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

\[
\begin{align*}
\frac{V_1}{10} + \frac{V_2 - V_3}{-j10} + \frac{V_2 - V_3}{10} &= 2 \angle \theta \quad (1) \\
\frac{V_2 - V_1}{20 \angle 45^\circ} &= 2 \angle 0 \quad (2) \\
\frac{V_3 - V_1}{-j10} + \frac{V_3 - V_2}{10} + \frac{V_3}{j10} &= 0 \quad (3)
\end{align*}
\]

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

\[
\begin{align*}
\frac{I_1}{10} + \frac{I_2 - I_3}{-j10} + \frac{I_2}{10} &= 2 \angle \theta \quad (1) \\
10 (I_1 - 20 \angle 45^\circ + 10 (I_2 - I_3)) + 10 I_2 &= 0 \quad (2) \\
10 (I_1 - 10 I_3) + 10 I_2 &= 0 \quad (3)
\end{align*}
\]

(b) Write all the equations necessary for mesh analysis using mesh currents already shown.
(c) Find $v_o(t)$ from any of the above two methods.

Solving for mesh currents,

\[ \tilde{I}_1 = 0.6846 \angle -85.9^\circ \ A \]
\[ \tilde{I}_2 = 2.16 \angle -18.43^\circ \ A \]
\[ \tilde{I}_3 = 1.55 \angle -28.2^\circ \ A \]

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

Solving for nodal voltages,

\[ \tilde{V}_1 = 6.846 \angle 94.1^\circ \ V \]
\[ \tilde{V}_2 = 25.03 \angle 56.9^\circ \ V \]
\[ \tilde{V}_3 = 21.6 \angle 71.6^\circ \ V \]

\[ \tilde{V}_0 = \tilde{V}_2 - \tilde{V}_3 = 6.85 \angle 4.1^\circ \ V \]
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.

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

\[ S_A = 40 \angle \cos^{-1} 0.8 = 40 \angle 36.87^\circ \text{ kVA} \]
\[ S_B = 50 + j \cdot 50 \tan (\cos^{-1} 0.7) = 50 + j \cdot 51 \text{ kVA} \]
\[ S_C = \frac{20}{\tan (\cos^{-1} 0.75)} - j \cdot 20 = 22.7 - j \cdot 20 \text{ kVA} \]
\[ S_t = S_A + S_B + S_C \]
\[ S_t = 118.3 \angle 27.7^\circ \text{ kVA = 104.7 } + j \cdot 55 \text{ kVA} \]

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

\[ Z_{eq} = \frac{V_{rms}}{S_t} = 1.45 - j \cdot 0.761 \]
\[ Z = 1.45 + j \cdot 0.761 = 1.64 \angle 27.7^\circ \Omega \]

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

\[ \text{pf} = \cos 27.7^\circ = 0.885 \text{ lagging} \]

Continued ------
(d) Determine the capacitance necessary to correct the power factor to 0.98.

\[ C = \frac{P}{\sqrt{\frac{\tan \Theta_{\text{new}} - \tan \Theta_{\text{old}}}{\omega}}^2} \]

\[ C = \frac{104.7 \times 10^3 \left[ 0.199 - 0.525 \right]}{(440)^2 \times 2\pi \times 60} \]

\[ C = 4.67 \mu F \]

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

\[ I_{\text{rms}}^* = \frac{5}{\sqrt{3}} = \frac{118.3}{440} \angle 27.7^\circ \times 10^3 \]

\[ I_{\text{rms}}^* = 269 \angle -27.7^\circ \text{ A (before)} \]

After correction.

\[ Q = P \tan \Theta = 20.8 \times 10^3 \text{ VA} \]

\[ S = 104.7 + \sqrt{20.8} \text{ kVA} \]

\[ I_{\text{rms}}^* = 242.6 \angle -11.25^\circ \text{ A} \]

(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.

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

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

\[ = \$ 81,33 \]