Wind power and frequency regulation in Sweden – Technical performance and economic evaluation

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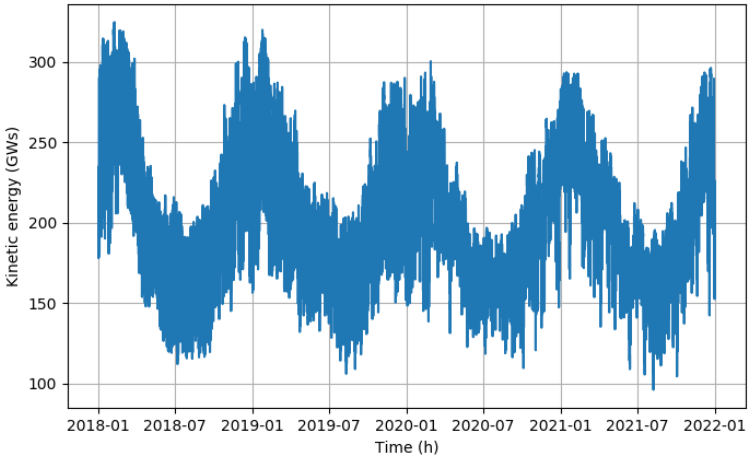
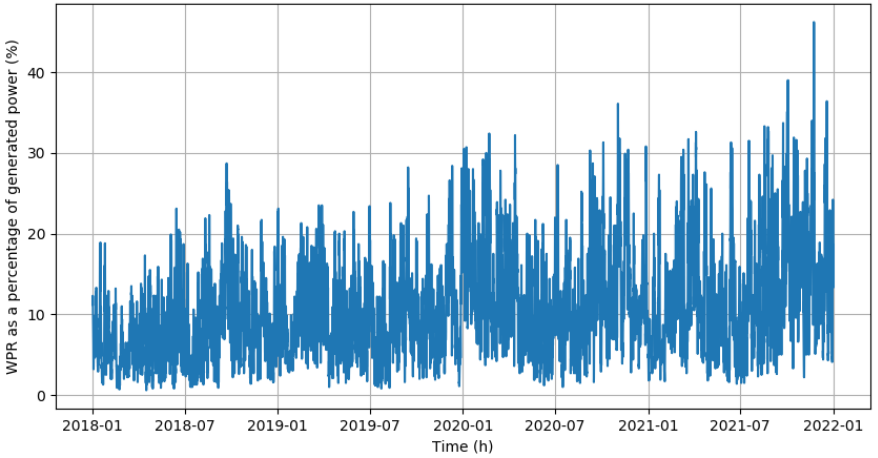
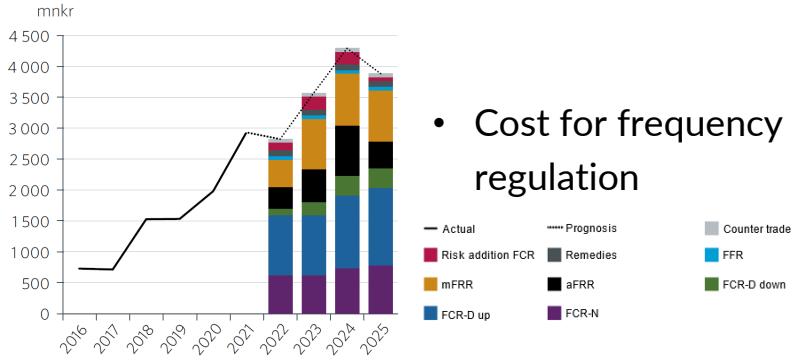
Motivation

- Inertia



- Wind penetration





- Cost for frequency regulation

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Tasks

- **A theory study** on the international experience in frequency control and the possibilities as well as the limitations of wind power for frequency control will be done.
- **A survey of** the ancillary services that are in use regarding the frequency control active in the Swedish electricity grid, as well as in countries with a high proportion of wind power.
- The **economic outcome** of different bid strategies for frequency services from wind farms, RISE.
- **Wind turbine modelling** of all services, control and impact on maintenance, RISE, Chalmers.
- **Practical tests** with **Chalmers wind turbine** – All services.
- **Practical tests** with **commercial** wind turbines – Selected services, Rabbalshede kraft, SR Energy, Centrica, WPD.
- **Evaluation** of practical test, Chalmers, RISE.

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Frequency regulation

Electric Power System

- Balance between power production and consumption give constant frequency
- Traditionally is hydro power production adapting its power output, other resources could do the same.
- The consumption can also be used.

Wind power

- Wind turbines can reduce the power production by spilling wind and
- Thereby also be able to increase the power production or
- Or shortly take out extra power from its rotating mass

Available wind power

- The wind power producer is paid for the spilling power and the power produced due to activation of the service.
- Svenska Kraftnät like to know how much wind power that are spilled

- 1. The estimated wind speed is calculated out of wind turbine operation data.
  Power, rotation speed of turbine and pitch angel and Cp(l)-curves
- 2. Available wind power is calculated out of estimated wind speed

$$P\_mec = \frac{1}{2}\rho ACpVw^3$$

$$Vind\_Est = \sqrt[3]{\frac{2P\_mec}{\rho ACp}}$$

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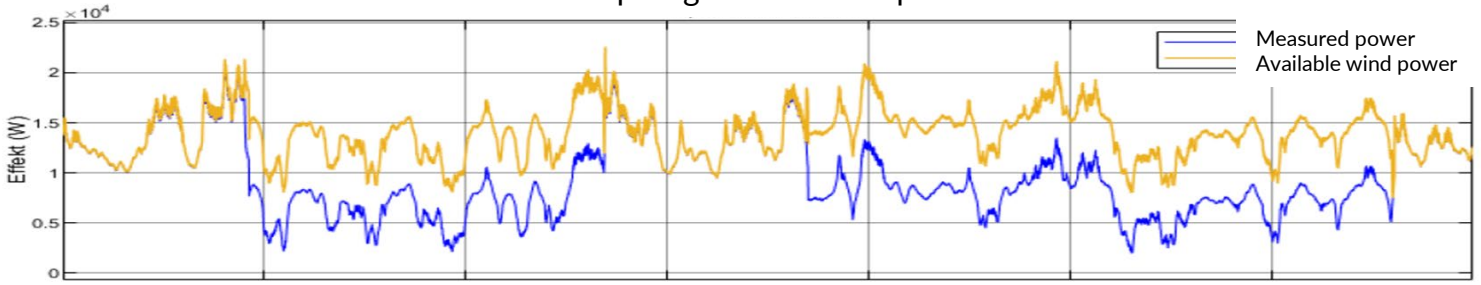
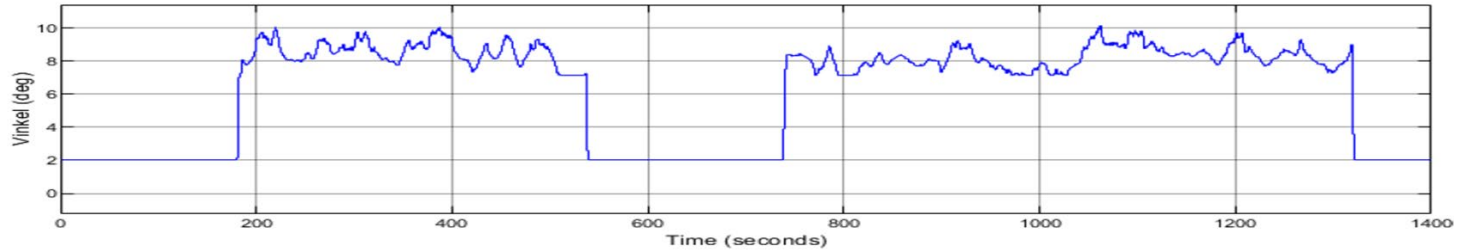
Actual tests - Chalmers

Spilling 7.5 kW wind power



Pitch angel



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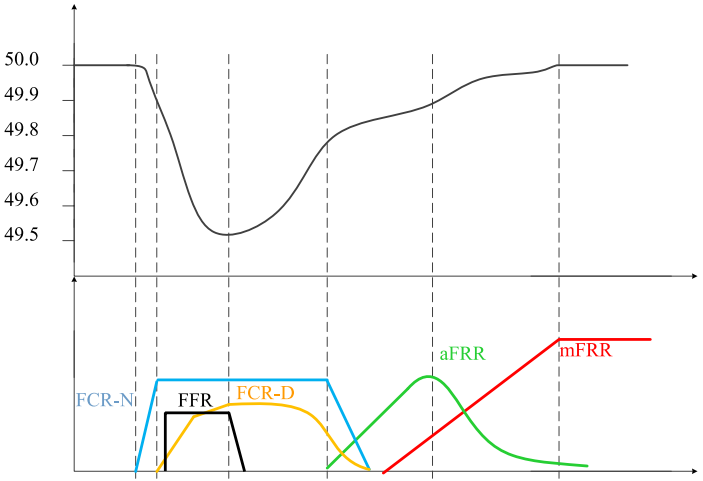
Actual tests – Wind farm – SR Energy wind farm

Financial evaluation



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Study Committee C5

ELECTRICITY MARKETS AND REGULATION

Paper 10824 2022

Possible wind farm earnings from frequency regulation markets in Nordic power system – Issues, examples, and policies

CAMILLE HAMON and MATTIAS PERSSON

Research Institutes of Sweden (RISE)

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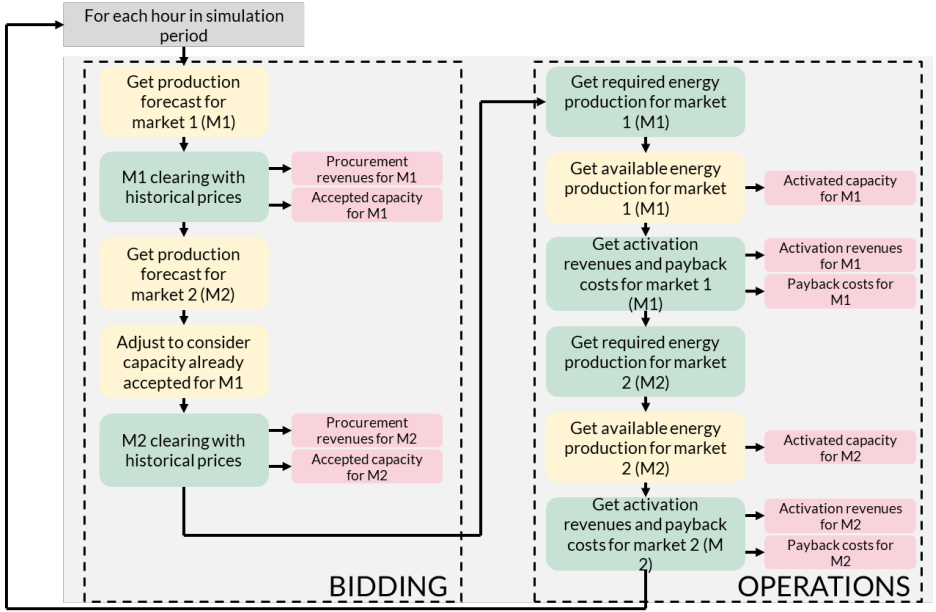
Financial - Method



Financial - Case

Case 1: Perfect forecast on minute basis. This corresponds to having no uncertainty on either the capacity that will be available for ancillary service or the hourly energy production.

Case 2: Perfect forecast on an hourly basis but uncertainty considered in the capacity forecast. In this case, quantile forecasts are used to generate capacity forecast with the perfect hourly energy production forecast as input.

Case 3: Production forecast both for capacity and hourly energy production.

Case 4: Same as Case 3 but with twice as large forecast errors.

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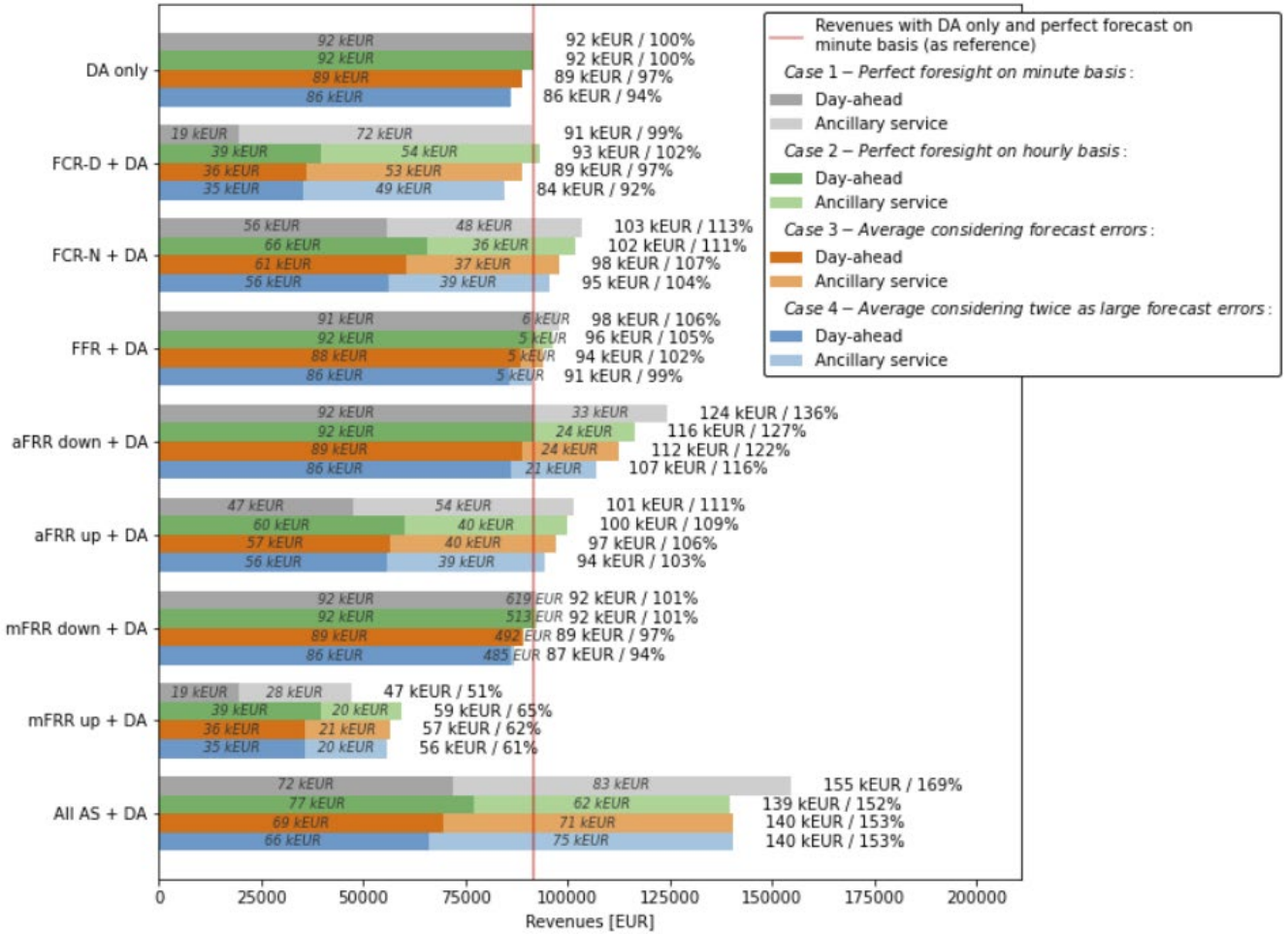
Financial - Results



Conclusions

- Not only down regulation is possible. -All services are available from a wind turbine.
- Price forecasts of both spot and frequency markets are of great importance.
- Base line calculations, available power from wind during curtailed operation, is important.
- New market structures, marginal pricing, split FCR-N bids, and new actors will greatly impact the analysis.
- Location (price area) is important when considering profitability compared to day ahead.
- An increased amount of buy-back costs will be experienced in the market.

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Thanks for listening!

Questions now or later !?

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