Theory -

With the use of swing equation of a synchronous machine to small perturbation, we have

$$\frac{2H}{\omega}\frac{d^2\Delta\delta}{dt^2} = \Delta P_M - \Delta P_E \tag{1}$$

Or in terms of small change in speed

$$\frac{d(\Delta\omega)}{dt} = \frac{1}{2H}(\Delta P_M - \Delta P_E) \tag{2}$$

Taking the Laplace Transformation gives,

$$\Delta\omega = \frac{1}{2Hs}(\Delta P_M - \Delta P_E) \tag{3}$$

1.2 Mathematical modelling of load:

The load on a power system consists of various electrical drives. The load speed characteristic of the load is given by:

$$\Delta P_E = (\Delta P_L + D\Delta\omega) \tag{4}$$

where, ΔP_L is the non-frequency sensitive change in load. On combining equation (3) and (4), we get the corresponding change in frequency with the change in the mechanical power and change in load.

$$\Delta\omega = \frac{1}{Ms+D}(\Delta P_M - \Delta P_L) \tag{5}$$

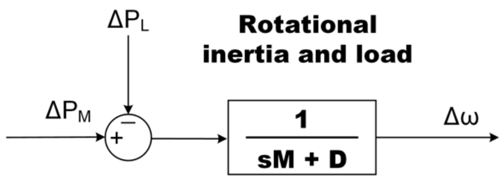

Fig 1: Mathematical modelling block diagram for a generator and load

1.3 Mathematical modelling for prime mover:

The source of power generation is the prime mover. It can be hydraulic turbines near waterfalls, steam turbine whose energy come from burning of coal, gas and other fuels. The model of turbine relates the changes in mechanical power output ΔP_M and the changes in the steam valve position ΔP_G. The transfer function of the turbine model is given by:

$$TF_T = \frac{\Delta P_M}{\Delta P_G} = \frac{1}{1+sT_T} \tag{6}$$

where the turbine constant is in the range of 0.3 - 4.0s.

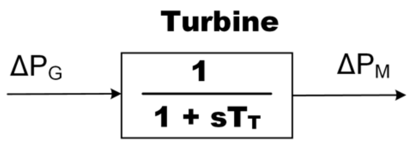

Fig 2: Mathematical modelling block diagram for a turbine

1.4 Mathematical modelling for governor:

When the electrical load is increased suddenly then the electrical power exceeds the input mechanical power. This deficiency of power in the load side is compensated from the kinetic energy of the turbine. Due to this reason the energy that is stored in the machine is decreased and the governor sends signal for supplying more volumes of water, steam or gas to increase the speed of the prime mover to compensate deficiency in speed.

$$(\Delta P_C - \frac{1}{R}\Delta\omega) = \Delta P_{ref} \quad (7)$$

The command ΔP_G is transformed through amplifier to the steam valve position command ΔP_C. We assume here a linear relationship and considering simple time constant, we get this s-domain relation as:

$$\Delta P_{ref}\,(\frac{1}{1+sT_G}) = \Delta P_G \quad (8)$$

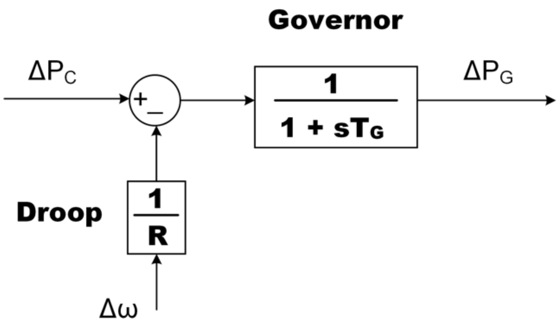

Fig 3: Mathematical modelling block diagram for a Governor

Combining all the above block diagrams, for an isolated single area power system we get the following:

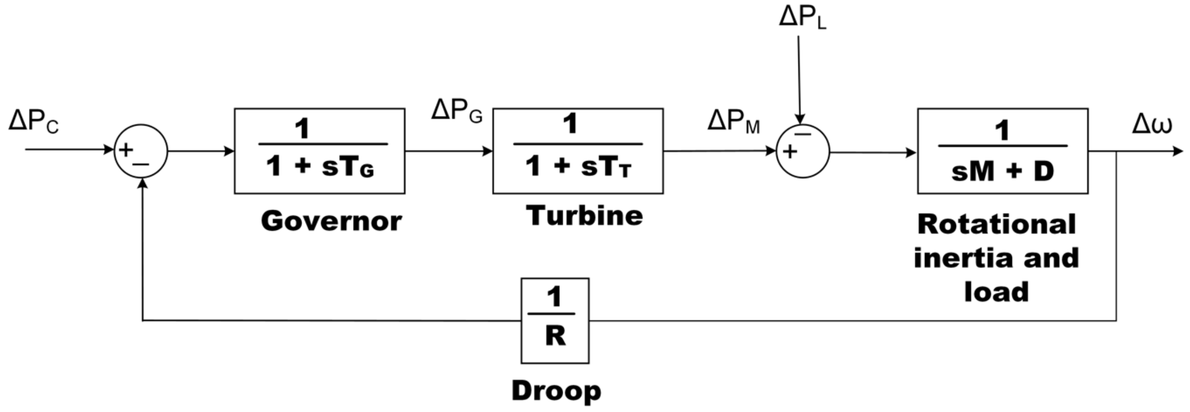

Fig 4: Complete mathematical model block diagram of a single area load frequency control