[Market Power in a Hydro-Thermal System under Uncertainty]

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Overview

Traditionally, bidding and unit commitment have been separated decisions for power plants generating electricity from hydrological forces [1]. Relating market results to a single hydropower plant decision is practically conducted by assuming the market forces as externalities to an optimization model.

Similar to those traditional approaches, the here proposed methodology uses stochastic inflows but instead of considering it an external parameter, actively models price impacts in form of a game played amongst generation companies.

Examples for approaches tackling a similar topic are given in [3] and [4]. However, both of these sources point out that little literature on the topic exists, with [6] providing an, even though strongly approximated, model that allows obtaining a Nash equilibrium for a hydropower Cournot game.

In addition to a new approach for solving a similar hydropower game, dispatch decisions of thermal plants participating in those games are considered in the here proposed model. This is based on the characteristic, that even in hydro power dominated systems, thermal units provide the marginal units [2], a result of the low production cost of the former.

As uncertainty determines the implicit value of storage and thus establishes an opportunity (production) cost for hydropower units, dealing with stochasticity provides a core research topic in both hydropower bidding and scheduling [1]. Generally, methods from stochastic optimization, mainly based on decomposition methods – e.g. Stochastic Dual Dynamic Programming - are applied to deal with uncertainty. As the game setup however requires conducting the program for several players and iterations, a more efficient algorithm from the field of robust optimization was selected, namely the technique of Column & Constraint Generation (CnCG) from robust optimization [6-8], will be applied.

In a similar process to [9] an iterative interpolation method will be used to clear the market for a Nash equilibrium, since traditional techniques (such as using Karush Kuhn Tucker conditions) do not hold considering the Mixed Integer Problem (MIP) form of the problem caused by CnCG.

Methods

Equilibrium Model

Mixed Integer Programming

Column & Constraint Generation

Results

To be delivered with manuscript submission.

Conclusions

The proposed method provides a tool to solve models that are rarely considered in literature: market games with state constraints. Through approximations and analysis a framework will be established that allows application on general cases, with focus on computation times to allow scaling the method to larger cases.

In addition, it will provide a tool to analyse the exercise of market power in hydrothermal systems, an area with little research due to the prevalent price-taker assumptions regarding hydropower bids. The general formulation of the hydropower units will also enable the concept to be utilized for other means of large-scale storage, giving it broader applicability and future importance in electricity markets.

References

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