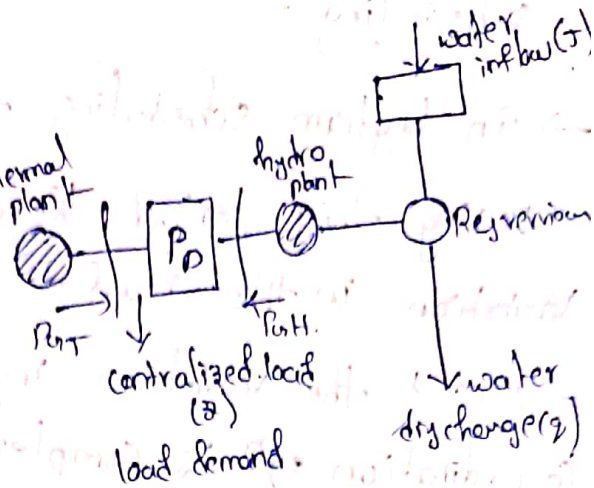
18/7/19

UNIT - 2

HYDRO THERMAL SCHEDULING

Introduction :-

→ one hydro plant & one thermal plant together supplies the power to a centerlized load then such system is called as "Hydro thermal system" (or) "Fundamental system" that is shown in fig.



→ The operation of system becomes complex when two different generating stations supplie power to a centrized load.

→ Hydro plants have low operating cost & high capital cost whearas as thermal plants have high operating cost & low capital cost.

→ so, it is to minimize the operating cost of a hydro thermal plant it is necessary to minimize the operating cost of a thermal power plant.

→ the operating cost of a thermal plant can be minimize by generating power through hydroplant for a given period of time when motor is available.

→ The hydro thermal system is classified into two types.

1. long term hydro thermal system.
2. short term co-ordination system..

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↓ long term hydro thermal System. (or) long term scheduling :-

→ In longterm scheduling the time period is one year
→ during this period their is a large amount of variation in the head of water.
→ due to the variation in head the determination of co-ordination eqn is complex.
→ It is divided into three catagerie.
  i, multi storage hydro thermal system.
  ii, cascade storage hydro thermal system.
  iii, multichade storage hydro thermal system.

① multistroage System :-

If the location of hydro plants are at different streams (a body of running water) and each hydro plants have it's own reservation then such system is called as "multistroage hydro electric System"

ii, cascade hydro electric system :-

If the location of hydroplants (or) at same stream then such system is called as "cascade hydro electric system".

iii, multichain :-

If the location of hydroplants are at different streams and each plant follow the stream then such system is called "multi chaine hydroelectric system"

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short term hydro thermal schedule:-

In short term hydrothermal scheduled the scheduled time period is conyider to be one day (or) one week two tyres.

1, Cayfant hydro thermal scheduled:-

The head of water in large capacity reyerviour is cayfant over whole period of operation.

2, Variable hydro thermal scheduled:-

The head of water in large capacity reyerviour is variable over whole period of operation

Hydroelectric powerplant model:-

1, cost of land:- The land selected for the conyentraction of hydroelectric power plant should be chep and capable to withstand the heavy weight of equipments

2, Cost of conyfruction:- cost of conyfruction capital cayt of a hydroelectric system is very high.

3, operatial cost:- It is alow where compared to other hydro power plants

4, cost of equipments and its inyfalation:-

Cost of equipments of hydroplants and its inyfalation is should be very ecoramical.

5, cayt of tranymiyyion:- As the location of hydroplantyrs near to the hills areay which is far away from the

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populated area. so, the cost of transmitting the energy is high.

6, Maintance cost :- The equipments of the hydro station should be maintane in a good condition to work effecently.

7, cost of energy generation:-

Generation of energy should be high w.r.to demanding the load.

19/7/19 Derivation of co-ordination eqn for hydro thermal schedule :-

for thermal plant, $\frac{dF_m}{dP_{GTm}}\left(1+\frac{\partial P_L}{\partial P_{GTm}}\right)=\lambda$ for $m=1,2\cdots a$.

for hydro plant, $V_n\frac{dw_n}{dP_{Gthn}}\left(1+\frac{\partial P_L}{\partial P_{Gthn}}\right)=\lambda$ for $n=a+1,a+2\cdots b$

where, P_{GTm} = o/p of m^{th} plant $\frac{\partial P_L}{\partial P_{GTm}}$ = Incremental T.L of m^{th} plant.

$\frac{dw_n}{dP_{Gthn}}$ = Incremental water rate of n^{th} hydroplant.

$\frac{\partial P_n}{\partial P_{Gthn}}$ = Incremental T.L of n^{th} hydroplant

V_n = Constant which converts incremental water rated of n^{th} hydroplant.

λ = legranzial multiplayer.

a = no. of thermal powerplant

b = no. of hydroplant

w_n = Turbine discharge or dyfance of n^{th} plant.

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proof:- The cost function is given by

$$\sum_{m=1}^{q} \int_{0}^{T} F_m dt = \text{Min (thermal)}$$

$$\sum_{n=a+1}^{b} \int_{0}^{T} w_n dt = \text{Min (hydro)}$$

$$\sum_{m=1}^{q} P_{Gm} + \sum_{n=a+1}^{b} P_{Gn} H_n = P_D + P_L \rightarrow (2)$$

$$\left(\begin{array}{l} \text{D/P} = \text{O/P} + (\text{o+y}) \\ P_1 + P_2 = P_D + P_L \end{array} \right)$$

∴ The total fuel cost is given by,

$$F = \sum_{m=1}^{q} \int_{0}^{T} F_m dt + \sum_{n=a+1}^{b} \int_{0}^{T} w_n dt \rightarrow (1)$$

The changing of eq^n (1) becomes

$$\Delta \left[\sum_{m=1}^{q} \int_{0}^{T} F_m dt + \sum_{n=a+1}^{b} \gamma_n \int_{0}^{T} w_n dt \right] = 0$$

$$\Rightarrow \sum_{m=1}^{q} \frac{dF_m}{dP_{Gm}} \Delta P_{Gm} + \sum_{n=a+1}^{b} \gamma_n \frac{dw_n}{dP_{Gn}} \Delta P_{Gn} = 0 \rightarrow (3)$$

→ from power balance eq^n (2) becomes,

$$\sum_{m=1}^{q} \Delta P_{Gm} - \sum_{m=1}^{q} \frac{\partial P_2}{\partial P_{Gm}} \Delta P_{Gm} + \sum_{n=a+1}^{b} \Delta P_{Gn} - \sum_{n=a+1}^{b} \frac{\partial P_2}{\partial P_{Gn}} \Delta P_{Gn} = 0 \rightarrow (4)$$

change in o/p power ΔP_{GK} for a perticular hydro plant (say K^{th} plant)

eq^n (4) $\Rightarrow$

$$\sum_{m=1}^{q} \Delta P_{Gm} - \sum_{m=1}^{q} \frac{\partial P_2}{\partial P_{Gm}} \Delta P_{Gm} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \Delta P_{Gn} - \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \frac{\partial P_2}{\partial P_{Gn}} \Delta P_{Gn} - \left(\Delta P_{GK} - \frac{\partial P_2}{\partial P_{GK}} \Delta P_{GK} \right) = 0$$

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$$\Rightarrow \sum_{m=1}^{q} \Delta P_{G_i} T_{im} - \sum_{m=1}^{q} \frac{\partial P_L}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \Delta P_{G_i} H_n - \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \frac{\partial P_L}{\partial P_{G_i} H_n} \Delta P_{G_i} H_n$$

$$= \left(\Delta P_{G_i} H_K - \frac{\partial P_L}{\partial P_{G_i} H_K} \Delta P_{G_i} H_K \right)$$

$$\Rightarrow \sum_{m=1}^{q} \Delta P_{G_i} T_{im} - \sum_{m=1}^{q} \frac{\partial P_L}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \Delta P_{G_i} H_n - \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \frac{\partial P_L}{\partial P_{G_i} H_n} \Delta P_{G_i} H_n$$

$$= \Delta P_{G_i} H_K \left(1 - \frac{\partial P_L}{\partial P_{G_i} H_K} \right) \rightarrow (5)$$

In eqn (3) let us consider particular hydro plant say K^{th} plant then the eqn (3) eqn becomes

$$\rightarrow \sum_{m=1}^{q} \frac{\partial f_m}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} V_n \frac{d\omega_n}{d P_{G_i} H_n} \Delta P_{G_i} H_n - V_K \frac{d\omega_K}{d P_{G_i} H_K} \Delta P_{G_i} H_K = 0$$

$$\sum_{m=1}^{q} \frac{\partial f_m}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} V_n \frac{d\omega_n}{d P_{G_i} H_n} \Delta P_{G_i} H_n = V_K \frac{d\omega_K}{d P_{G_i} H_K} \Delta P_{G_i} H_K$$

Multiplying with $\left(1 - \frac{\partial P_L}{\partial P_{G_i} H_K}\right)$ on b.s

$$\left(1 - \frac{\partial P_L}{\partial P_{G_i} H_K}\right) \left(\sum_{m=1}^{q} \frac{\partial f_m}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} V_n \frac{d\omega_n}{\partial P_{G_i} H_n} \Delta P_{G_i} H_n \right) = V_K \frac{d\omega_K}{d P_{G_i} H_K} \Delta P_{G_i} H_K \left(1 - \frac{\partial P_L}{\partial P_{G_i} H_K}\right) = \rightarrow (6)$$

Sub eqn (5) in (6)

$$\left(1 - \frac{\partial P_L}{\partial P_{G_i} H_K}\right) \left(\sum_{m=1}^{q} \frac{\partial f_m}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} V_n \frac{d\omega_n}{d P_{G_i} H_n} \Delta P_{G_i} H_n \right) =$$

$$V_K \frac{d\omega_K}{\partial P_{G_i} H_K} \left(\sum_{m=1}^{q} \Delta P_{G_i} T_{im} - \sum_{m=1}^{q} \frac{\partial P_L}{\partial P_{G_i} T_{im}} \Delta P_{G_i} T_{im} + \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \Delta P_{G_i} H_n - \sum_{\substack{n=a+1 \\ n \neq K}}^{b} \frac{\partial P_L}{\partial P_{G_i} H_n} \Delta P_{G_i} H_n \right)$$

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$$\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)\sum_{m=1}^{q}\frac{\partial f_m}{\partial P_{GTm}}\Delta P_{GTm}+\sum_{\substack{n=a+1\\ n\neq k}}^{b}V_n\frac{d\omega_n}{dP_{GHn}}\Delta P_{GHn}\left(1-\frac{dP_2}{dP_{GHK}}\right)=$$

$$\sum_{m=1}^{q}\Delta P_{GTm}V_k\frac{d\omega_k}{\partial P_{GHK}}-\sum_{m=1}^{q}\frac{\partial P_2}{\partial P_{GTm}}\Delta P_{GTm}V_k\frac{d\omega_k}{\partial P_{GHK}}+$$

$$\sum_{\substack{n=a+1\\ n\neq k}}^{b}\Delta P_{GHn}V_k\frac{d\omega_k}{\partial P_{GHK}}-\sum_{\substack{n=a+1\\ n\neq k}}^{b}\frac{\partial P_2}{dP_{GHn}}\Delta P_{GHn}V_k\frac{d\omega_k}{\partial P_{GHK}}$$

$$\sum_{m=1}^{q}\frac{\partial f_m}{\partial P_{GTm}}\Delta P_{GTm}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)+\sum_{\substack{n=a+1\\ n\neq k}}^{b}V_n\frac{d\omega_n}{dP_{GHn}}\Delta P_{GHn}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)=$$

$$\sum_{m=1}^{q}\Delta P_{GTm}V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{dP_2}{\partial P_{GTm}}\right)+\sum_{\substack{n=a+1\\ n\neq k}}^{b}\Delta P_{GHn}V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GHn}}\right)$$

$$\sum_{m=1}^{q}\frac{\partial f_m}{\partial P_{GTm}}\Delta P_{GTm}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)+\sum_{\substack{n=a+1\\ n\neq k}}^{b}V_A\frac{d\omega_n}{dP_{GHn}}\Delta P_{GHn}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)$$

$$-\sum_{m=1}^{q}\Delta P_{GTm}V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GTm}}\right)-\sum_{\substack{n=a+1\\ n\neq k}}^{b}\Delta P_{GHn}V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GHn}}\right)=0$$

$$\Rightarrow\sum_{m=1}^{q}\Delta P_{GTm}\left[\frac{df_m}{\partial P_{GTm}}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)-V_k\frac{d\omega_k}{\partial P_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GTm}}\right)\right]+$$

$$\sum_{\substack{n=a+1\\ n\neq k}}^{b}\Delta P_{GHn}\left[V_n\frac{d\omega_n}{dP_{GHn}}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)-V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GHn}}\right)\right]=0.$$

$$\sum_{m=1}^{q}\Delta P_{GTm}\left[\frac{df_m}{\partial P_{GTm}}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)-V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GTm}}\right)\right]=0$$

$$\frac{df_m}{dP_{GTm}}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)-V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{\partial P_{GTm}}\right)=0.$$

$$\frac{df_m}{dP_{GTm}}\left(1-\frac{\partial P_2}{\partial P_{GHK}}\right)=V_k\frac{d\omega_k}{dP_{GHK}}\left(1-\frac{\partial P_2}{dP_{GTm}}\right)$$

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For thermal plant,

$$\frac{\frac{dF_m}{dP_{GT_m}}}{1-\frac{\partial P_2}{\partial P_{GT_m}}} = \lambda \quad \text{for } m = 1,2 \text{ --- } a$$

(or)

$$\frac{dF_m}{dP_{GT_m}}\left(1+\frac{\partial P_2}{\partial P_{GT_m}}\right) = \lambda \quad \text{for } m = 1,2 \text{ --- } a$$

$$\sum_{\substack{n=a+1 \\ n\neq k}}^{b} \Delta P_{H_n} \left[V_n \frac{dw_n}{dP_{H_n}}\left(1-\frac{\partial P_2}{\partial P_{H_k}}\right) - V_k \frac{dw_k}{dP_{H_k}}\left(1-\frac{\partial P_2}{\partial P_{H_n}}\right)\right] = 0$$

$$V_n \frac{dw_n}{dP_{H_n}}\left(1-\frac{\partial P_2}{\partial P_{H_k}}\right) - V_k \frac{dw_k}{dP_{H_k}}\left(1-\frac{\partial P_2}{\partial P_{H_n}}\right) = 0$$

$$V_n \frac{dw_n}{dP_{H_n}}\left(1-\frac{\partial P_2}{\partial P_{H_k}}\right) = V_k \frac{dw_k}{dP_{H_k}}\left(1-\frac{\partial P_2}{\partial P_{H_n}}\right)$$

For hydro plant

$$\frac{V_n \frac{dw_n}{dP_{H_n}}}{1-\frac{\partial P_2}{\partial P_{H_n}}} = \lambda \quad \text{for } n = a+1, a+2 \text{ --- } b.$$

(or)

$$V_n \frac{dw_n}{dP_{H_n}}\left(1+\frac{\partial P_2}{\partial P_{H_n}}\right) = \lambda \quad \text{for } n = a+1, a+2 \text{ --- } b$$

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9, $C_1 = (26 + 0.009 P_{GT_1}) P_{GT_1}$ $\lambda = 65$ Rs/MWh

$w_2 = (7 + 0.008 P_{GH_2}) P_{GH_2}$

$V_2 = 4 \times 10^{-4}$; $B_{22} = 0.0025$ MW^{-1}

Sol:- $P_2 = B_{22} P_{GH_2}^2$ $\frac{dC_1}{dP_{GT_1}} = 26 + 0.09 P_{GT_1}$

$P_2 = (0.0025) P_{GH_2}^2$ $\frac{dw_2}{dP_{GH_2}} = 7 + 0.008 P_{GH_2}$

$\frac{\partial P_2}{\partial P_{GH_2}} = 0.005 P_{GH_2}$

$P_2 = B_{22} P_2^2$

$\frac{\partial P_2}{\partial P_{GH_2}} = 2 B_{22} P_2$

$= 2 (0.0025) P_2$

$P_2 = B_{11} P_1^2 + B_{12} P_1 P_2 + B_{22} P_2^2$

For thermal plant :-

$\frac{dC_T}{dP_{GT_1}} \left(1 + \frac{\partial P_2}{\partial P_{GH_2}}\right) = \lambda$

$(26 + 0.09 P_{GT_1})(1 + 0) = 65$

$26 + 0.09 P_{GT_1} = 65$

$P_{GT_1} = \frac{39}{0.09}$ $\Rightarrow$ $\boxed{P_{GT_1} = 433.3 \text{ MW}}$

For Hydel

$V_2 \frac{dw_2}{dP_{GH_2}} \left(1 + \frac{\partial P_2}{\partial P_{GH_2}}\right) = \lambda$

$(4 \times 10^{-4})(7 + 0.008 P_{GH_2})(1 + 0.005 P_{GH_2}) = 65$

$(0.0028 + 0.0000032 P_{GH_2})(1 + 0.005 P_{GH_2}) = 65$

$0.0028 + 0.000014 P_{GH_2} + 0.0000032 P_{GH_2} +$

$0.00000016 P_{GH_2}^2 = 65$

$0.00000016 P_{GH_2}^2 + 0.0000172 P_{GH_2} = 64.99$

$\boxed{P_{GH_2} = -537.5 \text{ MW}}$ $P_{GH_1} + P_{GH_2} = P_D + P_2$

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$P_{GH_1} + P_{GH_2} = P_D + P_L$

$433.3 - 537.5 = P_D + 722.26$

$-104.2 - 722.26 = P_D$

$\boxed{P_D = -826.37 \text{ MW}}$

(3) $\frac{dC_1}{dP_{GH}} = 60 + 0.2 P_{GH_1}$ $\quad A = 60$

$\frac{dw_2}{dP_{GH_2}} = 0.8 + 0.0006 P_{GH_2}$ $\quad V_2 = 77.5$

$P_L = B_{22} P_{GH}^2$

$\Rightarrow P_L = (0.001) P_{GH_2}^2$ $\quad \frac{dC_1}{dP_{GH}} \left(1 + \frac{\partial P_L}{\partial P_{GH}}\right) = \lambda$

$60 + 0.2 P_{GH_1} = 65 \Rightarrow \boxed{P_{GH_1} = 25 \text{ MW}}$

$\frac{dw_2}{dP_{GH_2}} \left(1 + \frac{\partial P_L}{\partial P_{GH_2}}\right) = \lambda$

$0.000093 P_{GH_2}^2 + 0.1705 P_{GH_2} = 23$

$\boxed{P_{GH_2} = 17.7 \text{ (or) } 1875.5 \text{ MW}}$

Note:- which type of turbine used in hydroelectric power plant?

Ans:- medium heady - Francis turbine used in (65 to 125%)

low heady - propeller turbine is used.

high heady - impulse (or) pelton turbine is used. (85 to 90%)

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