AC to DC Converter

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- Classification of rectifiers
- Single phase rectifiers
- Three phase rectifiers
- Input side performance
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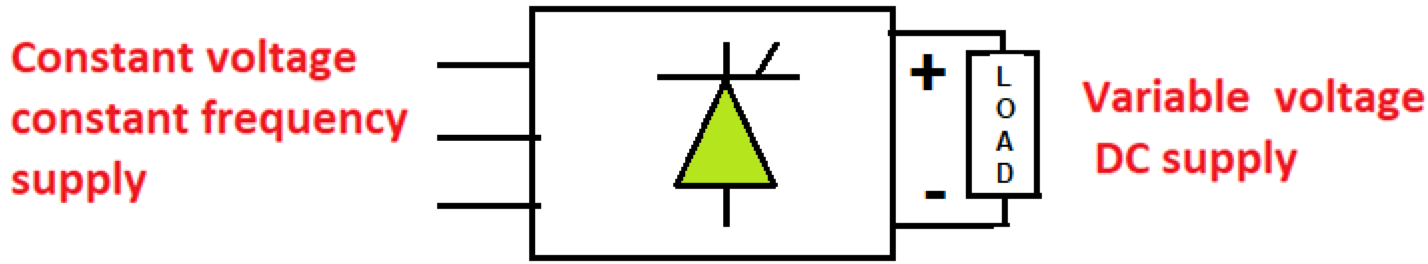
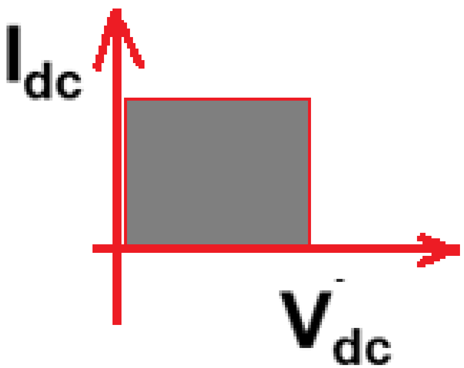
Rectifiers

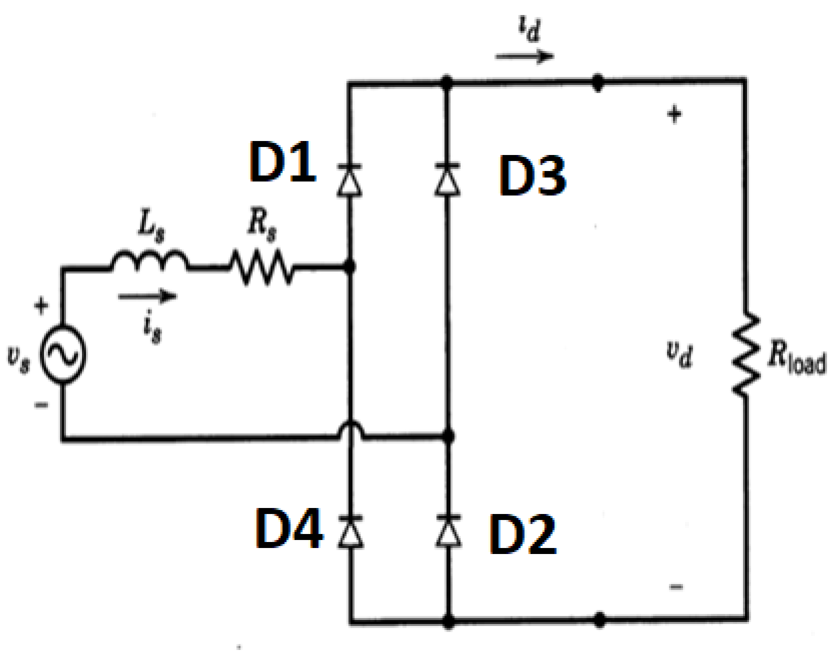
- Block diagram

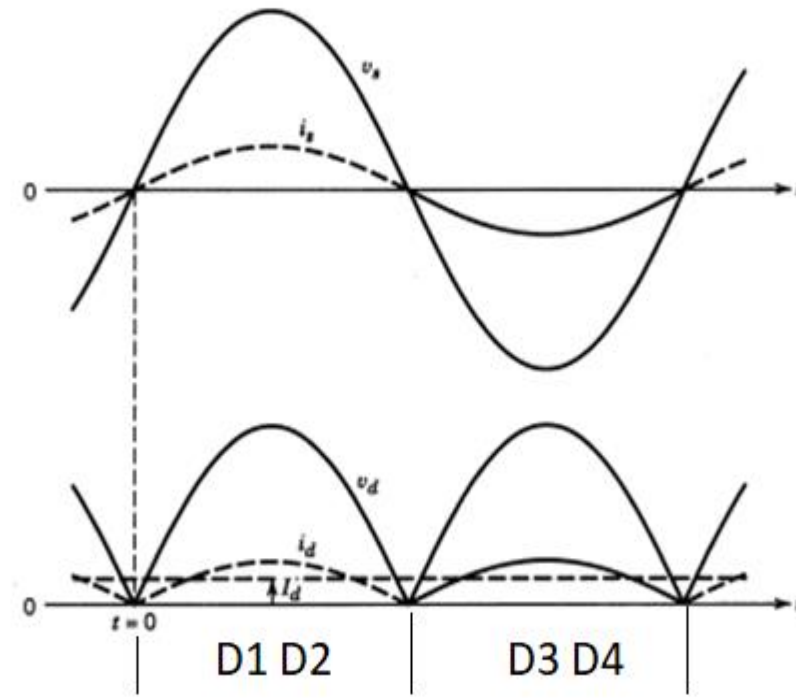


- Classification
- No of phases
- Half wave/ full wave rectification
- Pulse number
- Quadrant operation



1ϕ Diode bridge with R load





Each diode conducts for 180^0

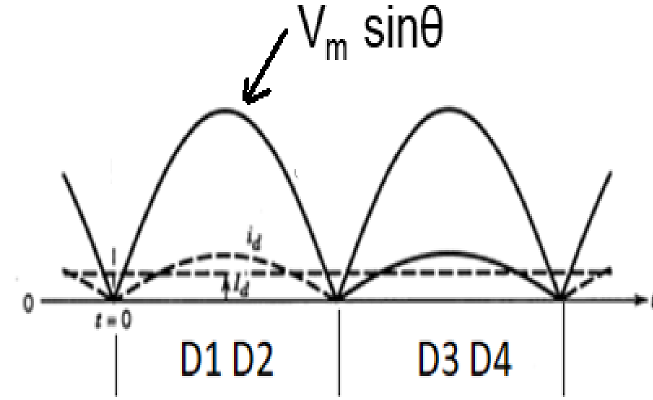
Average DC O/P voltage

Vdc $= 2/2\Pi \int_0^{\Pi} Vm\ Sin\theta\ d\theta$

1ϕ Diode bridge with R load

- $Vdc = \; Vm/\Pi \, (-\cos\theta)|_0^{\Pi}$
- $Vdc = 2\, V_m/\Pi$
- Average DC Voltage = 2 Vm/Π
- When D1 D2 conducts, supply current is +ve
- And waveshape is same as that of Idc
- When D3 D4 conducts, supply current is -ve
- And waveshape is same as that of Idc
- Source current is sinusoidal and in phase with voltage

Vdc (RMS) Value



$$V_{dc(rms)} = \left[\frac{2}{2\pi} \int_0^{\pi} V_m^2 \sin^2\theta \cdot d\theta \right]^{1/2}$$

$$= \left[\frac{V_m^2}{\pi} \int_0^{\pi} \sin^2\theta \cdot d\theta \right]^{1/2}$$

$$= \left[\frac{V_m^2}{\pi} \int_0^{\pi} \left(\frac{(1 - \cos 2\theta)}{2} \right) \cdot d\theta \right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi} \int_0^{\pi} (1 - \cos 2\theta) \cdot d\theta \right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi} \left\{ \int_0^{\pi} \cdot d\theta - \int_0^{\pi} \cos 2\theta \cdot d\theta \right]^{1/2}$$

Vdc (RMS) Value

$$V_{dc(rms)} = \left[\frac{V_m^2}{2\pi} \left\{ \theta \Big|_0^\pi - \frac{\sin 2\theta}{2} \Big|_0^\pi \right\} \right]^{1/2}$$

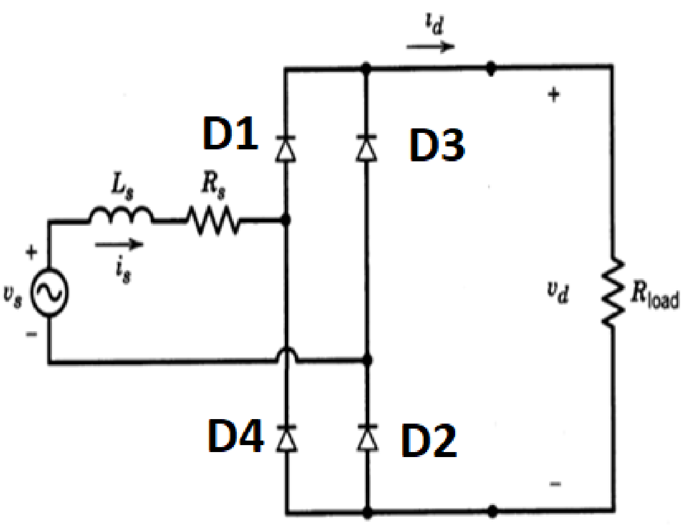
$$= \left[\frac{V_m^2}{2\pi} \left\{ (\pi) - 0 \right\} \right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi} \cdot \pi \right]^{1/2} = \left[\frac{V_m^2}{2} \right]^{1/2}$$

$$= \frac{V_m}{\sqrt{2}}$$

1ϕ Diode bridge with R load

- Power dissipated in R load
- P= V_{dc}(rms) x I_{dc} (rms)
- Input voltage 230 V (rms)
- R = 23 ohm
- I_{dc}(rms) = 10A
- Power in R =2300 W

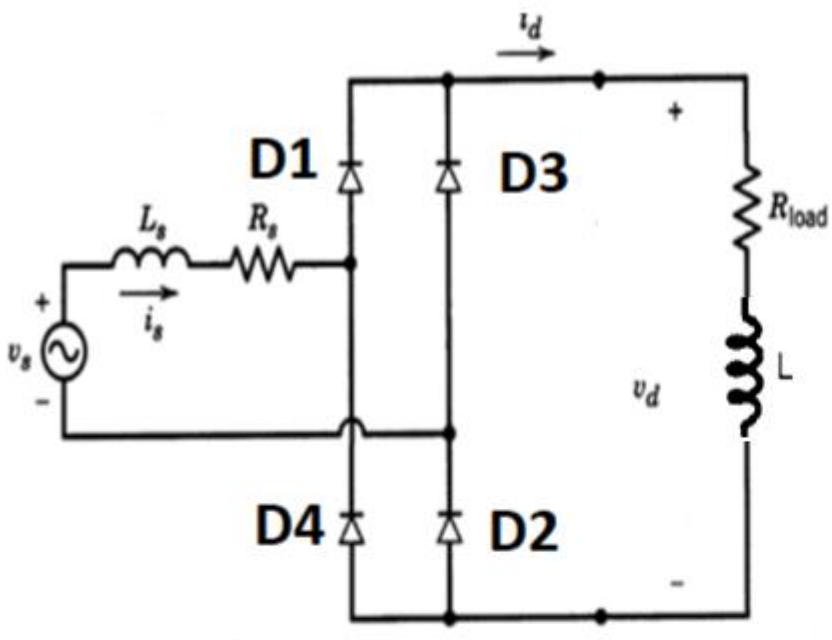


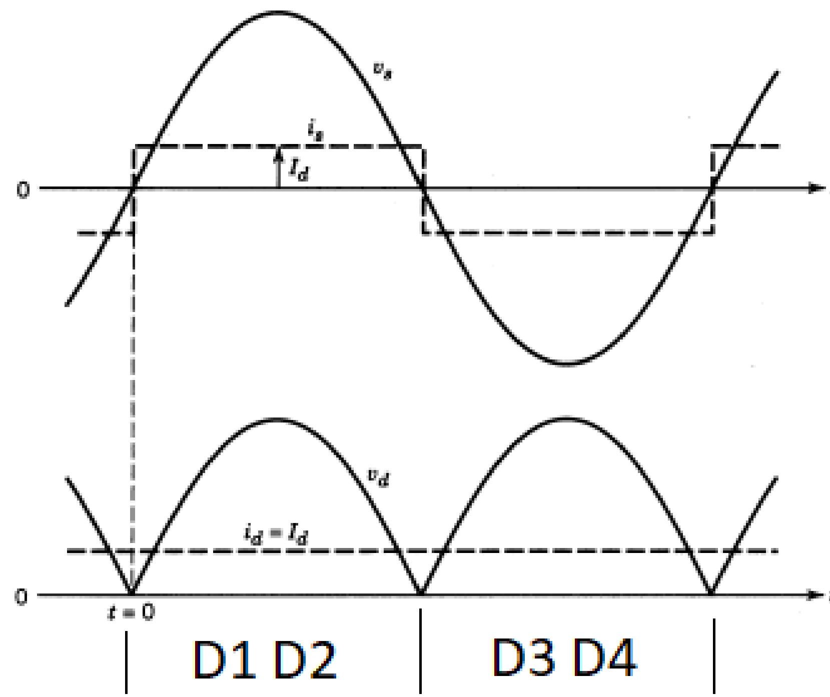
1ϕ Diode bridge with R load

- Procedure to determine the ripple content
- Determine the average and RMS value of the waveform
- Form factor (FF) = RMS Value/ Average Value
- % ripple = $\sqrt{FF^2 - 1}$
- Diode bridge with R load % ripple in o/p voltage
- RMS value = $V_m/\sqrt{2}$
- Average value = $2\,V_m/\pi$
- FF factor = $\pi/2\sqrt{2} = 1.11$
- Ripple factor = 48.2%

Single phase full wave rectifier

- RL load



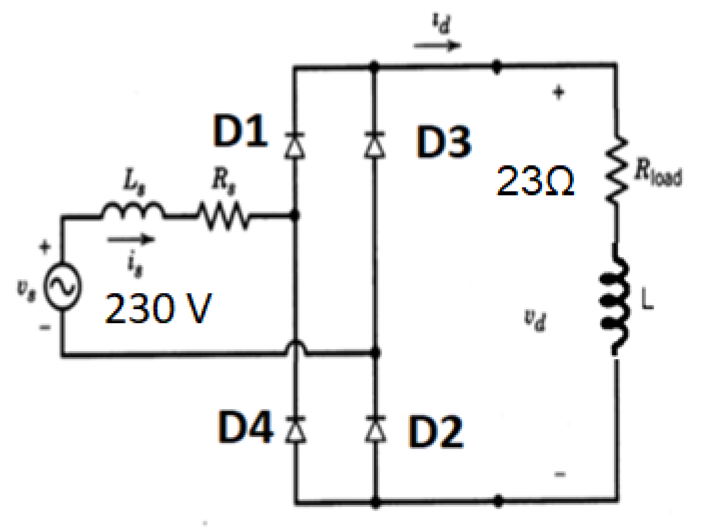


Single phase full wave rectifier: RL load

- O/P voltage waveform is same as resistive load
- DC current (Id) is smooth and ripple free due to inductance .
- When D1 D2 conducts, supply current is +ve And waveshape is same as that of Idc
- When D3 D4 conducts, supply current is -ve
- And waveshape is same as that of Idc
- The source current waveform is square wave

Single phase full wave rectifier: RL load

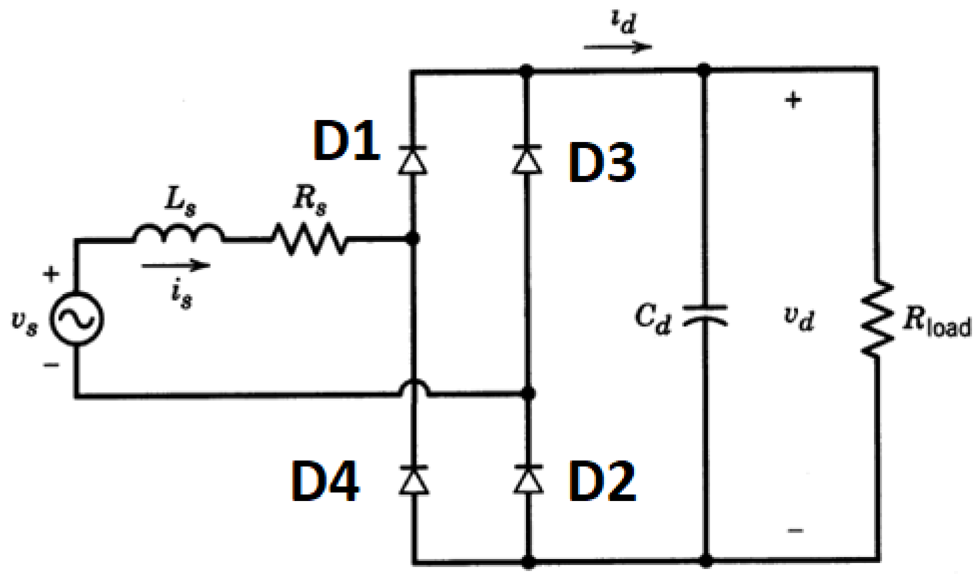
- Power dissipated in R=23Ω & Vs= 230V
- Idc is smooth & ripple free
- Voltage across R =smooth and ripple free and magnitude => Vdc(avg)
- P= V_{dc}(avg) x I_{dc}(avg)
- V_{dc}(avg) = 207.07 V
- I_{dc}(avg) = 9.0 A
- P= 1863.63 W

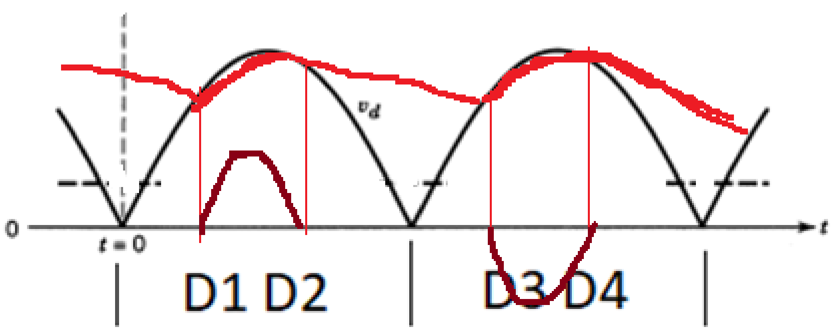


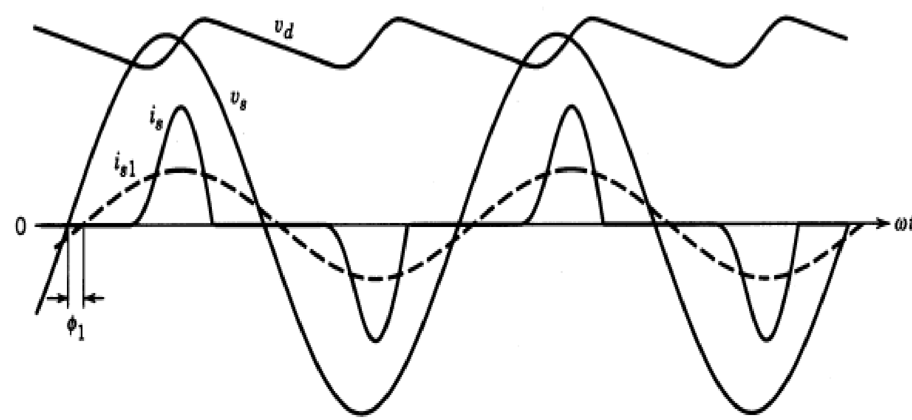
1ϕ Diode bridge with R C load

- Diode conduction period

- Source current

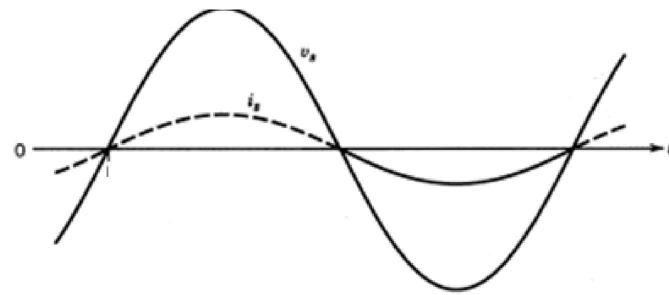




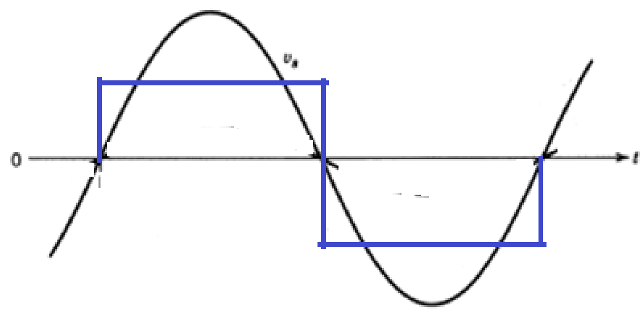


1ϕ Diode bridge: Source current Waveform

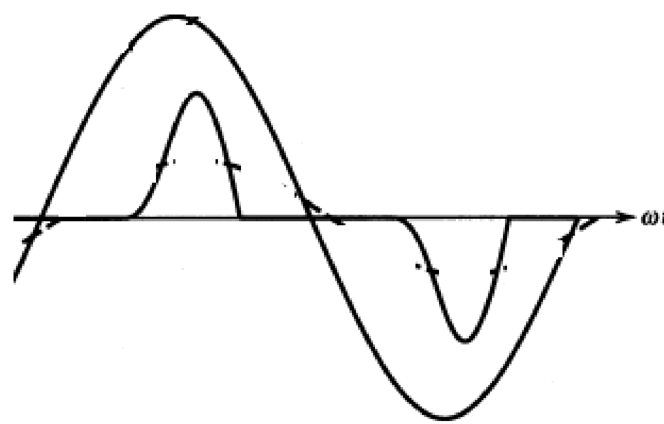
- R load



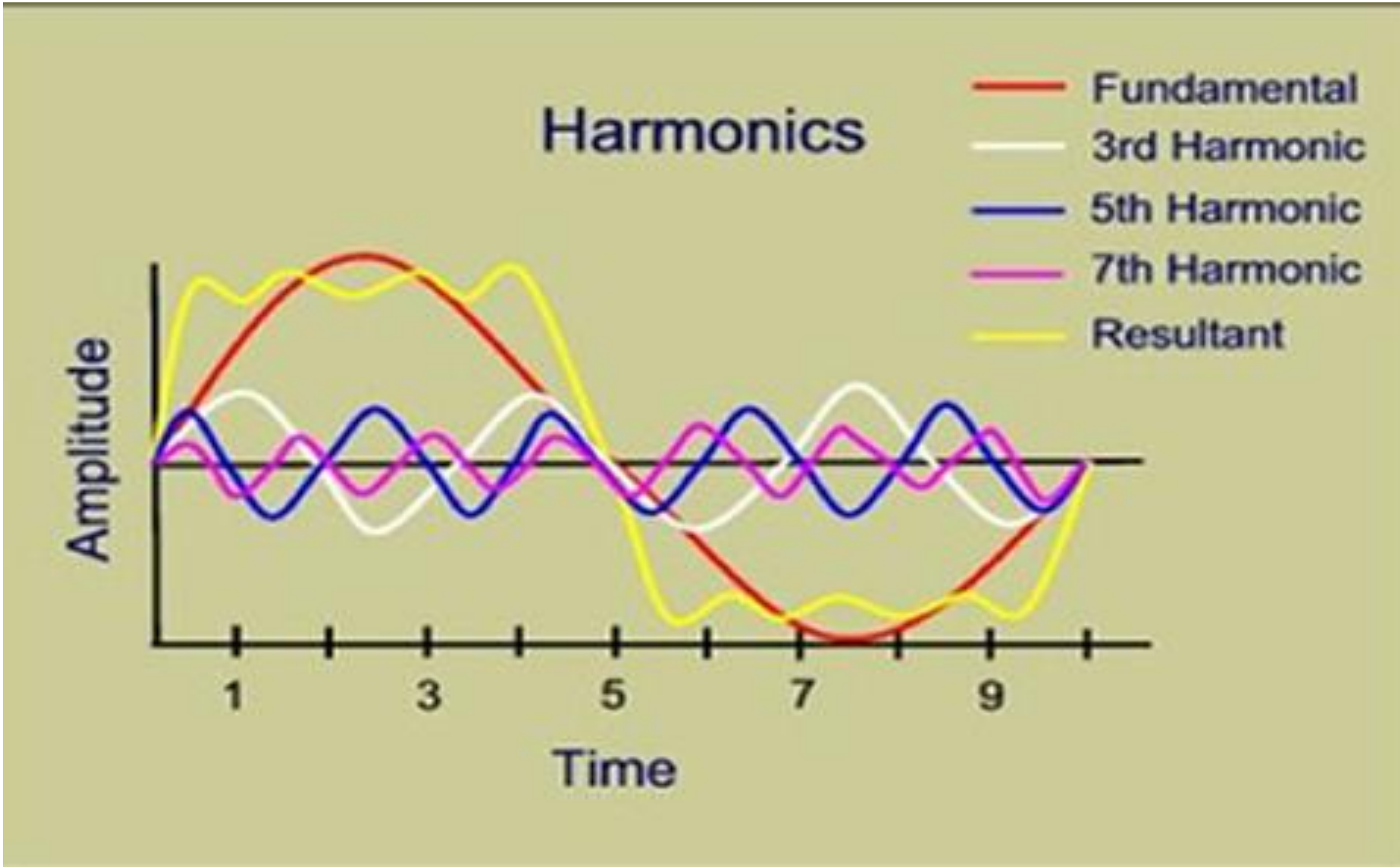
- RL Load



- RC parallel load



Harmonics



Harmonics
Fundamental
3rd Harmonic
5th Harmonic
7th Harmonic
Resultant
Amplitude
1
3
5
7
9
Time

Harmonics

- **Harmonics** are voltages or currents that operate at a frequency that is an integer (whole-number) multiple of the fundamental frequency.
- For 50Hz fundamental waveform, this means a 2nd **harmonic** frequency would be 100Hz (2 x 50Hz), a 3rd **harmonic** would be 150Hz (3 x 50Hz), a 5th at 250Hz, a 7th at 350Hz and so on.

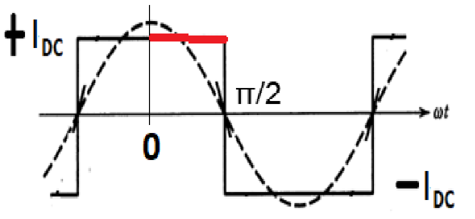
Harmonics

- The relationship between rms current, fundamental current and harmonic current
- $I^2_{rms} = I^2_{1rms} + I^2_{2rms} + I^2_{3rms} + I^2_{4rms} + I^2_{5rms} + \text{-----}$
- $I^2_{rms} = I^2_{1rms} + I^2_{hrms}$
- Where,
- Total harmonic current can be
- $I^2_{hrms} = I^2_{2rms} + I^2_{3rms} + I^2_{4rms} + I^2_{5rms} + \text{-----}$
- For the given waveform I^2_{rms} and I^2_{1rms} is computed
- $\%THD = (I_{hrms} / I_{1rms}) \times 100$

Harmonic spectrum of a waveform

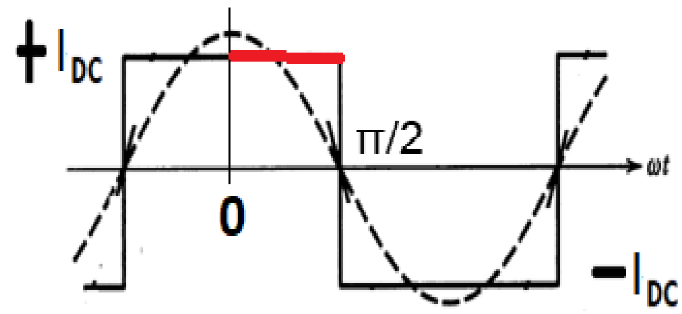
- Procedure

- Determine the RMS value of the waveform.= I
- Determine the peak amplitude of nth harmonic
- Considering quarter wave symmetry
- An= $\frac{8}{2\pi} \int_0^{\pi/2} F(\theta)\cos(n\theta)\,d\theta$
- Where An= peak amplitude of nth Harmonic.
- Determine peak amplitude of fundamental and the RMS value of fundamental = I_1
- $I^2 = I_1^{\,2} + I_h^{\,2}$
- %THD $= (I_h/I_1) \times 100$

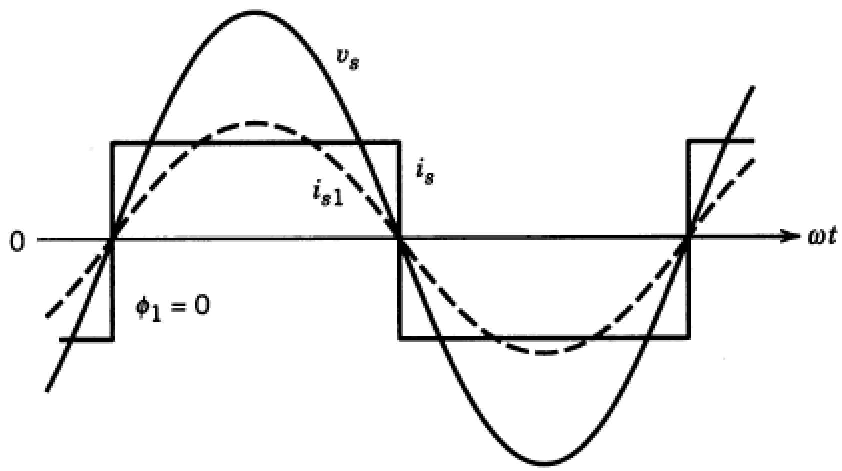


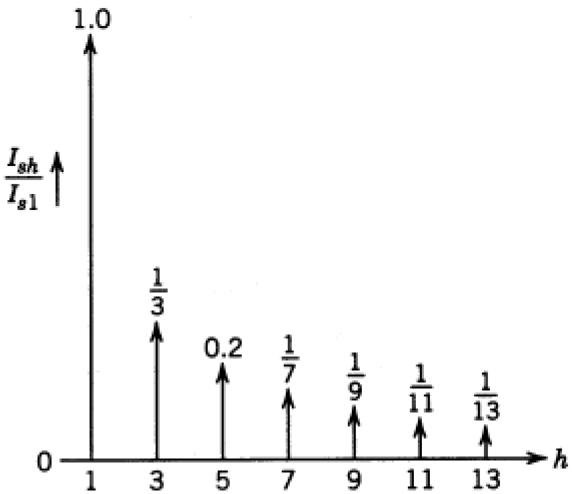
Harmonic spectrum of square wave

- Harmonic spectrum
- RMS value $I = I_{dc}$
- $A_n = \frac{8}{2\pi} \int_0^{\pi/2} I_{dc} \cos(n\theta)\, d\theta$
- $A_n = (4/n\pi)\, I_{dc} \sin(n\pi/2)$
- $A_1 = 4I_{dc}/\pi$ (Peak amplitude of fundamental)
- $I_1 = \frac{2\sqrt{2}}{\pi} I_{dc}$ and $I_h = I_{dc}\sqrt{(1 - \frac{8}{\Pi^2})}$
- $I_h/I_1 = 0.482$



Harmonic spectrum of 1ϕ diode bridge -RL load

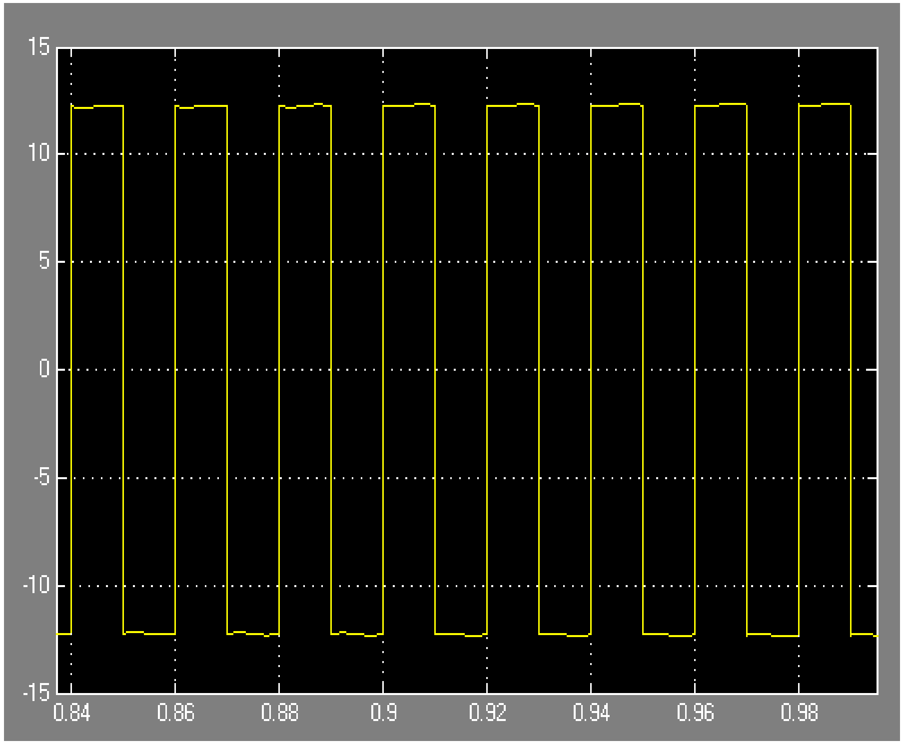


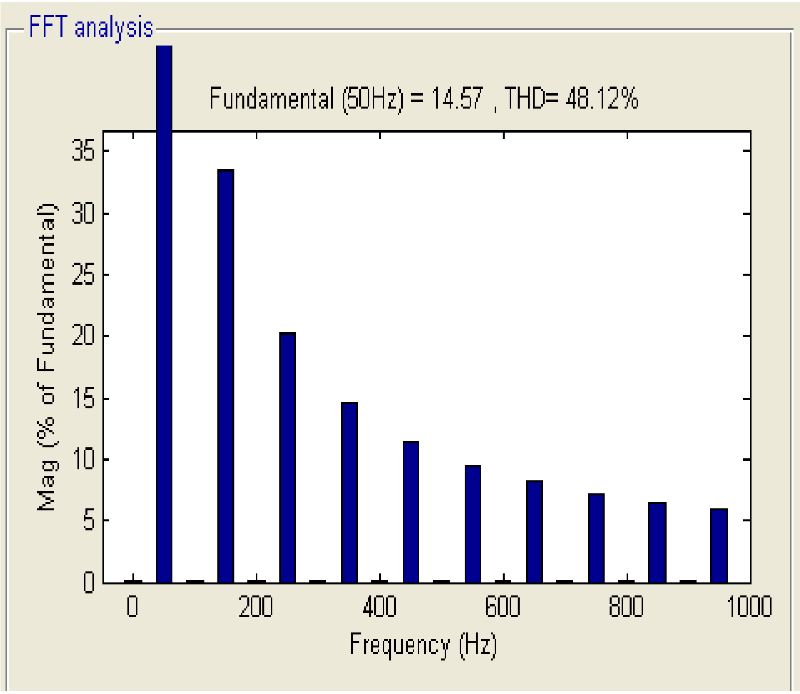


Peak value of harmonic component

$A_n = (4/n\pi)\ I_{dc} \sin(n\pi/2)$

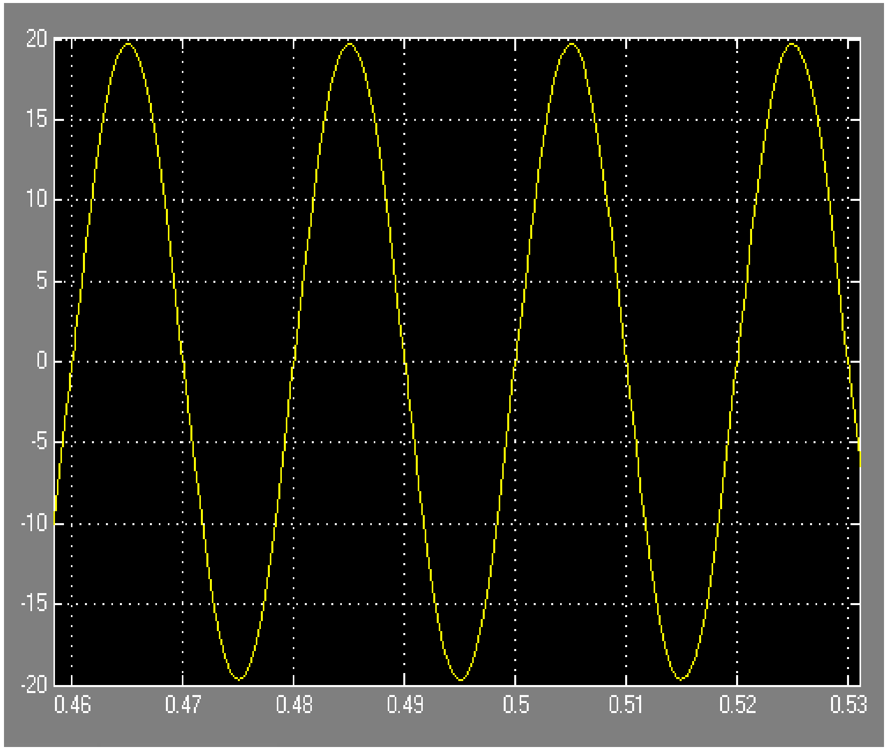
1 ϕ Diode bridge with RL load

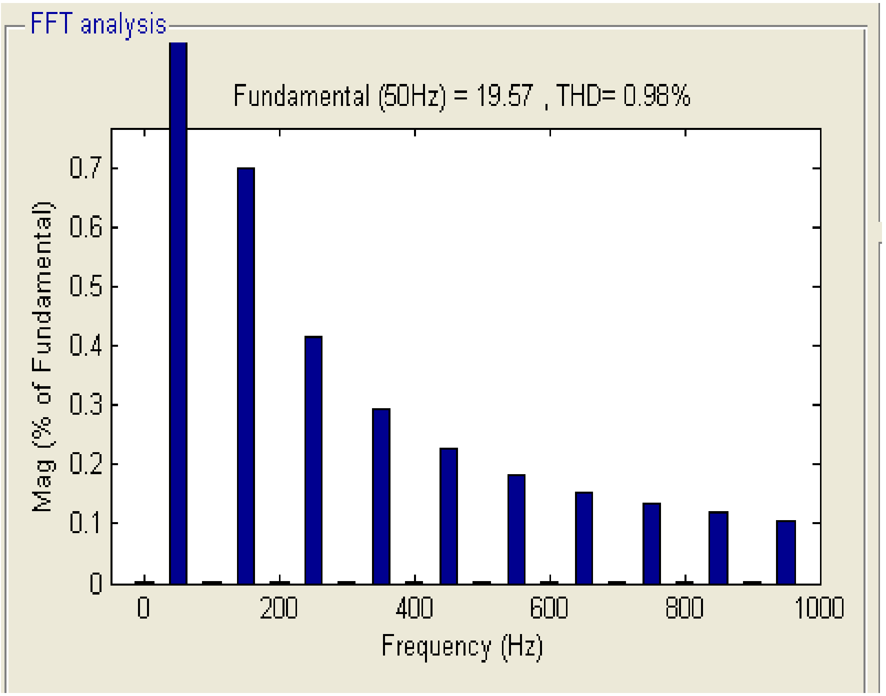




Harmonic spectrum depends upon type of load on the converter
THD in source current is 48.12%

1ϕ Diode bridge with R load





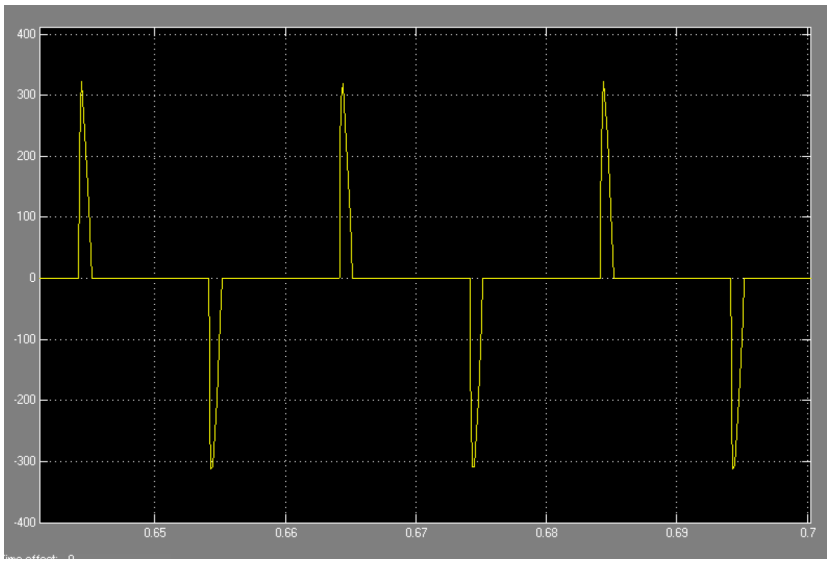
$$I = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt} = \sqrt{\sum_{n=1}^{\infty} I_n^2}$$

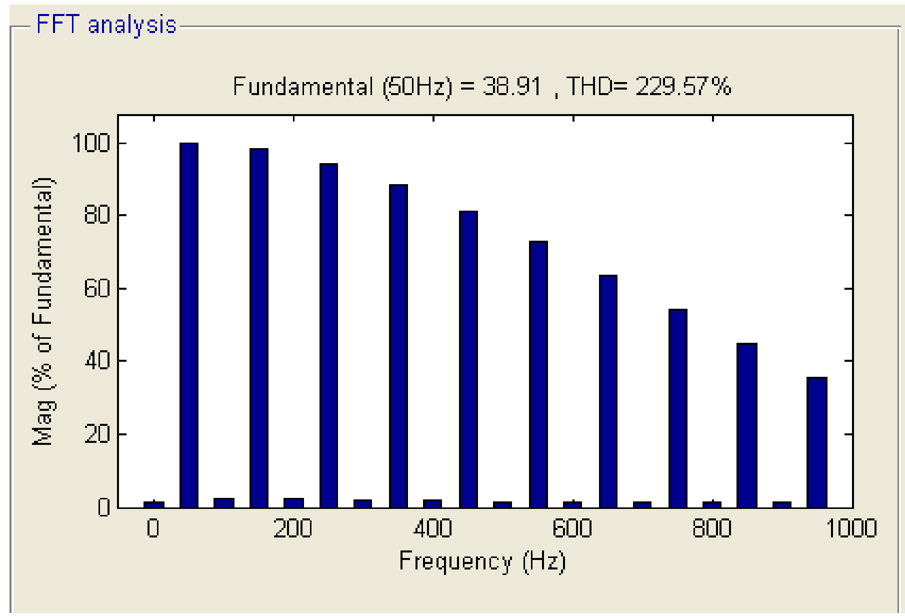
$$I^2 = I_1^2 + I_h^2$$

$$\%\ \text{Current THD} = (I_h / I_1) \times 100$$

1ϕ Diode bridge with RC load

Harmonic spectrum => All odd harmonics





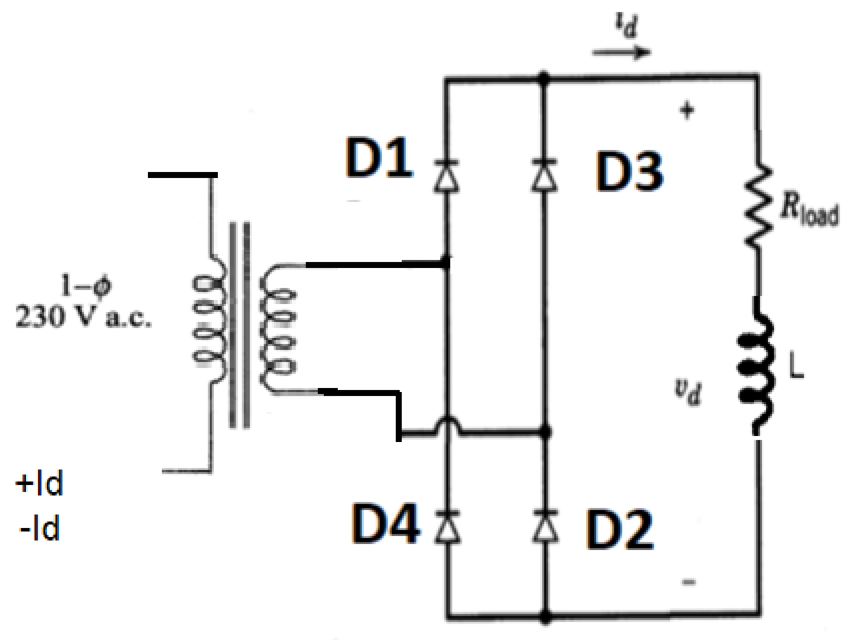
$$I = \sqrt{\frac{1}{T}\int_0^T i^2(t)dt} = \sqrt{\sum_{n=1}^{\infty} I_n^2}$$

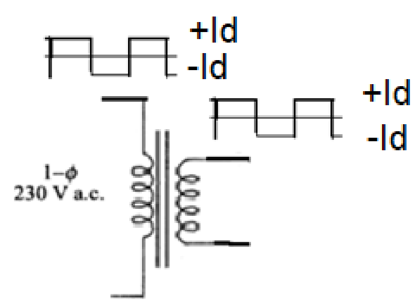
%THD= (I_h / I_1)X 100

THD of I_s = 230%

1ϕ Diode bridge : Tx rating

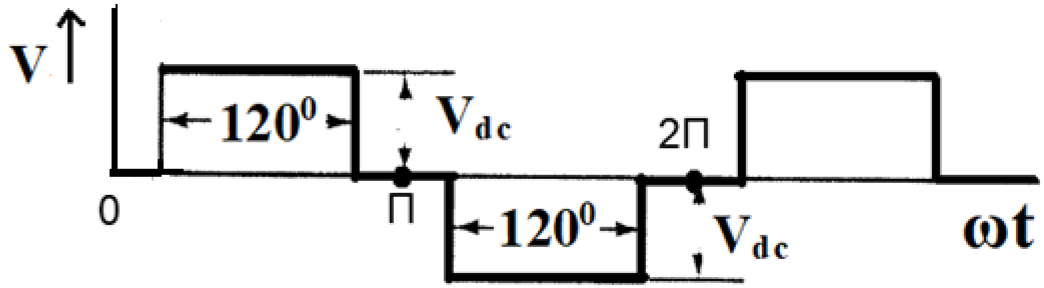
- Why transformer between supply &rectifier
- Adjustment of O/P DC voltage.
- Isolation between AC &DC system
- Load = RL load
- Primary & secondary currents are square wave

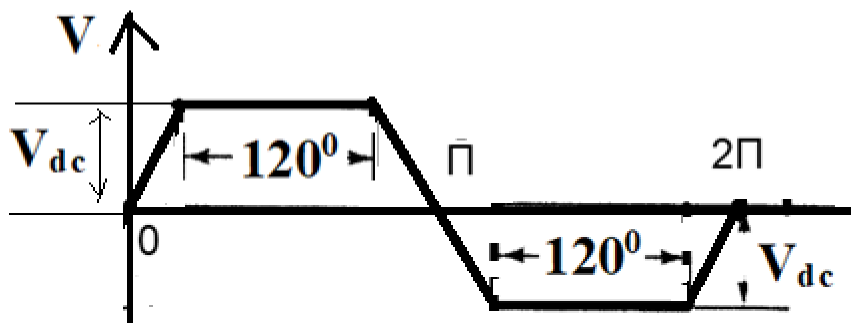




Exercise : Harmonic Spectrum

- Determine the THD of the following wave forms





1ϕ Diode bridge : Tx rating

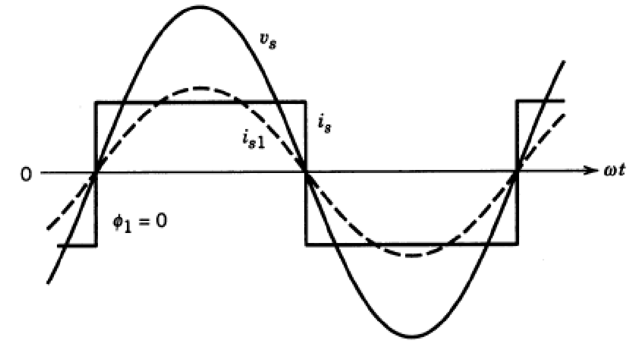
- tx turn ratio =1
- Dc o/p power = Vdc x Idc
- Transformer current Irms = Idc
- Transformer voltage= $Vm/\sqrt{2}$
- Transformer VA rating = Idc x $Vm/\sqrt{2}$
- Vdc = 2 Vm/Π => Vm= (Vdc X Π)/2
- VA rating of tx= Idc X (Vdc X Π)/ $2\sqrt{2}$
- 1.11 Vdc x Idc

1ϕ Diode bridge : Tx rating

- Transformer utilization factor = DC Power/VA rating
- TUF= Vdc x Idc /(1.11 Vdc x Idc)
- TUF= 0.9
- Transformer utilization factor =0.9
- For 1000 W DC power the transformer VA =1100VA

1ф Diode bridge : supply power factor

- Consider diode bridge with RL Load
- When current or voltage
  is non sinusoidal



- Displacement angle (θ)
- Is angle between fundamental component voltage &current
- diode bridge => displacement angle => 0^0
- Displacement factor= cosθ
- displacement factor =1

1ϕ Diode bridge : supply power factor

- When current or voltage is non sinusoidal

$$\text{Power factor} = \frac{\text{mean i/p power}}{\text{rms i/p VA}}$$

- Only fundamental component will contribute to mean power
- Mean power= $V_1 I_1 \cos\theta$
- Rms i/p VA = $V_{rms}\ I_{rms}$ $\quad$ $V_{rms} = V_1$

$$\text{Power factor} = \frac{I_1 \times \cos\theta}{I_{rms}}$$

1ϕ Diode bridge : supply power factor

- $\text{Distortion factor (DF)} = \dfrac{I_1}{I_{rms}}$
- $I_1 = \dfrac{2\sqrt{2}}{\pi} I_{dc}$ *and* $I_{rms} = I_{dc}$ $\Rightarrow DF = \dfrac{2\sqrt{2}}{\pi}$

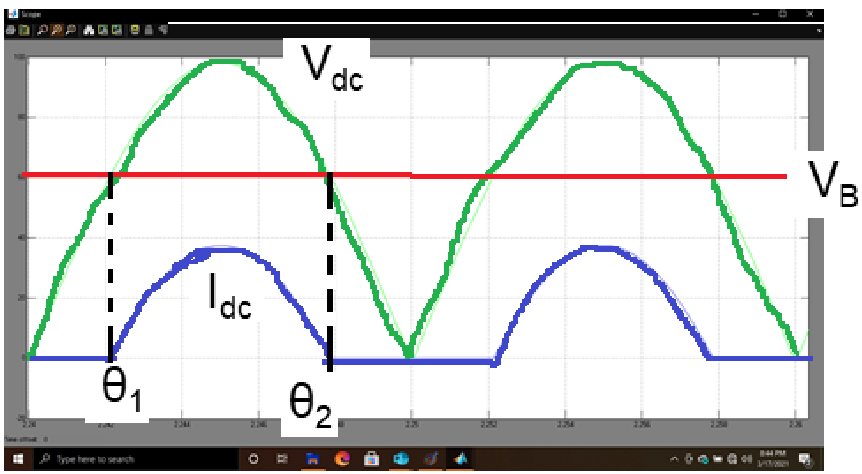
PF = Distortion factor X displacement factor

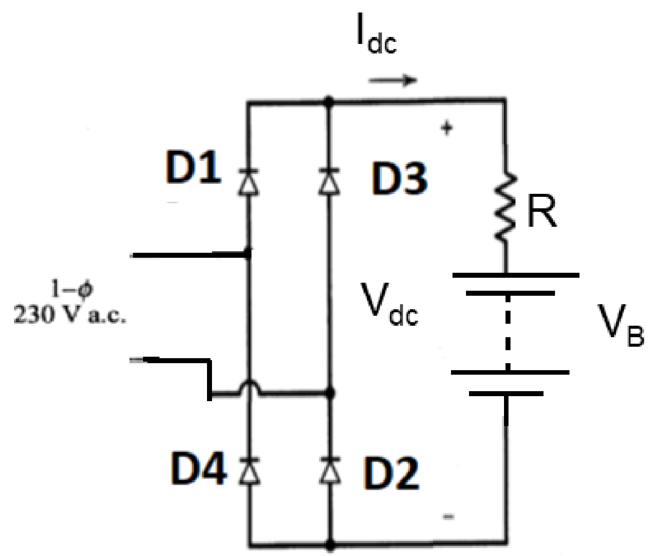
$$\text{Cos } \phi = \text{DF X cos } \theta$$

- For single phase diode bridge DF =0.9
- COS θ =1
- Hence power factor of 1ϕ diode bridge = 0.9

1ϕ Diode bridge : battery charging

- Battery charging application
- Supply voltage = 230 V 50 Hz
- Battery voltage = 150 V
- Internal resistance R=2Ω
- Determine average charging current





Average battery charging current

$V_m \sin\theta_1 = V_B$. Putting $V_m = \sqrt{2} \times 230$, $V_B = 150V$

$\therefore \sin\theta_1 = \frac{V_B}{V_m} = 0.4611 \quad \therefore \theta_1 = 27.46^\circ$

$\theta_2 = 152.54^\circ$

Inst. current $i = \frac{V_m \sin\theta - V_B}{R}$

$$I_{av} = \frac{2}{2\pi} \int_{27.46}^{152.54} \left(\frac{V_m \sin\theta - V_B}{R} \right) \cdot d\theta$$

$$I_{av} = \frac{1}{\pi R} \left[\int_{27.46}^{152.54} V_m \sin\theta \cdot d\theta - \int_{27.46}^{152.54} V_B \cdot d\theta \right]$$

Average battery charging current

$$I_{av} = \frac{1}{\pi R}\left[-V_m \cos\theta \Big|_{27.46}^{152.54} - V_B\left(\frac{\pi}{180}\times 152.54 - \frac{\pi}{180}\times 27.46\right)\right]$$

$$I_{av} = \frac{1}{\pi R}\left[-V_m \cos 152.54 + V_m \cos 27.46 - V_B \times 2.183\right]$$

$$= \frac{1}{\pi \times 2}\left[-\sqrt{2}\times 230 \cos 152.54 + \sqrt{2}\times 230 \cos 27.46 - 150 \times 2.183\right]$$

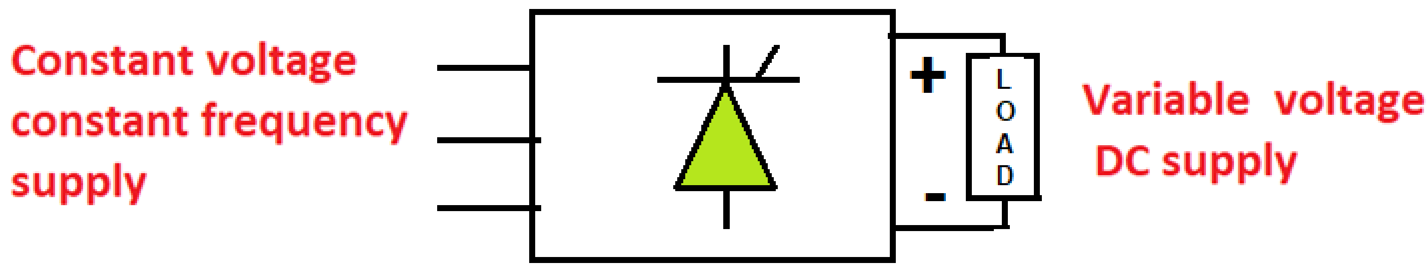
$$= \frac{1}{2\pi}\left[288.62 + 288.62 - 327.45\right]$$

$$= \frac{249.79}{2\pi} = 39.755 A$$

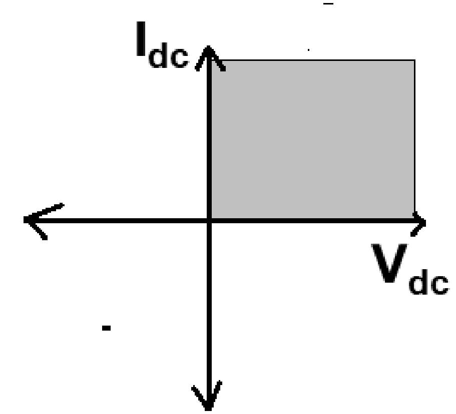
1ϕ Controlled converter

- Classification of controlled converter
- Half wave /Full wave converter
- Half controlled/ full controlled
- Pulse number => 1, 2, 3, 6. 12. 24
- Quadrant of operation
- Single quadrant
- Two quadrant
- Four quadrant

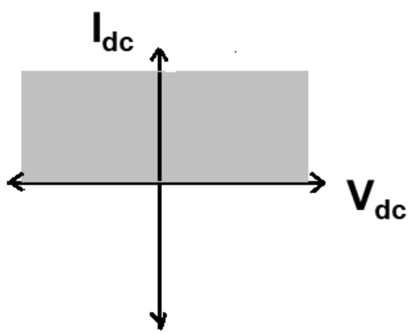
Quadrant operation of converter



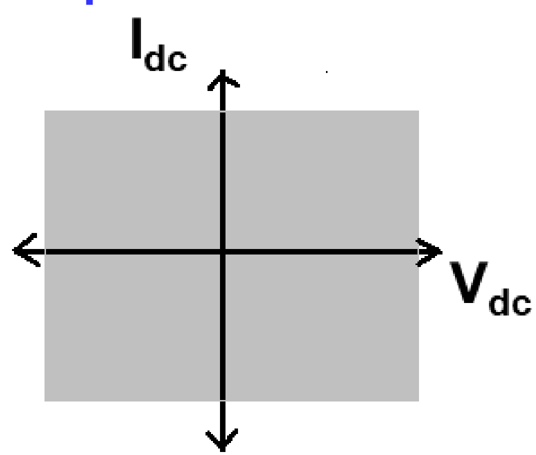
- Single quadrant =>



- <=Two quadrant

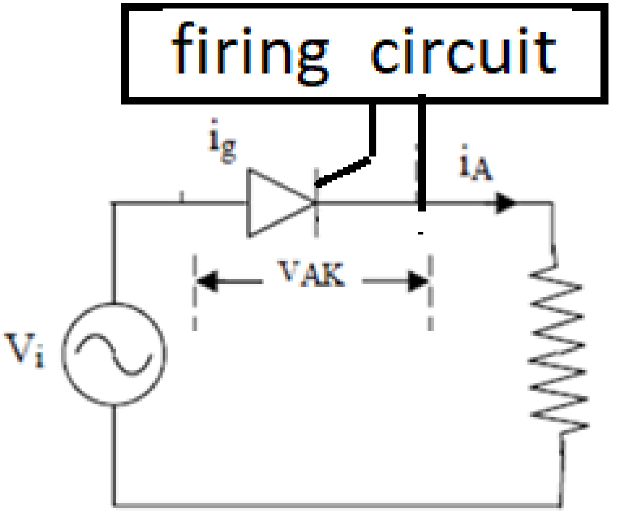


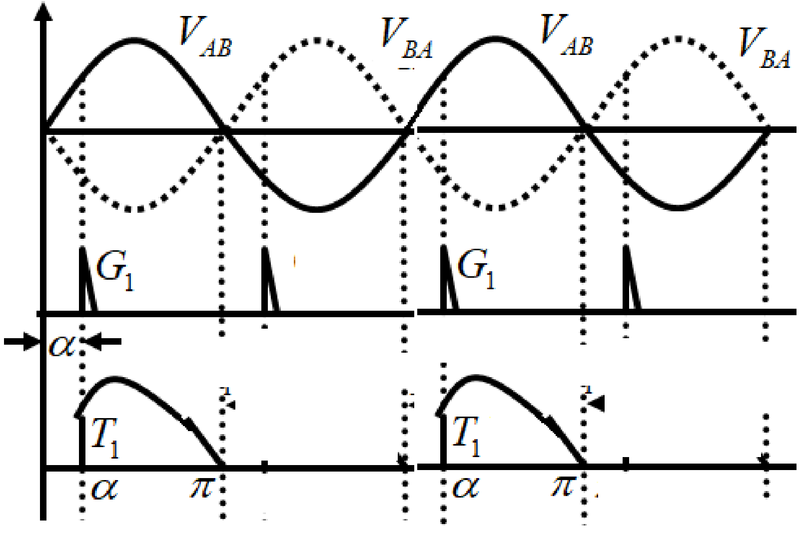
- Four quadrant =>



1ϕHalf wave-controlled converter

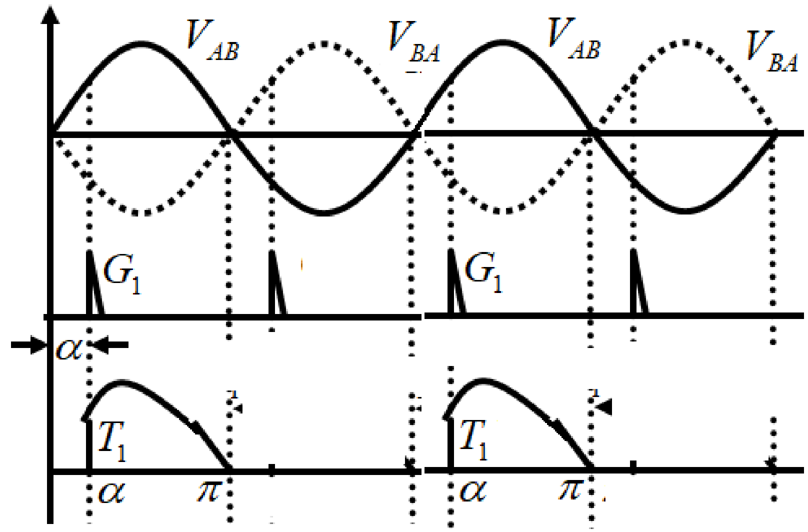
- Circuit diagram
- Half wave rectification





1ϕHalf wave-controlled converter

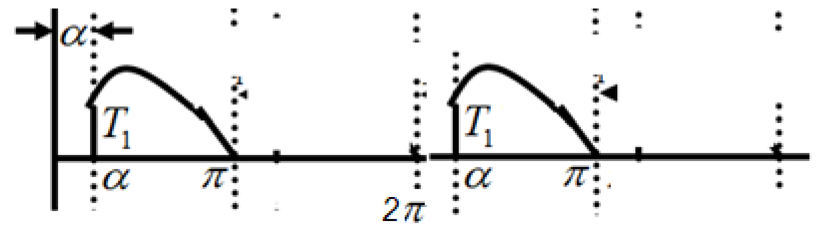
- O/P voltage waveform
- Supply voltage
- $V_m \sin\theta$



- Average and RMS value of the O/P voltage
- Form factor and ripple factor of the waveform

1ϕHalf wave-controlled converter

- Average DC voltage



$$V_{dc(avg)} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \cdot \sin\theta \cdot d\theta$$

$$= \frac{V_m}{2\pi}\Big[-\cos\theta\Big]\Big|_{\alpha}^{\pi}$$

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

- V_m => Peak amplitude of supply voltage

1ϕHalf wave-controlled converter Vdc (rms)

$$V_{dc(rms)} = \left[\frac{1}{2\pi}\int_{\alpha}^{\pi} V_m^2 \sin^2\theta \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\int_{\alpha}^{\pi} \sin^2\theta \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\int_{\alpha}^{\pi} \left(\frac{1-\cos 2\theta}{2}\right) \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{4\pi}\left\{\int_{\alpha}^{\pi} d\theta - \int_{\alpha}^{\pi} \cos 2\theta \cdot d\theta\right.\right]^{1/2}$$

$$= \left[\frac{V_m^2}{4\pi}\left\{\theta\Big|_{\alpha}^{\pi} - \frac{\sin 2\theta}{2}\Big|_{\alpha}^{\pi}\right\}\right]^{1/2}$$

1ϕHalf wave-controlled converter Vdc (rms)

$$V_{dc(rms)} = \left[\frac{V_m^2}{4\pi} \left\{ (\pi - \alpha) - \frac{1}{2}\left(0 - \sin 2\alpha\right) \right\} \right]^{1/2}$$

$$= \left[\frac{V_m^2}{4\pi} \left\{ (\pi - \alpha) + \frac{1}{2}\sin 2\alpha \right\} \right]^{1/2}$$

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

$$= \frac{V_m}{2} \sqrt{\frac{(\pi - \alpha) + \frac{1}{2}\sin 2\alpha}{\pi}}$$

Form factor & ripple factor

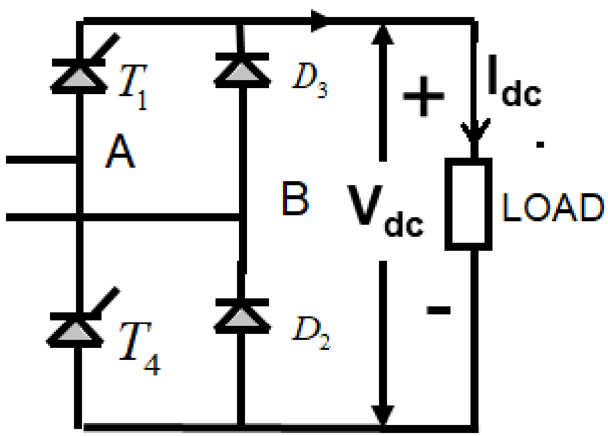
$$\text{Form Factor} = \frac{V_{dc}(rms)}{V_{dc}(avg)}$$

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

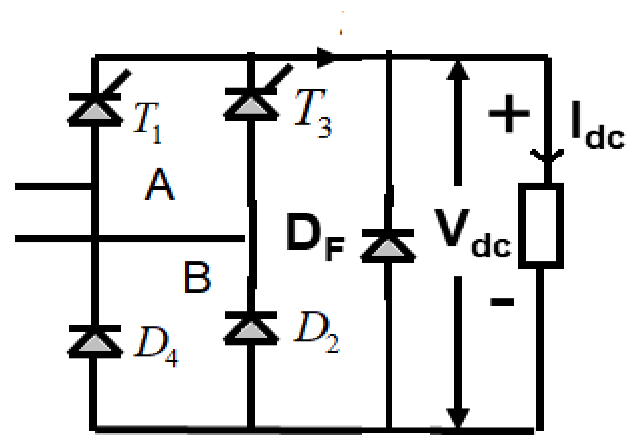
$$\text{RIPPLE FACTOR} = \sqrt{FF^2-1}$$

1 ϕ full wave half-controlled converter

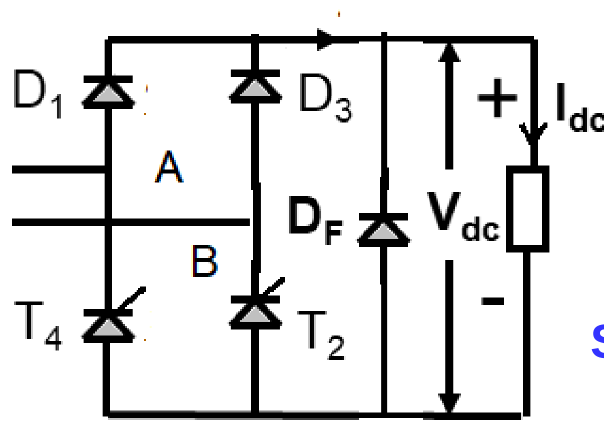
- Circuit configurations



Asymmetric



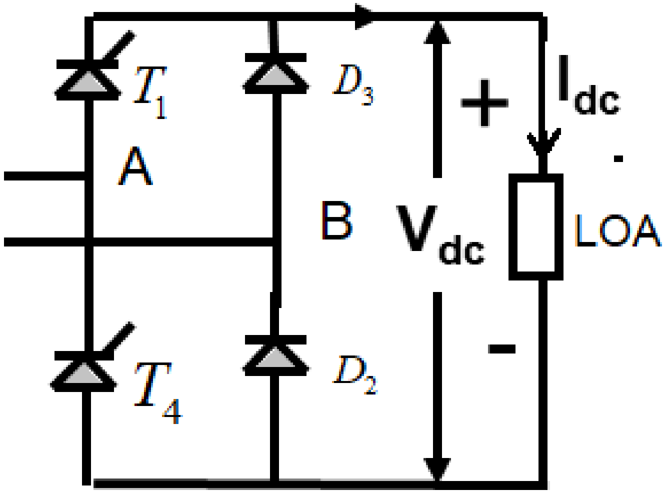
Symmetric

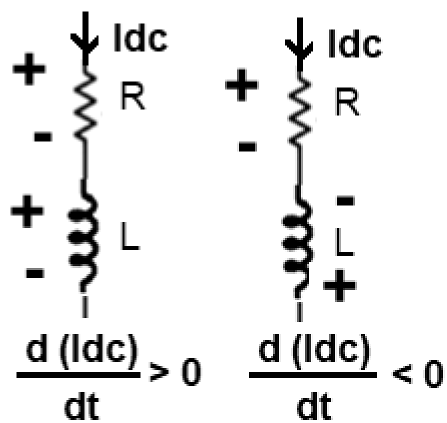


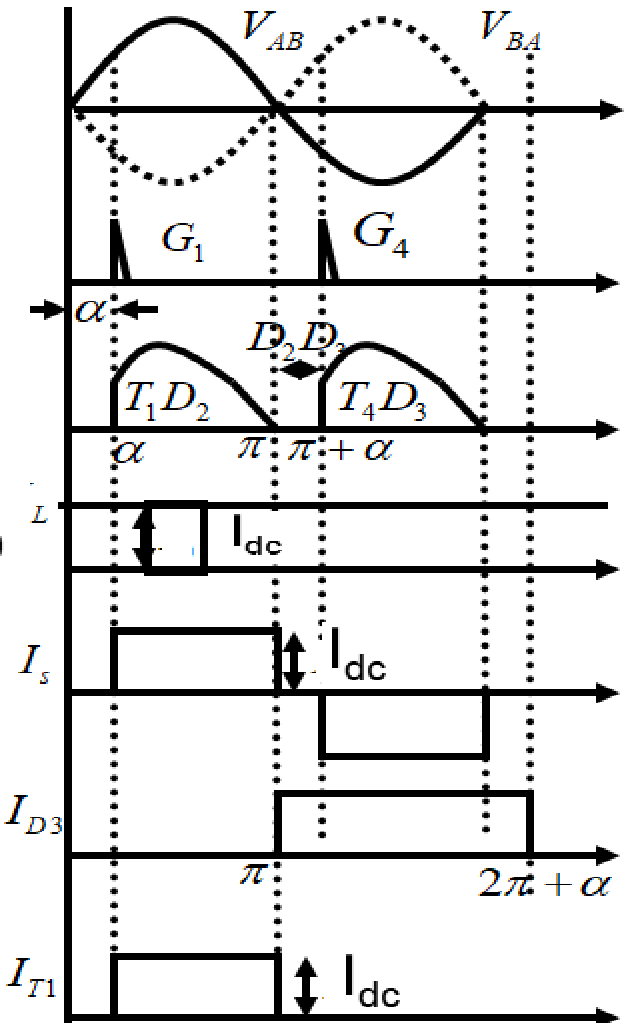
Symmetric

1 ф full wave half-controlled converter

- Asymmetric configuration RL Load



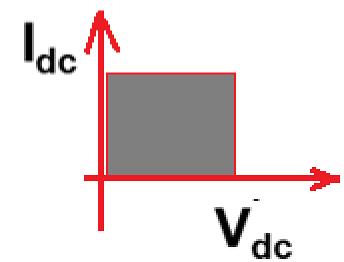


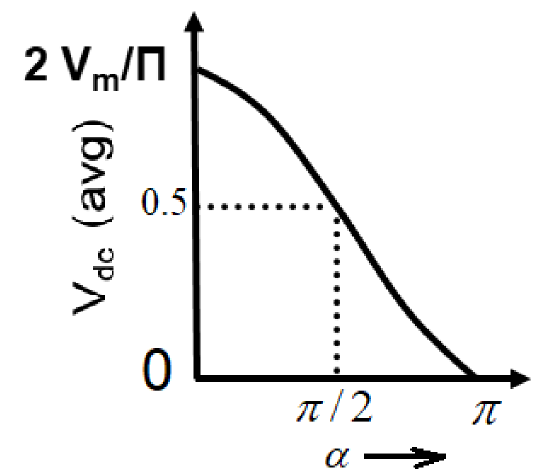


- Conduction period of diode is more than thyristor

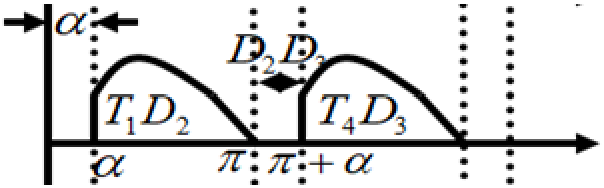
1ϕ full wave half-controlled converter

- Average value of DC O/P voltage
- V_{dc} (avg) $= (2/2\Pi) \int_{\alpha}^{\Pi} V_m \, Sin\, \theta \, d\theta$
- Vdc (avg) $= (V_m/\Pi)\ (-\cos\theta)$
- Vdc (avg) $= (V_m/\Pi)(-\cos\Pi+\cos\alpha)$
- Vdc (avg) $= (V_m/\Pi)(1+\cos\alpha)$
- Vdc and Idc are always +ve
- Single quadrant operation
- Unidirectional power flow
- Power flow from AC side to DC side





1ϕ full wave half-controlled converter : Vdc (rms)



$$V_{dc(rms)} = \left[\frac{2}{2\pi}\int_{\alpha}^{\pi} V_m^2 \sin^2\theta \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{\pi}\int_{\alpha}^{\pi} \sin^2\theta \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{\pi}\int_{\alpha}^{\pi} \frac{(1-\cos 2\theta)}{2} \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\int_{\alpha}^{\pi} (1-\cos 2\theta) \cdot d\theta\right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi}\left\{\int_{\alpha}^{\pi} d\theta - \int_{\alpha}^{\pi} \cos 2\theta \cdot d\theta\right\}\right]^{1/2}$$

1ϕ full wave half-controlled converter : Vdc (rms)

$$V_{dc(rms)} = \left[\frac{V_m^2}{2\pi} \left\{ \theta \Big|_{\alpha}^{\pi} - \frac{\sin 2\theta}{2} \Big|_{\alpha}^{\pi} \right\} \right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi} \left\{ (\pi - \alpha) - \frac{1}{2}\left(0 - \sin 2\alpha\right) \right\} \right]^{1/2}$$

$$= \left[\frac{V_m^2}{2\pi} \left\{ (\pi - \alpha) + \frac{1}{2}\sin 2\alpha \right\} \right]^{1/2}$$

$$= \frac{V_m}{\sqrt{2\pi}} \left\{ (\pi - \alpha) + \frac{1}{2}\sin 2\alpha \right\}^{1/2}$$

$$= \frac{V_m}{\sqrt{2\pi}} \sqrt{(\pi - \alpha) + \frac{1}{2}\sin 2\alpha}$$

Form factor & ripple factor

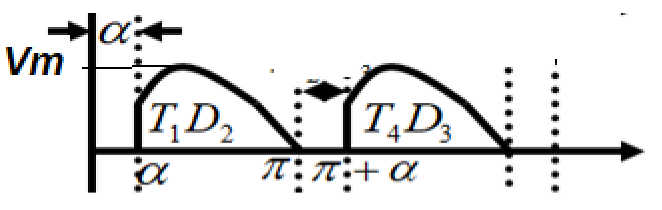
$$\text{Form factor} = \frac{V_{dc}(rms)}{V_{dc}(avg)}$$

$$FF = \frac{\frac{V_m}{\sqrt{2\pi}}\sqrt{(\pi-\alpha)+\frac{1}{2}\sin 2\alpha}}{\frac{V_m}{\pi}(1+\cos\alpha)}$$

$$\text{Ripple factor} = \sqrt{FF^2-1}$$

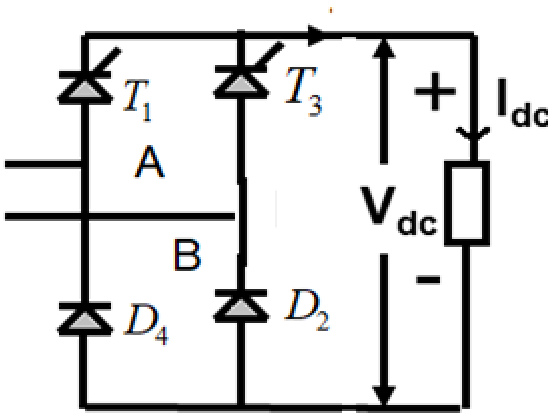
1ϕ half controlled converter

- Resistive load
- o/p voltage waveform is same as that of RL Load.
- No freewheeling action
- Dc current and source current are different
- Power dissipated in R load
- P = Vdc^2(rms)/R

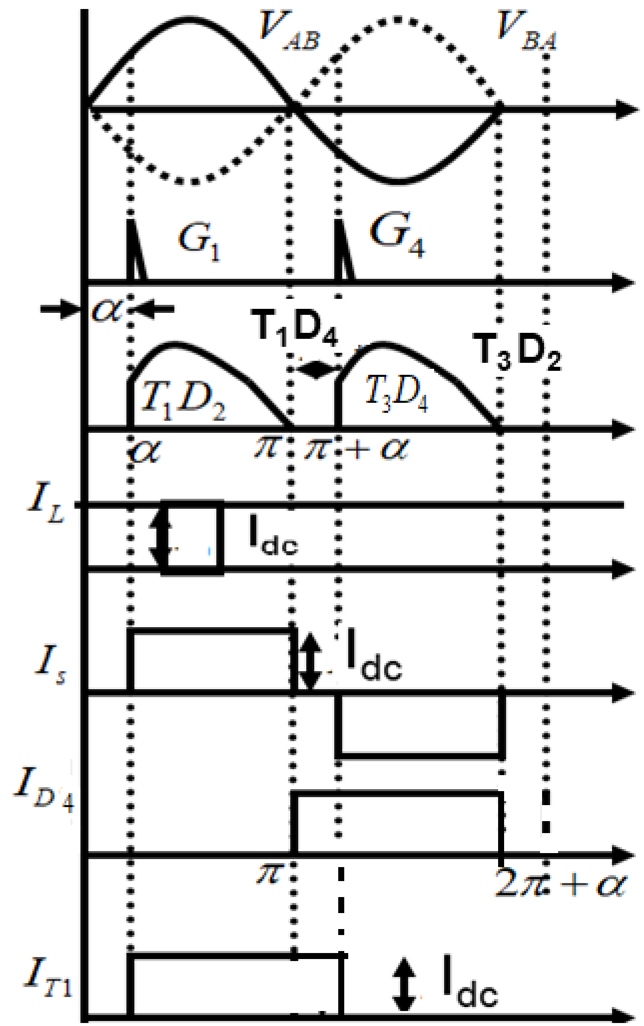


1ϕ full wave half controlled converter

- Symmetric configuration
- without Df



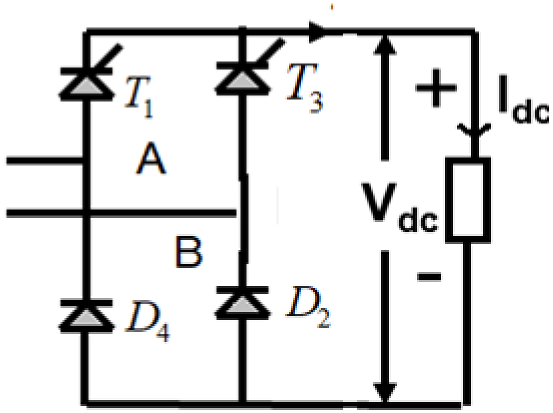
- RL load => each device
- Conducts for 180^0



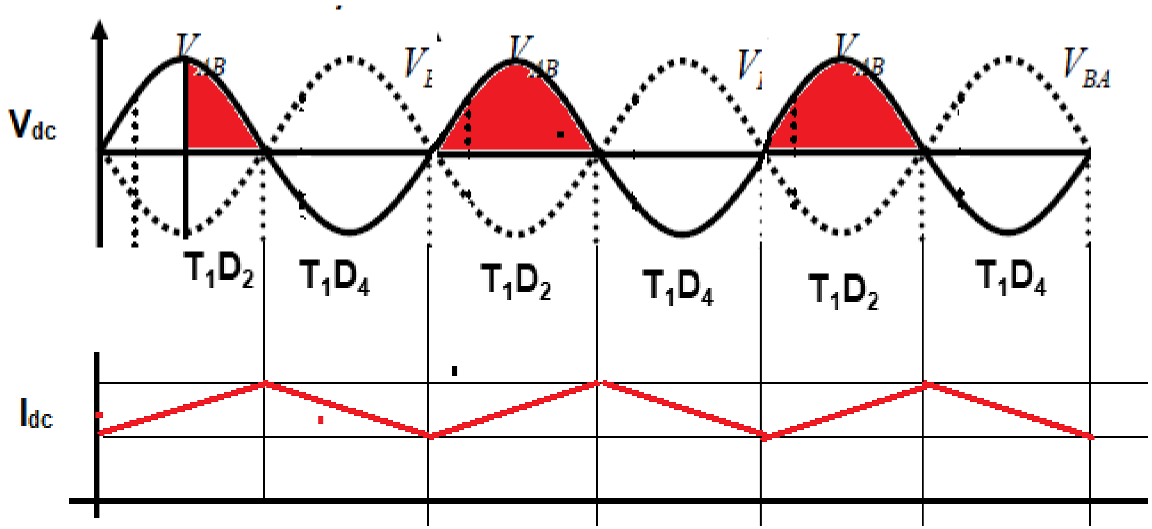
1ϕ full wave half-controlled converter => Symmetric conf.

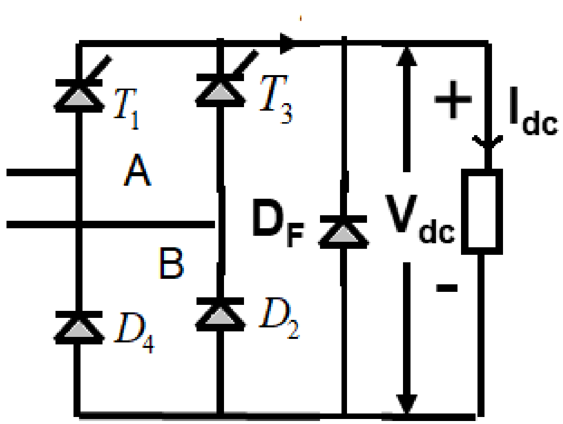
- Expressions for average and rms voltage, Form factor and ripple factor same as Asymmetric configuration
- T1 conducts till T3 turns on.
- If T3 fails to turn on, T1 and D4 will conduct for –ve half cycle => o/p voltage =0
- In positive half cycle T1 and D2 will conducts. T1 never turns off. Uncontrolled half wave DC O/P
- Half waving effect

Half waving effect



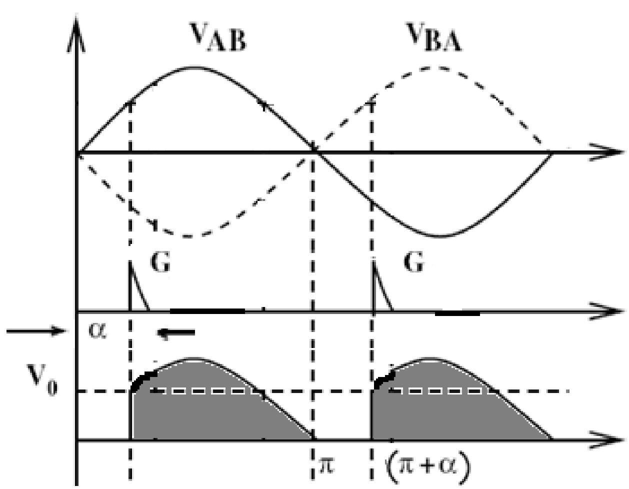
- T3 fails to turn on
- T1 will not turn off
- T1 will remain continuous on

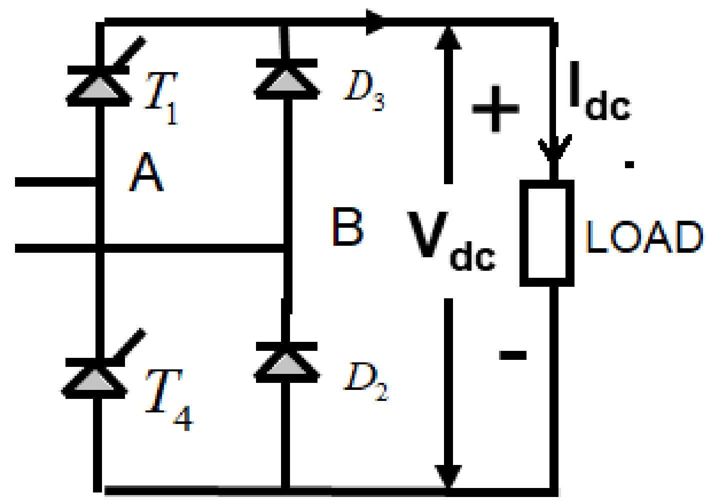




1ϕ full wave half controlled converter => R load

- Power dissipated in R load
- Supply voltage = 230V 1ϕ 50 Hz
- α =30^0 & R= 10 Ω
- Find out Vdc (rms)





1ϕ full wave half-controlled converter => R load

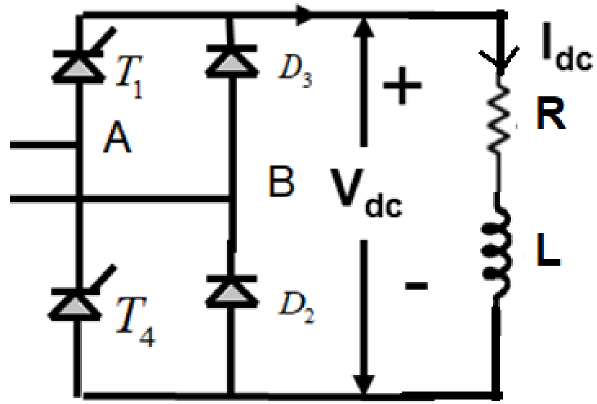
- Vdc(rms) is given by the expression

$$V_{dc}(rms) = \frac{V_m}{\sqrt{2\pi}} \sqrt{(\pi-\alpha) + \frac{1}{2}\sin 2\alpha}$$

- Substituting Vm => $\sqrt{2}\, X 230$ and α = 30^0
- Vdc(rms) = 226.56 V
- Power dissipated =$(226.56)^2$/ 10 = 5132.94 W

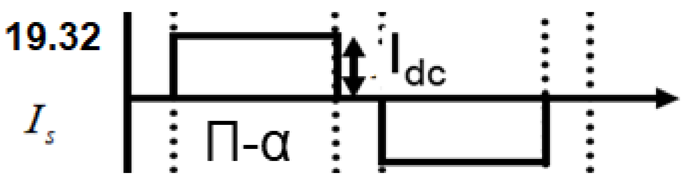
1ϕ full wave half controlled converter => RL load

- Supply voltage = 230V , R= 10Ω
- α =30^0 and large value of L
- Find the power dissipated in R Load
- Idc is smooth & ripple free
- VR= Cons. Ripple free DC
- Power dissipated = Vdc $(avg)^2$/ R
- Vdc (avg) = Vm/Π (1+cosα)
- Vdc (avg) = 193.2 V
- Pdc = 3732.68 W

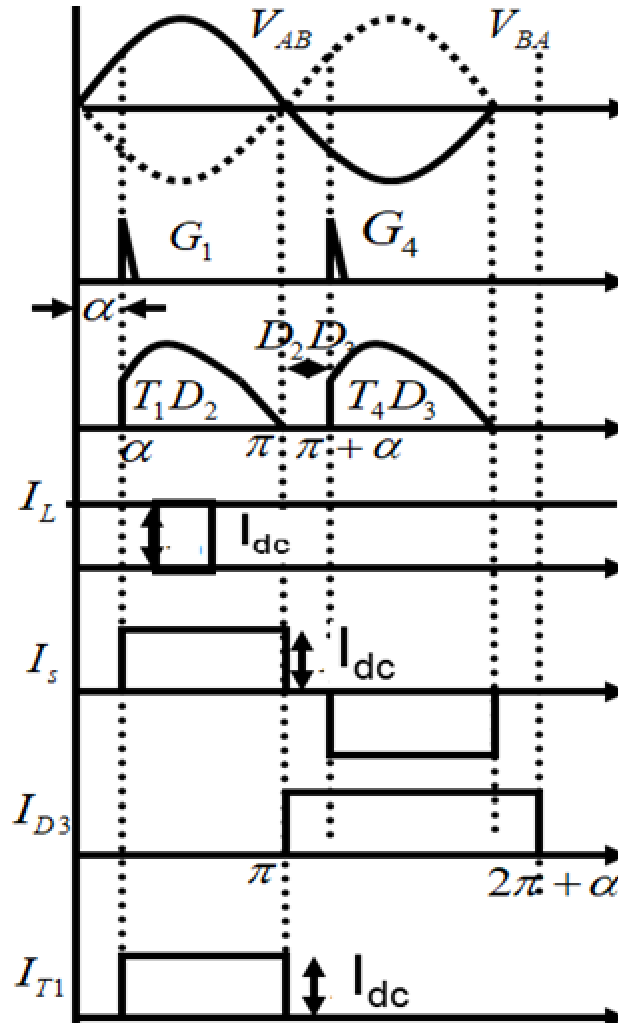


1ϕ full wave half controlled converter => RL load

- Source current & pf
- Idc = 19.32A



- Is (rms)= $[(I^2_{dc}x150X2)/360]^{1/2}$
- Is (rms)= 17.63A



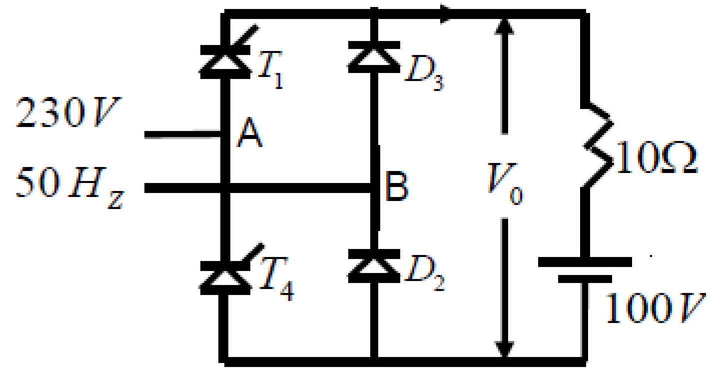
1ϕ full wave half controlled converter => RL load

- AC Power = DC power
- Vdc(avg) X Idc = Vs Is X cosϕ
- Putting values
- Vs = 230 V Is = 17.63 A Vdc (avg)= 193.2 V
- Idc = 19.32 A
- Power factor= Cos ϕ =0.9179 lag

1ϕ full wave half controlled converter => RE load

For the circuit shown in fig. determine average value of load current for $\alpha = 60^0$

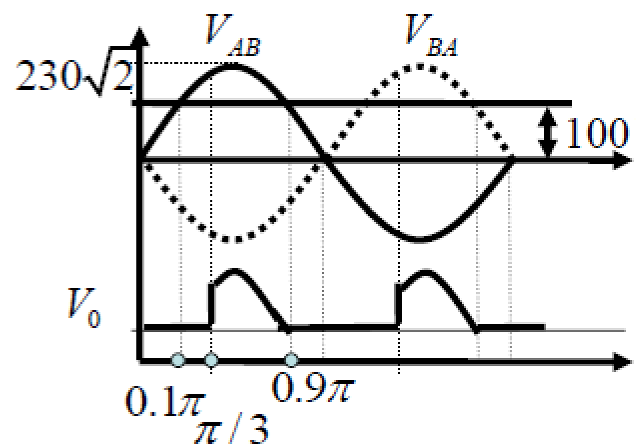
What is the new value of average current flowing through load if a large 'L' is connected in series with the load



Neglect the device drop

a) R-E Load:

$$\alpha_{\min} = \sin^{-1}\left(\frac{100}{230*\sqrt{2}}\right) = 18^0 = 0.1\pi^c$$



1ϕ full wave half controlled converter => RE load

$E = 100\,V$

$\sqrt{2}\, V_m \sin\theta_1 = 100$

$\therefore \sin\theta_1 = \dfrac{100}{V_m} = \dfrac{100}{\sqrt{2} \times 230} \quad \therefore \sin\theta_1 = 0.30743$

$\theta_1 = \sin^{-1} 0.307437 = 17.90^\circ \simeq 18^\circ$

But $\alpha = 60$ $\therefore$ conduction starts at 60°

and conduction ends at $180 - 18 = 162^\circ$

1ϕ full wave half controlled converter => RE load

$$\therefore i = \frac{V_m \sin\theta - E}{R}$$

$$\therefore I_{av} = \frac{2}{2\pi} \int_{60}^{162} \left(\frac{V_m \sin\theta - E}{R}\right) . d\theta$$

$$\therefore I_{av} = \frac{1}{\pi R} \left[\int_{60}^{162} V_m \sin\theta . d\theta - \int_{60}^{162} E . d\theta \right]$$

$$\therefore I_{av} = \frac{1}{10\pi} \left[V_m (-\cos\theta)_{60}^{162} - E \left(\frac{162}{180}\pi - \frac{60}{180} \times \pi \right) \right]$$

1ϕ full wave half controlled converter => RE load

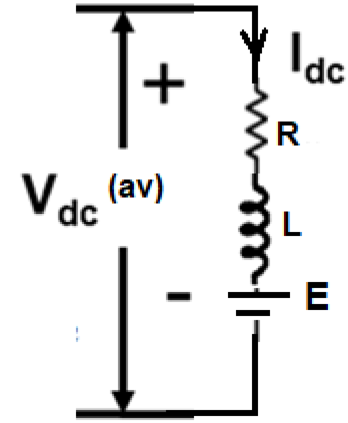
$$\therefore I_{av} = \frac{1}{10\pi}\left[\sqrt{2}\times 230(-\cos 162 + \cos 60) - 100(1.780\right.$$

$$= \frac{1}{10\pi}\left[\sqrt{2}\times 230(0.9510 + 0.5) - 178\right]$$

$$= \frac{1}{10\pi}\left[471.96 - 178\right] = 9.35\,A$$

1ϕ full wave half controlled converter => RLE load

- b With large inductance in series with the load current becomes continious.



$\alpha = 60^0$

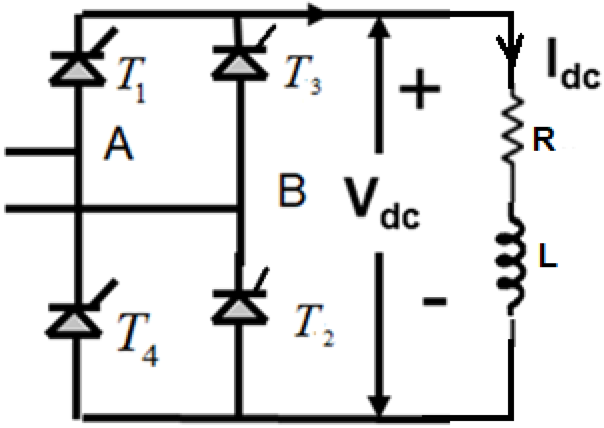
$$\text{Av. value of o/p } Voltage = \frac{230\sqrt{2}}{\pi}(1 + Cos\alpha)$$

$$= 155\ V$$

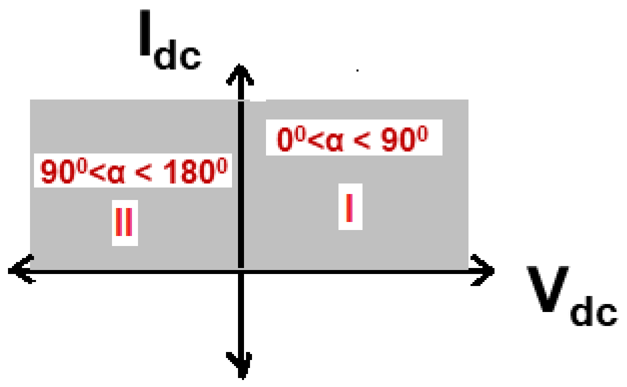
$$Av.value\ of\ I = \frac{155 - 100}{10} = 5.5A$$

1ϕ full wave full controlled converter

- With RL load & continuous conduction
- All devices are thyristors
- Range of α => 0 to 180
- Two quadrant converter
- Rectifier operation
- Inverter operation

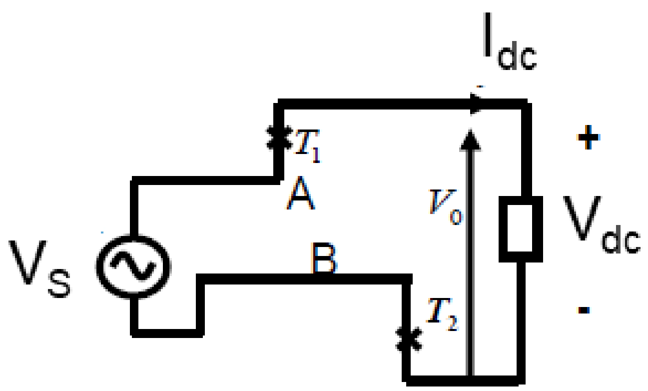


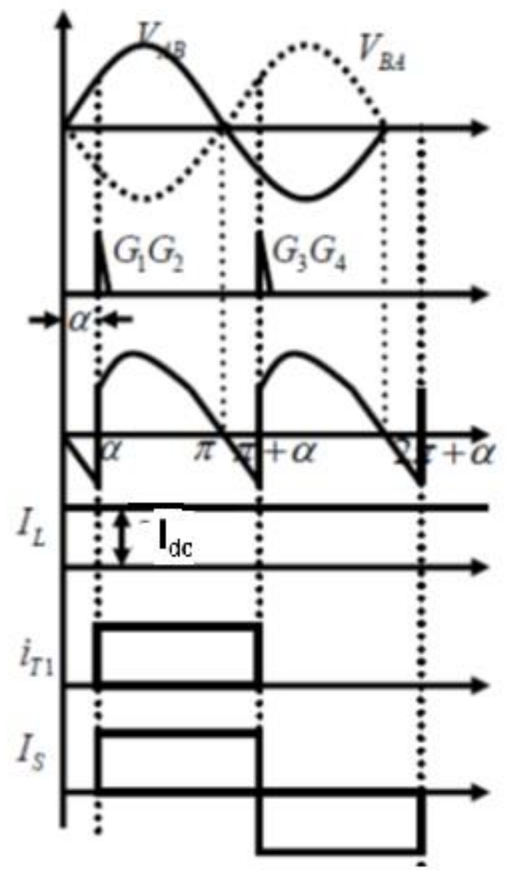
- Current direction remains same
- Polarity of O/P voltages changes



1ϕ full wave full controlled converter

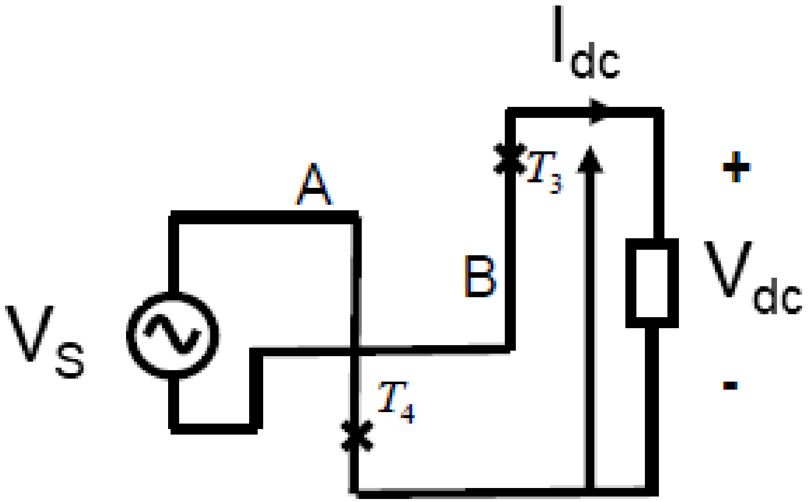
- operation
- Assume IL(I_{dc}) is continuous, smooth and ripple free
- As continuous conduction T_3 T_4 are conducting before turn on of T_1 T_2
- Positive half cycle V_{AB} +ve $T_1 T_2$ are are fired at α

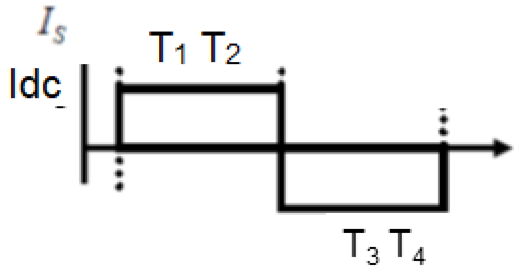




ϕ full wave full controlled converter

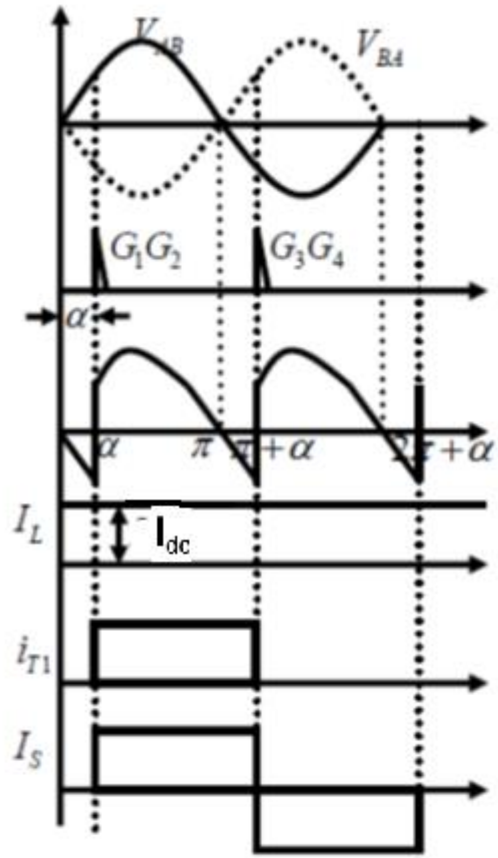
- operation
- At π+ α, T_3T_4 are turned on
- Each device Conducts for 180^0
- Source current is square wave





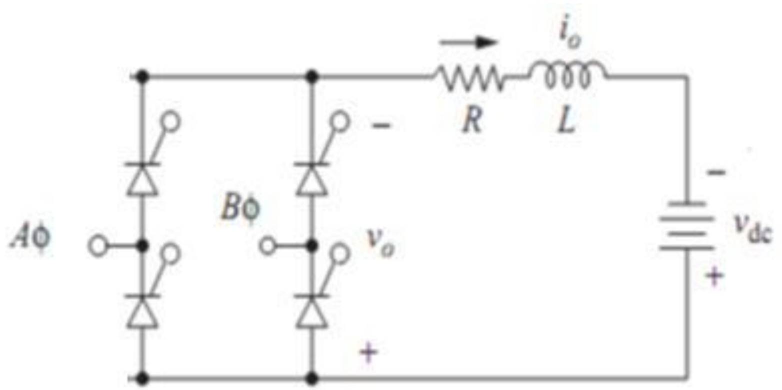
1ϕ full wave full controlled converter

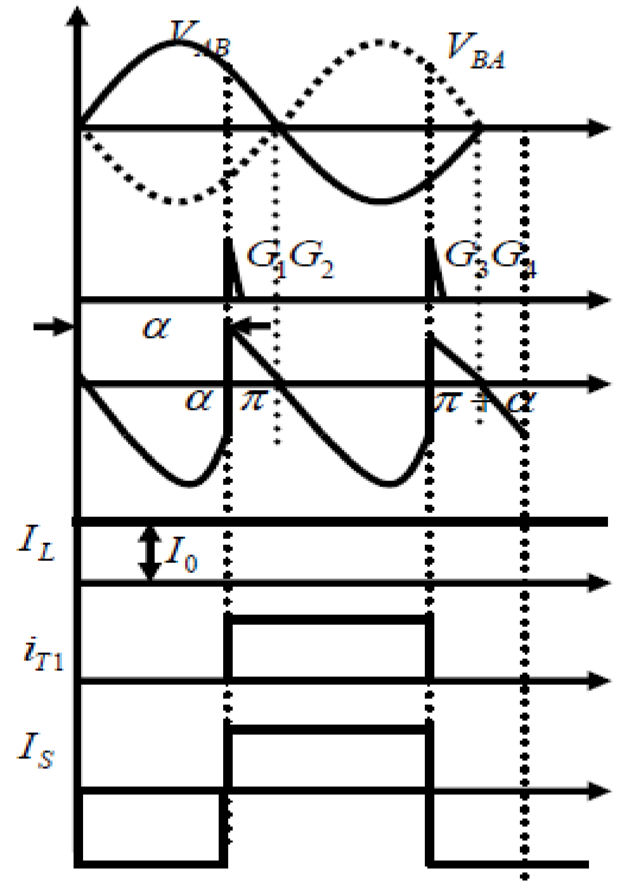
- Rectifier operation
- $0^0 < \alpha < 90^0$
- Each device conducts for 180^0
- T1 and T2 will turn off when T3
- T4 are turned ON
- Vdc (avg) = $2/2\pi \int_{\alpha}^{\pi+\alpha} V_m \, Sin\theta \, d\theta$
- Vdc (avg) = $V_m/\pi \int_{\alpha}^{\pi+\alpha} Sin\theta \, d\theta$
- Vdc (avg) = V_m/π $(-\cos\theta \;\; d\theta)$
- Vdc (avg) = $2\,(V_m/\pi)\cos\alpha$
- Vdc (avg) = $\dfrac{2V_m}{\pi}\cos\alpha$



1ϕ full wave full controlled converter

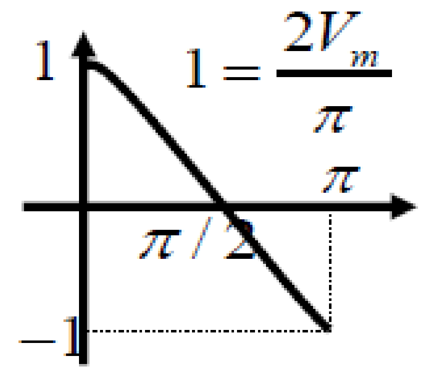
- Inverter operation
- Essential conditions for Inverter operation
- 1) $90^0 < \alpha < 180^0$
- 2) continuous conduction
- 3) DC source at the DC side





1ϕ full wave full controlled converter

- Voltage control
- source current => square wave
- $I_s(rms) = I_{dc}$
- $I_1(rms) = \frac{2\sqrt{2}}{\pi} I_{dc}$
- Vdc (rms) = $V_m/\sqrt{2}$
- Form factor (FF) = Vdc (rms)/ Vdc (avg)



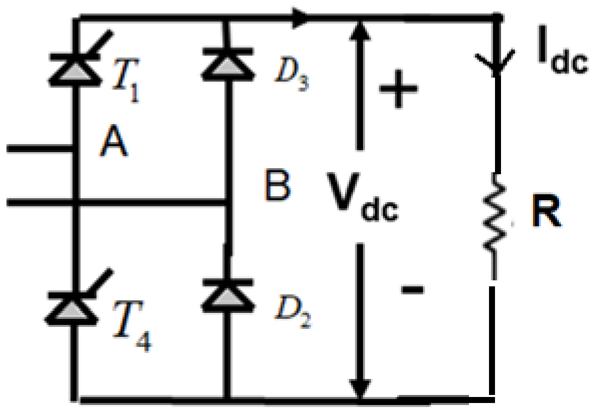
- $FF = \frac{Vm/\sqrt{2}}{= 2 (V_m/ \pi) \cos\alpha} = \frac{\pi}{2\sqrt{2}\cos\alpha}$

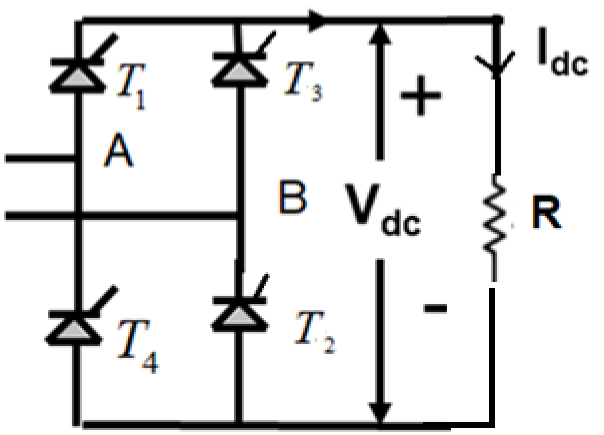
1ϕ full wave full controlled converter

- Ripple factor = $\sqrt{(FF^2 - 1)}$
- Power factor =
- Distortion factor X Displacement factor
- Distortion factor = $(2\sqrt{2})/\pi$
- Displacement factor= Cos α
- Power factor = $\dfrac{2\sqrt{2}}{\pi} \cos\alpha$

1ϕ full wave full controlled converter R load

- Half controlled Full controlled

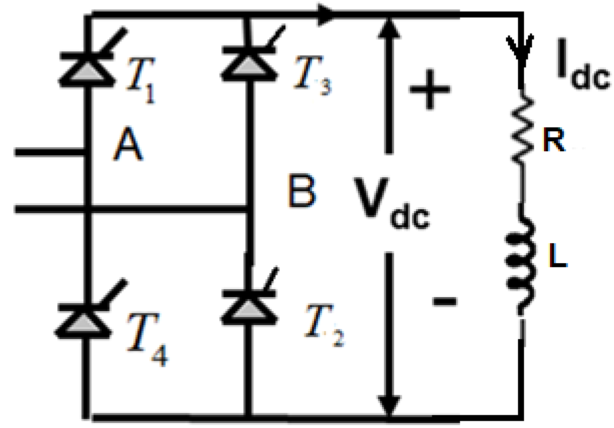




- Operation and performance is same for both converters

1ϕ full wave full controlled converter

- RL load continuous conduction
- Supply voltage =230 V
- $\alpha = 45^0$ R= 20 Ω &L=large
- Power dissipated in R load
- Source current & supply pf
- % ripple in DC O/P voltage



- Power dissipated in R load = Vdc (avg) X Idc(avg)
- Vdc (avg) = $2 (V_m/ \pi) \cos\alpha$
- Vdc (avg) = 146.42 V
- I dc is smooth and ripple free

RL load continuous conduction

- Idc = Vdc(av)/R = 146.42/20= 7.321A
- Power dissipated in R load Vdc(av) x Idc
- Pdc = 146.42 x 7.321 = 1071.94 W
- Source current is square wave with 7.321 amplitude
- Is (rms) = 7.321 A
- Vs Is Cosϕ = Pdc , putting values Cosϕ= 0.6366
- $$Pf = \frac{2\sqrt{2}}{\pi} \cos\alpha$$

RL load continuous conduction

- form factor= vdc (rms)/ Vdc(av)
- FF = 230/146.42 = 1.5708
- Ripple factor = 1.211
- %ripple = 121.1%