SJE(PAPER-II) -2018 MAINS OFFLINE TEST SERIES

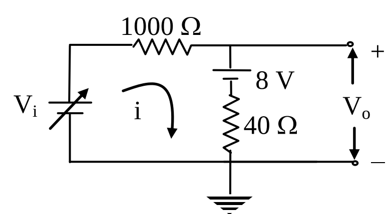
Electrical Engineering **Full Length Mock Test-2**

Solutions

1(a)

Sol: The range of input voltage is sufficient to operate zener satisfactorily

$$i = \frac{V_i - 8}{1040}$$



$$V_o = 8 + 40\,i$$

$$= 8 + 40\left(\frac{V_i - 8}{1040}\right)$$

$$= 8 + \left(\frac{V_i - 8}{26}\right)$$

When, $V_i = 12\text{ V} \Rightarrow V_o = 8 + \frac{4}{26} = 8.154\text{ V}$

When, $V_i = 20\text{ V} \Rightarrow V_o = 8 + \frac{12}{26} = 8.4615\text{ V}$

$\therefore\ V_o \rightarrow 8.154\text{ V to } 8.4615\text{ V}$

1(b)

Sol: A photon of energy E_g, where E_g is the band gap energy, can produce an electron-hole pair in a direct band gap semiconductor quite easily, because the electron does not need to be given very much momentum. An electron must undergo a significant change in its momentum for a photon of energy E_g to produce an electron –hole pair in an indirect band gap semiconductor. This is possible, but it requires such an electron to interact not only with the photon to gain energy, but also with a lattice vibration called a phonon in order to either gain or lose momentum.

The indirect process proceeds at a much slower rate, as it requires three entities to intersect in order to proceed an electron, a photon and a phonon.

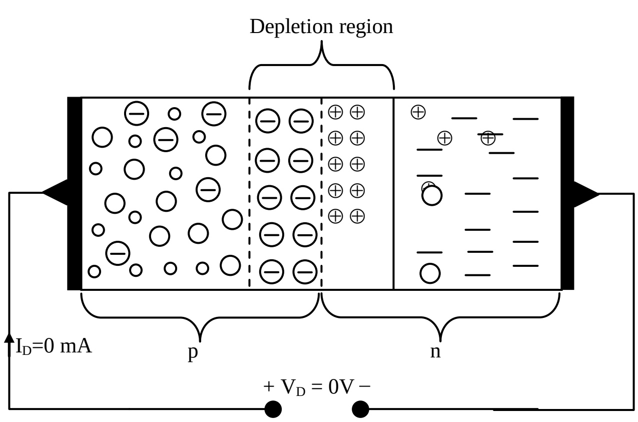
The same principle applies to recombination of electrons and holes to produce photons. The recombination process is much more efficient for a direct band gap semiconductor than for an indirect band gap semiconductor.

As a result of such considerations, gallium arsenide and other direct band gap semiconductors are used to make optical devices such as LED and semiconductor lasers, whereas silicon, which is an indirect band gap semiconductor, is not.

1(c)

Sol: 1. Depletion region:

At the instant when the p-type and n-type materials are joined together the electron and holes in the region of the junction will combine. Resulting in a lack of free carriers in the region near the junction as shown in fig.

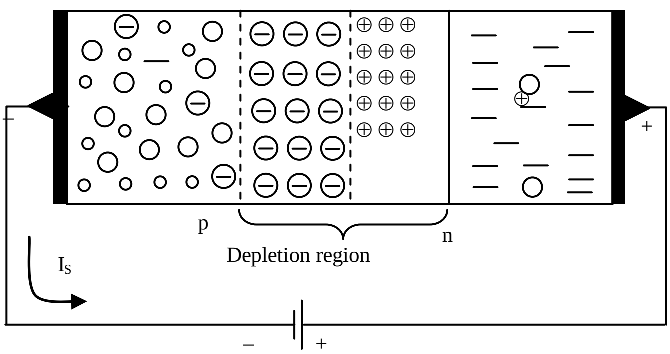


The only particles placed in the region are the +ve and –ve ions.

This region of uncovered +ve and –ve ions is called the depletion region due to the depletion of tree carriers in the region.

2. Reverse saturation current:

If an external potential of V volts is applied across the p-n junction such that the +ve terminals is connected to the n-type material and negative terminals is connected to the p-type material as shown in fig.



The number of uncovered positive ions in the depletion region of the n-type material will increase due to large number of free electrons drawn to the +ve potential of applied voltage for similar reasons. The number of uncovered –ve ions will increase in the p-type material. The net effect, therefore is a widening of the depletion region. This widening of the depletion region will establish too great a barrier of the minority carriers to overcome. Effectively reducing the majority carriers flow to zero.

The number of minority carriers, however, entering the depletion region will not change. Hence the current that exists under R.B conditions due to minority carriers is called reverse saturation current $I_{s.}$

3. Avalanche break down:

The minority carriers, under reverse biased conditions flowing through the junction acquires a kinetic energy which increases with increase in reverse voltage. At sufficiently high reverse voltage. The kinetic energy of minority carriers becomes so large such that they knockout electrons from the covalent bonds of the semiconductor material as a result of collisions, the liberated electrons intern liberate more electrons and the current become very large leading to the breakdown of crystal structure itself. The breakdown region is the knee of the characteristic curve. Now the current is not controlled by the junction voltage. But by the external circuit.

4. Transition (space-charge) capacitance

When P-N junction is reverse biased, the depletion region acts like an insulator or dielectric material. While the P and N type regions on either side have very low resistance and acts as the plates. Thus P-N junction may be considered as a parallel plate capacitor. The junction capacitance is formed as space change capacitance or transition capacitance or depletion capacitance. In reverse bias majority carriers moves away from the junction. There by uncovering more immobile charges. Thickness of depletion region increases.

$$C_T = \frac{dQ}{dV}$$

$$i = \frac{dQ}{dt} = C_T \frac{dV}{dt}$$

1(d)

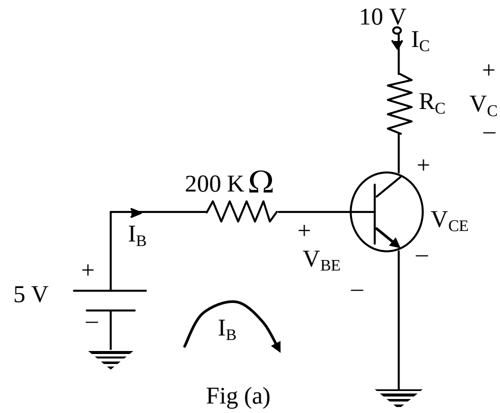


Fig (a)

Sol: Given information is shown in fig (a)

Given that

$V_{BE(sat)} = 0.8V$

$h_{fe} = 100$

$V_{CE(sat)} = 0.2V$

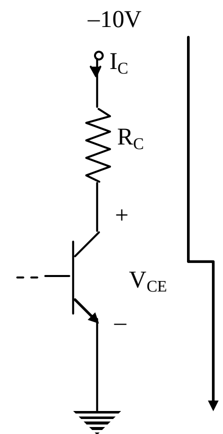
from the given circuit apply KVL in o/p loop

$-V_{CC} + I_C R_C + V_{CE} = 0$ (as shown in fig(b))

$I_C R_C = V_{CC} - V_{CE}$

$I_C R_C = 10 - 0.2$

$V_C = I_C R_C = 9.8V$ ----- (1)



Fig(b)

from i/p loop of fig (a)

$-5V + I_B\, 200k + V_{BE} = 0$

$$I_B = \frac{5-0.8}{200k} = \frac{4.2}{200k}$$

We know that $I_C = \beta\, I_B = 100 \times \dfrac{4.2}{200k} = 2.1$ mA

From (1) $V_C = I_C R_C = 9.8$ V

$$R_C = \frac{9.8V}{2.1\,mA}\ (\because I_C = 2.1\ mA) = 4.67\ k\Omega$$

$\therefore$ The minimum value of R_C for which the transistor remains in saturation is 4.67kΩ

2(a)

Sol:

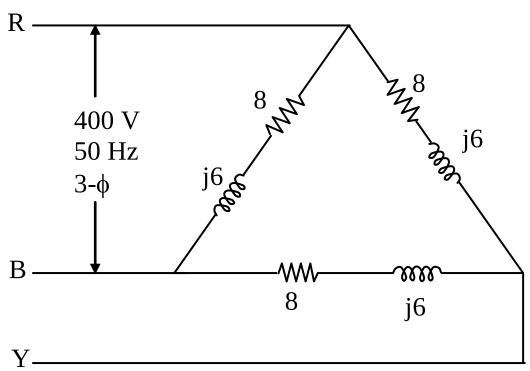


Fig.

Power factor angle of load (ϕ)

$$= \tan^{-1}\left(\frac{6}{8}\right) = 36.86^\circ$$

Active power consumed by the delta connected balanced load as in Fig. is

$P = 3 \times V_{ph} \times I_{ph} \times \cos\phi$

$$= 3 \times 400 \times \frac{400}{\sqrt{8^2+6^2}} \times \cos 36.86 = 38400\text{ W}$$

Reactive power consumed by the delta connected load is

$Q_1 = 3 \times V_{ph} \times I_{ph} \times \sin\phi$

$$= 3 \times 400 \times \frac{400}{\sqrt{8^2+6^2}} \times \sin 36.86$$

$= 28793.36$ VAR

Active power consumption remains same even after capacitor bank is connected Reactive power consumed by the delta connected load and the star-connected capacitances at a powerfactor of 0.9

$$Q_2 = \frac{P}{0.9} \times \sin(\cos^{-1} 0.9)$$

$$= \frac{38400}{0.9} \times \sin 25.84$$

$= 18597.96$ VAR

$\therefore$ Reactive power supplied by star connected capacitor bank $= Q_1 - Q_2$

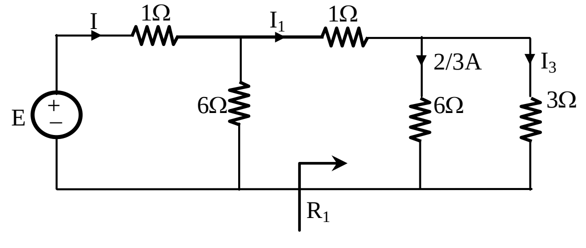
$= 28793.36 - 18597.96$

$= 10195$

$\cong 10.2$ kVAR

2(b)

Sol:



Given current through 6 Ω resistor $I_6 = \frac{2}{3}$ A

Voltage across 6 Ω and 3 Ω resistors are equal

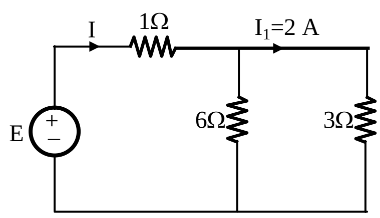
$$V_6 = V_3$$

$I_6 \times 6\Omega = I_3 \times 3\ \Omega$

Current through 3 Ω resistor $I_3 = I_6 \times \frac{6}{3} = \frac{2}{3} \times 2 = \frac{4}{3}$ A

Current through 1 Ω resistor $I_2 = \frac{4}{3} + \frac{2}{3} = 2$ A

Resistance $R_1 = (6 \parallel 3) + 1 = 3\ \Omega$



Current through 6 Ω resistor = 1 A (∵ current division rule)

Total current I = 1 + 2 = 3 A

Equivalent resistance $R = (6 \parallel 3) + 1$

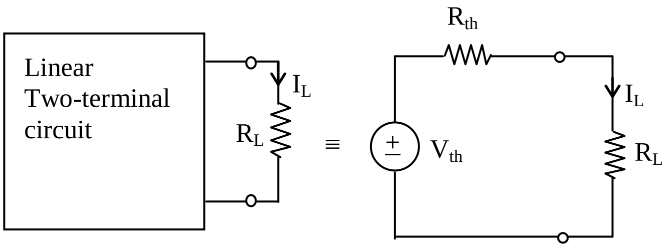
$$= 3\ \Omega$$

Source voltage $E = I \times R = 3 \times 3 = 9$ V

2(c)

Sol: Thevenin's theorem:

Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{th} in series with a resistor R_{th}, where V_{th} is the open circuit voltage at the load terminals and R_{th} is the input or equivalent resistance at the load terminals when the independent sources are turned off. i.e., killed.



V_{th} is found from Fig.1:

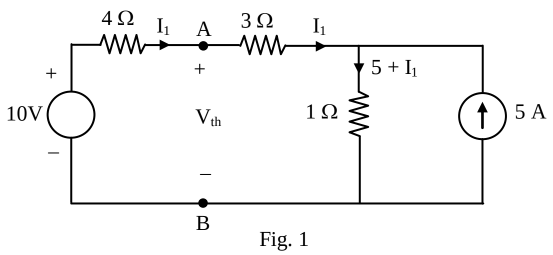


Fig. 1

$-10 + 7I_1 + (5 + I_1) = 0$

Which gives $I_1 = -\dfrac{5}{8}$ A.

$-10 + 4I_1 + V_{th} = 0$

$-10 + 4\times\dfrac{5}{8} + V_{th} = 0$

$V_{th} = 7.5$

R_{th} is found from Fig. 2

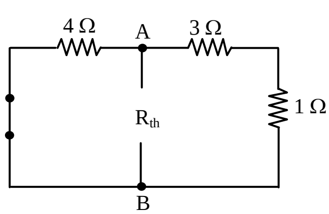


Fig. 2

$$R_{th} = \frac{4\times4}{4+4} = 2\,\Omega$$

The current through the 5.5 Ω is now found from Fig. 3 which shows 5 Ω connected across the terminals of the one-port network.

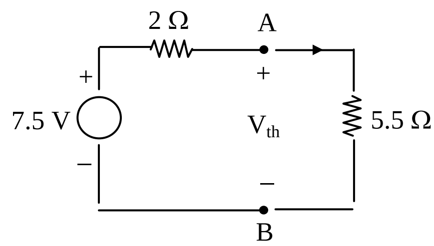


Fig.

$$I = \frac{7.5}{7.5} = 1\text{ A.}$$

2(d)

Sol: Let V_s be the applied voltage giving the current I in the series RLC circuit.

$$I = \frac{V_s}{Z}, \quad \text{where } Z = R + jX,$$

$$X = \omega L - \frac{1}{\omega C}, \; R = 10\ \Omega,\ L = 2\text{ H},\ C = 15\ \mu\text{F}$$

$$\text{Let } \theta = \angle Z = \tan^{-1}\left(\frac{X}{R}\right), \; \tan(\theta) = \frac{X}{R}$$

Let $\phi = \angle I = \angle V_s - \theta$

$\therefore$ Phase lead = $-\theta$ and Phase lag = θ

i) Phase lag = 45°, tan 45° = 1

$\therefore X = R$

$$\omega L - \frac{1}{\omega C} = R$$

$$\Rightarrow \omega^2 LC - 1 = \omega CR$$

$$\Rightarrow \omega^2 LC - \omega CR - 1 = 0$$

$$\text{Given: } \omega^2 - \frac{R}{L}\omega - \frac{1}{LC} = 0$$

$$\frac{R}{L} = \frac{10}{2} = 5 \text{ and}$$

$$\frac{1}{LC} = \frac{1}{2\times 15}\times 10^6 = \frac{10^5}{3}$$

$$\omega = \frac{5 \pm \sqrt{(5)^2 + \frac{4}{3}\times 10^5}}{2}$$

$= 185.09$ rad/sec

Frequency $f = \dfrac{185.09}{2\pi} = 29.458$ Hz.

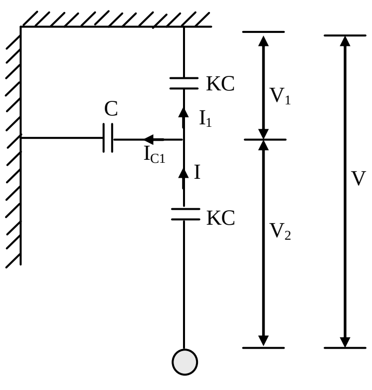
3(a)

Sol: String efficiency: It is a measure of the utilization of material in the string and is defined as

$$\eta = \frac{\text{voltage across the string}}{n \times \text{voltage across the unit near the power conductor}}$$

Let 'V' be the operating voltage and V_1, V_2 are the voltage drops across the units starting from the cross arm towards the power conductor.

$$\therefore V = V_1 + V_2$$



But we know that insulator disc near the power conductor has the maximum voltage across it.

$V_2 = 0.6$ V and $V_1 = 0.4$ V

$$K = \frac{\text{mutual capacitance (KC)}}{\text{capacitance to ground (C)}}$$

From the diagram, $I = I_1 + I_{C1}$

$V_2 K\omega C = V_1 K\omega C + V_1 \omega C$

$V_2 K\omega C = V_1 \omega C(K+1)$

$0.6\ V K\omega C = 0.4\ V\ \omega C\ (K+1)$

$$\frac{6}{4}=\frac{K+1}{K} \Rightarrow K=2$$

The ratio of capacitance of the insulator disc to that of capacitance to earth (K) = 2.

3(b)

Sol: Consider an alternator working at no load, rated voltage with solid neutral. If a solid LLG fault occurs as shown in Fig. (a)

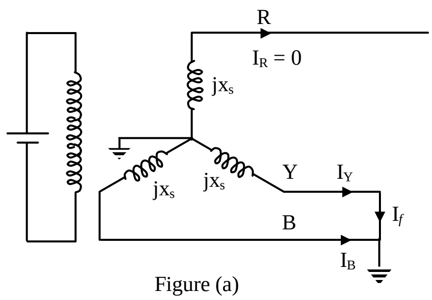


Figure (a)

During fault, Fault current $I_f = I_Y + I_B$

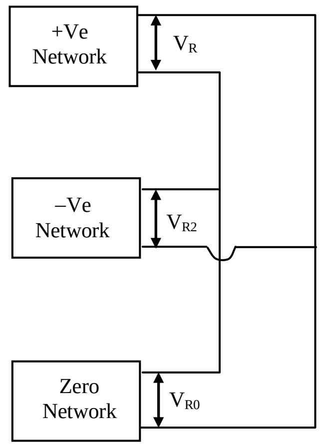
$$I_R = 0,\ V_Y = V_B = 0$$

Use the symmetrical components

$$V_{R0}=\frac{1}{3}\left(V_R+V_Y+V_B\right)=\frac{V_R}{3} \qquad V_{R1}=\frac{1}{3}\left(V_R+KV_Y+K^2V_B\right)=\frac{V_R}{3}$$

$$V_{R2}=\frac{1}{3}\left(V_R+K^2V_Y+KV_B\right)=\frac{V_R}{3} \qquad \therefore V_{R1}=V_{R2}=V_{R0}=\frac{V_R}{3}$$

In double line to ground fault, all the sequence components of voltage are same. Therefore, the positive, negative and zero sequence networks are connected in parallel.



3(c)

Sol: The CTs on the star side of the power transformer are connected in delta, and on the delta side, they are connected in star as the line currents of star-delta power transformer will be displaced in phase by 30^0. It is required that this phase displacement must be nullified by connecting the C.T.S in that fashion.

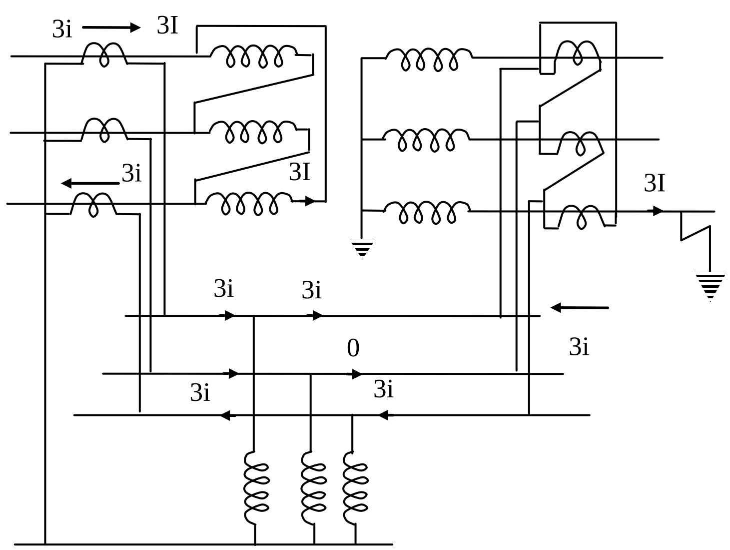


Figure: Delta/star grounded transform protection

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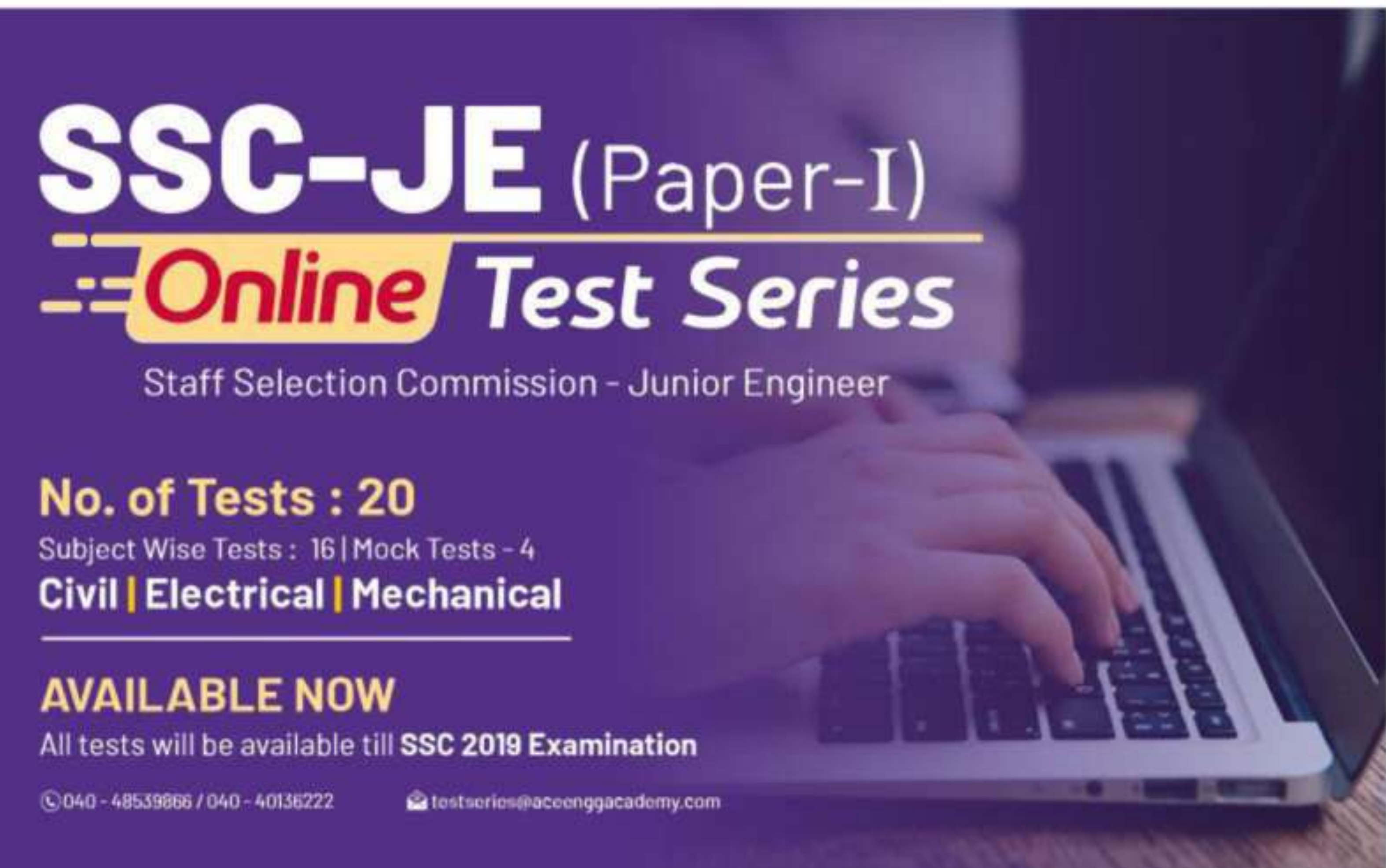

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3(d)

Sol: (i) Symmetrical breaking current: It is the rms value of the ac component of fault current that the circuit breaker is capable of breaking under specified conditions of recovery voltage.

$$I_{\text{symmetrical (rms).}} = \sqrt{\left(\frac{AB}{\sqrt{2}}\right)^2} = \frac{AB}{\sqrt{2}}$$

(ii) Asymmetrical breaking current: It is the rms value of the total current comprising of the both ac and dc components of the fault current that the circuit breaker can break under specified conditions of recovery voltage.

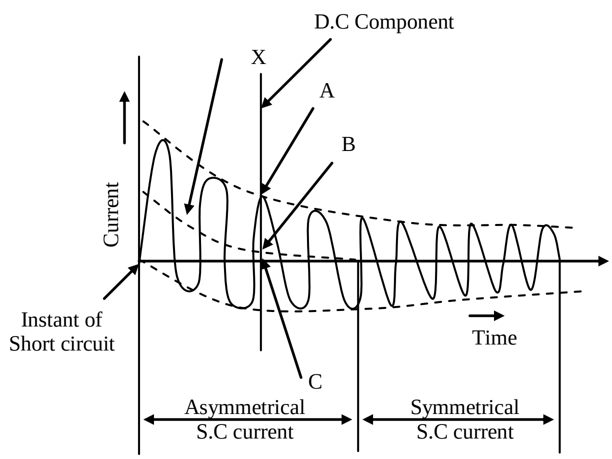


Figure: Short circuit current wave form

$$I_{\text{asymmetrical (rms).}} = \sqrt{\left(\frac{AB}{\sqrt{2}}\right)^2 + (BC)^2}$$

(iii)Rate of rise of Restriking voltage (RRRV): RRRV is expressed in Volts per micro second. The rate at which restriking voltage increases is important in the arc extinction process because the ionization process will depend on the RRRV. If the RRRV is smaller than the rate at which dielectric the arc is extinguished and If the RRRV is greater than the rate at dielectric strength between contacts of circuit breaker, the Arc does not extinguishes.

The average RRRV

$$= \frac{\text{Peak value of restriking voltage}}{\text{Time taken to reach to peak value}}$$

(iv)Making current: It is defined as the peak value of the current (including the dc component) at which a circuit breaker can be closed on to a short circuit. The capacity of a circuit breaker to be closed on to a short circuit depends upon its ability to withstand the effects of electromagnetic forces.

Making current

$$= \sqrt{2} \times 1.8 \times \text{symmetrical breaking current}$$

$$= 2.55 \times \text{Symmetrical breaking current}$$

The multiplication by $\sqrt{2}$ is to obtain the peak value and again by 1.8 to take the dc component in to account.

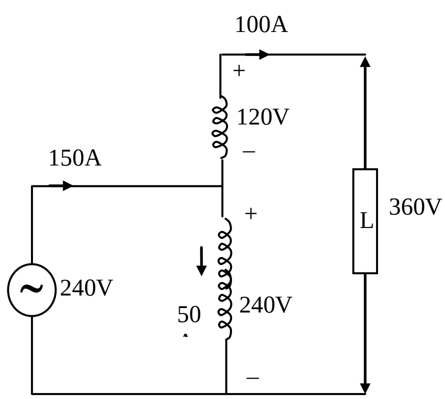
(v) Breaking capacity: The breaking capacity of a circuit breaker is generally expressed in MVA. For a three phase circuit breaker, it is given by

Breaking capacity = $\sqrt{3} \times$ rated voltage in kV$\times$ rated current in kA.

The breaking capacity will be symmetrical if the rated current is symmetrical and the breaking capacity will be Asymmetrical if rated current is asymmetrical.

4(a)

Sol: 240V/120V, 12kVA has rated current of 50 A/100 A. It's connected as an autotransformer as shown in figure.



Auto-transformer rating

$$= 360 \times 100 = 36 \text{ kVA}$$

It is 3-times then 2-winding connection.

As 2-winding connection Output, P_0

$$= 12 \times 1 = 12 \text{ kW}$$

$$\eta = \frac{P_0}{P_0 + P_L} = \frac{1}{1+\frac{P_L}{P_0}} = 0.962$$

From which find full-load loss

$$1 = 0.962 + 0.962\left(\frac{P_L}{P_0}\right)$$

(or) $\frac{P_L}{P_0} = \frac{0.038}{0.962}$; $P_L = 12 \times \frac{0.038}{0.962} = 0.474$ kW

In auto connection full-load loss remains the same. At 0.85 pf

$$P_0 = 36 \times 0.85 = 30.6 \text{ kW}$$

$$\eta = \frac{1}{1+\frac{0.474}{30.6}} = 0.985 \text{ or } 98.5\%$$

4(b)

Sol: Speed Control Methods of IM (Induction Motor):

The speed of Induction Motor is given as $N = \frac{120f}{P(1-s)}$

So obviously the speed of an IM can be controlled by varying any of three factors namely supply frequency, number of poles or slip.

The Main Methods employed for speed control of IM are as follows.

1. Pole changing
2. Stator voltage control
3. Supply frequency control
4. Rotor Resistance control

1. **Pole Changing:**

The number of stator poles can be change by

(i) Multiple stator windings

(ii) Method of consequent poles

(iii) Pole amplitude Modulation (PWM)

The Methods of speed control by pole changing are suitable for cage motors only because the cage Rotor automatically develops number of poles equal to the poles of stator windings.

(i) Multiple stator windings:

In this method the stator is provided with two separate Windings which are wound for two different pole numbers. One winding is energized at a time. This Method is less efficient and more costly, and therefore, Used only when absolutely necessary.

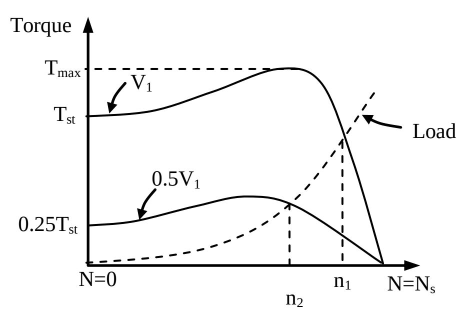
(ii) Method of consequent poles:

In this Method a single stator winding is divided into few coil groups. The terminals of all these groups are brought out. The number of poles can be changed with only simple changes in coil connections. In practice, the stator winding is divided only in two coil groups.

2. **Stator Voltage control:**

The torque developed by an IM is proportional to the square of the applied voltage. The variation of speed torque curves with respect to the applied voltage is shown in figure. These curves show that the slip at maximum torque s_m remains same, while the value of stall torque comes down with decrease in applied voltage.

Further, we also note that the starting torque is also lower at lower voltages. Thus, even if a given voltage level is sufficient for achieving the running torque; the M/c may not start. This method of trying to control the speed is best suited for loads that require very little starting torque, but their torque requirement may increase with speed $T \propto \omega^2$.



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3. Supply frequency Control:

The synchronous speed of an IM is given by $N_s = \frac{120 f_s}{P}$

Therefore, the speed of Motor can be controlled by varying the supply frequency.

The EMF induced in stator of an IM is given by

$$E = 4.44\ k\ \phi_m f_s N_1$$

So, as f_s changes, E_1 will also change to maintain the same air gap flux. If the stator voltage drop is neglected the terminal voltage V_1 is equal to E_1. In order to avoid saturation and to minimize losses, Motor is operated at Rated air gap flux by varying V_1 with frequency so as to maintain (V/f) ratio constant at rated value.

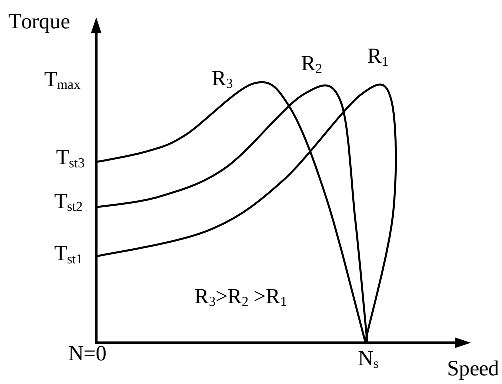
This type of control is known as constant volt per hertz, thus, the speed control of an IM using variable frequency supply requires a variable voltage power source.

4. Rotor Resistance control:

In wound rotor IM, It is possible to change the shape of the torque-speed curve by inserting extra resistance into rotor circuit of the M/C. The resulting T-N characteristic curves as shown in figure.

This method of speed control is very simple. It is possible to have a large starting torque and low starting current at small value of slip.

The Major disadvantage of this method is that the efficiency is low due to additional losses in resistors connected in the rotor circuit. Because of convenience and simplicity, it is often employed when speed is to be reduced for a short period only (ex: cranes)



4(c)

Sol: Reasons:

1. Rotor core losses in single-phase induction motor are more because of the backward rotating field, as compared to those in a 3-phase induction motor.
2. Rotor ohmic loss, because of the double of the double-frequency currents induced by the backward field, is also higher in single-phase motors.
3. For the same load torque, single-phase induction motor requires more stator current and operates at a higher slip. In view of this, single-phase motor has more stator copper losses
4. For the same size, single-phase induction motor output and has more losses because back ward field torque opposes the forward field torque
5. For same size, single phase motor has higher temperature rise and lower efficiency as compared to a poly-phase induction motor
6. The stator winding of a single phase motor carries magnetizing if the ratio of magnetizing current to the active component of stator current is much greater in a single-phase induction motor than the ratio of the same currents in poly-phase induction motor. In view of this single-phase induction motor operates at a poor pf as compared to a poly phase induction motor.
7. For the same power and speed rating, single-phase motor requires larger frame size than a poly phase induction motor. Therefore due to above reasons single phase induction motor has poor performance than poly-phase induction motor.

4(d)

Sol: Terminal voltage, $V = 240\text{ Volts}$

Armature resistance, $R_a = 0.1\text{ohm}$

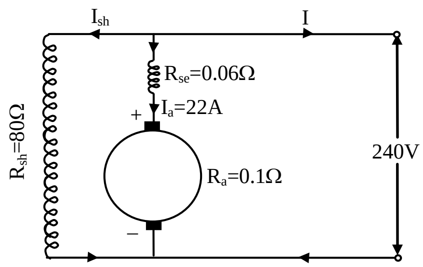
Series field resistance, $R_{se} = 0.06\text{ ohm}$

Shunt field resistance, $R_{sh} = 80\text{ ohms}$

Input line current, $I = 25A$

Stray losses = 610W

Overall efficiency:



Total input to the motor

$$= VI = 240 \times 25 = 6000\ W$$

Shunt field current, $I_{sh} = \frac{V}{R_{sh}} = \frac{240}{80} = 3A$

Series field current, $I_{se} = I_a = I - I_{sh}$

$$= 25 - 3 = 22A$$

Armature copper loss $I_a^2 R_a = 22^2 \times 0.1$

$$= 48.4\ W$$

Series field copper loss $= I_{se}^2 \times R_{se}$

$$= 22^2 \times 0.06 = 29\ W$$

Shunt field copper loss $= VI_{sh}$

$$= 240 \times 3 = 720\ W$$

Stray losses $= 610\ W$

$\therefore$ Total losses $= 48.4 + 29 + 720 + 610$

$$= 1407.4\ W$$

Useful output of the motor = input–losses

$$= 240 \times 25 - 1407.4 = 4592.6\ W$$

Overall efficiency of the motor $= \frac{4592.6}{6000}$

$$= 0.765 = 76.5\%$$

Hence, overall efficiency of the motor

=76.5%.

5(a)

Sol: (i) **Given data:**

$R_{sh} = 0.02\Omega$

$R_{coil} = 1k\Omega$

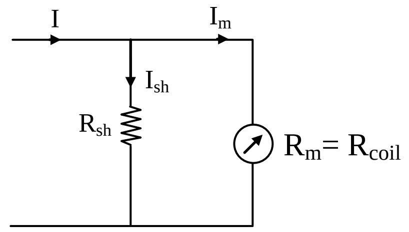


Fig: Ammeter with Shunt resistance

Voltage (Potential difference) = 0.5V

$$I_{sh} = \frac{0.5}{0.02} = 25$$

Current through the meter to give full scale deflection

$$I_m = \frac{0.5}{1000} = 0.5\times10^{-3}\,A$$

$$I = I_{sh} + I_m$$

$$= 25 + 0.5\times10^{-3}$$

$$= 25.0005A$$

ii) $R_{sh} = \dfrac{R_m}{m-1}$

$$m = \frac{I}{I_m}$$

$$I_{sh} = I - I_m = 10 - 0.5\times10^{-3}$$

$$= 9.9995A$$

$$m = \frac{10}{0.5\times10^{-3}} = \frac{10\times10^{3}}{0.5} = 20\times10^{3}$$

$$R_{sh} = \frac{1000}{20\times10^{3} - 1}$$

$$= 0.05\Omega$$

5(b)

Sol: The Kelvin bridge is a modification of the wheat-stone bridge and provides greatly increased accuracy in measurement of low value resistances.

- The Kelvin bridge arrangement may be obtained by a study of the difficulties that arise in a wheat-stone bridge on account of the resistance of the leads and the contact resistances while measuring low valued resistors.

Procedure: The Kelvin double bridge incorporates the idea of a second set of ratio arms-hence the name double bridge and the use of four terminal resistors for the low resistance arms. The first set of ratio arms is P and Q. The second set of ratio arms, p and q is used to connect the galvanometer to a point ‘d’ at the appropriate potential between points ‘m’ and ‘n’ to eliminate the effect of connecting lead of resistance ‘r’ between the known resistance, R and the standard resistance, S. The ratio p/q is made equal to P/Q under balance conditions at which, there is no current through the galvanometer. Which means that the voltage drop between ‘a’ and ‘b’, E_{ab} is equal to the voltage drop E_{amd} between a and c.

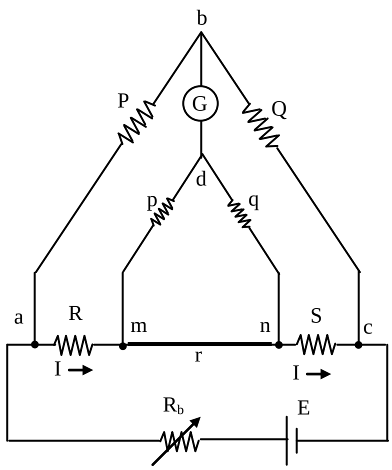


Fig: Kelvin Double bridge

Now $E_{ab} = \frac{P}{P+Q} E_{ac}$

$$E_{ac} = I\left[R + S + \frac{(p+q)r}{p+q+r}\right]$$

$$E_{amd} = I\left[R + \frac{p}{p+q}\left\{\frac{(p+q)r}{p+q+r}\right\}\right]$$

$$= I\left[R + \frac{pr}{p+q+r}\right]$$

For zero galvanometer deflection, $E_{ab} = E_{amd}$

(Or)

$$\frac{P}{P+Q} I\left[R + S + \frac{(p+q)r}{p+q+r}\right] = I\left[R + \frac{pr}{p+q+r}\right]$$

$$R = \frac{P}{Q}S + \frac{qr}{p+q+r}\left[\frac{P}{Q} - \frac{p}{q}\right]$$

Now if $\frac{P}{Q} = \frac{p}{q}$ then, $R = \frac{P}{Q}.S$

Above equation indicates resistance measurement, which is free from lead and contact resistance 'r'

$\therefore$ Accurate measurement will occur.

5(c)

Sol: The count range of $3\frac{1}{2}$ digit DVM is from 0 to 1999, i.e., 2000 counts.

Due to adding $\frac{1}{2}$ digit, the 1V range of this DVM extended to 2V and 10V range extended to 20V.

$$\left.\begin{array}{l}\text{resolution of } 3\frac{1}{2}\text{digit DVM}\\ \text{in 1V range of operation}\end{array}\right\} = \frac{1}{2\times10^3}\times 2V = \frac{2V}{2000\text{ counts}} \;\; \mathbf{= 1\ mV}$$

$$\left.\begin{array}{l}\text{resolution of } 3\frac{1}{2}\text{digit DVM}\\ \text{in 10V range of operation}\end{array}\right\} = \frac{1}{2\times10^3}\times 20V$$

$$= \frac{20V}{2000\text{ counts}} \;\; \mathbf{= 10\ mV}$$

05. (d)

Sol: (i) The phenomena of slow but continuous rotation of the disc when there is no current flowing through the current coil when only pressure coil is energized is called creeping

Causes:

- Main reasons are over voltages and over static friction compensation
- Excessive lubrications, vibrations, stray magnetic field of Instrument.

(ii) The disc revolves continuously in the field of the series magnet under load conditions and, therefore, there is a dynamically induced emf in the disc because of this rotation. This emf causes eddy currents which interact with series magnet, produces a self braking torque which is proportional to the square of the load current. Thus at high values of load current the registration tends to be lower than the actual. As a reason, an over-load compensating device is used, to minimize the self braking action.

6(a)

Sol: To possible series connections of inductors are

Mutually aiding $L_1 + L_2 + 2M = 420\ \mu H$ ………… (1)

Mutually opposing $L_1 + L_2 - 2M = 180\ \mu H$ ……….. (2)

Eq. (1) – (2)

$4M = 240$

$M = 60\ \mu H$

Substitute the value of M in eq. (1)

$L_1 + L_2 = 300\ \mu H$.

Given one of the self inductance $L_1 = 150\ \mu H$

Other self inductance $L_2 = 300 - 150 = 150\ \mu H$

$L_1 = 150\ \mu H$

$L_2 = 150\ \mu H$

$M = 60\ \mu H$

6(b)

Sol: **Magnetic induction (B)** or magnetic flux density is defined as the number magnetic lines of force passing perpendicularly through an unit area. Thus

$$B = \frac{\phi}{A} = \frac{\text{magnetic flux}}{\text{unit area}}$$

Unit : Weber / m^2 or Tesla.

It is also defined as the magnetic force experienced by an unit north pole placed at the given point in a magnetic field.

Thus $B = F / m$

Where F is expressed in Newton and m is defined as the pole strength expressed in ampere - meter.

Magnetic field intensity (H) When a magnetic field is applied to a material it gets magnetized. The actual magnetic field is sum of the applied magnetic field and the field due to magnetization. It is convenient to define a new vector field

$$\vec{H} = \frac{\vec{B}}{\mu_0} - \vec{I}$$

The unit of H is same as that of I that is amp/m.

Thus the three magnetic field vectors are related as $B = \mu_0(M + H)$

Susceptibility: 'χ' per unit volume of the medium is defined as the ratio between intensity of magnetization and applied field strength i.e., $\chi = \frac{M}{H}$. It has no unit.

$$\chi = \frac{\mu_0 \ell}{B}(\text{SI system})$$

Thus the susceptibility of a medium is a measure of magnetization produced in the specimen per unit field strength. When a material has high susceptibility, then it can be easily magnetized.

So a good magnetic material should have high permeability and high susceptibility.

6(c)

Sol: Series combination of C_1 and C_2 is used to find the resultant capacitance.

$d_1 = 6$ mm, $\varepsilon_{r1} = 4$

$d_2 = 8$ mm, $\varepsilon_{r2} = 2$

$A = 400 \times 400\ \text{mm}^2$

$$\frac{1}{C} = \frac{1}{\varepsilon_o\ A}\left[\frac{d_1}{\varepsilon_{r1}} + \frac{d_2}{\varepsilon_{r2}}\right]$$

$$\frac{1}{C} = \frac{36\pi\times10^8}{16}\left[\frac{6}{4} + \frac{8}{2}\right]$$

$$\frac{1}{C} = \frac{36\pi\times10^8}{16}\left[1.5 + 4\right]$$

$$= \frac{36\pi\times10^8}{16}\times 5.5$$

$$C = \frac{16}{36\pi\times10^8\times5.5}\ \text{F}$$

$$= \frac{160}{36\pi\times5.5}\ \text{nF} = 0.257\,\text{nF} = 257\ \text{pF}$$

6(d)

Sol: Data given: A Y – connected alternator

$V_L = 400\text{V}$, f = 50Hz, P = 4

Open circuit test:

V_{oc} = 400 V (rms – line to line) at $I_f = 2.3\text{A}$

Short circuit test: I_{sc} = 10A (rms – phase current) at I_f = 1.5A

The synchronous impedance, $Z_s = \dfrac{\text{O.C. voltage}}{\text{S.C. current}}$

Field current is same both for oc voltage & sc current.

At I_f = 1.5 A $\Rightarrow$ I_{sc} = 10 A

At I_f = 2.3 A $\Rightarrow$ $I_{sc} = \dfrac{10\times2.3}{1.5} = 15.33\text{A}$

$\therefore$ SCC is linear

Synchronous Impedance / phase at rated voltage is

$$Z_s = \frac{E_{oc}}{I_{sc}}$$

I_f is at $E_{oc} = V_{rated}$ i.e., $I_f = 2.3A$

$$\therefore \quad Z_s = \frac{400/\sqrt{3}}{15.33} = 15\,\Omega$$

6(e)

Sol: Arc heating:

- The arc drawn between two electrodes developed high temperature (about 3000 to 3500 °C) depending upon material of the electrode.
- The electric arc may used in the following different ways:

  (i) By striking the arc between the charge and electrode or electrodes. In this method heat is directly conducted and taken by the charge.

  – The furnaces operating on this principle are known as direct arc furnaces.

  (ii) By striking the arc between the two electrodes. In this method the heat is transferred to the charge by radiation.

  – The furnaces operating on this principle are known as indirect arc furnaces.

  (iii) By striking an arc between an electrode and the two metallic pieces to be joined, as in arc welding.

Direct induction heating:

In this method of heating the current is induced by electromagnetic action in the body to be heated. This induced current when flowing through the resistance of the body to be heated develop the heat and thus raise the temperature

- In induction furnace heat is used to melt the charge.
- Eddy current heaters are employed for heat treatment of metals.

Indirect induction heat:

In this heating method the eddy currents are induced in the heating element by electromagnetic induction. Eddy currents setups in the heating elements produce the heat which is transferred to the body to be heated, by radiation and convection.

- This principle is employed in certain ovens which are employed for heat treatment of metals.