Lesson 24: Photocell Electrical Characteristic and Circuit Model

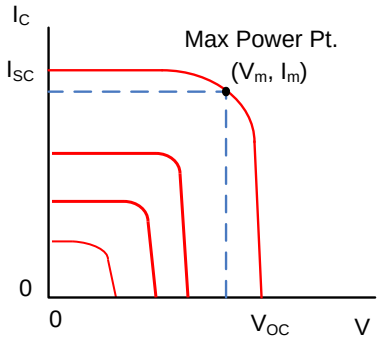
ET 332a
Dc Motors, Generators and Energy Conversion Devices

Learning Objectives

After this presentation you will be able to:

- Identify and interpret a photocell electrical characteristic
- Find the maximum power output from a photocell
- Calculate a photocell's efficiency
- Determine circuit model parameters for a photocell given its characteristic curve
- Perform a calculation using the circuit model of a photocell.

Photocell Characteristic Curve



P_m = Maximum cell power

Fill Factor = FF

$$P_M = I_M V_M$$

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

0.7 <FF<0.85 Typical FF range

Cell Efficiency $\eta_C = \frac{P_C}{P_I}$ P_I = incident solar power

3 Lesson 24 332a.pptx

Solar Cell Characteristics Example (1)

Example: A photocell has a saturation current of 2.5×10^{-12} A and a short circuit current of 35 mA. It has an area of 1.5 cm^2. The incident solar power is 1000 W/m^2. Assume that the cell operates at room temperature. Find V_{oc}, P_m, Fill Factor and conversion efficiency.

$I_S := 2.5 \cdot 10^{-12}$ A $\quad I_{SC} := 0.035$ A

$V_T := 0.026$ V $\quad I_L := I_{SC}$

$$V_{OC} := V_T \cdot \ln\left(1 + \frac{I_L}{I_S}\right) \qquad V_{OC} = 0.607 \text{ V}$$

4 Lesson 24 332a.pptx

Solar Cell Characteristics Example (2)

Find P_m graphically

Create function for plotting

$$I_c(V) := I_L - I_s \cdot \left(e^{\frac{V}{V_T}} - 1 \right)$$

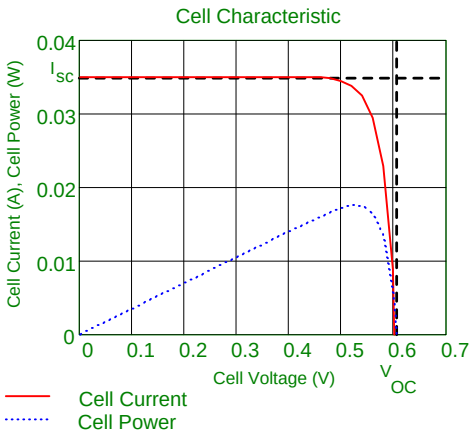
Define plot range

$$V := 0.0, 0.02 .. 0.62 \quad V$$

Calculate power as function of V

$$P(V) := I_c(V) \cdot V \quad W$$

Solar Cell Characteristics Example (3)



$V_m := 0.5360$ V $P_m := 0.0177$ W

$I_m := I_c(V_m)$ $I_m = 0.0328$ A

Find the Fill Factor (FF)

$$FF := \frac{P_m}{V_{OC} \cdot I_{sc}} \qquad FF = 0.8$$

Solar Cell Characteristics Example (4)

Find the cell efficiency at maximum power output

Find the incident power, P_I

$I := 1000 \cdot \frac{W}{m^2}$ $\quad A := 1.5 \cdot cm^2$

1,5 cm²

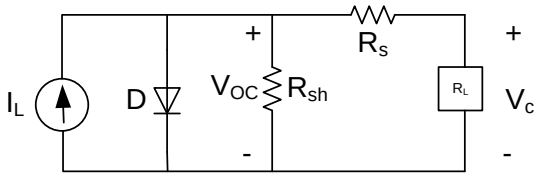
$A_m := A \cdot \frac{1 \cdot m^2}{10000 \cdot cm^2}$ $\quad A_m = 1.5 \times 10^{-4} m^2$

1000 W/m²

$P_I := A_m \cdot I$ $\quad P_I = 0.15\,W$ $\quad P_m := 0.0177 \cdot W$

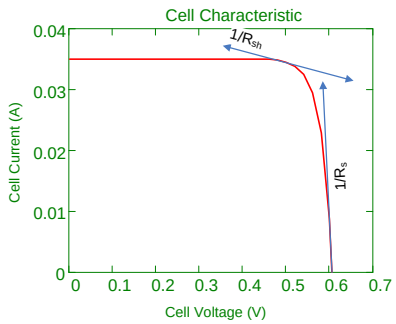
$\eta_C := \frac{P_m}{P_I}$ $\quad \eta_C = 0.1$ Cell efficiency is 10%

Circuit Model of Solar Cell

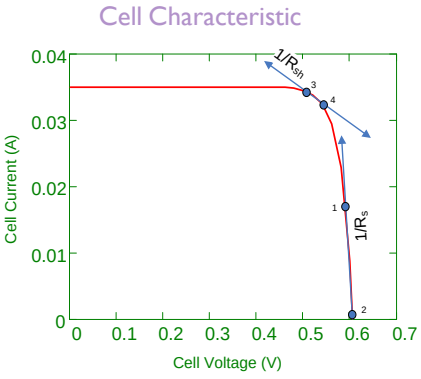


R_s slope of characteristic near V_{oc}
R_{sh} slope of characteristic near I_{sc}

Values determined by cell construction



Solar Cell Circuit Model Parameters



Finding Model Parameters, R_{sh} and R_s

Pick points on characteristic plot and compute slope.
For R_s use points 1 and 2.

1.) $V_{1s} := 0.5781$ V $I_{1s} := 0.02395$ A

2.) $V_{2s} := 0.6058$ V $I_{2s} := 3.9 \cdot 10^{-4}$ A

$$G_s := \left| \frac{I_{2s} - I_{1s}}{V_{2s} - V_{1s}} \right|$$ Conductance is $1/R_s$

$$R_s := \frac{1}{G_s}$$ $G_s = 0.8505$ S $R_s = 1.176$ Ω

For R_{sh} use points 3 and 4

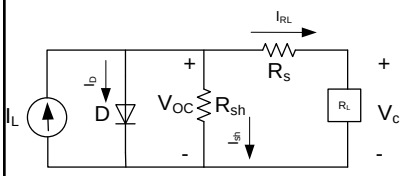
3.) $V_{1sh} := 0.512$ V $I_{1sh} := 0.0343$ A

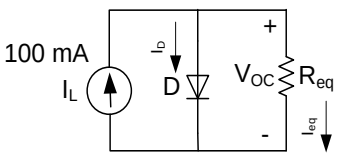
4.) $V_{2sh} := 0.550$ V $I_{2sh} := 0.0311$ A

$$G_{sh} := \left| \frac{I_{2sh} - I_{1sh}}{V_{2sh} - V_{1sh}} \right|$$ Conductance is $1/R_{sh}$

$$R_{sh} := \frac{1}{G_{sh}}$$ $G_{sh} = 0.0842$ S $R_{sh} = 11.875$ Ω

Solar Cell Circuit Model Example (1)





Example: Find the power delivered to a 30 ohm resistive load by the solar cell with a light current of 100 mA and model parameters of R_s=1.176 Ω and R_{sh} of 11.875 Ω. Determine the cell load voltage for this load resistance.

$I_L := 100 \cdot mA$ $V_{OC} := 0.71 \cdot volt$

$R_{sh} := 11.875 \cdot \Omega$ $R_s := 1.176 \cdot \Omega$ $R_L := 30 \cdot \Omega$

By KCL $I_L - I_D - I_{eq} = 0$

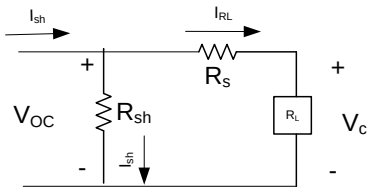
$$R_{eq} := \frac{(R_s + R_L) \cdot R_{sh}}{(R_s + R_L) + R_{sh}}$$ $R_{eq} = 8.599\ \Omega$

Parallel circuit so.....

$$I_{eq} := \frac{V_{OC}}{R_{eq}}$$ $I_{eq} = 82.6$ mA

$I_D := I_L - I_{eq}$ $I_D = 17.4$ mA

Solar Cell Model Example (2)



Use Current Divider rule to find I_{RL}

$$I_{RL} := I_{eq} \cdot \frac{R_{sh}}{R_{sh} + (R_L + R_s)} \qquad I_{RL} = 22.77\,mA$$

$$P_L := I_{RL}^{\,2} \cdot R_L \qquad P_L = 15.6\,mW$$

Find V_C from KVL

$$V_C := V_{OC} - I_{RL} \cdot R_s$$

$$V_C = 0.683\,V$$

Solar Cell Efficiency

- AM1.5 Solar Intensity (Incident power density) 1000 W/m^2 or 100 W/cm^2
  - Losses
    - Photon Energy -47% of photons have eV<1.1, 30% goes to heat
    - Voltage factor – ratio of energy given to energy required to produce electron 0.65
    - Recombination – electron/holes that recombine 10%
    - Reflection – reduced to 4%
    - Overall Efficiency η_c = (0.47)(0.65)(1-0.10)(.96)=.26
      - 26% Maximum efficiency using current technologies

End Lesson 24

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