RPSC AEn-2024 Main Test Series | **ELECTRICAL ENGINEERING** | **Test 6**

Test Mode : • Offline • Online

Subjects : Power Electronics

DETAILED EXPLANATIONS

PART-A

1. Solution:

(i) Step down chopper (or) Buck converter.

(ii) Step up chopper (or) Boost converter.

(iii) Step up step down chopper (or) Buck boost converter.

2. Solution:

1. Forward voltage triggering.
2. $\frac{dV}{dt}$ triggering.
3. Temperature triggering.
4. Light triggering.
5. Gate triggering.

3. Solution:

1. Speed control of ac motors.
2. Induction heating.
3. Lagging VAR compensation.
4. Synchronous motor starting.

4. Solution:

(i) Switching losses.

(ii) Turn-ON losses.

(iii) Turn-OFF losses.

5. Solution:

1. Load current wave form is improved.
2. Input power factor is improved.
3. FD allows the thyristor to regain its forward blocking capability.

6. Solution:

1. The output voltage control with this method can be obtained without any additional components.
2. With this method lower order harmonics can be eliminated or minimised along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimised.

7. Solution:

Maximum value of input voltage,

$$V_m = 400\sqrt{2}\ \text{V}$$

Since load is purely resistive, therefore peak instantaneous output voltage

$$V_m = 400\sqrt{2}\ \text{V}$$

8. Solution:

$$P = \frac{V_{rms}^2}{R} = \frac{(V_m/\sqrt{2})^2}{R}$$

$$= \frac{(200/\sqrt{2})^2}{50} = 400\ \text{W}$$

9. Solution:

1. By connecting a small inductor in anode circuit to limit the rise of current.
2. By applying a gate current nearer to the maximum specified gate current.

10. Solution:

1. It should act as line commutated inverter i.e. firing angle should be varied from 90° to 180°.
2. Load circuit emf E must be reversed.

PART-B

11. Solution:

For achieving load commutation of a thyristor, the commutating components L and C are connected in series with R if R is low. For high value of R, load R is connected across C and inductance L is connected in series with RC combination. The essential requirement for both the conditions is that overall circuit must be underdamped. For inverters when load is underdamped then forced commutation is not required and current itself decays to zero before voltage need to be forced to zero.

12. Solution:

1. IGBT has high input impedance like a MOSFET and low on state power loss as in a BJT.
2. IGBT is bipolar device like BJT but free from secondary breakdown.
3. Its power rating and switching frequency lies between BJT and MOSFET

   Power rating: BJT > IGBT > MOSFET.

   Switching frequency : MOSFET > IGBT > BJT.

13. Solution:

1. Triac is a bidirectional device while SCR is unidirectional device.
2. For ac voltage control a single triac is required because it can operate for positive and negative cycles both. But for same operation two SCRs must be connected in antiparallel.
3. Voltage and current ratings of triac are much below than that of SCR. Triacs are available upto 1200 V, 300 A.

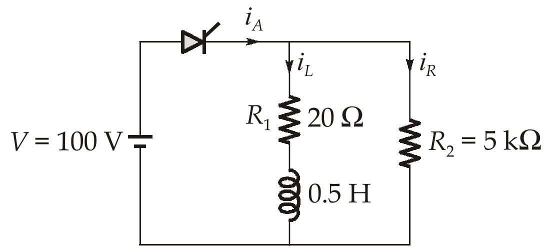
14. Solution:

A snubber circuit is a series combination of R and C, which connected across a SCR to provide $\frac{dV}{dt}$ protection to SCR. Due to high $\frac{dV}{dt}$, a SCR can false triggered without application of gate pulse. Although high $\frac{dV}{dt}$ rate is not harmful for SCR but it can false triggers the SCR.

15. Solution:

Due to the presence of source inductance, commutation of load current from one thyristor to the next, as they are triggered with a firing angle α, cannot be instantaneous. Outgoing thyristor does not commutate immediately. Instead, for some interval both incoming and outgoing thyristors continue to conduct. This interval is called as "overlap" interval.

16. Solution:



Current through 5 kΩ resistor,

$$i_R = \frac{V}{R_2} = \frac{100}{5\times10^3} = 20 \text{ mA} = 0.02 \text{ A}$$

Current through inductor, $$i_L = \frac{V}{R_1}(1 - e^{-R_1 t/L})$$

$$= \frac{100}{20}(1 - e^{20t/0.5}) = 5(1 - e^{-40t})$$

Anode current, $I_a = i_R + i_L = 0.02 + 5(1 - e^{-40t})$ A

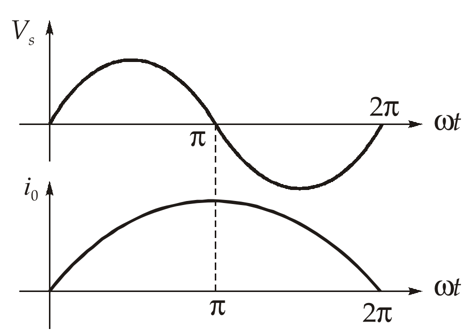
Let minimum pulse width is T

To turn on, $i_a \geq$ latching current

$\Rightarrow$ $0.02 + 5(1 - e^{-40\,t}) = 50 \text{ mA} = 0.05$

$T = 150$ µsec

17. Solution:



$$i_0 = \frac{V_m}{\omega L}(1 - \cos\omega t)$$

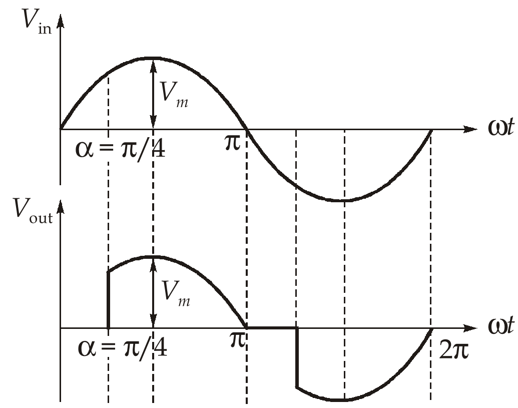
Diode conducts for 360°.

18. Solution:

Let V_m is the peak value of input voltage,

$$V_m = 230\sqrt{2} \text{ V}$$

As firing angle = $\alpha = \frac{\pi}{4}$, so peak voltage across resistance load is also V_m.



Peak power dissipation in the load

$$P = \frac{V_m^2}{R} = \frac{(230\sqrt{2})^2}{10} = 10580 \text{ W}$$

PART-C

19. Solution:

Peak value of resonant current,

$$I_p = V_S\sqrt{\frac{C}{L}} = 230\sqrt{\frac{30\times10^{-6}}{10\times10^{-6}}} = 398.37 \text{ A}$$

Resonant frequency,

$$\omega_0 = \frac{1}{\sqrt{LC}}$$

$$= \frac{10^6}{\sqrt{300}} = 57.735 \times 10^3 \text{ rad/sec}$$

(i) Conduction time for auxiliary thyristor

$$= \frac{\pi}{\omega_0} - \frac{\pi}{57.73\times10^3} = 54.41 \times 10^{-6}$$

$$= 54.41 \ \mu\text{sec}$$

(ii) Since,

$$\omega_0 \cdot \theta = \sin^{-1}\left(\frac{300}{398.37}\right) = 48.857°$$

Voltage across the main thyristor, when it gets turned off

$$V' = V_S \cos \omega_0 \cdot \theta$$

$$= 230 \cos 48.857°$$

$$V' = 151.34 \text{ volts}$$

(iii) Circuit turn off time for main thyristor

$$t_c = C \cdot \frac{V'}{I_0} = \frac{30 \times 10^{-6} \times 151.34}{300} = 15.132\ \mu\text{sec}$$

20. Solution:

- Number of series connected SCR,

$$n_s = \frac{11\text{ kV}}{1.8\text{kV} \times 0.9} = 6.79 \approx 7$$

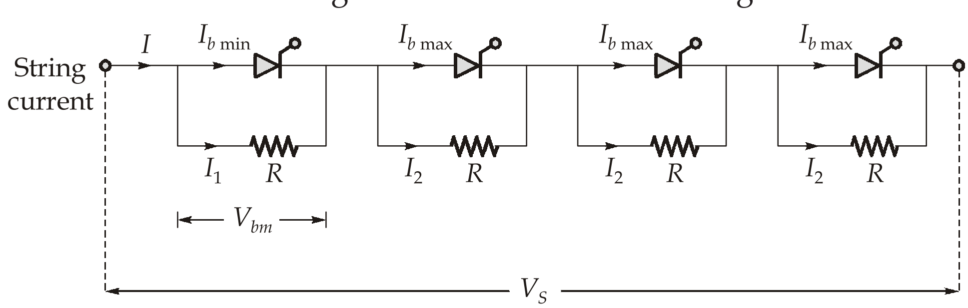
So, series connected SRC = 7

Number of parallel connected SCR

$$n_p = \frac{4\text{ kV}}{1\text{kV} \times 0.9} = 4.44 \approx 5$$

- Static equalization circuit resistance is used in case of series connected SCR only. Let us consider n thyristor connected in series. Let SCR 1 has minimum leakage current I_{bmn} and each of the remaining $(n-1)$ SCR have the same leakage current $I_{b\,\max} > I_{b\,\min}$.

Note: SCR with lower leakage current blocks more voltage



$$I_1 = I - I_{b\,\min}$$

and
$$I_2 = I - I_{b\,\max}$$

where, I = total string current

Voltage across SCR-1, $V_{b\,\max} = I_1 \cdot R$

Voltage across $(n-1)$ $SCR = (n-1)I_2R$

For a string voltage,

$$V_S = I_1R + (n-1)I_2 \cdot R$$
$$= V_{bm} + (n-1)\,R(I - I_{b\,\max})$$
$$= V_{bm} + (n-1)\,R[I_1 - (I_{b\,\max} - I_{b\,\min})]$$
$$= V_{bm} + (n-1)\,RI_1 - (n-1)R\,\Delta I_b$$

where, $\Delta I_b = I_{b\,max} - I_{b\,min}$

as $RI_1 = V_{bm}$

$$V_S = n\,V_{bm} - (n-1)R \cdot \Delta I_b$$

So, $$R = \frac{nV_{bm} - V_s}{(n-1)\Delta I_b}$$

The SCR data sheet contains only maximum blocking current $I_{b\,max}$ and rarely ΔI_b. In such a case, it is usual to assume $\Delta I_b = I_{b\,max}$ with $I_{b\,min} = 0$.

When, $I_{b\,max} = 12$ mA,

$V_{bm} = 1800$ V,

$n_s = 7$(SCR) and $V_s = 11$ kV

$\Delta I_b = I_{b\,max} = 12$ mA

$$R = \frac{nV_{bm} - V_s}{(n-1)\Delta I_b} = \frac{7 \times 1800 - 11000}{(7-1) \times 12 \times 10^{-3}}$$

$$= \frac{12600 - 11000}{6 \times 12 \times 10^{-3}} = 22.22 \text{ k}\Omega$$

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