Solar Panel Electrical Architecture and Shading

By-Pass Diodes and Half-cut Cells

How do modern solar panels avoid the damaging effects of partial shading due to leaves or localised soiling, and what advantages does half-cut cell technology offer?

1.0 Solar PV Panel Electrical Wiring

A solar panel is made up of many solar cells which produce electrical power when light strikes them. The cells are wired together in series with the top surface of one cell connected to the bottom surface of the next with thin conductive copper cables. To give the solar panel long life the cells are encapsulated between sheets of polymer and adhered to the back of a pane of toughened glass. Finally, an aluminium frame is assembled around the edges of the glass to give structural rigidity and allow mounting. The finished panels are electrically connected in series one to the next adding more cells into series electrical connection.

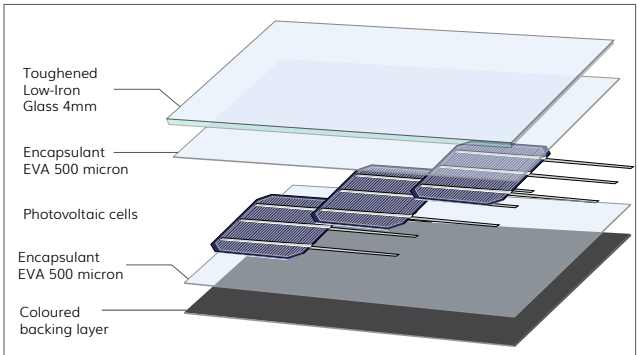

Figure 1. PV Laminate Cell Encapsulation

If solar cells are connected in series, then, by definition, they must have the same electrical current flowing through them. If one single cell is shaded (for example by a leaf or soiling) it restricts the current flow in all cells and bring down the power output of the whole string of panels to the performance level of that single cell. An analogy is that of water flowing through a hose pipe, with the effect of the shaded cell being like someone stepping on the pipe and reducing the flow of water through the whole pipe.

2.0 By-Pass Diodes and Shading

Fortunately, there is a simple way to reduce the impact of this kind of shading. By-pass diodes are added to the solar panel and act-like a short-cut for current to flow around shaded cells.

With all cells unshaded and performing equally the by-pass diode is in reverse bias and acts like an open circuit – it has no effect (figure 2a).

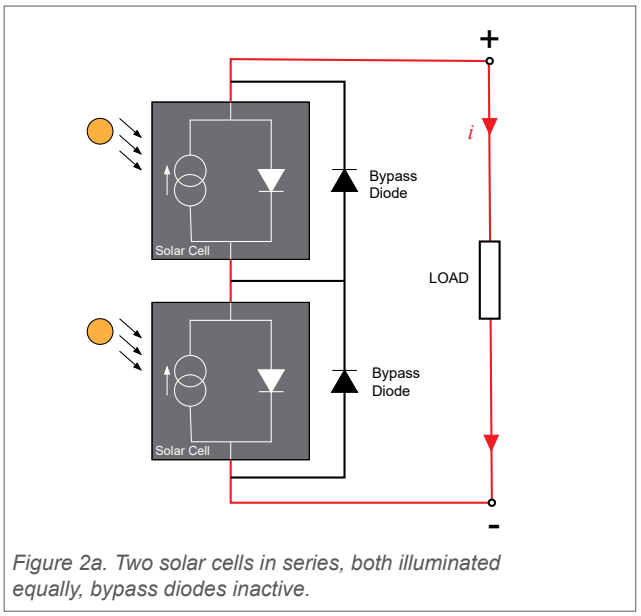

Figure 2a. Two solar cells in series, both illuminated equally, bypass diodes inactive.

If a cell is shaded, the by-pass diode is activated and allows current to flow around the affected cell, leaving the unshaded cells unaffected (figure 2b).

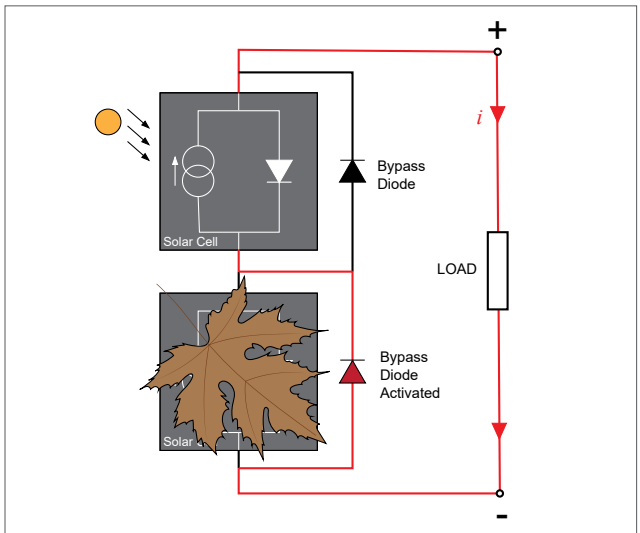

Figure 2b. Two solar cells in series, one shaded, by-pass diode activated.

3.0 PV Panel Electrical Architectures

In practice, by-pass diodes are not added to every cell. A balance needs to be struck between manufacturing complexity and the benefit of avoiding power loss from shading. For many years the classic solar panel arrangement had 60 cells, arranged into 6 columns of 10 cells, and wired as shown in figure 3, with three by-pass diodes per panel in the junction box on the rear of the panel. Each diode can allow current to by-pass a group (or substring) of two columns of 10 cells, or one third of the panel.

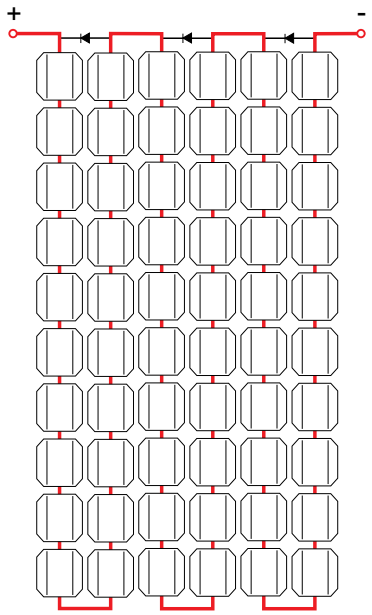

Figure 3. 60 cell panel wired in series with three bypass diodes, one for each substring of 20 cells

3.1 Half Cut Cells

Clearline fusion G1 and M10 solar panels use a newer solar panel architecture with 120 or 108 rectangular cells respectively wired into substrings of six equal groups. The rectangular cells are often called 'half-cut cells' because they are made by cutting a square solar cell into two halves. This arrangement results in an improvement to panel operating efficiency and durability.

The cells are divided into six substrings with pairs of substrings connected in parallel to divide the panel into an upper half and lower half (see figure 4).

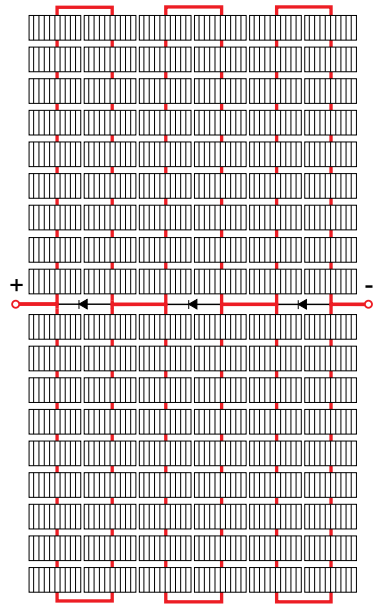

Figure 4. 108 half cell solar panel, with substrings of 18 half cells wired in parallel-series, and three bypass diodes at the centre of the panel

The parallel connection of substrings means the current of half-cut cells is halved compared to full ones. This improves the overall panel efficiency by reducing resistive losses in the conductors in the panel. Dividing the current amperage by two means that power losses due to the internal resistance in the panel is divided by four.

Durability is improved because the shorter cells are less fragile if the panel is subject to bending forces (for example wind loading or in installation handling).

Half cut cell panels also have three by-pass diodes in the panel, each diode when activated by-passing two substrings.

3.2 Impact of Partial Shading

If one cell or a few adjacent cells in one substring is shaded, then the by-pass diode for the substring activates and allows current to flow past to the next substring. The power output from the by-passed substrings is lost but the substrings that aren't by-passed continue to generate at full power, both in the shaded panel and all other panels in the array.

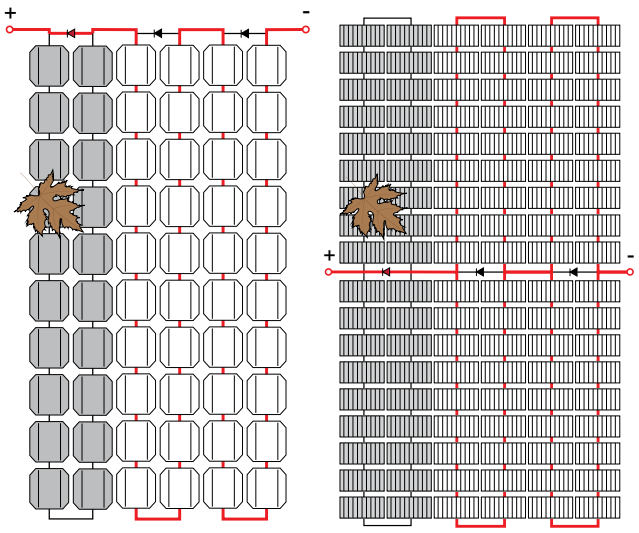

Figure 5. Partial shading causing by-pass diode to activate on both 60-cell and 108-half-cell panels. Output from the grey cells is reduced but the rest of the panel and solar array continues to operate at full output.

For example, if one cell is completely shaded and a substring is lost from one panel in a string of ten panels, the total output of the whole array drops as follows:
(1/10 x 2/3) + (9/10 x 3/3) = 96.6% of maximum

By-pass diodes greatly lower the power-reducing effect of partial shading while half-cut cell architecture brings advantages in overall panel efficiency and longevity.

Viridian Solar, 68 Stirling Way, Papworth
Cambridge. UK CB23 3GY
+44 1480 839865
www.viridiansolar.com