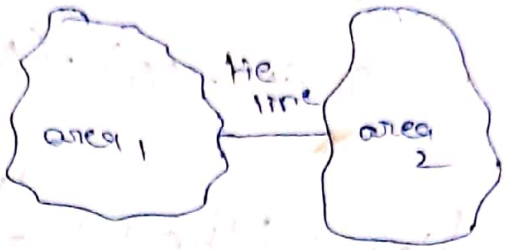
UNIT - 5

LOAD FREQUNCY CONTROl - II

25/9/19

derivation of two area load frequency controll (LFC) :-



→ power flow in control area 1 can be expressed as

$$P_{tie,1} = \frac{|V_1||V_2|}{X_{12}} \sin(\theta_1 - \theta_2) \rightarrow (1)$$

→ power flow in control area 2 can be expressed as

$$P_{tie,2} = \frac{|V_2||V_1|}{X_{21}} \sin(\theta_2 - \theta_1) \rightarrow (2)$$

where, $|V_1||V_2|$ are vtg magnitudes of area 1 & 2

→ X_{12} (or) X_{21} = Tie line reactance

→ If their is a change in load demand of two areas their will be a incremental changes in power angles $[\Delta\theta_1 \& \Delta\theta_2]$.

→ Then the change in tie line power is

$$P_{tie,1} + \Delta P_{tie,1} = \frac{|V_1||V_2|}{X_{12}} \sin\left[(\theta_1 - \theta_2) + (\Delta\theta_1 - \Delta\theta_2)\right]$$

$$\left(\because \sin(a-b) = \sin a\cos b + \cos a \sin b\right)$$

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$$P_{tie,1} + \Delta P_{tie,1} = \frac{|V_1||V_2|}{X_{12}} \left[\sin(\theta_1 - \theta_2) \cos(\Delta\theta_1 - \Delta\theta_2) + \cos(\theta_1 - \theta_2) \sin(\Delta\theta_1 - \Delta\theta_2) \right]$$

let $\Delta\theta_1 - \Delta\theta_2 = 0$

$\sin(\Delta\theta_1 - \Delta\theta_2) = (\Delta\theta_1 - \Delta\theta_2)$

$$P_{tie,1} + \Delta P_{tie,1} = \frac{|V_1||V_2|}{X_{12}} \left[\sin(\theta_1 - \theta_2) + \cos(\theta_1 - \theta_2)(\Delta\theta_1 - \Delta\theta_2) \right]$$

$$\Delta P_{tie,1} = \frac{|V_1||V_2|}{X_{12} P_{r_1}} \cos(\theta_1 - \theta_2)(\Delta\theta_1 - \Delta\theta_2)$$

Similarly

$$\Delta P_{tie,2} = \frac{|V_2||V_1|}{X_{21} P_{r_2}} \cos(\theta_2 - \theta_1)(\Delta\theta_2 - \Delta\theta_1)$$

$\Delta P_{tie,1} = T_{12}(\Delta\theta_1 - \Delta\theta_2)$; $\Delta P_{tie\,2} = T_{21}(\Delta\theta_2 - \Delta\theta_1)$

T_{12} (or) T_{21} = synchronizing coefficient of tie line power ① & ②

$$T_{12} = \frac{|V_1||V_2|}{X_{12} P_{r_1}} \cos(\theta_1 - \theta_2) \rightarrow ③$$

$$T_{21} = \frac{|V_2||V_1|}{X_{21} P_{r_2}} \cos(\theta_2 - \theta_1) \rightarrow ④$$

$$\frac{T_{21}}{T_{12}} = \frac{\frac{|V_2||V_1|}{X_{21} P_{r_2}} \cos(\theta_1 - \theta_2)}{\frac{|V_1||V_2|}{X_{12} P_{r_1}} \cos(\theta_2 - \theta_1)}$$

$X_{21} = X_{12}$

$\cos(-(\theta_1 - \theta_2)) = \cos(\theta_1 - \theta_2)$

$$\frac{T_{21}}{T_{12}} = \frac{P_{r_1}}{P_{r_2}}$$

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$$T_{21} = \frac{P_{r1}}{P_{r2}} T_{12} \qquad \because a_{12} = \frac{P_{r1}}{P_{r2}}$$

$$\boxed{T_{21} = a_{12} T_{12}} \rightarrow (5)$$

let $\frac{d(\Delta\theta)}{dt} = 2\pi\Delta f$

$$\Delta\theta = \int 2\pi\Delta f\, dt$$

$$\Delta\theta_1 = \int 2\pi\Delta f_1 dt \quad ; \quad \Delta\theta_2 = \int 2\pi\Delta f_2 dt$$

$$(1) \Rightarrow \Delta P_{tie,1} = T_{12}\left(\int 2\pi\Delta f_1 dt + \int 2\pi\Delta f_2 dt\right)$$

$$= 2\pi T_{12}\left[\int \Delta f_1 dt - \int \Delta f_2 dt\right]$$

laplace T/f.

$$\Delta P_{tie,1}(s) = 2\pi T_{12}\left[\frac{\Delta f_1(s)}{s} - \frac{\Delta f_2(s)}{s}\right]$$

$$\boxed{\Delta P_{tie,1}(s) = \frac{2\pi T_{12}}{s}\left[\Delta f_1(s) - \Delta f_2(s)\right]}$$

~~Similarly~~

$$(2) \Rightarrow \Delta P_{tie,2} = T_{21}\left[\int 2\pi\Delta f_2 dt - \int 2\pi\Delta f_1 dt\right]$$

$$= 2\pi T_{21}\left[\int \Delta f_2 dt - \int \Delta f_1 dt\right]$$

laplace T/f.

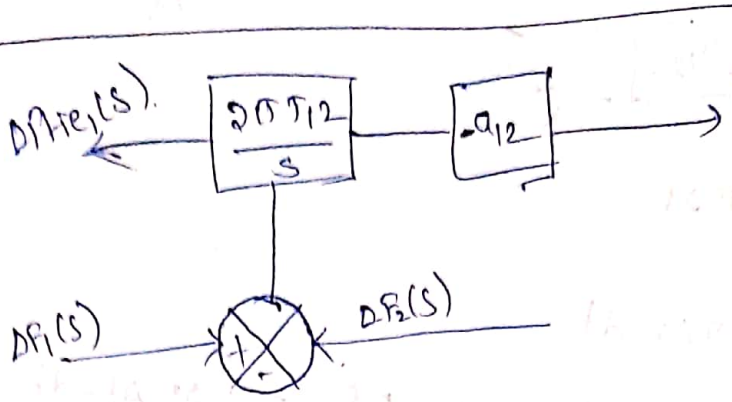
$$\Delta P_{tie,2}(s) = 2\pi T_{21}\left[\frac{\Delta f_2(s)}{s} - \frac{\Delta f_1(s)}{s}\right]$$

$$= \frac{2\pi T_{21}}{s}\left[\Delta f_2(s) - \Delta f_1(s)\right]$$

$$\boxed{\Delta P_{tie,2}(s) = \frac{-2\pi T_{21}}{s}\left[\Delta f_1(s) - \Delta f_2(s)\right]}$$

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$$\Delta P_{tie,2}(s) = \frac{-2\pi a_{12} T_{12}}{s}\left[\Delta f_1(s) - \Delta f_2(s)\right] \quad \text{--- eqn (5)}$$



→ Here, we take power balance eqn (or) simply power eqn is,

$$\Delta P_G - \Delta P_D = \frac{2H}{f^0}\frac{d(\Delta f)}{dt} + B\Delta f$$

→ For two area load frequency control the power balance eqn can be expressed as

area-1

$$\Delta P_{G_1} - \Delta P_{D_1} = \frac{2H}{f^0}\frac{d(\Delta f_1)}{dt} + B_1\Delta f_1 + \Delta P_{tie,1}$$

Apply laplace T/f

$$\Delta P_{G_1}(s) - \Delta P_{D_1}(s) = \frac{2H}{f^0} s\Delta f_1(s) + B_1\Delta f_1(s) + \Delta P_{tie,1}$$

$$\Delta P_{G_1}(s) - \Delta P_{D_1}(s) = \Delta f_1(s)\left[\frac{2Hs}{f^0} + B_1\right] + \Delta P_{tie,1}(s)$$

$$\Delta P_{G_1}(s) - \Delta P_{D_1}(s) - \Delta P_{tie,1}(s) = \Delta f_1(s)\left[\frac{2Hs}{f^0} + B_1\right]$$

$$\Delta f_1(s) = \frac{\Delta P_{G_1}(s) - \Delta P_{D_1}(s) - \Delta P_{tie,1}(s)}{\left[\frac{2Hs}{f^0} + B_1\right]}$$

$\left[\because K_{P_1} = \frac{1}{B_1},\ T_{P_1} = \frac{2H}{f^0}\right]$

$$\Rightarrow \Delta f_1(s) = \left[\Delta P_{G_1}(s) - \Delta P_{D_1}(s) - \Delta P_{tie,1}(s)\right]\left(\frac{K_{P_1}}{1+sT_{P_1}}\right)$$

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similarly,

$$\Delta f_2(s) = \frac{\Delta P_{G_2}(s) - \Delta P_{D_2}(s) - \Delta P_{tie_2}(s)}{\left[\frac{2Hs}{f^0} + B_2\right]}$$

$$\Rightarrow \Delta f_2(s) = \left(\Delta P_{G_2}(s) - \Delta P_{D_2}(s) - \Delta P_{tie_2}(s)\right)\left[\frac{K_{P_2}}{1+sT_{P_2}}\right]$$

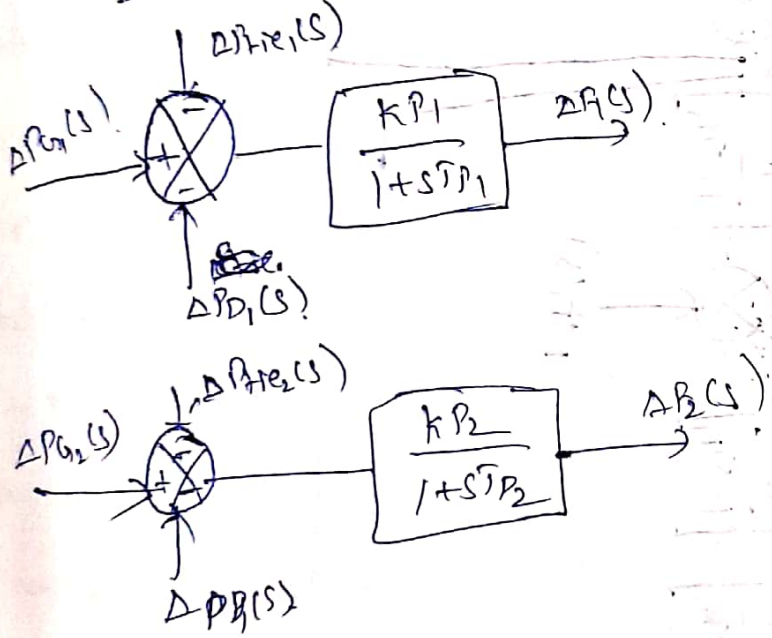
$$\therefore K_{P_2} = \frac{1}{B_2}; \quad T_{P_2} = \frac{2H}{f^0}$$

K_{P_1} = gain constant of generator (1)

K_{P_2} = " " " " (2)

T_{P_1} = Time " " " (1)

T_{P_2} = " " " " (2)



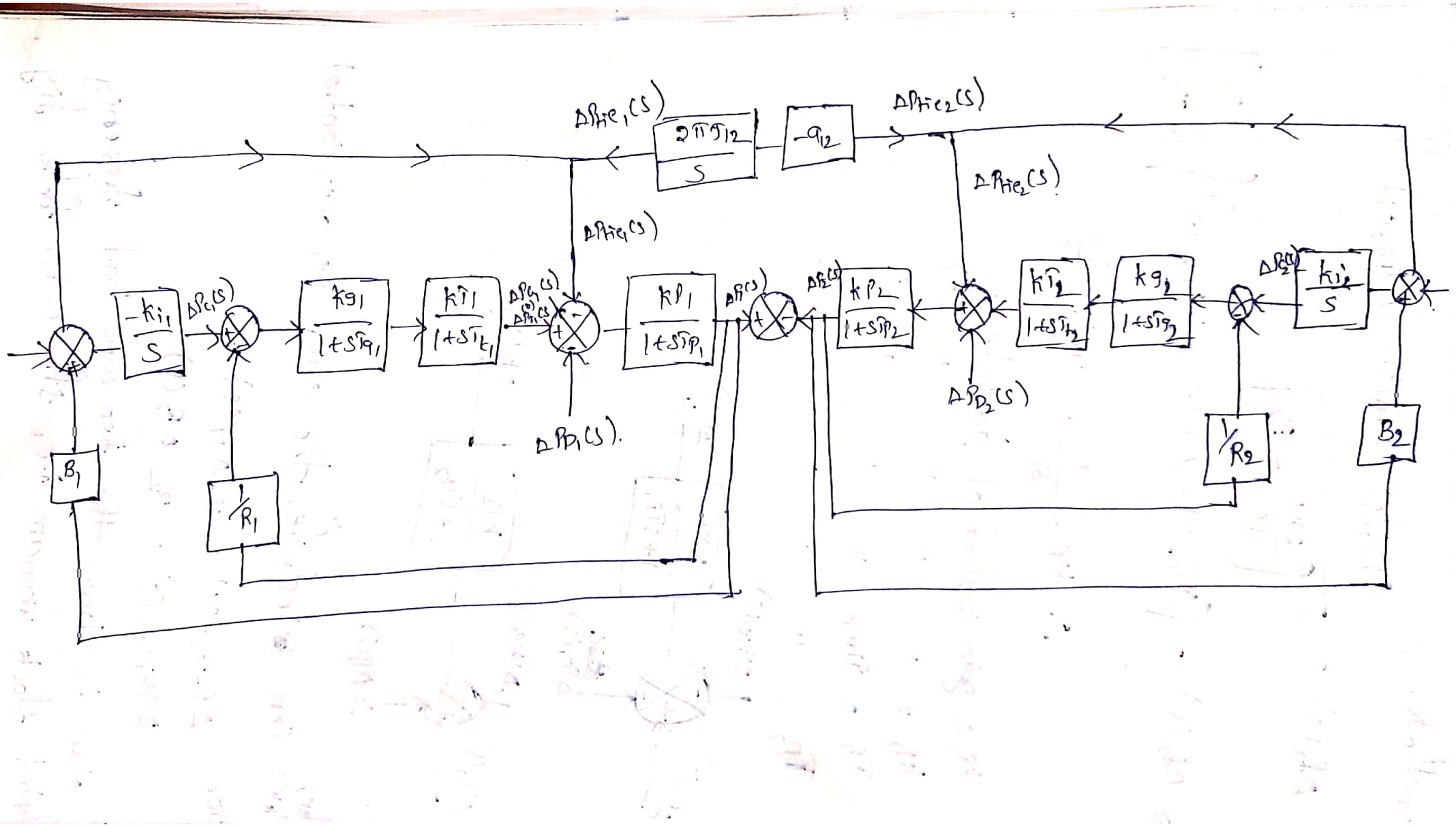
here, we can include the error i.e, area control error

$$\Delta P_{tie,1}(s) = B_1 \Delta F_1(s)$$

$$\Delta P_{tie,2}(s) = B_2 \Delta F_2(s)$$

Now, to draw the two area load frequency control block diagram i.e, shown in below fig.

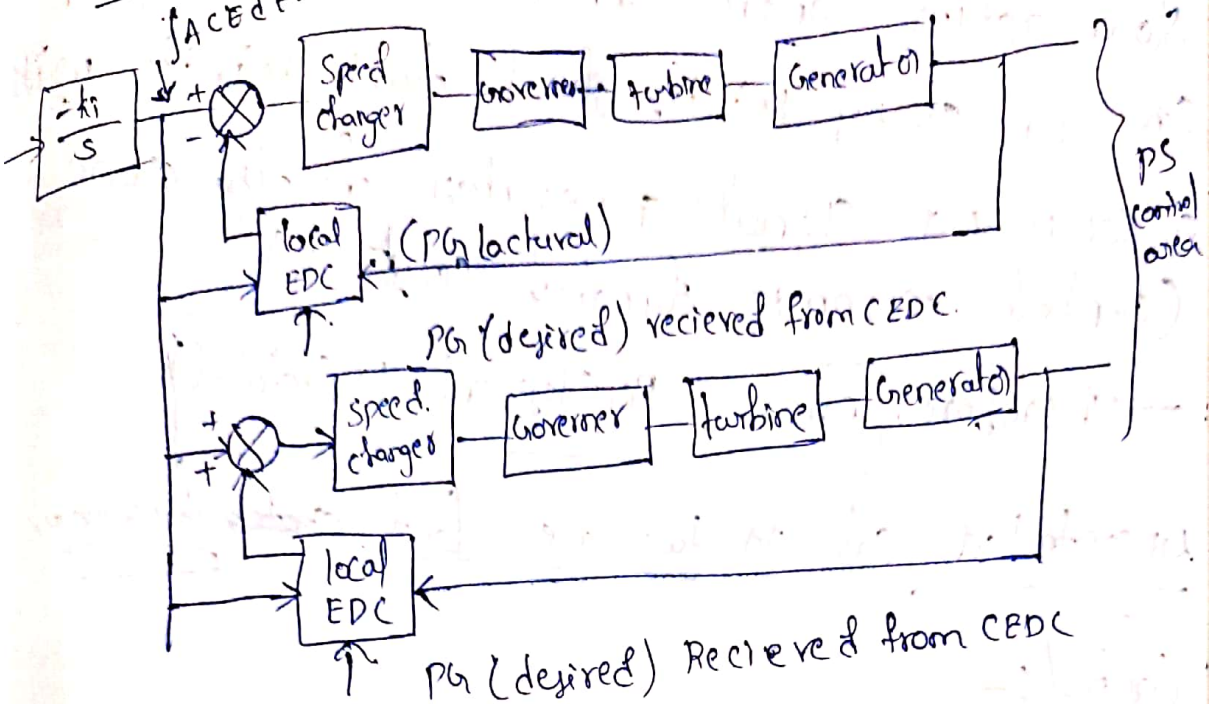
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6/9/19

Load frequency control & economic dispatch control :-



→ load frequency control with integral control achieves zero study state frequency but it excerises no control over the relative loading of various generating stations of the control area.

→ For example, if a sudden small increase in load (say one person) occurs in a control area, the LFC changes the speed changes a setting of the governers of all generating units of the area so, that these units match the load and the frequency returns to the scheduled the value. (This action takes place few seconds).

→ A satisfactory soln is achieved by using independent control's for load frequency and economic dispatch.

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→ while, the LFC is fast acting control (few secondy) and economic dispatch control is a slow acting control which adjects the speed changer every minite or half minite with a command signal generated by the CEDC (central economic dispatch control).

→ Therefore, $\boxed{\text{error} = P_{G1}(\text{desired}) - P_{G1}(\text{actural})}$

Uncontrolled case of two area load frequency control :-

→ we consider 1st uncontrolled case

$$\Delta P_{G1}(s) = \Delta P_{G2}(s) = 0$$

→ Due to the incremental load we shall have the frequency drop in the study state and the block will be equal to $\Delta f_1 static = \Delta f_2 static = \Delta f static$

And we will have incremental i.e, line power in steady state i.e, $\Delta P_{tie,1}$ stat

Refer the fig the incremental increase in generat in this static case is obtained by the static loop going only and we have

$$\Delta P_{G1,stat} = \frac{-1}{R_1} \Delta f_{stat} \rightarrow (1)$$

$$\Delta P_{G2,stat} = \frac{-1}{R_2} \Delta f_{stat} \rightarrow (2)$$

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Referring extending eqn for area ① & ②

Assume, $\frac{d(\Delta F)}{dt} = 0$ then.

$$\Delta P_G - \Delta P_D = \frac{2H}{f^\circ} \frac{d(\Delta F)}{dt} + B\Delta F + \Delta P_{tie,1}$$

Area-1 :- $\Delta P_{G_1} - \Delta P_{D_1} = B_1 \Delta F_1 + \Delta P_{tie,1}$

$$\Delta P_{tie,1} = \Delta P_{G_1} - \Delta P_{D_1} - B_1 \Delta F_1$$

$$\Delta P_{tie,1} = \frac{-1}{R_1} \Delta F_{stat} - \Delta P_{D_1} - B_1 \Delta F_{stat}$$

$$\Delta P_{tie,1} = -\Delta f_{stat} \left[\frac{1}{R_1} + B \right] - \Delta P_{D_1} \rightarrow ①$$

Area-2 :-

$$\Delta P_{G_2} - \Delta P_{D_2} = B_2 \Delta F_2 + \Delta P_{tie,2}$$

$$\Delta P_{G_2} - \Delta P_{D_2} = B_2 \Delta F_2 - a_{12} \Delta P_{tie,1}$$

$$-a_{12} \Delta P_{tie,1} = \Delta P_{G_2} - \Delta P_{D_2} - B_2 \Delta F_2$$

$$-a_{12} \Delta P_{tie,1} = \frac{-1}{R_2} \Delta F_{stat} - \Delta P_{D_2} - B_2 \Delta F_{stat}$$

$$-a_{12} \Delta P_{tie,1} = -\Delta f_{stat} \left[\frac{1}{R_2} + B_2 \right] - \Delta P_{D_2}$$

$$\Delta P_{tie,1} = \frac{\Delta F_{stat} \left(\frac{1}{R_2} + B_2 \right) + \Delta P_{D_2}}{a_{12}} \rightarrow ②$$

① = ②

$$-\Delta f_{stat} \left[\frac{1}{R_1} + B \right] - \Delta P_{D_1} = \frac{\Delta F_{stat} \left(\frac{1}{R_2} + B_2 \right) + \Delta P_{D_2}}{a_{12}}$$

$$-\Delta f_{stat} \left(\frac{1}{R_1} + B \right) a_{12} - \Delta P_{D_1} a_{12} = \Delta f_{stat} \left(\frac{1}{R_2} + B_2 \right) + \Delta P_{D_2}$$

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$$-\Delta f_{stat}\left[B_1+\frac{1}{R_1}\right]a_{12}-\Delta f_{stat}\left[B_2+\frac{1}{R_2}\right]=\Delta P_{D_2}+\Delta P_{D_1}a_{12}$$

$$-\Delta f_{stat}\left[\left(B_1+\frac{1}{R_1}\right)a_{12}+\left(B_2+\frac{1}{R_2}\right)\right]=\Delta P_{D_2}+\Delta P_{D_1}a_{12}$$

$$\Delta f_{stat}=-\left[\frac{\Delta P_{D_2}+\Delta P_{D_1}a_{12}}{\left(B_1+\frac{1}{R_1}\right)a_{12}+\left(B_2+\frac{1}{R_2}\right)}\right]\rightarrow(3)$$

put (3) in (1)

$$\Delta P_{tie,1}=\left[\frac{\Delta P_{D_2}+\Delta P_{D_1}a_{12}}{\left(B_1+\frac{1}{R_1}\right)a_{12}+\left(B_2+\frac{1}{R_2}\right)}\right]\left(\frac{1}{R_1}+B_1\right)-\Delta P_{D_1}$$

$$\Delta P_{tie,1}=\frac{\Delta P_{D_2}\left(\frac{1}{R_1}+B_1\right)+\Delta P_{D_1}a_{12}\left(\frac{1}{R_1}+B_1\right)-\Delta P_{D_1}a_{12}\left(\frac{1}{R_1}+\right.}{\left(B_1+\frac{1}{R_1}\right)a_{12}+\left(B_2+\frac{1}{R_2}\right)}$$

$$\left.-\Delta P_{D_1}a_{12}\left(\frac{1}{R_2}+B_2\right)\right.$$

$$=\frac{\Delta P_{D_2}\left(\frac{1}{R_1}+B_1\right)-\Delta P_{D_1}\left(\frac{1}{R_2}+B_2\right)}{\left(B_1+\frac{1}{R_1}\right)a_{12}+\left(B_2+\frac{1}{R_2}\right)}$$

let $\beta_1=B_1+\frac{1}{R_1}$; $\beta_2=B_2+\frac{1}{R_2}$

using the eqns we can write.

$$\Delta P_{stat}=\frac{-\left(\Delta P_{D_2}+a_{12}\Delta P_{D_1}\right)}{\beta_1 a_{12}+\beta_2}\quad \text{Ans.}\rightarrow(4)$$

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$$\Delta P_{tie,stat} = \frac{\beta_1 \Delta P_{D_2} - \beta_2 \Delta P_{D_1}}{\beta_1 a_{12} + \beta_2} \quad pu\ mw \rightarrow (5)$$

In case, we have two identical area parameters eqn (4) & (5) give the values of static change in p.& tie line power respectively, as a result of sudden step load changes in the two areas, it can be observed that f & tie line power deviations do not reduce to zero in an uncontrolled case.

i.e., $\beta_1 = \beta_2 = \beta$.

$R_1 = R_2 = R$ & $a_{12} = 1$

$$\Delta f_{stat} = \frac{-(\Delta P_{D_2} + \Delta P_{D_1})}{2\beta} \quad Hz$$

$$\Delta P_{tie,stat} = -\Delta P_{tie,2\ stat} = \frac{\Delta P_{D_2} - \Delta P_{D_1}}{2\beta} \quad pu\ mw$$

Suppose a step change in load occurs area-1 then we get $\Delta f_{stat} = \frac{-\Delta P_{D_1}}{2\beta}$ Hz

$$\Delta P_{tie,1} = \frac{-\Delta P_{D_1}}{2} \quad pu\ mw$$

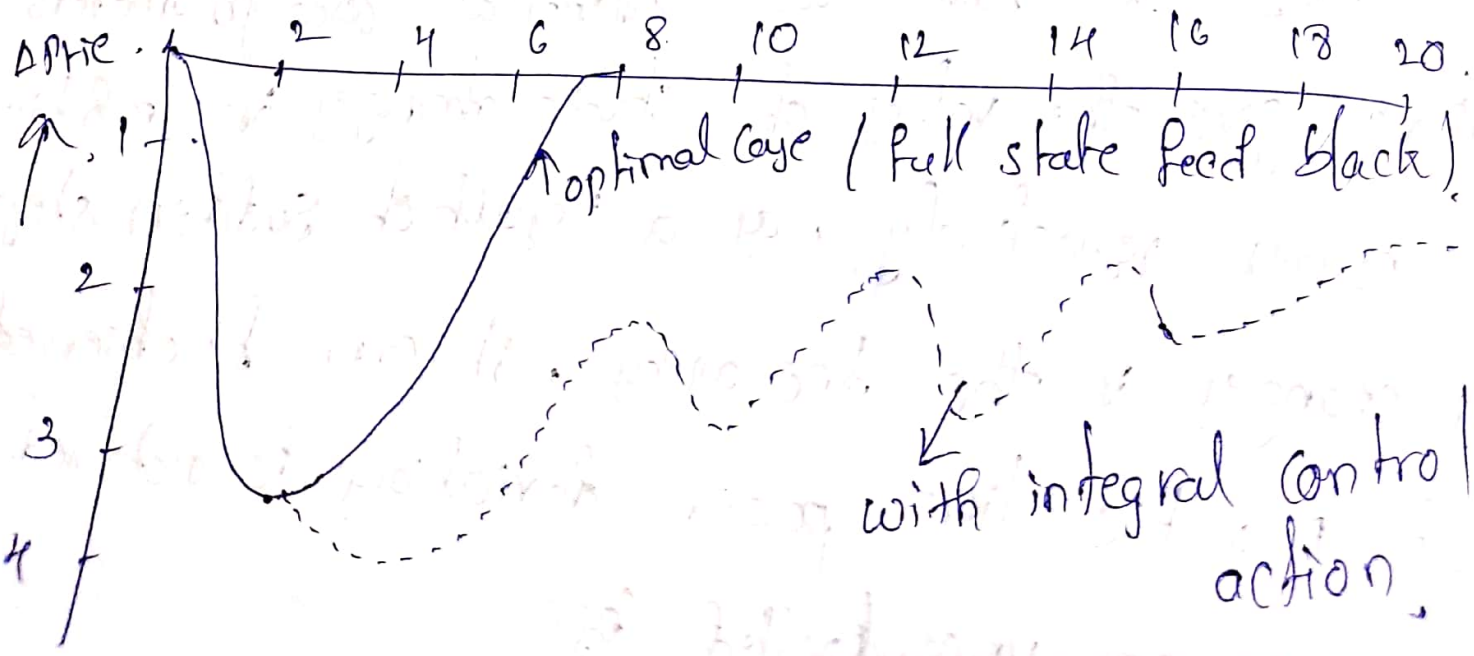
we concluded that by inter connecting two area the steady state freq error is reduced by 50%.

$$\left[\Delta f_{stat} = \frac{-PD}{\beta} \ Hz\right]$$

we observe that a load change in area-1 reduces that tie line flow by 50% of this amount & remaining 50% load increases is met by mains by

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increased generation & practically by decrease in load due to drop in f. Thus we conclude that there are advantages of pool operation.



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