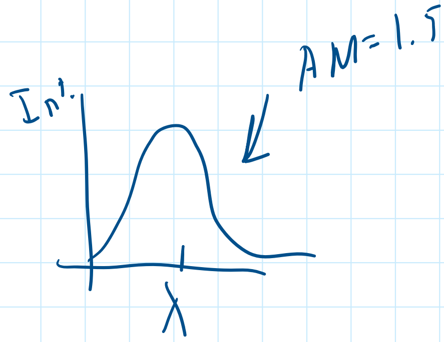
Today

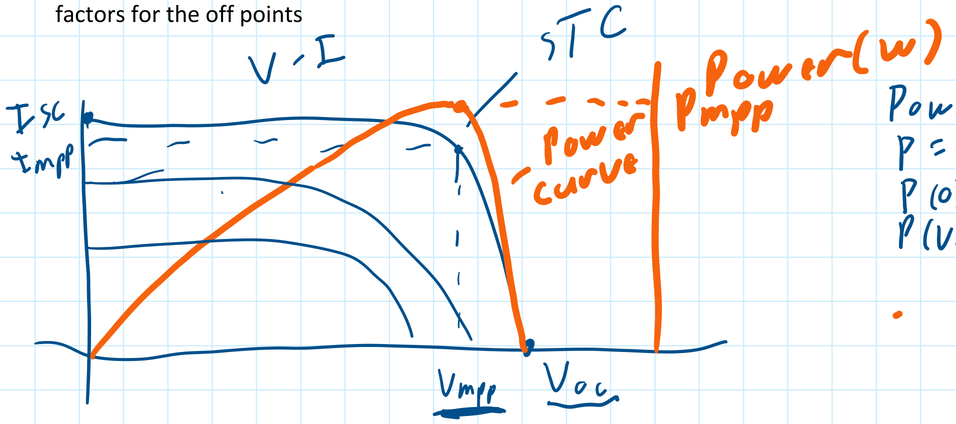
Monday, April 20, 2020 9:31 AM

- Solar "array" discussion
- Standard test conditions (5.6)
- PV system shading effects (5.8.1)

The PV I-V Curve Under Standard Test Conditions

- PV I-V curve shifts around continually
- Insolation changes -> changes Isc
  - Shading, clouds
- Temperature effects -> Rp, Rs, Voc…
- To compare cells in a uniform, "apples-to-apples" way, we use Standard Test Conditions (STC):
  - I_{BC} = 1 kW/m^2 (1 sun)
  - Air mass ratio, m =1.5 (AM 1.5) -> associated solar spectrum
  - T_{cell} = 25 C (298 k) -> cell temp, not ambient temp
- Manufacturers report cell/module specs at STC, with derating factors for the off points





Power = VI
P = f(V)
P(0) = 0 x Isc = 0
P(Voc) = Voc x 0 = 0

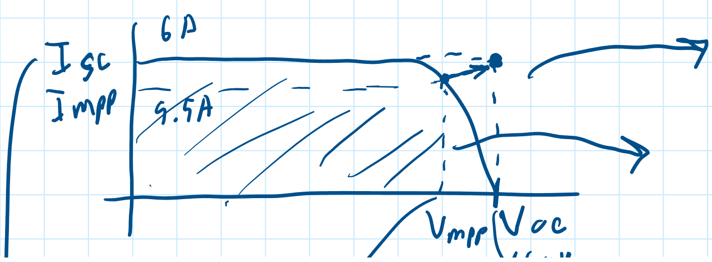
* If this curve is shown for STC

Vmpp = V_R ← R = rated value
Impp = I_R
Pmpp = P_R

Another value reported is Fill Factor

$$\text{Fill Factor} = \frac{P_{mpp}}{V_{oc} \times I_{sc}} = \frac{V_{mpp} \times I_{mpp}}{V_{oc}\ I_{sc}}$$

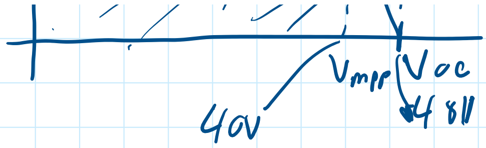
what does this look like



Area = Isc x Voc = 6 x 48 = 288 W

Area = Impp x Vmpp = 5.5 x 40 = 220 W

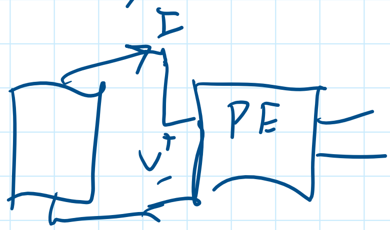
F = 220 / … = 0.76



$$F = \frac{220}{288} = 0.76$$

F.F. = Ratio of inner rectangle to outer

Power Elect



$V_R = ?$ $\quad V_{oc} \approx V_{mpp}$

$I_R = ?$ $\quad I_{sc} \approx I_{mpp}$

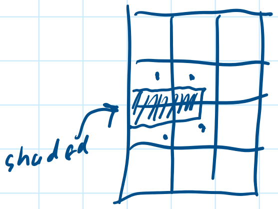
- Best commercial F.F. $\approx$ 70% or higher
- Typically P_R are "Peak watts", Wp - 220 W

Shading impacts on I-V curves

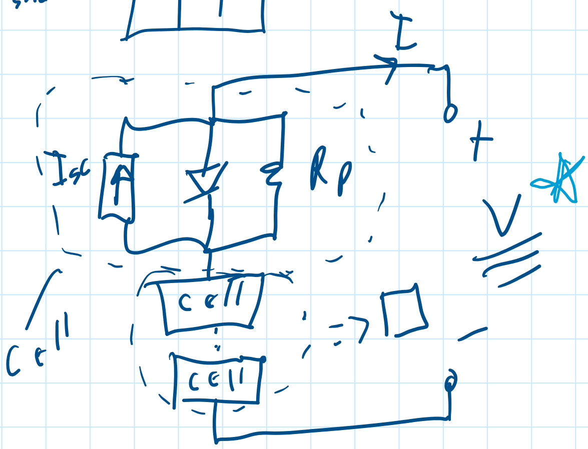
Monday, April 20, 2020 10:10 AM

- We've talked a bit about how shading can impact a P.V. cell.
  ↳ why we introduced R_p

- When even a single cell is shaded, the output of the entire module/array can be reduced



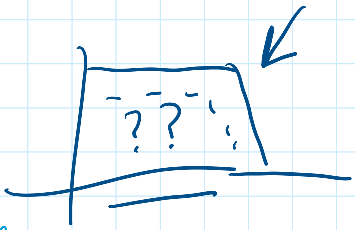
- small % of module covered, but 4 cells shaded ⇒ large impact



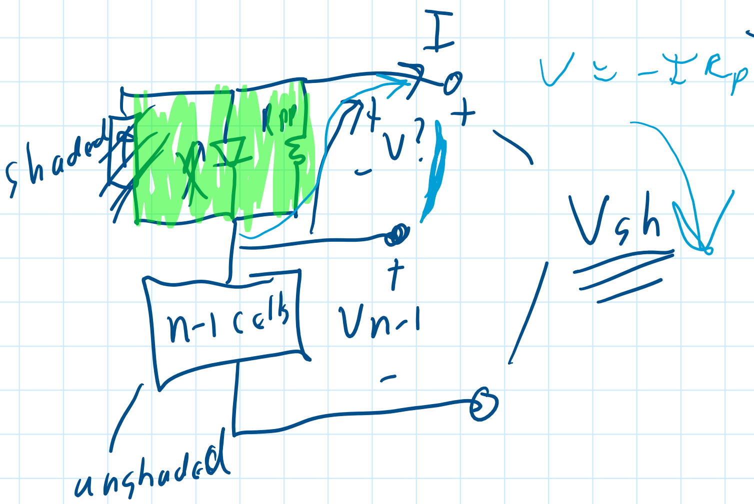
unshaded case with n cells

$V = n \cdot V_i = n \cdot V_d$

$V_{cell} = V/n$



1 shaded cell



n-cell is shaded
$I_{sc} = 0$

$V_d = -I R_p < 0 \Rightarrow$ diode is "off"

All module current flows through R_p in shaded cell

$$V_{sh} = V_{n-1} - I R_p$$

⇒ when unshaded, output voltage is V

⇒ each cell add V/n volts

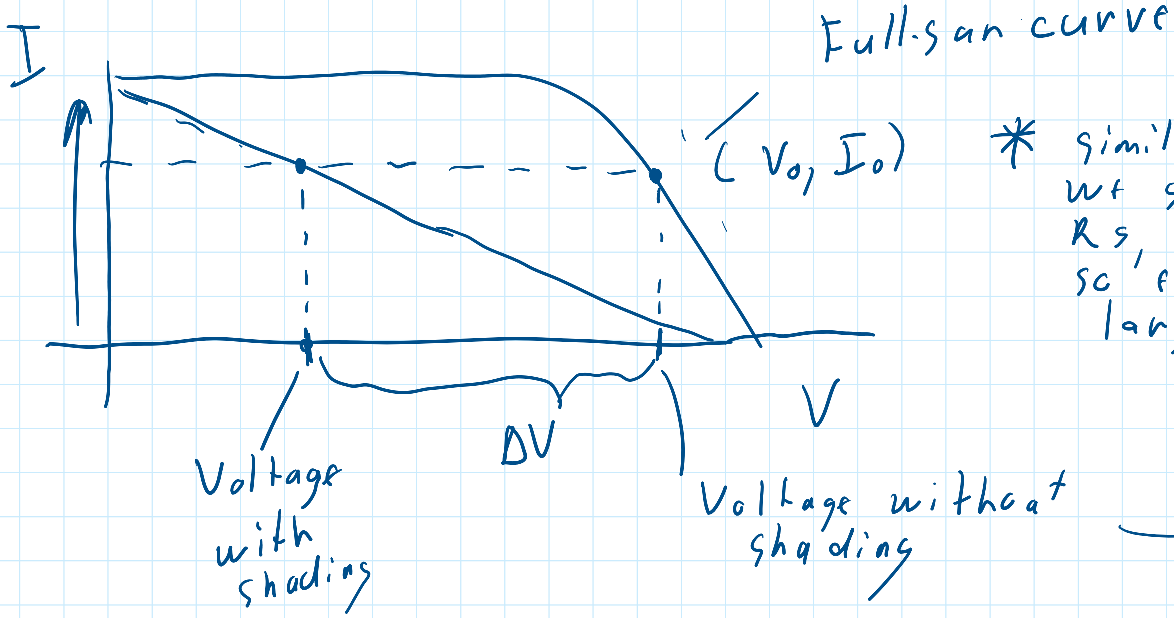
$$\Rightarrow V_{n-1} = (n-1) \cdot \frac{V}{n} = \left(\frac{n-1}{n}\right) V = V_{n-1}$$

*

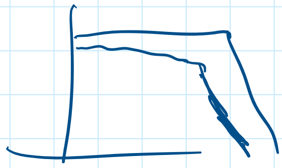
$$V_{sh} = \left(\frac{n-1}{n}\right) V - I R_p$$

$$\Delta V = V - V_{sh} = V - (1 - 1/n) V + I R_p = \frac{V}{n} + I R_p$$

$\Delta V = \frac{V}{n} + \underline{I} R_p$ => this is how much voltage decreases

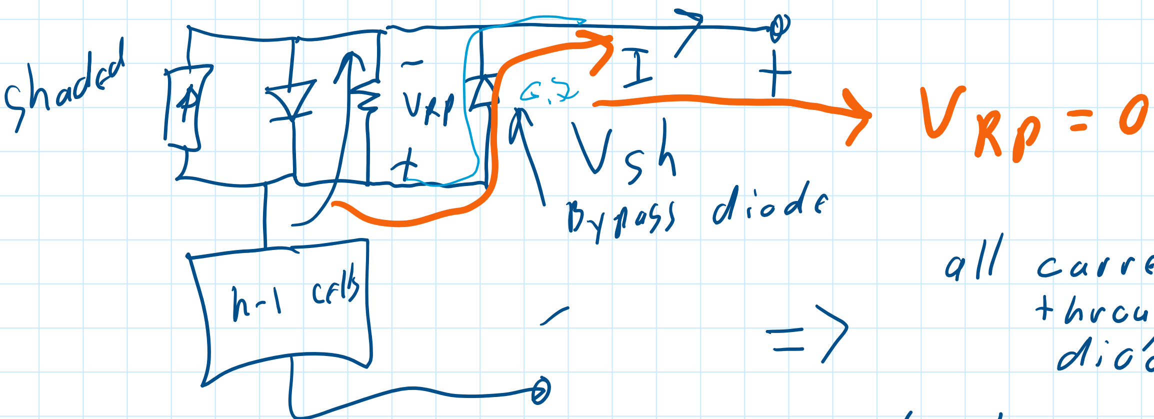


* similar to what we saw with R_s, but $R_p >> R_s$ so effect is larger



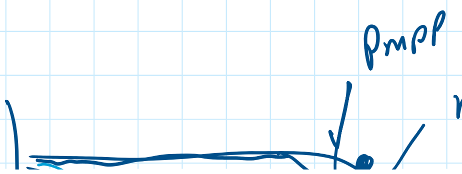
- For a given current, the mode voltage is reduced by ΔV
  - ↳ big deal
    - ↳ lose shaded cell voltage output
    - ↳ drop voltage across R_p → $I R_p$
      - * this is power loss in form of heat

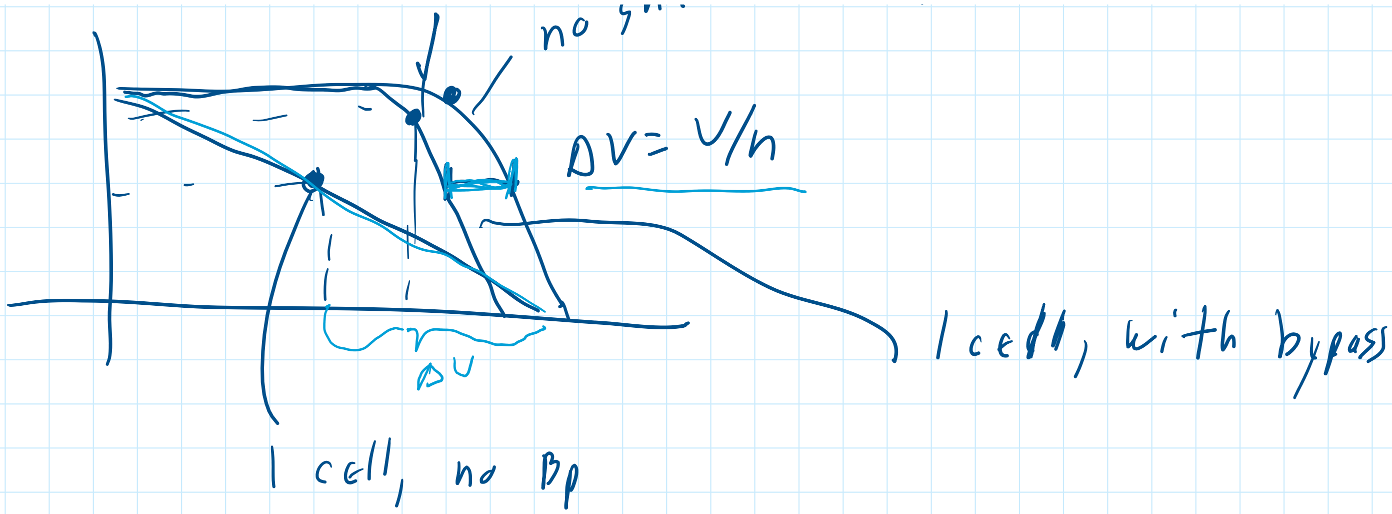
How do we fix this? => Bypass diodes

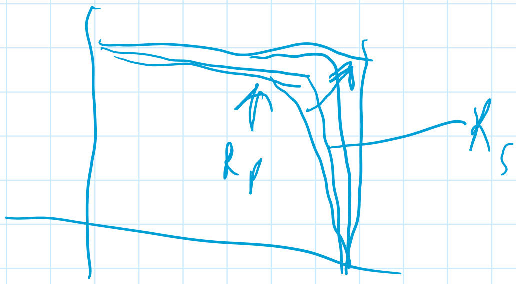


=> all current I flows through Bypass diode ($V = 0$)

no shade $\Delta V = \frac{V}{n}$




ΔV = V/n
1 cell, with bypass
1 cell, no Bp


Rp
Rs