Stochastic Methods for Water and Electricity Co-Optimisation: A South Australian Case Study

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Introduction

Broadly speaking, an optimal operation is the one that meets the demand while using the **minimum amount of resources**.

Water processing and pumping stations run on energy from the electricity grid. If this demand is large enough to change the system's marginal generator it will **directly affect the price of electricity**.

As a result, it becomes impossible for the water optimisation problem to be correctly optimised alone. **A water and electricity co-optimisation is required** to find the most efficient outcome.

To add to the complexity of the co-optimised problem, both the water and the electricity model have to account for **stochastic variables**, such as hydro inflows, wind generation, forced outages and demand.

This study proposes **a comparison of two stochastic methods** to run the co-optimised model of the state of South Australia.

Methodology

An integrated electricity and water model of the state of South Australia was built in PLEXOS® Integrated Energy Model software. The model used Mixed Integer Linear Programming to minimise the operations' overall running cost.

The chosen stochastic variables of this study were:

- The water inflow into the state's main reservoir
- South Australia's wind speed
- Energy prices in the neighbouring state of Victoria

Electricity and water demand were treated as deterministic inputs and included in PLEXOS using historical profiles.

The stochastic methods chosen to optimise the model were:

- Monte Carlo simulation with 14 historic samples
- Two-stage Stochastic Optimisation (non-recursive) with scenario reduction

Results & Discussion

A comparison of the cost incurred under Monte Carlo and the Stochastic Optimisation is presented in Table 1.

Table 1 – Water System One-Week Operation

Method	Avg. Total Cost ($)	Avg. Pumped Water (1000m³)	Avg. Pumping Cost ($/1000m³)
Monte Carlo	76,651.9	3,263.3	23.5
Stoch. Optimisation	93,247.7	3,244.4	28.7

If considering an average total cost of all samples, the Monte Carlo simulation produces a cheaper operation in comparison with the result of the Stochastic Operation.

This is expected given that each of the Monte Carlo's independent samples run with perfect foresight throughout the entire simulation period. That is, it may anticipate the future behaviour of the stochastic variables when making any operational decision at the present stages.

In Stochastic Optimisation the stochastic variables are non-anticipative. This means that these variables are uncertain at the decision stage and the decision is based only on the probabilities of each discrete scenario.

Thus, the results of the Stochastic Optimisation will reflect a more conservative and realistic operation of reservoirs compared with a method that has perfect foresight.

The main advantage of the Stochastic Optimisation is that it provides the optimal decision under uncertainty. That is, the SO solution will be the best policy over the simulation period if the stochastic variables are non-anticipative – better than any of the samples of the Monte Carlo simulation or their average.

Another advantage of SO can be seen in figures 1 and 2. The graphs show a one-day snapshot of the optimal operation of the water reservoir in the model.

Figure 01 – Monte Carlo's optimal water injection (blue) and withdrawal (red) over electricity prices (grey).

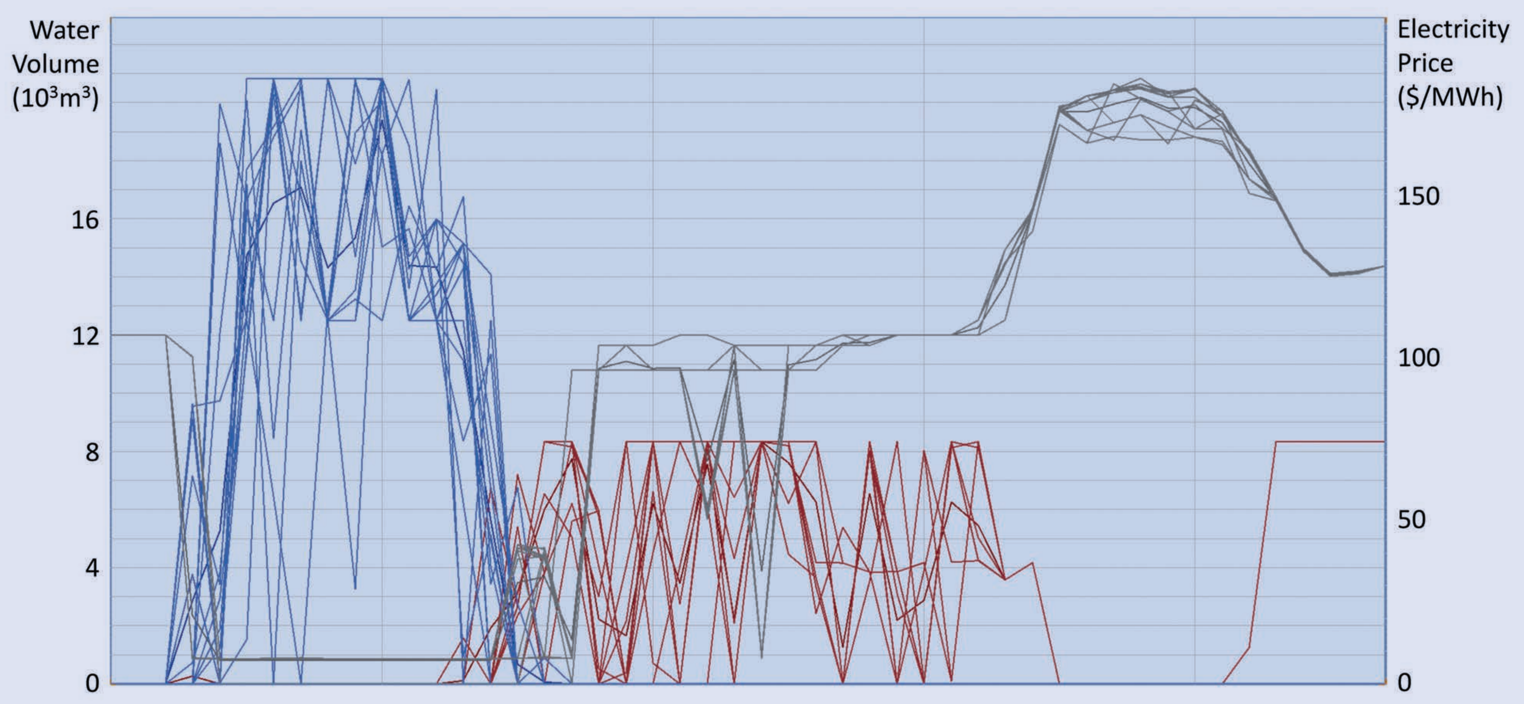
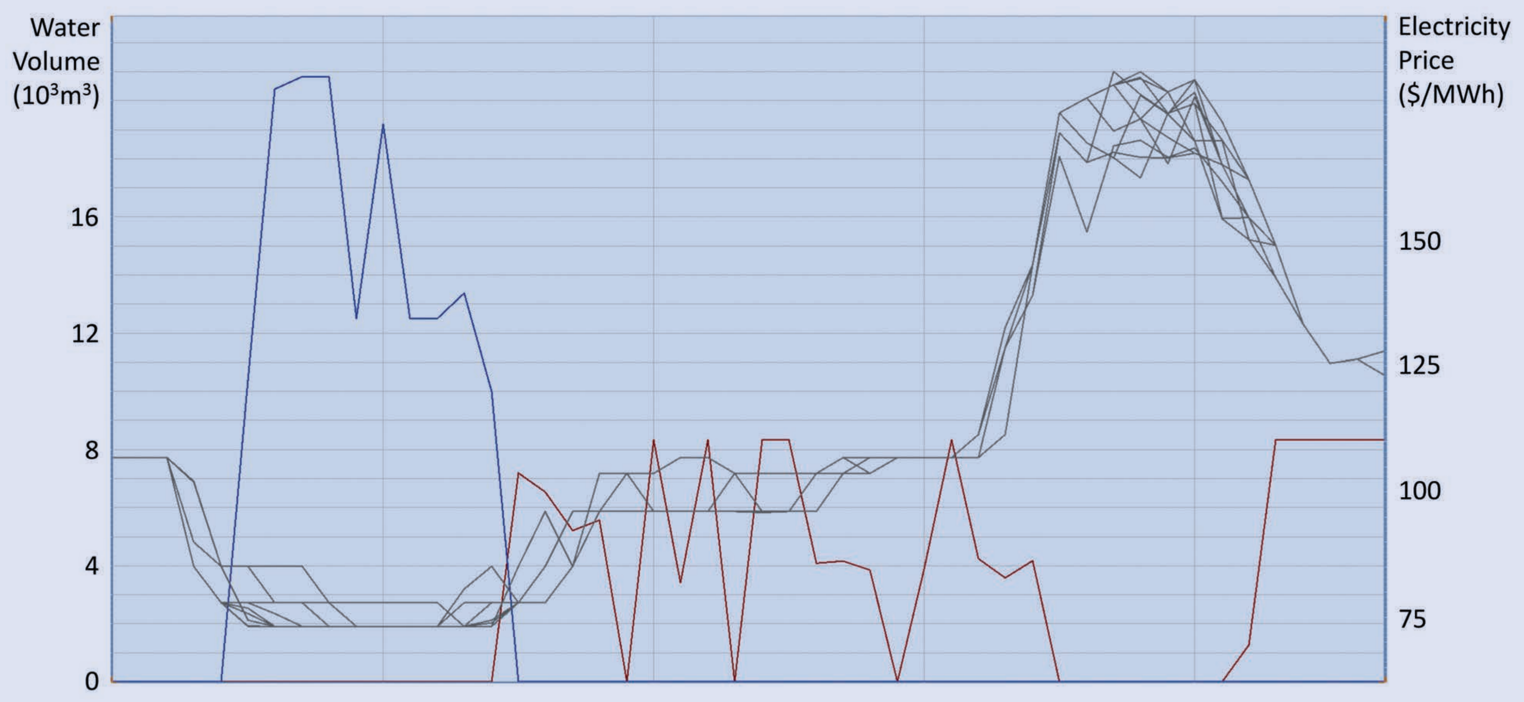


Figure 02 – Stochastic Optimisation's water injection (blue) and withdrawal (red) over electricity prices (grey).



Both solutions, as expected, see water operation in periods of low electricity prices. However, the Stochastic Optimisation provides one clear solution over different price outcomes while Monte Carlo gives a collection or 14 optimal decisions. One for each price outcome.

This may prove overwhelming when deciding the best course of action to take. On the other hand, Stochastic Optimisation clearly guides the planners over the best policy.

Conclusions

PLEXOS proved able **to co-optimise the operation of the water system in an integrated water-electricity** model with both Monte Carlo and two-stage Stochastic Optimisation methods. Although Monte Carlo apparently provided better solutions, this was only achieved through the perfect foresight of stochastic variables. **Stochastic Optimisation can model uncertainty at each decision stage, thus providing a more conservative and realistic solution.** Stochastic Optimisation also provides **a single optimal strategy, which is more useful for planners and operators**.

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