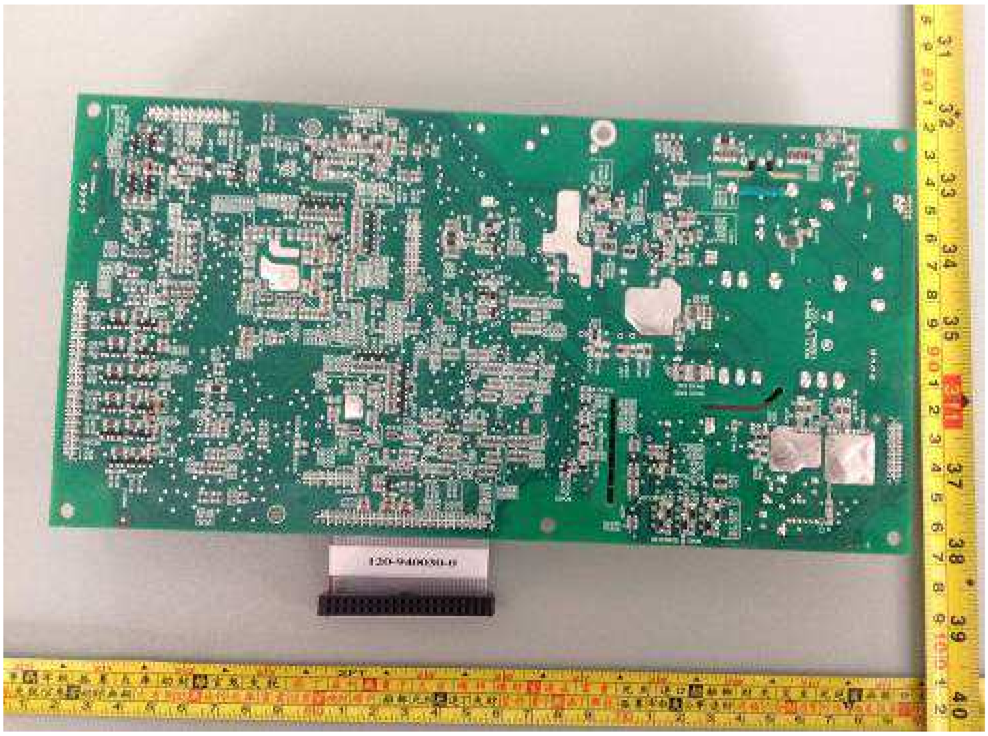
Input board, Control board, Output board



COM board, Fuse board, String detection board

Internal view of the unit

Front view of the control board



Bottom view of the control board