Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 87 (2016) 36 – 44

Energy Procedia

5th International Workshop on Hydro Scheduling in Competitive Electricity Markets

Hydropower Storage Optimization Considering Spot and Intraday Auction Market

Sebastian Braun[ab]*

[a]*EnBW Energie Baden-Württemberg AG, Durlacher Alle 93, 76131, Karlsruhe, Germany*
[b]*Institute for Renewable and Sustainable Energie Systems, TU München Arcisstraße 2,1 80333 München, Germany*

Abstract

This paper is a case-study based analysis of short-term hydro power optimization considering Spot and Intraday Auction markets. Both markets are closed order book auctions. The analysis shows that the usage of day-ahead price forecast-based water values in intraday trading leads to significantly different results than in the day-ahead market. This is because of the higher fluctuations and limited liquidity on the Intraday Auction market. A multistage quadratic optimization is presented that optimizes the Spot market dispatch on the first stage, and performs a post-optimization to exploit Intraday Auction optionalities on the second stage. The limited liquidity on the Intraday Auction market is accounted for. A case study based example is given and optimal production schedules and bidding strategies are calculated. Further, it is presented why different water values are needed for different markets and how they can be used in the practical short-term position management.

Peer-review under responsibility of SINTEF Energi AS

Keywords: pumped hydro storage, renewable integration, Spot market, Intraday Auction, hydro scheduling in multiple power markets

* Corresponding author. Tel.: +49 721 63 17149
E-mail address: se.braun@enbw.com

Peer-review under responsibility of SINTEF Energi AS
doi:10.1016/j.egypro.2015.12.355

1. Introduction

With the so called “Energiewende” the conditions on the German energy market have changed fundamentally. A lower price level but most notably the flattened regular price spread between peak and off-peak have influenced the profitability of pumped hydro storage power plants. Furthermore, to lessen the effects of production deviations during the intraday, the German government introduced a quarter-hourly Intraday Auction market that takes place at 3pm day-ahead. We present a multi-stage quadratic optimization approach to address the challenges of the markets. After giving a short overview on the literature in 1.1 the market environment for pumped hydro power plants is addressed in 1.2 and the new Intraday Auction is discussed in 1.3. In chapter 2 the optimization approach is presented. In 2.1 the first stage optimization is outlined, followed by 2.2 and the extensions that have been made to consider the quarter-hourly Intraday Auction market and liquidity. We conclude with a case-study example in chapter 3.

1.1. Literature review on short-term hydro storage optimization

The literature on solving hydro power storage scheduling problems can be separated into two general categories. On the one hand, the literature follows a system economic approach: e.g. Oliviera et al. (1993) solve a mixed integer linear program in a system context and integrate cost-efficient storage capacity. On the other hand, several papers focus on the individual plants and on how to operate a singular or a portfolio of hydro storages. These approaches are mainly based on using wholesale electricity prices and calculating an optimal control strategy. The latter approach usually separates the optimization between daily pumped hydro power storages with small reservoirs and seasonal hydro power storages with large reservoirs and relatively small machines in comparison to their reservoir size. The major literature on seasonal hydro storages focuses on improving the optimization methods. Wallace et al (2003) introduce stochastic programming models in energy. A literature review on reservoir operation optimization is given by Labadie (2004). Significant mathematical contributions have been done by Pereira et al. (1991) introducing a SDDP approach, which has been extended by Löhndorf (2013) including stochastic prices and inflows in one probability distribution and Shapiro et al. (2013) in terms of risk averse optimization. Abgottspon et al. (2012 and 2013) includes the long-term future and the hourly day-ahead market into one optimization and discusses the influence of a price maker. The influence of the Intraday Continuous market on storage evaluation has been pointed out by Dogan (2013). The used optimization model has been introduced in Braun (2015). An overview on the changes on the German energy market and future developments is given in the “Grünbuch” (BMWi 2015) published by the German government.

1.2. Market environment for pumped hydro storages

Due to the extensive expansion of the installed capacity of renewable energies, the market conditions in Germany have changed. Three different effects can be observed on the German energy market: Firstly, energy prices have dropped because renewable energy sources (RES) with low variable costs entered the Merit Order. Secondly, the classical peak-off-peak price profile fluctuates as photovoltaics (PV) generation adds supply particularly during midday and thus prevents the historical peak prices around noon. Thirdly, long periods with substantial wind feed-in are causing low-price periods with increasing frequency. Nevertheless, the production capacity of conventional power plants has remained nearly unchanged, which leads to a lack of scarcity prices in the energy only markets that would allow more expensive conventional generation to cover their costs. An overview on the price development on the various energy-only markets can be seen in Tab.1. This situation influences the position management of all existing power plants. The dispatch of seasonal hydro power storages in the short-term is steered by water values from a mid- and short-term optimization. These water values in turn are calculated using inflows and price forecasts. The latter is usually based on a price forward curve for the day-ahead market and an appropriate stochastic to model the fluctuations. Using the water values, bids are set up to trade the energy of the hydro power plants on the day-ahead market. After the auction has cleared the remaining flexibility can be traded on the Intraday markets. To generate offers for the various markets, normally, the same water values are used. Since the specifics of the 15 min Intraday markets have not been considered we present an approach below.