A simple gust estimation algorithm and machine learning based nowcasting for wind turbines

I. Schicker, P. Papazek
Introduction

Gusts:
- can cause damage to building, infrastructure, (wild) life, nature
- important for wind energy production, wind turbines, power lines, aviation, air-pollution dispersion, siting of turbines and turbine construction (turbulence, return time of extremes, etc.) and turbine management, Ski resorts / alpine skiing, ski jumping, biathlon, etc.
- provide important information on turbulence conditions at specific sites as turbulence is seldomly reported

Aims

- Develop a (super) simple gust estimation algorithm usable for hub height / wind turbines
- (Ultra) Short frequency nowcasting of gusts for turbines and surface sites
- Use machine learning and data mining
Data and pre-processing

• standard meteorological observation sites
• SCADA turbine data

pre-processing needed

Pre-processing SCADA data
• No recorded gusts → need to calculate gusts
• Different equations/definitions available from literature (selection):

Wieringa (1973) and Harper et al. (2010):

\[
u_{t,T} = \bar{u}_T + k \sigma_u
\]

\(u_{t,T}\) = gust (time t, duration T)
\(u_T\) = mean wind speed (averaged over T)
\(\sigma_u\) = standard deviation wind speed
\(k\) = constant of proportionality

→ Simple but missing e.g. convective parts

Cvitan (2004, based on CENELEC/TC 11 (SEC) 40):

\[
u_{t,T} = k_g \bar{u}_T
\]

\(u_{t,T}\) = gust (time t, duration T)
\(k_g\) = gust factor
\(\bar{u}_T\) = mean wind speed (averaged over T)
\(\sigma_u\) = standard deviation wind speed
\(k_g = 1 + \frac{2.28}{\ln\left(\frac{z}{z_0}\right)}\)

\(z\) = height above ground
\(z_0\) = Roughness length

Data and pre-processing

We have SCADA data measured:
- temperature
- power
- wind speed
- wind direction

Often don’t know exact location and/or surroundings!
→ Need to keep it simple!

Developed simple, artificial gust estimation algorithm:

\[ u_{t,T} = u_T(k - (\alpha u_T)) + \varepsilon \beta \]

scaling factor
Scaling factor

Noise

gaussian (white) noise

Depending on if hub height or surface measurement
Simple gust estimation - evaluation

observation site bias to measured gust

FINO 1 - 102m bias to measured gust

WFIP2 physics site 12, 80 m tower

Example artificial gust wind turbine (E101)
Short frequency nowcasting methodology

Data
Observations only
(changes in future when AROME-RUC available)

Perturbing observations for ensemble

Feature selection
(LASSO, XGBoost, Random Forest)

Ensemble nowcasting methods (single/multiple selections possible):
- Multilinear regression
- SVR (grid searched)
- Random Forest
- XGBoost
- FF ANN
- Complex NN
- Monte Carlo
- Stochastic Noise Forecast
- LightGBM
- Gradient Boosting
- .....
Result 10 m site – use cases short frequency nowcasting

meteorological observation site Wien Hohe Warte, forecast of 24.08.2019, init at 16 UTC

artificial gusts used in training&forecast, measured plotted
Conclusions

- Artificial/synthetic gust algorithm in general good. Adjustments still needed. Usable for wind turbine applications

- Nowcasting: need to be really careful with input data, feature selecting and training length. Especially for a feed forward neural network.

- Reliable high-frequency ensemble nowcasts using the new algorithm. However, some methods need hyperparameter tuning.

- Spread of ensemble approach using perturbed observations still too small for some of the methods (e.g. FFNN)