1. In the following circuit \( V_L = 240 \, \text{V (RMS)} \) at all times. The following information about the loads are given:

   \( d_1 \): absorbs 180 \, \text{Watts} and 240 \, \text{VARs}.

   \( d_2 \): absorbs 600 \, \text{VA} at 0.6 pf lagging.

   a) Assume there is no capacitor connected between a-b terminals. Find input impedance at the load side, source voltage \( V_s \) (in RMS) and pf. on source side.

   b) Now, the capacitor is connected between a-b terminals. Find value of \( C \) such that average power absorbed by 5 ohm resistor is minimum. Find \( V_s \) with the compensation capacitor.

   c) Find value of \( C \) such that load side pf. is 0.9 lagging. Find \( V_s \) with compensation capacitor.
Exam 4 Solutions

1) \[ S_{L1} = 180 + 5 \cdot 240 \]
\[ + S_{L2} = 600 \cos^{-1}(0.6) = 360 + 5 \cdot 480 \]
\[ S_{\text{Total}} = 540 + 5 \cdot 720 \]

a) \[ |I_{\text{Line}}| = \sqrt{\frac{|S_{\text{Total}}|}{240}} = \frac{900}{240} = 3.75 \text{ A (RMS)} \]
\[ S_{\text{Total}} = |I_{\text{Line}}|^2 \cdot Z \]
\[ Z = \frac{540 + 5 \cdot 720}{(3.75)^2} = 38.4 + 5 \cdot 51.2 \]
\[ Z = \frac{64}{53.1} \text{ ohms} \]

\[ S_{\text{Line}} = |I_{\text{Line}}|^2 \cdot (5 + 58) \]
\[ = 70.3125 + 5 \cdot 112.5 \]
\[ S_{\text{Source}} = S_{\text{Line}} + S_{\text{Total}} \]
\[ = 610.31 + 5 \cdot 832.5 \]

\[ |S_{\text{Source}}| = |I_{\text{Line}}| \cdot |V_s| \]
\[ |V_s| = \frac{|S_{\text{Source}}|}{3.75} = 275.26 \text{ V RMS} \]

Power on source side:
\[ \cos(\tan^{-1} \frac{832.5}{610.31}) = 0.59 \text{ leading} \]

b) \[ S_{\text{before}} = 540 + 5 \cdot 720 \]
\[ I_{\text{before}} = 3.75 \text{ A} \]
\[ S_{\text{after}} = 540 + 5 \cdot 720 - 5 \cdot 720 = 540 \]
\[ I_{\text{Line}} = \frac{540}{240} = 2.25 \text{ A} \]
\[ S_{\text{Line}} = (2.25)^2 (5 + 58) = 25.31 + 5 \cdot 40.5 \]
\[ S_{\text{Source}} = 540 + 25.31 + 5 \cdot 40.5 \]
\[ S_{\text{source}} = 565.31 + j40.5 \]
\[ |S_{\text{source}}| = 566.75 = 1V_s |, \left| I_{\text{Line}} \right| \rightarrow \left| I_{V_s} \right| = 251.89 \text{ V (RMS)} \]

\[ S_{\text{compensator}} = -3720 \cdot 240 \]
\[ S_{\text{compensator}} = \frac{1}{\omega C} \]

\[ X_C = \frac{V_{\text{cap}}^2}{S_{\text{comp}}^*} = \frac{(240)^2}{5720} \]
\[ X_C = -380 \]
\[ X_C = \frac{-j}{\omega C} \]
\[ X_C = -380 \rightarrow C = \frac{1}{\omega^2} = 39.8 \mu F. \]

\( c) \)
\[ A_{\text{After}} = 540 + j \tan(25.84^\circ) = 540 + j261 \]

\[ S_{\text{After}} = S_{\text{Before}} + S_{\text{Compensation}} \]
\[ S_{\text{Compensation}} = -j458.5 \]
\[ X_C = -j(\frac{240)^2}{458.5} = -j125.63; C = \frac{1}{100 \times 125.6} = 25.3 \mu F \]
\[ I_{\text{line}} \text{ after } 15 \text{ s} \text{ of power} = \frac{540/0.9}{240} = 2.5 \text{ A}. \]

\[ S_{\text{line}} = (2.5)^2 (5 + 58) = 31.25 + 550 \]

\[ S_{\text{source}} = 571.25 + 5301 \text{ (supplied)} \]

\[ |S_{\text{source}}| = |V_5| \cdot |I_{\text{line}}| \rightarrow V_5 = 258.27 \text{ V} \]

Diagram of a circuit with components labeled.