Experiment #2
PV Power Electronics Laboratory

Completed By:
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Step 1:

Nameplate Data:
P_max = 85W
I_sc = 5.54A
Vol_max = 600V
Vol = 22.2V
V_rate = 17.2V
Class C
Fuse = 20A

Step 2:

No deliverable required

Step 3:

Battery Voltage = 12.87V @ 1:37 pm
AC Power Monitor = 112.2V, 330mA, 36W, 62.1Hz

Step 4:

Irradiance 1200 W/m^2
Time: 2:10 pm
V_oc = 21.4V, I_sc = 5.6A
V_mpp = 17.4V, I_mpp = 4.5A

Step 5:

I_panel	V_panel
5.6A	4V
5.4A	5.8V
5.5A	10V
4.8A	16V
4.3A	17.4V
2.8A	18.9V
1.9A	19.6V
1.5A	19.9V

Step 6:

Time: 2:18 pm
V_oc = 21.4V, I_sc= 5.5A
V_mpp = 7.3V, I_mpp = 4.6A

I_panel	**V_panel**
5.4A	2.4V
5.3A	3.9V
5A	6.7V
4.6A	7.3V
2.9A	8.6V
1.8A	9.3V
1.8A	11.8V
1.7A	19.9V
1.6A	16.5V
1.5A	17.9V
1.5A	19.6V

Step 7:

Energy Recorded = 0.02 kWh
Battery Voltage = 12.47V @ 2.29 pm

Step 8:

V_panel = 12.7V
I_panel = 4.95A

We found the maximum power point to be at about 17.4V with 4.5A, therefore, our panel was not operating at its maximum power point.

Step 9:

No deliverable required

Step 10:

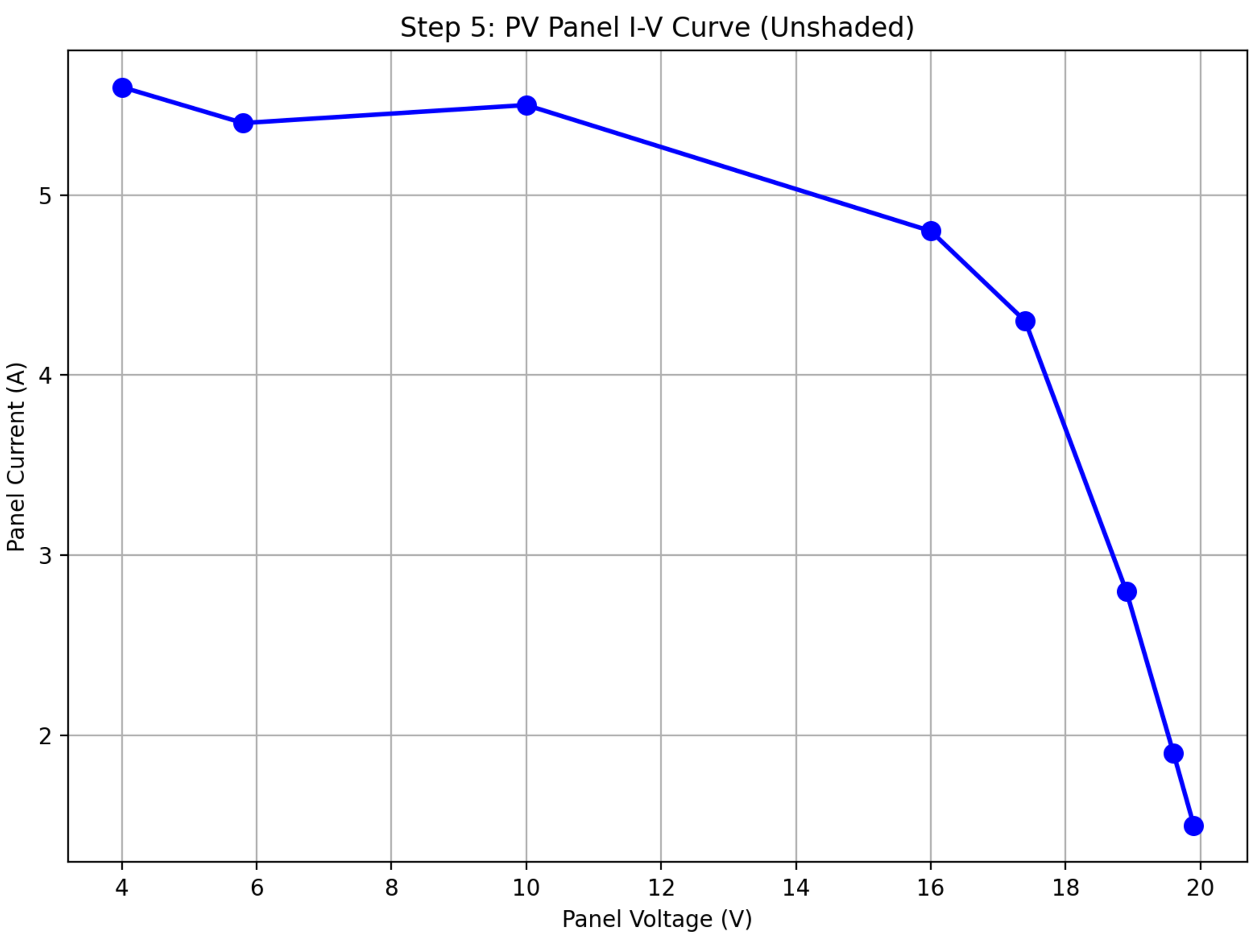
Irradiance estimate from NREL website for 2:00 pm = 1100 W/m^2
P_mmp = V_mmp x I_mmp = (17.4V)(4.5A) = 78.3W

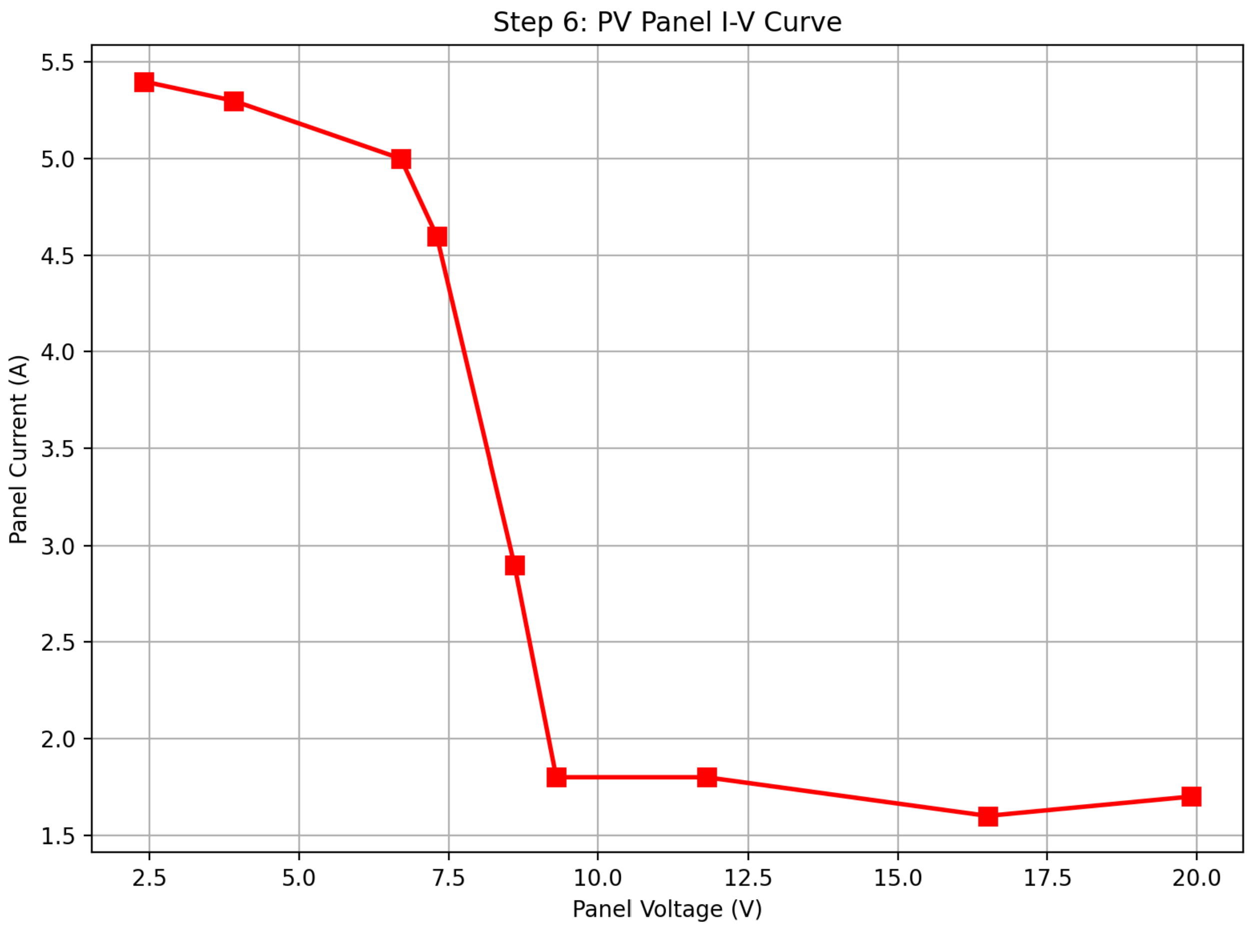
P_incident = (irradiance)(area) = (1100 W/m^2)(0.6324m^2) = 695.64W

Efficiency = P_mmp/P_incident = (78.3W)/(695.64W) x 100 = 11.26%
Efficiency_theoretical (STC) = 13.4%

Our measured efficiency is almost 2% lower than the theoretical value. This is most likely due to not moving the solar panel as the sun changed and losses incurred from banana clip wires for the current and voltage meters.

Step 11:



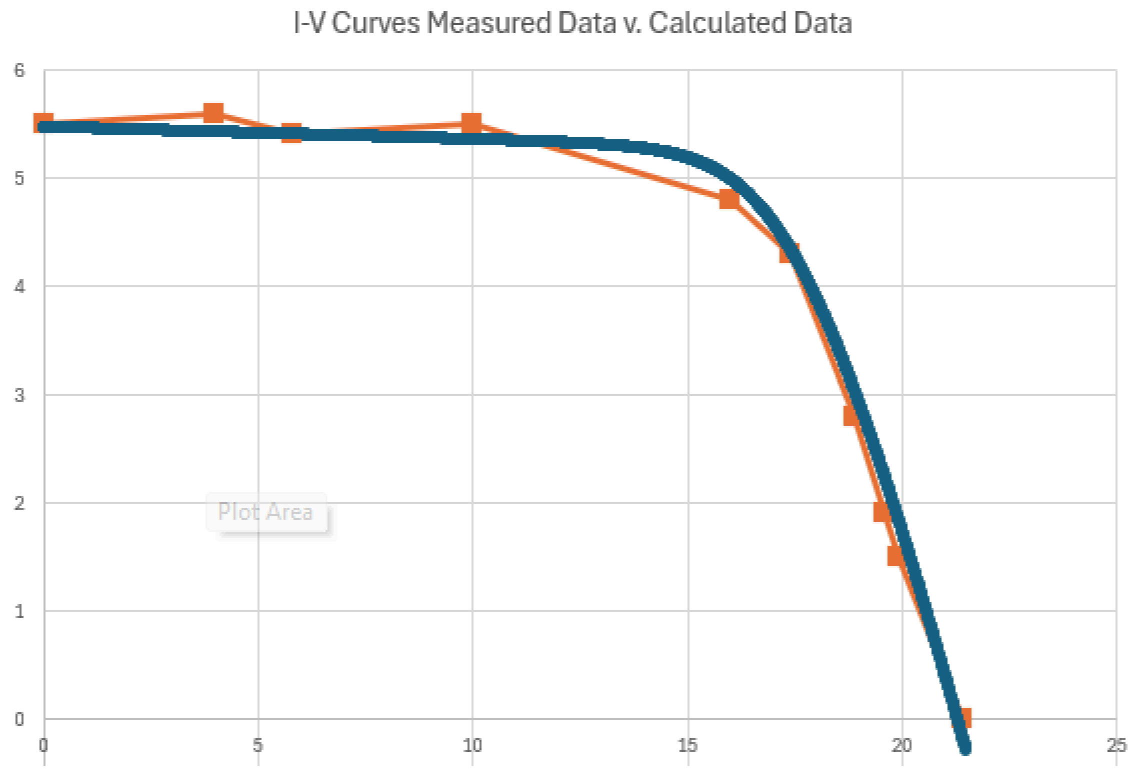


Step 12:

(i) Using a MATLAB script, we were able to compute the model parameter values in a similar way to Experiment 1. The model parameters are listed in the table below:

Model Parameters	
$\mathbf{k_i}$	0.0055 m^2/V
$\mathbf{I_{D0}}$	613.84 pA
$\mathbf{R_s}$	14.6 m**Ω**
$\mathbf{R_p}$	2.427 **Ω**

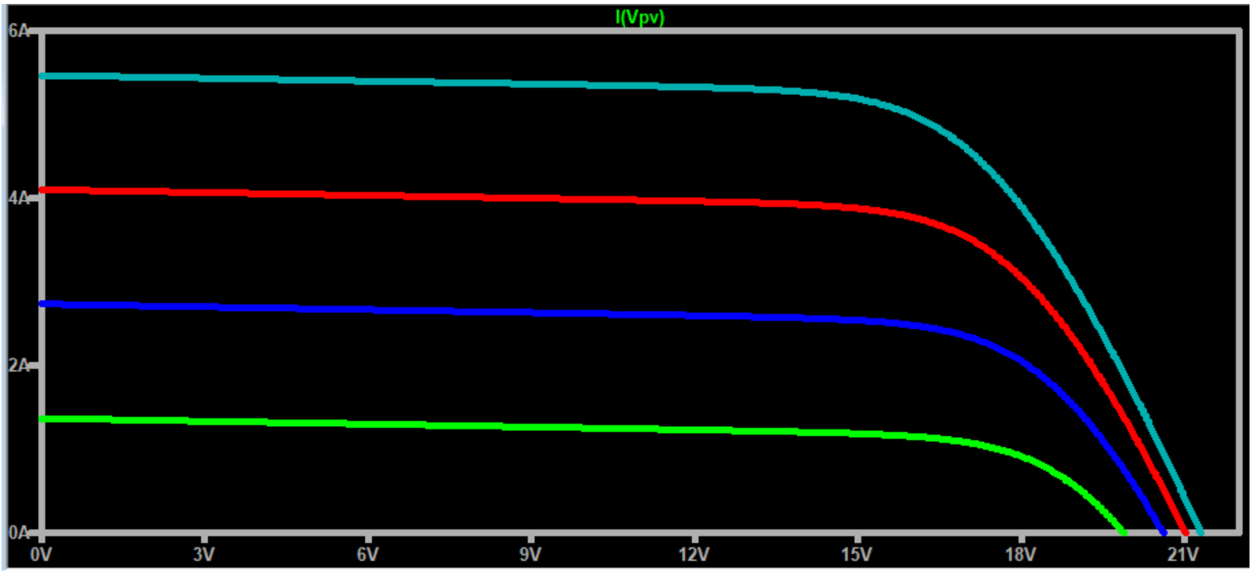
(ii) Measured data (orange) versus model data (blue)

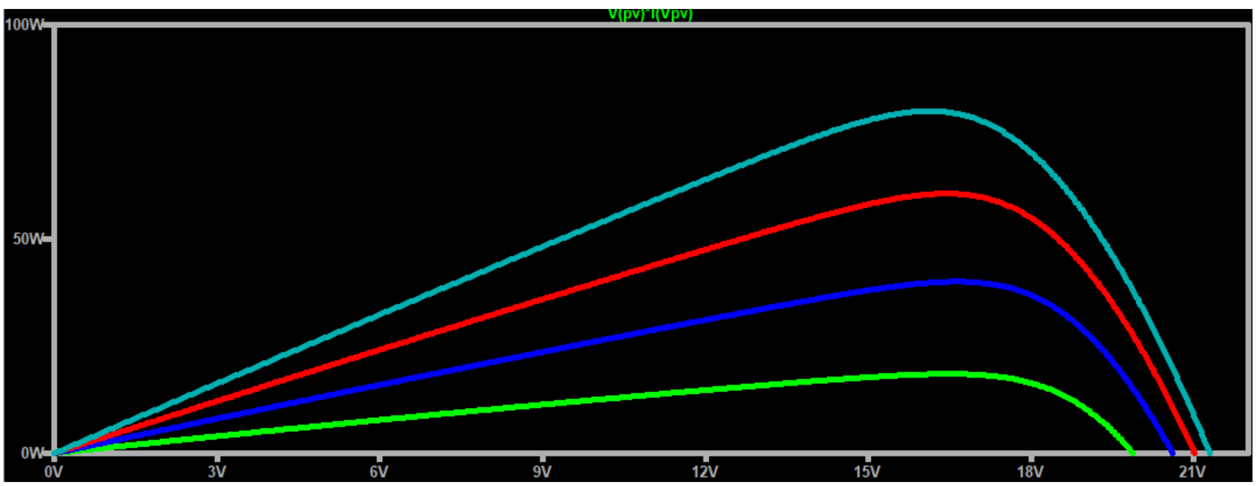


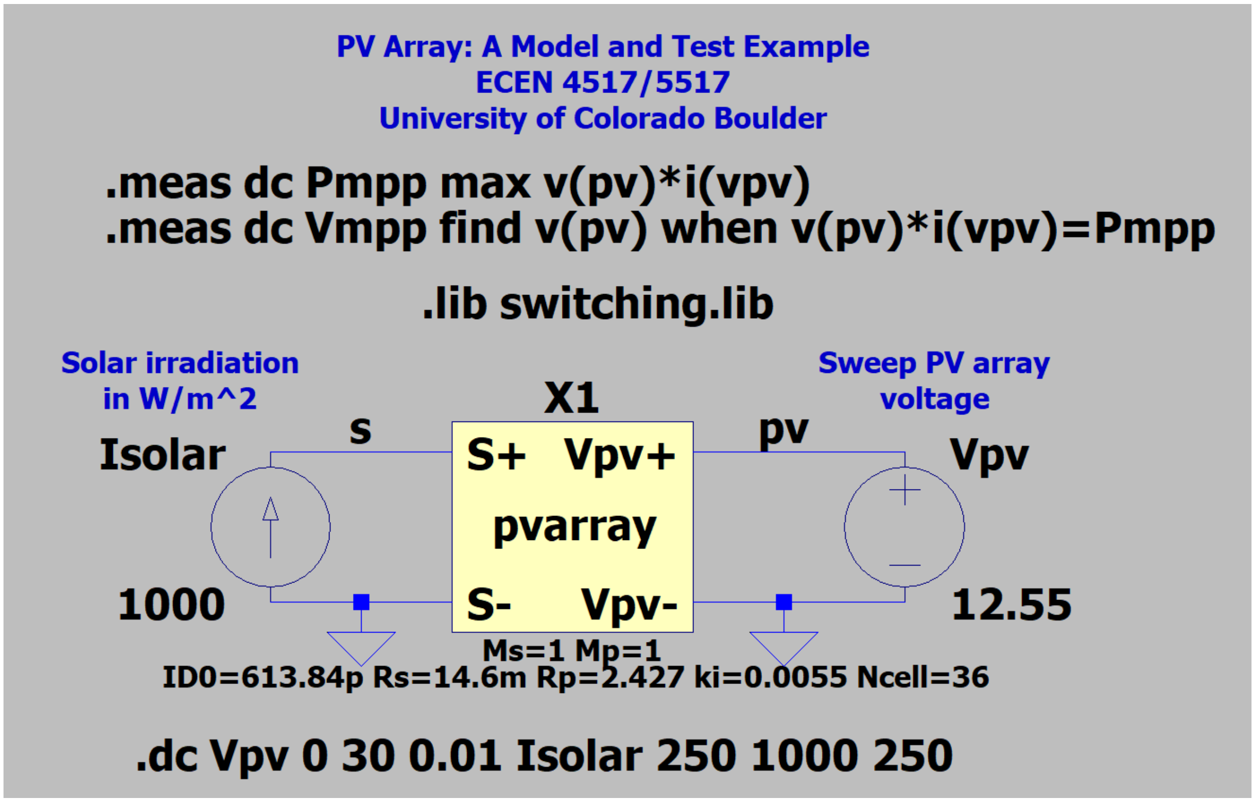
(iii) As can be seen above, the measured data is very close to the modeled data. V_{oc} is exactly the same based on the parameters that were found in the model, V_{mpp} is close to the same, the model calculated a little less than what was measured, I_{sc} in the model is also exactly the same as what was measured and I_{mpp} is a little higher than what was measured.

Step 13:

Below are the plots in LTspice that were made based on the model parameters found in the previous step. The schematic is also below.

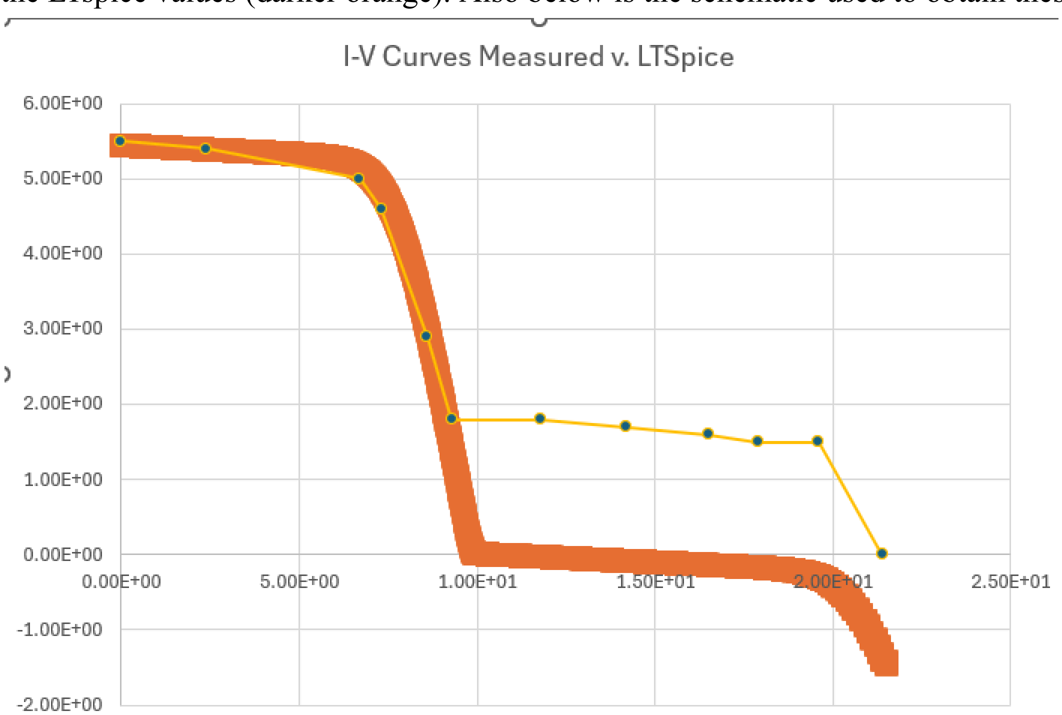


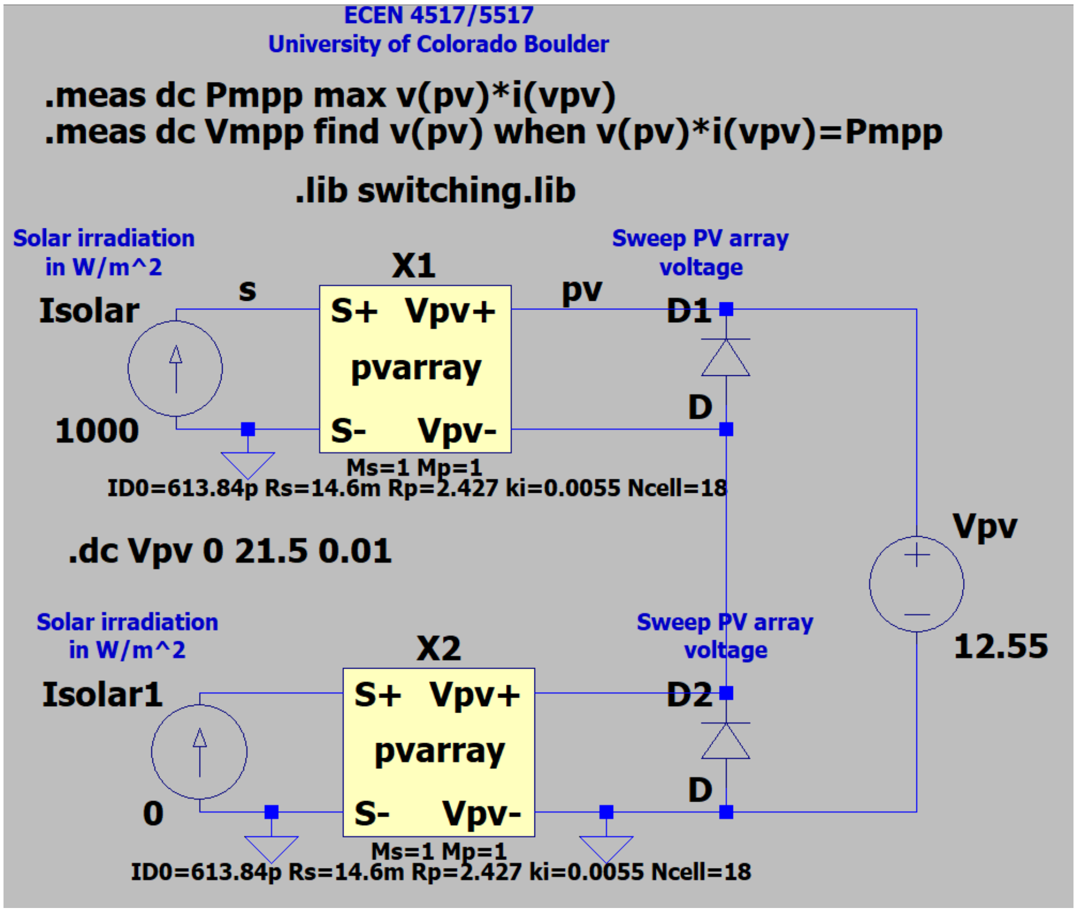




Step 14:

(i) The following plot below is the I-V curves of the measured values (light orange) and the LTspice values (darker orange). Also below is the schematic used to obtain these values.





(ii) The model data starts out very close to what was measured but changes significantly around 2 Amps. This is likely due to the fact that to cover the 4 panels in the experiment, we used a sheet of paper which would still let some light through. The diode across the second PV array section is the one that conducts to prevent reverse current flow and significantly lower the panel efficiency/damage the solar panel.

(iii) The maximum power point is about 36 Watts which is much lower than the unshaded case. I_{mpp} is around 5 Amps and V_{mpp} is about 7.25V

Step 15:

(i) E_battery = E_ac/n_inverter = (20Wh)/0.95 = 21.05 Wh
V_avg = (12.87+ 12.47)/2= 12.67V
Ah = 21.05Wh/12.67V = 1.66Ah

(ii) From the battery datasheet, at full charge it has 56 Ah.
SOC = (56 Ah - 1.666 Ah) / 56 Ah = 97%

(iii) Our battery supplied roughly 1.66Ah between steps 3 and 7. The battery discharged around 3% during that time

Step 16:

(i) In step 8, we calculated the operating point to be at 12.7 V and 4.95 A (62.865 Watts) which is not the maximum power point of 78.3 Watts that we calculated.

(ii) Maximum power point tracking would increase the efficiency of the buck converter which in turn raises the battery power. The battery is at a roughly constant voltage so this also means that the current increases with MPPT.

(iii) To track maximum power point, you could vary the duty cycle with code until the power hits a peak and then you could set the duty cycle at that point. This process can continue as the power changes from panels being shaded. So the power/current of the battery needs to be constantly monitored and the duty cycle can be adjusted accordingly.

Step 17:

Some specifications we decided on for the buck converter are listed below. These are based on what we believe to be the worst case scenario ranging to the best case scenario. The frequency was mostly picked for ease and falls within a reasonable range.

Converter Input Voltage Range: [0-35V]
Converter Input Current Range: [0-6A]
Converter Output Voltage Range: [0-25V]
Converter Output Current Range: [0-8A]
Converter Switching Frequency: 100 kHz
Converter Peak Efficiency: ~97%