PAGE NO.:
DATE: / /

Q. 33 kV, 3ϕ, 6.2 MVAr capacitor bank is to be installed at PCC where SC rating is 750 MVA load is 20 MW at 0.75 pf. Harmonic spectrum is $I_{L5} = 40\%$, $I_{L7} = 10\%$, $I_{L11} = 8\%$, $I_{L13} = 4\%$. $Q = 100$. Design filter for 5^{th} harmonic as for 11^{th} there are freq 5 and 7 which will cause issue in f_{f11}.

=>

Tunning freq → 5^{th} → 250 Hz

$$X_c = \frac{KV^2}{MVAr} = \frac{(33/\sqrt{3})^2}{6.2/3} = -j175.64\ \Omega$$

$$X_L = \frac{X_c}{n^2} = \frac{175.64}{25} = j7.025\ \Omega$$

$$C = \frac{1}{2\pi f X_C} = \frac{1}{100\pi(175.64)} = 1.81 \times 10^{-5}\ F = 18\ \mu F$$

$$L = \frac{X_L}{100\pi} = \frac{7.025}{100\pi} = 22.36\ mH$$

1) $X_{eff} = |X_c - X_L| = 168.61\ \Omega$

2) $$I_{F1} = \frac{V_P}{|X_c - X_L|} = \frac{19.05 \times 10^3}{168.61} = 113\ A$$

3) $$I_{nom} = \frac{V_P}{X_c} = \frac{19.05 \times 10^3}{175.64} = 108.46\ A$$

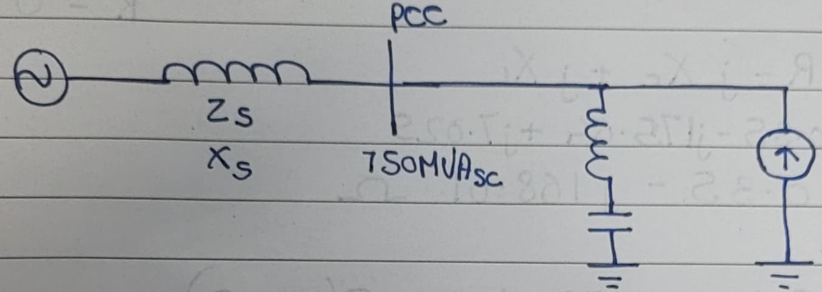
4) $V_{C1} = I_{F1}(X_{C1}) = 113(175.64) = 19.84\ kV$

5) $KVAr = V_{c1} \times I_{f1}$

$= 19.84 \times 10^3 \, (113)$

$= 2241.92 \ KVAr$

$= 2.241 \ MVar$



$$X_s = \frac{KV^2}{MVA_{sc}} = \frac{(33/\sqrt{3})^2}{750/3} = j1.45\,\Omega$$

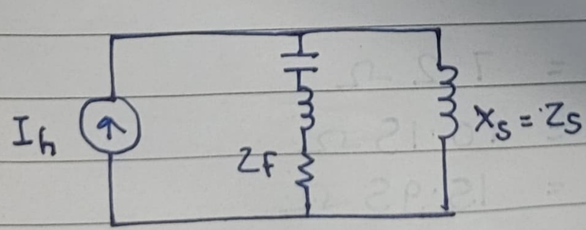
$$L_s = \frac{X_s}{2\pi f} = \frac{1.45}{100\pi} = 4.615\ mH$$

$$f_{p11} = \frac{1}{2\pi\sqrt{(L_s+L)C}} = \frac{1}{2\pi\sqrt{(22.36+4.61)\times 1.81\times10^{-8}}}$$

$$= 4.55 \times 50$$

$$h_{p11} = 4.55$$

b)



$$I_{L1} = \frac{P}{\sqrt{3} V_L \cos\phi} = \frac{20\times10^6}{\sqrt{3}(33\times10^3)\,0.75}$$

$$= 466.5\ A$$

$I_{L5} = 186.61\ A$ $\quad$ $I_{L7} = 46.65A$

$I_{L11} = 37.32\ A$ $\quad$ $I_{L13} = 18.66A$

$$Z_{f_h} = R - j\frac{X_c}{h} + jhX_L$$

$$Q = \frac{X_0}{R} = \frac{X_c/h}{R} = \frac{\frac{175.64}{5}}{R}$$

$$Z_{s_h} = hX_s$$

$$R = 0.35\ \Omega$$

$$Z_{f_1} = R - jX_c + jX_L$$
$$= 0.35 - j175.64 + j7.025$$
$$= 0.35 - j168.61\ \Omega$$

$$Z_{f_5} = 0.35 - j\frac{175.64}{5} + j5(7.025)$$
$$= 0.35\ \Omega$$

$$Z_{f_7} = 0.35 - \left(\frac{175.64}{7}\right) + j7(7.025)$$
$$= 0.35 + 24.08j\ \Omega$$

$$Z_{f_{11}} = 0.35 - j\left(\frac{175.64}{11}\right) + j11(7.025)$$
$$= 0.35 + 61.30j\ \Omega$$

$$Z_{f_{13}} = 0.35 - j\left(\frac{175.64}{13}\right) + 13(7.025)$$
$$= 0.35 + 77.81j\ \Omega$$

$$Z_{s_5} = 5(1.45) = 7.2\ \Omega$$
$$Z_{s_7} = 7(1.45) = 10.15\ \Omega$$
$$Z_{s_{11}} = 11(1.45) = 15.95\ \Omega$$
$$Z_{s_{13}} = 13(1.45) = 18.85\ \Omega$$

	5	7	11	13
Z_f	0.35	24.08	61.3	77.81
Z_s	7.2	10.15	15.95	18.85

DATE: / /

$I_{fh} = \frac{Z_{sh}}{Z_{sh}+Z_{fh}} I_{Lh}$ $\qquad I_{sh} = \frac{Z_{fh}}{Z_{sh}+Z_{fh}} \times I_{Lh}$

$I_{fs} = \frac{7.2}{7.2+0.35}(186.61)$ $\qquad I_{ss} = \frac{0.35}{7.2+0.35}\ 186.61$

$= 178.65$ $\qquad = 8.65$

$I_{f7} = \frac{10.15}{10.15+24.08}(46.65)$ $\qquad I_{s7} = \frac{24.08}{10.15+24.08}(46.65)$

$= 13.84\ A$ $\qquad = 32.81\ A$

$I_{f11} = \frac{15.95}{15.95+61.3}(37.32)$ $\qquad I_{s11} = \frac{61.3}{61.3+15.95}(37.32)$

$= 7.70\ A$ $\qquad = 29.61\ A$

$I_{f13} = \frac{18.85}{18.85+77.81}(18.66)$ $\qquad I_{s13} = \frac{77.81}{77.81+18.85}(18.66)$

$= 3.63\ A$ $\qquad = 15.01\ A$

	5	7	11	13
I_s	~~178~~ 8.65	32.81	29.61	15.01
I_F	~~8.65~~ 178	13.84	7.70	3.63

$I_{crms} = \sqrt{I_{f_1}^2 + I_{f_5}^2 + I_{f_7}^2 + I_{f_{11}}^2 + I_{f_{13}}^2}$

$= 211.46\ A$

$V_{cpeak} = V_{c1} + V_{c5} + V_{c7} + V_{c11} + V_{13}$

$V_{c5} = I_{f5} X_{c5} = 178\left(\frac{175.64}{5}\right) = 6.25\ kV$

$V_{c13} = 0.049\ kV$

$V_{c1} = 19.84\ kV$ $\qquad V_{c7} = 0.34\ kV$ $\qquad V_{c11} = 0.122\ kV$

$V_{cpeak} = 26.6\,kV$

$$V_{c(rms)} = \sqrt{V_{c1}^2 + V_{c5}^2 + V_{c7}^2 + V_{c11}^2 + V_{c13}^2}$$

$$= 20.8\,kV$$

$$\%\,V_{rms} = \frac{20.8}{19.05} \times 100 = 109\,\% \quad (\text{limit } 120\%)$$

$$\%\,I_{rms} = \frac{211.46}{108.46} \times 100 = 194\,\% \quad (\text{limit} = 180\%)$$

THD before compensation

$$\%\,THD = \frac{\sqrt{\sum_{1}^{n} I_{Lh}^2}}{I_1}$$

$$= \frac{\sqrt{I_{L5}^2 + I_{L7}^2 + I_{L11}^2 + I_{L13}^2}}{I_1}$$

$$= 42.09\%$$

After compensation

$$\%\,THD = \frac{\sqrt{\sum_{3}^{n} I_{Sh}^2}}{I_1^2}$$

$$= \frac{\sqrt{I_{S5}^2 + I_{S7}^2 + I_{S11}^2 + I_{S13}^2}}{I_{L1}}$$

$$= 10.4\%$$