Power system inertia

Does all generators pedal?

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Ringhals

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M. Persson, "Frequency response by wind farms in power systems with high wind power penetration", PhD thesis, 2017

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Agenda

1. What is inertia?
    i. How can we calculate it for a single generator?
    ii. What is the system inerta
    iii. How does it vary?
    iv. What happends in the future with the system inertia?
2. How does the power system inertia affect frequency stability?
    i. Basic frequency control
    ii. Large disturbances
    iii. Future scenarios
3. Solutions
    1. Solutions to lack of system inertia
    2. Focus: Wind turbines contribution
    3. Conclusions
    4. Backup

1. What is inertia?

   How can we calculate it for a single generator?

$$H = \frac{1}{2}\frac{J\omega_0^2}{S_b} \quad (s)$$

$$S_b = (MVA)$$

$$\omega_0 = (rad/s)$$

$$J = (\, kg \cdot m^2 \,)$$

1. What is inertia?

   How can we calculate the inertia constant for a generator?

Nuclear

- 3000 rpm @ 50Hz

Hydro

- 150 rpm @ 50 Hz

$$H = \frac{1}{2}\frac{J\omega_0^2}{S_b} \quad \text{(s)}$$

Inertia constants in Swedish production units (average values)

Nuclear

H = 6 s

Hydro

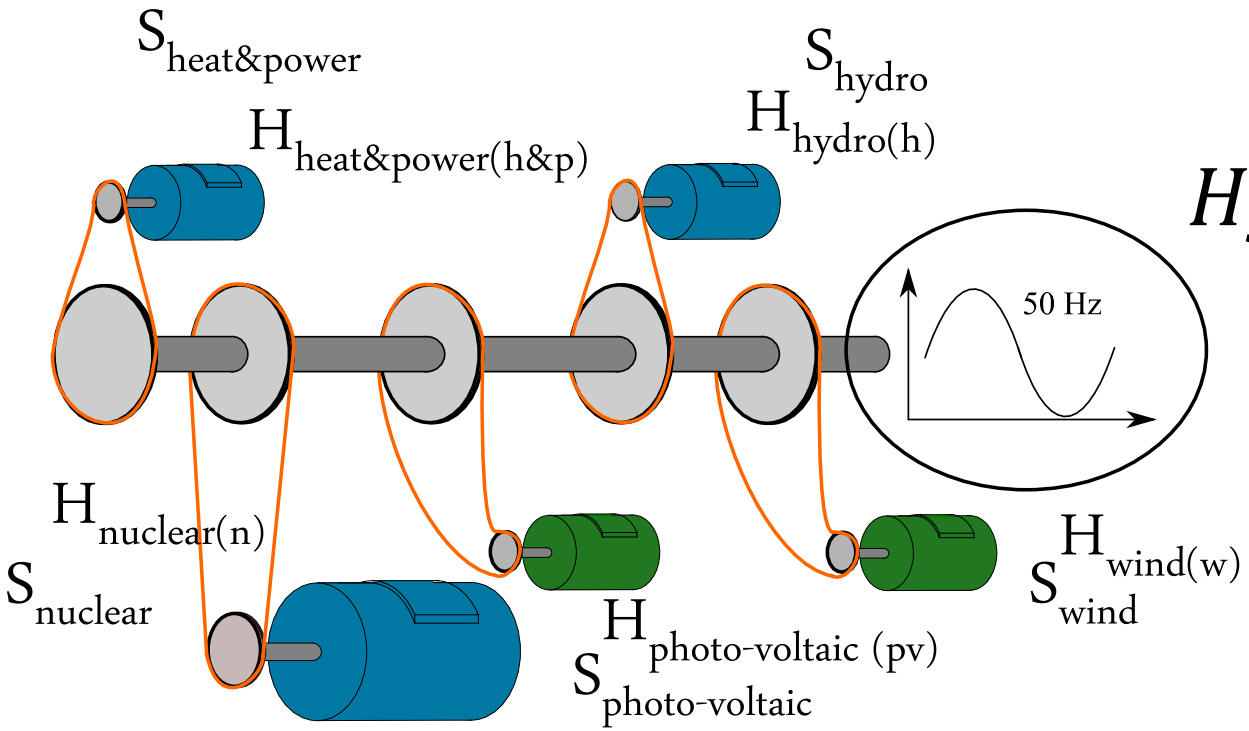
H = 4.5 s

Heat&Power

H = 3 s

1. What is inertia?

   What is the system inertia?

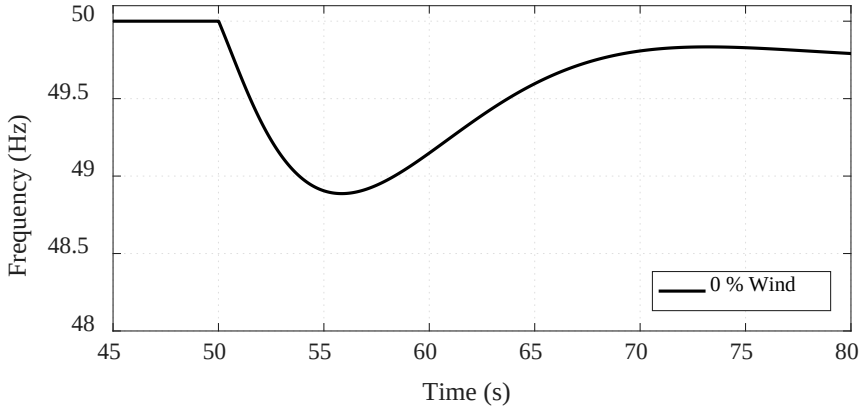


$$H_{sys} = \sum_{i=1}^{n} \frac{S_i H_i}{S_i}$$

$$H_{sys} = \frac{S_{h\&p}H_{h\&p} + S_h H_h + H_n S_n + H_w S_w + H_{pv} S_{pv}}{S_{tot}}$$

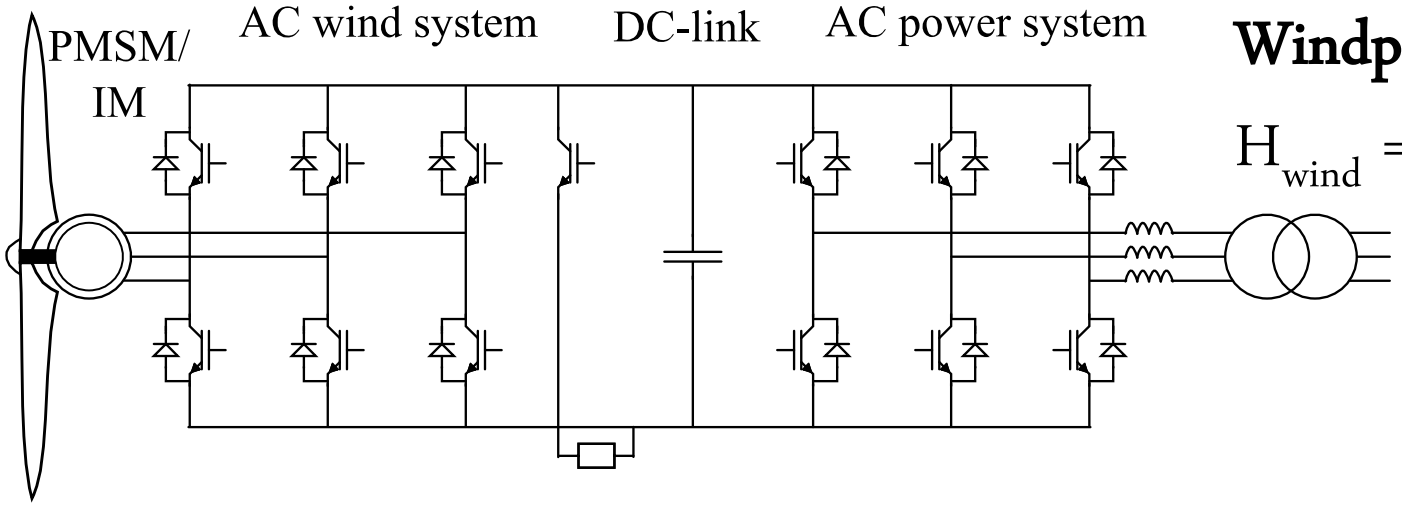
1. What is inertia?

   How does system inertia vary?



Turbine+generator

$H_{turbine}$ = 2.4 - 6 s



Windpower

H_{wind} = 0 s

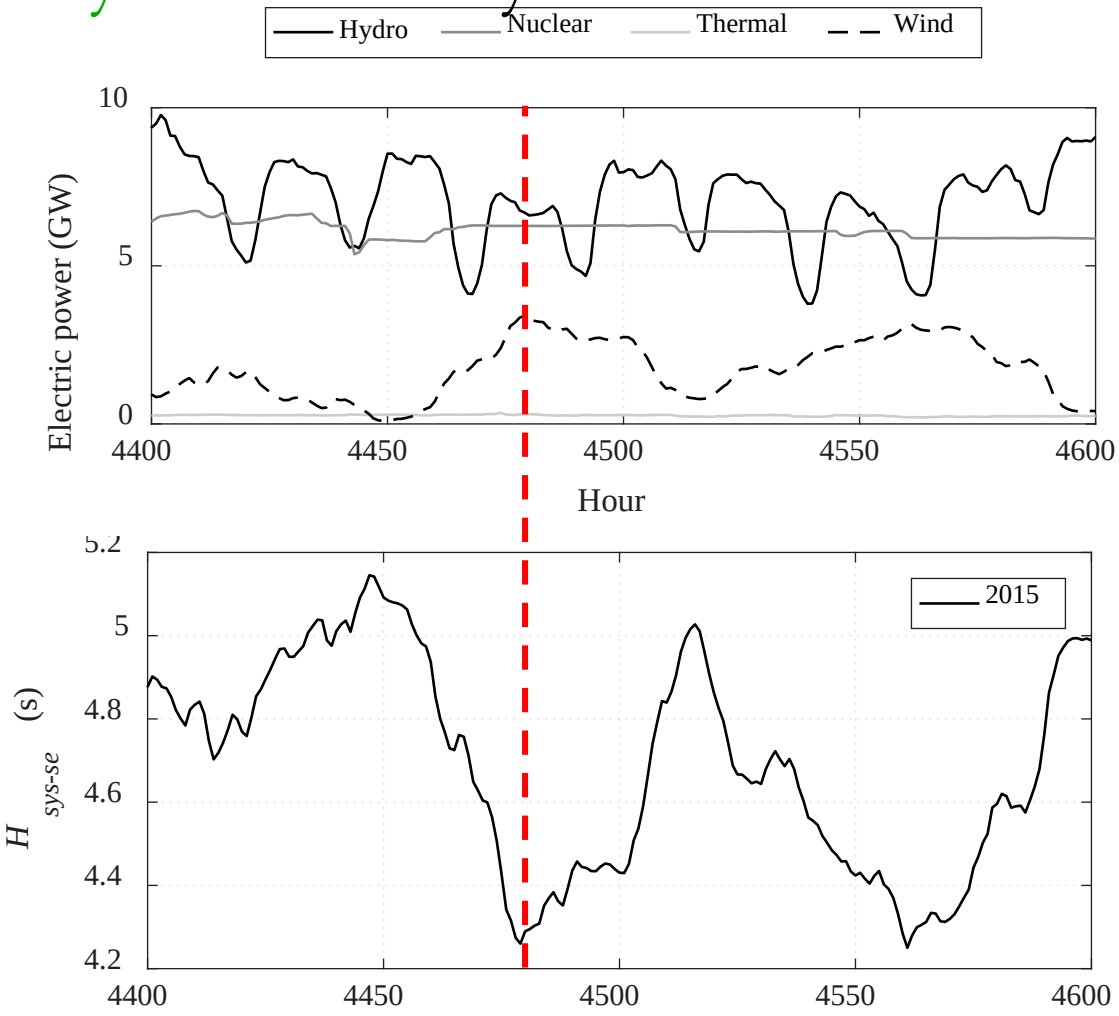
$$H_{sys} = \frac{S_{h\&p}H_{h\&p} + S_hH_h + H_nS_n + H_wS_w + H_{pv}S_{pv}}{S_{tot}}$$

1. What is inertia?

   How does system inertia vary?

20 % Wind

(instantaneous)



1. What is inertia?

   How does system inertia change in the future Nordic system?

- ❑ De-comissioned Swedish nuclear is balanced out by added Finish nuclear by 2025.
- ❑ Quadroupled wind power in Sweden until 2025, from 6000 MW installed capacity.
- ❑ Quadroupled wind power in Finland until 2025.
- ❑ Norway has 1000 MW (2015) and are building 1300 MW and has 4100 MW accepted projects.
- ❑ Multiple interconnecting HVDC transmission lines.

System inertia will reduce!

1. What is inertia?

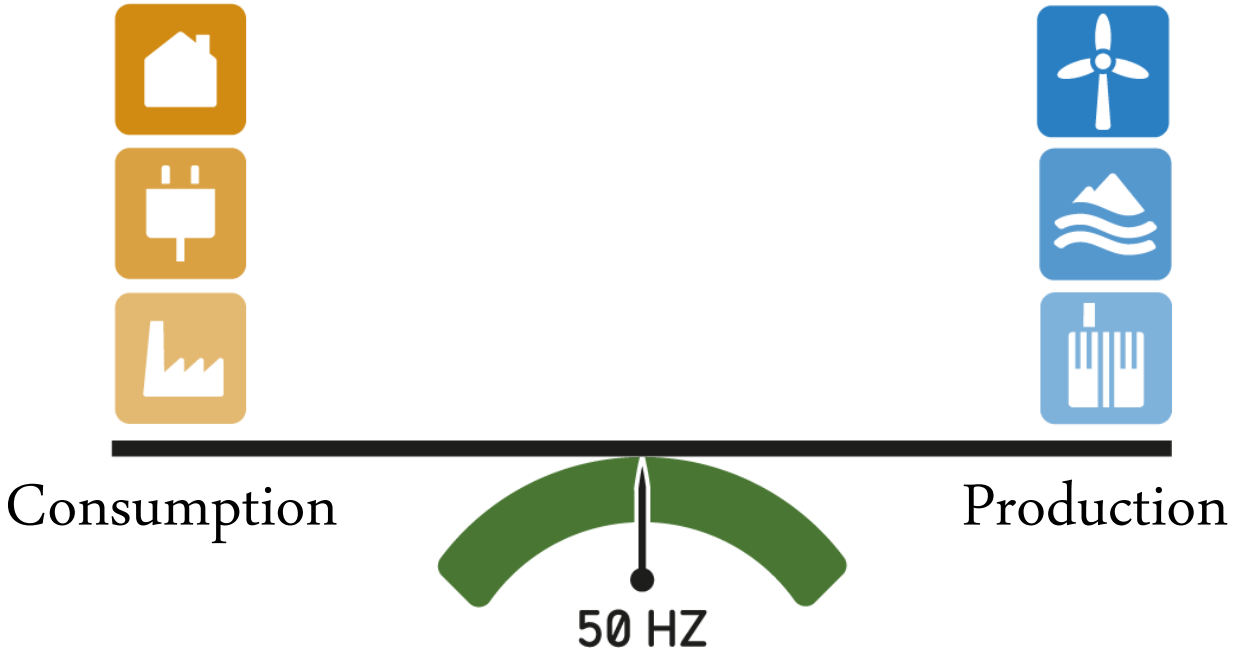
   How does system inertia change in the future?

Panic?

Relax?

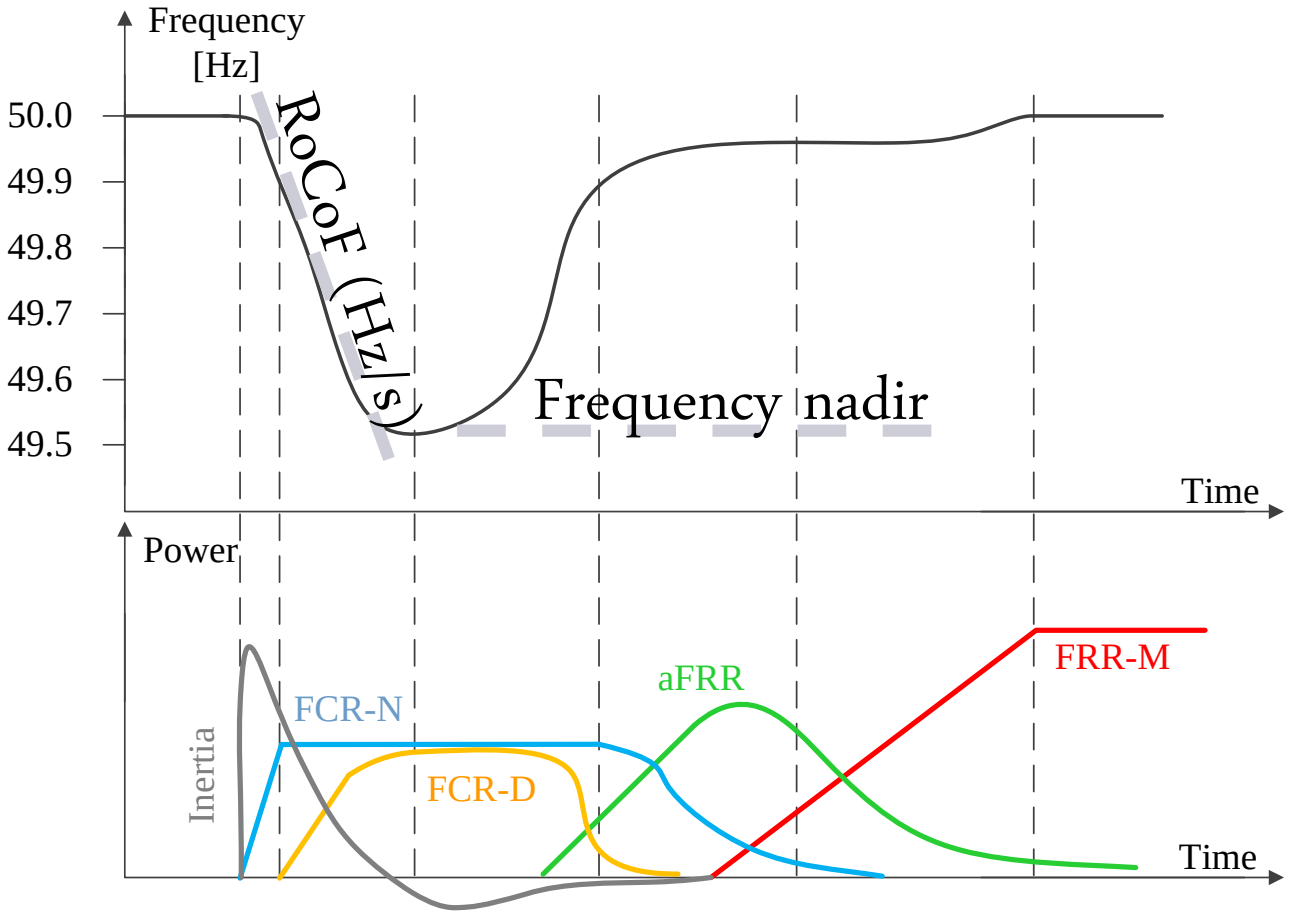
2. How does the power system inertia affect the frequency stability?

Intro: Frequency control



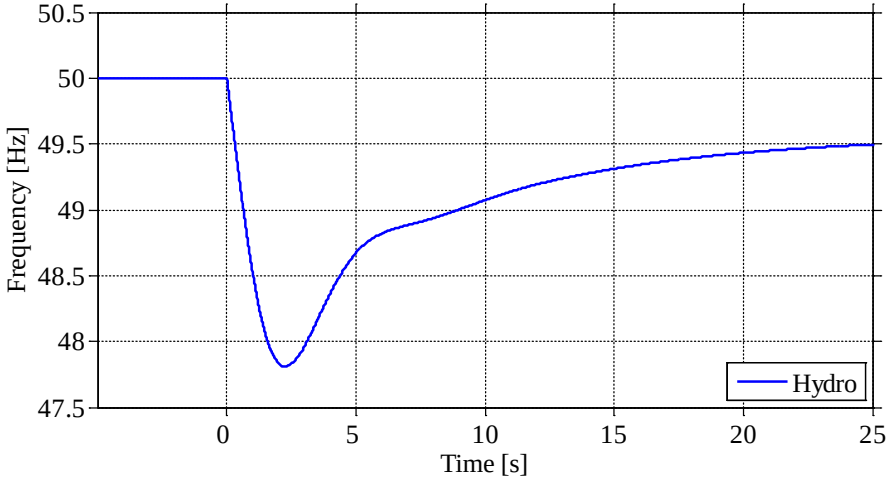
2. How does the power system inertia affect the frequency stability?

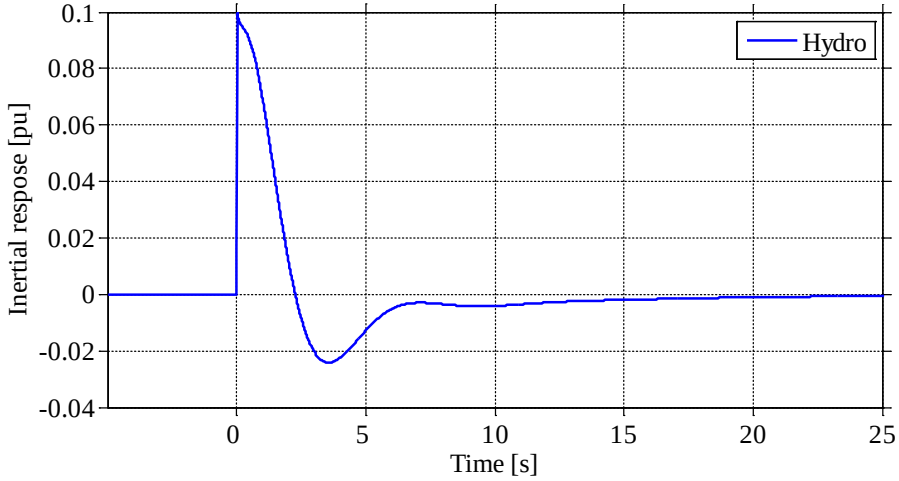
Intro: Frequency control

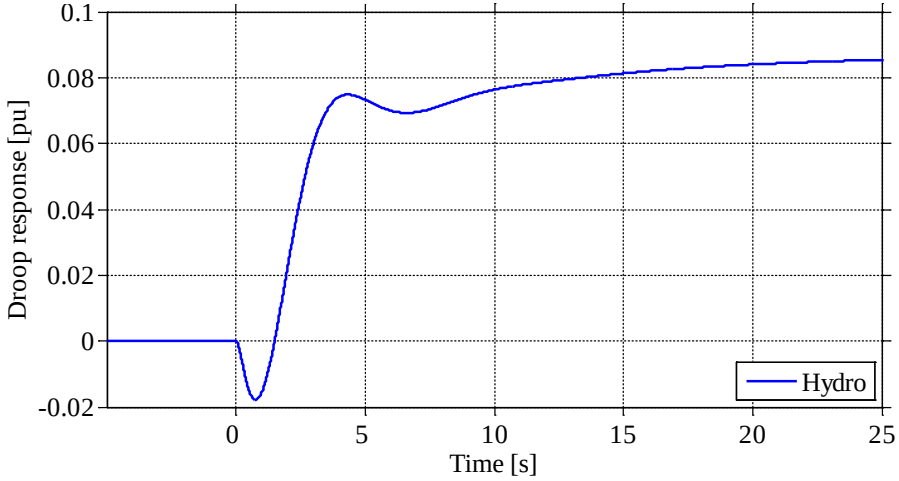


2. How does the power system inertia affect the frequency stability?

Intro: Frequency control – A disturbance and a hydro unit

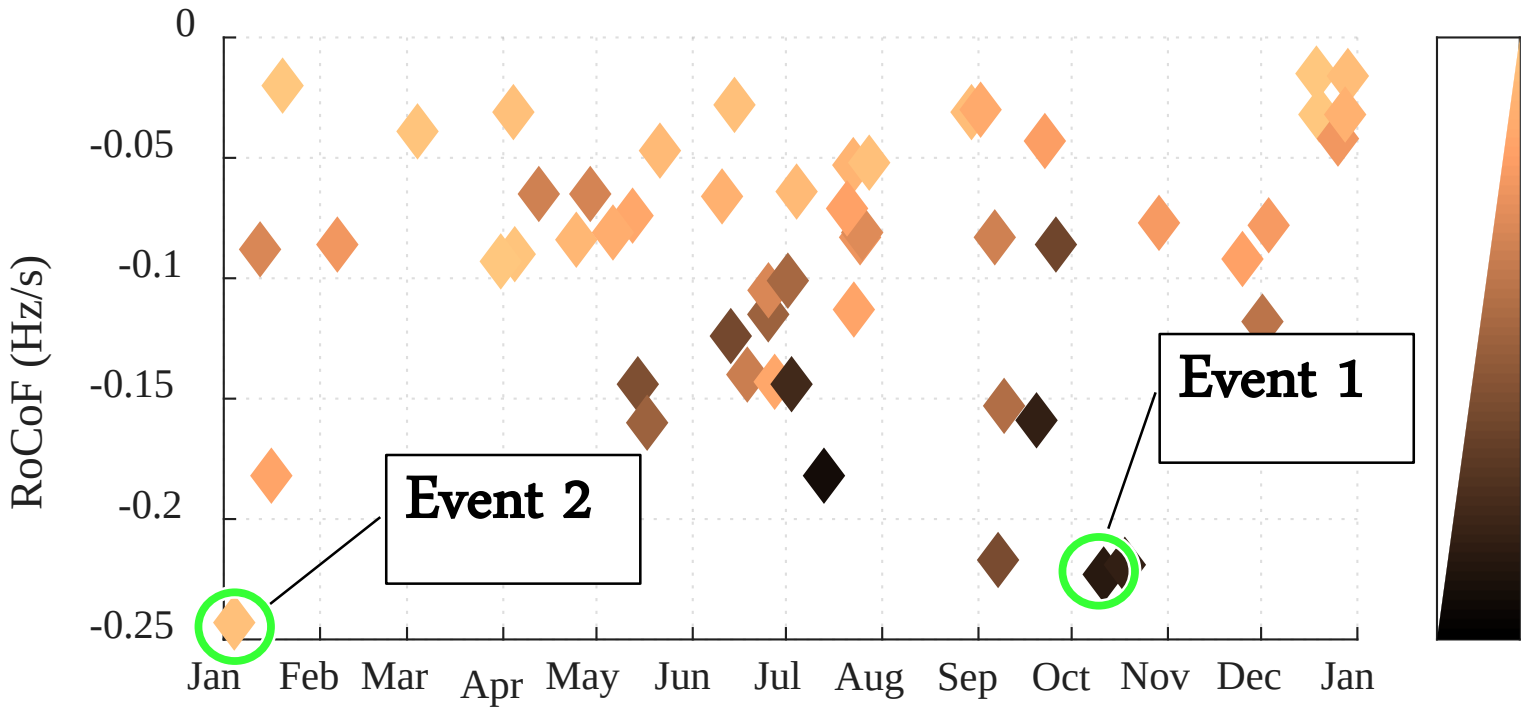






2. How does the power system inertia affect the frequency stability?

   Large disturbances

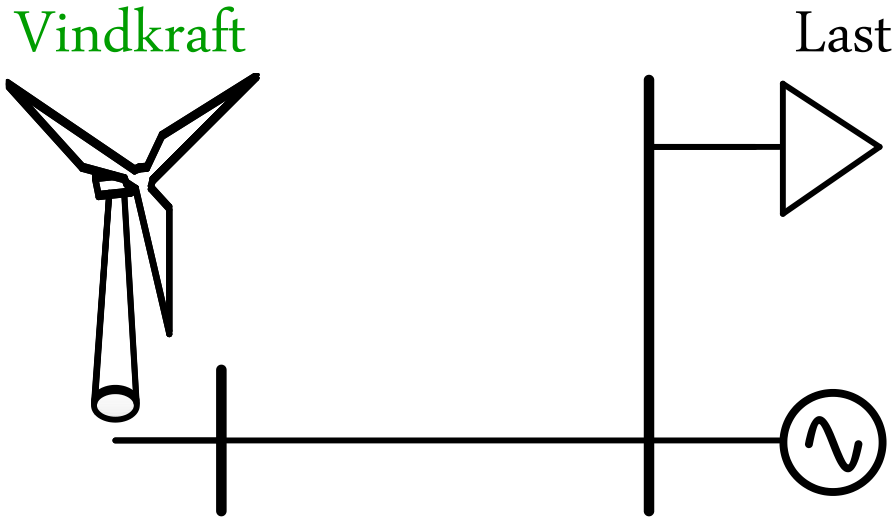


2. How does the power system inertia affect the frequency stability?

   Future scenarios

1. Increase of wind power (by replacing hydro).

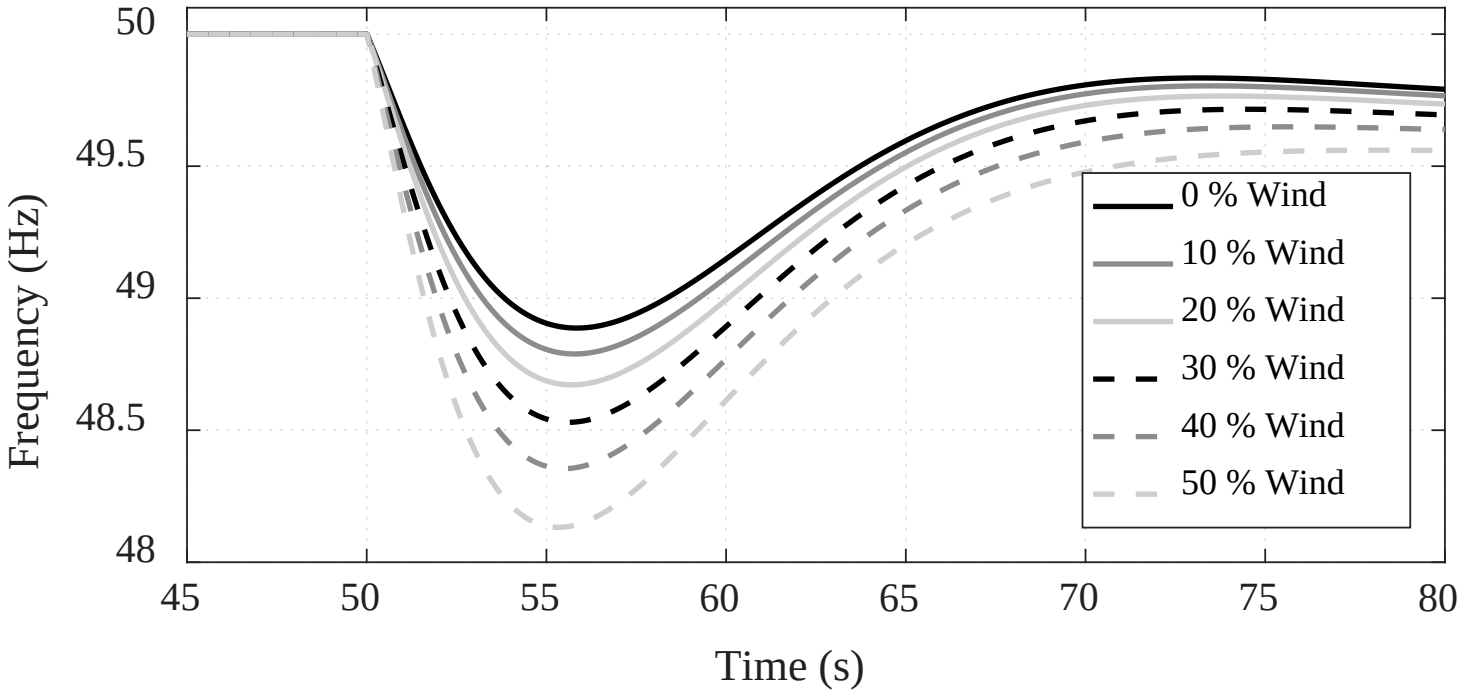
2. 10% production trip



What happends to the frequency swing with an increased wind power penetration?

2. How does the power system inertia affect the frequency stability?

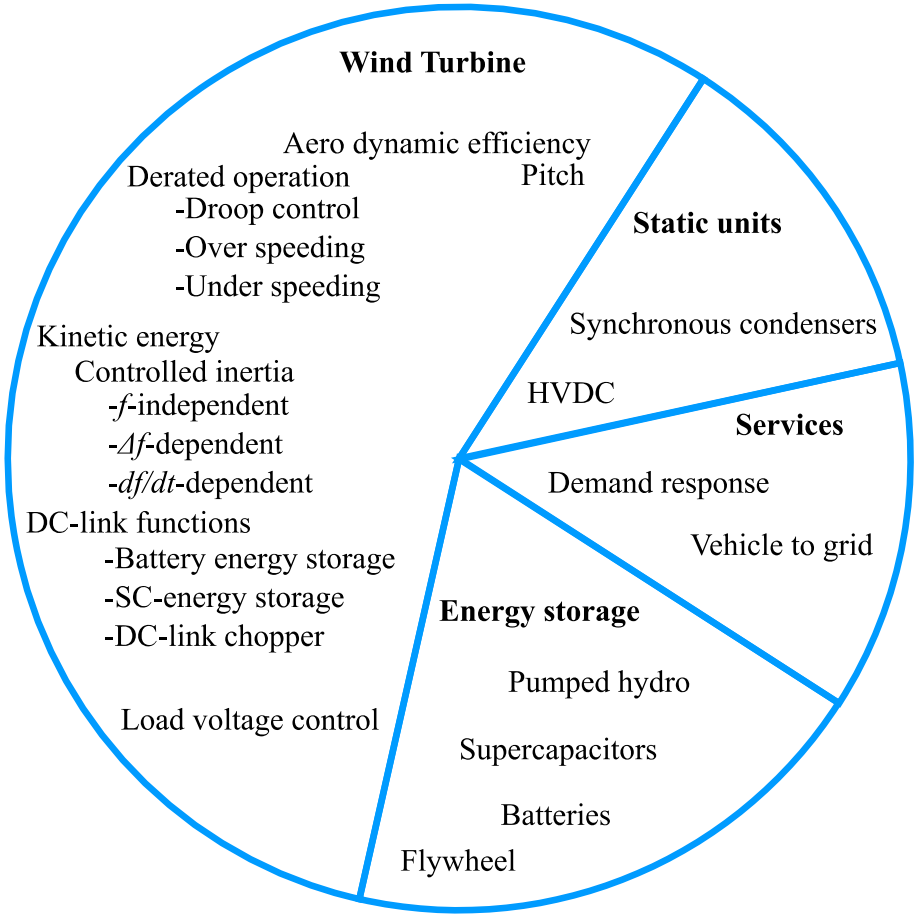
Future scenarios



A reduced system inertia (H_{sys}) cause lower frequency nadirs and steeper frequency derivatives during disturbances.

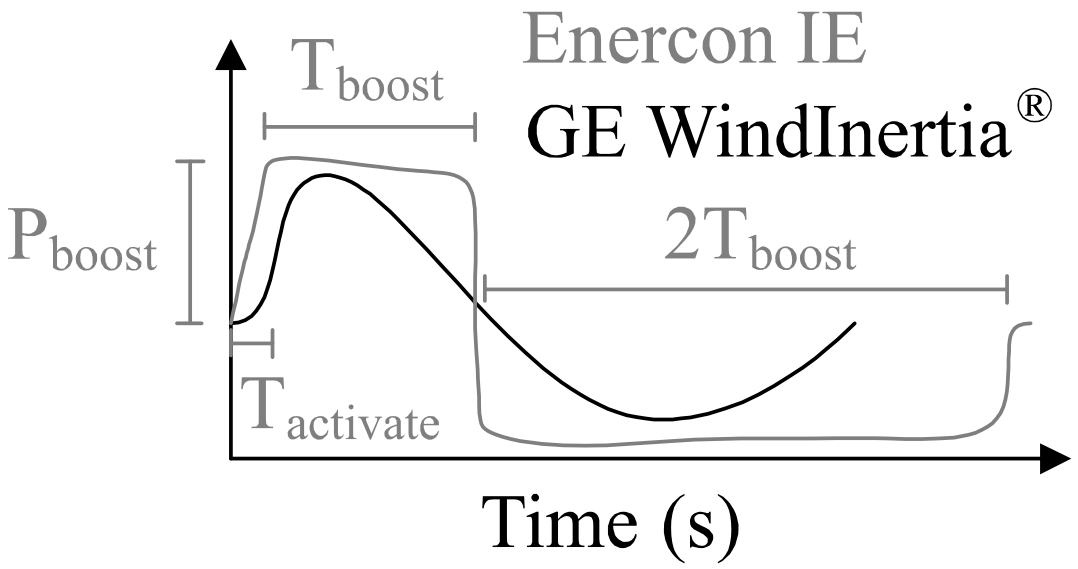
3. Solutions to lack of system inertia

Future solutions



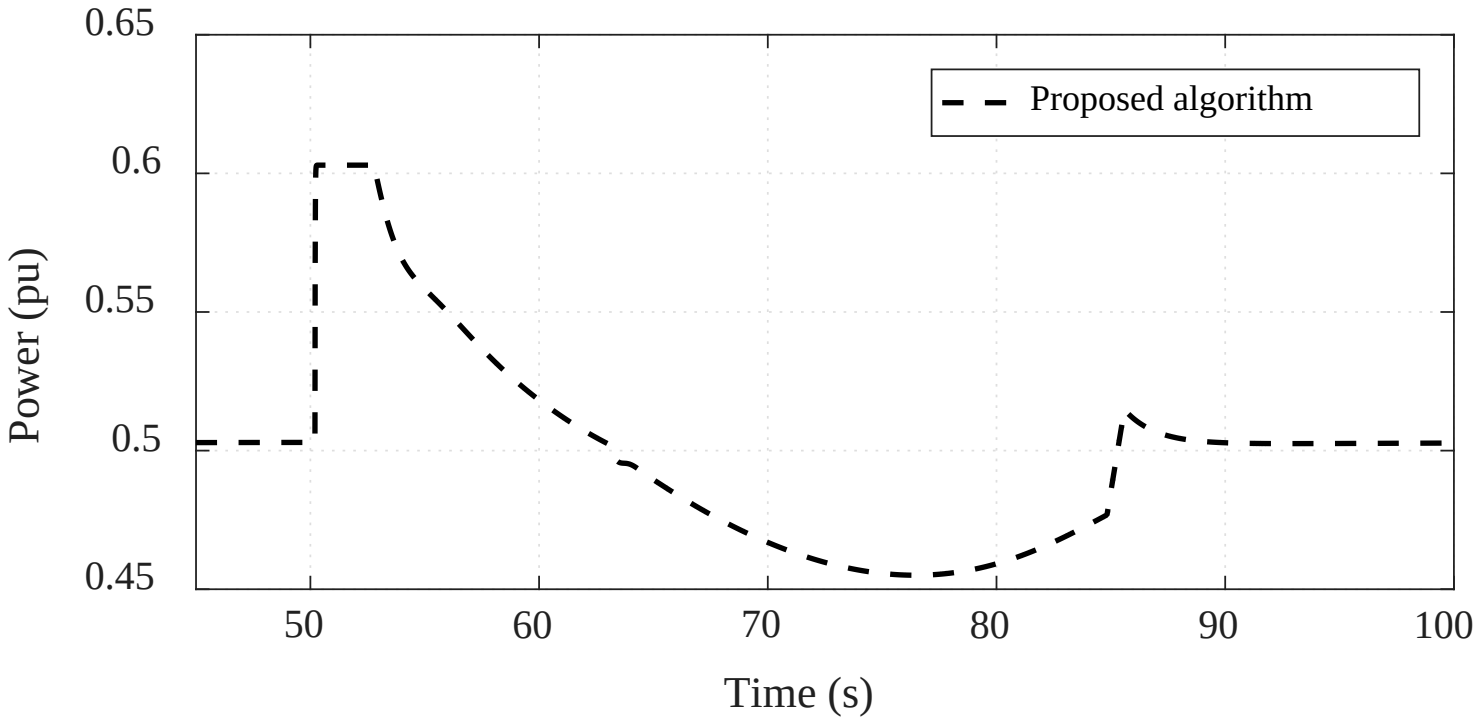
3. Solutions to lack of system inertia

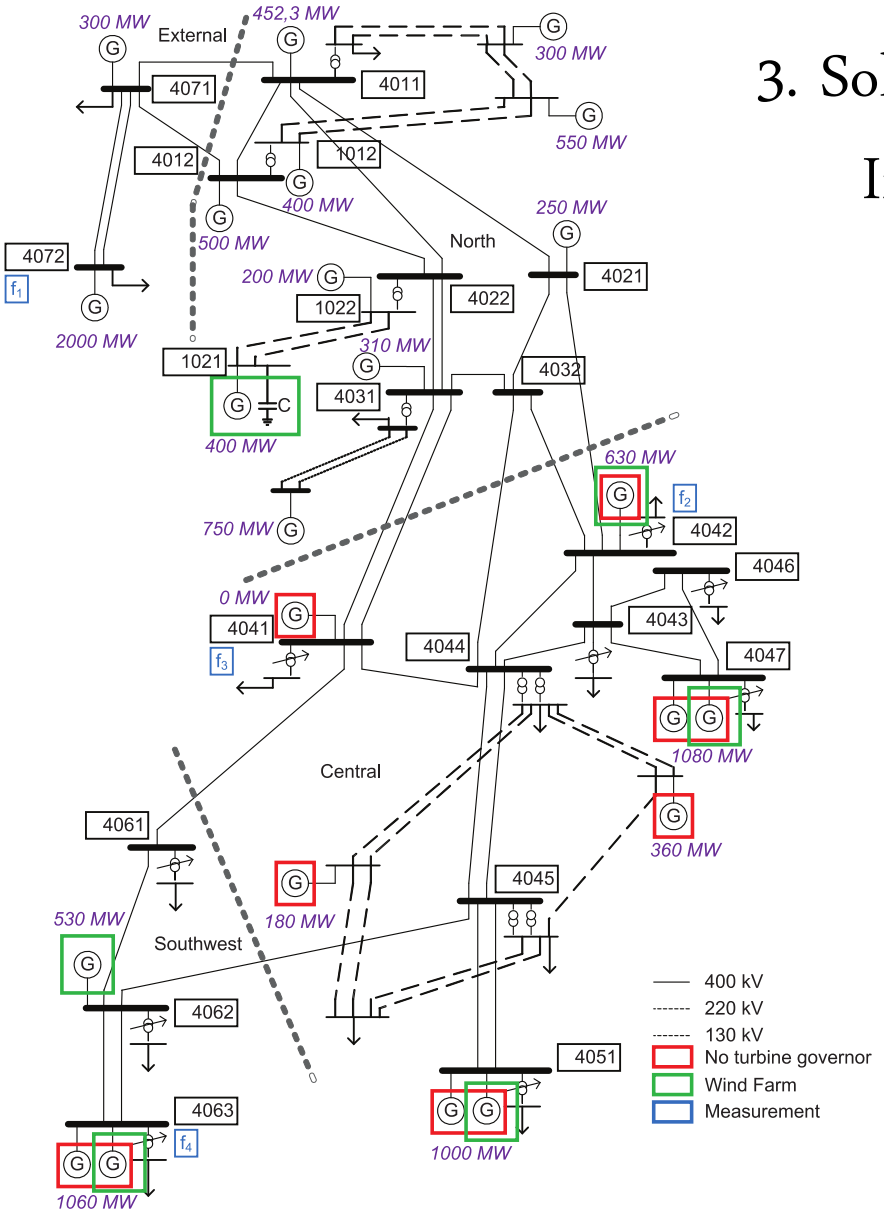
Focus: Wind turbines contribution



3. Solutions to lack of system inertia

Focus: Wind turbines contribution – An example (7.5 m/s)



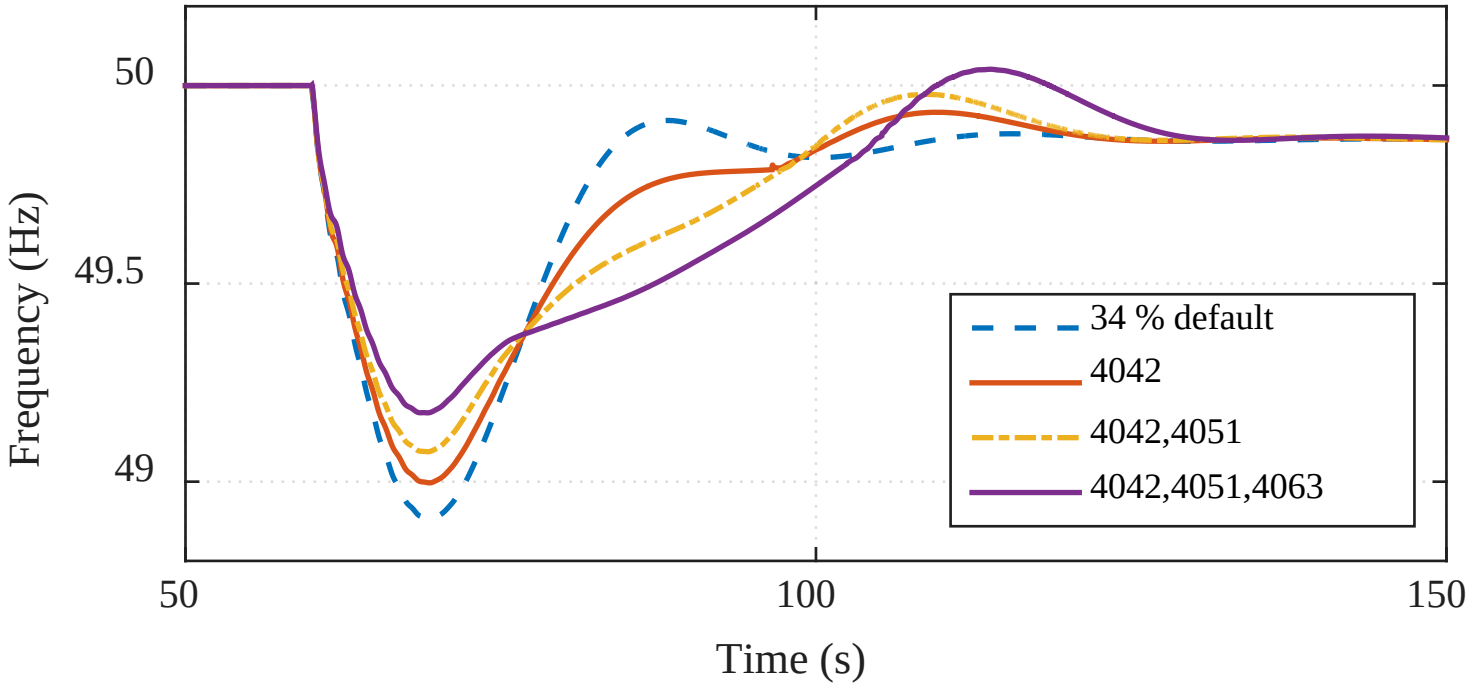


3. Solutions to lack of system inertia

Inertia from wind farms

Case

- 34% Wind power penetration
- H_{sys} = 2.76 s (prev. 3.97 s)
- Tripped generation = 400 MW (3.5%) at bus 1012



Case	f_{min} *(Hz)*
34 % default	48.91
4042 responding	49.00
4042,4051 responding	49.08
4042,4051,4063 responding	49.17

Slutsatser

- Power system inertia is expected to decrease in the Nordic (mainly due to wind integration)
- Solutions can be provided from a range of sources.
- The need for fast frequency reserves has been noted as a remedy for the deminishing system inertia.
- More HVDC interconnectors and dimensioning faults will probably cause more large frequency disturbances.

Future project

1 September at 13:00 – Dissertation, Elteknik, Chalmers.

"*Frequency response by wind farms in power systems with high wind power penetration*"

M. Persson, "Frequency response by wind farms in power systems with high wind power penetration", PhD thesis, 2017

Thanks!

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