EE2029 – Introduction to Electrical Energy Systems
(Solution for Tutorial #2 on AC Power)

Solution Q.1

$Z_R = 25\ \Omega$

$Z_C = -j\dfrac{1}{377 \times 100 \times 10^{-6}} = -j26.52\ \Omega$

$Z_{Load} = \left(\dfrac{1}{25} + \dfrac{1}{-j26.52}\right)^{-1} = 18.19\angle -43.31^o$

Total impedance seen by the source Z_{total}= $1 + 18.19\angle -43.31^o = 18.93\angle -41.23^o \Omega$

Current drawn from the source $I = \frac{230\angle 0^o}{18.93\angle -41.23^o} = 12.15\angle 41.23^o A$

Load voltage $V_{load} = V_s - I \times Z_{line} = 230\angle 0^o - 12.15\angle 41.23^o \times 1 = 221\angle -2.075^o$ V

Complex power delivered to the load $S_{load} = V_{load} I^* = 221\angle -2.075^o \times 12.15\angle -41.23^o =$ $2685.15\angle -43.31^o$ VA

Apparent power delivered to load $|S_{laod}| = 2685.15\ VA$

Power factor of the load = $\cos(-43.31^o) = 0.728$ leading

Apparent power supplied by the source = $230 \times 12.15 = 2794.5\ VA$

Solution Q.2

Current drawn by the load $|I_{old}| = \frac{P}{|V|\times(Power\ factor)} = \frac{25000}{500\ \times 0.5} = 100$ A

$\cos\theta = 0.5 \rightarrow\ \theta = cos^{-1}(0.5) = 60^o$

Current phasor $I = 100\angle - 60^o$ A

Complex power of the load $S_{old} = VI^* = 500 \times 100\angle 60^o = 50000\angle 60^o$ VA

$Q_{old} = 50000\sin(60^o) = 43301\ VAr$

After connecting the capacitor in parallel, new power factor =0.95 lagging

Current drawn from source $|I_{new}| = \frac{P}{|V|\times(Power\ factor)} = \frac{25000}{500\ \times 0.95} = 52.63$ A

$\cos\theta' = 0.5 \rightarrow\ \theta' = cos^{-1}(0.95) = 18.19^o$

Complex power drawn from the source $S_{new} = VI_{new}^* = 500 \times 52.63\angle 18.19^o = 24999.95 + j8214.73$ VA

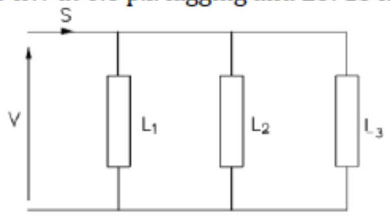
$Q_{new} = 8214.73\ VAr$

Reactive power supplied by the capacitor $Q_C = 8214.73 - 43301$ =-35086.27 VAr

The required capacitor value $C = \frac{Q_C}{\omega|V|^2} = \frac{35086.27}{2\pi\times 50\times 500^2} = 446.73\mu F$

Solution Q3:

L1: 5 kW at 0.8 p.f. lagging, L2: 10 kW at 0.6 p.f. lagging and L3: 15 kW at 0.8 p.f. leading



The complex power consumption of the loads are computed as follows:

$$
\begin{aligned}
P_1 &= |S_1| \times 0.8 \\
|S_1| &= 6250 \ \text{VA} \\
S_1 &= 6250\angle 36.87^\circ = 5000 + j3750 \\
P_2 &= |S_2| \times 0.6 \\
|S_2| &= 16666.67 \ \text{VA} \\
S_2 &= 16666.67\angle 53.13^\circ = 10000 + j13333.33 \\
P_3 &= |S_3| \times 0.8 \\
|S_3| &= 18750 \ \text{VA} \\
S_3 &= 18750\angle -36.87^\circ = 15000 - j11250
\end{aligned}
$$

Hence, overall power factor as seen by the source can be calculated as:

$$
\begin{aligned}
S &= S_1 + S_2 + S_3 \\
&= 30000 + j5833.33 \\
&= 30561.87\angle 11^\circ \ \text{VA} \\
\text{p.f.} &= cos\, 11^\circ = 0.982 \ \text{lagging}
\end{aligned}
$$

Solution Q4:

As the power delivered is 10kW at 0.5 p.f. lagging,

$$|I| \; = \; \frac{P}{V\,cos\,\phi} = \frac{10000}{200 \times 0.5} = 100 \text{ A}$$
$$I \; = \; 100\angle 60^\circ = 50 - j86.6 \text{ A}$$

When a capacitor of $1000\mu F$ is connected across the supply, the capacitor current is

$$I_C = j\omega CV = j314 \times 1000 \times 10^{-6} \times 200 = j62.8 \text{ A}$$

So the total current drawn from the supply is

$$I_T = I + I_C = 50 - j23.8 = 55.38\angle{-25.45^\circ}$$

The power factor as seen by the source is

$$\text{p.f.} = cos\,(-25.45^\circ) = 0.902 \text{ lagging}$$

Solution Q5:

Current drawn from the substation is

$$|I_1| = \frac{P}{|V|\,cos\,\theta} = \frac{1500 \times 10^3}{500 \times 0.6} = 5000 \;\; \text{A}$$

If the power factor could be improved to unity, then current drawn would be

$$|I_2| = \frac{P}{|V|\,cos\,\theta} = \frac{1500 \times 10^3}{500 \times 1.0} = 3000 \;\; \text{A}$$

The transmission line losses in both the cases are

$$P_{loss1} = R\,|I_1|^2 = 0.005 \times 5000^2 = 125 \;\; \text{kW}$$
$$P_{loss2} = R\,|I_2|^2 = 0.005 \times 3000^2 = 45 \;\; \text{kW}$$

So, cost of energy wasted will be high in the first case.

This example illustrates that for the same real power demand, if the power factor of the load decreases, then |I| increases, resulting in heavy transmission line losses.

A poor power factor results in higher current and hence higher power loss.