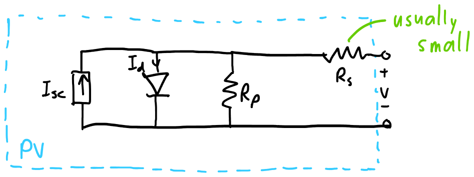
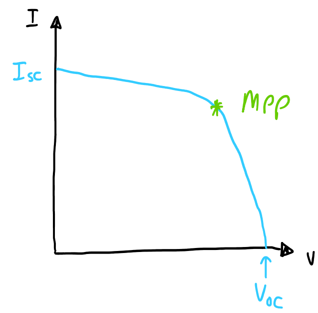
Shading+Bypass

Thursday, February 29, 2024 3:43 PM

MT coverage until this lecture, up to HW3

PV cell equivalent model

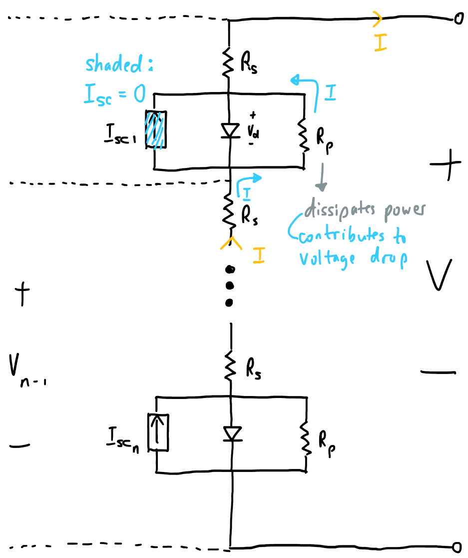




PV cells $\xrightarrow{\text{series}}$ module $\xrightarrow{\text{series/parallel}}$ array

Shading Impacts on I-V Curves

- Consider n cells in series



Suppose $I_{sc1} = I_{sc2} = \dots = I_{scn}$. Then,

$V = n(V_d - IR_s) \rightarrow V_d = \frac{V}{n} + IR_s$. Also,

$I = I_{sc} - I_d - \frac{V_d}{R_p} \xrightarrow{\text{substitute}} I = I_{sc} - I_o\left(e^{\frac{qV_d}{kT}} - 1\right) - \frac{V_d}{R_p}$

$= I_{sc} - I_o\left(e^{q\left(\frac{V}{n} + IR_s\right)/(kT)} - 1\right) - \frac{\frac{V}{n} + IR_s}{R_p}$

In practice, $I_{sc1} \neq I_{sc2} \neq \dots \neq I_{scn}$.

- Consider extreme case of $I_{sc1} = 0$ (total shading of 1 cell)
  - Diode is reverse bias
  - I goes through R_p and R_s
  - Shaded cell acts as a resistive load!
    - Causes voltage drop across shaded cells

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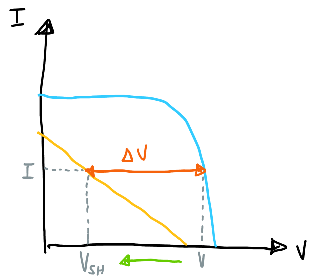
$$V_{SH} = V_{n-1} - I(R_p + R_s)$$
$$V_{n-1} = \left(\frac{n-1}{n}\right)V$$
$$V_{SH} = \frac{n-1}{n}V - I(R_p + R_s)$$
$$\Delta V = V - V_{SH} = V - \left(\frac{n-1}{n}\right)V + I(R_p + R_s)$$
$$= V - \left(1 - \frac{1}{n}\right)V + I(R_p + R_s)$$
$$= V - V + \frac{1}{n}V + I(R_p + R_s)$$



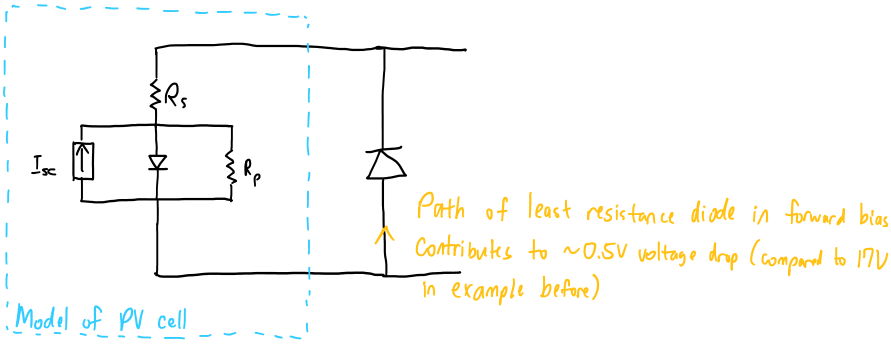
One cell, fully shaded

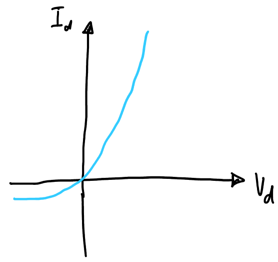
$$\Delta V \approx \frac{1}{n}V + IR_p \quad \text{because } R_s \ll R_p$$

- Example
  - 72 identical cells in a module, wired in series
  - 1-sun insolation ($1\,kW/m^2$)

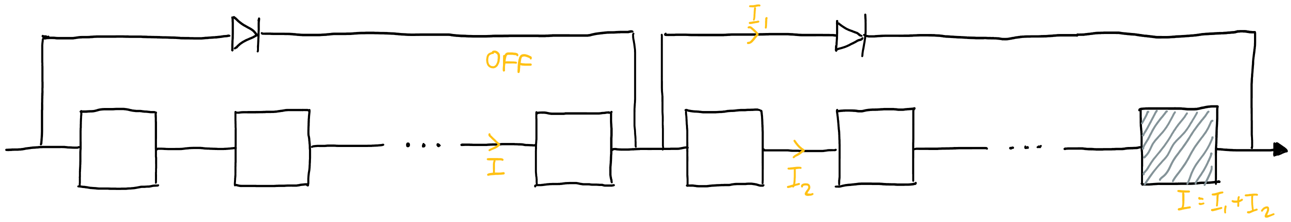
- Hot Spot
  - Power dissipated as heat can cause a local hot spot
  - May permanently damage plastic laminates enclosing the cell

- **Bypass Diodes**
  - Shaded cell contributes to voltage drop
    - consumes/dissipates instead of generates power ☹
  - IDEA 💡: limit amount of voltage drop by adding a bypass diode





  - IDEAL: Put a bypass diode across every cell
  - REALITY: Typically connected across every 18-24 cells, 3-4 bypass diodes in 72-cell string



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