STANDARDS DOCUMENT

MCS 006 ISSUE 3.0

The Small Wind Turbine Standard

(Product)

This Standard was prepared by the MCS Small Wind Turbine Working Group.

It is published by The MCS Service Company Ltd on behalf of the MCS Charitable Foundation.

The MCS Service Company Ltd welcomes comments of a technical or editorial nature and these should be sent to *meetings@mcscertified.com*

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ABOUT MCS

Giving you confidence in home-grown energy

With energy costs constantly rising and climate change affecting us all, low-carbon technology has a bigger and bigger role to play in the future of UK energy.

We're here to ensure it's a positive one.

Working with industry we define, maintain and improve quality – certifying products and installers so people can have confidence in the low-carbon technology they invest in. From solar and wind, to heat pumps, biomass and battery storage, we want to inspire a new generation of home-grown energy, fit for the needs of every UK home and community.

About

The Microgeneration Certification Scheme Service Company Ltd (MCSSCo Ltd) trades as MCS and is wholly owned by the non-profit MCS Charitable Foundation. Since 2007, MCS has become the recognised Standard for UK products and their installation in the small-scale renewables sector.

We create and maintain standards that allow for the certification of products, installers and their installations. Associated with these standards is the certification scheme, run on behalf of MCS by Certification Bodies who hold UKAS accreditation to ISO 17065.

MCS certifies low-carbon products and installations used to produce electricity and heat from renewable sources. It is a mark of quality. Membership of MCS demonstrates adherence to these recognised industry standards; highlighting quality, competency and compliance.

Vision

To see MCS certified products and installations in every UK home and community.

Mission

To give people confidence in low-carbon energy technology by defining, maintaining and improving quality.

Values

1. We are expert – ensuring quality through robust technical knowledge
2. We are inspiring – helping to reshape energy in UK homes and communities
3. We are collaborative – working with industry and government to create positive change
4. We are principled – operating in a way that's clear, open and fair
5. We are determined – supporting the UK's drive towards a clean energy future

CHANGES TO STANDARDS

When MCS Standards are revised, the issue number is also revised to indicate the nature of the changes. This can either be a whole new issue or an amendment to the current issue. Details will be posted on the website at www.mcscertified.com

Technical or other significant changes which affect the requirements for the approval or certification of the product or service will result in a new issue. Minor or administrative changes (e.g. corrections of spelling and typographical errors, changes to address and copyright details, the addition of notes for clarification etc.) may be made as amendments.

The issue number is given on the left of the decimal point, and the amendment number on the right. For example, issue 3.2 indicates that it is the third significant version of the document which has had two sets of minor amendments. The table below does not include minor amendments to early issues.

Users of this Standard should ensure that they are using the latest issue.

Amendments issued since publication

Issue No.	Amendment Details	Date
1.0	First Publication	
2.0	Revised following publication of IEC 61400-2 edition 3 and corresponding publication of a revision to the BWEA standard, now titled RenewableUK Small Wind Turbine standard (01 October 2013).	01/10/2013
3.0	Major changes in line with other MCS Product Standards, incorporation of RenewableUK Small Wind Turbine standard 15th January 2014 (no longer supported) and other updates.	01/08/2024

FOREWORD

This document contains references to other documents which may be either normative or informative. At the time of publication any editions of those documents, where indicated, were valid. However, as all documents are subject to revision, any users of this document should apply the most recent editions of those referenced documents (unless a dated version is specified). Use of earlier editions of the referenced documents can be used in limited circumstances where stated later in this document.

This issue 3.0 is a significant update to issue 2.0. It is available for reference from the date of publication 01/08/2024. Manufacturers or importers of microgeneration systems who have certified products, or wish to have products certified, in accordance with MCS 006 may start working in accordance with this update from the date of publication. Compliance with this update is mandatory for products to be certified in accordance with MCS 006 from the date of implementation 01/08/2026.

This Standard now incorporates the contents (updated where appropriate) of the RenewableUK Small Wind Turbine standard (15 January 2014) which was created by the small wind turbine industry, scientists, and consumers. It was designed to provide consumers with a measure of confidence in the quality of small wind turbine products and a basis for comparing their performance. It was largely derived from existing international wind turbine standards developed under the auspices of the International Electrotechnical Commission (IEC) and provides for the evaluation of wind turbine systems in terms of:

- Reliability.
- Power performance.
- Acoustic characteristics.

Finally, a technical note originally developed and published by RenewablesUK regarding inverter changes is also incorporated as an appendix.

1 INTRODUCTION & SCOPE

This Scheme document identifies the evaluation and assessment practices for the purposes of certification and listing of small wind turbine products. Certification and listing of products is based on evidence acceptable to the Certification Body:

- that the product meets the appropriate standards contained and referenced in this document;
- that the manufacturer has staff, processes, and systems in place to ensure that the product delivered meets the standards.

And on:

- periodic audits of the manufacturer, including testing as appropriate.
- compliance with the contract with the Certification Body for listing and approval including agreement to rectify faults as appropriate.

Whilst it is not possible to ensure safety, this Standard includes criteria which should help to mitigate potential safety risks from the installation and operation of the product.

Certification against this Standard does not imply compliance with regulations which may apply to such products unless explicitly stated.

The scope of this Standard includes small wind turbines that:

- have a rotor swept area of smaller than or equal to 200m^2**,**
- generate electricity at a voltage below 1000 volts AC or 1500 volts DC for both on and off-grid applications.

2 DEFINITIONS

This Standard applies to small wind turbine systems as defined in the table below.

As a summary and for the purposes of this Microgeneration Standard, small wind turbine products are defined as the wind turbine itself and all subsystems, including:

- Foundations
- Support structures
- Mechanical systems
- Internal electrical systems
- Electrical interconnection with the load
- Protection systems
- Turbine controller

- Charge controller/Inverter
- Electrical wiring
- Electrical disconnect
- Installation manual(s)
- Operation manual(s)
- Other documentation (e.g., warranty information)

For the avoidance of doubt the following definitions are applicable to this Standard and contained in the following publications:

Definition	Contained in Publication
Small Wind Turbine	BS EN 61400-2: 2014 Wind Turbines. Small wind turbines
Performance	BS EN IEC 61400-12-1: 2022 Wind energy generation systems. Power performance measurements of electricity producing wind turbines
Acoustic Noise	BS EN 61400-11:2013+A1:2018 Wind turbines. Acoustic noise measurement techniques
Sound Power Declaration	IEC TS 61400-14: 2005 Wind turbines. Declaration of apparent sound power level & tonality values
Additional Definitions (for reporting purposes)	
Maximum Power:	The maximum output power (being the one-minute definition, P60) as defined in BS EN 61400-2: 2014
Maximum Voltage	The maximum output voltage (being the one-minute definition, U60) as defined in BS EN 61400-2: 2014
Maximum Current	The maximum output current (being the one-minute definition, i60) as defined in BS EN 61400-2: 2014

3 APPLICATIONS TO JOIN THE SCHEME

Applications should be made to an accredited Certification Body operating this Scheme, who will provide the appropriate application form and details of the applicable fees.

4 CERTIFICATION AND APPROVAL

4.1

Certification and approval is based on the following:

a) An assessment of the evidence demonstrating compliance with the requirements set out in Section 6.

Evidence of compliance is generally accepted as independent third party testing by a UKAS (or equivalent) accredited test laboratory. However, other evidence of compliance may be considered at the discretion of the Certification Body (see document MCS 011 Testing Acceptance Criteria).

Evidence of compliance in the form of testing in accordance with earlier, superseded, versions of the standards in Section 6 may be acceptable subject to justification being provided by the manufacturer to the satisfaction of the Certification Body. Such justification should address any implications for the wind turbine system's safety and durability. The Certification Body should not unreasonably decline such evidence of compliance without sound technical justification for doing so.

Note: Evidence of compliance in the form of testing to withdrawn versions of standards is not permitted under any circumstances.

b) An assessment of the evidence demonstrating compliance with the requirements set out MCS 010 – Generic Factory Production Control and Product Quality Requirements.

c) Review of the technical documentation relating to the material or product.

4.2

This document makes continual reference to the 61400 series of standards for wind turbines and wind energy generation systems. Those with the prefix "BS EN" or similar are used most often but versions with other prefixes e.g. "IEC", are also considered valid.

4.3

The manufacturers of certified wind turbines shall comply with sections 11 and 12 of BS EN 61400-2: 2014, and the consumer label with the corresponding test summary report as per annex m shall be available from the manufacturer on demand.

The use of more detailed performance characterisations, such as power curves or estimated energy output graphs or tables, is allowed so long as this material was included in the certification.

Note: for the purposes of certification under this Standard the Consumer Label and Test Summary Report need not be published by a labelling organisation as detailed in Annex M.

4.4

Applications for a range of common products (product families) will be dealt with on a case-by-case basis in accordance with MCS 011 Acceptance Criteria for Testing Required for Product Certification, and with the provisions of the standard with which conformity is being claimed.

Note: for example, where one or more characteristics are the same for products with similar design, construction and functionality then the results of tests for these characteristics on one *product may be applied to other similar products, as agreed between the manufacturer/supplier and the Certification Body.*

4.5

A certificate is awarded following demonstration of satisfactory compliance with the appropriate standard and this Scheme document, taking into account any limitations imposed by the standard and other appropriate guidelines and satisfactory verification/assessment of the manufacturer's factory production control and technical documentation.

4.6

Certificates contain the name and address of the manufacturer, model and reference number of the small wind turbine product, a unique certificate reference number, and the issue number and date.

4.7

Certificates are valid from the date of issue and are maintained and held in force subject to satisfactory completion of the requirements for maintenance of certification (see item 8) but remain the property of the issuing certification body.

4.8

Details of the manufacturer and the certificated product(s) are listed at www.mcscertified.com.

5 TECHNICAL DOCUMENTATION

Technical documentation for the product must be submitted for review. This documentation shall be presented in English and shall be such that it can be assured that the products submitted for test are equivalent to those that are to be manufactured for normal production. The documentation must consist of the following as a minimum:

a) Details of intended use, application and classifications (if any) required.
b) Manufacturing drawings and/or specifications including tolerances, issue and revision numbers.
c) The revision number of the product.
d) Raw material and components specifications.
e) Details of the quality plan applied during manufacture to ensure ongoing compliance.
f) Where historical test data is requested to be considered for the application, full test report and details of any existing approvals is required. Each application will be dealt with on a case-by-case basis.
g) User and installation documentation, including commissioning requirements, use and maintenance instructions with evidence that the product, when installed into a system, is able to meet the installation requirements of Building Regulations of the country where the product will be installed.

6 PERFORMANCE AND TESTING CRITERIA

Tests to earlier versions of the standards given below may also be acceptable (see clause 4.1).

6.1 QUALITY ASSURANCE AND ENGINEERING INTEGRITY

The small wind turbine shall comply with BS EN 61400-2: 2014 except for Section 9 (electrical) which is not mandatory.

Note: In accordance with Section 1 of BS EN 61400-2: 2014, "Any of the requirements of this standard may be altered if it can be suitably demonstrated that the safety of the turbine system is not compromised."

6.2 ACOUSTIC NOISE MEASUREMENT

The wind turbine system acoustic noise performance shall be tested and documented in a test report as per BS EN 61400-11:2013+A1:2018 incorporating relevant additional guidance provided in BS EN 61400-2: 2014.

6.3 POWER PERFORMANCE TESTING

The wind turbine system power performance shall be tested and documented in a test report as per BS EN IEC 61400-12-1: 2022 incorporating relevant additional guidance provided in BS EN 61400-2: 2014.

6.4 TEST DATA

Test data may be taken, analyses may be performed, and test reports may be submitted by any party, including the manufacturer, but they must be provided in a manner acceptable to an accredited Certifying Body.

7 MAINTENANCE OF CERTIFICATION AND LISTING

Certificates and listing are maintained and held in force subject to satisfactory completion of the following requirements for maintenance of certification:

7.1 FACTORY AUDITS

Certification is maintained through on-going audits of the manufacturer's quality control system as appropriate, during which time a detailed check will be made that the product being manufactured is the same as the specification tested.

7.2 PRODUCT AUDITS

Product audits will be conducted as follows:

- Review of the product technical data files including materials.
- Review of end of line tests in accordance with the manufacturer's quality plan.
- Repeat testing of elements from the product standard as appropriate to confirm that the product continues to meet the requirements for certification and listing.

7.3 VARIATIONS AND MODIFICATIONS, INCLUDING TO CERTIFIED PRODUCTS

7.3.1 Modifications to a small wind turbine system could be for the purpose of creating variants of the original turbine system or improving the original turbine system. In principle, modifications include any aspect of the turbine system (in all cases, Annex A of BS EN 61400-2:2014 shall be complied with as if it is a normative Annex).

7.3.2 Where the inverter is changed, updated, or modified the guidance detailed in Appendix B should be followed.

7.4 ONGOING OBLIGATIONS

During and after turbine certification, the manufacturer shall notify the accredited Certifying Body of all significant changes to the product, including hardware and software. The accredited Certifying Body will determine whether there is a need for retesting and/or additional review.

This requirement to notify the Certifying Body is intended to be interpreted broadly and in a co-operative manner by both manufacturer and Certification Body such that any relevant information regarding the in-service performance of the wind turbine system and any of its variants is analysed and the design, manufacture, installation, operation, or maintenance varied accordingly in accordance with the underlying purpose of this Standard. This requirement includes significant incidents or failures of which the manufacturer is aware.

This requirement shall be fulfilled in a timely manner and to include all credible sources of information. Procedures can be agreed between the Certification Body and the manufacturer such that information is managed in a proportionate manner.

8 CERTIFICATION MARK AND LABELLING

All approved products listed under this Scheme shall be traceable to identify that they have been tested and certificated in accordance with the requirements of this Standard (e.g. via a unique serial number).

The Supplier shall use the Certification Mark(s) only in accordance with their Certification Body's instructions.

An example of the Certification Mark(s) to be used for certified products under for the Scheme is as follows:

Certificate Number MCS "XXX"
"Description of the Technology certificated"

Where 'XXX' is the certificate number, and the logo of the Certification Body issuing the certification would sit on the right-hand side of the logo.

Companies may only use the Mark while certification is maintained.

APPENDIX A - REFERENCES

For the purposes of this Standard, the following versions of 61400 series standards are considered equally valid to versions with other prefixes e.g. “BS EN”.

Reference No.	Reference Title	Publication Date	Edition	Stability Date
IEC 61400-2:2013	Wind Turbines – Part 2: Design Requirements	12th December 2013	3.0[1]	2021
IEC 61400-11:2012+AMD1:2018 CSV Consolidated Version	Wind Turbines – Part 11: Acoustic Noise Measurement Techniques	15th June 2018	3.1[2]	2020
IEC 61400-12-1:2017	Wind Energy Generation Systems – Part 12-1: Power Performance Measurements of Electricity Producing Wind Turbines	3rd March 2017	2.0	2020
IEC TS 61400-14:2005	Wind Turbines – Part 14: Declaration of Apparent Sound Power Level & Tonality Values	22nd March 2005	1.0	2020
MCS 010	Generic Factory Production Control & Product Quality Requirements	25th February 2009	2.0	
MCS 011	Acceptance Criteria for Testing Required for Product Certification	23rd November 2018	2.1	

[1]Note there is a one-page list of error corrections in document IEC 61400-2:2013/COR1:2019 Corrigendum 1 – Wind Turbines – Part 2: Design Requirements, published 10th October 2019.

[2]Note there is a one-page list of error corrections in document IEC 61400-11:2012/AMD1:2018/COR1:2019 Corrigendum 1 – Wind Turbines – Part 11: Acoustic Noise Measurement Techniques, published 10th October 2019.

Source: https://webstore.iec.ch/publication

APPENDIX B – TECHNICAL NOTE

GUIDANCE REGARDING INVERTER CHANGES IN SMALL WIND TURBINE SYSTEMS

B1 Purpose

B1.1 The purpose of this document is to provide guidance for Certification Bodies to assess the impact of changing, up-dating or modifying an inverter for use on a wind turbine already certified MCS 006. Following the assessment, it may be deemed appropriate that further testing of the revised system configuration is required if the impact of the change is considered sufficient to cause a material deviation from the representative configuration originally tested.

B2 Inverter Definition

B2.1 For this assessment, an "inverter" is defined as the necessary electronic arrangement (hardware and software) required to condition and control the electrical output of a wind turbine generator to that required by the load. The term "converter" would be the technically correct definition for such an arrangement; however "inverter" is retained for convenience of recognition. In some arrangements, the inverter may also be responsible for the following (not exhaustive) functions:

- Adjusting the level of turbine power with respect to speed or generator voltage
- Controlling external turbine peripherals, such as brakes etc.
- Assisting or starting the turbine

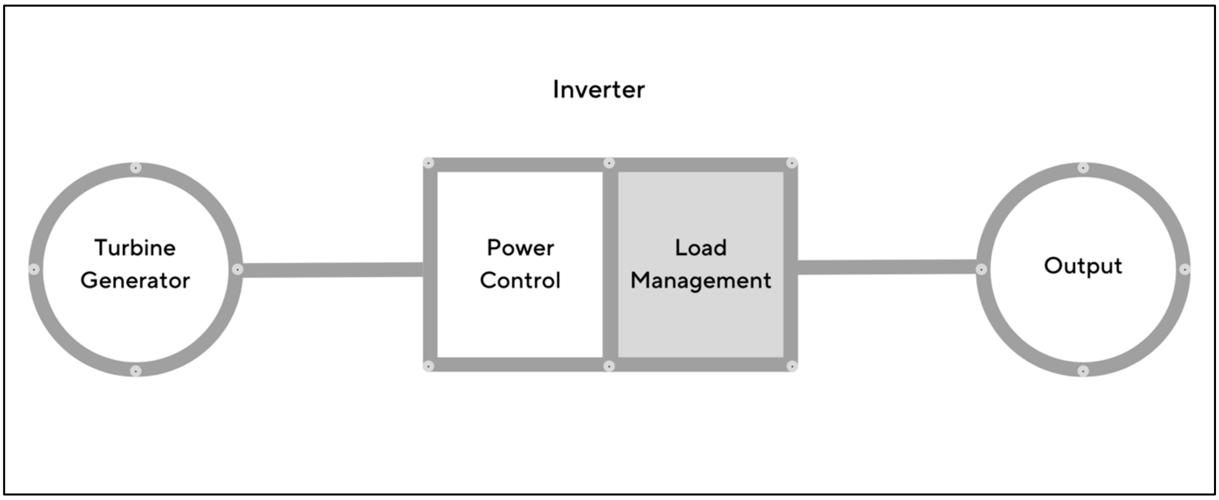


Figure 1: General functional description of an inverter

B2.2 As per figure 1, the inverter can be considered as having two core functions – the techniques deployed, both in hardware and software, to achieve these two functions differ depending on the application and the architecture chosen. This is therefore fundamental to assessing the impact of inverter change.

B2.3 For a given load type, as defined in Annex A, the difference in turbine performance and behaviour will be defined by the techniques deployed to achieve effective power control. An assessment of impact of change should therefore take this into account. Whereas an assessment of impact of change to load management need only be considered when changing between the load types defined in Annex A, providing that the inverter is type tested for the grid code relevant to the region of use or the equivalent off-grid standards.

B3 Electronic Architecture

B3.1 An inverter, as defined above, will have an architecture that provides the functionality illustrated in figure 2, where conversion to AC or DC output is implied.

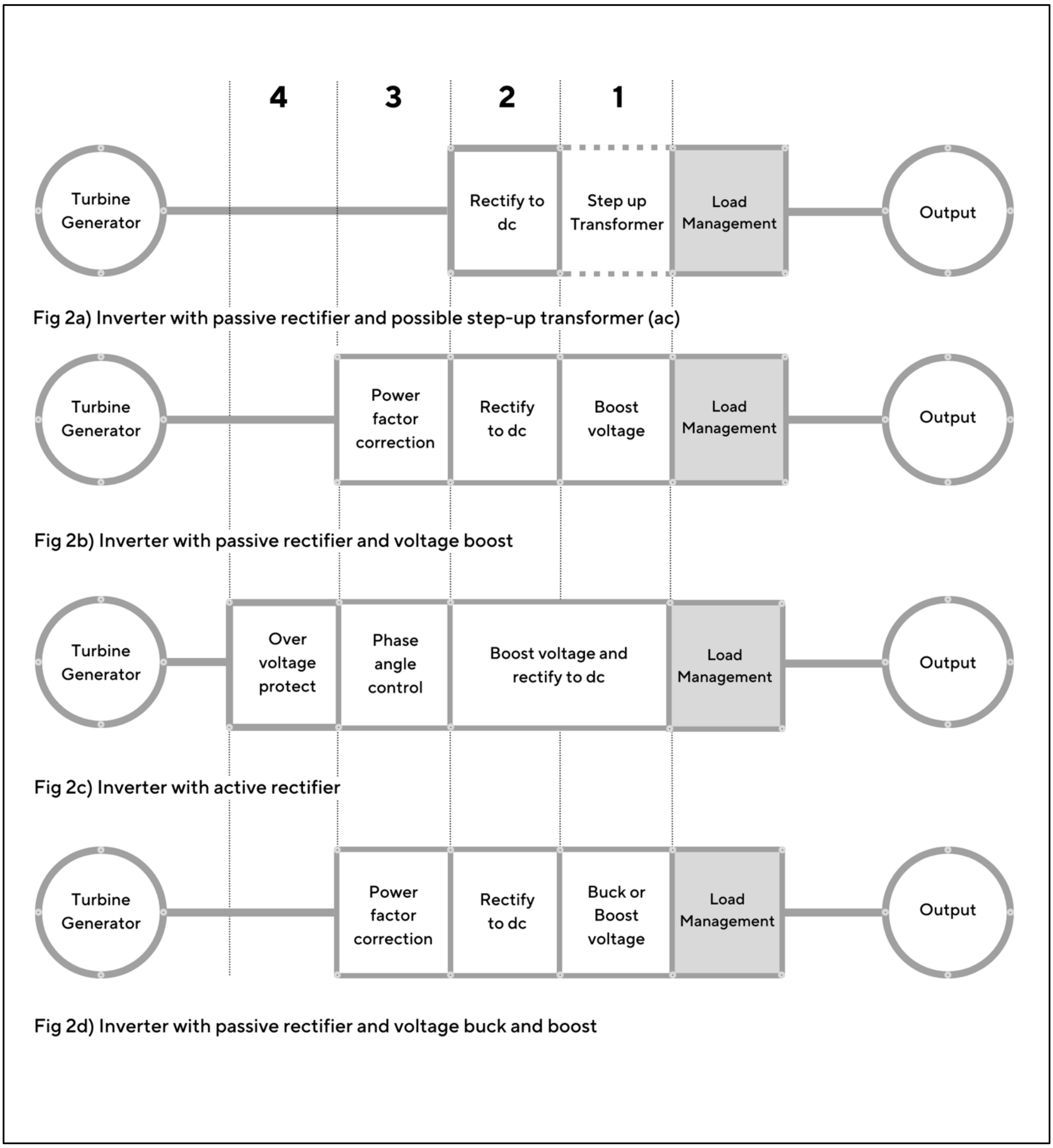


Figure 2: Inverter architecture and resulting functionality

Like for like changes where the same electronic architecture is retained, as defined by Figures 2a) to 2d) above will have very little impact on the safety and performance aspects of the system, providing that the rating of the inverter and the control setup of the turbine, as defined in paragraphs B5 to B10, are considered. Any replacement inverter however must be certified to the necessary regional grid code and/or safety standards.

B3.2 When a change in electronic architecture has been proposed between the options illustrated in Figures 2a) to 2d), differences in power control can result. Illustrated in Table 1 is a comparison of performance attributes that differentiate each architecture. Some differences are more significant than others in magnitude and hence overall turbine performance. However, a simple traffic light system has been illustrated to highlight incremental performance improvement, whereby red equates to worst case relative performance and green best case. An indicative scale of performance range is highlighted and the significance to overall performance assessed as low, medium or high.

Architecture (See Fig 2)	Inverter Efficiency	Cut-in Voltage	Generator Efficiency	Generator Stress	Generator Noise	Over-Voltage Protect
Affected by	1,2,3	1	2,3	3	3	1,4
Fig 2a)						
Fig 2b)						
Fig 2c)						
Fig 2c)						
Measure (indicative)	95-97%	50-200V	92-96%	0.65 – 1puA	Specific	Specific
Significance	L	H	M	M	M	H

Table 1: Relative Performance of electronic architectures

B4 Performance Curve and Energy Yield

B4.1 A modification to the "representative configuration" of the inverter can be as simple as a minor change to the power curve or a change of architecture between those defined in Figures 2a) to 2d). In the case of the latter, the architecture deployed can have a significant effect on the turbine cut-in and cut-out voltages and hence the operating turbine speed range. This can have a significant impact on the energy yield of the turbine, as indicated by the high (H) significance in Table 1.

B4.2 Other parameters afforded to the inverter solution of choice that will affect the energy yield include:

- Over-voltage protection used to enable continued generation in high wind speeds
- Input current rating
- Generator and inverter efficiency
- Internal consumption and stand-by strategy
- Rate of load acceptance and rejection on the turbine
- Method by which control of power is achieved

B4.3 Following consideration of paragraphs B5 to B10, if doubt or ambiguity remains, the approval body can request practical evidence of a power curve to validate performance.

B5 Cut-in, Cut-out and Over Voltage Protection

B5.1 An architecture that enables a solution with low cut-in voltage will facilitate the turbine to start generating power from relatively low wind, and hence low rotational speeds. Naturally this should enable generation of relatively more energy, particularly in lower wind speed sites, when compared against a system with higher cut-in voltage. However, it is recommended that cut-in be set at a minimum speed where the power available from the turbine is greater than the consumption of the inverter to always enable positive output.

B5.2 At higher wind and rotational speeds, the inverter will cut out if the maximum input voltage is exceeded and no additional over voltage protection has been included in the system. Over voltage protection by additional components are not considered here but may be specified by the turbine manufacturer. Clearly an inverter with higher maximum input voltage will enable continued generation than one with a lower value, auto-disconnect contactor on the input of the inverter, some inverter architectures can provide means by which to limit the generator voltage to enable continued generation. This is clearly illustrated in Figure 3, as is the relative cut-in performance of two identically rated inverters with differing voltage threshold specification.

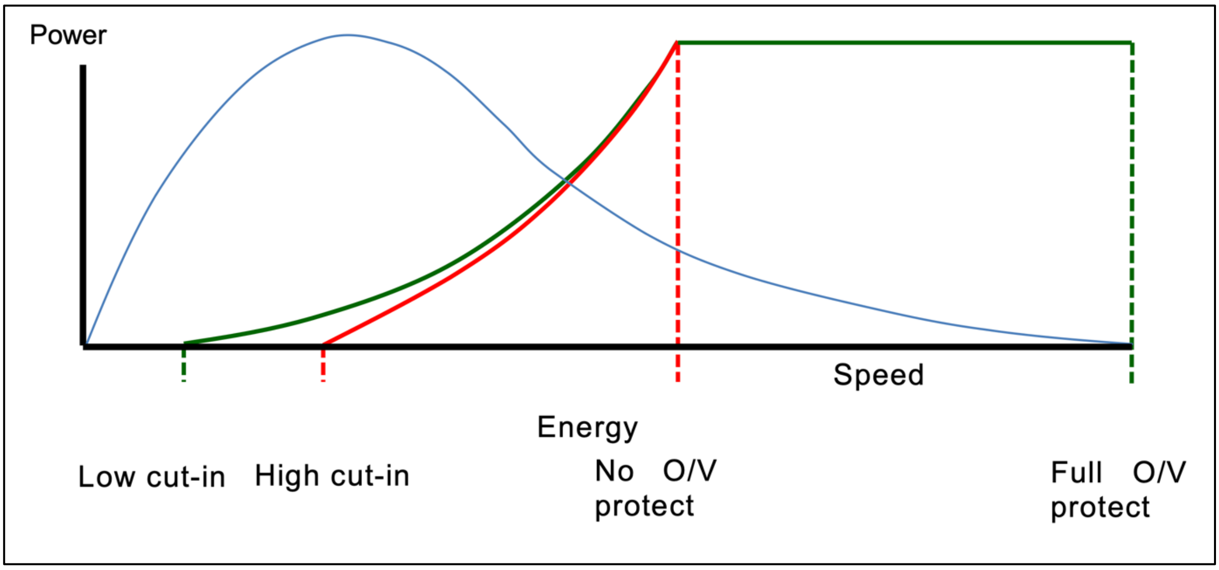


Figure 3: Effect of voltage threshold on turbine performance (O/V = Over Voltage).

B6 Generator Current and Rated Speed

B6.1 The inverter should be specified in such a way that its input current rating enables the power required at rated speed to be achieved. Illustrated in Figure 5 is a comparison of two identically rated inverters with identical cut-in, cut-out and over voltage protection features. However, their input current rating differs, and hence inverter with red characteristic yields a higher rated speed than that of green, thus affecting overall turbine performance and acoustic output.

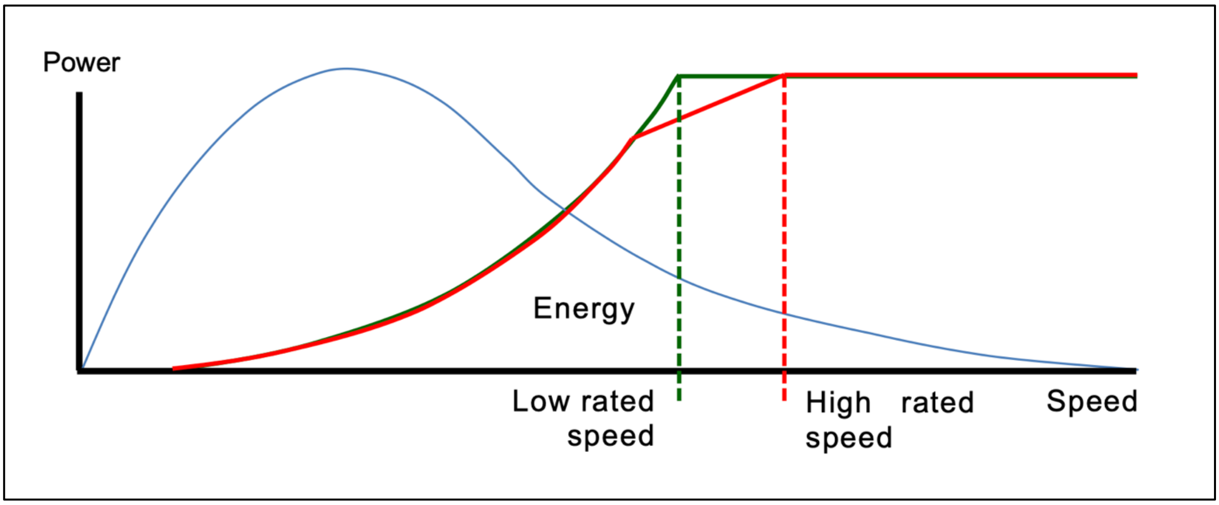


Figure 4: Effect of current rating on the performance of turbines with similar inverter architecture

B6.2 Like for like comparison of input current rating is important when comparing identical architectures outlined in Figures 2a) to 2b). However, when comparing the relative performance of the different architectures, a simple comparison of input current is not sufficient. This is due to the method achieved by the architecture to control generator phase angle – defined as block 3 in Figure 2.

B6.3 Without any phase angle compensation, the generator current will lag voltage and thus further contribute toward a relatively high voltage drop under load. Hence, the current drawn from the generator for a given power will be greater than that drawn by architecture capable of correcting this phase lag. An inverter with 'power factor correction' will require a lower input current rating to achieve the same power, due to the virtue of its ability to correct the angle between generator voltage and current to near zero. An inverter capable of full 'phase angle control' can enable the generator to operate at optimal phase angle to achieve rated power with lowest relative current.

B6.4 Given the variation of current between architectures for given power conditions, other performance factors are affected such as generator efficiency, temperature, and winding stress as per Table 1. The technique deployed to control generator current can also have an effect on audible noise as the harmonic content of the current – and hence ripple torques – will vary depending on the architecture and control used.

B6.5 The effect of phase angle control on the generator voltage should be considered when defining the appropriate power curve. For example, programming inverters of differing architectures outlined in Figures 2a) to 2b) using the same power curve with respect to voltage, can result in differing power curves with respect to speed and hence deviation in power control. Therefore, the programmed power curve should reflect the desired power performance versus speed.

B7 Inverter and Generator Efficiency

B7.1 Inverters of comparative architecture and rating outlined in Figures 2a) to 2d) are likely to have immaterial differences in efficiency. Inverters with differing architectures will have differing efficiencies due to the difference in the number of power handling switching semiconductors. In reality, this difference is small (95-97% at full load) and in isolation has a relatively small effect on energy yield when comparing inverters of similar rated outputs. However, the loss of inverter efficiency in moving to a solution with a greater number of power semiconductors (i.e. with voltage boost or active rectifier) can be compensated by the gain in generator efficiency achieved through power factor correction or full phase angle control. When considering inverter modification or change, it is advisable therefore not to primarily consider the impact of inverter efficiency on energy yield. Instead, working turbine envelope should be primarily considered, as outlined in Figures 3 and 4.

B8 Internal Consumption and Standby Strategy

B8.1 An inverter will consume a small amount of power when in standby mode and not switching the power handling semiconductors; this can be as low as a few watts (providing that any cooling fans are switched off) and in isolation should not result in a material difference between inverters. However, once the turbine has cut-in and the power handling semiconductors begin to switch, these losses will start to become significant. In conditions where the inverter is connected to both turbine and load and is fully operational with power handling semiconductors switching, the inverter itself can become a consumer at running speeds where its consumption exceeds that available from the turbine.

B8.2 Whilst seemingly attractive to have low cut-in speeds, it is recommended that the cut-in voltage of the inverter be set such that the power available from the turbine at the corresponding speed at cut-in is at least equal to the losses of the inverter itself so as not to negatively affect energy yield. At speeds lower than cut-in and, if separately programmed, low speed voltage cut-out the inverter should ideally cease switching the power handling components.

B9 Load Acceptance and Rejection

B9.1 The rate at which load on the turbine can be both accepted or rejected should be set-able and ideally defined as separate parameters in the inverter. These ramp rates not only affect the energy yield of the turbine, but also the mechanical shock loads applied to the turbine and generator components. Guidance should be provided by the turbine manufacturer as to the allowable limits of operation. This guidance should be reflected in the settings of the inverter. In making a modification or change to an inverter, the settings applied for load acceptance and rejection in the representative configuration tested under according to the Standards in Section 7 should be retained or transferred to the new inverter unless alternative guidance is provided by the manufacturer; else further testing may be required.

B10 Power Control

B10.1 The technique used to control power, and the discretisation at which it is achieved, can be implemented either in the inverter or by way of controlling the inverter as a slave unit through instruction from a separate controller. In the event of considering the latter, straight forward inverter change, or modification can be considered provided that the calibration of inverter output to demand signal is retained and the comparative performance metrics of Table 2 are considered.

B10.2 Where the turbine power control is achieved through setup of the inverter itself, several control techniques are possible. For consideration here, these techniques are categorised as two separate methods:

B10.2.1 Look-up Table.

Here a simple power output versus speed reference is programmed into the inverter. Speed reference can be made either with respect to generator speed, electrical frequency or voltage. The discretisation and flexibility in programming of this curve will determine the fit that can be achieved with respect to the ideal turbine characteristic. In making a modification or change to an inverter, best efforts should be made to replicate at least the characteristic tested in the "representative configuration". However, deviation in the characteristic that can be achieved may result due to the factors highlighted in sections B5 and B6, and as a result of a difference in the discretisation and flexibility of the curve that can be programmed. An assessment of any new power curve proposed will determine the likeness in fit and assure the integrity of energy output. **As a guideline only, it is recommended that the programmed Power versus voltage/speed curve not deviate in area from cut-in to rated speed by more than 10% from that considered in the reference test (Section 7.3) in order to retain certification. In addition, it is recommended that any single one point on the programmed power curve beyond 50% of the rating of the turbine, should not deviate by more than 10% from that considered in the reference test (Section 7.3). Practical evidence of achieving the proposed power curve should be presented by the proposer of the change or modification. Else, if expecting to exceed the maximum allowable deviations, further certification testing may be requested which could extend to repeated durability testing if deemed appropriate due to product lifetime concerns.**

B10.2.2 Iterative, Adaptive and Intelligent Load Control.

Where an inverter does not require a power characteristic to be programmed, it uses a process of learning and/or load iteration to determine an optimal method of control. Embedded within these control methods is the ability to, amongst other techniques, hunt for optimal power at given running speeds and in some instances to stall the turbine. In changing from a technique described in paragraph B10.2.1 to the method described here, evidence of accurate, consistent and reliable operation over a period of time is recommended in addition to an analysis of the power curve characteristic where the same measures of acceptance highlighted in paragraph B10.2.1 apply.

B11 Turbine Plant Control Integration

B11.1 Inverter functionality can include the ability to read data from external sensors, such as anemometers, and perform control actions either internally within the inverter or as instruction to external peripherals, such as braking systems and disconnection devices. Where such functionality is to be integrated within the inverter, it is recommended that the approval body review the control strategy and assess evidence of reliable and repeatable control action and operation provided by the turbine manufacturer.

B12 Durability

B12.1 Inverters and their associated components are subject to extensive testing to validate their performance specification and adherence to safety standards. If conforming to the appropriate certification standards defined in Annex A, adherence of the inverter to the specification stated by its manufacturer should be considered a given.

B12.2 The practice adopted by mature power generating industries to assure product robustness is one of 1000 hour Accelerated Life Testing of components or sub-systems in a representative test configuration* and environment. It is recommended that this be considered by the approval body when considering inverter replacement. Alternatively, the following can be considered as valid:

- History of in-field inverter deployment presented and reviewed
- 2,500hr system test, carried out by the turbine manufacturer

NOTE: Representative test environment considers turbine behaviour but does not explicitly have to be a turbine

B13 Turbine Starting and Assist

B13.1 Some VAWT turbines require assisted starting. Of the architectures illustrated in Figures 2a) to 2d), only an active rectifier solution will provide the bi-directional power capability to start the turbine without a separate power stage. When considering a non-self-starting VAWT, consideration should be given to this functionality and evidence provided by the manufacturer that the revised inverter solution will start the turbine either with or without separate power stage. Consumption of energy during the assisted start-up period should be considered. The ability to start the turbine may require an encoder to report position feedback to the inverter, alternatively this can be achieved using sensor-less position or speed techniques. Evidence should be provided by the turbine manufacturer to validate reliability where a position feedback device is used.

B14 Grid Compensation

B14.1 To date, reactive power compensation of the grid from distributed generators is forbidden by network operators in the UK. It is envisaged that in the future this will change. This functionality is therefore not considered here at this time.

B15 Multiple Inverters and Isolation

B15.1 Where multiple output inverter stages are proposed to achieve higher powers onto common phases, consideration needs to be given to isolating the output of each inverter to ensure safe and reliable operation. Where n inverters are used, n-1 isolation transformers are recommended. For example, where connecting a 12kW turbine to a single-phase supply via two 6 kW inverters, one isolation transformer of at least 6kW rating will be required on the output of one of the inverters. Some inverters have transformers integrated within their design; others require additional transformers to achieve this protection. Where isolation is required, the additional losses in the transformers will need to be taken into consideration when evaluating power and energy output – particularly if a solution is proposed where transformers are introduced as an addition to the configuration originally tested under MCS 006. As a guideline only, isolation transformers of a toroidal design introduce relatively low losses when compared to more designs.

B15.2 Alternatively, isolation of each inverter output may not be required where an appropriate transformer-less paralleling technique can be demonstrated.

B16 Differing Phase Outputs

B16.1 As is the case in the UK, there are four types of grid connection below 50kW; these are as follows:

- Single Phase
- Split phase with 180-degree separation
- Split phase created from three phases with 120-degree separation
- Three Phase

Above 50kW, grid connection is almost exclusively made at three phase.

B16.2 Achieving grid connection of a common turbine for a differing number of phases can be done in one of two ways:

- Using multiple, common single-phase inverters, for example 2 off 6kW inverters can be used for either 12kW single or split phase installations
- Using dedicated inverters, i.e. different products (or a combination of) for single, split and/or three phase installations

B16.3 If proposing a common inverter to achieve differing phase outputs, an approach can be considered to achieve MCS certification of all output phase variants based on EITHER the assessment outlined in paragraphs B6 to B19 having been carried out on one variant if making an assessment of inverter change OR full MCS test results achieved when certifying a new system for the first time. To certify a system with differing phase outputs, based on the results of either assessment or test of a single variant, the following shall be satisfied:

B16.3.1 Power Control, with reference to the approved configuration the programmed power curve (including ramp rate settings), or any alternative method of power control, shall cumulatively be the same as the programmed power curve for the base line MCS certified system within the allowable limits set out in paragraph B10.2.1.

B16.3.2 Load management, with reference to Annex A it shall be necessary to adhere to appropriate connection recommendations for the alternative phase configuration, for example EREC G98 or EREC G99; demonstrating type test certification for the proposed system.

B16.3.3 Isolation & Transformers may be necessary to protect the inverters in alternative phase configurations. If so, the cumulative losses of the transformer shall be deducted from the cumulative output of the inverters to derive the revised power output for the system; ensuring that performance within the allowable limits in paragraph B10.2.1 are achieved.

B16.4 If proposing a different inverter to achieve differing phase outputs, an approach can be considered to achieve certification of all output phase variants based on EITHER the assessment outlined in paragraphs B2 to B15 having been carried out on one variant if making an assessment of inverter change OR full MCS 006 test results achieved when certifying a new system for the first time. To certify a system with differing phase outputs, based on the results of either assessment or test of a single variant, the following in addition to the considerations of paragraph B16.3, shall be satisfied:

B16.4.1 Electronic Architecture, with reference to the approved configuration the inverter shall be of the same architecture as that defined in fig 2; else the full assessment outlined in paragraphs B2 to B15 will require consideration for the proposed differing phase configuration.

B16.4.2 Input rating, with reference to the approved configuration the cumulative input (turbine side) current rating of all inverters shall be at least equal as shall the operating window as defined by the cut-in to maximum allowable voltages. That is, except where overhead in the design of the approved configuration can be clearly demonstrated in this respect; then lower ratings can be considered. This is to ensure that the issues highlighted in figure 5 is avoided, thus preserving within allowable deviation, the certified power performance, acoustic and durability characteristics of the turbine.

B16.4.3 Output rating, with reference to the approved configuration the cumulative output (load side) current rating of all inverters shall be at least equal. That is, except where overhead in the design of the approved configuration can be clearly demonstrated in this respect then lower ratings can be considered.

B16.5 If considering the process described in paragraph B16.4 for differing inverters, it is recommended (but not essential) that the initial assessment carried out in paragraphs B2 to B15 be done for the "weakest" phase configuration; that being from the context of the turbine side (input) rating of the inverter. For example, if a dedicated three phase inverter were to have lower turbine side current rating than a proposed single phase inverter then justification for approval of the single phase configuration based on the full assessment of paragraphs B2 to B15 carried out on the three phase inverter would be easier to justify by consideration of this section B16 and would therefore not require consideration of limits defined in B10.2.1 in respect of input current rating.

B17 Consideration of Turbine Acoustic Performance

B17.1 In relation to the impact of inverter change on acoustic performance, there are two factors to consider that could affect the results of the original certification tests:

B17.1.1 Turbine running speed, if for any reason the inverter loads the turbine at a different power level than the configuration tested, the turbine itself may operate at a different running speed for that given power. The acoustic output of the turbine with reference to the wind speed could therefore be affected. Consideration shall therefore be given to the following factors:

a) Turbine side (Input) current rating of the inverter, this can affect the operating speed of the turbine as illustrated in section B6; care should be taken, however, not just to consider the current rating itself but also the electronic architecture for the reasons given in B6.3 (generator phase angle control method)

b) Programmed Power Curve (or equivalent) ultimately sets the demanded power from the turbine. Providing the hardware of the inverter is capable, namely the input current rating and operating input voltage window, retaining the existing power curve setup with respect to voltage and/or speed should maintain the operational speed characteristics of the turbine and hence its acoustic behaviour.

B17.1.2 Modal excitation and/or harmonic noise, inverters by the very nature of their operation, affect the harmonic content of the current waveform in the generator. Depending on the electronic architecture considered, and the level of filtering built into the inverter itself, the harmonic content will differ. The relative measure of noise given between architectures in Table 1 refers to this phenomenon. For example, passive rectification will superimpose 5th and 7th current harmonics onto the generator current waveform. This can be a noise differentiator, albeit not of huge significance. However, of more potential significance, the addition of current harmonics increases the likelihood of exciting a natural frequency in the turbine structure which could introduce a modal noise in the running envelope of the turbine. This should be taken into account when considering a change of electronic architecture.

B18 Checklist to assess the impact of inverter change and/or modification

Step 1: Compare the purpose of the inverter used in the representative configuration for and for the proposed change or modification. If deviating from one generic load type considered in Annex A to another, further testing may be required at the discretion of the accredited certification body.

Step 2: Using Annex B, consider the necessary certifications required for an inverter be-fitting of use with load type described in Annex A. Ensure that the proposed inverter is type tested accordingly.

Step 3: Compare inverter electronic architecture (Figure 2) used in the "representative configuration" and the relative effect of the proposed change in Table 1. Where performance deviation is expected, consider the relevant measure further using paragraphs B5 to B10 and/or discuss further with the turbine manufacturer and inverter supplier to assess the significance of the deviation where not covered in paragraphs B5 to B10. Further test may be required if the potential deviation is considered significant.

Step 4: Consider the guidance in paragraphs B5 to B10 and measures in B10.2.1 to assess the effect on turbine energy yield of the inverter change or modification. Where relevant, encourage the system installer to follow the guidance relating to relevant settings that will limit the impact of change. Consider:

- Cut-in, Cut-out voltages and over voltage protection capabilities
- Inverter input current and corresponding rated speed
- Significance of inverter and generator efficiency
- Internal consumption at low load and the standby strategy deployed
- The rate of load acceptance and rejection
- Technique used to control power drawn from the turbine

Where doubt or ambiguity remains, the approval body can request practical evidence of a power curve to validate performance using the new configuration.

Step 5: Assess the direct interaction of the inverter with measurement sensors and control peripherals. Where the inverter receives instruction from an external controller or passes on instruction to an external controller or peripheral, ensure that the functionality has been tested and proved to be reliable and repeatable.

Step 6: Where proposing inverter replacement, evidence should be made available to confirm durable operation through one of the following:

- 1000hr Accelerated Life Test of the inverter in a representative test environment
- History of in-field inverter deployment

- 2,500hr system test, carried out by the turbine manufacturer

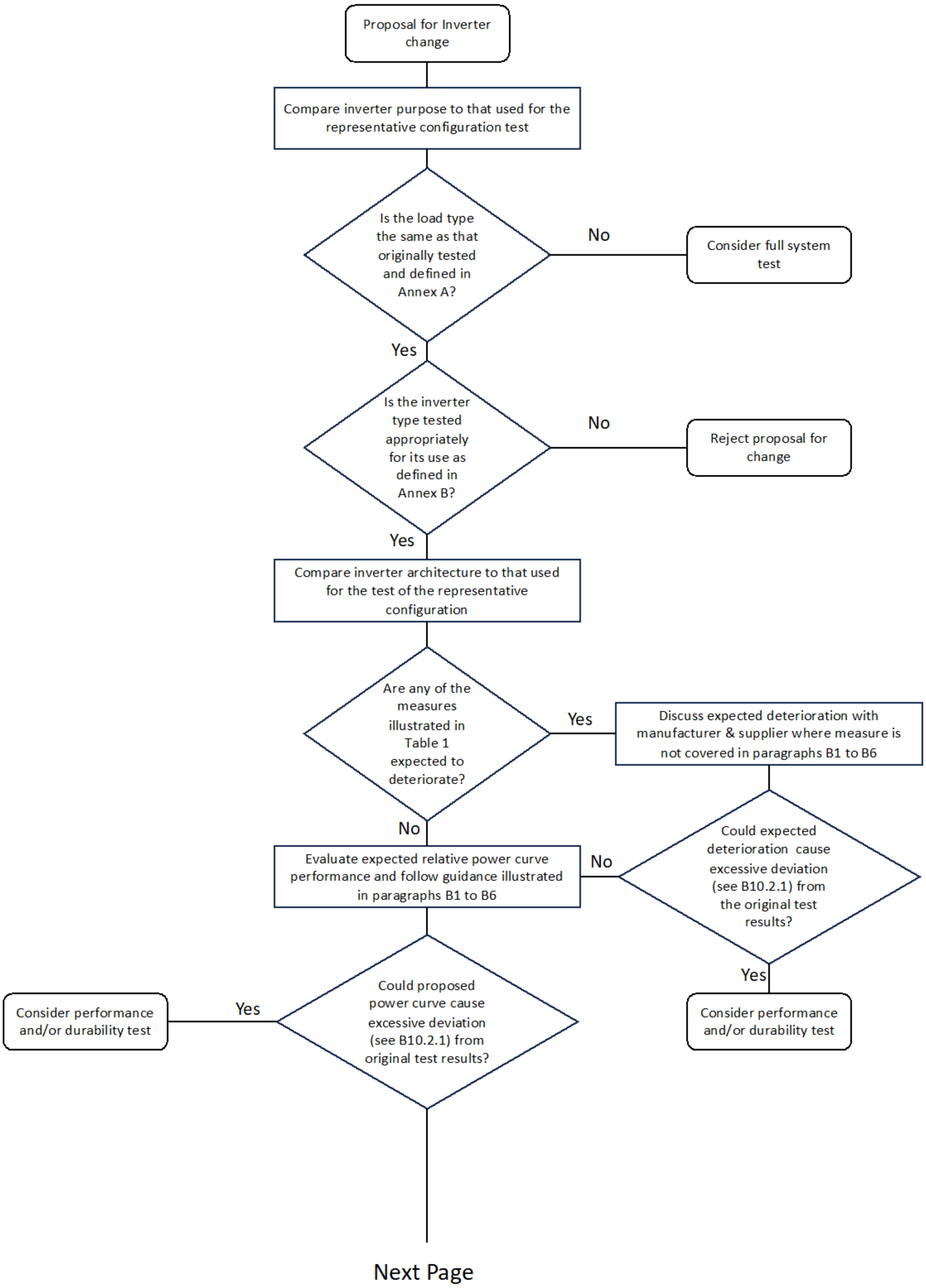
NOTE: Representative test environment considers turbine behaviour but does not explicitly have to be a turbine

Step 7: Where appropriate and relevant, consider the turbine starting and motoring requirement and impact on energy consumption & reliability as outlined in paragraph B13.

Step 8: Where multiple inverter output stages are to be used, ensure an appropriate means of isolation is considered, as outlined in paragraph B15.

Step 9: If considering approval of additional configurations to achieve differing grid (or other load) phase connection, follow the guidance outlined in paragraph B16.

B19 Inverter Modification Roadmap



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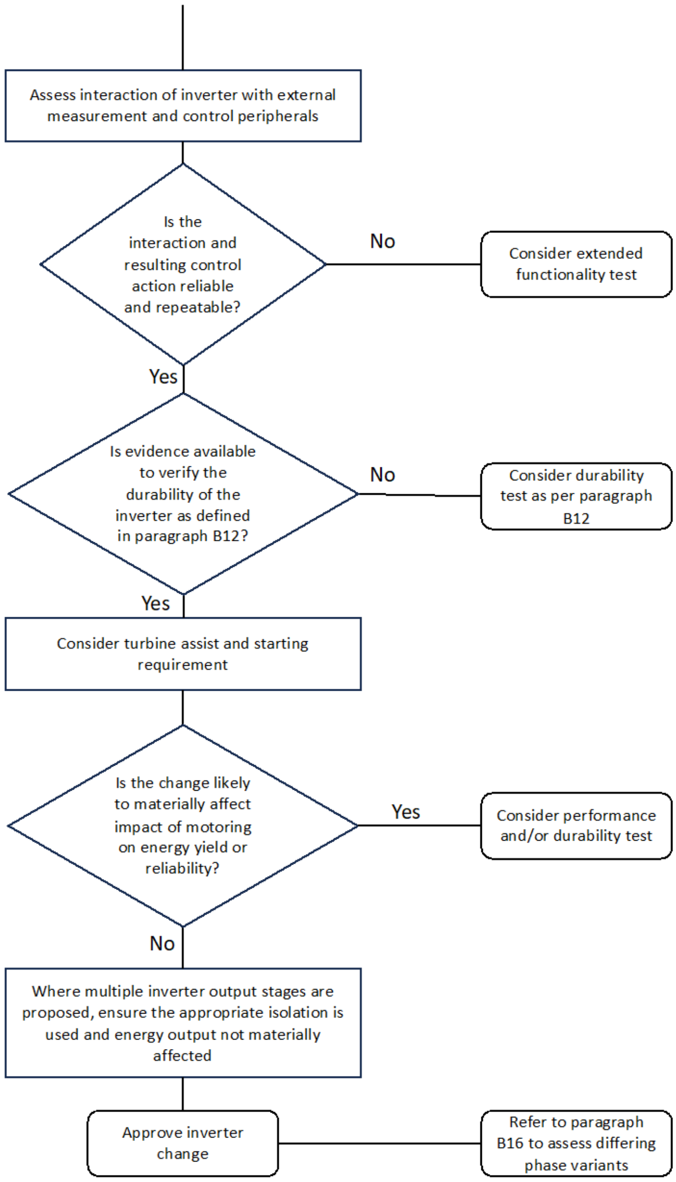

ANNEX A – LOAD TYPE DEFINITION

1. Grid Connected – as bound by EREC G98 and/or EREC G99 UK grid code requirements
2. Grid Connected with battery back-up
3. Off grid load
4. Off grid load including battery back-up
5. Hybrid on and off grid load
6. Hybrid on and off grid load including battery back-up

ANNEX B – INVERTER SAFETY AND GRID CODE STANDARDS

Grid connected inverters:

- BS-EN 50178:1998 Electronic equipment for use in power installations
- BS-EN 61000-6-1:2019 EMC: Generic standards – Immunity standard for residential, commercial and light industrial environments[1]
- BS-EN 61000-6-3:2021 EMC: Generic standards – Emission standard for residential, commercial and light industrial environments[1]
- Relevant Grid connection recommendation[2], for example in the UK:
  - o EREC G98 - Recommendations for the connection of small-scale embedded generators in parallel with public low voltage distribution networks, OR
  - o EREC G99 - Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators
- LVD 2014/35/EU Low Voltage Directive
- 2014/30/EU Electromagnetic Compatibility Directive
- 93/68/EEC CE Marking Directive
- 2011/65/EU the directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment
- 2012/19/EU, the directive on waste electrical and electronic equipment (WEEE)
- RohS compliance

NOTE 1: Alternatively, BS-EN 61000-6-2 and 6-4 may be considered where environment of use is deemed "industrial".

NOTE 2: Other European regions covered by EN50438 Requirements for the connection of micro generators in parallel with public low voltage distribution networks, including German requirement DIN VDE 0126-1-1 automatic disconnection device between a generator and the
public low voltage grid.