ElectricalOM User Manual

for Solar Photovoltaic (PV) Systems

1. Terms, definitions, symbols and abbreviated terms

Ns
The total number of parallel-connected PV strings in the PV array.

I_MOD_MAX_OCPR
The PV module's maximum overcurrent protection rating determined by IEC 61730-2.

I_SC_MAX
The maximum short-circuit current of a PV string.

U_OC_MAX
The maximum open-circuit voltage of the PV string or module under certain environmental conditions.

In
The rated current of the protective device being used.

I_Z
The continuous current-carrying capacity of the PV string cable.

N_p
The number of parallel strings connected to the same overcurrent protective device.

N_a
The number of sub-arrays connected in parallel.

STC
Standard Test Conditions reference values of in-plane irradiance (G_I,ref = 1 000 W·m–2), PV cell junction temperature (25 °C), and air mass (AM = 1,5) to be used during the testing of any PV device.

I_SC_STC
The short-circuit current of the PV array under Standard Test Conditions (STC).

U_OC_STC
The open-circuit voltage of the PV module under Standard Test Conditions (STC).

Solar PV Inverter
A system that converts the electrical power delivered by the PV array into the appropriate frequency and/or voltage values to be delivered to the load, or stored in a battery or injected into the electricity grid.

Power Optimiser
A unit connected to individual PV modules or groups of PV modules to allow DC conditioning of the PV output.

MPPT
Maximum Power Point Tracking is a control strategy that ensures the operation of a PV array remains at or near the point on a photovoltaic device's current-voltage characteristic where the product of electric current and voltage produces the maximum electrical power under specified operating conditions.

Blocking diode
Diode connected in series with module(s), panel(s), sub-arrays and array(s) to block reverse current into such module(s), panel(s), sub-array(s) and array(s).

Bypass diode
Diode connected across one or more cells in the forward current direction to allow the module current to bypass shaded or broken cells to prevent hot spot or hot cell damage resulting from the reverse voltage biasing from the other cells in that module.

Charge controller
Unit used between a battery and a PV array to regulate charge delivered to the battery.

PV array
Assembly of electrically interconnected PV modules, PV strings or PV sub-arrays.

PV cell
The most elementary device that exhibits the photovoltaic effect, i.e. the direct non-thermal conversion of radiant energy into electrical energy.

PV module
A complete and environmentally protected assembly of interconnected photovoltaic cells.

PV string
A circuit of one or more series-connected modules

PV sub-array
An electrical subset of a PV array formed of parallel connected PV strings.

SLD
Single-Line Diagram

2. Solar Photovoltaic Systems (PVs) Modelling

To model Solar Photovoltaic Systems (PVs) in ElectricalOM, the user must connect a 3-Ph + N or 3Ph + N **Solar PV Inverter** component to a distribution node (e.g. distribution board, switchboard, junction box).

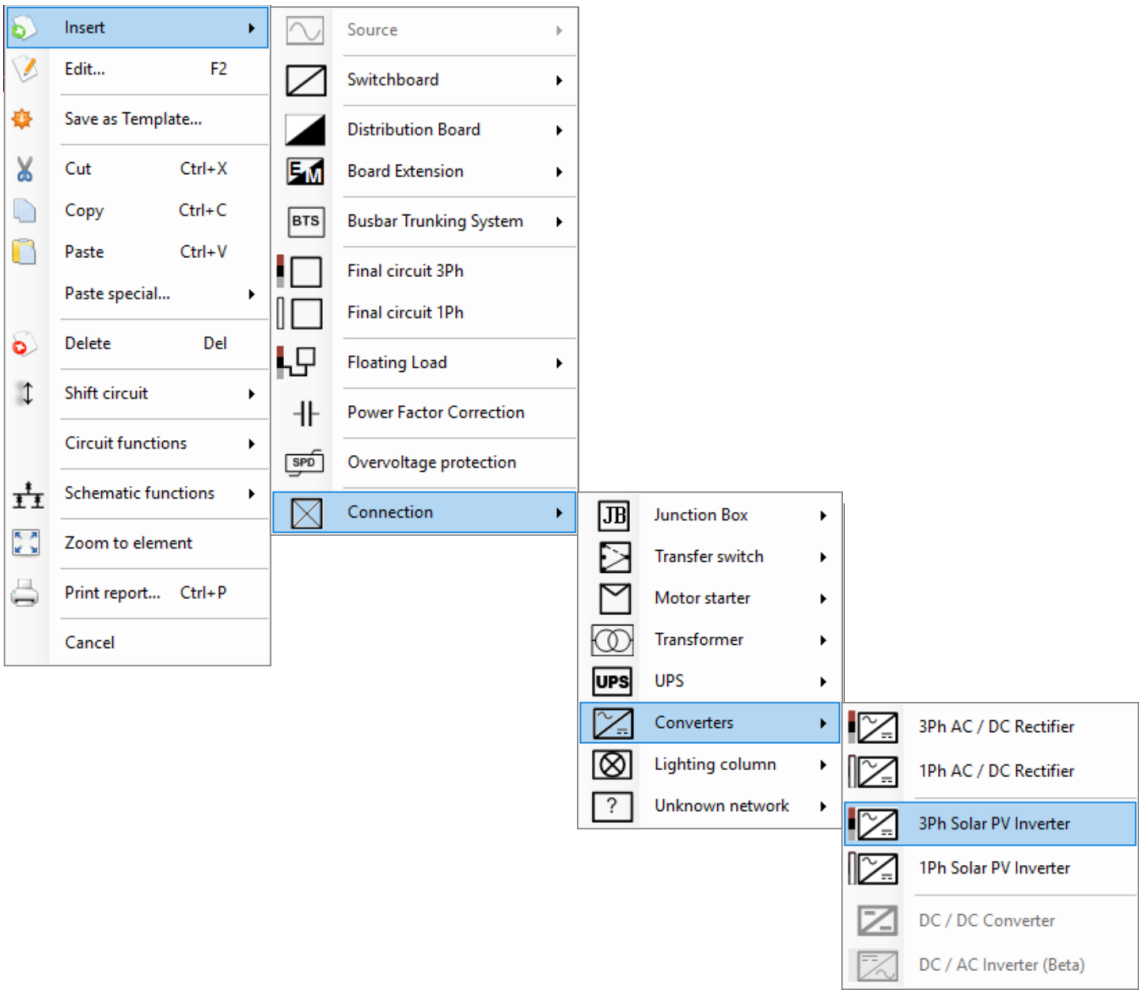


Figure 1: Inserting a Solar PV Inverter via the Actions Menu

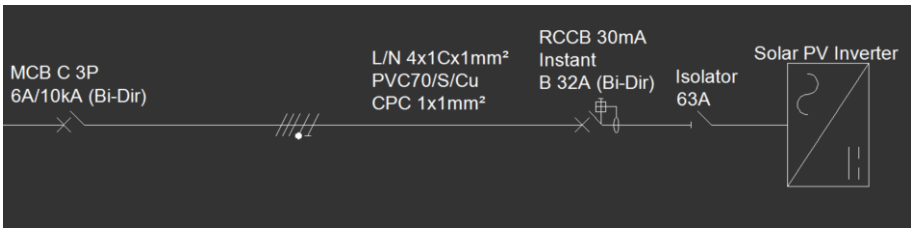


Figure 2: Single-Line Diagram (SLD) of the AC Side of a Solar PV Inverter

The Circuit Edit tab of a Solar PV Inverter component features the Inverter Settings section, where users can define various parameters related to the Solar PV Inverter.

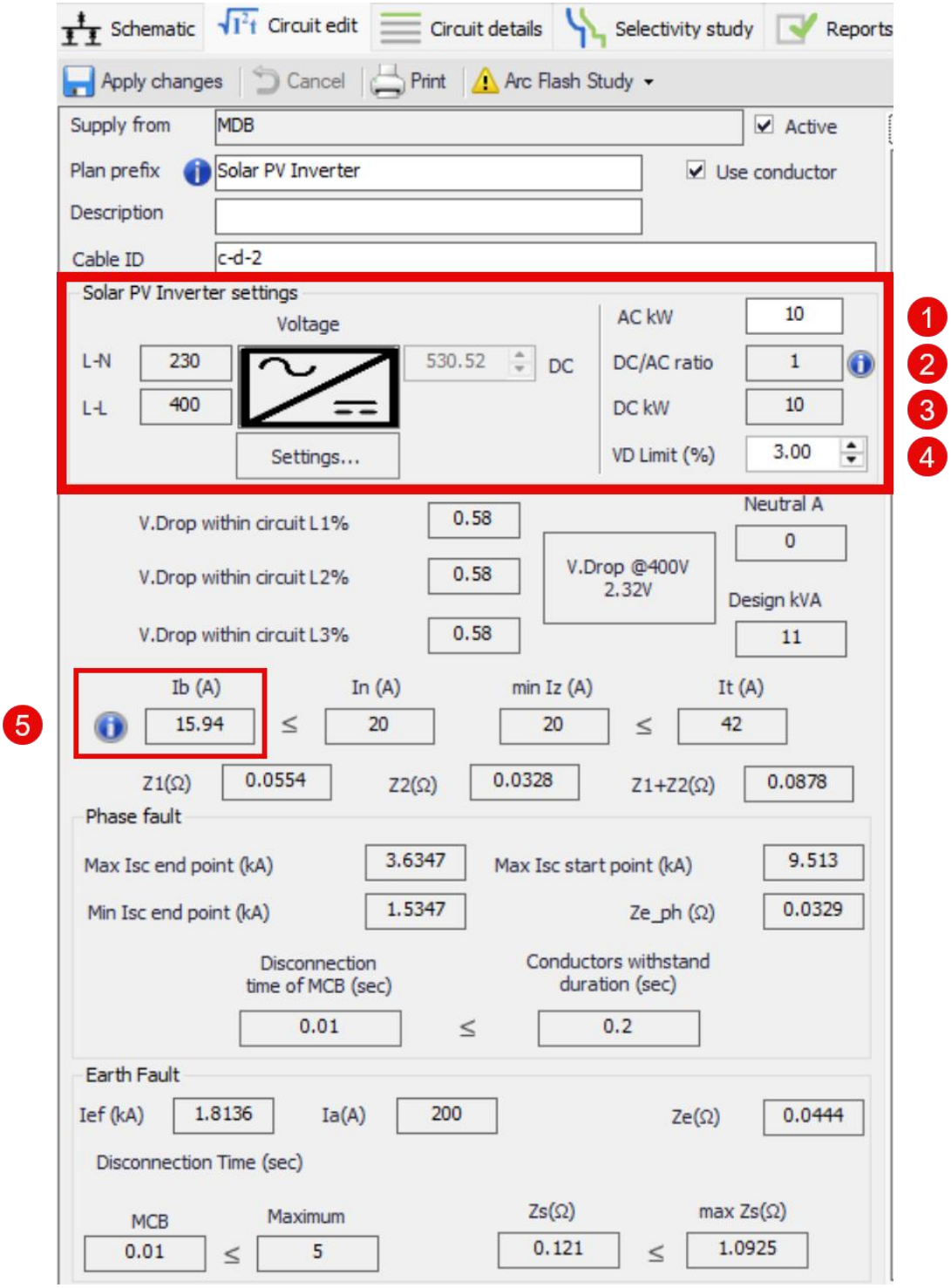


Figure 3: Solar PV Inverter Settings in the Circuit Edit Menu

Solar PV Inverter Settings

The inverter's settings section enables the user to define key operational parameters for integrating solar PV inverters. These settings influence current calculations, protection coordination, and voltage drop compliance:

1. **AC kW –** Specifies the inverter's nominal output power on the AC side. This value is used to calculate the inverter's design current (Ib) and supports the sizing of AC cables and protection devices.
2. **DC/AC Ratio –** This ratio defines the relationship between the installed PV array's DC capacity and the inverter's AC output. This parameter helps simulate realistic operating conditions and assess potential inverter clipping or overloading.
3. **DC kW –** Represents the total DC power of the connected PV array. It is automatically calculated based on the DC capacity.
4. **VD Limit (%) –** Sets the maximum allowable voltage drop on the DC side of the inverter.
5. **Ib (A) –** Indicates the calculated design current on the AC side of the inverter. It serves as a reference for selecting protective devices and ensuring that cable current-carrying capacities (Iz) are suitable, in accordance with regulatory standards.

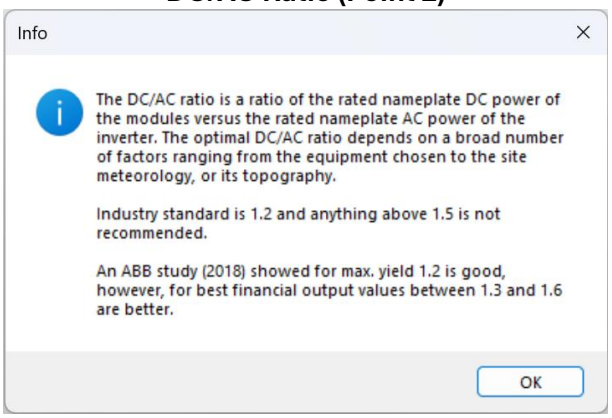
Information Icons in ElectricalOM

Throughout the Solar PV Inverter settings and calculation sections, info icon buttons (ℹ️) are provided next to critical parameters and computed values. These icons offer context-specific guidance to help users understand design inputs, regulatory checks, and industry best practices.

Clicking on an info icon reveals a pop-up explanation tailored to the specific field. This feature enhances usability, ensures informed decision-making, and facilitates alignment with established standards.

Info Icons (ℹ️)

DC/AC Ratio (Point 2)



Ib (A) (Point 5)

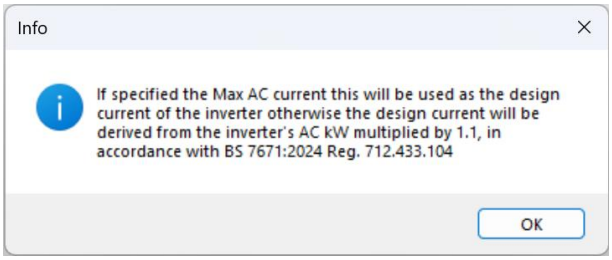


Figure 4: Circuit Edit Menu Info Icons – (A) DC/AC Ratio and (B) Ib (Design Current)

In addition to the main input parameters, users can access and configure additional inverter-specific options by clicking the **"Settings..."** button located beneath the Solar PV Inverter symbol. This section allows for the adjustment of advanced parameters related to the inverter's functional operational limits.

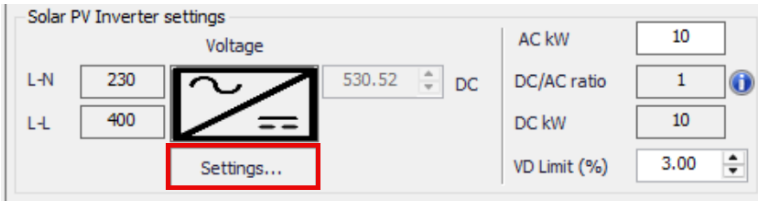


Figure 5: Solar PV Inverter Settings Button in the Circuit Edit Menu

Solar PV Inverter Settings – Input Limit Checks

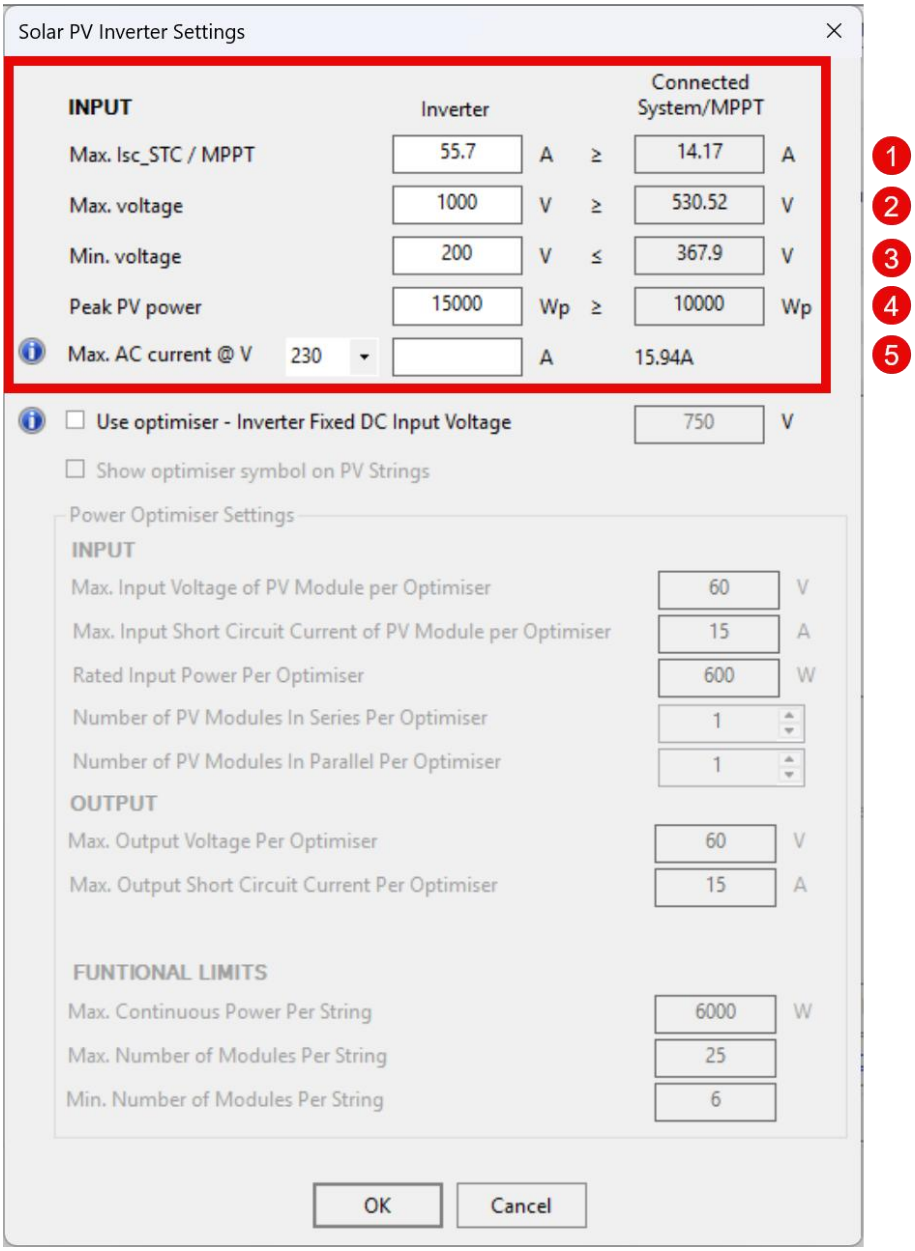


Figure 6: Solar PV Inverter Settings – Input Limit Checks

Inverter Input Limit Checks

The inverter parameters outlined below determine the acceptable DC input and AC output limits, as specified by the manufacturer. ElectricalOM verifies these parameters against the connected PV system and highlights any violations:

1. **Max. Isc_STC / MPPT (A)** – Sets the inverter's maximum allowable short-circuit current per MPPT, compared to the calculated PV string Isc @ STC.
2. **Max. Voltage (V)** – Defines the maximum DC voltage input the inverter can withstand, checked against the PV array's Voc at low temperatures.
3. **Min. Voltage (V)** – Specifies the minimum DC voltage required for inverter operation, validated against the PV system's lowest expected voltage.
4. **Peak PV Power (Wp)** – Limits the total DC power the inverter can accept, compared to the installed PV array's capacity.
5. **Max. AC Current @ V (A)** – Indicates the inverter's maximum AC output current at a given voltage. If specified, the design current (Ib) will be overwritten; otherwise, it will be automatically calculated based on the inverter's AC kW rating specified in the circuit edit.

Info Icon ( )

Max. AC Current @ V (A) (Point 5)

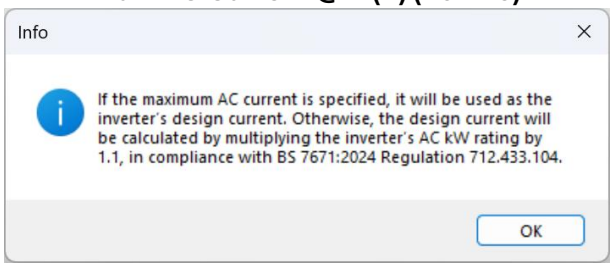


Figure 7: Info Icon in Inverter Settings – Max. AC Current at Specified Voltage

Solar PV Inverter Settings - Power Optimiser Settings

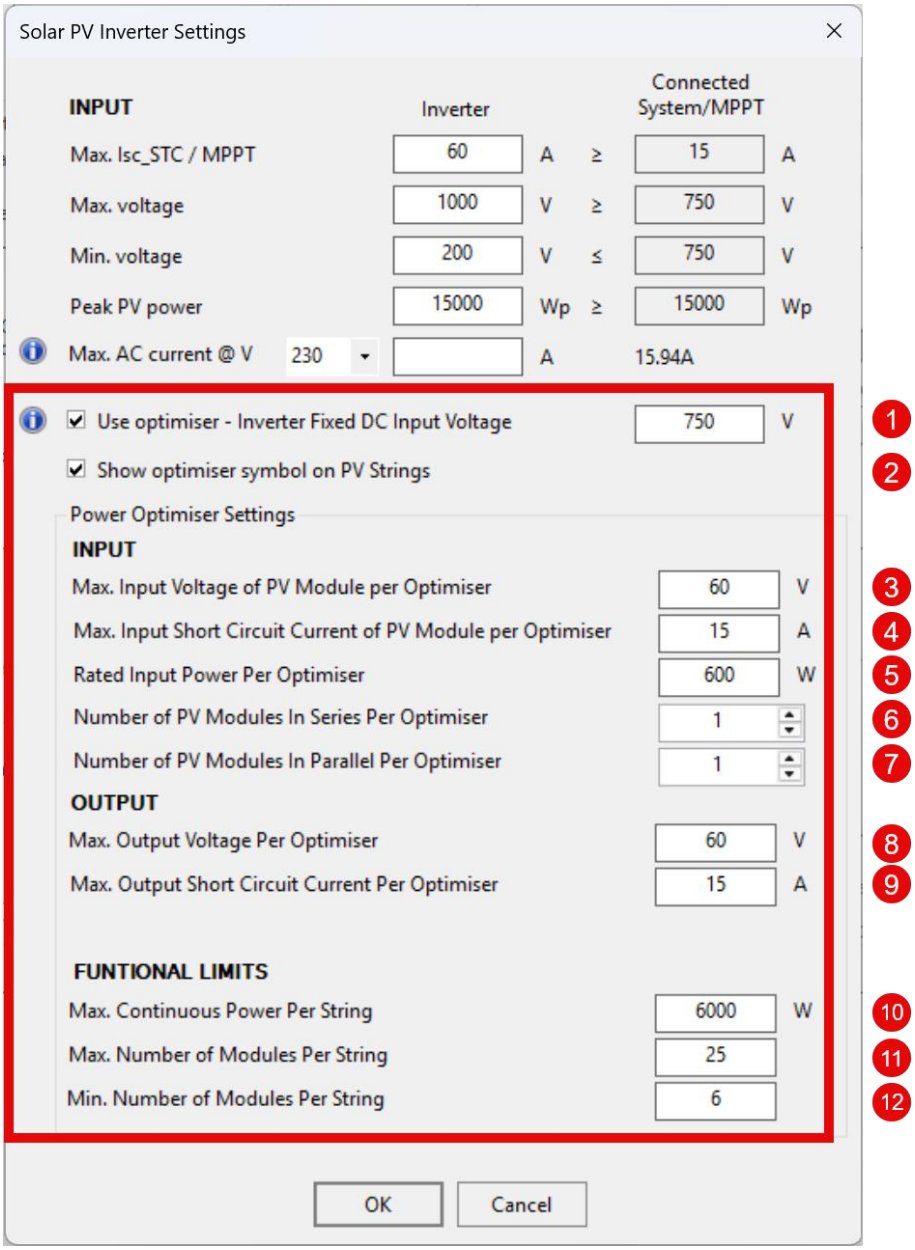


Figure 8: Solar PV Inverter Settings – Power Optimiser Configuration

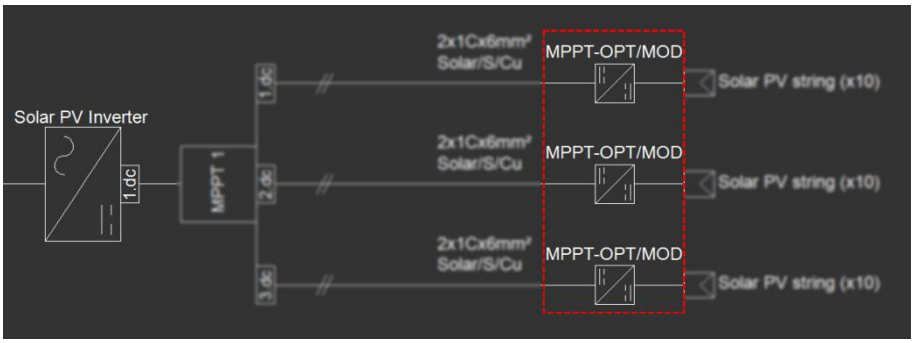


Figure 9: SLD of a Solar PV System with Power Optimisers

Power Optimiser Settings

When optimisers are enabled, ElectricalOM performs checks against the following parameters to ensure that each PV string and module configuration remains within safe and manufacturer-specified operational limits:

1. **Use optimiser – Inverter Fixed DC Input Voltage**
   Enables optimiser mode and sets the inverter's fixed DC input voltage when optimisers regulate the string voltage.
2. **Show optimiser symbol on PV Strings**
   Displays the optimiser icon on each string in the schematic to visually indicate the use of optimisers.
3. **Max. Input Voltage of PV Module per Optimiser (V)**
   Sets the highest voltage a PV module can deliver to an optimiser without exceeding its input tolerance.
4. **Max. Input Short Circuit Current of PV Module per Optimiser (A)**
   Defines the maximum current an optimiser can accept from a PV module under short-circuit conditions.
5. **Rated Input Power per Optimiser (W)**
   Specifies the maximum continuous DC power each optimiser is designed to handle safely.
6. **Number of PV Modules in Series per Optimiser**
   Determines the maximum number of PV modules that can be connected in series to a single optimiser.
7. **Number of PV Modules in Parallel per Optimiser**
   Determines the maximum number of PV modules that can be connected in parallel to a single optimiser.
8. **Max. Output Voltage per Optimiser (V)**
   Sets the maximum DC voltage an optimiser can output to the string.
9. **Max. Output Short Circuit Current per Optimiser (A)**
   Indicates the highest output current the optimiser can deliver during a short-circuit event.
10. **Max. Continuous Power per String (W)**
    Limits the total DC power a single string (with optimisers) can output continuously.
11. **Max. Number of Modules per String**
    Sets the maximum number of PV modules allowed in a string using optimisers.
12. **Min. Number of Modules per String**
    Sets the minimum number of PV modules required in a string using optimisers to maintain correct voltage and operation.

Info Icon ( )

Use optimiser – Inverter Fixed DC Input Voltage (Point 1)

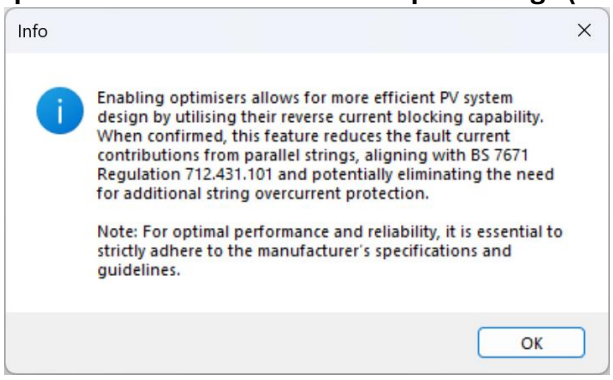


Figure 10: Info Icon – Optimiser Reverse Current Blocking and Overcurrent Protection Compliance

Available Components for the DC Side of a Solar PV Inverter

Only specific components can be inserted on the DC side of a Solar PV Inverter. As shown, options such as **(A)** Solar PV string, **(B)** Floating Solar PV string, **(C)** Overvoltage protection, and **(D)** Junction Box (1Ph) are available, while all other options are disabled (greyed out) for compliance and design consistency (Figure 11).

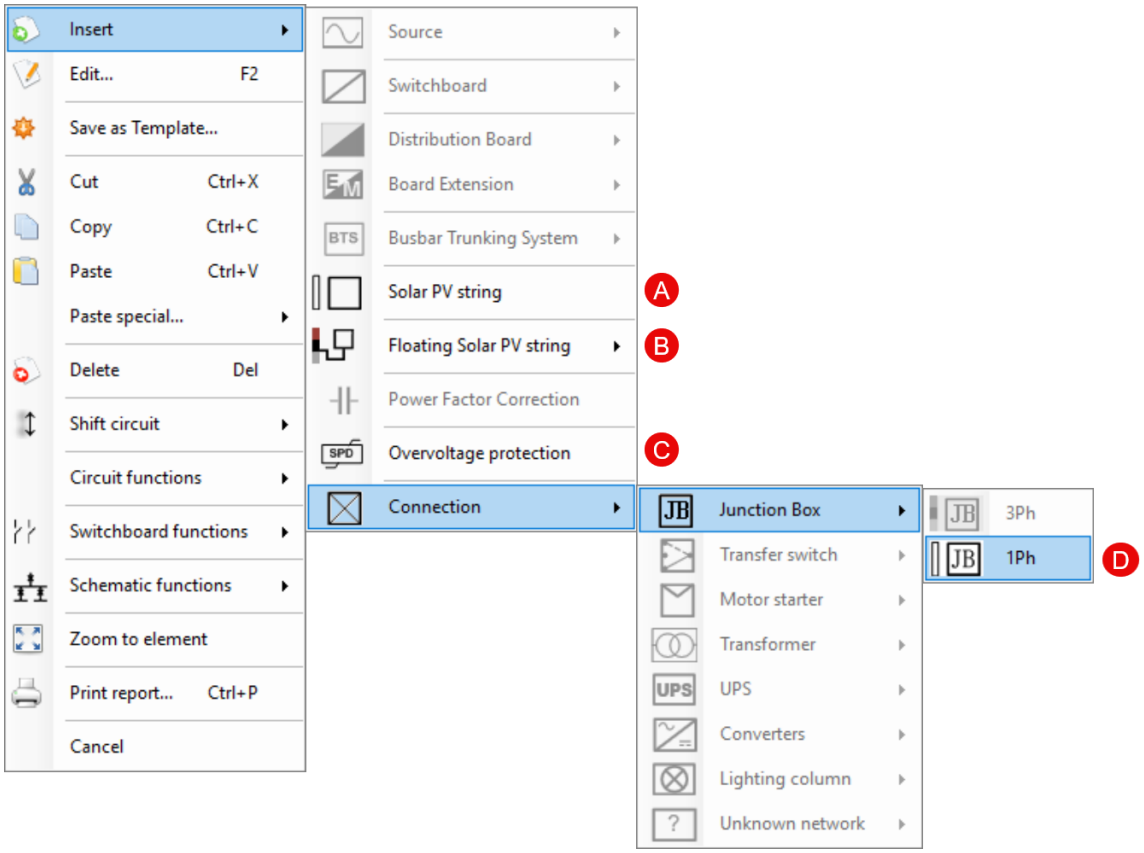


Figure 11: Actions Menu – Available Components for the DC Side of a Solar PV Inverter

Inverters with Independent MPPT DC Inputs and Internally-Connected DC Inputs

By default, ElectricalOM treats each inverter DC input as being connected to an independent MPPT (Figure 12). However, when modelling inverters with multiple DC inputs internally paralleled onto a common DC bus, or when multiple PV strings are connected via a combiner box, users can represent this configuration using the Junction Box component, as illustrated in Figures 13–14.

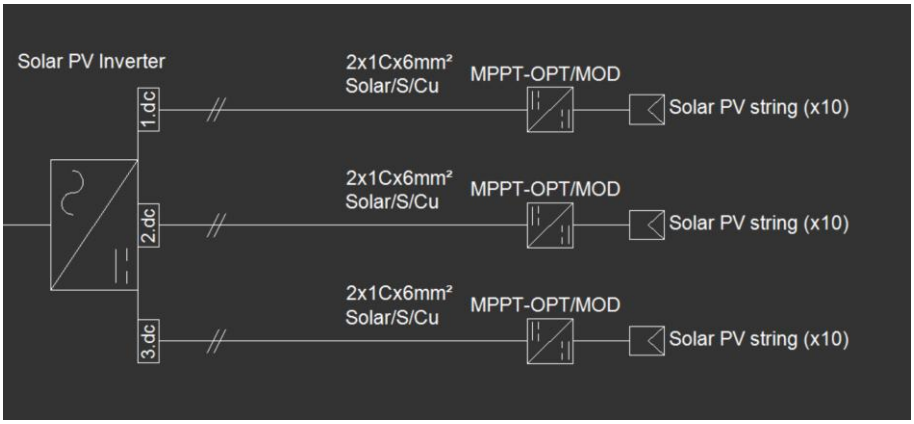


Figure 12: SLD of an Inverter with Independent MPPT DC Inputs

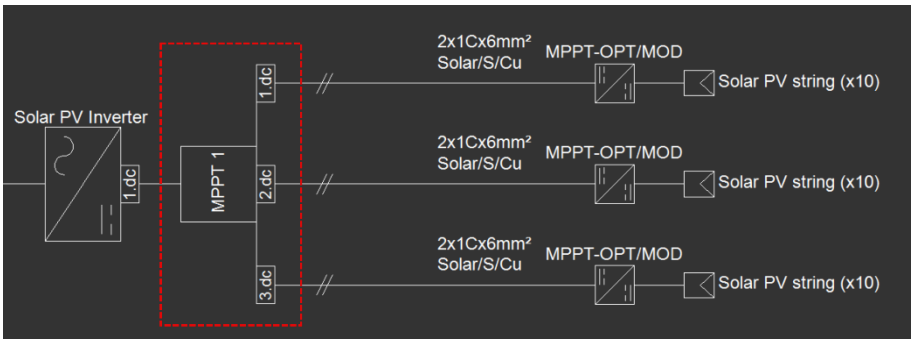


Figure 13: SLD of an Inverter with Internally-Connected DC Inputs

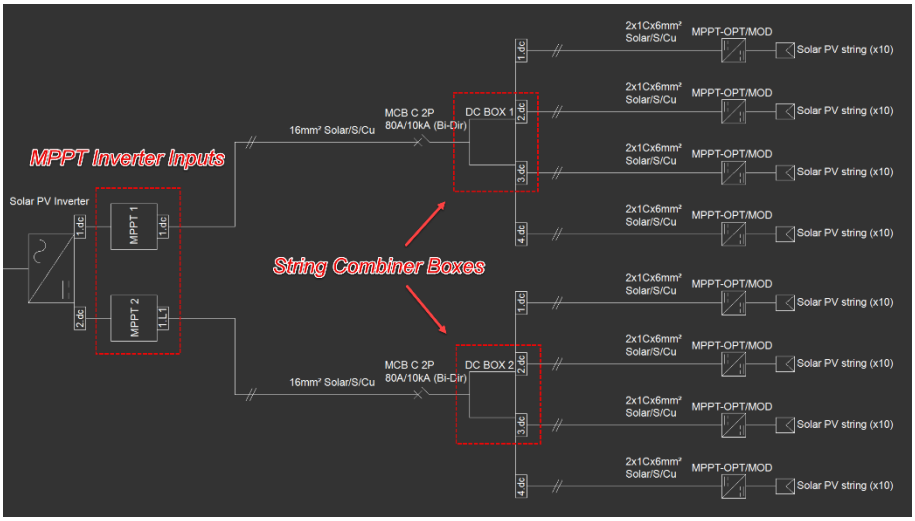


Figure 14: SLD of PV Arrays, PV String Combiner Boxes, and MPPT Inverter Inputs

Configuring PV Strings in the Circuit Edit Module

ElectricalOM allows users to configure PV strings efficiently (see Figure 15) through the Circuit Edit Module by providing an intuitive interface split across several functional areas, each serving a specific purpose in the design process:

1. **Tree-Network View of a Solar PV System**
   This panel displays the complete PV system layout in a hierarchical tree format, allowing users to navigate through inverters, MPPTs, and strings for easy access and organisation.
2. **PV String Configuration**
   Here, users input the key electrical parameters of each PV module and string, such as current, voltage, and power ratings, which are used to calculate total string performance.
3. **PV String Calculation Checks**
   This section performs automatic calculations and checks at the string level, ensuring compliance with Section 712 of BS 7671 and flagging configuration issues.
4. **String Power Optimisers Settings**
   Allows users to configure power optimisers when enabled from the Solar PV Inverter settings, which adjust system behaviour and protection logic when optimisers are integrated into the PV string design.
5. **Circuit Edit Tabs**
   This area provides access to tabs for configuring DC conductor properties, installation methods, DC protective devices, and correction factors, ensuring the PV string circuit is safely and efficiently designed.
6. **PV String Voltage**
   Displays the total design DC voltage of the PV string, calculated based on the number of modules and environmental factors, ensuring it stays within the inverter voltage limits.
7. **Warnings Area**
   Summarises any configuration or compliance issues detected in real time, guiding the user to resolve design conflicts and ensure regulatory alignment.

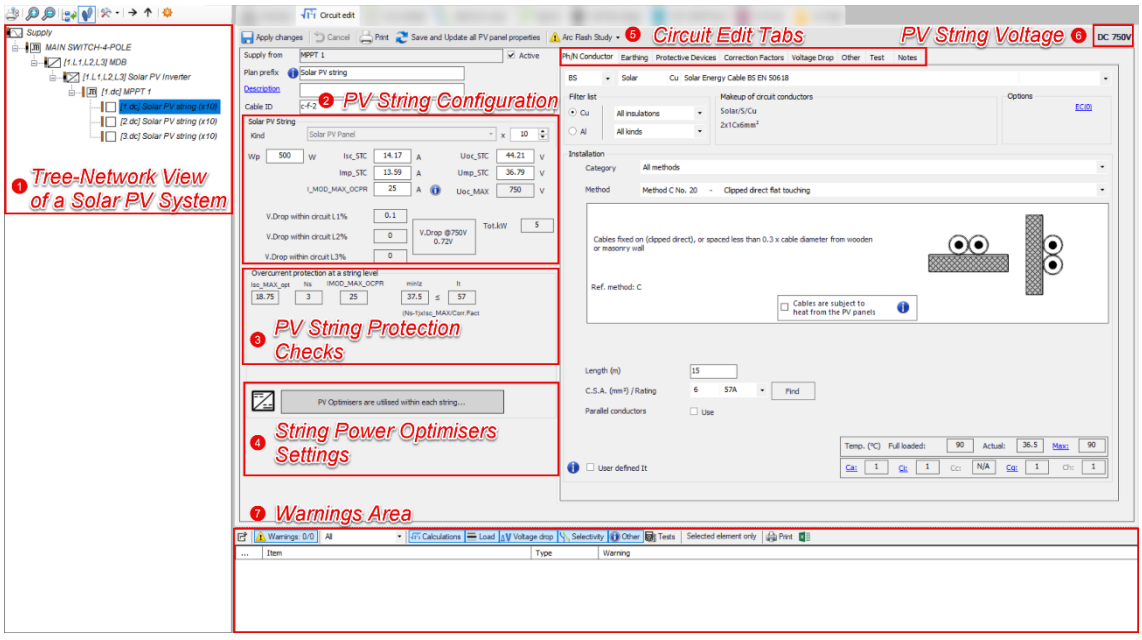


Figure 15: Circuit Edit Environment for Configuring PV String Parameters

PV Modules and String Configuration

As shown in Figures 11 (A) and (B), users can add a Solar PV String either directly to a Solar PV Inverter or via a Junction Box component, which serves as a connection point for MPPT inputs or a DC Combiner Box. ElectricalOM features a dedicated input section in the Circuit Edit Module, allowing users to define the electrical characteristics of each string. This enables accurate sizing, performance evaluation, and compliance checks.

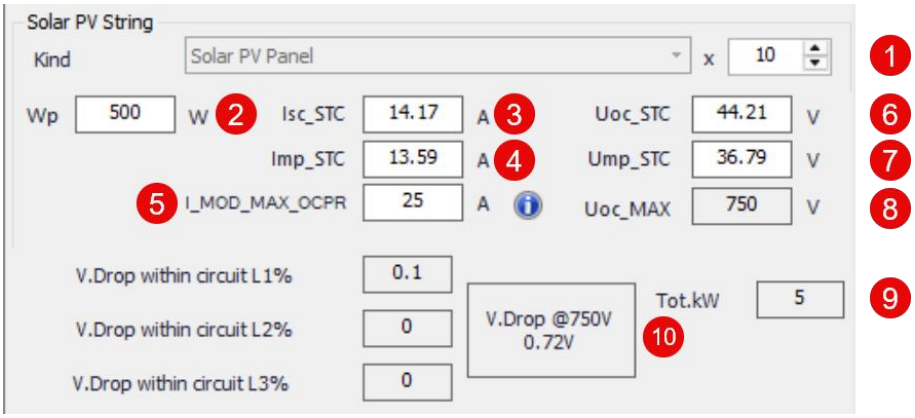


Figure 16: PV String Electrical Configuration in the Circuit Edit Module

PV String Parameter Descriptions:

1. **Number of Modules in the String –** Specifies the number of PV modules connected in series within the string.
2. **Module Rated Power (Wp) –** Indicates the nominal power output of each PV module under Standard Test Conditions (STC).
3. **Isc_STC (A) –** Short-circuit current per module at STC, used for overcurrent protection checks.
4. **Imp_STC (A) –** Operating current at maximum power under STC, used to determine the string's output.
5. **I_MOD_MAX_OCPR (A) –** Maximum allowable overcurrent protection rating for each module, based on standards or manufacturer data.
6. **Voc_STC (V) –** Open-circuit voltage per module at STC, used for total string voltage calculations.
7. **Vmp_STC (V) –** Voltage at the maximum power point under STC, relevant to string operating voltage.
8. **Voc_MAX (V) –** Maximum calculated open-circuit voltage under worst-case environmental conditions, used for inverter input checks.
9. **Total String Power (Tot. kW) –** Displays the total power output of the string based on the number of modules and their Wp.
10. **Voltage Drop at Design Voltage –** Displays the voltage drop across the string at a specified voltage (e.g., 750 V), facilitating verification of compliance with design limits.

Info Icon ( )

I_MOD_MAX_OCPR (A) (Point 5)

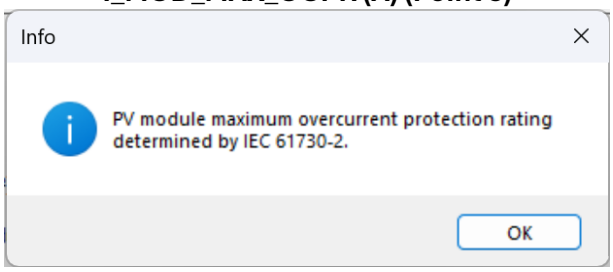


Figure 17: Info Icon – PV Module Maximum Overcurrent Protection Rating as per IEC 61730-2

PV String Calculation Checks

This section performs automated calculations and validation checks at the string, sub-array and array level to ensure compliance with Section 712 of BS 7671. Depending on the system's configuration, it evaluates key protection criteria, including:

1. Protection of PV modules and strings (Reg. 712.431.101 and 712.431.102):

$$1.35 \times I_{MOD\_MAX\_OCPR} < (N_s - 1) \times I_{SC\_MAX}$$
$$1.1 \times \mathrm{I_{SC\_MAX}} \leq \mathrm{I}_n \leq \mathrm{I_{MOD\_MAX\_OCPR}}$$
$$\mathrm{Np} \times 1.1 \times \mathrm{I_{SC\_MAX}} \leq \mathrm{I}_n \leq \mathrm{I_{MOD\_MAX\_OCPR}} - (\mathrm{N}_p - 1) \times \mathrm{I_{SC\_MAX}}$$

2. Choice of protective devices in line with IEC 62548:

$$1.5 \times I_{SC\_STC} < \mathrm{I}_n < 2.4 \times I_{SC\_STC}$$

3. Protection of PV string cables (Reg. 712.433.101):

$$\mathrm{I_{SC\_MAX}} \leq \mathrm{I_Z}$$
$$(N_s - 1) \times I_{SC\_MAX}$$
$$(N_s - 1) \times I_{SC\_MAX} \leq I_Z$$
$$\mathrm{I_n} \leq \mathrm{I_Z}$$

4. Calculation of maximum open-circuit voltage and short-circuit current (Reg. 712.433.101.1):

$$\mathrm{U_{OC_{MAX}}} = 1.2 \times \mathrm{U_{OC_{STC}}}$$
$$\mathrm{I_{SC\_MAX}} = 1.25 \times \mathrm{I_{SC\_STC}}$$

5. Protection of PV sub-array cables (Reg. 712.433.102):

$$\mathrm{I_{SC\_MAX}} \leq \mathrm{I_Z}$$
$$(N_a - 1) \times I_{SC\_MAX}$$
$$(N_a - 1) \times I_{SC\_MAX} \leq I_Z$$
$$1.1 \times I_{SC\_MAX} \leq \mathrm{I_n} \leq \mathrm{I_Z}$$

ElectricalOM automatically highlights any violations or non-compliance, supporting accurate and regulation-compliant PV system design (see Figures 18 - 19).

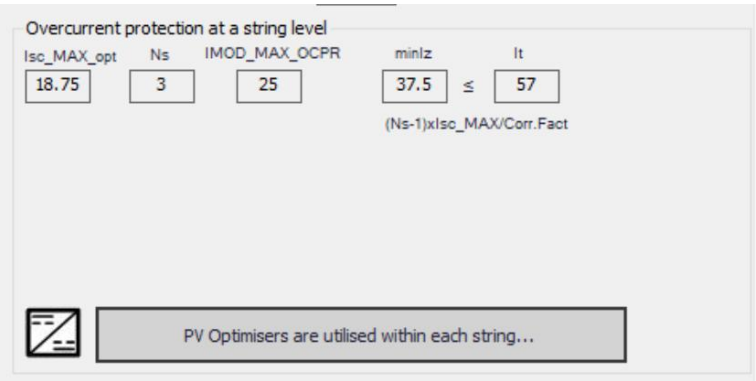


Figure 18: Overcurrent Protection Checks for a PV System with 3 Strings and Integrated Power Optimisers (No Additional String Protection Required)

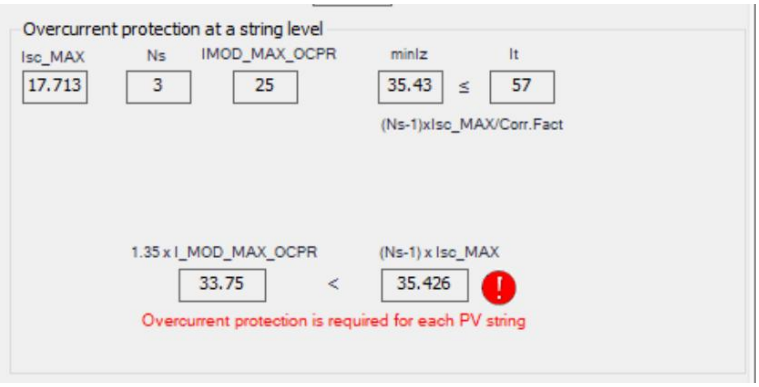


Figure 19A: Overcurrent Protection Checks for a PV System with 3 Strings without Power Optimisers

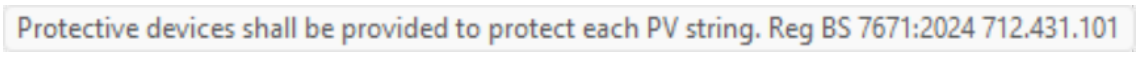


Figure 19B: Tooltip Warning Message – Overcurrent Protection Required for Each PV String (Reg. 712.431.101)

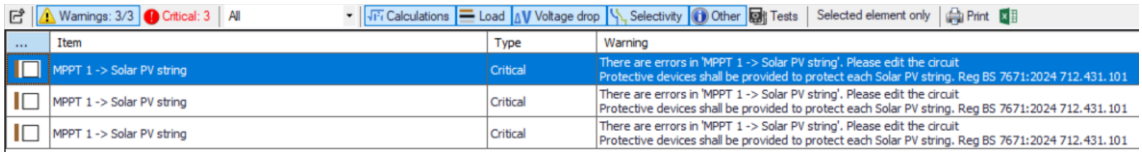


Figure 19C: Warning Area Message – Overcurrent Protection Required for Each PV String (Reg. 712.431.101)

Figures 18 and 19 illustrate different outcomes resulting from the use of power optimisers. In Figure 18, the system features optimisers that block reverse fault currents, enabling the PV strings to operate without requiring additional overcurrent protection. In contrast, Figure 19 depicts a system lacking optimisers, where the calculated reverse current exceeds the allowable limit, triggering a non-compliance warning under Regulation 712.431.101 and requiring separate protection for each PV string.

Configuring Power Optimisers within PV String Settings

When power optimisers are enabled in the Solar PV Inverter settings (see Figure 8), users can access the corresponding configuration parameters by clicking the PV Optimisers button within the PV String Circuit Edit section. This enables adjustment of optimiser characteristics at the string level, including verification of the rated string current (see Figures 20 - 21).

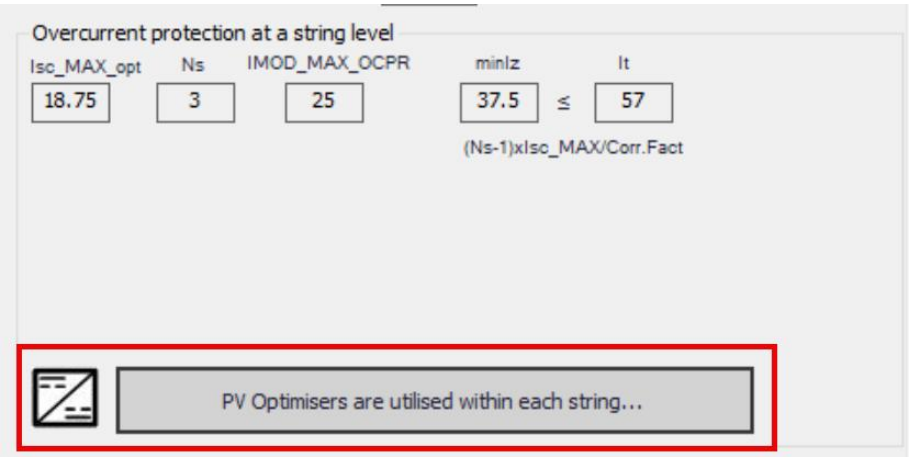


Figure 20: Power Optimiser Button in the PV String Circuit Edit Section

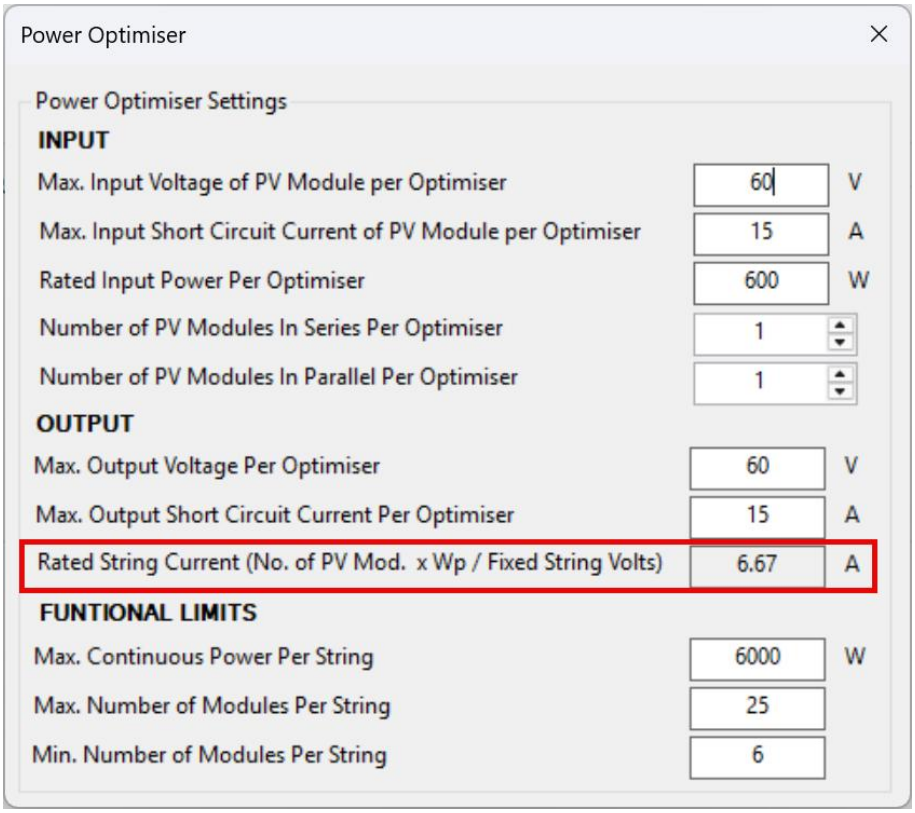


Figure 21: Power Optimiser Settings in the PV String Circuit Edit Section

Configuring DC Cable Properties

Within the Ph/N Conductor tab of the Circuit Edit Module, users can configure the DC cable properties by selecting the conductor material, size, installation method, and correction factors. A key option is the checkbox "Cables are subject to heat from the PV panels", which applies Regulation 712.523.101 of BS 7671:2018+A3:2024. When selected, ElectricalOM considers an ambient temperature of at least 70 °C for derating calculations, accounting for thermal effects from PV modules mounted directly above the cables. This ensures the cable sizing is compliant with heat exposure requirements under solar panels.

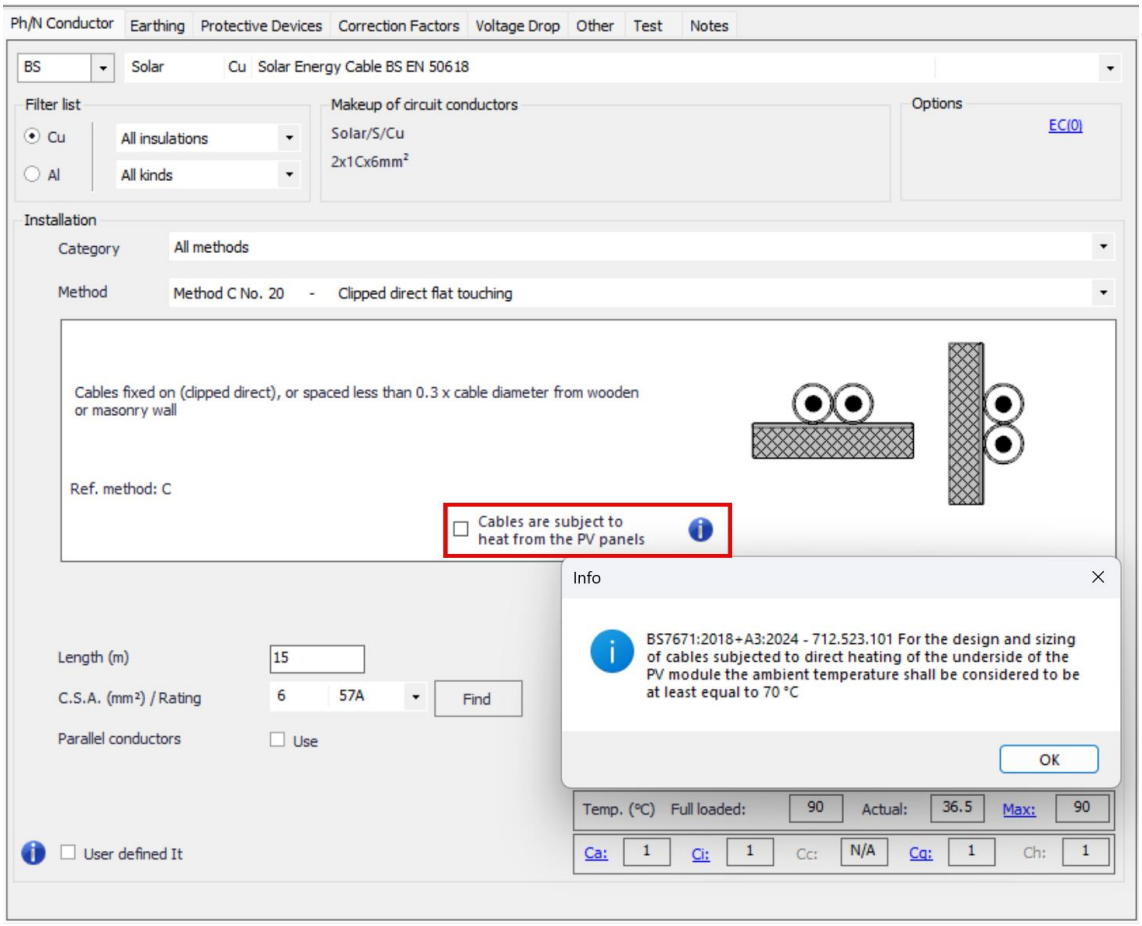


Figure 22: DC Cable Configuration in the Ph/N Conductor Tab

Examples of Single-Line Diagrams for Solar PV Configurations

The following examples illustrate typical Single-Line Diagrams (SLDs) for a range of Solar PV system configurations, including: a simple PV string inverter (with and without power optimisers), systems with multiple MPPT inputs, DC combiner boxes with multiple strings, setups featuring array and sub-array separation, and a utility-scale PV system layout. These diagrams help visualise practical design approaches and integration methods within ElectricalOM. For a detailed walkthrough, users are encouraged to watch the ElectricalOM Webinar – Solar PV Design Based on BS 7671 Section 712, available on YouTube [Click Here].

Simple Solar PV System Configuration

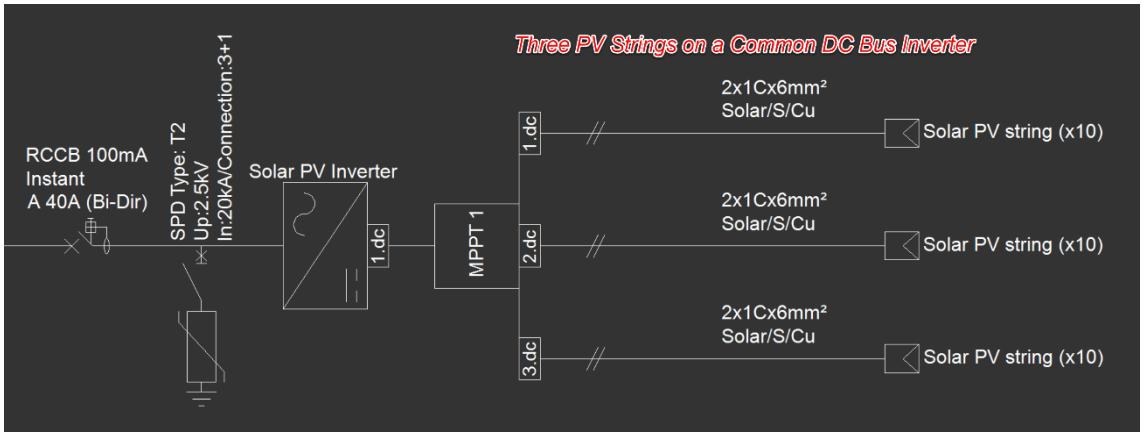


Figure 23A: SLD of a Simple Solar PV System Configuration

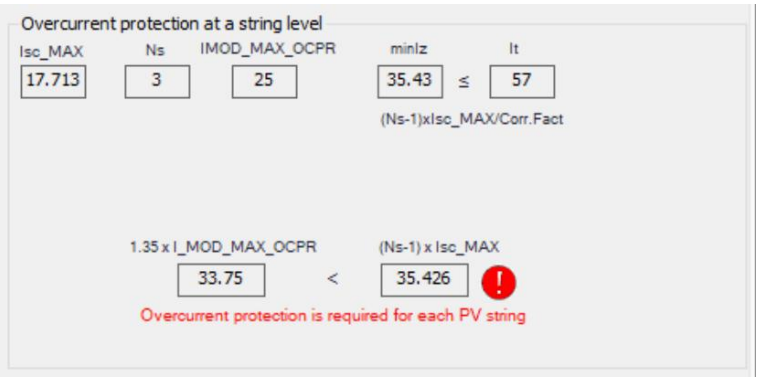


Figure 23B: Overcurrent Protection Checks for a Simple Solar PV System Configuration

Solar PV System with Power Optimisers

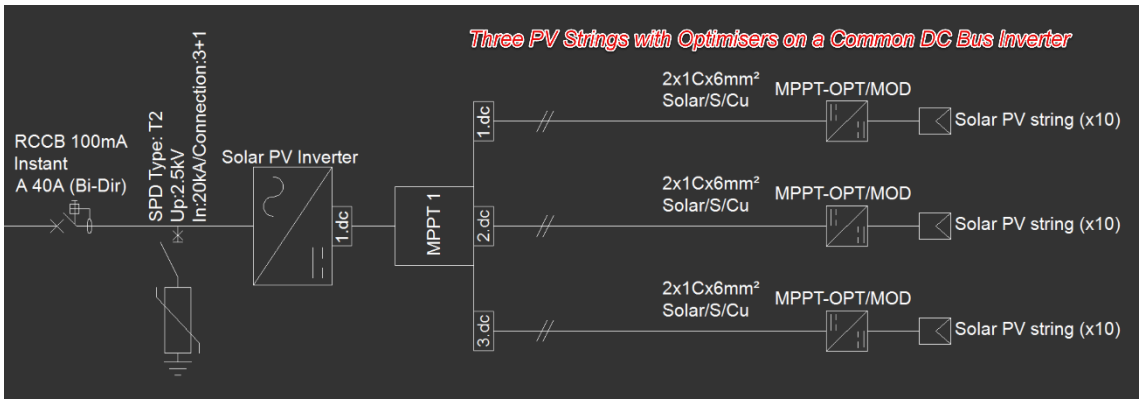


Figure 24A: SLD of a Solar PV System with Power Optimisers

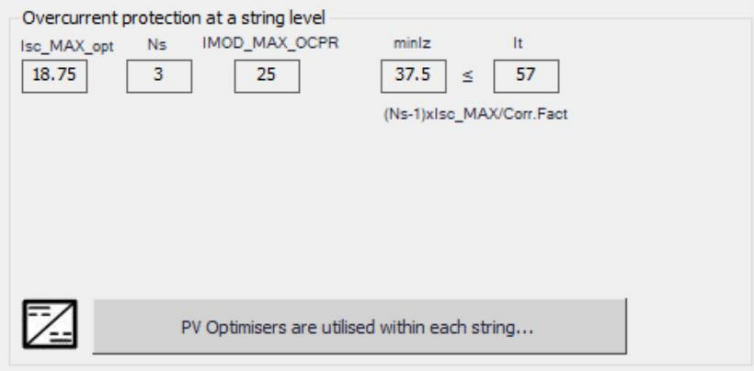


Figure 24B: Overcurrent Protection Checks for a Solar PV System with Power Optimisers

Solar PV System with Multi-MPPT Inputs and DC Combiner Boxes

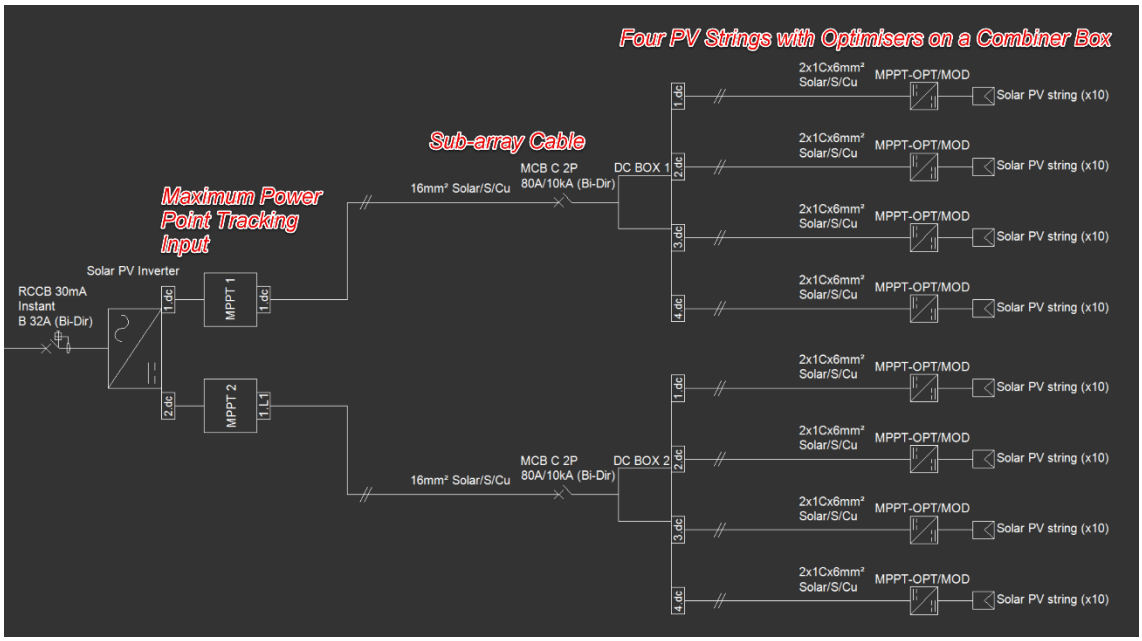


Figure 25A: SLD of a Solar PV System with Multiple MPPT Inputs and DC Combiner Boxes

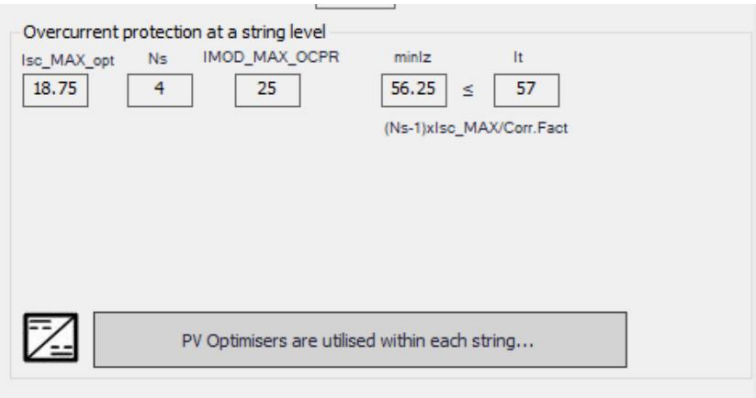


Figure 25B: Overcurrent Protection Checks for a Multi-String Solar PV System with Power Optimisers

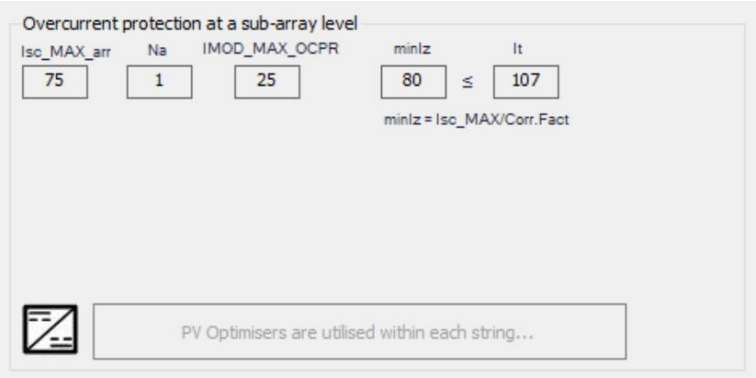


Figure 25C: Overcurrent Protection Checks for a Sub-array Solar PV System Cable

Single-MPPT Solar PV System with Sub-Arrays and DC Combiner Boxes

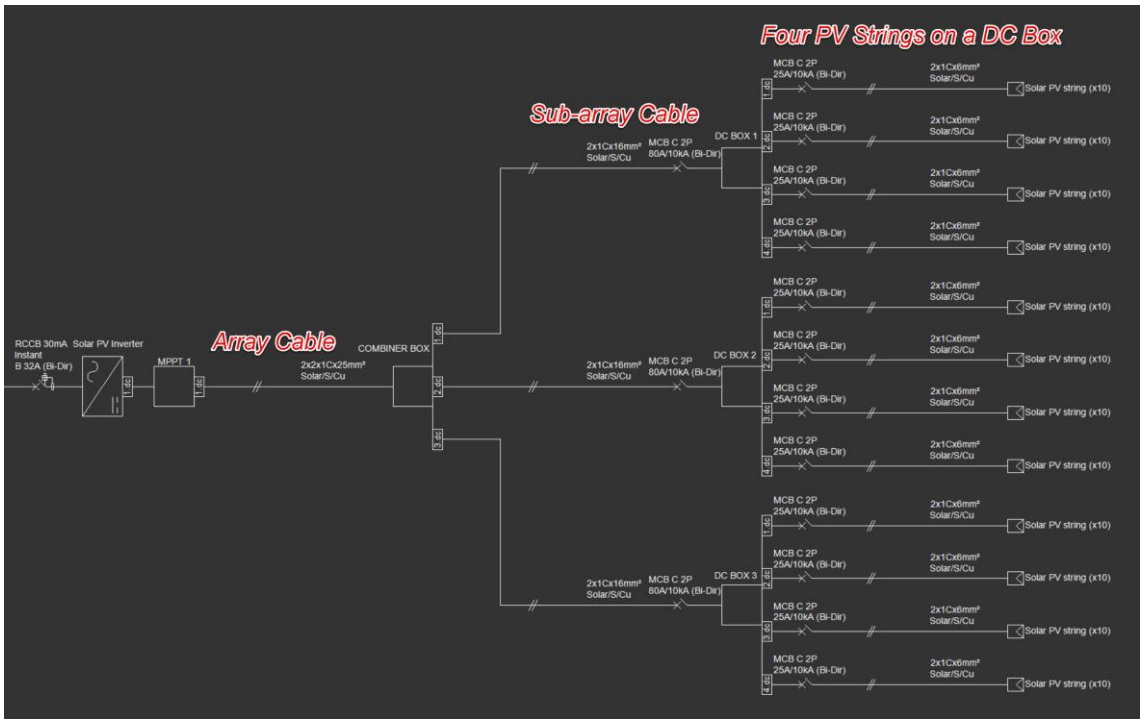


Figure 26A: SLD of a Single-MPPT Solar PV System with Sub-Arrays and DC Combiner Boxes

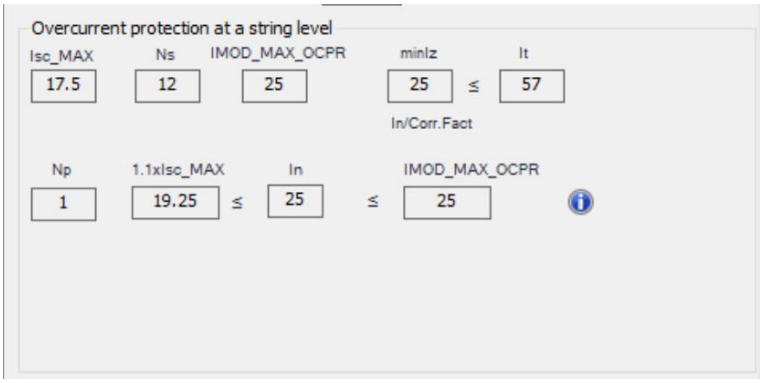


Figure 26B: Overcurrent Protection Checks for a Multi-String Solar PV System with Protection

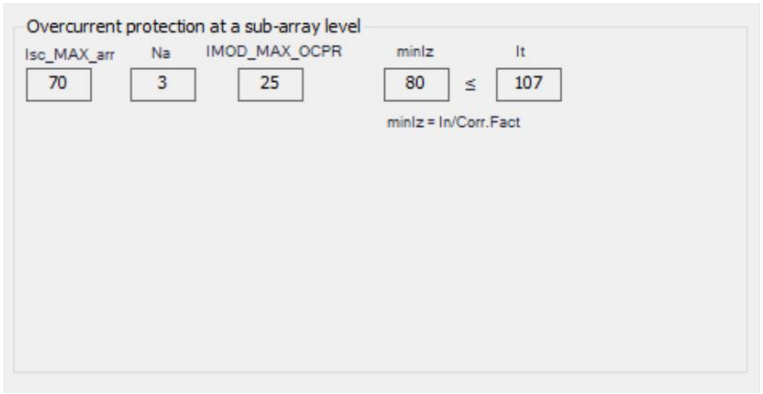


Figure 26C: Overcurrent Protection Checks for a Sub-array Solar PV System Cable

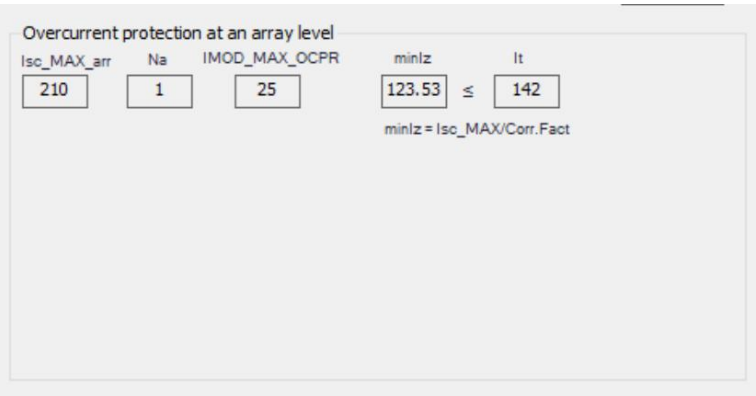


Figure 26D: Overcurrent Protection Checks for the Main Array Solar PV System Cable

Utility-Scale Solar PV System

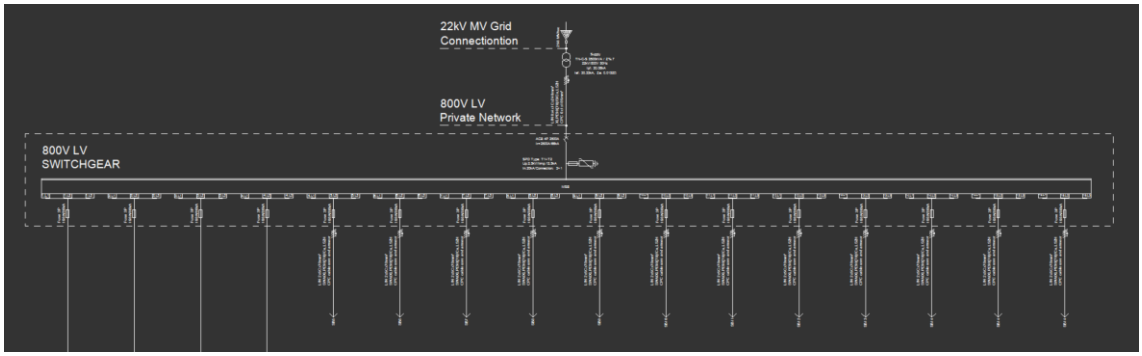


Figure 27A: SLD of MV/LV Switchgear in a Utility-Scale PV System

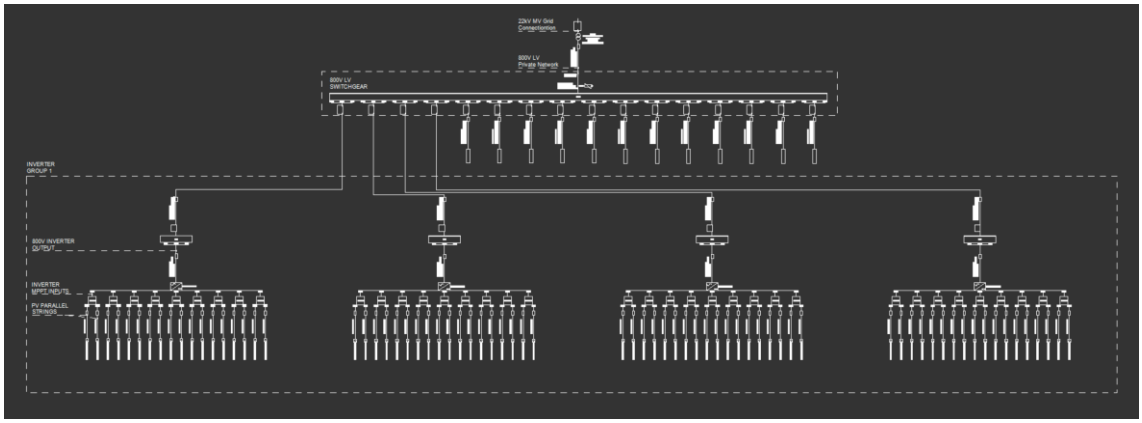


Figure 27B: SLD of Inverter Groups in a Medium Voltage Utility-Scale PV System

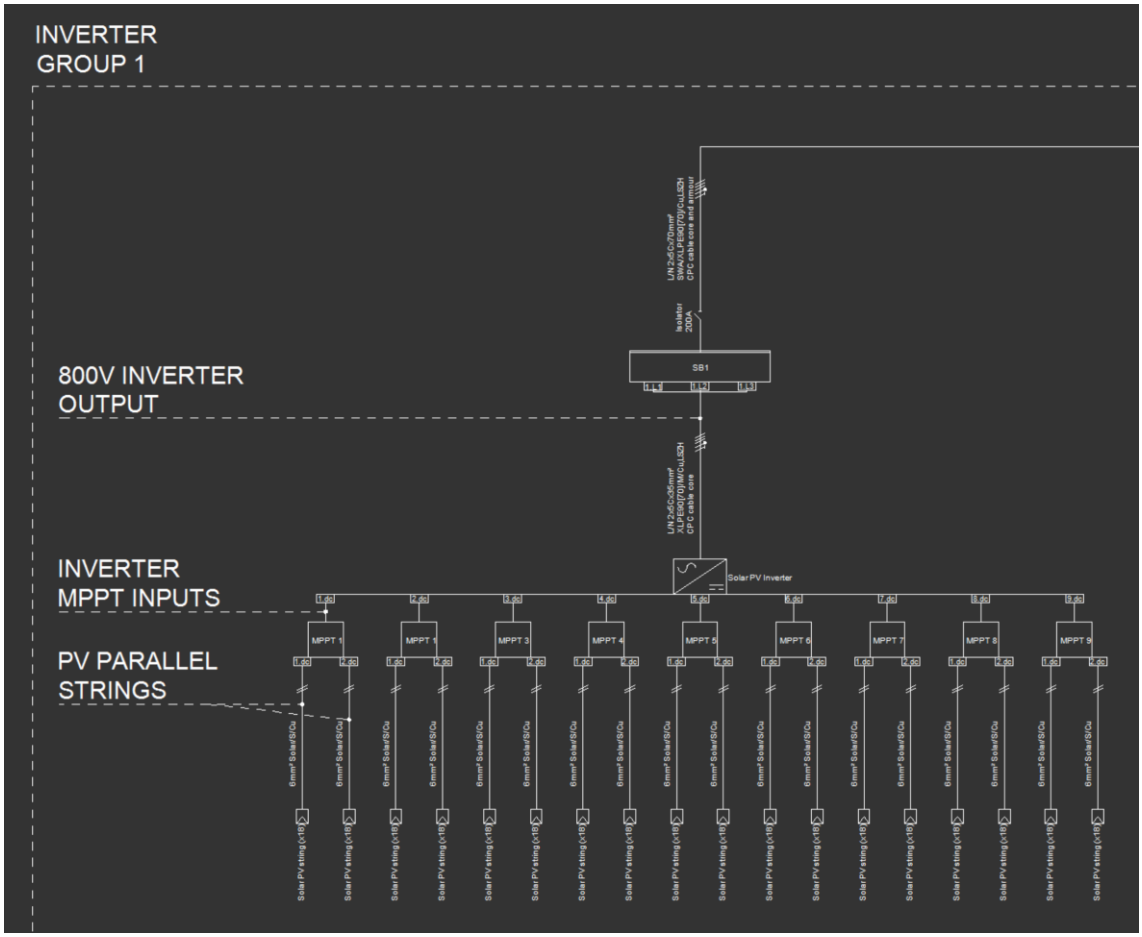


Figure 27C: SLD of Utility-Scale PV System Strings and Arrays

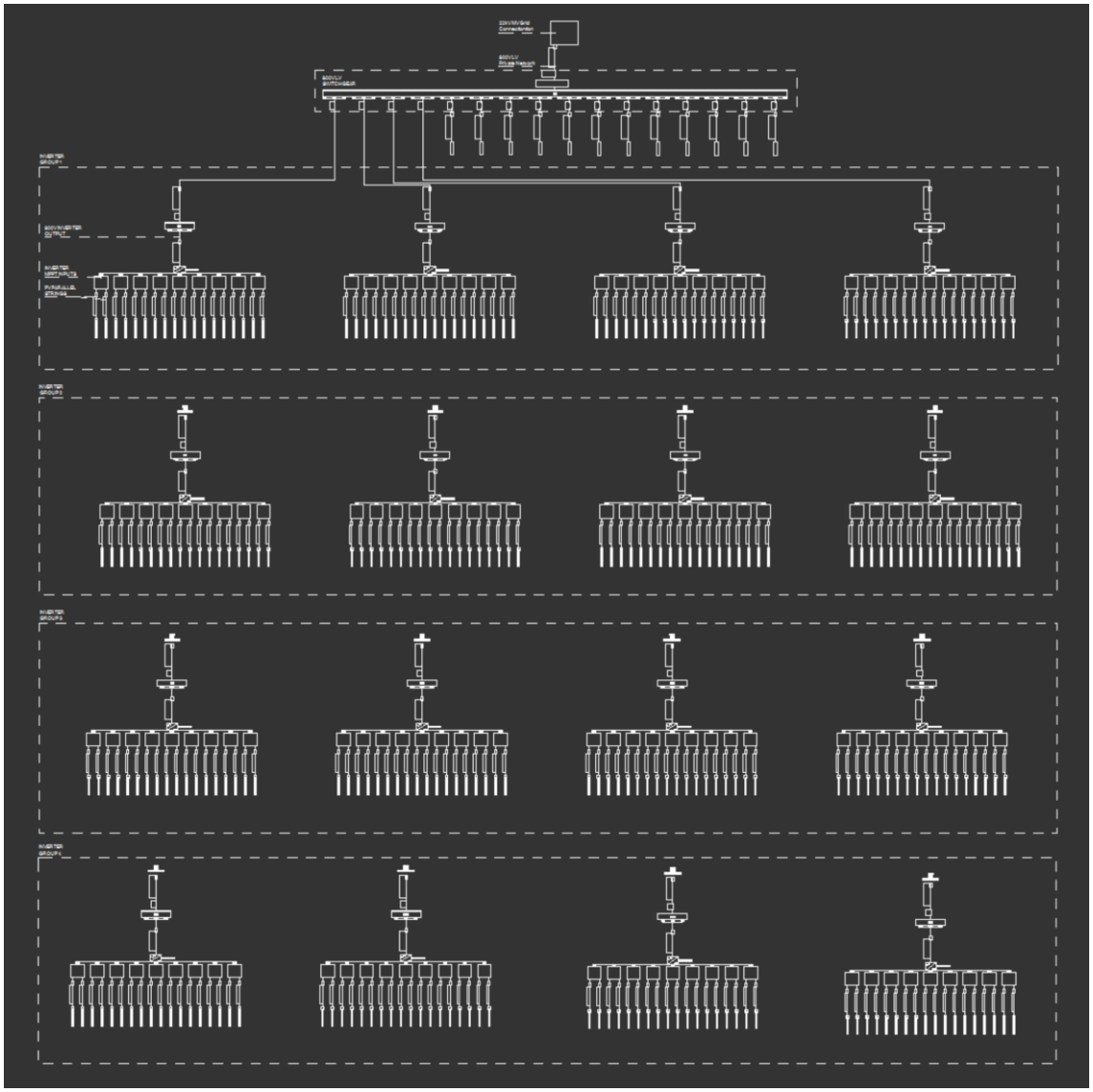


Figure 27D: SLD of a Medium Voltage Utility-Scale PV System Layout