Q.2 a. What are the various types of power electronics circuits? Explain briefly with their area of applications. (8)

Answer:

The switching characteristics of power devices permit the control and conversion of electric power from one form to another. These converters are called static power converters and consist of a matrix of switches. Using a combination of these devices allows us to create circuit configurations that allow us to convert between a.c. and d.c. signals.

The resulting power electronic circuits are classified into six types:

1. diode rectifiers
2. ac-dc converters (controlled rectifiers)
3. ac-ac converters (ac voltage controllers)
4. dc-dc converters (dc choppers)
5. dc-ac converters (inverters)
6. static switches

Refer Page No. 14 in Power Electronics for Technology by Ashfaq Ahmed.

b. What is the advantage of two series connected power diodes with reverse bias? Draw its circuit diagram and explain its V-I characteristics. (8)

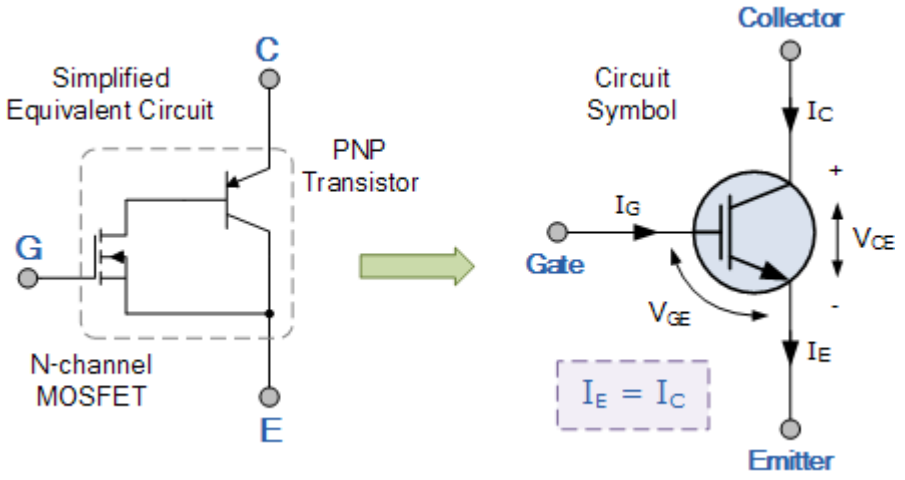
Answer:

Refer Page No. 30 from Power Electronics for Technology by Ashfaq Ahmed.

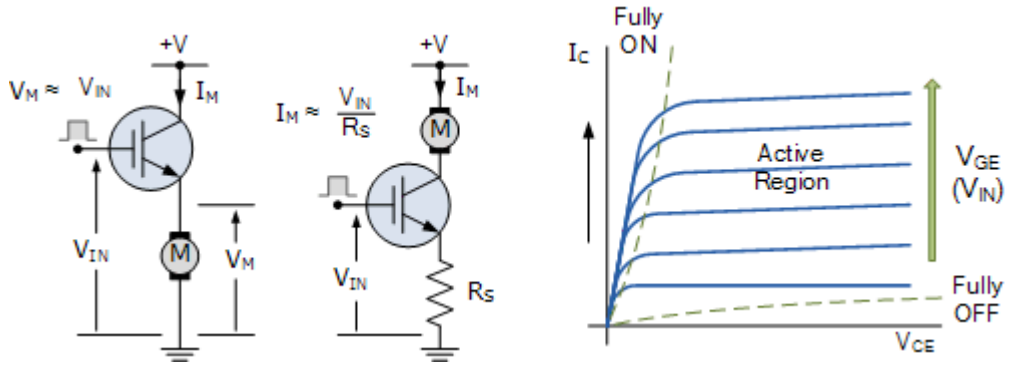
Q.3 a. What is IGBT? Draw the switching characteristics of IGBT. (8)

Answer:

IGBT is Insulated Gate Bipolar Transistor uses the insulated gate technology of the MOSFET with the output performance characteristics of a conventional bipolar transistor. The result of this hybrid combination is that the "IGBT Transistor" has the output switching and conduction characteristics of a bipolar transistor but is voltage-controlled like a MOSFET Insulated Gate Bipolar Transistor



IGBT Characteristics



As the IGBT is a voltage-controlled device, it only requires a small voltage on the Gate to maintain conduction through the device unlike BJT's which require that the Base current is continuously supplied in a sufficient enough quantity to maintain saturation.

Also the IGBT is a unidirectional device, meaning it can only switch current in the "forward direction", that is from Collector to Emitter unlike MOSFET's which have bi-directional current switching capabilities (controlled in the forward direction and uncontrolled in the reverse direction).

The principal of operation and Gate drive circuits for the insulated gate bipolar transistor are very similar to that of the N-channel power MOSFET. The basic difference is that the resistance offered by the main conducting channel when current flows through the device in its "ON" state is very much smaller in the IGBT. Because of this, the current ratings are much higher when compared with an equivalent power MOSFET.

b. Explain the working principle of UJT with corresponding VI characteristics. (8)

Answer:

Refer Page No. 65 – 67 from Power Electronics for Technology by Ashfaq Ahmed.

Q.4 a. Explain why gate triggering is preferred over voltage triggering. (8)

Answer:

The applied forward voltage is gradually increased beyond a point known as forward break over voltage VBO and gate is kept open. This method is not preferred because during turn on of thyristor, it is associated with large voltage and large electric current which results in huge power loss and device may be damaged.

This method of thyristor triggering is widely employed because of ease C8 control over the thyristor gate triggering of thyristor allows us to turn of the thyristor whenever we wish. Here we apply a gate signal to the thyristor. Forward biased thyristor will turn on when gate signal is applied to it. Once the thyristor starts conducting, the gate loses its control over the device and the thyristor continues to conduct. This is because of regenerative action that takes place within the thyristor when gate signal is applied.

When the thyristor is forward biased, and a gate signal is injected by applying positive gate voltage is applied between gate and cathode terminals, then the thyristor is turned on.

b. What is natural commutation? What are its types? Classify the types by which the SCR can be turned off. (8)

Answer:

Commutation : The term commutation basically means the transfer of current from one path to another.

It is not possible for a thyristor to turn itself OFF; the circuit in which it is connected must reduce the thyristor current to zero to enable it to turn-off.

Commutation is the term to describe the methods of achieving this. Broadly classified into two methods:1.NATURAL COMMUTATION2.FORCED COMMUTATION

NATURAL COMMUTATION

This widely used method of commutation makes use of the alternating, reversing nature of a.c voltage to effect the current transfer. As the current passes through natural zero, a reverse voltage will simultaneously appear across the device. This immediately turns-off the device. This process is called as

natural commutation since no external circuit is required for this purpose.

FORCED COMMUTATION

In case of d.c circuits, for switching off the thyristors, the forward current should be forced to be zero by means of some external circuits. The process is called *forced commutation.*

CLASSIFICATION OF FORCED COMMUTATION TECHNIQUES: The classification is based on the arrangement of commutating components and the manner in which zero currentis obtained in the SCR. The six distinct classes by which the SCR can be turned off are:

Class A Self commutated by a resonating load

Class B Self commutated by a L-C circuit

Class C C or L-C switched by another load carrying SCR -Complementary commutation

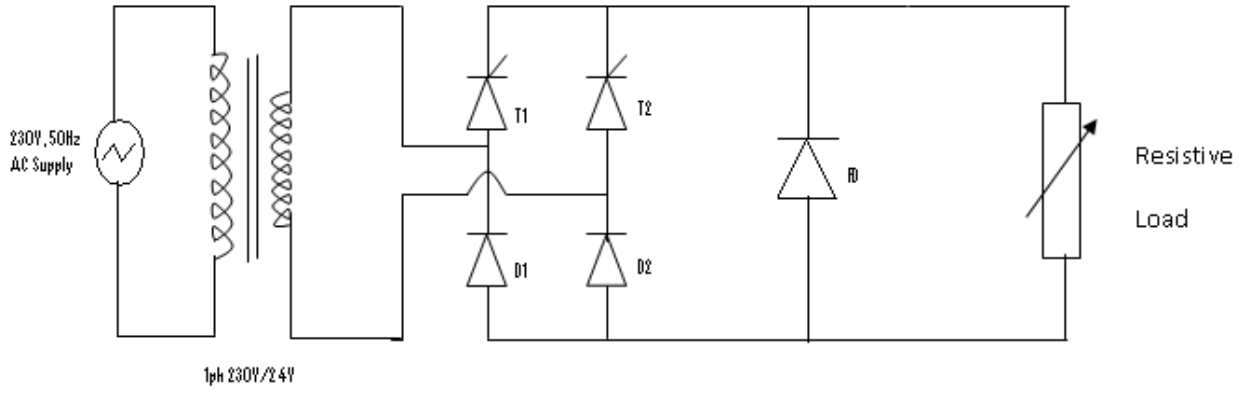
Class D C or L-C switched by an auxiliary SCR -Auxiliary commutation

Class E An external pulse source for commutation-External pulse commutation

Class F AC line commutation

Q.5 a. Explain with the help of a circuit diagram, the working principle of a single phase full wave half controlled bridge rectifier using two SCRs and two diodes. (10)

Answer:



A semi converter uses two diodes and two thyristors and there is a limited control over the level of dc output voltage. A semi converter is one quadrant converter. A one-quadrant converter has same polarity of dc output voltage and current at its output terminals and it is always positive. It is also known as two-pulse converter. Figure shows half controlled rectifier with R load. This circuit consists of two SCRs T1 and T2, two diodes D1 and D2. During the positive half cycle of the ac supply, SCR T1 and diode D2 are forward biased when the SCR T1 is triggered at a firing angle $\omega t = \alpha$, the SCR T1 and diode D2 comes to the on state. Now the load current flows through the path L - T1- R load –D2 - N. During this period, we output voltage and current are positive. At $\omega t = \pi$, the load voltage and load current reaches to zero, then SCR T1 and diode D2 comes to off state since supply voltage has been reversed. During the negative half cycle of the ac supply, SCR T2 and diode D1 are forward biased. When SCR T2 is triggered at a firing angle $\omega t = \pi + \alpha$, the SCR T2 and diode D1 comes to on state. Now the load current flows through the path N - T2- R load – D1 -L. During this period, output voltage and output current will be positive. At $\omega t = 2\pi$, the load voltage and load current reaches to zero then SCR T2 and diode D1 comes to off state since the voltage has been reversed. During the period ($\pi + \alpha$ to 2π) SCR T2 and diode D1 are conducting.

b. SCRs with peak forward voltage rating of 1000V and average on state current rating of 40 A are used in single phase midpoint converter and single phase bridge convertor. Find the power that these two converters can handle. Use a factor of safety of 2.5 (6)

Answer:

Maximum Voltage across SCR in single phase midpoint converter is 2Vm

Therefore this converter can be designed for maximum voltage of 1000/2x2.5 =200V

Maximum average power that mid point converter can handle

$= \{2V_m/\pi \cos\alpha\} I_{tav} = 2x200/\pi \times 40/4000 = 5.093$ kW

SCR in a single phase bridge converter is subjected to a maximum voltage of Vm Therefore Maximum voltage for which this converter can be designed

1000/2.5 = 4000V

Maximum average power rating of bridge converter

$= \{2V_m/\pi \cos\alpha\} I_{tav}$

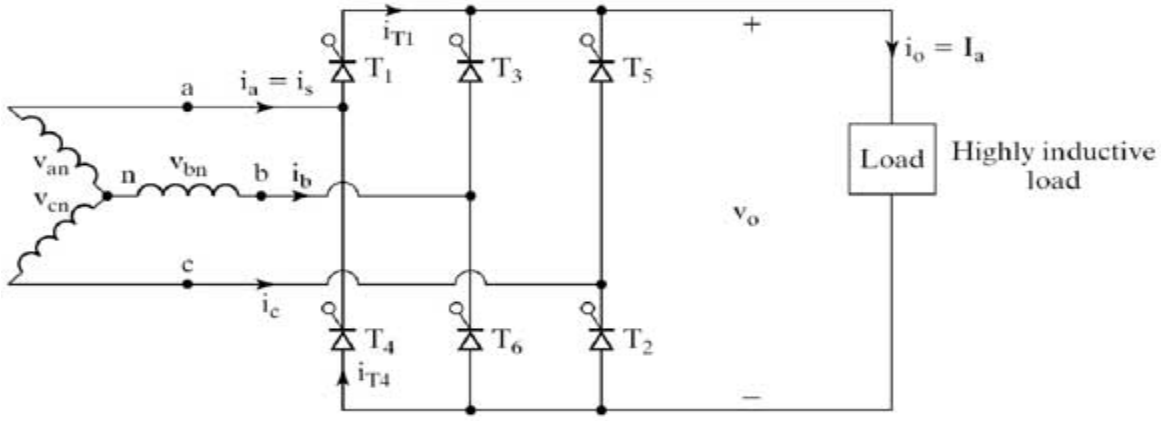
$= 2x400/1000x\pi \times 40 = 10.186$ kW

Q.6 a. Explain with the help of circuit diagram, the working principle of three phase full wave full controlled bridge rectifier. (8)

Answer:

Three phase full converter is a fully controlled bridge controlled rectifier using six thyristors connected in the form of a full wave bridge configuration. All the six thyristors are controlled switches which are turned on at a appropriate times by applying suitable gate trigger signals. The three phase full converter is extensively used in industrial power applications upto about 120kW output power level, where two quadrant operations is required. The figure shows a three phase full converter with highly inductive load. This circuit is also known as three phase

full wave bridge or as a six pulse converter. The thyristors are triggered at an interval of (∏/3) radians (i.e. at an interval of 30°). The frequency of output ripple voltage is 6fs and the filtering requirement is less than that of three phase semi and half wave converters. At ωt=(∏/6 +α) , thyristor is already conducting when the thyristor is turned on by applying the gating signal to the gate of . During the time period ωt=(∏/6 +α) to (∏/2 +α), thyristors and conduct together and the line to line supply voltage appears across the load. At ωt=(∏/2 +α), the thyristor T2 is triggered and T6 is reverse biased immediately and T6 turns off due to natural commutation. During the time period ωt=(∏/ +α) to (5∏/6 +α), thyristor T1 and T2 conduct together and the line to line supply voltage appears across the load. The thyristors are numbered in the circuit diagram corresponding to the order in which they are triggered. The trigger sequence (firing sequence) of the thyristors is 12, 23, 34, 45, 56, 61, 12, 23, and so on.



Three Phase Full Wave fully controlled bridge rectifier

b. A three phase half wave controlled rectifier is connected to a 220V source. If the delay angle is 45° and the load resistance R = 10Ω, find
(i) the average output current (ii) SCR average current
(iii) average power (iv) maximum reverse voltage (8)

Answer:

Delay angle =45° , the SCR turns ON before the supply voltage reches its max. Therefore the maximum output voltage is equal to V_m , the maximum value of phase voltage

V_{phase}= 220√3 = 127V

V_m = √2(127) = 180 V

i) $V_{0(avg)}$= 0.827 $V_m$cosα = 0.827 X 180 cos45° = 105V

so average output current= $I_{0(avg)}$= $V_{0(avg)}$/R =105/10 =10.5A

ii) SCR average current = $I_{0(avg)}$/3 = 10.5/3 3.5 A

iii) average power = Vf X $I_{0(avg)}$ /3 = 1,0 X 10.5 /3 = 3.5W

iv) mximum reverse voltage = √2 X 220 = 311 V

Q.7 a. What is a chopper? List out its various industrial applications. (6)

Answer:

Refer Page No. 269 from Power Electronics for Technology by Ashfaq Ahmed.

b. What is Step-Down chopper? Draw its circuit diagram and explain its operation for the ON state and OFF state. (10)

Answer:

Refer Page No. 273 – 274 from Power Electronics for Technology by Ashfaq Ahmed.

Q.8 a. A series Inverter circuit has an inductor of 10mH, a capacitor of 47μF connected in series with a load resistance of 5 Ω. Calculate (i) the resonance frequency (ii) the time period of oscillations. (6)

Answer:

L = 10mH C=47μF R= 5KΩ

Resonance frequency is given by

$F_c = \sqrt{1/LC - R^2/4L^2} =$

$\sqrt{2.037 \times 10^6} = 1427$ Hz

b. What is current source inverter? Draw the circuit of single-phase current source bridge inverter and explain its working with the help of load current waveform. (10)

Answer:

Refer Page No. 347 – 348 from Power Electronics for Technology by Ashfaq Ahmed.

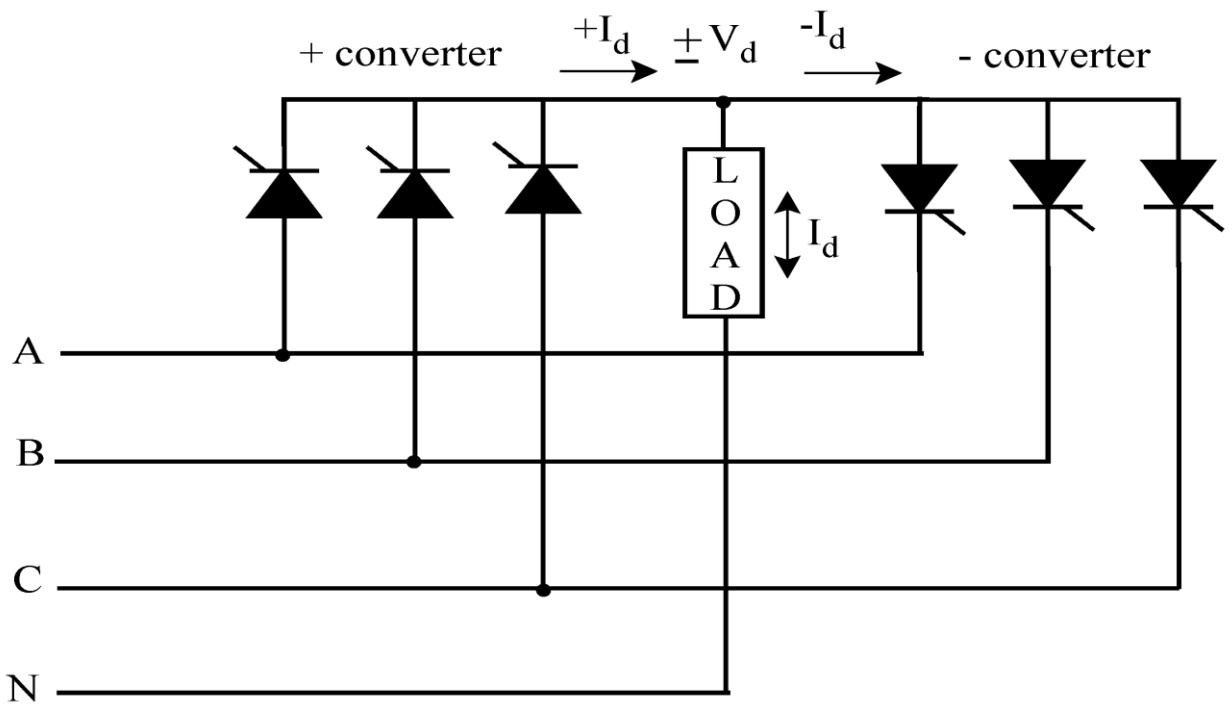
Q.9 a. Explain with the help of block diagram, the working principle of three phase to single phase cycloconverter. (8)

Answer:

The 3f-1f cycloconverter applies rectified voltage to the load. Both positive and negative converters can generate voltages at either polarity, but the positive converter can only supply positive current and the negative converter can only supply negative current. Thus, the cycloconverter can operate in four quadrants: (+v, +i) and (-v, -i) rectification modes and (+v, -i) and (-v, +i) inversion modes. Note that a is sinusoidally modulated over the cycle to generate a harmonically optimum output voltage The polarity of the current determines if the positive or negative converter should be supplying power to the load. Conventionally, the firing angle for the positive converter is named αP, and that of the negative converter is named αN. When the polarity of the current changes, the converter previously supplying the current is disabled and the other one is enabled. The load always requires the fundamental voltage to be continuous. Therefore, during the current polarity reversal, the average voltage supplied by both of the converters should be equal. Otherwise, switching from one converter to the other one would cause an undesirable voltage jump. To prevent this problem, the converters are forced to produce the same average voltage at all times

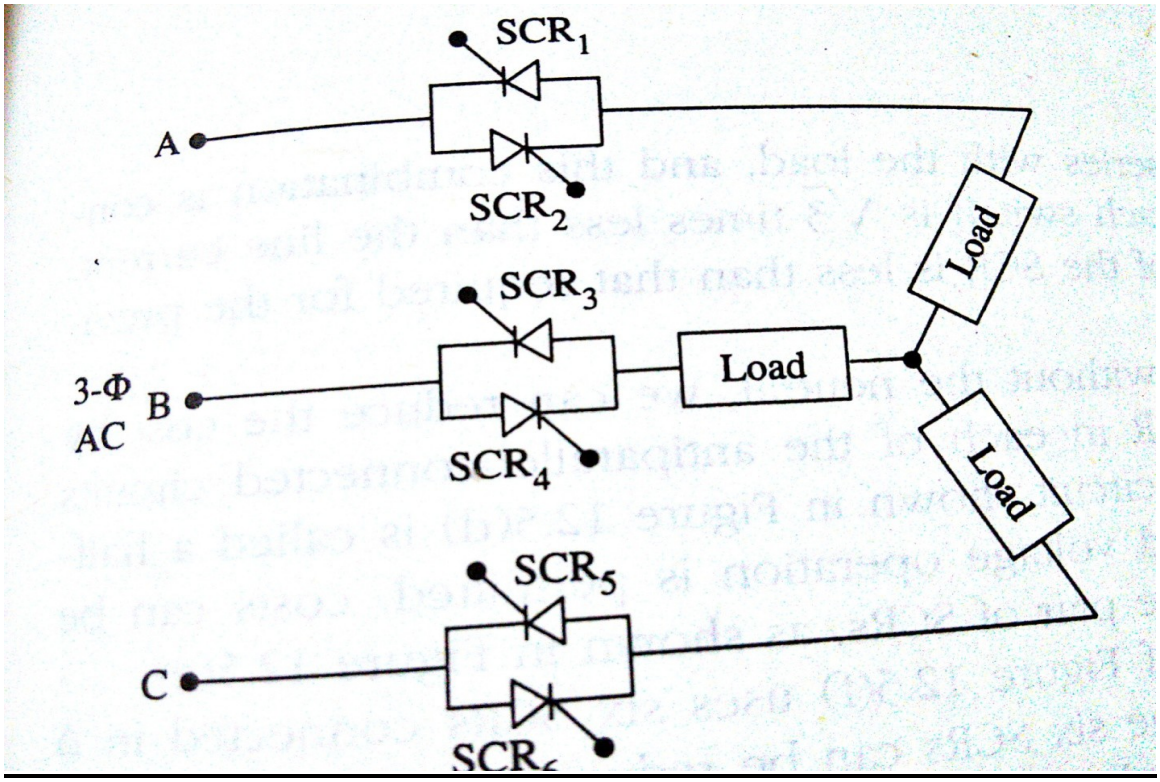
Thus, the following condition for the firing angles should be met.

$\alpha P, + \alpha N = p$



b. Draw the circuit diagram for three phase static switching circuit having star connected three phase load. (8)

Answer:



Three phase switch circuit with star connected load

A three phase circuit can be switched ON /OFF in the same way as single phase AC circuits. The semiconductor switch constructed from SCR in anti parallel connected in series with AC supply line of star connected load.
In a three phase system without the neutral , the cost can be reduced by substituting a diode for an SCR in each of the antiparallel connected circuits.

TEXT BOOK

I. Power Electronics for Technology, First Impression (2006), Ashfaq Ahmed, Purdue University - Calumet, Pearson Education