IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

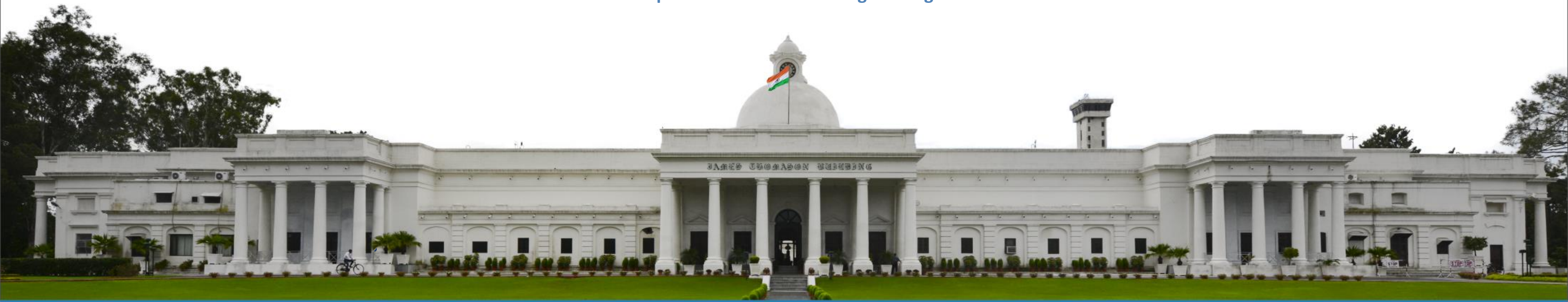
Charging Infrastructure

Lecture-26

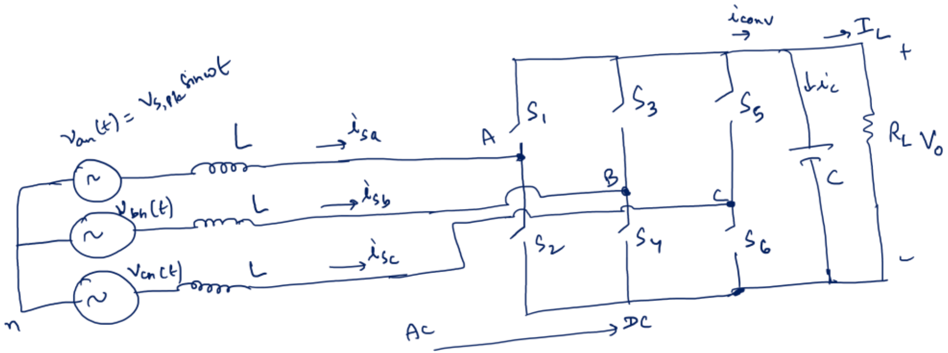
Closed loop control of three-phase AC-DC converter-I

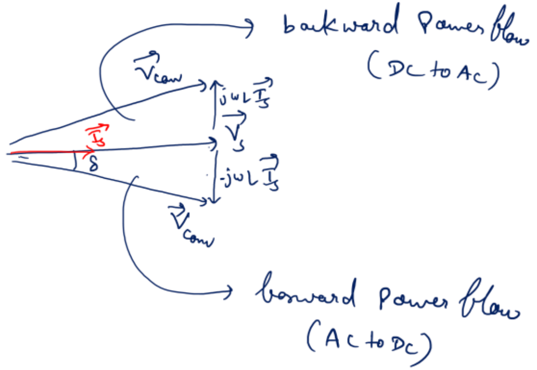
Dr. Apurv Kumar Yadav

Department of Electrical Engineering



Recap





AC → DC

AC ← DC

FEC

$v_{an}(t) = V_{s,pk}\sin\omega t$

$v_{bn}(t) = V_{s,pk}\sin(\omega t - 120)$

$v_{cn}(t) = V_{s,pk}\sin(\omega t - 240)$

→ $(\omega L \cdot I_{s,pk}) <$ 10% of $V_{s,pk}$

⇑ ensured

$$L = \sqrt{\frac{\left(\frac{mV_0}{2}\right)^2 - V_{s,pk}^2}{(2\pi f_s \cdot I_{s,pk})^2}}$$

→ m → modulation index → designer's choice (0.8 to 0.9)

$V_{s,pk}$ → specification

V_0 → specification

f_s → line frequency given in specification

$I_{s,pk} \rightarrow \dfrac{P_L \times \sqrt{2}}{3V_{ph,rms}}$ ⇐ assuming no loss in the Power Converter

→ the voltage drop across inductor (corresponding to fundamental) must be less than 10% of the $V_{s,pk}$

Recap

$$C_{min} \geq \frac{\Delta P_{max}\, T_d}{2\, V_0 \cdot \Delta V_0}$$

specification

designer choice

specification

specification

there is no 2nd line harmonic voltage ripple on output Capacitance

where ΔP_{max} → maximum power variation of the converter

T_d → response time of closed loop

ΔV_0 → the permissible voltage ripple

V_0 → output voltage

$$i_{c,rms} = I_{s,pk} \sqrt{\left(\frac{\sqrt{3}}{\pi} m \frac{5}{4}\right) - \frac{9}{16} m^2}$$

$$I_{s,pk} = \frac{\sqrt{2} P_L}{3 V_{ph,rms}}$$ (Converter is loss less)

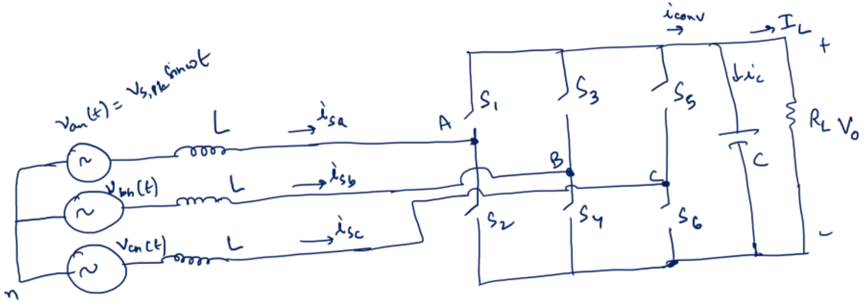
$$I_{s,pk} = \frac{\sqrt{2}\, P_L}{\eta \times 3\, V_{ph,rms}}$$ [η → efficiency of 3-ϕ AC-DC Converter]

⇒ the voltage rating of Capacitance > $V_0 + \frac{\Delta V_0}{2}$

Closed Loop Control

Control objectives

① To regulate the output voltage to a desired value. ($> \sqrt{2} V_{L-L}$)
$\simeq 565V \times 1.1$
$> 625V$

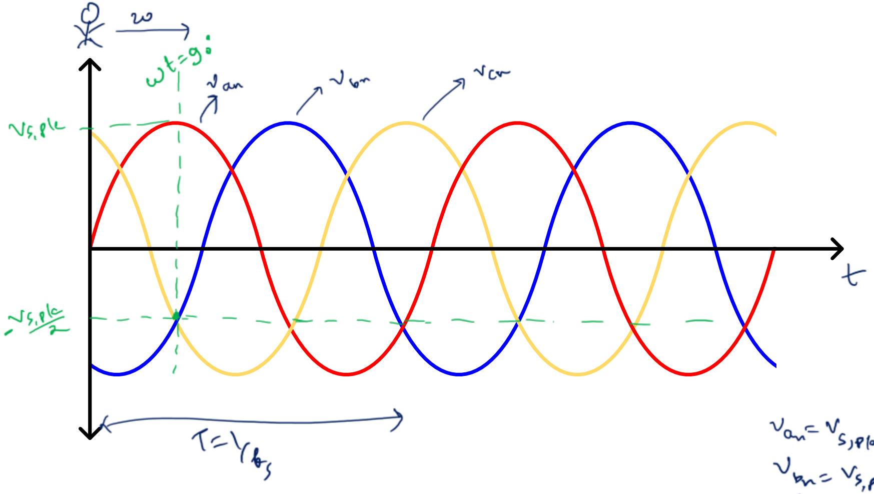


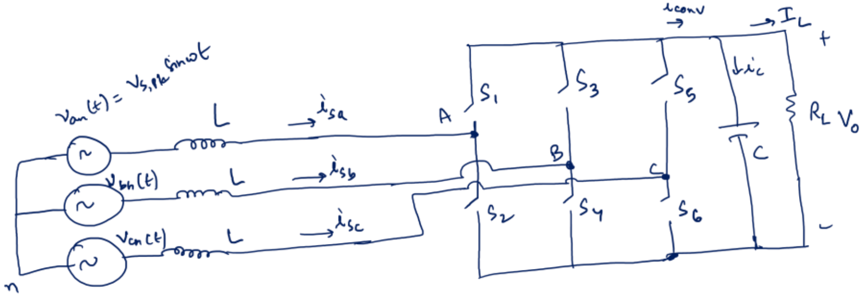
② The current drawn should have unity power factor (upf) operation

we have balanced three-phase operation,

$\Rightarrow \quad i_{sa} + i_{sb} + i_{sc} = 0$

$\Rightarrow$ the three-phase currents are dependent on each other





$v_{an} = V_{s,pk}\sin\omega t$

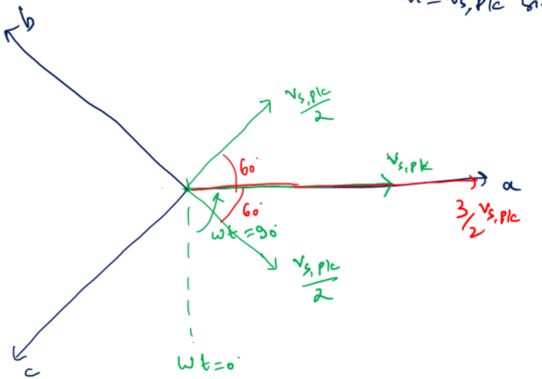
$v_{bn} = V_{s,pk}\sin(\omega t - 120)$

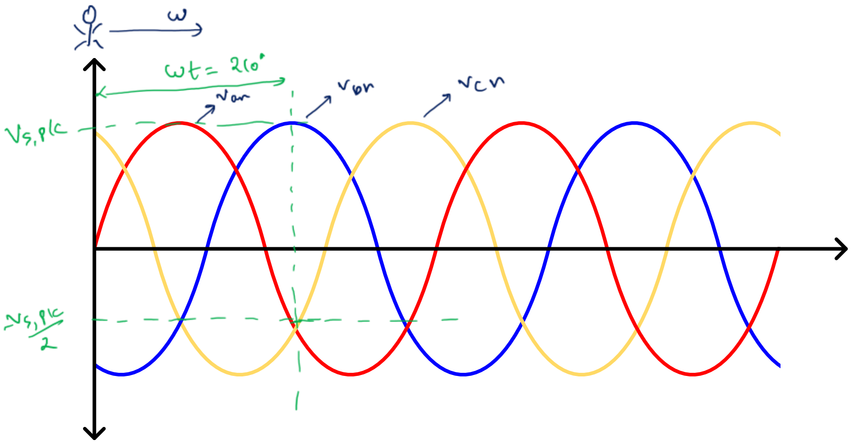
$v_{cn} = V_{s,pk}\sin(\omega t - 240)$

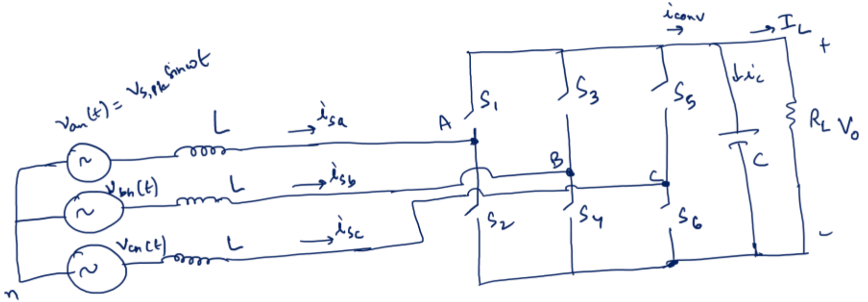
$\omega = 2\pi f_s$

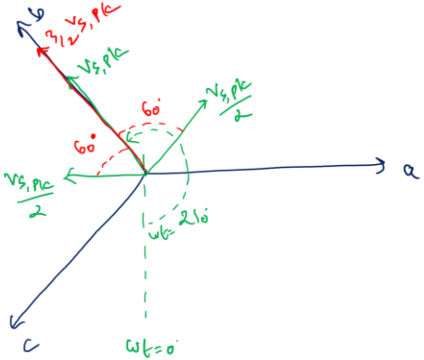
$= 2\pi/T$

$V_{s,resultant} = V_{s,pk} + \frac{V_{s,pk}}{2}\cos 60^\circ + \frac{V_{s,pk}}{2}\cos 60^\circ = \frac{3}{2}V_{s,pk}$



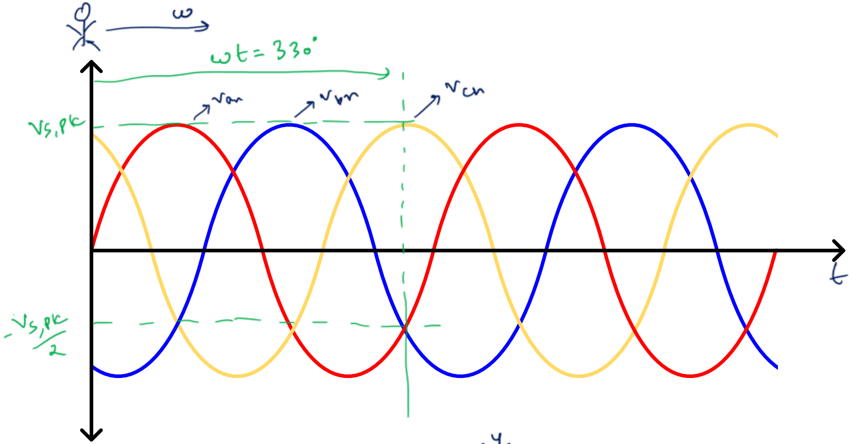


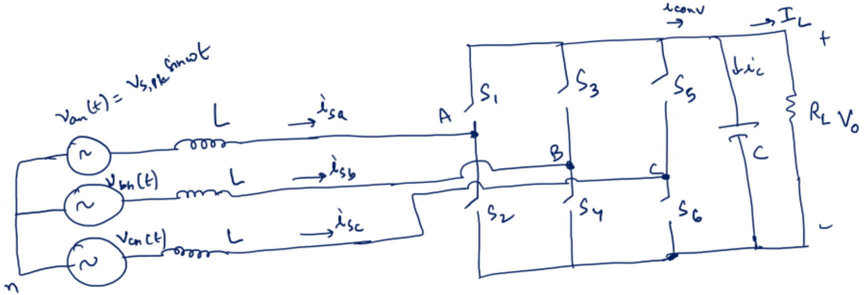


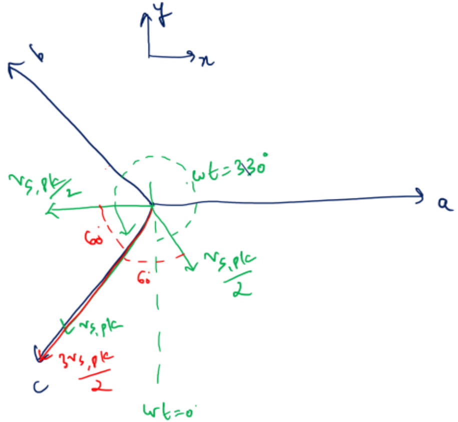


$$V_{s,resultant} = V_{s,pk} + \frac{V_{s,pk}}{2}\cos 60^\circ + \frac{V_{s,pk}}{2}\cos 60^\circ$$

$$= \frac{3}{2} V_{s,pk}$$





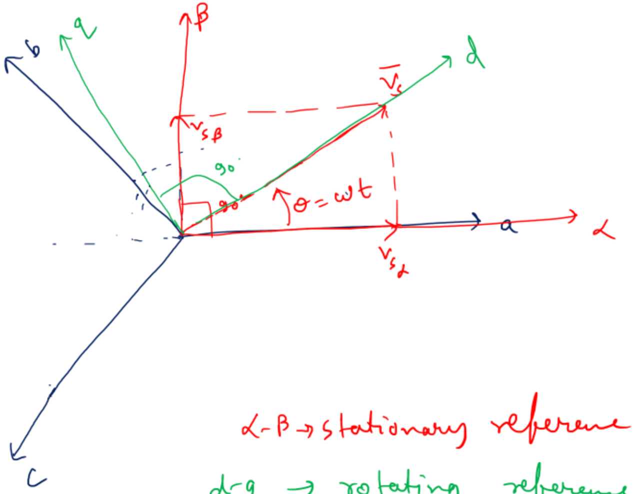


$$\Rightarrow V_{s,resultant} = \overset{\nearrow c}{V_{s,pk}} + \overset{\nearrow a}{\frac{V_{s,pk}}{2}\cos 60^\circ} + \overset{\nearrow b}{\frac{V_{s,pk}}{2}\cos 60^\circ}$$

$$= \frac{3}{2} V_{s,pk}$$

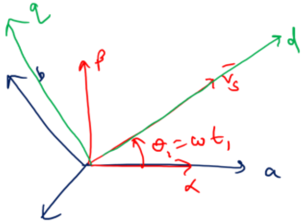
The resultant is a vector quantity, whose magnitude = $\frac{3}{2} v_{s,pk}$ and it is rotating with the speed = ω ($\omega = 2\pi f_s$)

⇒ The vector is rotating in a 2-D space, in order to obtain the independent component of vector, the representative axis has to be 90° apart from each other



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

$\cos 90 = 0$



α-β → stationary reference frame

d-q → rotating reference frame

at one of instant 't'

$a, b, c \rightarrow$ Sampled quantity

$$\Rightarrow \quad \alpha = a - b/2 - c/2 \quad \Rightarrow \quad \alpha = \frac{3a}{2}$$

$$\beta = a \cos 90 + b \cos 30 - c \cos 30 \Rightarrow \beta = \frac{\sqrt{3}}{2} b - \frac{\sqrt{3}}{2} c$$

$$\Rightarrow \quad d = \alpha \cos\theta + \beta \sin\theta$$

$$q = -\alpha \sin\theta + \beta \cos\theta$$

Thank You