Hydropower reservoir management using multi-factor price model and correlation between price and local inflow

Joakim Dimoski, Norwegian University of Science and Technology, Phone: +47 417 62 920, E-Mail: joakim.dimoski@gmail.com
Sveinung Nersten, Norwegian University of Science and Technology, Phone: +47 458 82 304, E-Mail: sveinung.nersten@gmail.com
Stein-Erik Fleten, Norwegian University of Science and Technology, Phone: +47 466 94 794, E-Mail: stein-erik.fleten@ntnu.no
Nils Löhndorf, Vienna University of Economics and Business, Phone: +43-1-31336/5629, E-Mail: nils.loehndorf@wu.ac.at

Overview

We study a new approach for medium-term scheduling for a single hydropower producer participating in the Nordic electricity spot market. We include two stochastic variables (spot price and reservoir inflow), and use a multi-factor Ito process describing possible movements in the price of forward contracts to find future spot price scenarios. The goal is to investigate the effect of correlation between price and inflow, as well as the effect of multiple factors in price modeling. We use a geometric periodic auto-regressive process to describe local inflow, and include a short term correlation between movements in inflow and the first factor in the price process. All spot price and inflow scenarios are discretized into a scenario lattice with weekly time steps and a two-year horizon, and we propose using approximate dual dynamic programming (ADDP) to obtain optimal decision policies of all lattice states. An important byproduct of the approach is estimates of marginal water values, which can be used for short-term scheduling. In our study, we are especially interested in figuring out how our approach performs compared to models considering 1) no correlation and 2) using only one factor instead of multiple to describe movements in price.

The paper is organized as follows: After the introduction the second section gives a brief overview of the stochastic decision problem faced by a hydropower producer. The third section revolves around the correlated processes of movements in inflow and price, and how ADDP can be used to obtain all optimal decision policies. Finally, we present some empirical results, and compare the performance of our approach as described above.

Methods

Construct smooth forward curves using multiple methods to obtain coefficients of price process. Use scenario lattice and ADDP to find optimal decision policies for hydropower scheduling.

Results

First, we show how the coefficients of the price process can be found by first constructing smooth forward curves. We also find the coefficients of the inflow process and the short term correlation of price and inflow. The correlation is found to be -0.17.

Second, using empirical data on spot price and reservoir inflow, we backtest our approach to see how its policies compare to the realized ones.

Third, we compare the performance of our approach to an approach in which price and local inow are assumed to be independent and an approach in which price movements are described using only one factor. We quantify the loss in expected discounted revenues of using the latter two approaches compared to ours when price movements are in fact driven by multiple factors and correlated with local inflow. In both cases, we find the loss to be approximately 2-3 %.

Conclusions

While they are often assumed to be independent in models of reservoir management, we show that there exists a non-negligible correlation between price and local inflow. We also quantify the loss in expected revenues of omitting this relationship when it does in fact exist can result in expected revenues that are 2 % lower than if it had been considered. This means that the producer can potentially loose revenues of multiple 100.000 EUR yearly, indicating the importance of including the relationship. Similar results are also found for models using one-factor processes to describe price movements when they are in fact described by multiple factors.

References

Steen Koekebakker and Fridthjof Ollmar. “Forward curve dynamics in the Nordic electricity market", Managerial Finance 31 (6), 2005, pp. 73-94.

Alexander Shapiro et al. “Risk neutral and risk averse Stochastic Dual Dynamic Programming method", European Journal of Operational Research 224 (2), 2013.

Nils Löhndorf and David Wozabal. “Indifference pricing of natural gas storage contracts". Working paper (2017), http://epub.wu.ac.at/5421/.

Stein W. Wallace and Stein-Erik Fleten. “Stochastic Programming Models in Energy".
In: Stochastic Programming, Handbooks in OR and MS. Ed. by Andrzej Piotr Ruszczynski and Alexander Shapiro. Vol. 10. Elsevier Science B.V., 2003. Chap. 10, pp. 637-677.

Ove Wolfgang et al. “Hydro reservoir handling in Norway before and after deregulation", Energy 34 (10), 2009, pp. 1642-1651.

Birger Mo, Anders Gjelsvik, Asbjørn Grundt and Kjetil Kåresen, “Optimisation of hydropower operation in a liberalised market with focus on price modelling", Porto Power Tech Conference. IEEE, 2001.