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Solution

(a) Ea:

$E_a = V_t + jX_s I_a + R_a I_a$

$\equiv V_p + jX_s I_a$

$\rightarrow \cos\theta = 0.8$

$\therefore \theta = 36.87$

$\rightarrow V_L = 415 \rightarrow V_p = \frac{415}{\sqrt{3}}$

$= 239.6 \angle 0$

$\rightarrow I_a = \frac{S_r}{\sqrt{3} \times V_L} = \frac{25 \times 10^3}{\sqrt{3} \times 415}$

$= 34.78$

$\simeq 34.78 \angle -36.87$

$E_a = V_t + jX_s I_a$

$\rightarrow E_a = 239.6 \angle 0 + 1.5 \angle 90^\circ \times 34.78 \angle -36.87$

$= 270.9 + j41.74$

$\simeq 274.1 \angle 8.76\,V$

(b) I_f: $I_a = \frac{E_a - V}{jX_s}$

$\therefore I_f = \frac{E_a - V_t}{jX_s}$

$E_{a_2} = 1.2 \times E_a = 1.2 \times 274.1$

$= 328.92$

$E_1 \sin\delta_2 = E_2 \sin\delta_2$

$\therefore \sin\delta_2 = \frac{E_1 \sin\delta_1}{E_2}$

$= \frac{274.1 \sin 8.76}{328.92}$

$\sin\delta_2 = 0.127$

$\therefore \delta_2 = 7.47$

$\therefore I_f = \frac{328.92 \angle 7.47 - 289.6 \angle 0}{1.5 \angle 90^\circ}$

$= 28.51 - j57.69$

$I_f \simeq 64.35 \angle -63.7$

(i) $P.f = \cos\theta$

$= \cos(-63.7)$

$= 0.4$ lagging

(ii) $Q = \sqrt{3} \times V_L \times I_L \times \sin\theta$

$= \sqrt{3} \times 415 \times 64.35 \times \sin 63.7$

$= 41466.85$

$\simeq 41.5$ KVAR

(iii) $I_f = \frac{E_f - V}{j x_s}$

Using same conditions as (ii)

$\therefore 274.1 \angle 90° - 239.6 \angle 0$

$1.5 \angle 90$

$= 164.73 + j\,159.73$

$I_{\Delta} \simeq 229.46 \angle 44.12$

(ii) $P.f = \cos\theta$

$= \cos(44.12)$

$= 0.7$ leading

(iii) $Q = \sqrt{3} \times V_L \times I_L \times \sin\theta$

$= \sqrt{3} \times 415 \times 229.46 \times \sin 44.12$

$= 114822.48 \simeq 11.5$ KVAR