Application of Dynamic Programming to the Determination of the Most Economical Operation of Reservoirs in Combined Hydro- and Thermal Power System

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The applications of Dynamic Programming will be described to compute optimal water storage policy in a power system with two reservoir power stations and one equivalent thermal plant (refer to Fig. 1).

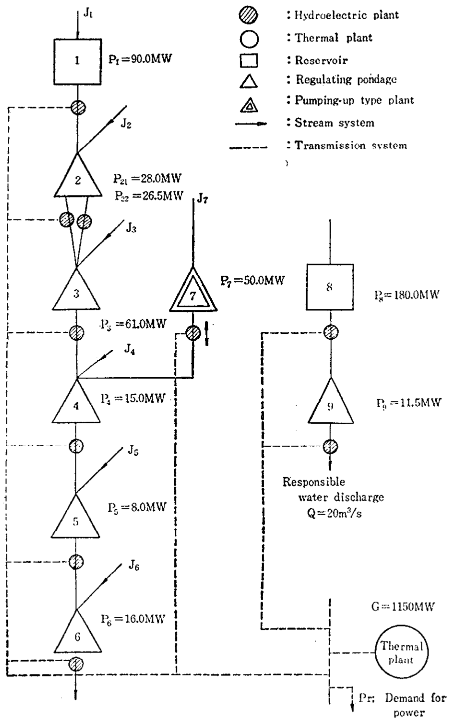

Fig. 1. The model system under consideration

The rate of inflow into the reservoirs and the power demand are assumed to be deterministic (refer to Figs. 2 and Figs. 3 (a) & 3 (b)). The relaxation method is used to treat the multi-reservoir problem.

In the pondage plant No. 2, two types of units, efficient and less effi-

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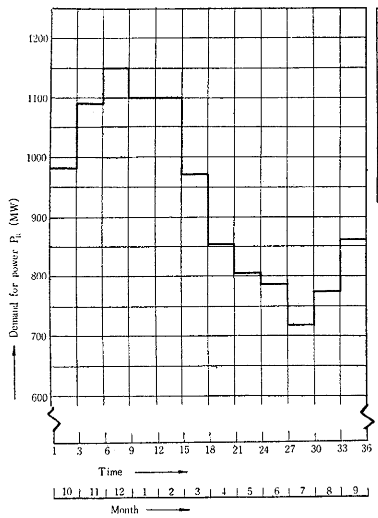

n	P_RMW
3	983
6	1091
9	1152
12	1101
15	1101
18	973
21	855
24	808
27	789
30	721
33	776
36	863

n ; Time point
P ; Demand for power

Fig. 2. Yearly load curve

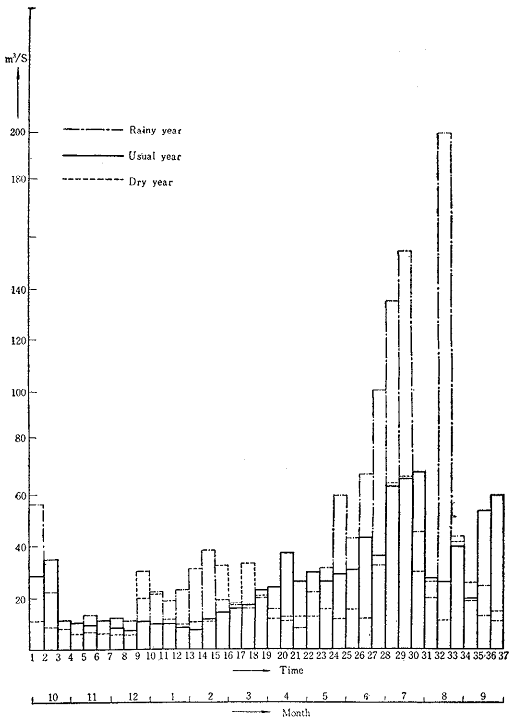

Fig. 3 (a). Yearly water inflow to the Reservoir No. 1

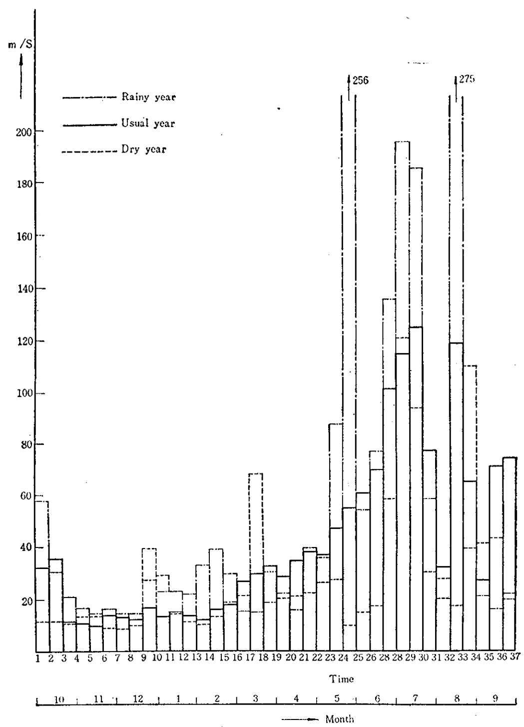

Fig. 3 (b). Yearly water inflow to the Reservoir No. 8

cient are operating in parallel. An amount of discharge water through each turbine is in proportion to the dP/dQ of each unit to make the best use of the water.

A pumping-up operation will start at plant No. 7, when the discharge of water gets lower than the prescribed lower bound.

Yearly Demand Curve:—We constructed a yearly demand curve in Fig. 2 due to the conditions on power sources and flood. The power generated in natural flow and scheduled operation and the purchase from other companies were subtracted from the total power demand at each subinterval of time to get a power demand, which a thermal and hydro-electric plants under consideration are responsible for (refer to Figs. 1 and 4).

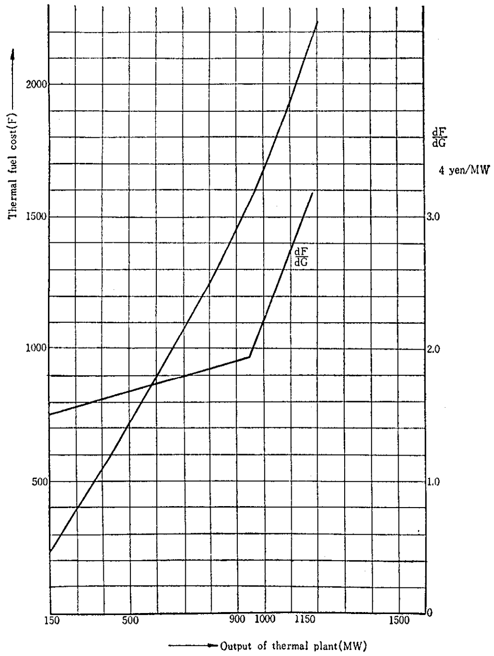

Fig. 4. Characteristic of fuel cost and incremental fuel cost of the thermal plant

Inflow of Water into Reservoirs and Pondages:—The rate of inflow of water is assumed constant during a subinterval of time as shown in Figs. 3 (a) and 3 (b).

Results. The behavior of convergence to the optimal operation is shown in Fig. 5 for a dry year. The detailed results are shown in Fig. 6 for each main reservoir in the same year.

The optimal operation was obtained after 3 to 6 iterations of relaxa-

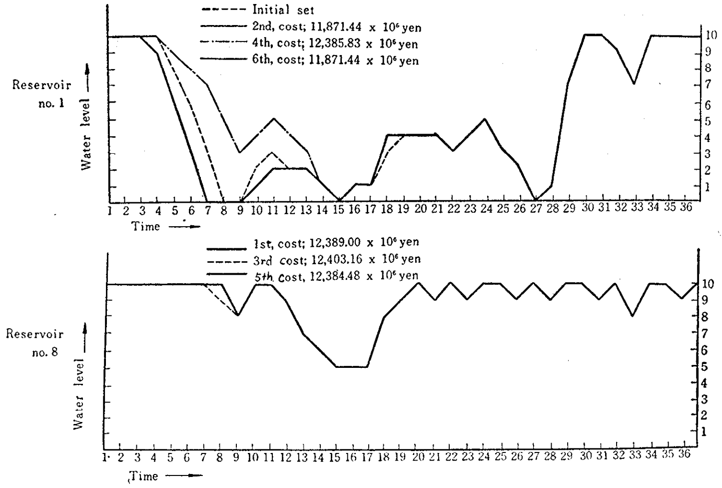

Fig. 5. Behavior of convergence to the solution (Dry year)

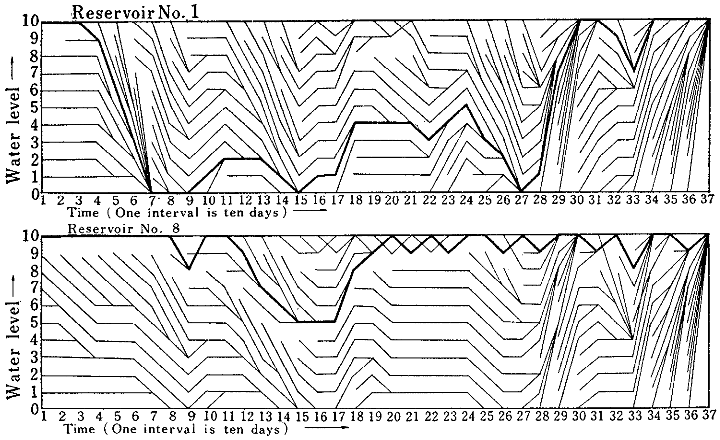

Fig. 6. The most economical operation of two reservoirs for a dry year

tion. The rapid convergence rate is due to the fact that two reservoirs are independent in stream with each other and that the water usage policy on one reservoir is connected to that of the other only in the sense that the policy affects the total fuel cost over the planning period.

The slow convergence in the subintervals from 6 to 18 implies that the operation around the optimal value does not affect the total fuel cost appreciably in these time intervals.

It is interesting to note that, in the case of the dry year in Fig. 5, the solution oscillates every four cycles of relaxation without convergence to a unique solution. This situation could result from the following.

(i) When the rate of discharge is outside of the upper or lower bound of the turbine capacity, an excessive penalty was put on the total fuel cost to get a policy within the bound.

(ii) The width between adjacent grids is so great that the optimal operation lies between them.

In the analysis above, the optimization was made over a year and the reservoirs were assumed to be full at the initial and the final time point. An operation of reservoirs could be optimized over a long period of time, resulting in the optimal store at the initial and the final stage of each year from a long range viewpoint.