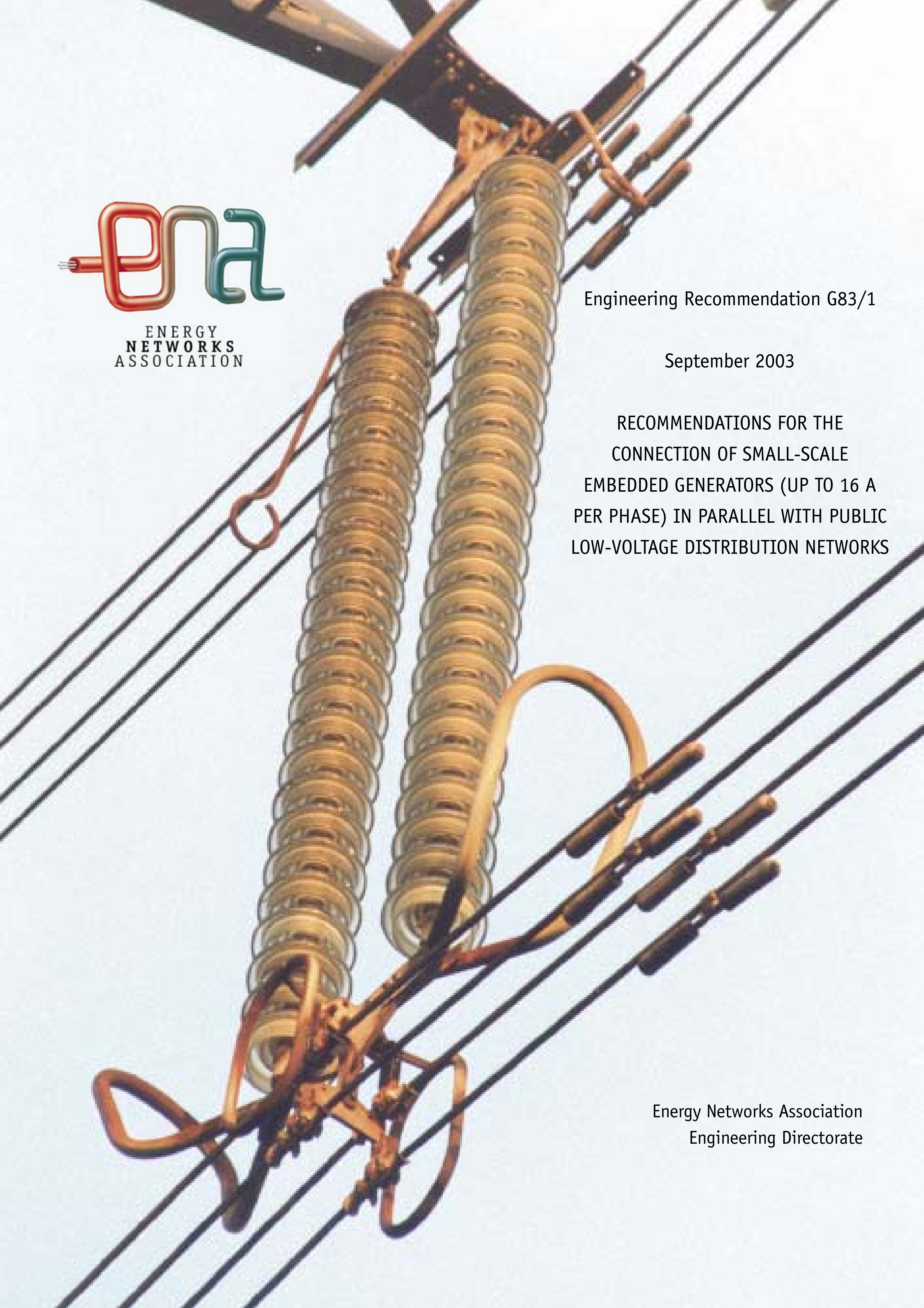

ENERGY
NETWORKS
ASSOCIATION

Engineering Recommendation G83/1

September 2003

RECOMMENDATIONS FOR THE CONNECTION OF SMALL-SCALE EMBEDDED GENERATORS (UP TO 16 A PER PHASE) IN PARALLEL WITH PUBLIC LOW-VOLTAGE DISTRIBUTION NETWORKS

Energy Networks Association
Engineering Directorate

Engineering Directorate
Energy Networks Association
18 Stanhope Place
Marble Arch
London
W2 2HH

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1 PURPOSE

The purpose of this Engineering Recommendation is to simplify and standardise the technical requirements for connection of small scale embedded generators (SSEGs) for operation in parallel with public low-voltage distribution Networks, by addressing all technical aspects of the connection process from standards of functionality to site commissioning.

The procedures described are designed to facilitate the connection of SSEG units whilst maintaining the integrity of the public low-voltage distribution Network, both in terms of safety and supply quality.

This Engineering Recommendation provides sufficient information to allow:

a. SSEG Manufacturers to design and market a product that is suitable for connection to the public low-voltage distribution Network;

b. Users, Manufacturers and Installers of SSEG Units to be aware of the requirements that will be made by the local Distribution Network Operator (DNO) before the SSEG installation will be accepted for connection to the DNO's Network;

c. DNOs to confirm that the SSEG installation is compliant with the relevant international, national and industry standards.

2 SCOPE

This Engineering Recommendation provides guidance on the technical requirements for the connection of small-scale embedded generators (SSEGs) in parallel with public low-voltage distribution Networks. For the purposes of this Engineering Recommendation a SSEG is a source of electrical energy rated up to and including 16 Ampere per phase, single or multi-phase, 230/400 Volts ac.

A two stage connection process is described. Stage 1 covers the connection of a single SSEG unit, either single or multi-phase within a single Customer's installation. Stage 2 covers the connection of multiple SSEGs in a close geographic region, under a planned programme of work.

This Engineering Recommendation only specifies the connection requirements applicable to those SSEG installations that are designed to normally operate in parallel with a public distribution Network. Those installations that operate in parallel with the DNO Network for short periods (i.e. less than 5 minutes) or as an islanded installation or section of Network are considered to be out of scope, on the basis that it is not possible to devise generic rules that will ensure safe operation under all operating conditions.

Note 1: For the connection of embedded generators with a rating greater than 16 A per phase, and for Islanding and short term parallel conditions, the reader is referred to Engineering Recommendation G59/1 and Engineering Technical Report 113.

Note 2: For the connection of small embedded generators with a rating greater than 16 A per phase the DNO may choose to use this Engineering Recommendation if it is considered to be more appropriate than G59/1. For example the connection of a 5kVA PV array or a 10kVA Wind Turbine.

The generic requirements for all types of SSEG unit are defined in the main text of this Engineering Recommendation, whilst the specific requirements for each different type / technology of SSEG are defined in the annexes. The generic requirements relate to the connection, installation and Network design requirements for connection of a SSEG to a public low-voltage distribution Network.

Annex A contains further information on Network design. Annexes B - F describe a methodology for testing the particular types of SSEG in order to demonstrate compliance with the generic requirements of this Engineering Recommendation. By satisfying the test conditions in the relevant annex the SSEG can be considered an Approved SSEG for connection to a public low-voltage distribution Network. In the event that there is no annex for a particular type of SSEG, the matter should be discussed with the local DNO prior to connection, taking guidance from the existing annexes.

The Appendices contain pro formas that have been designed to simplify and standardise type verification, Connection Application (for multiple installations) and Confirmation of Commissioning.

This document does not remove any statutory rights of an individual or organisation; equally it does not remove any statutory obligation on an individual or organisation.

Connection Agreements (i.e. the legal documentation supporting the connection of a SSEG), Energy trading and Metering are considered to be out of Scope. These issues are mentioned in this document only in the context of raising the reader's awareness to the fact that these matters might need to be addressed.

3 REFERENCES

Electricity Safety, Quality and Continuity Regulations (ESQCR)
The Electricity Safety, Quality and Continuity Regulations 2002 - Statutory Instrument Number 2665 -HMSO ISBN 0-11-042920-6 abbreviated to ESQCR in this document.

BS 7671: 2001 Requirements for Electrical Installations
IEE Wiring Regulations Sixteenth Edition.

BS EN 61000-3-2: 2000
Limits for harmonic current emissions (equipment input current up to and including 16 A per phase).

BS EN 61000-3-3: 2000
Limitation of voltage fluctuations and flicker in low voltage supply systems for equipment with rated current ≤ 16 A per phase and not subject to conditional connection.

BS EN 61034-4: 1995
Methods for determining synchronous machine quantities from tests.

IEC 60255-5: 1977 (BS 5992 Part 3) Electrical Relays
Electrical Relays: Specification for the Insulation Testing of Electrical Relays.

IEC 60364-7-712
Electrical installations of buildings - Part 7-712: Requirements for special installations or locations - Solar photovoltaic (PV) power supply systems.

IEC 60725
Considerations on reference impedances for use in determining the disturbance characteristics of household appliances and similar electrical equipment.

IEC 60909-1: 1988
Short circuit calculation in three-phase ac systems.

IEC 62282-3-2

Fuel cell technologies - Part 3-2: Stationary fuel cell power plants - Test methods for the performance.

Note: Currently this document is in draft format and therefore only available to members of the relevant IEC working group(s).

Engineering Recommendation G5/4 (2001)

Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission and distribution networks in the United Kingdom.

Engineering Recommendation G59/1, Amendment 1 (1995)

Recommendations for the Connection of Embedded Generating Plant to the Regional Electricity Companies' Distribution Systems.

Engineering Recommendation P28 (1989)

Planning limits for voltage fluctuations caused by industrial, commercial and domestic equipment in the United Kingdom.

Engineering Recommendation P29 (1990)

Planning limits for voltage unbalance in the UK for 132 kV and below.

Engineering Technical Report No. 113, Revision 1 (1995)

Notes of Guidance for the Protection of Embedded Generating Plant up to 5 MW for Operation in Parallel with Public Electricity Suppliers' distribution systems.

4 DEFINITIONS

For the purposes of this Engineering Recommendation the following definitions apply:

Approved small-scale embedded generator

In the absence of suitable national standards, an Approved small-scale embedded generator (SSEG) is one that has been shown to meet the type verification tests in the appropriate annex of this Engineering Recommendation.

Customer

Any person supplied or requiring to be supplied with electricity by a Supplier but shall not include any Authorised Electricity Operator in its capacity as such.

Note: other documentation may use the term *Consumer* when making reference to the functions and/or features that this document has attributed to the Customer.

Customer's installation

The electrical installation on the Customer's side of the Supply Terminals together with any equipment permanently connected or intended to be permanently connected thereto.

DC

A unidirectional current in which the changes in value are either zero or so small that they may be neglected. As ordinarily used the term designates a practically non-pulsating current.

Distributing main

A low voltage electric line which connects a source of voltage to one or more Customer's installation(s).

Distribution Network Operator (DNO)

The organisaton that owns or operates a Distribution Network and is responsible for confirming requirements for the connection of SSEG units to that Network. A DNO might also be referred to as a Distributor.

Installer

A competent person who has sufficient skills and training to apply safe methods of work to install a SSEG in compliance with the requirements of this Engineering Recommendation.

Islanding

Any situation where a section of electricity Network, containing generation, becomes physically disconnected from the DNOs distribution Network or User's distribution Network; and one or more generators maintains a supply of electrical energy to that isolated Network.

Interface Protection

The electrical protection required to ensure that the SSEG is disconnected for any event that could impair the integrity or degrade the safety of the Distribution Network. This protection will normally include the elements detailed in Table 1. of this Engineering Recommendation.

Inverter

A device for conversion from Direct Current to nominal frequency Alternating Current.

Manufacturer

A person or organisation who manufacturers a SSEG which can be type tested to meet the requirements of this Engineering Recommendation.

Meter Operator

A person who installs, maintains or removes metering equipment used for measuring the flow of energy to or from a network at or near the supply terminals.

Network

An electrical system supplied by one or more sources of voltage and comprising all the conductors and other electrical and associated equipment used to conduct electricity for the purposes of conveying energy to one or more Customer's installations, street electrical fixtures, or other Networks.

Nominal Voltage and Frequency

Low voltage: 230 volts ac (+10/-6 %) single-phase, 50 Hz (+/- 1%).
400 volts ac (+10/-6 %) multi-phase, 50 Hz (+/- 1%).

Note: DNO voltage and frequency is referenced to the Supply Terminals

Photovoltaic Small Scale Embedded Generator (PV SSEG)

A Photovoltaic (PV) generator connected to the distribution network via an inverter.

Small Scale Embedded Generator (SSEG)

A source of electrical energy and all associated interface equipment, rated up to and including 16 A per phase, single or multi phase 230/400 V ac and designed to operate in parallel with a public low voltage distribution Network.

Supplier
A person who contracts to supply electricity to Customers.

Supply Terminals
Means the ends of the electric lines at which the supply is delivered to a consumer's installation.

User
The person with responsibility for the premises in which the SSEG is installed, normally referred to in other documentation as the Customer.

5 REQUIREMENTS

5.1 Connection Procedure

A two stage procedure is recommended to facilitate the connection and operation of SSEG units in parallel with public low-voltage distribution Networks and to ensure that DNOs are made aware of these connections. Each stage can be considered to be mutually exclusive.

In accordance with ESQCR Regulation 22 (2) (c) the Installer is to ensure that the DNO is made aware of the SSEG installation at or before the time of commissioning. The DNO may not refuse to accept the connection providing the installation complies with the requirements of ESQCR Regulation 22. However under the terms of ESQCR Regulation 26 the DNO may require a SSEG to be disconnected if it is a source of danger or interferes with the quality of supply to other consumers.

5.1.1 Stage 1 Connection (single installation)

In most instances the installation of a single SSEG unit within a single Customer's installation, connected in parallel with the public distribution Network, will have negligible impact on the operation of the distribution Network, as such there will be no need for the DNO to carry out detailed network studies to assess the impact of the connection. In addition to the notification required under ESQCR the Installer shall provide the DNO with all necessary information on the installation within 30 days of the SSEG unit being commissioned; the format and content shall be as shown in Appendix 3.

5.1.2 Stage 2 Connection (multiple / planned installation)

In the case of a planned installation project where the proposal is to install multiple SSEG units in a close geographic region it is strongly recommended that the Installer discusses the installation project with the local DNO at the earliest opportunity. The DNO will need to assess the impact that these connections may have on the Network and specify conditions for connection. The initial application will need to be in a format similar to that shown in Appendix 2. The confirmation of commissioning will need to be made within 30 days of commissioning, using a format similar to that shown in Appendix 3. Examples of Stage 2 projects could be:

- As part of a housing refurbishment programme in the same road / street; or
- As part of a new housing development

5.2 Installation Wiring and Isolation

The installation that connects the SSEG to the Supply Terminals shall comply with the requirements of BS 7671. All wiring between the Supply Terminals and the SSEG shall be protected by a suitably rated protective device; and shall be of suitable size and type for the rating of the SSEG. The SSEG shall be connected directly to an isolation switch where for single-phase machines the phase and neutral are isolated and for multi-phase machines all phases and neutral are isolated. In each instance the manual isolation switch shall be capable of being secured in the 'off' (isolated) position; this switch is to be located in an accessible position within the Customer's installation.

5.3 Interface Protection

The purpose of the Interface Protection is to ensure that the connection of a SSEG unit will not impair the integrity or degrade the safety of the Distribution Network, however the SSEG should be designed to normally operate within the statutory limits for Nominal Voltage and Frequency.

5.3.1 General

Interface Protection shall be installed which disconnects the SSEG from the DNO's distribution system when any parameter exceeds the limits shown in Table 1. The SSEG shall be designed to withstand without adverse effect, voltage and frequency variations within the limits shown in Table 1 or within the setting values on the interface protection if they are lower than Table 1 values. As a minimum the SSEG should operate satisfactorily within the full tolerance range of the Nominal Voltage and Frequency.

In response to a protection operation the SSEG shall be disconnected from the DNOs Network, this disconnection must be achieved preferably by the separation of mechanical contacts or alternatively by the operation of a suitably rated solid state switching device. Where a solid state switching device is used to afford disconnection of the SSEG the switching device shall incorporate fail safe monitoring to check the voltage level at the output stage. In the event that the solid state switching device fails to disconnect the SSEG, the voltage on the output side of the switching device shall be reduced to a value below 50 volts within 0.5 seconds.

The protection function can either be incorporated within the SSEG or afforded by separate devices. In either case the Interface Protection shall meet the requirements of IEC 60255-5, or equivalent standard and comply with all other relevant standards as described in the appropriate Annex.

The interface protection will need to function correctly, i.e. operate within the required tolerance range as given in the relevant annex, across the expected range of ambient operating temperatures and other environmental factors.

Once the SSEG has been installed and commissioned the protection settings shall only be altered following written agreement between the DNO and the Customer or his agent.

Table 1. Protection Settings

Parameter	Trip setting (maximum range)	Trip time (maximum value) *
Over Voltage	264 volts (230 +14.7%)	1.5 seconds
Under Voltage	207 volts (230 –10%)	1.5 seconds
Over Frequency	50.5 Hz (50 Hz +1%)	0.5 seconds
Under Frequency	47 Hz (50 Hz –6%)	0.5 seconds
Loss of Mains	See 5.3.2	0.5 seconds

* For each protection function listed in Table 1 it is permissible to extend the relay operating time to 5.0 seconds for those SSEG units that can withstand being re-energised from a source that is 180 degrees out of phase with the SSEG output. Typically this will only be applicable to SSEG units connected via an inverter e.g. a PV array.

Note 1: Voltage and frequency is referenced to the Supply Terminals.

Note 2: To reduce the risk of nuisance tripping for normal system disturbances of short duration, the trip times for under and over voltage have been extended from the 0.5 seconds specified in Engineering Recommendation G59/1. In the event of the SSEG being installed on a circuit controlled by an auto-reclosing circuit breaker the Loss of Mains protection will ensure that the SSEG is disconnected before the circuit breaker can reclose after tripping on fault.

5.3.2 Loss of Mains Protection

The loss of mains protection shall use a recognised technique (as defined in the relevant Annex). Active methods which use impedance measuring techniques by drawing current pulses from, or injecting ac currents into, the DNO’s system are not considered to be suitable.

5.3.3 Automatic Reconnection

Some distribution Networks employ automatic circuit breakers that trip and re-close when a fault is detected. In order to prevent a SSEG being damaged by a DNO circuit breaker automatically closing onto the SSEG when it is out of synchronism with the rest of the Network, the protection system shall ensure that the SSEG remains disconnected from the DNO’s distribution Network until the voltage and frequency on the DNO’s Network have remained within the limits of Table 1 for a minimum of 3 minutes.

5.4 Quality of Supply

The connection of the SSEG in parallel with a DNO’s Network must not impair the quality of supply provided by the DNO to the User or any other Customer. In this respect the SSEG shall comply with the requirements of the EMC Directive and in particular the product family emission standards listed in Table 2.

Table 2. Basic Emission Standards

Parameter	SSEG rating	Standard	Class
Harmonics	≤ 16 A	EN 61000-3-2	Class A
Voltage fluctuations and Flicker	≤ 16 A	EN 61000-3-3	d_c = 4% max

Note 1: Compliance with EN 61000-3-2 will ensure compliance with Engineering Recommendation G5/4.

Note 2: Compliance with EN 61000-3-3 will ensure that the voltage changes caused during starting and stopping of the SSEG are within acceptable limits.

5.5 DC Injection

DC currents entering the ac distribution system can give rise to technical problems. Engineering Recommendation G5/4 deprecates the existence of dc currents on the UK distribution system but does not specify levels. It is recommended that the level of dc injection from a SSEG should not exceed 20 mA.

5.6 Power Factor

When operating at rated power the SSEG shall operate at a power factor within the range 0.95 lagging to 0.95 leading relative to the voltage waveform unless otherwise agreed with the DNO e.g. for power factor improvement.

5.7 Short Circuit Current Contribution

The Installer shall declare, to the DNO, the maximum short circuit current contribution from the SSEG and the conditions under which this exists. One method for determining the short circuit current contribution is described below.

The short circuit current contribution of the SSEG shall be measured upon application of a short circuit on the SSEG terminals (all phases / phase to neutral) with the machine operating at full load output steady state conditions.

Current measurements shall be taken from application of fault until the time the fault has been disconnected, following operation of the SSEG protection. A current decay plot shall be produced for each phase from inception of the fault until SSEG has been disconnected – trip time. The plot will need to show the highest value of peak short circuit current, e.g. for a generator supplying a purely inductive load the highest value of peak short circuit current will result when the fault is applied at a voltage zero. Where practicable the tests will need to determine values for all of the relevant parameters listed in Table 3. These parameters are described in IEC 60909 (1), whilst this standard is primarily for three-phase generators the methodology for determining these parameters can be applied to single-phase generators.

Table 3. SSEG Short Circuit Parameters

Parameter	Symbol	Method of Determination
Peak short-circuit current	i_p	Direct measurement
Initial value of aperiodic component	A	Direct measurement
Initial symmetrical short-circuit current	I''_k	Interpolation of plot
Decaying (aperiodic) component of short-circuit current	i_{DC}	Interpolation of plot & calculation
Reactance / Resistance Ratio of source	$^X/_R$	Calculation

5.8 Technologies not referenced in the Annexes

In order to simplify the connection process for generator technologies not detailed in the existing annexes, they should, where practicable, be grouped under the most appropriate annex of this Engineering Recommendation. Alternatively it may be necessary for the DNO and /or Generator to initiate the drafting of a new annex.

5.9 Certification Requirements

5.9.1 General

Type Test Certification is the responsibility of the SSEG Manufacturer. It is expected that as the market for a particular type of SSEG unit grows, recognised test houses will undertake this routine task.

5.9.2 Compliance

The SSEG unit shall comply with all relevant European Directives and should be labelled with a CE marking.

5.9.3 Verification Test Report

The Manufacturer shall make available upon request a verification test report confirming that the SSEG unit has been Type Tested to satisfy the requirements of this Engineering Recommendation. The report shall detail the type and model of SSEG unit tested, the test conditions and the results recorded, all of these details shall be included on a Test Sheet. A typical test sheet is shown in Appendix 4.

6 OPERATION AND SAFETY

6.1 Operational Requirements

In all cases the User shall ensure that the SSEG is so installed, designed and operated to maintain at all times, compliance with the requirements of ESQCR 22(1)(a).

6.2 Labelling

The Installer shall provide labelling at the Supply Terminals (Fused Cut-Out), meter position, consumer unit and at all points of isolation within the User's premises to indicate the presence of a SSEG. The labelling should be sufficiently robust and if necessary fixed in place to ensure that it remains legible and secure for the lifetime of the installation. The Health and Safety (Safety Signs & Signals) Regulations 1996 stipulates that labels should display the prescribed triangular shape, and size, using black on yellow colouring. A typical label, for both size and content, is shown below:

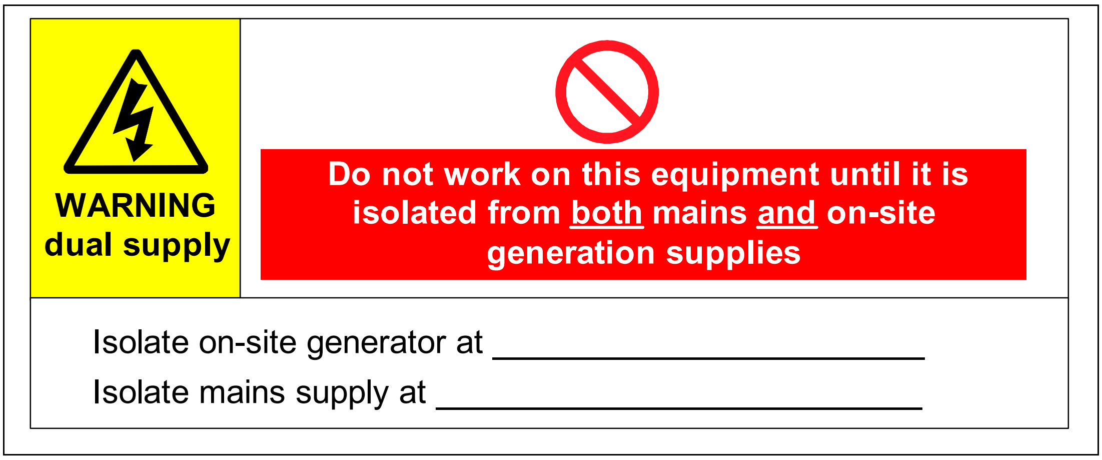


Figure 1. Warning label

Note: The safety sign does not imply a right on the Customer, User, Installer or maintainer to operate (remove / replace) the DNO's cut-out fuse.

In addition to the safety labelling, this Engineering Recommendation requires the following, up to date, information to be displayed at the point of interconnection with the DNOs Network:

a) A circuit diagram showing the circuit wiring, including all protective devices, between the SSEG and the DNOs fused Cut-Out. This diagram should also show by whom all apparatus is owned and maintained;

b) A summary of the protection settings incorporated within the equipment.

Figure 2 shows an outline example of the type of circuit diagram that will need to be displayed. Noting that Figure 2 is non-prescriptive and is for illustrative purposes only, as such it only shows the main components within the Scope of this document. Figure 2 does such it only shows the main components within the Scope of this document. Figure 2 does not show any metering devices, consumer unit or circuit protective devices within the customers installation, however these devices will need to be shown on the diagram required under item a) above.

The Installer shall advise the User that it is the User's responsibility to ensure that this safety information is kept up to date. The installation operating instructions shall contain the Manufacturer's contact details e.g. name, telephone number and web address.

6.3 Maintenance & Routine Testing

Periodic testing of the SSEG is recommended at intervals prescribed by the Manufacturer. This information shall be included in the installation and User Instructions. The method of testing and/or servicing should be included in the servicing instructions.

6.4 Earthing

When a SSEG is operating in parallel with a DNO's Network there shall be no direct connection between the generator winding (or pole of the primary energy source in the case of a PV array or fuel cell) and the DNO's earth terminal. For installations where the customer provides his own earth terminal, e.g. when connected to a TT system, it is also advisable to avoid connecting the generator winding to this earth terminal. The reason for this precaution is to avoid damage to the generator during faults on the distribution network and to ensure correct operation of protective devices.

Earthing of all exposed conductive parts shall comply with the requirements of BS 7671.

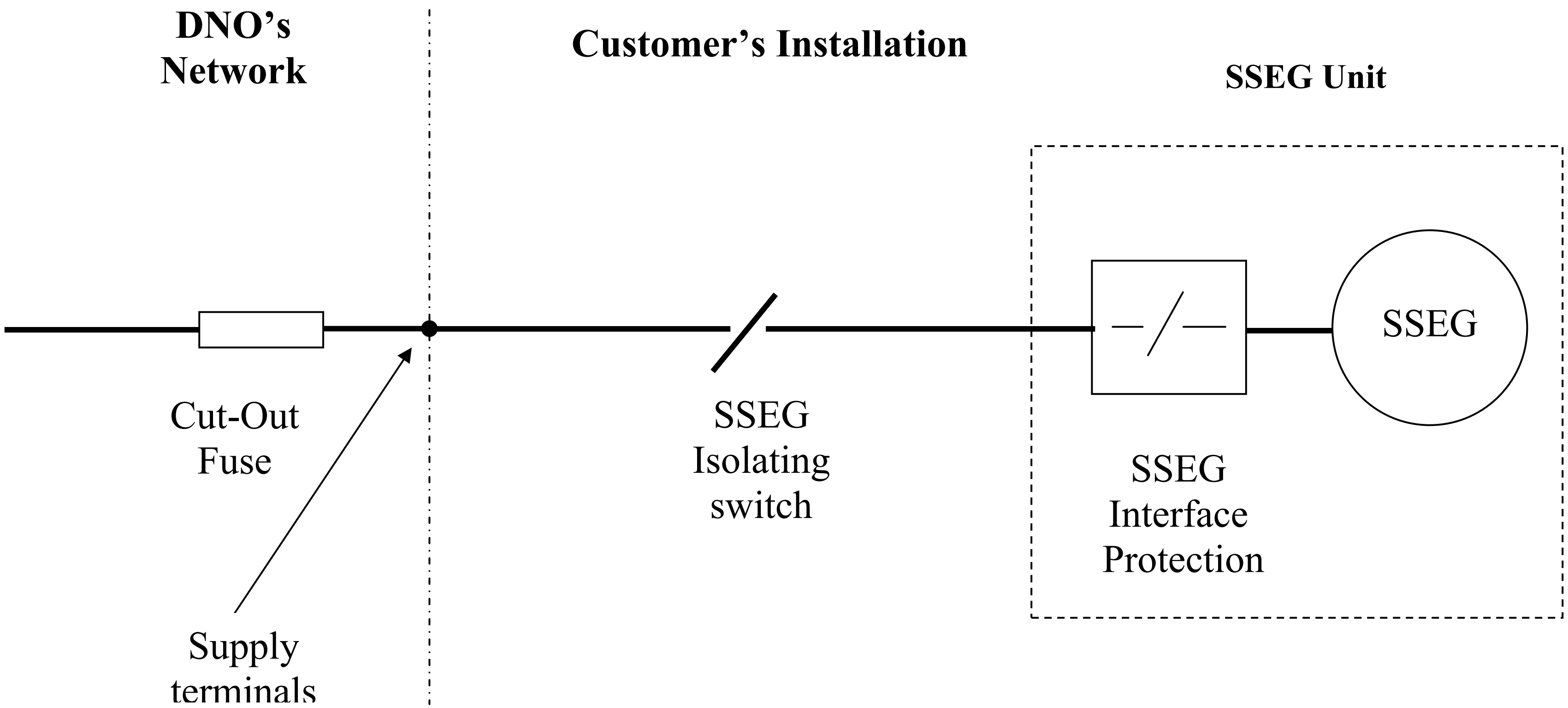


Figure 2. Example showing main components required on a circuit diagram for an SSEG installation

Note: This diagram shows only a simple representation of the relative positions of the SSEG and the DNO's network. In order to avoid being seen as overly prescriptive the diagram does not show: Metering equipment, Consumer Unit and Circuit protective devices, all of these will need to appear on the circuit diagram required under 6.2 a).

7 COMMISSIONING / DECOMMISSIONING AND ACCEPTANCE TESTING

7.1 General

Appendix 1 shows a flow diagram that describes the connection and commissioning process. The information typically required by a DNO under an Application for Connection (Stage 2 connections only) is shown in Appendix 2. The information typically required by a DNO to confirm commissioning is shown in Appendix 3. It is the responsibility of the Installer to ensure that the relevant information is forwarded to the local DNO in accordance with the requirements of Stage 1 and/or Stage 2 connection as appropriate. The pro formas in Appendices 2 and 3 are designed to:

a. Simplify the connection procedure for both DNO and SSEG Installer;

b. Provide the DNO with all the information required to assess the potential impact of the SSEG connection on the operation of the Network;

c. Inform the DNO that the SSEG installation complies with the requirements of this Engineering Recommendation;

d. Allow the DNO to accurately record the location of all SSEGs connected to the Network.

Compliance with the requirements detailed in the relevant Annex in addition to those cited in sections 5 and 6 will ensure that the SSEG is considered to be Approved for connection to the DNOs Network. It is intended that the Manufacturers of SSEG units will use the requirements of this Engineering Recommendation to develop type verification certification for each of their SSEG models.

Upon receipt of a Stage 2 application (multiple SSEGs) the DNO’s response will be in accordance with the standard conditions set by Ofgem for applications for connection to the Network.

7.2 Installation and Commissioning

The installation shall be carried out by Installers with recognised and approved qualifications relating to the fuels used and general electrical installations.

Notwithstanding the requirements of this Engineering Recommendation, the installation will be carried out to no lower a standard than that required in the Manufacturer’s installation instructions.

No parameter relating to the electrical connection and subject to type verification certification will be modified unless previously agreed in writing between the DNO and the Customer or his agent. User access to such parameters shall be prevented.

Note: As part of the on site commissioning tests it is seen as good practice for the Installer to carry out a functional check of the loss of mains protection, for example by removing the supply to the SSEG and checking that the Interface Protection operates to disconnect the SSEG from the DNO's network.

7.3 Notification of Commissioning

The installer shall notify the DNO that the SSEG has been installed at or before the time of commissioning in accordance with ESQCR Regulation 22. In addition within 30 working days of completing the commissioning of a SSEG installation, the Installer shall provide the local DNO with all relevant details on the SSEG installation as per Appendix 3.

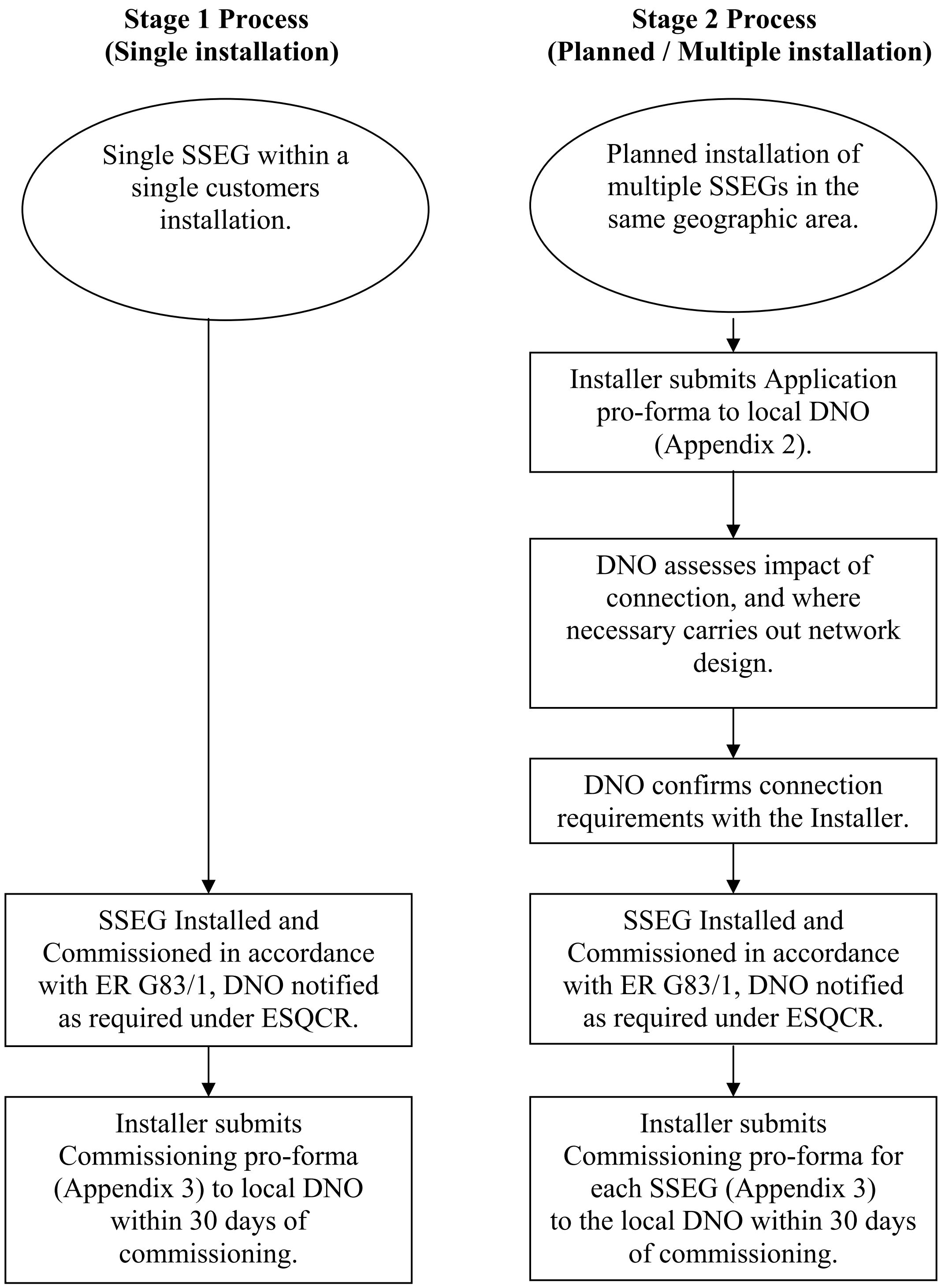
If during the lifetime of the SSEG it is necessary to replace a major component of the SSEG, it is only necessary to notify the DNO if the operating characteristics of the SSEG or the interface protection have been altered when compared against the unit that was originally commissioned.

7.4 Notification of Decommissioning

In the event that a SSEG Unit is to be decommissioned and will no longer operate as a source of electrical energy in parallel with the DNO's network, the User shall notify the DNO by providing the information as detailed under Appendix 5.

APPENDIX 1 CONNECTION PROCEDURE FLOW CHART

Note: The processes shown here only refer to the interface between the Installer and the DNO, it may also be necessary for the Installer / User to inform the relevant Meter Operator and Supplier that a SSEG has been installed.



APPENDIX 2 APPLICATION FOR CONNECTION

Application for the connection of multiple SSEG units in parallel with the public distribution Network – in accordance with Stage 2 of Engineering Recommendation G83/1. It is only necessary to submit one Application Pro-forma per multiple installation project.

This information is to be provided to the DNO prior to the installation of a SSEG unit(s) in order that a DNO can assess the potential impact that the connection will have on the Network.

Project Details	
Site / project address (inc. post code)	
Telephone number	
Customer supply number(s) (MPAN) use separate sheet if necessary	
Distribution Network Operator (DNO)	
Installer Details	
Installer	
Accreditation/Qualification:	
Address (incl post code)	
Contact person	
Telephone Number	
Fax Number	
E-mail address	
SSEG Details	
SSEG owner	
SSEG location within the installation	
Total number of SSEG units to be installed under this project, to include SSEG Unit capacity in kVA and location.	

Other Information to be Enclosed
SSEG type verification test certificate, to include the following information: • Manufacturer and model type • SSEG rating (A) and power factor • Single or Multi phase • Maximum peak short circuit current (A) • Type of prime mover and fuel source • Contact details – telephone numbers, web address etc.
Copy of system circuit diagram within the installation.
Earthing arrangements.
Site layout plan showing location of SSEGs - if applicable.
Declaration - to be completed by applicant
Comments (use separate sheet if necessary)
I declare that this installation has been designed to comply with the requirements of ER G83/1

Name and signature:	Date:
Accreditation/Qualification:	

DNO comments - to be completed by DNO representative following application	
A representative of the DNO will wish to witness the commissioning	yes/no
As a representative of the DNO, I give, in principle, permission for the connection of these SSEG units. If "no", see comments below	yes/no
Comments	

DNO:	Contact:	Date:

APPENDIX 3 SSEG INSTALLATION COMMISSIONING CONFIRMATION

Confirmation of commissioning of a SSEG unit connected in parallel with the public distribution Network – in accordance with Engineering Recommendation G83/1. One Commissioning Pro-forma per installation is to be submitted to the DNO.

Site Details	
Property address (inc. post code)	
Telephone number	
Customer supply number (MPAN)	
Distribution Network Operator (DNO)	
Contact Details	
SSEG owner	
Contact person	
Contact telephone number	
SSEG Details	
Manufacturer and model type	
Serial number of SSEG	
Serial number / version numbers of software (where appropriate)	
SSEG rating (A) and power factor (under normal running conditions)	
Maximum peak short circuit current (A)	
Type of prime mover and fuel source	
Location of SSEG within the installation	
Location of multi pole isolator	

Installer Details	
Installer	
Accreditation/Qualification:	
Address (incl post code)	
Contact person	
Telephone Number	
Fax Number	
E-mail address	

Information to be Enclosed	
Final copy of circuit diagram	
SSEG Test Report (Appendix 4) or web address if appropriate (not necessary if already provided e.g. under a Stage 2 connection)	
Computer print out (where possible) or other schedule of protection settings	
Electricity meter(s) make and model:	

Declaration - to be completed by Installer		
The SSEG installation complies with the relevant sections of Engineering Recommendation G83/1.		
Protection settings have been set to comply with Engineering Recommendation G83/1.		
The protection settings are protected from alteration except by prior written agreement between the DNO and the Customer or his agent.		
Safety labels have been fitted in accordance with section 6.2 of Engineering Recommendation G83/1.		
The SSEG installation complies with the relevant sections of BS7671 and an installation test certificate is attached.		
Comments (continue on separate sheet if necessary)		
Name:	Signature:	Date:

APPENDIX 4 TYPE VERIFICATION TEST SHEET

SSEG DETAILS

SSEG Type reference:		
SSEG Technology (as per Annex):		
Manufacturer:	Tel:	Address:
	Fax:	
Technical file reference No:		
Maximum export capability (SSEG rating less parasitic load)		

TEST HOUSE DETAILS

Name and address of test house	
Telephone number	
Facsimile number	
E-mail address	

TEST DETAILS

Date of test	
Name of tester	
Signature of tester	
Test location if different from above	

POWER QUALITY

Harmonic current emissions (A)								
Harmonic	2^{nd}	3^{rd}	5^{th}	7^{th}	9^{th}	11^{th}	13th	$15^{th} \leq n \leq 39^{th}$
Limit *	1.08	2.3	1.14	0.77	0.4	0.33	0.21	0.15 x (15/n)
Test value								

* Maximum permissible harmonic current As per BS EN 61000-3-2 Class A.

Voltage Fluctuations and Flicker				
	Starting	Stopping	Running	
Limit *	4%	4%	P_{st} = 1.0	P_{lt} = 0.65
Test value				

* Maximum permissible voltage fluctuation (expressed as a percentage of nominal voltage at 100% power) and flicker. As per BS EN 61000-3-3.

	DC injection			Power factor		
G83/1 Limit	20mA, tested at three power levels *			0.95 lag– 0.95 lead at three voltage levels		
Test level	10%	55%	100%	212 V	230 V	248 V
Test value #						

* Indicative values are shown for minimum, medium and maximum power levels.
# insert maximum value of dc injection and worst case pf value recorded during testing

UNDER / OVER FREQUENCY TESTS

	Under Frequency		Over Frequency	
Parameter	Frequency	Time	Frequency	Time
G83/1 Limit	47 Hz	0.5 sec *	50.5 Hz	0.5 sec *
Actual setting				
Trip value				

UNDER / OVER VOLTAGE TESTS

	Under Voltage		Over Voltage	
Parameter	Voltage	Time	Voltage	Time
G83/1 Limit	207 V	1.5 sec *	264 V	1.5 sec *
Actual setting				
Trip value				

Note: * For SSEG units that can withstand being re-energised from a source that is 180 degrees out of phase with the SSEG output, it is permissible to extend the operating time of the interface protection to 5.0 seconds, as described in 5.3.1. Table 1.

LOSS OF MAINS TEST

Method used			
Output power level *	10%	55%	100%
Trip setting			
Trip value			

* Indicative values are shown for minimum, medium and maximum power levels.

RECONNECTION TIMES

Reconnection Time	Under/Over voltage	Under/Over Frequency	Loss of mains
Minimum value	180 seconds	180 seconds	180 seconds
Actual Setting			
Recorded value			

FAULT LEVEL CONTRIBUTION

SSEG Short Circuit Test

This test should determine the value of short circuit current at the SSEG terminals as described in clause 5.7 in Engineering Recommendation G83/1.

For rotating machines and linear piston machines the test should produce a 0 – 2.0 second plot of the short circuit current as seen at the SSEG terminals.

SSEG Short Circuit Parameters

Parameter	Symbol	Value
Peak short-circuit current	i_p	
Initial value of aperiodic component	A	
Initial symmetrical short-circuit current *	I''_k	
Decaying (aperiodic) component of short-circuit current *	i_{DC}	
Reactance / Resistance Ratio of source *	$^X/_R$	

* Values for these parameters should be provided where the short circuit duration is sufficiently long to enable interpolation of the plot

SELF MONITORING – SOLID STATE SWITCHING

Test	Yes / No
It has been verified that in the event of the solid state switching device failing to disconnect the SSEG, the voltage on the output side of the switching device is reduced to a value below 50 volt within 0.5 sec.	

COMMENTS

APPENDIX 5 SSEG DECOMMISSIONING CONFIRMATION

Site Details	
Property address (inc. post code)	
Telephone number	
Customer supply number (MPAN)	
Distribution Network Operator (DNO)	
SSEG Details	
Manufacturer and model type	
Serial number of SSEG	
SSEG rating (A)	
Type of prime mover and fuel source	

Decommissioning Agent Details		
Name		
Accreditation/Qualification:		
Address (incl post code)		
Contact person		
Telephone Number		
Fax Number		
E-mail address		
Name:	Signature:	Date:

ANNEX A. NETWORK DESIGN CONSIDERATIONS

A1. General

In the event that the connection, or proposed connection, of a new SSEG unit(s) causes or is expected to cause operational difficulties for the DNO, the DNO in co-operation with the Installer / Manufacturer shall agree how best to alleviate these difficulties for example:

a. The Manufacturer may choose to make changes to the design and/or control of the SSEG; or

b. The DNO could propose changes / reinforcements to the distribution Network.

Note: The SSEG verification test certification may be invalidated if the protection settings are altered.

The generic impacts described below should be assessed when any SSEG is considered. However it is recognised that the majority of installations will comprise relatively small, single technology SSEGs hence the Network impact assessment required for such an installation can be much simplified.

The Annexes to this Engineering Recommendation contain information to assist in the assessment of Network impact for each SSEG technology group.

A2. LV Design Principles

Low voltage distribution Networks have been designed to cater for a unidirectional energy flow from the distribution substation to Customers installations. Network designs are based on After Diversity Maximum Demands (ADMDs) typically in the range 1-2kW per dwelling. The connection of multiple SSEG units could have an adverse effect on Network operation. Issues that need to be considered are identified below. Where a new low voltage infrastructure is intended to supply installations containing SSEGs, these factors should be considered at the design stage.

A3. Impact on Voltage Levels

A3.1 Over Voltage

Export from a SSEG will tend to increase the voltage profile on the LV Network. Under low load conditions, where voltages are at the upper end of the statutory voltage range (e.g. for installations close to the distribution transformer) the voltage level within the installation could increase above statutory limits and this could lead to nuisance tripping of the SSEG.

A3.2 Under Voltage

There is a risk that transient disturbances on the HV system could lead to voltage dips on the LV system which in turn could result in widespread tripping of SSEG units by operation of the undervoltage element within the Interface Protection. The original disturbance would then be compounded by the sudden increase in demand as the system supports the load that was previously supplied from the SSEGs.

A4. Short Circuit Levels

The connection of a SSEG unit or units to the low voltage Networks operated by DNOs and their Customers could result in the prospective short circuit current, from the source and the SSEG, exceeding the short circuit rating of equipment connected to the Network. The short circuit contribution from the SSEG must be considered to ensure that the single and three phase fault duty imposed on DNO and Customer’s equipment does not exceed the equipment rating.

The contribution to short circuit currents will depend upon the SSEG technology. As a general guide all SSEGs which supply electrical energy via the conversion of kinetic energy to electrical energy by electro-magnetic induction (e.g. Induction, Synchronous, Permanent Magnet, or Solenoid generators) can have a significant short circuit contribution to fault level.

A5. System Loading

Low voltage distribution systems have been designed with the assumption that power flows from the substation out to the Customer’s installations. With the wider introduction of SSEGs, the direction of power flow may reverse. The DNO may need to make an assessment of the magnitude and direction of power flow to ensure equipment thermal ratings are not exceeded.

A6. Voltage Unbalance

For multiple installations of single-phase SSEG units (e.g. housing estates), balancing the SSEG generation evenly against the load on the phases will need to be considered. Voltage unbalance is considered in Engineering Recommendation P29.

A7. HV design principles

The connection of significant quantities of SSEGs in the low voltage Network could have an adverse impact on the 11kV and higher voltage Networks. The issues are similar to those for the low voltage Network. In particular the impact of voltage changes and its effect on primary voltage control needs to be carefully considered.

A8. Metering

Metering is a matter for the Customer / User to agree with his Supplier and Meter Operator. However, it is worth noting that the typical single-phase electrical energy meter is designed to measure power flow in one direction only, typically from the public Network to the Customer, and should there be energy flow in the reverse direction then the meter may stop registering or register incorrectly.

A9. Energy Export

Unless advised otherwise the DNO should assume that any particular SSEG could export 100% of rating at any particular time.

A10. Information required by the DNO

In order to manage the impact on the Network, assess the contribution to Network capacity, maintain accurate records of SSEG installations and to meet the licence requirement to design and operate an efficient system, the local DNO will require certain generic information from the SSEG Installer, as detailed in the Appendices.

ANNEX B. DOMESTIC CHP (DCHP)

Bl. CERTIFICATION & TYPE TESTING GENERAL ARRANGEMENTS

This annex describes, in generic terms, a methodology for obtaining type certification and type verification for the SSEG incorporated in a small-scale CHP unit.

B2. CE MARKING AND CERTIFICATION

A small-scale CHP unit supplies heating and hot water to a domestic or light commercial environment as well as generating electrical power via a SSEG. It is necessary for the small scale CHP unit to be fitted with equipment that monitors the voltage and frequency.

The SSEG protection, monitoring and control functions may be incorporated into the small scale CHP unit control system, or may be fitted as discrete remotely mounted devices. In both cases the small scale CHP unit may be required to be submitted for Type Certification with the Protection Control either as a part of the appliance or as a separate control. There are several EU Directives that must be complied with, before the product can be supplied in the EU. The EU Directives that apply will to some extent depend on the design of the appliance and type of fuel or energy source used. The two EU directives that will almost certainly apply are the Low Voltage Directive and the EMC Directive.

The Type Testing procedure requires that the SSEG be certificated to the relevant requirements of the applicable Directives before the unit can be labelled with a CE marking. Where the protection control is to be provided as a separate device, this must also be Type Tested and certificated to the relevant requirements of the applicable Directives before it can be labelled with a CE marking. Currently small scale CHP units have no harmonised functional Standards that apply to the Interface Protection and will therefore require functional type verification as described in this annex and in Appendix 4.

B3. TYPE VERIFICATION FUNCTIONAL TESTING OF THE INTERFACE PROTECTION

Type verification testing is the responsibility of the Manufacturer. These tests are designed to verify that the SSEG Interface Protection will result in the safe disconnection of the SSEG from the DNOs Network. The Manufacturer may choose to carry out these tests himself or engage the services of a recognised test house to carry out the tests on his behalf.

Wherever possible the type verification testing of a particular SSEG or an appliance containing a SSEG component should be proved under normal conditions of operation for that technology (unless otherwise noted). For the loss of mains protection test it will require that the chosen SSEG Interface Protection is either incorporated into the system controls or is a discrete device connected to the SSEG, or appliance containing a SSEG component. Testing the voltage and frequency functions may be carried out either on the discrete protection device independently or on the SSEG complete. In either case it will be necessary to verify that a protection operation will disconnect the SSEG from the DNOs Network. For all tests of the Interface Protection it will be necessary to ensure that the operating levels (trip values) do not exceed the maximum values allowed under Table 1.

The manufacturer must declare the ambient operating temperature range of the SSEG, and verify that the interface protection will operate satisfactorily throughout this temperature range.

B3.1 Over / Under Voltage

The operation of the SSEG under/over voltage protection can be verified either under normal operating conditions (i.e. tripping the generator) or independently of the generator if suitable test attachments are provided. Operation of the under/over voltage protection will be demonstrated for each of the voltage ranges defined in section 5. For each voltage trip setting (upper and lower) the protection should operate within the specified trip times when the voltage is within ± 1.0% of the trip setting, e.g. for an overvoltage setting (upper) of 260V the permissible operating range is 260 V ± 2.6 V. The test voltage should be applied in steps of ± 1.0% of setting for a duration that is longer than the trip time delay, for example 2 seconds in the case of a delay setting of 1.5 seconds. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time, the test voltage at which this trip occurred is to be recorded as the certificated trip voltage.

B3.2 Over / Under Frequency

The operation of the SSEG under/over frequency protection can be verified either under normal operating conditions (i.e. tripping the generator) or independently of the generator if suitable test attachments are provided. In either case it will be necessary to verify that a protection operation will disconnect the SSEG from the DNOs Network.

Operation of the under/over frequency protection will be demonstrated for an increase or decrease of frequency within ± 0.5% of the trip settings, e.g. for an Over Frequency setting of 50.5 Hz the permissible operating range is 50.5 ± 0.2525 Hz. The test frequency should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 1 second in the case of a delay setting of 0.5 second. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time, the test frequency at which this trip occurred is to be recorded as the certificated trip frequency. The ramp rate should be sufficiently low to ensure that the loss of mains (LoM) relay remains stable during this test. It should not be necessary to disable LoM protection as the approach rates are deliberately specified to be less than the LoM trip settings.

B3.3 Loss of Mains Protection

Faults on a distribution Network are normally cleared by protection located close to a fault. This can result in an embedded generator supplying part of the Network that is disconnected, or islanded from the normal grid supplies. This event is known as a “Loss of Mains”. For reasons of safety, all embedded generators supplying the islanded part of the Network must be disconnected until the DNO protection operations have cleared and normal Network supplies have been restored.

Under most circumstances it is unlikely that a Small-Scale Embedded Generator will be able to supply the load connected to the islanded Network, indeed it may be severely overloaded. Over-current protection is recommended to protect the generator in this case. There remains a low but finite probability that a Small-Scale Embedded Generator will be able to supply the load connected to the islanded Network. Under these circumstances the generator will be operating under nominal conditions and therefore an additional protective device is required to recognise the Loss of Mains event and disconnect the generator.

Loss of Mains protection that is based on low power flow or reverse power flow is not suitable, because under certain conditions the SSEG may export.

Examples of SSEG protection systems suitable for Loss of Mains protection include but are not limited to existing accepted techniques such as Rate of Change of Frequency (ROCOF) and Vector Shift. Irrespective of which protection system is used, protection settings shall be applied that ensure tripping of the generator within 0.5 seconds for a change in load at the generator terminals in excess of ± 25%.

To model the interaction between local load and multiple parallel connected SSEGs the SSEG unit under test shall be connected to a Network combining two identical SSEG units and a variable load; the value of the load is to closely match the output of the two SSEG units and should have a power factor of 0.95 lagging – see Figure B1. To facilitate the test for loss of mains there shall be a switch (S) placed between the test load and SSEG combination and the DNO's distribution system, as shown below:

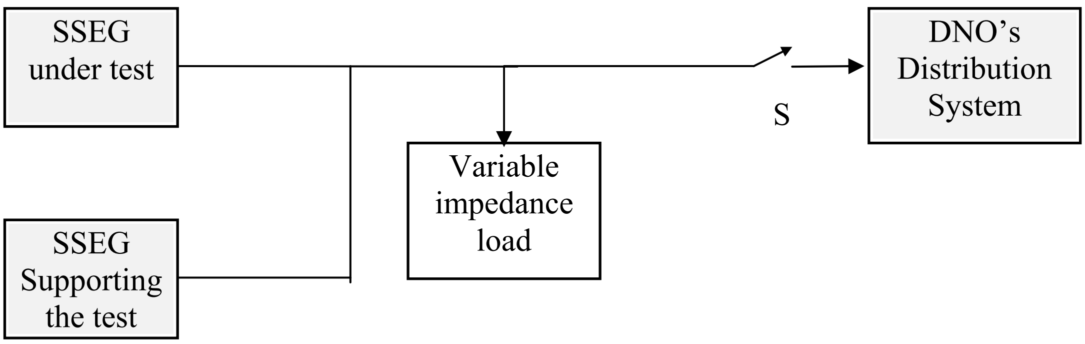


Figure B1. SSEG Test set up - Loss of Mains

The purpose of the test is to demonstrate that the LoM protection equipment is able to recognise a change of load condition associated with a LoM event and to disconnect the SSEG equipment within the required time. The SSEG equipment is to be tested at three levels of output power: minimum load, maximum load and at a point midway between the two. At each level of output power the SSEG equipment is to be tested for both positive and negative load changes. Each test is to be repeated five times.

For positive load change the variable impedance load is set at 125% (± 1%) of load match of the above power levels. For negative load change the variable impedance load is set at 75%

(± 1%) of load match of the above power levels. Load match conditions are defined as being when the power from the SSEG connected generator meets the requirements of the test load i.e. there is no appreciable export or import of power to or from the DNO's distribution system.

The tests will record the SSEG output voltage and frequency from at least 2 cycles before the switch is opened until 0.6 seconds after the switch is opened. The time from the test switch opening until the protection isolation occurs is to be measured and must comply with the requirements of section 5, under all conditions of output power.

B3.4 Re-connection

Following a protection initiated disconnection the SSEG is to remain disconnected from the DNOs Network until the voltage and frequency at the Supply Terminals has remained within the nominal limits for at least 3 minutes.

B4. POWER QUALITY

B4.1 Harmonics

The harmonic emissions from the SSEG shall be measured in accordance with BS EN 61000-3-2.

B4.2 Power Factor

For this test, the SSEG supplies full load at steady state conditions to an infinite busbar (DNO Distribution System) via the power factor (pf) meter and a Variac of rating equal to or greater than the SSEG as shown below. The SSEG pf should be in the range of 0.95 lagging to 0.95 leading inclusive, for three test voltages 230V – 8% (211.6), 230V and 230V + 8% (248.4). The test circuit is shown below.

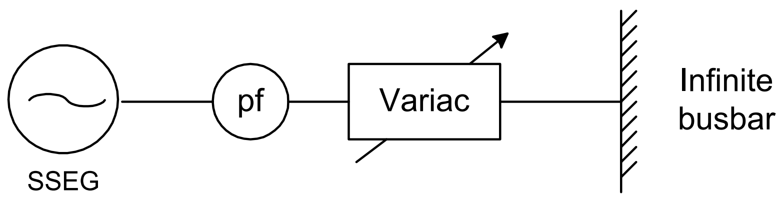


Figure B2. SSEG Test set up – Power Factor

Note 1: For reasons of clarity the points of disconnection are not shown
Note 2: It is permissible to use a voltage regulator or tapped transformer to perform this test rather than a variac as shown

B4.3 Voltage Fluctuations and Flicker

The voltage fluctuations and flicker emissions from the SSEG shall be measured in accordance with BS EN 61000-3-3. The operation of the SSEG including starting and stopping shall not result in a voltage change in excess of 4% of nominal voltage at the SSEG terminals when connected to a reference impedance Network, as defined in IEC 60725.

B4.4 DC Injection

The level of dc injection from the SSEG in to the DNO Network shall not exceed 20mA.

B4.5 Over Current Protection

Over current protection shall be provided to protect both the SSEG and the installation connected to the SSEG; the protection shall comply with the appropriate requirements of BS7671.

B4.6 Short Circuit Current Contribution

The SSEG short circuit parameters, as described in clause 5.8, shall be determined by means of a short circuit test conducted in a similar manner to that for larger generators as described in BS EN 61034-4.

ANNEX C. PHOTO-VOLTAIC (PV)

C1. CERTIFICATION & TYPE TESTING GENERAL ARRANGEMENTS

This Annex describes a methodology for obtaining type certification or type verification for the interface equipment between the PV SSEG and the Distribution Network. Typically, all interface functions are contained within the inverter and in such cases it is only necessary to type test the inverter. Alternatively, a package of specific separate parts of equivalent function may also be type tested.

Note 1: These requirements are based on those in Engineering Recommendation G77/1 (2002), which was withdrawn on the day when Engineering Recommendation G83/1 was published. However, an inverter previously certified to G77 type tests is by default considered as being certified in accordance with G83/1.

Note 2: Attention is drawn to Note 2 in the Scope of Engineering Recommendation which allows the DNO the opportunity to apply ER G83/1 to SSEG units rated above 16A per phase, e.g. 5kVA as per Engineering Recommendation G77/1 (now withdrawn). In line with this, inverters greater than 16A can be submitted to the type testing process.

Note 3: Other Annexes containing inverter connected equipment may make reference to the requirements specified in this Annex.

Note 4: This Annex applies for PV SSEG systems either with or without a battery bank

C2. CE MARKING AND CERTIFICATION

The type verification procedure requires that the SSEG interface be certified to the relevant requirements of the applicable Directives before the unit can be labelled with a CE mark. Where the protection control is to be provided as a separate device, this must also be Type Tested and certified to the relevant requirements of the applicable Directives before it can be labelled with a CE mark.

Currently there are no harmonised functional Standards that apply to the PV SSEG Interface Protection, therefore the inverter and any separate Interface Protection unit will require functional type verification as described in this Annex, and recorded in format similar to that shown in Appendix 4.

C3. TYPE VERIFICATION FUNCTIONAL TESTING OF THE INTERFACE PROTECTION

Type verification testing is the responsibility of the manufacturer. This test will verify that the operation of the SSEG interface protection shall result in the safe disconnection of the SSEG from the DNO's network. The manufacturer may choose to carry out the tests himself or engage the services of a recognised test house to carry out the tests on his behalf.

Wherever possible the type verification testing of a particular SSEG interface should be proved under normal conditions of operation for that technology (unless otherwise noted). This will require that the chosen SSEG Interface Protection is either already incorporated into the system controls or the discrete device is connected to the SSEG or appliance containing an SSEG component for the loss of mains protection test. Testing the voltage and frequency functions may be carried out on the discrete protection device independently or on the SSEG complete. In either case it will be necessary to verify that a protection operation will disconnect the SSEG from the DNO's network. In the case of PV inverters the current practice is to incorporate the interface protection within the inverter.

It should be noted in the test circuits below that the simulation of a PV array by a constant dc source in parallel with a diode presents some difficulties in performing some of these test procedures. The operation of the maximum power point tracker (all practical inverters include such a circuit) may interfere with testing when a simulated dc source is used. This can make the tests unduly severe, therefore it is recommended that a PV array is used whenever possible. The output of the source should remain stable within ± 5% for the duration of the test.

The manufacturer must declare the ambient operating temperature range of the SSEG, and verify that the interface protection will operate satisfactorily throughout this temperature range.

C3.1 Disconnection times

The required disconnect times, for tests in C3.2, C3.3 and C3.4, are presented in Table 1 in the Generic Section.

The required trip time is dependent on whether the inverter is able to withstand a 180 degree out of synchronisation re-connection. To guard against the risk of a non-synchronised connection between the inverter and the DNO's system (possibly as a result of the DNO's system being re-energised after a system fault), the inverter shall be tested for connection to a mains supply which is 180 degrees out of phase and at peak voltage to ensure no damage occurs. This test is not required for inverters with trip times ≤0.5 Seconds

For all tests of the Interface Protection it will be necessary to ensure that the operating levels (trip values) do not exceed the maximum values allowed under in Table 1.

For tests C3.2, C3.3 and C3.4, reconnection shall be checked as detailed in C3.5 below.

C3.2 Over / Under Voltage

The inverter equipment within the PV SSEG shall be tested by operating the SSEG in parallel with a variable ac test supply, see figure C1. Correct protection operation shall be confirmed at three power outputs, 10%, 55% and 100% of full power rating of the inverter. The set points for over and under voltage at which the inverter system disconnects from the supply will be established by varying the ac supply voltage. It should be noted that the trip settings quoted in Table 1 are maximum and minimum settings to be achieved on the network, and the actual value programmed into the inverter can be set to be within these to take into account the accuracy achieved by the inverter, within the limits set out below:

The Interface Protection should operate within the specified trip times of Table 1 when the voltage is at or within 1.5% of the trip setting of the inverter. For example an inverter with a stated accuracy of ±1.5% could be set with an overvoltage setting of 260V on the basis that the overvoltage protection should operate when the terminal voltage is in the range of 256.1V – 263.9V (260 ± 1.5%). The test voltage should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 2 seconds in the case of a delay setting of 1.5 seconds. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time, the test voltage at which this trip occurred is to be recorded as the certificated trip voltage. Test results should be recorded on the Test Sheet shown in Appendix 4.

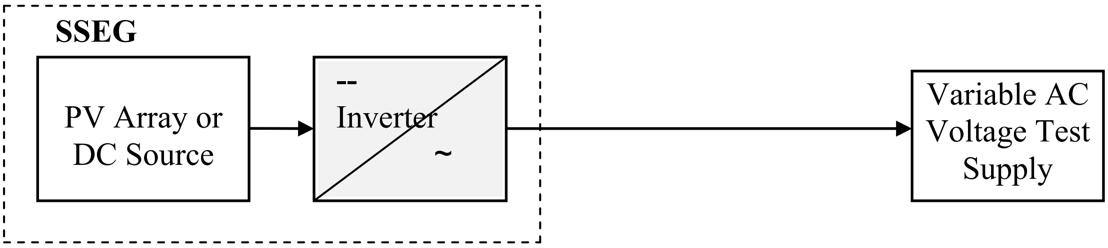


Figure C1. SSEG Test set up – Over / Under Voltage

C3.3 Over / Under Frequency

The inverter equipment within the PV SSEG shall be tested by operating the SSEG in parallel with a low impedance, variable frequency test supply system, see figure C2. Correct protection operation shall be confirmed at three power outputs, 10%, 55% and 100% of full power rating of the inverter. The set points for over and under frequency at which the inverter system disconnects from the supply will be established by varying the test supply frequency. It should be noted that the trip settings quoted in Table 1 are maximum and minimum settings to be achieved on the network, and the actual values programmed into the inverter can be set to be within these to take into account the accuracy achieved by the inverter, within the limits set out below:

Operation of the under/over frequency protection will be demonstrated for an increase or decrease of frequency within ± 0.5% of the trip settings, e.g. for an Over Frequency setting of 50.5 Hz the permissible operating range is 50.5 ± 0.2525 Hz. The test frequency should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 1 second in the case of a delay setting of 0.5 second. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time, the test frequency at which this trip occurred is to be recorded as the certificated trip frequency. The ramp rate should be sufficiently low to ensure that the loss of mains (LoM) relay remains stable during this test. It should not be necessary to disable LoM protection as the approach rates are deliberately specified to be less than the LoM trip settings. The results should be recorded on the Test Sheet of Appendix 4.

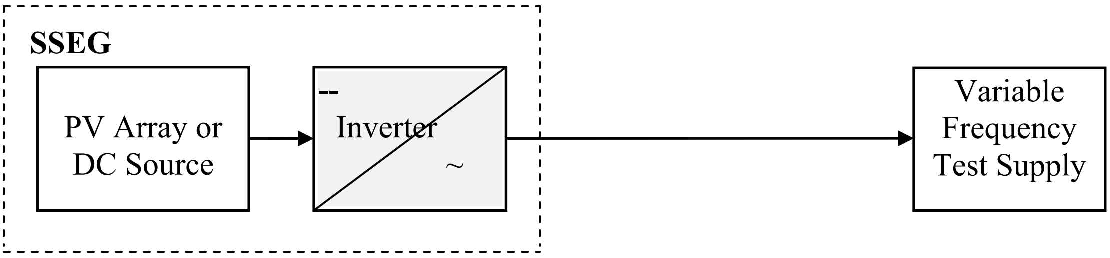


Figure C2. SSEG Test set up – Over / Under Frequency

C3.4 Loss of Mains Protection

For PV SSEGs the following test has been designed to verify correct operation. The resonant test circuit has been designed to model the interaction of the inverter under test with the local load including multiple parallel connected PV SSEGs.

The inverter equipment shall be fed from a dc source or PV array. The inverter output shall be connected to a network combining a resonant circuit with a Q factor of >0.5 and a variable load; the value of the load is to match the inverter output. To facilitate the test for loss of mains there shall be a switch placed between the test load/inverter combination and the DNO's distribution system, as shown below:

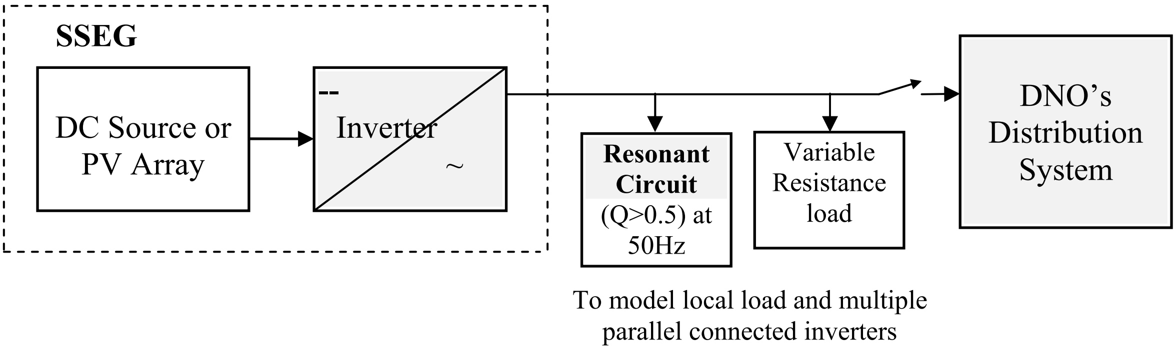


Figure C3. SSEG Test set up - Loss of Mains

- The inverter equipment is to be tested at three levels of inverter output power: 10%, 55% and 100% and the results recorded on the Test sheet of Appendix 4.
- Each test is to be repeated five times.
- For each test the Load Match is to be within +/- 5%.
- Load match conditions are defined as being when the current from the inverter-connected generator meets the requirements of the test load i.e. there is no export or import of supply frequency current to or from the DNO's distribution system

The tests will record the inverter output voltage and frequency from at least 2 cycles before the switch is opened until the inverter protection system operates and disconnects itself from the DNO's distribution system, or for five seconds whichever is the lower duration.

The time from the switch opening until the protection disconnection occurs is to be measured and must comply with the requirements of Table 1 of this Engineering Recommendation under all conditions of output power and test load.

C3.5 Re-connection

Further tests will be carried out with the three test circuits above to check the inverter time-out feature prior to automatic network reconnection. This test will confirm that once the ac supply voltage and frequency have returned to their nominal values following an automatic protection trip operation there is a minimum time delay of 3 minutes (clause 5.3.3) before the inverter output is restored (i.e. before the inverter automatically reconnects to the network).

C4. POWER QUALITY

C4.1 Harmonics

The harmonic emissions from the SSEG shall be measured in accordance with BS EN 61000-3-2.

C4.2 Power Factor

For this test, the inverter can be fed by a dc source to simulate the dc output of a PV generator. The test set up shall be such that the inverter supplies full load to the DNO system via the power factor (pf) meter and the variac as shown below. The inverter pf should be within the limits given in Clause 5.7, for three test voltages 230 V –8%, 230V and 230 V + 12.7%.

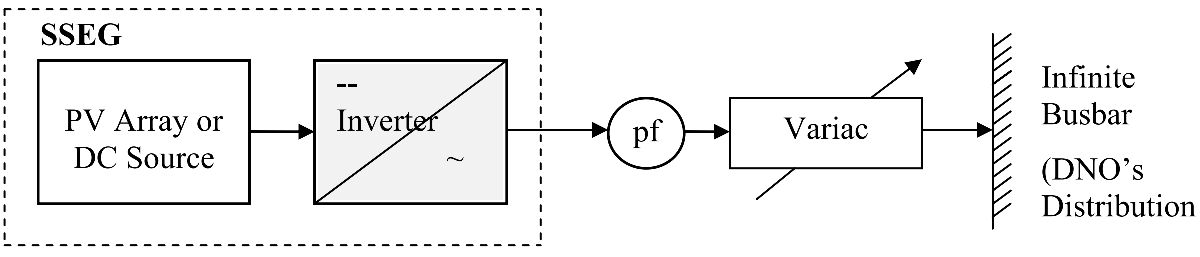


Figure C4. SSEG Test set up – Power Factor

Note 1: for reasons of clarity the points of isolation are not shown
Note 2: It is permissible to use a voltage regulator or tapped transformer to perform this test rather than a variac as shown

C4.3 Voltage Flicker

The voltage fluctuations and flicker emissions from the SSEG shall be measured in accordance with BS EN 61000-3-3.

C4.4 DC Injection

The level of dc injection from the inverter-connected PV generator in to the DNO network shall not exceed 20mA when measured during tests C3.2, C3.3, C3.4 and C4.2. This condition is satisfied by installation of a transformer on the ac side of the inverter-connected PV generator.

C4.5 Over Current Protection

Over current protection shall be provided to protect both the SSEG and the installation connected to the SSEG. Where appropriate the protection shall comply with the requirements of BS7671.

C4.6 Short Circuit Current Contribution

As Photovoltaic SSEGs are inverter connected, they are deemed to automatically comply with clause 5.8 and no further tests are required.

Note: Inverter connected Photovoltaic SSEGs generally provide a small short circuit fault current only slightly above the full load current, typically below 1.5 x I (full load) for a few milliseconds.

C4.7 Self Monitoring - Solid State Disconnection

Some small PV inverters include solid state switching devices to disconnect from the DNO's network. In this case Clause 5.3.1 requires the control equipment to monitor the output stage of the inverter to ensure that in the event of a protection initiated trip the output voltage is either disconnected completely or reduced to a value below 50 volts ac. This shall be verified either by self-certification by the manufacturer, or additional material shall be presented to the tester sufficient to allow an assessment to be made.

C4.8 Electromagnetic Compatibility (EMC)

All equipment shall comply with the generic EMC standards:
BS EN61000-6-3: 2001 Electromagnetic Compatibility, Generic Emission Standard
BS EN61000-6-1: 2001 Electromagnetic Compatibility, Generic Immunity Standard

C4.9 PV System Electrical Installation

Electrical Installation of PV systems is covered by a new section of IEC 60364-7-712 'Electrical installations of buildings – Special installations or locations – Solar photovoltaic

(PV) power supply systems'. It is expected that these regulations will be harmonised into the UK wiring regulations BS7671. An interpretation for the UK can be found in the DTI 'Photovoltaics in Buildings – Guide to the installation of PV systems' currently available on the DTI website www.dti.gov.uk/renewable.

ANNEX D. FUEL CELLS (FC)

D1. SCOPE OF ANNEX

This annex covers the certification and type testing arrangements for the following Fuel Cell (FC) systems: FC CHP systems; FC 'electric power only' systems; FC and battery storage hybrid systems (or other Energy Storage System (ESS)) for both CHP and 'electric power only' systems. This annex does not cover possible networked operation of a number of fuel cell units e.g. as a 'virtual' power plant.

D2. BACKGROUND TO FUEL CELLS AS SSEGS

A Fuel Cell (FC) is a device that allows the direct electrochemical conversion of the stored energy from a fuel source, into electric and thermal energy. The electrical energy produced is in the form of direct current (dc) power. This is principally achieved by the catalytic reaction of either hydrogen gas, or the reformate of a hydrogen rich fuel gas/liquid such as methane or methanol, with oxygen gas to form water vapour.

$$2H_2 + O_2 \Rightarrow 2H_2O + electrical\ energy + heat$$

Fuel cells are often described as 'continuously operating batteries' whereby power will continue to be produced as long as fuel gases are continuously present. They also have a broadly similar voltage/current relationship to batteries, characterised by a low single cell voltage (at full load) of typically 0.9 – 0.6V dc per cell (or theoretical Nernst voltage minus losses) and produce a current level commensurate with the cross-sectional area of the active electrodes (effectively the active chemical reaction area). This leads to a typically low voltage/high current characteristic per cell and hence a fuel cell SSEG will normally consist of a number of cells connected in a series/parallel arrangement to produce the optimum voltage/current profile for a declared power rating.

Fuel cells may be irreparably damaged and enter a state of electrolysis if power is permitted to flow back from the DNO's system and into the fuel cell. Under such conditions hydrogen and oxygen gases may be generated causing a potential explosion/fire risk. This condition must be prevented by either suitable power electronic 'blocking' of reverse power flow with associated monitoring of direction of current flow, or by appropriate monitoring of the fuel cell voltage (recognising that a minimum cell voltage of 1.23V dc is required to electrolyse water). The use of a power electronic inverter will act as a suitable reverse power 'blocking' element. As a reverse power flow condition in such a system would necessitate the malfunction of multiple elements (within the inverter and 'blocking' diode if fitted) then this condition does not have to be specifically tested for.

Additionally some FC types, particularly those that incorporate natural gas reformers, have limitations on the rate of change of current that may be drawn from the fuel cell due to gas delivery and thermal considerations. There may also be considerable differences between the rate of rise of current achievable from a 'cold' and 'hot' start up. Similarly, some FC types can not shed load instantaneously and a 'dump' load (typically comprising a fully rated resistive load) may be incorporated within the FC SSEG to transfer the FC SSEG power output to in the event of a sudden load disconnection. These FC characteristics do not directly impinge on the safety of the connection to the public low voltage distribution Network or the power quality supplied from a FC SSEG, and hence tests to define these characteristics are not included in this Annex.

A FC SSEG may be described as shown in Figure D1.

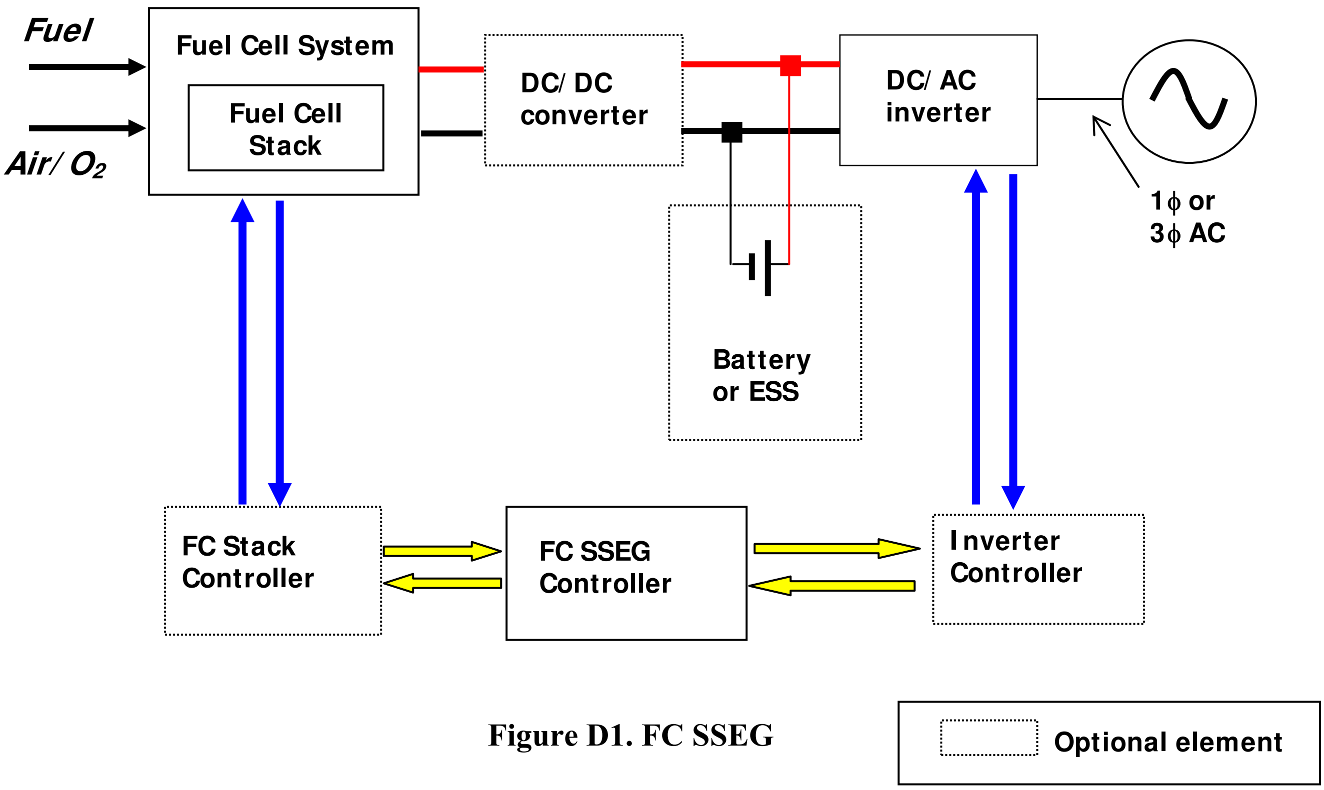


Figure D1. FC SSEG

Figure D1 shows the main constituent parts of a typical FC SSEG, however there are a number of potential 'options' available to developers that require explanation for this Annex:

a. The fuel for the FC stack may be derived from reformed natural gas or other hydrocarbon source. In such a case a reformer unit may be incorporated as part of the overall FC SSEG or, indeed, some FC types can perform a direct internal reformation of natural gas (e.g. a Solid Oxide FC). The use of an external reformer will affect the electrical performance of the FC SSEG due to the gas flow and reaction dynamics associated with it's operation and resulting impact on fuel flow to the FC stack. This Annex is intended to cover FC SSEGs either having a reformer unit or without such a unit.

b. A dc/dc converter may be required to boost low FC output dc voltages to a suitable level for use with existing inverters. Alternatively due to FC stack design (i.e. FC has suitable dc output voltage level) or appropriate inverter input design, a dc/dc converter may not be required.

c. A battery or other Energy Storage System (ESS) may be incorporated within an overall FC SSEG, to assist the FC SSEG to meet load peaks. From the point of grid connection the FC SSEG would then be viewed as a combined FC/battery source. Alternatively the battery or ESS may not be included.

d. The FC stack and inverter modules may have dedicated controllers as well as an overall FC SSEG controller (or other overall co-ordination of controller functions). In some instances this combination of controllers may be a single unit. Electrical interface protection settings would be programmed either into an individual inverter controller or the overall FC SSEG depending on manufacturer configuration.

D3. CE MARKING & CERTIFICATION

The fuel cell stack/module/system must have been tested and be able to demonstrate compliance with an appropriate fuel cell standard e.g. IEC 62282-3-2, ‘ Stationary Fuel cell power plants’ or equivalent (e.g. ANSI Z21.83-1998 or CSA FC1 due to replace Z21.83).

Note: IEC 62282 Standards remain in draft committee form at present and have not been formally accepted as National standards as of April 2003.

Compliance must also be demonstrated with appropriate EU Directives, principally the Low Voltage Directive and the EMC Directive. Each FC SSEG must also be tested and certificated with a CE mark.

If the FC SSEG utilises reformed natural gas from an integral gas reformer unit then compliance may also have to be demonstrated with the European Gas Appliance Directive and various Parts of the UK Building Regulations. If the fuel cell operates at pressure then there may be possible compliance obligations with pressure vessel regulations.

Demonstration of compliance with these Directives and CE marking is the responsibility of the FC SSEG manufacturer.

D4. TYPE VERIFICATION FUNCTIONAL TESTING OF THE INTERFACE PROTECTION

As the FC SSEG will connect to DNO’s distribution system via an inverter, much of the type verification testing and Interface Protection requirements will be as per the requirements defined for Photovoltaic Inverter connected SSEGs, as described in Annex C.

The type verification testing of the interface protection of the FC SSEG is the responsibility of the manufacturer and should be carried using the FC SSEG as a power source i.e. not using a dc power source as an equivalent. The manufacturer may choose to carry out the tests himself or engage the services of a recognised test house to carry out the tests on his behalf. In all instances the protection settings should not be capable of adjustment by the user.

A FC SSEG is a controllable dc power source and requires to be grid connected via an inverter. Typically the inverter/FC SSEG will employ a load power control signal rather than a maximum power point tracking system as used by PV inverters. A FC SSEG may, however, use an inverter primarily designed for PV but will typically employ additional power control mechanisms.

For all tests of the Interface Protection it will be necessary to ensure that the operating levels (trip values) do not exceed the maximum values allowed under Table 1.
The manufacturer must declare the ambient operating temperature range of the SSEG, and verify that the interface protection will operate satisfactorily throughout this temperature range.

D4.1 Disconnection Times

The required disconnect times, for tests in D4.2, D4.3 and D4.4, are presented in Table 1 in Clause 5.3.1. Note that the required trip time is dependent on whether the inverter is able to withstand a 180 degree out of synchronisation re-connection.

For tests D4.2, D4.3 and D4.4, reconnection shall be checked as in D4.5.

D4.2 Under/Over Voltage Protection

The inverter equipment within the FC SSEG shall be tested by operating the SSEG in parallel with a variable ac test supply, see figure D2. Correct protection operation shall be confirmed at three power outputs, 10%, 55% and 100% of full power rating of the inverter. The set points for over and under voltage at which the inverter system disconnects from the supply will be established by varying the ac supply voltage. It should be noted that the trip settings quoted in Table 1 are maximum and minimum settings to be achieved on the network, and the actual value programmed into the inverter can be set to be within these limits to take into account the allowable accuracy range of the inverter.

The Interface Protection should operate within the specified trip times of Table 1 when the voltage is at or within 1.5% of the trip setting of the inverter. For example an inverter with a stated accuracy of ±1.5% could be set with an overvoltage setting of 260V on the basis that the overvoltage protection should operate when the terminal voltage is in the range of 256.1V – 263.9V (260 ± 1.5%). The test voltage should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 2 seconds in the case of a delay setting of 1.5 seconds. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time, the test voltage at which this trip occurred is to be recorded as the certificated trip voltage. Test results should be recorded on the Test Sheet shown in Appendix 4.

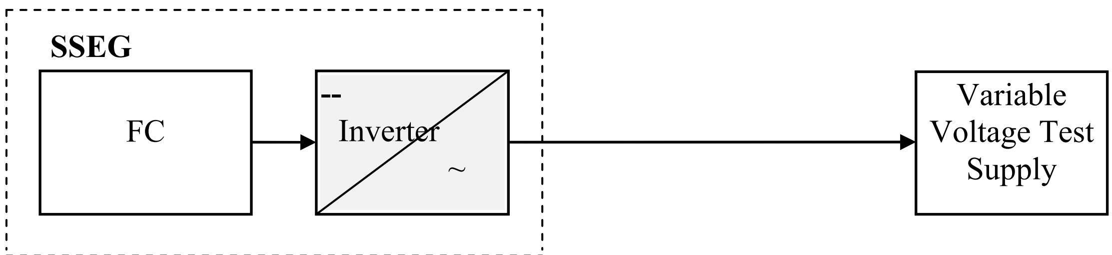


Figure D2 SSEG Test set up – Over / Under Voltage

D4.3 Under/Over Frequency Protection

The inverter equipment within the FC SSEG shall be tested by operating the SSEG in parallel with a low impedance; variable frequency test supply system, see figure D3. Correct protection operation shall be confirmed at three power outputs, 10%, 55% and 100% of full power rating of the inverter. The set points for over and under frequency at which the inverter system disconnects from the supply will be established by varying the test supply frequency. It should be noted that the trip settings quoted in Table 1 are maximum and minimum settings to be achieved on the network, and the actual values programmed into the inverter can be set to be within these to take into account the accuracy achieved by the inverter, within the limits set out below.

Operation of the under/over frequency protection will be demonstrated for an increase or decrease of frequency within ± 0.5% of the trip settings, e.g. for an Over Frequency setting of 50.5 Hz the permissible operating range is 50.5 ± 0.2525 Hz. The test frequency should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 1 second in the case of a delay setting of 0.5 second. It will be necessary to carry out five tests for each trip setting, the longest trip time is to be recorded as the certificated trip time, the test frequency at which this trip occurred is to be recorded as the certificated trip frequency. The ramp rate should be sufficiently low to ensure that the loss of mains (LoM) relay remains stable during this test. It should not be necessary to disable LoM protection as the approach rates are deliberately specified to be less than the LoM trip settings. The results should be recorded on the Test Sheet of Appendix 4.

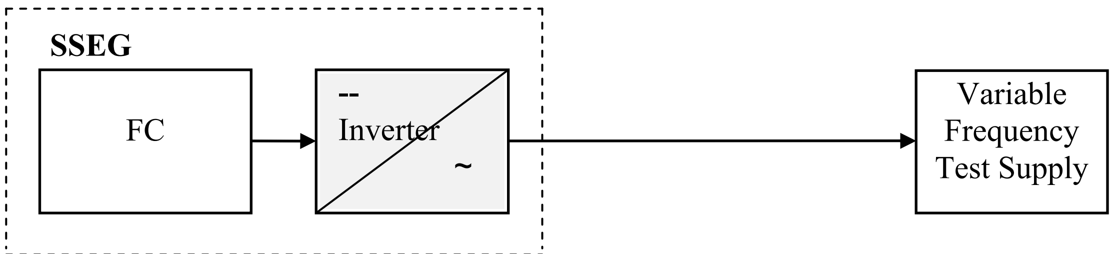


Figure D3 SSEG Test set up - O/U Frequency

D4.4 Loss of Mains Protection (LoM)

The following test has been designed to verify correct operation of the Loss of Mains (LoM) protection.

The LoM test circuit for the FC SSEG is shown in figure D4. The inverter equipment within the FC SSEG to be tested is connected in parallel with the DNO's network via a test circuit. The test circuit shall include a resonant circuit with a Q factor of >0.5 and a variable load; the value of the load is set to match the inverter output. The test circuit is designed to simulate the affect of other inverter connected SSEGs. To facilitate the test for loss of mains there shall be a switch placed between the test load/inverter combination and the DNO's distribution system, as shown in figure D4.

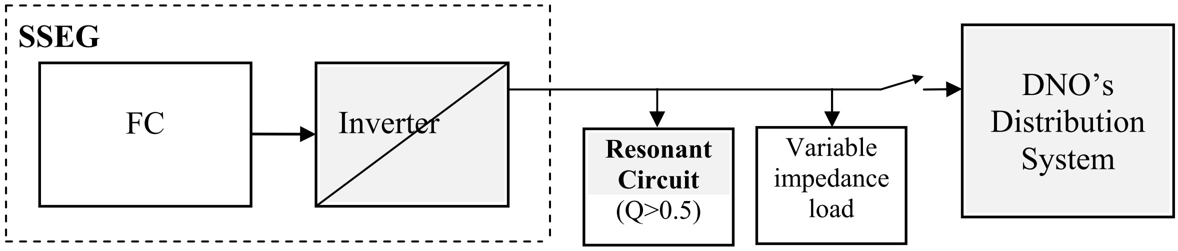


Figure D4: SSEG Test set up – LoM protection

The following conditions apply:

- The inverter equipment is to be tested at three levels of inverter output power, preferably 10%, 55% and 100% of full power rating of the inverter and the results recorded on the Test Sheet of Appendix 4. In instances where the FC SSEG is designed to shut down at a load level greater than 10% (e.g. due to losses associated with balance of plant items) then the tests shall be done at the lowest operating power level stated for the FC SSEG, 55% and 100%. In all such instances the lowest operating power level for the SSEG shall be defined and stated.10%, 55% and 100%.

- Each test is to be repeated five times.

- For each test the Load Match is to be within +/- 5%.

- Load match conditions are defined as being when the current from the inverter-connected generator meets the requirements of the test load i.e. there is no export or import of supply frequency current to or from the DNO's distribution system

The tests will record the inverter output voltage and frequency from at least 2 cycles before the switch is opened until the inverter protection system operates and disconnects itself from the DNO's distribution system, or for five seconds whichever is the lower duration.

The time from the switch opening until the protection disconnection occurs is to be measured and must comply with the requirements of this Engineering Recommendation under all conditions of output power and test load.

D4.5 Re-connection

Further tests will be carried out with the three test circuits above to check the inverter time-out feature prior to automatic network reconnection. This test will confirm that once the ac supply voltage and frequency have returned to their nominal values following an automatic protection trip operation there is a minimum time delay of 3 minutes (Clause 5.3.3) before the inverter output is restored (i.e. before the inverter automatically reconnects to the network).

D5. QUALITY OF SUPPLY

D5.1 Harmonics

The harmonic emissions from the SSEG shall be measured in accordance with BS EN 61000-3-2, and recorded on the Test Sheet in Appendix 4.

D5.2 Power Factor

The power factor of the FC SSEG and inverter will be recorded whilst supplying full load power to the DNO system. The power factor will be measured using a power factor (pf) meter at three different system voltages, controlled using a variac as shown in Figure D5. The inverter pf should be within the limits given in Clause 5.7, for the three test voltages: 230 V – 8%; 230V; and 230 V + 8%. The actual power factor values will be recorded on the test sheet in Appendix 4.

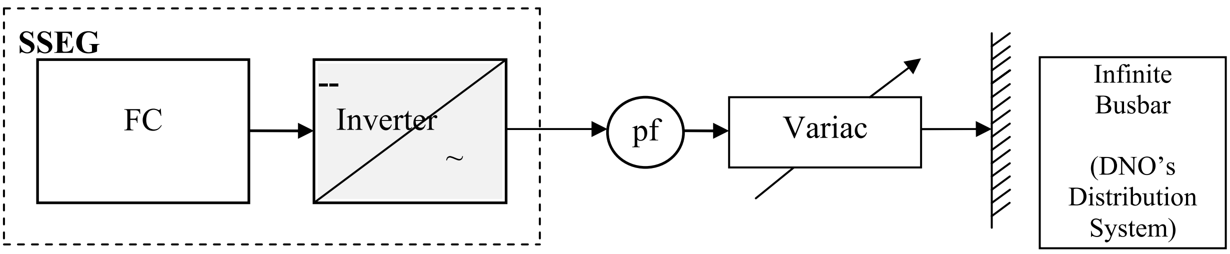


Figure D5: FC SSEG Test set up – Power Factor

Note 1: For reasons of clarity the points of isolation are not shown
Note 2: It is permissible to use a voltage regulator or tapped transformer to perform this test rather than a variac as shown

D5.3 Voltage Flicker

The FC SSEG shall comply with the limits specified in BS EN 61000-3-3: Limits concerning voltage fluctuations and flicker for equipment having an input current up to and including 16A per phase.

D5.4 DC Injection

The level of dc injection from the FC SSEG into the DNO network shall not exceed 20mA when measured during tests D4.1, D4.2, D4.3 and D5.2. This condition is satisfied by installation of a transformer on the ac side of the inverter- connected FC SSEG.

D5.5 Over Current Protection

Over current protection shall be provided to protect both the SSEG and the installation connected to the SSEG. Where appropriate the protection shall comply with the requirements of BS7671.

D5.6 Short Circuit Current Contribution

As FC SSEGs are inverter connected, they are deemed to automatically comply with Clause 5.8 and no further tests are required.

Note: Inverter connected FC SSEGs generally provide a small short circuit fault current only slightly above the full load current, typically below 1.5 x I (full load) for a few milliseconds.

D5.7 Self Monitoring - Solid State Disconnection

If the FC SSEG inverter includes solid state switching devices to disconnect from the DNOs network, then Clause 5.3.1 requires the control equipment to monitor the output stage of the inverter to ensure that in the event of a protection initiated trip the output voltage is either disconnected completely or reduced to a value below 50 volts ac. This shall be verified either by self-certification by the manufacturer, or additional material shall be presented to the tester sufficient to allow an assessment to be made.

D6. DECOMMISSIONING & FUEL CELL STACK REPLACEMENT

A FC SSEG may require the fuel cell stack to be replaced during the operational lifetime of the SSEG. Should this be the case the FC SSEG manufacturer, or their legal agents, are permitted to carry out a ‘like-for-like’ replacement of the fuel cell stack only (the FC stack being an integral part of the FC system as outlined in Figure D1) without a requirement to formally notify the DNO.

At the end of period of use, a formal decommissioning notice (see Appendix 5) must be provided to the DNO that the FC SSEG has been completely decommissioned and there is no potential for any future supply of power to the DNO system from this unit.

D7. EARTHING ARRANGEMENTS

As per Clause 6.3, neither pole of the fuel cell stack should be connected to the DNO’s earth terminal.

ANNEX E. MICRO WIND (MW)

Under Consideration

ANNEX F. MICRO HYDRO (MH)

F1. INTRODUCTION

This annex describes a methodology for obtaining type certification or type verification for a Micro-Hydro (MH) Small Scale Embedded Generator (SSEG).

Although there are many possible combinations of the primary components in a network connected MH SSEG these fall into two distinct categories, “Type A” and “Type B”. Both types have a rotating generator energised by the turbine, but “Type A” uses an inverter to convert the power to conform with the network’s requirements, “Type B” relies on the generator itself being able to provide a network compatible output. See Figures F1 and F2.

Other more unlikely configurations not explicitly described in this annex may apply for connection under G83/1, in these cases the Installer is advised to consult the DNO.

The inverter used in the “Type A” system will normally be an adaptation of a PV inverter. Provided this includes a type approved network protection system it will appear indistinguishable to an inverter intended for Photovoltaic applications.

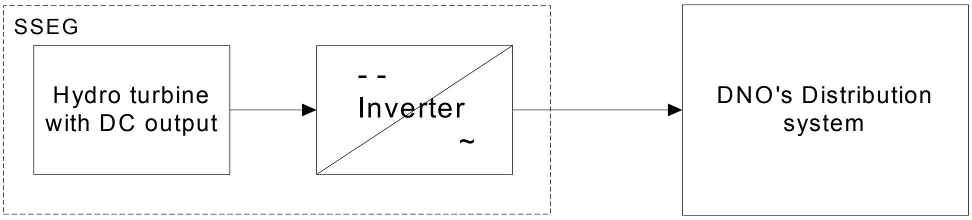


Figure F1. ‘Type A’ DC generator with inverter interface with distribution network

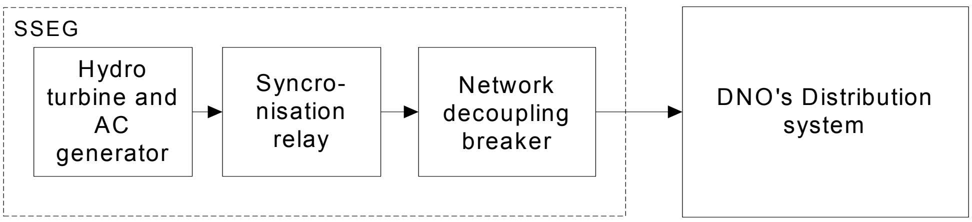


Figure F2. ‘Type B’ AC generator with separate network protection system

F2. ‘TYPE A’ DC GENERATOR & INVERTER

F2.1 Type A System Design Considerations

It is outside the scope of this document to describe the design philosophy of such systems. However, an area which has a bearing on the safe operation of the design is the open circuit voltage of the generator. Under conditions of minimal load, or in the event of disconnection from the network the output voltage from some types of alternator, especially ones without electronic voltage control, for instance permanent magnet alternators, may exceed the input voltage range of the inverter. Under these circumstances precautions should be taken to ensure the safe operation of the inverter. One possible way of achieving this is the use of a "dump load" controller to maintain a suitable load under these circumstances.

F3. 'TYPE B' AC ELECTRO-MECHANICAL GENERATORS

Engineering Recommendation G83/1 was primarily written to cater for the mass produced, type approved SSEGs in mind. This may raise specific issues for the micro hydro manufacturer or installer because:

- The potential market for such systems is relatively small compared to other SSEG technologies.

- Within this small market it is difficult to produce a standardised micro hydro system as they are usually engineered to optimise their performance for the presenting water flows and pressures.

The second factor leads to a wide range of alternators being required, both in terms of their power rating and operating speed. The provision for demonstrating conformity with the requirements for Quality of Supply (section 5.4) and the measurement of the Short Circuit Parameters (section 5.8) must be born in mind on a site by site basis.

The system supplier and installer is advised to bear these costs in mind when considering a "Type B" system. To avoid these costs connection under an alternative recommendation such as Engineering Recommendation G59/1 or a "Type A" system should be considered as possible options.

Within this document no distinction is made between synchronous and asynchronous alternators. As they both have the potential for self excitation they are treated in an identical manner with respect to their impact on the distribution network.

F4. CE MARKING AND CERTIFICATION

The type verification procedure requires that the SSEG be certified to the relevant requirements of the applicable Directives before the unit can be labelled with a CE mark. Where the protection control is to be provided as a separate device, this must also be Type Tested and certified to the relevant requirements of the applicable Directives before it can be labelled with a CE mark.

Currently MH SSEGs have no harmonised functional Standards that apply to the interface Protection and will therefore require functional type verification as described in this Annex, and presented in Appendix 4.

The manufacturer must declare the ambient operating temperature range of the SSEG, and verify that the interface protection will operate satisfactorily throughout this temperature range.

F5. TYPE VERIFICATION FUNCTIONAL TESTING – 'TYPE A'

F5.1 'Type A' MH SSEG Electrical Installation

Electrical installation of MH SSEG systems should conform to the IEE Wiring Regulations BS7671 with special reference to the accompanying guidance notes GN7 chapter 18 (currently in draft); Small scale embedded generators (SSEG). The installation work should be supervised by a suitably qualified electrician.

F5.2 'Type A' Interface Protection Functional Testing

The recommendations for a MH SSEG are identical to those for a PV SSEG as detailed in Annex C, subject to replacing the terms "PV" and "Photovoltaic" with "MH" or "micro hydro".

F6. TYPE VERIFICATION FUNCTIONAL TESTING – 'TYPE B'

F6.1 'Type B' MH SSEG Electrical Installation

Electrical installation of micro hydro systems should conform to UK wiring regulations BS7671 with special reference to the accompanying guidance notes GN7 chapter 18; Small scale embedded generators (SSEG). The installation work should be supervised by a suitably qualified electrician.

F6.2 'Type B' Interface Protection Functional Testing

In most cases it is expected that an Interface Protection relay approved to the appropriate standards will be used. At the time of writing these cost a few hundred pounds, which is considered an acceptably small proportion of the total cost of a typical installation. The adoption of this approach will satisfy most custom engineered applications, although a combined plant control and interface protection system is acceptable providing it meets the standards described in section 5.3.

F6.3 'Type B' Testing and Set-Up Requirements for Interface Protection Circuits

The most common situation is that interface protection will be provided by a separate interface protection relay conforming to the requirements of section 5.3.1. This does not obviate the need for type testing. This may be carried out on site, or at the Manufacturer's or Installer's premises after the final assembly of the electrical protection system has been completed.

F6.4 Interface Protection Configuration and Testing

The Interface Protection relay should be set up to operate in accordance with the settings shown in Table 1.

The type testing of the Interface Protection is best performed with a single or three phase ac simulator that has facilities for the automatic adjustment of frequency and voltage.

Alternatively the Interface protection can be tested on site on a case by case basis using the following techniques:

The Over / Under voltage tests may be carried out using an ac supply and a variac to simulate changes in network voltage.

The Over / Under frequency tests may be performed by any other suitable source of variable frequency ac, providing that it can be controlled and measured with sufficient accuracy.

The selected settings should take into account the accuracy of the relay over the required temperature operating range. The Manufacturer should supply data for the accuracy of the trip settings at a nominal operating temperature, and also provide a coefficient for how much this accuracy decreases as the temperature departs from its nominal value.

> For example:
> A relay with an accuracy of 0.5% of rated voltage at 25°C,
> A temperature coefficient of 0.02% per °C; and
> A rated voltage of 400V
>
> If the relay is to used between -10°C and 40°C the largest the temperature departs from 25°C is 35°C at -10°C.
>
> The “worst case” error is thus:
>
> 0.5 + 0.02 x 35 = 1.2%
> This results in a possible voltage error of 400 x 1.2/100 = 4.8V
>
> As it is not possible to determine whether this error will be added or subtracted from the true voltage, the worst case conditions should always be assumed. Thus the over voltage trip setting will be set 259.2V, (4.8V lower than the maximum permissible), and similarly the under voltage limit increased from 207V to 211.8V.

The same principles apply for under and over frequency settings.

F6.5 Verification of Disconnection Times

Disconnection times will not exceed those shown in Table 1.

F6.6 Over / Under Voltage Protection

Testing to be conducted as described in clause B3.2

F6.7 Over / Under Frequency Protection

Testing to be conducted as described in clause B3.3

F6.8 Loss of Mains Protection

There are several reasons why it may be necessary to disconnect a section of the Distribution Network from its source(s) of supply, typically it can be because of faults or the need to isolate a section of network in order to carry out maintenance or construction work. In the event that a distributed generator is connected to the section of network that becomes disconnected it is possible that the generator can continue to run and provide a supply to the isolated section of network, this situation is known as Islanding. The purpose of loss of mains (LoM) protection is to detect Islanding and to disconnect the generator before it could become a hazard to the staff of Network Operators or other persons who may have assumed that the network is dead.

Under most circumstances it is unlikely that a Small-Scale Embedded Generator will be able to supply the load connected to the islanded Network, indeed it may be severely overloaded. Over-current protection is recommended to protect the generator in this case. There remains a low but finite probability that a Small-Scale Embedded Generator will be able to supply the load connected to the islanded Network. Under these circumstances the generator will be operating under nominal conditions and therefore an additional protective device is required to recognise the LoM event and disconnect the generator.

For these reasons it is a requirement under the ESQC Regulations that all SSEGs be fitted with LoM protection.

LoM protection that is based on low power flow or reverse power flow is not suitable, because under certain conditions the SSEG may not export.

Examples of SSEG protection systems suitable for the detection of a LoM condition include, but are not limited to, Rate of Change of Frequency (ROCOF) and Vector Shift. Irrespective of which protection system is used, protection settings shall be applied that ensure tripping of the generator within 0.5 seconds for a change in load at the generator terminals in excess of ± 25% of full load rating.

The correct functioning of the LoM protection relay and associated circuits must be demonstrated, this may be achieved as follows:

To model the interaction between local load and the MH SSEG the SSEG unit under test shall be connected to a Network and a variable load; the value of the load is to closely match the output of the SSEG. To facilitate the test for loss of mains there shall be a switch (S) placed between the test load and SSEG combination and the DNO's distribution system, as shown below:

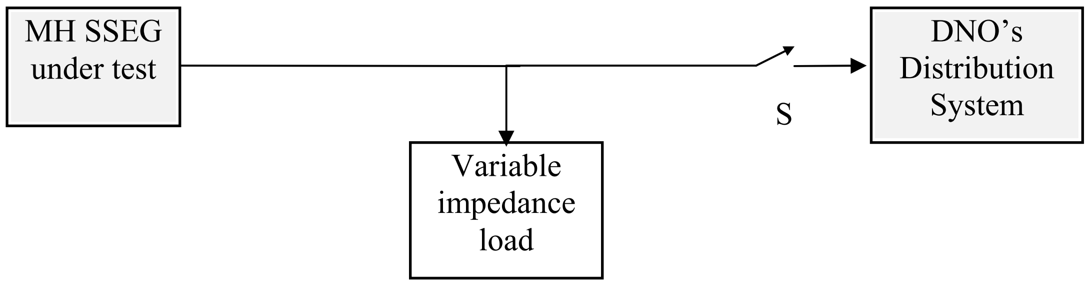


Figure F3. MH SSEG Test set up - Loss of Mains

The purpose of the test is to demonstrate that the LoM protection equipment is able to recognise a change of load condition associated with a LoM event and to disconnect the SSEG equipment within the required time. The SSEG equipment is to be tested at three levels of output power: minimum load, maximum load and at a point midway between the two. At each level of output power the SSEG equipment is to be tested for both positive and negative load changes. Each test is to be repeated five times.

For positive load change the variable impedance load is set at 125% (± 1%) of full load of the above power levels. For negative load change the variable impedance load is set at 75% (± 1%) of full load of the above power levels. Load match conditions are defined as being when the power from the SSEG connected generator meets the requirements of the test load i.e. there is no appreciable export or import of power to or from the DNO's distribution system.

The tests will record the SSEG output voltage and frequency from at least 2 cycles before the switch is opened until 0.6 seconds after the switch is opened. The time from the test switch opening until the protection isolation occurs is to be measured and must comply with the requirements of section 5, at output power levels of 10%, 55% and 100% of rated output.

For systems that are intended to operate over a limited range of powers, tests should be performed at the minimum power, the rated output, and a power output mid way between these two. If the MH SSEG is only able to operate at a single output power then a single test should be performed at this power level.

F6.9 Re-connection

Further tests will be carried out with the test circuits above to check the Interface Protection relay time-out feature prior to automatic network reconnection. This test must confirm that once the ac supply voltage and frequency have returned to their nominal values following an automatic protection trip operation there is a minimum time delay of 3 minutes (clause 5.3.3) before the inverter output is restored (i.e. before the SSEG automatically reconnects to the network).

Following a protection initiated disconnection the SSEG is to remain disconnected from the DNOs Network until the voltage and frequency at the Supply Terminals has remained within the nominal limits for at least 3 minutes, and the successful shutting down and restarting of the micro hydro system has taken place.

F6.10 Site Tests for Interface Protection

If the above tests have been performed before installation of the network protection system a final check must be made on site to verify that the fully operational SSEG disconnects in the prescribed manner from the network. This may be achieved by simulating any one of the conditions required to trip the protection circuits and checking the disconnection of the micro hydro plant from the network occurs in the required manner.

F7. 'TYPE B' POWER QUALITY FUNCTIONAL TESTING

F7.1 Harmonics

In the absence of conducting an emission test to confirm compliance with BS EN 61000-3-2, the MH SSEG should comply with emission limits specified Engineering Recommendation G5/4.

F7.2 Power Factor

Testing to be conducted as described in clause B4.2.

F7.3 Voltage Fluctuations and Flicker

In the absence of conducting an emission test to confirm compliance with BS EN 61000-3-3, the MH SSEG should comply with emission limits specified Engineering Recommendation P28.

F7.4 DC Injection

Not relevant for rotating generators.

F7.5 Over Current Protection

As per B4.5.

F7.6 Short Circuit Current Contribution

It may not be desirable to perform the required on site short circuit tests due to the potential mechanical and electrical damage to the installation. Under these circumstances it is acceptable to present the relevant short circuit characteristics if obtainable from the alternator manufacturer for devices conforming to IEC60909. These should be supplied in the same format specified in section 5.8.

F7.7 Electromagnetic compatibility

As per C 4.10.