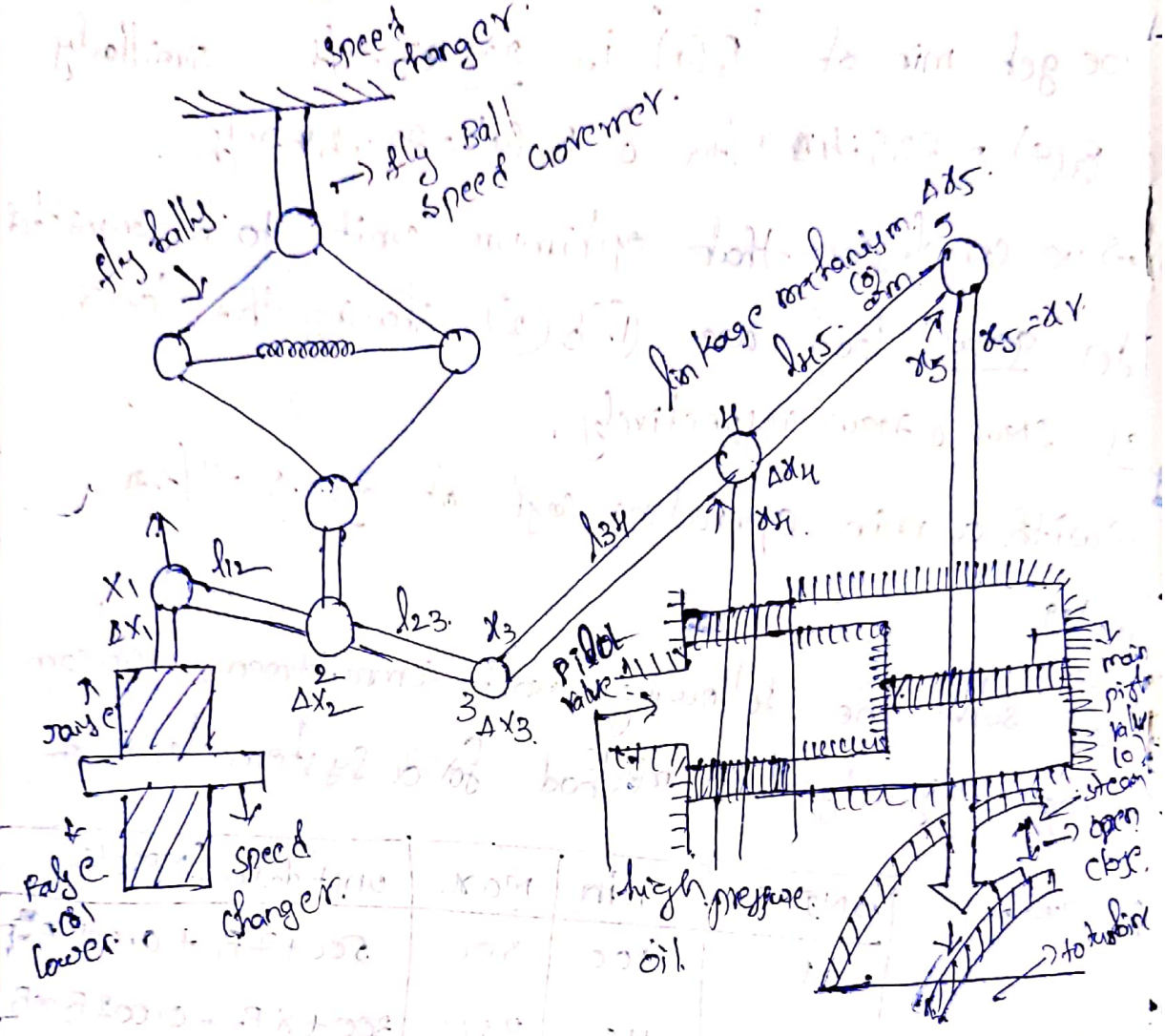
26/8/14

UNIT-4

LOAD FREQUANCY CONTROL-1

(MS)

Speed governing system :-



→ The speed governer is the main primary tool for the load frequency control

→ A schematic arrangement of the speed govering system as shown in fig.

→ It's main parts (or) components are as follows

1, flyball speed governer :- This is the heart of the system which senses the change in speed (frequency).

www.Jntufastupdates.com Scanned by CamScanner

→ As the speed increases the flyballs moves upwards and the point ② on linkage mechanism moves upwards.

→ The reverse happens when the speed decreases.

2. Hydrolic Amplifier :- It consists of pilot valve (v) and main piston valve (o).

→ with this arrangement hydralic Amplification is HA

→ i.e, The lower power level pilot value (v) is converted into high power level main piston value.

3. Linkage mechanism :-

→ 1, 2, 3 is a rigiedingly pivoted a point ② and 3, 4, 5 is a another rigidingly pivoted apoint ④

→ The function of theye linkage mechanism is to control the steam value.

4. Speed changer :-

→ It provides a studystate power o/p setting for a the turbine.

→ It's upward moment opens then more in theye admitted to the turbine under studystate condition.

www.Jntufastupdates.com Scanned by CamScanner

2 → The reverse happens for downward moment.

Speed change.

28/8/19

Mathematical modeling of Speed governing System :-

→ Now, we shell develop the mathematical model based on small variations.

→ let us consider steam is operating under steady state and is delevering power (P_G) from the generator at nominal speed (ω_0) of frequency.

→ with the help of speed changer we command power increases 'ΔP_c' due to this command the linkage point's distances Δx_1, Δx_2, Δx_3, Δx_4 & Δx_5

Therefore,

$$\Delta x_1 \propto \Delta P_c$$

$$\Delta x_1 = k_1 \Delta P_c \rightarrow (1)$$

link point ③ is,

$$\Delta x_3 = \Delta x_3' + \Delta x_3''$$

$$\Delta x_3' \propto -\Delta P_c$$

$$\Delta x_3' = -k_1 \Delta P_c$$

link point ④ is,

$$\Delta x_3'' \propto \Delta f$$

$$\Delta x_3'' = k_2 \Delta f$$

www.Jntufastupdates.com Scanned by CamScanner

$\Delta x_3 = \Delta x_3' + \Delta x_3''$

$\Delta x_3 = -k_1 \Delta P_c + k_2 \Delta f \longrightarrow (2)$

mk (4)

$\Delta x_4' \propto \Delta x_3$ | $\Delta x_4'' \propto \Delta x_5$

$\Delta x_4' = k_3 \Delta x_3$ | $\Delta x_4'' = k_4 \Delta x_5$

$\Delta x_4 = k_3 \Delta x_3 + k_4 \Delta x_5 \longrightarrow (3)$.

mk (5)

$\Delta x_5 = -k_5 \int_0^t \Delta x_4 dt \longrightarrow (4)$

Apply laplace T/f of eq^n (1)(2)(3)(4)(5)

$\Delta x_1(s) = k \Delta P_c(s) \longrightarrow (5)$

$\Delta x_3(s) = -k_1 \Delta_1 P_c(s) + k_2 \Delta f(s) \longrightarrow (6)$

$\Delta x_4(s) = k_3 \Delta x_3(s) + k_4 \Delta x_5(s) \longrightarrow (7)$

$\Delta x_5(s) = \frac{-k_5}{s} \Delta x_4(s) \longrightarrow (8)$

(8) $\Rightarrow \Delta x_5(s) = \frac{-k_5}{s} \Delta x_4(s)$

$= \frac{-k_5}{s} \left[k_3 \Delta x_3(s) + k_4 \Delta x_5(s) \right]$

$\Delta x_5(s) = \frac{-k_5}{s} \left[k_3 \left[-k_1 \Delta_1 P_c(s) + k_2 \Delta f(s) \right] + k_4 \Delta x_5(s) \right]$

$= \frac{-k_5}{s} \left[-k_3 k_1 \Delta_1 P_c(s) + k_2 k_3 \Delta f(s) + k_4 \Delta x_5(s) \right]$

$\Delta x_5(s) \left(\frac{s}{-k_5} \right) = +k_3 k_1 \Delta_1 P_c(s) - k_2 k_3 \Delta f(s) - k_4 \Delta x_5(s)$

$\Delta x_5(s) \left(\frac{s}{k_5} \right) + k_4 \Delta x_5(s) = k_3 k_1 \Delta_1 P_c(s) - k_2 k_3 \Delta f(s)$

www.Jntufastupdates.com Scanned by CamScanner

$$\Delta x_5(s)\left[\frac{s}{k_5}+k_4\right] = k_1 k_3 \Delta P_c(s) - k_2 k_3 \Delta f(s)$$

$$\Delta x_5(s) = \frac{k_1 k_3 \Delta P_c(s) + k_2 k_3 \Delta f(s)}{\left[\frac{s}{k_5}+k_4\right]}$$

$$= \frac{k_1 k_3 \left[\Delta P_c(s) - \frac{k_2}{k_1}\Delta f(s)\right]}{k_4\left[1+\frac{s}{k_4 k_5}\right]}$$

$$\Delta x_5(s) = \frac{k_1 k_3}{k_4} \cdot \frac{\left[\Delta P_c(s) - \frac{k_2}{k_1}\Delta f(s)\right]}{\left(1+\frac{s}{k_4 k_5}\right)} \quad \rightarrow (9)$$

$$\Delta x_5(s) = \left[\Delta P_c(s) - \frac{1}{R}\Delta f(s)\right]\frac{k_g}{1+sT_g} \quad \rightarrow (10)$$

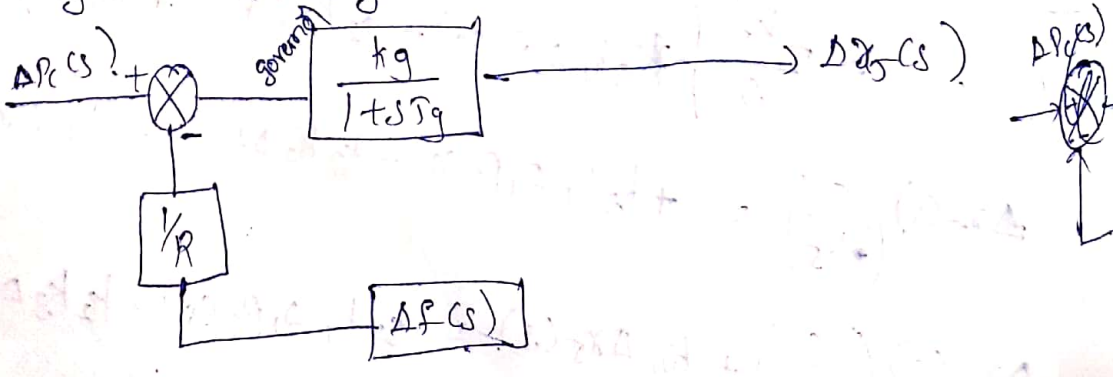
Compare (9) & (10)

$$k_g = \frac{k_1 k_3}{k_4} \quad ; \quad T_g = \frac{1}{k_4 k_5} \quad ; \quad R = \frac{k_1}{k_2}$$

k_g = gain constant for governor

R = Regulation of the governer

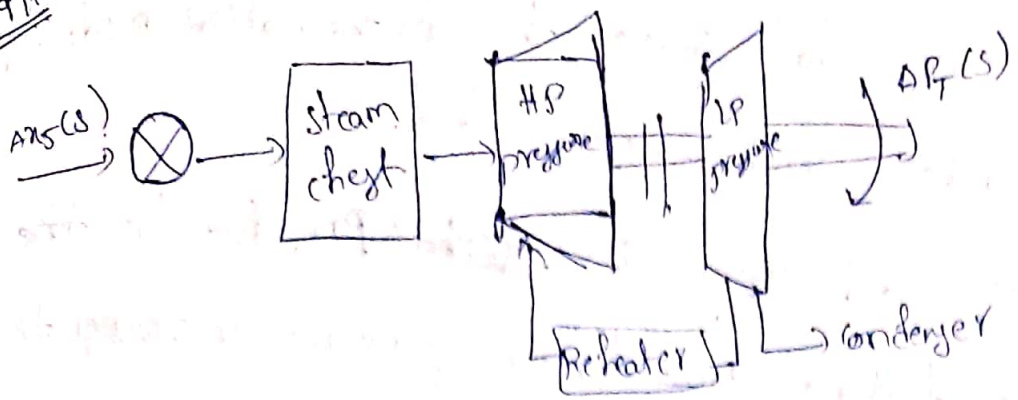
T_g = time constant of the governer



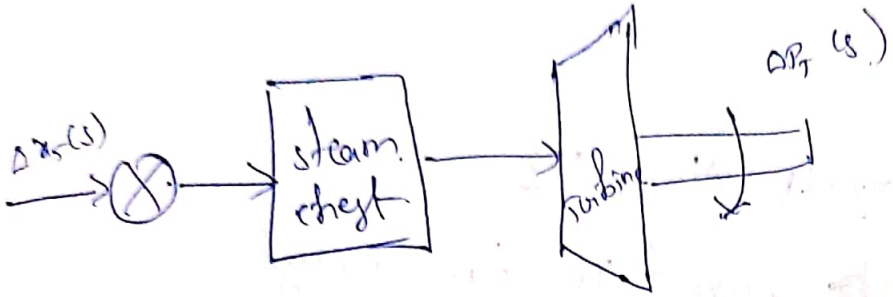
www.Jntufastupdates.com Scanned by CamScanner

Turbine model :- Two Types ① Reheat ② Non-Reheat

19/19



Reheat type

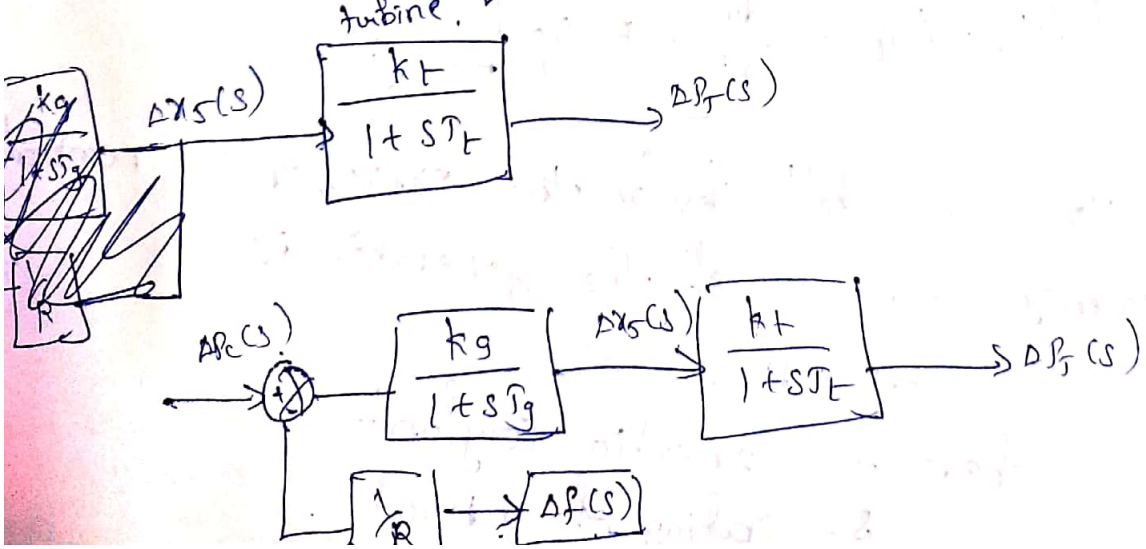


Non Reheat type

→ From the fig,

$$\frac{\Delta X_5(s)}{\Delta P_T(s)} = \frac{K_t}{1+sT_t}$$

$$\therefore \boxed{\Delta X_5(s) = \frac{K_t}{1+sT_t} \cdot \Delta P_T(s)}$$



www.Jntufastupdates.com Scanned by CamScanner

Generator model :-

Now, we shall develop the mathematical modeling of isolated generator which supplying load.

→ Suppose load change in ΔP_D, due to the action of turbine controller the generator increases the o/p power

→ ΔP_G

→ The surplus $\Delta P_G - \Delta P_D$

→ It is observed in two ways

1. By increasing the K.E (ω)
2. By increasing the load consumption.

$$B = \frac{\partial P_D}{\partial f}$$

where B = damping coefficient

→ W.K.T, the power balance eqn is given by

$$\Delta P_G - \Delta P_D = \frac{d\omega}{dt} + B \cdot \Delta f \longrightarrow (1)$$

→ Now, we shall develop the expression for nominal frequency and K.E of the generator is,

$$K.E = H \times S. = w^0$$

where H = Inertia constant

S = rating of generator.

www.Jntufastupdates.com Scanned by CamScanner

The K.E is directly proportional to square of the frequency (or) speed.

$\Rightarrow \omega \propto f^2$

The K.E at a frequency is, $f = \frac{f^0 + \Delta f}{f^0}$

i.e, $\omega \propto f^2$

$\omega = \omega^0 f^2$

$\omega = \omega^0 \left(\frac{f^0 + \Delta f}{f^0}\right)^2$ $\left[\because \omega^0 = HS\right]$

$= HS \left(\frac{(f^0 + \Delta f)^2}{f^{02}}\right)$

$= HS \left(\frac{f_0^2 + (\Delta f)^2 + 2f^0 \Delta f}{f_0^{02}}\right)$

$= HS \left(1 + \left(\frac{\Delta f}{f^0}\right)^2 + \frac{2\Delta f}{f^0}\right)$

$= HS \left(1 + \frac{2\Delta f}{f^0}\right)$ [Neglected the higher degree term.

$\omega = HS + 2HS \frac{\Delta f}{f^0}$

diff. with respect to 't'

$\frac{d\omega}{dt} = 0 + \frac{2HS}{f^0} \frac{d\Delta f}{dt}$

$\frac{d\omega}{dt} = \frac{2HS}{f^0} \frac{d(\Delta f)}{dt}$

www.Jntufastupdates.com Scanned by CamScanner

Sub $\frac{d\omega}{dt}$ value in eq ①

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

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

Rating of generator $S = 1$

Take the laplace T/f.

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

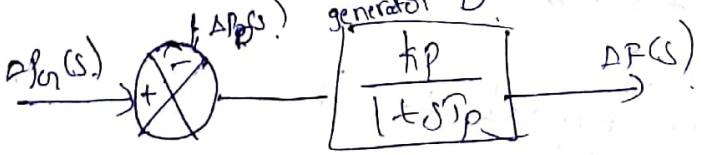
$$= \Delta f(s)\left[\frac{2HS}{f^0} + B\right]$$

$$\Delta P_G(s) - \Delta P_D(s) = B\Delta f(s)\left[\frac{2HS}{Bf^0} + 1\right]$$

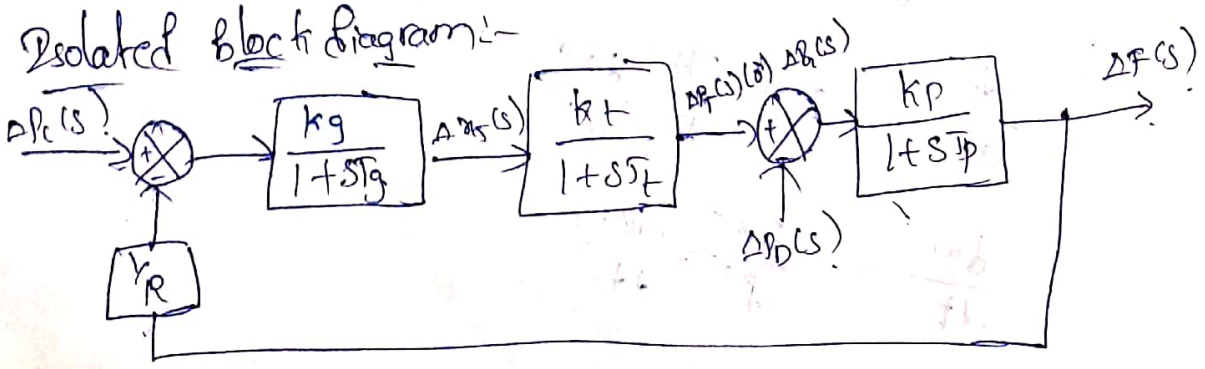
$$\Delta F(s) = \frac{\Delta P_G(s) - \Delta P_D(s)}{B\left(\frac{2HS}{Bf^0} + 1\right)}$$

Compare $\boxed{\Delta F(s) = \left(\Delta P_G(s) - \Delta P_D(s)\right)\frac{k_p}{1+sT_p}}$

$$k_p = \frac{1}{B} \quad ; \quad T_p = \frac{2H}{Bf^0}.$$



Isolated block diagram:-



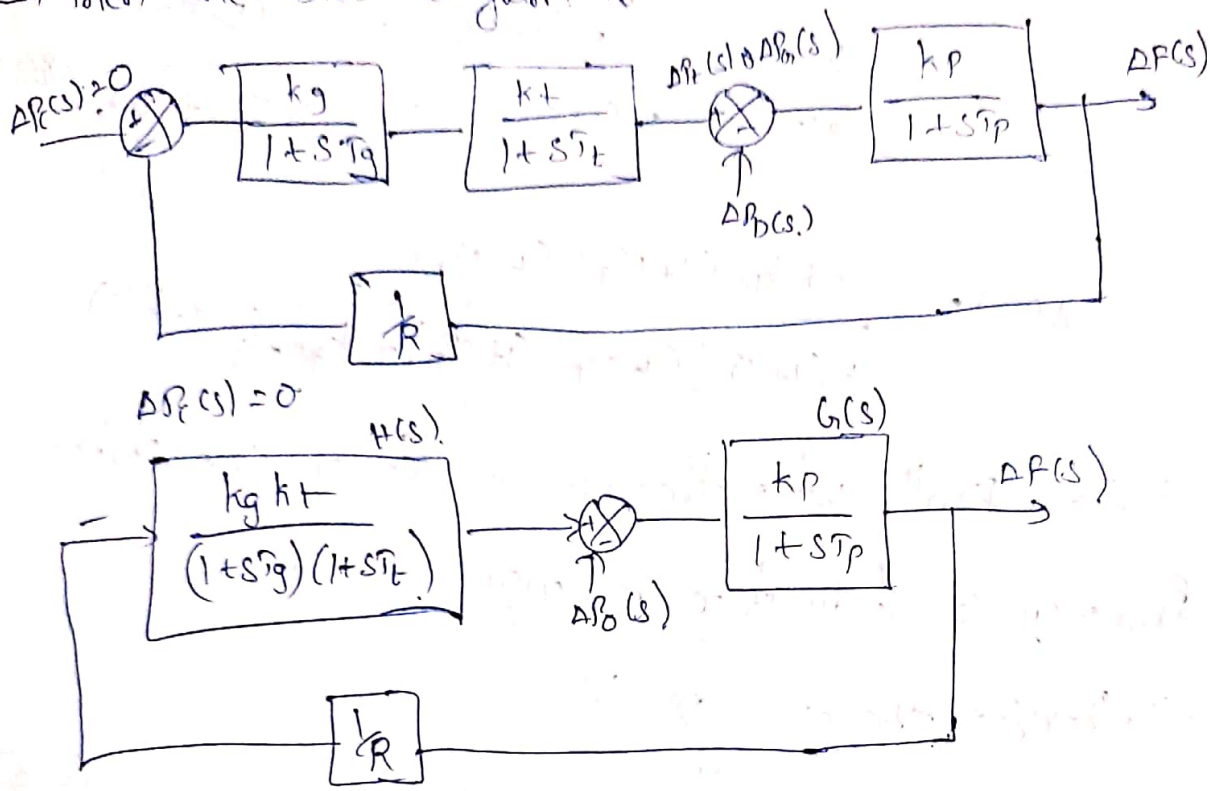
www.Jntufastupdates.com Scanned by CamScanner

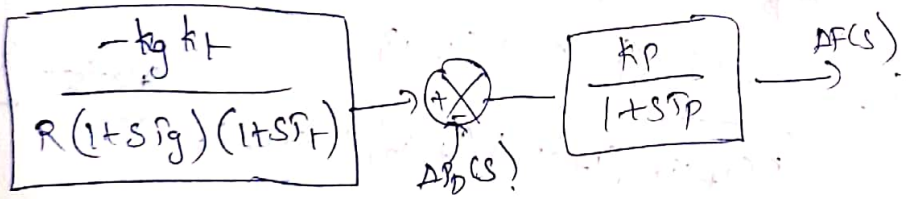
7/9/19

Uncontrolled case :-

→ Here, we consider uncontrolled case i.e, $\Delta P_c(s) = 0$

→ Then the block diagram is





$$T/F = \frac{O/p}{I/p} = \frac{G(s)}{1 + G(s)H(s)}$$

$$\frac{\Delta F(s)}{-\Delta P_D(s)} = \frac{\frac{k_p}{1+sT_p}}{1 + \left(\frac{-k_g k_t}{R(1+sT_g)(1+sT_t)}\right)\left(\frac{k_p}{1+sT_p}\right)}$$

$$\Delta F(s) = \frac{-\frac{k_p}{1+sT_p}}{1 + \left(\frac{k_p}{1+sT_p}\right)\left(\frac{k_g k_t}{R(1+sT_g)(1+sT_t)}\right)} \Delta P_D(s)$$

www.Jntufastupdates.com Scanned by CamScanner

$$\Delta F(s) = \frac{\frac{-k_p}{1+s\tau_p}}{\frac{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)+k_p k_g k_t}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)}} \Delta P_D(s)$$

$$= \frac{-k_p}{1+s\tau_p} \times \frac{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)+k_g k_p k_t} \Delta P_D(s)$$

$$\Delta F(s) = \frac{-Rk_p(1+s\tau_g)(1+s\tau_t)}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)+k_g k_p k_t} \Delta P_D(s)$$

Applying, final value theorem we can obtain static frequency (or) study state frequency.

→ Therefore, the above eqn is

$$\Delta P_D(s) = \frac{\Delta P_D}{s}$$

$$\Delta F(s) = \frac{-Rk_p(1+s\tau_g)(1+s\tau_t)}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)+k_g k_p k_t} \cdot \frac{\Delta P_D}{s}$$

$$\Delta f_{static} = \lim_{s \to 0} s.\Delta F(s).$$

$$\Delta f_{static} = \lim_{s \to 0} s \left[\frac{-Rk_p(1+s\tau_g)(1+s\tau_t)}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)+k_g k_p k_t} \right] \frac{\Delta P_D}{s}$$

$$= \lim_{s \to 0} \left[\frac{-Rk_p(1+s\tau_g)(1+s\tau_t)}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)+k_p k_g k_t} \right] \Delta P_D$$

$$\boxed{\Delta f_{static} = \frac{-Rk_p}{R+k_g k_p k_t} \Delta P_D}$$

www.Jntufastupdates.com Scanned by CamScanner

→ In load frequency controlled the product of governer constant (k_g) & Turbine constant (k_t) is equal to one.

$$k_g k_t = 1$$

∴ The above eqn is,

$$k_g k_t = 1$$

$$\Delta f_{static} = \frac{-R k_p}{R + k_p} \Delta P_D$$

$$= \frac{-R k_p}{R\left(1 + \frac{k_p}{R}\right)} \Delta P_D$$

$$\boxed{\Delta f_{static} = \frac{-k_p}{1 + \frac{k_p}{R}} \Delta P_D}$$

→ let us consider $k_p = \frac{1}{B}$ (or) $\frac{1}{D}$

∴ the above eqn is

$$\Delta f_{static} = \frac{-\frac{1}{B}}{1 + \frac{1/B}{R}} \Delta P_D$$

$$= \frac{-\frac{1}{B}}{1 + \frac{1}{BR}} \Delta P_D$$

$$= \frac{-\frac{1}{B}}{\frac{BR+1}{BR}} \Delta P_D$$

$$= -\frac{1}{B} \times \frac{BR}{1+BR} \Delta P_D$$

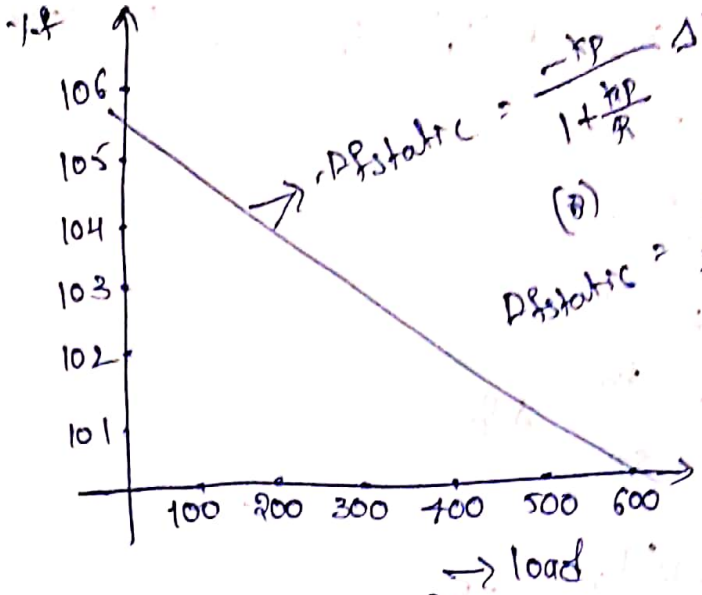
$$\Delta f_{static} = \frac{-R}{1+BR} \Delta P_D$$

$$= \frac{-R}{R\left(B + \frac{1}{R}\right)} \Delta P_D$$

$$\boxed{\Delta f_{static} = \frac{-1}{B + \frac{1}{R}} \Delta P_D}$$

www.Jntufastupdates.com Scanned by CamScanner

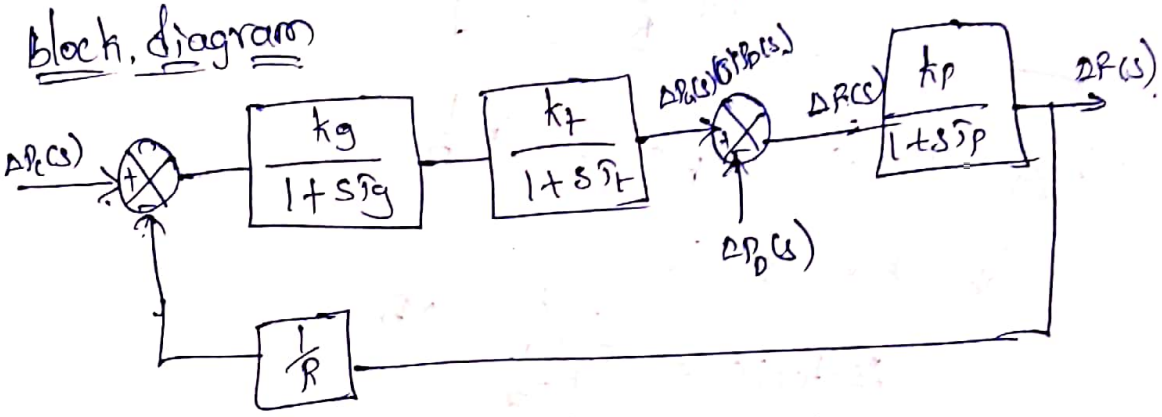
a/9/19 droop characteristic :-



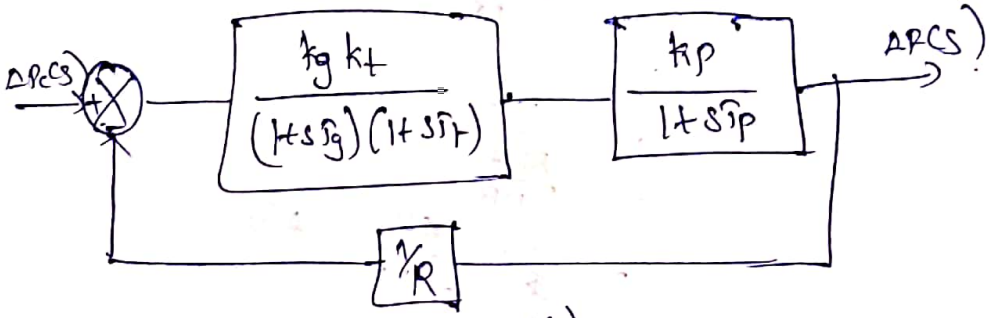
Gap with in the syllabus :-

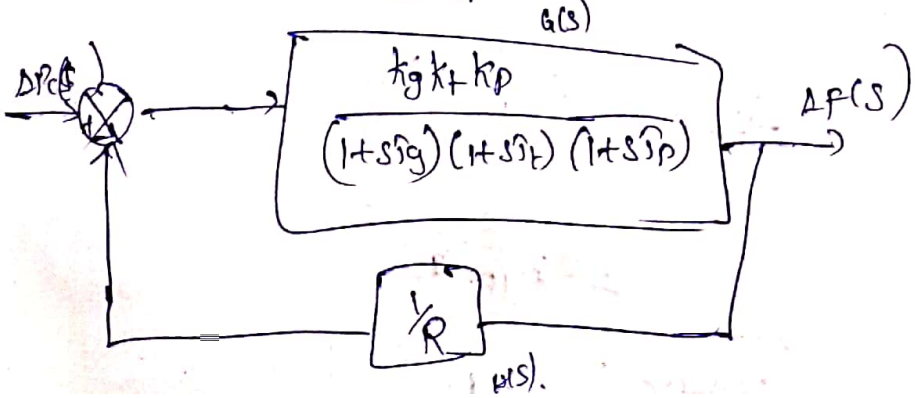
controlled caye :- $\Delta P_D(s) = 0$

block diagram



→ In controlled caye the g/f i/p $\Delta P_D(s) = 0$





www.Jntufastupdates.com Scanned by CamScanner

$$T = \frac{O/P}{I/P} = \frac{\Delta F(s)}{\Delta P_c(s)} = \frac{G(s)}{1 + G(s)H(s)}$$

$$\frac{\Delta F(s)}{\Delta P_c(s)} = \frac{\dfrac{k_g k_t k_p}{(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)}}{1 + \left(\dfrac{k_g k_t k_p}{(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)}\right)\left(\dfrac{1}{R}\right)}$$

$$\Delta F(s) = \frac{\dfrac{k_g k_t k_p}{(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)}}{\dfrac{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p) + k_g k_t k_p}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p)}} \Delta P_c(s)$$

$$= \frac{k_g k_t k_p}{1} \times \frac{R}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p) + k_g k_t k_p} \Delta P_c(s)$$

$$= \frac{R k_g k_p k_t}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p) + k_g k_t k_p} \Delta P_c(s)$$

$k_g k_t = 1$; $\Delta P_c(s) = \dfrac{\Delta P_c}{s}$

$$\Delta F(s) = \frac{k_p \cdot R}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p) + k_p} \frac{\Delta P_c}{s}$$

Final value theorem:

$$\Delta f_{static} = \lim_{s \to 0} s \cdot \Delta F(s)$$

$$\Delta f_{static} = \lim_{s \to 0} s \cdot \left(\frac{k_p R}{R(1+s\tau_g)(1+s\tau_t)(1+s\tau_p) + k_p}\right)\left(\frac{\Delta P_c}{s}\right)$$

$$\Delta f_{static} = \frac{k_p R}{R + k_p} \Delta P_c$$

www.Jntufastupdates.com Scanned by CamScanner

$$\Delta f_{static} = \frac{R \cdot k_p}{R\left(1 + \frac{k_p}{R}\right)} \Delta P_c$$

$$\boxed{\Delta f_{static} = \frac{k_p}{1 + \frac{k_p}{R}} \Delta P_c}$$

put $k_p = \frac{1}{B}(\delta)\frac{1}{D}$.

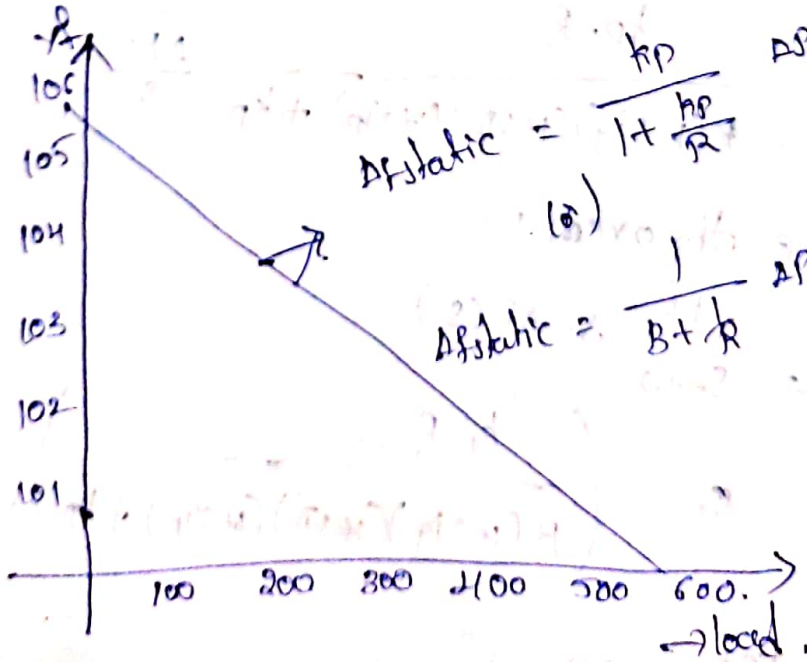
$$\Delta f_{static} = \frac{\frac{1}{B}}{1 + \frac{1}{BR}} \Delta P_c$$

$$= \frac{(R)\,BR}{BR+1} \Delta P_c$$

$$= \frac{R}{BR+1} \Delta P_c$$

$$= \frac{R}{R\left(B + \frac{1}{R}\right)} \Delta P_c$$

$$\boxed{\Delta f_{static} = \frac{1}{B + \frac{1}{R}} \Delta P_c}$$ droop characteristic eqn.



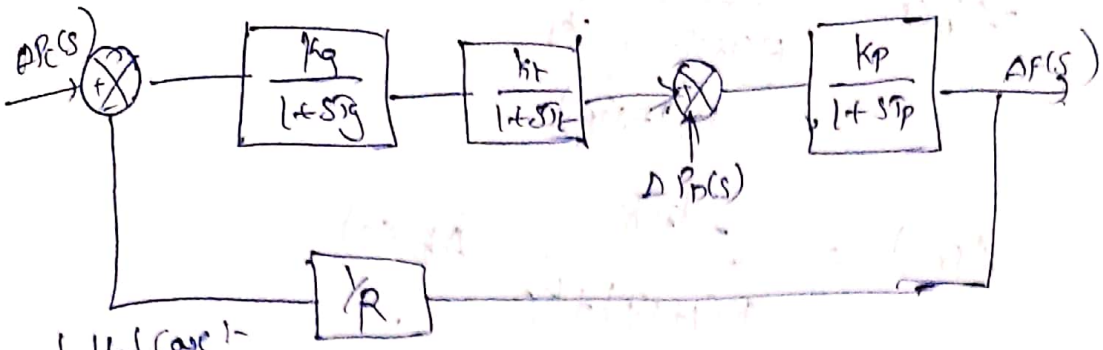
$$\Delta f_{static} = \frac{k_p}{1 + \frac{k_p}{R}} \Delta P_c$$

(or)

$$\Delta f_{static} = \frac{1}{B + \frac{1}{R}} \Delta P_c.$$

www.Jntufastupdates.com Scanned by CamScanner

5) Dynamic response :-

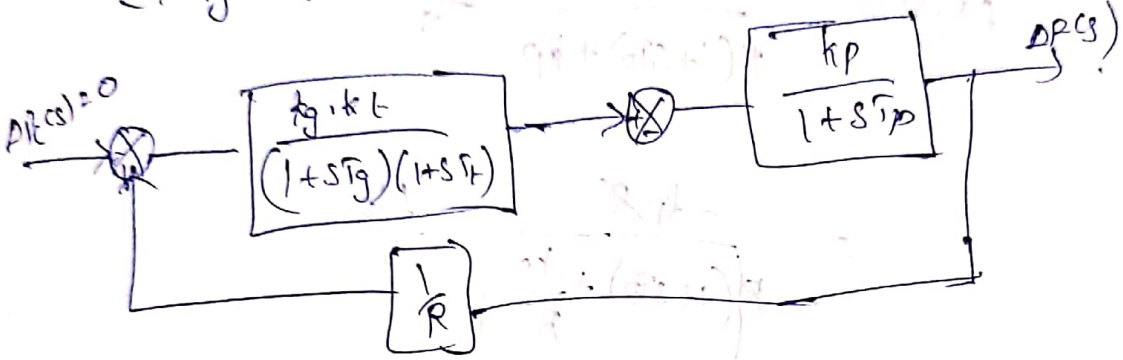


uncontrolled case :-

i) $\Delta P_c(s) = 0$

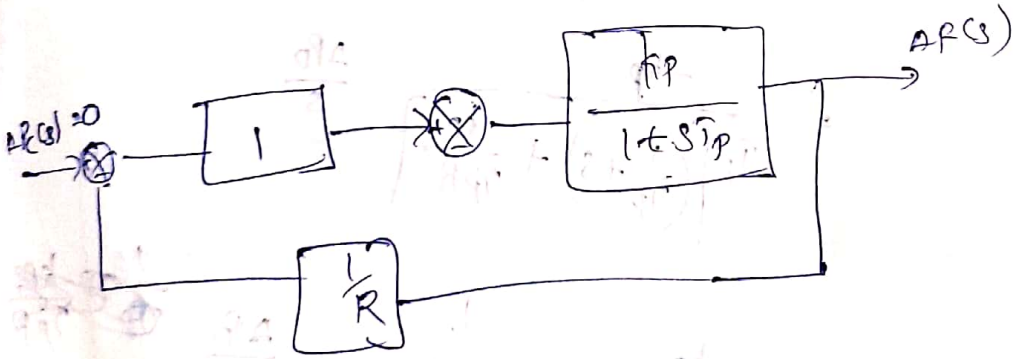
ii) $K_g \cdot K_t = 1$

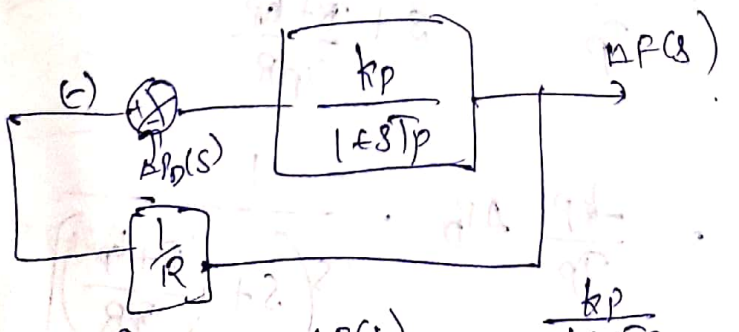
iii) $T_g = T_t = 0$



(2) $K_g \cdot K_t = 1$ & $T_g = T_t = 0$

Then the above block diagram is





$$\text{T.F} = \frac{O/P}{I/P} = \frac{\Delta F(s)}{-\Delta P_D(s)} = \frac{\frac{K_p}{1+sT_p}}{1+\left(\frac{K_p}{1+sT_p}\right)\left(\frac{1}{R}\right)}$$

www.Jntufastupdates.com Scanned by CamScanner

$$\frac{\Delta F(s)}{-\Delta P_D(s)} = \frac{\frac{k_p}{1+sT_p}}{\frac{R(1+sT_p)+k_p}{R(1+sT_p)}}$$

$$\Delta F(s) = \frac{-k_p R}{R(1+sT_p)+k_p}\,\Delta P_D(s)$$

$$\Delta P_D(s) = \frac{\Delta P_D}{s}$$

$$\Delta F(s) = \frac{-k_p R}{R(1+sT_p)+k_p}\,\frac{\Delta P_D}{s}$$

$$= \frac{-k_p R}{R\left((1+sT_p)+\frac{k_p}{R}\right)}\,\frac{\Delta P_D}{s}$$

$$\Delta F(s) = \frac{-k_p}{(1+sT_p)+\frac{k_p}{R}}\,\frac{\Delta P_D}{s}$$

$$= \frac{-k_p}{T_p\left(\left(\frac{1}{T_p}+s\right)+\frac{k_p}{T_p R}\right)}\,\frac{\Delta P_D}{s}$$

$$= \frac{-k_p}{T_p}\cdot\frac{1}{s+\frac{R+k_p}{T_p R}}\,\frac{\Delta P_D}{s}$$

$$= \frac{-k_p}{T_p}\,\Delta P_D\cdot\frac{1}{s\left(s+\left(\frac{R+k_p}{T_p R}\right)\right)}$$

www.Jntufastupdates.com Scanned by CamScanner

partial fraction

$$\frac{1}{s\left(s+\frac{(R+k_p)}{\tau_p R}\right)} = \frac{A}{s} + \frac{B}{s+\left(\frac{R+k_p}{\tau_p R}\right)}$$

$$1 = A\left[s+\left(\frac{R+k_p}{\tau_p R}\right)\right] + Bs$$

put $s=0$

$$1 = A\left(\frac{R+k_p}{\tau_p R}\right)$$

$$A = \frac{\tau_p R}{R+k_p}$$

put $s = -\left(\frac{R+k_p}{\tau_p R}\right)$

$$1 = B\left(-\frac{R+k_p}{\tau_p R}\right)$$

$$B = \frac{-\tau_p R}{R+k_p}$$

$$\frac{1}{s\left[s+\left(\frac{R+k_p}{\tau_p R}\right)\right]} = \frac{\frac{\tau_p R}{R+k_p}}{s} + \frac{\frac{-\tau_p R}{R+k_p}}{s+\left(\frac{R+k_p}{\tau_p R}\right)}$$

$$\Delta F(s) = \frac{-k_p}{\tau_p}\Delta P_D\left[\frac{\tau_p R}{R+k_p}\left[\frac{1}{s}-\frac{1}{s+\left(\frac{R+k_p}{\tau_p R}\right)}\right]\right]$$

$$\Delta F(s) = \frac{-k_p R}{R+k_p}\Delta P_D\left[\frac{1}{s}-\frac{1}{s+\left(\frac{R+k_p}{\tau_p R}\right)}\right]$$

Taking inverse laplace T/F

$$L^{-1}\left[\frac{1}{s}\right]=1 \; ; \; L^{-1}\left[\frac{1}{s+\frac{R+k_p}{\tau_p R}}\right] = e^{-\frac{R+k_p}{\tau_p R}t}$$

$$\Delta F(t)_{static} = \frac{-k_p R}{R+k_p}\Delta P_D\left[1-e^{-\left(\frac{R+k_p}{\tau_p R}\right)t}\right]$$

www.Jntufastupdates.com Scanned by CamScanner

→ let us take numerical values from above equation we have $T_p = 20\,sec$, $k_p = 100\ Hz/pu\,MW$, $R = 2.5\ Hz/pu\,MW$ →

$\Delta P_D = 0.1\ pu\,MW$

$$\Delta f(t) = \frac{-k_p R}{R + k_p}\,\Delta P_D\left(1 - e^{-t\left(\frac{R+k_p}{T_p R}\right)}\right)$$

$$= -\frac{(100)(2.5)}{2.5 + 100}(0.1)\left(1 - e^{-t\left(\frac{2.5+100}{(20)(2.5)}\right)}\right)$$

$$\boxed{\Delta f(t) = -0.243\left(1 - e^{-2.05t}\right)}$$

(P) (1) Two generators rated 250 MW & 500 MW are operating in parallel a droop characteristics of 4% & 6% respectively assuming that the generators are operating at 50 Hz at no-load how to a load of 750 MW be shared. what is the system frequency assume the governing action.

Sol?:- 12/9/19

Rating of generator (1) = 250 MW.

generator (2) = 500 MW

Droop characteristic G-(1) = 4%.

$= 0.02$.

" " G-(2) = 6% = 0.06

$f = 50\ Hz$.

Generators operating in parallel they will operate at the same frequency at sharing load.

www.Jntufastupdates.com Scanned by CamScanner

→ load on 750mw be sharing

Let x-mw is the load

for generator ① ⇒

$$\frac{\text{change in frequency}}{\text{load}} = \frac{\text{droop \%} \times \text{Normal frequency}}{\text{rating of generator ①}}$$

$$\frac{\Delta f}{x} = \frac{0.04 \times 50}{250}$$

$$\Delta f = 0.008x$$

for gen ② ⇒ $\frac{ch.f}{(750-x)} = \frac{Dx \times f}{\text{rating of ②}}$

$$\frac{\Delta f}{750-x} = \frac{0.06 \times 50}{10}$$

$$\Delta f = 0.006(750-x)$$

$$\Delta f = 4.5 - 0.006x$$

gen ① = gen ②

$$0.008x = 4.5 - 0.006x$$

$$0.014x = 4.5$$

$$x = 321.4 \text{ mw}$$

∴ for gen ① $x = 321.4$ mw

gen ② $750 - x = 321.4$

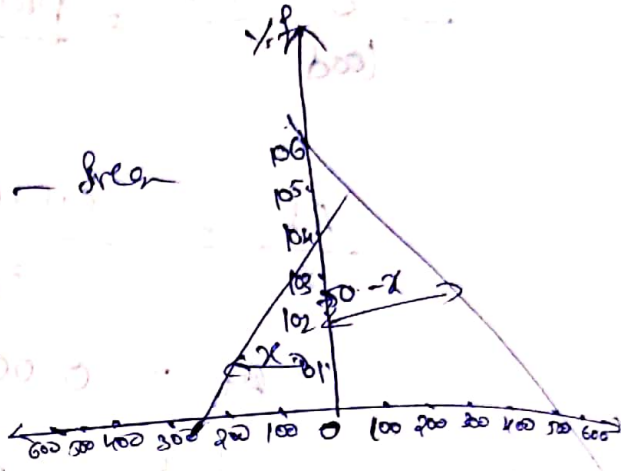
$$x = 428.5 \text{ mw}$$

www.Jntufastupdates.com Scanned by CamScanner

$$\frac{-\Delta f}{x} = \frac{0.04 \times 50}{250}$$

$$\Delta f = \frac{0.04 \times 50}{250} \times 321.4$$

$$\boxed{\Delta f = 2.57 \text{ Hz}}$$



Frequence = Normal freq − freq

= 50 − 2.57

$$\boxed{f = 48.43 \text{ Hz}}$$

(5) To synchronous generator operating parallel and supply a total load of 400MW the capacities of the machines are 200MW and 500MW and both have generator droop characteristics of 4% from no load to full load calculate the load taken by each machine assuming free governer action. and also find the system frequency at this load.

Sol:- let load for gen (1) = x MW.

rating of gen (1) = 200 MW

" " " (2) = 500 MW.

Droop % for gen (1) = 4% = 0.04

" " (2) = 4% = 0.04

load on gen (2) = 400 − x.

www.Jntufastupdates.com Scanned by CamScanner

For gen ① $= \frac{\Delta f}{x} = \frac{0.02 \times 50}{200}$

$\Delta f = 0.01x$.

gen ②

$\frac{\Delta f}{400 - x} = \frac{0.01 \times 50}{500}$

$\Delta f = 0.01(400 - x)$

$\Delta f = 1.6 - 0.01x$

eq ① = eq ②

$0.01x = 1.6 - 0.01x$.

$0.02x = 1.6$

$\boxed{x = 114.2 \text{ MW}}$

gen ① $x = 114.2$

gen ② $400 - x = 285.7 \text{ MW}$.

$\frac{\Delta f}{x} = \frac{0.01 \times 50}{200}$

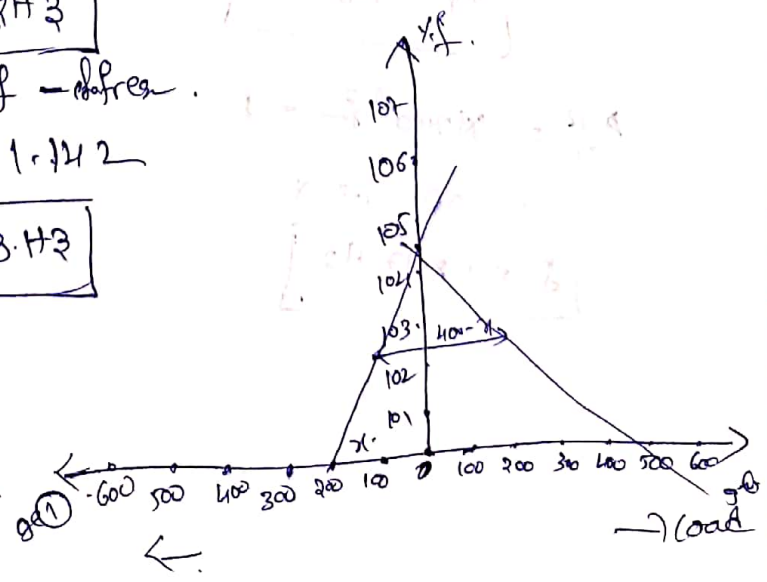
$\Delta f = (0.01)(114.2)$

$\boxed{\Delta f = 1.142 \text{ Hz}}$

freq = Normal f − dfreq.

freqe = 50 − 1.142

$\boxed{f = 48.8 \text{ Hz}}$



www.Jntufastupdates.com Scanned by CamScanner

③ two gen. 300 MW & 600 MW, Droop characteristics 4% & 5%. 750 MW shared. find out load, freq

④ 200 MW & 400 MW, Droop char. 4% & 5%. ⑤ 600 MW ⑥ 400 MW.

gen① ⇒ 300 ⇒ ① $R_1 = 0.04$

gen② ⇒ 600 ⇒ ② $R = 0.05$

750 MW

gen① ⇒ $\frac{\text{change in freq}}{100\text{ f}} = \frac{\%\text{Droop} \times \text{Normal freq}}{\text{rate of gen①}}$

$\frac{\Delta f}{x} = \frac{0.04 \times 50}{300}$

$\Delta f = 0.006x$.

gen② ⇒ $\frac{\Delta f}{750 - x} = \frac{0.05 \times 50}{600}$.

$\Delta f = 0.0041(750 - x)$

$= 3.075 - 0.0041x$.

$0.006x = 3.075 - 0.0041x$.

$0.0101x = 3.075$

$x = 304.4$ MW

$\Delta f = 1.82564$ Hz

$\Delta f = \text{Normal freq} - f$

$= 50 - 1.825$

$f = 48.17$ Hz

www.Jntufastupdates.com Scanned by CamScanner

Q: gen① = 200 MW. D = 0.04
② = 400 MW D = 0.05

①

① $\frac{\Delta f}{\gamma} = \frac{0.04 \times 50}{200} \Rightarrow \boxed{\Delta f = 0.01 \gamma}$

$\frac{\Delta f}{600 - \gamma} = \frac{0.05 \times 50}{400} \Rightarrow \Delta f = (600 - \gamma)(0.00625)$

$\Delta f = 3.75 - 0.00625 \gamma$

$0.01\gamma = 3.75 - 0.00625\gamma$

$\gamma = \frac{3.75}{0.01625}$

$\boxed{\gamma = 51.72.}$

$\Delta f = 0.01 \times 51.72 = 0.51$ Hz

$f = 50 - 0.51$

$\boxed{f = 49.48 \text{ Hz}}$

②

$\frac{\Delta f}{\gamma} = \frac{0.04 \times 50}{200} \Rightarrow \boxed{0.01\gamma = \Delta f}$

$\frac{\Delta f}{400 - \gamma} = \frac{0.05 \times 50}{400} = 0.0625$

$\Delta f = 2.5 - 0.00625\gamma$

$0.01\gamma = 2.5 - 0.00625\gamma$

$\gamma = 153.8$

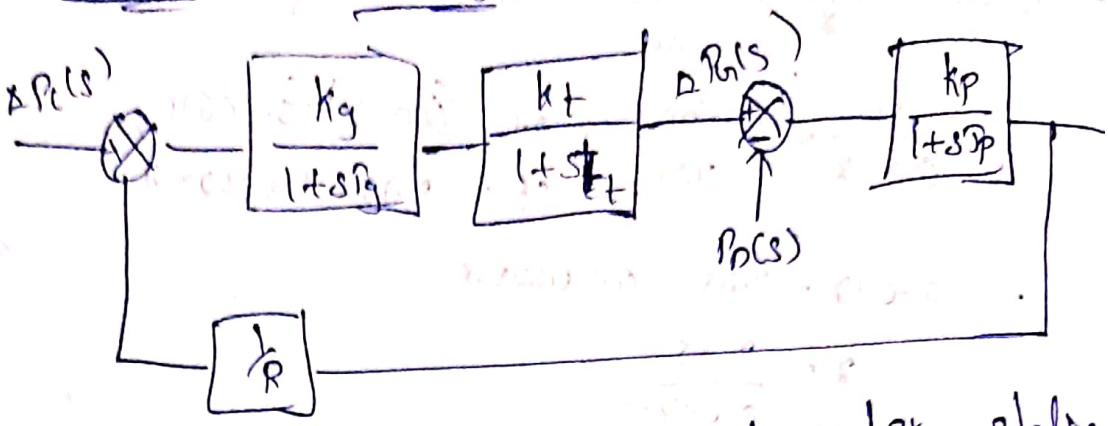
$\Delta f = 1.5$ Hz.

$f = 50 - 1.5$

$\boxed{f = 48.46 \text{ Hz}}$

Proportional plus integral of load frequency control

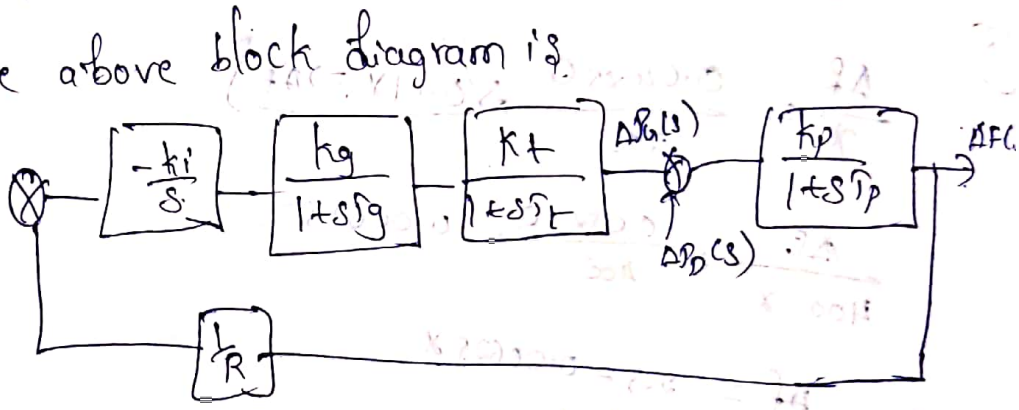
The isolated block diagram is,



By using proportional plus integrater static frequency is zero.

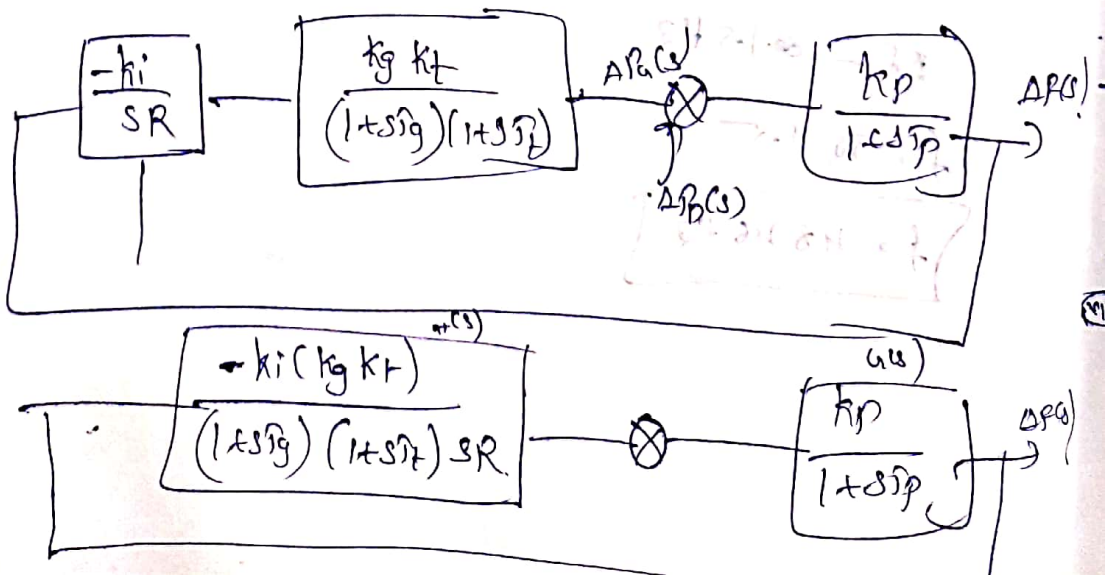
∴ Here we using the area controlled error (ACE)

The above block diagram is



Here we use the uncontrolled case $\Delta P_L(s) = 0$

∴ The above block diagram is



www.Jntufastupdates.com Scanned by CamScanner

$$\frac{\Delta F(s)}{\Delta P_D(s)} = \frac{\frac{K_P}{1+sT_P}}{1+\frac{K_P}{1+sT_P}\cdot\frac{K_i K_g K_t}{sR(1+sT_g)(1+sT_t)}}$$

$$\Delta F(s) = \frac{\frac{-K_P}{1+sT_P}(1+sT_P)sR(1+sT_g)(1+sT_t)}{(sR)(1+sT_g)(1+sT_t)(1+sT_P)+K_P K_i K_g K_t}\Delta P_D(s)$$

$$\Delta F(s) = \frac{-K_P R(1+sT_g)(1+sT_t)}{(sR)(1+sT_g)(1+sT_t)(1+sT_P)+K_P K_i K_g K_t}\Delta P_D$$

$K_g \cdot K_t = 1.$

$$\Delta F(s) = \frac{-K_P R(1+sT_g)(1+sT_t)}{(sR)(1+sT_g)(1+sT_t)(1+sT_P)+K_P K_i}\Delta P_D$$

$$\Delta f_{static} = \lim_{s\to 0} s\cdot\Delta F(s)$$

$$= \lim_{s\to 0} s\cdot\frac{-K_P R(1+sT_g)(1+sT_t)}{(sR)(1+sT_g)(1+sT_t)(1+sT_P)+K_P K_i}\Delta P_D$$

$$\therefore \boxed{\Delta f_{static} = 0}$$

→ we conclud that by the addition of the integral controller the static frequency error has been reduced to zero.

(3) Study state response of single area load frequency control:- uncontrolled

$$\Delta f_{static} = \frac{-K_P}{1+\frac{K_P}{R}}\Delta P_D \rightarrow (1)$$

www.Jntufastupdates.com Scanned by CamScanner

Controlled case

$$\Delta f_{static} = \frac{k_p}{1+\frac{k_p}{R}} \Delta P_c \longrightarrow (2)$$

adding (1) & (2)

$$2\Delta f_{static} = \frac{-k_p}{1+\frac{k_p}{R}} \Delta P_D + \frac{k_p}{1+\frac{k_p}{R}} \Delta P_c$$

$$0 = \frac{k_p}{1+\frac{k_p}{R}} \left(\Delta P_c - \Delta P_D \right)$$

$$\Delta P_c - \Delta P_D = 0$$

$$\boxed{\Delta P_c = \Delta P_D}$$

119

www.Jntufastupdates.com Scanned by CamScanner

3) find the primary ALFC load frequency control loop. analysis parameter for a controlled area having the following data.

control area capacity = 10000 MW

Normal operating load = 5000 MW (P_D)

inertia constant (H) = 5 sec

Regulation R = 3 Hz / p.u MW.

Assume that load frequency dependency is linear and a percent change in frequency corresponding to one percent change in load.

Sol:- change in f % = 1%.

ΔP_D = 1%.

Control area capacity = 10,000 MW

Normal operating load = 5,000 MW

inertia constant (H) = 5 sec.

regulation R = 3 Hz / p.u MW. ; f = 50 Hz.

$$B = \frac{\Delta P_D}{\Delta f} = \frac{\text{change in load} \times \text{load}}{\text{change in freq.} \times \text{frequency}}$$

$$= \frac{1\% \times P_D}{1\% \times f}$$

$$= \frac{0.01 \times 5000}{0.01 \times 50}$$

$$B = 100 \text{ MW/Hz}$$

$$B = \frac{100}{\text{control area capacity}} = \frac{100}{10,000} = 0.01 \text{ p.u MW/Hz}.$$

$$B = 0.01 \text{ p.u MW/Hz}$$

www.Jntufastupdates.com Scanned by CamScanner

$K_p = \frac{1}{B}$

$= \frac{1}{0.01}$

$K_p = 100.$ MW/Hz.

$T_p = \frac{2H}{Bf}$

$= \frac{2 \times 5}{0.01 \times 50}$ $= 20.$

$T_p = 20$ sec.

Ans

(a) For an isolated single area, consider the following data, control area capacity (P_R) = 1000 MW

Normal operating load (P_D) = 500 MW

inertia constant (H) = 5 sec.

regulation (R) = 5%

Nominal freq (f) = 50 Hz

load decreases by $\Delta P_D = 1\%$

for decreasing freq by $\Delta f = 1\%$

find the gain & time constant of power System representing with a 1st are the T.f.

If it is an uncontrolled area then finding change in frequency due to an increase of load by 75 MW.

Sol?!—

www.Jntufastupdates.com Scanned by CamScanner

given, $\Delta P_D = 75$ MW.

Soln:-

$$B = \frac{\partial P_D}{\partial f}$$

$$= \frac{1\% \times P_D}{1\% \times f}$$

$$= \frac{0.01 \times 500}{0.01 \times 50}$$

$$\boxed{B = 10 \text{ MW/Hz}}$$

$$B = \frac{100}{\text{C.a.C}} = \frac{10}{1000} = 0.01 \text{ p.u MW/Hz}.$$

$$K_p = \frac{1}{B} = \frac{1}{0.01} = 100 \text{ Hz/p.u MW}.$$

$$T_p = \frac{2H}{Bf}$$

$$= \frac{2 \times 5}{0.01 \times 50}$$

$$\boxed{T_p = 20 \text{ sec}}$$

$$\text{In p.u } \Delta P_D = \frac{75}{\text{C.a.C}}$$

$$= \frac{75}{1000} = \frac{3}{40}$$

$$\boxed{\Delta P_D = 0.075 \text{ p.u MW.}}$$

$$\text{Drop } R = 5\% = \frac{5}{100} = 0.05$$

$$R \text{ in p.u} = \frac{0.05}{\text{C.a.C}}$$

$$= \frac{0.05}{1000}$$

$$= 0.00005 \text{ (or) } 5 \times 10^{-5} \text{ p.u}.$$

www.Jntufastupdates.com Scanned by CamScanner

~~Δf increase~~ =

$$\Delta f_{static} = \frac{-k_p}{1+\frac{k_p}{R}} \Delta P_D$$

$$= \frac{-100}{1+\frac{100}{5\times10^5}} \times 0.075$$

$$\boxed{\Delta f_{static} = -3.74\times10^{-6}}$$

⑤ For an isolated power system shown in fig we have the following system data rating of generator $P_R = 100$ MW ; Nominal operating load $P_D = 50$ MW ; inertia constant $H = 5$ sec. ; regulation of governor $(R) = 2.5$ Hz/MW. If the load increase 1% for 1% freq., Find the static freq change for the uncontrolled case when the load is increased by 10 MW.

Soln:- $$B = \frac{\partial P_D}{\partial f} = \frac{1\% \times P_D}{1\% \times f}$$

$$= \frac{0.01 \times 50}{0.01 \times 50}$$

$$\boxed{B = 1 \text{ MW/Hz}}$$

$$B = \frac{1}{C.a.C} = \frac{1}{100} = 0.01$$

$$\boxed{B = 0.01 \text{ P.U MW/Hz}}$$

www.Jntufastupdates.com Scanned by CamScanner

$$k_p = \frac{1}{B} = \frac{1}{0.01}$$

$$\boxed{k_p = 100 \text{ Hz/p.u MW}}$$

$$T_p = \frac{2H}{Bf} = \frac{2 \times 5}{0.01 \times 50}$$

$$\boxed{T_p = 20 \text{ sec}}$$

$\Delta P_D = 10$ MW.

ΔP_D in p.u $= \frac{10}{100}$

$= 0.1$ p.u MW

$R = 2.5$ Hz/p.u MW.

R in p.u $= \frac{2.5}{100}$

$= 0.025$ Hz/p.u MW.

$$\Delta f_{static} = \frac{-k_p}{1 + \frac{k_p}{R}} \Delta P_D$$

$$= \frac{-100}{1 + \frac{100}{0.025}} \times (0.1)$$

$$\boxed{\Delta f_{static} = -0.24 \text{ Hz}}$$

System frequency = Nominal freq − static freq

$= 50 + 0.24$

$= 49.76$.

www.Jntufastupdates.com Scanned by CamScanner

(Ans)

Necessity of keeping frequency constant :-

In the power system w/o the real & reactive power demands are continuously varying with a falling & raising condition but never ~~steady~~ steady.

→ The system frequency & vtg are maintained at their normal values by monitoring the load variations by and taking suitable control action to match the real & reactive power generations with the load demand.

→ The system frequency is closely related to the real power balance in the power system.

→ The system vtg is mainly controlled by the reactive power balance in the power system

control area :-

All the generators in area constitute a coherent group so, that all the generators speed up & down together maintance their power angles.

→ Such an area is defined as "control area"

www.Jntufastupdates.com Scanned by CamScanner