Cycloconverter:
AC to AC converter

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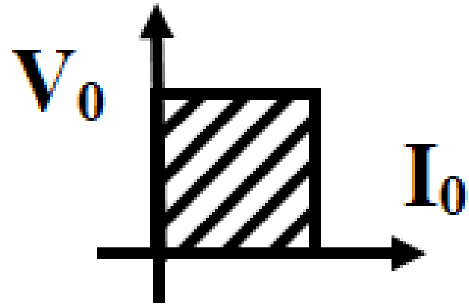
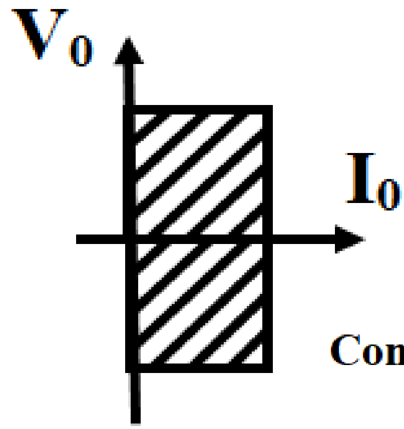
Classification of AC to DC Converter

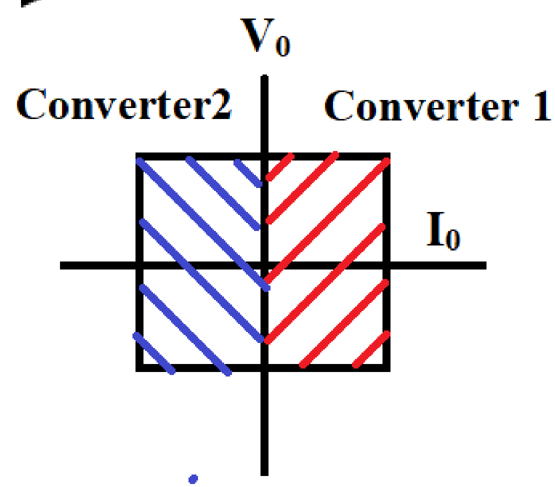
- Based on quadrant operation
- Single quadrant



- Two quadrant

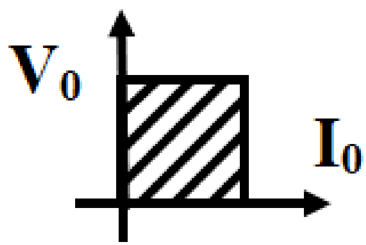


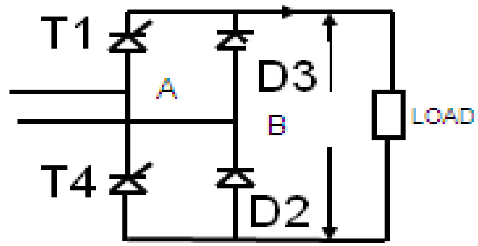
- Four quadrant

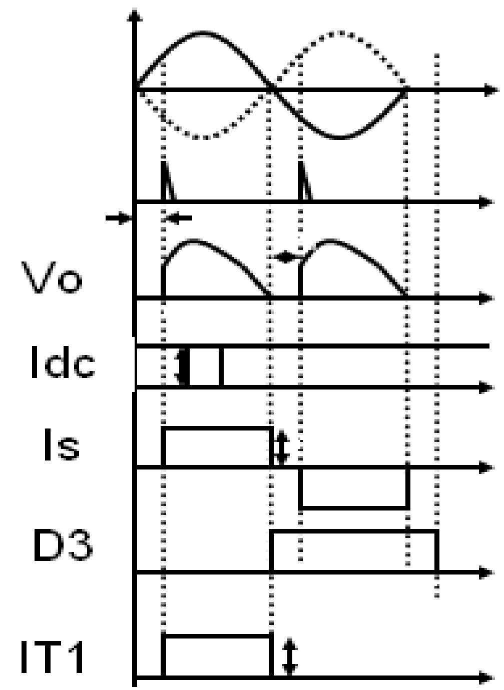


Single phase half controlled converter

- RL load with continuous conduction







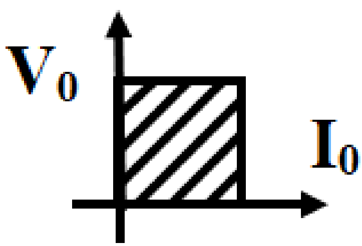
Range of α = 0 to 180^0

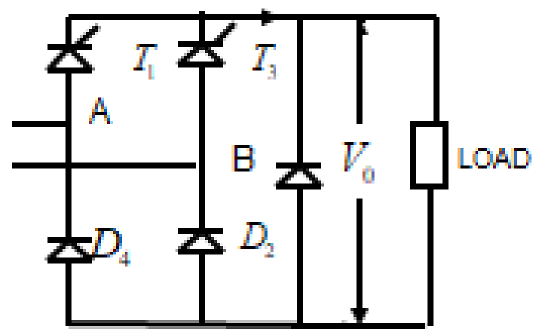
O/P voltage = $V_m/\pi\ (1+\cos\alpha)$

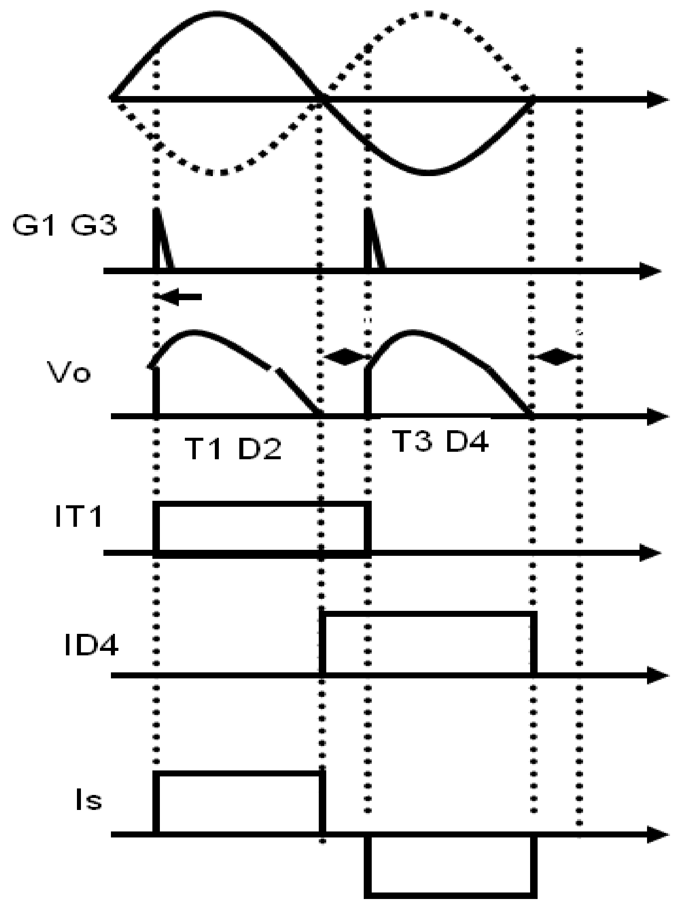
Conduction period of diodes >thyristors

Single phase half controlled converter –Symmetrical configuration

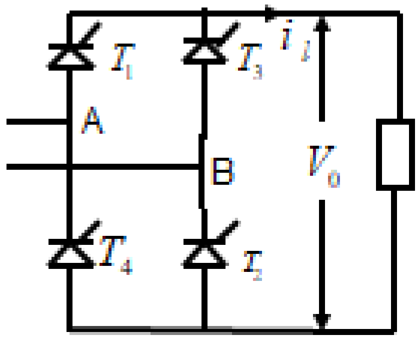
Freewheeling diode across the load to avoid the half waving effect

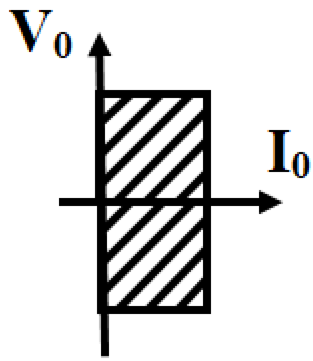


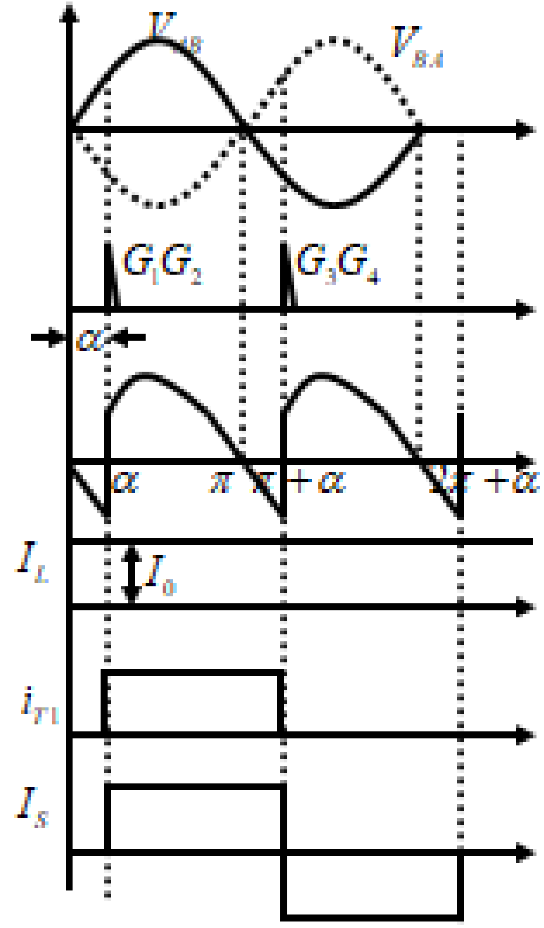




Single phase full controlled converter Rectifier operation





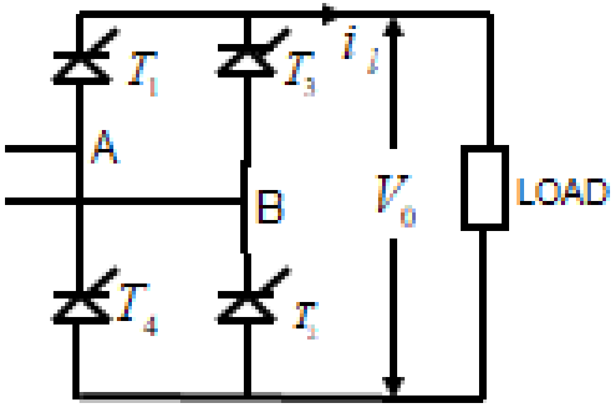


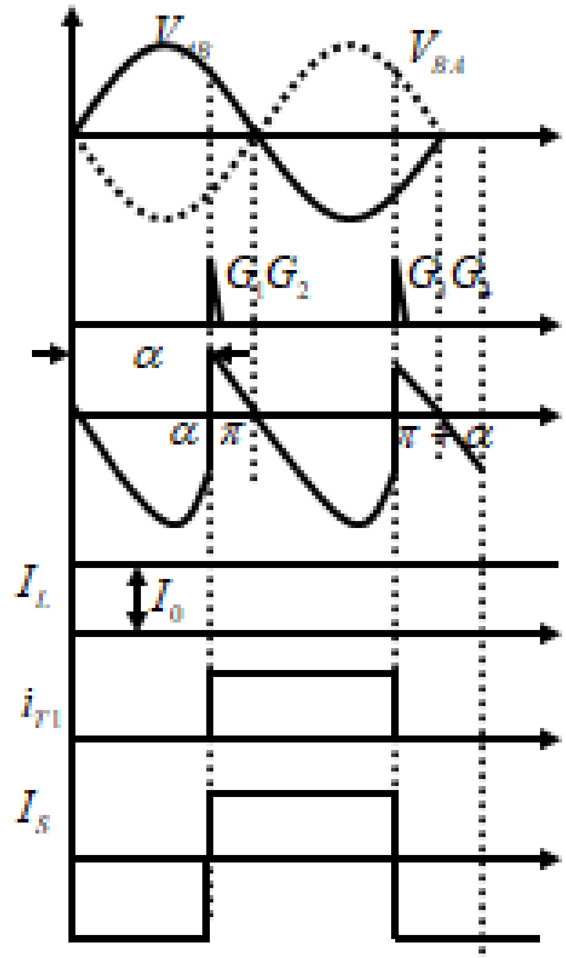
LOAD CURRENT IS CONSTANT & RIPPLE FREE

IN THE +VE HALF T1 ,T2 ARE F.B. & -VE HALF T3 T4 ARE F.B.

T1 ,T2 CONTINUE TO CONDUCT TILL T3 T4 ARE TRIGGERED
(Load current IS CONTINUOUS)

Single phase full controlled converter Inverter Operation





Inverter operation- Requirements

Firing angle > 90 degree,

Continuous Conduction

Active source on dc side to maintain DC current and sufficient L for continuous conduction

O/P voltage = $(2 V_m \cos\alpha) / \pi$

2 Pulse Dual Converter

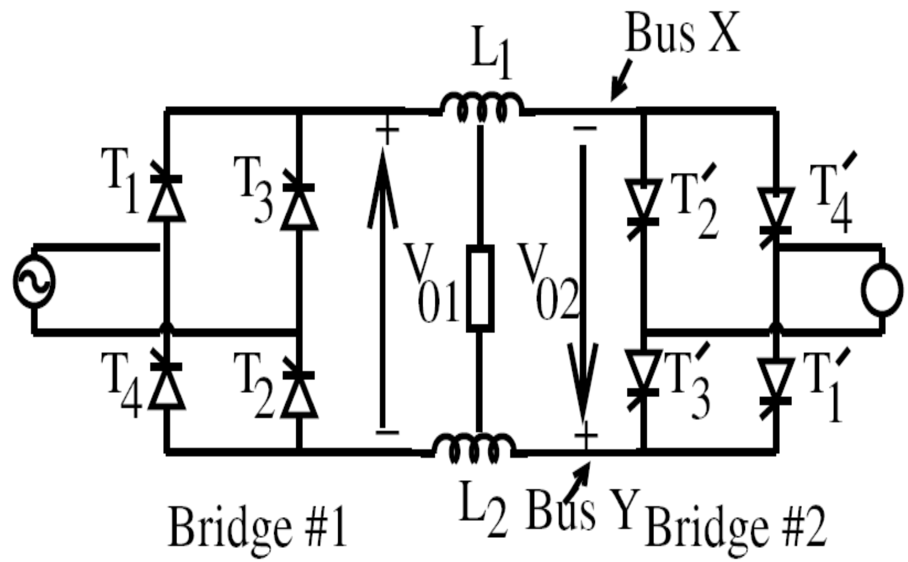
⇒ In a 2-quadrant converter,
'V' can be reversed, but not 'i'.

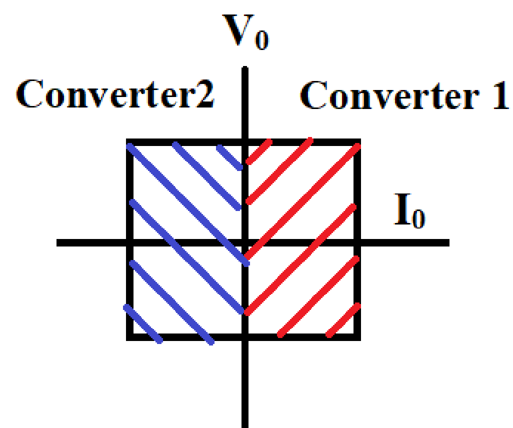
⇒ use one more bridge.

⇒ Dual converter
connect them back
to back.

⇒ 'i' can be reversed and
flows back to the source
through the 2nd bridge.

⇒ All 4 quadrant operation.





2 Pulse Dual Converter

- Two full controlled converters connected antiparallel with load
- Range of α variation => 0 to 180^0
- $\alpha_1 + \alpha_2 = 180^0$
- It consists of positive group and negative group
- One group works in rectifier mode other group works in inverter mode

2 Pulse Dual Converter

- Four quadrant converter

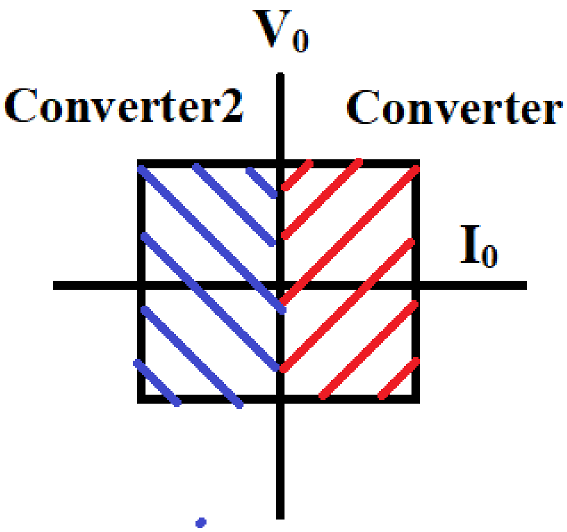
Assume that both bridges are ON

Let α_1 be the triggering angle for bridge-1

Let α_2 be the triggering angle for bridge-2

$$\therefore \; V_{01} = \frac{2V_m}{\pi}\cos\alpha_1$$

$$V_{02} = \frac{2V_m}{\pi}\cos\alpha_2$$



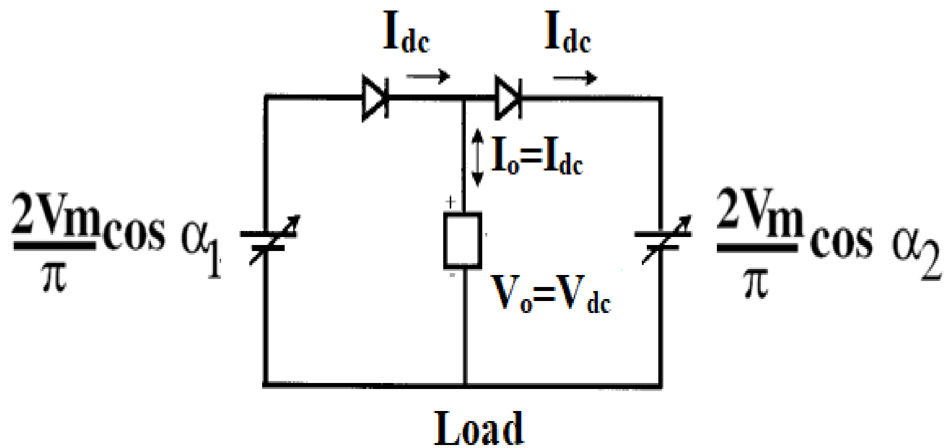
KVL gives $V_{01} + V_{02} = 0$

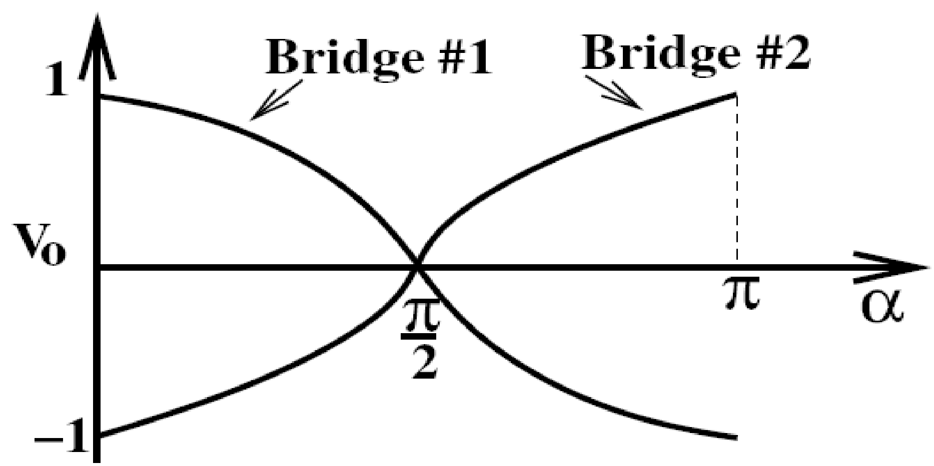
$$[\because \; (L\frac{di}{dt})_{avg} = 0]$$

$$\therefore \; \alpha_2 = \pi - \alpha_1$$

2 Pulse Dual Converter

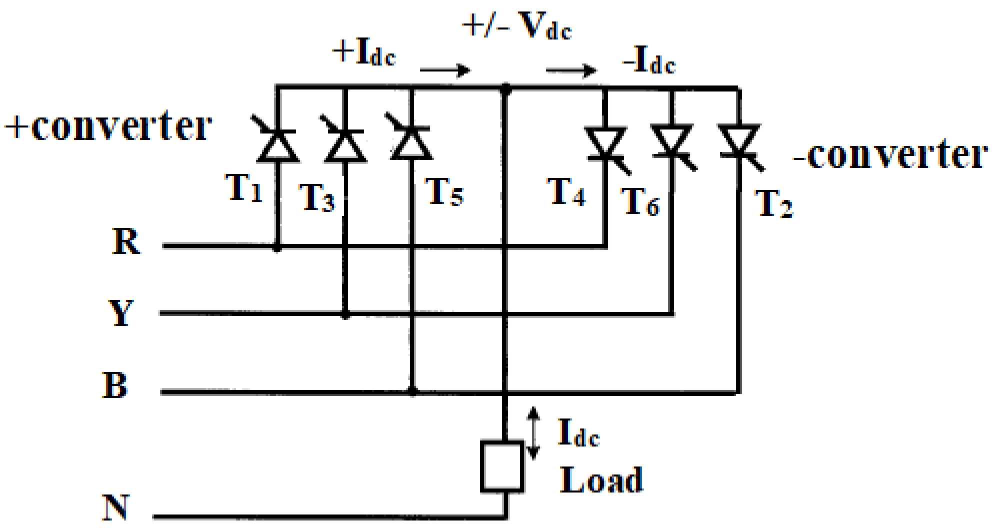
- Circulating current mode
- Both converter are ON
- One works in rectifier mode other works in inverter mode





3 Pulse Dual Converter

- Circuit diagram
- Each device conducts for 1200
- Four quadrant operation
- DC O/P voltage

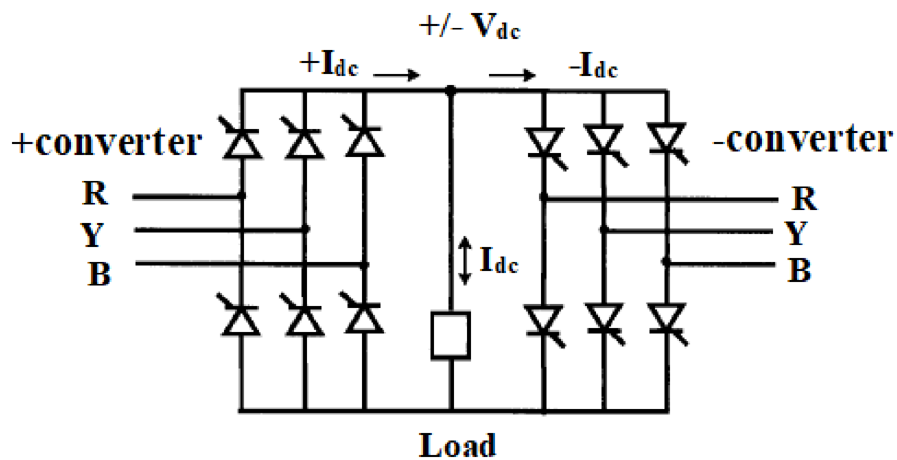


$V_{dc} = (3\sqrt{3}\, V_{mp} \cos\alpha)/2\pi$

where V_{mp} peak value of phase to neutral voltage

6 Pulse Dual Converter

- Circuit diagram
- Two full controlled converters connected anti parallel across load
- Four quadrant operation



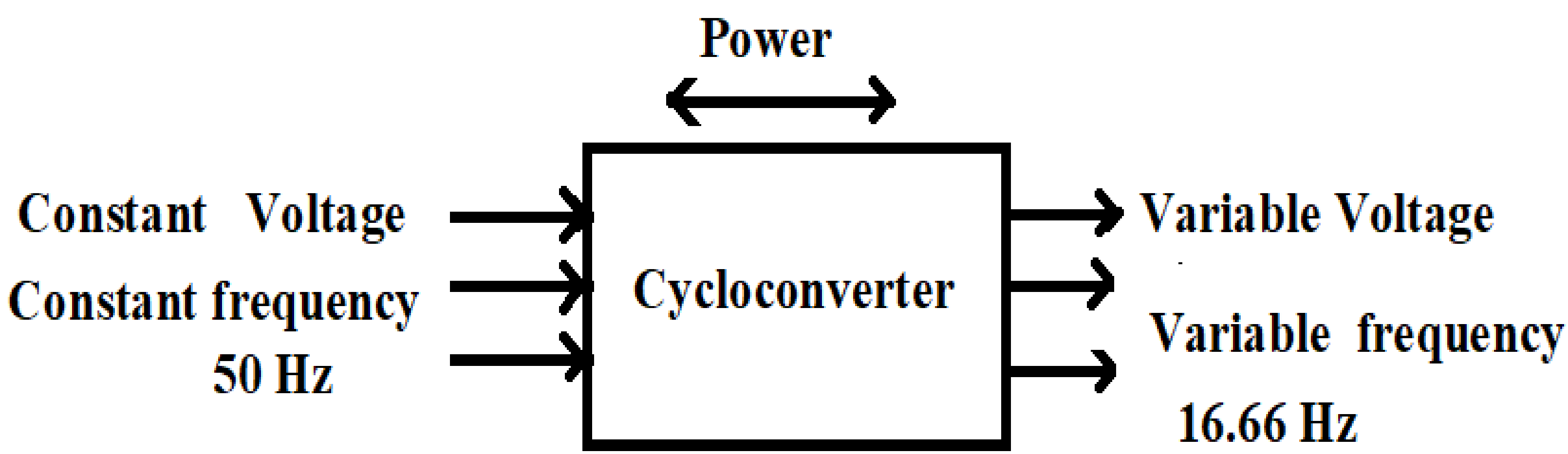
- O/P DC Voltage

$$V_{dc} = 3\,Vml\,Cos\,\alpha\,/\pi$$

where V_{ml} is peak value of line voltage

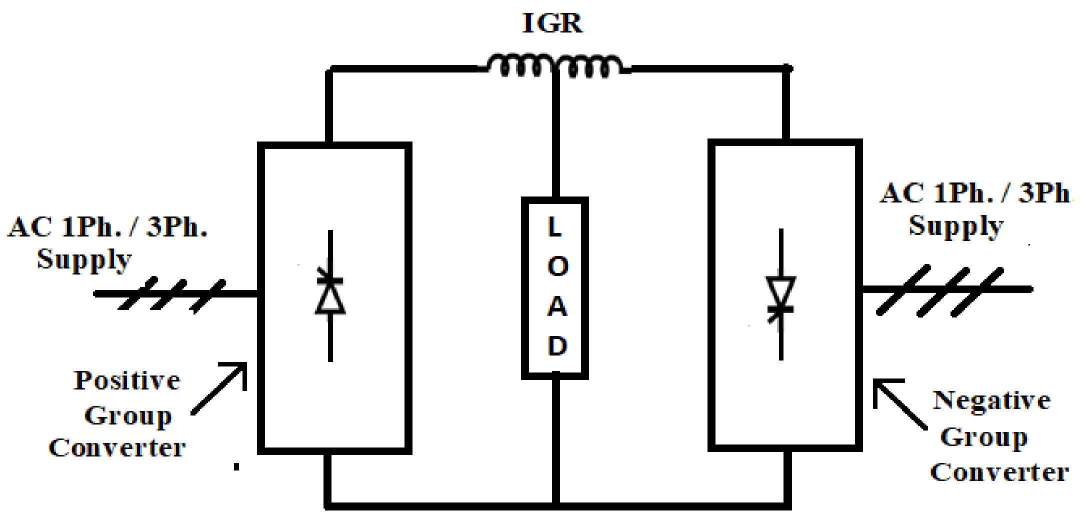
Cycloconverter

- Block diagram
- Direct AC to AC conversion
- Power flow is bidirectional
- O/P frequency is lower than i/p frequency



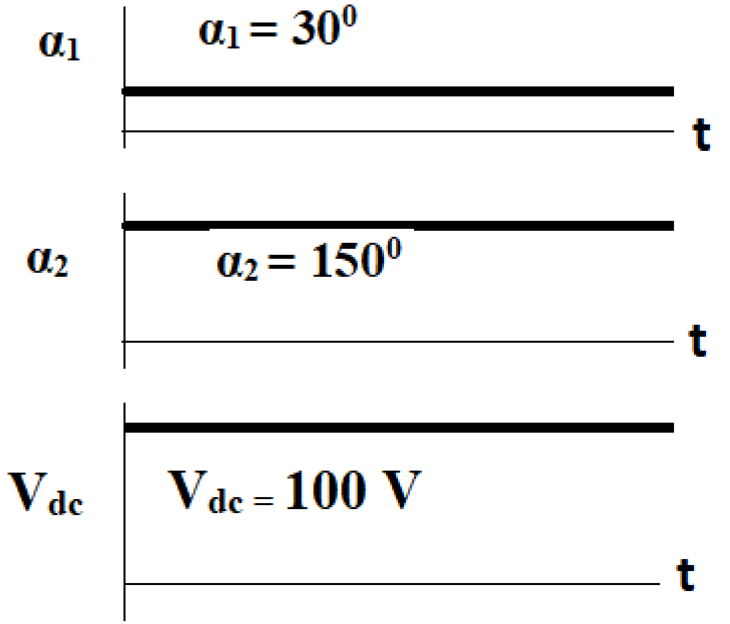
Cycloconverter

- Similarity between dual converter and 1ϕ Cycloconverter
- Power circuit diagram is same as dual converter but control is different
- It consists of +ve group and –ve groups connected anti parallel with load

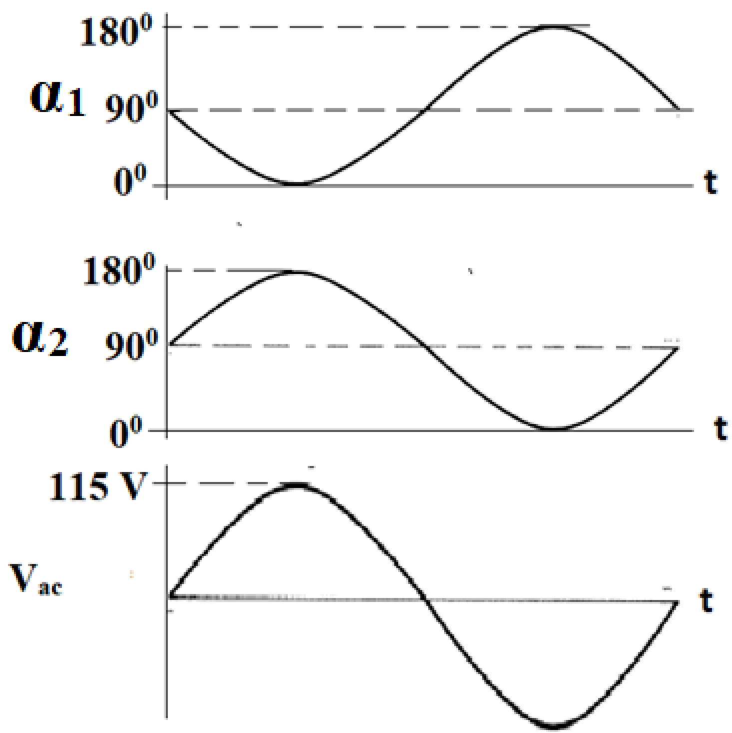


Control of Cycloconverter

- Variation of α_1 and α_2
- $\alpha_1 + \alpha_2 = \pi$
- Dual converter



Cycloconverter



Control of Cycloconverter

- Dual Converter
- For a particular dc o/p voltage α_1 and α_2 remains constant. (not changing with time)
- For example, for 100 DC , $\alpha_1 = 30^0$ and $\alpha_2 = 150^0$ remains constant. (not changing with time)
- Cycloconverter
- For a particular AC o/p voltage α_1 and α_2 are continuously changing with time.
- For obtaining 1cycle of AC O/P , α_1 variation
- 90-0-90-180-90

O/P Voltage Control

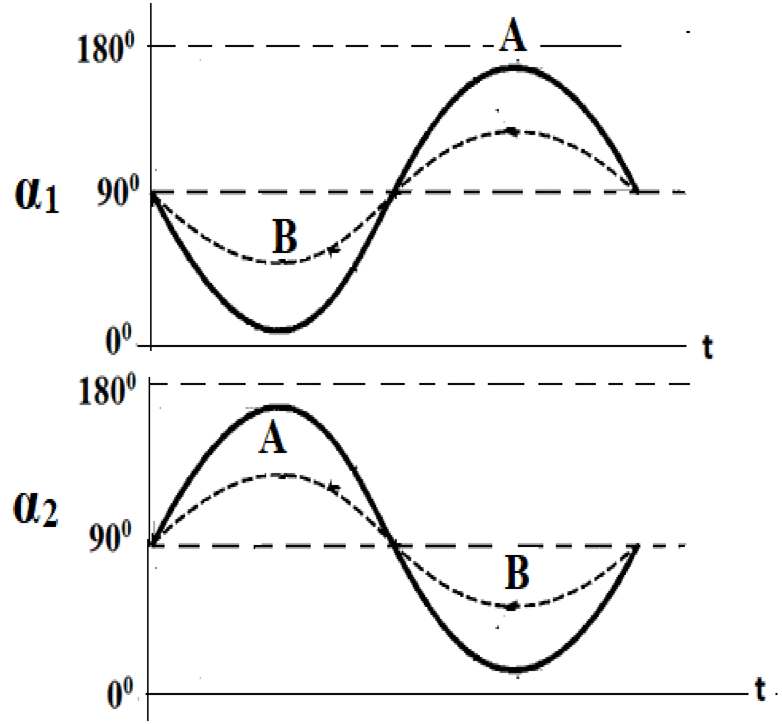
- Two cases of α variation

  A & B are shown.
- Case A variation

  90-10-90-170-90
- Case B variation

  90-60-90-120-90
- Case A variation provides

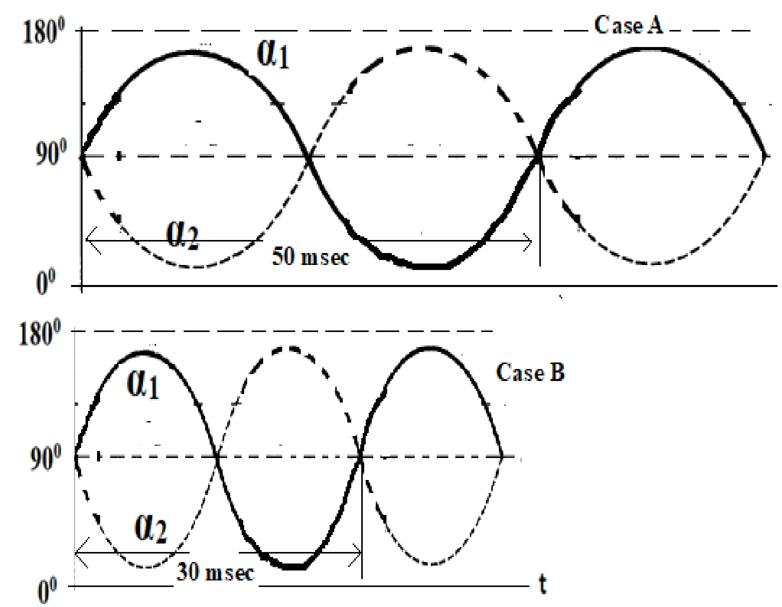
  more AC O/P than B case



- Range of variation of α around 90^0 decides the magnitude of O/P voltage O/P frequency is same

O/P Frequency Control

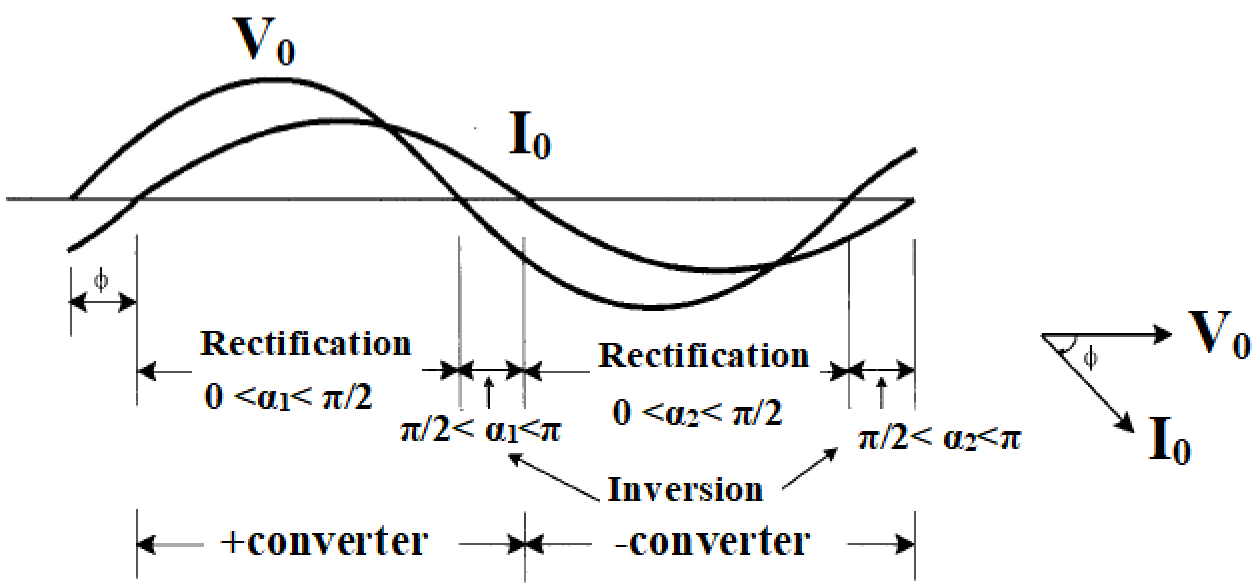
- For both cases α_{min} and α_{max} are the same hence O/P voltage is same(equal)
- Where as T period of cyclic variation of α determines the O/P frequency



- For case A O/P frequency is 20 Hz where as for case B O/P frequency is 33.33 Hz

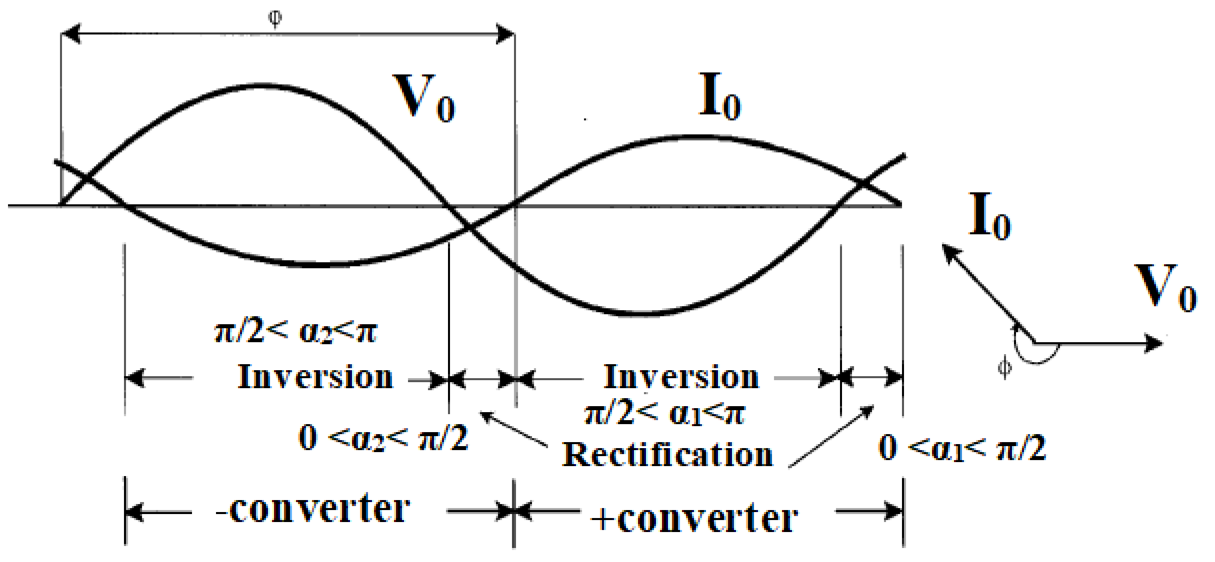
Cycloconverter- Operation

- + ve converter provides +ve current to the load
- -Ve converter provides -ve current to the load
- Depending upon V_0 I_0 requirement both converter operates in rectification and inversion mode



Cycloconverter- Operation

- Power flow from load to supply

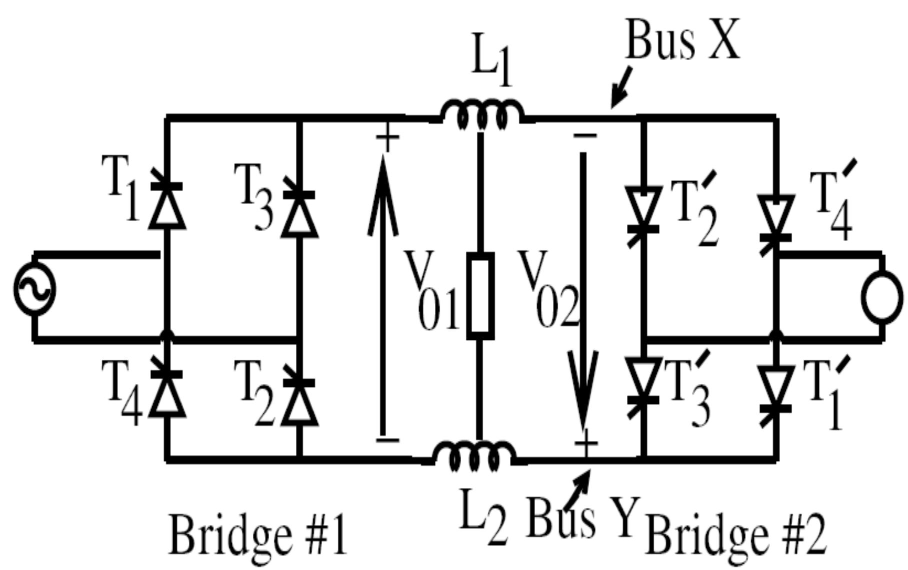


1ϕ to 1ϕ Cycloconverter

- It consists of 2 pulse full controlled converter as +ve and –Ve group Circuit diagram
- The AC output voltage is given by

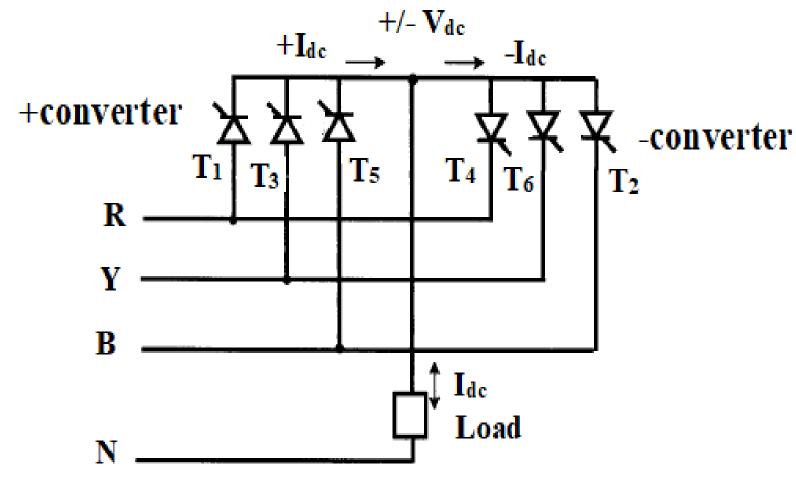
  $V_{ac} = (\sqrt{2}\ V_m/\pi) \cos \alpha_{1min}$

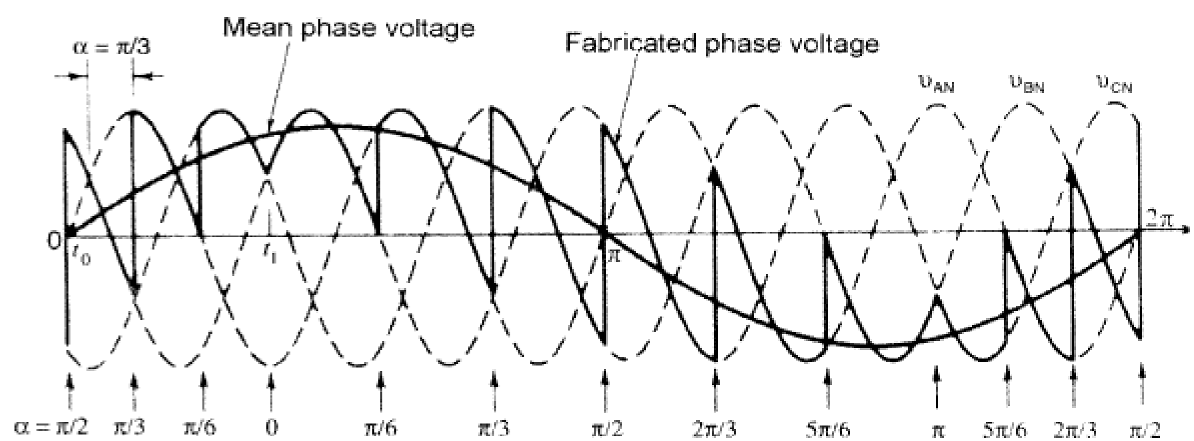
- V_m => Peak value supply voltage
- V_{ac} => RMS value of o/p voltage



3ϕ to 1ϕ Cycloconverter

- 3 pulse configuration
- α variation is 90, 60,30,0, 30, 60, 90, 120, 150, 180, 150, 120 and 90 in cyclic manner
- AC o/p voltage is given by
- $V_{ac} = (3\sqrt{3}\ V_{mp}\ \mathrm{Cos}\ \alpha_{1min})/\sqrt{2}\ 2\pi$





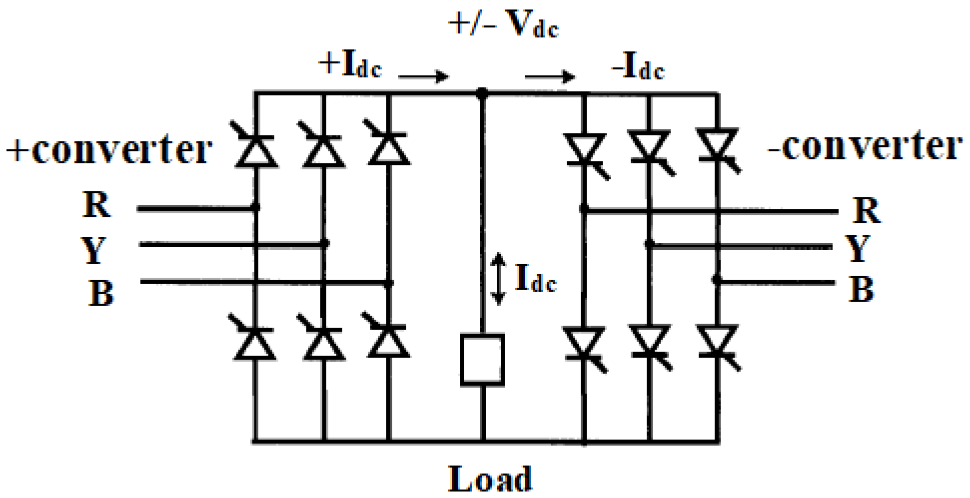
3ϕ to 1ϕ Cycloconverter

- 6 pulse converter groups
- Firing angle of the converter are continuously varied to obtain low frequency ac at the o/p.
- Cyclic variation of α is

$$90^0 \longrightarrow 0^0 \longrightarrow 90^0 \longrightarrow 180^0 \longrightarrow 90^0$$

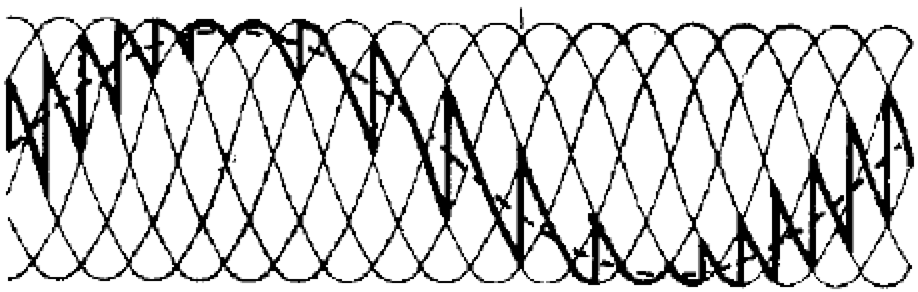
AC o/p voltage is given by

$$V_{ac} = \frac{3\,V_{ml}}{\sqrt{2}\,\pi}\ \mathrm{Cos}\ \alpha_{1\min}$$

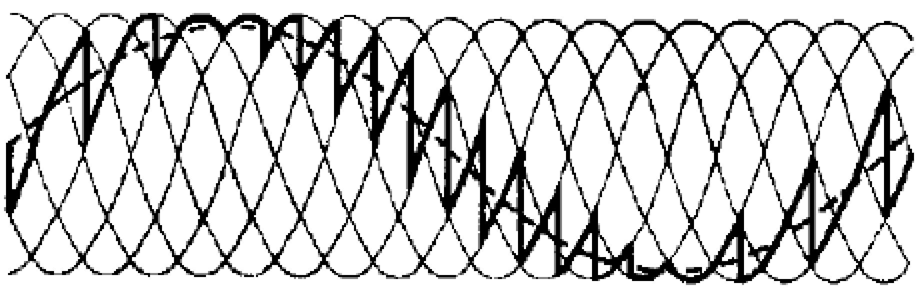


3ϕ to 1ϕ Cycloconverter

- o/p voltage waveform



+Ve group o/p voltage



-Ve group o/p voltage

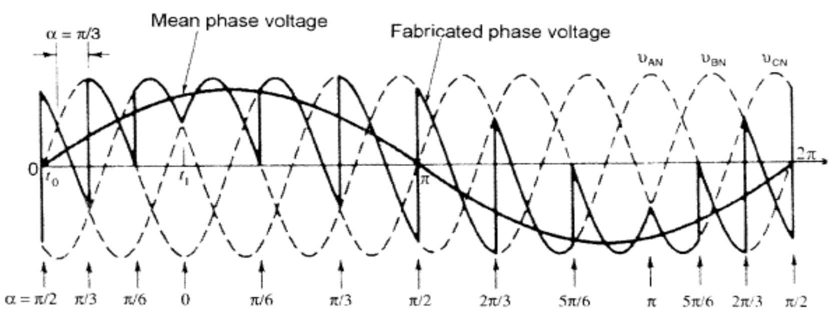
3ϕ to 3ϕ Cycloconverter

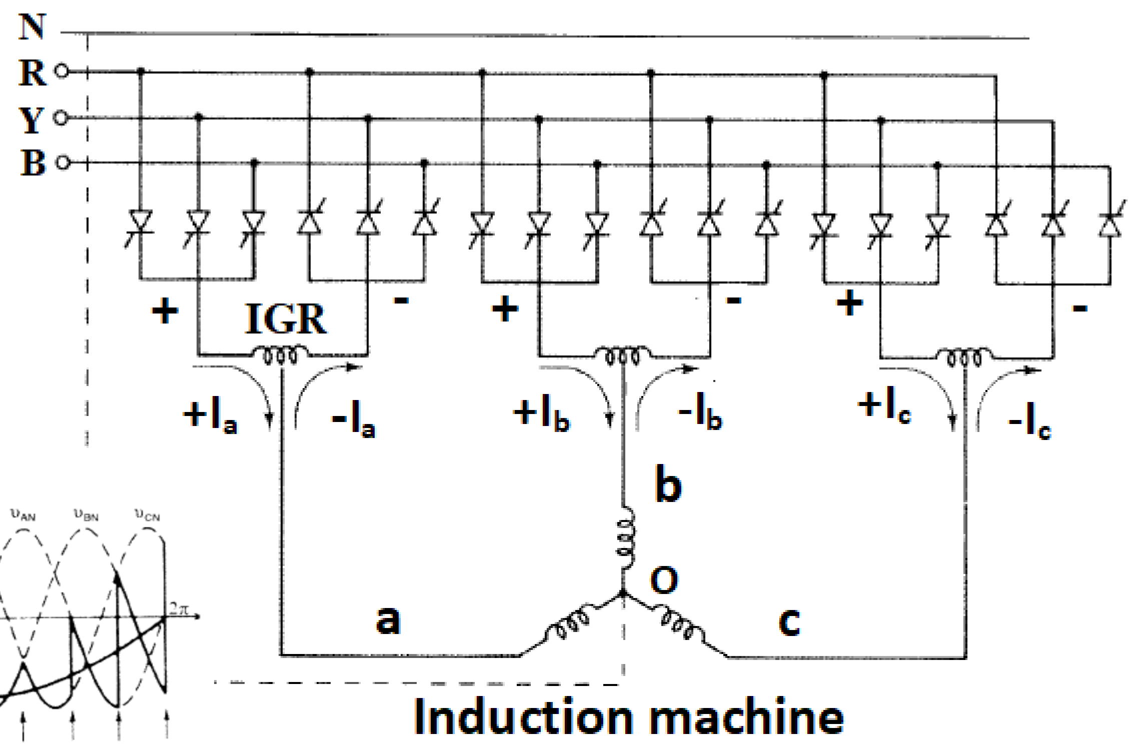
- 3ϕ to 3ϕ Cycloconverter consists of 3 numbers of 3ϕ to 1ϕ Cycloconverter.
- 3 numbers of 3ϕ to 1ϕ Cycloconverter produces 3 ac o/p which has 120^0 phase shift

- Two circuit configurations for 3ϕ to 3ϕ Cycloconverter
- +ve /-ve group using 3 pulse converter group
- +ve /-ve group using 6 pulse converter group

3ϕ to 3ϕ Cycloconverter

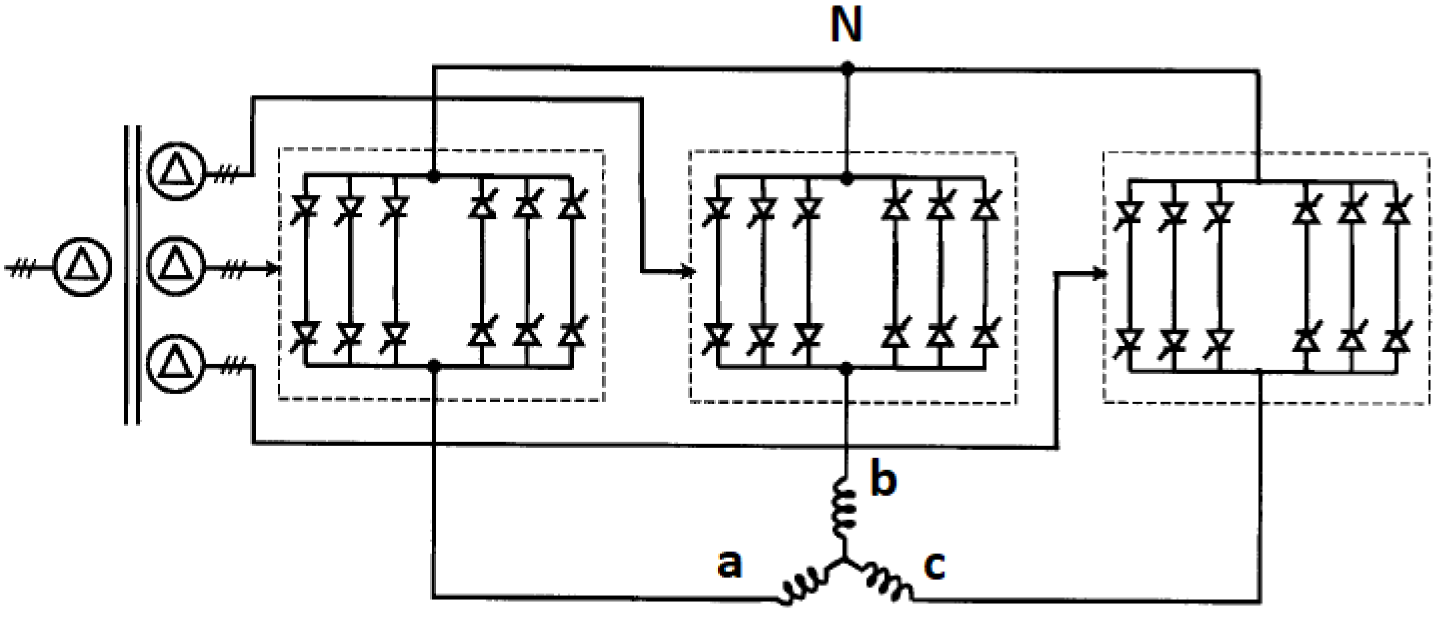
- Using 3 pulse converter





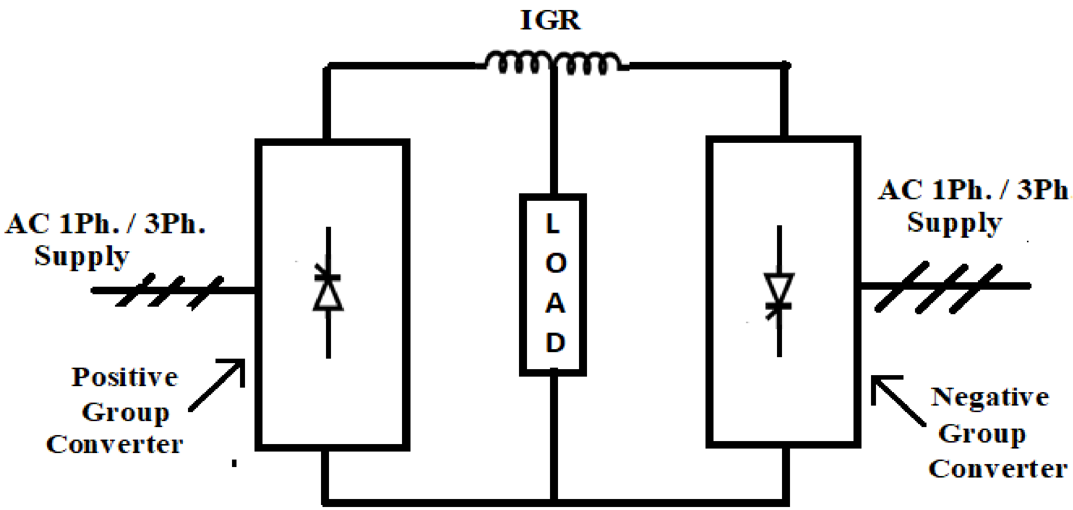
3ϕ to 3ϕ Cycloconverter

- Using 6 pulse converter with non circulating current mode



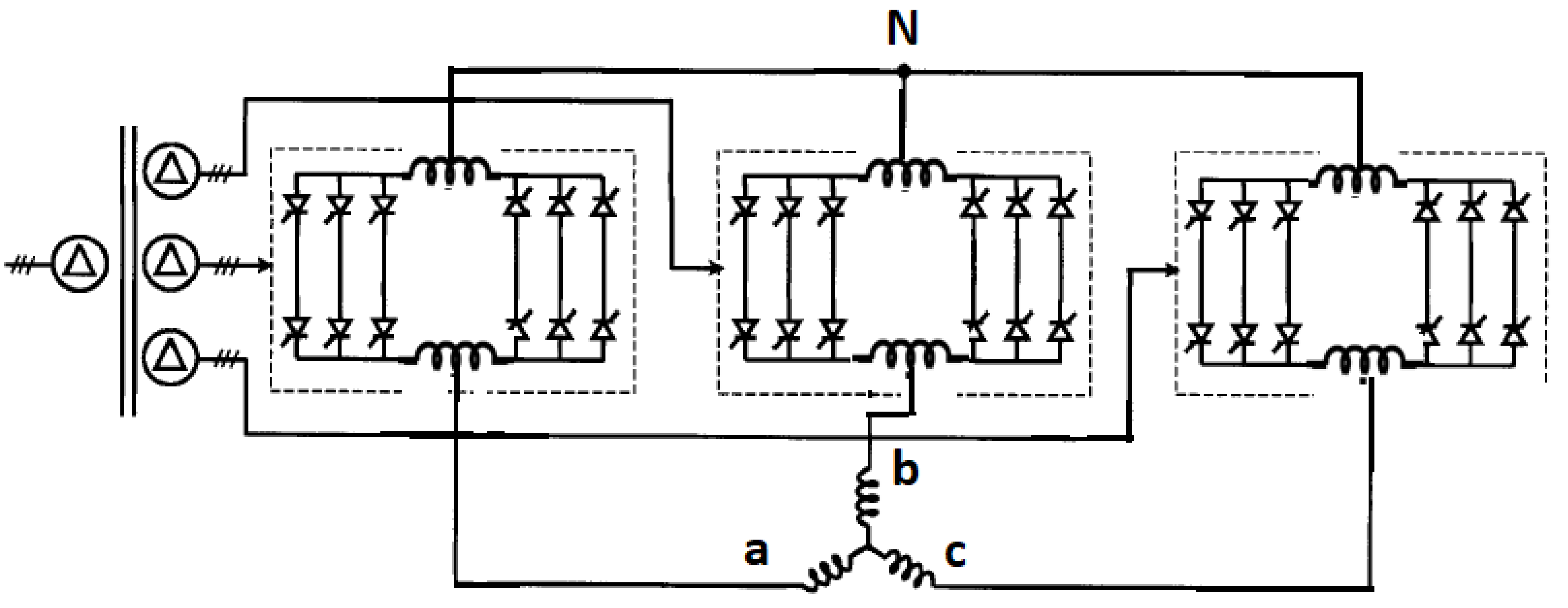
Circulating current Mode

- Both converter groups are simultaneously ON.
- Average voltage provided by both groups is same but instantaneous voltages are different
- To reduce circulating current IGR is required



3ϕ to 3ϕ Cycloconverter

- Using 6 pulse converter with circulating current mode



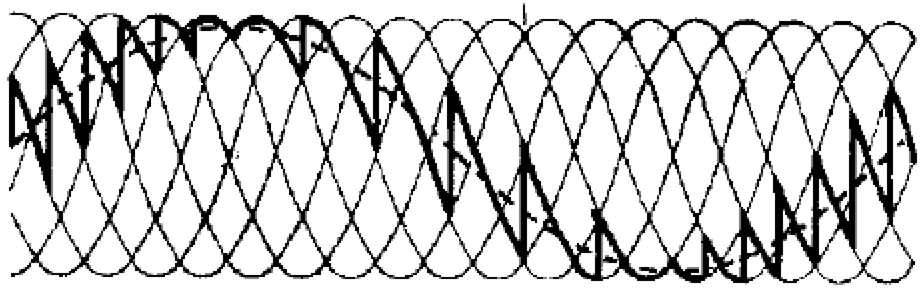
3ϕ to 3ϕ Cycloconverter

- O/P Voltage :

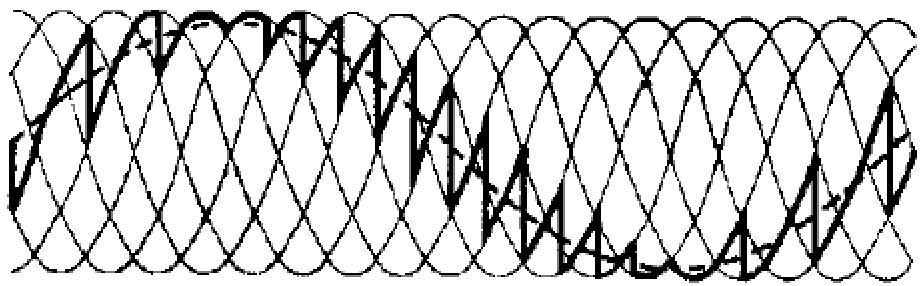
  Circulating

  Current

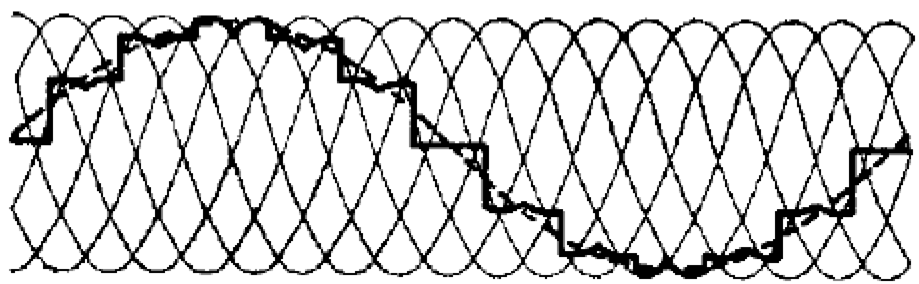
  Mode



+Ve group o/p voltage



-Ve group o/p voltage



Load o/p voltage

Circulating Current Mode

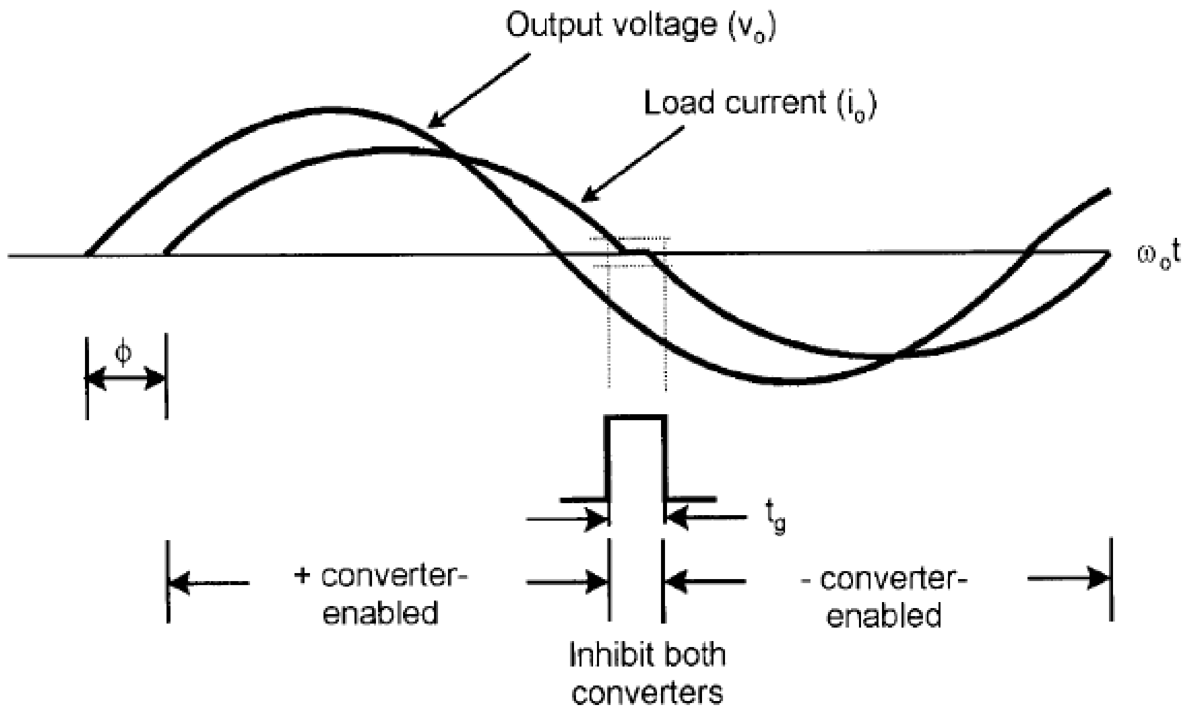
- Advantages as compared to non circulating current mode
- O/P voltage has less harmonics.
- Frequency range is higher
- Less sub harmonics in the load
- Control is simple
- Less harmonics are injected into the supply
- Line displacement power factor can be controlled

Circulating Current Mode

- Disadvantages as compared to non circulating current mode
- Bulky IGR increases losses and cost
- Circulating current increases additional loading to Thyristors and increase in losses in the devices
- Overdesign increases cost

Non circulating current mode

- Positive group provides +ve current to the load
- Negative group provides –ve current to the load



Cycloconverter Applications

- Multi megawatt low speed IM and synchronous motor drives for following applications
- Cement and Ball mill drives
- Rolling mill drives
- Slip power recovery scherbius drives
- Variable speed constant frequency power generation for aircraft

THANKS !

Any Questions?