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Detailed Solutions

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

Electrical Engineering Test No : 7

Q.1 (a) Solution:

For the current transformer,

Transformation ratio of CT is

$$R = n + \frac{I_\omega \cos\delta + I_m \sin\delta}{I_s} \quad \text{... (i)}$$

Where, n = turn ratio,

I_w = core loss component

I_μ = magnetizing component,

I_s = secondary current

Given, the secondary winding is resistive

$\therefore$ $\cos\delta = 1,$

$\sin\delta = 0$

as $\delta = 0°$

Voltage and current phasors are in phase

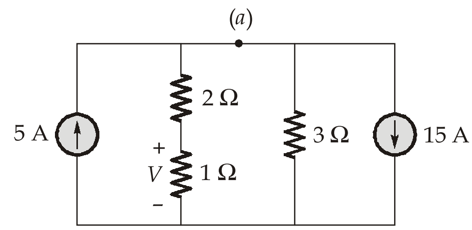
From equation (i), we get

$$R = n + \frac{I_w}{I_s} \quad \text{... (ii)}$$

$$\Rightarrow \quad 20.6 = 20 + \frac{I_w}{5}$$

$$I_w = 0.6 \times 5 = 3 \text{ A}$$

Q.1 (b) Solution:



Applying KCL at node (a), we get,

$$\frac{V_a}{3} + \frac{V_a}{3} = 5 - 15$$

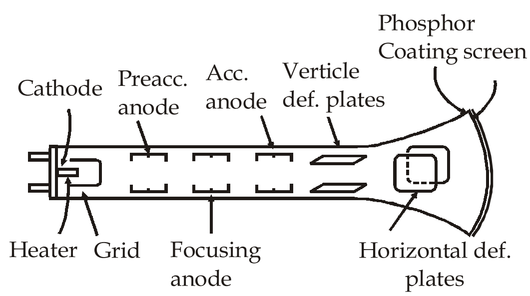
$$6V_a = -90 \qquad \Rightarrow V_a = -15 \text{ V}$$

$\because$ The current through 1 Ω resistor is $\frac{V_a}{3} = -\frac{15}{3} = -5$ A

$\therefore$ The voltage across 1 Ω resistor is –5 V.

Q.1 (c) Solution:

Cathode Ray Tube (CRT)



- CRT works on the principle of thermionic emission i.e. emission of electrons from a heated surface. The various part of CRT are discussed below:

Electron Gun

(a) Heater: Used to raise the temperature of Cathode.

(b) Cathode: Emits the electrons when heated, coated with Barium and strontium oxide. The cathode is cylindrical in shape which emits electrons at moderate temperature.

(c) Grid: Electron from cathode passes through Grid, made up of Ni cylinder having a hole at centre and placed coaxially with tube.
Grid is given –ve potential and it controls the number of electrons emitted from the cathode.
Hence the intensity of beam at screen is in control of grid.

(d) Pre-accelerating and accelerating anodes: These are positively charged electrodes which increases the speed of electrons emitted.

(e) **Focussing anode:** This anode is used to focus the e^- beam on the screen. Focusing of an electron beam can be done by two method:
- Electrostatic focusing technique achieved by formulation of two concave lenses.
- Magnetostatic focusing technique.

(f) **Screen:** It is front of the CRT also called face plate, made of fibre optics interval surface of face plate is coated with phosphor which converts electrical energy into light energy.

Q.1 (d) Solution:

Advantages and Disadvantages of M.I. Instruments

Advantages :

- Less Friction Errors
- Cheapness
- Robustness
- As the direction of the magnetic field changes with the change in polarity of AC parameter under measurement, MI instruments can be used for both AC and DC parameters.
- As the fixed system of instrument carries the current, the current carrying capacity of MI instrument is large.
- MI instruments exhibits square law response. Therefore, the angular deflection of instrument is directly in terms of the rms value of the AC parameter under measurement.
- **Accuracy:** The initial accuracy of high grade instruments is stated to be 0.75 percent for frequencies between 25 to 125 Hz and they may be expected to be accurate within 0.2% to 0.3% at 50 Hz if carefully designed.

Disadvantages :

- **Scale:** The scale of moving iron instruments is not uniform and is cramped at the lower end and therefore accurate readings are not possible at this end.
- **Errors:** These instruments are subjected to serious errors due to hysteresis, frequency changes and stray magnetic fields.
- As the compensation required for a.c. and d.c. is different, these instruments have different calibration for a.c. and d.c. parameter.

Q.1 (e) Solution:

Given: $X = 11\ \Omega/\text{phase}$

Total power transmitted is, $$P_R = \frac{|V_s||V_R|}{X}\sin\delta$$

For maximum power transmission,

$$\delta = 90°$$

$$P_{R\ (max)} = \frac{|V_s||V_R|}{X} = \frac{66 \times 66}{11} \times 10^6 = 396 \text{ MW}$$

Hence, maximum power transmission per phase

$$= \frac{P_{R(max)}}{3} = \frac{396}{3} = 132 \text{ MW}$$

Q.2 (a) Solution:

Given,

Total instrument resistance, R = 25 Ω

Full scale deflection, θ = 150°

Input voltage, V = 90 mV

Moving coil dimensions = 25 mm × 25 mm

Coil area = 625×10^{-6} m^2

Number of turns = 120

Spring constant, K = 0.45×10^{-6} N-m/deg

Specific resistance of conductor, ρ = 1.7×10^{-8} Ω-m

Coil resistance, R_C = 40% of instrument resistance

$$= \frac{40}{100} \times 25 = 10\,\Omega$$

Length of mean turn = $2\,(l + b) = 2(25 + 25) = 100$ mm

Let the cross section area of conductor be A

For n series turns resistance,

$$R_c = N\rho l / A$$

$$R_c = \frac{120 \times 1.7 \times 10^{-8} \times 100 \times 10^{-3}}{A}$$

$$\therefore \quad A = \frac{120 \times 1.7 \times 10^{-8} \times 100 \times 10^{-3}}{10} = 2.04 \times 10^{-8} \text{ m}^2$$

Let d be the diameter of conductor wire

$$A = \pi \frac{d^2}{4} = 2.04 \times 10^{-8}$$

$$\therefore \quad d = \left[\frac{4}{\pi} \times 2.04 \times 10^{-8}\right]^{1/2} = 0.161 \text{ mm}$$

$$\text{Current in the instrument} = \frac{\text{Voltage}}{\text{Instrument resistance}}$$

$$= \frac{90 \text{ mV}}{25\Omega} = 3.6 \text{ mA}$$

Using the torque relation for moving coil instrument

$$T_d = T_c$$

Where, Deflecting torque, $T_d = NBAI$

Controlling torque, $T_c = K\theta$

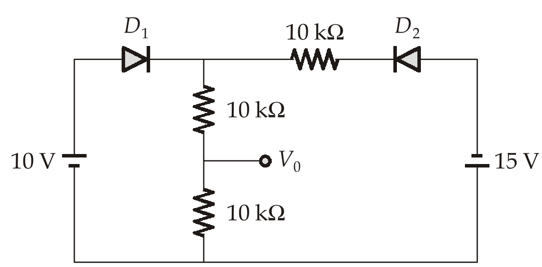
$$NBAI = K\theta$$

$$120 \times B \times 625 \times 10^{-6} \times 3.6 \times 10^{-3} = 0.45 \times 10^{-6} \times 150$$

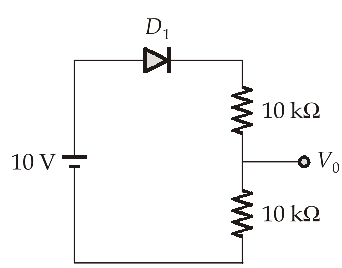
$$B = \frac{67.5 \times 10^{-6}}{2.7 \times 10^{-4}} = 0.25 \text{ Wb/m}^2$$

Q.2 (b) Solution:

Given circuit is,



We can observe that diode D_2 is always off so equivalent circuit is



D_1 is on in this condition, $V_0 = 10 \times \frac{10}{10+10} = 5 \text{ V}$

Q.2 (c) Solution:

The following are the three important operating characteristics of dc motors.

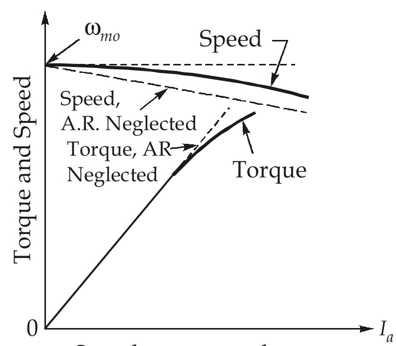
- Speed-armature current characteristic
- Torque-armature current characteristic and
- Speed-torque characteristic.

DC Shunt Motor:

For constant supply voltage, the field current is constant. At small values of armature current the demagnetizing effect of armature reaction is almost negligible and therefore the air gap flux is unaffected. For larger values of armature (or load) currents, the demagnetizing effect of armature reaction, decreases the air gap flux slightly.

$$\omega_m = \frac{V_t - I_a r_a}{K_a \phi}$$

Speed-Current Characteristic:



Speed current and torque current characteristics

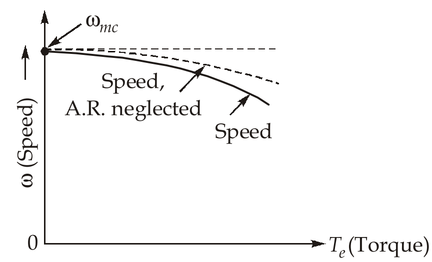
- For constant supply voltage V_t and constant field current I_f, the motor speed is affected by $I_a r_a$ drop and demagnetizing effect of armature reaction. With the increase of I_a, the demagnetizing effect of armature reaction increases which reduces the field flux, therefore the motor speed tends to increase.
- The speed of dc shunt motor with increase of I_a drops only slightly from its no-load speed ω_{mo}. Since I_a at no-load is negligibly small, the shunt motor no-load speed ω_{mo} is given by

$$\omega_{mo} = \frac{V_t}{K_a \phi}$$

Torque-Current Characteristic:

- $T_e = K_a \phi I_a$
- The torque would increase linearly with armature current I_a. However, for larger I_a, the net flux decreases due to the demagnetizing effect of armature reaction.

Speed-Torque Characteristic:



Speed torque characteristics

- Also called the mechanical characteristic,

$$\omega_m = \omega_{mo} - \frac{T_e}{K_a^2 \phi^2}$$

- For larger T_e, larger I_a is required and this has the effect of reducing the air gap flux ϕ, due to saturation and armature reaction.
- With increase of T_e, ϕ is reduced, T_e/ϕ^2 increases at a faster rate and the speed drops more rapidly with the increase of torque.
- If effect of AR is neglected, then $(K_a \phi)^2$ in equation remains constant. As a result, the speed drop with T_e is slow.

Q.2 (d) Solution:

For an RLC circuit,

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \quad \text{...(i)}$$

and

$$f_2 - f_1 = \text{Bandwidth (BW)} = \frac{1}{2\pi} \times \frac{R}{L} \quad \text{...(ii)}$$

from equation (i) and (ii),

$$\frac{BW}{f_0^2} = \frac{\frac{1}{2\pi} \times \frac{R}{L}}{\frac{1}{4\pi^2} \times \frac{1}{LC}} = 2\pi RC$$

or

$$C = \frac{BW}{2\pi \times R \times f_0^2} = \frac{7.2 \times 10^3}{2 \times \pi \times 4.5 \times 8 \times 10^6 \times 8 \times 10^6} = 3.978 \text{ pF}$$

Q.3 (a) Solution:

$$\text{Efficiency all day} = \frac{\text{Total every output during 24 hours}}{\text{Energy output during 24 hours} + P_i \times \text{24 hours} + x^2 P_{cu} \times \text{24 hours}}$$

Let, kVA rating of transformer = 5 kVA,

$$\eta_{max} = x^2_{P_{cu}} = p_i \text{ at } \cos\phi = 1$$

$$\eta_{max} = \frac{x\,(\text{kVA})\cos\phi}{x\,(\text{kVA})\cos\phi + P_i + P_i}$$

$$= \frac{x\,S\cos\phi}{x\,S\cos\phi + 2\,P_i} \qquad \because xS = 20 \text{ kVA}$$

$\because$ 98% at 20 kVA,

then, $S = 20$

and $\eta_{max} = 98\%;\ x = 1,$

$$0.98 = \frac{20\times1\times1}{20\times1\times1+2P_i}$$

$$P_i = 0.204 \text{ kW}$$

$\because$ $$xS = 20,\ x = \frac{20}{S}$$

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

$$\left(\frac{20}{S}\right)^2 P_{cu} = 0.204$$

$$P_{cu} = 5.1 \times 10^{-4}\, S^2 \text{ kW}$$

(i) $$P = 2 \text{ kW at } \cos\phi = 0.6$$

$$\text{Load kVA} = S_L = \frac{2}{0.6} = \frac{10}{3}\text{ kVA}$$

$\because$ $$xS = \frac{10}{3}\text{ kVA}$$

$$x = \left(\frac{10}{3}\right)\times\frac{1}{S}$$

Then, $$\text{Copper loss} = x^2\,P_{cu} = \left(\frac{10}{3}\right)^2 \times \left(\frac{1}{S}\right)^2 \times 5.1\times10^{-4}S^2$$

$$= 5.67\times10^{-3} \text{ kW}$$

For 12 hours, these loss are $5.76 \times 10^{-3} \times 12$ kWh

(ii) $$P = 10 \text{ kW, at } \cos\phi = 0.8,$$

$$S_L = \frac{P_L}{\cos\phi} = \frac{10}{0.8} = 12.5 \text{ KVA}$$

$\because$ $$xS = 12.5,\ x = \left(\frac{12.5}{S}\right)$$

$$\text{Copper loss} = x^2 P_{cu} = \left(\frac{12.5}{S}\right)^2 \times 5.1\times10^{-4}\times S^2$$

$$x^2P_{cu} = 0.07 \text{ kW}$$

$$\text{for 6 hours these losses are} = 0.07 \times 6 = 0.42 \text{ kWh}$$

(iii) $P = 20$ kW, at $\cos\phi = 0.9$, $S_L = \frac{20}{0.9}$ kVA,

$$xS = S_L = \frac{20}{0.9}\text{ kVA}$$

$$x = \left(\frac{20}{0.9}\right)\times\frac{1}{S}$$

$$x^2 P_{cu} = \left(\frac{20}{0.9}\right)^2 \times \frac{1}{S^2}\times 5.1\times10^{-4}S^2 = 0.25 \text{ kW}$$

$$\text{Copper loss for 6 hours} = 0.25 \times 6 \text{ kWh}$$

Total power output during the day i.e. 24 hours

$$= (2 \times 12) + (10 \times 6) + (20 \times 6) = 204 \text{ kWh}$$

Total iron loss during the day

$$= 0.204 \times 24 \text{ kWh} = 4.896 \text{ kWh}$$

Total copper loss during the day

$$= (5.67 \times 10^{-3} \times 12) + (0.07 \times 6)+(6 \times 0.25) = 1.98 \text{ kWh}$$

$$\eta_{\text{all-day}} = \frac{(\text{Output power})\times 24 \text{ hours}}{24\left[(\text{Output power}) + P_i + x^2P_{cu}\right]}$$

$$= \frac{204}{204\times4.896+1.98} = 96.7\ \%$$

Q.3 (b) Solution:

Let 'R' be the value of each resistor,

When connected in parallel, the equivalent resistor is given by

$$R_{eq} = \frac{1}{\frac{1}{R}+\frac{1}{R}+\frac{1}{R}+\frac{1}{R}} = \frac{R}{4}\ \Omega$$

$\therefore$ Power dissipated by the circuit,

$$P = \frac{V^2}{R_{eq}}$$

$$150 = \frac{V^2}{R/4}$$

or $$\frac{V^2}{R} = \frac{150}{4} \quad \text{...(i)}$$

Now, the resistors are connected in series,

The equivalent resistor is given by,

$$R_{eq} = R + R + R + R = 4R$$

$\therefore$ Power dissipated by the circuit,

$$P = \frac{V^2}{R_{eq}} = \frac{V^2}{4R} = \frac{1}{4}\left(\frac{150}{4}\right) = \frac{150}{16} = 9.375 \text{ W}$$

Q.3 (c) Solution:

The resistance of earth system depends upon the following factors:

- Condition of soil.
- Temperature of soil.
- Moisture content of soil.
- Size and spacing of earth electrodes
- Depth, at which the electrode is embedded.
- Material of conductor.
- Quality of coal, dust, charcoal and salt in the earth electrode pit.
- No. of electrodes connected in parallel.

Q.4 (a) Solution:

$$\text{Total time} = 24 \text{ hours}$$

$$\text{Maximum demand} = 100 \text{ MW}$$

$$\text{Average load} = \frac{\text{Area under curve}}{\text{Total hours}}$$

$$= \frac{40 \times 24 + \frac{1}{2} \times 24 \times 60}{24} = 70 \text{ MW}$$

$$\text{Load factor} = \frac{\text{Average load}}{\text{Maximum demand}} = \frac{70}{100} = 0.7 \text{ i.e. } 70\%$$

Q.4 (b) Solution:

Given,

$$N = 980 \text{ rpm};$$

$$P = 6,$$

$$f = 50 \text{ Hz}$$

$$\text{Synchronous speed, } N_s = \frac{120 \times 50}{6} = 1000 \text{ rpm}$$

$$\text{Slip, } s = \frac{1000 - 980}{1000} = 0.02$$

$$\text{Rotor copper loss} = \frac{s}{(1-s)} \times \text{Mechanical power developed}$$

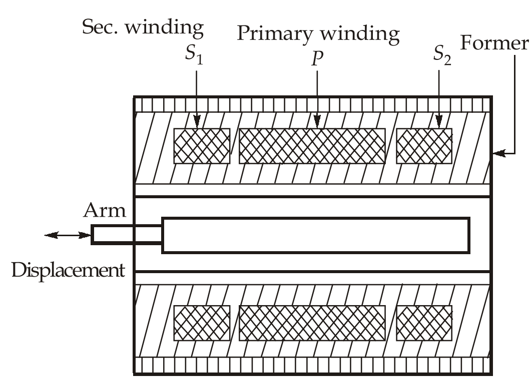
$$P_{cu} = \left(\frac{0.02}{1-0.02}\right) \times P_{mech}$$

Where, $P_{mech} = P_{shaft} + P_{mech.\ loss} = 5200 + 800 = 6000\text{ W}$

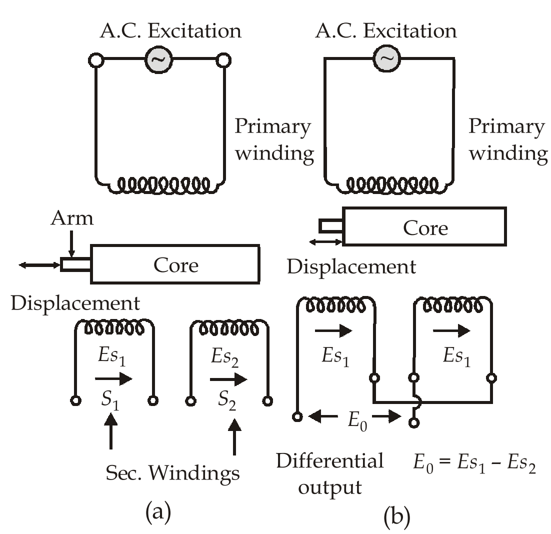
$$\text{Rotor copper loss; } P_{cu} = \frac{0.02}{0.98} \times 6000 = 122.45\text{ W}$$

Q.4 (c) Solution:

LVDT (Linear Variable Differential Transformer):



Linear variable differential transformer (LVDT):



- LVDT is the most widely used inductive transducer for converting the linear into proportional output electrical voltage.

Construction:

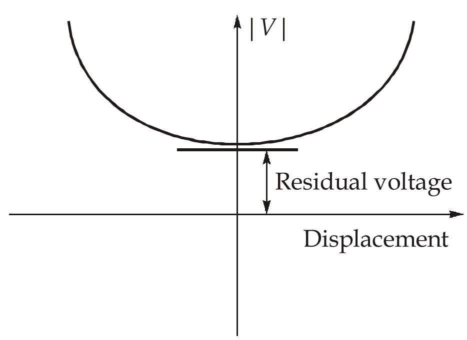
- It consists of centrally placed magnetic core made up of hydrogen annealed Ni-iron alloy with high permeability.
- The windings are coaxially placed on the stator. The secondary winding is divided into two equal parts and placed symmetrically around primary winding as shown in diagram.

Working:

- An AC supply is given to the primary winding; the output is the differential voltage of two sections of secondary windings as shown in circuit diagram.
- As the core moves in either direction the flux linkage with the two secondary winding differs so their output voltage differs and differential output voltage of the LVDT is non-zero which can be used to indicate the displacement of core.

  Therefore a LVDT can be used for the conversion of displacement to electrical signal where it is used as Secondary transducers and it can be used for measurement of displacement where it is used as primary transducer.

Voltage Displacement Characteristics:



- From the characteristic curve, we see that there is small differential output of secondary even the displacement of core is zero.
- This voltage is called residual voltages.

Residual Voltages:

Reasons

(i) Due to harmonics in supply voltage.

(ii) Due to external magnetic field or stray capacitances.

Sensitivity of LVDT

$$S = \frac{E_o}{l}(\text{V/mm})$$

Advantages of LVDT:

(i) High Range (1.25 mm to 250 mm).

(ii) No frictional losses.

(iii) High sensitivity $\left(\dfrac{\text{Change in output}}{\text{Change in input}}\right)$ (40 V/mm).

(iv) Low hysteresis losses.

(v) Low power consumption, (less than 1 watt).

(vi) Simple in construction and rugged.

Disadvantages:

(i) It is sensitive to stray magnetic fields so shielding is needed.

(ii) Affected by vibrations.

(iii) The dynamic response is limited by mass of the core and frequency of supply.

(iv) Large displacement are required.

Applications of LVDT:

(i) To measure the displacement, and used as primary transducer.

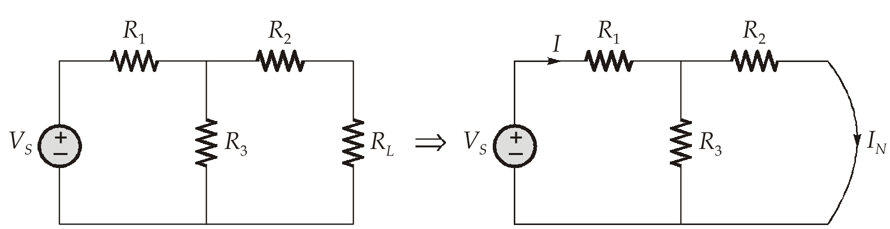
(ii) To measure the pressure, force etc. and used as secondary transducer.

Q.4 (d) Solution:

Norton's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a current source I_N in parallel with a resistor R_N, where I_N is the short-circuit current through the terminals and R_N is the input or equivalent resistance at the terminals when the independent sources are turned-off.

Explanation:

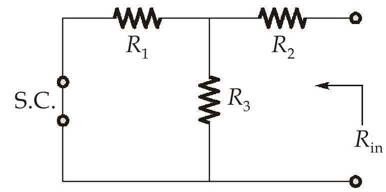
In order to find the current through the load R_L by Norton's is theorem, replace R_L by short-circuit.



Current, $$I = \frac{V_s}{R_1 + \left(\dfrac{R_2 R_3}{R_2 + R_3}\right)} \quad \text{and} \quad I_N = I \cdot \left(\frac{R_3}{R_2 + R_3}\right)$$

Next, the short-circuit is removed and the independent source is deactivated

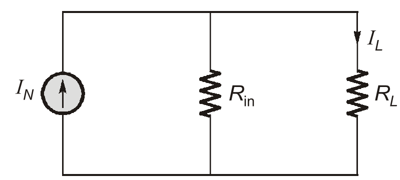
$$R_{in} = R_2 + \left(\frac{R_1 R_3}{R_1 + R_3}\right)$$



As per Norton's theorem, the equivalent source circuit would contain a current source in parallel to the internal resistance, the current source being the short-circuited current across the shorted terminals of the load resistor.

Norton's Equivalent Circuit:

$$I_L = I_N\left(\frac{R_{in}}{R_{in}+R_L}\right)$$



Norton's theorem is always valid irrespective of

(*i*) Nature of elements contain in the network.

(*ii*) Nature of voltage and current sources.

Norton's theorem is not valid for the network containing

(*i*) Non-linear elements

(*ii*) Unilateral elements such as p-n junction diode, transistor etc.

Steps for solving a network using Norton's theorem:

Step-1: Remove the load resistor and find the internal resistance of source network by deactivating the independent sources:

- all independent voltage sources are short-circuited or replaced by their internal impedances.
- all independent current sources are open-circuited or replaced by their internal impedances.
- all dependent voltage and current sources remain as it is.

Step-2: Short the load terminal and find the short-circuit current flowing through the shorted load terminals.

Step-3: Norton's equivalent circuit is drawn by keeping R_{in} in parallel to I_N.

Step-4: Reconnect the load resistance R_L across the load terminals and the current through it is I_L.

$$I_L = I_N\left(\frac{R_{in}}{R_{in}+R_L}\right)$$

Q.5 (a) Solution:

Under balanced condition,

$$(R_1 + j\omega L_1) \times \left(R_4 \,||\, \frac{1}{j\omega C_4} \right) = (R_3) \times (R_2)$$

Separating real and imaginary parts,

$$(R_1 + j\omega L_1)\left(\frac{R_4}{1 + j\omega C_4 R_4}\right) = R_2 R_3$$

$$(R_1 + j\omega L_1)R_4 = (R_2 R_3)(1 + j\omega C_4 R_4)$$

$$R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega C_4 R_4 R_2 R_3$$

Equating real and imaginary parts, we get

$$R_1 = \frac{R_2 R_3}{R_4}$$

and $$L_1 = \frac{C_4 R_4 R_2 R_3}{R_4} = R_2 R_3 C_4$$

$$R_1 = \frac{450 \times 900}{600} = \frac{450 \times 3}{2} = 225 \times 3 = 675\,\Omega$$

and $$L_1 = R_2 R_3 C_4 = 450 \times 900 \times 0.6 \times 10^{-6} = 0.243\text{ H}$$

$$\text{Storage factor i.e. Q factor} = \frac{\omega L_1}{R_1} = \frac{2\pi \times 1000 \times 0.243}{675} = 2.262$$

Q.5 (b) Solution:

Output voltage, $$V_0 = V_Z - V_{BE}$$
$$= 8.3 - 0.7 = 7.6\text{ V}$$

$$\text{Current through, } R = \frac{V_i - V_z}{R} = \frac{15 - 8.3}{1.8}\text{mA} = 3.72\text{ mA}$$

$$I_L = \frac{V_0}{R_L} = \frac{7.6}{2} = 3.8\text{ mA}$$

$$I_B = \frac{I_C}{\beta} = \frac{I_L}{\beta} = \frac{3.8}{100}\text{mA} = 0.038\text{ mA}$$

$$I_Z = I_R - I_B$$
$$= 3.72 - 0.038 = 3.684\text{ mA}$$

Q.5 (c) Solution:

Classification of Water Turbines:

1. **On the basis of type of water flow:**
   It is of four types:
   - Axial flow turbines : Kaplan turbine
     Here, water flows along the shaft axis
   - Radial flow turbine:
     Here water flows radially
   - Tangential flow turbine : Pelton turbine
     Here water flow tangentially
   - Mixed flow turbines
2. **On basis of action of water on moving blades**
   - Impulse turbine : eg: Pelton wheel turbine
   - Reaction turbine : eg: Francis, Kaplan turbines
3. **On the basis of water head**
   - High head turbine (Above 500 m) : Pelton wheel turbine
   - Medium head turbine (70 m - 500 m) : Francis turbine
   - Low head turbine (Below 70 m) : Kaplan turbine

Q.5 (d) Solution:

Given,

$$V_s = 110 \text{ V},$$
$$T = 0.6 \text{ N-m},$$
$$R_a = 1.5\ \Omega$$

No load speed, $N_0 = 4000$ rpm

at no load; $E_b = V_s = K\,\phi\,\omega_m$

therefore,
$$K\phi = \frac{V_s}{\omega_m} = \frac{110}{2\pi \times \frac{4000}{60}} = \frac{110 \times 60}{8000\,\pi} = \frac{66}{80\pi} = 0.2626$$

Also load torque, $T = K\,\phi\,I_a$ [at load]

or,
$$I_a = \frac{T}{K\phi} = \frac{0.6 \times 80\pi}{66}$$
$$I_a = 2.284 \text{ A}$$

Now at load back emf;

$$E_b = V_s - I_a R_a = 55 - 2.284 \times 1.5$$
$$E_b = 51.574 \text{ V}$$

Now speed at load,

$$E_b = K\,\phi\,\omega$$

or, $$\omega = \frac{E_b}{K\phi} = \frac{51.574 \times 80\pi}{66}$$

$$\omega = 196.393 \text{ rad/sec}$$

or, $$N = 1875.4 \text{ rpm}$$

Q.6 (a) Solution:

(i) Grading of Cables:

- A single core cable having maximum value g_{max} at the conductor surface and decreases towards sheath.
- It is advantageous to try to have more uniform stress distribution across the dielectric. This will minimize the quantity of insulation needed for a given r and operating voltage.
- The technique of making the uniform dielectric stress is called "grading of cables".

There are two methods for grading of cables:

(a) Capacitance grading:

- In this two or more insulating materials are used with different primitivities and one having larger permittivity is nearer to the conductor.
- Disadvantage: When a dielectric is damaged it must be replaced by similar dielectric and thereby increasing investment.

(b) Intersheath grading:

- In this method of cable grading, a homogenous dielectric is used, which is divided into various layers by suitably placing the metallic intersheath.
- Metallic intersheaths are maintained at appropriate potential by being connected to tappings on winding of an auxiliary transformer supplying the cable.

(ii) Per unit system: It is defined as "the ratio of the quantity (in some unit) to its base value (in same unit)".

- i.e. pu value = $\dfrac{\text{Actual value in any unit}}{\text{Base value in same unit}}$

Advantages:

- Per unit system will convert a multi voltage level circuit into a single voltage level circuit hence problem of refering is avoided.
- Calculation is easier in per unit system.

(a) For single-phase system:

Let, Base MVA = $(\text{MVA})_b$

Base kilovolt = $(\text{kV})_b$

$$\text{Base current} = \frac{\text{Base MVA}}{\text{Base Voltage}}$$

$$Z_b = \text{basic impedance} = \frac{(\text{kV})_b^2}{(\text{MVA})_b}$$

(b) For three-phase system:

Base MVA = $(\text{MVA})_b$

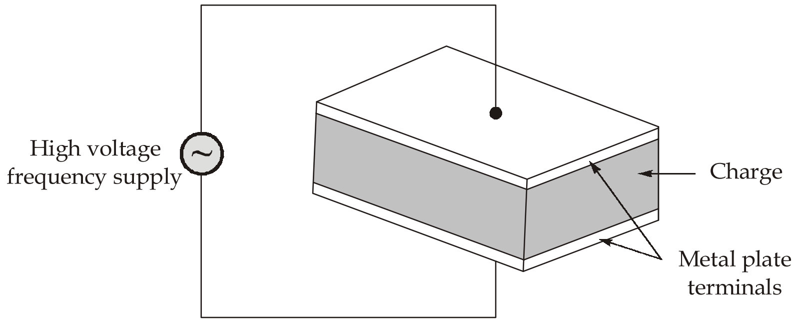
Line to line base kV = $(\text{kV})_b$

$$\text{Base current } (I_b) = \frac{(\text{MVA})_b \times 1000}{\sqrt{3} \times (\text{kV})_b}$$

$$\text{Basic impedance} = Z_b = \frac{(\text{kV})_b^2}{(\text{MVA})_b}$$

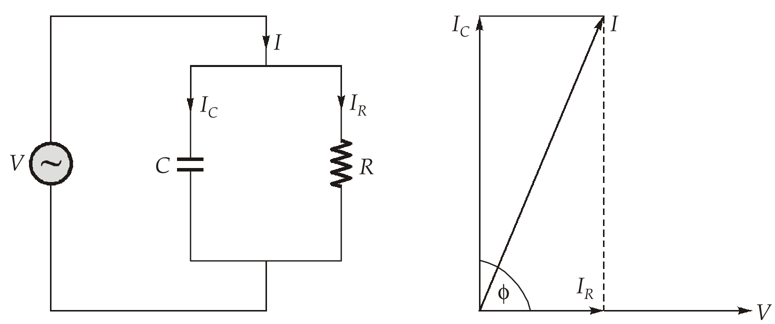
(iii) Dielectric Heating:

- When non-metallic parts such as wood, plastics, bones ceramics are subjected to an alternating electrostatic field, dielectric loss occurs. These losses are usd in dielectric heating which appears in the form of heat. The material to be heated is placed as a slab between two metallic electrodes across which high frequency voltage is applied.
- To ensure sufficient loss and to give an adequate amount of heating, frequencies between 10 to 30 mega cycle per second must be used and the voltage needed may be as high as 20 kV. The necessary high frequency supply voltage is obtained from a valve oscillator.
- The current drawn by the capacitor, when an a.c. supply voltage is applied across its two plates, does not lead the supply voltage by 90° exactly. Due to this component of current, heat is always produced in dielectric material placed in between the two plates of the capacitor.



Dielectric heating

- The electric energy dissipated in the form of heat energy in the dielectric material is known as dielectric loss. The dielectric loss is directly proportional to the frequency of a.c. supply.
- This method of heating is also employed for drying of textiles, manufacture of plywood etc. The overall efficiency in case of dielectric heating is about 50%.
- In insulators or non-conducting materials, the amount of heat produced by dielectric heating can be calculated as follows:



(a) Equivalent circuit (b) Phasor diagram

- The material to be heated may be considered imperfect dielectric of a condenser and may be, therefore represented as a capacitance placed in parallel with a resistance as shown in Fig. (a). The phasor diagram of the circuit is shown in Fig. (b). If V is the supply voltage, f is the supply frequency in Hz, cosf is the power factor of the load and C is the capacitance of the condenser in Farads.

Capactiance, $C = \epsilon_0 \epsilon_r \dfrac{A}{d}$ F

where, ϵ_0 = Permittivity of vacuum and its value is 8.854×10^{-24} F/m

ϵ_r = Relative permittivity or dielectric constant

A = Surface area of electrodes in m^2

d = distance between two electrodes in meter

Now current through the capacitor,

$$I_C = \frac{V}{X_C} = \frac{V}{2\pi fC} = 2\pi fCV \text{ Ampere}$$

Current drawn from supply,

$$I = I_C = 2\pi fCV \text{ Amp.}$$

where C is in Farads and V is in volts

Power produced, $P = VI \cos\phi$

$$= V \times 2\pi fCV \times \cos\phi$$

$$P = 2\pi fCV^2 \text{ watts}$$

Voltage, $C = \sqrt{\dfrac{P}{2\pi fC}}$ Volts

Advantages of Dielectric Heating:

1. Since the heat is produced throughout the whole mass of material, we get uniform heating. By conventional method of heating, it is not possible to achieve this.
2. Short time is required to complete the process as compared to other method.
3. Materials heated by this method are non-conducting, so by other methods heat cannot be conducted to inside so easily.

Disadvantages of Dielectric Heating:

1. Only those materials can be heated which have high dielectric loss.
2. The cost equipment required for dielectric heating so high that it is employed only where other methods are impracticable.

Applications of Dielectric Heating:

1. It is used in drying tabacco, paper, wood, gluing and bonding of woods.
2. Welding of PVC
3. Sterilization of medical supplies.
4. For producing artificial fibres, heating of bones and tissues etc.
5. Food processing.

Q.6 (b) Solution:

Line current taken from the supply;

$$I_{st} = x^2 I_{sc} \quad \text{...(i)}$$

The supply line current at start $= 2 I_{fl}$

short circuit current, $I_{sc} = 5 I_{fl}$

From equation (i),

$$2 I_{fl} = x^2 \times 5 I_{fl}$$

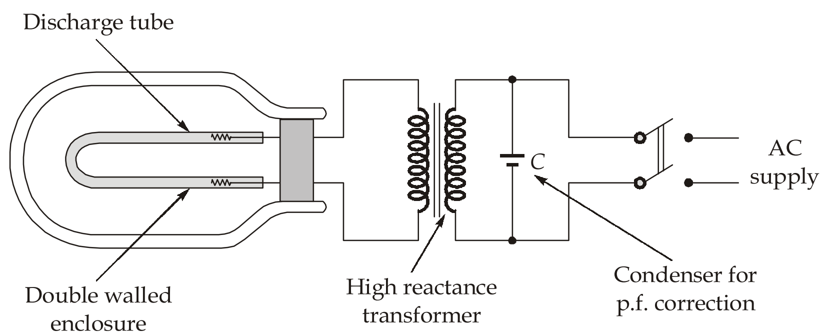
$$x^2 = \frac{2}{5}$$

or, $$x = 0.6324 \approx 63.24\%$$

Q.6 (c) Solution:

Sodium Vapour Lamp:

The major application of this type of lamp is for highway and general outdoor lighting where colour discrimination is not required. The sodium vapour lamp is most efficient of discharge lamp, the efficiency being of the order 60 to 70 lumens per watt. However, in terms, of input power and output, the overall efficiency is only about 20% [Rest being heat and other invisible radiation]. The sodium vapour lamp is only suitable for alternating current.



Sodium vapour lamp

Construction:

It consists of a U-type of special resistance glass which is known as discharge tube. A small quantity of neon gas and sodium vapour are introduced in the tube. The presence of neon gas serves to start the discharge.

In order to reduce the heat losses, this U tube is enclosed in a double walled evacuated glass jacket known as outer tube. A high leakage reactance transformer is connected in the circuit as shown. It provides a high voltage (about 480 V) to start the discharge. Also, because of its high reactance, it works as a stabilizer. A static capacitor C is used in order to improve the power factor.

Working:

As the lamps is switched on, electrons are emitted from cathode and attack the gas molecules. This starts the process of ionization and the discharge commences. The sodium is vapourised due to heat of the discharge and the lamp assume normal operation. The lamp will come up to its rated light output in about 15 minutes.

Drawbacks of Gaseous Discharge Lamps:

1. Low power factor
2. High initial cost
3. Takes time to come to full brilliancy
4. Can be used only in a particular position
5. Starting is complicated
6. Light output fluctuates at twice the supply frequency hence produces stroboscopic effect.

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