**Assignment**

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Electrical Transmission System

**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 ×100 = 10

ΩTotal reactance/phase.*XL*= 0·2 ×100 = 20

 Capacitive susceptance, *Y*= 0·04 ×10−4×100 = 4 ×10−4S

Receiving end voltage/phase, *VR*= 66,000/√ 3 = 38105 *V*

Load current, *IR =* $\frac{10 000×10^{3},}{\sqrt{3 }×66×10^{3×}0.8}$ = 109A

cos$θ$R = 0·8; sin$θ$*R* = 0·6

Impedance per phase, *Z*=*R*+ *j XL*= 10 + *j*20

1. Taking receiving end voltage as the reference phase

 We have,

Receiving end voltage, *VR*=*VR*+ *j*0 = 38,105 *V*

Load current, IR = IR (cos $θ$*R*-*j* sin $θ$*R*) = 109 (0·8 -*j*0·6) = 87·2 -*j*65·4

Voltage across *C*, *V*1 = *Vr +Ir Z/2* = 38, 105 + (87·2 -*j*65·4) (5 +*j*10)=38,105 + 436 + *j*872 −*j*327 + 654 = 39,195 + *j*545

Charging current, *IC =* *j Y* $V\_{1}$ 14×$10^{-4}$ (39,195+ j 545) -0.218 + j15.6

Sending end current, IS *=* $I\_{r}÷I\_{c }$= (87·2 *j* 65·4) + (0·218 + *j*15·6)

 = 87·0 *j* 49·8 = 100 $⦜ $29º47′A

 Sending end current= 100A

1. Sending end voltage, VS= $V\_{1}+I\_{s}$ Z/2= (39,195 + *j* 545) + (87·0*j* 49·8) (5+*j* 10)

 = 39,195 + *j* 545 + 434·9 + *j* 870−*j*249 + 498

= 40128 + *j 1170* = 40145 < 1$°$40′V

Line value of sending end voltage

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

1. Referring to phases =

 ,$θ$1 = angle between $V\_{r}$and $V\_{s}$= 1$°$40′

$θ$2 = angle between $V\_{r}$and $I\_{s}$= 29$°$47′∴

$θ$*S* = angle between $V\_{s}and I\_{s} $

=$ θ$1 + $θ$2= 1$°$40′+ 29$°$47′= 31$°$27′

Sending end power = cos$θ$s = cos31$°$27 = 0.853 lag

1. Sending end power = 3 $V\_{s }I\_{s}$ cos$θ$s = 3.40,145 ×100×0.853

= 10273105W = 10273.105 KW

Power delivered = 10,000KW

:. Transmission efficiency = $\frac{10,000}{10273.105}$ × 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

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 × 100 = 25ohms

 Total reactance, $X\_{l}$ = 0.8 × 100 = 80 ohms

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

 Receiving end voltage, $V\_{R}$ = 66,000V

 :. Load current $I\_{R}$ = $\frac{15000×10^{3}}{66,000×0.8}$ = 284A

Cos$θ$R = 0.8: sin$θ$R = 0.6

Taking receiving end voltage as the reference phasor we have,

 $V\_{R}$ = $V\_{R}$ + J0 = 66,000V

 Load current $I\_{R} $= $I\_{R} $(Cos$θ$R - j sin$θ$R) -284 ( 0.8 – j 0.6) -27 – j170

 Capacitive current $I\_{c}$ = jY× $V\_{R}$ = -j14×$10^{-4}$ × 66000-j92

1. Sending end current, $I\_{S}$ = $I\_{R}$+$I\_{C}$= (227-j170+j92

 = 227-j78

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

(II) Voltage drop = $I\_{S} Z=$ $I\_{S}$(R+j$X\_{L}$) = (227-j78) (25+j80)

 = 5.675+j1816-j1950+6240

 = 11,915+j16210

 Sending end voltage, $V\_{S}$ = $V\_{R}$+$I\_{S} $Z = 66000+11915+j16210

 = 77915 =+j16210

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

 (III) % voltage regulation = $\frac{V\_{S}-V\_{R}}{V\_{R}}×100$ = $\frac{79583-66000}{66000}×100$ = 20.58%

(IV) referreing to exp (i), phase angle between $V\_{R}and I\_{R}$ is :

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

 Referring to exp (ii), phase angle between $V\_{R}$ and $V\_{S}$ is;

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

Supply power factor angle, $∅\_{S}$ = 18.96° + 11.50° = 30.46°

 Supply p.f = cos$∅\_{S}$ - cos 30.46°= 0.86lag

**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.

**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.



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.



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, 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

For the lines of overhead, 1/√LC = 3×108m/s (velocity of electromagnetic wave transmission on the broadcast lines).1/√LC = 3×108m/s

√LC = 1/3×108

LC = 1/(3×108 )2

VS-VR = – ½ W2S2 . (1/(3×108 )2) Vr

W = 2πf

VS-VR = – ((4π2/18)\* 10-16) f2S2Vr

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

### 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.