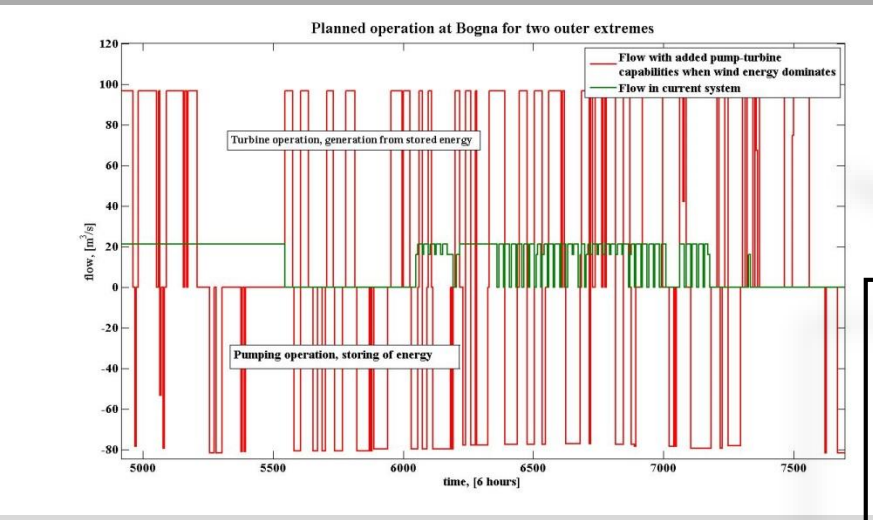
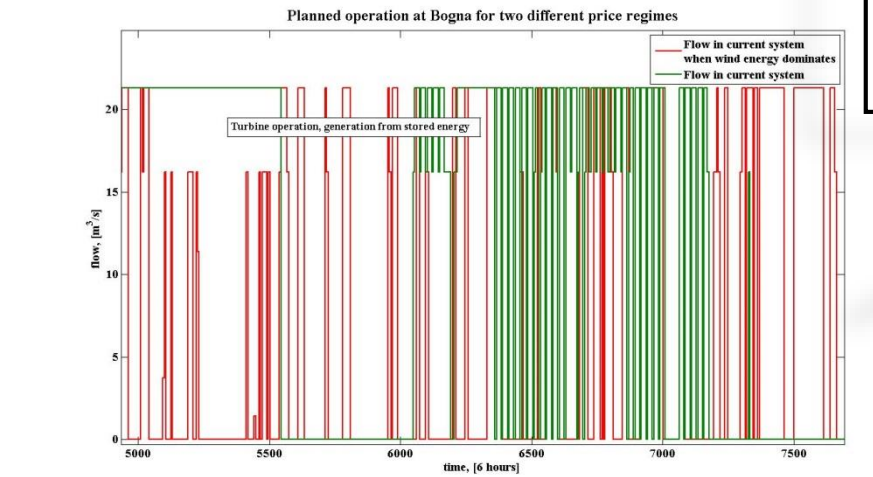
Hydropeak WP5: Frequency and load governing

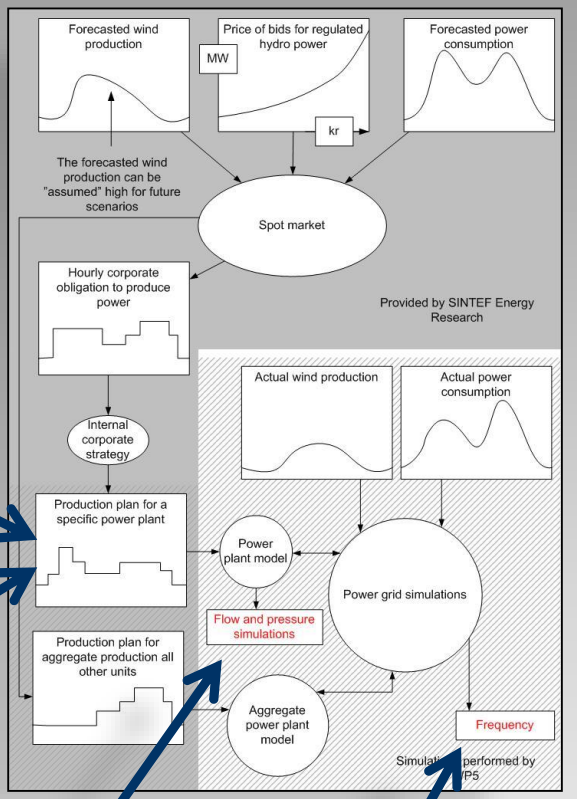
Post.doc researcher Pål-Tore Storli
Prof. Torbjørn K. Nielsen

More intermittent energy production means that the rapid balancing feature of hydropower must be utilized more extensively.





We have four system descriptions for which 61 scenarios with a duration of 61 years (!) with six hour resolution have been simulated, from which we can choose the most interesting inputs to use for further simulations.



The power plant simulations will reveal if the dynamic loads on the hydraulic system will be unacceptable.

The power grid simulations will reveal if the extensive use of the speed droop will have undesired consequences on the frequency.

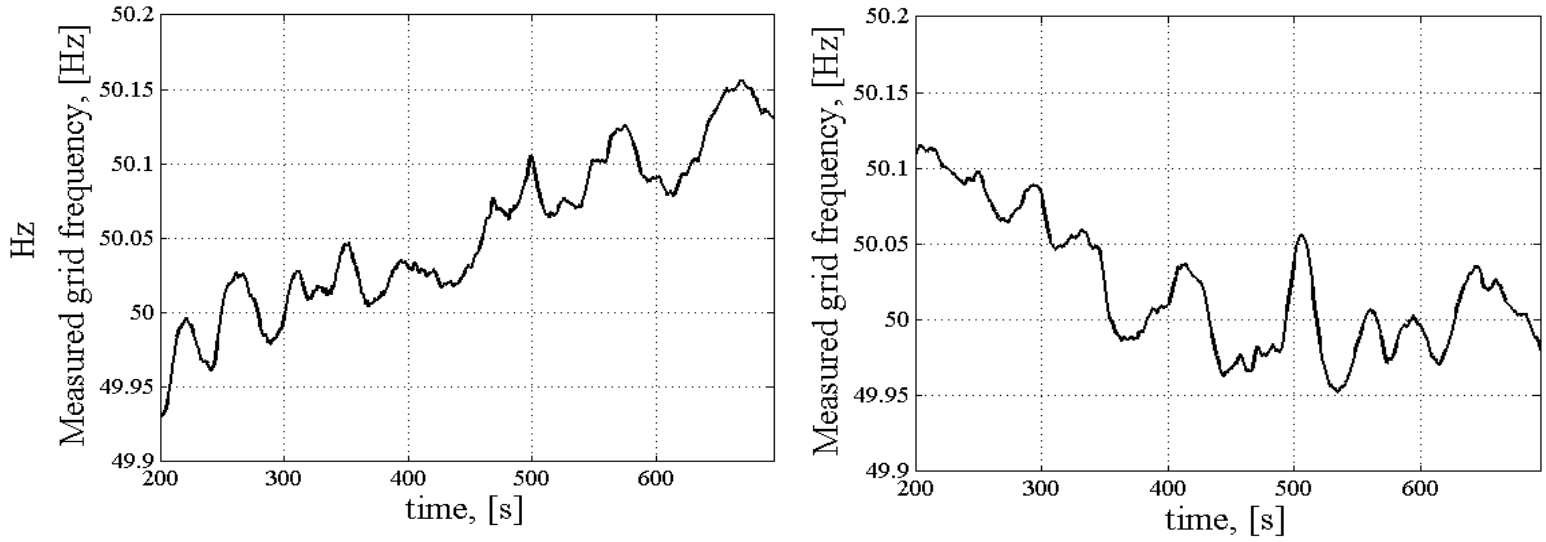
What has happened since then?

We ended up discarding the desire for simultaneous simulations of the grid and powerplant

- grid frequency becomes a necessary input to the simulations
- What is the grid frequency like?

We measured the grid frequency in the lab and realized the frequency is much more volatile than we thought

- Measurements we performed at Brattset power plant in August 2013 of grid frequency, as well as logging of the signals for rotational speed, power and guide vane opening from the unit going to the remote control center
  - Only a partial success
- The measurements were repeated at Brattset powerplant and Grana powerplant during November and December 2014



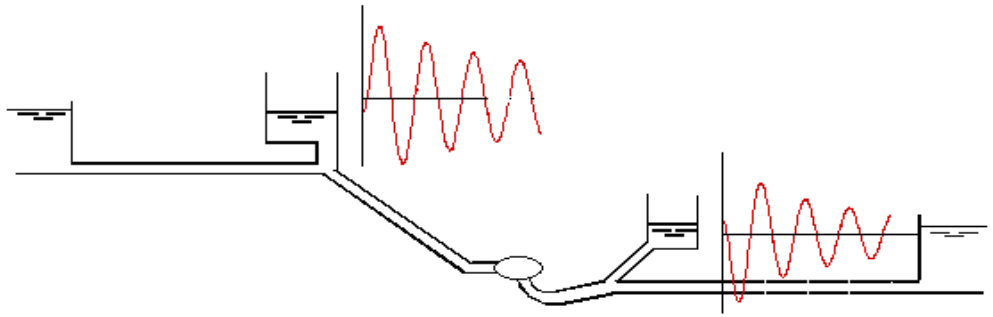
Measurements of the frequency during a day, highlighted the periods where the changes were highest for a 500 second period (for the entire measurement period of close to two months)

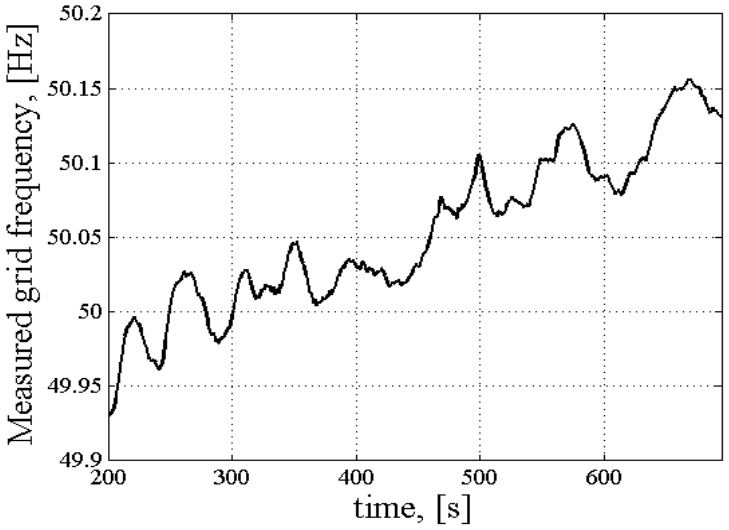
In a synchronous machine, the rotational speed is directly proportional to the grid frequency, so all the volatility in grid frequency is appearing as volatility in rotational speed

How much is this stressing the runners? Several new high head Francis runners in Norway have broken down the recent years!

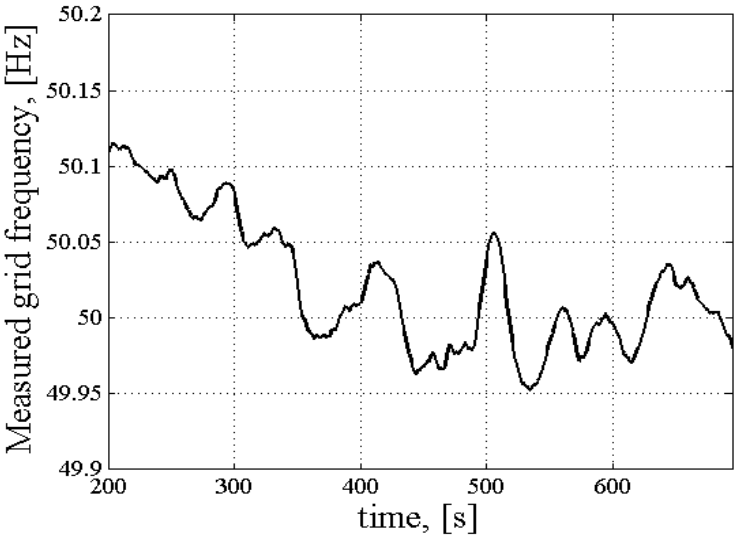
Speed droop operation is adding to the trouble by increasing load when grid frequency decreases

Simulations using these frequencies as an input to a simulation program including speed droop operation (1D in-house Matlab code simulating the hydraulic (elastic), mechanical rotating (stiff), magnetic and electrical energy domains)





The time series are used as input to the generator stator magnetic field



1D analysis: Cannot provide any detailed results. However, it can provide aggregated information.

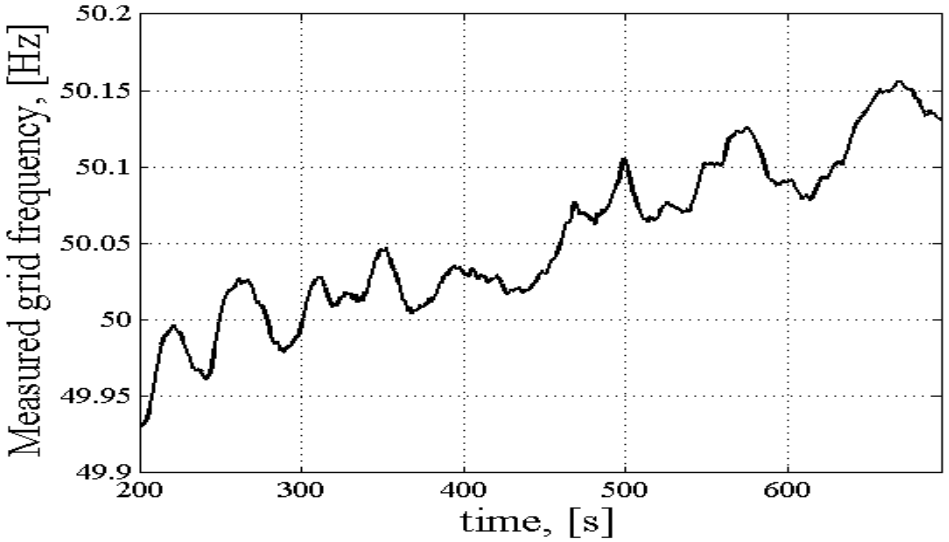
From the simulation results, we constructed a parameter as a qualitative measure for the material stresses, T_{stress}

$$T_{\text{stress}} = \frac{T_{\text{hydraulic}} + T_{\text{magnetic}}}{2} + T_{\text{dampening}}$$

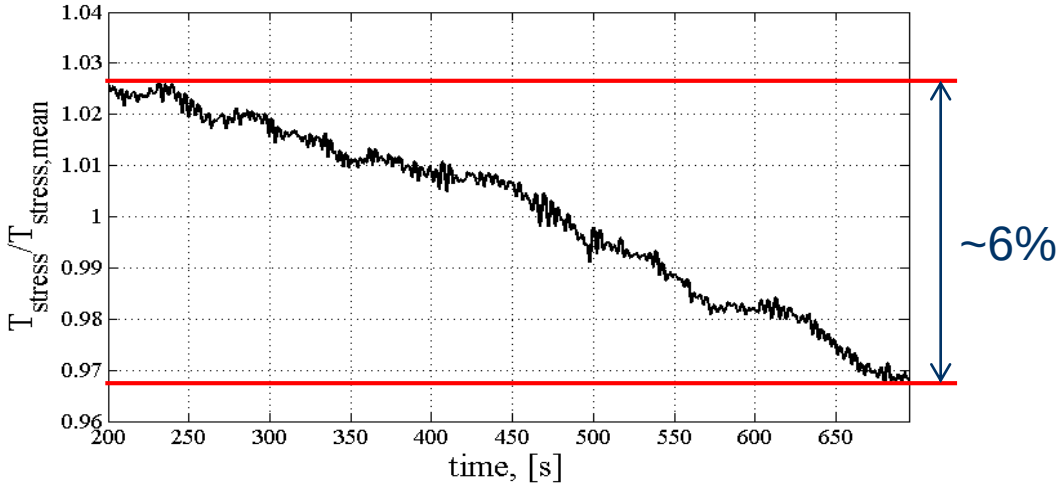
Where

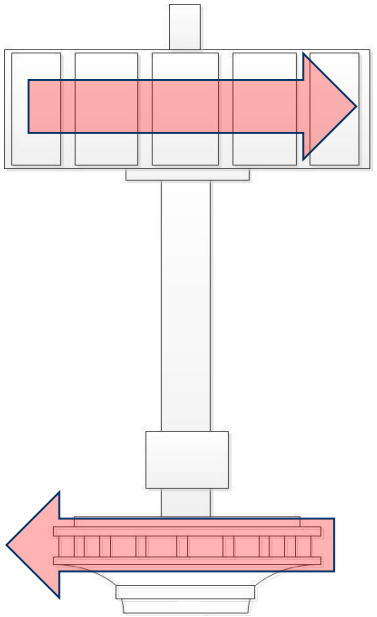
$$T_{hydraulic} = \frac{\rho g H Q \eta_h}{\omega} \qquad T_{magnetic} = T_{nom} \frac{\sin\delta}{\sin\delta_{nom}} \qquad T_{dampening} = m_d \frac{d\delta}{dt}$$

Increasing frequency…..

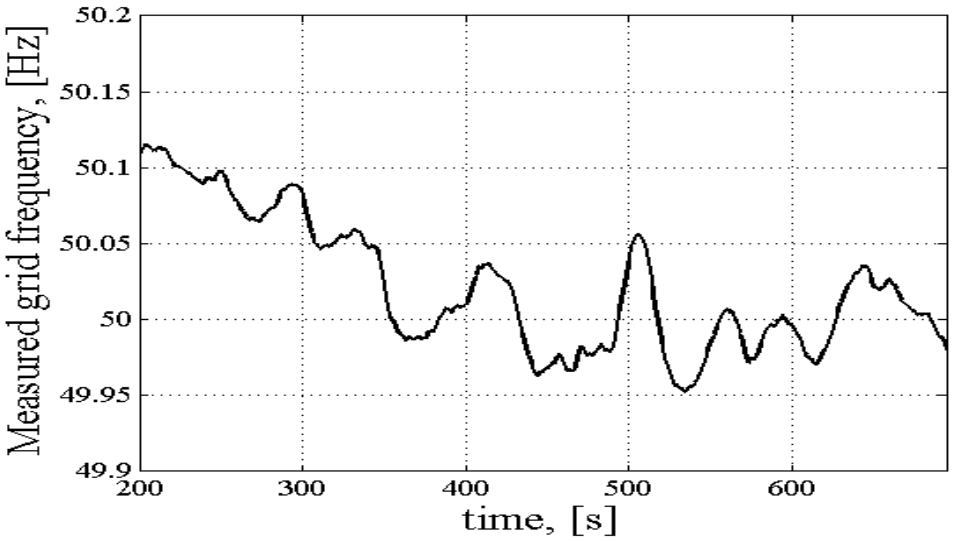


..is relieving the runner from stress

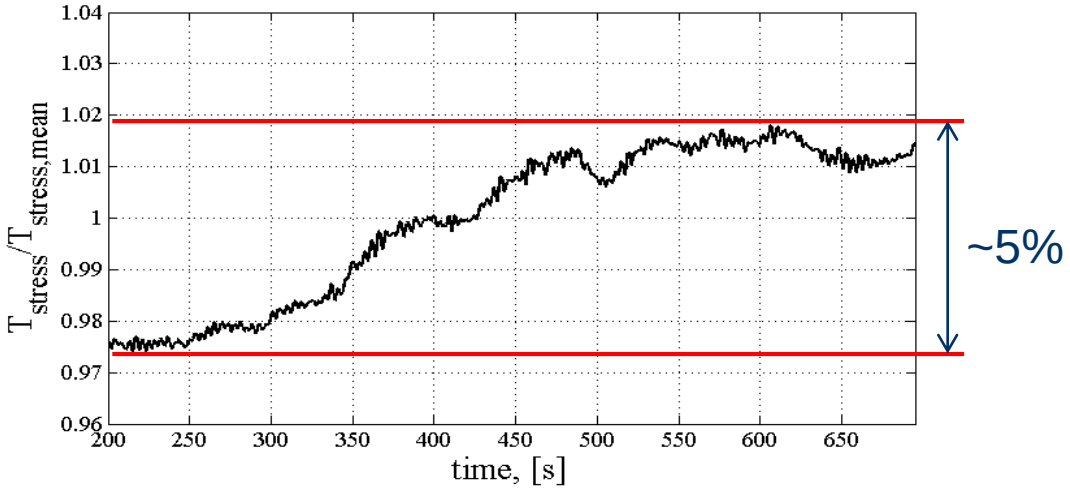


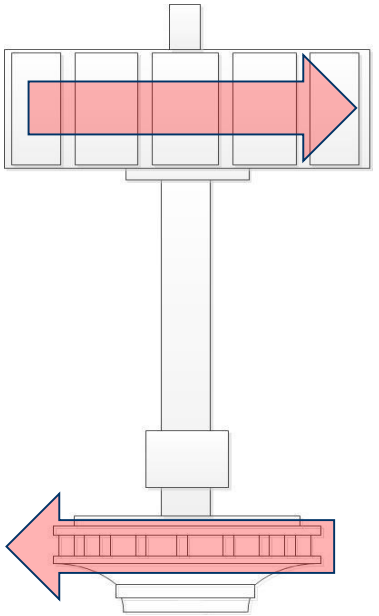


Decreasing frequency….

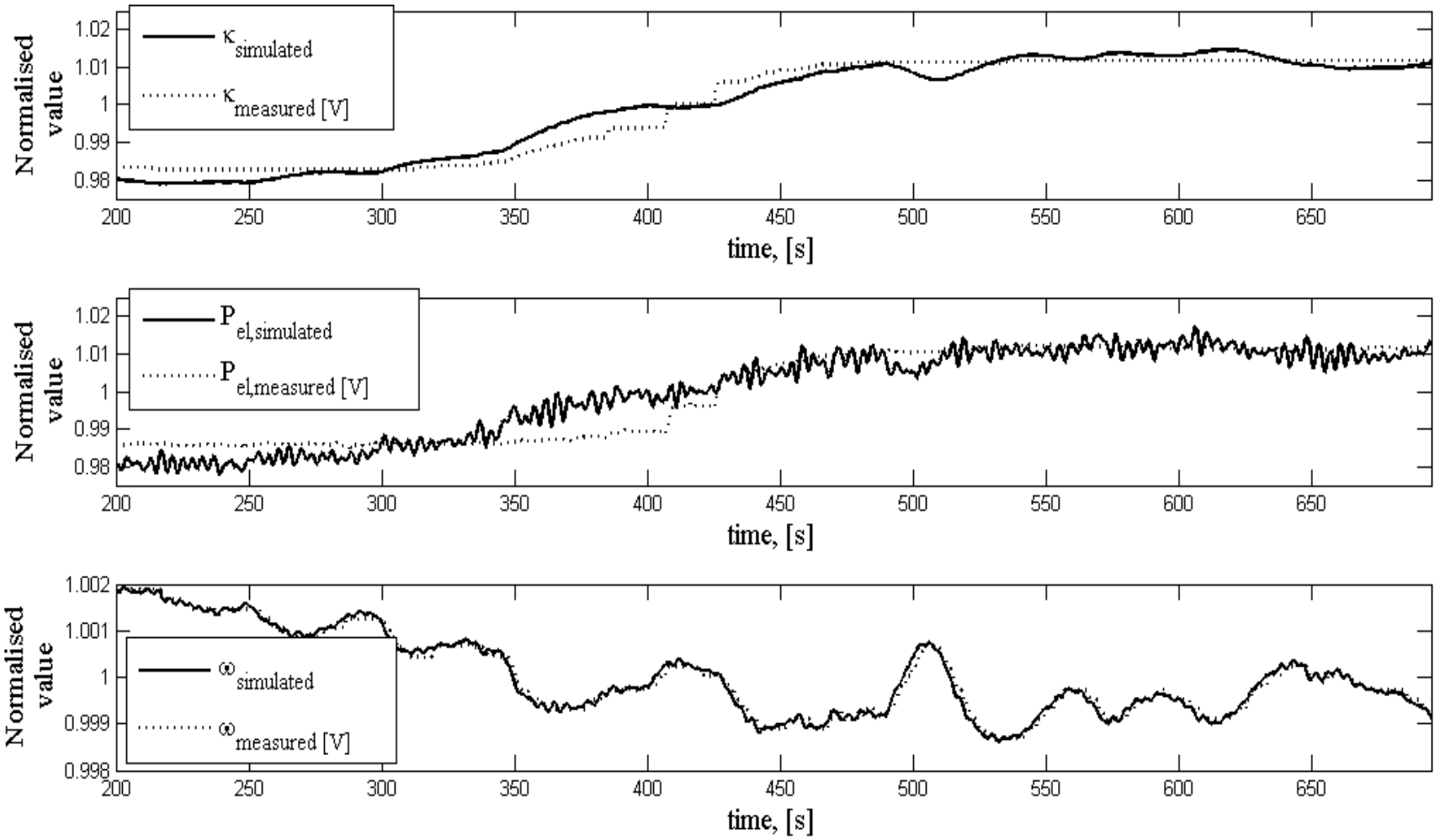


…is adding stress to the runner





Is this trustworthy?



The main conclusion is that the grid frequency volatility should be taken into account when dimensioning the runner

- Several new and replacement runners have broken down after short periods of operation in Norway
- This huge volatility and extensive speed droop operation is not «known» in continental Europe where the large manufacturers have their R&D resources

This was reported at a conference in Montreal this fall(Now everone knows that the manufacturers «know»)

More intermittent renewable energy sources will most likely increase grid frequency volatiliy and the demand for regulating power from hydropower, so from a (C)EDREN perspective it is important to design hydropower turbines so that they dont break down.

So, what's next?

The work is not finished, a lot of work for NTNU during the post.doc period will be «paid back» in the future.

- At least two reports will be made, including simulations of Bogna power plant, the power plant SINTEF has simulated the production plan for
- The interesting problem of Fluid Structure Interaction (FSI) will be carried forward as a research topic within the newly established NVKS, with at least one PhD student (who has already started, Rakel Ellingsen)
- Funds from the Norwegian Research Council will hopefully be granted for increased research on the topic (EnergiX)