Today

Monday, April 13, 2020 10:47 AM

- Exam 2 Review
- Solar Cell Circuit Models

Electric Circuit Equivalent Circuit

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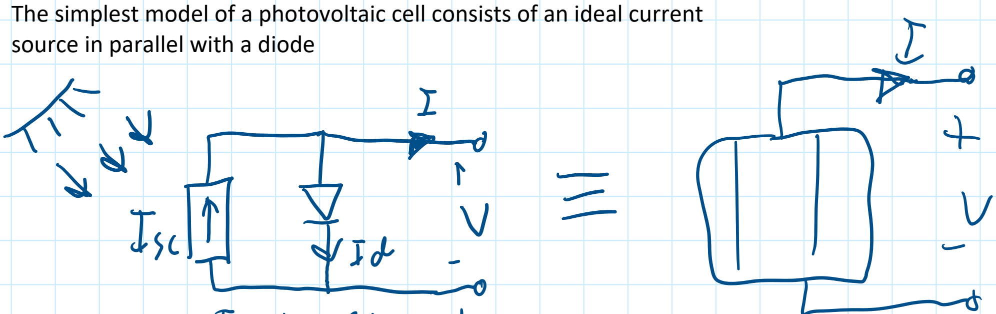
The simplest model of a photovoltaic cell consists of an ideal current source in parallel with a diode



Equiv. Circuit   Cell

As with any other electric device, we want to obtain the V-I characteristics to compute currents, voltages and power once it is part of a larger circuit.

Recall: Id = diode current from PN junction

$$I_d = I_o \left(e^{\left(\frac{qV_d}{kT}\right)} - 1 \right)$$

where: V_d = Voltage across diode terminals
I_o = reverse saturation current
q = electron charge ($1.602 \cdot 10^{-19}$ C)
K = Boltzmann's constant ($1.381 \cdot 10^{-23}$ J/K)
T = Temp in Kelvin

Note, $V_d = V$

$I_{sc} = I_d + I \Rightarrow I = I_{sc} - I_d = I_{sc} - I_o(e^{qV/kT} - 1)$

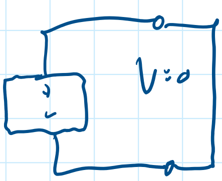
$$I = f(I_{sc}, V)$$

For any given I_{sc}, we can find the relation between the cell current and voltage

$f(I_{sc}, v)$ = diode I-V characteristic turned upside-down and shifted by I_{sc}

Lets look at 2 key conditions:

1) Short circuit

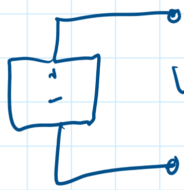


$I = I_{sc}$
↳ short-circuit current

$P = VI = 0$

↳ gives magnitude of the ideal

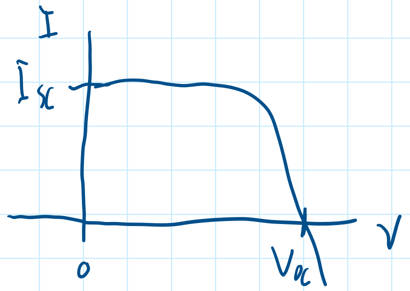
2) Open circuit



$V = V_{oc}$
↳ open circuit Voltage

$P = VI = 0$

↳ gives magnitude of the ideal current source



Let's make life easier:

$$\left.\frac{q}{KT}\right|_{T=298K} = 38.1\,[1/V] \qquad \frac{KT}{q} = \frac{1}{38.9} = 0.0257\,[V]$$

$$I_d = I_o\left(e^{38.9V} - 1\right)$$

$$I_{sc} = I_d + I = \left. I_o\left(\cancel{e^{38.9V}}^{\,1} - 1\right)\right|_{V=0} + I = I$$

- measure this It will vary with light, for example $I_{sc} = 4A$

V_{oc}, $I = 0$

$$0 = I_{sc} - I_o\left(e^{38.9V_{oc}} - 1\right)$$

$$V_{oc} = \left[\ln\left(\frac{I_{sc}}{I_o}\right) + 1\right]\frac{1}{38.9} = \boxed{0.0257\ln\left(\frac{I_{sc}}{I_o} + 1\right)}$$

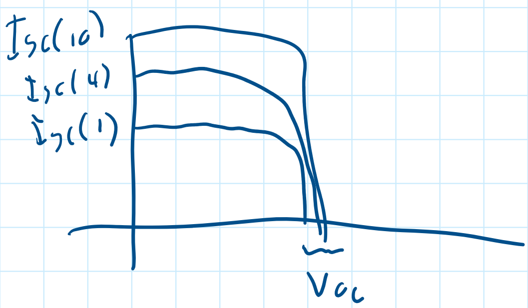
Example, $I_o = 10^{-9}$ A, $I_{sc} = 4A$

$$V_{oc} = 0.0257\ln\left(\frac{4}{10^{-9}} + 1\right) = 0.57\text{ V}$$

$I_{sc} = 10$

$$V_{oc} = 0.0257\ln\left(\frac{10}{10^{-9}} + 1\right) = 0.59\text{ V}$$

} this doesn't change much



A more accurate model

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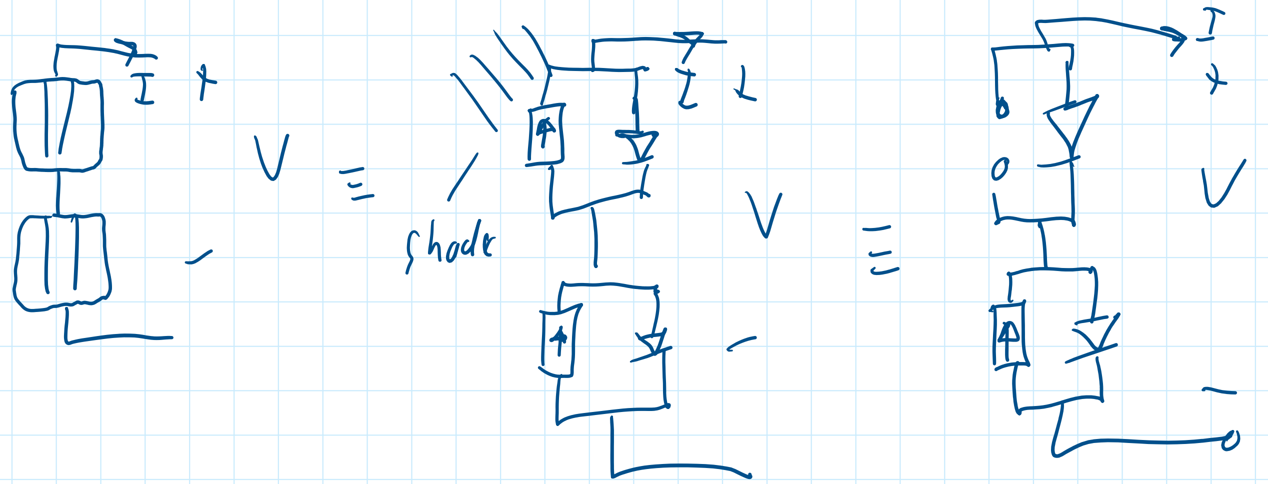
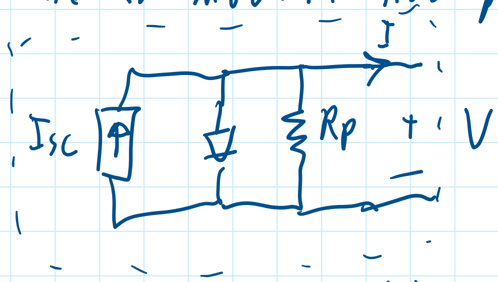
- First model is not realistic when discussing shading effects
- assume we connect cells in series (more on this later)



$I = 0$

when one cell is shaded, our model says that $I=0$. while shading effects have a big impact on power output, it is not as dramatic as this simplified model suggests

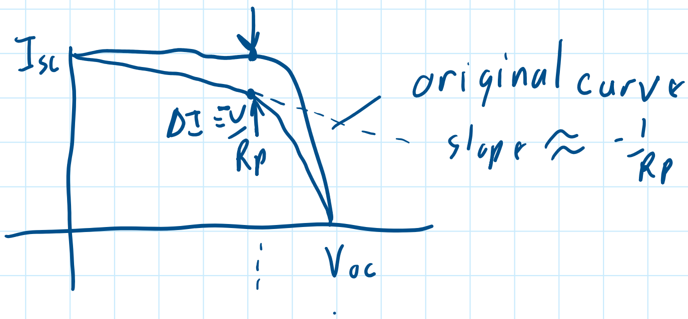
Better model: Add parallel resistance → due to leakage current paths through cell



pv cell model

$$I = I_{sc} - I_s - V/R_p$$

For any output voltage, current is reduced from simplified model by V/R_p

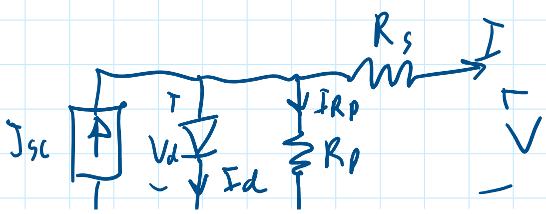


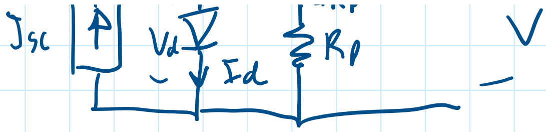
for cell to have less than 1% loss in R_p,

$$R_p > \frac{100 V_{oc}}{I_{sc}}$$

Better model: add series resistance → accounts for the fact that diode voltage ≠ output voltage

- contact resistance between cell & wire leads
- Resistance of semiconductor





$I = I_{sc} - I_d - I_{Rp}$

$I = I_{sc} - I_o(e^{38.9V_d} - 1) - \frac{V_d}{R_p}$ ⇒ want in terms of V, $V_d = V + IR_s$

$$I = I_{sc} - I_o\left(e^{38.9(V+IR_s)} - 1\right) - \frac{V + IR_s}{R_p}$$

- yuck! I is on both sides of Eqn. no good way to solve for I or V in terms of the other

↳ how do we use this?

↳ Matlab
or

1) write $I = I_{sc} - I_o(e^{38.9V_d} - 1) - V_d/R_p$ (parallel model)
2) Pick value for V_d ($0 \leq V_d \leq V_{oc}$)
3) Find I
4) $V_d = V + IR_s$ → Solve for V
5) sweep V_d, repeat (2-4) to generate VI curve

Result