ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

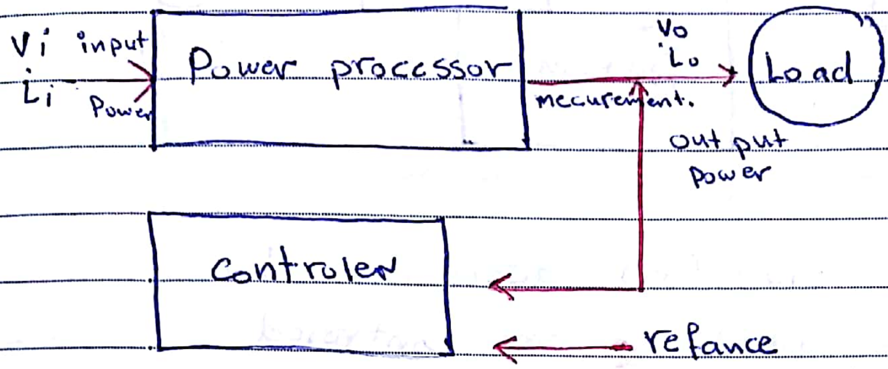
الكترونيات القوى

من شرح:

د.محمد وديان

جزيل الشكر للطالبة:

روند قطيشات



Block Digrom of PE System.

* power processor

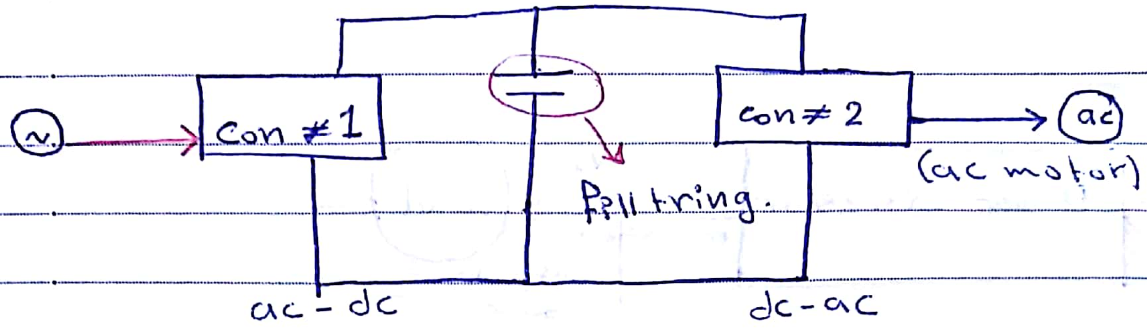
1. dc → (constant).
   ⓐ regulated magnitude.
   ⓑ adjustable "

2. Ac
   ⓐ constant frequancy adjustable magnitude.
   ⓑ adjustable frequancy, adjastable magnitude.

power Converters.
- Inverter
- rectifier.

1- ac to dc ⇒ rectifier
2- dc to ac ⇒ inverter
3. dc to dc ⇒ converter
   - set up
   - set down
   - set up - set down
   - full bridge

4- ac to ac ⇒ rectifier + inverter.



* converters are classified accuriding to how the Switches with in it are controled

1- Line frequancy converter the switches within the converter are turned on and off at the line frequancy (50 HZ) (Diode) ⇒ on and off by the nature of the input Power.

2- Switched (forced - commutated) converter :-
The Switches with in the converter are turned on and off at frequencies much higher - then the line frequency (5 K HZ - 25 K HZ) using additional (external) control Signal.

* Overview of power Semiconductor Switches :-

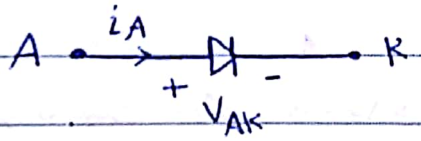
According to the degree of controlabitity, Power Semiconductor devices can be classification.

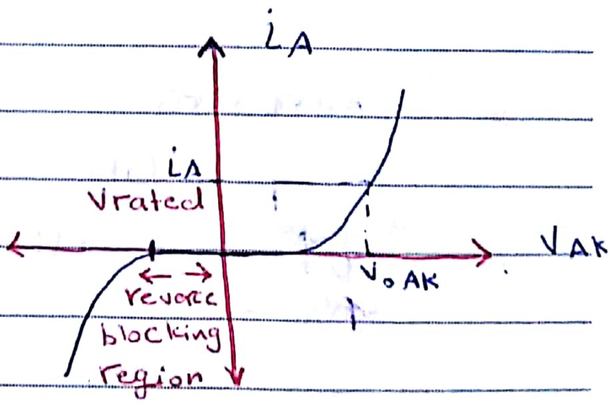
1- Diode :- on and off by the nature of the input voltage. (un controled)

2- Thyrstors :- on by additional control signal and off by the nature of the ~~Input source~~ supply (Semi - controled)

3- controlled switches :- on and off by external (additional) Signals (controlled).
(BJT, IGBT, MosFET, GTO).

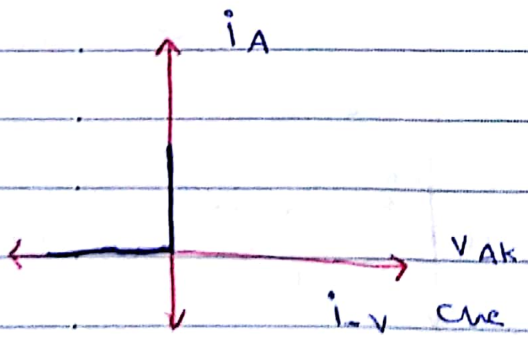
* Diodes :-





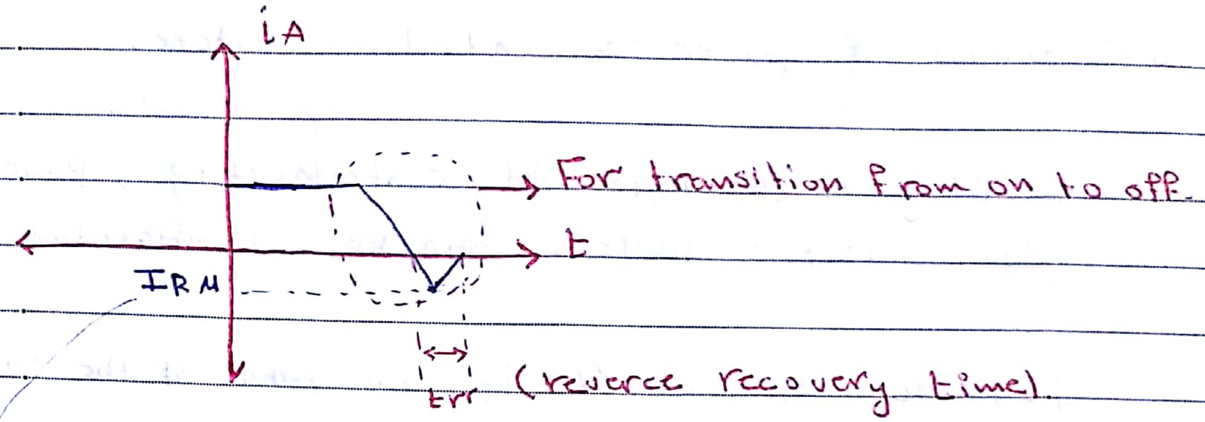
i - v che (partical)

$$R_D = \frac{V_{AK}}{i_A}$$



i-v che (ideal)

$$R_D = \frac{V_{AK}}{i_A} = \frac{0}{i_A} = 0$$



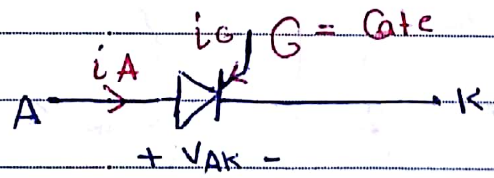
IRM :- Maximum reverce ~~[illegible]~~ value.

* ~~[illegible] Diodes~~ *(Types Power Semiconductor Diodes) :-

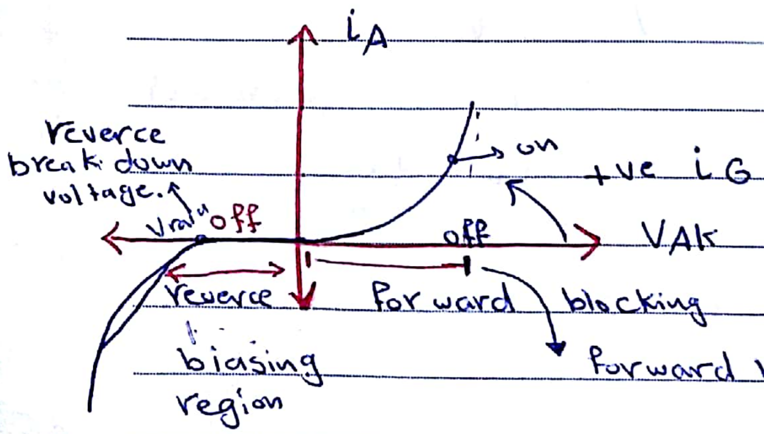
1- Schottky Diodes. (50 -100) Vrated
2- Fast Recovery Diodes.
3- Line Frequency.

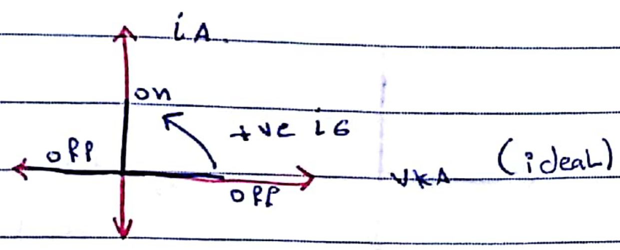
Check Vrated from the book.

* Thyristors :-



* يتصرف مثل Diode في حالة on
* لتحويل on → off بحاجة
لـ +ve V and +ve iG

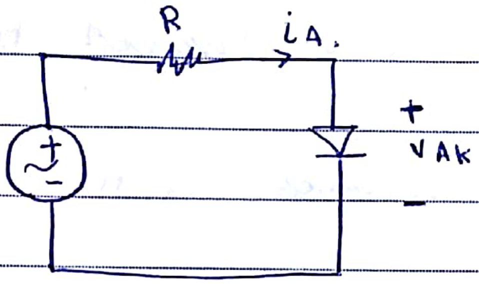


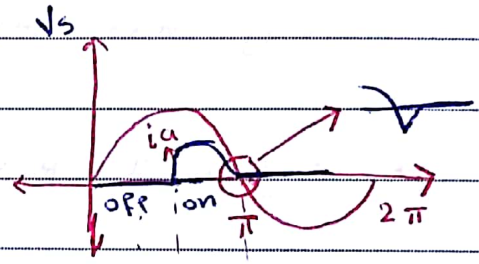


becomes off.

* The Thyristors when the current tries to be negative.

* The Thyristors has the same chara of the Diode whiches reverce recouverre time. (trr).
* The thyristor become on which +ve gate and +ve voltage are applied.



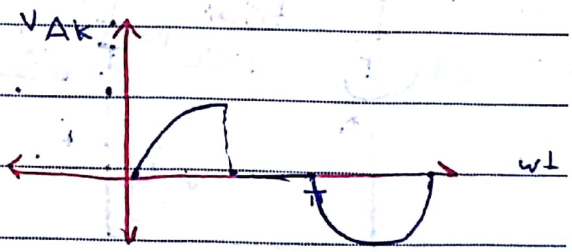


$0 \rightarrow \alpha \Rightarrow$ off

$\alpha \rightarrow \pi \Rightarrow$ on

$\pi \rightarrow 2\pi \Rightarrow$ off.

$i_A =$ [illegible] $\Rightarrow V_{AK} =$ Zero.



* ضروري switched
* تتحمل تيار عالي في حالة on
* تتحمل جهد عالي في حالة off
* Power Low ⇒ on
* Power = ∞ ⇒ off

* Desired characterisitice of controllable Switiches (BJT ...) :-

* Block Large forward and reverse voltages with Zero current when off.

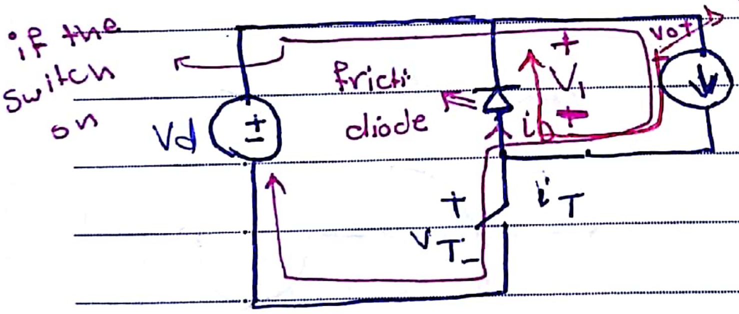
* conduct large current with Zero voltage drop when on.

* Switching from on to off vice versa with very short interval. when ~~triggered~~ triggered

* very Small power consumed by the control cct

* Consider the following commonely encountered Ciruit in power electrones.

if the switch off



I_o = highly inductive Load (DC motor)

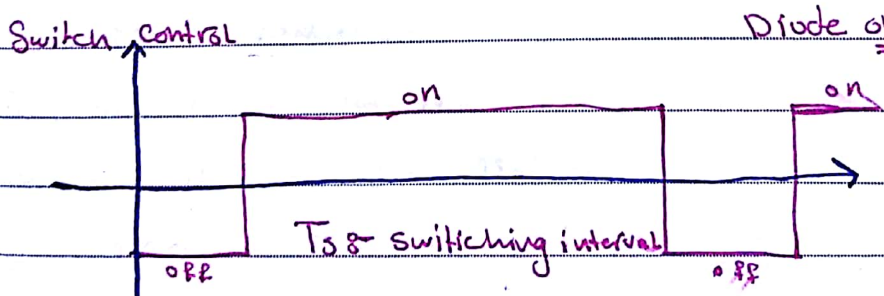
R

L

L,R عبارة عن I_o

عند ما يتغير التيار I_o فإن حيبه L

Diode on ينعكس فيمر

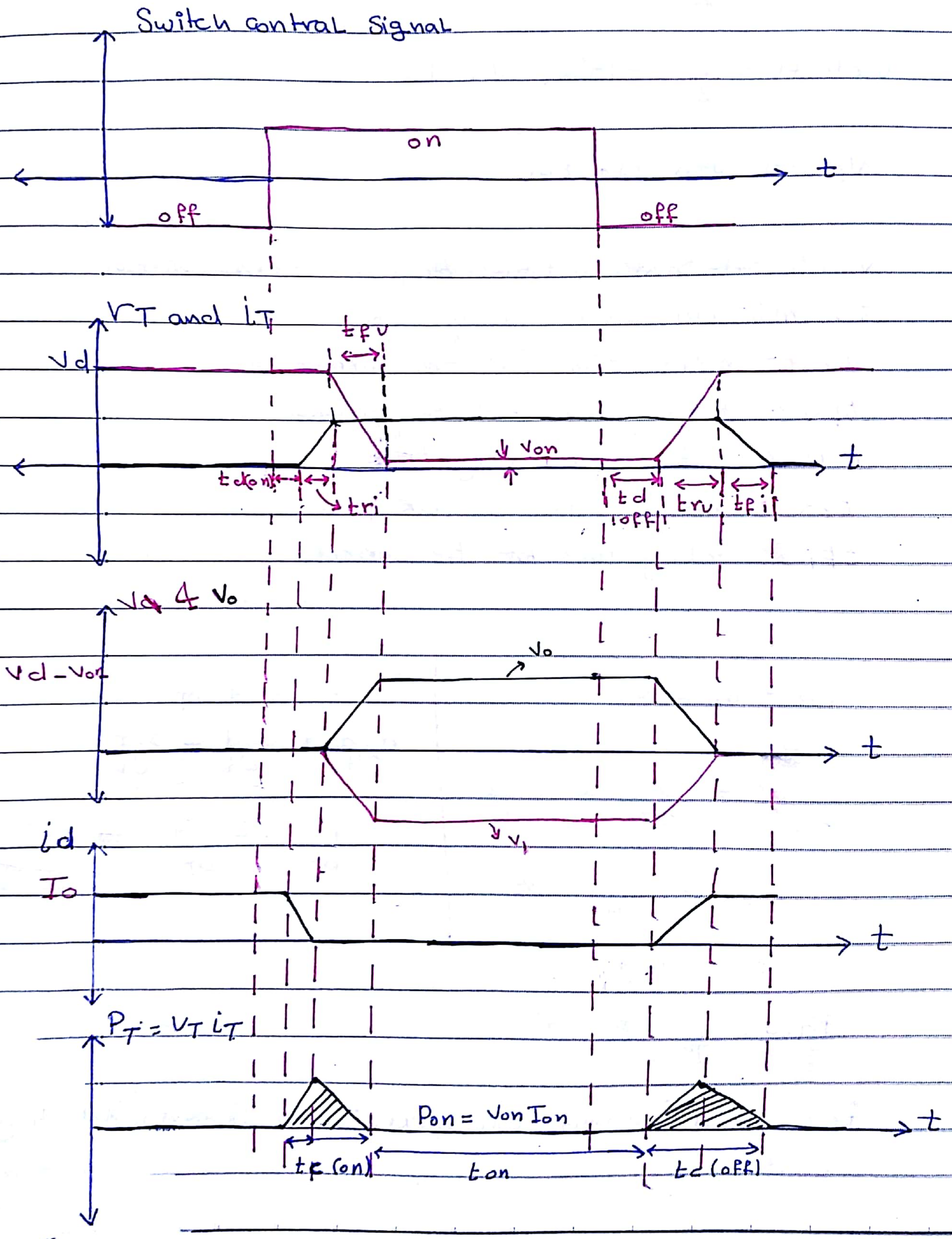


$$-V_d + V_o + V_T = 0$$

$$V_o + V_T = V_d \Rightarrow \frac{dv_o}{dt} + \frac{dv_T}{dt} = 0$$

$$\frac{dv_o}{dt} = -\frac{dv_T}{dt}$$

if the Switch on → Diode on (reverce).



$$W_{c(on)} = \frac{1}{2} t_{c(on)} V_d I_o$$

$$W_{c(off)} = \frac{1}{2} t_{c(off)} V_d I_o$$

$$W_{on} = V_{on} I_o t_{on}$$

V_{on} :- on-state voltage drop across the switch
$t_{d(on)}$:- on-state delay time
t_r :- rising time for the current
t_{fv} :- falling time for the voltage
$t_{d(off)}$:- off-state delay time.
t_{rv} :- rising time for the voltage
t_{fi} :- falling time for the current

$$V_d = V_o + V_T$$

$$\underbrace{\cancel{\frac{dV_d}{dt}}}_{} ^{\text{Zero}} = \frac{dV_o}{dt} + \frac{dV_T}{dt}$$

$$\frac{dV_o}{dt} = -\frac{dV_T}{dt} \#$$

$$I_o = i_d + i_T$$

$$\cancel{\frac{dI_o}{dt}} = \frac{di_d}{dt} + \frac{di_T}{dt}$$

$$\frac{di_d}{dt} = -\frac{di_T}{dt} \#$$

$$P_{avg} = \frac{1}{T} \int_0^T P(t)\, dt$$

P_s : Power avarage consumed by the switch (switching power)

$$P_s = \frac{1}{2} V_d I_o \frac{1}{T_s}\left[t_c(on) + t_c(off)\right]$$

$$= \frac{1}{2} V_d I_o f_s \left[t_c(on) + t_c(off)\right]$$

$$P_{on} = \frac{V_{on} I_o t_{on}}{T_s} = V_{on} I_o t_{on} f_s, \quad P_{off} = 0$$

$P_{off} = 0$, $i_T \Rightarrow 0$ durring the off State.

$$P_{total} = P_s + P_{on} + \cancel{P_{off}}_{\swarrow 0}$$

$$P_{total} = P_s + P_{on}.$$

* Desired characheristies of Controllable 8-

1. Small Leakage (Reversed) current in the off-State

~~2) Small time of change on & off~~.

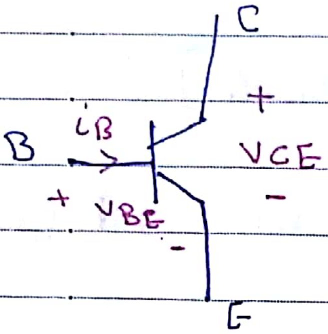
2- Small on state voltage drop.

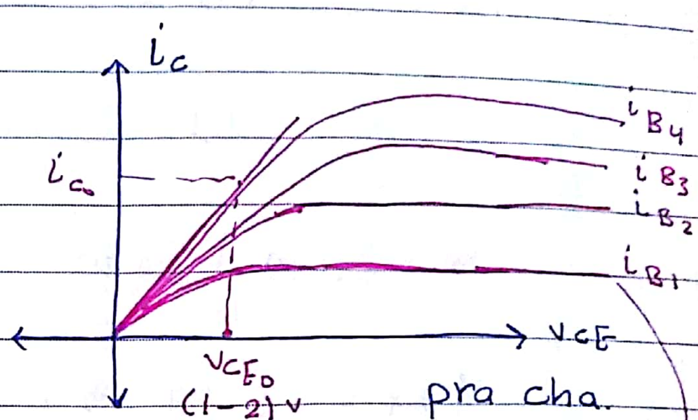
3) Small power consumed by the control cct.

4) Short turn-on & off time intervals.

5) High on-State current rating.

* BJT :-



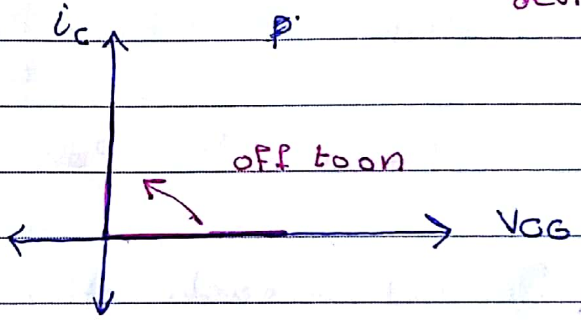


pra cha.

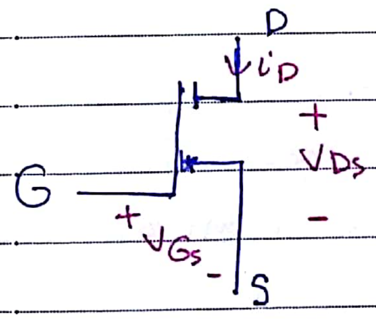
current Controlled device

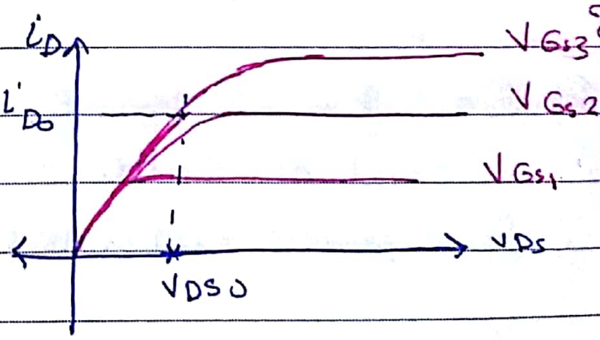
off [illegible] 1400 V

few handred Ampers

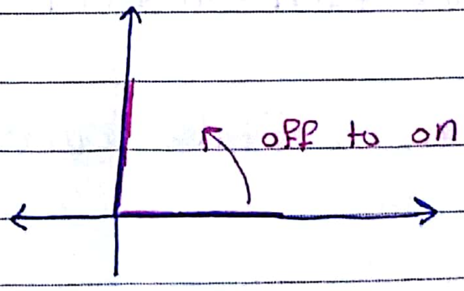


* Mosfet :-



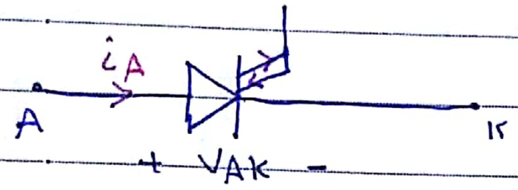


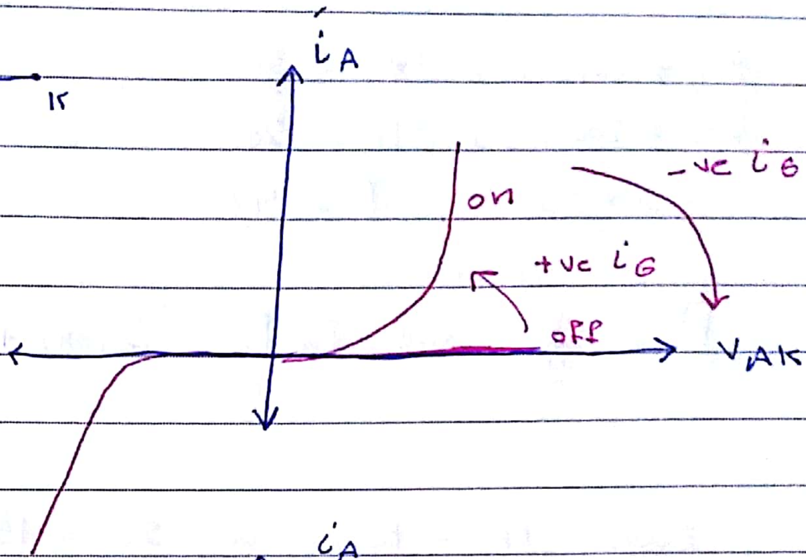
Voltage Controlled Device



Scanned by CamScanner

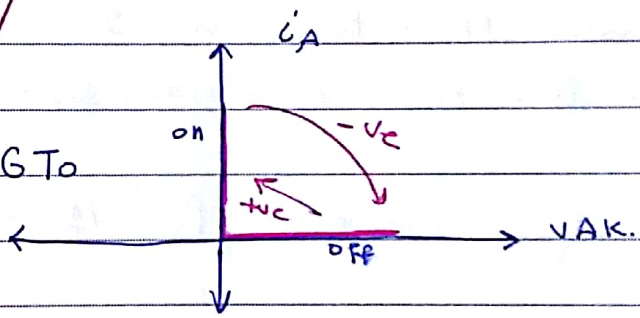
* GTo (Gate Turn off Thyristors) :-





Description:- Like the thyristor, GTo is turned on by +ve gate pulse.

unlike → the thyristor, GTo is turned off by −ve gate pulse.



* Justifications of using idealized Cha of ~~sw~~ switches

* The switches will be treated in this course as ideal, because:-

1- on State Voltage drop is very small compared with rated voltage. (o

2- off state Current is very small compared with rated current (Large resistance in off state).

3- Very small time required for Switching.

*P(2-1) Page(32) :-

$t_{ri} = 100\,ns$, $t_{fv} = 50\,ns$

$t_{rv} = 100\,ns$, $t_{fi} = 200\,ns$

$V_d = 300$, $I_o = 4A$.

$$P_s = \frac{1}{2} V_d I_o f_s (t_{c(on)} + t_{c(off)})$$

$t_{con} = t_{ri} + t_{fv} = 100 + 50 = 150\ ns$

$t_{c\,off} = t_{rv} + t_{fi} = 100 + 200 = 300\ ns.$

$$P_s = \frac{1}{2} * 300 * 4 * f_s [150 + 300] * 10^{-9}$$

$$= 2.7 * 10^{-4}\ f_s$$

If $f_s = 25\ KHZ$. $\therefore P_s = 6.75\ w$

If $f_s = 100\ KHZ$ $\therefore P_s = 27\ w.$

$P_{rated} = 300 * 4 = 1200\ w.$

* Idealized cha of controllable switches
1 - Zero or - State voltage drop
2 - Zero ~~reversed~~ current in the off state
3 - Zero time duration for switching.
4 - Power required for the control cct is zero

CH3: Review of basic Electrical circuit concepts

* Average power and rms current :-

$$p(t) = v(t)\, i(t).$$

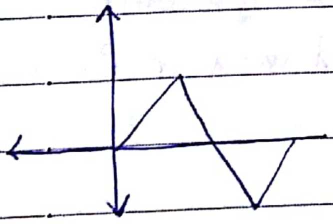
$$P_{avg} = \frac{1}{T}\int_0^T p(t)\,dt = \frac{1}{T}\int_0^T v(t)\, i(t)\,dt.$$

$$= \frac{1}{T}\int_0^T i^2(t)\, R\,dt =$$

$$= \frac{R}{T}\int_0^T i^2(t)\,dt.$$

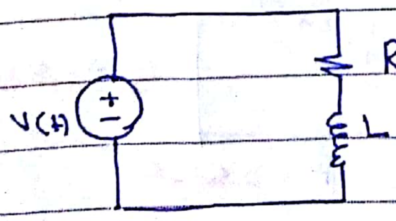
$$= R\, I^2 \quad \#$$

$$I = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} \Rightarrow \text{rms value of } I.$$



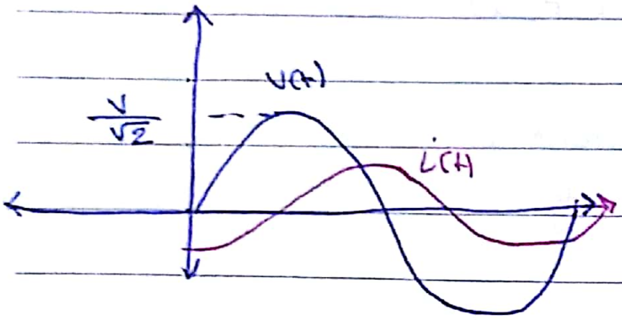
$$I_{rms} = \frac{I}{\sqrt{3}}$$

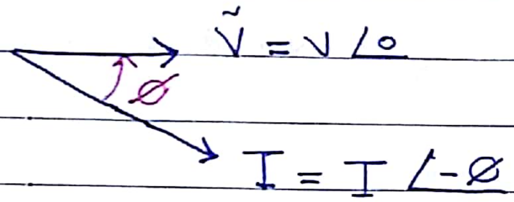
* Steady - state wave forms with sinusoidal voltages and currents.



$$v(t) = \sqrt{2}\, V \cos\omega t$$

$$i(t) = \sqrt{2}\, I \cos(\omega t - \theta).$$





$\tilde{V} = V e^{j0} \Rightarrow$ exponential form

$\tilde{I} = I e^{-j\phi} \Rightarrow$ exponential form.

$$\tilde{Z} = \frac{\tilde{V}}{\tilde{I}} = \frac{V e^{j0}}{I e^{-j\phi}} = \frac{V}{I} \angle \phi$$

$$= \frac{V}{I}(\cos\phi + j\sin\phi) = Z\cos\phi + jZ\sin\phi$$

rectangular form.

$$\tilde{S} = \tilde{V}\,\tilde{I} = V e^{j0}(I e^{-j\phi})$$

↳ complex power.

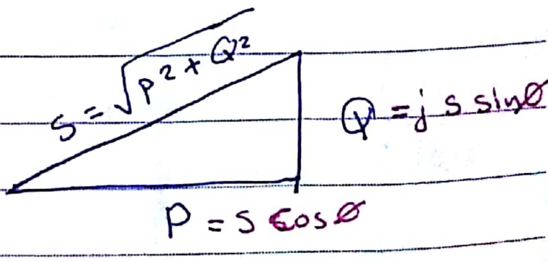
$$= V I e^{j\phi} = \underbrace{S\cos\phi}_{\text{active}} + \underbrace{jS\sin\phi}_{\text{reactive.}}$$

$S \Rightarrow$ apparent power

PF = 1 ⇒ pure R.

PF ⇒ Lagging ⇒ R and L or L

PF ⇒ leading ⇒ R and C or C



Scanned by CamScanner

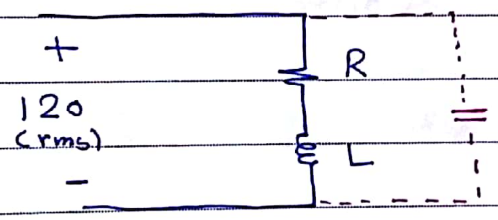
$$PF = \cos\phi = \frac{P}{S}$$

$$= \cos\left[\tan^{-1}\frac{Q}{P}\right] = \cos\left[\sin^{-1}\frac{Q}{S}\right].$$

PF ⇒ Lagging $= R + j\omega L$ or $j\omega L$.

PF ⇒ leading $= R + \frac{1}{j\omega C}$ or $\frac{1}{j\omega C}$

Ex 8-



$P = 1\ kW$

$P_F = 0.8$

$C = ?$ $F = 60\ Hz$.

P_F combined $= 0.95$ Lagging.

Before conecting C

$$P_F = \frac{P}{S} \Rightarrow 0.8 = \frac{1000}{S}$$

$$S = 1250\ VA.$$

$$Q = \sqrt{S^2 - P^2} = 750$$

$$\tilde{S} = 1000 + j750\ VA.$$

After connecting C

$P = 1000\ W$

$P.f = \frac{P}{S} \Rightarrow 0.95 = \frac{1000}{S}$

$$S = \sqrt{1000^2 + (750 - Q_c)^2}$$

$$0.95 = \frac{1000}{\sqrt{1000^2 + (750 - Q_c)^2}}$$

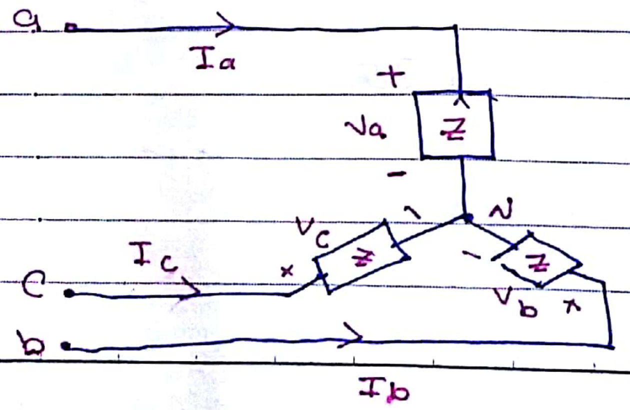
$Q_c = 421.3\ VAR$ Q After.

$Q_c = \frac{V^2}{\frac{1}{wc}} = w c V^2.$

$421.3 = (120)^2 (2\pi 60)\ C.$

$C = 77.6\ \mu F.$

* Three-phase Circuts.



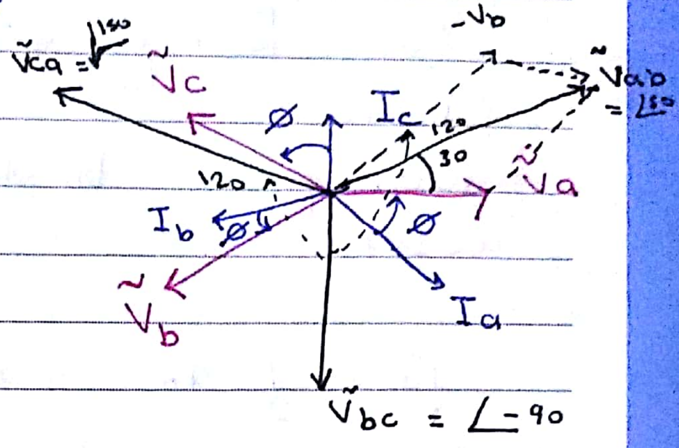
$$\tilde{I}_a = \frac{\tilde{V}_a}{Z} = \frac{V_a}{Z} e^{-j\phi}$$

$\xrightarrow{} +R_C$

$\xrightarrow{} -R_L$

$$\tilde{I}_b = \frac{V_a}{Z} e^{-j(\phi - 120)}$$

$$\tilde{I}_c = \frac{V_a}{Z} e^{-j(\phi + 120)}$$



$$\tilde{V}_L = \tilde{V}_{LL} = \tilde{V}_a - \tilde{V}_b = V_a\angle 0 - V_a\angle -120$$

$$= \sqrt{3}\, V_a \angle 30$$

* $P = \sqrt{3}\, V_L I_L \cos\phi$
  $= 3\, V_\phi I_\phi \cos\phi.$

* $Q = \sqrt{3}\, V_L I_L \sin\phi$
  $= 3\, V_\phi I_\phi \sin\phi$

→ for both Δ or Y.

* $S = \sqrt{3}\, V_L I_L = 3 V_\phi I_\phi.$

$+$ seq (abc)

$-$ seq (acb)

* Non SinuSoidoL Waveforms in Steady-State :-

* The steady-state voltage and current in power Electronic are nomaily periodic but non SinSuidaL.

* Fouiries Analysis of Repitive waveforms :

$$f(t) = F_0 + \sum_{h=1}^{\infty} f_h(t) = F_0 + \sum_{h=1}^{\infty} \left\{ a_n \cos(h\omega_0 t) + b_n \sin(h\omega_0 t) \right\}.$$

Periadic Function

$\omega = 2\pi f$

$$F_0 = \frac{1}{2} a_0 \Rightarrow \text{avarge value}$$

$$a_h = \frac{1}{\pi} \int_0^{2\pi} f(t) \cos(h\omega t) \, \underset{\theta}{d\omega t}, \quad h = 0, 1, 2, 3 \ldots$$

$$b_h = \frac{1}{\pi} \int_0^{2\pi} f(t) \sin(h\omega t) \, \underset{\theta}{d\omega t}, \quad h = 1, 2, 3, \ldots$$

if $h = 0$

$$a_0 = \frac{1}{\pi} \int_0^{2\pi} f(t) \cos(0) \, d\omega t.$$

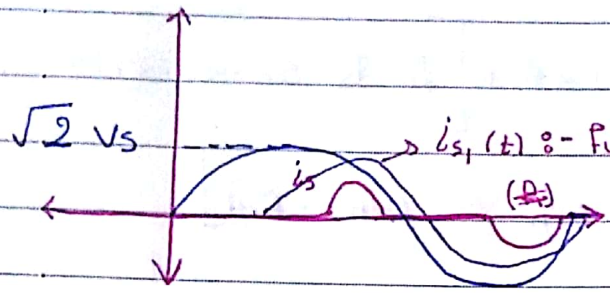
$$= \frac{1}{\pi} \int_0^{2\pi} f(t) \, d\omega t = 2F_0$$

* The rms Value of $f(t)$ is.

$$F = \sqrt{F_0^2 + F_1^2 + \cdots + F_n^2}$$

$$\sqrt{\frac{1}{2\pi} \int_0^{2\pi} (f(t))^2 \, d\omega t}$$

* Line current Distuction :-



$i_{s_1}(t)$:- Fundamental companienot of $i_s(t)$ } 1^{st} compents
(f)

$$i_s(t) = i_{s_1}(t) + \sum_{h \neq 1}^{\infty} i_{sh}(t).$$

$i_{s_1}(t)$ Fundamental component of $i_s(t)$.

i_{sh} :- the componentsat the h harmonic
$f_h = h f_1$.

$$i_s(t) = \sqrt{2}\, I_{s_1} \sin(\omega_1 t - \phi_1) + \sum_{h \neq 1}^{\infty} \sqrt{2}\, I_{sh} \sin(\omega_h t - \phi_h)$$

I_{sh} ↳ rms of the h component

I_{s_1} ↓ rms value of fundamental

ϕ_1 ↓ the phase Shift between V_s & i_{s_1}

$$* \ THD\% = \sqrt{\frac{I_s^2 - I_{s_1}^2}{I_{s_1}^2}} * 100\ \%$$ ⇒ total harmonic Distution

$THD = 0$ Signal sin لو كانت Sin عن بعد مقدار تقيس *

$$P_1 = \frac{1}{T} \int_0^T P(t)\, dt$$

$$= \cancel{\frac{1}{T}} \cancel{\int_0^T} v_s(t)\, \cancel{i_s(t)}\, \cancel{dt}$$

$$P_1 = \frac{1}{T_1}\int_0^{T_1} v_s(t)\; i_s(t)\; dt.$$

$$P_1 = \frac{1}{T_1}\int_0^{T_1} \sqrt{2}\, V_s \sin(\omega_1 t) * \left[\sqrt{2}\, I_{s_1} \sin(\omega_1 t - \phi_1) + \sum_{n\neq 1}^{\infty} \sqrt{2}\, I_{sn} \sin(\omega_n t - \phi_n)\right]$$

$$= V_s\, I_{s_1} \cos(\phi_1)$$

$$\int_0^{2\pi} \sin\theta \; \sin 2\theta \; d\theta = 0$$ ذاكر

Conclusion

* The ~~[illegible]~~ Conclusion of the current compents at harmunic freq ~~[illegible]~~ of avargy value of the power with pure sinsouidal voltage is zero.

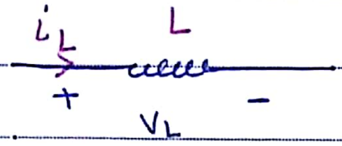
* $S = V_s\, I_s$

$$Pf = \frac{P}{S} = \frac{V_s\, I_{s1} \cos(\phi_1)}{V_s\, I_s}$$

$$= \frac{I_{s1}}{I_s} \cos(\phi_1).$$ $\left[\begin{array}{l} V \to \sin t \\ I \to \text{not } \sin t \end{array}\right]$ لما يكون

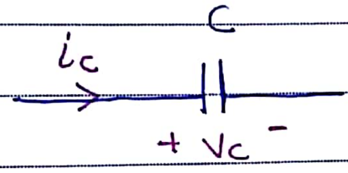
$\cos(\phi_1) \to$ DPF : Displacement power facter.

* Inductor and capacitor Responses.



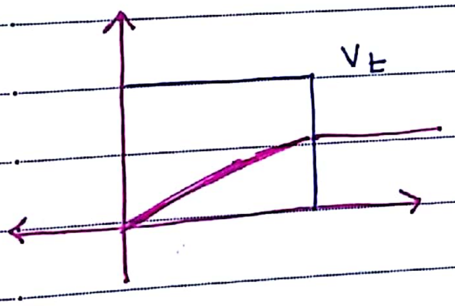
$$V_L = L \frac{di_L(t)}{dt}.$$

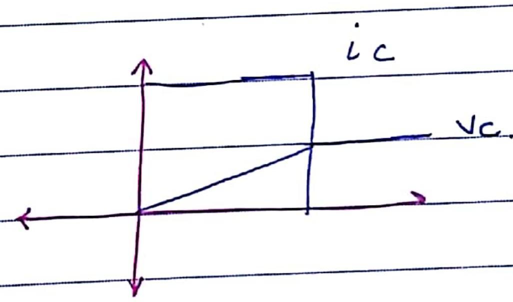
$$i_L(t) = \frac{1}{L} \int V_L(t)\, dt + k.$$

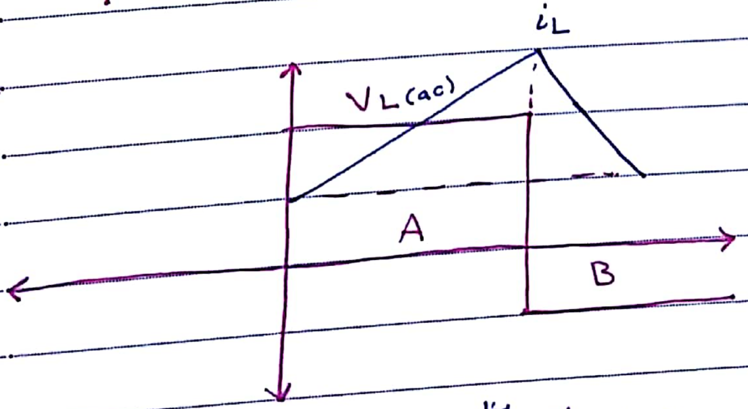


$$i_c = C \frac{d\, v_c(t)}{dt}$$

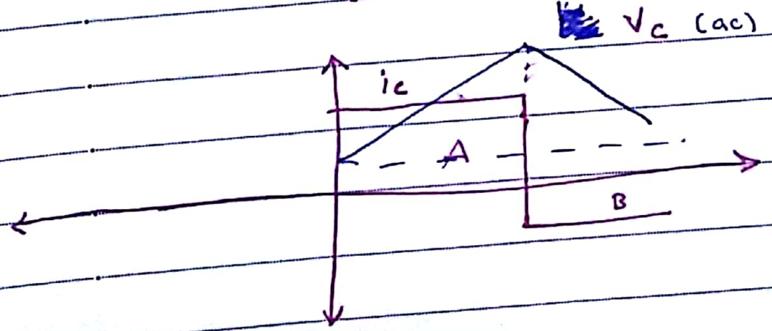
$$V_c = \frac{1}{c} \int i_c\, dt + k.$$







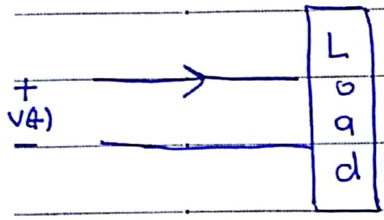
A = B



The avargy value of voltage acroec inductor in steady state = zero.

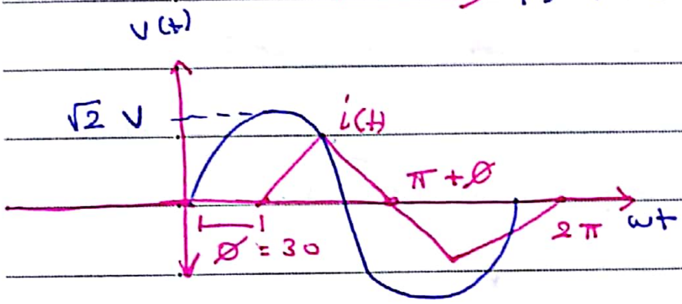
The avarge value of current throught the capacitor at steady state = Zero.

3-6 pp (58) :-



* $V(t) = \sqrt{2}\, V \sin(\omega t)$, $V = 120$
* $i(t)$ is a trigulow wave with an amplitude $A = 10\,A$
* $i(t)$ Lags $v(t)$ by $30°$ ($\phi = 30$)

Find → P, DPF, THD, PF = ??



$$P = V I_1 \cos\phi$$

$$I_1 = \frac{i_1(t)}{\sqrt{2}}$$, * $i(t)$ is symmetric on the x-axis

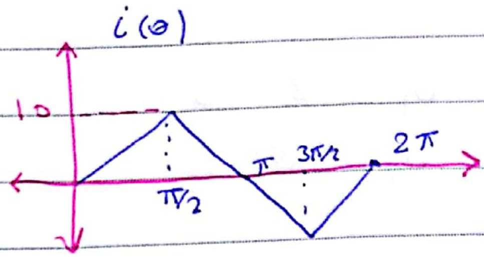
$a_n = 0$, $b_n = 0$ for even numbers of n

b_1, b_3, b_5, -----.

$$I_1 = \frac{b_1}{\sqrt{2}}$$

$$b_n = \frac{1}{\pi} \int_0^{2\pi} i(t) \sin(n\omega t)\, d\omega t$$

$$= \frac{1}{\pi}\int_0^{2\pi} i(\theta)\,\sin(n\theta)\,d\theta$$



$$i(\theta) = \begin{cases} \frac{20}{\pi}\theta , & 0 < \theta < \frac{\pi}{2} \\ -\frac{20}{\pi}\theta + 20 , & \frac{\pi}{2} < \theta < \frac{3\pi}{2} \\ \frac{20\theta}{\pi} - 40 & \frac{3\pi}{2} < \theta < 2\pi \end{cases}$$

$\left(\frac{\pi}{2}, 10\right)$, $(\pi, 0)$

$$m = \frac{10 - 0}{\pi/2 - \pi} , \quad \frac{10}{-\pi/2} = -\frac{20}{\pi}$$

$$y - 0 = -\frac{20}{\pi}(\theta - \pi)$$

$$y = -\frac{20\theta}{\pi} + 20$$

$$\cancel{b_n = \frac{1}{\pi}\left[\int_0^{\pi/2} \frac{20\theta}{\pi}\,d\theta + \int_{\pi/2}^{3\pi/2}\left(20 - \frac{20}{\pi}\theta\right)d\theta + \int_{3\pi/2}^{2\pi}\left(\frac{20}{\pi}\theta - 40\right)d\theta\right]}$$

$$b_n = \frac{1}{\pi}\left[\int_0^{\pi/2} \frac{20\theta}{\pi}\sin(n\theta)\,d\theta + \int_{\pi/2}^{3\pi/2}\left(20 - \frac{20}{\pi}\theta\right)\sin(n\theta)\,d\theta + \int_{3\pi/2}^{2\pi}\left(\frac{20\theta}{\pi} - 40\right)\sin(n\theta)\,d\theta\right]$$

$b_1 = 8.106$

$b_3 = -0.9006$

1- $P = V\, I_1 \cos\theta = 120 \times \frac{8.106}{\sqrt{2}} \cos 30$

$= 596\ w$

2- $DPF = \cos\phi = \cos 30 = 0.866$

3- $THD = \sqrt{\frac{I^2 - I_1^2}{I_1}} \times 100$

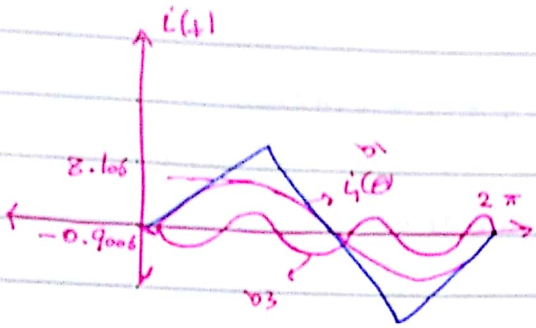
$$I = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} [i(\theta)]^2 d\theta}$$

$$I = \sqrt{\frac{1}{2\pi} \left[\int_0^{\pi/2} \left(\frac{20\pi}{0}\right)^2 d\theta + \int_{\pi/2}^{\frac{3\pi}{2}} \left[20 - \frac{20\theta}{\pi}\right]^2 + \int_{3\pi/2}^{2\pi} \left(\frac{20\theta}{\pi} - 40\right)^2 d\theta \right]}$$

$I = 5.7736$

$$THD = \frac{\sqrt{(5.7736)^2 - \left(\frac{8.106}{\sqrt{2}}\right)^2}}{\frac{8.106}{\sqrt{2}}} \times 100\% = 12.1\%$$

$$PF = \frac{I_1}{I} \cos\theta = \frac{8.106}{\sqrt{2} \times 5.7736} \cos(30) =$$



* How to Integration Symblically MATLAB :-

```
>> Syms a x
>> A = int (a * sin(x) , x)
>> A =
        -a.* Cos (x)
>> B = int ( a * Sin (x) , a)
>> B =
        (1/2)* a^2 * sin (x).
>> C = int (a * sin (x) , x, 0, pi)
```

$= \int_0^{\pi} a \sin x \, dx$

حدود تكامل.

```
>> C =
        2*a
>> F = a^2 * exp (x).
>> D = in t (F, X, 1, 2)
>> D =
        a^2 exp (2) - a^2 exp (1).
```

Variable precision aritmatic

```
>> Vpa (D, 5)
   = 4.6708 * a^2.
```

جواب D مقرب ل 5 digit

$$b_h = \frac{1}{\pi}\Big[\underbrace{\int_0^{\pi/2} \frac{20\theta}{\pi}\sin(h\theta)\,d\theta}_{F_1} + \int_{\pi/2}^{3\pi/2} \underbrace{\left(-\frac{20\theta}{\pi}+20\right)\sin(h\theta)}_{F_2}$$

$$+ \int_{3\pi/2}^{2\pi} \underbrace{\left(\frac{20\theta}{\pi}-40\right)\sin(h\theta)\,d\theta}_{F_3}\Big]$$

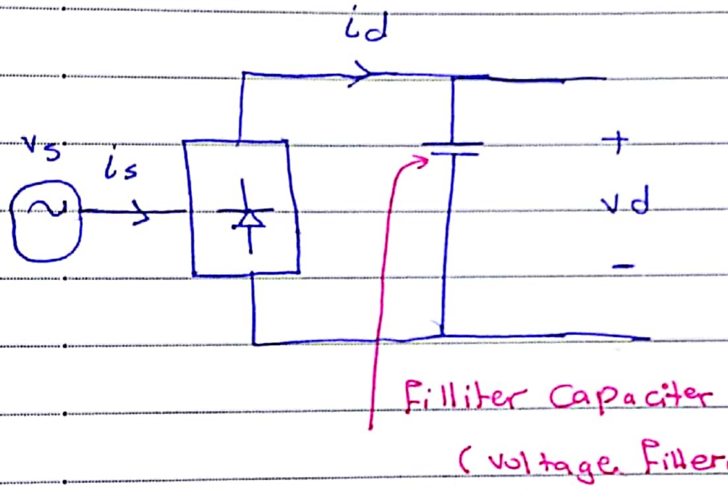
```
>> syms h th
>> F1 = int[((20*th)/pi)*sin(h*th), th, 0, (pi/2)]

>> F1 =

>> F2 = int[((-20*th)/pi)*sin(h*th), th, (pi/2), (3pi/2)]

>> F2 =

>> F3 =

>> F3 =

>> bh = (1/pi)[F1 + F2 + F3]

      =

>> b1 = subs(bh, h, 1)

   b1 = 8.106
>> b2 = subs(bh, h, 2)
   b2 = 1.6 * 10^-19
```

>> b3 = subs (bn, n, 3)

b3 = 0.9006

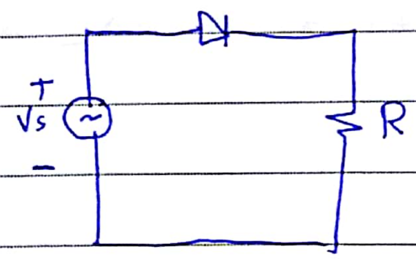
* Line Frequency Diode uncontrolled Rectifiers.

Line frequency = 50 or 60 HZ.

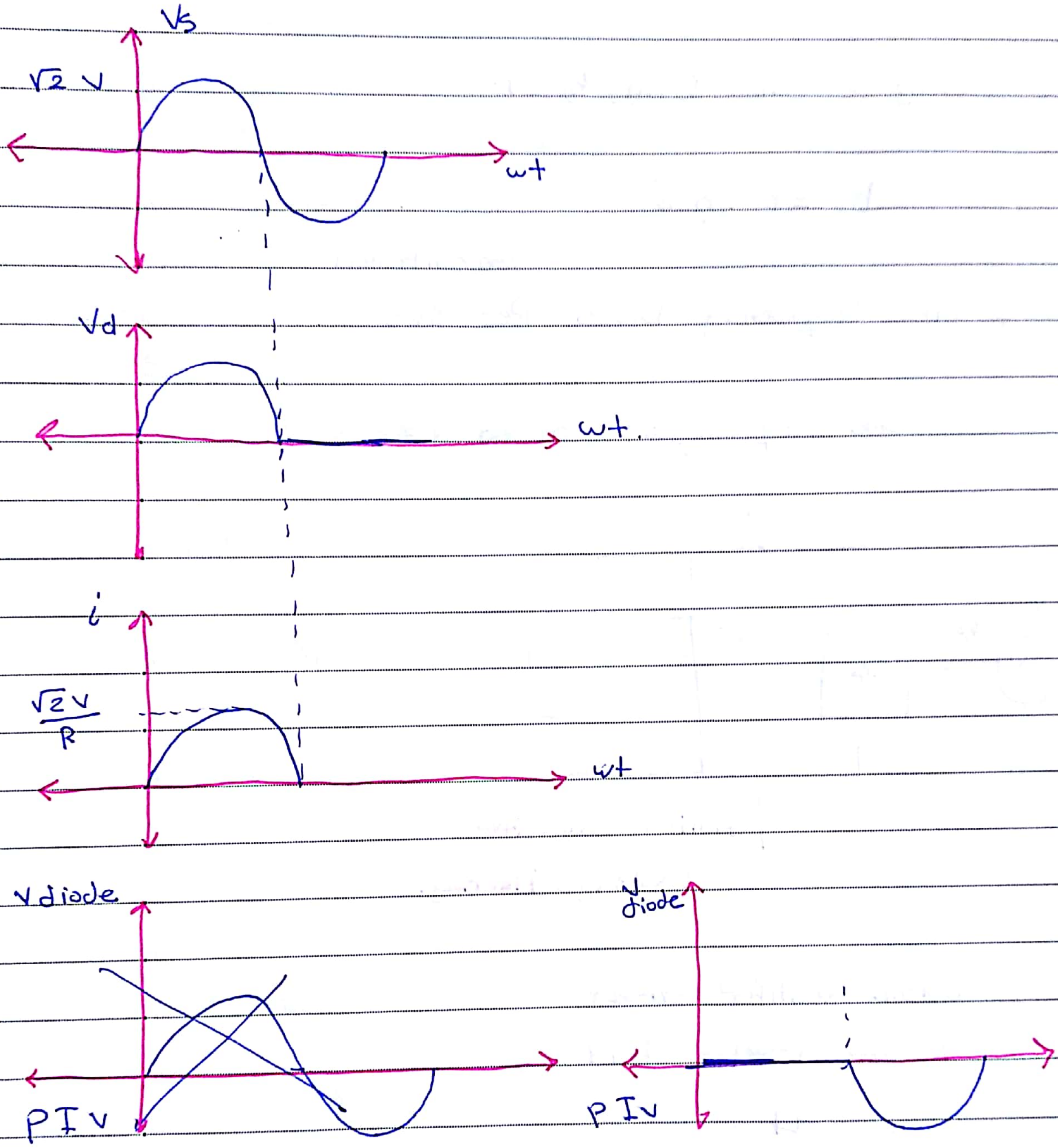


* Basic Rectifer consept

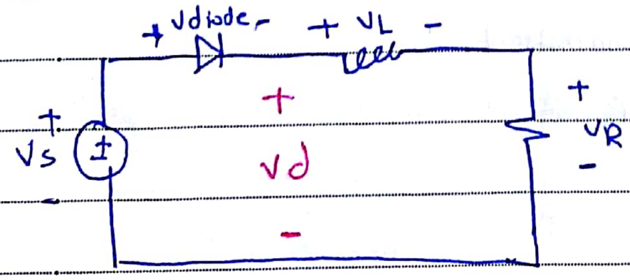
1- pure resistive Load



Half - wave uncontrolled rectifer with pure resister Load.
crt



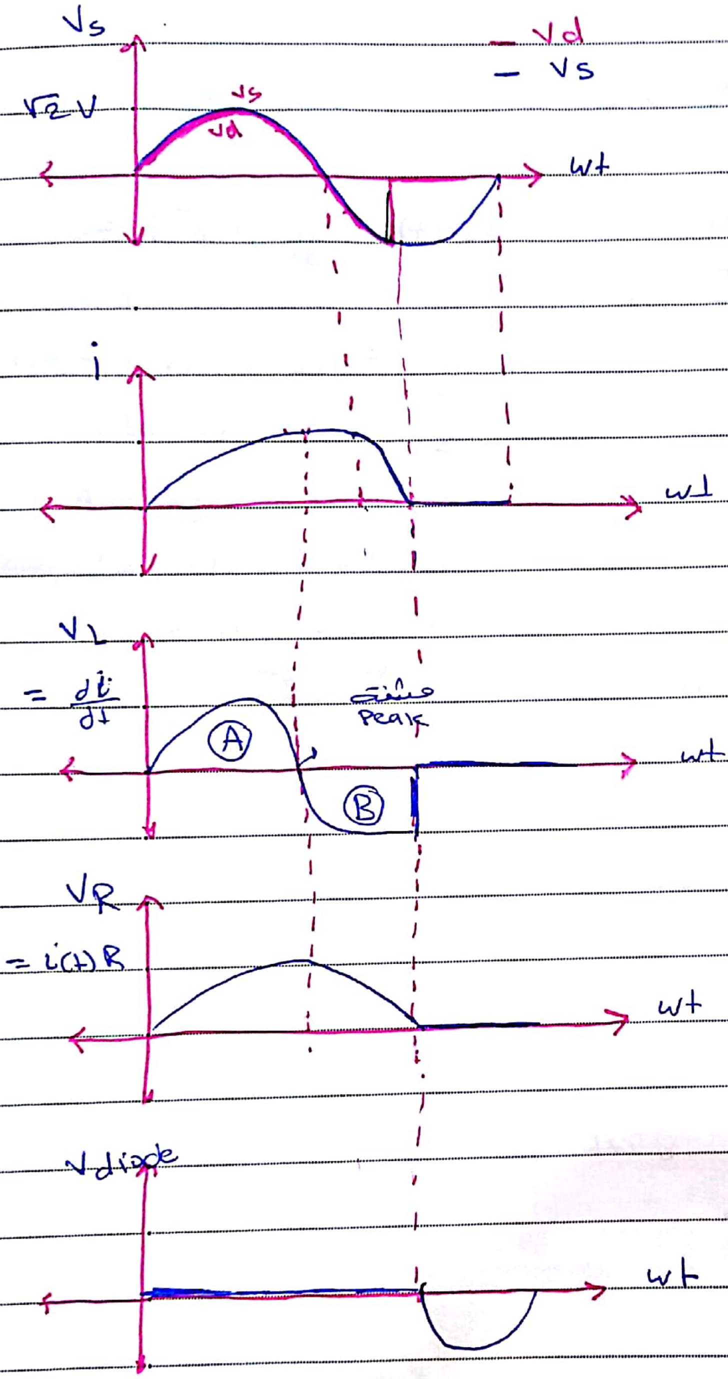
2- Inductive Load

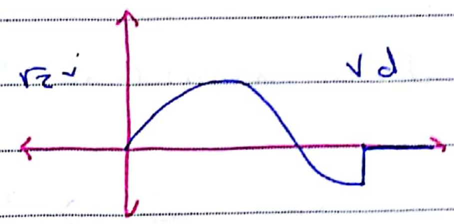


$$-V_s(t) + L\frac{di}{dt} + Ri = 0$$

$$L\frac{di}{dt} = \sqrt{2}\, V \sin\omega t - R\, i(t)$$

$i(t)$ is not pure sinusiodil





Filter ك يعمل inductance
ل current زيادة تدريجية
و نقصان تدريجي.

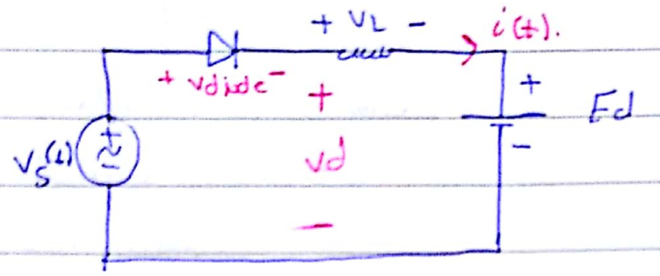
Diode on

$V_d = V_s$

Diode off

$V_d = 0$

③ Load with an internal dc voltage.



$$-V_s(t) + L\frac{di}{dt} + E_d = 0$$

$$L\frac{di}{dt} = \sqrt{2}\, V \sin\omega t - E_d$$

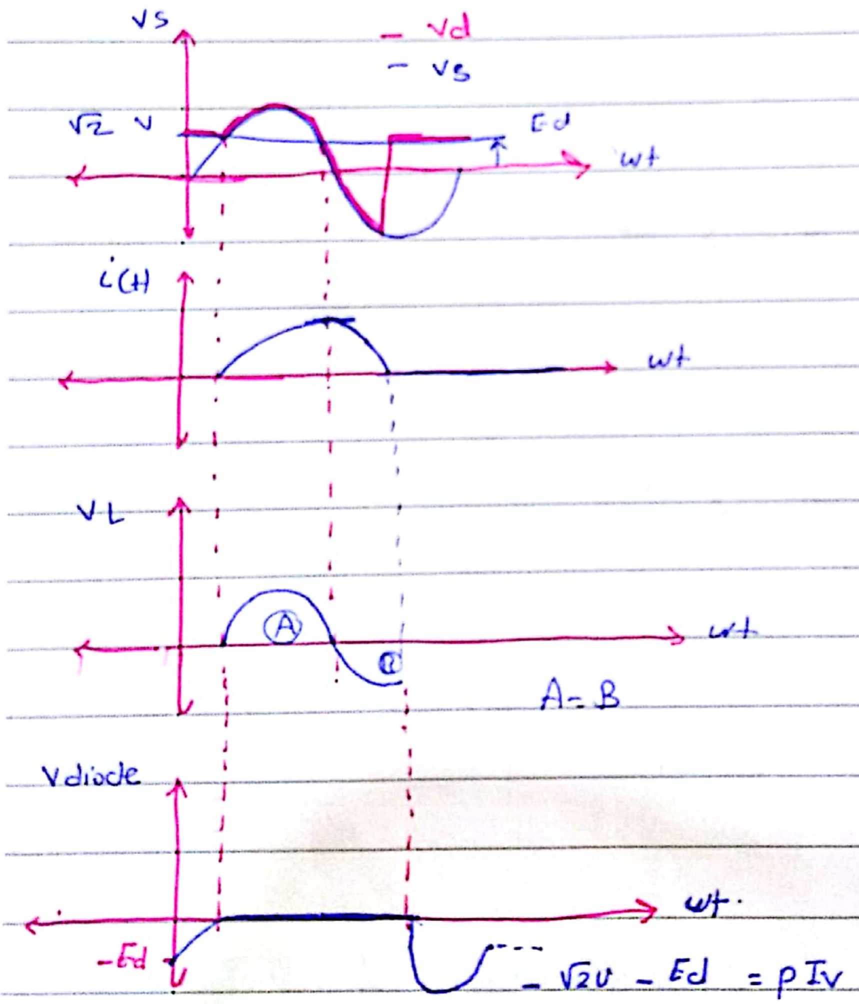
$$V_L = V_s - E_d$$

i = peak حتى تكمج

مشتقة تيار صفر لازم يكون

اعلى قيمة عند تساوي

Vs مع Ed.



Diode on V_{diode} = Zero (ideal) , $V_d = V_s$

off ⟹ $-V_s(t) + V_{diode} + \cancel{V_L} + E_d =$

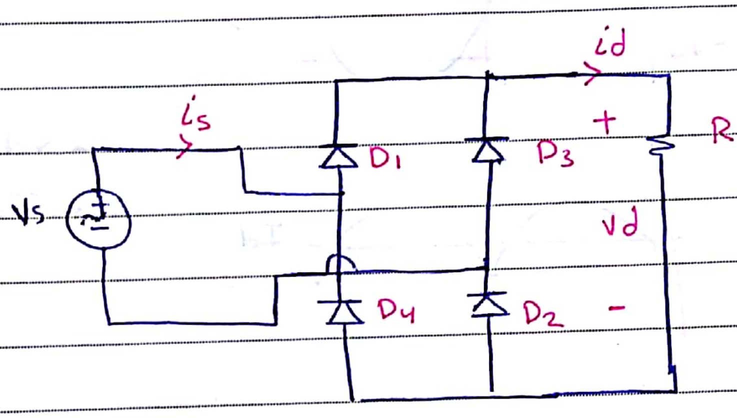
$$V_d = V_s - E_d$$

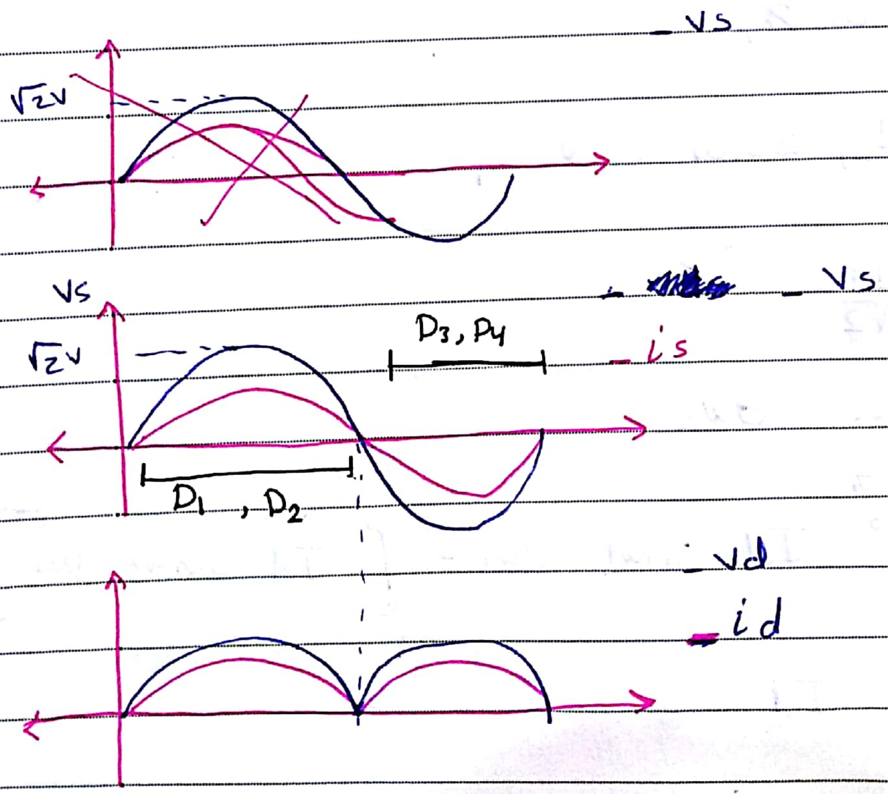
Diode off ⟹ $v_d = E_d$

Diode on ⟹ $v_d = v_s$

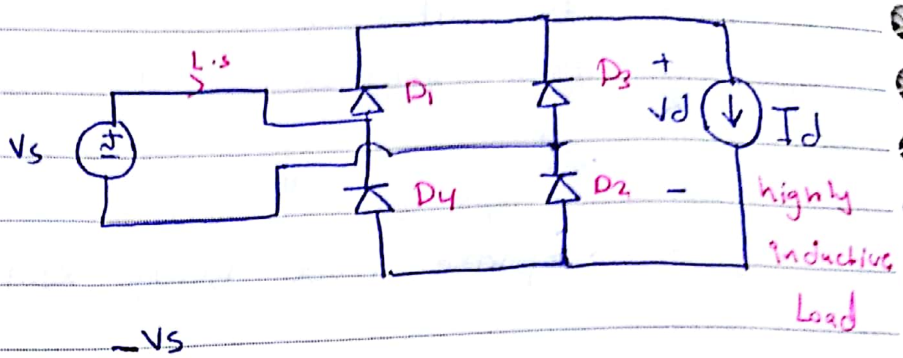
* Single phase Diode Bridge Rectifers.

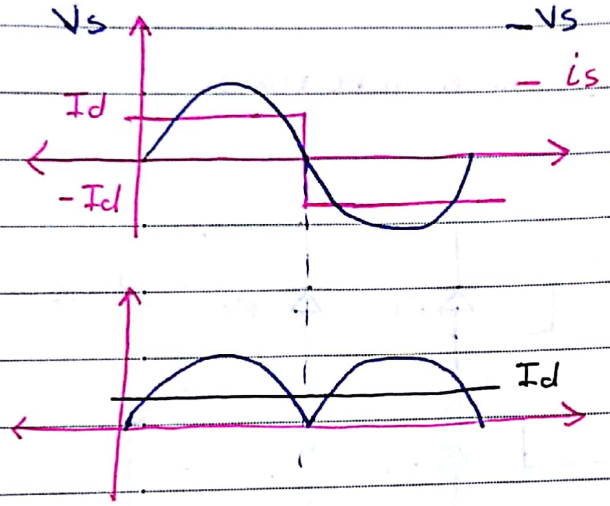
1_ Idealized case ($L_s = 0$). ⟹ Source inductance.





$V_s = \sqrt{2}\, V \sin\omega t$





$P = V\, I_{s_1} \cos\phi_1$

$= V\, I_{s_1} \cos(0) = V\, I_{s_1}$

$= V \dfrac{b_1}{\sqrt{2}}$

$b_n = \dfrac{1}{\pi} \int_0^{2\pi} \cdots\cdots \, d\omega.$

$b_n = \dfrac{1}{\pi} \left[\int_0^{\pi} I_d \sin\omega t \, d\omega t - \int_0^{2\pi} I_d \sin\omega t \, d\omega t \right]$

$b_1 = \sqrt{2}\; 0.9\; I_d$

$P_{ac} = V \times \dfrac{\sqrt{2} \times 0.9\, I_d}{\sqrt{2}} = 0.9\, V\, I_d$

$$P_{dc} = \frac{1}{2\pi}\int_0^{2\pi} v_d(\theta)\, i_d(\theta)\, d\theta$$ ⇒ قانون للحساب الباور في ac , dc.

$$= 2 * \frac{1}{2\pi}\left[\int_0^{\pi} \sqrt{2} * V * \sin\theta\, I_d\, d\theta\right]$$

$$= \frac{1}{\pi} I_d \sqrt{2} * V \cos\theta\Big]_{\pi}^{0}$$

$$= \frac{I_d}{\pi} * \sqrt{2} * V * 2$$

$$= \frac{2\sqrt{2}}{\pi} V I_d = 0.9\, V I_d$$

$$P_{ac} = P_{dc}.$$

$$THD\% = \sqrt{\frac{I_s - I_{s_1}}{I_{s_1}}} * 100\%$$

$$I_s = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} I(\theta)^2\, d\theta}$$

$$= \sqrt{\frac{1}{2\pi}\left[\int_0^{\pi} I_d^2\, d\theta + \int_{\pi}^{2\pi} (-I_d)^2\, d\theta\right.}$$

$$I_s = I_d$$

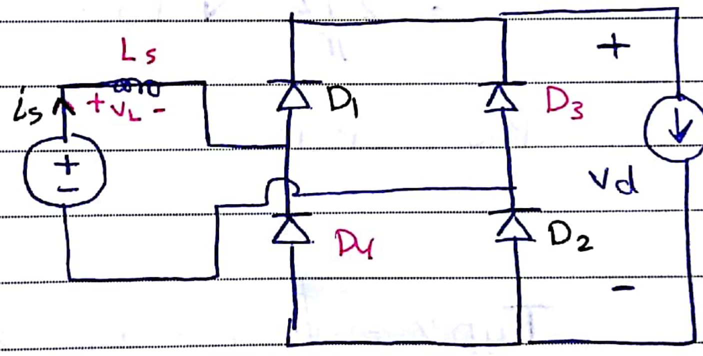
$$THD\% = \frac{\sqrt{(I_d)^2 - (0.9\, I_d)^2}}{0.9\, I_d} \times 100\% = 48.43\%$$

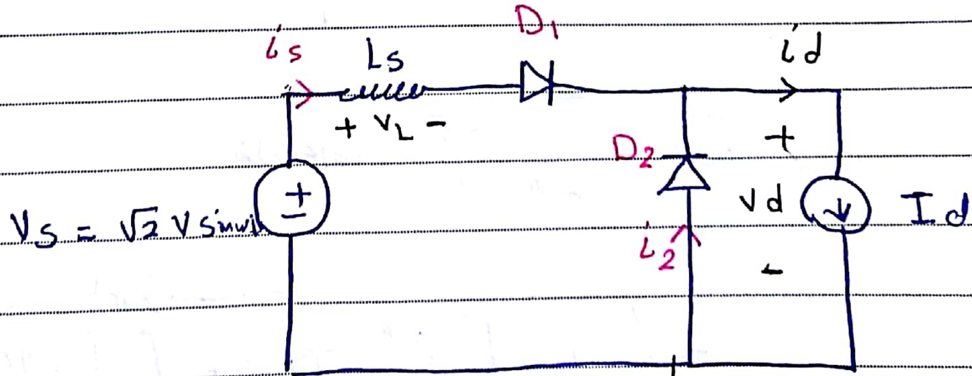
$DPF = 1$, $\cos(\phi) = 1 \rightarrow \phi = 0$

$$Pf = \frac{I_{s1}}{I_s} DPF = \frac{0.9\, I_d}{I_d}(1)$$

$$= 0.9 \; \#$$

2- Effect of Source inductance on Current Commutition.

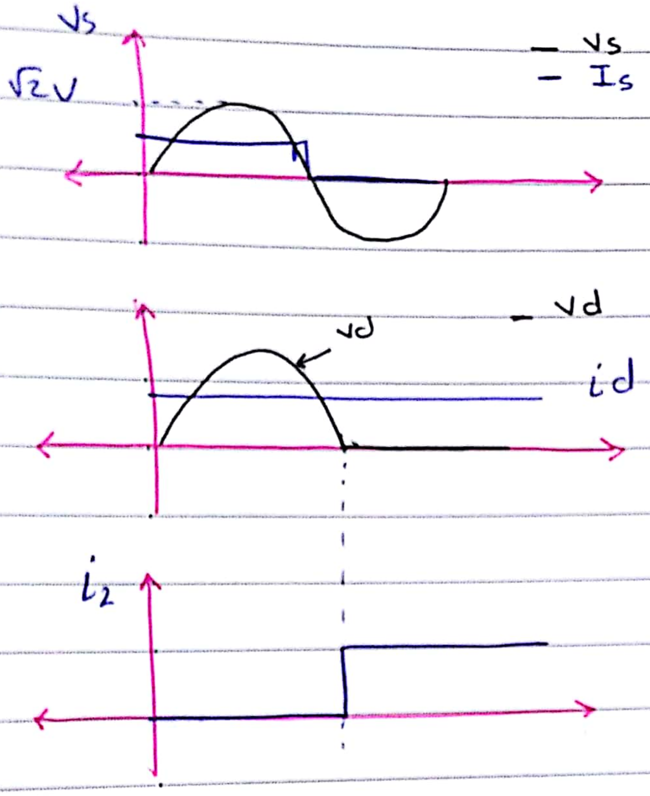




* If $L_s = 0$

↳ free wheeling Diode.

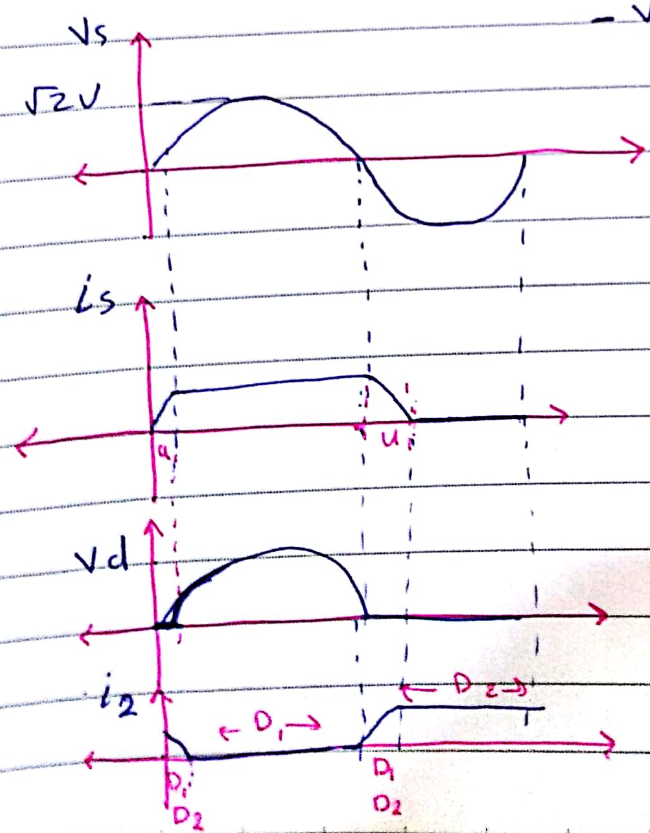
* Ip $L_s = 0$ (الشكل ‹)



* with L_s :-

* اي لحظة يكون

فيها D_2 = on ← $v_d = 0$

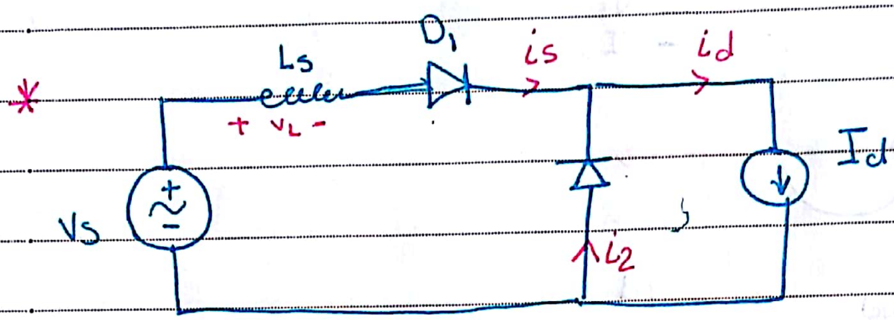


$$-i_s + i_d + i_2 = 0$$

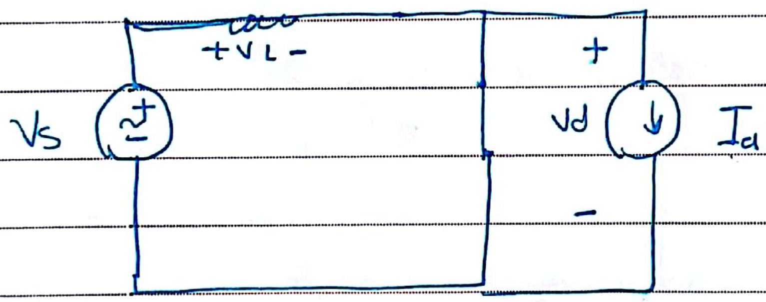
$$-\frac{di_s}{dt} + \frac{di_d}{dt} - \frac{di_2}{dt} = 0$$

$$\frac{di_s}{dt} = -\frac{di_2}{dt}.$$

$v_d = v_{d_2}$



$$V_L = L \frac{di_s}{dt}$$



$0 < \omega t < u$. (two Diode on).

* During commutation :-

$$V_L = V_s$$

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

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

$$\omega L_s \int_0^{i_d} di_s = \int_0^{u} \sqrt{2}\, V \sin\omega t \; d\omega t$$

$$\omega L_s I_d = \sqrt{2}\, V \cos\omega t \Big]_u^0$$

$$\omega L_s I_d = \sqrt{2} V [1 - \cos u]$$

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

$$u = \cos^{-1}\left[1 - \frac{\omega L_s I_d}{\sqrt{2} V}\right]$$

* If $L_s = 0$

$$u = \cos^{-1}(1) = 0$$

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

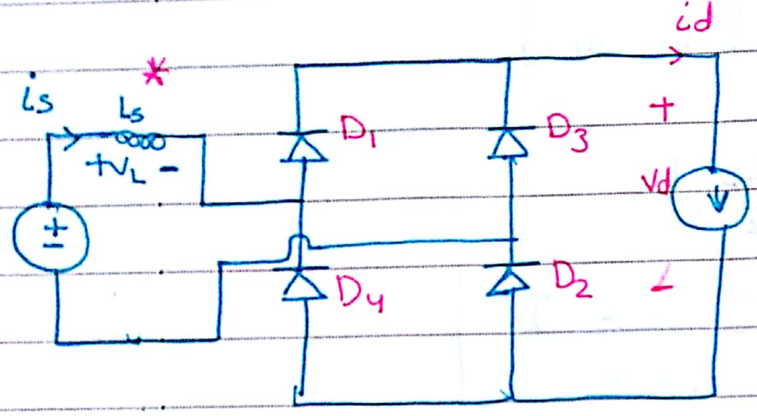
$$= \frac{1}{2\pi}\int_u^{\pi} \sqrt{2} V \sin\theta\, d\theta$$

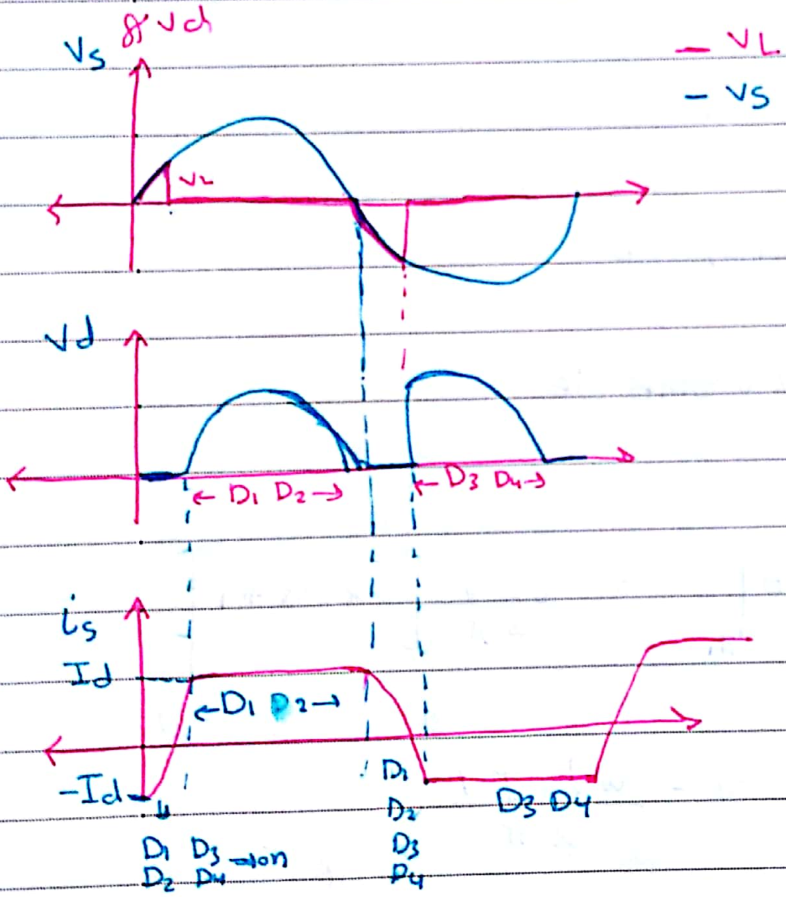
$$= \frac{\sqrt{2} V}{2\pi} \cos\theta \Big]_{\pi}^{u} = \frac{\sqrt{2} V}{2\pi}\left[\cos u + 1\right]$$

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

If $L_s = 0$, $V_d = 0.45 V$

$$P_d = V_d I_d$$


is
Ls
+VL -
id
D1
D3
D4
D2
+
Vd
-


Vs & Vd
— VL
— Vs
VL
Vd
← D1 D2 →
← D3 D4 →
is
Id
-Id
← D1 D2 →
D1 D2 D3 D4
D3 D4
D1 D3 → on
D2 D4

* During Commtation :-

$$V_L = V_s$$

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

$$\omega L_s \int_{-I_d}^{I_d} di_s = \sqrt{2} V \int_{0}^{u} \sin \omega t$$

$$2 \omega L_s I_d = \sqrt{2} V \cos \omega t \Big]_u^0$$

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

$$\cos u = 1 - \frac{2 \omega L_s I_d}{\sqrt{2} V} \quad \#$$

$$* \quad V_d = \frac{1}{2\pi} \int_{0}^{2\pi} V_d(\theta) \, d\theta$$

$$= \frac{2}{2\pi} \int_{u}^{\pi} \sqrt{2} V \sin\theta \, d\theta$$

$$= \frac{\sqrt{2} V}{\pi} \cos\theta \Big]_{\pi}^{u} = \frac{\sqrt{2} V}{\pi} \left[\cos u + 1 \right]$$

$$V_d = 0.9 V - \frac{2 \overbrace{\omega L_s}^{X_s} I_d}{\pi} \quad \#$$

* وجود Ls

at highly inductive Load [interduce u , Pd , Vd تقل]

constant current. + inductive وجود

During commutation

$V_L = V_s$.

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

$\omega L_s \int di_s = \sqrt{2} V \int \sin\omega t \; + K$

$i_s(0) = -I_d$

$\omega L_s \, i(\theta) = \sqrt{2} V \cos\omega t + K$

$P = V I_1$ (ac)

$I_1 = \frac{b_1}{\sqrt{2}}$

$$i(\theta) = \begin{cases} & , 0 < \theta < u \\ I_d & , u < \theta < \pi \\ & , \pi < \theta < \pi + u \\ -I_d & \pi + u < \theta < 2\pi \end{cases}$$

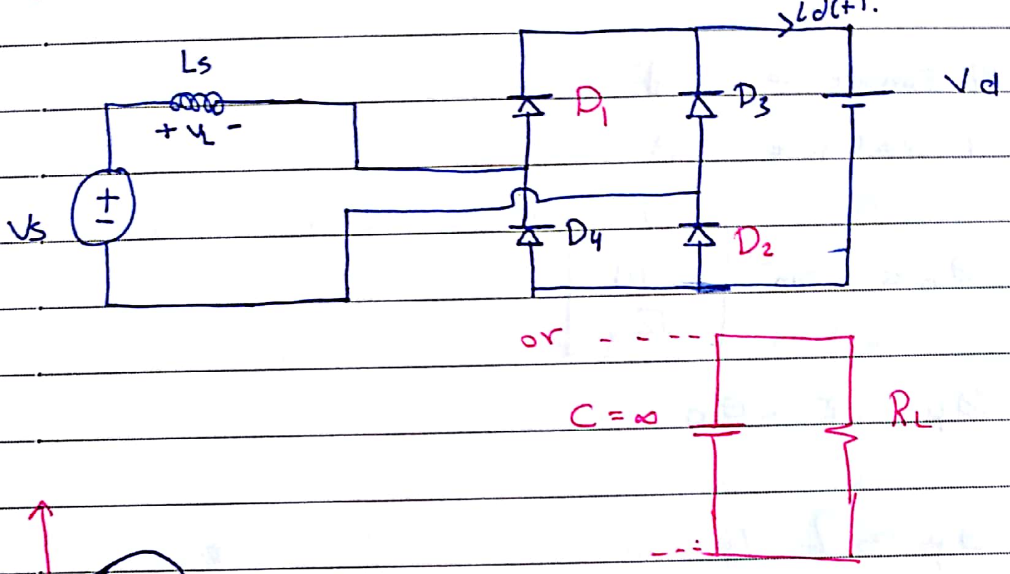
≈ ac side.

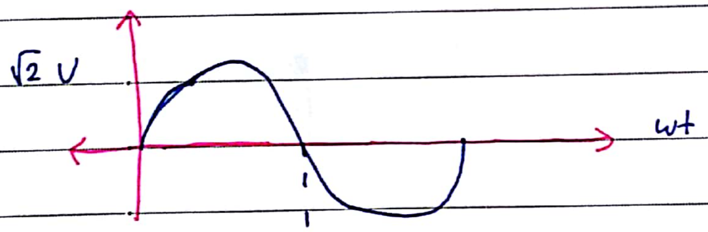
* Power (dc). :-

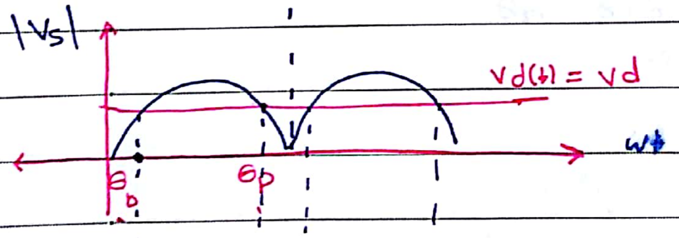
$P_d = V_d I_d$

$P_d = P$.

* Constant dc - side voltage $v_d(t) = V_d$.





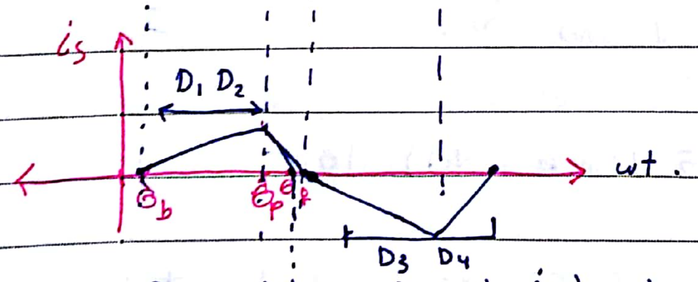


D_1 and D_2 (on):-

$$-v_s(t) + L_s \frac{di_s}{dt} + V_d = 0$$

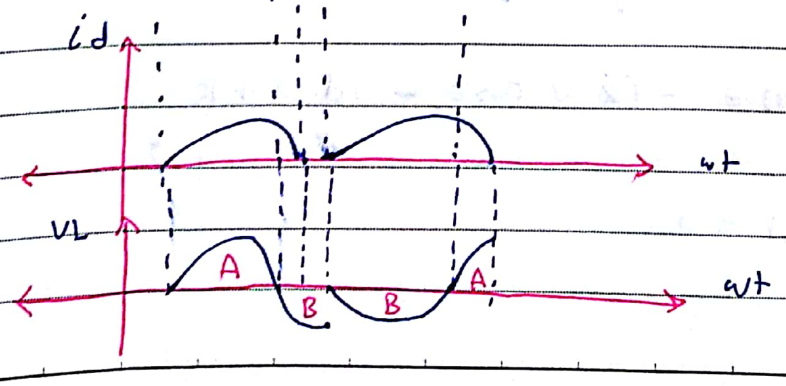
$$\omega L_s \frac{di_s}{dt} = \sqrt{2}\, V \sin\omega t - V_d$$

لم حتى نطلع فيها شكل تيار



$\theta_p = \pi - \theta_b$

Peak value current $i(s) \Rightarrow V_d = V_s$.



$V_s = V_d.$

$\sqrt{2}\, V \sin\omega t = V_d$

$\sqrt{2}\, V \sin\theta_b = V_d$

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

$\theta_p = \pi - \theta_b.$

$\theta_f = ?$

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

For $i_d(\theta)$. $\Rightarrow$

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

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

$$\omega L_s \int d i_d(\theta) = \int \sqrt{2}\, V \sin\theta - V_d \; d\theta + K$$

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

$i_d(\theta_b) = 0$

$$\omega L_s \; i_d(\theta_b) = -\sqrt{2}\, V \cos\theta_b - V_d\,\theta_b + K.$$

$$0 = -\sqrt{2}\, V \cos(\theta_b) - V_d\,\theta_b + K.$$

$$K = \sqrt{2}\, V \cos(\theta_b) + V_d\,\theta_b.$$

$$i_d(\theta) = \frac{1}{\omega L_s}\left[-\sqrt{2}\, V \cos\theta - V_d\,\theta + \sqrt{2}\, V \cos\theta_b + V_d\,\theta_b\right]$$

$$i_d(\theta_f) = 0 = \frac{1}{\omega L_s}\left[-\sqrt{2} \cos(\theta_f) - V_d\,\theta_f + \underbrace{\sqrt{2}\, V \cos\theta_b + V_d\,\theta_b}_{\text{constant.}}\right]$$

$\Downarrow$

non linear algebraic equation.

$\Downarrow$

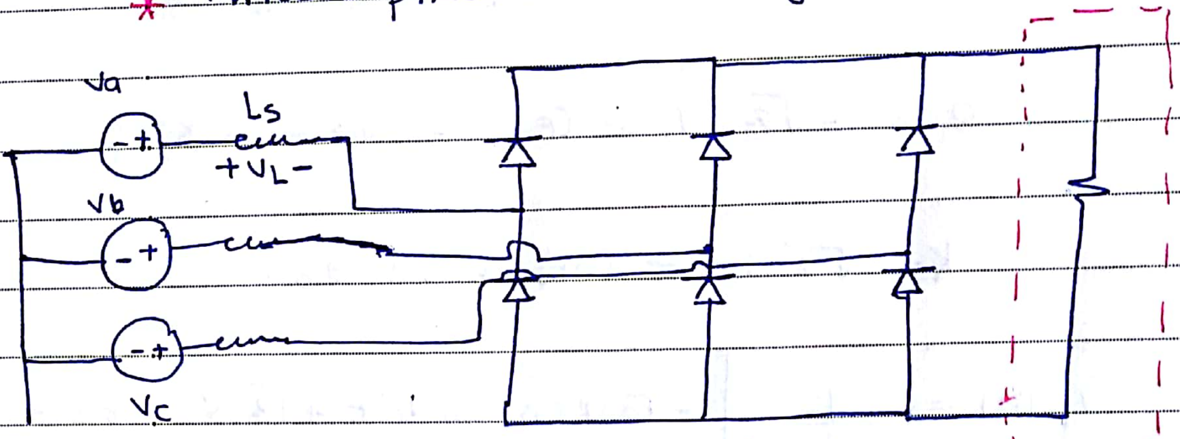
Trial & Error

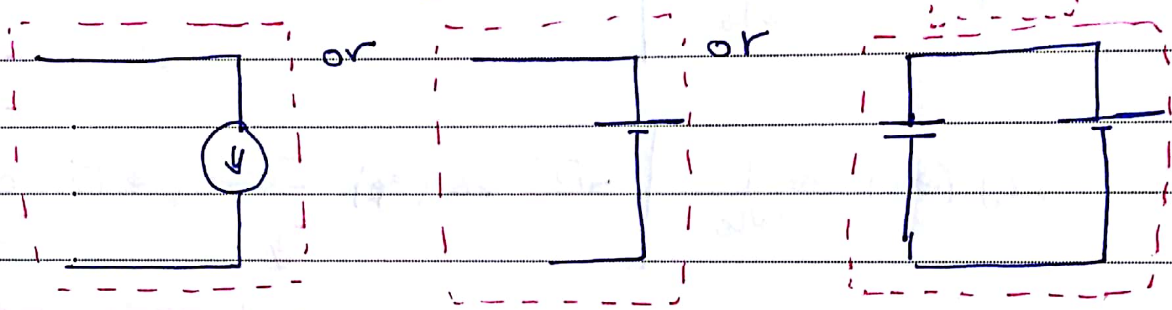
$$I_d = \frac{2}{2\pi} \times \frac{1}{2}\, i_d^2(\theta)\Big]_{\theta_b}^{\theta_f}$$

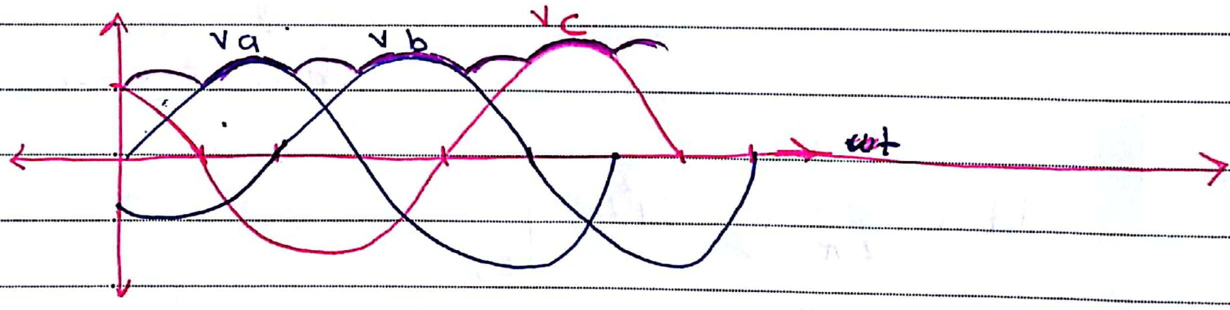
$$= \frac{1}{2\pi}\left[i_d^2(\theta_f) - i_d^2(\theta_b)\right] =$$

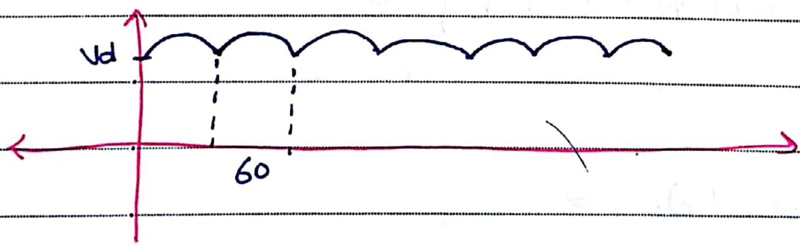
$$P = I_d V_d. =$$

* Three-phase Full-Bradge Rectifier.









1- Smoother output voltage (Lower ripple).

2- Higher power.

$V_d = 1.35\, V_L$ ↳ rms.

$V_a(t) = \sqrt{2}\ V \sin(\omega t)$

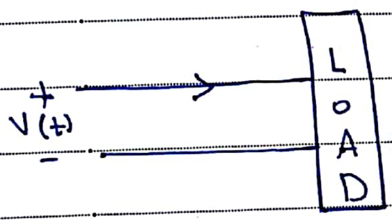
$V_b(t) = \sqrt{2}\ V \sin(\omega t - 120)$

$V_c(t) = \sqrt{2}\ V \sin(\omega t + 120)$.

$$V_{LL} = \sqrt{3}\, V$$

$$V_d = 1.35\, V_{LL} = 1.33 * \underbrace{\sqrt{3}}_{1.73} V$$

5_3 pp. 114 :-



$v(t) = V_d + \sqrt{2} V_1 \cos(\omega_1 t) + \sqrt{2} V_1 \sin(\omega_1 t)$.
$+ \sqrt{2}\ V_3 \cos(\omega_3 t)$ V

$$i(t) = I_d + \sqrt{2}\, I_1 \cos(\omega_1 t) + \sqrt{2}\, I_3 \cos(\underbrace{\omega_3}_{3\omega_1} t - \phi_3)$$

(a) $P = ?$

$$P = \frac{1}{T_1} \int_0^{T_1} v(t)\, i(t)\, dt.$$

$$= \frac{1}{T_1} \Big[\int_0^{T_1} [V_d + \sqrt{2} V_1 \cos(\omega_1 t) + \sqrt{2} V_1 \sin(\omega_1 t)$$
$$+ \sqrt{2} V_3 \cos(\omega_3 t)] [I_d + \sqrt{2} I_1 \cos(\omega_1 t)$$
$$+ \sqrt{2}\ I_3 \cos(\omega_3 t - \phi_3)] dt =$$

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

$\int \sin x . \sin x = 0$

$\int \cos x . \cos 3x = 0$

① sin * cos نفس freq = صفر

② sinf* sin3f ⇐ صفر

① بور عند نفس freq ⇐ phase shift أقواس .٩.

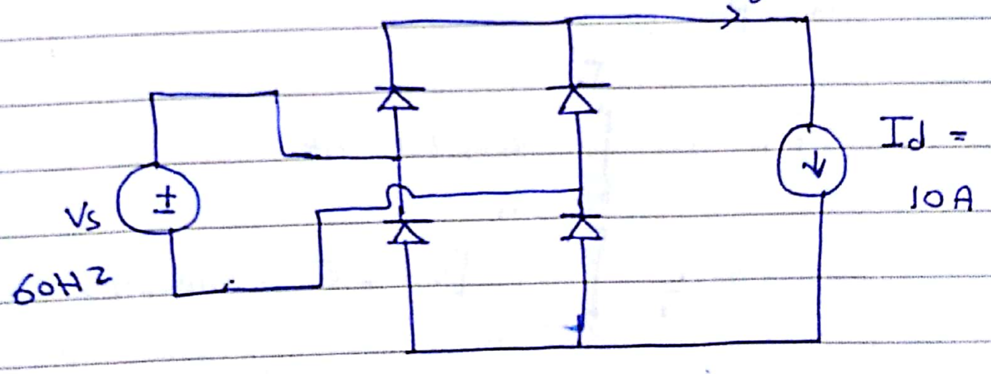
b) $V_{rms} = \sqrt{(V_d)^2 + V_1^2 + V_1^2 + V_3^2}$

$I_{rms} = \sqrt{(I_d)^2 + I_1^2 + I_3^2}$

c) $S = V_{rms} I_{rms} =$

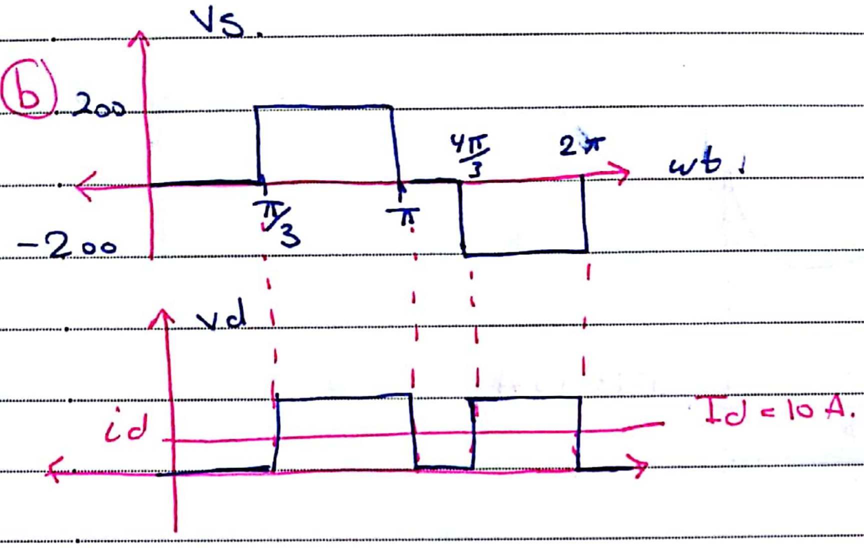
d) $PF = \frac{P}{S} = \frac{V_d I_d + V_1 I_1 + V_3 I_3 \cos \phi_3}{S}$

5-4)



(a) If Vs is sinusoidal with V = 120V.

(b)



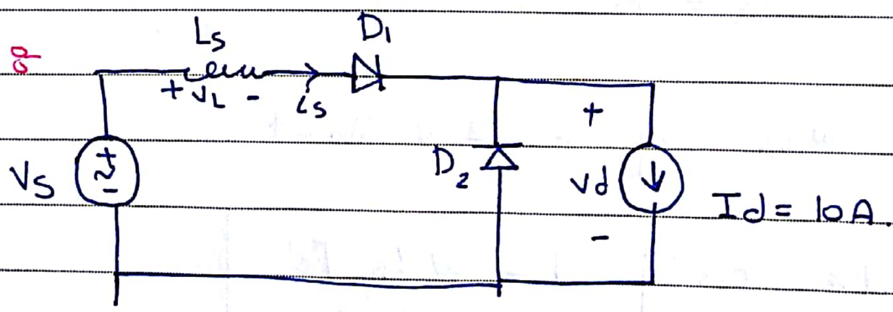
$$P = \frac{1}{2\pi}\int_0^{2\pi} V(\theta)\, I(\theta)\, d\theta.$$

$$= \frac{2}{2\pi}\int_{\pi/3}^{\pi} (200)(10)\, d\theta.$$

$$= \frac{1}{\pi} * 2000 \left(\frac{3\pi}{3} - \frac{\pi}{3}\right) = \frac{1}{\pi} * 2000 * \frac{2\pi}{3}$$

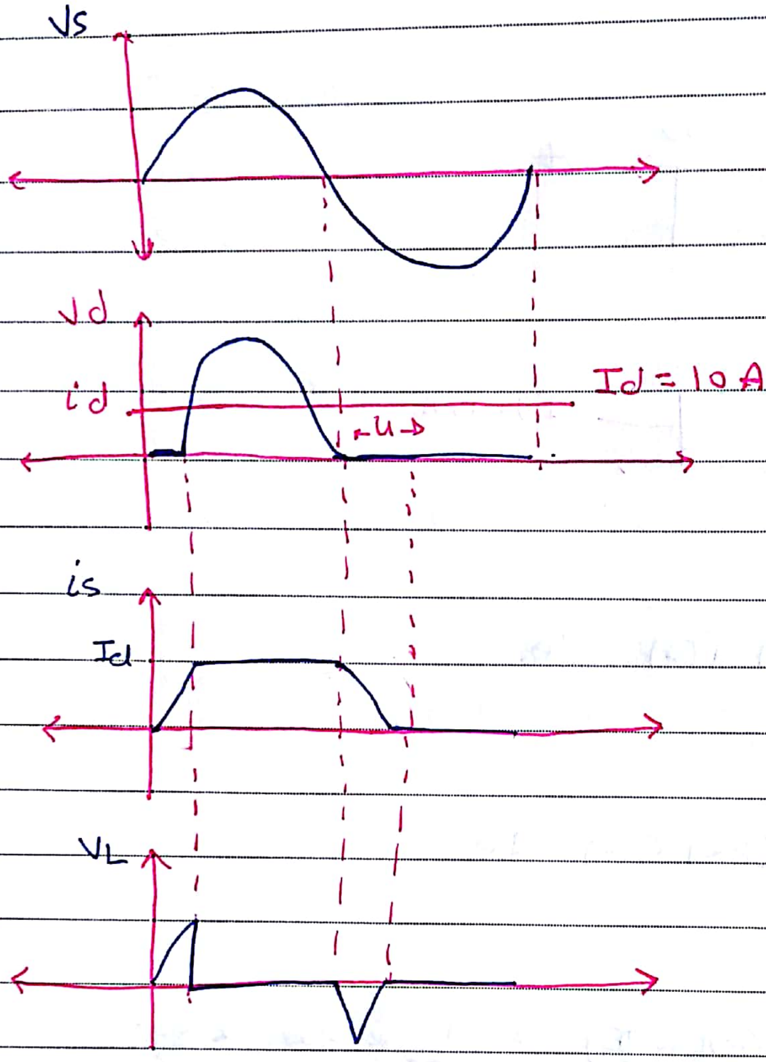
$$= 13333.33 \text{ w.}$$

5-5) :



$L_s = 5mH$. 60Hz . u, vd, Pd ?

V = 120.



During commutation.

$$V_L = V_s$$

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

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

$$= \cos^{-1}\left[1 - \frac{2\pi f (5 \times 10^{-3}) \times 10}{\sqrt{2} \times 120}\right] = \cos^{-1}(0.8886)$$

$$=$$

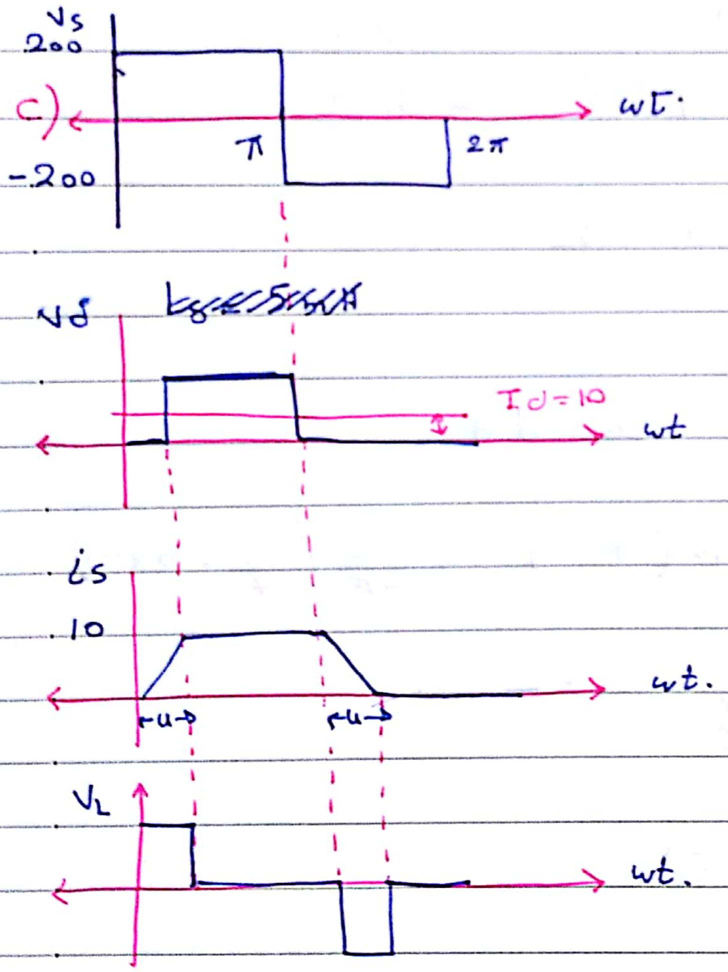
$$V_d = 0.45\,V - \frac{\omega L_s I_d}{2\pi}$$

$$= 0.45 * 120 - \frac{(2\pi * 60) \times 5 \times 10^{-3} \times 10}{2\pi}$$

$$=$$

$$P_d = V_d I_d = V_d * 10 =$$

c) , $L_s = 5mH$



During commutation.

$$V_L = V_S$$

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

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

$$\omega L_s I_d = 200u.$$

$$u = \frac{\omega L_s I_d}{200} = \frac{(2\pi 60)\, 5\times10^{-3} \times 10}{200}$$

$$= 0.094 \text{ rad} \qquad = 5.40$$

$$= 0.094 \times \frac{180}{\pi} = 5.4^\circ$$

$$V_d = \frac{1}{2\pi} \int_u^{\pi} 200 \, d\omega t.$$

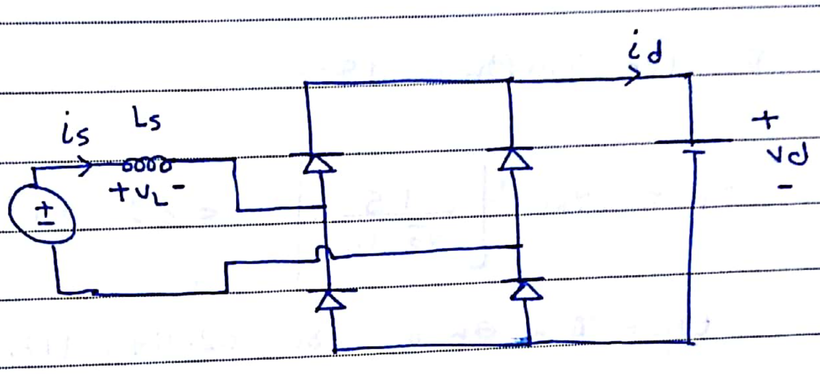
$$= \frac{1}{2\pi} 200 (\pi - u) = \frac{200}{2\pi}\left(\frac{22}{7} - 0.094\right)$$

$$=$$

$$P_d = V_d I_d$$

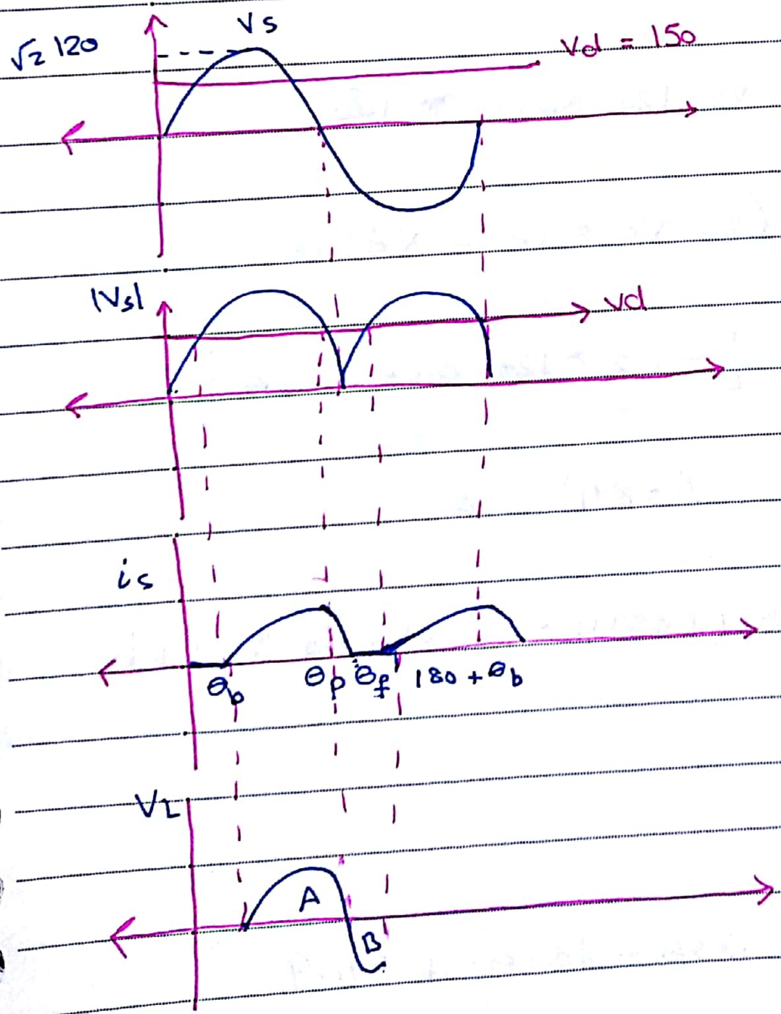
Scanned by CamScanner

* P(5-11) PP (115).



$V_s = 120$, 60 HZ , $L_s = 1\,mH$, $v_d = 50\,V$

i_d , θ_b , f , I_d peak , I_d = ??



$V_s = V_d$

$\sqrt{2}\ 120\ \sin\theta_b = 150$

$\theta_b = \sin^{-1}\left[\frac{150}{\sqrt{2}\ 120}\right] = 62.114^\circ - (1.0841\ rad)$

$\theta_p = \pi - \theta_b = 180 - 62.114 = 117.89.$

$= 2.0575\ rad.$

$-V_s + L_s \frac{d\,i_s}{dt} + V_d = 0$

$\omega L_s \frac{d\,i_d}{dt} = \sqrt{2}\ 120\ \sin\omega t - 150.$

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

$i_d(\theta) = \frac{1}{\omega L_s}\left[-\sqrt{2} * 120\ \cos\theta - V_d\theta\right]$

$i_d(\theta_b) = i_d(1.0841) = 0$

$\frac{1}{\omega L_s}\left[-\sqrt{2}\ V_s\ \cos(1.0841) - (150)\cdot(1.0841)\right] + K.$

$K = 641.9.$

$i_d(\theta) = 2.65\left[-169.7\ \cos\theta - 150\,\theta\right] + 641.9$

* peak value i_d when θ_p.

$$i_d(\theta_p) = i_d(2.0575) = 2.65\left[-169.7\cos(2.0575) - 150 * 2.0575\right] + 641.9$$

$$=$$

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

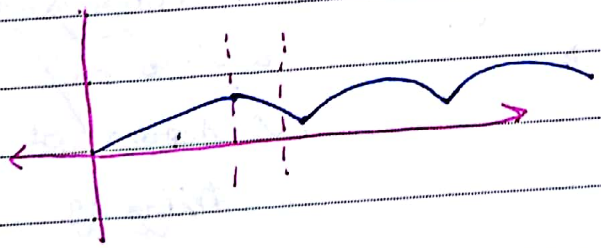
$$= \frac{1}{\pi}\int_{1.0841}^{\theta_f} 2.65\left[-169.7\cos(\theta) - 150\,\theta\right] + 641.9\, d\theta.$$

$$\theta_f = ?$$

$$i_d(\theta_f) = 0. = 2.65\left[-169.7\cos(\theta_f) - 150\theta_f\right] + 641.9$$

بالتجريب نحصل على θ_f من (130 ~ 140)

لوكانت θ_f اكبر $\pi + \theta_b$ رح يصلك ripple في رسمة تبل

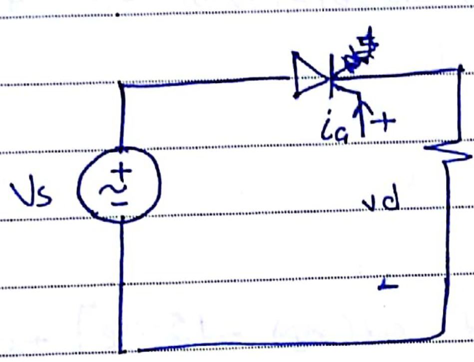


Ch6:-

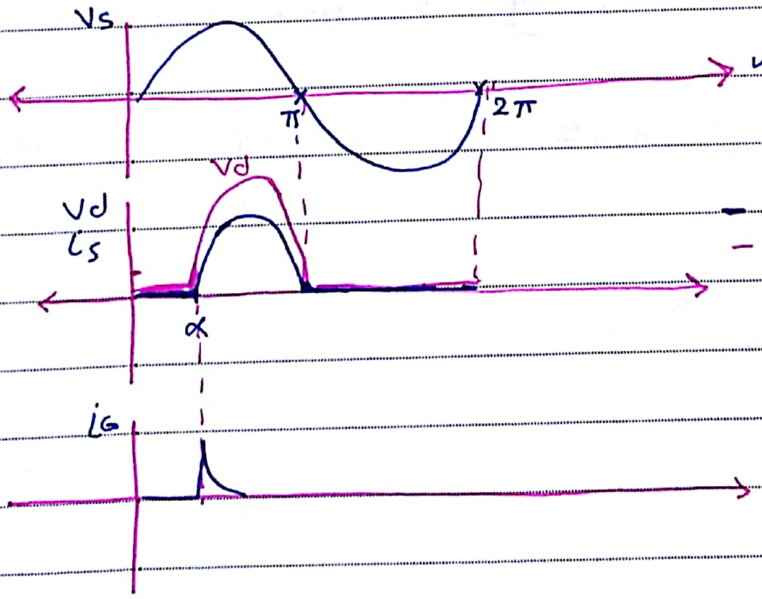
Line frequency phase - controlled Rectifiers and Inverters:-

Line frequency ac ⟹ $\underbrace{\text{Controlled}}_{\text{Thyristors}}$ dc

* Basic Thyristors Circuits.



Half - wave controlled Rectifer Circuit with Pure resistive Load



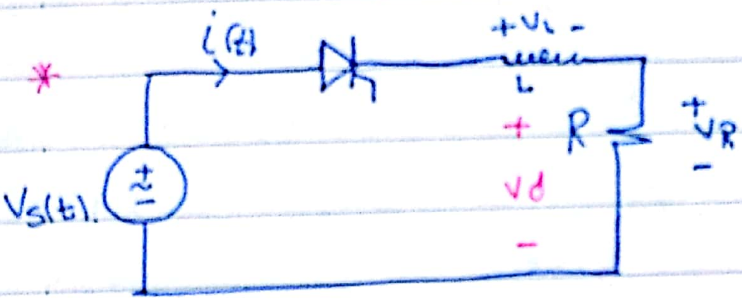
~~α i: firing angle~~
~~α = wo to~~
~~to:- instant of trigging.~~

α fri
α wo t
t_o instant of trigging

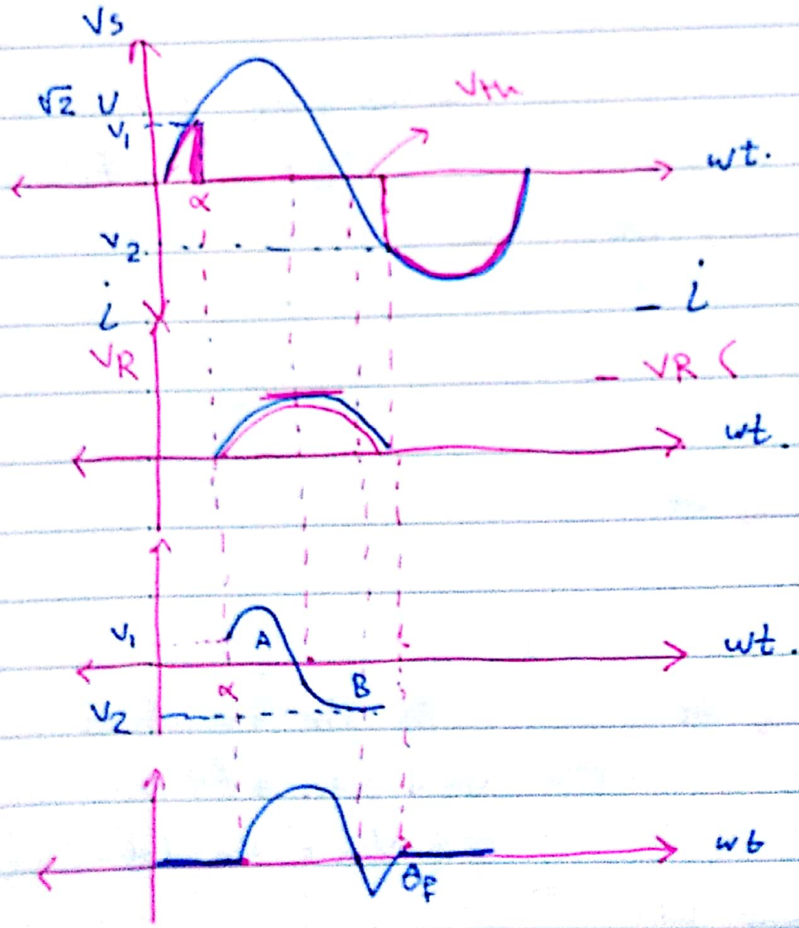
$$V_d = \frac{1}{2\pi}\int_{\alpha}^{\pi} \sqrt{2}\, V_s \sin\theta \, d\theta$$

$$= \frac{\sqrt{2}V}{2\pi} \cos\theta \Big]_{\alpha}^{\pi}$$

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



$$-\sqrt{2}V \sin wt + L\frac{di}{dt} + Ri = 0$$

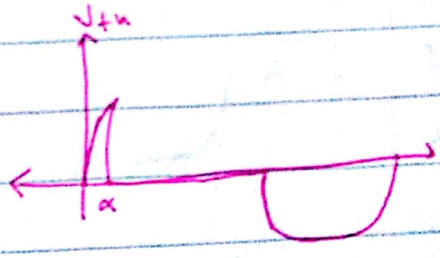


$V_L = \sqrt{2}V \sin wt - Ri$

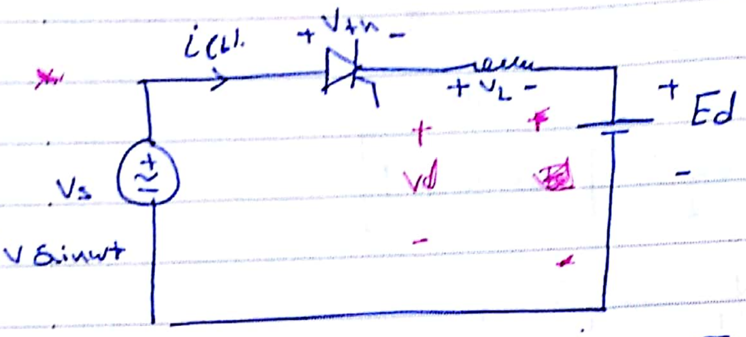
هاحسب لعمل بيانه V_L

من Zero بين Vs.

لحد قيمة المقارنة.



$$V_d = \frac{1}{2\pi}\int_{\alpha}^{\theta_f} \sqrt{2}\, V \sin\theta \, d\theta .$$

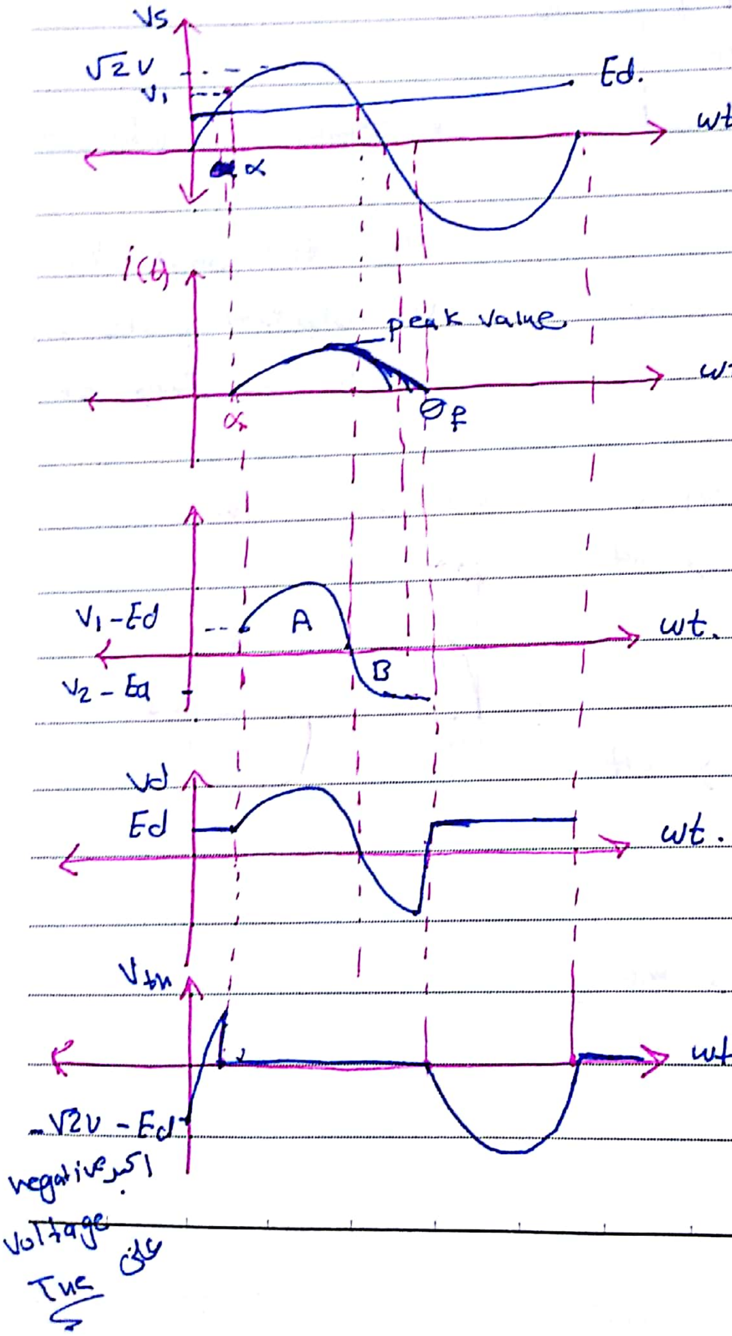


$V_s = \sqrt{2}\, V \sin wt$

The (on) => لما تكون Vs اكبر من Ed وتيار موجب .

$-V_s + V_L + E_d = 0$

$V_L = V_s - E_d .$



if the the off :-

$-V_s + V_{th} + E_d = 0$

$V_{th} = V_s - E_d .$

$$V_L = V_s - E_d.$$

$$\omega L \frac{di}{d\omega t} = \sqrt{2}\, V \sin \omega t - E_d.$$

$$\omega L \, di = (\sqrt{2}\, V \sin \omega t - E_d)\, d\omega t.$$

$$\omega L \, i(\theta) = -\sqrt{2}\, V \cos(\theta) - E_d \theta + k.$$

$$i(\alpha) = 0 \Rightarrow k = ??$$

α is known.

$$V_L = L \frac{d\, i(\theta)}{d\theta}.$$

$$i(\theta_f) = 0 \Rightarrow \theta_f.$$

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

$$= \frac{1}{2\pi} \left[\int_0^{\alpha} E_d \, d\theta + \int_{\alpha}^{\theta_f} \sqrt{2}\, V \sin\theta \, d\theta + \int_{\theta_f}^{2\pi} E_d \, d\theta \right]$$

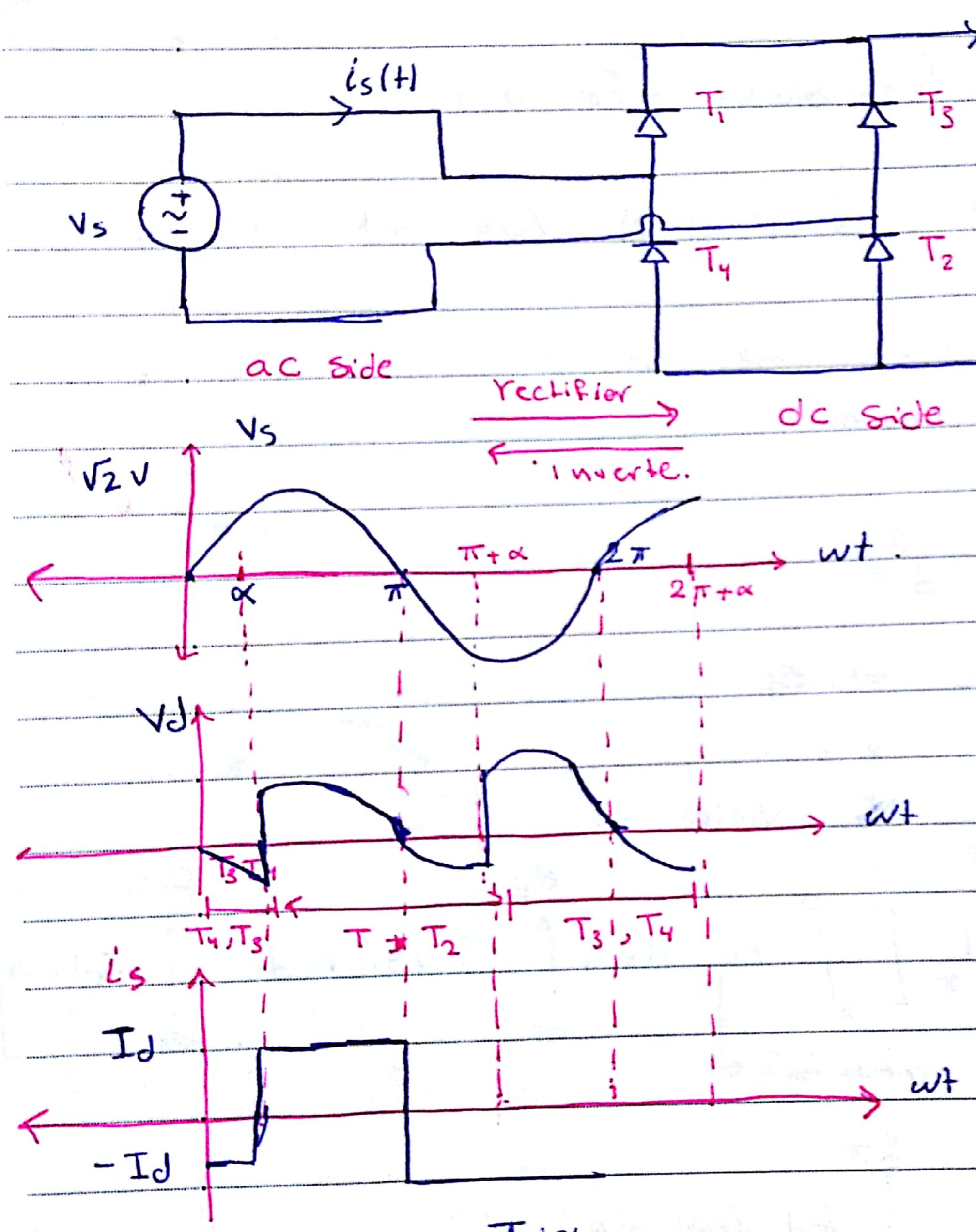
يكون معطى يا لسؤال.

$$P_d = \frac{1}{2\pi} \int_0^{2\pi} E_d \, i(\theta)\, d\theta.$$

$$P_d = \frac{E_d}{2\pi} \int_{\alpha}^{\theta_f} i(\theta)\, d\theta \Rightarrow W.$$

* Signle-phase converter.

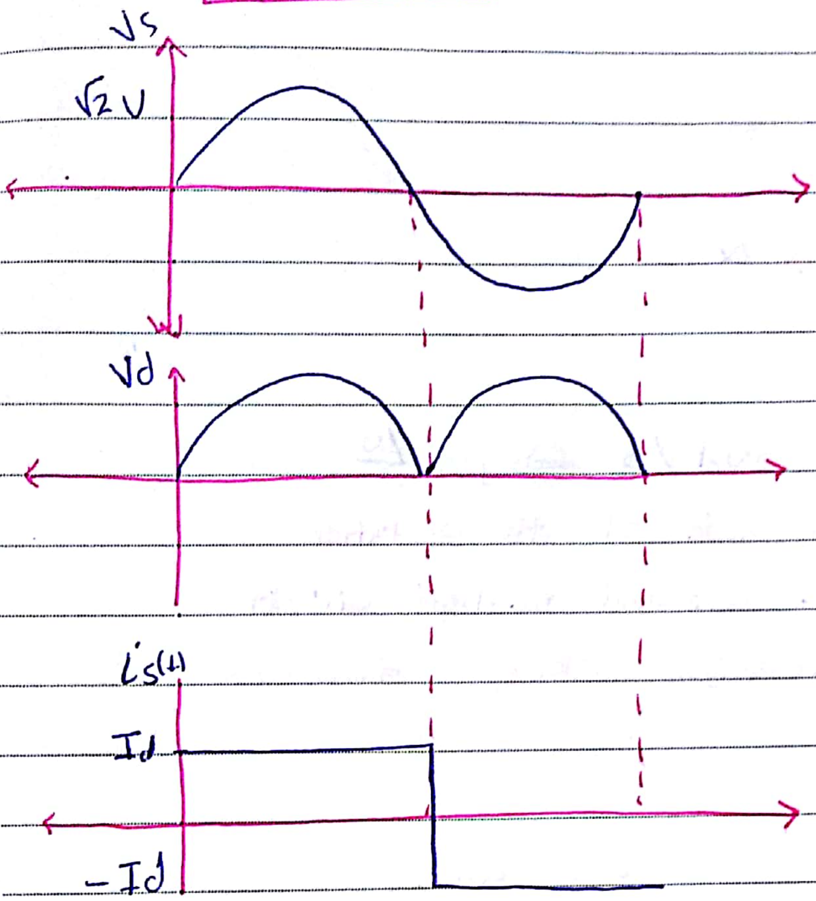
Idealized case ($L_s = 0$) and $i_d(t) = I_d$.



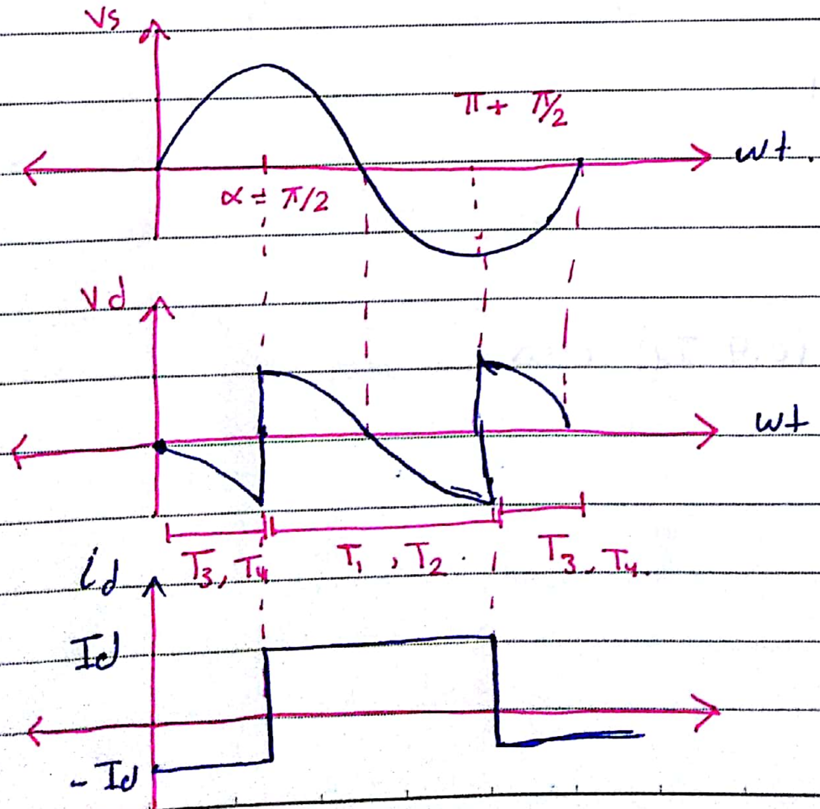
$$V_d = \frac{2}{2\pi} \int_{\alpha}^{\pi+\alpha} \sqrt{2} V \sin\theta \, d\theta = \frac{\sqrt{2} V}{\pi} \cos\theta \Big]_{\pi+\alpha}^{\alpha}$$

$$= \frac{\sqrt{2} V}{\pi} \left[\cos\alpha - \cos(\pi+\alpha) \right] = 0.9 V \cos(\alpha)$$

2. $\boxed{\text{if } \alpha = 0}$



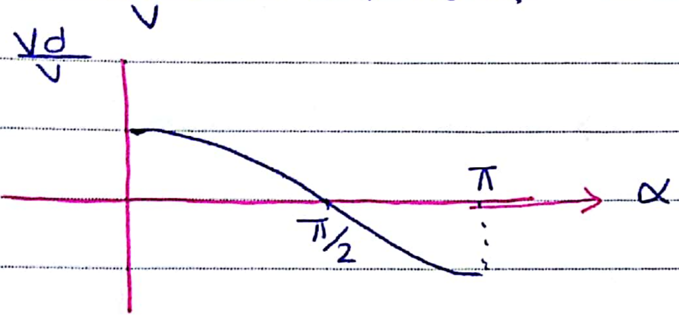
3. $\boxed{\text{if } \alpha = \pi/2}$



* اذا كانت زاوية اكبر من 9.

يصبح value avg بسالب .

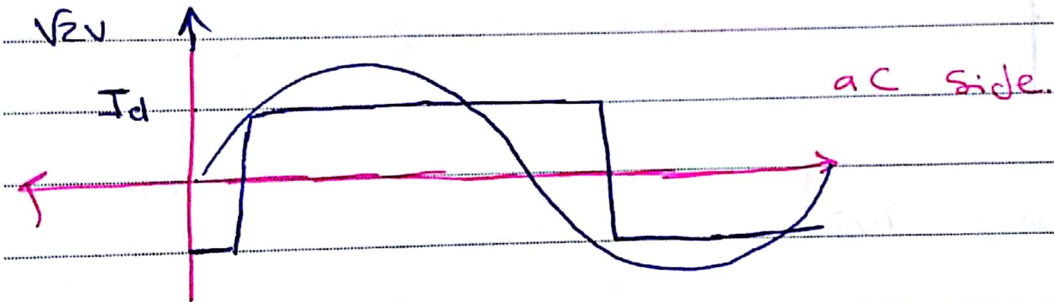
$$\frac{V_d}{V} = 0.9 \cos\alpha$$



$\pi/2 < \alpha < \pi \qquad V_d < 0 \Rightarrow P_d < 0$.

inverter mode of ~~the~~ operation of the controlled rectifier cirwit.

~~reg.~~ ~~[illegible]~~ Regenerative braking عملية عكسية

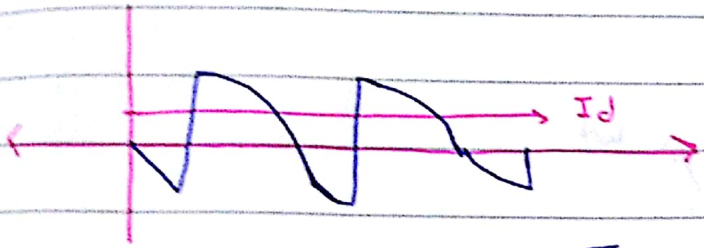


$P = V I_{S_1} \cos\theta_1$

$\theta_1 = \alpha$.

rms value of fundamental components. $I_{S_1} = 0.9\, I_d$.

$P = V\,(0.9\, I_d) \cos\alpha$.



Dc Side.

$P_{dc} = V_d I_d$

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

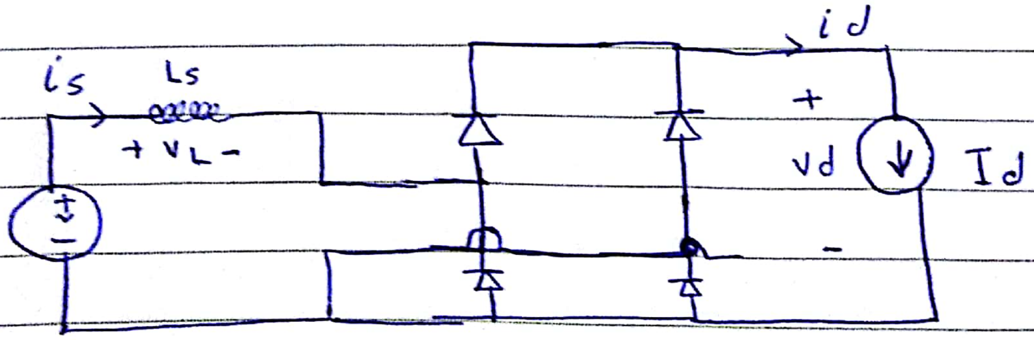
$I_s = I_d$

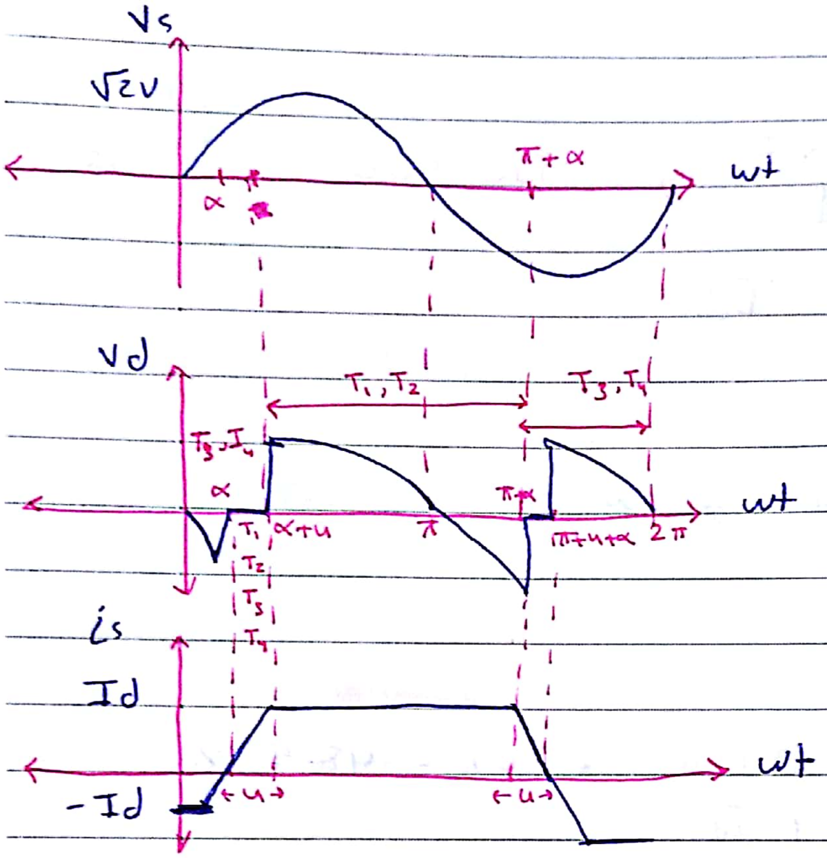
$= \sqrt{\frac{I_d^2 - (0.9 I_d)^2}{0.9 I_d}} * 100\% = 48.43\%$

$DPF = \cos \phi = \cos \alpha$

$PF = \frac{I_{s1}}{I_d} \cos \alpha = 0.9 \cos \alpha$

* Effect of Source inductance ($L_s \neq 0$).





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

$$= \frac{\sqrt{2}\,V}{\pi} \cos\theta \Big]_{\pi+\alpha}^{\alpha+u} = \frac{\sqrt{2}\,V}{\pi}\left[\cos(\alpha+u) - \cos(\pi+\alpha)\right]$$

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

* حتى تصبح سالبة لازم اعلي زاوية الجبر من α .

During commtation.

$$V_L = V_s$$

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

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

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

$$2\omega L_s I_d = \sqrt{2}\, V \cos\theta \Big]_{\alpha+u}^{\alpha}$$

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

بحسب u

بلاقي احسب معادلة current

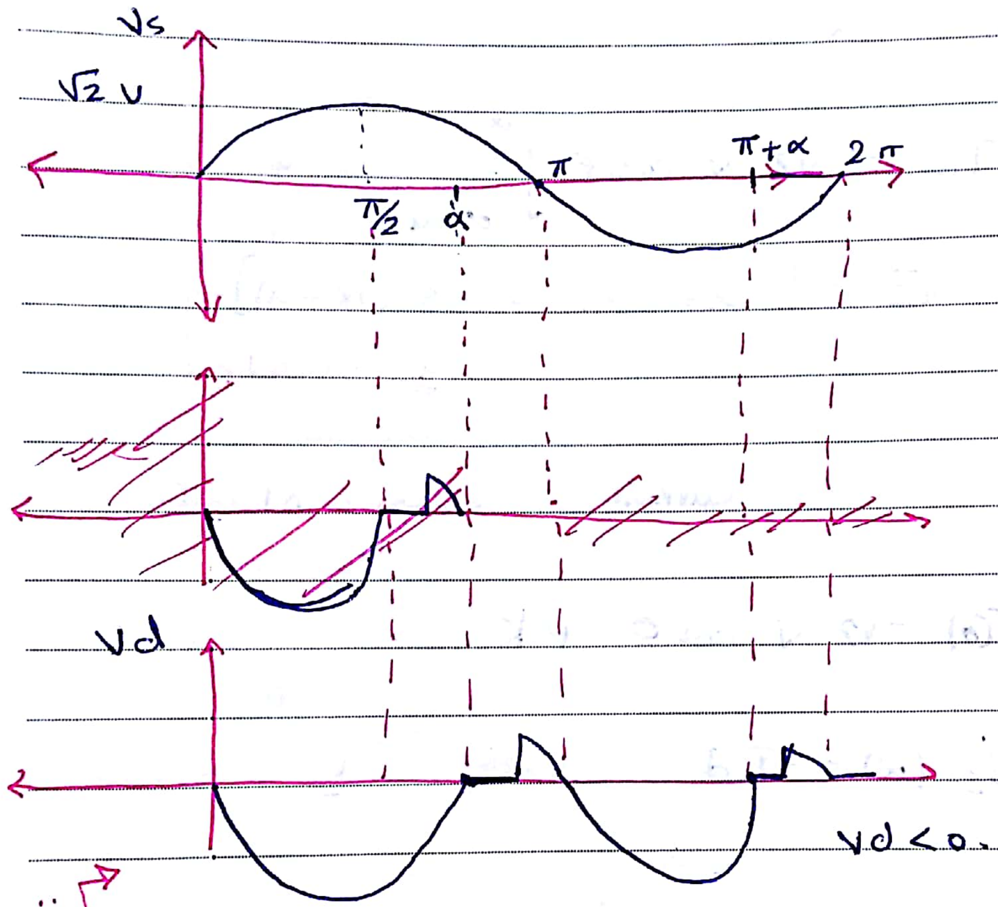
*

$$\omega L_s I(\theta) = -\sqrt{2}\, V \cos\theta + K.$$

$$i_s(\alpha) = -I_d \Rightarrow \ldots\ldots \text{ ، } \underline{K} \text{ بحسب }$$

* Inverter mode of operation.

① $V_d < 0 \Rightarrow$ if $L_s = 0$ $\quad \alpha > 90^\circ$

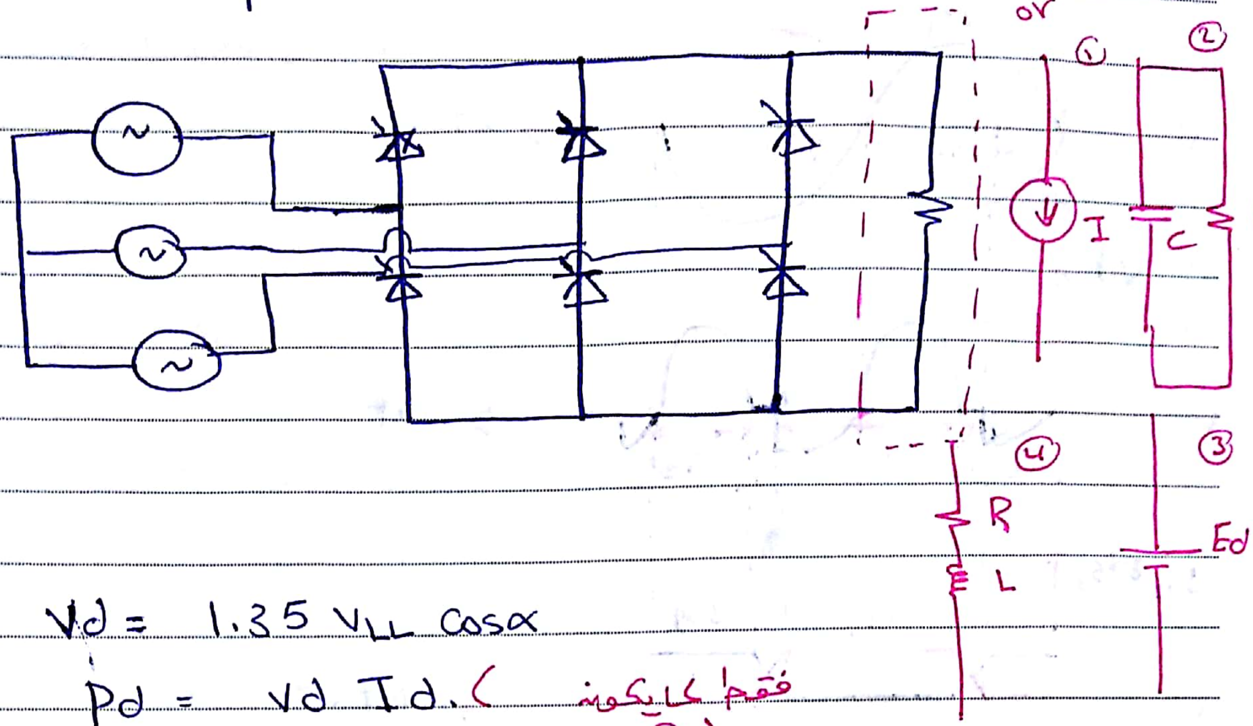


نفس رسمات .

② Source in the Load or energy storage device.

*

* Three-phase Converters :-



$V_d = 1.35\, V_{LL} \cos\alpha$

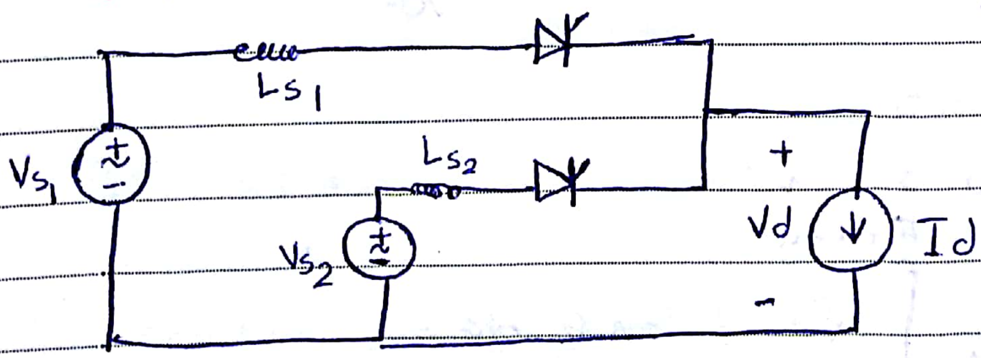
$P_d = V_d\, I_d$. (فقط لما يكون
و I_d ↓)

$P = V\, I_1 \cos\phi_1$

$\underbrace{V}_{\text{non sin or cos}}$

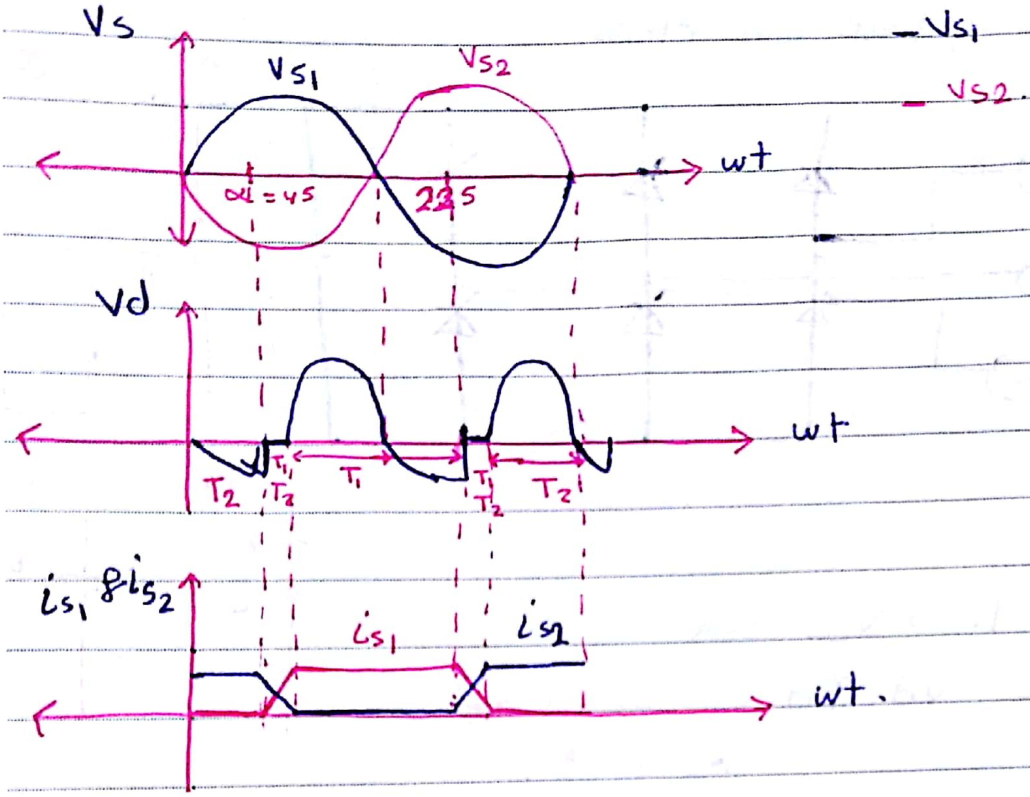
$$P = \frac{1}{2\pi}\int_0^{2\pi} v_d(\theta)\, i_d(\theta)\, d\theta.$$

* Problem 6-1



$V_{s_1} = V_{s_2} = 120$ (rms) out of phase 180

$L_s = 5\,mH$, $I_d = 10\,A$ 60 HZ. , $\alpha = 45$ & 225



* During commtation. 8-

$$-V_{s_1} + L_s \frac{di_{s_1}}{dt} + V_d = 0. \quad \text{---}(1)$$

$+$

$$-V_{s_2} + L_s \frac{di_{s_2}}{dt} + V_d = 0 \quad \text{---}(2)$$

$$-\cancel{V_{s_1}} + L_{s_1} \cancel{\frac{di_{s_1}}{dt}} + V_d - \cancel{V_{s_2}} + L_s \cancel{\frac{di_{s_2}}{dt}} + V_d = 0.$$

لـ عكس V_{s_2} في الإشارة ومتساويين في مقدار.

$$2 V_d = 0$$

$$V_d = 0 \quad ✓.$$

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

During Commutation :-

تسلسل ٧

$V_{L_1} = V_{s1}$

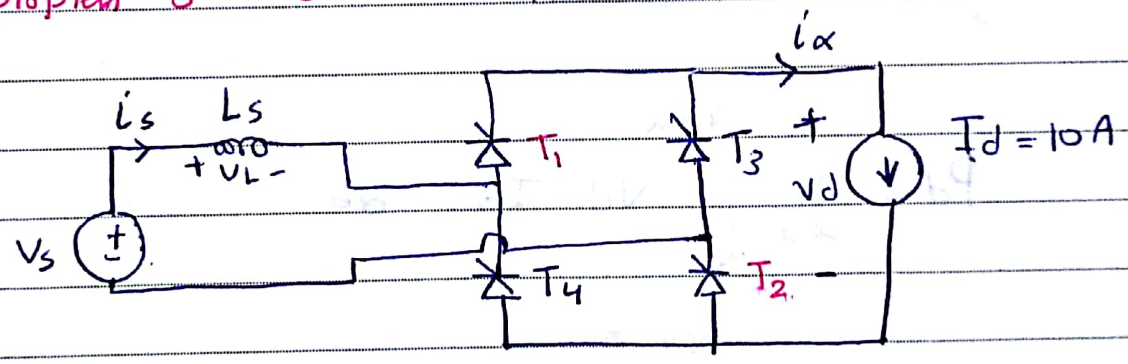
$\omega L_s \frac{di_{s1}}{d\omega t} = \sqrt{2}\, V \sin\omega t.$

inverter 5 جدل

$\omega L_s \int_0^{I_d} di_{s1} = \int_{\alpha}^{\alpha+u} \sqrt{2}\, V \sin\theta \cdot d\theta$

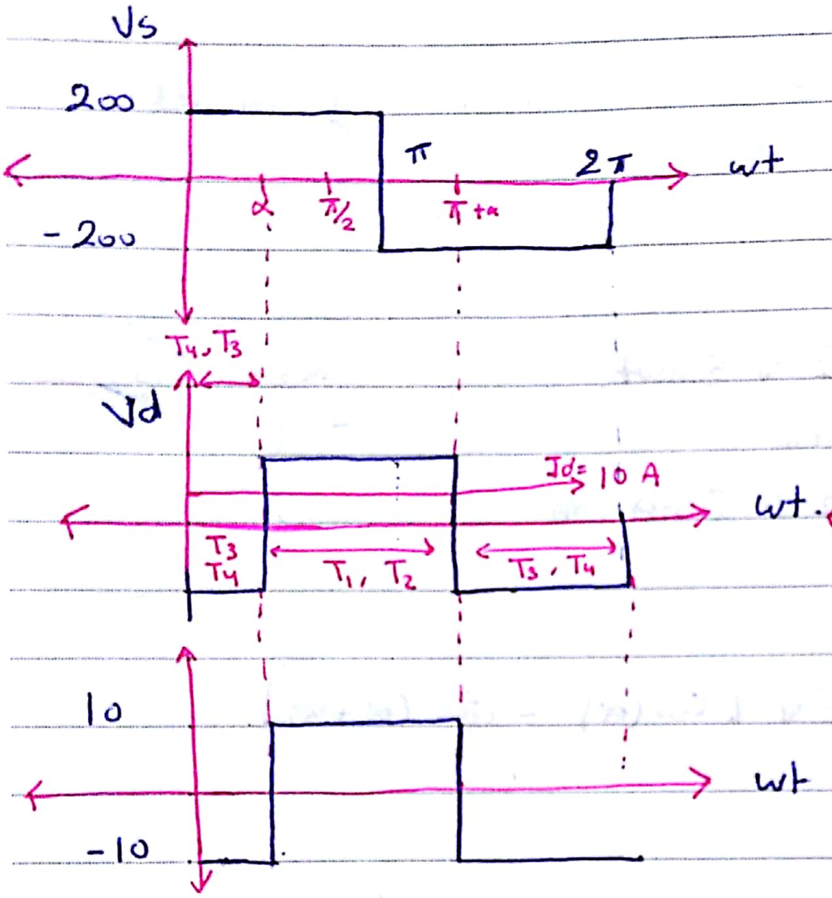
$\omega L_s I_d = \sqrt{2}\, V \left[\cos(\alpha) - \cos(\alpha+u)\right].$

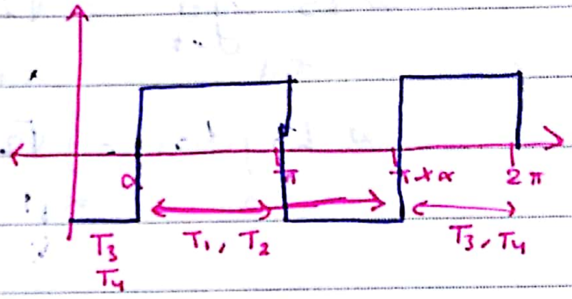
* proplem 6-4 :-



Vs is a square wave with amplitude of 200 V , 60 HZ ; $L_s = 3\,mH$. $\alpha = 45$.

ⓐ If $L_s = 0$.





$$P_d = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} V_d \; I_d \; d\theta.$$

$$= \frac{1}{\pi}\int_{\alpha}^{\alpha+\pi} 200 * 10 \; d\theta$$

$$= \frac{2000}{\pi}\left(\cancel{\alpha}+\pi-\cancel{\alpha}\right) = 2000 \text{ watt.}$$

$$\cancel{V_d = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} 200 \; d\theta} = \cancel{200 \text{ watt.}}$$

$$V_d = \frac{2}{2\pi}\left[\int_{\alpha}^{\pi} 200 \; d\theta + \int_{\pi}^{\pi+\alpha} -200 \; d\theta\right]$$

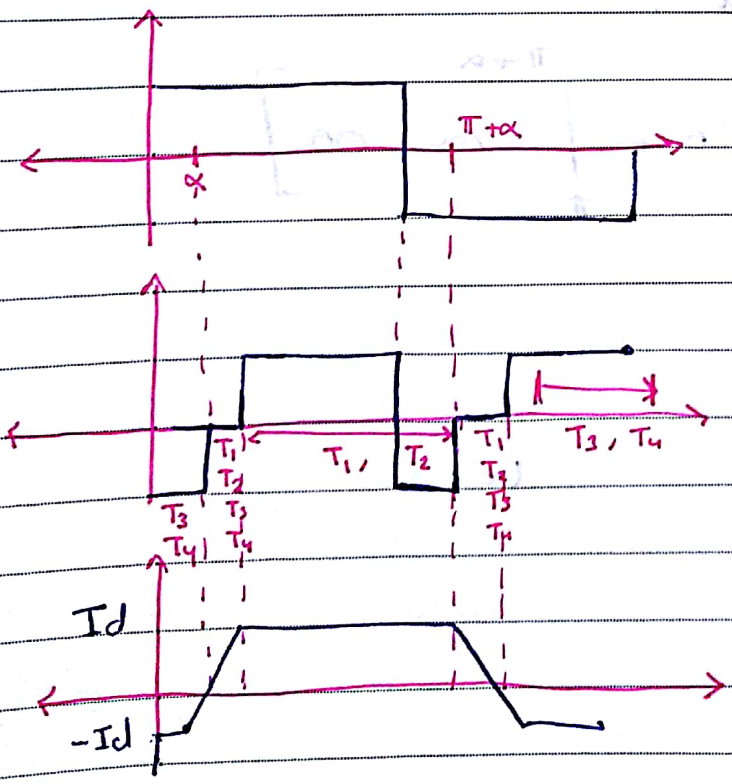
$$P_d = \frac{1}{\pi}\left[\int_{\alpha}^{\pi} 200 * (10)\, d\theta + \int_{\pi}^{\pi+\alpha} (-200)(10)\, d\theta\right]$$

→ D.C Side

* a.c Side

$$P_{ac} = \frac{1}{2\pi}\left[\int_{0}^{\alpha} 200 * (-10)\, d\theta + \int_{\alpha}^{\pi} 200 * 10\, d\theta + \int_{\pi}^{\pi+\alpha} -200 * 10\, d\theta + \int_{\pi+\alpha}^{2\pi} -200 * -10\, d\theta\right]$$

b) If $L_s = 3mH$.



During commutation

$$V_L = V_S.$$

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

$$\omega L_s \int_{-I_d}^{I_d} di_s = \int_{\alpha}^{\alpha+u} 200 \, d\theta$$

$$2 \omega L_s I_d = 200(\alpha + u - \alpha)$$

$$(2)(2\pi f)(3 \times 10^{-3})(10) = 200u$$

$$u = 0.11 \quad \text{rad.}$$

$$= 6.48°.$$

$$V_d = \frac{2}{2\pi}\left[\int_{\alpha+u}^{\pi} 200 \, d\theta + \int_{\pi}^{\pi+\alpha} -200 \, d\theta\right]$$

$$=$$

$$P_d = V_d I_d = \quad W.$$

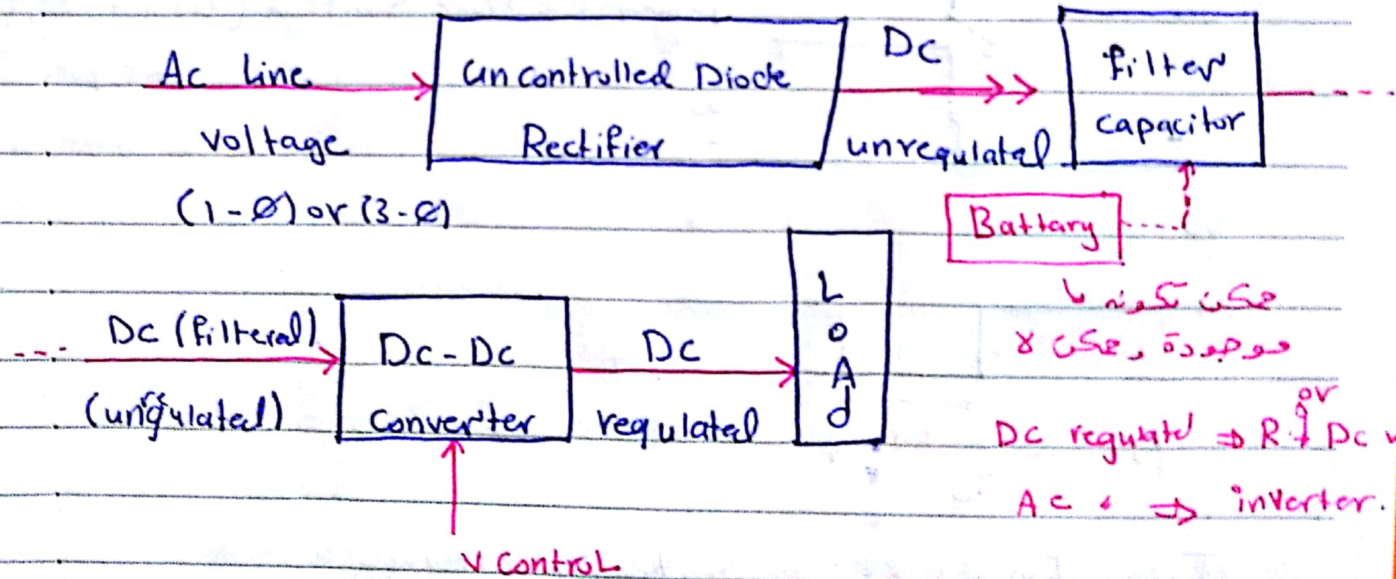
CH 7. dc - dc Switch mode converters :-

* Applications.

1- dc motor drive system.
2- Regulated power supplies
3- Renwable energy system.

* Based on the value of the output voltage compared with the input :-

1- step-down converter (Buck)
2- Step-up converter (boost).
3- Step-up step down (buck-boost).
4- Full bridage



entral Block digram.

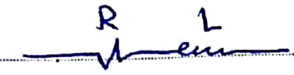
The cct

*

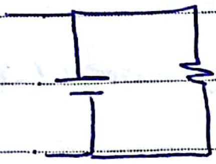
1 - The cct.

2 - The Switech are ideal

3 - The capaciter and inducter

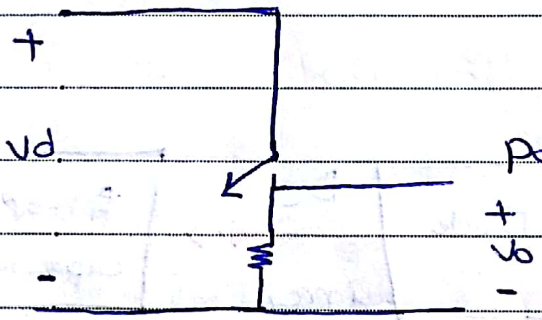


⇒ ideal L , R = 0

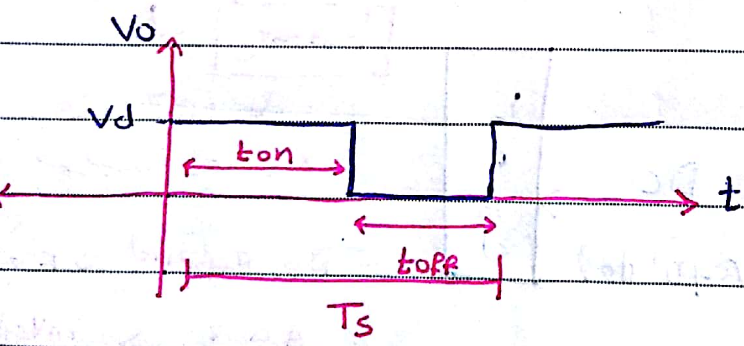


→ ideal C , R = ∞.

* Control of dc - dc converters.



Power electronic switch (Mosfet, BJT, GTO).



$T_s = t_{on} + t_{off}$ = Switching interval.

$f_s = \frac{1}{T_s}$ ≡ Switching frequency. (1 KHz → 25 KHz).

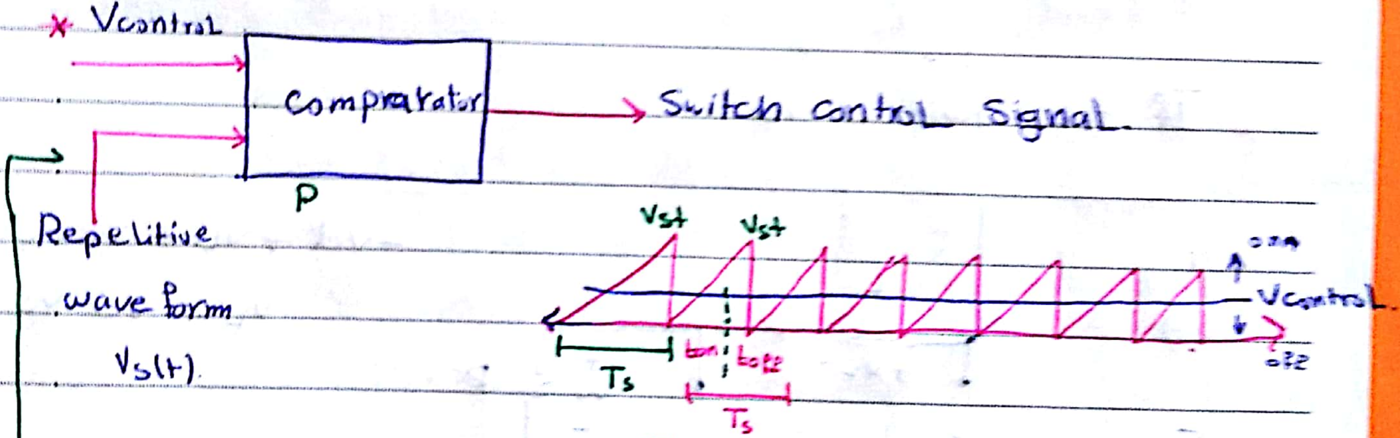
$$V_o = \frac{1}{T_s}\int_0^{T_s} v_o(t)\,dt$$

$$= \frac{1}{T_s}\int_0^{t_{on}} V_d\,dt = V_d\,\frac{t_{on}}{T_s} = V_d\,D$$

$D \rightarrow$ duty cycle.

To change the avarage output voltage. Either ~~others~~ change t_{on} or T_s

* طريقة متبعة نغير t_{on} وتثبت T_s.



$T_s = t_{on} + t_{off}$.

$V_{control} < V_{st} \Rightarrow$ Signal off

$V_{control} > V_{st} \Rightarrow$ " on.

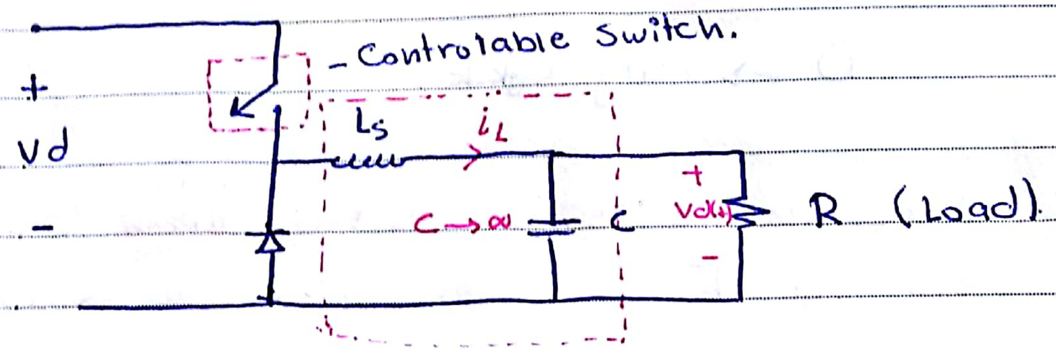
~~pulse~~ * PWM technique for controlling the Switches of Dc-Dc converters.

* Dc to Dc convert Run in to mode

1: Continuious ~~cond~~ current condution mode.

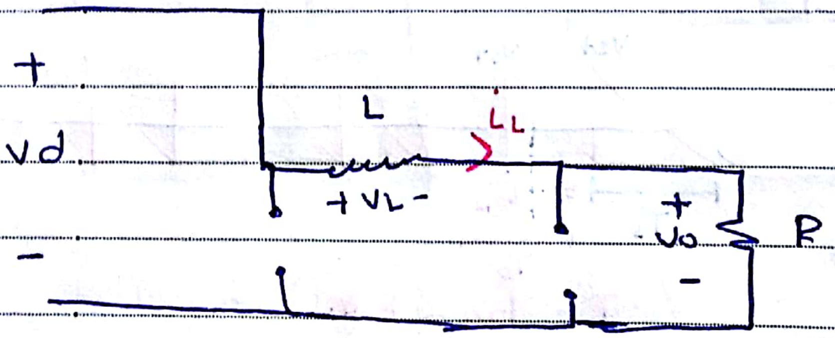
2 dis continuous current condution. Applitaion ٣ حسب للأحمال

* Step down (Buck) converter



$C \to \infty$ such that $V_o(t) \approx V_o$.

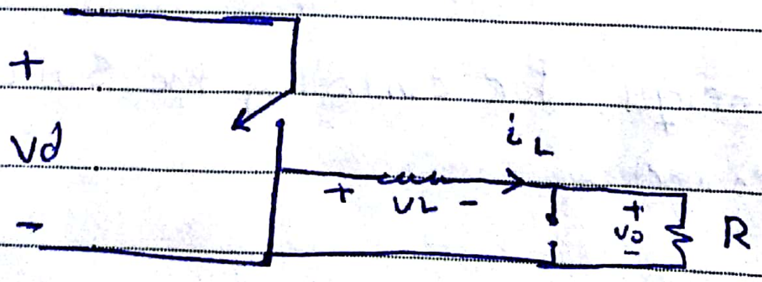
* If the switch is



$-Vd + VL + Vo = 0$

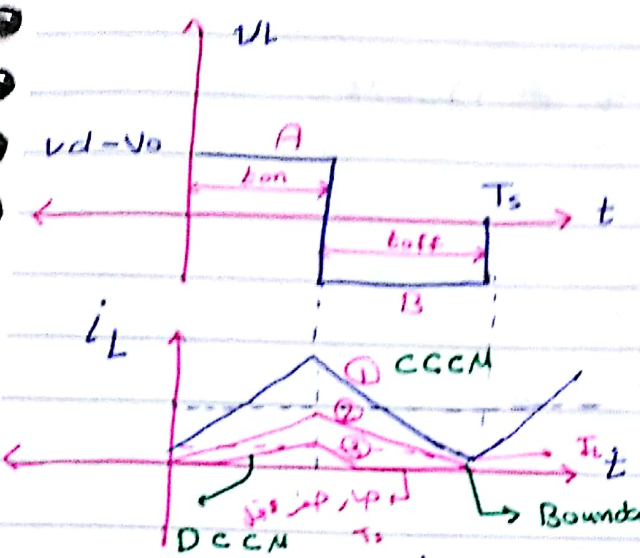
$VL = Vd - Vo$

* If the Switch is off



$VL + Vo = 0$

$VL = -Vo$.



$I_L\,(avg)$

$(A = B)$

$D = \frac{t_{on}}{T_s}$

$V_L = 0$

Boundary between CCCM & DCCM.

$$V_L = \int_0^{t_{on}} V_d - V_o \, dt + \int_{t_{on}}^{T_s} -V \, dt = 0.$$

$$(V_d - V_o)(t_{on}) + -V_o(T_s - t_{on}) = 0$$

① CCCM

$$V_d t_{on} - V_o \cancel{t_{on}} - V_o T_s + V_o \cancel{t_{on}} = 0$$

$$V_d \, t_{on} = V_o \, T_s$$

$$\frac{V_o}{V_d} = \frac{t_{on}}{T_s} = D.$$

$V_o = D V_d$, $D = 0 \rightarrow 1$, $\frac{I_o}{I_d} = \frac{1}{D}$

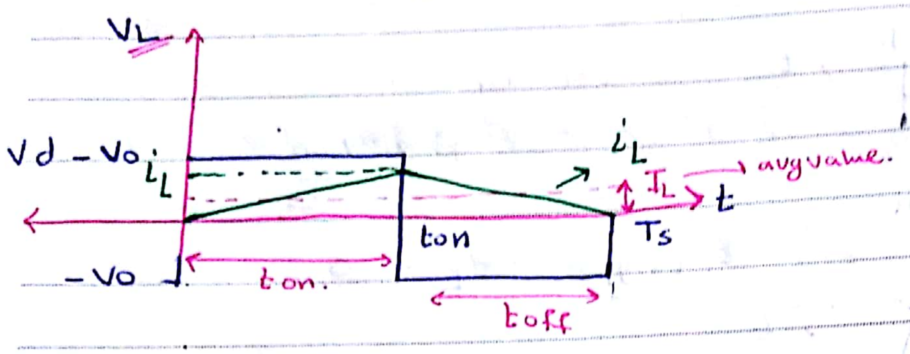
$V_o I_o = V_d I_d.$

$V_o < V_d \Rightarrow$ Step down convert.

* علاقة Load مع current علاقة طردية.

* Load صغير جدا ل i_L قليل قريب للصفر.

* Boundary between CCCM & DCCM



$$I_{LB} = \frac{1}{2} i_{L\,peak}$$

$$I_{LB} = \frac{1}{T_s}\left[\frac{1}{2} t_{on}\, i_{L\,peak} + \frac{1}{2} t_{off}\, i_{L\,peak}\right]$$

$$= \frac{1}{2} i_{L\,peak}\left[\frac{t_{on} + t_{off}}{T_s}\right] \quad ①$$

$$= \frac{1}{2} i_{L\,peak}$$

$$i_{L\,peak} = \frac{1}{L}(V_d - V_o)\, t_{on}$$

$$i_L = \frac{1}{L}\int (V_d - V_o)\, dt$$

$$i_L = \frac{1}{L}(V_d - V_o)\, t + K \qquad i_L(0) = 0, \quad K = 0$$

$$i_{L\,peak} = \frac{1}{L}(V_d - V_o)\, t_{on}$$

Scanned by CamScanner

* $I_{LB} = \frac{1}{2} \frac{1}{L} (V_d - V_o)\, t_{on}$

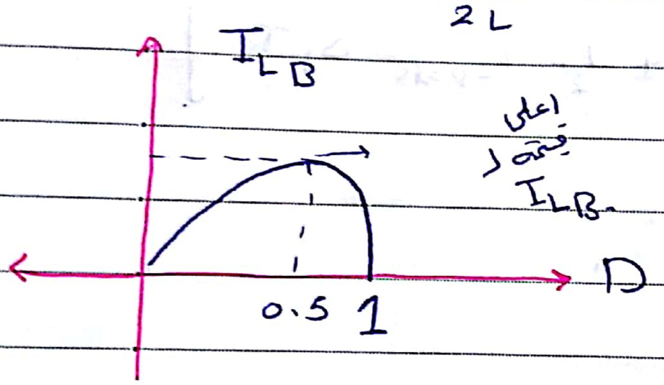
$$= \frac{t_{on}}{2L} (V_d - V_o)$$

$$D = \frac{t_{on}}{T_s} \Rightarrow t_{on} = D\,T_s$$

$$I_{LB} = \frac{D\,T_s}{2L} (V_d - V_o).$$

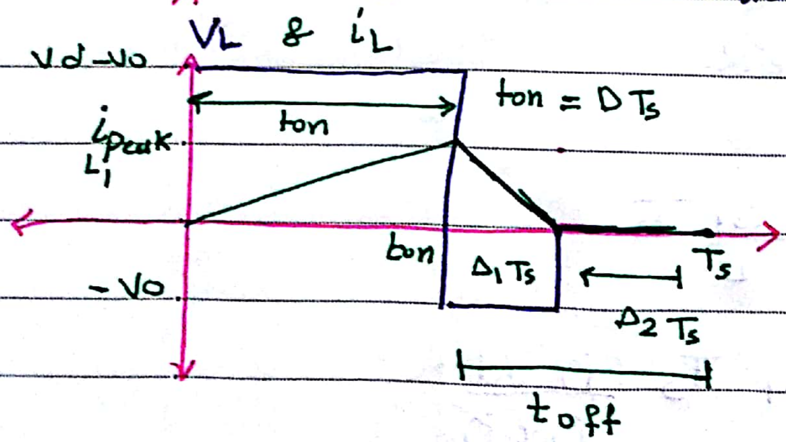
$$= \frac{D\,T_s}{2L} (V_d - D\,V_d).$$

$$= \frac{D\,T_s}{2L} V_d - \frac{D^2\,T_s}{2L} V_d.$$



$$I_{LB}\Big|_{D=0.5} = \frac{T_s\,V_d}{8L}$$

* Dis continuous conduction Mode.



$V_L = 0 \Rightarrow A = B.$

$(V_d - V_o)\, t_{on} = V_o\, \Delta_1 T_s$

$(V_d - V_o)\, D T_s = V_o\, \Delta_1 T_s$

$V_d D T_s - V_o D T_s = V_o \Delta_1 T_s$

$$\frac{V_o}{V_d} = \frac{D}{D + \Delta_1} \rightarrow ?$$

$$I_L = \frac{1}{T_s}\left[\frac{1}{2} i_{L\,peak}\, D T_s + \frac{1}{2} i_{L\,peak}\, \Delta_1 T_s\right]$$

$$= i_{L\,peak}\left(\frac{D + \Delta_1}{2}\right)$$

$(V_d - V_o)\, D T_s = V_o D T_s$

$$i_{L\,peak} = \frac{V_o\, \Delta_1 T_s}{L}$$

$$I_L = \frac{(D + \Delta_1)}{2}\, i_{L\,peak}.$$

$$= \frac{(D + \Delta_1)}{2}\, \frac{V_o\, \Delta_1 T_s}{L}$$

$$= \frac{(\cancel{D + \Delta_1})}{2}\, \frac{1}{L}\, \Delta_1 T_s\, \frac{D V_d}{\cancel{D + D_1}}$$

$$I_L = \frac{1}{2L} \Delta_1 T_s D V_d$$

$$\Delta_1 = \frac{2 L I_L}{D T_s V_d}$$

$$\frac{V_o}{V_d} = \frac{D}{D + \frac{2L I_L}{D T_s V_d}}$$

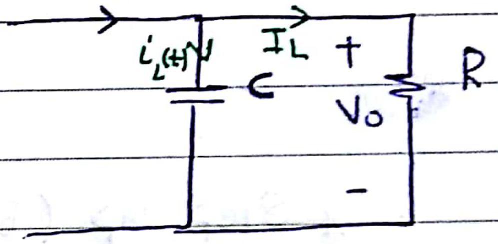
given

$$\underbrace{D\, T_s\, V_d}_{\text{given}}$$

وقياس بالمختبر.

* output Voltage Ripple :-

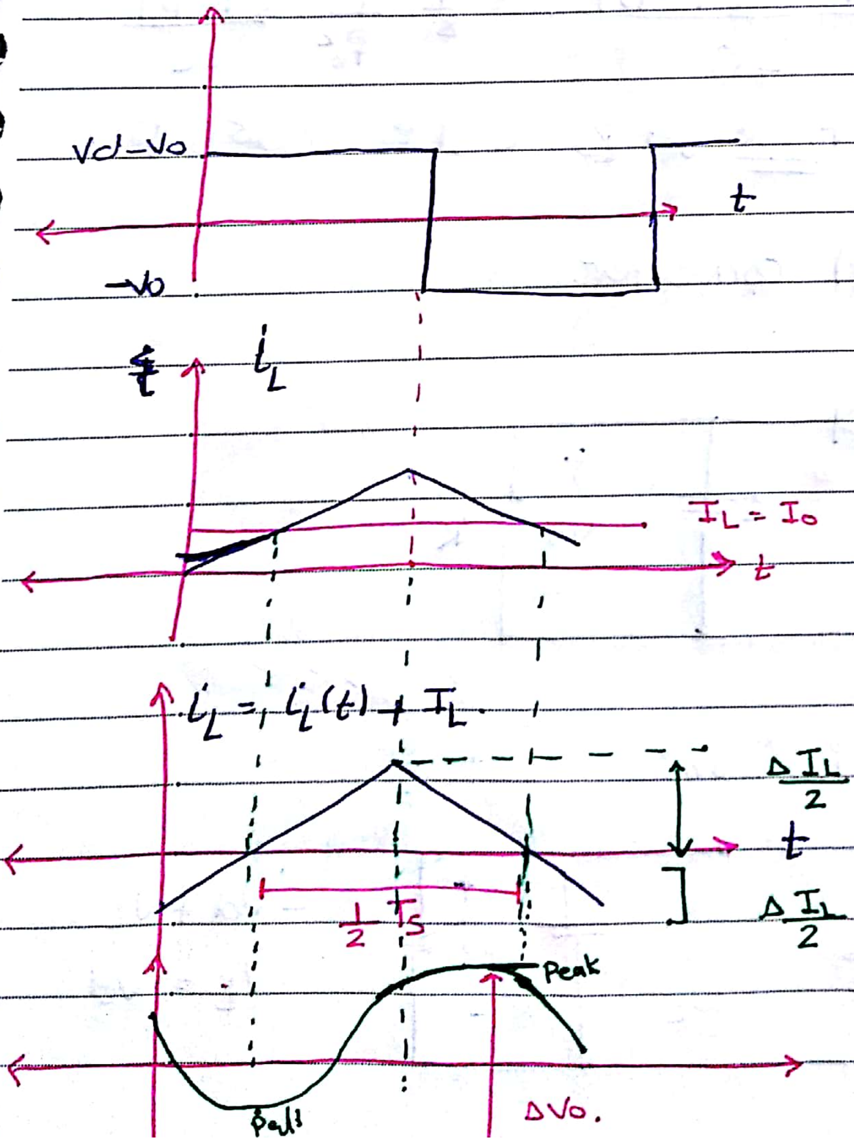
$$i_L = I_L + i_L(t).$$



$$X_C = \frac{1}{wC} \to 0$$

$$i_C = C \frac{dv_C}{dt}$$

$$i_L(t) = C \frac{dv_o}{dt}$$



~~شكل الثاني~~

$$\Delta V_o = \frac{\Delta Q}{C} = \frac{1}{C}\,\frac{1}{2}\,\frac{1}{2}\,T_s\,\Delta I_L = \frac{1}{4C}\,T_s\,\frac{\Delta I_L}{2}$$

$$Q = \int i_L(t)\,dt = \frac{1}{8C}\,T_s\,\Delta I_L$$

$$\Delta I_L = \frac{V_o}{L}(1-D)\,T_s.$$

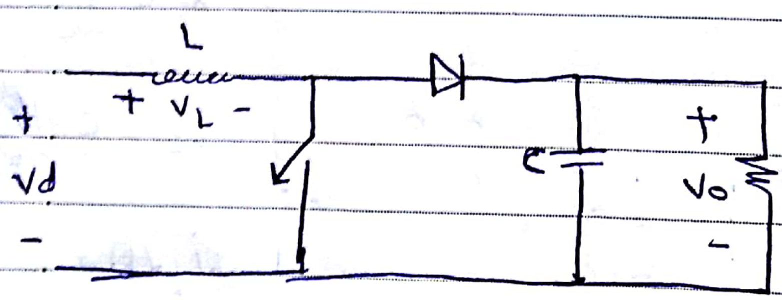
$$i_L = \frac{1}{L}\int v_L\,dt \ldots$$

$$\Delta V_o = \frac{1}{8C}\,T_s\,\frac{V_o}{L}(1-D)\,T_s.$$

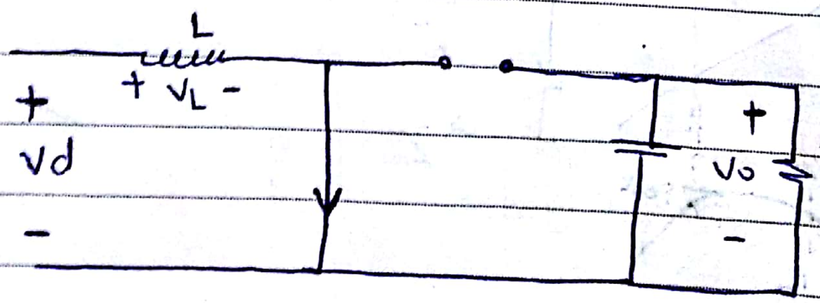
$$\frac{\Delta V_o}{V_o} = \frac{1}{8}\,\frac{T_s^2(1-D)}{LC} = \frac{1}{8}\,\frac{1}{f_s^2}\,\frac{(1-D)}{LC}$$

كل ما كبرت f_s ال رح يقل ripple.

* Step up (Boost) converter.



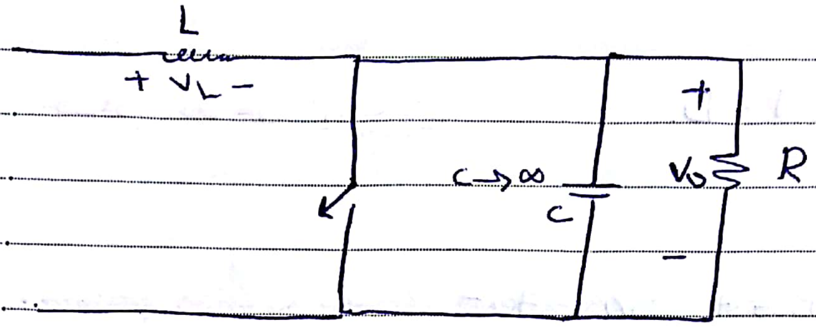
If the switch is "on"



$$-V_d + V_L = 0$$

$$V_L = V_d$$

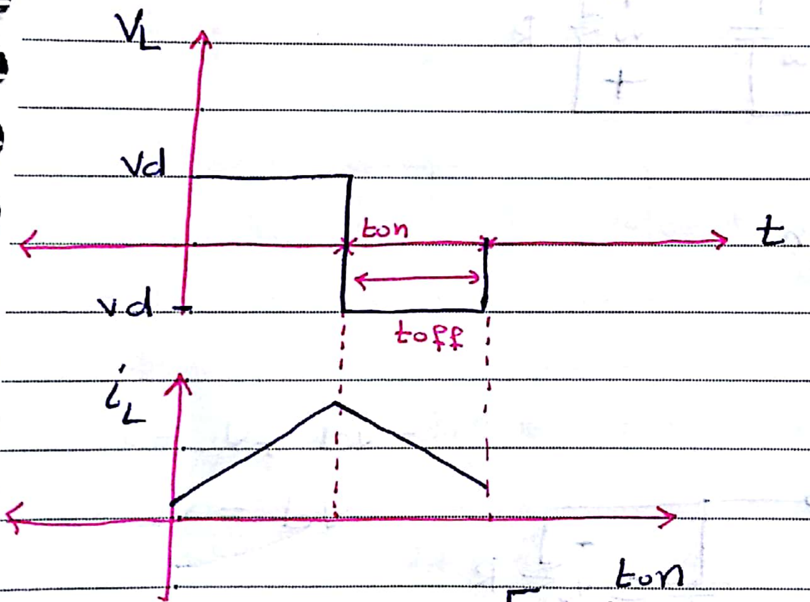
* If the Switch is "off"



*بوجود قيمة عالية لـ C
تبدل في DC

$$-V_d + V_L + V_o = 0$$

$$V_L = V_d - V_o .$$



$$V_L = 0 = \left[\int_0^{t_{on}} V_d \, dt + \int_{t_{on}}^{T_s} (V_d - V_o) \, dt \right]$$

$$V_d t_{on} + V_d T_s - V_d t_{on} - V_o T_s + V_o t_{on} = 0$$

$$V_d T_s = V_o (T_s - t_{on}).$$

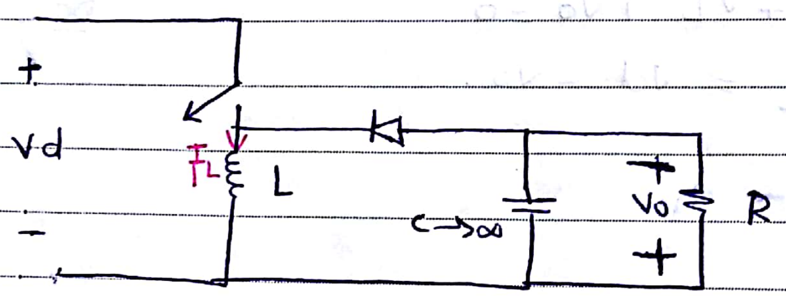
Scanned by CamScanner

$$\frac{V_o}{V_d} = \frac{T_s}{T_s - t_{on}} = \frac{T_s}{T_s - DT_s} = \frac{1}{1-D}$$

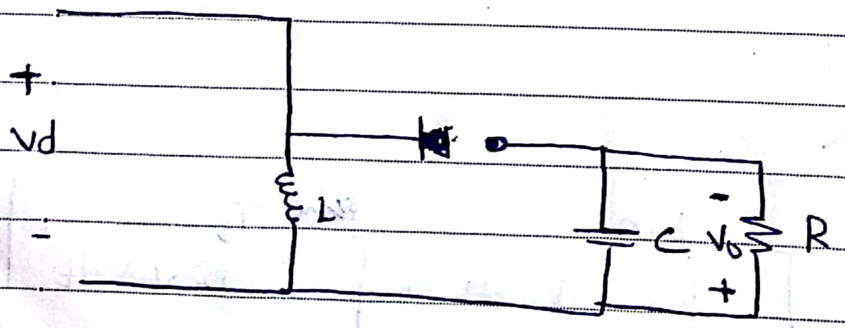
$$\frac{I_o}{I_d} = 1 - D.$$

CCCM مطلوب مناسس

* Buck - Boost converter. (step up - step down)



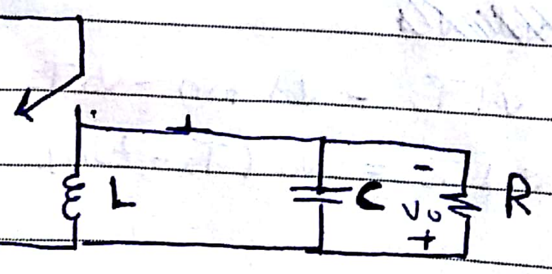
* "on" the switch.



$$-V_d + V_L = 0$$

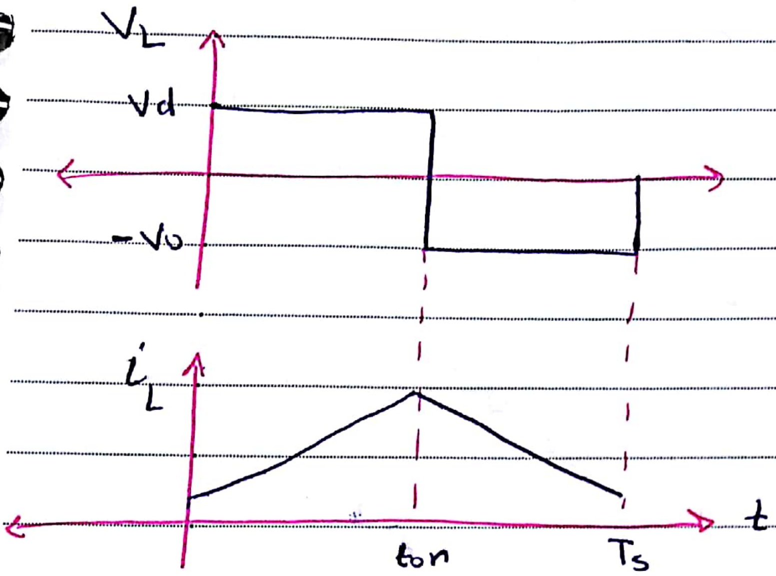
$$V_d = V_L$$

* "off" the switch



$$-V_L - V_o = 0$$

$$V_L = -V_o$$



$$V_L = 0 = \int_0^{t_{on}} V_d \, dt + \int_{t_{on}}^{T_s} -V_o \, dt.$$

$$V_d \, t_{on} - V_o (T_s - t_{on}) = 0$$

$$V_d \, t_{on} = V_o T_s - V_o t_{on}$$

$$\frac{V_o}{V_d} = \frac{t_{on}}{T_s - t_{on}} = \frac{D T_s}{T_s - D T_s} = \frac{D}{1 - D}.$$

Step down $0 \longrightarrow 0.5$

step up $0.5 \longrightarrow 1$

$$\frac{I_o}{I_d} = \frac{1 - D}{D}$$

EICoM ELECTRICAL COMPUTER MECHATRONICS

* Full Bridge dc-dc converter :-

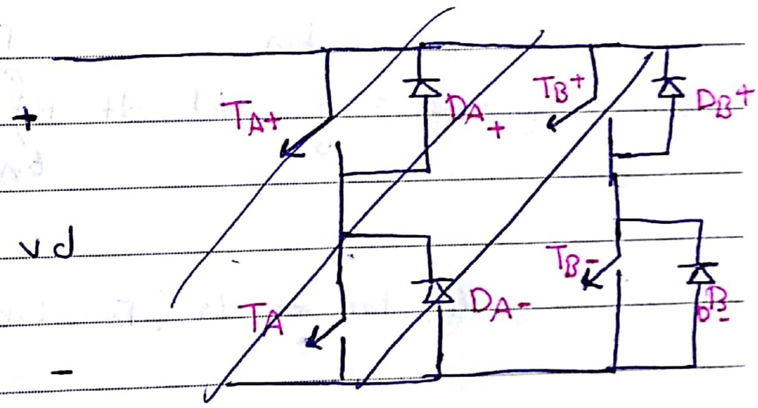
* Applications.

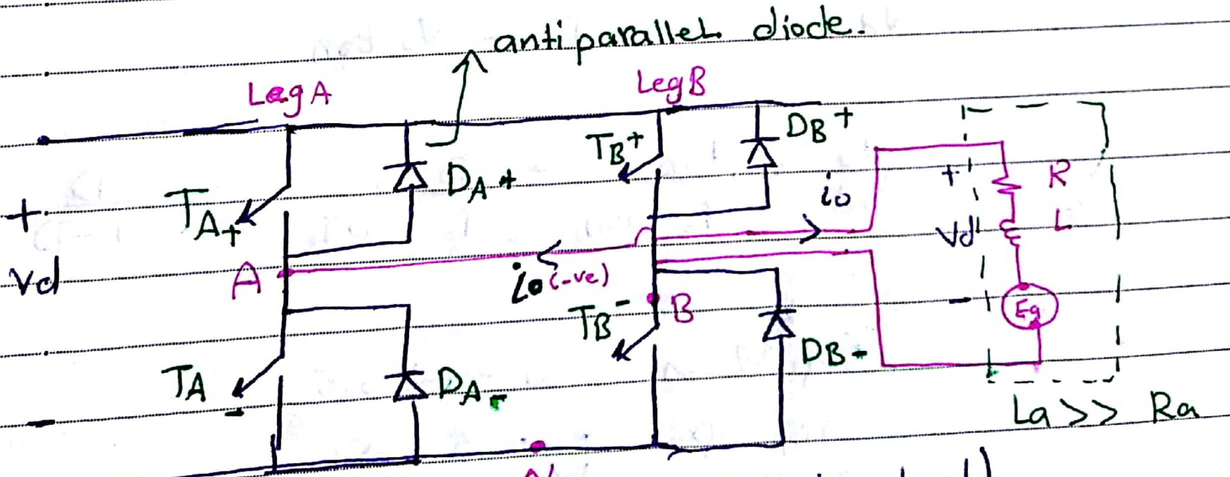
1- dc motor drives.

2- dc to ac conversion.

3- Renevable energy system.

4- Ups (uninterr





Dc motor (Load) (highly inductive Load).

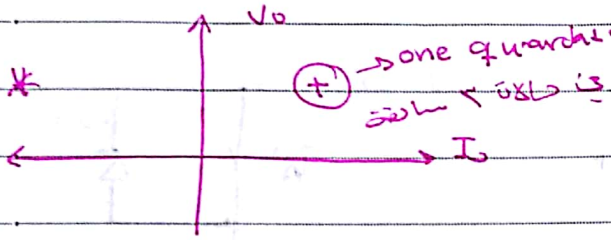
i_o :- +ve direction of the current.

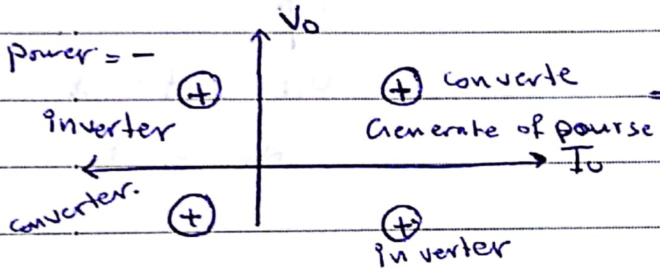
* ممنوع Swith
على تمس Lag
بيكونوا سوى on.

i_o :- -ve driection of the current.

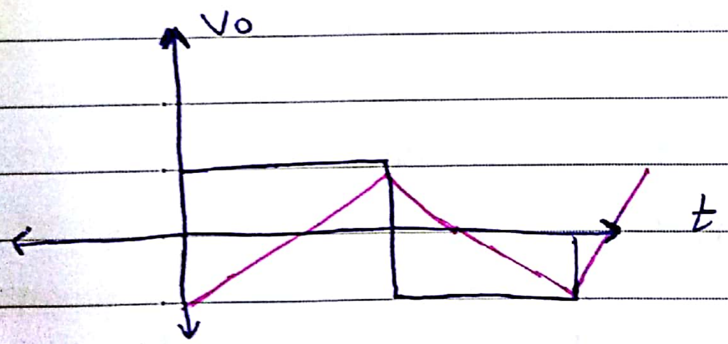
*لما يكون تيار -ve ممنوع يمشي ب Switch لازم يمشي ب Diode.

*





لباقي الحالة تقدر اشتغل
ب ٤ ارباع.

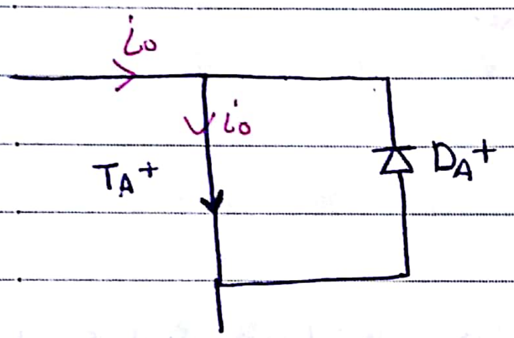


* on State of the Switch:-
the Switch is on and may or may not conduct the current.

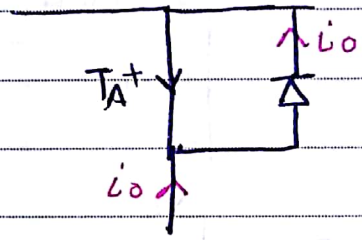
* Conducting state of the Switch :-

The Switch on and the current flows through the Switch.

* لا تعطي تيار negative في لا طاقة في cct.



Conducting state.



on State of the Switch.

$T_B^- \Rightarrow on \Rightarrow V_{BN} = 0.$

* All the case

$V_o = V_{AN} - V_{BN}.$

1. T_B^+ on $\quad T_A^-$ on $\quad V_{AN} = 0 \quad V_o = -V_{BN}.$

$V_{BN} = V_d$

2. T_B^+ on $\quad T_A^+ \quad V_{AN} = V_d \quad V_o = 0.$

$V_{BN} = V_d$

1- when T_A^+ is on, i_o flows through T_A^+ if i_o +ve

2- when T_A^+ is on, i_o flows through D_A^+ if i_o is -ve.

3- In both case, T_A^+ is on $V_{AN} = V_d$.

(T_A^+ is on & T_A^- is off).

* when T_A^- is on, i_o flows through T_A^- if i_o is -ve.

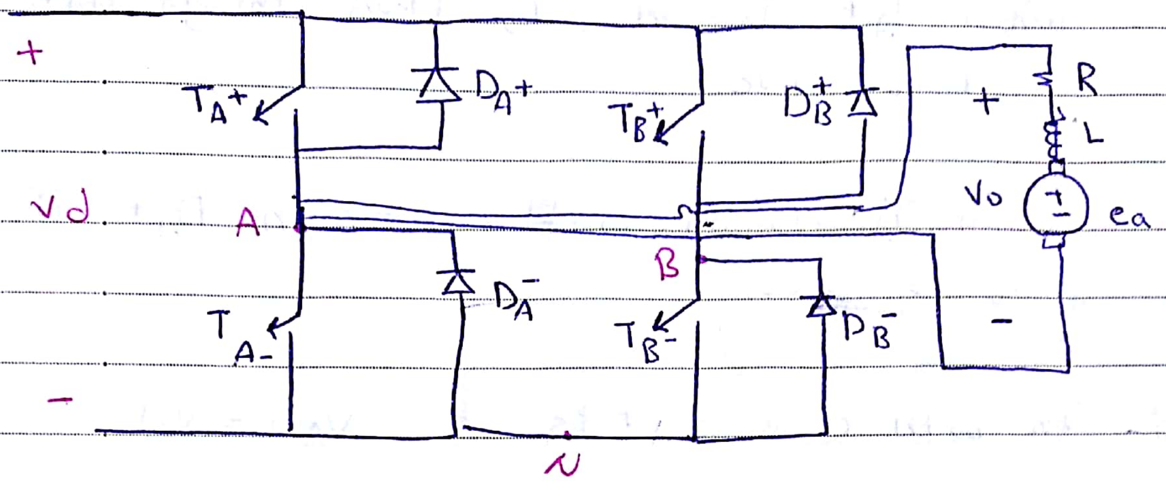
* when T_A^- is on, i_o flows through D_A^- if i_o is +ve.

In both case, T_A^- is on, $V_{AN} = 0$.

* مش ممكن يكون T_A^- و T_A^+ سوا on *.

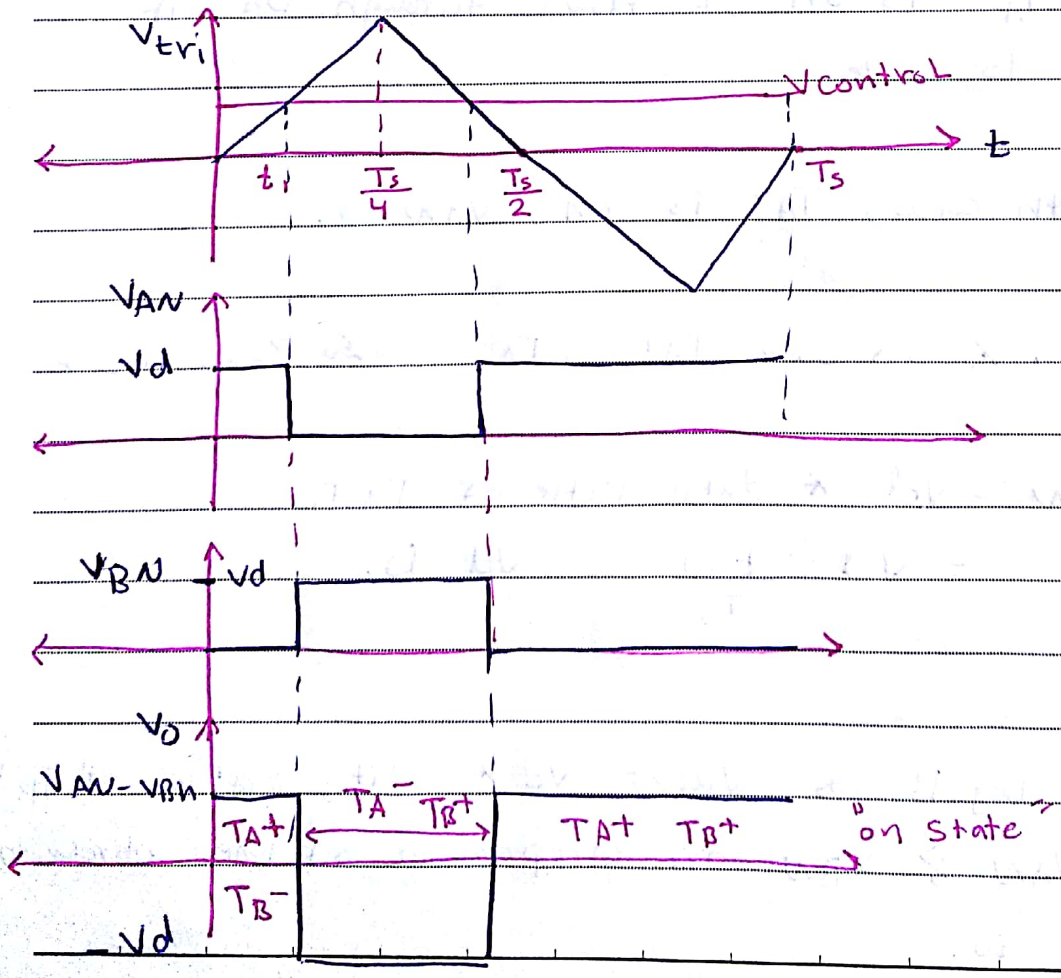
For Leg A
* $V_{AN} = V_d$ * duty ratio of T_A^+.
$= V_d \dfrac{t_{on}}{T_s} = V_d D.$

for Leg B
For Leg B ⇒ $V_{BN} = V_d$ * duty ratio of T_B^+
* V_{AN} & V_{BN} are independant of the direction of i_o.



① PWM with bipolar voltage switch

(T_A^+, T_B^-) & (T_B^+, T_A^-) are turned on and off simulta (inverter).



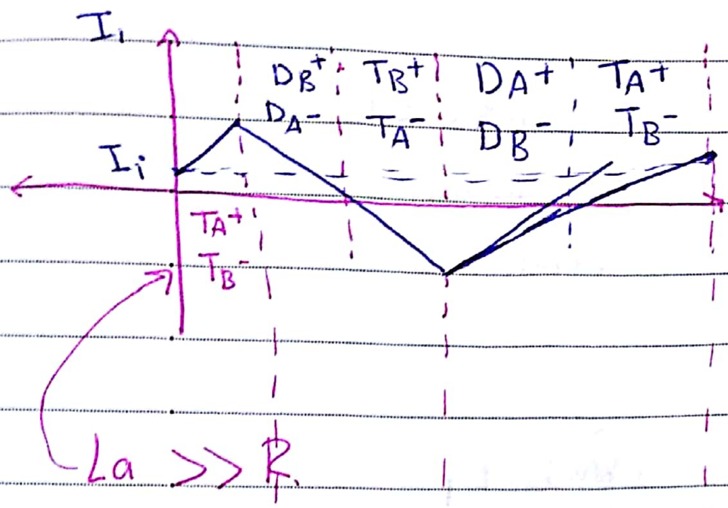
Vcontrol > Vtri

T_A^+ T_B^- "on"

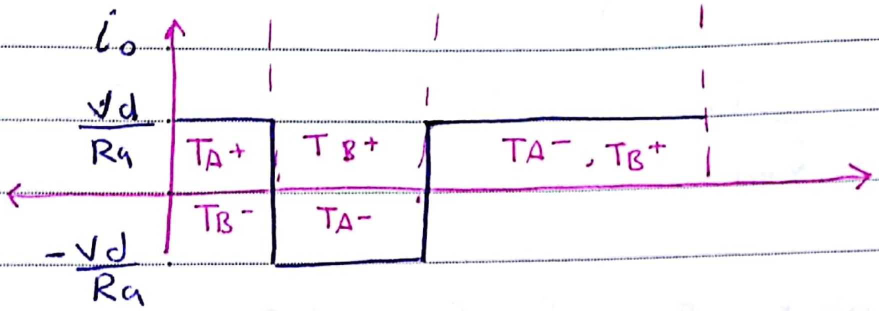
Vcontrol < Vtri

T_A^- T_B^+ on

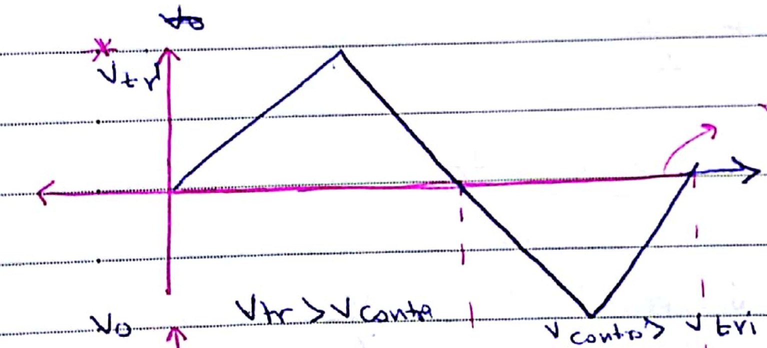
" Conductive state "

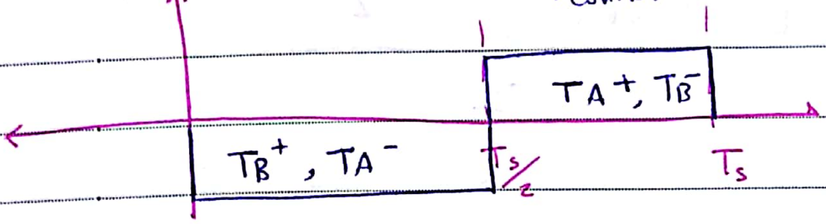


(pure R)

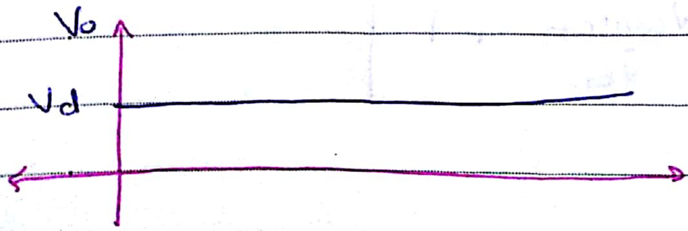


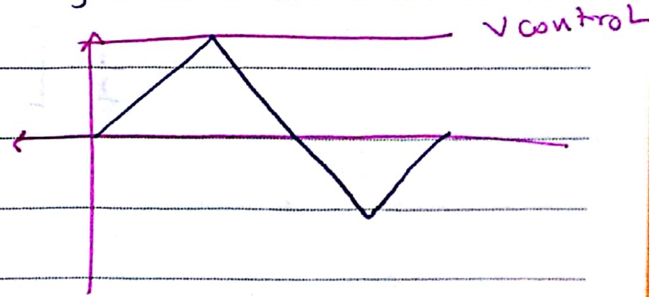
$V_{control} = Zero.$





* $V_{control} = V_{tri}$. , $V_o = V_d$.





* $V_{tri} = \dfrac{\hat{V}_{tri}}{\frac{T_s}{4}} t$, $0 < t < t_1$

Tricon

$= \dfrac{4 \hat{V}_{tri}}{T_s} t$, ton

when $t = t_1$

$V_{control} = V_{tri} = \dfrac{4 \hat{V}_{tri}}{T_s} t_1$

$t_1 = \dfrac{V_{control} T_s}{4 \hat{V}_{tri}}$

The one duration t_{on} of T_A+ T_B- is :-

$t_{on} = 2 t_1 + \dfrac{T_s}{2}$

$D_1 = \dfrac{t_{on}}{T_s} = \dfrac{2 t_1 + \frac{T_s}{2}}{T_s}$

$D_1 = \dfrac{2\left[\dfrac{V_{control} T_s}{4 V_{tri}}\right] + \dfrac{T_s}{2}}{T_s}$

$D_1 = \dfrac{1}{2} \dfrac{V_{control}}{V_{tri}} + \dfrac{1}{2}$

$= \dfrac{1}{2}\left[\dfrac{V_{control}}{\hat{V}_{tri}} + 1\right]$

* The on duration of T_{B+}, T_{A-} is.

$$D_2 = 1 - D_1$$

$$V_o = V_{AN} - V_{BN}.$$

$$= D_1 V_d - D_2 V_d.$$

$$= D_1 V_d - (1 - D_1) V_d.$$

$$= D_1 V_d - 1 + D_1 V_d.$$

$$V_o = (2D_1 - 1) V_d$$

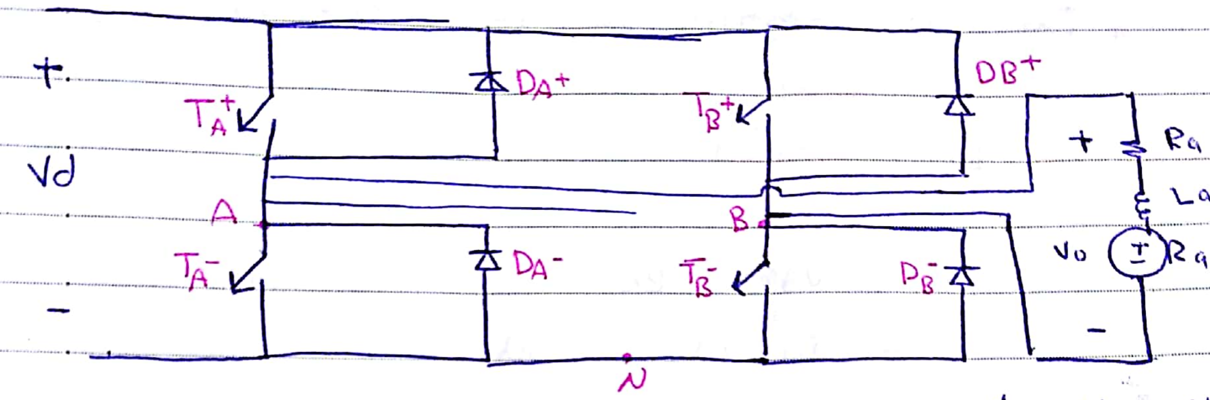
$$V_o = \frac{V_{control}}{\hat{V}_{tri}} V_d.$$

$$V_o = K \; V_d.$$

, $V_{control} = 0$, avg V_o = Zero.

Scanned by CamScanner

*

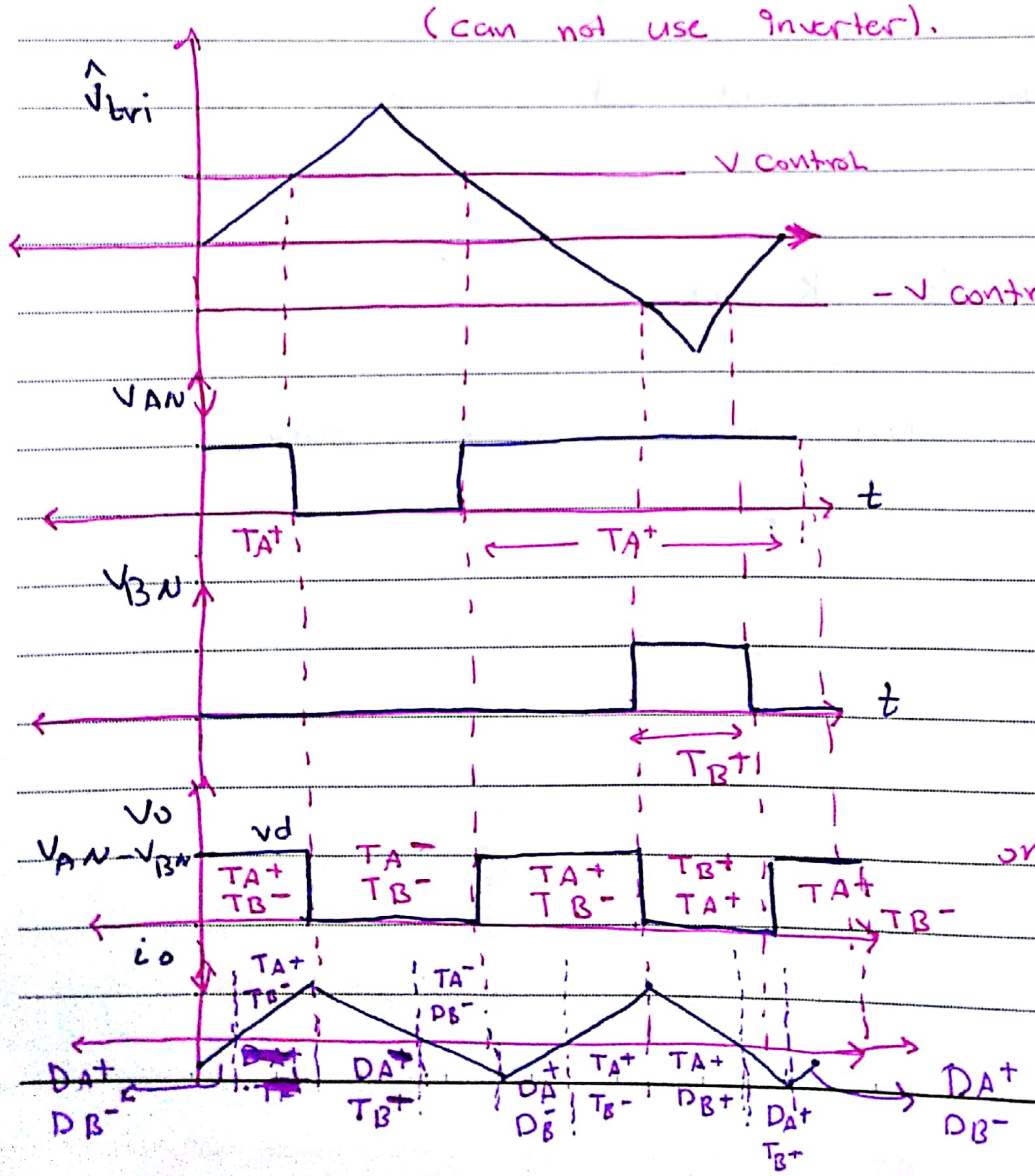


$V_o = V_{AN} - V_{BN}$

* PWM with unipolar voltage Switching :-

The switches in each inverter Leg are controlled independently of the other Leg.

(can not use inverter).



T_A^+ "on" if $V_{control} > V_{tri}$

T_B^+ "on" if $-V_{control} > V_{tri}$

on state of the Switches.

$V_o = \frac{V_{control}}{\hat{V}_{tri}} V_d.$

* يسبح ابو T_B^+ T_A^+ بكونوا on

* يسبح D_A^+ T_A^+ switch مع دايود .

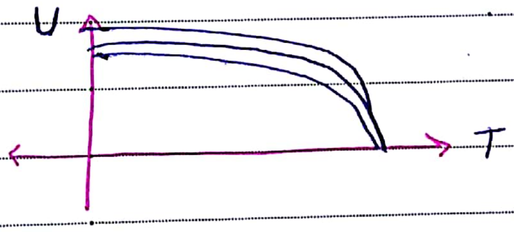
* كل cycle stedy state ، ~~...~~ ~~...~~

داخل كل cycle ← Fransim. (عيز ثابت مبد $L \neq 0$).

مهم جداً

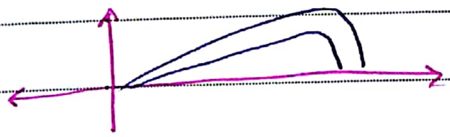
prod CH7 : 1, 2, [(19, 18,) , 22]

متغيرة



* بيعتمد على قيمة Load
I

using Dc - Dc converter. to set (constat voltage.). on pV - generater.



CH7 * Switch mode dc → ac Inverters.

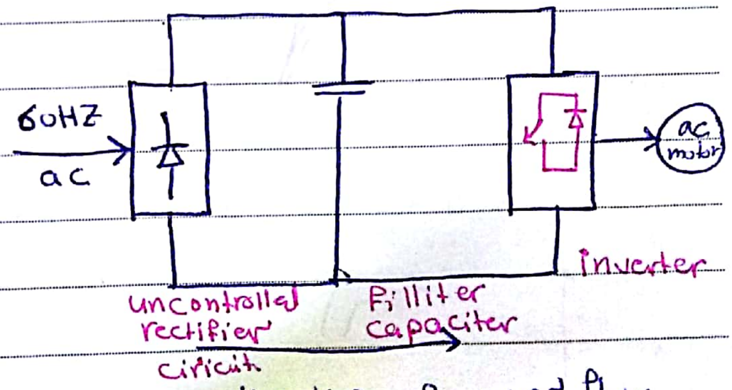
dc → Sinusoidal ac.

* Application :-

1_ ac motor drives.
2- UPs
3- pv system.
4- wind energy systems.

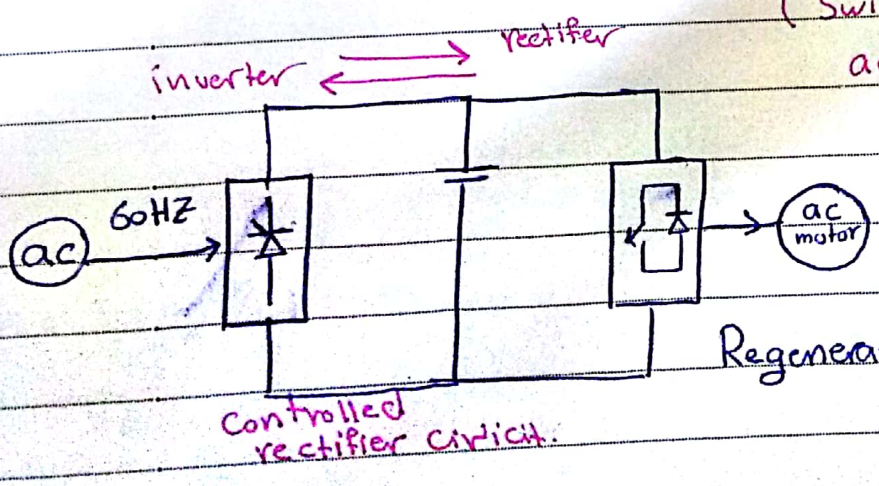
Rerenable energy system.

* Objective :- To produce a sinusoidal ac output Voltage (current) with controlled frequency and magnitude.



direction of power flow.

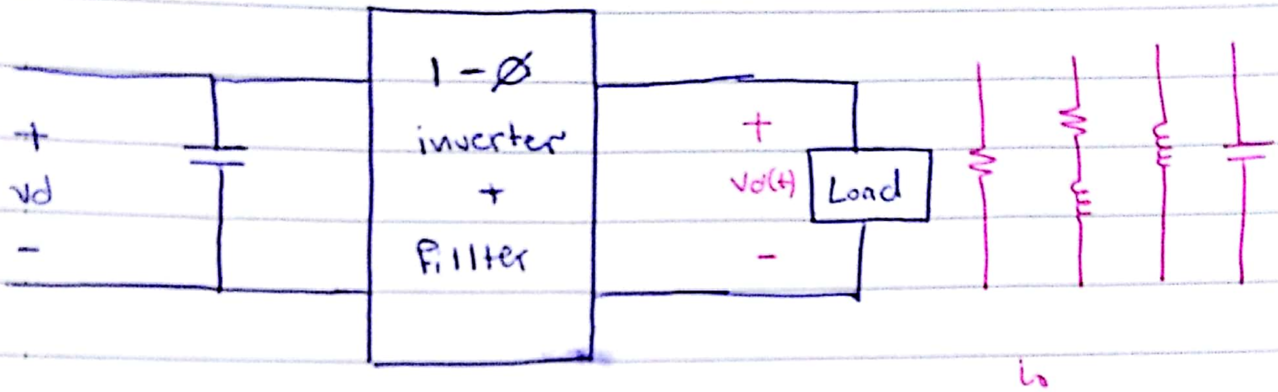
(Switch - mode inverter in ac motor drive system)

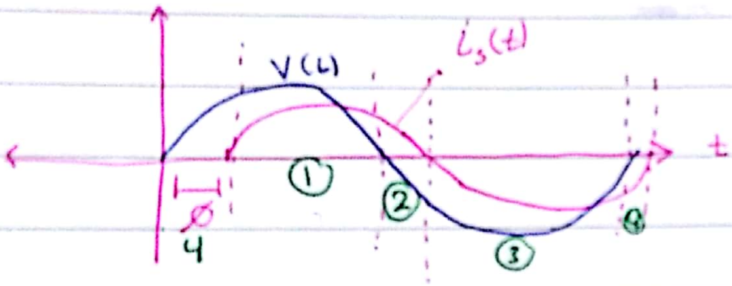


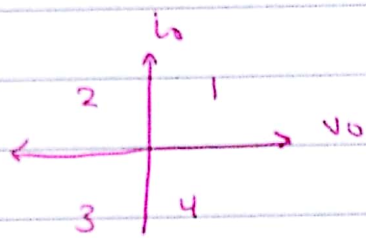
Regenerative braking principle.

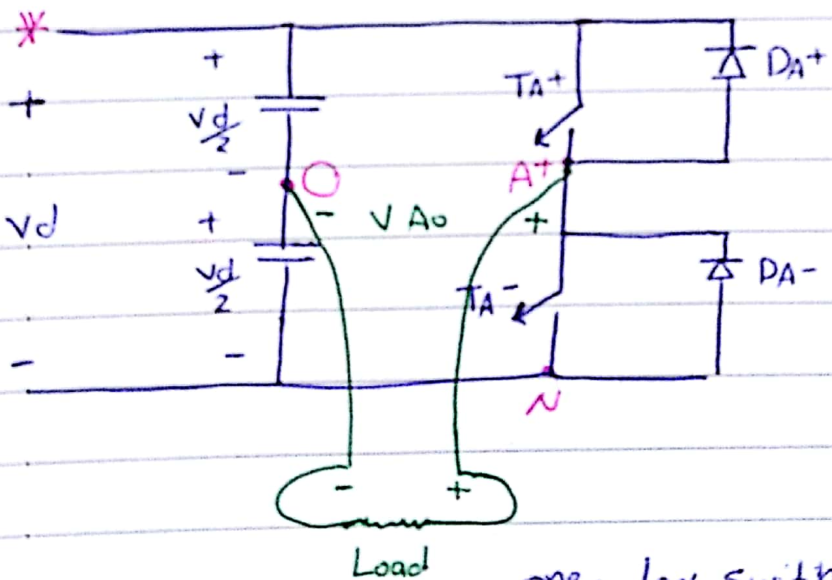
رقم ٥ ل ٤

* Basic concept of switch - mode. Inverter.



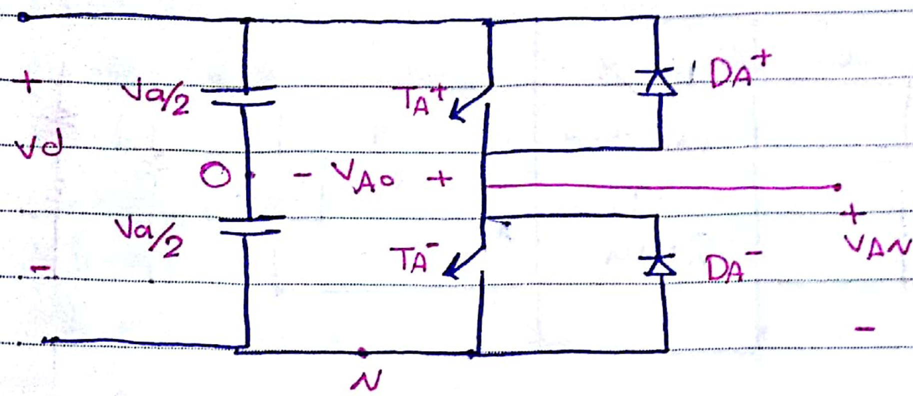




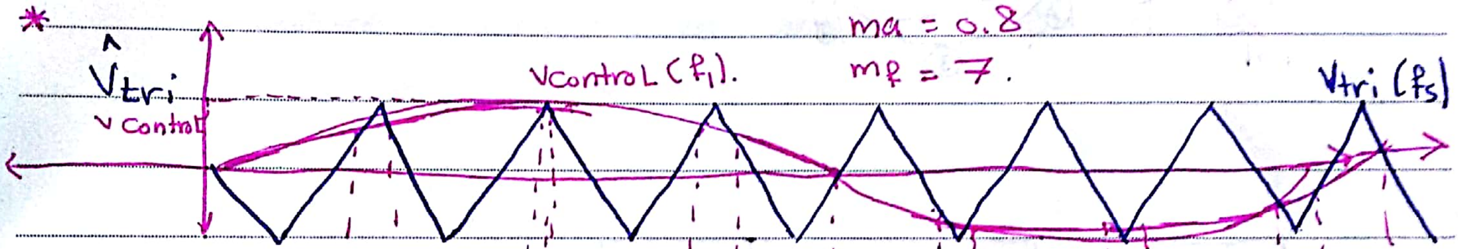


one - leg switch mode inverter.

* on Leg inverter. (single phase).

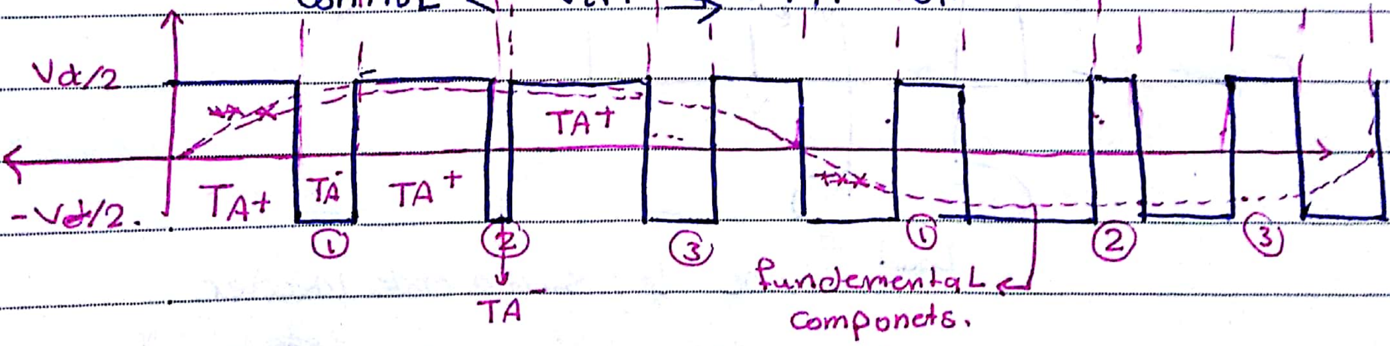


* pulse width Modulate Switching Schem:-

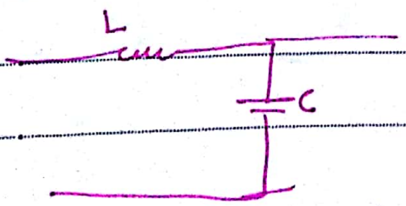


Vcontrol > Vtri ⟹ T_A^+ "on"

Vcontrol < Vtri ⟶ T_A^- "on"



(Filliter LPF) بركب pure sin ~~Sine~~ لازم تطلع



لازم اعمله صفة للازمة freq

L, C. صفة اصلا

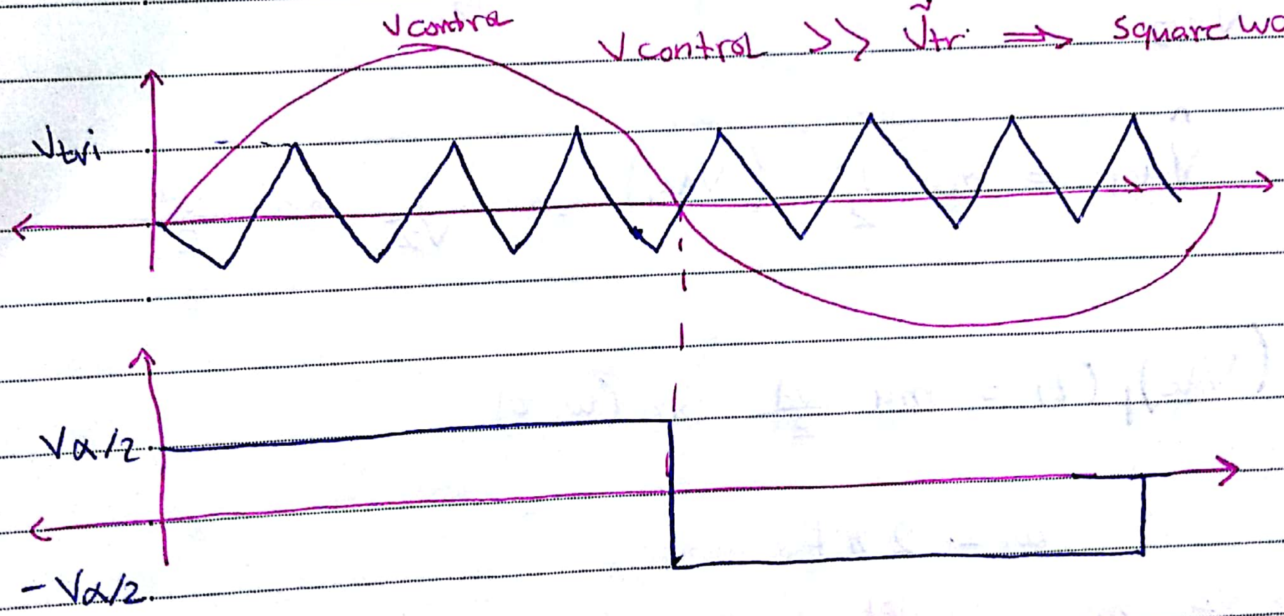
* f_s :- the frequency of which the inverter switche are switched (carrier frequency) ⇒ Switching freque

* f_1 the frequency which is desired fundanetal frequency of the inverter output voltage (modulating frequency).

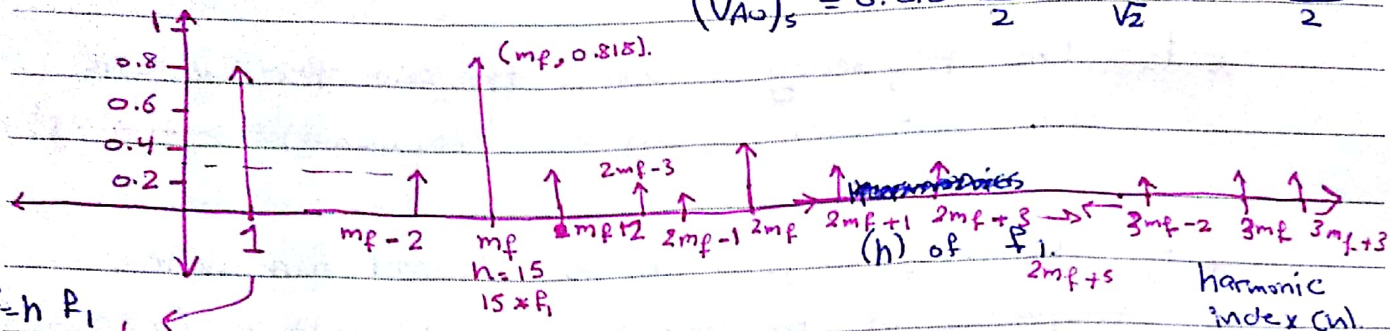
$$m_a = \frac{\hat{V}_{control}}{\hat{V}_{tri}}$$ → amplitude modulation index (ratio)

$$m_f = \frac{f_s}{f_1}$$ ⇒ frequency modulation index (ratio).

$V_{control} >> \hat{V}_{tri}$ ⇒ square wave



$$(\hat{V}_{Ao})_s = 0.818\ \frac{V_d}{2} = \frac{1}{\sqrt{2}}\ 0.818\ \frac{V_d}{2}$$



$f = h\, f_1 = f_1$

Fundemental Frequency.

Harmonic spectrum of Avo for ma = 0.8 and & mf = 15. for one-leg Switch mode DC-AC inverter.

* Note one Leg DC-Ac inverter :-

At $f_1 \Rightarrow$ 50 HZ, 60 HZ, 100 HZ, 25 HZ.

$$\frac{\hat{V}_{Ao_1}}{V_d/2} = 0.8 \Rightarrow \hat{V}_{Ao1} = 0.8\ \frac{V_d}{2}$$

$$\hat{V}_{Ao_1} = ma\ \frac{V_d}{2} \quad (V_{Ao1})_{rms} = \frac{1}{\sqrt{2}}\ ma\ \frac{V_d}{2}.$$

$$(V_{Ao})_1 (t) = ma\ \frac{V_d}{2}\ \sin(\omega_1 t).$$

$$\omega_1 = 2\pi f_1.$$

*للذا نعمل Design لـ fillter حتى نتخلص من order mp لانه قيمتها كبيرة.

(LpF $\Rightarrow$ (L, C) Series)

* $ma < 1 \Rightarrow$

* The harmunic in the inverter output Voltage wave form are side band centered ~~arund~~ around the Switching frequency and it multipls (mf, 2mf, 3mf)

2- the number of harmonic is infinite.

3- the amplitude of the harmonics are independent of m_f.

3- their frequencei is ~~calc~~ caulated $\Rightarrow$ ~~[illegible]~~.

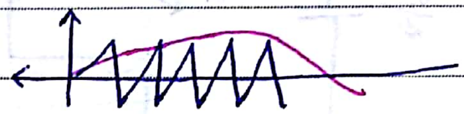
$$f_h = (j m_f \pm k) f_1 = h f_1.$$

j odd $\Longrightarrow$ k even

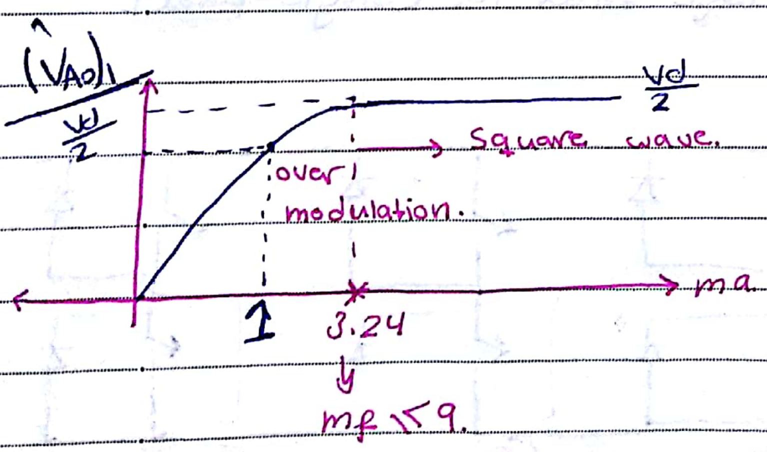
j even $\longrightarrow$ k odd

4- for odd value of j the value of k is even

for even " " " " " " " odd.

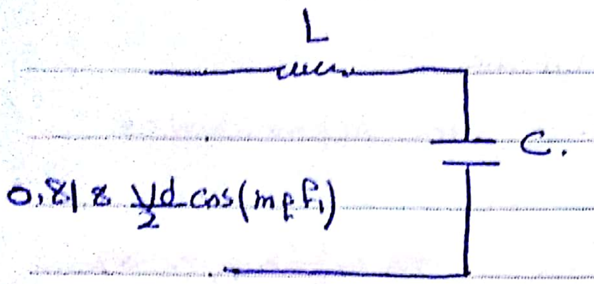
* for $m_a > 1 \Rightarrow$ 

1. $m_a >> 1$ $\Rightarrow$ ما رح تتقاطع معها.



* The square wave out voltage is obtiem condition if m_a much grater one ($m_a >> 1$) the general condition if the control signal does not intersect with $\hat{V}_{tri}$.

* Design LpF :-

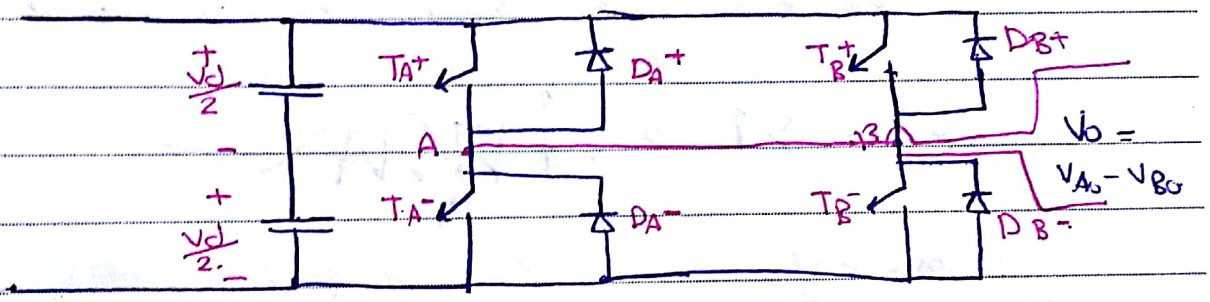


$$0.818 \frac{V_d}{2} \cos(1 f_s) = 15 * 50 = 750$$

$$wL = (2\pi)(750) L = \dots \ \Omega$$

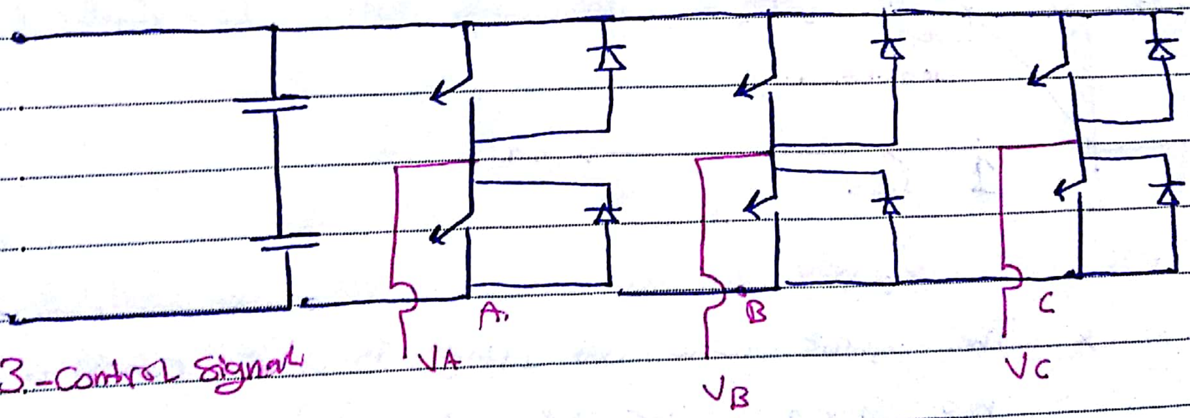
$$\frac{1}{wc} = \frac{1}{2\pi(750)C}$$

*



2- Control Signal

full _ Bridge Inverter (Single-phase)



3-Control Signal

3-∅ full Bridge Inverter.