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LAB-MANUAL

VI SEM EE

DEPARTMENT OF ELECTRICAL ENGINEERING

LAB MANUAL -2020

LAB NAME: ELECTRIC DRIVE LAB (6EE4-22)

PREPERED BY: Mr. K.D. KANSAL

6EE4-22: ELECTRIC DRIVE LAB

LIST OF EXPERIMENTS

1. Study and test the firing circuit of three phase half controlled bridge converter.
2. Power quality analysis of 3 phase half controlled bridge converter with R and RL loads.
3. Power Quality analysis of 3-phase full controlled bridge converter feeding R and RL load.
4. Study and obtain waveforms of 3-phase full controlled bridge converter with R and RL loads.
5. Experimental analysis of 3-phase AC voltage regulator with delta connected, star connected (with floating load), R& RL load
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 a 3-phase BLDC motor.
10. Control speed of a 3-phase PMSM motor using frequency and voltage control
11. Control speed of universal motor using AC voltage regulator.
12. Study 3-phase dual converter.
13. Study speed control of dc motor using 3-phase dual converter.
14. Study three-phase cyclo-converter and speed control of synchronous motor using cyclo-converter.
15. Control of 3-Phase Induction Motor in variable frequency V/f constant mode using 3-phase inverter.

EXPERIMENT NO. 1

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

APPARATUS:

S.NO.	EQUIPMENT	RATING	QUANTITY

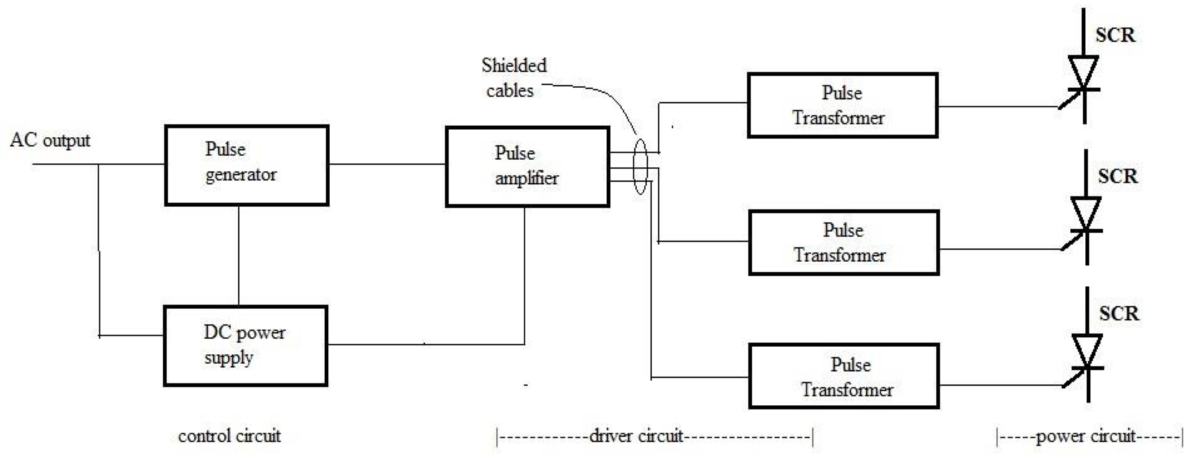
1.	Three Phase SCR Module kit	PEC14HV5P	1.
2	SCR	1600 Volt, 90Amp	
3	Connecting Leads		A.P.R
4	Load	R….. , RL…….	
5	Triggering Module	PEC16HV2B	1

THEORY: The most common method for controlling the onset of conduction in a SCR is by means of gate voltage controlling .The gate voltage circuit also called as firing circuit.

A firing circuit should fulfil following two functions.

(i) If power circuit has more than one SCR, the firing circuit should produce gating pulses for each SCR at the desired instance for proper operation of the power circuit.

(ii) The control signal generated by a firing circuit mar not be able to turn on an SCR. It is therefore common to feed the voltage pulses to driver circuit and then to gate cathode circuit.



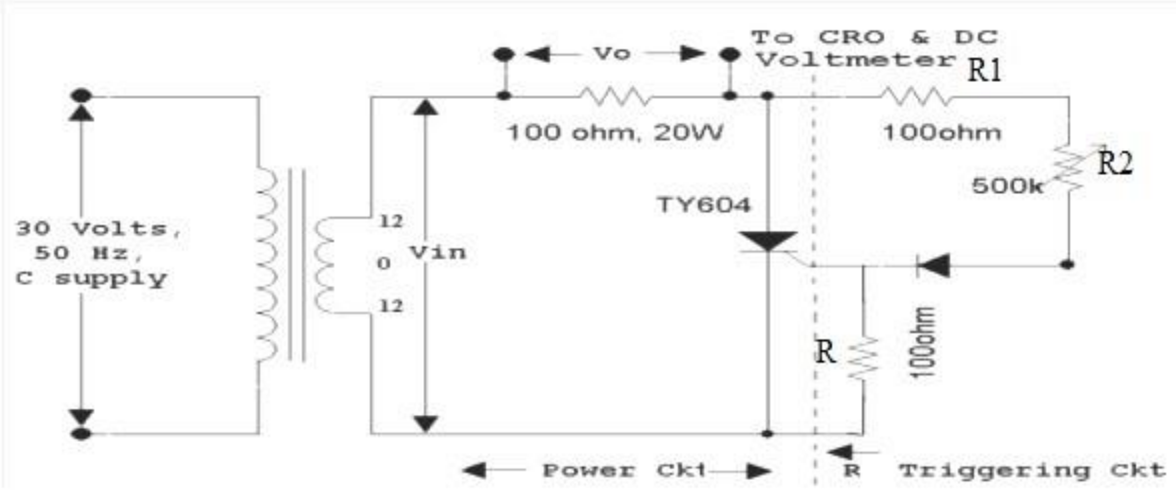
A General layout of the firing circuit scheme of SCRs

Some firing circuit schemes are described in this section.

I. Resistance triggering

II. RC firing circuit III. UJT firing circuit. **1-**

Resistance Triggering: Resistance trigger circuits are the simplest & most economical method. During the positive half cycle of the input voltage, SCR become forward biased but it will not conduct until its gate current exceeds Igmin . Diode D allows the flow of current during positive half cycle only. R2 is the variable resistance &R is the stabilizing resistance .R1 is used to limit the gate current. During the positive half cycle current Ig flows. Ig increases and when Ig= Igmin the SCR turns ON .The firing angle can be varied from 0 — 90° by varying the resistance R



Here R_1 can be found from relation,

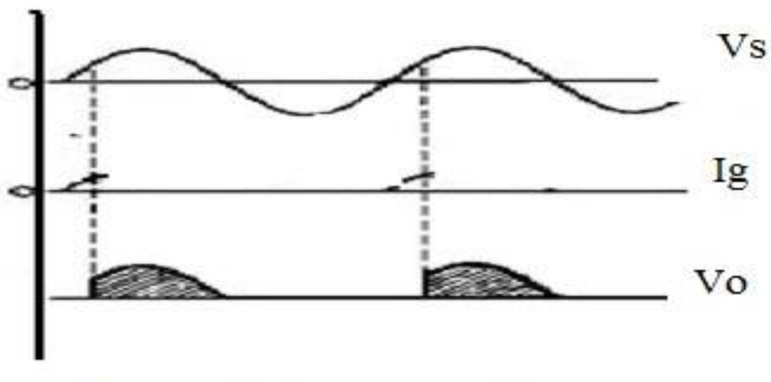
$$R_1 \geq \frac{V_m}{I_{gm}}$$

whereV_m= maximum value of source. Value resistance Rsuch that maximum value across it does not exceed maximum possible gate voltage V_{gm}. R is given by

$$R \leq \frac{V_{gm} \cdot R_1}{V_m - V_{gm}}$$

Firing angle relation is given by $\alpha = \sin^{-1}\left[\frac{V_{gt}(R_1+R_2+R)}{V_m R}\right]$.

But as V_{gt},R_1, R and $V_m$are fixed for a circuitry then $\alpha \propto \sin^{-1} R_2$ or $\alpha \propto R_2$.

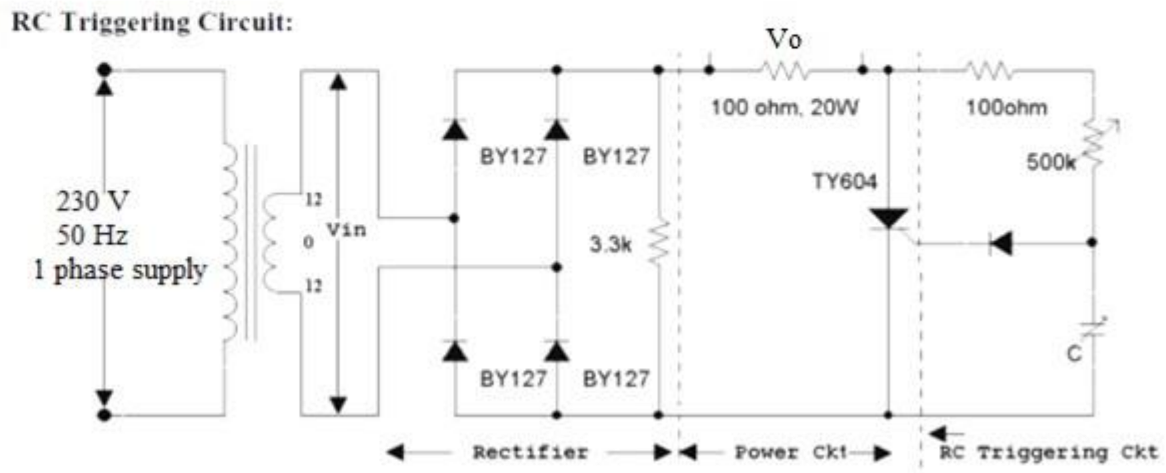


Resistance firing circuit waveforms

2. R -C Triggering:

By varying the variable resistance R, the firing angle can be varied from 0 —180° .In the negative half cycle the capacitance C charges through the diode D_2 with lower plate positive to, the peak supply voltage E_{max} .This Capacitor voltage remains constant at until supply voltage attains zero value.

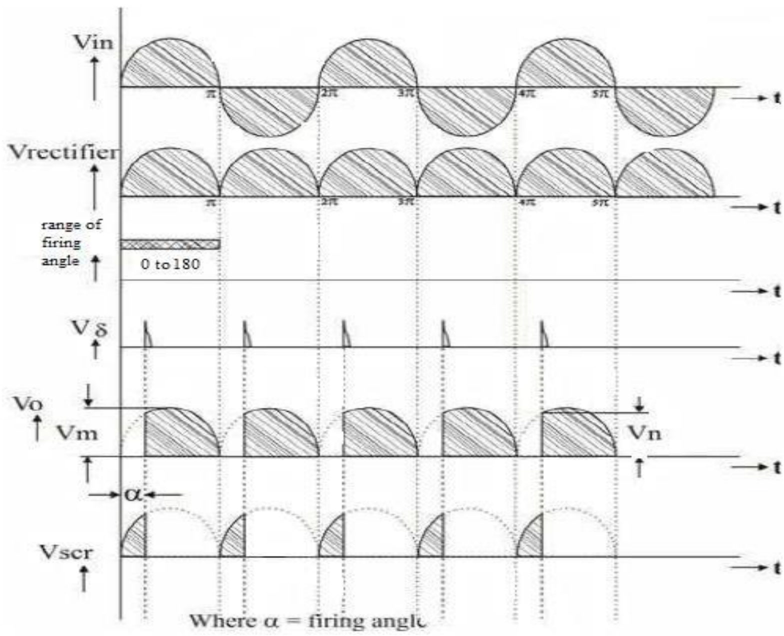
During the positive half cycle of the input voltage, C begins to charge through R. When the capacitor voltage reaches the minimum gate trigger voltage SCR will turn on.



Maximum value of R is given by:-

$$R \leq \frac{Vs - Vgt - vd}{Igt}$$

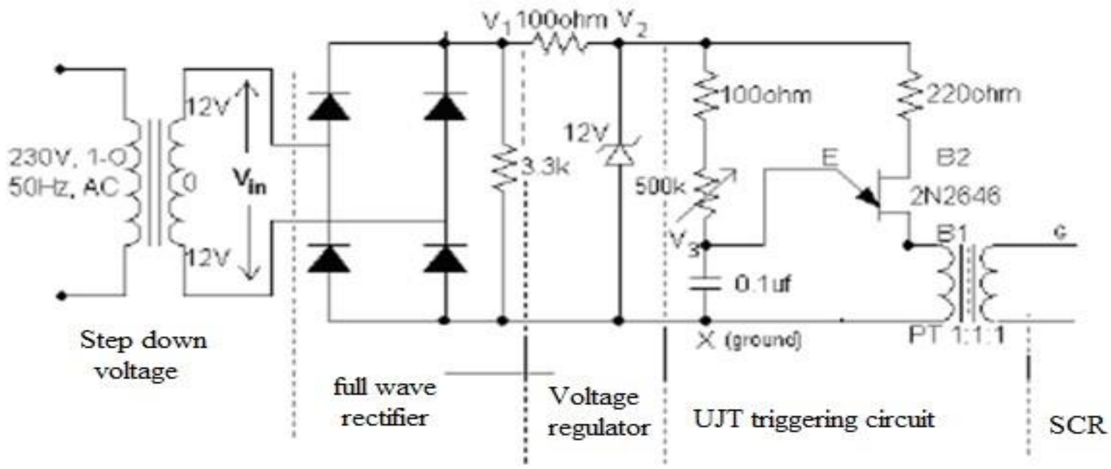
Where V_s source voltage at which thyristor turns on.Waveforms are shown below:-



3.UJT : Resistance and RC triggering circuits described above give prolonged pulse. As a result, power dissipation in the gate circuit is large. At the same time R and RC triggering circuitscann't be used for automatic and feedback systems. These difficulties can be overcome by the use of UJT triggering circuits.

A synchronized UJT triggered circuit using an UJT is shown in the figure. Diodes ‘D1’ to ‘D4’ rectify ac to dc. Resistor R1 lowers V_{dc} to a suitable value for the zener diode and UJT. Zener diode ‘Z’ functions to clip the rectified voltage to a standard level, ‘V_z’ which remains constant except near the V_{dc} zero. The voltage Vz is applied to the charging circuit RC. Current ‘I’, charges capacitor ‘c’ at a rate determined by ‘R’ voltage across capacitor is marked by ‘V_c’ as shown. When ‘V_c’ reaches the uni junction threshold voltage Vz, the t-B1 junction of UJT breaks down and the capacitor ‘c’ discharges through the primary of pulse transformer sending a current ‘C_2’ as shown.

As the current ‘i_2’ is in the form of pulse, windings of the pulse transformer have pulse voltages at their secondary terminals. Pulse at the two secondary windings feeds the same in phase pulse to two SCRs of a half wave circuits. SCR with positive anode voltage would turn ON. As soon as the capacitor discharges, it starts to recharge as shown. Rate of rise of capacitor voltage can be controlled by varying ‘R’. The firing angle can be controlled up to above 1500.



Circuit Diagram: UJT Triggering Circuit

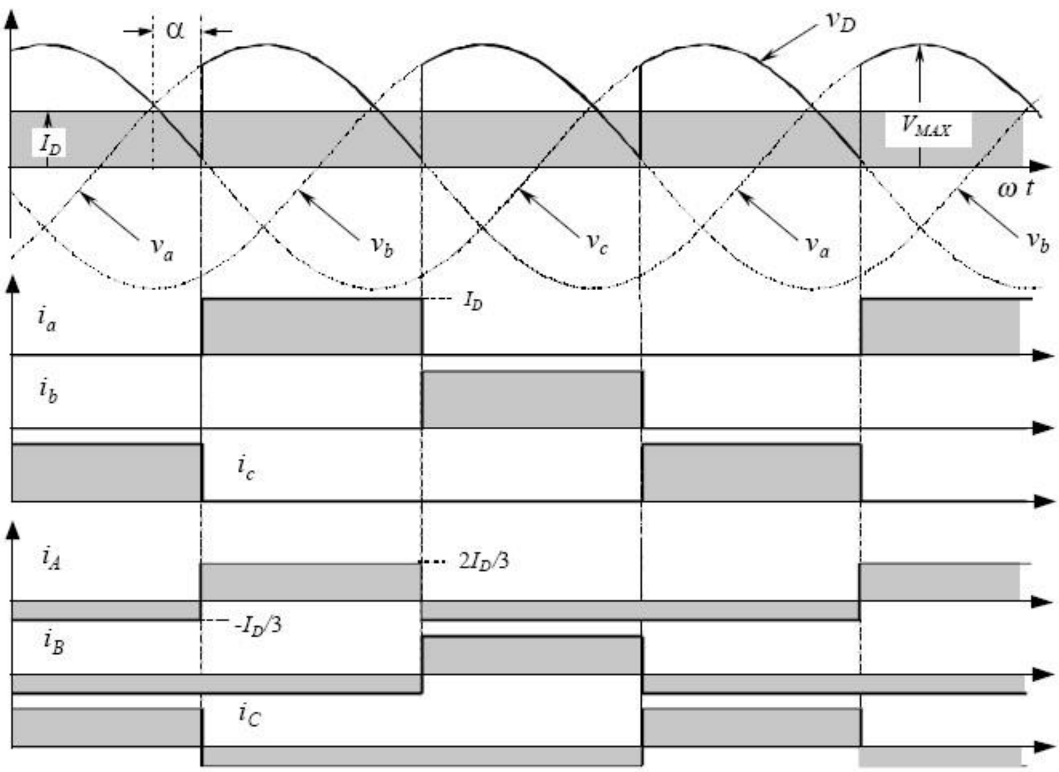
We have intrinsic stand off ratio. Typical values of $\acute{\eta}$ are 0.51 to 0.82

$$\acute{\eta} = \frac{R_{B1}}{R_{B1} + R_{B2}}$$

The time required for capacitor C to charge

$T = \frac{1}{f} = \frac{1}{1-\eta} RCln(\quad)$

Wave form of UJT



Now the above firing circuits can be used in 3 phase half controlled converter and we can have desired output voltage.

Theoretical value is given by the equation:-

$$V_{dc} = 2v/\pi$$

Observation for different firing circuit can be noted down in below table…

CONCLUSION: Thus study and test the firing circuit of three phase half controlled bridge converter is done.

EXPERIMENT NO. 2

OBJECT- Power quality analysis of three phase half controlled bridge convertor with R-load and RL-load

APPRATUS REQUIRED-

S.NO.	EQUIPMENT	RATING	QUANTITY
1.	Three Phase SCR Module kit	PEC14HV5P	01
2	SCR	1600 Volt, 90Amp	
3	Connecting Leads		A.P.R
4	Load	R….. , RL…….	
5	Triggering module	PEC14HV5P	01

THEORY-Three-phase controlled rectifiers have a wide range of applications, from small rectifiers to large High Voltage Direct Current (HVDC) transmission systems. They are used for electro-chemical process, many kinds of motor drives, traction equipment, controlled power supplies, and many other applications. From the point of view of the commutation process, they can be classified in two important categories: Line Commutated Controlled Rectifiers *(*Thyristor Rectifiers), andForce Commutated PWM Rectifiers.

RATING-440 Volt, Three phase 50 Hz AC Supply
With 5Amp. Fuse

Half controlled bridge converter-

The fully controlled three-phase bridge converter shown in figure has six thyristors. this circuit operates as a rectifier when each thyristor has a firing angle, a, which is less than 90 degrees, and functions as an inverter for a greater than 90 degrees. If inverter operation is not required, the circuit may be simplified by replacing three controlledrectifiers with power diodes, as in figure 12.15 a). This simplification is economically attractive because diodes are considerably less expensive than thyristors, and they do not require firing angle control electronics.

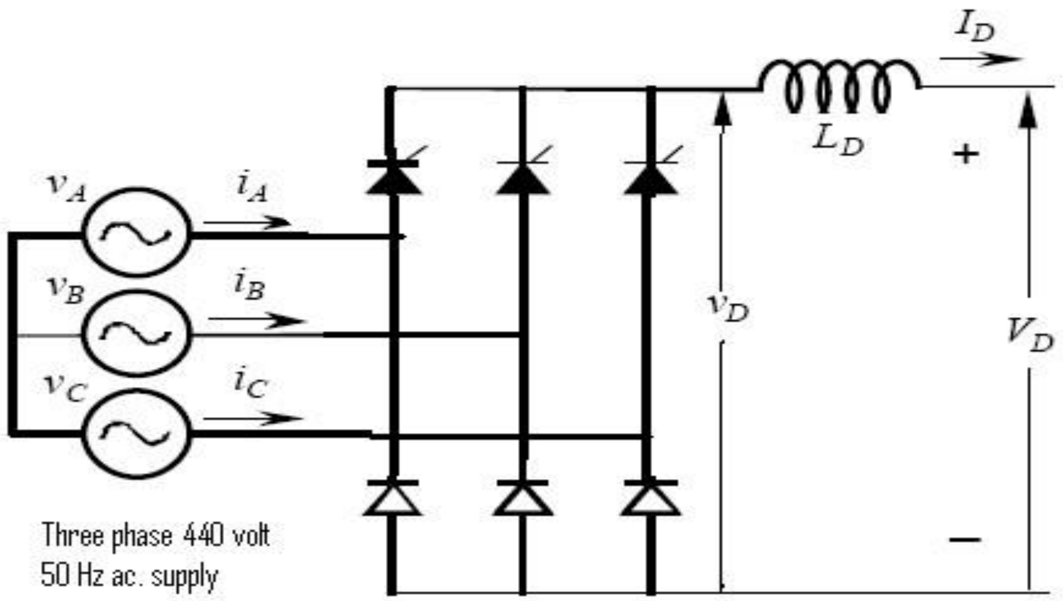
The half controlled bridge, or "semiconverter", is analyzed by considering it as a phasecontrolled half-wave circuit in series with an uncontrolled half wave rectifier. The average *dc* voltage is given by the following equation:

$V_{dc} = \frac{3}{2\pi}\left[\int_{\pi/3}^{(2\pi/3)+\alpha} v_{RY}\, d(\acute{\omega}t) + \int_{(2\pi/3)+\alpha}^{\pi} v_{RB}\, d(\acute{\omega}t)\right]$

$= \frac{3}{2\pi}\left[\int_{\pi/3}^{((2\pi/3)+\alpha)} (\sqrt{3}_{V_m}) \sin \acute{\omega}t\ (d\acute{\omega}t) - \int_{(2\pi/3)+\alpha}^{(\pi)} (\sqrt{3}V_m) \sin(\acute{\omega}t - 240)(d((\acute{\omega}t))\right]$

$V_{dc} = \frac{3\sqrt{3}}{\pi} Vm \left(\frac{1 + \cos\alpha}{2}\right)$

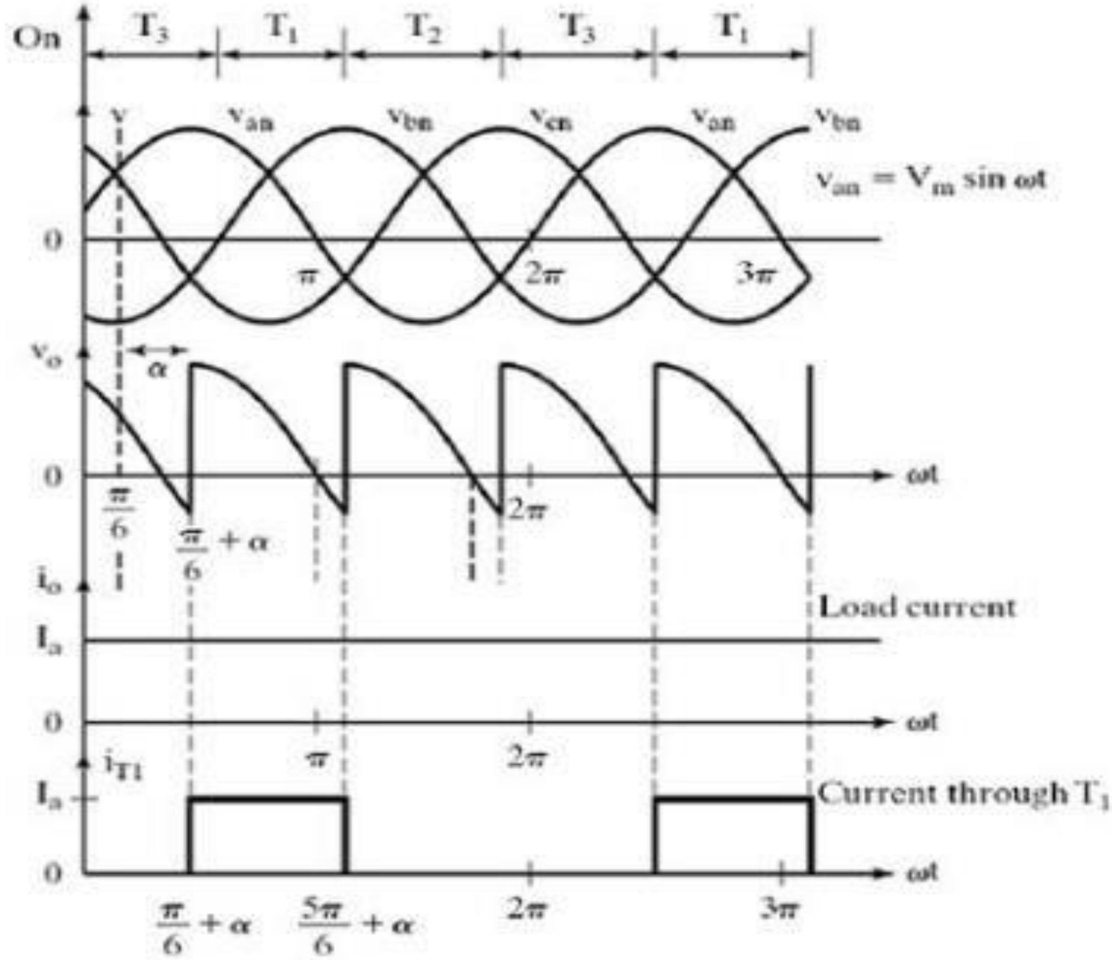
CIRCUIT DIAGRAM=



One-quadrant bridge converter circuits half-controlled bridge

Then, the average voltage *VD* never reaches negative values. The output voltage waveforms of half-controlled bridge are similar to those of a fully controlled bridge with a free-wheeling diode.The advantage of the free-wheeling diode connection, shown in figure is that there is always a path for the *dc* current, independent of the status of the *ac* line and of the converter. This can be important if the load is inductive-resistive with a large time constant, and there is a interruption in one or more of the line phases. In such a case, the load current could commutate to the free-wheeling diode

WAVEFORM-



OBSERVATION TABLE-

S.NO	INPUT VOLTAGE	FIRING ANGLE	OUTPUT VOLTAGE

RESULT-Studied and obtained waveform of three phase full controlled bridge convertor with R-load and RL-load

PRECAUTIONS:

1. Make connection carefully.
2. Give an appropriate value of "*a*" and obtain waveforms.
3. Error free measuring instruments should be used.

EXPERIMENT NO. 3

OBJECT: To study and test the firing circuit of three phase fully controlled bridge converter with R and RL loads.

APPARATUS:

S.NO.	EQUIPMENT	RATING	QUANTITY
1.	Three Phase SCR Module kit	PEC14HV5P	1.
2	SCR	1600 Volt, 90Amp	
3	Connecting Leads		A.P.R
4	Load	R….. , RL…….	

THEORY: The most common method for controlling the onset of conduction in a SCR is by means of gate voltage controlling .The gate voltage circuit also called as firing circuit.

A firing circuit should fulfil following two functions.

(iii) If power circuit has more than one SCR, the firing circuit should produce gating pulses for each SCR at the desired instance for proper operation of the power circuit.

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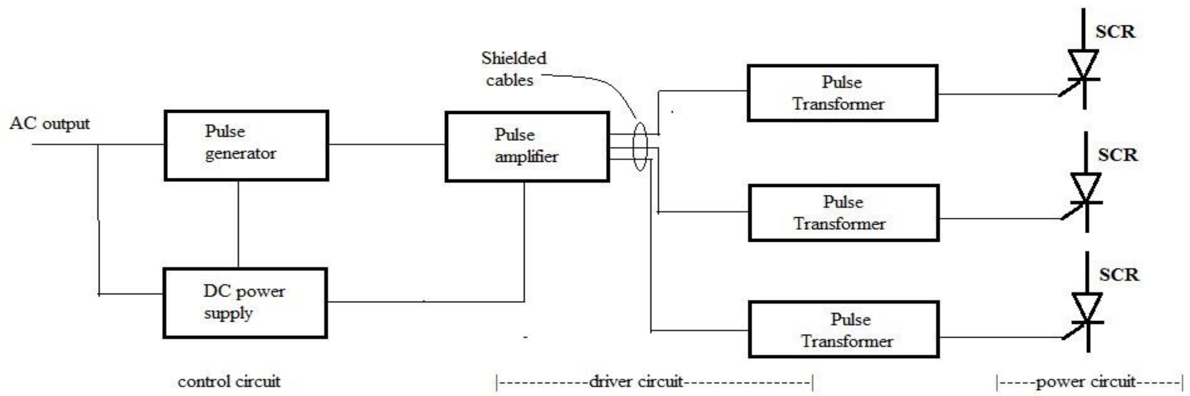

A General layout of the firing circuit scheme of SCRs

Some firing circuit schemes are described in this section.

I. Resistance triggering II.
RC firing circuit III.
UJT firing circuit.

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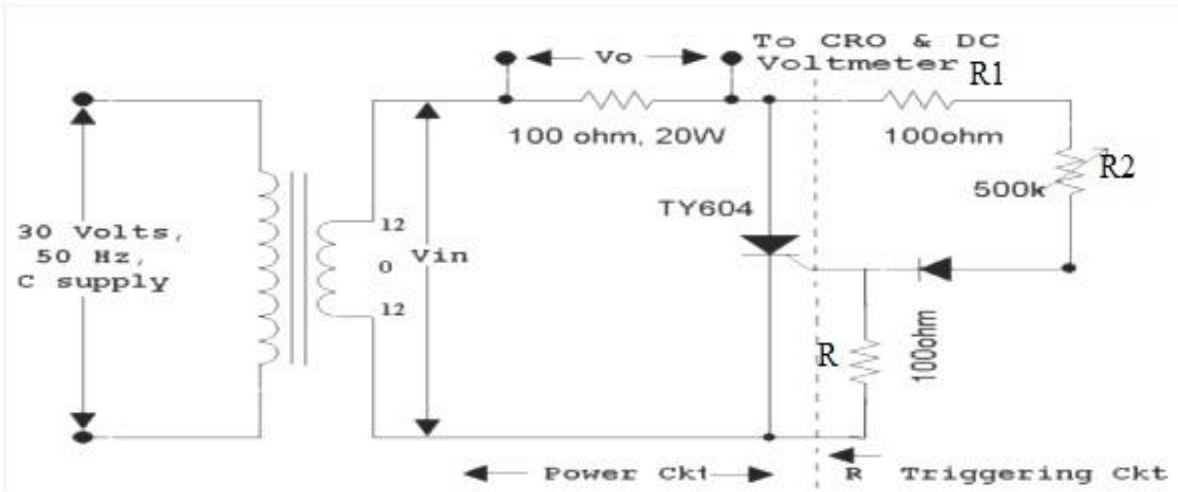

Here R_1 can be found from relation,

$$R_1 \geq \frac{V_m}{I_{gm}}$$

whereV_m= maximum value of source. Value resistance Rsuch that maximum value across it does not exceed maximum possible gate voltage V_{gm}. R is given by

$$R \leq \frac{V_{gm}.R_1}{V_m - V_{gm}}$$

Firing angle relation is given by$\alpha = \sin^{-1}\left[\frac{V_{gt}(R_1+R_2+R)}{V_m R}\right]$.

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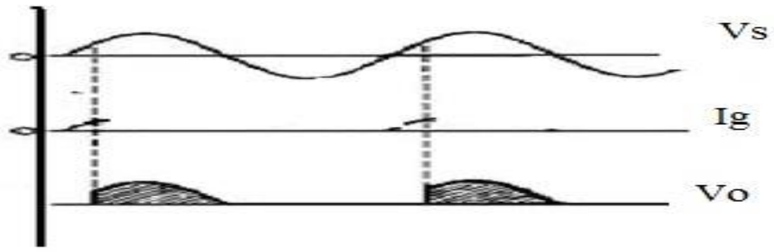
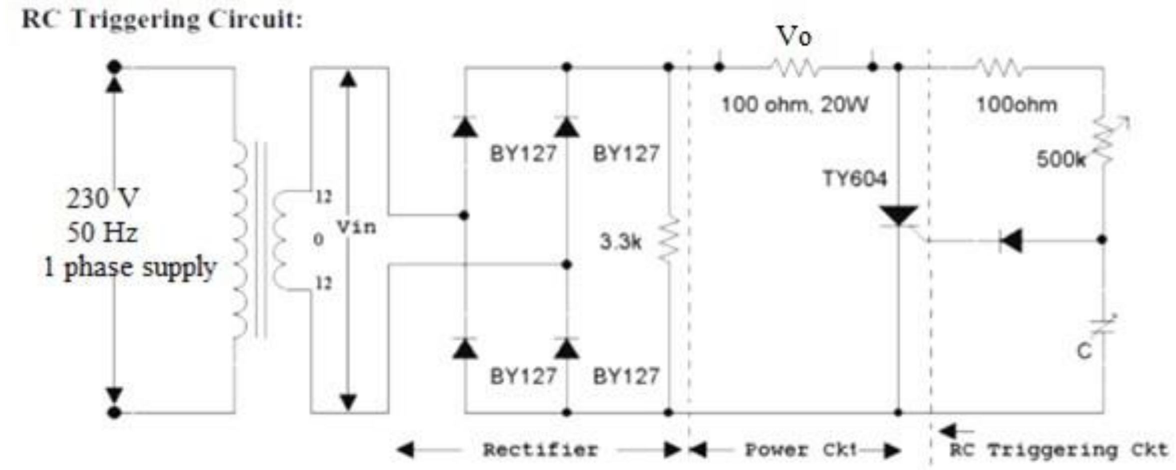


Resistance firing circuit waveforms

2-R —C Triggering:

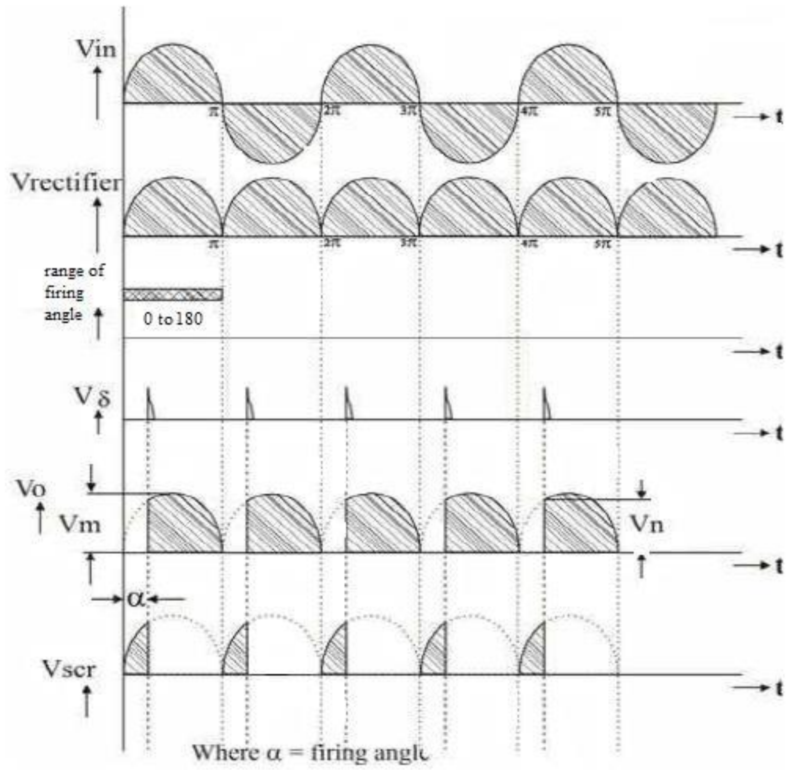
By varying the variable resistance R, the firing angle can be varied from 0 —180° .In the negative half cycle the capacitance C charges through the diode D_2 with lower plate positive to, the peak supply voltage E_{max} .This Capacitor voltage remains constant at until supply voltage attains zero value. During the positive half cycle of the input voltage, C begins to charge through R. When the capacitor voltage reaches the minimum gate trigger voltage SCR will turn on.



Maximum value of R is given by:-

$$R \leq \frac{Vs - Vgt - vd}{Igt}$$

Where V_s source voltage at which thyristor turns on. Waveforms are shown below:-

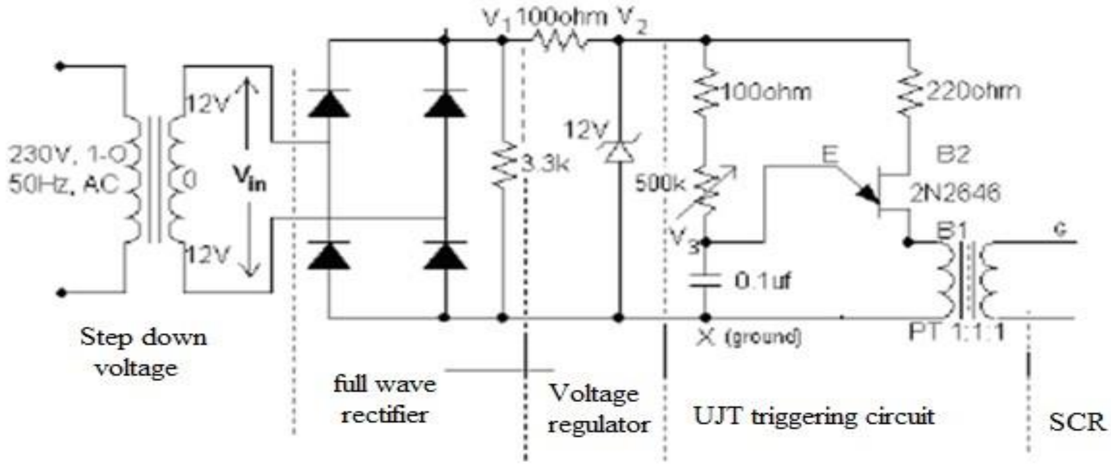


3-UJT

Resistance and RC triggering circuits described above give prolonged pulse. As a result, power dissipation in the gate circuit is large. At the same time R and RC triggering circuits can not be used for automatic and feedback systems. These difficulties can be overcome by the use of UJT triggering circuits.

A synchronized UJT triggered circuit using an UJT is shown in the figure. Diodes 'D1' to 'D4' rectify ac to dc. Resistor R1 lowers V_{dc} to a suitable value for the zener diode and UJT. Zener diode 'Z' functions to clip the rectified voltage to a standard level, 'V_z' which remains constant except near the V_{dc} zero. The voltage Vz is applied to the charging circuit RC. Current 'I', charges capacitor 'c' at a rate determined by 'R' voltage across capacitor is marked by 'V_c' as shown. When 'V_c' reaches the uni junction threshold voltage Vz, the t-B1 junction of UJT breaks down and the capacitor 'c' discharges through the primary of pulse transformer sending a current 'C_2' as shown.

As the current 'i_2' is in the form of pulse, windings of the pulse transformer have pulse voltages at their secondary terminals. Pulse at the two secondary windings feeds the same in phase pulse to two SCRs of a full wave circuits. SCR with positive anode voltage would turn ON. As soon as the capacitor discharges, it starts to recharge as shown. Rate of rise of capacitor voltage can be controlled by varying 'R'. The firing angle can be controlled up to above 1500.



Circuit Diagram: UJT Triggering Circuit

We have intrinsic stand off ratio. Typical values of $\acute{\eta}$ are 0.51 to 0.82

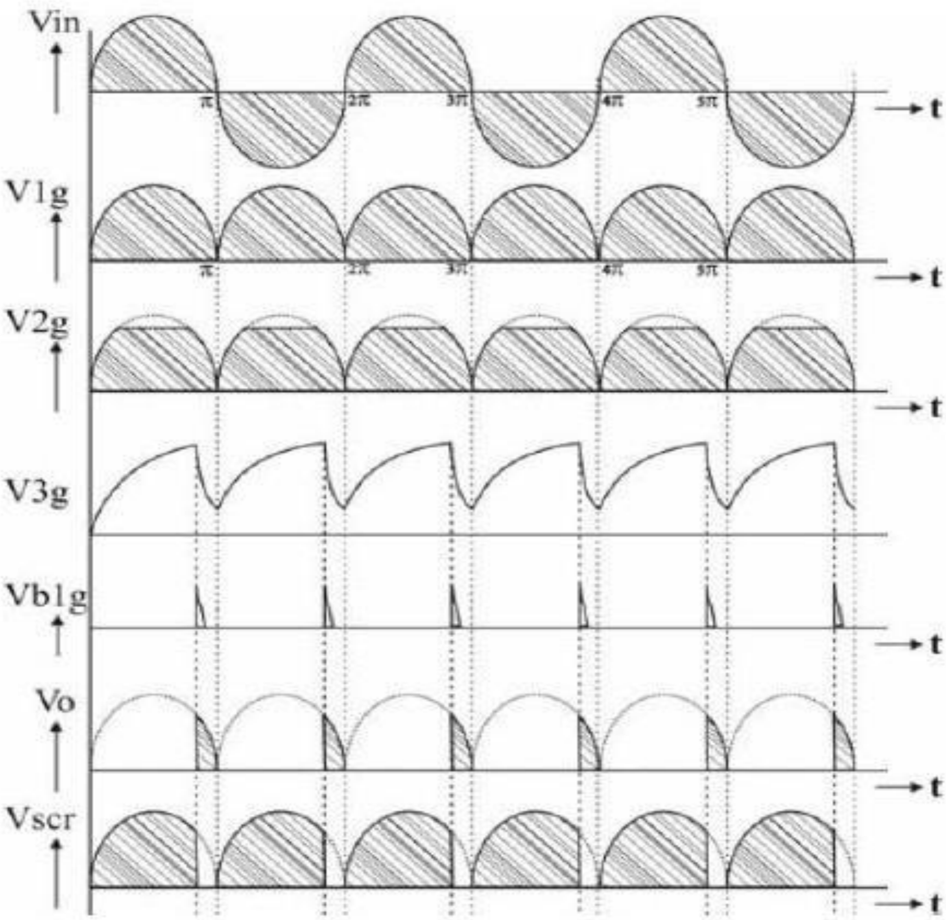
R_{B1}

$$\acute{\eta} = \frac{}{R_{B1} + R_{B2}}$$

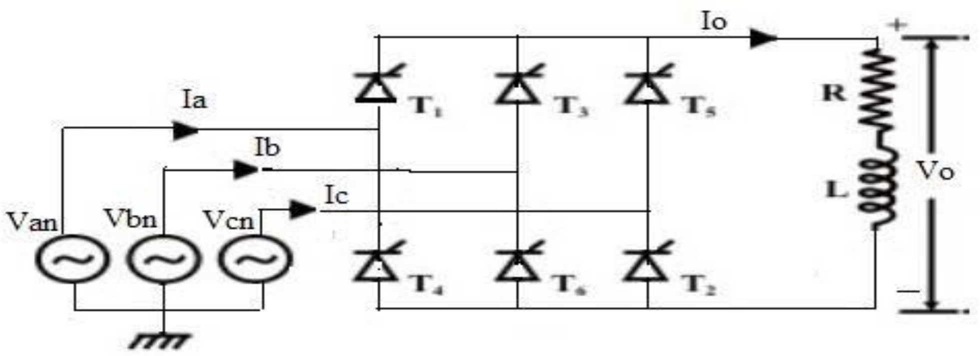
The time required for capacitor C to charge

$$T = \frac{1}{f} = RC \quad \frac{1}{1-\acute{\eta}} \; ln\,(\quad)$$

Wave form of UJT



Now the above firing circuits can be used in 3 phase full controlled converter and we can have desired output voltage.



Theoretical value is given by the equation:-

$$V_{dc} = \sqrt{2V}/_{2\pi} \ (1 + \cos\alpha)$$

Observation for different firing circuit can be noted down in below table…

OBSERVATION TABLE

S.No	**Time Period**	**Firing Angle**	**$V_{dc\ theoretical}$ (volts)**	**$V_{dcpract}$(volts)**

RESULT: Thus study and test the firing circuit of three phase fully controlled bridge converter is done.

EXPERIMENT NO. -4

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

APPARATUS:

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

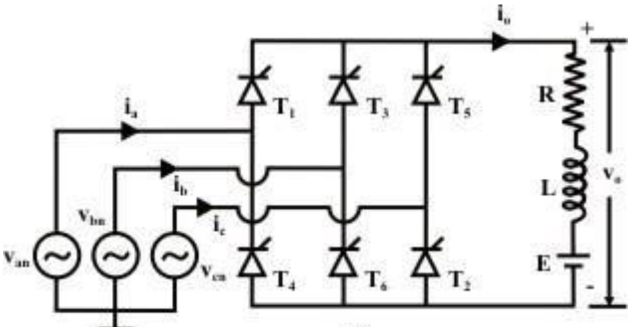
BASIC CONCEPT:

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”.

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.

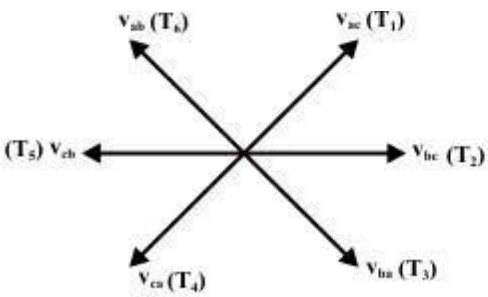
CIRCUIT DIAGRAM:



(a)

Device / Mode	v_{T1}	v_{T2}	v_{T3}	v_{T4}	v_{T5}	v_{T6}	v_o
T_1T_2	0	0	v_{ba}	v_{ca}	v_{ca}	v_{cb}	v_{ac}
T_2T_3	v_{ab}	0	0	v_{ca}	v_{cb}	v_{cb}	v_{bc}
T_3T_4	v_{ab}	v_{ac}	0	0	v_{cb}	v_{ab}	v_{ba}
T_4T_5	v_{ac}	v_{ac}	v_{bc}	0	0	v_{ab}	v_{ca}
T_5T_6	v_{ac}	v_{bc}	v_{bc}	v_{ba}	0	0	v_{cb}
T_6T_1	0	v_{bc}	v_{ba}	v_{ba}	v_{ca}	0	v_{ab}
NONE	-	-	-	-	-	-	E

(b)



(c)

Fig. 13.1: operation of a three phase full controlled bridge converter
(a) circuit diagram,
(b) conduction table,
(c) phaser diagram of line voltages.

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 $T_1 \rightarrow T_2 \rightarrow T_3 \rightarrow T_4 \rightarrow T_5 \rightarrow T_6$

→ 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.

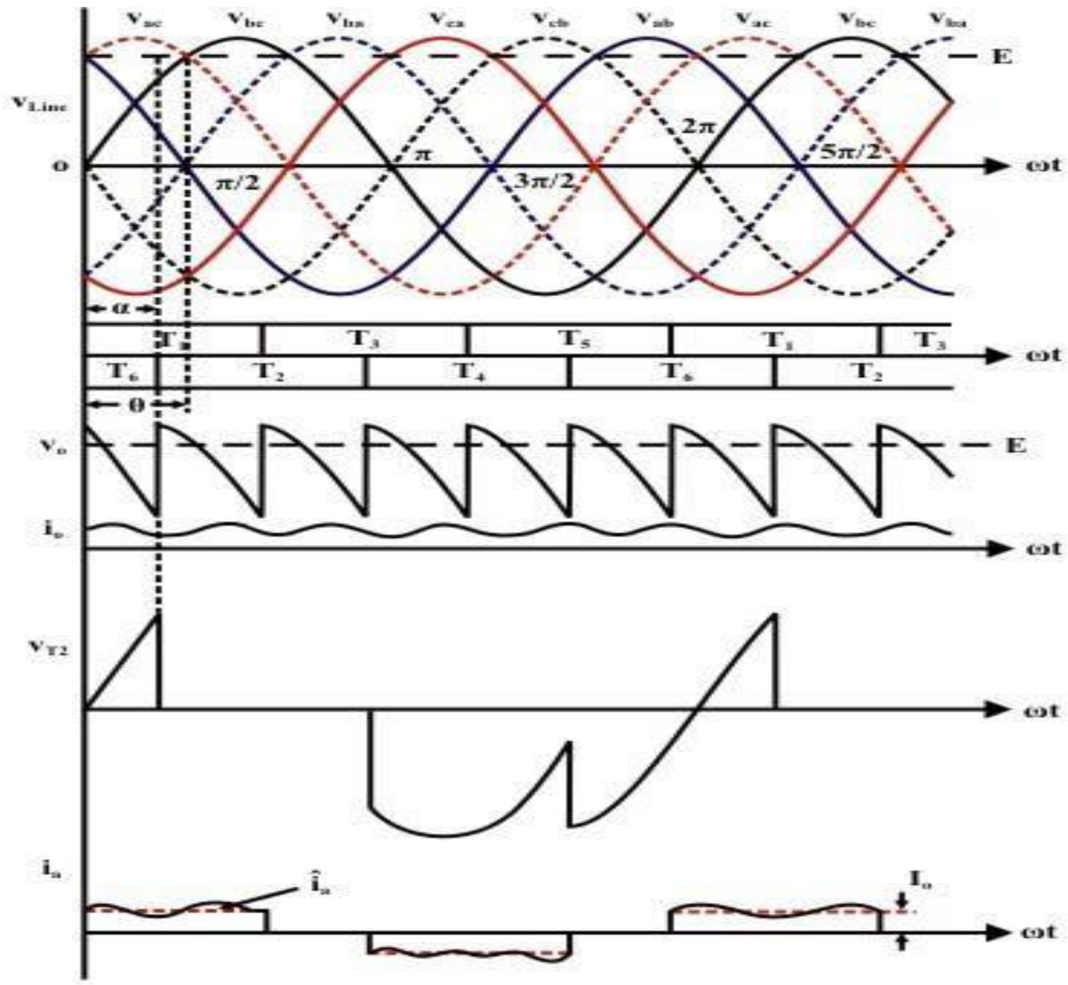
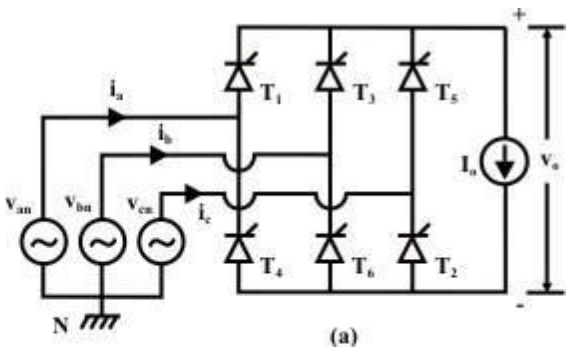


Fig. 13.2: Waveforms of three phase fully controlled converter 13.2.1 Analysis of the converter in the rectifier mode.

<u>The converter in the inverting mode:</u>

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)

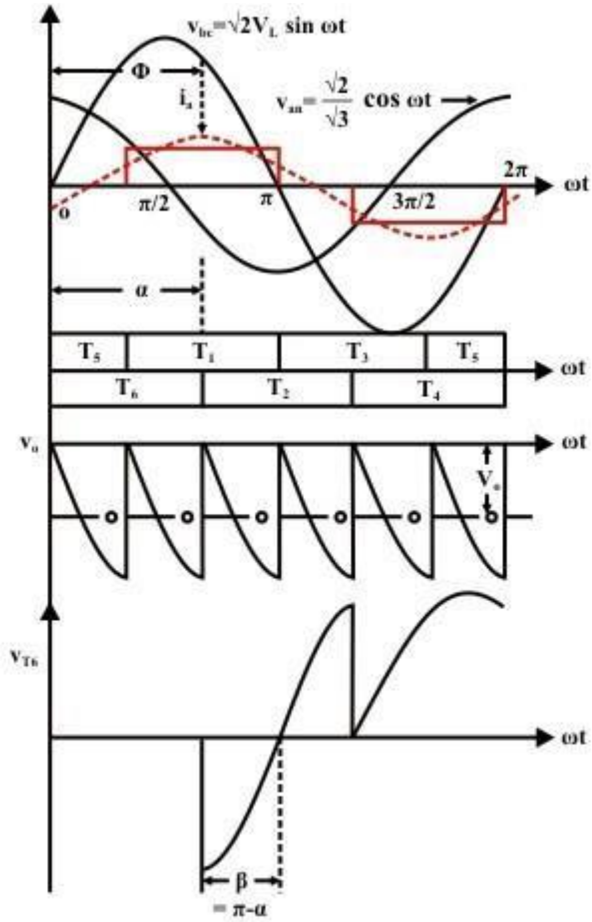


Fig. 13.3(b): Inverter mode of operation of the three phase fully controlled bridge converter (a) circuit diagram (b) waveforms.

PROCEDURE : As per requirement.

OBSERVATION: Self

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

EXPERIMENT NO. 5

OBJECT: Control speed of DC Motor using 3-phase half controlled bridge converter and Plot armature voltage versus speed characteristics.

APPARATUS REQUIRED:

S.No.	EQUIPMENT	SPECIFICATION	QUANTITY
1.	3 Phase SCR Module	PEC14HVSP	01
2.	DC Motor	220V, 5.1Amp, 1 HP,1500 RPM	01
3.	3 Phase Auto Transformer	415V, 8 Amp, 50 Hz	01
4.	Power Supply	440V AC, 50Hz	01
5.	Chopper/ Inverter PWD control Module	PEC16HV2B	01
6.	CRO	...	01
7.	Patch chords	...	As per required

THEORY: The commonly used dc separately excited motor shown in fig. In a separately excited motor, the field and armature voltages can be controlled independent of such other. Basic equations applicable to all dc motors are

$$E = Ke\phi\, Wm \quad (1)$$
$$V = E + Ra * Ia \quad (2)$$
$$T = Ke\phi\, Ia \quad (3)$$

Where ϕ = flux per pole, webers;

Ia = the armature current, Amp.

V = the armature voltage, Volts

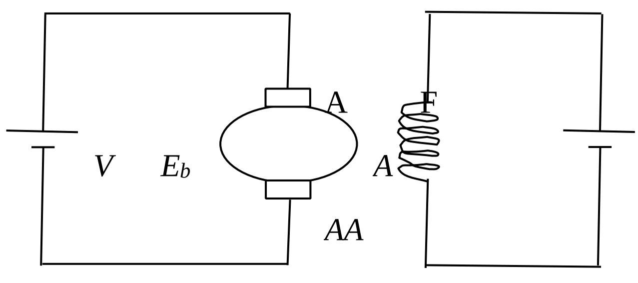
Ra = the resistance of the armature circuit,

ohms Wm = the speed of the armature, rad./sec.

T = the torque developed by the motor, N-m

Ke=the motor constant.

Vf



Fig(a) : separately excited dc motor

From eqs (1) to (3)

$$Wm = \frac{V}{\;} - \frac{Ra}{\;} Ia \quad (4)$$

$Ke\phi \quad Ke\phi$

$$Wm = \frac{V}{Ke\phi} - \frac{Ra}{(Ke\phi)^2}T \qquad (5)$$

In case of separately excited motors, with a constant field current, the flux can be assumed to be constant. Let $Ke\phi = K(constant)$ (6)

Then from eqs. (1), (3), and (4) to (6)

$$T = K*Ia \qquad (7)$$

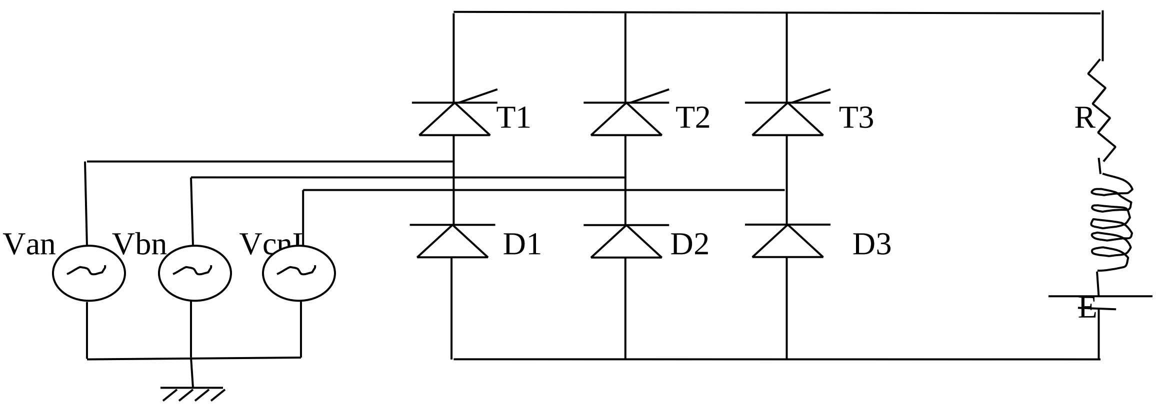
$$E = K*w_m \qquad (8)$$

$$Wm = \frac{V}{K} - \frac{Ra}{K}Ia \qquad (9)$$

$$Wm = \frac{V}{K} - \frac{Ra}{K^2}T \qquad (10)$$

CIRCUIT DESCRIPTION:

Threephase fully controlled (6 pulse) rectifier fed separately excited DC motor drive is shown in fig (b). Thyristors are fired in the sequence of their numbers with a phase difference of 60 degree by gate pulses of 120 degree duration. Each thyristor conducts for 120 and one thyristors conduct at a time-one from upper group (odd numbered thyristor) and the other from lower group (even numbered thyristors) applying respective line voltages to the motor.



Fig(b) circuit diagram of three phase half controlled converter.

Transfer of current from an outgoing to incoming thyristor can take place when the respective line voltage is of such a polarity that only if forward biases the incoming thyristor, but if leads to reverse biasing of the outgoing when incoming turn-off. Thus, firing angle for a thyristor is measured from the instant when respective line voltage is zero and increasing. For example, the transfer of current from the thyristor D1 to thyristor T1can occur as long as the If line voltage Vab is taken as reference voltage, then

$$V_{ab} = V_m \sin wt$$

And $$a = wt - \pi/3$$

Where, Vm is the peak of line voltage.

Motor terminal voltage and current waveforms for continuous conduction are shown in figs (b) and (c) For motoring and braking operations, respectively. Devices under conduction are also shown in the figure. The discontinuous conduction is neglected here because it o curs is a narrow region of its operation. For the motor terminal voltage cycle from $(a+\pi/3)$ to $(a+2\pi/3)$ (from figs (b) and (c)).

$$VVm \sin wt \quad = \frac{3}{2\pi}\{\int_{(a+\pi/3)}^{(a+2\pi/3)} \;^{/3}\; d(wt) + Vm \sin \int_{\pi/3}^{2\pi} wt\, d(wt)\}$$

$$= 3/2\pi\, Vm\,(1 + \cos a)$$

OBSERVATION TABLE:

S.No.	Input Voltage	Firing Angle	utput voltage	Speed

RESULT:

We have successfully studied and obtain the waveform of 3-phase half controlled bridge converter.

PRECAUTIONS:

1. Make connection carefully.
2. Give an appropriate value of "*a*" and obtain waveforms.
3. Error free measuring instruments should be used.

EXPERIMENT NO. 6

OBJECT: Control speed of DC Motor using 3-phase full controlled bridge converter and Plot armature voltage versus speed characteristics.

APPARATUS REQUIRED:

S.No.	EQUIPMENT	SPECIFICATION	QUANTITY
1.	3 Phase SCR Module	PEC14HVSP	01
2.	DC Motor	220V, 5.1Amp, 1 HP,1500 RPM	01
3.	3 Phase Auto Transformer	415V, 8 Amp, 50 Hz	01
4.	Power Supply	440V AC, 50Hz	01
5.	Chopper/ Inverter PWD control Module	PEC16HV2B	01
6.	CRO	...	01
7.	Patch chords	...	As per required

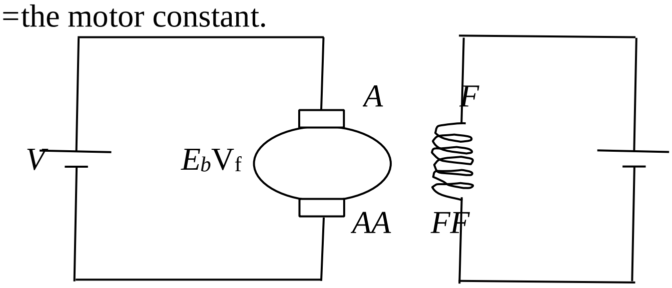
THEORY: The commonly used dc separately excited motor shown in fig. In a separately excited motor, the field and armature voltages can be controlled independent of such other.

Basic equations applicable to all dc motors are

$$V = E + Ra * Ia. (1) \qquad T = Ke\phi\, Ia \qquad (2)$$

Where $\phi =$ flux per pole, webers;

a. Ia = the armature current, Amp.
b. V = the armature voltage, Volts
c. Ra = the resistance of the armature circuit, ohms
d. T = the torque developed by the motor, N-m
e. Ke=the motor constant.



Fig(a) : separately excited dc motorFrom eqs (1) to (3)

$$Wm = \frac{V}{Ke\phi} - \frac{Ra}{Ke\phi} Ia \tag{4}$$

$$\mathrm{Wm} = \frac{\mathrm{V}}{\mathrm{Ke}\phi} - \frac{\mathrm{Ra}}{(\mathrm{Ke}\phi)^2} \mathrm{T} \tag{5}$$

In case of separately excited motors, with a constant field current, the flux can be assumed to be constant. Let $Ke\phi = K(constant)$ (6)

Then from eqs. (1), (3), and (4) to (6)

$$\mathrm{T} = \mathrm{K}^*\mathrm{Ia} \tag{7}$$

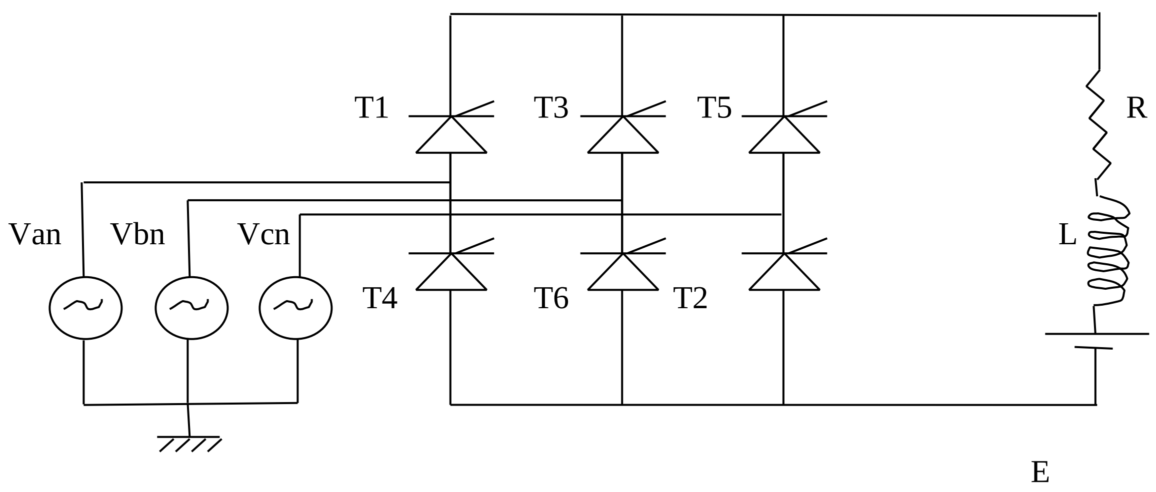
$$\mathrm{E} = \mathrm{K}^* w_m \tag{8}$$

$$Wm = \frac{V}{K} - \frac{Ra}{K} Ia \tag{9}$$

$$Wm = \frac{V}{K} - \frac{Ra}{K^2} T \tag{10}$$

CIRCUIT DESCRIPTION:

Three phase fully controlled (6 pulse) rectifier fed separately excited DC motor drive is shown in fig (b). Thyristors are fired in the sequence of their numbers with a phase difference of 60 degree by gate pulses of 120 degree duration. Each thyristor conducts for 120 and two Thyristors conduct at a time-one from upper group (odd numbered thyristor) and the other from lower group (even numbered Thyristors) applying respective line voltages to the motor.



Fig(b). Circuit diagram of three phase full controlled converter.

Transfer of current from an outgoing to incoming thyristor can take place when the respective line voltage is of such a polarity that not only if forward biases the incoming thyristor, but also leads to reverse biasing of the outgoing when incoming turn-on. Thus, firing angle for a thyristor is measured from the instant when respective line voltage is zero and increasing. For example, the transfer of current from the thyristor $T_5$to thyristor T_1 can occur as long as the If line voltage Vab is taken as reference voltage, then

$$V_{ab} = V_m \sin wt$$

And $$a = wt - \pi/3$$

Where, Vm is the peak of line voltage.

Motor terminal voltage and current waveforms for continuous conduction are shown in figs (b) and (c) For motoring and braking operations, respectively. Devices under conduction are also shown in the figure. The discontinuous conduction is neglected here because it o curs is a narrow region of its operation. For the motor terminal voltage cycle from $(a+\pi/3)$ to $(a+2\pi/3)$ (from figs (b) and (c)).

$$Va = Vm \sin wt\ d(wt) \qquad \frac{3}{\pi}\int_{(a+\pi/3)}^{(a+2\pi/3)}$$

$$= 3/\pi\ Vm \cos a$$

From eqs. (1), (2), (3) and (4)

$$Wm = \frac{3Vm}{\pi K} \cos a - \frac{Ra}{K_2} T$$

OBSERVATION TABLE:

S. No.	Input Voltage	Firing Angle	Output voltage	Speed

RESULT:

We have successfully studied and obtain the waveform of 3-phase full controlled bridge converter.

PRECAUTIONS:

1. Make connection carefully.
2. Give an appropriate value of "*a*" and obtain waveforms.
3. Error free measuring instruments should be used.

EXPERIMENT NO. – 7

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

$$T_e = \frac{3}{\omega_s} \cdot \frac{(KV_1)^2 \frac{r_2}{s}}{\left(r_1 + \frac{r_2}{s}\right)^2 + (x_1 + x_2)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

CIRCUIT DIAGRAM:

Refer P.S. Bhimbra for fig.12.27(a & b).

PROCEDURE: As per requirement

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

$$T_e = \frac{3}{\omega_s} \cdot \frac{(KV_1)^2 \frac{r_2}{s}}{\left(r_1 + \frac{r_2}{s}\right)^2 + (x_1 + x_2)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

OBSERVATION: Self

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. – 8

AIM:- Control speed of a 3-phase BLDC motor.

Basic Concept

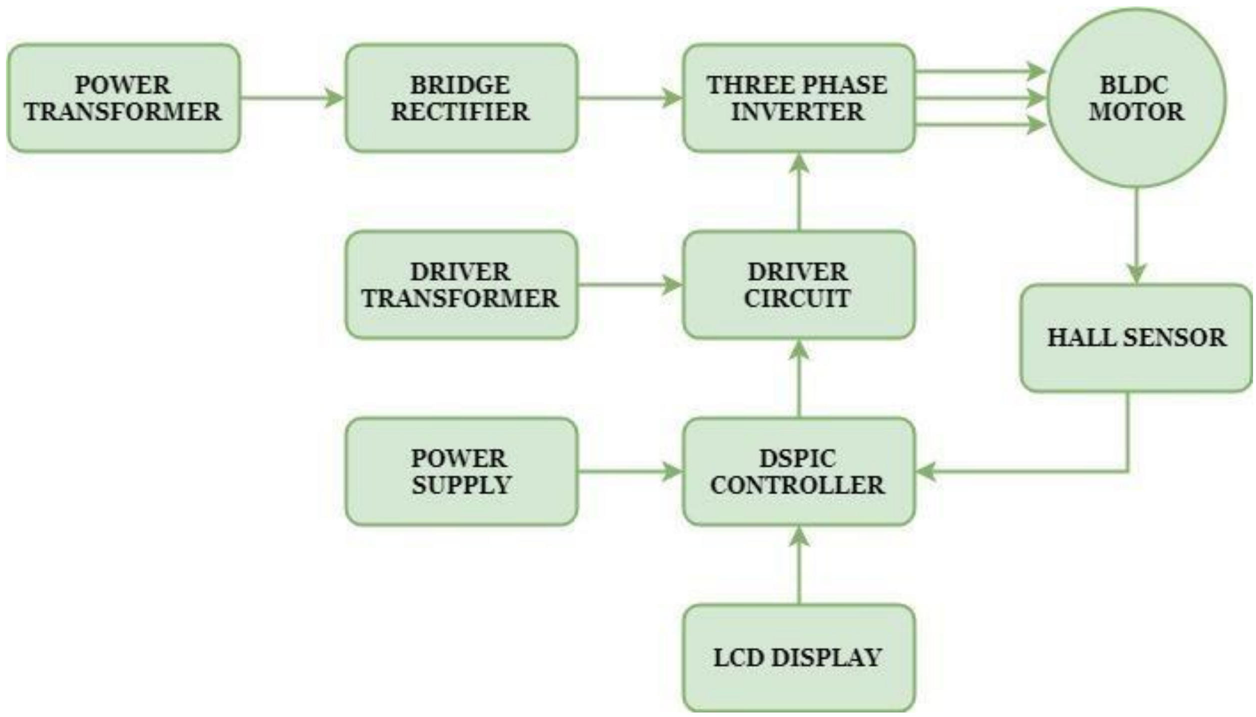
This project is mainly used to control the speed of the BLDC motor by varying the frequency. The BLDC motor has high reliability, high efficiency high torque/inertia ratio, improved cooling, low radio frequency interference, and noise and requires practically no maintenance. The BLDC motor speed is depends on the frequency of the three phase inverter circuit.

The boost converter exhibits the advantages over the conventional buck, boost, buck– boost and Cuk converter when employed in SPV-based applications. The DC voltage is applied to three phase inverter circuit. Three phase inverter converts the dc voltage into three phase ac voltage. The boost converter operates to increase the output voltage.

Proposed System

This project is proposed to control the speed of BLDC motor. The AC supply is applied to the bridge rectifier, the bridge rectifier converts ac supply into dc supply. That dc supply is applied to three phase inverter; it converts the dc voltage into three phase ac voltage. Three phase ac voltage is connected to the BLDC motor. The BLDC motor have hall sensor. The hall sensor output is feedback to the controller. The three phase inverter Pulse depends on the hall sensor of BLDC motor. The DSPIC controller key functions are used to control the BLDC motor speed.

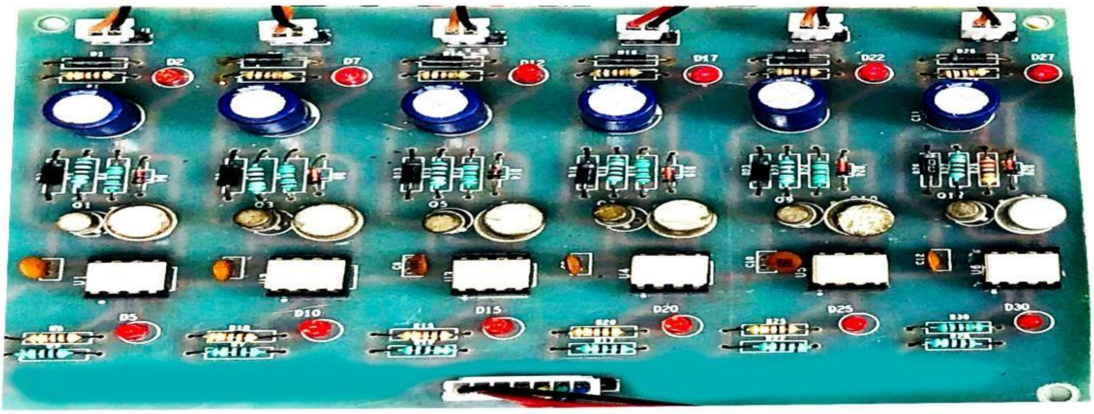
Block Diagram



Block Diagram Explanation

- Pulse generator: - Here we have used DSPIC microcontroller (DSPIC 30F4011) to generate PWM signal.
- Driver circuit: -It is used to amplify the pulses and provided isolations using opto coupler. It has two functions,
  - Amplification
  - Isolation
- Bridge Rectifier: It converts AC supply to DC Supply.
- Three phase Inverter: It converts DC supply into three phase AC Supply to drive the BLDC motor.

Driver Board

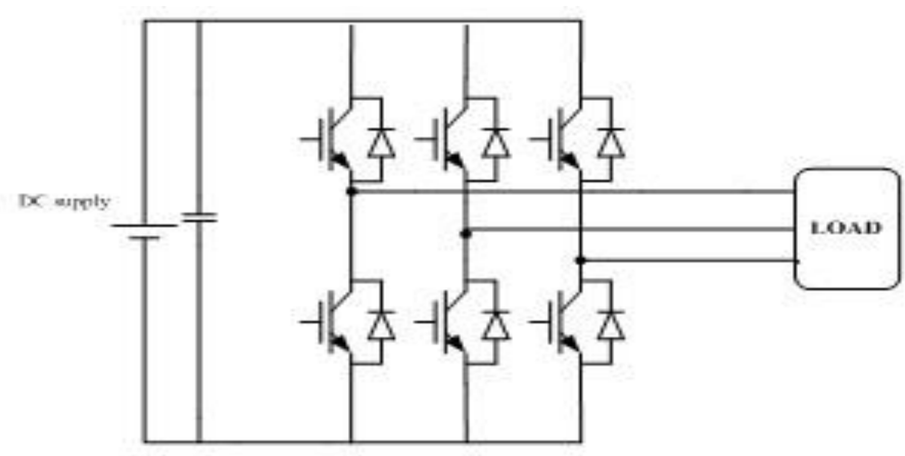


DSPIC Controller Board

Working

The DSPIC controller is used to generate the PWM pulses for inverter circuit. The DSPIC controller pulses are given to the driver circuit as input. Driver board is mainly used to isolate and amplify the input signals from the controller. The amplified driver output is connected to the main power circuit devices. Three phase inverter PWM is generated based on Hall sensor feedback.

Circuit Diagram for Three Phase Inverter



Advantages

- Easy to control speed
- Highly reliable
- High efficiency and less maintenance
- Less noise

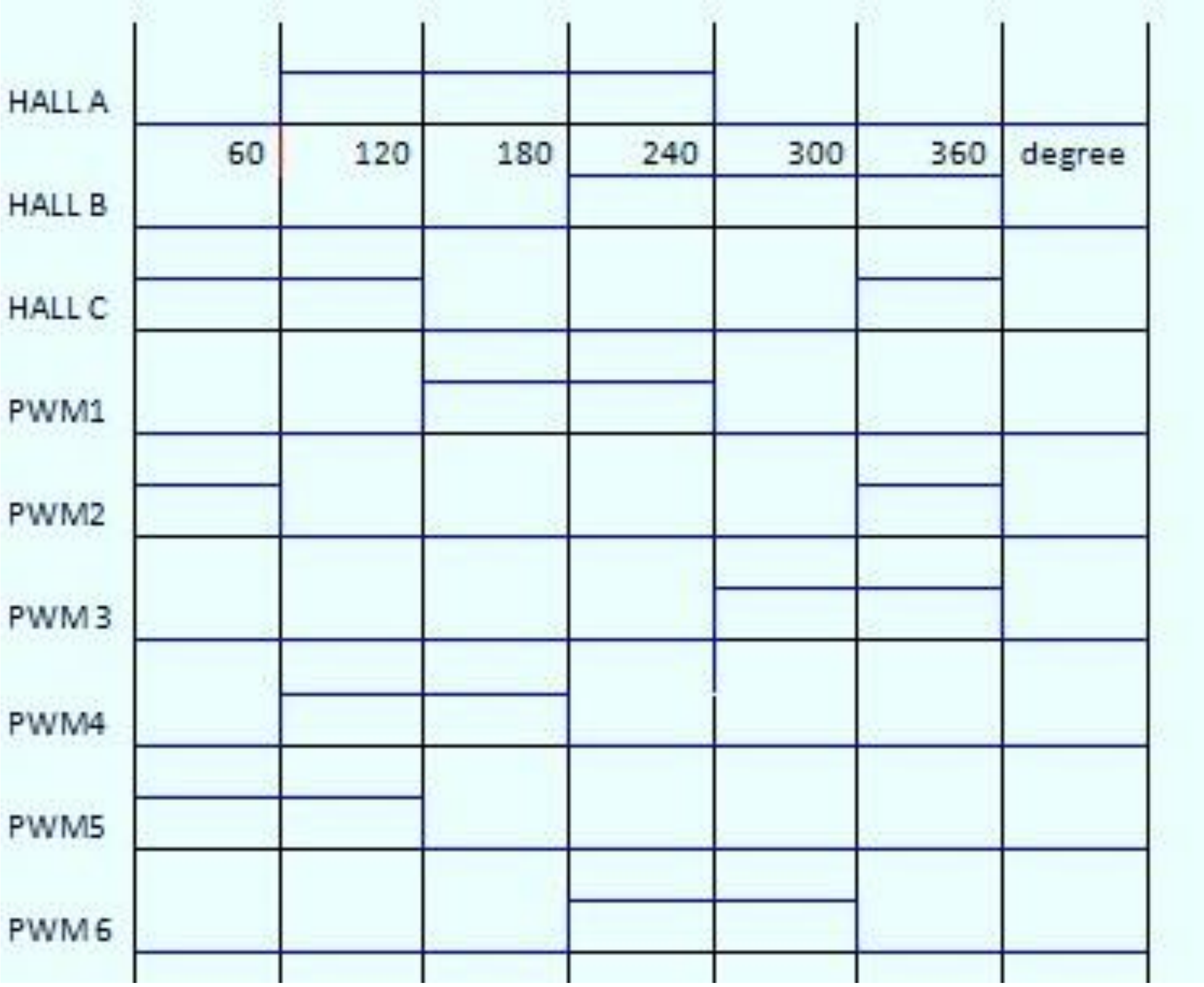
Applications

- Industrial applications
- Water pumping system

Conclusion

This project is used to control the speed of the BLDC motor. This inverter has low switching losses and BLDC motor control without any additional control. And also study the response of the all characteristics and theory. This project is highly reliable and obtains high efficiency of this control technique.

BLDC Motor Working Pattern



EXPERIMENT NO. -9

AIM: Control speed of universal motor using AC voltage regulator.

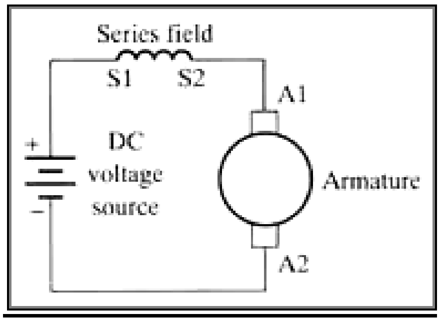
APPARATUS:

1. Universal motor
2. AC voltage regulator

BASIC CONCEPT:

A series-wound motor is referred to as a universal motor when it has been designed to operate on either AC or DC power. It can operate well on AC because the current in both the field and the armature (and hence the resultant magnetic fields) will alternate (reverse polarity) in synchronism, and hence the resulting mechanical force will occur in a constant direction of rotation.

CIRCUIT DIAGRAM:



RESULT: we have successfully completed the study of Control speed of universal motor using 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 operations is required without any mechanical changeover switch, two full converters can be connected back to back to the load circuit .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 diag. 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 circuit must be energized from single-phase or three-phase full converter.

CIRCUIT DIAGRAM: Refer P.S.Bimbra fig. no (12.19)

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 ,

$$.\alpha_1 + \alpha_2 = 180 \text{ degree}$$

OBSERVATION:

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

EXPERIMENT NO. -11

Aim: Study speed control of dc motor using 3 phase dual converter.

Apparatus:

1. Three phase dual converter
2. CRO
3. Connecting leads **Basic concept:**

When variable dc voltage is to be obtained from fixed dc voltage, dc chopper is the ideal choice. A chopper is inserted in between a fixed voltage dc source and the dc motor armature for its speed control below base speed. In addition, chopper is easily adaptable for regenerative braking of dc motors and thus kinetic energy of the drive can be returned to the dc source.

Motoring control:

The chopper consists of a force-commutated thyristor. It offers one quadrant drive. Armature current is assumed continuous & ripple free. The waveform for the source voltage, armature terminal voltage, armature current, dc source current and freewheeling-diode current.

Average motor voltage $V_0 = V_t = T_{on}/T$

$V_s = \alpha V_s = fT_{on}..V_s$

Where α = duty cycle f=

chopping frequency

Power delivered to motor = (Average motor voltage). (Average motor current)

$= V_t.I_a = \alpha.V_{s.}I_a$

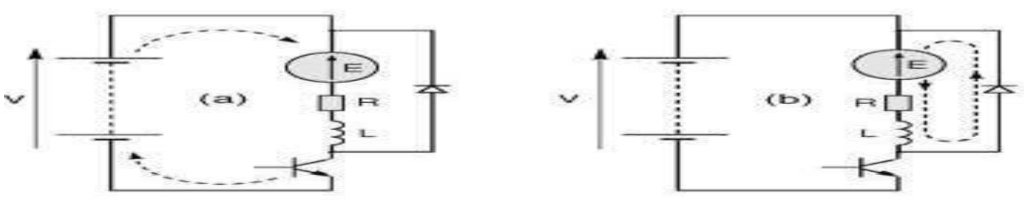
Average source current = $\frac{Ton}{T}.I_a = \alpha.I_a$

Input power to chopper = $V_s.\alpha\ I_a$

For the motor armature circuit $Vt = \alpha Vs$

By varying the duty cycle of α of the chopper, armature terminal voltage can be controlled and thus speed of the dc motor can be regulated. Actually the motor armature current will rise during chopper on period and fall during off period.

11.4 Circuit diagram:



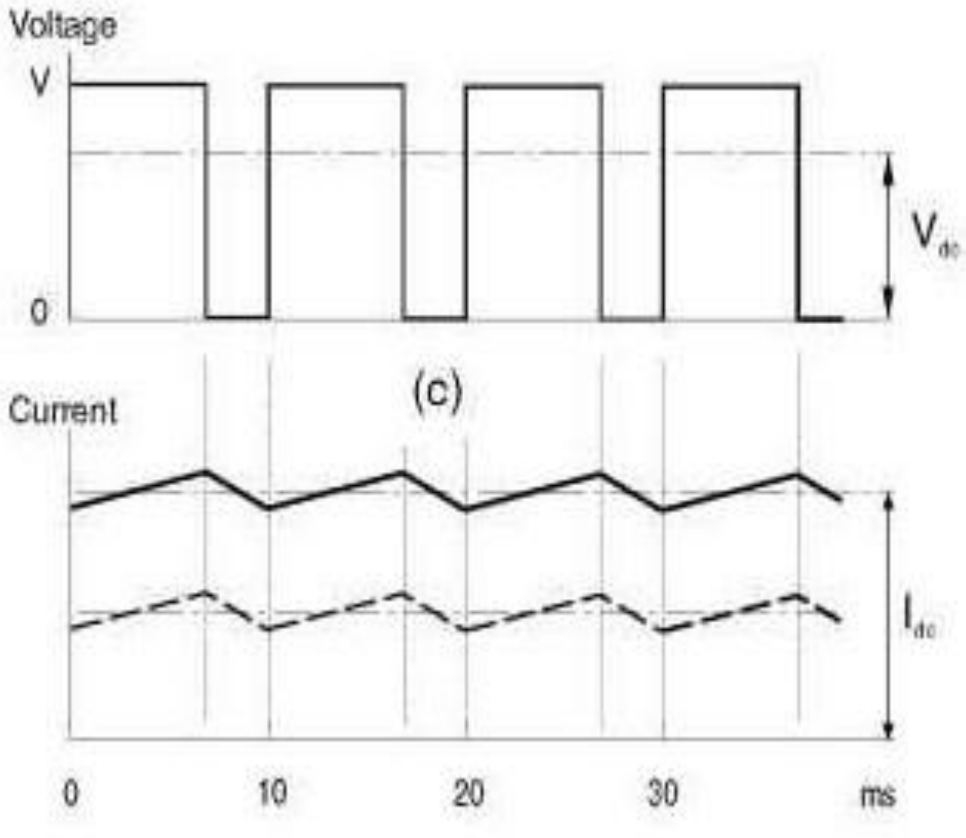


Fig 1. (a) Circuit of 3 phase dual converter (b) waveforms

Result: We have studied about the speed control of dc motor using 3-phase dual converter.

EXPERIMENT NO. -12

AIM: Study 3- phase cyclo-converter and speed control of synchronous motor using Cyclo-converter.

APPARATUS:

1. Three-phase cyclo-converter.
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 cyclo-converter.

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. 30.1. Two threephase 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: Refer P.S. Bhimbra for fig.

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 threephase 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 noncirculating 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 triplen harmonics.

Fig. 4: Output voltage waveform for m-phase converter with firing angle α.

<u>PROCEDURE:</u> As per requirement.

<u>OBSERVATION:</u> Self

<u>RESULT :</u> 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 3phase 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 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.

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: Refer P.S. Bhimbra for fig12.27 (a) & 12.28

PROCEDURE: As per requirement.

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

$$I_2 = \frac{V}{[(\frac{r_2}{s})^2 + (x_1 + x_2)^2]^{1/2}}$$ ……………….(2)

Synchronous speed,

$$w_s = \frac{4\pi f_1}{P}$$ ……………….(3)

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

$$T_e = \frac{3}{w_s} I_2^2 \frac{r_2}{s}$$ ……………….(5)

$$T_e = \frac{3P}{2w_{s1}} \cdot \frac{(V_1)^2}{(\frac{r_2}{s})^2 + (x_1 + x_2)^2} \cdot \frac{r_2}{s}$$ ……………….(6)

Slip, $s = \frac{f_2}{f_1} = \frac{w_2}{w_1}$ ……………….(7)

Or

$w2 = sw1$ ……………….(8)

OBSERVATION: Self.

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