Digital datadriven model learning for online testing of hydro power plants

Sigurd Hofsmo Jakobsen

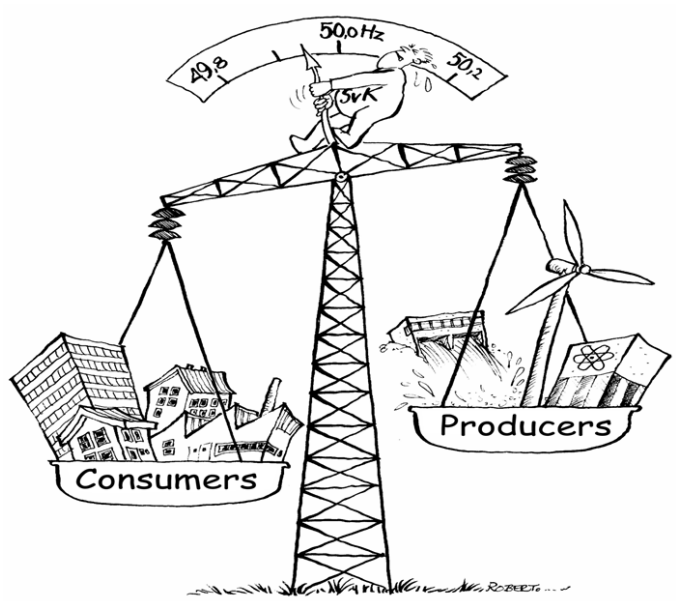
Norwegian university of technology and science Department of electrical engineering

September 20, 2019

Outline

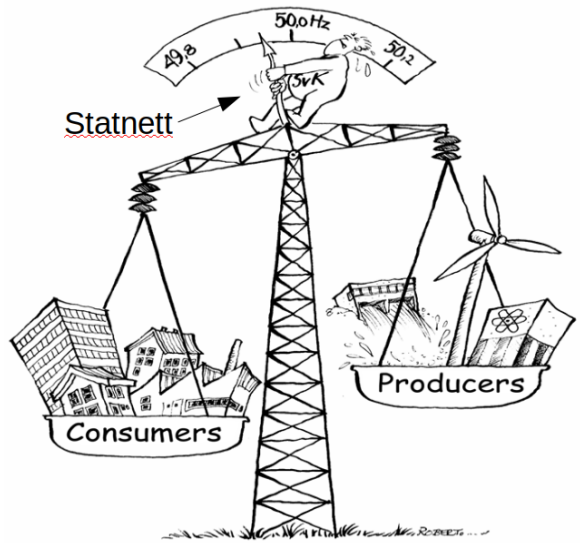
Load and production balancing

- The power system frequency measures the power balance.



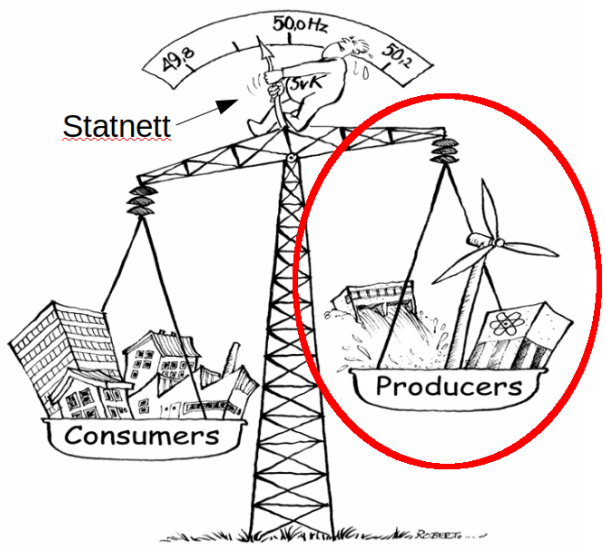
Load and production balancing

- The power system frequency measures the power balance.
- It is the responsibility of Statnett to control the frequency.



Load and production balancing

- The power system frequency measures the power balance.
- It is the responsibility of Statnett to control the frequency.
- However, it is the power plant owners who can control the frequency.



Buying frequency control

- Statnett pays all power plant owners to provide frequency control.

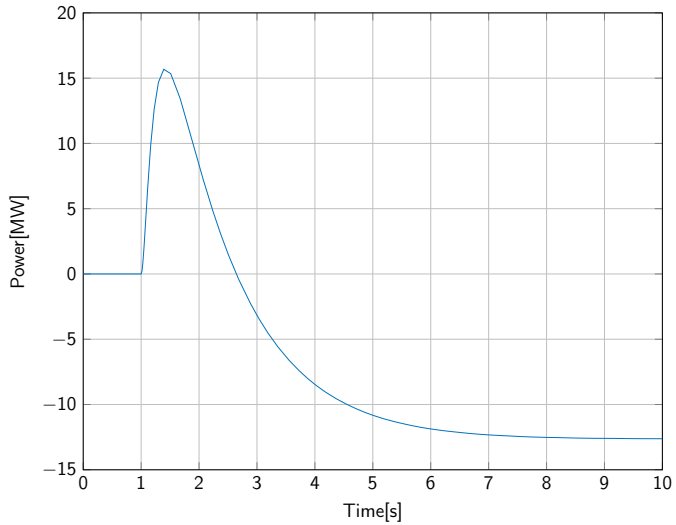


Figure: Frequency control response to step change in frequency

Buying frequency control

- Statnett pays all power plant owners to provide frequency control.
- However, they don't provide the same quality of service.

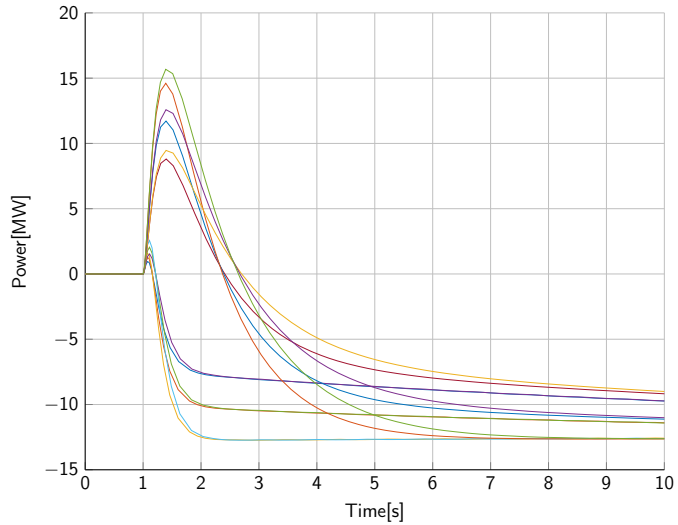


Figure: Frequency control response to step change in frequency

Buying frequency control

- Statnett pays all power plant owners to provide frequency control.
- However, they don't provide the same quality of service.
- Renewable energy sources such as wind and solar don't contribute.

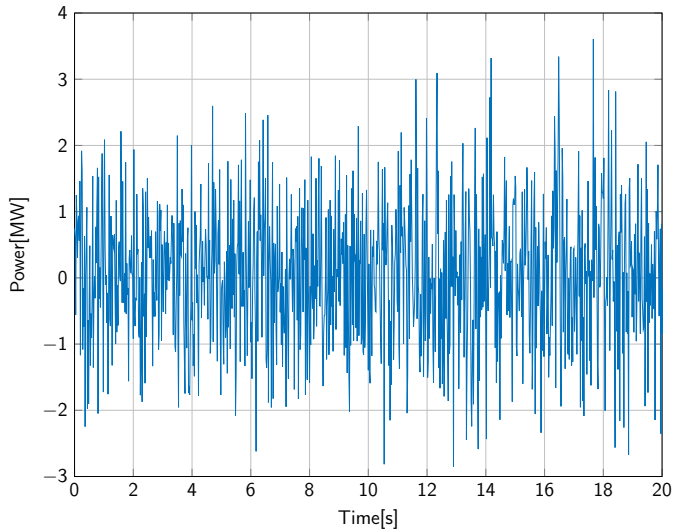


Figure: Frequency control response to step change in frequency

Future of frequency control

- Power plants have to pass tests to get paid to provide frequency control.
- Only those who pass the tests get paid for the service.

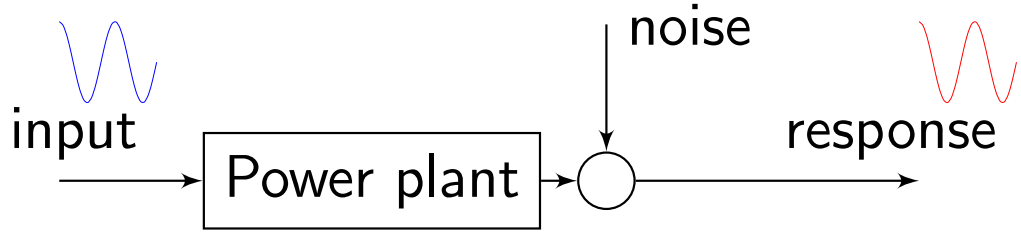
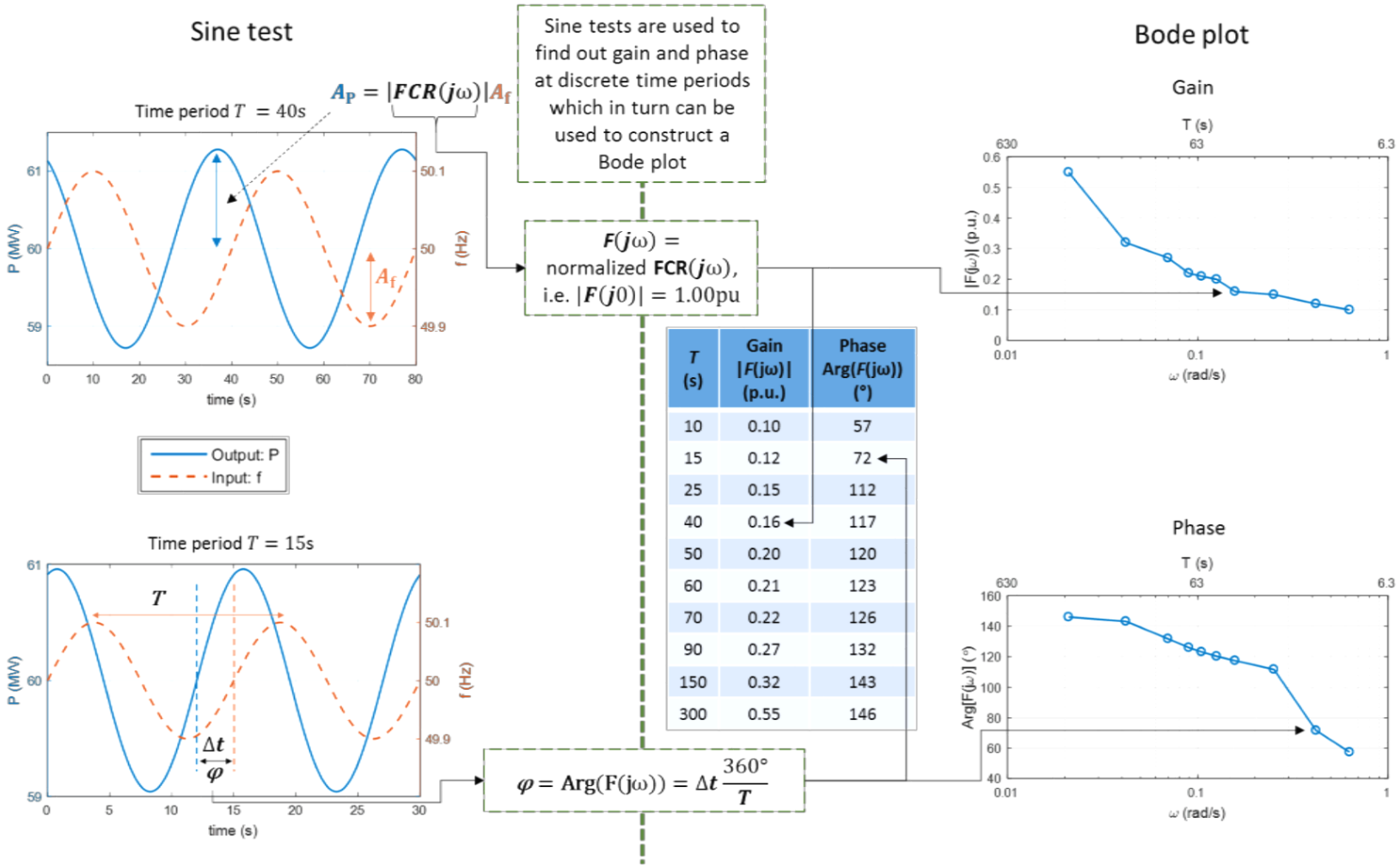


Figure: Test of power plant

Tests proposed by the industry

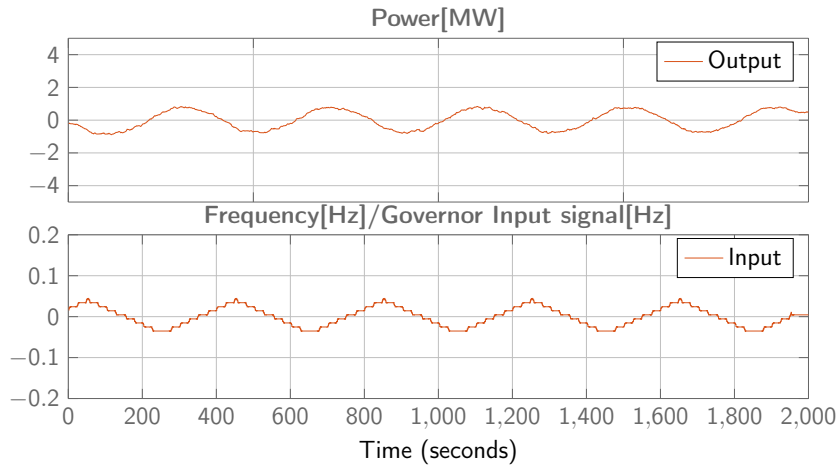


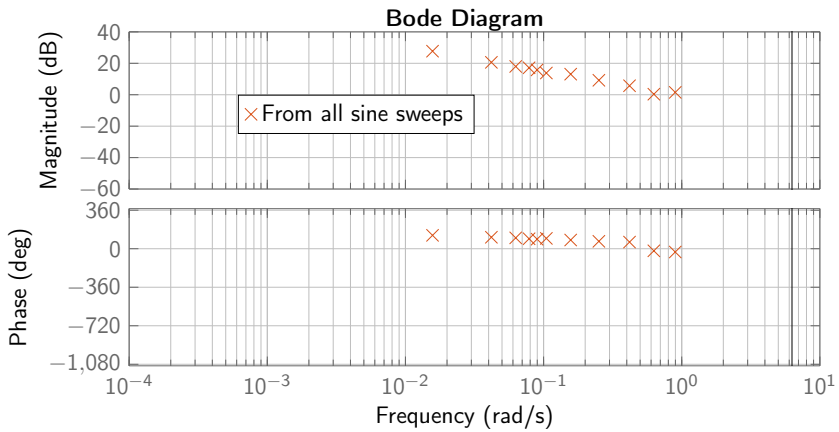
T (s)	Gain $\lvert F(j\omega)\rvert$ (p.u.)	Phase Arg($F(j\omega)$) (°)
10	0.10	57
15	0.12	72
25	0.15	112
40	0.16	117
50	0.20	120
60	0.21	123
70	0.22	126
90	0.27	132
150	0.32	143
300	0.55	146

Figure: Testing procedure [source:ENTSO-E]

Example from real tests

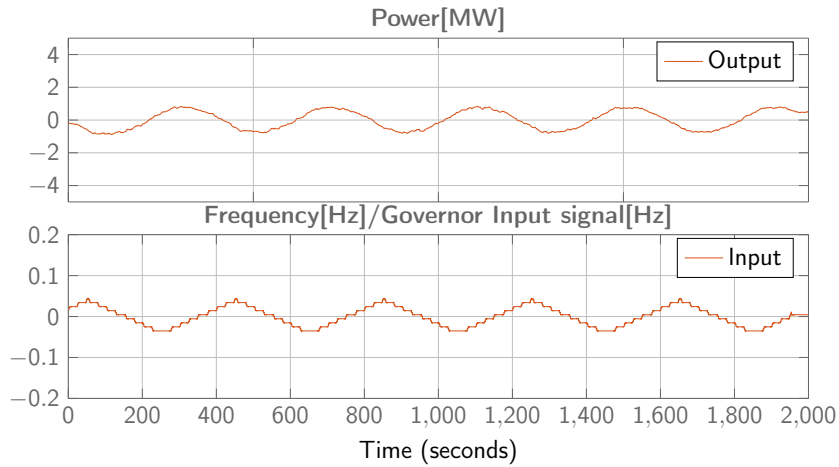
- The power plant needs to be disconnected
- Takes up to 20 hours.

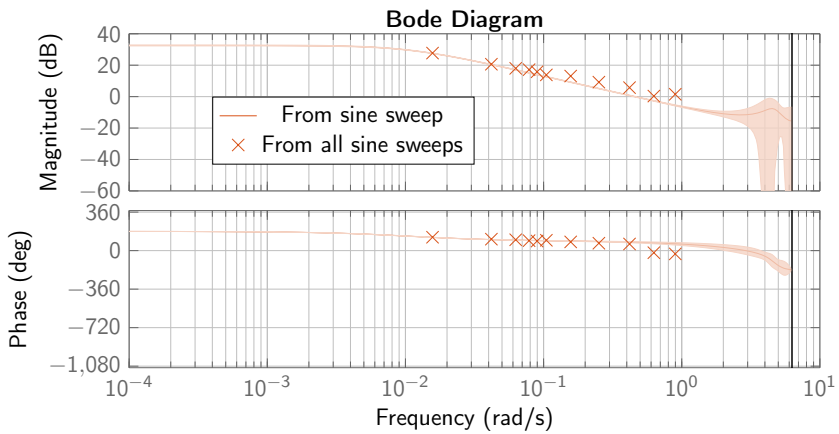




Example from real tests

- The power plant needs to be disconnected
- Takes up to 20 hours.
- Only one sine test needed with model learning.

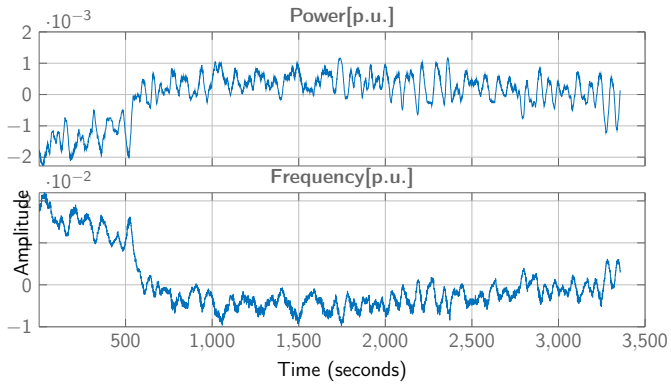




Outline

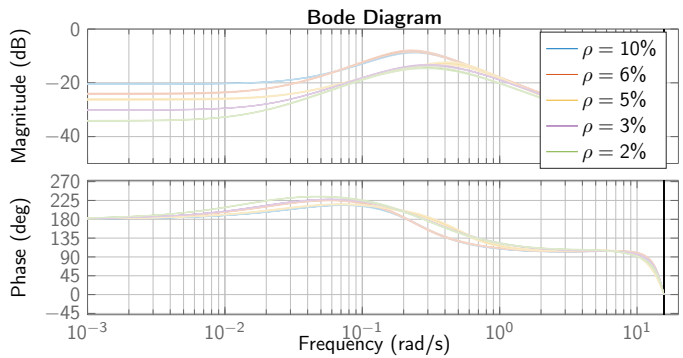
Idea

- Can power plants be tested without testing?



Idea

- Can power plants be tested without testing?
- Yes!

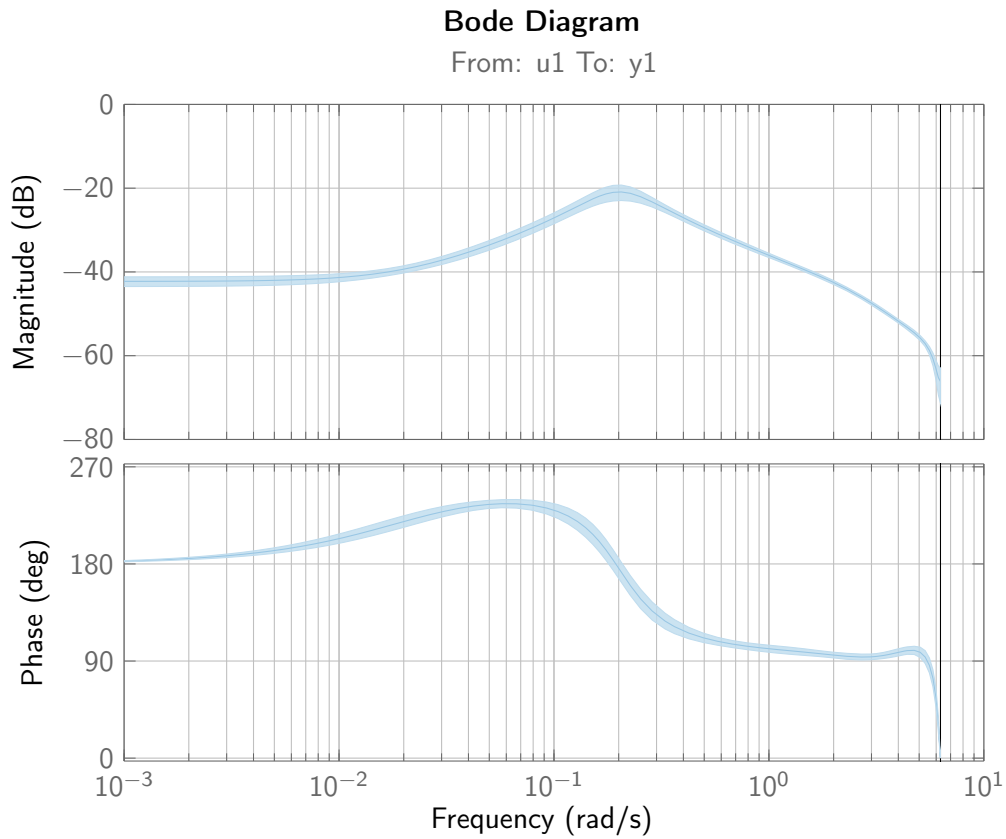


Product

- A small pc with analog and digital output.
- Software for interfacing with turbine control systems and TSO measurements.
- Software for performing model learning and analysing results.

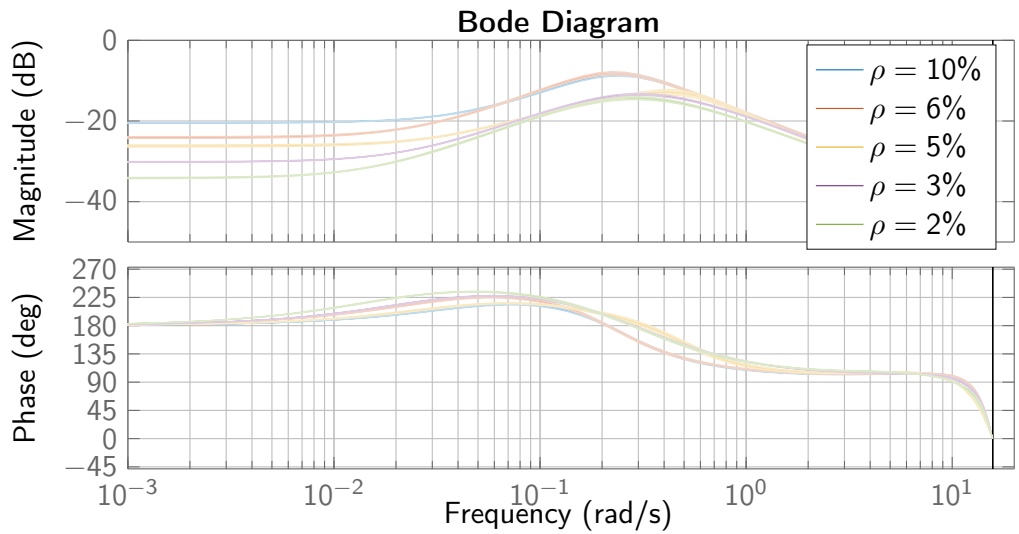
Use cases

- Statnett can check plants using their own data.



Use cases

- Statnett can check plants using their own data.
- Power plant owners can test their plants continuosly.



Use cases

- Statnett can check plants using their own data.
- Power plant owners can test their plants continuosly.
- Testing with defined accuracy.

Outline

Customers and market potential

- TSOs
  - Approximately one per country
- Hydro power plant owners
  - Approximately 1300 hydro power plants in Norway.
  - Norway is the sixth largest hydro power plant producer in the world

Competition

- DNV GL offer a product according to the industry proposal.
- It requires disconnection of the plant.
- It takes very long time.

SAFER, SMARTER, GREENER

DNV·GL

ENERGY

VERIFICATION OF FREQUENCY CONTROL SERVICES

DNV GL has developed new streamlined test equipment for the verification of frequency control services, designed to meet the new comprehensive requirements in the Nordics for frequency containment reserves, FCR-N, FCR-D and FFR. In the future, all units providing frequency control services in the Nordics must fulfil the new requirements.

DNV GL's new test and verification equipment has been developed to meet the new FCR requirements in the synchronized Nordic power system. The equipment meets the new verification requirements by breaking up the frequency feedback loop to the turbine governor, and replacing the feedback frequency signal with a synthetic frequency signal. The test equipment is significantly smaller than traditional test equipment making it portable and easy to place in control rooms or cabinets. It can also be connected when the production unit is running and synchronized to the grid, reducing the stand still costs.

The test equipment is highly flexible and can be adapted to test all requirements related to frequency or voltage control, such as speed of response, overshoot or stability. The equipment is designed to operate in "hardware in the loop" mode, which means it can be used to test small islanded systems in a safe way while being synchronized to the grid.

Test and verification of frequency control has become an important as well as an emergent issue in the last few decades,

- Frequency quality deterioration in the Nordics
- Reduced system inertia in the Nordics due to closing of nuclear power plants and large-scale implementation of renewables
- Fewer frequency dependent loads
- Market based solutions for FCR resulting in increased costs for the TSOs
- A need to optimize the frequency control to meet the power system needs of stability and performance

Therefore, a mandatory qualification process is now applied in the Nordics for production units selling FCR services.

IPR

- Difficult to patent:
  - Results have been published.
  - Results rely on standard methods.
- shared rights:
  - NTNU
  - Ampere Lab
  - TTO renounced their rights

Competitive advantage

- We are the experts.
- We already have all the code and the know how.
- We have contacts in the industry.
- The industry are not likely to trust anyone.
- Our product is cheaper and more precise than the competition.

Outline

Goal for the project

- To develop a working prototype.
- Demonstrate the prototype in the lab.
- Demonstrate the prototype on a real power plant.

What is the money for

- Energy Transition funding
  - Components needed for the prototype
  - Renting the lab
  - A part time student for creating a good design for the prototype
- Other funding
  - NTNU innovasjonsstipend
    - Salary for me.
    - More tests at power plants.
    - Networking with the industry
    - Commercialization plan

Project team

- Project leader: Me
- Power system expert: Professor Kjetil Uhlen (NTNU)
- Model learning expert: Professor Xavier Bombois (Ampere lab)
- Prototype design: Student
- Needed in the future: Person for performing tests or educating the industry

Future plans

- Sell the prototype to a company that will do tests.
- or start a company for performing and selling test equipment.
- The second option requires that we establish a strong connection with the industry during the project