Longterm hydro and geothermal reservoir operation

In order to find the optimal way to model a hydro dominated system one needs to avoid unnecessary spillage of water. The operation cost of thermal plants is in accordance with used fuels while the source of energy for geothermal plants is free and for short time considerations unlimited supply. Hydro plants on the other hand also have a free source of energy but limited supply. To avoid unnecessary spillage Lindqvist (1962) essentially proposed a method to give value to the water stored in a reservoir in order to find optimal ways for the operation of power systems. This water value method is used in Landsvirkjun proprietary long term reservoir simulation software named LpSim but has been developed futher. LpSim simulates the system operation iteratively in a two step process.

First a dynamic programming algorithm is used for water value calculation. The water value is the price of water formulated as a function of reservoir volume and time. The water value defines the strategy used for releasing water from the reservoirs. The second step is the simulation of system operation for a period of N years with time resolution down to one day. Simulated values are; releases from reservoirs, generation in hydro, geothermal and thermal power stations, transmission on a simplified DC transmission system and delivery of energy to customers. Stochastic nature of inflows is accounted for by simulating the operation several times for different inflow scenarios.

One of the main drawbacks of using dynamic programming for water value calculation is it's sensitivity to dimensions often called ,,the curse of dimensionality". To avoid this problem a simplified version of the power system is used in water value calculation often containing only one equivalent reservoir.

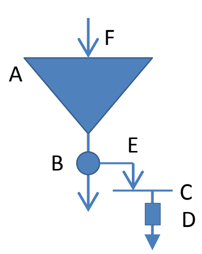
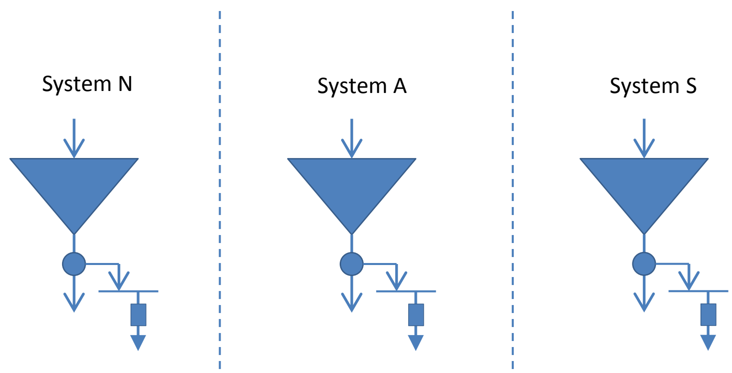


Figure 1 : Simplified system used in water value calculation. A. Reservoir, B. Generator, C. Bus, D. Load,E. Transmission line.

A widely known method for addressing this simplified problem is to combine all reservoir volumes and power plants into one and then the inflow into the equivalent reservoir becomes the sum of inflow into individual reservoirs in the original system. By doing this the characteristics of the inflow into the equivalent reservoir become the mix of inflow characteristics into individual reservoirs. However, since the original inflow characteristics are essential to the operation of the whole system this mixture of characteristics can potentially become a bad approximation.

To avoid this problem, LpSim constructs three equivalent reservoirs, each having a sum of inflows that have similar characteristics and belong to the same subsystem. The water value for each subsystem is then calculated. This way the main inflow characteristics can be preserved and mapping the watervalue onto the true system can be done in a simple way.



This method has the drawback that the load for each subsystem is not known as this method does not take into account the transmission of energy between subsystems using the transmission system.

To solve this problem Landsvirkjun has developed a simple iterative process.

1. The water value for the system is calculated by combining all reservoirs and hydroelectric stations into a three reservoir equivalent system
2. The water value is applied to all reservoirs not accounting for different inflow characteristics

3. The operation of the original system is simulated with week long timesteps. Comparing the cost of hydroelectrinc generation to thermal using the water value.
4. Now a second water value calculation is prepared by splitting the system into subsystems. The load for each system is the local load plus the exported energy to other subsystems minus the import from other subsystems as it was simulated in the first simulation phase (3). This way the method accounts for transmission possibilities between the subsystems.
5. Based on new water values the operation of the original system is simulated again.
6. Step 4 is repeated if the last simulation resulted in better operation than the last simulation.

The heuristic approach described here has been tested extensively on Landsvirkjuns system and outperforms the original method (step 1 to 3) when system load is high. That is sufficient for Landsvirkjun a hight load is essential in many practical studies. The water value converges under normal conditions after three calculation steps (1 and 4) but the convergence must constantly be monitored.

Typical reduction is cost of thermal production and power purchases is in the range of 20-40%.

References

Lindquist, J. 1962. "Operation of a hydrothermal electric system: A multistage decision process", AIEE Journal (April 1962).

Skuli Johannsson, Elias B Eliasson, "Simulation Model of the Hydro-Thermal Power System in Iceland", www.veldi.is (2002)