Guide to the Installation of PV Systems
3rd Edition

DRAFT FOR COMMENT

Editor's note: This version is an initial draft that has not undergone any work on layout or presentational style. We recognise that there are numerous example where style, font and layout vary within the text. This will be all be addressed at a later stage in the process. All diagrams and charts will also be addressed at this stage.

This guide is based upon the publication "Photovoltaics in Buildings, Guide to the installation of PV systems 2nd Edition" (DTI/Pub URN 06/1972).

Whilst this guide is based up the original content of the above publication, this guide has been written independently of any government departments.

Acknowledgments
To be added in

Preface to 1st edition 2011

This the first edition sees changes and additions to the original guide and on the following topics

- Notification to DNO's referencing changes to Engineering Recommendations G83/2 and G59/2
- Updates to BS7671
- Earthing & Bonding
- Application of RCD's
- Performance estimates
- Wind uplift calculations
-
- More to be added here once finished

Notes to Public consultation:

This document builds on standards development work being undertaken across many sectors that touch on the installation of PV systems (both internationally and in the UK). We have assembled this information into one concise document which we feel reflects best practice.

We also realise that there are many areas of the sector that need better explanation …whilst this document attempts to deal with the most pressing issues, we appreciate that there are still areas that require additional work

We would be pleased to have feedback from anyone on areas they feel that require further work

Contents

GUIDE TO THE INSTALLATION OF PV SYSTEMS

1 INTRODUCTION

1.1 Scope

The scope of this document is to provide solar PV system designers and installers with information to ensure that a grid-connected PV system meets current UK standards and best practice recommendations. It is primarily aimed at typical grid connected systems of up to 50kWp (total combined DC output). However most of what is contained here will also be applicable for larger systems. Systems that include a battery are addressed Annex A.

1.2 Standards and Regulations

The following documents are of particular relevance for the design and installation of a PV system:

- Engineering Recommendation G83/1 (2003) – Recommendations for the connection of small scale embedded generators (up to 16A per phase) in parallel with public low voltage distribution networks

  NOTE: the time of writing this guide, a new version of G83 (G83/2) is being prepared – this is expected to be released in the spring of 2012.

Editor's note: There are a few changes that will come in through G83/2 … we are currently in consultation with the ENA & DNO's to determine if we put the new requirements into this version of the guide.

- Engineering Recommendation G59/2 (2010) – Recommendations for the connection of generating plant to the distribution systems of licensed distribution network operators.

- BS7671 - Requirements for electrical installations (all parts – but in particular Part 7-712 Requirements for special installations or locations – Solar photovoltaic (PV) power supply systems)

- BS EN 62446 (2009) - Grid connected photovoltaic systems - Minimum requirements for system documentation, commissioning tests and inspection

1.3 Safety

From the outset, the designer and installer of a PV system must consider the potential hazards carefully, and systematically devise methods to minimise the risks. This will include both mitigating potential hazards present during and after the installation phase.

The long-term safety of the system can be achieved only by ensuring that the system and components are correctly designed and specified from the outset, followed by correct installation, operation and maintenance of the system. Consideration of operation under both normal and fault conditions is essential in the design stage to ensure the required level of safety. This aspect is covered in the DESIGN section of this guide.

It is then important to ensure that the long-term safety of the system is not compromised by a poor installation or subsequent poor maintenance. Much of this comes down to the quality of the installation and system inspection and testing regime. This is covered in the INSTALLATION section of this guide.

Similarly, much can be done during the planning and design stage to ensure that the installation is safe for the installers. In some circumstances the application of the CDM regulations will be required. All key safety issues affecting the design and installation process are discussed in the guide. The main safety issues are:

- The supply from PV modules cannot be switched off, so special precautions should be made to ensure that live parts are either not accessible or cannot be touched during installation, use and maintenance.
- PV modules are current-limiting devices, which require a non-standard approach when designing fault protection systems, as fuses are not likely to operate under short-circuit conditions.
- PV systems include d.c. wiring, with which few electrical installers are familiar.
- The installation of PV systems presents a unique combination of hazards – due to risk of electric shock, falling and simultaneous manual handling difficulty. All of these hazards are encountered as a matter of course on a building site, but rarely all at once. While roofers may be accustomed to minimising risks of falling or injury due to manual handling problems, they may not be used to dealing with the risk of electric shock. Similarly, electricians would be familiar with electric shock hazards but not with handling large objects at heights.

1.4 Parallel Generation

A mains-connected PV installation generates electricity synchronised with the electricity supply. Installers are obliged to liaise with the relevant Distribution Network Operator (DNO) in the following manner:

Single installation covered by G83/1

- Notification at or before day of commissioning followed by G83/1 paperwork (G83/1 commissioning form) within 30 days.

Multiple installations covered by G83/1 or installations in close geographical proximity to one another

- Application to proceed (G83/1 multiple system application form)

- On commissioning – notification and commissioning form as per single installation

Larger installations under G59/2

- Written approval from DNO to be gained prior to works
- Commissioning process as required by DNO

As stated above, consideration needs to be given to the number of SSEG's in a close geographical area, it is important to note that there may be two or more different types of SSEG in a single installation or close geographical proximity, for example a photovoltaic system that is intended to be installed at a location where there is already a combined heat and power system, if this is the case then the DNO should be consulted and the procedure for connecting multiple installations under G83/1 may need to be applied.

1.5 Note on Layout

This guide is split into two main parts, the first detailing issues that need to be addressed during the design phase of a project, and the second covering installation and site based work. It is important to note, however, that many 'design' issues covered in the first section may have a significant impact on the practical installation process covered in the second.

Throughout the guide the following format has been adopted to show the levels of authority for each guideline:

Bold text in blue against a shaded box with two ticks indicates mandatory and/or broadly recognised requirements ('must').
Text in blue with one tick indicates recommended practice ('should').
Text marked in green indicates specific requirements to comply with MCS scheme requirements
Text marked as notes and in italics indicates explanatory material.

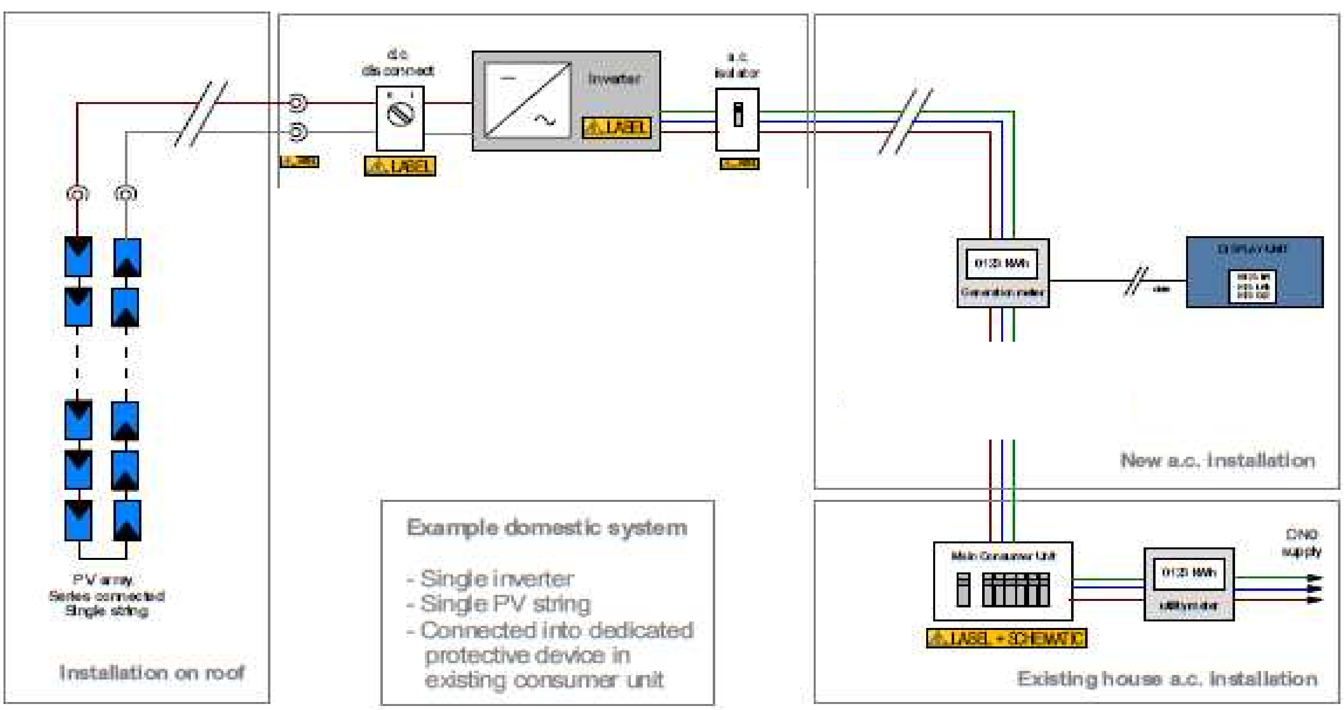
Editors Note – Use of coloured text and italics to be reviewed at layout/design stage. Italic use in particular to be reviewed as there is inconsistency within current text.

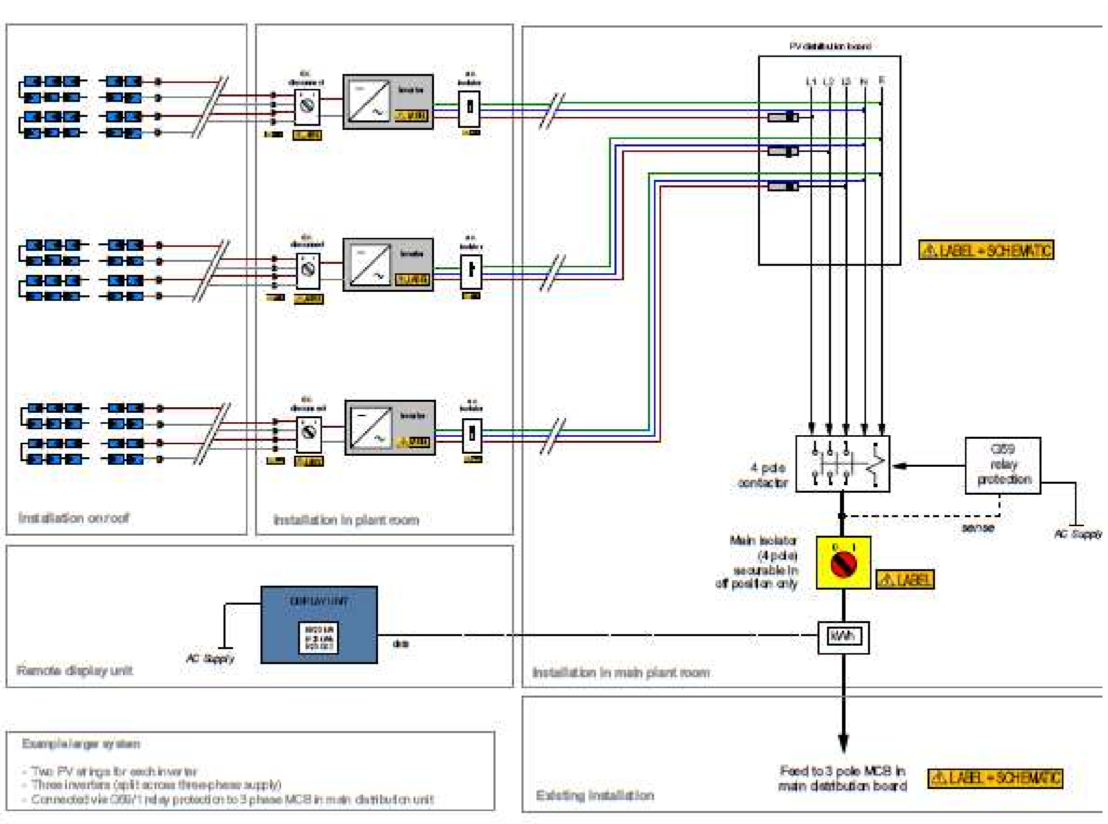
1.6 Ready Reference to the Guide

Example schematics for the two main types of system are shown below to help when reading this Guide. They should not be used for a particular installation without taking into account the special circumstances of each individual installation.

Editors Note – All diagrams to be re-created in final version. Diagrams from old guide pasted here to aid reading

Two circuit diagrams – to be edited to suit updated guidance





These drawings to be replicated in the appendix to show 6-8 typical arrangements for users to photocopy and fill in gaps as a schematic

1.7 Definitions

Editors Note – Definitions to be reviewed on completion of first draft

a.c. side
part of a PV installation from the a.c. terminals of the PV inverter to the point of connection of the PV supply cable to the electrical installation

d.c. side
part of a PV installation from a PV cell to the d.c. terminals of the PV inverter

Distribution Network Operator (DNO)
The organisation that owns or operates a Distribution Network and is responsible for confirming requirements for the connection of generating units to that Network.

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

Equipotential Zone
where exposed-conductive parts and extraneous-conductive parts are maintained at substantially the same voltage

$I_{sc(stc)}$, Short-circuit current
short-circuit current of a PV module, PV string, PV array or PV generator under standard test conditions

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

Isolating Transformer
Transformer where the input & output windings are electrically separated by double or reinforced insulation

Isolation
A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy.

Isolator
A mechanical switching device which, in the open position, complies with the requirements specified for the isolating function. An isolator is otherwise known as a disconnector.

PME – Protective Multiple Earthing
where the supply neutral and earth are combined into a single conductor – otherwise known as TN-C-S

PV a.c. module
Integrated module/inverter assembly where the electrical interface terminals are a.c. only. No access is provided to the d.c. side

PV array cable
cable that carries the combined output of a PV array

PV array junction box
enclosure where all PV strings of any PV array are electrically connected and where protection devices can be located if necessary

PV String
One or more PV modules connected in series

PV array
one or more PV strings, and other necessary components, connected to a form the PV installation

PV cell
basic PV device which can generate electricity when exposed to light such as solar radiation

PV module
A combination of a number of PV cells in parallel and / or series to create the required voltage and current for the module

PV Charge Controller
A device that provides the interface between the PV array and a battery

PV d.c. main cable
cable connecting the PV array junction box to the d.c. input of the inverter

PV grid-connected system
a PV generator operating in 'parallel' with the existing electricity network

PV installation
erected equipment of a PV power supply system

PV inverter / Convertor
device which converts d.c. voltage and d.c. current into a.c. voltage and a.c. current

PV Kilowatts peak (kWp)
unit for defining the rating of a PV module where kWp = watts generated at stc

PV module maximum series fuse
the maximum series fuse is a value provided by the module manufacturer on the module nameplate & datasheet (a requirement of IEC61730-2)

PV module
smallest completely environmentally protected assembly of interconnected PV cells

PV MPP Tracker
Maximum Power Point Tracker – a component of the d.c. input side of an inverter designed to maximise the input from the array by tracking voltage and current

PV self-cleaning
The cleaning effect from rain, hail etc on PV arrays which are sufficiently steeply inclined

PV Standard test conditions (stc)
test conditions specified for PV cells and modules (25°C, light intensity 1000W/m2, air mass 1.5)

PV string cable
cable connecting PV modules to form a PV string

PV string fuse
a fuse for an individual PV string

PV supply cable
cable connecting the a.c. terminals of the PV inverter to a distribution circuit of the electrical installation

Simple separation
separation provided between circuits or between a circuit and earth by means of basic insulation terminals of the PV inverter

$V_{oc(stc)}$, Open-circuit voltage
voltage under standard test conditions across an unloaded (open) PV module, PV string, PV array, PV generator, or on the d.c. side of the PV inverter

2 DESIGN

2.1 Design Part 1 – d.c. System

2.1.1 PV Modules

2.1.1.1 Standard Modules

Modules must comply with the following international standards:

- **IEC 61215 in the case of crystalline types**
- **IEC 61646 in the case of thin film types**
- **IEC 61730 - Photovoltaic (PV) module safety qualification**
- **Modules must also carry a CE mark**

The use of Class II modules is generally recommended, and strongly recommended for array open-circuit voltages of greater than 120 V.

For an installation to comply with the requirements of MCS - modules must be certificated and listed on the MCS product database

2.1.1.2 Building integrated products/modules

PV products shall be designed and constructed to meet the requirements within the relevant Building Regulations for the particular application that the PV product is intended. The PV installer must be able to demonstrate such compliance for all relevant projects. MCS012 or MCS017 (as relevant) may assist in demonstrating such compliance.

PV systems mounted above or integrated into a pitched roof should utilise products that have been tested and approved to MCS012 (test procedures used to demonstrate the performance of solar systems under the action of wind loads, fire, rainfall and wind driven rain).

PV systems utilising bespoke building integrated PV modules should utilise products that have been tested and approved to MCS017 Product Certification Scheme Requirements: Bespoke Building Integrated Photovoltaic Products

The use of products listed to MCS012 or MCS017 is still recommended, even if MCS compliance is not required

2.1.2 d.c. System – minimum voltage and current ratings

All d.c. component ratings (cables, isolators/disconnectors, switches, connectors, etc) of the system must be derived from the maximum voltage and current of the relevant part of the PV array adjusted in accordance with the safety factors as below. This must take into account system voltage/currents of the series/parallel connected modules making up the array. It must also take into account the maximum output of the individual modules:

Mono- and multi-crystalline silicon modules:
All d.c. components must be rated, as a minimum, at:
Voltage: $V_{oc(stc)}$ x 1.15
Current: $I_{sc(stc)}$ x 1.25

Note: When considering the voltage and current requirements of the d.c. system, the maximum values that could occur need to be assessed. The maximum values originate from two PV module ratings – the open-circuit voltage (Voc) and the short-circuit current (Isc) which are obtained from the module manufacturer. The values of Voc and Isc provided by the module manufacturer are those at standard test conditions (stc) – irradiance of 1000 W/m^2, air mass 1.5 and cell temperature of 25°C. Operation of a module outside of standard test conditions can considerably affect the values of Voc(stc), Isc(stc).

In the field, irradiance and particularly temperature can vary considerably from stc values. The above multiplication factors allow for the maximum values that may be experienced under UK conditions.

All other module types
All d.c. components must be rated, as a minimum, from:

a) **Specific calculations of worst case Voc and Isc, calculated from manufacturer's data for a temperature range of -15°C to 80°C and irradiance up to 1250 W/m^2**
b) **A calculation of any increase in Voc or Isc over the initial period of operation. This increase is to be applied in addition to that calculated above.**

Note: Some types of PV modules have temperature coefficients considerably different to those of standard mono- and multi-crystalline modules. The effects of increased irradiance may also be more pronounced. In such cases the multiplication factors used for crystalline silicon modules may not cover the possible increase in voltage/current.

In addition, some thin film modules have an electrical output that is considerably higher during the first weeks of exposure to sunlight. This increase is on top of that produced by temperature/irradiance variation. Typically, operation during this period will take Voc, Isc (and nominal *power output) well above any value calculated using a standard multiplication factor. To avoid oversizing the inverter for this eventuality the array could be left disconnected for that initial period.*

Refer to the manufacturer for this information.

2.1.3 PV String & Array voltages

It is always desirable to keep voltages low to minimise associated risks, however in many systems, the d.c. voltage will exceed levels that are considered to reduce the risk to a minimum (120v d.c.)

Where this is the case, double insulation is usually applied as the method of shock protection. In this instance the use of suitably rated cables, connectors and enclosures along with controlled installation techniques becomes fundamentally important to providing this protective measure as defined in B7671. Similarly, double insulation of the d.c. circuit greatly minimises the risk of creating accidental shock current paths and the risk of fire.

Where the PV array voltage exceeds 120V:
Double insulation (insulation comprising both basic & supplementary insulation) or reinforced insulation, appropriate barriers and separation of parts must be applied to all parts of the DC circuit to facilitate a level of protection equivalent to the protective measure "double or reinforced insulation" as defined in BS7671.

Where the PV array open circuit voltage exceeds 1000V:
The PV array should not be installed on a building and have access restricted to only competent or instructed persons.

2.1.4 d.c. Cables – General

2.1.4.1 Cable sizing

Cables must be rated, as a minimum, to the voltage and current ratings derived using the multiplication factors in 2.1.2.

Standard de-rating factors must also be applied in accordance with BS 7671.

Cables should be sized such that overall voltage drop at stc between the array and the inverter is <3%.

2.1.4.2 Cable type and installation method

The cables used for wiring the d.c. section of a grid-connected PV system need to be selected to ensure that they can withstand the environmental, voltage and current conditions at which they may be expected to operate. This will include heating effects of both the current and solar gain, especially where installed in close proximity to the modules.

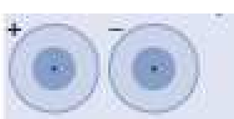
Purpose designed "PV cables" are readily available and it is expected that all installations would use such cables. An IEC PV cable standard is under development and it is expected cables in compliance with this standard will be required once it is issued. In the interim, it is recommended that cables should comply with UL 4703, or TUV 2 Pfg 1169 08.2007.

Cables routed behind a PV array must be rated for a temperature range of at least of -15°C to 80°C.

Cables must be selected and installed so as to minimise the risk of earth faults and short-circuits.

This can be achieved by reinforcing the protection of the wiring either through:

a) Single conductor "double insulated" cable



b) Single conductor cable suitably mechanically protected conduit/trunking. Alternatively an SWA cable may be a suitable mechanically robust solution.

c) **Multi core Steel Wire Armoured SWA (typically only suitable for main d.c. cable between a combiner box and inverter position due to termination difficulties between SWA and the plug and socket arrangements pre-fitted to modules.**

External cables should be UV stable, water resistant, and it is recommended that they be flexible (multi-stranded) to allow for thermal/wind movement of arrays/modules.

Because PV array cables almost exclusively rely on double or reinforced insulation as their means of shock protection they should not be buried in walls or otherwise hidden in the building structure as mechanical damage would be very difficult to detect and may lead to increase instances of shock and fire risk.

Where this cannot be avoided conductors should be suitably protected from mechanical damage, suitable methods may include the use of metallic trunking or conduit or the use of steel wire armoured cable.

Exterior cable colour coding is not required for PV systems. Consideration must be given to the UV resistance of all cables installed outside or in a location that may be subject to UV exposure, PV cables are therefore commonly black in colour to assist in UV resistance.

Where long cable runs are required (eg over 20m), it is good practice to label along the d.c. cables as follows:

“Danger solar PV array cable – high voltage d.c. - live during daylight”.

Labels fixed every 5 to 10m is considered sufficient on straight runs where a clear view is possible between labels.

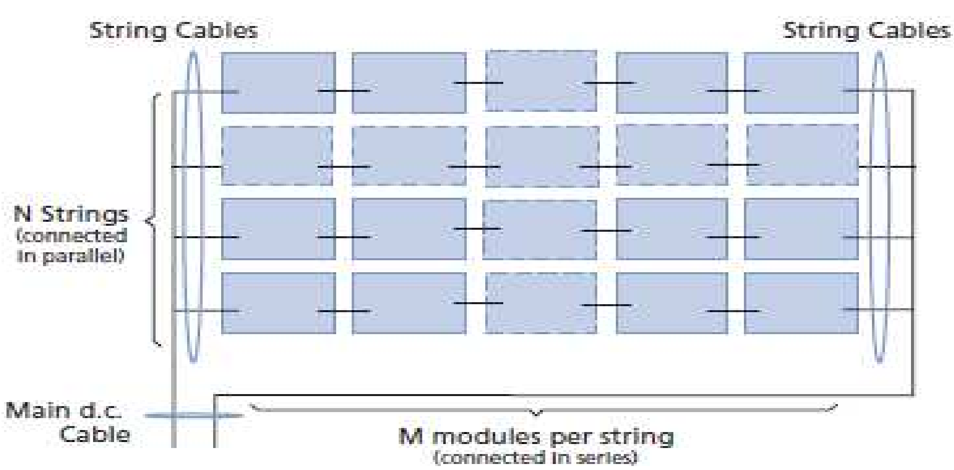
To minimise the risk of faults, PV d.c. cable runs should be kept as short as practicable.
Note: *See also section 2.1.12 (additional d.c. switches for long cable runs)*

Where multiple PV sub-arrays and or string conductors enter a junction box they should be grouped or identified in pairs so that positive and negative conductors of the same circuit may easily be clearly distinguished from other pairs.

2.1.5 String Cables

A string is a circuit in which PV modules are connected in series, in order for a PV array to generate the required output voltage.

In a PV array formed from a number of strings, fault conditions can give rise to fault currents flowing though parts of the d.c. system. Two key problems need addressing – overloaded string cables and excessive module reverse currents, both of which can present a considerable fire risk. For small system where it is determined that string fuses are not required for module protection (reverse currents less than module reverse current rating), a common approach is to ensure that the string cables are suitably rated such that they may safely carry the maximum possible fault current. This method relies on oversizing the string cables such that any fault current can be safely accommodated. Such a method does not clear the fault but simply prevents a fire risk from overloaded cables. See also section 2.1.11 - string fuses.



For a system of N parallel connected strings, with each formed of M series connected modules:

String cables must be rated as a minimum as follows:

- **Voltage > $V_{oc(stc)}$ x M x 1.15**
  Current > $I_{sc(stc)}$ x (N-1) x 1.25

- **The cable Current Carrying Capacity (CCC) must be calculated according to the requirements of BS7671 to include cable de-rating factors, taking into account factors such as cable installation method, solar gains and grouping**

Where a system includes string fuses, the cable size may be reduced, but in all cases the CCC after de-rating factors have been applied must exceed the string fuse rating and must exceed: $I_{sc(stc)}$ x 1.25

2.1.6 Main d.c. Cable

For a system of N parallel connected strings, with each formed of M series connected modules:

DC main cables must be rated as a minimum as follows:

- **Voltage: $V_{oc(stc)}$ x M x 1.15**
- **Current: $I_{sc(stc)}$ x N x 1.25**
- **The cable Current Carrying Capacity (CCC) must be calculated according to the requirements of BS7671 to include cable de-rating factors to take into account factors such as cable installation method and grouping**

2.1.7 d.c. Plug and Socket Connectors

PV specific plug and socket connectors are commonly fitted to module cables by the manufacturer. Such connectors provide a secure, durable and effective electrical contact. They also simplify and increase the safety of installation works.

Plugs and socket connectors mated together in a PV system shall be of the same type from the same manufacturer and shall comply with the requirements of BS EN 50521. Different brands may only be interconnected where a test report has been provided confirming compatibility of the two types to the requirements of BS EN 50521.

Connectors used in a PV string circuit must comply with the minimum voltage and current ratings as detailed in string cable section above (section 2.1.5)

Connectors used in a dc main cable circuit must comply with the minimum voltage and current ratings as detailed in the main dc cable section above (section 2.1.6)

Connectors should have a UV, IP and temperature rating suitable for their intended location and should be compatible with the cable they are fixed to.

Connectors readily accessible to ordinary persons shall be of the locking type requiring a tool or two separate actions to separate and shall have sign attached that reads: 'Do not disconnect d.c. plugs and sockets under load'

Cable connectors must not be used as the means for d.c. switching or isolation under load (see 2.1.12) as d.c. arcs can cause permanent damage to some connectors.

Note: Plugs used in this application can be damaged by arc currents if disconnected under load. While connectors are sometimes suggested as an alternative to a means of isolation, such use is not permitted by this guide.

Plug and socket "Y" connectors can also be used to replace a junction box. It is good practice to keep "Y" connectors in accessible locations and where possible note their location on layout drawings, to ease troubleshooting in future.

2.1.8 Other inline cable junctions

In general cable junctions shall either be by an approved plug and socket connector or contained within a d.c. Junction Box (see below). However in certain limited circumstances it may be necessary for an in-line cable junction to be made (eg soldered extension to a module flying lead) although this should be avoided if at all possible.

Note: Great care needs to be applied in the design and installation of in-line junctions. Where unavoidable, such junctions need to maintain the 'double or reinforced insulated' nature of the cables as described in section 2.1.4 (eg by the use of two layers of appropriately rated adhesive lined heat shrink sleeving), and be provided with appropriate strain relief. Such junctions would typically be completed off-site, prior to works, using fittings and tools appropriate to the cable to be jointed.

2.1.9 d.c. Junction Box

If there is more than one string, the d.c. junction box (sometimes called a combiner box) is normally the point at which they are connected together in parallel. The box may also contain string fuses and test points.

The d.c. junction box must be labelled as 'PV array d.c. junction box', and also labelled with 'Danger, contains live parts during daylight'. All labels must be clear, legible, located so as to be easily visible, and durably constructed and affixed to last the lastime of the installation.

Note: A PV system cannot be turned off – terminals will remain live at all times during daylight hours. It is important to ensure that anyone opening an enclosure is fully aware of this.

The short-circuit protection afforded by the cable installation throughout the rest of the d.c. circuit needs to be maintained in the construction and makeup of the d.c. junction box. (See IEC 60536 and IEC 61140).

It is recommended that short-circuit protection shall be achieved by:
- Fabrication of the enclosure from non-conductive material
- Positive and negative busbars and terminals adequately separated and segregated within the enclosure and/or by a suitably sized insulating plate, or separate positive and negative junction boxes.
- Cable and terminal layout such that short-circuits during installation and subsequent maintenance are extremely unlikely.

2.1.10 String Fuses

The following requirements apply where the PV array provides the only source of fault current, such as in a typical grid connected system with no battery. For a system with a battery or other source of fault current see also Section 2.5.

For a system of N parallel connected strings, with each formed of M series connected modules:

- **String fuses must be provided for all arrays where: (N – 1) × Isc > module maximum series fuse rating**
- **Where fitted, fuses must be installed in both positive and negative string cables for all strings.**
- **The string fuse must be of a type gPV - according to IEC60269-6**
- **The string fuse must be rated for operation at $V_{oc(stc)}$ x M x 1.15**
- **The string fuse must be selected with an operating current I_n such that:**
    - **I_n > 1.5 x Isc stc**
    - **$I_n \leq$ 2.4 x Isc stc**
    - **$I_n \leq$ Maximum series fuse value**

The use of fuses or MCBs (miniature circuit breakers) is permissible provided they meet the above criteria and are rated for use in an inductive circuit and will operate for currents flowing in either direction through the device.

A system fitted with suitable removable string fuses provides a means to achieve the requirements for string isolation (section 2.1.10)

The short circuit current of a module is little more than the operating current, so in a single string system, a circuit fuse would simply not detect or operate to clear a short circuit fault. However, in systems with multiple strings some fault scenarios can result in the current from several adjacent strings flowing through a single string and, the prospective fault current may be such that overcurrent protective devices are required. Hence, the selection of overcurrent protective measures depends upon the system design and the number of strings.

While string cable sizes can be increased as the number of parallel connected strings (and the potential fault current) increases, the ability of a module to withstand the reverse current must also be considered. Where currents exceed the modules maximum reverse current rating, there is the potential for damage to the affected modules and also a fire risk. IEC61730-2 Photovoltaic (PV) module safety qualification – Part 2: Requirements for testing [5], includes a reverse current overload test. This reverse current test is part of the process that enables the manufacturer to provide the maximum overcurrent protection rating or maximum series fuse. Fault currents above the maximum series fuse rating present a safety risk and must be addressed within the system design.

The maximum module reverse current to be experienced under fault conditions is: $I_R = (N - 1) \times Isc$. Hence, overcurrent protection is required where (N – 1) × Isc is greater than the module maximum series fuse rating. While some fault combinations are less likely than others, in order to provide full protection of all cables and modules – string fuses are required in both the positive and negative legs of the string cabling.

Note: For small system where it is determined that fault currents do not present a risk to the modules, only the string cables & connectors need to be considered. A common approach in this case relies on oversizing string cables & connectors - such that they may safely carry the maximum possible fault current. Such a method does not clear the fault but simply prevents a fire risk from overloaded cables. See also section 2.1.5 - string cables

2.1.11 Blocking Diodes

Blocking diodes are not commonly used in a grid-connect system as their function is better served by the installation of a string fuse. However, for multi-string arrays with some types of PV module, particularly thin-film types, it may not be possible to provide adequate overcurrent / reverse current protection with string fuses or MCBs alone, since it may not be possible to specify a fuse/MCB which is greater than Isc x 1.25 but less than the reverse current rating of the module. In this situation blocking diodes should be used in addition to string fuses.

It is to be noted that:

- *The installation of a blocking diode results in a small voltage drop across the diode*
- *Blocking diodes may fail as a short-circuit and therefore require regular testing.*

In most cases Specification of string fuses can provide sufficient reverse current protection without the problems and power losses associated with a blocking diode. If blocking diodes are used, they should be supplemented by string fuses.

If specified, a blocking diode must have:

- **A reverse voltage rating > 2 x maximum system voltage (as calculated in section 2.1.2)**
- **A current rating > 1.4 x Isc (where Isc is the relevant short circuit current for the string / sub array / array)**
- **Have adequate cooling (heatsinks) if required**

Note that blocking diodes should not be confused with bypass diodes. Bypass diodes are normally encapsulated into the module junction box at the back of the PV module. Bypass diodes allow any reverse current to bypass the actual PV cells.

2.1.12 String isolation

A readily accessible means of isolation shall be provided to isolate individual strings. Isolation shall be provided in both positive and negative string cables.

String isolation can be achieved by any suitable means such as appropriately located plug and socket connectors or removable string fuses.

String isolation measures are intended for use only once the system has been switched off elsewhere – they are not designed for and should not be used as load break disconnection devices.

2.1.13 d.c. isolation and switching

To allow for maintenance and inspection tasks to be carried out safely, a means of isolation needs to be provided on the dc side of an inverter. The means of isolation shall:

- **Isolate all live conductors (PV array positive and negative)**
- **Be readily accessible and immediately adjacent to or <u>incorporated into the inverter</u>**

Note: For many smaller systems, inverter isolation and string isolation (see section 2.1.12) may be provided by the same devices (eg plug and socket connectors). As noted in section 2.1.7, plug and socket connectors must be labelled "Do not disconnect d.c. plugs and sockets under load".

A switch disconnector shall be provided on the dc side of the inverter.

- **The switch must isolate all live conductors (typically double pole to isolate PV array positive and negative conductors)**
- **The switch must be rated for dc operation at the system <u>voltage</u> maxima as calculated in section 2.1.2.**
- **The switch must be rated for dc operation at the system <u>current</u> maxima as calculated in section 2.1.2.**
- **The switch must be labelled as 'PV array d.c. isolator', with the ON and OFF positions clearly marked. Switch enclosures must also be labelled with 'Danger - contains live parts during daylight'. All labels must be clear, easily visible, constructed and affixed to last and remain legible for as long as the enclosure.**
- **The switch should be located adjacent to, or integrated into the inverter.**

A circuit breaker may be used as the d.c. switching device provided it meets all the above requirements.

Note: Switching a.c. is less demanding than switching d.c. (with an a.c. supply, the voltage passes through 0 V many times a second). A switch must be rated to break dc, an ac rated switch is not acceptable or safe.

An additional d.c. switch may be specified for systems with long d.c. cable runs (typically at the point of cable entry into the building) – so as to provide a means of isolating the cable for safety reasons or maintenance works.

Editors note – as requested, I have added a section for micro-inverters … this is very much a first draft and open for comment …

Systems using micro-inverters may omit the d.c. switch disconnector where all of the following requirements are met:

- **The micro inverter is located immediately to the rear of the PV modules**
- **The micro inverter is plugged directly into the flying leads provided by the module manufacturer (no extensions to the flying leads may be used)**
- **The micro inverter and dc cables are generally inaccessible or only accessible to trained or authorised personnel**
- **The d.c. conductors between the module and micro inverter are adequately protected against mechanical damage**

NOTE: A roof mounted PV installation where the micro-inverters are located on the rear of the PV modules and where access is only possible by first removing some of the PV modules is a typical scenario where switch disconnectors can be omitted. Where the same inverters are brought into a loft void, it is expected that a switch disconnector would be required.

2.2 Design Part 2 – Earthing, Protective equipotential Bonding and Lightning Protection

Editors note – need to align style of this section with rest of document and also need to identify thel single/double tick requirements

Earthing, bonding and lightning protection of PV systems has been a widely discussed subject. In order to fully apply any measures required it is important that the terminology used is clearly defined;

Lightning protection – A means of applying protective measures to afford protection to persons, property and livestock against the effects of a lightning strike.

Earthing - Connection of the exposed-conductive-parts of an installation to the main earthing terminal of that installation.

Protective Equipotential Bonding - (also referred to as Equipotential bonding) - Electrical connection maintaining various exposed-conductive-parts and extraneous-conductive-parts at substantially the same potential.

Exposed-conductive-part - Conductive part of equipment which can be touched and which is not normally live, but which can become live when basic insulation fails.

Extraneous-conductive-part - A conductive part liable to introduce a potential, generally Earth potential, and not forming part of the electrical installation.

Lightning Protection

Whilst this installation guide does not cover specific guidance on selection, or application of lightning protection, it was felt that a brief overview was required as given below, where further information is required this can be referenced from BS EN 62305.

In most cases the ceraunic value (number of thunderstorm days per year for a given installation location in the UK) does not reach a level at which particular protective measures need to be applied. However where buildings or structures are considered to be at greater risk, for example very tall, or in an exposed location, the designer of the AC electrical system may have chosen to design or apply protective measures such as installation of conductive Air rods or tapes.

Where this is the case the designer of the PV array must consider the measures that are in place, or if applicable consider where they have altered the conditions originally considered by the installation of a conductive frame and apply any additional measures required.

If the building or dwelling is fitted with a lightning protection system (LPS), a suitably qualified person should be consulted as to whether, in this particular case, the array frame should be connected to the LPS, and if so what size conductor should be used.

Where an LPS is fitted, PV system components should be mounted away from lightning rods and associated conductors (see BS 6651). For example, an inverter should not be mounted on an inside wall that has a down lead running just the other side of the brickwork on the outside of the building.

Where there is a perceived increase in risk of **direct strike** as a consequence of the installation of the PV system, specialists in lightning protection should be consulted with a view to installing a separate lightning protection system in accordance with BS 6651.

Note: It is generally accepted that the installation of a typical roof-mounted PV system presents a very small increased risk of a direct lightning strike. However, this may not necessarily be the case where the PV system is particularly large, where the PV system is installed on the top of a tall building, where the PV system becomes the tallest structure in the vicinity, or where the PV system is installed in an open area such as a field.

Earthing

Earthing is a means of connecting the exposed conductive parts to the main earthing terminal, typically this definition means the connection of metallic casings of fixtures and fittings to the main earthing terminal using a cpc.

Importantly it must be noted that we only make this connection when the accessory or appliance requires it. This connection is required when it is considered to be a class I appliance or accessory and is reliant on a connection with earth for safety using automatic disconnection of supply as the protective measure (ADS).

As the d.c side of PV systems is a current limiting generating set, the protective measure ADS is almost never used and is outside of the scope of this guidance, virtually all systems in the UK rely on double or reinforced insulation as the protective measure.

In these circumstances where the d.c. side of the installation is constructed to meet the requirements of an installation using double or reinforced insulation, no connection to earth between the PV Modules or frame and main earthing terminal would be required.

Earthing of the inverter at the AC terminations will be necessary where the inverter is a Class I appliance and must be applied where necessary. Where class I inverters are used externally particular considerations may apply to the requirements to earth or bond them.

Protective equipotential bonding

Protective equipotential bonding is a measure applied to parts of the electrical installation which, under fault conditions may otherwise have a different potential to earth. By applying this measure you are limiting the risk of electric shock as there should be little or no difference in voltages (potential difference) between these parts that may otherwise become live. These parts are categorised as either Exposed-conductive-parts or extraneous-conductive-parts

In order to apply this measure correctly it must be ascertained which of the given parts of the system may require protective equipotential bonding, and the conditions under which they may require “bonding”.

Exposed-conductive-part - an exposed conductive part usually only has one layer of insulation called “basic” insulation between live and metallic or conductive parts of the accessory or appliance, in the case of a PV system (d.c. side) we have usually attained a level of protection through application of both basic and supplementary insulation or one reinforced layer of insulation that is equivalent to basic and supplementary insulation.

Editors Note – May need to these definitions to definitions section of guide?

In most PV systems there are no parts that are considered to be an exposed-conductive-part, therefore Protective equipotential bonding is not usually required.

Extraneous-conductive-part - A conductive part liable to introduce a potential, generally Earth potential, and not forming part of the electrical installation.

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On the d.c. side of the PV installation the designer will have usually already selected double or reinforced insulation as the protective measure and therefore the component parts of the installation will be isolated from earth, the frame of the array has to be assessed as to whether it is likely to introduce a potential into the installation. This aim of this assessment is to find out if the frame has any direct contact with ground that would make it introduce a potential.

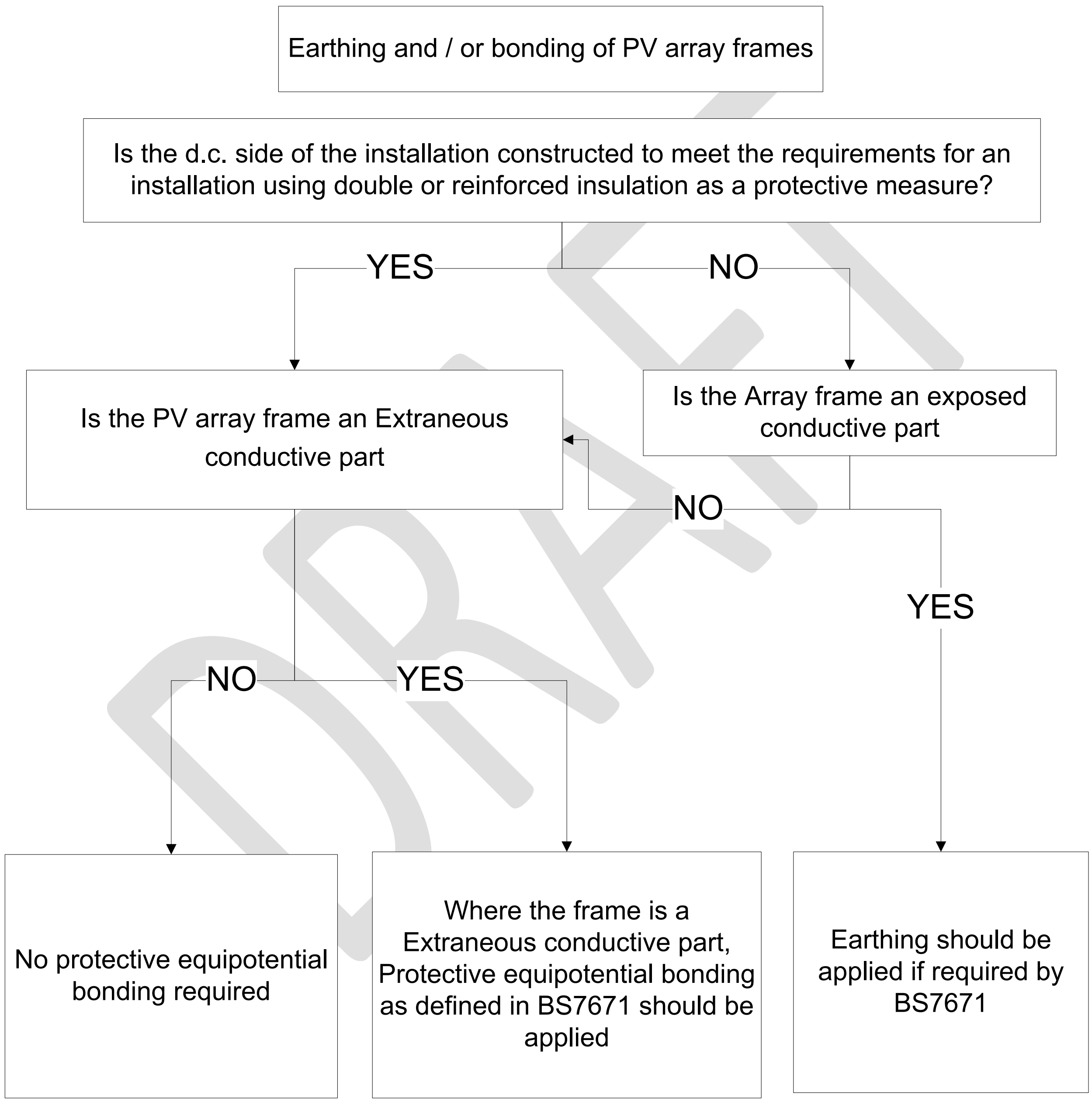
The details on carrying out these tests are best given in the IET’s BS7671 guidance note 8 (earthing and Bonding) and this should be referred to before undertaking a test, however the principle behind the test is to ascertain whether or not there is a low enough conductivity between the part under test and the Main earthing terminal (MET) to say that it could introduce an earth potential.

To find this out a resistance test should be carried out between the part in question (the array frame) and the (MET) of the building and value recorded, if the value is greater than 22kΩ then, in most cases the part will exceed this measurement and can consider the part to be isolated from earth and NOT an extraneous conductive part. If however the reading is less than 22kΩ then the part is considered to be extraneous and protective equipotential bonding as required by BS7671 should be applied.

Careful consideration needs to be given to systems that are ground mounted as they may initially present to be an extraneous-conductive-part, however as they are usually a good distance away from the earthed equipotential zone, by bonding them you may well be introducing a shock risk that wasn't there initially, and in the case of an installation supplied by a TN-C-S (PME) supply you may be contravening the supply authorities regulations (ESCQR 2002). In most cases these installations wouldn't require bonding however the designer must make an informed decision based on the electrical design of the entire installation, not just the PV system in isolation.

Where the array frame is mounted on a domestic roof or similar the likelihood of the frame being an extraneous-conductive-part is very low due to the type and amount of material used between the ground and the roof structure, which will mainly be non-conductive. Even in the case of an array frame being mounted on a commercial building where mostly steelwork is used, it is likely that the frame will be either isolated, and therefore not required to be bonded, or will be bolted to the framework or steelwork of the building which will often be sufficient to maintain bonding continuity and a sufficiently low enough resistance to consider it to be bonded through the structure itself.

The following decision tree shall be used to determine if earthing or bonding is required:



2.2.1 System earthing (d.c. Conductor earthing)

There are a variety of possible PV array system earthing scenarios which can be broadly summarized as follows:

- No earth connection
- Hardwired connection of positive or negative conductor to earth
- Centre tapped array – with / without earth connection
- High impedance connection of positive or negative conductor to earth (for functional reasons)

The manufacturer's instructions for both the PV modules and the equipment to which the PV array is connected must be taken into account in determining the most appropriate earthing arrangement.

A connection to earth of any of the current carrying d.c. conductors is not recommended. However, earthing of one of the live conductors of the d.c. side is permitted, if there is at least simple separation between the a.c. and the d.c. side. Where a functional earth is required, it is preferable that this be done through a high impedance where possible (rather than directly).

The designer must confirm whether the inverter is suitable for earthing of a DC conductor. Transformerless inverters will not be suitable, and an earthed conductor may interfere with the inverter's built-in DC insulation monitoring. Hence, if an earthed DC conductor is required, this is ideally done in the inverter in accordance with guidance from the inverter manufacturer.

NOTE: In the case of PV systems connected to an inverter, IEC62109-2 (Safety of Power convertors for use in photovoltaic power systems – Part 2: Particular requirements for inverters), includes requirements according to the type of earthing arrangement (and inverter topology). These include minimum inverter isolation requirements, array ground insulation resistance measurement requirements and array residual current detection and earth fault alarm requirements.

2.2.1.1 Systems with direct connection to earth

Where there is a hardwired connection to earth, there is the potential for significant fault currents to flow if an earth fault occurs somewhere in the system. A ground fault interrupter and alarm system can interrupt the fault current and signal that there has been a problem. The interrupter (such as a fuse) is installed in series with the ground connection and selected according to array size. It is important that the alarm is sufficient to initiate action, as any such earth fault needs to be immediately investigated and action taken to correct the cause.

An earth fault interrupter shall be installed in series with the earth connection of the PV array such that if an earth fault occurs the fault current is interrupted. When the earth fault interrupter operates, an alarm shall be initiated. The nominal overcurrent rating of the interrupter shall be as follows:

Array size	Overcurrent rating
≤3kWp	≤1A
3- 100KWp	≤3A
>100kWp	≤5A

The earth fault alarm shall be of a form that ensures that the system operator or owner of the system becomes immediately aware of the fault. For example, the alarm system may be a visible or audible signal placed in an area where operational staff or system owners will be aware of the signal or another form of fault communication like Email, SMS or similar

NOTE: In grid connected systems, an earth fault alarm may be a feature of the inverter. In such systems and where the inverter is located in a remote location, the system should be configured so that a secondary alarm is triggered that will be immediately seen by the system operator.

2.2.1.2 Systems with high impedance connection to earth

A high impedance connection to earth of one of the current carrying conductors may be specified where the earth connection is required for functional reasons. The high impedance connection fulfills the functional requirements while limiting fault currents.

Where a functional earth is required, it is preferred practice that systems be functionally earthed through a high impedance rather than a direct low impedance connection (where possible).

2.2.1.3 Surge Protection measures

All d.c. cables should be installed to provide as short runs as possible, and positive and negative cables of the same string or main d.c. supply should be bundled together, avoiding the creation of loops in the system. This requirement includes any associated earth/bonding conductors.

Long cables (eg PV main d.c. cables over about 50 m) should be installed in earthed metal conduit or trunking, or be screened cables such as armoured.

Note: These measures will act to both shield the cables from inductive surges and, by increasing inductance, attenuate surge transmission. Be aware of the need to allow any water or condensation that may accumulate in the conduit or trunking to escape through properly designed and installed vents.

Most grid connect inverters have some form of in-built surge suppression; however discrete devices may also be specified.

Note: Surge protection devices built into an inverter may only be type D and a designer may wish to add additional (type B or C) devices on the DC or AC side. To protect the a.c. system, surge suppression devices may be fitted at the main incoming point of a.c. supply (at the consumer's cut-out). To protect the d.c. system, surge suppression devices can be fitted at the inverter end of the d.c. cabling and at the array. To protect specific equipment, surge suppression devices may be fitted as close as is practical to the device.

2.3 Design Part 3 – a.c. System

2.3.1 a.c. Cabling

An inverter supplied from a PV array should be installed in a dedicated final circuit in which:

- **no current-using equipment is connected, and**
- **no provision is made for the connection of current-using equipment, and**
- **no socket-outlets are permitted.**

Note: a datalogger is not considered current-using equipment.

The final connection into a distribution board that contains one or more circuits protected by an RCD, shall be made in such a way that the outgoing circuit for the PV system is not connected into the outgoing side of an RCD installed for the protection of other circuits (ie in a split board – connected into the part not protected by the RCD) .

Where one circuit feeds more than one inverter, the protective device for that circuit shall be less than the maximum MCB rating provided by the inverter manufacturer(s).

An inverter must not be connected by means of a plug with contacts which may be live when exposed.

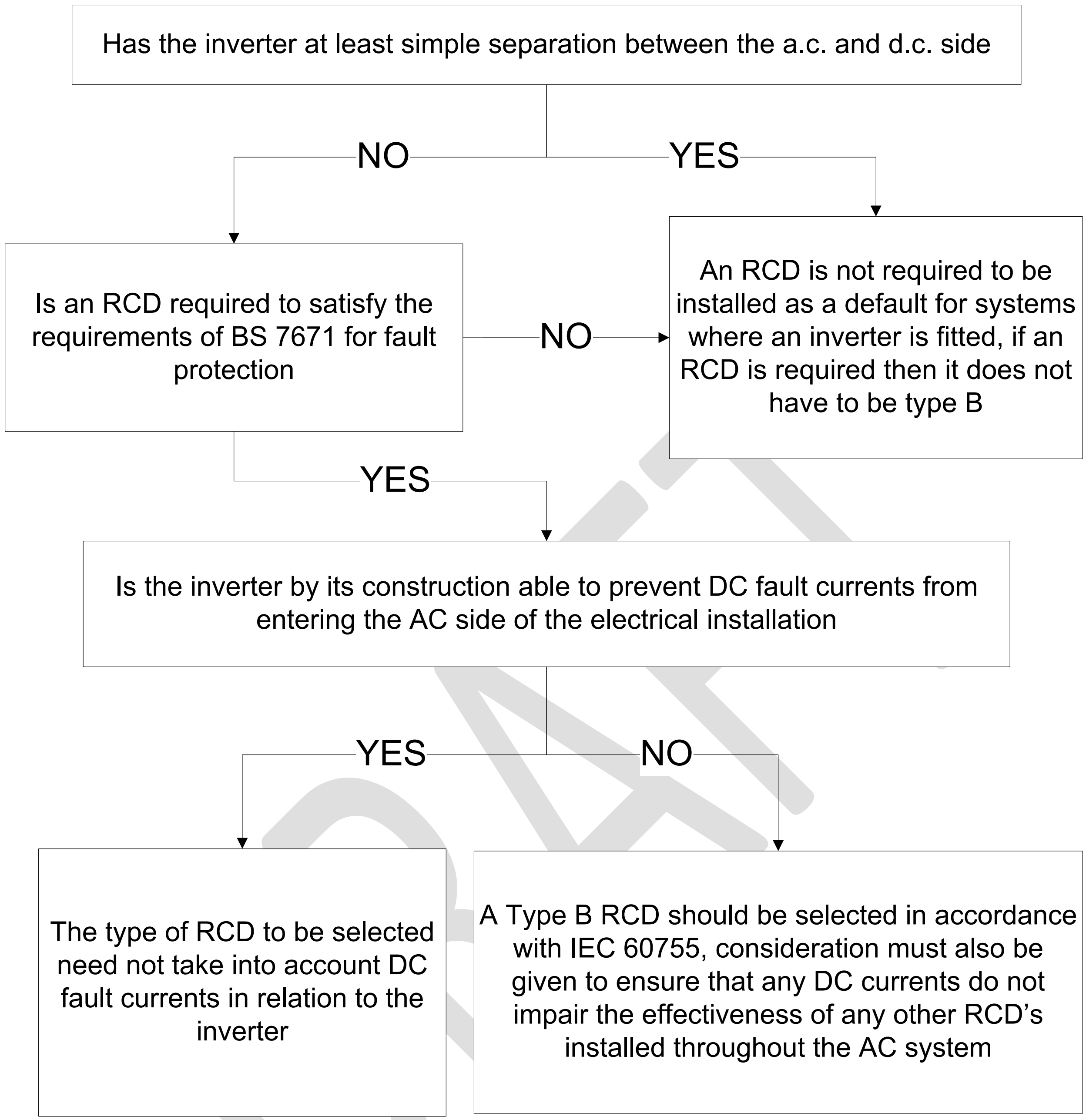
a.c. cables are to be specified and installed in accordance with BS 7671.

The a.c. cable connecting the inverter(s) to the consumer unit should be sized to minimise voltage drop. A 1% drop or less is recommended. However in larger installations this may not be practicable or economic due to the very large size of cable resulting. In this case the designer should minimise voltage drop as far as possible and must remain within voltage drop limits as prescribed by BS 7671.

Note: the requirement for a 1% voltage drop is due to two reasons: firstly when generating, the voltage at the inverter terminals is higher than the voltage at the suppliers cutout – during periods of high power output this voltage drop must be kept to a minimum in order to prevent the inverter nuisance tripping on over voltage ; secondly the requirement ensures losses from the PV system are minimised.

Where an electrical installation includes a PV power supply system that <u>cannot prevent</u> d.c. currents from entering the a.c. side of the installation, and where an RCD is needed to satisfy the general requirements of the electrical installation in accordance with BS 7671 then the selected RCD should be a Type B as defined in IEC 60755, where any doubt exists in relation to the ability the inverter the manufacturer shall be consulted.

The following decision tree can be used to determine the correct application of RCD protection in relation to Regulation 712.411.3.2.1.2 from BS7671:2008 (amd.1):



2.3.2 a.c. switching device

Switching of the a.c. side of the installation shall comply with the requirements of BS7671,

An a.c. switch or combination of switches must be provided for isolation and maintenance in the installation.

A switch for mechanical maintenance shall be provided in close proximity to the Inverter and shall fulfil the following conditions:

- **switch all live and neutral conductors**
- **be securable in the OFF position only**
- **clearly show the ON and OFF positions and be labelled as 'PV system – main a.c. isolator'**

An accessible means of isolation shall be provided to isolate the a.c. circuit. MCB's, RCD's and main switches installed in accordance with BS7671 and in an accessible location can be used to fulfil the requirements for an accessible means of isolation.

Note: At the point of installation of any a.c. switch-disconnector, the public supply should be considered the source and the PV installation the load.

Editors note – this section has been edited to match proposed G83/2 requirements – checks are underway with DNOs and ENA that we are OK to incorporate these changes prior to the release of G83/2

2.3.3 Inverters

Inverters must carry a Type Test certificate to the requirements of Engineering Recommendation G83/1 or G59/2 (as applicable) unless specifically agreed by an engineer employed by or appointed by the DNO for this purpose, and in writing.

Note: A key safety consideration is that the PV system will disconnect when the distribution system is not energised. This is to prevent the hazardous situation of the photovoltaic system feeding the network or local distribution system during a planned or unscheduled loss of mains. Such an event is termed 'islanding' and presents a potential danger to those working on the network/distribution system. Engineering recommendations G83/1 and G59/2 ensure that a PV system is properly prevented from such islanding operation. Other considerations addressed by these Engineering Recommendations include the prevention of harmonics, EMC compatibility and d.c. injection.

2.3.3.1 Inverter sizing

The sizing an inverter for a grid connected PV system is influenced by a number of factors, including:

- The inverters available for use in the UK (not all manufacturers have G83 / G59)
- Array voltage fluctuations due to operating temperature
- The maximum permissible DC input voltage of the inverter
- The mpp (maximum power point) voltage range of the inverter
- The desired inverter – array power ratio

Inverter matching is to be done following the guidance from the inverter manufacturer – typically from the manufacturer's system sizing software.

Where a system features multiple strings or arrays with differing orientation or pitch that may affect the performance of the system, the strings or arrays should be connected to and inverter with a multiple Mpp function or different inverters should be utilised.

The inverter must be selected to safely withstanding the maximum array voltage and current as calculated in section 2.1.2. This must include any initial overvoltage period which is a feature of some module types. This is to include verifying that the inverter can safely withstand the array open circuit voltage maxima at -15°C.

Temperature range: While an inverter must be able to safely withstand array operation between -15°C to 80°C (see section 2.1.2), it is permissible for a narrower temperature band (e.g. -10°c to 70°c) to be used when looking at the operational mpp range of the inverter. In such cases, an assessment should be made as to the temperature range acceptable and appropriate for that particular site and array mounting method (eg some building integrated systems will operate at higher temperatures than "on-top" systems)

Power ratio: It is common practice for an inverter power to be less than the PV array rating. In the UK, inverters are typically sized in the range of 100 - 80% of array capacity. However, in certain circumstances and depending on the inverter used, ratios outside this are sometimes utilised (NB: Inverter power is taken to be maximum steady state a.c. power output).

It is recommended that Inverters carry a sign 'Inverter - isolate a.c. and d.c. before carrying out work'.

Inverter ventilation – Inverters dissipate heat and should be provided with sufficient ventilation. Clearance distances as specified by the manufacturer (e.g to a heatsink) should also be observed. Failure to follow this can cause a loss in system performance as the inverter will de-rate when it reaches its maximum operating temperature. This should be highlighted within the O&M manual and perhaps with a label – not to block ventilation – placed next to the inverter.

2.3.4 a.c. cable protection

Protection for the cable from the inverter(s) must be provided at the distribution board. This protective measure shall be specified and installed in accordance with the requirements of BS 7671.

The fault contribution from the inverter end of the circuit is defined by the current-limiting nature of the PV-array and the inverter, so "conventional" overcurrent measures typically applied in ac circuit design may not always be necessary. In very many cases the current limiting nature of the device omits the requirements for overload protection and therefore the designer only need fault current protection on the ac side of the system. In any case where protection is afforded at the origin of the circuit (the distribution board) in accordance with BS7671, there is no requirement for additional overcurrent protection to be installed at the inverter end of the a.c. installation.

If using an RCD on the a.c. circuit feeding the inverter (see section 2), protection is not normally needed at the inverter end of the circuit. It is usual for the inverter to have an RCMU (residual current monitoring unit) integrated in to the inverter to afford protection in the event of a fault to earth on the ac side of the system.

2.3.5 Metering

Inverter output meter: As a minimum, metering at the inverter output should be installed to display/record energy delivered by the PV system (kWh). In addition it is highly recommended for instantaneous power output (kW) to be displayed. This will not only add to customer satisfaction it should lead to more effective fault detection. An approved kWh meter connected to measure generation will be required to facilitate payments of any financial incentives (e.g Feed in Tariff payments).

The meter should be located where the consumer can readily observe it.

Building Export meter: Although not directly part of the PV system, where required in order to enable payment on exported electricity, an approved kWh export meter with appropriate reading capabilities may be required. The appropriate Energy Supplier should be contacted to find out any particular requirements and to arrange for its fitting.

2.4 Design Part 4 – Design Approval

2.4.1 DNO approval (grid connected systems)

Editors note – this section has been edited to match proposed G83/2 requirements – I am checking with DNOs and ENA that we are OK to incorporate these changes prior to the release of G83/2

Installers are required to inform that the relevant distribution Network Operator (DNO) of the installation of a grid connected PV system in the following manner:

a) Single installation ≤ 16A/phase using G83/1 type tested inverter(s)

- **Notification using G83 commissioning form within 30 days following commissioning of the installation, to the DNO's designated contact details.**

b) Multiple installations in close geographical proximity ≤ 16A/phase using G83/1 type tested inverter(s)

- **Application to connected submitted to DNO using G83/1 multiple system application form**
- **Approval for connection to be received prior to installation.**
- **Notification within 30 days of commissioning using G83/1 commissioning form**

c) Systems up to 50kW (AC) 3-phase or 17kW single phase using G59/2 type approved inverters(s)

- **Application to connect submitted to DNO using G59/2 application form**
- **Approval for connection to be received prior to installation**
- **Commissioning to be performed to the requirements of the DNO (witness testing <u>not</u> typically required)**
- **Notification within 30 days of commissioning using G59/2 Appendix A13.2 commissioning form**

d) All other systems

- **Application to connect submitted to DNO using G59/2 application form**
- **Approval for connection to be received prior to installation.**
- **Additional interface protection measures to be approved by DNO**
- **Commissioning to be performed to the requirements of the DNO**
- **Notification within 30 days of commissioning using G59/2 Appendix A13.3 commissioning form**

2.4.2 Planning permission

The relevant planning authority should be consulted at an early stage to determine if planning permissions are required. Under most circumstances for domestic dwellings, the PV array can be installed under the amendments made in the General Permitted Development Order (GPDO), or the Town and Country Planning (General Permitted Development) (Domestic Microgeneration) (Scotland) Amendment Order 2009 which grants rights to carry out certain limited forms of development on the home, without the need to apply for planning permission. However this may not be the case in areas of outstanding natural beauty (AONB), national parks conservation areas etc.

For further information you should consult the planning portal at www.planningportal.gov.uk/planning

2.4.3 Building Regulations

All installation work in or around occupied structures will be covered by the building regulations. Different sets of regulations apply depending on the geographical area. There are different sets of regulations for: England, Wales, Northern Ireland and Scotland. Whilst all of the regulations are set out and worded slightly differently, they all have the same aims and objectives of ensuring that the buildings that they cover are built and maintained in safe, reliable and most energy efficient way.

2.4.3.1 England & Wales

These regulations are segregated into parts A-P which individually cover key aspects of the building. When installing a Photovoltaic system the work has to comply with all parts of the building regulations, these parts of the regulations cover the following aspects of work;

A. Structure ✓
B. Fire Safety
C. Resistance to contaminants and moisture ✓
D. Toxic Substances
E. Resistance to sound
F. Ventilation
G. Sanitation, Hot water safety and water efficiency
H. Draininag and waste disposal
J. Heat Producing Appliances
K. Protection from falling
L. Conservation of fuel and power
M. Access to and use of buildings
N. Glazing safety
P. Electrical safety ✓

Those which are most immediately relevant to the installation of a PV system have been highlighted above (✓), however it must be noted that other parts may also apply, and where they do compliance must be achieved.

In all cases notification has to be made to the local area building control (LABC) that the work has taken place. Notification can take place several ways but the two principle methods are;

1. Submitting a building notice to the LABC (has to be to work commencing)
2. Notifying the work through a competent persons scheme done prior – this can be done after the work has been completed

Note: Where it is determined that structural work is required to strengthen a roof prior to the installation of the PV system – such works will always require a building notice to be submitted.

Generally those involved with PV installation work will want to use method 2 or employ contractors who use method 2 as method 1 can be expensive and time consuming.

When registering with a competent person's scheme you can register for one or more categories of work, for PV you will need to register under a scheme that offers notification work categories under Microgeneration and part P to cover both of the most relevant aspects. Successful registration will mean that you will be able to install and then notify the work after completion (within 30 days).

It is important to note that although registered under a "key" category of work the registrant is also responsible for ensuring compliance with all other categories of work and to know that these are covered by the certificate of compliance that the householder receives from the competent person's scheme.

This is especially important factor to PV installers as it means that not only are they specifically notifying that the electrical and microgeneration work is compliant, but it also covers all other applicable aspects of the building regulations including part A (structure). The following table summarises the routes for registering an installation:

			Activities that require notification	
Installer status			**PV array notification** **Row 17 of schedule 3 of the building regulations (microgeneration)**	**New AC circuit / installation of a generator notification** **Row 12 of schedule 3 of the building regulations (electrical)**
MCS Only	**MCS and CPS for renewables only**	**MCS, CPS for renewables & Part P**		
✓			• Notification must be done direct to LABC	• Notification done direct to LABC unless installer uses a Part P registered subcontractor
	✓		• Notification made through competent persons scheme for row 17 (microgeneration)	• Notification done direct to LABC unless installer uses a Part P registered subcontractor
		✓	• Notification made through competent persons scheme for row 17 (microgeneration)	• Notification made through competent persons scheme for row 12

Notes:

1. A full list of Competent Person Scheme (CPS) providers can be found on the CLG website at:
http://www.communities.gov.uk/planningandbuilding/buildingregulations/competentpersonsschemes/existingcompetentperson/

2.4.3.2

Sections to be added on other regional regulations other than England and wales

3 System performance

3.1 Array orientation and pitch

The effect of variations in array orientation and pitch on system performance are shown in the chart below:

Chart – To be recreated by graphic designer Note – depending on the resolution of the charts we may want to do 2 or 3 charts (north, midlands & south)

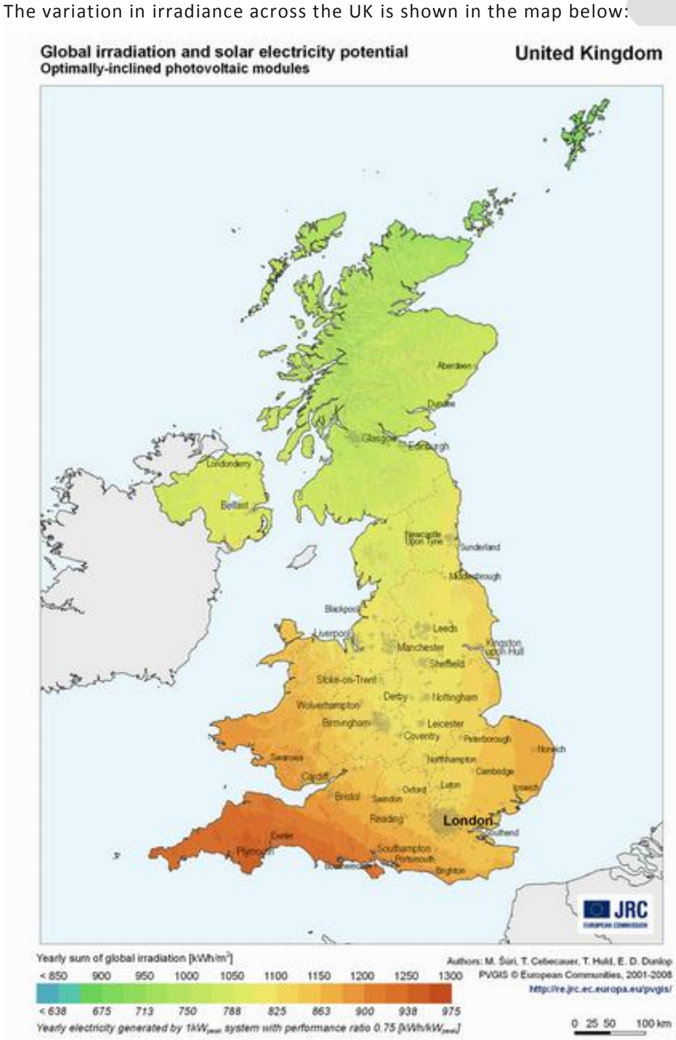
3.2 Shade effects

Shade makes a big impact on the performance of a PV system. Even a small degree of shading on part of an array can have a very significant impact on the overall array output. Shade is one element of system performance that can be specifically addressed during system design – by careful selection of array location, equipment selection and layout and in the electrical design (string design to minimise shade effects).

Shading from objects adjacent to the array (for example: vent pipes, chimneys, and satellite dishes) can have a very significant impact on the system performance. Where such shading is apparent, either the array should be repositioned out of the shade zone, or where possible the object casting the shade should be relocated.

3.3 Geographical location

The variation in irradiance across the UK is shown in the map below:



3.4 Temperature effects

Module temperature – An increase in module temperature results in a decrease in performance (eg 0.5% per 1°C above stc for a crystalline module). Sufficient ventilation must be provided behind an array for cooling (typically a minimum 25mm vented air gap to the rear). For building integrated systems, this is usually addressed by the provision of a vented air space behind the modules. On a conventional pitched roof, batten cavity ventilation is typically achieved by the use of counterbattens over the roof membrane and by the installation of eaves and ridge ventilation.

Note: It may be possible to omit counterbattens with some integrated PV roofing products / roof construction. This is acceptable where there is test data showing that a specific integrated PV product and associated roof construction provide a similar PV cell temperature performance to a roof with a ventilated counterbatten space.

3.5 Other factors

A variety of other factors will also affect system performance, including:

- Panel characteristics & manufacturing tolerances
- Inverter efficiency
- Inverter – array matching
- Cable losses
- Soiling of the array (more relevant in certain locations)
- Grid availability
- Equipment availability (system down-time due to equipment failiures)

3.6 Daily and annual variation

Typical daily and annual insolation curves, together with the monthly and seasonal trend in system performance are shown in the charts below.

3.7 Photovoltaic Performance Estimation

As can be seen, the annual performance of a grid connected PV system depends on a large number of factors. Against this background, the methodology described below is necessarily simplified in order to create a standard method that can be used to achieve a reasonable estimation of performance without it being an unduly complex procedure.

The purpose of a standardised procedure is intended to prevent miss-selling of PV systems – such that all customers will receive a system performance estimation done to a standardised procedure. Under the MCS scheme:

A generation estimate, as described in the procedure below, shall be communicated with the client before the point that the contract is awarded and shall be accompanied by a document containing all of the relevant factors for the performance calculation (ascertained during the survey), and the following disclaimer:

"The performance of solar PV systems is impossible to predict with certainty due to the variability in the amount of solar radiation (sunlight) from location to location and from year to year. This estimate is based upon the standard Microgeneration Certification Scheme procedure is given as guidance only. It should not be considered as a guarantee of performance."

Additional estimates may be provided using an alternative methodology but any such estimates must clearly describe and justify the approach taken and factors used and must not be given greater prominence than the standard MCS estimate. In addition, it must be accompanied by warning stating that it should be treated with caution if it is significantly greater than the result given by the standard method.

3.7.1 Site evaluation

Pitch, orientation and shading are the three main site factors that influence the performance of a PV system. While drawings, maps or photos are a suitable means to determine pitch and orientation, an accurate estimation of any shade effects will typically require a site visit. In some circumstances however, data may need to be estimated or taken remotely. In such circumstances, any performance estimate provided to a customer should include the following statement:

This system performance calculation has been undertaken using estimated values for array orientation, pitch or shading. Actual performance may be significantly lower or higher if the characteristics of the installed system vary from the estimated values.

In all cases where pitch, orientation or shade has been estimated at quotation stage, a site survey should be undertaken before installation commences. Where any factors do not match those given in the original performance estimate, the certified installation company shall recalculate the performance estimate and supply this in writing to the client. If the adjusted performance estimate is worse than originally predicted, the client shall be given the same cooling off period and cancellation rights (to include any right to cancel without financial penalties) that applied to the original quote.

Editors note: MIS 3002 to be aligned to suit above wording

3.7.2 Standard estimation method

The approach is as follows:

1) Establish the electrical rating of the PV array in kilowatts peak (kWp)
2) Determine the level of annual solar irradiance (Ra) - by reference to table(s) A1
3) Determine the orientation and pitch factor (OP) – by reference to chart A2.1, A2.2, A2.3
4) Determine the shading factor of the array (SF) due to objects blocking the horizon - using horizon procedure (below)

The estimated annual electricity generated in kWh/year of installed system shall then be determined using the following formula:

Annual output (kWh) = kWp x Ra x OP x SF x 0.8

3.7.2.1 kWp of array (kWp)

The kWp value used shall be the sum of the data plate value of all modules installed (the value printed on the module label).

3.7.3 Annual Solar Irradiance (Ra)

Determine the mean annual solar irradiance figure (Ra) by use of the table below; the values given are in Wp per M^2 over a 12 month period

Table A1 - showing postcodes and associated irradiance values to be inserted – NB there are 124 potential 2 digit prefixes (CA, DL, W2 etc) - Postcode table will also indicate which OP chart to use.

3.7.3.1 Orientation and Pitch factor (OP)

The charts below show the variations (from optimum) in system output for different array orientations and inclinations for three key geographical areas in the UK (South, Mid and North of the UK).

The values in the table are percentage values – hence "79" represents an OP multiplier of 0.79. It can be seen that OP = 1.0 for systems facing due South and pitched at 35°for the Mid UK.

Orientation

North | North West | West | South West | South | South East | East | North East | North

Inclination	-180°	-165°	-150°	-135°	-120°	-105°	-90°	-75°	-60°	-45°	-30°	-15°	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
90°	25	27	32	37	40	44	50	57	60	66	70	70	70	70	70	66	60	57	50	44	40	37	32	27	25
80°	28	29	34	38	45	50	56	61	68	73	78	79	78	79	78	73	68	61	56	50	45	38	34	29	28
70°	32	34	37	42	48	55	66	69	75	80	85	87	87	87	85	80	75	69	66	55	48	42	37	34	32
60°	37	38	41	48	54	62	69	75	80	85	91	92	93	92	91	85	80	75	69	62	54	48	41	38	37
50°	42	45	48	52	59	68	72	78	85	91	95	96	97	96	95	91	85	78	72	68	59	52	48	45	42
45°	46	49	52	56	62	70	74	80	87	92	95	97	98	97	95	92	87	80	74	70	62	56	52	49	46
40°	50	52	55	60	65	73	76	82	88	93	96	98	99	98	96	93	88	82	76	73	65	60	55	52	50
35°	55	57	59	65	67	75	79	85	90	94	97	99	100	99	97	94	90	85	79	75	67	65	59	57	55
30°	60	60	61	67	70	78	80	85	91	94	96	98	98	98	96	94	91	85	80	78	70	67	61	60	60
20°	70	70	71	73	75	72	84	86	91	92	95	96	96	96	95	92	91	86	84	72	75	73	71	70	70
10°	78	78	79	80	82	85	85	88	90	91	92	92	93	92	92	91	90	88	85	85	82	80	79	78	78
0°	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

The Figures are based on the EU JRC SPLIT INTO 3 CHARTS

Note: that although the tables show irradiance factors for East, West, North-East and North-West, some of these may not normally be considered to be an economic PV orientation.

Editors note – we need 3 charts – one for N of England, one for midland and one for S … and we will use a chart with a less resolution

3.7.3.2 Shade factor (SF)

Standing as near as possible to the base of the array (e.g. through an upstairs window), use the diagram below (a sunpath diagram) to plot all the objects (near and far) that obstruct the horizon.

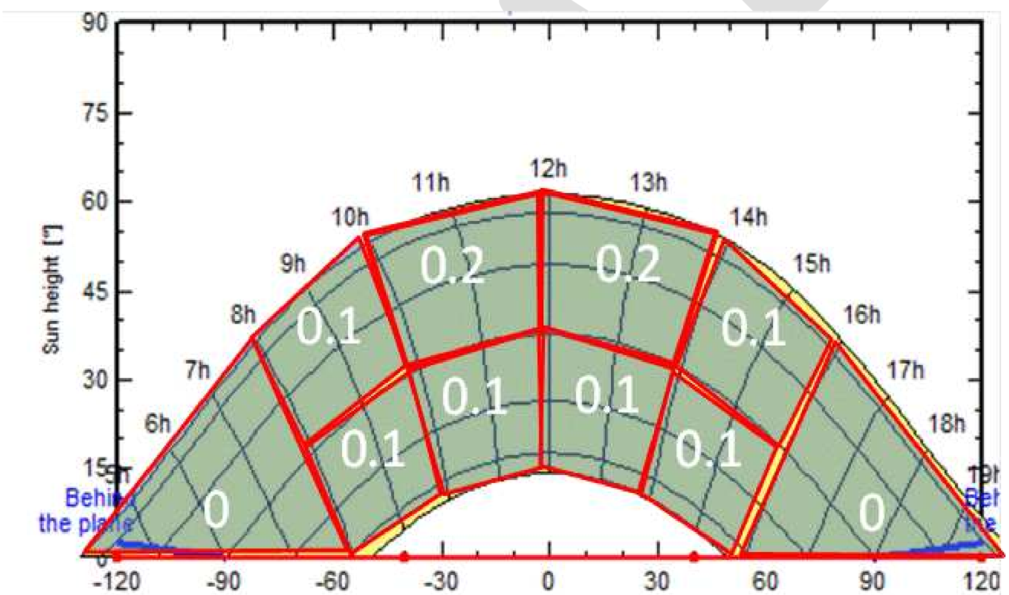
Where there is a clear horizon and no near shading, the assessment of SF can be skipped and an SF value of 1 used in all subsequent calculations.

Where shade exists, the reading should be undertaken from the section of the array that is most affected by any shade. For systems with near shading this will typically be just to the North of the near shading object.

Note: installing a system will any significant near shading will have a considerable effect on array performance. Where possible any near shading on the array should be avoided.

For systems connected to multiple inverters, it is acceptable to do a separate reading (calculation of SF) for each sub array (each array connected to a dedicated mpp tracker)

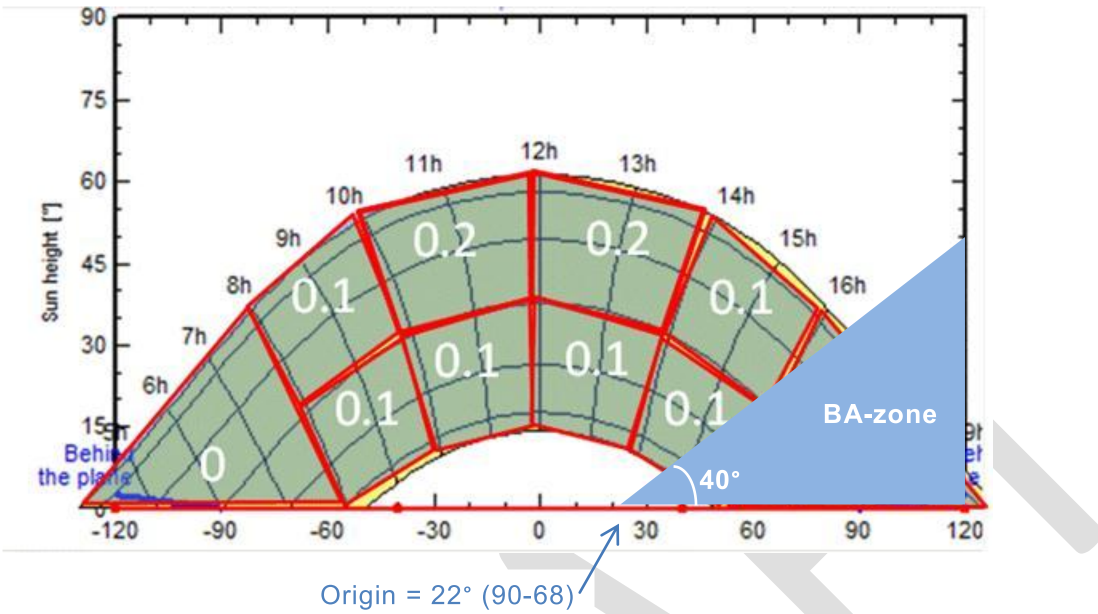
NOTE: See Appendix C for more information on how to perform the horizon assessment



Zone behind the array plane

If the array does not face exactly south, obstructions located behind the plane of the array can be ignored. This is achieved by plotting a "behind the array" zone (BA-Zone) on the sun path diagram. This is drawn as follows:

Draw a line with its origin equal to the (90° - azimuth of the array) and a slope equal to the pitch of the array … then ignore any shade beneath the line. The example below shows the BA-zone for an array facing ESE (azimuth = 68°) and pitched at 40° from the horizontal.



IMPORTANT NOTE: Only sun path diagrams with the proportions shown in this guide should be used for this process. If a different chart is used, or a chart that has be stretched in one direction is used (ie chart made either wider or taller), the above simplified procedure for estimating the behind the array zone will not be effective.

Once the BA-zone is plotted - only those squares that are fully exposed or more than half exposed are to be considered.

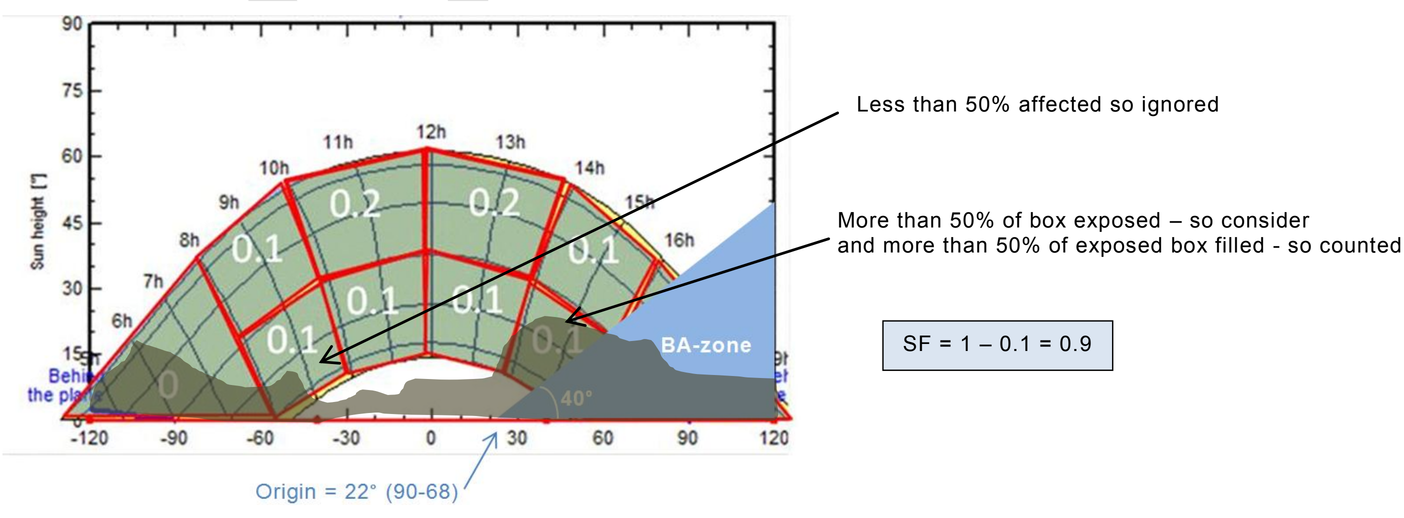
Estimating shade effects

Once the horizon line is drawn, any square that is more than half affected should be counted (add up the figures for all exposed squares that are miore than half covered by shade).

The shade factor (SF) is then calculated using the following formula:

SF = 1 – (sum of affected squares)

An example of a SF calculation is shown below:



Worked examples of performance estimations, including SF calculations, are contained in appendix C.

3.7.3.3 Sites with near shading sources

As noted previously, shading from objects adjacent to the array (for example: vent pipes, chimneys, and satellite dishes) can have a very significant impact on the system performance. Where such shading is apparent, either the array should be repositioned out of the shade zone, or where possible the object casting the shade should be relocated.

Where an array is affected by near shading (shading due to items within 10m) the following needs to be implemented:

a) **The horizon line drawn to calculate the shade factor should be drawn to represent the worst case (drawn from the array location most affected by shade)**

b) **The following statement should be added to the performance estimation quoted to the customer (in addition to the statement contained in clause 3.7):**

"The proposed PV array has near shading objects which may significantly affect annual performance of the PV system. The standard performance estimation procedure does not fully address the impact of near shading and as a consequence actual performance may be worse than the figure quoted."

4 INSTALLATION/SITEWORK

4.1 General

Standard health and safety practice and conventional electrical installation practice must apply to the installation of a PV system. Issues such as working on roofs or standard domestic a.c. wiring are covered thoroughly in other publications and are not detailed in this guide.

4.2 PV Specific Hazards

When compiling a method statement and risk assessment for the installation of a PV system, there are a number of PV specific hazards that need to be addressed. These will be in addition to standard considerations such as PPE (Personal Protective Equipment), working at height, manual handling, handling glass and the application of the CDM regulations.

- PV modules produce electricity when exposed to daylight and individual modules cannot be switched off. Hence, unlike most other electrical installation work, the electrical installation of a PV system typically involves working on a live system. See requirements of Regulation 14 of Electricity at Work Regulations 1989.

- As current limiting devices, PV module string circuits cannot rely on fuse protection for automatic disconnection of supply under fault conditions, as the short-circuit current is little more than the operating current. Once established, a fault may remain a hazard, perhaps undetected, for a considerable time.

- Good wiring design and installation practice will serve to protect both the system installers and any persons subsequently coming into contact with the system from an electric shock hazard (operator, owner, cleaner, service engineers, etc).

- Undetected, fault currents can also develop into a fire hazard. Without fuse protection to clear such faults, protection from this fire hazard can be achieved only by both a good d.c. system design and a careful installation.

- PV presents a unique combination of hazard – due to risk of shock, falling, and simultaneous manual handling difficulty. All of these hazards are encountered as a matter of course on a building site, but rarely all at once. While roofers may be accustomed to minimising risks of falling or injury due to manual handling problems, they may not be used to dealing with the risk of electric shock. Similarly, electricians would be familiar with electric shock hazards but will not be used to handling large objects at heights.

Hazards associated with PV installation are outlined in the DTI's free manual, 'Photovoltaics in Buildings – Safety and the CDM Regulations'.

4.3 d.c. Circuits - installation

4.3.1 Personnel

All persons working on the live d.c. cabling of a Photovoltaic (PV) system must be experienced / trained in working with such systems and fully acquainted with the voltages present on that system in particular.

Plug and socket connectors simplify and increase the safety of installation works – see section 2.1.7. They are recommended in particular for any installation being performed by a non-PV specialist – eg a PV array being installed by a roofer.

4.3.2 Sequence of works

All d.c. wiring should if possible be completed prior to installing a PV array. This will allow effective electrical isolation of the d.c. system (via the d.c. switch-disconnector and PV module cable connectors) while the array is installed; and effective electrical isolation of the PV array while the inverter is installed.

Typically this would require an installation of:

- d.c. switch-disconnector and d.c. junction box(es)
- String/array positive and negative cables - from the d.c. disconnect/junction box to either end of the PV string/array;
- PV array main cables from d.c. switch to inverter.

This should be carried out in such a way that it should never be necessary for an installer to work in any enclosure or situation featuring simultaneously accessible live PV string positive and negative parts.

Note: While the installer will be handling live cables during the subsequent module installation, because the circuit is broken at the d.c. switch-disconnector, there is no possibility of an electric shock current flowing from the partially completed PV string. The maximum electric shock voltage that should ever be encountered is that of one individual PV module.

Where it is not possible to pre-install a d.c. isolator (eg a new-build project where a PV array is installed prior to the plant room being completed), cable ends/ connectors should be put temporarily into an isolation box and suitably labelled (as per d.c. junction box – section 2.1.9).

Cables are to be well supported, especially those cables exposed to the wind. Cables must be routed in prescribed zones or within mechanical protection. They must also be protected from sharp edges.

4.3.3 Live working

If it is unavoidable to work in any enclosure or situation featuring simultaneously accessible live PV string positive and negative parts, this must be performed either by utilising insulating gloves, tools, insulating materials for shrouding purposes and appropriate personal protective equipment (see Regulations 4(4),14 and 15 of Electricity at Work Regulations 1989; HSE HSG 85; and BS EN 60903 and BS EN 60900) or by covering the PV array; or by working at night (with appropriate task lighting). When covering PV panels during installation, the covering must be opaque, cover the whole array and be well secured.

A temporary warning sign and barrier must be posted for any period while live PV array cables or other d.c. cables are being installed.

Note: Covering a PV array can provide a means to prevent the need for live working but is not recommended. In practice this is often difficult due to achieve due the practical problems of keeping the array covered as the installation proceeds and protecting the covering from the effects of the weather.

4.3.4 Shock hazard (safe working practices)

It is important to note that, despite all the above precautions, an installer or service engineer may still encounter an electric shock hazard:

Always test for the presence of voltage of parts before touching any part of the system.

An electric shock may be experienced from a capacitive discharge – a charge may build up in the PV system due to its distributed capacitance to ground. Such effects are more prevalent in certain types of modules and systems, namely amorphous (thin film) modules with metal frames or steel backing. In such circumstances, appropriate and safe live working practices must be adopted.

An example of where such hazards may be encountered is the case where an installer is seated on earthed metal roof wiring a large PV array. In such circumstances the installer must touch the PV cabling and can get an electric shock to earth. The electric shock voltage will increase with the number of series connected modules. The use of insulated tools and gloves, together with insulating matting to stand or sit on, can mitigate this hazard.

An electric shock may also be experienced due to the PV array developing a ground leakage path. Good wiring practice, double insulation and modules of Class II construction can significantly reduce this problem, but in any installed systems, leakage paths may still occur. Any person working on a PV system must be aware of this and take the necessary precautions.

4.4 Array mounting structures

Editors note – this section is an initial draft based on work within roofing group. Waiting on comments & review form the group.

4.4.1 Load calculations

The design and specification of the PV array mounting system should take into account the wind and snow loads to be expected. Wind loads vary considerably across the UK and are influenced by factors such as site altitude, building height and local topography. Even where an approved mounting system kit is utilised, site specific calculations will be required to ensure that the system proposed is sufficient to withstand the imposed loads.

For each site the imposed wind and snow loads should be derived using the procedures within Eurocode-1 (BS EN 1991-1).
The pressure coefficients used to calculate loading on the array shall be derived as follows:

- For PV arrays that are mounted above a pitched roof, where there is a clear gap between the array and the roof - the pressure coefficients shall be taken from BRE digest 489
- For flat roof systems - the pressure coefficients shall be taken from BRE digest 489
- For roof integrated, nominally airtight systems - the pressure coefficients shall be taken from Eurocode-1
- For roof integrated, air permeable "PV tile" type systems - the pressure coefficients shall be taken from BS5534 and treating the PV array as roof tiles

In determining the appropriate pressure coefficient to use in calculations, the location of the PV array on the roof needs to be determined as some or all of the array may be in the "Edge Zone" as defined in BS EN 1991-1. Pressure coefficients for the *Edge Zone* will be higher than those in the *Central Zone* of the roof. BRE digest 489 and the other sources listed above include pressure coefficient values for both Edge and Central zones.

Note: A simplified method to derive wind loads is described in annex B

As described within Eurocode-1 tables A1.1 and A1.2, safety factors need to be applied to the calculated loads. Taken in isolation, a safety factor of 1.5 is to be applied to the derived wind and snow loads and a factor of 1.0 to the dead load (self weight).

Load calculations shall be done by a suitably trained person.

4.4.2 Fixing and building structure calculations

The PV array fixings (type and quantity) shall be checked to ensure that they can withstand the imposed wind uplift as calculated. Examples of how this can be achieved include:

- For systems approved to MCS012 - ensuring that the imposed loads are within the range specified by the product manufacturer and then fixing according to the manufacturer's instructions
- Using fixing data from Eurocode 5 (design of timber structures)
- Using fixing bracket test data

Note: Many standard above roof systems for pitched roofs, suggest the use screws into rafters where the requirements of Eurocode 5 to keep fixings a certain number of screw diameters away from the rafter edge and each other is not achievable. In such cases one solution is to fix the mounting bracket to a timber noggin fitted between the rafters. Alternatively, the fixing resilience can be determined from test data.

In all cases it is expected an appropriate safety factor to have been applied to the fixing withstand capacity (for systems listed to MCS012, a safety factor will have been applied as a part of the certification process and will be shown in the MCS012 certification).

Load and structural calculations shall be done by a suitably competent person.

The roof structure shall be checked to ensure it can withstand the imposed loads as calculated. This is to include a site inspection by a suitably trained person.

4.4.3 PV roofing and cladding works

PV systems should not adversely affect the weather tightness of the structure to which they are fitted. The system should be designed and installed to ensure this is maintained for the life of the system.

For integrated systems the weather tightness of the PV systems should be the same or better than the roof or cladding systems they are replacing and should not adversely affect the weather tightness of the surrounding covering.

For above roof PV systems the array fixing brackets should not affect the weather tightness of the roof they are fitted to. For example, systems attached to tile roofs should be designed and installed such that the fixing brackets do not displace the tiles and cause gaps more than naturally occurs between the tiles. Fixing methods must not subject roof coverings to imposed loads which may degrade their primary purpose of maintaining weather-tightness.

Photo of notched tile and roof hook

It is good practice to notch tiles when fixing a roof bracket

Tiles or slates removed for fixing a mounting bracket should be re-attached to include a means of mechanical fixing.

Mounting systems on slate or tile roofs that rely on a fixing bolt through the tiles/slates are not recommended. This is due to the potential for damage to the slates/ tiles and the difficulty for ensuring a lasting weather tight seal.

Bolt through fixings systems that incorporate a rubber sealing washer (originally designed for metal roofs) are sometimes suggested as a way of ensuring a lasting weathertight seal on slate or clay tile roofs. However, due to the potential for cracking slates and subsequent worries over long term durability, this method is not considered appropriate in most cases. Only installations on large stone slate roofs, where the slates are very large, thick and robust – are considered suitable for this method.

Photo of slate & roof hook

Using a standard roof hook on a slate roof

The roof underlay should be inspected for damage during installation works. Any damage should be repaired or the underlay replaced as necessary.

Damaged underlay will not provide an effective weather and air barrier and can affect weather tightness and the wind loads imposed on the roof cladding.

Unless **specifically designed to do so**, systems should be kept away from the roof perimeter. For a domestic roof, a suitable minimum clearance zone is around 40-50cm.

The requirement to keep an arrays away from a the edge of a roof is suggested because: wind loads are higher in the edge zones; keeping edge zones clear facilitates better access for maintenance; taking arrays close to the roof edge may adversely affect rain drainage routes; and when retrofitting systems, there is the potential for damage to ridge, hip, valley or eaves details.

Note – on many roofs a 50cm gap from the edge will still mean that PV modules are fitted in the "Edge Zone" as defined in BS EN 1991-1 where higher pressure coefficients need to be implemented due to the higher imposed wind loads.

Cable penetrations through the roof should not affect the weather tightness of the roof and should be durably sealed to accommodate the movement and temperatures expected. The use of a purpose made product is an example of a durable means to achieve this.

Cable penetrations though underlay should be achieved using purpose made products or, if taken through a lap in the underlay, the cable should be carefully routed, clipped and tensioned so as to leave a minimal residual gap in the underlay lap joint.

Thermal expansion should be considered when installing larger arrays. The module and mounting system manufacturer should be consulted to determine the maximum array width and continuous rail length that can be permitted without the need for an expansion gap.

4.4.4 Pitched roof system requirements (Aligned to MCS requirements)

PV systems mounted above or integrated into a pitched roof should utilise products that have been tested and approved to MCS012 (test procedures used to demonstrate the performance of solar systems under the action of wind loads, fire, rainfall and wind driven rain).

In roof products (eg PV tiles) – All fixing and flashing components used to mount and make weather-tight the solar roofing product must be packaged and listed as part of a complete kit that includes the PV module. *The MCS installer must ensure that the system is installed to comply with the manufacturer's instructions.*

In roof mounting system – All fixing and flashing components used to mount and make weather-tight the PV system must be specifically approved to work together (e.g. supplied and listed as a kit of parts) and listed to work with either the named PV module, or listed as a universal type where PV module type is immaterial to the performance of the system. *The MCS installer must ensure that the system is installed to comply with the manufacturer's instructions for both the mounting system and the PV module.*

Above roof mounting systems – All components used to mount the system must be specifically approved to work together or be listed as universal components. The mounting system must also be listed to work with either the named PV module, or listed as a universal type where PV module type is immaterial to the performance of the system. *The MCS installer must ensure that the system is installed to comply with the manufacturer's instructions for both the mounting system components and the PV module.*

In all cases it is expected that the manufacturers fixing instructions are followed with respect to wind loading. Wind loads vary from site to site and the installer must ensure that the design wind load is within the range as specified by the manufacturer; and/or for high wind sites, any required additional fixings are correctly installed. Where an installer has chosen to utilise a mounting assembly comprised of "universal" components, the installer must ensure that all components are suitable for the wind load imposed on that component.

4.4.5 Standing seam and other metal roofs

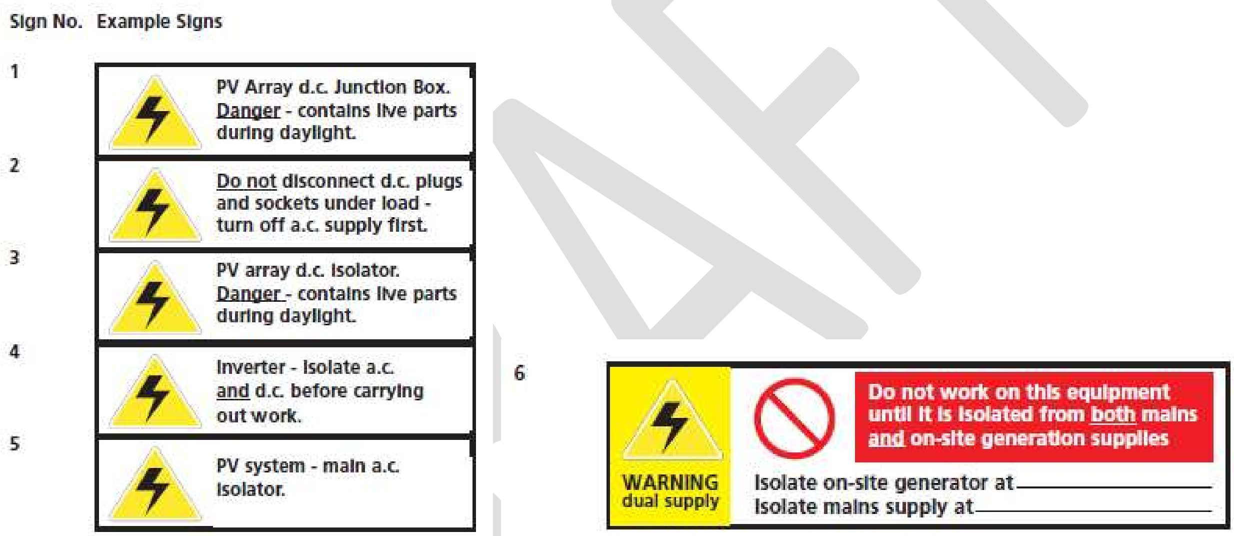
Some PV array mounting systems rely on securing the array to the metal roof cladding. In such circumstances, the adequacy of the roof covering to transfer all additional loads back to the supporting structure should be verified. This should include consideration of all elements of the roof construction that could be affected by the additional loading. Calculations will include consideration of the array configuration (pitched or parallel to the roof) and the type, quantity and locations of PV array fixings.

Sitework should include verification to confirm that all the design requirements have been satisfied and that the roof covering has not been adversely affected by the installation work.

5 Signs and labels

Requirements for labelling are contained within the relevant sections of this guide. Example labels can be seen below.

All labels must be clear, easily visible, constructed and affixed to last and remain legible for the lifetime of the system.

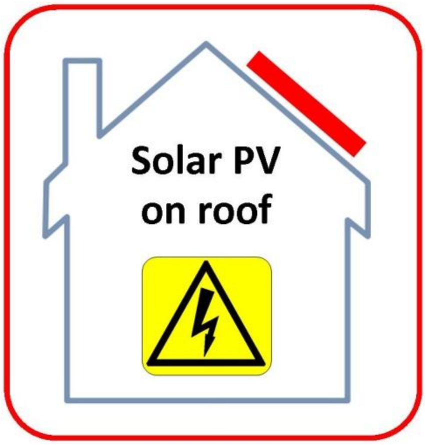


In addition to the labels described elsewhere in this document, the following labels are also to be to be fitted:

- **Dual supply labelling should be provided at the service termination, meter position and all points of isolation between the PV system and supplier terminals to indicate the presence of on-site generation and indicating the position of the main a.c. switch disconnector (for suitable label see ER G83/1 or G59/2 see the sample reproduced in 'Example Signs' and on the back cover of this guide).**

- **At the point of interconnection, the following information is to be displayed (typically all displayed on the circuit diagram):**
  - **Circuit diagram showing the relationship between the inverter equipment and supply.**
  - **A summary of the protection settings incorporated within the equipment.**
  - **A contact telephone number for the supplier/installer/maintainer of the equipment.**
  - It is also good practice for shutdown and start-up procedures to be detailed on this diagram.

For PV systems fitted on roofs - to ensure the Fire and Rescue Service are aware that a PV system is installed on the roof - the following sign shall also be fitted next to the suppliers cutout in the property:



Editors note – label and location being checked with fire and rescue service

6 Test and commissioning requirements

6.1 Inspection and testing – ac side

Inspection and testing of the completed system to the requirements of BS 7671 must be carried out and documented

The inspection and testing of a.c. circuits is comprehensively covered within BS 7671 and supporting technical guides. The a.c forms are also available to download free of charge from the IET's website.

Inspection and testing documentation for the a.c. side typically comprises 3 forms

- electrical installation certificate,
- schedule of items inspected
- schedule of test results

6.2 Inspection and testing – PV Array

The inspection and testing of the DC side of the PV system shall be in accordance with the requirements of BS7671 and also BS EN 62446 *Grid connected photovoltaic systems — Minimum requirements for system documentation, commissioning tests and inspection*

The verification sequence contained within BS EN 62446 includes

- Inspection schedule
- Continuity test of protective earthing and/or equipotential bonding conductors (where fitted)
- Polarity test
- String open circuit voltage test
- String short circuit current test
- Functional tests
- Insulation resistance of the DC circuits

These tests shall be recorded on a PV array test report

Full details of the inspection schedule and guidance on test procedures is contained with BS EN 62446. This document also includes the following three pro-forma documents which will need to be completed for each installation:

- electrical installation certificate,
- schedule of items inspected
- test results

Editors note – Do we add more info on how to do these tests in an annex?

6.3 E.R. G83 and G59 requirements

Depending on the size of the PV installation, the requirements of either Engineering Recommendation G83 or G59 are to be followed when commissioning a grid connected PV system.

Systems up to 16A per phase come under ER G83. These systems will not require any extra commissioning procedures (measures other than those described elsewhere in this document).

Systems over 16A per phase come under ER G59. These systems may require additional commissioning tests to verify the correct and safe operation of the grid interface protection circuits. Smaller systems using G59/2 type approved inverters may not require any additional tests. However, larger systems or systems where separate protection relays are fitted (a "G59 relay"), on site testing of the relay and protection system will often be required. For some systems, particularly those over 50kWp, the DNO may wish to witness the tests. In all cases, the DNO needs to be consulted over the test procedure required and whether the tests need to be witnessed by a DNO representative. Further information on testing procedures is contained with ER G59/2.

Standard forms are provided by the DNO's to document the commissioning of a PV system. See section 2.4.1 for more details on the process to be followed.

7 Documentation

The system user should be provided as a minimum with the information as described in of BS EN 62446 *Grid connected photovoltaic systems — Minimum requirements for system documentation, commissioning tests and inspection*

The following provides a summary of the information required:

- Basic system information (parts used, rated power, installation dates etc)
- System designer information
- System installer information

- Wiring diagram, to include information on:
  - Module type & quantities
  - String configurations
  - Cable specifications – size and type.
  - Over-current protective device specifications (where fitted) - type and ratings.
  - Array junction box locations (where applicable).
  - DC isolator type, location and rating
  - Array over-current protective devices (where applicable) – type, location and rating
  - Details of all earth / bonding conductors – size and connection points.
  - Details of any connections to an existing Lightning Protection System (LPS).
  - Details of any surge protection device installed (both on AC and DC lines) to include
  - location, type and rating.
  - AC isolator location, type and rating.
  - AC overcurrent protective device location, type and rating.
  - Residual current device location, type and rating (where fitted).

- Module datasheets
- Inverter datasheets
- Mounting system datasheet

- Operation and maintenance information, to include
  - Procedures for verifying correct system operation.
  - A checklist of what to do in case of a system failure.
  - Emergency shutdown / isolation procedures.
  - Maintenance and cleaning recommendations (if any).
  - Considerations for any future building works related to the PV array (e.g. roof works).

- Warranty documentation for PV modules and inverters - to include starting date of warranty and period of warranty.
- Documentation on any applicable workmanship or weather-tightness warranties.
- Test results and commissioning data

Annex A … Battery systems

This section of the guide covers the additional requirements where a battery forms part of a PV installation – whether as part of a true stand-alone (off-grid) system or part of a hybrid (e.g. grid-linked/ batteries) system.

Note: The design and requirements of any of the load circuits within such a system are outside the scope of this document.

A1 PV array charge controller

This provides the regulator/dump interface between the PV array and the battery so as to prevent overcharging of the battery. The unit may also provide other functions such as maximum power point tracking, voltage transformation, load control and metering.

Diagram – martin has original

- **The charge controller must be rated for the current and voltage maxima (see Section 2.1.2, minimum voltage and current ratings)**
- **The charge controller must be labelled as per the d.c. junction box requirements in section 2.1.9.**
- **The charge controller must carry a CE Mark.**

A full recharge is important for good battery health. A small size cable between the charge control unit and the battery – with an associated high voltage drop – may lead to the control system prematurely halting the charge cycle. These cables should therefore be sized for a maximum voltage drop of less than 1% at peak PV array output. For controllers with a separate battery sense function, a fused battery sense cable can be installed.

A2 Battery over current protection

A battery stores significant energy and has the capacity to deliver large fault currents. Proper fault protection must be provided.

An over current device must be installed in all live (non-earthed) conductors between the battery and the charge controller.

The over current device (either a fuse or circuit-breaker) must:

- **have a trip value and response time as specified within the charge controller manual**
- **be rated for operation at d.c., at 125% of the nominal battery voltage**
- **have an interrupt rating greater than the potential battery shortcircuit current.**

The length of cable between the over current device and battery terminal must be as short as practicable.

A3 Battery disconnection

A means of manual isolation must be provided between the charge controller and the battery, either combined with the over current device or as a separate unit. The isolator must be double pole, d.c. rated and load break, and the length of the cable between it and the battery must be as short as practicable. In positioning this device, the requirements of section A7 are also to be observed.

Note: In order to keep the cable run as short as practicable and to keep the device away from battery gasses – isolation devices will typically be located immediately to the side of the battery bank (rather than directly above).

Isolation is to be installed and the system designed so that the PV array cannot directly feed the loads when the battery has been disconnected.

Combined fault protection and isolation:

- **A circuit-breaker provided for battery fault current protection may be used to provide isolation, if it is rated as an isolation device.**
- **A fuse assembly provided for fault current protection may be used to provide isolation if it has readily removable fuses (eg fuse unit with disconnect mechanism)**

A4 Cables in battery systems

The requirements set out in the main sections of this guide apply: *Note: In some circumstances, a voltage drop greater than that in section 2.1.4.1 may be justified on economic grounds.* In addition:

All cables must have a current rating above that of the relevant over current device (nearest downstream fuse / circuit breaker). Cable current ratings are to be adjusted using standard correction factors for installation method, temperature, grouping and frequency to BS 7671.

A5 PV String cable and fuse ratings

String cables (upstream of the charge controller) must be rated to the trip current of the nearest downstream device plus the rating as calculated in section 2.1.5.

A PV–battery system must be designed such that the string cable/ string fuse design and specification reflects that fault currents may come either from the array itself, from the battery or from both. Again, cable current ratings are to be adjusted using standard correction factors for installation method, temperature, grouping and frequency to BS 7671.

Note: Specification & labelling for the PV cables/ junction boxes/ connectors/ etc should be as in the main sections of the guide.

A6 Battery selection and sizing

The selection of a battery is generally out of the scope of this document. However, some key considerations are:

- is the battery fit for purpose, i.e. appropriately rated for its duties? In the majority of cases a true 'deep cycle' battery will be required
- does it have an adequate storage capacity (days of autonomy) and cycle life?
- is a sealed or vented battery more appropriate for the particular installation?
- will the battery be made up of series cells or parallel banks? While series cells will generally give better performance, practical considerations may influence the design. In general, though, banks with more than four parallel units are to be avoided.

The sizing of a battery is generally out of the scope of this document. However, for an effective charging regime where a PV array is the only charge source, the battery would normally be sized so that the output of the PV array falls between the manufacturer's maximum and minimum recommended charge rates.

Charge/discharge rates (C) are commonly expressed as an hourly rate derived from the formula: Rate = Capacity (Ah) / Time (h) For example, a C10 charge rate for a 500Ah battery would take place at 50A.

Charge rates between C5 and C20 are often used in systems with vented lead acid batteries, for example.

A7 Battery installation/labelling

In an enclosed location, ventilation must be provided to battery installations with an air inlet at low level and an outlet at the highest point in the room or enclosure.

Sufficient ventilation is needed to remove battery gases. It is particularly important in the case of vented lead acid units as hydrogen is given off during charging (which is lighter than air) – and a concentration of more than 4% creates an explosion hazard. Ventilation also prevents excessive heat build up.

BS 6133 'Safe operation of lead acid stationary batteries' gives a procedure for calculating ventilation requirements.

Battery banks must be housed in accordance with BS 6133 and such that:

- **access can be restricted to authorised personnel**
- **adequate containment is assured**
- **appropriate temperature control can be maintained**

Battery terminals are to be guarded so that accidental contact with persons or objects is prevented.

The ideal operating temperature for a lead acid battery is around 25ºC, temperatures significantly above or below this will lead to reduced lifetime and capacity. Indeed, at very low temperatures, discharged batteries may freeze and burst; at high temperatures, thermal runaway can occur in sealed batteries.

Items which could produce sparks (e.g. manual disconnects, fuses, relays) should not be positioned within a battery box or directly above one.

Battery gases are corrosive, so cables and other items inside a battery enclosure need to be corrosion resistant. Sensitive electronic devices should not be mounted in, or above, a battery box.

To ensure proper load/charge sharing in a battery bank made up of units connected in parallel, the units need to have the same thermal environment and the same electrical connection resistance.

In larger battery banks, fusing each parallel unit should be considered.

A typical connection configuration for a small series-parallel bank (take-offs are on opposite corners):

Diagram – martin has original

The following warning signs are to be displayed:

- **No Smoking or Naked Flames**
- **Batteries contain acid – avoid contact with skin or eyes**
- **Electric shock risk – xxx Vd.c.**

Note: Circuit protection, and all points of isolation should also be labelled with “d.c. Supply – xxx Vd.c.”

All labels should be clear, easily visible and should be constructed and fixed so as to remain legible and in place throughout the design life of the system.

Protective equipment, including appropriate gloves and goggles – together with an eye wash and neutralising agent – should be stored adjacent to the battery installation.

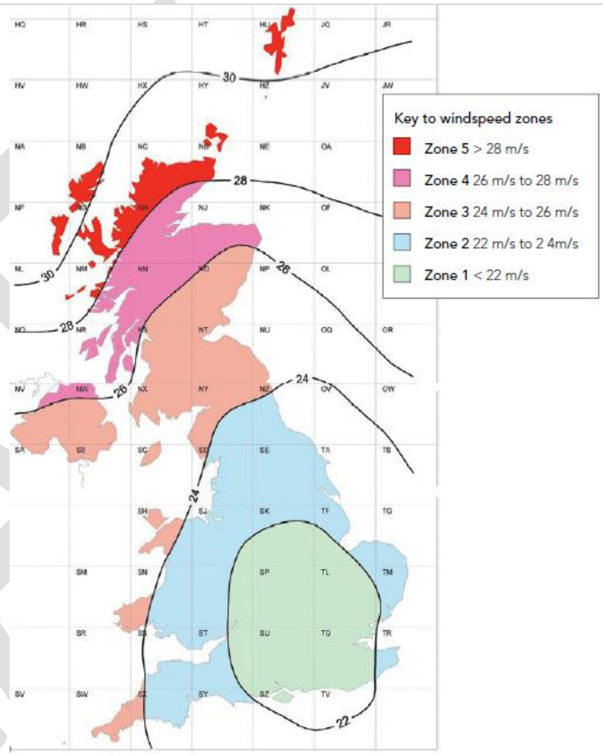
Annex B - Simplified method for determining peak wind loads

The following simplified procedure to calculate wind loads is based on the on the peak velocity pressures derived from Eurocode-1 (BS EN 1991-1-4). A more accurate, typically lower value can be determined using the methodology and tables within Eurocode-1.

Note: This method is taken from work undertaken by the NHBC Foundation, who's contribution is gratefully acknowledged.

a) With reference to the site wind zone, site type (rural – urban), the ridge height of the building and the distance of the site from the sea - derive the peak velocity pressure (qp) from the table:

Peak Velocity pressures (q_p) in Pascals							
Wind zone	Ridge height (m)	Country terrain			Urban terrain		
		Distance to sea			Distance to sea		
		<2km	2-20km	>20km	<2km	2-20km	>20km
1	5	869	783	718	688	620	569
1	10	1009	955	872	883	836	763
1	15	1094	1062	977	1012	982	904
1	20	1122	1108	1017	1066	1052	966
1	25	1166	1166	1072	1137	1137	1045
2	5	1034	931	854	819	738	677
2	10	1201	1136	1038	1050	994	908
2	15	1302	1264	1163	1204	1169	1075
2	20	1335	1318	1210	1268	1253	1149
2	25	1388	1388	1276	1353	1353	1244
3	5	1213	1093	1003	961	866	794
3	10	1409	1334	1218	1233	1167	1066
3	15	1527	1483	1364	1413	1372	1262
3	20	1567	1547	1420	1489	1470	1349
3	25	1629	1629	1498	1588	1588	1460
4	5	1407	1268	1163	1115	1004	921
4	10	1634	1547	1413	1430	1353	1236
4	15	1772	1720	1582	1639	1591	1464
4	20	1817	1795	1647	1726	1705	1565
4	25	1889	1889	1737	1842	1842	1694
5	5	1703	1534	1407	1349	1215	1115
5	10	1977	1872	1710	1730	1638	1496
5	15	2144	2081	1915	1983	1925	1771
5	20	2199	2171	1993	2089	2063	1893
5	25	2286	2286	2102	2229	2229	2049



Notes:

- Sites less than 300 m from the edge of a town should be assumed to be in country terrain
- Where a site is less than 1 km from a lake which then extends for at least 1km in that same direction - the "distance to sea" should be taken as <2 km
- Interpolation between values is permitted

b) Apply correction factors for site altitude (h) in meters:

Height above sea level	Correction factor
0-100m	None
>100m	$1 + \left[\frac{h-100}{100} \times 0.2 \right]$

Note: the altitude correction formula for sites over 100m above sea level calculates a 20% increase for each 100m above the initial 100m. Hence a site at 180m above sea level would have a correction factor of 1.16.

c) Apply correction factor for topography

Site classification	Correction factor	
Zone 1	None	Diagram showing scarp & hill top
Zone 2 – slope up to 10%	1.2	
Zone 2 – slope up to 20%	1.45	
Zone 2 – slope up to 30%	1.7	

d) Calculate wind pressure using the following formula

$$\mathbf{w = q_p \times c_p}$$

Where: w … is the wind pressure in Pascals
qp … is the peak velocity pressure derived in steps a-c
cp … is the pressure coefficient for the particular installation

Note: the pressure coefficient cp will depend upon the type of system and the array location on the building. The procedure for selecting the appropriate pressure coefficient is covered in clause xxx.

Note: A safety factor will also need to be applied to the derived load – see clause xx for more details

Example calculation #1

- Above roof PV array, mounted away from edges in central zone of roof (Cp uplift = -1.3)
- Site located in central London (more than 2km from edge of town)
- Site more than 20km from the sea
- Building height = 10m
- Site altitude = 20m
- Topography = not significant

a) Site in in zone 1 (22 m/s) → Table gives value for q_p = 763Pa

b) Altitude correction factor = none
c) Topography correction factor =

d) W_{uplift} = 763 x -1.3 = -992Pa *(value excludes safety factor)*

Example calculation #2

- Above roof PV array, mounted away from edges in central zone of roof (Cp uplift = -1.3)
- Site located in rural Yorkshire near the top of a hill of 8% slope
- Site more than 20km from the sea
- Building height = 10m
- Site altitude = 150m

e) Site in in zone 2 (24 m/s) → Table gives value for q_p = 1038Pa

f) Altitude correction factor = 1 + (150-100/100)*0.2 = 1.1
g) Topography correction factor = 1.2

h) W_{uplift} = 1038 x 1.1 x 1.2 x -1.3 = -1781Pa *(value excludes safety factor)*

Annex C – Annual output estimation - worked examples

To be updated once procedure confirmed.

Not yet edited the final sections

FURTHER READING

- NB: Check corrosion clause in MIS 3002 on external metal work.
- NB: Reference docs only referred to in the guide.
- BS 7671: 2001 'Requirements for Electrical Installations, IEE Wiring Regulations', Sixteenth Edition (incorporating Amendments), ISBN: 0 86341 373 0, www.iee.org/publish/books/WireAssoc

- IEE Guidance Note 7 - Special Locations, (2nd Edition), ISBN 0 85296 995 3, www.iee.org/publish/books/WireAssoc Note: IEE Guidance Note 7 - Special Locations, Chapter 12 covers 'Solar photovoltaic (PV) power supply systems' as a 'special location' as defined in IEE Regs. The guidance is based on IEC 60364-7-712: 'Requirements for special installations or locations – Solar photovoltaic (PV) power systems'.

- Part P (Electrical safety) - Building Regulations, www.odpm.gov.uk/index.asp?id=1130906 Note: From 1st January 2005, people undertaking electrical work in homes and gardens in England and Wales have had to follow new rules in Building Regulations. Virtually all domestic PV installations will fall under the scope of Part P.

There are two routes to comply with the requirements of Part P:
• Notify the relevant Building Control department before starting the work
• The contractor registers under a Competent Person Scheme (as approved by the office of the deputy prime minister)
Note: An electronic version of the form is available at the Local Authority Building Control (LABC) website www.link2content.co.uk/uploads/buildingnotice%202005%20unprotected (1).doc, and it can be submitted using their 'Submit-a-Plan' scheme www.labc-services.co.uk/buildingregs/default.asp.

- Engineering Recommendation G83/1: Sept 2003, 'Recommendations for the connection of Small-scale Embedded Generators (up to 16A per phase) in parallel with Public Low-Voltage Distribution Networks', (Energy Networks Association, 2003), www.energynetworks.org/dg01.asp
Note: This simplified connection route applies to 'type tested' inverters for systems up to about 5kVA per phase (see sect 2.4.1). Prior-notification of the Distribution Network Operator (DNO) is not required for 'single' installations, but is required for 'multiple' single phase installations. It refers to the Electricity Safety, Quality and Continuity Regulations (ESQCR), 2002. Draft prEN 50438 'Requirements for the connection of micro-cogenerators in parallel with public low-voltage distribution networks' is a European version, which once issued, will also cover systems up to 16A..
_ Engineering Recommendation G59/1, 'Recommendations for the connection of Embedded Generating Plant to the Regional Electricity Companies' Distribution Systems', (Electricity Association, 1991), www.energynetworks.org/dg01.asp Note: This is the Electricity Industry Recommendation for connection of generators. It is applicable if the inverter is not covered under G83/1.

- IEC 61215 Building Control Approval 'Crystalline silicon terrestrial photovoltaic (PV) modules – Design qualification and type approval', www.iec.ch Note: This is the International standard for crystalline PV. It specifies requirements for the design qualification and type approval of terrestrial photovoltaic modules suitable for long-term operation in general open-air climates, as defined in IEC 60721-2-1. It determines the electrical and thermal characteristics of the module and shows, as far as possible, that the module is capable of withstanding prolonged exposure in certain climates.
- IEC 61646 'Thin film terrestrial photovoltaic (PV) modules – Design qualification and type approval', www.iec.ch Note: This is the International standard for thin film PV. It specifies requirements for the design qualification and type approval of terrestrial thin-film photovoltaic modules suitable for long-term operation in moderate open-air climates.
- IEC 61730-1 'Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction & IEC 61730-2 'Photovoltaic (PV) module safety qualification - Part 2: Requirements for testing', www.iec.ch Note: Part 1 is Fundamental construction requirements, Part 2 is Testing requirements. These two international standards specify requirements for photovoltaic modules in order to provide safe electrical and mechanical operation during their expected lifetime. They address the prevention of electrical shock, fire hazards, and personal injury due to mechanical and environmental stresses. Pertains to the particular requirements of construction and is to be used in conjunction with IEC 61215 or IEC 61646.
- IEC61215 Building Control Approval, www.odpm.gov.uk/index.asp?id=1130474, www.labc-services.co.uk/buildingregs/default.asp Note: For 'integrated products' in the UK where the PV forms part of the building envelope (eg PV roof tiles), proof of compliance with relevant Building Regulations may be required by the local Building Control Inspector, eg compliance to: • Fire resistance standards (eg BS 476- part 3) • Relevant wind uplift and weatherproofing standards (eg BS 6399, BS 5534). See also BRE Digest 489 & 495 below which are specific to PV.
- PPS22 'Planning Policy Statement 22: Renewable Energy, ISBN 0 11 753924 4, 2004, www.odpm.gov.uk/index.asp?id=1143908 Note: UK Planning Consent (if required). PPS22 replaces UK Planning Policy Guidance note (PPG)22. It sets out the Government's planning policies for renewable energy, which planning authorities should have regard to when preparing local development documents and when taking planning decisions. Also see 'Planning for Renewable Energy; A companion Guide to PPS22', which provides additional guidance for PV in Technical Annex 6 Active Solar (Photovoltaics), ISBN 1 85112 7542.
- BRE Digest 489 – 'Wind loads on roof-based photovoltaic systems', ISBN 1 86081 713 0, 2004, www.brebookshop.com Note: This Digest reviews the wind loading information appropriate for roof-based PV systems and gives recommendations and guidance for the design of roof-based PV systems for wind loads. It covers both PV tiles or slates integrated into pitched roofs and PV modules mounted on or above pitched roofs.
- BRE Digest 495 – Mechanical installation of roof-mounted photovoltaic systems, ISBN 1 86081 869 23, 2005, www.brebookshop.com Note: This Digest gives guidance on installing and using photovoltaic systems on roofs. The guidance refers only to the mechanical installation of roof mounted integrated and stand-off photovoltaic systems; it provides best practice guidance on installation requirements and does not constitute fixing instructions.

References

- 'Photovoltaics in Buildings – Safety and the CDM Regulations', (BSRIA/DTI Feb 2000, ISBN 0 86022 548 8), www.bsria.co.uk/bookshop/system/index.html Note: This covers larger systems, although most of the safety advice is also relevant to small installations that may be exempt from the Regulations. It provides a simple guide to the Construction Design and Management Regulations 1994 (CDM Regulations), with regard to the design, installation, operation, maintenance, decommissioning and disposal of PV installations in buildings. It also provides a commentary on the UK legislative framework with particular reference to CDM Regulations, hazards and risks associated with PV installations, and PV issues that must be addressed in the Health and Safety Plan and Health and Safety File.

- Draft IEC 62446 Ed.1 'Grid connected PV systems – Minimum system documentation, commissioning tests and inspection requirements'. Note: This standard will define the minimum information and documentation required to be handed over to a customer following the installation of a grid connected PV system. This document also describes the minimum commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system. This document is not written for AC module systems or systems that utilize energy storage (e.g. batteries) or hybrid systems.

- Guide CE72 'Installing small wind-powered electricity generating systems', Energy Efficiency Best Practice in Housing, 2004 Note: A companion Guide for small wind systems 500W to 25kW.

- Draft IEC 62257-7-2 Technical Specification: 'Recommendations for small renewable energy and hybrid systems for rural electrification – Part 7-1: Generators – Photovoltaic arrays Note: This is a draft Technical Specification not a Standard, but includes much useful guidance and explanation of international best practice for installation of PV systems.

- BS 6133:1995, 'Code of practice for Safe operation of lead-acid stationary batteries' Note: This includes guidance on design, operation & maintenance of battery systems.

- BSI PD 6484:1979, 'Commentary on corrosion at bimetallic contacts and its alleviation' Note: This includes guidance on the selection of metals for mechanical design of arrays

- BS 476 'Fire tests on building materials and structures'

- BS 6399 'Loading for buildings. Code of practice.'

- BS 5534 'Code of practice for slating and tiling (including shingles)'

- BS 3535 'Specification for safety isolating transformers for industrial and domestic purposes'

- BS 60947 'Specification for low-voltage switchgear and controlgear'

- BS3858 'Specification for binding and identification sleeves for use on electric cables and wires'

- PD 6484 'Commentary on corrosion at bimetallic contacts and its alleviation'

Note: Information on the current Government's Grant scheme 'Low Carbon Buildings Programme' can be found on the Energy Saving Trust website www.est.org.uk

Sample Dual Supply Label G83/1 – Martin has original

Isolate on-site generator at Isolate mains supply at WARNING dual supply