OPTIMUM PLANNING AND OPERATION OF COMPRESSED AIR ENERGY STORAGE WITH WIND ENERGY INTEGRATION

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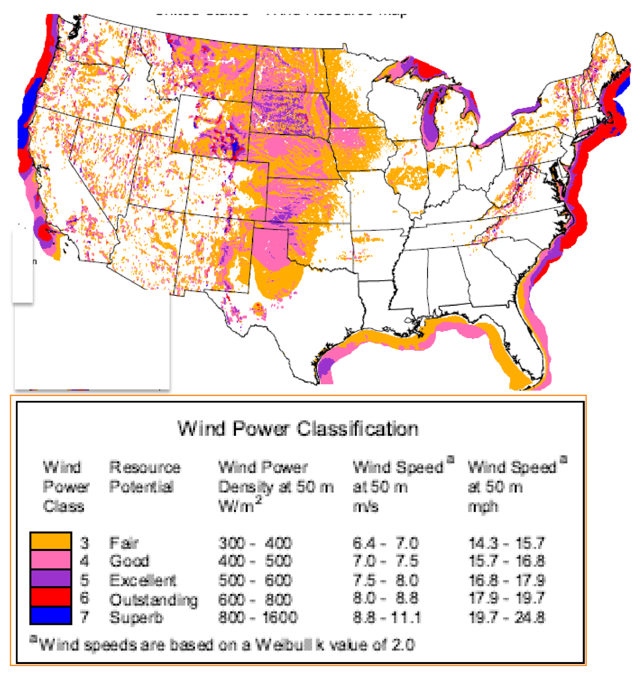
Goals and Objectives

1. To develop an optimization methodology based on the particle swarm optimization (PSO) in order to investigate the feasibility, and perform economic analysis of a wind generation-CAES system.
2. To determine the optimum short-term decision variables based on the day-ahead data such that the revenue from the operation of wind generation–CAES is maximized. The variables considered in this study include electricity market price, wind speed, gas price, etc.
3. To determine the optimum wind generation and CAES capacities to maximize the long-term profit.
4. To determine the profitability of the project under different conditions using sensitivity analysis.

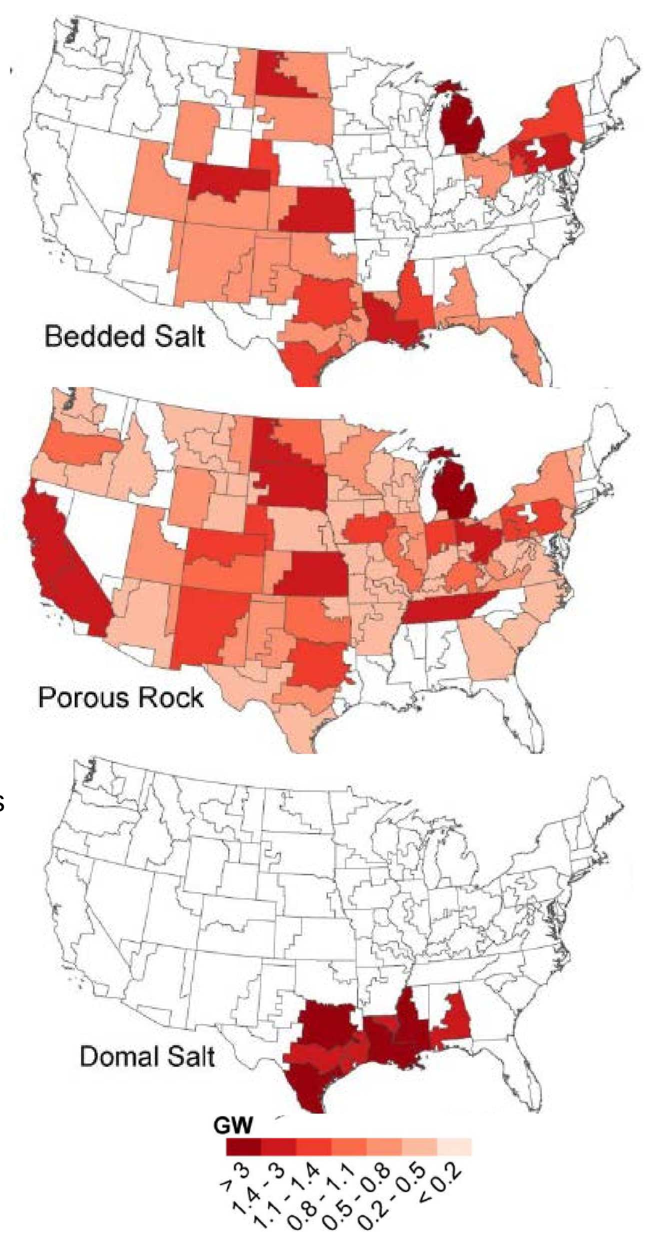
Motivation

The integration of increased and abundant renewable energy sources such as wind energy into the grid will have the potential to reduce the dependence on fossil fuel and minimize the greenhouse gas emission. However, due to stochastic nature of the renewable generation, balancing of generation and load becomes difficult. Energy storage is expected to play a major role in promoting the development of renewable energy, by intermittent power source balancing, storing surplus generation, and providing electricity during high demands. One of the various emerging energy storage technologies is Compressed Air Energy Storage (CAES).

Wind Energy Resources:



CAES Resources:



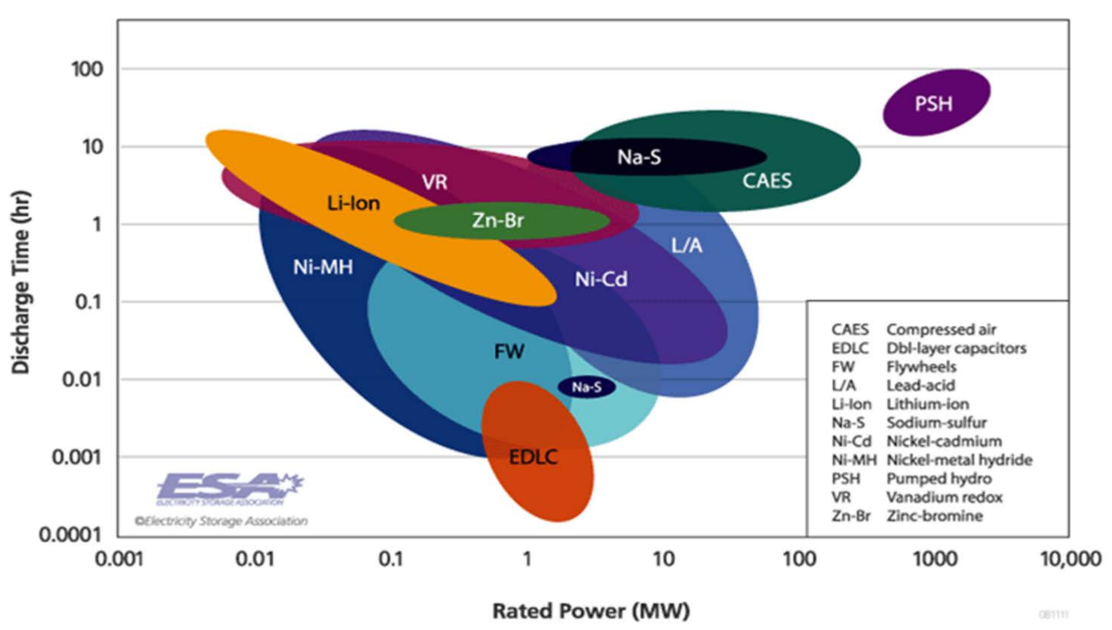
Estimation of Resource Availability:

- 75% of the land area of the United States could provide suitable geology for CAES projects
- Potential CAES resource was estimated to exceed 120 GW: 23 GW in domal salt, 37 GW in bedded salt, 62 GW in porous rock.

Expected Benefits:

- Increase transmission utilization
- Managing peak power
- Increase capacity factor
- Reducing carbon emission
- Balancing resources
- Improvement in the delivery of power from wind farms

Comparison of Energy Storage Systems:



Background

CAES Plants Built:

- Huntorf, Germany; 290 MW with 2 hours of capacity; built in 1978.
- McIntosh, Alabama; 110 MW with 26 hours of capacity; built in 1991.

CAES Plants Studied:

Owner/Developer	Location	Size (MW)	Primary Application
PG&E	Kern County, California	300	Load leveling/firm capacity/ancillary services
NYSEG	Reading, New York	150	
FirstEnergy	Norton, Ohio	2,700	
El Paso Energy	Markham, Texas	540	
ISEPA	Des Moines, Iowa	270	

Cost Estimation:

- \$900/kW with salt domes.
- \$1,050/kW with bedded salt.
- \$1,200/kW with aquifers.

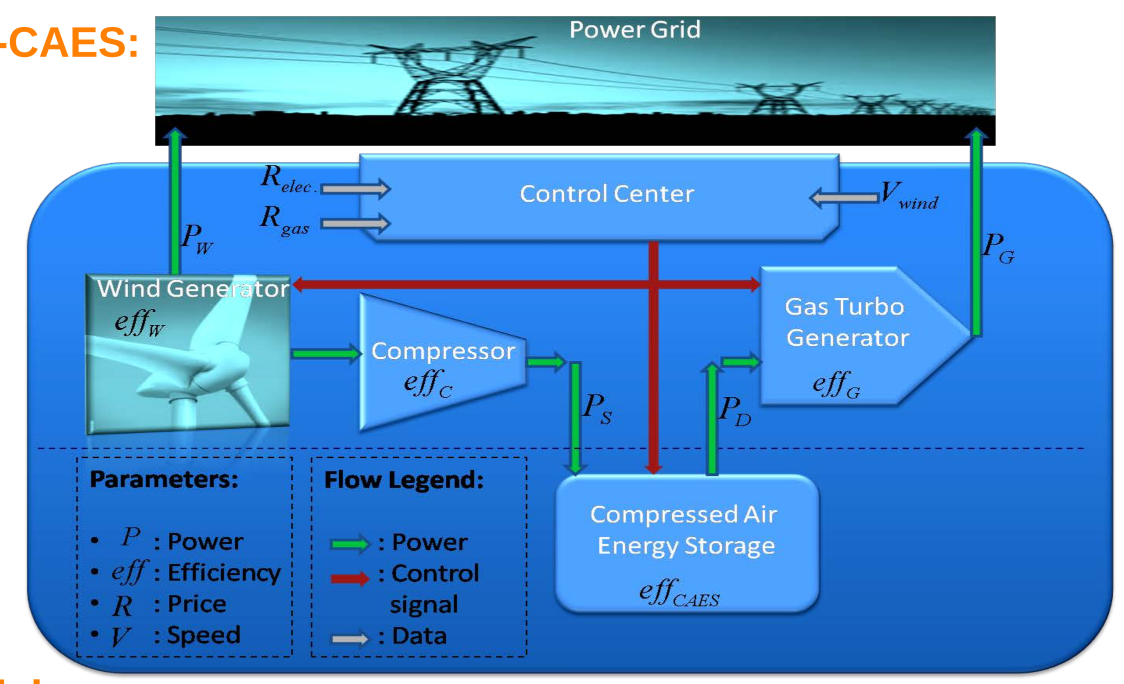
Component	Fraction of Total
Compressor	11%
Heat exchanger	4%
High pressure expander	8%
Low pressure expander	19%
Electrical	6%
Construction, labor, indirect costs	42%
Cavern development	10%
Total	100%

Challenges:

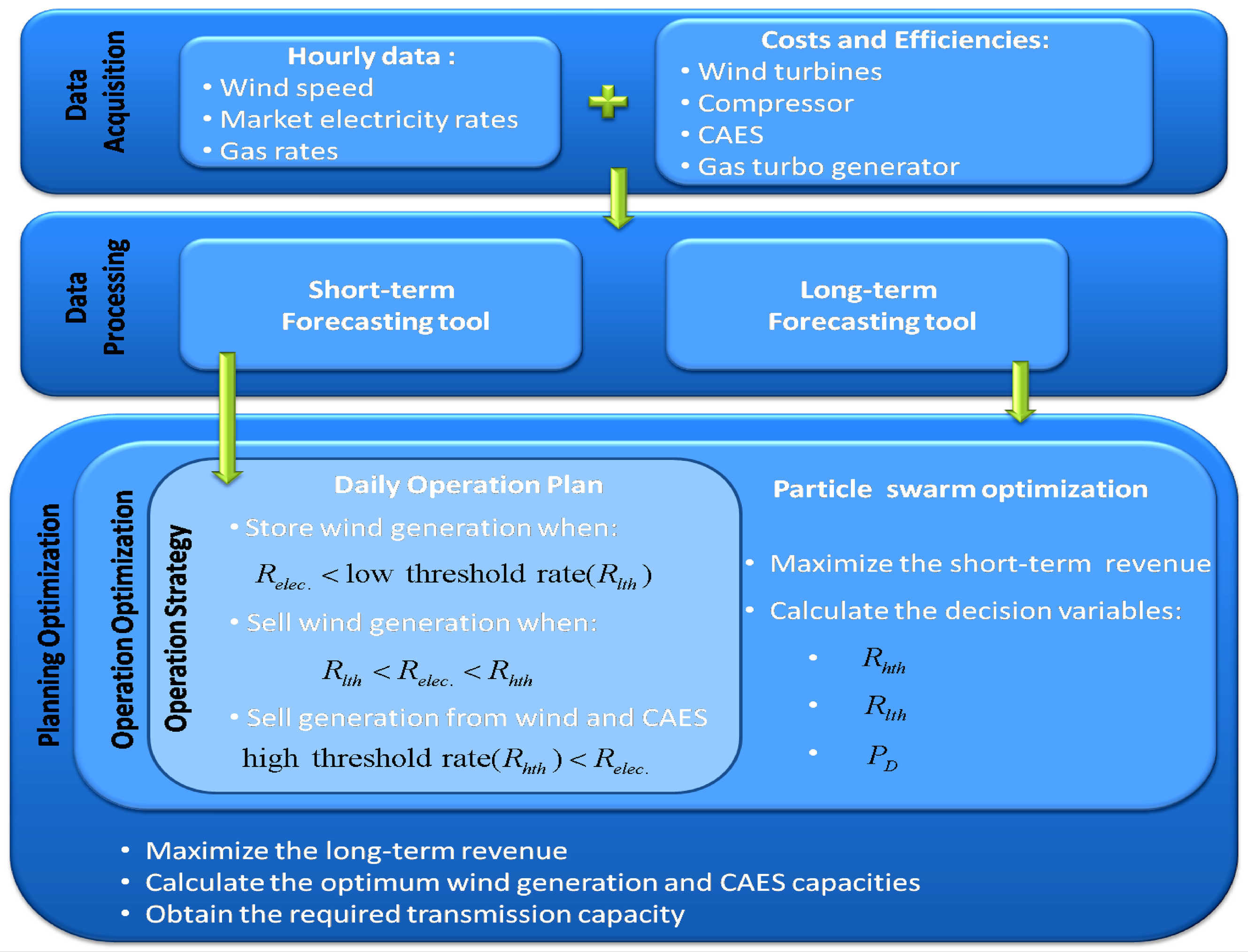
- Finding suitable geological location
- Cost of CAES system
- Need for new high-voltage transmission lines due to typically large CAES capacities in remote areas

Methodology

Wind Generation-CAES:



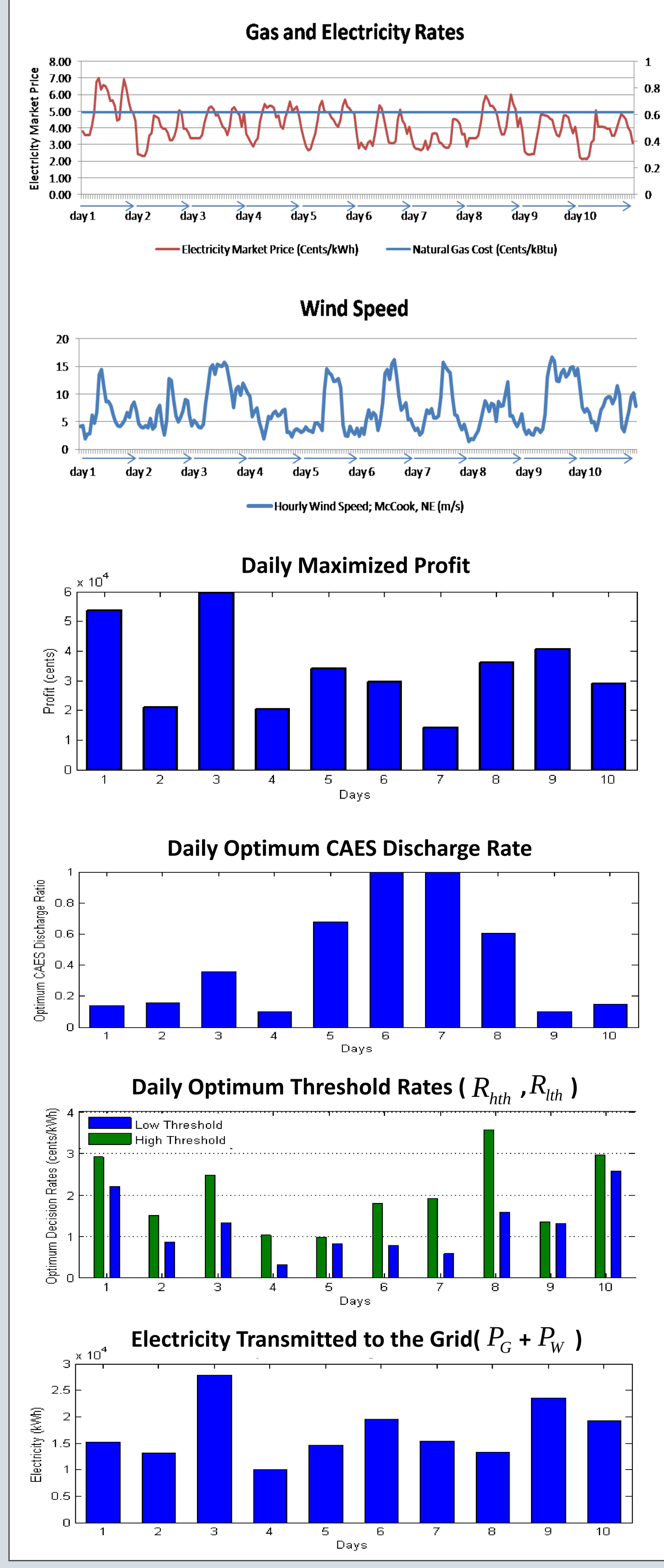
Optimization Model:



Optimization Results

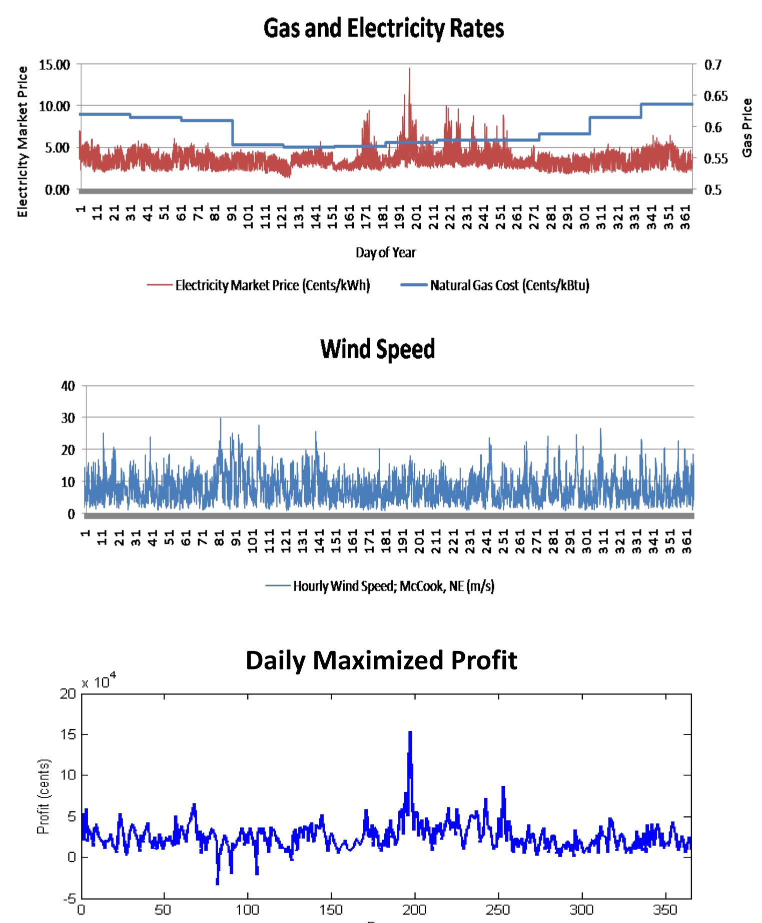
Operation:

(Heat rate=3.8 Btu/Wh; Energy ratio=0.9; Transfer limit=1.5MW)
(Wind generation capacity=1 MW; CAES capacity=2.5 MW)



Planning:

(Heat rate=3.8 Btu/Wh; Energy ratio=0.9; Transfer limit=1.5MW)

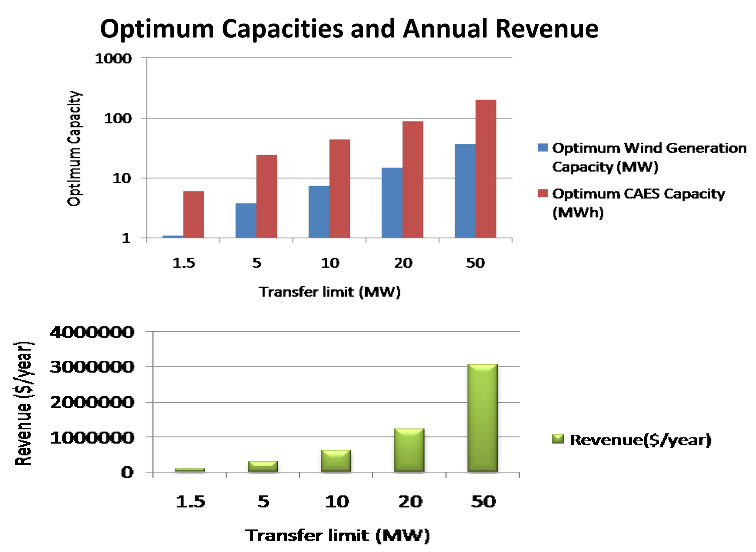


Optimum Capacities:

- Wind generation capacity=1.1 MW
- CAES capacity= 6 MW

Sensitivity Analysis:

(Transfer limit=1.5MW; 5MW; 10MW; 20MW; 50MW)



Conclusions

- Developed a model for the wind generation-CAES system considering:
  - Efficiencies and levelized costs of the system components.
  - Electricity market price, gas price, and wind speed.
- Studied the optimum operation and planning of the wind generation-CAES system:
  - Determined the day-to-day optimum decision variables based on short-term forecasting.
  - Determined the long-term optimum wind generation and CAES capacities to maximize the revenue.
- The cost-effectiveness of the CAES plant highly depends on its efficiency and costs.
- The daily maximized revenue is mainly correlated with the electricity rates and wind speed.
- The optimum CAES capacity calculated is 5-6 times the optimum capacity of wind generation in the case studies.

References

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