453 Register No.: ______

April 2018

Time – Three hours
(Maximum Marks: 75)

[N.B: (1) Q.No. 8 in PART – A and Q.No. 16 in PART – B are compulsory. Answer any FOUR questions from the remaining in each PART – A and PART – B

(2) Answer division (a) or division (b) of each question in PART - C.

(3) Each question carries 2 marks in PART – A, 3 marks in Part – B and 10 marks in PART – C.]

PART – A

1. Specify the various types of forced commutations.
2. Define firing angle and extinction angle.
3. Define cycloconverter.
4. Specify the various types of DC–DC converters.
5. Name the various types of PWM techniques commonly used in inverters.
6. What are static VAR compensators?
7. What is soft start of induction motor?
8. Define holding current and latching current.

PART – B

9. Write short notes on various types of power electronic circuit.
10. With the diagram explain snubber circuit.
11. Explain the principle of phase control in AC voltage controller.
12. With the diagram explain step up converter.
13. Explain sinusoidal pulse width modulation.
14. State the difference between ON line UPS and OFF line UPS.
15. Write notes on speed control by varying stator frequency and voltage.
16. State the advantages of circulating current in single phase dual converters.

PART – C

17. (a) With the diagram explain the principle of operation of SCR.

(Or)

(b) (i) With the circuit diagram explain the operation of UJT based triggering circuit.

(ii) With the circuit diagram explain the operation of class B commutation.

18. (a) Draw the circuit diagram of single phase full converter and explain its operation.

(Or)

(b) With diagram explain three phase cycloconverter.

19. (a) (i) With diagram explain the continuous conduction mode of buck-boost converter.

(ii) Explain the operation of cuk DC-DC converter with diagram.

(Or)

(b) With diagram and waveforms explain the operation of 120° conduction mode of three phase inverter.

20. (a) With diagram explain the operation of high frequency fluorescent system.

(Or)

(b) With diagram explain the high voltage DC transmission.

21. (a) With the diagram, explain the operation of variable frequency PWM-VSI drives.

(Or)

(b) Explain the speed control of slip ring induction motor by static slip power recovery.

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675 Register No.:

October 2018

Time – Three hours
(Maximum Marks: 75)

[N.B: (1) Q.No. 8 in PART – A and Q.No. 16 in PART – B are compulsory. Answer any FOUR questions from the remaining in each PART – A and PART – B

(2) Answer division (a) or division (b) of each question in PART – C.

(3) Each question carries 2 marks in PART – A, 3 marks in Part – B and 10 marks in PART – C.]

PART – A

1. Define dv/dt and di/dt.
2. Specify the various parts for designing power electronics equipment.
3. Define AC voltage controller. Mention its two types of control.
4. Name the types of line commutated converters.
5. Write the relationship between torque-speed characteristics of induction motor.
6. Write on AC solid state relay using pulse transformer.
7. Define slip and slip speed.
8. Define modulation index.

PART – B

9. Explain the VI characteristics of SCR.
10. What is the effect of rate of rise in current?
11. Write short notes on rectifying and inverting modes of full converter.
12. Explain multiple pulse width modulation.
13. Draw the block diagram of high frequency fluorescent lighting system and explain.
14. Write the types of static VAR controllers.
15. Write short notes on induction motor capability below and above rated speed.
16. Explain the reduced voltage starting of induction motor.

[Turn over.....

PART – C

17. (a) With the diagram, explain the principle of operation of IGBT.

(Or)

(b) Explain the driver and buffer circuits for thyristor.

18. (a) With diagram, explain the operation of three phase dual converter.

(Or)

(b) Explain the operation of twelve pulse converter with circuit diagram.

19. (a) With diagram, explain the operation of single phase full bridge inverter.

(Or)

(b) (i) Explain the operation of buck converter.
(ii) Explain sinusoidal pulse width modulation with a diagram.

20. (a) Explain induction heating with a diagram.

(Or)

(b) (i) With the block diagram, explain the wind and small hydro interconnection.
(ii) With a diagram, explain thyristor switched capacitors.

21. (a) Explain the line frequency converters with the diagram.

(Or)

(b) With the diagram, explain the variable frequency PWM-VSI drives.

876
Answer Key
October 2019
POWER ELECTRONICS
Time: Three hours
(Maximum Marks: 75)

{NB. (1) Q.No.8 in ***PART-A*** and Q.No.16 in ***PART-B*** are compulsory. Answer any four questions from the remaining in each ***PART-A*** and ***PART-B***
(2) Answer division (a) or division (b) of each question in ***PART- C***
(3) Each question carries 2 marks in ***PART-A*** , 3 marks in ***PART-B*** and 10 marks in ***PART-C*** }

PART -A

1. **Define SCR ratings.**
Thyristor ratings or SCR (Silicon Controlled Rectifier) ratings are very much required for operating it in a safe zone. A thyristor, or SCR may have several ratings, such as voltage, current, power, turn on time, turn off time, etc. Generally these ratings are specified in the data sheet given by manufacturer.

2. **Define Commutation**
The turn OFF process of an SCR is called commutation. The term commutation means the transfer of currents from one path to another. The commutation circuit does this job by reduces the forward current to zero so as to turn OFF the SCR or Thyristor.

3. **Define AC Voltage regulator and mention its two types of control.**
An AC voltage controller or AC regulator is an electronic module based on either thyristors, TRIACs, SCRs or IGBTs, which converts a fixed voltage, fixed frequency alternating current (AC) electrical input supply to obtain variable voltage in output delivered to a resistive load.
Two Types of control:
1.ON-OFF type AC voltage Controller
2. Phase angle type AC voltage controller

4. **Write the average DC output voltage expression of three phase full converter.**

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi}\cos\alpha$$

5. **Specify the various types of PWM techniques commonly used in inverters.**
   - Single-pulse width modulation
   - Multiple-pulse width modulation
   - Sinusoidal-pulse width modulation

6. **Specify the important types of static VAR compensators.**
Thyristor controlled reactor (TCR)
Thyristor-switched capacitor (TSC)
Self Reactor (SR)
Thyristor controlled reactor – Fixed capacitor (TCR-FC)
Thyristor-switched capacitor – Thyristor controlled reactor (TSC-TCR)

7. **Define slip and Slip speed**

The **speed** at which the induction motor work is known as the **slip speed**. The difference between the synchronous **speed** and the actual **speed** of the rotor is known as the **slip speed**. Speed of the rotor of an **induction motor** is always less than its synchronous speed. It is usually expressed as a percentage of synchronous speed (Ns) and represented by the symbol 'S'.

AC Induction Motor Slip Formula

$$slip = \frac{(n_s - n)}{n_s} * 100$$

n_s – *synchronous speed in rpm*

n – *rotational speed in rpm*

8. **State the basic differences between VSI and CSI**

- VSI requires constant DC-link voltage, and generates AC voltages in the form of voltage pulses; CSI requires constant DC-link current, and generates AC currents in the form of current pulses.
- VSI requires DC-link capacitor and AC filter inductors; CSI requires DC-link inductor and AC filter capacitors.
- VSI is susceptible to leg short circuit fault and requires dead time in switching upper and lower switches; CSI is susceptible to leg open-circuit fault and requires overlap time in switching upper and lower switches.
- VSI is a buck inverter (magnitude of ac voltage is always smaller or equal to the dc voltage) but a boost rectifier; CSI is a boost inverter but a buck rectifier.

PART -B

9. **State the thyristor gate requirements.**

- Produce a gate signal of suitable magnitude and sufficiently short rise time
- Produce a gate signal of adequate duration
- Provide accurate firing control over the required range
- Provide accurate firing control over the required range
- Ensure that triggering does not occur from false signals or noise
- In AC applications, ensure that the gate signal is applied when the SCR is forward-biased
- In three phase circuits, provide gate pulses that are 120^{O} apart with respect to the reference point
- Ensure simultaneous triggering of SCRs connected in series or in parallel

10. **Explain the principle of On-Off control in AC voltage controller.**

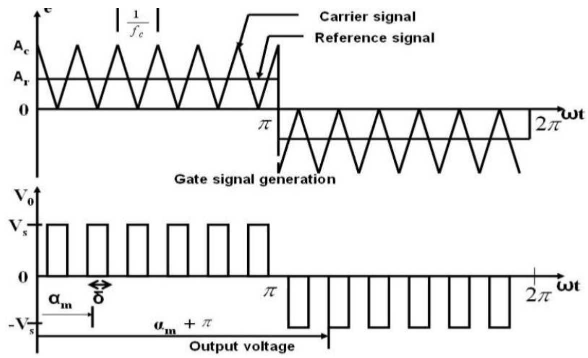
The on-off control is also called an integral cycle control. To avoid the fluctuations at the output the turning on and off operation should be fast. In integral cycle control, the switch is turned on for the certain number of complete cycle and the switch is turned off for the certain number of cycles. The integral cycle control is not very popular. Because it introduces sub-harmonics in line current. Integral cycle control is used for heating applications and speed control of AC motors.

11. **Explain the principle of phase control in AC voltage controller.**

By **controlling** the **phase angle** or the trigger **angle** 'α' (delay **angle**), the output RMS **voltage** across the load can be **controlled**. The trigger delay **angle** 'α' is defined as the **phase angle** (the value of ωt) at which the thyristor turns on and the load current begins to flow.

12. Explain multiple pulse width modulation.

In order to reduce the harmonic content, the **multiple PWM** technique is used, in which several **pulses** are given in each half cycle of output voltage. The frequency of reference signal sets the output frequency, fo, and the carrier frequency, fc, determines the number of pulses per half-cycle.



13. Briefly explain induction heating.

Induction heating is a non-contact heating process. It uses high frequency electricity to heat materials that are electrically conductive. Since it is non-contact, the heating process does not contaminate the material being heated. It is also very efficient since the heat is actually generated inside the workpiece. This can be contrasted with other heating methods where heat is generated in a flame or heating element, which is then applied to the workpiece. For these reasons Induction Heating lends itself to some unique applications in industry.

14. Define pull out torque.

Pull-out, or breakdown torque is the maximum torque the motor can produce at full rated voltage and frequency. If the motor is running and is loaded beyond the pull-out torque, it will “pull out” or stall.

15. Write notes on speed control by varying stator frequency and voltage

Whenever three phase supply is given to three phase induction motor rotating magnetic field is produced which rotates at synchronous speed given by

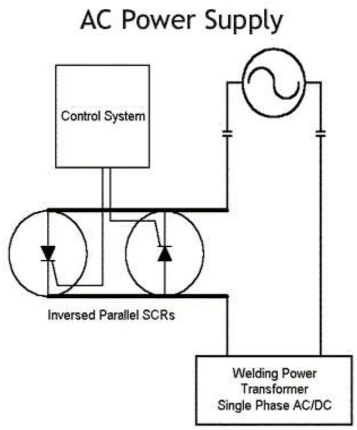
$$N_s = \frac{120f}{P}$$

In three phase induction motor emf is induced by induction similar to that of transformer which is given by

$$E \text{ or } V = 4.44\phi K.T.f \text{ or } \phi = \frac{V}{4.44KTf}$$

Where, K is the winding constant, T is the number of turns per phase and f is frequency. Now if we change frequency synchronous speed changes but with decrease in frequency flux will increase and this change in value of flux causes saturation of rotor and stator cores which will further cause increase in no load current of the motor . So, its important to maintain flux , φ constant and it is only possible if we change voltage. i.e if we decrease frequency flux increases but at the same time if we decrease voltage flux will also decease causing no change in flux and hence it remains constant. So, here we are keeping the ratio of V/f as constant. Hence its name is V/ f method.

16. Describe about electric welding.



The low frequency welding control utilizes an inverse parallel pair of Silicon Controlled Rectifiers (SCR) to control the output of the welding power transformer. SCRs are turned on by pulsing a gate with a voltage signal. The welding control uses predictive algorithms to determine the best point to pulse the gate of the SCRs during the half cycle of the alternating current supply. The SCRs are turned off only when the alternating current supply is below the threshold point called "minimum holding current". This occurs near the zero crossing point of the AC power supply.

PART - C

17.(a) Explain any two types of commutation circuits.

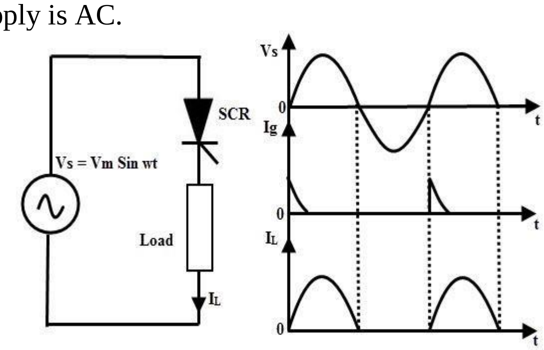
The reverse voltage which causes to commutate the SCR is called commutation voltage. The commutation methods are classified into two major types.

Those are 1) Forced commutation and 2) Natural commutation.

Natural Commutation

It happens only when the input is an AC Supply. If the SCR is connected to an AC supply, at every end of the positive half cycle the anode current goes through the natural current zero and also immediately a reverse voltage is applied across the SCR. These are the conditions to turn OFF the SCR.

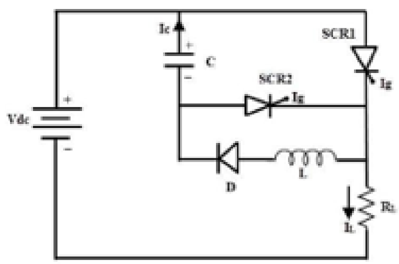
This method of commutation is also called as source commutation, or line commutation, or class F commutation. This commutation is possible with line commutated inverters, controlled rectifiers, cyclo converters and AC voltage regulators because the input supply is AC.



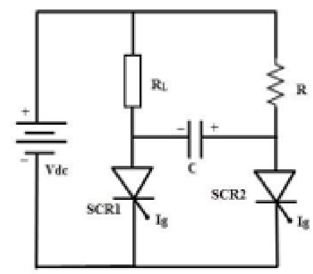
Forced Commutation

In case of DC circuits, there is no natural current zero to turn OFF the SCR. In such circuits, forward current must be forced to zero with an external circuit hence named as forced commutation. This commutating circuit consists of components like inductors and capacitors called as commutating components. These commutating components apply a reverse voltage across the SCR that immediately bring the anode current in the SCR to zero. Based on the zero current achievement forced commutation is classified into different types such as class A, B, C, D, and E.

Class D commutation



Class C commutation



(OR)

17.(b) Explain the operation of GTO.

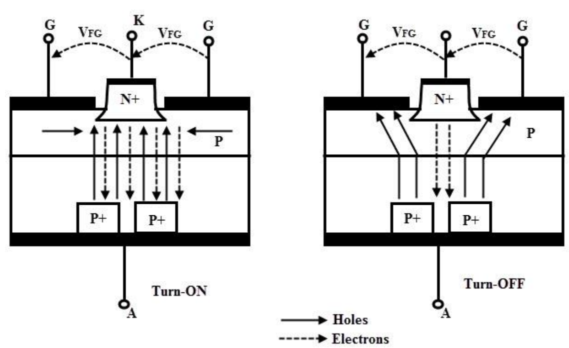
Principle of Operation

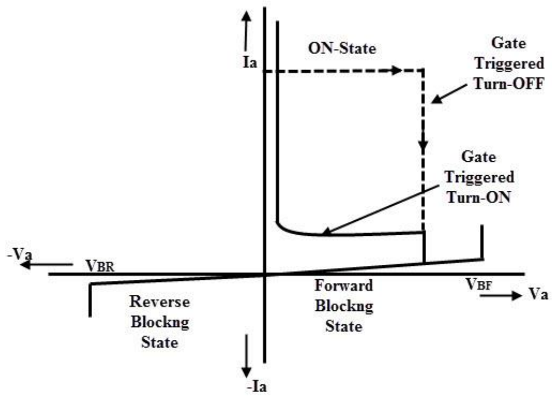
The turn ON operation of GTO is similar to a conventional thyristor. When the anode terminal is made positive with respect to cathode by applying a positive gate current, the hole current injection from gate forward bias the cathode p-base junction.

This results in the emission of electrons from the cathode towards the anode terminal. This induces the hole injection from the anode terminal into the base region. This injection of holes and electrons continuous till the GTO comes into the conduction state.

In case of thyristor, the conduction starts initially by turning ON the area of cathode adjacent to the gate terminal. And thus, by plasma spreading the remaining area comes into the conduction.

Unlike a thyristor, GTO consists of narrow cathode elements which are heavily interdigitated with gate terminal, thereby initial turned ON area is very large and plasma spreading is small. Hence the GTO comes into the conduction state very quickly.





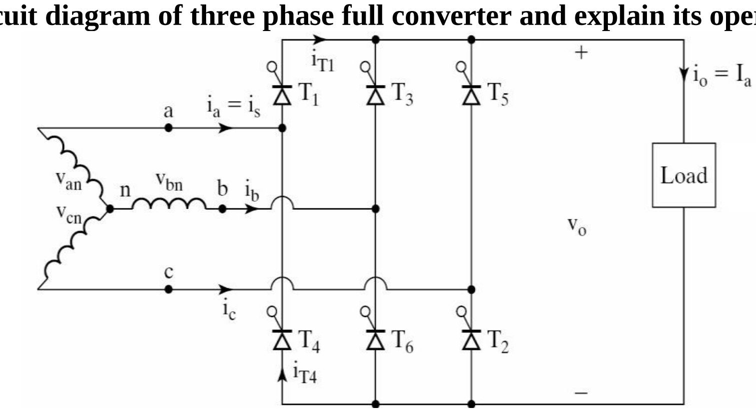
To turn OFF a conducting GTO, a reverse bias is applied at the gate by making the gate negative with respect to cathode. A part of the holes from the P base layer is extracted through the gate which suppress the injection of electrons from the cathode.

In response to this, more hole current is extracted through the gate results more suppression of electrons from the cathode. Eventually, the voltage drop across the p base junction causes to reverse bias the gate cathode junction and hence the GTO is turned OFF.

During the hole extraction process, the p-base region is gradually depleted so that the conduction area squeezed. As this process continuous, the anode current flows through remote areas forming high current density filaments. This causes local hot spots which can damage the device unless these filaments are extinguished quickly.

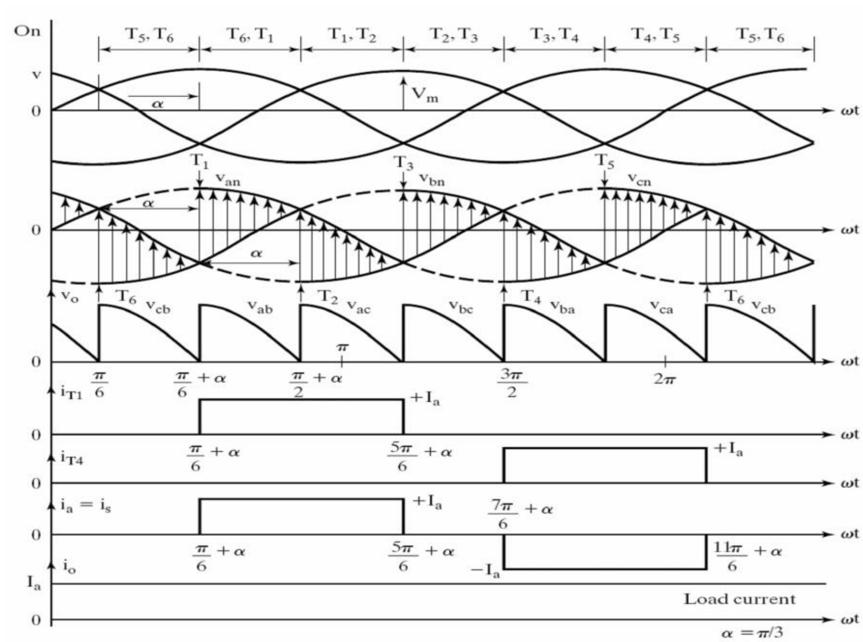
By the application of high negative gate voltage these filaments are extinguished rapidly. Due to the N base region stored charge, the anode to gate current continues to flow even though the cathode current is ceased. This is called a tail current which decays exponentially as the excess charge carriers are reduced by the recombination process. Once the tail current reduced to a leakage current level, the device retains its forward blocking characteristics.

18.(a) Draw the circuit diagram of three phase full converter and explain its operation.



Three phase full converter is a fully controlled bridge 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 operation is required. The figure shows a three phase full converter with high inductive load. This circuit is also known as three phase full wave bridge or a six pulse converter. The thyristors are triggered at an interval of $\pi/3$.

$$V_{dc} = \frac{3\sqrt{3}V_m}{\pi}\cos\alpha$$

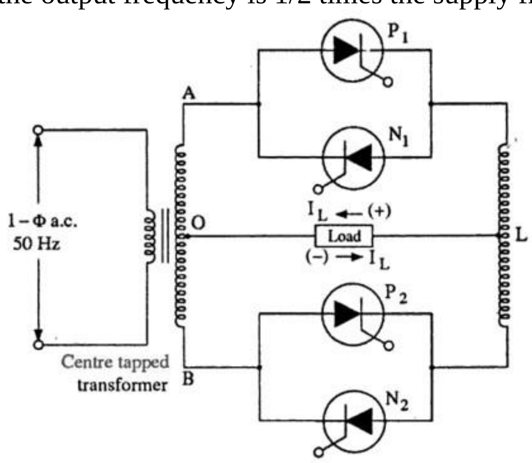


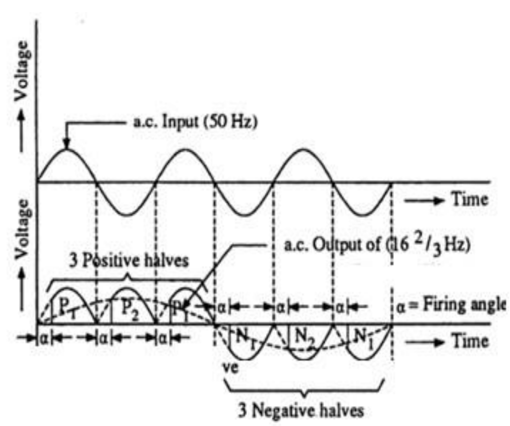
(OR)

18.(b) With the diagram, explain the operation single phase cyclo converter.

In a 1-φ Cycloconverter, the output frequency is less than the supply frequency. These converters require natural commutation which is provided by AC supply. During positive half cycle of supply, thyristors P1 and N2 are forward biased. First triggering pulse is applied to P1 and hence it starts conducting.

As the supply goes negative,P1 gets off and in negative half cycle of supply, P2 and N1 are forward biased. P2 is triggered and hence it conducts. In the next cycle of supply,N2 in positive half cycle andN1 in negative half cycle are triggered. Thus, we can observe that here the output frequency is 1/2 times the supply frequency.





19.(a) With the diagram, explain continuous conduction mode of buck boost converter.

The buck boost converter is a DC to DC converter. The output voltage of the DC to DC converter is less than or greater than the input voltage. The output voltage of the magnitude

depends on the duty cycle. These converters are also known as the step up and step down transformers and these names are coming from the analogous step up and step down transformer. The input voltages are step up/down to some level of more than or less than the input voltage.
For the step up mode, the input voltage is less than the output voltage (Vin < Vout). It shows that the output current is less than the input current. Hence the buck booster is a step up mode.

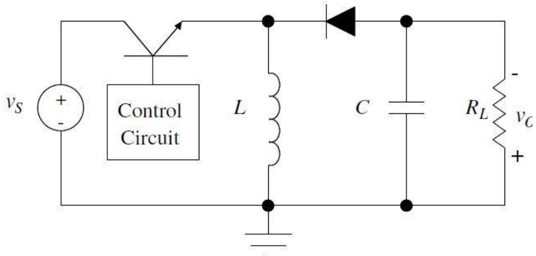
Vin < Vout and Iin > Iout

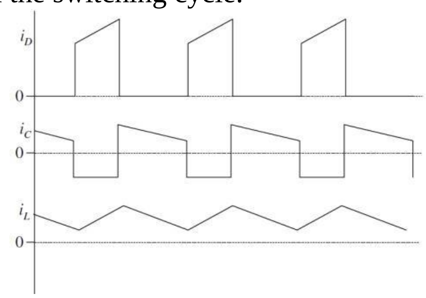
In the step down mode the input voltage is greater than the output voltage (Vin > Vout). It follows that the output current is greater the input current. Hence the buck boost converter is a step down mode.

Vin > Vout and Iin < Iout

Continuous Conduction Mode

In the continuous conduction mode the current from end to end of inductor never goes to zero. Hence the inductor partially discharges earlier than the switching cycle.

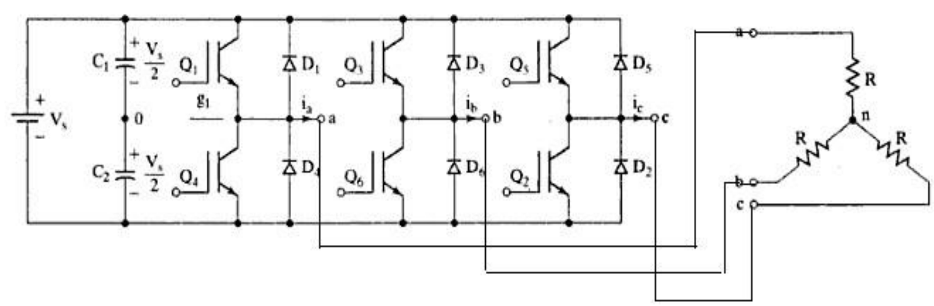


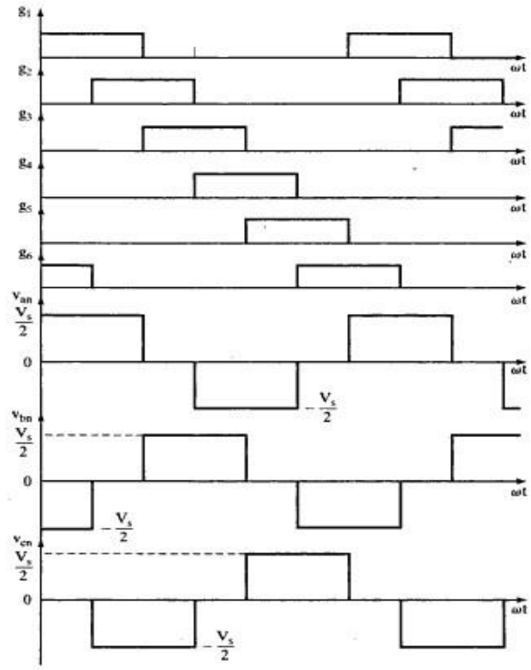


(OR)

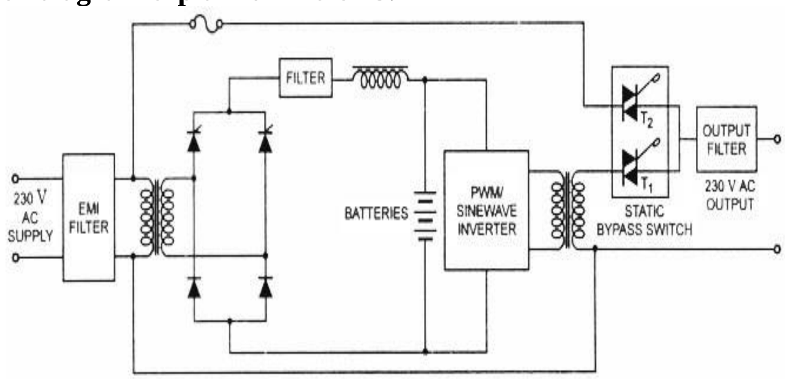
19.(b) With diagram, explain 120° conduction mode of three phase inverter.

In this type of control, each thyristor (or Transistor) conducts for 120°. Only two thyristors remain "ON" at any instant of time. Three-phase inverters are normally used for high-power applications. The gating signals of single-phase inverters should be advanced or delayed by with respect to each other in order to obtain three phase balanced (fundamental) voltages. The transformer primary windings must be isolated from each other, while the secondary winding may be connected in wye or delta. The transformer secondary is normally connected in wye to eliminate triple harmonics (n = 3, 6, 9…) appearing on the output voltages. When transistor Q1 is switched on, terminal a is connected to the positive terminal of the dc input voltage. When transistor Q4 is switched on, terminal a is brought to the negative terminal of the dc source.





20.(a)(i) With the block diagram explain online UPS.

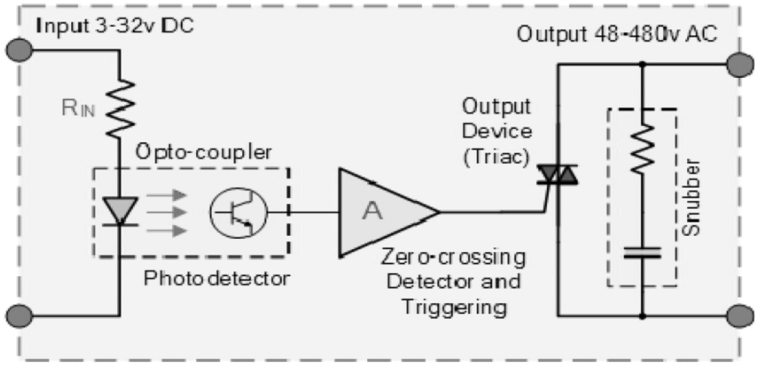


In case of On-line UPS, the battery-operated inverter works continuously whether the mains supply is present or not. Triac T_1 is on for all the times while Triac T_2 has been provided to bypass the UPS inverter, only when a fault develops in the UPS inverter. When the mains supply fails, the UPS supplies power from the batteries. However, once the mains power resumes, the batteries will get charged again. The switching times of these supplies is considered to be zero. Usually sealed maintenance free batteries are used and the running time of the inverter is low (approximately 10 to 30 minutes).

20.(a)(ii) With a diagram, explain AC solid state relay.

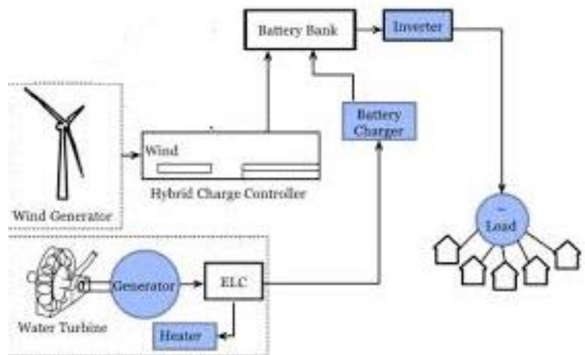
The AC type Solid State Relay turns "ON" at the zero crossing point of the AC sinusoidal waveform, prevents high inrush currents when switching inductive or capacitive loads while the inherent turn "OFF" feature of Thyristors and Triacs provides an improvement over the arcing contacts of the electromechanical relays.

Resistor-Capacitor (RC) snubber network is generally required across the output terminals of the SSR to protect the semiconductor output switching device from noise and voltage transient spikes when used to switch highly inductive or capacitive loads. In most modern SSR's this RC snubber network is built as standard into the relay itself reducing the need for additional external components.



(OR)

20.(b) With a block diagram, explain wind/ hydro generator.

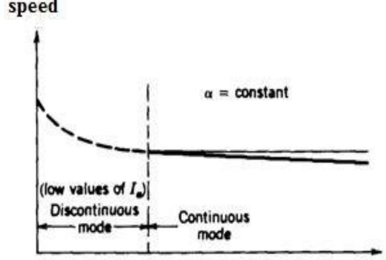


The setup essentially works as a hydro pump station. When electricity is needed, water flowing downhill from the reservoirs will power the hydro plant. When the energy supply is high, the hydro plant will pump the water back up the hill to the reservoirs and will act as the giant battery. The hydro plant will benefit from this arbitrage, making power when the price is high and using power when the price is low, while complementing the wind farm. The combination of the two power sources (which will work in parallel to each other) will ensure that electricity is always flowing from the plant.

For it to work, the wind turbines must sit at the top of a hill, and there must be room in the valley for a man-made lake.

21.(a)(i) Explain the effect of discontinuous armature current.

In line frequency controlled converters, the armature current may be discontinuous at light load condition. For a fixed firing angle α, the discontinuous current causes the output voltage to go up. This voltage rise causes the motor speed to rise at low armature current. With a continuously flowing armature current, the voltage drop is due to IaRa and commutation voltage drop in ac side inductance. These effects results in poor regulation under on open loop operation.

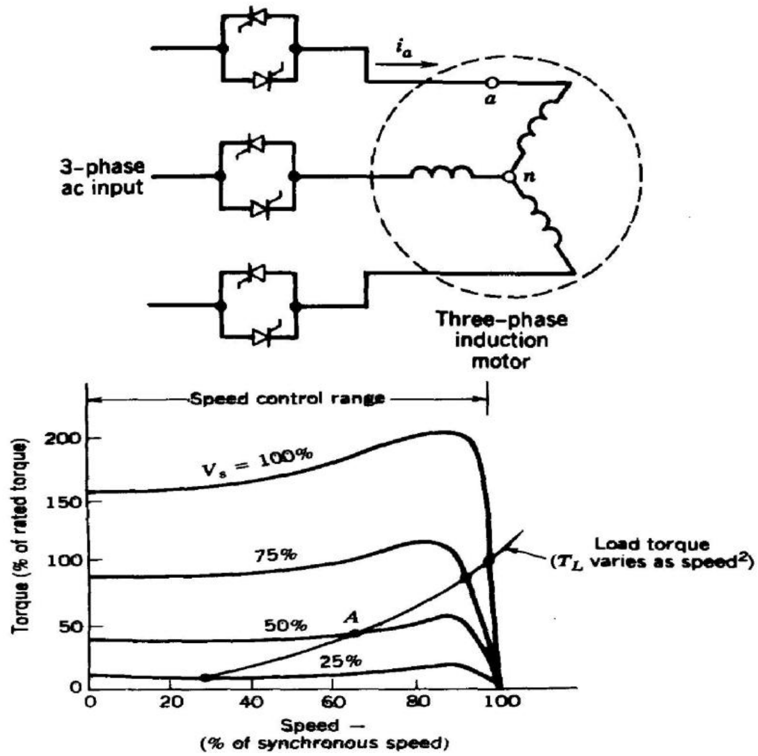


21.(a)(ii) Explain the reduced voltage starting of induction motors.

In induction motor, the torque is proportional to square of the supply voltage.

$$T = kV_s^2$$

Based on equation, Figure shows the motor speed-torque curves at various values of V_s. The load torque of a fan or pump-type load varies approximately as the square of the speed. Therefore a small torque is required at low speeds, and as figure shows, the speed can be controlled over a wide range.



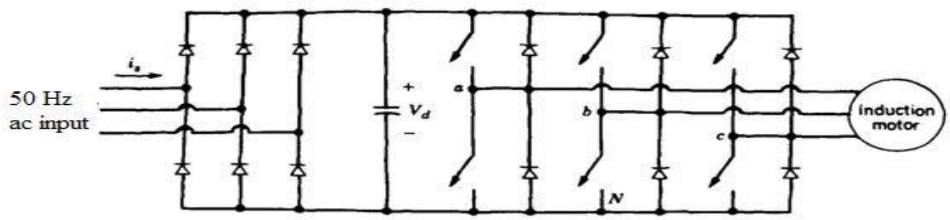
The circuit used for stator voltage control can also be used in constant-speed drives to reduce the motor voltage and hence current at start-up. If the torque developed at reduced voltage is sufficient to overcome the load, the motor accelerates. During starting, the firing angles of the thyristors are high. During the steady state operation, each thyristor conducts for an entire half cycle. Then, these thyristors are shorted by mechanical contactors to eliminate the power loss in the thyristors.

(OR)

21.(b) With the diagram, explain variable frequency PWM-VSI drives.

Figure (a) shows a schematic of PM-VSI drive, assuming a three phase utility input. PWM inverter controls both the magnitude and frequency of the voltage output. Therefore, at the input, an uncontrolled diode bridge rectifier is generally used.

One possible method of generating the inverter switch control signal is by comparing three sinusoidal control voltages (at the desired output frequency and proportional to the output voltage magnitude) with a triangular waveform at a selected switching frequency as shown in figure (b).



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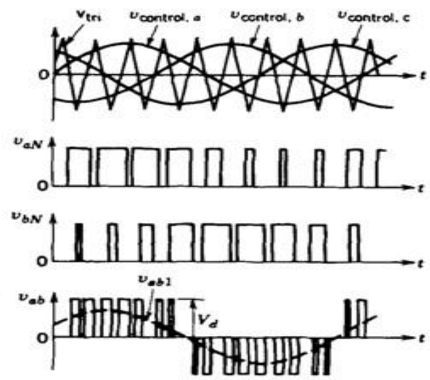

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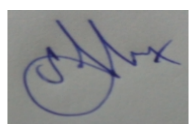

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