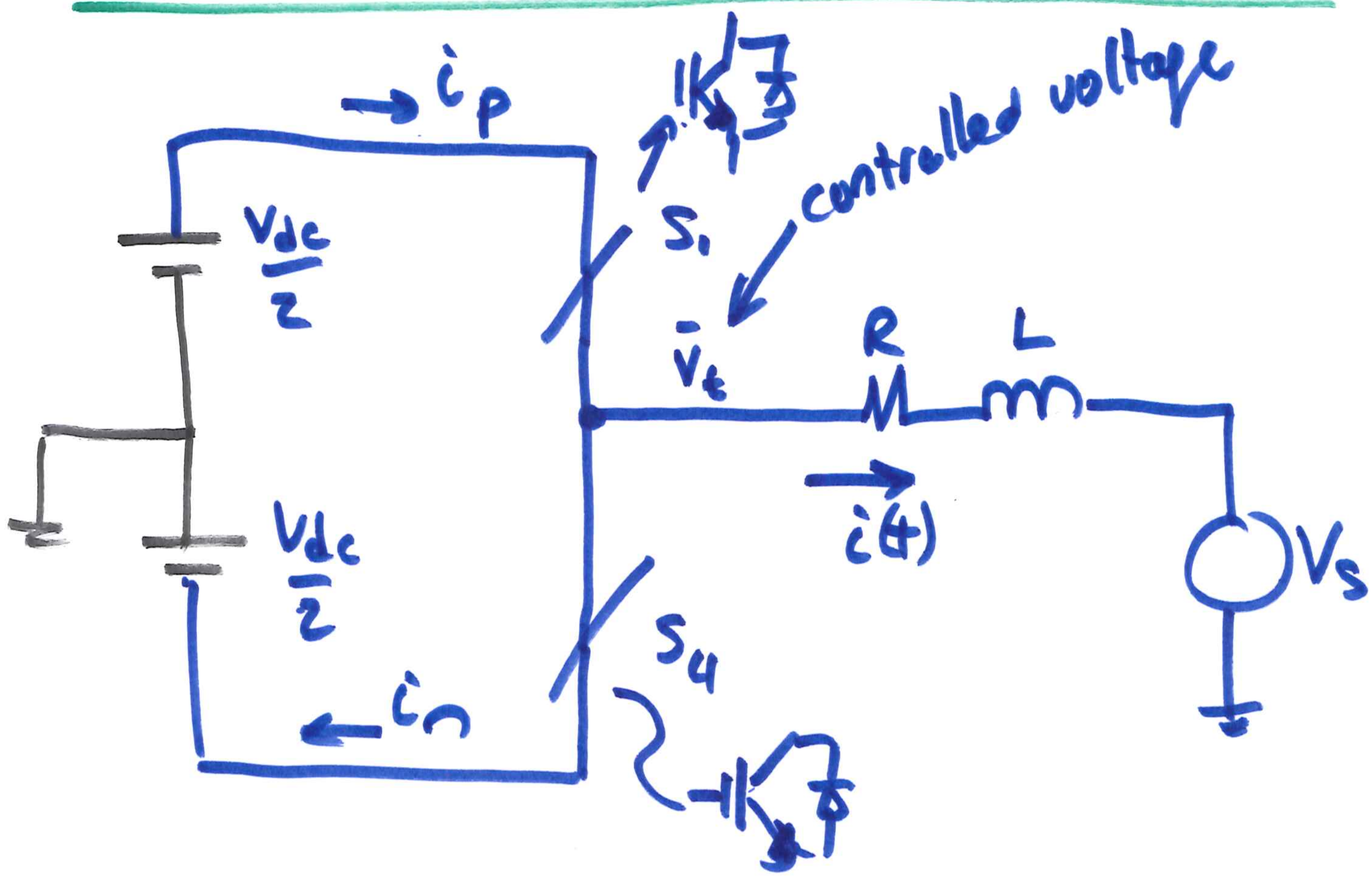
ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

SESSION no. 29

Averaged Models of Power Converters



$i(t) \rightarrow \quad v_t(t) - v_s(t) = R\,i(t) + L\frac{di}{dt}$

$$v_t = \frac{1}{T_s}\int_0^{T_s} v_t(\tau)\,d\tau + \underbrace{\sum_{h=1}^{\infty} a_h \cos(h\omega_s t) + b_h \sin(h\omega_s t)}_{\text{harmonics}}$$

$$L\frac{d\bar{i}}{dt} + R\bar{i} = \frac{1}{T_s}\int_0^{T_s} v_t(\tau)\,d\tau - V_s$$

$$L\frac{d\tilde{i}}{dt} + R\tilde{i} = \sum_{h=1}^{\infty} a_h\cos(h\omega_s t) + b_h\sin(h\omega_s t) - V_s$$

- 2 equations to find components of current

→ for most applications the part with harmonics isn't a concern goal - design a controller to regulate $\bar{i}$

→ don't want details of switching behavior, want the averaged behavior

Switching functions

$S_1 \rightarrow \bar{S}_1 = d \rightarrow$ contributes $d \cdot \frac{V_{dc}}{2}$ to V_t

Switch 4 $\bar{S}_4 = (1-d)$ $\quad -(1-d)\frac{V_{dc}}{2}$ to V_t

Based on the above discussion

- to get output

$$\overline{V_t} = d\,\frac{V_{dc}}{2} - (1-d)\,\frac{V_{dc}}{2}$$

$$= \frac{V_{dc}}{2}(2d-1)$$

$$\overline{i_p} = d \cdot i$$

$$\overline{i_n} = (1-d)\,i$$

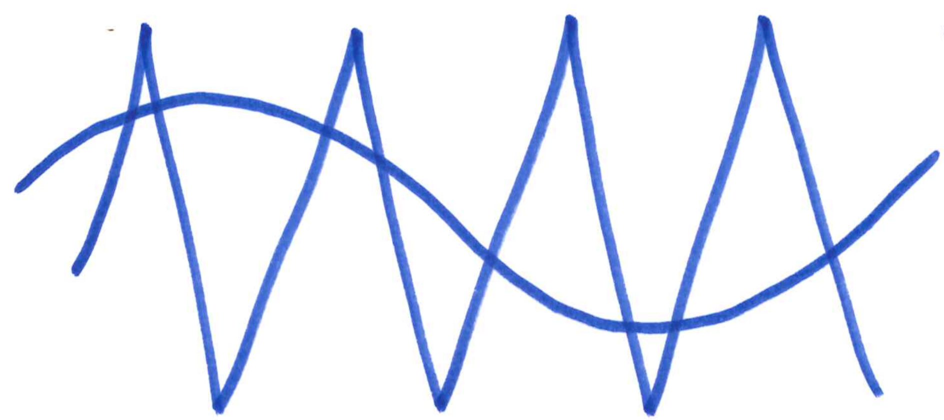
$$P_{DC} = \frac{V_{dc}}{2}(i_p - i_n) = \frac{V_{dc}}{2}(2d-1)\,i$$

$$P_t = \bar{v}_t \bar{i} = \frac{V_{dc}}{2}(2d-1)i$$

ac side of switch

→ No converter losses

If we define our switching based on carrier



$m = 2d - 1$

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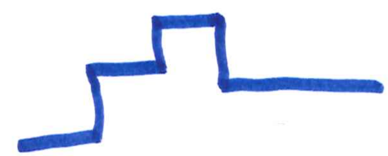
$$\bar{V}_t = m\frac{V_{dc}}{2}$$

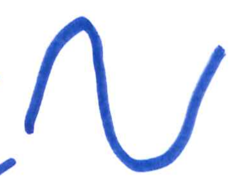
$$i_p = \left(\frac{1+m}{2}\right) i$$

$$i_n = \frac{(1-m)}{2} i$$

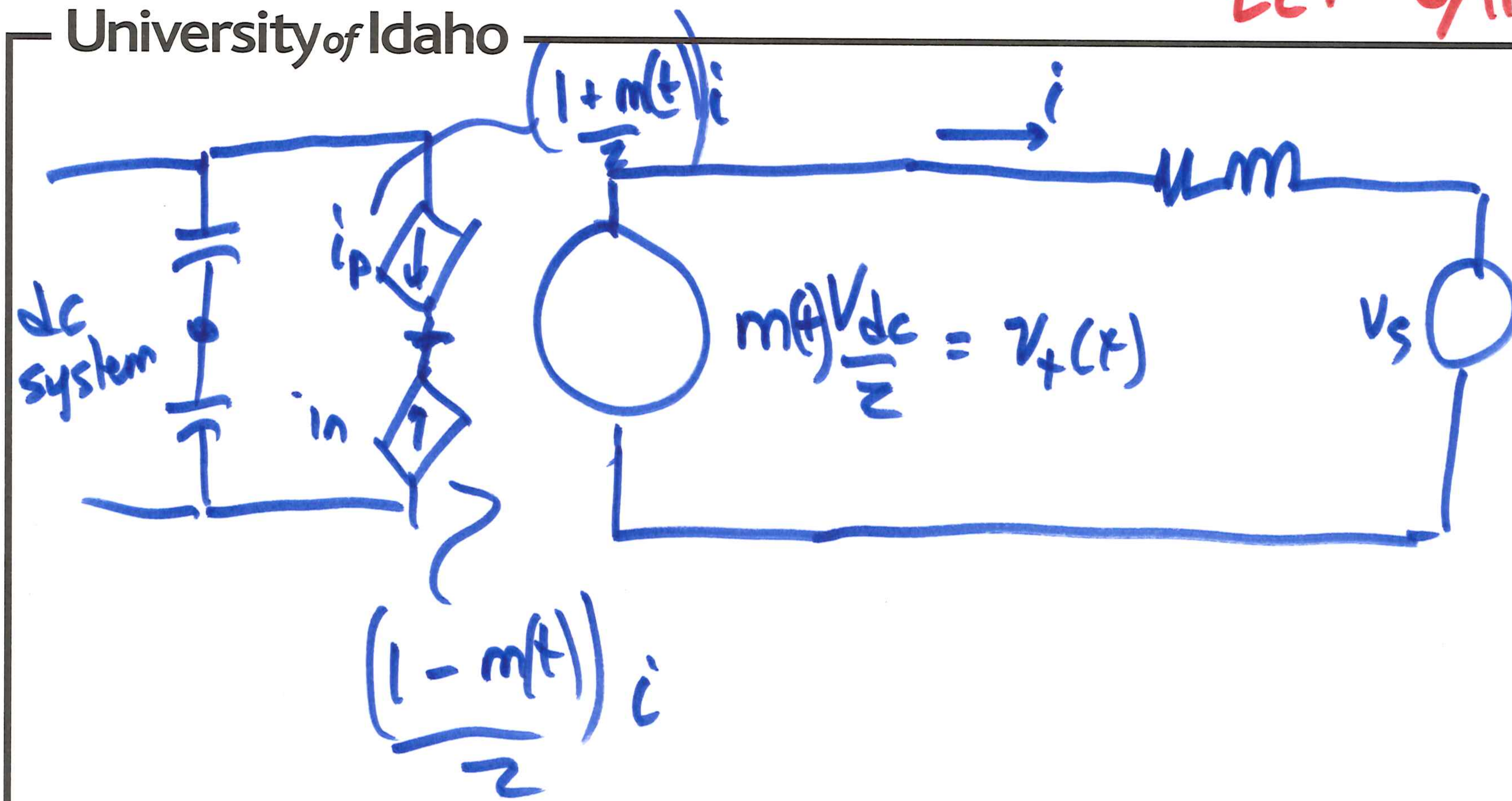
$$P_{dc} = P_i = m\frac{V_{dc}}{2} i$$



→ m can be ① constant, quasi dc value

② sinusoidal reference 

$\sqrt{2}|V|\cos(\omega t+\delta)$



$\left(\frac{1+m(t)}{2}\right)i$
i
i_p
i_n
dc system
$m(t)\frac{V_{dc}}{2} = v_t(t)$
v_s
$\left(\frac{1-m(t)}{2}\right)i$

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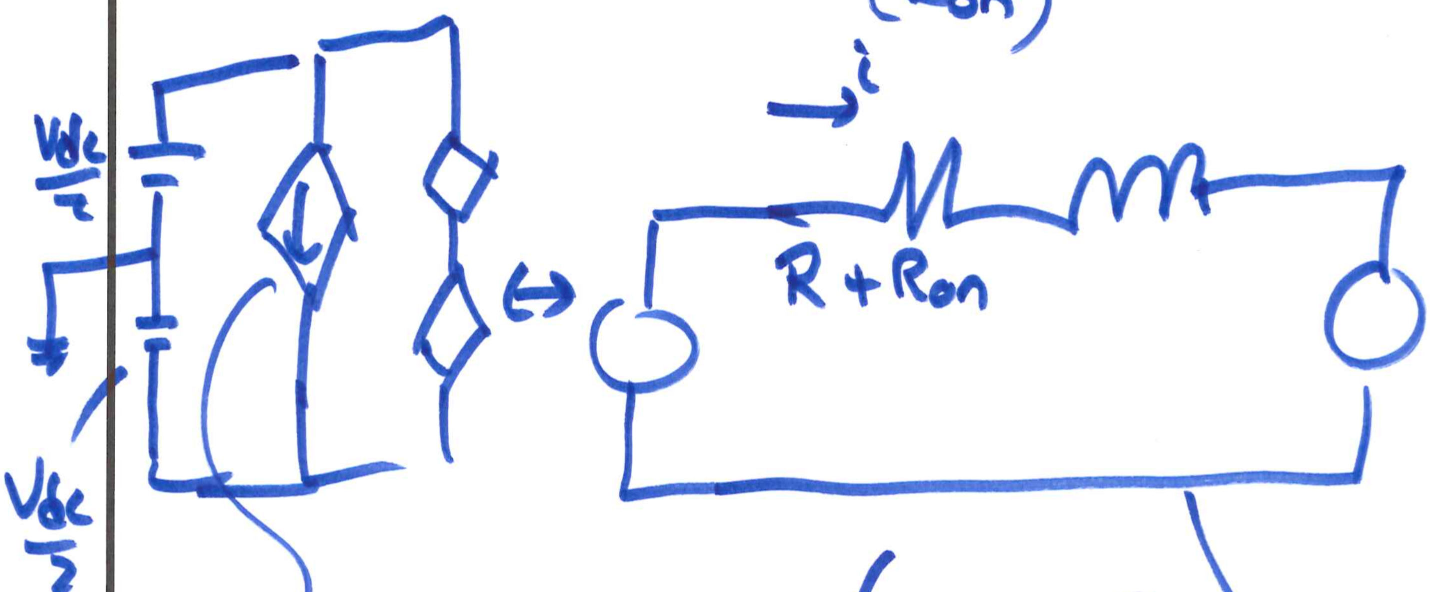
Adding losses in converter

→ conduction losses (R_{on})



switching losses $\left(\frac{Q_{rr} + Q_{tc}}{T_s}\right) \cdot V_{dc}$

in most cases these are neglected

fig 2.17 in text

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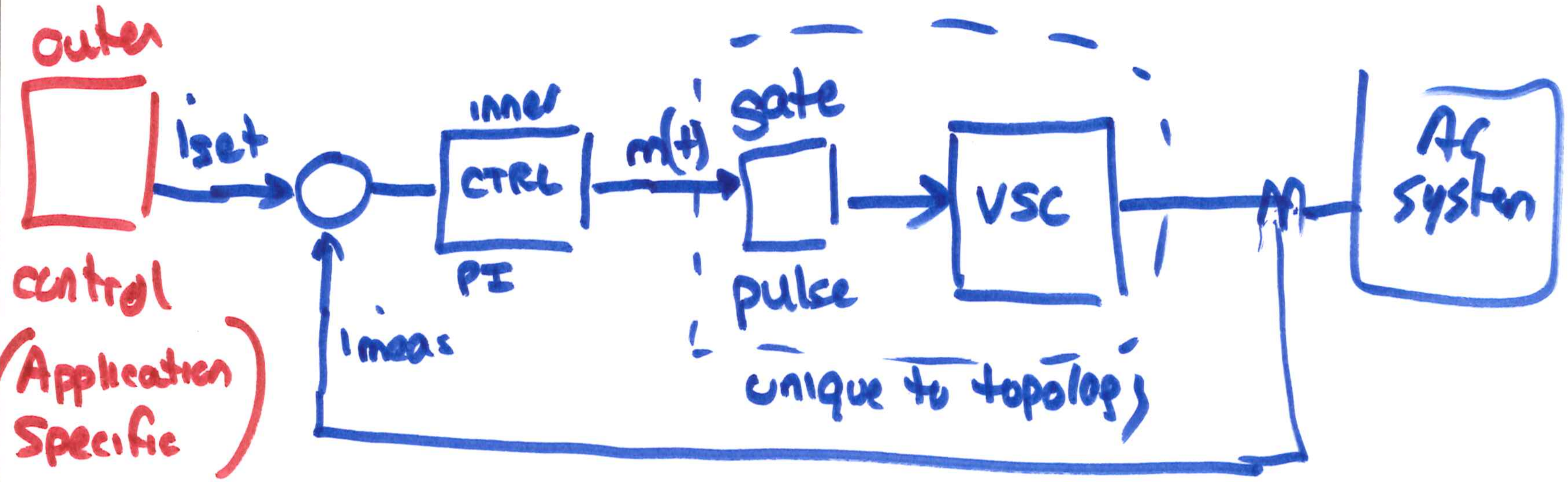
AC Current regulation (inner control)

- inner control loop is a current regulator
- outer control determines commands



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