SUBJECT: POWER SYSTEM OPERATION AND CONTROL

SUBJECT CODE: EE 403

SEMESTER: VII

LECTURE-4

Hydrothermal Coordination

Module-III

- INTRODUCTION

- SCHEDULING HYDRO SYSTEMS

- HYDROTHERMAL SCHEDULING IN POWER SYSTEM

Classification of Hydrothermal Scheduling Problem

- Long range problem
- Short range problem

- Fixed head hydro thermal scheduling
- Variable head hydro thermal scheduling

PROBLEM FORMULATION

The objective function of the hydrothermal scheduling problem is the minimization of the thermal power generation cost

$$F_{CTk} = \sum_{t=1}^{T} \sum_{i=1}^{n} FC_i(P_{sti}(t))$$

Constraints

- Power balance equation

$$D_t = \sum_{i=1}^{n} P_{sti}(t) + \sum_{j=1}^{m} P_{hyj}(t) - P_L$$

- Thermal generation capacity

$$P_{stimin} \leq P_{sti}(t) \leq P_{stimax}$$

- Hydro generation capacity

$$P_{hyjmin} \leq P_{hyj}(t) \leq P_{hyjmax}$$

- Hydraulic Continuity

$$V_j(t+1) = V_j(t) + q_j(t-m) + s_j(t-m) - q_j(t) - s_j(t) + r_j(t)$$

- Initial and final reservoir storage

$$V_j(0) = V_0 \; ; \; V_j(T) = V_T$$

Constraints

- Reservoir storage $V_{jmin} \leq V_j(t) \leq V_{jmax}$
- Water discharge rate $q_{jmin} \leq q_j(t) \leq q_{jmax}$
- Total water discharge $q_{jtot} = \sum_{t=1}^{T} q_i(t)$

Where,

D_t : System load demand at interval t

F_{CTk} : Objective function value of k_{th} individual of a population

n : Number of thermal generating units

Psti (t) : Thermal generation of unit i at interval t

Pstimin , Pstimax: Minimum and maximum generation capacity limits of thermal unit

Phyjmin , Phyjmax: Minimum and maximum generation capacity limits of hydro unit

qj (t) : Water discharge rate of plant j at interval t

rj (t) : Inflow rate into the storage reservoir of plant j at interval t

T : Number of hours in the study period

V0 , VT : Initial and final reservoir storage

$FC_i(P_{sti}(t))$: Fuel cost function of the i_{th} thermal unit

PL : Total Transmission loss

m : Number of hydro generating units

Phyj (t) : Hydro generation of plant j at interval t

sj (t) : Spillage of reservoir j at interval t

Vj (t) : Reservoir storage volume of plant j at interval t

Short Term Hydrothermal Scheduling Using $\gamma - \lambda$ Iterations

The objective function is to minimize the total operating cost (C- Thermal) represented by the fuel cost of thermal generation over the optimization interval (k).

$$C_{Thermal} = \mathrm{Min} \sum_{k=1}^{N_T} t_k C(P_{Tk}); \quad N_T = 96$$

$$C(P_{Tk}) = \alpha P_{Tk}^2 + \beta P_{Tk} + \theta \quad \mathrm{Rs/hr}$$

Hydro Model

Hydro Electric Power Plant is represented by the quadratic equation

$$q(P_H) = aP_H^2 + bP_H + c \quad m^3/hr$$

Water Availability Constraint

The total water discharge is $$q_{total} = \sum_{k=1}^{N_T} t_k q_k ; \quad k = 1,2,3,\ldots,96$$

In the current study, constant head operation is assumed and the water discharge rate, q_k is assumed to be a function of the hydro generation, PHk as in

q_k = q_k (PHk)

where, t_k is number of hours in k_{th} time block and q_k is the water discharge rate for k_{th} time block.

- **Power Balance Equation**

  ✓ Total generated power is equal to the total demand $_{PDK}$ including losses P_{Lk} in each time interval. Mathematically:

$$P_{Tk} + P_{Hk} = P_{Dk} + P_{Lk}; \quad k = 1,2,\ldots,96$$

- **Thermal and Hydro Power Limits**

✓ Thermal and hydro units can generate power between specified upper and lower limits:

$$P_T^{min} \le P_{Tk} \le P_T^{max}; \quad k = 1,2,\ldots,96$$

$$P_H^{min} \le P_{Hk} \le P_H^{max}; \quad k = 1,2,\ldots,96$$

Solution Technique

$$\pounds = \sum_{k=1}^{N_T} \left[t_k C(P_{Tk}) - \lambda_k (P_{Tk} + P_{Hk} - P_{Dk} - P_{Lk}) \right] + \gamma \left[\sum_{k=1}^{N_T} t_k q_k (P_{Hk}) - q_{total} \right]$$

The co-ordination equation from the above function can be obtained as

$$t_k \cdot \frac{dC(P_{Tk})}{dP_{Tk}} + \lambda_k \frac{dP_{Lk}}{dP_{Tk}} = \lambda_k$$

$$\gamma . t_k \cdot \frac{dq(P_{Hk})}{dP_{Hk}} + \lambda_k \frac{dP_{Lk}}{dP_{Hk}} = \lambda_k$$