Bhartiya Instituite of Engineering & Technology, Sikar

ELECTRICAL DRIVES & THEIR CONTROL

LAB MANUAL
OF
ELECTRICAL DRIVES & THEIR CONTROL

DO’S

- Maintain strict discipline.
- Proper handling of apparatus must be done.
- Before switching on the power supply get it checked by the lecturer.
- Switch off your mobile.
- Be a keen observer while performing the experiment

DONT’S

- Do not touch or attempt to touch the mains power directly with bare hands.
- Do not manipulate the experiment results.
- Do not overcrowd the tables.
- Do not tamper with equipment’s.
- Do not leave the lab without prior permission from the teacher.

INSTRUCTIONS TO THE STUDENTS

GENERAL INSTRUCTIONS

- Maintain separate observation copy for each laboratory.
- Observations or readings should be taken only in the observation copy.
- Get the readings counter signed by the faculty after the completion of the experiment.
- Maintain Index column in the observation copy and get the signature of the faculty before leaving the lab.

BEFORE ENTERING THE LAB

- The previous experiment should have been written in the practical file, without which the students will not be allowed to enter the lab.
- The students should have written the experiment in the observation copy that they are supposed to perform in the lab.
- The experiment written in the observation copy should have aim, apparatus required, circuit diagram/algorithm, blank observation table (if any), formula (if any), programme (if any), model graph (if any) and space for result.

WHEN WORKING IN THE LAB

- Necessary equipment's/apparatus should be taken only from the lab assistant by making an issuing slip, which would contain name of the experiment, names of batch members and apparatus or components required.
- Never switch on the power supply before getting the permission from the faculty.

BEFORE LEAVING THE LAB

- The equipment's/components should be returned back to the lab assistant in good condition after the completion of the experiment.
- The students should get the signature from the faculty in the observation copy.

They should also check whether their file is checked and counter signed in the index

8EE6 ELECTRICAL DRIVES AND CONTROL LAB

1. Study and test the firing circuit of three phase half controlled bridge converter.
2. Study and obtain waveforms of 3 phase half controlled bridge converter with R and RL loads.
3. Study and test the firing circuit of 3-phase full controlled bridge converter.
4. Study and obtain waveforms of 3-phase full controlled bridge converter with R and RL loads.
5. Study and test 3-phase AC voltage regulator.
6. Control speed of dc motor using 3-phase half controlled bridge converter. Plot armature voltage versus speed characteristic.
7. Control speed of dc motor using 3-phase full controlled bridge converter. Plot armature voltage versus speed characteristic.
8. Control speed of a 3-phase induction motor in variable stator voltage mode using 3-phase AC voltage regulator.
9. Control speed of universal motor using AC voltage regulator.
10. Study 3-phase dual converter.
11. Study speed control of dc motor using 3-phase dual converter.
12. Study three-phase cycloconverter and speed control of synchronous motor using cycloconverter.
13. Control of 3-Phase Induction Motor in variable frequency V/f constant mode using 3-phase inverter.

EXPERIMENT NO. -1

AIM: study and test the firing circuit of three phase half controlled bridge converter.

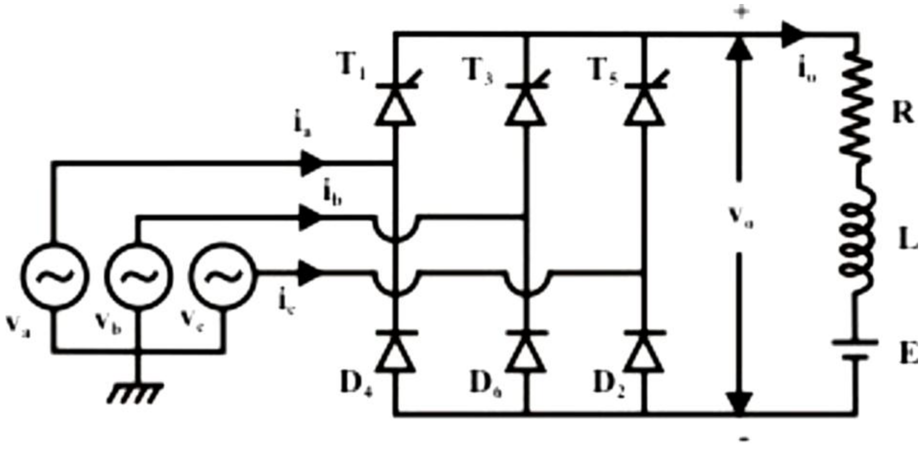
APPARATUS:

1. 3-Phase half controlled bridge converter.
2. C.R.O
3. Connecting leads.

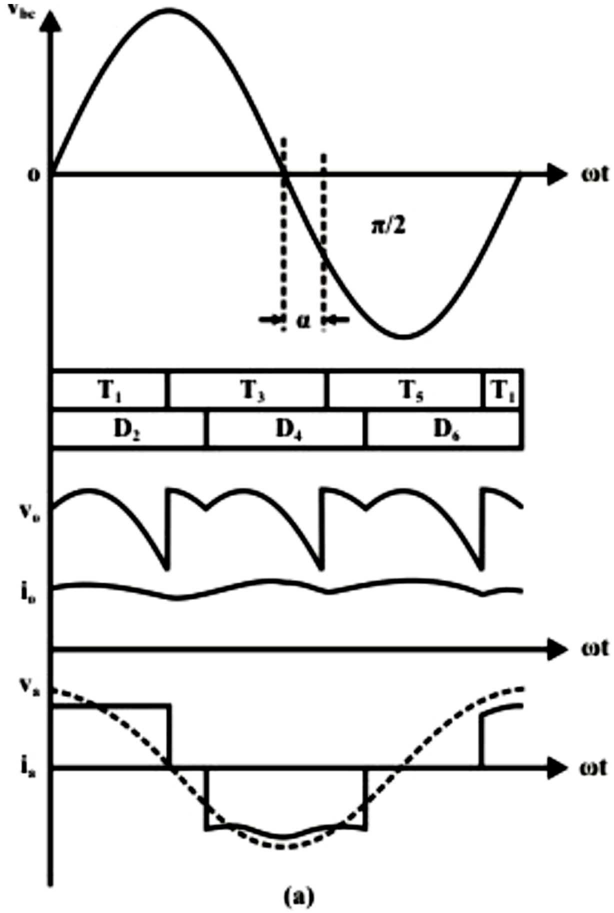
BASIC CONCEPT:

- Three phase fully controlled converters are very popular in many industrial applications particularly in situations where power regeneration from the dc side is essential. It can handle reasonably high power and has acceptable input and output harmonic distortion. The configuration also lends itself to easy series and parallel connection for increasing voltage and current rating or improvement in harmonic behavior.
- However, this versatility of a three phase fully controlled converters are obtained at the cost of increased circuit complexity due to the use of six thyristors and their associated control circuit. This complexity can be considerably reduced in applications where power regeneration is not necessary.The three phase half controlled converter has several other advantages over a three phase fully controlled converter.
- For the same firing angle it has lower input side displacement factor compared to a fully controlled converter. It also extends the range of continuous conduction of the converter. It has one serious disadvantage however.
- The output voltage is periodic over one third of the input cycle rather than one sixth as is the case with fully controlled converters. This implies both input and output harmonics are of lower frequency and require heavier filtering. For this reason half controlled three phase converters are not as popular as their fully controlled counterpart.
- Although, from the point of view of construction and circuit complexity the half controlled converter is simpler compared to the fully controlled converter, its analysis is considerably more difficult.

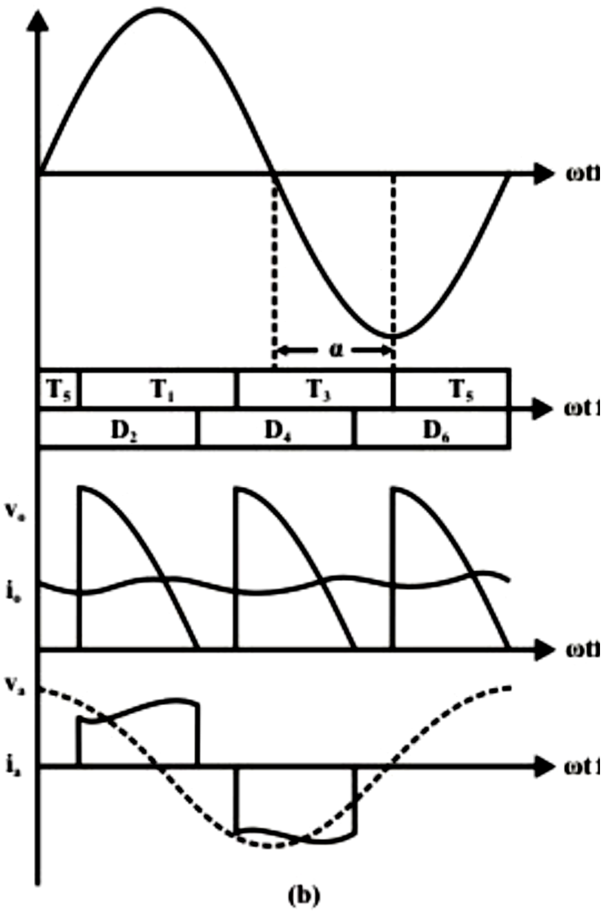
CIRCUIT DIAGRAM:



(a)



(a)



(b)

CALCULATION:

Consider conduction of T_1. The firing sequence of the thyristor is $T_1 \rightarrow T_3 \rightarrow T_5$. Therefore before T_1 comes into conduction T_5 conducts and voltage across T_1 is $V_{ac} = \sqrt{2}V_l \sin(\omega t + \pi/3)$. If the firing angle of T_1 is α then T_1 starts conduction at $\omega t = \alpha - \pi/3$ and conducts upto $\alpha + \pi/3$. Similarly T_3 and T_5 conducts during $\alpha + \pi/3 \leq \omega t \leq \alpha + \pi$ and $\alpha + \pi \leq \omega t \leq 2\pi + \alpha - \pi/3$. From this discussion the following conduction diagrams can be drawn for continuous conduction mode.

The waveforms of v_0 and i_0 (for $\alpha < \pi/3$ and $\alpha > \pi/3$) both of which are periodic over one third of the input voltage time period. Therefore examining v_0 for the conduction period of any one thyristor (for example T_1) will be sufficient to deduce information regarding output voltage.

T_1 conducting there can be three conduction modes namely, T_1D_6, T_1D_2 and T_1D_4.

Now, T_1 conducts in the interval $\alpha - \pi/3 \leq wt \leq \alpha + \pi/3$

D_2 conducts in the interval $0 \leq wt \leq 2\pi/3$

D_4 conducts in the interval $2\pi/3 \leq wt \leq 4\pi/3$

D_6 conducts in the interval $4\pi/3 \leq wt \leq 2\pi$

∴ Conduction interval T_1D_6 exists only if $\alpha \leq \pi/3$

Conduction interval T_1D_4 exists only if $\alpha > \pi/3$

So for $\alpha \leq \pi/3$

In the interval $\alpha - \pi/3 \leq wt \leq 0$

RMS value of v_0 can be found in a similar manner and is left as an exercise.

From the waveforms of Fig. 14.2, v_0 is periodic over one third of the input cycle. Therefore one can write.

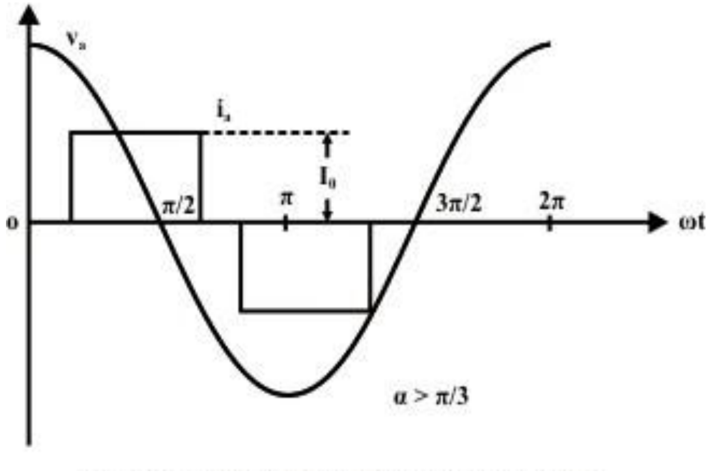
$$Vo = Vo + \sum_{n=1}^{\alpha} [\, VAn \cos 3n\omega t \; + \; VBn \sin 3n\omega t]$$

$$V_{An} = \frac{3}{\pi} \int_{\alpha-\frac{\pi}{3}}^{\alpha+\frac{\pi}{3}} Vo \cos 3nwt \; dwt$$

$$V_{Bn} = \frac{3}{\pi} \int_{\alpha-\frac{\pi}{3}}^{\alpha+\frac{\pi}{3}} Vo \, s\, in 3nwt \; dwt \, \frac{\pi}{2}$$

Similar analysis can be done for $\alpha > \pi/3$

The Fourier series of the input ac line current the load may be replaced by a constant current source having the same value as the average load current. This approximation will be valid provided the load current ripple is relatively small. With this assumption the last waveformof Fig. 14.2(b) can be redrawn as follows.



RESULT : Hence, we study and test the firing circuit of three phase half controlled bridge converter.

EXPERIMENT NO. -2

AIM: Study and obtain waveforms of 3-phase half controlled bridge converter with R and RL and loads.

APPARATUS:

1. 3-Phase half controlled bridge converter.
2. C.R.O
3. Connecting leads.

BASIC CONCEPT:

- Three phase fully controlled converters are very popular in many industrial applications particularly in situations where power regeneration from the dc side is essential. It can handle reasonably high power and has acceptable input and output harmonic distortion.
- The configuration also lends itself to easy series and parallel connection for increasing voltage and current rating or improvement in harmonic behavior. However, this versatility of a three phase fully controlled converters are obtained at the cost of increased circuit complexity due to the use of six thyristors and their associated control circuit. This complexity can be considerably reduced in applications where power regeneration is not necessary.
- The three phase half controlled converter has several other advantages over a three phase fully controlled converter. For the same firing angle it has lower input side displacement factor compared to a fully controlled converter. It also extends the range of continuous conduction of the converter.
- It has one serious disadvantage however. The output voltage is periodic over one third of the input cycle rather than one sixth as is the case with fully controlled converters. This implies both input and output harmonics are of lower frequency and require heavier filtering. For this reason half controlled three phase converters are not as popular as their fully controlled counterpart.

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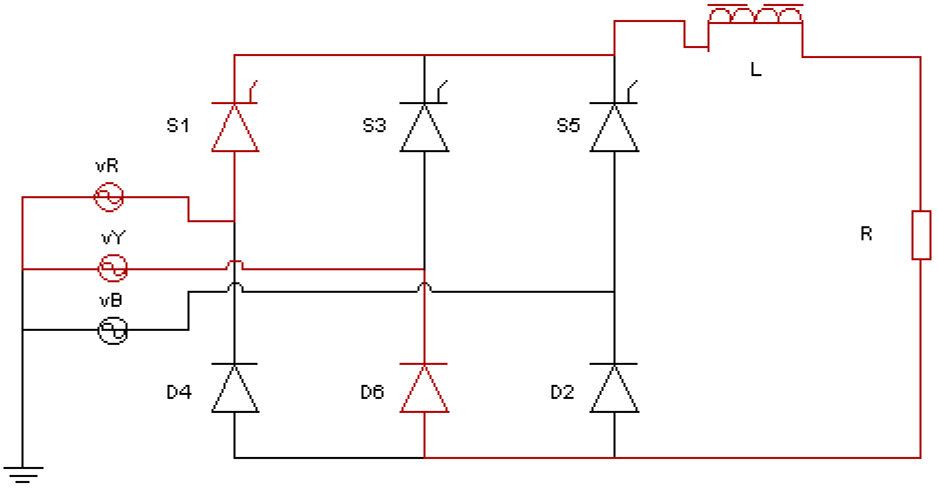
CIRCUIT DIAGRAM:



SEMI-CONTROLLED THREE-PHASE BRIDGE RECTIFIER

CALCULATION:

Consider conduction of T_1. The firing sequence of the thyristor is $T_1 \rightarrow T_3 \rightarrow T_5$. Therefore before T_1 comes into conduction T_5 conducts and voltage across T_1 is $Vac = \sqrt{2}Vl\sin(\omega t + \pi/3)$. If the firing angle of T_1 is α then T_1 starts conduction at $\omega t = \alpha - \pi/3$and conducts upto $\alpha + \pi/3$. Similarly T_3 and T_5 conducts during $\alpha + \pi/3 \leq \omega t \leq \alpha + \pi$ and $\alpha + \pi \leq \omega t \leq 2\pi + \alpha - \pi/3$. From this discussion the following conduction diagrams can be drawn for continuous conduction mode.The waveforms of v_0 and i_0 (for $\alpha < \pi/3$and $\alpha > \pi/3$) both of which are periodic over one third of the input voltage time period. Therefore examining v_0 for the conduction period of any one thyristor (for example T_1) will be sufficient to deduce information regarding output voltage.

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Conduction interval T_1D_4 exists only if $\alpha > \pi/3$

So for $\alpha \leq \pi/3$

In the interval $\alpha - \pi/3 \leq wt \leq 0$

RMS value of v_0 can be found in a similar manner and is left as an exercise.

From the waveforms of Fig. 14.2, v_0 is periodic over one third of the input cycle. Therefore one can write.

$$Vo = Vo + \sum_{n=1}^{\alpha}[\, VAn \cos 3n\omega t \;+\; VBn \sin 3n\omega t]$$

$$VAn = \frac{3}{\pi}\int_{\alpha-\frac{\pi}{3}}^{\alpha+\frac{\pi}{3}} Vo \cos 3nwt\ dwt$$

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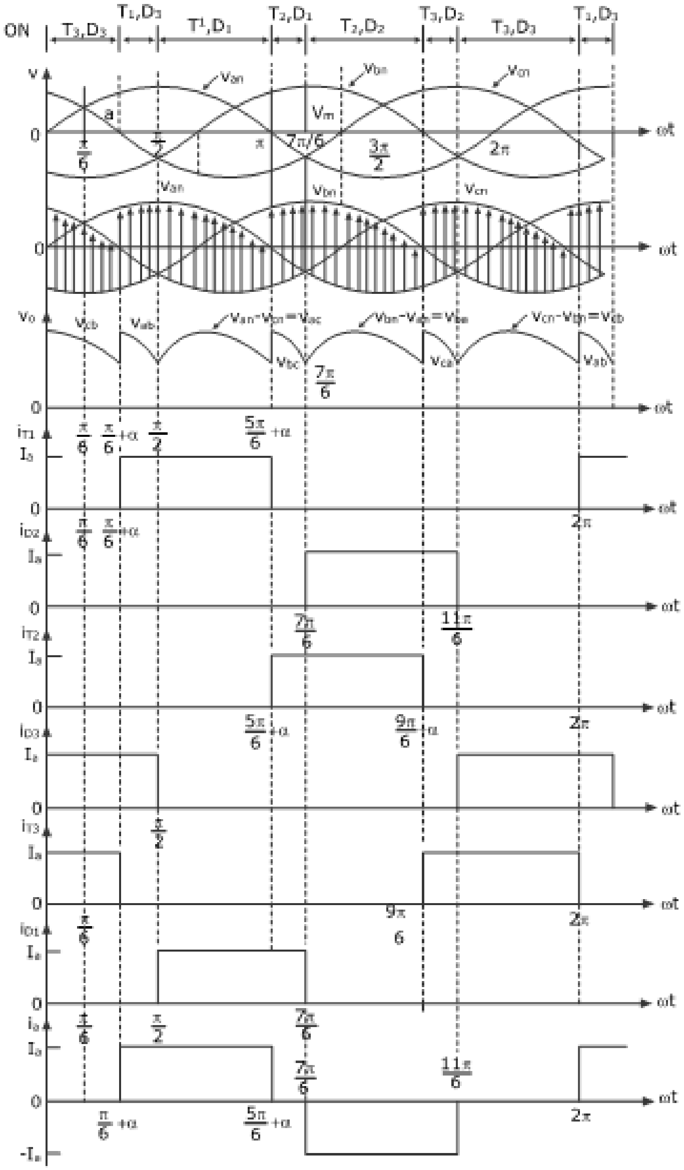
Similar analysis can be done for α > π/3



The Fourier series of the input ac line current the load may be replaced by a constant current source having the same value as the average load current. This approximation will be valid provided the load current ripple is relatively small. With this assumption the last waveform of Fig. 14.2(b) can be redrawn as follows.

RESULT : Hence, we study and obtain waveforms of 3-phase half controlled bridge converter with R and RL and loads.

EXPERIMENT NO. -3

AIM: Study andTest the firing circuit of Three Phase Full Controlled Bridge Converter.

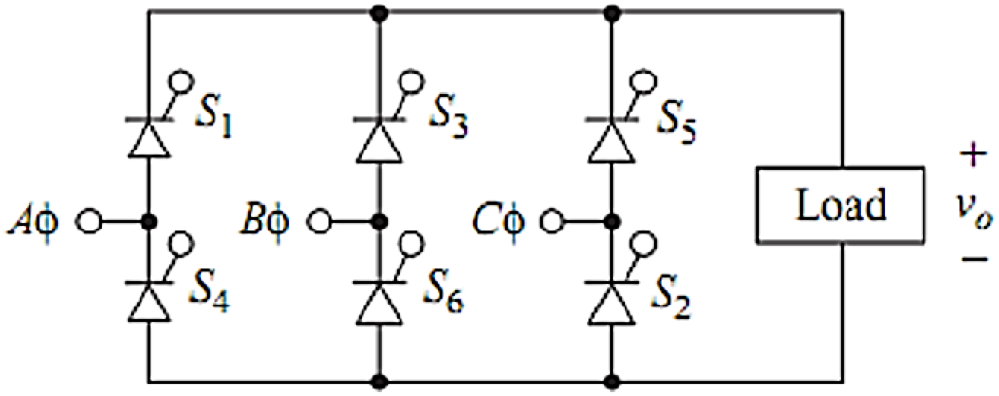
APPARATUS:

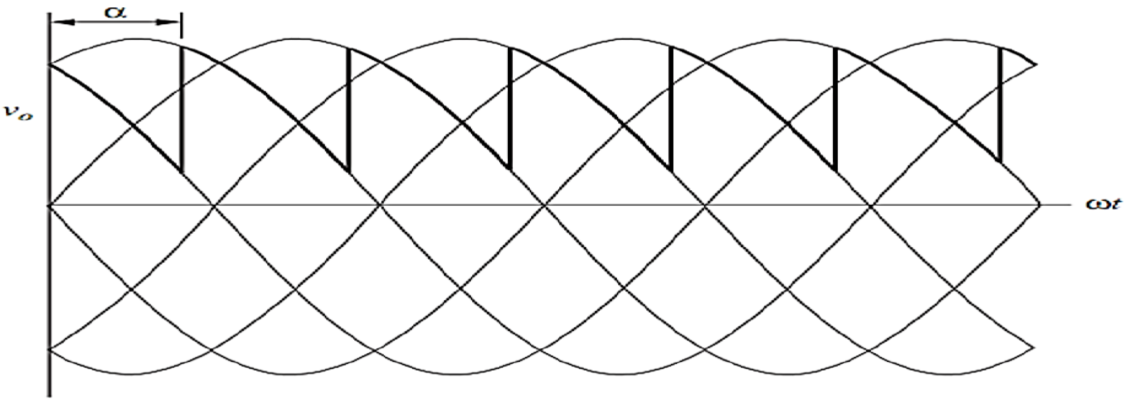
1. 3-Phase full controlled bridge converter.
2. C.R.O
3. Connecting leads.

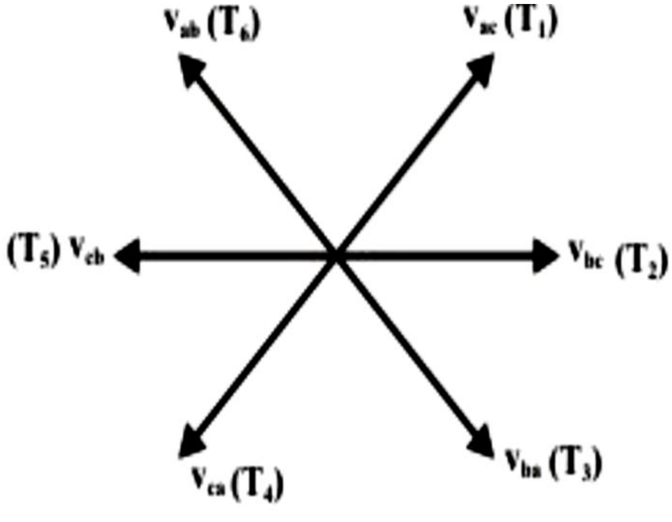
BASIC CONCEPT:

- The three phase fully controlled bridge converter has been probably the most widely used power electronic converter in the medium to high power applications. Three phase circuits are preferable when large power is involved. The controlled rectifier can provide controllable out put dc voltage in a single unit instead of a three phase autotransformer and a diode bridge rectifier.
- The controlled rectifier is obtained by replacing the diodes of the uncontrolled rectifier with thyristors. Control over the output dc voltage is obtained by controlling the conduction interval of each thyristor. This method is known as phase control and converters are also called “phase controlled converters”.
- A three phase fully controlled converter is obtained by replacing all the six diodes of an uncontrolled converter by six thyristors as shown in Fig. (1)
- The control circuit become considerably complicated and the use of coupling transformer and / or inter phase reactors become mandatory.
- With the introduction of high power IGBTs the three phase bridge converter has all but been replaced by dc link voltage source converters in the medium to moderately high power range.
- However in very high power application (such as HV dc transmission system, cycloconverter drives, load commutated inverter synchronous motor drives, static scherbius drives etc.) the basic B phase bridge converter block is still used. In this lesson the operating principle and characteristic of this very important converter topology will be discussed in source depth.

CIRCUIT DIAGRAM:

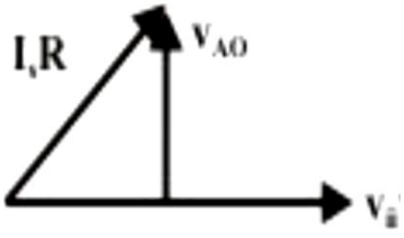






(c)

FIRING CIRCUIT:



(b)

- In the circuit of Fig. 13.6(a) a phase shift network is used to obtain a waveform leading v_i by 90º. The phasor diagram of the phase shift circuit is shown in Fig. 13.6(b). The output of the phase shift waveform (and its inverse) is compared with v_c. The firing pulse is generated at the point when these two waveforms are equal.
- Therefore this method of generation of converter firing pulses is called “inverse cosine” control. The output of the phase shift network is called carrier waveform.

RESULT : Hence, we study and test the firing circuit of three phase full controlled bridge converter.

EXPERIMENT NO. -4

AIM: Study and obtain waveforms of 3-phase full controlled bridge converter with R and RL and loads.

APPARATUS:

1. 3-Phase full controlled bridge converter.
2. C.R.O
3. Connecting leads.

BASIC CONCEPT:

- The three phase fully controlled bridge converter has been probably the most widely used power electronic converter in the medium to high power applications. Three phase circuits are preferable when large power is involved.
- The controlled rectifier can provide controllable out put dc voltage in a single unit instead of a three phase autotransformer and a diode bridge rectifier. The controlled rectifier is obtained by replacing the diodes of the uncontrolled rectifier with thyristors. Control over the output dc voltage is obtained by controlling the conduction interval of each thyristor. This method is known as phase control and converters are also called "phase controlled converters".
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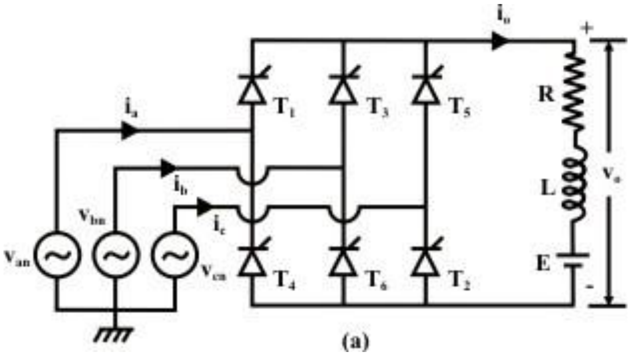
- With the introduction of high power IGBTs the three phase bridge converter has all but been replaced by dc link voltage source converters in the medium to moderately high power range. However in very high power application (such as HV dc transmission system, cycloconverter drives, load commutated inverter synchronous motor drives, static scherbius drives etc.) the basic B phase bridge converter block is still used. In this

lesson the operating principle and characteristic of this very important converter topology will be discussed in source depth.

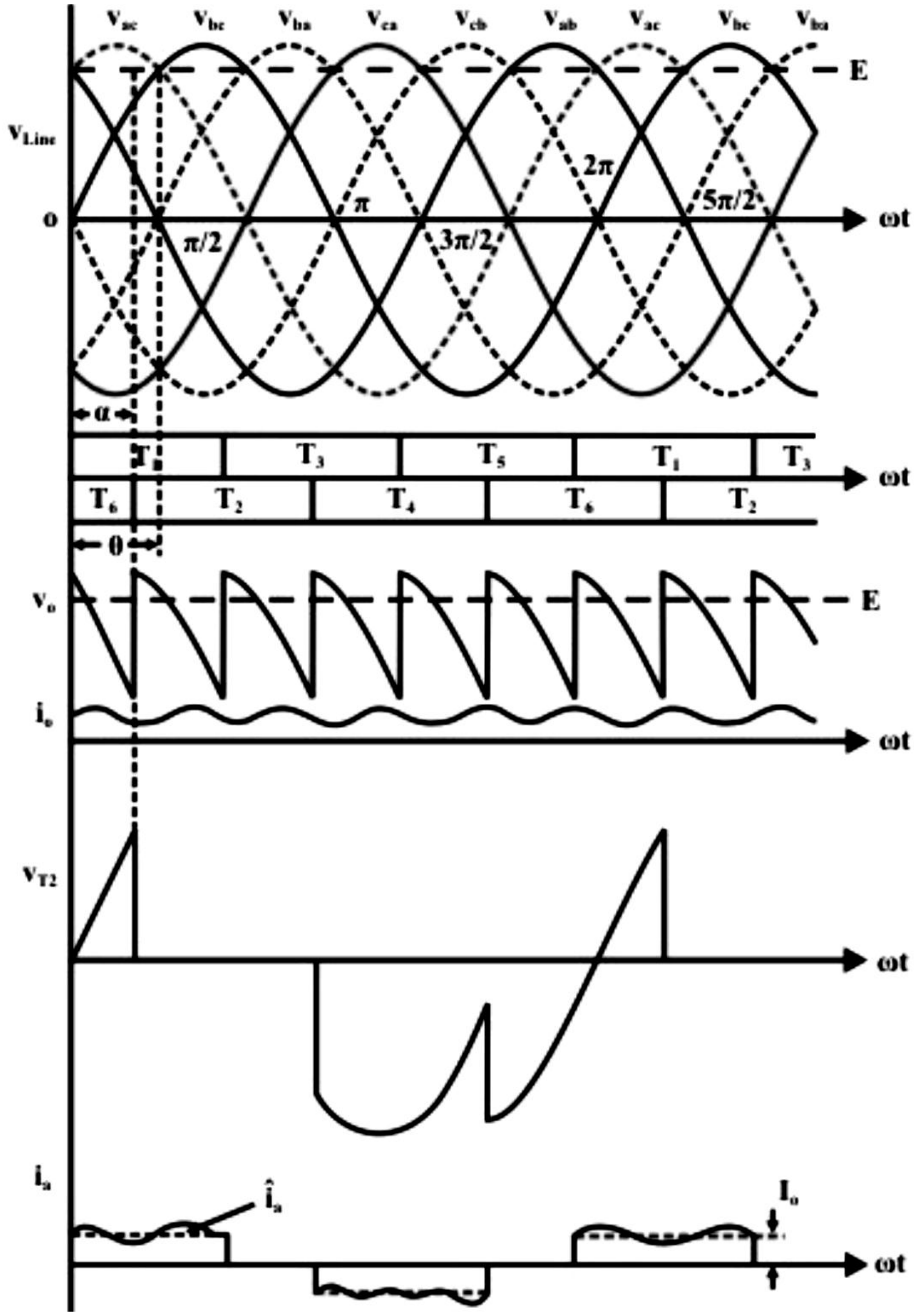
CIRCUIT DIAGRAM:



(a)

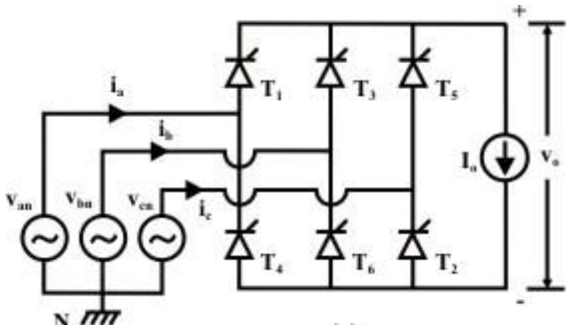
- For any current to flow in the load at least one device from the top group (T_1, T_3, T_5) and one from the bottom group (T_2, T_4, T_6) must conduct. It can be argued as in the case of an uncontrolled converter only one device from these two groups will conduct.
- Then from symmetry consideration it can be argued that each thyristor conducts for 120° of the input cycle. Now the thyristors are fired in the sequence $T_1 \rightarrow T_2 \rightarrow T_3 \rightarrow T_4 \rightarrow T_5 \rightarrow T_6 \rightarrow T_1$ with 60° interval between each firing. Therefore thyristors on the same phase leg are fired at an interval of 180° and hence can not conduct simultaneously.
- This leaves only six possible conduction mode for the converter in the continuous conduction mode of operation. These are T_1T_2, T_2T_3, T_3T_4, T_4T_5, T_5T_6, T_6T_1. Each conduction mode is of 60° duration and appears in the sequence mentioned. The conduction table of Fig. 13.1 (b) shows voltage across different devices and the dc output voltage for each conduction interval. The phasor diagram of the line voltages appear in Fig. 13.1 (c).
- Each of these line voltages can be associated with the firing of a thyristor with the help of the conduction table-1. For example the thyristor T_1 is fired at the end of T_5T_6

conduction interval. During this period the voltage across T_1 was v_{ac}. Therefore T_1 is fired α angle after the positive going zero crossing of v_{ac}. Similar observation can be made about other thyristors. The phasor diagram of Fig. 13.1 (c) also confirms that all the thyristors are fired in the correct sequence with 60° interval between each firing.

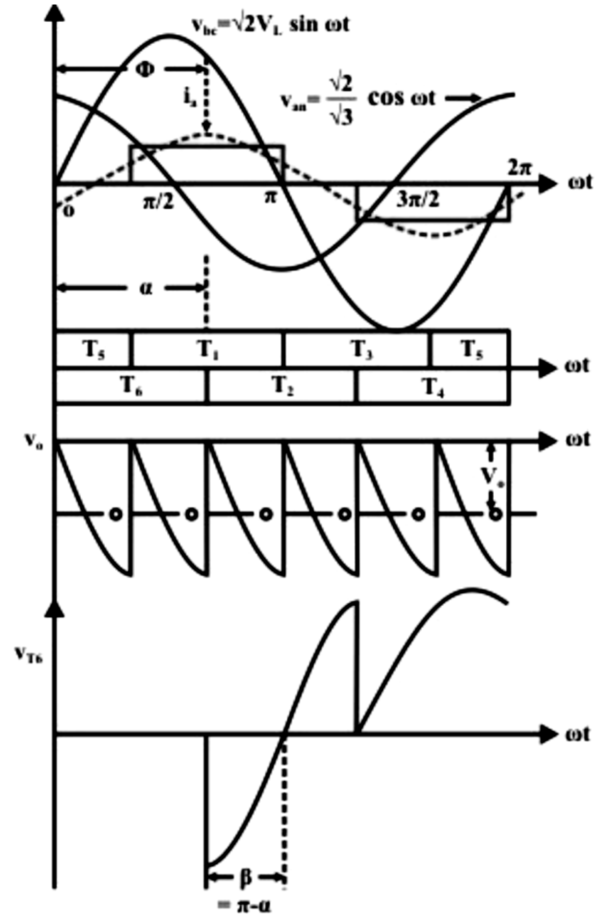


The converter in the inverting mode:

The circuit connection and wave forms in the inverting mode of operation where the load current has been assumed to be continuous and ripple free.



(a)



RESULT : Hence, we study and obtain waveforms of 3-phase full controlled bridge converter with R and RL and loads.

EXPERIMENT NO. -5

AIM: Study and test 3-phase AC voltage regulator.

APPARATUS:

1. Three-phase, Three-wire AC Regulator
2. C.R.O
3. Connecting leads.

BASIC CONCEPT:

There are many types of circuits used for the three-phase ac regulators (ac to ac voltage converters), unlike single-phase ones. The three-phase loads (balanced) are connected in star or delta. Two thyristors connected back to back, or a triac, is used for each phase in most of the circuits as described. Two circuits are first taken up, both with balanced resistive (R) load.

Three-phase, Three-wire AC Regulator with Balanced Resistive Load

- The circuit of a three-phase, three-wire ac regulator (termed as ac to ac voltage converter) with balanced resistive (star-connected) load .It may be noted that the resistance connected in all three phases are equal.
- Two thyristors connected back to back are used per phase, thus needing a total of six thyristors. Please note the numbering scheme, which is same as that used in a three-phase full-wave bridge converter or inverter.
- The thyristors are fired in sequence starting from 1 in ascending order, with the angle between the triggering of thyristors 1 & 2 being (one-sixth of the time period of a complete cycle).
- The line frequency is 50 Hz, with $f=1/T=$ 20 ms. The thyristors are fired or triggered after a delay of α from the natural commutation point. The natural commutation point is the starting of a cycle with period of output voltage waveform, if six thyristors are replaced by diodes. Note that the output voltage is similar to phase-controlled waveform for a converter, with the difference that it is an ac waveform in this case.

- The current flow is bidirectional, with the current in one direction in the positive half, and then, in other (opposite) direction in the negative half. So, two thyristors connected back to back are needed in each phase.
- The turning off of a thyristor occurs, if its current falls to zero. To turn the thyristor on, the anode voltage must be higher that the cathode voltage, and also, a triggering signal must be applied at its gate.

CIRCUIT DIAGRAM:

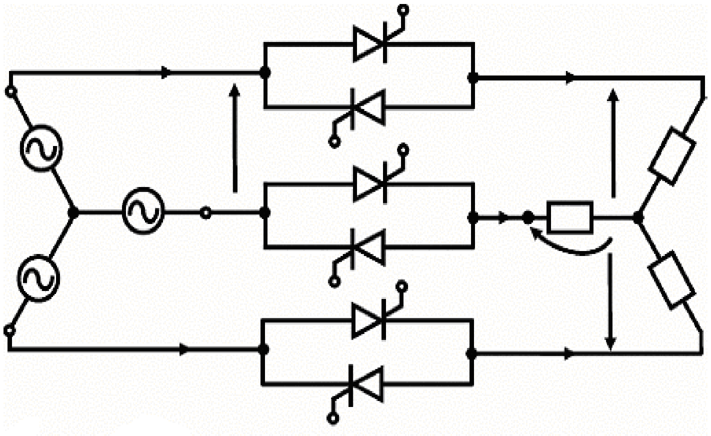


Fig.1 Three-phase, three-wire acregulator .

CALCULATION:

Balanced star-connected resistive load, which depends on range of firing angle, as shown later, is described. If is the rms value of the input voltage per phase, and assuming the voltage, as the reference, the instantaneous input voltages per phase are,

$$e_{AN}= \sqrt{2\ E_s \sin wt,}$$

$$e_{BN}= \sqrt{2\ E_s \sin(wt-120`),}$$

and

$$e_{CN}= \sqrt{2\ E_s \sin(wt+120`),}$$

Then, the instantaneous input line voltages are,

$$e_{AB}= \sqrt{6\ E_s \sin(wt+30`),}$$

$$e_{BC}= \sqrt{6\ E_s \sin(wt-90`),}$$

and

$$e_{AC}= \sqrt{6\ E_s \sin(wt+150`),}$$

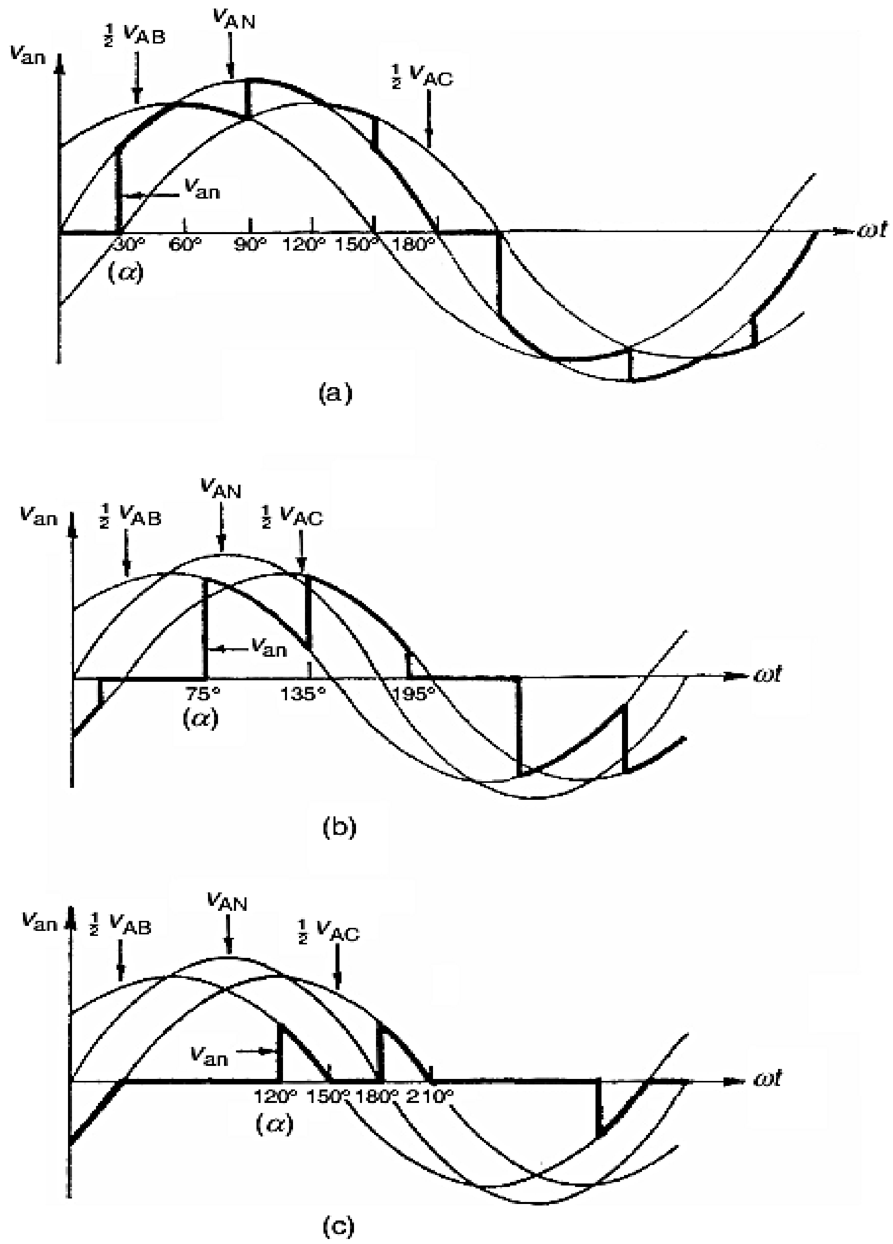


Fig.2 Waveforms for three-phase three-wire ac regulator at different firing angle

RESULT : Hence, we study and test 3-phase AC voltage regulator.

EXPERIMENT NO. – 8

AIM: Control speed of a 3-phase induction motor in variable stator voltage mode using 3-phase AC voltage regulator.

APPARATUS:

1. Three-phase AC voltage regulator.
2. C.R.O
3. Connecting leads.
4. Three-phase induction motor.

BASIC CONCEPT:

Three phase induction motors are admirably suited to fulfil the demand of loads requiring substantially a constant speed.. Several industrial applications,however,need adjustable speeds for their efficient operation. . The object of the present section is to describe the basic principles of speed control techniques employed to three phase induction motors through the use of power electronics converters. The various methods of speed control through semiconductor devices are as under:

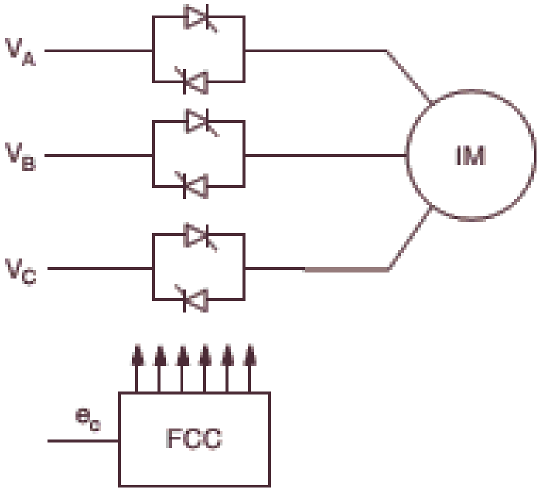
1. Stator Voltage Control.
2. Stator Frequency Control
3. Stator Voltage And Frequency Control.
4. Stator Current Control.
5. Rotor Voltage Control.
6. Voltage, Current And, Frequency Control.

STATOR VOLTAGE CONTROL:

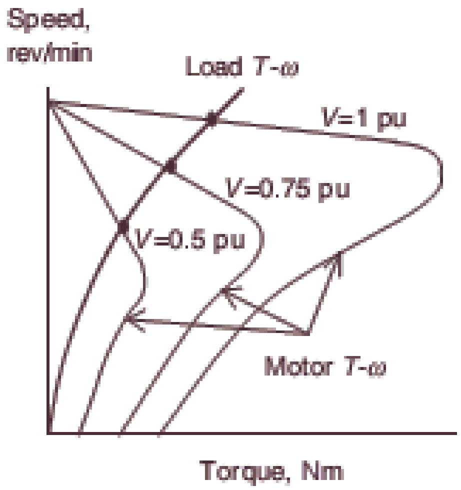
It is seen in eq. (1) that motor torque T_e is proportional to the square of the stator supply voltage. A reduction in the supply voltage will reduce the motor torque and therefore the speed of the drive . If the motor terminal voltage is reduced to KV1 where K < 1,then the motor torque is given by

$$\mathbf{T_e} = \frac{3}{w_s} \cdot \frac{(KV1)2}{\left(r1+\frac{r2}{s}\right)2+(x1+x2)2} \cdot \frac{r_2}{s} \quad \text{..................(1)}$$

CIRCUIT DIAGRAM:



(a)



(b)

CALCULATION:

Motor torque T_e is proportional to the square of the stator supply voltage. A reduction in the supply voltage will reduce the motor torque and therefore the speed of the drive . If the motor terminal voltage is reduced to KV1 where K < 1, then the motor torque is given by

$$\mathbf{T_e} = \frac{3}{w_s} \cdot \frac{(KV1)2}{\left(r1+\frac{r2}{s}\right)2+(x1+x2)2} \cdot \frac{r_2}{s} \quad \text{..................(2)}$$

RESULT: Hence, we study Control speed of a 3-phase induction motor in variable stator Voltage mode using 3-phase AC voltage regulator.

EXPERIMENT NO. -10

AIM: To study the three-phase dual converter.

APPARATUS:

1] 3-phase dual converter.

2] C.R.O

3] Connecting links.

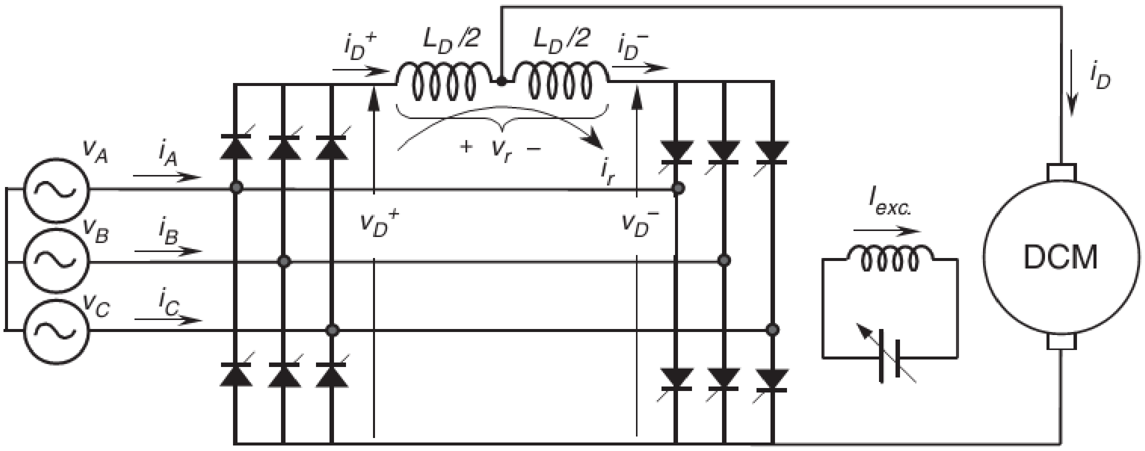
BASIC CONCEPT:

In case four quadrant operation is required without any mechanical changeover switch, two full converters can be connected back to back to the load ckt .Such an arrangement using two full converters in anti parallel and connected to the same DC load is called a DUAL CONVERTER.

There are two functional modes of a dual converter, one is non-circulating current mode and the other is circulating current. Non-circulating types of dual converters using single phase and three phase configuration.

The schematic dig. For a 3-phase dual converter dc drives is shown in fig(1).Converter 1 allows motor control in I and IV quadrants whereas with converter 2, the operation in II and III quadrants is obtained. The applications of dual converter are limited to about 2 MW drives. For reversing the polarity of motor generated emf for regeneration purposes, field ckt must be energized from single-phase or three-phase full converter.

CIRCUIT DIAGRAM:



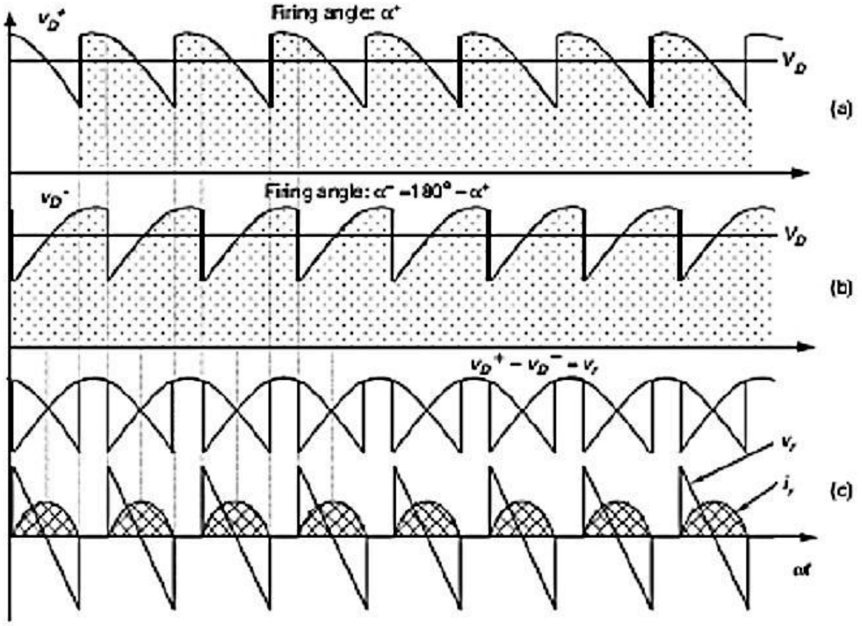


FIGURE Waveform of circulating current: (a) instantaneous *dc* voltage from positive converter: (b) instantaneous *dc* voltage from negative converter; and (c) voltage difference between v_D^+ and v_D^-, v_r, and circulating current i_r.

PROCEDURE:

For resistive load

1. Connect the 3 phase input supply in lagging sequence R,Y,B.

2. Connect three series lamp of 200W on back panel lamp holder.

3. keep speed pot at min. position.

4. Turn direction switch to forward position.

5. press start button and increase speed pot.

CALCULATION:

From the fig 1),

When converter 1, or 2, is in operation, average output voltage is

$V_o = V_t = 3V_{ml}\cos_{\alpha 1}/\pi$

for $0 \leq \alpha_1 \leq \pi$ ………………….(1)

With a 3 phase full converter in the field ckt,

$V_f = 3V_{ml}\cos\alpha f/\pi$

For $0 \leq \alpha f \leq \pi$ ………………….(2)

In case circulating current-type dual converter ,

$.\alpha_1 + \alpha_2 = 180$ degree

RESULT : Hence, we study the 3-phase dual converter.

EXPERIMENT NO. -12

AIM: Study 3- phase cycloconverter and speed control of synchronous motor using Cycloconverter.

APPARATUS:

1. Three-phase cycloconverter.
2. C.R.O
3. Connecting leads.

BASIC CONCEPT:

In a cyclo-converter, ac power at one frequency is converted directly to a Lower frequency in a single conversion stage.

There are two types of cycloconverter.

1. Three-phase to Single-phase Cyclo-converter.
2. Three-phase to Three-phase Cyclo-converter.

1.Three-phase to Single-phase Cyclo-converter

- The circuit of a three-phase to single-phase cyclo-converter is shown in Fig.. Two three-phase full-wave (six-pulse) bridge converters (rectifier) connected back to back, with six thyristors for each bridge, are used.
- The ripple frequency here is 300 Hz, six times the input frequency of 50 Hz. So, low value of load inductance is needed to make the current continuous, as compared to one using single-phase bridge converters described with ripple frequency of 100 Hz.
- Also, the non-circulating current mode of operation is used, where only one converter − bridge 1 (positive) or bridge 2 (negative), conducts at a time, but both converters do not conduct at the same time.
- It may be noted that each thyristor conducts i.e., one-third of one complete cycle, whereas a particular thyristor pair, say 1& 2 conduct i.e., one-sixth of a cycle. The thyristors conduct in pairs as stated, one (odd-numbered) thyristor in the top half and the

other (even-numbered) one in the bottom half in two different legs. Two thyristors in one leg are not allowed to conduct at a time, which will result in short circuit at the output terminals.

- The sequence of conduction of the thyristors is 1 & 6, 1 & 2, 3 & 2, and so on. When thyristor 1 is triggered, the conducting thyristor in top half, being reverse biased at that time, turns off. Similarly, when thyristor 2 is triggered, the conducting thyristor in bottom half, being reverse biased at that time turns off. This sequence is repeated in cyclic order. So, natural or line commutation takes place in this case.

CIRCUIT DIAGRAM:

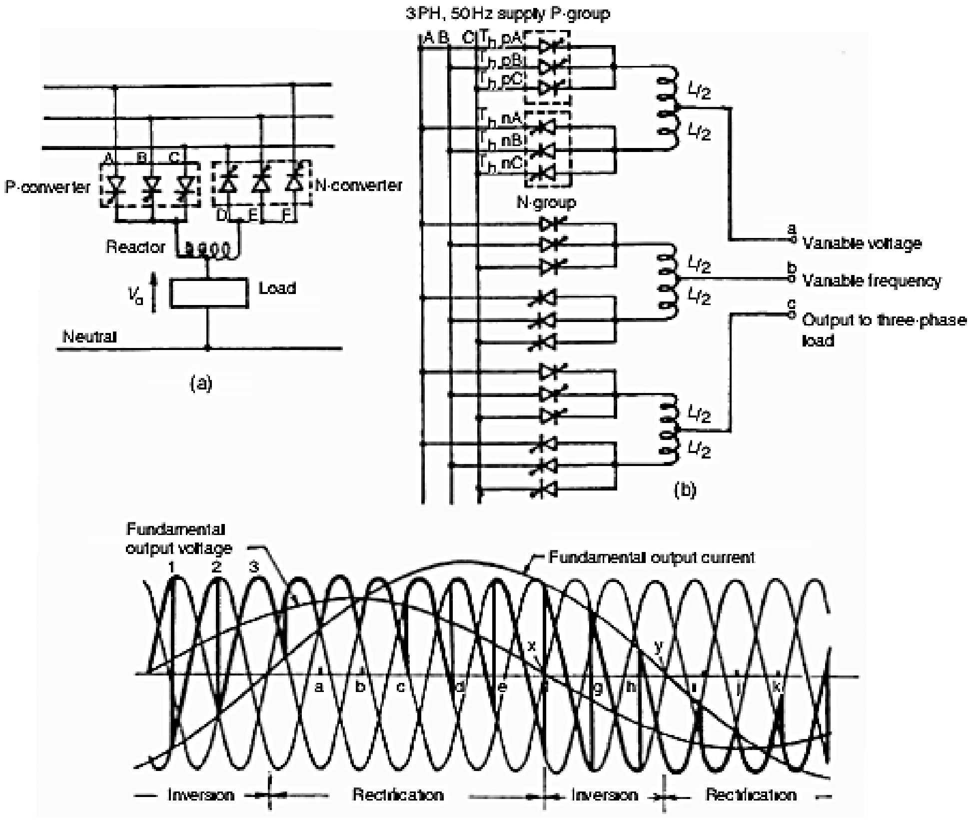


Fig.1: Three-phase to single-phase cycloconverter .

- The firing angle (α) of two converters is first decreased starting from the initial value of to the final value of , and then again increased to the final value of , as shown in.2. Also, for positive half cycle of the output voltage waveform, bridge 1 is used, while bridge 2 is used for negative half cycle. The two half cycles are combined to form one complete cycle of the output voltage, the frequency being decided by the number of half cycles of input voltage waveform used for each half cycle of the output. As more no. of segments of near the output voltage waveform becomes near sinusoidal, with its frequency also being reduced.

- The initial value of firing angle delay is kept at α1 ≈90`
- the points, M, N, O, P, Q, R & S, shown in Fig. 30.2. From these segments, the first quarter cycle of the output voltage waveform from to, is obtained. The second quarter cycle of the above waveform from to, is obtained, using the segments starting from the points, T, U, V, W, X &Y (fig. 30.2). It may be noted that the firing angle delay at the point, Y is 0°90°180°= α, and also the firing angle is increased from (T) to(Y) in this interval.
- the points, M, N, O, P, Q, R & S, shown in Fig. 2. From these segments, the first quarter cycle of the output voltage waveform from to, is obtained. The second quarter cycle of the above waveform from to, is obtained, using the segments starting from the points, T, U, V, W, X &Y (fig..2). It may be noted that the firing angle delay at the point, Y is 0°90°180°=α, and also the firing angle is increased from (T) to(Y) in this interval.

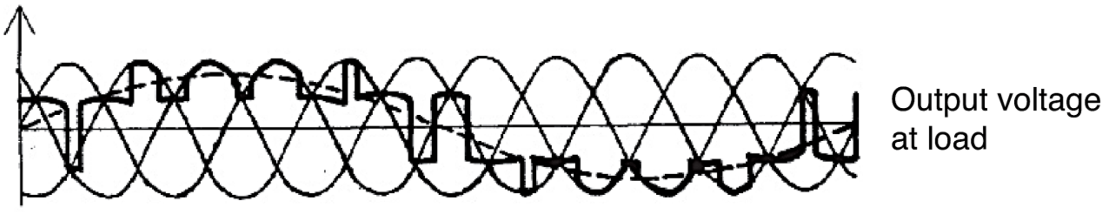


Fig.2 Output voltage waveforms for a three-phase to single phase cycloconverter .

2.Three-phase to Three-phase Cyclo-converter.

- The circuit of a three-phase to three-phase cyclo-converter is shown in Fig. 1.1. Two three-phase half-wave (three-pulse) converters connected back to back for each phase, with three thyristors for each bridge, are needed here. The total number of thyristors used is 18, thus reducing the cost of power components, and also of control circuits needed to generate the firing pulses for the thyristors, as described later.

- This may be compared to the case with 6 (six) three-phase full-wave (6-pulse) bridge converters, having six thyristors for each converter, with total devices used being 36. Though this will reduce the harmonic content in both output voltage and current waveforms, but is more costly.
- This may be used, where the total cost may be justified, along with the merit stated. The ripple frequency is 150 Hz, three times the input frequency of 50 Hz. In Fig. 1.1, the circulating current mode of operation is used, in which both (positive and negative) converters in each phase, conduct at the same time. Inter-group reactor in each phase as shown, is needed here.
- But, if non-circulating current mode of operation is used, where only one converter (positive or negative) in each phase, conducts at a time, the reactors are not needed.

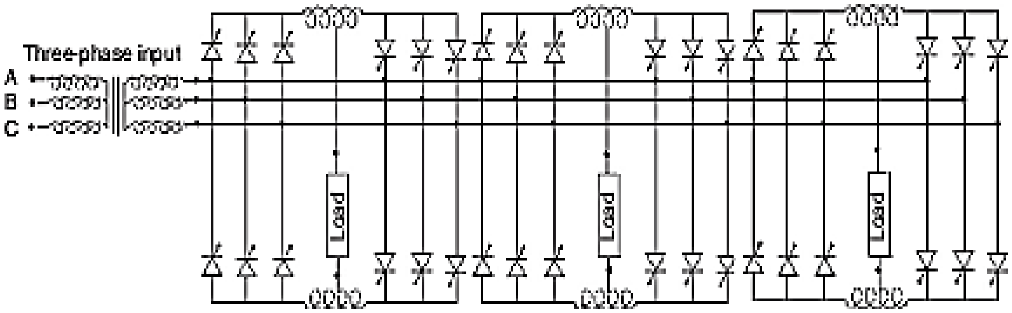


Fig 3: Three-phase to three-phase cycloconverter.

- The firing sequence of the thyristors for the phase groups, B & C are same as that for phase group A, but lag by the angle, and , respectively. Thus, a balanced three-phase voltage is obtained at the output terminals, to be fed to the three-phase load.
- The average value of the output voltage is changed by varying the firing angles of the thyristors, whereas its frequency is varied by changing the time interval, after which the next (incoming) thyristor is triggered. With a balanced load, the neutral connection is not necessary, and may be omitted, thereby suppressing all triple harmonics.

RESULT : Hence, we study 3- phase cycloconverter and speed control of synchronous motor using cycloconverter.

EXPERIMENT NO. -13

AIM: Control of a 3-phase induction motor in variable frequency V/f constant mode using 3-phase inverter.

APPARATUS:

1. Three-phase Inverter.
2. C.R.O
3. Connecting leads.
4. Three-phase induction motor

BASIC CONCEPT:

Three phase induction motors are admirably suited to fulfill the demand of loads requiring substantially a constant speed.. Several industrial applications,however, need adjustable speeds for their efficient operation. . The object of the present section is to describe the basic principles of speed control techniques employed to three phase induction motors through the use of power electronics converters. The various methods of speed control through semiconductor devices are as under:

1. Stator voltage control.
2. Stator frequency control
3. stator voltage and frequency control.
4. Stator current control.
5. Rotor voltage control.
6. Voltage, current and, frequency control.

Variable frequency V/f constant mode using 3-phase inverter.

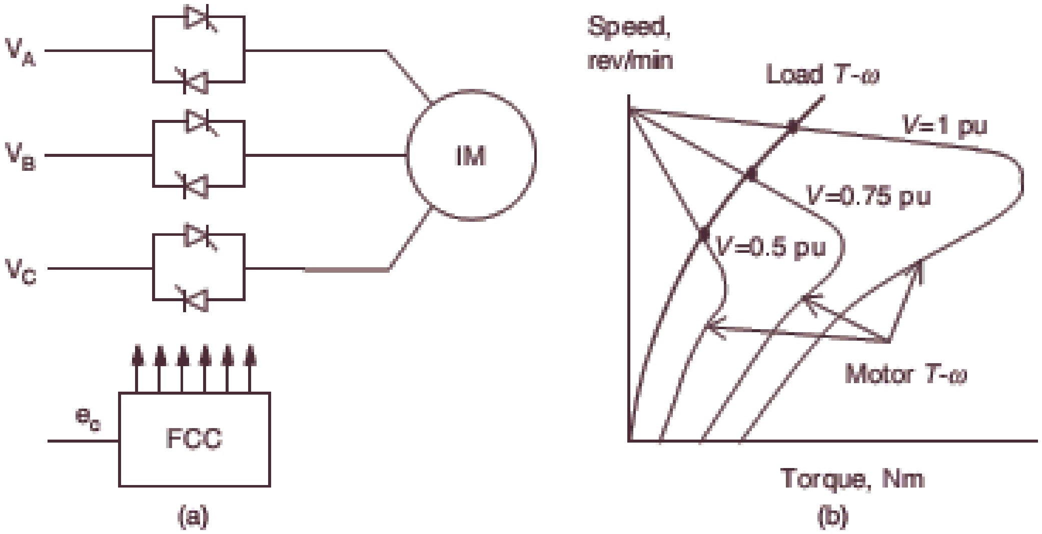
Due to changing the supply frequency, motor synchronous speed can be altered and thus torque and speed of a 3-phase induction motor can be controlled .For a 3-phase induction motor, per phase supply voltage is

$V1 = \sqrt{2}\ \pi f1N1\varphi k_{w1}$ ……………….(1)

This expression shows that under rated voltage and frequency operation, flux will be rated .

In case of supply frequency is reduced with constant V1, the air gap flux increases and the induction motor magnetic circuit gets saturated.

CIRCUIT DIAGRAM:



(a) (b)

CALCULATION:

For a 3-phase induction motor, per phase supply voltage is

$V_1 = \sqrt{2}\ \pi f_1 N_1 \varphi k_{w1}$ …………………………………………..….(1)

This expression shows that under rated voltage and frequency operation, flux will be rated .
Thus the rotor current under this assumption is given by

$I_2 = \frac{V_1}{[(\frac{r_2}{s})} 2 + (x1 + x2)2]1/^2$ ……………………………………..….(2)

Synchronous speed ,

$\boldsymbol{W_{s=\frac{4\pi f1}{P}}}$ ………………………………………………….……….(3)

$w_{s=\frac{4\pi f_1}{P}} = \frac{2w_1}{P}$ rad/s ……………………………………...…….(4)

$$T_e = \frac{3}{w_s} \cdot {I_2}^2 \frac{r_2}{s} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(5)}$$

$$\boldsymbol{T_e = \frac{3P}{2w_{s1}} \cdot \frac{(V1)2}{\left(\frac{r2}{s}\right)2+(x1+x2)2} \cdot \frac{r_2}{s}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(6)}$$

Slip $\quad s = \frac{f2}{f1} = \frac{w2}{w1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$ (7)

Or

$$w2 = sw1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(8)}$$

RESULT: we study Control of a 3-phase induction motor in variable frequency V/f constant mode using 3-phase inverter.