Solar Design Algorithm

The document below defines the calculations used to design and evaluate a PV system in preparation for creating electrical drawings.

The secondary documents are automatically created from this source:

- A printable PDF document describing the algorithm, with no computer code (SDA_standard.pdf).
- Key computer code used in FSEC's online express drawing creation application (SDA.js).
- A printable PDF document describing the algorithm and it's related computer code (SDA.pdf).

Note: For each section, the symbols are pre-pended by a section name to assist with their use in the computer code, in the form of "section.symbol".

Modules, source circuits, and array

Solaredge arrays operate at a DC voltage that is determined from the AC grid voltage.

Grid VAC	String voltage (VDC)
208	325
240	350
277	400

Calculation summary:

Description	Symbol	Calculation
Maximum Power (W)	inverter.dc_voltage_nominal	inverter.mppt_max
Maximum Power (W)	source.max_power	module.pmp * array.largest_string
Maximum Power Voltage (V)	source.vmp	inverter.dc_voltage_nominal
Maximum Power Current (A)	source.imp	source.max_power / source.vmp
Open-Circuit Voltage (V)	source.voc	1 * array.largest_string
Short-Circuit Current (A)	source.isc	0.6
Maximum Circuit Current (A)	source.i_max	optimizer.max_output_current
Source Circuit Maximum Current (A), Isc x 1.25	source.Isc_adjusted	module.isc * 1.25
Maximum system voltage	array.max_sys_voltage	500
Maximum system current	array.max_sys_current	15 * array.num_of_strings
Minimum array voltage (module temp. correction factor)	array.min_voltage	array.smallest_string * module.vmp * (1 + module.tc_vpmax_percent / 1
Maximum Power (W)	array.pmp	array.num_of_modules * module.pmp
Maximum Power Voltage (V)	array.voc	source.voc
Maximum Power Current (A)	array.isc	source.isc
Open-Circuit Voltage (V)	array.vmp	string_nominal_voltage[inverter.grid_voltage]
Short-Circuit Current (A)	array.imp	array.pmp / array.vmp
Short-Circuit Current (A)	array.imp	array.imp > inverter.imax_channel ? inverter.imax_channel : array.imp
Enter Maximum Number of Parallel Source Circuits per Output Circuit (1-2)	array.circuits_per_MPPT	Math.ceil(array.num_of_strings / inverter.mppt_channels)
PV Output Circuit Maximum Current per MPPT (A)	array.combined_isc	source.isc * array.circuits_per_MPPT
Total PV Output Circuit Maximum Current (A)	array.total_isc	optimizer.max_output_current * array.num_of_strings
Maximum module voltage	module.max_voltage	module.voc * (1 + module.tc_voc_percent / 100 * (array.min_temp - 25)

Inverter

If max_ac_ocpd is not provided by the manufacturer, it is calculated as follows:

AC_OCPD_max = max_ac_output_current * 1.25

The nominal_ac_output_power is selected from fields based on the user selected grid voltage. As an example, if the user selects 240 VAC, then:

nominal_ac_output_power = nominal_ac_output_power_240
max_ac_output_current = max_ac_output_current_240

Array checks

The maximum array voltage is must not exceed the maximum system voltage allowed by the module.

The maximum array voltage is must not exceed the maximum system voltage allowed by the building code.

The maximum array voltage must not exceed the maximum system voltage allowed by the inverter.

The minimum array voltage must be greater than the inverter minimum operating voltage.

The total array power must be less than 10,000W.

The DC array can be oversized relative to the inverter, but the total DC power can not exceed 135% of the inverters AC output power.

Array source checks

The largest number of optimizers per branch must not exceed the maximum number allowed by the manufacturer.

error_check.optimizer_micro_branch_too_many_modules = array.largest_string > optimizer.max_optis_per_string;
// If error check is true, flag system design failure, and report notice to user.
if(error_check.optimizer_micro_branch_too_many_modules){ report_error('The system has too many inverters per array source circuit.');}

error_check.optimizer_micro_branch_too_few_modules = array.smallest_string < optimizer.min_optis_per_string;
// If error check is true, flag system design failure, and report notice to user.
if(error_check.optimizer_micro_branch_too_few_modules){ report_error('The system has too many inverters per array source circuit.');}

The total nominal module power output for each branch must not exceed the manufacturer's limit.

error_check.optimizer_micro_branch_too_much_power = source.max_power > optimizer.max_power_per_string;
// If error check is true, flag system design failure, and report notice to user.
if(error_check.optimizer_micro_branch_too_much_power){ report_error('The array source power limit has exceeded the manufacturer's limit.');}

Module - Optimizer checks

The module(s) power and voltage must be within the inverter manufacturer's limits.

The module's operating voltage must be less than the inverter maximum operating voltage.
The modules maximum voltage, and the lowest temperature, can not exceed the optimizer's limit.

Conductor and conduit schedule

For string inverters, these are the circuit names:

- Exposed source circuit wiring: DC wires exposed on the roof.
- PV DC source circuits: DC wires in conduit.
- Inverter AC output circuit: AC circuits between the inverter and panel OCPD.

The array temperature adder is found in NEC table 310.15(B)(3)(c), or Table 1 in appendix, with module.array_offset_from_roof as "Distance Above Roof to Bottom of Conduit (in)".
The maximum current and voltage for the array DC circuits are equal to source.isc and source.voc.

The number of DC current carrying conductors is equal to twice the number of strings in the array (array.num_of_strings * 2).
Total conductors adds one more for the ground.

The AC grid voltage is defined by system specifications (user input).

The maximum AC output is defined by the inverter manufacturer specifications.

AC conductors numbers are defined by the grid voltage.

For each circuit, calculate the following.

Select circuit details based on code requirements and best practices.

Exposed source circuit wiring:

- Conductor: 'DC+/DC-, EGC'
- Location: 'Free air'
- Material: 'CU'
- Type: 'PV Wire, bare'
- Volt rating: 600
- Wet temp rating: 90
- Conduit type: '-'

PV DC source circuits:

- Conductor: 'DC+/DC-, EGC'
- Location: 'Conduit/Exterior'
- Material: 'CU'
- Type: 'THWN-2'
- Volt rating: 600
- Wet temp rating: 90
- Conduit type: 'Metallic'

Inverter ac output circuit:

- Conductor: 'L1/L2, N, EGC'
- Location: 'Conduit/Interior'
- Material: 'CU'
- Type: 'THWN-2'
- Volt rating: 600
- Wet temp rating: 90
- Conduit type: 'Metallic'
  The array maximum temperature of the array is equal to the 2% maximum temperature at the install location, or nearest weather station.
  For a state wide design, the largest maximum temperature for the state is used.
  Rooftop array circuits also have a temperature adjustment defined above.

There are three options to calculate the minimum required current:

1. circuit.max_current * 1.25;
2. circuit.max_current / (circuit.temp_correction_factor * circuit.conductors_adj_factor);
3. circuit.max_current * 1.25 * 1.25;

For AC circuits, the maximum of 1 and 2 is used. For DC circuits, the maximum of 2 and 3 is used.

For strings per MPP tracker of 2 or less, or for inverters with built in OCPD, additional DC OCPD is not required. The AC circuits do require OCPD at the panel.

Choose the OCPD that is greater or equal to the minimum required current.

Choose the conductor with a current rating that is greater than the OCPD rating from NEC table 310.15(B)(16).
NEC chapter 9 table 8 provides more details on the conductor. For DC circuits, 10 AWG wire is used as a best practice.

The NEC article 352 and 358 tables are used to find a conduit with a sufficent 40% fill rate to hold the total conductor size for all the conductors.

Interconnection

At least one of the following checks must not fail:

- The sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar exceeded the ampacity of the busbar.
- The sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar exceeded 120 percent of the ampacity of the busbar.
- The sum of the ampere ratings of all overcurrent devices on panelboards exceeded the ampacity of the busbar.

The panel's main OCPD must not exceed the bussbar rating.