Review :

1. Peak value of $V_o = \sqrt{3} V_m$ for $0 < \alpha < 30°$
2. $V_o \geq 0$ for $\alpha \leq 60°$
3. $V_o \leq 0$ for $\alpha \geq 120°$
4. For $\alpha > 90°$ operation is known as 'Inversion' or 'Inverter'

$\Rightarrow \alpha \rightarrow$ Phase angle delay $\rightarrow$ Converter

$\beta \rightarrow$ Phase advance (35°)

Device is triggered at 180-35=145°

5. P.F. is always lagging

   As $\alpha \uparrow$, P.F. $\downarrow$

6. Incoming device should be triggered again after 60°
   Continuous gate pulses for 70-75° are desired

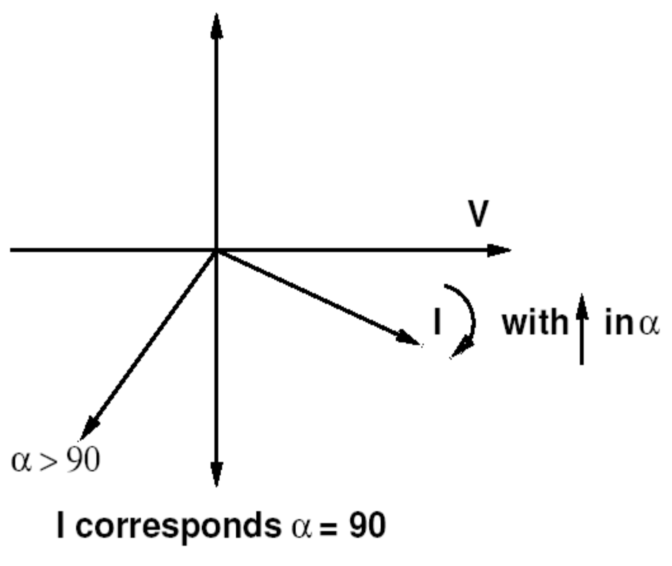
7. During commutation

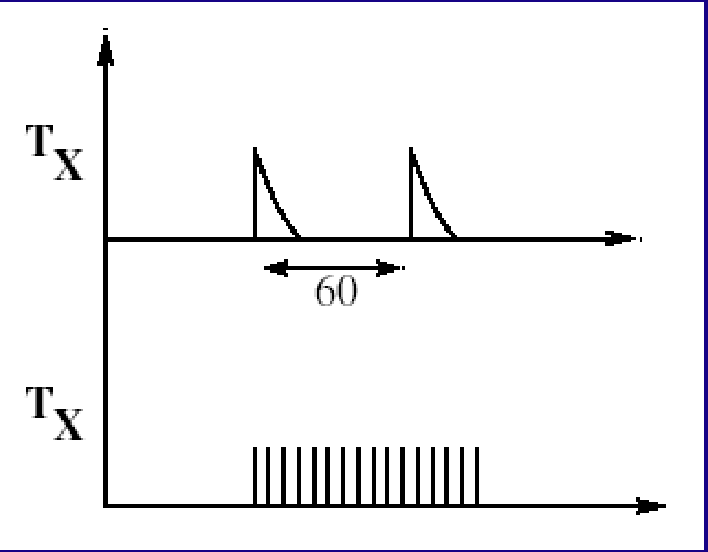
$$V_o = \frac{V_{on} + V_{in}}{2}$$

on $\rightarrow$ outgoing phase

in $\rightarrow$ Incoming phase

provided $\mu < 60°$

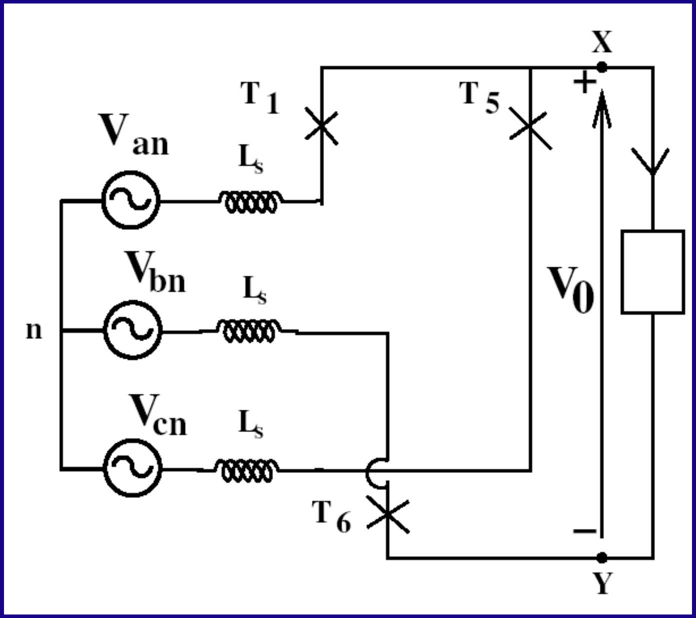




3 Phase Bridge :

Assume T_5 & T_6 are ON &

T_1 is triggered

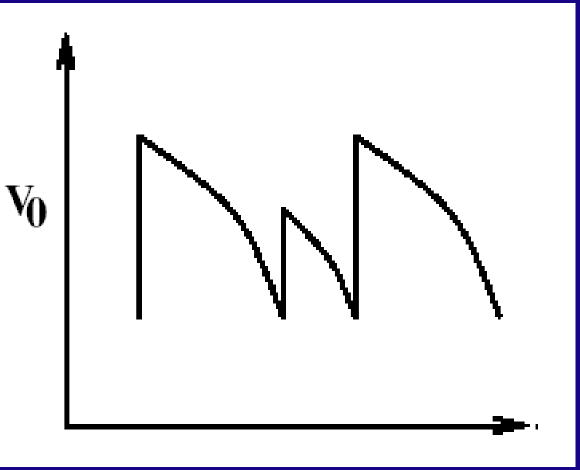


$$\text{Pot. of } X = \frac{V_{an} + V_{cn}}{2} \qquad \text{w.r.t. n}$$

$$\text{Pot. of } Y = V_{bn} \qquad \text{w.r.t. n}$$

$$\therefore V_o = V_{xy} = \frac{V_{an} + V_{cn}}{2} - V_{bn}$$

$$\text{\& after } \mu, \; V_o = V_{an} - V_{bn}$$



Expression of voltage drop due to μ

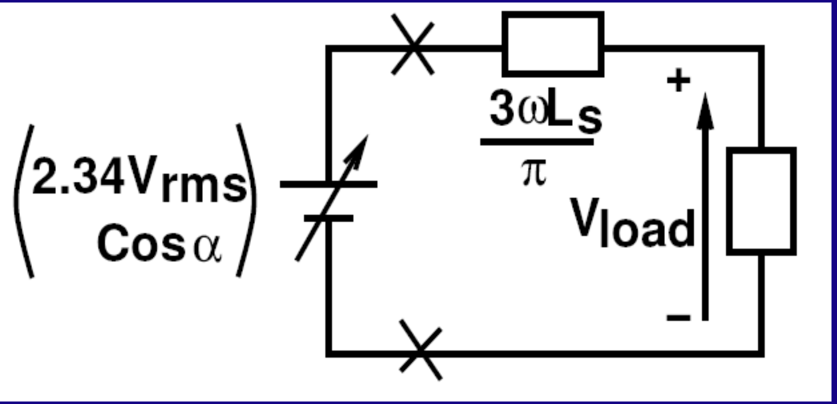
For single phase, total V drop $= \dfrac{\omega L_s}{\pi} I_o$

$$= 2L_s I_o f = \frac{2L_s I_o}{T}$$

$\therefore$ Volt sec. loss due to 1 commutation $= L_s I_o$

In 6 pulse converter there are 6 commutation per cycle

$$\therefore \text{Voltage drop} = \frac{6L_s I_o}{T} = \frac{3\omega L_s I_o}{\pi}$$



Other useful expression:

$$\therefore \text{Avg. } V_{Load} = \frac{3V_m}{2\pi}[\cos\alpha + \cos(\alpha + \mu)]$$

$$= 1.17\, V_{rms}[\cos\alpha + \cos(\alpha + \mu)]$$

$$V_o = \frac{3V_m}{\pi}\cos\alpha = 2.34\, V_{rms}\cos\alpha$$

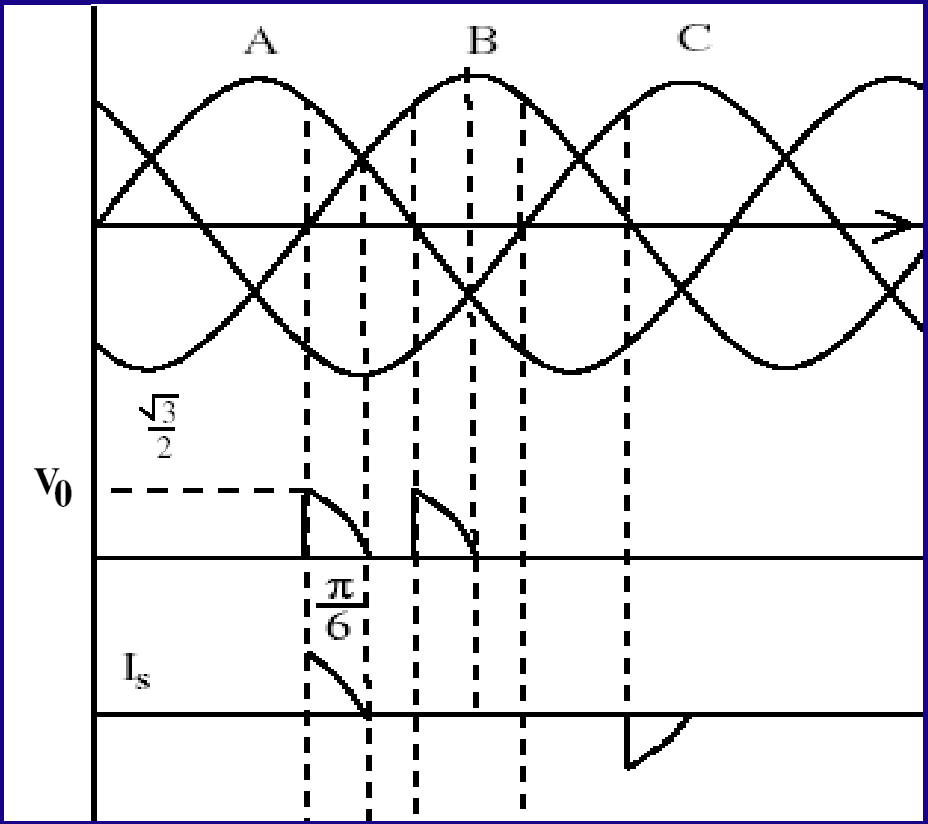
$$\frac{3V_m}{2\pi}[\cos\alpha + \cos(\alpha + \mu)] + \frac{3\omega L I_L}{\pi} = \frac{3V_m}{\pi}\cos\alpha$$

$$\therefore I_L = \frac{V_m}{2\omega L}[\cos\alpha - \cos(\alpha + \mu)]$$

$$= \frac{1.22\, V_{rms}}{\omega L}[\cos\alpha - \cos(\alpha + \mu)]$$

V_m is peak L-L voltage

Pb.1: 3-phase fully controlled converter is supplying power to a purely resistive load. If $\alpha = 90°$, Determine avg. o/p voltage. Input to the bridge is 400 V, 50Hz. Draw the o/p voltage & phase A current.



Solution :

$$V_o = \frac{6}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{\pi}{6}+\alpha+\frac{\pi}{6}} (V_A - V_B)\, d\omega t$$

$$= \frac{3\sqrt{3}V_m}{\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{\pi}{6}+\alpha+\frac{\pi}{6}} \sin\left(\omega t + \frac{\pi}{6}\right) d\omega t$$

$$= \frac{3\sqrt{3}V_m}{\pi}\left[\frac{\cos\alpha}{2} - \left(\frac{\sqrt{3}}{2} - 1\right)\sin\alpha\right]$$

$$= \frac{3\sqrt{3} * 400 * (\sqrt{2}/\sqrt{3})}{\pi}[0.134]$$

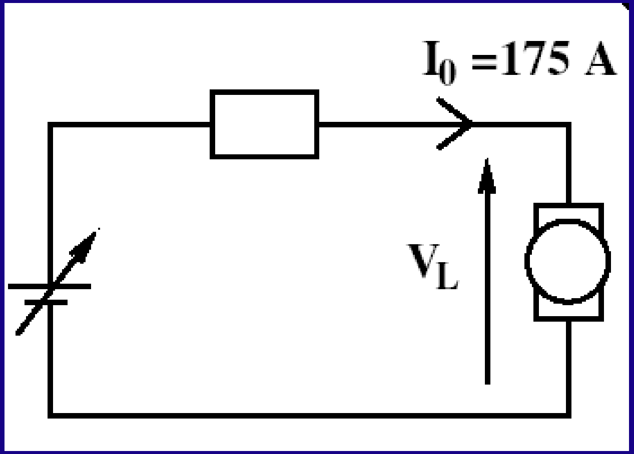
$$= 72.4\,V$$

Pb. 2

A 3-phase fully controlled bridge is feeding a 100HP, 400V, 1500rpm S.E. dc motor having arm. resistance=0.1Ω and filter choke which is connected in series with armature. The current is almost constant at 175A. The bridge is connected to a 3ϕ, 400V, 50Hz supply. L_s=0.5mH

The back emf constant = 0.25 V/rpm.

Determine the triggering angle 'α'



Soln:

E_b=0.25*1500=375V

$I_a R_a$=17.5V

∴Voltage across arm. terminal=392.5V

$\therefore$ Voltage across arm. terminal=392.5V

Voltage drop due to inductance $= \dfrac{3\omega L}{\pi} I_o$

$= \dfrac{3*314*0.5*10^{-3}}{\pi} *175$

$=26.24\,V$

$2.34*V_{rms}\cos\alpha=392.5+26.24$

$V_{rms}=\dfrac{400}{\sqrt{3}}=231V$

$\therefore \alpha=39.2°$

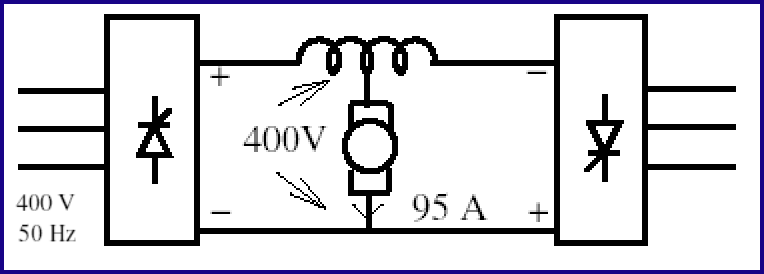
$$1.17V_{rms}\left[\mathrm{Cos}\alpha+\mathrm{Cos}(\alpha+\mu)\right]=2.34V_{rms}\mathrm{Cos}\alpha-\frac{3\omega L}{\pi}I_o$$

$=392.5\ V$

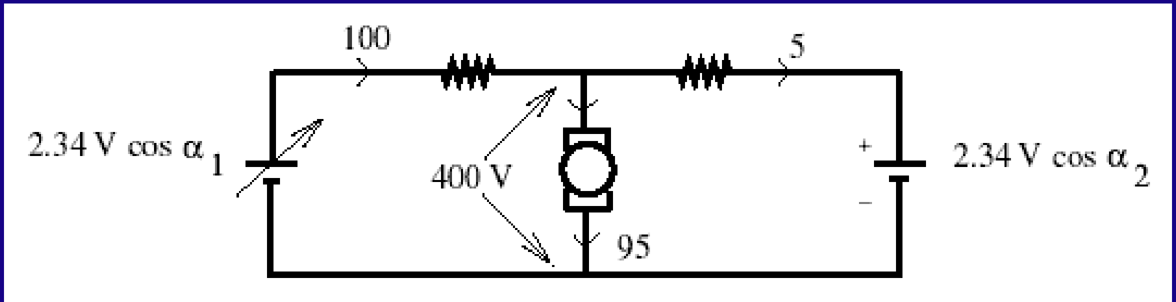
$\therefore$ μ=8.2°

Pb.3

A separately excited DC machine is controlled by a circulating type dual converter. Total resistance of the inductor is 1 Ω. Average value of armature current while driving a particular load is found to be 95A and the average value of circulating current is found to be 5A. The terminal voltage is maintained at 400V. Determine the triggering angle for both the bridges.



The equivalent circuit is



V $\rightarrow$ RMS value of phase voltage=231V

$\alpha_1 + \alpha_2 \neq 180$

2.34*231*cosα_1=400+0.5*100

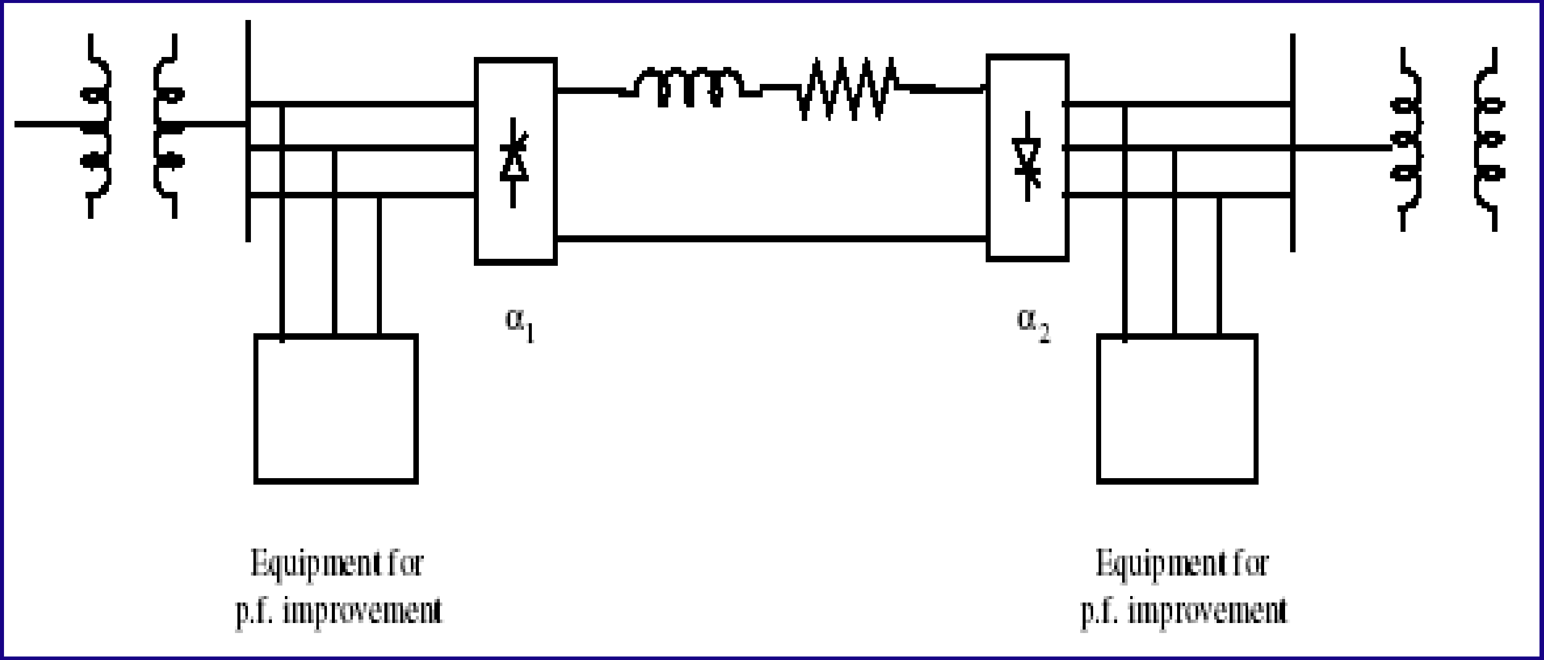
=450

$\Rightarrow \alpha_1$ =33.64°

2.34*231*cosα_2=-400+5*0.5 =-397.5

$\Rightarrow \alpha_2$=137.4°

HVDC Power Transmission

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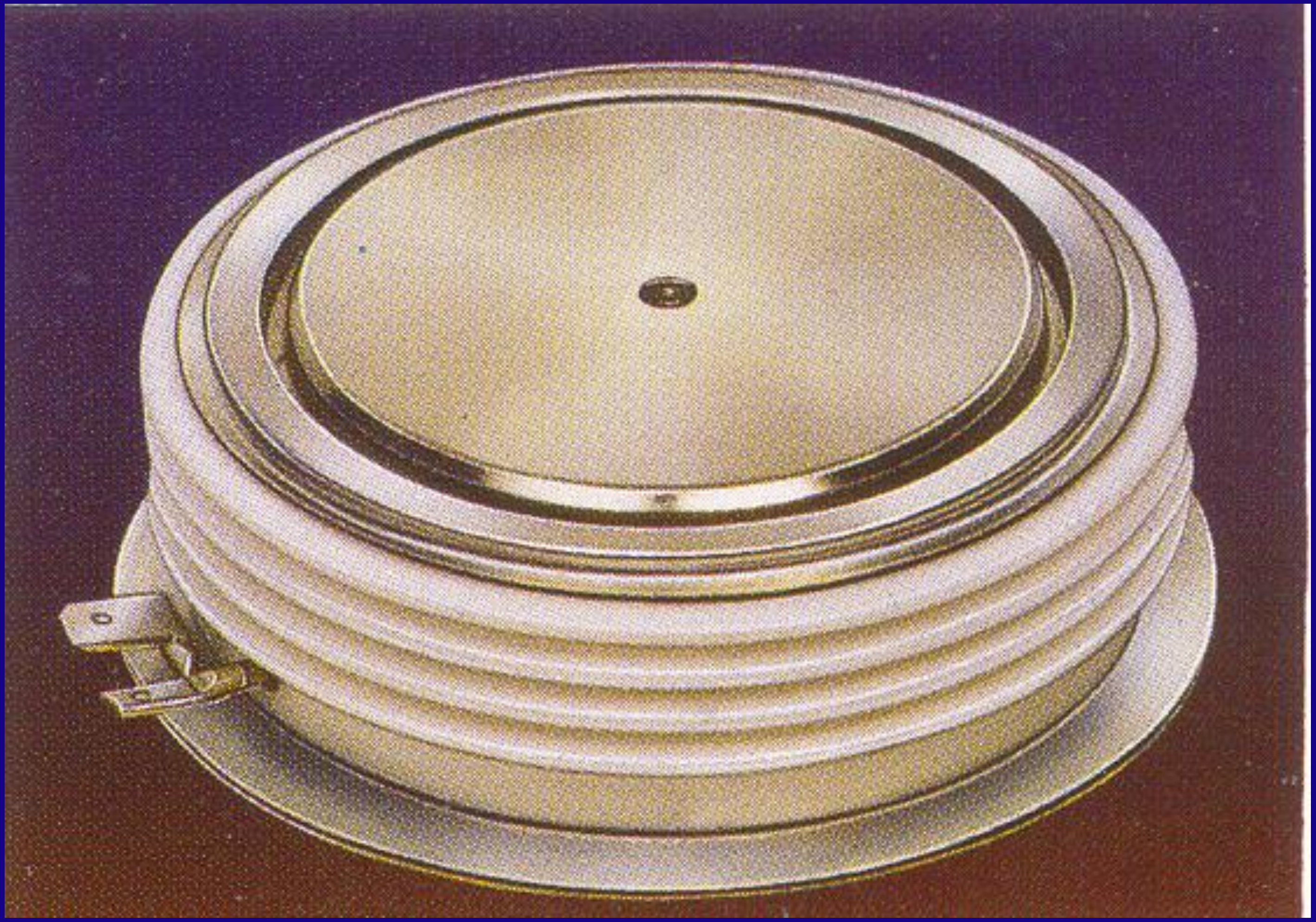


AC System Data	Barsoor	L. Sileru
Nominal system voltage	220 kV	220 kV
Nominal AC system Frequency	50 Hz	50 Hz
Rated Power	100 Mw	
Rated current	1000 A	
DC Link Voltage	100 kV	

3 phase half controlled bridge

at $\alpha=30°(\omega t=60)$

$V_0=V_{an}-V_{bn}$

$V_{an}\propto \text{Sin}60=\sqrt{3}/2$

$V_{bn}\propto \text{Sin}300=-\sqrt{3}/2$

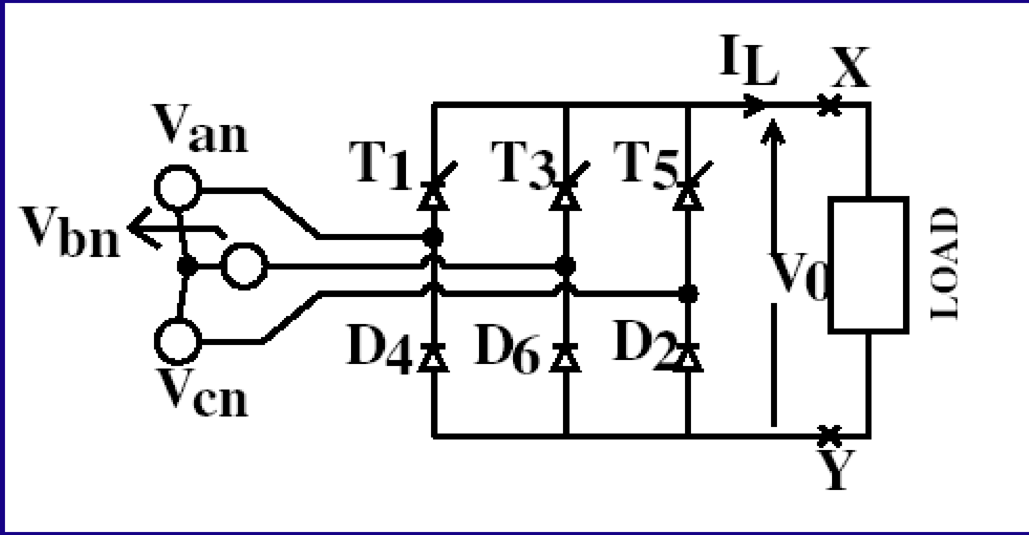
$\therefore V_0=\sqrt{3}$

at $\omega t=90°$

$V_{an}\propto \text{Sin}90=1$

$V_{bn}\propto \text{Sin}330=-1/2$

$\therefore V_0=1.5$



at $\omega t=90^{+}$, D_2 starts conducting

at $\omega t=120°$

$V_{an} \propto \text{Sin}120=\sqrt{3}/2$

$V_{cn} \propto \text{Sin}240=-\sqrt{3}/2 \quad \therefore V_0=\sqrt{3}$

at $\omega t=150°$

$V_{an} \propto \text{Sin}150=1/2$

$V_{cn} \propto \text{Sin}270=-1 \qquad \therefore V_0=1.5$

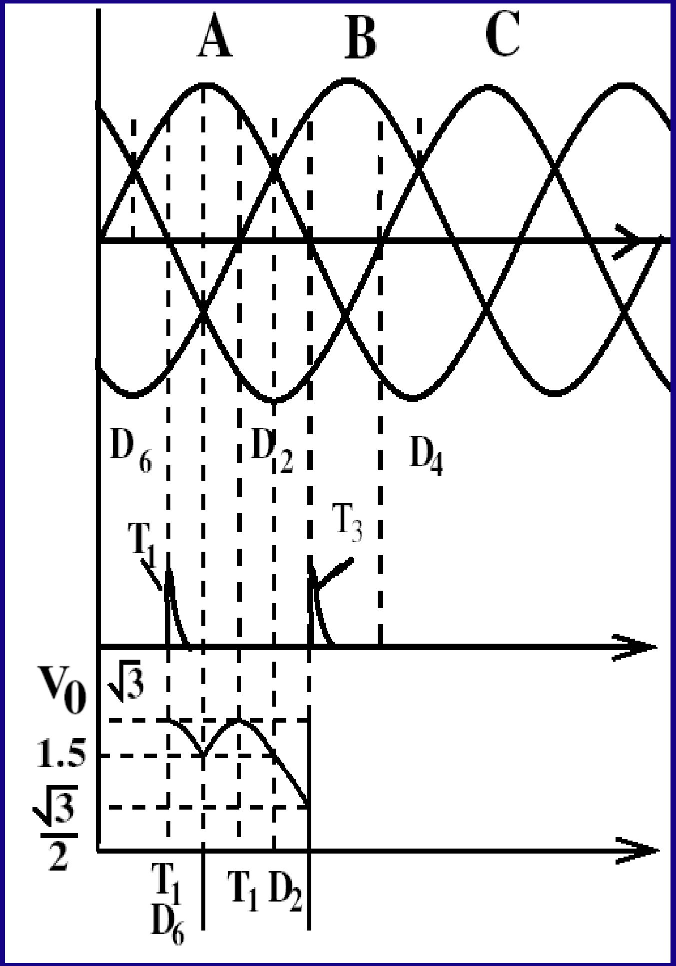
at $\omega t=180^{-}$

$V_{an}=0$, $V_{cn}=-\sqrt{3}/2 \qquad \therefore V_0=\sqrt{3}/2$

at $\omega t=180^{+}$, T_3 is triggered

$V_o=\sqrt{3}$

$V_o=1.17*V_{rms}\left[1+\cos\alpha\right]$



Limitations of line commutated converter

	Uncontrolled	Half controlled	Full controlled
Displacement angle	0	$\alpha / 2$	α
P.F.	Highest	$f(\alpha)$	$f(\alpha)$
THD	48%	$f(\alpha)$	48%

$\Rightarrow$ P.F. is max. in uncontrolled bridge

$\Rightarrow$ controlled bridge with $\alpha = 0$

$\Rightarrow$ No control over $V_o = \left(\dfrac{2V_m}{\pi}\right)$ =constant