7th International Conference on Smart Energy Systems
21-22 September 2021
#SESAAU2021

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Funded by the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement no. 846463

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

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# Contents

# 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

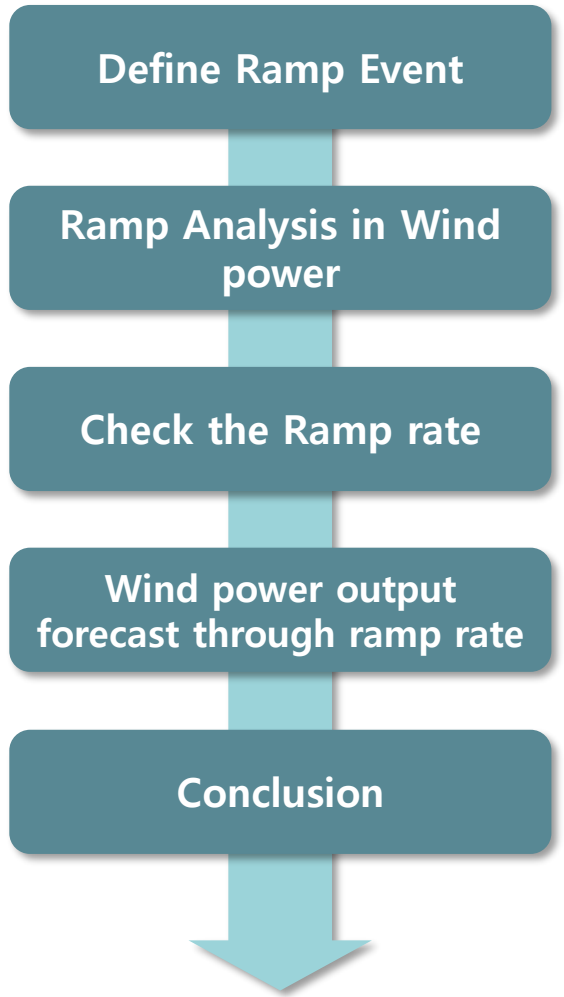
- Fluctuations in power output and instability in the power system
  - the intermittency and uncertainty in renewable energy sources
- Necessary to secure stable operation plans and reliability of power systems

## 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**

| | |
|---|---|
| **Magnitude ($\Delta P_r$)** | **Variation in power produced in the wind farm or wind turbine during ramp events** |
| **Duration ($\Delta t_r$)** | **Time period during which a ramp event is produced** |
| **Ramp Rate ($\Delta P_r / \Delta t_r$)** | **The intensity of the ramp** |

# 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**

$$R_t = P_{t-\Delta t_r} / P_t$$

*** Subscript "r" : ramp events**
*** Time interval = 1h**

- **Ramp Rate : Increase or reduction in output per minute**

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

*** Capacity factor = 16MW**

# Characteristics

## 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 1h**
- **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

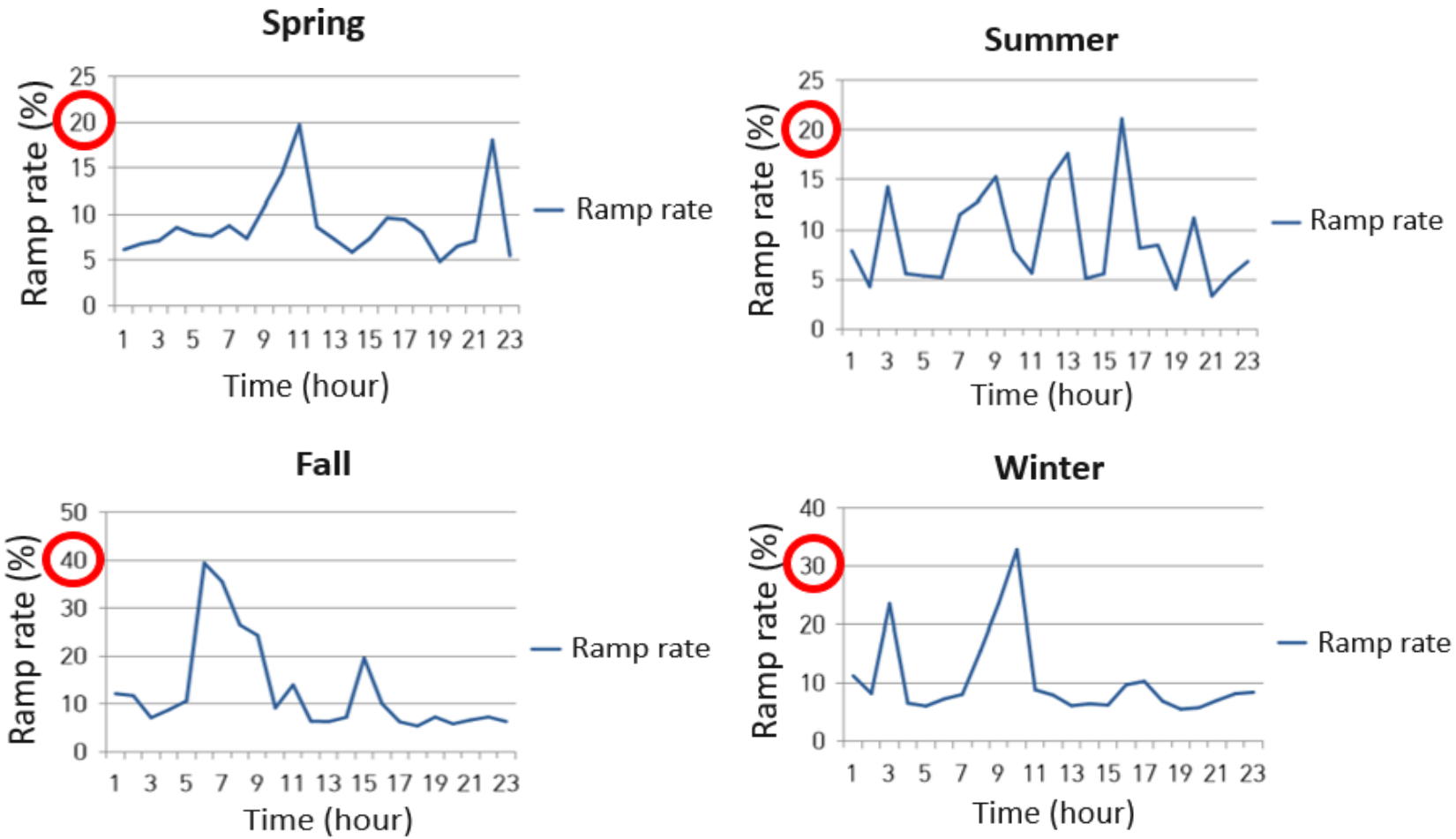
## Data

- 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

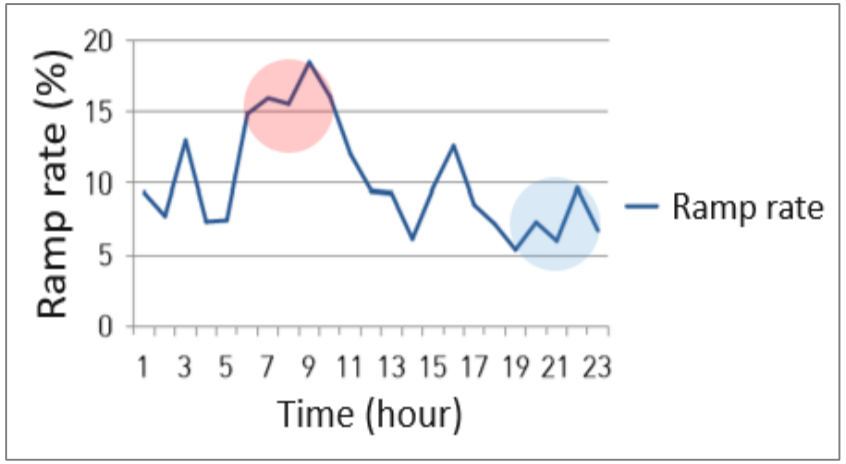
# Data Analysis

## Results for seasonal analysis



# 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

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

* Capacity factor = 16MW

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

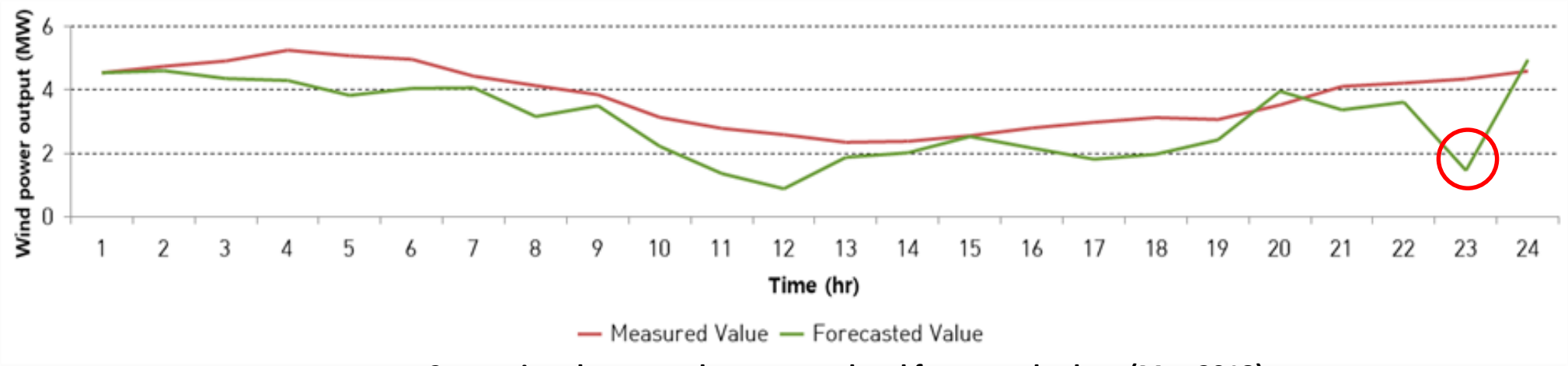
# Ramp Forecasting Results

## Results

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

$$RE = \frac{|Measured\ value - Foreacsted\ Value|}{Measured\ value}$$

- **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)>**

# 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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