W'08 : 3 AN : EL 412/422/432 (1470)

POWER ELECTRONICS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A**, ANY TWO *from* **Group B** *and* ALL *from* **Group C**.

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Draw the layer structured diagram and explain the working principle of the following devices : 5 x 3

(*i*) IGBT

(*ii*) MOSFET

(*iii*) Bipolar Junction Transistor (BJT).

(*b*) Diode half-wave rectifier supplies a resistive load of 100 Ω from a 100 V a.c. RMS voltage source. Calculate the (*i*) d.c. output voltage, (*ii*) d.c. (average) load current, (*iii*) a.c. (RMS) load current, and (*iv*) power input to rectifier. The diode is a resistance of 5 Ω during conduction state. 5

2. (*a*) Draw the cross-sectional structure of a general purpose thyristor. Explain latching and holding current of SCR. 8

(*b*) Explain the two transistor analogy of thyristor. Also, explain the gate characteristics of thyristor. 8

(*c*) What is a snubber circuit? Why is it used? Explain functional requirement of it in power electronic converter circuits. 4

3. (*a*) Explain the need of commutation in thyristor circuits. What are different methods of commutation? 4

(*b*) Explain the merits and demerits of self-commutation of SCR and its other methods of commutation. 8

(*c*) Describe the working of single-phase full wave rectifier with pure inductive load. Draw the load voltage and line current waveforms. 8

4. (*a*) What is the basic principle of choppers? Explain the classification of choppers. Also, describe the working of step-up and step-down choppers. 10

(*b*) In an ideal type A chopper circuit, the supply voltage is 250 V, chopping frequency 3000 Hz, duty cycle 0·5, load resistance $R_L = 5\,\Omega$, load inductance $L_L = 5$ mH. If the load has a back emf of 100 V, find the average output current of chopper. Also, find the maximum and minimum values of steady state output current and average values of source current. 10

Group B

5. (*a*) Explain the working principle of single-phase half wave thyristor converter with R-L load. Draw the various waveforms. 8

(*b*) A single-phase full bridge converter delivers power to a resistive load R for a.c. source voltage, V_s. Show that average output voltage, V_0, is given by

$$V_0 = (\sqrt{2}\ V_s/\pi)(1 + \cos\alpha)$$

Sketch the time variation of various voltage and currents. 8

(*c*) What do you understand by UPS? Explain its working using a block diagram. 4

6. (*a*) What is an inverter? List a few applications of inverter. 4

(*b*) Describe the working of single-phase series inverter with appropriate circuit and waveforms. 8

(*c*) Explain the voltage source inverter in 120° mode with suitable circuit and waveforms. 8

7. (*a*) Draw the circuit diagram to explain the separation of six-pulse cycloconverter. What is the output voltage wave shape? 8

(*b*) Describe the speed control of d.c. motor, using chopper, with neat schematic diagrams and waveforms. 8

(*c*) Explain the principle of phase control in thyristor converter. 4

8. (*a*) Write a short note on the speed control of 3-ϕ induction motor using frequency control methods. 8

(*b*) A separately excited d.c. motor, operating from a single-phase half controlled bridge at a speed of 1400 rpm, has an input voltage of 330 sin 314 t and a back emf of 80 V. The SCRs are fired symmetrically at $\alpha = 30°$ in every half cycle and the armature has a resistance of 4Ω. Calculate the average armature current and the motor torque. 6

(*c*) A 220 V, 1000 rpm, 60 A separately excited d.c. motor has an armature resistance of 0·1Ω. It is fed from a single-phase full bridge converter with an a.c. source voltage of 230 V, 50 Hz. Assuming continuous conduction, compute firing angle for rated motor torque at 600 rpm. 6

Group C

9. Choose the *correct* answer for the following: 1 x 20

(*i*) As compared to power MOSFET, a BJT has

(*a*) lower switching losses but higher conduction loss

(*b*) higher switching losses and higher conduction loss

(*c*) higher switching losses but lower conduction loss

(*d*) lower switching losses and lower conduction loss.

(*ii*) An IGBT has three terminals called

(*a*) collector, emitter and base

(*b*) drain, source and base

(*c*) drain, source and gate

(*d*) collector, emitter and gate.

(*iii*) A single-phase one-pulse diode rectifier is feeding an $R-L$ load with free wheeling diode across the load, for conduction angle β, the main diode and free wheeling diode would conduct for

(*a*) $\pi, \pi-\beta$

(*b*) $\pi, \beta-\pi$

(*c*) β, π

(*iv*) When anode is positive with respect to cathode in an SCR, the number of blocked p-n junction is

(*a*) 1

(*b*) 2

(*c*) 3

(*d*) 4.

(*v*) In a thyristor, holding current is

(*a*) more than latching current I_L

(*b*) less than I_L

(*c*) equal to I_L

(*d*) very small.

(*vi*) For an SCR, *di/dt* protection is achieved through the use of

(*a*) R in series with SCR

(*b*) R-C in parallel with SCR

(*c*) L in series with SCR

(*d*) R-C in series with SCR.

(*vii*) The function of snubber circuit connected across an SCR is to

(*a*) suppress dv/dt

(*b*) increase dv/dt

(*c*) decrease di/dt

(*d*) keep transient overvoltage constant.

(*viii*) In a single-phase one pulse circuit with R_L load and a free wheeling diode, extinction angle β is less than π for a firing angle α. The SCR and free wheeling diode would conduct, respectively for

(*a*) $\pi-\alpha$, β

(*b*) $\beta-\alpha$, $\pi-\alpha$

(*c*) $\beta-\alpha$, 0

(*d*) $\beta-\alpha$, α.

(*ix*) In a single-phase semi-converter for continuous conduction, each SCR conducts for

(*a*) α

(*b*) π

(*c*) $\alpha+\pi$

(*d*) $\pi-\alpha$.

(*x*) For a three-phase, six-pulse diode rectifier, the average output voltage is

(*a*) $3\sqrt{2}\ V_m/\pi$

(*b*) $3\ V_m/\pi$

(*c*) $3\sqrt{3}\ V_m/2\pi$

(*d*) $3\sqrt{3}\ V_m/\pi$.

(*xi*) A step-up chopper has V_s as the voltage and α the duty cycle. The output voltage for this chopper is given by

(*a*) $V_S(1 + \alpha)$

(*b*) $V_S/(1 - \alpha)$

(*c*) $V_S(1 - \alpha)$

(*d*) $V_S/(1 + \alpha)$.

(*xii*) In single-pulse modulation of PWM inverters, fifth harmonics can be eliminated, if pulse width is equal to

(*a*) 30°

(*b*) 72°

(*c*) 36°

(*d*) 108°.

(*xiii*) A three-phase to three-phase cycloconverter requires

(*a*) 18 SCRs for three-pulse device

(*b*) 18 SCRs for six-pulse device

(*c*) 36 SCRs for three-pulse device

(*d*) 9 SCRs for six-pulse device.

 (*Continued*)

(*xiv*) In a single-phase semi-converter, if output voltage has peak and average values of 325 V and 133 V, respectively, the firing angle is

(*a*) 40·4°

(*b*) 140·3°

(*c*) 73·40°

(*d*) 80·5°.

(*xv*) In type *A* chopper, source voltage is 100 V d.c. on-period 100 μs, off-period 50 μs and load RLE consists of $R = 2\Omega$, $L = 5$ mH, $E = 10$ V. For continuous conduction, average output voltage and average output current is

(*a*) 40 V, 15 A

(*b*) 66·6 V, 28·3 A

(*c*) 60·2 V, 25·1 A

(*d*) 40 V, 20 A.

(*xvi*) In a single-phase CSI, if frequency of output voltage is f Hz, then frequency of voltage input to CSI is

(*a*) f

(*b*) $2f$

(*c*) $f/2$

(*d*) $3f$.

(*xvii*) For a pulse transformer, the material used for its core and the possible turn-ratio are

(*a*) ferrite; 20 : 1

(*b*) laminated iron; 1 : 1

(*c*) ferrite; 1 : 1

(*d*) laminated iron; 20 : 1.

(*xviii*) In d.c. motor drive, the d.c. motor is equivalent to load

(*a*) R

(*b*) RL

(*c*) RLE

(*d*) None of the above.

(*xix*) In regenerative braking control,

(*a*) motor acts as motor

(*b*) motor acts as a generator

(*c*) motor acts as R load

(*d*) None of the above.

(*xx*) In an UJT, with V_{BB} as the voltage across two base terminals, the emitter potential at peak point is given by

(*a*) ηV_{BB}

(*b*) ηV_D

(*c*) $\eta V_{BB} + V_D$

(*d*) $\eta V_D + V_{BB}$.

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Group A

1. (*a*) What do you mean by an ideal rectifier? How does it differ from an actual one? When are the rectifiers required to be connected in series and in parallel? 1 + 1 + 2

(*b*) Describe clearly the various techniques used in practice to take corrective action against unequal distribution of forward currents between the rectifiers connected to a load in parallel. 4

(*c*) A full-wave 1-ϕ rectifier circuit, using two diodes as shown in *Fig.* 1, feeds into a load resistance of 3 kΩ.

(Turn Over)

Assume the practical diode ≈ 0 and the secondary transformer voltage to C-T to be 300 V. Calculate the (*i*) d.c. load current, (*ii*) d.c. current in each diode, (*iii*) a.c. voltage across each diode, (*iv*) d.c. output power, (*v*) % regulation, and (*vi*) % efficiency. 2 × 6

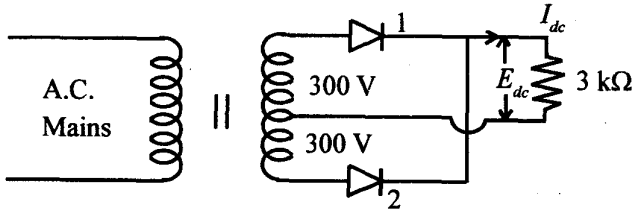

Fig. 1

2. (*a*) Draw the circuit diagram and voltage output waveform of a 3-ϕ full-wave rectifier assembly and explain its operation. What is E_{dc} in terms of rms input voltage per phase and ideally E_{dc} is not a function of VA rating? Calculate the approximate % ripple present in the unfiltered output voltage. What is the fundamental ripple frequency when the supply frequency is 60 Hz? 5 + 5

(*b*) Rectifiers, with PIV rating of 500 V and a current rating of 30 A, are available. Determine whether these would be better used in a 1-ϕ or a 3-ϕ full-wave bridge circuit. 10

3. (*a*) A 1-ϕ half-wave uncontrolled rectifier supplies an R-L load along with a free-wheeling diode. Draw voltage waveforms across the load, the rectifier, and the free-wheeling diode. Also, calculate the average and rms load currents as well as average and rms load voltages. 12

(*b*) An electromagnetic vibrator coil, having an inductance of 80 mH and negligible resistance, is connected to a 1-ϕ, 230 V, 50 Hz a.c. supply through a half-wave uncontrolled rectifier. Calculate rms and average values of coil current as well as the peak diode current. What is % increase in the rms value of the rectified load current as compared to rms value of the load current without the rectifier? 8

4. (*a*) What is a snubber circuit? What does it do in a thyristor operated controller? Calculate values of the snubber circuit components for a thyristor; given $(di/dt)_{max} = 40\ A/\mu s$ and $(dv/dt)_{max} = 100\ V/\mu s$ and supply voltage is equal to 230 V, 50 Hz. Assume suitable values for any other data, if necessary. 2 + 2 + 4

(*b*) With reference to V-I characteristics of a thyristor for different gate currents, define its 'holding current', 'latching or pick-up current' and 'repetitive peak inverse voltage' ratings. From the two-transistor analogy, explain the 'OFF' and 'ON' conditions of a thyristor. What are the mechanisms and methods used to 'turn-on' and 'turn-off' a thyristor? 6 + 6

Group B

5. (*a*) What are the various 1-ϕ a.c. phase-control techniques applied to regulate power into a load? Explain the techniques showing only power-control circuits. The details of firing and protection circuits need not be drawn. 12

(*b*) Calculate the rms voltage output of a 1-ϕ full-wave half-controlled a.c. phase-controller operated from a 230 V, 50 Hz mains supply when the thyristors are fired at an angle of 90° and the load is resistive. 5

(*c*) Calculate the output voltage in rms value of an 'on-off' controller using 1-ϕ, 230 V, 50 Hz supply when the 'on-time' is 16 cycles and the 'off-time' is 6 cycles. 3

6. (*a*) With the help of suitable diagrams, discuss the operation of a series inverter. Derive a performance equation for the basic series inverter circuit. How can the drawbacks of a series inverter be removed? Discuss with the help of diagrams. 6 + 6

(*b*) A 1-ϕ half-wave bridge inverter feeds a resistive load of $R = 10\,\Omega$. The d.c. voltage of the inverter is given as 200 V. Determine (*i*) RMS value of the fundamental component of output voltage, (*ii*) output power, (*iii*) average current of each thyristor, and (*iv*) PIV of each thyristor. 8

7. (*a*) Derive the expressions for average and rms load voltage of 1-ϕ full-wave fully controlled thyristorized bridge rectifier with inductive load. The average voltage available from a 1-ϕ full-wave fully controlled bridge rectifier is 200 V with a firing angle of 40° when the load is inductive. Calculate the rms load voltage. 8 + 6

(*b*) A 3-ϕ full-converter is operated from a 3-ϕ, 415 V, 50 Hz supply. It is delivering a constant load current of 45 A at a firing angle of 30° to a highly inductive load. Determine (*i*) average output voltage, (*ii*) average power output, (*iii*) rms and average values of thyristor current, and (*iv*) PIV requirement of each thyristor. 6

8. (*a*) (*i*) How are the choppers classified? Show the quadrants of operation of different choppers. Draw their circuits and briefly explain their working. 8

(*ii*) Explain, with a diagram, how a step-up chopper works. 6

(*b*) A separately excited d.c. motor has a rated speed of 1000 rpm, rated current of 25 A and an armature resistance of 0·4 Ω. The supply voltage is 220 V d.c. It is desired to control the speed using a d.c. chopper. (*i*) Find the duty cycle of the chopper so that the motor may operate at 600 rpm and develop the rated torque, and (*ii*) find the duty cycle, if the motor operates at 600 rpm and develops half the rated torque. 6

Group C

9. Choose the *correct* answer for the following: 2 × 10

(*i*) When a semiconductor diode is damaged by excessive forward current, then the damaged diode will show

(*a*) very high resistance in both the directions

(*b*) high in one and low resistance in the other direction

(*c*) very low resistance in both the directions

(*d*) either (*a*) or (*c*) above.

(*ii*) What would be the maximum reverse voltage that each rectifier must withstand in a full-wave C-T transformer circuit, if the rms value of the voltage across one half of the transformer secondary is 20 V?

(*a*) 20 V

(*b*) 28·2 V

(*c*) 40 V

(*d*) 56·4 V.

(*iii*) When a semiconductor rectifier is damaged by excessive reverse voltage, then the damaged rectifier will show

(*a*) very high resistance in both the directions

(*b*) high in one and low resistance in the other direction

(*c*) very low resistance in both the directions

(*d*) either (*a*) or (*c*) above.

(*iv*) An RC snubber circuit is used to protect a thyristor against

(*a*) failure to turn on

(*b*) switching transients

(*c*) false triggering

(*d*) failure to commutate.

(*v*) If a 1-ϕ converter is fed by a source having an inductance, L, and the load current is I_0, then the decrease in output voltage due to overlap is

(*a*) $\omega L I_0 / 3\pi$

(*b*) $\omega L I_0 / 2\pi$

(*c*) $\omega L I_0 / \pi$

(*d*) $\omega L I_0 / 4\pi$.

(*vi*) In a 1-ϕ dual converter, r_1 and r_2 are firing angles of two converters, then

(*a*) $r_1 + r_2 = \pi$

(*b*) $r_1 - r_2 = \pi/2$

(*c*) $r_1 + r_2 = \pi/2$

(*d*) $r_1 - r_2 = \pi$.

(*vii*) In a series inverter, the commutating elements

(*a*) do not carry the load current

(*b*) carry 50% of the load current

(*c*) carrry the full load current

(*d*) Any one of the above.

(*viii*) (*A*) A half-bridge inverter needs a 3-wire d.c. supply

(*B*) A half bridge inverter does not need a 3-wire d.c. supply

(*C*) A full-bridge inverter needs a 3-wire d.c. supply

(*D*) A full bridge inverter does not need a 3-wire d.c. supply.

Select which ones of the above are correct.

(*a*) (*A*) and (*B*)

(*b*) (*B*) and (*C*)

(*c*) (*C*) and (*D*)

(*d*) (*D*) and (*A*).

(*ix*) The p.f. at input terminals of a cycloconverter is generally

(*a*) high and lagging

(*b*) high and leading

(*c*) low and lagging

(*d*) low and leading.

(*x*) A bridge type 1-ϕ cycloconverter changes the frequency from f to $f/3$; then one-half of the output contains

(*a*) three half-waves of input

(*b*) three full-waves of input

(*c*) six half-waves of input

(*d*) six full-waves of input.

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Group A

1. (*a*) Define and distinguish between latching current and holding current of SCR. 5

(*b*) For the power circuit, shown in *Fig.* 1 , following data are given :

$V_{CC} = 100\,V$, $R_C = 10$ ohms, $V_{CE\,sat} = 1\,V$, $V_{BE\,sat} = 1{\cdot}5\,V$, $B = 9$, $V_B = 9\,V$.

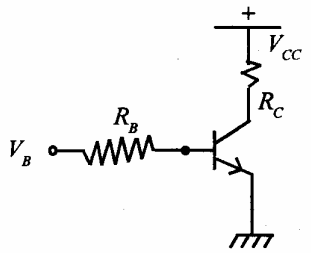


Fig. 1

With an overdrive factor of 2·5, find the required value of R_B. 5

(*c*) Define and compare d.c. triggering and pulse-triggering of a SCR. Give typical applications. 5

(*d*) What is a GTO? Briefly explain its operation. 5

2. (*a*) Compare transistor and SCR for inverter applications. Suggest a suitable device for domestic inverter. 4

(*b*) For a three-phase full-wave bridge rectifier, the respective phase-voltages are given below :

$$V_R = E_m \sin \theta$$
$$V_y = E_m \sin (\theta - 120°)$$
$$V_B = E_m \sin (\theta - 240°).$$

Draw the output voltage waveform and derive an expression for average output voltage. 8

(*c*) The junction structure of a two terminal device is PN PNP. Give its V-I characteristics and applications. 4

(*d*) Define and compare natural and forced commutation in SCRs. 4

3. (*a*) What is a UJT? Define interbase-resistor and intrinsic stand-off ratio. Give typical application. 4

(*b*) Using two transistor analogy, explain the operation of a thyristor. 6

(*c*) The forward voltage drop of a power diode is $V_D = 1{\cdot}0$ V, at the diode current of 200 A. Assume the emission coefficient $\eta = 2$ and the thermal voltage $V_T = 25{\cdot}7$ mV, find the reverse-saturation current. 5

(*d*) Briefly explain the operation of a class-B turn-off using LC circuit. Give typical application. 5

4. (*a*) Define and compare linear and switching mode regulators. 4

(*b*) A half-controlled rectifier carries an average current of 60 A. It is mounted on a heat sink. At this current, the manufacturer's curve for 180° conduction specifies 100 W dissipation. If the maximum case temperature is not to exceed 100°C at an ambient of 60°, what should be the thermal resistance from the case-to-ambient? 4

(*c*) Define *dv/ dt* rating of a SCR. How snubber circuit controls applied '*dv/ dt*' to SCR? 4

(*d*) What is a step-up chopper. Briefly explain the operation and derive an expression for the output voltage. 8

Group B

5. (*a*) Define rectification and inversion mode in a full-wave controlled rectifier with *R* - *L* load. 4

(*b*) Define a dual-converter. How can it be used to realize a single-phase variable frequency a.c. source? 6

(*c*) A half-wave converter is required to give an average output voltage of 30 V across a resistive load of 6 ohms. Assume 230 V/50 Hz a.c. supply. Calculate trigger angle α and output peak current. 4

(*d*) Briefly explain the operation of a typical complementary commutated thyristor inverter. 6

6. (*a*) For the circuit, shown in *Fig*.2, derive an expression for the average output voltage :

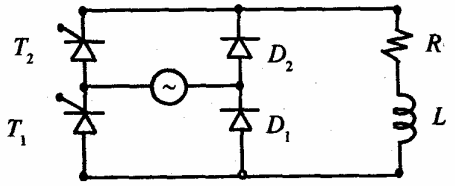


Fig. 2

Also, draw the voltage and current waveforms of thyristors T_1 and T_2. 6

(*b*) Define and compare voltage source and current source inverters. Briefly explain the operation of a single-phase current source inverter. 8

(*c*) Compare dynamic and regenerative breaking of a d.c. motor. Briefly explain the operation of a regenerative scheme without circulating currents. 6

7. (*a*) Compare semi-controlled and fully-controlled rectifiers. 4

(*b*) Briefly explain the principle of *v/f* control for induction motors. How PWM achieves *v/f* control? 6

(*c*) A single-phase half-wave converter with resistive load has following data :

Delay angle = 45°, $R = 5$ ohms

Assume 230 V/50 Hz a.c. supply. Calculate the power factor. 4

(*d*) What is a series inverter? Briefly describe its operation with waveforms. 6

8. (*a*) Compare a.c. and d.c. drives. Also, give their typical applications. 4

(*b*) A 230 V, 50 Hz half-wave controlled converter is triggered at an angle of 45° and the load current extinguishes at an angle of 220°. Find the average output voltage and comment on the nature of load. 4

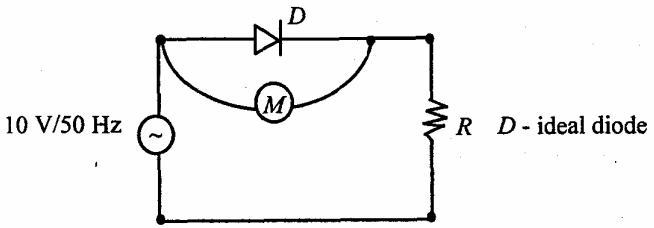
(*c*) Briefly explain the operation of a auxiliary commutated thyristor inverter. How is commutating capacitor selected? 6

(*d*) Write a note on 12-pulse converters giving the typical application. 6

Group C

9. Choose the *correct* answer for the following : 2x10

(*i*) An ideal moving-iron voltmeter M will read in the circuit shown below :

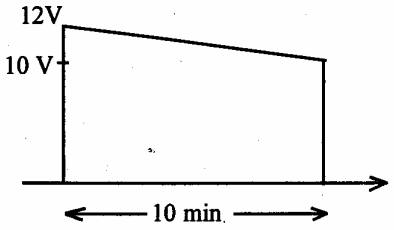


(*a*) 7·07 V
(*b*) 12·24 V
(*c*) 14·14 V
(*d*) 20 V.

(*ii*) A d.c. voltage source is connected across a series R, L, C circuit. Under steady-state conditions, the applied d.c. voltage drops entirely across

(*a*) R - only
(*b*) L - only
(*c*) C - only
(*d*) R and L combination.

(*iii*) A fully charged mobile phone with a 12 V battery is good for a 10 min talk-time. Assume that during the talk-time the battery delivers a constant current of 2 A and its voltage drops linearly from 12 V to 10 V as shown below. How much energy does the battery delivers during this talk-time?



(*a*) 220 J
(*b*) 12 kJ
(*c*) 13·2 kJ
(*d*) 14·4 kJ.

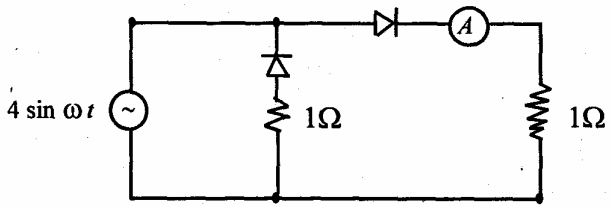
(*iv*) Which one of the following statement is true for an ideal power diode?

(*a*) Forward voltage-drop is zero and reverse saturation current is non-zero
(*b*) Reverse-recovery time is non-zero and reverse saturation current is zero
(*c*) Forward voltage drop is zero and reverse recovery time is zero
(*d*) Forward voltage drop is non-zero and reverse recovery time is zero.

(*v*) In a MOSFET, the threshold-voltage refers to

(*a*) drain-to-source voltage at which drain-to-source current is zero
(*b*) gate-to-source voltage at which gate-to-source current is zero
(*c*) drain-to-source voltage at which gate-to-source current is zero
(*d*) gate-to-source voltage at which drain-to-source current is zero.

(*vi*) For the circuit shown below, assume that the diodes are ideal and the ammeter is an average indicating meter with zero internal resistance. The ammeter reading is



(*a*) $4/\pi$ *A*
(*b*) $8/\pi$ *A*
(*c*) $4/\sqrt{2}$ *A*
(*d*) $8/\sqrt{2}$ *A*.

(*vii*) Which one of the following statement is not true?

(*a*) For SCRs to be in the conduction state, the forward anode current must be greater than latching current
(*b*) When SCRs are in conduction state, they can be turned off by applying a suitable gate pulse
(*c*) When avlanche breakdown takes place, SCRs enter into conduction
(*d*) For SCRs to be in the forward blocking state, the forward anode current must be lower than holding current.

(*viii*) Two single phase inverters, one half-bridge and the other full-bridge, operating with equal input voltages, deliver power to identical loads. The ratio of power delivered for full-wave inverter to half-bridge inverter is

(*a*) 4
(*b*) 2
(*c*) $\sqrt{2}$
(*d*) $1/\sqrt{2}$.

(*ix*) Which one of the following statement is true for d.c. switched-mode power supply?

(*a*) It cannot provide isolation between input and output
(*b*) It can remove ripple as in linear regulator
(*c*) It offers negative input resistance
(*d*) It operates at a.c. mains frequency.

(*x*) The unit of (q/K_T) is

(*a*) *V*
(*b*) V^{-1}
(*c*) Joules
(*d*) Joules/Kelvin.

S'10 : 3 AN : EL 412/422/432 (1470)

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Group A

1. (*a*) Discuss briefly the voltage commutation and current commutation techniques used for the commutation of thyristors. 6

(*b*) Compare and contrast an IGBT with a power transistor. 4

(*c*) What are (dV/dt) and (di/dt) ratings of a thyristor? Explain the methods of measurements of these ratings. 6

(*d*) A thyristor has half-cycle surge current rating of 3000 A for 50 Hz supply. Calculate its one cycle surge current rating and $(i^2 t)$ rating. 4

2. (*a*) A diode, used as a half-wave rectifier, has a forward resistance of 500 ohms. If the secondary voltage is 400 sin 314 *t*, calculate (*i*) I_m, I_{rms}, and I_{av}, (*ii*) d.c. output voltage, (*iii*) a.c. power input and d.c. power output for a load of 3·4 kΩ, and (*iv*) transformer utilization factor. 8

(*b*) Explain why the load voltage for an *m*-phase rectifier, in which the leakage inductance of the transformer has a significant value, is less than that for a rectifier with a negligible leakage inductance. 4

(*c*) Explain how unwanted harmonics can be eliminated using the selective harmonic elimination method. What are its merits and demerits for improving the power factor? 4

(*d*) Discuss why a 'zigzag' type of secondary winding is preferred for a three-phase transformer with a star primary for a three-phase half-wave rectifier. Support your argument with suitable waveforms. 4

3. (*a*) What is a PUT ? How does it differ from UJT ? Discuss basic UJT (2N 2646) relaxation oscillator circuit operation and explain V_A - I_A characteristics of this oscillator. 5

(*b*) Design an UJT relaxation oscillator using UJT-2 N 2646 for triggering a thyristor. The UJT has following characteristics :
Intrinsic stand-off ratio = 0·7, valley current = 6 mA, maximum interbase voltage = 20 V, valley voltage = 2 V, interbase resistance = 7 kΩ, emitter-leakage current = 2 mA, and peak point current = 50×10^{-6} A. 6

(*c*) What are the basic requirements for the current to be supplied to the gate terminal of a thyristor for its successful firing? 4

(*d*) What is an optoisolator? What advantages do optoisolators have over electromechanical relay? Under what circumstances should one consider using an optoisolator? 5

4. (*a*) With the basic power circuit diagram and output voltage waveforms, explain the working of Jones choppers. 4

(*b*) A step-down d.c. chopper has a resistive load of $R = 15$ ohm and an input voltage $E_{dc} = 200$ V. When the chopper remains 'ON', the voltage drop is 2·5 V, the chopper frequency is 1 kHz for a given duty cycle of 50%. Determine (*i*) average output voltage, (*ii*) r.m.s. output voltage, (*iii*) chopper efficiency, (*iv*) effective input resistance of chopper. 8

(*c*) Explain time-ratio and control limit control strategies employed in d.c. choppers, with the circuit diagrams and associated output waveforms. 4

(*d*) Explain in brief how average voltage across the load is made more than d.c. supply voltage using chopper. Derive the expression for the average voltage. 4

Group B

5. (*a*) Explain the basic principle of operation of a cycloconverter with a neat equivalent circuit diagram. Also, draw and discuss the waveforms illustrating the operation of the idealized cycloconverter circuit with loads of various displacement angles. 5

(*b*) A six-pulse, blocked group cycloconverter is fed from a three-phase, 600 V (line), 50 Hz supply. The supply has an inductance of 1·146 mH/phase. If the cycloconverter is supplying a variable resistive load with a current of 28 A, estimate the peak and RMS value of load voltage for firing angles of 0°, 30°, and 60°. 8

(*c*) Explain the principle of load commuted cycloconverter and discuss its advantages and disadvantages over line commuted converters. 5

(*d*) What are the applications of cycloconverters. 2

6. (*a*) An inductive load is supplied from a single-phase, 230 V, 50 Hz a.c. supply. The load current varies between the two extreme limits (4 - J0) Amp and (6-J12) Amp. A thyristor control inductor (TCI) is installed to compensate for the reactive power, thus making the power factor equal to unity. Find the values of 'L' and 'C' of the TCI. 8

(*b*) What is a thyristor controlled inductor (TCI) and why is it necessary on transmission lines ? Discuss various aspects of bus control using a TCI. 4

(*c*) How does a switch mode regulator differ from a linear regulator ? Use a block diagram in support of your answer. 4

(*d*) Derive expressions for the real power transmitted and reactive power taken by converters used in HVDC transmission. 4

7. (*a*) With the help of a neat circuit diagram and associated waveforms, explain the operation of single phase half-bridge MOSFET based voltage-source inverter with resistive and inductive (RL) load. 6

(*b*) Explain the following performance parameters of inverters : (*i*) Harmonic factor of n^m harmonic, (*ii*) total harmonic distortion, (*iii*) distortion factor, and (*iv*) lowest order harmonic. 4

(*c*) A single-phase half-bridge inverter has a resistive load of $R = 3$ ohm and the d.c. input voltage $E_{dc} = 24$ V. Determine (*i*) IGBT ratings, (*ii*) total harmonic distortion, (*iii*) distortion factor, and (*iv*) harmonic factor and distortion factor of the lowest order harmonic. 8

(*d*) Compare between voltage source and current source inverters. 2

8. (*a*) Derive the expression which relates the average speed to average motor current for speed control of a d.c. series motor by a single-phase semiconverter. 5

(*b*) The speed of a 20 HP, 210 V, 1000 rpm series motor (d.c.) is controlled by a single-phase (*i*) semiconverter, and (*ii*) full converter. The combined field and armature circuit resistance is 0·25 ohm. Motor constants are $K_{af} = 0 \cdot 03\,N - mA^2$ and $K_{res} = 0 \cdot 075$ V-s/rad. The supply voltage is 230 V. Assuming continuous and ripple for motor current, determine the motor current, motor torque and supply power factor. 8

(*c*) Explain the induction motor operation when the (*V*/*f*) ratio is held constant. Also, derive the expression for maximum torque. 5

(*d*) Explain the advantages of variable frequency induction motor drive. 2

Group C

9. Choose the *correct* answer for the following : 2 x 10

(*i*) Photomultipliers are based on the principle of
- (*a*) pyro-electric effect
- (*b*) photovoltaic effect
- (*c*) photo-conduction
- (*d*) secondary emission.

(*ii*) Typical value of open circuit voltage of a solar cell is
- (*a*) 10 mV
- (*b*) 100 mV
- (*c*) 0·5 V
- (*d*) 1·0 V.

(*iii*) The effect of d.c. saturation in a rectifier transform is to
- (*a*) decrease the output
- (*b*) increase the output
- (*c*) decrease the a.c. component of the output
- (*d*) reduce the tripler harmonic.

(*iv*) Ripple frequency of a six-phase half-wave rectifier for 230 V, 50 Hz input will be
- (*a*) 150 Hz
- (*b*) 50 Hz
- (*c*) 300 Hz
- (*d*) 100 Hz.

(*v*) For a thyristor, pulse triggering is preferred to d.c. triggering because
- (*a*) gate dissipation is low
- (*b*) pulse system is simpler
- (*c*) triggering signal is required for very short duration
- (*d*) No harmonic content.

(*vi*) Converter is a circuit which
- (*a*) converts a.c. to d.c. only
- (*b*) converts d.c. to a.c. only
- (*c*) converts a.c. to d.c. and vice-versa
- (*d*) converts a.c. to a.c. at different frequency.

(*vii*) The fundamental ripple frequency of a six pulse circuit with supply frequency of 50 Hz is

(*a*) 100 Hz

(*b*) 200 Hz

(*c*) 300 Hz

(*d*) 600 Hz.

(*viii*) The average load voltage of three-phase half-wave controlled circuit using thyristor is given by

(*a*) $(3\sqrt{6}/2\pi)\, E_m \cos\alpha$

(*b*) $(3\sqrt{6}/\pi)\, E_m \cos\alpha$

(*c*) $(3\sqrt{3}/\pi)\, E_m \cos\alpha$

(*d*) $(3\sqrt{2}/2\pi)\, E_m \cos\alpha$.

(*ix*) Cycloconvert has

(*a*) low input power factor

(*b*) high input power factor

(*c*) low output power factor

(*d*) high output power factor.

(*x*) A d.c. motor armature, supplied through a phase-controlled thyristor, receives a smoother voltage shape at

(*a*) higher d.c. motor speeds

(*b*) lower d.c. motor speeds

(*c*) rated d.c. motor speeds

(*d*) None of the above.

W'10:3AN:EL 412/422/432 (1470)

POWER ELECTRONICS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a, b, etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Briefly explain the thyristor operation using two transistor analogy. 6

(*b*) Compare linear and switching mode regulators. 4

(*c*) For the circuit, shown in Fig. 1, find the energy lost in the diode. 4

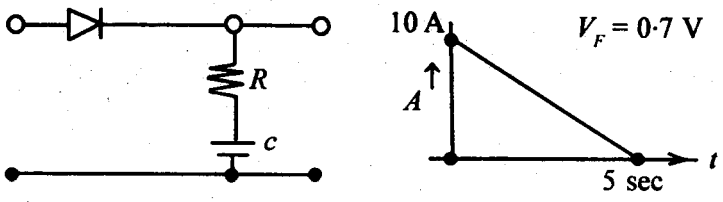

Fig. 1

(*d*) Compare GTO and thyristors. Give typical applications of GTO. 6

2. (*a*) Briefly explain the working of a synchronized UJT triggering circuit for a single-phase full-wave bridge converter. 6

(*b*) A thyristor assembly dissipates 500 W power with junction temperature limited to 105°C. Assume that the ambient temperature is 40 °C and the junction to heat sink thermal-resistance is 0·1°C/W. Find the heat sink to ambient thermal resistance. 4

(*c*) How are choppers classified? Briefly explain the operation of a type-C chopper. 6

(*d*) Compare silicon diode and Schottky diode. 4

3. (*a*) Define and compare natural and forced-commutation of thyristors. 6

(*b*) Figure 2 shows two MOSFETs connected in parallel. Calculate the power dissipation of each transistor. 4

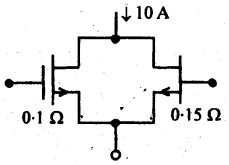

Fig. 2

(*c*) Compare step-down and step-up choppers. A step-up chopper is used to deliver load voltage of 500 V from a 200V d.c. source If the

(*b*) A three-phase fully-controlled bridge converter is feeding a load that draws a constant and ripple-free load current of 10 A at a firing angle of 30°. Find the approximate total harmonic distortion and the R.M.S. value of fundamental component of input. 6

(*c*) Suggest a method to reduce the harmonics of a cycloconverter. 5

(*d*) Compare off-line and on-line UPS. 5

6. (*a*) Briefly explain the operation of a 6-pulse full-wave converter with RL load and derive an expression for the output voltage. 10

(*b*) A single-phase half-bridge inverter has a input supply of 120 V d.c. Find the (*i*) total RMS current in 10 ohms resistive load; (*ii*) RMS value of output voltage; and (*iii*) fundamental and third harmonic RMS voltage. 3 x 2

(*c*) Compare voltage-source and current-source inverters. 4

7. (*a*) What is a regenerative drive? Briefly explain the working of a four-quadrant minimum delay drive for d.c. motor speed control. 8

(*b*) Briefly describe the operation of bipolar HVDC system. Also, give advantages and disadvantages of HVDC system. 8

(*c*) A half-wave controlled rectifier with R-L load has 230 V/50 Hz input supply. Find the RMS value of output voltage, if current becomes zero at $\alpha = 30^\circ$ (beyond 180°). 4

off-period of switching device is 80 μs, find the ON period of switch. 6

(*d*) Give necessary requirements for paralleling the diodes. How can dynamic current sharing be achieved ? 4

4. (*a*) For a UJT oscillator, derive an expression for frequency of oscillations. Give considerations for selection of timing resistor. 6

(*b*) A thyristor is connected to 230 V/50 Hz a.c. supply and has to supply maximum load current of 100 A. The maximum permissible *di/dt* rating is 50 A/μs. Calculate the value of series inductor to limit the rate of current rise to *di/dt* rating. Also, calculate the energy stored in the inductor. 4

(*c*) For a pulse-width modulated chopper shown in Fig. 3, derive an expression for output voltage. 6

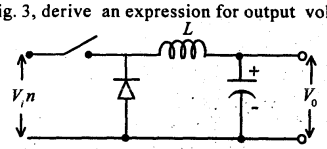

Fig. 3

(*d*) How is inductor value selected? Compare BJT and IGBT transistors. 4

Group B

5. (*a*) Define and compare semi-converter, full converter and dual converter. 4

8. (*a*) Briefly explain the operation of a single-phase cycloconverter which accepts 230 V/50 Hz a.c. and provides output voltage at 16·6 Hz. 8

(*b*) Briefly explain the *V/f* control of induction motor. 6

(*c*) Briefly explain how single pulse-width modulation reduces harmonics. Show that, for pulse-width of 120°, third harmonic is eliminated. 6

Group C

9. Choose the *correct* answer for the following: 10 x 2

(*i*) The trigger circuit of a thyristor is shown in Fig. 4. The thyristor requires a gate current of 10 mA for guaranteed turn-on. The value of resistor '*R*' required to turn-on reliably under all conditions is

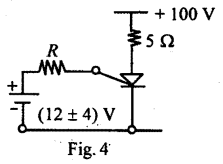

Fig. 4

(*a*) 10 kΩ
(*b*) 1600 Ω
(*c*) 1200 ohms
(*d*) 800 Ω

(*ii*) Figure 5 shows a three-phase half-wave rectifier. The source is a symmetrical three-phase, four-wire system. The line-to-line source voltage is

100 V. The supply frequency is 400 Hz. The ripple frequency at the output is

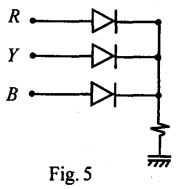

Fig. 5

(*a*) 400 Hz
(*b*) 800 Hz
(*c*) 1200 Hz
(*d*) 2400 Hz

(*iii*) Find the RMS value of the output current waveform shown in Fig. 6 :

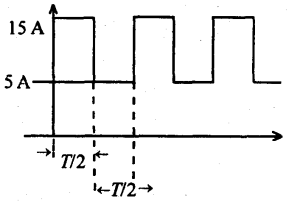

Fig. 6

(*a*) 10 A
(*b*) 8·6 A
(*c*) 15 A
(*d*) 11·2 A

(*iv*) Figure 7 shows a phase-controlled converter. The thyristor is fired at an angle 'α' during every positive half-cycle of the input voltage. If the peak value of the instantaneous output voltage equals 230 V, the firing angle 'α' is close to

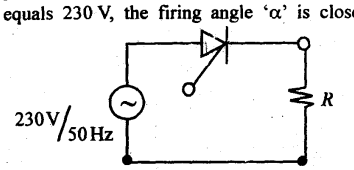

Fig. 7

(*a*) 45°
(*b*) 90°
(*c*) 135°
(*d*) 83·6°

(*v*) An SCR is considered to be a semi-controlled device because

(*a*) it conducts during one half-cycle of an alternating waveform.

(*b*) it can be turned on only during the half-cycle of an alternating waveform.

(*c*) it can be turned on but not turned off with a gate pulse.

(*d*) it can be turned on and turned off by a pulsed gate signal.

(*vi*) A three-phase bridge rectifier is fed by a 400 V (RMS)/50 Hz, three-phase a.c. source. If the load is purely resistive, then peak instantaneous voltage is equal to

(*a*) 400 V
(*b*) $400\sqrt{2}$
(*c*) $400\sqrt{2/3}$
(*d*) $400/\sqrt{3}$

(*vii*) For HVDC system, the switching device that can be used effectively is

(*a*) GTO
(*b*) Triac
(*c*) IGBT
(*d*) LASCR.

(*viii*) The triac circuit, shown in Fig. 8, controls the a.c. output power to the resistive load. The peak-power dissipated in load is

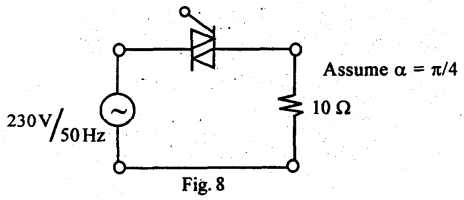

Fig. 8

(*a*) 3968 W
(*b*) 5290 W
(*c*) 7935 W
(*d*) 10,580 W

(*ix*) Four-quadrant operation requires

(*a*) two full-converters in series.

(*b*) two full-converters connected back-to-back.

(*c*) two full-converters connected in parallel.

(*d*) two semi-converters connected back-to-back.

(*x*) For full-wave rectification, a four-diode bridge rectifier is claimed to have the following advantages over two diode circuit :

1. Less expensive transformer
2. Smaller size transformer.
3. Suitability for high voltage and high-power applications.

The correct answer is

(*a*) only 1 and 2 are true.
(*b*) only 1 and 3 are true.
(*c*) only 2 and 3 are true.
(*d*) only 1, 2 and 3 are true.

S'11 : 3 AN : EL 412/422/432 (1470)

POWER ELECTRONICS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A**, ANY TWO *from* **Group B** *and* ALL *from* **Group C**.

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Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. What is power electronics? Give some applications of power electronics. What are the advantages and disadvantages of power electronic circuits compared with its electromechanical parts? 4 + 6 + 10

2. A 220 V, 1·5 kW heater is energised from a 200 V, 50 Hz supply through a diode. Find the power absorbed by the heater element, average value of the load current, peak value of the diode current, and input power factor. Derive the formula used. 20

3. (*a*) Describe the working of a single-phase fully controlled bridge converter with resistive load, and then explain how can it be operated in rectifier as well inverter mode. 10

(*b*) A three-phase diode bridge is used to provide rectified output from a 400 V, 50 Hz, 3-phase supply to a R-L load with 10 Ω resistance and 300 mH inductance. Determine the (*i*) d.c. level of the output voltage, (*ii*) rms value of the diode current, (*iii*) rms value of the source current, and (*iv*) apparent power drawn from the mains. 10

4. Write short notes on the following : 4×5

(*i*) GTO

(*ii*) MOSFET

(*iii*) BJT

(*iv*) IGBT.

Group B

5. (*a*) What is an inverter ? List a few industrial applications of inverters. Explain its principle of operation with the aid of a diagram. 2 + 2 + 6

(*b*) A single-phase half bridge inverter, supplied from 200 V d.c. supply, is connected to a resistive load of 20 Ω. Find (*i*) r.m.s. value of fundamental component of the output voltage and current, (*ii*) power delivered to the load due to fundamental component, (*iii*) peak and average current of each thyristor, (*iv*) PIV rating of each thyristor, (*v*) power delivered by each source due to fundamental component. 10

6. (*a*) What is a cycloconverter ? Give some of its industrial applications. 5

(*b*) What do you mean by pulse width modulation ? What are the advantages and disadvantages of this method ? 5

(*c*) A three-phase to single-phase cycloconverter employs a 6-pulse bridge circuit. This circuit is fed from 400 V, 50 Hz supply through a delta/star transformer, whose turns ratio per phase is 3 : 1. For an output frequency of 2 Hz, the load impedance is $4 + j3\Omega$. The commutation overlap and thyristor turn off time limit the firing angle delay (α) in the inversion mode to 165°. Compute (*i*) peak value of rms output voltage, (*ii*) rms output current, and (*iii*) output power. 10

7. (*a*) Define firing angle of a converter. 4

(*b*) Derive an expression for average and rms voltages of *m*-pulse phase controlled converter. 16

8. The speed of a 10 kW, 230 V, 1000 rpm separately excited d.c. motor is controlled by means of two 3-phase full converters, one in the armature circuit and other in the field circuit and both are fed from 400 V, 50 Hz source. The armature and field resistances are 0·3 Ω, and 300 Ω, respectively. With magnetic saturation neglected, the motor voltage constant is 1·1 V.s/A.rad. The armature and field current are continuous and ripple-free. Determine the following :

(*a*) Firing angle of the armature converter, if the field converter is operated at maximum field current and developed torque is 80 N.m at rated speed. 7

(*b*) Motor speed, if the field converter is set for maximum field current, the developed torque is 80 N.m, and the firing angle of the armature converter is 0°. 7

(*c*) Firing angle of the field converter, if the speed is to be increased to 3000 rpm for the same load requirement in part (*b*). Neglect converter losses. 6

Group C

9. Choose the *correct* answer for the following : 20 x 1

(*i*) A thyristor can be termed as
- (*a*) d.c. switch.
- (*b*) a.c. switch.
- (*c*) either (*a*) or (*b*) above.
- (*d*) square-wave switch.

(*ii*) On-state voltage drop across a thyristor used in a 220 V supply system is of the order of
- (*a*) 100 - 110 V
- (*b*) 200 - 220 V
- (*c*) 1 to 1·5 V
- (*d*) 0·5 to 1 V.

(*iii*) While operating on variable frequency supplies, the a.c. motor requires variable voltage as well in order to
- (*a*) protect the insulation.
- (*b*) avoid the effect of saturation.
- (*c*) improve the capabilities of the inverter.
- (*d*) protect the thyristor from dv/dt.

(*iv*) In d.c. choppers, per unit ripple is maximum when duty cycle, k, is
- (*a*) 0·2
- (*b*) 0·5
- (*c*) 0·7
- (*d*) 0·9

(*v*) The main switching element of a SMPS in the operating range of 20 kHz to 100 kHz is
- (*a*) SCR
- (*b*) UJT
- (*c*) GTO.
- (*d*) MOSFET

(*vi*) The main reason for connecting a pulse transformer at the output stage of a thyristor triggering circuit is to
- (*a*) amplify the power of the triggering pulse.
- (*b*) provide electrical isolation.
- (*c*) reduce the turn on time of the thyristor.
- (*d*) avoid spurious triggering of the thyristor due to noise.

(*vii*) In case of an armature controlled separately excited d.c. motor drive with closed speed control, an inner control loop is useful because it
- (*a*) limits the speed of the motor to a safe value.
- (*b*) helps in improving the drive energy efficiency.
- (*c*) limits the peak current of the motor to the permissible value.
- (*d*) reduces the steady state speed error.

(*viii*) Line commutation is used with converters. The forced commutation will be used with

(*a*) converters.

(*b*) inverters.

(*c*) choppers.

(*d*) both (*b*) and (*c*) above.

(*ix*) Commutation overlap in the phase controlled a.c. to d.c. converter is due to

(*a*) load inductance

(*b*) harmonic content of load current

(*c*) switching operation in the converter.

(*d*) source inductance.

(*x*) In d.c. choppers feeding highly inductive loads, the waveforms for input and output currents are

(*a*) discontinuous and continuous, respectively.

(*b*) both continuous.

(*c*) both discontinuous.

(*d*) continuous and discontinuous, respectively.

(*xi*) When a thyristor is negatively biased,

(*a*) all three junctions are negatively biased.

(*b*) outer junctions are positively biased and inner junction is negatively biased.

(*c*) outer junctions are negatively biased and inner junction is positively biased.

(*d*) junction near the anode is negatively biased and the one near the cathode is positively biased.

(*xii*) Resonant converters are basically used to

(*a*) generate large peak voltage.

(*b*) reduce switching losses.

(*c*) eliminate harmonics.

(*d*) convert a square wave into a sine wave.

(*xiii*) A voltage source inverter is normally employed when

(*a*) source inductance is large and load inductance is small.

(*b*) source inductance is small and load inductance is large.

(*c*) both source and load inductances are small.

(*d*) both source and load inductances are large.

(*xiv*) A single-phase voltage source square wave inverter feeds pure inductive load. The waveform of the load current will be

(*a*) sinusoidal

(*b*) rectangular.

(*c*) trapezoidal.

(*d*) triangular.

(*xv*) A 3-phase semi-converter feeds the armature of a separately excited d.c. motor, supplying a non-zero torque. For steady state operation, the motor armature current is found to drop to zero at certain instances of time. At such instances, the voltage assumes a value

(*a*) equal to the instantaneous value of the a.c. phase voltage.

(*b*) equal to the instantaneous value of the motor back emf.

(*c*) arbitrary.

(*d*) zero.

(*xvi*) A thyristorised 3-phase fully controlled converter feeds a d.c. load that draws a constant current. Then the input a.c. line to the converter has

(*a*) an rms value equal to the d.c. load current.

(*b*) an average value equal to the d.c. load current.

(*c*) a peak value equal to the d.c. load current.

(*d*) a fundamental frequency component, whose rms value equal to the d.c. load current.

(*xvii*) Triangular PWM control, when applied to a 3-phase, BJT based voltage source inverter introduces

(*a*) low order harmonic voltages on the a.c. side.

(*b*) very high order harmonic voltages on the d.c. side.

(*c*) very high order harmonic voltages on the a.c. side.

(*d*) low order harmonic voltages on the d.c. side.

(*xviii*) In a three-phase controlled bridge rectifier, with an increase of overlap angle, the output d.c. voltage

(*a*) decreases.

(*b*) increases.

(*c*) does not change.

(*d*) depends upon load inductance.

(*xix*) Out of the following which semiconductor power device is not a current triggered device?

(*a*) Thyristor

(*b*) GTO

(*c*) Triac

(*d*) MOSFET

(*xx*) Which one of the following does not cause permanent damage of an SCR?

(*a*) High current

(*b*) High rate of rise of current

(*c*) High temperature rise

(*d*) High rate of rise of voltage.

S'12:3AN : EL412/422/432 (1470)

POWER ELECTRONICS

Time : Three hours

Maximum Marks : 100

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Group A

1. What is power electronics ? Give some applications of power electronics. What are the advantages and disadvantages of power electronic circuits as compared with its electro-mechanical parts ? 4 + 6 + 10

2. A 220 V, 1.5 kW heater is energised from a 200 V, 50 Hz supply through a diode. Find the power absorbed by the heater element, average value of the load current, peak value of the diode current, and input power factor. Derive the formula used . 20

3. (*a*) Describe the working of a single-phase fully controlled bridge converter with resistive load. Explain how can it be operated in rectifier as well as inverter mode. 10

(*Turn Over*)

(*b*) A diode, with an internal resistance of 20 Ω, is to supply power to a resistive load 1000 Ω from a 200 V supply. Calculate the (*i*) peak load current, (*ii*) d.c. load current, (*iii*) d.c. diode voltage, and (*iv*) percentage regulation from no load to full load. 10

4. (*a*) What is a d.c. chopper ? Explain its principle of operation. Where is it normally employed ? 3 + 5 + 2

(*b*) A d.c. chopper (ideal), fed from 200 V supply, is connected to resistive load. The output voltage consists of rectangular pulses of 2 ms, with a chopping frequency of 200 Hz. Calculate the (*i*) ripple factor, (*ii*) average and rms values of output voltage, (*iii*) rms value of fundamental component of output voltage, (*iv*) a.c. ripple voltage, and (*v*) chopper efficiency, if the load being a resistance of 10 Ω. 5 × 2

Group B

5. (*a*) What is an inverter ? List a few industrial applications of inverters. Explain its principle of operation with the aid of a diagram. 2 + 2 + 6

(*b*) A single-phase full bridge inverter delivers power to a RLC load in series ($R = 1\Omega$, $\omega L = 2{\cdot}0\ \Omega$, and $1/\omega C = 1.5\Omega$) from 200 V d.c. source. The output voltage is controlled by single pulse modulation and the pulse width is 90°. Determine the magnitude rms values of fundamental (first), fifth and seventh harmonic components of the output (load) current. Also, determine the power delivered to the load. 10

6. (*a*) What is a cycloconverter ? Give some of its industrial applications. 5

(*b*) What do you mean by pulse width modulation ? What are the advantages and disadvantages of this method ? 5

(*c*) A three-phase to single-phase cycloconverter employs a 6-pulse bridge circuit. This circuit is fed from 400 V, 50 Hz supply through a delta/star transformer, whose turns ratio per phase is 3 : 1. For an output frequency of 2 Hz, the load impedance is 4 + j 3 Ω. The commutation overlap and thyristor turn-off time limit the firing angle delay (α) in the inversion mode to 165°. Compute the (*i*) peak value of rms output voltage, (*ii*) rms output current, and (*iii*) output power. 10

7. (*a*) Define firing angle of a converter. 4

(*b*) Derive an expression for average and rms voltages of *m*-pulse phase-controlled converter. 16

8. The speed of a 12 kW, 220 V, 1000 rpm d.c. series motor is controlled using a single-phase half controlled bridge converter. The combined armature and field resistance is 0·2 Ω. Assuming continuous and ripple-free motor current and speed of 1000 rpm and $k = 0{\cdot}03$ N.m/A², determine motor current and motor torque for a firing angle $\alpha = 30°$. The supply voltage is 250 V, 50 Hz. Derive the formula used. 20

Group C

9. Choose the *correct* answer for the following : 20 × 1

(*i*) A thyristor can be termed as

(*a*) d.c. switch.

(*b*) a.c. switch.

(*c*) either (*a*) or (*b*) above.

(*d*) square-wave switch.

(*ii*) On-state voltage drop across a thyristor used in a 220 V supply system is of the order of

(*a*) 100 – 110 V
(*b*) 200 – 220 V
(*c*) 1 to 1·5 V
(*d*) 0·5 to 1 V

(*iii*) While operating on variable frequency supplies, the a.c. motor requires variable voltage as well in order to

(*a*) protect the insulation.
(*b*) avoid the effect of saturation.
(*c*) improve the capabilities of the inverter.
(*d*) protect the thyristor from *dv/dt*.

(*iv*) In d.c. choppers, per unit ripple is maximum when duty cycle *k* is

(*a*) 0·2
(*b*) 0·5
(*c*) 0·7
(*d*) 0·9

(*v*) The main switching element of a SMPS in the operating range of 20 kHz to 100 kHz is

(*a*) SCR
(*b*) UJT
(*c*) GTO
(*d*) MOSFET

(*vi*) The main reason for connecting a pulse transformer at the output stage of a thyristor triggering circuit is to

(*a*) amplify the power of the triggering pulse.

(*b*) provide electrical isolation.
(*c*) reduce the turn on time of the thyristor.
(*d*) avoid spurious triggering of the thyristor due to noise.

(*vii*) In case of an armature controlled separately excited d.c. motor drive with closed speed control, an inner control loop is useful because it

(*a*) limits the speed of the motor to a safe value.
(*b*) helps in improving the drive energy efficiency.
(*c*) limits the peak current of the motor to the permissible value.
(*d*) reduces the steady state speed error.

(*viii*) Line commutation is used with converters. The forced commutation will be used with

(*a*) converters.
(*b*) inverters.
(*c*) choppers.
(*d*) both (*b*) and (*c*) above.

(*ix*) Commutation overlap in the phase controlled a.c. to d.c. converter is due to

(*a*) load inductance.
(*b*) harmonic content of load current.
(*c*) switching operation in the converter.
(*d*) source inductance.

(*x*) In d.c. choppers feeding highly inductive loads, wave forms for input and output currents are

(*a*) discontinuous and continuous, respectively.
(*b*) both continuous.
(*c*) both discontinuous.
(*d*) continuous and discontinuous, respectively.

(*xi*) When a thyristor is negatively biased,

(*a*) all three junctions are negatively biased.

(*b*) outer junctions are positively biased and inner junction is negatively biased.

(*c*) outer junctions are negatively biased and inner junction is positively biased.

(*d*) the junction near the anode is negatively biased and the one near the cathode is positively biased.

(*xii*) Resonant converters are basically used to

(*a*) generate large peak voltage.

(*b*) reduce switching losses.

(*c*) eliminate harmonics.

(*d*) convert a square wave into a sine wave.

(*xiii*) A voltage source inverter is normally employed when

(*a*) source inductance is large and load inductance is small.

(*b*) source inductance is small and load inductance is large.

(*c*) both source and load inductances are small.

(*d*) both source and load inductances are large.

(*xiv*) A single-phase voltage source square wave inverter feeds pure inductive load. The waveform of the load current will be

(*a*) sinusoidal.

(*b*) rectangular.

(*c*) trapezoidal.

(*d*) triangular.

(*xv*) A 3-phase semi-converter feeds the armature of a separately excited d.c. motor supplying a non-zero torque. For steady state operation, the motor armature current is found to drop to zero at certain instances of time. At such instances, the voltage assumes a value

(*a*) equal to the instantaneous value of the a.c. phase voltage.

(*b*) equal to the instantaneous value of the motor back emf.

(*c*) arbitrary.

(*d*) zero.

(*xvi*) A thyristorised, 3-phase, fully controlled converter feeds a d.c. load that draws a constant current. Then the input a.c. line to the converter has

(*a*) an rms value equal to the d.c. load current.

(*b*) an average value equal to the d.c. load current.

(*c*) a peak value equal to the d.c. load current.

(*d*) a fundamental frequency component, whose rms value equal to the d.c. load current.

(*xvii*) Triangular PWM control, when applied to a 3-phase BJT based voltage source inverter, introduces

(*a*) low order harmonic voltages on the a.c. side.

(*b*) very high order harmonic voltages on the d.c. side.

(*c*) very high order harmonic voltages on the a.c. side.

(*d*) low order harmonic voltages on the d.c. side.

(*xviii*) In a 3-phase controlled bridge rectifier, with an increase of overlap angle, the output d.c. voltage

(*a*) decreases.

(*b*) increases.

(*c*) does not change.

(*d*) depends upon load inductance.

(*xix*) Which semiconductor power device, out of the following, is not a current triggered device ?

(*a*) Thyristor

(*b*) GTO

(*c*) Triac

(*d*) MOSFET

(*xx*) Which one of the following does not cause permanent damage of an SCR ?

(*a*) High current

(*b*) High rate of rise of current

(*c*) High temperature rise

(*d*) High rate of rise of voltage.

W'13:3AN:EL412/422/432(1470)

POWER ELECTRONICS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a,b,etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Discuss briefly the voltage commutation and current commutation techniques used for the commutation of thyristors. 5

   (*b*) Design various elements of an UJT relaxation oscillator, given the following data for the UJT: $V_P = 24$ V, $I_P = 48$ μA, $V_v = 0{\cdot}75$, $I_V = 5{\cdot}1$ mA, $\eta = 0{\cdot}72$, $R_{BB} = 6{\cdot}5$ kΩ, and $R_{B(con)} = 60$ Ω. Also, compute pulse height obtained as per the design and maximum frequency range. 6

   (*c*) Explain the difference in construction of power MOSFET as compared to a conventional MOSFET. 4

   (*d*) Comment on the statement : 'When subjected to standby increasing overvoltages, the thyristor needs over-current protection but not overvoltage protection'. 5

2. (*a*) The circuit shown in Fig. 1 is used to determine $(di/dt)_{max}$ and $(dv/dt)_{max}$ ratings of the thyristor. Resistance R_v is increased in steps and the switch, S_w, is closed to trigger the thyristor. In this process, at a value of $R_v = 1{\cdot}2\ \Omega$, the thyristor gets triggered. Determine the value of $(di/dt)_{max}$ and $(dv/dt)_{max}$. Given : $E = 120$ V, $L = 10\ \mu$H, $V_{C(0)} = 0$ V and $R_{ed} = 18\ \Omega$. 6

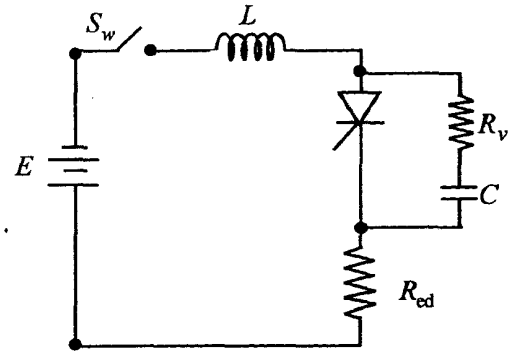


Fig. 1

(*b*) Compare and contrast the features of IGBT with those of power transistor. 4

(*c*) Explain the turn-off and turn-on processes of a GTO with the help of two transistor analogy. 5

(*d*) Explain the difference in construction and operation of an inverter grade thyristor over a conventional one. 5

3. (*a*) Explain the following thermal ratings of thyristors : (*i*) Junction temperature, and (*ii*) transient thermal resistance. 3 + 3

(*b*) The IGBT used in the circuit of Fig. 2 has the following data : $t_{on} = 3\ \mu$s, $t_{off} = 1{\cdot}2\ \mu$s, $D = 0{\cdot}7$ (duty cycle), $V_{CE(sat)} = 2$ V, and $f_s = 1$ kHz. Calculate (*i*) average load current, (*ii*) conduction power loss, and (*iii*) switching power loss during turn-on and turn-off. 6

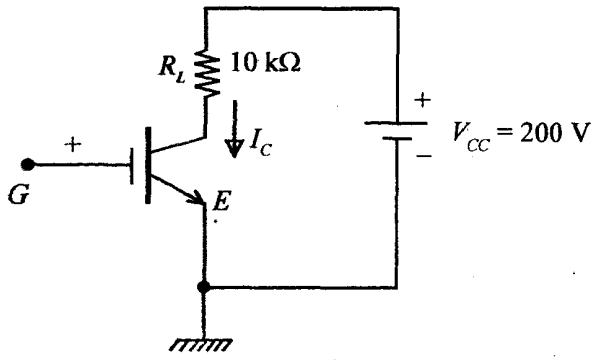


Fig. 2

(*c*) With the help of a structure diagram and equivalent circuit, explain the behaviour of a MOS-controlled SCR. 4

(*d*) Explain the principle of operation of emitter-turn-off thyristor (ETO). 4

4. (*a*) On the basis of 'four-quadrant' operation and configuration, explain the working of a dc-dc chopper. 6

(*b*) A 250 V, 105 A, separately excited d.c. motor operating at 600 rpm has an armature resistance of $0{\cdot}18\ \Omega$. Its speed is controlled by a two-quadrant chopper with a chopping frequency of 550 Hz. Compute the (*i*) speed for motor operation with a duty ratio of 0·5 at 7/8 times the rated torque, and (*ii*) motor speed, if it regenerates at $\delta = 0{\cdot}7$ with rated unit. 8

(*c*) Explain time ratio control (TRC) and current limit control strategies employed for d.c. choppers. Also, enumerate applications and limitations of individual strategies. 6

Group B

5. (*a*) Explain, with the help of a neat power diagram and associated waveforms, the operation of a single-phase half-controlled converter with inductive load. 6

(*b*) Explain the effect of free-wheeling diode in a half-controlled converter with a resistive-inductive (series combination) load, and justify that the diode improves the power factor of the converter. 6

(*c*) A single-phase half-controlled converter is operated from a 120 V, 50 cps supply load resistance is of 10 Ω. If the average output voltage is 25 percent of the maximum possible average output voltage, determine (*i*) firing angle, (*ii*) rms and average output currents, and (*iii*) average and rms SCR currents. 8

6. (*a*) Draw and explain the operation of a speed-control of a d.c. series motor by a single-phase full converter for continuous motor control. Draw a neat circuit diagram along with associated voltage and current waveforms. 6

(*b*) A separately excited d.c. motor is fed from a 230 V, 50 cps, single-phase supply, half-controlled bridge rectifier. The d.c. motor parameters are given as armature resistance and inductance, respectively 0·3 Ω and 0·06 H, voltage constant is 0·9 V/A rad/sec and field resistance is 104 Ω. The field current is also controlled by a semiconverter and is set to the maximum possible value. Load torque $T_L = 50$ Nm at 800 rpm. Compute the (*i*) field current, I_f, (*ii*) firing angle of the converter in the armature circuit, and (*iii*) input power factor of the armature circuit converter. The inductance of the armature and field circuits are sufficient enough to make the armature and field currents continuous and ripple-free also. 9

(*c*) Explain various schemes of d.c. motor speed control with their specific applications and limitations. 5

7. (*a*) Explain the induction motor (slip ring) speed control using GTO as a chopper switch, and show that fundamental rotor current (I_r) is given by an expression $(3/\pi)I_{rms}$). 6

(*b*) Explain the operation of switched reluctances motor (SRM). Also, list their advantages that have sparked interest in its use as an adjustable-speed drive. 8

(*c*) Discuss the speed-torque curves for a chopper-controlled induction motor. 6

8. (*a*) With the help of a neat circuit diagram and associated waveforms, explain the operation of single-phase-full bridge MOSFET based voltage source inverter watt-resistive load. 6

(*b*) A single-phase full-bridge inverter is operated from a 48 V battery and is supplying power to a pure-resistive load of 10 Ω. Determine the (*i*) fundamental output voltage and first five harmonics, (*ii*) Output rms power and output fundamental power, and (*iii*) transistor switch rating. 8

(*c*) Explain why a PWM inverter is superior to a square-wave inverter. 6

Group C

9. Choose the *correct* answer for the following : 10 × 2

(*i*) If the latching current in the circuit shown in Fig. 3 is 4 mA, the minimum width of the gating pulse required to turn-on SCR properly will be

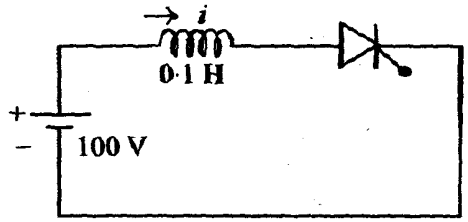


Fig. 3

(*a*) 4 μs
(*b*) 4·4 μs
(*c*) 0·4 μs
(*d*) 40 μs

(*ii*) If three-phase, six pulse bridge circuit is having input voltage of 415 V for given voltage safety factor of 2.1, the peak-inverse voltage (PIV) of the thyristor (connected to the bridge) is given by

(*a*) 123·249 V
(*b*) 1232·49 V
(*c*) 12·32 V
(*d*) 1·232 V

(*iii*) The forward voltage-drop across the SCR during ON state is of the order of

(*a*) 10 V to 15 V
(*b*) 100 V to 150 V
(*c*) 1 V to 1·5 V
(*d*) 0·1 V to 0·15 V

(*iv*) Two-quadrant chopper provides flexibility for the d.c. motor to operate in

(*a*) motoring mode only.
(*b*) regenerative mode only.
(*c*) both motoring as well as regenerative mode.
(*d*) breaking mode only.

(*v*) Owing to the reverse LC-oscillatory current stops the conduction of the SCR, the modified parallel resonant turn-off circuit comes under the category of

(*a*) current-commutated chopper.
(*b*) voltage-commutated chopper.
(*c*) load commutated chopper.
(*d*) frequency commutated chopper.

(*vi*) The output power of a single-phase chopper with a resistive load is characterized by power factor given by

(*a*) $V_{\text{ld(rms)}}/V_m$

(*b*) $[\sqrt{2}\,V_{\text{ld}(rms)}]/V_m$

(*c*) $\left[V_{\text{ld(rms)}}\right]/\sqrt{2}\,V_m$

(*d*) $\sqrt{2V_{\text{ld(rms)}}/V_m}$

where $V_{\text{ld(rms)}}$ = half-cycle r.m.s. value.

(*vii*) Three-phase a.c. choppers (controllers) of category B consists of

(*a*) 3ϕ, λ connection with a neutral.
(*b*) 3ϕ, λ connection with an isolated neutral.
(*c*) 3ϕ, Δ connection with load in series
(*d*) 3ϕ, V connection with load in parallel, keeping an a.c. chopper on load side.

(*viii*) For the 3ϕ, a.c. chopper of category B, the line-to-line voltage (supply) is 300 V and the load consists of a 6 Ω resistance. Find the maximum forward and reverse thyristor voltages.

(*a*) 424·2 voltage in forward as well as in reverse direction.

(*b*) 42·42 voltage in forward as well as in reverse direction.

(*c*) 4·24 voltage in forward as well as in reverse direction.

(*d*) 245 voltage in forward as well as in reverse direction.

(*ix*) The phase-controlled rectifiers can be operated in the inverting mode with a firing angle

(*a*) greater than 90°.
(*b*) less than $(-)90^{\circ}$.
(*c*) greater than 180°.
(*d*) equals 0°.

(*x*) PWM inverters suffer from one of the disadvantages as

(*a*) high (*di*/*dt*) rating leading to (*dv*/*dt*) to be high.

(*b*) high (*di*/*dt*) rating leading to a low (*dv*/*dt*) rating.

(*c*) lower (*di*/*dt*) rating leading to a low (*dv*/*dt*) rating.

(*d*) lower (*di*/*dt*) rating leading to a high (*dv*/*dt*) rating.

S'14:3AN:EL412/422/432 (1470)

POWER ELECTRONICS

Time : Three hours

Maximum Marks : 100

Answer FIVE *questions, taking* ANY TWO *from* **Group A,** ANY TWO *from* **Group B** *and* ALL *from* **Group C.**

All parts of a question (a,b,etc.) should be answered at one place.

Answer should be brief and to-the-point and be supplemented with neat sketches. Unnecessary long answers may result in loss of marks.

Any missing or wrong data may be assumed suitably giving proper justification.

Figures on the right-hand side margin indicate full marks.

Group A

1. (*a*) Explain the working of thyristor using two transistor analogy. 5

(*b*) Define transformer utilization factor (TUF). Determine TUF for a single-phase center-tap rectifier. Also, state assumptions. 5

(*c*) A semiconductor device dissipates 60 W. The maximum case temperature is 95 °C and the ambient temperature is 60°C. The thermal-resistance between case and sink is 0·2 °C/W. Find sink to ambient thermal resistance. 5

(*d*) What is a step-up chopper ? Derive an expression for output voltage. 5

2. (*a*) Compare BJT and MOSFET as switching devices. 5

(*b*) What is a buck-converter ? Derive an expression for output voltage. Assume steady-state conditions and time-ratio control. 5

(*c*) A full-wave bridge-rectifier is fed with 6V/50 Hz supply. Load-resistance is 0·2 Ω. Calculate output voltage and current for the following cases : (*i*) Ideal diode and (*ii*) practical diode with $V_c = 1V$. 5

(*d*) What is a UJT relaxation oscillator ? Derive an expression for frequency of oscillations. 5

3 (*a*) Compare linear and switching-mode regulators. 5

(*b*) Define peak-point voltage, V_p, and valley voltage V_v. How is peak-point voltage stabilized ? 5

(*c*) Define power-factor in non-linear circuits. State problems arising due to poor power-factor. 5

(*d*) Define *di/dt* rating of a switching device. Suggest scheme to limit it. 5

4. (*a*) Define thermal-resistance and thermal-capacity. Compare semiconductor devices and electrical machines for above thermal parameters. 5

(*b*) Briefly explain the working of a voltage commutated chopper. 5

(*c*) Compare SCR and GTO. 5

(*d*) Following data is available for a power diode : (*i*) Cut-in voltage = 1V, $I_F = 0$, (*ii*) forward-voltage drop = 1·5 V, $I_F = 50A$. Determine (*i*) forward-resistance, (*ii*) forward voltage at 25 A and (*iii*) power dissipation at 25 A. 5

Group B

5. (*a*) Distinguish between fully-controlled and semi-controlled converters. Give typical applications. 5

(*b*) For a 1ϕ half-wave controlled bridge converter, with R-L load, derive an expression for output voltage. Assume load current is continuous. 5

(*c*) A single-phase full bridge inverter has a resistive load of 10 ohm. The input d.c. voltage is 220 V. Determine (*i*) r.m.s. output voltage at the fundamental frequency, (*ii*) RMS output voltage and (*iii*) output power. 5

(*d*) Explain in brief the operation of a single-phase to single-phase step-down cycloconverter. Assume resistive load. 5

6. (*a*) Distinguish between voltage source and current source inverters. 5

(*b*) Compare on-line and off-line UPS. Briefly describe an on-line UPS. 5

(*c*) A single-phase half-controlled rectifier is driving a separately excited d.c. motor. The d.c. motor has back e.m.f. constant of 0.25 V/rpm. The armature current is 5 A without any ripple. The armature resistance is 2 Ω. The converter is operating from a single-phase 230 V a.c. source with firing angle of 30°. Determine the speed of motor. 5

(*d*) What is a step-up cycloconverter ? Briefly explain the operation of a single-phase bridge type step-up cycloconverter. Assume resistive load. 5

7. (*a*) Define rectification and inversion mode in controlled rectifiers. Suggest application of inversion mode. 5

(*b*) What are inverter requirements for driving an induction motor ? 5

(*c*) Write a note on harmonic reduction in single-phase to single-phase cycloconverters. 5

(*d*) Calculate firing angles for a three-phase half-controlled and full-controlled bridge converters when they supply half of their maximum voltage. 5

8. (*a*) For a three-phase fully controlled bridge converter, derive an expression for output voltage with resistive load. Assume continuous current condition. 5

(*b*) An a.c induction motor is driven from an inverter with constant V/f control. Its ratings are : No. of poles = 2, supply voltage = 415 V, 3-phase/50 Hz, N = 2850 r.p.m. The motor is run with the inverter output frequency set at 40 Hz and with half the rated slip. Determine the running speed of motor. 5

(*c*) Define circulating currents in dual converters. Briefly explain the operation of a non-circulating type of dual converter. 5

(*d*) Write a note on HVDC system. 5

Group C

9. Answer the following in brief : 10 × 2

(*i*) For the waveshape shown in Fig.1, the value of first odd harmonic is given by

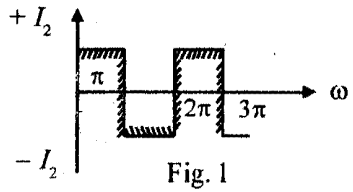


Fig. 1

(*a*) $(4/\pi)I_2$

(*b*) $(4/\pi)(I_2/5)$

(*c*) $(2/\pi)(I_2/3)$

(*d*) $(4/\pi)(I_2/3)$

(*ii*) Figure 2 shows, a composite switch consisting of a power transistor in series with a diode. Assuming that transistor and diode are ideal, the composite VI characteristics is given by

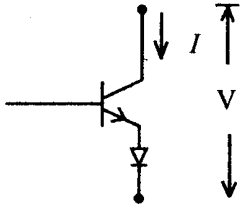
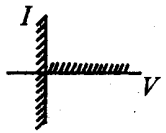
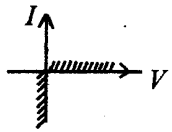
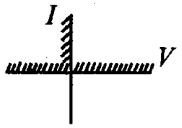
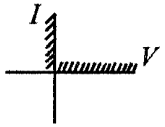


Fig. 2

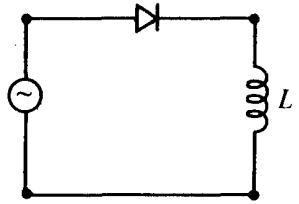
(*a*)


(*b*)


(*c*)


(*d*)


(*iii*) For the circuit shown in Fig. 3, the inductor is pure (lossless). The diode conducts for



(*a*) 90°

(*b*) 180°

(*c*) 270°

(*d*) 360°

(*iv*) A P-N junction diode in series with 5Ω resistor is forward-biased so that a current of 20 A flows. If the voltage across combination is reversed to −100 V at $t = 0$, the reverse-current that flows through the diode at $t = 0$ is

(*a*) 0 A

(*b*) 20 A

(*c*) 40 A

(*d*) 10 A

(*v*) A single-phase full-wave bridge converter supplies a load drawing constant and ripple-free load current. If the trigger angle is 30°, then the input power factor is given by

(*a*) 0·65

(*b*) 0·78

(*c*) 0·85

(*d*) 0·866

(*vi*) Figure 4 shows a chopper operating from a 100 V d.c. input. The duty ratio is 0.8. The load is sufficiently inductive. The average current through the diode D_1 is

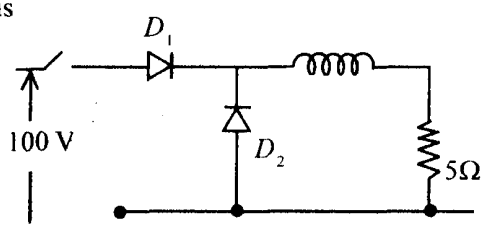


Fig. 4

(*a*) 13.2 A

(*b*) 12.8 A

(*c*) 16 A

(*d*) 20 A

(*vii*) A MOSFET rated for 20 A carries a periodic-current as shown in Fig. 5. The MOSFET resistance is 0·1 ohm. The average ON-state loss in MOSFET is

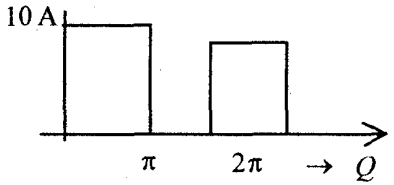


Fig. 5

(*a*) 19·6 W

(*b*) 10 W

(*c*) 5 W

(*d*) 2·5 W

(*viii*) A periodic waveform observed on an oscilloscope across a load is shown Fig.6 A permanent magnet

moving coil (PMMC) meter is connected across the load. The meter reads

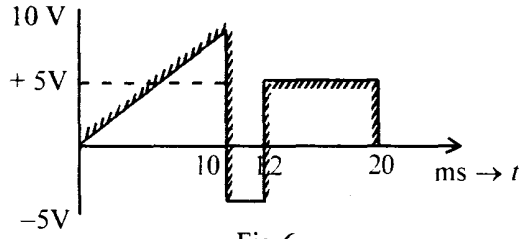


Fig. 6

(*a*) 4 V

(*b*) 5 V

(*c*) 8 V

(*d*) 10 V

(*ix*) A silicon P-N junction diode is forward-biased with a constant current at room temperature. When the temperature is increased by 10°C, the forward-bias voltage across the diode

(*a*) increases by 60 mv

(*b*) decreases by 60 mv

(*c*) increases by 25 mv

(*d*) decreases by 25 mv

(*x*) The ripple frequency in the output voltage of a three-phase semiconverter depends on

(*a*) firing and load resistance.

(*b*) firing and load inductance.

(*c*) firing angle and supply frequency.

(*d*) load circuit parameters.