Prime Mover Model

Prime Mover Model – It is the source of mechanical power which maybe a steam turbine or hydraulic turbine. In the case of prime mover model the change in mechanical power output ΔP_m is related to the change in steam valve position ΔP_V as

$$G_T(s) = \frac{\Delta P_m(s)}{\Delta P_v(s)} = \frac{K_T}{1 + s\tau_T}$$

where $G_T(s)$ = transfer function of prime mover
τ_T = time constt of turbine ranging from 0.2 to 2 sec.

The block dig. of a prime mover is given by fig (6).

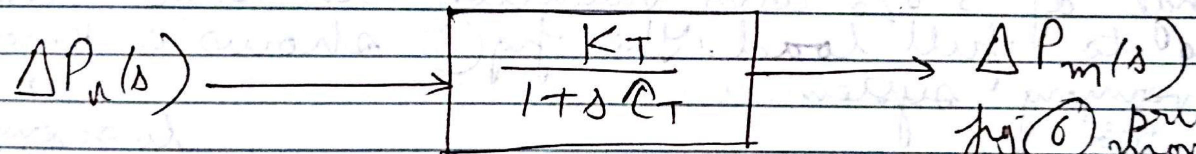

fig (6) prime mover block dig

Governor Model

Governor Model – When the generator electrical load is suddenly increased, the electrical power exceeds the mechanical power input. This deficiency is supplied by the K.E. stored in the rotating system. This results in decrease in turbine speed because K.E. is reduced ultimately resulting in generator frequency to fall. The change in speed is sensed by turbine governer which acts to adjust the turbine input valve to change the mechanical power output to bring the speed to a new steady state. The governors are designed to allow speed to drop with increase in load for stable operation. The steady state characteristic of such a governor is shown in fig (7)

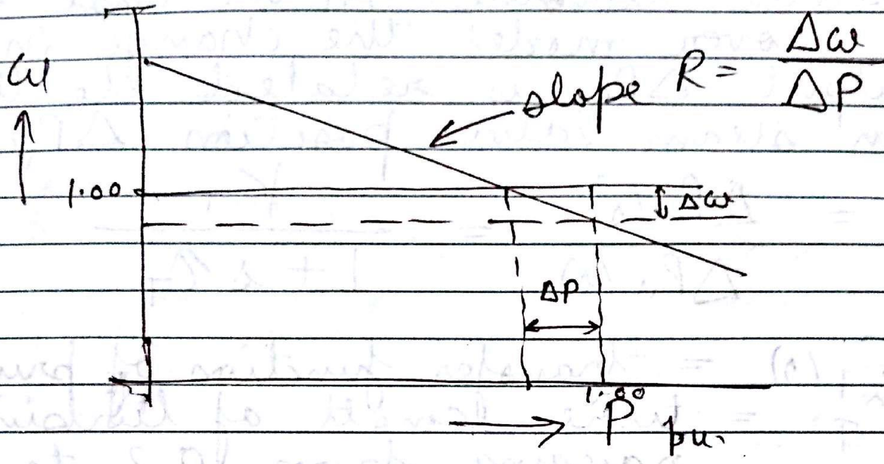

fig (7)

The slope of the curve represents the speed regulation R which generally lies in the range of 5-6% with variation in load from zero to full load. The fig (8) shows a speed governing system.

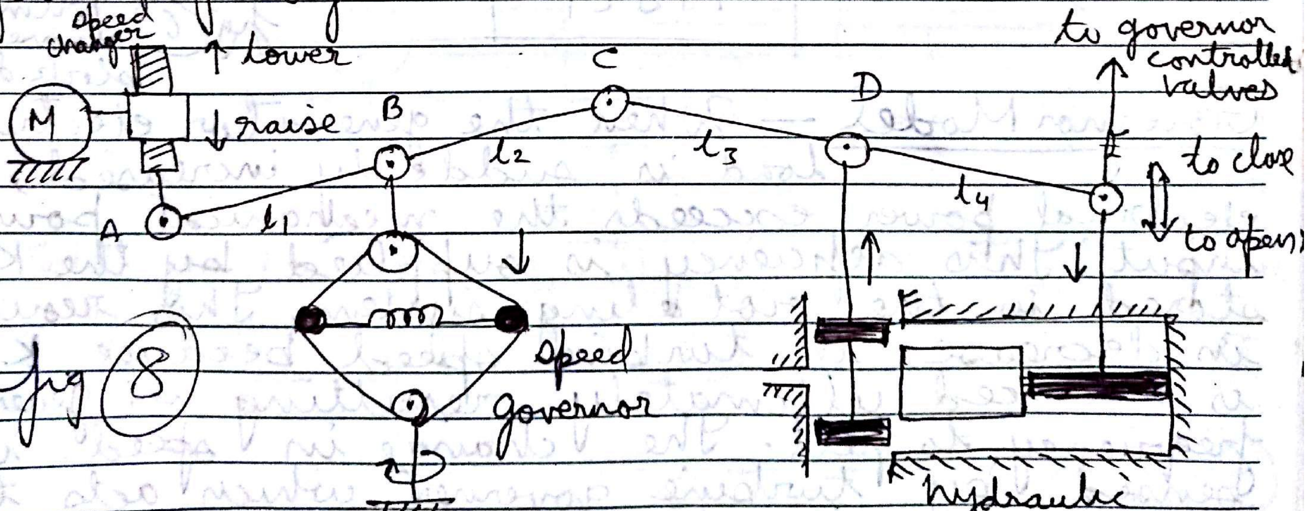

fig (8) Speed Governing System

Let the point A of speed changer moves down by an amount ΔX_A as a result commanded increase in power is ΔP_C then

$$\Delta X_A = K_1 \Delta P_C$$

The movement of linkage point A causes small position changes ΔX_C and ΔX_D of linkages point C and D. With the movement of D upwards by ΔX_D the steam valve will move downwards a small distance ΔX_I which results in increased turbine torque and hence power increase ΔP_G. The increase in frequency Δf causes link point B to move downward a small distance ΔX_B proportional to Δf. Since movements are small, we have linear relationship

$$\Delta X_C = K_1 \Delta f - K_2 \Delta P_C \quad \text{--- (1)}$$

where K_1 and K_2 are positive constants depending on the length of the linkages arms AB and BC, and upon proportional constants of speed changer & speed governor. The movement of pt D is contributed by the movement of C and I and therefore

$$\Delta X_D = K_3 \Delta X_C + K_4 \Delta X_I \quad \text{--- (2)}$$

where K_3 and K_4 are positive constants depending upon the length of linkages CD and DI. Assuming that oil flow into hydraulic cylinder is proportional to position ΔX_D of

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of the pilot valve the value of ΔX_I is given by

$$\Delta X_I = K_5 \int_0^t -(\Delta X_D)\, dt \quad — (3)$$

where K_5 is a constant depending upon fluid pressure and geomatries of the orifice and cylinder.

Taking Laplace transform of eq (1), (2) and (3) we get

$$\Delta X_C(s) = K_1 \Delta F(s) - K_2 \Delta P_C(s) \quad — (4)$$

$$\Delta X_D(s) = K_3 \Delta X_C(s) + K_4 \Delta X_I(s) \quad — (5)$$

$$\Delta X_I(s) = -\frac{K_5}{s} \Delta X_D(s) \quad — (6)$$

Subsituting eq (4) in eq. (5) we get

$$\Delta X_D(s) = K_3 \{K_1 \Delta F(s) - K_2 \Delta P_C(s)\} + K_4 \Delta X_I(s)$$

$$\Delta X_D(s) = K_1 K_3 \Delta F(s) - K_2 K_3 \Delta P_C(s) + K_4 \Delta X_I(s) \quad — (7)$$

Subsituting value of $\Delta X_D(s)$ from eq. (7) in eq (6) we get

$$\Delta X_I(s) = -\frac{K_5}{s}\left[K_1 K_3 \Delta F(s) - K_2 K_3 \Delta P_C(s) + K_4 \Delta X_I(s)\right]$$

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14	15	16	17	18	19	20	21	22	23	24	25	26	27
28	29	30	31										

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or $\Delta X_E(s)\left(1+\frac{K_4K_5}{s}\right) = \frac{K_2K_3K_5}{s}\Delta P_C(s) - \frac{K_1K_3K_5}{s}\Delta F(s)$

or $\Delta X_E(s)(s+K_4K_5) = K_2K_3K_5\,\Delta P_C(s) - K_1K_3K_5\,\Delta F(s)$

or $\Delta X_E(s) = \frac{K_2K_3K_5\,\Delta P_C(s) - K_1K_3K_5\,\Delta F(s)}{s+K_4K_5}$

or $\Delta X_E(s) = \frac{K_5\left[K_2K_3\,\Delta P_C(s) - K_1K_3\,\Delta F(s)\right]}{K_5\left(K_4 + s/K_5\right)}$

$\Delta X_E(s) = \frac{K_2K_3\left(\Delta P_C(s) - K_1/K_2\,\Delta F(s)\right)}{K_4 + s/K_5}$

or $\Delta X_E(s) = \frac{K_2K_3\left(\Delta P_C(s) - \frac{1}{R}\Delta F(s)\right)}{K_4(1+s/K_4K_5)}$

or $\Delta X_E(s) = \frac{K_2K_3/K_4}{(1+s/K_4K_5)}\left[\Delta P_C(s) - \frac{1}{R}\Delta F(s)\right]$

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or $\Delta X_E(s) = \frac{K_G}{1+s\tau_G}\left[\Delta P_c(s) - \frac{1}{R}\Delta F(s)\right]$

where

$K_G = \frac{K_2 K_3}{K_4}$ = gain of speed governor

$\tau_G = \frac{1}{K_4 K_5}$ = time constt of speed governor

$R = \frac{K_2}{K_1}$ = speed regulation of governor

<u>Block Dig of governor system for steam turb</u>

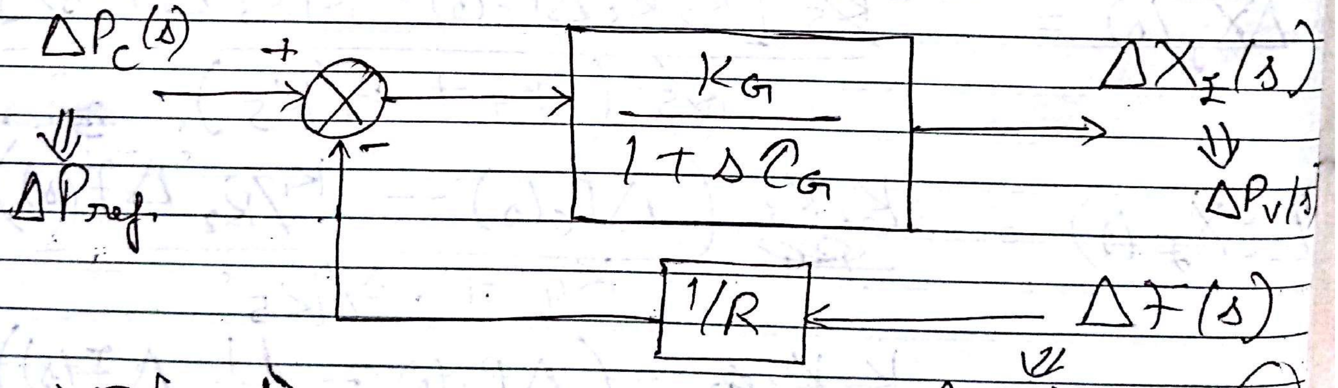

fig (9)

~~Block dig of governor~~

Since we know that

$$\frac{\Delta\Omega(s)}{\Delta P_m(s) - \Delta P_L(s)} = \frac{1}{2Hs + D}$$

$$= \frac{1/D}{1 + \frac{2H}{D}s} = \frac{K_p}{1 + s\tau_p}$$

where $K_p = \frac{1}{D}$ = power system gain

$\tau_p = \frac{2H}{D}$ = power system time constant

Hence governor-load model block dig. is modified as

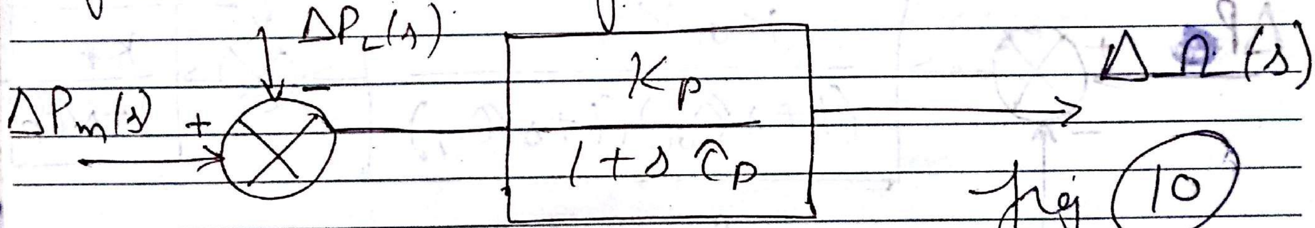

fig (10)

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