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Charging Infrastructure

Lecture-16

Closed Loop Control of Single-phase Boost PFC Converter-IV

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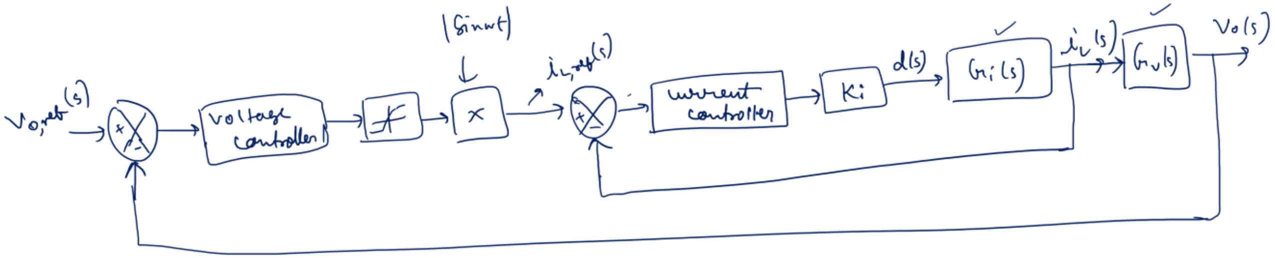
Recap



$$G_i(s) = \frac{i_L(s)}{d(s)}$$

$$G_v(s) = \frac{v_o(s)}{i_L(s)} \approx \frac{v_c(s)}{i_L(s)}$$

$$\left.\frac{\tilde{i}_L(s)}{\tilde{d}(s)}\right|_{|\tilde{v}_s(s)|=0} = \frac{|V_s|}{R_L(1-D)^3}\left[\frac{R_L C s + 2}{\frac{s^2 LC}{(1-D)^2} + \frac{s}{R_L(1-D)^2} + 1}\right] = G_i(s)$$

Power balance

$$\Rightarrow \quad \frac{V_{s,pk}}{\sqrt{2}} \cdot \frac{I_{s,pk}}{\sqrt{2}} = V_0 \cdot i_{conv}$$

$$\Rightarrow \quad i_{conv} = \frac{V_{s,pk} I_{s,pk}}{2\, V_0} \longrightarrow (1)$$

$$\Rightarrow \quad \tilde{i}_{conv}(s) = \frac{V_{s,pk}}{2V_0}\, \tilde{i}_L(s) \qquad \left(|\tilde{v}_s| = 0 \right)$$

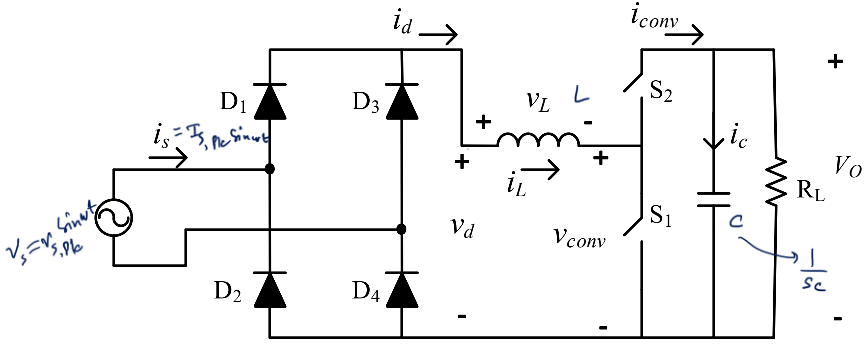
$V_0 \rightarrow$ is the operating point

$\longrightarrow (2)$

$$\Rightarrow \quad \tilde{V}_0(s) = \tilde{i}_{conv}(s) \left(\frac{\frac{R_L}{sC}}{R_L + \frac{1}{sC}} \right)$$

$$= \tilde{i}_{conv}(s) \left[\frac{R_L}{R_L C s + 1} \right]$$

$$\tilde{V}_0(s) = \frac{V_{s,pk}}{2V_0}\, \tilde{i}_L(s) \left[\frac{R_L}{R_L C s + 1} \right]$$

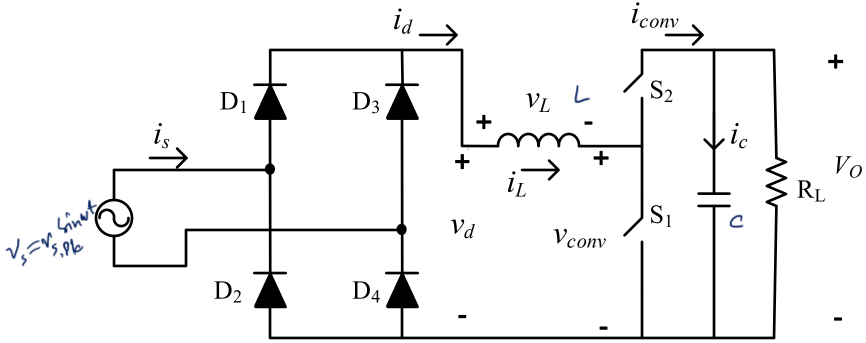


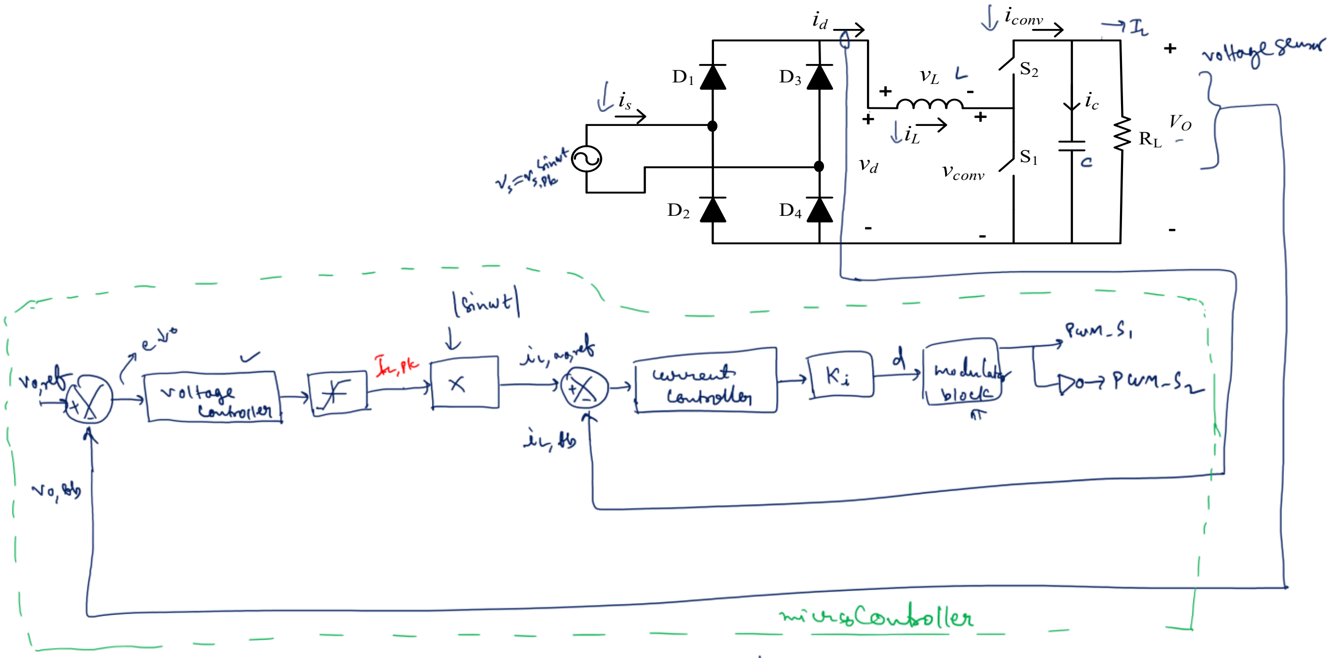
$$\Rightarrow \quad \frac{\tilde{v}_o(s)}{\tilde{i}_L(s)} = \frac{V_{s,pk}}{2V_o}\left[\frac{R_L}{R_L C s+1}\right] \qquad \Big|_{|\tilde{v}_s|=0}$$

$$\Rightarrow \quad G_{vi}(s) = \frac{V_{s,pk}}{2V_o}\left[\frac{R_L}{R_L C s+1}\right]$$

$$\text{gain}, K_i = \frac{\text{peak value of (control voltage)}}{\text{peak value of input current}}$$

duty

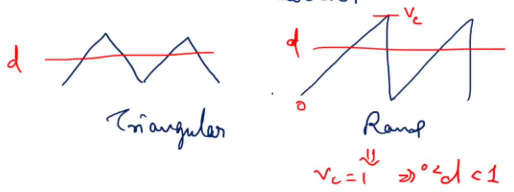




Switching frequency (f_{sw}) is kept constant

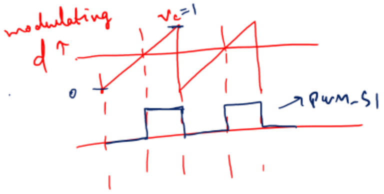
$0 < d < 1$

⇒ carrier signal → triangular or ramp carrier



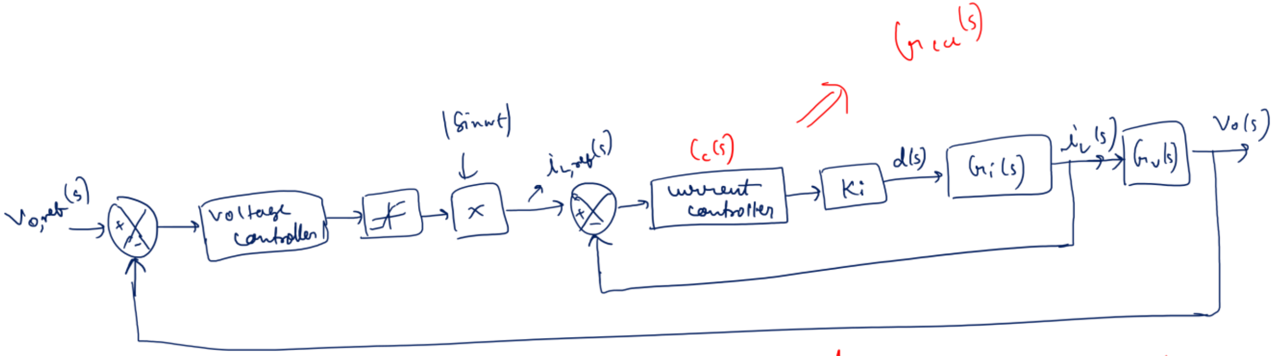
$f_c >> f_s$

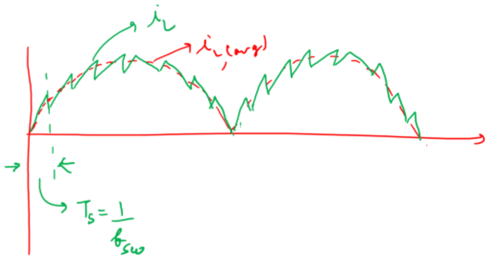
⇒ $f_c >> f_m$

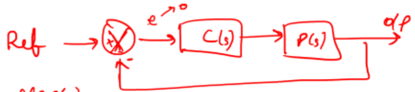


Carrier > modulating
$PWM_{S1} = 1$

Carrier < modulating
$PWM_{S1} = 0$

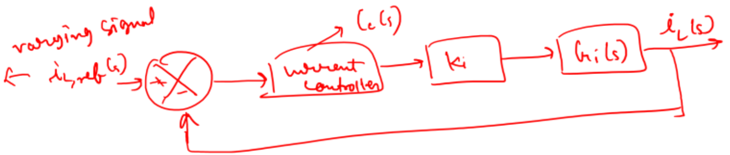






Inner current loop is faster than the outer voltage loop

this is a "$2f_s$" varying signal



$\Rightarrow$ open loop T/F of inner current loop: $G_c(s) \cdot K_i \cdot G_i(s)$

$\Rightarrow \frac{o/p}{Ref} = \frac{C(s)P(s)}{1+C(s)P(s)} \Rightarrow C(s) \cdot P(s) >> 1$

$\Rightarrow \frac{o/p}{Ref} = \frac{C(s)P(s)}{C(s)P(s)} = 1$

$\Rightarrow o/p = Ref$

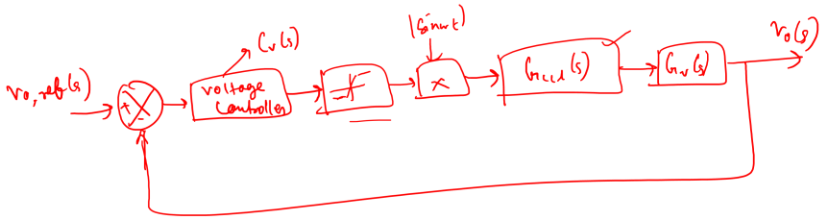
(1) The current controller must be designed to track the "$2f_s$" component

$\Rightarrow$ the gain of open loop transfer function must be very high at "$2f_s$"

(2) $B.W_i << f_{sw}$ $\approx$ $B.W_i = \frac{f_{sw}}{10}$ $\Rightarrow$ good attenuation at 'f_{sw}' frequency

(3) Sufficient PM, GM (PM = 35° to 60°)

$$\Rightarrow \quad G_{ccl}(s) = \frac{C_c(s) \cdot K_i \cdot G_i(s)}{1 + C_c(s) \cdot K_i \cdot G_i(s)}$$



$\Rightarrow$ Open loop T/F for voltage loop $= C_v(s) \cdot G_{ccl}(s) \cdot G_v(s)$

Criteria for voltage controller

1. The very high gain at $s=0$
2. $B \cdot \omega_r = 20 - 40\,Hz$

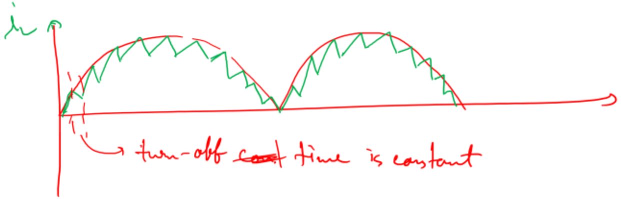
The switching freq. is constant

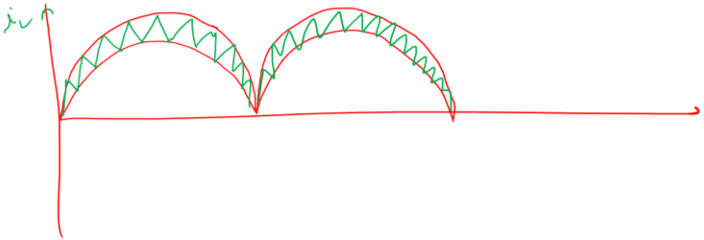
$\rightarrow$ Constant frequency control

Other control methods

① Peak current control → variable frequency case

② Variable hysterises control





Thank You