PV System

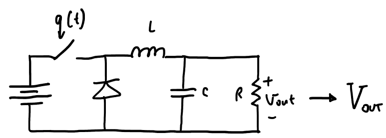
Thursday, March 7, 2024 4:04 PM

RECAP DC-DC power converters — L. C. switches

$\langle V_L \rangle = 0$

$\langle i_C \rangle = 0$

- DC-DC Buck Converter



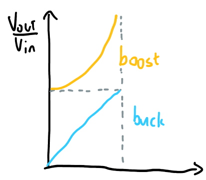
SWITCH ON : $V_L(t) = V_{in} - V_{out} \geq 0 \rightarrow i_L(t) \uparrow$

SWITCH OFF : $V_L(t) = -V_{out} \leq 0 \rightarrow i_L(t) \downarrow$

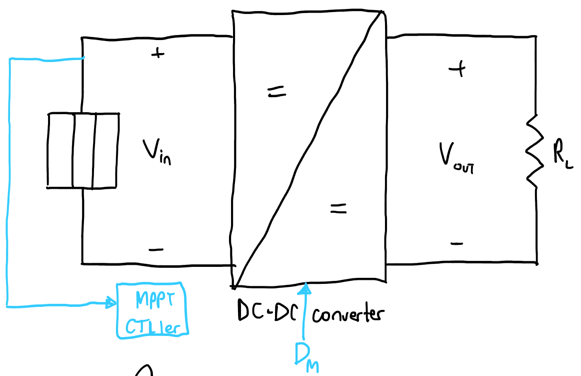
$\langle V_L(t) \rangle = 0 \rightarrow V_{out} = D V_{in}, \quad 0 \leq D \leq 1$

- DC-DC Boost Converter

$V_{out} = \frac{1}{1-D} V_{in}$



How do converters fit into PV systems?



$V_{out} = f(D)\, V_{in}$

Also, if 100% efficient :

$I_{out} = \frac{1}{f(D)} I_{in}$

Example Resistive load $V_{out} = I_{out} R$

$f(D) V_{in} = \frac{1}{f(D)} I_{in} R$

Denote by D_M as duty cycle that ensures $V_{in} = V_M$, $I_{in} = I_M$

$(f(D))^2 = \frac{I_{in}}{V_M} R = \frac{R}{R_M}$ where $R_M = \frac{V_M}{I_M}$

$(*)\ D_M = f^{-1}\left(\sqrt{\frac{R}{R_M}}\right)$

For buck: $f(D) = D$

For boost: $f(D) = \frac{1}{D}$

For buck: $D^2 = \frac{I_m}{V_m} R = \frac{R}{R_m}$

$D_m = \sqrt{\frac{R}{R_m}}$

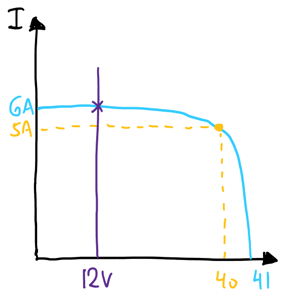
For boost: $\left(\frac{1}{1-D}\right)^2 = \frac{R}{R_m}$

... Solve for D to get D_m

Determine D_m such that (*) is satisfied.

- MPPT determines R_m (or V_m and I_m) to give to converter

Example PV module with following specifications: $V_{oc} = 41\ V$, $I_{sc} = 6A$, $V_m = 40V$, $I_m = 5A$



Want to deliver power to charge a 12V battery

Want to use a DC-DC converter to extract maximum power from module

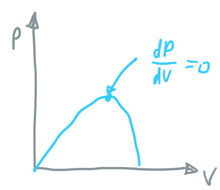
1) Topology $\longrightarrow$ Buck converter because $V_{out} < V_{in}$
2) Duty Cycle $\longrightarrow$ $V_{out} = D\ V_{in}$

$12 = D \cdot 40 \longrightarrow D = 0.3$

3) If solar irradiance increases, would the required duty cycle increase or decrease?

solar irradiance $\uparrow \longrightarrow I_{sc} \uparrow \longrightarrow V_M = ?$

$I = I_{sc} - I_o\left(e^{\frac{qV}{kT}} - 1\right)$ ideal equivalent circuit model



$P = VI = VI_{sc} - VI_o\left(e^{\frac{qV}{kT}} - 1\right)$

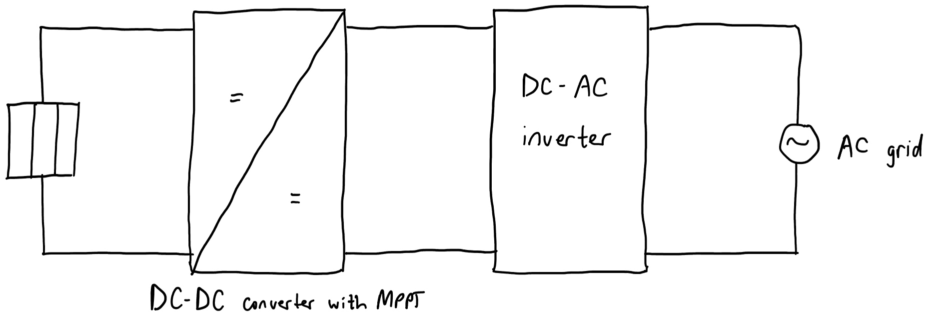
$\frac{dP}{dV} = I_{sc} - I_o\left(e^{\frac{qV}{kT}} - 1\right) - VI_o \frac{q}{kT} e^{\frac{qV}{kT}} = 0$

$0 = I_{sc} - I_o e^{\frac{qV}{kT}} + I_o - VI_o \frac{q}{kT} e^{\frac{qV}{kT}}$

$I_{sc} = I_o e^{\frac{qV}{kT}}\left(1 + \frac{qV}{kT}\right) - I_o$

$I_{sc} \uparrow \longrightarrow V_M \uparrow \longrightarrow D \downarrow$

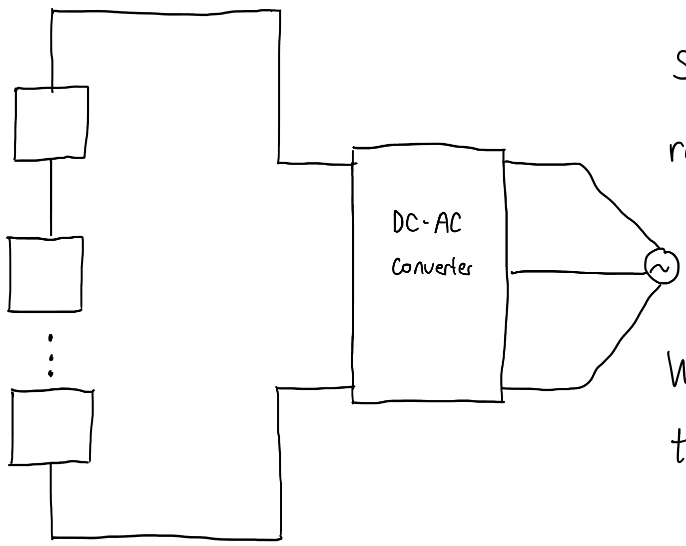
Grid Interface (DC-AC Inverter)



Design considerations:

- losses, cost, footprint, power ratings, power density, harmonics

Ex.



Suppose that the inverter input voltage is rated for 1000V.

What is the maximum number of modules that can be connected in series?

Idea: maximum number of modules in series $= \left\lfloor \frac{1000}{V_{oc}} \right\rfloor$ → We know voltage will be less than V_{oc}

$= \left\lfloor \frac{1000}{67.9} \right\rfloor = 14$

↳ from spec sheet

NOT the whole story, spec sheet data is obtained at STC (25°C, AM 1.5, 1 kW/m²)

Say the module will be installed at a location where ambient temperature can be as low as -10°C.

How does V_{oc} change with temperature?

$$\frac{dV_{oc}}{dT} = -167.4 \text{ mV/°C}$$

$$\text{At } -10^\circ C, \; V_{oc}' = V_{oc} + \frac{dV_{oc}}{dT}\Delta T$$

$$= 67.9 + (-0.1674)(-10-25)$$

$$= 73.8 \text{ V} \longrightarrow \quad T\downarrow \rightarrow V_{oc}\uparrow$$

Now Maximum number of modules in series = $\left\lfloor \frac{1000}{73.8} \right\rfloor = 13!$

- Micro inverters — embed MPPT
  - increase reliability
  - easier to repair/maintain
  - flexible footprint
  - could be more expensive $$