Sol3

(3) let's take 11 kV as V_{Base}

1 MVA as S_{Base}

S.C. MVA = $\left(\frac{20}{1}\right) = 20$ PU

$X_{th} = \frac{1}{20} = 0.08$ PU

$S = VI$

$V = 1$ PU

load = 1 MVA @ 0.8 lagg PF

$\therefore (I) = (0.8 - j0.6)$ PU

$\boxed{(I)_L = 0.6 \text{ P.U}}$

$V_t = V + (I_C - I_L)X_{th}$ — (I)

& $V_t = (V_t)_{ref} - \alpha I_C$ — (II)

* when SVC off

V_t varies from 10.4 kV to 11.2 kV

$\Rightarrow$ 0.945 PU to 1.0182 PU.

$\therefore V_1 = (0.945) + (0.6 * 0.05)$

$\boxed{V_1 = 0.975 \text{ PU}}$

and $V_2 = 1.0182 + (0.6 * 0.5)$

$\boxed{V_2 = 1.0482 \text{ PU.}}$

(i)

(a) for $V_{ref} = 1$ PU and droop constant = 0.04 PU = α

$$\boxed{I_C = \frac{(V_t)_{ref} - V}{\alpha + X_{th}} + \frac{X_{th} I_L}{\alpha + X_{th}}}$$

$$= \frac{1 - 0.975}{0.04 + 0.05} + \frac{0.05 * 0.6}{0.04 + 0.05} = 0.27778 + 0.333$$

$= 0.611$

CamScanner

$$(I_c)_{max} = \omega C (V_t)_{ref}$$
$$= \frac{1}{X_C} \cdot (V_t)_{ref}.$$

Capacitive MVAR = 1 MVAR

for 1 P.U V_{ref}

$$\frac{1}{X_C} = 1 \text{ P.U}$$

Inductive MVAR = 0.3 MVAR

$$\frac{1}{X_L} = 0.3 \text{ P.U} \quad | V = 1 \text{ PU}$$

$$(I_c)_{max} = 1 * 1 \text{ PU} = 1 \text{ PU}$$

$$(I_c)_{min} = -\frac{(V_t)_{ref}}{\omega L} = 0.3 * 1 = -0.3 \text{ PU}.$$

$$\boxed{\text{SO: } I_C = 0.611 \text{ P.U} < (I_c)_{max}.}$$

$$\cancel{V_{t_1} = (V_t)_{ref} \frac{(X_{th})/\alpha}{1 + \left(\frac{X_{th}}{\alpha}\right)} + \frac{V}{1 + \left(\frac{X_{th}}{\alpha}\right)} - \frac{I_L X_{th}}{1 + \frac{X_{th}}{\alpha}}}$$

$$\cancel{= 1 * \frac{(0.05)/0.04}{1 + \left(\frac{0.05}{0.04}\right)} + \frac{0.975}{1 + \left(\frac{0.05}{0.04}\right)} - \frac{0.6 * 0.05}{1 + \left(\frac{0.05}{0.04}\right)}}$$

$$\cancel{= 0.5556 + 0.4333 - 0.0133}$$

$$\cancel{\boxed{V_{t_1} = 0.97556 \text{ PU}}}$$

$$\cancel{V_{t_1} = (0.9755) * 11 * 10^3}$$

$$\cancel{V_{t_1} = 10.7312 \text{ KV}}$$

$$V_{t_1} = (V_t)_{ref} - I_c \alpha$$
$$= 1 - 0.611 * 0.04$$
$$= 0.97556 \text{ PU}$$
$$= 10.73116 \text{ KV}$$

for $V_2 = 1.0482$ PU

$$I_C = \frac{(V_t)_{ref} - V}{\alpha + X_{th}} + \frac{X_{th} I_L}{\alpha + X_{th}}$$

$$= \frac{1 - 1.0482}{0.04 + 0.05} + \frac{0.05 * 0.6}{0.04 + 0.05}$$

$$= -0.5355 + 0.333$$

$$= -0.202 \text{ PU} \checkmark\checkmark \text{ in the Range}$$

$$\boxed{(I_c)_{min} = -0.3 \text{ PU}}$$

$$V_{t_2} = (V_t)_{ref} \cdot \frac{X_{th}/\alpha}{1 + \left(\frac{X_{th}}{\alpha}\right)} + \frac{V}{1 + \frac{X_{th}}{\alpha}} - \frac{I_L X_{th}}{1 + \frac{X_{th}}{\alpha}}$$

$$= 1 * \frac{0.05/0.04}{1 + \left(\frac{0.05}{0.04}\right)} + \frac{1.0482}{1 + \left(\frac{0.05}{0.04}\right)} - \frac{0.6 * 0.05}{1 + \frac{0.05}{0.04}}$$

$$= 0.5556 + 0.46586 - 0.0133$$

$$= 1.0081 \text{ PU}$$

$$= 1.0081 * 11 \times 10^3$$

$$= 11.0891 \text{ KV}$$

$$V_{t_2} = V_{t\,ref} - I_c \alpha$$

$$= 1 - (-0.202) * 0.04$$

$$= 1.008$$

$$= 11.088 \text{ KV}$$

so;

$$\boxed{10.732 \text{ KV} \le V_t \le 11.089 \text{ KV}}$$

$V_1 = 0.975$ PU
$V_2 = 1.0482$ PU

(ii) for $\alpha = 0.1$

for V_1

$$I_c = \frac{(V_t)_{ref} - V}{\alpha + X_{th}} + \frac{X_{th} I_L}{\alpha + X_{th}}$$

$$= \frac{1 - 0.975}{0.1 + 0.05} + \frac{0.05 * 0.6}{0.1 + 0.05}$$

$$= 0.1667 + 0.2$$

$$= 0.3667 \text{ PU} < (I_c)_{max}$$

$$V_{t_1} = \frac{(V_t)_{ref} \cdot \left(\frac{X_{th}}{\alpha}\right)}{1 + \left(\frac{X_{th}}{\alpha}\right)} + \frac{V}{1 + \frac{X_{th}}{\alpha}} - \frac{I_L X_{th}}{1 + \frac{X_{th}}{\alpha}}$$

$$= \frac{1 * (0.05/0.1)}{1 + \left(\frac{0.05}{0.1}\right)} + \frac{0.975}{1 + \frac{0.05}{0.1}} - \frac{0.6 \times 0.05}{1 + \frac{0.05}{0.1}}$$

$$= 0.33 + 0.65 - 0.02$$

$$= 0.96 \text{ PU}$$

$$= 10.56 \text{ KV}$$

$$V_t = (V_t)_{ref} - \alpha I_c$$

$$= 1 - (0.1) * 0.3667$$

$$= 0.9633 \text{ PU}$$

$$= 10.596 \text{ KV}$$

and for V_2

$$I_c = \frac{(V_t)_{ref} - V}{\alpha + X_{th}} + \frac{X_{th} I_L}{\alpha + X_{th}}$$

$$= \frac{1 - 1.0482}{0.1 + 0.05} + \frac{0.05 \times 0.6}{0.1 + 0.05}$$

$$= -0.32133 + 0.2$$

$$V_{t_2} = \frac{(V_t)_{ref}\left(\frac{X_{th}}{\alpha}\right)}{1+\left(\frac{X_{th}}{\alpha}\right)} + \frac{V}{1+\left(\frac{X_{th}}{\alpha}\right)} - \frac{I_c X_{th}}{1+\left(\frac{X_{th}}{\alpha}\right)}$$

$$= \frac{1 * \frac{0.05}{0.1}}{1+\frac{0.05}{0.1}} + \frac{1.0482}{1+\frac{0.05}{0.1}} + \frac{0.6 \times 0.05}{1+\frac{0.05}{0.1}}$$

$$= 0.33 + 0.6988 - 0.02$$

$$= 1.0088 \text{ PU}$$

$$= 11.0968 \text{ kV}$$

$$V_{t_2} = (V_t)_{ref} - I_c \alpha$$

$$= 1 - (-0.12133) * 0.1$$

$$= 1.012133 \text{ PU}$$

$$= \underline{11.1334 \text{ kV}}$$

$$10.56 \text{ kV} \le V_t \le \cancel{11.0968} \text{ kV}$$

$$\boxed{10.596 \text{ kV} \le V_t \le 11.1334 \text{ kV}}$$

Ques (4) 110 kV, 50 Hz

TSC-TCR Unit

MVAR Rating = 25 MVAR → Cap.

7.5 MVAR → inductive

S.C MVA = 250 MVA @ 0 lagg

no. of units = 5

Soln :-

Base V = 110 kV

Base MVA = 50 MVA

$\alpha = 0.05$ PU, P.M = 50°

$$S.C\ MVA = \left(\frac{250}{50}\right) = 5\ P.U$$

$$X_{th} = \frac{1}{SC\ MVA} = \frac{1}{5} = 0.2\ PU$$

Now; $f = 50$ Hz

$T = 20$ msec.

$T_d = \left(\frac{T}{3}\right) = 6.67$ msec.

$$f_{co} = \frac{1}{10\,T_d} = \frac{1}{10 * 6.67\,msec} = 15\ Hz.$$

$$\omega_{co} = 2\pi f_{co}$$

$$= 30\pi$$

sensing function $T_s = \frac{1}{2\pi \times 15} = 10.6$ msec

Sensing funcn. $= \frac{1}{(1 + 0.0106 S)}$

$$(360^\circ - \phi) = 180 + 90 + \left(w_{co} T_d \cdot \frac{180}{\pi}\right) + \left(\tan^{-1} w_{co} \cdot T_s\right) - \tan^{-1}(w_{co} T_i) - \tan^{-1}\left(\frac{w_{co} \cdot \alpha T_s}{\alpha + x_{th}}\right)$$

$$\Rightarrow (360^\circ - 50^\circ) = 270 + \left(30\cancel{\pi} \cdot 6.67 \times 10^{-3} \times \frac{180}{\cancel{\pi}}\right) + \tan^{-1}\left(30\pi \times 10.6 \times 10^{-3}\right) - \tan^{-1}\left(30\pi \times T_i\right) - \tan^{-1}\left(\frac{30\pi \times 0.05 \times 10.6 \times 10^{-3}}{0.05 + \cancel{0.05}\ 0.2}\right)$$

$$310^\circ = 270^\circ + \left(36^\circ\right) + \underbrace{\tan^{-1}\left(\ \right)}_{44.972^\circ \simeq 45^\circ} - \tan^{-1}(w_{co} T_i) - \underbrace{\tan^{-1}(0.1998)}_{11.299^\circ \simeq 11.3^\circ}$$

$$310^\circ = 270^\circ + 36^\circ + 45^\circ - \tan^{-1}(w_{co} T_i) - 11.3^\circ$$

$$\tan^{-1}(w_{co} T_i) = 29.7^\circ$$

$$w_{co} T_i = 0.57038$$

$$T_i = \left(\frac{0.57038}{30\pi}\right) = 0.006052 = 6.052 \times 10^{-3}$$

$$\frac{K_p}{K_i}$$

<u>Now;</u>

$$K_i(\alpha + X_{th}) \cdot \frac{\sqrt{1+(\omega_{co}T_i)^2}}{\omega_{co}} \quad \frac{\sqrt{1+\left(\frac{\omega_{co}\alpha T_s}{\alpha + X_{th}}\right)^2}}{\sqrt{1+(\omega_{co}T_s)^2}} = 1$$

$$K_i(0.2+0.05) \cdot \frac{\sqrt{1+(30\pi * 6.052\times10^{-3})^2}}{30\pi} \quad \frac{\sqrt{1+\left(\frac{30\pi\times0.05*10.6*10^{-3}}{0.05+0.2}\right)^2}}{\sqrt{1+(30\pi \cdot 10.6 * 10^{-3})^2}} = 1$$

$$K_i(0.25) \cdot \left(\frac{1.1512}{30\pi}\right) \cdot \left(\frac{1.01976}{1.4135}\right) = 1$$

$$\boxed{K_i = 453.9188}$$

$$\left(\frac{K_p}{K_i}\right) = 6.052\times10^{-3}$$

$$K_p = (6.052 * 10^{-3}) * 14$$

$$\boxed{K_p = 2.747}$$