PRODUCED BY THE OPERATIONS DIRECTORATE OF ENERGY NETWORKS ASSOCIATION

Engineering Recommendation G98

Issue 1 WORKING DRAFT – (May 2018)

Requirements for the connection of Fully Type Tested Micro-generators (up to and including 16 A per phase) in parallel with public Low Voltage Distribution Networks on or after 17 May 2019

PUBLISHING AND COPYRIGHT INFORMATION

Operations Directorate
Energy Networks Association
6th Floor, Dean Bradley House
52 Horseferry Rd
London
SW1P 2AF

DRAFT First published, May 2018

Amendments since publication

Issue	Date	Amendment

Contents

Foreword

This Engineering Recommendation (EREC) G98 is published by the Energy Networks Association (ENA) and comes into effect on 17 May 2019 for **Micro-generators** first commissioned on or after that date. The definition of **Micro-generators** within this document includes electricity storage devices and hence this document also applies to electricity storage devices.

Micro-generators that conform to this EREC G98 can be connected in advance of 17 May 2019 as they also conform to the pre-existing EREC G83 requirements.

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

Micro-generators must meet all of the requirements set out in this document. They must have the formal status of **Fully Type Tested** and have provided proof that the requirements have been met.

In order to conform to this EREC G98, the relevant part of the **Customer Installation** shall conform to the requirements of EN 50438 together with additional requirements also detailed in this document. The purpose of this EREC G98 is to explain the technical requirements for connection of **Micro-generators** for operation in parallel with a public **Low Voltage Distribution Network,** by addressing all technical aspects of the connection process, from standards of functionality to on-site commissioning.

The procedures described are designed to facilitate the connection of **Micro-generators** whilst maintaining the integrity of the **GB** public **Low Voltage Distribution Network**, both in terms of safety and supply quality.

This EREC G98 provides sufficient information to allow:

a) **Micro-generator Manufacturers** to design and market a product that is suitable for connection to the **GB** public **Low Voltage Distribution Network**; and
b) **Customers**, **Manufacturers** and **Installers** of **Micro-generators** to be aware of the requirements of the **Distribution Network Operator** (**DNO**) before the **Micro-generator** installation will be accepted for connection to the **DNO's Distribution Network.**

1 Legal aspects

1.1. In accordance with the **Electricity Safety, Quality and Continuity Regulations** (**ESQCR**) Regulation 22(2)(c) and the exemption to **ESQCR** Regulation 22(2) (c) granted in August 2008 by the Health & Safety Executive the **Installer** is required to ensure that the **DNO** is made aware of the **Micro-generator** installation before the time of commissioning or no later than 28 days (inclusive of the day of commissioning) after commissioning.

1.2. The **DNO** is under a legal obligation to disallow the connection of **Micro-generating Plant** unless it complies with this EREC G98 and relevant legal requirements such as the Distribution Code and the **ESQCR**.

1.3. Under the terms of **ESQCR** Regulation 26 the **DNO** may require a **Micro-generator** to be disconnected if it is a source of danger or interferes with the quality of supply to other consumers.

1.4. In addition to the requirements specified in this document which allows connection to the **GB** public **Low Voltage Distribution Network**, the **Micro-generator** and all of its components shall conform to all relevant legal requirements including European Directives and CE marking.

1.5. 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.

2 Scope

2.1 This EREC G98 provides guidance on the **GB** technical requirements for the connection of **Micro-generators** in parallel with public **Low Voltage Distribution Networks**. The requirements set out in this EREC G98 are in addition to those of European standard EN 50438 which should be complied with in full.

2.2 There are two connection procedures described in this document. The first connection procedure covers the connection of a single **Micro-generating Plant**. A **Micro-generating Plant** is a single electrical installation that contains one or more **Micro-generators**, either single or multi-phase, the aggregate **Registered Capacity** of which is no greater than 16 A per phase[1]. The second connection procedure covers the connection of multiple **Micro-generators** (other than within a single **Customer's Installation**) in a **Close Geographic Region**, under a planned programme of work.

2.3 This document is applicable to **Fully Type Tested Micro-generators** for which a **Micro-generator Type Test Verification Report** demonstrates that the **Micro-generator** design meets all the requirements set out in this EREC G98. For **Micro-generators** greater than 16 A per phase the procedures described in EREC G99 apply.

2.4 For the purposes of this EREC G98 the **Registered Capacity** of 16 A per phase, single or multi-phase, 230/400 V **AC** 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 (i.e. 230 V) as defined in BS EN 50160 and the **ESQCR.**

2.5 Where there is an existing **Micro-generator** commissioned under EREC G83, any additional **Micro-generators** will be treated separately. Only the additional **Micro-generators** need to conform to EREC G98. However, if the total aggregate capacity of the installation exceeds 16 A per phase the EREC G99 process applies and the **DNO** needs to be consulted before the installation is undertaken.

2.6 Where **Micro-generators** 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 **Registered Capacity**.

2.7 Where the **Micro-generator** includes an **Inverter** its **Registered Capacity** is deemed to be the **Inverter's** continuous steady state rating.[2]

2.8 For the avoidance of doubt where a **Customer's Installation** comprises a single **Connection Point** and more than one **Inverter**, which have an aggregate **Registered Capacity** of less than 16 A per phase, single or multi- phase, 230/400 V **AC;** the installation shall be considered as a single **Micro-generating Plant**.

2.9 This EREC G98 only specifies the requirements applicable to those **Micro-generators** 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

---

[1] The **Manufacturer** may restrict the rating of the **Micro-generator** by applying software settings provided these settings are not accessible to the **Customer**

[2] As footnote 1

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.

2.10 Appendix 3 contains pro forma that relate to the connection, commissioning, testing, and decommissioning of **Micro-generators**.

2.11 EN 50438 Annex D together with Annexes A1 and A2 of this EREC G98 describe a methodology for testing various types of electrical interface between the **Micro-generator** 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 requirements of this EREC G98. The **Micro-generator** can be considered an approved **Micro-generator** for connection to the **GB** public **Low Voltage Distribution Network** by:

- completing the **Type Test Verification Report** in Appendix 3 Form C of this EREC G98;
- satisfying the tests in EN 50438 Annex D; and
- satisfying the supplementary tests in Annex A1 (for **Inverter** connected **Micro-generators**) or Annex A2 (for synchronous **Micro-generators**) as appropriate of this EREC G98.

2.12 A **Manufacturer** of a **Fully Type Tested Micro-generator** should allocate a **Manufacturer**'s reference number, which should be registered on the Energy Networks Association (ENA) **Type Test Verification Report** Register as the Product ID. It is not necessary for **Manufacturers** of **Fully Type Tested Micro-generators** to complete a **Type Test Verification Report**, Appendix 3 Form C, for each I**nstallation**.

2.13 **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.

2.14 For **Micro-generators** classified as emerging technology, electricity storage devices and **Micro-generators** with a **Registered Capacity** of < 800 W, some clauses of this EREC G98 shall not apply. Details of emerging technology and their requirements are given in Appendix 1. The exclusions for electricity storage devices and **Micro-generators** with a **Registered Capacity** of < 800 W are also given in Appendix 1.

2.15 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

Section	Subject	Applicable parties
5	Terms and Definitions	All
6	Connection Process and Testing Requirements	**Customer**, **Installer**, **Manufacturer**, **DNO**
7	Certification Requirements	**Manufacturer**, **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 and other Exceptions	Emerging Technology Manufactures, **Manufacturer**
Appendix 2	Connection Procedure Flow Chart	**Customer, Installer, DNO**
Appendix 3	Micro-generator Documentation	All
Form A	Application for connection	**Customer, Installer, DNO**
Form B	Installation Document	**Customer**, **Installer**, **DNO**
Form C	Type Test Verification Report	**Customer**, **Installer**, **DNO**
Form D	Decommissioning Confirmation	**Customer**, **Installer**, **DNO**
Appendix 4	Certificate of Exemption	**Customer**, **Installer**, **DNO**
Annex A1	Requirements for Testing of Inverter Connected Micro-generators	**Manufacturer**
Annex A2	Requirements for Testing of Synchronous Micro-generators	**Manufacturer**

182
183

3 References

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 **Micro-generator** shall take precedence.

3.1 Standards publications

BS 7671 Requirements for Electrical Installations
IEE Wiring Regulations Seventeenth (Amendment 3 2015) Edition.

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).

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

IEC 60909-1 (Second Edition)
Short circuit calculation in three-phase AC systems.

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.

3.2 Other publications

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.

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 G99
Requirements for the connection of generation equipment in parallel with public distribution networks on or after 17 May 2019

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.

Engineering Recommendation G100
Technical Guidance for Customer Export Limiting Schemes

COMMISSION REGULATION (EU) No 2016/631
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.

4 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

Active Power (P)

The product of voltage and the in-phase component of alternating current measured in units of watts, normally measured in kilowatts (kW) or megawatts (MW).

Active Power Frequency Response

An automatic response of **Active Power** output, from a **Micro-generator,** to a change in 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; i.e. 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 500 m 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 **Micro-generating Plant**.

Connection Point

The interface at which the **Customer's Installation** is connected to a **Distribution Network**, as identified in the **Connection Agreement**.

Controller

A device for controlling the functional operation of a **Micro-generator**.

Customer

A person who is the owner or occupier of premises that are connected to the **Distribution Network**.

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 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).

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 **Registered 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.

Fully Type Tested

A **Micro-generator** which has been tested to ensure that the design meets the relevant technical and compliance requirements of this EREC G98, and for which the **Manufacturer** has declared that all similar **Micro-generators** supplied will be constructed to the same standards and will have the same performance. In the case where **Interface Protection** functionality is included in the tested equipment, all similar products will be manufactured with the same protection settings as the tested product

Great Britain or GB

The landmass of England & Wales and Scotland, including internal waters.

Installation Document

A simple structured document containing information about a **Micro-generator** and confirming its compliance with the relevant requirements set out in this EREC G98.

Installer

The person who is responsible for the installation of the **Micro-generator**(s).

Interface Protection

The electrical protection required to ensure that any **Micro-generator** is disconnected from the **Distribution Network** for any event that could impair the integrity or degrade the safety of the **Distribution Network. Interface Protection** may be installed on each **Micro-generator** or at the **Connection Point** for the **Micro-generating Plant**.

Inverter

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

Limited Frequency Sensitive Mode - Overfrequency (LFSM-O)

A **Micro-generator** 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 (50 V) but not exceeding 1000 V AC or 1500 V **DC** between conductors or 600 V AC or 900 V **DC** between conductors and earth.

Manufacturer

A person or organisation that manufactures **Micro-generators,** and also 'packages' components manufactured by others to make **Micro-generators,** which can be **Fully Type Tested** to meet the requirements of this EREC G98.

Micro-generating Plant

An electrical installation with one or more **Micro-generators** with nominal currents in sum not exceeding 16 A per phase.

Micro-generator

A source of electrical energy and all associated interface equipment able to be connected to an 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.

Registered Capacity

The normal full load capacity of a **Micro-generator**, as declared by the **Manufacturer** which should exclude the **Active Power** consumed by the **Micro-generator** when producing the **Registered Capacity**; i.e. this will relate to the maximum level of **Active Power** deliverable to the **DNO's Distribution Network**. For **Micro-generators** connected to the **DNO's Distribution Network** via an **Inverter**, the **Inverter** rating is deemed to be the **Micro-generator's Registered Capacity**.

Type Tested

A product which has been tested to ensure that the design meets the relevant requirements of this EREC G98, and for which the **Manufacturer** has declared that all similar products supplied will be constructed to the same standards and 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.

Examples of products which could be **Type Tested** include **Generating Units**, **Inverters** and the protection system.

Type Test Verification Report

A report compiled by the **Manufacturer** that can be used to demonstrate compliance with this document.

5 Connection Procedure

5.1 Single Premises Connection Procedure

5.1.1 In most instances the installation of **Micro-generating Plant**, the aggregate **Registered Capacity** of which is no greater than 16 A per phase, connected in parallel with the public **Low Voltage Distribution Network**, will have negligible impact on the operation of the public **Low Voltage Distribution Network**; as such there will be no need for the **DNO** to carry out detailed network studies to assess the impact of the connection. As required by the **ESQCR** Certificate of Exemption (2008) the **Installer** shall provide the **DNO** with all necessary information on the installation no later than 28 days after the **Micro-generating Plant** has been commissioned; the format and content shall be as shown in Appendix 3 Form B **Installation Document**.

5.1.2 This procedure will not apply where an **Installer** plans (within the next 28 days) or has already installed (in the previous 28 days) other **Micro-generating Plants** in a **Close Geographic Region**; in this case the procedure in 5.2 shall be followed. Failure to comply with this requirement may lead to the disconnection of the **Micro-generating Plant** under **ESQCR** (26) or failure of the **Micro-generating Plant** to operate as intended.

5.2 Multiple Premises Connection Procedure

5.2.1 In the case of projects where the proposal is to install single or multiple **Micro-generators** in a number of **Customer Installations** in a **Close Geographic Region**, the **Installer** shall discuss the installation project with the local **DNO** at the earliest opportunity. The **DNO** will need to assess the impact that these connections may have on the **Distribution Network** and specify conditions for connection. The initial application will need to be in a format similar to that shown in Appendix 3 Form A. Connection of the **Micro-generator** is only allowed after the application for connection has been approved by the **DNO** and any **DNO** works facilitating the connection have been completed. Confirmation of the commissioning of each **Micro-generator** will need to be made no later than 28 days after commissioning; the format and content shall be as shown in Appendix 3 Form B **Installation Document**.

6 Certification Requirements

6.1 Type Test Certification

6.1.1 **Type Tested** certification is the responsibility of the **Manufacturer**. The **Manufacturer** shall make available upon request a **Type Test Verification Report** confirming that the **Micro-generator** has been tested to satisfy the requirements of this EREC G98. The report shall detail the type and model of **Micro-generator** 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 3 Form C. It is intended that **Manufacturers** of **Micro-generators** will use the requirements of this EREC G98 to develop type verification certification for each of their **Micro-generator** models.

6.1.2 **Manufacturers** of a **Fully Type Tested Micro-generator** should allocate a **Manufacturer**'s reference number with the required details of the **Micro-generator** with the Energy Networks Association **Type Test Verification Report** Register.

6.2 Compliance

6.2.1 Compliance with the requirements detailed in this EREC G98 will ensure that the **Micro-generator(s)** is considered to be approved for connection to the **DNO's Distribution Network**.

6.2.2 The **Micro-generator(s)** shall conform to all relevant European Directives and should be labelled with a CE marking.

7 Operation and Safety

7.1 Operational Requirements

7.1.1 Compliance with this EREC G98 in respect of the design, installation, operation and maintenance of a **Micro-generating Plant**, 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.

7.2 Isolation

7.2.1 The **Micro-generator(s)** 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.

7.3 Labelling

7.3.1 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.

7.3.2 In addition to the warning label, this EREC G98 requires the following, up to date, information to be displayed at the **Connection Point** with the **DNO's Distribution Network.**

a) A circuit diagram relevant to the installation showing the circuit wiring, including all protective devices, between the **Micro-generator** and the **DNO's** fused cut-out. This diagram should also show by whom all apparatus is owned and maintained; and

b) A summary of the **Interface Protection** settings incorporated within the **Micro-generator**.

7.3.3 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.

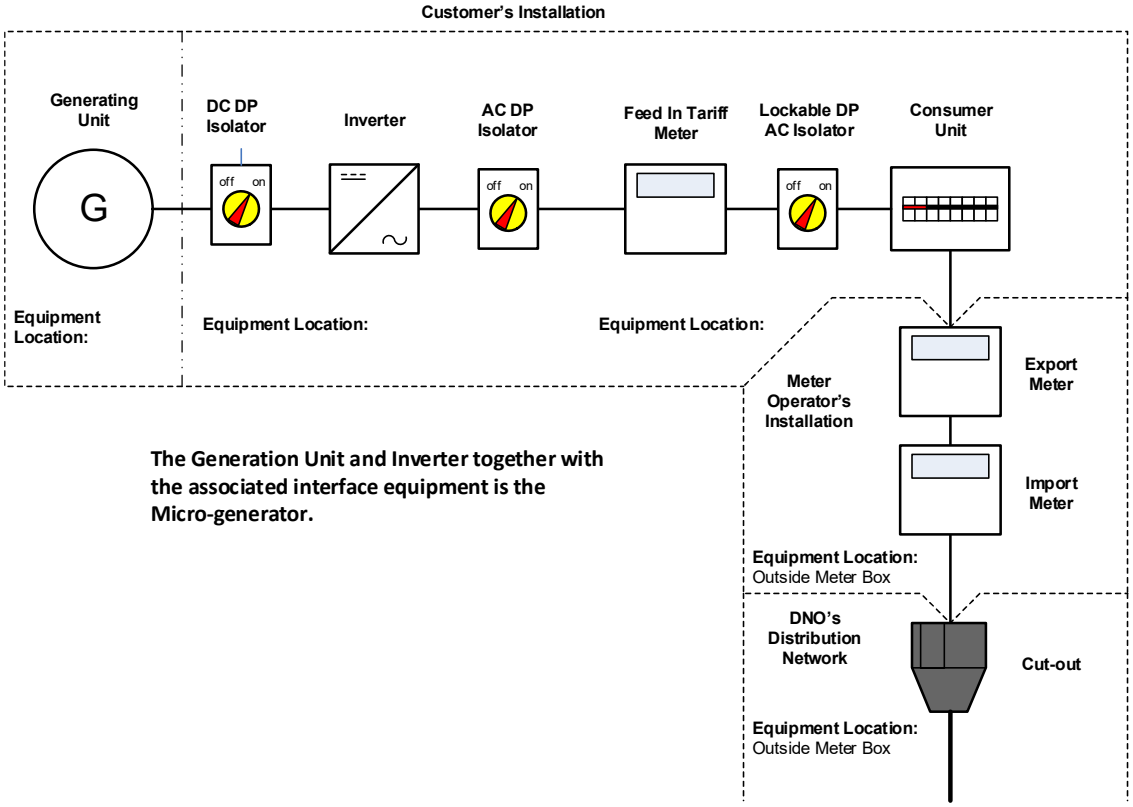


Figure 1 – Example of the type of circuit diagram

7.3.4 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 e.g. name, telephone number and web address.

7.4 Maintenance & Routine Testing

7.4.1 Periodic testing of the **Micro-generator** 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.

7.5 Phase Unbalance

7.5.1 There is no requirement to balance phases on installations below or equal to 16 A per phase.

7.5.2 For multiple installations of **Micro-generators** (e.g. new housing developments), balancing the **Micro-generators** evenly against the load on the three phases will need to be considered by the **DNO**. The **DNO** will advise the **Installer** of any phase balancing requirements.

8 Commissioning, Notification and Decommissioning

8.1 General

8.1.1 The installation shall be carried out by **Installers** who are competent and have sufficient skills and training (complete with recognised and approved qualifications relating to the fuels used and general electrical installations) to apply safe methods of work to install a **Micro-generator** in compliance with this EREC G98.

8.1.2 Notwithstanding the requirements of this EREC G98, the installation will be carried out to no lower a standard than that required in the **Manufacturer's** installation instructions.

8.1.3 The information required by a **DNO** under an Application for Connection is shown in Appendix 3 Form A. The information required by a **DNO** to confirm commissioning is shown in Appendix 3 Form B.

8.1.4 It is the responsibility of the **Installer** to ensure that the relevant information as specified in sections 5 and 6 is forwarded to the local **DNO** as appropriate. The pro forma in Appendix 3 are designed to:

a) simplify the connection procedure for both **DNO** and **Micro-generator Installer**;
b) provide the **DNO** with all the information required to assess the potential impact of the **Micro-generator** connection on the operation of the **Distribution Network**;
c) inform the **DNO** that the **Micro-generator** installation complies with the requirements of this EREC G98; and
d) allow the **DNO** to accurately record the location of all **Micro-generators** connected to the **Distribution Network**.

8.1.5 Upon receipt of a multiple premises connection application the **DNO's** response will be in accordance with the electricity generation standards set by the Authority for applications connecting to the **Distribution Network**.

8.2 Commissioning

8.2.1 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.

8.2.2 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 **Micro-generator** during operation and checking that the **Interface Protection** operates to disconnect the **Micro-generator** 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 **Micro-generator** has shut down. Testing for the loss of a single phase is covered in the type testing of **Inverter**s, see section 10.2.

8.3 Notification of Commissioning

8.3.1 In accordance with **ESQCR** and the HSE Certificate of Exemption (2008) (see Appendix 4) the **Installer** shall ensure that the **DNO** is advised of the intention to use the **Micro-generator** in parallel with the **Distribution Network** no later than 28 days

(inclusive of the day of commissioning) after commissioning the **Micro-generator**. Notification that the **Micro-generator** has been commissioned is achieved by completing an **Installation Document** as per Appendix 3 Form B (**Installation Document**), which also includes the relevant details on the **Micro-generator** installation required by the **DNO**.

8.3.2 The **Installer** shall supply separate **Installation Documents** for each premises in which **Micro-generators** are installed under EREC G98. Documentation may be submitted via an agent acting on behalf of the **Installer** and may be submitted electronically.

8.4 Notification of Changes

8.4.1 If a **Micro-generator** requires modification the **Manufacturer** must re-submit the **Type Test Verification Report** prior to the modification being made and the **Micro-generator** being recommissioned.

8.4.2 The **DNO** shall be notified of any operational incidents or failures of a **Micro-generator** that affect its compliance with this EREC G98, without undue delay, after the occurrence of those incidents.

8.4.3 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 **Micro-generator'**s compliance with this EREC G98.

8.5 Notification of Decommissioning

8.5.1 The **Customer** shall notify the **DNO** about the permanent decommissioning of a **Micro-generator** by providing the information as detailed under Appendix 3 Form D. Documentation may be submitted by an agent acting on behalf of the **Customer** and may be submitted electronically.

9 General Technical Requirements

9.1 Frequency withstand

9.1.1 The **Micro-generator** shall be capable of remaining connected to the **Distribution Network** and operating 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 Micro-generator has to be capable of operating within different frequency ranges without disconnecting from the Distribution Network

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

9.2 Rate of Change of Frequency

9.2.1 With regard to the rate of change of frequency withstand capability, a **Micro-generator** shall be capable of staying connected to the **Distribution Network** and operate at rates of change of frequency up to 1 Hzs^{-1} measured over 500 ms.

9.3 Limited Frequency Sensitive Mode – Overfrequency

9.3.1 With regard to the **Limited Frequency Sensitive Mode — Overfrequency (LFSM-O)**, the **Micro-generator** 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 2 s.

9.3.2 The **Micro-generator** will continue to reduce power with rising frequency with a **Droop** of 10% until 52.0 Hz, at which point the **Micro-generator** should disconnect.

9.4 Active Power Output

9.4.1 The **Micro-generator** shall be capable of maintaining constant output at its **Registered Capacity** regardless of changes in frequency, except where the output follows the changes defined in the context of paragraphs 9.3.1 and 9.4.2.

9.4.2 The **Micro-generator** shall be capable of maintaining constant output at its **Registered Capacity** 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 pro-rata with frequency,

i.e. the maximum permitted requirement is 100% power at 49.5 Hz falling linearly to 95% power at 47.0 Hz as illustrated in Figure 2.

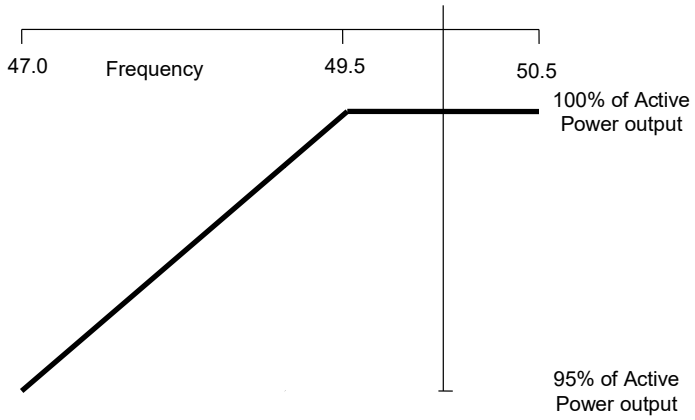


Figure 2 – Change in output power with falling frequency

9.4.3 The **Micro-generator** shall be equipped with a logic interface (input port) in order to cease **Active Power** output within 5 s following an instruction being received from the **DNO** at the input port. By default the logic interface will take the form of a simple binary output that can be operated by a simple switch or contactor. When the switch is closed the **Micro-generator** can operate normally. When the switch is opened the **Micro-generator** will reduce its **Active Power** to zero within 5 s. The signal from the **Micro-generator** that is being switched can be either AC (maximum value 240 V) or **DC** (maximum value 110 V). The **DNO** may specify any additional requirements particularly regarding remote operation of this facility.

9.5 Power Factor

9.5.1 The power factor capability of the **Micro-generator** shall conform to EN 50438. When operating at **Registered Capacity** the **Micro-generator** shall operate at a power factor within the range 0.95 lagging to 0.95 leading relative to the voltage waveform unless otherwise agreed with the **DNO** e.g. for power factor improvement.

9.6 Automatic Connection

9.6.1 **Micro-generators** shall conform to 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.

10 Interface Protection

10.1 General

10.1.1 The **Micro-generator** shall conform to the **Interface Protection** settings set out below (Table 2). Means shall be provided to protect the settings from unpermitted interference (e.g. via a password or seal).

10.1.2 The **DNO** is responsible under the **Distribution Code** for ensuring, by design, that the voltage and frequency at the **Connection Point** remains within statutory limits. The **Interface Protection** settings have been chosen to allow for voltage rise or drop within the **Customer's Installation** and to allow the **Micro-generator** to continue to operate outside of the statutory frequency range as required by the EU Network Code on Requirements for Grid Connection of Generators.

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

Table 2 – Interface Protection settings

Protection Function	Trip Setting	Time Delay Setting
U/V	Vφ-n† - 20% = 184 V	2.5 s
O/V stage 1	Vφ-n† +14% = 262.2 V	1.0 s
O/V stage 2	Vφ-n†+ 19% = 273.7 V[3]	0.5 s
U/F stage 1	47.5 Hz	20 s
U/F stage 2	47 Hz	0.5 s
O/F	52 Hz	0.5 s
LoM (RoCoF)	0.2 Hz/s	

† A value of 230 V phase to neutral

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

10.1.4 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 + 0.5 s.

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

10.1.6 **Fully Type Tested Micro-generators** shall have protection settings set during manufacture.

10.1.7 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 **Micro-generator** and confirm that it is the correct **Micro-generator** by means of a serial number permanently fixed to the **Micro-generator** and visible on the PC screen at the same time as the settings; or
- Display of all **Interface Protection** settings and nominal voltage and current outputs, alongside the serial number of the **Micro-generator**, permanently fixed to the **Micro-generator**.

10.1.8 The provision of loose documents, documents attached to the **Micro-generator** 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.

10.1.9 In response to a protection operation the **Micro-generator** 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 **Micro-generator,** 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 **Micro-generator**, the voltage on the output side of the switching device shall be reduced to a value below 50 V within 0.5 s of the protection and trip delay timer operation.

10.1.10 Where a common protection system is used to provide the protection function for multiple **Micro-generators** the complete installation cannot be considered to comprise **Fully Type Tested** M**icro-generators** if the protection and connections are made up on site and so cannot be factory tested or **Fully Type Tested**. In accordance with Annex A1 or Annex A2 if the units or M**icro-generators** are specifically designed with plugs and sockets to be interconnected on site, then

provided the assembly passes the function tests required in Appendix 3 Form C, the M**icro-generator**(s) can retain **Fully Type Tested** status.

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

10.2 Loss of Mains Protection

10.2.1 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 **Micro-generators** 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 3 Form C.

10.3 Frequency Drift and Step Change Stability Test

10.3.1 Under normal operation of the **Distribution 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 **Distribution Network** component which does not cause a loss of supply.

10.3.2 In order to ensure that such phenomena do not cause unnecessary tripping of **Micro-generators**, stability type tests shall be carried out.

10.3.3 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 in Table 2 and vector shifts of up to 9º. Both stability tests shall be carried out in all cases.

10.3.4 The stability tests are to be carried out as per the table in Appendix 3 Form C of this document and the **Micro-generator** should remain connected during each and every test. The tests shall check that the **Micro-generator** remains stable and connected during the following scenarios:

- RoCoF: 0.19 Hzs^{-1} from 49.5 Hz to 51.5 Hz and from 50.5 Hz to 47.5 Hz; and
- Vector shift: 9º plus from 49.5 Hz and 9º minus from 50.5 Hz.

11 Quality of Supply

11.1 The power quality requirements set out in EN 50438 should be met along with the requirements described in this section of EREC G98.

11.2 **Micro-generators** are likely to be installed in large numbers on **LV Distribution Networks**. They are likely to operate for long periods with no diversity between them, and adjacent **Micro-generators** are likely to be of the same technology. Therefore, in order to accommodate a high number of **Micro-generators** on a **Distribution Network,** procedures are specified in Annex A1 and Annex A2, which need to be applied when testing for harmonic current emissions and flicker.

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

12 Short Circuit Current Contribution

12.1 Directly Coupled Generation

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

12.2 Inverter Connected Generation

12.2.1 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 **Distribution Networks** without exceeding design fault levels for switchgear and other circuit components; and

- 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 **Distribution Network** fault.

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

Appendix 1 Emerging Technologies and other Exceptions

Emerging Technologies

Ofgem 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 Table 3 below for reference.

Table 3 – Emerging Technology Exceptions

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 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 **Micro-generators** classified as an emerging technology at the time of their connection to a **DNO's Distribution Network**, the following sections of EREC G98 do not apply.

- The frequency withstand capability in 9.1;
- The rate of change of frequency requirements in 9.2;
- The **Limited Frequency Sensitive Mode – Overfrequency** requirements in 9.3;
- The constant **Active Power** output requirements in section 9.4; and
- The **Interface Protection** settings in 10.1.3.

Performance requirements for these emerging technologies and other exemptions will conform to the voltage protection setting limits in Table 2 in Section 10.1 of this document, but they do not have to extend to the full ranges of the frequency protection requirements. For example, if a technology can only operate in a frequency range from 49.5 Hz 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. Appropriate protection settings should be agreed with the **DNO**.

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

Micro-generators 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.

Other Exceptions

For electricity storage devices and/or **Micro-generators** with a **Registered Capacity** of less than 800 W the following sections EREC G98 do not apply:

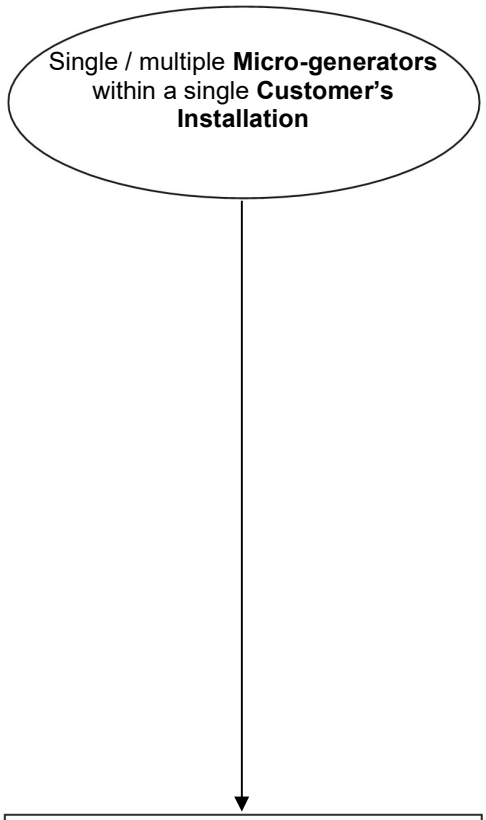
- The **Limited Frequency Sensitive Mode – Overfrequency** requirements in 9.3; and
- The constant **Active Power** output and interface requirement in 9.4.2 and 9.4.3.

Appendix 2 Connection Procedure Flow Chart

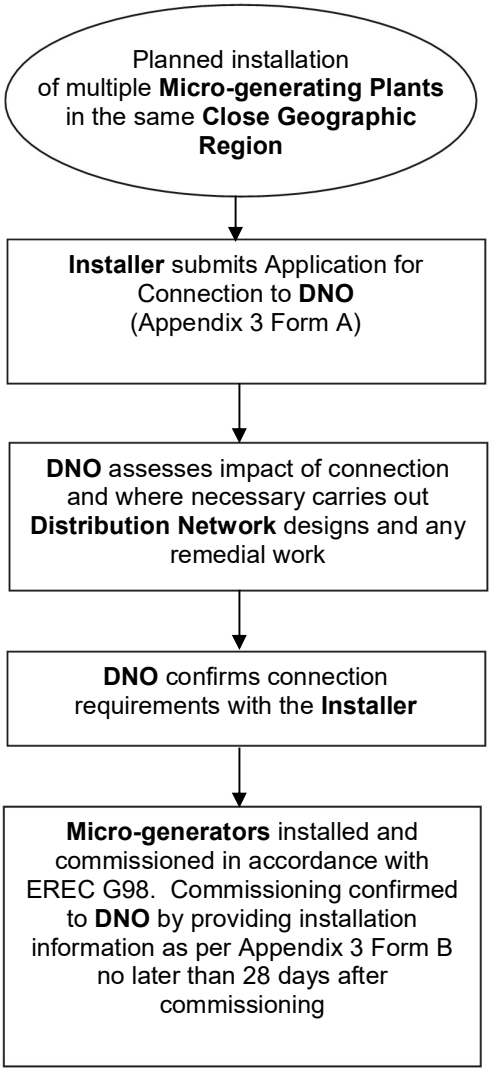
The following flow charts are for installations with aggregate **Registered Capacities** of 16 A per phase or less. For an installation with aggregate **Registered Capacity** in excess of 16 A per phase refer to EREC G99.

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 **Micro-generator** has been installed.

Connecting Micro-generators in a single premises



Connecting Micro-generators in multiple premises



Appendix 3. Micro-generator Documentation

A number of forms are required to be completed and submitted to the **DNO** for **Micro-generator** installations and any subsequent modifications to equipment, and/or permanent decommissioning. These are summarised in the table below. The stages in the table below are described in more detail in the Distributed Generation Connection Guides, which are available free of charge on the Energy Networks Association website[4].

Stage	Form	Notes / Description	Single premises	Multiple premises	Complete
1. Find an **Installer**	N/A	No form required – see ENA Distributed Generation Connection Guides for more information. Outside of the scope of this document.	✓	✓	
2. Discuss with the **DNO**	N/A	As above.	✗	✓	
3. Submit application	A: Application form	Submit an application, so that the **DNO** can assess whether there is a requirement for network studies and **Distribution Network** reinforcement, and whether they want to witness the commissioning.	✗	✓	
4. Application acceptance	N/A	If the **DNO** determines that **Distribution Network** reinforcement is required to facilitate connecting your **Micro-generator**s, they will make you a Connection Offer. Once you have accepted the **DNO's Connection Offer**, construction can begin. See ENA Distributed Generation Connection Guides for more information.	✗	✓	
5. Construction and commissioning	See below.	Where the **DNO** does not witness commissioning, the forms (below) should be	✓	✓	

[4] http://www.energynetworks.org/electricity/engineering/distributed-generation/dg-connection-guides.html

		submitted within 28 days. Where the **DNO** does witness, the forms can be signed and submitted on the day.			
6. Inform the **DNO**	B: **Installation Document**	Submit one form per premises, signed by the **Customer** and **Installer**.	✓	✓	
	C: **Type Test Verification Report**	To be provided, unless a **Manufacturer**'s reference number registered with the ENA is available.	✓	✓	
7. Ongoing responsibilities	N/A	If a modification is made to the **Micro-generator** that affects its technical capabilities and compliance with this document a new **Type Test Verification Report** must be provided.	✓	✓	
	D: Notification of decommissioning	Notify the **DNO** about the permanent decommissioning of a **Micro-generator**.	✓	✓	

The forms have been designed with the same format of **Customer** and **Installer** information at the top of each form. If you are completing forms electronically, this will allow you to copy and paste your information from one form to another, as you move through the stages of the connection process, unless you need to update your contact details.

Form A: Application for connection of multiple Micro-generator installations

To ABC electricity distribution DNO

99 West St, Imaginary Town, ZZ99 9AA abced@wxyz.com

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

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

Proposed Micro-generator Details:

Address	Post Code	MPAN	**Micro-generator Registered Capacity** in kW at 230 V AC			**Manufacturer's** Ref No (this number should be registered on the ENA **Type Test Verification Report** Register as Product ID)
			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 Registered Capacity** in kW at 230 V AC, to one decimal place, under PH1 for single phase supplies and under the relevant phase for two and three phase supplies. For example 2.8 kW.

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

843
844

Form B: Installation Document for connection under G98

Please complete and provide this document for each premises, once **Micro-generator** installation is complete.

To ABC electricity distribution **DNO**

99 West St, Imaginary Town, ZZ99 9AA abced@wxyz.com

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

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

Installation details	
Address	
Post Code	
MPAN(s)	
Location within **Customer's Installation**	

Location of Lockable Isolation Switch			
Details of Micro-generator			
Manufacturer / Reference			
Date of Installation			
Primary Energy source			
Power Factor			
Manufacturer's reference number			
Emerging technology classification (if applicable)			
Micro-generator Registered Capacity in kW	3-Phase Units		
	Single Phase Units	PH1	
		PH2	
		PH3	
Declaration – to be completed by Installer for Micro-generators Tested to EREC G98			
I declare that the relevant **Micro-generators** and the installation which together form a **Micro-generating Plant** within the scope of EREC G98 at the above address, conform to the requirements of EREC G98. This declaration of compliance is confined to **Micro-generating Plant** tested to EREC G98 or EREC G83 as applicable at the time of commissioning.			
Signature:		Date:	

Summary details of Micro-generators - where multiple **Micro-generators** will exist within one premises.

Manufacturer	Date of Installation	Technology Type	Type Test Ref No. Or **Manufacturer's** Ref No.	**Micro-generator Registered Capacity** in kW				
				3-Phase Units	Single Phase Units			Power Factor
					PH1	PH2	PH3	

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

Form C: Type Test Verification Report

Type Approval and **Manufacturer** declaration of compliance with the requirements of G98.

This form should be used when making a Type Test submission to the Energy Networks Association (ENA).

If the **Micro-generator** is **Fully Type Tested** and already registered with the ENA **Type Test Verification Report** Register, the **Installation Document** should include the **Manufacturer**'s Reference Number (the Product ID), and this form does not need to be submitted.

Where the **Micro-generator** is not registered with the ENA **Type Test Verification Report** Register this form needs to be completed and provided to the **DNO**, to confirm that the **Micro-generator** has been tested to satisfy the requirements of this EREC G98.

Manufacturer's reference number	
Micro-generator technology	
Manufacturer name	
Address	

Tel		Fax	
E-mail		Web site	

Registered Capacity, use separate sheet if more than one connection option.	Connection Option	
		kW single phase, single, split or three phase system
		kW three phase
		kW two phases in three phase system
		kW two phases split phase system

Manufacturer Type Test declaration. - I certify that all products supplied by the company with the above **Type Tested** 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.

Signed		On behalf of	

Note that testing can be done by the **Manufacturer** of an individual component 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.
Operating Range: This test should be carried out as specified in EN 50438 D.3.1. **Active Power** shall be recorded every second. The tests will verify that the **Micro-generator** can operate within the required ranges for the specified period of time. The **Interface Protection** shall be disabled during the tests. In case of a PV **Power Park Module** the PV primary source may be replaced by a **DC** source. In case of a full converter **Power Park Module** (e.g. wind) the primary source and the prime mover **Inverter**/rectifier may be replaced by a **DC** source. In case of a DFIG **Power Park Module** the mechanical drive system may be replaced by a test bench motor.
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
Test 3 Voltage = 110% of nominal (253 V). Frequency = 52.0 Hz Power factor = 1 Period of test 15 minutes

846

Power Quality – Harmonics: These tests should be carried out as specified in BS EN 61000-3-2. 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 **Registered Capacity**. The test requirements are specified in Annex A1 A.1.3.1 (**Inverter** connected) or Annex A2 A.2.3.1 (Synchronous).

Micro-generator tested to BS EN 61000-3-2

Micro-generator rating per phase (rpp)			kW			
Harmonic	At 45-55% of **Registered Capacity**		100% of **Registered Capacity**			
	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	
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
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.

Power Quality – Voltage fluctuations and Flicker: These tests should be undertaken in accordance with EREC G98 Annex A1 A.1.3.3 (**Inverter** connected) or Annex A2 A.2.3.3 (Synchronous).

	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 **Micro-generators**.

^ Applies to single phase **Micro-generators** and **Micro-generators** using two phases on a three phase system.

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

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

Single phase units reference source resistance is 0.4 Ω

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

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

Three phase units reference source resistance is 0.24 Ω.

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

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

The duration of these tests need to conform to 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	20%	50%	75%	100%
Recorded value in Amps				
as % of rated AC current				
Limit	0.25%	0.25%	0.25%	0.25%
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.				
	216.2 V		230 V	253 V
20% of **Registered Capacity**				
50% of **Registered Capacity**				
75% of **Registered Capacity**				
100% of **Registered Capacity**				
Limit	>0.95		>0.95	>0.95

Protection – Frequency tests: These tests should be carried out in accordance with EN 50438 Annex D.2.4 and the notes in EREC G98 Annex A1 A.1.2.3 (**Inverter** connected) or Annex A2 A.2.2.3 (Synchronous)

Function	Setting		Trip test		"No trip tests"	
	Frequency	Time delay	Frequency	Time delay	Frequency /time	Confirm no trip
U/F stage 1	47.5 Hz	20 s			47.7 Hz 25 s	
U/F stage 2	47 Hz	0.5 s			47.2 Hz 19.98 s	
					46.8 Hz 0.48 s	
O/F stage 1	52 Hz	0.5 s			51.8 Hz 89.98 s	
					52.2 Hz 0.48 s	

Protection – Voltage tests: These tests should be carried out in accordance with EN 50438 Annex D.2.3 and the notes in EREC G98 Annex A1 A.1.2.2 (**Inverter** connected) or Annex A2 A.2.2.2 (Synchronous)

Function	Setting		Trip test		"No trip tests"	
	Voltage	Time delay	Voltage	Time delay	Voltage /time	Confirm no trip
U/V	184 V	2.5 s			188 V 3.50 s	
					180 V 2.48 s	
O/V stage 1	262.2 V	1.0 s			258.2 V 2.0 s	
O/V stage 2	273.7 V	0.5 s			269.7 V 0.98 s	
					277.7 V 0.48 s	

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

848

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 **Registered Capacity**	95% of **Registered Capacity**	95% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**
Trip time. Limit is 0.5 s						
For Multi phase **Micro-generators** 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 **Registered Capacity**	95% of **Registered Capacity**	95% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**
Trip time. Ph1 fuse removed						
Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded network	95% of **Registered Capacity**	95% of **Registered Capacity**	95% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**
Trip time. Ph2 fuse removed						
Test Power	10%	55%	100%	10%	55%	100%
Balancing load on islanded network	95% of **Registered Capacity**	95% of **Registered Capacity**	95% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**	105% of **Registered Capacity**
Trip time. Ph3 fuse removed						
Note for technologies which have a substantial shut down time this can be added to the 0.5 s in establishing that the trip occurred in less than 0.5 s. Maximum shut down time could therefore be up to 1.0 s for these technologies.						
Indicate additional shut down time included in above results.						ms

849

For **Inverters** tested to BS EN 62116 the following sub set of tests should be recorded in the following table.						
Test Power and imbalance	33% -5% Q Test 22	66% -5% Q Test 12	100% -5% P Test 5	33% +5% Q Test 31	66% +5% Q Test 21	100% +5% P Test 10
Trip time. Limit is 0.5 s						

Protection – Frequency change, Vector Shift Stability test: This test should be carried out in accordance with EREC G98 Annex A1 A.1.2.6 (**Inverter** connected) or Annex A2 A.2.2.6 (Synchronous).			
	Start Frequency	Change	Confirm no trip
Positive Vector Shift	49.5 Hz	+9 degrees	
Negative Vector Shift	50.5 Hz	- 9 degrees	

Protection – Frequency change, RoCoF Stability test: The requirement is specified in section 11.3, test procedure in Annex A.1.2.6 (**Inverter** connected) or Annex A2 A.2.2.6 (Synchronous).			
Ramp range	Test frequency ramp:	Test Duration	Confirm no trip
49.0 Hz to 51.0 Hz	+0.19 Hzs^{-1}	2.1 s	
51.0 Hz to 49.0 Hz	-0.19 Hzs^{-1}	2.1 s	

850

Limited Frequency Sensitive Mode – Overfrequency 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 **Registered Capacity** >80%	Measured **Active Power** Output	Frequency	Primary Power Source	**Active Power** Gradient
Step a) 50.00 Hz ±0.01 Hz				-
Step b) 50.45 Hz ±0.05 Hz				-
Step c) 50.70 Hz ±0.10 Hz				-
Step d) 51.15 Hz ±0.05 Hz				-
Step e) 50.70 Hz ±0.10 Hz				-
Step f) 50.45 Hz ±0.05 Hz				-
Step g) 50.00 Hz ±0.01 Hz				
Test sequence at **Registered Capacity** 40% - 60%	Measured **Active Power** Output	Frequency	Primary Power Source	**Active Power** Gradient
Step a) 50.00 Hz ±0.01 Hz				-
Step b) 50.45 Hz ±0.05 Hz				-
Step c) 50.70 Hz ±0.10 Hz				-
Step d) 51.15 Hz ±0.05 Hz				-
Step e) 50.70 Hz ±0.10 Hz				-
Step f) 50.45 Hz ±0.05 Hz				-
Step g) 50.00 Hz ±0.01 Hz				
Steps as defined in EN 50438				

851

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 Power** Output	Frequency	Primary power source
Test a) 50 Hz ± 0.01 Hz			
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			

Re-connection timer.						
Test should prove that the reconnection sequence starts after a minimum delay of 20 s for restoration of voltage and frequency to within the stage 1 settings of Table 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 266.2 V	At 196.1 V	At 47.4 Hz	At 52.1 Hz
Confirmation that the **Micro-generator** does not re-connect.						

Fault level contribution: These tests shall be carried out in accordance with EREC G98 Annex A1 A.1.3.5 (**Inverter** connected) and Annex A2 A.2.3.4 (Synchronous).					
For machines with electro-magnetic output			For **Inverter** output		
Parameter	Symbol	Value	Time after fault	Volts	Amps
Peak Short Circuit current	i_p		20 ms		
Initial Value of aperiodic current	A		100 ms		
Initial symmetrical short-circuit current*	I_k		250 ms		
Decaying (aperiodic) component of short circuit current*	i_{DC}		500 ms		
Reactance/Resistance Ratio of source*	X/R		Time to trip		In seconds
For rotating machines and linear piston machines the test should produce a 0 s – 2 s plot of the short circuit current as seen at the **Micro-generator** terminals. * Values for these parameters should be provided where the short circuit duration is sufficiently long to enable interpolation of the plot					

Logic Interface.	Yes
Self-Monitoring solid state switching: No specified test requirements. Refer to EREC G98 Annex A1 A.1.3.6 (**Inverter** connected).	Yes/or NA
It has been verified that in the event of the solid state switching device failing to disconnect the **Micro-generator**, the voltage on the output side of the switching device is reduced to a value below 50 V within 0.5 s.	
Additional comments	

852
853

Form D: Micro-generator Decommissioning Confirmation

Micro-generator 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 **Micro-generators** in a **Customer's Installation**.

To ABC electricity distribution DNO

99 West St, Imaginary Town, ZZ99 9AA abced@wxyz.com

Customer Details:	
Customer (name)	
Address	
Post Code	
Contact person (if different from **Customer**)	
Telephone number	
E-mail address	
MPAN(s)	
Installer Details:	
Installer	
Accreditation / Qualification	
Address	
Post Code	
Contact person	
Telephone Number	
E-mail address	
Installation details:	
Address	
Post Code	
MPAN(s)	
Details of removed **Micro-generator(s)**	

Manufacturer and model type	**Type Tested** Reference number or **Manufacturer's** reference number	Prime mover and fuel source	**Registered Capacity** in kW		
			Phase 1	Phase 2	Phase 3
Details of remaining **Micro-generator(s)**					
Manufacturer and model type	**Type Tested** Reference number or **Manufacturer's** reference number	Prime mover and fuel source	**Registered Capacity** in kW		
			Phase 1	Phase 2	Phase 3
I confirm that the **Micro-generator** installation noted above has totally de-commissioned and that any remaining **Micro-generating Plant** continues to conform to the requirements of EREC G83 or EREC G98 as appropriate, 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.					
Installer Name		Signed		Date	

854
855

Appendix 4 Relaxation of Commissioning Notification Timescales for Micro-generator: HSE Certificate of Exemption (August 2008)

Electricity Act 1989

Health & Safety At Work Etc Act 1974

The **Electricity Safety Quality and Continuity Regulations** 2002

Certificate of Exemption

The Health and Safety Executive, in pursuance of the powers conferred on it by section 33 of the **Electricity Safety Quality and Continuity Regulations** 2002 (the "Regulations") Health & Safety At Work Etc Act 1974 (as amended by the Legislative Reform (Health and Safety Executive) Order 2008) and by the Agreement dated 2 October 2006 between the Secretary of State for Trade and Industry and the Health and Safety Commission, and being satisfied as required by regulation 33(2) hereby grants an exemption to the person or persons installing the source of energy from the requirements imposed by regulation 22(2)(c) of the regulations subject to the condition set out in paragraph 2 of this certificate.

The condition referred to in paragraph 1 of this certificate is that in so far as Regulation 22(2)(c) of the regulations applies to a source of energy, the person or persons installing the source of energy will ensure that the distributor is advised of the intention to use the source of energy in parallel with network no later than 28 days (inclusive of the day of commissioning) after commissioning the source.

This certificate shall come into force on 4 August 2008 and will remain in force until revoked by the Health and Safety Executive by a certificate in writing

A.1 Annex A1 Requirements for Testing of Inverter Connected Micro-generators

A.1.1 General

This Annex describes a methodology for obtaining type certification or type verification for **Micro-generators** which are connected to the **Distribution Network** via an **Inverter**.

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

Typically, all interface functions are contained within an **Inverter** and in such cases it is only necessary to have the **Inverter Type Tested**. Alternatively, a package of specific separate parts of equivalent function may also be **Type Tested** but for a **Fully Type Tested Micro-generator** the completed **Micro-generator's Interface Protection** must not rely on interconnection using cables which could be terminated incorrectly on site i.e. the interconnections must be made by plug and socket which the **Manufacturer** has made and tested prior to delivery to site.

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

BS EN 61000 (Electromagnetic Standards)
BS EN 60255 (Electrical Relays)
BS EN 61810 (Electrical Elementary Relays)
BS EN 60947 (Low Voltage Switchgear and Control gear)
BS EN 60044 (Instrument Transformers)

Currently there are no harmonised functional standards that apply to the **Microgenerator's Interface Protection**. Consequently, in cases where power electronics is used for energy conversion along with any separate **Interface Protection** unit they will need to be brought together and tested as a complete **Microgenerator** as described in this EREC G98, and recorded in a format similar to that shown in Form C (Appendix 3). Where the **Interface Protection** is physically integrated within the overall **Micro-generator** control system, the functionality of the **Interface Protection** unit should not be compromised by any failure of other elements of the control system (fail safe).

This Annex applies to **Micro-generators** either with or without load management or without energy storage systems connected on the energy source or prime mover side of the **Micro-generator**.

A.1.2 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 or by the supplier of the complete system, or any combination of them as appropriate.

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

a) in the safe disconnection of the **Micro-generator** from the **DNO's Distribution Network** in the event that the protection settings specified in Table 2 are exceeded;

and

b) in the **Micro-generator** remaining connected to the **DNO's Distribution Network** while **Distribution Network** conditions are:
    1) within the envelope specified by the settings plus and minus the tolerances specified for equipment operation in Table 2; and
    2) within the time delay settings specified in Table 2.

Wherever possible the type testing of a **Micro-generator** designed for a particular type of prime mover should be proved under normal conditions of operation for that technology (unless otherwise noted).

A 1.2.1 Disconnection times

The minimum trip time delay settings, for over / under voltage, over / under frequency and loss of mains tests below, are presented in Table 2.

For over / under voltage, over / under frequency and loss of mains tests, reconnection shall be checked as detailed below.

A 1.2.2 Over / Under Voltage

In addition to the EN 50438 over / under voltage tests the tests in this paragraph shall be undertaken.

The **Interface Protection** shall be tested by operating the **Controller** in parallel with a variable AC test supply, as an example see Figure A1.1. Correct protection and ride-through operation shall be confirmed. The set points for over and under voltage at which the **Interface Protection** disconnects from the supply will be established by varying the AC supply voltage. The disconnect sequence should be initiated when the network conditions mean the protection should trip in accordance with the settings in Table 2, otherwise normal operation should continue.

To establish the certified trip voltage, the test voltage should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 1 s in the case of a delay setting of 0.5 s. It will be necessary to carry out five tests for each trip setting. The test voltage at which this trip occurred is to be recorded as the certified trip voltage.

To establish the certified trip time, the test voltage should be applied starting from ± 1.8% below the certified trip voltage in a step of at least ± 0.5% of setting for a duration that is longer than the trip time delay, for example 1 s in the case of a delay setting of 0.5 s. Where the **Interface Protection** functionality is implemented in the **Controller** it will be necessary to carry out five tests for each trip setting. The longest trip time is to be recorded as the certified trip time.

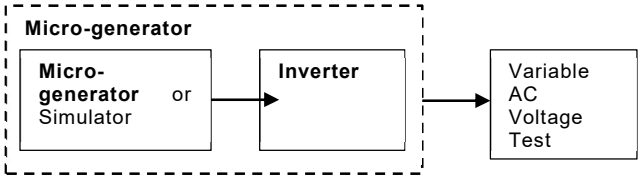
For example to test overvoltage setting stage 1 which is required to be set at nominally 262.2 V the circuit can be set up as shown below and the voltage adjusted to 254.2 V. In integrated designs where there is no separate way of establishing that the **Micro-generator** is disconnected, the **Micro-generator** should be powered up to export a measurable amount of energy so that it can be confirmed that the **Micro-generator** has ceased to output energy. The variable voltage supply is then increased in steps of no more than 0.5% of nominal (1.15 V) maintaining the voltage for at least 1.5 s (trip time plus 0.5 s) at each voltage level. At each voltage level confirmation that the **Micro-generator** 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 261 V. The variable voltage supply should be set to 257 V, the **Micro-generator** set to produce a measurable output (if necessary) and then the voltage raised to 265 V in a single step. The time from the step change to the disconnection of the **Micro-generator** should be recorded as the trip time.

The **Micro-generator** then needs to operate at 4 V below the nominal overvoltage stage 1 setting which is 258.2 V for a period of at least 2 s without tripping and while producing a measurable output. This can be confirmed as a no trip in the relevant part of the **Type Test Verification Report**, Appendix 3 Form C. The voltage then needs to be stepped up to the next level of 269.7 V for a period of 0.98 s and then back to 258.2 V 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 277.7 V and with a time of 0.48 s. The **Micro-generator** is allowed to shut down during this period to protect itself as allowed by footnote 3 of Table 2 of this document, but it must resume production again when the voltage has been restored to 258.2 V 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 the **Micro-generator** restart timer has not operated so it must begin producing again in less than 20 s.

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 0.1 Hz
(2) Measurement of operating time should be measured at a value of 0.2 Hz (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 to ensure that the protection will not trip in error.

Figure A1.1. Micro-generator Test set up – Over / Under Voltage



A 1.2.3 Over / Under Frequency

In addition to the EN 50438 over / under frequency tests the tests in this paragraph shall be undertaken into account.

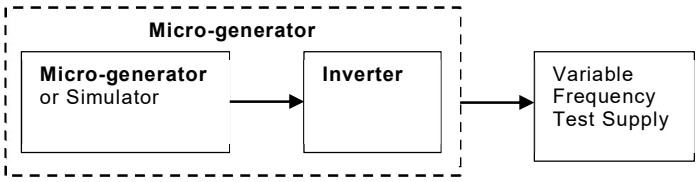
The **Micro-generator** shall be tested by operating in parallel with a low impedance, variable frequency test supply system, see figure A1.2. Correct protection and ride-through operation should be confirmed during operation of the **Micro-generator**. The set points for over and under frequency at which the **Micro-generator** 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 0.1 Hzs^{-1}, or if this is not possible in steps of 0.05 Hz for a duration that is longer than the trip time delay, for example 1 s in the case of a delay setting of 0.5 s. 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 Test Verification Report**, Appendix 3 Form C.

To establish the trip time, the test frequency should be applied starting from 0.3 Hz below or above the recorded trip frequency and should be changed to 0.3 Hz above or below the recorded trip frequency in a single step. The time taken from the step change to the **Micro-generator** tripping is to be recorded on the **Type Test Verification Report**, Appendix 3 Form C. 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 ± 0.2 Hz and for the relevant times shown in the **Type Test Verification Report**, Appendix 3 Form C.

Figure A1.2. Test set up – Over / Under Frequency



A 1.2.4 Loss of Mains Protection

The tests should be carried out in accordance with BS EN 62116 and a subset of results should be recorded as indicated in the Protection – Loss of Mains test section of the **Type Test Verification Report**, Appendix 3 Form C.

A 1.2.5 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 s before the **Micro-generator** output is restored (i.e. before the **Micro-generator** automatically reconnects to the **Distribution Network**).

A 1.2.6 Frequency Drift and Step Change Stability test

The tests will be carried out using the same circuit as specified in A1.2.3 above and following confirmation that the **Micro-generator** 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 **Micro-generator** should not trip during the test.

For the step change test the **Micro-generator** 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 s to complete the test. The **Micro-generator** should not trip during this test.

For frequency drift tests the **Micro-generator** should be operated with a measurable output at the start frequency and then the frequency changed in a ramp function at 0.95 Hzs^{-1} to the end frequency. On reaching the end frequency it should be maintained for a period of at least 10 s. The **Micro-generator** should not trip during this test.

A 1.2.7 Active power feed-in at under-frequency

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

A 1.2.8 Power response to over-frequency

EN 50438 shall be complied with in respect of power response to over-frequency using a specific standard frequency threshold of 50.4 Hz and a **Droop** setting of 10%.

A.1.3 POWER QUALITY

A 1.3.1 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 **Registered Capacity**.

The test must be carried out with a minimum of 2 kW of rated **Micro-generators**. Where an individual **Micro-generator** is smaller than 2 kW 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 3.68 kW.

The results for all **Micro-generators** should be normalised to a rating of 3.68 kW. 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

A 1.3.2 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 1.3.3 Voltage Flicker

The test must be carried out with a minimum of 2 kW of rated **Micro-generators**. Where an individual **Micro-generator** is smaller than 2 kW 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 3.68 kW.

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 **Micro-generator** being tested (kW) per phase / 3.68

The results for groups of **Micro-generators** should be normalised to a rating of 3.68 kW and to the standard source impedance. Single **Micro-generators** need to be normalised to the standard source impedance, these normalised results need to conform to the limits set out in the **Type Test Verification Report**, Appendix 3 Form C.

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 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.

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

The dates and location of the tests need to be noted in the **Type Test Verification Report**, Appendix 3 Form C.

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 1 ms^{-1} below cut-in to 1.5 times 85% of the rated power. The wind speed range should be divided into contiguous bins of 1 m/s centred on multiples of 1 ms^{-1}. The dataset shall be considered complete when each bin includes a minimum of 10 mins 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 **Micro-generator** 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 30 ms 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 Ws^{-1};
- Two phase units in a split phase system and three phase units, maximum ramp up rate 860 Ws^{-1}.

It should be noted that units conforming to 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 Micro-generators where the output is controlled by varying the load on the generator using the **Inverter** and which therefore produce variable output need to conform to the maximum voltage 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 the **Type Test Verification Report**, Appendix 3 Form C.

A 1.3.4 DC Injection for Inverters

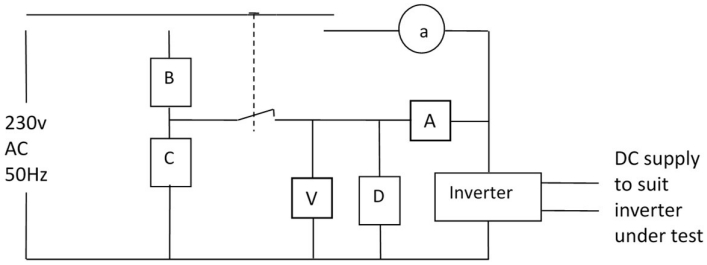
DC injection compliance testing in EN 50438 shall be applicable to all **Inverter** connected **Micro-generators** regardless of connection configuration.

A 1.3.5 Short Circuit Current Contribution for Inverters

Inverter connected **Micro-generators** 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 the **Type Test Verification Report**, Appendix 3 Form C.

Figure A3. Test circuit



Test procedure

In Figure A3 ‘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% **Registered Capacity** of the **Micro-generator**. 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 **Registered Capacity** of the **Micro-generator** in Amps.

Component ‘C’ should be short term rated to carry the load which would appear through it should it be energised at 253 V for at least 1 s. Component ‘B’ is to have an impedance of between 10 and 20 Ω per phase. If components ‘B’ and ‘C’ are short time rated then 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 **Micro-generator** and load 'D' to produce and then absorb the **Registered Capacity** 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 it from the normal connection. The make contact is an early make and the break contact a late break so that the **Micro-generator** is not disconnected from a mains connection for any significant time.

The values of voltage and current should be recorded for a period of up to 1 s 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 Verification Report** (Appendix 3 Form C) including the time taken for the **Micro-generator** to trip. (It is expected that the **Micro-generator** will trip on either loss of mains or under voltage in less than 1 s).

A 1.3.6 Self-Monitoring - Solid State Disconnection

Some **Micro-generators** include solid state switching devices to disconnect from the **DNO's Distribution Network**. In this case 10.1.9 requires the control equipment to monitor the output stage of the **Micro-generator** 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 V 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 1.3.7 Electromagnetic Compatibility (EMC)

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

A.2 Annex A2 Requirements for Testing of Synchronous Micro-generators

A.2.1 General

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

This Annex describes a methodology for obtaining type certification or type verification for the interface equipment between a directly coupled **Micro-generator** and the **DNO's Distribution Network**. Interface functions can be provided either as an integrated part of the **Controller** or by incorporating a **Type Tested** protection relay but for a **Fully Type Tested Micro-generator** the completed **Micro-generator's Interface Protection** must not rely on interconnection using cables which could be terminated incorrectly on site ie the interconnections must be made by non-reversible plug and socket which the **Manufacturer** has made and tested prior to delivery to site.

The **Interface Protection** of synchronous **Micro-generators** shall satisfy the requirements of all of the following standards. Where these standards have more than one part, the requirements of all such parts shall be satisfied, so far as they are applicable.

- BS EN 61000 (Electromagnetic Standards)
- BS EN 60255 (Electrical Relays)
- BS EN 61810 (Electrical Elementary Relays)
- BS EN 60947 (Low Voltage Switchgear and Control gear)
- BS EN 60044 (Instrument Transformers)

Currently there are no harmonised functional standards that apply to the **Micro-generator Interface Protection**, therefore in order to achieve **Fully Type Tested** status the **Controller** and any separate **Interface Protection** unit will require their functionality to be **Type Tested** as described in this Annex, and recorded in format similar to that shown in the **Type Test Verification Report**, Appendix 3 Form C. Where the **Interface Protection** is physically integrated within the overall **Micro-generator** control system, the functionality of the **Interface Protection** unit should not be compromised by any failure of other elements of the control system (fail safe).

This Annex applies to **Micro-generators** either with or without load management or energy storage systems connected on the alternator side of the **Controller**.

Wherever possible the type testing of a **Micro-generator** utilising a particular type of prime mover should be proved under normal conditions of operation for that prime mover (unless otherwise noted).

This Annex can also be used for asynchronous **Micro-generators** that are not connected to the **Distribution Network** via an **Inverter** as appropriate.

This Annex also applies to any synchronous **Micro-generators** that are powered by stored energy (e.g. compressed air), but the requirement to demonstrate the **LFSM-O** will not be required.

A.2.2 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, by an external test house or by the supplier of the complete system, or any combination of them as appropriate.

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

a) in the safe disconnection of the **Micro-generator** from the **DNO's Distribution Network** in the event that the protection settings specified in Table 2 are exceeded; and

b) in the **Micro-generator** remaining connected to the **DNO's Distribution Network** while **Distribution Network** conditions are:
    1) within the envelope specified by the settings plus and minus the tolerances specified for equipment operation in Table 2; and
    2) within the time delay settings specified in Table 2.

A.2.2.1 Disconnection times

The minimum trip time delay settings, for over / under voltage, over / under frequency and loss of mains tests below, are presented in Table 2.

For over / under voltage, over / under frequency and loss of mains tests, reconnection shall be checked as detailed below.

In some systems it may be safer and more convenient to test the trip delay time and the disconnection time separately. This will allow the trip delay time to be measured in a test environment (in a similar way as for a protection relay). The disconnection time can be measured in the **Miro-generator** normal operation, allowing accurate measurement with correct inertia and prime mover characteristics. This is permitted providing the total disconnection time does not exceed the value specified in Table 2. When measuring the disconnection time where the **Interface Protection** is included in the **Controller**, 5 s disconnections should be initiated, and the average time recorded.

A.2.2.2 Over / Under Voltage

In addition to the EN 50438 over / under voltage tests the tests in this paragraph shall be undertaken.

The **Interface Protection** shall be tested by operating the **Controller** in parallel with a variable AC test supply, as an example see Figure A2.1. Correct protection and ride-through operation shall be confirmed**.** The set points for over and under voltage at which the **Interface Protection** disconnects from the supply will be established by varying the AC supply voltage. The disconnect sequence should be initiated when the network conditions of Table 2 are met, otherwise normal operation should continue.

To establish the certified trip voltage, the test voltage should be applied in steps of ± 0.5% of setting for a duration that is longer than the trip time delay, for example 1 s in the case of a delay setting of 0.5 s. It will be necessary to carry out five tests for each trip setting. The test voltage at which this trip occurs is to be recorded as the certified trip voltage.

To establish the certified trip time, the test voltage should be applied starting from ± 1.8% below the certified trip voltage in a step of at least ± 0.5% of setting for a duration that is longer

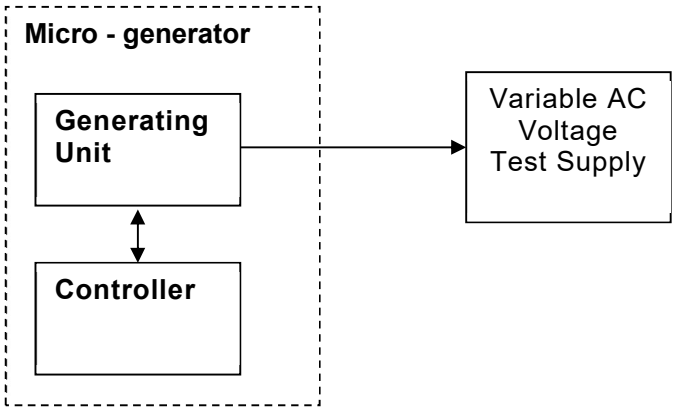
than the trip time delay, for example 1 s in the case of a delay setting of 0.5 s. Where the **Interface Protection** functionality is implemented in the **Controller**, it will be necessary to carry out five tests for each trip setting. The longest trip time is to be recorded as the certified trip time.

For example, to test overvoltage setting stage 1 which is required to be set at nominally 262.2 V the circuit can be set up as shown below and the voltage adjusted to 254.2 V. In integrated designs where there is no separate way of establishing that the **Micro-generator** is disconnected, the **Micro-generator** should be powered up to export a measurable amount of energy so that it can be confirmed that the **Micro-generator** has ceased to output energy. The variable voltage supply is then increased in steps of no more than 0.5% of nominal voltage (1.15 V) maintaining the voltage for at least 1.5 s (trip time plus 0.5 s) at each voltage level. At each voltage level confirmation that the **Micro-generator** 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 261 V. The variable voltage supply should be set to 257 V, the **Micro-generator** set to produce a measurable output (if necessary) and then the voltage raised to 265 V in a single step. The time from the step change to the disconnection of the **Micro-generator**, the output of the **Micro-generator** falling to zero, should be recorded as the trip time.

To confirm that the protection does not trip before the required time, the test voltage should be applied at each setting ± 4V and for the relevant times shown in the **Type Test Verification Report**, Appendix 3 Form C.

Test results should be recorded on the Test Sheet shown in the **Type Test Verification Report**, Appendix 3 Form C.

Figure A2.1. Micro-generator Test set up – Over / Under Voltage



A.2.2.3 Over / Under Frequency

In addition to the EN 50438 over / under frequency tests the tests in this paragraph shall be taken into account.

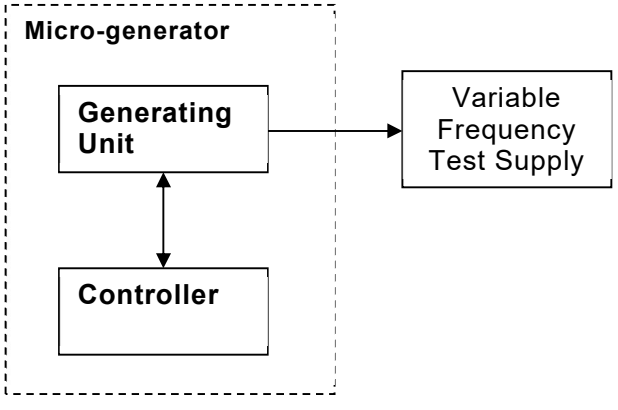
The **Interface Protection** shall be tested by operating the **Controller** in parallel with a low impedance, variable frequency test supply system, as an example see Figure A2.2. Correct protection and ride-through operation should be confirmed during the test. The set points for over and under frequency at which the **Interface Protection** 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 0.1 Hzs^{-1}, or if this is not possible in steps of 0.05 Hz for a duration that is longer than the trip time delay, for example 1 s in the case of a delay setting of 0.5 s. 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 Test Verification Report** Appendix 3 Form C.

To establish the trip time, the test frequency should be applied starting from 0.3 Hz below or above the recorded trip frequency and should be changed to 0.3 Hz above or below the recorded trip frequency in a single step. The time taken from the step change to the **Micro-generator** tripping is to be recorded on the **Type Test Verification Report** Appendix 3 Form C. 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 and if possible the loss of mains protection should be turned off in order to carry out this test. Otherwise a much smaller step change should be used to initiate the trip and establish a trip time, which may require the test to be repeated several times to establish that the time delay is correct.

To confirm that the protection does not trip before the required time the test frequency should be applied at each setting ± 0.2 Hz and for the relevant times shown in the table in the **Type Test Verification Report**, Appendix 3 Form C.

Figure A2.2. Test set up – Over / Under Frequency



A.2.2.4 Loss of Mains Protection

The test described in EN 50438 should be completed at 10%, 55%, and 100% of the **Registered Capacity**. In both cases a subset of results should be recorded as indicated in the Protection – Loss of Mains test section of the **Type Test Verification Report**, Appendix 3 Form C.

A.2.2.5 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 s before the **Micro-generator** output is restored (i.e. before the **Micro-generator** automatically reconnects to the **Distribution Network**).

A.2.2.6 Frequency Drift and Step Change Stability test

The tests will be carried out using the same circuit as specified in A.2.2.3 above and following confirmation that the **Micro-generator** 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 **Micro-generator** should not trip during the test.

For the step change test the **Micro-generator** 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 s to complete the test. The **Micro-generator** should not trip during this test.

For frequency drift tests the **Micro-generator** should be operated with a measurable output at the start frequency and then the frequency changed in a ramp function at 0.95 Hzs^{-1} to the end frequency. On reaching the end frequency it should be maintained for a period of at least 10 s. The **Micro-generator** should not trip during this test.

A.2.2.7 Active power feed-in at under-frequency

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

A.2.2.8 Power response to over-frequency

EN 50438 shall be complied with in respect of power response to over-frequency using a specific standard frequency threshold of 50.4 Hz and a **Droop** setting of 10%.

A.2.3 POWER QUALITY

A.2.3.1 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 **Registered Capacity**.

The test must be carried out with a minimum of 2 kW of rated **Micro-generators**. Where an individual **Micro-generator** is smaller than 2 kW 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 3.68 kW.

A.2.3.2 Power Factor

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

A.2.3.3 Voltage Flicker

The test must be carried out with a minimum of 2 kW of rated **Micro-generators**. Where an individual **Micro-generator** is smaller than 2 kW 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 3.68 kW.

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 **Micro-generator** being tested (kW) per phase / 3.68

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 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.

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

The dates and location of the tests need to be noted in the **Type Test Verification Report**, Appendix 3 Form C.

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

A.2.3.4 Short Circuit Current Contribution for Directly Coupled technology

DNOs need to understand the contribution a **Micro-generator** 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.

The tests in EN 50438 shall apply.

For rotating machines and linear piston machines the test should produce a 0 – 2 s plot of the short circuit current as seen at the **Micro-generator** terminals.

A.2.3.5 Electromagnetic Compatibility (EMC)

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