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ROLL N0: U20EE079

Experiment 5

Aim: To find compensator reactive power to obtain zero voltage regulation using MATLAB.

For a supply at 10 kV line to neutral voltage with short circuit level of 250 MVA and X_s/R_s ratio of 5, supplying a star connected load inductive load whose mean power is 25 MW and whose reactive power is 50 MVAr, all quantities per phase. Determine compensator reactive power such that voltage regulation is zero using MATLAB. Also, develop Simulink Model for the given problem in continuous and phasor mode.

Apparatus Required: MATLAB 7.0 and above

Theory:

Voltage regulation can be defined as the proportional change in voltage magnitude at the load bus due to change in load current (say from no load to full load). The voltage drop is caused due to feeder impedance carrying the load current as illustrated in Fig. 1.

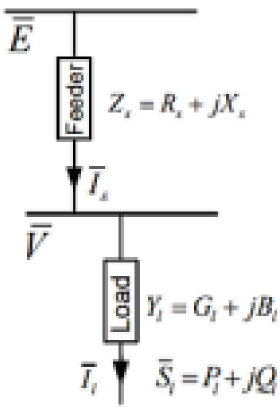


Fig. (1) Single phase system with feeder impedance.

If the supply voltage is represented by Thevenin's equivalent, then the voltage regulation (VR) is given by,

$$VR = \frac{|\overline{E}| - |\overline{V}|}{|\overline{V}|} = \frac{|\overline{E}| - |V|}{|V|} \quad (1)$$

for $\bar{V}$ being a reference phasor.
In absence of compensator, the source and load currents are same and the voltage drop due to the feeder is given by,

$$\Delta\overline{V} = \overline{E} - \overline{V} = Z_s\overline{I_l} \quad (2)$$

The feeder impedance, $Z_s = R_s + jX_s$. The relationship between the load powers and its voltage and current is

$$\overline{S_l} \;=\; \overline{V}\,(\overline{I_l})^* = P_l + jQ_l \quad (3)$$

Since $\bar{V} = V$, the load current can be expressed as

$$\overline{I_l} \;=\; \frac{P_l - jQ_l}{V} \quad (4)$$

Substituting, I_l from above equation into (3),
we get

$$\begin{aligned}\Delta\overline{V} = \overline{E} - \overline{V} &= (R_s + jX_s)\left(\frac{P_l - jQ_l}{V}\right)\\ &= \frac{R_sP_l + X_sQ_l}{V} + j\frac{X_sP_l - R_sQ_l}{V}\\ &= \Delta V_R + j\Delta V_X \end{aligned} \quad (5)$$

The voltage drop across the feeder has two components, one in phase (ΔVR) and another is in phase quadrature (ΔVX) as illustrated in Fig. 2.

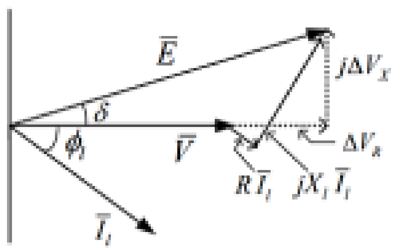


Fig. (2) Phasor diagram

Voltage regulation can be made zero if the compensator consisting of purely reactive components, has enough capacity to supply to required amount of the reactive power as shown in fig. (3).

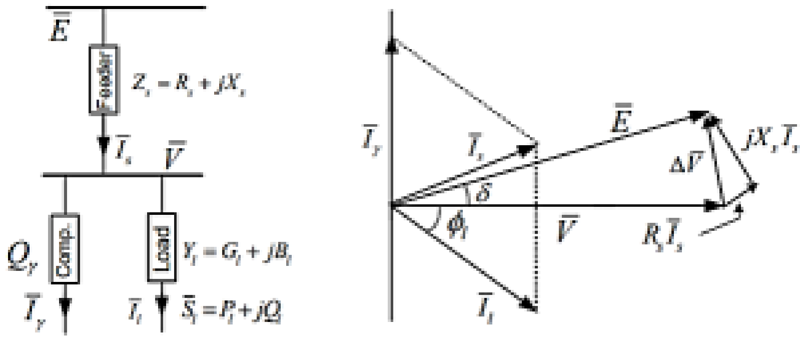


Fig. 3 (a) Voltage with compensator (b) Phasor diagram

The net reactive at the load bus is now Qs = Qγ + Ql. The compensator reactive power (Qγ) has to be adjusted in such a way as to rotate the phasor ΔV until $|\bar{E}| = |\bar{V}|$. From equation (5) and fig. 3 (b),

$$E\angle\delta = \left(V + \frac{R_s P_l + X_s Q_s}{V}\right) + j\left(\frac{X_s P_l - R_s Q_s}{V}\right) \quad (6)$$

$$E^2 = \left(V + \frac{R_s P_l + X_s Q_s}{V}\right)^2 + \left(\frac{X_s P_l - R_s Q_s}{V}\right)^2 \quad (7)$$

$$\begin{aligned} E^2V^2 &= (V^2 + R_s P_l)^2 + X_s^2 Q_s^2 + 2(V^2 + \cancel{R_s P_l})\, X_s Q_s \\ &\quad + X_s^2 P_l^2 + R_s^2 Q_s^2 - \cancel{2X_s P_l R_s Q_s} \end{aligned} \quad (8)$$

$$(R_s^2 + X_s^2)\, Q_s^2 + 2V^2 X_s Q_s + (V^2 + R_s P_l)^2 + (X_s P_l)^2 - E^2 V^2 = 0 \quad (9)$$

Thus, the above equation is quadratic in Qs and can be represented using coefficients of Qs as given below

$$a\, Q_s^2 + b\, Q_s + c = 0 \quad (10)$$

Where $a = R_s^2 + X_s^2$, $b = 2V^2 X_s$ and $c = (V^2 + R_s P_l)^2 + X_s^2 P_l^2 - E^2 V^2$ (11)

$$Q_s = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

$$Q_s = Q_l + Q_\gamma$$

MATLAB Code

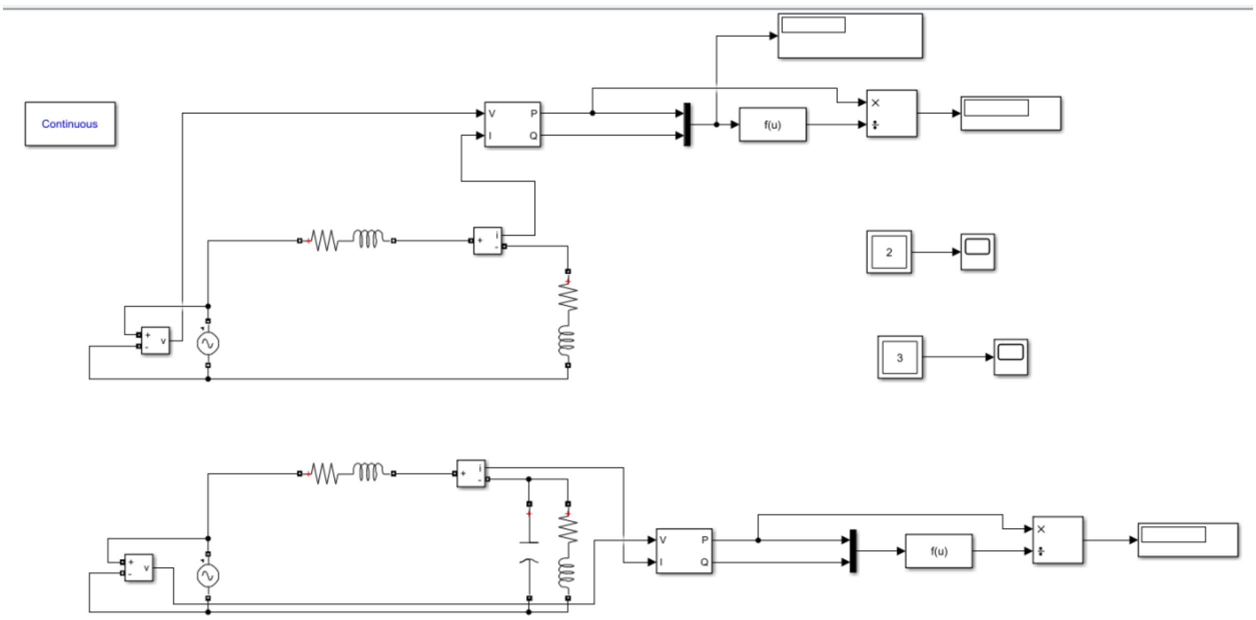
```
clc;
clear all;
E=10;
V=10;
PL=25;
QL=50;
Rs=0.0784;
Xs=0.3922;
a=Rs^2+Xs^2;
b=2*V^2*Xs;
c=2*V^2*Rs*PL+Rs^2*PL^2+Xs^2*PL^2+V^4-E^2*V^2;
p=[a b c];
Qs =max(roots(p));
Qcomp=Qs-QL;
display(Qcomp);
```

Output

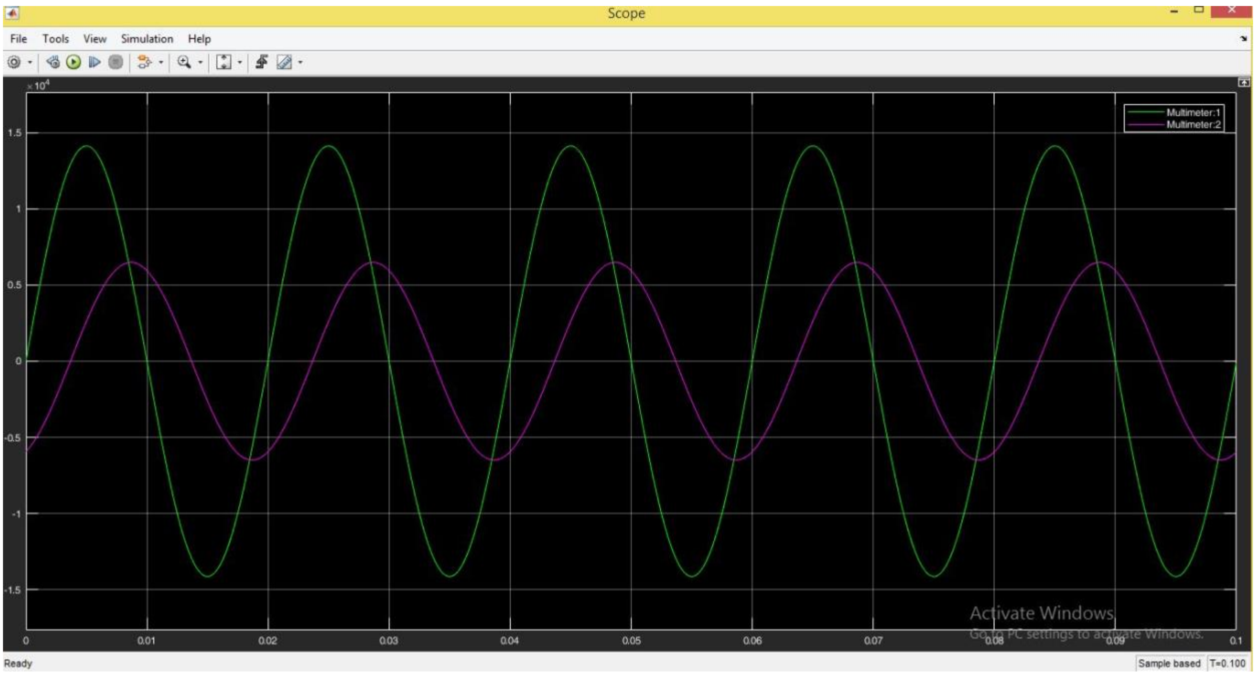
```
Qcomp =

  -56.3544
```

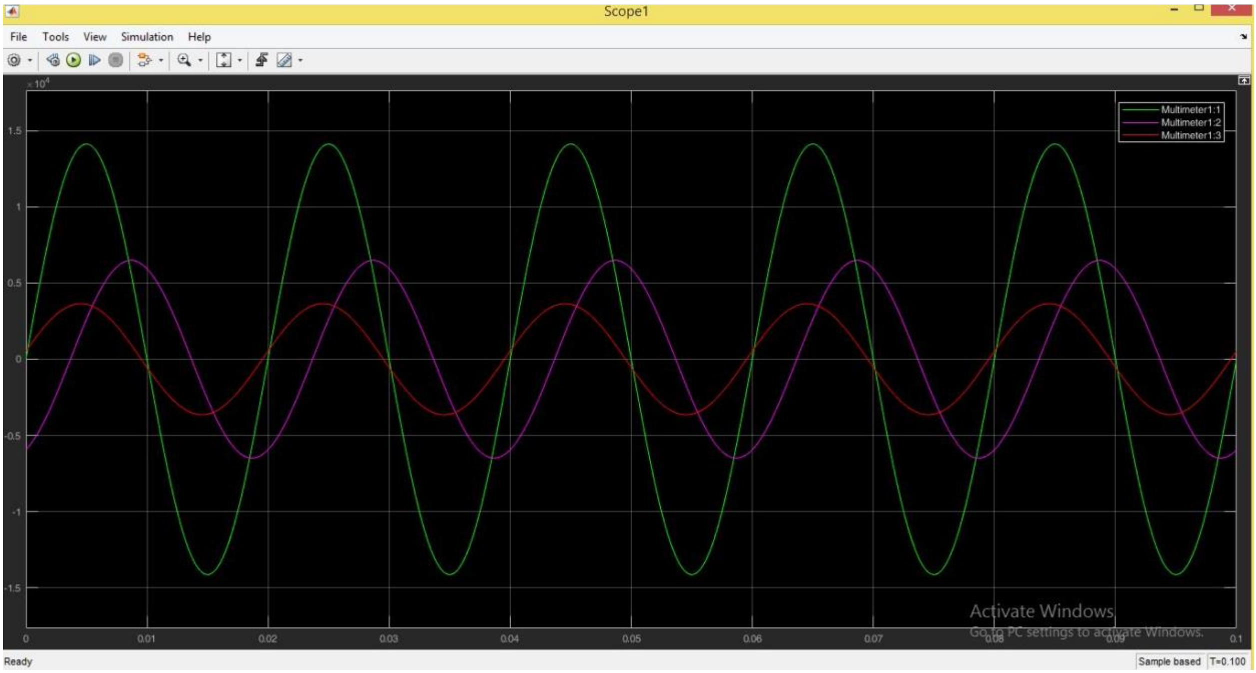
MATLAB Circuit diagram



Without compensator (Voltage and current graphs)



With compensator (voltage and current graphs)



Conclusion: From the experiment, we have seen that by adding capacitor in parallel to load power factor is improved and also calculated value of capacitance required for voltage regulation to be zero.

Questions:

Q1. What is load compensation in power system?

Q2. What is the difference between shunt and series compensation?

ANSWERS:

HP.

[Ans 1] load compensation is the management of reactive power to improve power quality i.e. V profile and pf. Here the reactive power flow is controlled by installing shunt compensating devices at the load end bringing proper balance b/w generated and consumed reactive power.

[Ans-2] The Shunt capacitor does it by changing the power factor of the load. whereas the series capacitor ~~directly does~~ it by directly affecting the inductive reactance of the circuit to which it is applied.