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Detailed Solutions

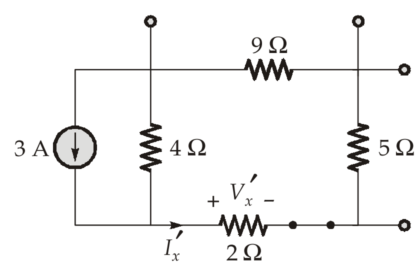
SSC-JE 2018 Mains Test Series (PAPER-II)

Electrical Engineering Test No : 2

Q.1 (a) Solution:

To determine V_x using superposition theorem :

- When 3 A current source is acting alone,

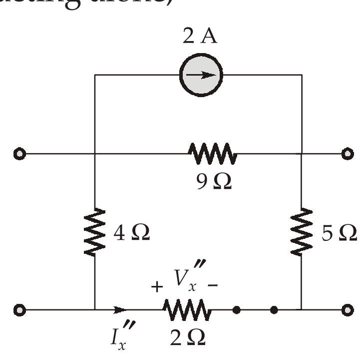


Using current division rule,

$$I_x' = 3\text{ A} \times \frac{4}{9+4+5+2} = 3 \times \frac{4}{20}\text{ A} = \frac{3}{5}\text{ A}$$

$$V_x' = I_x' \times 2\ \Omega = \frac{6}{5}\text{ V} = 1.2\text{ V}$$

- When 2 A current source is acting alone,

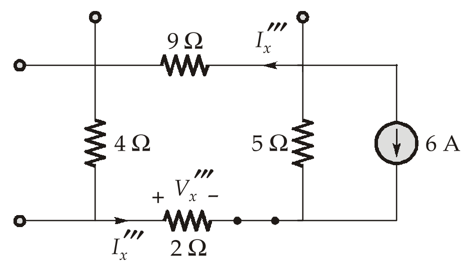


Using current division rule,

$$I_x'' = -2\text{ A} \times \frac{9}{9+4+2+5} = -\frac{18}{20}\text{ A}$$

$$V_x'' = I_x'' \times 2\ \Omega = -1.8\text{ V}$$

- When 6 A current source is acting alone,

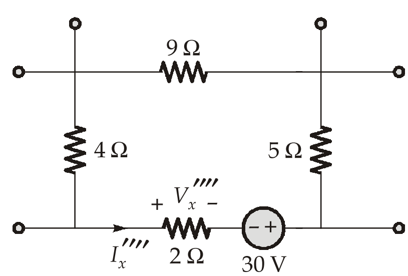


Using current division rule,

$$I_x''' = -6\text{ A} \times \frac{5}{9+4+2+5} = -\frac{3}{2}\text{ A}$$

$$V_x''' = I_x''' \times 2\ \Omega = -3\text{ V}$$

- When 30 V voltage source is acting alone,



$$I_x'''' = \frac{30}{9+5+4+2}\text{ A} = \frac{3}{2}\text{ A}$$

$$V_x'''' = I_x'''' \times 2\ \Omega = 3\text{ V}$$

- When all the 4 sources are acting simultaneously,

$$V_x = V_x' + V_x'' + V_x''' + V_x'''' = 1.2 - 1.8 - 3 + 3 = -0.6\text{ V}$$

Q.1 (b) Solution:

The sensitivity of meter movement for dc.

$$S_{dc} = \frac{1}{I_{fs}} = \frac{1}{10^{-3}} = 1000\ \Omega/\text{V}$$

For half wave rectifier, the a.c. sensitivity,

$$S_{ac} = 0.45 \times 1000 = 450\ \Omega/\text{V}$$

Total resistance of circuit for a.c. operation

$$= S_{ac}V = 450 \times 10 = 4500\ \Omega$$

Resistance of multiplier, $R_s = S_{ac}V - R_m - R_d$

$$= 4500 - 300 - 0$$

$$= 4200\ \Omega$$

Q.1 (c) Solution:

$$P_c = 100\text{ W};$$

$$P_{\text{cu}\,fL} = 60\text{ W} \times 4 = 240\text{ W}$$

$$x^2 P_{\text{cu}} = P_i$$

$$x = \sqrt{\frac{100}{240}} = 0.645$$

$$\text{Per unit rating} = 0.645$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{out}} + P_{\text{Losses}}} \times 100$$

$$\eta = \frac{10^4 \times 0.645 \times 0.9}{10^4 \times 0.645 \times 0.9 + 100 \times 2} = 96.67\%$$

Q.1 (d) Solution:

Average real power delivered to inductor and capacitor is zero,

∴ average real power delivered to load Z_L is

$$P = I_{\text{rms}}^2 R$$

Given, $i(t) = 4\sin(\omega t + 20°)\text{ A}$

$$I_{\text{rms}} = \left(\frac{4}{\sqrt{2}}\right)$$

Given, $Z_L = (4 - j2)\Omega$

∴ $R = 4\ \Omega$

$$P = \left(\frac{4}{\sqrt{2}}\right)^2 \times 4 = 32\text{ W}$$

Q.1 (e) Solution:

Given, $\cos\phi = 0.5$

$$\phi = 60°$$

Total input power, $P = W_1 + W_2 = 50000\text{ W}$

Now, $$V_L I_L = \frac{P}{\sqrt{3}\cos\phi} = \frac{100000}{\sqrt{3}}$$

∴ readings of the wattmeters are

$$W_1 = V_L I_L \cos(30° - \phi)$$
$$= \frac{100000}{\sqrt{3}}\cos(-30°) = 50 \text{ kW}$$
$$W_2 = V_L I_L \cos(30° + \phi)$$
$$= \frac{100000}{\sqrt{3}}\cos 90° = 0 \text{ kW}$$

Q.2 (a) Solution:

Coil turns = 500

Self inductance = 0.25 H

The expression of mutual inductance between the two coils is given as:

$$M = \frac{N_2\phi_2}{I_1}$$

∵ $N_1 = 500, \quad L_1 = 0.25 \text{ H}, \quad \phi_2 = 0.6\,\phi_1, \quad N_2 = 10000$

∴ $$L_1 = \frac{N_1\phi_1}{I_1}$$

$$\frac{L_1}{N_1} = \frac{\phi_1}{I_1} = \frac{0.25}{500}$$

$$\phi_2 = 0.6\,\phi_1$$

$$\frac{\phi_2}{I_1} = \frac{0.6\phi_1}{I_1} = \frac{0.6 \times 0.25}{500}$$

(i) So, $$M = \frac{N_2\phi_2}{I_1} = 10000 \times \frac{(0.6 \times 0.25)}{500}$$

$$M = 3 \text{ H}$$

(ii) The emf induced in the second coils is given as: (induced due to current in coil 1)

$$E_2 = -M\frac{dI_1}{dt} = -3 \times 100 \quad \left(\because \frac{dI_1}{dt} = 100 \text{ A/s}\right)$$
$$= -300 \text{ Volt}$$

Q.2 (b) Solution:

(i) Core loss, $P_{OC} = 361$ W

$$\phi_0 = \cos^{-1}\left(\frac{361}{2200\times 0.6}\right) = 74.12°$$

$$I_C = I_0\cos\phi_0 = 0.6\cos 74.12° = 0.1642 \text{ A}$$

$$I_\phi = I_0\sin\phi_0 = 0.6\sin 74.12° = 0.577 \text{ A}$$

$$\vec{I}_0 = 0.6\angle -74.12°\text{A}$$

(ii)

$$\vec{I}_2 = 60\angle -\cos^{-1}0.8$$

$$\vec{I}_2' = \frac{\vec{I}_2}{a} = \frac{60}{10}\angle -\cos^{-1}0.8 = 6\angle -\cos^{-1}0.8$$

$$\vec{I}_1 = \vec{I}_0 + \vec{I}_2'$$

$$= 0.6\angle -74.12° + 6\angle -\cos^{-1}0.8$$

$$\vec{I}_1 = 6.488\angle -40.08° \text{ A}$$

$$\text{Input pf} = \cos\phi_1 = \cos(40.08°)$$

$$= 0.765 \text{ (lagging)}$$

Q.2 (c) Solution:

$$\frac{\text{Input (unknown) voltage}}{\text{Output voltage}} = \frac{V_x}{V_2} = \frac{100}{2} = 50$$

Also, $$\frac{R_1 + R_2}{R_2} = \frac{V_x}{V_2} = 50$$

or, $R_1 = 49R_2$

But, $R_1 + R_2 = 100\ \text{M}\Omega$

$\therefore$ $R_2 = 2\ \text{M}\Omega$ and $R_1 = 98\ \text{M}\Omega$

Q.2 (d) Solution:

$$V(t) = \begin{cases} t & 0 < t < 1 \\ 1 & 1 < t < 2 \end{cases}$$

$$V_{avg} = \frac{1}{T}\int_0^T V(t)dt = \frac{1}{2}\left[\int_0^1 t\,dt + \int_1^2 1\,dt\right]$$

$$= \frac{1}{2}\left\{\left[\frac{t^2}{2}\right]_0^1 + [t]_1^2\right\}$$

$$= \frac{1}{2}\left[\frac{1}{2} - 0 + 2 - 1\right] = \frac{3}{4} = 0.75 \text{ V}$$

Q.3 (a) Solution:

Advantages of ac over dc:

1. The generation of ac is cheaper than that of dc.
2. ac machines are simple, robust and do not require much attention for their repairs and maintenance during their use.
3. Wide range of voltage are obtained by the use of transformer.
4. The magnitude of current can be reduced by using an inductance or a conductor without any appreciable loss of energy.
5. ac can easily be converted into dc with the help of rectifiers.
6. When ac is supplied at higher voltages in distance transmission, the line losses are small compared to dc transmission.

Disadvantages of ac over dc:

1. Peak value of ac is high and it is dangerous to use so better insulation is required.
2. ac causes more interference with the near by communication line.
3. An ac is transmitted from surface of the conductor and hence need several strands of thin wires insulated from each other.
4. In ac transmission, voltage regulation is poor than that of dc transmission.
5. In ac line cannot rapid changes in magnitude and direction of power flow as dc line.

Q.3 (b) Solution:

Given,
$$V = \frac{11 \times 10^3}{\sqrt{3}} = 6350.853 \text{ V}$$

$$R = 1.2\ \Omega,$$
$$jX = j25\ \Omega$$

$$|I| = \frac{1.4375 \times 10^6}{3 \times 6350.853} = 75.45 \text{ A}$$

$$I = 75.45\angle{-36.87^\circ}$$

$$E = 6350.853 + (1.2 + j25)(75.45\angle{-36.87^\circ})$$
$$= 7693.807\angle 10.898^\circ \text{ V}$$

$$\text{Voltage regulation} = \frac{|E| - |V|}{|V|} \times 100$$

$$= \frac{7693.807 - 6350.853}{6350.853} \times 100 = 21.14\%$$

Q.3 (c) Solution:

$$Z_{in} = j\omega L + \frac{-jRX_C}{R - jX_C} = j\omega L + \frac{RX_C^2 - jR^2X_C}{R^2 + X_C^2}$$

$$= j\omega L + \frac{RX_C^2}{R^2 + X_C^2} - \frac{jR^2X_C}{R^2 + X_C^2}$$

At resonance imaginary part of $Z_{eq} = 0$,

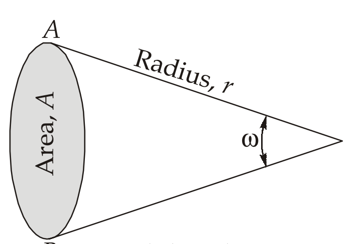
$$\text{Real of } Z_{eq} = \frac{RX_C^2}{R^2 + X_C^2}$$

$$= \frac{50 \times \left(\frac{10^6}{100 \times 50}\right)^2}{(50)^2 + \left(\frac{10^6}{100 \times 50}\right)^2} = 47\ \Omega$$

Q.3 (d) Solution:

(i) Solid Angle: The solid angle is measured in steradians (ω). Solid angle is the angle generated by the surface passing through the point space and periphery of the area. It is denoted by ω.

Solid angle is given by the ratio of the area of the surface of the square of the distance between the area and the point.



i.e. $$\omega = \frac{A}{r^2}$$

Since the surface of a sphere has an area equal to $4\pi r^2$.

$\therefore$ Total angle,

$$\omega = \frac{4\pi r^2}{r^2} = 4\pi \text{ steradians}$$

(ii) Luminous Intensity (I): It is the amount of luminous flux emitted by a source per unit solid angle. It is measured in candela or lumens per steradian.

i.e.,

$$I = \frac{\phi}{\omega}$$

$$1 \text{ Candela} = 1 \text{ Lumen/steradian}$$

(iii) Candle Power (C.P.): The candle power of a source of light in any direction is the number of lumens per unit solid angle in that direction.

Total flux emitted by a source of 1 candle power in all directions = 4π Lumens

(iv) Luminous Efficiency or Radiant Efficiency: The rays emitted by a hot body depend upon its temperature. The rays consists of not only of light but also of heat and other electromagnetic radiation such as infrared and ultraviolet rays.

$$\text{Luminous or Radiant efficiency} = \frac{\text{Energy radiated as light}}{\text{Total energy radiated}}$$

It is measured in lumens/watt.

The efficiency of a source in lumens/watt is given by

$$\eta = 4\pi \times \frac{\text{Mean spherical candle power}}{\text{Watts}}$$

Q.4 (a) Solution:

Imagin zener diode is in its off state,

$$V_L = V_i \times \frac{1.2\text{k}}{1\text{k} + 1.2\text{k}}$$

$$= 16 \times \left(\frac{1.2}{1.2 + 1}\right) = 8.727 \text{ V}$$

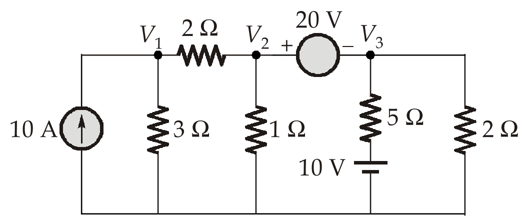
Hence voltage across zener diode is less than its breakdown voltage and hence it carries no current.

$\therefore$

$$I_Z = 0$$

$$P_Z = V_Z I_Z = 0 \text{ W}$$

Q.4 (b) Solution:



Writing Node equation at Node 1;

$$\frac{V_1}{3} + \frac{V_1 - V_2}{2} = 10$$

$\therefore$ $$0.83\,V_1 - 0.5\,V_2 - 10 = 0 \quad \text{...(i)}$$

Now, writing super-node equation at node 2 and node 3 :

$$\frac{V_2 - V_1}{2} + \frac{V_2}{1} + \frac{V_3 - 10}{5} + \frac{V_3}{2} = 0$$

$$-0.5\,V_1 + 1.5\,V_2 + 0.7\,V_3 - 2 = 0 \quad \text{...(ii)}$$

Also, $$V_2 - V_3 = 20 \quad \text{...(iii)}$$

Solving (i), (ii) and (iii) simultaneously:

$$V_3 = -8.42 \text{ volts}$$

So, current in 5Ω resistor:

$$I_5 = \frac{V_3 - 10}{5} = \frac{-18.42}{5}$$

$\therefore$ $$I_5 = -3.68 \text{ A}$$

Q.4 (c) Solution:

$$\text{Current in each lamp, } I = \frac{P}{V} = \frac{100}{120}$$

$$= \frac{5}{6}\text{A}$$

$$\text{Total load current, } I_L = \frac{5}{6} \times 60 = 50 \text{ A}$$

$$\text{Field current, } I_{sh} = \frac{120}{60} = 2\text{A}$$

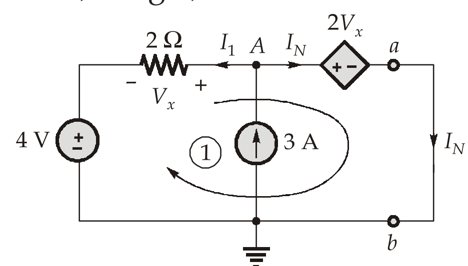
$$\text{Armature current, } I_a = I_{fL} + I_{sh} = 50 + 2 = 52 \text{ A}$$

A wave winding has 2 parallel paths, so current in each armature conductor $= \frac{52}{2} = 26\text{A}$

Q.4 (d) Solution:

- To determine the Norton's equivalent current I_N,

  By applying KVL in loop (1) of the circuit shown below, we get,



$$-4\text{ V} - V_x + 2V_x = 0$$
$$V_x = 4\text{ V}$$

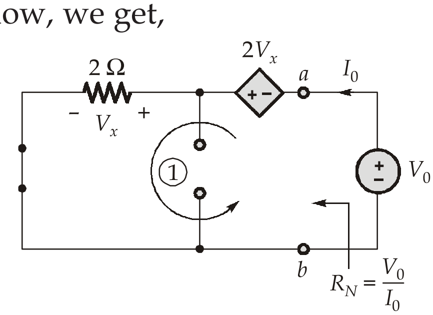
and
$$I_1 = \frac{V_x}{2\,\Omega} = 2\text{ A}$$

By applying KCL at node A, we get,

$$I_1 + I_N = 3\text{ A}$$
$$I_N = 3\text{ A} - I_1 = 3\text{ A} - 2\text{ A} = 1\text{ A}$$

- To determine the Norton's equivalent resistance R_N,

  By applying KVL in loop (1) of the circuit shown below, we get,

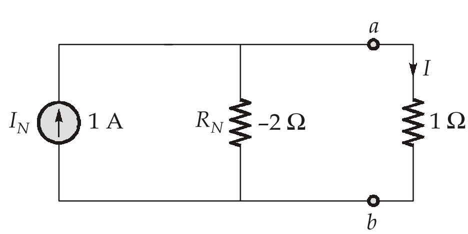


$$-2V_x + V_x = V_0$$
$$V_x = -V_0$$

and
$$I_0 = \frac{V_x}{2\,\Omega} = -\frac{V_0}{2\,\Omega}$$

So,
$$R_N = \frac{V_0}{I_0} = -2\,\Omega$$

- To determine the average power absorbed by the 1 Ω resistor using the Norton's equivalent circuit,



$$I = \frac{R_N}{R_N + 1\,\Omega} \times I_N = \frac{-2\,\Omega}{-2\,\Omega + 1\,\Omega} \times 1\text{ A} = 2\text{ A}$$

The average power absorbed by 1 Ω resistor is,

$$P_{1\,\Omega} = I^2(1\,\Omega) = (2)^2\,(1)\text{ W} = 4\text{ W}$$

Q.5 (a) Solution:

For dc generator,

$$\text{generated emf, } E = \frac{P\phi N}{60}\frac{Z}{A}$$

$$\text{Speed, } N \propto \frac{E_g}{\phi} \quad \text{...(i)}$$

As a generator armature current,

$$I_a = \frac{2 \times 1000}{400} = 5 \text{ A}$$

$$E_g = 400 + 0.4 \times 5 = 402 \text{ V}$$

As a motor,
$$E_m = 400 - 0.4 \times 5 = 398 \text{ V}$$

Since flux per pole is increased by 20% when operated as motor, we can write

$$\phi_m = 1.2\ \phi_g$$

Using equation (i),

$$\frac{N_g}{N_m} = \frac{E_g\,\phi_m}{E_m\,\phi_g} = \frac{402 \times 1.2\phi_g}{398 \times \phi_g} = 1.21$$

Q.5 (b) Solution:

Resonant frequency,
$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$\frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.2 \times 10 \times 10^{-6}}} = 112.5\text{Hz}$$

Quality factor,
$$Q = \frac{\omega L}{R} = \frac{2\pi \times 112.5 \times 0.2}{50} = 2.83$$

Voltages across inductor and capacitor;

$$|V_L| = |V_C| = QV = 2.83 \times 20 = 56.6 \text{ volts}$$

Lower frequency limit,
$$f_L = f_0 - \frac{R}{4\pi L}; \qquad f_0 = f_0 - \frac{\text{BW}}{2}(\text{Hz}) \ \because \ \text{BW} = R/L)$$

$$= 112.5 - \frac{50}{4\pi \times 0.2} = 92.6 \text{ Hz}$$

Similarly, upper frequency limit;

$$f_H = f_0 + \frac{R}{4\pi L} = 112.5 + \frac{50}{4\pi \times 0.2} = 132.39 \text{ Hz}$$

Bandwidth;
$$\text{BW} = f_H - f_L = 132.39 - 92.6$$
$$= 39.79 \text{ Hz}$$

Q.5 (c) Solution:

(i) Magnetic Field Intensity (H): The magnetic field intensity of a circuit is given by the mmf per unit length.

$$H = \frac{NI}{l} \text{ AT/m}$$

The magnetic flux density (B) and its intensity (field strength) in a medium can be related by the following equation,

$$B = \mu H$$

where, $\mu = \mu_0 \mu_r$ is the permeability of the medium in Henry/meter (H/m).

μ_0 = Absolute permeability of free space and is equal to $4\pi \times 10^{-7}$ H/m.

μ_r = Relative permeability of the medium.

μ_r = 1 for air and non-magnetic materials.

(ii) Magnetic Flux Density (B): The magnetic flux lines start and end in such a way that they form close loops. Weber (Wb) is the unit of magnetic flux (ϕ). Flux density (B) is flux per unit area Tesla(τ) or Wb/m² is the unit of flux density.

$$B = \frac{\phi}{A} \text{ Wb/m}^2 \text{ (or) Tesla}$$

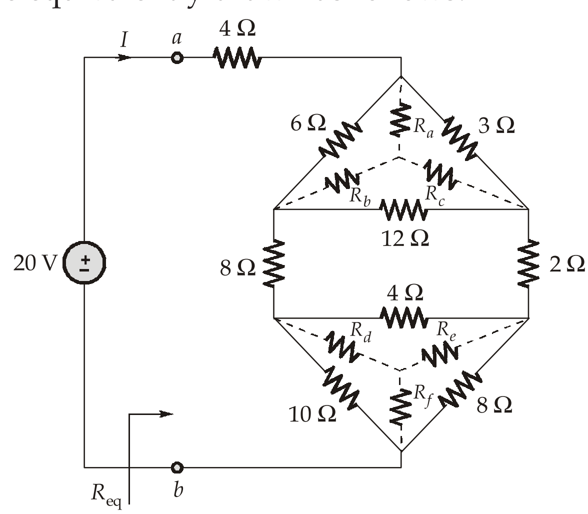
Where B is a quantity called magnetic flux density in tesla, ϕ is the total flux in Webers and A is the area perpendicular to the lines in m².

(iii) Magnetomotive Force (MMF): A measure of the ability of a coil to produce a flux is called the magneto-motive force (mmf). A coil with 'N' turns which is carrying a current of 'I' amperes constitutes a magnetic circuit and produce an mmf of NI ampere turns.

$$\text{MMF} = NI \; AT$$

Q.5 (d) Solution:

The given circuit can be equivalently drawn as follows:

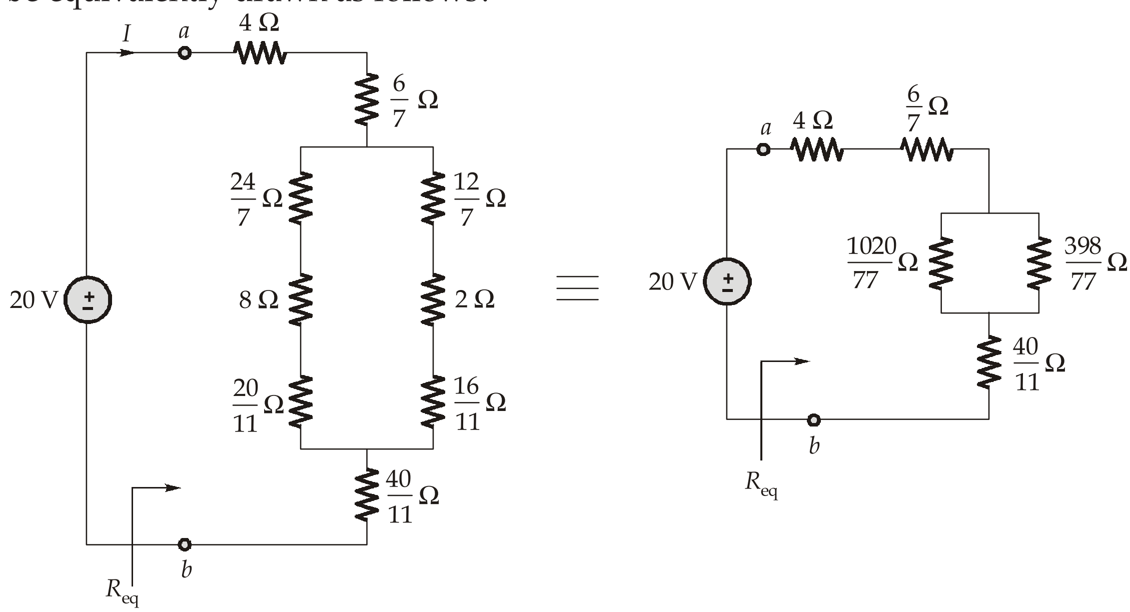


From the properties of star-delta transformation,

$$R_a = \frac{6\times3}{6+3+12}\,\Omega = \frac{6\times3}{21}\,\Omega = \frac{6}{7}\,\Omega\ ;\ R_b = \frac{6\times12}{21}\,\Omega = \frac{24}{7}\,\Omega\ ;\ R_c = \frac{3\times12}{21}\,\Omega = \frac{12}{7}\,\Omega$$

$$R_d = \frac{4\times10}{4+10+8}\,\Omega = \frac{4\times10}{22}\,\Omega = \frac{20}{11}\,\Omega\ ;\ R_e = \frac{4\times8}{22}\,\Omega = \frac{16}{11}\,\Omega\ ;\ R_f = \frac{8\times10}{22}\,\Omega = \frac{40}{11}\,\Omega$$

By replacing the delta network portions with their star equivalents, the given network can be equivalently drawn as follows:



$$R_{eq} = 4+\frac{6}{7}+\frac{40}{11}+\left(\frac{1020}{77}\,\Bigg\|\,\frac{398}{77}\right)\Omega = 12.21\ \Omega$$

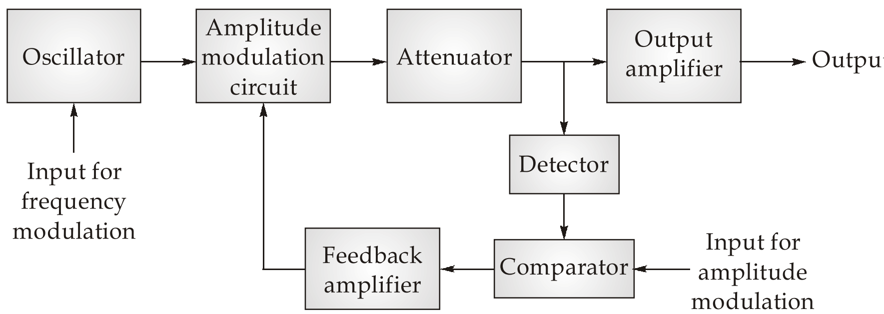
$$I = \frac{20\text{ V}}{R_{eq}} = \frac{20}{12.21}\text{ A} = 1.64\text{ A}$$

Q.6 (a) Solution:

(i) Signal generator:

These instruments usually produce a fixed frequency sine wave, whose output can be frequency or amplitude modulated by another signal. The instruments cover a frequency range of 0.001 Hz-50 GHz, but not from the same device. Figure shows a signal generator circuit. Frequency modulation is achieved by varying the voltage across a variable capacitance diode in the tuning of the oscillator. This gives a system with low output distortion, for modulation depths below 1% of the carrier frequency. Above this modulation level the waveform applied to the tuning diode needs to be deliberately distorted, in order to compensate for its non-linear characterstics. During frequency modulation manual or automatic methods may be used to keep the amplitude of the output constant.

Amplitude modulation is most conveniently done by varying the supply voltage to the oscillator. This method is, however only suitable for small modulation depths, up to about 50%. It also gives phase modulation due to the effect on the components used within the oscillator circuit. Feedback can be used to reduce output distortion, as shown in figure, by detecting the output to obtain the modulation envelope, comparing this with the amplitude modulation input, and then amplifying and feeding back the difference as the modulation signal. This technique is known as envelope feedback.



(ii) Loss Load Factor:

It is defined as the ratio of actual loss during a period to the loss assuming maximum current to flow over the same period.

Loss load factor (G)

$$= \frac{\text{Actual loss (kWh) during a period}}{\text{Loss (kWh) assuming maximum current to flow over the same period}}$$

If the load factor of a plant is 100%, the copper loss will be at its full value throughout the period approximately as the square of load. Which in turn keeps on varying throughout the period. Therefore the annual copper losses not only vary with the mean height of annual load curve (i.e. load factor) but also depends on it shape.

The least possible loss will occur with the some load factor if the mean current flows continuously except when a peak current-I is reached momentarily when the copper could be considered negligible under this condition.

$$\text{Loss} \propto I^2 F^2 \Rightarrow [\text{Copper loss} \propto (\text{mean current})^2]$$

where, $F \rightarrow$ load factor

The greatest possible loss will occur if maximum current flow for fraction of the year and no current in the remaining part of the year.

Under this condition, $\text{Loss} \propto I^2 F$

Now it is convenient to omit the factor I^2 from both the cases and express the losses as a fraction of those which would occur if the maximum current flows continuously. This factor which is actually load factor of losses called as load factor by definition would be F^2 in the first case and F in the second case.

In any given situations, the losses would be somewhere between these extreme situations and the most convenient to assume will be a load factor of 50%. It gives a simple formula for the loss factor as,

$$G = 0.5\,F + 0.5\,F^2$$

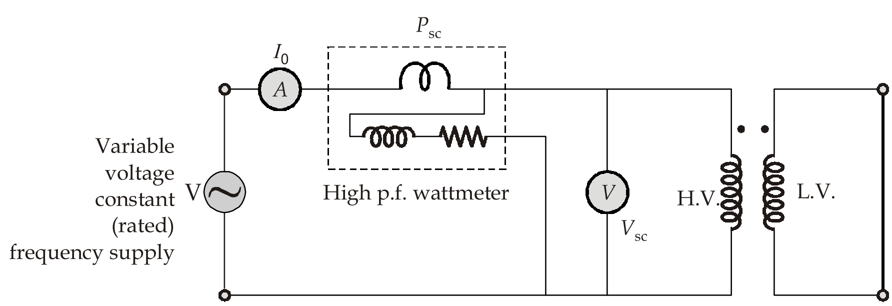
But generally, in practice the peak load occurs for a relatively short time and the above formula seems to give a relatively high value of loss.

A better approximation could be that, there tenths of the consumption take place at maximum load and the remainder is the mean load. This gives the loss factor as

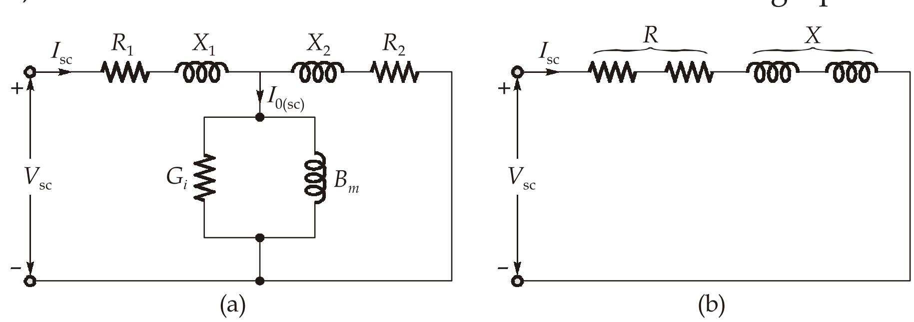
$$G = \underbrace{0.3F}_{\text{Factor of max. load}} + \underbrace{0.7F^2}_{\text{Remainder at mean load }(1-0.3)}$$

This is process through which loss load factor can be determined.

(iii) Short Circuit Test:



- Short circuit test is carried out on a transformer to determine the full load copper loss. Accordingly this test is carried out at rated current and frequency although the requirement of rated frequency is not necessary.
- Instruments are placed on high voltage side with low voltage short circuited by a very thick wire of less resistance. Input voltage of 8-10% of rated voltage is sufficient to generate full load current on the secondary side. At this input voltage the exciting branch current reduces to 0.1-0.5% of the full load current (When input voltage is rated voltage, this current is around 2-5% of the full load current). Hence, the shunt branch is removed. This results in following equivalent circuit.



Equivalent circuit under short-circuit conditions

- The instruments are placed on high voltage side because this rated current on high voltage side is lower than low voltage side. Hence, ammeters, wattmeters and instruments transformers if any, of low current rating may be used.

From short circuit test:

P_{sc} = full load input power,

V_{sc} = short circuit voltage,

I_{sc} = full load current

To find:

R_{eq} = equivalent resistance of windings,

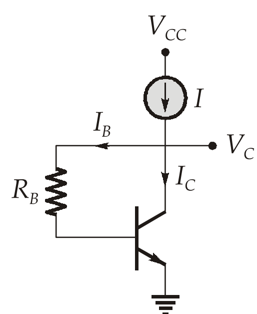
X_{eq} = equivalent reactance of windings

$$\vec{Z}_{eq} = \frac{V_{sc}}{I_{sc}} \angle \cos^{-1}\left(\frac{P_{sc}}{V_{sc} I_{sc}}\right) = R_{eq} + jX_{eq}$$

Q.6 (b) Solution:

The current through R_B, $I_B = I - I_C$

Using KVL we have,



$$V_C - I_B R_B - 0.7 = 0$$

$$1.5 - (I - I_C)R_B - 0.7 = 0$$

$$(I - I_C)R_B = 0.8 \quad \text{...(i)}$$

$$I_B = \frac{I_C}{\beta}$$

$$I - I_C = \frac{I_C}{\beta}$$

$$90\,I - 90\,I_C = I_C$$

$$90\,I = 91\,I_C$$

$$I = \frac{91}{90} I_C \quad \text{...(ii)}$$

From equation (i) and (ii),

$$\left(\frac{91}{90}I_C - I_C\right)R_B = 0.8$$

$$\frac{1}{90}\times 3\times 10^{-3}\times R_B = 0.8$$

$$\Rightarrow \quad R_B = 24\text{ k}\Omega$$

$$\text{Current, } I = \frac{91}{90}\times 3\times 10^{-3}$$

$$\Rightarrow \quad I = 3.033\text{ mA}$$

Q.6 (c) Solution:

(i) Wire Earthing: In this system of earthing strip electrodes of cross section not less than 25 mm x 1.6 mm if of copper and 25 mm x 4 mm if galvanized iron or steel are buried in horizontal trenches of minimum of depth 0.5 meter. If round conductors are used, their cross-sectional area shall not be smaller than 3.0 mm^2 if of copper and 6 mm^2 if of galvanized iron or steel. The length of buried conductor shall be sufficient to give the required earth resistance. It shall, however, be not less than 15 meters. The electrodes shall be as widely distributed as possible, preferably in a single or circular trench or in a number of trenches radiating from a point, If conditions require use of more than one strip, they shall be laid either in parallel trenches or in radial trenches. This type of earthing is used at places which have rocky earth bed because at such placed excavations work for plate earthing is difficult.

(ii) Rod Earthing: In this system of earthing 12.5 mm diameter solid rod of copper or 16 mm diameter solid rod of galvanized iron or steel; or hollow section 25 mm G I pipes of length not less than 2.5 meters are driven vertically into the earth either manually or by pneumatic hammer. In order to increase the embedded length of electrodes under the ground, which is sometimes necessary to reduce the earth resistance to desired value, more than one rod sections are hammered on above the other. This system of earthing is suitable for areas which are sandy in character. This system of earthing is very cheap as no excavation work is involved.

(iii) Pipe Earthing: Pipe earthing is the best form of earthing and is very cheap in cost. In this method of earthing, a galvanized and perforated pipe of approved length and diameter is placed up right in a permanently wet soil. The size of the pipe depends upon the current to be carried and the type of the soil. Usually the pipe used for this purpose is of diameter 38 mm and 2.5 meters in length for ordinary soil or of greater length in case of dry and rocky soil. The depth at which the pipe must be buried depends upon the moisture of the ground. The pipe is placed at a depth of 3.75 meters (minimum). The pipe is provided with a tapered casing at the lower end in order to facilitate the driving. The pipe at the bottom is surrounded by broken pieces of coke to increase the effective area of the earth and to the earth and to decrease the earth resistance respectively. Another pipe of 19 mm diameter and minimum length 1.25 meter is connected at the top to G I pipe through reducing socket. In our country in summer the moisture in the soil decrease which cause increase in earth resistance. So a cement concrete work, is done in order to keep the water arrangement accessible, and in summer to have an effective earth, 3 or 4 buckets of water are put through the funnel connected to 19 mm diameter pipe, which is further connected to G I pipe. The earth wire (either G I wire or G I Strip of sufficient cross section to carry faulty current safely) is carried in a G I pipe of diameter 13 mm at a depth of about 60 mm from the ground). Care should be taken that earth wire is well protected from mechanical injury, when it is carried over from one machine to another.

(iv) **Plate Earthing :** In plate earthing an earthing plate either of copper of dimensions 60 cm x 60 cm x 3 mm or of galvanized iron of dimensions 60 cm x 60 cm x 6 mm is buried into the ground with its face vertical at a depth of not less than 3 meters from ground level. The earth plate is embedded in alternate layers of coke and salt for a minimum thickness of 15 cm. The earth wire (G I wire for G I plate earthing and copper wire for copper plate earthing) is securely bolted to an earth plate with the help of a bolt, nut and washer made of material of that of earth plate (made of copper in case of copper plate earthing and of galvanized iron in case of G I plate earthing).

A small masonry brick wall enclosure with a cast iron cover on top or an R C C pipe round the earth plate is provided to facilitate its identification and for carrying out periodical inspection and tests.

For smaller installations G I pipe earthing is used and for larger stations and transmission lines, where the fault current, likely to be high, plate earthing is used.

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