Test ID:- E15

ZONE TECH

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OFFLINE & ONLINE TEST SERIES

SOLUTIONS

ELECTRICAL ENGINEERING : PAPER-1

Full Length Test -15

Exam Date :- 01 March 2026

2 Marks

Q.1

Sol. Magnetic susceptibility (x) measures the degree of magnetization (M) of a material in response to an applied magnetic field intensity (H). It is defined as x = M/H. It indicates whether a material is diamagnetic, paramagnetic, or ferromagnetic based on its value.

Q.2

Sol. Ferromagnetism is a phenomenon where materials get strongly magnetized in the direction of an applied magnetic field due to aligned magnetic moments of domains. Ferromagnetic materials have high retentivity and coercivity, making them suitable for permanent magnets.

Examples: iron, cobalt, nickel.

Q.3

Sol. The intrinsic impedance (η) of a dielectric is given by:

$$\eta = \sqrt{\frac{\mu}{\epsilon}}$$

where, μ = permeability,

ϵ = permittivity of the medium. For free space,

$\eta_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} \approx 377\Omega$ It quantifies the ratio of electric to magnetic field strengths in a plane electromagnetic wave in the medium.

Q.4

Sol. The magnetic field intensity at any point in the magnetic field is defined as the force experienced by a unit north pole of one weber strength, when placed at that point. Magnetic field intensity is measured in newtons/weber (N/Wb) or amperes per metre (A/m) or ampere-tums/metre (AT/m). It is denoted as $\overline{H}$.

Q.5

Sol. The current will be interrupted before its natural zero is known as current chopping in such a situation the energy stored in magnitude field will appear in form or electrostatic energy

$$\frac{1}{2}LI^2 = \frac{1}{2}CV^2$$

$$v = i\sqrt{\frac{L}{C}}$$

Current chopping phenomena mainly occur in air blast circuit breaker (ABCB), vacuum circuit breaker (VCB)

Q.6

Sol. It is used in medium and high head plant. In case of sudden load thrown off water hammering effect occur inside the penstock due to sudden closing of control value. This may damage the penstock, to protect the penstock from water hammering surge tank is used. In case of sudden load demand addition water in the surge tank is used to meet the load demand.

Q.7

Sol. Generally symmetrical fault is serious but in case of fault at generator side the L-G fault is more severe for generator

Q.8

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

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

Q.9

Sol.

$$C_{AB} = \frac{\pi \in}{\ell n \dfrac{d}{r\sqrt{1+\left(\dfrac{d}{2h}\right)^2}}}$$

Earth consisting of infinite no. of positive and negative charge carrier. These charge carrier interact with the charge of the transmission line conductor. Due to this effect the capacitance between conductor increases which causes increases in the charging current. Which produces more reactive power one these disturb the voltage profile of transmission line. To reduce this effect height of the tower is increased as the voltage level of transmission line is increased.

$$h >> d \qquad C_{AB} = \frac{\pi \in}{\ell n(d/r)}$$

If height is increases, then effect of earth is neglected.

Q.10

Sol. In short circuit test the low voltage side is short circuited and we take measurements on the HV side due to the following reasons :

1. The rated current on HV side is lower than that of LV side. This current can be safely measured with the available laboratory ammeters.

2. Since, the applied voltage is less than 5% of the rated voltage of the winding greater accuracy in the reading of the voltmeter is possible when the HV side is used as the primary.

Q.11

Sol. Induction motor device is called generalized transformer.

Difference is that transformer is an alternating flux machine while induction motor is rotating flux machine. In transformer the flux produced is time alternating and not rotating.

Q.12

Sol. $i(t) = 5\delta(t)$

Voltage across capacitor,

$$V_c = \frac{1}{C}\int_{-\infty}^{\infty} i(t)\,dt = \frac{1}{C}\int_{-\infty}^{\infty} 5\delta(t)\,dt$$

$$V_c = \frac{5}{C}\int_{-\infty}^{\infty} \delta(t)\,dt \qquad \left\{\because \int_{-\infty}^{\infty} \delta(t)\,dt = u(t)\right\}$$

$$V_c = \frac{5}{C}u(t)$$

Thus, the voltage across the capacitor will be $\frac{5}{C}u(t)$.

Q.13

Sol. Time constant of RC circuit, $\tau = RC$

$$C_{eq} = 1\ F \| 1\ F \text{ and connected with series}$$

$$C_{eq} = 2\ F \| 1\ F = \frac{2}{3} F$$

$$R_{eq} = 3 + 3 = 6\ \Omega$$

$$\tau = R_{eq} \times C_{eq} = \frac{2}{3} \times 6 = 4 \text{ sec}$$

Q.14

Sol. At $t = \infty$, then $s = 0$

Apply final value theorem at $F(s)$,

$$\lim_{s \to 0} sF(s) = \lim_{t \to \infty} f(t) = \frac{1}{2}$$

$$\lim_{s \to 0} \frac{s2(s+1)}{s(s+a)} = \frac{1}{2}$$

$$\frac{2(0+1)}{0+a} = \frac{1}{2}$$

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

$$a = 4$$

Q.15

Sol. Reluctance (S) $= \frac{l_1}{\mu_0 A_1}$

Where, $l_1 =$ Length, $l_2 = 0.5 l_1$, $A_2 = 1.5 A_1$

$A_1 =$ Area

$$\frac{S_1}{S_2} = \frac{\frac{l_1}{\mu_0 A_1}}{\frac{l_2}{\mu_0 A_2}} = \frac{\frac{l_1}{\mu_0 A_1}}{\frac{0.5 l_1}{\mu_0 1.5 A_1}} = 3$$

$$S_2 = \frac{S_1}{3} = \frac{2000}{3} = 666.67 \text{ AT/Wb}$$

Q.16

Sol. When C open $R_A + R_B = 6$ ...(i)

When A open $R_B + R_C = 11$ ...(ii)

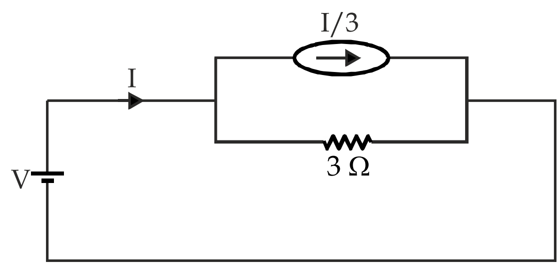
When B open $R_A + R_C = 9$ ...(iii)

Solving equation (i), (ii) and (iii),

$R_A = 2$ ohm, $R_B = 4$ ohm and $R_C = 7$ ohm

Q.17

Sol.



Current through 3Ω resistor $= I - \frac{I}{3} = \frac{2I}{3}$

Since both parameter are connected in parallel so, from figure,

$$V = \frac{2I}{3} \times 3$$

$$\frac{V}{I} = 2\Omega$$

$$R_{eq} = 2\Omega$$

Q.18

Sol. Maximum torque occurs at a slip

Rotor resistance $R_2 = 6\Omega$

Maximum torque occurs at slip, $s_m = \frac{R_2}{X_2}$

$$0.6 = \frac{6}{X_2}$$

Rotor reactance, $X_2 = \frac{60}{6} = 10\Omega$

At standstill condition s = 1

Standstill rotor reactance, $X_1 = \frac{X_2}{s} = \frac{10}{1} = 10\Omega$

Q.19

Sol. The speed of synchronous speed of stator is always greater than rotor speed in induction motor-Hence. Synchronous speed N_s = 600 rpm

Synchronous speed, $N_s = \frac{120f}{P}$

Number of poles, $P = \frac{120f}{N_s} = \frac{120 \times 50}{600} = 10$

Q.20

Sol. Fractional pitch angle $= \frac{4}{5} \times 180^0 = 144^0$

Chording angle $\alpha = 180^0 - 144 = 36^0$

Now, to remove n^{th} harmonic, $\cos\frac{n\alpha}{2} = 0$

$\therefore \quad \frac{n\alpha}{2} = 90^0$

$\therefore \quad \frac{n\,36}{2} = 90^0$

$\therefore \quad n = \frac{90 \times 2}{36} = 5$

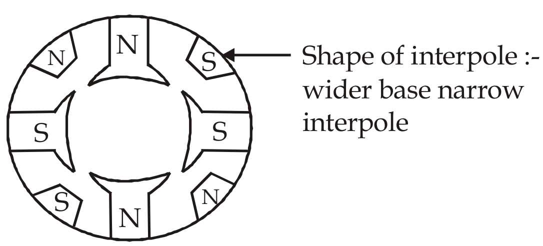
$\therefore$ 5th Harmonic emf is removed.

5 Marks

Q.21

Sol. 1. **Resistance Commutation:-** If the contact resistance between brush and commutator is made large than the current divided in the inverse ratio of contact resistance which improve commutation. This can be achieved by using carbon brushes which has high contact resistance. This method does not effect the reactance voltage (main cause of sparking) but it only help in improving commutaiton.
Time constant= L/R
If the resistance of coil increases then time taken in commutation decreases

2. **EMF Commutation :-** In EMF commutation the reactance voltage is neutralize by producing a reversal voltage or commutating voltage in the coil undergoing commutation. This can be achieved by using interpoles. These are the small pole fixed to the yoke and place between the main pole. The interpole winding is bound for few turn and connected in series with the armature. So that it carry the armature current.The polarity of interpole is same as the next main pole in the direction of rotation for the generator and visa-versa for motor.



Q.22

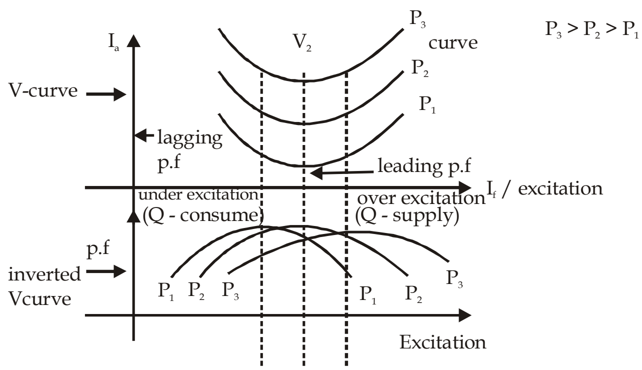
Sol. V- Curve shows the Effect of excitation on armature current for constant power output.
Inverted V- Curve shows the Effect of excitation on power factor for constant power output.
P = constant V = constant

$\frac{EV}{X}\sin\delta = \text{const}$

$E\sin\delta = \text{const}$

$VI_a\cos\theta = \text{constant}$

$I_a\cos\theta = \text{constant}$

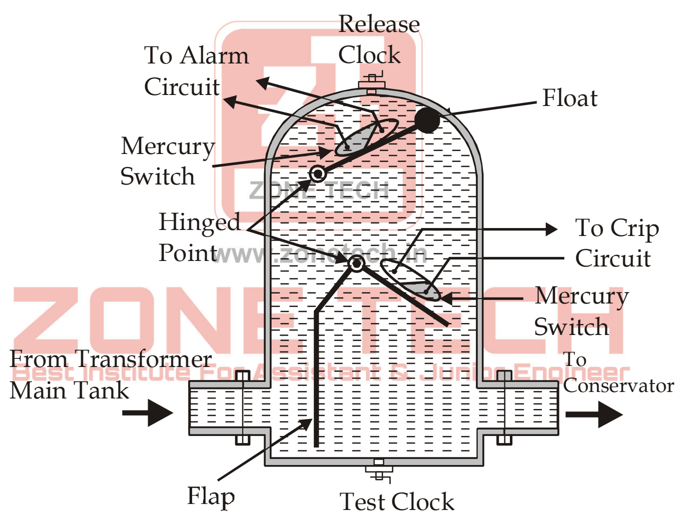


Q.23

Sol. It is a gas actuated relay

It is usually installed in the pipe connected between conservator and the main T/F tank.

It is used for oil immerged T/F of rating more than 750 kVA



The upper element consist of a mercury type switch attach to a float

The lower element consist of a mercury switch mounted on a flap located in the direct path of the flow of oil is a serious fault occur in the transformer gas is generated.

When a fault take place in T/F. The oil as the tank get overheated ad gases are formed. The generation of gases is depending upon the fault is or the major (heavy short CKT)

Q.24

Sol- Transformer connection $Y - \Delta$

$$\text{VA rating } S = 25\text{kVA}$$

$$\text{Turns ratio } \frac{N_1}{N_2} = 5$$

$$\text{Line voltage of primary side, } V_{L1} = 3.3\text{kV}$$

$$\text{Phase voltage of primary side, } V_{ph1} = \frac{V_{L1}}{\sqrt{3}} = \frac{3.3}{\sqrt{3}}\text{ kV}$$

Secondary phase voltage,

$$V_{ph2} = V_{ph1} \times \frac{N_2}{N_1} = \frac{3.3}{\sqrt{3}} \times \frac{1}{5} = \frac{0.66}{\sqrt{3}} \text{ kV}$$

Secondary line voltage $V_{L2} = V_{ph2} = \frac{0.66}{\sqrt{3}}$ kV

Power $S = \sqrt{3} V_{L2} I_{L2}$

Primary line current,

$$I_{L2} = \frac{S}{\sqrt{3} V_{L2}} = \frac{25 \times 10^3 \times \sqrt{3}}{\sqrt{3} \times 0.66 \times 10^3} = 37.87 A$$

Q.25

Sol.

$$T(s) = \frac{s+1}{(s+1)^2 + 1} \quad R(t) = u(t)$$

$$\frac{C(s)}{R(s)} = \frac{s+1}{(s+1)^2 + 1} \quad R(s) = 1/s$$

$$C(s) = R(s) \frac{(s+1)}{(s+1)^2 + 1}$$

Steady state value

$$\lim_{t \to \infty} c(t) = \lim_{s \to 0} sC(s)$$

$$= \lim_{s \to 0} \frac{s}{s} \frac{(s+1)}{\left[(s+1)^2 + 1)\right]}$$

$$= 0.5$$

Q.26

Sol.

$$Z(s) = \frac{(s+2)(s+4)}{(s+1)(s+3)} = \frac{s^2 + 6s + 8}{s^2 + 4s + 3}$$

$$M_1 = s^2 + 8, \; N_1 = 6s$$

$$M_2 = s^2 + 3, \; N_2 = 4s$$

$$M_1 M_2 - N_1 N_2 \geq \; = 0$$

$$(s^2 + 8)(s^2 + 3) - 6s4s \geq 0$$

$$s^4 - 13s^2 + 24 \geq 0$$

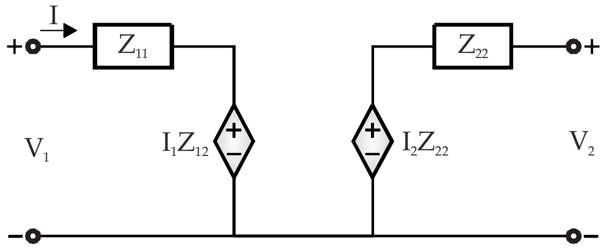
$$\omega^4 + 13\omega^2 + 24 \geq 0$$

Z(s) positive real.

Q.27

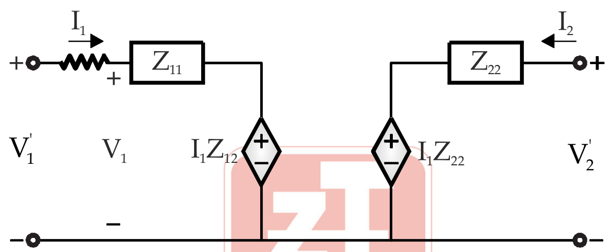
Sol.

Z-parameter



$$V_1 = Z_{11}I_1 + Z_{12}I_2$$

$$V_2 = Z_{21}I_1 + Z_{22}I_2$$



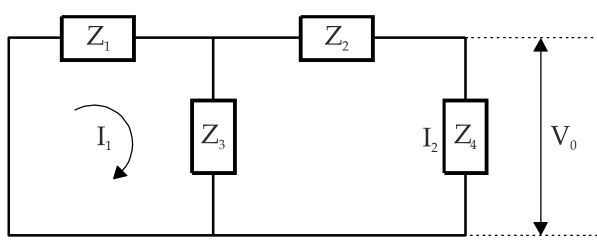
$$V_1 = (1 + Z_{11})I_1 + Z_{12}I_2$$

$$V_2 = Z_{21}I_1 + Z_{22}I_2$$

$$\therefore \quad Z_{\text{modified}} = \begin{bmatrix} Z_{11}+1 & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

Q.28

Sol. Given network



Applying KVL in loop (I)

$$V_1 = Z_1I_1 + Z_3I_1 - Z_3I_2$$

$$V_1 = (Z_1 + Z_3)I_1 - Z_3I_2$$

If $I_2 = 0$

$$\left.\frac{I_1}{V_1}\right|_{I_2=0} = \frac{1}{Z_1 + Z_3} \quad \ldots\text{(i)}$$

If $V_1 = 0$

$$\frac{I_1}{I_2} = \frac{Z_3}{(Z_1 + Z_3)} \quad \ldots\text{(ii)}$$

Applying KVL in loop (ii)

$$Z_4I_2 + Z_2I_2 + Z_3I_2 - Z_3I_1 = 0$$

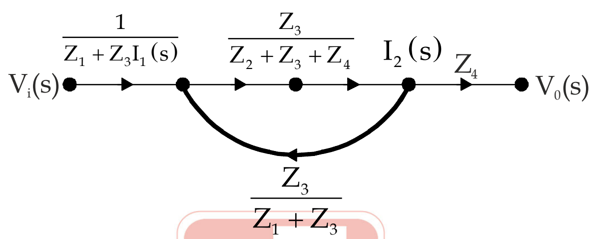
$$I_2(Z_2 + Z_3 + Z_4) - Z_3 I_1 = 0$$

$$\frac{I_2}{I_1} = \frac{Z_3}{(Z_2 + Z_3) + Z_4} \quad \ldots(iii)$$

$$V_0 = I_2 Z_4$$

$$\frac{V_0}{I_2} = Z_4 \quad \ldots(iv)$$

By equation (i), (ii), (iii) and (iv) signal flow graph for the system is



Q.29

Sol. Output power $P_0 = 100\,kW$,

Terminal voltage $V_t = 230\,V$

Armature resistance $R_a = 0.05\ \Omega$

Shunt field resistance $R_{sh} = 57.5\ \Omega$

Load current $I_L = \frac{P_0}{V_t} = \frac{100 \times 10^3}{230} = 434.78\ A$

Shunt field current $I_{sh} = \frac{V_t}{R_{sh}} = \frac{230}{57.5} = 4\ A$

Armature current $I_a = I_L + I_{sh} = 4 + 434.78$

$$I_a = 438.18\ A$$

Generated emf, $E_g = V_t + I_a R_a$

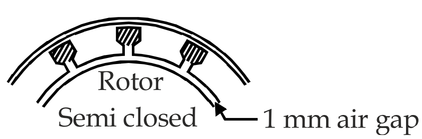
For half load $E_g = V_t + \frac{I_a}{2} \times R_a$

$$E_g = 230 + \frac{438.18}{2} \times 0.05 = 230 + 10.95$$

$$E_g = 240.95\ V$$

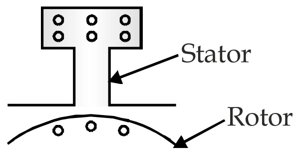
Q.30

Sol. **Semi-closed slots :**The representation of semi closed type slots is shown in figure.



Advantages :

(i) The average air gap length between stator and rotor is less as shown below figure.



(ii) Flux distribution is uniform and harmonics are less.

(iii) The operation of motor is smooth.

Due to above advantages Semi-closed slots generally used in induction motors.

Q.31

Sol. $A = D = 0.94\angle 1^0$, $B = 130\ \angle 73^0$, $C = 0.001\ \angle 90^0$

Sending end voltage, $V_s = 240\,kV$

Full load receiving end voltage is $(V_R)_{FL} = 220\,kV$

$$V_s = AV_R + BI_R \qquad \ldots(i)$$

At no load $I_R = 0$

So, from equation (i),

$$V_{R(NL)} = \frac{V_s}{A}$$

Percentage voltage regulation is given by,

$$\%\ V.R. = \frac{(V_R)_{NL} - (V_R)_{FL}}{(V_R)_{FL}} \times 100\%$$

Both in line or in phase

$$\%\ V.R. = \frac{\frac{V_s}{A} - V_R}{V_R} \times 100\%$$

$$\%\ V.R. = \frac{\frac{240}{0.94} - 220}{220} \times 100 = 16.05\ \%$$

Q.32

Sol. Three phase factory load :

$V_b = 11\,kV$, $P = 100\,kW$,

$\cos\phi_1 = 0.7$ lag, $\cos\phi_2 = 0.95$ lag.

Reactive power supplied by capacitor is given by,

$$Q_C = P(\tan\phi_1 - \tan\phi_2)$$

$$\phi_1 = \cos^{-1} 0.7 = 45.57^0$$

$$\phi_2 = \cos^{-1}(0.95) = 18.19^0$$

Hence,

$$Q_C = 100\left[\tan 45.57^0 - \tan 18.19^0\right]$$

$$Q_C = 100 \times 0.6915$$

$$Q_C = 69.15\ kVAR$$

Hence, the reactive power supplied (rating) by the capacitor is **69.15 kVAR**.

20 Marks

Q.33

Sol. **Comparison between Synchronous and Induction Motors**:

1. For a given frequency, the synchronous motor runs at a constant average speed whatever the load, while the speed of an induction motor falls some what with increase in load.
2. The synchronous motor can be operated over a wide range of power factors, both lagging and leading, but induction motor always runs with a lagging p.f. which may become very low at light loads.
3. A synchronous motor is inherently not self-starting.
4. The changes in applied voltage do not affect synchronous motor torque as much as they affect the induction motor torque. The breakdown torque of a synchronous motor varies approximately as the first power of applied voltage whereas that of an induction motor depends on the square of this voltage.
5. A d.c. excitation is required by synchronous motor but not by induction motor.
6. Synchronous motors are usually more costly and complicated than induction motors, but they are particularly attractive for low-speed drives (below 300 r.p.m.) because their power factor can always be adjusted to 1.0 and their efficiency is high. However, induction motors are excellent for speeds above 600 r.p.m.
7. Synchronous motors can be run at ultra-low speeds by using high power electronic converters which generate very low frequencies. Such motors of 10 MW range are used for driving crushers, rotary kilns and variable-speed ball mills etc.

Synchronous Motor Applications:

Synchronous motors find extensive application for the following classes of service:

1. Power factor correction
2. Constant-speed, constant-load drives
3. Voltage regulation

(a) Power factor correction

Overexcited synchronous motors having leading power factor are widely used for improving power factor of those power systems which employ a large number of induction motors figure and other devices having lagging p.f. such as welders and flourescent lights etc.

(b) Constant-speed applications

Because of their high efficiency and high-speed, synchronous motors (above 600 r.p.m.) are well-suited for loads where constant speed is required such as centrifugal pumps, belt-driven reciprocating compressors, blowers, line shafts, rubber and paper mills etc.

Low-speed synchronous motors (below 600 r.p.m.) are used for driver such as centrifugal and screw-type pumps, ball and tube mills, vacuum pumps, clippers and metal rolling mills etc.

(c) Voltage regulation

The voltage at the end of a long transmission line varies greatly especially when large inductive loads are present. When an inductive load is disconnected suddenly, voltage tends to rise considerably above its normal value because of the line capacitance. By installing a synchronous motor with a field regulator (for varying its excitation), this voltage rise can be controlled.

When line voltage decreases due to inductive load, motor excitation is increased, thereby raising its p.f. which compensates for the line drop. If, on the other hand, line voltage rises due to line capacitive effect, motor excitation is decreased, thereby making its p.f. lagging which helps to maintain the line voltage at its normal value.

Q.34

Sol. Short-circuit test is conducted on hv side i.e.. delta side.

Hence

$$V_{phase} = V_{l-l} = 300 \text{ V}$$

$$I_{phase} = \frac{I_{l-l}}{\sqrt{3}} = \frac{131.21}{\sqrt{3}} = 75.75 Amp$$

Copper loss/phase $= \frac{30}{3} = 10 kW$

Hence $I^2_{phase} R_\Delta = 10 \times 10^3$

$$R_\Delta = \frac{10 \times 10^3}{75.75^2} = 1.74\Omega$$

$$Z_\Delta = \frac{V_{phase}}{I_{phase}} = \frac{300}{75.75} = 3.96\Omega$$

$$X_\Delta = \sqrt{Z_\Delta^2 - R_\Delta^2} = \sqrt{3.96^2 - 1.74^2} = 3.55\Omega$$

Converting R_Δ, X_Δ into equiavalent star R_Y, X_y,

$$R_Y = \frac{R_\Delta}{3} = \frac{1.74}{3} = 0.58\Omega;\ X_y = \frac{3.58}{3} = 1.18$$

$$Z_{Base} = \left(\frac{(kV_B)^2}{MVA_B}\right) = \frac{6.6^2}{1.5} = 29.04\Omega$$

Percentage resistance drop $= \in_r$

$$= \frac{R_Y}{Z_{Base}} = \frac{0.58}{29.04} = 0.0199 pu$$

$$\in_r = 1.99\%$$

Percentage reactance drop $= \in_x$

$$= \frac{X_Y}{Z_{Base}} = \frac{1.18}{29.04} = 0.0406 pu$$

$$\in_x = 4.06\%$$

$$\cos\phi = 0.8 \text{ lagging}$$

$$\sin\phi = 0.6$$

Percentage voltage regulation

$$= (\in_r \cos\phi + \in_x \sin\phi) \times 100$$

$$= (0.0199 \times 0.8 + 0.0406 \times 0.6) \times 100$$

$$= 4.028\%$$

losses = copper loss + iron loss

$$= 30 + 25 = 55 \text{ kW}$$

$$\text{efficiency} = \frac{output}{output + losses} \times 100 = \frac{1500 \times 0.8}{1500 \times 0.8 + 55} \times 100 = 95.61\%$$

Q.35

Sol. The transient stability refers to the maximum flow of power possible through a point without losing the stability with sudden and large changes in the network conditions which can occur due to faults, by sudden large increment of loads etc.

When synchronous machines are operated along with fast acting voltage regulator, the stability limits of the system are higher than when rather slow acting regulator are used. Dynamic stability also corresponds to slow changes in load as in the case of steady state stability but the main difference between the two is that dynamic stability is made possible by the action of fast acting voltage regulators which are capable of changing the flux at a faster rate than caused by the system in falling out of step, whereas in steady state stability the assumption is that, the regulator acts slowly in order to adjust the terminal voltage to the prescribed value.

Recent means for maintaining and improving transient stability is given below:

(i) HVDC links: A DC link is asynchronous i.e. the two AC system at either end do not have to be controlled in phase or even be at exactly the same frequency as they do for an AC link and the power transmitted can be readily controlled. There is no risk of a fault on one system causing loss of stability in the other system.

(ii) Braking Resistors : For improving stability where clearing is delayed or large load is suddenly lost, a resistive load called a braking resistor is connected at or near the generator bus. This load compensates for at least some of the reduction of load on the generators and hence reduces the acceleration.

(iii) Turbine fast valving or Bypass valving: The mechanical input power to turbine by the help of fast valving is one other way of improving stability. Here the difference between mechanical input and reduced electrical output of a generator under a fault, as sensed by a control scheme initiates the closing of a turbine valve to reduce the power input.

Q.36

Sol.
- The Foster forms are obtained by partial fraction expansion of a given driving point impedance function F(s) and the Cauer forms by continued fraction expansion of F(s)
- The Foster first form deals with the driving point impedance function and the second form deals with the admittance function
- The Cauer first form is obtained by expending the given function in continued fraction about infinity and the second form is obtained by expanding the given function into a continued fraction about origin

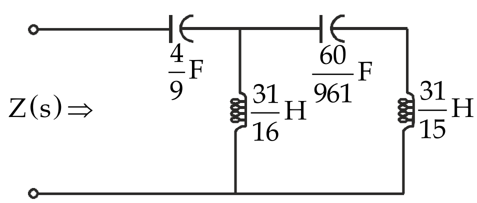
$$Z(s) = \frac{s^4 + 10s^2 + 9}{s^3 + 4s}$$

Causer second form of realisation can be obtained by continued fraction expansion of Z(s) till all the terms are exhausted after arranging numerators and denominator polynomial of Z(s) in ascending order of 's' as

$$Z(s) = \frac{9 + 10s^2 + s^4}{4s + s^3}$$

$$4s+s^3 \,\big)\, 9+10s^2+s^4 \,\big(\, \frac{9}{4s} \rightarrow Z$$
$$9+\frac{9}{4}s^2$$
$$\frac{31}{4}s^2+s^4 \,\big)\, 4s+s^3 \,\big(\, \frac{16}{31s} \rightarrow Y$$
$$4s+\frac{16}{31}s^3$$
$$\frac{15}{31}s^3 \,\big)\, \frac{31}{4}s^2+s^4 \,\big(\, \frac{961}{60s} \rightarrow Z$$
$$\frac{31}{4}s^2$$
$$s^4 \,\big)\, \frac{15}{31}s^3 \,\big(\, \frac{15}{31s} \rightarrow Y$$
$$\frac{15}{31}s^3$$
$$\times$$

$$Z(s)=\frac{9}{4s}+\cfrac{1}{\frac{16}{31s}+\cfrac{1}{961+\cfrac{1}{\frac{15}{31s}}}}$$



Q.37

Sol. Grading of a cable is the process of achieving uniform electrostatic stress in the dielectric of cable.This is achieved by making potential gradient equal throughout the dielectric layer.It can be done in two ways

(i) capacitance grading

(ii) Inter sheath grading.

Due to the Grading of cable Uniform stress in dielectric and there is Reduction in quantity of insulation.

$$V_r = 6.6 \text{ kV},$$

$$d = 1.5 \text{ cm}, \; r=\frac{d}{2}=0.75\,\text{cm},$$

$$D = 3\,\text{cm}, \; R=\frac{D}{2}=1.5\,\text{cm},$$

$$\rho = 1.3 \times 10^{12}\ \Omega - m,$$

$$\varepsilon_r = 3.5$$

Line length, $l = 4\,km$

(a) Insulation resistance is given by,

$$R_{ins} = \frac{\rho}{2\pi l} \ln\frac{R}{r}$$

$$R_{ins} = \frac{1.3 \times 10^{12}}{2\pi \times 4 \times 10^3} \times \ln\left(\frac{1.5}{0.75}\right)$$

$$R_{ins} = 3.585 \times 10^7 = 35.85\ M\Omega$$

Hence, the insulation resistance is $35.85\ M\Omega$.

(b) Capacitance of cable is given by,

$$C = \frac{2\pi\varepsilon_0\varepsilon_r}{\ln\frac{R}{r}} = \frac{2\pi \times 8.854 \times 10^{-12} \times 3.5}{\ln\frac{1.5}{0.75}}$$

$$C = 280.9 \times 10^{-12}\ F/m$$

Total capacitance is given by,

$$C_T = C \times l = 280.9 \times 10^{-12} \times 4 \times 10^3$$

$$C_T = 1.123 \times 10^{-6} = 1.123\,\mu F$$

Hence, the capacitance is $1.123\ \mu F$.

(c) Maximum electric stress is given by,

$$g = \frac{V}{r\ln\left(\frac{R}{r}\right)} = \frac{\frac{6.6 \times 10^3}{\sqrt{3}}}{0.75 \times 10^{-2} \times \ln\left(\frac{1.5}{0.75}\right)}$$

$$g = 7.329 \times 10^5\ V/m = 732.9\ kV/m$$

Hence, the maximum electric stress in the insulation is **732.9 kV/m**.