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ENROLLMENT - BT18EE009
POWER ELECTRONICS ASSIGNMENT 6.

Q.1 (a) Explain the need of commutation in thyristor circuits. What are the different methods of commutation scheme? Discuss one of them, involving two thyristors, with a neat schematic.

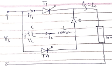
(b) A circuit employing parallel resonance turn off (or class B commutation) circuit has $C = 50 \mu F$, $L = 20 \mu H$, $V_s = 200 V$ and initial voltage across capacitor is 200V. Determine the circuit turn off time for main thyristor for load $R = 15 \Omega$

Ans (a) Thyristor, mainly SCR is a device which when gated or starts conducting, cannot stop conduction by itself or by removing the gate pulse.

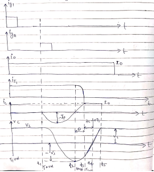
That's why we need a commutation circuits to turn it off.

There are five methods of commutation

(i) Load commutation (type A)
(ii) Current commutation (type B)
(iii) Complementary commutation (type C)
(iv) Impulse commutation (type D)
(v) External pulse commutation (type E)



schematic diagram with two thyristors.



When we connect the circuit the capacitor gets charged to V_s and $i_c = 0$. Then at $t = 0$, T_1 is triggered and I_0 flows through the load.

When we want to turn off T_1 then at time $t = t_1$ we trigger TA and a negative current $(-i_c)$ flows through $C \rightarrow TA \rightarrow L \rightarrow C'$

$$i_c = -V_s\sqrt{C/L}\,\sin\omega_0 t$$

where $$V_s\sqrt{C/L} = I_p$$

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

After half cycle of this i_c current, it will try to reverse its direction and as a result TA will be turned off. then this current will flow through $C \rightarrow L \rightarrow D \rightarrow T_1 \rightarrow C$. This i_c current will now oppose i_0 and as its magnitude will be equal to i_0 then the T_1 will be turned off.

So for turning off T_1

$$V_s\sqrt{C/L}\,\sin\omega_0 t = I_0$$

where $t = t_3 - t_2$.

(b) Given $C = 50\mu F$, $L = 20\mu H$, $V_s = 200V$, $R = 1.5\Omega$

As we know main thyristor is turned off when

$$V_s\sqrt{\frac{C}{L}}\sin\omega_0(t_3-t_2) = I_0$$

$$\Rightarrow \sin\omega_0(t_3-t_2) = \frac{I_0}{V_s\sqrt{\frac{C}{L}}}$$

$$= \frac{200/1.5}{200 \times \sqrt{\frac{50\times10^{-6}}{20\times10^{-6}}}}$$

$$= \frac{1}{1.5\sqrt{2.5}} = 0.4216$$

$$\Rightarrow \omega_0(t_3-t_2) = \sin^{-1}(0.4216) = 24.9^\circ$$

voltage across main thyristor when it turns off $= V_s \cos\omega_0(t_3-t_2)$

$$= 200\cos 24.9 = 181.4$$

Hence the circuit turn off time for main thyristor

$$= t_4 - t_3 = C\,\frac{181.4}{I_0}$$

$$= \frac{50\times10^{-6}\times181.4}{133.33}$$

$$= 68\mu s. \text{ ans}.$$

Q.2 (a) Distinguish clearly between voltage commutation and current commutation in thyristor circuits

(b) Discuss how the voltage across the commutating capacitor is reversed in commutating circuits

(c) For the circuit in fig 3.3(a), supply voltage $V_s = 230\,V\,dc$, load current $I_0 = 200\,A$, circuit turn off time for main thyristor $= 25\mu s$ and reverse of circuit is limited to 150% of I_0. Determine the values of commutating component L and C.

Ans (a) Voltage commutation :- This is possible in ac circuits. The thyristor gets turned off by reverse bias voltage applied across it. This is also called as line commutation.

Current commutation :- This is possible in dc circuits. This type of commutation makes use of auxillary circuits which contains inductor, capacitor, diode and even a thyristor. This is called forced commutation.

(b) In commutating circuits the voltage across capacitor is given by

$$V_c = V_s \cos \omega t$$

Since V_c is sinusoidal so after every half cycle it will be reversed.

(c) $I_p = V_s\sqrt{\frac{C}{L}} = \frac{150 \times 200}{100} = 300\,A$.

$\because V_s\sqrt{C/L}\,\sin\omega_0 t = I_0$ [for commutation].

$\Rightarrow \sin\omega_0 t = \frac{I_0}{I_p} = \frac{200}{300}$

$\Rightarrow \omega_0 t = \sin^{-1}(200/300) = 41.81^\circ$.

$\therefore$ voltage across main thyristor when it turns off

$= V_s \cos\omega_0 t = 230 \cos 41.81^\circ = 171.432\,V$

$\because t_c = C \cdot \frac{171.432}{200}$

$\Rightarrow 25 \times 10^{-6} = C \times \frac{171.432}{200}$

$\Rightarrow C = \frac{25 \times 200}{171.432} \times 10^{-6} = 29.166\,\mu F$.

Now,

$$300 = 230 \times \sqrt{\frac{29.166 \times 10^{-6}}{L}}$$

$\Rightarrow \frac{29.166 \times 10^{-6}}{L} = \left(\frac{30}{23}\right)^2 = \frac{900}{529}$

$\Rightarrow L = \frac{29.166 \times 10^{-6} \times 529}{900} = 17.143\,\mu H$

Hence $C = 29.166\,\mu F$ and $L = 17.143\,\mu H$.

Q.3 (a) Explain the merits and demerits of self commutation of SCR and its other method of commutation.

(b) For the circuit shown in figure 5.10, given that the load current I_0 to be commutated is 10 A, circuit turn off time required is 40 μs and the supply voltage is 100 V. Obtain the proper values of commutating components. Take peak resonant current equal to twice the load current.

Ans:- Merits of self commutation
(i) No need of extra SCRs.
(ii) It commutates the SCR after half cycle itself.
(iii) The circuit is very simple

Demerits of self commutation
(i) Underdamped condition of circuit is required. It cannot be operated in overdamped and critically damped circuits.
(ii) It's applicable only to dc supply.

Merits of other commutation processes is that we can commutate the SCR whenever we want.

Demerits is that there are two or more no. of SCRs have been used for commutation of single SCR.

(b) Given $I_0 = 10A$, $I_p = V_s\sqrt{C/L} = 20A$, $V_s = 100V$.

$I_p \sin\omega_0 t = I_0 \Rightarrow \sin\omega_0 t = 10/20 \Rightarrow \omega_0 t = 30°$.

$\therefore$ Voltage across SCR when it's turned off

$= V_{ab} = 100 \cos 30° = 50 \times 1.732V$

$t_c = C\frac{V_{ab}}{I_0} \Rightarrow 40\mu s = C \times \frac{50 \times 1.732}{10}$

$\Rightarrow C = \frac{40 \times 10^{-6}}{5 \times 1.732} = 4.619\mu F$.

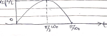
Now, $V_s\sqrt{C/L} = 20 \Rightarrow 100\sqrt{\frac{4.619}{L}} = 20$

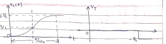
$\Rightarrow L = 25 \times 4.619 = 115.475 \mu H$.

Q.4. (a) Discuss with relevant waveforms class A and class D types of commutations employed for thyristors.

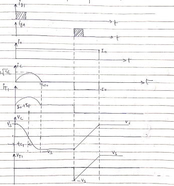
(b) For the circuit shown in figure 5.10 peak thyristor current = 2.5 times the constant load current, $L = 18\mu H$, $C = 4\mu F$, find the time elapsed from the instant thyristor is turned on to the instant it gets turned off.

Ans:- (a)





Wave forms of class A commutation.



Waveforms of class D commutation process

(b) let load current $= I_0$

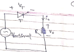
$\therefore \quad V_s\sqrt{C/L} = 2.5\, I_0$

Q.5 (a) Enumerate the various commutation technique used for thyristors.

(b) Describe the line commutation and class E commutation for thyristors. Name the circuit configuration where line commutation is used?

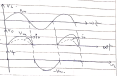
Ans:- (a) Class A commutation (self commutation)
Class B commutation (current commutation)
Class C commutation (complimentary commutation)
Class D commutation (voltage commutation)
Class E commutation (Impulse commutation)
Class F commutation (line commutation)

(b) Line-commutation:- This type of commutation is also known as natural commutation



Here, the thyristor carrying the load current is reverse biased by the ac source voltage and the device is turned off when anode current falls below the holding current.

Circuit



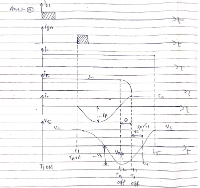
wave forms.

Line commutation is used in phase-controlled converters, line commutated inverters, ac voltage controllers and step-down cycloconverters.

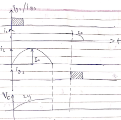
Q.6 (a) Discuss with relevant wave forms class B and class E types of commutation employed for thyristor circuits.

(b) A circuit employing resonant pulse commutation has $C = 20\,\mu F$ and $L = 3\,\mu H$. The initial capacitor voltage = source voltage = $V_s = 230\,V$ dc. Determine conduction time for auxiliary thyristor and circuit turn off time for main thyristor in case constant load current is (i) 300 A (ii) 60 A.

Ans:- (a)



wave forms of class A commutation



waveform of class E commutation

(b) Given $C = 20\,\mu F$ and $L = 3\,\mu H$

$V_s = V_c = 230V.$

(i) $I_o = 300A$

conduction time for auxillary thyristor $= \pi\sqrt{LC}$

$= 3.14\sqrt{3\times20\times10^{-12}}$

$= 24.322\,\mu s.$

t_c of main thyristor $= C\times\frac{V_{as}}{I_o}$

$230\sqrt{\frac{20}{3}}\sin\omega_0 t = 300 \Rightarrow \omega_0 t = \sin^{-1}\left[\frac{300}{593.857}\right]$

$= 30.3427^\circ$

$V_{ab} = 230 \cos 30.3427° = 198.494$

$\therefore \quad t_c = 20 \times 10^{-6} \times \frac{198.494}{300} = 13.23 \mu s.$

(ii)

$230 \sqrt{\frac{20}{3}} \sin \omega_0 t = 50$

$\Rightarrow \omega_0 t = \sin^{-1}\left[{}^{60}/_{593.857}\right] = 5.7987°$

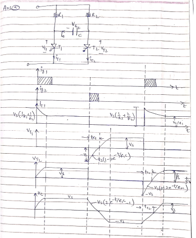
$V_{ab} = 230 \cos 5.7987° = 228.823$

$t_c = 20 \times 10^{-6} \times \frac{228.823}{60} = 76.273 \mu s.$

Q.7 (a) Describe type-C of commutation used for thyristors with appropriate current and voltage wave forms.

(b) An impulse commutated circuit is shown in fig 5.5(a). In this circuit capacitor is initially charged to source voltage $V_s = 200V$ with upper plate negative. When auxillary thyristor is turned ON, main thyristor turns off in 50 μs. Find the value of C in case load resistance = 20 Ω. If peak current through main thyristor is twice load current calculate value of commutating inductance.

Ans (a)


R1
R2
VC
+
−
iC
C
T1
T2
VT1
VT2
iT1
iT2
ig1
ig2
t
iT1
Vs(1/R1 + 1/R2)
Vs(1/R1 + 2/R2)
Vs/R1
VT1
tc1
Vs
−Vs
−Vs(1−2e^{−t/R1C})
VT2
Vs
tc2
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−Vs(1−2e^{−t/R2C})
VC
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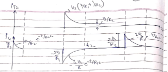
−Vs
tc2



(b) given $V_s = 200\,V$.

$t_c = 50\,\mu s$.

$I_0 = \frac{200}{20} = 10\,A$

$\because \quad t_c = C \cdot \frac{V_s}{I_0} \Rightarrow 50\times10^{-6} = C \times \frac{200}{10}$

$\Rightarrow C = 2.5\,\mu F$

Q.8. What is complimentary impulse commutation. Describe this type of commutation by a neat diagram and waveforms. Define expression for current through and voltage across commutating capacitor. Find also the circuit turn off time for complimentary thyristors.

Ans:- In this type of commutation, a thyristor carrying load current is commutated by transfering its load current to another incoming thyristor.

When T_1 is turned on at $t=0$, current through R_1 is $I_1 = V_s/R_1$ and through R_2 is

$i_c = V_s/R_2$. Capacitor c becomes charging from 0V. So the charging current is given by

$$i_c(t) = \frac{V_s}{R_2} e^{-t/R_2 C}.$$

and voltage $V_c = V_s\left(1 - e^{-t/R_2 C}\right)$

When T_1 is to be turned off, T_2 is triggered on at $t = t_1$, then capacitor voltage V_c applies a reverse potential V_s across SCR T_1 and turns it off.

Using KVL,

$$R_1 i_c + \frac{1}{C}\int i_c \, dt = V_s$$

taking laplace transform,

$$R_1 I_c(s) + \frac{1}{C}\left[\frac{I_c(s)}{s} + \frac{CV_s}{s}\right] = V_s/s$$

taking inverse laplace

$$i_c(t) = \frac{2V_s}{R_1} e^{-t/R_1 C}$$

As this current flows opposite to the direction indicated so

$$i_c(t) = -\frac{2V_s}{R_1} e^{-t/R_1 C}$$

$$V_c(t) = \left[\frac{1}{C}\int_0^t i_c \, dt + V_s\right] = \left[\frac{1}{C}\int_0^t -\frac{2V_s}{R_1} e^{-t/R_1 C} + V_s\right]$$

$$= V_s\left[2e^{-t/R_1 C} - 1\right]$$

Circuit turn off time for T1

$$V_{T_1} = 0 = V_s\left[1 - 2e^{-t/R_1 C}\right]$$

$$\Rightarrow t_{c_1} = R_1 C \ln(2)$$

Circuit turn off time for T2

$$V_{T_2} = 0 \Rightarrow t_{c_2} = R_2 C \ln(2).$$

Q.9. In the circuit of fig 5.4(a) employing complementary commutation: $V_s = 200V$, $R_1 = 20\Omega$ and $R_2 = 100\Omega$. Determine the minimum value of C so that thyristor do not get turned off due to re-applied dV/dt. Each SCR has a min. current of 4mA to turn it off and its junction capacitance is 20 pF.