Blue text = from G83 (and G59 where equivalent)

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Green text = from other EU documents eg EN 50438

Black text = Changes/ additional words

To incorporate the EU Network Code Requirement for Generators (RfG) with existing GB documentation a number of new Engineering Recommendations are being drafted.

G98 Part 1 covers the connection procedure and technical requirements for Type Tested Generating Units up to 16 A per phase which are referred to as Micro-generators. (G83/2 single premises)

G98 Part 2 covers the connection procedure and technical requirements for (1) multiple Type Tested Micro-generating Plants in a Close Geographic Region and connected at Low Voltage within the Customer's Installations and (2) Type Tested Generating Units greater than 16 A per phase with a maximum capacity of up to 1 MW and connected at Low Voltage within the Customer's Installation. (G83/2 multiple premises and G59/3 <50 kW but expanded for Type A threshold).

G99 covers the connection procedure and technical requirements for all non-Type Tested Generating Units that G59/3 covers at present.

This draft references EN 50438 which is the EU equivalent of G83/2. This is to demonstrate GB coming more into line with the EU. CENELEC are developing a new standard EN 50549-which will supersede EN 50438. This document should be reviewed prior to the removal of EN 50438.

In respect of rate of change of frequency this draft has been updated in line with GC0079 recommendations but it should be noted that this has not yet had Ofgem approval.

It is intended to have text in the Distribution Code similar to the existing DPC7.1.3 which sends the appropriate reader to G98 Part 1 and removes any further Distribution Code obligations in respect of generation to which this document is applicable.

This EREC G98 Part 2 draft uses text from a number of sources and is therefore colour coded to demonstrate where the words have come from as follows.

Blue text = from G83 (and G59 where equivalent)

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Brown text = from Requirement for Generators (RfG)

Green text = from other EU documents eg EN 50438

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Ricardo Energy & Environment is undertaking the drafting on behalf of the Energy Networks Association. Please send any comments to sarah.carter@ricardo.com.

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Engineering Recommendation G98 Part 2

Connection procedure and technical requirements for (1) multiple Type Tested Micro-generating Plants in a Close Geographic Region and (2) Type A Type Tested Power Generating Modules (PGM) greater than 16 A per phase and connected at Low Voltage within the Customer's Installation.

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1. Foreword

1.1 This Engineering Recommendation (EREC) G98 Part 2 is published by the Energy Networks Association (ENA) and comes into effect on 17 May 2019 for the following **Power Generating Modules (PGMs)** first installed on or after that date:

(1) Multiple **Type Tested Micro-generating Plants** in a **Close Geographic Region** and connected at **Low Voltage** within the **Customer's Installation**, and

(2) **Type A Type Tested PGMs of** greater capacity than 16 A per phase and connected at **Low Voltage** within the **Customer's Installation**;

The definition of **Micro-generating Plants** and **PGMs** within this document includes electricity storage devices and hence this document also applies to electricity storage devices.

1.2 It has been prepared and approved under the authority of the **Great Britain Distribution Code Review Panel.** This EREC G98 Part 2 has been written to take account of the EU Network Code on Requirements for Grid Connection of Generators 14 April 2016.

1.3 **PGMs** that meet all of the requirements set out in this document can be considered to be **Type Tested**, provided that there is proof that the requirements have been met. EREC G99 applies to those that do not meet all the requirements of this document.

1.4 For one or more **Type Tested Micro-generators** forming a **Micro-generating Plant** in single premises not installed in a **Close Geographic Region** under a planned programme of work, reference should be made to EREC G98 Part 1.

1.5 In order to comply with this EREC G98 Part 2, installations shall comply with the requirements of EN 50438 and the requirements set out in this document. The purpose of this EREC G98 Part 2 is to explain the technical requirements for connection of **Generating Units** for operation in parallel with a **Distribution Network**, by addressing all technical aspects of the connection process from standards of functionality to onsite commissioning.

1.6 The procedures described are designed to facilitate the connection of **Generating Units** whilst maintaining the integrity of the **GB** public **low-voltage Distribution Network**, both in terms of safety and supply quality.

1.7 This EREC G98 Part 2 provides sufficient information to allow:

a) **Manufacturers** of **Generating Units** to design and market a product that is suitable for connection to the **GB** public **low-voltage Distribution Network**;

b) **Customers**, **Manufacturers** and **Installers** of **Generating Units** to be aware of the requirements of the **Distribution Network Operator (DNO)** before the **Generating Unit** installation will be accepted for connection to the **DNO's Distribution Network**.

2. Legal Aspects

2.1 **Generating Units** which do not meet the requirements set out in EREC G98 Part 1 or EREC G98 Part 2 can only be connected under the procedure set out in EREC G99.

2.2 A **DNO** is under a legal obligation to disallow the connection of **a PGM** unless it complies with this EREC G98 Part 2 and other relevant legal requirements.

2.3 In addition to the requirements specified in this document which allows connection to the **GB** public **low-voltage Distribution Network**, the **Generating Unit** and all of its components shall comply with all relevant legal requirements including European Directives and CE marking.

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2.4 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.

3. Scope

3.1 This EREC G98 Part 2 provides guidance on the **GB** technical requirements for the connection of **Type Tested PGMs** in parallel with **Distribution Networks**. The requirements set out in this EREC G98 Part 2 are in addition to those of European standard EN 50438 which should be complied with in full.

3.2 **Generating Units** covered in this EREC G98 Part 2 are:

(1) Multiple **Type Tested Micro-generating Plants** in a **Close Geographic Region** under a planned programme of work and connected at **Low Voltage** within the **Customer's Installations**, and

(2) **Type A Type Tested PGMs of** greater capacity than 16 A per phase and connected at **Low Voltage** within the **Customer's Installation**; provided that any existing connected **PGMs** are also **Type Tested**.[1]

3.3 For the purposes of this EREC G98 Part 2 a **Micro-generator** is a source of electrical energy rated up to and including 16 Ampere per phase, single or multi- phase, 230/400 V **AC**. This corresponds to 3.68 kilowatts (kW) on a single-phase supply and 11.04 kW on a three-phase supply. The kW rating shall be based on the nominal voltage (ie 230 V) as defined in BS EN 50160 and the **Electrical Supply Quality and Continuity Regulations (ESQCR)**.

3.4 Where **Generating Units** form part of a combined heat and power facility the impact on the **DNO**'s **Distribution Network** shall be assessed on the basis of their electrical **Maximum Capacity**.

3.5 Where the **Generating Unit** includes an **Inverter,** its rating is deemed to be the **Inverter's** continuous steady state rating.[2]

3.6 For the avoidance of doubt where an installation comprises a single **Connection Point** and more than one **Inverter**, which have an aggregate rating of less than 16 Amperes per phase, single or multi phase, 230/400 V **AC**; the installation shall be considered as a single **Micro-generator**.

3.7 The connection of one or more **Type Tested Micro-generators** forming a **Micro-generating Plant** in a single premise is covered by EREC G98 Part 1, except where being installed as part of a programme of work in a **Close Geographic Region**.

3.8 Where one or more new synchronous **PGM(s)** is to be connected to an existing installation then each new **PGM** will be treated as a separate synchronous **PGM**.

3.9 Where a new asynchronous or **Inverter** connected **PGM** is connected to an existing installation the treatment of the addition will depend on the EREC under which the existing installation was connected. If the existing installation was connected under EREC G59 or EREC G83 then the new **PGM** will be treated as a separate **PGM** and managed for compliance with this EREC G98 as a separate **PGM**. If, however, the existing installation was completed in compliance with EREC G98 (Parts 1 or 2) or EREC G99, then the new **PGM**

[1] **Generating Units** that were installed prior to 17 May 2019 are considered **Type Tested** here if they met the Type Test requirements in EREC G83 or G59

[2] The **Manufacturer** may restrict the rating of the **Generating Unit** by applying software settings provided these settings are not accessible to the **Customer**

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must be added to the aggregate capacity of the complete installation which must be used to determine which EREC is applicable irrespective of technology.

3.10 This EREC G98 Part 2 only specifies the requirements applicable to those **PGMs** that are designed to normally operate in parallel with a public **low-voltage Distribution Network**. Those installations that are designed to operate in parallel with the **DNO's Distribution Network** for short periods (i.e. less than 5 minutes per month) or as an islanded installation 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.

3.11 **PGMS** that are not **Type Tested** to conform to the requirements of this document can only be connected in accordance with the process set out in EREC G99.

3.12 EN 50438 Annex D together with Annex A1 of this EREC G98 Part 2 describe a methodology for testing various types of electrical interface between the **Generating Unit** and the public **low-voltage Distribution Network.** The purpose of the type tests set out in EN 50438 Annex D is to demonstrate compliance with the requirements of EN 50438 and hence the generic requirements of this EREC G98 Part 2. The **Generating Unit** can be considered an approved **Generating Unit** for connection to the **GB** public **low-voltage Distribution Network** by:

- satisfying the test conditions set out in EN 50438 Annex D,
- satisfying the supplementary tests in Annex A1 of this EREC G98 Part 2 and
- completing the Type Test Verification Report in Appendix 5 of this EREC G98 Part 2.

3.13 The Appendices contain pro forma that relate to the connection, commissioning, type testing, and decommissioning of **Generating Units**.

3.14 **Connection Agreements**, 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.

3.15 For **Generating Units** classified as emerging technology some clauses of this EREC G98 Part 2 shall not apply. Details of emerging technology and their requirements are given in Appendix 1.

3.16 The structure of this document is as follows:

Section	Subject	Applicable parties
1	Foreword	All
2	Legal Aspects	All
3	Scope	All
4	References	All
5	Terms and Definitions	All
6	Connection Process and Testing Requirements	**Customer, Installer, Manufacturer, DNO**

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7	Certification Requirements	**Customer, DNO**
8	Operation and Safety	**Customer, Installer, DNO, Manufacturer**
9	Commissioning, Notification and Decommissioning	**Customer, Installer, DNO**
10	General Technical Requirements	**Manufacturer**
11	Interface Protection	**Manufacturer**
12	Quality of Supply	**Manufacturer, DNO**
13	Short Circuit Current Contribution	**Manufacturer, DNO**
Appendix 1	Emerging Technologies Exceptions	Emerging Technology Manufactures
Appendix 2	Connection Procedure Flow Chart	**Customer, Installer, DNO**
Appendix 3a	Application for connection of multiple Micro-generator installations	**Customer, Installer, DNO**
Appendix 3b	Application for connection of Type A Type Tested PGMs	**Customer, Installer, DNO**
Appendix 4a	Installation Document	**Customer, Installer, DNO**
Appendix 4b	Site summary form	**Customer, Installer, DNO**
Appendix 5	Type Test Verification Report	**Customer, Installer, DNO**
Appendix 6	Decommissioning Confirmation	**Customer, Installer, DNO**
Appendix 7	Not used	**-**
Appendix 8	Example calculations to determine if unequal generation across different phases is acceptable or not	**Installer, DNO**
Annex A1	Requirements for Testing	**Manufacturer**

4. References

4.1 The following referenced documents, in whole or part, are indispensable for the application of this document. It is expected that it will be appropriate to use the most recent version of the documents below. Where any conflict arises the version in place at the time of commissioning of the **PGM** shall take precedence.

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4.2 Standards publications

BS 7671 Requirements for Electrical Installations
IEE Wiring Regulations.

BS EN 50160
Voltage characteristics of electricity supplied by public electricity networks.

EN 50438
Requirements for the connection of micro-generators in parallel with public low-voltage distribution networks.

BS EN 60034-4
Rotating electrical machines. Methods for determining synchronous machine quantities from tests.

BS EN 60255 series*
Measuring relays and protection equipment.

BS EN 60664-1
Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests (IEC 60664-1:2007).

BS EN 60947 series*
Low-voltage switchgear and controlgear.

BS EN 61000 series*
Electromagnetic Compatibility (EMC).

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

BS EN 61000-3-3
Electromagnetic compatibility (EMC) Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current < 16A per phase and not subject to conditional connection.

BS 7430
Code of Practice for Earthing

BS EN 61896-2
Instrument Transformers Additional requirements for current transformers

BS EN 61508 series*
Functional safety of electrical/ electronic/ programmable electronic safety-related systems.

BS EN 61810 series*
Electromechanical Elementary Relays.

BS EN 62116
Test procedure of islanding prevention measures for utility-interconnected photovoltaic Inverters.

IEC 60364-7-712
Electrical installations of buildings – special installations or locations – Solar photovoltaic (PV)

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power supply systems

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

IEC 60909 series*
Short circuit currents in three-phase AC systems. Calculation of currents

IEC 62282-3-2 ed1.0
Fuel cell technologies - Part 3-2: Stationary fuel cell power systems - Performance test methods.

**Where standards have more than one part, the requirements of all such parts shall be satisfied, so far as they are applicable.*

4.3 Other publications

Health and Safety at Work etc Act (HASWA)
The Health and Safety at Work etc Act 1974 also referred to as HASAW or HSW, is the primary piece of legislation covering occupational health and safety in the United Kingdom. The Health and Safety Executive is responsible for enforcing the Act and a number of other Acts and Statutory Instruments relevant to the working environment.

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.

Electricity at Work Regulations (EaWR)
The Electricity at Work regulations 1989 abbreviated to EaWR in this document.

Engineering Recommendation G5/4-1
Planning levels for harmonic voltage distortion and the connection of non-linear equipment to transmission and distribution networks in the United Kingdom.

Engineering Recommendation G98 part 1
Requirements for the connection of Type Tested Micro-generators (Up to and including 16A per Phase) in Parallel with Low-Voltage Distribution Systems

Engineering Recommendation G99
Requirements for the connection of non-Type Tested Generating Plant, and Generating to the Distribution systems of Licensed Distribution System Operators at less than 110kV

Engineering Recommendation P28
Planning limits for voltage fluctuations caused by industrial, commercial and domestic equipment in the United Kingdom.

Engineering Recommendation P29
Planning limits for voltage unbalance in the UK for 132kV and below.

Engineering Recommendation G74
Procedure to meet the requirements of IEC 60909 for the calculation of short-circuit currents in three-phase **AC** power systems.

COMMISSION REGULATION (EU) No 2016/631

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Establishing a network code on Requirements for Grid Connection of Generators

Directive 2009/72/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
Concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC

Regulation (EC) No 714/2009 of the European Parliament and of the Council
on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003

Regulation (EC) No 765/2008 of the European Parliament and of the Council
Setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93

5. Terms and Definitions

Active Power Frequency Response	An automatic response of active power output, from a **Generating Unit,** to a change in system frequency from the nominal system frequency;
Close Geographic Region	Either: a) The area typically served by a single **Low Voltage** feeder circuit fed from a single distribution transformer; or b) An area confirmed by the **DNO** on request; or c) An area that meets at least one of the following criteria: 1) The postcodes of any of the premises where a **Micro-generator** installation is planned by the same organisation are the same when the last two letters are ignored…ie AB1 2xx, where xx could be any pair of letters or where x could be any letter. 2) The premises where a **Micro-generator** installation is planned by the same organisation are within 500m of each other.
Connection Agreement	A contract between the **Distribution Network Operator** and the **Customer**, which includes the relevant site and specific technical requirements for the **Power Generating Module**.
Connection Point	The interface at which the **Customer's Installation** is connected to a **Distribution Network**, as identified in the **Connection Agreement**.
Customer	Any person supplied or entitled to be supplied with electricity at any premises within **Great Britain** but shall not include any person (other than the **DNO** in its capacity as an operator of a **Distribution Network**) who is authorised to generate, participate in the transmission of, distribute or supply electricity, in their capacity as such.
Customer's Installation	The electrical installation on the **Customer**'s side of the **Connection Point** together with any equipment permanently connected or intended to be permanently connected thereto.
Direct Current or DC	The movement of electrical current flows in one constant direction, as opposed to Alternating Current or AC, in which the current constantly reverses direction.
Distribution Code Review Panel	The standing body established under the Distribution Code.
Distribution Network	An electrical network for the distribution of electrical power from and to third party[s] connected to it, a transmission or another **Distribution Network**.
Distribution Network Operator (DNO)	The person or legal entity named in Part 1 of a distribution licence and any permitted legal assigns or successors in title of the named party. A distribution licence is granted under Section 6(1)(c) of the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004).

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Droop	The ratio of the steady-state change of frequency, referred to as nominal frequency, to the steady-state change in active power output, referred to as **Maximum Capacity**, expressed in percentage terms;
DNO's Distribution Network	The system consisting (wholly or mainly) of electric lines owned or operated by the **DNO** and used for the distribution of electricity
Electricity Safety, Quality and Continuity Regulations (ESQCR)	The statutory instrument entitled The **Electricity Safety, Quality and Continuity Regulations** 2002 as amended from time to time and including any further statutory instruments issued under the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004) in relation to the distribution of electricity.
Generating Unit	.Any apparatus which produces electricity. This includes **Micro-generators** and electricity storage devices.
Great Britain or GB	The landmass of England & Wales and Scotland, including internal waters.
Installation Document	A simple structured document containing information about a **Generating Unit** and confirming its compliance with the relevant requirements set out in this EREC G98 Part 2.
Installer	The person who is responsible for the installation of the **PGM**(s).
Interface Protection	The electrical protection required to ensure that any **Generating Unit** is disconnected for any event that could impair the integrity or degrade the safety of the **Distribution Network.** The **Interface Protection** is typically not installed at the interface between the **DNO** and **Customer's Installation**.
Inverter	A device for conversion from **Direct Current** to nominal frequency Alternating Current.
Limited Frequency Sensitive Mode - overfrequency (LFSM-O)	A **Generating Unit** operating mode which will result in active power output reduction in response to a change in system frequency above a certain value.
Low Voltage or LV	A voltage normally exceeding extra-low voltage (50V) but not exceeding 1000V AC or 1500V **DC** between conductors or 600V AC or 900V **DC** between conductors and earth.
Manufacturer	A person or organisation that manufactures **Generating Units** and also 'packages' components manufactured by others to make **PGMs** which can be **Type Tested** to meet the requirements of this EREC G98 Part 2.
Maximum capacity	The maximum continuous active power which a **Power Generating Module** can feed into the **network** as defined in the **Connection Agreement** or as agreed between the **DNO** and the **Customer**.
Meter Operator	A person, registered with the registration authority, appointed by either a **Supplier** or **Customer** to provide electricity meter operation services.
Micro-generating Plant	An electrical installation with one or more **Micro-generators** with nominal currents in sum not exceeding 16 A per phase. For the avoidance of doubt this definition of **Micro-generating Plant** includes electricity storage devices.
Micro-generator	Source of electrical energy and all associated interface equipment able to be connected to a regular electric circuit in a **Low Voltage** electrical installation and designed to operate in parallel with a public **Low Voltage Distribution Network** with nominal currents up to and including 16 A per phase. For the avoidance of doubt this includes electricity storage devices.
Network	Plant and apparatus connected together in order to transmit or distribute electricity.
Power Generating Module (PGM)	Either: • a synchronous **Generating Unit** (or units that cannot be individually operated) or • one or more Generating Units which is/are either non-synchronously connected to the **Network** or connected through power electronics, and which also has a single **Connection Point** to a **Distribution Network**.

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Supplier	(a) A person supplying electricity under an Electricity Supply Licence; or (b) A person supplying electricity under exemption under the Electricity Act 1989 (as amended by the Utilities Act 2000 and the Energy Act 2004)**;** in each case acting in its capacity as a **Supplier** of electricity to **Customers.**
Type A	A **Power Generating Module** with a **Connection Point** below 110 kV and a **Maximum Capacity** of less than 1MW.
Type Tested	**Micro-generating Plant or PGM** design which has been tested to ensure that the design meets the requirements of this EREC G98 Part 2, and for which the **Manufacturer** has declared that all similar products supplied will be constructed to the same standards, will have the same performance. The **Manufacturer's** declaration will define clearly the extent of the equipment that is subject to the tests and declaration. In the case where protection functionality is included in the tested equipment, all similar products will be manufactured with the same protection settings as the tested product.

6. Connection Process and Testing Requirements

6.1 This document is aimed at two generation installation scenarios:

(1) The installation of one or more **Type Tested Micro-generators** in multiple **Micro-generating Plants** in a **Close Geographic Region** under a planned programme of work, and

(2) The installation of **Type A Type Tested PGMs**t (>16 A per phase and connected at **Low Voltage** within the **Customer's Installation**).

6.2 The use of **Type Tested** equipment simplifies the connection process, the protection arrangements and reduces the commissioning test requirements. The connection process for **Type Tested PGMs** is described in this document.

6.3 Guidance for **Manufacturers** on type testing is included in Annex A1 of this document.

6.4 The **Installer** shall discuss the installation project with the local **DNO** at the earliest opportunity. The connection application will need to be in a format similar to that shown in Appendix 3a for **Micro-generator** installations and Appendix 3b for other **PGMs**. Where a **PGM** is **Type Tested** and registered with the Energy Networks Association Type Test Verification Report Register, the application should include the Type Test Reference Number, and the Type Test results do not need to be submitted as part of the application. Where a reference number is not available, the **Customer** or **Installer** shall provide the **DNO** with a Type Test Verification Report as per Appendix 5 confirming that the **PGM** has been **Type Tested** to satisfy the requirements of this EREC G98 Part 2. On receipt of the application, the **DNO** will assess:

- whether any **Distribution Network** studies are required;
- whether there is a need for work on the **Distribution Network** before the **PGM** can be connected to the **Distribution Network**; and
- whether there is a requirement to witness the commissioning tests.

Connection of the **PGM** is only allowed after the application for connection has been approved by the **DNO** and any **DNO** works facilitating the connection have been completed.

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6.5 Where commissioning tests are not witnessed, confirmation of the commissioning of each **PGM** will need to be made no later than 28 days after commissioning; the format and content shall be as shown in Appendix 4a and 4b. Appendix 4a is an **Installation Document**; one of these is required per **PGM**. Appendix 4b is the Site Summary Form; one of these is required per installation site. The Site Summary Form captures information on each site location, such as **Customer** and **Installer** contact details. Where tests are witnessed, the **Installer** or **Customer**, as appropriate, shall complete the declaration at the bottom of the both the **Installation Document** and Site Summary Form, sign and date them and provide a copy to the **DNO** at the time of commissioning.

7. Certification Requirements

7.1 Verification Test Report

7.1.1 **Type Tested** certification is the responsibility of the **Manufacturer**. The **Manufacturer** shall make available upon request a Type Test Verification Report confirming that the **PGM** has been **Type Tested** to satisfy the requirements of this EREC G98 Part 2. The report shall detail the type and model of **PGM** tested, the test conditions and results recorded. All of these details shall be included in a Type Test Verification Report. The required verification report and declaration are shown in Appendix 5. It is intended that the **Manufacturers** will use the requirements of this EREC G98 Part 2 to develop type verification certification (i.e. the Type Test Verification Report as shown in Appendix 5) for each of their **PGM** models.

7.2 Compliance

7.2.1 Compliance with the requirements detailed in this EREC G98 Part 2 will ensure that the **PGM** is considered to be approved for connection to the **DNO's Distribution Network**.

7.2.2 The **PGM** shall comply with all relevant European Directives and should be labelled with a corresponding CE marking.

8. Operation and Safety

8.1 Operational Requirements

8.1.1 Compliance with this EREC G98 Part, 1 in respect of the design, installation, operation and maintenance of a **PGM**, will ensure that the **Customer** is discharging their legal obligations under **ESQCR** 22(1)(a) and the EU Network Code on Requirements for Grid Connection of Generators.

8.1.2

8.2 Isolation

8.2.1 The **PGM** shall be connected via an accessible isolation switch that is capable of isolating all phases and neutral. The isolation switch shall be capable of being secured in the 'off' (isolated) position.

8.2.2 The **Customer** must grant the **DNO** rights of access to the means of isolation in the event that disconnection becomes necessary for safety reasons and in order to comply with statutory obligations.

8.3 Labelling

8.3.1 Labelling shall be placed in accordance with EN 50438. It should be noted that the warning label does not imply a right on the **Customer**, **Installer** or maintainer to operate (remove / replace) the **DNO's** cut-out fuse and a note to this effect should be included on the warning label.

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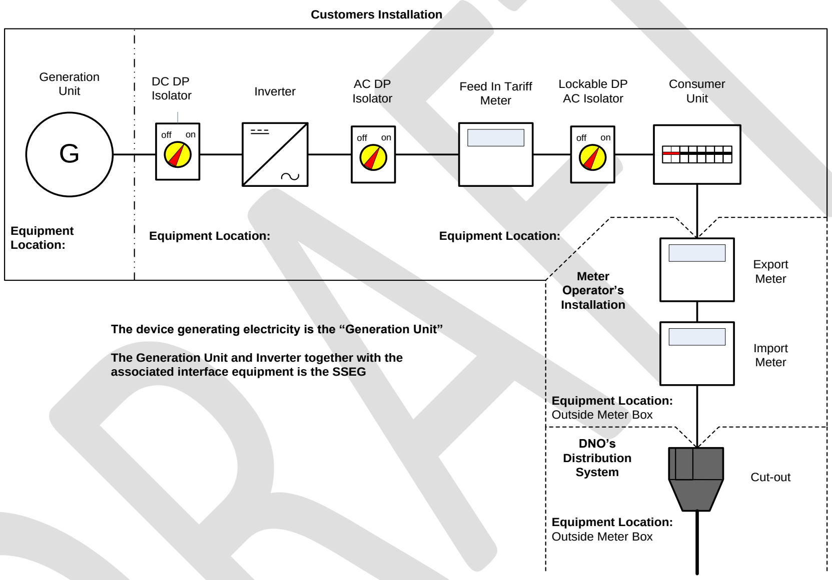
8.3.2 In addition to the warning label, this EREC G98 Part 2 requires the following, up to date, information to be displayed at the point of interconnection with the **DNO's Distribution Network**.

(a) A circuit diagram relevant to the installation showing the circuit wiring, including all protective devices, between the **PGM** 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 **PGM**.

8.3.3 **Figure** 1 shows an outline example of the type of circuit diagram that will need to be displayed. Figure 1 is non-prescriptive and is for illustrative purposes only.

Figure 1 - Example of the type of circuit diagram required



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

8.4 Maintenance and Routine Testing

8.4.1 Periodic testing of the **PGM** 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.

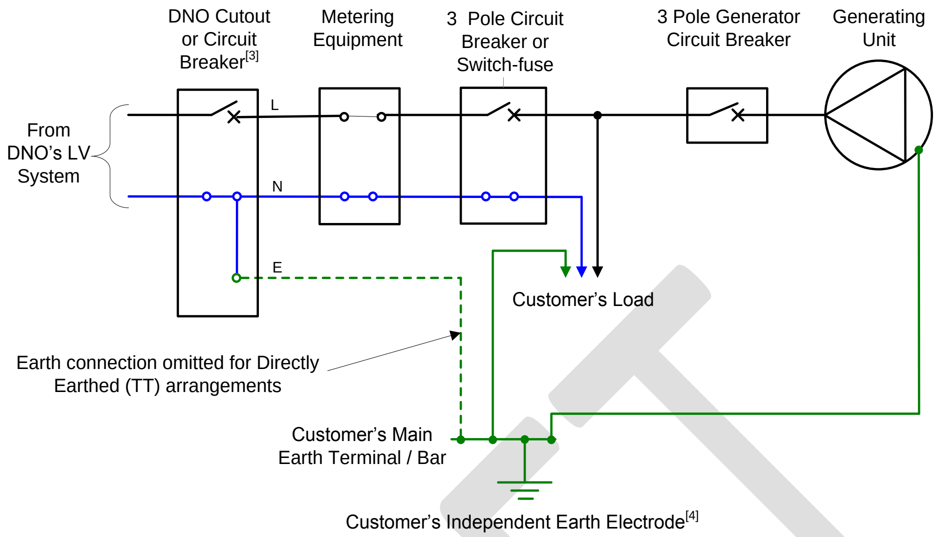
8.5 Earthing

8.5.1 Earthing shall be undertaken in accordance with BSEN 50438 noting that **LV Distribution Networks** are always solidly earthed, and the majority are multiple earthed.

8.5.2 The following diagrams show typical installations.

Blue text = from G83 (and G59 where equivalent)
Purple text = from G59 definitions
Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

Figure 2 - Typical Earthing Arrangement for a **PGM** Embedded within a **Customer LV** System and Designed for Parallel Operation Only



NOTES:

(1) Only one phase of the three phase system is shown to aid clarity.
(2) **PGM** is not designed to operate in standby mode.
(3) The **DNO** cut-out / circuit breaker shows a PME (TN-C-S) connection, however, the **PGM** earthing arrangement is also applicable to SNE (TNS) and direct earthing (TT) arrangements.
(4) The **Customer**'s independent earth electrode is only required if the installation is Directly Earthed (TT).

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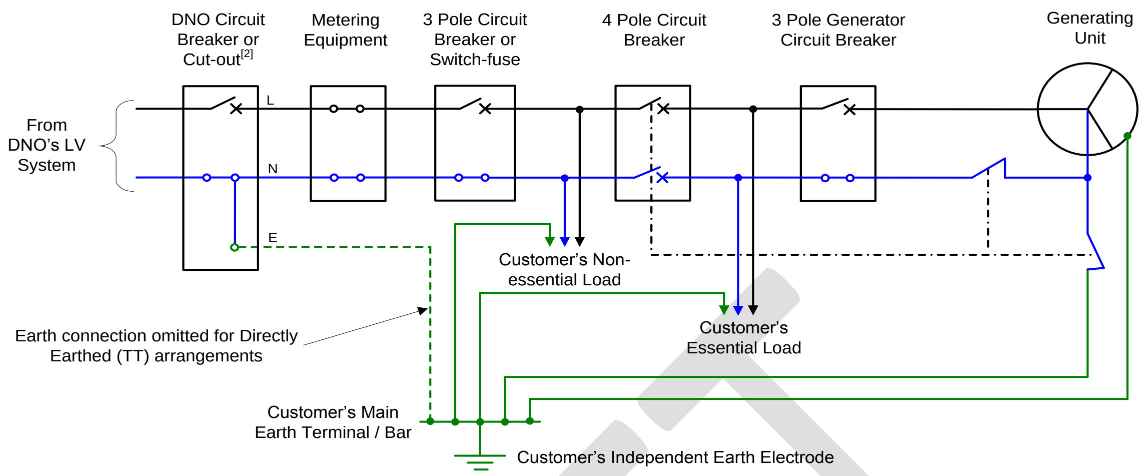
Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

Figure 3 - Typical Earthing Arrangement for a **PGM** Embedded within a **Customer LV** System and Designed for both Independent Operation (ie Standby Operation) and Parallel Operation**.**



NOTES:

(1) Only one phase of a three phase system is shown to aid clarity.

(2) The **DNO** cut-out / circuit breaker shows a PME (TN-C-S) connection, however, the **Generating Unit** earthing arrangement is also applicable to SNE (TNS) and direct earthing (TT) arrangements.

(3) When the **PGM** operates independently from the **DNO's Distribution Network**, the switch that is used to isolate between these two systems must disconnect each phase and neutral (ie for a three phase system a 4 pole switch is required). This prevents **PGM** neutral current from inadvertently flowing through the part of the **Customer's Installation** that is not supported by the **PGM.** This switch should also close the generator neutral and earth switches during independent operation.

8.6 Phase Balance

8.6.1 Connection of either **Micro-generators** in multiple premises in **a Close Geographic Region** or single phase **PGM**s may require **Network** reinforcement and extension before commissioning for technical reasons (such as voltage issues and unacceptable phase imbalance) depending on the point of connection and **Network** design.

8.6.2 A solution to these voltage issues and phase imbalance issues may be to utilise 3-phase **PGM**s or to use multiple single phase **PGM**s connected across three phases. For this arrangement the same export power will result in lower voltage rises due to decreased line currents and a 3 phase connected **PGM** will result in voltage rises of a sixth of those created by a single phase connected **PGM**. If the individual **PGMs** have different ratings, current and voltage imbalance may occur. To maintain current and voltage imbalance within limits the **Installer** shall consider the phase that each **PGM** is connected to in an installation. In addition the **DNO** may define to an **Installer** the phases to which the **PGMs** in any given installation should be connected.

8.6.3 An **Installer** should design an installation on a maximum imbalance in output of 16A between the highest and lowest phase. Where there are a mixture of different technologies, or technologies which may be operational at different times (eg. wind and solar) **PGM**s shall be connected to give a total imbalance of less than 16A based on assumed worst case conditions, those being:

(a) One **PGM** at maximum output with the other(s) at zero output – all combinations to be considered.

(b) Both / all **PGMs** being at maximum output.

8.6.4 A **PGM** technology which operates at different times due to location eg east and west facing roofs for PV, must allow for the PV on one roof to be at full output and the PV on the other roof to be at zero output.

8.6.5 In order to illustrate this requirement examples of acceptable and unacceptable connections have been given in Appendix 8.

8.7 Generation Unit capacity for single and split LV phase supplies

8.7.1 The maximum aggregate capacity of **PGMs** that can be connected to a single phase supply is 17kW. The maximum aggregate capacity of **PGMs** that can be connected to a split single phase supply is 34kW.

8.7.2 There is no requirement to provide intertripping between single phase **Inverters** where these are installed on multi-phase supplies up to a limit of 17kW per phase (subject to balance of site output as per section 8.6). A single phase 17kW connection may result in an imbalance of up to 17kW following a **Distribution Network** or **PGM** outage. However the connection design should result in imbalance under normal operation of below 16A between phases as noted above.

8.7.3 The requirement to disconnect all phases following a fault in the **Customer's Installation** or a **Distribution Network** outage applies to three phase **Inverters** only and will be tested as part of the type testing of the **PGM**.

8.8 Voltage Management Units in Customer's premises

8.8.1 Voltage Management Units are becoming more popular and use various methods, in most cases to reduce the voltage supplied from the **DNO's Distribution Network**. In some cases where the **DNO's Distribution Network** voltage is **Low Voltage**, Voltage Management Units can increase the voltage supplied to the **Customer**. Some technologies are only designed to reduce voltage and cannot increase the voltage.

8.8.2 The use of such equipment has the advantage to the **Customer** of running appliances at a lower voltage and in some cases this can reduce the energy consumption of the appliance. A higher current consumption will result for some appliances when running at a lower voltage as the device needs to take the same amount of energy from the **Distribution Network** to carry out its task.

8.8.3 If a Voltage Management Unit is installed between the **Connection Point** and the **PGM** in a **Customer's Installation**, it may result in the voltage at the **Customer** side of the Voltage Management Unit remaining within the limits of the protection settings defined in section 11.1.3, while the voltage at the **Connection Point** side of the unit might be outside the limits of the protection settings. This would negate the effect of the protection settings. Therefore

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this connection arrangement is not acceptable and all **PGMs** connected to **a LV Distribution Network** under this EREC G98 Part 2 must be made on the **Connection Point** side of any Voltage Management Unit installed in a **Customer's Installation.**

8.8.4 **Customers** should note that the overvoltage setting defined in Table 2 is 4% above the maximum voltage allowed for the voltage from the **DNO's Distribution Network** under the ESQCR and that provided their **Installer** has designed their installation correctly there should be very little nuisance tripping of the **PGM**. Frequent nuisance tripping of a **PGM** may be due to a fault in the **Customers Installation** or the operation of the **DNO's Distribution Network** at too high a voltage. **Customers** should satisfy themselves that their installation has been designed correctly and all **PGMs** are operating correctly before contacting the **DNO** if nuisance tripping continues. Under no circumstances should they resort to the use of Voltage Management Units installed between the **Connection Point** and the **PGM**.

9. Commissioning, Notification and Decommissioning

9.1 General

9.1.1 The information required by a **DNO** under an Application for Connection is shown in Appendix 3. The information required by a **DNO** to confirm commissioning is shown in Appendix 4.

9.1.2 It is the responsibility of the **Installer** to ensure that the relevant information as specified in section 7 is forwarded to the local **DNO**. The pro forma in Appendices 2 and 3 are designed to:

(a) simplify the connection procedure for both **DNO** and **Installer**;

(b) provide the **DNO** with all the information required to assess the potential impact of the **PGM** connection on the operation of the **Network**;

(c) inform the **DNO** that the **PGM** installation complies with the requirements of this EREC G98 Part 2;

(d) allow the **DNO** to accurately record the location of all **PGMs** connected to the **Distribution Network**.

9.2 Commissioning

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

9.2.2 As part of the on-site commissioning tests the **Installer** shall carry out a functional check of the loss of mains protection, for example by removing the supply to the **PGM** during operation and checking that the **Interface Protection** operates to disconnect the **PGM** from the **DNO's Distribution Network**. For three phase installations this test can be achieved by opening a three phase Circuit Breaker or isolator and confirming that the **PGM** has shut down. Testing for the loss of a single phase is covered in the type testing of **Inverters** see section 12.2.

9.3 Witnessing of Tests

9.3.1 The **DNO** may decide to witness the **PGM** commissioning tests and checks for which the **DNO** shall charge the **Customer** for attendance of staff at its own commercial rates.

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9.3.2 The **DNO** will not normally witness the commissioning checks and tests for **Type Tested PGM**. In such cases, where the **DNO** does decide to witness they will advise this as part of the connection offer. Reasons for witnessing such installations may include:

(a) A new **Installer** with no track record in the **DNO** area.

(b) A check on the quality of an installation either on a random basis or as a result of problems that have come to light at previous installations.

9.3.3 Where commissioning tests and checks are to be witnessed the **Installer** shall discuss and agree the scope of these tests with the **DNO** at an early stage of the project. The **Installer** shall submit the scope, date and time of the commissioning tests at least 15 days before the proposed commissioning date.

9.4 Commissioning Tests for Type A PGMs >16 A per phase

9.4.1 The following tests and checks shall be carried out by the **Installer** on all **Type A PGM**greater than 16 A per phase and connected at **LV** within the **Customer's Installation**.

(a) Inspect the **PGM** to check compliance with BS7671. Checks should consider:

- **i.** Protection
- **ii.** Earthing and bonding
- **iii.** Selection and installation of equipment

(b) Check that suitable lockable points of isolation have been provided between the **PGMs** and the rest of the installation.

(c) Check that warning labels have been installed in accordance with section 9.3 of this EREC G98 Part 2;

(d) Check interlocking operates as required. Interlocking should prevent **PGMs** being connected to the **DNO's Distribution Network** without being synchronised;

(e) Check that the correct protection settings have been applied (in accordance with section 12.1.3);

(f) Complete functional tests to ensure each **PGM** synchronises with, and disconnects from, the **DNOs Distribution Network** successfully and that it operates without tripping under normal conditions;

(g) After all other tests have been completed successfully (including where required additional tests for non **Type Tested** equipment) carry out a functional test to confirm that the **Interface Protection** operates and trips each **PGM** when supplies are disconnected between the **PGM** and the **DNO**'s **Distribution Network**.

1. This test may be carried out by opening a suitably rated switch (not the one expected to open for a protection operation) between the **PGM** and the **Connection Point** and checking that the **PGM** disconnects quickly (eg within 1s);

2. Alternatively, the test may be carried out by removing one or all of the voltage sensing supplies to the protection relay and checking that the **PGM** disconnects quickly (eg within 1s);

(h) Check that once the phases are restored following the functional test described in (g) at least 20s elapses before the **PGM** re-connects.

9.5 Notification of Commissioning

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9.5.1 Notification that the **PGM** has been connected / commissioned is achieved by completing an **Installation Document** and Site Summary Form as per Appendices 4a and Appendix 4b, which also includes the relevant details on the **PGM** installation required by the **DNO**.

9.5.2 The **Installer,** or an agent acting on behalf of the **Installer,** shall supply separate **Installation Documents** (Appendix 4a) for each **PGM** within the **Customer's Installation** and a Site Summary Form (Appendix 4b) to the **DNO.** Documentation shall be supplied either at the time of commissioning (where tests are witnessed) or within 28 days of the commissioning date (where the tests are not witnessed) and may be submitted electronically.

9.6 Notification of Changes

9.6.1 The **Customer** shall notify the **DNO** about any planned modification of the technical capabilities of the **PGM** which may affect its compliance with the requirements of this EREC G98 Part 2, before initiating that modification.

9.6.2 The **DNO** shall be notified of any operational incidents or failures of **PGMs** that affect its compliance with this EREC G98 Part 2, without undue delay, after the occurrence of those incidents.

9.6.3 The **DNO** shall have the right to request that the **Customer** arrange to have compliance tests undertaken after any failure, modification or replacement of any equipment that may have an impact on the **PGM's** compliance with this EREC G98 Part 2.

9.6.4 Where one or more **PGMs** are to be added or replaced at an existing **Customer's Installation** which was installed prior to the introduction of this EREC G98 Part 2, it is not necessary to modify the other existing **PGMs** to comply with this document. For the avoidance of doubt, this also applies where the changes increase the capacity of the **Customer's Installation** above the 16A per phase threshold.

9.6.5 For example the addition of a new 3kW single phase **PGM** to an existing **Customer's Installation** comprising an existing 3kW single phase **PGM** complying with EREC G83 or G98 Part 1 increases the capacity of the **Customer's Installation** from 3kW (13.04A per phase) to 6kW (26.08A per phase). In this case the new **PGM** will have to comply with EREC G98 Part 2 but the existing **PGM** will not need to be modified.

9.6.6 If a **PGM** is changed at a **Customer's Installation** the replacement must comply with the current version of EREC G98 Part 2.

9.7 Notification of Decommissioning

9.7.1 The **Customer** shall notify the **DNO** about the permanent decommissioning of a **PGM** by providing the information as detailed under Appendix 6. Documentation may be submitted by an agent acting on behalf of the **Customer** and may be submitted electronically.

9.7.2 Where the presence of **a PGM or any Generating Unit** is indicated in a bespoke **Connection Agreement**, it will be necessary to amend the **Connection Agreement** appropriately.

10. General Technical Requirements

10.1 Frequency Withstand

10.1.1 The **PGM** shall be capable of remaining connected to the **Distribution Network** and operate within the frequency ranges and time periods specified in Table 1 unless disconnection was triggered by Rate of Change of Frequency type loss of mains protection.

Table 1. Minimum time periods for which a **PGM** has to be capable of operating on different frequencies, deviating from a nominal value, without disconnecting from the **Network**.

Blue text = from G83 (and G59 where equivalent)
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47.0 Hz – 47.5 Hz	20 seconds
47.5 Hz – 48.5 Hz	90 minutes
48.5 Hz -49.0 Hz	90 minutes
49.0 Hz – 51.0 Hz	Unlimited
51.0 Hz – 51.5 Hz	90 minutes
51.5 Hz – 52.0 Hz	15 minutes

10.2 Rate of Change of Frequency

10.2.1 With regard to the rate of change of frequency withstand capability, a **PGM** shall be capable of staying connected to the **Distribution Network** and operate at rates of change of frequency up to 1 Hz/s.

10.3 Limited Frequency Sensitive Mode – Over Frequency

10.3.1 With regard to the **Limited Frequency Sensitive Mode — Overfrequency (LFSM-O)**, the **PGM** shall be capable of activating the provision of **Active Power Frequency Response** according to EN 50438. The **GB** specific standard frequency threshold shall be 50.4 Hz; the **Droop** setting shall be 10 %. No intentional delay should be programmed to ensure that the initial delay is as short as possible with a maximum of 2s.

10.4 Active Power Output

10.4.1 The **PGM** shall be capable of maintaining constant output at its target active power value regardless of changes in frequency, except where the output follows the changes defined in the context of paragraphs 11.3.1 and 11.4.2 as applicable.

10.4.2 The **PGM** shall be capable of maintaining constant output at its target active power value regardless of changes in frequency in the range 49.5 – 50.4 Hz. Below 49.5 Hz the power output should not drop by more than prorata with frequency, ie the maximum permitted requirement is 100% power at 49.5 Hz falling linearly to 95 % power at 47.0 Hz.

10.4.3 The output power should not be affected by voltage changes in the operating ranges as defined by the interface protection settings of section 11.1.3 below.

10.4.4 The **PGM** shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received from the **DNO** at the input port. The **DNO** may define requirements for equipment to make this facility operable remotely.

10.4.5 Other than under sections 11.4.1 and 11.4.2 of this EREC G98 Part 2, requirements relating to the capability to maintain constant active power output or to modulate active power output shall not apply to **PGMs** or **Generating Units** of facilities for combined heat and power production embedded in the **Networks** of industrial sites, where all of the following criteria are met:

(a) the primary purpose of those facilities is to produce heat for production processes of the industrial site concerned; and

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(b) heat and power generation is inextricably interlinked, that is to say any change of heat generation results inadvertently in a change of active power generation and vice versa.

10.5 Power Factor

10.5.1 The power factor capability of the **PGM** shall comply with EN 50438. When operating at rated power the **PGM** shall operate at a power factor within the range 0.95 lagging to 0.95 leading relative to the voltage waveform unless otherwise agreed with the **DNO** eg for power factor improvement.

10.6 Automatic Connection

10.6.1 **The PGM** shall comply with EN 50438 in respect of connection and starting to generate electric power. This includes automatic reconnection where the minimum observation time shall be as stated in Annex A12 of EN 50438.

11. Interface Protection

11.1 General

11.1.1 The **PGM** shall comply with the **Interface Protection** settings set out below (Table 2). Means shall be provided to protect the settings from unpermitted interference (eg via a password or seal).

11.1.2 The **DNO** is responsible under the **Distribution Code** for ensuring, by design that the voltage and frequency at the **Connection Point** remains compliant with the statutory limits. The **Interface Protection** settings have been chosen to allow for voltage rise or drop within the **Customer's Installation** and to ensure that the **PGM** will continue to operate under network conditions as required by Section 10 above.

11.1.3 **Interface Protection** shall be installed which disconnects the **PGM** from the **DNO's Distribution Network** when any parameter is outside of the settings shown in Table 2.

Table 2. **Interface Protection** settings

	LV Protection(1)		HV Protection (1)	
Protection Function	Trip Setting	Time Delay Setting	Trip Setting	Time Delay Setting
U/V stage 1	Vφ-n† -13% = 200.1V	2.5s	Vφ-φ‡ -13%= 200.1V	2.5s
U/V stage 2	Vφ-n† - 20% = 184V	0.5s	Vφ-φ‡ - 20% = 184V	0.5s
O/V stage 1	Vφ-n† +14% = 262.2V	1.0s	Vφ-φ‡ + 10% = 253V	1.0s
O/V stage 2	Vφ-n†+ 19% = 273.7V[3]	0.5s	Vφ-φ‡ + 13% = 259.9V	0.5s
U/F stage 1	47.5Hz	20s	47.5Hz	20s
U/F stage 2	47Hz	0.5s	47Hz	0.5s
O/F	52Hz	0.5s	52Hz	0.5s
Loss of Mains*	1.0 Hz per second	0.5s		

3 For voltages greater than 230V +19% which are present for periods of <0.5s the **PGM** is permitted to reduce/cease exporting in order to protect the equipment.

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(RoCoF)				

(1) HV and **LV Interface Protection** settings are to be applied according to the voltage at which the voltage related protection reference is measuring, eg:

- If the EREC G98 Part 2 protection takes its voltage reference from an **LV** source then **LV** settings shall be applied. Except where a private none standard **LV** network exists, in this case the settings shall be calculated from **HV** settings values as detailed in Appendix 9;
- If the EREC G98 Part 2 protection takes its voltage reference from an **HV** source then **HV** settings shall be applied.

† A value of 230V phase to neutral

‡ A value to suit the nominal voltage of the HV System connection point.

* Other forms of Loss of Mains techniques may be utilised but the aggregate of the protection operating time, disconnection device operating time and time delay setting shall not exceed 1.0 second.

11.1.4 The total disconnection time for voltage and frequency protection including the operating time of the disconnection device shall be the time delay setting with a tolerance of, -0s + 0.5s.

11.1.5 For the avoidance of doubt, where the **Network** voltage or frequency exceed the trip settings in Table 2 for less than the time delay setting, the **PGM** should not disconnect from the **Network**.

11.1.6 Only **PGMs** that have protection settings set during manufacture can be considered as **Type Tested.**

11.1.7 The **Manufacturer** shall establish a secure way of displaying the **Interface Protection** setting information in one of the following ways:

- A display on a screen;
- A display on a PC which can communicate with the **PGM** and confirm that it is the correct **PGM** by means of a serial number permanently fixed to the **PGM** and visible on the PC screen at the same time as the settings;
- Display of all protection settings and nominal voltage and current outputs, alongside the serial number of the **PGM**, permanently fixed to the **PGM**.

11.1.8 The provision of loose documents, documents attached to the **PGM** by cable ties etc, or provision of data on adhesive paper based products which are not likely to survive due to fading, or failure of the adhesive, for at least 20 years is not acceptable.

11.1.9 In response to a protection operation the **PGM** shall be automatically disconnected from the **DNO's Distribution 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 **PGM,** the switching device shall incorporate fail safe monitoring to check the voltage level at its output stage. In the event that the solid state switching device fails to disconnect the **PGM**, the voltage on the output side of the switching device shall be reduced to a value below 50 volts within 0.5 seconds of the protection and delay timer operation. For the avoidance of doubt this disconnection is a means of providing Loss of Mains disconnection and not as a point of isolation to provide a safe system of work.

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11.1.10 Where a common protection system is used to provide the protection function for multiple **PGMs** the complete installation cannot be considered to comprise **Type Tested PGMs** as the protection and connections are made up on site and so cannot be factory tested or **Type Tested**.

11.1.11 Once the **PGM** has been installed and commissioned the protection settings shall only be altered following written agreement between the **DNO** and the **Customer** or their agent.

11.2 Loss of Mains Protection

11.2.1 Loss of mains protection shall be incorporated and tested as defined in the compliance type testing annex of EN 50438. Active methods which use impedance measuring techniques by drawing current pulses from or injecting **AC** currents into the **DNO's Distribution Network** are not considered to be suitable. For **PGMs** which generate on more than one phase, the loss of mains protection should be able to detect the loss of a single phase of the supply **Network**. This should be tested during type testing and recorded in the Type Test Verification Report as per Appendix 5.

11.3 Frequency Drift and Step Change Stability Test

11.3.1 Under normal operation of the **Network** the frequency changes over time due to continuous unbalance of load and generation, or can experience a step change due to the loss of a **Network** component which does not cause a loss of supply.

11.3.2 In order to ensure that such phenomena do not cause un-necessary tripping of **PGMs**, stability Type Tests shall be carried out.

11.3.3 The Rate of Change of Frequency (RoCoF) and Vector Shift values required for these tests are marginally less than the corresponding protection settings for RoCoF protection Table 2. Both stability tests shall be carried out in all cases.

11.3.4 The stability tests are to be carried out as per the table in Appendix 5 of this document and the generator should remain connected during each and every test. The tests shall check the following:

- RoCoF : 0.95Hz per second from 49.5Hz to 51.5Hz and from 50.5Hz to 47.5Hz
- Vector shift : 50º plus from 49.5Hz and 50º minus from 50.5Hz

12. Quality of Supply

12.1 General

12.1.1 The power quality requirements set out in EN 50438 should be met along with the requirements described in this section of EREC G98 Part 2. **PGMs** are likely to be installed in large numbers on **LV Networks**, they are likely to operate for long periods with no diversity between them, and adjacent **PGMs** are likely to be of the same technology. Therefore, in order to accommodate a high number of **PGMs** on a **Network** the following procedures need to be applied when testing for harmonic current emissions and flicker.

12.1.2 The procedure for **Micro-generators** is in paragraphs 12.2 and 12.3. The procedure for other **PGMs**, to which this EREC G98 Part 2 is applicable, is in paragraphs 12.4 to 12.5. Paragraph 12.6 applies to all **PGMs** connecting under EREC G98 Part 2.

12.2 Testing for Harmonic Emissions for Micro-generators

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Green text = from other EU documents eg EN 50438
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12.2.1 The test must be carried out with a minimum of 2kW of rated **Micro-generators**. Where an individual **Micro-generator** is smaller than 2kW it should be tested as a group. However where a **Micro-generator** is designed to be installed singly in an installation then this can be tested alone, for example a domestic CHP unit. The maximum group size for the test is 3.68kW.

12.2.2 The results for all **Inverters** should be normalised to a rating of 3.68kW. The **Micro-generator** or group shall meet the harmonic emissions of Table 1 in BS EN 61000-3-2 with a scaling factor applied as follows for each harmonic current:

- BS EN 61000-3-2 Table 1 current limit **×** rating of **Micro-generator** being tested (kW) per phase / 3.68.

12.3 Testing for Flicker from Micro-generators

12.3.1 The test must be carried out with a minimum of 2kW of rated **Micro-generators**. Where an individual **Micro-generator** is smaller than 2kW it should be tested as a group. However where a **Micro-generator** is designed to be installed singly in an installation then this can be tested alone, for example a domestic CHP unit. The maximum group size for the test is 3.68kW.

12.3.2 The **Micro-generator** or group shall meet the required d_{max}, d_c, $d_{(t)}$, P_{st}, P_{lt} requirements of BS EN 61000-3-3 with a scaling factor applied as follows for each voltage change component:

- d_{max}, d_c, $d_{(t)}$, P_{st}, P_{lt} **×** rating of **SSEG** being tested (kW) per phase / 3.68.

12.3.3 The results for groups of **Inverters** should be normalised to a rating of 3.68kW and to the standard source impedance. Single **Inverters** need to be normalised to the standard source impedance, these normalised results need to comply with the limits set out in Appendix 5.

12.3.4 For voltage change and flicker measurements the following simplified formula is to be used to convert the measured values to the normalised values where the power factor of the generation output is 0.98 or above:

- Normalised value = Measured value × reference source resistance/measured source resistance at test point.

Where the power factor is less than 0.98 then compliance with the full requirements of BS EN 61000-3-3 is required.

12.3.5 And for units which are tested as a group:

- Normalised value = Measured value × reference source resistance/measured source resistance at test point × 3.68/rating per phase.

12.3.6 Reference source resistances to be used in the above tests are as follows:

- Single phase units reference source resistance is 0.4 ohms;
- Two phase units in a three phase system reference source resistance is 0.4 ohms;
- Two phase units in a split phase system reference source resistance is 0.24 ohms;
- Three phase units reference source resistance is 0.24 ohms.

Blue text = from G83 (and G59 where equivalent)
Purple text = from G59 definitions
Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

12.3.7 The stopping test should be a trip from full load generation.

12.3.8 The duration of these tests need to comply with the particular requirements set out in the testing notes for the technology under test and can be found in Annex A1.

12.3.9 The dates and location of the tests need to be noted in the Type Test Verification Report as per Appendix 5.

12.3.10 Note: For wind turbines, flicker testing should be carried out during the performance tests specified in IEC 61400-12-1. Flicker data should be recorded from wind speeds of 1m/s below cut-in to 1.5 times 85% of the rated power. The wind speed range should be divided into contiguous bins of 1m/s centred on multiples of 1m/s. The dataset shall be considered complete when each bin includes a minimum of 10 minutes of sampled data. The highest value of each parameter measured across the entire range of tests shall be recorded.

12.3.11 Note that as an alternative to type testing the **Manufacturer** of a **Micro-generator** incorporating an **Inverter** may give a guarantee that rates of change of output do not exceed the following ramp rate limits. The output needs to ramp up at a constant rate.

- Single phase units and two phase units in a three phase system, maximum ramp up rate 333 watts per second;
- Two phase units in a split phase system and three phase units, maximum ramp up rate 860 watts per second.

12.3.12 Where the output changes in steps of over 30ms rather than as a ramp function this exception to site testing does not apply and a site test is required for these units.

12.3.13 It should be noted that units complying with this declaration are likely to be less efficient at capturing energy during times when the energy source is changing.

12.3.14 For technologies other than wind turbines, testing should ensure that the controls or automatic programs used produce the most unfavourable sequence of voltage changes.

12.4 Harmonic Emissions for Type A Generating Units >16 A per phase

12.4.1 Harmonic voltages and currents produced within the **Customer**'s **Installation** may cause excessive harmonic voltage distortion in the **Distribution Network**. The **Customer's Installation** must be designed and operated to comply with the planning criteria for harmonic voltage distortion as specified in EREC G5. EREC G5, like all planning standards referenced in this recommendation, is applicable at the time of connection of additional equipment to a **Customer**'s **Installation**.

12.4.2 Harmonic measurements as required by BS EN 61000-3-12 shall be made and recorded in the type test declaration for the **Generating Unit**.

12.4.3 The **DNO** will use these declared figures to calculate the required maximum supply impedance required for the connection to comply with BS EN 61000-3-12 and will use this data in their design of the connection for the **Generating Unit**. This standard requires a minimum ratio between source fault level and the size of the **Generating Unit**, and connections in some cases may require the installation of a transformer between 2 and 4 times the rating of the **Generating Unit** in order to provide an acceptable connection to a **DNO's Distribution Network.**

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12.4.4 Alternatively, if the harmonic emissions are low and they are shown to meet the requirements of BS EN 61000-3-2 then there will be no need to carry out the fault level to **Generating Unit** size ratio check. **Generating Units** meeting the requirements of BS EN 61000-3-2 will need no further assessment with regards to harmonics.

12.5 Flicker for Type A Generating Units >16 A per phase

12.5.1 Where the input motive power of the **PGM** may vary rapidly, causing corresponding changes in the output power, flicker may result. The operation of the **PGM** including synchronisation, run-up and desynchronisation shall not result in flicker that breaches the limits for flicker in EREC P28.

12.5.2 The fault level of the **Distribution Network** needs to be considered to ensure that the emissions produced by the **PGM** do not cause a problem on the **Distribution Network**. Three phase voltage step change and flicker measurements as required by BS EN 61000-3-11 shall be made and recorded in the type test declaration for the **Generating Unit**.

12.5.3 The **DNO** will use these declared figures to calculate the required maximum supply impedance required for the connection to comply with EREC P28. This calculation may show that the voltage fluctuations will be greater than those permitted and hence reinforcement of the **Distribution Network** may be required before the **PGM** can be connected.

12.5.4 For wind turbines, flicker testing should be carried out during the performance tests specified in IEC 61400-12. Flicker data should be recorded from wind speeds of 1ms^{-1} below cut-in to 1.5 times 85% of the rated power. The wind speed range should be divided into contiguous bins of 1ms^{-1} centred on multiples of 1ms^{-1}. The dataset shall be considered complete when each bin includes a minimum of 10 minutes of sampled data.

12.5.5 The highest recorded values across the whole range of measurements should be used as inputs to the calculations described in BS EN 61000-3-11 to remove background flicker values. Then the required maximum supply impedance values can be calculated as described in Appendix 5. Note that occasional very high values may be due to faults on the associated HV **Network** and may be discounted, though care should be taken to avoid discounting values which appear regularly.

12.5.6 For technologies other than wind, the controls or automatic programs used shall produce the most unfavourable sequence of voltage changes for the purposes of the test.

12.6 DC Injection

12.6.1 The requirements of EN 50438 shall be met for **DC** injection.

13. Short Circuit Current Contribution

13.1 Directly Coupled Generation

13.1.1 The short circuit parameters of synchronous **PGMs** shall be determined by means of a short-circuit test in accordance with EN 50438.

13.2 Inverter Connected Generation

13.2.1 In addition to EN 50438 **Manufacturers** of **Inverters** shall take account of the following:

- **DNOs** need to understand the contribution that **Inverters** make to system fault levels in order to determine that they can continue to safely operate their **Networks** without exceeding design fault levels for switchgear and other circuit components.

- As the output from an **Inverter** reduces to zero when a short circuit is applied to its terminals, a short circuit test does not represent the worst case scenario; in most cases the voltage will not collapse to zero for a **Network** fault.

13.2.2 To address this issue a test, which ensures that at least 10% of nominal voltage remains and which allows the **Generating Unit** to feed into a load with an X to R ratio of 2.5, is specified as detailed in Annex A1.

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Appendix 1 Emerging Technologies Exceptions

Ofgem have published details of **Micro-generators** which are classified as emerging technologies in **Great Britain** in their document "Requirement for generators – 'emerging technology' decision document", 17 May 2017. The list is reproduced in the table below for reference:

Manufacturer	Micro-generator
Baxi	'Baxi Ecogen' generators (the specific products are the Baxi Ecogen 24/1.0, Baxi Ecogen 24/1.0 LPG and Baxi Ecogen System).
KD Navien	KD Navien stirling engine m-CHP (Hybrigen SE) (the specific products that use this PGM are the 'NCM-1130HH – 1 KWel' and the 'NCM-2030HH – 2 kWel').
OkoFEN	Pellematic Smart_e
SenerTec	Dachs Stirling SE Erdgas and Dachs Stilring SE Flussiggas

For **Generating Units** classified as an emerging technology at the time of their connection to a **DNO's Distribution Network** the following sections of EREC G98 Part 2 do not apply.

- The frequency withstand capability in 10.1;
- The rate of change of frequency requirements in 10.2;
- The **Limited Frequency Sensitive Mode – Overfrequency requirements** in 10.3;
- The constant active power output requirement in 10.4;
- The **Interface Protection** settings in 11.1.3.

Performance requirements for these emerging technologies will be within the protection setting limits in Table 2 of section 11, but they do not have to extend to the full ranges of the protection requirements. For example if a technology can only operate in a frequency range from 49.5Hz to 50.5 Hz and outside of this it will disconnect from the **Distribution Network**, this technology would still be deemed to meet this EREC G98 Part 2.

Emerging technology classification may be revoked as detailed in the Ofgem document "Requirement for generators – 'emerging technology' decision document", 17 May 2017.

Generating Units classified as emerging technologies and connected to the **Distribution Network** prior to the date of revocation of that classification as an emerging technology shall be considered to be existing generators, and this appendix continues to apply.

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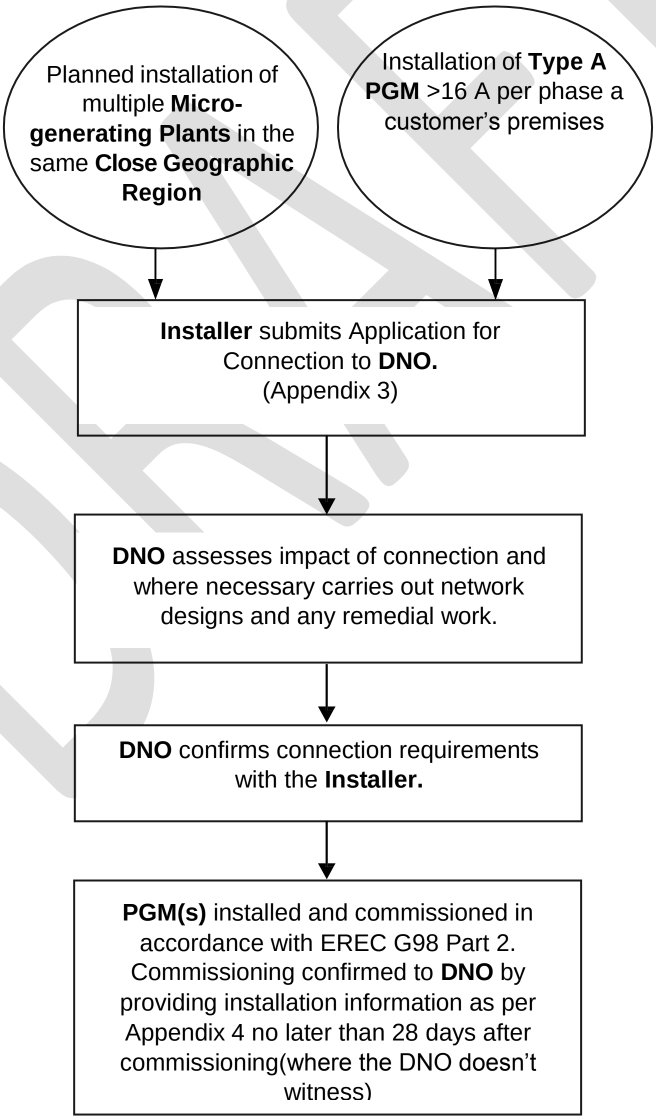
Appendix 2 Connection Procedure Flow Chart

Connection Procedure Flow Chart - For multiple **Micro-generating Plants** in a **Close Geographic Region** under a planned programme of work made up of **Type Tested Micro-generators** and for **Type A Type Tested PGM** greater than 16 A per phase and connected at **LV** within the **Customer's Installation**. For **Micro-generating Plants** using **Type Tested** equipment in a single premises see the current version of EREC G98 Part 1. For non **Type Tested** equipment see the current version of EREC G99.

NOTE: The processes shown here only refer to the interface between the **Installer** and the **DNO**. It may also be necessary for the **Installer** / **Customer** to inform the relevant **Meter Operator** and **Supplier** that a **PGM** has been installed.

Connecting Type Tested Micro-generator(s) in multiple premises and Type A Type Tested PGM(s) >16 A per phase in single premises and connected at LV within the Customer's Installation



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Appendix 3a Application for Connection of multiple Micro-generator installations

[Note: All forms in the Appendices will be reviewed as part of the current work being undertaken on compliance.]

Application for connection of multiple Micro-generator installations	
To ABC electricity distribution 99 West St, Imaginary Town, ZZ99 9AA	DNO or IDNO abced@wxyz.com
Installer Details:	
Installer	
Accreditation / Qualification	
Address	
Post Code	
Contact person	
Telephone Number	
E-mail address	
Customer Details:	
Customer (name)	
Address	
Post Code	
Contact person (if different from **Customer**)	
Telephone number	
E-mail address	
MPAN(s)	

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Black text = Changes/ additional words

Proposed Micro-generator Details:						
Address	Post Code	MPAN	**Micro-generator** installed capacity in kW at 230V AC			Type Test Ref No
			PH1	PH2	PH3	

Use continuation sheet where more than 10 **Micro-generator**s are to be installed.

Please include an electronic map with the location of each property highlighted in red.

Record **Micro-generator** capacities, in rated output kW at 230V AC, to one decimal place, under PH1 for single phase supplies and under the relevant phase for two and three phase supplies. For example 2.8kW

Detail on a separate sheet if there are any proposals to limit export to a lower figure than that of the **Micro-generator**

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Appendix 3b. Application for connection of Type A Type Tested PGMs part of the current work being undertaken on compliance.]

Application for Connection of Type A Type Tested PGM connected at LV within the Customer's Installation

To	ABC electricity distribution 99 West St, Imaginary Town, ZZ99 9AA	DNO or IDNO abced@wxyz.com

Installer Details:	
Installer	
Accreditation / Qualification	
Address	
Post Code	
Contact person	
Telephone Number	
E-mail address	

Customer Details:	
Customer (name)	
Address	
Post Code	
Contact person (if different from **Customer**)	
Telephone Number	
E-mail address	

Details of Existing and PGM(s):

<table>
<tr><td rowspan="3">Address</td><td rowspan="3">Post code</td><td rowspan="3">MPAN</td><td rowspan="3">Proposed date of Installation</td><td colspan="9">PGM installed capacity in kW at 230 V AC
E = existing; P = Proposed</td><td rowspan="3">Type Tested reference number</td></tr>
<tr><td colspan="2" rowspan="2">3 phase units</td><td colspan="6">Single/ split phase units</td><td rowspan="2">Power factor</td></tr>
<tr><td colspan="2">Phase 1</td><td colspan="2">Phase 2</td><td colspan="2">Phase 3</td></tr>
<tr><td></td><td></td><td></td><td></td><td>E</td><td>P</td><td>E</td><td>P</td><td>E</td><td>P</td><td>E</td><td>P</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Blue text = from G83 (and G59 where equivalent)
Purple text = from G59 definitions
Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

Balance of Multiple Single Phase PGMs – where applicable	
I confirm that design of the complete installation has been carried out to limit output power imbalance to below 16 A per phase, as required by EREC G98 Part 2.	
Signed:	Date:

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Appendix 4a Installation Document

[Note: All forms in the Appendices will be reviewed as part of the current work being undertaken on compliance.]

The following form needs to be provided for every **PGM** installed at a site.

Installation Document for Generating Units connected under EREC G98 Part 2	
Please complete and provide this document for every **PGM** installed. Where multiple **PGMs** will exist within one premises once installation is complete please provide **Installation Document**s for each **PGM**. For example, if three **PGMs** are to be installed in a single location then three **Installation Documents** need to be provided.	
To ABC electricity distribution DNO or IDNO 99 West St, Imaginary Town, ZZ99 9AA abced@wxyz.com	
Customer contact details	
Name	
Address Including Postcode	
Telephone number	
Email address	
Customer signature	
Installer contact details	
Name	
Accreditation/ qualification	
Address Including Postcode	
Telephone number	
Email address	
Installer signature	
Installation details	
Address	

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Including Post code	
Location within **Customer's Installation**	
Location of Lockable Isolation Switch	

Installers of Micro-generating Plants should leave this section blank. This section is for **Type A Type Tested PGM**s greater than 16 A per phase connected at **LV** within the **Customer's Installation**	
Information to be enclosed	
Description	Confirmation
Final copy of circuit diagram	Yes / No*
Schedule of protection settings (may be included in circuit diagram)	Yes / No*
Commissioning Checks	
Installation satisfies the requirements of BS7671 (IET Wiring Regulations).	Yes / No*
Suitable lockable points of isolation have been provided between the **PGMs** and the rest of the installation.	Yes / No*
Labels have been installed at all points of isolation in accordance with EREC G98 Part 2.	Yes / No*
Interlocking that prevents **PGM**s being connected in parallel with the **DNO** system (without synchronising) is in place and operates correctly.	Yes / No*
The **Interface Protection** settings have been checked and comply with EREC G98 Part 2	Yes / No*
PGMs successfully synchronise with the **DNO's Distribution Network** without causing significant voltage disturbance.	Yes / No*
PGMs successfully run in parallel with the **DNO Distribution Network** without tripping and without causing significant voltage disturbances.	Yes / No*
PGMs successfully disconnect without causing a significant voltage disturbance, when they are shut down.	Yes / No*
Interface Protection operates and disconnects the **PGM**s quickly (within 1s) when a suitably rated switch, located between the **PGMs** and the **DNO**s incoming connection, is opened.	Yes / No*
PGM(s) remain disconnected for at least 20s after switch is reclosed.	Yes / No*
Loss of tripping and auxiliary supplies Where applicable, loss of supplies to tripping and protection relays results in either **PGM** lockout or an alarm to a 24hr manned control centre.	Yes / No*

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Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

Balance of Multiple Single Phase PGMs Confirm that design of the complete installation has been carried out to limit output power imbalance to below 16 A per phase, as required by EREC G98 Part 2.	Yes / No*
Additional Comments / Observations:	

Declaration – to be completed by Installer for Generating Units Type Tested to EREC G98 Part 2	
I declare that the **Generating Unit** and the installation which together form a **PGM** at the above address, which were installed on or after 17th May 2019, comply with the requirements of EREC G98 Part 2 and the commissioning checks have been successfully completed where applicable. The **PGM** comprises only **Generating Units Type Tested** to EREC G98 Part 2 or later,	
Signature:	Date:

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Black text = Changes/ additional words

Appendix 4b Site Summary Form

[Note: All forms in the Appendices will be reviewed as part of the current work being undertaken on compliance.]

This form should be submitted with all **installation documents** for each Installation site.

Site Summary Form

Please complete and provide this document for every site where a **PGM** is installed. Where multiple **Generating Units** and **PGM**s will exist within one premise once installation is complete please provide **Installation Documents** for each **Generating Unit and PGM**. For example, if three **PGMs** are to be installed in a single location then three **Installation Documents** plus this Site Summary Form need to be provided.

To	ABC electricity distribution 99 West St, Imaginary Town, ZZ99 9AA	DNO or IDNO abced@wxyz.com

Customer contact details	
Name	
Address Including Postcode	
Telephone number	
Email address	

Installer contact details	
Name	
Accreditation/ qualification	
Address Including Postcode	
Telephone number	
Email address	

Installation details	
Address Including Post code	
Location within **Customer's Installation**	
Location of Lockable Isolation Switch	

Details of PGM(s) and Generating Unit(s) - where applicable

Manufacturer / Reference	Date of Installation	Technology Type	Type Test Ref No.	**PGM/Generating Unit installed capacity in kW**				
				3-Phase Units	Single Phase Units			Power Factor
					PH1	PH2	PH3	

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Use a separate line for new and existing installations and for different Primary Energy sources above. Use PH 1 column for single phase supply								

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Black text = Changes/ additional words

Appendix 5 Type Test Verification Report

<table>
<tr><td colspan="6">Type Approval and Manufacturer declaration of compliance with the requirements of EREC G98 Part 2.</td></tr>
<tr><td colspan="3">Type Tested reference number</td><td colspan="3"></td></tr>
<tr><td colspan="3">PGM technology</td><td colspan="3"></td></tr>
<tr><td colspan="3">Manufacturer name</td><td colspan="3"></td></tr>
<tr><td colspan="3">Address</td><td colspan="3"></td></tr>
<tr><td>Tel</td><td colspan="3"></td><td>Fax</td><td></td></tr>
<tr><td>E:mail</td><td colspan="3"></td><td>Web site</td><td></td></tr>
<tr><td colspan="2" rowspan="5">Maximum rated capacity, use separate sheet if more than one connection option.</td><td colspan="4">Connection Option</td></tr>
<tr><td></td><td colspan="3">kW single phase, single, split or three phase system</td></tr>
<tr><td></td><td colspan="3">kW three phase</td></tr>
<tr><td></td><td colspan="3">kW two phases in three phase system</td></tr>
<tr><td></td><td colspan="3">kW two phases split phase system</td></tr>
<tr><td colspan="6">Manufacturer declaration. - I certify that all products supplied by the company with the above Type Test reference number will be manufactured and tested to ensure that they perform as stated in this document, prior to shipment to site and that no site modifications are required to ensure that the product meets all the requirements of EREC G98 Part 2.</td></tr>
<tr><td>Signed</td><td colspan="2"></td><td colspan="2">On behalf of</td><td></td></tr>
<tr><td colspan="6">Note that testing can be done by the Manufacturer or by an external test house.
Where parts of the testing are carried out by persons or organisations other than the Manufacturer then that person or organisation shall keep copies of all test records and results supplied to them to verify that the testing has been carried out by people with sufficient technical competency to carry out the tests.</td></tr>
</table>

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Operating Range. This test should be carried out as specified in EN 50438 D.3.1. Active power shall be recorded every second. The **Interface Protection** shall be disabled during the tests.
Test 1 Voltage = 85% of nominal (195.5 V) Frequency = 47.5 HZ Power factor = 1 Period of test 90 minutes
Test 2 Voltage = 110% of nominal (253 V). Frequency = 51.5 HZ Power factor = 1 Period of test 90 minutes

Power Quality. Harmonics. These tests should be carried out as specified in 61000-3-2 or 61000-3-12. The relevant table applicable to the size of the **Generating Unit** should be completed. The chosen test should be undertaken with a fixed source of energy at two power levels a) between 45 and 55% and b) at 100% of maximum export capacity.

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

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

Generating Unit tested to BS EN 61000-3-2						
Generator Unit rating per phase (rpp)				kW		
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value MV in Amps		Measured Value MV in Amps		Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
2					1.080	
3					2.300	
4					0.430	

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Generating Unit tested to BS EN 61000-3-2						
Generator Unit rating per phase (rpp)				kW		
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value MV in Amps		Measured Value MV in Amps		Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
5					1.140	
6					0.300	
7					0.770	
8					0.230	
9					0.400	
10					0.184	
11					0.330	
12					0.153	
13					0.210	
14					0.131	
15					0.150	
16					0.115	
17					0.132	
18					0.102	
19					0.118	
20					0.092	
21					0.107	0.160
22					0.084	
23					0.098	0.147
24					0.077	
25					0.090	0.135
26					0.071	
27					0.083	0.124
28					0.066	
29					0.078	0.117

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Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

Generating Unit tested to BS EN 61000-3-2						
Generator Unit rating per phase (rpp)				kW		
Harmonic	At 45-55% of rated output		100% of rated output			
	Measured Value MV in Amps		Measured Value MV in Amps		Limit in BS EN 61000-3-2 in Amps	Higher limit for odd harmonics 21 and above
30					0.061	
31					0.073	0.109
32					0.058	
33					0.068	0.102
34					0.054	
35					0.064	0.096
36					0.051	
37					0.061	0.091
38					0.048	
39					0.058	0.087
40					0.046	

Note the higher limits for odd harmonics 21 and above are only allowable under certain conditions, if these higher limits are utilised please state the exemption used as detailed in part 6.2.3.4 of BS EN 61000-3-2 in the box below.

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Green text = from other EU documents eg EN 50438
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Generating Unit tested to BS EN 61000-3-12						
Generating Unit rating per phase (rpp)				kVA	Harmonic % =Measured Value (Amps) x 23/rating per phase (kVA)	
Harmonic	At 45-55% of rated output		100% of rated output		Limit in BS EN 61000-3-12	
	Measured Value MV in Amps	%	Measured Value MV in Amps	%	1 phase	3 phase
2					8%	8%
3					21.6%	Not stated
4					4%	4%
5					10.7%	10.7%
6					2.67%	2.67%
7					7.2%	7.2%
8					2%	2%
9					3.8%	Not stated
10					1.6%	1.6%
11					3.1%	3.1%
12					1.33%	1.33%
13					2%	2%
THD					23%	13%
PWHD					23%	22%

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Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

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

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

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

* Applies to three phase and split single phase **Generating Unit**s

^ Applies to single phase **Generating Unit**s and **Generating Unit**s using two phases on a three phase system

For voltage change and flicker measurements the following formula is to be used to convert the measured values to the normalised values where the power factor of the generation output is 0.98 or above.

Normalised value = Measured value*reference source resistance/measured source resistance at test point

Single phase units reference source resistance is 0.4 Ω

Two phase units in a three phase system reference source resistance is 0.4 Ω

Two phase units in a split phase system reference source resistance is 0.24 Ω

Three phase units reference source resistance is 0.24 Ω

Where the power factor of the output is under 0.98 then the Xl to R ratio of the test impedance should be close to that of the Standard Impedance.

Blue text = from G83 (and G59 where equivalent)
Purple text = from G59 definitions
Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

The stopping test should be a trip from full load operation. The duration of these tests need to comply with the particular requirements set out in the testing notes for the technology under test. Dates and location of the test need to be noted below			
Test start date		Test end date	
Test location			

Power quality. DC injection. This test should be carried out in accordance with EN 50438 Annex D.3.10.				
Test power level	10%	50%	75%	100%
Recorded value in Amps				
as % of rated AC current				
Limit	0.5%	0.5%	0.5%	0.5%

Power Quality. Power factor. This test shall be carried out in accordance with EN 50538 Annex D.3.4.1 but with nominal voltage -6% and +10%. Voltage to be maintained within ±1.5% of the stated level during the test.			
	216.2V	230V	253V
20% of active power			
50% of active power			
75% of active power			
100% of active power			
Limit	>0.95	>0.95	>0.95

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Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

Protection. Frequency tests. These tests should be carried out in accordance with EN 50438 Annex D.2.4 and the notes in EREC G98 Part 2 Annex A1 A 1.3.2.						
Function	Setting		Trip test		"No trip tests"	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
U/F stage 1	47.5Hz	20s			47.7Hz 25s	
U/F stage 2	47Hz	0.5s			47.2Hz 19.98s	
					46.8Hz 0.48s	
O/F stage 1	52Hz	0.5s			51.8Hz 89.98s	
					52.2Hz 0.48s	

Protection. Voltage tests. These tests should be carried out in accordance with EN 50438 Annex D.2.3 and the notes in EREC G98 Part 2 Annex A1 A 1.3.1.						
Function	Setting		Trip test		"No trip tests"	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
U/V stage 1	200.1V	2.5s			204.1V 3.5s	
U/V stage 2	184V	0.5s			188V 2.48s	
					180V 0.48s	
O/V stage 1	262.2V	1.0s			258.2V 2.0s	
O/V stage 2	273.7V	0.5s			269.7V 0.98s	
					277.7V 0.48s	
Note for Voltage tests the Voltage required to trip is the setting ±3.45V. The time delay can be measured at a larger deviation than the minimum required to operate the protection. The No trip						

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

Protection. Loss of Mains test. For PV **Inverters** shall be tested in accordance with BS EN 62116. Other **Inverters** should be tested in accordance with EN 50438 Annex D.2.5 at 10%, 55% and 100% of rated power.						
To be carried out at three output power levels with a tolerance of plus or minus 5% in Test Power levels.						
Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded **Network**	95% of output	95% of output	95% of output	105% of output	105% of output	105% of output
Trip time. Limit is 0.5 seconds						
For Multi phase **Generating Units** confirm that the device shuts down correctly after the removal of a single fuse as well as operation of all phases.						
Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded **Network**	95% of output	95% of output	95% of output	105% of output	105% of output	105% of output
Trip time. Ph1 fuse removed						
Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded **Network**	95% of output	95% of output	95% of output	105% of output	105% of output	105% of output
Trip time. Ph2 fuse removed						
Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded **Network**	95% of output	95% of output	95% of output	105% of output	105% of output	105% of output
Trip time. Ph3 fuse removed						
Note for technologies which have a substantial shut down time this can be added to the 0.5 seconds in establishing that the trip occurred in less than 0.5s. Maximum shut down time could therefore be up to 1.0 seconds for these technologies.						
Indicate additional shut down time included in above results.					ms	
For **Inverters** tested to BS EN 62116 the following sub set of tests should be recorded in the following table.						
Test Power and	33%	66%	100%	33%	66%	100%

imbalance	-5% Q Test 22	-5% Q Test 12	-5% P Test 5	+5% Q Test 31	+5% Q Test 21	+5% P Test 10
Trip time. Limit is 0.5s						

Protection. Frequency change, Vector Shift Stability test This test should be carried out in accordance with EREC G98 Part 2 Annex A1 A 1.3.5.				
	Start Frequency	Change	End Frequency	Confirm no trip
Positive Vector Shift	49.5Hz	+50 degrees		
Negative Vector Shift	50.5Hz	- 50 degrees		

Protection. Frequency change, RoCoF Stability test The requirement is specified in section 5.3.3, test procedure in Annex A or B 1.3.6			
Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0Hz to 51.0Hz	+0.95Hzs^{-1}	2.1s	
51.0Hz to 49.0Hz	-0.95Hzs^{-1}	2.1s	

Protection. Limited Frequency Sensitive Mode – Over frequency test This test should be carried out in accordance with EN 50438 Annex D.3.3 Power response to over-frequency. The test should be carried out using the specific threshold frequency of 50.4 Hz and **Droop** of 10%.				
Test sequence at power level >80%	Measured Active Output Power	Frequency	Primary Power Source	Active Power Gradient
Step a) 50.00Hz ±0.01Hz				-
Step b) 50.45Hz ±0.05Hz				-
Step c) 50.70Hz ±0.10Hz				-
Step d) 51.15Hz ±0.05Hz				-
Step e) 50.70Hz ±0.10Hz				-
Step f) 50.45Hz ±0.05Hz				-

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Step g) 50.00Hz ±0.01Hz				
Test sequence at power level 40% - 60%	Measured Active Output Power	Frequency	Primary Power Source	Active Power Gradient
Step a) 50.00Hz ±0.01Hz				-
Step b) 50.45Hz ±0.05Hz				-
Step c) 50.70Hz ±0.10Hz				-
Step d) 51.15Hz ±0.05Hz				-
Step e) 50.70Hz ±0.10Hz				-
Step f) 50.45Hz ±0.05Hz				-
Step g) 50.00Hz ±0.01Hz				
Steps as defined in EN 50438				

Protection. Power output with falling frequency test This test should be carried out in accordance with EN 50438 Annex D.3.2 active power feed-in at under-frequency.			
Test sequence	Measured Active Output Power	Frequency	Primary power source
Test a) 50Hz ± 0.01Hz			
Test b) Point between 49.5 Hz and 49.6 Hz			
Test c) Point between 47.5 Hz and 47.6 Hz			
NOTE: The operating point in Test (b) and (c) shall be maintained for at least 5 minutes.			

Protection. Re-connection timer.						
Test should prove that the reconnection sequence starts after a minimum delay of 20 seconds for restoration of voltage and frequency to within the stage 1 settings of Table 2.						
Time delay setting	Measured delay		Checks on no reconnection when voltage or frequency is brought to just outside stage 1 limits of Table 2.			
			At 266.2V	At 196.1V	At 47.4Hz	At 51.6Hz
Confirmation that the **PGM** does not re-connect.						

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Fault level contribution. These tests shall be carried out in accordance with EREC G98 Part 2 Annex A1 A 1.4.6 and A 1.4.7.					
For machines with electro-magnetic output			For **Inverter** output		
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	i_p		20ms		
Initial Value of aperiodic current	A		100ms		
Initial symmetrical short-circuit current*	I_k		250ms		
Decaying (aperiodic) component of short circuit current*	i_{DC}		500ms		
Reactance/Resistance Ratio of source*	$^{X}/_{R}$		Time to trip		In seconds
For rotating machines and linear piston machines the test should produce a 0s – 2s plot of the short circuit current as seen at the **Generating Unit** terminals. * Values for these parameters should be provided where the short circuit duration is sufficiently long to enable interpolation of the plot					

Self-Monitoring solid state switching, No specified test requirements. Refer to EREC G98 Part 2 Annex A1 A 1.4.8.	Yes/or NA
It has been verified that in the event of the solid state switching device failing to disconnect the **PGM**, the voltage on the output side of the switching device is reduced to a value below 50 volts within 0.5 seconds.	

Additional comments

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Appendix 6 Decommissioning Confirmation

[Note: All forms in the Appendices will be reviewed as part of the current work being undertaken on compliance.]

Type A PGM (including Micro-generator) DECOMMISSIONING CONFIRMATION						
Type A PGM de-commissioning form and declaration, to be provided to the **DNO** by the **Installer** no later than 28 days after de-commissioning all, or some of the **PGMs** in a **Customer's Installation**.						
To ABC electricity distribution 99 West St, Imaginary Town, ZZ99 9AA			DNO or IDNO abced@wxyz.com			
Electricity **Customer** at site						
Customer contact telephone						
Generating Unit Site address						
Post code						
MPAN						
Generating Unit owner - if different from above						
Contact address						
Contact telephone number						
Details of removed **PGM**s or **Generating Unit(s)**						
Manufacturer and model type	**Type Tested** Reference number	Prime mover and fuel source	Capacity in kW			
			Phase 1	Phase 2	Phase 3	
Details of remaining **PGM**s or **Generating Unit(s)**						
Manufacturer and model type	**Type Tested** Reference number	Prime mover and fuel source	Capacity in kW			
			Phase 1	Phase 2	Phase 3	

I confirm that the **PGM**s or **Generating Unit** installation noted above has been modified or totally de-commissioned and continues to comply with the requirements of EREC G98 Part 2 as required by

the Distribution Code of **Great Britain**. I enclose a copy of the system schematic which has been left on site at the **Customer's** incoming meter location.					
Name		Signed		Date	
On behalf of **Installer**					
Accreditation / Qualification					
Installer address					
Post code					
Contact person					
Telephone number					
E:mail address					

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Appendix 7

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Appendix 8 Example calculations to determine if unequal generation across different phases is acceptable or not

A **Customer Installation** might have 12kW of PV and a 3kW CHP plant. Due to the areas of roof available the PV plant comprises 2 by 4.5kW **Inverter**s and a 3kW **Inverter**.

A. The following connection would be deemed acceptable:

- Ph 1 4.5kW PV
- Ph 2 3kW PV plus 3kW CHP
- Ph 3 4.5kW PV

This would lead to:

- 1.5kW imbalance with CHP at zero output
- 1.5kW imbalance with CHP and PV at maximum output
- 3kW imbalance with CHP at maximum output and PV at zero output.

All of which are below the 16A imbalance limit.

B. The following alternative connection for the same plant would be deemed unacceptable:

- Ph1 4.5kW PV plus 3kW CHP
- Ph 2 3kW PV
- Ph3 4.5kW PV

This is not acceptable as at full output Ph1 would have 4.5kW more output than Ph2 and this exceeds the 16A limit described above even though on an individual technology basis the limit of 16A is not exceeded.

If a **Customer Installation** has a single technology installed which has **Generating Units** with different output patterns for example PV mounted on roofs facing different directions then they should be regarded separately

(For these cases the assumption is that in the morning the east roof would produce full output and the west roof zero output with the opposite in the afternoon. Whilst this might not be strictly true the simplification makes the calculations much simpler)

A. The following connection would be deemed acceptable.

- Ph 1 6kW east roof 6kW west roof
- Ph 2 6kW east roof 6kW west roof
- Ph 3 5kW east roof 5kW west roof

B. The following alternative connection for the same plant would be deemed unacceptable.

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- Ph1 12kW east roof
- Ph2 5kW east roof 5kW west roof
- Ph 3 12kW west roof

This is not acceptable as Ph 1 would produce more than Ph 3 in the morning and in the afternoon Ph 3 would produce more than Ph 1 in each case by a margin greater than 16A.

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Appendix 9 Non-Standard private LV networks calculation of appropriate protection settings

The standard over and under voltage settings for **LV** connected **Generating Units** have been developed based on a nominal **LV** voltage of 230V. Typical **DNO** practice is to purchase transformers with a transformer winding ratio of 11 000:433, with off load tap changers allowing the nominal winding ratio to be changed over a range of plus or minus 5% and with delta connected **HV** windings. Where a **DNO** provides a connection at **HV** and the **Customer** uses transformers of the same nominal winding ratio and with the same tap selection as the **DNO** then the standard **LV** settings in table 10.5.7.1 can be used for **Generating Units** connected to the **Customers LV** network. Where a **DNO** provides a connection at **HV** and the **Customers** transformers have different nominal winding ratios, and he chooses to take the protection reference measurements from the **LV** side of the transformer, then the **LV** settings stated in table 10.5.7.1 should not be used without the prior agreement of the **DNO**. Where the **DNO** does not consider the standard **LV** settings to be suitable, the following method shall be used to calculate the required **LV** settings based on the **HV** settings for **Small Power Station**s stated in table 10.5.7.1.

Identify the value of the transformers nominal winding ratio and if using other than the nominal tap, increase or decrease this value to establish a **LV System** nominal value based on the transformer winding ratio and tap position and the **DNO**s declared **HV system** nominal voltage.

For example a **Customer** is using a 11 000V to 230/400V transformer and it is proposed to operate it on tap 1 representing an increase in the high voltage winding of +5% and the nominal HV voltage is 11 000V.

$V_{LVsys} = V_{LVnom} \text{ x } V_{HVnom/}V_{HVtap}$

V_{LVsys} = 230 x 11 000/11 550 = 219V

Where:

V_{LVsys} – LV system voltage

V_{LVnom} - LV system nominal voltage (230V)

V_{HVnom} - HV system nominal voltage (11 000V)

V_{HVtap} – HV tap position

The revised **LV** voltage settings required therefore would be;

OV stage 1	=	219x1.1	=	241V
OV stage 2	=	219x1.13	=	247.5V
UV stage 1	=	219x0.87	=	190.5V
UV stage 2	=	219x0.8	=	175V

The time delays required for each stage are as stated in table 10.5.7.1.

Where **Generating Units** are designed with balanced 3 phase outputs and no neutral is required then phase to phase voltages can be used instead of phase to neutral voltages.

This approach does not lend itself to **Type Tested Generating Unit**s and should only be used by prior arrangement with the host **DNO**. Where all other requirements of EREC G59 would allow the **Generation Unit** to be **Type Tested**, the **Manufacturer** may produce a declaration in a similar format to section 13.1 for presentation to the **DNO** by the **Installer**, stating that all **Generating Units** produced for a particular **Power Station** comply with the revised over and under voltage settings. All other required data should be provided as for **Type Tested Generating Unit**s. This declaration should make reference to a particular **Power Station** and its declared **LV System** voltage. These documents should not be registered on the ENA web site as they will not be of use to other **Installer**s who will have to consult with the **Manufacturer** and **DNO** to agree settings for each particular **Power Station**.

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Annex A1 Requirements for Testing: Common Inverter Connected Generating Unit requirements

A 1.1 General

The compliance testing annex of EN 50438 should be complied with except where exceptions are detailed in this Annex.

A 1.2 CE Marking and Certification

The type verification procedure requires that the **Generating Unit** 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 **Generating Unit Interface Protection**, therefore the **Inverter** and any separate **Interface Protection** unit will be required to follow functional type testing as described in this EREC G98 Part 2, and recorded in format similar to that shown in Appendix 5.

A 1.3 Type Verification Functional Testing of the Interface Protection

Type testing is the responsibility of the **Manufacturer**.

The type testing can be done by the **Manufacturer** of an individual component or by an external test house.

The type testing will verify that the operation of the **Interface Protection** shall result:

a) in the safe disconnection of the from the **DNO's Distribution Network** in the event that the protection settings specified in Table 2 are exceeded; and
b) in the remaining connected to the **DNO's Distribution Network** while **Network** conditions are:
    a. within the envelope specified by the settings plus and minus the tolerances specified for equipment operation in Table 2; and
    b. within the trip delay settings specified in Table 2.

A 1.3.1 Over / Under Voltage

In addition to the EN50438 over / under voltage tests the tests in this paragraph shall be undertaken.

The **Inverter** shall be tested by operating the **Inverter** in parallel with a variable **AC** test supply, see figure A2. Correct protection and ride-through operation shall be confirmed during operation 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.

To establish a trip voltage, the test voltage should be applied in steps of ± 0.5% or less, of the nominal voltage 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 starting at least 4V below or above the setting. The test voltage at which this trip occurred is to be recorded. Additional tests just above and below the trip voltage should be undertaken to show that the test is repeatable and the figure at which a repeatable trip occurs should be recorded on the type verification test report Appendix 5 of this Engineering Recommendation.

To establish the trip time, the test voltage should be applied starting from 4V below or above the recorded trip voltage and should be changed to 4V above or below the recorded trip voltage in a single step. The time taken from the step change to the **Generating Unit** tripping is to be recorded on the type verification test report Appendix 5 of this Engineering Recommendation.

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To establish correct ride-through operation, the test voltage should be applied at each setting plus or minus 4V and for the relevant times shown in the table in Appendix 5.

For example to test overvoltage setting stage 1 which is required to be set at nominally 262.2V the circuit should be set up as shown below and the voltage adjusted to 254.2 volts. The **Inverter** should then be powered up to export a measurable amount of energy so that it can be confirmed that the **Inverter** has ceased to output energy. The variable voltage supply is then increased in steps of no more than 0.5% of nominal (1.15V) maintaining the voltage for at least 1.5 seconds (trip time plus 0.5 seconds) at each voltage level. At each voltage level confirmation that the **Inverter** has not tripped after the time delay is required to be taken. At the voltage level at which a trip occurs then this should be recorded as the provisional trip voltage. Additional tests just below and if necessary just above the provisional trip voltage will allow the actual trip voltage to be established on a repeatable basis. This value should be recorded. For the sake of this example the actual trip level is assumed to have been established as being 261V. The variable voltage supply should be set to 257V the **Inverter** set to produce a measurable output and then the voltage raised to 265V in a single step. The time from the step change to the output of **Inverter** falling to zero should be recorded as the trip time.

The **Inverter** then needs to operate at 4 volts below the nominal overvoltage stage 1 setting which is 258.2V for a period of at least 2 seconds without tripping and while producing a measurable output. This can be confirmed as a no trip in the relevant part of Appendix 5. The voltage then needs to be stepped up to the next level of 269.7V for a period of 0.98 seconds and then back to 258.2V during which time the output of the relay should continue with no interruption though it may change due to the change in voltage, this can be recorded as a no trip for the second value. The step up and step down test needs to be done a second time with a max value of 277.7V and with a time of 0.48 seconds. The **Inverter** is allowed to shut down during this period to protect its self as allowed by note 1 of Table 1 of this document, but it must resume production again when the voltage has been restored to 258.2V or it may continue to produce an output during this period. There is no defined time for resumption of production but it must be shown that restart timer has not operated so it must begin producing again in less than 20 seconds.

Note that this philosophy should be applied to the under voltage, over and under frequency, RoCoF and Vector shift stability tests which follow.

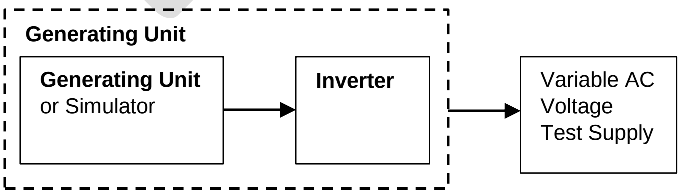
Note:

(1) The frequency required to trip is the setting plus or minus 0.1Hz

(2) Measurement of operating time should be measured at a value of 0.2Hz (suggestion – 2 x tolerance) above/below the setting to give "positive" operation

(3) The "No trip tests" need to be carried out at the relevant values and times as shown in the table above to ensure that the protection will not trip in error.

Figure A2. Generating Unit Test set up – Over / Under Voltage



A 1.3.2 Over / Under Frequency

In addition to the EN50438 over / under frequency tests the tests in this paragraph shall be undertaken into account.

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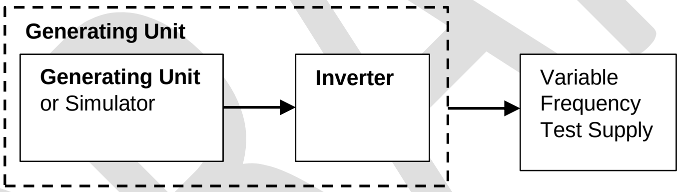
The **Inverter** shall be tested by operating the **Inverter** in parallel with a low impedance, variable frequency test supply system, see figure A3. Correct protection and ride-through operation should be confirmed during operation of the **Inverter**. The set points for over and under frequency at which the **Inverter** system disconnects from the supply will be established by varying the test supply frequency.

To establish a trip frequency, the test frequency should be applied in a slow ramp rate of less than 0.1Hz/second, or if this is not possible in steps of 0.05Hz 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. The test frequency at which this trip occurred is to be recorded. Additional tests just above and below the trip frequency should be undertaken to show that the test is repeatable and the figure at which a repeatable trip occurs should be recorded on the type verification test report Appendix 5 of this Engineering Recommendation.

To establish the trip time, the test frequency should be applied starting from 0.3Hz below or above the recorded trip frequency and should be changed to 0.3Hz above or below the recorded trip frequency in a single step. The time taken from the step change to the **Generating Unit** tripping is to be recorded on the type verification test report Appendix 5 of this Engineering Recommendation. It should be noted that with some loss of mains detection techniques this test may result in a faster trip due to operation of the loss of mains protection. To avoid this it is necessary to establish an accurate frequency for the trip to enable the use of a much smaller step change to initiate the trip and establish a trip time. This may require the test to be repeated several times to establish that the time delay is correct.

To establish correct ride-through operation, the test frequency should be applied at each setting plus or minus 0.2Hz and for the relevant times shown in the table in Appendix 5.

Figure A3 Test set up – Over / Under Frequency



A 1.3.3 Loss of Mains Protection

The tests for all **Inverters** should be carried out in accordance with BS EN 62116. For all other technologies the test described in EN 50438 should be completed at 10%, 55%, and 100% of the output power. In both cases a subset of results should be recorded as indicated in the Protection – Loss of Mains test section of Appendix 5 Type Test Verification Report.

A 1.3.4 Reconnection

Further tests will confirm that once the **AC** supply voltage and frequency have returned to be within the stage 1 settings specified in table 2 following an automatic protection trip operation there is a minimum time delay of 20 seconds before the **Inverter** output is restored (ie before the **Inverter** automatically reconnects to the **Distribution Network**).

A 1.3.5 Frequency Drift and Step Change Stability test

The tests will be carried out using the same circuit as specified in A1.3.2 above and following confirmation that the **Generating Unit** has passed the under and over frequency trip tests and the under and over frequency stability tests.

Four tests are required to be carried out with all protection functions enabled including loss of mains. For each stability test the **Generating Unit** should not trip during the test.

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For the step change test the **Generating Unit** should be operated with a measurable output at the start frequency and then a vector shift should be applied by extending or reducing the time of a single cycle with subsequent cycles returning to the start frequency. The start frequency should then be maintained for a period of at least 10 seconds to complete the test. The **Generating Unit** should not trip during this test.

For frequency drift tests the **Generating Unit** should be operated with a measurable output at the start frequency and then the frequency changed in a ramp function at 0.19Hz per second to the end frequency. On reaching the end frequency it should be maintained for a period of at least 10 seconds. The **Generating Unit** should not trip during this test.

A 1.3.6 Active power feed-in at under-frequency

EN 50438 shall be complied with in respect of active power feed-in at under-frequency

A 1.3.7 Power response to over-frequency

EN 50438 shall be complied with in respect of Power response to over-frequency.

A 1.4 POWER QUALITY

A 1.4.1 Harmonics

The tests should be carried out as specified in BS EN 61000-3-2 and can be undertaken with a fixed source of energy at two power levels firstly between 45 and 55% and at 100% of maximum export capacity.

The test must be carried out with a minimum of 2kW of rated **Generating Units**. Where an individual **Generating Unit** is smaller than 2kW it should be tested as a group. However where a **Generating Unit** is designed to be installed singly in an installation then this can be tested alone, for example a domestic CHP unit. The maximum group size for the test is 3.68kW.

The results for all **Inverters** should be normalised to a rating of 3.68kW. The **Generating Unit** or group shall meet the harmonic emissions of table 1 in BS EN 61000-3-2 with a scaling factor applied as follows for each harmonic current;

Table 1 current limit **×** rating of **Generating Unit** being tested (kW) per phase / 3.68

A 1.4.2 Power Factor

The test should be undertaken as laid out in EN 50438 with the following three test voltages 230 V – 6%, 230V and 230 V +10%.

A 1.4.3 Voltage Flicker

The test must be carried out with a minimum of 2kW of rated **Generating Units**. Where an individual **Generating Unit** is smaller than 2kW it should be tested as a group. However where a **Generating Unit** is designed to be installed singly in an installation then this can be tested alone, for example a domestic CHP unit. The maximum group size for the test is 3.68kW.

The **Generating Unit** or group shall meet the required d_{max}, d_c, $d_{(t)}$, P_{st}, P_{lt} requirements of BS EN 61000-3-3 with a scaling factor applied as follows for each voltage change component.

d_{max}, d_c, $d_{(t)}$, P_{st}, P_{lt} **×** rating of **Generating Unit** being tested (kW) per phase / 3.68

The results for groups of **Inverters** should be normalised to a rating of 3.68kW and to the standard source impedance. Single **Inverters** need to be normalised to the standard source impedance, these normalised results need to comply with the limits set out in Appendix 5.

For voltage change and flicker measurements the following simplified formula is to be used to convert the measured values to the normalised values where the power factor of the generation output is 0.98 or above. Where it is less than 0.98 then compliance with the full requirements of BS EN 61000-3-3 is required.

Normalised value = Measured value × reference source resistance/measured source resistance at test point.

And for units which are tested as a group.

Normalised value = Measured value × reference source resistance/measured source resistance at test point × 3.68/rating per phase.

Single phase units reference source resistance is 0.4 ohms

Two phase units in a three phase system reference source resistance is 0.4 ohms

Two phase units in a split phase system reference source resistance is 0.24 ohms

Three phase units reference source resistance is 0.24 ohms.

The stopping test should be a trip from full load generation.

The dates and location of the tests need to be noted in Appendix 5.

Note: For wind turbines, flicker testing should be carried out during the performance tests specified in IEC 61400-12-1. Flicker data should be recorded from wind speeds of 1m/s below cut-in to 1.5 times 85% of the rated power. The wind speed range should be divided into contiguous bins of 1m/s centred on multiples of 1m/s. The dataset shall be considered complete when each bin includes a minimum of 10 minutes of sampled data. The highest value of each parameter measured across the entire range of tests shall be recorded.

Note: As an alternative to type testing the **Manufacturer** of a **Generating Unit** incorporating an **Inverter** may give a guarantee that rates of change of output do not exceed the following ramp rate limits. Output needs to ramp up at a constant rate.

This exception to site testing does not apply to devices where the output changes in steps of over 30ms rather than as a ramp function, a site test is required for these units.

- Single phase units and two phase units in a three phase system, maximum ramp up rate 333 watts per second;
- Two phase units in a split phase system and three phase units, maximum ramp up rate 860 watts per second.

It should be noted that units complying with this declaration are likely to be less efficient at capturing energy during times when the energy source is changing.

For technologies other than wind turbines, testing should ensure that the controls or automatic programs used produce the most unfavourable sequence of voltage changes.

Hydro Generating Units with manually fixed output or where the output is fixed by controlling the water flow through the turbine to a steady rate, need to comply with the maximum voltage change requirements of BS EN 61000-3-2 but do not need to be tested for P_{st} or P_{lt}.

Hydro Generating Units where the output is controlled by varying the load on the generator using the **Inverter** and which therefore produces variable output need to comply with the maximum voltage

Blue text = from G83 (and G59 where equivalent)
Purple text = from G59 definitions
Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

change requirements of BS EN 61000-3-2 and also need to be tested for P_{st} and P_{lt} over a period where the range of flows varies over the design range of the turbine with a period of at least 2 hours at each step with there being 10 steps from min flow to maximum flow. P_{st} and P_{lt} values to recorded and normalised as per the method laid down in Appendix 5.

A 1.4.4 DC Injection

DC injection compliance testing in EN 50438 shall be applicable to all **Generating Units** regardless of connection configuration.

A 1.4.5 Overcurrent Protection

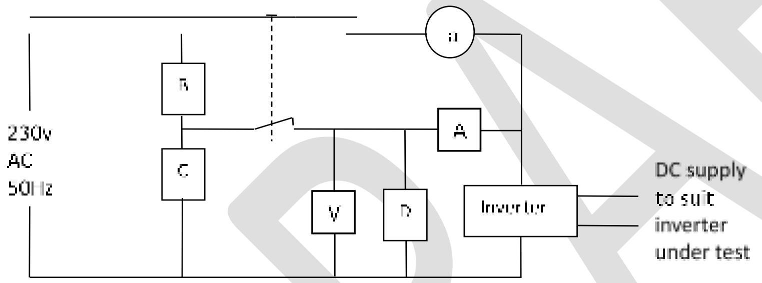
Where appropriate the protection shall comply with the requirements of BS7671.

A 1.4.6 Short Circuit Current Contribution for Inverters

Inverter connected **Generating Units** generally have small short circuit fault contributions however **DNO**'s need to understand the contribution that they do make to system fault levels in order to determine that they can continue to safely operate without exceeding design fault levels for switchgear and other circuit components.

The following type tests shall be carried out and the results noted in Appendix 5.

Test circuit



Test procedure

'A' and 'V' are ammeters and voltmeters used to record the test data required. Component 'D' is a resistive load plus resonant circuit as required for the loss of mains test as specified in BS EN 62116 set up to absorb 100% rated output of the **Inverter**. Component 'a' is an ammeter used to confirm that all the output from the **Inverter** is being absorbed by component D. Components 'B' and 'C' are set up to provide a voltage of between 10% and 40% of nominal when component 'C' carries the rated output of the **Inverter** in Amps.

Component 'C' should be short term rated to carry the load which would appear through it should it be energised at 253V for at least 1s. Component 'B' is to have an impedance of between 10 and 20 ohms per phase. If components 'B' and 'C' are short time rated than an additional switch in series with 'B' and 'C' can be inserted and arranged to be closed shortly before the main change over switch shown on the drawing and opened at the end of the test period. Components 'B' and 'C' are to have an X to R ratio of 2.5 to 1.

The test is carried out by setting up the **Inverter** and load 'D' to produce and then absorb full rated output of the **Inverter**. When zero export is shown by ammeter 'a' then the changeover switch shown is operated connecting the **Inverter** to the reduced voltage connection created by components 'B' and 'C' and disconnecting if from the normal connection. The make contact is an early make and the break contact a late break so that the **Inverter** is not disconnected from a mains connection for any significant time.

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Brown text = from Requirement for Generators (RfG)
Green text = from other EU documents eg EN 50438
Black text = Changes/ additional words

The values of voltage and current should be recorded for a period of up to 1 second when the changeover switch should be returned to the normal position. The voltage and current at relevant times shall be recorded in the type test report (Appendix 5) including the time taken for the **Inverter** to trip. (It is expected that the **Inverter** will trip on either loss of mains or under voltage in less than one second).

A 1.4.7 Short Circuit Current Contribution for Common Directly Coupled technology

DNOs need to understand the contribution a makes to system fault levels in order to determine that they can continue to safely operate without exceeding design fault levels for switchgear and other circuit components.

For non **Inverter** connected machines the tests in EN 50438 shall be applicable.

For rotating machines and linear piston machines the test should produce a 0 – 2 second plot of the short circuit current as seen at the **Generating Unit** terminals.

A 1.4.8 Self-Monitoring - Solid State Disconnection

Some **Inverters** include solid state switching devices to disconnect from the **DNO's Distribution Network**. In this case 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.

A 1.4.9 Electromagnetic Compatibility (EMC)

All equipment shall comply with the generic EMC standards: BS EN61000-6-3: 2007 Electromagnetic Compatibility, Generic Emission Standard; and BS EN61000-6-1: 2007 Electromagnetic Compatibility, Generic Immunity Standard.