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Lecture-28

Closed loop control of three-phase AC-DC converter-III

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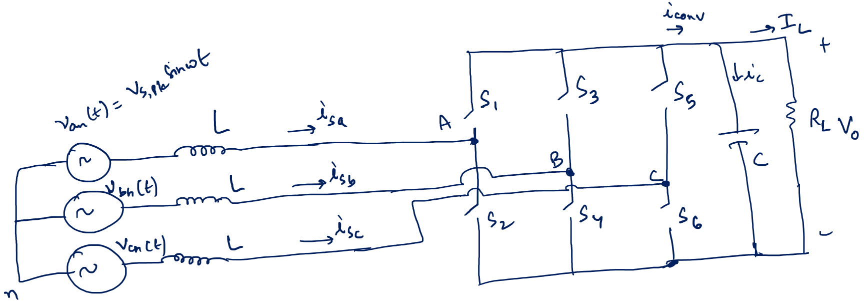
Recap

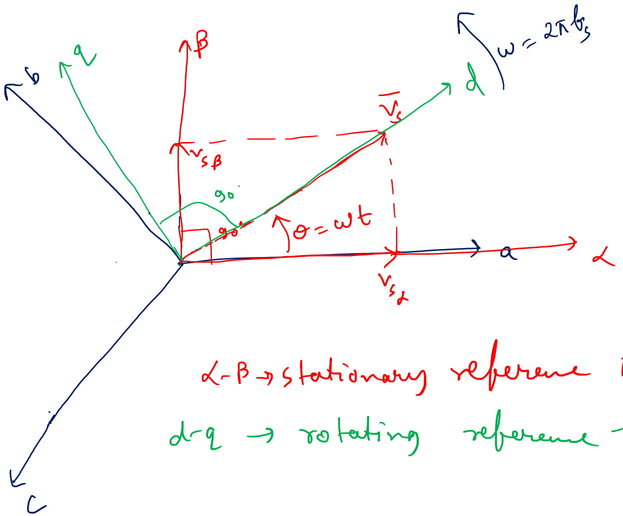
Control Objectives

① To regulate the output voltage to a desired value. ($> \sqrt{2}\, V_{L-L}$)

② The current drawn should have unity power factor (upf) operation



Recap



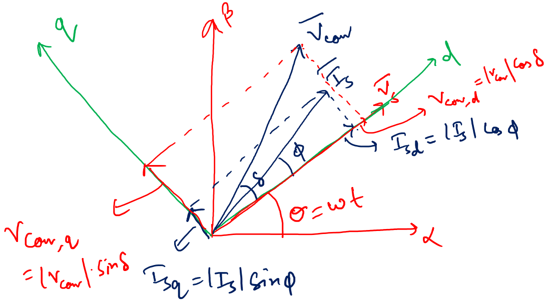
α-β → stationary reference frame

d-q → rotating reference frame

$i_{sa} + i_{sb} + i_{sc} = 0$

3ph → 2-phase → d-q
α-β

$v_{sq} = 0$
→ d-axis is aligned along the $\bar{V}_s$



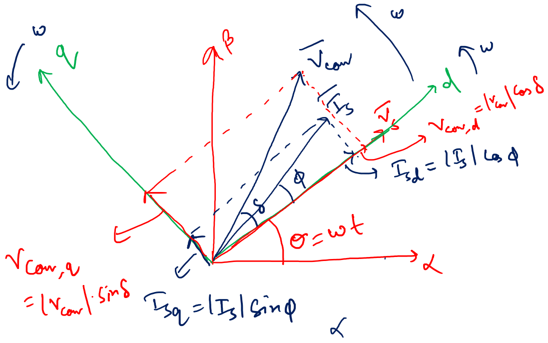
d-axis model, $L\frac{d}{dt} I_{sd} + R_s I_{sd} = -V_{conv,d} + \underbrace{\omega L I_{sq}}_{\text{cross-coupling}} + V_{sd}$

q-axis model, $L\frac{d}{dt} I_{sq} + R_s I_{sq} = -V_{conv,q} - \omega L I_{sd}$ → cross-coupling d-axis model, $L\frac{d}{dt}I_{sd} + R_s I_{sd} = -V_{con,d} + \omega L I_{sq} + V_{sd}$

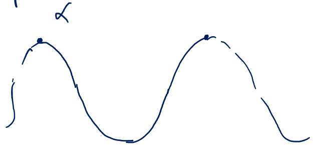
q-axis model, $L\frac{d}{dt}I_{sq} + R_s I_{sq} = -V_{con,q} - \omega L I_{sd}$

To have UPF $\rightarrow$ $\bar{I}_s$ is aligned along the $\bar{V}_s$ $\Rightarrow \phi = 0 \Rightarrow I_{sq} = 0$

$\bar{I}_s = I_{sd} + j0$



α-β $\rightarrow$ i_{sa}, i_{sb}, i_{sc} $\longrightarrow$ $i_{s\alpha}, i_{s\beta}$ $\rightarrow$ varying sinusoidally with a phase difference of 90° w.r.t. time



$v_{s\alpha}, v_{s\beta}$

$v_{con,\alpha}, v_{con,\beta}$

$\downarrow$

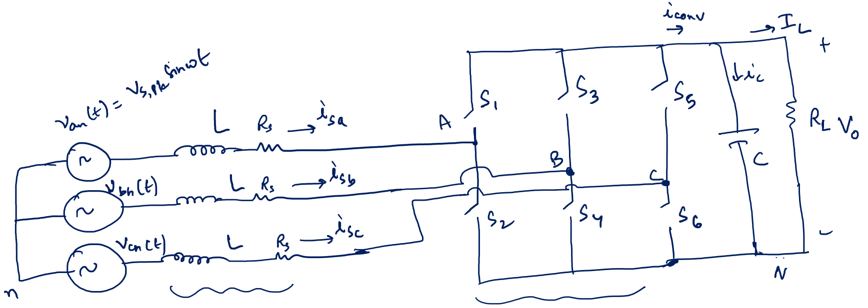
$\left.\begin{array}{l} I_{sd}, I_{sq} \\ v_{sd}, v_{sq} \\ v_{con,d}, v_{con,q} \end{array}\right\}$ DC-quantities

Since, the d-q quantities are DC quantities, we can apply conventional PI controller to control the dq DC quantities

$K_p + \frac{K_i}{s} \Rightarrow \frac{K_p s + K_i}{s}$

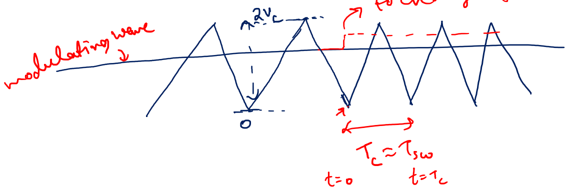
d-axis model, $L\frac{d}{dt}I_{sd} + R_s I_{sd} = -V_{con,d} + \omega L I_{sq} + V_{sd}$

q-axis model, $L\frac{d}{dt}I_{sq} + R_s I_{sq} = -V_{con,q} - \omega L I_{sd}$



Assume the three half-bridges are modulated using SPWM

to change the average pole voltage variation



$f_c \gg f_s$
(f_{sw})

$\left(T_{sw} = T_c = 1/f_c = \frac{1}{f_{sw}}\right)$

Average time delay in response towards change in modulating wave, $T_d = \frac{0 + T_{sw}}{2}$

$\Rightarrow T_d = \frac{T_{sw}}{2}$

$\Rightarrow$ The Transfer function of 3-ϕ half-bridge $= \frac{G}{1+sT_d}$

Gain, $G = \frac{V_o}{2V_c}$

Source: Siva Prasad, J.S., Bhavsar, T., Ghosh, R. *et al.* Vector control of three-phase AC/DC front-end converter. *Sadhana* **33**, 591–613 (2008)

d-axis model, $L\frac{d}{dt}I_{sd} + R_s I_{sd} = -V_{con,d} + \underline{\underline{\omega L I_{sq}}} + \underline{\underline{V_{sd}}}$

q-axis model, $L\frac{d}{dt}I_{sq} + R_s I_{sq} = -V_{con,q} - \underline{\underline{\omega L I_{sd}}}$

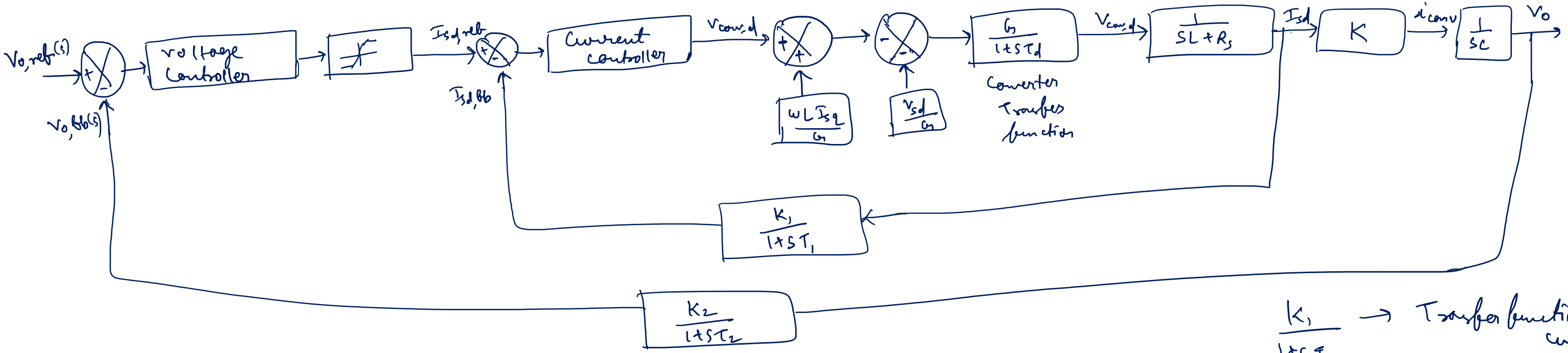
$\Rightarrow (SL + R_s) I_{sd}(s) = -V_{con,d} + V_{ff,d} + \frac{\omega L I_{sq}}{G} + \frac{V_{sd}}{G}$

$\Rightarrow (SL + R_s) I_{sq}(s) = -V_{con,q} + V_{ff,q} - \frac{\omega L I_{sd}}{G}$

$$V_{ff,d} = -\frac{\omega L I_{sq}}{G} - \frac{V_{sd}}{G}$$

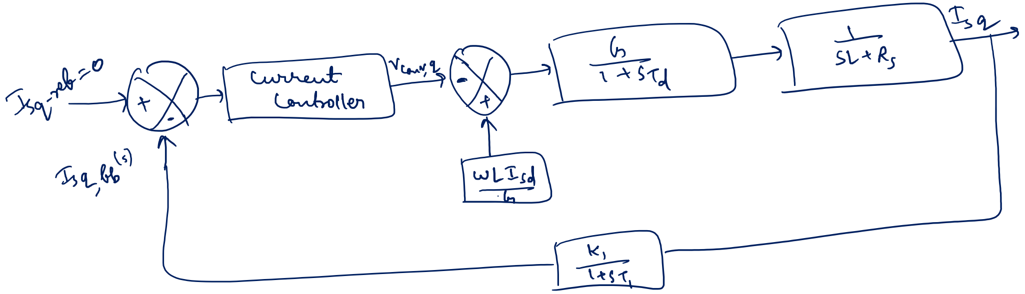
$$V_{ff,q} = \frac{\omega L I_{sd}}{G}$$

Source: Siva Prasad, J.S., Bhavsar, T., Ghosh, R. *et al.* Vector control of three-phase AC/DC front-end converter. *Sadhana* **33**, 591–613 (2008)



$\frac{K_1}{1+sT_1} \rightarrow$ Transfer function of current sensor

$\frac{K_2}{1+sT_2} \rightarrow$ Transfer function of output voltage sensor



Source: Siva Prasad, J.S., Bhavsar, T., Ghosh, R. *et al.* Vector control of three-phase AC/DC front-end converter. *Sadhana* **33**, 591–613 (2008)

Thank You