ElCoM
ELECTRICAL COMPUTER MECHATRONICS

تقدم لجنة ElCoM الاكاديمية

دفتر لمادة:

الكترونيات القوى

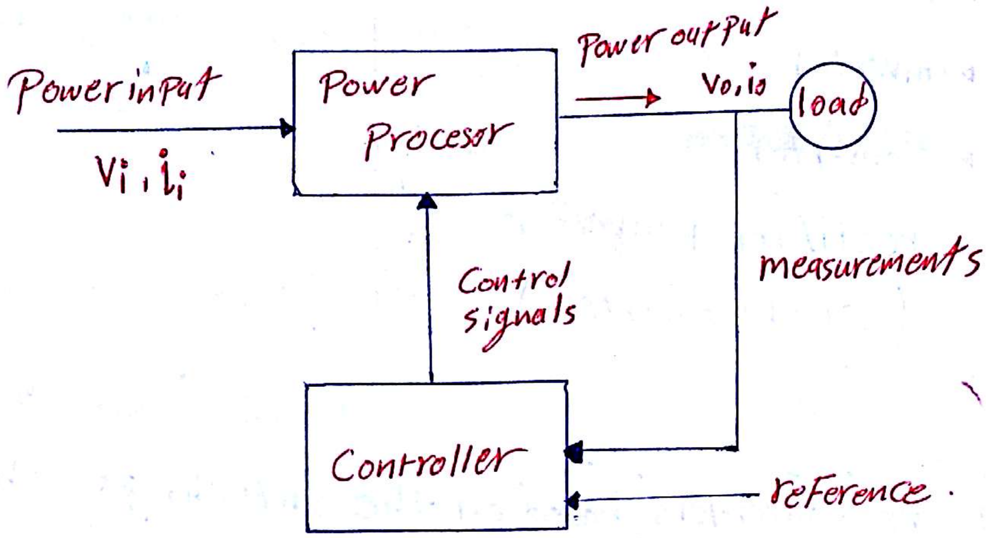
من شرح:

د.محمد وديان

جزيل الشكر للطالب:

عمر الدغيم

Power Electronics:- 1 30/1/2017 الاثنين

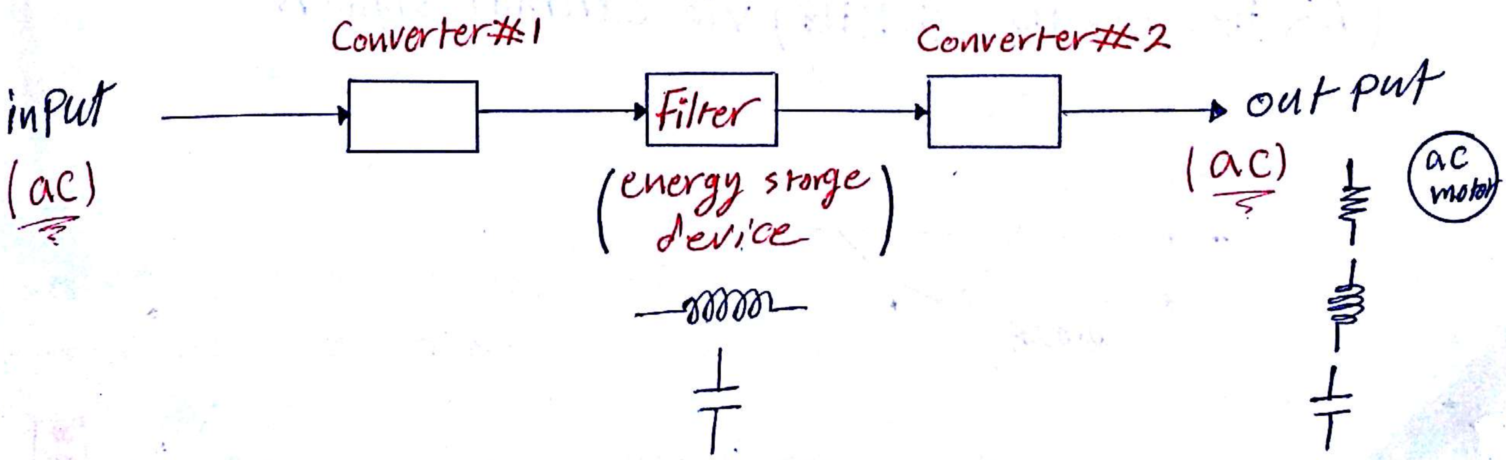


"Block diagram of PE system"

* Power Processor :-

1. Dc
   - a) regulated (constant) magnitude
   - b) adjustable (constant) magnitude

2. Ac
   - a) Constant Frequency adjustable magnitude.
   - b) adjustable Frequency adjustable magnitude



* Power Converters:-

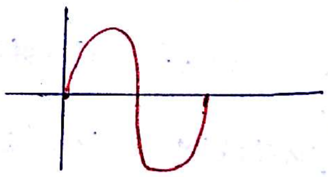
1. Ac - Dc → rectifiar
2. Dc - Ac → inverter
3. Dc - Dc → Converter
4. Ac - Ac → rectifier + inverter (cycloconverters)

Converters

* Classifications of Converters based on the switchings scheame of the swites:-

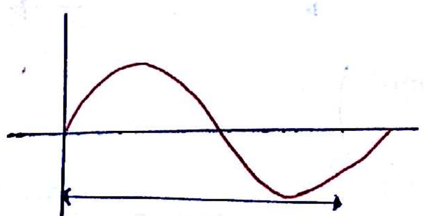
1 line Frequency (naturally commutated) converters:-

⇒ the switches (Diodes) inside the converter are turned on & OFF at the line Frequncy (50 or 60 Hz)



2 Switched (Forced commutated) Converters:-

⇒ the switches inside the convertor are turned on & OFF at Frequencies mach higher than the line Frequncy (5K Hz, 20 K Hz, 25 K Hz) via external signals



0.02s

Power elec　　　$\boxed{13}$　　　1/2/2017

Ch2

* Overview of Power semicondctor switches:-

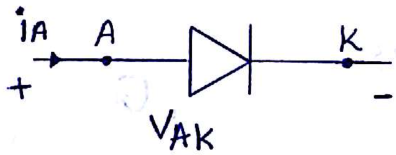
* According to the degree of controllability:-

$\boxed{1}$ Diodes: on and OFF by nature of the Power supply. "un controlled"

$\boxed{2}$ Thyristors: on by the an external signal and OFF the nature OF the Power supply ("semicontrolled")

$\boxed{3}$ Controllable switches: on and OFF by external signals through additional circuits (GTO, BJT, IGBT, MosFET)

* Diodes:-



$r_{on} \Rightarrow$ on stated device resistance.

$$r_{on} = \frac{V_{AK0}}{i_{A0}}$$

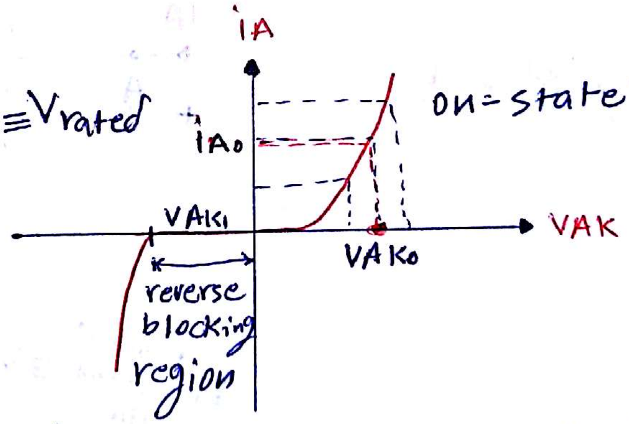
$$r_{OFF} = \frac{-V_{AK0}}{0} \rightarrow \infty$$

$$V_{on} = i_{A0}\, r_{on}$$

$$P_{on} = (i_{A0})^2 r_{on}$$

PIV ≡ Vrated

$\boxed{1\times10^{-9}\,A}$



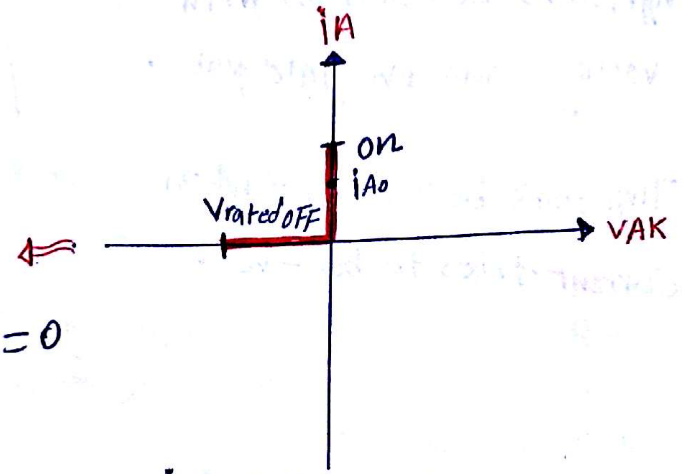
i-v cha OF diode (Practical)

$$r_{on} = \frac{0}{i_{A0}} = 0$$

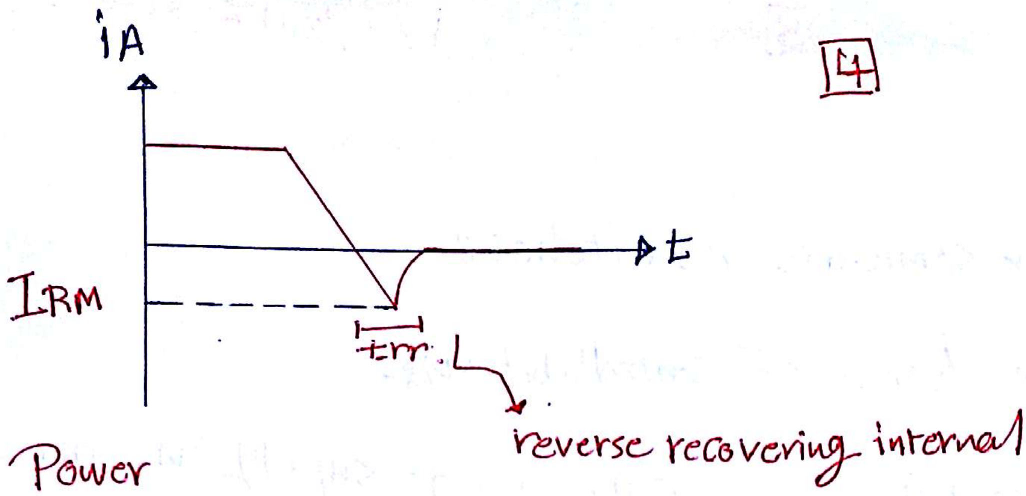
$$r_{OFF} = \infty$$

$V_{on} = 0$, $V_{OFF} = r_{OFF}\, I_{OFF} = 0$

$P_{on} = 0$, $P_{OFF} = 0$



ideal i-v cha

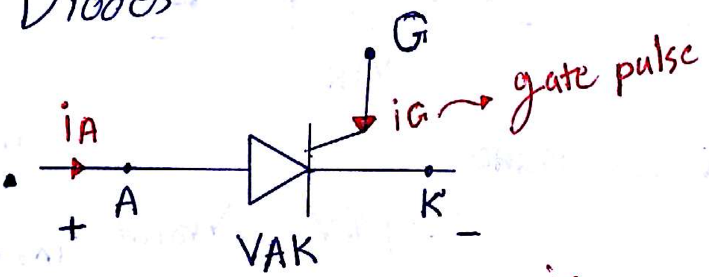


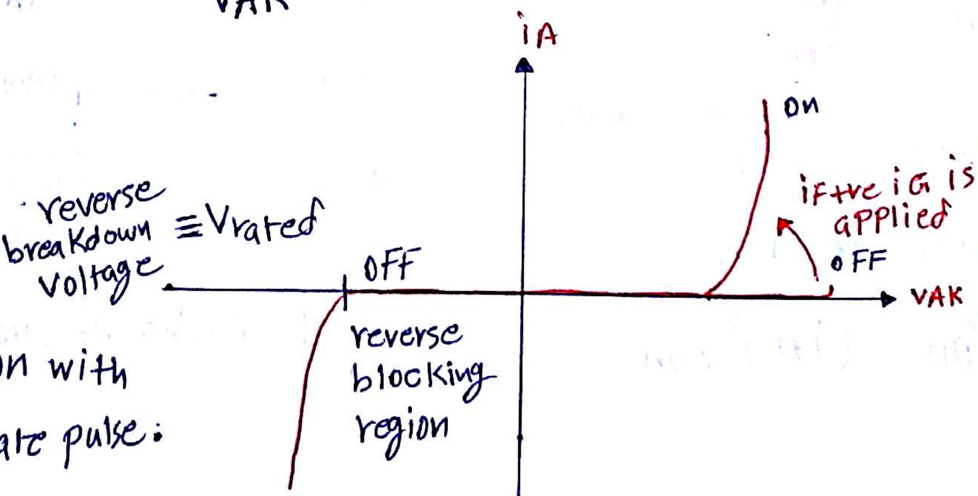
Power semiconductor diodes

Power semiconductor Diodes

1. Schottky Diodes
2. Fast recovering Diodes
3. line-Frequency Diodes

Thyristors:-

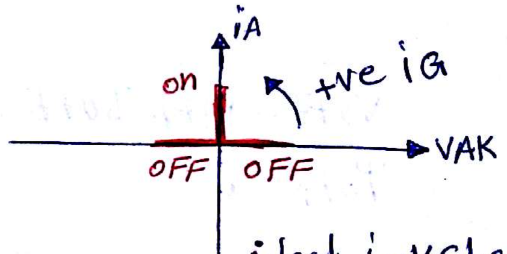




Practical i-v cha

* the thyristors becomes on with +ve voltage and +ve gate pulse.

* the Thyristors becomes OFF when the current tries to be -ve.



ideal i-vcha

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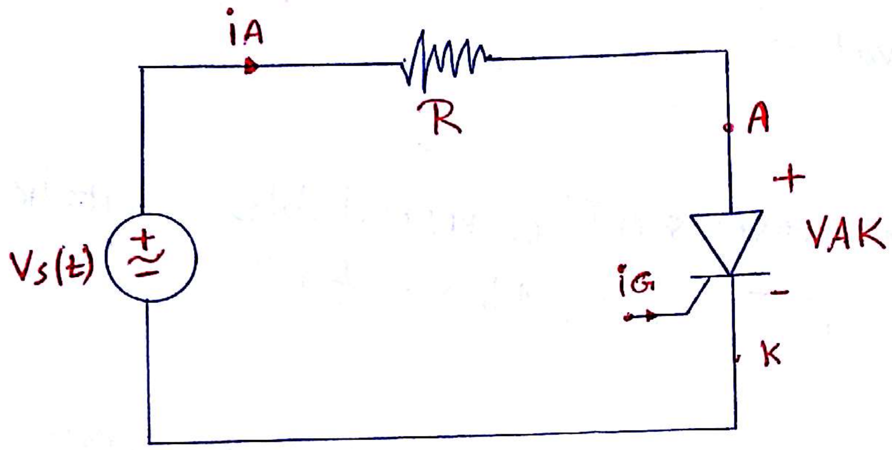
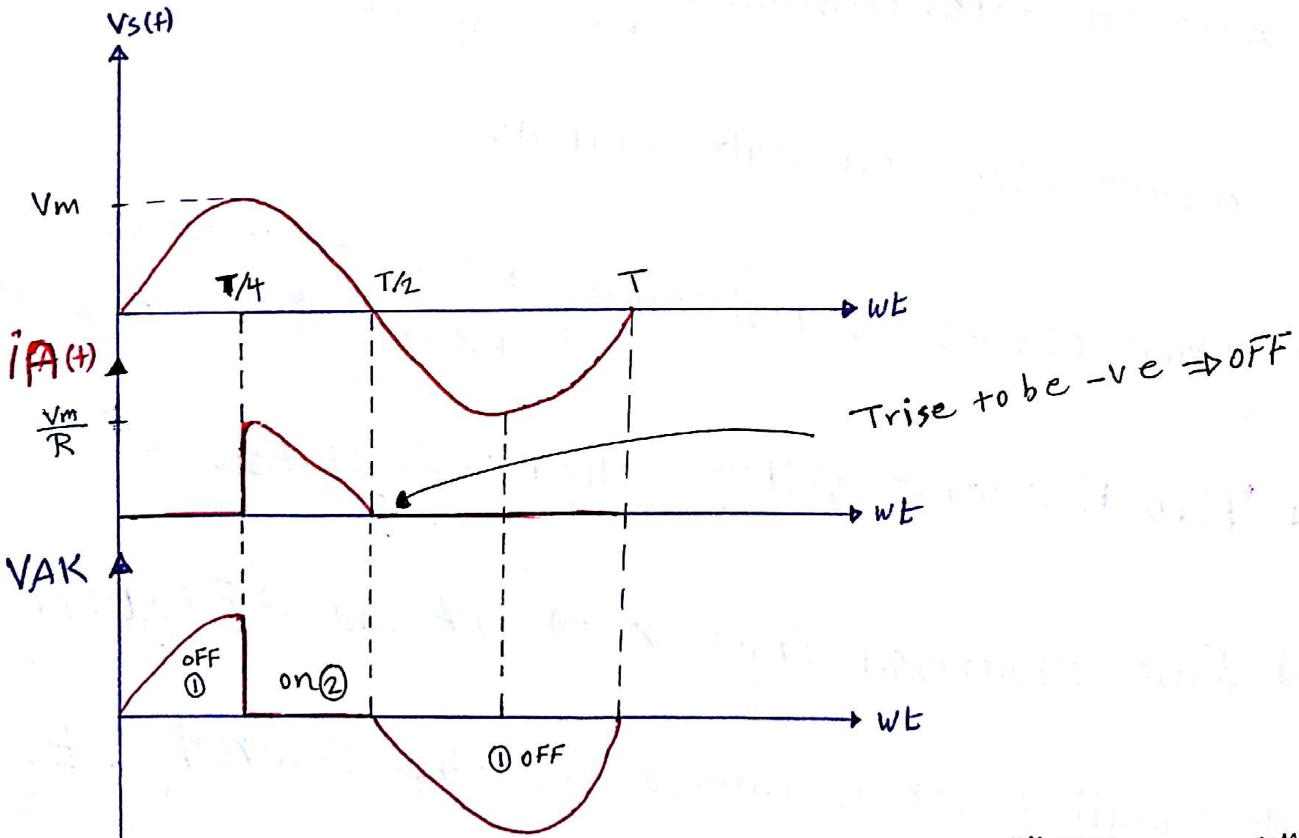
Ex:- Consider the Following cct Draw the waveForm OF (V_s, i_A, V_{AK}) For trigurring pulse at $t = \frac{T}{4}$ where T is the Period oF $V_s(t)$?

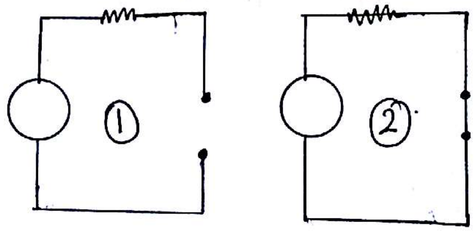
($V_s(t) = V_m \sin \omega t$ volt) --- ?





ON لمايكون
⇒ VAK = Zero
OFF ولمايكون
نفس ال Vs

"Ideal"



* Types OF thyristors :-

1. Phase controlled.
2. Inverter grade.
3. Light activated.

* Desired characteristics OF Controllable Switches.

"BJT, IGBT, GTO, MOSFEET"

* Zero on states resistance → Zero on-state voltage drop → Zero on-state power loss

* Conduct a large on state current

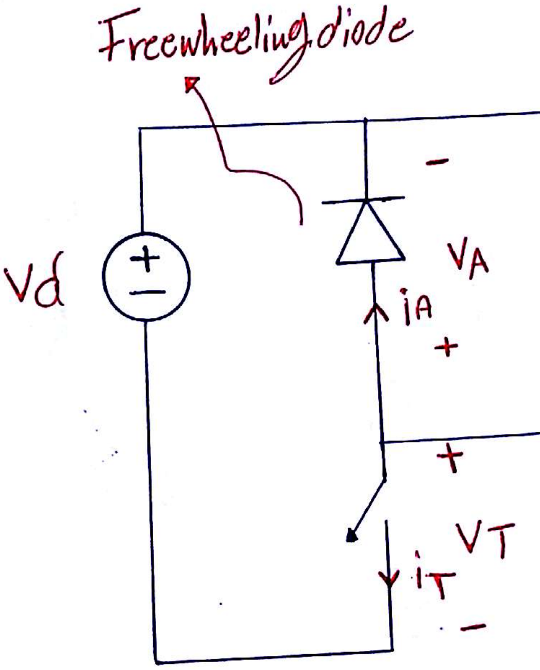
* infinit OFF-State resistance → zero OFF-state voltage drop → zero OFF-state power loss

* Block a large Voltage when OFF-state.

* Fast transtion From on to OFF and OFF to on.

* Small Power Consumed by the controll ckt.

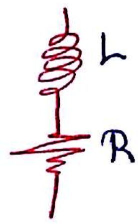
* Consider the Following commonly encountered cct in PE systems



$$V = L\frac{di}{dt}$$

$$i = C\frac{dv}{dt}$$

$I_o \equiv$ highly inductive load



$L \gg R$

$I_o = i_A + i_T$.

* anti Paralle diode:

- switch on $\rightsquigarrow$ diode OFF.
  (−ve) voltage.

- switch OFF $\rightsquigarrow$ diode on.

يبدأ ⓘ في الحل (التفريغ) وينقص الجهد
وتمثل د فولتية ـــ سالبه (−ve) تشغل (الدايود)

$I_o = i_A + i_T$.

Power elec

6/2/2017 الاثنين

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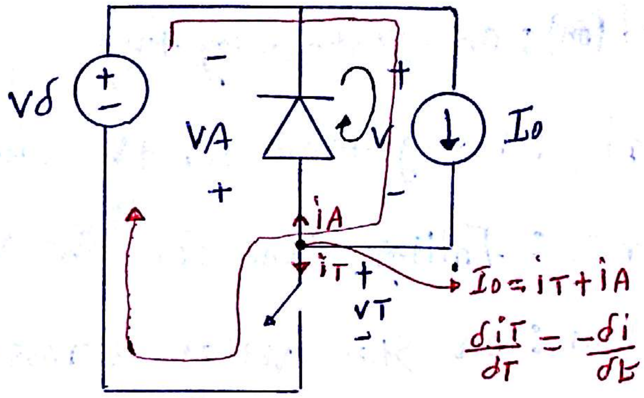
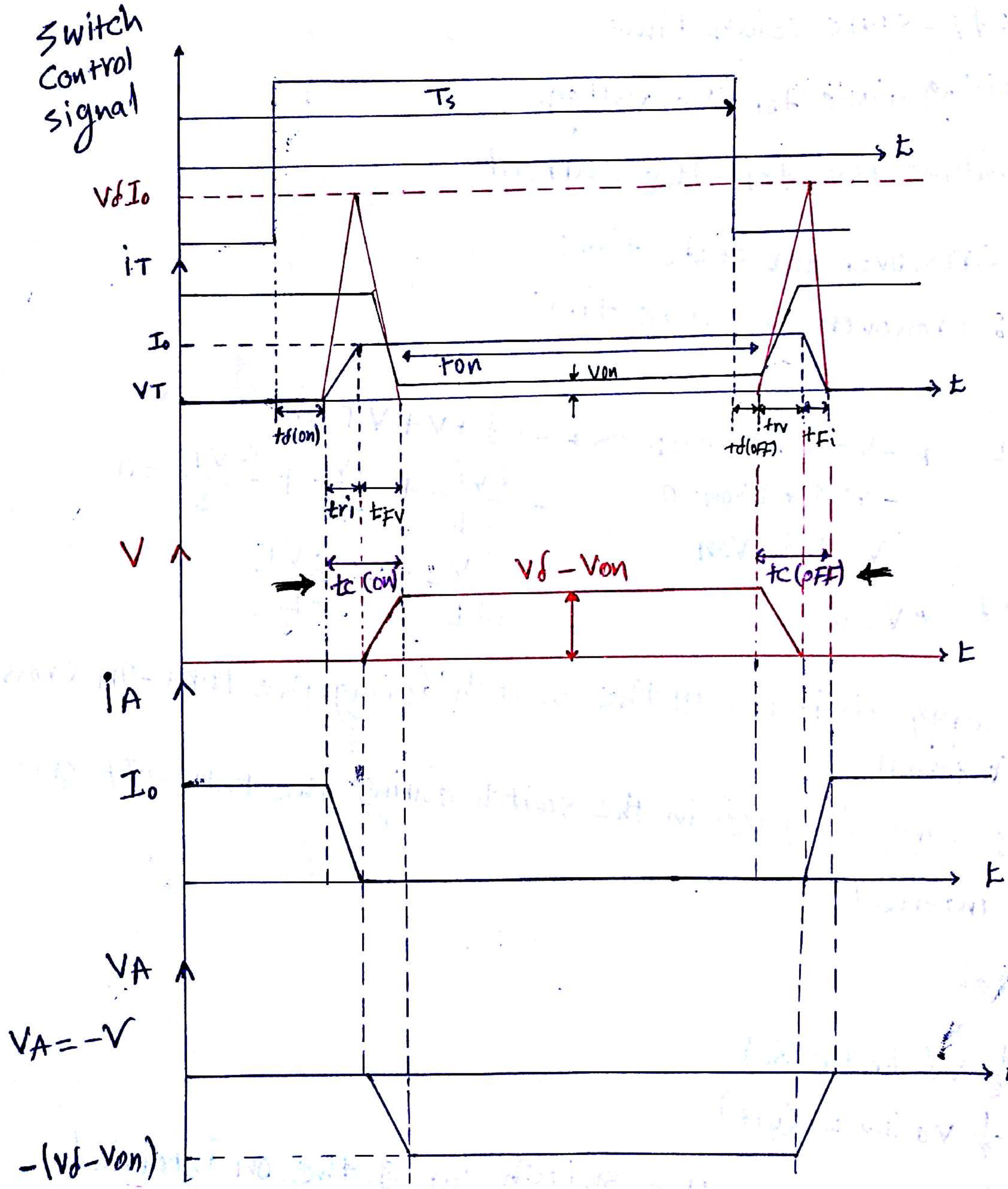
* $t_{c(on)} = t_{ri} + t_{fv}$

* $t_{c(off)} = t_{rv} + t_{fi}$





$t_{d(on)}$: On-State delay time

t_{ri} : rising time For the current

t_{rF} : Falling time For the Voltage

V_{on} : on-State Voltage across the switch

$t_{d(OFF)}$: OFF-State delay time

t_{rv} : rising time For the Voltage

t_{Fi} : Falling time For the current

$t_{c(on)}$: Crossover on state time

$t_{c(OFF)}$: Crossover OFF State time

Switch on $\rightarrow -V_\delta + V + V_T = 0 \rightarrow -V_\delta + V + V_T = 0$

$-V_\delta + V + V_{on} = 0$

$V = V_\delta - V_{on}$

$$-\frac{\delta V_\delta}{\delta t} + \frac{\delta V}{\delta t} + \frac{\delta V_T}{\delta t} = 0$$

$$\frac{\delta V}{\delta t} = -\frac{\delta V_T}{\delta t}$$

Switch OFF $\rightarrow V = 0$

$W_{c(on)}$: energy dissipated in the switch during the turn-On Crossover internal

$W_{c(OFF)}$: energy dissipated in the switch during the turn-OFF crossover internal.

$$W = \int P(t)\, \delta t$$

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

$$W_{c(OFF)} = \frac{1}{2} V_\delta I_o t_{c(OFF)}$$

W_{on} : energy dissipated in the switch during the on internal.

W_{on} : $V_{on} I_o t_{on}$.

* Average switching Power dissipated in the switch.

$$P_s = \frac{1}{2} V_d I_o f_s \left[t_{c(on)} + t_{c(OFF)} \right]$$

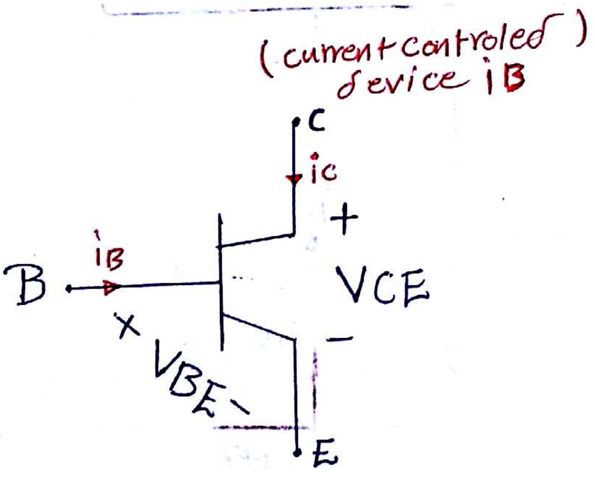
$$= \frac{\frac{1}{2} V_d I_o \left[t_{c(on)} + t_{c(OFF)} \right]}{T_s}$$

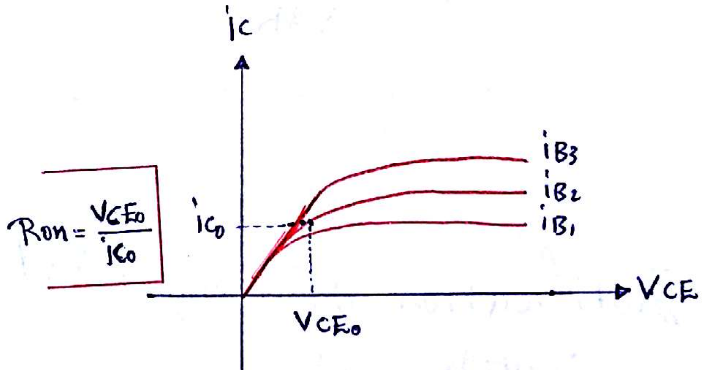
$$P_s = \frac{1}{T_s} \int_0^{T_s} v(t)\, i(t)\, dt$$

$$P_{on} = \frac{V_{on} I_o t_{on}}{T_s} \equiv$$ averge on state Power in the switch

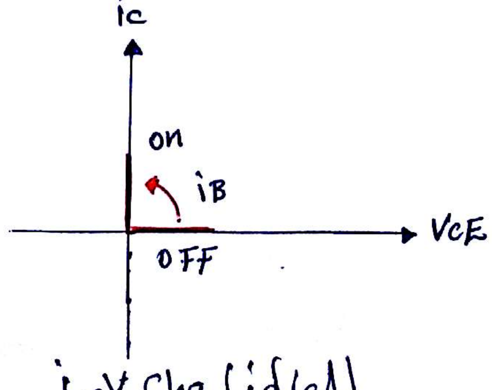
$$P_{tot} = P_s + P_{on}$$

* BJT :-





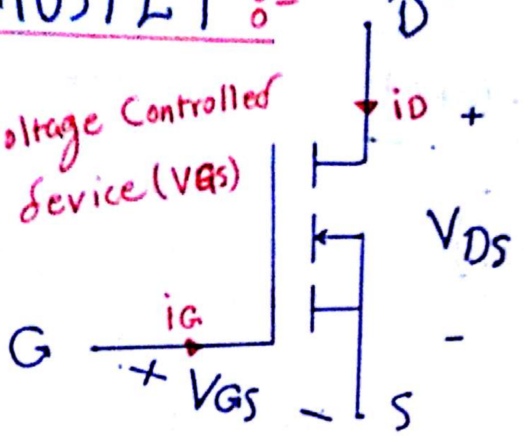
i-v cha

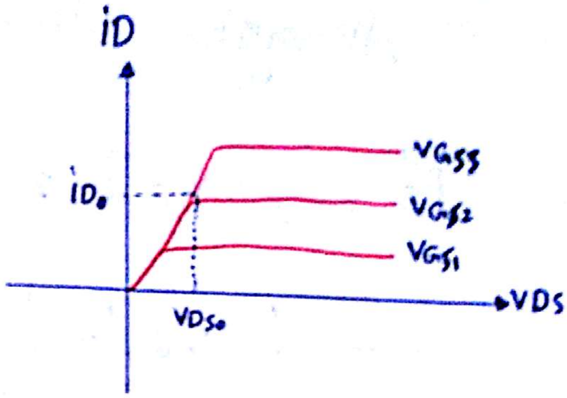


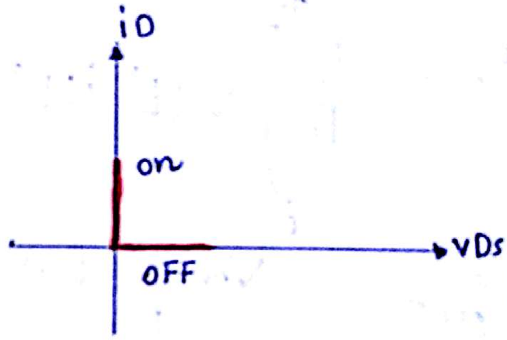
i-v cha (idial)

* MOSFET :-

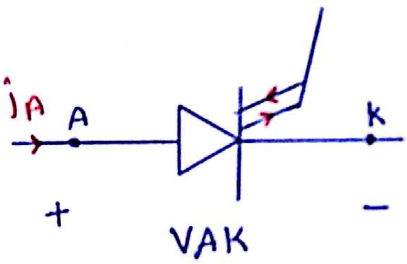
Voltage Controlled device (V_{GS})

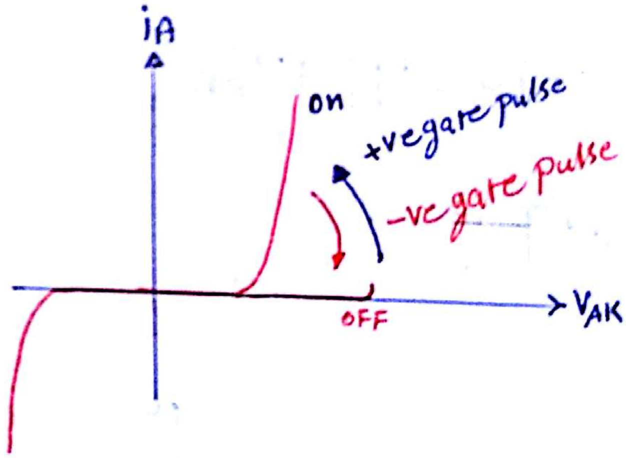


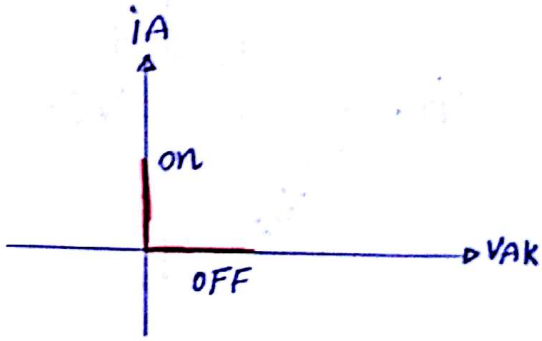




* GTO :-







* Justifications of using ideal switch Cha

Ex:- 2-1

$t_{ri} = 100ns \quad t_{fv} = 50ns \quad t_{rv} = 100ns \quad t_{fi} = 200ns \quad V_d = 300\,V$

$I_o = 4A$

→ Calculate P_s as fn of F (f_s) in the range of (25-100) KHz? ↓ switching freq

Sol:-

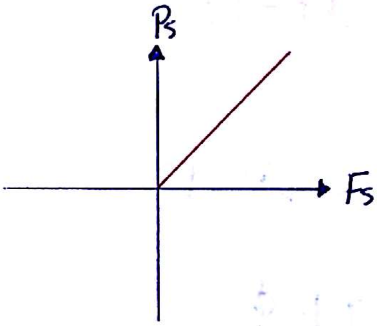
P_s → average switching Power losses

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

$$t_{c(on)} = t_{ri} + t_{fv} = 150ns$$

$$t_{c(off)} = t_{rv} + t_{fi} = 300ns$$

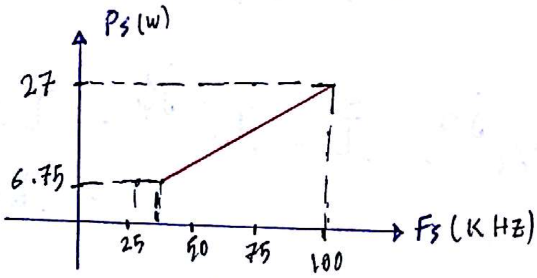
$$P_s = 2.7 \times 10^{-4} f_s$$



$$f_s = 25 - 100 \text{ KHz}$$

$$P_s\Big|_{f_s = 25KHz} = 6.75W$$

$$P\Big|_{f_s = 100KHz} = 27W$$



* Review of Basic Electrical Circuits Concepts.

* Averge Power and RMS Current:-

$$P(t) = V(t) \cdot i(t)$$

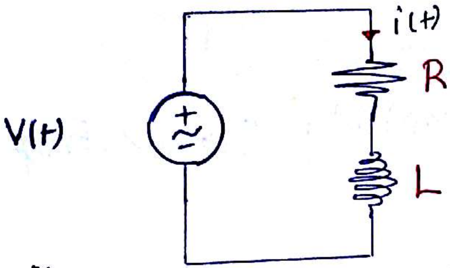
$$P = \frac{1}{T}\int_0^T P(t)\,dt = \frac{1}{T}\int_0^T V(t)\, i(t)\, dt$$

For Pure resistive load.

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

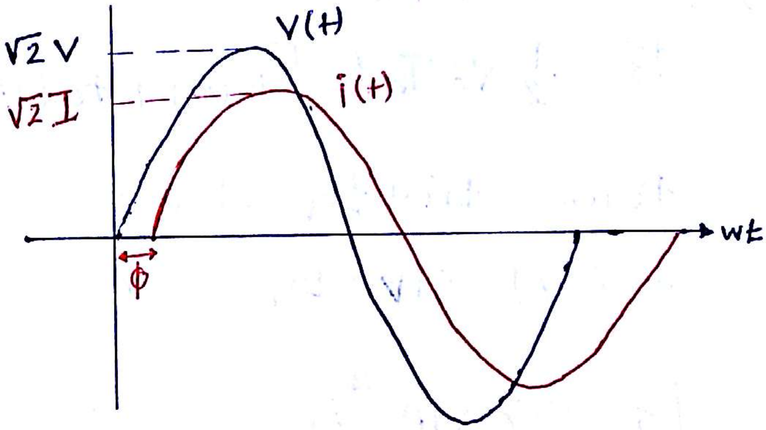
$$= RI^2 \Rightarrow I = \sqrt{\frac{1}{T}\int_0^T (i(t))^2\, dt}$$ → "rms current"

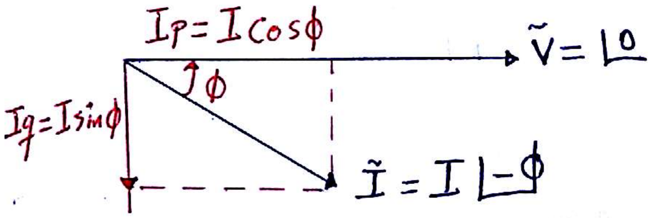
* Steady-State ac waveforms with sinusoidal voltages and currents.



((لازم يكونوا ال V(t) و I(t) نفس ال Freq ← نفس Period))

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



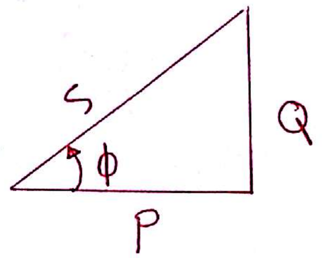


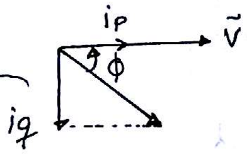
$$\tilde{V} = Ve^{j0}, \quad \tilde{I} = Ie^{-j\phi} = I\cos(-\phi) + jI\sin(-\phi)$$
$$= I\cos\phi - jI\sin\phi$$

rectangular
$$= V\cos 0 + V\sin 0$$

$$\tilde{Z} = \frac{\tilde{V}}{\tilde{I}} = \frac{V\angle 0}{I\angle{-\phi}} = \frac{V}{I}\angle\phi = Z\angle\phi$$

$$\tilde{S} = \tilde{V}\,\tilde{I}^* \rightarrow \text{Complex Power}$$
$$= V\angle 0\,(I\angle{-\phi})$$
$$= VI\angle\phi = \underbrace{VI\cos\phi}_{\text{active Power}} + j\underbrace{VI\sin\phi}_{\text{reactive Power}}$$





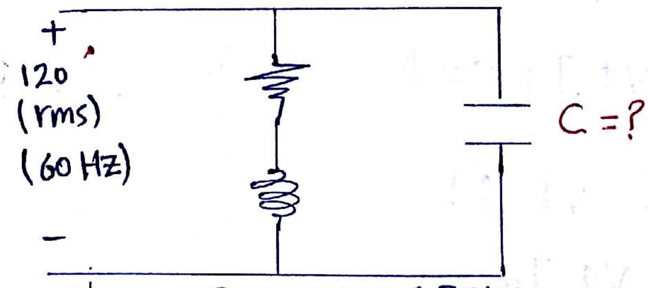
$$i(t) = i_p(t) + i_q(t)$$
$$= (\sqrt{2}\, I \cos\phi) \cos\omega t + (\sqrt{2}\, I \sin\phi) \sin\omega t$$

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

PF is Unity ($PF = 1$) → R

PF is lagging → RL

PF is leading → RC



$P = 1000\,W$ 0.8 PF lag

$\underbrace{\qquad\qquad\qquad}_{PF = 0.95 \text{ lagging}}$

Ex8-

before C

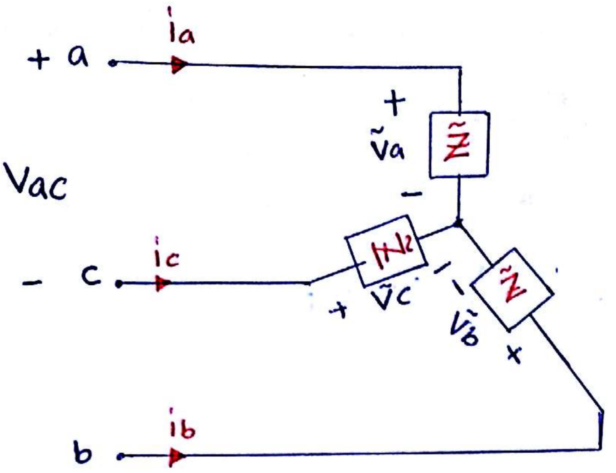
$$PF = \frac{P}{S} = \frac{1000}{S} = 0.8$$
$$S = 1250\ VA$$
$$Q = \sqrt{S^2 - P^2} = 750\ VAR$$
$$\tilde{S} = 1000 + j\,750\ VA$$

with C

$$0.95 = \frac{P}{S_{new}} = \frac{1000}{S_{new}}$$
$$0.95 = \frac{1000}{\sqrt{P^2 + \underbrace{(750 - Q_c)^2}_{Q_{new}}}}$$
$$Q_c = 421.3\ VAR$$
$$Q_c = \frac{V^2}{X_c} = \frac{V^2}{\frac{1}{\omega C}}$$
$$421.3 = \omega C V^2 = (377)\, C\, (120)^2$$
$$C = 77.6\,\mu F$$

$X_c = \frac{1}{\omega C}$
$\omega = 2\pi F$

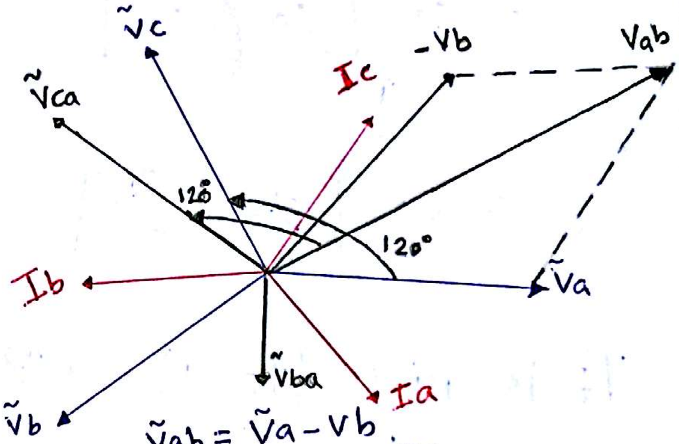
* Three-Phase Circuits



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

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

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



$$\tilde{V}_{ab} = \tilde{V}_a - V_b$$
$$= \sqrt{3}\,|\tilde{V}_a| \angle 30$$

* line voltage leads the phase voltage by 30° +ve

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

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

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

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

Δ or Y

$$P_{3\text{-}\phi} = 3 P_\phi$$

$$Q_{3\text{-}\phi} = 3 Q_\phi$$

$$S_{3\text{-}\phi} = 3 S_\phi$$

* NONsinusoidal waveForm in steady state.

* The steady state voltage and currents in power electronic systems are normally periodic but not sinusoidal

* Fouries Analysis OF Repetitive waveForms

* IF $f(t)$ is Periodic and nonsinusoidal, than

$$f(t) = F_0 + \sum_{h=1}^{\infty} f_h(t) = \frac{1}{2} a_0 + \sum_{h=1}^{\infty} \left\{ a_h \cos(hwt) + b_h \sin(hwt) \right\}$$

$F_0 = \frac{1}{2} a_0 \Rightarrow$ average value OF $f(t)$

$$\rightarrow a_h = \frac{1}{\pi} \int_0^{2\pi} f(t) \cos(hwt)\, dwt, \quad h = 0, ---, \infty$$

$$\rightarrow b_h = \frac{1}{\pi} \int_0^{2\pi} f(t) \sin(hwt)\, dwt, \quad h = 1, ---, \infty$$

$$F_0 = \frac{1}{2} a_0 = \frac{1}{2\pi} \int_0^{2\pi} f(t)\, \underline{dwt} \Rightarrow \text{average value}$$

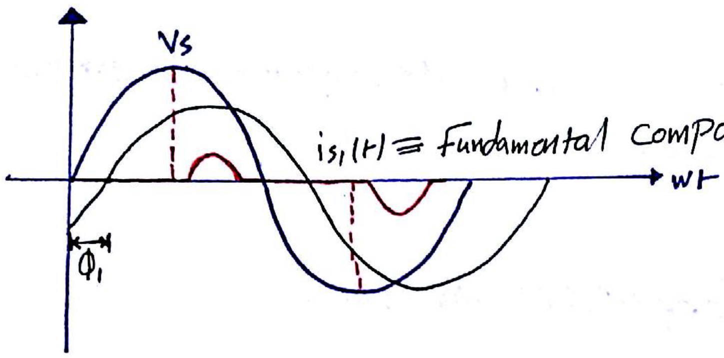
$d\theta$

$$F_0 = \frac{1}{T} \int_0^{T} f(t)\, dt$$

* $F = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} [F(t)]^2 dwt} \Rightarrow$ rms value oF $f(t)$

$$= \sqrt{F_0^2 + F_1^2 + -- + F_\infty^2}$$

* Line Current Distortion



$i_{s_1}(t) \equiv$ Fundamental componet of $i_s(t)$ } First component

$$v_s(t) = \sqrt{2}\, V \sin \omega_1 t$$

$$i_s(t) = \underbrace{i_{s_1}(t)}_{\text{Fundamental Component}} + \underbrace{\sum_{h \neq 1}^{\infty} i_{sh}(t)}_{\text{harmonic Component}}$$

$$i_s(t) = \sqrt{2}\, \underbrace{I_{s_1}}_{\text{rms value of the Fundamental Component}} \sin(\omega_1 t - \phi_1) + \sum_{h \neq 1}^{\infty} \sqrt{2}\, \underbrace{I_{sh}}_{\text{rms value of the harmonic Component}} \sin(\omega_h t - \phi_n)$$

$\omega_h t = h \omega t$

* THD: Total Harmonic Distortion.

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

⇒ indicates how far the signal from sine wave

* Power and Power Factor

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

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

$$= \frac{1}{T_1}\left[\int_0^{T_1} [\sqrt{2} V_s \sin w_1 t]\left[\sqrt{2} I_{s1} \sin(w_1 t - \phi_1) + \sum_{h\neq 1}^{\infty} \sqrt{2} I_{sh} \sin(w_h t - \phi_h)\right] dt\right]$$

$$\Rightarrow \boxed{P = V_s I_{s1} \cos\phi_1}$$ ~> Calculation From the AC Variables

⇒ IF the voltage is sinusoidal and the current Not sinusoidal then current Component at harmonic Freqs do not Contribute to the averge value OF the Power

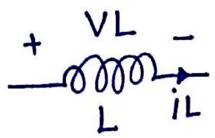
$$S = V_s I_s$$

$$PF = \frac{P}{S} = \frac{V_s I_{s1} \cos\phi_1}{V_s I_s}$$

$$= \frac{I_{s1}}{I_s} \cos\phi_1$$

$$DPF = \cos\phi_1 \Rightarrow \text{Displacement PF}$$

* Inductor and Capcitor Responses.

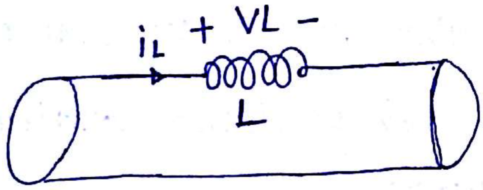


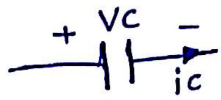
$$V_L = L \frac{di_L}{dt}$$

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

IF pure sine waves:-

$$\tilde{V}_L = jwL\tilde{I}_L$$



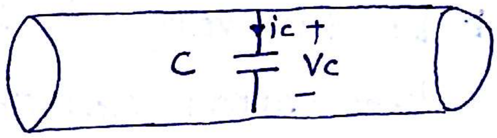


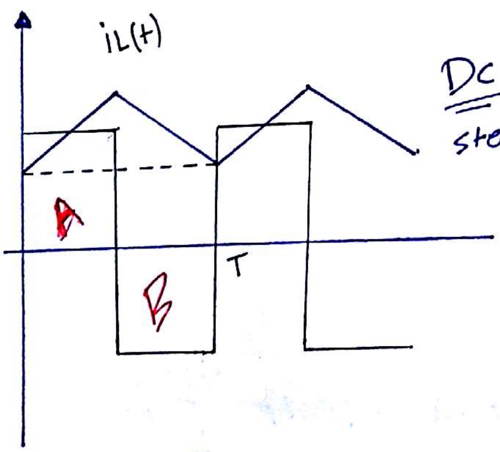
$$i_c = C\frac{dv_c}{dt}$$

$$V_c(t) = \frac{1}{C}\int i_c(t)\,dt + K$$

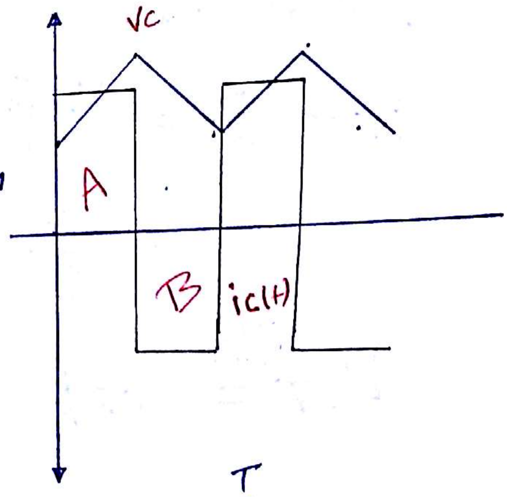
IF pure sine waves:-

$$\tilde{I}_c = jwC\,\tilde{V}_c$$





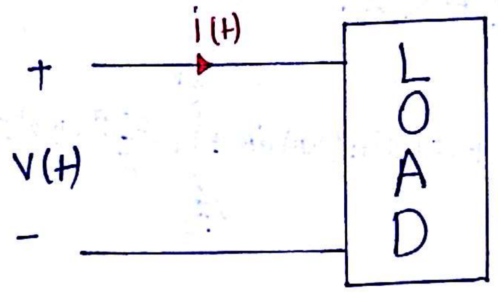
DC steady-state DC waveform

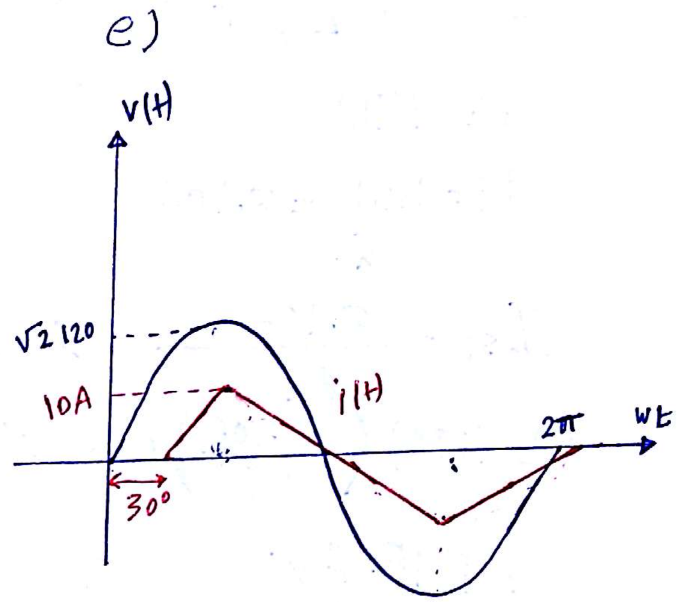


$$V_L = \frac{1}{T}\int_0^T V_L(t)\,dt = 0 \qquad \underline{\underline{A = B}}$$

$$I_c = \frac{1}{T}\int_0^T i_c(t)\,dt = 0$$

3-6





* $v(t) = \sqrt{2}\, V \sin wt$
* $i(t) \Rightarrow$ is a triangular wave
* with amplitude of 10A
* $i(t)$ lags $v(t)$ by 30°

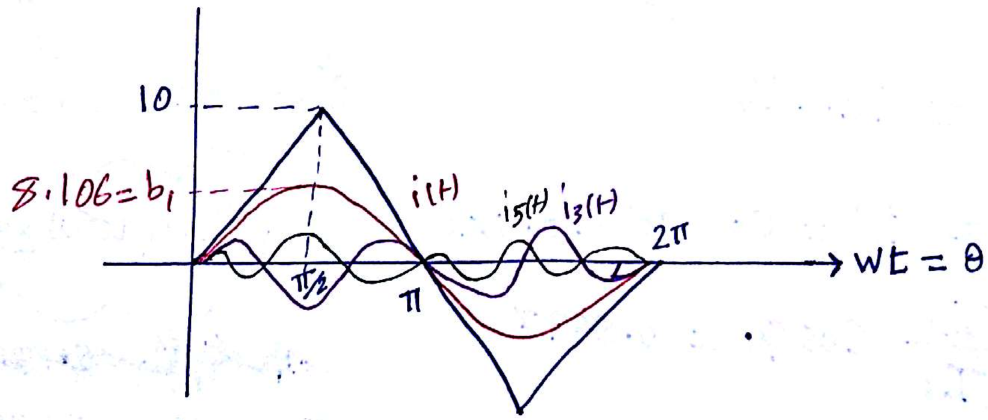
Find:- $\Rightarrow$ P, THD, PF, DPF ?

$$P = V I_{s1} \cos\phi$$

* $i(t)$ is symmetric on the x-axis

$a_h = 0$, $\cancel{b_h = 0}$ $h = 2, 4, 6, \ldots, \infty$

$$b_h = \frac{1}{\pi} \int_0^{2\pi} i(t) \sin(hwt)\, d wt$$



$\boxed{21}$

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

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

$$b_h = F(h)$$

$$b_1 = b_h\Big|_{h=1} = 8.106$$

$$I_{s1} = \frac{8.106}{\sqrt{2}} = 5.7318 \text{ A rms}$$

$$P = (120)\left(\frac{8.106}{\sqrt{2}}\right) \cos 30^\circ$$

$$= 595.7 \text{ W}$$

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

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

$$= 5.7736 \text{ A}$$

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

$$= 12.1\%$$

$$DPF = \cos(\phi_1) = \cos(30) = 0.866$$

* ارجع للكتاب ص 59

$$PF = \frac{I_{s1}}{I_s} \cos \phi_1 = 0.8597$$

$\cancel{I_{s1} = \frac{8.106}{\sqrt{2}} = 5.7318}$

$\cancel{I_s = \frac{10}{\sqrt{3}} = 5.7736}$

$\boxed{2}$

* Matlab:-

①

$$\int a \sin x \, dx$$

```
>> syms a x
>> A = int(a*sin(x),x)
A = -a*cos(x)
>> B = int(a*sin(x),a)
B = 1/2*a^2*sinx
>> C = subs(A,x,(pi/2))
C = 0
>> D = subs(B,a,2)
D = 2*sin(x)
```

②

$F(x) = e^x$

$$\int_1^4 e^x \, dx$$

```
>> syms x
>> F = exp(x);
>> E = int(F,x,1,4)
E = ......
```

int:- integration

subs:- subsutute

③

$$\int_1^2 a^2 e^x \, dx$$

```
>> syms a x
>> R = a^2*exp(x);
>> Q = int(R,x,1,2)
Q = a^2*exp(2)-a^2*exp(1)
>> Q1 = vpa(Q,5)
Q1 = 4.6708*a^2
```

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$$b_h = \frac{1}{\pi}\left[\underbrace{\int_0^{\pi/2} \frac{20\theta}{\pi} \sin(h\theta)\, d\theta}_{A_1} + \underbrace{\int_{\pi/2}^{3\pi/2} \left(\frac{-20\theta}{\pi} + 20\right) \sin(h\theta)\, d\theta}_{A_2} + \underbrace{\int_{3\pi/2}^{2\pi} \left(\frac{20\theta}{\pi} - 40\right) \sin(h\theta)\, d\theta}_{A_3} \right]$$

```
>> syms h th → θ
>> A1 = int((((20*th)/Pi)* sin(h*th)), th, 0, (Pi/2);
>> A2 = int((((-20*th)/Pi) +20)*sin(h*th), th, (Pi/2),(3*Pi/2));
>> A3 = int
>> bh = (1/Pi)*(A1+A2+A3)
>>
>> b1 = subs(bh, h, 1)
   b1 = ........
>> b1 = vpa(b1, 6)
>> b2 = subs(bh, h, 2)
>> b2 = 1.6*10^-16
```

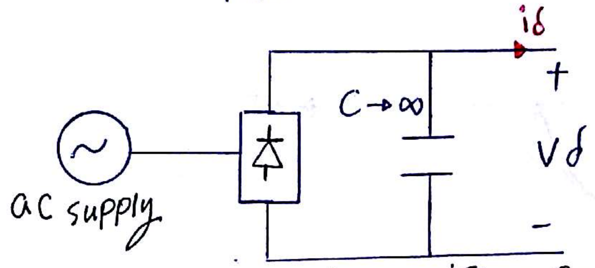
* line Frequency Diode Rectifiers

- line Frequency ac → uncontrolled dc

line Frequency ≡ 50 or 60 Hz

Rectifiers :- Circuits which change From ac into dc

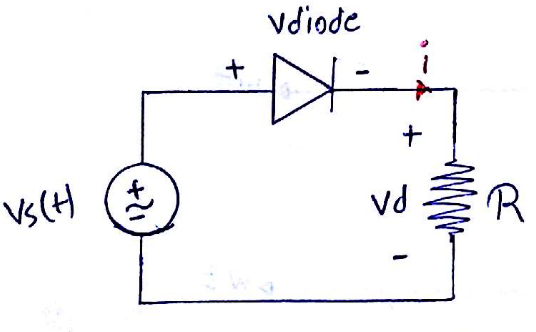
uncontroled :- the divices are turned on & OFF by the nature of the Power supply.



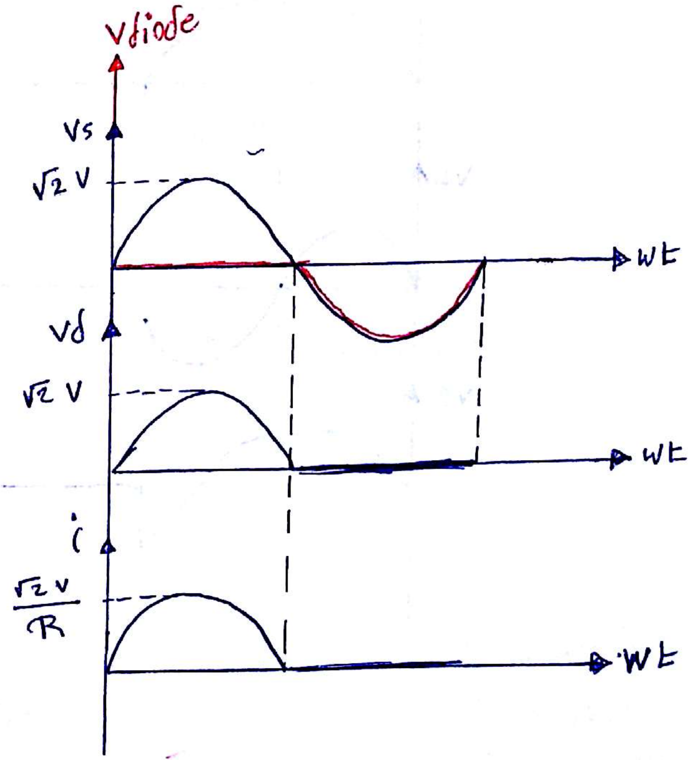
« Basic rectifier Concept »

* Basic Rectifier Concepts :-

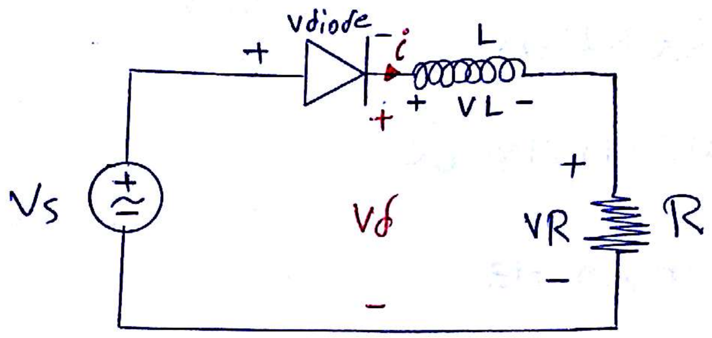
[1] Pure resistive load :-



half-wave uncontrolled rectiFer circuit with Pure resistive load



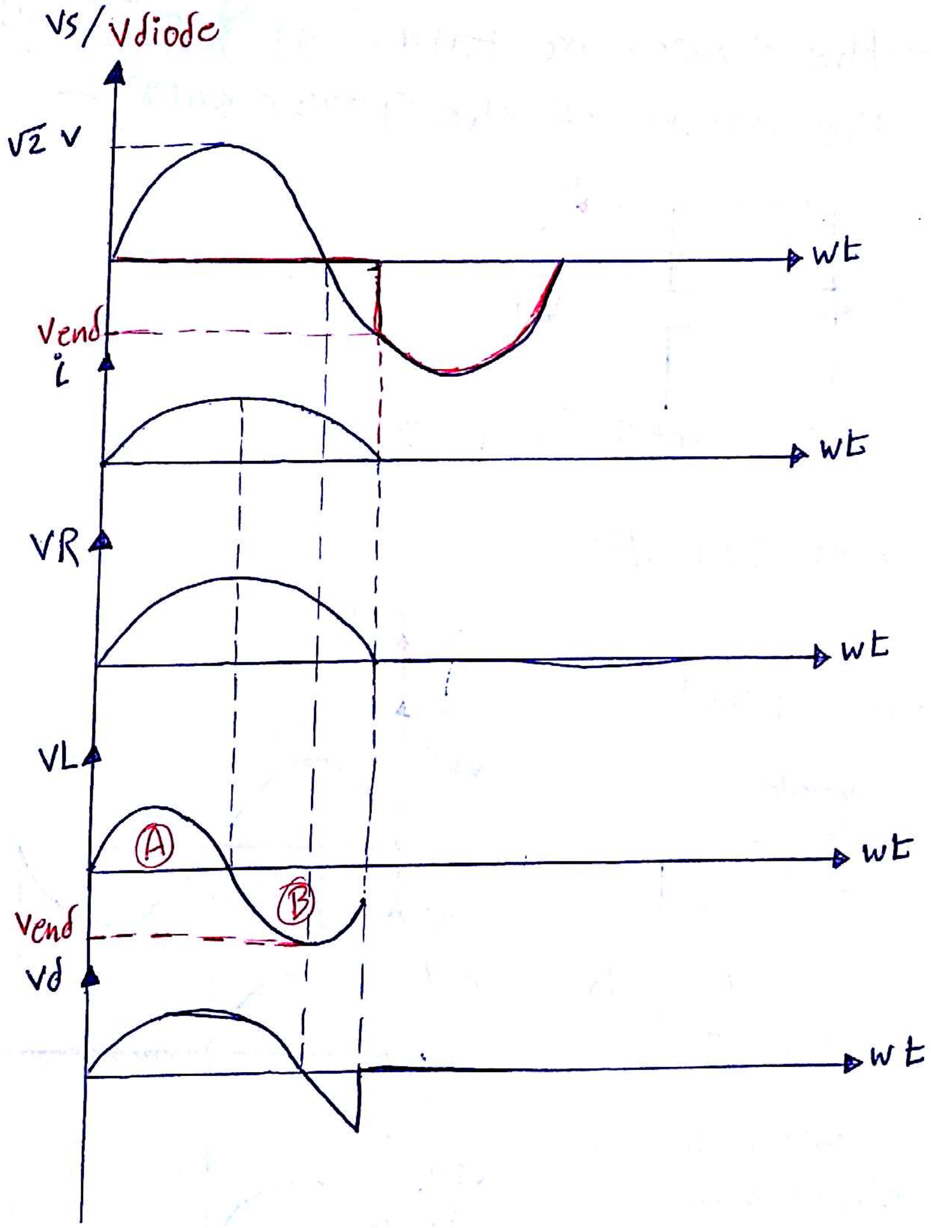
2 Inductive load:-



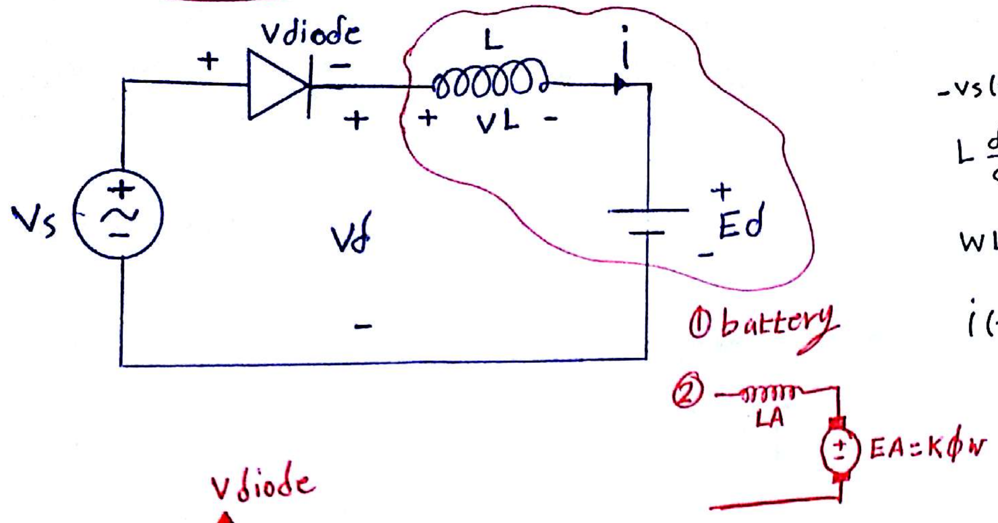
$$-V_s(t) + L\frac{di}{dt} + Ri = 0$$

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

$$i(t) = \ldots\ldots$$



3 Load with internal dC Voltage:-

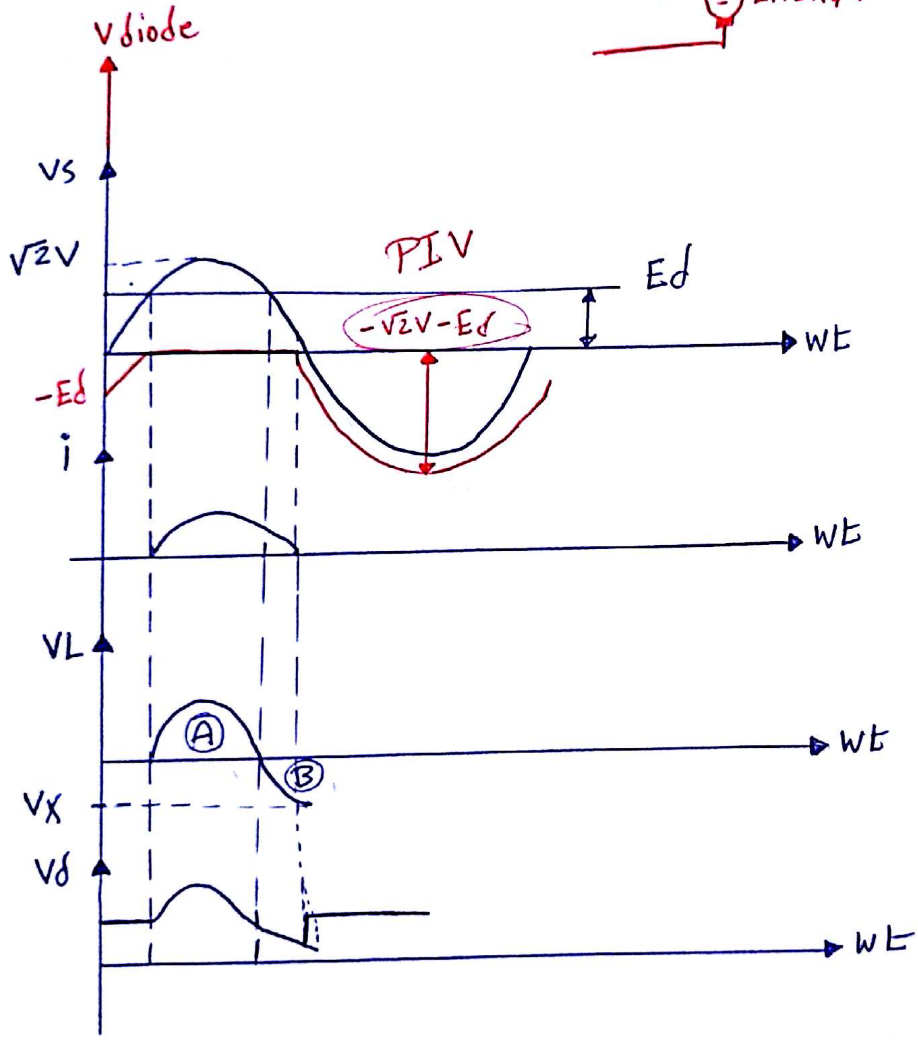


$$-v_s(t) + L\frac{di}{dt} + Ed = 0$$

$$L\frac{di}{dt} = \sqrt{2}\,V\sin wt - Ed$$

$$wL\frac{di}{dwt} = \sqrt{2}\sin wt - Ed$$

$$i(t) = \left(\frac{1}{wL}\right)\int(\sqrt{2}\,V\sin wt - Ed)\,dwt + K$$



* $Vd = Vs$ if the diode is "on"
* $Vd = Ed$ if the diode is "OFF"

$$-Vs + Vdiode + VL + Ed = 0$$

$$Vdiode = Vs - Ed$$

لعيونه الفيرست
1/3/2017
وقت المحاضرة

* Power elec

22/2/2017 الاربعاء

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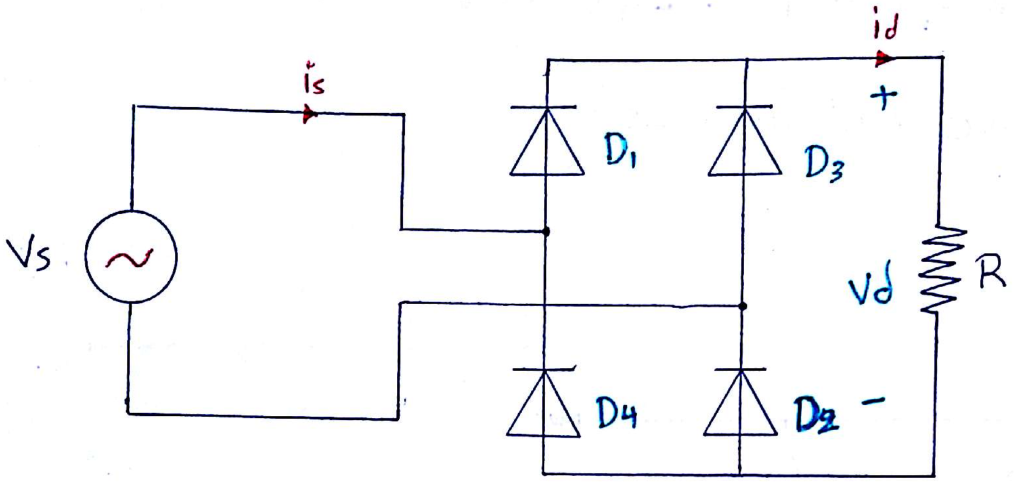
Omar AL.Bghelm

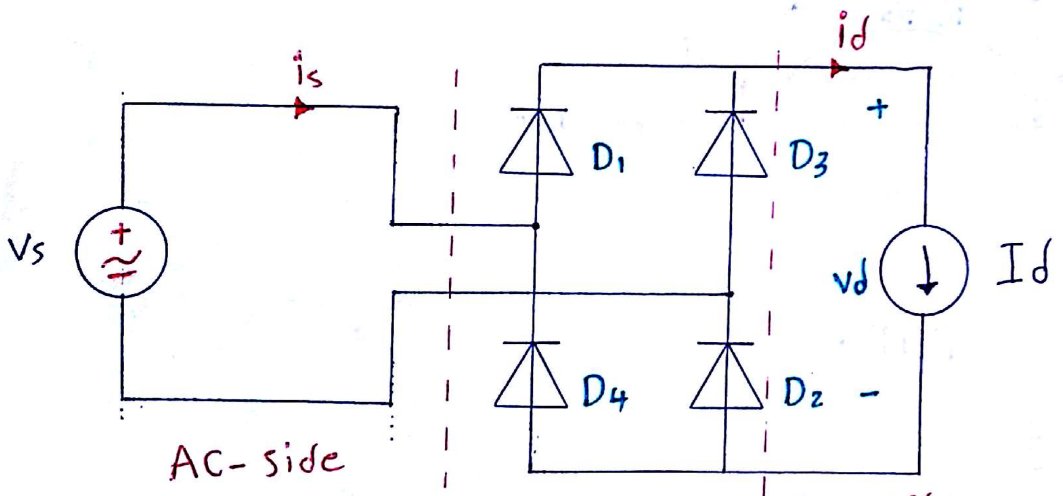
* Single - Phase Diode Bridge Rectifiers :-

* Idealized case ($L_s = 0$)



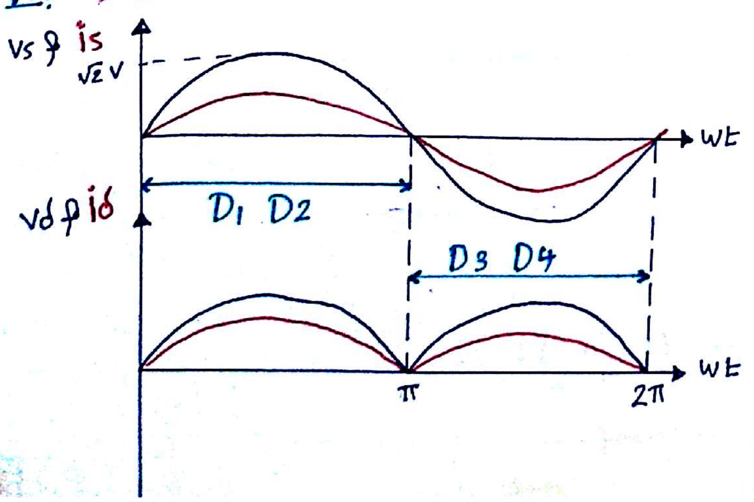
source indctance

Full-wave uncontrolled rectifier circuit with pure resistive load and zero source indactance



highly inductive load like Dc motor

[1] Pure Resistive Load without Ls :-



[1]

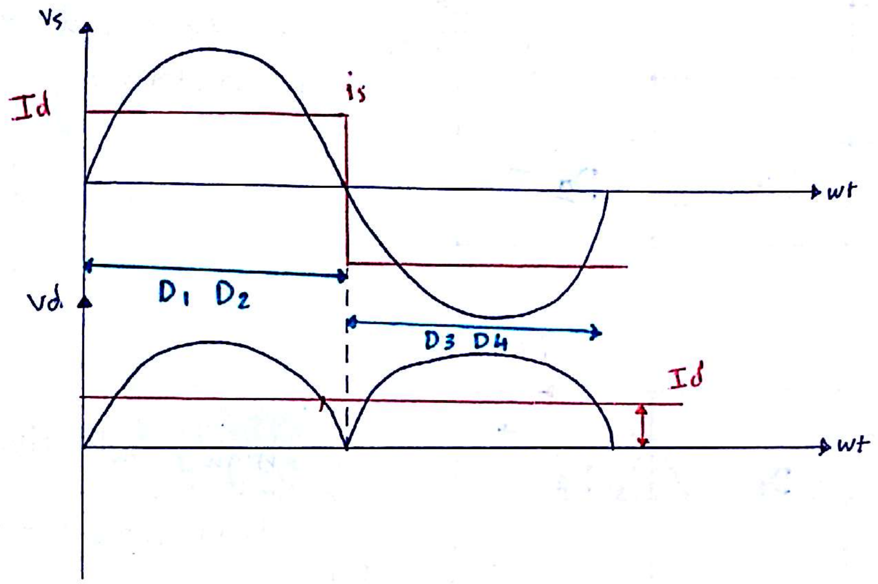
[28]

- $V_d = \frac{1}{2\pi} \int_0^{2\pi} V_{d(t)} \cdot d\omega(t) = \frac{2}{2\pi} \int_0^{\pi} \sqrt{2}\, V \sin \omega t \, d\omega t = 0.9V$

- $I_d = \frac{0.9V}{R}$

- $P_d = V_d I_d = 0.81 \frac{V^2}{R} = P_s = I_{s_1} V \cos(0) = I_{s_1}^2 R$

[12] highly inductive load with $L_s = 0$



$\Rightarrow$ P, PF, DPF, THD.

$*$ $I_s = I_d$

$I_{s_1} = 0.9\, I_d$

$P = V\, 0.9\, I_d \cos 0$

$P_{ac} = 0.9\, V I_d \Rightarrow$ ac side

$P_F = \frac{I_{s1}}{I_s}\, DPF = 0.9$

$DPF = 1$

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

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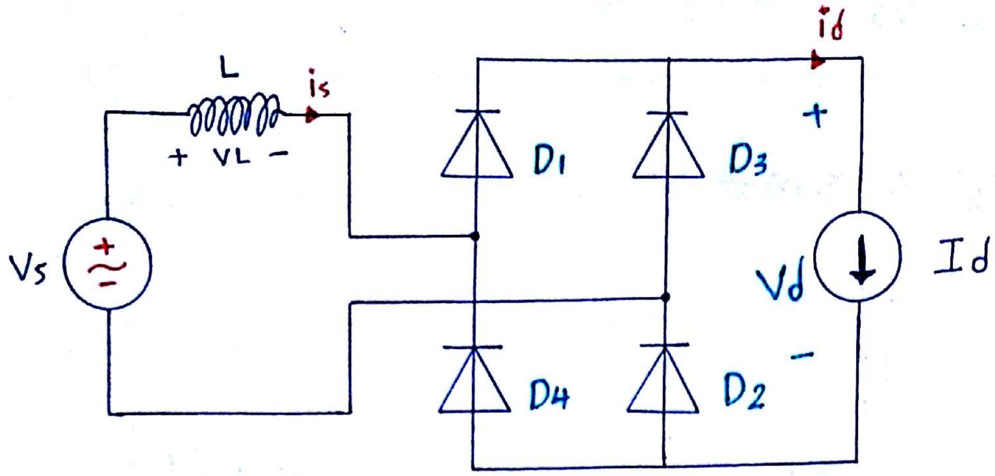
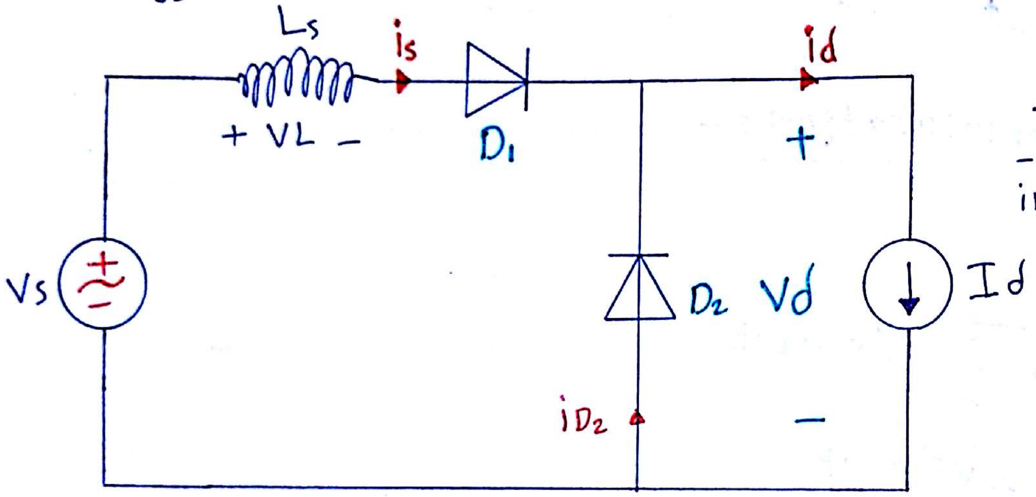


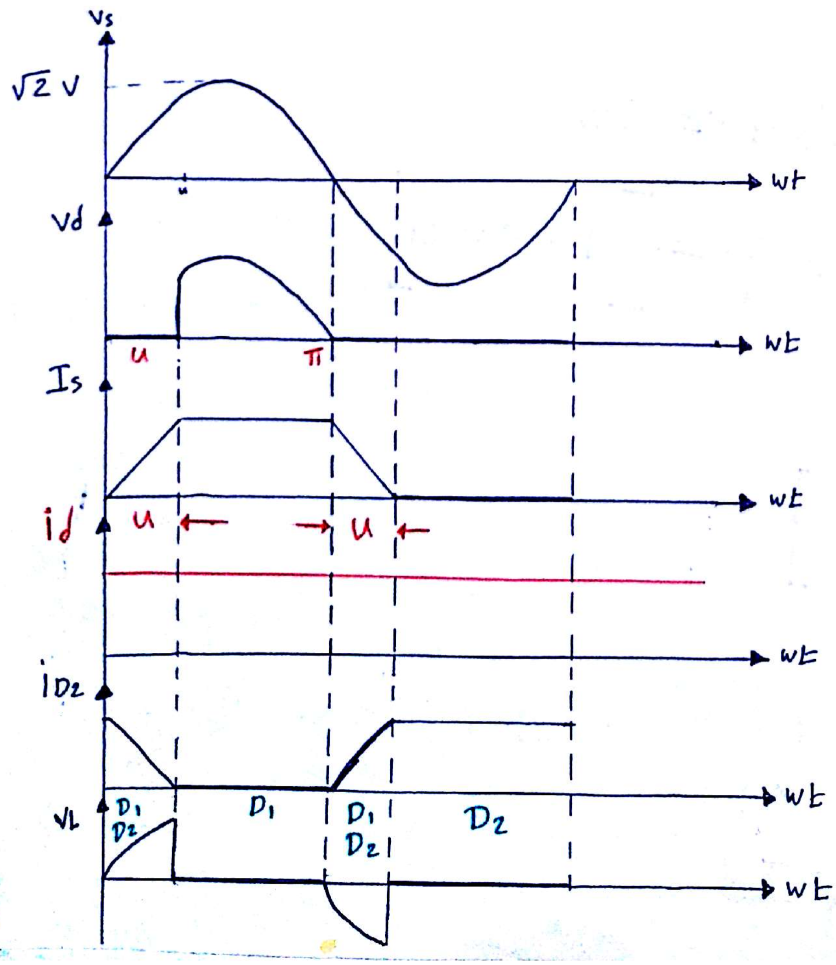
$V_L = L \frac{di_s}{dt}$



$-i_s - i_{D2} + I_d = 0$

$-i_{D2} = -I_d + i_s \Rightarrow \frac{di_s}{dt} = -\frac{di_{D2}}{dt}$

$i_{D2} = I_d - i_s$



$$* \; V_d = \frac{1}{2\pi}\int_0^{2\pi} \sqrt{2}\, V_s \sin wt \, dwt$$

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

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

$$V_d = \frac{\sqrt{2}V}{2\pi}\left[\cos u + 1\right] \Rightarrow \boxed{V_d = 0.45\,V - \frac{wL_s I_d}{2\pi}}$$

* During Commutation:-

$$V_L = V_s$$

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

$$wL_s \frac{di_s}{dwt} = \sqrt{2}\, V \sin wt$$

$$\int_0^{I_d} di_s = \int_0^{u} \frac{1}{wL_s}\sqrt{2}\, V \sin wt \, dwt$$

$$I_d = \frac{\sqrt{2}V}{wL_s} \cos wt \Big]_u^0 = \frac{\sqrt{2}V}{wL_s}\left[1 - \cos u\right]$$

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

$$\Downarrow$$

$$u = \cos^{-1}\left[\qquad\right]$$

* If $L_s = 0$

$V_d = 0.45V$

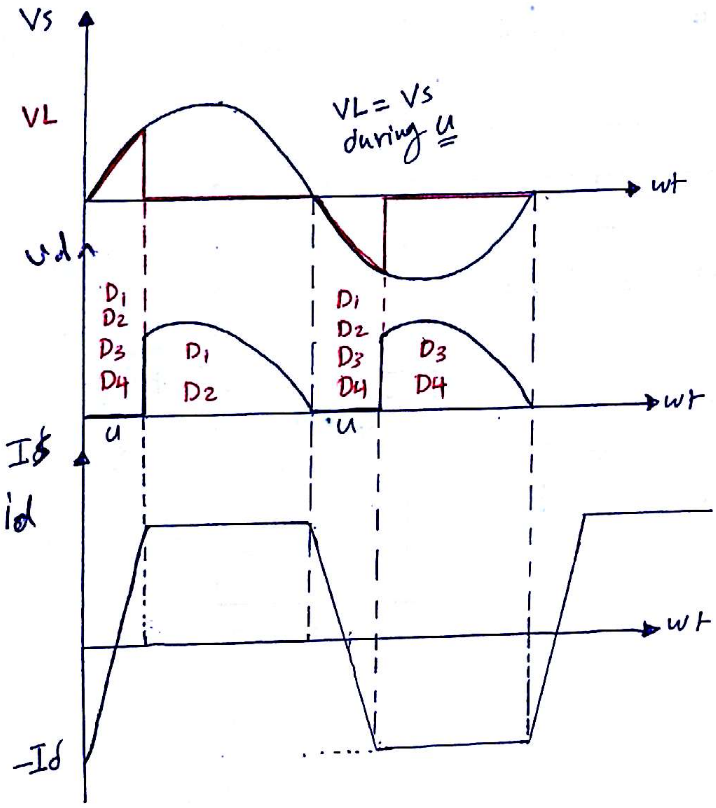
$u = 0$

$$P_d = V_d I_d = 0.45\, V I_d$$

* نتيجة !!!! 31

effect of "Ls" ال قلت Source Inductance وجود ال

* reduces the Avg value of the out voltage.
* reduces the Avg output power.
* introduces the Commutation interval.



Full wave

* During Commutation:-

$$V_L = V_s$$

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

$$wL_s \frac{di_s}{dwt} = \sqrt{2}\, V \sin wt$$

$$\int_{-I_d}^{I_d} di_s = \int_0^u \frac{1}{wL_s} \sqrt{2}\, V \sin wt \, dwt$$

$$2 I_d = \frac{\sqrt{2} V}{wL_s} \cos wt \Big]_u^0 = \frac{\sqrt{2} V}{wL_s}\left[1 - \cos u\right]$$

$$\cos u = - - - -$$

$$V_d = \frac{1}{2\pi} \int_0^{2\pi} \sqrt{2}\, V \sin wt \, dwt$$

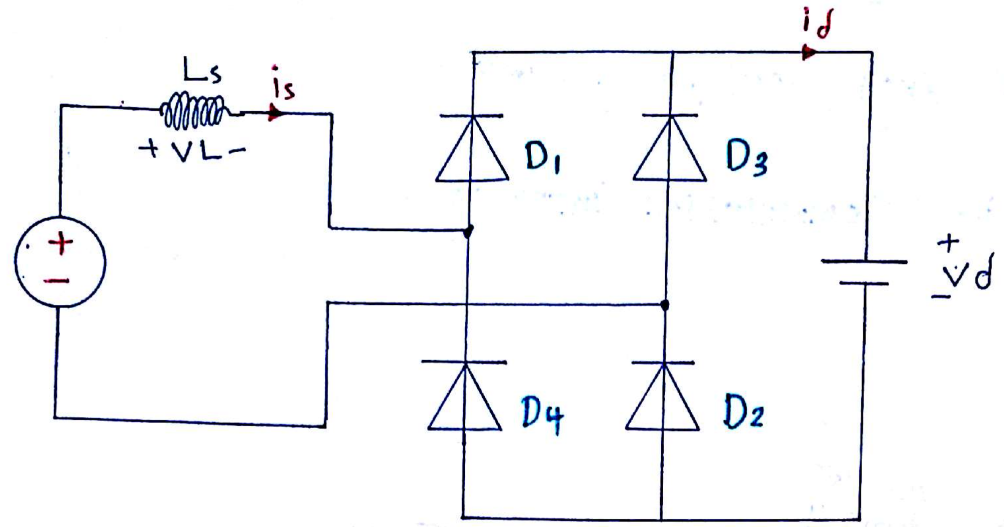
$$= \frac{2}{2\pi} \int_u^{\pi} \sqrt{2}\, V \sin\theta \, d\theta$$

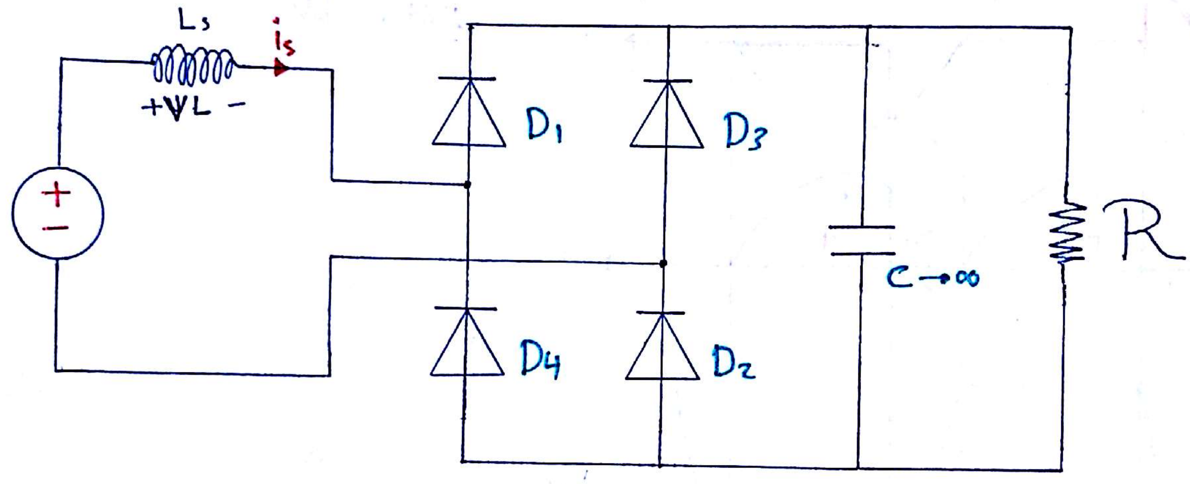
$$= \frac{\sqrt{2} V}{\pi} \cos wt \Big]_{\pi}^{u} = \frac{\sqrt{2} V}{\pi}\left[\cos u + 1\right]$$

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

$$P_d = V_d I_d$$

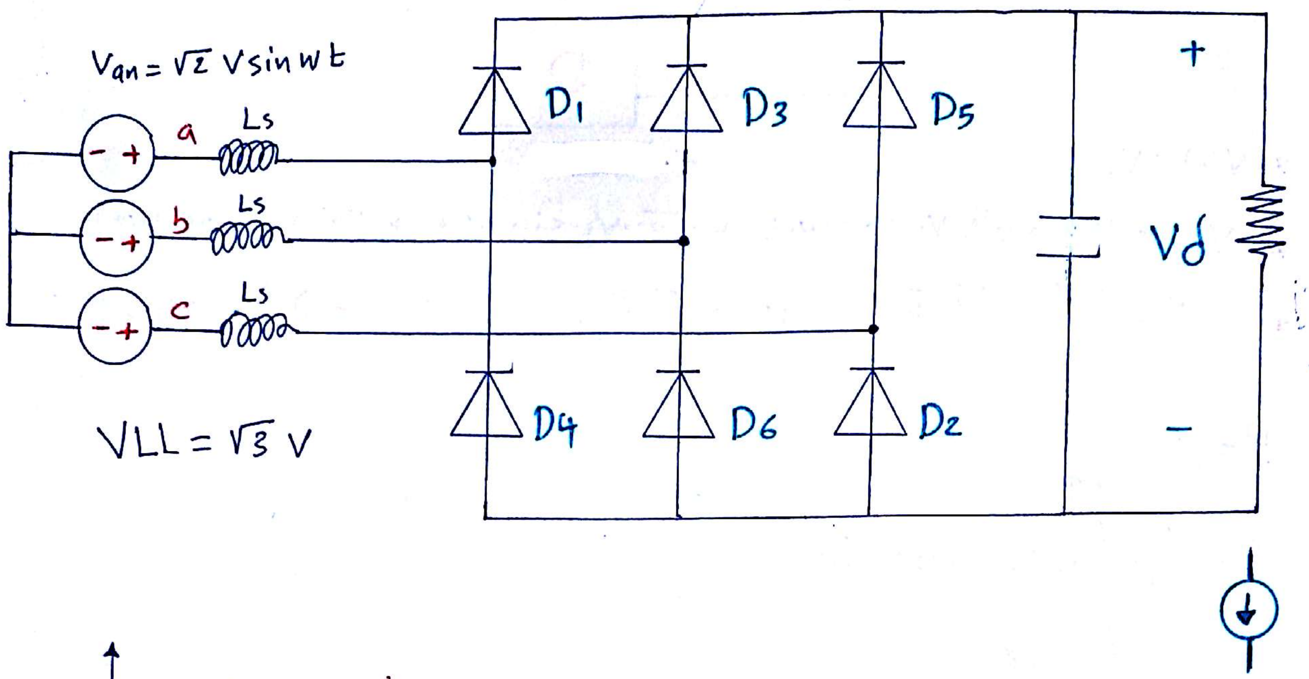
* Constant Dc Voltage across the Load $v_d(t) = V_d$:-



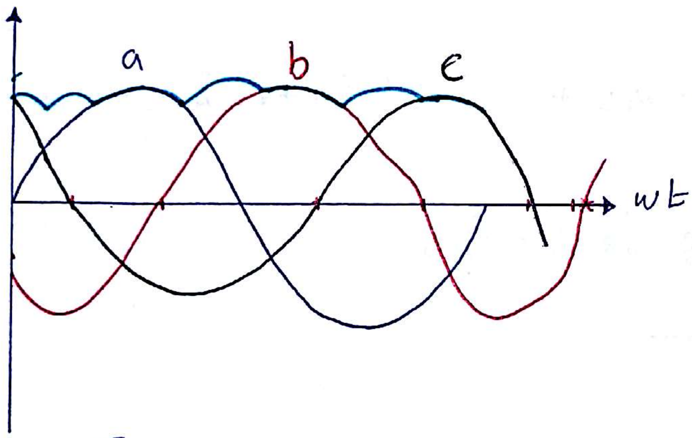


* Three - Phase - Full - Bridge Rectifiers :-

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



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



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

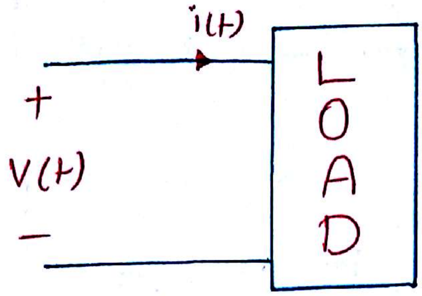
$$= \frac{3}{\pi} \int_0^{\frac{\pi}{3}} \sqrt{2}\, V \sin \omega t \, d\omega t$$

$= 1.35\, V_{LL}$ rms value of the line input voltage

$P_d = V_d I_d$

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

Exe- 5-3



* $v(t) = V_d$
* $v(t) = V_d + \sqrt{2}\, V_1 \cos w_1 t + \sqrt{2}\, V_1 \sin w_1 t + \sqrt{2}\, V_3 \cos w_3 t$
* $i(t) = I_d + \sqrt{2}\, I_1 \cos w_1 t + \sqrt{2}\, I_3 \cos(w_3 t - \phi_3)$, $w_3 = 3w_1$

[a] $P = ??$

$$P = \frac{1}{2\pi} \int_0^{2\pi} v(t)\, i(t)\, d\theta$$

$$= \frac{1}{2\pi} \left[\int_0^{2\pi} (V_d + \sqrt{2} \cos w_1 t + \cdots)(I_d + \sqrt{2} I_1 \cos w_1 t + \cdots)\, d\theta \right]$$

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

[b] $V = \sqrt{V_d^2 + V_1^2 + V}$

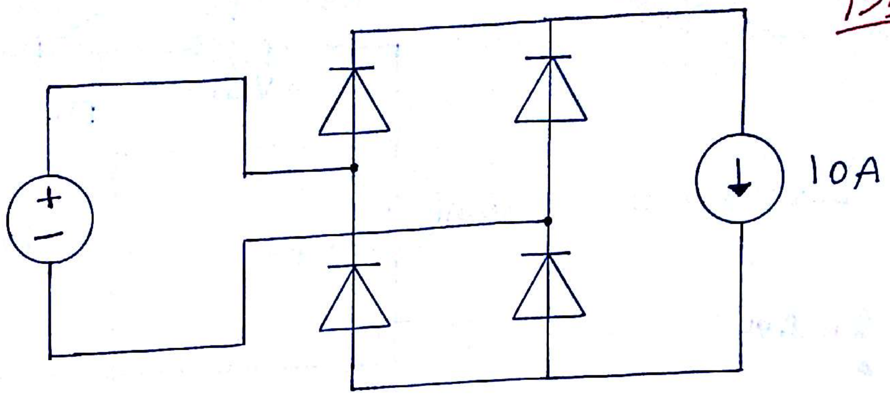
$$I = \sqrt{I_d^2 + I_1^2 + I_3^2}$$

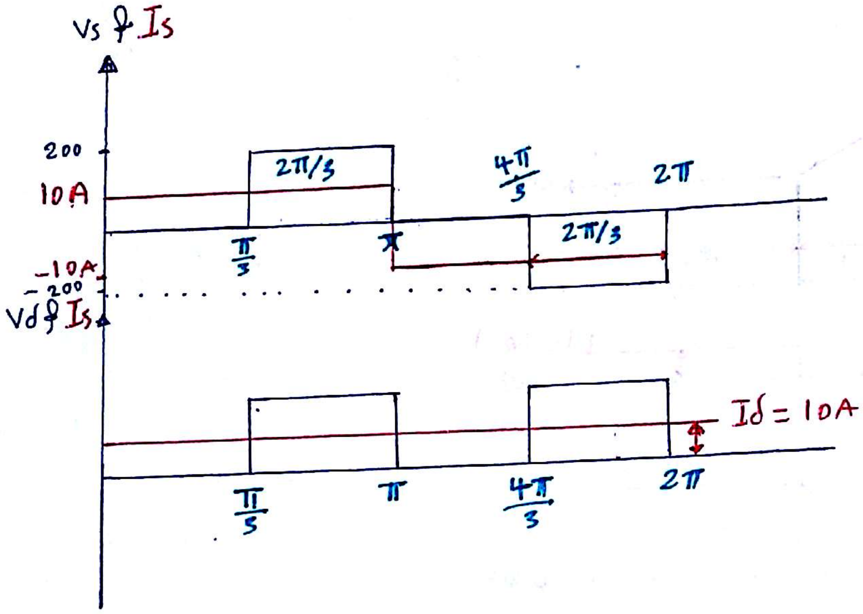
[c] $S = V I$

$$PF = \frac{P}{S} = \cdots$$

5-4

b





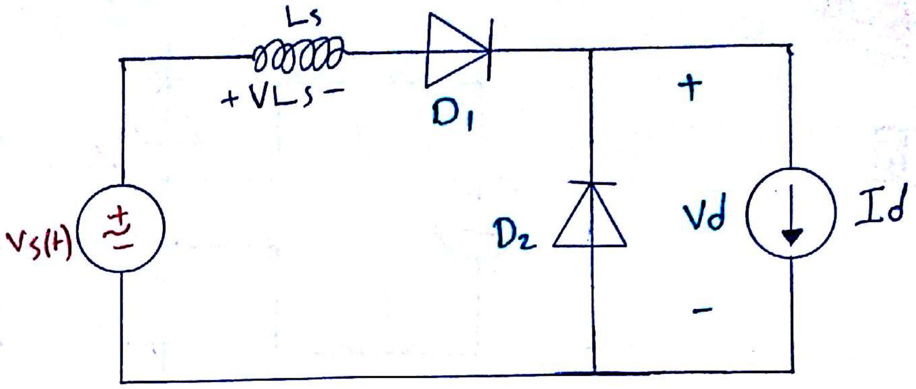
$$P_d = \frac{1}{2\pi}\int_0^{2\pi} v_d(t)\, i_d(t)\, d\theta$$

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

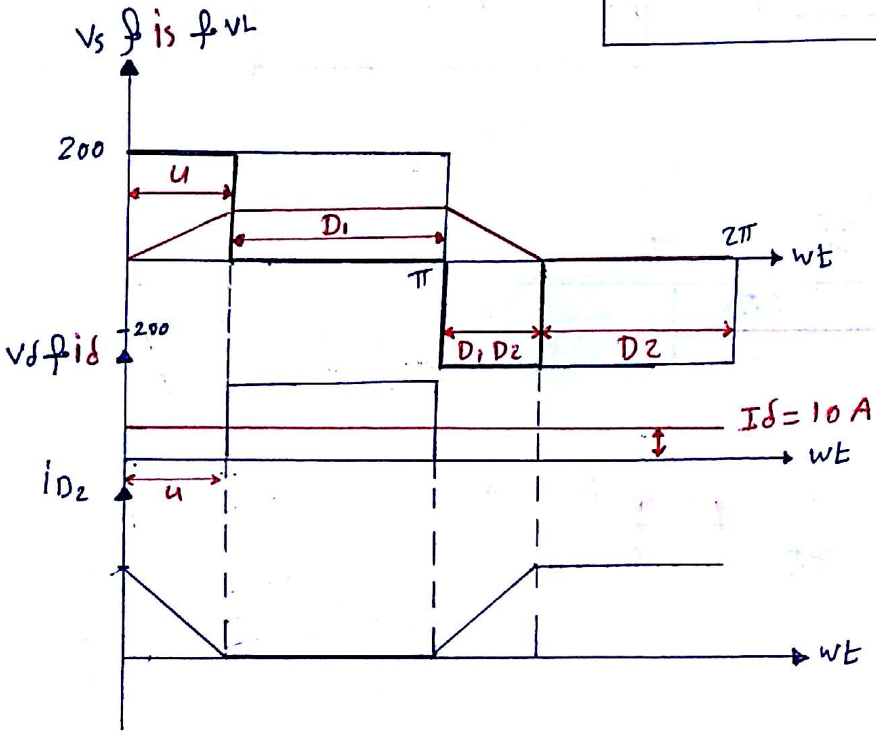
$$= \frac{4000}{2\pi}\left(\pi - \frac{\pi}{3}\right)$$

$$= \frac{4000}{3} \text{ W}$$

5-5 $\boxed{36}$



$\boxed{C}$ $L_s = 5\,mH$



* During Commutation :-

$$VL = Vs$$

$$wL_s \frac{di_s}{dwt} = 200$$

$$wL_s \int_0^{Id} di_s = \int_0^{u} 200\, dwt$$

$$wL_s\, Id = 200\, u$$

$$u = \frac{wL_s \cdot Id}{200} = \frac{(377)(5\times10^{-3})(10)}{200}$$

$$u = \frac{5.4 * \pi}{180} \text{ rad}$$

$$u = 5.4$$

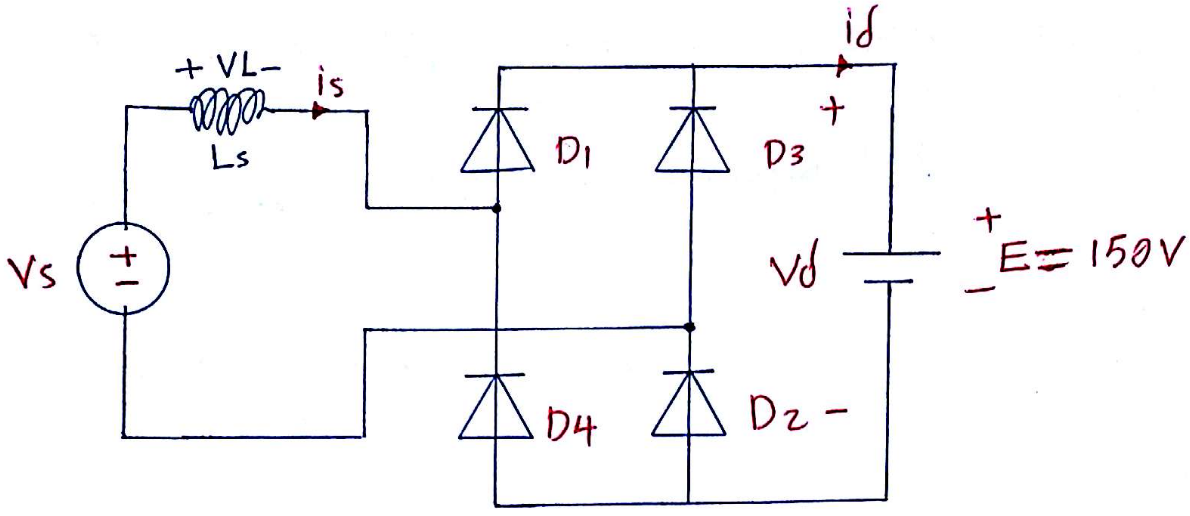
$$Vd = \frac{1}{2\pi}\int_u^{\pi} 200\, d\theta = \frac{1}{2\pi} 200(\pi - u)$$

$$= \frac{1}{2\pi} 200\left[\pi - \frac{5.4 * \pi}{180}\right] = \dots$$

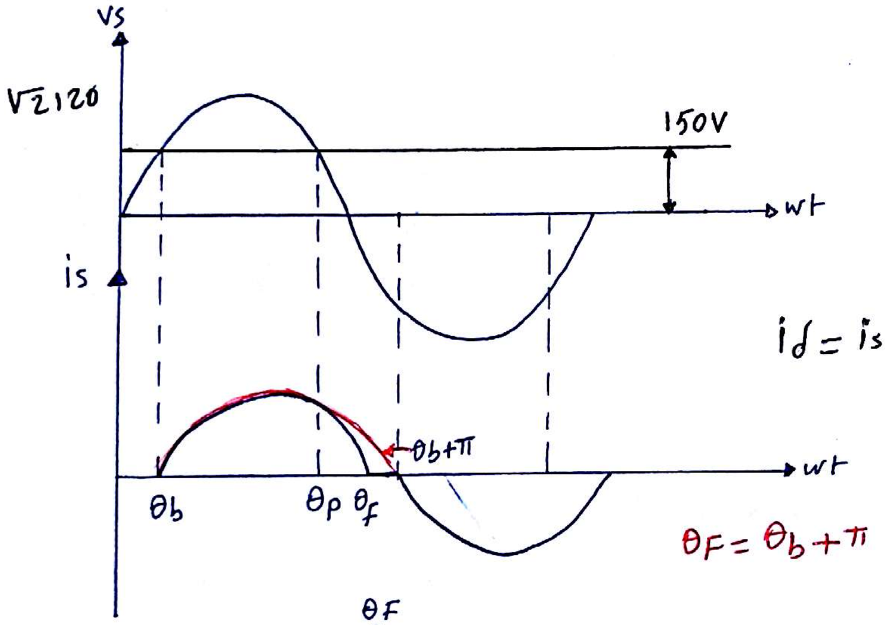
, $Pd = Vd\; Id$

$=$

5-11 [37]



$$V_s = \sqrt{2}\, V \sin wt = \sqrt{2}\, 120 \sin wt$$



$i_d = i_s$ in the First half cycle

$\theta_F = \theta_b + \pi$

$$I_d = \frac{1}{\pi}\int_{\theta_b}^{\theta_F} i_d(\theta)\, d\theta$$

$i_d(\theta) = \square \cos\theta - \square\,\theta + \square$

$i_d(\theta_F) = 0 = \square \cos\theta_F - \square\,\theta_F + \square$

$\theta_F = ----$ Trial & Error

$\theta_b = \sin^{-1}\left(\frac{150}{\sqrt{2} * 120}\right) =$

$\theta_p = \pi - \theta_b$

$\theta_F = ?$ $\quad i_d(\theta_F) = 0$

$$-V_s(t) + L_s \frac{di_d}{dt} + E = 0$$

$$wL_s \frac{di_d}{d\theta} = \sqrt{2}\, V \sin\theta - E$$

$$di_d = \left(\frac{1}{wL_s}\sqrt{2}\, V \sin\theta - \frac{1}{wL_s} E\right) d\theta$$

$$i_d(\theta) = -\frac{1}{wL_s}\sqrt{2}\, V \cos\theta - \frac{1}{wL_s} E\theta + K$$

$$i_d(\theta_b) = 0 = \frac{-\sqrt{2}\,V}{wL_s}\cos\theta_b - \frac{E}{wL_s}\theta_b + K$$

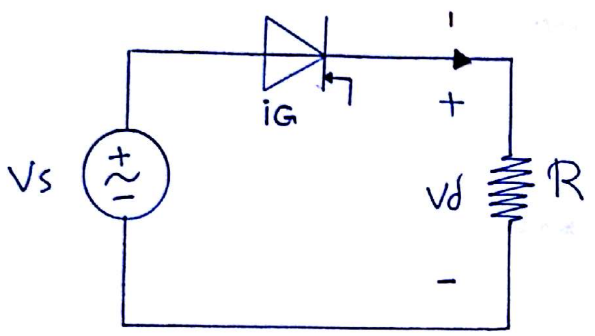
$K = ----$

5

* Controlled Rectifiers And Inverters :-

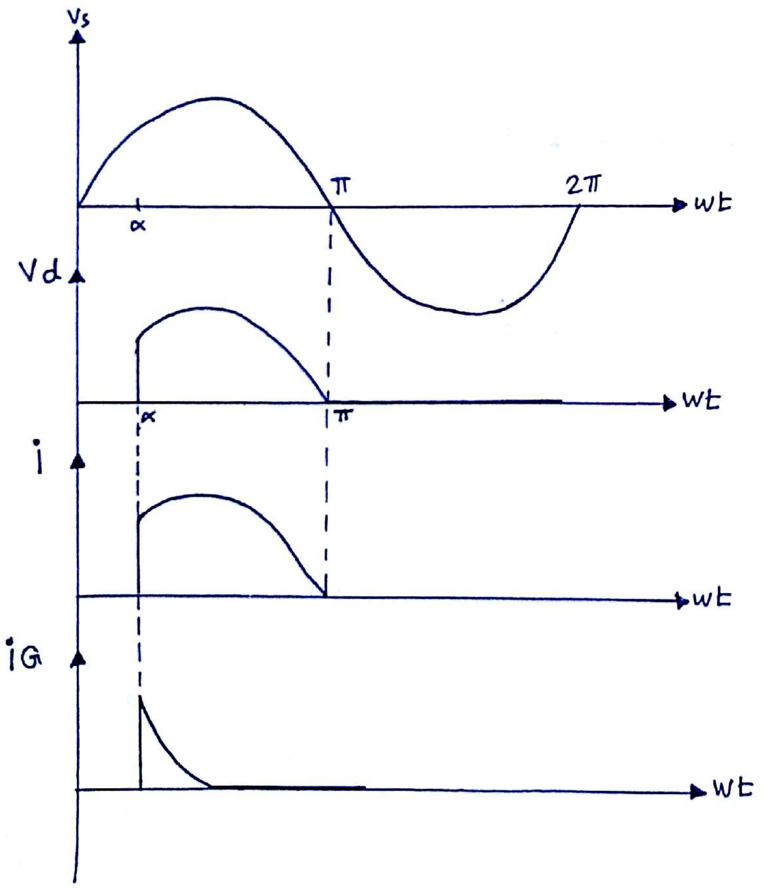
line Frequncy Ac → Controlled Dc.

* Basic Thyristor Circuits :-



α: Firing angle

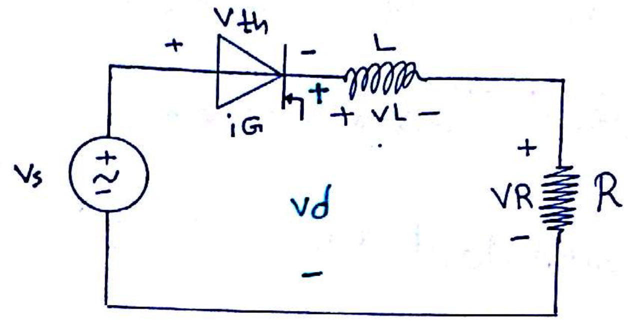
half-wave controlled rectifier cct with pure resistive

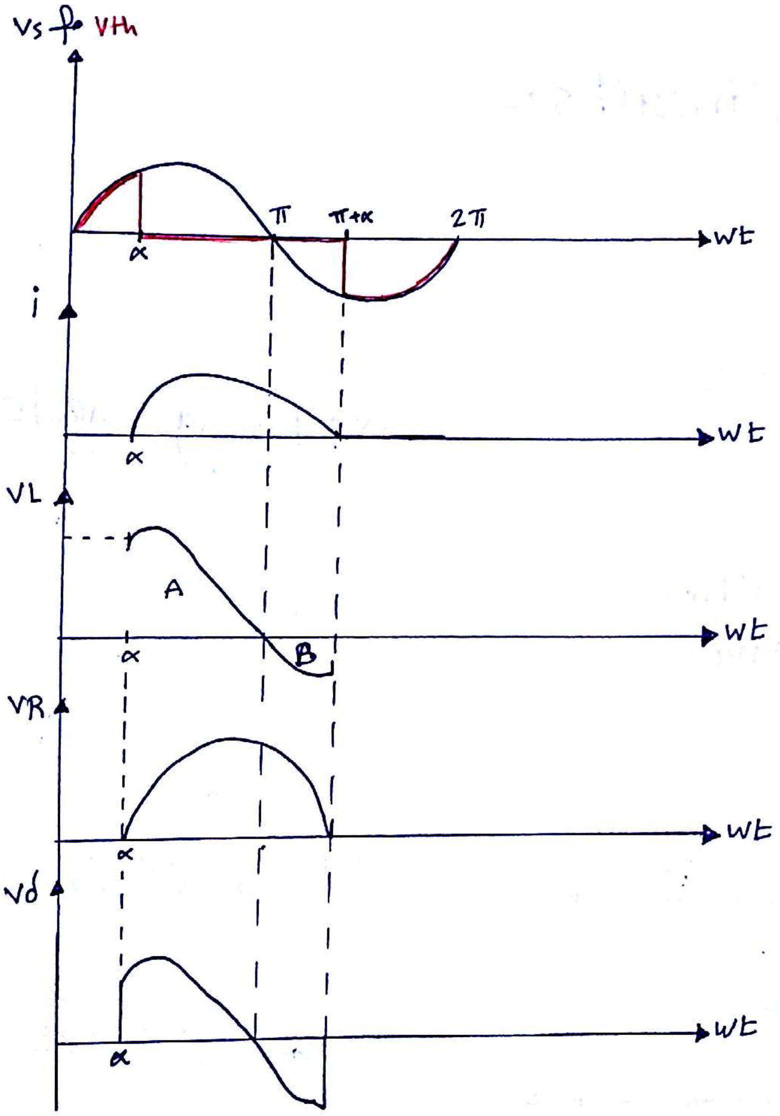


$$Vd = \frac{1}{2\pi}\int_{\alpha}^{\pi} \sqrt{2}\, V \sin wt \, dwt$$

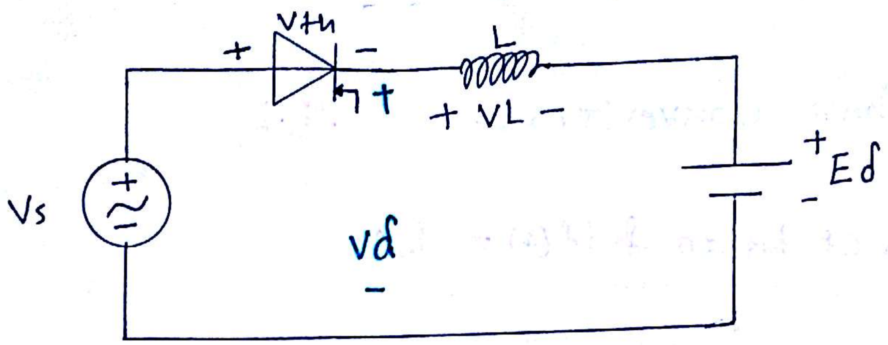
$$= \frac{\sqrt{2}V}{2\pi} \cos wt \Big]_{\pi}^{\alpha}$$

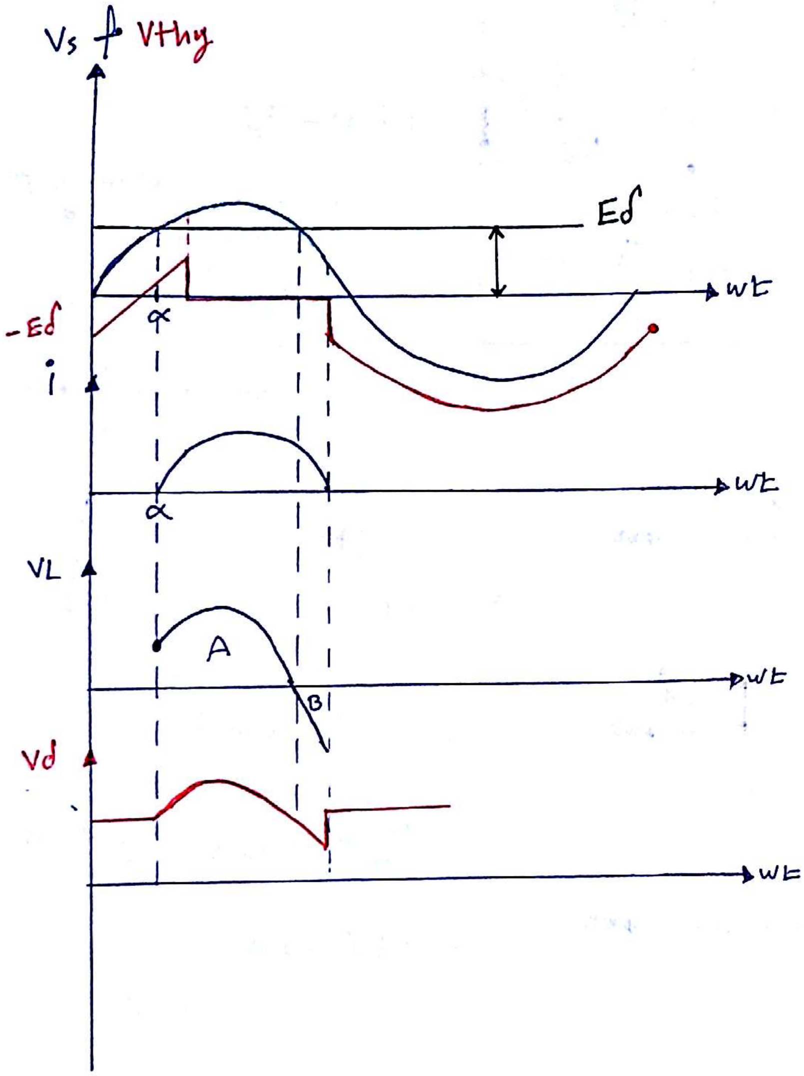
$$= \frac{\sqrt{2}V}{2\pi}\left[\cos\alpha + 1\right]$$


Vth
+
-
L
iG
+ VL -
Vs
Vd
+
VR
-
R


Vs & Vth
π
π+α
2π
α
wt
i
VL
A
B
VR
Vd

140





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

$$V_L = V_s(t) - E_d$$

*

* Single - Phase Converters :-

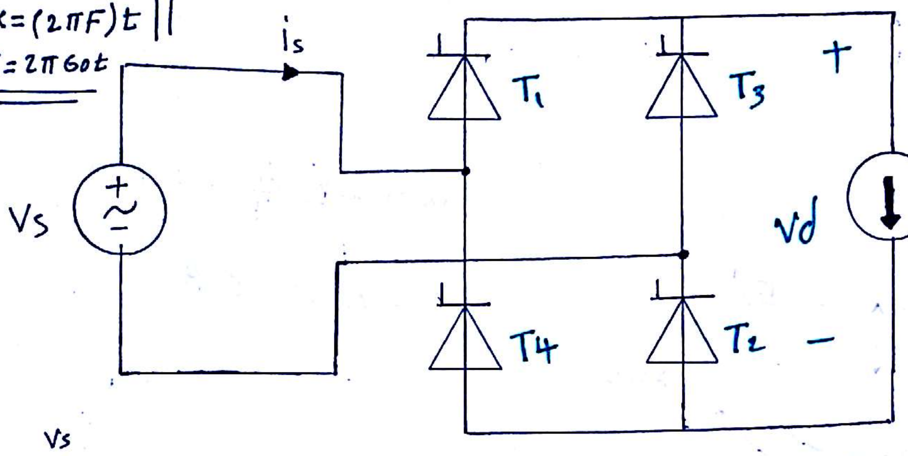
* Idealized cct $L_s = 0$ & $i_d(t) = I_d$

ex:-

$\alpha = \omega t$

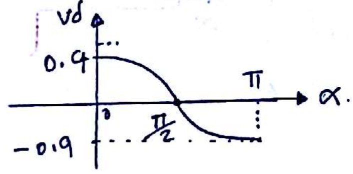
$\alpha = (2\pi F)t$

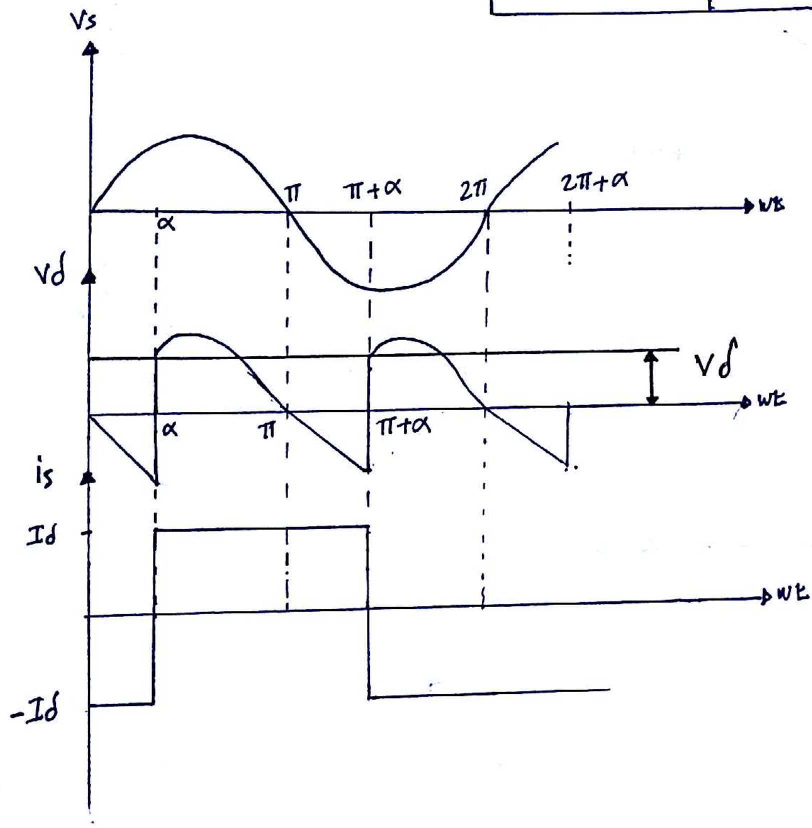
$45 = 2\pi 60 t$



$i_d(t) = I_d$

(highly inductive) DC Motor load



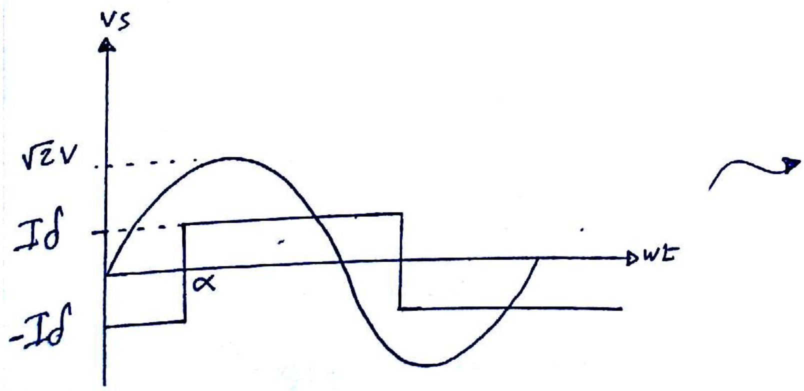


$$V_d = \frac{2}{2\pi}\int_{\alpha}^{\pi+\alpha} \sqrt{2}\, V \sin \omega t \, d\omega t$$

$$= \frac{\sqrt{2}V}{\pi}\left[\cos \omega t\right]_{\pi+\alpha}^{\alpha} = \text{—}$$

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

$$= 0.9 V \cos\alpha$$



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

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

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

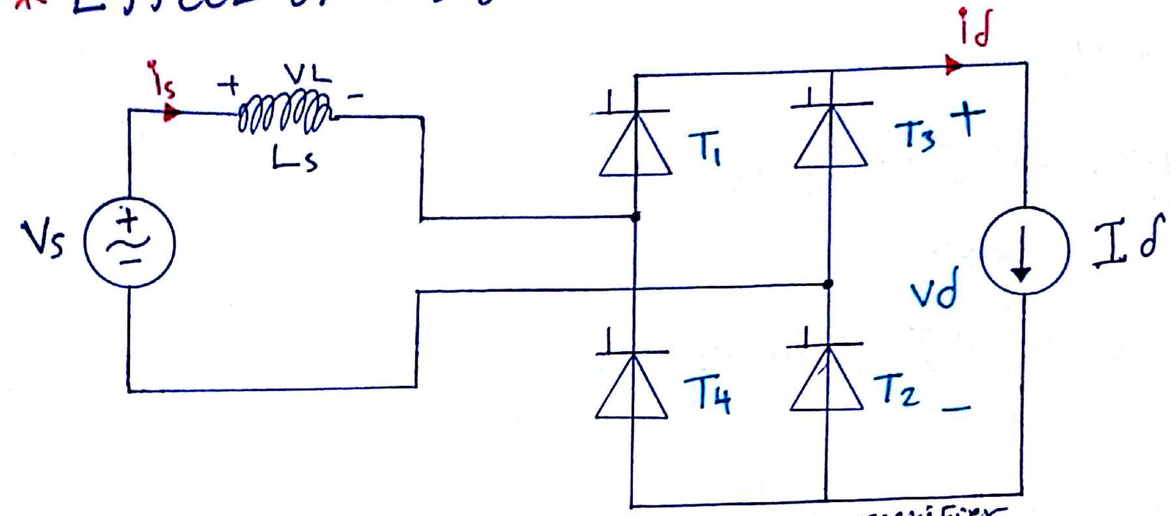
$DPF = \cos\alpha$

$I_s = I_d$

$I_{s1} = 0.9 I_d$

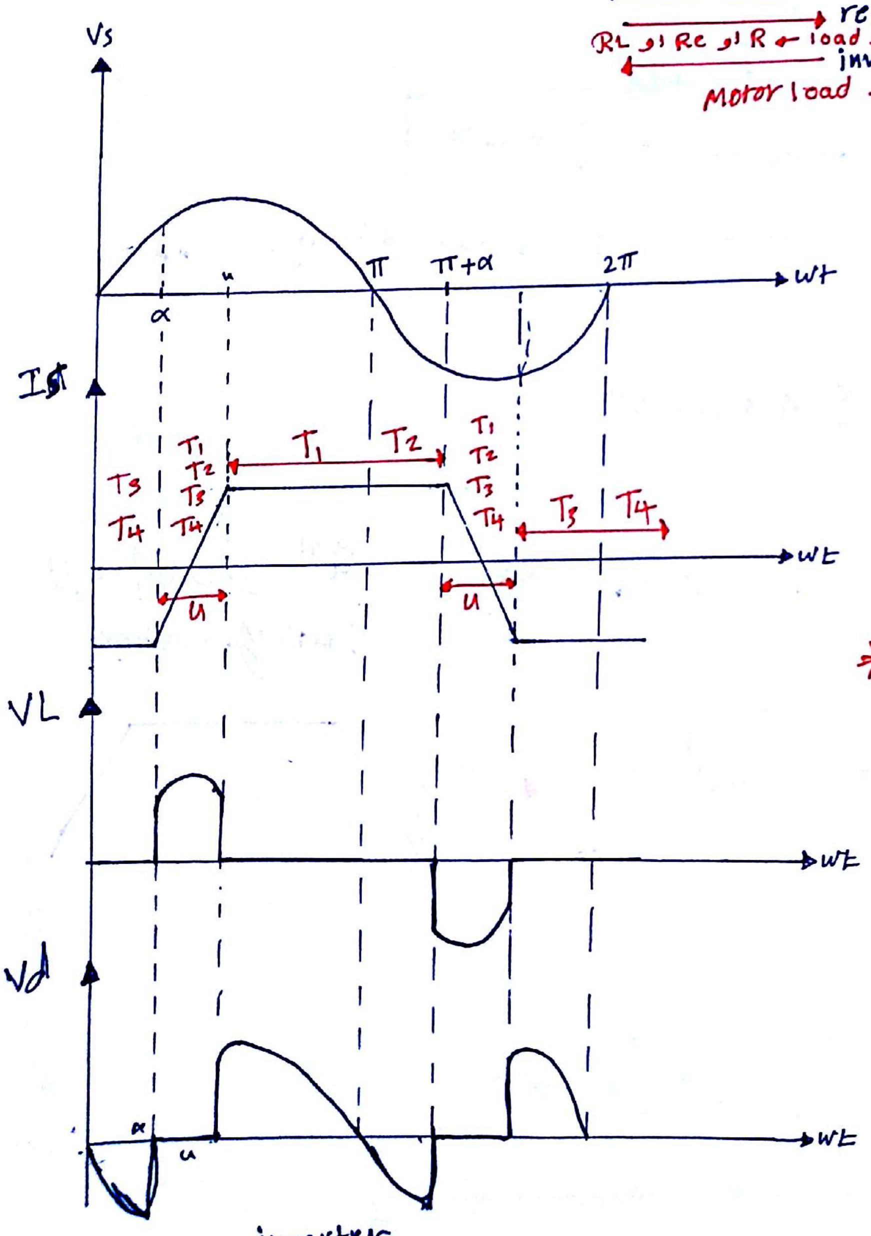
$THD = 48.43\%$

* Effect of Ls :-



rectifier →
اذا كان ال load R او Rc او RL

← inverter
اذا كان ال Motor load



inverter ←

regenerative braking.

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

$$= \frac{\sqrt{2}V}{\pi} \cos\omega t \Big]_{\pi+\alpha}^{\alpha+u}$$

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

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

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

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

* *

During Commutation

$$V_L = V_s$$

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

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

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

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

$\cos(\alpha+u) = - - - - - - - - -$ نعوضها بمعادلة (*)

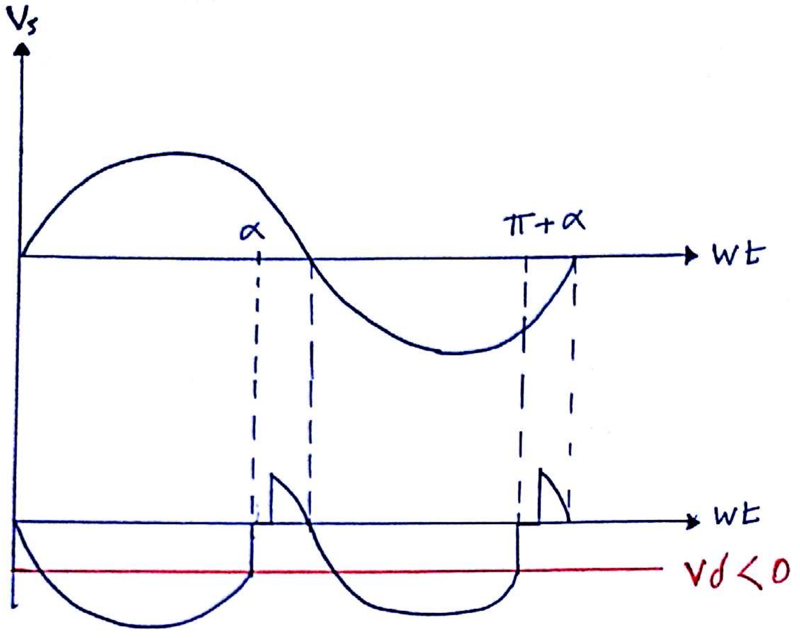
$$\omega L_s \int di_s = \int \sqrt{2}\, V \sin \omega t \, d\omega t$$

$\omega L_s\, i_s(\theta) = -\sqrt{2}\, V \cos\theta + K$ → ايجاد التيار في حالة During Comm

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

$i_s(\alpha) = - - - - - = -I_d$

* Inverter Mode of operation :-

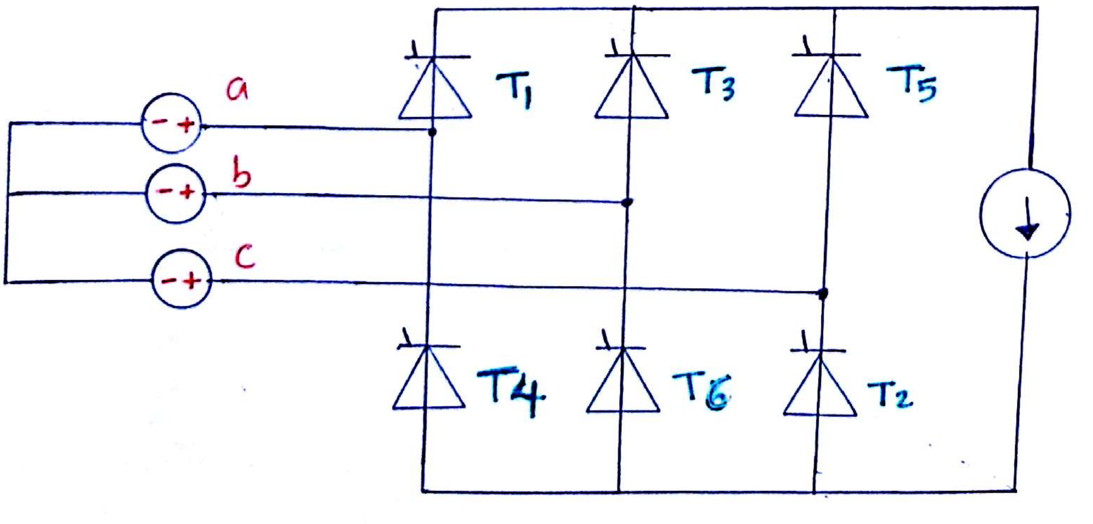


$$V_d = 0.9 V \cos\alpha - \frac{2 w L_s I_d}{\pi} < 0$$

① $\alpha < 90$

② storge element

* Three- Phase Controlled rectifier Circuit :-

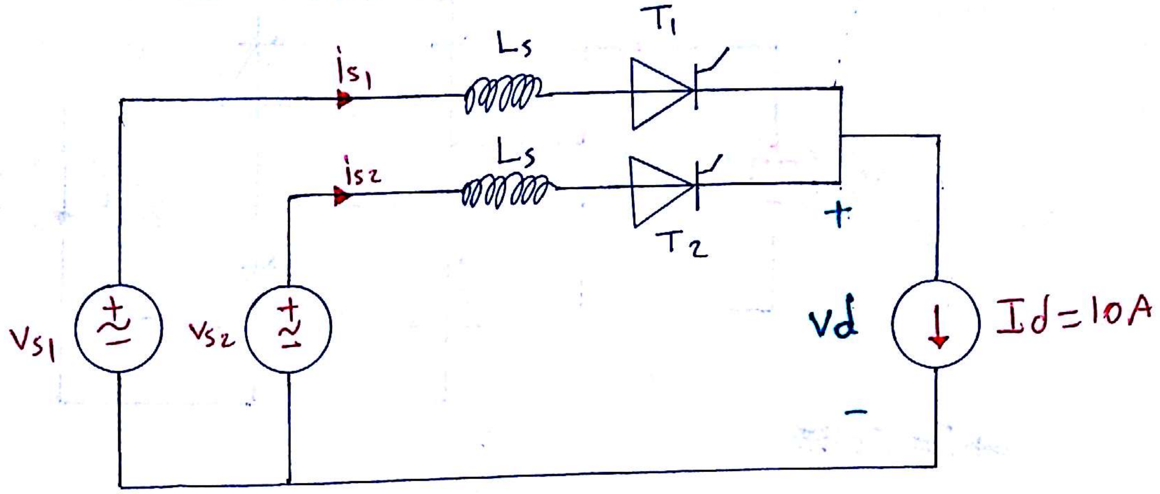


$V_d = 1.35\ V_{LL} \cos\alpha$

rms value
of line - line voltage .

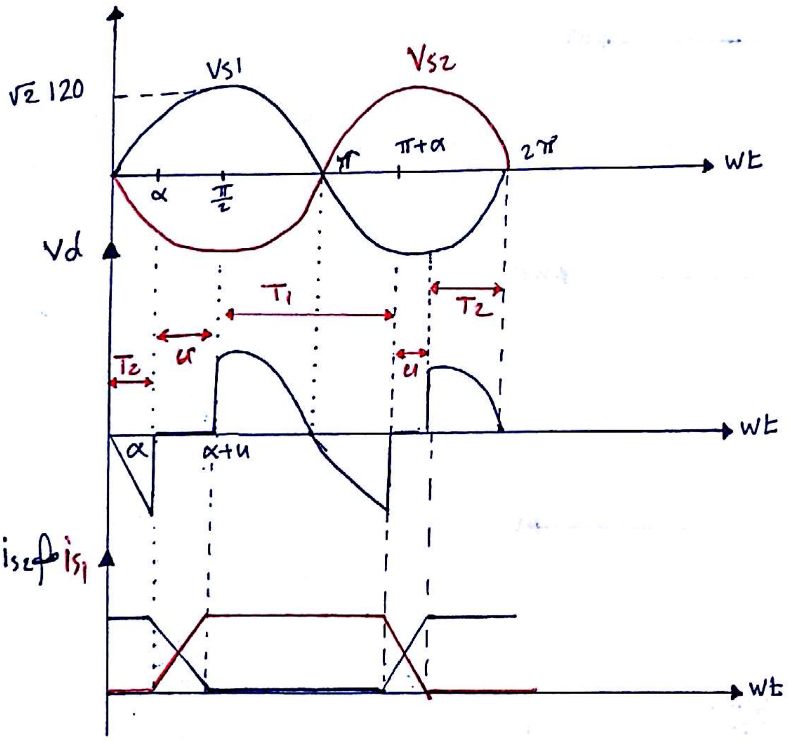
Power elec $\boxed{145}$ 15/3/2017 الاربعاء

P. 6-1



$V_{s1} = V_{s2} = 120V$, 60 Hz (Out OF Phase by 180°) , $L_s = 5mH$

$\boxed{a}$ $\alpha = 45°$



During Commutation

$$V_L = V_s$$

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

$$\int_0^{I_d} d\,i_s = \int_{\alpha}^{\alpha+u} \frac{1}{\omega L_s} \sqrt{2}\, V \sin\omega t \, d\omega t$$

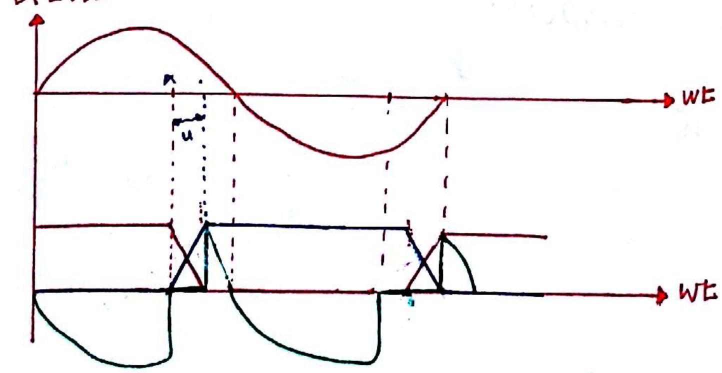
$$\Downarrow$$

$$u = ?$$

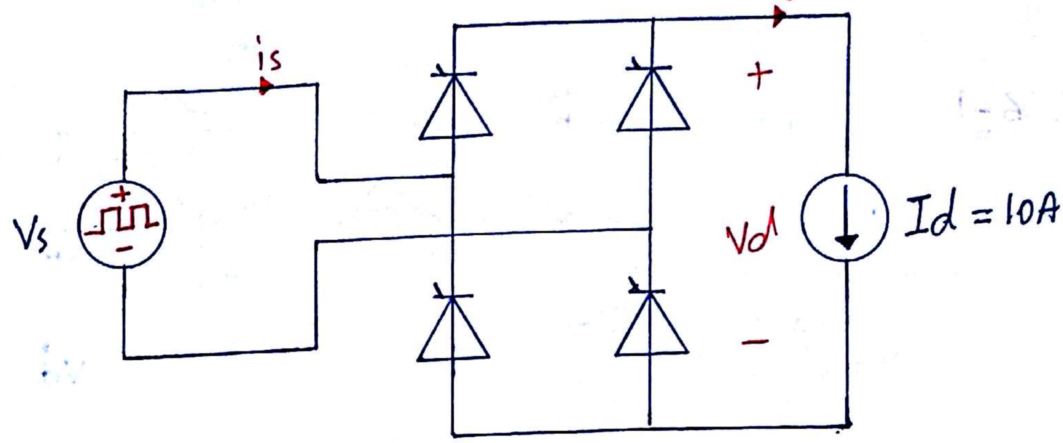
$$V_d = \frac{2}{2\pi} \int_{\alpha+u}^{\pi+\alpha} \sqrt{2}\, V_{s1} \sin \omega t \, d\omega t$$

$= \ldots\ldots\ldots V.$

$\alpha = 135°$



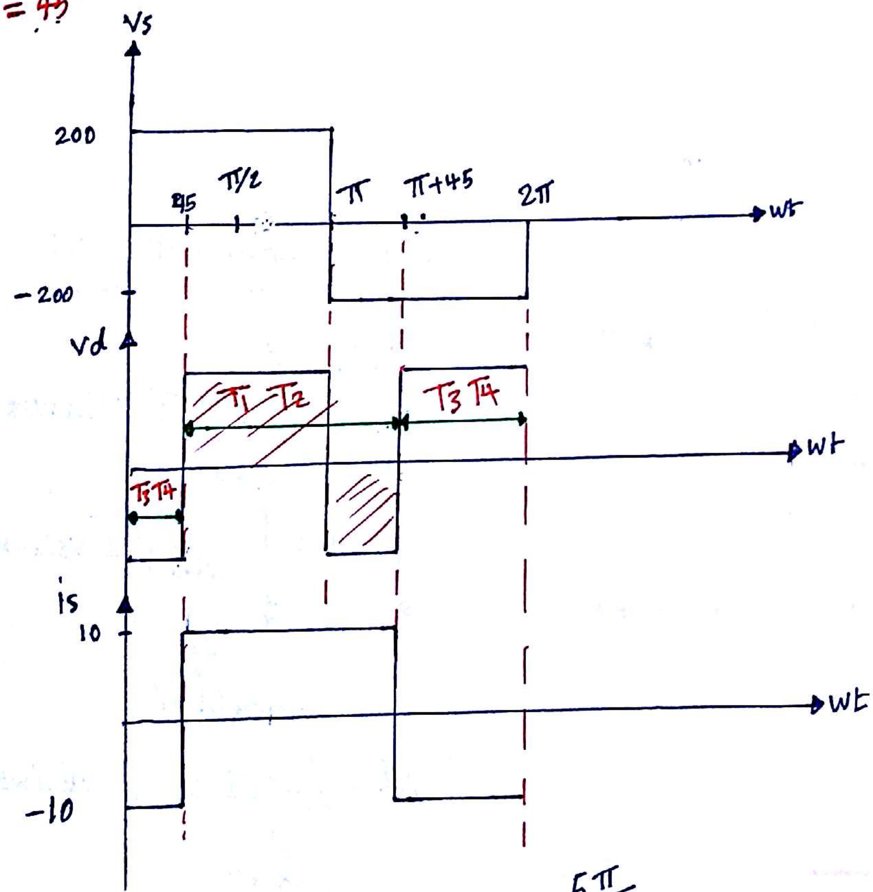
6-3



→ F = 60HZ

→ Vs is a square waveform with a peak of 200 V.

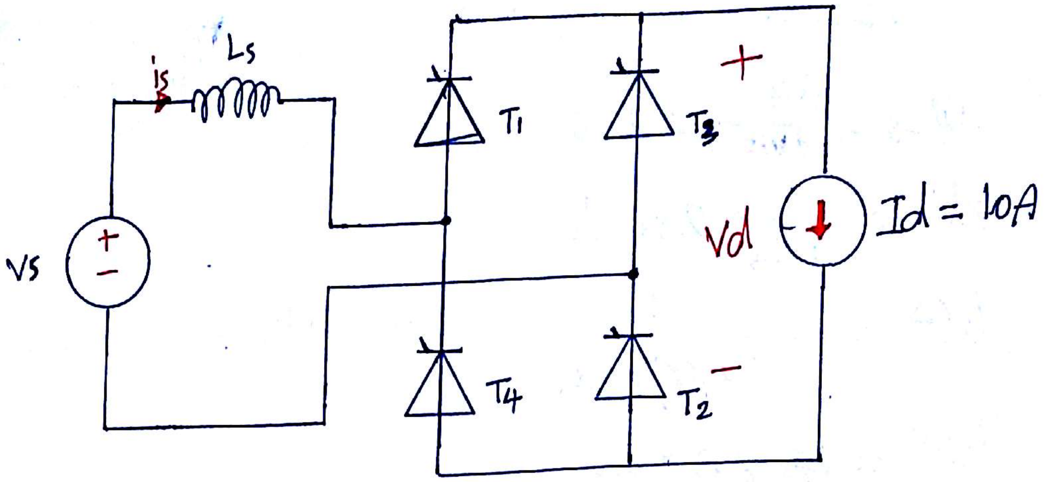
$\alpha = 45^\circ$

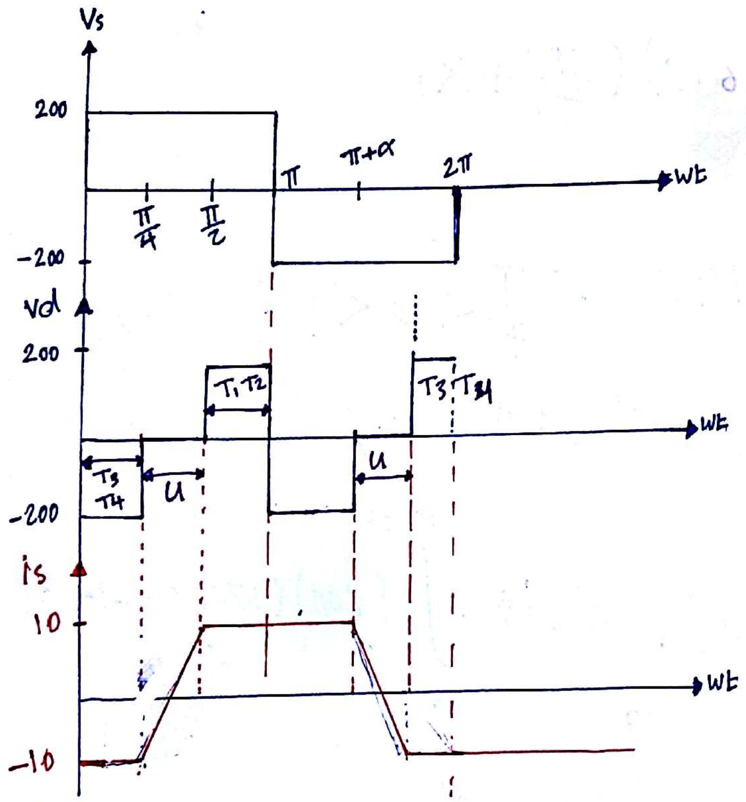


$$Vd = \frac{1}{\pi}\left[\int_{\frac{\pi}{4}}^{\pi} 200\, d\theta + \int_{\pi}^{\frac{5\pi}{4}} -200\, d\theta\right]$$

P-6-4

$F = 60\,Hz$
$L_s = 3\,mH$





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

$$P_d = V_d I_d .$$

During Commutation:-

$$V_L = V_s$$

$$wL_s \frac{di_s}{dwt} = 200$$

$$\int_{-10}^{10} di_s = \int_{\alpha}^{\pi/4+u} \frac{1}{wL_s}\, 200\, d\theta$$

$$20 = \frac{200\,(u)}{(377)(3\times10^{-3})} \rightarrow u = 0.11\ rad = 6.3^{\circ}$$

* Mathematical expression of (i_s) during Commutation

$$V_L = V_s$$

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

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

$$i_s(\theta) = \frac{1}{(377)(3\times10^{-3})} 200\,\theta + K_1$$

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

$$i_s\left(\frac{\pi}{4}\right) = -10 = (176.8)\left(\frac{\pi}{4}\right) + K_1$$

$$K_1 = -148$$

$$i_s(\theta) = 176.8\,\theta - 148 \qquad \frac{\pi}{4} < \theta < \left(\frac{\pi}{4} + u\right)$$

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

$$= \frac{1}{2\pi}\left[\int_0^{\alpha} (200)(-10)\, d\theta + \int_{\alpha}^{\alpha+u} (200)(176.8\theta - 148)\, d\theta + \int_{\alpha+u}^{\pi} (200)(10)\, d\theta\right]$$

* Dc - Dc Switch Mode Converters :-

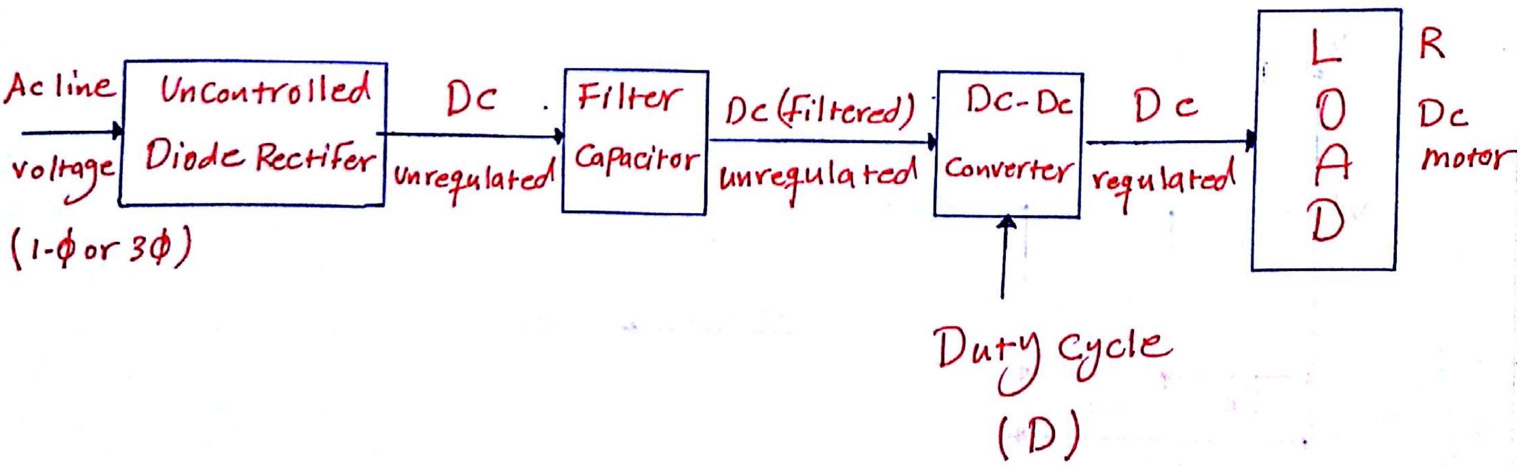
→ **Applications :-**

1. Dc Motor drive applications.
2. regulated power supply.

→ **Types :-**

1- step down (Buck)
2- step up (Boost)
3- step up down (Buck-Boost)
4- Full bridge converter.

* Dc - Dc Converter system :-



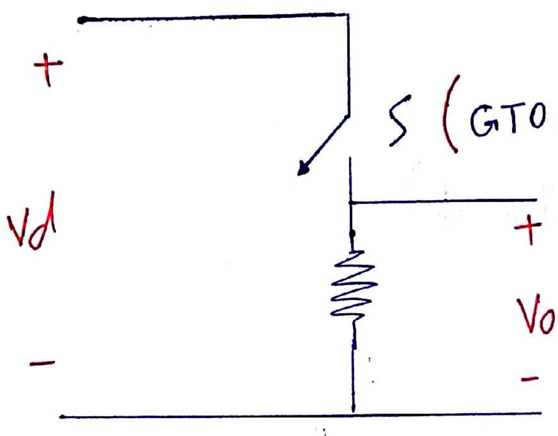
Note

* The converter

*

*

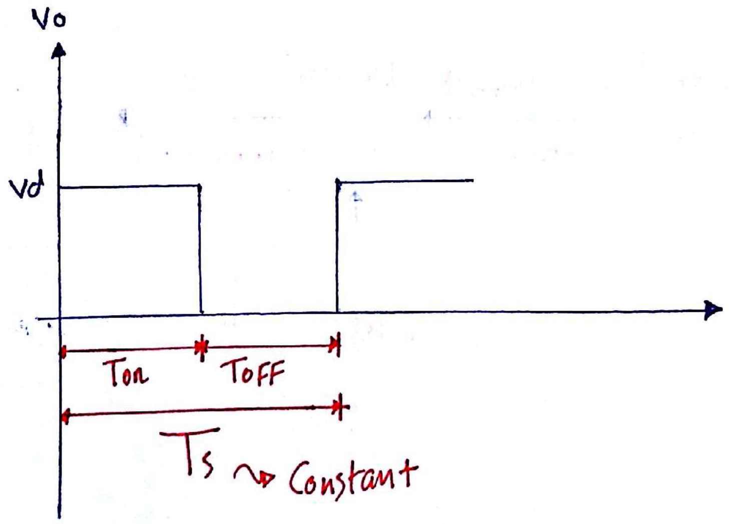
* Control of Dc - Dc Converters :-



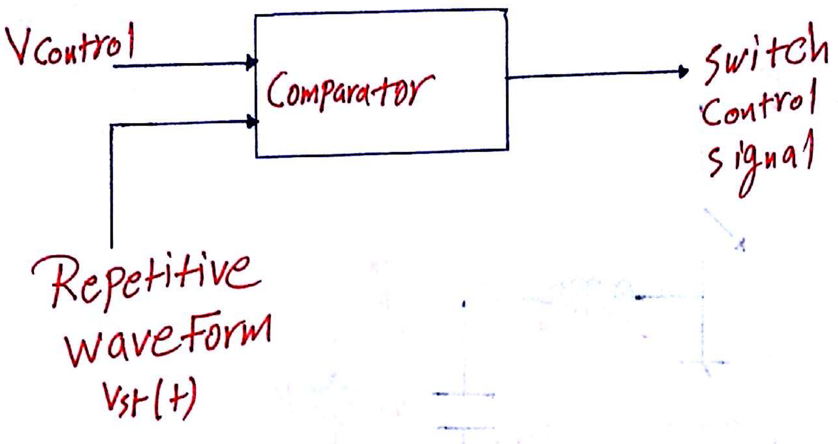
S (GTO, BJT, MosFET, ...)

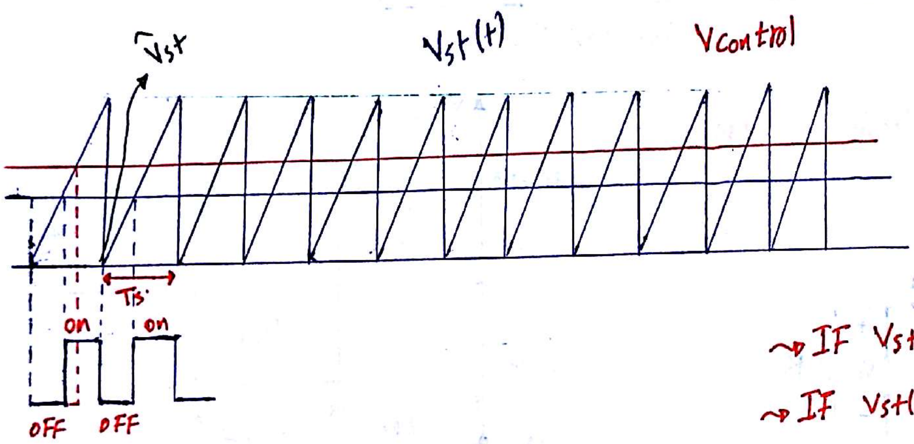
$$V_o = \frac{1}{T_s} \int_0^{t_{on}} V_d \, dt$$

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



* Pulse width Modulation (PWM) Technique :-





→ IF $V_{st}(t) > V_{control}$ (on)

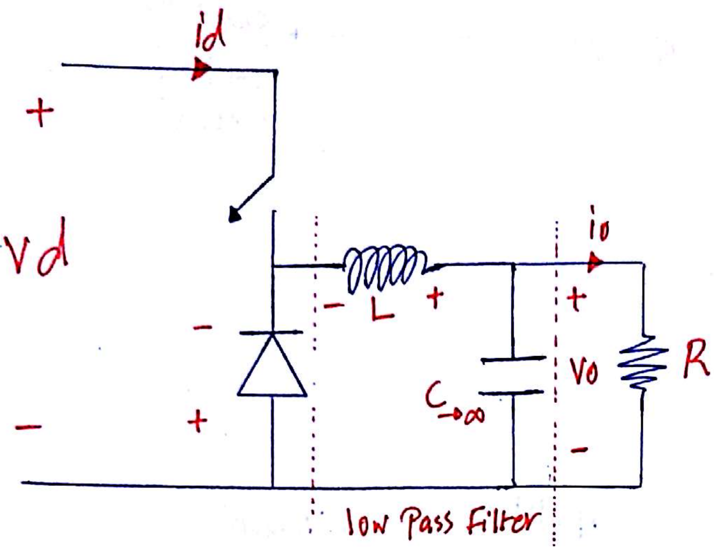
→ IF $V_{st}(t) < V_{control}$ (OFF)

→ $D = \dfrac{t_{on}}{T_s} = \dfrac{V_{control}}{\hat{V}_{st}}$

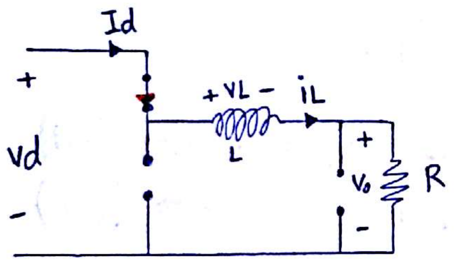
Note in Dc - Dc Converters there are two Modes of Operation :-

1. Continuous Condction mode.
2. discontinuous Condction Mode.

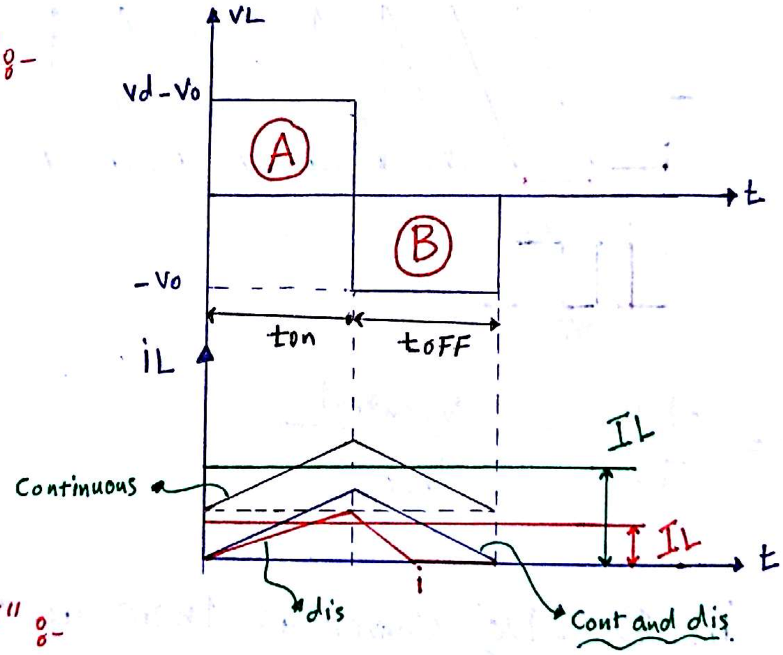
* Step down (Buck) Converter:-



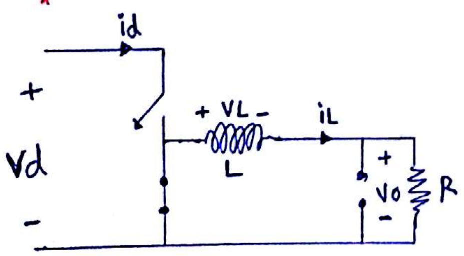
* If the Switch is "on":-



$$V_L = V_d - V_0$$



* If the Switch is "OFF":-



$$V_L = -V_0$$

$$t_{on} + t_{OFF} = T_s$$

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

$$V_L = 0 = \frac{1}{T_s}\left[\int_0^{t_{on}} (V_d - V_o)\,dt + \int_{t_{on}}^{T_s} -V_o\,dt\right]$$

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

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

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

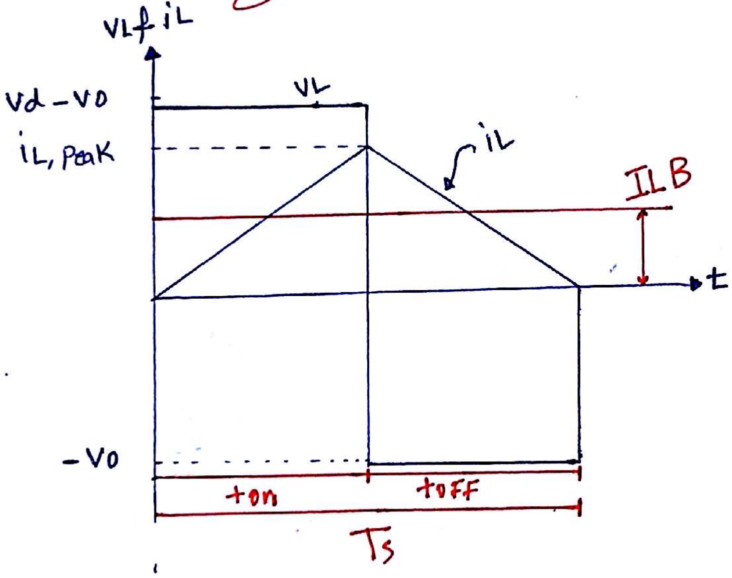
$$\frac{V_o}{V_d} = \frac{t_{on}}{T_s} = D$$

$$V_o = D V_d$$

$$\frac{V_o}{V_d} = \frac{I_d}{I_o} = D.$$

Continuous & Boundary

* Boundary Between Continuous & DisContinuous :-



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

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

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

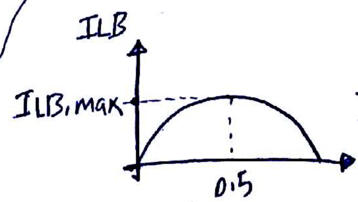
$$I_{LB} = \frac{1}{2}\,\frac{1}{L}(V_d - V_o)\,t_{on}$$

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

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

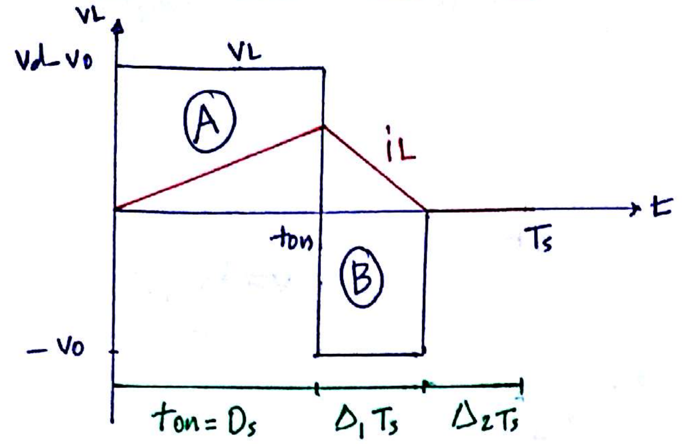
$$= \frac{D T_s}{2L} V_d - \frac{D T_s V_o}{2L}$$

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



$$\frac{T_s V_d}{8L} = I_{LB,max}$$

* Discontinuous Conduction Mode:-



$$A = B$$

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

$$V_d\, D T_s = V_o\, \Delta_1 T_s + V_o\, \Delta_2 T_s$$

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

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

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

$$i_{L,Peak} = \frac{V_d - V_o}{L} D T_s$$

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

$$I_L = \left(\frac{D + \Delta_1}{2}\right) \frac{V_o}{L} \Delta_1 T_s$$

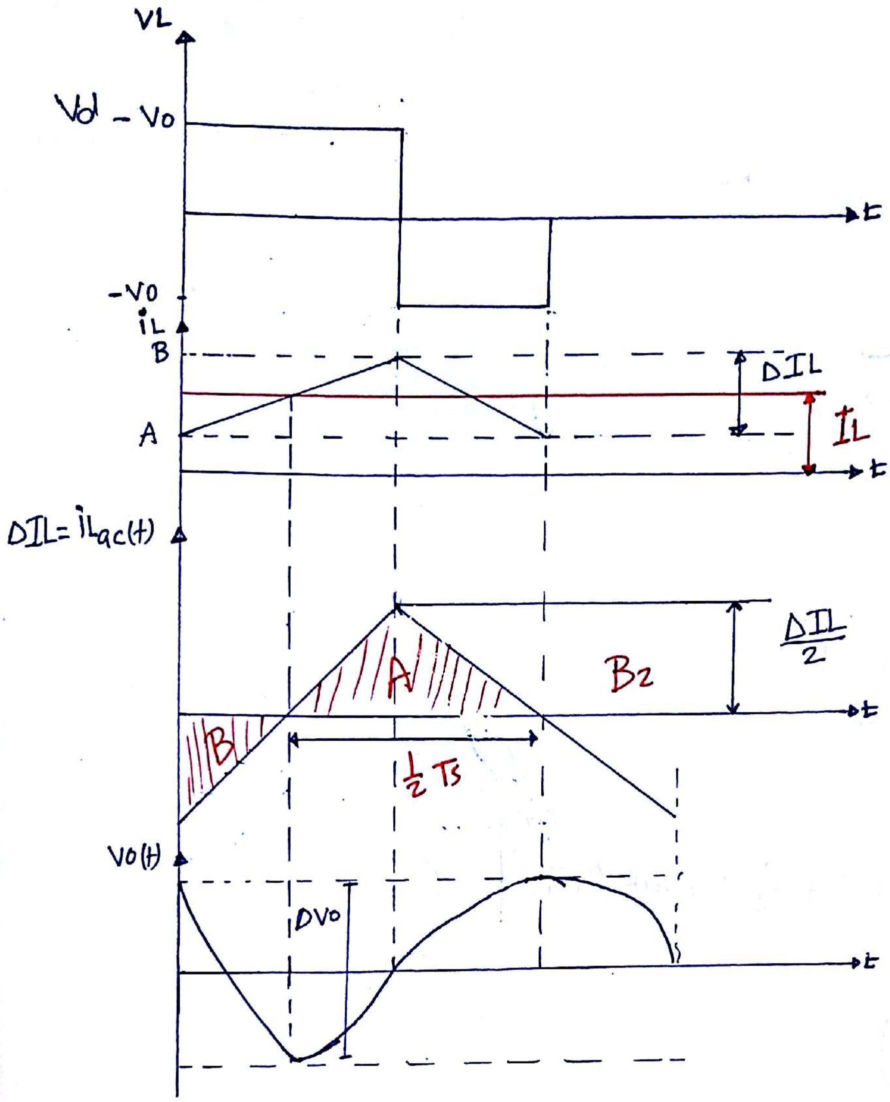
$$= \left(\frac{D + \Delta_1}{2}\right) \frac{1}{L} \Delta_1 T_s \frac{D V_d}{D + \Delta_1}$$

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

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

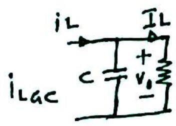
$$\frac{V_o}{V_d} = \frac{D}{D + \frac{2 L I_L}{V_d T_s D}}$$

Output Voltage Ripple:-



$$v = L\frac{di}{dt}$$

$$i_L(t) = i_{Lac}(t) + I_L$$



$$\bar{v}_o = V_o + v_o(t)$$

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

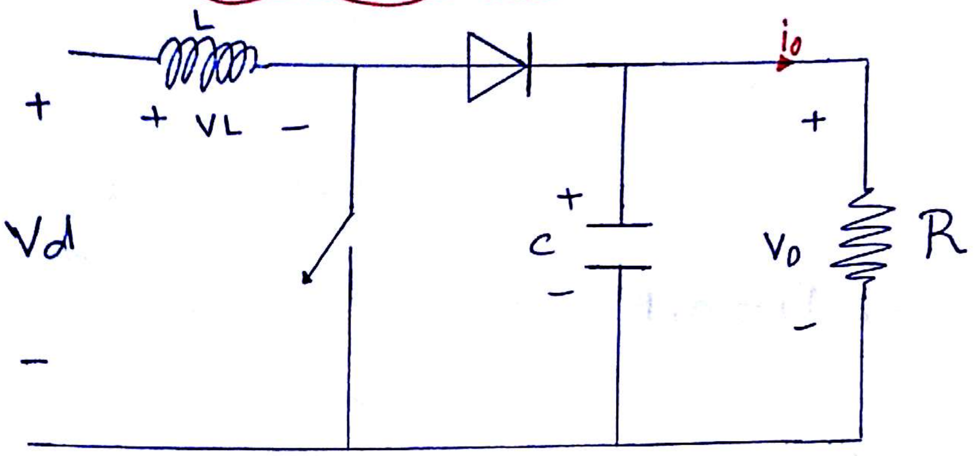
$$\Delta I_L = \frac{V_o}{L}(1-D)T_s \Rightarrow ?$$

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

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

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

* Step-Up (Boost) Converter:-



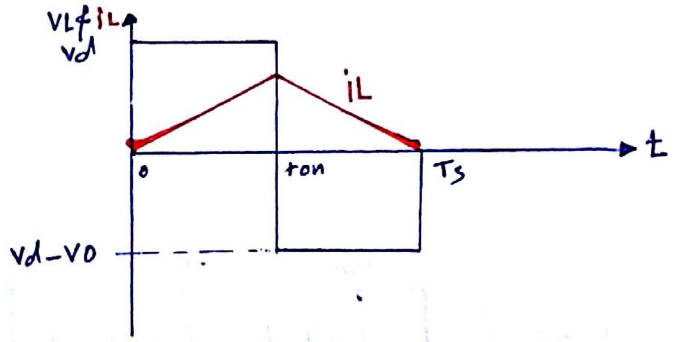
If the switch is "ON"

$-Vd + VL = 0 \Rightarrow VL = Vd$

If the switch is "OFF"

$-Vd + VL + Vo = 0$

$VL = Vd - Vo$



$$VL = 0 = \frac{1}{Ts}\left[\int_0^{ton} Vd\,dt + \int_{ton}^{Ts} (Vd - Vo)\,dt\right]$$

$Vd\,ton + (Vd - Vo)(Ts - Ton) = 0$

$Vd\,ton + Vd\,Ts - Vd\,ton - Vo\,Ts + Vo\,ton = 0$

$Vd\,Ts + Vo(ton - Ts) = 0$

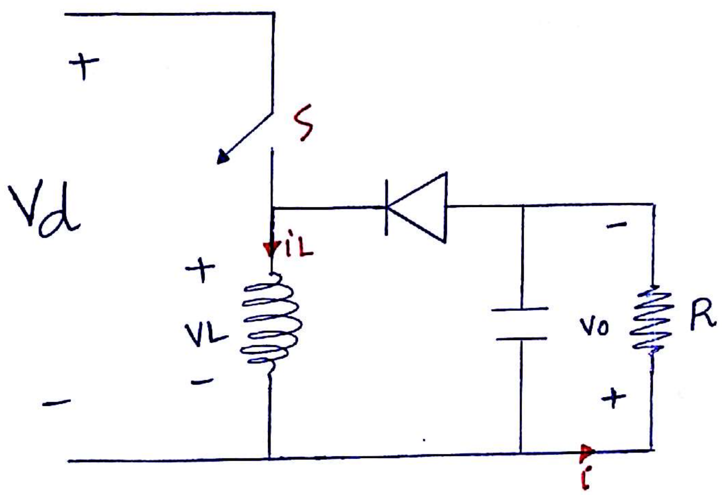
$Vd\,Ts = Vo(Ts - ton)$

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

$$= \frac{T_s}{T_s - DT_s}$$

$$\frac{V_o}{V_d} = \frac{1}{1-D} \geqslant 1 \quad \rightsquigarrow D = 0.1$$

* Buck-Boost Converter :-

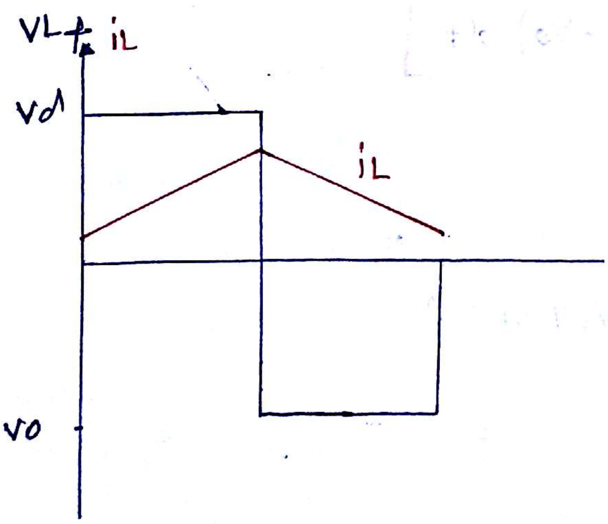


IF "S" "on"

$V_L = V_d$

IF S "OFF"

$V_L = -V_o$



$$V_L = 0 = \frac{1}{T_s}\left[\int_0^{t_{on}} V_d\,dt + \int_{t_{on}}^{T_s} -V_o\,dt\right]$$

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

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

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

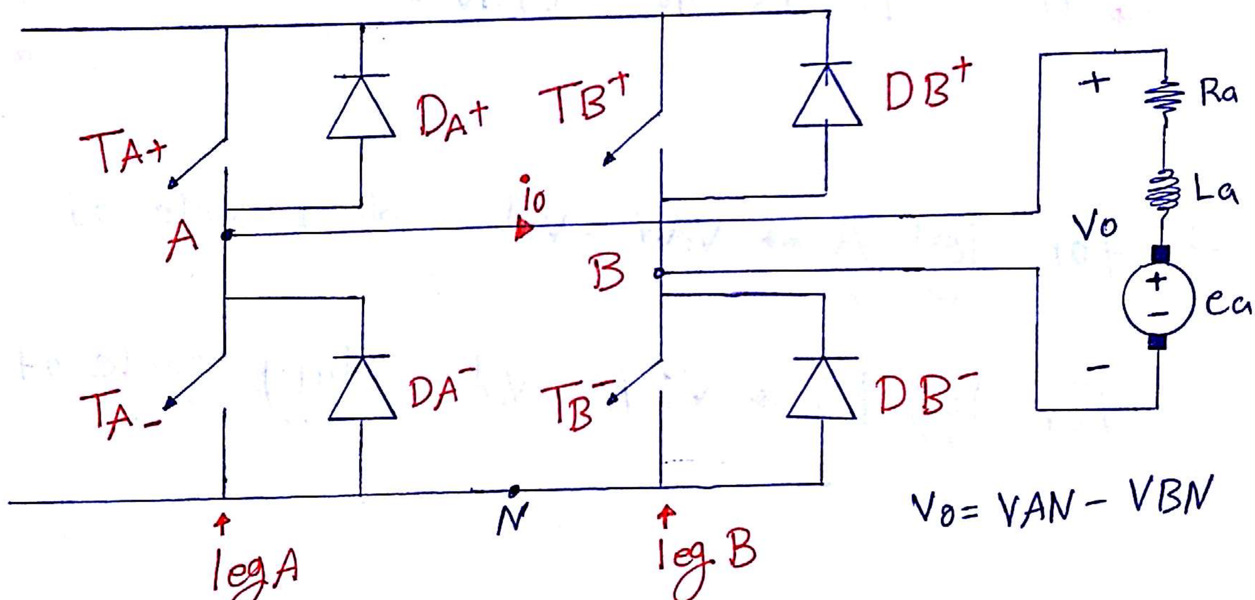
$0 < D \leqslant 0.5$ down

$0.5 \leqslant D < 1$ UP

* Full - Bridge Dc-Dc Converter :-

→ **Application :-**

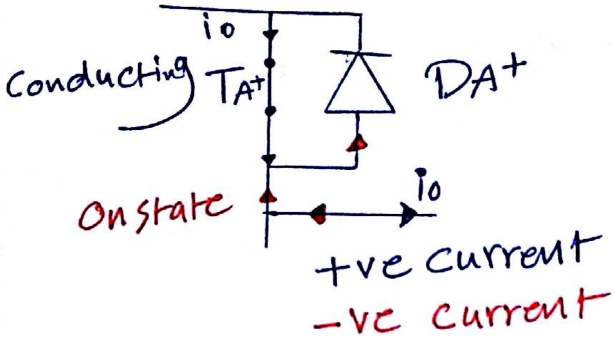
1. Dc Motor drives.
2. Dc - Ac inverters.
3. Renewable energy systems,
4. regulated Power supplies.



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

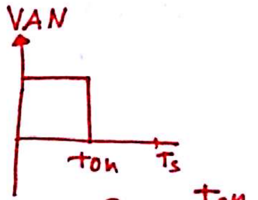
On state of the switch :- the switchs ON and May or May not Conduct the Current (depending of the direction current)

Conduct state of the Switch :- the switch is on and the current flows through it



كل onstate ← Cond
ويكون مش كل cond ← onstate

- if TA^+ is ON $V_{AN} = V_d$
- if TB^+ is ON $V_{BN} = V_d$
- if TA^- is ON $V_{AN} = 0$
- if TB^- is ON $V_{BN} = 0$



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

* For leg A ⇒ $V_{AN} = V_d$ duty cycle of TA^+

For leg B ⇒ $V_{BN} = V_d$ duty cycle of TB^+

* PWM with "bipolar voltage" Switching :-

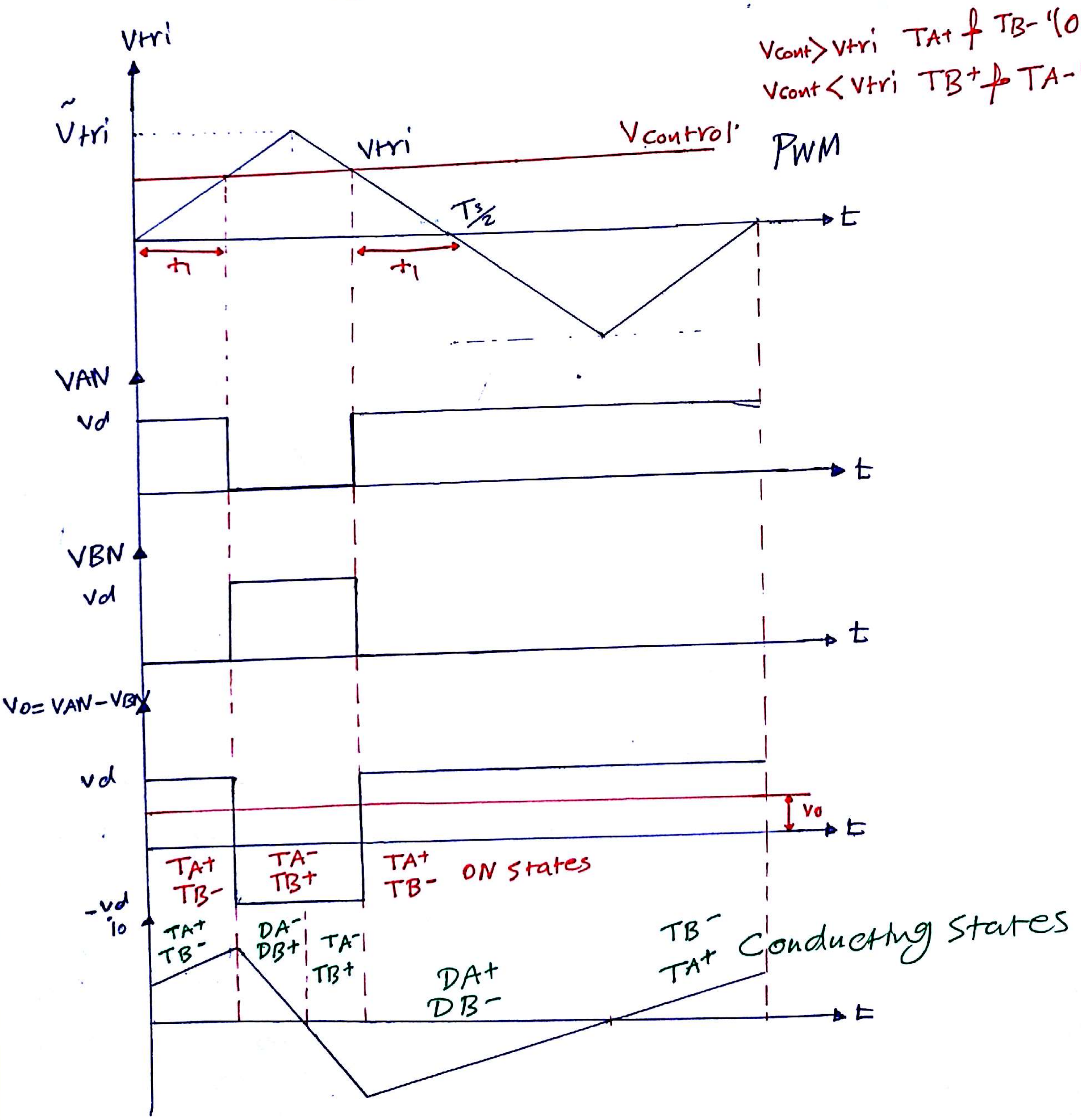
(TA+, TB−) ON & (TB+, TA−) ON

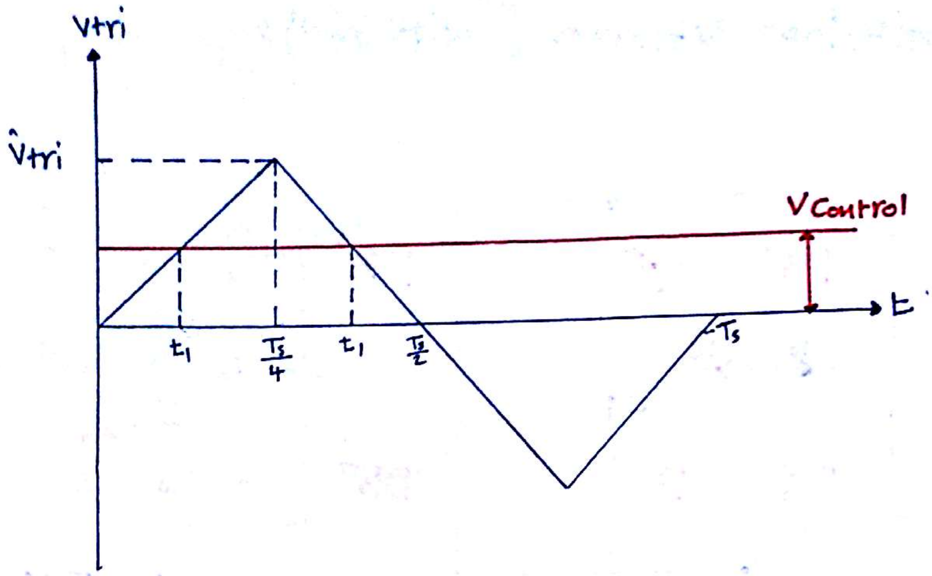
⇓ 1st Part of Ts

⇓ 2nd Part of Ts

Vcont > Vtri TA+ & TB− "(ON)"
Vcont < Vtri TB+ & TA− (ON)

PWM





$$Vtri = \frac{\hat{V}tri}{\frac{Ts}{4}} t \qquad 0 < t < \frac{Ts}{2}$$

$$Vtri = \frac{4\hat{V}tri}{Ts} t$$

at $t = t_1$, $V control = \frac{4\hat{V}tri}{Ts} t_1$

$$t_1 = \frac{V control \; Ts}{4 \hat{V}tri}$$

* The on duration of TA^+ TB^- is:-

$$ton = 2t_1 + \frac{1}{2} Ts$$

$$D_1 = \frac{ton}{Ts} = \frac{2t_1 + \frac{1}{2} Ts}{Ts} = \frac{2\left(\frac{V control \; Ts}{4\hat{v}tri}\right) + \frac{1}{2} Ts}{Ts}$$

$$D_1 = \frac{1}{2}\left(1 + \frac{V control}{\hat{V}tri}\right)$$

* The on duration of TB^+ TA^- is:-

$$D_2 = 1 - D_1 = 1 - \frac{ton}{Ts}$$

$$= 1 - \frac{1}{2}\left(1 + \frac{V control}{\hat{V}tri}\right)$$

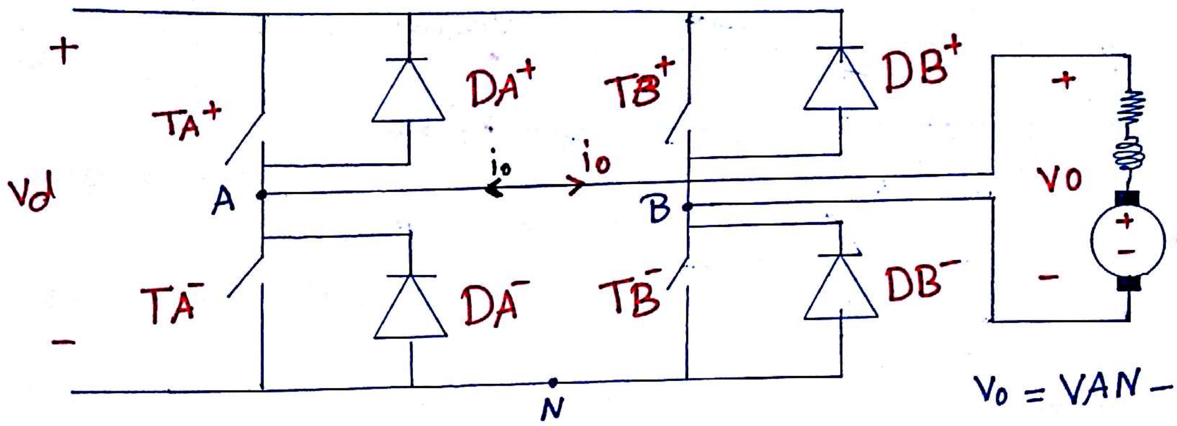
$$Vo = VAN - VBN$$

$$= D_1 Vd - (1 - D_1) Vd$$

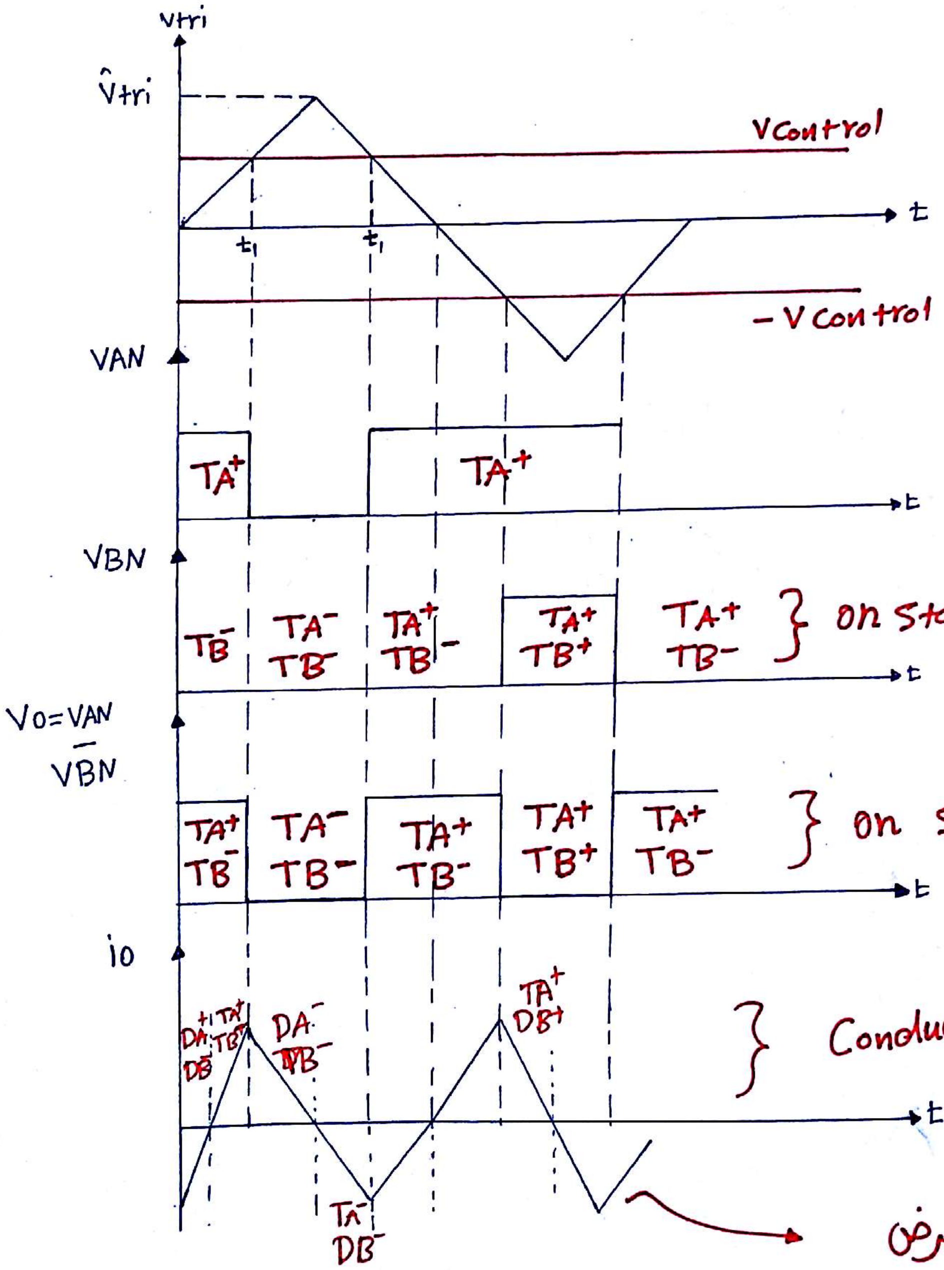
$$= (2D_1 - 1) Vd$$

$$Vo = \frac{V control}{\hat{V}tri} Vd = K Vd$$

PWM with Unipolar Voltage Switching:-



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



$V_{control} > V_{tri}$ TA^+ ON

$-V_{control} > V_{tri}$ TB^+ ON

} on State

} on State

} Conducting State

فرض

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

* Switch Mode Dc - AC Inverters :-

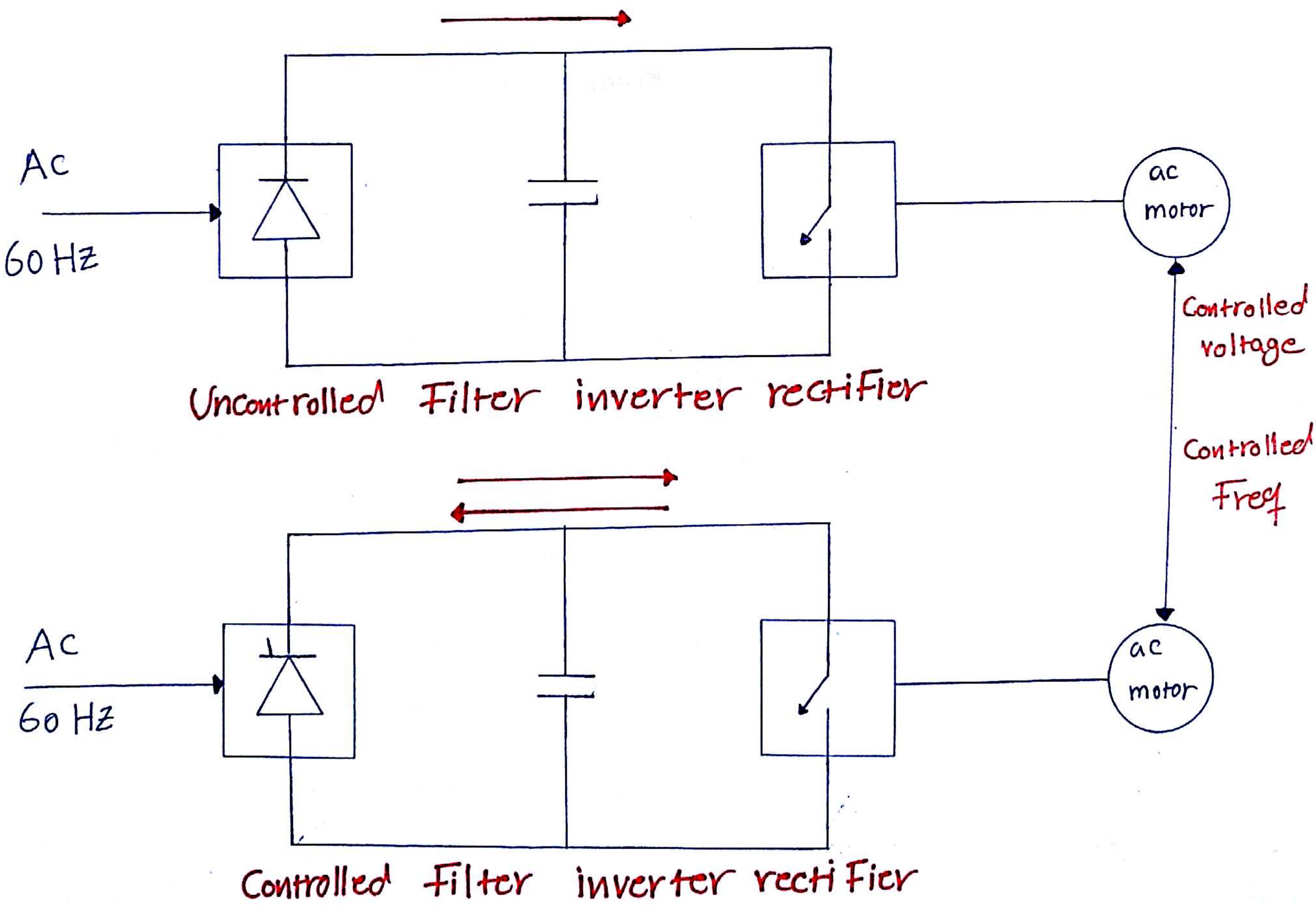
* Dc - Sinusoidal AC.

* Applications :-

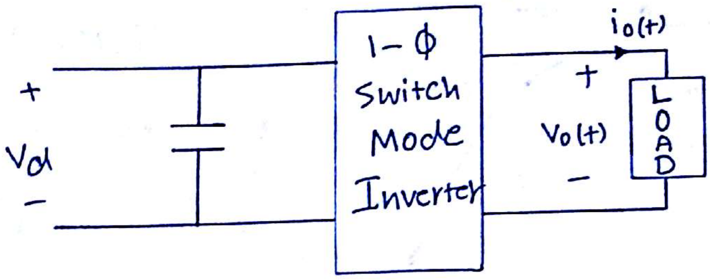
a- Ac motor drives.

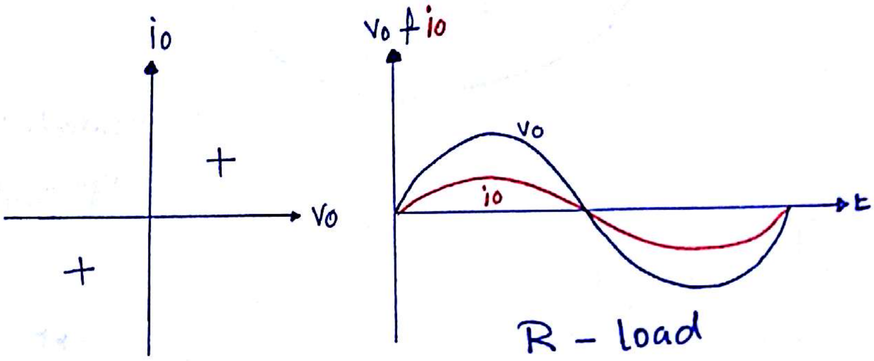
b- Ups

c- Renuable Energy System → PV, wind, FC

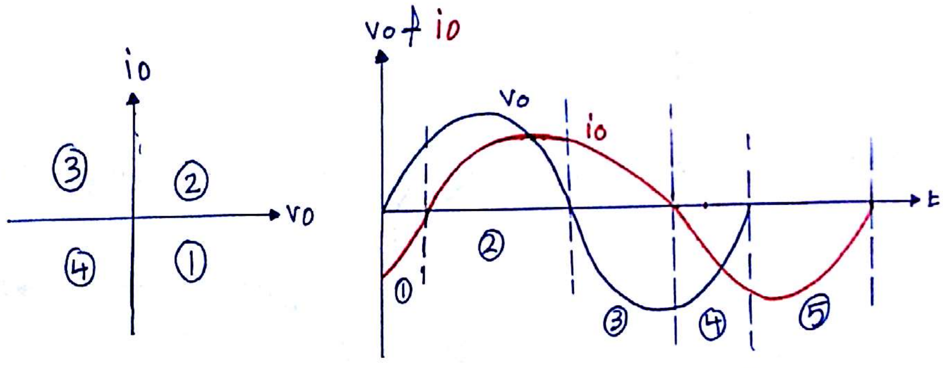


* Basic Concept of Switch Mode Inverters :-

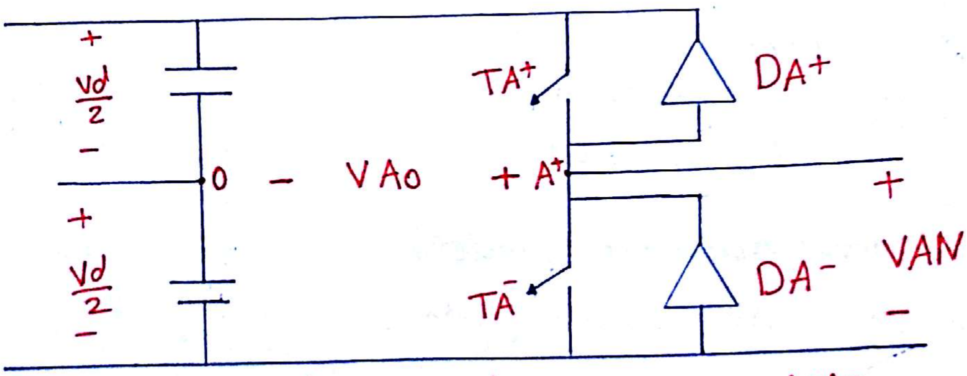




R - load

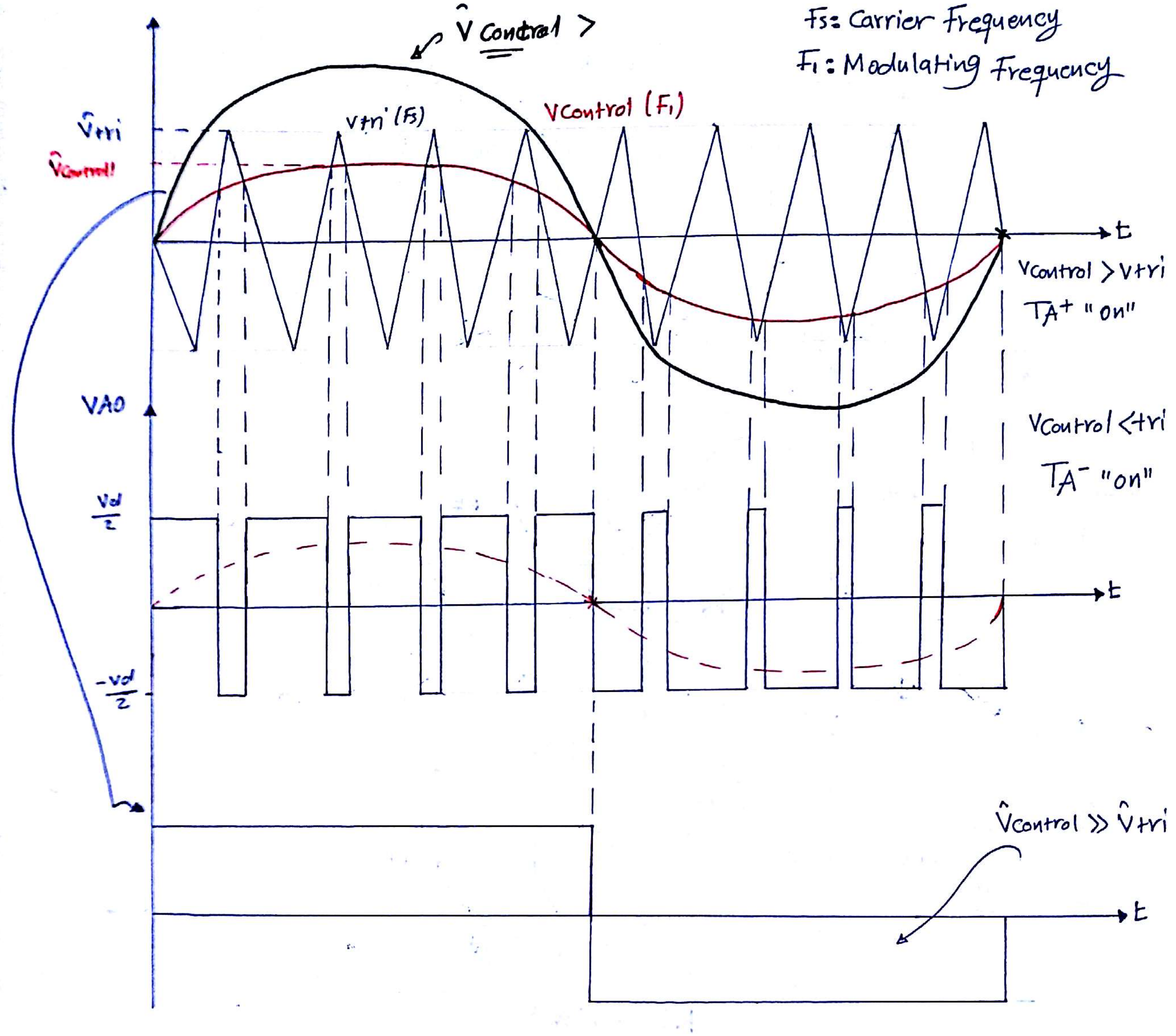


RL - load



one-leg 1-φ Switch Mode inverter

* Pulse-Width-Modulated Switching Scheme:-



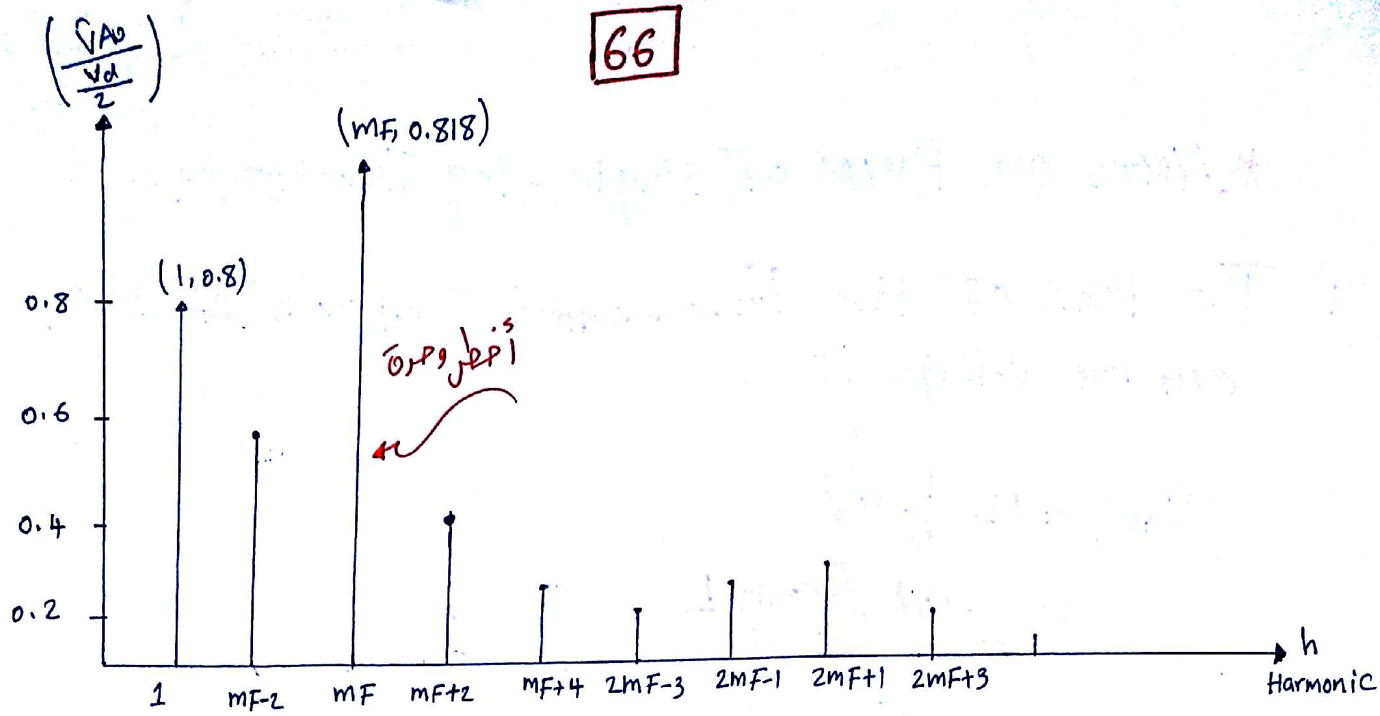
$$ma = \frac{V_{control}}{\hat{V}_{tri}}$$

$$mF = \frac{F_s \rightsquigarrow tri}{F_1 \rightsquigarrow control}$$

ma: amplitude modulation ratio (index)

mF: Frequency modulation ratio (index)

Note:- The Freq of Fund Comp of the output Voltage VAo
The Freq of the Control Signal.



Harmonic Spectrum of VAo For of F_1

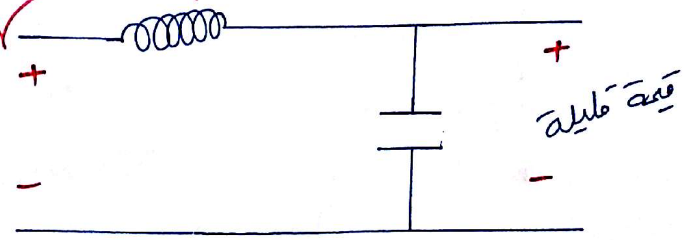
$$m_a = 0.8 \quad \& \quad m_F = 15$$

$$(V_{AO})_1 = 0.8\,\frac{V_d}{2}$$

$$(V_{AO})_1(t) = 0.8\,\frac{V_d}{2}\sin \underbrace{w_1}_{2\pi F_1} t$$

$$(\hat{V}_{AO})_{15} = (0.818)\,\frac{V_d}{2}$$

$$(V_{AO})_{15} = 0.818\,\frac{V_d}{2}\sin(15 w_1)t$$



قيمة قليلة

قيمة عالية mF

دخلة على

Comp فلتر عشان اتخلص من أخطر

* Notes on PWM of single-leg Inverter:-

1- The Peak of the Fundamental Component of the output voltage is

$$(\hat{V}_{AO})_1 = M_a \frac{1}{2} V_d$$
$$= \frac{1}{2} V_d \frac{\hat{V}_{control}}{\hat{V}_{tri}}$$

$$(V_{AO})_1(t) = \frac{1}{2} M_a V_d \sin(w_1 t), \quad w_1 = 2\pi F_1$$

2- The harmonics in the inverter output voltage appear as Sidebands Centered around the Switching Freq and its multiples (around m_F, $2m_F$, $3m_F$, - - - -)

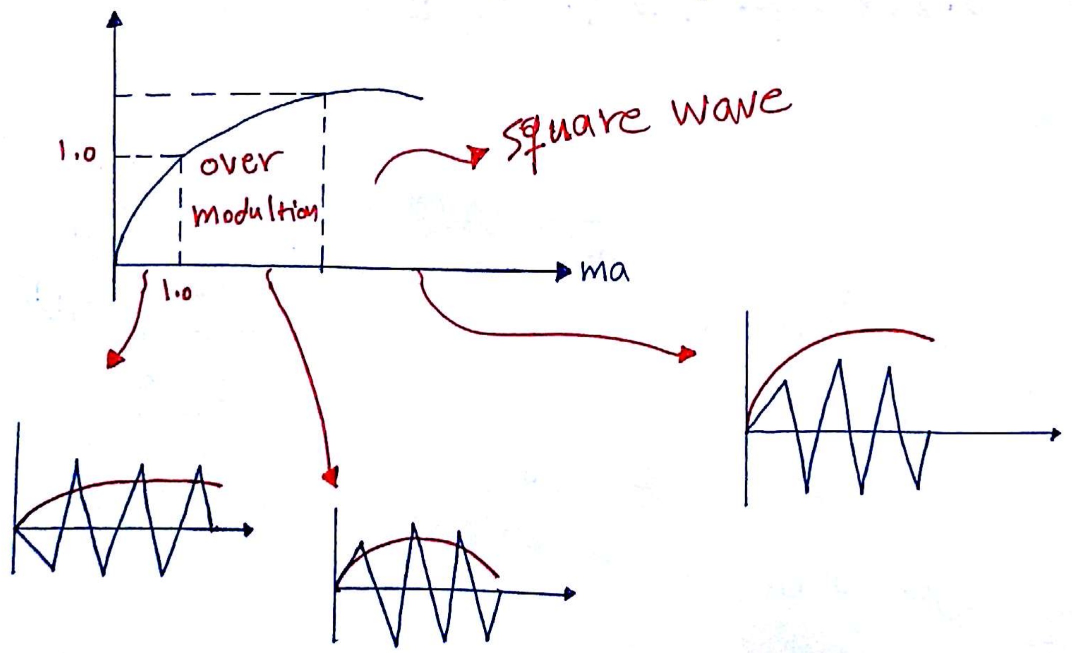
3- The Frequencyes at which voltage harmonics occur:-

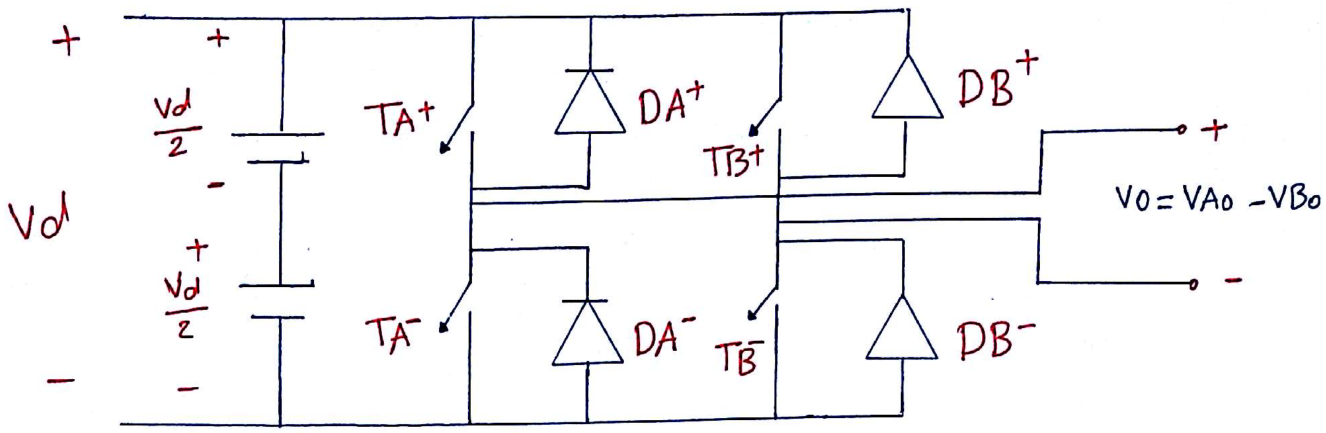
$$F_h = (j m_F \pm K) F_1$$

with odd $j \rightarrow K$ is even

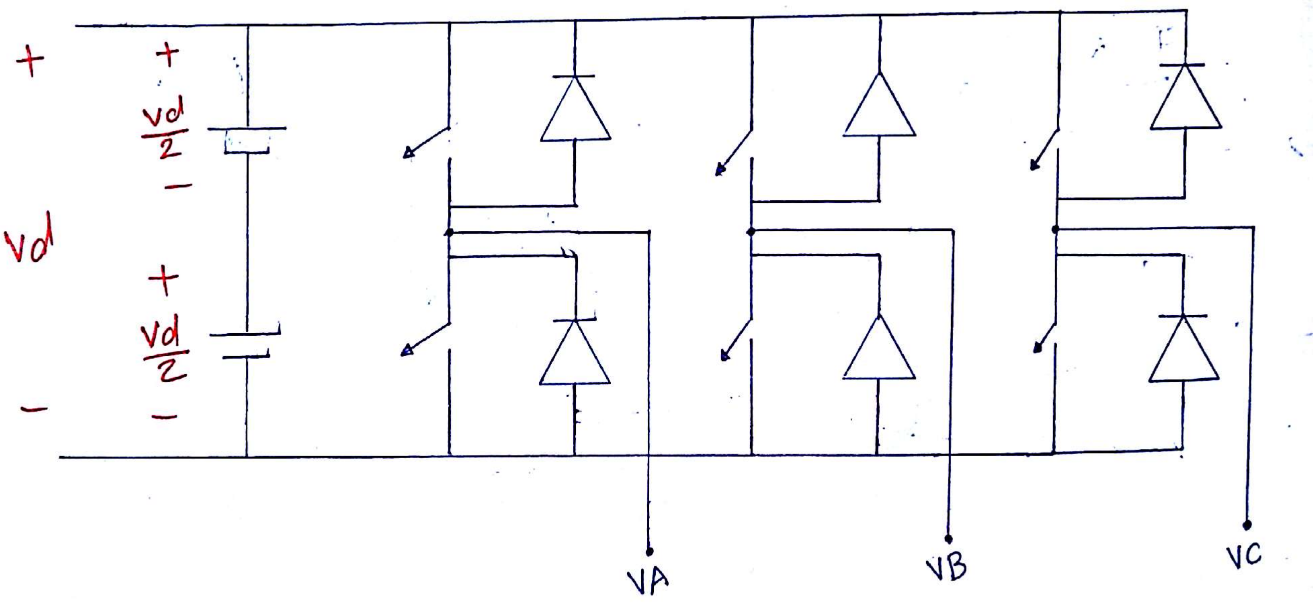
with even $j \rightarrow K$ is odd

over modulation ($m_a > 1$)





1-φ Full- Bridg Inverter



3-φ Full Bridg Inverter

(3 Control Signals)

⇓

Sinusoidal Phase Shifted 120°