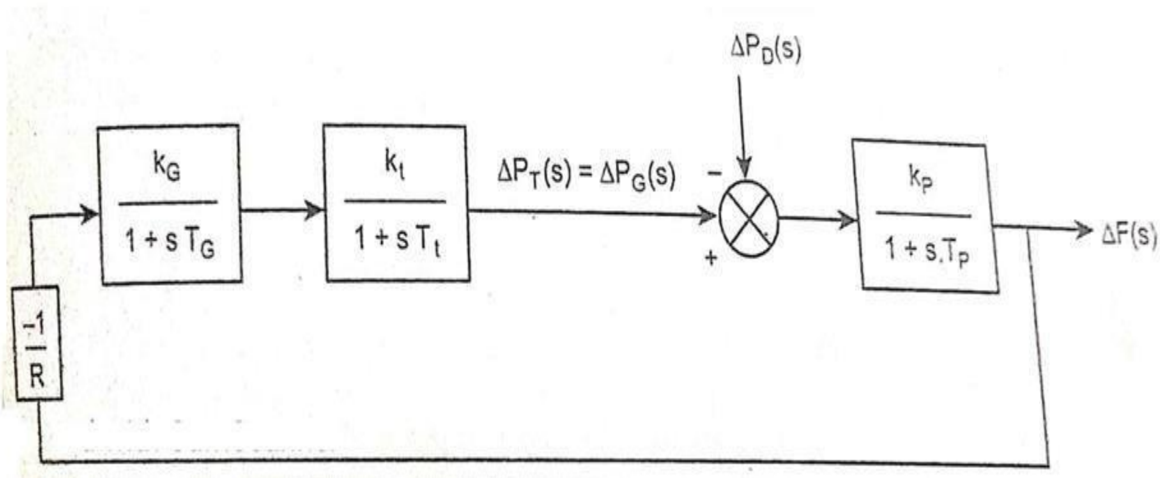
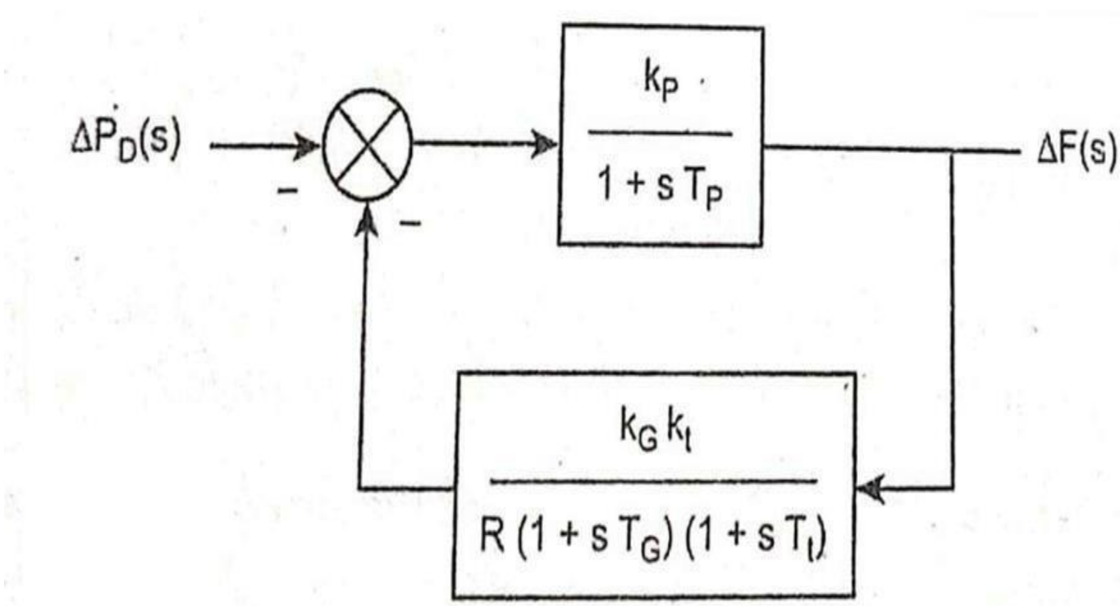
Static Analysis or Steady state response of uncontrolled case

- The basic objective of the primary ALFC loop is to maintain constant frequency in spite of changing loads. The primary ALFC loop as shown in the fig. has one output and two inputs. $\Delta P_{ref}(s)$ and $\Delta P_D(s)$
- Consider the speed changer has a fixed setting. Under this condition $\Delta P_C = 0$ and the load demand changes. This is known s free governor operation. The block diagram is shown infig drawn from substituting $\Delta P_C = 0$.





$$\Delta F(s) = \frac{\frac{Kp}{1+sTp}}{1+\frac{Kp}{1+sTp} \times \frac{KgKt}{R(1+sTg)(1+sTt)}} [-\Delta P_D(s)]$$

$$\Delta F(s) = \frac{Kp}{1+sTp+\frac{KpKgKt}{R(1+sTg)(1+sTt)}} [-\Delta P_D(s)]$$

For a step load change $\Delta P_D(s) = \frac{\Delta P_D}{s}$

$$\Delta F(s) = \frac{-Kp}{1+sTp+\frac{KpKgKt}{R(1+sTg)(1+sTt)}} [\frac{\Delta P_D}{s}]$$

$$\Delta F(s) = \frac{-Kp}{1+sTp+\frac{KpKgKt}{R(1+sTg)(1+sTt)}} [\frac{\Delta P_D}{s}]$$

Applying final value theorem,

$$\Delta f_{stat} = \lim_{s \to 0} S.\Delta F(s) = \frac{-Kp}{1+\frac{KpKgKt}{R}} \times \Delta P_D \quad \ldots\ldots\ldots\ldots (1)$$

Practically Kg Kt =1

$$\Delta f_{stat} = \frac{-Kp}{1+\frac{Kp}{R}} \Delta PD$$

$$K_p = \frac{1}{B} \quad \text{and } \Delta P_D = M$$

$$\Delta f_{stat} = \frac{-\frac{1}{B}}{1+\frac{1}{BR}} \Delta PD$$

$$\Delta f_{stat} = \frac{-M}{B+\frac{1}{R}} = (-)\frac{M}{\beta} ; \beta = B + \frac{1}{R}$$

In practice $B << \frac{1}{R}$, neglecting B,

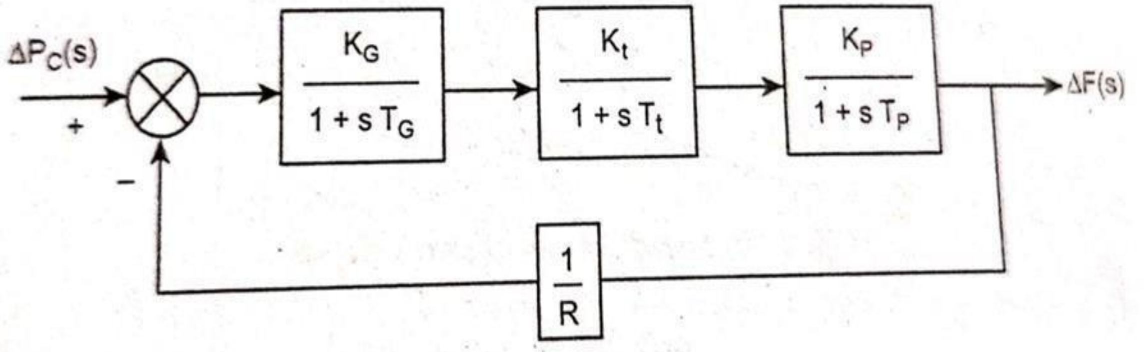
$$\frac{\Delta f_{stat}}{\Delta P_D} = (-)R \quad \text{Hz/MW}$$

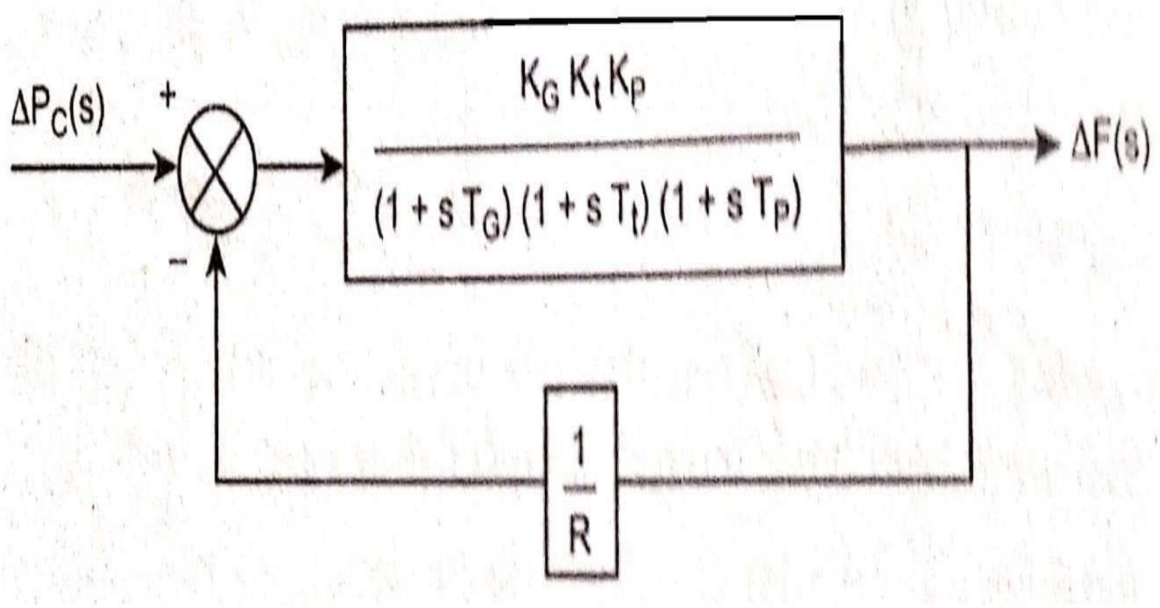
When several generators with governor speed regulations $R_1, R_{2 \ldots\ldots} R_n$ are connected to thesystem the steady state deviation in frequency is given by

$$\Delta f_{stat} = \frac{-\Delta P_D}{B+\frac{1}{R_1}+\frac{1}{R_2}+\cdots\frac{1}{R_n}}$$

Static Analysis or Steady state response of controlled case

In this case, there is a step change ΔP_C force for speed changer setting and the load demand remains fixed i.e $\Delta P_D = 0$





$$\Delta F(s) = \frac{KgKtKp}{(1+sTg)(1+sTt)(1+sTp)+\frac{KgKtKp}{R}} \times \Delta P_C\,(s)$$

Practically Kg Kt =1 ; $T_g = T_t = 0$

For a step load change, $\Delta P_C\,(s) = \frac{\Delta P_c}{s}$

$$\Delta F(s) = \frac{Kp}{(1+sTg)(1+sTt)(1+sTp)+\frac{Kp}{R}} \times \frac{\Delta P_c}{s}$$

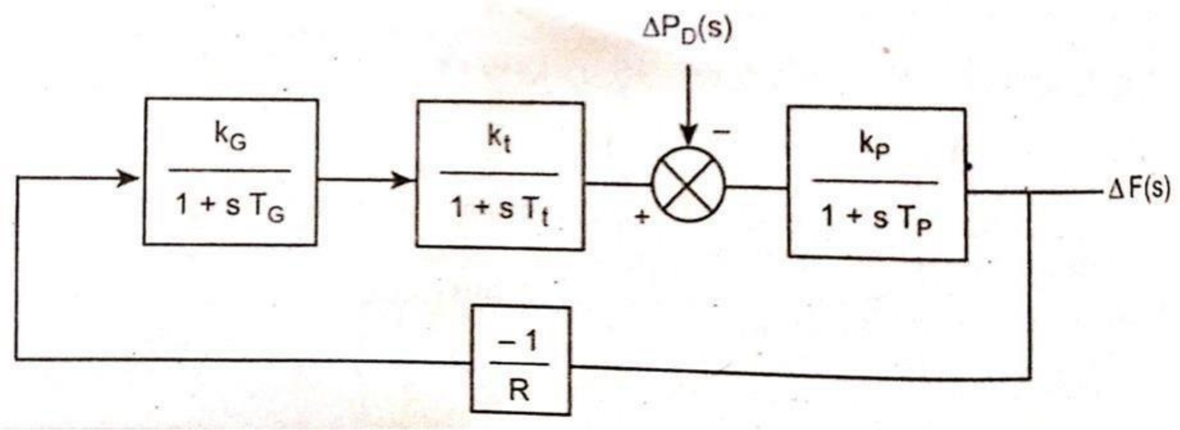
Applying final value theorem,

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

$$\frac{\Delta f_{stat}}{\Delta P_C} = \frac{1}{B+\frac{1}{R}} \quad \text{Hz/MW}$$

Dynamic Analysis of Uncontrolled case (Single Area)

To obtain the dynamic response representing the change in frequency as a function of time for a stepchange in load. The block diagram reduces as shown in fig.



$$\Delta F(s) = \frac{\frac{Kp}{1+sTp}}{1+ \frac{Kp}{1+sTp} \; x \; \frac{KgKt}{R(1+sTg)(1+sTt)}} [-\Delta P_D(s)]$$

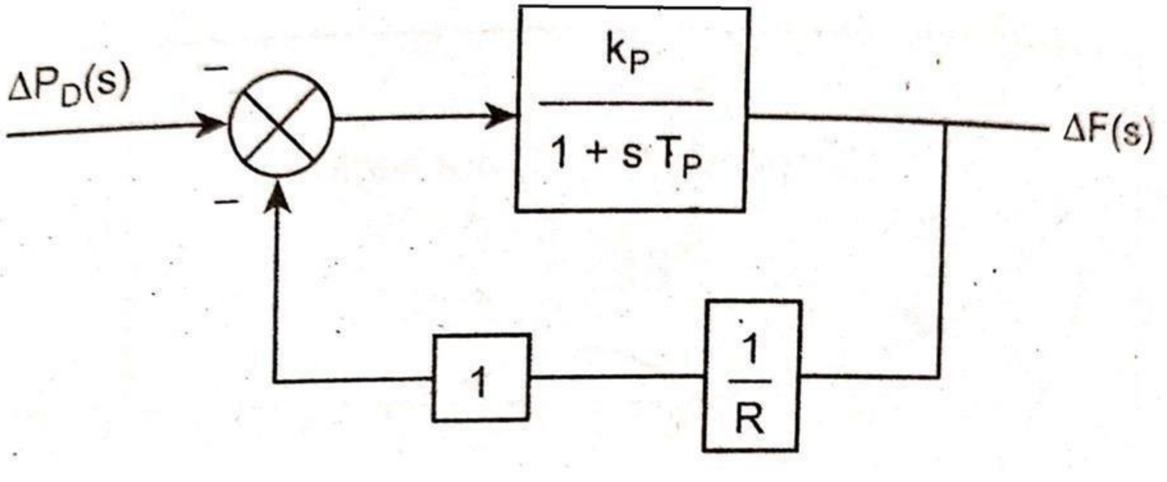
Taking inverse Laplace transform for an expression ΔF(s) is tedious, because the denominator will be third order. We can simplify the analysis by making the following assumptions.

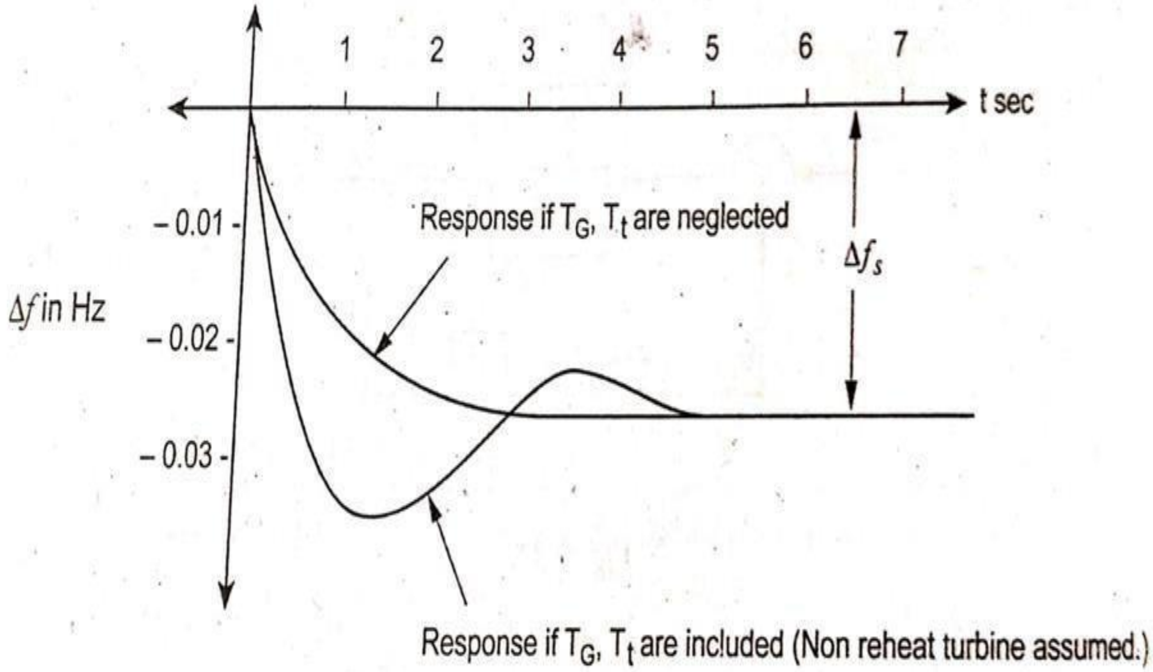
1. The action of speed governor and turbine is instantaneously compared with rest of the power system.
2. The time constant of the power systemTp=20 sec, Tg = 0.4sec. Tt = 0.5sec

Approximate Analysis : letting $T_G = T_t = 0$

$K_G = K_t = 1$

The block diagram reduces as shown in fig.




1
2
3
4
5
6
7
t sec
– 0.01
– 0.02
– 0.03
Δf in Hz
Response if T_G, T_t are neglected
Δf_s
Response if T_G, T_t are included (Non reheat turbine assumed.)

Important points for uncontrolled Single Area

1. By reducing value of R it is possible to increase AFRC. Hence static frequency error may bereduced.

2. With smaller time constant Tg and Tt, the system response shows some oscillations before settling down with a drop in frequency. But if these time constants are neglected, response is purely exponential.

3. If the overall closed loop system time constant is calculated from the response curve, it is
found to be much smaller than the open loop time constant of the power system.

4. For the uncontrolled system there exists a steady state frequency error as a result of increasein load demand, however small it may be.

5. When the load demand increases speed or frequency of the system drops though initially kinetic energy of rotating inertia may be used to meet up the demand. Eventually it will be balanced by an increase in system generation and decrease in load as associated with the dropping frequency.