TECHNICAL REPORT

ELECTRICAL CONNECTIONS

Photovoltaic panels can be wired in series or in parallel.

- Series: only panels with the same current (same kind of cells) can be connected together. The group current remains the same of the single panel, while the voltage is the sum of the voltages of the single panels.

- Parallel: only panels with the same output voltage can be connected in parallel. In this case, the currents add up while the voltage remains that of a single panel.

The choice of the most suitable electrical connection must be assessed depending on the type of installation, the orientation and the position of photovoltaic modules. Series connection (Fig. c) is quite sensitive to shading and to different panels orientation, while parallel connection (Fig. d) resolves the shading problem but rarely has an optimal matching with the controllers MPPT algorithm. Moreover parallel wiring needs blocking diodes which produce a small power loss and make the installation more complicate.

The best way to harvest all the possible energy from photovoltaic panels, is to connect any single panel with a proper MPPT controller (Fig. b). In this way all the panels are independent one from each other and any one works at its best. Solbian selected some of the best MPPT controllers to use with a single panel and they can adapt the output voltage to any kind of battery from 12 to 48 V.

If the one panel-one controller solution is not deemed suitable, for technical or economic reasons, panels can be connected in series or in parallel, or in mixed series/parallel connection.
Pros and cons of different configurations are analyzed below.

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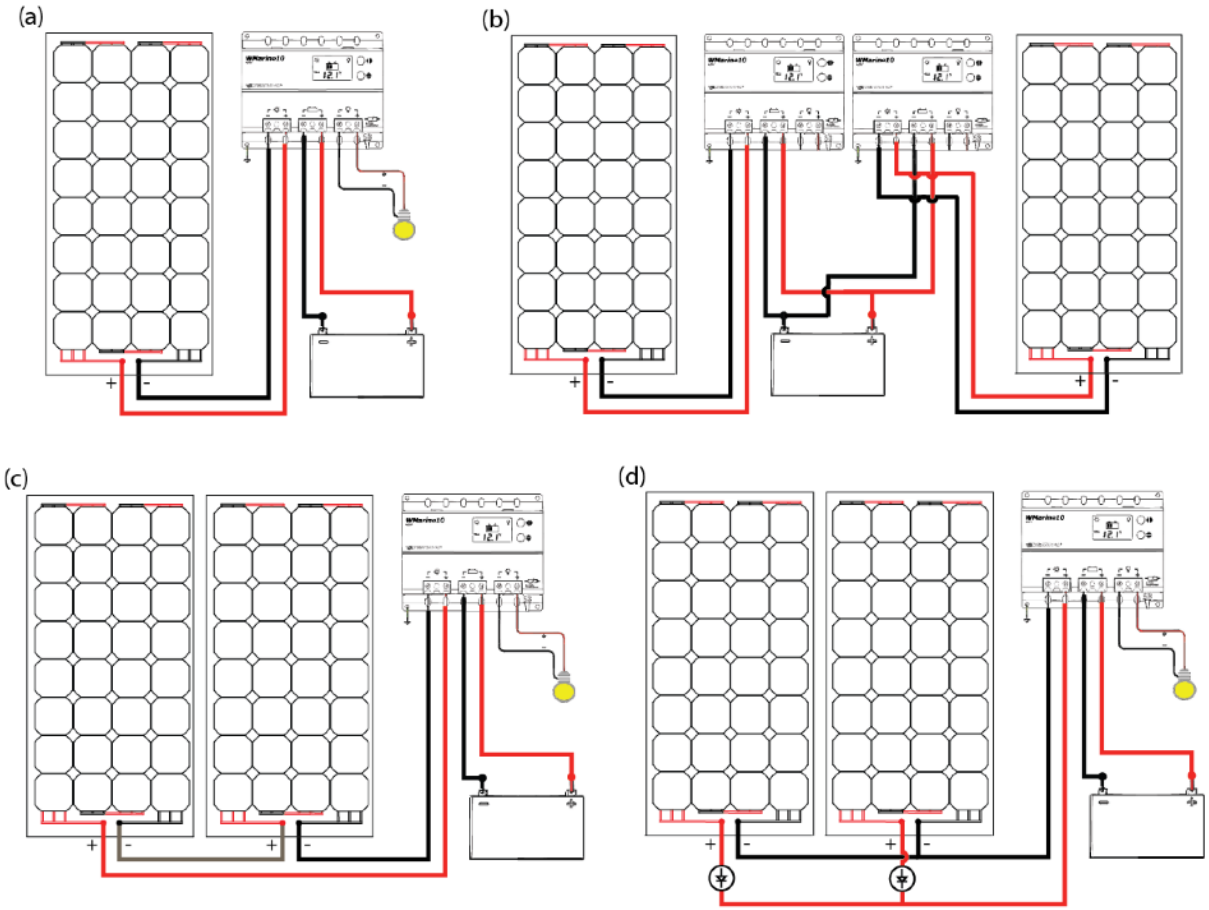

SERIES CONNECTION (C)

Panels must have the same type of cells, i.e. the same output current.

Total current remains the current of a single panel:

$$A_{tot} = A_1 = A_2 = A_3 \ldots$$

Output voltage is the sum of the voltages of single panels:

$$V_{tot} = V_1 + V_2 + V_3 \ldots$$

In a series of panels, if one is producing less current than the others (for shading or bad orientation), then the others suffer of the same current reduction: the less efficient panel affects the whole group.
This means that in case of complete shading a single panel can be turned off completely, and thus all the series is turned off.

Bypass diodes are introduced to avoid this condition. A bypass diode creates an alternative path for the current flow, even when the panel is not working. With bypass diodes the shading effect is less important but cannot be avoided completely. All Solbian panels have bypass diodes.

Series connection is recommended when panels have the same orientation and there is few probability of shading along the series.
If we look, for example, a sailing boat with four panels, two on the right side and two on the left side, during navigation the shade of the sails are on one side or on the other. The best solution (if a series connection is needed) is to connect the two panels on the right together and the same with the two on the left. Namely, to use a controller for each two series connected panels.

Series connection need to be surely avoided when the panels have different orientation toward the sun, even if there are not shadings.

PARALLEL CONNECTION (D)

Panels must have the same kind of cells and the same number of cells, that means the same output voltage.
Total voltage remains the one of the single panel:

$$V_{tot} = V_1 = V_2 = V_3 \ldots$$

Output current is the sum of the currents of the single panels:

$$A_{tot} = A_1 + A_2 + A_3 \ldots$$

In a parallel of panels, if one is producing less current than the other (for shading or poorer orientation) it does not affect the efficiency of the other panels.

All panels are exposed to the voltage produced by the other panels. In case of shading or in case of manufacturing tolerances or cells damage, the current produced by one panel can flow in the other, resulting in waste of power, overheating, even fire.

In parallel connection it is compulsory to use blocking diodes!

Blocking diodes cannot be inserted in panels but they need to be introduced during wiring. There exist distribution boxes containing diodes for the parallel connection of panels. Parallel connection increases the output current and thus large size cables must be used and stronger attention must be addressed in cables joining or welding.

ONE PANEL – ONE CONTROLLER (B)

The best way to harvest all the possible energy from photovoltaic panels is to drive any single panel with a proper MPPT controller. In this way all the panels are independent one from the other and any one is working at its best.

This configuration means you have more controllers connected to a battery (or bank of batteries) and this is made by connecting all of them in parallel. That is surely possible being any controller protected from reverse current and thus acting as an isolated one.

Any battery is charged in different steps, depending on its type.

For Lead Batteries there are:

- Discharged Battery: the controller sets its output voltage slightly higher than the battery voltage and it controls only the current flow to avoid a too strong current. In the case of solar charging, the current is limited by the panel itself.

- Battery almost fully charged: the current is limited further, to reach smoothly the charged state and avoid overcharging.

The maximum current flow through the controller depends on the battery status and not only on the photovoltaic panel.