Power Electronics & PLC

(Th-05)

(Asperthe2020-21syllabuspreparedbythe SCTE&VT, Bhubaneswar, Odisha)

Fifth Semester

Electrical Engg.

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POWER ELECTRONICS & PLC

CHAPTER WISE DISTRIBUTION OF PERIODS & MARKS

Sl. No.	Chapter No.	Topics	Periods as per syllabus	Expected marks
1	1	Understand The Construction And Working Of Power Electronic Devices	18	23
2	2	Understand The Working Of Converters ,Ac Regulators And Choppers.	12	25
3	3	Understand The Inverters And Cyclo-Converters	08	22
4	4	Understand Applications Of Power Electronic Circuits	10	20
5	5	PLC And Its Applications	12	20
TOTAL			**60**	**75**

CHAPTER NO.-01

Understand the Construction and Working of Power Electronic Devices

Learning Objectives:

Construction,Operation,V-Icharacteristics&applicationofpowerdiode, SCR,DIAC, TRIAC, Power MOSFET, GTO &IGBT

- *TwotransistoranalogyofSCR.*
- *GatecharacteristicsofSCR.*
- *SwitchingcharacteristicofSCRduringturnonandturnoff.*
- *TurnonmethodsofSCR.*
- *TurnoffmethodsofSCR(LinecommutationandForcedcommutation)*
  - *LoadCommutation*
  - *Resonantpulsecommutation*
- *VoltageandCurrentratingsof SCR.*
- *ProtectionofSCR*
  - *Overvoltageprotection*
  - *Overcurrentprotection*
  - *Gateprotection*
- *FiringCircuits*
  - *Generallayoutdiagramoffiringcircuit*
  - *Rfiringcircuits*
  - *R-Cfiringcircuit*
  - *UJTpulsetriggercircuit*
  - *Synchronoustriggering(RampTriggering),DesignofSnubberCircuits*

INTRODUCTION:

The Power electronics have eased the concept of power control. Power electronics signifies the word power electronics and control or we can say the electronic that deal with power equipment for power control.

Power electronics based on the switching of power semiconductor devices. With the development of power semiconductor technology, the power handling capabilities and switching speed of power devices increased.

PowerSemiconductorDevices:

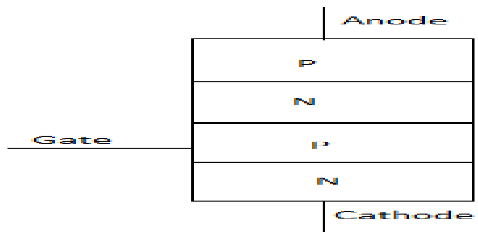
1. Thyristors
2. Transistors
3. Powerdiodes

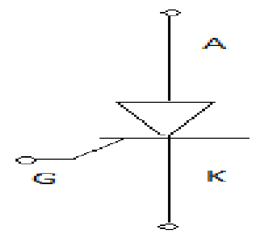
Construction,Operation,V-Icharacteristics&applicationofSCR:

Thyristors

Thyristorisafourlayerthreejunctionp-np-nsemiconductorswitchingdevice.Ithas3 terminalsthesearetheanode,cathodeandgate.SCRsaresolidstatedevice,sotheyare compact, possess high reliability and have low loss.

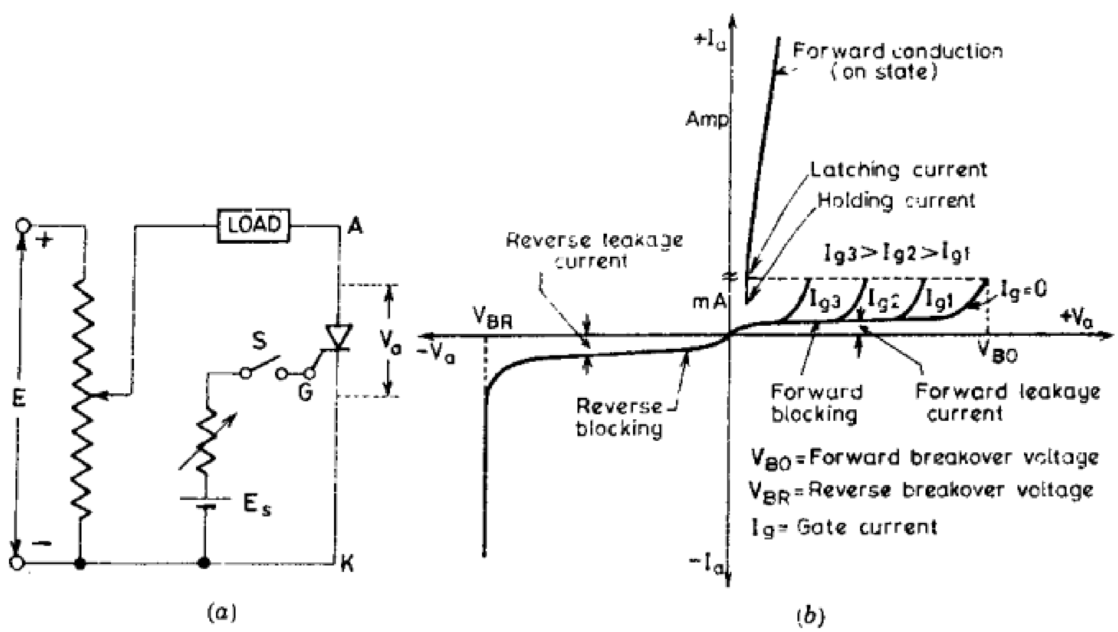
SCRismadeupofsilicon,itactasarectifier;it hasverylowresistancein theforward direction and high resistance in the reverse direction. It is a unidirectional device.





StaticV-IcharacteristicsofaThyristor

The circuit diagram and V-I characteristics of a Thyristor is as shown below.Where Anode andcathodeareconnectedtomainsourcevoltagethroughthe load.Thegateandcathodeare fed from source ES.



Where

V_{BO}=Forwardbreakover voltage
V_{BR}=Reversebreakovervoltage
I_g=Gatecurrent
V_a=AnodevoltageacrossthethyristorterminalA,K.
I_a=Anodecurrent

TheSCR have3modesofoperation:

1. Reverseblockingmode
2. Forwardblockingmode(offstate)

3. Forwardconductionmode(onstate)

ReverseBlockingMode

- Whencathodeofthethyristorismadepositivewithrespecttoanodewith switch open thyristor is reverse biased. Junctions $J1$ and $J2$ are reverse biasedwhere junction $J2$ is forward biased. The device behaves as if two diodes are connected in series with reverse voltage applied across them.
- A small leakage current of the order of few mA only flows. As the thyristoris reverse biased and in blocking mode. It is called as acting in reverse blocking mode of operation.
- Now if the reverse voltage is increased, at a critical breakdown level called reverse breakdown voltage VBR,an avalanche occurs at $J1$ and $J3$ and the reverses current increases rapidly. As a large current associated with VBR and hence more losses to the SCR. This results in Thyristor damage as junction temperature may exceed its maximum temperature rise.

ForwardBlocking Mode

- When anode is positive with respect to cathode, with gate circuit open, thyristorissaidtobeforwardbiased.Thusjunction $J1$and$J3$areforward biased and $J2$ is reverse biased. As the forward voltage is increases junction $J2$ will have an avalanche breakdown at a voltage called forward break over voltageVBO.
- When forward voltage is less then VBO thyristor offers high impedance. Thus a thyristor acts as an open switch in forward blocking mode.

ForwardConductionMode

- Herethyristorconductscurrentfromanodetocathodewithavery small voltage drop across it. So a thyristor can be brought from forward blockingmode to forward conducting mode:

  1. Byexceedingtheforward breakovervoltage.
  2. Byapplyingagatepulsebetweengateandcathode.
- Duringforwardconductionmodeofoperationthyristorisinonstate and behave like a close switch. Voltage drop is of the order of 1 to 2mV. Thissmall voltage drop is due to ohmic drop across the four layers of the device.

Construction,Operation,V-Icharacteristics&applicationofpowerdiode :

1. PowerDiodes:

BasicstructureofPowerDiode:

- Powerdiodeconsistsofthreelayers.ToplayerisaheavilydopedP$^+$layer.Middle layeris lightly doped n$^-$ layer and the last layer is a heavily doped n$^+$ layer.
- Theheavilydopedp$^+$layeract asananode. Lastlayeroftheheavilydoped n$^+$act as a cathode. Middle layer of lightly doped n$^-$ is known as a drift layer. The thickness of thedrift layer depends on the required breakdown voltage.
- Thebreakdownvoltageincreaseswithanincreaseinthewidthofthedrift layer.Resistivity of this layer is high because of the low level of doping.
- Ifthewidthofthedriftlayerincreased,thentheon-statevoltagedropincrease thereforepower loss is more.
- The junction is form between the anode layer (p$^+$) and drift layer (n$^-$). The cross-sectionarea of the diode depends on the magnitude of current to be handled. Higher the currentto handle, more the area required.

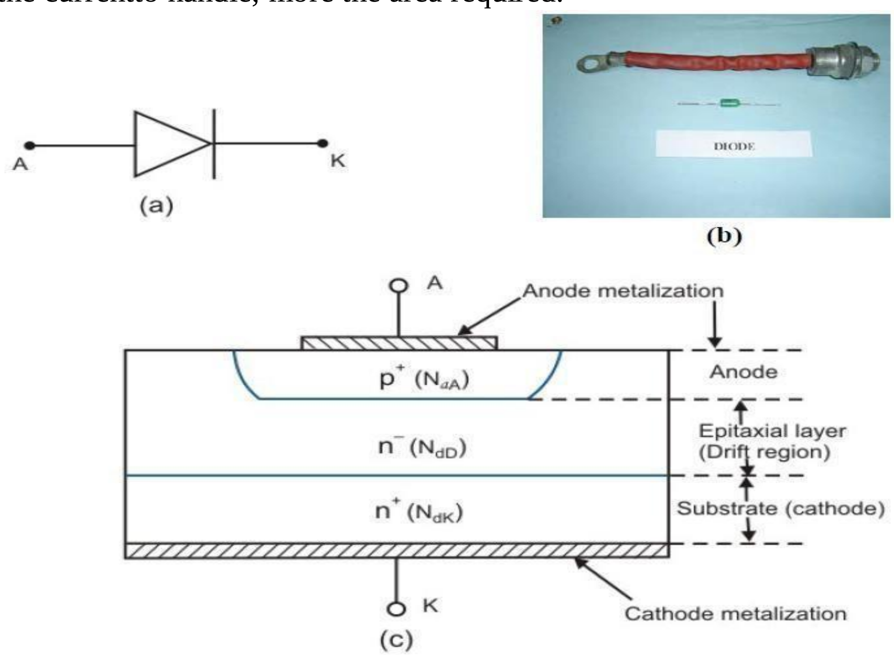
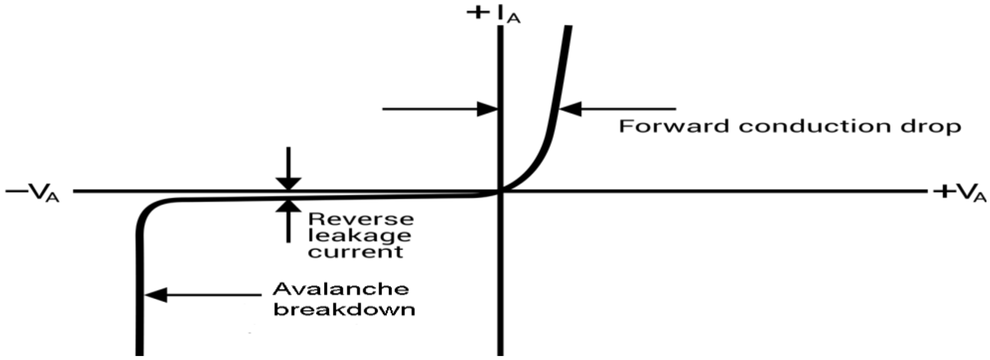


Fig.1 : Diagram of a power; (a) circuit symbol (b) photograph; (c) schematic cross

OperatingPrincipleofPowerdiode:

- Theoperatingprinciple ofpowerdiodeissameastheconventional PNjunction diode.
- Adiode conducts when the anode voltage is higher than the cathode voltage. The forwardvoltagedropacrossthediodeisverylowaround0.5Vto1.2V.Inthisregion, thediode works as a forward characteristic.
- If the cathode voltage is higher than the anode voltage, then the diode works as blockingmode.Inthismode,diodeworksaccordingtothereversecharacteristic.

I-VcharacteristicofPowerDiode:



TheI-Vcharacteristicof powerdiodeisasshowninthefigure.

- Theforwardcurrentincreaselinearlywithanincreaseinforwardvoltage.
- Averysmall amount of leakagecurrent flowsinthereversebias(blocking mode).
- Theleakagecurrentisindependentoftheappliedreversevoltage.
- The leakage current flows due to the minority charge carriers. When the reverse voltagereachesthereversebreakdownvoltage,avalanchebreakdownoccurs.Once the reverse breakdown occurs, the reverse current increase drastically with small increase in reversevoltage. The reverse current can control by an external circuit.
- Inthecaseofreversebreakdown,Asthevoltageandcurrentofthediodearelarge, thepower dissipation is dangerously high and it can destroy the device.

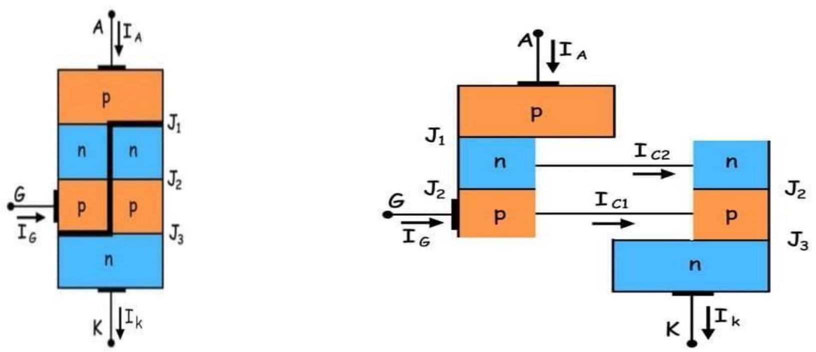
ApplicationofPowerDiodeinPowerElectronics:

- Highvoltagerectifier
- Asfreewheeling diode
- Asfeedback diode

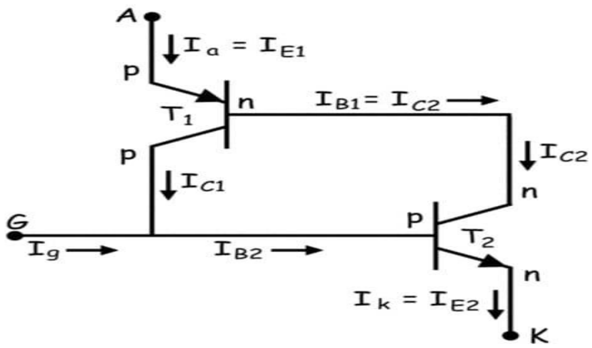
TwotransistoranalogyofSCR:

BasicoperatingprincipleofSCR,caneasilybeunderstoodbythetwotransistormodelof SCR, as it is a combination of p and n layers.

Thisisap-n-p-nthyristor.i.e.onep-n-ptransistorwithJ1andJ2junctionsandanothern-p- n is with J2and J3 junctions as shown in figure below.



Therelationbetweenthecollectorcurrentandemittercurrentisshown below



fromtheabove diagram

I_a=Anodecurrent,I_k=cathodecurrent,I_g=Gate

current Ie_1=emitter current of transistor T_1

Ic_1=collector current of

TransistorT$_1$

I_{b1}=BasecurrentoftransistorT$_1$

Ie_2=emitter current of transistor

T_2 Ic_2=collectorcurrent of

transistor T_2

Ib_2=Base current of

transistorT$_2$α=current gain

oftransistor

Fromtheabovefig.itisclearthatcollectorcurrentofT$_1$isequaltothebasecurrentofT$_2$and vice versa.

Mathematically: $Ic_1=Ib_2$& $Ib_1=Ic_2$

AlsoIk=Ia+Ig .... (i)

FromtransistoranalysisIb1=Ie1-Ic1--------------------- (ii)

Alsocurrentgain,α1=Ic1/Ie1

Ic1= α1Ie1---------------- (iii)

Substitutingtheequation(iii)in

equation(ii) we get

$Ib_1=Ie_1–\alpha_1Ie_1$

$Ib_1=Ie_1(1-\alpha_1)$ ------------------- (iv)

From the fig. it is clear that$Ia = Ie_1$

So $Ib_1 = Ia(1-\alpha_1)$-------------------- (v)

Currentgainoftransistor $T_2,\alpha_2= Ic_2/Ie_2$

$Ic_2=\alpha_2Ie_2$

$Ic_2 =\alpha_2Ik$------------ -(vi)(as$Ie2=Ik$)

Fromtheabovefig.$Ib_1 =Ic_2$

Equatingequation(v)and(vi)we getIa

$(1-\alpha_1) = \alpha_2 Ik$

$Ia- \alpha_1 Ia = \alpha2(Ia + Ig)$ (as$Ik=$

$Ia+Ig$)$Ia - \alpha_1Ia – \alpha_2Ia = \alpha_2 Ig$

$Ia =\alpha_2Ig/(1-\alpha_1 –\alpha_2)$ --------------(vii)

Theaboveistheanodecurrent ofaThyristor.

Gatecharacteristicsof SCR:

Thegatecharacteristicsdrawn inbetweengatevoltageand gatecurrentofaSCR.

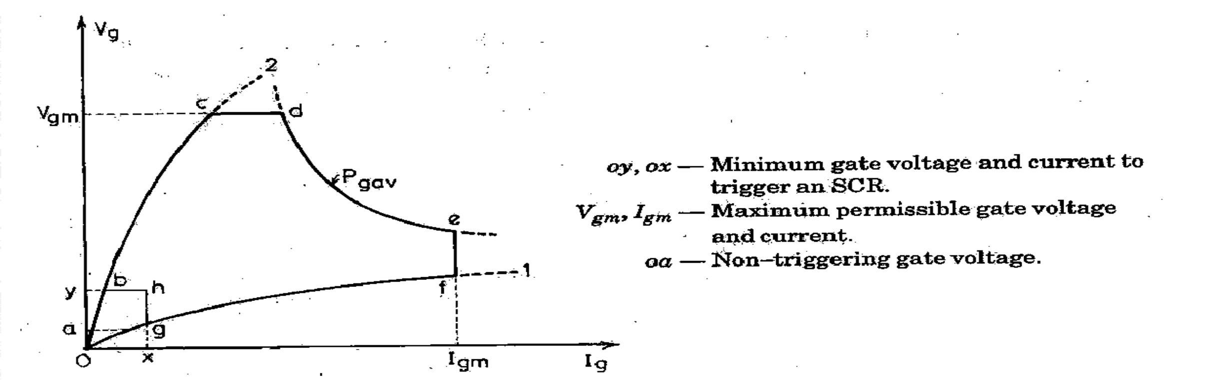


Fig. 4.9. Forward gate characteristics of thyristor.

Vg=+vegatetocathodevoltage.
Ig=+ve gatetocathode current.
As the gate cathode characteristic of a thyristor is a p-n junction, gate characteristic of the deviceissimilartodiode.Curve1thelowestvoltagevaluesthatmustbeapplied toturnon the SCR.

Curve2highestpossiblevoltagevaluesthatcanbesafelyappliedtogetcircuit.

Vgm=Maximumlimitforgatevoltage.

Igm=Maximumlimitforgate current.

Pgav=Rated gatepowerdissipationforeachSCR.

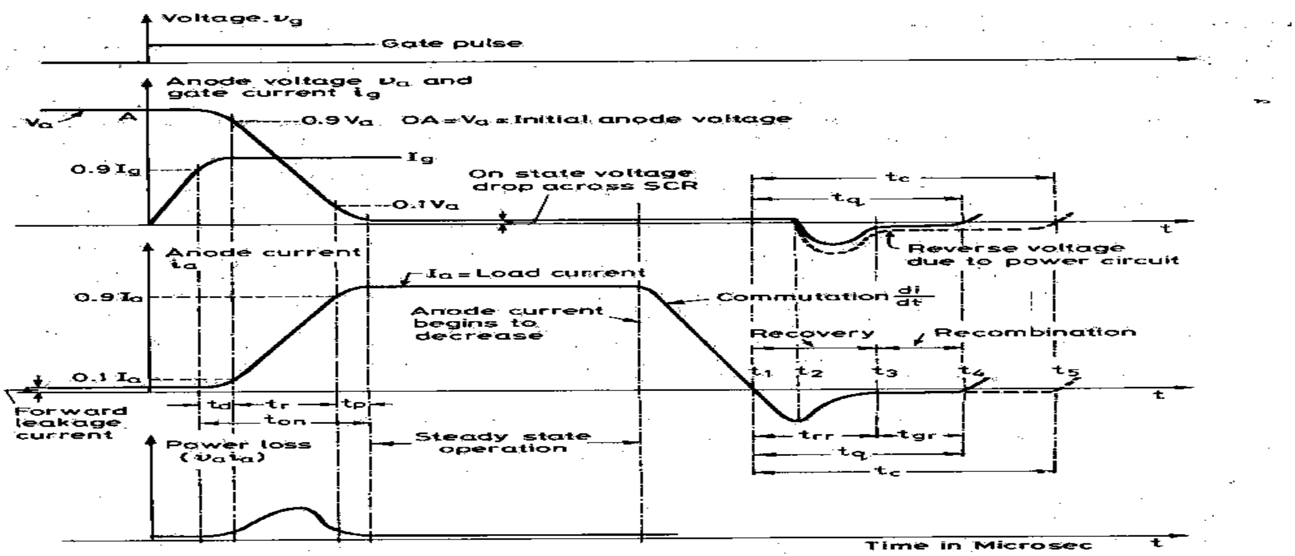
These limits should not be crossed in order to avoid the permanent damage ofthedevice junction$J3$.

OY=Minimumlimit ofgatevoltagetoturn ON.OX=minimumlimitofgatecurrentto turn ON.

IfVgm,Igm,Pgavareexceededthethyristorwilldamagesothepreferred gatedrive area of SCR is bcdefghb.

oa=Thenon-triggeringgatevoltage.

SwitchingcharacteristicofSCRduringturnonandturnoff:



Thetimevariationofvoltageacrossthethyristorandcurrentthroughitduringturnonandturnoff process gives the dynamic or switching characteristic of SCR.

(a) Switchingcharacteristicsduringturnonprocessof Thyristors:

ItisthetimeduringwhichitchangesfromforwardblockingstatetoONstate.Total turn ontime is divided into 3 intervals:

- Delay time
- Rise time
- Spreadtime

Delay time(td)

IfIg and$I$representthefinalvalueofgatecurrentandanodecurrent. Then the delay time can be explained as time during which

- Gatecurrent0.9$Ig$to 0.1Ia.
- AnodevoltagefallsfromVato0.9Va.
- Anodecurrentrisesfromforwardleakagecurrentto0.1Ia.

Risetime(tr)

Timeduringwhich

- Anodecurrent risesfrom0.1 $Ia$to 0.9 Ia
- Forwardblockingvoltagefallsfrom0.9Va to0.1Va.Va istheinitialforward blockingvoltage.

Spreadtime(tp)

- Timetaken bytheanode currenttorisefrom0.9IatoIa.
- Timeforthe forward voltagetofallfrom 0.1$Vo$to onstatevoltagedropof1to 1.5V.

(b) Switchingcharacteristicsduringturnoffprocessof Thyristors:

- Thyristor turn off means it changed from ON to OFF state. This process which is appliedis called as turn off process or commutation.
- Once thyristor is ON there is no role of gate. As we know thyristor can be made turn OFFby reducing the anode current below the latching current.
- The turn off time can be different as the instant anode current becomes zero to the instantwhen SCR regains its forward blocking capability.

Theturnofftimeisdividedintotwo intervals i.e.off=trr+tqr

a) Reverserecoverytime(trr)
b) Gate recoverytime (tgr)

a) Reverserecoverytime(trr):-

- Itisdefinedasthetimebetweentheinstantforwardthyristorcurrentbecomeszero & thatinstantreverserecoverycurrentdecaysto 25percentageofitsreversepeak.
- Reverse recover process is the process by which the excessive charge carriers from upperP layer to the button N layer is removed , the time taken by this process is known as reverse recovery time(trr)

b) Gaterecoverytime(tgr)

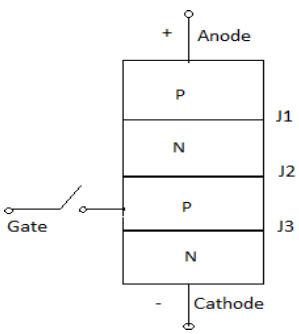
- It is theprocess bywhich theexcess charge carriersfrom theunction J2 isremovedis called as gaterecoveryprocess. Thetimetaken fordoingthis process is called as gate recovery time.

Turnonmethodsof SCR:

Therearefivemethods areadopted to turn on theSCR that are:-

1. Forwardvoltagetriggering
2. Gatetriggering
3. dv/dttriggering
4. Lighttriggering
5. Temperaturetriggering

1. Forwardvoltagetriggering



Aforwardvoltageisappliedbetweenanodeandcathodewithgatecircuitopen.

- Junction$J1$ and$J3$isforwardbiasedandJunction$J2$isreversebiased.
- Astheanodetocathodevoltageisincreasedbreakdownofthereversebiased junction $J2$ occurs. This is known as avalanche breakdown and the voltage at whichthis phenomena occurs is called forward breakover voltage.
- The conduction of current continues even if the anode cathode voltage reduces below VBOtillIawillnot go belowIh .Where$Ih$is theholdingcurrent forthethyristor.

2. Gatetriggering

- In this type of triggering a forward voltage is given between the anode & cathode & simultaneously a positive gate pulse is applied in between gate & cathode so the thyristor can be turn on .
- It is due to that when a positive voltage is applied between the gate & cathode of a forward biased SCR the charge carriers are injected into the inner player their by reducing the depletion layer as the forward voltageincrease & giving the positivegate pulsethethyristor gate turned on.

3. dv/dttriggering

- When forward voltage is applied between anode & cathode of SCR with gate circuit open, the junction j1& j3 are forward biased & junction j2 is reverse biased so in this case junction j1 & j3 acts like two plates of capacitor & j2 acts like a insulating mediumbetween the two plates.
- Thecurrentflowingthecapacitorisgivenbytheanodecurrentsoweknowthat current flowingthrow a capacitor
- I=dq/dt
  Q=C.V

  I=d(cv)/dt
  =v*dc.dt+c*dv.dt

  Ia=c dv/dt

Where,c=capacitance of the capacitor with is constant as dv/dt go on increasing, in also increases & at acertain stage then it start conducting

3. **Light triggering**

- AnSCRturnedonbylightradiationiscalledaslightactivatedsilicon-controlled rectifier (LASCR)
- Thistypeoftriggeringisemployedforphase-controlledconverterinHVDCtransmission line.
- Inthismethodlightrayswithappropriatewavelengthandintensityareallowedto break the junction j2.
- ThistypeSCRareconsistinganicheintheinner player thereforewhenlightstrikeon this niche the electron hole pair are generated at the junction j2 which provides additional change carriers at the junctions & it leads to turn on the SCR

4. **TemperatureTriggering**

- During forward blocking mode most of the applied voltage appears across reverse biased junction j2,This voltage across j2 associated with large current ,it would increasethetemperatureofthis junction,withincreaseintemperaturethewidthofthe deflection layer decreases .At sum high temperaturedepletion layer will vanish so the thyristor will turned on.

TurnoffmethodsofSCR(Linecommutationand Forcedcommutation)

- Theturnofprocessisthyristormeansbringingthedeviceformforward conductionstatetoforward blocking state.
- Thethyristorturnedoffrequiresthatit'sanodecurrentfallsbelowtheholdingcurrent & a reversevoltage is applied to the thyristor for a sufficient time to recover the forward blocking state.
- Commutationisdefinedastheprocess ofturningoffthethyristor.
- Oncethethyristorstartsconductinggatelosesthecontroloverthedevicetherefore

externalmeansmayhavetobeadductedtocommutate the thyristor.

1. Latchingcurrent

- It is the minimum value of anode current which is most attain during turn on process to maintainthe conduction when the gate sign a1 is removed.

2. Holdingcurrent

- Itistheminimumvalueofanodecurrent belowwhichitmustfall turningoffthyristor.

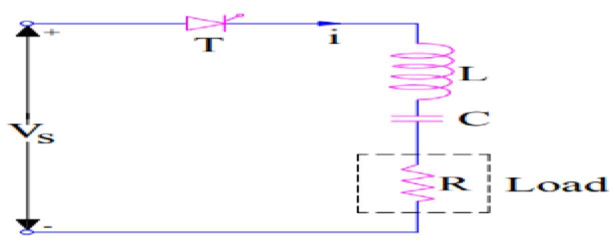
TurnoffmethodsofSCR(LinecommutationandForcedcommutation)

Commutationis aprocess of turningoff a Thyristor.

ClassificationofCommutationMethods

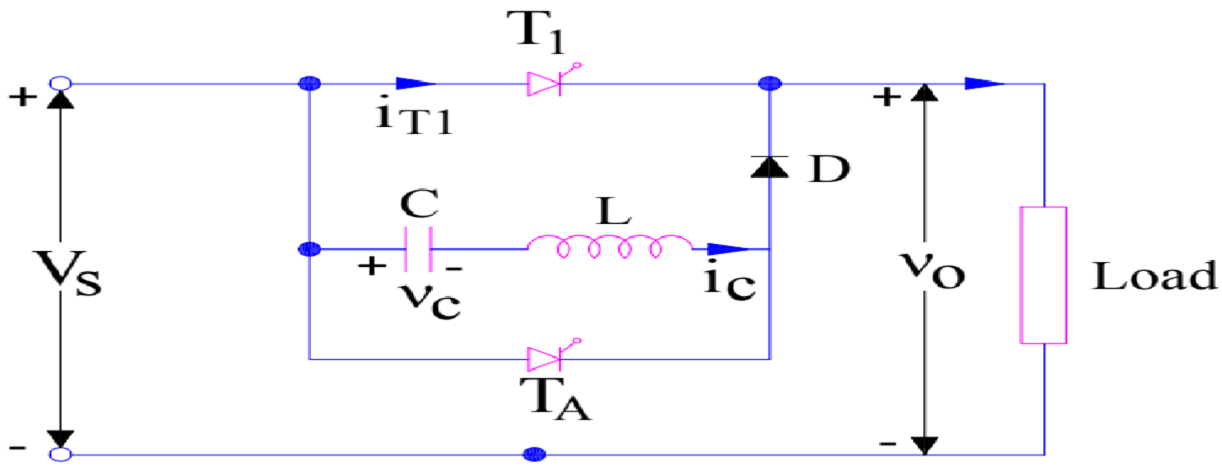
1. classAcommutationorloadcommutation
2. classBcommutation orresonatepulsecommutation
3. classCcommutation orcomplementarycommutation.
4. classDcommutationorimpulsecommutation
5. classEcommutation orexternal pulsecommutation
6. classFcommutationorlinecommutation.

ClassAcommutationorload commutation



- ClassAcommutationisalsoknownasloadcommutation,self-commutationor resonant commutation .
- For achieving load commutation of a thyristor the commutative element L& C are connected inseries with load R ,and for higher value ,R is connected across the capacitor .
- Theessentialrequirementofthiscircuitisthattheoverallcircuitmustbeunder damped.
- When the circuit is energized from DC source the current will rises to maximumvalue & thenbegins to fall.
- When the currentdecreasesto zero & tends to reverse the thyristor & is turned offatits ownmeans the circuit shows that the current have the natural tendency decreased to zero.

1.6.2.ClassBcommutationorresonantpulse commutation

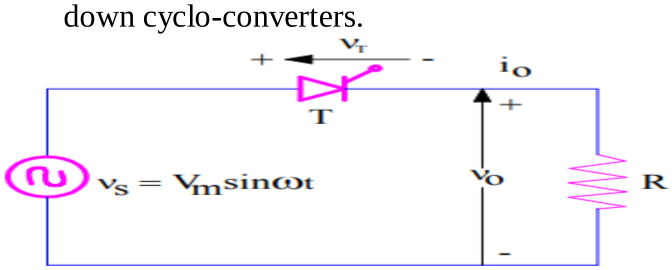


- Initiallythecapacitorcchangestoavoltage Vswithlefthandpositiveatthat conditionthethyristor T_1&Ta at areoff.
- Now the thyristor is turn on at T=thyristor T_1 gets turned on so the current 1o is flowing throwthe load so at thatinstant Io=It_1=I_l&Vc=Vs.
- Tocommutatethemain thyristorT_1 the auxiliarythyristorTaisgatedatt=t_1.
- With Ta on a resonant current Ie begins to flow from a –L &back to c (c+-Ta-L-C).So the $I_C$current will be ic =-ip sinwt ,the –sign before Iq is due to the opposition of current as marked before .
- WhenareversecurrentflowsthrowTa,Tgetsoffautomatically.
- Nowthepolarity ofthecapacitorgateschangedsointhatcasethediodeget turnedon&thecapacitorchargesthevoltage–Vs.nowthecapacitorcurrentflows throw (C+-L-D-T1-C)
- In this casethe capacitor current is opposite to the thyristor current so the thyristor t1 gets turnedoff .

- TheclassBcommutationisalsoknownasresonantpulsecommutationorcurrent commutation.

1.6.3.ClassFcommutation orLineorNatural Commutation

- Natural or Line commutation is a Class-F SCR commutation technique in which, a thyristor is turned off due to natural current zero and voltage reversal after every half cycle.
- This commutation method is onlyapplicableforAC circuit and mostlyused in Phase-Controlled Converters, Line-Commutated Inverters, AC voltage controllers and Step-down cyclo-converters.



- Let us assume that, thyristor T is fired or gated at firing angle equal to zero i.e. $\omega t = 2n\pi$ where n is 0,1,2,3…..,.
- Sinceloadisresistive,with zerodegreefiringangle, theSCR behaveslikeadiode.
- During positive half cycle, the SCR will conduct as it is forward biased. The output voltage$V_0=(V_S/R)$willhavesamewaveshapeasthatofsourceV_S.Loadcurrent$i_0$will be in phase with the load voltage v_0, hence i_0 will have wave shape similar to load voltage v_0& vs.
- At$\omega t=\pi$,sourcevoltage$v_S=0$,loadvoltage$v_0=0$andloadcurrent$i_0=0$. Therefore,thecurrent throughtheSCR becomeszeroat this instantanditisreversed biased form $\omega t= \pi$ to 2π.

VoltageandCurrentratingsof SCR:

- The thyristor rating indicate voltage, current, power and temperature limits with in whicha thyristor can be used without damage.
- For reliable operation of a thyristor it should be ensure that it's current & voltage rating are not enhanced during it's working.
- If a thyristor handles voltage ,current &power greater than it's specified rating ,the junction temperature may rise above the safe limit at a result the thyristor may get damage therefore to an SCR are selected the rating of that SCR should not excited their normal working voltage.
- A thyristor has several ratings such as voltage, currentpower,dv/dt,di/dt, turn on time, turn of timeetc.

AnodeVoltageRating

- Athyristorismadeupofseverallayers.Themiddlejunctionj2blocksthe forwardvoltagewhereasthetwo-endjunctionj1&j3blocksthereversevoltage.
- The anode voltage rating indicates the value of maximum voltage that a thyristor can week standwith the breakdown of the junction are with gets circuit open.

Anodecurrent rating

- Athyristorismadeupofsemiconductormaterial,soitsnormalcapacityisverysmall. At high
- anode current the junction temperature may exceed the rated value so the devicemay be damaged.
- As the junction temperature is depended on the current handed by the thyristor, a currentchoice of current rating is essential for long working life of the device.

ProtectionofSCR:

Forreliableoperation ofthyristorprotectiontechniqueis neededforthyristor.

1) Overvoltageprotection
2) Overcurrentprotection
3) Gateprotection
4) dv/dt Protection
5) di/dt protection

Overvoltageprotection

Over voltage transients are perhaps the main cause of thyristor failure. Transient over voltagescausefalseoperationofthecircuitbyunwantedturnonofathyristoror permanent damage tothe device due to reverse break down.

A thyristor maybe subjected to internal or external over voltage .The internal over voltage is caused by the thyristor operation whereas the external over voltage comes from the supply lines or the load circuit.

1. Internalovervoltage

Large voltage maybe generated internallyduring the commutation of thyristor after thyristor anode currentreducesto zero,anode current reversedueto stored charges,thiscauseinternal over voltage due to this internal over voltage the thyristor may be destroyed permanently.

2. Externalovervoltage

External over voltage are caused due to interference or short circuit of the supplyand also dueto lighting strokes on the lines feeding the thyristor . over voltage may damage the thyristor by inverse breakdown for reliable operation over voltage must be suppressed by adopting suitable technique.

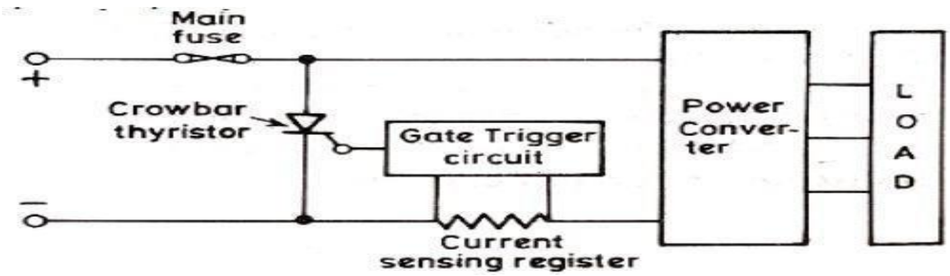
Suppressionofovervoltage

In order keep the protective component to a minimum thyristors are chosen with their peak voltage rating of 2.5 to 3 times of their normal peak working voltage. The effect of over voltage is usually minimized by using RC circuit and nonlinear resistors called voltage clampingdevices.

OverCurrentprotection

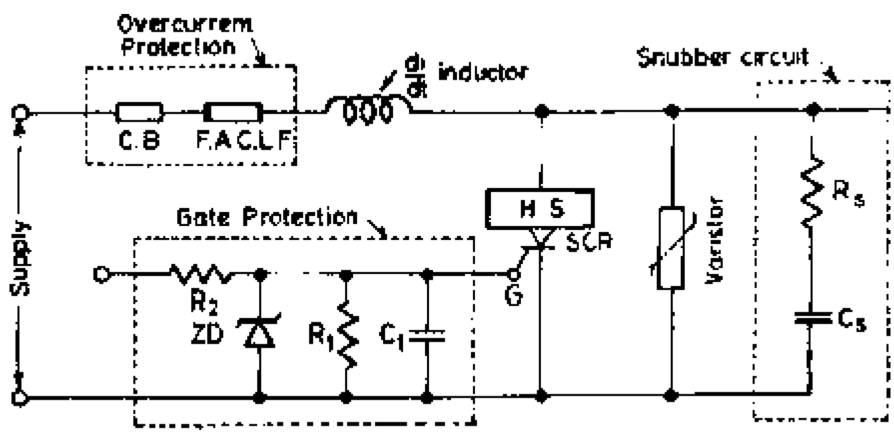
- Thyristorissubjectedtoovercurrentduetofaultshortcircuitorsurgecurrentsdue tothisovercurrentjunctiontemperaturemayexceedtheratedvalueandthe device may bedamaged thus there is a need for the over current protection of SCR.
- Overcurrentprotectioninthyristorcircuitachievedthrowtheuseofcircuit breakers &fast acting current limiting fuse (FACLF)

Electriccrowbarprotection



Athyristorpossesshighsurgecurrentcapability,itcanbeusedinanelectroniccrowbar circuit for over current protection of power converters using SCR. An electronic crowbar protection provide rapid isolation of the power converter before any damage occurs. The circuitfor electronic crowbar protection circuit is shown above.

Gateprotection:



- TheGatecircuitshouldbeprotectedfrom overvoltagesandovercurrents.
- Overvoltagesinthegatecircuitcancausefalsetriggeringandovercurrentcan causehigh junction temperature.
- Overvoltagesthyristorprotectionisachievedbyusinga Zenerdiodeandaresistor can beused to protect the gate circuit from over current.
- Noiseingatecircuitcan alsocausefalsetriggeringwhichcanbeavoidedby using aresistor R1 and a capacitor C1 in parallel.
- Adiode(D)maybeconnectedinseriesorinparallelwiththegatetoprotectitfrom highreverse voltage.

dv/dtProtection:

- If rate of rise of suddenly applied voltage across the thyristor is high the device may get turnedonwithabsenceofgatesignalsuchphenomenonofturningONathyristoris called dv/dt triggering.
- Itmustbeavoidedwhichcanbeachievedbyusing Snubbercircuitinparallelwiththe device.

FiringCircuits:

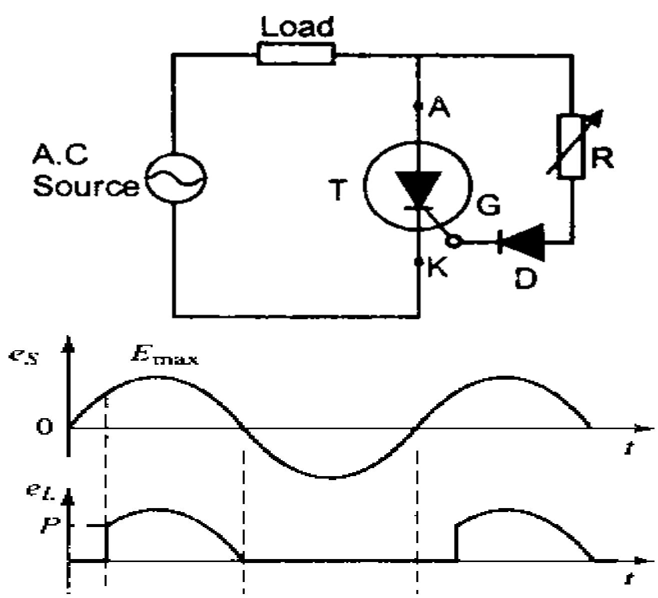
Generallayoutdiagramoffiringcircuit

ThedifferentfiringcircuitsusedinSCRare R-

- firing circuit
- RC-firingcircuit
- UJTpulsetrigger circuit
- Synchronoustriggering(Ramp Triggering)circuit

RfiringcircuitsorResistancetriggeringcircuit

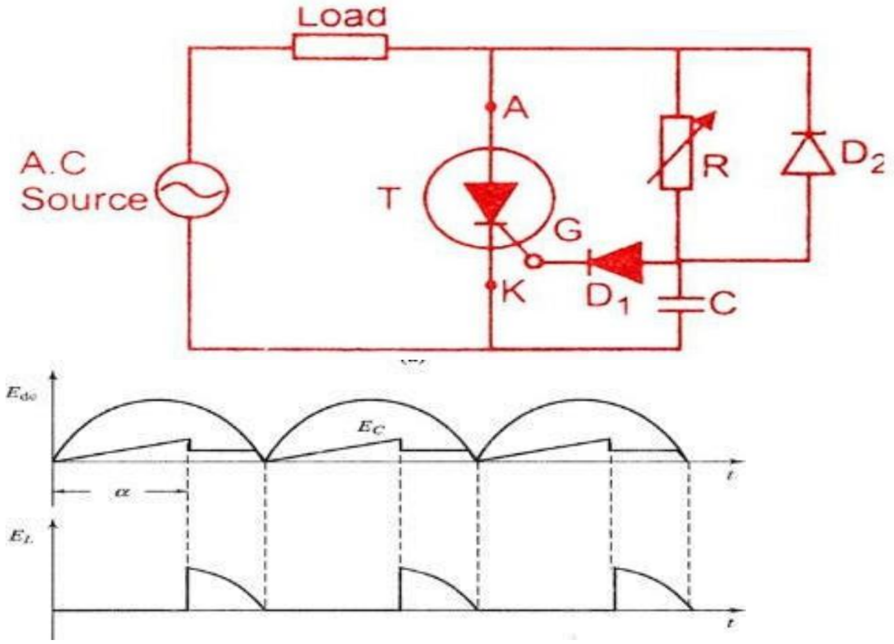
- Thecircuit diagramandwaveformofresistancetriggering isshownbelow.



- Inthismethod,thevariableresistanceRisusedtocontrolthegatecurrent.
- DependinguponthevalueofR,whenthemagnitudeofthegatecurrentreachesthe latching current of the device the SCR starts to conduct.
- The diode D is called as blocking diode. It prevents the gate cathode junction from getting damaged in the negative half cycle.
- Byconsidering that the gate circuit is purely resistive, the gate current is inphase with the appliedvoltage.
- Byusingthismethodwecanachievemaximumfiringangle up to90°.

R-Cfiring circuit

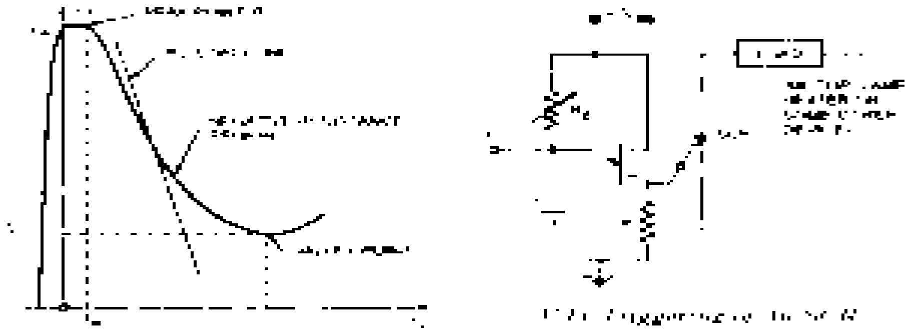
 The circuitdiagram and waveform of resistance-Capacitance triggeringis shown below.



- Byusingthis method wecan achievethe firingangle morethan90°.
- In the positive half cycle, the capacitor is charged through the variable resistance R up tothe peak value of the applied voltage.
- Thevariableresistor R controlsthechargingtimeofthe capacitor.
- Dependsuponthevoltageacrossthecapacitor,whensufficientamountofgatecurrentwill flow in the circuit, the SCR starts to conduct.
- In the negative half cycle, the capacitor C is charged up to the negative peak value through the diode D_2.
- DiodeD_1isusedtopreventthereversebreakdownofthegatecathodejunctioninthe negative half cycle.

1.9.4.UJTpulsetriggercircuit

- Thecircuitdiagram andwaveform ofUJT pulsetriggeringisshownbelow



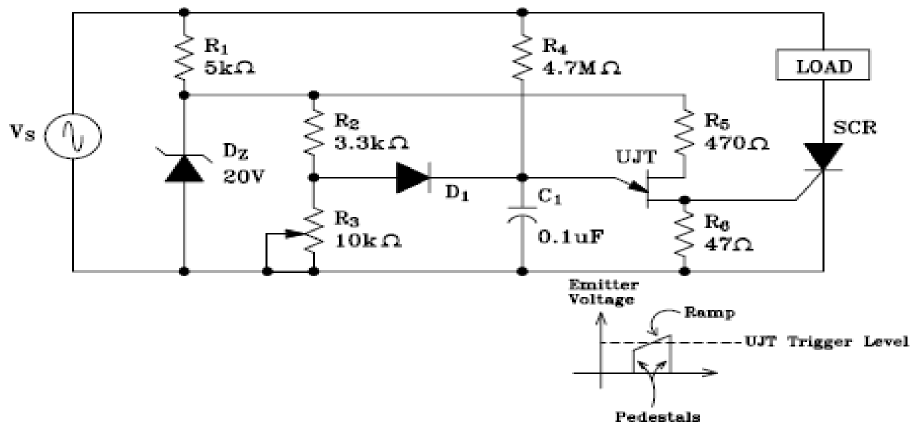
- OnecommonapplicationoftheUni-junctiontransistoristhetriggeringoftheotherdevices such as the SCR, triac etc.
- The basic elements of such a triggering circuit are shown in figure. The resistor $R_E$is chosen sothat the load line determined by R_E passes through the devicecharacteristic inthe negative resistance region, that is, to the right of the peak point but to the left of the valley point, as shown in figure.
- IftheloadlinedoesnotpasstotherightofthepeakpointP,thedevicecannotturnon. For
- ensuring turn-on of UJT $R_E < V_{BB} – Vp/I_P$
- Thiscanbeestablishedasbelow
- Considerthepeakpoint atwhichI_{RE}= IpandV_E=V_P
- Thecapacitor C determinesthetimeinterval betweentriggeringpulses andthetime duration of each pulse.
- Byvarying R_E, we can change the time constant R_EC and alter the point at which the UJT fires.

Thisallowsustocontrol theconduction angleoftheSCR, whichmeans thecontrolofloadcurrent.

1.9.5 Synchronoustriggering(RampTriggering)

- Thecircuit, shownbelow, usesaUJTto triggeraSCR.
- The UJT is used to more accurately trigger the SCR. When the sourcevoltage exceeds20V, the Zener diode (D_Z) will begin to conduct, applying a DC voltage across the base connections of the UJT.
- At the same time, diode D_1 will be forward biased, and the capacitor will quickly charge through R_1 and R_2.
- OncethecapacitorchargestothevoltageacrossR_3,D_1willbecomereversebiasedandthe

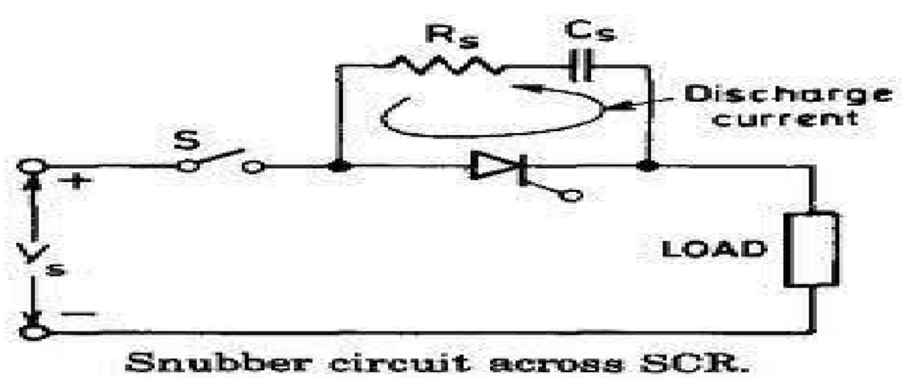
capacitor will continue to slowlycharge through R_4. This represents the ramp portion of the emitter voltage.



The capacitor continues to charge until the UJT fires. At this point the capacitor will quickly discharge through R_6.

- The capacitor discharge is sufficient to trigger the SCR. The point at which the UJT fires canbeadjustedbyvaryingthepotR_3.WithalargesettingonR_3,the capacitormustcharge to a larger value before D_1 becomes reverse biased.
- ThiscausestheUJTtofirefaster,resultinginmoreofthesourcevoltageappearing across the SCR.

<u>DesignofSnubberCircuits:</u>



Snubber circuit across SCR.

- ItconsistsofacapacitorCsconnectedinserieswitharesistorRswhichis appliedparallel with the thyristor.
- whenSisclosedthenvoltageV_S isappliedacrossthedeviceC_S behaveslikea shortcircuit. Therefore voltage across the device is zero.

- GraduallyvoltageacrossC$_S$ buildsupataslowratesodv/dtacrossthethyristor willstay in specified range.
- Beforeturningonofthyristor,C$_S$ isfullycharged andafterturningonof thyristor itdischarges through the SCR.
- This discharging current can be limited with the help of a resistance (R$_S$) connectedinserieswiththecapacitor(C$_S$)tokeepthevalueofcurrentandrate of change of current in a safe limit.

di/dtProtection:

- Whenathyristoristurnedonbygatepulsethenchargecarriersspreadthroughits junction rapidly.
- Iftherateofriseofanodecurrent,i.e.di/dtisgreaterthanthespreadingofcharge carriersthenlocalizedheatgenerationwill takeplacewhichisknownaslocalhot spots.This may damage the thyristor.
- Toavoidlocalhotspotsweuseaninductorinserieswiththedeviceasitprevents highrate of change of current through it.

Construction,Operation,V-Icharacteristics&applicationofIGBT

Thisdevicecombinesinto ittheadvantagesofbothMOSFETand BJT.SoanIGBThashighinput impedance like a MOSFET and low-on-state power loss as in a BJT

BASICSTRUCTURE:

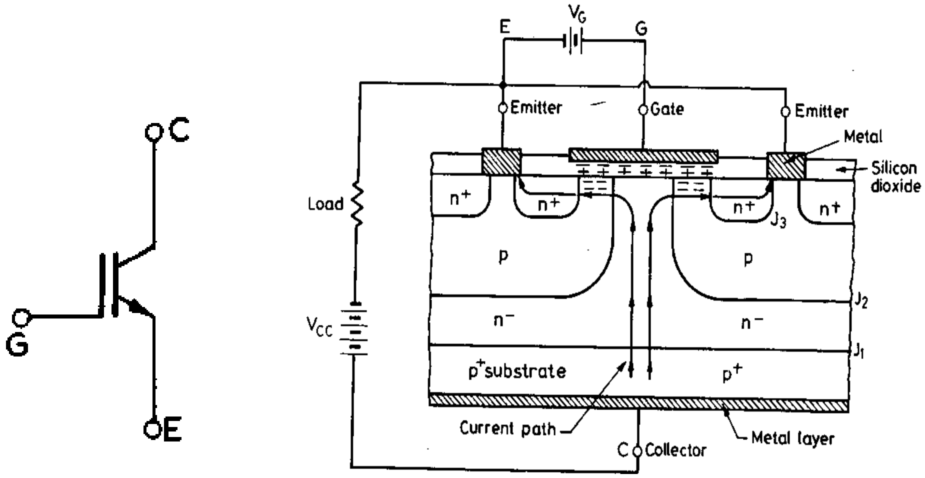


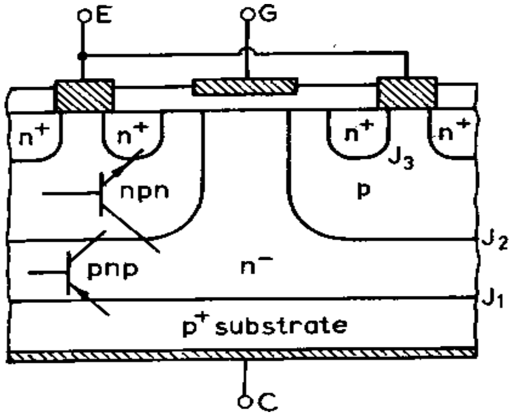
Fig1(a) SymbolofIGBT (b)Basic structureofaninsulatedgate bipolartransistor (IGBT).

- Ithasfourlayers that are P+, n-,P,n+,threejunctionssuchasJ_1-Pn+, J_2-Pn-,J_3-P+n-.andthreeterminalsuchasEmitter,Collector,Gate.
- Itisconstructedvirtuallyinthesamemanner asapowerMOSFET.
- Thereis,however,amajordifferenceinthesubstrate.Then+layersubstrateatthe draininapowerMOSFETisnowsubstitutedintheIGBTbyap+layersubstrate

calledcollector.

- LikeapowerMOSFET,anIGBThasalsothousandsofbasicstructurecells connected appropriately on a single chip of silicon.

OOPERATION:



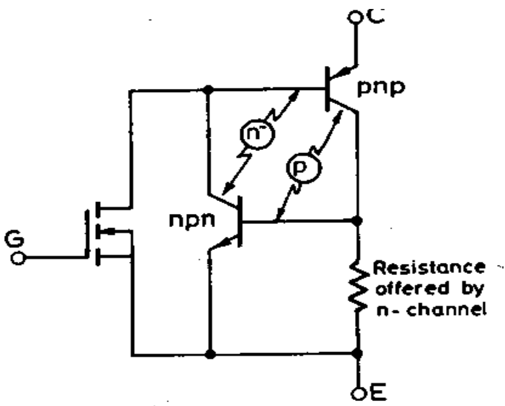


FIG:2(a)Basicstructure **Fig2(b)ItsequivalentCircuit**

Itshowsthreemodesofoperationssuchas

i. Reverseblockingmode.
ii. Forwardblocking mode
iii. Forwardconductionmode.

I. Reverseblockingmode.

WhenanegativevoltageappliedtothecollectoroftheIGBTthenthejunctionJ3 behavesas reverse biased so current conduction in it is not possible this condition iscalled as reverse blocking mode.

II. Forwardblockingmode.

WhenapositivevoltageisappliedtothecollectorofIGBT,gatetocollectorshortcircuits, junctionJ3isforwardbiasedbut junctionJ2isreversebiasedso current conduction isnot possible this condition is called as forward blocking mode.

III. Forwardconductionmode.

When a positive voltage is applied to the collector and a positive gate to emitteris applied in IGBTthenjunctionJ3isforwardbiasedandainversionlayerorn-channeliscreatednearthe junction J1 inside the P-region thus the IGBT behaves as a PN Junction with gate control so current conduction is possible in it from collector to emitter through collector ,P+ substrate , N- , N channel in p, N+, emitter.

CHARACTERISTICS:

ThoughIGBTbehaves asaPNjunctiondiodeinforwardconductionmodesoits characteristicsissameasPNjunction.inIGBTthegatecontrolismainadvantage.

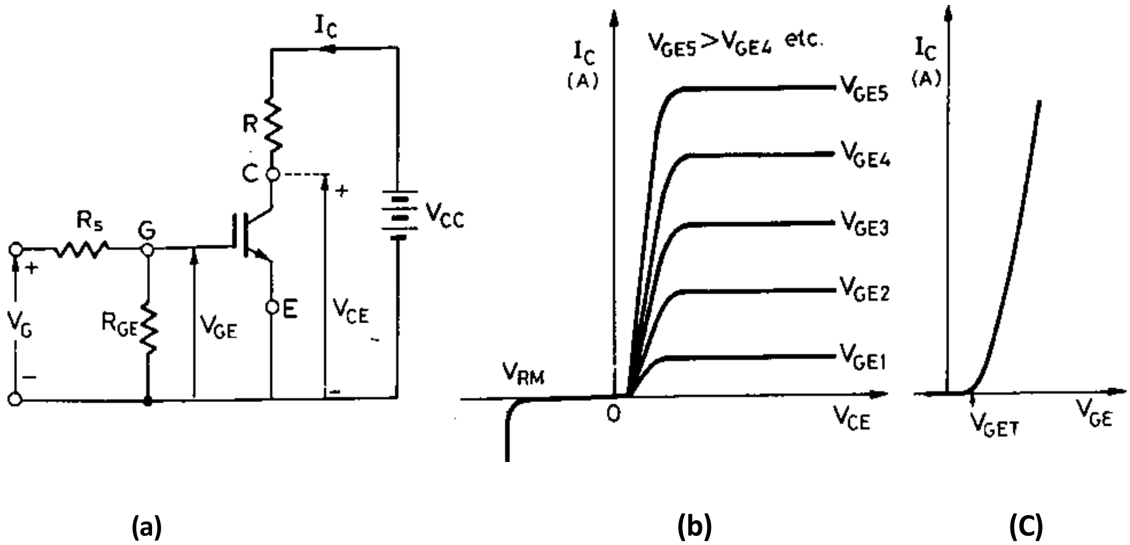


Fig3(a)Circuit Diagram (b)StaticV-Icharacteristics (c)TransferCharacteristics

APPLICATIONOFIGBT:

IGBTsareusedinvariousapplicationssuchas

- ACand DCmotordrives,
- UnregulatedPowerSupply(UPS),
- SwitchModePower Supplies(SMPS),
- tractionmotorcontrolandinduction heating,
- inverters

Construction,Operation,V-Icharacteristics&applicationofMOSFET:

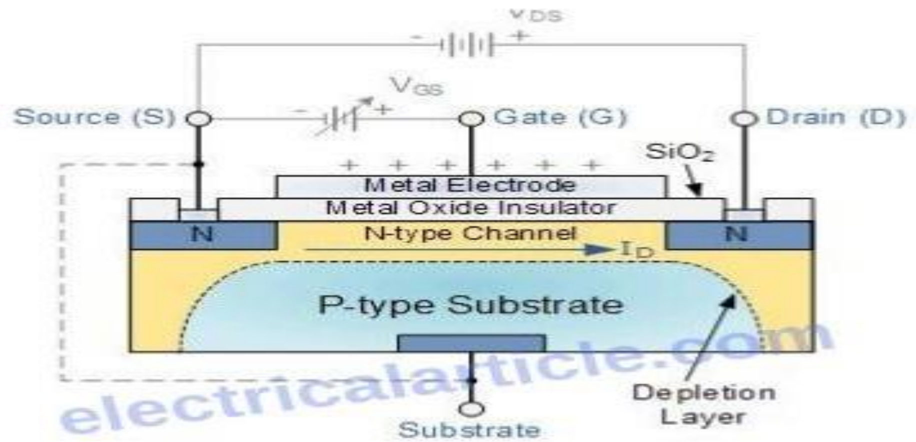
MetalOxideSiliconFieldEffectTransistorscommonlyknownasMOSFETsareelectronicdevices usedto switch oramplifyvoltages in circuits. It is a current controlled deviceand is constructed by three terminals. MOSFET has four terminals called Drain (D), Source (S), Gate (G), and Substrate (SS)**.**

Therearetwo typesof MOSFET, whicharelistedbelow:

1. DepletionType MOSFET
2. EnhancementType MOSFET

<u>Constructionof MOSFET</u>

PowerMOSFEThasaverticallyorientedfour-layerstructure.Thep-typemiddlelayertermas thebody**.**The n^-layer is thedrift layer**.**This layer is lightly dropped as compared to the drain and sourcelayer.The breakdownvoltageofpowerMOSFETdetermines from thewidthofthedriftlayer. First and last both layers are an n^+layer. First layer is the source layerand the last layer is the drain layer.



Thegateterminal is not directly connected with p-type, there is an oxide layer between the metal and semiconductor. This oxide layer act as a dielectric layer between the metal and the semiconductor.

Operatingprinciple of MOSFET

Theoperation ofMOSFET divides into two parts

1. Formationof thedepletion layer
2. CreationofInversion Layer

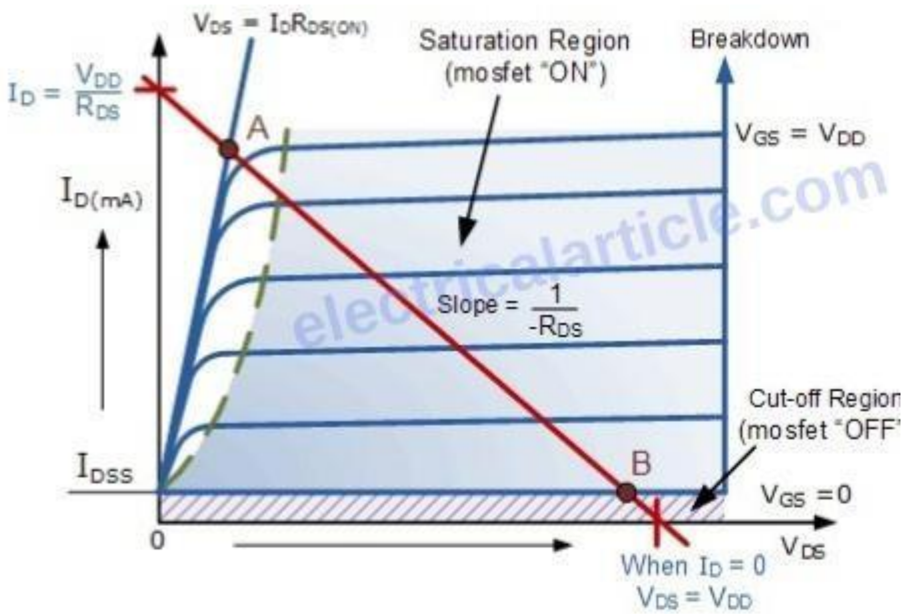
1) Formationofthedepletionlayer

By connecting a positive voltage to the drain with respect to the source and the gate is positive with respect to the body, the MOSFET works as forward biased. The p-layer has a large number of holes and few electrons. The holes are the majoritycharge carrier and electrons areminoritycharge carrier. Due to the positive voltage applied between the gate and the body, these electrons are attracted towards the gate and gather below the oxide layer and produce the depletion layer.

2) CreationofInversionLayer

The number of electrons below the oxide layer will greater than the number of holes if the positive gate voltage increases further. Hence, n-type of sublayer form below the oxide layer. This process is known as the creation of the inversion layer**.**

I-Vcharacteristic



MOSFETapplications

- RadiofrequencyapplicationsuseMOSFETamplifiersextensively.
- MOSFETbehavesasapassivecircuitelement.
- PowerMOSFETscanbe usedtoregulateDCmotors.
- MOSFETsareusedinthedesignofthechopper circuit.

AdvantagesofMOSFET

- MOSFETsoperateatgreaterefficiencyatlowervoltages.
- Absenceof gate currentresultsinhigh inputimpedanceproducinghighswitching speed.

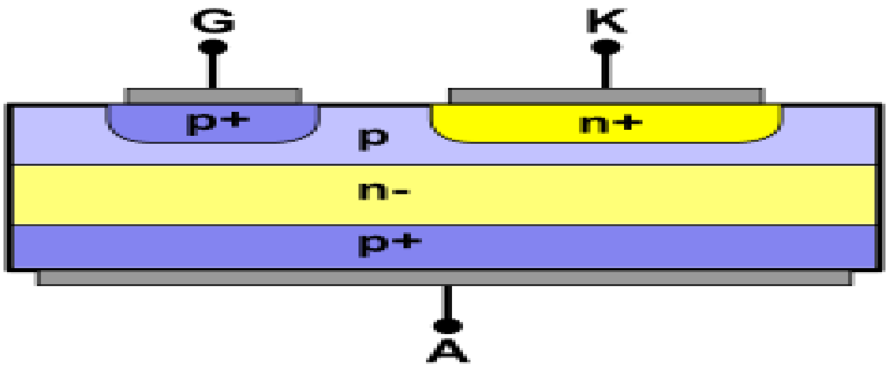
Disadvantagesof MOSFET

- MOSFETsarevulnerableto damagebyelectrostaticchargesdueto thethin oxide layer.
- OverloadvoltagesmakeMOSFETs unstable.

1.1.Construction,Operation,V-Icharacteristics&applicationofGTODIAC,TRIAC:

1.1GTO(Gateturn-offThyristor)

- Agateturnoffthyristorisapnpndevice. InwhichitcanbeturnedONlikean ordinary SCR by a positive gate current. However it can be easily turned off by anegative gate pulse of appropriate magnitude.



- Conventional SCR are turned on bya positive gate signal but once the SCR is turned ongatelosescontroloverit.Sototurnitoffwerequireexternal commutationcircuit. These commutation circuits are bulky and costly. So due tothese drawbacks GTO comes into existence.

ThesalientfeaturesofGTOare:

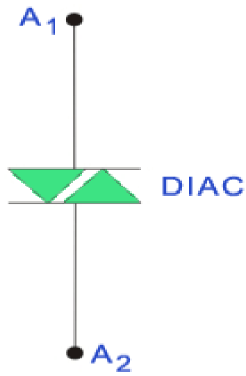
- GTOturnedonlikeconventionalSCRandisturnedoffbyanegativegatesignalof sufficient magnitude.
- Itisanon-latchingdevice.
- GTOreducesacousticandelectromagneticnoise.Ithashighswitchingfrequencyand efficiency.
- Agateturnoffthyristorcanturnonlikeanordinarythyristorbutitisturnoffby negative gate pulse of appropriate magnitude.
- Thenegativegatecurrentrequiredtoturnoff aGTOisquitelargethatis20%to30% of anode current.
- Itiscompactandcost less.

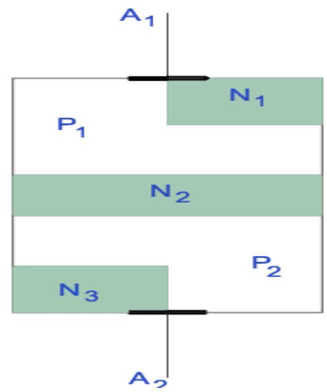
1.1.THEDIAC

- ADIAC isa device whichhas twoelectrodes, two terminals and four layers and itisa member of the thyristor family.

- DIACsareusedinthe triggeringofthyristors.

- The figure below shows a symbol of a DIAC, which resembles the connection oftwo diodes in series.



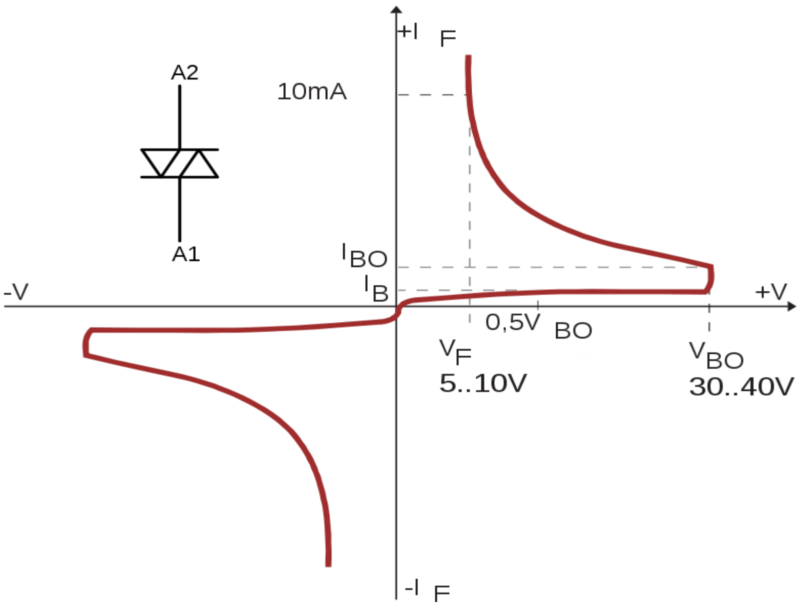


- DIACshavenogateelectrode,unlikesomeotherthyristorsthattheyarecommonly used to trigger, such as a TRIAC.
- DIAC=DIODE+AC
- The advantage of a DIAC is that it can be turned on or off simply by reducing the voltage level below its avalanche breakdown voltage.

<u>DIACCharacteristics</u>

- Fromthefigureabove, wecanseethataDIAChastwop-typematerialandthreen-type materials also, it does not have any gate terminal in it.
- TheDIAC can beturned on forboth thepolarityofvoltages.
- WhenA2ismorepositivewithrespecttoA1thenthecurrentdoesnotflow through the corresponding N-layer but flows from P2-N2-P1-N1.
- WhenA1ismorepositiveA2thenthecurrentflowsthroughP1-N2-P2-N3.
- Whentheappliedvoltageissmallineitherpolarity, averysmallcurrentflows which isknownasleakagecurrentbecauseof thedriftofelectronsandholesinthedepletion region.
- Althoughasmallcurrentflow,itisnotsufficienttoproduceavalanche breakdown, hence the device remains in the non-conducting state.

- Whentheappliedvoltageineitherpolarityexceedsthebreakdownvoltage,DIAC current rises and the device conducts in accordance with its V-I characteristics.



Applicationof DIAC

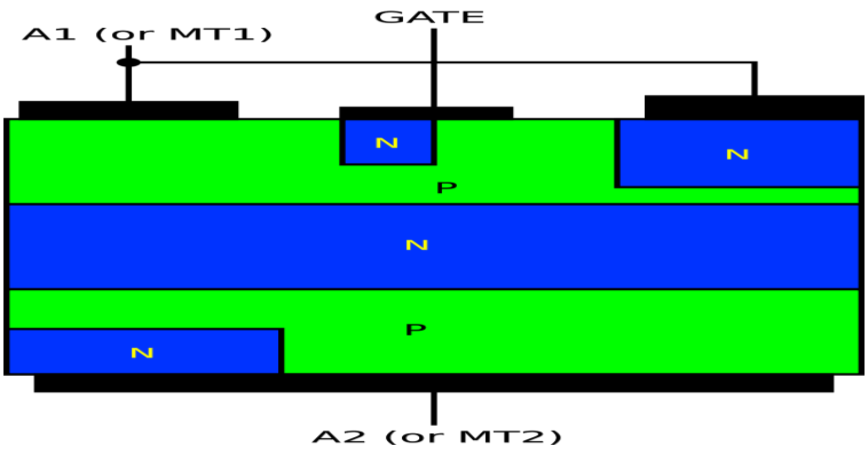
- ItisitsuseinaTRIACtriggeringcircuit.
- TheDIACisconnectedtothegateterminaloftheTRIAC. It can
- be used in the lamp dimmer circuit.
- Itisusedinaheat control circuit.
- Itisusedinthespeedcontrol ofauniversal motor.

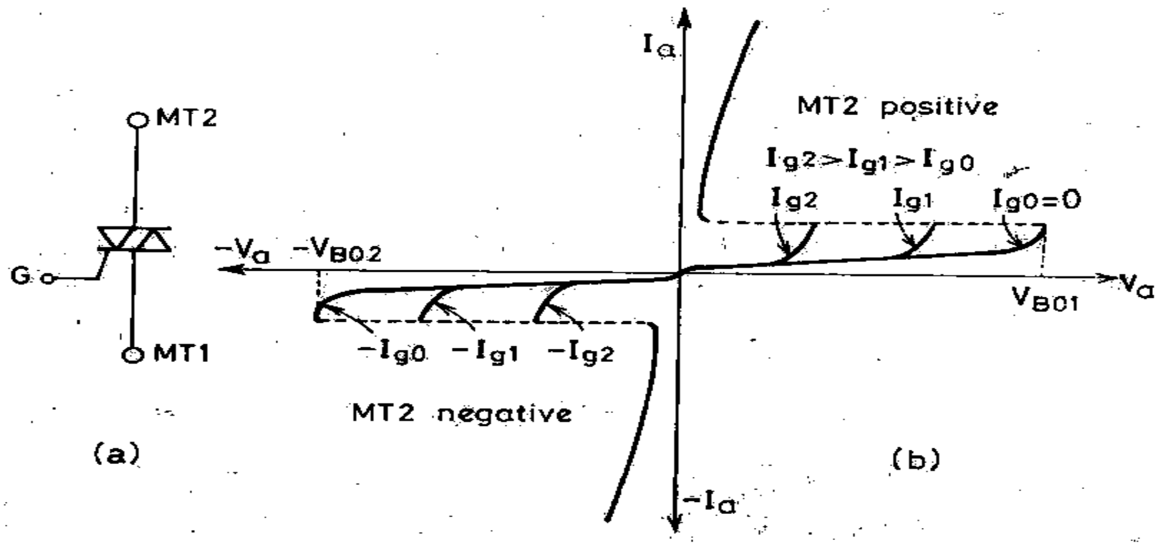
THETRIAC

- As SCR is a unidirectional device, the conduction is from anode to cathodeandnotfromcathodetoanode.Itconductsinbothdirection.Itisa bidirectional SCR with three terminal.

TRIAC=TRIODE+AC

- HereitisconsideredtobetwoSCRSconnectedinanti-parallel.As itconductsinbothdirection soitisnamedasMT$_1$,MT$_2$ andgateG.





SALIENT FEATURES

- Bidirectionaltriodethyristor.
- TRIACmeanstriodethatworksonac. It
- conducts in both directions.
- Itisacontrolleddevice.
- Itsoperationissimilartotwodevicesconnectedinanti-parallelwithcommongate connection.
- Ithas3terminalsMT1,MT2andgateG.

SHORTQUESTIONSWITHANSWERS.

1. **Definelatchingcurrent.[W-17,19,S-19]**

Ans-Itistheminimumvalueofanodecurrentwhichismostattainduringturnonprocess to maintain the conduction when the gate signa1 is removed

2. **Defineholdingcurrent.[W-16,S-19]**

- **Ans-**Itistheminimumvalueofanodecurrentbelowwhichitmustfallturningoff thyristor.

3. **Whatarethe modeof operationsof anSCR?[W-10]**

Ans-TheSCRhave3modesofoperation:

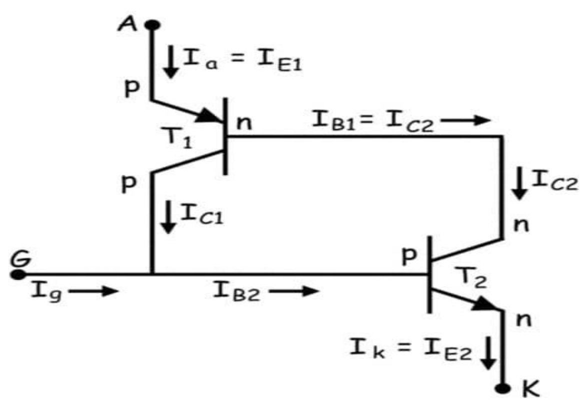
1. Reverseblockingmode
2. Forwardblockingmode(off-state)
3. Forwardconductionmode(on-state)

4. **Writedowntheturningonmethod of SCR. [W-2009,14,16,17]**

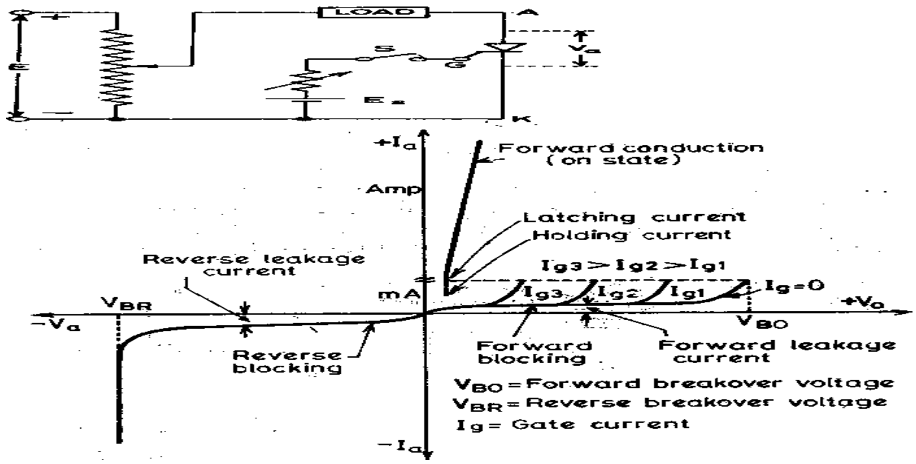
Ans-Therearefive methodsare adopted to turnon the SCR that are:-

1. Forwardvoltagetriggering
2. Gate triggering
3. dv/dttriggering
4. Lighttriggering
5. Temperaturetriggering

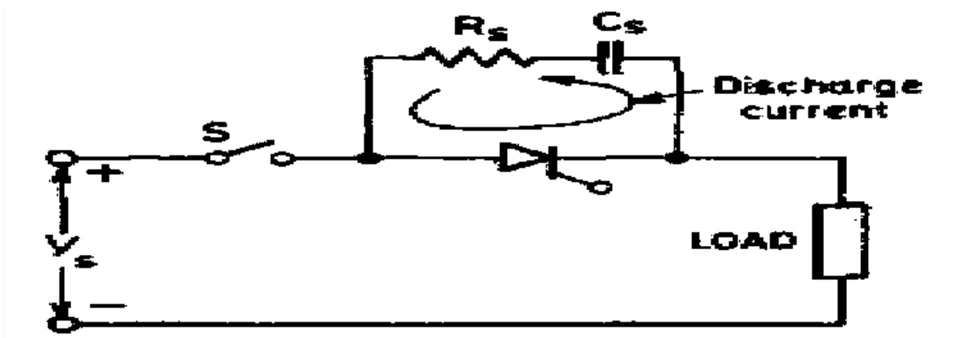
6. **DrawthemodelofTwotransistoranalogyofSCR.[W-11] Ans-**



7. **DrawtheV-Icharacteristicsof SCR.[W-19]**



8. **DrawthesnubbercircuittoprotectSCR.[W-20]**



Snubber circuit across SCR.

Long Questions.

1. Explain V-Icharacteristics of SCR. [W-17]
2. Whatarethetriggeringschemeseenin SCR?
3. Write ashort-note onDIAC.
4. Explain turn-on methodofSCR. [W-16,18, S-19,W-20]
5. Describeanytwo turn-off method of SCR. [W-10,16]
6. Drawthe DynamiccharacteristicsofSCR.Explainindetail.
7. Explaingate protectionandover voltageprotection ofSCR.
8. Write ashort-note onTRIAC.
9. Describebrieflyabout Snubber circuit and its essential. [W-19]
10. Brieflydescribe about two transistor model of SCR. [W-19, 20]

CHAPTER-2

UNDERSTANDTHEWORKINGOFCONVERTERS,ACREGULATORSANDCHOPPERS.

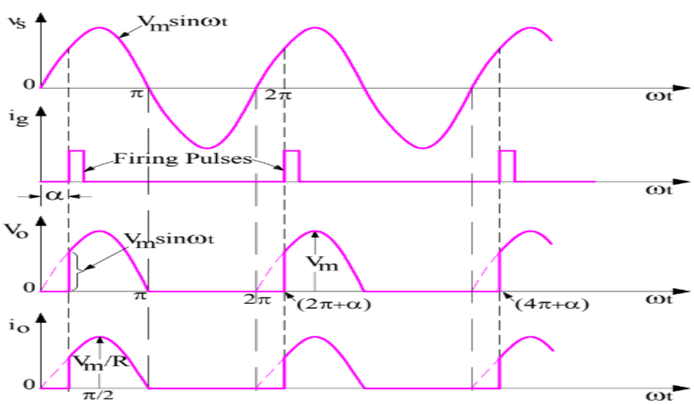
LearningObjectives:

ControlledrectifiersTechniques(PhaseAngle,ExtinctionAnglecontrol),Singlequadrant semi converter, two quadrant full converter and dual Converter
Workingofsingle-phasehalfwavecontrolledconverterwithResistive andR-Lloads.
Understandneedoffreewheelingdiode.
Workingofsinglephasefully controlledconverterwith resistiveand R-L loads.
Workingofthree-phasehalfwavecontrolledconverterwithResistiveload
Workingofthreephasefullycontrolledconverterwithresistiveload.
WorkingofsinglephaseACregulator.
Workingprincipleofstep up&stepdown chopper.
Controlmodes of chopper
Operationofchopper inallfour quadrants.

:ControlledrectifiersTechniques(PhaseAngle,ExtinctionAnglecontrol)

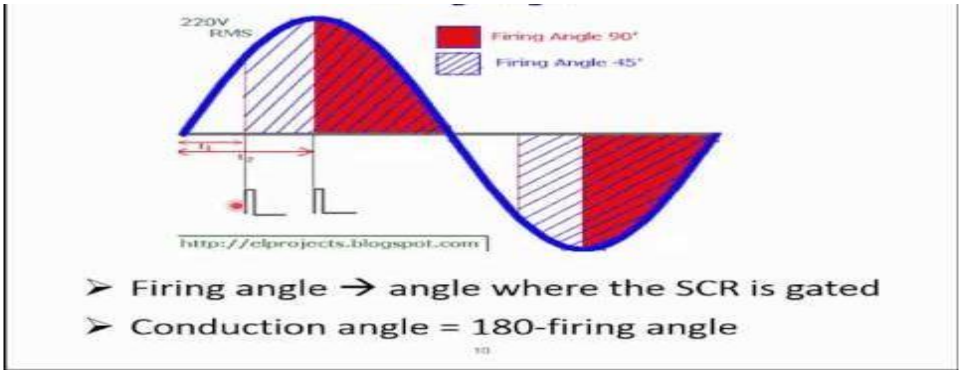
1. PHASEANGLECONTROL:

- Inaccircuit theSCR canbeturned onbythegate atanyanglewith respectto theapplied voltage.
- Thefiringangle isdenoted byalpha(α) ,α=0
- Ifthentherectifierbehavesasanuncontrolledrectifier,byvaryingthefiringangle(α)wecan control the turning on process of SCR which is known as phase angle control.
- Thewave formofhalfwavecontrolledrectifier usingphase anglecontrolmethodisshown below.



2.EXTINCTIONANGLECONTROL:

- Thewave formforextinctionangle controlisshownbelow.



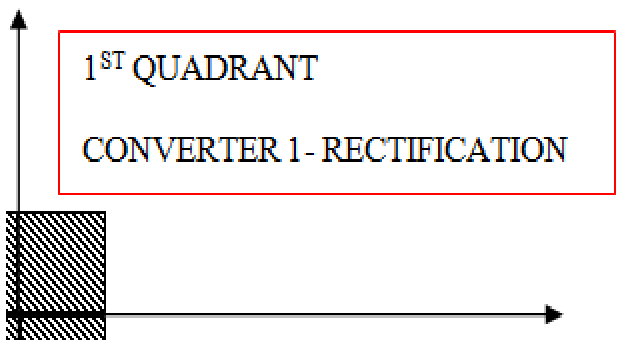
- Extinctionangleis denotedby β.
- Byconnectingβwecanalso get output dc voltagewhich iscontrolled infallingedgeor falling size.

Singlequadrantsemiconverter,twoquadrantfullconverteranddualConverter:

- Accordingtooperationalpointofviewrectifierorconverteroperationsareofthree types.
    1. SingleQuadrantOperation.
    2. TwoQuadrantOperation./twoquadrantfullconverter.
    3. FourQuadrantOperation. /dual converter.

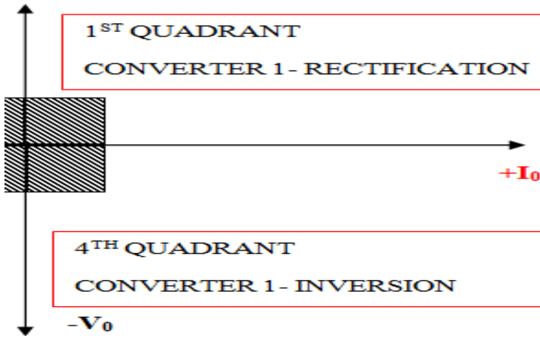
1. SINGLEQUADRANTOPERATION:-

- Ahalfcontrolledconverterorsemiconverterisanonequadrantorsinglequadrantconverteri.ethe output voltage and currenthave one polarity or single polarity.
- Thesymbolicdiagramofhalfcontrolledsemiconverteranditsfirstquadrantoperationisshown below.



2. TWOQUADRANTOPERATION:-

- Intwoquadrantfullconverterthevoltagepolaritycanreversebutcurrentdirectioncan’treverse.
- Thesymbolicdiagramandquadrantoperationisshown below.



3. FOURQUADRANTOPERATION:-

- Infourquadrantdualconverter bothvoltageandcurrent polaritycanbereversed.
- Fourquadrant converter can beobtained byconnectingtwoquadrant converterback to back.
- Thesymbolicdiagram&quadrant operationisshown below

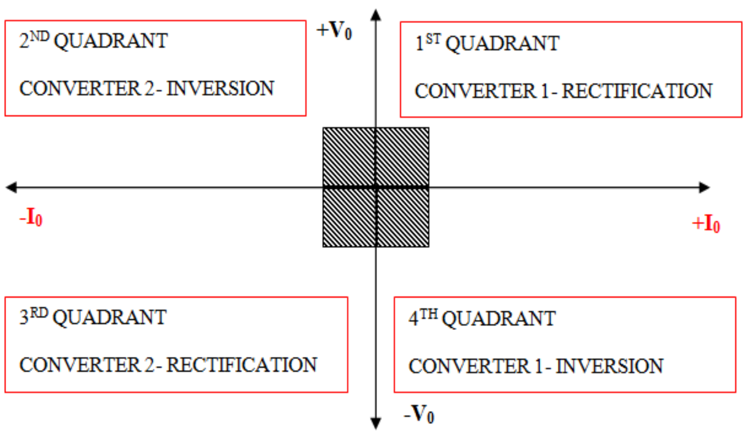


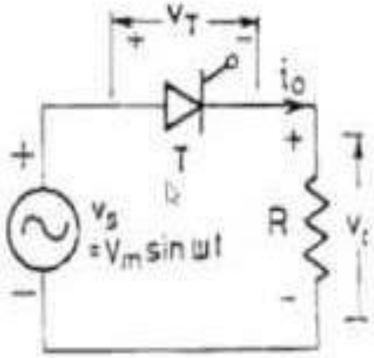
Figure 2

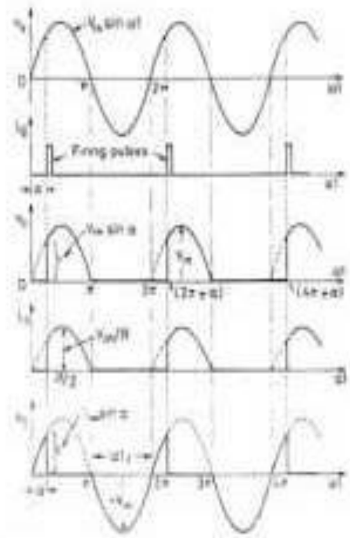
CONVERTERS/RECTIFIERS:

- Rectificationisaprocessofconvertingalternatingcurrentorvoltageintodirectcurrentorvoltage.
- Rectifierisaconverter whichconvertsalternatingcurrentorvoltageintodirectcurrentorvoltage.
- Rectifiercircuitcanbe classifiedintothreetypes
  - I. UncontrolledRectifier.
  - II. Fullycontrolled Rectifier.
  - III. HalfcontrolledorSemicontrolledRectifier.
- Diodesareusedinuncontrolledrectifierforrectificationwhereasthyristorsareusedinfullycontrolled rectifier and half control rectifier contains mixture of diodes & thyristors.
- Half controlled rectifier is otherwise known as semi converter and fullycontrolled rectifier is known as full converter.

Workingofsingle-phasehalfwavecontrolledconverterwithResistiveload.

- ThecircuitdiagramandwaveformofsinglephasehalfwavecontrolledrectifierwithR-loadis shown below.fig





- Duringthepositivehalfcycleoftheacsupplyanodeispositiveandcathodeisnegativesothe thyristor is forward biased at that instant .V_T=It follows the input voltage. $V_o=0, I_0=0$
- Atwt=αthethyristoristriggeredsoitstartsconductingatthatinstant,atthatinstant$V_T=0$itfollows the input voltage, I_0= it follows the input voltage .
- Duringnegativehalfcycleanodeisnegativeandcathodeispositivesothethyristorisreversebiased, at that instantV_T follows the input voltage . $V_o=0, I_0=0$
- Soinreversebiasedconditionas theoutput currentiszero sothethyristorgetsturned off.
- Theoutputvoltage andcurrentequationis

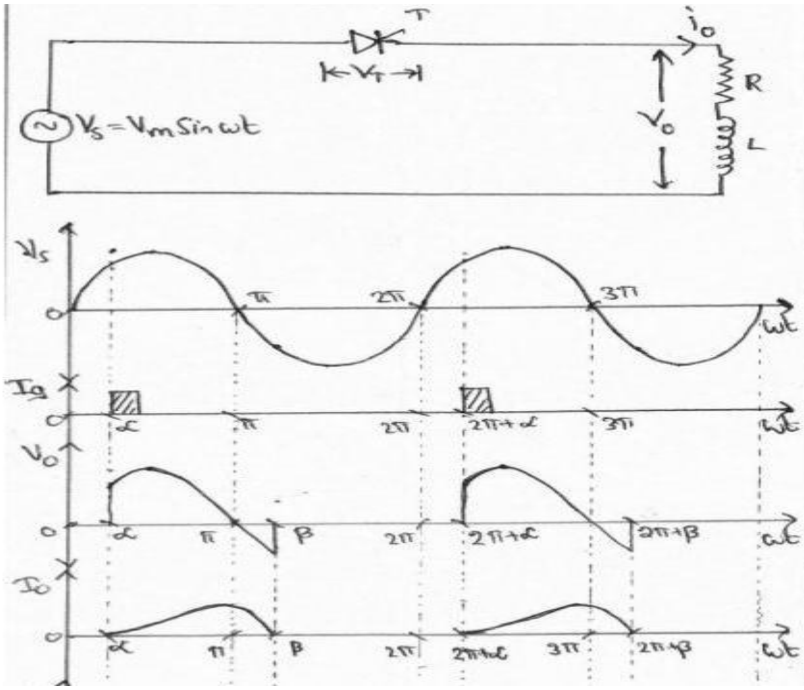
$$\therefore V_0(Avg) = \frac{1}{2\pi} \int_0^{2\pi} V_m sin(wt)\, dwt$$

$$= \frac{V_m}{2\pi} [-coswt]_\alpha^\pi$$

$$= \frac{V_m}{2\pi} (1 + cos\alpha)$$

2.2Workingofsingle-phasehalfwavecontrolledconverterwithR-L load.

- Thecircuit diagram andwaveform ofsinglephasehalf waverectifierwith R-Lload is shown below.



- InthegivenfiguretheinputvoltageisV_s=V_mSin(wt)
 V_T=Voltage across the thyristor.
 V_0=Output voltage of thyristor
 I_T=current through the thyristor
 I_0=output current or load current.

- In the positive half cycle of the ac supply anode is positive and cathode is negative so the thyristor is forward biased at that instant .
 V_T=$V_s$andfollowstheinputvoltageorsupplyvoltage. V_o=0, I_0=0

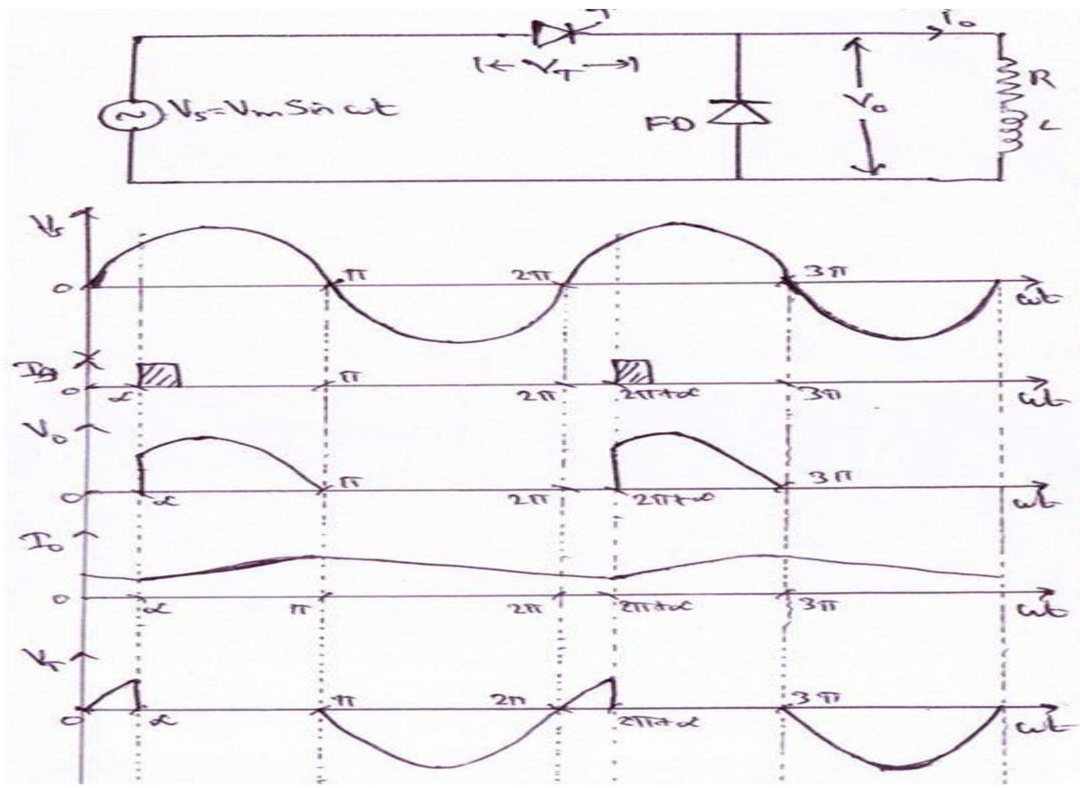
- Atwt=α,thethyristoris firedsoitstartsconductingatthatinstant,V_0=V_s,V_T=0, I_0= rises to its maximum point.

- Duringnegative half cycle, at wt=πanode is negative and cathode is positive so the thyristor is said to be reverse biased but not turned off because excess of charge carriers stored in the inductor so at that instant
 V_0=follows the input voltage up to β. V_T=
 it follows the input voltage from β,
 I_0=decreases in the positive half cycle.

- When the current through the load decreases and reaches to zero or below the holding current of the thyristor at that instant the thyristoris turned off so at that condition
  V_T=Itfollowstheinputvoltage V_o=0,
  I_0=0

Workingofsingle-phasehalfwavecontrolledconverterR-LloadwithFreewheeing Diode.

- Thecircuitdiagramandwaveformofsinglephasehalfwaverectifierwith R-Lloadand Freewheeling diode is shown below.



- Duringthepositivehalfcycleanodeispositiveandcathodeisnegativesothethyristorisforward biased at that condition
  Vt=Vsoritfollowstheinputvoltage
  Vo=0
  Io=0
- Atωt=α,thethyristoristriggeredsoitstartsconducting,atthatinstanttheFreewheelingdiodeis reverse biased and
  V_T=0
  Vo=followstheinputvoltageVs. Io=
  rises to its maximum point.

- During negative half cycle at ωt=∏ the anode is negative and cathode is positive so the thyristor is set to be reverse biased and gets turned off. At that time freewheeling diode is forward biased and startsconductingsotheexcesschargecarriersstoredintheinductorflowsthroughthefreewheeling diode, at that instant
  Vo=0,
  V_T=Vs,itfollowstheinputvoltage. Io=
  Decreases from its peak value.

- Sothecurrentthroughtheloaddoesnotbecomezeroasbeforeturningoffthefreewheelingdiode, the thyristor again starts conducting so it shows that the load current is continuous.
- Theoutputvoltage equation is

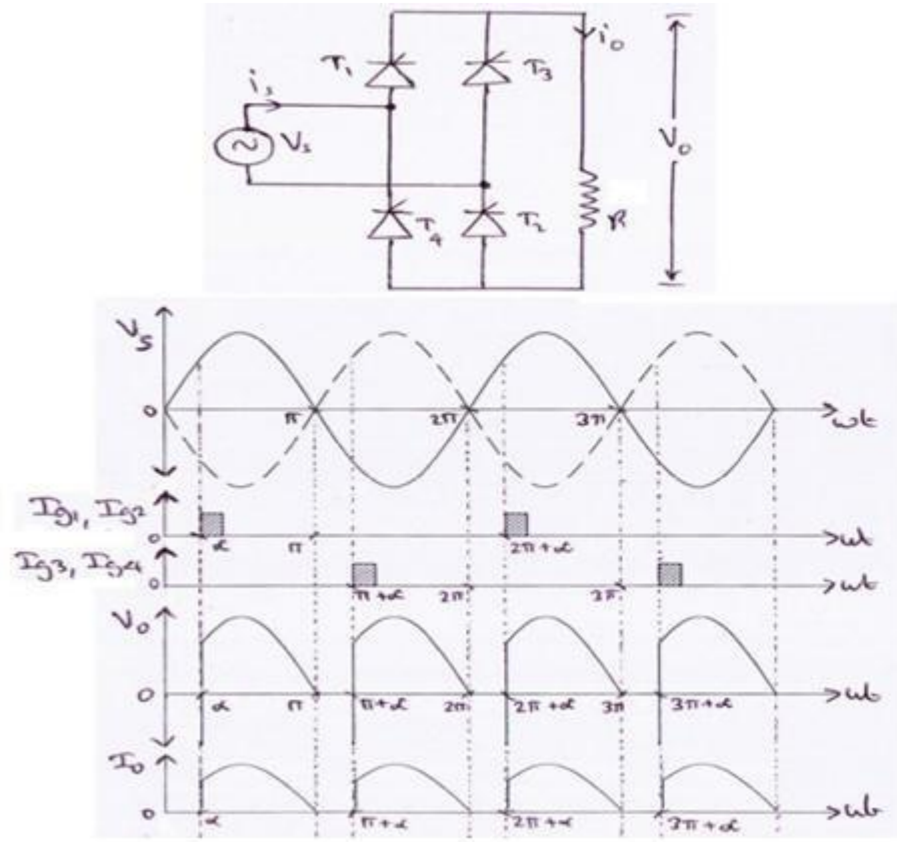
$$\therefore V_0(Avg) = \frac{1}{2\pi}\int_0^{2\pi} V_m sin(wt)\,dwt$$
$$= \frac{V_m}{2\pi}[-coswt]_\alpha^\pi$$
$$= \frac{V_m}{2\pi}(1+cos\alpha)$$

:Understandneedoffreewheelingdiode.

- Thefreewheelingdiodeis commonlydescribe as acommutatingdiodeor bypass diodeas its function is to commutatethe loadcurrent awayfrom the rectifier whenever the load voltage flows into reverse state.
- Freewheeling diodes are also known as kickback diode, clamp diodes, commutating diodes, suppression diodes, or snubber diode etc.
- By using freewheeling diode in R-L load, the load current graph will be improved and the output voltage curve will not be extended in reverse direction.
- It will give better performance so the efficiency will be high and the diode is also known as conducting diode.

Workingofsinglephasefullwavefullycontrolledconverterwithresistive loads:

- Thecircuitdiagramandwaveformofsinglephasefullwaveconverterorrectifierwith Rloadare shown below.



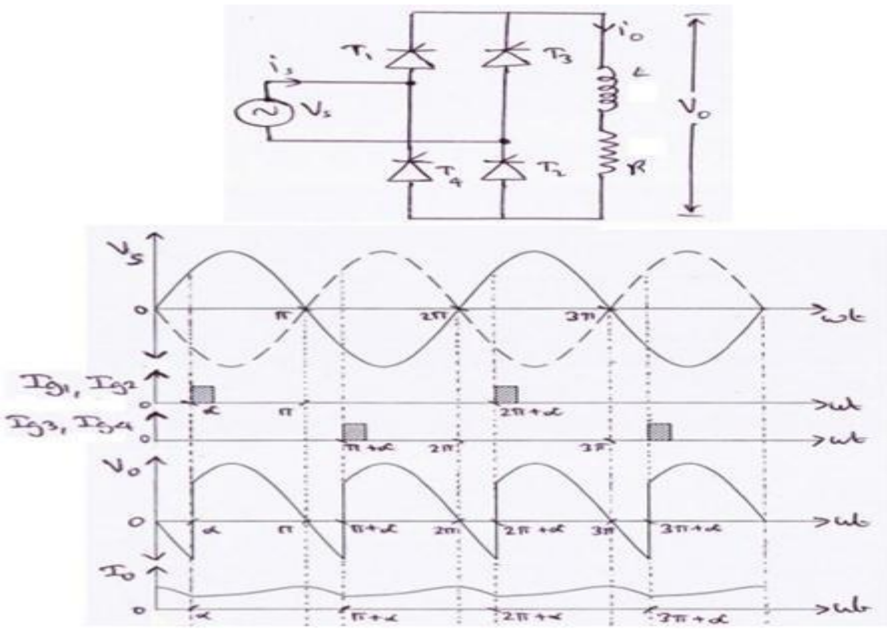
- All four devices used are thyristors. The turn-on instants of these devices are dependent on the firing signals that are given.
- Inthisbridgecircuitdiagonallyelementsoroppositepairofthyristorsmadetoconductand commutate simultaneously.
- InpositivehalfcyclethyristorsT1,T2areforwardbiasedanditfired atanangleαsimultaneouslyT1 and T2 are conducts at that instant

  Vo=Vs

  Io=Vo/R=Vs/RflowsthroughthepathVs-T1-R-T2-VsandT3,T4are reverse biased.
- In negative half cycle of input voltage, SCR's T3 &T4 are forward biased and triggered at an angleof (∏+α) so T3 and T4 are conducts at that instant output currentflows through the path Vs-T3-R- T4-Vs which is positive and the output voltage also positive and T3 & T4 becomes off at 2л.

Workingofsinglephasefullwavefullycontrolledconverterwith R-Lloads.

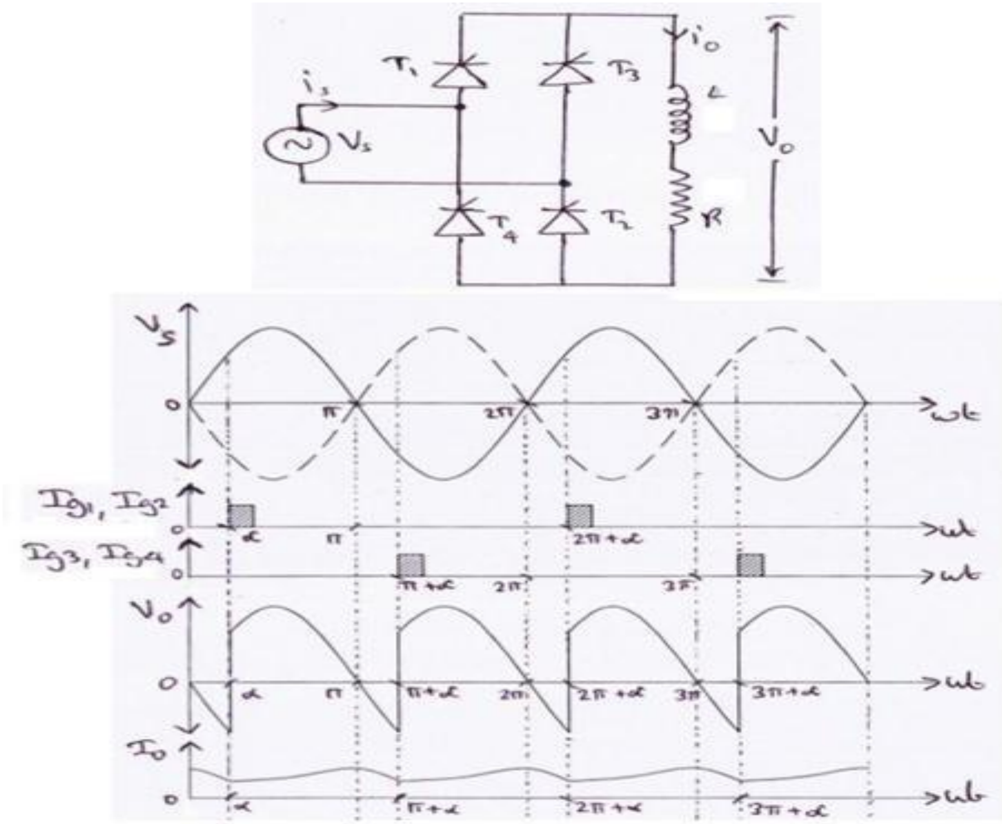
- Thecircuitdiagramandwaveformofsinglephasefullwavefullycontrolledconverterorrectifier with R-L load are shown below.



- Thecircuitconsist offour thyristorsT1,T2,T3andT4, avoltagesourceandaRLload.
- During thepositive half cycleofthe acsupplythethyristors T1 and T2 areforward biased but it does not conduct until a gate supply is applied to it.
- When a gate pulse is given to the thyristor T1 and T2 at ωt=α, it gets turned ON and begins to conduct.
- When thethyristors T1 and T2are ON, theinput voltageis applied to theload but dueto theinductor presentintheloadthecurrentthroughtheloadbuildsupslowlythroughthepathVs-T1-Load-T2-Vs.
- During the negative half cycle, T3 & T4 are forward biased, the thyristor T1 and T2 gets reverse biased but the current through but the current through them is not zero due to the inductor and does not turns OFF.
- The current through the inductor begins to decay to zero and T1 & T2 conducts for a small durationin negative half cycle.
- When a gate pulse is given to the thyristor T3 & T4 at ωt=л+α, it gets turned ON and begins to conduct.
- When the thyristor T3 & T4 are ON, the load current shifts its path to T3 & T4 and turns offT1 & T2 at ωt=л+α.
- When T3 & T4 are ON, the current through the load builds up slowly through the path Vs-T3-Load-T4-Vs.
- Theload receivesvoltageduringboththehalf cycles.
- Theaveragevalue ofoutputvoltagecan bevariedbyvaryingthe firingangle α.
- Thewaveformshows the plot ofinputvoltage, outputvoltageandoutput current.

2.4Workingofsinglephasefullwavefullycontrolledconverterwith R-Lloads.

- The circuit diagram andwave form of single phase full wave fully controlled converter or rectifier with R-L load are shown below.

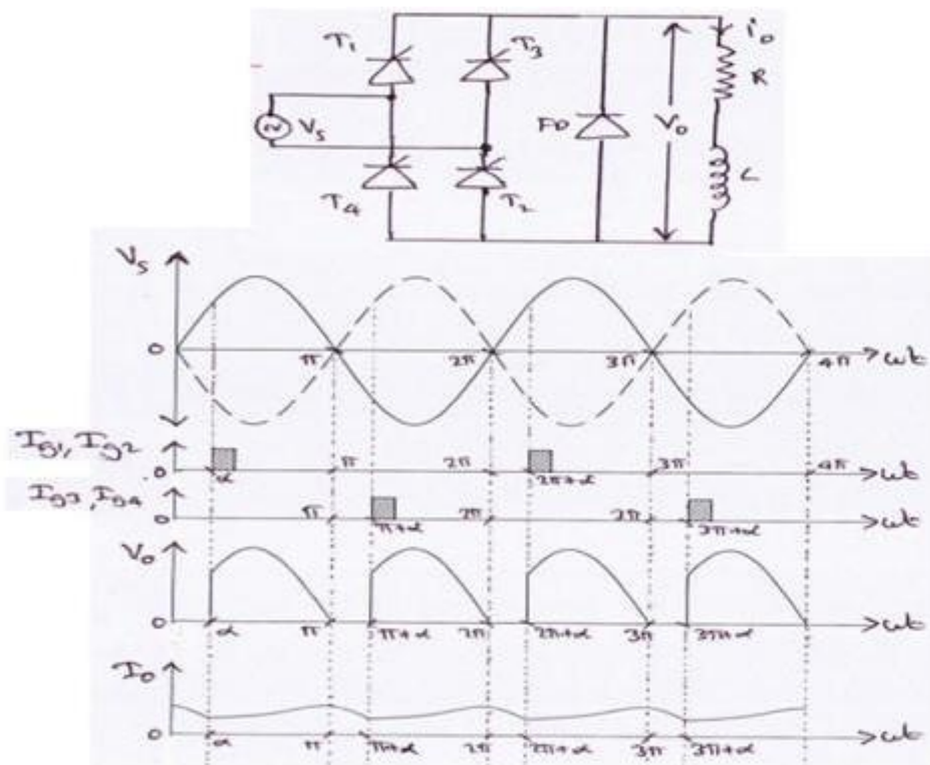


- Thecircuitconsist offour thyristorsT1,T2,T3andT4, avoltagesourceandaRLload.
- During thepositive half cycleofthe acsupplythethyristors T1 and T2 areforward biased but it does not conduct until a gate supply is applied to it.
- When a gate pulse is given to the thyristor T1 and T2 at $\omega t=\alpha$, it gets turned ON and begins to conduct.
- When thethyristors T1 and T2are ON, theinput voltageis applied to theload but dueto theinductor presentintheloadthecurrentthroughtheloadbuildsupslowlythroughthepathVs-T1-Load-T2-Vs.
- During the negative half cycle, T3 & T4 are forward biased, the thyristor T1 and T2 gets reverse biased but the current through but the current through them is not zero due to the inductor and does not turns OFF.
- The current through the inductor begins to decay to zero and T1 & T2 conducts for a small durationin negative half cycle.
- When a gate pulse is given to the thyristor T3 & T4 at $\omega t=\pi+\alpha$, it gets turned ON and begins to conduct.
- When the thyristor T3 & T4 are ON, the load current shifts its path to T3 & T4 and turns offT1 & T2 at $\omega t=\pi+\alpha$.

- When T3 & T4 are ON, the current through the load builds up slowly through the path Vs-T3-Load-T4-Vs.
- Theload receivesvoltageduringboththehalf cycles.
- Theaveragevalue ofoutputvoltagecan bevariedbyvaryingthe firingangle α.
- Thewaveformshowstheplotofinputvoltage, outputvoltage andoutput current.

Workingofsinglephasefullwavefullycontrolledconverterwith R-Lload & Freewheeling Diode.

- The circuit diagram andwave form of single phase full wave fully controlled converter or rectifierwith R-L load and freewheeling diode are shown below.

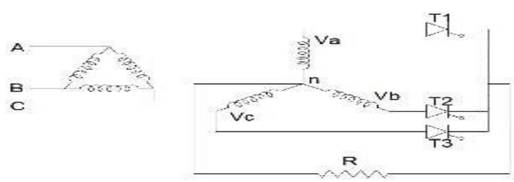


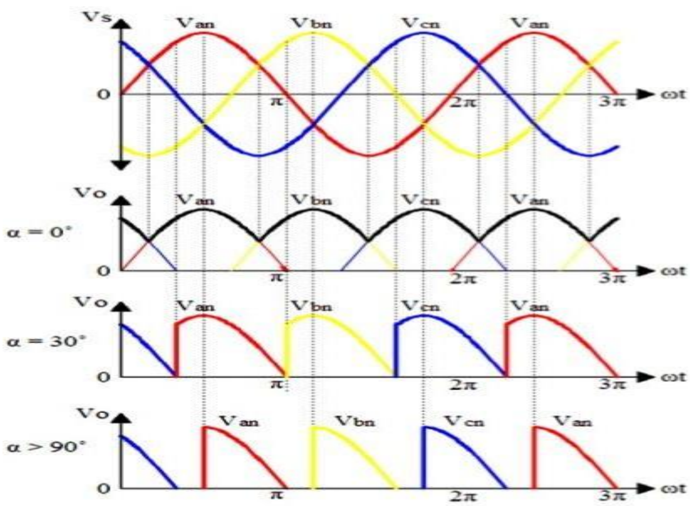
- ThecircuitconsistsoffourthyristorsT1,T2,T3,T4,avoltagesourceVs,aRLloadanda freewheeling diode across the load.
- DuringthepositivehalfcycleoftheinputvoltagethethyristorsT1&T2areforwardbiasedbutit does not conduct until a gate signal is applied to it.
- Whenagatepulseisgiventothethyristor T1 &T2at ωt=α,itgetsturnedONandbeginsto conduct.
- When T1 & T2 are ON, the input voltage is applied to the load but due to the inductor present in the load , the current through the load build up slowly through the path Vs-T1-Load-T2-Vs.
- During the negative half cycle at ωt=л, T3&T4 are forward biased , the thyristor T1 & T2 getsreversebiased and thecurrent shifts its path to the freewheeling diodeand circulates through theloop FD-R-L-FD thus T1 & T2 turns off at ωt=л.

- WhenagatepulseisgiventothyristorT3&T4atωt=л+α,itgetsturnedONandbeginstoconduct ,thecurrentthrough theload buildsup slowlythrough thepath Vs-T3-Load-T4-Vs.
- During the next positive half cycle (at ωt=2л), T1 & T2 are forward biased, the thyristor T3 & T4gets reverse biased and the current shifts its path to freewheeling diode and circulates through the loop FD-R-L-FD thus T3 & t4 turns off at ωt=2л.
- Theaveragevalue ofoutputvoltagecan bevariedbyvaryingthe firingangle α.

Workingofthree-phasehalfwavecontrolledconverterwithResistiveload.

- Thecircuitdiagramandwaveformofthree-phasehalfwavecontrolledconverterwithResistiveload are shown below.

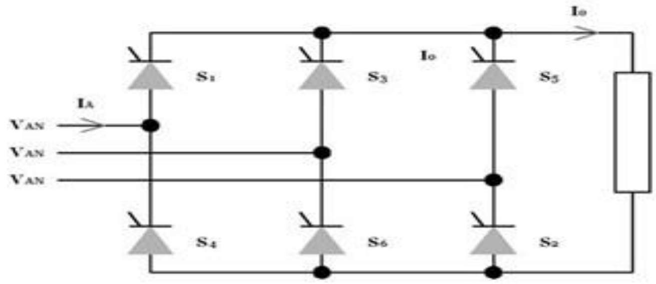




- The circuit consist of a delta star transformer and three thyristors T1, T2, T3 which are connected on the secondary star connected winding and a resistive load.
- WhenVaispositive,T1becomesforwardbiasedandconducts.DuringthenegativecycleofVa, T1turns off.
- SimilarlyT2and T3 conductsonlyduringthe positivecyclesof Vband Vc respectively.
- Theaverageoutput voltagecanbevaried byvaryingthefiringangles ofthethyristors.
- Thewaveformshowsthe output voltageforvariousfiringangles.
- Inthe waveform,Vaisdenotedas Van,Vbas Vbn,Vcas Vcn.

Workingofthree-phasefullycontrolledconverter:

- Thecircuit diagramandwaveform of three-phasefullycontrolled converteris shown below.



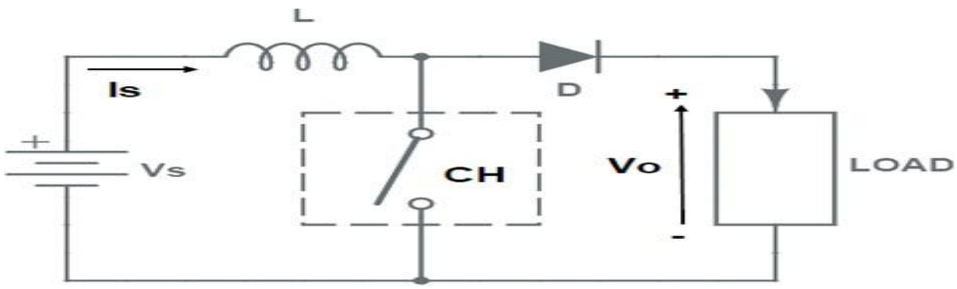
- When thyristor S2 is triggered at ωt=(5π/6α), S1 becomes reverse biased and turns-off. The load current flows through the thyristor and through the supply phase winding 'b-n'. When S2 conducts the phase voltage Vbn appears across the load until the thyristor S3 is triggered.
- The 3-phase input supply is applied through the star connected supply transformer as shown in the figure. The common neutral point of the supply is connected to one end of the load while the other end of the load connected to the common cathode point.
- When the thyristor S1 is triggered at ωt=(π/6 + α)=(30° + α) , the phase voltage Van appears across the load when S1 conducts. The load current flows through the supply phase winding 'a-n' and through thyristor S1 as long as S1 conducts.
- When the thyristor S3 is triggered at ωt=(3π/2 + α)=(270°+α) , S2 is reversed biased and hence S2 turns-off. The phase voltage Van appears across the load when S3 conducts.
- When S1 is triggered again at the beginning of the next input cycle the thyristor S3 turns off as it is reverse biased naturally as soon as S1 is triggered.
- For a purely resistive load where the load inductance 'L = 0' and the trigger angle α >(π/6), the load current appears as discontinuous load current and each thyristor is naturally commutated when the polarity of the corresponding phase supply voltage reverses. The frequency of output ripplefrequency for a 3-phase half wave converter is fs, where fs is the input supply frequency.

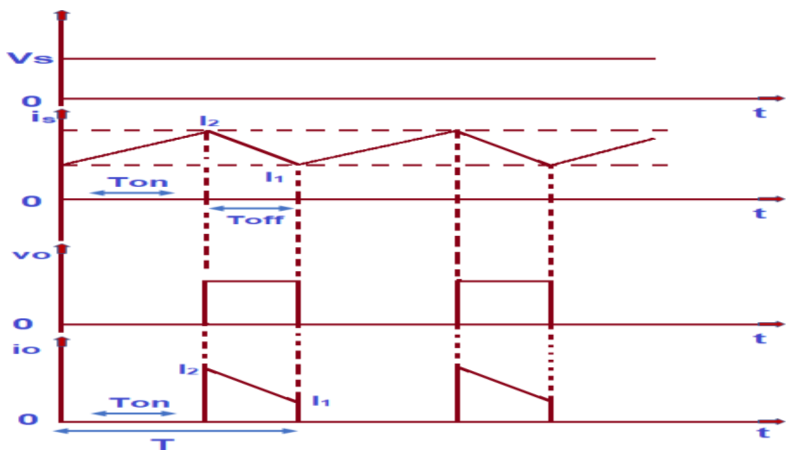
2.8CHOPPER:

- A chopper is a static device that converts fixed DC input voltage to variable output voltage directly. Chopper are mostly used in electric vehicle, mini haulers.
- Chopperareusedforspeedcontrolandbraking.Thesystemsemployingchopperoffersmooth control, high efficiency and have fast response.
- Generallychopper istwotypes1>stepup chopper.2>stepdown chopper

2.8Workingprincipleofstepupchopper:

- Step-upchopperisastaticdevicewhoseaverageoutputDCvoltageisgreaterthanitsinputDC voltage.
- Thecircuitdiagramandwaveformofstep upchopperisdrawn below



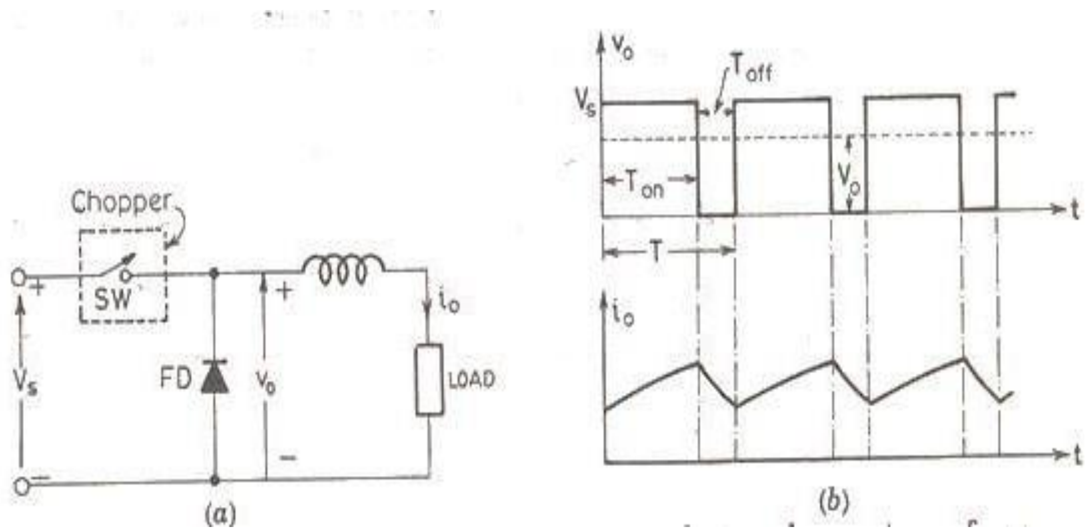


- When chopper (CH) is switched ON, the current will flow through the closed path formed by supply source Vs,inductor L and chopper CH. During this period, no current will flow through the load. Only source current i_s will flow and the value of load current i_o will be ZERO during the ON period.
- During the T_{ON}period, energy is stored in the inductor L. This energy storage in L is essential to boost the load output voltage above the source voltage. Therefore, a large value of L is essential in a step-up chopper.
- WhenthechopperCHis switchedOFF,thecurrentthroughthe Lcannotdieinstantaneouslyratherit decays exponentially. Dueto this behaviorof L, it will forcethecurrent through thediodeDand load for the entire time period T_{OFF}.
- Since, the current through the inductor L tends to decrease, the polarity of the emf induced ininductor L is reversed. As a result, the voltage across the load becomes equal to the sum of source voltage and emf induced in inductor. Thus, the output voltage exceeds the source voltage V_s.
- Theload/output voltage.$\mathbf{V_o = V_s + L(di/dt)}$
- Thus, the circuit works as a step-up chopper. The voltage across the load increases because the inductor releases its stored energy to the load during the OFF period.

Workingprincipleofstep-downchopper:

- Step-down chopper is a static device whose average output DC voltage is lesser than its input DC voltage.

- Thecircuitdiagramandwaveformofstep upchopperisdrawn below



- WhenCHisswitchedON,thesourceisdirectlyconnectedtoloadandhencetheoutputvoltage $V_o$becomes equal to V_s.Thetimeperiodforwhich chopperis kept ONis called ONTimeofchopper and represented by T_{ON}. Thus, Vo will be equal to Vs for time T_{ON}.
- During the ON period of chopper, the current will build in the load exponentially and will reach its maximum value at the end of T_{ON}
- Free-wheelingdiode(D) is reversed biased during T_{ON}, hence it doesn't come into circuit during this period.
- WhenchopperswitchedOFF,theloadisdisconnectedfromthesource$V_s$andhenceloadvoltage $V_o$will be ZERO during the entire period for with CH is OFF. The time for which chopper is kept OFF is known as OFF time and represented by T_{OFF}.
- As the CH is switched OFF, the current through the inductor L (i_o) cannot suddenly drop to zero. Rather, it starts decreasing and hence the polarity of induced emf across the inductor reverses This inducedemfofinductormakesfree-wheelingdiodeforwardbiasedandhence,free-wheelingdiode (D)actsas ashort during T_{OFF}.
- Thus, the load current continues to decay through inductor L, free-wheeling diode D and load even though the source V_s is disconnected.
- Hencetheoutput voltage is lesserthantheinput voltage.

Controlmodesofchopper:

There are two kinds of control strategies used inDC choppers namelytime ratio controland current limitcontrol

1>TimeRatio Control

- In the time ratio control the value of the dutyratio, K =Ton /T is changed. Here 'K' is called the duty cycle. There are two ways to achieve the time ration control, namelyvariable frequency and constant frequency operation.

2>CurrentLimitControl

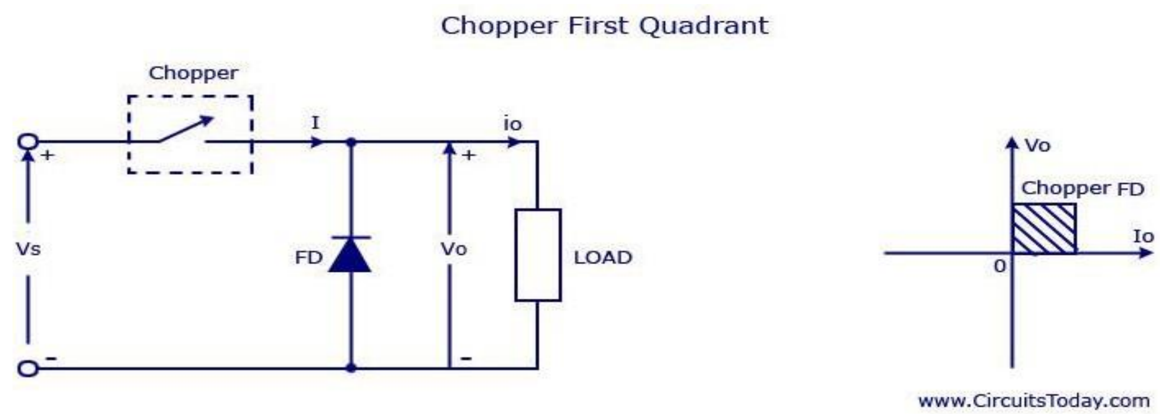
- In a DC to DC converter, the current value varies between the maximum as well as the minimum level of constant voltage. In this method, the DC to DC converter is turned ON & then OFF to confirm that current is preserved constantlybetween the upper limits and also lower limits. When the current energies beyond the extreme point, the DC-DC converter goes OFF.
- While the switch is in its OFF state, current freewheels through the diode and falls in an exponential manner. The chopper is turned ON when the flow of current spreads the minimum level. This technique can be utilized either when the ON time 'T' is endless or when the frequency f=1/T.

Operationofchopperinallfourquadrants.

we can classify chopper circuits according to their working in anyof these four quadrantsastypeA, type B, type C, type D and type E.

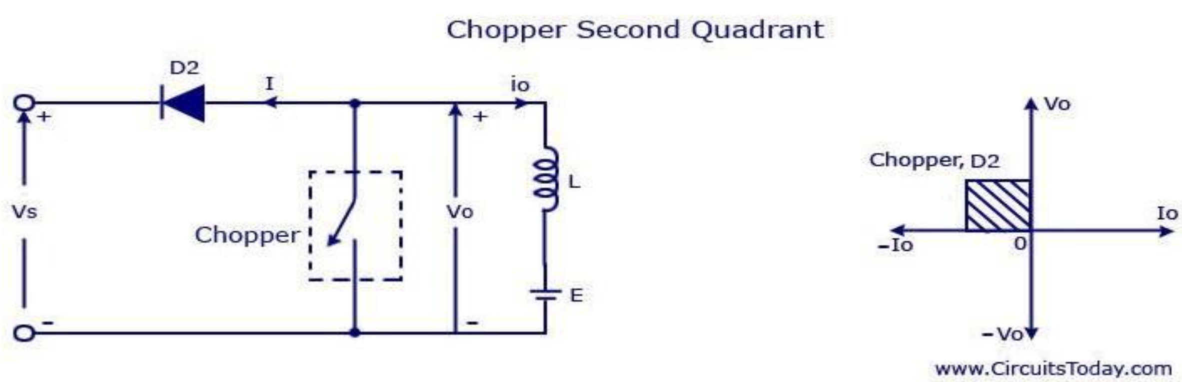
TypeAChopperorFirst–Quadrant Chopper

- This type of chopper is shown in the figure. It is known as first-quadrant chopper or type A chopper. Whenthechopperison,$v_{0}=V_{S}$asaresult andthecurrentflowsinthedirectionoftheload.Butwhen the chopper is off $v_0$is zero but I_0continues to flow in the same direction through the freewheeling diode FD, thus average value of voltage and currentsay $V_0$and I_0will be always positive as shown in the graph.



- In type A chopper the power flow will be always from source to the load. As the average voltage $V_0$is less than the dc input voltage V_s -

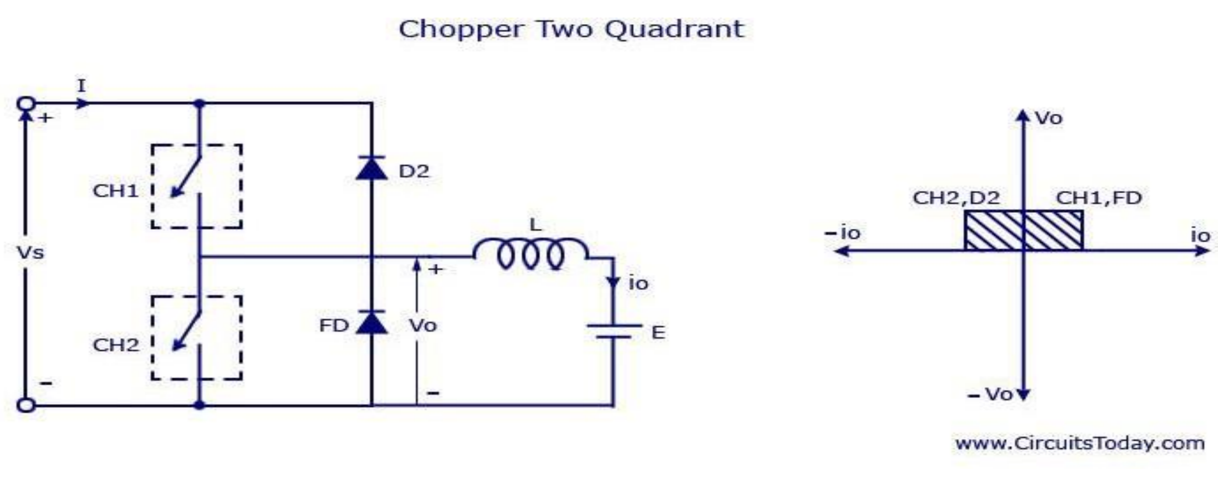
TypeBChopperorSecond-Quadrant Chopper



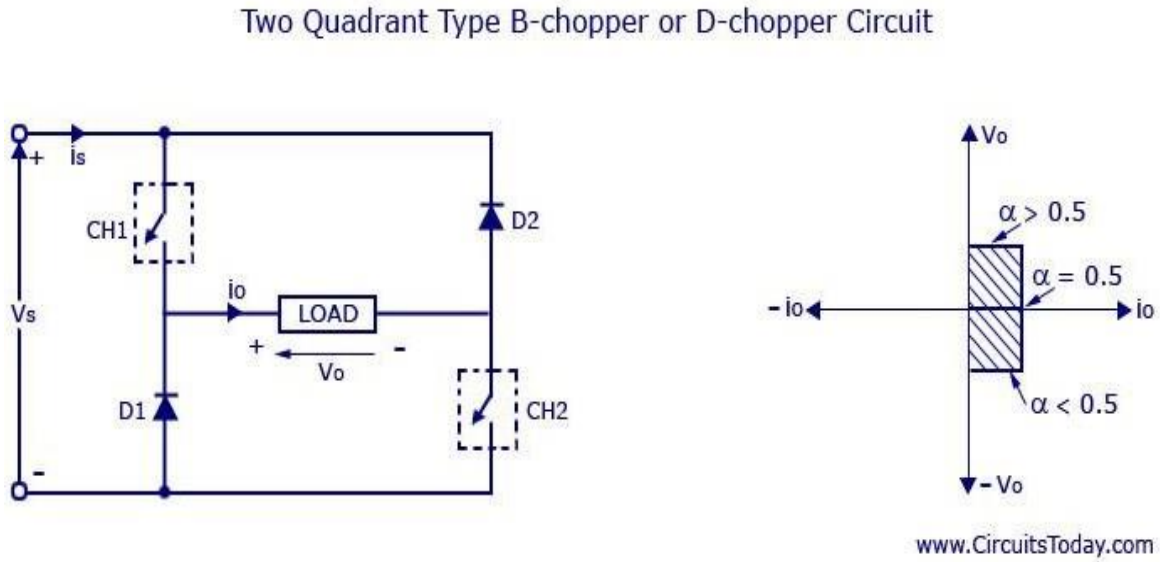
- IntypeBorsecondquadrantchoppertheloadmustalwayscontainadcsourceEWhenthe chopperis on, $v_0$is zero but the load voltage E drives the current through the inductor L and the chopper, L stores the energy during the time $T_{on}$of the chopper .
- Whenthe chopper is off , v_0=(E+ L .di/dt)will be more than the source voltageV_s. Because of this the diode D2 will beforward biased and begins conducting and hence the power starts flowingto the source.
- The chopper may be on or off the current I_0will be flowing out of the load and is treated negative . Since $V_O$is positive andthe current $I_0$is negative , the direction of power flow will be from load to source.TheloadvoltageV$_0$=(E+L.di/dt)willbemorethanthevoltage$V_s$sothetypeBchopper is also known as a step up chopper .

Type-CchopperorTwo-quadranttype-AChopper:

- TypeCchopper is obtained byconnectingtype–Aand type–Bchoppersin parallel.
- We will always get a positive output voltage V_0 as the freewheeling diode FD is present across the load.
- Whenthe chopper is on the freewheeling diode starts conducting and the output voltage $v_0$will be equal to V_s. The direction of the load current $i_0$will be reversed. The current i_0 will be flowing towards the sourceandit will be positive regardless the chopper is on orthe FD conducts.
- Theload current will be negative if the chopper is or the diode D2 conducts.We can saythe chopper andFDoperatetogether astype-A chopperin firstquadrant. Inthesecondquadrant,the chopper and D2 will operate together as type –B chopper.
- The average voltage will be always positive but the average load current might be positive or negative. Thepowerflowmaybelifethefirst quadrant operation i.efrom sourceto loadorfrom load to source like the second quadrant operation.
- The two choppers should not be turned on simultaneously as the combined action my cause a short circuit in supply lines.



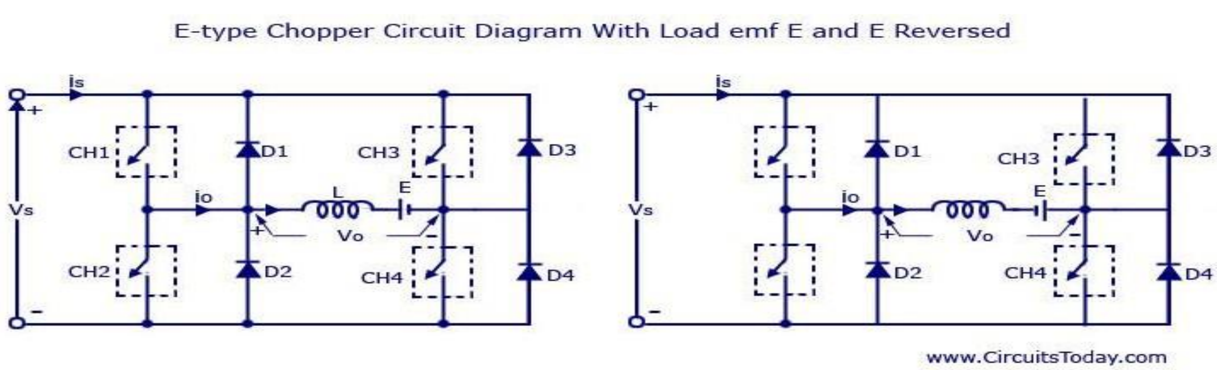
TypeDChopperorTwo-QuadrantType–BChopper



- When the two choppers are on the output voltage$v_0$will be equal to V_s . When v_0= – V_s the two choppers will be off but both the diodes D1 and D2 will start conducting. V_0 the average output voltage will be positive when the choppers turn-onthe time T_{on}will be more than the turn off time T_{off} its shown in the wave form below. As the diodes and choppers conduct current only in one direction the direction of load current will be always positive.
- Thepowerflowsfromsourcetoloadastheaveragevaluesofboth$v_0$and$i_0$ispositive.From thewave formit is seen that theaveragevalueof $V_0$is positivethus theforth quadrant operation of type D chopper is obtained.
- FromthewaveformstheAveragevalueofoutputvoltageisgivenby V0= $(V_s T_{on}-V_sT_{off})/T= V_s.(T_{on}-T_{off})/T$

Type–EchopperortheFourth-Quadrant Chopper

- Type E or the fourth quadrant chopper consists of four semiconductor switches and four diodes arranged in anti parallel.The 4 choppers are numbered according to which quadrant they belong. Their operation will be in each quadrant and the corresponding chopper only beactive inits quadrant.



- **FirstQuadrant**

During the first quadrant operation the chopper CH4 will be on . Chopper CH3 will be off and CH1 will be operated.AS the CH1 and CH4 is on the load voltage v_0 will be equal to the source voltage $V_s$and the load current$i_0$will begin to flow. $v_0$and $i_0$will bepositiveas thefirst quadrantoperation is takingplace. Assoon as the chopper CH1 is turned off, the positive current freewheels through CH4and the diode D2 .The type E chopper acts as a step- down chopper in the first quadrant.

- **Second Quadrant**

In this case the chopper CH2 will be operational and the other three are kept off. AsCH2 is onnegative current will starts flowing through the inductor L . CH2 ,E and D4.Energy is stored in the inductor L as the chopper CH2 is on. When CH2 is off the current will be fed back to the source through the diodes D1 and D4. Here (E+L.di/dt) will be more than the source voltage V_s. In second quadrant the chopper will act as a step-up chopper as the power is fed back from load to source

- **Third Quadrant**

In third quadrant operation CH1 will be kept off , CH2 will beon and CH3 is operated. For this quadrant workingthepolarityoftheloadshould bereversed. AsthechopperCH3is on, theloadgets connected to the source$V_s$and$v_0$and $i_0$will benegativeand the thirdquadrant operation will takes place. This chopperacts as a step-down chopper

- **FourthQuadrant**

CH4 will be operated and CH1, CH2 and CH3 will be off. When the chopper CH4 is turned on positive current starts to flow through CH4, D2 ,E and the inductor L will store energy. As the CH4 is turned off the current is feedback to the source through the diodes D2 and D3 , the operation will be in fourth quadrant as the load voltage is negative but the load current is positive. The chopper acts as a step up chopper as the power is fed back from load to source.

SHORTQUESTIONSWITHANSWER:

Mentionsomeof theapplicationsofcontrolledrectifier.

1. Steelrollingmills,printingpress,textilemills andpapermills employingdcmotordrives.
2. DC traction
3. Electrochemicalandelectro-metallurgical process
4. Portablehandtool drives
5. Magnetpower supplies
6. HVDCtransmissionsystem

Whatisthefunctionoffreewheelingdiodesin controlledrectifier?(S-09,W-11,17,19,20)

Itservestwoprocess.

1. Itpreventstheoutputvoltagefrombecomingnegative.
2. The load current is transferred from the main thyristors to the freewheeling diode, thereby allowingall ofits thyristors to regain their blocking states.

Whataretheadvantagesof freewheelingdiodesin acontrolledinacontrolledrectifier?

1. Inputpowerfactorisimproved.
2. Loadcurrentwaveformisimprovedandthustheloadperformanceis better.

Whatismeantbydelayangle?

The delay angle is defined as the angle between the zero crossing of the input voltage and the instant the thyristor is fired.

Whataretheadvantages of single phasebridgeconverteroversinglephase mid-point converter?

1. SCRs are subjected to a peak-inverse voltage of 2Vm in a fully controlled bridge rectifier. Hence for same voltage and current ratings of SCRs, power handled by mid-point configuration is about
2. Inmid-pointconverter,eachsecondarywindingshouldbeabletosupplytheloadpower.Assuch,the transformer rating in mid-point converter is double the load rating.

Whatiscommutationangleoroverlap angle?

The commutation period when outgoing and incoming thyristors are conducting is known as overlap period. The angular period, when both devices share conduction is known as the commutation angle or overlapangle.

Whatarethedifferentmethodsof firingcircuitsforlinecommutatedconverter?

1. UJT firingcircuit.
2. Thecosine wavecrossingpulse timingcontrol.
3. Digitalfiringschemes.

Whataretheadvantages of sixpulse converter?

1. Commutation is made simple.
2. Distortionontheacsideisreducedduetothe reductioninlowerorder harmonics.
3. Inductancereducedinseriesisconsiderablyreduced.

Whatismeantbydcchopper?

Adcchopperis ahigh speed staticswitch usedtoobtainvariable dcvoltagefrom aconstant dc voltage.

Whataretheapplicationsof dcchopper? (W-06,S-09)

1. Batteryoperated vehicles
2. Tractionmotorcontrolinelectrictraction
3. Trollycars
4. Marine hoists
5. Minehaulers
6. Electric braking.

Whatismeantbystep-upandstep-downchopper?

Inastep-downchopperorBuck converter,theaverageoutputvoltageislessthan theinputvoltage.Ina step- up chopper or Boost converter, the average output voltage is more than the input voltage.

Whatisdutycycleofchopper?(W-16,17,19)

IttheratioofTurnontimetothetotalchoppingtimeofthechopper. It is represented by α.

LONGQUESTIONS:

DrawthecircuitdiagramofsinglephasehalfwavecontrolledrectifierwithR-Lloadandfreewheeling diode & explain the working when firing angle is changed. (W-07, 17,18)

Explainwith neat sketch theoperation ofasingle phasefullycontrolled bridgerectifier.(S-09,W-17)

Explainfullycontrolled bridgerectifierwithRload.

ExplainsinglephasefullwavefullycontrolledbridgerectifierwithR-Lloadandfreewheeling diode.(W-05,20)

Withnecessarydiagram explain the phasecontrolled technique.

Explain about theA,B&Cchopper.

WhatisChopper?ExplainStep-downChopperwithaneatdiagram?(W-10,11,14)

DescribeabouttheprincipleofStep-up Chopper.(W-10,16)

CHAPTER-3

UNDERSTANDTHEINVERTERSANDCYCLO-CONVERTERS

LearningObjectives:

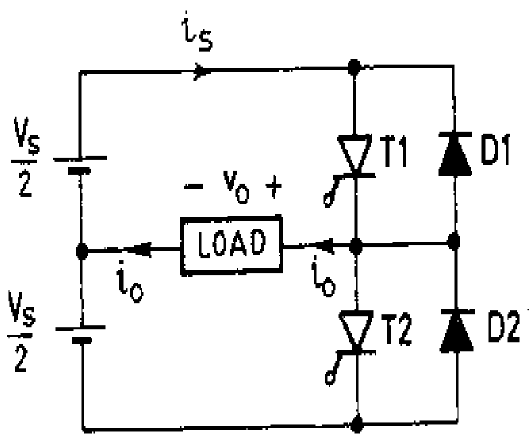
Classifyinverters.
Explaintheworking ofseries inverter.
Explaintheworkingofparallelinverter
Explainthebasic principleofCyclo-converter.
Explaintheworking ofsingle-phasestep up &step downCycloconverter.
ApplicationsofCyclo-converter.

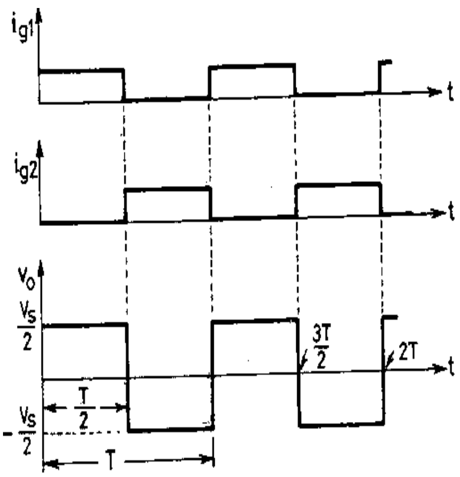
Classifyinverters:

- Inverterisastaticdevice whichDCpowertoACpoweratdesiredoutputvoltageandfrequency.
- Invertersaremainlyclassifiedintotwotypes :
    1. Voltagesourceinverter(VSI)
    2. Currentsourceinverter (CSI)
- Accordingtothemethodofcommutationinvertersareclassifiedas:
    1. Linecommutatedinverter.
    2. Forcecommutatedinverter.
- Accordingtotheconnectiontheinvertersareclassifiedas :
    1. Seriesinverter.
    2. Parallelinverter.
    3. Bridgeinverter.(halfbridge&fullbridge)

Explaintheworkingofsingle-phasehalfbridgevoltagesourceinverter.

Thecircuitdiagramandwaveformofsinglephasehalfbridgevoltagesourceinverteris shown below.



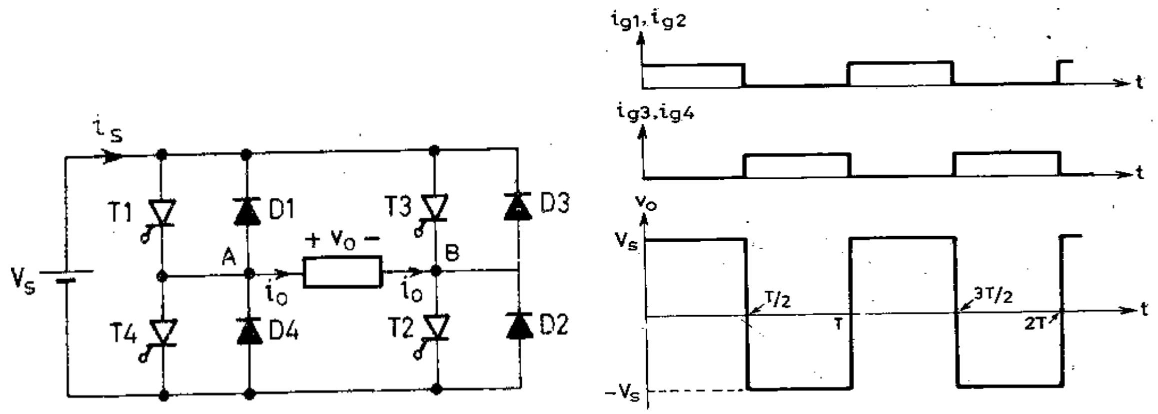


- ItconsistoftwothyristorsT1,T2,andtwodiodesD1,D2andthreewiresupply,load and a DC source.
- Here Ig1andIg2arethe gatesignalsappliedtothethyristorT1& T2respectively.
- Forthetimeperiod0toT/2thegatesignal Ig1is appliedtotheSCRT1soT1 conductsandthe load is subjected to a voltage Vo=Vs/2 due to the upper voltage source Vs/2.

- AtthetimeperiodT/2thyristorT1iscommutatedandthethyristorT2isturnedON by applying gate signal Ig2.
- DuringthetimeperiodT/2toTthyristorT2conductsandtheloadissubjectedtoavoltageVo= -Vs/2duetothelowervoltagesourceVs/2.
- Thus the load voltage or output voltage Vo is an alternating voltage waveformofamplitude Vs/2 and of frequency 1/T Hz.
- Frequencyoftheinvertercanbechangedbycontrollingthetime periodT.
- In case of R-L load the energy is feed back to the DC source throw the diodesD1&D2 sothe diodes are called as feed backdiode.
- Feedbackdiodesare alwaysconnectedantiparallarlywiththemainthyristors.

Explaintheworkingofsingle-phasefullbridgevoltagesourceinverter.

- Thecircuitdiagramandwaveformofsinglephasefullbridgevoltagesourceinverterisshown below.



- ItconsistoffourthyristorsT1,T2,T3,T4,fourdiodesD1,D2,D3,D4,adcvoltagesourceanda load.
- HereIg1,Ig2,Ig3, Ig4arethegatesignalsappliedtothethyristorT1,T2,T3,T4respectivelyfor their conduction mode.
- Forthetimeperiod0toT/2thegatesignals Ig1 & Ig2areappliedtothethyristors T1 & T2 respectively so T1 & T2 conducts thus load is subjected toa voltage Vo=Vs.
- AtthetimeperiodT/2thethyristorsT1&T2arecommutatedandT3,T4are turnedONby applying gate signal Ig3 & Ig4.
- DuringthetimeperiodT/2toT,thyristorT3,T4areconducts andloadis subjectedto avoltage Vo= -Vs.
- ThustheloadvoltageoroutputvoltageVoisanalternatingvoltagewaveform ofamplitudeVs and frequency 1/T Hz.
- Frequencyoftheinvertercanbechangedbycontrollingthetimeperiod.

Explaintheworkingofseriesinverter:

- Thecommutatingcomponents LandCareconnectedinserieswiththeloadthereforethis inverter is called as Series Inverter.
- Thevalueofcommutatingcomponentsisselectedsuchthatthecircuitbecomesunder damped.
- Theanodecurrentitselfbecomeszerointhis inverterresultingtheSCRturnsoffautomatically therefore this inverter is also called as self commutated or load commutated inverter.

PowerCircuitDiagram:

- ThepowercircuitdiagramoftheseriesinverterisshowninthefigureA.
- TheSCRT1andSCRT2areturnedonatregularintervalinordertoachieve desirableoutput voltage and output frequency.
- TheSCRT2 iskeptoffatstartingconditionandpolarityof voltageacross capacitoris shownin the figure A.

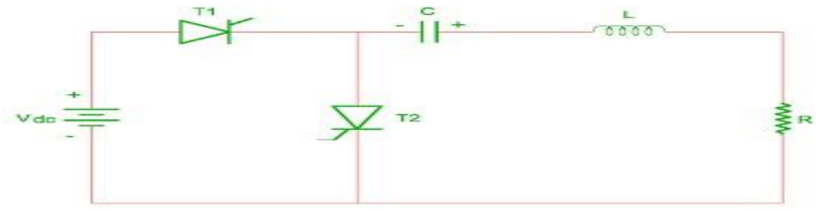


FIGURE A : BASIC SERIES INVERTER

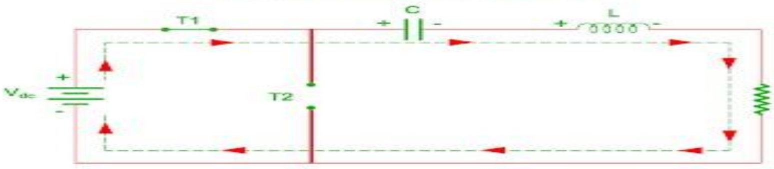


FIGURE B : EQUIVALENT CIRCUIT WHEN SCR T1 'ON'

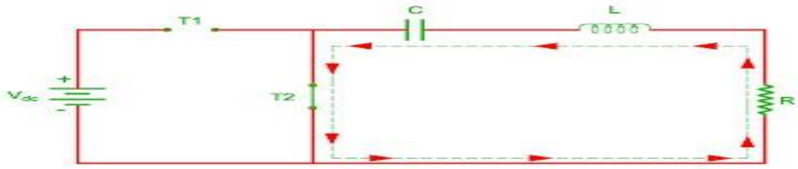


FIGURE C : EQUIVALENT CIRCUIT WHEN SCR T2 'ON'

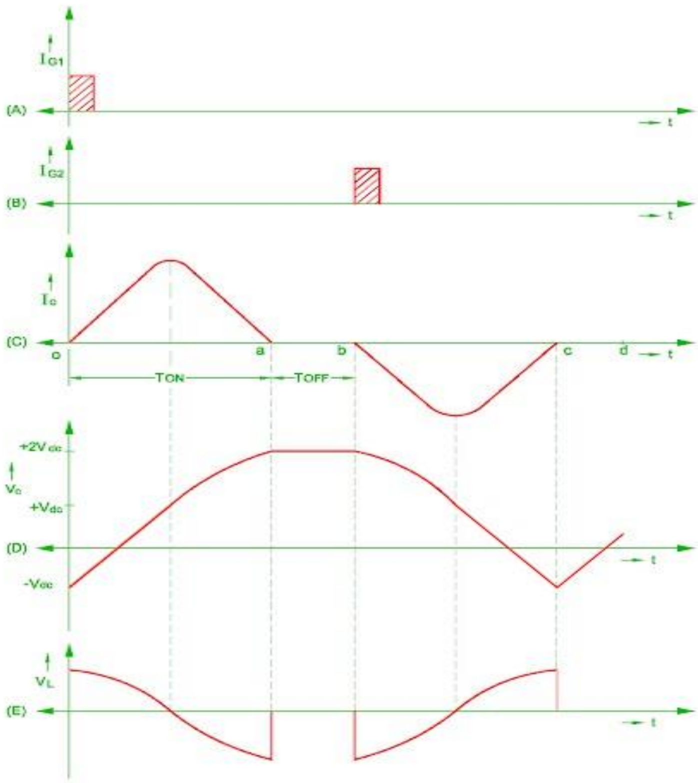


FIGURE D : VOLTAGE AND CURRENT WAVEFORMS OF SERIES INVERTER
(A) Gate pulse for SCR T1 (B) Gate pulse for SCR T2 (C) output current,
(D) Capacitor voltage (E) Load voltage

Operation:

Mode1

- The voltageV_{dc}directlyappliestoRLCseriescircuitassoonastheSCR T1isturnedon.
- Thepolarityofcapacitor chargingis shownin thefigure B.
- Thenatureoftheload currentisalternatingasthereis underdampedcircuitofthe commutating components.
- Thevoltageacrosscapacitorbecomes+V_{dc}whentheloadcurrentbecomesmaximum.
- Thevoltageacrosscapacitorbecomes+2V_{dc}whentheloadcurrentbecomeszeroatpointa(figure D).
- TheSCRT1automaticallyturns offatpointabecausetheloadcurrentbecomeszero.

Mode2

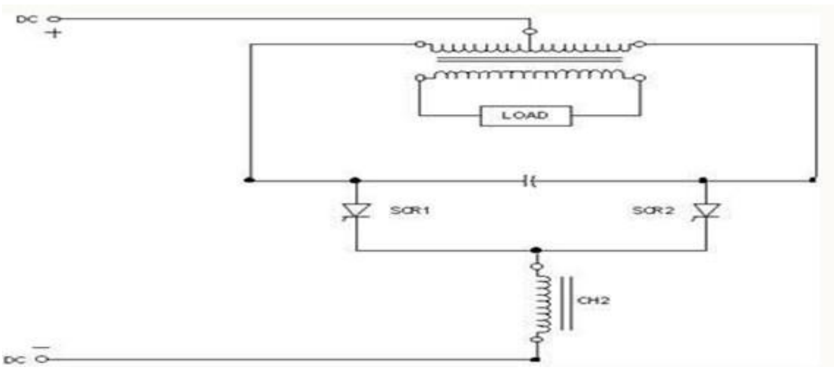
- Theloadcurrentbecomeszerofrompointatobas theSCRT1turnsoffinthistimeperiod.
- TheSCRT1andSCRT2areturnedoffinthistimedurationandvoltageacross capacitor becomes equal to +2 V_{dc}.

Mode3

- TheSCR T2isturnedonatpointbduetoitreceivespositivecapacitorvoltage.
- ThedischargingofcapacitorisdonethroughSCRT2andR–Lcircuitas showninthefigureC.
- Theloadcurrentbecomeszeroafteritbecomesmaximuminthenegative direction.
- Thecapacitordischarges from+2$V_{dc}$to–V_{dc}duringthistimeand SCRT2turnsoff automatically at point C due to load current becomes zero.
- TheSCRT2turnsoffduringpointCtoDand SCRT1againturnson.Thiswaycycle repeat after it complete one turns.
- Thetimedurationabandcd mustbegreaterthantheSCRspecificturnofftimeand it is called as dead zone.

<u>Explaintheworkingofparallelinverter:</u>

- Thesinglephaseparallelinvertercircuitconsistsoftwo SCRsT1andT2,aninductorL, an output transformer and a commutating capacitor C.
- TheoutputvoltageandcurrentareVoandIorespectively.
- The function of L is to make the source current constant. During the working of this inverter, capacitorCcomesinparallelwiththeloadvia the transformer. Soitis calledaparallelinverter.



- Theoperationofthisinvertercan beexplainedin thefollowingmodes.

ModeI

- In this mode, SCR T1 is conducting and a current flow in the upper half of primary winding. SCR T2 is OFF. As a result an emf Vs is induced across upper as well as lower half of the primary winding.
- In other words total voltage across primary winding is 2 Vs. Now the capacitor C charges to a voltage of 2Vs with upper plate as positive.

ModeII

- Attime to, T2is turned ONbyapplyingatrigger pulse to its gate.
- At this time t=0, capacitor voltage 2Vs appears as a reverse bias across T1, it is therefore turned OFF. A currentIobeginstoflowthroughT2andlowerhalfofprimarywinding.
- Nowthecapacitor has charged (upper plate as negative) from +2Vs to -2Vs at time t=t1. Load voltage also changes from Vs at t=0 to – Vs at t=t1.

ModeIII

- Whencapacitorhaschargedto–Vs,T1maybetunedONatanytimeWhenT1istriggered, capacitor voltage 2Vs applies a reverse bias across T2, it is therefore turned OFF.
- After T2 is OFF, capacitor starts discharging, and charged tothe opposite direction,the upperplate as positive.

3.5Explainthebasicprincipleof Cyclo-converter:

- Acyclo-converterisadevicethatconvertsAC,poweratonefrequencyintoACpowerofan adjustable but lower frequency without any direct current.

CircuitDiagram:

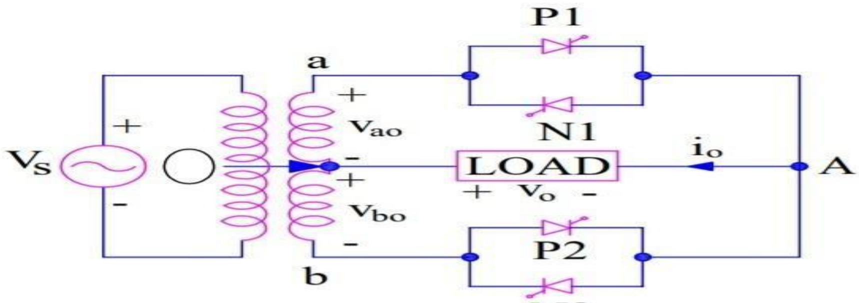


Fig. - 1

- Thecircuitconsistsofasinglephasetransformerwithmidtaponthesecondarywindingand four thyristors.
- Twoofthesethyristors P1&P2 areforpositivegroup.
- Herepositivegroup meanswheneitherP1 orP2conducts, theload voltageis positive.
- OthertwothyristorsN1 &N2arefornegativegroup.
- Loadisconnectedbetweensecondarywindingmid-pointOandterminal A.
- Theloadisassumedresistiveforsimplicity.Assumedpositivedirectionforvoltageandcurrent are marked in the circuit diagram.

TypesofCycloconverter:

Mainlytherearetwotypescycloconverter accordingtotheoutput frequency

1. Step-upcycloconverters
2. Step-down cycloconverters.

3.6Explaintheworkingofsingle-phasestepupCyclo-converter:

Itcanprovideanoutputhavingthefrequencygreaterthantheinputfrequencybyusingline commutation.

Thecircuitdiagramand waveformaredrawnbelow:

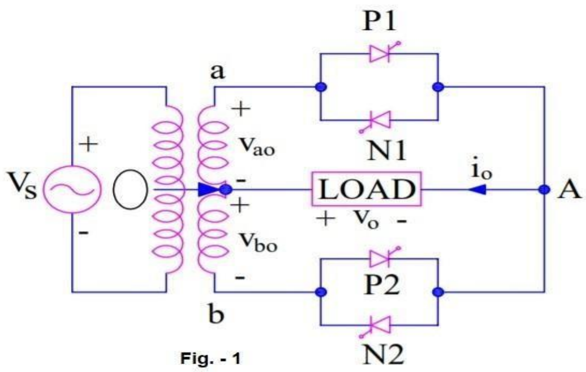


Fig. - 1

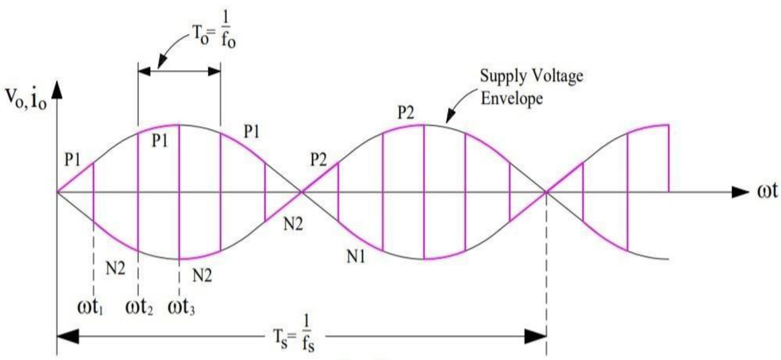


Fig. - 2

Operation:

- Duringthepositivehalf cycleof input supplyvoltage, positive group thyristors P1 &N2 are forwardbiasedforωt=0 toωt=π.AssuchSCRP1isfiredtoturnitONatωt=0suchthat load voltage is positive with terminal A positive and O negative.
- Theload voltage, thus,follows the positive envelop of theinput supplyvoltage.
- Atsometimeinstantωt=ωt1,theconductingthyristorP1isforcecommutatedandtheforward biased thyristorN2 is fired to turn it ON.
- During the period N2 conducts, the load voltage is negative because O is positive& A is negativethistime.Theloadoroutputvoltagetracesthenegativeenvelopofthe supplyvoltage. This is shown in figure below.
- Atωt=ωt2,N2isforcecommutatedandP1isturnedON.Theloadvoltageisnowpositive and follows the positive envelop of the supply voltage.
- At ωt = π, terminal "b" is positive with respect to terminal "a"; both SCRs P2 & N1 are thereforeforwardbiased fromωt=πtoωt=2π.ATωt=π,N2isforcecommuatedandforward biased SCR P2 is turned ON.
- Theload voltageis positive and followsthe positive envelop of supplyvoltage.
- Ifthesupplyfrequencyis $f_s$andoutputfrequencyisf_o,P2willbeforcecommutatedatωt= ($1/2f_s$) + ($1/2f_o$).
- WhenP2isforcecommutated,forwardbiasedSCRN1isturnedON.Thistime,theload voltage is negative and follows the negative envelop of the supply input.
- Inthismanner,SCRsP1,N2forthefirsthalfcycle;P2,N1inthesecondhalfcycleandsoon are switched alternately between positive and negative envelops at a high frequency.
- Thisresults inoutput frequency$f_o$morethan theinput supplyfrequencyf_s.

3.6 Explain the working of single-phase step down Cyclo-converter:

- It provides output having lower frequency than the input frequency by using forced commutation.
- The working principle of step-down cyclo-converter is explained for discontinuous and continuous load current.
- The load is assumed to be comprised of resistance(R)&inductance(L). The

circuit diagram and waveform are drawn below:

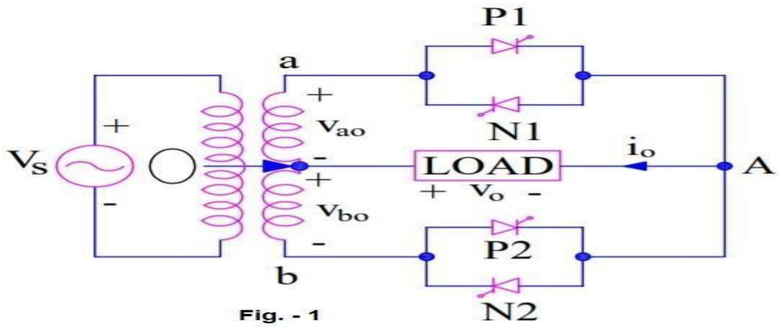


Fig. - 1

Discontinuous Load Current:

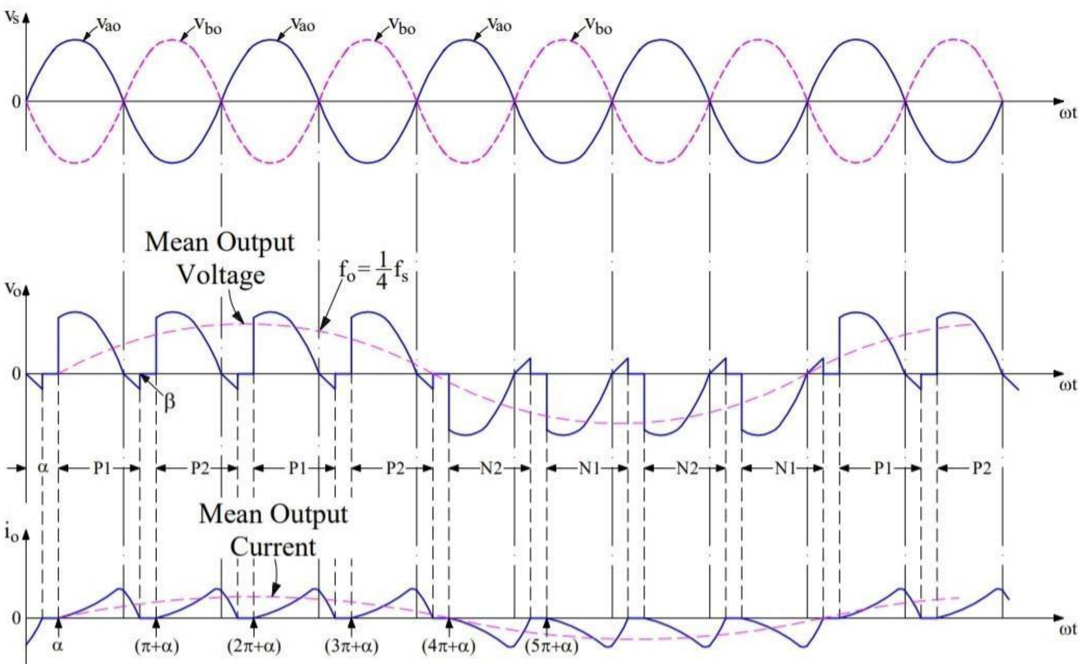


Fig.-2

- For positive cycle of input AC supply, the terminal A is positive with respect to point O. This makes SCRs P1 forward biased. The forward biased SCR P1 is triggered at ωt=0. With this, load current i_O starts building up in the positive direction from A to O.
- Load current i_O becomes zero at ωt=β>π but less than(π+α). The thyristor P1 is thus, naturally commutated at ωt = β which is already reversed biased after π.
- After half a cycle, b is positive with respect to O. Now forward biased thyristor P2 is fired at ωt =(π+α). Load current is again positive from A to O and builds up from zero as shown in figure 2.
- At ωt=(π+β), i_O decays to zero and P2 is naturally commutated. At ωt=(2π+α), P is again turned ON. Load current in figure-2 is seen to be discontinuous.

- Afterfourpositivehalfcyclesofloadvoltageandloadcurrent,thyristorN2isgatedat (4π+α) when O is positive with respect to b.
- AsN2 is forward biased,itstarts conductingbutthedirection ofloadcurrent is reversethistime i.e.itflowsfromOtoA. AfterN2istriggered, Oispositivewithrespectto"a"butbeforeN1is fired, i_O decays to zero and N2 is naturally commutated.
- NowwhenN1isgatedat(5π+α),$i_O$againbuildsupbutitdecaysto zerobeforethyristorN2in sequence is again gated.
- Inthismanner,fournegativehalfcyclesofloadvoltageandloadcurrent,equalto numberof positive half cycles of load voltage & current, are generated.
- Itisclearthattheoutputfrequencyofloadvoltage&currentis(¼)timesofinputsupply frequency.

ContinuousLoadCurrent:

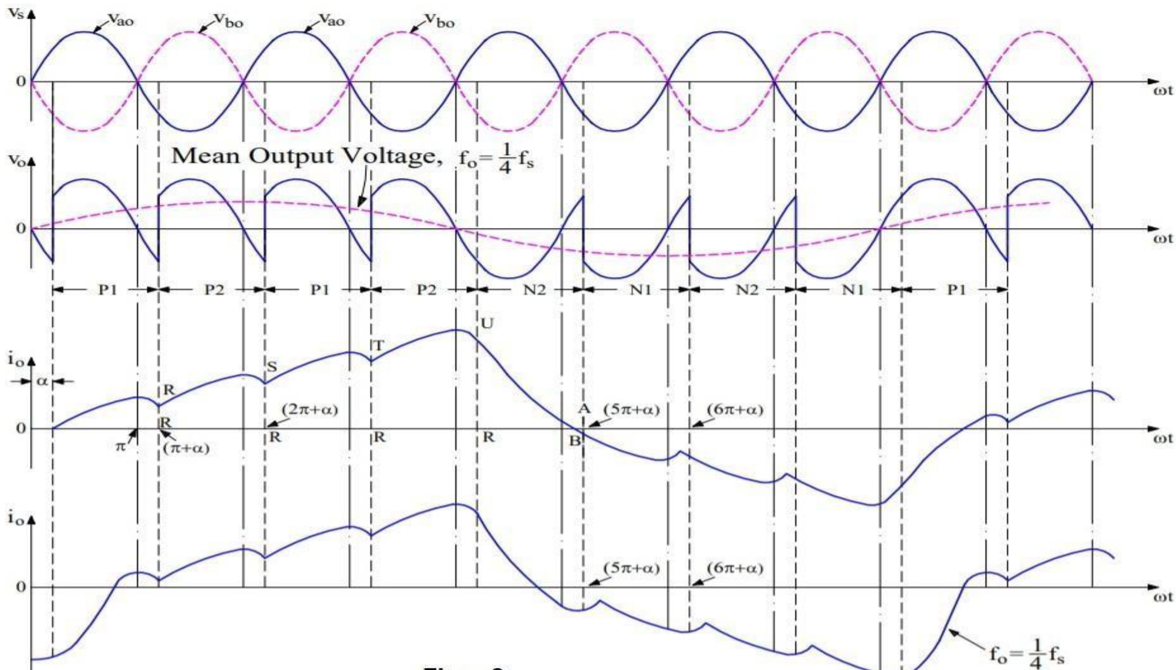


Fig. - 3

- When"a"ispositivewithrespecttoOinfigure-1,P1istriggered atωt=α,positiveoutput voltage appears across load and load current starts building up as shown in figure-3.
- Atωt=π,supplyandloadvoltages arezero.Afterωt=π,P1isreversedbiased.Asloadcurrent is continuous, P1 is not turned OFF at ωt = π.
- WhenP2istriggeredinsequenceat(π+α),areversevoltageappearsacrossP1,itistherefore turned OFF by natural commutation.
- WhenP1iscommutated,loadcurrenthasbuildsuptoavalueequaltoRR.WiththeturnON of P2 at (π+α), output voltage is again positive. As a consequence, load current builds up further than RR as shown in figure-3.
- At(2π+α),whenP1isagainturnedON,P2isnaturallycommutatedandloadcurrentthroughP1 builds up beyond RS.
- Atthe end offour positivehalf cyclesof output voltage,load current is RU.
- WhenN2istriggeredafterP2,loadissubjectedtonegativevoltagecycleandloadcurrenti_O decreases from RU to negative AB.
- NowN2iscommutatedandN1isgatedat(5π+α).Loadcurrent $i_O$becomesmorenegative than AB at (6π+α), this is because with N1 ON, load voltage is negative.

- Forfournegativehalfcyclesofoutputvoltage,current$i_o$isshowninfigure-3. Loadcurrent waveform is redrawn in the last waveform of figure-3.
- Themean waveformofloadvoltageisalso shownin loadvoltagewaveform.
- Itisclearfromtheloadcurrentandmeanloadvoltagewaveformthattheoutputfrequencyis one fourth of the input supply frequency i.e. f_o = (¼)f_s.

3.7ApplicationsofCyclo-converter:

1. SpeedcontrolofhighpowerAC drive.
2. InductionHeating.
3. StaticVARcompensation.
4. Forconvertingvariablespeedalternatorvoltagetoconstantfrequencyoutputvoltageforuseas power supply in aircraft or shipboard.

SHORTQUESTIONSWITHANSWER:

Statethefunctionofthecycloconverter.(W-18,19)
Ans:Thefunctionofthecycloconverteristoconvertconstantvoltage,constantfrequencyinto variable voltage, and variable frequency without any intermediate stage.

DescribethePrincipleofoperation ofthe cycloconverter.
Ans:Thecycloconverter consistsofdualconverterinwhichoneconverterworksaspositiveconverter whereas the other as the negative converter.
Thefiringangleofthebothconverterareadjustedsuchthat $\alpha_p + \alpha_n = \pi$

α_p = Firing angle of positive converter
α_n=Firingangleofnegativeconverter.

Describethedifferenttypesofcycloconverter. Ans:
Types of cycloconverter
Accordingto frequency:(1)Step up cycloconverter and
(2) Step down cycloconverter
Accordingtooutputvoltage:(1)Singlephasetosinglephase:
(a)Centre tapedcycloconverter .
(b)Bridgeconfigurationcycloconverter. (2) Single phase to three phase
(3)Threephaseto threephase.

Describetheadvantagesanddisadvantagesofthecycloconverter. Ans:
Advantages :
- Higherefficiencyduetosinglestageconversion.
- Allthecycloconverterworksonlinecommutationexceptstepupcycloconvertertherefore itis not necessary for extra commutating components.
- Thepower transfer fromsupplyto load and viceversaatanypowerfactor.
- Itcanoperate atdistortedoutputwaveforminthe caseofoneSCRgetsdamaged.

Disadvantages:
- ControlcircuitbecomescomplexduetohighernumberofSCRs.
- Lowpower factor forlowoutput voltage
- Thesupplyshould beshort circuited duetofailureofcommutation circuit.

Statetheapplicationsofthecycloconverter.(W-18,19)

Ans: The application of Cycloconverter are:
- SpeedcontrolofACdrives.
- Grindingmilldrives.
- Inductionheating.
- Variable frequencysupplyforshipyard or aircraft.
- StaticVAr generation.
- HVDCtransmissionline.

DescribethefunctionoftheInverter. (W-11,16)
Ans:ThefunctionoftheinverteristoconvertfixedDCintovariablevoltage,variablefrequency alternating supply.

DefineSeriesInverter.
Ans:ThecommutatingcomponentsLandCareconnectedinserieswiththeloadtherefore this inverter is called as Series Inverter.

DifferentiatebetweenVoltageSourceInverter(VSI) –CurrentSourceInverter(CSI). Ans:

- TheoutputvoltageremainsconstantforagiventypeofloadintheVSIwhereasthe input current remains constant in the CSI.
- AlargecapacitorisconnectedattheinputsideoftheVSIwhereasalargeinductorisconnected at the input side of the CSI.

LONGQUESTIONS:

whatarethedifferenttypesofinverterandexplaintheworkingofseriesinverterwithneat diagram and draw its waveform.(W-17,18)

Explaintheworkingof1-ph parallelinverter withneat diagram.(W-09)

Explaintheprinciple ofCyclo-converter &itsoperation. (S-09,W-14)

Explainaboutthe1-phto 1-phCyclo-converterwithresistiveload. (W-16,17,18.S-19)

Explainwithneatcircuitdiagram,Step-upandstep-downmidpointCyclo-converter.(W-19,20)

Explaintheoperation of1-phhalf bridgevoltagesourceinverter with resistiveload.(W-19)

Explaintheworkingof1-ph parallelinverter withaneat diagram.(W-19)

CHAPTER-4

UNDERSTANDAPPLICATIONSOFPOWERELECTRONICCIRCUITS

LearningObjectives:

Listapplicationsofpowerelectroniccircuits.
Listthefactorsaffectingthespeedof DCMotors.
Speedcontrol forDC Shuntmotor using converter.
Speedcontrol forDC Shuntmotor using chopper.
Listthefactorsaffectingspeedofthe ACMotors.
Speedcontrolof Induction Motorbyusing ACvoltageregulator.
Speedcontrol of inductionmotorbyusingconvertersand inverters(V/F control).
WorkingofUPS withblock diagram.
BatterychargercircuitusingSCRwith thehelp ofa diagram.
BasicSwitched modepower supply(SMPS) -explain its working& applications

Listapplicationsofpowerelectroniccircuits:

Theapplicationofpowerelectronicscircuitsare:

- Aerospace
- Commercial
- Industrial
- Residential
- Telecommunication
- Transportation
- ElectricDrive

ListthefactorsaffectingthespeedofDCMotors.

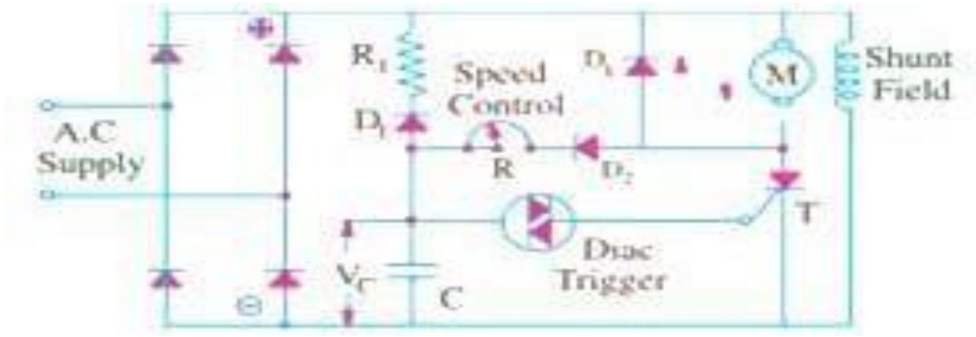
- The operation of a DC motor is typicallydesigned such that when a current carryingconductor isplacedwithinamagneticfield,thereisboundtobethemechanical forcethat goes throughthe conductors.
- ThefactorsaffectingDC controlare:
  1. Theappliedvoltage.
  2. Theflux.
  3. Thevoltageacrossanarmature.

  Consideringthesefactors,speedcontrolcanthenbeachievedthroughthefollowingtechniques:

  i. Flux controlmethod:Thisisdonebyvaryingthecurrentviathefieldwinding,thus altering the flux.
  ii. Rheostaticcontrol:changingthearmaturerouteresistancewhichalsochangestheapplied voltage across the armature.
  iii. Voltagemethod:changingtheapplied voltage

SpeedcontrolforDCShuntmotorusingconverter:

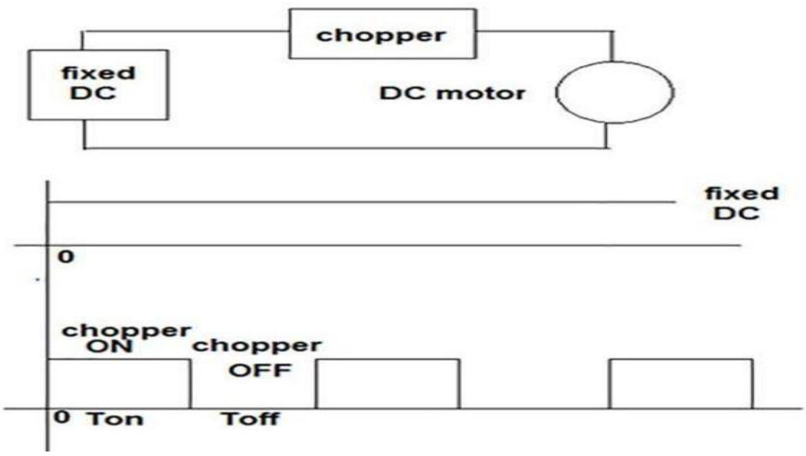
- Thecircuituses abridge circuitforfull-wave rectificationofthea.c.supply.
- Theshuntfieldwindingispermanentlyconnectedacrossthe outputofthebridgecircuit.The armature voltage is supplied through thyristor*T*.



- ThemagnitudeofthisvoltagecanbechangedbyturningT_{ON}atdifferentpointsineachhalf- cycle with the help of *R*.
- Free-wheelingdiodeD3 providesacirculatingcurrentpathfortheenergystoredinthe armature winding at the time *T* turns OFF.
- At the beginning of each half-cycle, *T* is the OFF state and *C* starts charging up via motor armature,diodeD2andspeed-controlvariable resistor*R*.Whenvoltageacross *Ci.e.,VC*builds up to the breakover voltage of diac, diac conducts and applies a sudden pulse to *T* there by turning it ON.
- Hence,poweris supplied to themotorarmatureinnextthat half-cycle.
- At the end of each half-cycle, *C* is discharged through *D*1, *R*1 and shunt field winding. The delayangleadependson thetimeittakes *VC*tobecome equal to thebreakovervoltageofthe diac.
- Bychanging*R*,*VC* canbemadetobuild-upeither slowlyorquicklyand thuschangethe angle. In this way, the average value of the d.c. voltage across the motor armature can be controlled.
- Itfurtherhelpstocontrolthemotorspeedbecauseitisdirectlyproportional to thearmature voltage.
- Now,whenload isincreased, motortends toslow down.Hence,*Eb*is reduced.
- Thevoltageofpoint *A*isincreasedbecauseitisequaltothed.c.outputvoltageofthebridge rectifier.

SpeedcontrolforDCShuntmotorusingchopper:

- chopperisadevicethatgivesvariableDCoutputfromappliedfixedDC input.
- ItsimplychopsfixedDCandgeneratesvariable DC.



- Asshownin figurethe choppersupplies fixedDC voltageto motor.
- WhenchopperisONmotorgetssupplybutwhenchopperisoffmotordoesnotgetthesupply. So chopper is on for Ton time and it is off for T_{off}time, depending upon the T_{on} and T_{off} time the DC voltage applied to motor is

$$Vdc=[T_{on} /(T_{on}+T_{off})]\times V_{fixed}$$

But $$T_{on}+T_{off}=T_{total}$$

$$Vdc=[T_{on}/T_{total}]\times V_{fixed}$$

- HereT_{on} /T_{total}iscalleddutycycle.SoasdutycycleismoretheaverageDCvoltagesuppliedto motor is more and so speed of motor is increased. So as dutycycle is varied byvarying on and off time of chopper, the speed of motor can be varied.

ListthefactorsaffectingspeedoftheACMotors:

ThefactorsaffectingspeedoftheACMotorsareaffectedbyvariousfactorslikeappliedvoltage,R2'and frequency.

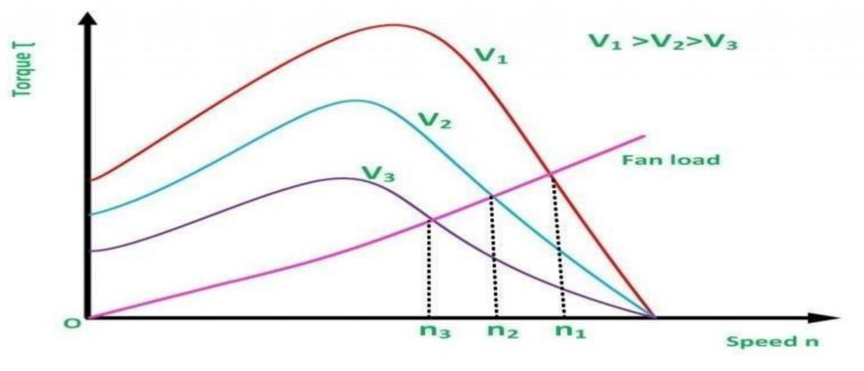
(a) Appliedvoltage:WeknowthatT αV.Thusnot onlythestationarytorquebut alsothetorqueunderrunning conditions changes with change in supply voltage.

(b) Supplyfrequency :Themajoreffect ofchangeinsupplyfrequencyisonmotorspeed.Thestartingtorqueis reduced with increase in frequency.

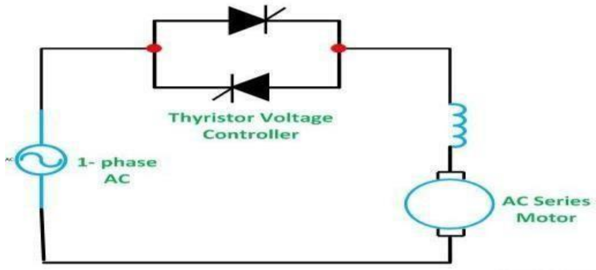
(c) Rotor resistance : The maximum torque produced does not depend on R2'. However, with increase in R2', thestartingtorqueincreases.Theslipat whichTmaxisreachedincreasestoowhichmeansthatTmaxisobtained at lower motor speeds

SpeedcontrolofInductionMotorbyusingACvoltageregulator:

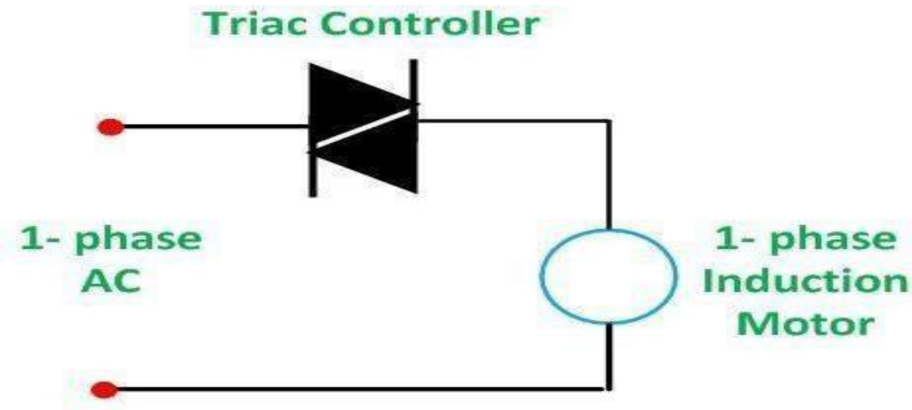
- StatorVoltageControlisamethodused tocontrolthe speedof anInductionMotor**.**
- Thespeed ofathreephaseinductionmotor can bevaried byvaryingthesupplyvoltage.
- TheTorque-SpeedCharacteristicsofthethreephaseInductionmotorsforvaryingsupply voltage and also for the fan load are shown below.



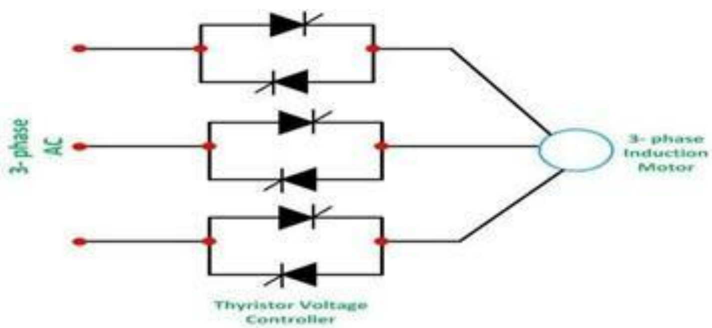
- TheThyristorvoltagecontrollermethodispreferredforvaryingthevoltage.
- Forasinglephasesupply,twoThyristors areconnectedbacktoback asshowninthefigure below.



- Thedomesticfanmotors,whicharesinglephasearecontrolledbyasinglephase TriacVoltage Controller as shown in the figure below.



- Speedcontrolisobtainedbyvaryingthefiringangleofthe Triac.These controllersareknown as Solid State fan regulators.
- Asthesolidstateregulatorsaremorecompactandefficient ascomparedtotheconventional variable regulator. Thus, they are preferred over the normal regulator.
- In caseofathreephaseinduction,motorthreepairsofThyristorarerequiredwhichare connected back to back.
- Eachpair consistsoftwoThyristor.
- ThediagrambelowshowstheStatorVoltageControlofthethreephaseinductionmotorsby Thyristor Voltage Controller.



- Eachpair oftheThyristor controlsthevoltageof thephaseto whichit isconnected.
- Speedcontrol isobtainedbyvaryingthe conductionperiod oftheThyristor.
- Forlowerpowerratings,thebacktobackThyristorpairsconnectedineachphase isreplacedby Traic.

Speedcontrolofinductionmotorbyusingconvertersandinverters (V/F control).

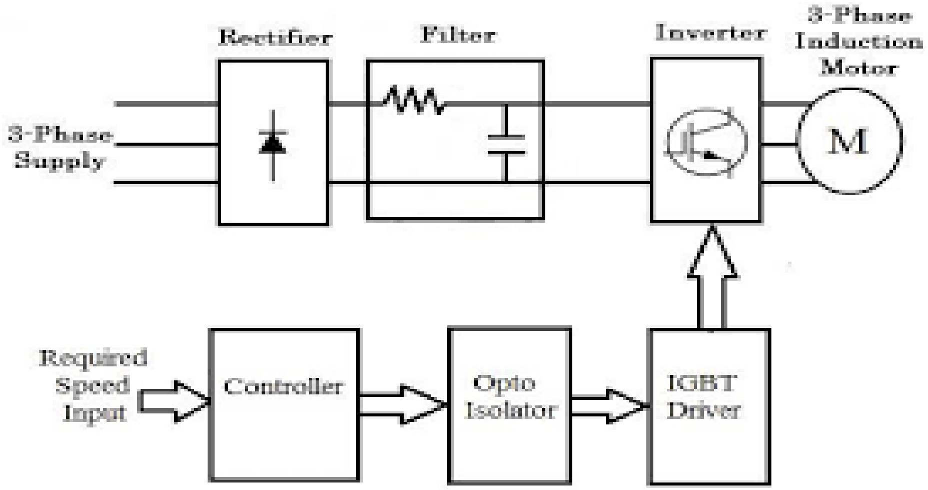
- VariableFrequencyControlisamethodwhichisusedtocontrolthespeed ofaninduction motor.
- Thesynchronousspeedandtherefore,thespeedofthe motorcanbecontrolledbyvaryingthe supply frequency.
- Thesynchronous speedof aninduction motorisgiven bytherelation shownbelow.

$$N_s = \frac{120f}{P}$$

- TheEMFinducedin thestatorofthe inductionmotoris givenbytheequationshown below.

$$E_1 = 4.44 k_{w1} T_1$$

- Therefore,ifthesupplyfrequencyis changedinducedEMFwillalsochangetomaintainthe same air gap flux.
- TheterminalvoltageV$_1$ isequal totheinducedEMFE$_1$ ifthestatorvoltagedropisneglected.
- Inordertominimizethelossesandtoavoidthesaturation,themotoris operatedatratedair gap flux.Thisconditionisobtainedbyvaryingthe terminalvoltagewithfrequencysoastomaintain (V/f) ratio constant at therate value.
- Thistypeof controlis knownasConstant VoltsPer Hertz.
- Thus,thespeedcontrolofaninductionmotorusingvariablefrequencysupplyrequiresa variable voltage power source.
- Thevariable frequencysupplyisobtainedbythefollowing converters.
    1. Voltagesourceinverter.
    2. Currentsourceinverter.
    3. Cycloconverter



- AninverterconvertsafixedvoltageDCtoafixedorvariablevoltageACwithvariable frequency.
- Cycloconverterconvertsafixedvoltageandfixed frequencyACto avariablevoltageandvariableAC frequency.
- Thevariablefrequencycontrolallowsgoodrunningandtransientperformancetobeobtainedfromacage induction motor.
- Cycloconvertercontrolledinductionmotordriveissuitableonlyforlargepowerdrivesandtogetlower speeds.

WorkingofUPSwithblockdiagram:

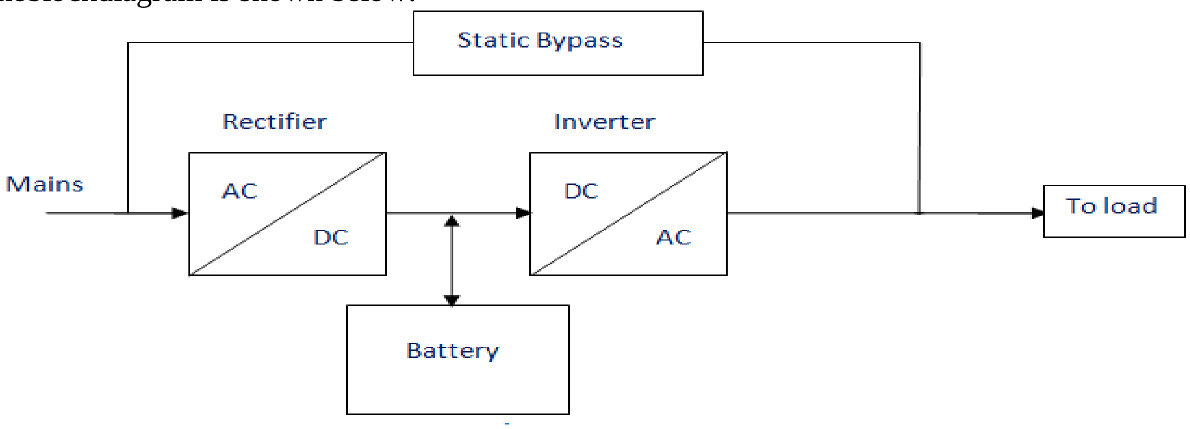
- TheUPSstandsstands foruninterruptiblepower source.
- Itisanelectricaldevice, givesemergencypowertovariousloadswhenthe input powertypically fails.

UPSaremainlytwotypes

1. OnlineUPS(uninterruptiblepowersupply).
2. OfflineUPS(uninterruptiblepowersupply).

1.On-lineUPS :

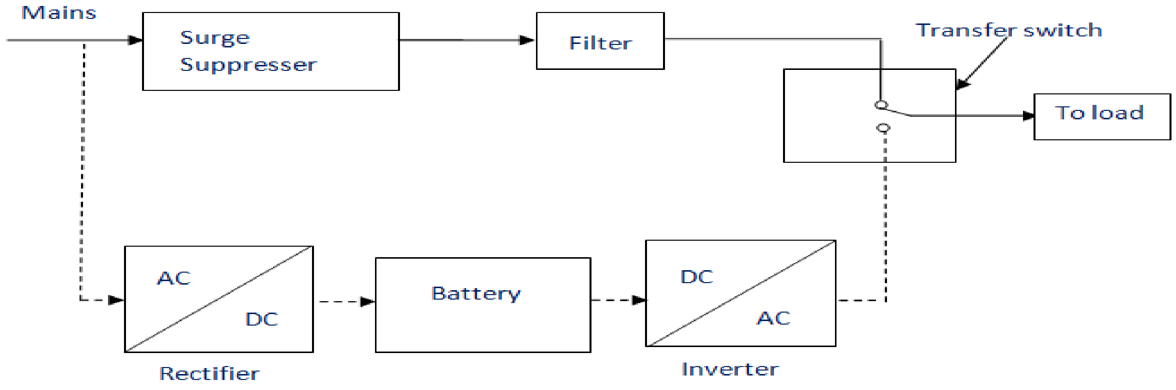
- Inthistypeof UPS,double conversionmethodisused.
- Here, first the AC input is converted into DC by rectifying process for storing it in the rechargeablebattery.ThisDCis convertedintoACbytheprocessofinversionandgivento the load or equipment which it is connected.
- Thistypeof UPS is used whereelectricalisolationis mandatory.
- Here,therectifierwhichispowered withthenormalACcurrentisdirectlydrivingtheinverter. Hence it is also known as Double conversion UPS.
- Theblockdiagram is shown below.



- When there is any power failure, the rectifier have no role in the circuit and the steady power storedinthebatterieswhichisconnectedtotheinverteris giventotheloadbymeansoftransfer switch.
- Oncethepowerisrestored,therectifier beginstochargethebatteries.Topreventthe batteries from overheating due to the high power rectifier, the charging current is limited.

Off-lineUPS:

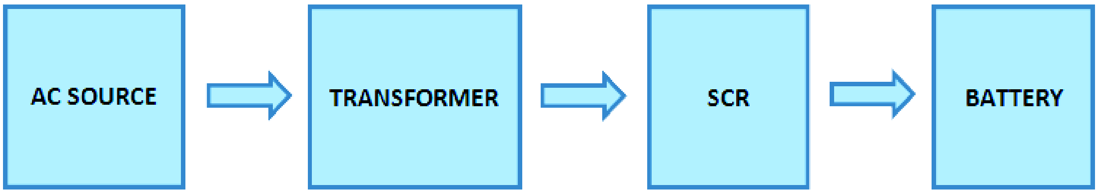
- TheOff -lineUPS is alsocalled asStandbyUPS system .
- The blockdiagramis shownbelow.



- Here,theprimarysourceisthefilteredACmains.Whenthepowerbreakageoccurs,thetransfer switch will select the backup source .Thus the stand by system will start working only when there is anyfailure in mains.
- Inthissystem,theACvoltageisfirstrectified andstoredinthestoragebatteryconnectedto the rectifier.
- Whenpowerbreakageoccurs,thisDCvoltageisconvertedtoACvoltagebymeansofapowerinverter, and is transferred to the load connected to it.
- Thisistheleast expensiveUPS system anditprovides surgeprotectionin additiontobackup.

BatterychargercircuitusingSCRwiththehelpofadiagram:

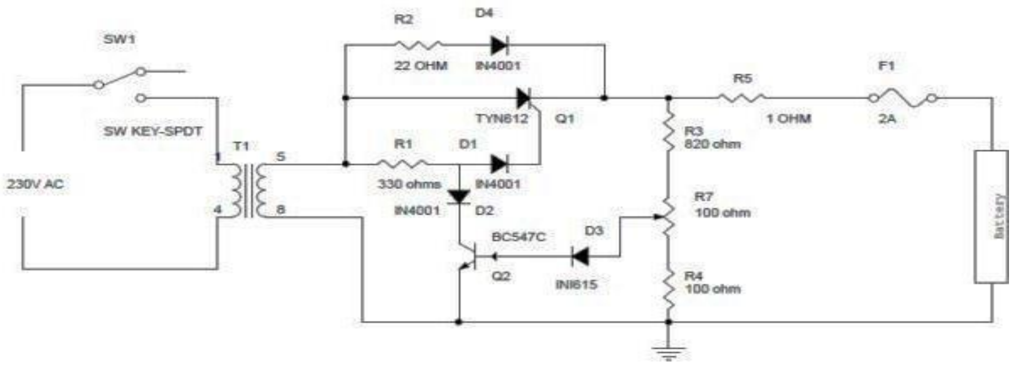
- The battery is charged with small amount of DC voltage. So to charge the battery with AC sourcesomestepsshould follow,firstlimitthe large ACvoltage,needto filtertheACvoltage toremovethenoise,regulateand gettheconstant voltageandthengivetheresultingvoltageto the battery for charging.
- Oncechargingis completed thecircuit should automaticallyturned off.
- BlockDiagramofBatteryChargerUsingSCRisdrawn below:



- TheACsourceis giventothestepdowntransformerwhichconvertsthe large ACsourceinto limitedACsource,filtertheACvoltageandremovethenoiseandthengivethatvoltagetothe SCR where it will rectify the AC and give the resulting voltage to the battery for charging.

CircuitDiagram:

Thecircuit diagramoftheBatteryCharger CircuitusingSCRcanbeseenbelow :

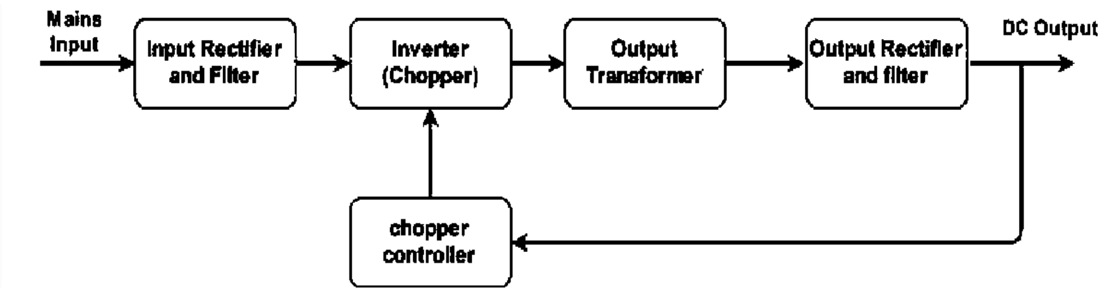


- TheACmainvoltageisgiventothestepdowntransformerthevoltageshould be down to 20V approx. the step down voltage is given to the SCR for rectification and SCR rectifies AC main voltage. This rectified voltage is used to charge battery.
- When the batteryconnecterto the chargingcircuit, the batterywill not be dead completelyand it will get discharged this will give the forward bias voltage to the transistor through the diode D2 and resistor R7 whichwill get turned on. When the transistor is turned on the SCR will get off.

- Whenthebatteryvoltageisdroppedtheforwardbiaswillbedecreased andtransistor gets turned off. When the transistor is turned off automatically the diode D1 and resistor R3 will get the currenttothe gateof the SCR, this will triggers the SCR and gets conduct. SCR will rectifies the AC input voltage and give to the battery through Resistor R6.
- This will charge the battery when the voltage drop in the battery decreases the forward bias current also gets increasedtothetransistor whenthebatteryiscompletelycharged theTransistor Q1 will be again turned on and turned off the SCR.

BasicSwitchedmodepowersupply(SMPS) - explainitsworking&applications:

- A switched-mode power supply (SMPS) is an electronic circuit that converts power using switchingdevicesthatareturnedonandoffathighfrequencies, andstoragecomponentssuchas inductors or capacitors to supplypower whenthe switching device is inits non-conductionstate.
- AbasicisolatedACtoDCswitched-modepower supplyconsistsof:
  1. Inputrectifierandfilter.
  2. InverterconsistingofswitchingdevicessuchasMOSFETs.
  3. Transformer.
  4. Outputrectifierandfilter.
  5. Feedbackandcontrolcircuit



- TheinputDCsupplyfromarectifierorbatteryisfedtotheinverterwhereitisturnedonandoff at high frequencies of between 20 KHz and 200 KHz by the switching MOSFET or power transistors.
- Thehigh-frequencyvoltagepulses fromtheinverter arefedto thetransformerprimarywinding, and the secondary AC output is rectified and smoothed to produce the required DC voltages.
- Afeedbackcircuitmonitorstheoutputvoltageandinstructsthecontrolcircuittoadjusttheduty cycle to maintain the output at the desiredlevel.

ApplicationofSMPS:

1. Machinetoolindustries
2. SecuritySystems(Closedcircuitcameras)
3. SupportsupplieswithPLC’s
4. PersonalComputers.
5. MobilePhone chargers.

ShortQuestionswithAnswer:

Whatarettheapplicationsof powerelectronics circuits?

Ans-Theapplicationofpowerelectronicscircuitsare:

- Aerospace
- Commercial
- Industrial
- Residential
- Telecommunication
- Transportation
- ElectricDrive

Whatarethefactors affectingspeedof DCmotor?

Ans-ThefactorsaffectingDCcontrolare:

1. Theappliedvoltage.
2. Theflux.
3. Thevoltageacrossanarmature

WhatisSMPS&Whyitispreferredin comparisontolinearregulator?(W-10,14.20)

Ans-SMPSmeansSwitchmodepowersupply. Formediumtohighpowerapplicationand alsoforthe power supply of computers, it is essential. It has low power dissipation, high efficiency, small size and low weight in comparison to linear regulator

WhatistheutilityofUPS?(S-09)

Ans-TheutilityofUPSare

i. Inmedicalintensivecaresystems
ii. Chemicalplantprocess control
iii. Safetymonitors ormajorcomputer installation

Whataretheusesofno-breakUPS?(W-19) Ans-

Uses of no break UPS-

1. Inductionmotor drive
2. ICUmedical equipment
3. Chemicalplant process
4. Control,safetymonitor
5. Majorcomputerinstallationscommunicationlinks
6. Microwaverelaystation

Longquestions:

1. **Explainwithneatsketch theoperationofUPS.(S-07,09,W-16,17)**
2. **Whatarethedifference betweenonlineUPSandofflineUPS?(W-16)**
3. **ExplainSpeedcontrolofinductionmotorbyusingconvertersandinverters.**
4. **ExplainSpeedcontrolof InductionMotorbyusingACvoltageregulator.**
5. **ExplaintheworkingandapplicationofSMPS.**

CHAPTER-5
PLCANDITSAPPLICATIONS

LearningObjectives:

IntroductionofProgrammableLogicController(PLC)
AdvantagesofPLC
Differentparts ofPLC bydrawingtheBlockdiagram andpurposeof eachpart of PLC.
ApplicationsofPLC
Ladderdiagram
Descriptionofcontactsandcoils inthefollowingstates
i)Normallyopen ii) Normallyclosed iii)Energized output iv)latched Output v) branching
Ladderdiagramsfori)ANDgateii)ORgateandiii)NOTgate.
Ladderdiagramsfor combinationcircuitsusingNAND,NOR,AND,ORandNOT
Timers-i)TONii)TOFFandiii)Retentivetimer
Counters-CTU,CTD
LadderdiagramsusingTimersand counters
PLCInstructionset
Ladderdiagramsforfollowing
(i)DOLstarterandSTAR-DELTAstarter(ii)Staircaselighting(iii)Trafficlight Control (iv)Temperature Controller
Specialcontrolsystems-BasicsDCS &SCADA systems
ComputerControl–DataAcquisition,DirectDigitalControlSystem(Basicsonly)

IntroductionofProgrammableLogicController(PLC):

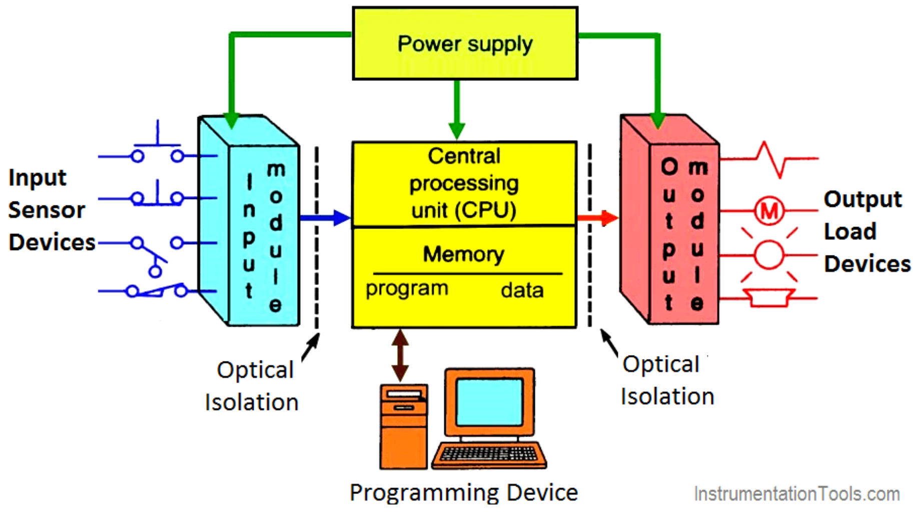
- PLCstandsforProgrammableLogicControllers.
- Itis basicallyusedtocontrol automatedsystems in industries.
- Itisoneofthemostadvancedandsimplestformsofcontrolsystemswhicharenowreplacing hard-wired logic relays at a large scale.

AdvantagesofPLC:

- Theyareuserfriendlyandeasytooperate.
- Theyeliminate the need forhard-wiredrelaylogic.
- Theyarefast.
- Itissuitableforautomationinindustries.
- Itsinputandoutputmodules canbe extendeddependingupon therequirements.

DifferentpartsofPLC bydrawingtheBlockdiagramandpurposeof each part ofPLC :

AbasicPLCsystemconsistsofthefollowingsections:



Input/OutputSection:

- Theinput sectionorinput moduleconsistsofdevices likesensors,switches,andmanyother real-world inputsources.
- Theinputfrom thesourcesis connectedto thePLCthroughtheinputconnectorrails.
- Theoutputsectionoroutputmodulecanbeamotor orasolenoidoralamporaheater,whose functioning is controlled by varying the input signals.

CPUorCentralProcessingUnit:

- ItisthebrainofthePLC.
- Itcanbe ahexagonaloranoctalmicroprocessor.
- It carries out all the processingrelatedtotheinputsignalsinordertocontroltheoutputsignals based on the control program.

ProgrammingDevice:

- Itistheplatformwheretheprogramor thecontrollogiciswritten.
- Itcanbeahandhelddeviceoralaptoporacomputer itself.

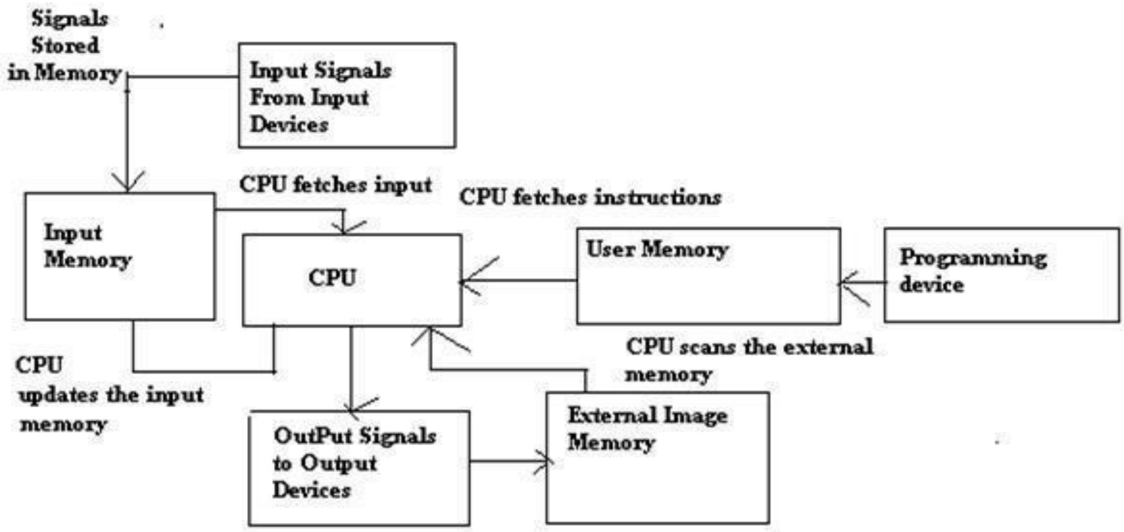
PowerSupply:

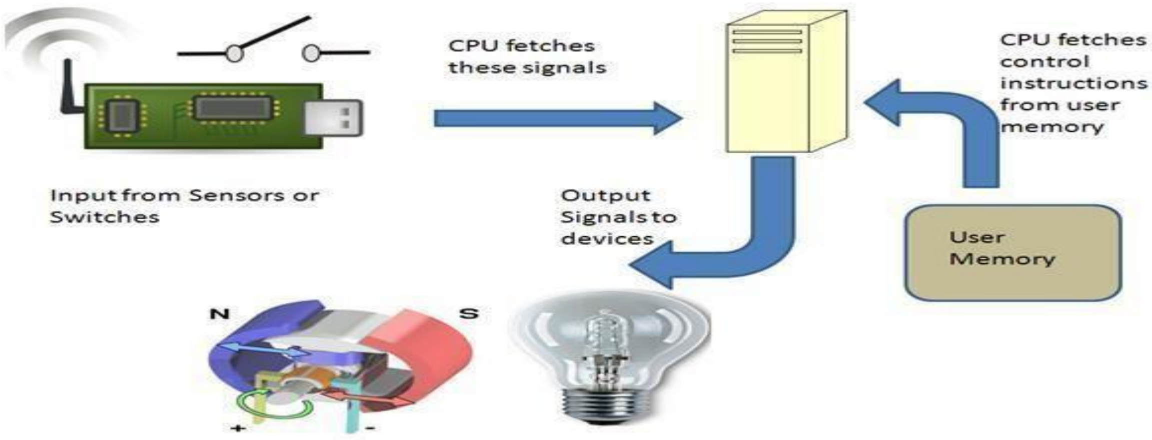
- Itgenerallyworks on apower supplyof about24V, used topowerinputand outputdevices.

Memory:

- Thememoryis divided into two parts-Thedatamemoryand theprogrammemory.
- Theprograminformationorthecontrollogicisstoredin theusermemoryortheprogram memory from where the CPU fetches the program instructions.
- Theinputand outputsignalsandthetimerand countersignalsarestoredintheinputandoutput external image memory respectively.

WorkingofaPLC:





- The input sources convert the real-time analog electric signals to suitable digital electric signals and these signals are applied to the PLC through the connector rails.
- TheseinputsignalsarestoredinthePLCexternalimagememoryinlocationsknownasbits. This is done by the CPU
- The control logic or the program instructions are written onto the programming device through symbols or through mnemonics and stored in the user memory.
- TheCPUfetchestheseinstructionsfromtheusermemoryandexecutestheinputsignalsby manipulating, computing, processing them to control the output devices.
- The executionresultsare thenstoredintheexternalimagememory whichcontrolsthe output drives.
- The CPU also keeps a check on the output signals and keeps updating the contents of the input image memory according to the changes in the outputmemory.
- The CPUalsoperformsinternalprogrammingfunctionslike setting andresetting of the timer, checking the user memory.

5.4.Applicationofprogrammablelogiccontroller(PLC):

Therearesomeapplicationsofprogrammablelogiccontroller(PLC).

- Itisusedincivilapplicationssuchaswashingmachine,elevators workingandtrafficsignals control.
- ItisusedinaerospaceforWatertankquenchingsystem.
- Itisusedtoreducingthehumancontrolallocationofhumansequencegivento thetechnical equipment’s that is called Automation**.**
- Itisusedinbatchprocessinchemical,cement,foodandpaperindustriesaresequentialinnature, requiring time or event-based decisions.
- Itisusedintheburnermanagementsystemtocontroltheprocessof purging,pilotlightoff, flame safety checks, main burner light off and valve switching for change over of fuels.
- ItisusedinprintingindustryformultistagescreenwashingsystemandOffsetwebpressprint register control system.
- Itisusedintravelindustryforescalatoroperation,monitoredsafetycontrolsystem.

Ladderdiagram:

- Aladderdiagramisatypeofschematicdiagram usedinindustrialautomationthatrepresents logic control circuits.
- Ladderdiagramsarecomposedoftwoverticalpowerrailsandhorizontallogicrungstoform what looks like a ladder.
- Thecontrollogicin aladderdiagramiscontainedwithin therungs.
- Ladderdiagramsactuallylooklikealadderandaremorecommonlyknownasladderlogic programming.

ProceduretoDrawLadderLogicDiagrams:

- Therailsinaladderdiagramrepresent thesupplywiresofarelaylogiccontrolcircuit.
- Thereisapositivevoltagesupplyrailonthelefthandsideandazero voltagerailontheright hand side.
- In aladderdiagramthelogicflow isfromthelefthandrailtotherighthandrail.
- Therungsinaladderdiagramrepresentthewires thatconnectthe componentsofarelaycontrol circuit.
- In aladderdiagramsymbolsareusedtorepresenttherelaycomponents.Thesymbolsareplaced in the rung to form anetwork of logic expressions.

Tounderstanddrawladderlogicdiagramsthesevenbasicpartsofaladderdiagramaredetailedbelow:

1. **Rails**– Therearetwo railsin a ladderdiagram which aredrawnasvertical lines.

2. **Rungs**– Therungsaredrawn as horizontallines andconnect therails tothelogicexpressions.

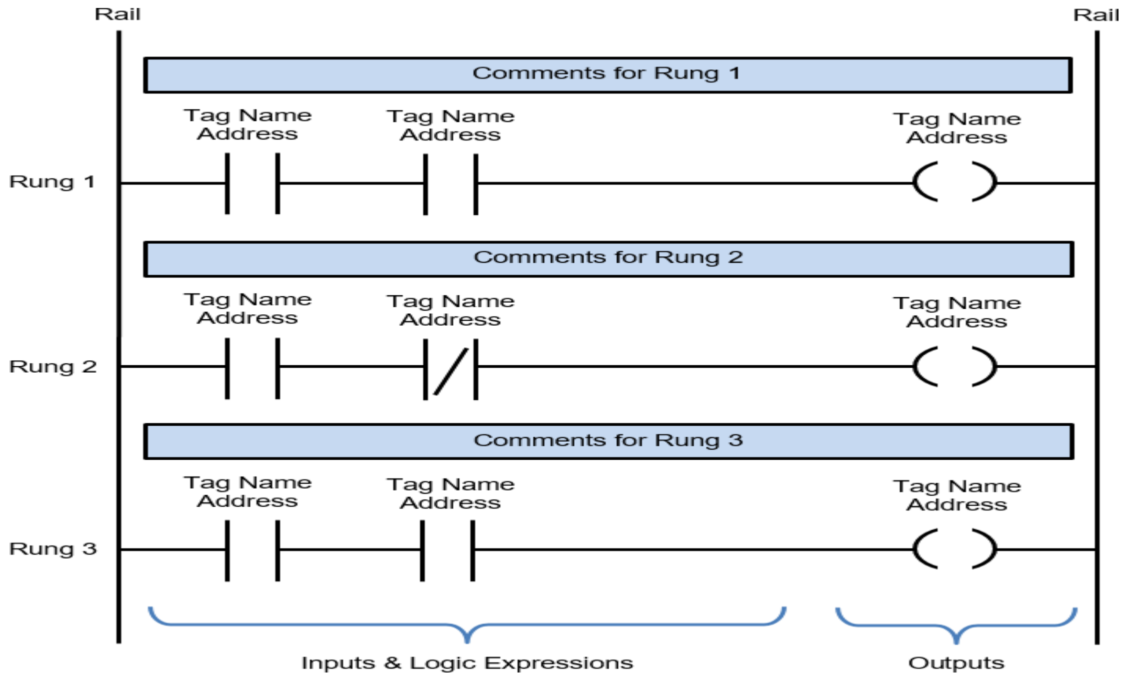
3. **Inputs** – The inputs are external control actions such as a push button being pressed or a limit switchbeingtriggered.TheinputsareactuallyhardwiredtothePLCterminalsandrepresentedin the ladder diagramby a normally open (NO) or normally closed (NC) contact symbol.

4. **Outputs** – The outputs are external devices that being are turned on andoff such as an electric motor or a solenoid valve. The outputs are also hardwired to the PLC terminals and are represented in the ladder diagram by a relay coil symbol.

5. **Logic Expressions** – The logic expressions are used in combination withthe inputs and outputs to formulate the desired control operations.

6. **Address Notation & Tag Names** – The address notation describes the input, output and logic expression memory addressingstructureof thePLC. Thetagnamesarethe descriptions allocated to the addresses.

7. **Comments** -Comments are displayed at the start of each rung and are used to describe the logical expressions and control operations that therung, or groups of rungs, are executing. Understanding ladder diagramsis made a lot easier by using comments.



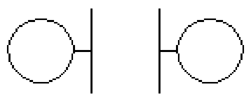
HowtoReadLadderLogic:

1or0
True or FalseOn orOff High orLow Yesor No

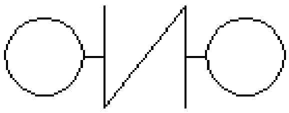
Descriptionofcontactsandcoilsinthefollowingstates i)Normallyopenii)Normallyclosediii)Energizedoutputiv)latched Output v) branching

Closed=Currentflow
Open=Nocurrentflow

I. **Normally open**- Is acontactthatdoesnot flowcurrentinitsnormalstate.Energizingit and switching it on will close the contact, causing it to allow current flow.



II. **Normallyclosed**-Isacontactthatflowscurrentinitsnormalstate.Energizingitand switching it on will open the contact, causing it to not allow current flow.



III. **Energized output**: The OTE, also known as Output Energize, instruction will energize a single bit of data if the input leading to it is true. It's a fundamental instruction used in Programmable Logic Controllers (PLCs). If the same instructions evaluate to false, the OTE instruction will set the specified bit to a LOW state.

IV. **latched Output:**Output Latch is a Flip Flop that is Set or Cleared, to control and keep the Output state of each Pin. Output Latches are organized into a register, with one bit for each pin of a Port. The register will be written when addressed by the peripheral address and data bus.

V. **Branching:**Branching simply means adding more rungs that are associated with the same output, or having multiple outputs for the same inputs. We can also have a combination of both, like having multiple inputs and multiple outputs for each rung, all depending on the logic and how to solve the program. .

Ladderdiagramsfori)ANDgateii)ORgateandiii)NOTgate:

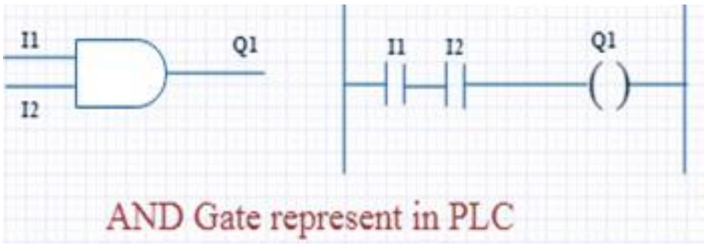
i)AND gate:

- In AND Gate, when both inputs (I1 andI2) are high then the output (Q1) will be high.For allother inputs, output (Q1) will be the low.

Input (I1)	Input (I2)	Output (Q1)
0	0	0
0	1	0
1	0	0
1	1	1

ANDGateinPLC programming:

- UsingLadderdiagramprogramming,weareconnectingtwoswitches(I1andI2)asinput and coil/lamp (Q1) as output.
- Inthe caseofboth switches(I1andI2)areclosed,thelamp(Q1)willglow.
- Inanothercase,if anyof theswitches(I1 or I2) areopenthenlamp(Q1)willnot glow.
- SymbolicRepresentationas,



ii) ORgate:

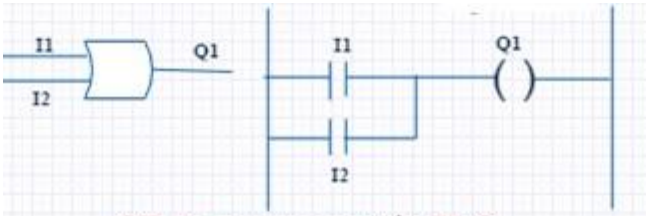
- IfbothinputsarelowintheORgate,thentheoutputwillbelow.Forallothercases,theoutput will be high.

LogicGateTruthTableforORGate:

Input (I1)	Input (I2)	Output (Q1)
0	0	0
0	1	1
1	0	1
1	1	1

ORGateinPLC programming:

- Incasebothoranyoneinputs(I1andI2) areclosedthencoil(Q1)willon.
- SymbolicRepresentationas,



OR Gate represent in PLC

iii) NOTgate:

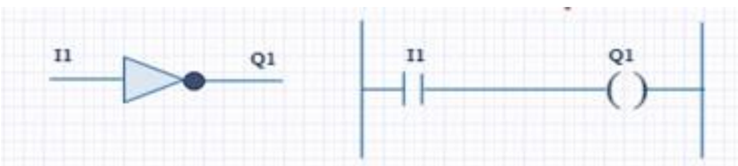
- NOTgateworksasinversion.Ittakesoneinputandgivesoneoutput.Whentheinputishigh then the output is low and vice-versa.

LogicGateTruthTableforNOT Gate:

Input (I1)	Output (Q1)
0	1
1	0

NOTGateinPLC programming:

- In thecaseofPLC ladder,therewillbeapush buttontoprovideinput.When(I1)ispressedthen the coil (Q1) is on. And when Input (I1) is released then coil(Q1 is off.
- SymbolicRepresentation.



NOT Gate represent in PLC

Ladderdiagramsforcombinationcircuitsusing NAND,NOR,AND,OR and NOT

1.NANDGate:

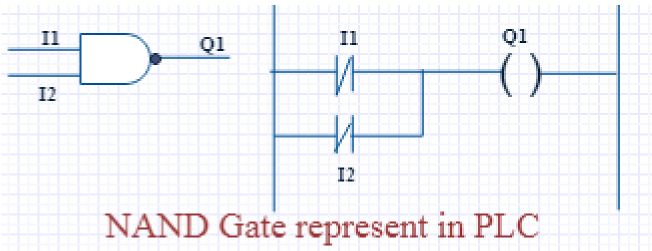
- In NANDGate,theoutputwillbelowwhenbothinputsarehigh. Forallothercases,theoutput will be high.

LogicGateTruthTable forNANDGate:

Input (I1)	Input (I2)	Output (Q1)
0	0	1
0	1	1
1	0	1
1	1	0

NANDGateinPLCprogramming:

- Ifbothswitches(I1 and I2)oranyoneswitch(I1orI2)areclosed,thelamp willbeglow. Inthe case, both switches are open then the lamp will not be glow.
- SymbolicRepresentationas,



ii.NORGATE:

- NORGateis operatedORGate followed bythe NOT Gate.
- Whenbothinputsarelowthentheoutputwillbehigh.Otherwise,thelow outputwilloccur if both inputs are high.

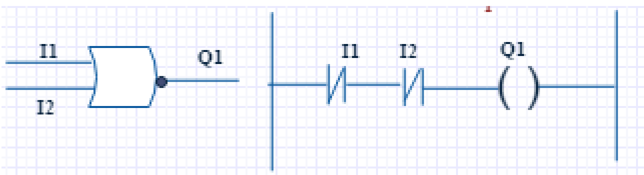
LogicGateTruth TableforNORGate:

Input (I1)	Input (I2)	Output (Q1)
0	0	1
0	1	0
1	0	0
1	1	0

NORGateinPLC programming:

- TheCoil(Q1)willbeactivatedifbothinputsareclosed.Coil(Q1)willbe deactivatedifanyone or both the inputs are open.

- SymbolicRepresentationas,



NOR Gate represent in PLC

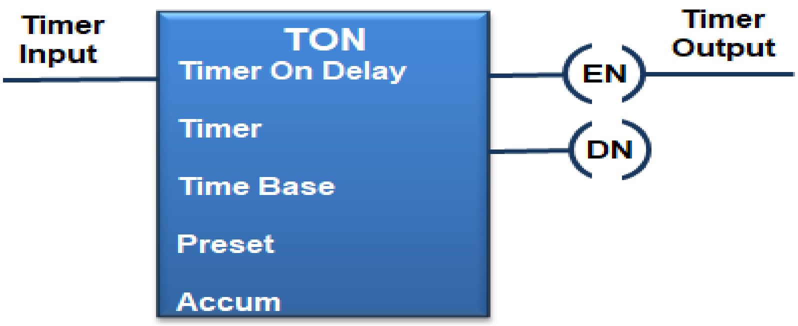
Timers-i)TONii)TOFFandiii)Retentivetimer:

Forladderdiagramprogramminglanguages,thethreedifferenttypesofPLCtimerinstructionareused. These three timers are,

1. OnTimer(Ton)
2. OffTimer (Toff)
3. RetentiveOn-OffTimer (RTO).

1. OnTimer(Ton)

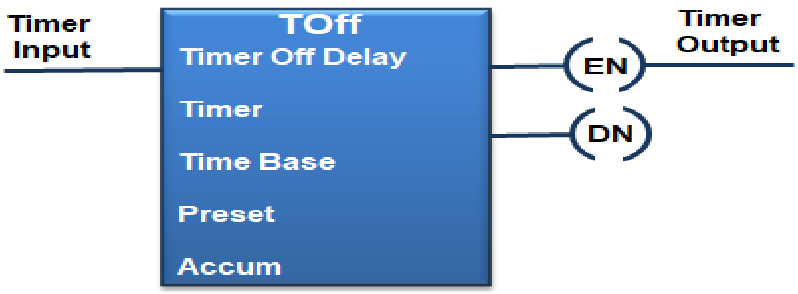
- Toniscalled 'OnDelay Timer'.
- Anon-delaytimer(T_{on})isaprogramminginstructionwhichusetostartmomentarypulsesfora set period of time.



On Delay PLC Timer

2. OffTimer(Toff):

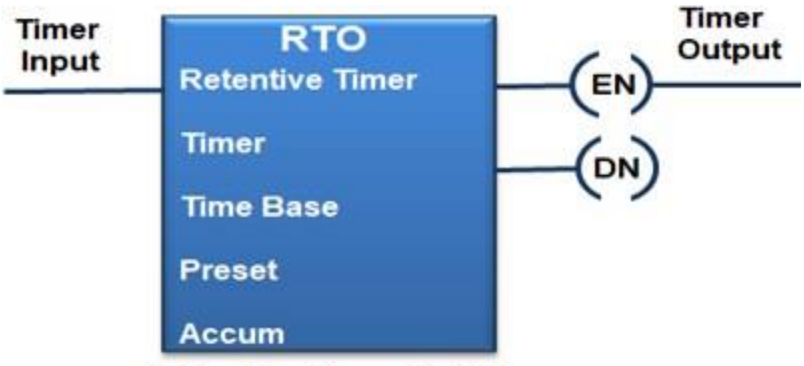
- TOFFisalso knownasan'Off-DelayTimer'.
- Aoff-delay(TOF)timerisaPLCprogramminginstructionwhichusetoswitchofftheoutputor system after a certain amount of time.



Off Delay PLC Timer

3. RetentiveTimerOn/Off(RTO)

- Themain functionofthe RTO isused tohold orstoretheset (accumulated)time.
- RTOisusedinthecasewhenthereis achangein therungstate,powerloss,oranyinterruption in the system.



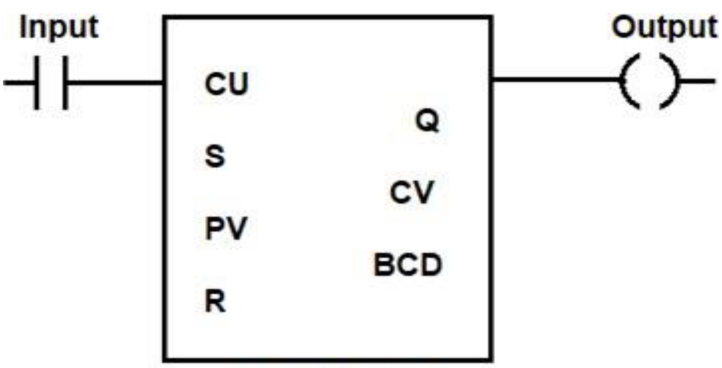
Retentive Timer On/Off

Counters-CTU,CTD:

- Itisdefineasthecounterin PLCprogrammingas…"aninstructionwhichisusefulforsequential countingas digital signal pulse or the number of digits." This instruction is denoted by the 'C' in LD programming.
- CountersinPLCareclassifiedintothreemaindifferentparts.
  1. UpCounter(operatesup mode).
  2. DownCounter(operatedindown mode).
  3. Up/DownCounter(operatesinbidirectionalandquadraturemode)

1.Up Counter:

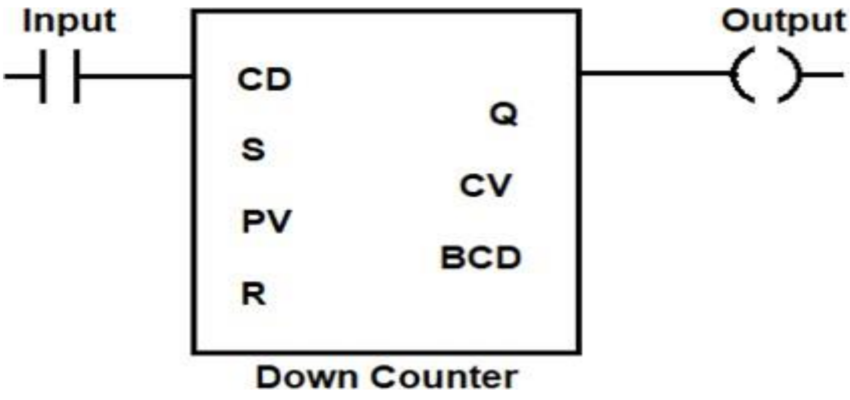
- Upcountercountsfrom zerotothepreset value.Basically,itincreases the pulseornumber.
- Upcounterisknown asthe'CTU'or 'CNT'or 'CC'or 'CTR'.
- Upcounterfunctionblockdiagramisdrawnbelow::



Up Counter

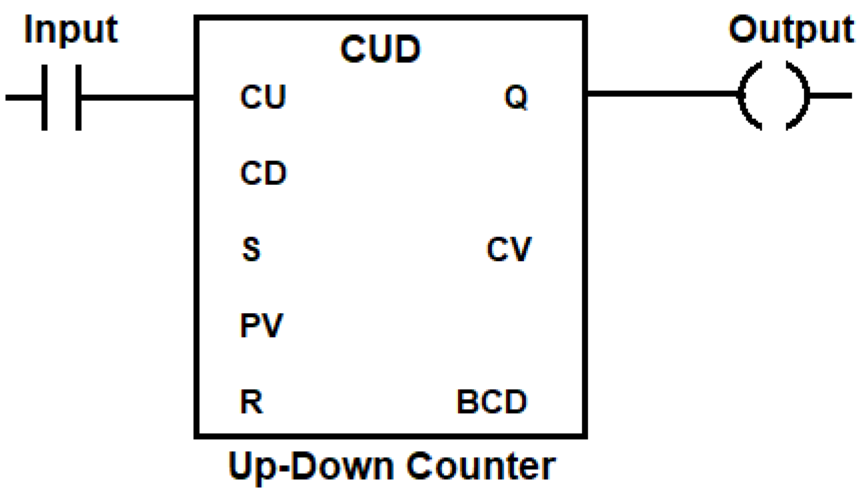
2. Down Counter:

- Thedowncountercountsfrom thepresetvaluetozero. It decreasesthepulseor number.
- Downcounterisshortlyknown asthe'CTD' or 'CD'.
- Downcounter functionblockdiagramisdrawnbelow:

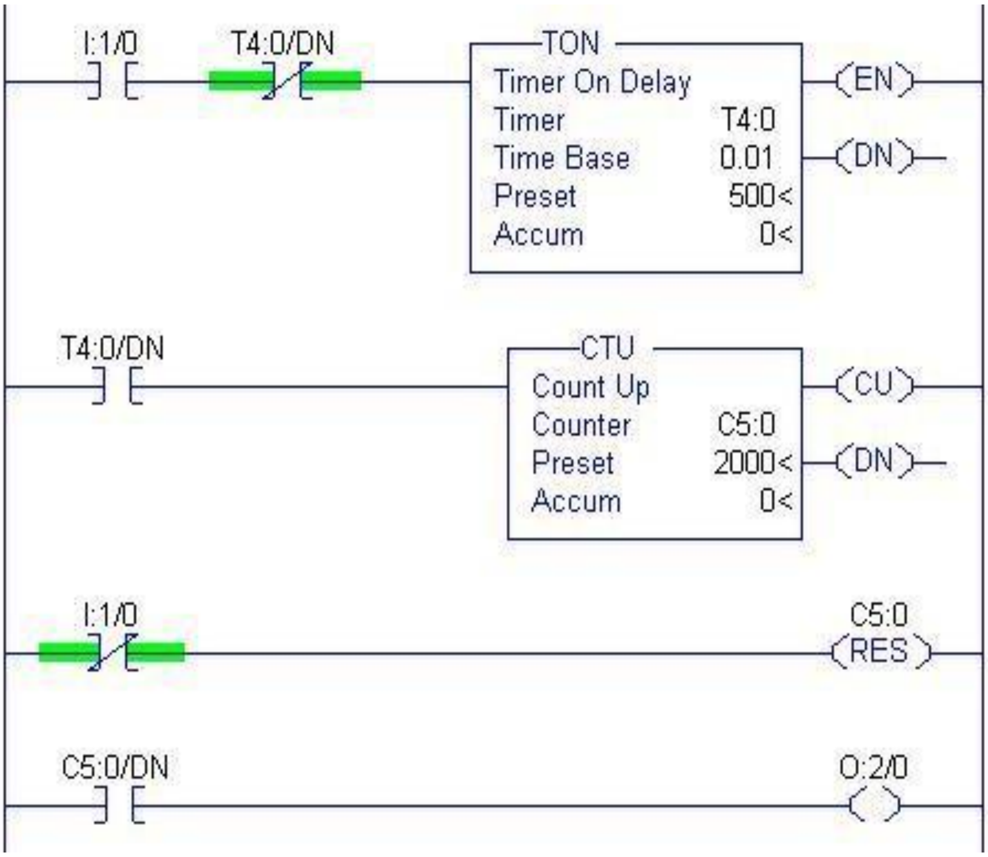


3. Up-DownCounter:

- Theup-downcountercountsthevaluefromzerotothepresetvalueorfromthepresetvalueto zero.
- Inotherwords, thiscountercan beactasdowncounterorupcounter.
- Up-downcounterisknownas 'CTUD'.
- Forthebidirectionaland quadratureoperationmode,theup-downcounterisselecteddepending on the status (high or low) of the specified count input terminal.
- Up-downcounterfunction blockdiagramisdrawnbelow:



LadderdiagramsusingTimersandcounters:



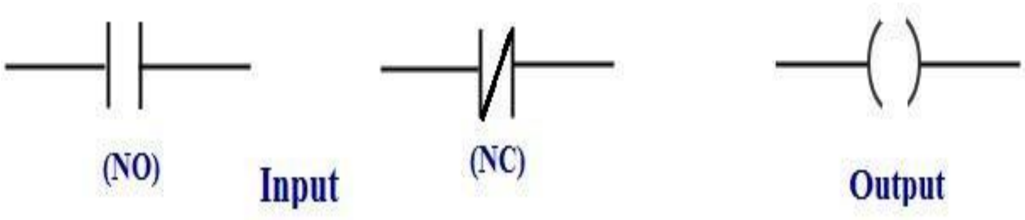
5.12.PLCInstructionset:

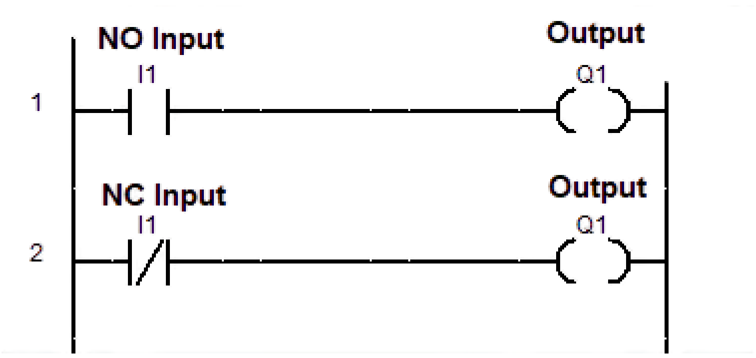
- Instruction is nothing but the command that we give to the machine to perform certain tasks. multipleinstructionstoperformonelogicaloperation.Thesetsofmultipleoperationsarecalled as 'Program'.
- AccordingtodifferentPLCsoftwarebrands,therearedifferentinstructionssets. Every instruction has input and output.

Input/Output Basics:

InPLCprogramming,inputsandoutputsareverybasicterms.

- Inputis shownbytwo parallellines-NormallyOpen (NO)orNormallyClosed(NC)
- Outputis shownbyParenthesesor roundbrackets.





Thedifferenttypesofinstructions setwhichareusedfortheladderdiagramPLC programming.

1. BasicPLCProgrammingInstructions:

1) Input (Ior X)Instruction.
2) Output (O orQ) Instruction.
3) Set(S)and Reset(R)Instruction.
4) Latch(L) andUnlatch (U) Instruction.

2. Time-BasedPLCProgrammingInstructions

Thetimerinstructionsfollow taskorcommandfor/at aparticular durationof time.

1) SinglePulse(Monoflop) TimerInstruction
2) FlashingTimerInstruction
3) On DelayTimer(TON)Instruction
4) OffDelayTimer(TOFF)Instruction
5) RetentiveTimer(RTO)Instruction
6) PulseTimer(S-Pulse)Instruction
7) PulseExtendedTimer(S-PEXT) Instruction
8) On DelayTimer(S-ODT)Instruction
9) OffDelayTimer(S-OFFDT) Instruction
10) ExtendedOn DelayTimer(S-ODTS)Instruction
11) OnDelaywith RandomTime TimerInstruction

3. Counting-BasedPLCProgrammingInstruction:

Counterinstructionsareusedforcountingpulseinthe PLCprogram.Theclassificationofdifferent Counter instructions are-

1) UpCounter(CTU)Instruction
2) DownCounter(CTD)Instruction
3) Up-DownCounter Instruction

4.ComparisonBasedPLCProgrammingInstruction:

Theseinstructionsareusedtocompare inputs.

1) Greaterthan(GET)Instruction
2) Lesserthan(LET)Instruction
3) Equalto(EQU)Instruction
4) NotEqualto(NEQ)Instruction

5) Greaterthanor equalto(GEQ) Instruction
6) Lesserthanor equalto(LEQ) Instruction
7) IncrementandDecrementInstruction
8) Limit(LIM) Instruction

5. MathematicalPLCProgrammingInstruction:

ThesePLCinstructionsareusedtoperformdifferentmathematicaloperationslikearithmetic, trigonometric and logarithmic operations.

1) Addition(ADD) Instruction
2) Subtraction(SUB)Instruction
3) Multiplication(MUL) Instruction
4) Division(DIV)Instruction
5) SquareRoot (SQRT)Instruction
6) Absolute(ABS)Instruction
7) Sine(SIN) Instruction
8) Cosine(COS)Instruction
9) Tangent(TAN)Instruction
10) ArcSine(ASN)Instruction
11) ArcCosine(ACS) Instruction
12) ArcTangent(ATN) Instruction
13) NaturalLog(LN)Instruction
14) LogtoBase10(LOG)Instruction

6. DataTransferBasedPLCProgrammingInstruction:

1) FillFile(FLL) Instruction
2) Move(MOV)Instruction
3) Copy(COP)Instruction
4) Jump(JMP) Instruction
5) JumpNot(JMPN) Instruction
6) ConditionalJumpInstruction
7) JumptoSubroutine(JSR)Instruction
8) Subroutine(SBR)Instruction
9) Return(RST) Instruction
10) Suspend(SUS)Instruction
11) Lable(LBL)Instruction
12) JumpandLable(JMP&LBL) Instruction
13) MasterControl Set(MCS) instruction
14) MasterControl Reset (MCR) instruction
15) One-ShotRising(OSR) Instruction
16) One-ShotFalling(OSF) Instruction
17) ConvertfromIntegertoBCD(TOD) Instruction
18) ConvertfromBCDto Integer(FRD)Instruction
19) TemporaryEnd(TND)Instruction
20) ConvertRadianstoDegrees(DEG)Instruction
21) ConvertDegreestoRadians(RAD) Instruction

7. LogicalorBitwisePLCProgrammingInstruction:

Manytimes,weneedtoperformlogicaloperationsoninputdata.Thelogicalinstruction basically depends on the logic gate concept.

1) BitwiseNOT(NOT)Instruction
2) BitwiseAND (AND) Instruction
3) BitwiseOR(OR) Instruction
4) BitwiseExclusiveOR(XOR)Instruction
5) Flip-Flop(RSorSRFlip-Flop) Instruction
6) PositiveHTrigger(P)Instruction
7) NegativeHTrigger(N)Instruction

8. Sequence-BasedPLCProgrammingInstruction:

1) SequencerInput(SQI)
2) SequencerOutput(SQO)
3) BitShift Left(BSL)
4) BitShiftRight(BSR)
5) Sequencerload(SQL)
6) Sequencercompare(SQC)

Ladderdiagramsforfollowing : (i)DOLstarterandSTAR-DELTAstarter(ii)Staircaselighting (iii)TrafficlightControl(iv)TemperatureController :

1.DOLstarter:

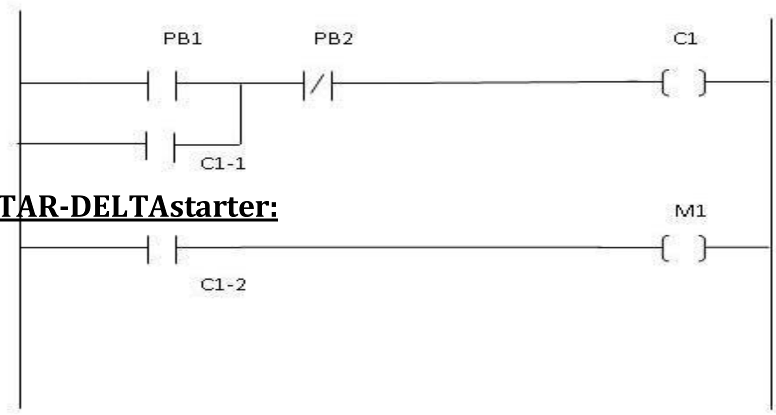
ProblemStatement:TostartamotorusingDOLstarter. Inputs:
PB1- To start the motor

PB2-Tostopthemotor Output:

M1- Motor

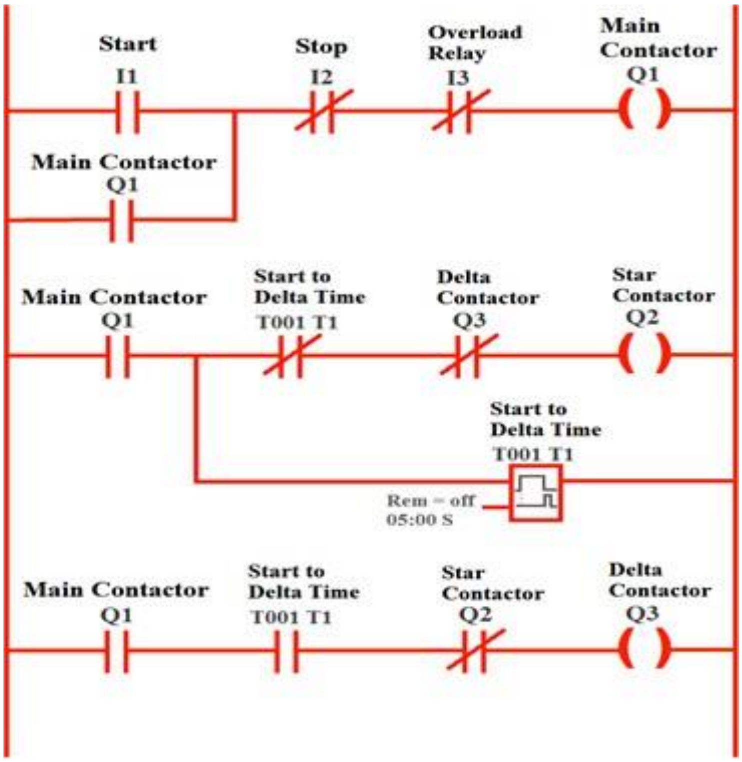
Sequenceof Events:

1. WhenStartpushbutton(PB1)ispressed,Motor(M1)hasto start.
2. IfStartpushbutton(PB1)isreleasedandStoppushbutton(PB2)isnotpressed,Motor(M1)should remain on.
3. WhenStoppushbutton (PB2ispressed,Motor(M1)hasto stop.
4. Ifstoppushbuttonisreleasedandstartisnotpressed(released)motorshouldremainoff.

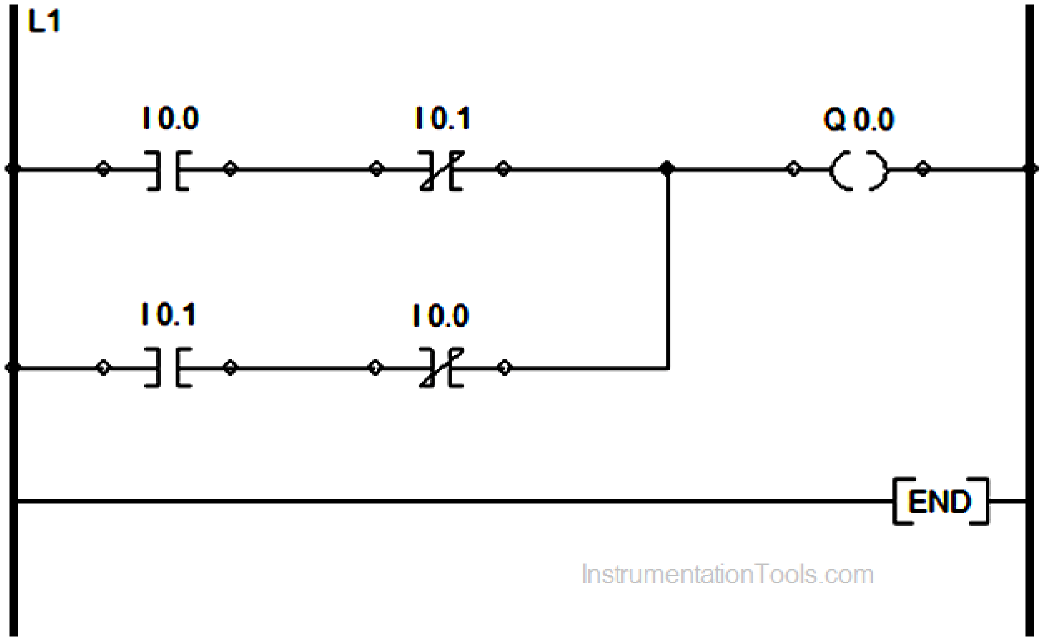


STAR-DELTAstarter:

STAR-DELTAstarter:

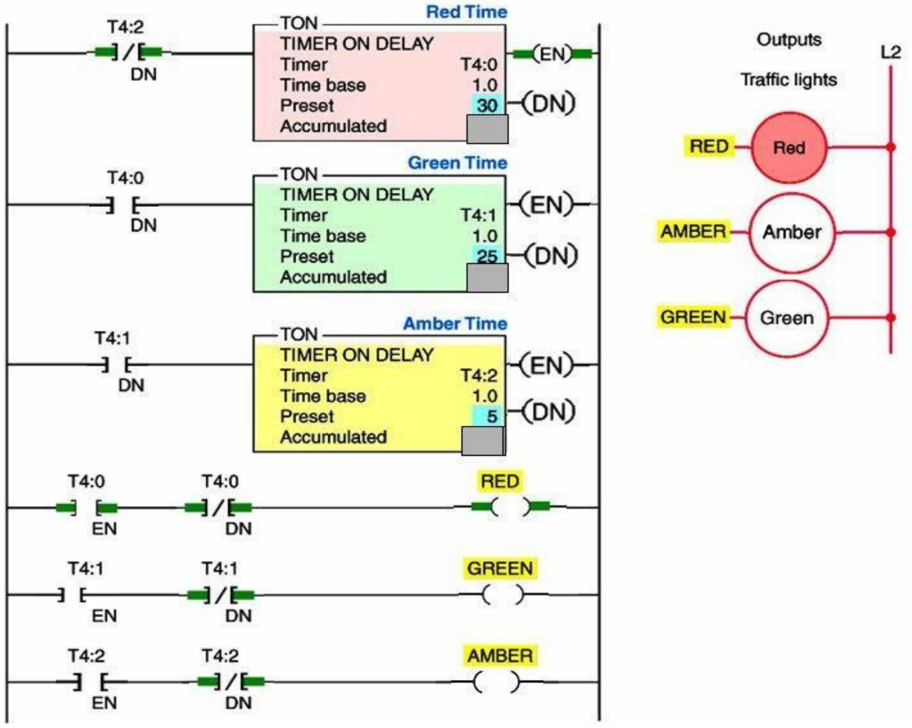


(ii) Staircaselighting:

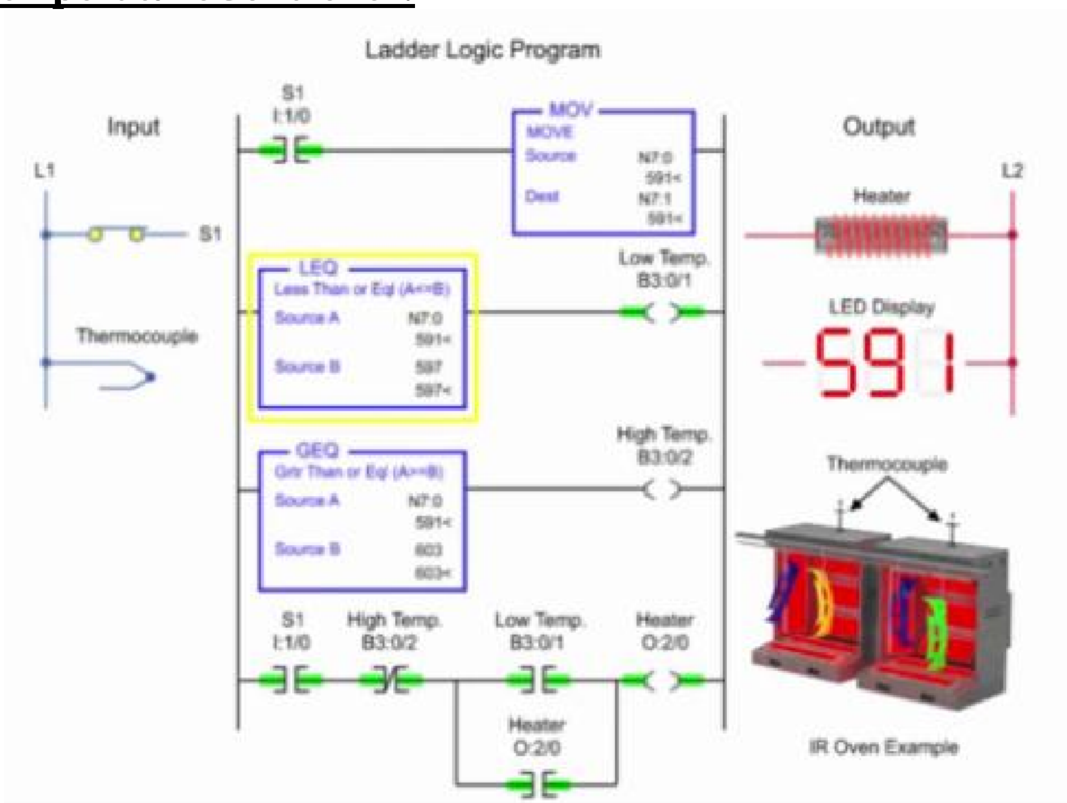


(iii) TrafficlightControl:

Control of Traffic Lights in One Direction

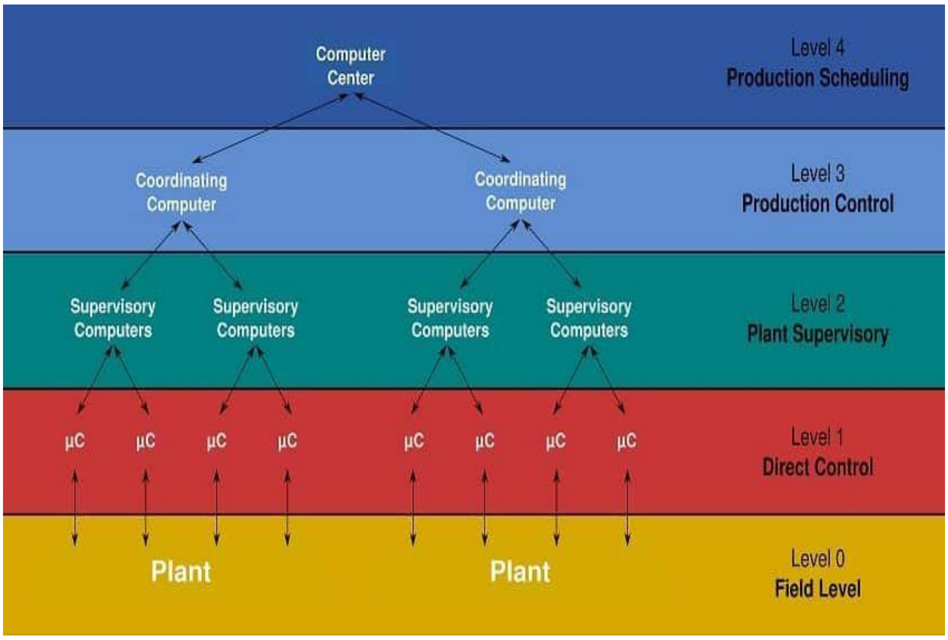


(iv) TemperatureController:



Specialcontrolsystems-BasicsDCS&SCADAsystems:

DCS-DistributedControlSystem:

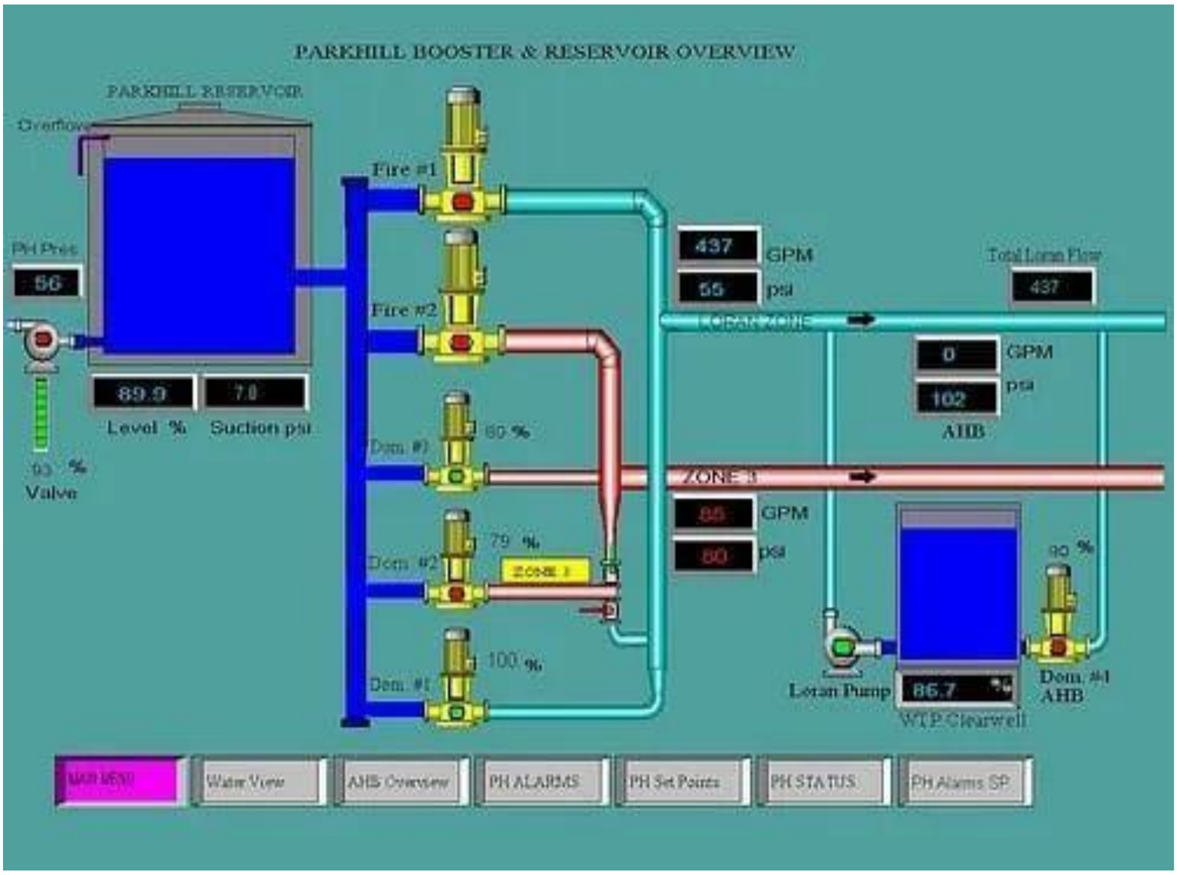


DCSArchitecture:

1. The distributed control system is designed to perform more complex and geographically larger industrial processes. The whole industrial process is divided into various control zones and is controlled by dedicated autonomous controllers.
2. Field devices communicate with the controllers at the particular zone of control. These controllers are interconnected through a high-speed communication network and are connected to engineeringPC where overall control, monitoring, data logging and alarmingfunctions occur.
3. In a distributed control system, control decisions are made by the plant operator rather than the controllers itself. DCS is a pre-engineered solution that requires configuration rather than programming (as that of PLC).

SCADA-SupervisoryControlandDataAcquisitionSystem:

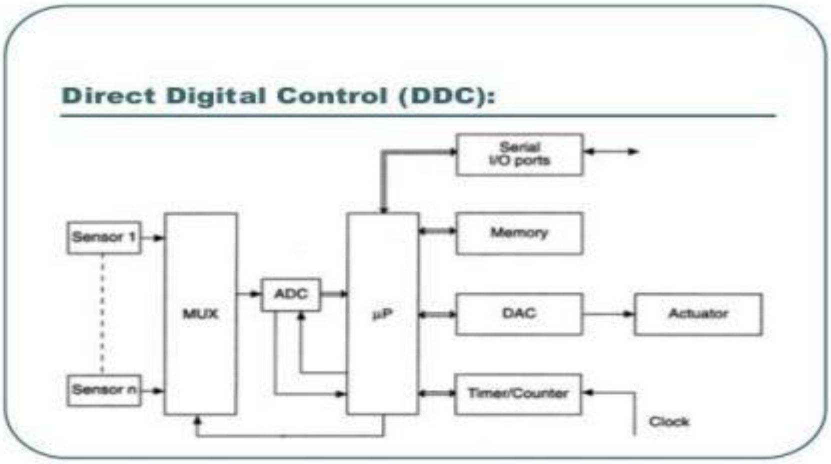
1. Supervisorycontroland dataacquisitionsystemisasoftwareinterfacethatoffersplantoperators ease of control and supervision over various equipment in the industry/plant. In addition, it performs data acquisition also.
2. The operator can monitor parameters and give commands to the field equipment through PLC/ SCADA. SCADA cannot directly communicate to the field equipment but through PLC. Alldata from the field goes to the I/O modules in the PLC and is stored in specific memorylocations or registers. SCADA, in turn, reads or writes to those memory locations. The entire control logic is saved in the PLC and not in the SCADA.



ComputerControl–DataAcquisition,DirectDigitalControlSystem:

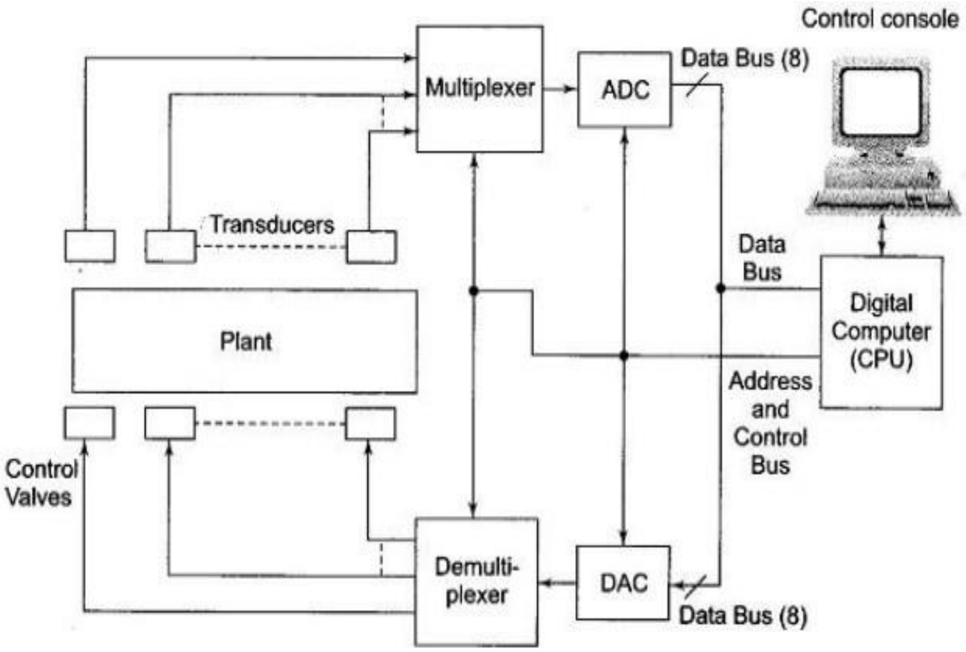
DirectDigitalControlSystem:

1. The first system used was Direct Digital Control (DDC), in which a computer measured each variableintheprocess,thesesignalsbeingusedtomaintaintherequired setpointsintheprocess
2. A basic Direct Digital Control System is shown in Fig. In this system a large number of transducers are sited around the plant, each transducer being connected to one input of a Mux.
3. A Mux can be considered as- the electronic equivalent of a switch with a contact or blade which rotates very rapidly so that it moves from one transducer to another, the blade remaining in contact with the transducer long enough for an ADC to sample and digitize or to quantize the analog signal. The quantized data are then transmitted along the data bus of the system to the CPU.



DataAcquisition:

1. Thereal-timesystemconsistsofthousandsofcomponentsandsensors.Itisveryimportantto know the status of components and sensors.
2. Forexample,somesensorsmeasurethewaterflowfromthereservoirtothewatertankand some sensors measure the value pressure as the water is a release from the reservoir.



Direct Digital Control of an Industrial Process

ShortQuestionsWithAnswer:

1. **WhatisPLCstands for?Writedown theapplication ofPLC.**
   Ans-PLCstandsforProgrammableLogic Controllers.

Advantagesof PLC:

- Theyareuserfriendlyandeasytooperate
- Theyeliminate the need forhard-wiredrelaylogic
- Theyarefast
- Itissuitableforautomationinindustries.
- Itsinputandoutputmodules canbe extendeddependingupon therequirements

2. **Writedowntheapplication of PLC.**

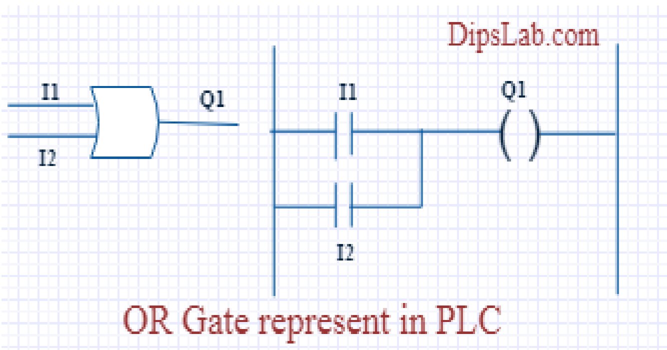
Ans-Therearesomeapplicationsofprogrammablelogiccontroller(PLC).

- Itisusedincivilapplicationssuchaswashingmachine,elevatorsworkingandtraffic signals control.
- Itisusedinaerospacefor Watertankquenchingsystem.
- Itisusedtoreducingthehumancontrolallocationofhumansequencegiventothetechnical equipments that is called Automation.
- Itisusedinbatchprocessinchemical,cement,foodandpaperindustriesaresequentialin nature, requiring time or event-based decisions.

3. **Whatis LadderDiagram?**

Ans-Aladderdiagramis atypeofschematicdiagramusedinindustrialautomationthat represents logic control circuits. Ladder diagrams are composed of two vertical power rails and horizontal logic rungs to form what looks like a ladder.

4. **DrawtheLadderDiagramof ORGate.**



5. **Whatarethetypesof counterseeninPLC?**

Ans-Thesethreetimersare,

1. OnTimer(Ton).
2. OffTimer (Toff).
3. RetentiveOn-OffTimer (RTO)
4. **Whatarethedifferentmodulesof PLC?(W-20)**

Ans-DifferentmodulesofPLCare-

i. Rackorchases
ii. Powersystem module
iii. CPU
iv. Interfacemodule
v. Signalmodule
vi. Functionmodule
vii. Communication Processor

5. **Whatisthepurposeof latchedcoil?(W-20)**

Ans-i.Thepurposeoflatchedcoilistoallowcontrolofacircuitbyprovidingasinglepulsetoa relay control circuit.
ii. Itisalsousedwhenit isnecessarytohavearelaythatwillmaintainitscontactpositionduring power interruption.

LONGQUESTIONS:

1. DrawtheLadderdiagramofStar-Delta Starter.

2. Drawthe Ladderdiagramofstaircase lightening.

3. DrawtheLadderdiagramofTrafficlightcontroller.

4. ExplaindifferenttypesoftimersinPLC.(W-20)

5. Drawtheladderdiagramoffull-addercircuit .(W-2020)

6. DrawtheblockdiagramofPLC systemandexplaineachblockin details.(W-2020)