PAGE : 1   NAME : AZHAD NIAZ   ID : 15493

Electrical Transmission System   Sessional Assignment
Total Marks=20

Question No 1: A 3-phase, 50-Hz overhead transmission line 100 km long has the following constants:

Resistance/km/phase = 0.1 Ω

Inductive reactance/km/phase = 0·2 Ω

Capacitive Susceptance/km/phase = 0·04 × 10^{-4} siemen

Determine (i) the sending end current (ii) sending end voltage (iii) sending end power factor and (iv) transmission efficiency when supplying a balanced load of 10,000 kW at 66 kV, p.f. 0·8 lagging. Use nominal T method.

Question No 2: A (medium) single phase transmission line 100 km long has the following constants:

Resistance/km = 0·25 Ω ; Reactance/km = 0·8 Ω

Susceptance/km = 14 × 10−6 siemen; Receiving end line voltage = 66,000 V

Assuming that the total capacitance of the line is localised at the receiving end alone, determine

(i) The sending end current (ii) The sending end voltage (iii) Regulation and (iv) supply power factor. The line is delivering 15,000 kW at 0.8 power factor lagging. Draw the phasor diagram to illustrate your calculations.

Question No 3: Describe Ferranti Effect, Why Ferranti effect occurs? Detail explanation of the Ferranti effect by considering a nominal pi (π) model. How to reduce Ferranti effect.

PAGE : 2

Question No 1: A 3-phase, 50-Hz overhead transmission line 100 km long has the following constants:

Resistance/km/phase = 0.1 Ω

Inductive reactance/km/phase = 0·2 Ω

Capacitive Susceptance/km/phase = 0·04 × 10^{-4} siemen

Determine (i) the sending end current (ii) sending end voltage (iii) sending end power factor and (iv) transmission efficiency when supplying a balanced load of 10,000 kW at 66 kV, p.f. 0·8 lagging. Use nominal T method.

SOLUTION:

Total resistance/phase= $0·1 \times 100 = 10$

ΩTotal reactance/phase.$XL= 0·2 \times 100 = 20$

Capacitive susceptance, $Y= 0·04 \times 10^{-4} \times 100 = 4 \times 10^{-4}$S

Receiving end voltage/phase, $VR= 66,000/\sqrt{3} = 38105$ V

Load current, $IR = \dfrac{10\,000 \times 10^{3},}{\sqrt{3} \times 66 \times 10^{3} \times 0.8} = 109$A

$\cos\theta R = 0·8; \sin\theta R = 0·6$

Impedance per phase, $\vec{Z}=R+ j\, XL= 10 + j20$

   (i)   Taking receiving end voltage as the reference phase
        We have,
        Receiving end voltage, $\vec{VR}=VR+ j0 = 38,105$ V

        Load current, $\overset{\leftarrow}{IR} = \vec{IR}$ (cos θR-j sin θR) $= 109$ (0·8 -j0·6) $= 87·2$ -j65·4

        Voltage across C, $\vec{V1} = \vec{Vr} + \vec{Ir}\; \vec{Z/2} = 38, 105 + (87·2$ -$j65·4)$ $(5 +j10)=38,105 + 436 + j872 -j327 + 654 = 39,195 + j545$

        Charging current, $\vec{IC} = j\, Y \vec{V_1}$ 14×10^{-4} (39,195+ j 545) -0.218 + j15.6

Sending end current, $\vec{IS} = \vec{I_r} \div \vec{I_c} = (87·2 -j\,65·4) + (-0·218 + j15·6)$
        $= 87·0 -j\,49·8 = 100 \llcorner 29º472$A

PAGE : 3

Sending end current= 100A

(ii) Sending end voltage, $\vec{V_S}$ = $\vec{V_1}+\vec{I_s}$ Z/2= (39,195 + j 545) + (87·0–j 49·8) (5+j 10)

= 39,195 + j 545 + 434·9 + j 870□j249 + 498

= 40128 + j 1170 = 40145 < 1°402 V

:. Line value of sending end voltage

$$= 40145 \cdot \sqrt{3} = 69\ 533\ V = 69.53\ KV$$

(iii) Referring to phases =

,$\theta 1$ = angle between $\vec{V_r}$ and $\vec{V_s}$= 1°402

$\theta 2$ = angle between $\vec{V_r}$ and I_s= 29°4724

θS = angle between $\vec{V_s}$ and $\vec{I_s}$

= $\theta 1$ + $\theta 2$= 1°402+ 29°472= 31°272

Sending end power $= \cos\theta s = \cos 31°27 = 0.853$ lag

(iv) Sending end power $= 3\ V_s\ I_s\ \cos\theta s = 3.40,145 \times 100 \times 0.853$

$= 10273105W = 10273.105\ KW$

Power delivered $= 10,000KW$

:. Transmission efficiency $= \dfrac{10,000}{10273.105} \times 100 = 97.34\%$

Question No 2: A (medium) single phase transmission line 100 km long has the following constants:

Resistance/km = 0·25 Ω ; Reactance/km = 0·8 Ω

Susceptance/km = 14 × 10−6 siemen; Receiving end line voltage = 66,000 V

Assuming that the total capacitance of the line is localised at the receiving end

PAGE : 4

alone, determine

(i) The sending end current (ii) The sending end voltage (iii) Regulation and (iv) supply power factor. The line is delivering 15,000 kW at 0.8 power factor lagging. Draw the phasor diagram to illustrate your calculations.

SOLUTION:

Total resistance, $R = 0.2 \times 100 = 25$ohms

Total reactance, $X_l = 0.8 \times 100 = 80$ ohms

Total susceptance, $Y = 14 \times 10^{-6} \times 100 - 14 \times 10^{-4}$ S

Receiving end voltage, $V_R = 66,000$V

$\therefore$ Load current $I_R = \dfrac{15000 \times 10^3}{66,000 \times 0.8} = 284$A

$Cos\theta R = 0.8: \quad sin\theta R = 0.6$

Taking receiving end voltage as the reference phasor we have,

$\overrightarrow{V_R} = V_R + J0 = 66,000$V

Load current $\overrightarrow{I_R} = I_R (Cos\theta R - j \sin\theta R)$ -284 (0.8 – j 0.6) -27 – j170

Capacitive current $\overrightarrow{I_c} = jY \times V_R = $ -j14×10^{-4} × 66000-j92

(i) Sending end current, $\overrightarrow{I_S} = \overrightarrow{I_R} + \overrightarrow{I_c} = $ (227-j170+j92
$= 227$-j78

Magnitude of $I_S = \sqrt{(227)^2 + (78)^2} = 240$A

(II) Voltage drop $= \overrightarrow{I_S} Z = \overrightarrow{I_S}(R+jX_L) = $ (227-j78) (25+j80)
$= 5.675$+j1816-j1950+6240

PAGE : 5

$$= 11{,}915 + j16210$$

Sending end voltage, $\vec{V_S} = \vec{V_R} + \vec{I_S}\,Z = 66000 + 11915 + j16210$

$$= 77915 = +j16210$$

Magnitude of $V_S = \sqrt{(77915)^2 + (16210)^2} = 79583V$

(III) % voltage regulation $= \dfrac{V_S - V_R}{V_R} \times 100 = \dfrac{79583 - 66000}{66000} \times 100 = 20.58\%$

(IV) referreing to exp (i), phase angle between $V_R\, and\, I_R$ is :

$$\theta_1 = \tan^{-1}\!- 78/227 - \tan^{-1}(-0.3436) = -18.96°$$

Referring to exp (ii), phase angle between $\vec{V_R}$ and $\vec{V_S}$ is;

$$\theta_1 = \tan^{-1}\frac{16210}{77915} = \tan^{-1}(0.236) = 11.50°$$

Supply power factor angle, $\emptyset_S = 18.96° + 11.50° = 30.46°$

Supply p.f $= \cos\emptyset_S - \cos 30.46° = 0.86\text{lag}$

Question No 3: Describe Ferranti Effect, Why Ferranti effect occurs? Detail explanation of the Ferranti effect by considering a nominal pi (π) model. How to reduce Ferranti effect.

ANS:

Ferranti Effec:

Definition: The effect in which the voltage at the receiving end of the transmission line is more than the sending voltage is known as the Ferranti effect. Such type of effect mainly occurs because of light load or open circuit at the receiving end.

PAGE : 6

Ferranti effect occurs:

Capacitance and inductance are the main parameters of the lines having a length 240km or above. On such transmission lines, the capacitance is not concentrated at some definite points. It is distributed uniformly along the whole length of the line.

When the voltage is applied at the sending end, the current drawn by the capacitance of the line is more than current associated with the load. Thus, at no load or light load, the voltage at the receiving end is quite large as compared to the constant voltage at the sending end

Ferranti effect by considering a nominal pi (π) model:

Let us consider the long transmission line in which OE represents the receiving end voltage; OH represents the current through the capacitor at the receiving end. The phasor FE represents the voltage drop across the resistance R. The voltage drop across the X (inductance). The phasor OG represents the sending end voltage under a no-load condition.

Nominal pi model of the line at no load.

Circuit Globe
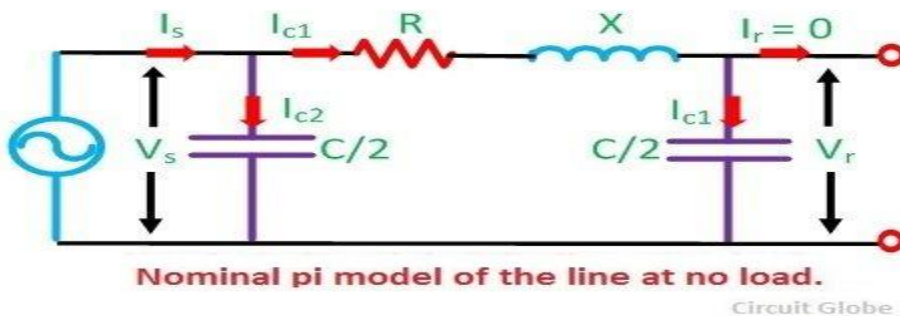
It is seen from phasor diagram that OE > OG. In other words, the voltage at the receiving end is greater than the voltage at the sending end when the line is at no load.

Phasor Diagram Circuit Globe
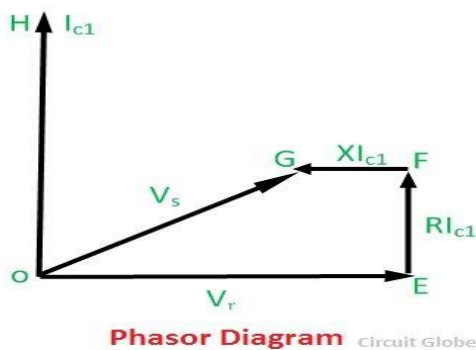
PAGE : 7

For a small Pi (π) replica

$$Vs = (1+ZY/2)Vr + ZIr$$

Where, Ir =0 at no load condition

$$Vs = (1+ZY/2)Vr + Z (0)$$

$$= (1+ZY/2) Vr$$

$$Vs-Vr = (1+ZY/2)Vr- Vr$$

$$Vs-Vr = Vr [1+ZY/2-1]$$

$$Vs-Vr = (ZY/2) Vr$$

$$Z= (r + jwl)S, \text{ and } Y = (jwc)S$$

If the transmission line's resistance is unnoticed

$$Vs-Vr = (ZY/2) Vr$$

Substitute Z= (r + jwl)S, and Y = (jwc)S in the above Vs

$$Vs-Vr= ½ (jwls) (jwcs) Vr$$

$$Vs-Vr= - ½ (W2S2) lcVr$$

PAGE : 8

For the lines of overhead, $1/\sqrt{LC} = 3\times10^8$m/s (velocity of electromagnetic wave transmission on the broadcast lines).$1/\sqrt{LC} = 3\times10^8$m/s

$$\sqrt{LC} = 1/3\times10^8$$

$$LC = 1/(3\times10^8)^2$$

$$VS-VR = -\tfrac{1}{2}\,W^2S^2\,.\,(1/(3\times10^8)^2)\,Vr$$

$$W = 2\pi f$$

$$VS-VR = -((4\pi^2/18)* 10^{-16})\,f^2S^2Vr$$

The above **eq** illustrates that (VS-Vr) is negative, that means Vr is greater than VS. This is also illustrated that this effect will also determine by the electrical period of the transmission lines and frequency.

Generally, for each line

$$Vs = AVr + BLr$$

On no load state,

$$Ir =0,\ Vr = Vrnl$$

$$Vs = AVrnl$$

$$|Vrnl| = |Vs|/|A$$

PAGE : 9

How to Reduce Ferranti Effect In Transmission Line:

Electrical machines work on specific electrical energy. If the voltage is far above the ground at the consumer end their device get damaged, and the windings of the device also burn due to high electrical energy.

Ferranti effect on extensive transmission lines at no-load status, then the voltage will increase at the collecting end. This can be restricted by keeping the shunt-reactors next to the collecting end of the transmission lines.

This reactor allied between the lines along with neutral to give back the capacitive current as of transmission lines. As this outcome happens in lengthy transmission lines, these reactors pay off the transmission lines & thus the voltage is regulated within the set limits.