(1) Consider the following circuit in frequency domain. Both the sources have 60-Hz frequency.

\[ \frac{\tilde{V}_1}{10} + \frac{\tilde{V}_1 - \tilde{V}_3}{-j10} + \frac{\tilde{V}_2 - \tilde{V}_3}{10} = 2 \angle 0^\circ \quad (1) \]
\[ \tilde{V}_2 - \tilde{V}_1 = 20 \angle 45^\circ \quad - \quad (2) \]
\[ \frac{\tilde{V}_3 - \tilde{V}_1}{-j10} + \frac{\tilde{V}_3 - \tilde{V}_2}{10} + \frac{\tilde{V}_3}{j10} = 0 \quad (3) \]

15 (a) Write all the equations necessary for nodal analysis. Use the reference node and nodal voltages already shown.

15 (b) Write all the equations necessary for mesh analysis using mesh currents already shown.

\[ \tilde{I}_2 - \tilde{I}_1 = 2 \angle 0^\circ \quad - \quad (1) \]
\[ 10 \tilde{I}_1 - 20 \angle 45^\circ + 10 (\tilde{I}_2 - \tilde{I}_3) + j10 \tilde{I}_2 = 0 \quad (2) \]
\[ 10 \tilde{I}_1 - j10 \tilde{I}_3 + j10 \tilde{I}_2 = 0 \quad - \quad (3) \]

Continued ------------
(c) Find \( v_0(t) \) from any of the above two methods.

Solving for mesh currents,
\[ \tilde{I}_1 = 0.6846 \angle -85.9^\circ \text{ A} \]
\[ \tilde{I}_2 = 2.16 \angle -18.43^\circ \text{ A} \]
\[ \tilde{I}_3 = 1.55 \angle -28.2^\circ \text{ A} \]

\[ \tilde{V}_0 = 10 (\tilde{I}_2 - \tilde{I}_3) \]
\[ \tilde{V}_0 = 6.85 \angle 4.1^\circ \text{ V} \]
\[ v_0(t) = 6.85 \cos(120\pi t + 4.1^\circ) \text{ V} \]

Solving for nodal voltages,
\[ \tilde{V}_1 = 6.846 \angle 94.1^\circ \text{ V} \]
\[ \tilde{V}_2 = 25.03 \angle 56.9^\circ \text{ V} \]
\[ \tilde{V}_3 = 21.6 \angle 71.6^\circ \text{ V} \]
\[ \tilde{V}_0 = \tilde{V}_2 - \tilde{V}_3 = 6.85 \angle 4.1^\circ \text{ V} \]
A source operating at 60 Hz provides power to three loads as follows:
Load A: 40 kVA @pf = 0.8 lagging,
Load B: 50 kW @ pf = 0.7 lagging,
Load C: 20 kVAR @ pf = 0.75 leading.

(a) Find the total complex power provided by the source.

\[
\begin{align*}
S_A &= 40 \angle \cos^{-1} 0.8 = 40 \angle 36.87^\circ \text{ kVA} \\
S_B &= 50 + j 50 \tan (\cos^{-1} 0.7) = 71.42 \angle 45.56 \text{ kVAR} \\
S_C &= \frac{20}{\tan (\cos^{-1} 0.75)} - j 20 = 30.25 \angle -41.4^\circ \text{ kVAR} \\
S_t &= S_A + S_B + S_C \\
S_t &= 118.3 \angle 27.7^\circ \text{ kVA} = 104.7 + j 55 \text{ kVA}
\end{align*}
\]

(b) What is the equivalent impedance seen by the source?

\[
\begin{align*}
\vec{Z}^* &= \frac{V_{\text{rms}}}{\vec{S}} = 1.45 - j 0.761 \\
\vec{Z} &= 1.45 + j 0.761 = 1.64 \angle 27.7^\circ \Omega
\end{align*}
\]

(c) What is the power factor seen by the source?

\[
\text{pf} = \cos 27.7^\circ = 0.885 \text{ lagging}
\]
10 (d) Determine the capacitance necessary to correct the power factor to 0.98.

\[ C = \frac{P (\tan \theta_{\text{new}} - \tan \theta_{\text{old}})}{\sqrt{V_{\text{rms}}^2 - W}} \]

\[ C = \frac{104.7 \times 10^3 [0.199 - 0.525]}{(4.40)^2 \times 2\pi \times 60} \]

\[ C = 4.67 \mu F \]

10 (e) Find the source RMS current phasors before and after the pf correction.

\[ \tilde{I}_{\text{rms}}^{\text{new}} = \frac{s_{\text{rms}}}{\sqrt{V_{\text{rms}}^2}} = \frac{118.3}{440} \times 10^3 \]

\[ \tilde{I}_{\text{rms}}^{\text{new}} = 269 \angle -27.7^\circ \text{ A (before)} \]

After correction:

\[ Q = P \tan \theta_{\text{new}} = 20.8 \times 10^3 \text{ VAR} \]

\[ S_{\text{new}} = 104.7 + j20.8 \text{ kVAR} \]

\[ \tilde{I}_{\text{rms}}^{\text{new}} = 242.6 \angle -11.25^\circ \text{ A} \]

5 (f) If the daily expenses in line losses were $100 before the pf correction, find the expenses associated with daily line losses after the correction.

\[ P_{\text{line}} = I_{\text{rms}}^{\text{line}}^2 R_{\text{line}} \]

\[ \text{New expenses} = \frac{(242.6)^2}{(269)^2} \times 100 \]

\[ \text{New expenses} = \# 81.33 \]