Power and frequency fluctuations on an offshore oil & gas platform power system with connected wind turbines

Til Kristian Vrana

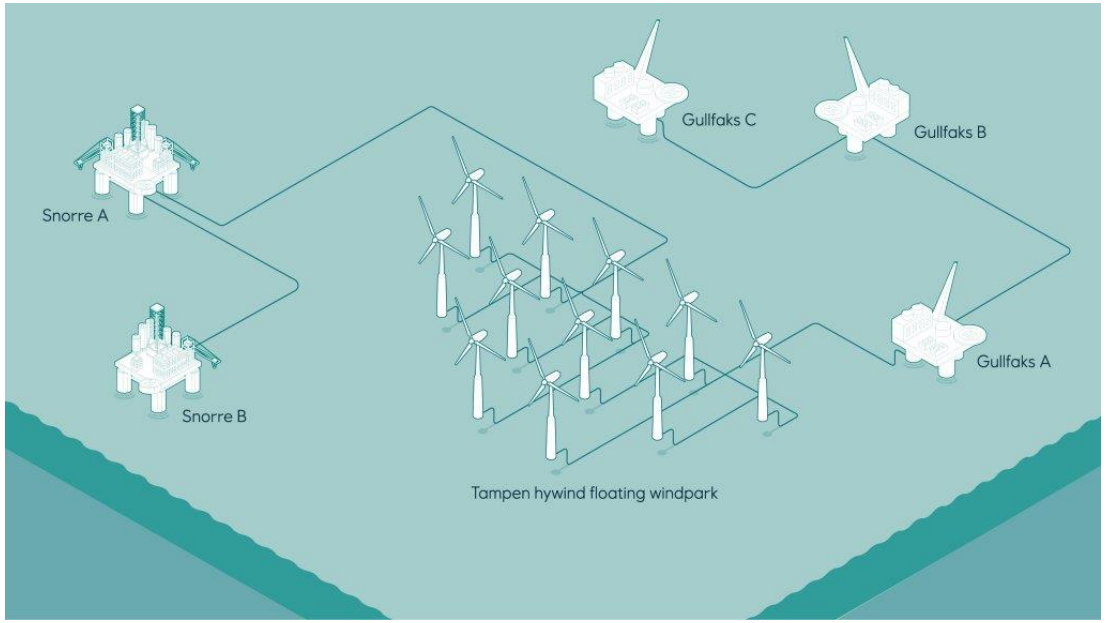
Contributors:
Valentin Chabaud
Henrik Døvle Andrews
Harald G Svendsen
Andrzej Holdyk
Heiner Schümann

Agenda

- Oil&gas platforms with wind turbines
- LEOGO platform
- Wind park layouts
- TurbSim.farm
- Preliminary results

Oil&gas platforms with wind turbines
Is it real?

- Operational: Hywind Tampen
- Study: Ekofisk Wind
- Potential: Aasta Hansteen, more?



Picture = Equinor

Oil&gas platforms with wind turbines
Motivation

- Benefits:
  - Reduce fuel consumption of operating gas turbines
  - Enable turning off some of the gas turbines
    - Saving even more fuel
- Challenges:
  - Introducing power fluctuations to the electric power system
  - Gas turbines need to compensate for them
  - Additional wear and tear on the gas turbines
- Less wind power output fluctuations = better
  - Less fluctuations = less fuel consumption

(also true onshore, but more relevant in small power system)

Oil&gas platforms with wind turbines Opportunities

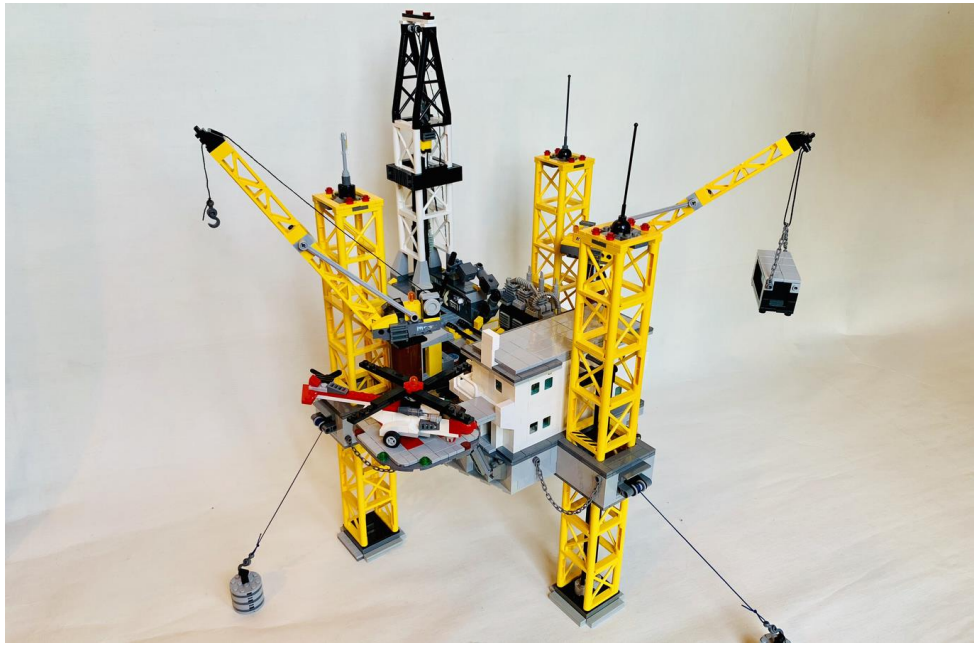
- Playground to test technology
  - E.g. Floating turbines at Tampen
- Integration of weather-driven sources into island grids
- Power system with very large share of wind power

Picture = Equinor

An arena to address wind power integration problems already today which the main power system will face in the future

LEOGO platform
Low Emission Oil & Gas Open platform

- An *Open* platform model
- enabling cooperation
  - With universities/students
  - Suppliers
  - Competitors
- enabling publication
- enabling (open) innovation



...without the barrier of confidentiality

LEOGO platform
Get involved

- Journal article
  - published
  - ask for a copy!

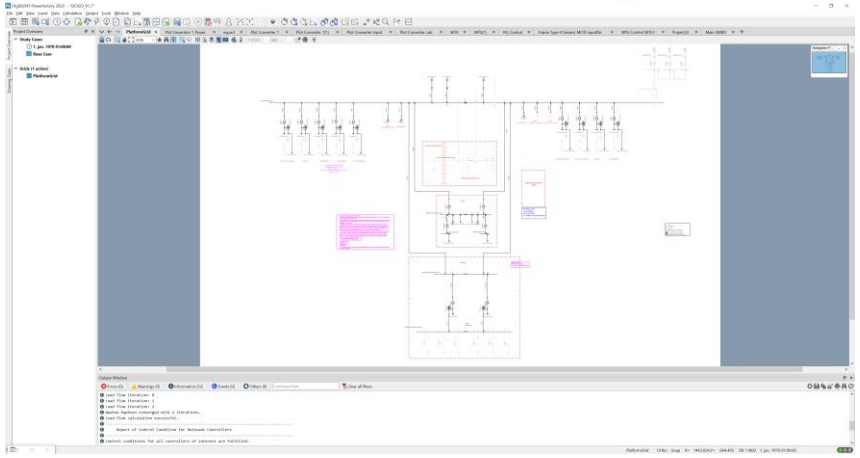
- PowerFactory model
  - free to download
  - free to modify
  - free to use

ORIGINAL RESEARCH

IET Energy Systems Integration

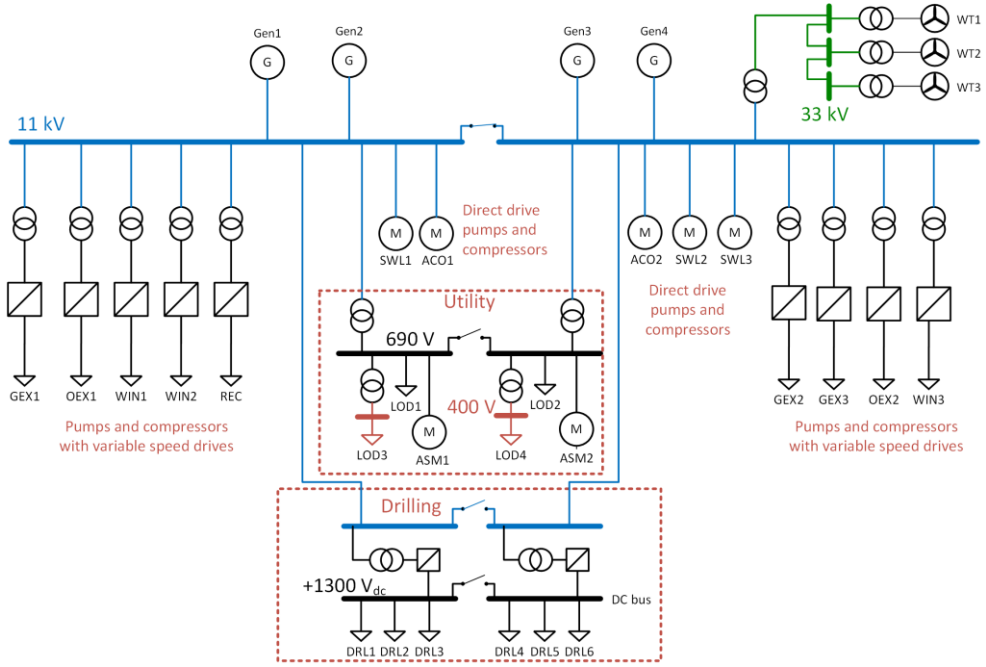
The Low Emission Oil and Gas Open reference platform—An off-grid energy system for renewable integration studies

Harald G. Svendsen | Til Kristian Vrana | Andrzej Holdyk | Heiner Schümann



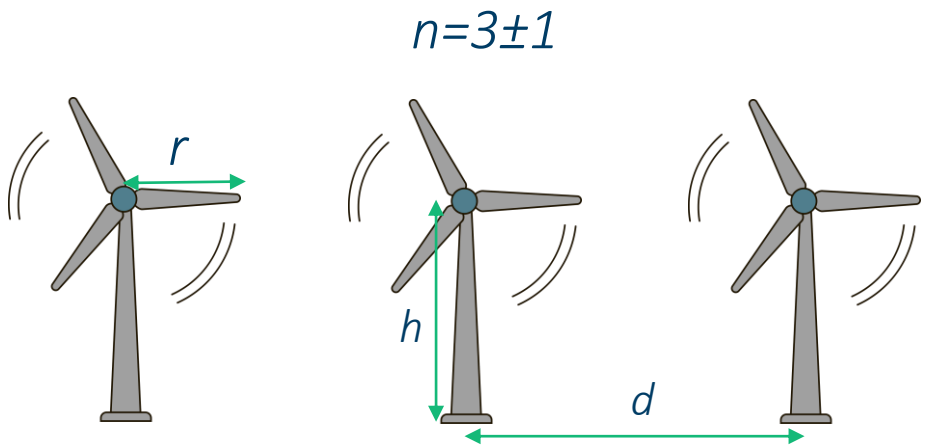
LEOGO Platform
Electrical Model in PowerFactory

- Main bus 11 kV AC
  - 4 gas turbine generators (4x 28 MVA)
  - 9 VSDs
  - 5 Motors
- Utility buses (690 V AC / 400 V AC)
  - Smaller loads
- Drilling busbar +1300 V DC
- 33 kV Wind power collector (3x 8 MW)



Wind park layouts
Basic parameters

- Basic wind park parameters
  - Number of rows = 1
  - Number of turbines per row
  - Rotor radius
  - Hub height
  - Turbine distance
- Single row orthogonal to wind direction
- Hub height = rotor radius plus fixed offset



Wind turbine clip art = Thanks to Creazilla

Wind park layouts considered in this study

- 24 MW of wind power
  - 2 x 12 MW
  - 3 x 8 MW
  - 4 x 6 MW

-> Max power is the same

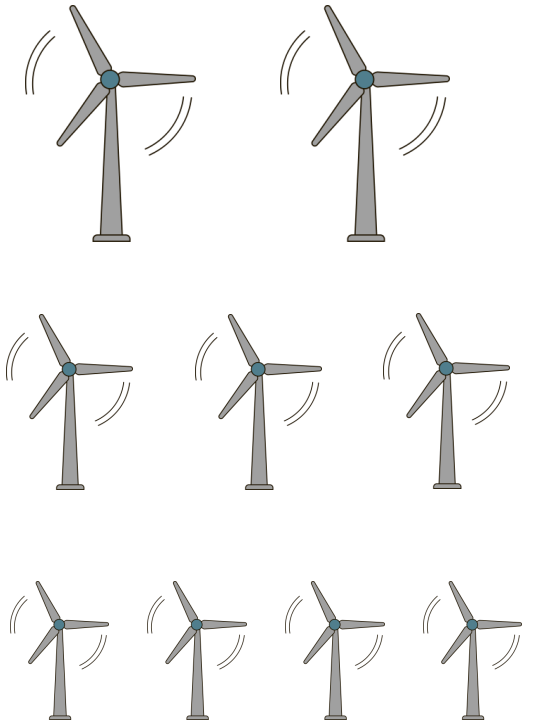
- Rotor diameter taken from real 8 MW turbine
  - Scaled for 6 MW and 12 MW to achieve same capacity factor

-> Average power is the same

  - Total swept area is similar but not the same

Simplyfied view -> It should make no difference

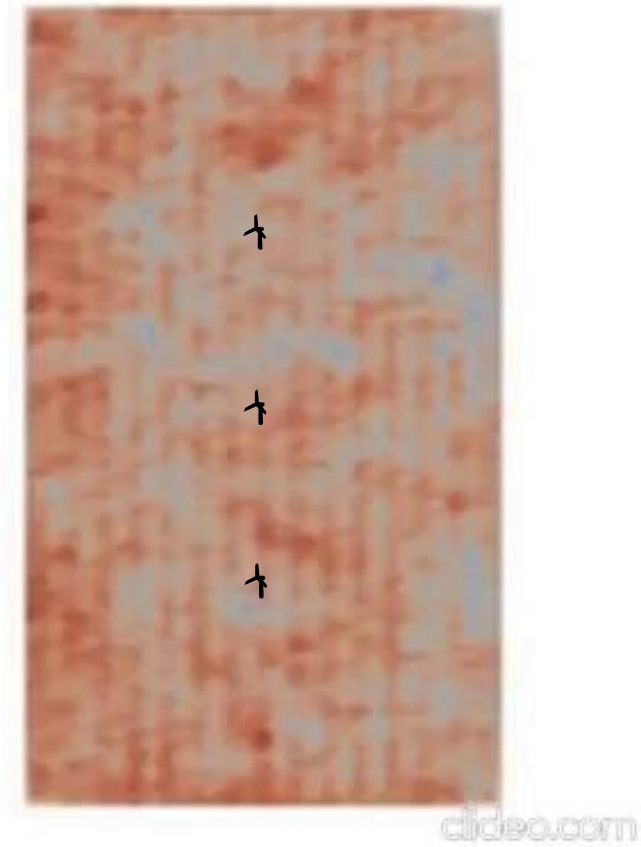
But the details?



Wind turbine clip art = Thanks to Creazilla

TurbSim.Farm

- Farm-wide synthetic turbulence model
  - Correlated, aggregated (rotor-averaged) wind field
  - Farm-level spectrum & coherence models
  - No frozen turbulence assumption
- Multiple realisations
  - Stochastic (Monte Carlo) simulations
- Simulate aggregated wind speed at hub heigtht for each turbine



More information on TurbSim.Farm:
Valentin Chabaud, "Testing a quasi-static reinforcement learning approach for wake steering in dymanimc wind farm simulations", Session 6B Wind Farm Control, Today 15:20

Preliminary Results

- Calculate wind power production from wind speed data
- Low-pass filter: 1 mHz -> 1000 s ≈ 17 min
- Expectation: 4 x 6 MW should fluctuate less
  - Similar swept area
  - better dispersed in space
- Results are more complicated than that

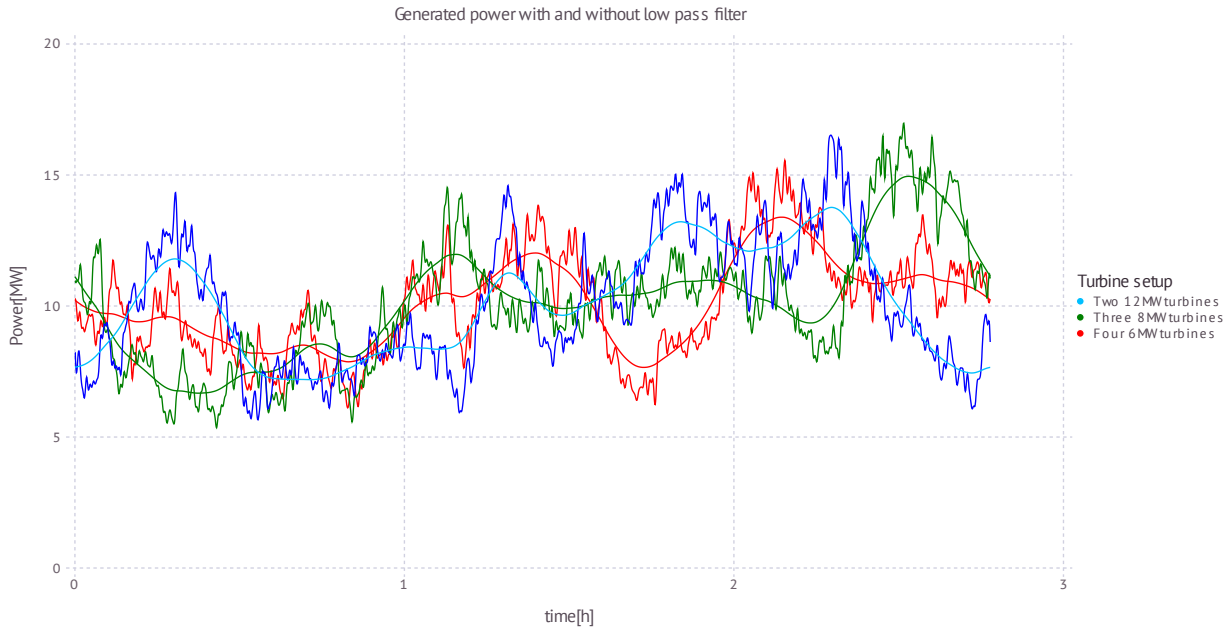
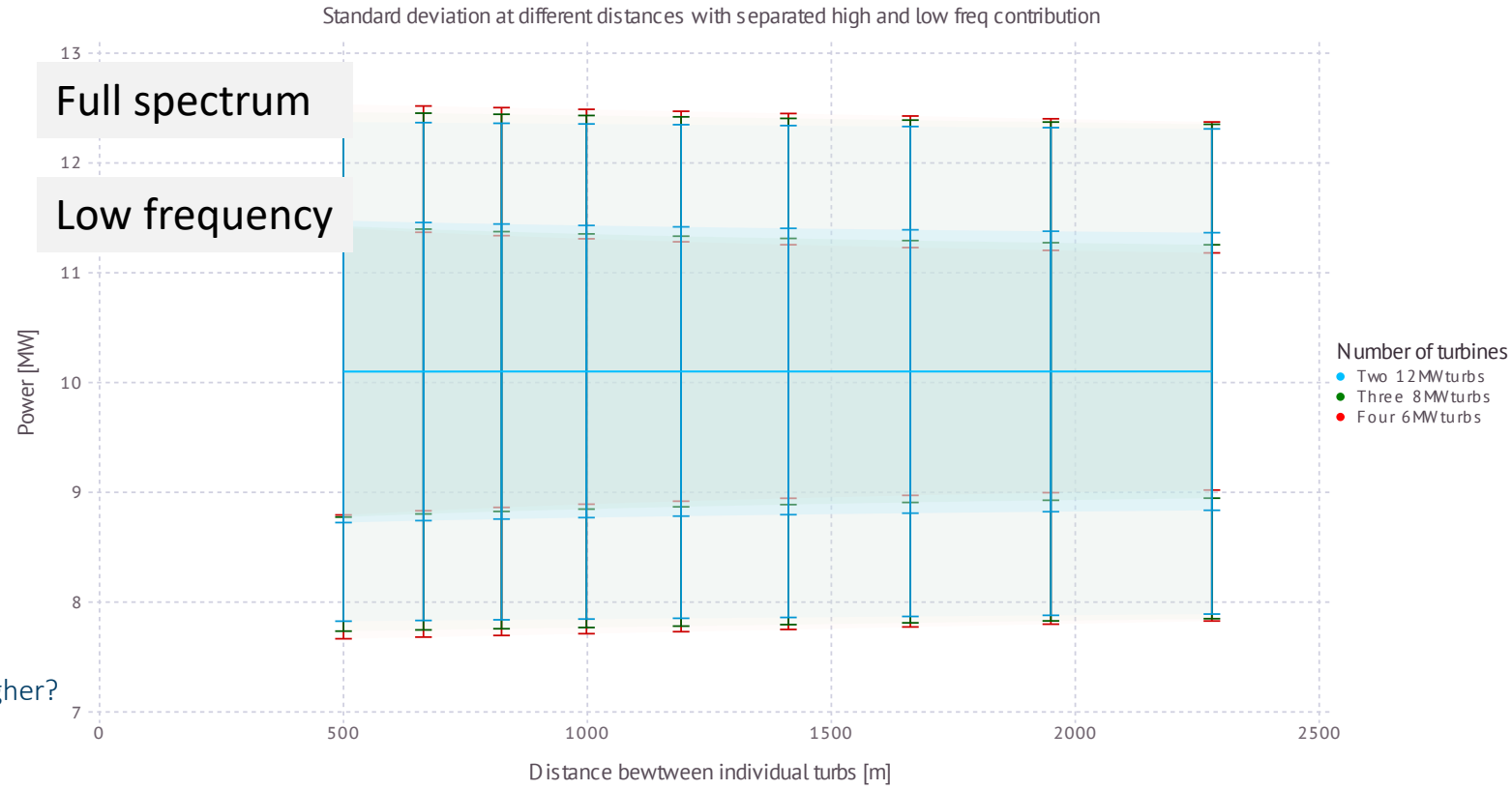


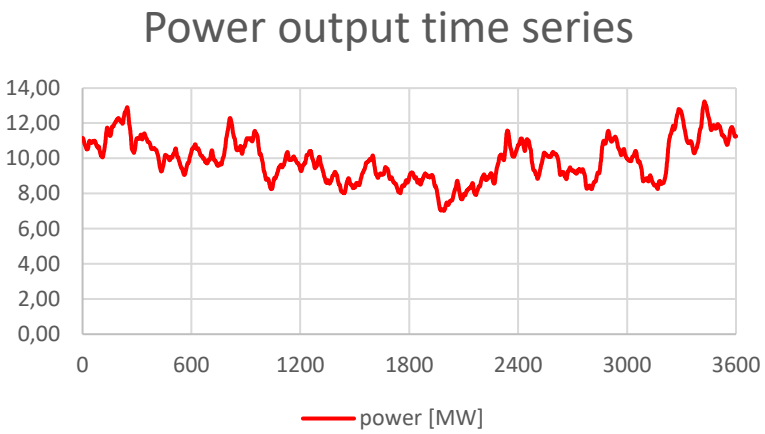
Figure: power time series and low frequency component
(high frequency conponent not shown)
Distance between turbines: 10D

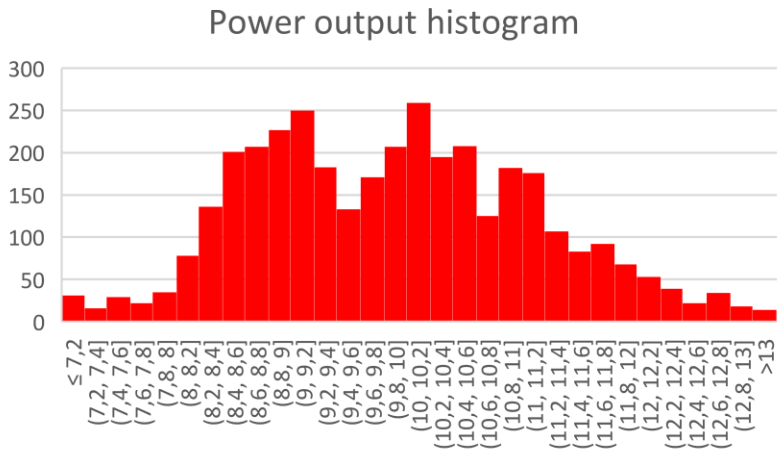
Preliminary Results

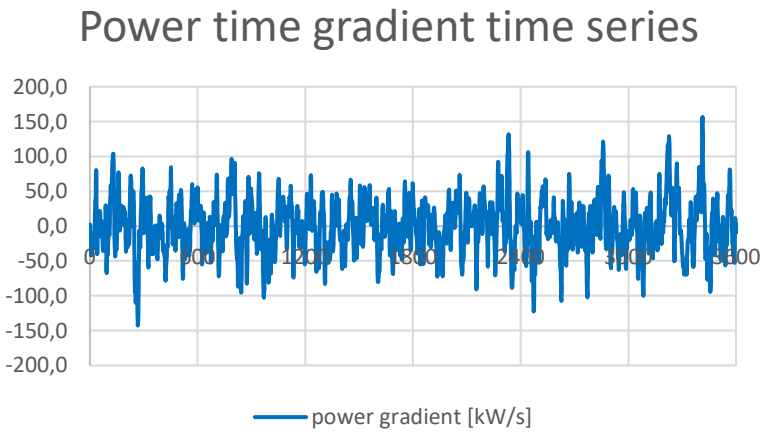
- Full spectrum
  - With narrow spacing, large turbines perform better
  - With increasing spacing, difference diminishes
- Low frequency components
  - With wide spacing, small turbines perform better
  - Wind decreasing spacing, difference diminishes
- No clear winner
- Rather small differences
- More investigations needed
  - Do the larger turbines gain advantages from being higher?
  - What about 4 x 6 MW rotors on high towers?

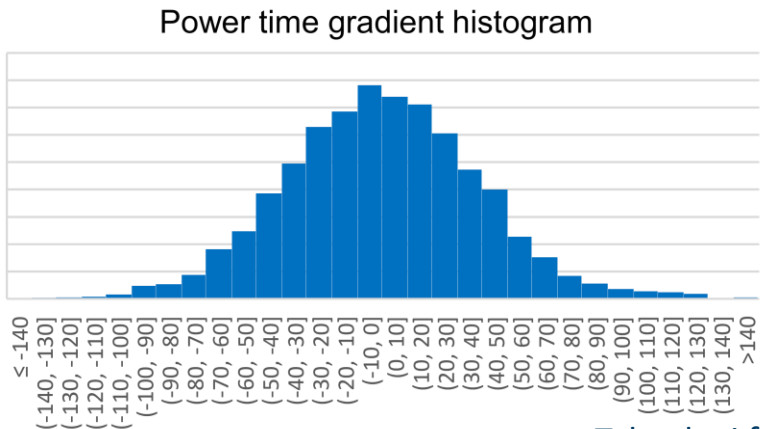


Preliminary Results









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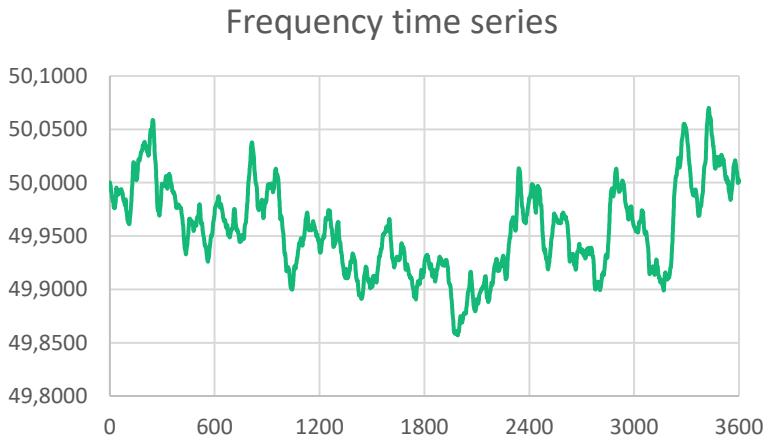

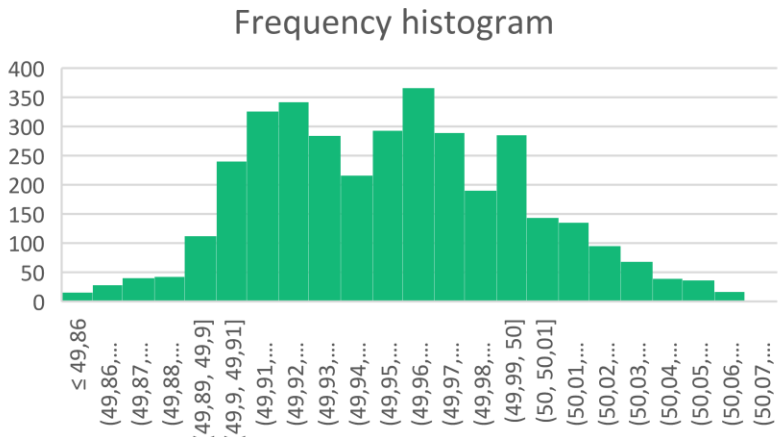

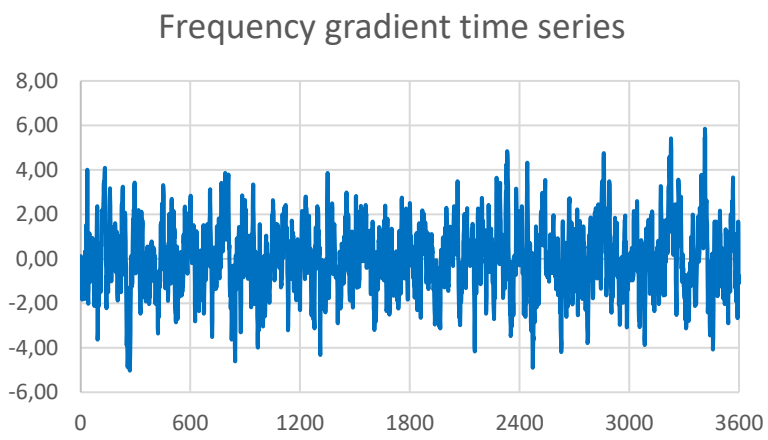

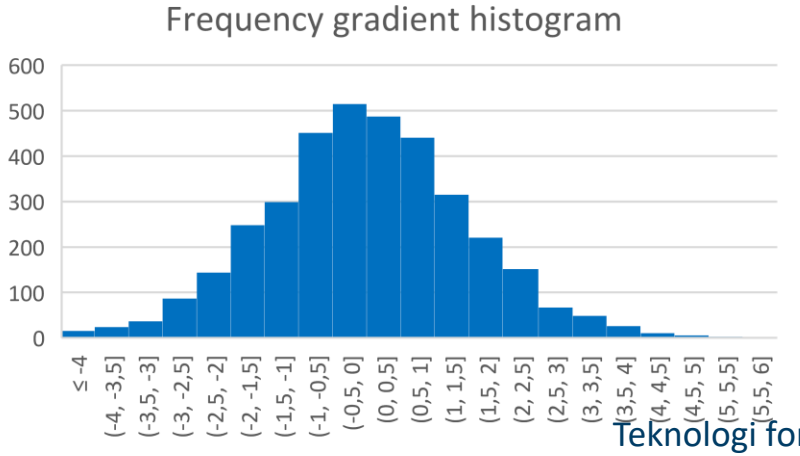

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