Hedging Wind Risk through a Power-to-Gas enabled Integrated Energy System

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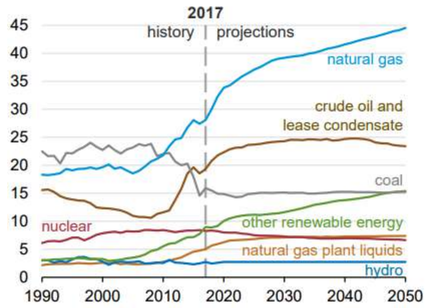
Overview

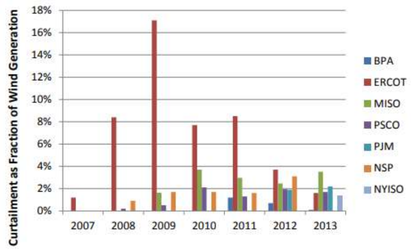
Most generation capacity will be natural gas and renewables

- Result of low natural gas prices
- Result of declining renewables technology costs
- Result of supportive policies



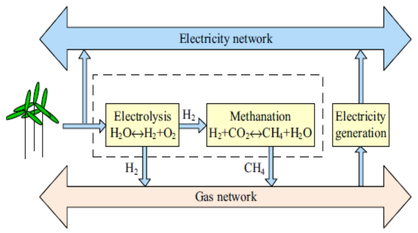
Renewable generation curtailment happens on an involuntary basis

- Transmission congestion
- Excess generation
- Voltage, or interconnection issues



Power-to-Gas (P2G) technology

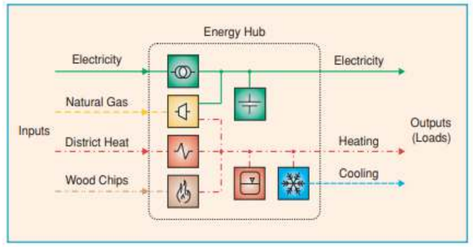
- Reduce the greenhouse gas
- Exploit the excess generation



Problem Formulation

Modeling the energy hub

- A key element in future energy networks
- An interface between different energy



Security constrained unit commitment for integrated system

- The goal is to minimize the total cost over the scheduling horizon
- Subject to the security constraints of power networks, natural gas networks, and energy hubs equipped with P2G
- Uncertainty is modeled as interval numbers

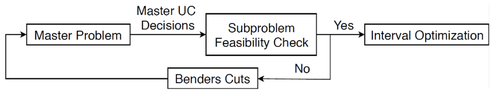
Technical Approach

Interval quadratic optimization

- A special scenario reduction method
- The object value and solution are intervals
- Solving two deterministic optimization problems instead of solving a large-scale stochastic optimization problem

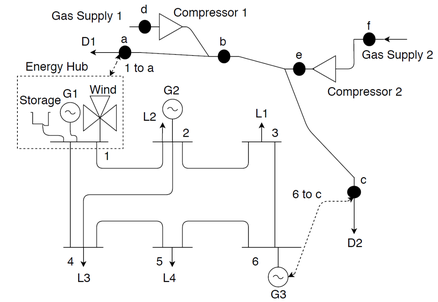
Benders Decomposition

- Computational intractability of the interval quadratic optimization due to binary variables
- Decomposing the stochastic mixed-integer quadratic programming problem into one deterministic mixed-integer quadratic problem, and one stochastic quadratic programming problem that is solved by interval quadratic optimization



Case Study

An integrated energy system comprised of a 6-bus power network and a 6-node gas network



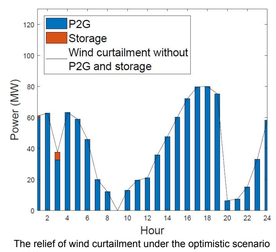
- Evaluate the value of energy hub
- Investigate the impact of transmission constraints: adjust the transmission capacity of line 1-4 from 100 MW to 50 MW

The Total Gas Supply over the Scheduling Horizon

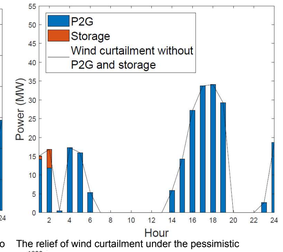
Total Supply (Mcf)	Optimistic Scenario	Pessimistic Scenario	Expected Supply
With Energy Hub	18,672	22,189	20,580
Without Energy Hub	19,805	22,854	21,493

The Total Cost over the Scheduling Horizon

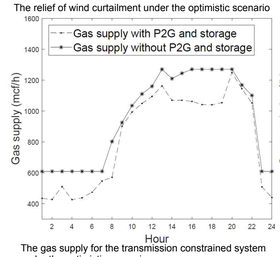
Total Cost ($)	Optimistic Scenario	Pessimistic Scenario	Expected Cost
With Energy Hub	199,130	214,820	206,920
Without Energy Hub	206,410	217,340	211,840



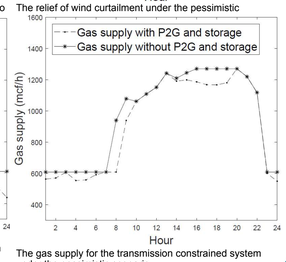
The relief of wind curtailment under the optimistic scenario



The relief of wind curtailment under the pessimistic



The gas supply for the transmission constrained system under the optimistic scenario



The gas supply for the transmission constrained system under the pessimistic scenario

Accomplishments

- An interval optimization based stochastic SCUC model for an electric-gas integrated energy system is proposed to optimally coordinate the operation of integrated system
- Energy hubs equipped with P2G technology are modeled in detail
- Interval optimization and Benders Decomposition are used to reduce computational burden without loss of optimality
- A case study verifies the applicability of the proposed method
- A case study demonstrates that P2G can be a promising method to reduce the wind curtailment
- A case study indicates that P2G can reduce the total operational cost and the total gas supply, especially when the curtailment is serious

Next Step

System level

- The economic viability of P2G
- The siting and the sizing of energy hubs
- Other uncertainties such as gas prices
- Dynamic model of the natural gas networks

Energy hub level

- Bidding strategy with the emergence of P2G
- Other ancillary services provided by P2G such as demand response
- Expansion planning of energy hub equipped with P2G

P2G is a new technology, many questions remain unknown!