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Coupled Electricity and Natural Gas Markets

Exploiting Flexibility in Coupled Electricity and Natural Gas Markets: A Price-Based Approach

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INTRODUCTION

Renewable energy makes up a significant share of the total electricity production today and its share is expected to increase further in the future. The transition to a green energy system can be made, among other ways, by using gas-fired power plants (NGFPPs). That is an ideal choice for facilitating the transition due to their operational flexibility and high efficiency.

The **coupling of electricity and natural gas markets** can enhance the integration of renewables in the energy system. Several technical and regulatory challenges need to be addressed towards that goal. These include; alignment of electricity and natural gas market timing; establishment of effective mechanisms to couple the operation; and increasing short-term trading in the natural gas market.

METHOD

A market-based coupling where the market timing between electricity and natural gas market is concurrent and the quantities are traded in short-term markets has been developed. The method used was a stochastic programming method which allowed benchmarking of three dispatch models in terms of expected cost. Moreover, a stochastic bilevel model that explicitly captures the temporal coordination between the day-ahead and balancing markets was proposed.

Sequential Dispatch Model
" Seq "
This model clears the day-ahead and balancing markets independently. The optimal schedule that minimizes the day-ahead and balancing costs of the integrated system individually is calculated.

Stochastic Dispatch Model
" Stoch "
This model optimizes the day-ahead and balancing stages of the coupled electric power and natural gas systems jointly. The problem is formulated as a two-stage stochastic program aiming at minimizing the total expected cost.

Proposed Dispatch Model
" P-B "
The price-based model aims at minimizing the expected cost of the coupled energy system and defining the optimal natural gas price adjustment. The day-ahead and balancing markets are cleared independently.

RESULTS

The system comprises three thermal power plants and two NGFPPs, which participate in the natural gas market to acquire their fuel. Figure 1 shows the expected cost of the **coupled electricity and natural gas system** for different proportions of installed wind power capacity on the system's demand. It is observed that *Stoch* results in lowest expected cost in all cases. It also utilizes the increase of wind power production efficiently. The expected cost of *Seq* diverges from the other dispatch models for a wind power penetration level above 25% and shows a significant increase when the share is higher than 40%. On the contrary, the expected cost of the proposed dispatch model ***P-B*** remains close to *Stoch* over the whole range of wind power penetration. Moreover, a larger expected savings is observed as wind power penetration increases, while the expected payment/charge remains at the same level that is relatively small.

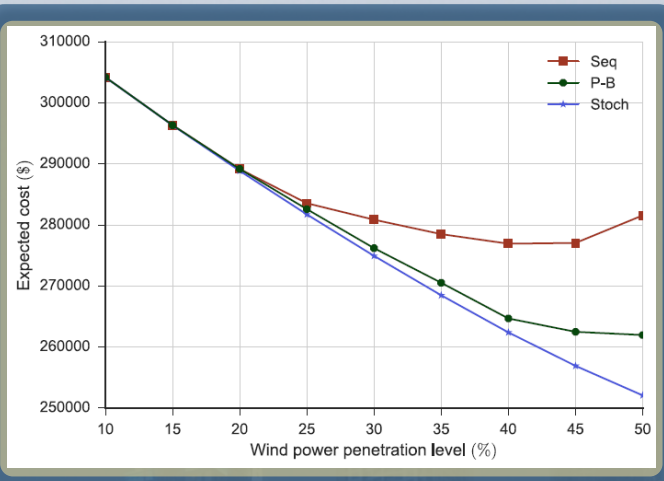

Fig.1 Impact of wind power penetration level on the expected system cost

The natural gas price is reduced most of the time periods when 50% wind power penetration is considered, which results in a deficit for the system operator during these hours. However, this deficit is offset by the surplus generated in periods when the natural gas price adjustment is positive, retaining this action as cost-neutral at the day-ahead stage. In addition, when the electricity demand is higher, part of this demand is covered by NGFPP and that results in revealing flexibility to handle wind power uncertainty.

DISCUSSION

This paper proposes a price-based coordination between electricity and natural gas markets to move the expected cost closer to the stochastic ideal solution. A stochastic bilevel model was implemented that allows the system operator to anticipate the real-time operation of the integrated system taking the economic link between electricity and natural gas markets into account. The proposed method ensures that the natural gas price adjustment only affects the payment/charge at the balancing stage, where the traded quantities are significantly lower.

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