DETAILS EXPLANATIONS

EE : Paper-2 (Paper-6) [Full Syllabus]

[PART : A]

1.
- Distortion of Supply
- Low Power Factor
- Ripple in Motor Current
- Harmonics overheat the machine winding, therefore we cannot use the machine for full power rating. Drives should be derated when it is feel to the converter.
- Harmonics produce pulsating torque in the rotor therefore the drive may not run smoothly. If it is used for power motors the rotor inertia will damp the pulsating torque produced by harmonics.
- At high value of firing angle α the converter operates with lesser PF and draw more reactive power from AC Line.

2. The importance of digital instruments is increasing mainly because of the widespread use of digital computers in both data processing and automatic control systems.

3.
- Feedback in control system greatly improves the speed of its response.
- Effect in the controlled variable of external disturbances other than those associated with the feedback sensor are greatly reduced.
- Effect of variation in controller and process parameters (the forward path) on system performance is reduced to acceptable levels.

4. The primary sensing element is that which makes contact with the physical quantity under measurement, receives energy from the measured medium and produces an output depending in some way on the measurand.

5.
- SCR should be forward biased.
- The load impedance should not be too high so that, if SCR turn ON, the current in the SCR would reach more than the latching current value.
- The gate terminal must be made positive with respect to cathode.
- For feedback control, the delay angle is controllable by a low-level DC voltage V_C.
- The driver circuits are provided with an INHIBIT input terminal which is used for the logical control of the converter.

6. The difference between the measured value A_m and the true value A of the unknown quantity measurand is known as the absolute error at measurement δA i.e.

$$\delta A = A_m - A$$

7. $X(t) = A_C \cos(2\pi f_c t) + \frac{A_C}{4} m(t).\cos 2\pi f_c t$

$$\mu = \frac{1}{2}$$

% of modulation = 50%.

8. At small loads, exciting current I_0 is a greater portion of primary current I_p owing to the curvature of B-H curve of the core material at low flux densities. Thus the ratio error is made more negative and phase angle error more positive normally. This means increased errors with relatively small loads than at the rated current.

9. $A + \bar{A}B$

$(A + \bar{A})\cdot(A + B)$ [Distributive Law]

$1 \cdot (A + B)$ $[\because A + \bar{A} = 1]$

$A + B$ [Using Property]

Hence

$A + \bar{A}B = A + B$

10. Ordinary electrodynamometer wattmeter is not suitable for measurement of power in low power factor circuits owing to (i) small deflecting torque on the moving system even when the current and pressure coils are fully excited and (ii) introduction of large error due to inductance of pressure coil at low power factor.

11. Noise may be classified in two broad groups as under : (i) External Noise (ii) Internal Noise.

12. Owing to the fact that a polarization emf is set up whenever a current passes through an electrolyte, the usual methods of measuring resistance cannot be used for measuring resistance of electrolytes.

13. If transfer function has poles or zeros lie in right half of s-plane then transfer function is called non-minimum phase transfer function.

14. An imperfect capacitor (i.e. a capacitor having dielectric loss) is represented diagrammatically as a perfect capacitor C in parallel or in series with a resistance R.

15. For $\alpha \le 60°$

Conduction angle of each Thyristor $= \dfrac{2\pi}{3}$ for every 2π radian

Conduction angle of each Diode $= \dfrac{2\pi}{3}$ for every 2π radian

16. The hole in a grid of a CRO is provided to allow passage for electrons through it and concentrate the beam of electrons along the axis of the tube.

17.
- This type of inverter has small impedance on source side and input voltage is almost constant.
- Voltage source inverter required feedback diode.
- A VSI is normally employed when both the source and load have low values of impedance and reactance.
- The VSI requires forced commutation because no source for turning off the thyristor.

18. The megger is an instrument used for the measurement of high resistance and insulation resistance. Essentially the megger insulation tester consists of a hand driven DC generator and a direct reading true ohmmeter.

19. Impulse response= L^{-1} (Transfer function)

$$C(t) = L^{-1}\,(H(s))$$

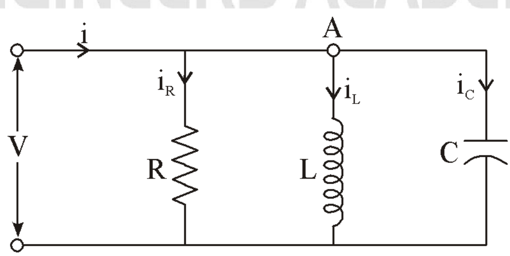
$$C(t) = L^{-1}\left(\frac{5}{s+1}\right) - L^{-1}\left(\frac{2}{s+3}\right) + L^{-1}\left(\frac{6}{s+4}\right)$$

$$C(t) = 5e^{-t} - 2\,e^{-3t} + 6\,e^{-4t}$$

20. Transformers used in conjunction with instruments for measurement are called instrument transformer.

[PART : B]

21. Apply KCL at node "A" we have



$$i_R + i_L + i_C = i$$

$$\frac{V}{R} + \frac{1}{L}\int v\,dt + C\frac{dv}{dt} = i \qquad \left[\because V = \frac{d\phi}{dt}\right]$$

ϕ = Magnetic flux

$$C\frac{d^2\phi}{dt^2}+\frac{1}{R}\frac{d\phi}{dt}+\frac{\phi}{L} = i$$

This equation represent the mathematical model of parallel RLC network.

22. When the error is specified as a percentage of full scale deflection, the magnitude of limiting error at full scale

$$= \pm\frac{1}{100}\times 1000 = \pm 10 \text{ W}$$

Thus the wattmeter reading when, the true reading is 100 W may be 100 ± 10 W i.e., between 90 to 110 W.

$$\text{Relative error} = \frac{\pm 10}{100}\times 100 = \pm 10\%$$

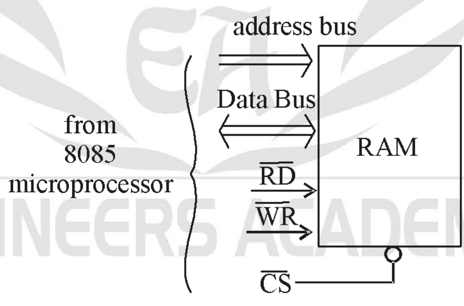
Now suppose the error is specified as percentage of true value. The magnitude of error

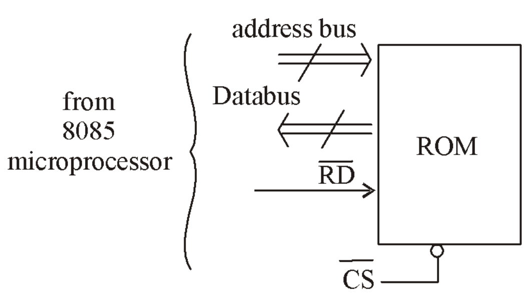
$$= \pm\frac{1}{100}\times 100 = \pm 1 \text{ W}$$

Therefore the meter may read 100 ± 1 W or between 99 to 101 W.

23. In memory interfacing the required number of address lines to the memory are directly connected to memory of microprocessor and remaining lines are used to generate chip select signal of corresponding memory.

For example :





24.
- The chopping frequency has to be varied over a wide range for the control of output voltage in frequency modulation filter design for such wide frequency variation is difficult.
- For the control of δ, frequency variation would be wide. As such, there is a possibility of interference with signalling and telephone lines in the frequency modulation scheme.
- The large off-time is frequency modulation scheme may make the load current discontinious.

25. Absolute error δ A is equal to the difference of the measured value A_m and the true value A of the measurand.

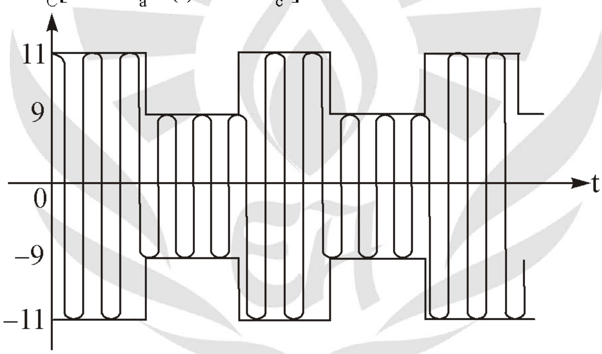
i.e. $\delta A = A_m - A$

But relative error is equal to the ratio of absolute error to the true value of the quantity under measurement.

i.e. Relative error,

$$\varepsilon_r = \frac{\delta A}{A} = \frac{\varepsilon_0}{A} = \frac{\text{Absolute error}}{\text{True value}}$$

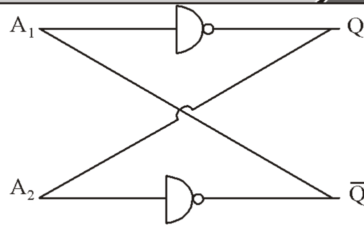
26. $S(t) = A_C[1 + k_a m(t)\cos 2\pi f_c t]$



27. A basic memory cell is a circuit that stores one bit of information. This one bit memory element is called flip-flop. The flip flop is made up of an assembly of logic gates. Even though a logic gate by itself has no storage capacity, several logic gates can be connected together in ways that permit information to be stored. A flip-flop known more formally as a bistable multivibrator, has two stable states.

It can remain in either of states indefinitely and the state can be changed by applying proper triggering signal. Flip flop is also called binary or one bit memory.

The flip flop can also be realized by the cross connection of NAND gates or NOR gates. The two NAND gates connected in feedback loop are shown in fig.



Basic memory element

28. The bridge has the advantage of requiring only a relatively low value resistor for R_4 whereas, for large inductance low resistance coils, the Maxwell Wien bridge would require a parallel resistance R_4 of very high value, perhaps 10^5 or 10^6 Ω. Resistance boxes of such high values are very costly.

This bridge gives very simple expressions for unknown inductance for high-Q coils and for Q-factor too. The bridge is not suited for the measurement of low Q-factor of the inductors, because in that case, the term $\omega^2 C_4^2 R_4^2$ in the denominator becomes very important. And then it is required to know the bridge frequency to a very accurate limit. Moreover, with low value of Q-factor, it gives poor convergence in balancing.

29. Characteristic Equation

$s^4 + 8s^3 + 18s^2 + 16s + 5 = 0$

s^4	1	18	5
s^3	8	16	
s^2	16	5	
s^1	13.5	0	
s^0	5		

Since no sign change in first column hence no roots of characteristic equation lie in right half of s-plane

All 4 roots lie in left half of S-plane & system is stable

30. Actual energy consumption during the test period

$$= \sqrt{3} \times \text{ratio of PT} \times \text{ratio of CT} \times V_S I_S \cos\phi \times t \times 10^{-3} \text{ kWh}$$

$$= \sqrt{3} \times \frac{22{,}000}{220} \times \frac{100}{5} \times 220 \times 10 \times 1 \times \frac{30}{3{,}600} \times 10^{-3} \text{ kWh}$$

$= 63.5$ kWh

Energy recorded by meter during the test period

$$= \frac{\text{Number of revolutions made}}{\text{Meter constant in rev / kWh}} = \frac{10}{0.2} = 50 \text{ kWh}$$

Percentage error $= \frac{50-63.5}{63.5}\times 100 = -21.3\%$

31. In electrical terms, noise may be defined as an unwanted of energy which tend to interfere with the proper reception and reproduction of transmitted signals. For example, in receivers, several electrical disturbances produce noise and thus modifying the required signal in an unwanted form. In case of radio receivers, noise may produce hiss type sound in the output of loudspeaker. Similarly, in, T.V. receivers, noise may produce 'snow' which becomes superimposed on the picture output. In addition to this, in pulse communications, noise may produce unwanted pulses or cancel the required pulses. In other words, we can say that noise may limit the performance of a communication system.

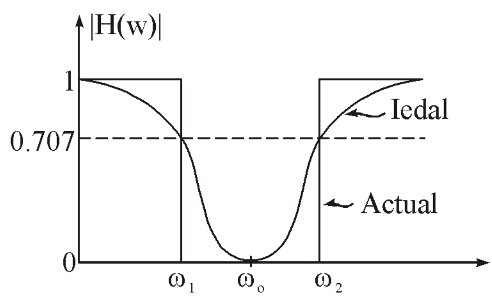
32. A filter that prevents a band of frequencies between two designated values from passing is variably known as bandstop, bandreject, or notch filter. A bandstop filter is formed when the output RLC series resonant circuit is taken off the LC series combination as shown in figure.

Figure : A Band stop filter

The transfer function is

$$H(\omega) = \frac{V_o}{V_i} = \frac{j(\omega_L - 1/\omega c)}{R + j(\omega_L - 1/\omega c)}$$

The plot of |H(w)| along with the ideal characteristic is shown below.



The corner or cutoff frequency is

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

A band stop filter may be obtained by parallel connection a low pass filter with a high pass filter, where cut off frequency f_{C_2} of high pass filter is greater than the cut off frequency f_{C_1} of low-pass filter the block diagrams for band stop is shown in figure.

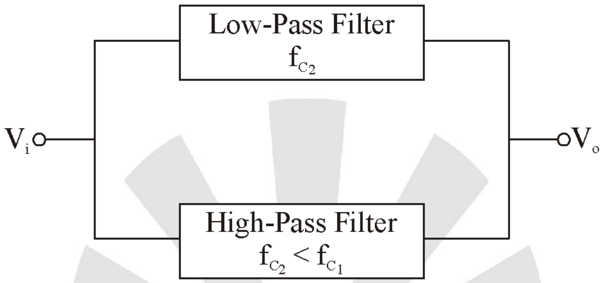


Figure: Band Stop Filter

[PART : C]

33. Galvanometer current, $I_g = I\frac{R_1}{R_1 + R_3 + R_g}$

Galvanometer current,

$$I_{g1} = I \times \frac{1}{1+450+R_g}, \text{ When, } R_3 = 450\ \Omega \quad ...(1)$$

$$I_{g2} = I \times \frac{1}{1+950+R_g}, \text{ When } R_3 = 950\ \Omega \quad ...(2)$$

Dividing equation (1) by equation (2) we have

$$\frac{I_{g1}}{I_{g2}} = \frac{951+R_g}{451+R_g} = \frac{d_1}{d_2}$$

$\because$ Deflection, d $\propto$ Galvanometer current, I_g

or $$\frac{951+R_g}{451+R_g} = \frac{150}{75} = 2$$

(i) or $R_g = 49\ \Omega$

(ii) Total resistance of the circuit,

$$R_t = R_2 + \frac{R_1(R_3+R_g)}{R_1+R_2+R_3} = 2500 + \frac{1(950+49)}{1+950+49} = 2501\ \Omega$$

Total current through circuit,

$$I = \frac{V}{R_t} = \frac{2}{2501} = 0.8 \times 10^{-3} \text{ A}$$

Galvanometer current,

$$I_g = 0.8 \times 10^{-3} \times \frac{1}{1+450+49}$$

$$= 1.6 \times 10^{-6} \text{ A or } 1.6 \ \mu\text{A}$$

$$\therefore \text{ Current sensitivity} = \frac{\text{Deflection in mm}}{\text{Current in } \mu\text{A}} = \frac{150}{1.6}$$

$$= 93.75 \text{ mm}/\mu\text{A}$$

(iii) Galvanometer current when deflection is 100 mm

$$I_{g2} = \frac{100}{93.75} = 1.0667 \ \mu\text{A}$$

Also galvanometer current,

$$I_{g2} = 0.8 \times 10^{-3} \times \frac{1}{1+R_3+49}$$

or $$1.0667 \times 10^{-6} = 0.8 \times 10^{-3} \times \frac{1}{R_3+50}$$

or $$R_3 + 50 = \frac{0.8\times10^{-3}}{1.0067\times10^{-6}} = 750 \ \Omega$$

or $$R_3 = 750 - 50 = 700 \ \Omega$$

34. A pulse E(t) is applied to RC circuit through a switch K, the circulating current being i(t) figure (b) we assume the initial charge to be zero in the capacitor. Application of kVL in the loop of figure (b) yields.

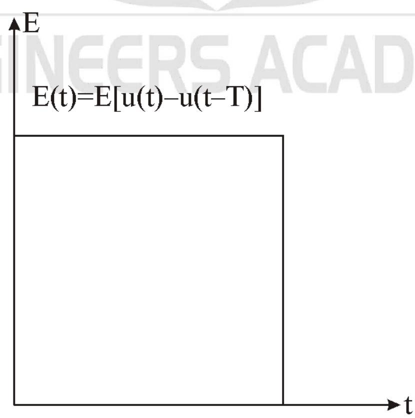
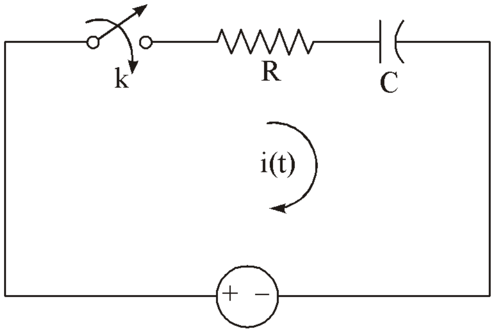


Figure (a) : Pulse input



E(t)=E[u(t)–u(t–T)]

Figure (b) : Pulse input in RC circuit

$$E(t) = Ri(t) + \frac{1}{C}\int i(t)\,dt \qquad ...(1)$$

or $E[u(t) - u(t-T)] = Ri(t) + \frac{1}{C}\int i(t)\,dt$

Taking the laplace transform of above equation

$$RI(s) + \frac{1}{C}\left[\frac{Q_o}{s} + \frac{I_{(s)}}{s}\right] = \frac{E}{s}\left[1 - e^{-Ts}\right] \qquad ...(2)$$

But $Q_o = 0$ [Following the initial condition]

Thus the equation (2) becomes

$$RI(s) + \frac{1}{C}\left[\frac{I(s)}{s}\right] = \frac{E}{s}\left(1 - e^{-Ts}\right)$$

$$\therefore \quad I(s) = \frac{E}{s}\frac{1-e^{-Ts}}{R + 1/Cs} = \frac{E}{R}\frac{1-e^{-Ts}}{(s+1/RC)}$$

$$I(s) = \frac{E}{R}\left[\frac{1}{s+1/RC} - \frac{e^{-Ts}}{s+1/RC}\right]$$

Taking the inverse laplace of equation then comes.

$$i(t) = \frac{E}{R}\left[e^{-\frac{t}{Rc}} - e^{-\frac{t}{Rc}}u(t-T)\right]$$

35. ***Optical Fibers :***

The second communication channel, an optical fiber, in a dielectric waveguide which transports light signals from one place to another just as a metallic wire pair or a co-coxial cable, transports electrical signals.

An optical fiber consists of a central core within which the propagating electromagnetic field is confined and which is surrounded by a cladding layer, which is itself surrounded by a thin protective jacket. Basically, the core and cladding are both made of pure silica glass, whereas, the jacket is made of plastic. Optical fibers have unique characteristics that make them highly attractive as a transmission medium.

The following Advantages :

(i) Enormous Potential Bandwidth

For optical fibers, enormous potential bandwidth results from the use of optical carrier frequencies around 2×10^{14} Hz. With such a high carrier frequency and a bandwidth roughly equal to 10 percent of the carrier frequency, the theoretical bandwidth of a light wave system is around 2×10^{13} Hz, which is very large.

(ii) Low Transmission Losses

Optical fibers offer low transmission losses as low as 0.2 dB/km.

(iii) Immunity to Electromagnetic Interference

In fact, immunity to electromagnetic interference is an inherent characteristic of an optical fiber which is viewed as a dielectric waveguide.

(iv) Small Size and Weight

For optical fibers, small size and weight are characterized by a diameter which is no greater than that of a human hair.

(v) Ruggedness and Flexibility

Optical fibers offer unique advantage of ruggedness and flexibility because of very high tensile strengths and the possibility of being bent or twisted without damage.

36. Close loop transfer function

$$\frac{C(s)}{R(s)} = \frac{G(s)}{1+G(s)H(s)} = \frac{100}{s^2+6s+25}$$

Comparing with standard second order transfer function.

We get $\omega_n^2 = 25$ there for $\omega_n = 5$ rad/sec

$$2\xi\omega_n = 6 \Rightarrow \xi = \frac{6}{2\times 5} = 0.6$$

Damping frequency of oscillations

$$\omega_d = \omega_n\left(\sqrt{1-\xi^2}\right) = 5\left(\sqrt{1-(0.6)^2}\right) = 4 \text{ rad/sec}$$

Maximum overshoot

$$= 100e^{\frac{-\pi\xi}{\sqrt{1-\xi^2}}}\% = 100e^{\frac{-0.6\pi}{\sqrt{1-(0.6)^2}}}\%$$

$$= 100e^{-2.356}\% = 9.478\%$$

Manimum overshoot

$$= 100e^{-\frac{2\pi\xi}{\sqrt{1-\xi^2}}}\% = 100e^{-2\times 2.356}\%$$

$$= 0.898\%$$

Setting time = time required for settling the output within 2% of final value

$$= \frac{4}{\xi\omega_n} = \frac{4}{0.6\times 5} = 1.33 \text{ sec}$$

time period of the damped cycles

$$= \frac{2\pi}{\omega_d} = \frac{2\pi}{4}$$

$$\text{Number of cycles} \simeq \frac{t_s}{\text{time period}}$$

$$= \frac{1.33\times 4}{2\pi} = 0.846 \text{ cycles}$$

Peak time

$$t_p = \frac{\pi}{\omega_d} = \frac{\pi}{4} = 0.7853 \text{ sec}$$

$$T_{min} = \frac{2\pi}{\omega_d} = \frac{2\pi}{4} = 1.57 \text{ sec}$$

therefore, time interval between first peak and first minimum

$$= 1.57 - 0.7853 \text{ sec}$$

$$= 0.7847 \text{ sec}$$

37. If F is the force of attraction and dx is the displacement of the moving plates, then,

$$Fdx = \frac{1}{2}V^2dC \text{ or } F = \frac{1}{2}V^2\frac{dC}{dx} \text{ newtons}$$

where, V = Applied pd in volts

C = Farads

and x = Metres

Now the controlling force is proportional to displacement

$$F_C \propto x$$

or F_C = kx where k is torsion constant in newtons/meter Since controlling force = Displacement force,

$$kx = \frac{1}{2}V^2\frac{dC}{dx} \text{ or } x = \frac{1}{2}\frac{V^2}{k}\frac{dC}{dx}$$

If x_0 be the initial displacement in metre, then

$$x - x_0 = \frac{1}{2}\frac{V^2}{k}\frac{dC}{dx} \qquad ...(1)$$

Now the capacitance,

$$C = \frac{2\varepsilon_0\varepsilon_r A}{d} \qquad (\because \text{ two capacitors are in parallel})$$

$$= \frac{2\times 8.854\times 10^{-12}\times 1\times 0.25x}{0.05} \qquad (\because \varepsilon_r \text{ for air} = 1.0)$$

$$= 88.54 \times 10^{-12} \text{ x Farads}$$

and $\frac{dC}{dx} = 88.54 \times 10^{-12}$ F/m ...(2)

When V = 12 kV, i.e., 12000 V and $x = \frac{0.25}{4} = 0.0625$ m

Substituting V = 12000 V and x = 0.0625 m

and $\frac{dC}{dx} = 88.54 \times 10^{-12}$ F/m in equation (1)

We have $0.0625 - x_0 = \frac{1}{2} \times \frac{(12000)^2}{k} \times 88.54 \times 10^{-12}$

or $0.0625 - x_0 = \frac{6.375\times 10^{-3}}{k}$ ...(3)

When V = 32 kV i.e., 32000 V

and $x = \frac{0.25}{2} = 0.125$

Substituting V = 32000 V, x = 0.125 m

and $\frac{dC}{dx} = 88.54 \times 10^{-12}$ F/m in equation (1), we have

$$0.125 - x_0 = \frac{1}{2}\frac{(32000)^2}{k}\times 88.54\times 10^{-12}$$

or $0.125 - x_0 = \frac{45.33\times 10^{-3}}{k}$ ...(4)

Dividing equation (4) by equation (3) we have

$$\frac{0.125 - x_0}{0.0625 - x_0} = \frac{45.33 \times 10^{-3}}{6.375 \times 10^{-3}} \text{ or } x_0 = 0.0523 \text{ m}$$

Substituting $x_0 = 0.0523$ m in equation (3) we have

$$0.0625 - 0.0523 = \frac{6.375 \times 10^{-3}}{k} \text{ or } k = 0.624 \text{ N/m}$$

Now for determining voltage required to pull the plate three quarter way in, substitute $x = \frac{3}{4} \times 0.25$ i.e., 0.1875 m

$x_0 = 0.0523$ m; $k = 0.624$ N/m

and $\frac{dC}{dx} = 88.54 \times 10^{-12}$ F/m in equation (1)

So, $0.1875 - 0.0523 = \frac{1}{2} \times \frac{V^2}{0.624} \times 88.54 \times 10^{-12}$

or $V^2 = 1906 \times 10^6$

or $V = \sqrt{1906 \times 10^6} = 43654$ V or 43.654 kV

38. Voltage commuated chopper in this scheme, a conducting thyristor is commutated by the application of a pulse of large reverse voltage. This reverse voltage is usually applied by switching a previously charged capacitor. The sudden application of reverse voltage across the conducting thyristor reduces the anode current to zero rapidly. Then presence of reverse voltage across the SCR aids in the completion of its turn-off process.

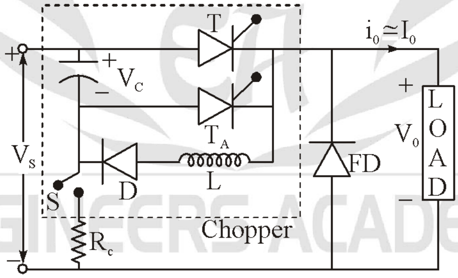


Figure : Voltage Commutated Chopper

The working of voltage commutated chopper shown below can be discussed as follows, let initially 'C' is charged upto V_s i.e., $V_c(0) = V_s$. Main thyristor T is fired at t = 0, when T → ON D gets forward biased due to $V_c = +V_s$

For t > 0

$$V_c(t) = V_s \cos \omega_o t \quad \text{and } i_c(t) = I_{CP} \sin \omega_o(t)$$

where $\omega_o = \frac{1}{\sqrt{LC}}$ $I_{CP} = V_S\sqrt{\frac{C}{L}}$

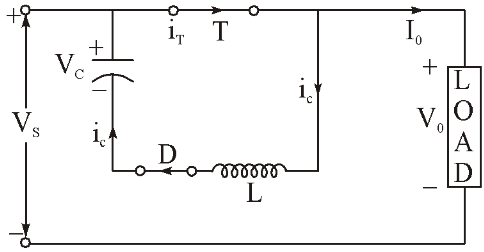


Figure : Capacitor Discharge to Inductor Through Thyristor and Diode-D

Thyristor current $i_T = I_o + i_c$

At $\omega_o t_1 = \frac{\pi}{2}$; $V_c = 0$ and $i_c = I_{CP}$

at $\omega_o t_2 = \pi$; $V_c = -V_s$ and $i_c = 0$

at $t = t_2$; $i_c = 0$ i.e., $D \rightarrow$ off

It is mode-I operation i.e. $0 < t < t_2$ and

Mode-II i.e. $t_2 < t < t_3$

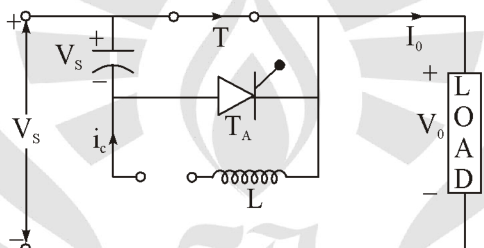


Figure : Mode-II

During mode-II, Auxilary thyristor T_A remains forward biased after On-duration of chooper T_{ON}, i.e., at $t = t_3$ T_A is fired to commutate main thyristor T.

Mode-III : $t > t_3$

As T_A conducts, main thyristor T gets reverse biased due to capacitor voltage So, T gets voltage commutated, during mode-III i.e. $t > t_3$, C is charge through constant current I_o.

$$i_C = -I_o$$

and $V_C(t) = -V_s + \frac{I_o}{C}t$

C gets charged linearly from $-V_s$ to $+V_s$ after Δt_4 , $V_C = 0$

$$\Rightarrow \quad 0 = -V_S + \frac{I_o}{C}\Delta t_4$$

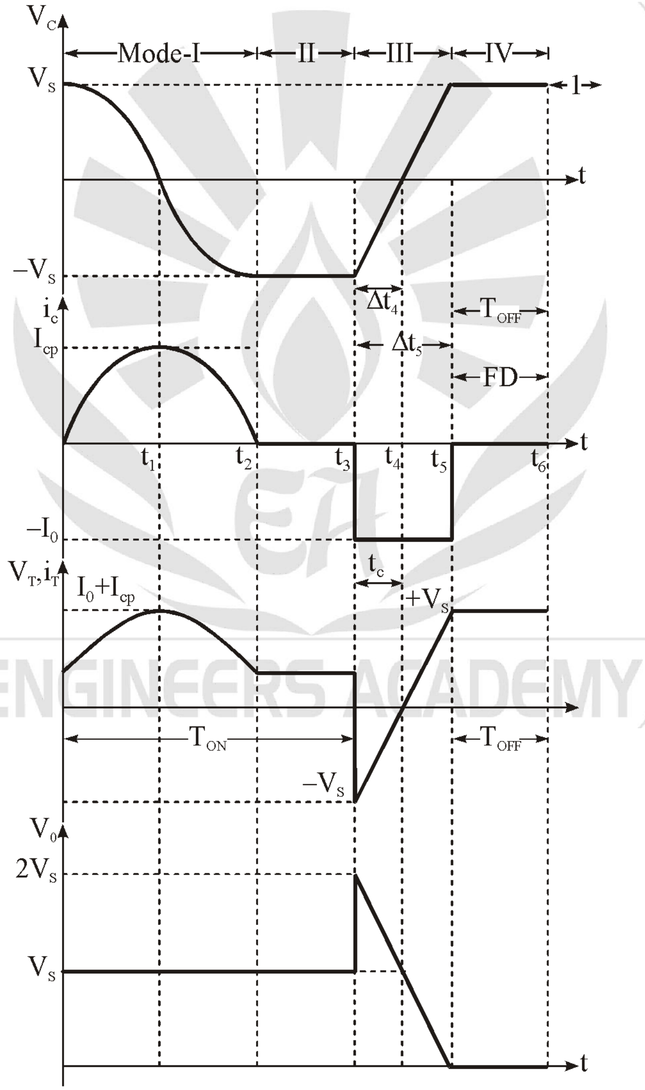
$$\Rightarrow \quad \Delta t_4 = \frac{CV_s}{I_o}$$ after Δt_5, $V_c = +V_S$

$\Rightarrow \quad +V_S = -V_S + \frac{I_o}{C}\Delta t_5 \Rightarrow \Delta t_S = \frac{2CV_S}{I_o}$

Form loop (1) $V_T = V_C$

From loop (2) $V_o = V_S - V_C$

Due to V_C, T remains reverse biased during $t_C = \Delta t_4$ so circuit turn off time available for main thyristor T, $t_c = \Delta t_4 = \frac{CV_s}{I_o}$ during mode-III, V_o decrease from $2V_s$ to 0 linearly. At $t = t_5$. $V_o = 0$, so FD start conducting i.e. OFF duration $T_{OFF.}$



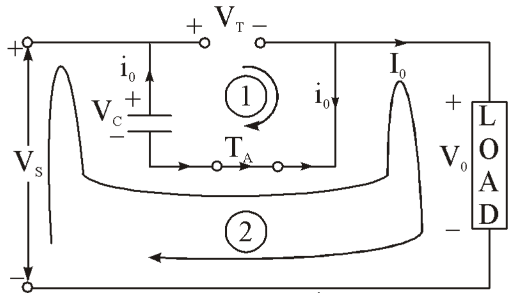


Figure : Mode-III

Mode-IV :

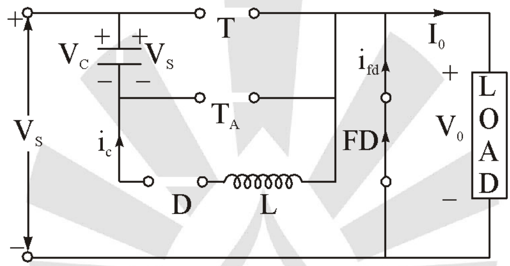
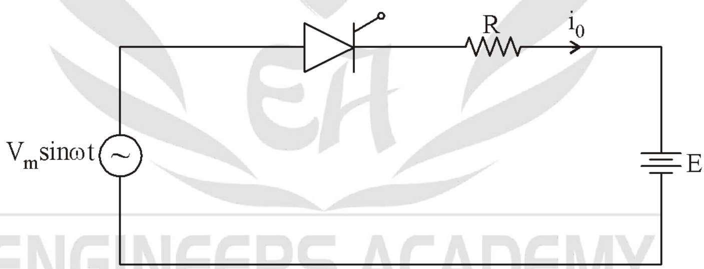
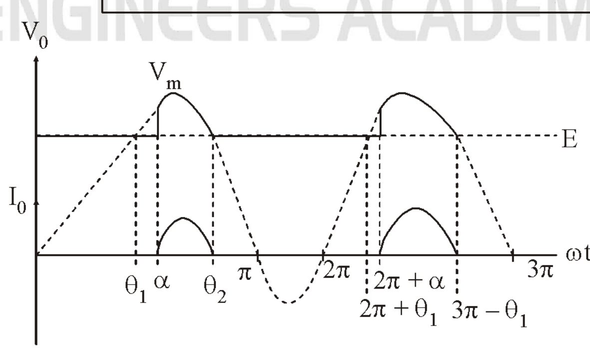


Figure : Mode-IV

So during FD mode $V_o = 0$, $i_{fd} = I_o$ after T_{OFF} (i.e. chopping period $T = T_{ON} + T_{OFF}$) T is fired again for next cycle.

39.





For thyristor conduction

$$V_m \sin\omega t \geq E$$

$$\theta_1 = \sin^{-1}(E/V_m)$$

$$\theta_2 = \pi - \theta_1$$

$$I_0 = \frac{1}{2\pi}\int_{\alpha}^{\theta_2}\left(\frac{V_m \sin\omega t - E}{R}\right)d(\omega t)$$

$$= \frac{1}{2\pi R}\left[V_m(-\cos\omega t)_{\alpha}^{\theta_2} - E(\omega t)_{\alpha}^{\theta_2}\right]$$

$$I_0 = \frac{1}{2\pi R}\left[V_m(\cos\alpha - \cos\theta_2) - E(\theta_2 - \alpha)\right]$$

(i) $I_0 = \dfrac{1}{2\pi(8)}\left[230\sqrt{2}(\cos\alpha - \cos\theta_2) - 150(\theta_2 - \alpha)\right]$

For SCR continuously fired $\alpha = \theta_1 = \sin^{-1}\left(\dfrac{150}{230\sqrt{2}}\right)$

$$= 27.46° = 0.479 \text{ rad}$$

$$\theta_2 = \pi - \theta_1 = 152.538°$$

$$I_0 = \frac{1}{2\pi(8)}\left[\begin{array}{r}230\sqrt{2}(\cos 27.46° - \cos 152.538°) \\ -150(153.528 - 27.46)\times\dfrac{\pi}{180}\end{array}\right]$$

$$= \frac{1}{16\pi}\left[230\sqrt{2}\times 1.77 - 150(2.20)\right] = 4.88 \text{ A}$$

(ii) Power supplied to battery $= EI_0$

$$= 150 \times 4.88$$

$$= 733.15 \text{ W}$$

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