Electrical properties of a PhotoVoltaic cell

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The code

The code utilizes the Shockley Solar equation to plot the curve.

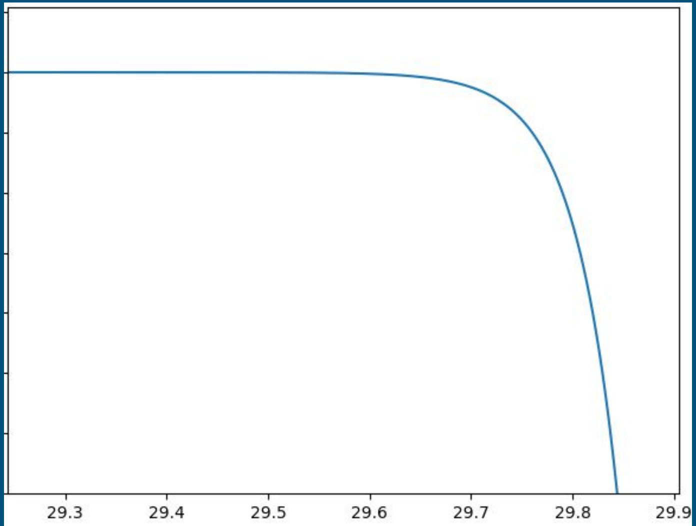
$$I = I_{ph} - I_o\left(e^{\frac{qV}{k_B T}} - 1\right)$$

GitHub link

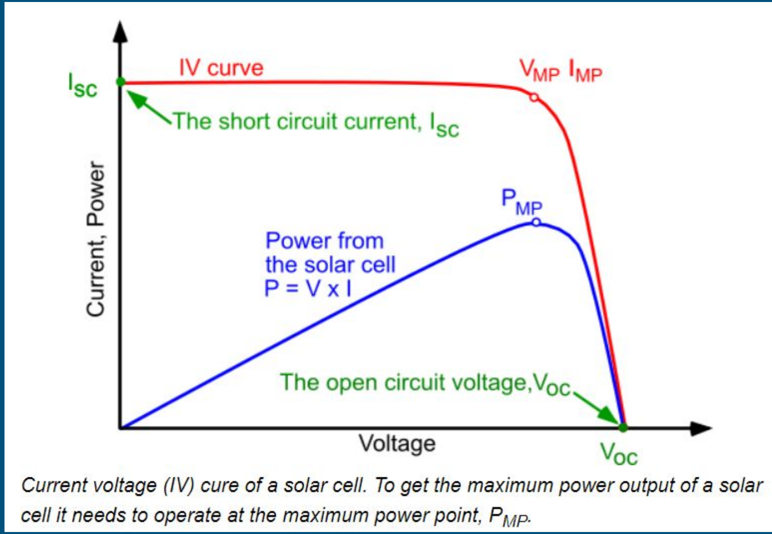
```
import numpy as np
import math
import matplotlib.pyplot as plt

V   = np.linspace(0, 30, num=10000) # X axis

I_0 = math.pow(10,-12) # saturation current
I_l = 2.7 # current generated by the photoelectric effect

q_by_kb = 11594 # electron charge / Boltzmann constant

abs_temp = 500 # absolute temperature

# Shockley solar cell equation
I_pv = I_l - (I_0 * (np.exp(q_by_kb*V / (abs_temp)) -1))

# plotting the result using matplotlib
plt.plot(V, I_pv)
plt.tight_layout()
plt.show()
```

Plotting the I-V characteristic curve

Here we use the code described before to plot the curve.

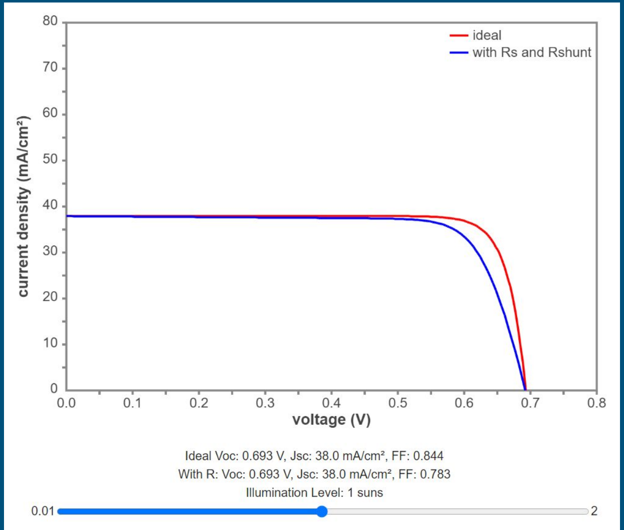


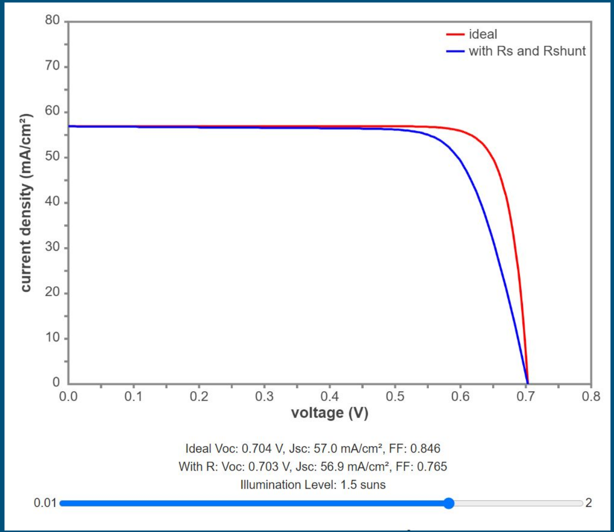
Curve obtained using our code

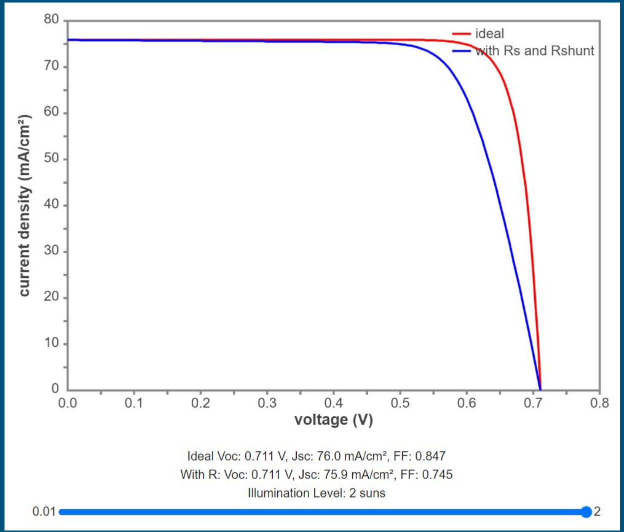


The actual curve (Red)

Variation of J-V curve with a change in intensity





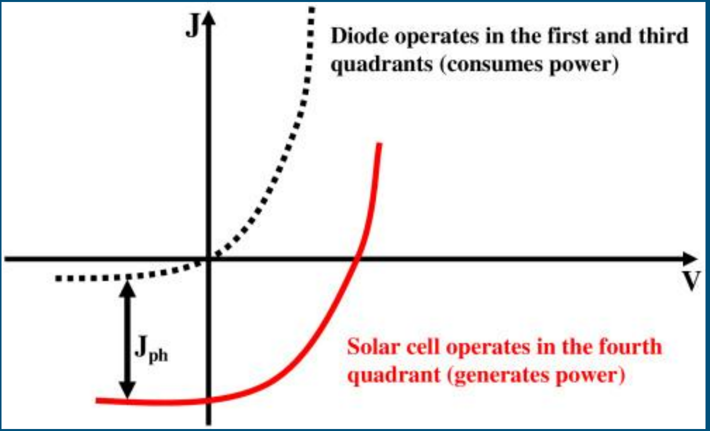


Simulation

Why in the 4th quadrant?

A solar cell does not draw current but supplies the same to the load.

Without light, the solar cell behaves like a diode but when the light is incident on the cell, the I-V curve goes in the fourth quadrant since the cell becomes to produce power.



Fill Factor and Efficiency

Fill Factor is the area of the largest rectangle that can fit in the I-V curve of a solar cell, it can be calculated using the equation -

$$FF = \frac{V_{MP} I_{MP}}{V_{OC} I_{SC}}$$

Efficiency is defined as the ratio of energy output from the solar cell to input energy from the Sun. The equation that describes efficiency is -

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{\text{in}}}$$

Calculating Fill Factor and Efficiency

```python
j_max = float(input("Enter J max\n"))
v_max = float(input("Enter V max\n"))
j_sc = float(input("Enter J sc\n"))
v_oc = float(input("Enter V oc\n"))
fill_factor = (j_max*v_max) / (j_sc*v_oc)
print("Fill Factor =", fill_factor, "\n")
i_sc = float(input("Enter I sc\n"))
p_light = float(input("Enter P light\n"))
efficiency = (i_sc*fill_factor*v_oc) / p_light
print("Efficiency =", efficiency, "\n")
```

Increasing efficiency

- An increase in solar cell temperatures of approximately 1 degree celsius causes an efficiency decrease of about 0.45%. To prevent this, a transparent silica crystal layer can be applied to solar panels.
- Thin film materials show a lot of promise for solar cells in terms of low costs and adaptability to existing structures and frameworks in technology. The efficiency of these solar cells can be increased by one third of that of the traditional ones.

References

- Study on the Influence of Light Intensity on the Performance of Solar Cell
- Modeling and Simulation of Photovoltaic cells
- pvlib documentation
- Effect of light intensity on IV curve
- Wikipedia: Solar cell efficiency
- Solar Cells Efficiency Increase Using Thin Metal Island Films

Thank You