# *OPTIMAL STORAGE IN A RENEWABLE SYSTEM – IGNORING RENEWABLE FORECAST IS NOT A GOOD IDEA!*

Joachim Geske, Imperial College Business School, +44 (0)20 7594 2744, j.geske@imperial.ac.uk
Richard Green, Imperial College Business School, +44 (0)020 7594 2611, r.green@imperial.ac.uk

## Overview

The large-scale integration of intermittent renewable electricity generation into the electrical system will increase expected and unexpected residual load variations. In order to limit frictions resulting from this transition and to guarantee a smooth evolution, restricting costs associated with the increase in residual load uncertainty is crucial. Therefore, a vast body of literature has emerged on improving forecasts of renewable feed-in. These approaches proved to be successful for wind power. Nevertheless, significant uncertainties remain in cloud-rich regions for the prognosis of solar radiation. An early knowledge of residual load fluctuations can be interpreted as a "longer" view into the future, which reduces the need for expensive, short-term flexible generation capacity, thus planning power generation more efficiently. In addition to electricity generation, the quality of the residual load forecast has an impact on the efficiency of storage systems. Analyses of the optimal operation of electrical storage show that uncertainty about the residual load results in a regular "freezing" of the storage while waiting for additional information on future loads. If this short-term uncertainty could be reduced, the storage could operate more efficiently.

However, the forecasting quality of the wind speed – even from large data-intensive weather models - decreases within a forecasting period of only 7 days to the level that can already be achieved with just a simple time series of historical wind speed data. Therefore, while perfect foresight is a good approximation of the knowledge in the short term, residual load can at best be considered as stochastic in the long run. For this reason it is clear that a realistic modelling of optimal storage management requires a stochastic optimization approach. With this approach it is possible to derive the optimal storage strategy including even an extreme and unpredictable residual load pattern. The optimal strategy to limit the negative impact of these patterns on the system prescribes the reservation of a "buffer" storage for "bad times" that is withheld from short-term arbitrage.

But a straightforward stochastic optimization (Markov Decision Process) suffers from the fact that the knowledge about future residual load decreases too fast (within a day towards the long term stationary distribution) compared with the residual load forecast (7 days). In other words: the forecast is ignored. Thus, analyses based on too fast decrease of knowledge overestimate the impact of uncertainty on the storage strategy. To avoid this imprecision we will develop methods to deal with the influence of forecasting on the optimal generation and storage decisions in the electricity system. The inclusion of the residual load forecast impacts spot markets, and also the medium-term stabilization of the system. Consequently, this effect will also be included in the analysis.

This research highly improves the stochastic analysis of storage in the system context with residual load uncertainty by explicitly including load forecasting. Thereby storage functionality as arbitrage, buffering and short-term stabilization is taken into account in a common framework.

## Methods

The modelling of short-term perfect foresight and long-term uncertainty is feasible even in simple stationary Markov models of the residual load. But the quality of the residual load forecast in these models deteriorates much faster than in wind speed forecasts. Therefore, the impact of uncertainties on the optimal storage strategy and value of the storage is over-estimated. The inclusion of additional information as one state variable per forecasted hour is too expensive in terms of computational complexity for a reasonable forecasting horizon of several days. Perfect Foresight models with rolling horizon include – if at all – an unrealistic, oversimplified, expectation.

We will develop a model with an explicit representation of the information available to the storage operator without changing the load duration expected in the long term based on Geske and Green (2016) with optimized generation capacity and management decisions and a storage device.

To avoid the intractability of additional state variables we apply 24-hour load patterns. This makes it possible to substitute the optimization of storage over an infinitely repeated stochastically perturbated hour by the optimization of the final storage level at the end of each of an infinitely repeated 24-hour period. So, within the 24-hour period load and renewable generation is perfectly anticipable and the optimal "within" storage strategy can be determined. The initial state of charge is given. It is however unknown which residual load pattern will follow. Therefore the "period out" level of storage must be determined, that is suitable for the next – expected – period as its "period in" state of charge. Thereby the trade-off between short- and long-term usage of the storage is made explicit. In this model, we will numerically determine the value of the storage and the optimal storage strategy. The impact of the information on the value of the storage and the optimal storage strategy is explicitly analysed in a Markov Decision Process (MDP) framework.

The high relevance of the forecasting quality for efficient generation and storage has already been emphasized. A qualified analysis of the value of the storage in the system context thus requires the quantification of these efficiency gains.

## Results

We will develop a Markov Decision Process under consideration of forecasting options. This component will be integrated into the stochastic system model based on Geske and Green (2016) and the model will be solved numerically as a linear program. This will enable us to quantify the value of storage for different information scenarios.

## Conclusions

Our analysis of the value of storage under residual load uncertainty in the system context includes the storage functions of arbitrage, buffering and stabilization. We are thus extending the difficult but particularly realistic stochastic analysis of optimal storage management. The special consideration of information-economic aspects is the second decisive step in this article. Both steps will contribute to the improvement of the evaluation of storage in the system context.

## References


- Geske, J. and Green, R., 2016: "Optimal storage investment under uncertainty", Power electronics and motion control conference (IPEMC-ECCE Asia), 2016, IEEE Xplore, doi: 10.1109/IPEMC.2016.7512341