EPC403 Power Electronics – Tutorial 01

1)

Fill in the blank(s) with the appropriate word(s)
i. A thyristor is a ________________ carrier semi controlled device.
ii. A thyristor can conduct current in ________________ direction and block voltage in ________________ direction.
iii. A thyristor can be turned ON by applying a forward voltage greater than forward ________________ voltage or by injecting a positive ________________ current pulse under forward bias condition.
iv. To turn OFF a thyristor the anode current must be brought below ________________ current and a reverse voltage must be applied for a time larger than ________________ time of the device.
v. A thyristor may turn ON due to large forward ________________.

Answers: (i) minority; (ii) one, both; (iii) break over, gate; (iv) holding, turn off;(v) dv/dt

2)

Do you expect a thyristor to turn ON if a positive gate pulse is applied under reverse bias condition (i. e cathode positive with respect to anode)?

Answer: With a positive gate pulse applied it may appear that the device should turn ON as in the forward direction. However, the constituent transistors have very low current gain in the reverse direction. Therefore no reasonable value of the gate current will satisfy the turn ON. Hence the device will not turn ON.

3)

Fill in the blank(s) with the appropriate word(s)
i. Forward break over voltage of a thyristor decreases with increase in the ________________ current.
ii. Reverse ________________ voltage of a thyristor is ________________ of the gate current.
iii. Reverse saturation current of a thyristor ________________ with gate current.
iv. In the pulsed gate current triggering of a thyristor the gate current pulse width should be larger than the ________________ time of the device.
v. To prevent unwanted turn ON of a thyristor all spurious noise signals between the gate and the cathode must be less than the gate ________________ voltage.

Answer: (i) gate; (ii) break down, independent; (iii) increases; (iv) Turn ON; (v) non-trigger.

4)

A thyristor has a maximum average gate power dissipation limit of 0.2 watts. It is triggered with pulsed gate current at a pulse frequency of 10 KHZ and duly ratio of 0.4. Assuming the gate cathode voltage drop to be 1 volt. Find out the allowable peak gate current magnitude.
Answer: On period of the gate current pulse is

$$T_{ON} = \delta T_s = \delta / f_s = \frac{0.4}{10^4} \text{ sec} = 40\,\mu s < 100\,\mu s.$$

Therefore, pulsed gate power dissipation limit Pgm can be used.

$$\delta P_{gm} \leq P_{gav}(Max)$$

$$\text{or } P_{gm} \leq \frac{0.2}{\delta} \text{ watts} = .5\text{watts}$$

$$\text{But } P_{gm} = I_g V_g;\ V_g = 1V \quad \therefore\ I_g\Big|_{Max} = \frac{.5}{1} = 0.5\text{Amps.}$$

5)

Fill in the blank(s) with the appropriate word(s)

i. Peak non-repetitive over voltage may appear across a thyristor due to ________________ or ________________ surges in a supply network.

ii. VRSM rating of a thyristor is greater than the ________________ rating but less than the ________________ rating.

iii. Maximum average current a thristor can carry depends on the ________________ of the thyristor and the ________________ of the current wave form.

iv. The ISM rating of a thyristor applies to current waveforms of duration ________________ than half cycle of the power frequency where as the ∫i2dt rating applies to current durations ________________ than half cycle of the power frequency.

v. The gate non-trigger voltage specification of a thyristor is useful for avoiding unwanted turn on of the thyristor due to ________________ voltage signals at the gate.

Answer: (i) switching, lightning; (ii) VRRM, VBRR; (iii) case temperature, conduction angle; (iv) greater, less; (v) noise

6)

A thyristor has a maximum average current rating 1200 Amps for a conduction angle of 180°. Find the corresponding rating for Φ = 60°. Assume the current waveforms to be half cycle sine wave.

Answer: The form factor of half cycle sine waves for a conduction angle ϕ is given by

$$F.F = \frac{I_{RMS}}{Iav} = \frac{\sqrt{\frac{1}{2\pi}\int_o^{\phi} \text{Sin}^2\theta\ d\theta}}{\frac{1}{2\pi}\int_o^{\phi}\text{Sin}\theta\ d\theta} = \frac{\sqrt{\pi\left(\phi - \frac{1}{2}\text{Sin}\,2\phi\right)}}{1-\text{Cos}\,\phi}$$

$$\text{For } \phi = 180°,\quad F.F = \pi/2$$

$$\therefore \text{RMS current rating of the thyristor} = 1200 \times \pi/2 = 1885 \text{ Amps.}$$

$$\text{For } \phi = 60°,\ F.F = 2\sqrt{\pi\left(\pi/3 - \sqrt{3}/4\right)} = 2.778$$

Since RMS current rating should not exceeded

$$\text{Maximum } I_{av} \text{ for } \phi = 60° = \frac{1200 \times \pi}{4\sqrt{\pi\left(\pi/3 - \sqrt{3}/4\right)}} = 679.00 \text{ Amps.}$$

7)

Fill in the blank(s) with the appropriate word(s)

i. A thyristor is turned on by applying a ________________ gate current pulse when it is ________________ biased.

ii. Total turn on time of a thyristor can be divided into ________________ time ________________ time and ________________ time.

iii. During rise time the rate of rise of anode current should be limited to avoid creating local ________________.

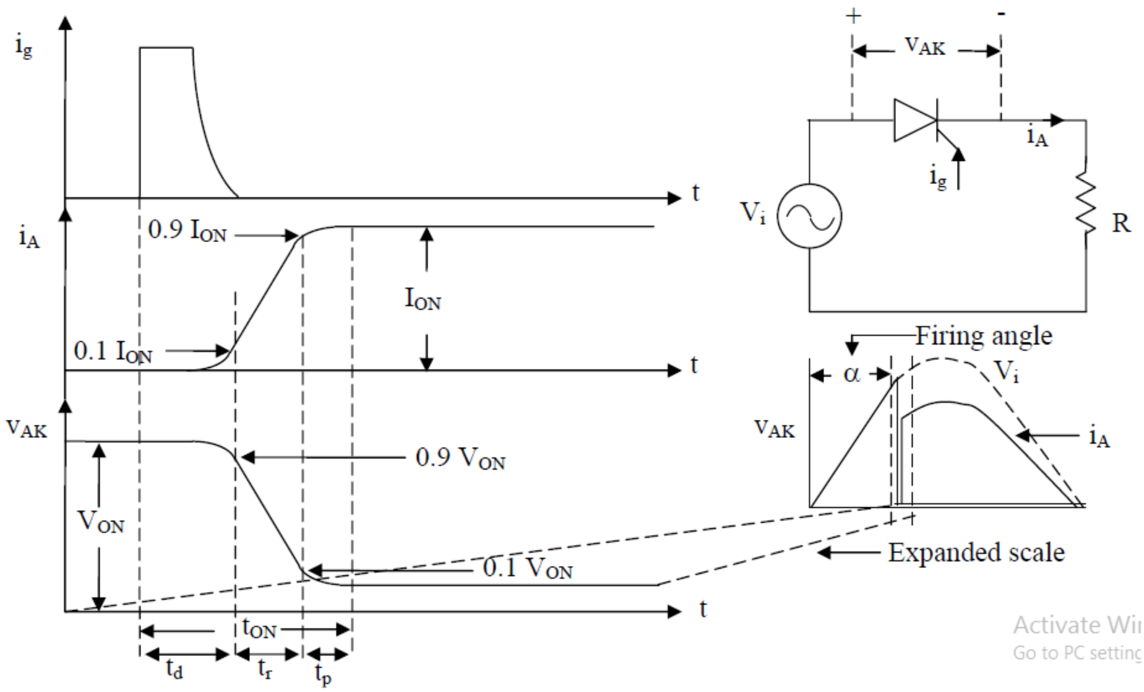
iv. A thyristor can be turned off by bringing its anode current below ________________ current and applying a reverse voltage across the device for duration larger than the ________________ time of the device.

v. Reverse recovery charge of a thyristor depends on the ________________ of the forward current just before turn off and its ________________.

vi. Inverter grade thyristors have ________________ turn off time compared to a converter grade thyristor.

Answer: (i) positive, forward; (ii) delay, rise, spread; (iii) hot spots (iv) holding, turn off; (v) magnitude, rate of decrease (vi) faster

8)



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With reference to Fig find expressions for (i) turn on power loss and (ii) conduction power loss of the thyristor as a function of the firing angle ∝. Neglect turn on delay time and spread time and assume linear variation of voltage and current during turn on period. Also assume constant on state voltage V_H across the thyristor.

(i) For a firing angle ∝ the forward bias voltage across the thyristor just before turn on is

$$V_{ON} = \sqrt{2}V_i \ \text{Sin} \propto ; V_i \ = \ \text{RMS value of supply voltage.}$$

Current after the thyristor turns on for a resistive load is

$$I_{ON} = {}^{V_{ON}}\!/_{R} \ = \ \sqrt{2}\ {}^{V_i}\!/_{R} \ \text{Sin} \propto$$

Neglecting delay and spread time and assuming linear variation of voltage and current during turn on

$$V_{ak} = \sqrt{2}\ V_i \ \text{Sin} \propto \left(1 - {}^{t}\!/_{t_{ON}}\right). \text{ where } V_H \text{ has been neglected.}$$

$$i_a \ = \ \frac{\sqrt{2}\ V_i \ \text{Sin} \propto}{R} \ \ {}^{t}\!/_{t_{ON}}$$

∴ Total switching energy loss

$$E_{ON} \ = \int_o^{t_{ON}} v_{ak}\, i_a \, dt \ = \ \frac{2Vi^2}{R}\ \text{Sin}^2 \propto \int_o^{t_{ON}} \left(1 - {}^{t}\!/_{t_{ON}}\right) \ {}^{t}\!/_{t_{ON}} \ dt$$

$$= \frac{2Vi^2}{R} \text{Sin}^2 \propto \ \frac{t_{ON}}{2} \left(1 \ - \ \frac{2}{3}\right) \ = \ \frac{Vi^2}{3R}\ \text{Sin}^2 \propto \ t_{ON}$$

E_{ON} occurs once every cycle. If the supply frequency is f then average turn on power loss is given by.

$$P_{ON} \ = \ E_{ON}\, f \ = \ \frac{Vi^2}{3R}\ \text{Sin}^2 \propto t_{ON}\, f$$

(ii) If the firing angle is ∝ the thyristor conducts for π-∝ angle. Instantaneous current through the device during this period is

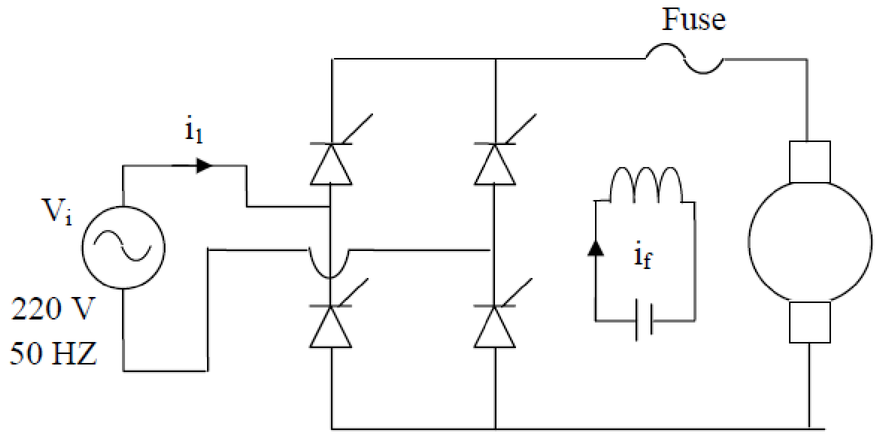
$$i_a = R\, \frac{\sqrt{2}\ V_i \ \text{Sin}\ \omega t}{R} \quad \propto \ \ < \omega\, t \leq \ \pi$$

Where t_{ON} & V_H have been neglected for simplicity.

∴ total conduction energy loss over one cycle is

$$E_C = \int_{\propto/\omega}^{\pi/\omega} V_{ak}\, i_a\, dt = \frac{1}{\omega}\int_{\alpha}^{\pi} V_H \frac{\sqrt{2}\,V_i}{R} \sin\theta\, d\theta = \frac{\sqrt{2}\,V_i\,V_H}{\omega R}\,(1+\cos\propto)$$

$$\therefore \text{ Average conduction power loss } = P_C = E_c f = \frac{\sqrt{2}\,V_i\,V_H}{2\pi R}\,(1+\cos\propto)$$



9)

In the ideal single phase fully controlled converter T_1 & T_2 are fired at a firing angle ∝ after the positive going zero crossing of V_i while T_3 & T_4 are fired ∝ angle after the negative going zero crossing of V_i, If all thyristors have a turn off time of 100 μs, find out maximum allowable value of ∝.

Answer: As T_1 & T_2 are fired at an angle ∝ after positive going zero crossing of V_i, T_3 & T_4 are subjected to a negative voltage of $-V_i$. Since this voltage remain negative for a duration (π-∝) angle (after which $-V_i$ becomes positive) for safe commutation $(\pi - \text{Max}) \geq \omega t_{off}$ $\therefore$ $\propto_{Max} = 178.2^0$.