Experiment 1
Introduction to Photovoltaic Systems and Power Electronics
ECEN 5517

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Date Performed: January [redacted], 20[redacted]
Instructor: Professor [redacted]

1 Objectives

- To characterize the SQ-85 photovoltaic panel, and find numerical parameters of the equivalent circuit model
- To test the sine wave inverter provided
- To charge the deep-discharge lead-acid battery using the Direct Energy Transfer approach

This report is structured in the same order as the sequence of tasks given in the Experiment 1 procedure document.

2 Experimental Data

2.1 SQ-85 PV Panel Nameplate Details

Parameter	**Value**
Maximum Power Output	85 W
Short Circuit Current	[redacted]
Rated Current	[redacted]
Maximum Open Circuit Voltage	600 V (UL) / 715 V (TUV)
Open Circuit Voltage	22.2 V
Rated Voltage	[redacted]
Fire Rating	Class C
Series Fuse	20 A
Field Wiring	14 AWG (min) Insulated for 90°C

2.2 Initial Readings

Time of Day	[redacted]
Battery Open-Circuit Voltage	
AC Voltage	
AC Current	
AC Power	
AC Frequency	

2.3 PV Panel Measurements (all cells uniformly irradiated)

Solar irradiance measured with pyranometer = [redacted] W/m^2.

2.3.1 Maximum Power Readings

Maximum Power	[redacted]
Panel Voltage at MPP	
Panel Current at MPP	
Time of Day	

2.3.2 v_{PV} vs. i_{PV}

v_{PV} [V]	i_{PV} [A]
0 (SC)	[redacted]
2.07	
5.8	
7.0	
8.0	
11.5	
13.5	
14.6	
15.8	
16.67	
16.86	
17.0	
17.2	
17.3	
17.6	

17.7	[redacted]
17.85	
18.0	
18.14	
18.46	
18.6	
18.86	
19.0	
19.25	
19.4	
19.53	
19.7	
19.8	
19.84	
19.9	
20.0	
20.1	
20.64	

2.4 PV Panel Measurements (4 cells shaded along left side)

2.4.1 Maximum Power Readings

Maximum Power	[redacted]
Panel Voltage at MPP	
Panel Current at MPP	
Time of Day	

2.4.2 v_{PV} vs. i_{PV}

v_{PV} [V]	i_{PV} [A]
0 (SC)	[redacted]
2.5	
4.3	
6.0	
7.3	
7.95	

8.45	[redacted]
8.84	
9.02	
9.15	
9.25	
9.4	
9.55	
9.63	
19.0	

2.5 Final Readings

2.5.1 After measuring PV characteristics

AC Energy Consumed	[redacted]
Battery Voltage (Loaded)	
Battery Voltage (Open-Circuited)	
Time of Day	

2.5.2 After removing AC load and connecting PV panel to battery

Panel Voltage	[redacted]
Panel Current	

Observation: [redacted]
power at this
maximum powe

3 Calculations and Observations

3.1 PV Panel Efficiency

Maximum po[redacted]
estimated fro
Panel area, A
$\Rightarrow$ Input Pow
Maximum PV
$\Rightarrow$ Estimated

3.2 Measured $i - v$ Curves

3.2.1 With all cells uniformly irradiated

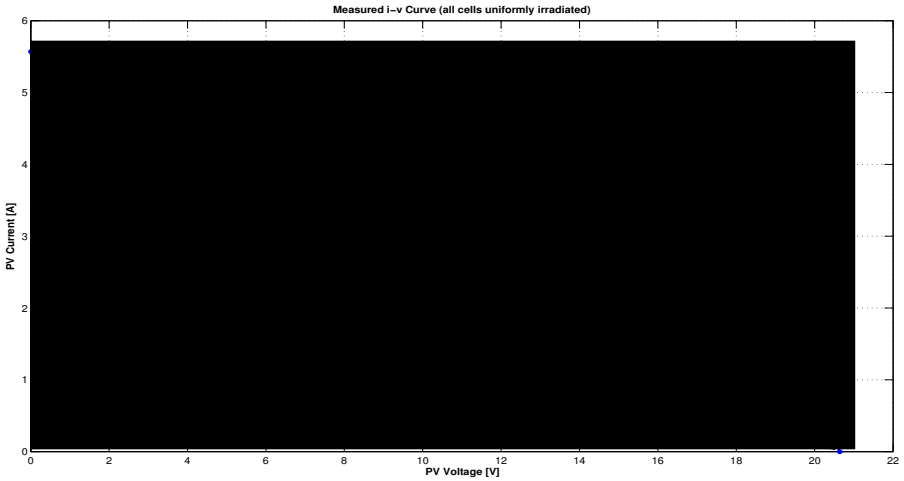


Figure 1: PV voltage vs. current for uniform irradiation

3.2.2 With 4 cells shaded along left side

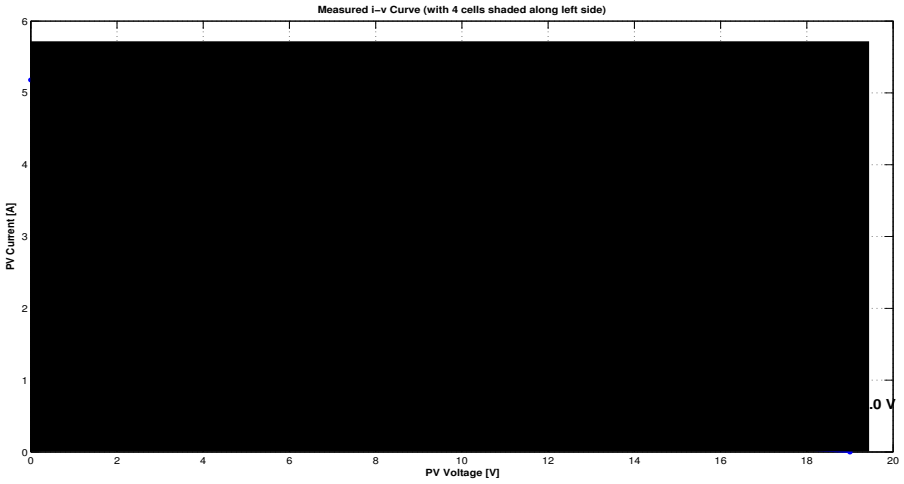


Figure 2: PV voltage vs. current for partial shading

Observation: Under p[redacted]s of current, and the op[redacted]e

condition.
Explanation: [redacted]
values of curren[redacted]

3.3 Calculation of PV Circuit Model Parameters

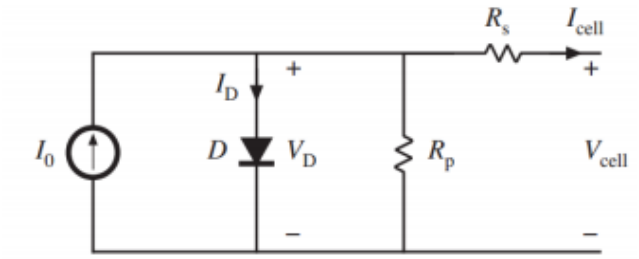


Figure 3: Equivalent circuit model of a PV cell

The equiva[redacted] the
equation:

(1)

where λ =

The circui[redacted] med
for the foll

R_s was cal[redacted] urve
shown in [redacted] d as
follows:

(2)

where pan[redacted]

Similarly, [redacted] hort
circuit poi[redacted]

To obtain [redacted]

(3)

(4)

$V_{OC,cell}$ (c[redacted] the
$i - v$ curv[redacted] pen-
circuit volt[redacted]
It may be [redacted] $_D$ =

$V_{OC,cell}$. [redacted]
These equations were solved for I_0 and I_{D0} numerically using MATLAB.
Values obtained for the four circuit parameters are listed below:

R_s	[redacted] Ω
R_p	
I_0	A
I_{D0}	A

3.4 Comparison of Measured and Model-Predicted $i - v$ Curves with Uniform Irradiation

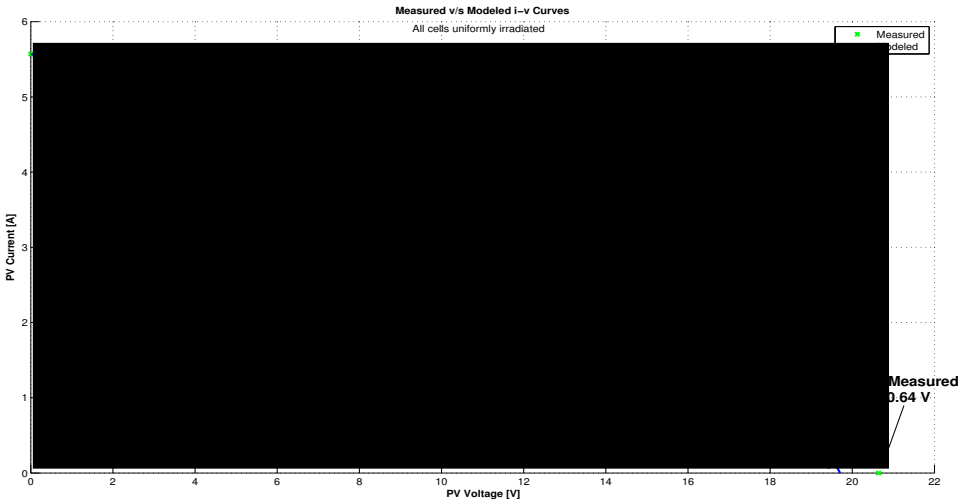


Figure 4: Measured and model-predicted $i - v$ curves

The two curves are shown overlaid in 4, with short-circuit currents, open-circuit voltages and maximum power points marked.

Observation: As can be seen in Fig. 4, the short-circuit current predicted by the model is [redacted] voltage of the model is slightly lower than [redacted] st significant deviation is in the maximum

Explanation: Deviations between modeled and measured curves may be explained as under:

- [redacted] r of cies
- The c [redacted] mode junct[redacted]

- [redacted]istics were being
  [redacted]ing temperature,

3.5 Modeled $i - v$ and Power-Voltage Curves for Various Values of Insolation (Uniform Irradiation)

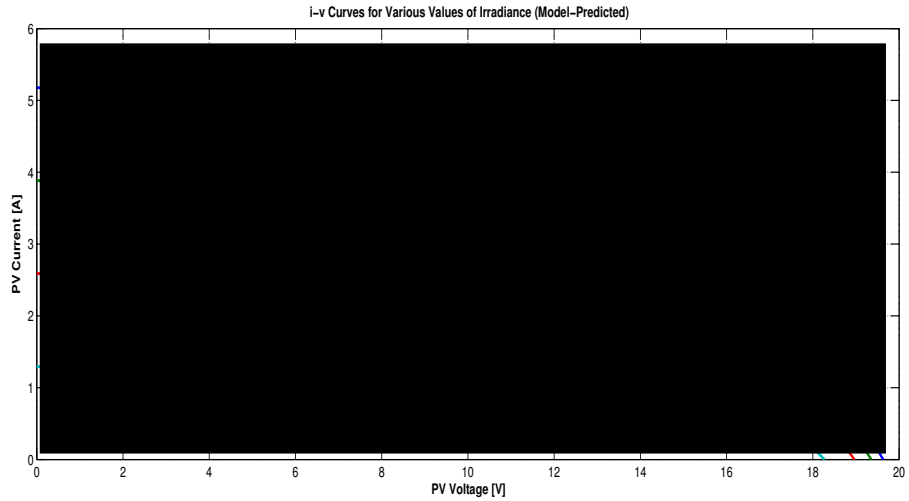


Figure 5: Modeled $i - v$ curves for various values of solar insolation

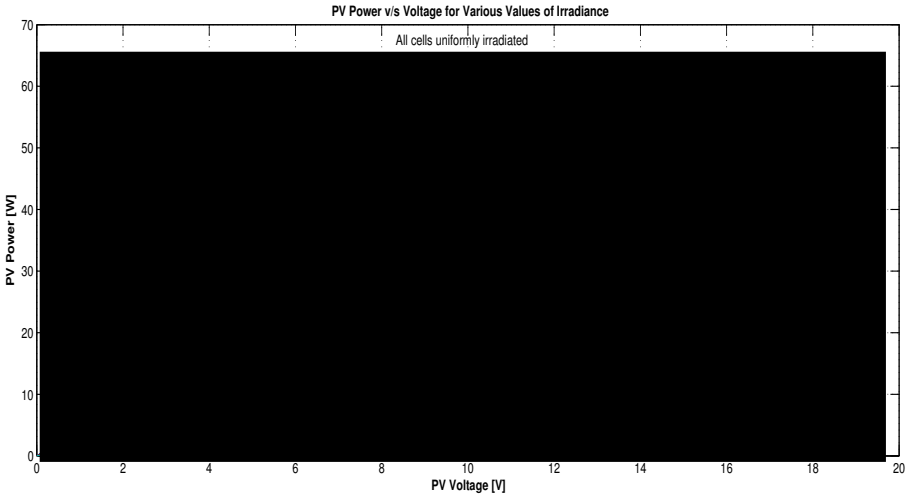


Figure 6: Modeled power vs. voltage curves for various values of solar irradiance

3.6 Comparison of Measured and Model-Predicted $i - v$ Curves with 4 Cells Shaded

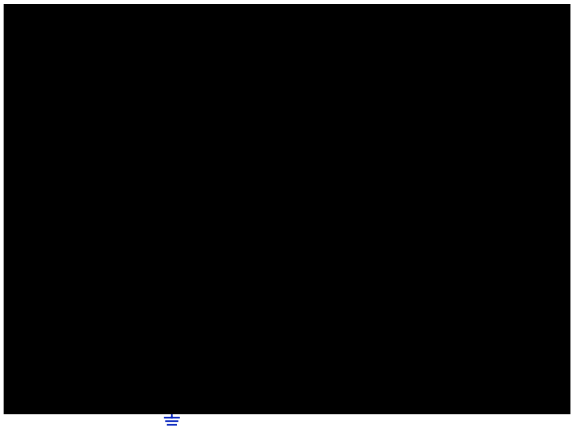


Figure 7: Circuit model implemented in ADS software for partial shading condition

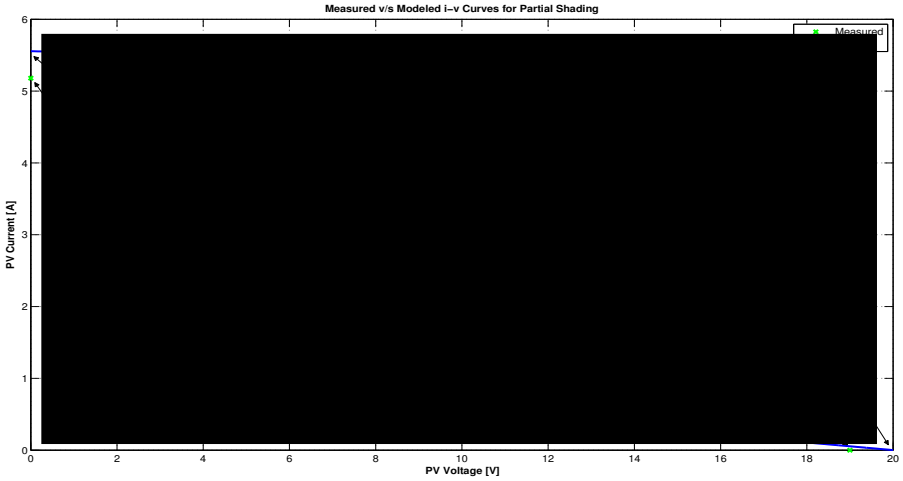


Figure 8: Measured vs. modeled $i - v$ curves for partial shading condition

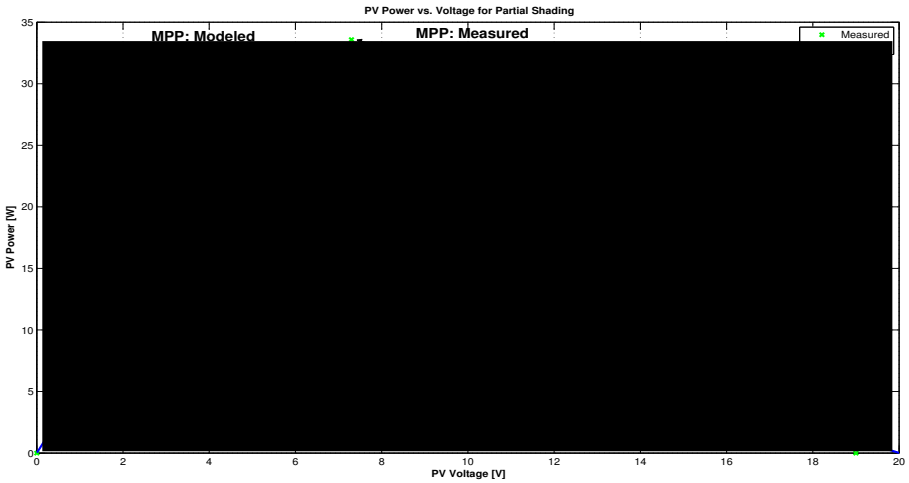


Figure 9: Measured and modeled power vs. voltage curves for partial shading condition

The circui [redacted] for the shaded cel [redacted] This effect was m [redacted] circuit model is sl [redacted] The result [redacted] l modeled $i - v$ [redacted] circuit currents, c [redacted] Power vs. [redacted] ese are shown in F [redacted]

Observation: [redacted] e reasonable approximations.

Explanation: [redacted] sured with unif [redacted] ll temperature pla [redacted]

3.7 Battery Discharge Calculations

AC power c [redacted]
Inverter effi [redacted]
$\Rightarrow$ DC powe [redacted]
Assuming t [redacted] also approximat [redacted] 2.65-12.85 V, a r [redacted] $_{avg} \approx$ 12.5 V
(Also, a rea [redacted] ich is = 12.38 V. [redacted] nable approximati [redacted]

⇒ Average battery current [redacted]
Time elapsed between initia[redacted]
⇒ Average ampere-hours s[redacted]

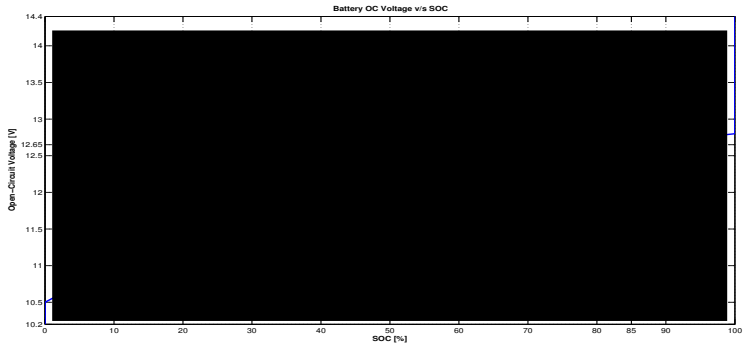


Figure 10: Battery open-circuit voltage vs. SOC

Battery open-circuit voltage vs. SOC characteristics were plotted using the data from Table 1, and additional data provided regarding maximum and minimum open-circuit voltage (6×2.4 V and 6×1.7 V). This is shown in Fig. 10.
Final op[redacted]
⇒ As sh[redacted]

3.8 PV Operating Point during Direct Energy Transfer

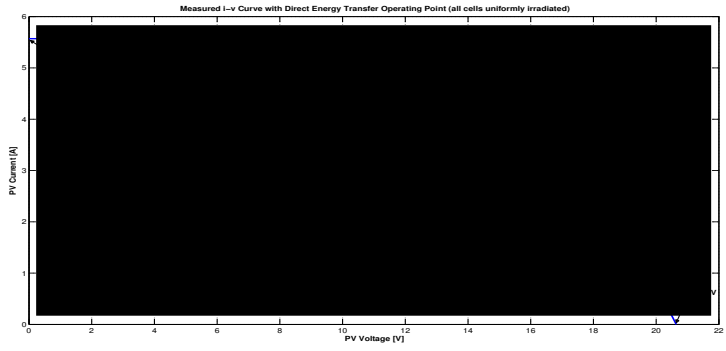


Figure 11: Direct Energy Transfer Operating Point

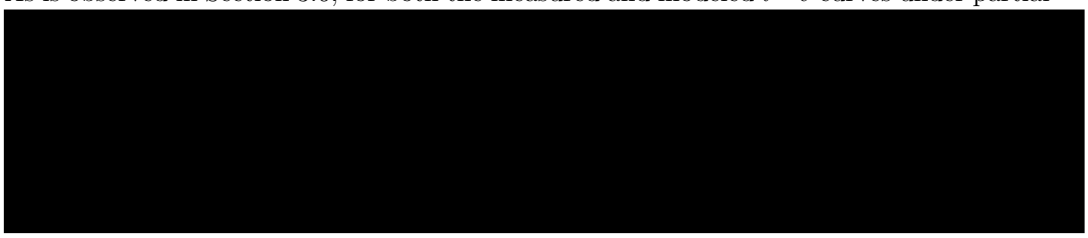
As recorded in Section 2.5.2, when battery was connected directly to the PV panel output, [redacted]**1 A**. This operating point is shown on the measured $i - v$ curve in Fig. 11. The PV output power at this operating point, $P_{PV,DT} = V_{PV,DT} \times$ [redacted].

3.8.1 Comparison with MPPT Implementation

With MPPT implementation using a buck converter, PV panel will now operate at its

3.8.2 MPPT under Partial Shading Conditions

As is observed in Section 3.6, for both the measured and modeled $i-v$ curves under partial



4 Conclusions

- The
  both
  tions
  chan
  appr
- Und
  imun
  SEP
- The
  powe
  the c