UK MARINE TRAINING CENTRE (UMTC)

SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.

EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

ELECTROTECHNOLOGY THEORY

Q.1

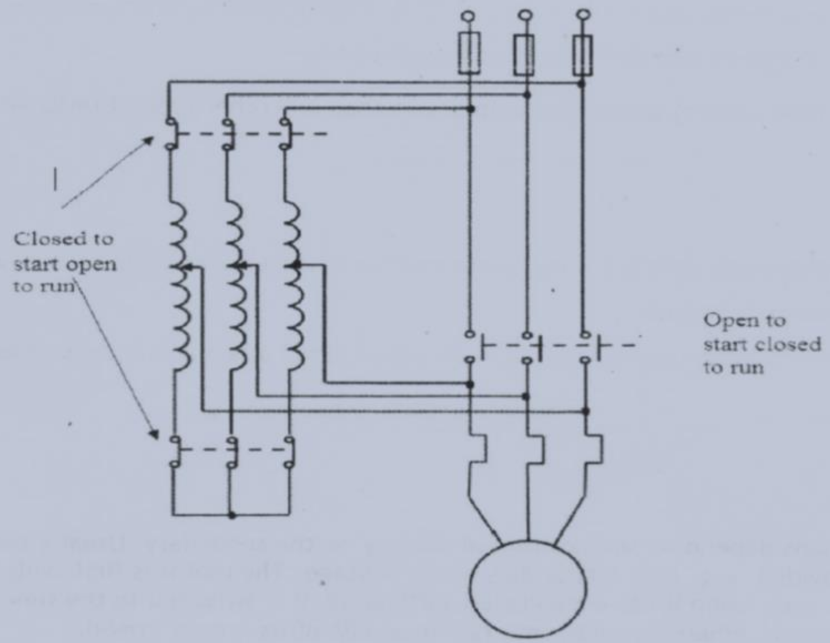
(a) Explain, with the aid of a circuit diagram, the *auto transformer* method of starting a squirrel cage induction motor. (8)

(b) State two advantages and two disadvantages of the auto transformer method of starting over the star delta method of starting. (4)

(c) Explain why it is desirable to disconnect the auto transformer when the starting sequence is completed. (4)

Solution:

a)



During the first stage, the auto-transformer is star connected, and the line contactor is closed. This starts the motor with a reduced voltage, the value of which depends upon the ratio selected for the transformer. Auto-transformers are normally provided with taps to allow the best ratio to be chosen during commissioning.

In the second stage, the star connection is opened, and the auto-transformer acts as an inductor connected in series with the motor. This transition is normally timed to occur when the motor speed has stabilised at the end of the run-up period.

The third stage then follows almost immediately, and involves shunting the transformer completely, so that the motor is direct-connected to the supply. The starting current and torque are reduced as a function of the reduced starting and run-up voltages (Usupply/Ustarting)2 . Typical values for peak starting current are 1.7 to 4 times nominal full-load current and, for peak starting torque, 0.5 to 0.85 times nominal operating torque.

b)

Advantages:

1) Auto-transformer starting is particularly used for large motors (above 100kW)

2) It is possible to vary the tapping from 65% to 80% or even up to 90% of the supply voltage in order to ensure that the motor starts satisfactorily

3) They provide best starting torque per amp drawn than any other type of reduced voltage starter.

Disadvantages:

1) The compensating switch is much more expensive than a Star-Delta starter due to the auto-transformer.

Due to the size of the auto-transformer starter, much larger control panels are required which increases the price

c)

Starting conditions depend on the position of tapping on the secondary. Usually three tapping are provided, e.g. 40%, 60% or 80% of line voltage. The motor is first switched to the tapping, then when it has accelerated sufficiently it is switched to the running or full-voltage position. When the motor has ran up to 80% of its normal speed, connections are so changed that auto transformers are cut out and full supply voltage is applied across the motor. The motor is first connected to the reduced voltage output, and when the current has fallen to the running value, the motor leads are switched over to the full voltage. The autotransformers need not have high capacity as they are only used for a very short period of time.

Since we know that the torque is proportional to square of the voltage. By auto transformers the starting voltage and current are reduced to overcome the problem of overheating due to very high current flow. During starting the ratio of the transformer is set in a way that the starting current does not exceed the safe limit. Once the induction motor starts running and reaches a steady state value, the autotransformer is disconnected from the supply.

Q.2

(a) Sketch the reverse current/voltage characteristic for a low power Zener diode with a breakdown voltage of 10 V. (5)

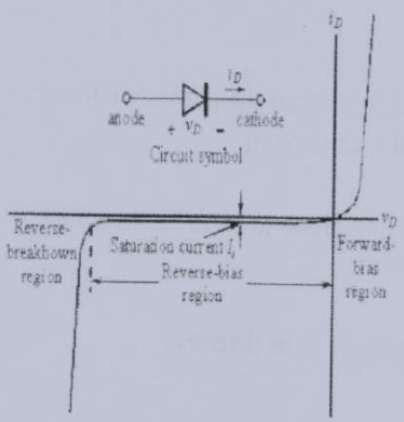
(b) Sketch a simple voltage regulator circuit using a Zener diode. (5)

(c) State which factors determine the value of the series resistor used in the circuit described in part (b). (3)

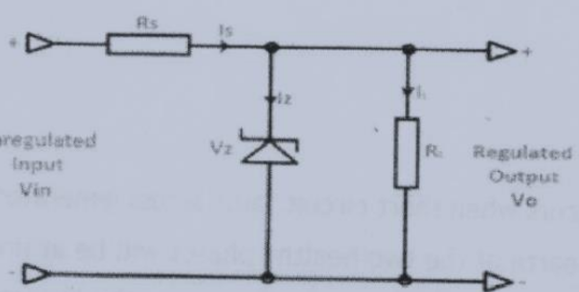
(d) State which factors determine the power rating of the Zener diode in the circuit described in part (b). (3)

Solution:

a)



b)



c)

1. Input voltage (V_{in})
2. Source current (I_S)
3. Load current (I_L)

d)

1. Zener voltage (V_Z)
2. Zener current (I_Z)

Q.3

(a) Explain why it is necessary to monitor and detect faults between the phase windings and earth of a star connected alternator with an earthed neutral point. (4)

(b) Sketch a circuit diagram of one arrangement for detecting phase to earth faults within a star connected alternator with earthed neutral. (7)

(c) Explain how the circuit given in part (b) enables earth faults to be detected. (5)

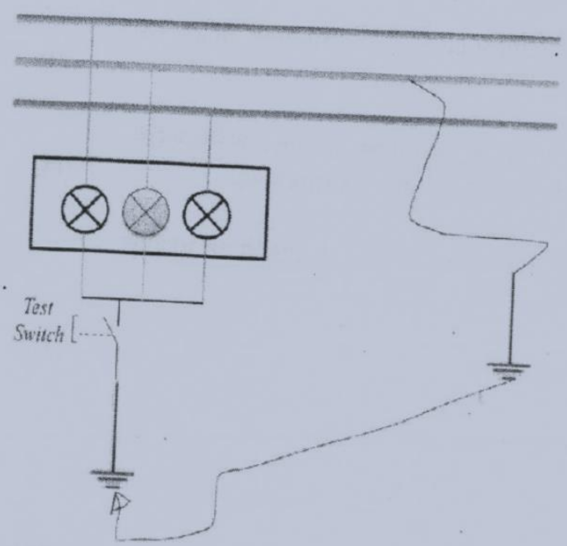
Solution:

a)

Large fault current occurs when short circuit fault across generator. While earth fault exists, the voltage to earth of the two healthy phases will be at line volts which increase possibility of second earth fault, further stress the insulation. Line protective devices immediately trip out to isolate the faulty circuit. Loss of electrical power could create a hazardous situation.

b)

Earth fault Monitoring Lamps



c)

Earth fault Monitoring Lamps

A resistance is connected in series with each of the lamps. In case of any earth fault occurs on one phase the voltage across the lamp falls to zero and the full line voltage would be applied across the remaining two lamps. When the system is healthy all three lamps are of equal brilliance. If there is an earth fault on line 1 lamp 1 will go out and lamps 2 and 3 will become brighter. Partial earth faults are difficult to detect with this system as slight voltage differences on the lamps can be visually difficult to see.

Q.4

(a) State the main reason why switchboard instruments are supplied via instrument transformers from the power circuits which they monitor (4)

(b) Explain why it is hazardous to open circuit a current transformer whilst its primary is still energised. (4)

(c) Sketch a circuit diagram showing an ammeter, a voltmeter and a wattmeter fed from a single phase supply via current and voltage transformers. (4)

(d) An ammeter, a voltmeter and a wattmeter monitoring a single phase supply read 40 A, 240 V and 8 kW respectively.

Calculate the power factor of the circuit. (4)

Solution:

a)

1. The normal range voltmeter and ammeter can be used along with these transformers to measure high voltage and currents.

2. The rating of low range meter can be fixed irrespective of the value of high voltage or current to be measured.

3. These transformers isolate the measurement from high voltage and circuits. This ensures safety of the operator and makes the handling of the equipment very easy and safe.

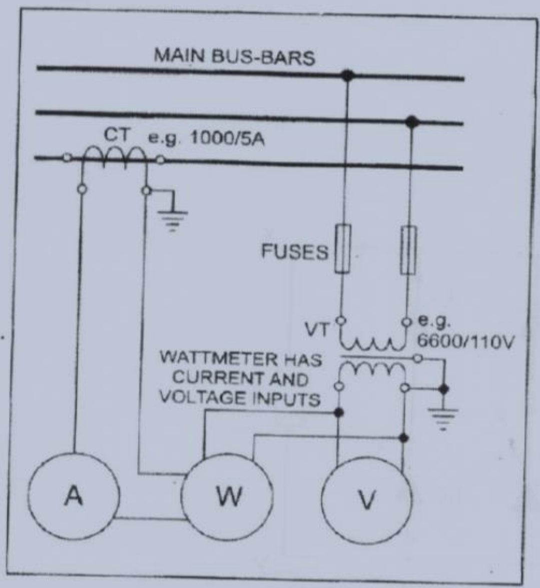
4. These can be used for operating many types of protecting devices such as relays or pilot lights.

5. Several instruments can be fed economically by single

b)

The secondary circuit of a CT must never be opened while mains primary load current is flowing. Excessive heating will be developed in an open- circuited CT with an extremely high voltage, arising at the open secondary terminals. If an ammeter is to be removed from circuit, the CT secondary output terminal must be first short-circuited, with the primary circuit switched off. The secondary short circuit will not damage the CT when the primary current is switched on. For further safety,.one end of the secondary winding of a CT is connected to earth.

c)



d)

Power= V x I x cosØ

Power factor, cosØ = ~~$\frac{8000}{240\times40}$ = 0.83 ×~~ $\frac{P}{V \times I} = \frac{8000}{240 \times 40} = 0.83$

Q5

(a) Sketch the circuit arrangement for a full wave three-phase rectifier indicating on your sketch the current directions for both positive and negative half cycles of one phase. (8)

(b) Sketch the output waveform for the circuit in part (a) above. (3)

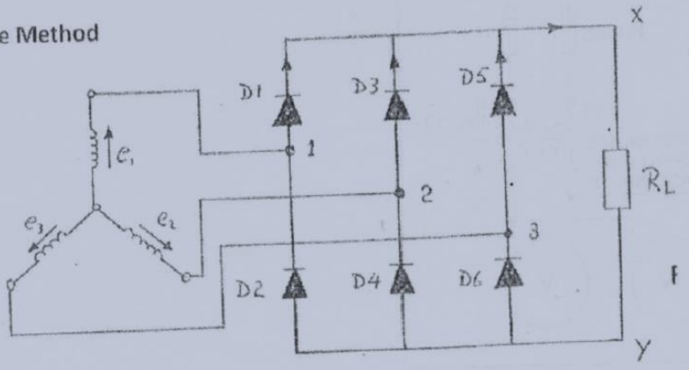
(c) Add a smoothing capacitor to the rectifier circuit and explain why less capacitance is required for a three-phase rectifier circuit than for a single phase rectifier circuit for the same acceptable 'ripple' on the output voltage. (5)

Solution:

a)

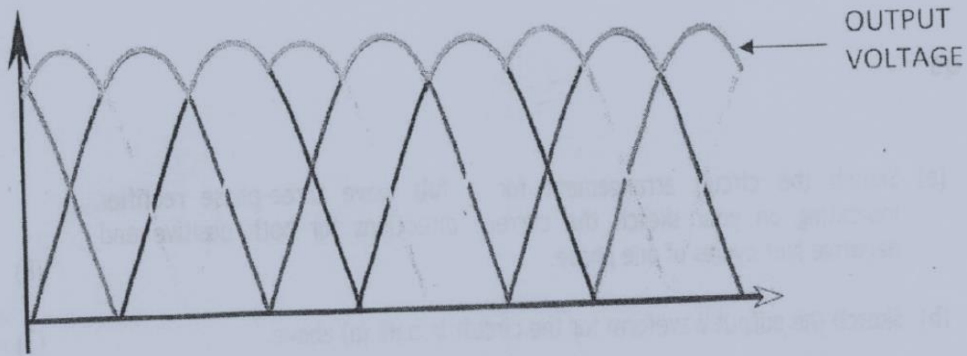
Full wave three phase rectifier:

6 Diode Method



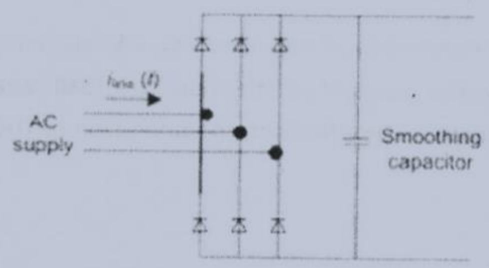
b)

Output waveform:



c)

3-phase rectifier with smoothing capacitor



The advantage of three phase rectification over single phase is the ease of achieving a reasonable level of smoothing for larger power loads without the requirement for expensive smoothing components. It can be observed from output voltage waveform, for each full cycle of any waveform there are six positive peaks. This produces DC with a much smaller ripple compared to the single phase circuit. The distance and therefore time between peaks is shorter therefore a smaller capacitor can be used for smoothing without compromising the percentage ripple. The smaller capacitors are cheaper and occupy less space.

Q.6

(a) Explain the term *power factor correction*. (3)

(b) State TWO advantages of power factor correction. (4)

(c) Explain, with the aid of a circuit diagram, how power factor correction can be effected in a three-phase circuit using capacitors. (5)

(d) State ONE method, other than the use of capacitors, by which power factor correction can be effected in a 3 ph. circuit (4)

Solution:

a)

Power Factor is a measure of how efficiently electrical power is consumed. In the ideal world Power Factor would be unity (or 1). Unfortunately in the real world Power

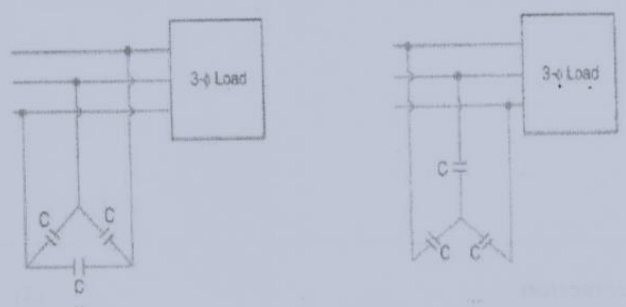
Factor is reduced by highly inductive loads to 0.7 or less. This induction is caused by equipment such as lightly loaded electric motors, luminaire transformers and fluorescent lighting ballasts and welding sets, etc.

This is normally achieved by the addition of capacitors to the electrical network which compensate for the reactive power demand of the inductive load and thus reduce the burden on the supply. There should be no effect on the operation of the equipment.

b) Advantages:

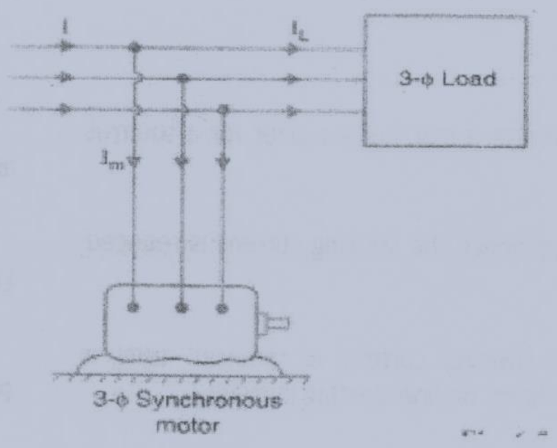
1. Increase in efficiency of system and devices
2. Reduction in size of a conductor and cable which reduces cost of the Copper
3. Line Losses (Copper Losses) I2R is reduced
4. Saving in the power bill
5. Saving in energy as well as rating and the cost of the electrical devices and equipment is reduced

c)



The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load. For three phase loads, the capacitors can be connected in delta or star as shown in fig. Static capacitors are invariably used for power factor improvement in factories. They have low losses and require little maintenance as there are no rotating parts. They can be easily installed as they are light and require no foundation.

d)



An over-excited synchronous motor operating at no load is termed as synchronous condenser. When it is connected in parallel with the load that operating at low power factor, it takes the leading current, thereby it neutralizes the lagging reactive component of the current similar to a capacitor.

Synchronous condenser has a stationary three phase armature winding which is connected to the load terminals where the power factor has to be improved. And its rotating field is excited from a DC supply (which is drawn from three phase supply and then by rectification), sometimes it is provided by a small DC generator which is mounted on the shaft of synchronous condenser. So the amount of rotor field current of synchronous condenser is controlled by the amount of DC excitation provided by the DC generator, in other words the amount of power factor correction is controlled by the amount of DC excitation.

Q.7

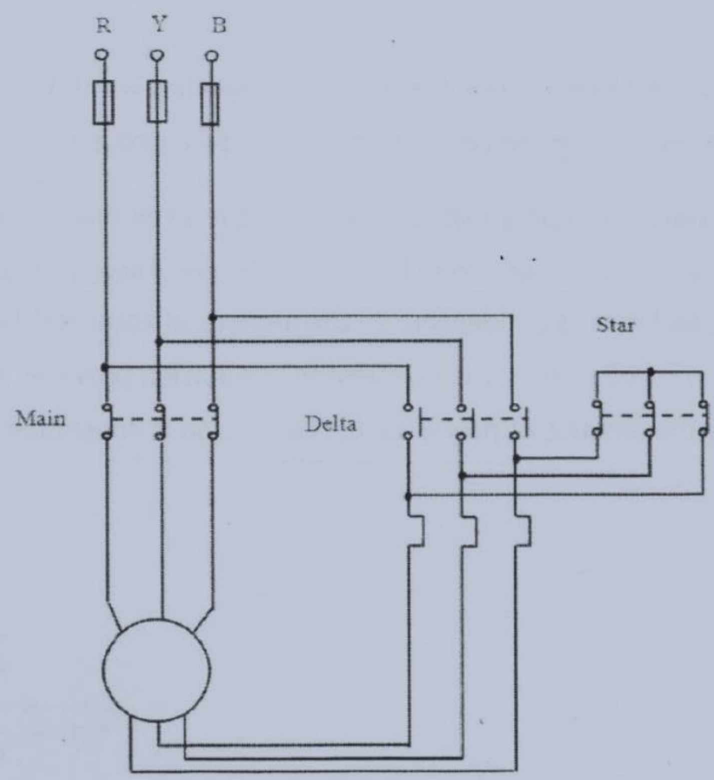
(a) Sketch a basic power circuit diagram for a star/delta starter for a squirrel cage motor. (8)

(b) Explain why the starting voltage and hence the starting current is reduced using a star/delta starter. (4)

(c) State by what factor the initial starting current is reduced using a star/delta starter compared to the direct on line starting current. (4)

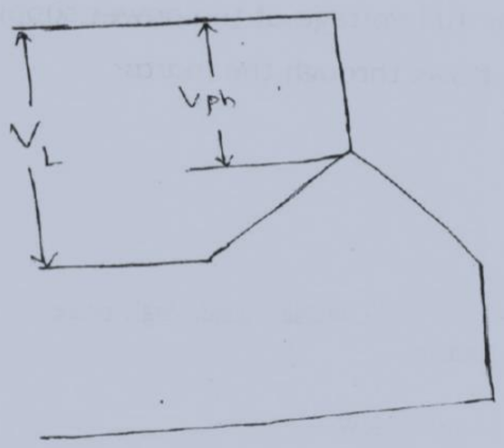
Solution:

a)



UK MARINE TRAINING CENTRE (UMTC)
SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

b)



STAR
$I_{ph} \propto V_{ph}$
$I_L\sqrt{3} \propto V_L$

STAR
$V_L = \sqrt{3} V_{ph}$
$I_{ph} = I_L$

This starter is used in the case of motors which are built to run normally with a delta connected stator winding. It consists of two way switch which connects the motor in star for starting and then in delta for normal running. When star connected, the applied voltage over each motor phase is reduced by a factor of $1/\sqrt{3}$ and hence the torque developed becomes 1/3 of that which would have been developed if motor were directly connected in delta. The line current is reduced to 1/3. Hence during starting period when motor is Y- connected, it takes 1/3rd as much starting current.

c)
In starting position of Star Delta starter, current supply to the stator windings is connected in **star (Y) for starting.** In the running position, current supply is reconnected to the windings in **delta (Δ) once the motor has gained speed.**

Star-delta connections give a low starting current of only about one third of that found with direct-on-line starting.

A DOL starter connects the motor terminals directly to the power supply. Hence, the motor is subjected to the full voltage of the power supply. Consequently, high starting current flows through the motor.

Q.8

(a) Describe, with the aid of a sketch, the construction of a double wound, single phase transformer and explain the principle of its operation. (4)

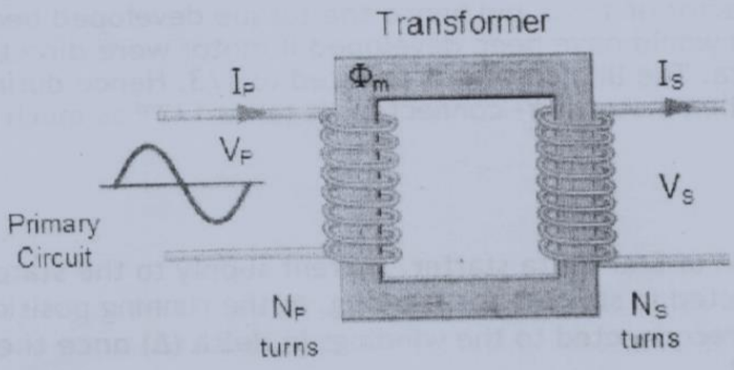
(b) Explain why a transformer is rated in KVA rather than KW. (4)

(c) State why the iron loss in a transformer is not load dependent. (4)

(d) State how the copper losses in the two windings of a transformer vary with the loading of the transformer. (4)

Solution:

a) Principle of operation of single phase transformer:



Electrical power transformer is a static device which transforms electrical energy from one circuit to another without changing its frequency and with the help of mutual induction between two windings.

Primary winding which is supplied by an alternating electrical source. The alternating current through the winding produces a continually changing flux or alternating flux that surrounds the winding. If any other winding is brought nearer to the previous one, obviously some portion of this flux will link with the second. As this

flux is continually changing in its amplitude and direction, there must be a change in flux linkage in the second winding or coil.

According to Faraday's law of electromagnetic induction, there must be an EMF induced in the second. The size of induced e.m.f.'s is determined by the ratio of primary turns(N_1) and secondary turns(N_2). If the circuit of the secondary winding is closed, there must be an current flowing through it. This is the simplest form of electrical power transformer and this is the most basic of **working principle of transformer.**

b)

Cu loss of a transformer depends on current and iron loss on voltage. Hence, total transformer loss depends on Volt-ampere (VA) and not on phase angle between voltage and current i.e. it is independent of load power factor. That is why rating of transformer is in KVA and not in KW.

c)

Iron losses occur in the core of the transformer and are generated due to the variation in the flux. These losses depend upon the magnetic properties of the materials which are present in the core. Flux remains constant from no load to full load. They are known as constant losses since they do not vary according to the loading on the transformer.

d)

Copper loss is due to ohmic resistance of the transformer windings. Copper loss for the primary winding is $I_1^2R_1$ and for secondary winding is $I_2^2R_2$. Where, I_1 and I_2 are current in primary and secondary winding respectively, R_1 and R_2 are the resistances of primary and secondary winding respectively. It is clear that Cu loss is proportional to square of the current, and current depends on the load. Hence copper loss in transformer varies with the load because the current varies with the variation in the load.

Q.10

(a) State the conditions necessary to *turn on* and *turn off* a thyristor ('SCR'). (4)

(b) Describe the operation of the circuit shown in Fig Q8. (8)

(c) Sketch the voltage waveform across the load for EACH of the following trigger delay angles:

(i) 60°; (2)

(ii) 120°. (2)

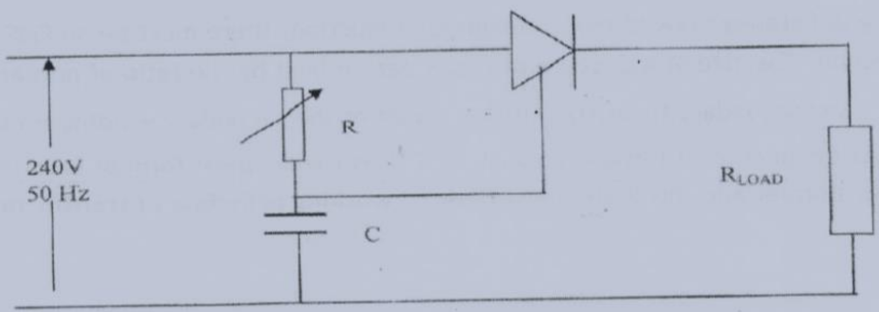


Fig Q8

Solution:

a)

Conditions necessary to Turn on a Thyristor:

The SCR can be switched on either by increasing the forward voltage beyond forward break over voltage VFB0 or by applying a positive gate signal when the device is forward biased.

Conditions necessary to Turn OFF a Thyristor:

1) IA < IH (Anode current must be less than holding current)

2) A reverse voltage is applied to SCR for sufficient time enabling it to recover its blocking state.

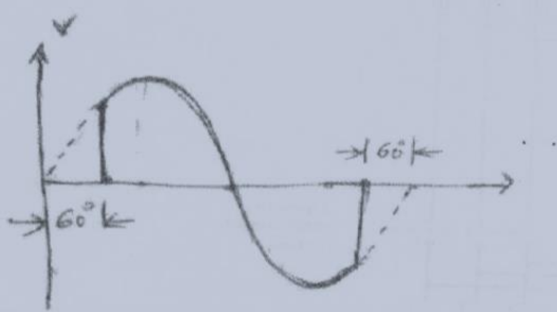
b)

Phase control is the most common form of thyristor AC power control. Here the thyristors Gate voltage is derived from the RC charging circuit.

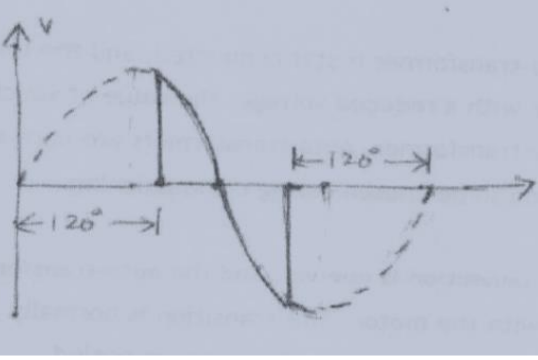
During the positive half-cycle when the thyristor is forward biased, capacitor, C charges up via resistor R_1 following the AC supply voltage. The Gate is activated only when the voltage has raised enough to conduct and the capacitor discharges into the Gate of the thyristor turning it "ON". The time duration in the positive half of the cycle at which conduction starts is controlled by RC time constant set by the variable resistor, R.

Increasing the value of R has the effect of delaying the triggering voltage and current supplied to the thyristors Gate which in turn causes a lag in the devices conduction time. As a result, the fraction of the half-cycle over which the device conducts can be controlled between 0 and 180°, which means that the average power dissipated by the load can be adjusted. However, the thyristor is a unidirectional device so only a maximum of 50% power can be supplied during each positive half-cycle.

a) i)



ii)



Q.11

(a) Explain, with the aid of a circuit diagram, the auto transformer method of starting a large induction motor. (8)

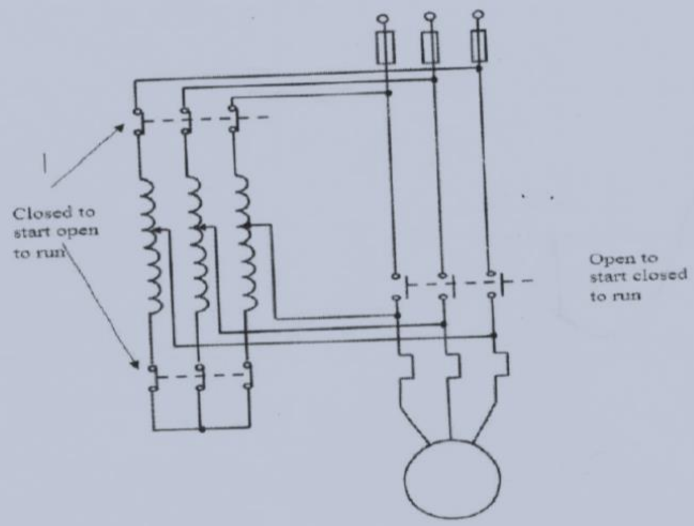
(b) State ONE advantage of this method of starting compared to star delta starting. (2)

(c) State ONE disadvantage of the auto transformer method of starting. (2)

(d) State the advantage which accrues from the use of the Korndorfer modification to the basic auto transformer starter. (4)

Solution:

a)



During the first stage, the auto-transformer is star connected, and the line contactor is closed. This starts the motor with a reduced voltage, the value of which depends upon the ratio selected for the transformer. Auto-transformers are normally provided with taps to allow the best ratio to be chosen during commissioning.

In the second stage, the star connection is opened, and the auto-transformer acts as an inductor connected in series with the motor. This transition is normally timed to occur when the motor speed has stabilised at the end of the run-up period.

The third stage then follows almost immediately, and involves shunting the transformer completely, so that the motor is direct-connected to the supply. The starting current and torque are reduced as a function of the reduced starting and run-up voltages $(Vsupply/Vstarting)^2$. Typical values for peak starting current are 1.7 to 4 times nominal full-load current and, for peak starting torque, 0.5 to 0.85 times nominal operating torque.

b)

Advantage:

In Auto transformer starter, it is possible to vary the tapping from 65% to 80% or even up to 90% of the supply voltage in order to ensure that the motor starts satisfactorily. It can decrease the starting current as required because of number of tappings.

In star delta starter the starting current reduced by only 1/3 times.

c)

Disadvantage:

The compensating switch is much more expensive than a Star-Delta starter due to the auto-transformer.

Due to the size of the auto-transformer starter, much larger control panels are required which increases the price.

d)

Advantages of Korndorfer starter:

1. The Korndorfer starter limits significantly the inrush current.

2. It is used for large motors, in which start by direct connection to the network is not possible. For large motors also the star-delta starter cannot be used, especially if they are started with a significant load.

3. The circuit has advantage over starting with a regular autotransformer, which needs to be at some point completely disconnected during the start inducing high voltage impulses, which can damage the electrical insulation of the stator.

4.The most effective ratio of the autotransformer is between 65-80%.

Q.12

With reference to an a.c. generator used in marine practice:

(a) state an expression for the frequency of the generated e.m.f. in terms of the speed of the machine and the number of poles; (3)

(b) explain the difference between the generated e.m.f. 'E' and the terminal voltage 'V' if the resistance of the stator output windings is low enough to be ignored; (5)

(c) state an expression for the regulation of the generator in terms of 'E' and 'V'; (3)

(d) explain the effect on the terminal voltage of increasing the load power factor without changing the excitation or the power input to the machine. (5)

Solution:

a)

Let P = total number of magnetic poles

N = rotative speed of the rotor in r.p.m.

f = frequency of generated e.m.f. in Hz.

Since one cycle of e.m.f. is produced when a pair of poles passes past a conductor, the number of cycles of e.m.f. produced in one revolution of the rotor is equal to the number of pair of poles.

Therefore,

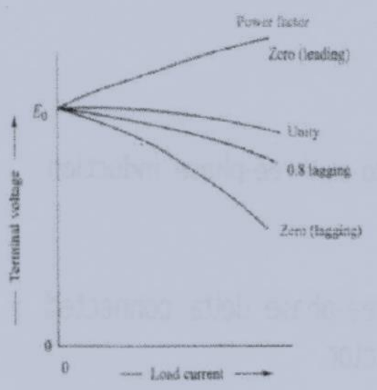
No. of cycles/revolution = $P/2$ and No. of revolutions/second = $N/60$

Frequency(f) = 2 × 60 = 120

b)

Effect of Power Factor on the Terminal Voltage

The variation of the terminal voltage of an alternator with load current at different power factors is shown in Fig. 5.22. The rotor excitation current is



maintained constant so as to generate an emf E_0 on no-load. When the power factor of the load is unity, the reduction in the terminal voltage is small. But when the load is inductive (lagging power factor), the stator mmf opposes the rotor mmf as explained earlier in the previous section, resulting in a reduction in the generated emf which consequently reduces the terminal voltage. The reduction in the terminal voltage is more when the power factor is low. On the other hand, when the load across the alternator is capacitive (leading power factor), the magnetising effect of the armature reaction causes the terminal voltage to increase with an increase in load.

c)

The voltage regulation of an alternator is defined as "the rise in voltage when full-load is removed (field excitation and speed remaining the same) divided by the rated terminal voltage."

So if V = Rated terminal voltage

E_0 = No load induced e.m.f.

the voltage regulation is defined as,

% regulation = $\frac{E_0 - V}{V}$ × 100

Q.13

(a) Explain the term *single phasing* when applied to a three-phase induction motor. (6)

(b) Describe the effect of single phasing on a three-phase delta connected motor operating at 75% full load and 0.8 power factor. (6)

(c) Describe ONE method of protecting a three-phase motor against the effects of single phasing. (4)

a)

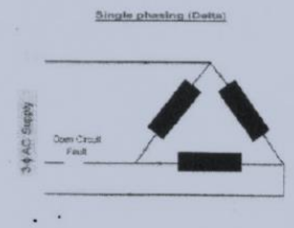
For proper working of any 3 phase induction motor it must be connected to a 3 phase alternating current (ac) power supply of rated voltage and load. Once these three phase motors are started they will continue to run even if one of the three phase supply lines gets disconnected. The loss of current through one of these phase supply is described as single phasing.

In Star connection, single phasing means the live phase windings will form a series circuit and overall circuit impedance increases hence the current passing through the circuit is less while remaining phase carries zero current.

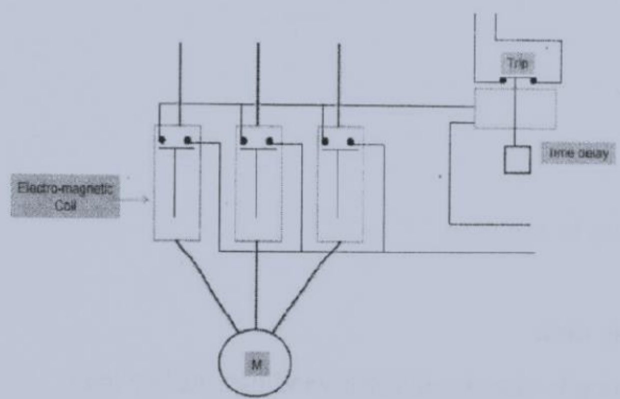
In Delta connection, single phasing means one of the phase winding will be exposed to two live supply phases and increased current passes through it while the remaining two phases will carry less amount of carries zero current through them.

Single Phasing is usually caused due to one of the three back up fuses blow, one of the contactor for motor is open circuited, wrong setting of the protection devices provided on the motor, contactors are coated due to oxidation hence not conducting and Relay contacts may be damage or broken.

b)



c)



The most commonly used protection devices for single phasing is **Electromagnetic Overload Device.** In this device all the three phases of the motor are fitted with an overload relay. If there is any increase in the value of the current then this relay activates automatically and the motor trips. This device works on the principle of electromagnetic effect produced due to the current.

As the current value increases, the electromagnet in the coil also increases which pulls the relay and activates the trip relay and the motor is stopped. The time delay is provided in this system because during starting the motor draws a lot of current which can trip the motor.

(a) List the various losses which occur in the squirrel cage induction motor on load. (4)

(b) State which of these losses is:

(i) independent of load and speed; (4)

(ii) dependent on load; (4)

(iii) dependent on speed. (4)

Solution:

a)

i) Stator copper loss and iron loss

ii) Rotor copper loss

iii) Windage and friction losses

b)

i)Iron or core losses:

It depends on frequency any flux density in the core.

ii)Stator copper loss and Rotor copper loss:

These losses occur due to current flowing in stator and rotor windings. As the load changes, the current flowing in rotor and stator winding also changes and hence these losses also changes. Therefore these losses are called variable losses. The copper losses are obtained by performing blocked rotor test on three phase induction motor.

iii)

Mechanical and Brush Friction Losses:

Mechanical losses occur at the bearing and brush friction loss occurs in wound rotor induction motor. These losses occurs with the change in speed. In three phase induction motor the speed usually remains constant. Hence these losses almost remain constant.

Q.14

(a) Describe the FOUR conditions which have ideally to be met before an alternator can be connected to live busbars. (8)

(b) Explain the process by which load can be taken up by a newly synchronised alternator. (3)

(c) Describe the result of increasing the excitation of an alternator which is sharing load without increasing the shaft power input to the machine. (5)

Solution:

a) Conditions required for paralleling or *synchronizing*

1. Equal voltage: The terminal voltage of incoming alternator must be equal to the bus-bar voltage.
2. Similar frequency: The frequency of generated voltage must be equal to the frequency of the bus-bar voltage.
3. Phase sequence: The phase sequence of the three phases of alternator must be similar to that of the grid or bus-bars.
4. Phase angle: The phase angle between the generated voltage and the voltage of grid must be zero.

b) KW load sharing:

When generator sets operate in parallel, the **engine speed governor** of each generator set determines the proportional sharing of the total **active power requirements (kW)** of the system. The **kW load sharing** is achieved by increasing or decreasing fuel to the systems' engines.

KVAR load sharing:

The **kVAR load sharing** is achieved by increasing or decreasing the field excitation to the systems' alternators. The reactive power is adjusted by trimming the AVR.

c)

As the field excitation of one generator set in a group is **increased** i.e. overexcited it will not lead to an increase in voltage (as it would if it were operating alone) but it will lead to an increase in the proportion of the total **kVAR** load it will deliver and a decrease in its power factor.

As the field excitation of one generator set in a group is decreased i.e. underexcited it will not lead to a decrease in voltage (as it would if it were operating alone) but it will lead to a decrease in the proportion of the total kVAR it will deliver an increase in its power factor.

An undesirable circulating reactive current (cross current) will flow in the system if the excitation of the alternators is not matched. The voltage control system of the generator sets (via the alternator voltage control system) monitors and controls the

sharing of the total kVAR load in proportion to the relative rating of the alternators on the systems' generator sets.

Q.15

(a) State TWO advantages and TWO disadvantages of the wound rotor induction motor starting method. (4)

(b) Sketch a circuit diagram showing the rotor/slip rings/starting resistor connection for a 3 ph wound rotor induction motor. (6)

(c) A 3 ph 4 pole wound rotor induction motor has a rotor induced e.m.f. of 230 V 60 Hz between the slip rings at standstill.

Calculate EACH of the following:

(i) the rotor phase e.m.f. and frequency at a slip 0.04 p.u.; (4)

(ii) the synchronous speed. (2)

Solution:

a)Advantages:

1. Ideal for high-inertia loads which need to be started on load.

2. The machine is started with all resistances in circuit giving a high starting torque but limiting the drawn current and also improves power factor.

3. It is possible to add external resistance during starting period compared to other types of starter.

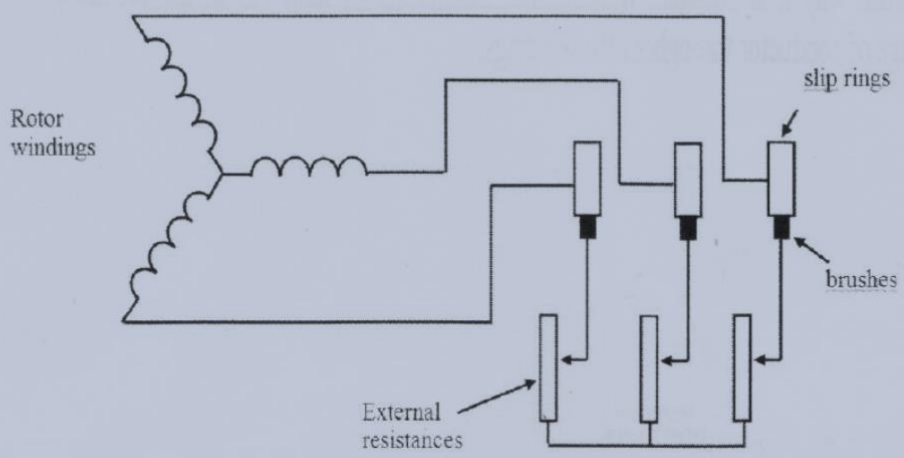
Disadvantages:

1. High maintenance cost.

2. It is not suitable for squirrel cage induction motor.

3. Speed regulation is poor when operated with external resistances in rotor circuit

b)



UK MARINE TRAINING CENTRE (UMTC)

SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.

EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

c)i)

Rotor e.m.f per phase at standstill= $230/\sqrt{3} = 132.79V$

Frequency, f' =S x f = 0.04 x 60 = 2.4HZ

ii)

synchronous speed,= 1800 RPM

$$N_s = \frac{120f}{P} = \frac{120 \times 60}{4} = 1800\ RPM$$

Q.16

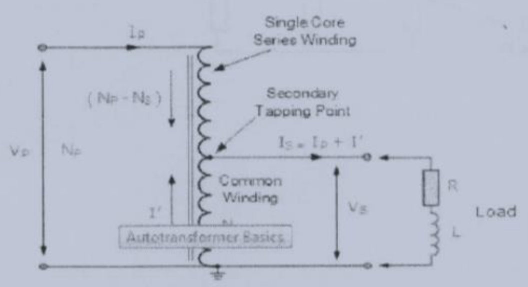
(a) Explain, with the aid of a sketch, the principle of the *auto transformer*. (8)

(b) Explain why the auto transformer is not a suitable choice of transformer for applications where the transformation ratios differs widely from 1:2 or 2:1. (4)

(c) Explain why it is possible, with an auto transformer of ratio 1:2, to use the same gauge of conductor throughout the windings. (4)

Solution:

a)



An **Autotransformer** has only one single voltage winding which is common to both sides. This single winding is "tapped" at various points along its length to provide a percentage of the primary voltage supply across its secondary load. Then the *autotransformer* has the usual magnetic core but only has one winding, which is common to both the primary and secondary circuits.

Therefore in an autotransformer the primary and secondary windings are linked together both electrically and magnetically. The main advantage of this type of transformer design is that it can be made a lot cheaper for the same VA rating, but the biggest disadvantage of an autotransformer is that it does not have the primary/secondary winding isolation of a conventional double wound transformer.

The section of winding designated as the primary part of the winding is connected to the AC power source with the secondary being part of this primary winding. An autotransformer can also be used to step the supply voltage up or down by reversing the connections. If the primary is the total winding and is connected to a supply, and the secondary circuit is connected across only a portion of the winding, then the secondary voltage is "stepped-down" as shown.

When the primary current I_P is flowing through the single winding in the direction of the arrow as shown, the secondary current, I_S, flows in the opposite direction. Therefore, in the portion of the winding that generates the secondary voltage, V_S the current flowing out of the winding is the difference of I_P and I_S.

b)

The main disadvantage of an autotransformer is that it does not have the primary to secondary winding isolation of a conventional double wound transformer. Then auto transformer's cannot safely be used for stepping down higher voltages to much lower voltages suitable for smaller loads. So its application is rather limited because of the absence of isolation between input and output circuits.

The larger the transformation ratio, the less economical an autotransformer becomes. As a result, autotransformers with transformation ratios over 2 are seldom used.

c)

A variable autotransformer contains a variable tap in the form of a carbon brush that slides up and down the primary winding which controls the secondary winding length and hence the secondary output voltage is fully variable from the primary supply voltage value to zero volts.

The variable autotransformer is usually designed with a significant number of primary windings to produce a secondary voltage which can be adjusted from a few volts to fractions of a volt per turn. This is achieved because the carbon brush or slider is always

SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

in contact with one or more turns of the primary winding. As the primary coil turns are evenly spaced along its length. Then the output voltage becomes proportional to the angular rotation.

Q.17

(a) Explain how torque is produced in a 3 phase squirrel cage induction motor. (5)

(b) State why the starting current is several times higher than the full load current. (3)

(c) State why the power factor is very low on starting. (3)

(d) Describe ONE method of construction by means of which the starting power factor may be raised, the starting current reduced and the starting torque improved. (5)

a)

Three phase windings on stator are spread 120^0 apart mechanically. When the stator windings are connected to a 3 phase, 120^0 spaced electrically, supply each winding produces a pulsating magnetic field. The speed of the rotating magnetic field is dependent on the applied frequency and is described by the equation S = 120F/P where S is the speed of the field in RPM, F is the frequency of the applied voltage in Hz, and P is the number of poles (always a multiple of two) in the motor windings. As the rotating magnetic field passes over the bars on the rotor an emf is induced in the conducting bars which creates a current because of the shorting rings. This current creates a second magnetic field on the rotor which reacts with the rotating field produced by the stator producing a torque on the rotor causing the rotor to turn. The rotor rotates at less than synchronous speed in order that the rotating magnetic field can cut the bars.

b)

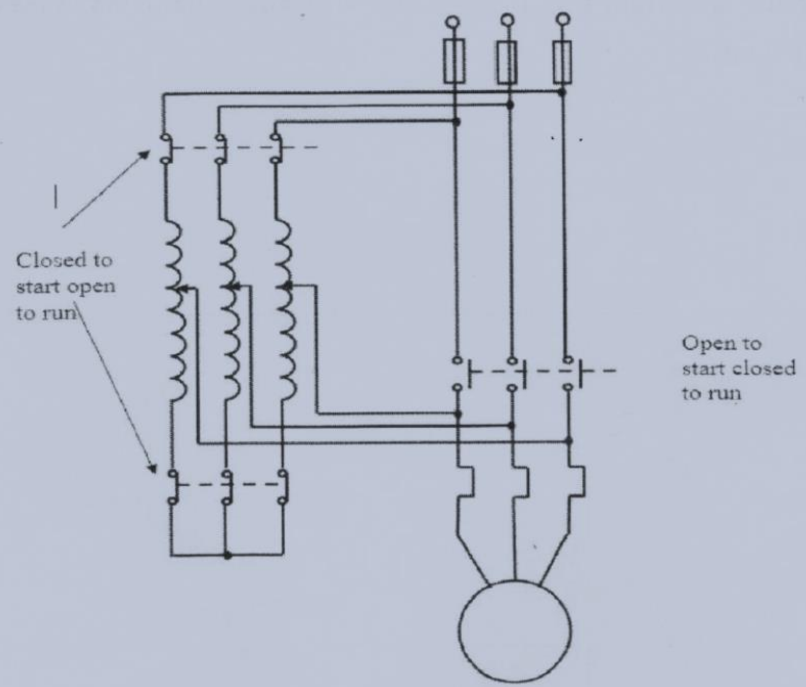
An induction motor is similar to a poly-phase transformer whose secondary is short circuited. Thus, at normal supply voltage, like in transformers, the initial current taken by the primary is very large for a short while. If an induction motor is directly switched on from supply, it takes 5 to 7 times its full load current, and develops a torque which is only 1.5 to 2.5 times the full load torque. This large starting current will produce large voltage drop in line, which may affect the operation of other devices connected in the line.

c)

At starting leakage reactance is more than the resistance as slip is unity. Current lags voltage by a large angle due to high inductance of the circuit. So power factor is least at the starting.

In an Induction motor, the air gap is large. Because of the larger Air gap, reluctance of the air gap path is large. Since the reluctance is large, a large magnetizing current is required to produce a (sufficiently) large rotating MMF. Since the magnetizing current is reactive in nature and it is more at starting than at no load, pf of IM should be low at starting.

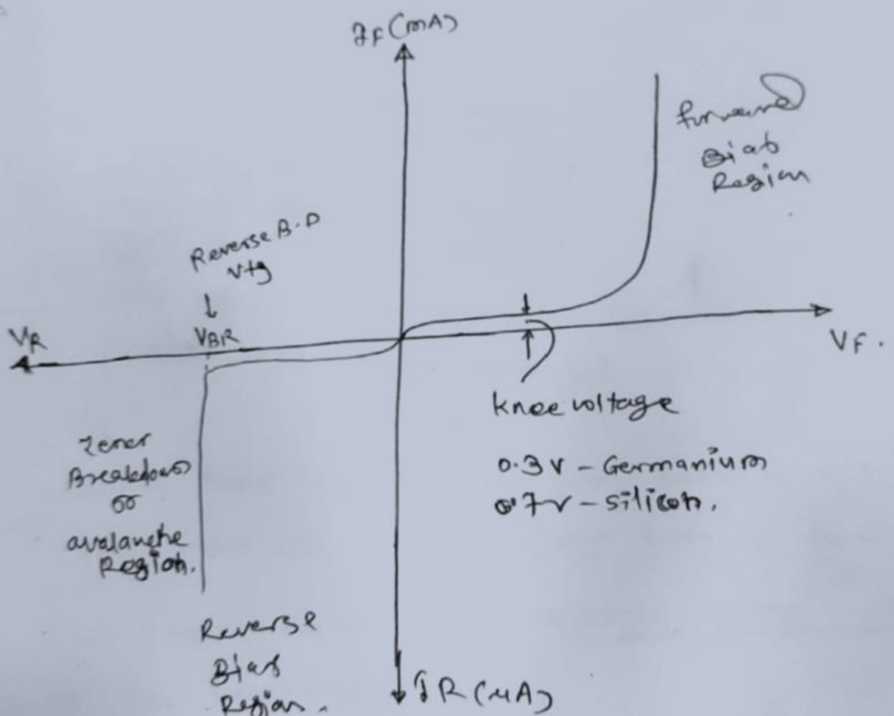
d)



Semiconductor Devices.

1) Diode

- Semiconductor device, with two terminals, typically allowing the flow of current in one direction only.



Knee voltage :- Also called cut in voltage.

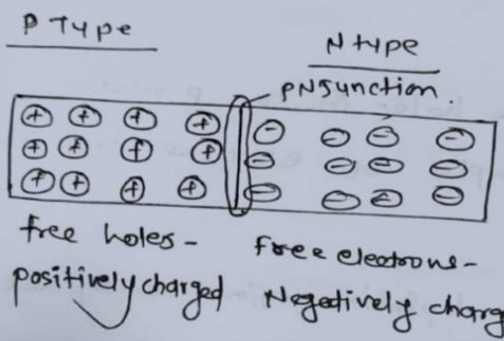
- It is the minimum ammount of voltage required for conducting the diode is known as knee voltage or cut-in vtg.
- It is the forward voltage at which the current thr P-N junction starts increasing rapidly is known as knee voltage.

UK MARINE TRAINING CENTRE (UMTC)
SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

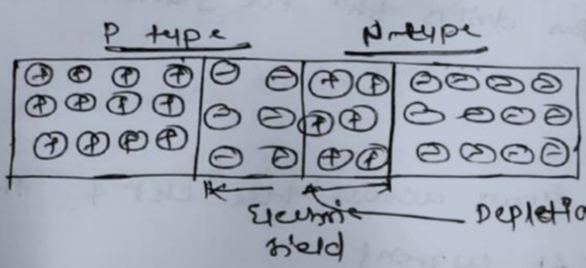
* P-N Junction working

* What is P-N Junction semiconductor & how it formed.
→ • It's a combination of P type semiconductor with N type semiconductor to achieve the practical utility of both.

• It's formed, when a P type semiconductor is joined to a N type semiconductor



• Electrons near the junction jump from N to P.
• Holes near the junction jump from P to N.
This phenomenon creates a space charge region at the junction.

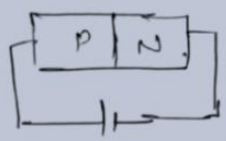


In space charge region electrons to P region & Holes in N region.

SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

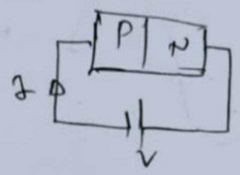
- some e⁻ move back from p to N in space region & some holes move back from N to p in space region.
- this continuous to happen till equilibrium is reached.
- this movement of e⁻ & holes in space region gives rise to Diffusion current.

* Forward Bias

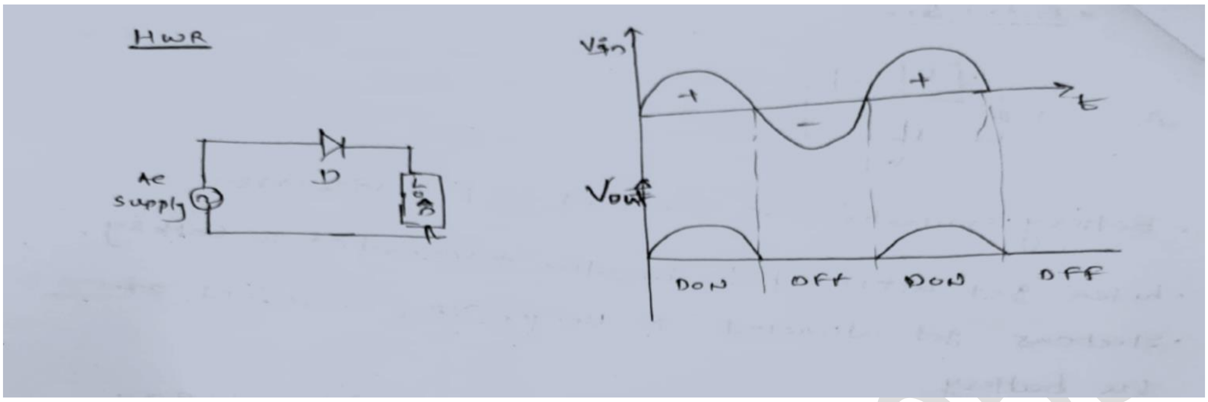


- positive terminal repels the holes in the p region. & negative terminal repels the electrons towards the junction.
- Due to this repulsion the depletion region or space region narrows down.
- If the voltage in the forward Bias is above a specified range. the electrons in the range 'N' region drifts through the junction and migrates to the 'p' region & the holes in the p region drifts thr the junction & migrates to the N region.
- Now the current flows across the ckt & this current is called the drift current.

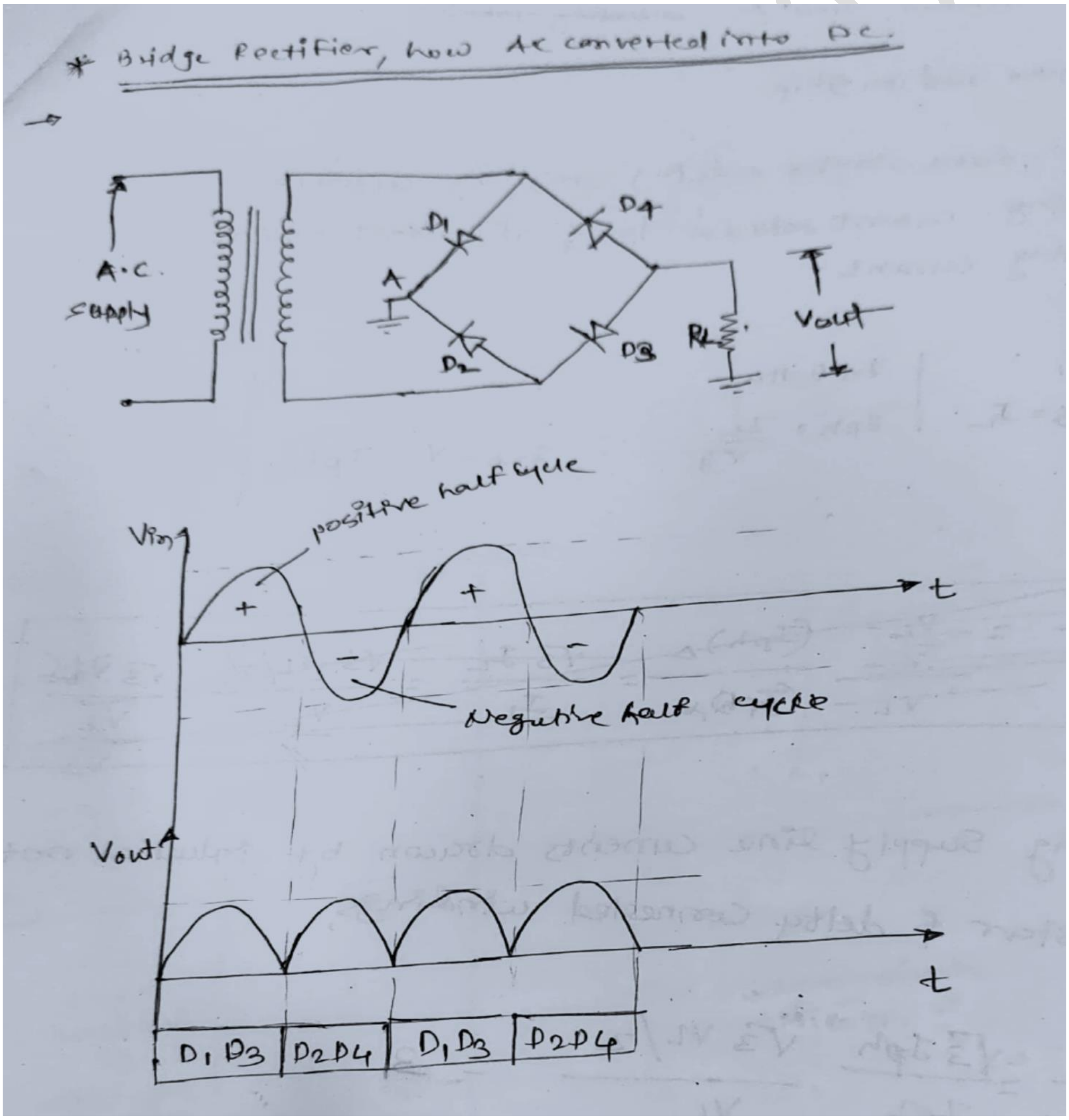
* Reverse Bias



- Battery connected -ve terminal to P & vice versa.
- holes get attracted to negative terminal of the Battery.
- Electrons get attracted to the positive terminal of the battery.
- this results in increase of depletion ~~region~~ layer.
- Now P-N junction acts as a insulator & will not allow any current to flow in the circuit.
- If the battery voltage is above a particular limit (Reverse bias breakdown voltage). Electrons & the holes breakdown thr the PN junction & cross resulting in the current to flow through the circuit this breakdown is called avalanche breakdown
- In this process current flowing thr the PN junction is very high & ultimately the PN junction gets damaged due to overheating caused by the excess flow of current.



HWR
AC supply
D
Load
Vin
t
Vout
ON
OFF
ON
OFF



* Bridge Rectifier, how AC converted into DC.
A.C. supply
D1
D2
D3
D4
A
RL
Vout
Vin
positive half cycle
Negative half cycle
t
Vout
t
D1 D3
D2 D4
D1 D3
D2 D4

UK MARINE TRAINING CENTRE (UMTC)
SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

SCR (silicon controlled Rectifier)

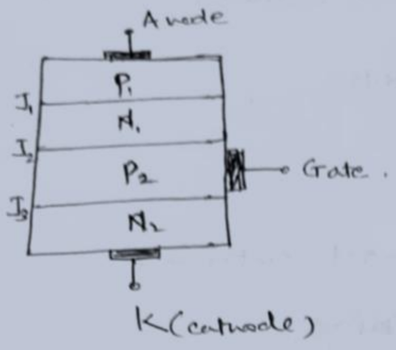


Fig:- Internal structure of SCR

fig:- SCR symbol.

- when anode is positive w.r.t cathode → Forward Bias.
- when anode is negative w.r.t cathode ↔ Reverse Bias.
- Gate terminal controlling current flowing anode to cathode during forward Bias.

SCR works in three Different modes.

1) forward Blocking mode.
2) forward conduction mode.
3) Reverse Blocking mode.

SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

- For forward Bias -
  - anode should be positive w.r.t cathode.
  - J_1 & J_3 in F.B & J_2 in R.B.

- For Reverse Bias
  - anode should be -ve w.r.t cathode.
  - J_1 & J_3 in Reverse Bias
  - J_2 is forward Bias.

* Forward Blocking mode →

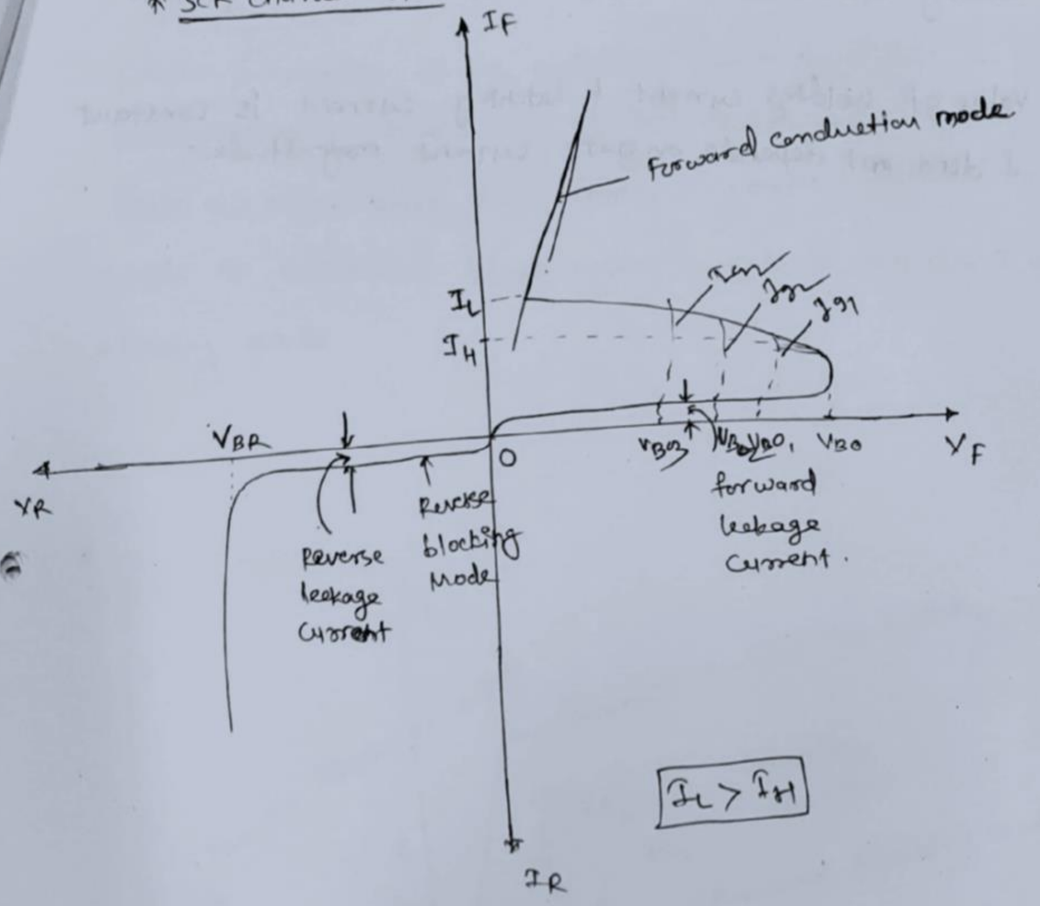
SCR is in forward Bias but current is Blocked dueto reverse bias of J_2 junction.

* forward Conduction Mode →

- SCR is in forward bias but dueto breakdown of junction (J_2) high ammount of current flows through anode to cathode. forward conduction mode could be controlled by gate current.
- As we increase gate current forward triggering of SCR from anode to cathode will be earlier.

UK MARINE TRAINING CENTRE (UMTC)
SAI POOJA BUILDING, SHOP NO. 4, PLOT NO. 36, SECTOR - 34. KAMOTHE, NAVI MUMBAI - 410 209 MAHARASHTRA, INDIA.
EMAIL : umtcindia1234@gmail.com | PH : +91 9673855053, +91 7021406134

* SCR characteristics [VI chara]



Latching current

It is the minimum anode current when SCR changes state from OFF state to ON state after VBD.

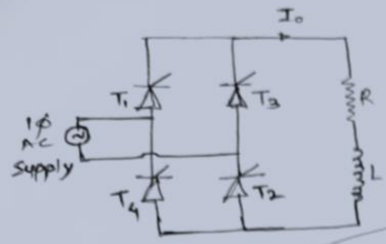
Defn: It is defined as the minimum anode current requires keeping turned ON SCR after removing gate signal.

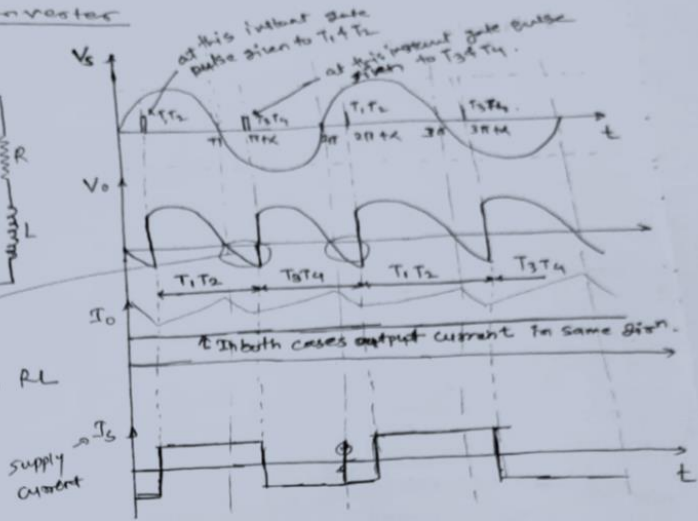
Holding current

It is the minimum current when SCR changes state from ON state to OFF state. below IH SCR turns off.

- Latching current is associated with turned on process.
- Value of holding current & latching current is constant & does not depends on gate current magnitude.

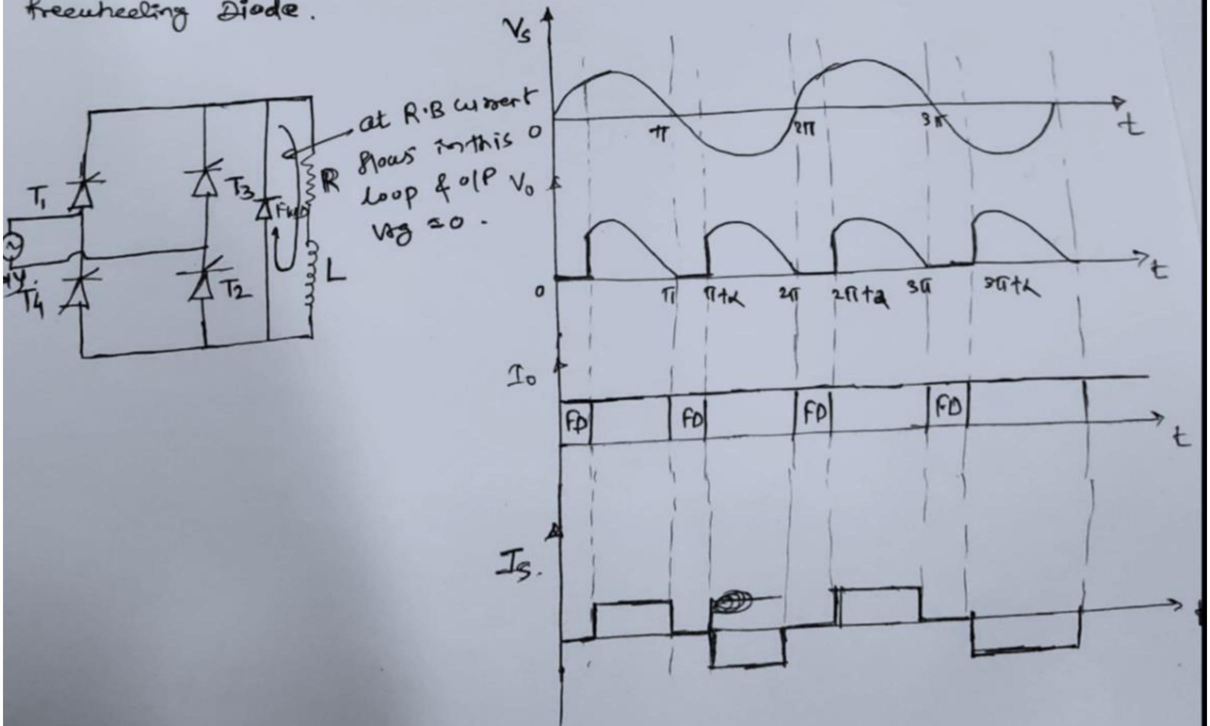
(i) Full wave Bridge converter

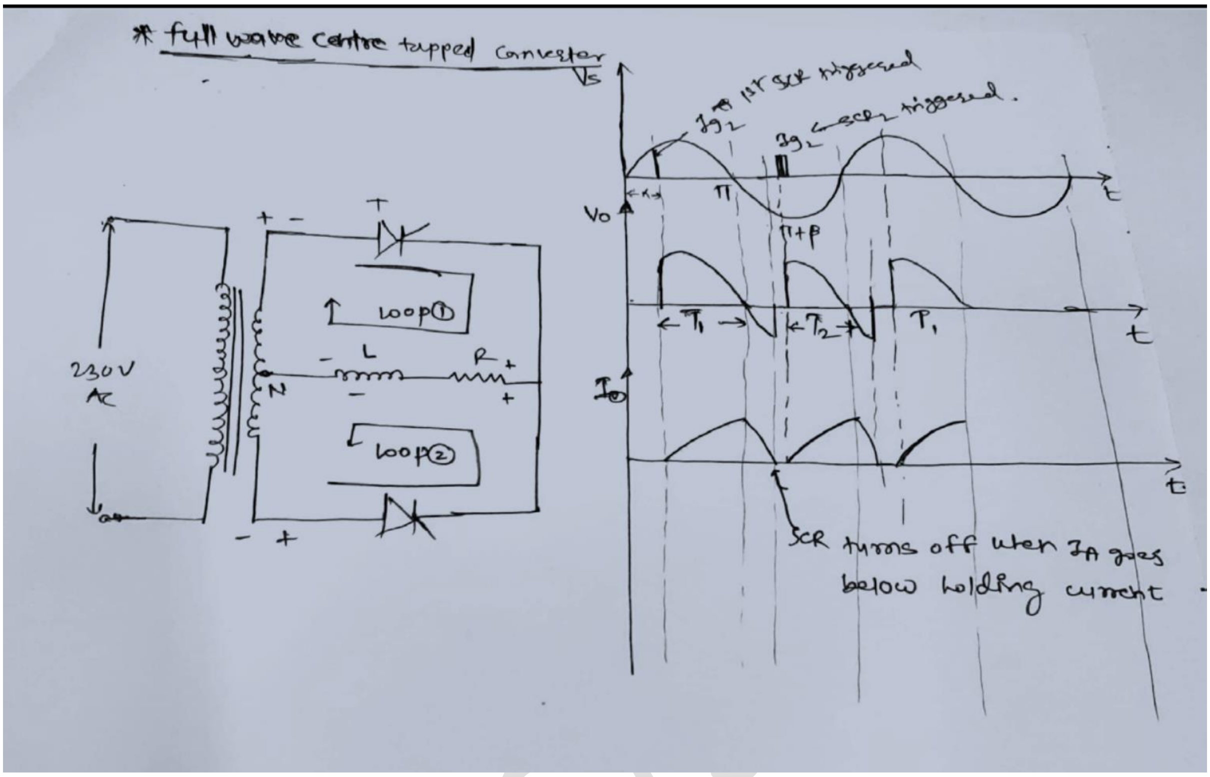




-ve ripple comes due to RL load.

To remove -ve ripple content in output side we connect freewheeling Diode.





* full wave centre tapped Converter
230V
AC
N
L
R
Loop①
Loop②
Vs
Vo
Io
t
π
π+β
T1
T2
SCR turns off when IA goes below holding current