ON DIFFERENT APPROACHES FOR REALISTIC HYDROPOWER BIDDING STRATEGIES TO DAY-AHEAD MARKET CONSIDERING REAL-TIME MARKET

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1 Overview

The ongoing growth in the renewable energy sources like wind power introduce huge amount of uncertainties to the power market. The stochastic nature of these power sources increases the need for the reserve power in real-time market. Having a flexible power source, hydropower producer can provide reserve power and increase its profit. Therefore, to build a planning model, which will allocate available capacity in different market places is an essential task for the price-taker hydropower producer.

This paper uses optimal bidding model to the day-ahead market considering real-time balancing market under the uncertainties of the day-ahead and real-time market prices. Specifically, the model is built using stochastic linear programming approach. According to the results, for simultaneous bidding to day-ahead and real-time markets two extreme cases are happening. To make the bidding strategies more realistic and robust different novel approaches are modeled and assessed. Discussions on the results are provided and summarized.

2 Methods

Modeling of prices in spot and real-time market Significant amount of work has been done in the literature related to the modeling and forecasting of the spot market prices. Statistical models like ARIMA and ARMA to forecast spot market prices are applied in [2], [8]. GARCH processes are used to forecast spot market prices in [4].

Several approaches to model real-time market prices are presented in [7]. In this work the combination of SARIMA and Markov chain is used.

Hydropower Planning model The short-term hydropower planning and bidding process under uncertainty can be modeled as a multi-stage stochastic program [1, 6].

The following papers apply multi-stage stochastic optimization to plan short-term hydropower production [3], [5].

The model,which is a two-stage stochastic bidding strategy to the spot market while considering the real-time market, is based on the model developed in [7]. Unlike [7] we used linear bidding rules to real-time market.

3 Results

For the case study three cascaded reservoirs are studied. The upper reservoir is larger, which is followed by two smaller reservoirs.

The optimization model is programmed in GAMS and CPLEX solver is used to solve it. The simulated result gives bidding volumes to different market places for each hour, which can be seen from Figure 1. According to Figure 1 for most of the hours

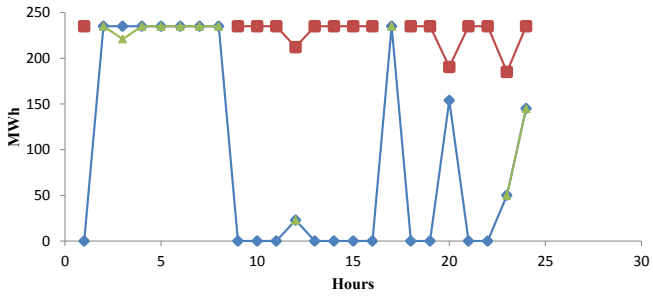

Figure 1: Base case:$\diamond$ represents traded spot volume, /Δ traded up/down regulation volume.

either the maximum amount is bidden to upward regulating market or the maximum amount is bidden to day ahead market and offered to buy back in downward regulating market.

Similar results have been observed for example in [7]. The solution is optimal; however the solution is not realistic: in reality the hydropower producer hardly will act in this way. It is expected that, the hydropower producer for each hour will bid the main volume to spot market and only small quantity will offer to up or down regulating market.

The different modifications of the base model are simulated and the results are summarized Table 1.

From all cases above it is obvious that the most promising and applicable approach is the fourth one: it gives flexible results, keeps the optimization problem linear and it is fast to solve.

4 Conclusion

The model used in this paper is an optimal bidding strategy to the day-ahead market

Table 1: Summary of the results

Approaches	Model type	Results	Sol. time
Base case	Linear	Optimal but not realistic	12 second
Trivial	Linear	Optimal but not interesting	9 second
Fixed end res.	Linear	Optimal but little improvement	9 second
Nonlinear	Nonlinear	Locally optimal but realistic	10 hours
Discretized	Linear	Optimal and realistic	9 second

while considering real-time market. The results of this model are not realistic. They tend to follow two dominant trends: either to participate only in upward regulating market or sell the whole capacity in day-ahead market and put an offer to bring back in downward regulation market. For a hydropower producer this is not a realistic case. Therefore, the purpose of this study is to suggest some modifications of the base model, which will provide more robust results. Different modeling approaches are tested and evaluated. The approach, where upward/downward market prices are discretized and available volume is bidden according to that, is suggested as the most promising one.

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