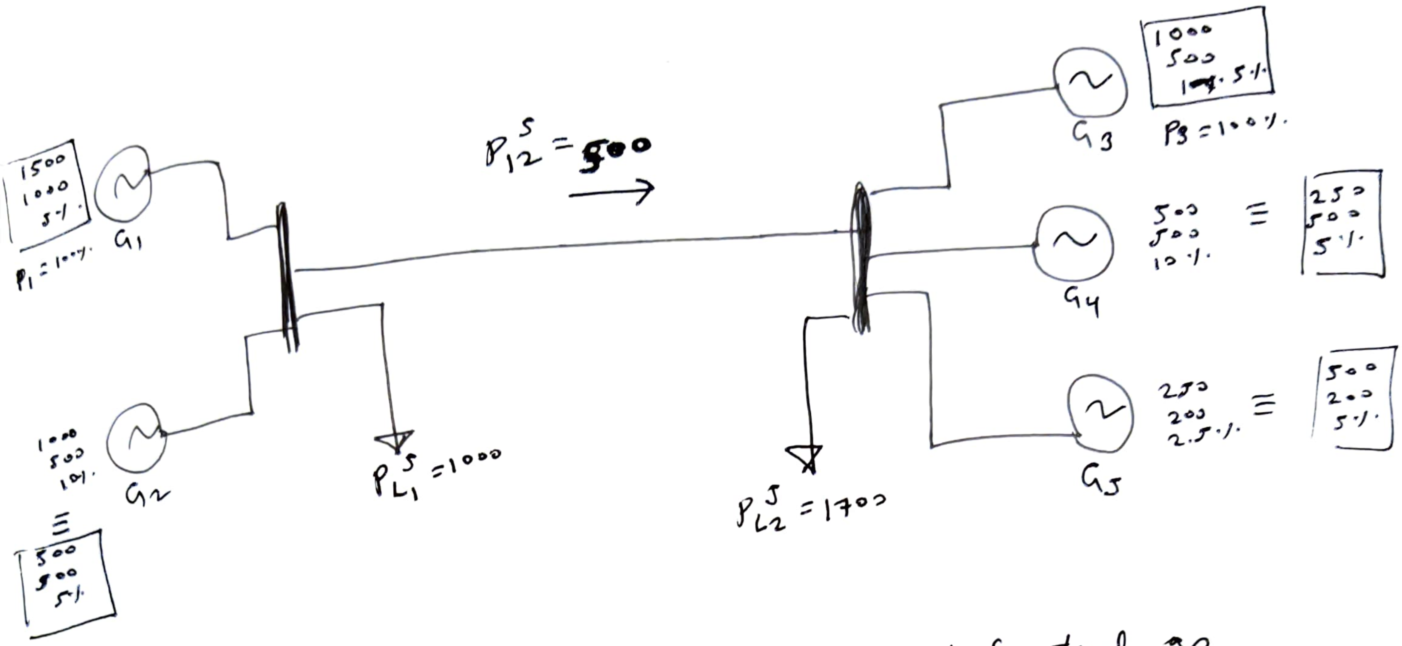
$\boxed{7.1.1}$



Note: G_4 will NOT participate in Droop Control as

$$P_{G_4} = \underbrace{G_4}_{\text{gen. rating}} \text{ already}$$

$$G_{system} = 1500 + 500 + 1000 + 0 + 500$$

$$\Rightarrow \boxed{G_{system} = 3500\,\text{MVA}}$$

$\boxed{\text{Scenario 1}}$

P_{L_1} ↑es by +100 MW.

$$P_{L_1}^{a} = 1100\,\text{MW}.$$

$$-\frac{1}{R_1}\underbrace{\Delta\omega_1}_{(\omega_1 - 1)} = \Delta P_{L_1}$$

$$\boxed{\Delta P_L = \Delta P_{L_1} = +0.02857\,\text{pu}} \rightarrow y$$

$$\Rightarrow \omega_1 - 1 = -0.05 \times \frac{(+100)\,\text{MW}}{3500\,\text{MVA}}$$

$$\Rightarrow \boxed{\omega_1 = \overset{x}{0.9986}\,\text{pu}} \boxed{= 59.9143\,\text{Hz}}$$

$$\boxed{\Delta P_{G_i} = \Delta P_{L_i}[\text{pu}] \times \underset{\text{Machine Rating}}{G_i}} \quad i = 1,2,3,5$$

~~$\Delta P_{M_1} = -R_1 \Delta\omega_1$~~

~~$\Rightarrow \Delta P_{G_1} = (+100) \times \frac{1500}{3500}$~~

Governor action

$$\Delta P_{G_1} = +42.8571\,\text{MW}$$
$$\Delta P_{G_2} = +14.2857\,\text{MW}$$
$$\Delta P_{G_3} = +28.5714\,\text{MW}$$
$$\Delta P_{G_4} = 0\,\text{MW}$$
$$\Delta P_{G_5} = +14.2857\,\text{MW}$$

Ans

$\boxed{7.1.2}$

$$ACE_1 = \underset{[pu]}{\Delta P_{net_1}} + \beta_1 \underset{(pu)}{\Delta \omega_1}$$

$$\text{or } ACE_1 = \left\{ \underset{(pu)}{P_1^a} - \underset{[pu]}{P_1^s} \right\} + \frac{1}{R_1} \underset{(pu)}{\Delta \omega_1}$$

$$\text{or } ACE_1 = \left\{ \left(\underset{(pu)}{P_{G_1}^a} + \underset{(pu)}{P_{G_2}^a} - \underset{(pu)}{P_{L_1}^a} \right) - \underset{[pu]}{P_{12}^s} \right\} + \frac{1}{R_1} \underset{[pu]}{\Delta \omega_1}$$

$$\text{or } ACE_1 = \left\{ \underset{\frac{\cancel{y} \times G_1}{G_{A_1}}}{\underset{\downarrow}{\Delta P_{G_1}}} + \underset{\frac{\cancel{y} \times G_2}{G_{A_1}}}{\underset{\downarrow}{\Delta P_{G_2}}} - \underset{\frac{\cancel{y} \times G_{sup}}{G_{A_1}}}{\underset{\downarrow}{\Delta P_{L_1}}} \right\} + \underset{20}{\underset{\downarrow}{\frac{1}{R_1}}} \underset{(n-1)}{\underset{\downarrow}{\Delta \omega_1}}$$

$\text{or } \cancel{\boxed{ACE_1 = -0.04082}}$

$\text{or } \boxed{ACE_1 = -0.05_{pu}} \Rightarrow \underset{AGC}{\Delta P_{Area_1}} = -ACE_1 \times G_1 = 100 MW$

$\Rightarrow \Delta P_{G_1} = \Delta P_{Area_1} \times 100\%$

$\text{or } \boxed{\Delta P_{G_1} = +100 MW}$ Ans

$\boxed{\text{AGC Action}}$

$$ACE_2 = \underset{(pu)}{\Delta P_{net_2}} + \beta_2 \underset{(pu)}{\Delta \omega_2}$$

$$\text{or } ACE_2 = \left\{ \left(P_{G_3}^a + P_{G_4}^a + P_{G_5}^a - \underset{[pu]}{P_{L_2}^a} \right) - \underset{(pu)}{P_2^s} \right\} + \frac{1}{R_2} \Delta \omega_2$$

$$\text{or } ACE_2 = \left\{ \Delta P_{G_3} + \Delta P_{G_4} + \underset{(pu)}{\Delta P_{G_5}} - \underset{(pu)}{\Delta P_{L_2}} \right\} + \frac{1}{R_2} \Delta \omega_2$$

$\text{or } \cancel{ACE_2 =}$

$$\text{or } ACE_2 = \left\{ \frac{y \cdot G_3}{G_{A_2}} + 0 + \frac{y \cdot G_5}{G_{A_2}} - 0 \right\} + 20(n-1)$$

$$\text{or } \boxed{ACE_2 = 0_{pu}}$$

$\boxed{\text{Scenario 2}}$ $\boxed{7.2.1}$

$P_{L2} \uparrow_{es}$ by $+100\,MW$

$P_{L2}^{a} = 1800\,MW$

$$\boxed{\underset{(pu)}{\Delta P_L} = \underset{(pu)}{\Delta P_{L2}} = \frac{+100\,MW}{3500\,MVA} = +0.02857\,pu \rightarrow y}$$

$$\Delta\omega = \Delta\omega_2 = \Delta\omega_1 = \cancel{\frac{-1}{R_2}} - R_2 \Delta P_{L2}^{(pu)}$$

$$\cancel{\Delta\omega_2 =} \Rightarrow \boxed{\omega_2 = \omega_1 = \omega = 0.99857\,pu \rightarrow x} = 59.9143\,Hz$$

$$\underset{[MW]}{\Delta P_{G_i}} = \underbrace{-\frac{1}{R_i}(\omega_i - 1)}_{\Delta P_L\,(pu)} \times G_i \quad i = 1, 2, 3, 5$$

governor action

$$\Delta P_{G_1} = \underbrace{-20(x-1)}_{y} \times 1500 = +42.8571\,MW$$

$$\Delta P_{G_2} = \underbrace{-20(x-1)}_{y} \times 500 = +14.2857\,MW$$

$$\Delta P_{G_3} = \underbrace{-20(x-1)}_{y} \times 1000 = +28.5714\,MW$$

$$\Delta P_{G_4} = 0 = 0\,MW$$

$$\Delta P_{G_5} = \underbrace{-20(x-1)}_{y} \times 500 = +14.2857\,MW$$

$$ACE_1 = \Delta P_{Net_1} + \underbrace{\beta_1 \Delta\omega_1}_{-y}$$

$$\text{or } ACE_1 = \left\{ \frac{\Delta P_{G_1} + \Delta P_{G_2} - \cancel{\Delta P_{L_1}}}{G_{Area\,1}} \right\} + \underbrace{\frac{1}{R_1}\Delta\omega_1}_{-y}$$

$$\text{or } ACE_1 = \left\{ \frac{y G_1 + y G_2}{G_1 + G_2} \right\} - y$$

$$\therefore ACE_1 = y - y$$

$$\boxed{\therefore ACE_1 = 0}$$

$$ACE_2 = \underset{(pu)}{\Delta P_{Net_2}} + \overbrace{\underset{(pu)}{\beta_2 \Delta \omega_2}}^{-y}$$

$$\text{or } ACE_2 = \underset{(pu)}{\left\{\Delta P_{G_3} + \Delta P_{G_4} + \Delta P_{G_5} - \Delta P_{L_2}\right\}} + \underbrace{\frac{1}{R_2}\Delta \omega_2}_{-y}$$

$$\text{or } ACE_2 = \left\{\frac{G_3 y + G_4 \times 0 + G_5 y - G_{sup}\, y}{G_{Ar2}}\right\} - y$$

$$\text{or } ACE_2 = y\left\{\frac{G_3 + G_5 - G_{sup}}{G_3 + G_5}\right\} - y$$

$$\text{or } \boxed{ACE_2 = -0.0667 \text{ pu}}$$

$$\Rightarrow \Delta P_{G Ar2} = -ACE_2 \times G_{Ar2}$$

$$\text{or } \Delta P_{G Ar2} = 0.0667 \times 1500 \text{ MW}$$

$$\text{or } \Delta P_{G Ar2} = +100 \text{ MW} \Rightarrow \underset{\text{or } P_{G_3} = 100\%}{\overset{\text{AGC Action}}{\boxed{\Delta P_{G_3} = +100 \text{ MW}}}}$$

Ans

$\boxed{\text{Scenario 3}}$

P_{L1} ↓es by 200 MW ⇒ $\Delta P_{L1} = -200$ MW

&&

P_{L2} ↑es by 100 MW ⇒ $\Delta P_{L2} = +100$ MW.

$\Delta P_L = \Delta P_{L1} + \Delta P_{L2} = -100$ MW

$$\boxed{\Delta P_L\,[pu] = \frac{-100\text{ MW}}{3500\text{ MVA}} = \underbrace{-0.02857}_{y}\ pu}$$

$\Delta \omega = \cancel{\frac{1}{R}} - R\,\Delta P_L\,(pu)$

or ~~$\Delta\omega$ =~~

→ $\boxed{\omega = \underbrace{1.001428\ pu}_{x}} = \boxed{60.0857\ Hz}$

$\cancel{\Delta}$ $\underset{[MW]}{\Delta P_{G_i}} = \underbrace{-\Delta P_{L_{sys}}}_{y} \times G_i \qquad i = 1, 2, 3, 5$

governor action

$\Delta P_{G1} = -42.8571$ MW

$\Delta P_{G2} = -14.2857$ MW ~~-28.5714 MW~~

$\Delta P_{G3} = -28.5714$ MW

$\Delta P_{G4} = 0$ MW

$\Delta P_{G5} = -14.2857$ MW

$ACE_1 = \underset{(pu)}{\Delta P_{Net\,1}} + \underbrace{\beta_1 \Delta\omega_1}_{-y\ (pu)}$

or $ACE_1 = \{\Delta P_{G1} + \Delta P_{G2} - \Delta P_{L1}\}_{(pu)} - y$

or ~~$ACE_1 = yG_1 + yG_2 + \ldots$~~

→ $ACE_1 = \left\{\dfrac{yG_1 + yG_2 + 200\text{ MW}}{G_1 + G_2}\right\} - y = \cancel{y} - \cancel{y} + \dfrac{200}{(G_1+G_2)}$

or $\boxed{ACE_1 = +0.1\ pu}$ ⇒ $\Delta P_{G_{Area\,1}} = -ACE_1 \times G_{Area\,1}$

→ $\boxed{\Delta P_{G\,A\,1} = -200\text{ MW}}$ ⟹ $\boxed{\Delta P_{G1} = -200\text{ MW}}$

@ $P_{G1} = 100\%$.

$\boxed{7.3.2}$

$$ACE_2 = \underset{[pu]}{\Delta P_{Net2}} + \underset{[pu]}{\overbrace{\beta_2 \Delta \omega_2}^{-y}}$$

$$\text{or } ACE_2 = \left\{ \Delta P_{G3} + \Delta P_{G4} + \underset{[pu]}{\Delta P_{G5}} - \Delta P_{L2} \right\} - y$$

$$\text{or } ACE_2 = \left\{ \frac{yG_3 + 0 + yG_5 - 100\,MW}{G_{Area2}} \right\} - y$$

$G_{Area2} \rightarrow G_3 + G_5$

$$\text{or } ACE_2 = \left\{ \frac{yG_3 + yG_5 - 100\,MW}{G_3 + G_5} \right\} - y$$

$$\text{or } ACE_2 = \cancel{y} - \frac{100\,MW}{G_3 + G_5} - \cancel{y}$$

$$\text{or } \boxed{ACE_2 = -0.0667\ pu}$$

$$\Rightarrow \Delta P_{G_{Area2}} = -ACE_2 \times \overset{G_3+G_5}{G_{Area2}}$$

$$\text{or } \boxed{\Delta P_{G_{Area2}} = +100\,MW}$$

$$\Rightarrow \boxed{\Delta P_{G3} = +100\,MW} \text{ Ans}$$

@ $P_{G3} = 100\%$

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