POWER ELECTRONICS LAB
Experiment-III

STUDY OF THYRISTOR (SCR) BASED BUCK CONVERTER CONSISTING OF CLASS-D COMMUTATION CIRCUIT

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Part-A: Simulate the ideal thyristor based buck converter in open-loop using following parameters, Input Voltage $V_i = 1000V$, Output Voltage $V_o = 600\ V$, Switching Frequency $F_s = 500Hz$ & $T_s = 1/F_s$, Filter Capacitor $C_f = 330\mu F$, Filter Inductor $L_f = 24mH$, Load Resistance $R_l = 30\Omega$, Commutation Capacitor $C_c = 3\mu F$, Diodes and switches drops =0V. Set the initial voltage of the C_c = +Vi (otherwise it would cause commutation failure)

1. Choose the commutation inductor L_c in such a way that the peak current through the main thyristor remains at 120A (±5% is considerable).

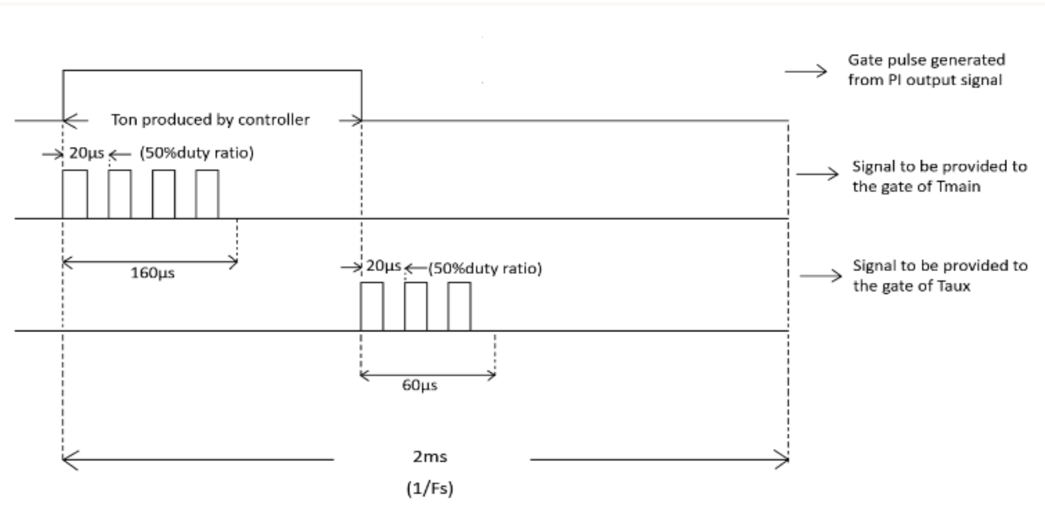
2. Calculate the theoretical duty cycle value (the T_{on} time for steady state) & incorporate it to trigger both the thyristors in the proper way. Monitor the o/p voltage, whether it is coming 600 V or not. If it’s not, then check the actual T_{on} time the main thyristor is having. Manipulate the theoretical T_{on} time (steady state) accordingly & recheck whether the o/p voltage is 600 V or not.

(i) Note the required turn on time manipulation to get 600V output voltage.

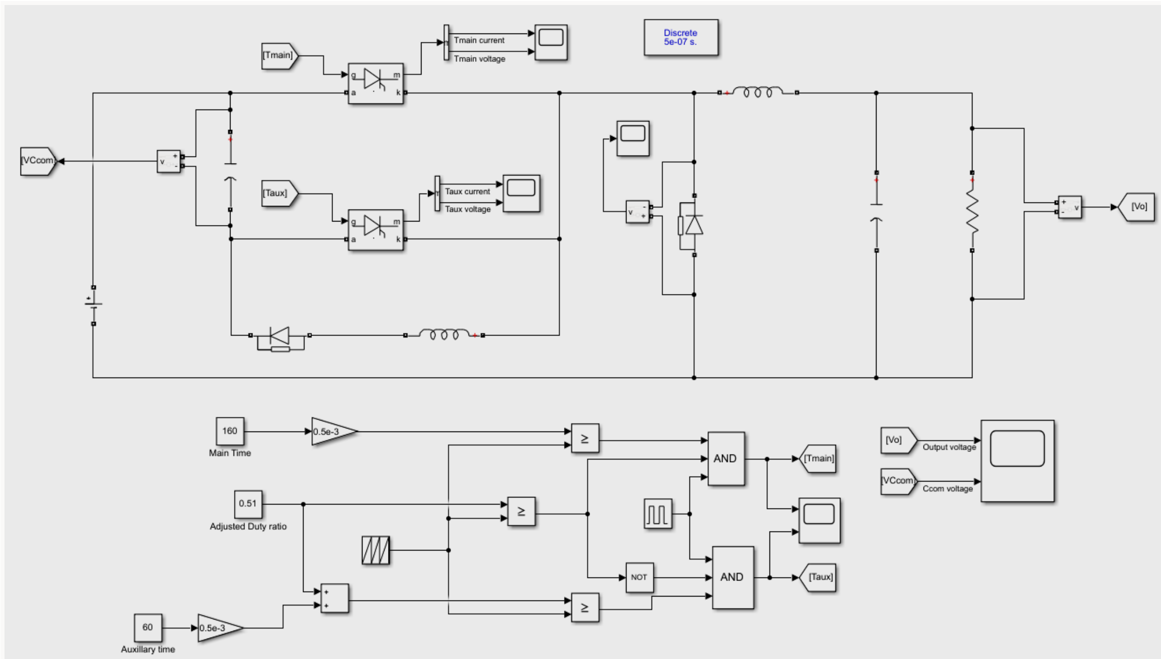
(ii) Note the circuit turn-off time of main & auxiliary thyristors.

(iii) Show the waveform of the voltage across the C_c(for 3 switching cycle in steady state).

(iv) For C_c= 1μF& C_c= 0.2μF, comment on the commutation failure of main thyristor for both the cases. (in the Simulink commutation failure of the thyristor can't be directly inspected, comment on it by analysing the voltage waveform across the main thyristor) [t_q(main thyristor) = 30μs]



Thyristor(SCR) based Buck Converter Circuit:-



1.

For the buck converter circuit,

L_f=24mH, C_f=330μF,T_{sw}=2ms, R_L=30Ω, V_i=1000V, V_o= 600V

Hence D=0.6

$$I_{L,av} = \frac{V_o}{R} = 20A$$

$$\Delta I_L = \frac{(V_i - V_o)DT_{sw}}{L} = 20A$$

Hence, $i_{L,min}$=10A

Now for commutation circuit,

C_c=3μF And limit of peak current through main thyristor =120A

$$i_{peak}^{main} = i_{L,min} + V_i\sqrt{\frac{C_c}{L_c}}$$

Hence, L_c = 247.93μH

We have chosen L_c=255μH for our circuit.

2.

Theoretical duty cycle should be 0.6. But, we have used thyristor as a switching device so, the switching is not ideal and will depend on the commutative circuit.

2.i.

Observations to find the adjusted duty ratio for desired output voltage:-

Duty ratio	**V_{output}(V)**	**Comment**
0.6	686.7	Higher than 600,decrease D
0.55	640.0	Higher than 600,decrease D
0.5	594.0	Lower than 600,increase D
0.52	612.1	Higher than 600,decrease D
0.51	603.0	**Adjusted value of D**

Hence, we need to change the theoretical turn-on time of $0.6 \times 2ms = 1.2ms$ to $0.51 \times 2ms = 1.02ms$ to get the desired output voltage,as thyristor switching is non-ideal.

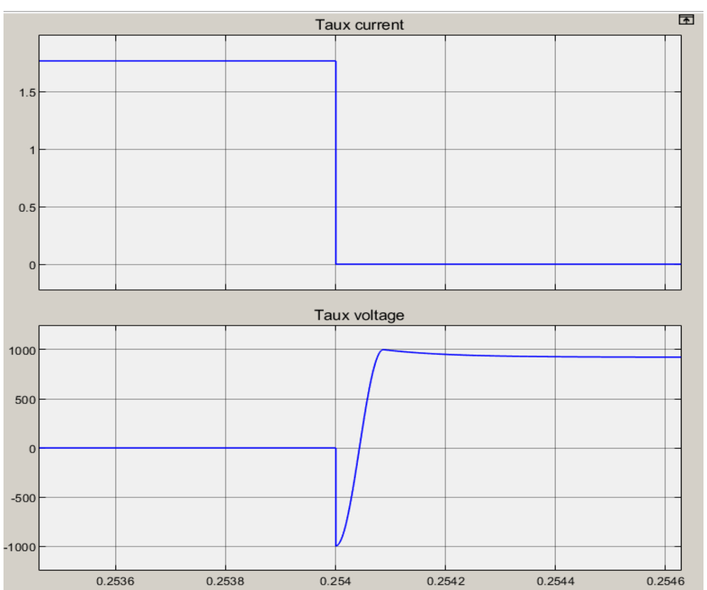
2.ii.

Main Thyristor waveform:-

As we can observe here, when the thyristor switch is off the thyristor voltage doesn't become 1000V instantly. The time it takes to come back from -1000V to 0V is denoted as turn-off time here, which is 89.716μs(Turn-off time of main thyristor).

It takes almost 194.52μs for the main thyristor voltage to reach 1000V after the thyristor current becomes 0.

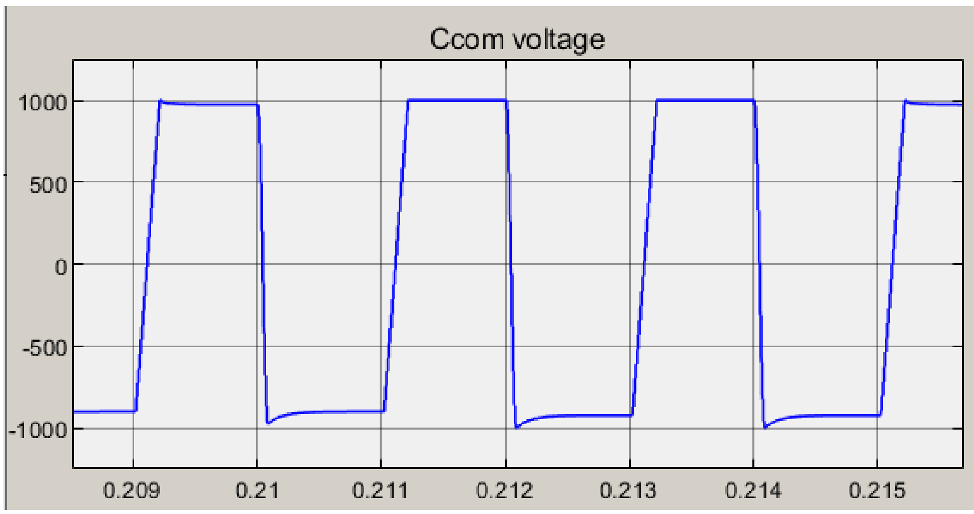
<u>Auxiliary thyristor waveform:-</u>



Turn-off time of auxiliary thyristor = 44.291μs
It takes 85.58μs for the auxiliary thyristor voltage to reach maximum value after the thyristor current becomes 0.

2.iii.

Voltage waveform across C_c:

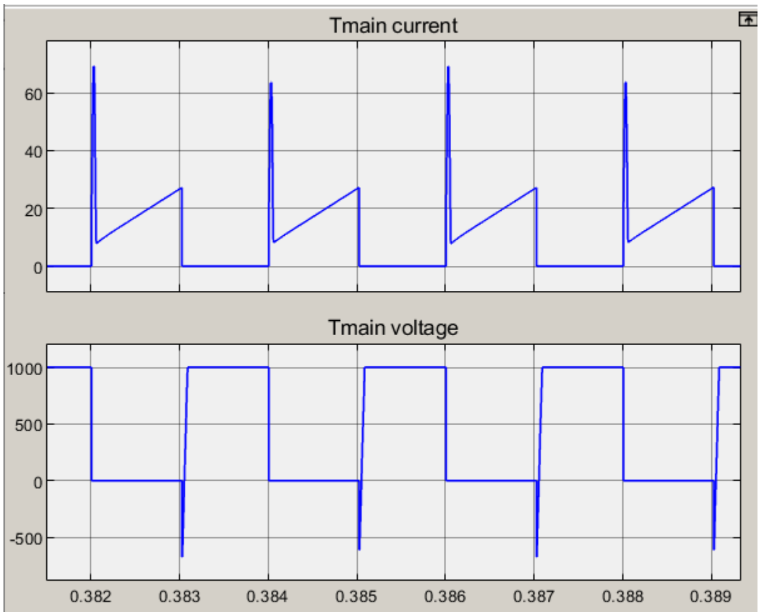


2.iv.

If we reduce the capacitance of the commutation capacitor, commutation failure occurs i.e. the turn-off time of the thyristor increases, hence due to switching the thyristor doesn't have enough time to turn off. The turn-off time of the switch becomes insufficient for the thyristor to regain it's blocking capacity and so it never turns off.

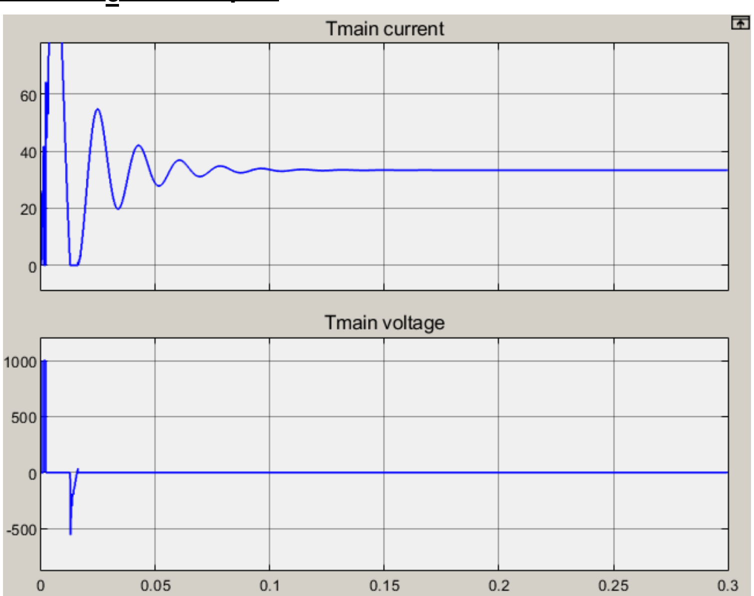
We have simulated the same circuit in simulink for C_c= 1μF and 0.2μF. When we change the commutation capacitor to 0.2μF we can observe commutation failure in the circuit.

For C_c = 1μF



In this case, we can observe that the thyristor is functioning perfectly as it has a lower turn-off time due to the 1μF commutation capacitor

For C_c = 0.2μF



Due to commutation failure, after the first few cycles in transition state, the main thyristor voltage becomes 0 and current through it becomes constant(switch never turns off).

Discussions:-

1. Why is the commutation circuit required?

When a thyristor moves in the mode of forward conduction, then its gate terminal loses its control. To turn it off we need to,
 i. Decrease the forward current to zero.
ii. Provide sufficient reverse voltage to recover it's forward blocking condition.
So, the auxiliary thyristor and <u>commutation circuit is used to turn the main thyristor off</u> during the off period.
The commutation capacitor and inductor creates a resonating LC circuit, but due to the diode current direction, the commutation current(after firing the main thyristor) doesn't change direction after charging the capacitor. So when we fire the auxiliary transistor the voltage across the capacitor generates sufficient reverse voltage on the main thyristor turning it off.

2. What will happen if we decrease the switch-on period below thyristor turn-off time?

The auxiliary thyristor turns off during the switch-on period using the capacitor voltage to apply the reverse bias across it to turn on it's forward blocking capability.
If we decrease the switch-on period below thyristor turn-off time <u>the auxiliary thyristor will have commutation failure</u>, as it won't be able to turn off during the switch-on period. Due to commutation failure of the thyristor switching circuit, output voltage will be equal to the input voltage after initial transient behaviour.

3. Can we use a polarised capacitor as the commutation capacitor (C_c) here?Justify your answer.

No, we cannot use a polarised capacitor as the commutation capacitor here. During the on-off period the voltage across the capacitor varies from +V_{in} to -V_{in}(as observed in **2.iii**),so the electrode voltage of the capacitor changes its polarity in every switching cycle. So we must use a non-polarised capacitor as the commutation capacitor.

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