تقدم لجنة ElCoM الاكاديمية

ELECTRICAL COMPUTER MECHATRONICS

تلخيص سكند لمادة:

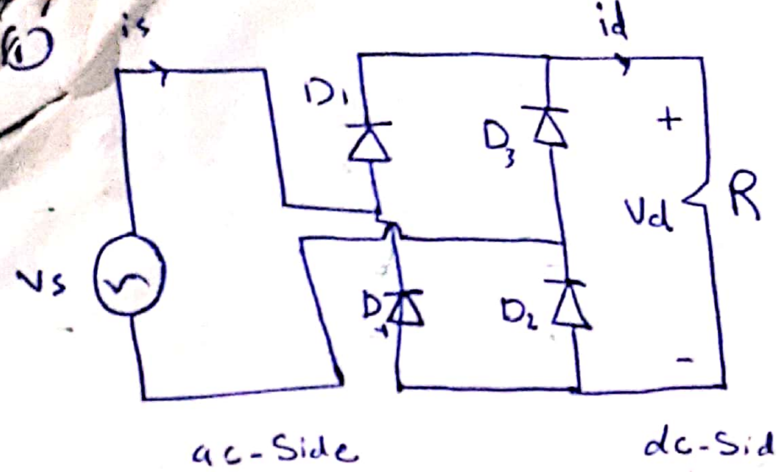
# الكترونيات القوى

جزيل الشكر للطالب:

## بدر بلبيله

[redacted]

1

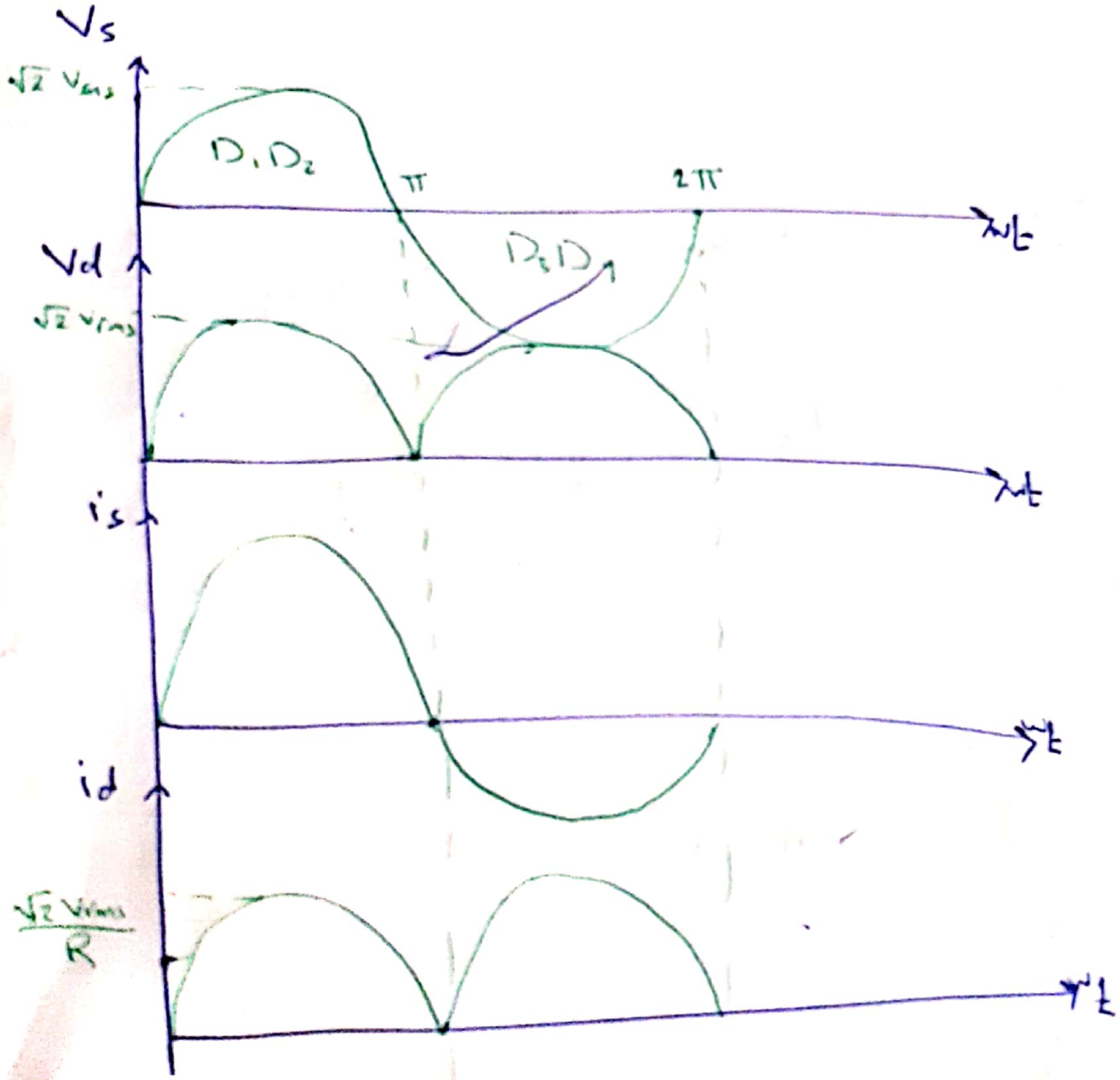



-Vs .Vd

$\boxed{V_d = -V_s}$

uncontrolled

.Vq1<00105

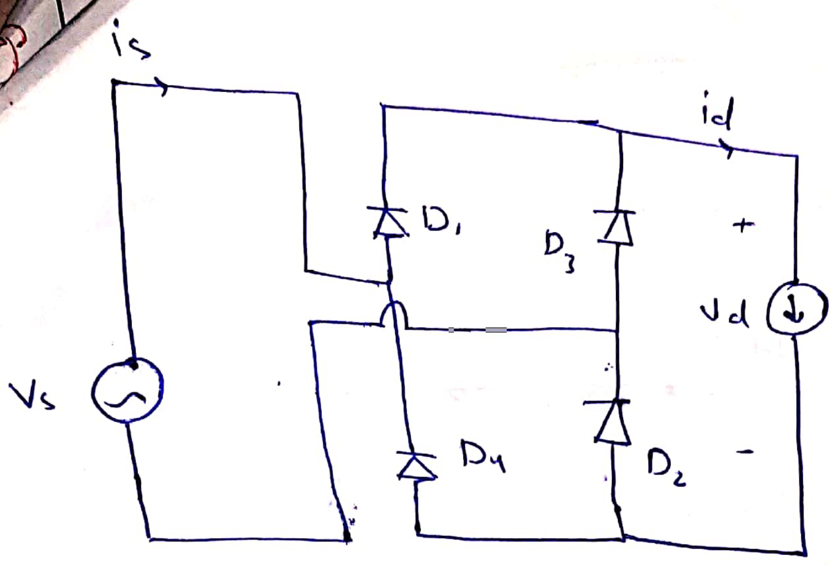



[redacted]

in Thyristor can't use different Ac waveform
just Ac Sinusoidal

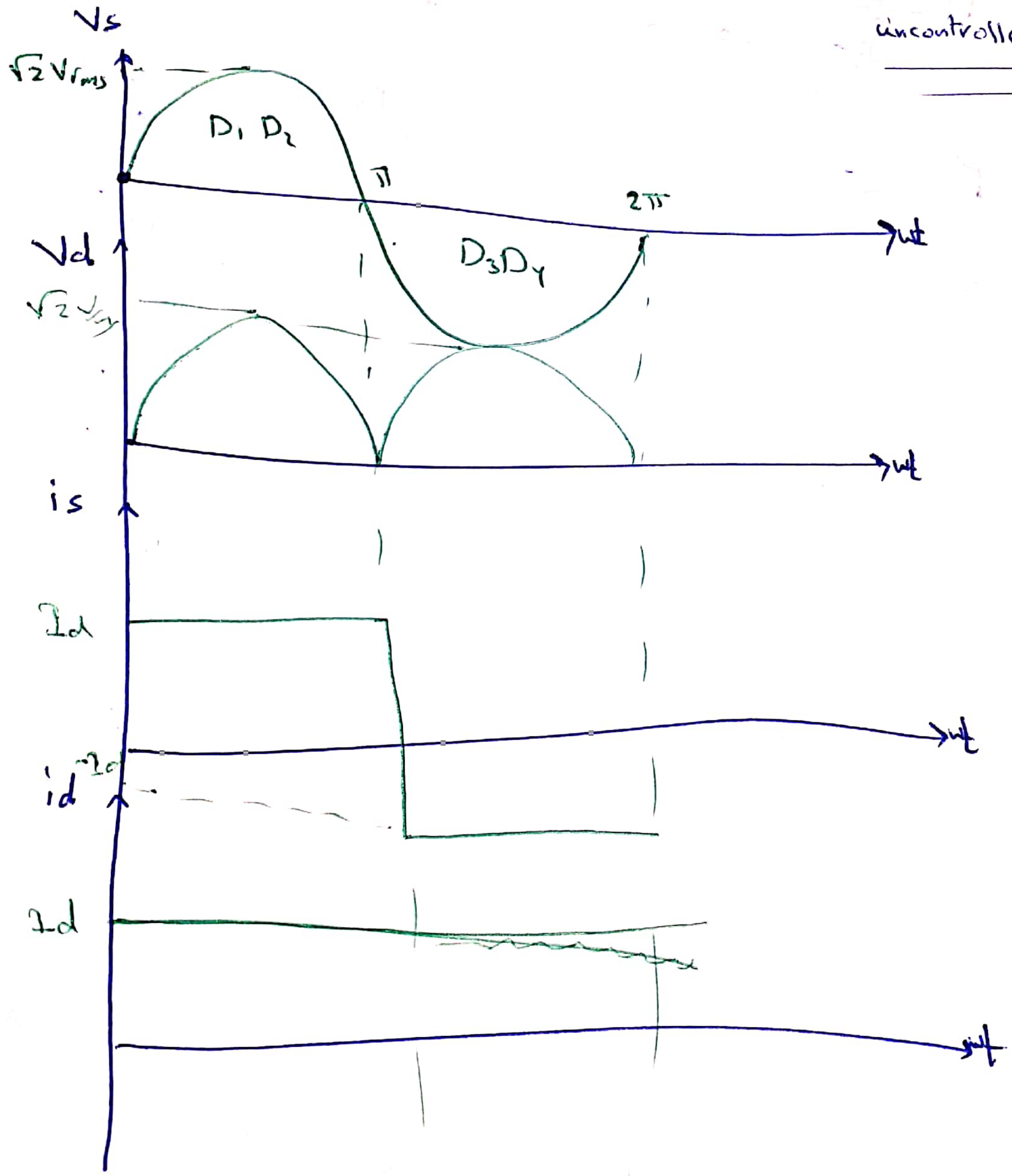
$\boxed{PIV = V_{sp} + V_{battery}}$

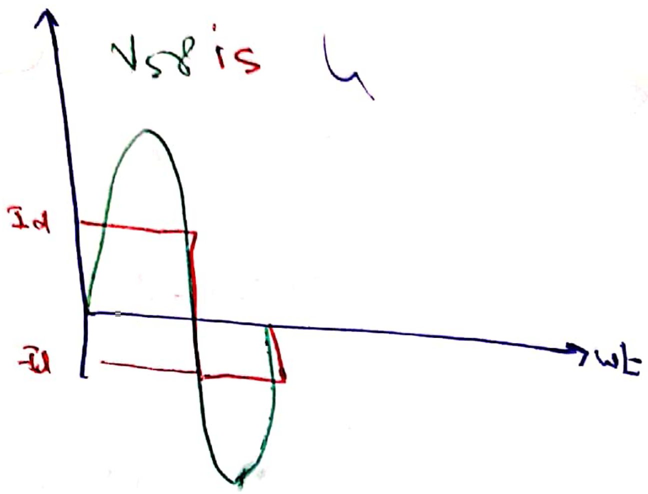
~~2π — π-α~~




(highly inductive load)

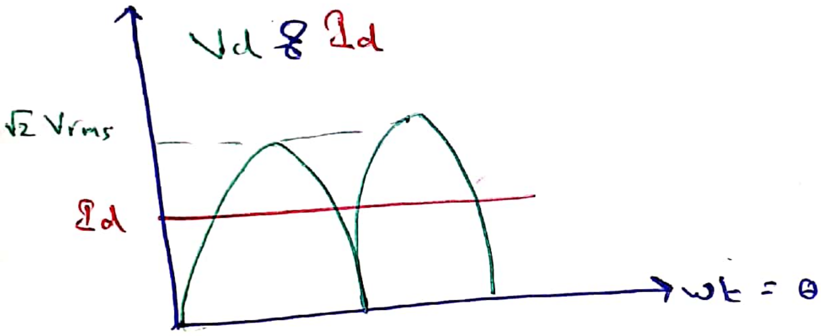
uncontrolled full bridge






$I_{s1} = 0.9\, I_d \Rightarrow$ rms value of the fundemental component of $i_s(t)$

$P = V\, I_{s1} \cos\theta_1 = V(0.9 I_d) = 0.9\, V_{rms}\, I_d$ (avg Power from the ac-Side)




$$P = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\, i_d(\theta)\, d\theta$$

$$= \frac{I_d}{2\pi}\int_0^{2\pi} \sqrt{2}\, V \sin(\theta)\, d\theta$$

$$\frac{I_d}{\pi}\int_0^{\pi} \sqrt{2}\, V \sin(\theta)\, d\theta$$

$$2\,\frac{\sqrt{2}}{\pi} \cdot I_d \cdot V \cdot \cos(\theta)\Big|_{\pi}^{0}$$

$\boxed{P = 0{,}9 \cdot V \cdot I_d}$ (avg Power from the dc-Side)

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* Back to ac-Side $\boxed{I_s = I_d}$

4

$$THD\% = \frac{\sqrt{I_s^2 - I_{s1}^2}}{I_{s1}} * 100\% =$$

$$= \frac{\sqrt{Id^2 - (0.9 Id)^2}}{0.9 Id} * 100\% = 48.43\%$$

$$DPF = \cos(0) = 1$$

$$Pf = \frac{I_{s1}}{I_s} \cdot \cos\theta = 0.9$$

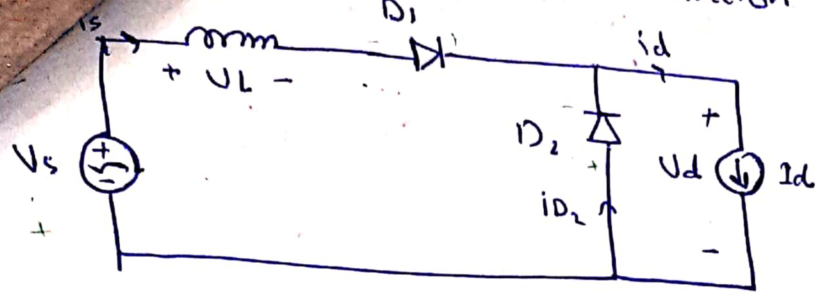
$I_{s1} = 0.9\, I_d$

$\boxed{I_s = I_d}$

$$\boxed{P = 0.9\, V_d . I_d}$$

ac or dc

of ($L_s$) on current commutation

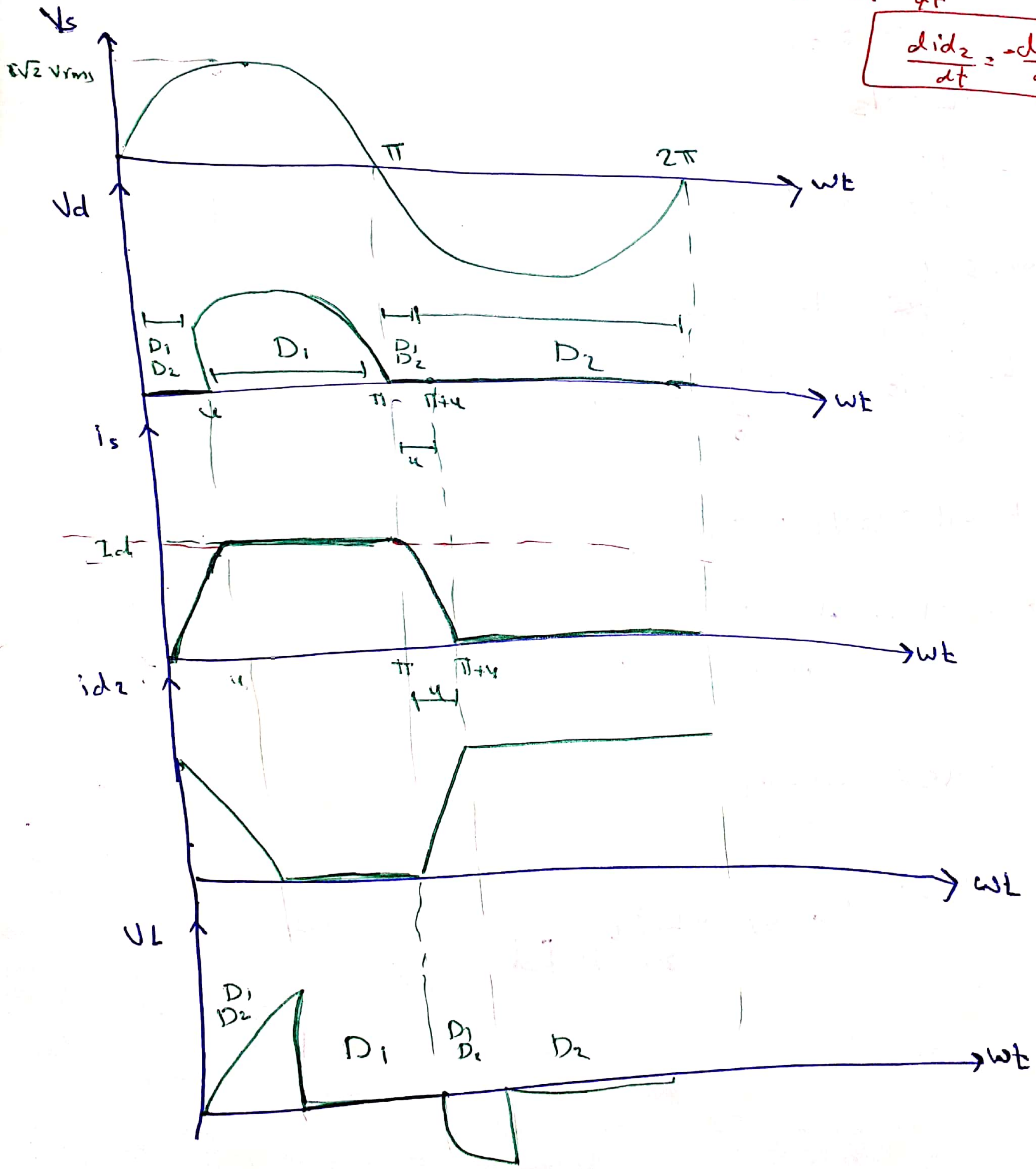



(Half wave-rectifier)

$i_s + i_{d2} = i_{d1}$

$\frac{di_s}{dt} + \frac{di_{d2}}{dt} = \cancel{\frac{di_{d1}}{dt}}$

$\boxed{\frac{di_{d2}}{dt} = -\frac{di_s}{dt}}$



$$* \quad V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\,d\theta = \frac{1}{2\pi}\int_u^{\pi}\sqrt{2}\,V \sin(\theta)\,d\theta$$

$$\boxed{V_d = \frac{\sqrt{2}\,V}{2\pi}\left[\cos(u)+1\right]}$$

* During Commutation

$$V_L = V_s$$

$$L_s \frac{di_s}{dt} = \sqrt{2}\,V \sin\omega t$$

$$\omega L_s \frac{di_s}{\cancel{dt}\; d\omega t} = \sqrt{2}\,V \sin\omega t$$

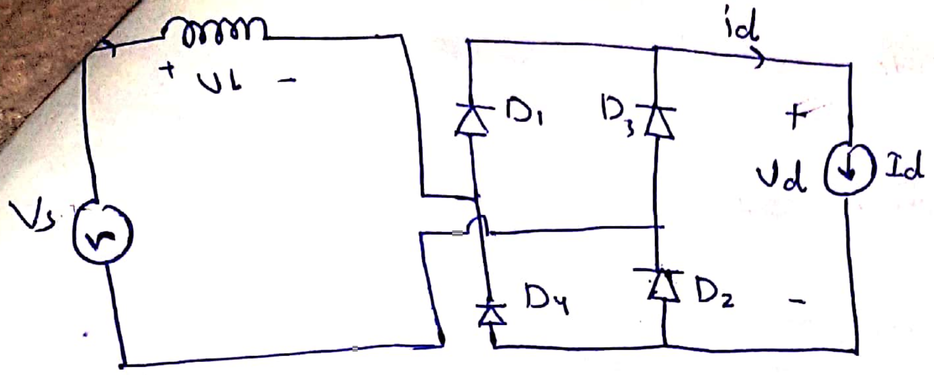
$$\omega L_s \int_0^{I_d} di_s = \sqrt{2}\,V \int_0^{u} \sin(\theta)\,d\theta$$

$$\omega L_s I_d = \sqrt{2}\,V\left[1-\cos(u)\right]$$

$$\cos(u) = 1 - \frac{\omega L_s I_d}{\sqrt{2}\,V}$$

$$V_d = 0.45V - \frac{\omega L_s I_d}{2\pi}$$

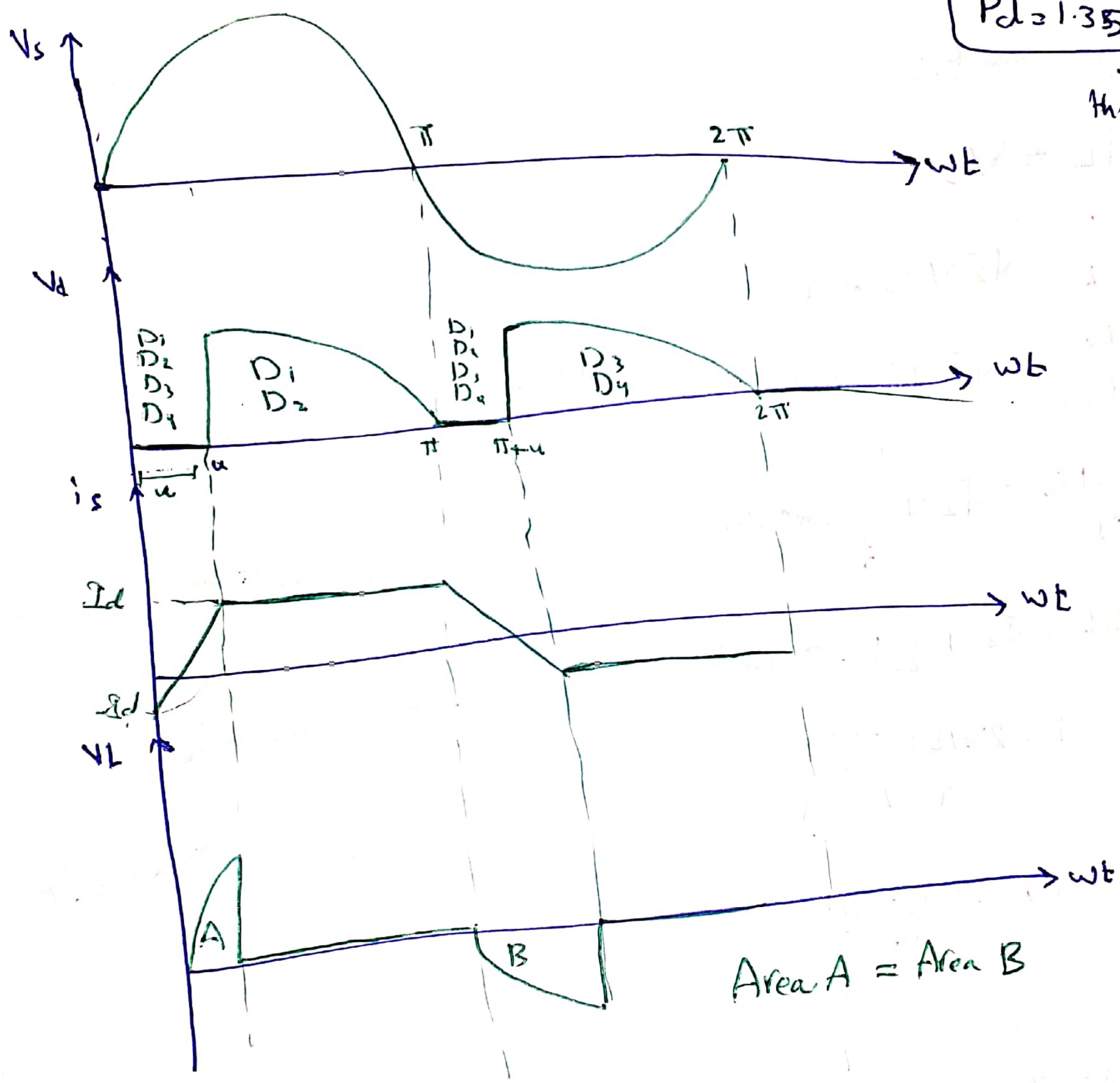
$$P = I_d . V_d = \left(0.45V - \frac{\omega L_s I_d}{2\pi}\right). I_d$$




Full-wave Bridge rectifier (Single-phase) with constant current and inductor

$$\boxed{P_d = 1.35\, V_{LL} \cdot I_d}$$

three phase




* effect of "Ls" تأثير ال Source inductance وجود

1. reduces the Avg value of the out voltage
2. reduces the Avg output Power
3. introduces the commutation interval, all diode on and $V_d = 0$

* The commutation interval increase with Ls and Id and decrease with Vs

$$* \quad V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\, d\theta$$

$$V_d = \frac{1}{\cancel{2\pi}} \times \cancel{2} \int_u^{\pi} \sqrt{2}\, V \sin(\theta)\, d\theta$$

$$V_d = \frac{\sqrt{2}\, V}{\pi}\left[\cos(u) + 1\right]$$

* During commutation

$$V_L = V_s$$

$$L_s \frac{di_s}{dt} = \sqrt{2}\, V \sin(wt)$$

$$wL_s \frac{di_s}{dwt} = \sqrt{2}\, V \sin(wt) \longrightarrow \int wL_s\, di_s = \int \sqrt{2}\, V \sin wt \cdot dwt$$

$$wL_s \int_{-I_d}^{I_d} di_s = \sqrt{2}\, V \int_0^{u} \sin(\theta)\, d\theta$$

$$\cancel{wL_s \int di_s = \int \sqrt{2}\, V \sin(wt)\, dwt}$$

$$2 wL_s I_d = \sqrt{2}\, V \left[1 - \cos(u)\right]$$

$$\cancel{wL_s \frac{di_s}{d\theta} = \sqrt{2}\, V \sin(\theta)}$$

$$\boxed{\cos(u) = 1 - \frac{2 wL_s I_d}{\sqrt{2}\, V}}$$

$$\cancel{wL_s \int di_s = \int \sqrt{2}\, V \sin(\theta)\, d\theta}$$

$$V_d = 0.9 V - \frac{2 wL_s \cdot I_d}{\pi}$$

---

* $i_s(t)$ during $u$

$$P_d = V_d \cdot I_d$$

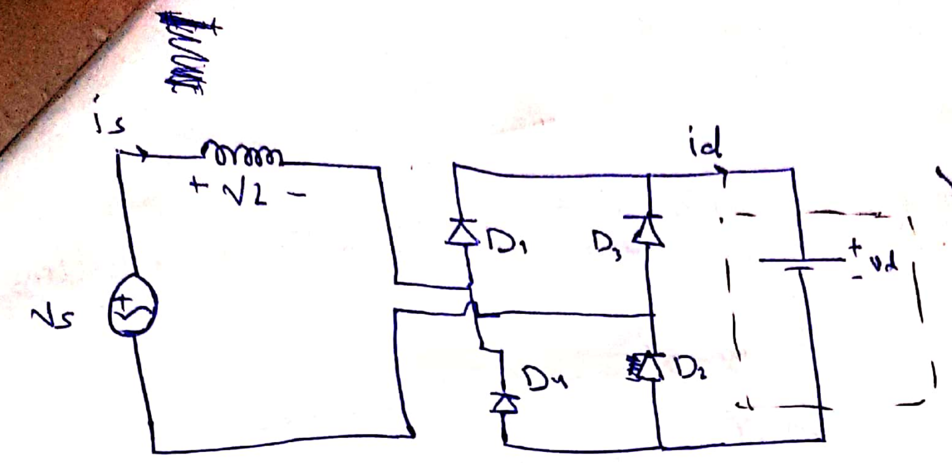
$$wL_s \frac{di_s}{d\theta} = \sqrt{2}\, V \sin \cancel{wt}\, \theta$$

$$wL_s \int di_s = \sqrt{2}\, V \int \sin(\theta)\, d\theta + K$$

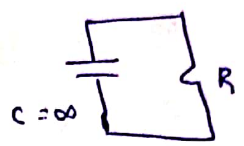
$$i_s(0) = -I_d = \frac{-\sqrt{2}\, V}{wL_s} + K_1$$

$$wL_s\, i_s(\theta) = -\sqrt{2}\, V \cos(\theta) + K$$

$$i_s(\theta) = \frac{-\sqrt{2}\, V \cos(\theta)}{wL_s} + K_1$$

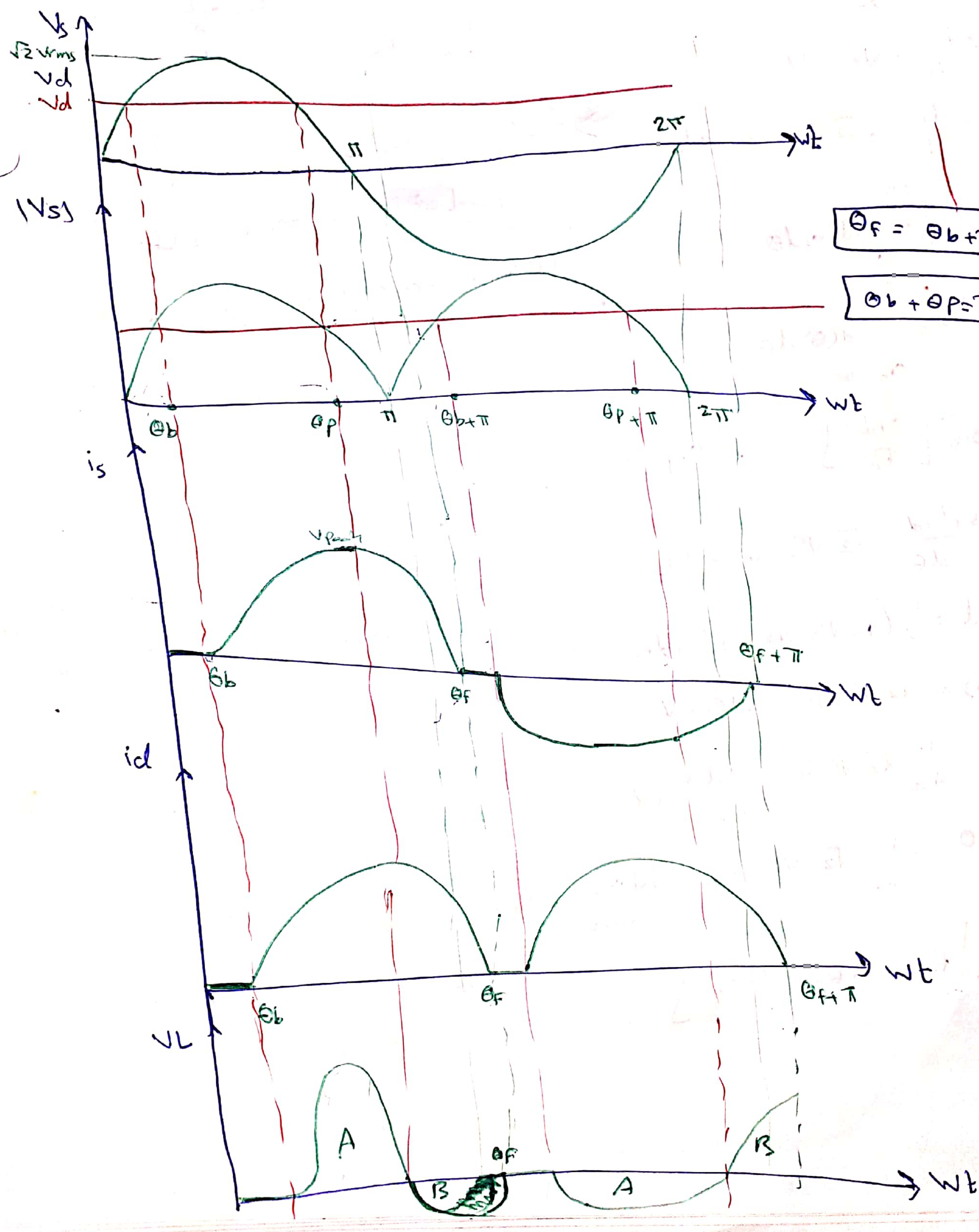



$V_d(t) = V_d$




$\tau = \infty = RC$

$\Rightarrow$ DC-Voltage




$\boxed{\theta_f = \theta_b + \pi}$

$\boxed{\theta_b + \theta_p = \pi}$

$\theta_b + \pi - \theta_p = 0$

at

$$V_d = V_s$$

$$V_d = \sqrt{2} V_{rms} \sin\theta_b$$

$$\theta_b = \sin^{-1}\left[\frac{V_d}{\sqrt{2}V_{rms}}\right]$$

$$\theta_p = \pi - \theta_b$$

$$\theta_f \geq \theta_p$$

$$-V_s + L_s\frac{di_s}{dt} + V_d = 0$$

$$L_s\frac{di_s}{dt} = V_s - V_d$$

$$\omega L_s\frac{di_s}{d\omega t} = \sqrt{2}V\sin(\omega t) - V_d$$

$$I_d = \frac{1}{2\pi}\int_0^{2\pi} i_d(\theta)\,d\theta$$

$$I_d = \frac{\cancel{2}}{\cancel{2}\pi}\int_{\theta_b}^{\theta_f} i_d(\theta)\,d\theta$$

$$\theta_b = \sin^{-1}\left[\frac{V_d}{\sqrt{2}V}\right], \quad \theta_p = \pi - \theta_b$$

$$\omega L_s\frac{di_d}{d\theta} = \sqrt{2}V\sin(\theta) - V_d$$

$$\omega L_s\int di_d = \int\left(\sqrt{2}V\sin\theta - V_d\right)d\theta$$

$$\omega L_s i_d(\theta) = -\sqrt{2}V\cos(\theta) - V_d\theta + K$$

$$i_d(\theta) = \frac{-1}{\omega L_s}\cdot\sqrt{2}V\cos\theta - \frac{V_d\theta}{\omega L_s} + K_1$$

$$i_d(\theta_b) = 0 = \frac{-1}{\omega L_s}\sqrt{2}\cdot V\cos(\theta_b) - \frac{V_d\theta_b}{\omega L_s} + K_1$$

$$K_1 = \frac{1}{\omega L_s}\left[\sqrt{2}V\cos\theta_b + V_d\theta_b\right]$$

~~integ~~

$$\boxed{i_d(\theta) = \frac{-1}{\omega L_s}\cdot\sqrt{2}V\cos\theta - \frac{V_d\theta}{\omega L_s} + \underbrace{\frac{1}{\omega L_s}\cdot\sqrt{2}V\cos(\theta_b) + \frac{1}{\omega L_s}V_d\theta_b}_{\text{Constant}}}$$

general form :- $i_d(\theta) = C_1\cos\theta + C_2\theta + C_3$

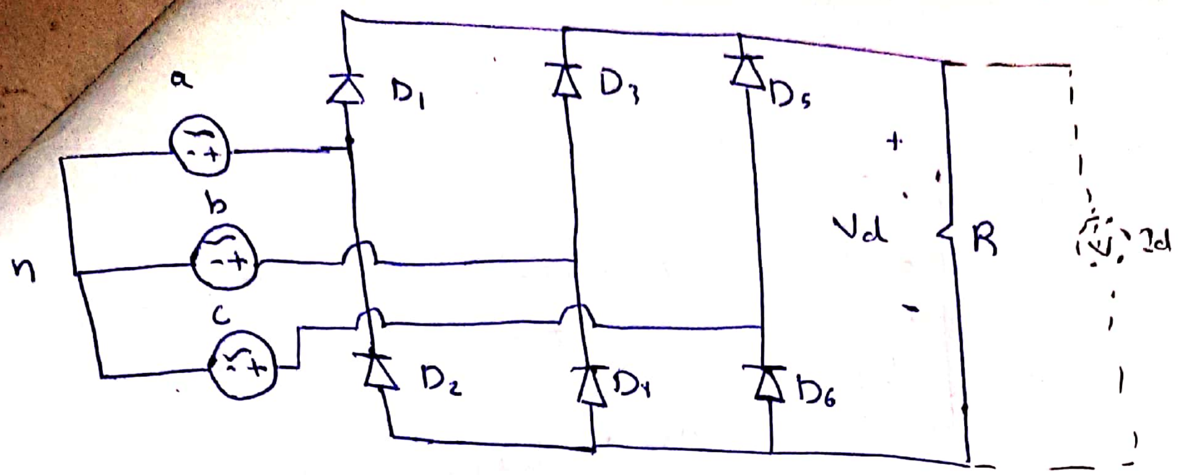
$$0 = i_d(\theta_f) = \frac{-1}{\omega L_s}\cdot\sqrt{2}V\cos(\theta_f) - \frac{1}{\omega L_s}V_d\theta_f + \frac{1}{\omega L_s}\cdot\sqrt{2}V\cos(\theta_b) + \frac{1}{\omega L_s}V_d\theta_b$$

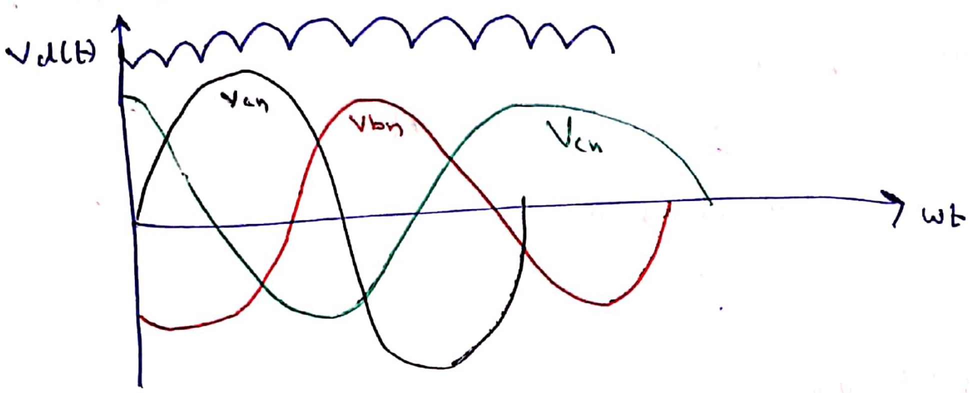
$\Rightarrow$ conducting interval

$\omega t_{cond} = \theta_f - \theta_b \Rightarrow \omega = 2\pi f$

$$\boxed{i_d(\theta_f) = 0 = C_1\cos(\theta_f) + C_2\theta_f + C_3}$$

$$\boxed{I_d = \frac{1}{\pi}\int_{\theta_b}^{\theta_f}\left(-\frac{\sqrt{2}V\cos\theta}{\omega L_s} - \frac{V_d\cdot\theta}{\omega L_s} + \frac{\sqrt{2}V}{\omega L_s}\cos(\theta_b) + \frac{1}{\omega L_s}V_d\theta_b\right)d\theta}$$




* Three phase rectifier circuit have, compared to single phase rectifier

① Lower ripple content in the wave form

② higher power-handling capacity

* average value of the o/p voltage $\Leftarrow V_d = 1.35\, V_{LL}$ → rms value of the three phase line voltage

$$V_d = \frac{6}{2\pi}\int_0^{\frac{\pi}{3}} V_d(\theta)\,d\theta$$

$$= \frac{3}{\pi}\int_0^{\frac{\pi}{3}} \sqrt{2}\,V\sin(\theta)\,d\theta = 1.35\, V_{LL}$$

$$\boxed{P_d = 1.35\, V_{LL} \cdot I_d}$$

↓

Diodes (3 phase)

$$\boxed{P_d = 1.35\, V_{LL}\, I_d \cdot \cos\alpha}$$

↓

Thyristores (3 Phase)

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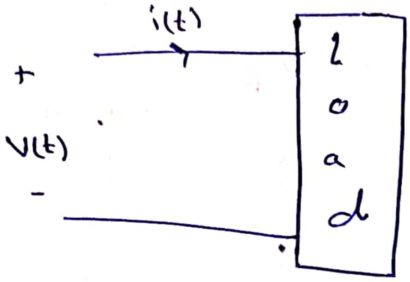


$v(t) = V_d + \sqrt{2}\, V_1 \cos\omega t + \sqrt{2}\, V_1 \sin\omega_1 t + \sqrt{2}\, V_3 \cos(\omega_3 t)$ volt

$i(t) = I_d + \sqrt{2}\, I_1 \cos(\omega_1 t) + \sqrt{2}\, I_3 \cos(\omega_3 t - \phi_3)$ A

(a $P = \frac{1}{T}\int_0^T v(t).i(t)dt = \frac{1}{T}\int_0^T (\quad).(\quad)\,dt$

$= V_d.I_d + V_1.I_1 + V_3 I_3 \cos\phi_3$

(b $V = \sqrt{V_d^2 + V_1^2 + V_1^2 + V_3^2}$

$I = \sqrt{I_d^2 + I_1^2 + I_3^2}$

(c $S = V I$

$Pf = P/S = \dfrac{V_d I_d + V_1 I_1 + V_3 I_3 \cos\phi_3}{V I}$

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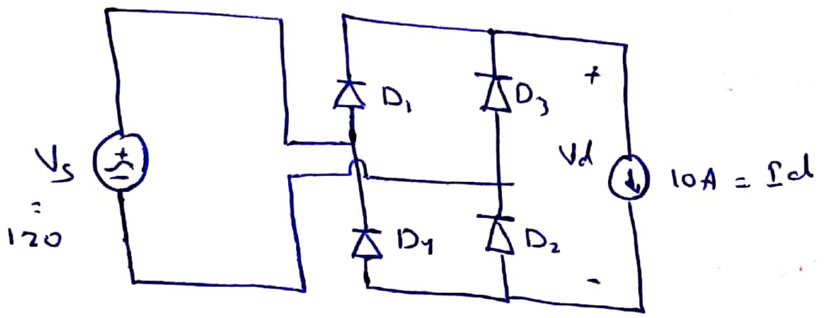
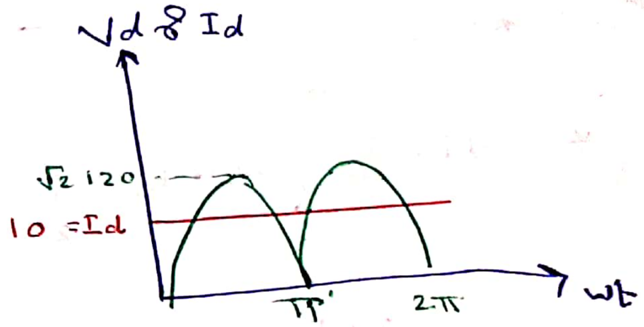
$\tilde{x}(t) \rightarrow$ Symm about t-axis $\Rightarrow a_0 = 0$

$x(t) \rightarrow$ even Signal $\Rightarrow b_n = 0$

$x(t) \rightarrow$ odd signal $\Rightarrow a_n = 0$

Ex $\Rightarrow$



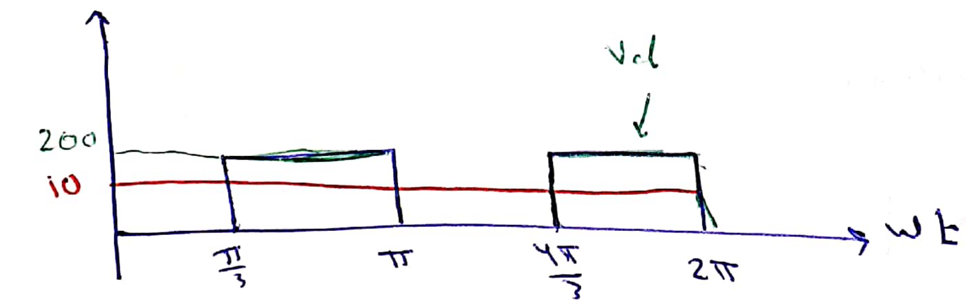




calculate P

$$P = \frac{1}{T}\int_0^T v(t)\cdot i(t)\, dt$$

$$= \frac{1}{2\pi}\left[\int_0^{\pi} 10\cdot\sqrt{2}\cdot 120\cdot \sin(\omega t)\, d\omega t + \int_{\pi}^{2\pi} 10\cdot\sqrt{2}\cdot 120\cdot \sin(\omega t)\, d\omega t\right]$$

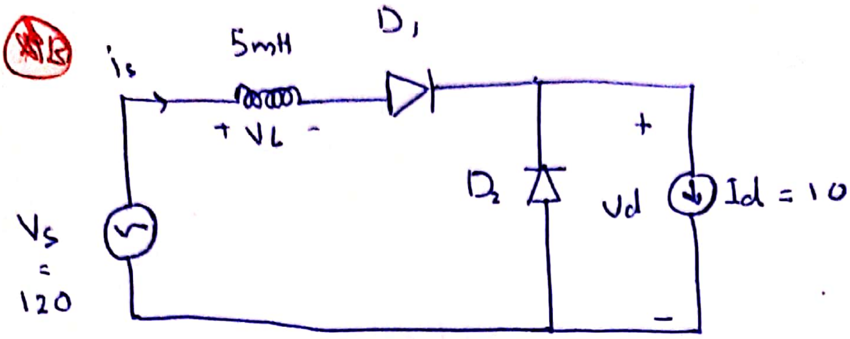
$$= 0.9\, V\cdot I_d = (0.9)(120)(10) = 1080\,W$$




$$P = \frac{1}{2\pi}\left[\int_{\pi/3}^{\pi} (200)(10)\, d\omega t + \int_{4\pi/3}^{2\pi} (200)(10)\, d\omega t\right]$$

$$= 1333.33\,W$$

E.x ⇒




$L_s = 5mH$

$$* \quad V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\,d\theta = \frac{1}{2\pi}\int_u^{\pi} \sqrt{2}\cdot 120\cdot \sin(\theta)\,d\theta$$

$$V_d = \frac{\sqrt{2}\cdot 120}{2\pi}\left[\cos(u) + 1\right]$$

* During commutation

$$V_L = V_s$$

$$L_s \frac{di_s}{dt} = \sqrt{2}\cdot 120\cdot \sin(\omega t)$$

$$\omega L_s \frac{di_s}{d\omega t} = \sqrt{2}\cdot 120\cdot \sin\omega t$$

$$\omega L_s \int_0^{I_d} di_s = \int_0^{u} \sqrt{2}\cdot 120\cdot \sin(\theta)\,d\theta$$

$$\omega L_s I_d = \sqrt{2}\cdot 120\cdot \cos\theta \Big|_u^0$$

$$\omega L_s\cdot I_d = \sqrt{2}\cdot 120\left[1 - \cos(u)\right]$$

$$\cos(u) = 1 - \frac{\omega L_s I_d}{\sqrt{2}\cdot 120} = 0.8889$$

$\boxed{V_d = 51.01 \text{ volt}}$ $\boxed{u = 27.2^\circ}$ $\boxed{u = 0.47589 \text{ radian}}$

$\boxed{P_d = 510.1 \text{ W}}$

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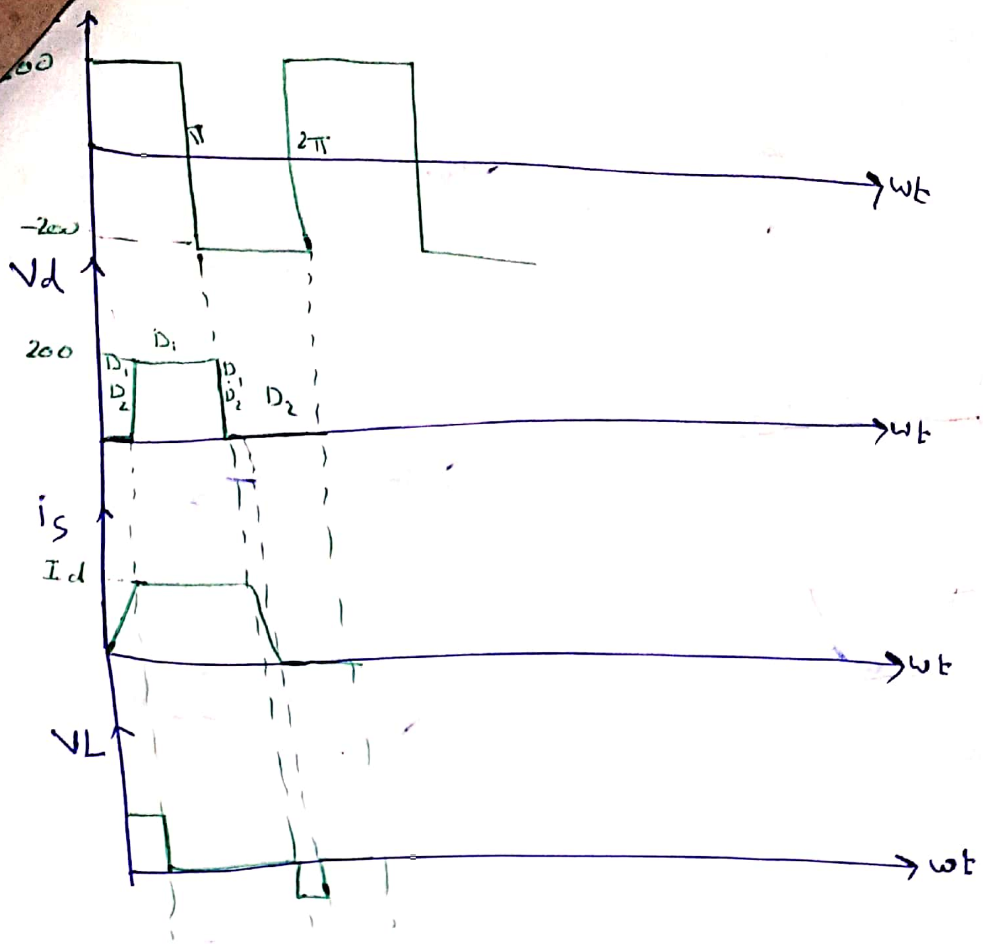
(c)






$$* \quad V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\,d\theta = \frac{1}{2\pi}\int_u^{\pi} 200\, d\theta = \frac{1}{2\pi}\cdot 200(\pi - u) = \cancel{100}\ 97 \text{ Volt}$$

* During commutation

$$V_L = V_s$$

$$L_s \frac{di_s}{dt} = 200$$

$$\omega L_s \frac{di_s}{d\omega t} = 200$$

$$\omega L_s \int_0^{I_d} di_s = \int_0^{u} 200\, d\omega t$$

$$\omega L_s I_d = 200 u$$

$$u = \frac{\omega L_s \cdot I_d}{200} = \frac{2\pi(60)(5m)(10)}{200} = 0.09424 \text{ radian}$$

$$P_d = (97)(10) = 970 \text{ W}$$

* $i_s(\theta)$ during commutation

$$\omega L_s \int di_s = \int 200\, d\omega t$$

$$i_s(0) = 0$$

$$\omega L_s\, i_s(\theta) = 200\theta + K$$

$$\boxed{0 = K_1}$$

$$i_s(\theta) = \frac{200\theta}{\omega L_s} + K_1$$

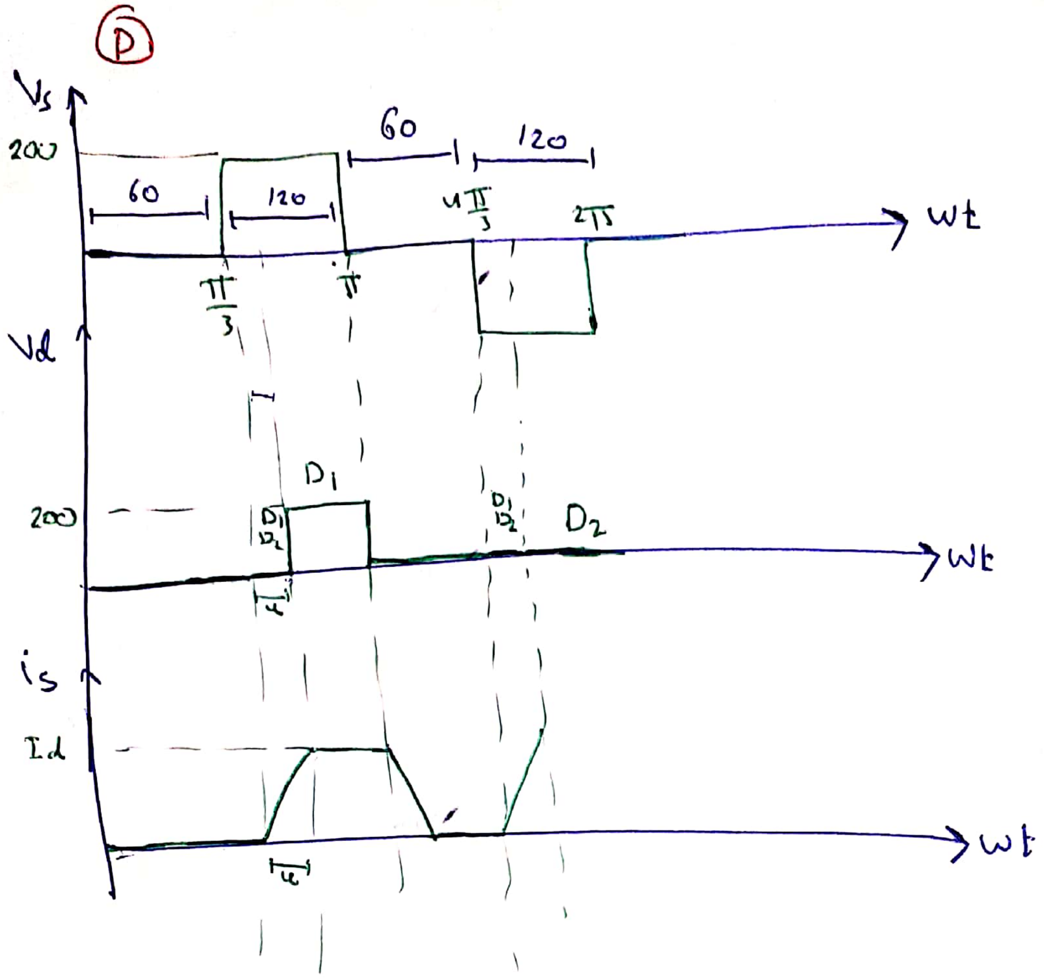
$$\boxed{i_s(\theta) = \frac{200\theta}{\omega L_s}}$$

$$\cancel{i_s(0) = 0 = K_1}$$

$$\boxed{\cancel{K_1 = \frac{-200\theta}{\omega L_s}}}$$

$$\cancel{i_s(\theta) = \frac{200\theta}{\omega L_s}}$$

Ⓓ




* during commutation

$$V_L = V_s$$

$$\omega L_s \frac{di_s}{d\omega t} = 200$$

$$\omega L_s \int di_s = \int_{\frac{\pi}{3}}^{u} 200\, d\omega t$$

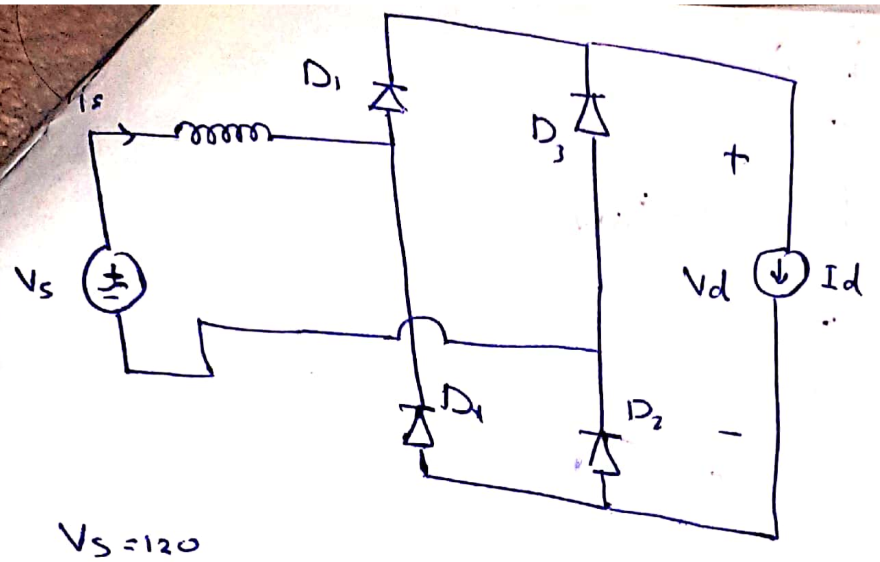
$$\omega L_s I_d = 200\left[u - \frac{\pi}{3}\right]$$

$$\omega L_s I_d = 200u - \frac{200\pi}{3}$$

$$\frac{\omega L_s I_d + \frac{200\pi}{3}}{200} = \boxed{u = 1.1414} \text{ radian}$$

* $V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\,d\theta = \frac{1}{2\pi}\int_u^{\pi} 200\,d\theta = \frac{1}{2\pi}\cdot 200\left[\pi - u\right] = 63.66$ Volt

* $P_d = V_d \cdot I_d = 636.7$ W




$V_s = 120$

$L_s = 1mH$

$I_d = 10A$

$$* \; V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\,d\theta = \cancel{\frac{1}{2\pi}}\; \frac{1}{\pi}\int_u^{\pi} \sqrt{2}\cdot 120\cdot \sin(\theta)\,d\theta$$

$$V_d = \frac{\sqrt{2}\cdot 120}{\pi}\left[\cos(u)+1\right]$$

* During commutation

$$V_L = V_s$$

$$L_s\frac{di_s}{dt} = \sqrt{2}\cdot 120\cdot \sin(\omega t)$$

$$\int_{-I_d}^{I_d} \omega L_s \, di_s = \int_0^u \sqrt{2}\cdot 120\cdot \sin(\omega t)\cdot d\omega t$$

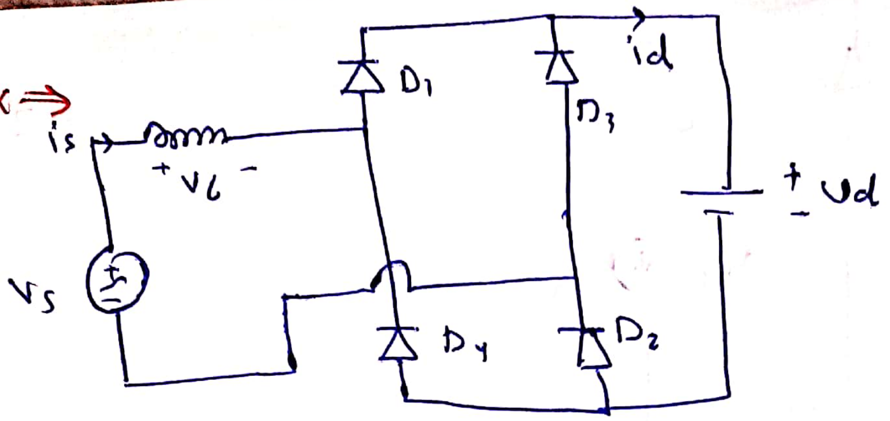
$$2\omega L_s I_d = \sqrt{2}\cdot 120\left[\cos(0) - \cos(u)\right]$$

$$\cos(u) = 1 - \frac{2\omega L_s I_d}{\sqrt{2}\cdot 120} = 0.9555$$

$$V_d = 105.634$$

$$\boxed{u = 17.157^\circ}$$

E.X ⇒




$V_s = 120$

$f = 60\,Hz$

$L_s = 1\,mH$

$V_d = 150$

Solu:-

$* \frac{\pi}{180}$

$$\theta_b = \sin^{-1}\left(\frac{V_d}{\sqrt{2}.V}\right) = \sin^{-1}\left(\frac{150}{\sqrt{2}.120}\right) = 62.11^\circ = 1.0841\ rad$$

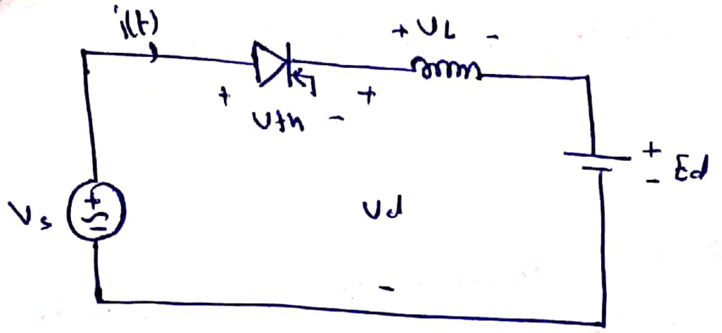
$$\theta_P = \pi - \theta_b = 117.886 = 2.058\ rad$$

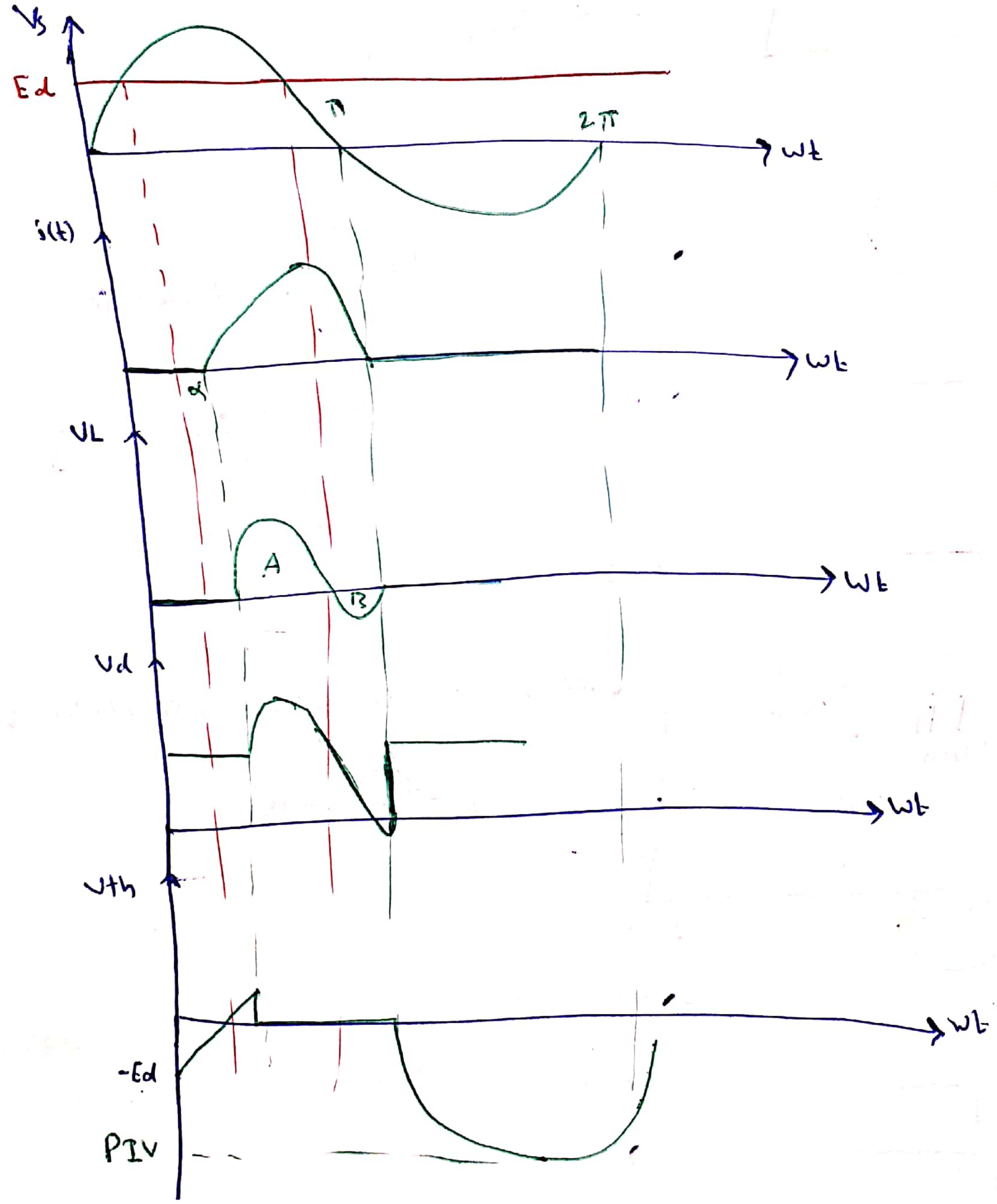
$$i_d(\theta) = \frac{\sqrt{2}.V}{\omega L_s}\left[\cos\theta_b - \cos\theta\right] - \frac{V_d.\theta}{\omega L_s} + \frac{V_d.\theta_b}{\omega L_s}$$

$$i_d(\theta_f) = 0 = \frac{\sqrt{2}.V}{\omega L_s}\left[\cos\theta_b - \cos\theta_f\right] - \frac{V_d.\theta_f}{\omega L_s} + \frac{V_d.\theta_b}{\omega L_s}$$

$$\theta_f = 0.4819\ rad = 27.61^\circ$$

$$\boxed{I_d = 1.1\,kA}$$



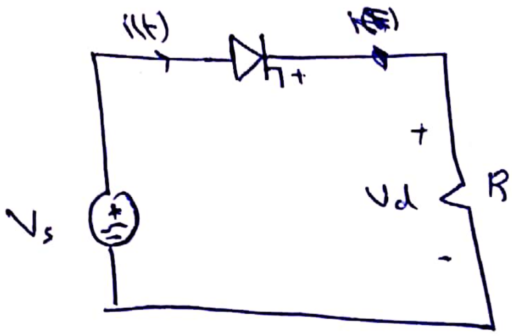




$$PIV = \sqrt{2}V_s - E_d$$

* Controlled rectifiers and inverters

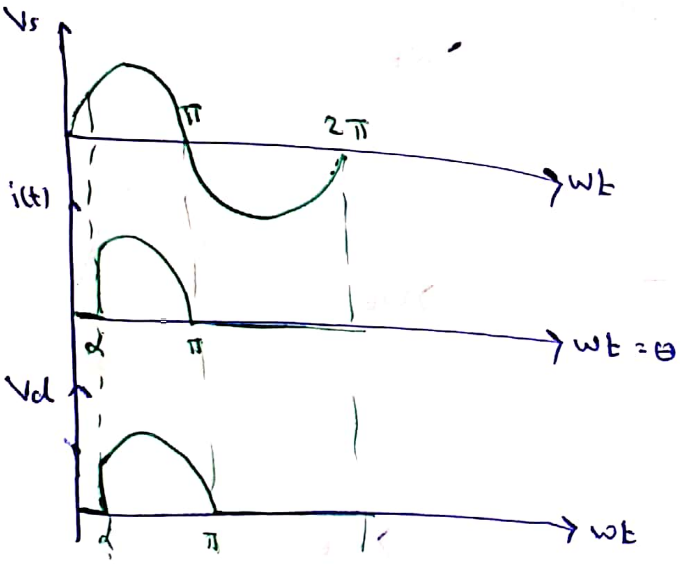
Line freq Ac $\longrightarrow$ controlled DC

## "Basic Thyristor circuit"




* Half wave controlled rectifier circuit with Pure resistive

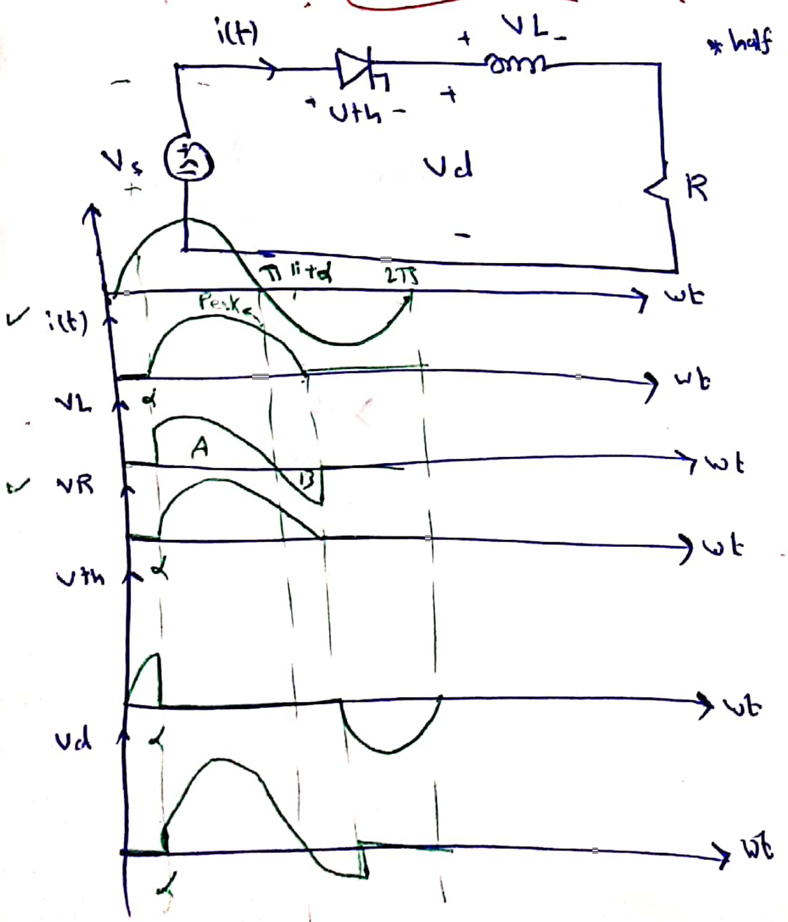
* $\alpha$ : Firing angle




$$V_d = \frac{1}{2\pi}\int_{\alpha}^{\pi} \sqrt{2}\cdot V \sin(\theta)\, d\theta$$

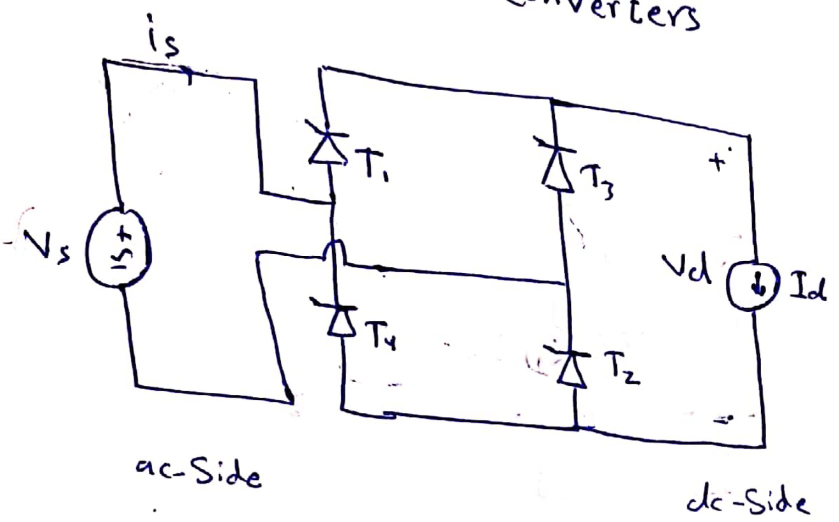
$$= \frac{\sqrt{2}\cdot V}{2\pi}\left[\cos(\alpha)+1\right]$$

* half wave controlled rectifier with inductive Load




$\boxed{V_d = V_L + V_R}$

# "Single Phase Converters"

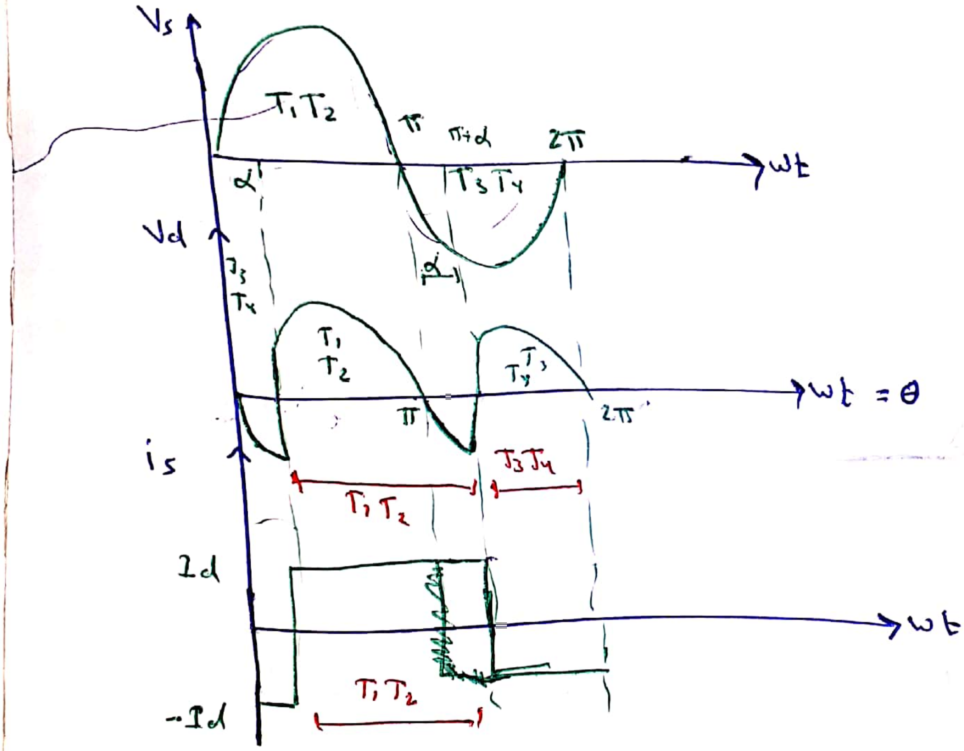



$L_s = 0$

(highly inductive Load)

$-V_s - V_d = 0$

$\boxed{V_d = -V_s}$




* $T_1$ and $T_2$ on at $\alpha$
* $T_3$ and $T_4$ on at $\pi+\alpha$

$$V_d = \frac{1}{2\pi}\int_0^{2\pi} V_d(\theta)\,d\theta = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} \sqrt{2}\,V\sin(\theta)\,d\theta = \frac{\sqrt{2}\,V}{\pi}\left[\cos(\alpha) - \cos(\pi+\alpha)\right]$$

$$= 0.9\,V\cos(\alpha)$$

* $THD\% = \dfrac{\sqrt{(I_d)^2 - (0.9\,I_d)^2}}{0.9\,I_d} \times 100\%$

$= 48.43\,\%$

* $DPF = \cos\alpha$
* $PF = 0.9\cos\alpha$

$$\boxed{\begin{array}{l} I_s = I_d \\ I_{s1} = 0.9\,I_d \end{array}}$$

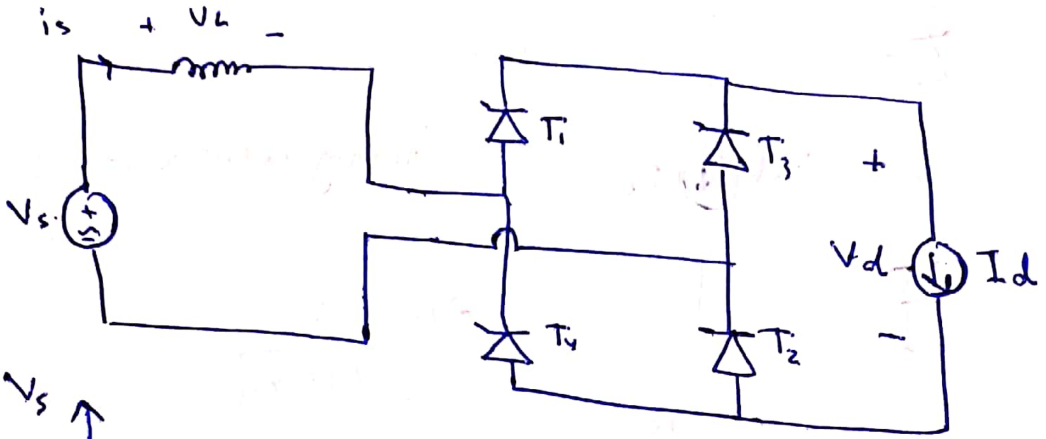
* $P_d = V_d \cdot I_d$

$P = V\,I_{s1}\cos\alpha$

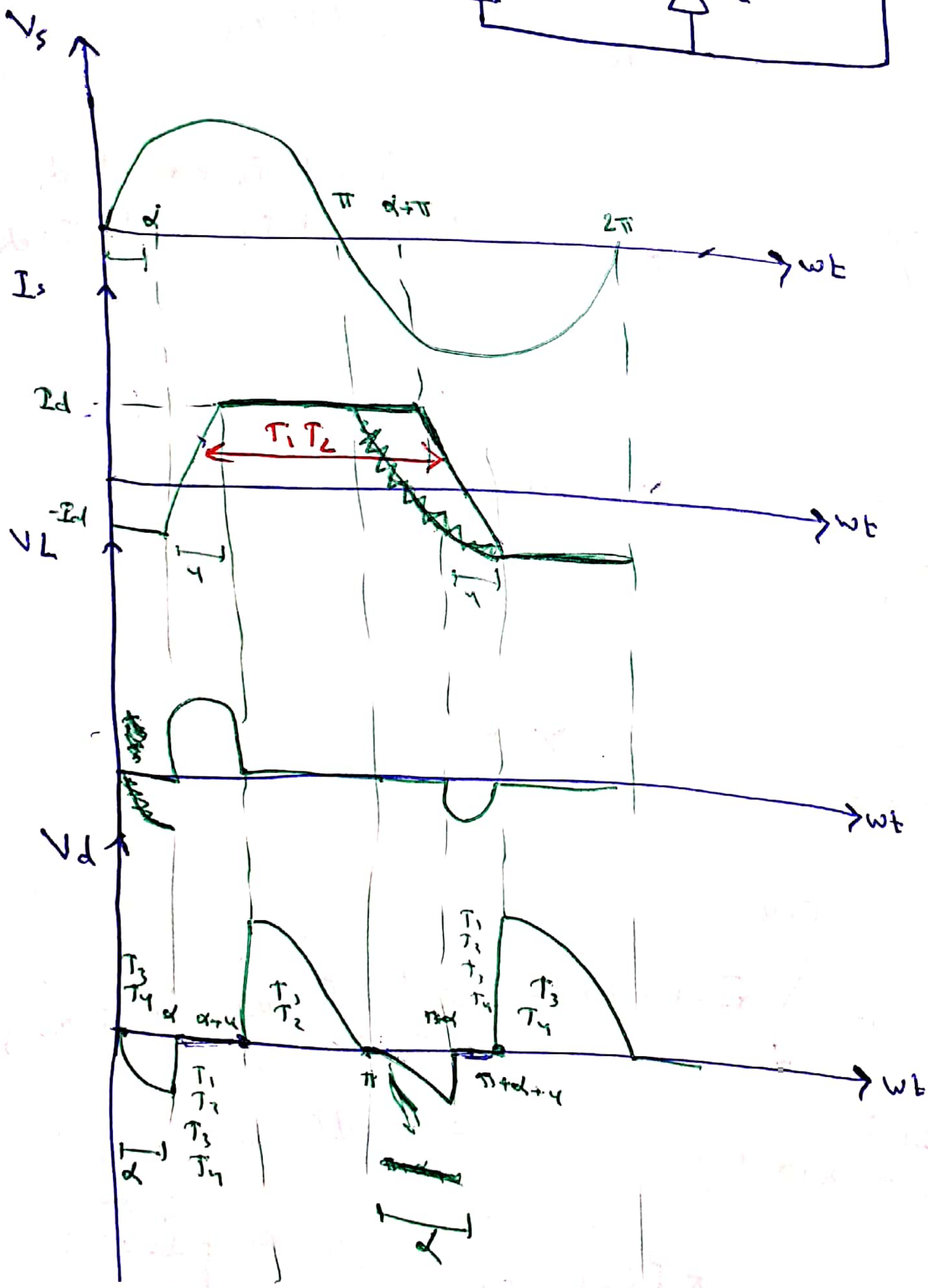
$= V[0.9\,I_d]\cdot\cos\alpha$

$P_d = 0.9\,V\,I_d\cos\alpha$

* effect of $L_s$ :-



is
+ VL -
Vs
T1
T3
T4
T2
+
Vd
Id
-

Vs
α
π
α+π
2π
wt
Is
Id
T1 T2
-Id
wt
VL
u
u
wt
Vd
T3
T4
α
α+u
T1
T2
T1
T2
T3
T4
π
π+α
T1
T2
T3
T4
π+α+u
T3
T4
wt
α
α

$$V_d = \frac{2}{2\pi} \int_{\alpha+u}^{\alpha+\pi} \sqrt{2}.V \sin\theta \, d\theta = \frac{\sqrt{2}.V}{\pi} \cos\theta \Big|_{\alpha+\pi}^{\alpha+u}$$

$$V_d = \frac{\sqrt{2}.V}{\pi} \left[ \cos(\alpha+u) - \cos(\alpha+\pi) \right]$$

$$\Rightarrow V_d = \frac{\sqrt{2}V}{\pi} \left[ \cos(\alpha+u) + \cos\alpha \right]$$

* During Commutation

$$V_L = V_s$$

$$\frac{L_s \, di_s}{dt} = \sqrt{2}.V \sin\omega t$$

$$\frac{\omega L_s \, di_s}{d\omega t} = \sqrt{2}.V.\sin\omega t$$

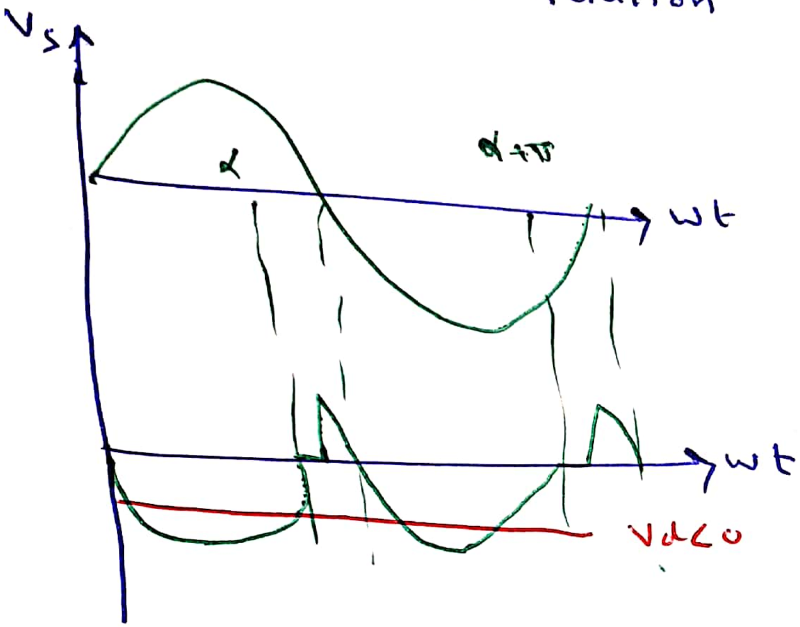
$$\omega L_s \int_{-I_d}^{I_d} di_s = \int_{\alpha}^{\alpha+u} \sqrt{2}.V \sin\theta \, d\theta$$

$$I_d.2\omega L_s = \sqrt{2}.V \left[ \cos(\alpha) - \cos(\alpha+u) \right]$$

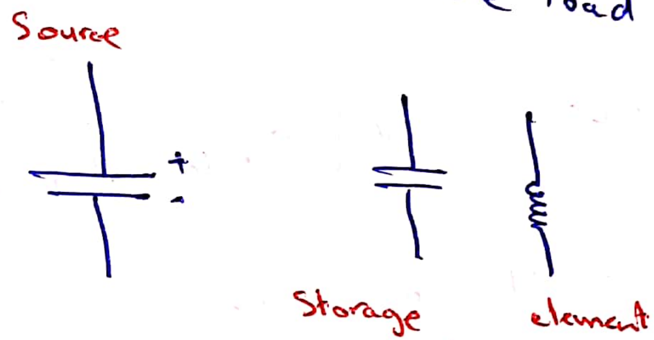
$\omega L_s$

$$V_d = 0.9 V \cos\alpha - \frac{2\omega L_s I_d}{\pi}$$

* inverter mode of operation




Controlled rectifier ccts can run in the inverter mode if $\alpha$ is greater than $90°$; and there is a Source in the load




$$V_d = 0.9\,V\cos\alpha - \frac{2\,\omega L_s I_d}{\pi} < 0$$

① $\alpha < 90$

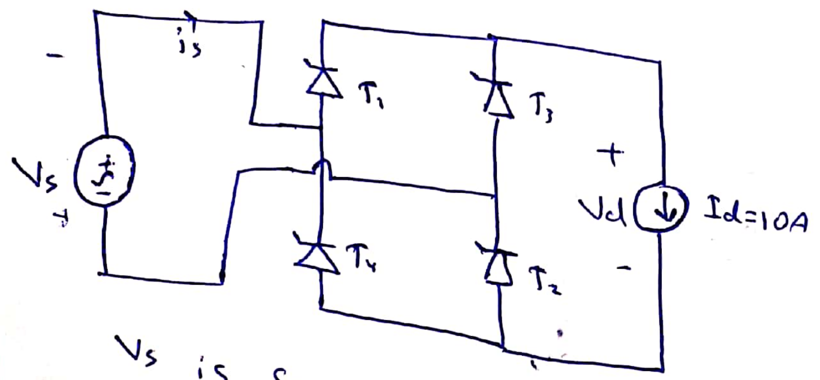
② Storage element

* $3_\phi$ Phase converter

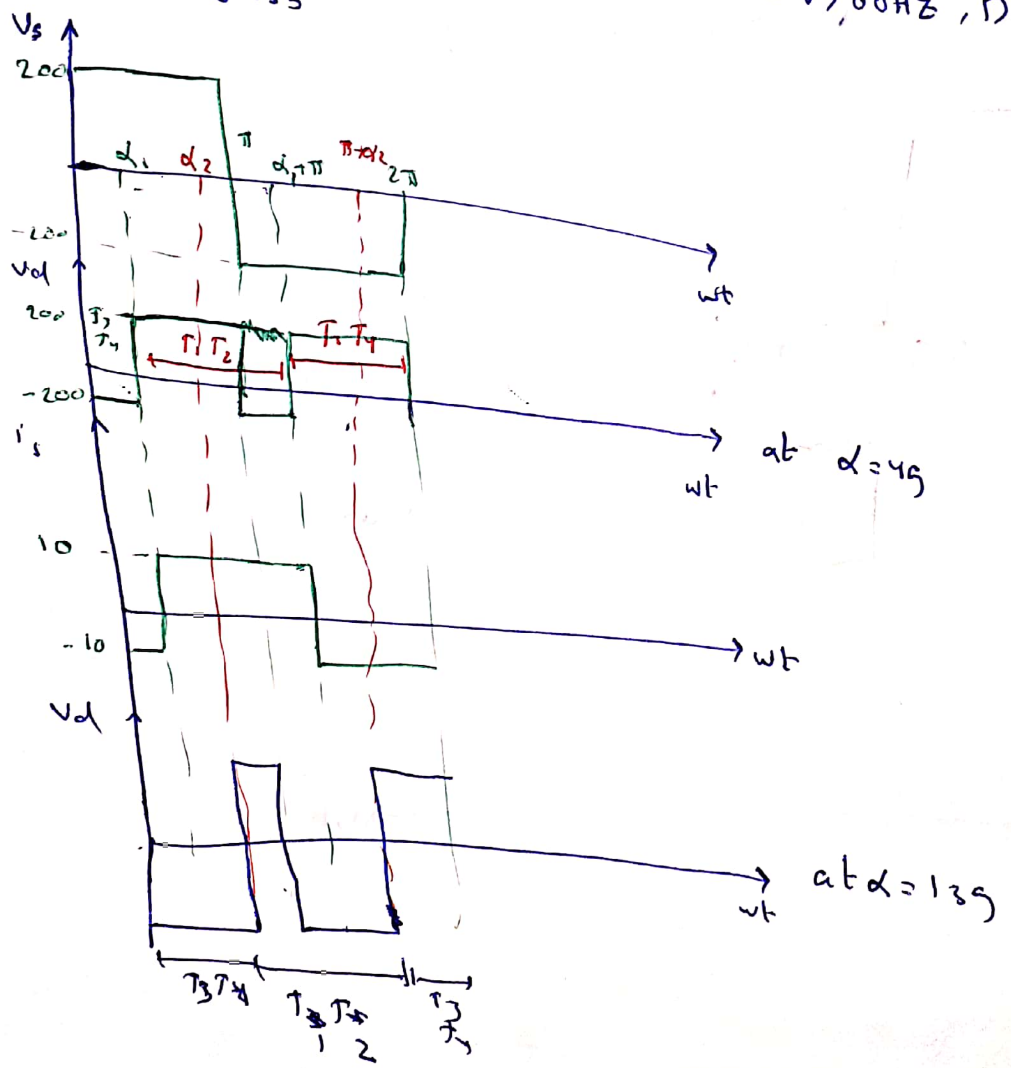
$V_d = 1.35\, V_{LL} \cos\alpha \Rightarrow \frac{3\sqrt{2}}{\pi} V_{LL}$

Line to line value of the input voltage

Ex⇒ 6-3




$V_s$ is Square wave with amplitude of 200 V, 60HZ, Draw wave-forms at $\alpha = 45°$ & $135°$



$$V_d = \frac{1}{\pi}\left[\int_{\alpha_1}^{\pi} 200\, d\theta + \int_{\pi}^{\pi+\alpha_1} -200\, d\theta\right]$$

$$P_d = V_d I_d = 10 \cdot V_d$$

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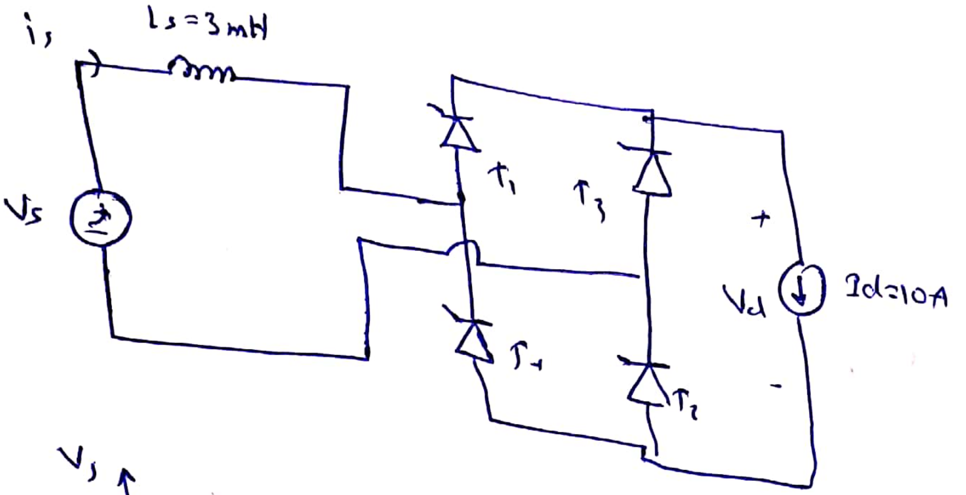
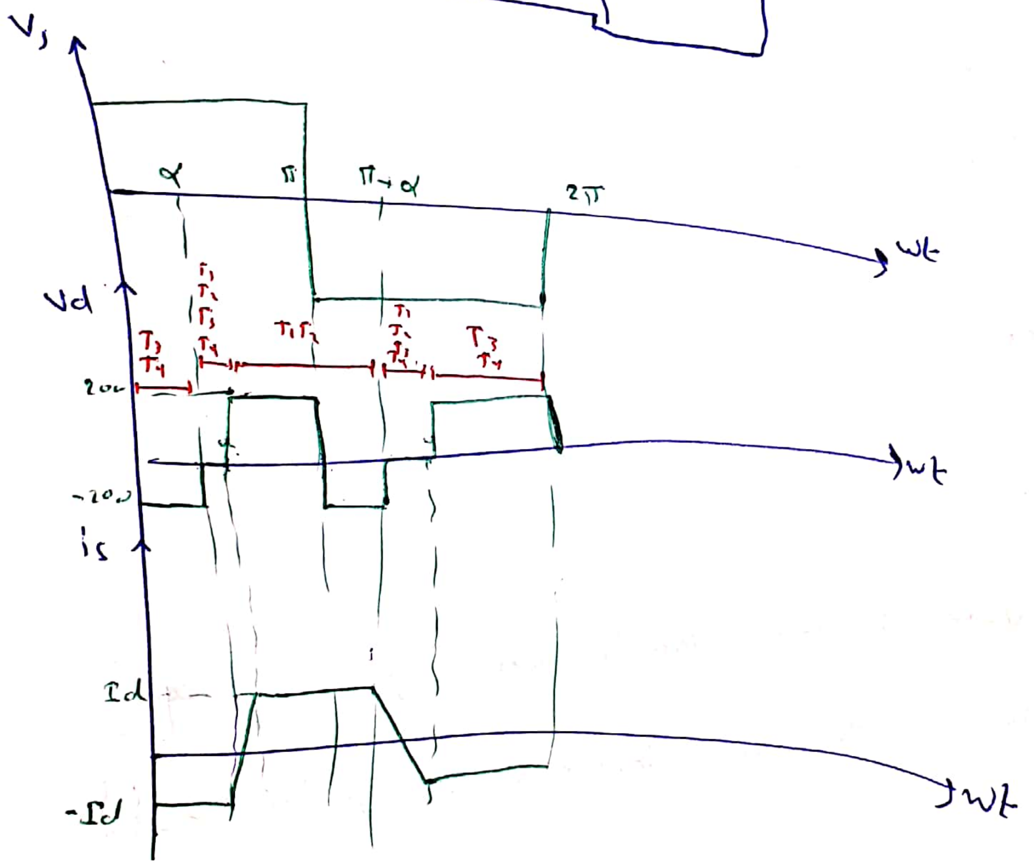
Scanned with CamScanner

E.x →




* During commutation

$V_L = V_s$

$$\omega L_s \frac{di_s}{d\omega t} = 200$$

$$\omega L_s \int_{-I_d}^{I_d} di_s = \int_{\alpha}^{\alpha+u} 200\,d\theta = 2\omega L_s I_d = 200(\alpha+u) - 200\alpha \rightarrow \boxed{u = 0.11} \text{ rad}$$

$$\boxed{u = 6.3^\circ}$$

$$V_d = \frac{1}{\pi}\left[\int_{\alpha+u}^{\pi} 200\,d\theta + \int_{\pi}^{\pi+\alpha} -200\,d\theta\right] = \ldots$$

* $i_s(t)$ during commutation

$$V_L = V_s$$

$$\omega L_s \int \frac{di_s}{d\omega t} = \int 200$$

$$di_s = \frac{1}{\omega L_s} 200 \, d\theta$$

$$i_s(\theta) = \frac{1}{(377)(3m)} 200\theta + K_1$$

$$i_s(\theta) = 176.8\theta + K_1$$

$$i_s(\tfrac{\pi}{4}) = -10 = (176.8)(\tfrac{\pi}{4}) + K_1$$

$$\boxed{K_1 = -148}$$

$$i_s(\theta) = 176.8\theta - 148$$

* Some information

① The average value of current through each Thyristors is Zero

② The rms value of the current through each Thyristor is $\underline{I_d}$