Simulation of a Solar Cell & a PV Module on LTspice

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I. Introduction

The simulations are done on the LTspice software by Analog Devices Inc. This software is basically a simulation software based on designing and modelling various electronic and digital circuits. I got lots of practice on this software during my under-graduation in India and from then on, I've been fascinated by its ease of use. I carried out many simulations in my under-graduation subject VLSI Design. This time I got to use it after a year for this course at the University of Waterloo. I have basically designed a solar cell and a corresponding PV module that consists of 36 cells. More detailed explanation is given in further sections of the project report.

In this simulation, firstly, I designed a simple circuit of a solar cell whose Norton equivalent circuit is just a current source with a diode in parallel to it. The circuit diagram and simulation results are displayed in the next section. Secondly, I thought why not design a PV module which is not a single cell but multiple cells. In this design, I used 36 solar cells for the simulation.

II. Simulation Design and Results

The equivalent circuit diagram of a solar cell is given in the figure below.

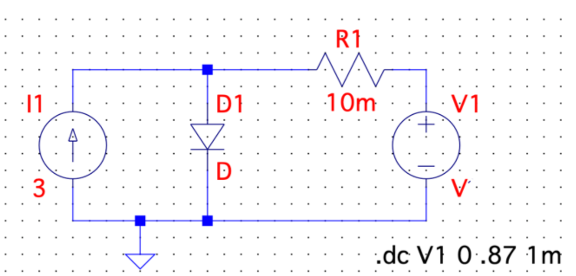

Figure 1. Equivalent Circuit of a Solar Cell

As you can see, the current source I1 has an amplitude of 3 A and a PN junction diode is connected in parallel. The configuration of the diode is the default setting by LTspice. The resistance R1 has a value of 10 mΩ and a voltage source V1 to calculate the output voltage that will give us the I-V curve of the cell. Before actually seeing the I-V curve, I calculated the short circuit current I_{sc} and the open circuit voltage V_{oc}. The following values were obtained by the shorting and disconnecting the circuitry respectively.

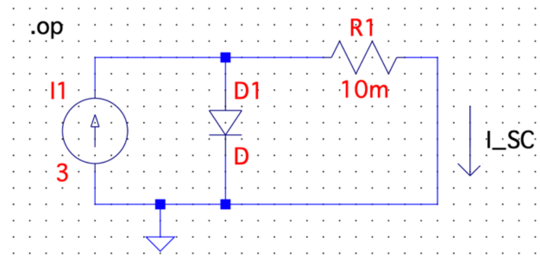

Figure 2. Shorting the Circuit for I_{sc} Value

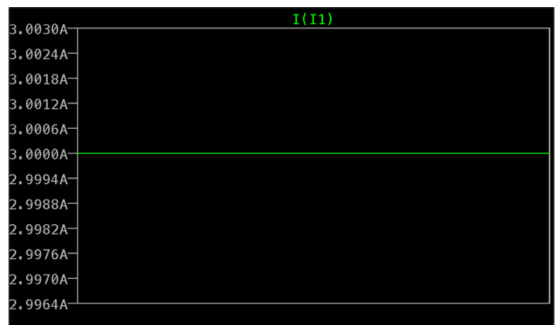

Figure 3. Corresponding I_{sc} Value = 3.0 A

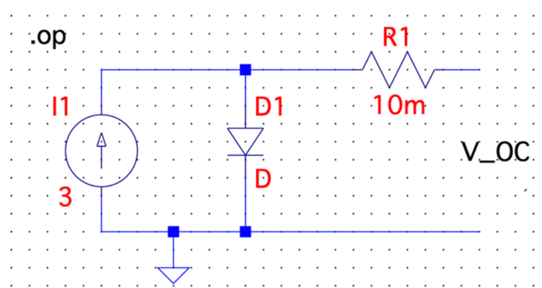

Figure 4. Open Circuit for V_{oc} Value

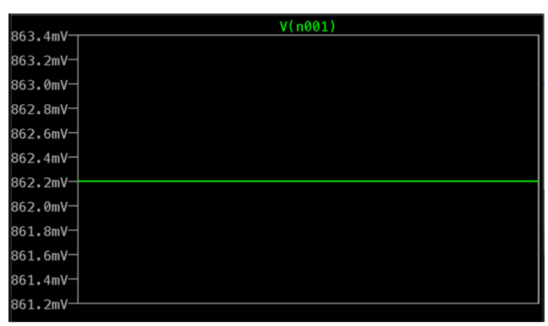

Figure 5. Corresponding V_{oc} Value = 862.2 mV

For the final I-V curve I used the circuit shown in Figure 1. The results were as follows. The (.dc V1 0 .87 1m) command is for initiating the circuit with a dc sweep. Here the value of V1 goes from 0 V to 0.87 V with an increment of 1mV.

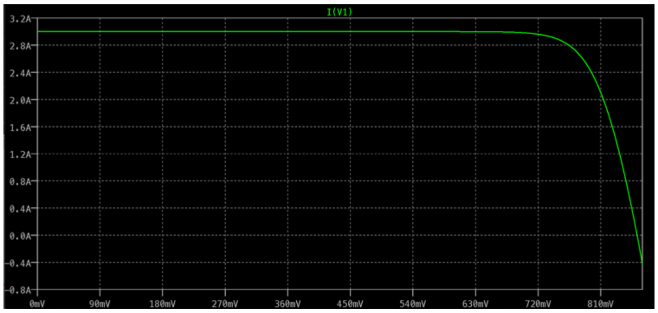

Figure 6. I-V Curve Generated

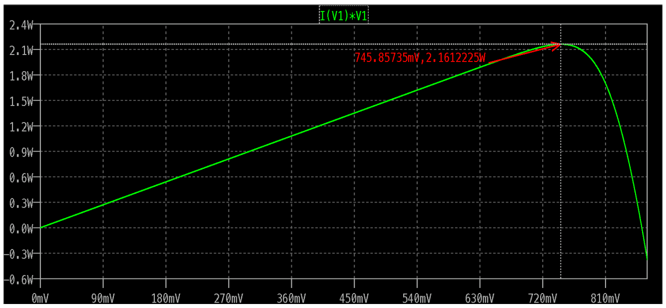

Figure 7. Power-Voltage Characteristic Generated with MPP = 2.16 W

Thus, it was successfully shown that the circuit in the simulation generated the I-V curves same as that of a solar cell.

Next, I designed a PV module which consists of 36 individual solar cells and it generated a family of 6 curves for different values of currents. The circuit for the PV module is as shown in Figure 9.

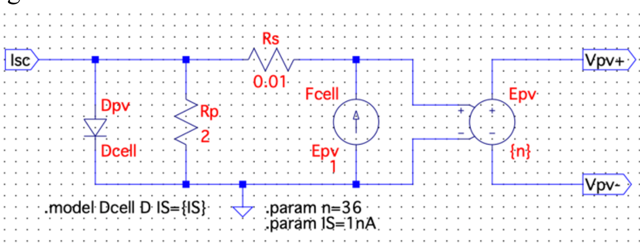

Figure 9. PV Module Design in LTspice

As you can see here, there are 2 output terminals Vpv+ and Vpv- corresponding to the output voltage of the PV module itself and 1 input terminal Isc which corresponds to the short-circuit current. The diode is a default configuration by LTspice, though, the current in the diode is given a value of 1nA. The Fcell is a linear current controlled current source that is connected to Epv, a voltage dependent voltage source. The (.model Dcell D IS={IS}) is a command to set the diode current to a certain value, which, in this case, is 1nA as seen in the command (.param IS=1nA). The (.param n=36) command sets the number of cells in the Epv to 36 units instead of just 1. This can be any value depending on the user.

This is just a design for the PV module and has no input and output yet. Hence, I converted it into a symbol and connected the 3 open terminals to the corresponding values as shown in the figure below.

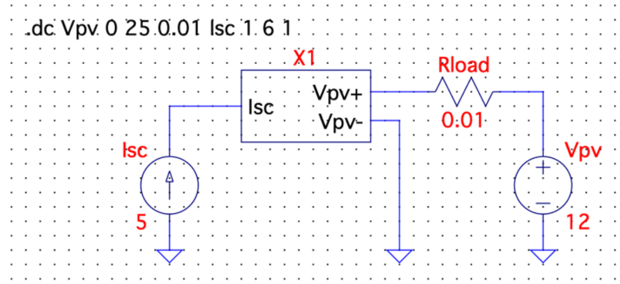

Figure 10. PV Module Complete Circuit

Here, you can see that the block X1 is the circuit shown in Figure 9 and has the Isc, Vpv+ and Vpv- as its terminals. Isc has been given a value of 5 A. Vpv- is connected to the ground (= 0V) and Vpv+ is connected to a load resistor (=0.01 Ω) and Vpv+ is connected to Vpv with a value of 12 V. The (.dc Vpv 0 25 0.01 Isc 1 6 1) command is a DC sweep command to initiate the values of Vpv and Isc. Here, Vpv goes from 0-25 V with an increment step of 0.01 V and Isc goes from 1 A to 6 A with a step of 1 A which generates 6 different curves as shown below.

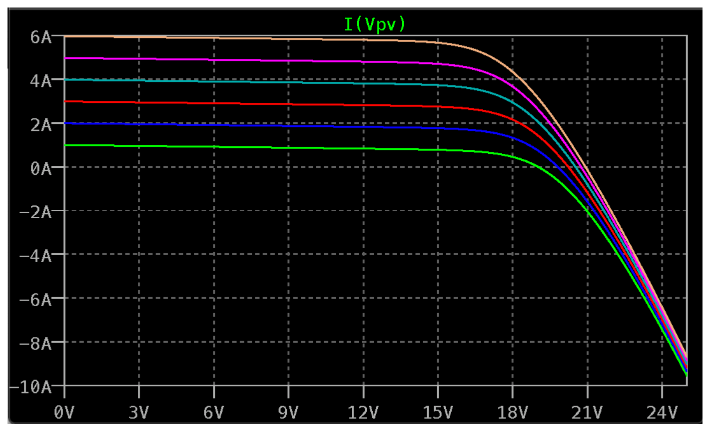

Figure 11. I-V Curve of the PV Module

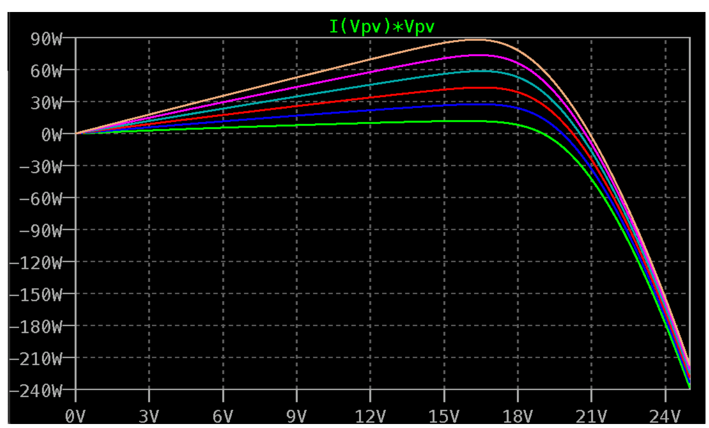

Figure 12. Power-Voltage Characteristic of the PV Module

Though, the values are pretty small as compared to real-life scenarios. This was just done to show the generated curves and the design was successful in generating the I-V and P-V curves for both the solar cell and the PV module.