Wind Generation Curtailment Reduction based on Uncertain Forecasts

Authors

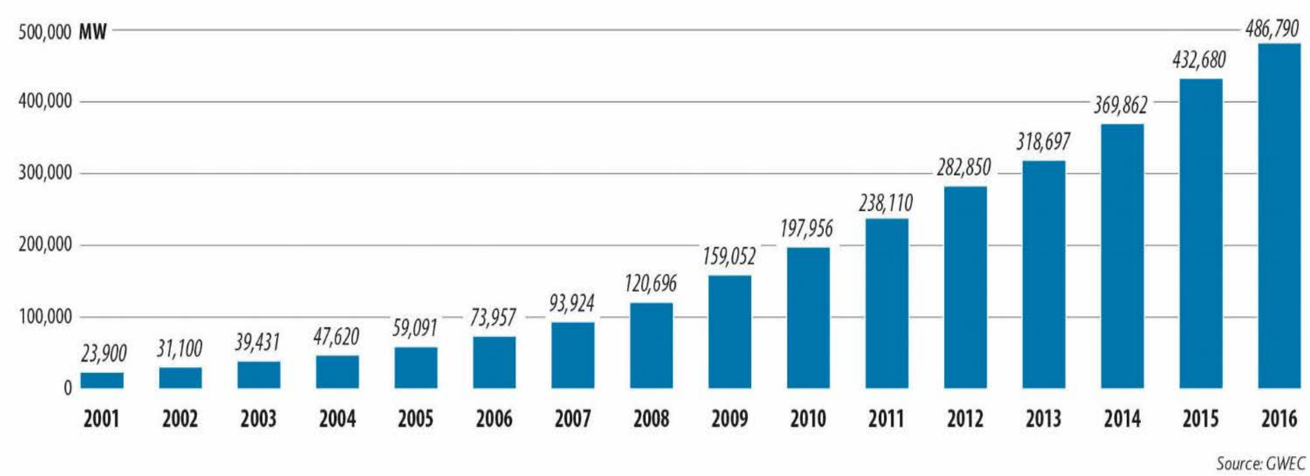
A. Alanazi & A. Khodaei
University of Denver
USA

M. Chamana & D. Kushner
ComEd
USA

Presenter
Manohar Chamana

Introduction

- Wind generation is fast growing technology among renewables.
- Global Installed wind generation capacity:
    - In 2015, 432.7 GW
    - In 2016, reached 486.8 GW (an increase of 12.5%)



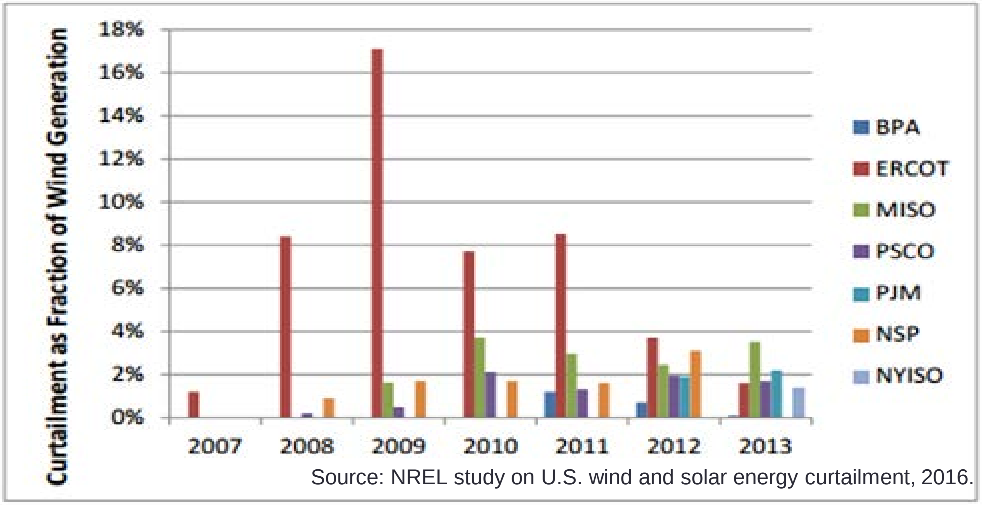
Global cumulative installed capacity of wind generation
(GLOBAL WIND REPORT 2016 | GWEC)

Introduction

- Wind energy advantages:
  - Clean
  - Inexpensive
  - Easy/fast to install
- Wind energy disadvantages:
  - Intermittency
  - Volatility
- The variable generation issues:
  - Supply/demand imbalance
- Variability of wind generation has to be mitigated by:
  - Installing pump hydro storage system
  - Installing battery energy storage system
  - Wind generation curtailment

Wind generation curtailment

- The wind generation curtailment in different balancing areas in the United States from 2007 to 2013.



- CAISO renewable curtailment:
  - In 2016, 21 GWh and 47 GWh in February and March, respectively
  - In 2017, 60 GWh and 80 GWh in same months

Wind generation curtailment

- The wind generation curtailment definition:
  - Using less than what a wind turbine could potentially generate
  - Reducing the wind generation (to be below MPPT)
  - Disadvantage: energy waste, not desirable
  - Advantage: avoiding oversupply
- To reduce the wind generation curtailment:
  - Increase the power system flexibility
  - Install battery energy storage system (BESS)
- BESS helps to reduce the wind curtailment by:
  - Storing the surplus wind generation (instead of curtailment)
  - Discharging it at low wind generation hours

Problem Statement

- The main objective:
  - maximize the economic benefit of wind generation
  - reducing the wind curtailment considering forecast uncertainty (robust solution)
  - Optimally sizing the BESS: because of high BESS investment cost

- The robust solution ensures:
  - Minimum total planning cost
  - The worst scenario of wind generation forecast

The robust optimization model

- The objective function of the proposed model:
  - minimizing the total annual system planning cost,
  - Simultaneously maximizing the uncertainty of wind generation forecast (the worst-case solution)
- The objective function is subject to the following constraints:
  - Operation and power flow constraints
  - The wind generation forecast uncertainty constraint:
    - Identifying the worst-case solution
    - The upper/lower limits of the uncertainty range
  - The uncertainty limit constraint:
    - A certain limit of wind generation forecast uncertainty
    - Restricting the number of hours of uncertain forecast

The robust optimization model

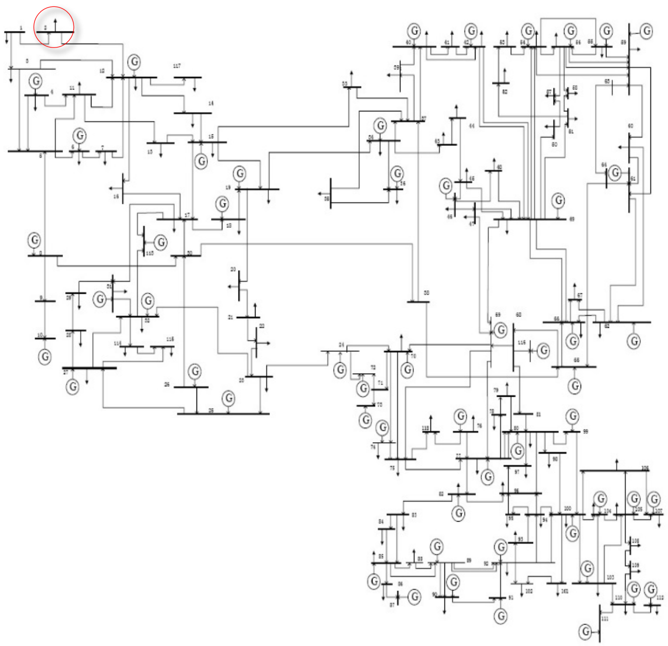
- Three kinds of risk-aversion to measure the robustness degree of the solution:
  - **The conservative:**
    - Larger uncertainty limit
    - More robust solution against uncertainty
    - Large total planning cost
    - Lower risk of unserved energy
  - **The aggressive:**
    - Smaller uncertainty limit
    - Low total planning cost
    - Less robustness degree of the solution
  - **The moderate:**
    - Solutions between the conservative and aggressive solutions

Numerical simulation

- Using IEEE 118-bus test system with:
  - A 200 MW wind farm connected to bus 2
  - Upper and lower limit of the uncertainty range: +10% and -10%

The BESS Characteristics

Power Rating Capital Cost ($/MW-yr)	Energy Rating Capital Cost ($/MWh-yr)	Depth of Discharge (%)	Efficiency (%)
20,000	11,000	80	90



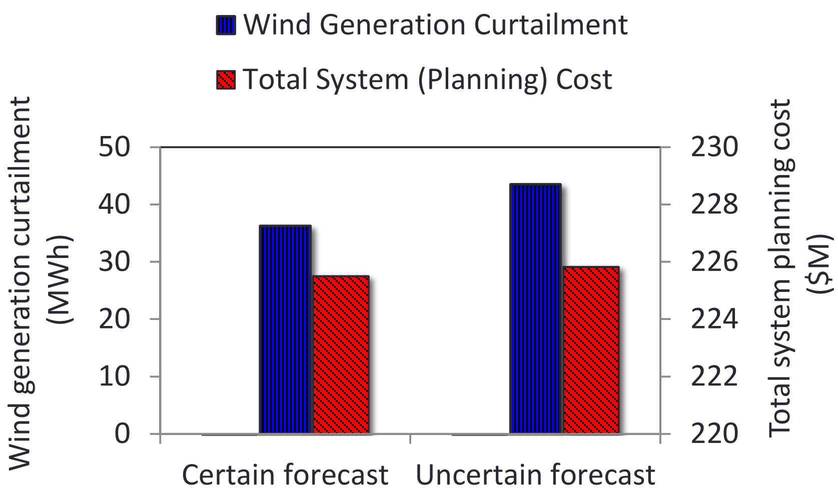
IEEE 118-bus test system

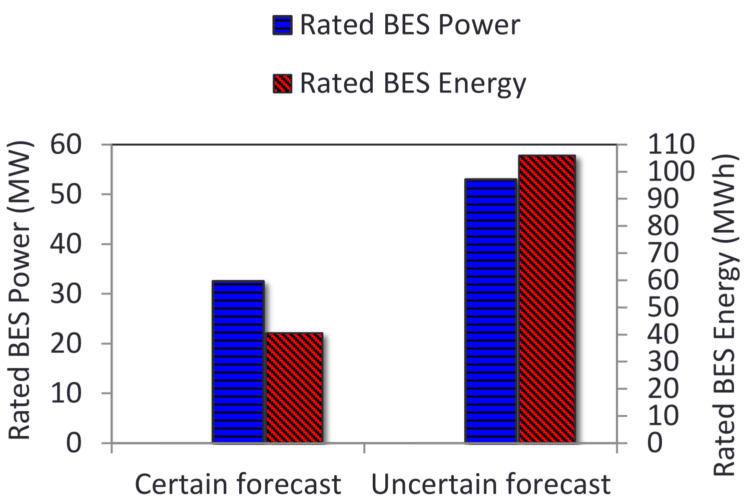
Numerical simulation

- The model is solved for the following cases:
  - Ignoring wind generation uncertainty
  - Considering wind generation uncertainty
  - Impact of changing the upper and lower limits of the uncertainty range to be 0, ±5%, ±10%, and ±15%
- **Case 1: Ignoring wind generation uncertainty (base case)**
  - Solved for a one-year period
  - Total of 36 MWh of wind generation curtailment
  - Total planning cost : $225,500,500
  - Optimal BESS size: 32 MW and 40 MWh for power and energy ratings, respectively

Numerical simulation

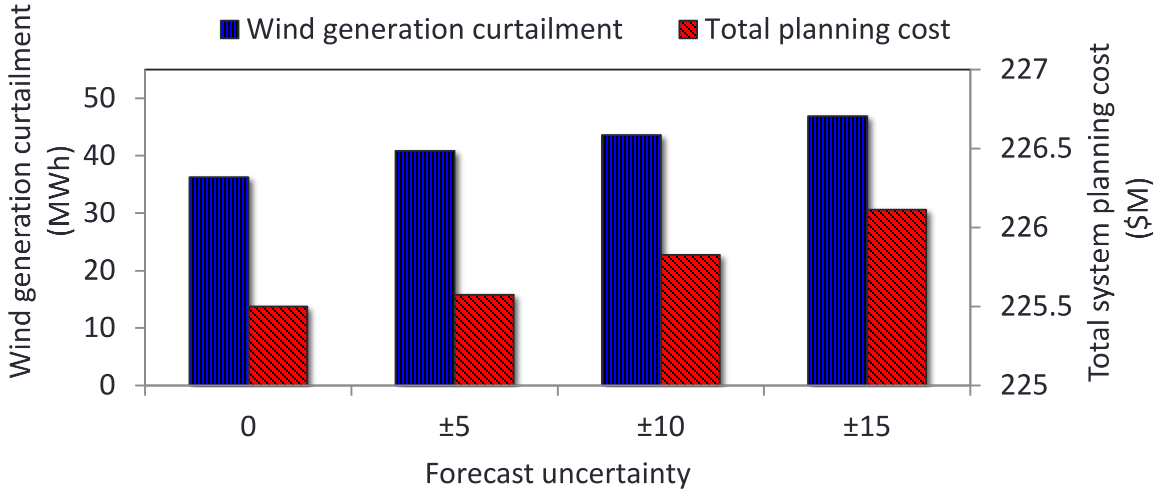
- **Case 2: Considering wind generation uncertainty**
  - The wind generation curtailment: 43 MWh (an increase of 19.4% compared to the previous case)
  - Total planning cost: $225,827,300 (increased by 0.15%)
  - Optimal BESS size: 53 MW and 106 MWh for rated power and rated energy, respectively





Numerical simulation

- **Case 3: Impact of changing the forecasting uncertainty range**
  - The forecast is 100% accurate:
    - Minimum total planning cost
    - Solution not practical
  - The uncertainty range increases:
    - A larger total planning cost.
    - Higher wind generation
    - Higher degree of solution robustness



Impact of changing forecast uncertainty

Conclusion

- The model was capable of determining the worst-case solution under prevailing uncertainty of wind generation forecast.
- The model succeeded to:
    - Install the optimal BESS size
    - Optimally reduce the energy waste (wind generation curtailment)
- The total planning cost, wind generation curtailment and the optimal BESS size increased compared to ignoring uncertainty.
- However, including wind forecast uncertainty in the planning problem helps to:
    - Provide a more practical solution
    - Avoid further investments in support of existing electricity infrastructure

Thank you