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Stochastic Integrated Market for Electric Power and Natural Gas Systems

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Introduction

- Decision making models in energy markets
- Uncertainty introduced by renewable energy sources (RES)
- Optimization models that account for uncertainty
- Market clearing based on stochastic programming
- Capture uncertainty in a flexible and intuitive manner
- Stochastic market clearing with uncertain wind production

Energy System Integration

- Efficiently align existing synergies towards the optimal operation of energy systems.
- Propose new market structures to provide adequate incentives to all market participants.
- Manage high uncertainty on both supply and demand sides.

Electricity and Natural Gas

Strong link between the electricity and natural gas systems is increased by integration of renewable energy sources and the need for flexible reserves provided by GFPPs.

Market Clearing Approaches

Day-Ahead Market

- Real-Time Operation

Conventional market clearing

Sequential clearing of two trading floors:
1. Day-ahead market is cleared based on deterministic description of uncertain wind power production.
2. A balancing market is cleared for real-time operation.

Stochastic market clearing

Co-optimization of two trading floors:
1. Day-ahead dispatch is determined by co-optimizing day-ahead and real-time dispatch, where wind power uncertainty is probabilistically described.
2. A balancing market is cleared for real-time operation.

Optimization Models

The following models are used to determine the day-ahead dispatch of the electric and natural gas systems.

### Decoupled Approach

Minimize Day-ahead electricity cost.

Subject to:
- Day-ahead operating constraints of electricity system.
- Wind power is constrained by its expected value.

The following model represents real-time operation. It is solved for a specific realization of wind power production.

### Integrated Approach

Minimize Day-ahead natural gas cost.

Subject to:
- Day-ahead operating constraints of natural gas system.

The following model represents real-time operation. It is solved for a specific realization of wind power production.

### Conventional – Decoupled

Minimize Balanced electricity and natural gas cost.

Subject to:
- Real-time operating constraints of electricity and natural gas systems.
- Wind power production is considered known.

Solution procedure
1. Day-ahead dispatch of power and natural gas systems is determined. Models Conv-Dec, Conv-Int and Stoch-Int are solved and 10 wind power scenarios are given as input.
2. In Conv-Dec, we introduce parameter k that helps us define the electricity marginal cost of GFPPs (C = LMP Int(\(k\))). The LMP gas is determined from Conv-Int model.
3. Given the day-ahead dispatch from (1), balancing model is evaluated for 30 different wind power realizations to determine the total operating cost.

Conclusions and Future Plans

- Integrating the operation of power and natural gas systems under stochastic market clearing results in a significant reduction of daily operating cost.
- The case of \(k=1\) reflects the case when GFPPs have perfectly foreseen the ideal natural gas price (i.e., the one stemming from Conv-int model).
- It is noticed that the total operating cost further increases in the cases of \(k\geq 1\).
- In future work, the introduction of CHP plants to cover heat demand will be examined, as well as power-to-gas technology.

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