LAB # 08

Analyzing the Shading Impact on PV System

Objectives:

- To understand the physics of shading
- To learn the working of bypass diode for shade mitigation
- To analyzing the working of different modules with different values of irradiance
- Analyzing results of I-V and P-V curves on different irradiance values

Components Required:

- PV Arrays
- Capacitors
- Constants
- To Workspace Block
- Diode
- Current Measurements, Voltage Measurements
- Product Block
- Power GUI Block
- Scope

Related Theory:

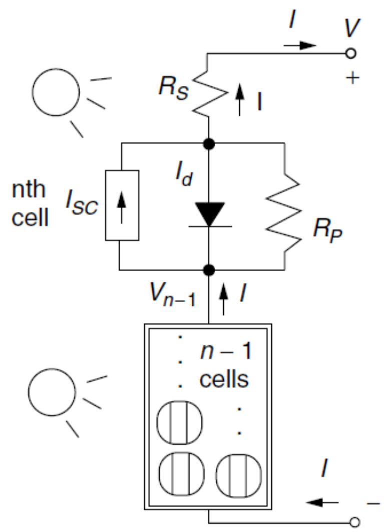
The output of a PV module can be reduced dramatically when even a small portion of it is shaded. Unless special efforts are made to compensate for shade problems, even a single shaded cell in a long string of cells can easily cut output power by more than half.

External diodes, purposely added by the PV manufacturer or by the system designer, can help preserve the performance of PV modules. The main purpose for such diodes is to mitigate the impacts of shading on PV I –V curves. Such diodes are usually added in parallel with modules or blocks of cells within a module.

Physics of Shading:

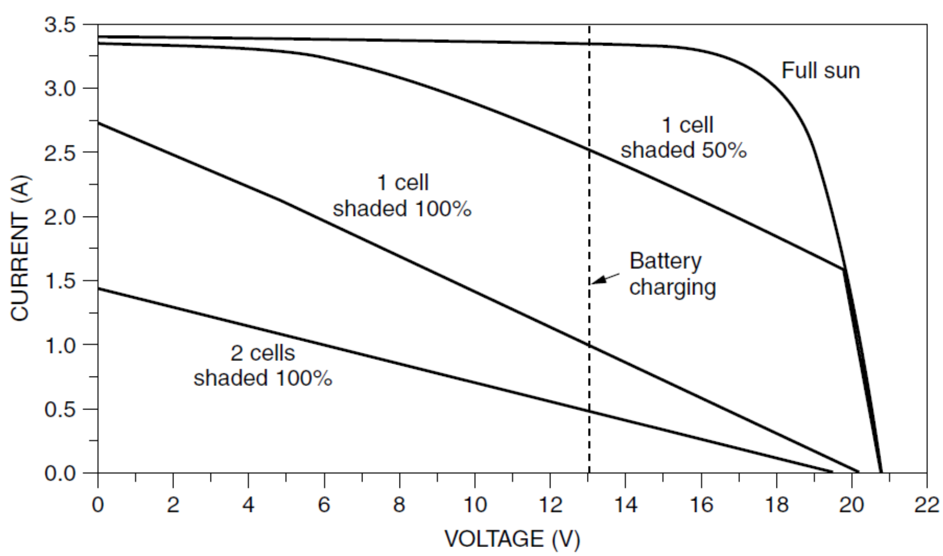
To help understand this important shading phenomenon, consider figure shown below, in which an n-cell module with current I and output voltage V shows one cell separated from the others (shown as the top cell, though it can be any cell in the string). While the other $(n - 1)$ cells in the string are shown as just a module with current I and output voltage V_{n-1}.

In the figure shown below (Part a), all of the cells are in the sun and since they are in series, the same current I flow through each of them. In the figure shown (Part b), however, the top cell is shaded and its current source I_{SC} has been reduced to zero. The voltage drop across R_P as current flows through it causes the diode to be reverse biased, so the diode current is also (essentially) zero. That means the entire current flowing through the module must travel through both R_P and R_S in the shaded cell on its way to the load. That means the top cell, instead of adding to the output voltage, actually reduces it.



(a) All cells in the sun (b) Top cell shaded

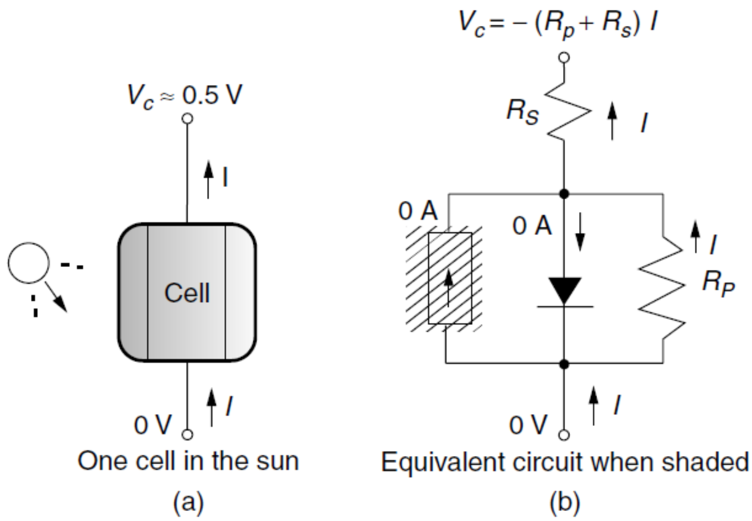
Figure shown below exhibits curves for the PV module under full-sun conditions and with one cell 50% shaded, one cell completely shaded, and two cells completely shaded. Also shown on the graph is a dashed vertical line at 13 V, which is a typical operating voltage for a module charging a 12-V battery. The reduction in charging current for even modest amounts of shading is severe. With just one cell shaded out of 36 in the module, the power delivered to the battery is decreased by about two-thirds.



Bypass Diodes for Shade Mitigation:

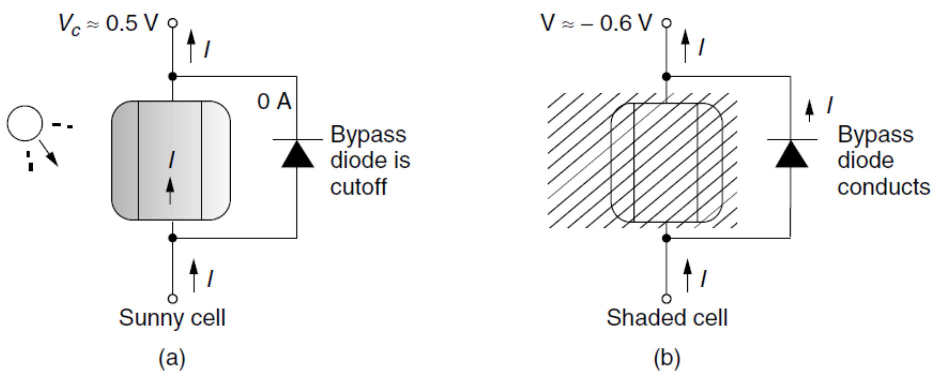
Above mentioned graph not only shows how drastically shading can shift the I –V curve, but also, how local, potentially damaging hot spots can be created in shaded cells.

Below shown Figure is a typical situation. In this figure (Part a), a solar cell in full sun operating in its normal range contributes about 0.5 V to the voltage output of the module, but in the equivalent circuit shown in Part b, a shaded cell experiences a drop as current is diverted through the parallel and series resistances. This drop can be considerable.

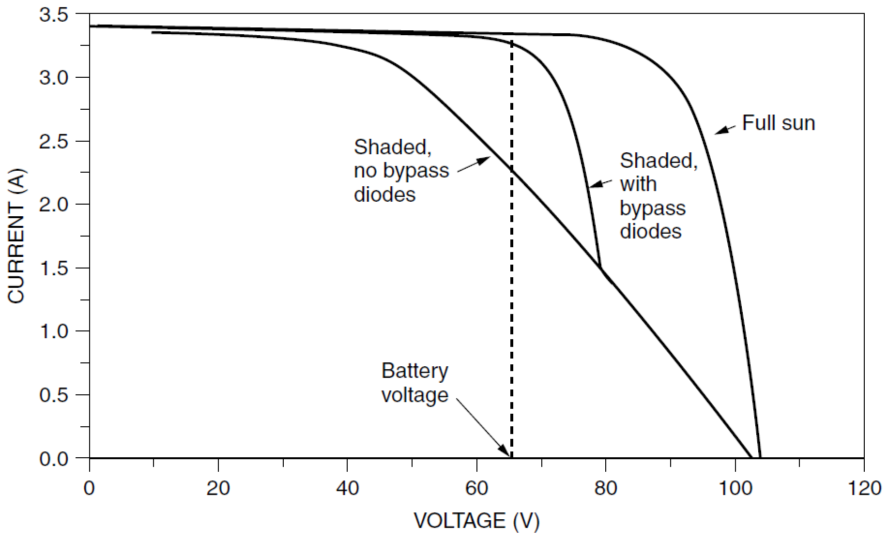


The voltage drop problem in shaded cells could be to corrected by adding a bypass diode across each cell, as shown below. When a solar cell is in the sun, there is a voltage rise across the cell, so the bypass diode is cut off and no current flows through it. It is as if the diode is not even there. When the solar cell is shaded, however, the drop that would occur if the cell conducted any current would turn on the bypass diode, diverting the current flow through that diode. The bypass diode, when it conducts, drops about 0.6 V.

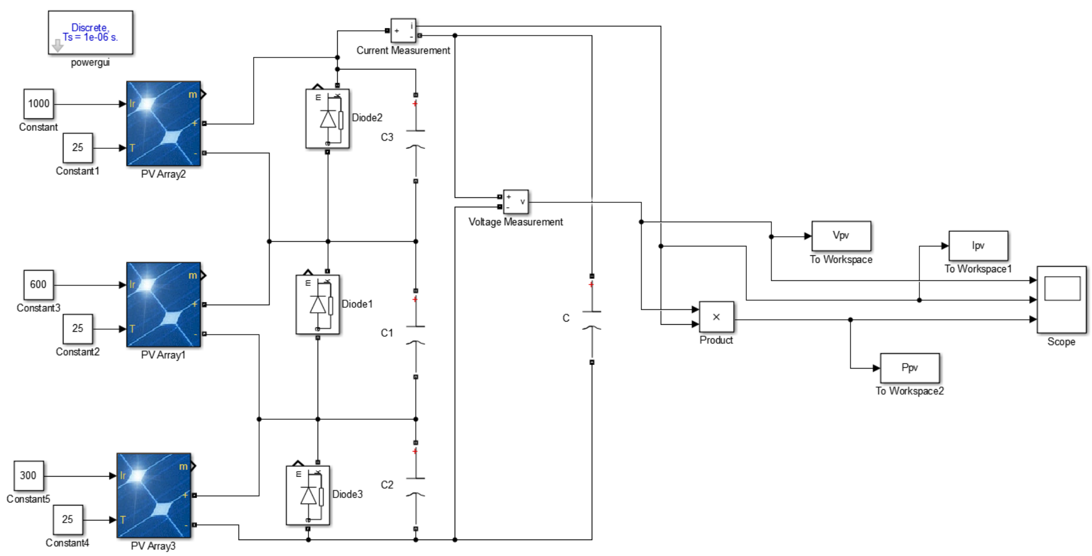
So, the bypass diode controls the voltage drop across the shaded cell, limiting it to a relatively modest 0.6 V, instead of the rather large drop that may occur without it.



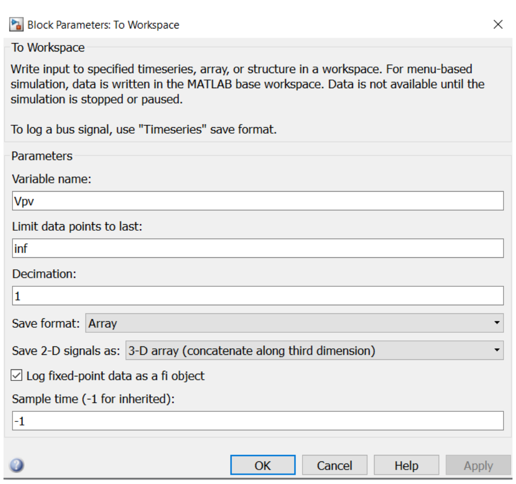
To see how bypass diodes wired in parallel with modules can help mitigate shading problems, consider the figure shown below, which shows I –V curves for a string of five modules. The graph shows the modules in full sun as well as the I –V curve that results when one module has two cells completely shaded. Imagine the PVs delivering charging current at about 65V to a 60V battery bank. As can be seen, in full sun about 3.3 A are delivered to the batteries. However, when just two cells in one module are shaded, the current drops by one-third to about 2.2 A. With a bypass diode across the shaded module, however, the I –V curve is improved considerably as shown in the figure.



Block Simulation Diagram:



To Workspace Block:


Block Parameters: To Workspace

To Workspace

Write input to specified timeseries, array, or structure in a workspace. For menu-based simulation, data is written in the MATLAB base workspace. Data is not available until the simulation is stopped or paused.

To log a bus signal, use "Timeseries" save format.

Parameters

Variable name: Vpv

Limit data points to last: inf

Decimation: 1

Save format: Array

Save 2-D signals as: 3-D array (concatenate along third dimension)

☑ Log fixed-point data as a fi object

Sample time (-1 for inherited): -1

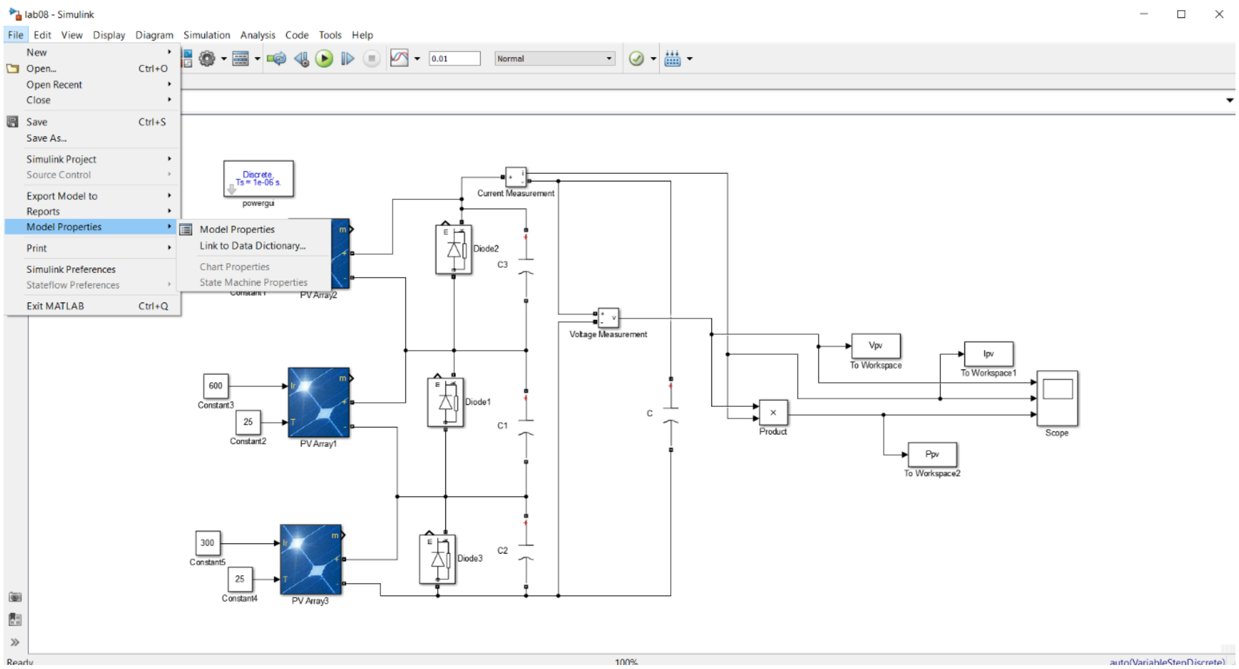
OK Cancel Help Apply

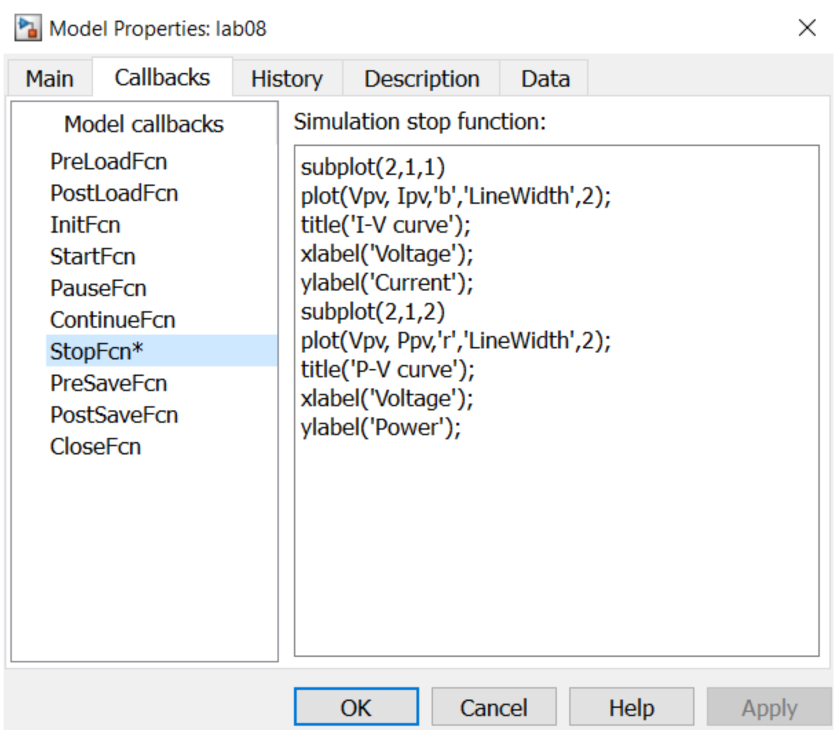
Capacitor Values:

C = 1e-3 F

C1, C2, C3 = 1e-5 F

Plotting Graph between I-V and P-V:





Output Waveform of Voltage, Current and Power Curves W.r.t Simulation Time:

Output Waveform of I-V and P-V Curves:

Conclusion and Comments: