


<p><b>TEST REPORT</b>  <b>Engineering Recommendation G99</b>  <b>Issue 1- Amendment 4</b>  <b>June 2019</b>  <b>Requirements for the connection of generation equipment in parallel with public distribution networks</b></p>	
<p><b>Report Reference No.</b> .....</p> <p>Tested by (name + signature) .....</p> <p>Approved by (name + signature) .....</p> <p>Date of issue .....</p> <p>Contents .....</p>	<p>190114153GZU-002</p> <p>Jason Fu Senior Project Engineer</p> <p>Tommy Zhong Technical Manager</p> <p>18 April., 2019, Revision 1: 29 Aug 2019</p> <p>52 Pages</p>
<p><b>Testing Laboratory</b> .....</p> <p>Address.....</p> <p>Testing location / procedure .....</p> <p>Testing location / address.....</p>	<p>Intertek Testing Services Shenzhen Ltd. Guangzhou Branch</p> <p>Block E, No.7-2 Guang Dong Software Science Park, Caipin Road, Guangzhou Science City, GETDD, Guangzhou, China</p> <p>TL <input checked="" type="checkbox"/> SMT <input type="checkbox"/> TMP <input type="checkbox"/></p> <p>Same as above</p>
<p>Applicant's name .....</p> <p>Address.....</p>	<p>Shenzhen SOFAR SOLAR Co., Ltd.</p> <p>401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community, XinAn Street, BaoAn District, Shenzhen, China</p>
<p><b>Test specification:</b></p> <p>Standard .....</p> <p>Test procedure.....</p> <p>Non-standard test method.....</p>	
<p><b>Test Report Form/blank test report</b></p> <p>Test Report Form No.....</p> <p>TRF Originator .....</p> <p>Master TRF .....</p> <p>This publication may be reproduced in whole or in part for non-commercial purpose as long as Intertek is acknowledged as copyright owner and source of the material. Intertek takes no responsibility and will not assume liability for damages resulting from the reader's interpretation of the reproduced material due to its placement and context.</p>	

<b>Test item description</b> .....	Hybrid Inverter
Trade Mark .....	
Manufacturer .....	Same as applicant
Model/Type reference.....	HYD 4000-ES, HYD 5000-ES, HYD 6000-ES
Rating.....	<p>Max. DC Input Voltage: 600Vdc</p> <p>Operating MPPT Voltage Range: 90Vdc – 580Vdc</p> <p>Max. PV Isc: 2 X 15A</p> <p>Battery Type: Lead-acid, Lithium-ion</p> <p>Battery Voltage Range: 42-58V</p> <p>Max. Charging Current: 65A</p> <p>Max. Discharging Current: 70A</p> <p>Max. Charging &amp; Discharging Power: 3000VA</p> <p>Nominal Grid voltage: 230Vac</p> <p>Nominal Output Voltage (backup): 230Vac</p> <p>Max. output current: 18.2A (for HYD 4000-ES), 22.8A (for HYD 5000-ES), 27.3A (for HYD 6000-ES),</p> <p>Nominal Grid Frequency: 50Hz</p> <p>Power Factor: 1 (adjustable +/-0.8)</p> <p>Nominal output power: 4000VA (for HYD 4000-ES), 5000VA (for HYD 5000-ES), 6000VA (for HYD 6000-ES),</p> <p>Backup Rated current: 13.2A</p> <p>Backup Rated Apparent Power: 3000VA</p> <p>Ingress Protection: IP 65</p> <p>Protective Class: I</p> <p>Operating temperature range: -25 — +60°C</p> <p>The Software version: V1.00</p>

<p><b>Test item particulars</b>..... :</p> <p>Temperature range ..... : -20°C ~60°C</p> <p>IP protection class ..... : IP 65</p>
<p><b>Possible test case verdicts:</b></p> <p>- test case does not apply to the test object..... : N/A</p> <p>- test object does meet the requirement ..... : P(Pass)</p> <p>- test object does not meet the requirement ..... : F(Fail)</p>
<p><b>Testing</b>..... :</p> <p>Date of receipt of test item..... : 28 Aug 2019</p> <p>Date (s) of performance of tests..... : 28 Aug 2019</p>
<p><b>General remarks:</b></p> <p><b>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.</b></p> <p><b>Installer and relevant persons shall comply with G99 and relevant standard and Grid Code in G99</b></p> <p>This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.</p> <p>"(see Enclosure #)" refers to additional information appended to the report.</p> <p>"(see appended table)" refers to a table appended to the report.</p> <p>Throughout this report a point is used as the decimal separator.</p> <p>Determination of the test result includes consideration of measurement uncertainty from the test equipment and methods.</p> <p>The test results presented in this report relate only to the item tested. The results indicate that the specimen partially complies with standard"ER G99/1-4: 2019". See general product information next for details information.</p> <p><b>Revision 1:</b></p> <p><b>This report is based on and superseded original report No.190114153GZU-002, dated 18 April 2019 due to the following reason:</b></p> <p><b>1, Re-tested Limited Frequency Sensitive Mode and update the testing data.</b></p> <p><b>2, Updated the standard from G99/1-3 to G99/1-4.</b></p>

**General product information:**

The unit is a single-phase hybrid inverter, it can convert the high PV voltage and Grid voltage to low DC for charge battery, also convert PV voltage and battery voltage to AC output .

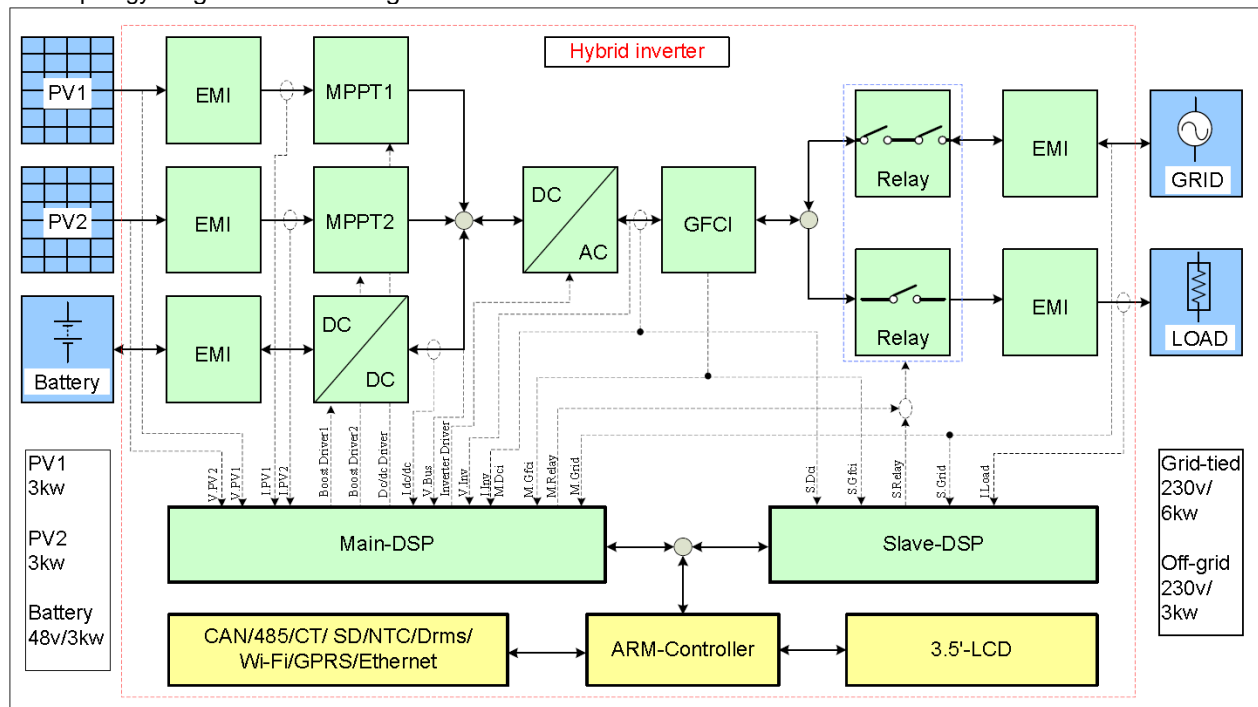
The unit is providing EMC filtering at the PV and battery side. It does provide basic insulation separation from PV side to Grid. The battery circuit does provide high frequency isolation to PV side and AC mains.

The unit has two controllers. the master DSP controller monitor the charge or discharge statue; measure the PV voltage and current, battery voltage, bus voltage, buck voltage and current, AC voltage, current, GFCI and frequency.

The slave DSP controller monitor AC voltage , current ,frequency , GFCI and communicate with the master controller

The master DSP and slave DSP are used together to control relay open or close, if the single fault on one DSP, the other one DSP can be capable to open the relay, so that still providing safety means

The topology diagram as following:



**Model differences:**

All the models have same structure, components and circuit layout, except that the quantities of bus capacitor, value of inverter chock, and also power derated by software.

**The product was tested on:**

The Software version: V1.00

The Hardware version: V1.00

Other than special notes, typical model HYD 6000-ES used as representative for testing in this report.

**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.

**Hybrid Inverter**










<b>Model No:</b>	<b>HYD 6000-ES</b>
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	27.3A
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	6000VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25-+60°C
Protective Class	Class I

Manufacturer : Shenzhen SOFAR SOLAR Co.,Ltd.  
 Address : 401, Building 4, AnTongDa Industrial Park,  
 District 68, XingDong Community,XinAn Street,  
 BaoAn District, Shenzhen, China  
 SAA183423  
 VDE0126-1-1,VDE-AR-N4105,G99,EN50438,  
 AS4777,UTE C15-712-1

**Hybrid Inverter**

<b>Model No:</b>	<b>HYD 5000-ES</b>
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	22.8A
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	5000VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25-+60°C
Protective Class	Class I

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 AS4777,UTE C15-712-1

 Hybrid Inverter	
<b>Model No:</b>	<b>HYD 4000-ES</b>
Max.DC Input Voltage	600V
Operating MPPT Voltage Range	90V~580V
MAX.PV Isc	2x15A
Battery Type	Lead-acid,Lithium-ion
Battery Voltage Range	42-58V
Max.Charging Current	65A
Max.Discharging Current	70A
Max.Charging&Discharging Power	3000VA
Nominal Grid Voltage	230Vac
Nominal Output Voltage	230Vac
Max.Output Current	18.2A
Nominal Grid Frequency	50/60Hz
Power Factor	1(adjustable+/-0.8)
Nominal Output Power	4000VA
Backup Rated Current	13.2A
Backup Rated Apparent Power	3000VA
Ingress Protection	IP65
Operating Temperature Range	-25~+60°C
Protective Class	Class I
Manufacturer : Shenzhen SOFAR SOLAR Co.,Ltd. Address : 401, Building 4, AnTongDa Industrial Park, District 68, XingDong Community,XinAn Street, BaoAn District, Shenzhen, China SAA183423 VDE0126-1-1,VDE-AR-N4105,G99,EN50438, AS4777,UTE C15-712-1	
       	

**Note:**

1. The above markings are the minimum requirements required by the safety standard. For the final production samples, the additional markings which do not give rise to misunderstanding may be added.
2. Label is attached on the side surface of enclosure and visible after installation.

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
5	LEGAL ASPECTS	Shall be complied while installation	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	The Power Generating Module shall satisfy the requirements of DPC4 of the distribution code	N/A
9	Network 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 Networks. These obligations will influence the options for connecting Power Generating Modules.		N/A
9.1.2	The technical and design criteria to be applied in the design of the Distribution Network and Power Generating Module connection are detailed in this document and DPC 4 of the Distribution Code. The criteria are based upon the performance requirements of the Distribution Network necessary to meet the above obligations.		N/A
9.1.3	The Distribution Network, and any Power Generating Module connection to that network, shall be designed		P
	a. to comply with the obligations (to include security, frequency and voltage; voltage disturbances and harmonic distortion; auto reclosing and single phase protection operation).		P
	b. according to design principles in relation to Distribution Network'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.	The Power Generating Module shall satisfy the requirements of DPC4 of the distribution code	N/A
9.1.4	Power Generating Modules 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 as applicable. The technical connection requirements in this chapter are common to all Power Generating Modules.	Only parts requirements comply with and test.	N/A

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
9.1.5	In addition requirements for Type A Power Generating Modules are detailed in Section 11. Requirements for Type B Power Generating Modules are detailed in Section 12. Requirements for Type C and Type D Power Generating Modules are detailed in Section 13.	Type A	P
9.2	Network Connection Design for Power Generating Modules	NA on generating inverter	N/A
9.3	Step Voltage Change and Rapid Voltage Change		P
9.3.1	The Step Voltage Change and Rapid Voltage Change caused by the connection and disconnection of Power Generating Modules from the Distribution Network must be considered and be subject to limits to avoid unacceptable voltage changes being experienced by other Customers connected to the Distribution Network. The magnitude of a Step Voltage Change depends on the method of voltage control, types of load connected and the presence of local generation.	NA on generating inverter	N/A
9.3.2	Limits for Step Voltage Change and Rapid Voltage Change caused by the connection and disconnection of any Customers equipment to the Distribution Network should be within the limits set out in EREC P28.		N/A
9.3.3	The voltage depression arising from transformer magnetising inrush current is a short-time phenomenon captured by considerations of Rapid Voltage Change. In addition the size of the depression is dependent on the point on wave of switching and the duration of the depression is relatively short in that the voltage recovers substantially in less than 1 s.		N/A
9.3.4	Generator Installations shall be designed taking account of the advice in EREC P28 in respect of transformer energisation assessment such that transformer magnetising inrush current associated with normal routine switching operations does not cause voltage fluctuations outside those in EREC P28. To achieve this it may be necessary to install switchgear so that sites containing multiple transformers can be energised in stages.		N/A
9.3.5	These threshold limits shall be complied with at the Point of Common Coupling as required by EREC P28.		N/A
9.4	Power Quality		P
9.4.1	Introduction		--
9.4.1.1	The connection and operation of Power Generating Modules may cause Phase (Voltage) Unbalance and/or a distortion of the Distribution Network voltage waveform resulting in voltage fluctuations and harmonics.		--
9.4.2	Flicker		P
9.4.2.1	Where the input motive power of the Power Generating Module may vary rapidly, causing corresponding changes in the output power, flicker may result. The operation of a Power Generating Module including synchronisation, run-up and desynchronisation shall not result in flicker that breaches the limits for flicker that is non-compliant with EREC P28.	Only consider the single generating inverter	P



ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
9.4.2.2	The supply impedance of the Distribution Network needs to be considered to ensure that the emissions produced by the Power Generating Module do not cause a problem on the Distribution Network.		P
9.4.2.3	For Power Generating Modules up to 17 kW per phase or 50 kW three phase voltage step change and flicker measurements as required by BS EN 61000-3-11 shall be made and recorded in the test declaration form A2-1 or form A2-3 as applicable for the Power Generating Module. The DNO will use these declared figures to calculate the required maximum supply impedance required for the connection to comply with EREC P28. This calculation may show that the voltage fluctuations will be greater than those permitted and hence reinforcement of the Distribution Network may be required before the Power Generating Module can be connected. Detailed testing requirements are described in Annex A.7.		P
9.4.3	Harmonic Emissions		P
9.4.3.1	Harmonic currents produced within the Generator's system and modification of the harmonic impedance caused by the addition of the Generator's installation may cause excessive harmonic voltage distortion in the Distribution Network. The Generator's Installation must be designed and operated to comply with the planning criteria for harmonic voltage distortion as specified in EREC G5. EREC G5, like all planning standards referenced in this recommendation, is applicable at the time of connection of additional equipment to a Generator's Installation.		P
9.4.3.2	For Power Generating Modules of up to 17 kW per phase or 50 kW three phase harmonic measurements as required by BS EN 61000-3-12 shall be made and recorded in the test declaration form A2-1 or form A2-3 as applicable for the Power Generating Module. The DNO will use these declared figures to calculate the required maximum supply impedance required for the connection to comply with BS EN 61000-3-12 and will use this data in their design of the connection for the Power Generating Module. This standard requires a minimum ratio between source fault level and the size of the Power Generating Module, and connections in some cases may require the installation of a transformer between 2 and 4 times the rating of the Power Generating Module in order to accept the connection to a DNO's Distribution Network. Detailed testing requirements are described in Annex A.7	Comply with BS EN 61000-3-12	P
9.4.3.3	Where the Power Generating Module is connected via a long cable circuit the likelihood of a resonant condition is greatly increased, especially at 132 kV. 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 Power Generating Module then a full harmonic study should be carried out.		N/A

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
9.4.4	Voltage imbalance	Single phase inverter	N/A
9.4.4.1	<p>EREC P29 is a planning standard which provides limits for voltage unbalance caused by uneven loading of three phase supply systems. Power Generating Modules should be capable of performing satisfactorily under the conditions it defines. The existing voltage unbalance on an urban Distribution Network rarely exceeds 0.5% but higher levels, in excess of 1%, may be experienced at times of high load and when outages occur at voltage levels above 11 kV. 1% may exist continuously due to unbalance of the system impedance (common on remote rural networks). In addition, account can be taken of the neutralising effect of rotating plant, particularly at 11 kV and below. BS EN 50160 contains details of the variations and disturbances to the voltage which shall be taken into account in selecting equipment from an appropriate specification for installation on or connected to the Distribution Network.</p>		N/A
9.4.4.2	<p>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 33 kV, or 1% for other systems with a nominal voltage no greater than 132 kV. Overall, voltage unbalance should not exceed 2% when assessed over any one minute period. EREC P29, like all planning standards, is applicable at the time of connection.</p>		N/A
9.4.4.3	<p>For Power Generating Facilities of 50 kW or less Section 7.5 of this document specifies maximum unbalance of Power Generating Modules. Where these requirements are met then no further action is required by the Generator.</p>		N/A
9.4.5	<p>Power Factor correction equipment is sometimes used with Power Park Modules to decrease Reactive Power flows on the Distribution Network. 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.</p>		P
9.4.6	DC Injection		P
9.4.6.1	<p>The effects of, and therefore limits for, DC currents injected into the Distribution Network is an area currently under investigation. Until these investigations are concluded the limit for DC injection is less than 0.25% of the AC rating per Power Generating Module.</p>		P
9.4.6.2	<p>The main source of these emissions are from transformer-less Inverters. Where necessary DC emission requirements can be satisfied by installing a transformer on the AC side of an Inverter.</p>		N/A
9.5	System Stability	NA on generating inverter	N/A
9.6	Island Mode	It is depend on DNO	N/A
9.7	Fault Contributions and Switchgear Considerations	NA on generating inverter	N/A

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
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 Power Generating Module supporting an islanded section of the Distribution Network when it would or could pose a hazard to the Distribution Network or Customers connected to it. The settings recognize the need to avoid nuisance tripping and therefore require a two stage approach where practicable, ie to have a long time delay for smaller excursions that may be experienced during normal Distribution Network operation, to avoid nuisance tripping, but with a faster trip, where possible, for greater excursions.		P
10.1.2	In accordance with established practice it is for the Generator to install, own and maintain this protection. The Generator can therefore determine the approach, ie per Power Generating Module or per installation, and where in the installation the protection is sited.		N/A
10.1.3	Where a common protection system is used to provide the protection function for multiple Power Generating Modules the complete installation cannot be considered to comprise Fully Type Tested Power Generating Modules if the protection and connections are made up on site and so cannot be factory tested or Type Tested. If the units or Power Generating Modules are specifically designed to be interconnected on site via plugs and sockets, then provided the assembly passes the function tests required in Annex A.2 (Form A2-4), the Power Generating Modules can retain Type Tested status.		P
10.1.4	Type Tested Interface Protection shall have protection settings set during manufacture.		P
10.1.5	Once the Power Generating Modules has been installed and commissioned the protection settings shall only be altered following written agreement between the DNO and the Generator.		P
	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

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
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
	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.		N/A
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

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
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
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

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
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
	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 Power Generating Module supporting an islanded section of the Distribution Network when it would or could pose a hazard to the Distribution Network or Customers connected to it. The settings recognize the need to avoid nuisance tripping and therefore require a two stage approach where practicable, ie to have a long time delay for smaller excursions that may be experienced during normal Distribution Network operation, to avoid nuisance tripping, but with a faster trip, where possible, for greater excursions.	Only considered on inverter	P
10.1.2	In accordance with established practice it is for the Generator to install, own and maintain this protection. The Generator can therefore determine the approach, ie per Power Generating Module or per installation, and where in the installation the protection is sited.		N/A



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Clause	Requirement - Test	Result - Remark	Verdict
10.1.3	Where a common protection system is used to provide the protection function for multiple Power Generating Modules the complete installation cannot be considered to comprise Fully Type Tested Power Generating Modules if the protection and connections are made up on site and so cannot be factory tested or Type Tested. If the units or Power Generating Modules are specifically designed to be interconnected on site via plugs and sockets, then provided the assembly passes the function tests required in Annex A.2 (Form A2-4), the Power Generating Modules can retain Type Tested status.	Only considered on inverter	P
10.1.4	Type Tested Interface Protection shall have protection settings set during manufacture.		P
10.1.5	Once the Power Generating Modules has been installed and commissioned the protection settings shall only be altered following written agreement between the DNO and the Generator.		P
10.1.6	In exceptional circumstances additional protection may be required by the DNO to protect the Distribution Network and its Customers from the Power Generating Module.		P
10.1.7	Note that where the Generator installs an Export Limiting Scheme in accordance with EREC G100 the installation will also need to comply with the requirements of that EREC.		N/A
10.2	Co-ordinating with DNO's Distribution Network's Existing Protection		N/A
10.2.1	It will be necessary for the protection associated with Power Generating Modules to co-ordinate with the Protection associated with the DNO's Distribution Network as follows:		N/A
	For Power Generating Modules directly connected to the DNO's Distribution Network the Power Generating Module must meet the target clearance times for fault current interchange with the DNO's Distribution Network in order to reduce to a minimum the impact on the DNO's Distribution Network of faults on circuits owned by the Generator.  The DNO will ensure that the DNO protection settings meet its own target clearance times.  The target clearance times are measured from fault current inception to arc extinction and will be specified by the DNO to meet the requirements of the relevant part of the Distribution Network.		N/A
	The settings of any protection controlling a circuit breaker or the operating values of any automatic switching device at any point of connection with the DNO's Distribution Network, as well as the Generator's maintenance and testing regime, shall be agreed between the DNO and the Generator in writing during the connection consultation process.		N/A

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Clause	Requirement - Test	Result - Remark	Verdict
	It will be necessary for the Power Generating Module protection to co-ordinate with any auto-reclose policy specified by the DNO. In particular the Power Generating Module protection should detect a loss of mains situation and disconnect the Power Generating Module in a time shorter than any auto reclose dead time. This should include an allowance for circuit breaker operation and generally a minimum of 0.5 s should be allowed for this. For auto-reclosers set with a dead time of 3 s, this implies a maximum Interface Protection response time of 2.5 s. Where auto-reclosers have a dead time of less than 3 s, there may be a need to reduce the operating time of the Interface Protection. For Type Tested Power Park Modules no changes are required to the operating times irrespective of the auto-reclose times. In all other cases where the auto-recloser dead time is less than 3 s the Generator will need to agree site-specific Interface Protection settings with the DNO.		N/A
10.2.2	Specific protection required for Power Generating Modules		P
	In addition to any protection installed by the Generator to meet his own requirements and statutory obligations on him, the Generator must install protection to achieve the following objectives		P
	(a) For all Power Generating Modules:		P
	i. To disconnect the Power Generating Module from the system when a system abnormality occurs that results in an unacceptable deviation of the frequency or voltage at the Connection Point, recognizing the requirements to ride through faults as detailed in Sections 12.3 and 13.4;		P
	ii. To ensure the automatic disconnection of the Power Generating Module, or where there is constant supervision of an installation, the operation of an alarm with an audio and visual indication, in the event of any failure of supplies to the protective equipment that would inhibit its correct operation.		P
	(b) For polyphase Power Generating Modules:		N/A
	i. To inhibit connection of Power Generating Modules to the system unless all phases of the DNO's Distribution Network are present and within the agreed ranges of protection settings;		N/A
	ii. To disconnect the Power Generating Module from the system in the event of the loss of one or more phases of the DNO's Distribution Network;		N/A
	(c) For single phase Power Generating Modules:		P
	i. To inhibit connection of Power Generating Modules to the system unless that phase of the DNO's Distribution Network is present and within the agreed ranges of protection settings;		P
	ii. To disconnect the Power Generating Module from the system in the event of the loss of that phase of the DNO's Distribution Network;		P
10.3	Protection Requirements		P



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Clause	Requirement - Test	Result - Remark	Verdict
10.3.1	<p>Suitable protection arrangements and settings will depend upon the particular Generator installation and the requirements of the DNO's Distribution Network. These individual requirements must be ascertained in discussions with the DNO. To achieve the objectives above, the protection must include the detection of:</p> <ul style="list-style-type: none"> <li>• UnderVoltage (1 stage);</li> <li>• OverVoltage (2 stage);</li> <li>• UnderFrequency (2 stage);</li> <li>• OverFrequency (1 stage);</li> <li>• Loss of Mains (LoM).</li> </ul>		P
	The LoM protection will depend for its operation on the detection of some suitable parameter, for example, rate of change of frequency (RoCoF), or unbalanced voltages. More details on LoM protection are given in Section 10.4.		P
	There are different protection settings dependent upon the system voltage at which the Power Generating Module is connected (LV or HV).	Only considered LV connection	P
	Protection settings for Power Generating Facilities over 100 MW Registered Capacity must be consistent with Grid Code requirements. Loss of Mains protection will only be permitted at these sites if sanctioned by the NETSO– see Section 10.4.2 below.		N/A
	It is in the interest of Generators, DNOs and NETSO that Power Generating Modules remains synchronised to the Distribution Network during system disturbances, and conversely to disconnect reliably for true LoM situations. Frequency and voltage excursions less than the protection settings should not cause protection operation. As some forms of LoM protection might not readily achieve the required level of performance (eg under balanced load conditions), the preferred method for Power Generating Facilities with a Registered Capacity greater than 50 MW is by means of intertripping. This does not preclude consideration of other methods that may be more appropriate for a particular connection.		N/A
10.3.2	The protective equipment, provided by the Generator, to meet the requirements of this section must be installed in a suitable location that affords visual inspection of the protection settings and trip indicators and is secure from interference by unauthorised personnel.		P
10.3.3	Installation of automatic reconnection systems for Type B, Type C and Type D shall be subject to prior authorisation by the DNO. Unless Generators of Type D Power Generating Modules have prior authorisation from the DNO for the installation of automatic reconnection systems, they must obtain authorisation from the DNO, or NETSO as applicable, prior to synchronisation.	Type A considered	N/A

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
10.3.4	The frequency and voltage at the DNO's side of the supply terminals at the Connection Point must be within the frequency and voltage ranges of the Interface Protection as listed in paragraph 10.6.7 for at least 20 s before the Power Generating Module is allowed to automatically reconnect to the DNO's Distribution Network. There is in general no maximum admissible ramp rate for Active Power output on connecting or reconnecting, although it is a requirement to state the assumed maximum ramp rate for the Power Generating Module as part of the application for connection. If a network specific issue requires a maximum admissible ramp rate of Active Power output on connection it will be specified by in the Connection Agreement.		P
10.3.5	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 20 s. Reset times may need to be co-ordinated where more than one Power Generating Module is connected to the same feeder. The automatic reset must be inhibited for faults on the Generator's Installation.		P
10.3.6	Protection equipment is required to function correctly within the environment in which it is placed and shall satisfy the following standards: <ul style="list-style-type: none"> <li>• BS EN 61000 (Electromagnetic Standards);</li> <li>• BS EN 60255 (Electrical Relays);</li> <li>• BS EN 61810 (Electrical Elementary Relays);</li> <li>• BS EN 60947 (Low Voltage Switchgear and Control gear);</li> <li>• BS EN 61869 (Instrument Transformers; Additional requirements for current transformers).</li> </ul> Where these standards have more than one part, the requirements of all such parts shall be satisfied, so far as they are applicable.		P
10.3.7	Protection equipment and protection functions may be installed within, or form part of the Power Generating Module control equipment as long as:		P
	the control equipment satisfies all the requirements of Section 10 including the relevant standards specified in paragraph 10.3.6;		P
	the Power Generating Module 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; and		P
	the equipment is designed and installed so that protection calibration and functional tests can be carried out easily and safely using secondary injection techniques (ie using separate Low Voltage test equipment).		P
10.4	Loss of Mains (LoM)		P

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
10.4.1	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 Power Generating Module from the Distribution Network in the event of loss of one or more phases of the DNOs supply. This LoM protection is required to ensure that the Power Generating Module is disconnected, to ensure that the requirements for Distribution Network earthing, and out-of-Synchronism closure are complied with and that Customers are not supplied with voltage and frequencies outside statutory limits.		P
10.4.2	LoM protection is required for all Type A, Type B and Type C Power Generating Modules. For Type D Power Generating Modules the DNO will advise if LoM protection is required. The requirements of paragraph 10.6.2 apply to LoM protection for all Power Generating Modules.		P
10.4.3	A problem can arise for Generators who operate a Power Generating Module in parallel with the Distribution Network prior to a failure of the network supply because if their Power Generating Module 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 Power Generating Module will be out of Synchronism with the Total System and suffer damage. LoM protection can be employed to disconnect the Power Generating Module immediately after the supply is lost, thereby avoiding damage to the Power Generating Module.		P
10.4.4	Where the amount of Distribution Network load that the Power Generating Module will attempt to pick up following a fault on the Distribution Network is significantly more than its capability the Power Generating Module will rapidly disconnect, or stall. However, depending on the exact conditions at the time of the Distribution Network failure, there may or may not be a sufficient change of load on the Power Generating Module to be able to reliably detect the failure. The Distribution Network failure may result in one of the following load conditions being experienced by the Power Generating Module:		P
	(a) The load may slightly increase or reduce, but remain within the capability of the Power Generating Module. 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 Power Generating Module 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 Power Generating Module, in which case the following easily detectable conditions will occur: <ul style="list-style-type: none"> <li>• Overload and accompanying speed/frequency reduction</li> <li>• Over current and under voltage on the alternator</li> </ul>		P

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
10.4.5	Conditions (b) and (c) are easily detected by the under and over voltage and frequency protection required in this document. However, condition (a) presents most difficulty, particularly if the load change is extremely small and therefore there is a possibility that part of the Distribution Network supply being supplied by the Power Generating Module will be out of Synchronism with the Total System. LoM protection is designed to detect these conditions.		P
10.4.6	LoM signals can also be provided by means of intertripping signals from circuit breakers that have operated in response to the Distribution Network fault.		N/A
10.4.7	The LoM protection can utilise one or a combination of the passive protection principles such as reverse Active Power flow, reverse Reactive Power and rate of change of frequency (RoCoF). Alternatively, active methods such as reactive export error detection or frequency shifting may be employed. These may be arranged to trip the interface circuit breaker at the DNO Generator interface, thus, leaving the Power Generating Module available to satisfy the load requirements of the site or the Power Generating Module circuit breaker can be tripped, leaving the breaker at the interface closed and ready to resume supply when the Distribution Network supply is restored. The most appropriate arrangement is subject to agreement between the DNO and Generator.	Active and passive protection	P
10.4.8	Protection based on measurement of reverse flow of Active Power or Reactive Power can be used when circumstances permit and must be set to suit the Power Generating Module rating, the site load conditions and requirements for Reactive Power.		N/A
10.4.9	Where the Power Generating Facility capacity is such that the site will always import power from the Distribution Network, 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
10.4.10	However, where the Power Generating Facilities 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. The protection should then be specifically designed to detect loss of the mains connection using techniques to detect the rate of change of frequency and/or Power Factor. All these techniques are susceptible to Distribution Network 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

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
10.4.11	RoCoF relays use a measurement of the period of the mains voltage cycle. The RoCoF technique measures the rate of change in frequency caused by any difference between prime mover power and electrical output power of the Power Generating Module over a number of cycles. RoCoF relays should normally ignore the slow changes but respond to relatively rapid changes of frequency which occur when the Power Generating Module becomes disconnected from the Total System. The voltage vector shift technique is not an acceptable loss of mains protection.		P
10.4.12	Should spurious tripping present a nuisance to the Generator, the cause must be jointly sought with the DNO. 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. Annex D.2 provides some guidance for assessments, which assume that during a short period of islanding the trapped load is unchanged. 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, eg intertripping.		P
10.4.13	For a radial or simple Distribution Network controlled by circuit breakers that would clearly disconnect the entire circuit and associated Power Generating Module, for a LoM event an intertripping scheme can be easy to design and install. For meshed or ring Distribution Networks, 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
10.4.14	It is the responsibility of the Generator to incorporate what they believe to be 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 Power Generating Module, site and network load conditions. The DNO will assist in the decision making process by providing information on the Distribution Network and its loads. The settings applied must be biased to ensure detection of islanding under all practical operating conditions.		P
10.5	Additional DNO Protection	Shall be considered in the end installation	N/A
10.6	Protection Settings		P
10.6.1	The following notes aim to explain the settings requirements as given in Section 10.6.7 below.		P
10.6.2	Loss of Mains		P

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Clause	Requirement - Test	Result - Remark	Verdict
	A LoM protection of the RoCoF type will generally be appropriate for Type A, Type B and Type C Power Generating Modules, but this type of LoM protection must not be installed for Power Generating Facilities at or above 50 MW. In those cases where the DNO requires LoM protection this must be provided by a means not susceptible to spurious or nuisance tripping, eg intertripping.		P
10.6.3	Under Voltage		P
	In order to help maintain Total System Stability, the protection settings aim to facilitate transmission fault ride through capability (as required in Sections 12.3 and 13.3 below). The overall aim is to ensure that Power Generating Module is not disconnected from the Distribution Network unless there is material disturbance on the Distribution Network, as disconnecting generation unnecessarily will tend to make an under voltage situation worse. To maximize the transmission fault ride through capability a single undervoltage setting of - 20% with a time delay of 2.5 s should be applied.		P
10.6.4	Over Voltage		P
	Over voltages are potentially more dangerous than under voltages and hence the acceptable excursions from the norm are smaller and time delays shorter, a 2-Stage over voltage protection <sup>6</sup> is to be applied		P
	<p>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);</p> <ul style="list-style-type: none"> <li>• 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);</li> </ul>		P
	<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);</p> <ul style="list-style-type: none"> <li>• 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).</li> </ul>		N/A



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Clause	Requirement - Test	Result - Remark	Verdict
	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
10.6.5	Over Frequency		P
	Power Generating Modules are required to stay connected to the Total System for frequencies up to 52 Hz for up to 15 minutes so as to provide the necessary regulation to control the Total System frequency to a satisfactory level. In order to prevent the unnecessary disconnection of a large volume of smaller Power Generating Module for all LV and HV connected Power Generating Module a single stage protection is to be applied that has a time delay of 0.5 s and a setting of 52 Hz. If the frequency rises to or above 52 Hz as the result of an undetected islanding condition, the Power Generating Module will be disconnected with a delay of 0.5 s plus circuit breaker operating time.		P
10.6.6	Under Frequency		P
	All Power Generating Facilities are required to maintain connection unless the Total System frequency falls below 47.5 Hz for 20 s 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;		P
10.6.7	Protection Settings		P
10.6.7.1	Settings for Long-Term Parallel Operation		P
10.6.7.2	Settings for Infrequent Short-Term Parallel Operation		N/A
10.6.8	Over and Under voltage protection must operate independently for all three phases in all cases.		N/A
10.6.9	The settings in Table 10.1 should generally be applied to all Power Generating Modules. In exceptional circumstances Generators have the option to agree alternative settings with the DNO if there are valid justifications in that the Power Generating Module may become unstable or suffer damage with the settings specified in Table 10.1. The agreed settings should be recorded in the Connection Agreement.		N/A
10.6.10	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.		P

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Clause	Requirement - Test	Result - Remark	Verdict
10.6.11	The under/over voltage and frequency protection may be duplicated to protect the Power Generating Module when operating in island mode although different settings may be required.		P
10.6.12	For LV connected Power Generating Modules the voltage settings will be based on the 230 V nominal system voltage. In some cases Power Generating Modules may be connected to LV systems with non-standard operating voltages. Paragraph 10.6.14 details how suitable settings can be calculated based upon the HV connected settings in Table 10.1. Note that Power Generating Modules with non-standard LV protection settings need to be agreed by the DNO on a case by case basis.		N/A
10.6.13	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
10.6.14	Non-Standard private LV networks calculation of appropriate protection settings		N/A
10.6.15	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:	The way (b) is used	P
	(a) A display on a screen which can be read;		N/A
	(b) A display on an electronic device which can communicate with the Power Generating Module 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;		P
	(c) Display of all settings including nominal voltage and current outputs, alongside the identification number / name of the device, permanently fixed to the Power Generating Module.		N/A
	The provision of loose documents, documents attached by cable ties etc., a statement that the device conforms with a standard, or provision of data on adhesive paper based products which are not likely to survive due to fading, or failure of the adhesive, for at least 20 years is not acceptable. The protection arrangements (including changes to protection arrangements) for individual schemes will be agreed between the Generator and the DNO in accordance with this document.		P
10.6.16	Whilst the protection schemes and settings for internal electrical faults should mitigate any damage to the Power Generating Module they must not jeopardise the performance of a Power Generating Module, in line with the requirements set out in this EREC.		P



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Clause	Requirement - Test	Result - Remark	Verdict
10.6.17	The Generator shall organise its protection and control devices in accordance with the following priority ranking (from highest to lowest) for Type B, Type C and Type D Power Generating Modules:	Type A	N/A
10.6.18	For the avoidance of doubt where an internal fault on the Power Generating Module occurs during any significant event on the Total System, the Power Generating Module's internal protection should trip the module to ensure safety and minimise damage to the Power Generating Module.		P
10.7	Typical Protection Application Diagrams		N/A
11	Type A Power Generating Module Technical Requirements		P
11.1	Power Generating Module Performance and Control Requirements – General		P
11.1.1	The requirements of this Section 11 do not apply in full to Power Generation Facilities that are designed and installed for infrequent short term parallel operation only nor to storage Power Generation Modules within the Power Generating Facility – refer to Annex A.4.		P
11.1.2	The Active Power output of a Power Generating Module should not be affected by voltage changes within the statutory limits declared by the DNO in accordance with the ESQCR.		P
11.1.3	Power Generating Modules connected to the DNO's Distribution Network shall be equipped with a logic interface (input port) in order to cease Active Power output within 5 s following an instruction being received at the input port.		P
11.1.3.1	By default the DNO logic interface will take the form of a simple binary output that can be operated by a simple switch or contactor. When the switch is closed the Power Generating Module can operate normally. When the switch is opened the Power Generating Module will reduce its Active Power to zero within 5 s. The signal from the Power Generating Module that is being switched can be either AC (maximum value 240 V) or DC (maximum value 110 V). If the DNO wishes to make use of the facility to cease Active Power output the DNO will agree with the Generator how the communication path is to be achieved.		P
11.1.4	Each item of a Power Generating Module and its associated control equipment must be designed for stable operation in parallel with the Distribution Network.		P
11.1.5	When operating at rated power the Power Generating Module shall be capable of operating 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.		P
11.1.6	As part of the connection application process the Generator shall agree with the DNO the set points of the control scheme for voltage control, Power Factor control or Reactive Power control as appropriate. These settings, and any changes to these settings, shall be agreed with the DNO and recorded in the Connection Agreement. The information to be provided is detailed in Schedule 5a and Schedule 5b of the Data Registration Code.		N/A

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
11.1.7	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 EREC P2) involving a mixture of fault and planned outages. The Connection Agreement should include details of the relevant outage conditions. It may be necessary under these fault conditions, where the combination of Power Generating Module output, load and through flow levels leads to circuit overloading, to rapidly disconnect or constrain the Power Generating Module.		N/A
11.2	Frequency response		P
11.2.1	Under abnormal conditions automatic low-frequency load-shedding provides for load reduction down to 47 Hz. In exceptional circumstances, the frequency of the DNO's Distribution Network could rise above 50.5 Hz. Therefore all Power Generating Modules should be capable of continuing to operate in parallel with the Distribution Network in accordance with the following:  (a) 47 Hz – 47.5 Hz Operation for a period of at least 20 s is required each time the frequency is within this range.  (b) 47.5 Hz – 49.0 Hz Operation for a period of at least 90 minutes is required each time the frequency is within this range.  (c) 49.0 Hz – 51.0 Hz Continuous operation of the Power Generating Module is required.  (d) 51.0 Hz – 51.5 Hz Operation for a period of at least 90 minutes is required each time the frequency is within this range.  (e) 51.5 Hz – 52 Hz Operation for a period of at least 15 minutes is required each time the frequency is within this range.		P
11.2.2	With regard to the rate of change of frequency withstand capability, a Power Generating Module shall be capable of staying connected to the Distribution Network and operate at rates of change of frequency up to 1 Hzs-1 as measured over a period of 500 ms unless disconnection was triggered by a rate of change of frequency type loss of mains protection or by the Power Generating Module's own protection system for a co-incident internal fault as detailed in paragraph 10.6.18.		P
11.2.3	Output power with falling frequency		P
11.2.3.1	Each Power Generating Module, must be capable of:		P
	(a) continuously maintaining constant Active Power output for system frequency changes within the range 50.5 to 49.5 Hz; and		P

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Clause	Requirement - Test	Result - Remark	Verdict
	(b) (subject to the provisions of paragraph 11.2.1) maintaining its Active Power output at a level not lower than the figure determined by the linear relationship shown in Figure 11.1 for system frequency changes within the range 49.5 to 47 Hz for all ambient temperatures up to and including 25°C, such that if the system frequency drops to 47 Hz the Active Power output does not decrease by more than 5%.		P
11.2.3.2	For the avoidance of doubt in the case of a Power Generating Module using an Intermittent Power Source where the power input will not be constant over time, the requirement is that the Active Power output shall be independent of system frequency under (a) above and should not drop with system frequency by greater than the amount specified in (b) above.		P
11.2.4	Limited Frequency Sensitive Mode – Over frequency		P
11.2.4.1	Each Power Generating Module shall be capable of reducing Active Power output in response to frequency on the Total System when this rises above 50.4 Hz. The Power Generating Module shall be capable of operating stably during LFSM-O operation. If a Power Generating Module has been contracted to operate in Frequency Sensitive Mode the requirements of LFSM-O shall apply when frequency exceeds 50.5 Hz.		P
	(a).The rate of change of Active Power output must be at a minimum a rate of 2% of output per 0.1 Hz deviation of system frequency above 50.4 Hz (ie a Droop of 10%) as shown in Figure 11.2. For the avoidance of doubt, this would not preclude a Generator from designing their Power Generating Module with a Droop of less than 10%, but in all cases the Droop should be 2% or greater.		P
	(b) The Power Generating Module shall be capable of initiating a power frequency response with an initial delay that is as short as possible. If the initial delay exceeds 2 s the Generator shall justify the delay, providing technical evidence to the DNO, who will pass this evidence to the NETSO. As much as possible of the proportional reduction in Active Power output must result from the frequency control device (or speed governor) action and must be achieved within 10 s of the time of the frequency increase above 50.4 Hz.		P
	(c) If the reduction in Active Power is such that the Power Generation Module reaches its Minimum Generation, it must continue to operate stably at this level.		P
11.2.4.2	When the Power Generating Module is providing Limited Frequency Sensitive Mode Over frequency (LFSM-O) response it must continue to provide the frequency response until the frequency has returned to, or is below, 50.4 Hz.		P

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
11.2.4.3	Steady state operation below Minimum Generation is not expected but if system operating conditions cause operation below Minimum Generation which give rise to operational difficulties then the Generator shall be able to return the output of the Power Generating Module to an output of not less than the Minimum Generation.		P
11.3	Fault Ride Through and Phase Voltage Unbalance		N/A
11.3.1	Where it has been specifically agreed between the DNO and the Generator that a Power Generating Facility will contribute to the DNO's Distribution Network security, (eg for compliance with EREC P2) the Power Generating Module(s) may be required to withstand, without tripping, the effects of a close up three phase fault and the Phase (Voltage) Unbalance imposed during the clearance of a close-up phase-to-phase fault, in both cases cleared by the DNO's main protection. The DNO will advise the Generator in each case of the likely tripping time of the DNO's protection, and for phase-phase faults, the likely value of Phase (Voltage) Unbalance during the fault clearance time.		N/A
11.3.2	In the case of phase to phase faults on the DNO's system that are cleared by system back-up protection which will be within the plant short time rating on the DNO's Distribution Network the DNO, on request during the connection process, will advise the Generator of the expected Phase (Voltage) Unbalance.		N/A
11.4	Voltage Limits and Control		N/A
11.4.1	Where a Power Generating Module is remote from a Network voltage control point it may be required to withstand voltages outside the normal statutory limits. In these circumstances, the DNO should agree with the Generator the declared voltage and voltage range at the Connection Point. Immunity of the Power Generating Module to voltage changes of $\pm 10\%$ of the declared voltage is recommended, subject to design appraisal of individual installations.		N/A
11.4.2	The connection of a Power Generating Module to the Distribution Network shall be designed in such a way that operation of the Power Generating Module does not adversely affect the voltage profile of and voltage control employed on the Distribution Network. ETR 126 provides DNOs with guidance on active management solutions to overcome voltage control limitations. Information on the voltage regulation and control arrangements will be made available by the DNO if requested by the Generator.		N/A
11.4.3	The final responsibility for control of Distribution Network voltage does however remain with the DNO.		N/A

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
11.4.4	Automatic Voltage Control (AVC) schemes employed by the DNO often assume that power flows from parts of the Distribution Network operating at a higher voltage to parts of the Distribution Network operating at lower voltages. Export from Power Generating Modules in excess of the local loads may result in power flows in the reverse direction. In this case AVC referenced to the low voltage side may not operate correctly without an import of Reactive Power and relay settings appropriate to this operating condition. When load current compounding is used with the AVC and the penetration level of Power Generating Modules becomes significant compared to normal loads, it may be necessary to switch any compounding out of service.		N/A
11.4.5	Power Generating Modules can cause problems if connected to networks employing AVC schemes which use negative reactance compounding and line drop compensation due to changes in Active Power and Reactive Power flows. ETR 126 provides guidance on connecting generation to such networks using techniques such as removing the generation circuit from the AVC scheme using cancellation CTs.		N/A
12	Type B Power Generating Module Technical Requirements		N/A
13	Type C and Type D Power Generating Module Technical Requirements		N/A
14	Installation, Operation and Control Interface		N/A
15	Common Compliance and Commissioning Requirements for all Power Generating Modules		N/A
16	Type A Compliance Testing, Commissioning and Operational Notification		P
16.1	Type Test Certification		P
	The Power Generating Module can comprise Fully Type Tested equipment or be made up of some Type Tested equipment and require additional site testing prior to operation. The use of Fully Type Tested equipment simplifies the connection process, the protection arrangements and reduces the commissioning test requirements.	Type test equipment	N/A
16.1.2	Type Tested certification is the responsibility of the Manufacturer. The Manufacturer shall submit the Type Test Verification Report confirming that the product has been Type Tested to satisfy the requirements of this EREC G99 to the Energy Networks Association (ENA) Type Test Verification Report Register. The report shall detail the type and model of product tested, the test conditions and results recorded. The report can include reference to Manufacturers' Information. Examples of the combination of the use of type testing and the provision of Manufacturers' Information are given in Section 22.1. Further information about Manufacturers' Information in respect of Power Park Modules is given in Section 21. A Manufacturer of a Type Tested product should allocate a Manufacturer's reference number, which should be registered on the ENA Type Test Verification Report Register as the Product ID.		P

ER G99			
Clause	Requirement - Test	Result - Remark	Verdict
16.1.3	The required Type Test Verification Report and declarations including that for a Fully Type Tested Power Generating Module are shown in Annex A.2:	Form A2-3 used	P
16.1.4	Guidance for Manufacturers on type testing for Power Generating Modules is included in Annex A.7 of this document.		P
16.1.5	Compliance with the requirements detailed in this EREC G99 will ensure that the Power Generating Module is considered to be approved for connection to the DNO's Distribution Network.		N/A
16.1.6	The Power Generating Module shall comply with all relevant European Directives and should be labelled with a corresponding CE marking.		P
16.2	Connection Process		N/A
16.3	Witnessing and Commissioning		N/A
16.4	Operational Notification		N/A
17	Type B Compliance Testing, Commissioning and Operational Notification		N/A
18	Type C Compliance Testing, Commissioning and Operational Notification		N/A
19	Type D Compliance Testing, Commissioning and Operational Notification		N/A
20	Ongoing Obligations		N/A
21	Manufacturers' Information applicable to Power Park Modules		N/A
22	Type Testing and Annex information	Type test equipment as per form A2-3	P
A7.1.2	Type Verification Functional Testing of the Interface Protection		P
A7.1.2.1	Disconnection times		P
A7.1.2.2	Over / Under Voltage		P
A7.1.2.3	Over / Under Frequency		P
A7.1.2.4	Loss of Mains (LoM) Protection		P
A7.1.2.5	Re-connection		P
A7.1.2.6	Frequency Drift and Step Change Stability test.		P
A.7.1.3	Limited Frequency Sensitive Mode – Over (LFSM-O)		P
A.7.1.4	Power Quality		P
A.7.1.5	Short Circuit Current Contribution		P
A.7.1.6	Self-Monitoring - Solid State Disconnection		N/A

**Appendices A:**

**A2-3 Compliance Verification Report –Tests for Type A Inverter Connected Power Generating Modules – test record**

1. Operating Range: Two tests should be carried with the Power Generating Module operating at Registered Capacity and connected to a suitable test supply or grid simulation set. The power supplied by the primary source shall be kept stable within  $\pm 5\%$  of the apparent power value set for the entire duration of each test sequence.

Frequency, voltage and Active Power measurements at the output terminals of the Power Generating Module shall be recorded every second. The tests will verify that the Power Generating Module can operate within the required ranges for the specified period of time.

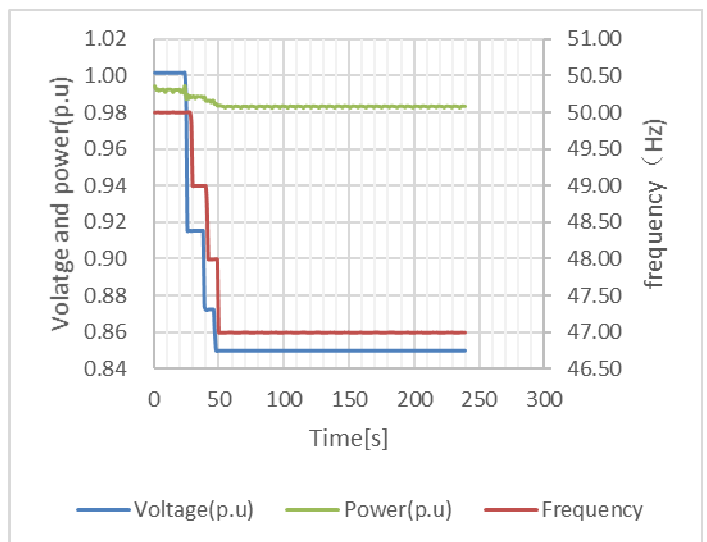
The Interface Protection shall be disabled during the tests.

In case of a PV Power Park Module the PV primary source may be replaced by a DC source.

In case of a full converter Power Park Module (eg wind) the primary source and the prime mover Inverter/rectifier may be replaced by a DC source.

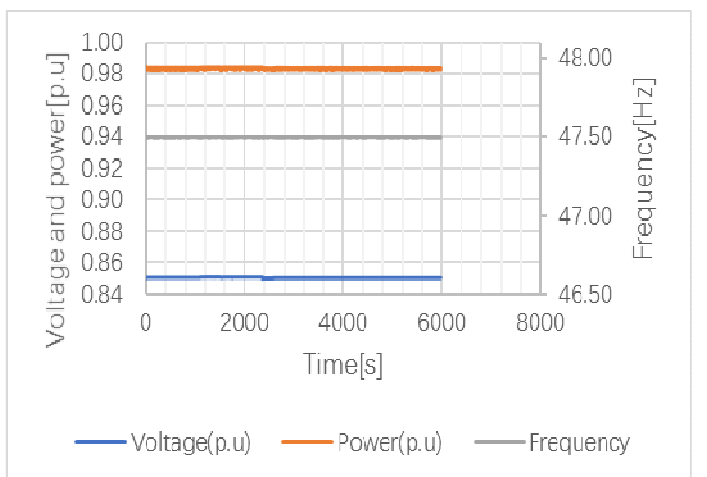
**Test 1**

Voltage = 85% of nominal (195.5 V),  
 Frequency = 47 Hz,  
**Power Factor = 1**,  
 Period of test 20 s



**Test 2**

Voltage = 85% of nominal (195.5 V),  
 Frequency = 47.5 Hz,  
**Power Factor = 1**,  
 Period of test 90 minutes





<p>Test 3</p> <p>Voltage = 110% of nominal (253 V),          Frequency = 51.5 Hz,  <b>Power Factor = 1</b>,          Period of test 90 minutes</p>	<p>Graph showing Voltage [p.u.] (blue line), Power [p.u.] (orange line), and Frequency [Hz] (grey line) over Time [s]. The x-axis ranges from 0 to 8000s. The left y-axis ranges from 0.96 to 1.12 p.u. The right y-axis ranges from 49.50 to 51.00 Hz. Voltage is constant at 1.10 p.u., Power is constant at 1.00 p.u., and Frequency is constant at 51.5 Hz.</p>
<p>Test 4</p> <p>Voltage = 110% of nominal (253 V),          Frequency = 52.0 Hz,  <b>Power Factor = 1</b>,          Period of test 15 minutes</p>	<p>Graph showing voltage [p.u.] (blue line), Power [p.u.] (orange line), and Frequency [Hz] (grey line) over Time [s]. The x-axis ranges from 0 to 1500s. The left y-axis ranges from 0.96 to 1.12 p.u. The right y-axis ranges from 49.40 to 51.80 Hz. Voltage is constant at 1.10 p.u., Power is constant at 1.00 p.u., and Frequency is constant at 52.0 Hz.</p>
<p>Test 5 RoCoF withstand</p> <p>Confirm that the <b>Power Generating Module</b> is capable of staying connected to the <b>Distribution Network</b> and operate at rates of change of frequency up to 1 Hz/s as measured over a period of 500 ms. Note that this is not expected to be demonstrated on site.</p>	<p>Graph showing Power [W] (orange line) and Frequency [Hz] (blue line) over Time [s]. The x-axis ranges from 0 to 20s. The left y-axis ranges from 0.00 to 7000.00 W. The right y-axis ranges from 48.50 to 52.00 Hz. Power is constant at 6000 W, and Frequency oscillates between 49.0 Hz and 51.0 Hz.</p>



**2. Power Quality – Harmonics:**

For Power Generating Modules of Registered Capacity of less than 75 A per phase (ie 50 kW) the test requirements are specified in Annex A.7.1.5. These tests should be carried out as specified in BS EN 61000-3-12 The results need to comply with the limits of Table 2 of BS EN 61000-3-12 for single phase equipment and Table 3 of BS EN 61000-3-12 for three phase equipment.

Power Generating Modules 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 Power Generating Module in order to accept the connection to a Distribution Network.

For Power Generating Modules of Registered Capacity of greater than 75 A per phase (ie 50 kW) the installation must be designed in accordance with EREC G5.

Power Generating Module tested to BS EN 61000-3-12

Power Generating Module rating per phase (rpp)		6.0	kVA	Harmonic % = Measured Value (A) x 23/rating per phase (kVA)		
Harmonic	At 45-55% of Registered Capacity		100% of Registered Capacity		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	%	Measured Value MV in Amps	%	1 phase	3 phase
2	0.0242	0.0940	0.0595	0.2312	8%	8%
3	0.1357	0.5273	0.1510	0.5868	21.6%	Not stated
4	0.0114	0.0443	0.0258	0.1003	4%	4%
5	0.0419	0.1628	0.0304	0.1181	10.7%	10.7%
6	0.0099	0.0385	0.0319	0.1240	2.67%	2.67%
7	0.0284	0.1104	0.0684	0.2658	7.2%	7.2%
8	0.0077	0.0299	0.0368	0.1430	2%	2%
9	0.0203	0.0789	0.0308	0.1197	3.8%	Not stated
10	0.0051	0.0198	0.0269	0.1045	1.6%	1.6%
11	0.0111	0.0431	0.0199	0.0773	3.1%	3.1%
12	0.0029	0.0113	0.0102	0.0396	1.33%	1.33%
13	0.0106	0.0412	0.0157	0.0610	2%	2%
THD	1.174%		0.813%		23%	13%
PWHD	0.261%		0.319%		23%	22%

This test performed on model HYD 6000-ES

**2. Power Quality – Harmonics:**

For Power Generating Modules of Registered Capacity of less than 75 A per phase (ie 50 kW) the test requirements are specified in Annex A.7.1.5. These tests should be carried out as specified in BS EN 61000-3-12 The results need to comply with the limits of Table 2 of BS EN 61000-3-12 for single phase equipment and Table 3 of BS EN 61000-3-12 for three phase equipment.

Power Generating Modules 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 Power Generating Module in order to accept the connection to a Distribution Network.

For Power Generating Modules of Registered Capacity of greater than 75 A per phase (ie 50 kW) the installation must be designed in accordance with EREC G5.

Power Generating Module tested to BS EN 61000-3-12

Power Generating Module rating per phase (rpp)		4.0		kVA		Harmonic % = Measured Value (A) x 23/rating per phase (kVA)	
Harmonic	At 45-55% of Registered Capacity		100% of Registered Capacity		Limit in BS EN 61000-3-12		
	Measured Value MV in Amps	%	Measured Value MV in Amps	%	1 phase	3 phase	
2	0.0163	0.0945	0.0347	0.2013	8%	8%	
3	0.1033	0.5991	0.1365	0.7917	21.6%	Not stated	
4	0.0056	0.0325	0.0264	0.1531	4%	4%	
5	0.0397	0.2303	0.019	0.1102	10.7%	10.7%	
6	0.0046	0.0267	0.0206	0.1195	2.67%	2.67%	
7	0.0225	0.1305	0.0211	0.1224	7.2%	7.2%	
8	0.0029	0.0168	0.0158	0.0916	2%	2%	
9	0.0137	0.0795	0.0298	0.1728	3.8%	Not stated	
10	0.0026	0.0151	0.0197	0.1143	1.6%	1.6%	
11	0.0057	0.0331	0.0165	0.0957	3.1%	3.1%	
12	0.0015	0.0087	0.0045	0.0261	1.33%	1.33%	
13	0.0071	0.0412	0.0179	0.1038	2%	2%	
THD	1.346%		0.961%		23%	13%	
PWHD	0.266%		0.346%		23%	22%	

This test performed on model HYD 4000-ES

**3. Power Quality – Voltage fluctuations and Flicker:**

For Power Generating Modules of Registered Capacity of less than 75 A per phase (ie 50 kW) these tests should be undertaken in accordance with Annex A.7.1.4.3. 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.

For Power Generating Modules of Registered Capacity of greater than 75 A per phase (ie 50 kW) the installation must be designed in accordance with EREC P28.

	Starting			Stopping			Running	
	d max	dc	d(t)	d max	dc	d(t)	P st	P It 2 hours
Measured Values at test impedance	--	-	-	-	-	-	-	-
Normalised to standard impedance	2.15	1.77	0.00	2.15	1.77	0.00	0.43	0.41
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				XI			
Standard Impedance	R	0.24 * 0.4 ^			XI	0.15 * 0.25 ^		
Maximum Impedance	R				XI			
<p>* Applies to three phase and split single phase Power Generating Modules.</p> <p>^ Applies to single phase Power Generating Module and Power Generating Modules using two phases on a three phase system</p> <p>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.</p> <p>Normalised value = Measured value x reference source resistance/measured source resistance at test point</p> <p>Two phase units in a split phase system reference source resistance is 0</p> <p>Where the Power Factor of the output is under 0.98 then the XI to R ratio of the test impedance should be close to that of the Standard Impedance.</p> <p>The stopping test should be a trip from full load operation.</p> <p>The duration of these tests need to comply with the particular requirements set out in the testing notes for the technology under test. Dates and location of the test need to be noted below</p>								
Test start date	24 Mar 2019			Test end date	24 Mar 2019			
Test location	Intertek Testing Services Shenzhen Ltd. Guangzhou Branch							

<b>4. Power quality – DC injection:</b> The tests should be carried out on a single Generating Unit. Tests are to be carried out at three defined power levels $\pm 5\%$ . At 230 V a 50 kW three phase Inverter has a current output of 217 A so DC limit is 543 mA. These tests should be undertaken in accordance with Annex A.7.1.4.4.			
Model: HYD 6000-ES			
Test power level	10%	55%	100%
Recorded value in Amps	0.0090	0.0079	0.0027
as % of rated AC current	0.0345	0.0303	0.0104
Limit	0.25%	0.25%	0.25%
Model: HYD 4000-ES			
Test power level	10%	55%	100%
Recorded value in Amps	0.0032	0.0034	0.0042
as % of rated AC current	0.018	0.019	0.023
Limit	0.25%	0.25%	0.25%

<b>5. Power Factor:</b> The tests should be carried out on a single Power Generating Module. Tests are to be carried out at three voltage levels and at Registered Capacity. Voltage to be maintained within $\pm 1.5\%$ of the stated level during the test. These tests should be undertaken in accordance with Annex A.7.1.4.2.			
Voltage	0.94 pu (216.2 V)	1 pu (230 V)	1.1 pu (253 V)
Measured value	0.9991	0.9991	0.9988
<b>Power Factor Limit</b>	>0.95	>0.95	>0.95

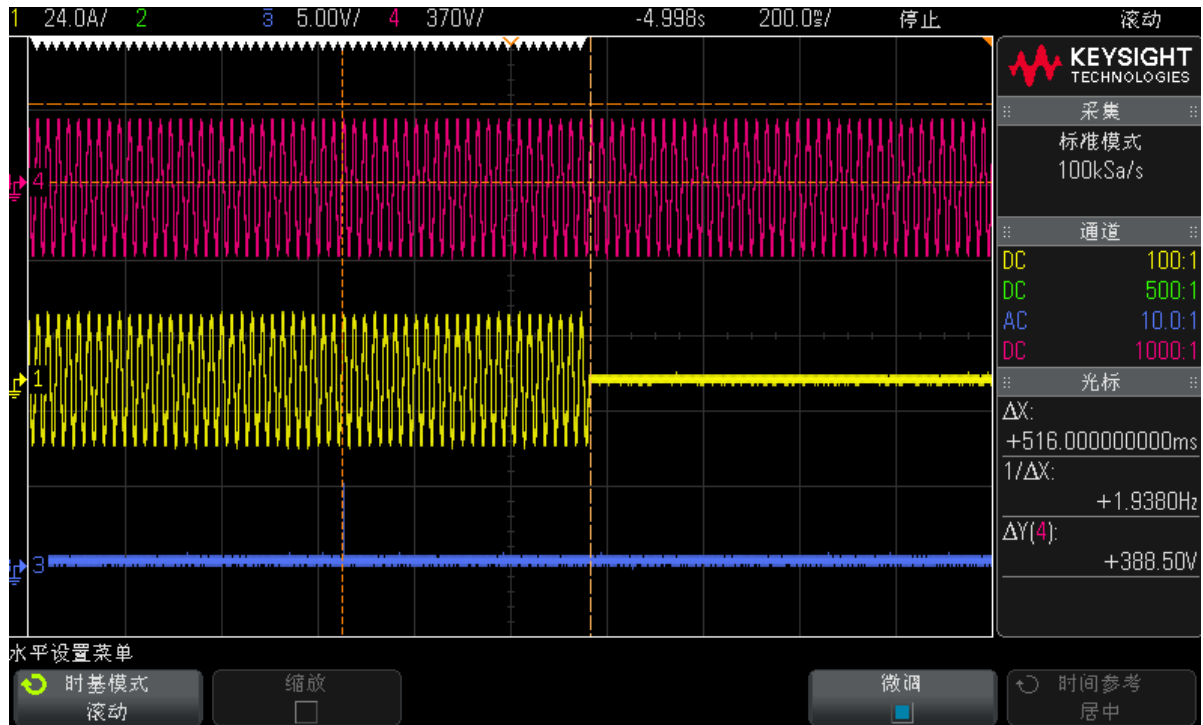
**6. Protection – Frequency tests:** These tests should be carried out in accordance with the Annex A.7.1.2.3.

Function	Setting		Trip test		"No trip tests"	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
U/F stage 1	47.5 Hz	20 s	47.49Hz	20.20s	47.7 Hz 30 s	40.0s No trip
U/F stage 2	47 Hz	0.5 s	47.0Hz	0.52s	47.2 Hz 19.5 s	20.1s trip
					46.8 Hz 0.45 s	0.6s trip
O/F	52 Hz	0.5 s	52.01Hz	0.54s	51.8 Hz 120.0 s	120.0s No trip
					52.2 Hz 0.45 s	0.55s trip

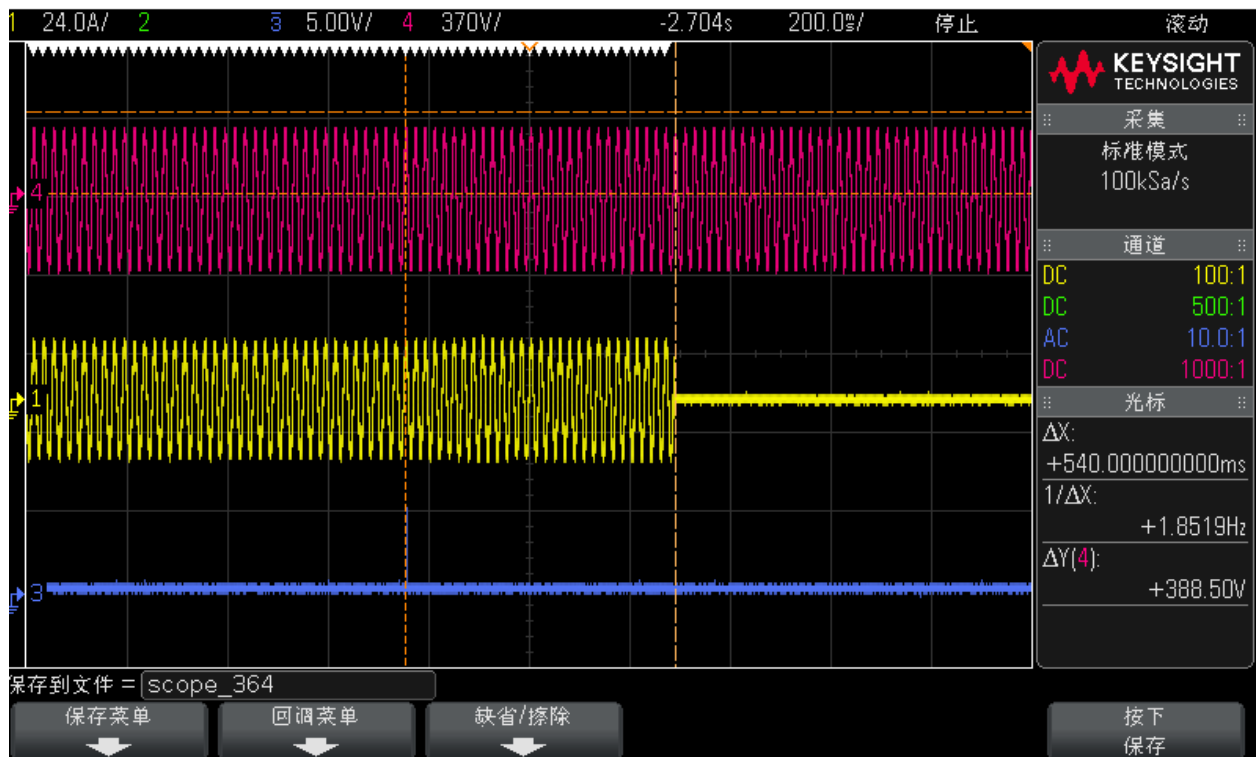
Note. For frequency trip tests the frequency required to trip is the setting  $\pm 0.1$  Hz. In order to measure the time delay a larger deviation than the minimum required to operate the projection can be used. The "No trip tests" need to be carried out at the setting  $\pm 0.2$  Hz and for the relevant times as shown in the table above to ensure that the protection will not trip in error.



U/F stage 1



U/F stage 2

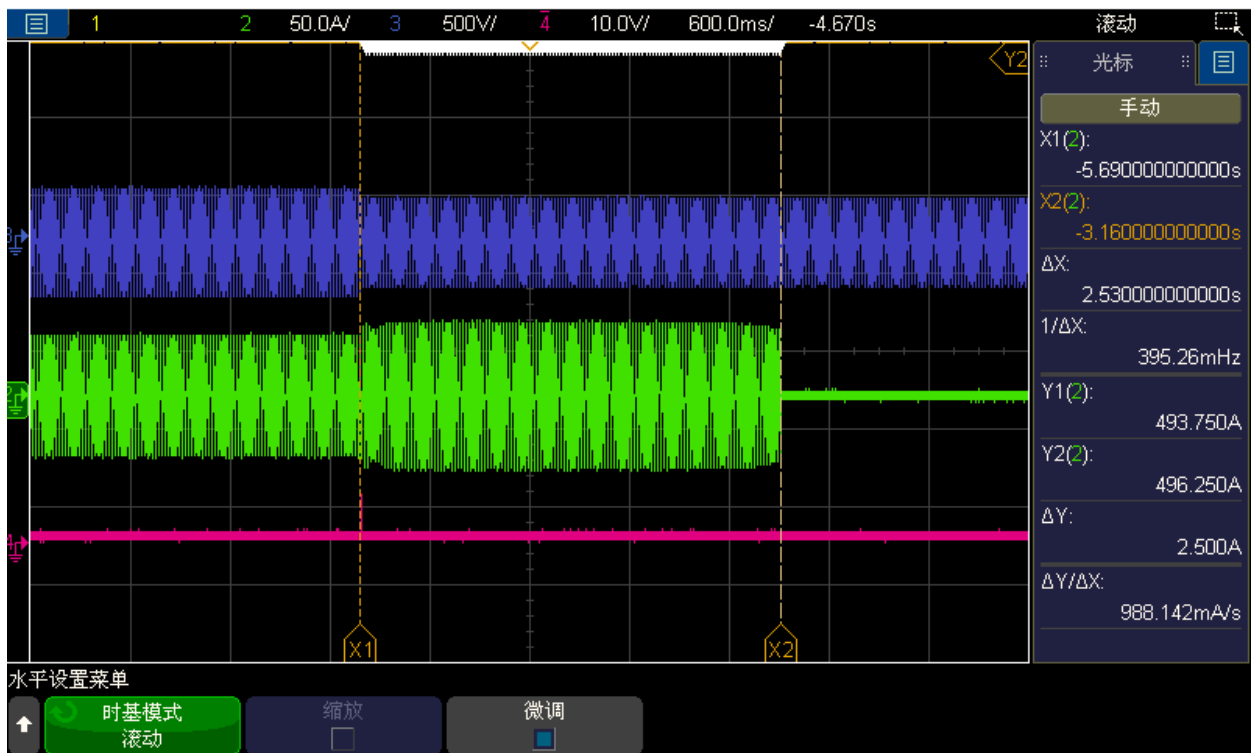


Over frequency at 52.0Hz

Channel 3 represents trip signal, channel 1 represents output current of EUT, channel 4 represents output voltage of EUT,

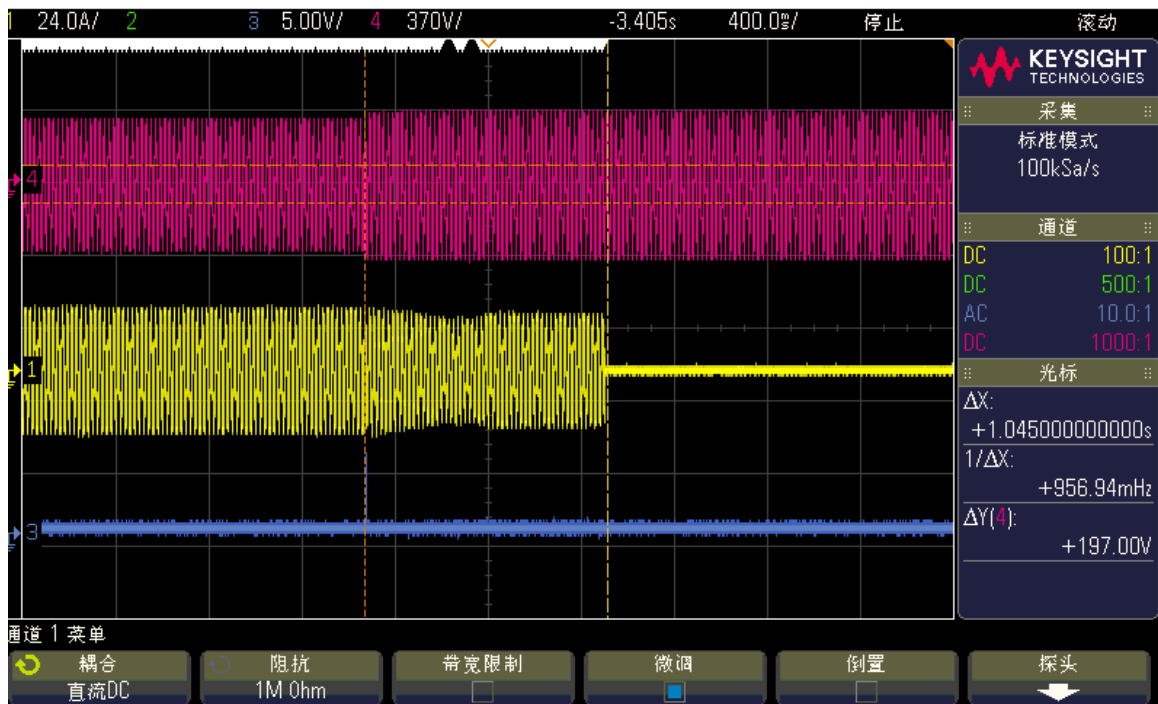
7. Protection – Voltage tests: These tests should be carried out in accordance with Annex A.7.1.2.2.						
Function	Setting		Trip test		“No trip tests”	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
U/V	0.8 pu (184 V)	2.5 s	183.47V	2.53s	188 V	5.0s
					5.0 s	No trip
					180 V	2.60s trip
					2.45 s	
O/V stage 1	1.14 pu (262.2 V)	1.0 s	261.5V	1.045s	258.2 V	5.0s
					5.0 s	No trip
O/V stage 2	1.19 pu (273.7 V)	0.5 s	272.5V	0.524s	269.7 V	1.09s trip
					0.95s	
					277.7 V	0.530s trip
					0.45 s	

Note for Voltage tests the Voltage required to trip is the setting  $\pm 3.45$  V. The time delay can be measured at a larger deviation than the minimum required to operate the protection. The No trip tests need to be carried out at the setting  $\pm 4$  V and for the relevant times as shown in the table above to ensure that the protection will not trip in error.

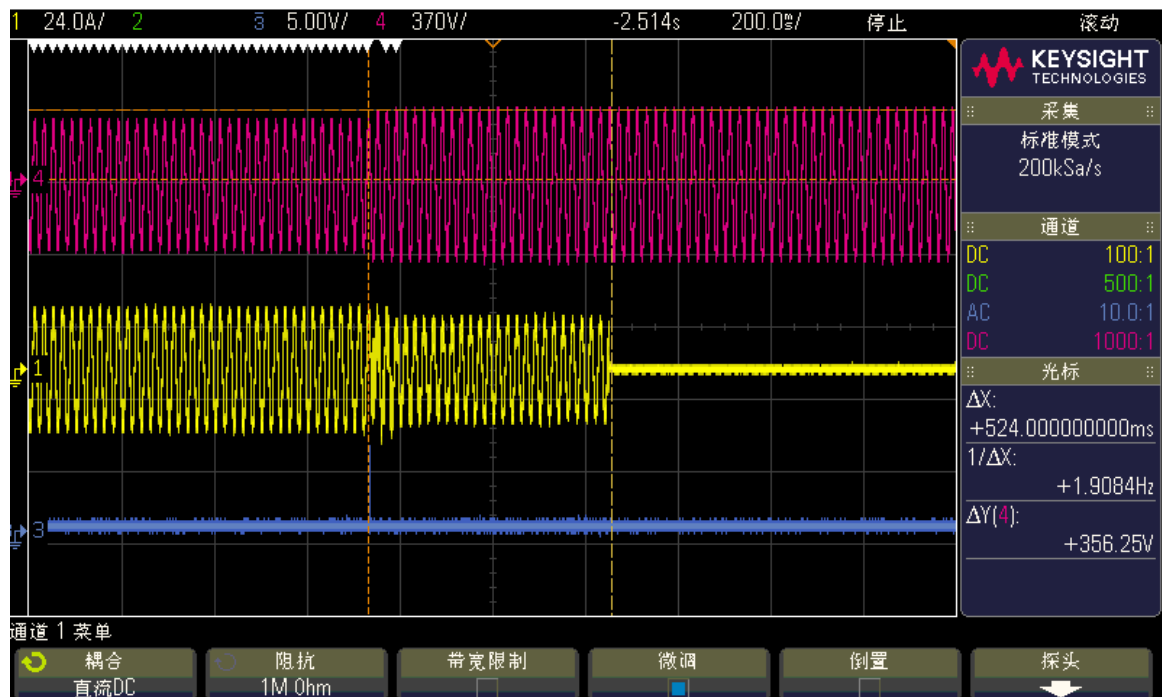


Under voltage at 184V





O/V stage1



O/V stage 2

**8. Protection – Loss of Mains test:** These tests should be carried out in accordance with BS EN 62116. Annex A.7.1.2.4.

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	252.9ms	300.0ms	194.5ms	216.9ms	259.2ms	288.0ms

**Loss of Mains Protection, Vector Shift Stability test.** This test should be carried out in accordance with Annex A.7.1.2.6.

	Start Frequency	Change	Confirm no trip
Positive Vector Shift	49.5 Hz	+50 degrees	No trip
Negative Vector Shift	50.5 Hz	- 50 degrees	No trip

**Loss of Mains Protection, RoCoF Stability test:** This test should be carried out in accordance with Annex A.7.1.2.6.

Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+0.95 Hzs <sup>-1</sup>	2.1 s	No trip
51.0 Hz to 49.0 Hz	-0.95 Hzs <sup>-1</sup>	2.1 s	No trip

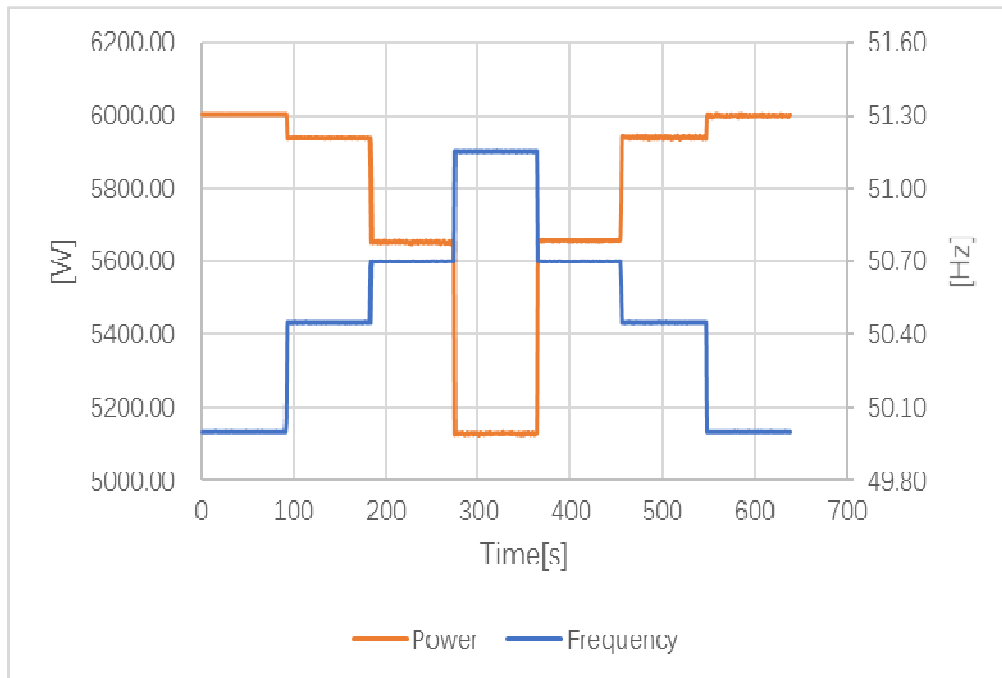
**9. Limited Frequency Sensitive Mode – Over frequency test:** The test should be carried out using the specific threshold frequency of 50.4 Hz and **Droop** of 10%.

This test should be carried out in accordance with Annex A.7.1.3.

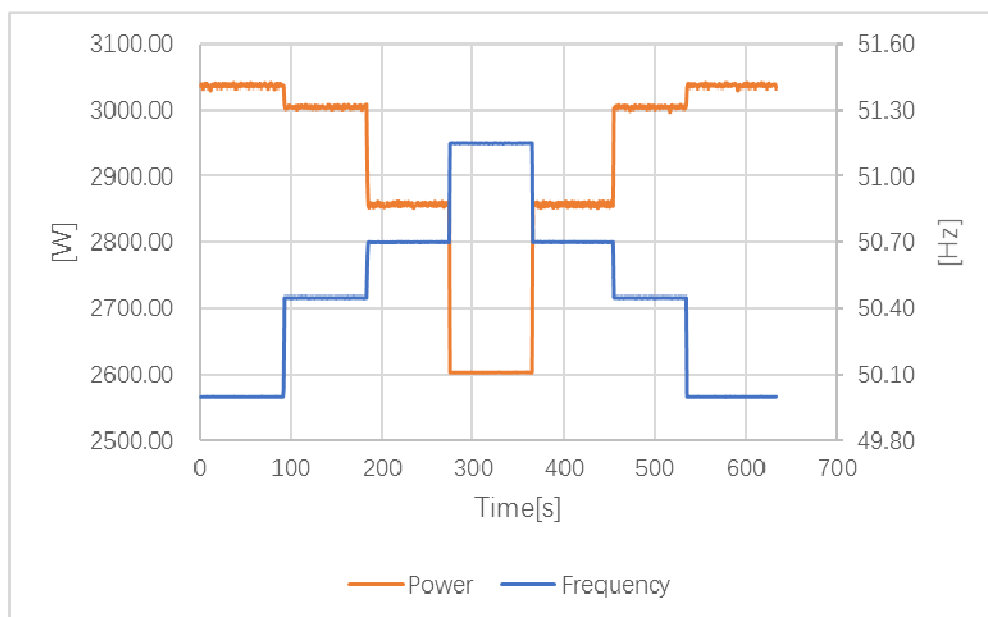
Active Power response to rising frequency/time plots are attached if frequency injection tests are undertaken in accordance with Annex A.7.2.4.	Y
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Alternatively, simulation results should be noted below:

Test sequence at Registered Capacity >80%	Measured Active Power Output	Frequency	Primary Power Source	Active Power Gradient Droop(%)
Step a) 50.00Hz ±0.01Hz	6005.08W	50.00Hz	6198.59W	N/A
Step b) 50.45Hz ±0.05Hz	5941.00W	50.45Hz		9.64
Step c) 50.70Hz ±0.10Hz	5654.60W	50.70Hz		10.33
Step d) 51.15Hz ±0.05Hz	5128.66W	51.15Hz		10.30
Step e) 50.70Hz ±0.10Hz	5659.13W	50.70Hz		10.47
Step f) 50.45Hz ±0.05Hz	5942.73W	50.45Hz		9.91
Step g) 50.00Hz ±0.01Hz	6001.52W	50.00Hz		N/A
Test sequence at Registered Capacity 40% - 60%	Measured Active Power Output	Frequency		Primary Power Source
Step a) 50.00Hz ±0.01Hz	3037.73	50.00Hz	3121.45W	N/A
Step b) 50.45Hz ±0.05Hz	3004.90	50.45Hz		9.23
Step c) 50.70Hz ±0.10Hz	2857.79	50.70Hz		10.12
Step d) 51.15Hz ±0.05Hz	2602.53	51.15Hz		10.47
Step e) 50.70Hz ±0.10Hz	2857.20	50.70Hz		10.09
Step f) 50.45Hz ±0.05Hz	3004.87	50.45Hz		9.22
Step g) 50.00Hz ±0.01Hz	3037.90	50.00Hz		N/A



Test sequence at Registered Capacity =100%

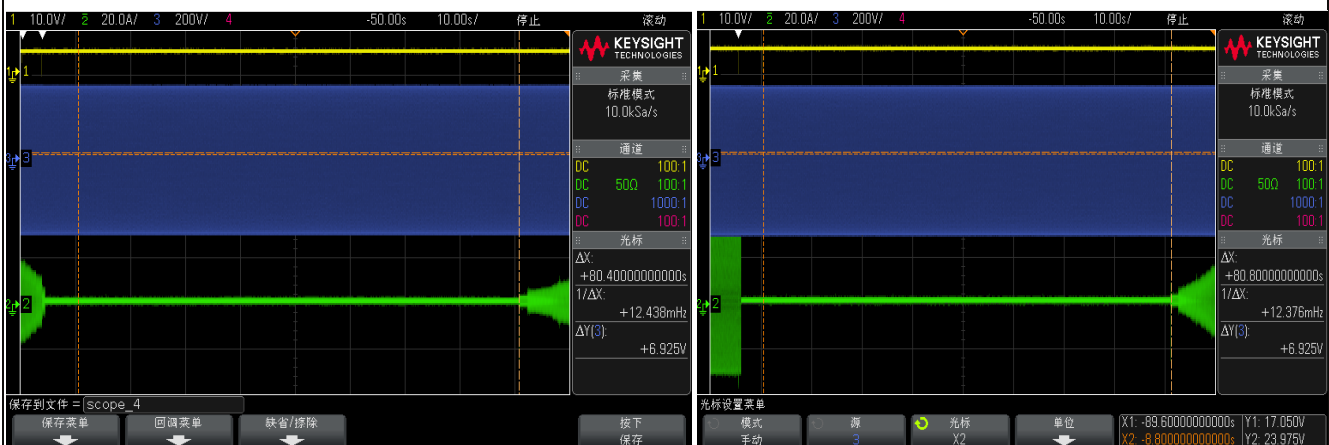


Test sequence at Registered Capacity =50%

10. Protection – Re-connection timer.					
Test should prove that the reconnection sequence starts after a minimum delay of 20 s for restoration of voltage and frequency to within the stage 1 settings of Table 10.1.					
Time delay setting	Measured delay	Checks on no reconnection when voltage or frequency is brought to just outside stage 1 limits of Table 10.1.			
20s	33.6s	At 1.16 pu (266.2 V)	At 0.85 pu (180.0 V)	At 47.4 Hz	At 52.1 Hz
Confirmation that the Power Generating Module does not re-connect.		Not connection	Not connection	Not connection	Not connection



Re-connection after voltage fault



Re-connection after frequency fault

<b>11. Fault level contribution:</b> These tests shall be carried out in accordance with EREC G99 Annex A.7.1.5.		
For <b>Inverter</b> output		
Time after fault	Volts	Amps
20ms	157.4V	40.22A
100ms	--	--
250ms	--	--
500ms	--	--
Time to trip	0.073	In seconds

<b>12. Self-Monitoring solid state switching:</b> No specified test requirements. Refer to Annex A.7.1.7.	
It has been verified that in the event of the solid state switching device failing to disconnect the Power Park Module, the voltage on the output side of the switching device is reduced to a value below 50 volts within 0.5 s.	N/A

<b>13. Wiring functional tests:</b> If required by para 15.2.1.	
Confirm that the relevant test schedule is attached (tests to be undertaken at time of commissioning)	N/A

<b>14. Logic interface (input port).</b>	
Confirm that an input port is provided and can be used to shut down the module.	Yes
Additional comments.	
Stated in installation manual	

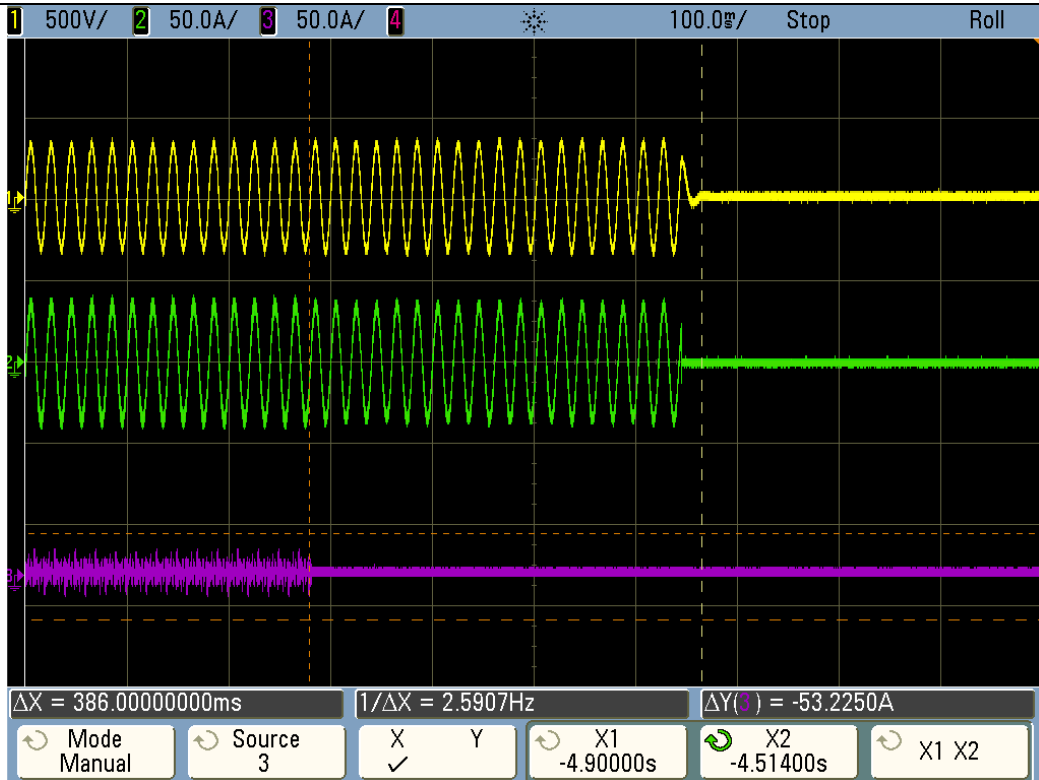
**Protection. Loss of Mains test.-BS EN 62116**

List of tested condition and run on time									
No.	PEUT <sup>1)</sup> (% of EUT rating)	Reactive load (% of QL in 6.1.d)1)	PAC <sup>2)</sup> (% of nominal)	QAC <sup>3)</sup> (% of nominal)	Run on time (ms)	PEUT (W)	Actual Qf	VDC	Remarks <sup>4)</sup>
1	100	100	0	0	386.0	6040	1.00	550	Test A at BL
2	66	66	0	0	242.0	3960	1.00	340	Test B at BL
3	33	33	0	0	312.0	1980	1.00	130	Test C at BL
4	100	100	-5	-5	210.0	6040	1.02	550	Test A at IB
5	100	100	-5	0	194.5	6040	1.00	550	Test A at IB
6	100	100	-5	+5	244.5	6040	0.97	550	Test A at IB
7	100	100	0	-5	199.0	6040	1.02	550	Test A at IB
8	100	100	0	+5	204.0	6040	1.00	550	Test A at IB
9	100	100	+5	+5	268.0	6040	0.97	550	Test A at IB
10	100	100	+5	-5	288.0	6040	1.02	550	Test A at IB
11	100	100	+5	0	274.0	6040	1.00	550	Test A at IB
12	66	66	0	-5	300.0	3960	1.02	340	Test B at IB
13	66	66	0	-4	345.0	3960	1.02	340	Test B at IB
14	66	66	0	-3	228.5	3960	1.01	340	Test B at IB
15	66	66	0	-2	228.0	3960	1.01	340	Test B at IB
16	66	66	0	-1	209.5	3960	1.00	340	Test B at IB
17	66	66	0	1	292.0	3960	0.99	340	Test B at IB
18	66	66	0	2	397.0	3960	0.99	340	Test B at IB
19	66	66	0	3	254.8	3960	0.98	340	Test B at IB
20	66	66	0	4	277.6	3960	0.98	340	Test B at IB
21	66	66	0	5	259.2	3960	0.97	340	Test B at IB
22	33	33	0	-5	252.9	1980	1.02	130	Test C at IB
23	33	33	0	-4	292.5	1980	1.02	130	Test C at IB
24	33	33	0	-3	198.8	1980	1.01	130	Test C at IB
25	33	33	0	-2	357.0	1980	1.01	130	Test C at IB
26	33	33	0	-1	231.3	1980	1.00	130	Test C at IB
27	33	33	0	1	315.0	1980	0.99	130	Test C at IB
28	33	33	0	2	234.4	1980	0.99	130	Test C at IB
29	33	33	0	3	266.4	1980	0.98	130	Test C at IB
30	33	33	0	4	247.8	1980	0.98	130	Test C at IB
31	33	33	0	5	216.9	1980	0.97	130	Test C at IB

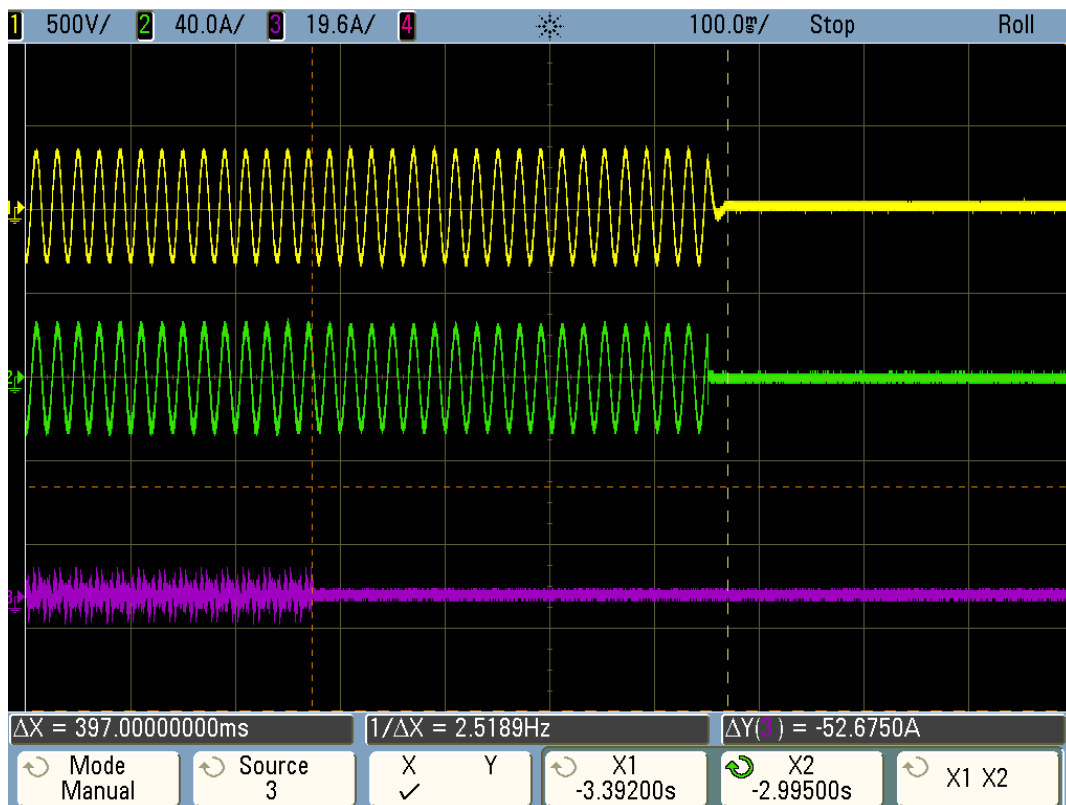
Remark:

- 1) PEUT: EUT output power
- 2) PAC: Real power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.
- 3) QAC: Reactive power flow at S1 in Figure 1. Positive means power from EUT to utility. Nominal is the 0% test condition value.
- 4) BL: Balance condition, IB: Imbalance condition.

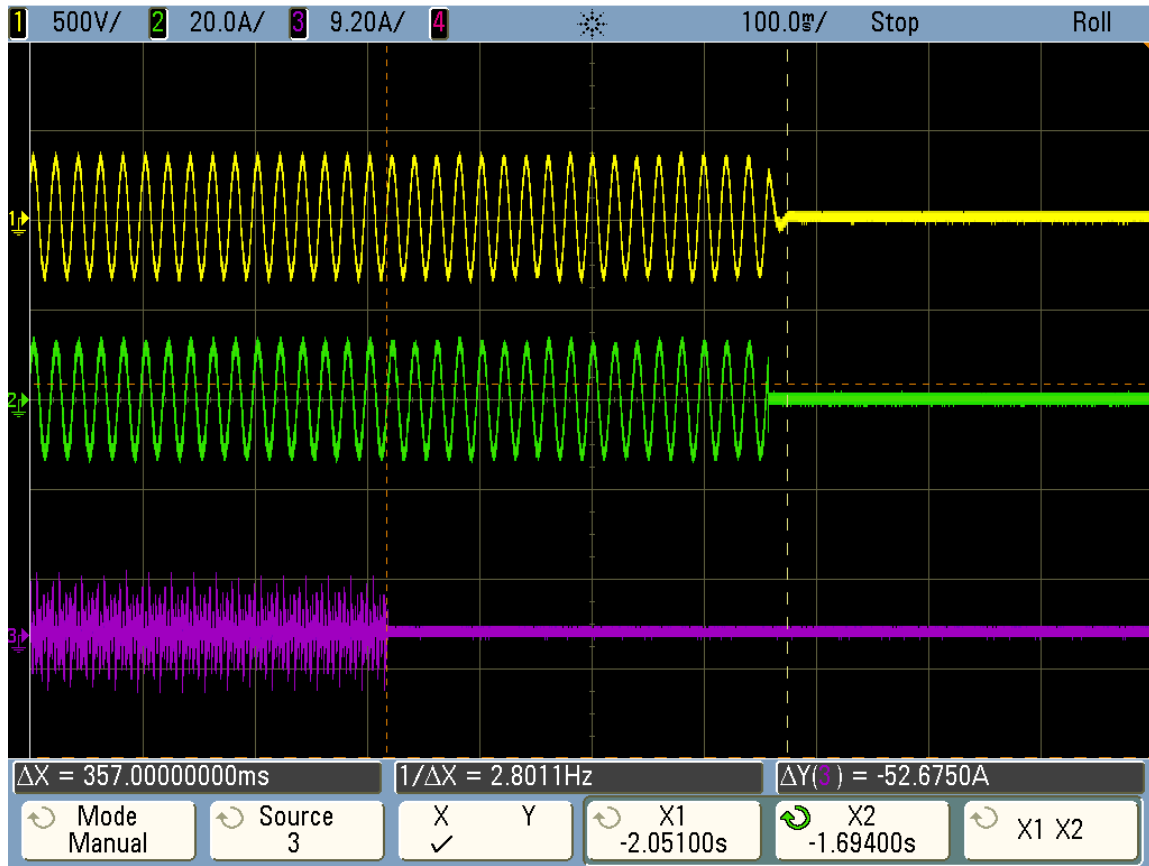




$P_{EUT} 100\%$ ,  $P_{AC} 0\%$ ,  $Q_{AC} 0\%$ , = 386.0ms



$P_{EUT} 66\%$ ,  $P_{AC} 0\%$ ,  $Q_{AC} 2\%$ , = 397.0ms



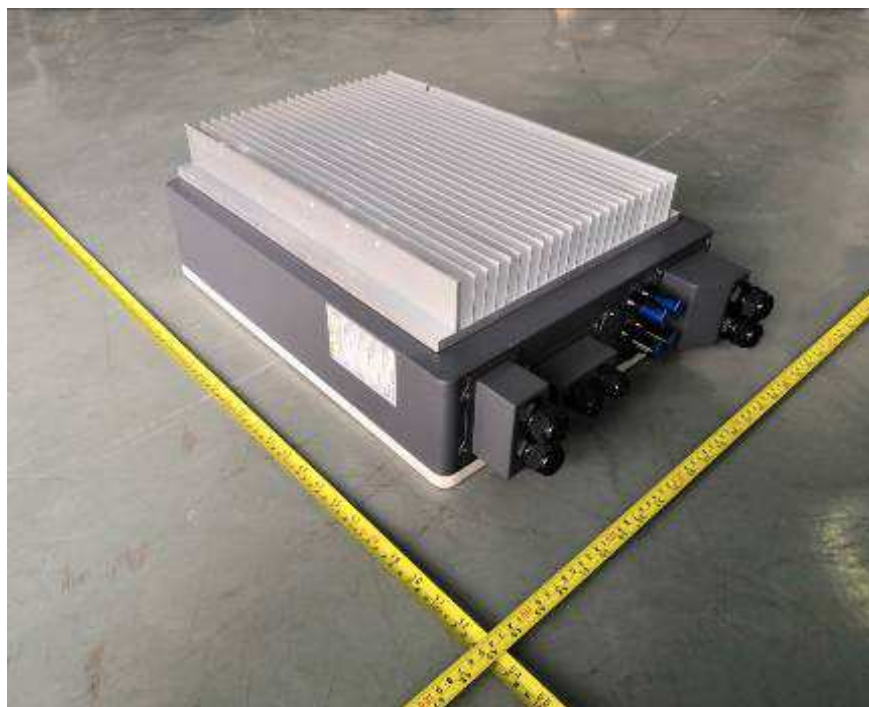
$P_{EUT} 33\%, P_{AC} 0\%, Q_{AC} -2\%, = 357.0\text{ms}$

Note: CH2 denotes current of EUT; CH3 denotes current of signal (the signal from Grid), CH1 denotes Voltage of EUT

**Appendices B Photos:**



Overview



Bottom view



Connection view



Internal view for model HYD 4000-ES





Internal view for model HYD 5000-ES, HYD 6000-ES



Internal view

(End of Report)