A PRACTICAL METRIC TO EVALUATE THE RAMP EVENTS OF WIND GENERATING RESOURCES TO ENHANCE THE SECURITY OF SMART ENERGY SYSTEMS

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Overview

Paradigm shift in the power industry

- Renewable energy is the fastest growing energy source globally
  - ’18: made up 26.2% of global electricity generation
  - ’40: expected to rise to 45%
- Major renewable energy sources:
  Solar, Wind, and Hydropower

Prospects due to the interconnection of renewable energy resources

- Fluctuations in power output and instability in the power system
  - the intermittency and uncertainty in renewable energy sources
- Necessary to secure stable operation plans and reliability of power systems
Ramp Event

- Local events in wind power time series, characterized by sharp variations in power
  - Results in both financial and physical impacts
- Standards should be established considering wind power ramp events

→ Analyzed the characteristics of ramp events to maintain power system stability considering renewable energy characteristics

→ Forecast the ramp rate of wind power outputs to use ramping information in power systems operations effectively
Ramp Events

General Definition of Ramp Events

- Large fluctuations in the wind power in a short time interval which can cause unexpected variations in the electric power grid
- Usually parameterized by the following features:
  - Ramping start/end, ramping duration, rate and magnitude
- Several ramp definitions should be considered simultaneously to identify the possibility of ramp event occurrence

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<thead>
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<tbody>
<tr>
<td><strong>Magnitude</strong></td>
<td>Variation in power produced in the wind farm or wind turbine</td>
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<tr>
<td><strong>Duration</strong></td>
<td>Time period during which a ramp event is produced</td>
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<tr>
<td><strong>Ramp Rate</strong></td>
<td>The intensity of the ramp</td>
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\[
\Delta P_r \quad \Delta P_r / \Delta t_r
\]
Ramp Events

Definition of ramp events in this study

• Definition: A ramp event is defined as a ratio between the power currently measured and the power measured time $\Delta t_r$ ahead

• Terminology: Usually parameterized by the following features:
  - $R_t$: Ramp function
  - $P_t$: Power production at the wind farm or wind turbine

$$R_t = \frac{P_t - \Delta t_r}{P_t}$$

* Subscript “r” : ramp events
* Time interval = 1h

• Ramp Rate: Increase or reduction in output per minute

$$\text{Ramp rate} \% = \left(\frac{\text{Ramp}}{\text{Capacity}}\right) \times 100$$

* Capacity factor = 16MW
Characteristics of ramp events

• Wind ramps are influenced by different time and geographic scales

• Classified as upward (ramp-ups) and downward (ramp-downs) ramps
  – Upward ramps: result from phenomena such as intense low-pressure systems, low-level jets, and thunderstorms
  – Downward ramps: result from a reduction in wind power or when high-speed winds cause wind turbines to reach cut-out limits

• Upward and downward ramps can be defined based on different level of risks
  1) An important downward ramp occurs only if the power changes at least 15% of the total capacity within 1 h
  2) An important upward ramp occurs only if the power changes at least 20% of the total capacity within 1 h

• Generally, downward ramp is riskier than upward ramp
Data Analysis

Background

- Large ramps: affect power system economics and reliability
- Analyzing the trend of ramp rates is important for forecasting ramp events and stabilizing the wind power grid
- In this study, the seasonal and hourly trend is defined through analyzing the data

Data

- Location: Mountain Taebaek wind farm in Gangwon-do, South Korea
- Period: January 1, 2018 ~ December 31, 2018
- Spring: March, April, May   Summer: June, July, August
  Fall: September, October, November   Winter: December, November, January
- Time interval: 1 hour
Data Analysis

Results for seasonal analysis

Spring

Ramp rate (%)

Time (hour)

Summer

Ramp rate (%)

Time (hour)

Fall

Ramp rate (%)

Time (hour)

Winter

Ramp rate (%)

Time (hour)
Data Analysis

Results for hourly analysis

- Average ramp rate for fall and winter: above 10%
- Average ramp rate for spring and summer: below 10%

Results
- Spring, Summer < Fall, Winter
- Morning < Night
Ramp Forecasting

Background

- Forecasting a wind power output through ramp rate analysis
- Improve the reliability of the wind power output forecast
- A statistical approach for predicting the next 1 h wind power output

Method

- Through ramp event data analysis, the hourly seasonal average ramp rate can be calculated
- The wind power output value measured 1 h ago is used

\[
\frac{\text{Measured wind power output value} \times 10000}{\text{Seasonal ramp rate} \times \text{Capacity factor}}
\]

* Capacity factor = 16MW

- Compare the measured values and forecasted values through graphs and RE(Relative Error)
Ramp Forecasting Results

Results

- The average error (RE) value for every month: 0.28

\[ RE = \frac{|\text{Measured value} - \text{Forecasted Value}|}{\text{Measured value}} \]

- May was the most predictable month

- The forecasted value at 23:00 appears to be plummeting

<Comparison between the measured and forecasted values (May, 2018)>
# Part 4

## Conclusion and Future Work

### Conclusion

- Due to uncertainty and volatility of the renewable energy output,
  - Unstabilization in renewable energy interconnection occurs
  - Maintaining the balance between power production and load balance is becoming harder
- Improved ramp forecasting can help maintain the stability of the power grid
- Data from Taebaek (Gangwon-do, South Korea), collected in 2018 is used to the analysis
- Variability (ramp events) is higher during fall and winter than spring and summer
- Using the ramp event data analysis, 1 hour wind power output forecasting is conducted
- The average RE value between the forecasted and measured values: 0.28
  - Analyze all the values measured daily and hourly
  - Various models and evaluation metrics will be more applied to verify the accuracy of the study and to find the best model
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