ADVICE ON AS/NZS 5033

Version 2, May 2023

PREFACE

About this document.

This Advice document has been prepared by the Clean Energy Council to assist industry understand and interpret **AS/NZS 5033:2021 – Installation and safety requirements for photovoltaic (PV) arrays.**

This advice alone does not constitute a fully definitive set of rules and should be read in conjunction with existing relevant standards, codes, and network service provider rules.

Where possible, this advice document has been written to align with the section references of AS/NZS 5033:2021.

While all care has been taken to ensure this advice is free from omission and error, no responsibility can be taken for the use of this information.

The CEC have created further tools to assist the industry. These tools can be accessed using the following link:

CEC Advice | Clean Energy Council

The CEC encourage feedback or requests for additional clarification of requirements using the following online form:

Feedback | Clean Energy Council

The CEC will continue to work with the Clean Energy Regulator (CER), state & territory electrical safety regulators and industry bodies to keep this document updated.

The performance of a reliable installation that fulfils system owner expectations requires both careful design and correct installation practice.

The objective of this advice is to:

- improve the safety, performance, and reliability of photovoltaic (PV) arrays
- encourage industry best practice for all design and installation work
- Clarify some of the requirements in AS/NZS 5033:2021

NOTE: AS/NZS 5033:2021 superseded AS/NZS 5033:2014 and is now mandatory in all states and territories.

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1 INTRODUCTION AND SCOPE

1.1 Scope and General

AS/NZS 5033 underwent a significant rewrite in recent years. The current published version was released on 19 November 2021.

This advice document aims to provide advice on requirements that are complex or open to interpretation but does not go beyond the scope of AS/NZS 5033:2021 as outlined in clause 1.1 of the standard.

There are several changes to requirements in AS/NZS 5033:2021. They include but are not limited to:

- increase in maximum PV array voltage for residential systems
- PV Array isolation – load breaking disconnectors and disconnection points
- installation of DC wiring systems and wiring enclosures
- earthing
- changes to d.c. optimisers and micro inverters
- testing and verification.

NOTE: The numbering and titles used in this document align with the clause numbers and titles found in AS/NZS 5033:2021 and as such may not be sequential in all instances

1.2 References

Licensed electricians working on PV and battery systems should have access to the following standards when reading this document. This advice is designed to be read in conjunction with the documents listed below.

AS 1768	Lightning protection
AS/NZS 1170.2	Structural design actions, Part 2: Wind actions
AS/NZS 3000	Electrical installations [known as the Wiring rules]
AS/NZS 3008 (series)	Electrical installation – Selection of cables
AS/NZS 4509 (series)	Stand-alone power systems
AS/NZS 4777 (series)	Grid connection of energy systems via inverters
AS/NZS 5033	Installation and safety requirements for photovoltaic (PV) arrays
AS/NZS 5139	Electrical installations – Safety of battery systems for use with power conversion equipment

The system shall comply with the relevant electrical Codes of Practice, Service and Installation Rules (SIRs) for the state or territory where the system is installed.

The network service provider (NSP) may have additional requirements, including pre-approval applications, export requirements and provision of documentation to enable connection to the grid.

1.3 Terms and Definitions

Throughout this document, the definitions in AS/NZS 3000 and AS/NZS 5033:2021 apply.

1.4 Notations

AS/NZS 5033:2021 has a detailed list of notations relating to formulas and measurements that designers and installers will need to be aware of.

2 PV SYSTEM CONFIGURATION

2.1 Configuration

2.1.1 General

One of the first new terms used in this standard is “application circuit”. This is defined in the standard as – final circuit supplied by the PV array (Cl 1.3.2).

The new version of the standard considers the following as types of application circuits.

- PV array connected to d.c. loads.
- PV array connected to an a.c. system via a separated PCE.
- PV array connected to an a.c. system via a non-separated PCE.

2.1.2 PV system architectures

The standard refers to the architecture of a system as the way in which the PV system relates to earth and is determined by:

- any functional earthing of the array in use
- the earth status of the application circuit to which the array is connected.

Both issues may affect the safety of the array and installers shall follow all manufacturer’s instructions (including the PCE manufacturers) when considering earthing arrangements.

2.1.3 Array electrical diagrams

The standard provides some possible configurations of PV systems. Figures 2.2 to 2.4 in the standard show some basic typical electrical configurations of single string, multiple parallel strings and multi-sub-array PV respectively.

2.1.4.1 Use of PCE with multiple d.c. inputs - General

PV array/s are often connected to PCE with Multiple d.c. inputs.

These inputs can either be separate maximum power point tracking (MPPT) inputs OR multiple inputs internally connected (paralleled) in the PCE.

The input circuits of the PCE will have a critical impact on the selection of overcurrent protection and cable sizing.

Each PV section connected to a MPPT input may be treated as a separate PV array. For the purposes of this standard see Figure 2.5. Manufacturer's specifications will need to be referenced.

Key points

- PCEs with multiple d.c. inputs and the various sections of the PV array(s)
- overcurrent protection and cable sizing requirements are critically dependent on internal input circuits of the PCE.
- each PV section connected to a MPPT input may be treated as a separate PV array.
- manufacturer's specifications required.
- see AS/NZS 5033:2021 Cl 2.1.4.2 & 2.1.4.3
- see AS/NZS 5033:2021 Figures 2.5 and 2.6

3 SAFETY ISSUES

3.1 Maximum voltage limits

In domestic installations the PV array maximum voltage has been raised to 1000V d.c. allowing greater flexibility with string configurations.

Be aware, for grid connected systems the voltage limits of AS/NZS 4777.1 takes precedence.

In non-domestic installations the PV array maximum voltage is allowed to be up to or equal to 1500V d.c.

Note: 'domestic' is defined in AS/NZS 3000 Cl 1.4.53

Key points:

- The calculated PV maximum voltage of PV d.c. circuits shall not be greater than 1000V d.c. for domestic electrical installations.
- The calculated PV maximum voltage of PV d.c. circuits shall not be greater than 1500V d.c. for other electrical installations.
- *NOTE: See Clause 4.2.1.3 for PV d.c. circuit maximum voltage calculation.*

Note: AS/NZS 4777.1:2016 Clause 2.3 prohibits domestic dwellings from having a d.c maximum voltage greater than 600V for grid connected systems.

Worked example

Max voltage limits (cl. 3.1)
PV module maximum voltage calculation (cl. 4.2.1.2, 4.2.1.3.2)

SCENARIO:
You have an array of 10 modules 3 of which have optimisers, calculate the PV maximum voltage of the array.

VDCU string max = (VDCU max x number of DCUs in series) + (Vmod max x m)

Optimised panels;

VDCU max = DCU maximum output voltage as determined by the DCU manufacturer = 50V (from spec sheet)
For the 3 optimised PV modules in series = 150V

Non-optimised panels;

Use the formula VMOD MAX = VOC MOD + yv(Tmin – TSTC)

Where;
VOC MOD = 49.5 (from spec sheet)
Yv = Voltage temp co-efficient (V/°C) = -0.27%/°C (from spec sheet – convert by multiplying Voc by -0.27/100 = -0.13V/°C)

Tmin = expected minimum daily cell temperature (°C) (use lowest temperature recorded for the area on the BOM website) = -2°C
TSTC = Cell temp at standard test conditions = 25°C

VMOD MAX = 49.5 + -0.13x(-2 – 25)
= 49.5 + 3.51
= 53.01V

For 7 non-optimised PV modules in series = 371.07

Therefore, VDCU string max = 150 + 371.07 = 521.07V

3.3 Protection against overcurrent

3.3.3.1 Calculation of maximum string current

- String containing no DCUs:
  - $I_{STRING\ MAX} = 1.25 \times K_I \times I_{SCMOD}$
    K_I will be 1 unless using bifacial modules.
- Strings containing partial DCUs, the greater of the following:
  - $I_{STRING\ MAX} = I_{DCU\ STRING\ MAX}$
    OR
  - $I_{STRING\ MAX} = 1.25 \times KI \times I_{SC\ MOD}$
    K_I will be 1 unless using bifacial modules.
- Strings with DCUs on all modules:
  - $I_{STRING\ MAX} = I_{DCU\ string\ max}$
- See AS/NZS 5033:2021 Appendix J for the determination of KI.

3.3.4.1 Strings

When strings are connected in parallel there is the potential for fault conditions to occur where current can backfeed and damage PV modules. For modules only this formula can be used,

$I_{F\ STRING} = (S_A-1) \times I_{STRING\ MAX}$

Faults could occur from any combination of d.c. equipment connected in parallel.

Examples:
- multiple parallel strings of PV modules ($I_{F\ STRING}$)
- a single string of PV modules ($I_{F\ STRING}$) and a d.c. coupled battery ($I_{BF\ TOTAL}$).

To protect against this, overcurrent protection shall be provided when:

$I_{F\ STRING} + I_{BF\ TOTAL} > I_{MOD\ MAX\ OCPR}$

Where:

$I_{F\ STRING}$ = potential fault current in a string from other parallel strings (see clause 3.3.3.)
$I_{BF\ TOTAL}$ = total continuous backfeed current from all sources not originating at the PV modules such as from PCEs or other external sources that are directly connected to the array. This value should be provided by the PCE manufacturer.
$I_{MOD\ MAX\ OCPR}$ = PV module maximum overcurrent protection rating as determined by IEC 61730-2

If overcurrent protection is required see AS/NZS 5033:2021 Cl 3.3.5.
Additional voltage and current calculations for PV d.c. can be found in AS/NZS 5033:2021 Cl 4.2

Key points

- When strings are connected in parallel there is the potential for fault conditions to occur where current can backfeed and damage PV modules.
- This could be any combinations of d.c. equipment connected in parallel.
- To protect against this, overcurrent protection shall be provided when:
- $I_{F\ STRING} + I_{BF\ TOTAL} > I_{MOD\ MAX\ OCPR}$.
- If overcurrent protection is required see AS/NZS 5033:2021 Cl 3.3.5

Voltage and current calculations for PV d.c. can be found in AS/NZS 5033:2021 Cl 4.2

Worked example

EXAMPLE 01

Max string current (cl. 3.3.3.1)

SCENARIO:

You have a string of 13 panels, 3 of which have optimisers. The maximum string current will be the greater of the following;

$I_{STRING\ MAX} = I_{DCU\ string\ max}$

$I_{DCU\ string\ max}$ = DCU maximum overcurrent protection on the DCU string side

= 18.75A (from manufacturer's specifications)

OR

$I_{STRING\ MAX} = 1.25 \times K_I \times I_{SC\ MOD}$

Where K_I = adjustment factor = 1, except for bifacial panels in beneficial light incidence on the back surface conditions whereby the ISC BNPI must be obtained from the manufacturer, $K_I = I_{scBNPI}/I_{SC\ MOD}$) (AS/NZS5033:2021 appendix J)

$I_{SC\ MOD}$ = 10.12A (from spec sheet)

= 1.25 X 1 x 10.12

= 12.65A

Therefore, the max string current = 18.75A.

EXAMPLE 02

Protection against overcurrent (cl. 3.3.3.2) – Fuse sizing

SCENARIO
You have 3 strings in parallel with no optimisers, if the following equation is met, string fusing is required.

$I_{F\ STRING} + I_{BF\ TOTAL} > I_{MOD\ MAX\ OCPR}$

Where;
$I_{F\ STRING} = (S_A-1) \times I_{STRING\ MAX}$

S_A = number of strings in the array

$I_{STRING\ MAX} = 1.25 \times K_I \times I_{SC\ MOD} = 1.25 \times 1 \times 10.12 = 12.65A$

$I_{BF\ TOTAL}$ = 0, There is no battery or other sources connected

$I_{MOD\ MAX\ OCPR}$ = 20A (sometimes called series fuse rating or reverse current rating)

Therefore $I_{F\ STRING} = (3-1) \times 12.65A$
= 25.3A, which is greater than 20A therefore string fusing is required.

Sizing the fuses; (Table 3.1)

For this string with no DCUs the fuse size can range between
$1.2 \times I_{STRING\ MAX} < In < I_{MOD\ MAX\ OCPR}$
Where;
In = the nominal overcurrent protection rating of the overcurrent protection device

Therefore the fuse size can be between 1.2 x 12.65A and 20A
= 15.18A and 20A

4 SELECTION AND INSTALLATION OF ELECTRICAL EQUIPMENT

4.1 General

The order of Section 4 is written to start at the array, move through the disconnection methods, overcurrent protection and wiring systems, then finishes with connection to the PCE. Earthing requirements are towards the end. The section encourages use of disconnection points, string overcurrent protection and inverter integrated isolators through requirements for drainage devices, additional isolators, larger array earth conductors and strict isolator shroud requirements where other methods are utilised.

4.3 PV arrays

4.3.2.3.2 Restricted access to PV modules

Restricted access shall be provided to PV modules and wiring systems where installed within 2.5m from the ground, floor or platform and are not installed on a roof. This may be achieved through use of a fence or barrier. (Also see 4.4.5.2.2 on additional mechanical protection)

Note: Restricted access is defined in AS/NZS5033:2021 Clause 1.3.37
AS/NZS4509.1 may provide a guide as to what constitutes a fence or barrier.

4.3.3.1 Part 1 – PV modules installed within 1.5m of the inverter

A disconnection device must be installed adjacent to the PV module(s).
For string systems using disconnection points see cl 4.3.8, selection of plugs, sockets and connectors.
For more detail relating to Micro inverters see AS/NZS3000 relating to isolators on electricity generation systems and AS/NZS4777.1 relating to isolators adjacent inverters.

4.3.3.1 Part 2 – Disconnection points

A disconnection point shall be provided to isolate each string at the PV modules when the calculated PV d.c. circuit maximum voltage exceeds 120V, unless there is a load-break disconnection device installed adjacent to the array (refer to exception).

The requirements for disconnection points are described in AS/NZS 5033:2021 Clause 4.3.5.2.1

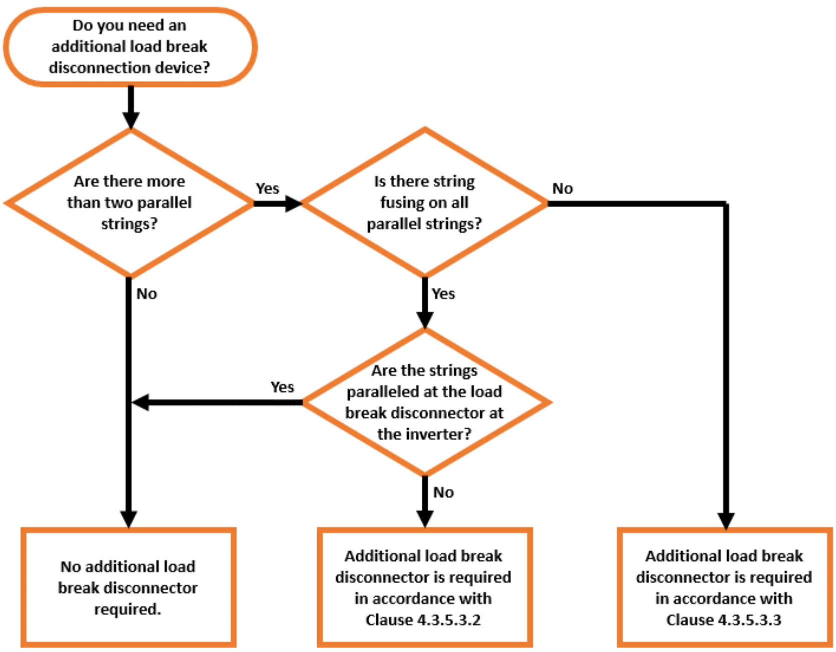
The decision tree in Figure 4.2 is used to determine if an additional load break disconnection device is required.

An additional load break disconnector is required in arrays with more than two parallel strings where the strings are fused or if they are fused but **NOT** paralleled at the load break disconnector at the inverter.

Where a load break disconnection device is required in addition to the disconnection point, it shall be selected in accordance with AS/NZS 5033:2021 Clause 4.3.4.2 and installed in accordance with AS/NZS 5033:2021 Clause 4.3.5.3.

Key points:

- a disconnection point shall be provided when PV d.c. circuit maximum voltage exceeds 120V
- there is an exception to this requirement where a disconnection point is not required to isolate each string, where a load break disconnection device is installed adjacent to the PV modules of the PV array that is being isolated.
- use Figure 4.2 decision tree to determine requirements



4.3.4.2.2 Switch disconnectors

Suitably rated load break switch disconnectors or circuit breakers may be used to disconnect the PV circuits under load.

The ratings of load break switch disconnector or circuit breakers shall consider full load and prospective fault currents that may originate at the PV array and any other connected power sources (such as batteries).

Key points:

- When selecting a switch disconnector, they shall:
- be rated for d.c. use
- interrupt all live conductors simultaneously (i.e.- have at least one pole per polarity)
- be capable of being secured in the open position.
- be an independent manual operation
- not be polarity sensitive
- conform with switch disconnector requirements of AS 60947.3 with utilization category d.c.-PV2
- be rated according with AS/NZS 5033:2021 Cl 4.3.4.2.3

4.3.5.2.1 Disconnection point

A disconnection point is a **non-load break disconnection device** that can be used at the array, where permitted, in the place of an alternative disconnection device.
It must be selected as per AS/NZS 5033:2021 Cl 4.3.8 and installed as per AS/NZS 5033:2021 Cl 4.3.9

Key points

- When selecting a disconnection point, they shall:
    - be adjacent to the PV modules of the array
    - be readily available
    - be protected against weather and water, no more than 150mm from the edge of the module that they are installed under
    - adequately supported so that there is no undue stress on the connection, but able to be disconnected
    - have both the positive and negative disconnection device located together
    - labelled in accordance with AS/NZS 5033:2021 Cl 5.5.2.2
    - documented in accordance with AS/NZS 5033 Cl 5.6
- Selected in accordance with AS/NZS 5033:2021 Cl 4.3.8
- Installed in accordance with AS/NZS 5033:2021 Cl 4.3.9.

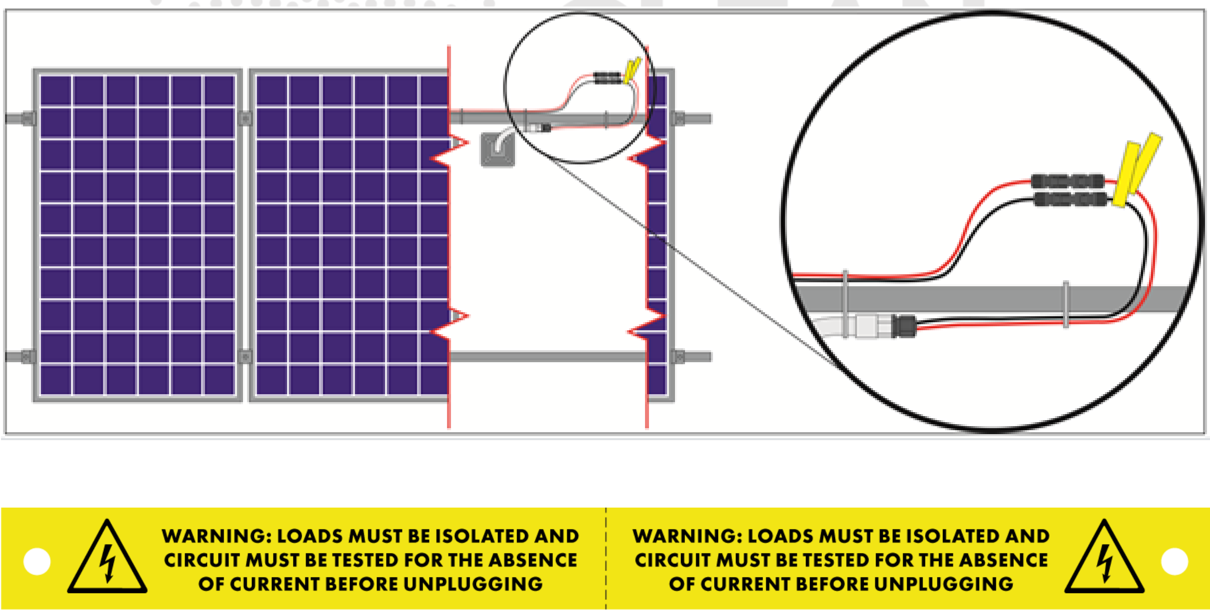


Figure A4.1: Disconnection points

CEC recommends using stainless steel cable clips to support the cables to the module frame either side of the connectors, ensuring the DP is readily available.

4.3.5.3 Load break disconnection device

4.3.5.3.1 General

Where required to be installed by other clauses, a load break disconnection device must meet the requirements of AS/NZS 5033:2021 Cl 4.4.7.

This clause also contains location, marking and documentation requirements and a number of methods to protect against the spread of fire.

Key points

- The load break disconnection device shall;
  - Meet the requirements of AS/NZS 5033:2021 Cl 4.4.7
  - Be readily available
    (*Note 1 of clause 4.3.5.3.1(b) specifies additional requirements for devices mounted under modules to be considered readily available)*
  - Marked in accordance with AS/NZS 5033:2021 Cl 5.5.2.1
  - Documented in accordance with AS/NZS 5033:2021 Cl 5.6
- Be installed external to the building

Meet one or more of the requirements of the clause to protect against the spread of fire by being installed in a metal enclosure, on a non-combustible surface, or mounted on a shroud, with specific requirements for each specified by the standard.
(*with any penetration through a surface that protects against the spread of fire that has an internal free space greater than 5mm diameter, sealed with fire retardant.)*

4.3.5.3.2 Load break disconnection devices on systems with string fusing

When a load break disconnection device is required according to AS/NZS 5033:2021 Cl 4.3.3.1 and Figure 4.2 it shall be installed at the connection point, where the strings are paralleled together.

Key points

- Determine if a load break disconnection device is required according to AS/NZS 5033:2021 Cl 4.3.3.1 and Figure 4.2.
- When a load break disconnection device is required, it shall be installed at the connection point where the paralleling occurs.
- There are exceptions to this clause if being applied to PV arrays on large scale ground mounted PV power plants, if they are electing to apply the standard to meet safety requirements. (Not applicable for arrays installed within the scope of the standard).

Note: The requirement for this load break disconnection device to be installed at the array can be avoided by ensuring strings are paralleled at the inverter. See AS/NZS5033:2021 Figure 4.2

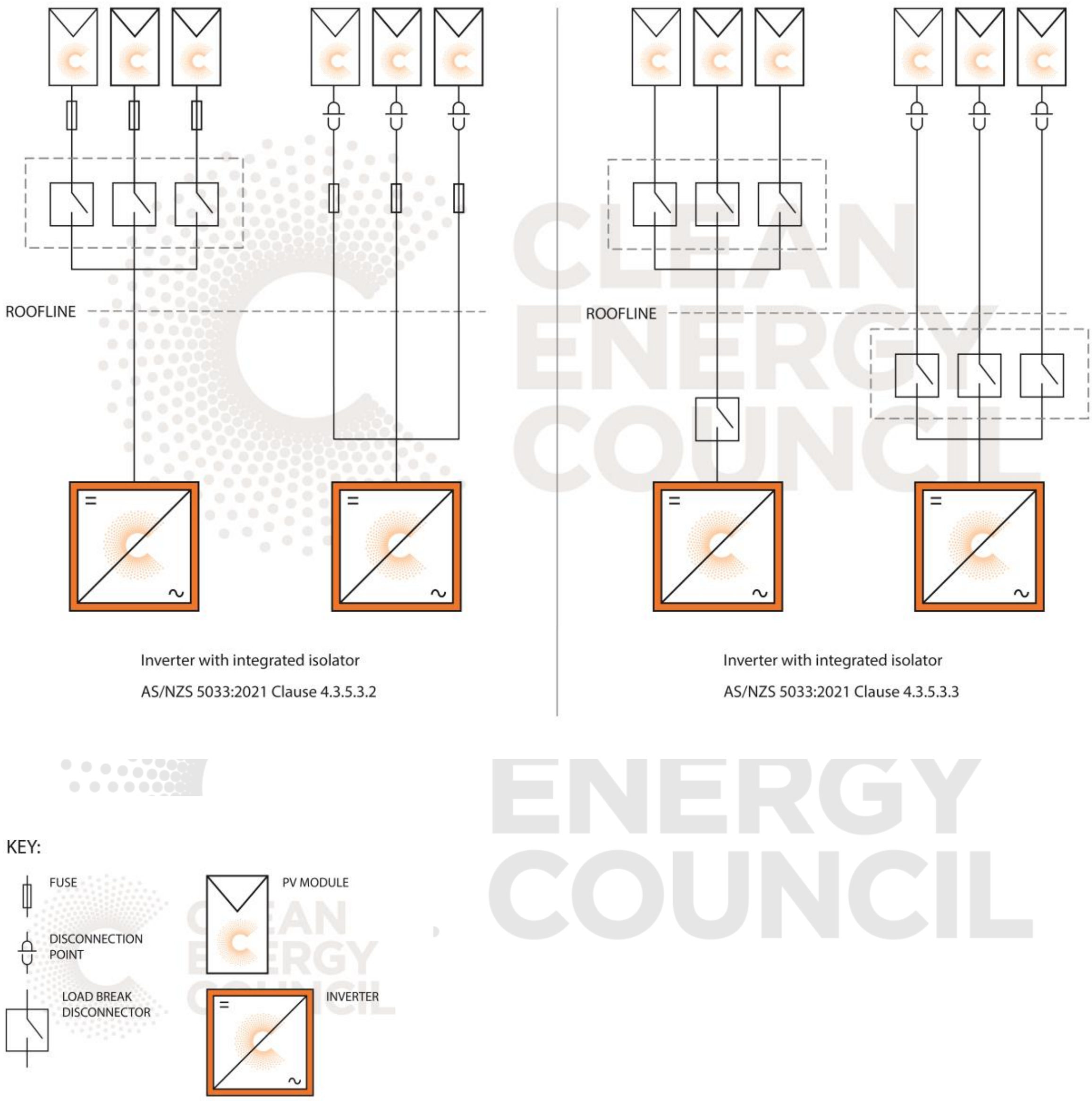


Figure A4.2 : Common fusing and load break disconnector configurations.

String fusing and paralleling at an inverter with an integrated isolator may aid in avoiding additional load break disconnectors, depending on array cable routes.

4.4 Wiring systems

4.4.2 Cables

Installation requirements for above ground use of solar PV cable.

Key points:

- PV d.c. cables, where not installed underground, shall conform to the International Electrotechnical Commission (IEC) standard IEC 62930 in accordance with Clause 4.4.2.1 of AS/NZS 5033:2021.
  Note: Cables that conform to the IEC standard are marked with "62930 IEC" on the sheath.

Example markings are 62930 IEC 131; 62930 IEC 132; 62930 IEC 133; 62930 IEC 134

- Cables that conform only to IEC 62930 cannot be installed underground. For underground PV d.c. installations, cables complying with a relevant standard applying to underground cables must be used. This means that cable used in an underground application must meet IEC 62930 and an applicable standard for underground use.
  Note: UL 493 may be useful for direct buried applications.

Worked example

PV d.c. cables may be sized in the same way a.c. cables are with reference to AS/NZS3008.1.1, commonly referencing Table 5, bearing in mind the derating effects of running cables together in enclosures outlined in Tables 22-26 and rating effects of high temperatures outlined in Tables 27-29. The current used when sizing PV components such as cables is the calculated value (for string inverters this is commonly using the formula 1.25 x KI x Isc per string).

EXAMPLE 01

Conditions:
You have one compliant 4mm^2 array cable you wish to run in a HD conduit through the roof space 800mm from the external wall laying on thermal insulation. For the location it is assumed the roof space could reach a temperature of 70˚C.
The conduit continues down on the surface of a wall to the inverter installed indoors.
The array has a calculated current of 15.53A with no back feed current from any other sources.
Voltage drop is within tolerance.
Method:
Establish the most limiting section of the cable run. In this case, in the roof.
Referencing Table 5 column 18, you note that a 4mm^2 cable has a current carrying capacity of 30A.
Now moving to Table 27(1), column 13, row 3, you note a rating factor of 0.57 shall be applied.
30 x 0.57 = 17.1A current carrying capacity.
17.1A > 15.53A
This configuration is permissible.

EXAMPLE 02

Conditions:
You have two compliant array cables you wish to run in a single conduit across the roof and down an insulated brick veneer cavity wall to the string inverter.
Each array has a calculated current of 15.53A with no backfeed current from any other sources.
Voltage drop is within tolerance.
Method:
Establish the most limiting section of the cable run. In this case, exposed to sun.
Referencing Table 5 column 11, you note that a $4mm^2$ cable has a current carrying capacity of 28A.
Moving to Table 22, Item No. 2, column 5, you note a derating factor of 0.8 must be applied, 28 x 0.8 = 22.4A current carrying capacity for each cable.
22.4A > 15.53A
This configuration is permissible.

EXAMPLE 03

Conditions:
You have an array cable you wish to run in a single HD conduit in a shed.
The array has a calculated current of 15.53A with no backfeed current from any other sources.
Voltage drop is within tolerance.
Method:
Establish the most limiting section of the cable run. In this case, enclosed.
Referencing Table 5 column 15, you note that a $4mm^2$ cable has a current carrying capacity of 38A.
38A > 15.53A
This configuration is permissible.

Underground:
Cables compliant to IEC 62930 AND another standard specific to undergrounds may be acceptable. Speak to your wholesaler or manufacturer to source the appropriate product.

4.4.5 Wiring enclosures for the wiring system

4.4.5.2.1 General

The installation requirements for wiring enclosures are dependent on the location of the wiring system. There are four installation conditions that relate to different sections of the wiring system.

- Between the PV modules and the disconnection point. See AS/NZS 5033:2021 Cl 4.3.2.3.
- Between a load break disconnection device(s) and application circuit. See AS/NZS 5033:2021 Cl 4.4.5.2.2.
- Between the disconnection point and a load break disconnection device. See AS/NZS 5033:2021 Cl 4.4.5.2.2 & 4.4.5.2.3.
- Between non-adjacent groups of PV modules. See AS/NZS 5033:2021 Cl 4.4.5.2.4.

Installation requirements for above ground use of solar PV cable.

4.4.5.2.2 Additional mechanical protection requirements

The installation requirements for additional mechanical protection are dependent on the location of the wiring system. These requirements are in conjunction with the mechanical protection requirements of AS/NZS 3000.

There are requirements that relate to PV d.c. cables installed within buildings and that relate to PV d.c. cables installed external to a building.

Note: Where the wiring system is installed near building surfaces (such as those concealed within 50 mm from a surface), extra protection methods beyond the requirements of this Clause may be required to meet AS/NZS 3000 Cl 3.9.4

Key points

Where PV d.c. cables are installed within buildings:

- Enclosed in metal or heavy-duty insulating conduit where installed within a ceiling space, in wall cavities or under a floor or;
- Installed in medium duty insulating wiring enclosure in other locations within buildings.

Note: There is an exception for non-domestic. Where PV d.c. cables are installed external to the building, and not in a restricted access location, they shall be installed in a wiring enclosure to ensure restricted access of the PV d.c cables. Where PV d.c. cables are installed external to the building and in a restricted access location, there are no additional mechanical protection requirements for the wiring system.

A maximum distance of no more than 300 mm of unprotected PV d.c. cable is allowed at the PCE or the load break disconnection device, provided the location is not subject to mechanical damage.

4.4.5.2.3 Wiring systems between disconnection point and load break disconnection device or an application circuit

This clause applies to the wiring system between the **disconnection point/s** and the **load breaking disconnection device** or **application circuit** when the wiring system is run through a ceiling space. This means, if you do not install a load breaking disconnection device on the roof (roof top isolator) and only install disconnection point/s, then you will need to follow this clause.

Key points

- This clause in conjunction with other clauses in this standard provides a method to install a PV array/s without load breaking disconnection device/s (roof top isolator) on the roof.
- Wiring systems installed within a ceiling space shall not be located within 0.6 m above the surface of the ceiling unless—
  - the wiring system is located within 1 m from the internal surface of the external wall, see Zone 1 in AS/NZS 5033:2021 Figure 4.6.
  - the wiring system is located within 1 m to 1.5 m from the internal surface of an external wall, and it is attached to roof structure, see Zone 2 in AS/NZS 5033:2021 Figure 4.6; or
  - the wiring system is located within a vertical plane that extends 0.2 m from the external edge of the load break disconnection device at the PCE or the application circuit, see vertical conduit zone in AS/NZS 5033:2021 Figure 4.5.
- Where the ceiling height is not greater than 0.6m in height, the wiring system shall remain within 1m from the internal surface of the external wall.

- Where wiring systems are installed within buildings, additional mechanical protection is required, see AS/NZS 5033:2021 Cl 4.4.5.2.2.
- Wiring systems installed within a ceiling space shall be secured to prevent inadvertent dislodgement from conduit support.
- Wiring systems installed within a ceiling space shall not be fixed in a position within 50 mm from the underside of the roofing material.
- Where PV d.c. cables are installed in an accessible roof or floor space, a sign as per AS/NZS 5033:2021 Cl 5.3.1.2 shall be installed.

NOTE: Some of these requirements are also for wiring in ceilings between groups of non-adjacent panels. See AS/NZS 5022:2021 Clause 4.4.5.2.4

See Figures 4.5, 4.6 and A1 in AS/NZS 5033:2021 for more detail.

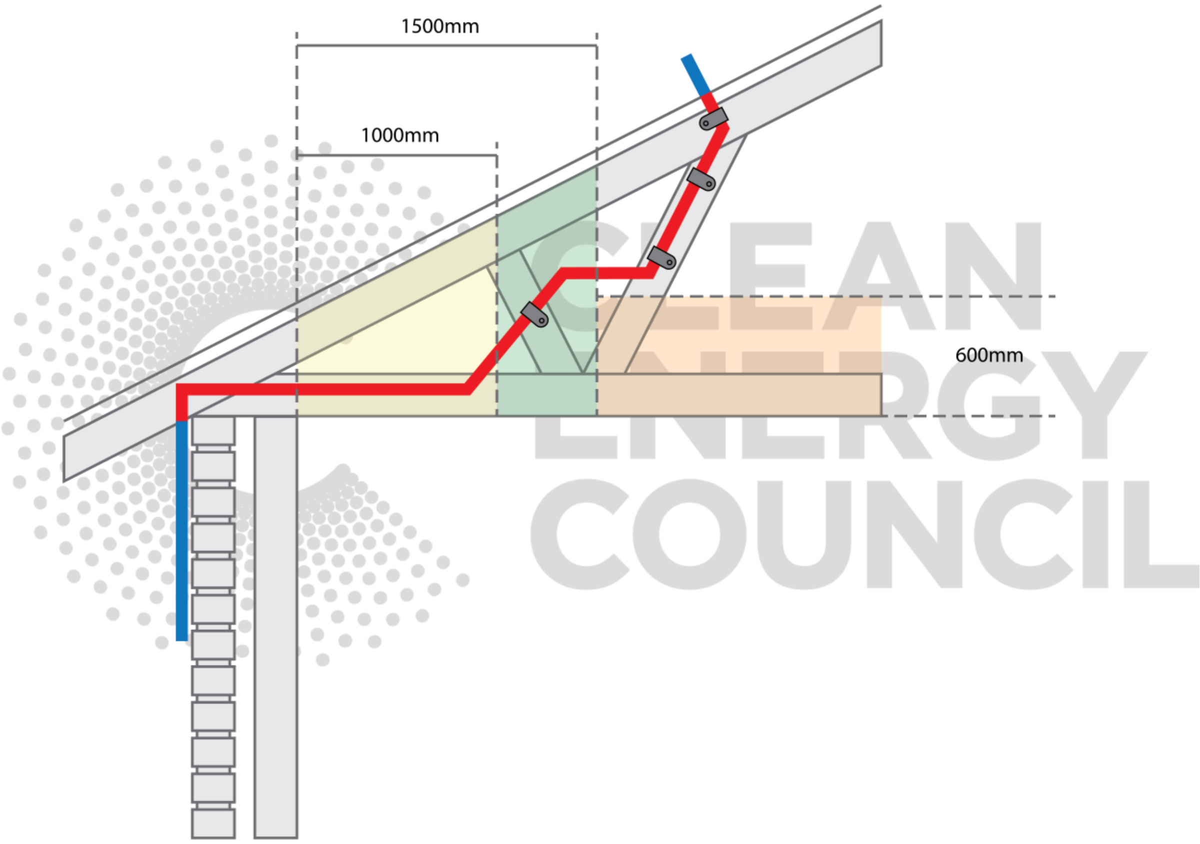


Figure A4.3: Domestic example – truss style with disconnection point

There is an exception for non-domestic.
The conduit in red shall be a minimum of metal or HD, whilst the conduit in blue shall be a minimum of MD.
Conduits installed in the green zone may be within 600mm above the ceiling so long as they are saddled to the members.
Conduits installed in the yellow zone may be within 600mm above the ceiling.
Conduits shall not be installed in the orange zone.

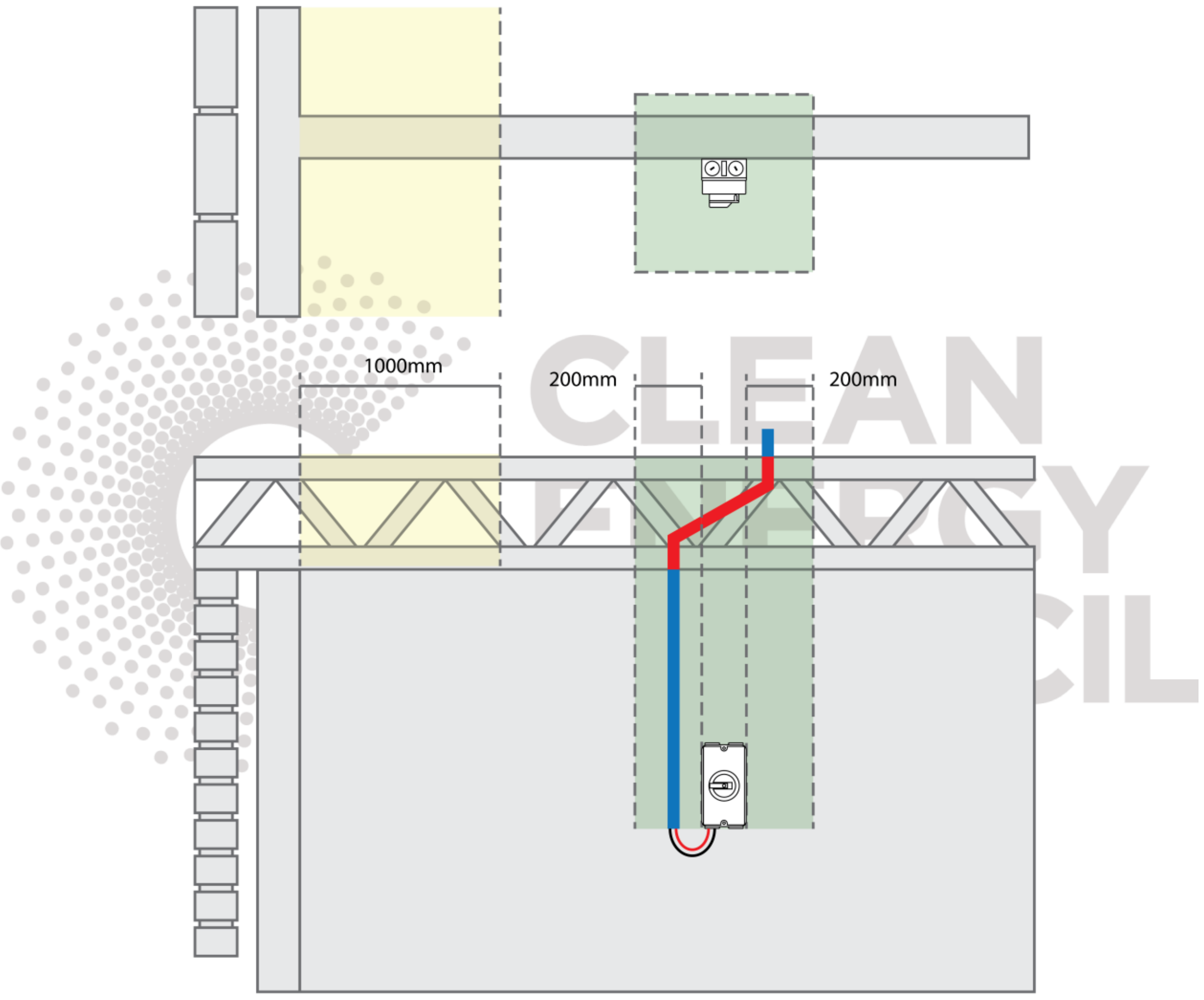


Figure A4.4: Skillion roof (<600mm) with disconnection points

Internal wall
Where conduits descend to an inverter isolator installed on an internal wall, the conduit may pass through the roof space that is less than 600mm, so long as it is within 200mm either side of the isolator, shown here as the green zone.
Conduits may be installed in the yellow zone.

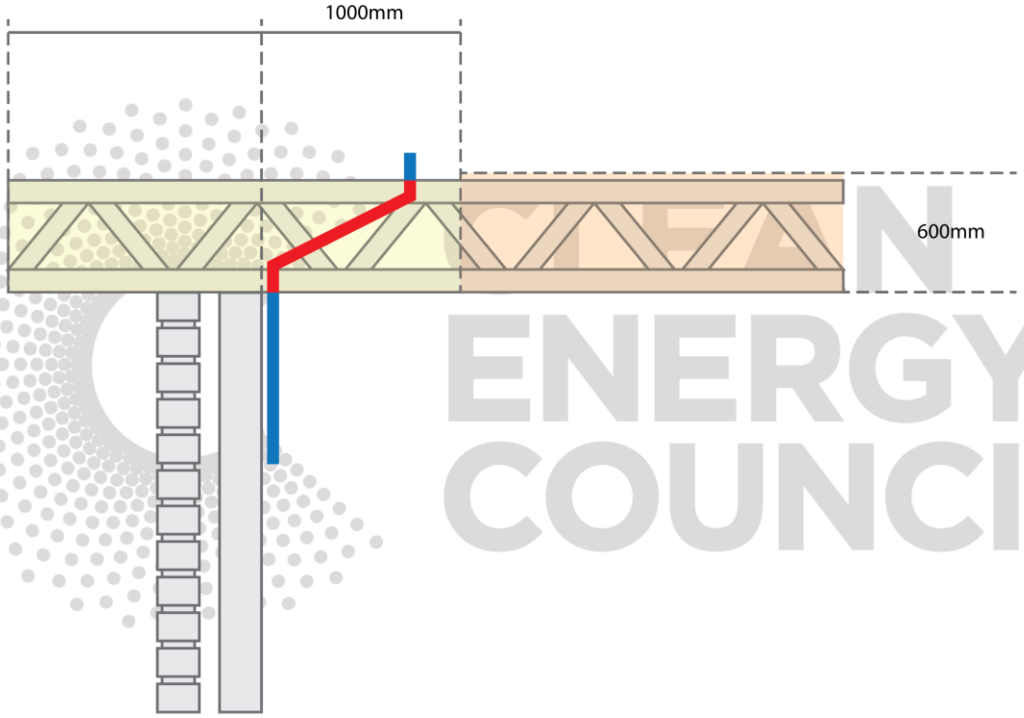


Figure A4.5: Skillion roof with disconnection points

External wall
Conduit in red shall be minimum of metal or HD, whilst blue shall be minimum of MD.
Conduits may be installed in the yellow zone.
Conduits shall not be installed in the orange zone.

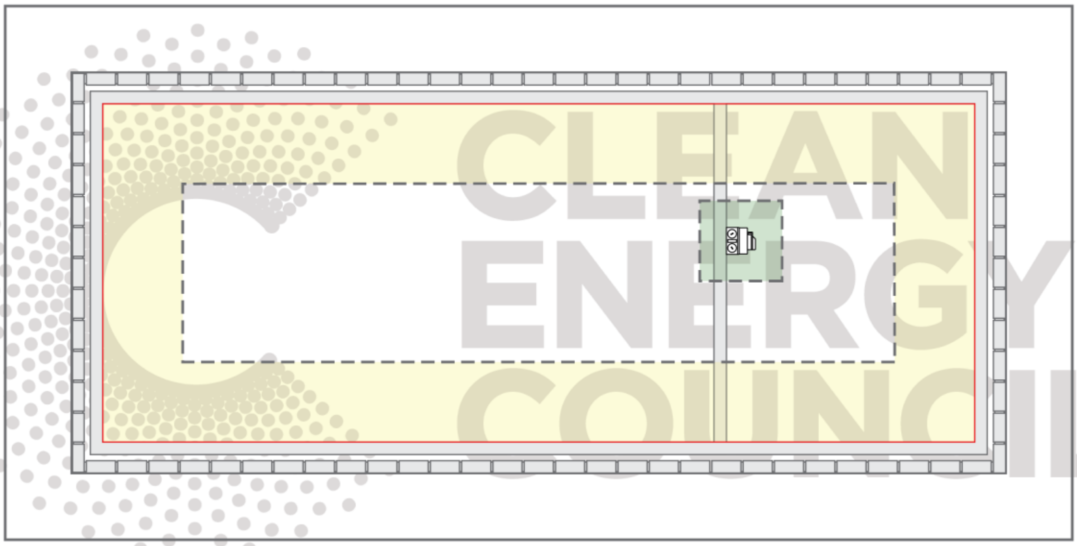


Figure A4.6: skillion roof with disconnection points

PV cables shall not be in a roof space less than 600mm unless within 1m from internal surface of external wall (yellow zone) or within 200mm of the d.c. isolator at the inverter (green zone).

Worked example

Roof types, disconnection methods and the resulting conduit run

EXAMPLE 01 - 20kW System with the following conditions:

- 3 strings
- Tin skillion (<600mm roof space)
- Disconnection Points
- No string fusing
- Conduit
- Inverter Integrated isolator
- 3 MPPTs (1 string per).

RESULT: Conduit may be run on the surface or in the roof space within 1m of the internal face of an external wall.

EXAMPLE 02 - 20kW system with the following conditions:

- 3 strings
- Tin truss (>600mm roof space)
- rooftop isolators
- no string fusing
- conduit
- Inverter integrated isolator
- 1 MPPT.

RESULT - Conduit may be run on the surface or in the roof space. An additional isolator is required at the paralleling point and/or at the inverter.

EXAMPLE 03 - 20kW system with the following conditions:

- (3 strings)
- Tin skillion (<600mm roof space)
- rooftop isolators
- no string fusing
- conduit
- inverter integrated isolator
- 3 MPPTs (1 string per).

RESULT - Conduit may be run in the roof space or on the surface.

EXAMPLE 04 - 20kW system with the following conditions:

- (3 strings)
- Tin truss (>600mm roof space)
- Disconnection Points
- string fusing
- conduit
- inverter integrated isolator
- 1 MPPT

RESULT - Conduit may be run on the surface or in the roof space.

4.4.6.2 Wiring Selection of enclosures containing disconnection devices

Enclosures containing disconnection devices shall be selected as specified in AS/NZS 5033:2021 Table 4.5.

Depending on the disconnection device you select and the environment it is installed in, the enclosure will need to meet different requirements.

Key points

- Enclosures containing disconnecting devices installed in an outdoor environment shall have pressure equalization valves fitted in the enclosure except where a pressure equalization valve is integrated into other equipment installed within 300mm of the enclosure.
- AS/NZS 5033:2021 Table 4.5 breaks down the selection process based on the type of disconnection device being used.
- Minimum IP 56 and in some cases IP 56NW.
- There are additional requirements contained within the clause relating to:
    - maintaining double insulation
    - earthing of enclosures
    - flaps and covers on IP rated enclosures

See Table 4.5 in the standard for more detail.

4.4.7 Installation of enclosures containing conductor terminations

4.4.7.1 General

This clause identifies broad requirements that apply to the installation of any enclosure containing d.c. conductor terminations.

Water ingress into d.c. systems can lead to arcing and fires. Effective work practices that comprehensively prevent the ingress of water into enclosures should be used.

Key points

- Manufacturer's mounting instructions shall be followed including screw location and screw type.
- Silicone and other sealants shall not be relied on unless specified by the manufacturer.
- Enclosures shall be free from dust and debris at completion of installation.
- Conductor terminations shall be provided with strain relief. This may be achieved using a gland connector or securing the cables as they enter the enclosure.
- Double insulation shall be maintained.

4.4.7.2 Entries/exits of enclosures containing conductor terminations

4.4.7.2.1 General

Entries/exits of an enclosure that contains conductor terminations can be achieved by two methods: cable glands and conduit systems.
There are specific requirements for enclosures that contain disconnection devices and relate to AS/NZS 5033:2021 Cl 4.4.7.2.2 & 4.4.7.2.3

In all instances, only manufacturer's entry/exit points shall be used.

Cable glands and conduit fittings shall not enter/exit the top face of the enclosure. There are exceptions to this relating to indoor installations but the wiring system coming from the roof must not enter/exit the top face.

Conduit and fittings shall be installed to manufacturer's instructions, including being glued.

Silicone or other sealant product as means of sealing entry/exit points shall not be used unless it is a type specified by disconnector manufacturer's instructions.

Key points

- Entries/exits of an enclosure that contains conductor terminations can be achieved by two methods: cable glands and conduit systems.
- Only manufacturer's entry/exit points shall be used.
- Cable glands and conduit fittings shall not enter/exit the top face of the enclosure.

4.4.7.2.2 Cable glands in outdoor locations

Where a cable gland is used in an outdoor environment, the cable gland must meet several requirements.

The beginning of the clause covers the requirements for the cable gland as a piece of equipment and then moves into the installation of cable glands.

A non-continuous conduit system can be less onerous on installation requirements. e.g. where the conduit is butted up to a multi-hole gland installed in an isolator.

There are a number of figures in the clause that assist in explaining the installation requirements for cable glands in outdoor locations.

Ensure that you read all the notes in this clause as they assist in understanding the requirements of the clause and how it relates to other figures and clauses in this standard.

Key points

The cable gland/s shall -

- be used to enter/exit an enclosure containing conductor terminations;
- be rated at least IP56;
- be installed so that each cable enters/exits through an individual hole and have hole diameter to maintain IP rating for the outside diameter of the cable used;
- have any spare holes sealed with the manufacturer approved sealing plug.

Installation of cable gland/s –

- Cable glands may enter/exit the bottom face of an enclosure containing conductor terminations, see AS/NZS 5033:2021 Figure 4.7.
- Where cable glands enter/exit the side face of an enclosure installed in an outdoor location, the entry/exit point into the enclosure containing conductor terminations shall be higher than the lowest point of the wiring system (i.e. to create a drip loop), see AS/NZS 5033:2021 Figure 4.7, and —
    - be within 30 degrees of the space contained by the soffit and the plane from the outer edge of the soffit; or
    - be within 30 degrees from the top of the shroud and a plane from the outer edge of the mounting surface, see AS/NZS 5033:2021 Figure 4.8 and Figure 4.9.

See Figures 4.7, 4.8 and 4.9 in the standard for more detail.

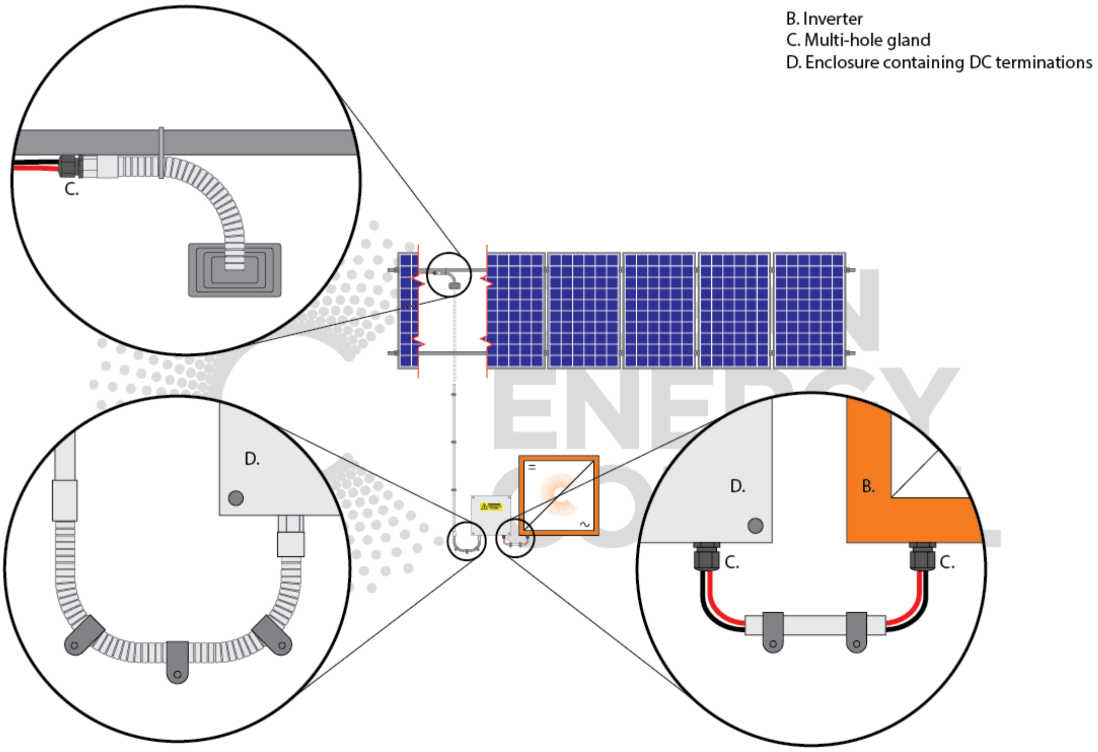


Figure A4.7 (cl. 4.4.7.2.2)

A continuous conduit system that has a section outdoors and terminates into an enclosure containing d.c. terminations.

Enclosures containing terminations (e.g. fuse box) installed outdoors shall maintain at least IP55.
Cable glands shall be rated to IP56.
A drainage device is not required here because the wiring enclosure does not terminate into an enclosure containing a disconnection device.
Cables shall be supported in accordance with AS/NZS3000
This inverter has an integrated isolator.

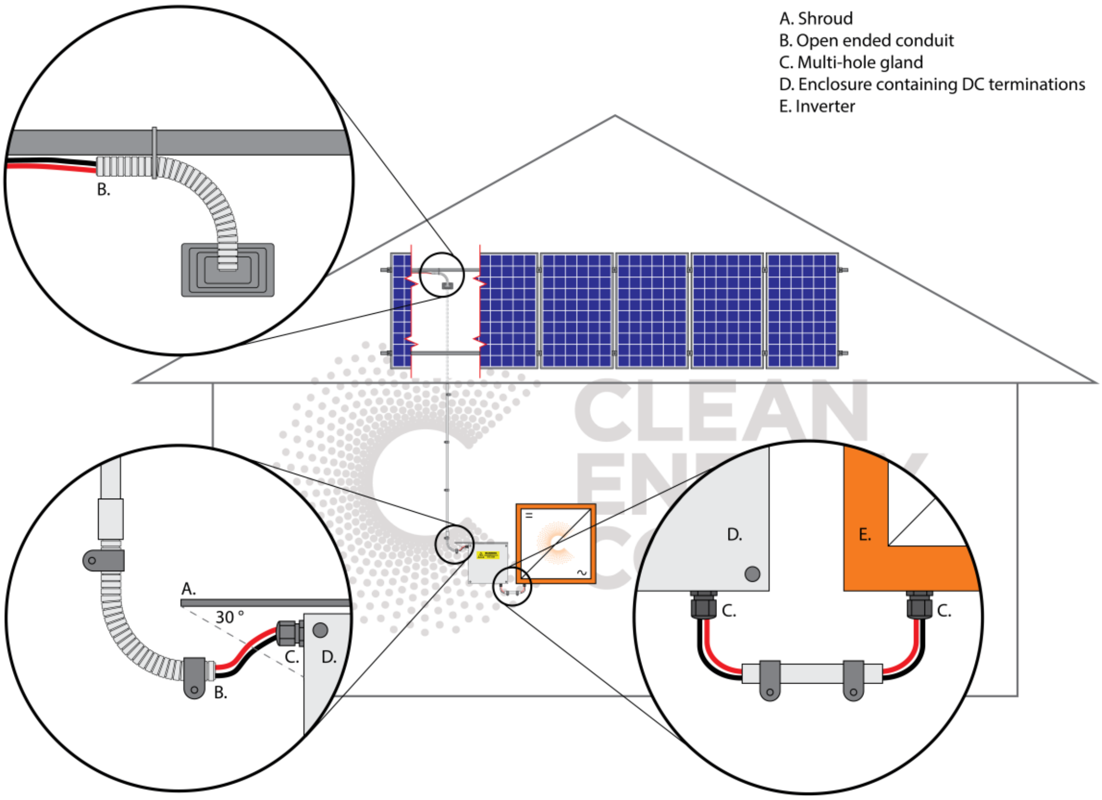


Figure A4.8: (cl. 4.4.7.2.2)

Enclosures containing terminations (e.g. fuse box) installed outdoors with a cable gland on the side require protection of 30 degrees by the soffit or a shroud.

This inverter has an integrated isolator.
Note: This installation has avoided multi hole glands on the conduit. For conduit terminating indoors, multi hole glands could be used to avoid water tracking into the building envelope.

4.4.7.2.3 Conduits terminating into enclosures containing disconnection devices

There are different requirements for a continuous conduit system that has a section in an outdoor environment, depending on what the conduit system is terminated into.

Key points:

Where a continuous conduit system has a section in an outdoor environment that terminates into an enclosure containing a disconnection device, it shall have a device to drain liquid from the conduit system.

- the device to drain shall –
  - be installed at the lowest point of the conduit system and;
  - shall be rated to at least IP 56.
- see AS/NZS 5033:2021 Figure 4.10 and Figure 4.11.

Where a continuous conduit system has a section that is in an outdoor environment, and that terminates into an enclosure containing conductor terminations, any open ends of the conduit system shall be sealed with a gland conforming to AS/NZS 5033:2021 Cl 4.4.7.2.2.

Where conduits and fittings enter/exit the side face of an enclosure installed in an outdoor location, the entry/exit point into the enclosure containing conductor terminations shall be in accordance with item (i) or item (ii) of AS/NZS 5033:2021 Cl 4.4.7.2.2.

See Figures 4.10, and 4.11 in the standard for more detail.

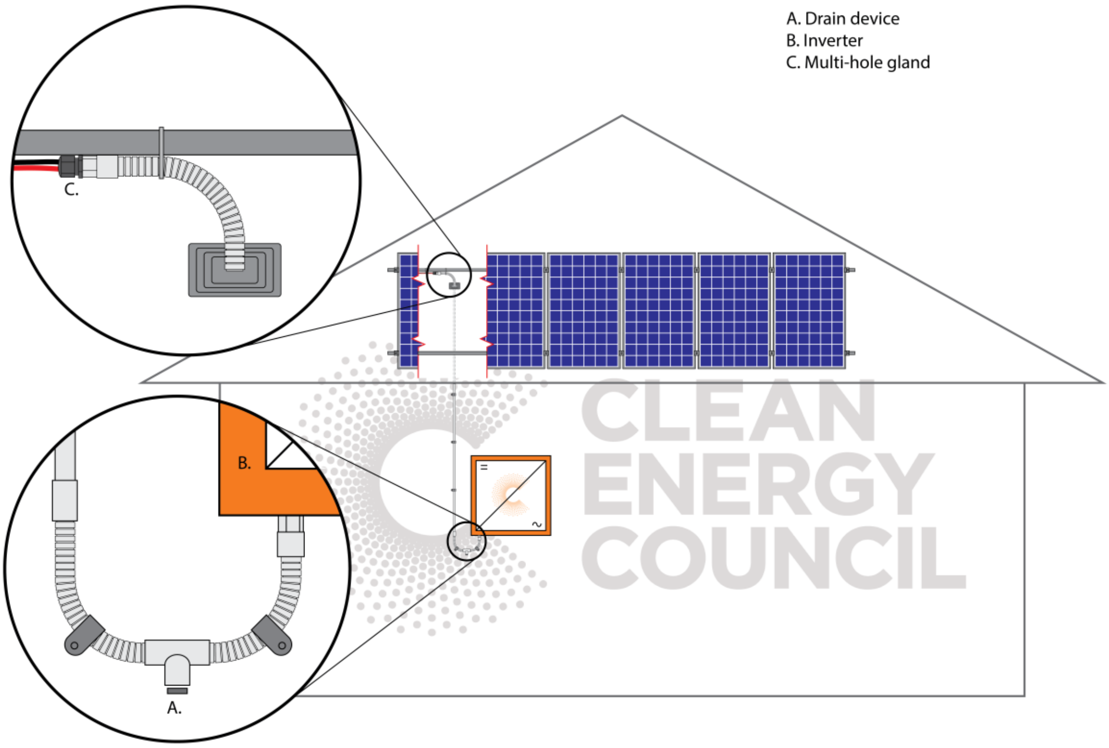


Figure A4.9: (cl. 4.4.7.2.3)

A continuous conduit system that has a section outdoors and terminates into an enclosure containing a disconnection device.

Because the conduit system terminates directly into the inverter enclosure, which contains a disconnection device, a drain is required at the lowest point of the conduit system and a multi-hole gland is required at the roof to maintain the IP rating of the conduit system.

The intention behind this requirement is to keep water out of enclosures that could track down from the roof through the conduit system.

NOTE: To avoid the need for a drain, the conduit system can end prior to the inverter and a multi-hole gland can be used at the bottom of the inverter to maintain the IP rating of the enclosure containing the disconnection device. Up to 300mm of exposed cable is permissible, provided it is not subject to mechanical damage or restricted access requirements of AS/NZS4777.1:2016.

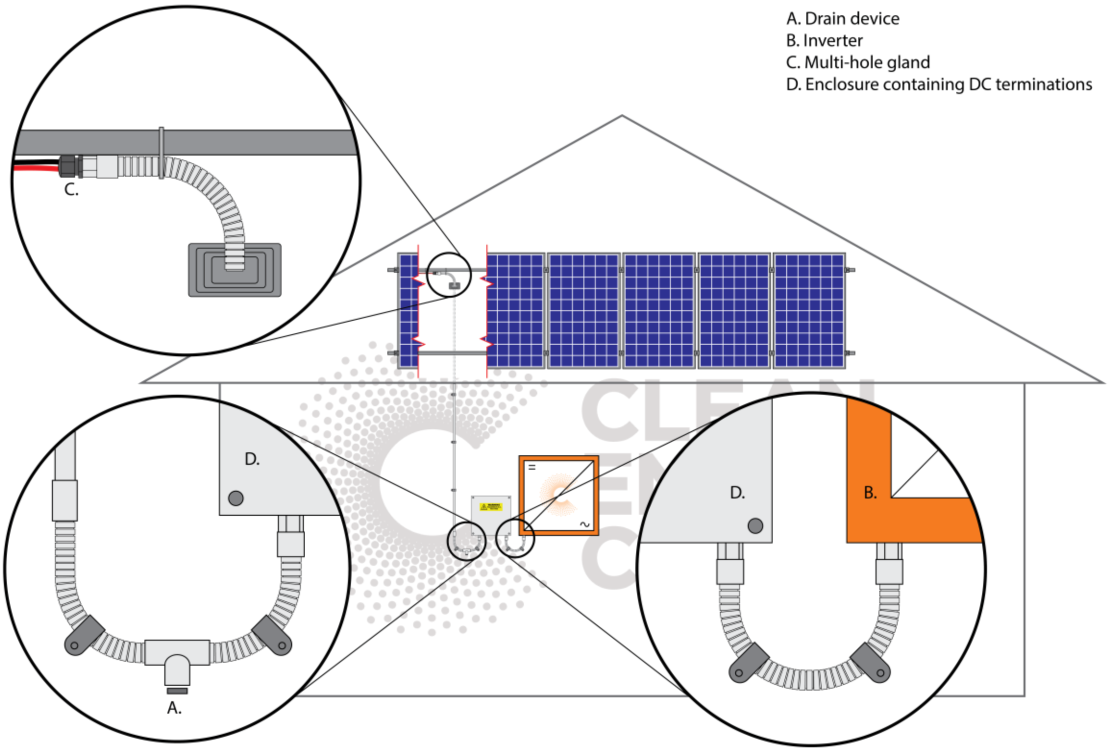


Figure A4.10 (cl. 4.4.7.2.3)

A continuous conduit system that has a section outdoors and terminates into an enclosure containing d.c. terminations and then into an integrated isolator.

Enclosures containing terminations (e.g. fuse box) installed outdoors shall maintain at least IP55.

Cable glands shall be rated to IP56.
This inverter has an integrated isolator and the wiring enclosure is continuous, therefore a drainage device is required at the lowest point.

NOTE: To avoid the need for a drain, the conduit system can end prior to the inverter and a multi-hole gland can be used at the bottom of the inverter to maintain the IP rating of the enclosure containing the disconnection device. Up to 300mm of exposed cable is permissible, provided it is not subject to mechanical damage or restricted access requirements of AS/NZS4777.1:2016.

4.4.7.3 Protection against weather and water for dedicated individual enclosures containing switch disconnectors

Where a dedicated individual enclosure contains a switch disconnection device it shall be protected against the effects of weather and water.

Dedicated individual enclosures containing switch disconnection devices are considered to be protected against the effects of weather and water when installed either—

- Within the space contained by the soffit and a plane from the outer edge of the soffit, at an angle of 30 degrees continuing to the surface that the enclosure is mounted on, see AS/NZS 5033:2021 Appendix K Figure K.1; or
- Within a non-combustible, and mechanically stable shroud resistant to ultraviolet radiation (UV) exposure where the shroud protects the switch disconnectors and meets at least the requirements of AS/NZS 5033:2021 Appendix K Figures K.2 and Figure K.3.

See Figures K1, K2 and K3 in the standard for more detail.

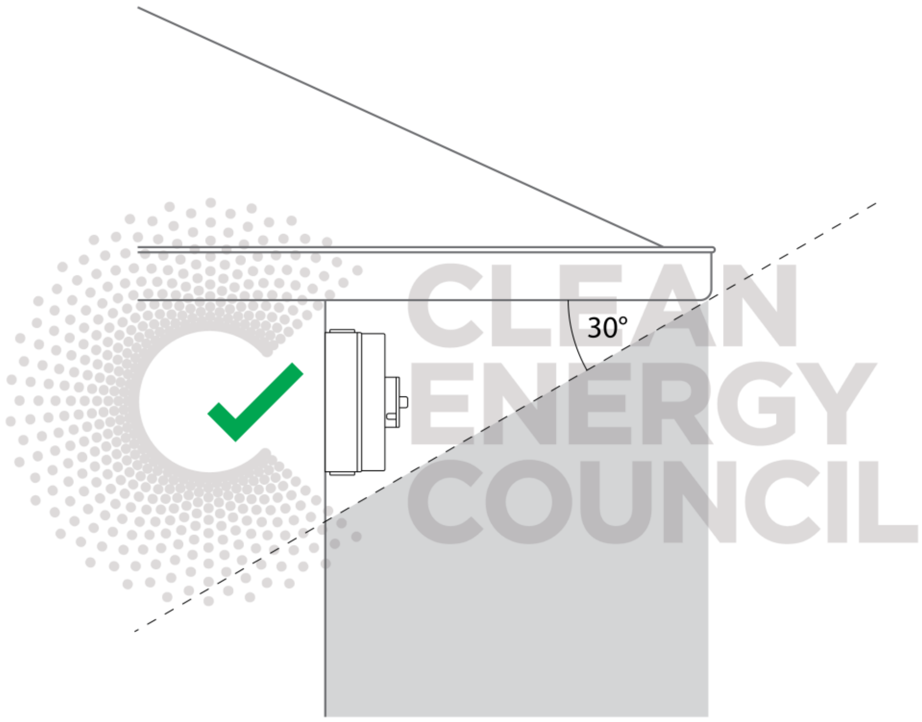
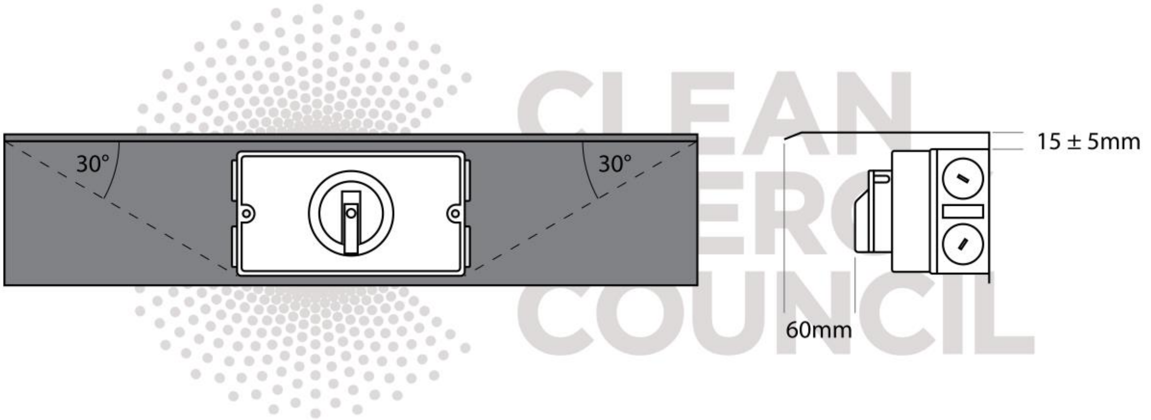


Figure A4.11 (cl. 4.4.7.3)

Dedicated individual enclosures containing a switch disconnector

Dedicated enclosures containing a disconnector mounted outdoors shall be within 30 degrees from the soffit or protected by a shroud meeting at least the following two figures.

Note: Physically separate load break disconnection devices for PCE shall be readily available and adjacent (within arm's reach) to that PCE (cl 4.5.4.1)



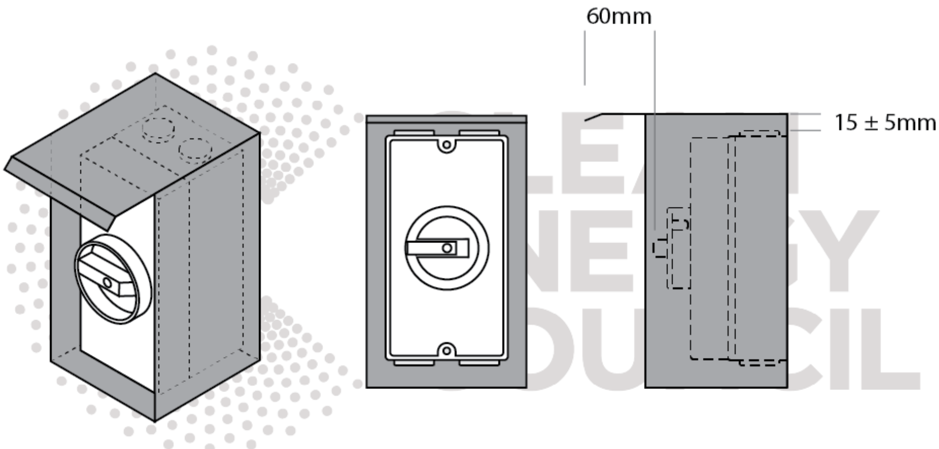


Figure A4.12 (cl. 4.4.7.3)

Dedicated individual enclosures containing a switch disconnector

Dedicated enclosures containing a disconnector mounted outdoors shall be within 30 degrees from the soffit or protected by a shroud meeting at least the following two figures.

Note: Physically separate load break disconnection devices for PCE shall be readily available and adjacent (within arm's reach) to that PCE (cl 4.5.4.1)

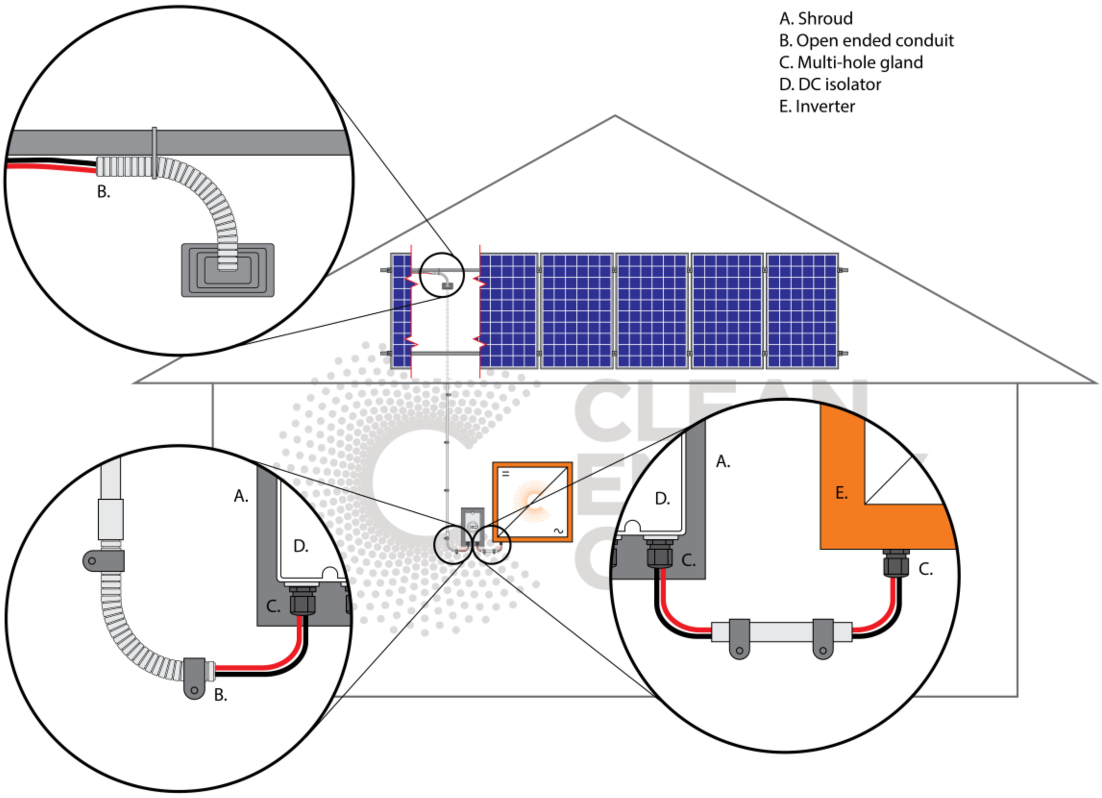


Figure A4.13 (cl. 4.4.7.3)

Dedicated individual enclosure containing a disconnection device mounted outdoors.

Dedicated enclosures containing a disconnector mounted outdoors require a shroud (exception integrated isolators) unless they're within 30 degrees of a soffit. The shroud doubles as a non-combustible barrier when installing on combustible materials. Cl. 4.5.3.
The switch disconnector/s pictured here has it's IP rating maintained with multi hole glands, avoiding the need for multi hole glands on the conduit.
Multi-hole glands can also double as cable retention devices.
Cables shall be supported in accordance with AS/NZS3000

4.5 Power conversion equipment

4.5.1 Selection of power conversion equipment

4.5.1.1 General

The current rating of the PV input of the PCE (Isc PV) shall be at least the current rating of the circuit they will be fitted to, according to cl. 4.2.2 -> Table 4.2 the greater of I_{ARRAY} or $I_{BF\ TOTAL}$ where array overcurrent protection is not provided.
Where I_{ARRAY} = total current on the circuit that carries the total output current of the array. More simply, the maximum array current.
This can be calculated by S_A x $I_{STRING\ MAX}$, unless $I_{BF\ TOTAL}$ is greater.
Where S_A = total number of parallel connected PV strings in the PV array.
See cl. 3.3.3.1 for $I_{STRING\ MAX}$ (1.25 x K_I x $I_{sc\ mod}$)

EXAMPLE

20kW system with the following conditions:
A system has been designed for a customer requiring 2 arrays of PV modules, one with a PV array max of 400V and one with 500V. The modules are not bifacial and have Isc at STC (standard test conditions) of 12.42A.
Using a string inverter and no DCUs, the inverter maximum short circuit current must be at least: 1.25 x 1 x 12.42 = 15.53A on both MPPTs.
The PV inputs of the MPPTs shall be rated to at least 500V.

4.5.4 Isolators adjacent PCE

To protect against the spread of fire, isolators installed adjacent to PCE shall be either;

i. In an enclosure of metal with thickness of at least 0.2mm
ii. Mounted on a non-combustible surface extending at least 200mm beyond the extremities of the isolator. Non-combustible surface may meet AS1530.1 or be brick or masonry block, concrete, compressed cement sheet, ceramic or terracotta tiles or a metallic surface of at least 0.2mm thick.
iii. Mounted on non-combustible shrouds that are either made of metal surfaces at least 0.2mm thick or meet 4.4.7.3

4.6 Earthing arrangements

4.6.2 Earthing of PV array exposed conductive parts

Where the calculated PV d.c. circuit maximum voltage is greater than 35 V, there are several earthing requirements for the conductive parts of the PV array.
This clause covers:

- conductive PV module frames.
- array mounting frames that are directly in contact with PV d.c. cables.
- conductive cable support systems or conductive wiring enclosures that are directly in contact with PV d.c. cables.

PV array cabling that is installed in an insulating wiring enclosure is not deemed to be in direct contact.

PV systems that are connected to a non earth referenced system, exposed conductive parts of all associated equipment shall be equipotentially bonded. An example of this is an independent water pumping system that does not have direct connection to earth.

Key points

- all conductive PV modules frames shall be earthed.
- array mounting frames that are directly in contact with PV d.c. cables shall be earthed.
- conductive cable support systems or conductive wiring enclosures that are directly in contact with PV DC cables shall be earthed.
- PV array cabling that is installed in an insulating wiring enclosure is not deemed to be in direct contact.
- PV systems that are connected to a non earth referenced system, exposed conductive parts of all associative equipment shall be equipotentially bonded.

4.6.3 Earthing or bonding connections requirements

There are multiple methods to create earthing or bonding connections withing the PV array frame. PV array frames consist of conductive PV module frames and conductive mounting frames.

- A purpose-made fitting providing earthing or bonding connections for dissimilar metals and installed according to the manufacturer's instructions. (Some of these fittings are not designed for stranded cable).
- Purpose-made washers with serrations or teeth, designed to penetrate the surface for the connection of dissimilar metals between the PV module and mounting frames. These shall be installed at every connection between the PV module and mounting frame or in accordance with manufacturer's instructions.
- Tinned cable lugs of earthing and bonding cables fixed by stainless steel bolts washers and star washers to aluminium frames.
- Self-tapping screws and rivets shall not be used.
- Earthing or bonding connections to PV array frames shall be protected against corrosion.

- The earthing or bonding connections shall be arranged so that the removal of any one PV module will not affect the continuity of the earthing or bonding connections to any other PV module.

Key points

- Self-tapping screws and rivets shall not be used.
- Earthing or bonding connections to PV array frames shall be protected against corrosion.
- The earthing or bonding connections shall be arranged so that the removal of any one PV module will not affect the continuity of the earthing or bonding connections to any other PV module. Earthing or bonding connections to PV array frames shall be protected against corrosion.

See AS/NZS 5033:2021 Cl 4.7.3.2 for testing requirements.

4.6.4 Connection to installation earth

The type of earthing required in PV systems is dependent on whether the site is subject to lightning.

When a site is ***not*** subject to lightning the inverter main earth conductor in the a.c. cable may be used as the earth connection point, subject to cable size.

When earthing PV systems as part of a Lightning Protection System (LPS), the bonding conductors shall be connected to the electrical installation earthing systems as specified in AS 1768.

The PV array earthing conductors shall be connected to the electrical installation earthing system in all other applications.

Key points

- Sites not subject to lightning may use the inverter main earth conductor in the a.c. cable as the earth connection point, subject to cable size.
- Sites subject to lightning have to comply with AS 1768 and cannot use the inverter main earth conductor in the a.c. cable.

4.6.5 Earthing or bonding conductor size

The earthing conductor between the exposed conductive parts of a PV system (above 35V) and the installation earthing system shall have a resistance of no more than 0.5Ω and shall be selected in accordance with Figure 4.13 – PV array exposed conductive parts earthing or bonding decision tree.

The decision tree will either provide you with the minimum earthing or bonding conductor size or refer you to Table 4.6 – Earth conductor size.

There are several NOTES that must be read in conjunction with the decision tree.

NOTE 3 – Examples of separated PCEs are transformer based inverters.

NOTE 4 – Examples of non-separated PCEs with powered neutral are single phase and three phase transformerless inverters with voltage balancing capability and multiple mode inverters.

If using a non-separated PCE, Figure 4.13 will refer you to Table 4.6 to determine earth conductor sizing.

Key points

- The earthing conductor between the exposed conductive parts of a PV array and the installation earthing system shall have a resistance of no more than 0.5Ω.
- Use Figure 4.13 decision tree to determine minimum earthing or bonding conductor size
- Minimum earth conductor size should be 4mm.

If using a non-separated PCE, Figure 4.13 will refer you to Table 4.6 to determine earth conductor sizing.

Worked example

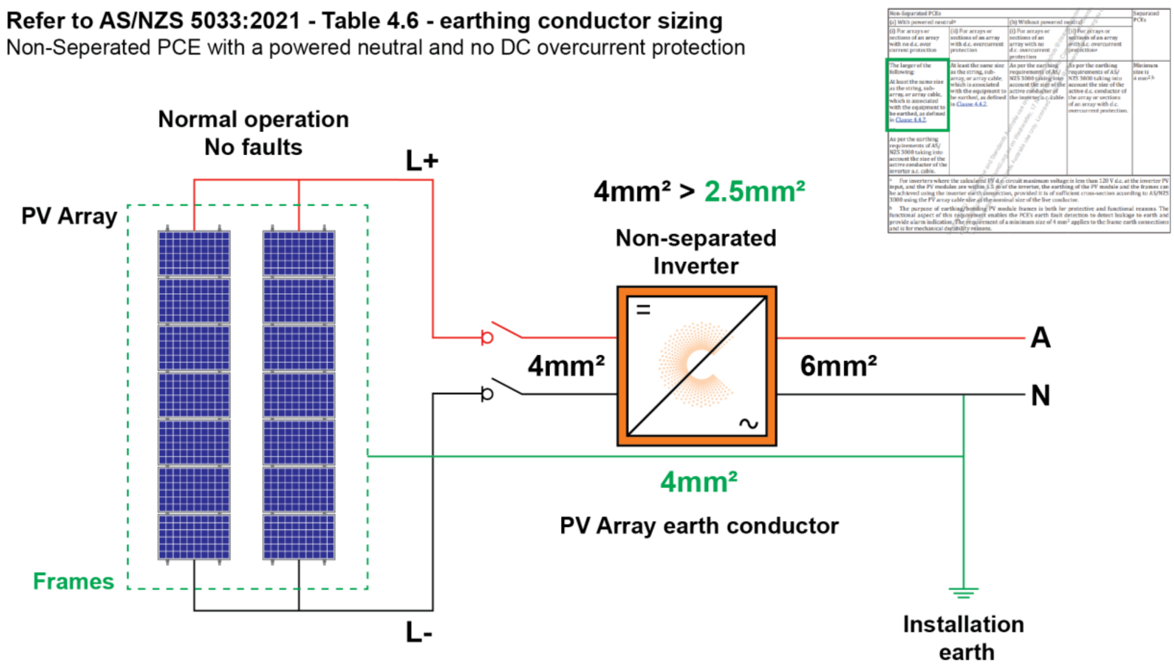
Earthing or bonding conductor size

The following pages provide a series of different scenarios and how you would determine the appropriate size earth for each system using AS/NZS 5033:2021 Figure 4.13 and Table 4.6.

Note: the table in the top right corner of each diagram shows the relevant section of Table 4.6 that inside the green rectangle.

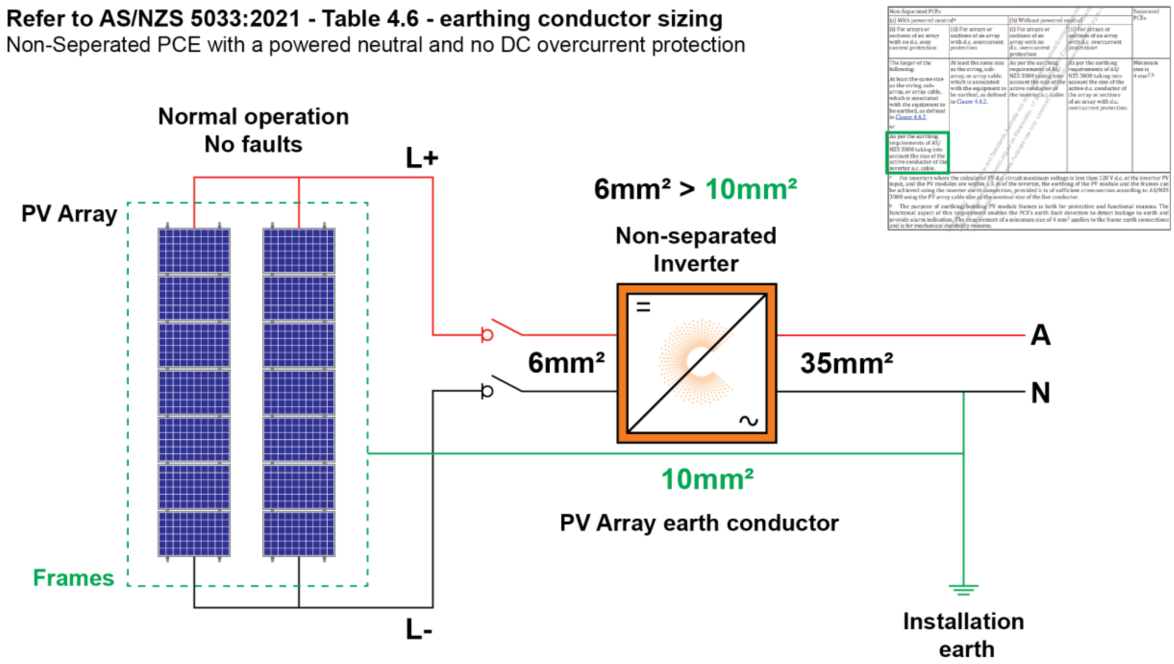
EXAMPLE 01 (a) (i)

The 4mm^2 array cable is larger than the 2.5mm^2 carried earth in the 6mm^2 inverter cable.



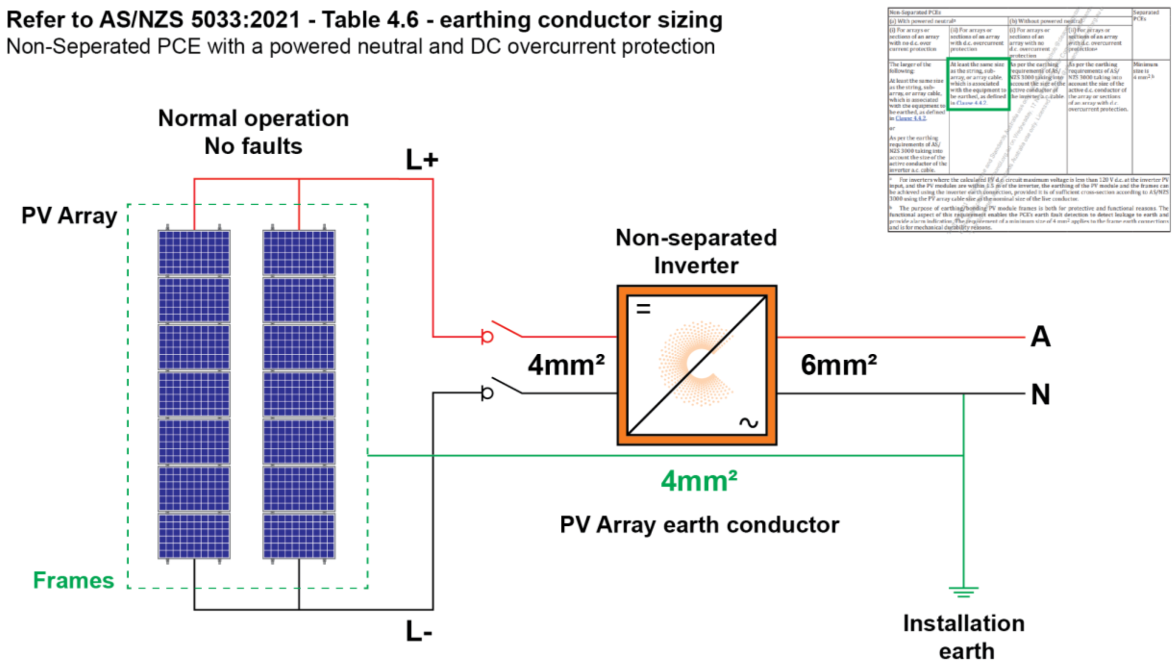
EXAMPLE 02 (a) (i)

The 10mm^2 carried earth in the 35mm^2 inverter cable is larger than the 6mm^2 array cable.



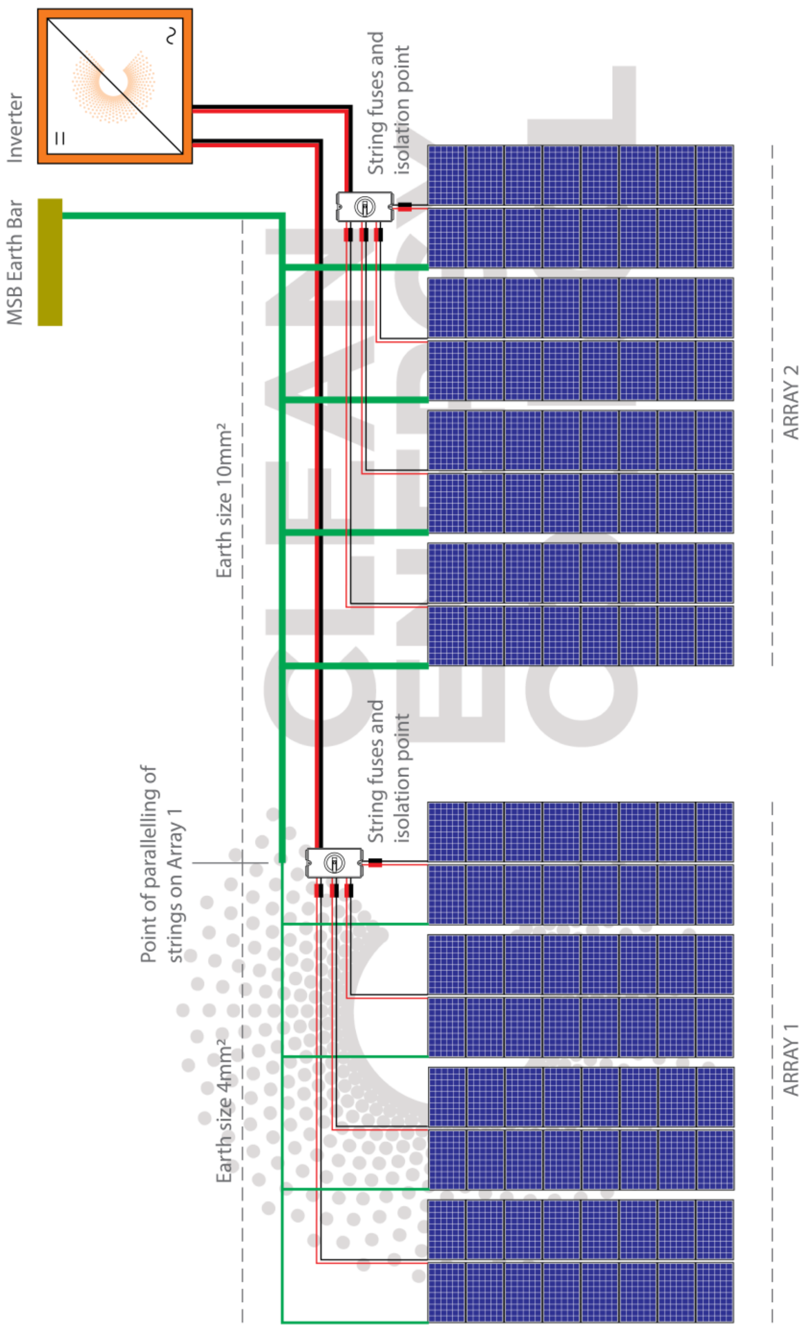
EXAMPLE 03 (a) (ii)

4mm^2 array cable is the largest of the array cable, subarray cable and string cable.



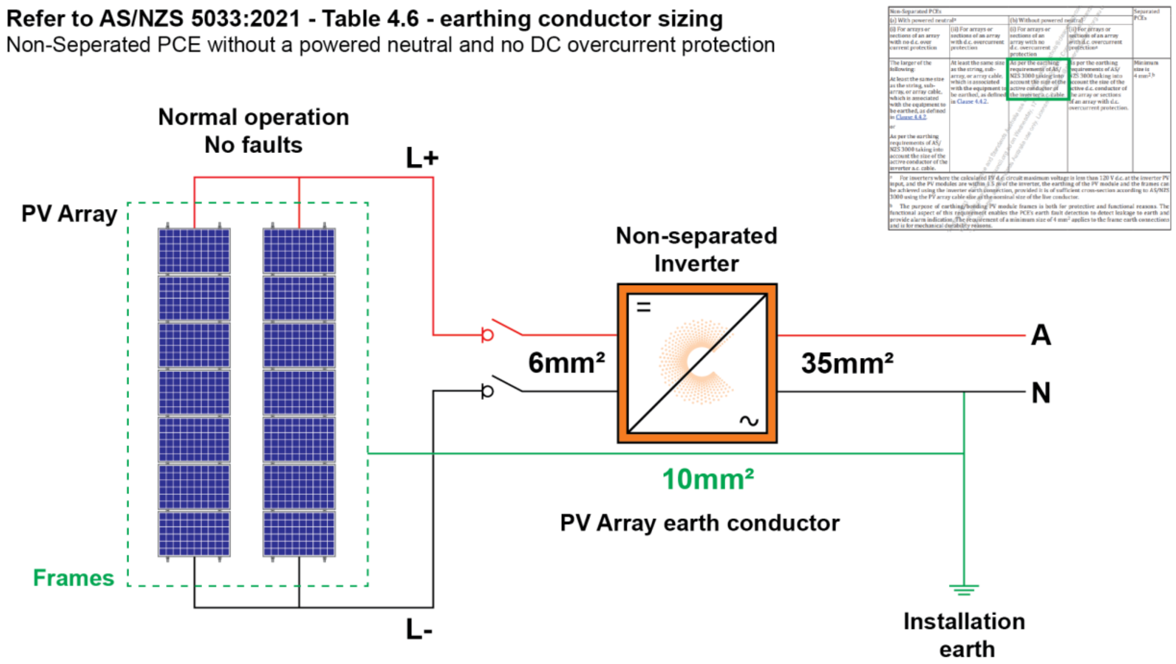
EXAMPLE 04 (Larger sized system)

On larger systems with powered neutral, string fusing and many parallel strings, the fault current possible increases in the zones where array cables run.



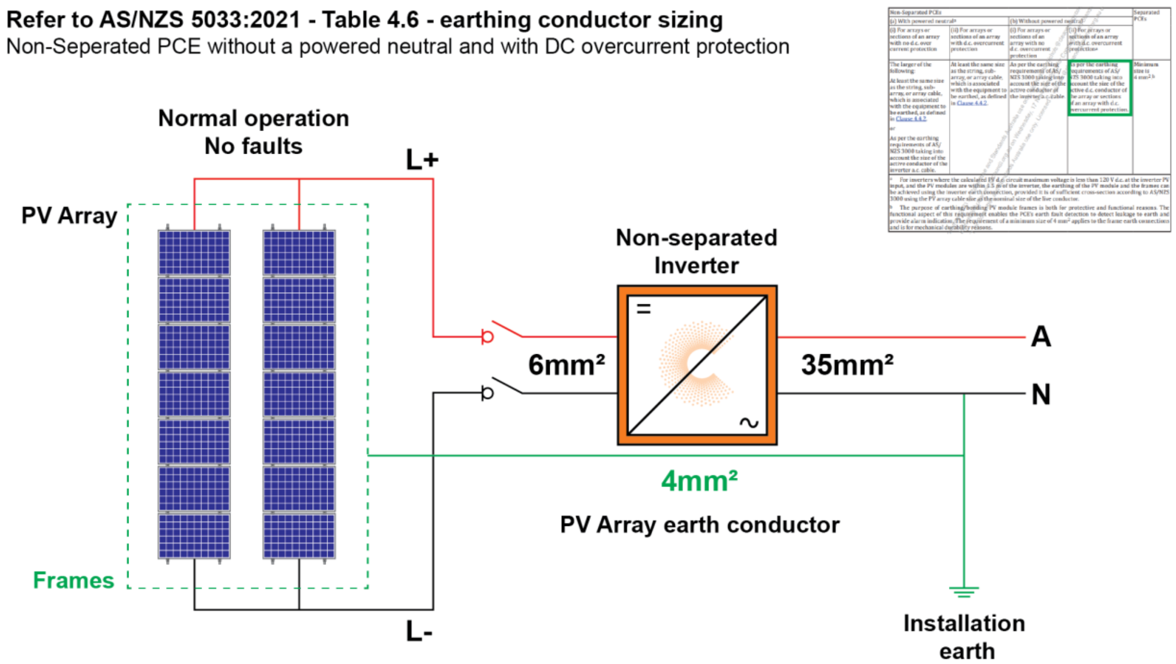
EXAMPLE 05 (b) (i)

The 35mm² inverter cable is usually paired with a 10mm² earth as per AS/NZS 3000.



EXAMPLE 06 (b) (ii)

A 6mm² cable is usually paired with a 2.5mm² earth as per AS/NZS 3000. AS/NZS 5033:2021 recommends 4 mm², noting that resistance shall be 0.5Ω or less. 4mm² earth cable shall be used at the array as per NOTE 5 in Figure 4.13.



Worked example

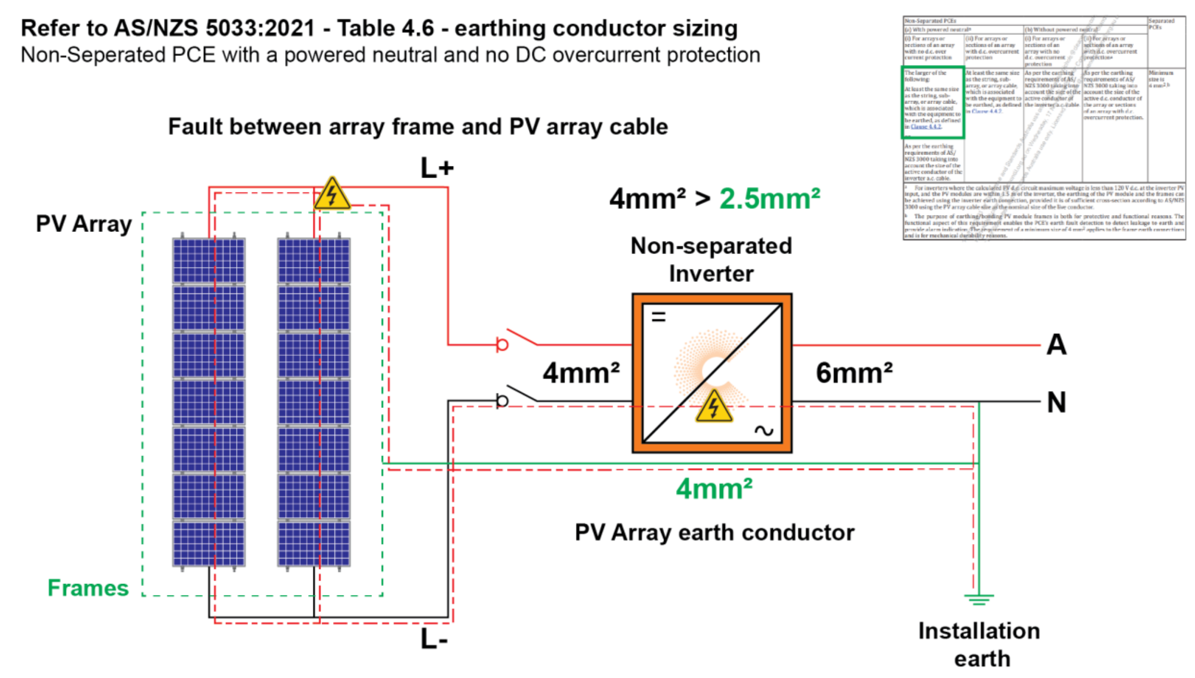
Corresponding faults

When a d.c. to earth fault occurs on the array, it can result in a second fault occurring in transformerless inverters whereby an a.c. fault or a d.c. fault path is completed.

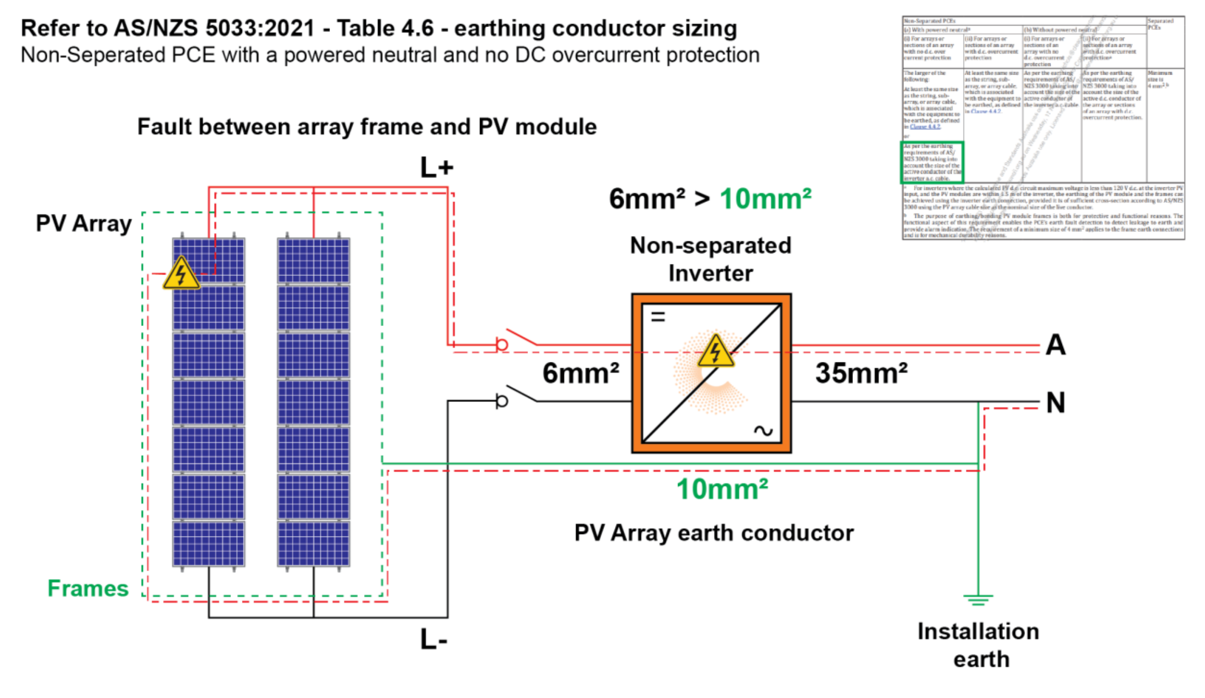
d.c. faults may persist as they do not reach the trip threshold of the d.c. overcurrent protection if present, so earth conductors shall be sized to carry the fault current.

a.c. faults will trip the a.c. overcurrent protection device so long as the impedance is low enough, therefore earth conductors shall be sized so the overcurrent protection device trips within the required time frame.

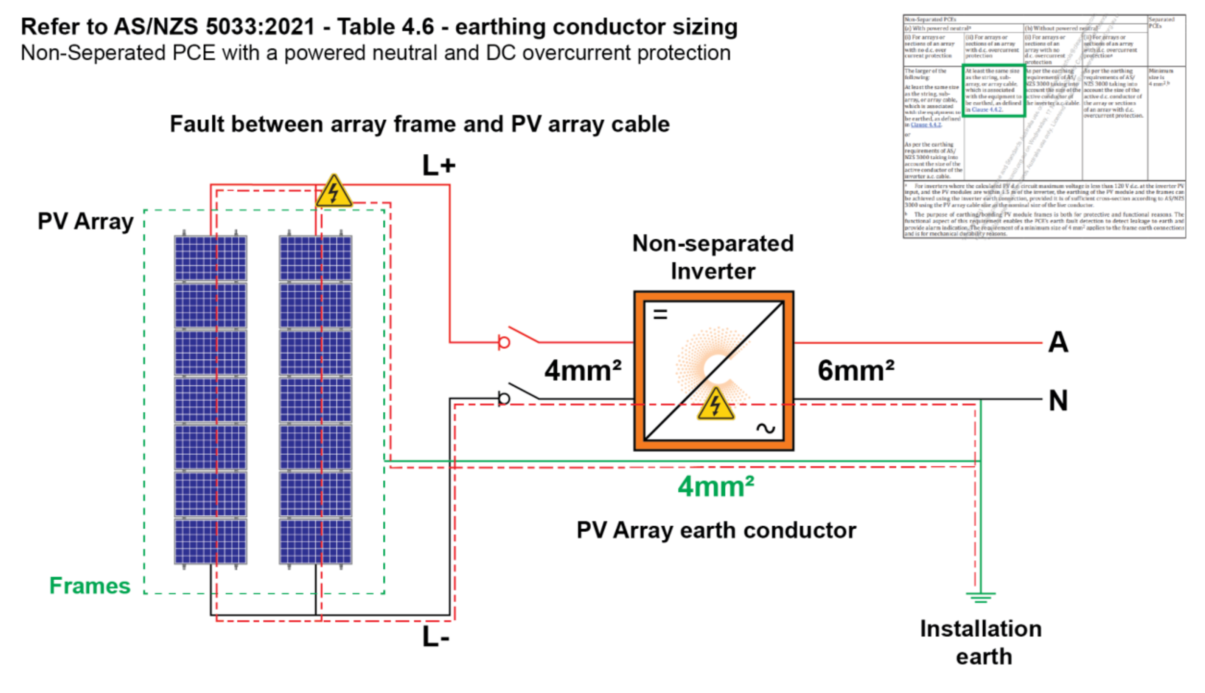
EXAMPLE 01 (a) (i) – Earthing fault (d.c.)



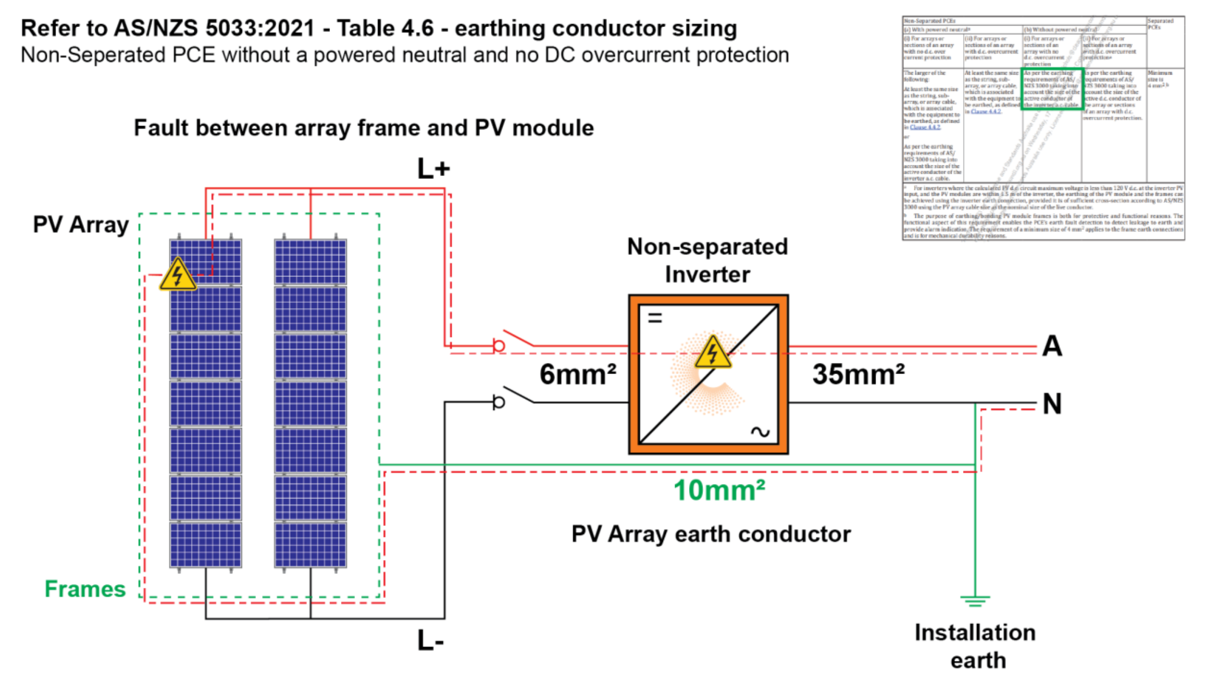
EXAMPLE 02 (a) (i) – Earthing fault (a.c.)



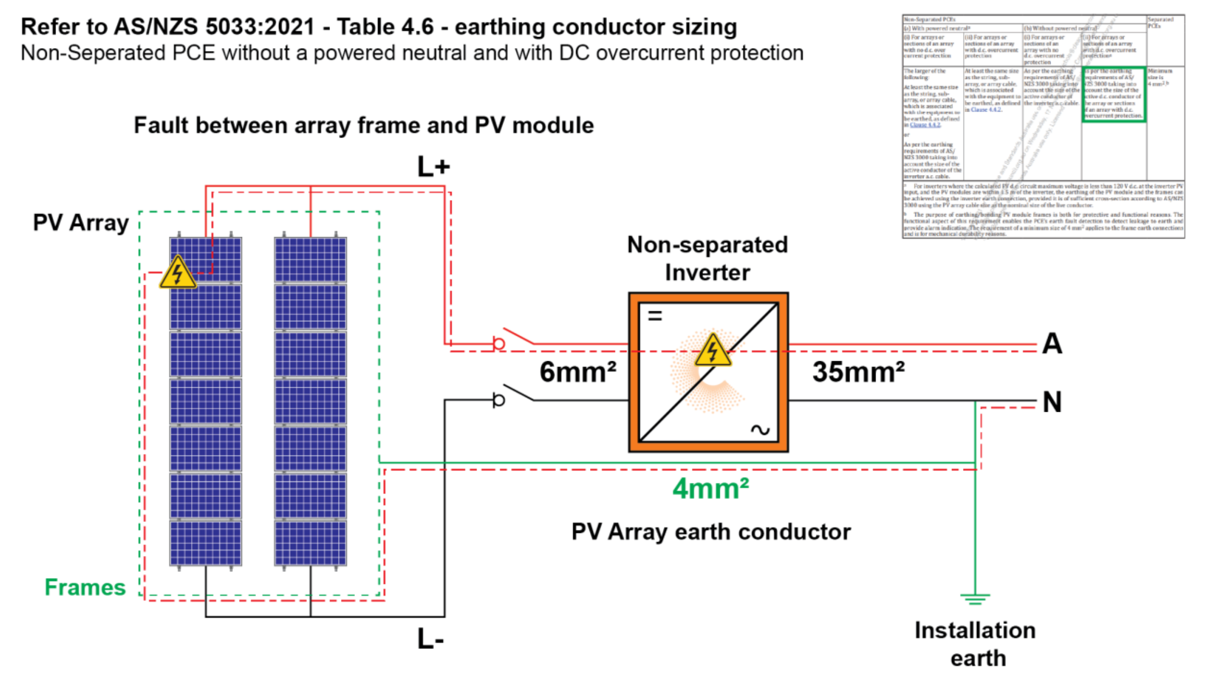
EXAMPLE 03 (a) (ii) – Earthing fault (d.c.)



EXAMPLE 03 (b) (i) – Earthing fault (a.c.)



EXAMPLE 03 (b) (ii) – Earthing fault (a.c.)



5 MARKING

5.1 Equipment marking

All electrical equipment shall be marked as per the requirements for marking to local standards and regulations where applicable.

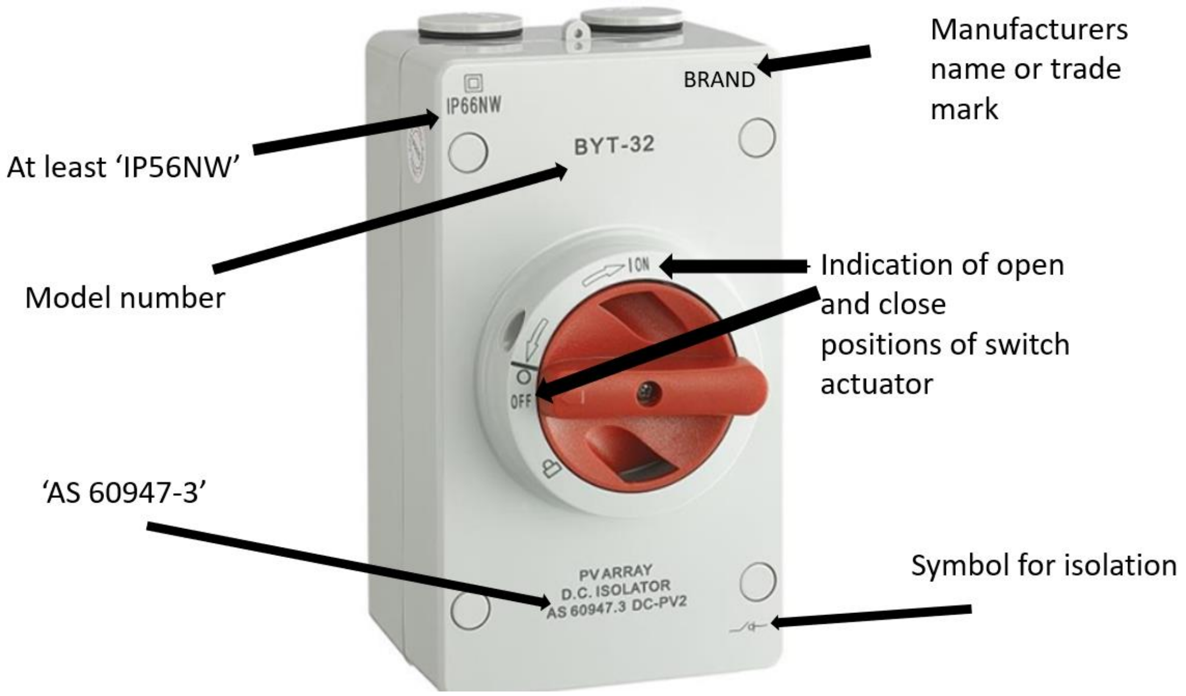


Figure A4.14 (cl. 4.4.6.2)

Marking requirements for Dc isolators

See the 'CEC Advice on Labelling' for more information.

5.2 Requirements for labels and signs

5.2.1 General

All labels and signs required shall be –

- durable and designed to have a lifetime greater than or equal to the service life of the PV system.
- constructed of appropriate materials suitable for the location.
- fixed in a manner appropriate for the location.
- in English.
- legible and the letter size to be appropriate for the location.
- Indelible.
- *NOTE: permanent marker often wears off over time, especially when exposed to UV.*
- visible where applicable (e.g. some signs may be enclosed in a switchboard cabinet, but not visible when an operator opens the switchboard to perform maintenance or emergency services).
- where installed exposed to direct sunlight conform to Clause 5.2.2.

See the 'CEC Advice Document on Labelling' for more information.

6 SYSTEM DOCUMENTATION AND COMMISSIONING

6.1 General

At the completion of the installation of a PV system, documentation shall be provided in accordance with the requirements of this section in the standard. This documentation should ensure key system information is readily available to customers, inspectors, maintenance service providers and emergency service personnel.

See the 'CEC Advice Document on Documentation' for more information.

The CEC MyJobs tool already provides some of the documentation required. For more information on MyJobs go to:

https://www.cleanenergycouncil.org.au/account/jobs