KATHMANDU UNIVERSITY
End Semester Examination [C]
December, 2024

Marks Scored:

Level : B.E.
Year : III

Course : EPEG 318
Semester : II

Exam Roll No. :

Time: 30 mins.

F. M. : 10

Registration No.:

Date : 19 DEC 2024

SECTION "A"
[20 Q. × 0.5 = 10 marks]

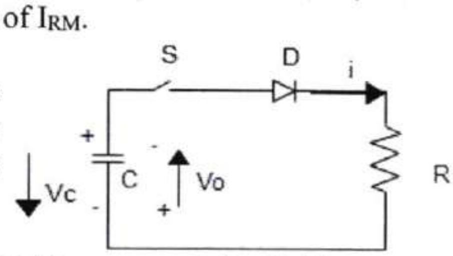
Choose and encircle in the most appropriate option from each set of choices

1. Which of the following is an example of controlled turn-on and uncontrolled turn off device?
   a. Diode. b. SCR. c. MOSFET. d. IGBT.

2. The time constant (τ) for a circuit which consists of a diode with an RL load in series is______
   a. L/R. b. R/L. c. RL. d. 1/RL.

3. For a diode, reverse recovery current time is defined as the time between the instant diode current becomes zero and the instant reverse recovery current decays to________
   a. Zero. b. 10% of reverse peak current (I_{RM}).
   c. 25% of I_{RM}. d. 15% of I_{RM}.

4. The voltage across capacitor, v_c and current, i when switch, S is closed at t=0 , if capacitor is initially charged with voltage V_0 with upper plate positive as shown in figure is



   a. 0, V_0/R. b. -V_0, V_0/R. c. -V_0, -V_0/R. d. V_0, V_0/R.

5. A single phase one pulse diode rectifier is feeding an RL load with freewheeling diode across the load. For conduction angle, β the main diode and free-wheeling diode would conduct respectively for
   a. π, π-β. b. π, β. c. β-π, π. d. π, β-π.

6. In a thyristor
   a. Latching current, I_L is associated with turn off process and holding current, I_H with turn on process.
   b. Both I_L and I_H are associated with turn off process.
   c. I_L is associated with turn on process and holding current, I_H with turn off process.
   d. Both I_L and I_H are associated with turn on process.

7. For a three phase half wave converter, the average output voltage is given as
   a. $\frac{3V_{ml}}{2\pi}(1+\cos\alpha)$ b. $\frac{3V_{ml}}{\pi}(1+\cos\alpha)$ c. $\frac{V_{ml}}{3\pi}(\cos\alpha)$ d. $\frac{3V_{ml}}{2\pi}(\cos\alpha)$

8. For a three phase converter, which of the following offers four quadrant operation
   a. Half wave converter. b. Semi converter.
   c. Full converter. d. Dual converter.

9. The firing sequence for a three phase full converter with firing angle $\alpha = 0^0$ is
a. $60^0, 120^0, 180^0, 240^0, 300^0, 360^0$. b. $120^0, 180^0, 240^0, 300^0, 360^0, 420^0$.
c. $150^0, 210^0, 270^0, 330^0, 390^0, 450^0$. d. $210^0, 270^0, 330^0, 390^0, 450^0, 510^0$.

10. Each diode of a 3 phase half-wave diode rectifier conducts for ______
a. 60^o. b. 180^o. c. 120^o. d. 90^o.

11. The maximum value of phase voltage for a three phase 120^0 voltage source inverter is
a. $V_s/3$. b. $2V_s/3$. c. V_s. d. $V_s/2$.

12. In dc choppers, if T_{ON} is the on period and f is the chopping frequency, then output voltage in terms of input voltage V is
a. $V*T_{ON}/f$. b. $V*f/T_{ON}$. c. V/f *T. d. $V*f*T_{ON}$.

13. The cycloconverter requires natural or forced commutation as under
a. Natural commutation in both step up and step down cycloconverters.
b. Forced commutation in both step up and step down cycloconverters.
c. Forced commutation in step up cycloconverters.
d. Forced commutation in step down cycloconverters.

14. The input power to the step down converter equals the output power from the converter under lossless condition and is expressed as
a. $P = kVs^2 /R$. b. $P = kVs/R$. c. $P = Vs^2 /k*R$. d. $P = k*Vs^{1/2}/R$.

15. The thyristors on same leg of for a 180^0 conduction mode three phase inverter conducts for an interval of ______________ and the maximum value of phase voltage obtained is ______________ volts.
a. 180 degree, $2V_s/3$. b. 180 degree, $V_s/3$.
c. 120 degree, $2V_s/3$. d. 60 degree, $2V_s/3$.

16. In a sinusoidal pulse modulated (SPWM) inverter there a N pulses per half cycle if
a. Triangular carrier wave peak coincides with zero of reference sinusoid waveform.
b. Triangular carrier wave zero coincides with zero of reference sinusoid waveform.
c. Triangular carrier wave peak coincides with peak of reference sinusoid waveform.
d. Sinusoid reference wave peak coincides with zero of carrier triangular waveform.

17. The load current is continuous for a three phase half wave converter with resistive load for delay angle
a. $\alpha > \pi/6$. b. $\alpha \geq \pi/6$. c. $\alpha \leq \pi/6$. d. $\alpha < \pi/6$.

18. If the chopper frequency is 200 Hz and T_{on} is 2 ms, the duty cycle is
a. 0.4 b. 0.8 c. 0.6 d. 0.2

19. A step down chopper is operated in the continuous conduction mode in steady state with a constant duty ratio, D. if V_o is the magnitude of the dc output voltage and V_s is the magnitude of dc input voltage, the ratio V_o/V_s is given by
a. D. b. 1-D. c. 1/1-D. d. D/1-D.

20. An ideal rectifier should have rectification efficiency, effective rms value of ac component of output voltage, ripple factor, transformer utilization factor and total harmonic distortion respectively
a. 50%, 0,0,1,0. b. 80%, 0,0,1,0. c. 100%, 0,0,1,0. d. 100%, 0.5, 0.5, 0.5, 0.5.

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F. M. : 40

SECTION "B"
[5 Q. × 8 = 40 marks]

Attempt *ANY FIVE* questions. *Assume any suitable data if required.*

1.

a. A diode circuit as shown in Figure 1 below with capacitor having an initial voltage; V_C (t=0) = V_0 = 110V, capacitance, C = 10 μF; and inductance, L = 10 μH. If switch S is closed at t = 0, determine (i) peak current through the diode (ii) conduction time of diode, and (iii) final steady state capacitor voltage. [1+1+1=3]

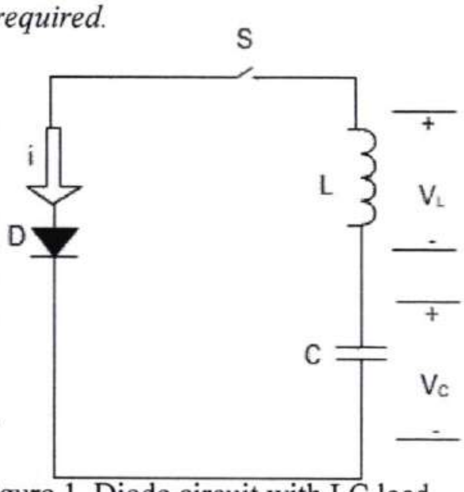

Figure 1. Diode circuit with LC load

b. Describe the static reverse blocking state, forward blocking state and forward conduction state of a thyristor showing I-V characteristics. [5]

2.

a. A single phase ac switch with configuration as shown in Figure 2 below is used between a 120V-50Hz and an inductive load. The load power is 15 kW at a power factor (pf) of 0.89 lagging. Determine (i) peak thyristor current, I_m (ii) average thyristor current, I_{av} (iii) rms thyristor current, I_{rms} (iv) Peak Inverse Voltage of thyristor (PIV) and (v) firing angle of thyristors. T_1 and T_2. [1+1+1+1+1=5]

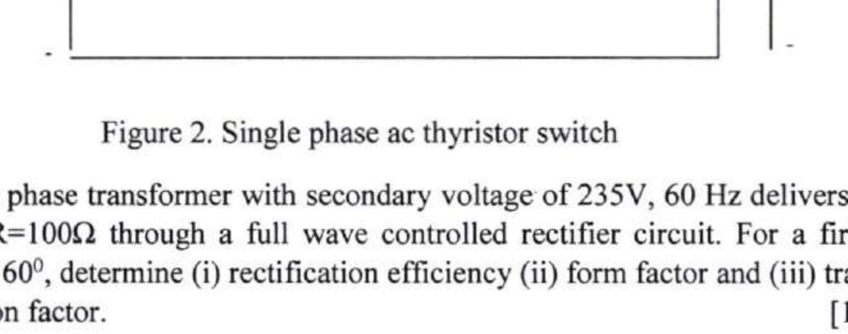

Figure 2. Single phase ac thyristor switch

b. A single phase transformer with secondary voltage of 235V, 60 Hz delivers power to a load R=100Ω through a full wave controlled rectifier circuit. For a firing angle delay of 60^0, determine (i) rectification efficiency (ii) form factor and (iii) transformer utilization factor. [1+1+1=3]

P.T.O.

3.

a. Plot the load voltage, load current and source current waveforms with reference to source voltage considering discontinuous load current for a single phase full converter feeding RL load. Assume the firing angle to be 15^0 and extinction angle to be 190^0.

[4]

b. Prove that for a step up converter, output voltage $V_o = V_{in} *[1/(1-K)]$; where V_{in} is the input voltage to the converter and $K = T_{ON} / T$ is the duty cycle of the converter. Plot the source voltage, source current, output voltage and output current waveforms considering RL load.

[4]

4.

a. A step up chopper has input dc voltage of 220 V and output dc voltage of 600 V. If the non-conducting time of the thyristor chopper is 90 μs,
   i. Compute the pulse width of the output voltage.
   ii. In case pulse width is halved for constant frequency operation, find the new output voltage [2+2=4]

b. A single phase voltage controller using integral cycle control has input voltage of 230V, 50 Hz and a load of R = 15Ω. For 6 cycles on and 4 cycles off, determine
   i. rms output voltage.
   ii. Input power factor. [2+2=4]

5.

a. A single phase half wave controlled rectifier is connected to a 220V source. Calculate the firing angle necessary to deliver 500W power to a 25Ω load. [4]

b. "*The maximum phase voltage, V_{an} for a three phase 180^0 mode bridge voltage source inverter is $2V_s/3$, where V_s is the supply input dc voltage*". Prove the statement with an illustration for only one phase voltage, V_{an} for conduction period of 0 to π only. [4]

6.

a. Explain class A and class B chopper along with its quadrant operation. Plot its output voltage and current waveforms. [4]

b. Explain the working principle of a three phase full wave controlled rectifier with input and output voltage waveform with a resistive load for a firing angle of 0^0. [4]

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EPEG 318: Formulae sheet

Single Phase Half Wave Diode Rectifier:

With R Load:

- **RMS value of output voltage**

  $V_{o\,rms} = \frac{V_m}{2}$

  V_m= Maximum value of source voltage (V_s)

- Average value of output voltage,

  $V_{o\,DC} = \frac{V_m}{\pi}$

- Average value of output voltage,
- Power delivered $P = I^2_{0rms} \cdot R$

  I_0 rms = rms value of load current = $\frac{\text{Power delivered to load}}{\text{Input } V_s}$

- Input power Factor = $\frac{V_{0rms} \cdot I_{0rms}}{V_s - I_{0rms}} = 0.707$

With L load:

- Output current $I_0 = \frac{V_m}{\omega L}(1 - \cos\omega t)$
- Maximum value of current $I_0 = \frac{2X_m}{\omega L}$
- Average value of current $I_0 = \frac{I_{max}}{2}$
- RMS value of fundamental current

  $I_{1rms} = \frac{I_0}{\sqrt{2}}$

- Output voltage $V_0 = V_m \sin\omega t = V_s$
- Average value of current voltage $V_0 = 0$

With C Load:

- Output voltage $V_0 = V_m \sin \omega t = V_s = V_c$
- Diode voltage $V_D = V_m (\sin \omega t - 1)$
- Output current $I_0 = \omega c\, V_m \cos \omega t$
- Average value of diode voltage $V_D = V_m$
- RMS value of diode voltage

  $V_{rms\,D} = 1.225\, V_m$

Single-Phase Full wave Mid-point Diode Rectifier:

Average output voltage,

$$V_0 = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t\, d(\omega t)$$

$$\boxed{V_0 = \frac{2V_m}{\pi}}$$

Average output current,

$$i_0 = \frac{V_0}{\pi}$$

Rms value of load voltage,

$$V_{0(rms)} = \sqrt{\left[\frac{1}{2}\int_0^{\pi} V_m^2 \sin\omega t\, d(\omega t)\right]}$$

$$\boxed{V_{0(rms)} = \frac{V_m}{\sqrt{2}} = V_s}$$

Rms value of load current,

$$I_{0(rms)} = \frac{V_s}{R}$$

Power delivered to load = $V_{0(rms)}\, I_{0(rms)}$

$\therefore$ Input power factor = $\frac{V_{0(rms)} I_{0(rms)}}{V_s I_{0(rms)}}$

Single-Phase Full wave Diode Bridge Rectifier:

Average value of diode current,

$$I_D = \frac{1}{2\pi}\int_0^{\pi} I_m \sin\omega t . d(\omega t) = \frac{I_m}{\pi}$$

Rms value of diode current,

$$I_{D(rms)} = \sqrt{\left[\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t . d(\omega t)\right]}$$

$$\boxed{I_{D(rms)} = \frac{I_m}{2}}$$

Single phase half wave-controlled rectifier with R Load

Average output voltage,

$$V_0 = \frac{V_m}{2\pi}(1 + \cos\alpha)$$

Average output current,

$$I_0 = \frac{V_m}{2\pi R}(1 + \cos\alpha)$$

Rms value of output voltage,

$$V_{or} = \frac{V_m}{2\sqrt{\pi}}\left[(\pi - \alpha) + \frac{1}{2}\sin 2\alpha\right]^{1/2}$$

Commutation time or turn off time of the thyristor,

$$t_c = \frac{\pi}{\omega} \text{ sec}$$

Input power factor of the converter,

$$p.f. = \frac{V_{or} I_{or}}{V_s . I_{or}} = \frac{1}{\sqrt{2\pi}}\left[\pi - \alpha + \frac{1}{2}\sin 2\alpha\right]^{1/2}$$

EPEG 318: Formulae sheet

Single phase half wave-controlled rectifier with RL load:

Average output voltage,

$$V_0 = \frac{V_m}{2\pi}(\cos\alpha - \cos\beta)$$

Average output current,

$$I_0 = \frac{V_m}{2\pi R}(\cos\alpha - \cos\beta)$$

Rms value of output voltage.

$$V_{or} = \frac{V_m}{2\sqrt{\pi}}\left[(\beta-\alpha) - \frac{1}{2}(\sin 2\beta - \sin 2\alpha)\right]^{\frac{1}{2}}$$

Commutation time or turn off time for the thyristor,

$$t_c = \frac{2\pi - \beta}{\omega}\sec$$

Single phase half wave-controlled rectifier with RLE load:

The minimum value of firing angle at which thyristor can be triggered is

$$\theta_1 = \sin^{-1}\left(\frac{E}{V_m}\right)$$

Average output current,

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

Average output voltage,

$$V_0 = \frac{1}{2\pi}\left[V_m(\cos\alpha - \cos\beta) + E(2\pi + \alpha - \beta)\right]$$

Input power factor,

$$p.f. = \frac{(I_{or}^2 R + EI_0)}{V_s I_{or}}$$

Commutation time or turn off time of thyristor,

$$t_c = \frac{2\pi - \beta}{\omega}\sec$$

Bridge Inverter: Bridge circuits are commonly used in DC-AC conversion. Moreover, an output transformer is not essential in a bridge circuit.

1φ Half Bridge Inverter - The output voltage volt $V_0 = \sum_{n=1,3,5...}^{\infty} \frac{2V_s}{n\pi}\sin n\omega t$

1φ Full Bridge Inverter- The output voltage

$$V_0 = \sum_{n=1,3,5...}^{\infty} \frac{4V_s}{n\pi}\sin n\omega t$$

Where, n = order of harmonic

$\omega = 2\pi f$, is frequency of the output voltage in red/sec

Key points:

- The load impedance (Z_n) at frequency

$$n_i Z_n = \left[R^2 + \left(n\omega L - \frac{1}{n\omega C}\right)^2\right]^{-1/2}$$

- Phase angle, (ϕ_n), $\phi_n = \tan^{-1}\frac{\left[n\omega L - \frac{1}{n\omega C}\right]}{R}$ red
- Output current or load current at the instant of commutation $I_0 = I_c = \frac{V_0}{Z_n}$ or $\omega t = \pi$ rad
- Fundamental load power

$$(P_{01})\, P_{01} = I_{01}^2 R = V_{01} \cdot I_{01}\cos\phi_1$$

Three Phase Half Wave Diode Rectifier:

The peak inverse voltage (PIV) = $\sqrt{3}\,V_{mp}$ for each of the three diode D_1, D_2 and D_3. The average output voltage.

$$V_0 = \frac{1}{2\pi/3}\int_{\pi/6}^{5\pi/6} V_{mp}\sin\omega t\, d(\omega t)$$

$$= \frac{3\sqrt{3}}{2\pi}V_{mp}$$

$$= \frac{3\sqrt{6}}{2\pi}V_{ph} \qquad (\because V_{mp} = \sqrt{2}\,V_{ph})$$

$$= \frac{3}{2\pi}V_{ml} \qquad (\because V_{ml} = \sqrt{3}\,V_{mp} = \sqrt{6}\,V_{ph})$$

Rms value of output voltage,

$$V_{0(rms)} = \sqrt{\left[\frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} V_{mp}^2 \sin^2\omega t\, d(\omega t)\right]}$$

$$\boxed{V_{0(rms)} = 0.84068\ V_{mp}}$$

Three-Phase Mid-point 6-Pulse Diode Rectifier:

Average output voltage,

$$V_0 = \frac{1}{\pi/3}\int_{\pi/3}^{2\pi/3} V_{mp}\sin\omega t\, d(\omega t)$$

$$\boxed{V_0 = \frac{3V_{mp}}{\pi}}$$

Rms value of output voltage,

$$V_{0(rms)} = \sqrt{\left[\frac{1}{\pi/3}\int_{\pi/3}^{2\pi/3} (V_{mp}\sin\omega t)^2 d(\omega t)\right]}$$

$$\boxed{V_{0(rms)} = 0.9558\ V_{mp}}$$

THREE PHASE DIODE BRIDGE RECTIFIER

Average Value of load voltage,

$$V_0 = \frac{1}{\pi/3}\int_{\pi/3}^{2\pi/3} V_{ml}\sin\omega t\,(d\omega t)$$

$$\boxed{V_0 = \frac{3V_{ml}}{\pi}}$$

Rms value of output voltage,

$$V_{0(rms)} = \sqrt{\left[\frac{1}{\pi/3}\int_{\pi/3}^{2\pi/3} V_{ml}^2 \sin^2\omega t\, d(\omega t)\right]}$$

$$\boxed{V_{0(rms)} = 0.9558\ V_{ml}}$$

THREE PHASE HALF-WAVE-CONTROLLED RECTIFIER:

If V_{mp} is the peak value of phase voltage, the average value of the output voltage,

$$V_0 = \begin{cases} \frac{3\sqrt{3}}{2\pi}V_{mp}\cos\alpha & ;\text{for } 0 < \alpha < 30^\circ \\ \frac{3}{2\pi}V_{mp}\left(1 + \cos(\alpha + 30^\circ)\right) & ;\text{for } 30^\circ < \alpha < 150^\circ \end{cases}$$

If V_{ml} is the peak value of line voltage, average output voltage,

$$V_0 = \frac{3V_{ml}}{\pi}\cos\alpha$$

If I_0 is the load current, average value of source current,

$$I_s = I_0\sqrt{\frac{2}{3}}$$

Average value of thyristor current,

$$I_s = I_0\sqrt{\frac{1}{3}}$$

EPEG 318: Formulae sheet

Three phase half-wave converter drive

1. $V_m = \sqrt{2}V_s$
2. Average value of output voltage $V_o = \frac{3V_m}{2\pi}\cos\alpha$ [For $0\le\alpha\le\pi$]
3. RMS value of phase or line current $I_{sr} = I_a\sqrt{\frac{1}{3}}$
4. Average thyristor current $I_{TA} = I_a\frac{1}{3}$
5. RMS thyristor current $I_{TR} = I_a\sqrt{\frac{1}{3}}$
6. Input PF $= \frac{V_o * I_a}{\sqrt{3}*V_s*I_{sr}} = \frac{3}{\pi\sqrt{2}}\cos\alpha$

Three phase Full-wave converter drive

1. Average value of armature voltage $V_a = \frac{3V_m}{\pi}\cos\alpha$ [For $0\le\alpha\le\pi$]
2. Average value of field voltage $V_f = \frac{3V_m}{\pi}\cos\alpha_f$ [For $0\le\alpha_f\le\pi$]
3. RMS value of line current $I_{sr} = I_a\sqrt{\frac{2}{3}}$
4. Average thyristor current $I_{TA} = I_a\frac{1}{3}$
5. RMS thyristor current $I_{TR} = I_a\sqrt{\frac{1}{3}}$
6. Input PF $= \frac{V_O * I_a}{\sqrt{3}*V_s*I_{sr}} = \frac{3}{\pi}\cos\alpha$

Three phase Dual converter drive

1. Average value of output and field circuit voltage $V_f = \frac{3V_m}{\pi}\cos\alpha_f$ for $0\le\alpha_f\le\pi$

Three phase semi converter drive

1. Average value of armature voltage $V_a = \frac{3V_m}{2\pi}(1+\cos\alpha_a)$ [For $0\le\alpha_a\le\pi$]
2. Average value of field voltage $V_f = \frac{3V_m}{2\pi}(1+\cos\alpha_f)$ [For $0\le\alpha_f\le\pi$]
3. RMS value of line current $I_{sr} = I_a\sqrt{\frac{2}{3}}$ [For $\alpha<60°$]
4. RMS thyristor current $I_{TR} = I_a\sqrt{\frac{1}{3}}$ [For $\alpha<60°$]
5. Average thyristor current $I_{TA} = I_a\frac{1}{3}$ [For $\alpha<60°$]
6. RMS value of line current $I_{sr} = I_a\sqrt{\frac{180-\alpha}{180}}$ [For $60°<\alpha<180°$]
7. RMS thyristor current $I_{TR} = I_a\sqrt{\frac{180-\alpha}{360}}$ [For $60°<\alpha<180°$]
8. Average thyristor current $I_{TA} = I_a*(\frac{180-\alpha}{360})$ [For $60°<\alpha<180°$]
9. Freewheeling diode RMS current $I_{FR} = I_a*\sqrt{\frac{\alpha-60}{120}}$ [For $60°<\alpha<180°$]
10. Freewheeling diode average current $I_{FA} = I_a*\frac{\alpha-60}{120}$ [For $60°<\alpha<180°$]
11. Input PF $= \frac{V_a * I_a}{\sqrt{3}*V_s*I_{sr}} = \frac{3}{2\pi}(1+\cos\alpha)$ [For $\alpha<60°$]
12. Input PF $= \frac{V_a * I_a}{\sqrt{3}*V_s*I_{sr}} = \frac{\sqrt{6}(1+\cos\alpha)}{2\pi}\sqrt{\frac{\pi-\alpha}{\pi}}$ [For $60°<\alpha<180°$]

$$V_{DS(\max)} = \frac{V_s + (n_s - 1)RI_{D2}}{n_s}$$

$$\mathrm{DRF} = 1 - \frac{V_s}{n_s V_{DS(\max)}}$$

$$V_{DT(\max)} = \frac{1}{n_s}\left[V_s + \frac{(n_s - 1)Q_2}{C_1}\right]$$

$$i(t) = \sum_{n=1,3,5}^{\infty}\left(\frac{4I}{n\pi}\sin\frac{n\pi}{3}\sin(n\omega t - n\alpha)\right)$$