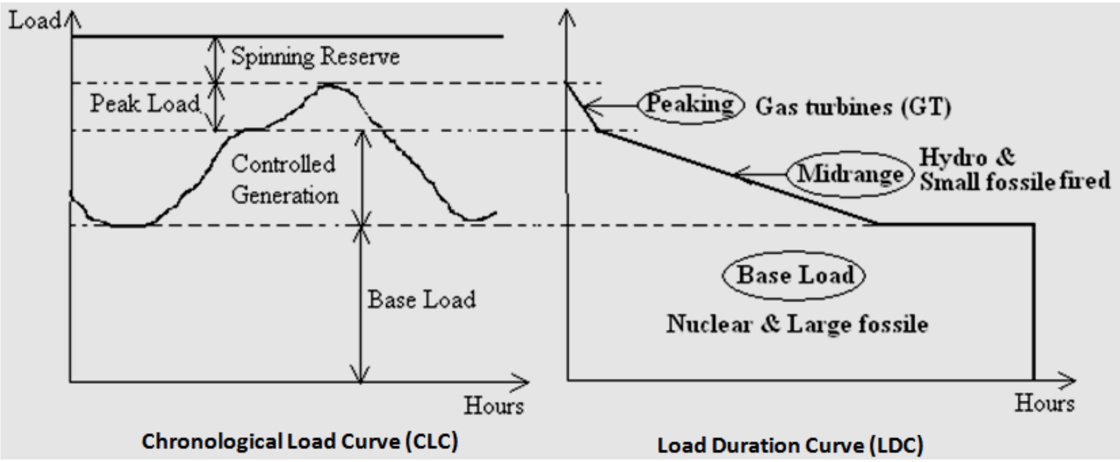
EPM 333: Economics of Generation &Operation

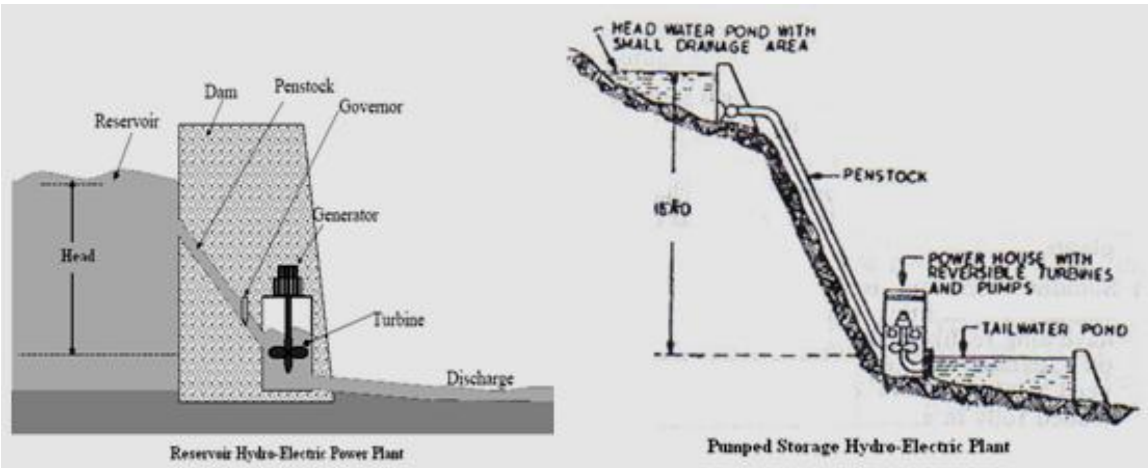
Hydro-Thermal Coordination – 2008/2009

Report: Problems 7 to 10

1. "The power demand is met by a generator mix that depends on the unit rate limits (MW/sec) characteristics". Explain based on the following load curves. Also, compare between these load curves.



2. Briefly explain the function of each item and applications of each of the following hydro-electric power plants shown in the following figures. Also, explain the factors and basis on which the economic operation of a hydrothermal system depends on.



3. The daily load curve data for a certain area is shown in Table 1 for weekdays and table 2 for weekends. It is proposed to install a run off river plant and a steam plant for supplying the above load (see figure below). The run off data indicated that a flow of 50 m^3/sec is available for 97% of the time during the year. The head is 90 m, hydro plant efficiency is 90%

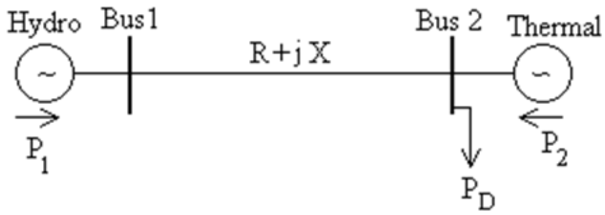
and transmission losses are 5%. Determine the capacity of both plants. Suggest a schedule of plant output for a weekday and for a weekend day.

Table 1: Load curve - weekdays

Time	12 – 5	5 – 8	8 - 12	12 – 1	1 - 5	5 - 9	9 – 12
	AM			Noon	PM		
Load, MW	100	150	250	100	250	350	150

Table 2: Load curve - weekends

Time	12 – 5AM	5AM – 5PM	5PM – 9PM	9PM – 12
Load, MW	100	150	200	150



4. A hydrothermal system consists of one hydro unit, one thermal unit, and a lossless transmission system. The daily load cycle is divided into three intervals where the optimal water discharge rate Q is found as shown in Fig. Q4. Assume that the thermal plant cost model is given by

$$C_1 = 100 + 3.385P_1 + 0.007P_1^2 \quad \$/\text{hr}$$

The hydro plant's discharge model is given by

$$Q = 1.8 + 0.14P_2 + 2.2\text{x}10^{-4}P_2^2 \quad \text{MCF/hr}$$

where P_1 and P_2 are in MW.

It is required to calculate:

a) The active power generated by the hydro plant for each time interval, and to calculate the available volume of water per day.
b) The incremental cost of power delivered, and the thermal power generation, as well as, the power demand for each of the time intervals. Assuming an optimal water conversion coefficient value of 21.

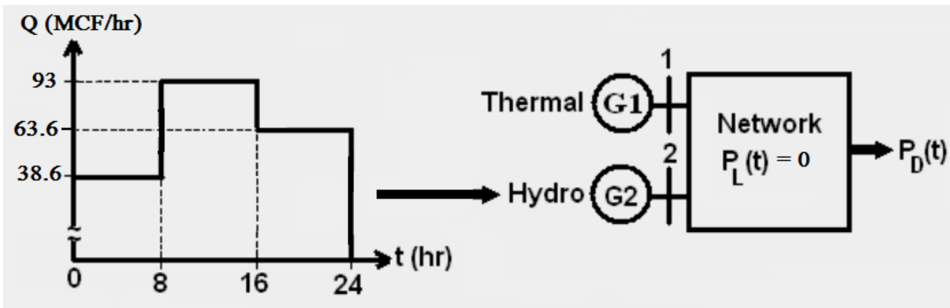
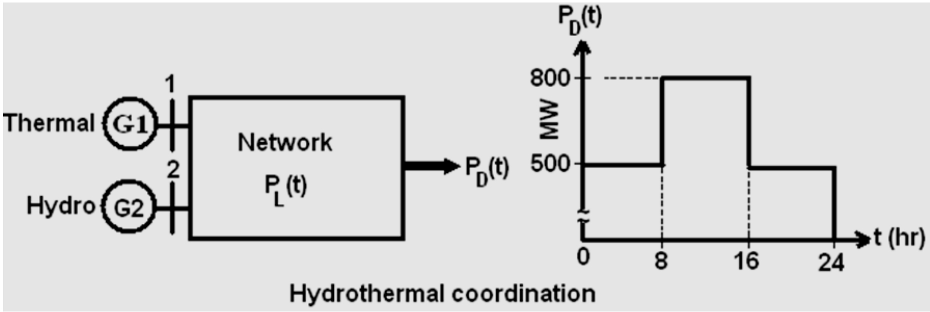


Fig. Q4: Hydrothermal coordination

5. Consider the system shown in figure below, $\gamma 1$ = 0.003 $/MW^{2}h, $\gamma 2$ = 0.0024 MCF/MW^{2}h, $\alpha 2$ = 28 MCF/h, and b2 = 3500 MCF. ***It is required to***:
    a. Obtain the optimal power generation P1(t) and P2(t).
    b. The incremental cost λ(t).
    c. The water conversion coefficient $\nu 2$.

   Hint: neglect $\beta 1$ and $\beta 2$.



6. A two-plant system, having a steam plant near load center and a hydro plant at remote location. The load demand is 700 MW for 14 hours/day and 500 MW for 10 hours/day.

   The characteristics of the units are:

$$C_1 = \alpha_1 + 24P_1 + 0.02P_1^2 \quad \$/\text{hr}; 50 \le P_1 \le 400\text{MW}$$
$$Q_2 = a_2 + 6P_2 + 0.0025P_2^2 \quad \text{m}^3/\text{sec}; 20 \le P_2 \le 500\text{MW}$$

   Loss coefficient B_{22} = 0.0005.

   For a water conversion coefficient of r2 = 2.5 $/hr/m^3/sec. ***It is required to find***:

   (a) The generation schedule,
   (b) The daily water used by the hydro plant, and
   (c) The daily operating cost of the thermal plant.

   Hint: The coordination equations take the form $\frac{dC_i}{dP_i} + \lambda \frac{dP_L}{dP_i} = \lambda$.

7. Consider a hydro-thermal system with one thermal and one hydro plant. The thermal fuel cost and hydo-discharge characteristics are respectively given by:

$$F_1 = \alpha_1 + \beta_1 P_1 + \gamma_1 P_1^2$$
$$q_2 = \alpha_2 + \beta_2 P_2 + \gamma_2 P_2^2$$

The transmission loss is expressed as:

$$P_L = B_{11}P_1^2 + 2B_{12}P_1P_2 + B_{22}P_2^2$$

It is required to write down the coordination equations for this system.

8. Write down the optimality conditions for the system of Problem 7 considering that network losses are neglected and $\beta 1 = \beta 2 = 0$.

9. Obtain the optimal power generation P1(t), and P2(t), the incremental cost of power delivered λ(t), and the water conversion coefficient $\upsilon 2$ for the system described in Problem 7 considering the simplifications placed on the system in Problem 8. The following data are available:

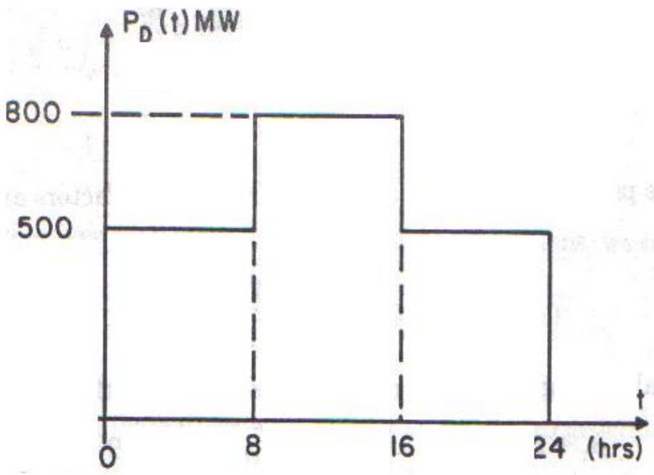
$\gamma_1 = 0.003$ \$/MW^{2}h

$\alpha_2 = 28$ MCF/h $\gamma_2 = 0.0024$ MCF/MW^{2}h

$b_2 = 3500$ MCF/day

Million Cubic Feet (MCF)

The power demand is shown in figure below.



10. In a system with negligible transmission losses, the power plants are equipped with water desalination plants, to produce fresh water using waste steam as the energy source. The cost of power and water generation is hypothetically given by:

$$C_i(P_i, W_i) = \alpha_i + \beta_i P_i + \gamma_i P_i^2 + \delta_i W_i + \zeta_i W_i^2$$

where W_i is the production rate of desalinated water in m^3/sec, and P_i is the electric output power in MW.

Two generators whose cost coefficients are given in the table below feed the system:

Unit	α	β	γ	δ	ζ
1	1.0	1.0	1.0	1.0	1.0
2	1.0	0.5	2.0	0.5	2.0

If the demand is 10 MW of electric power and 10 m3/sec of desalinated water, ***it is required to***:

(a) Write the Lagrangian.
(b) State the necessary conditions of optimality
(c) Obtain the economic allocation.

Hint. In this problem the plants limits are neglected and the problem can be written as

Min $C = C_1 + C_2$
s.t.
$P_1 + P_2 - 10 = 0$
$W_1 + W_2 - 10 = 0$

Good luck

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