Design of new hydroelectric power projects in Iceland

The design of new hydroelectric projects at Landsvirkjun is aided by simulation of their operation. New projects can, however, change the optimal operation of existing reservoirs and hydroelectric stations. For that reason simulations always include the total existing power system plus the project being studied. Landsvirkjun uses it proprietary simulation model LpSim based on a well known two step process of water value calculation and simulation of operation as described in Lindqvist 1962.

LpSim uses a two step process to simulate the operation of the power system. 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.

Now let's formulate the simulation as the function f that returns the net income I (revenue from energy sales minus the cost of thermal operation/purchased energy from other players) and the minimum reservoir level r_l. The input to the model is a set of inflow scenarios F, the system description S, the load L and simulation period T

$$I = f(F, S, L, T)$$

For a given set of flow scenarios and a given system the net income is maximized by scaling the load.

$$L^* = arg \max_L f(F, S, L, T)$$

> With the constraint that reservoir levels in the simulations must be higher than a given minimum

$$r_l \geq r_{min}$$

The load L^* that maximizes the net income is defined as the maximum load for system S, noted as L_S^*.

Now the tool needed to describe how Landsvirkjun uses it's simulation software for design have been defined.

For a new hydroelectric station, or any other part of the system for that matter, its effect on the maximum load can be used as a measure of increase in income created by the investment.

For a hydroelectric station s under consideration the following optimization problems can be solved:

$$L_S^* = arg\max_L f(F, S, L, T) \tag{A}$$

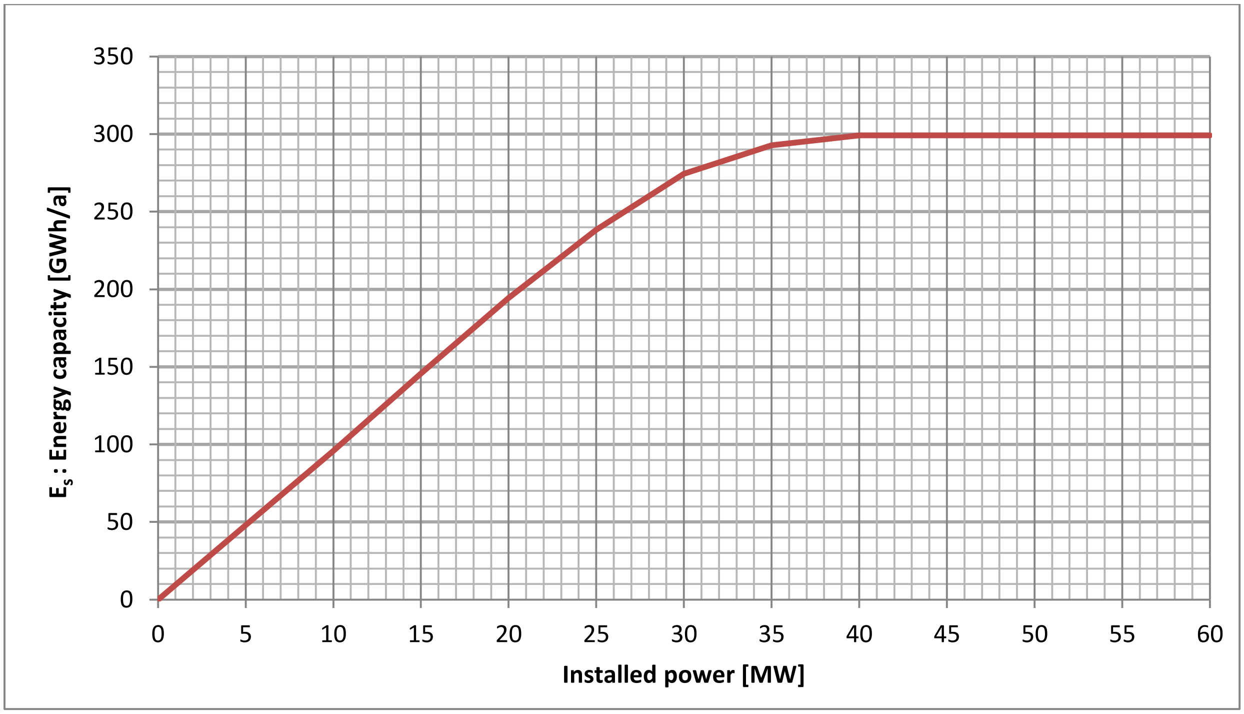
$$L_{S+s}^* = arg\max_L f(F, S+s, L, T) \tag{B}$$

The difference between (A) and (B) defines the energy that can be sold from the total system because of investment in hydroelectric station s. This difference is called the energy capacity of s defined as:

$$E_s = L_{S-s}^* - L_S^*$$

When taking a decision on installed capacity of the station s, the energy capacity of the station can be calculated as a function of installed capacity p

$$E_s(p) = L_{S-s(p)}^* - L_S^*$$



Figures 1 : An example of the energy capacity function $E_s(p)$ as a function of installed power for a single hydroelectric power station. Adding more than 40 MW does not increase the systems capability to serve higher load.

Different design attributes of system objects, such as reservoir size or transmission capacity, can be estimated using the same method.

As the whole system is always simulated, the energy capacity of a power project can be higher than its energy production. When hydroelectric power stations in different drainage basins are connected, the synergic effect can be considerable. This was, for instance, the case when Karahnjukar HEP in East Iceland was built. Estimating the energy capacity of that project as a stand-alone underestimated the energy capacity by 20%.

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 (June 2002)