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Frequency control in power systems with large scale wind power

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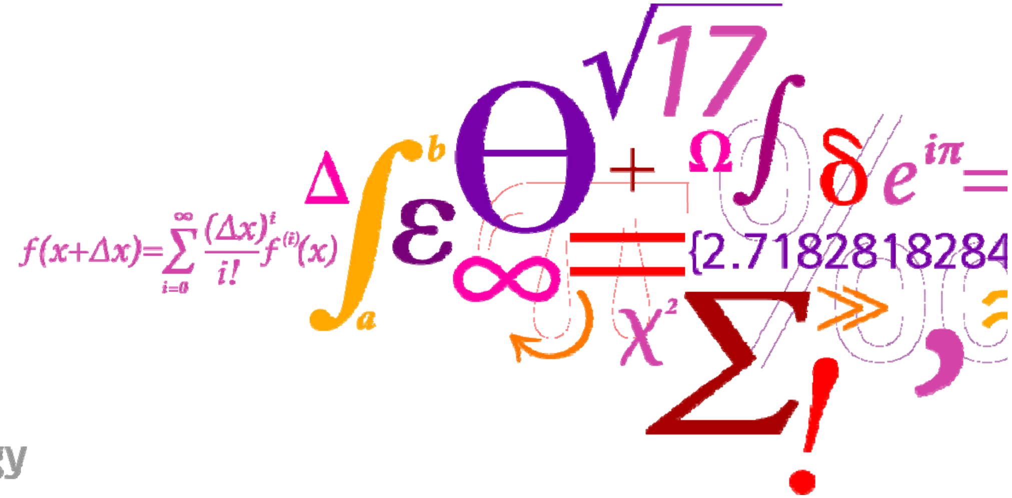
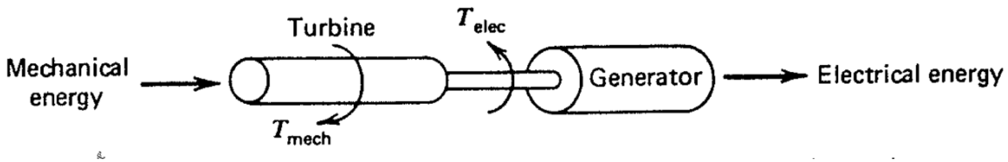
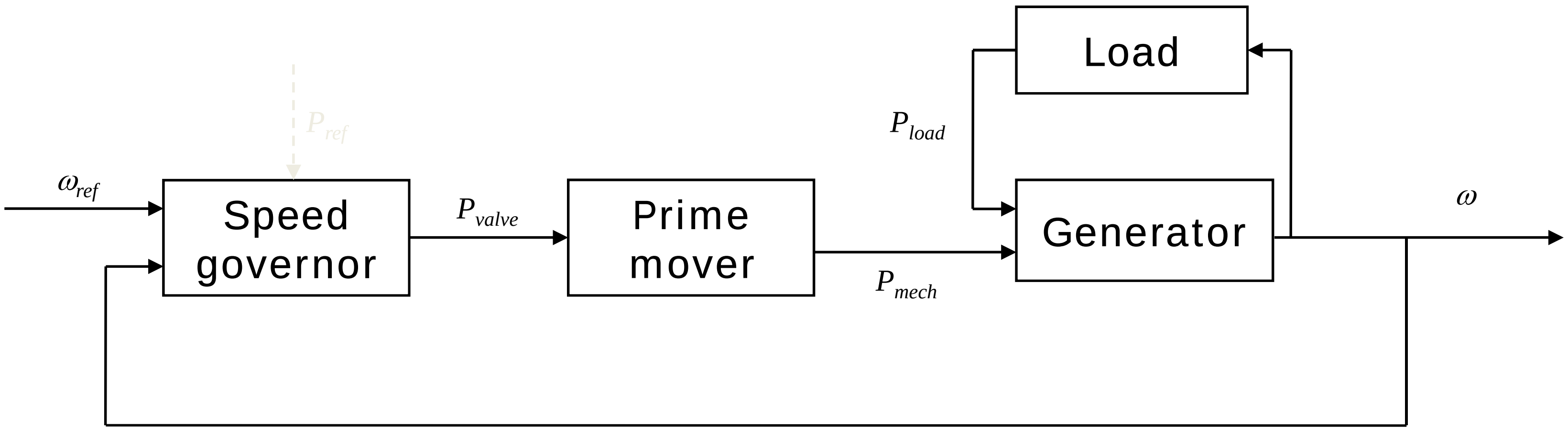


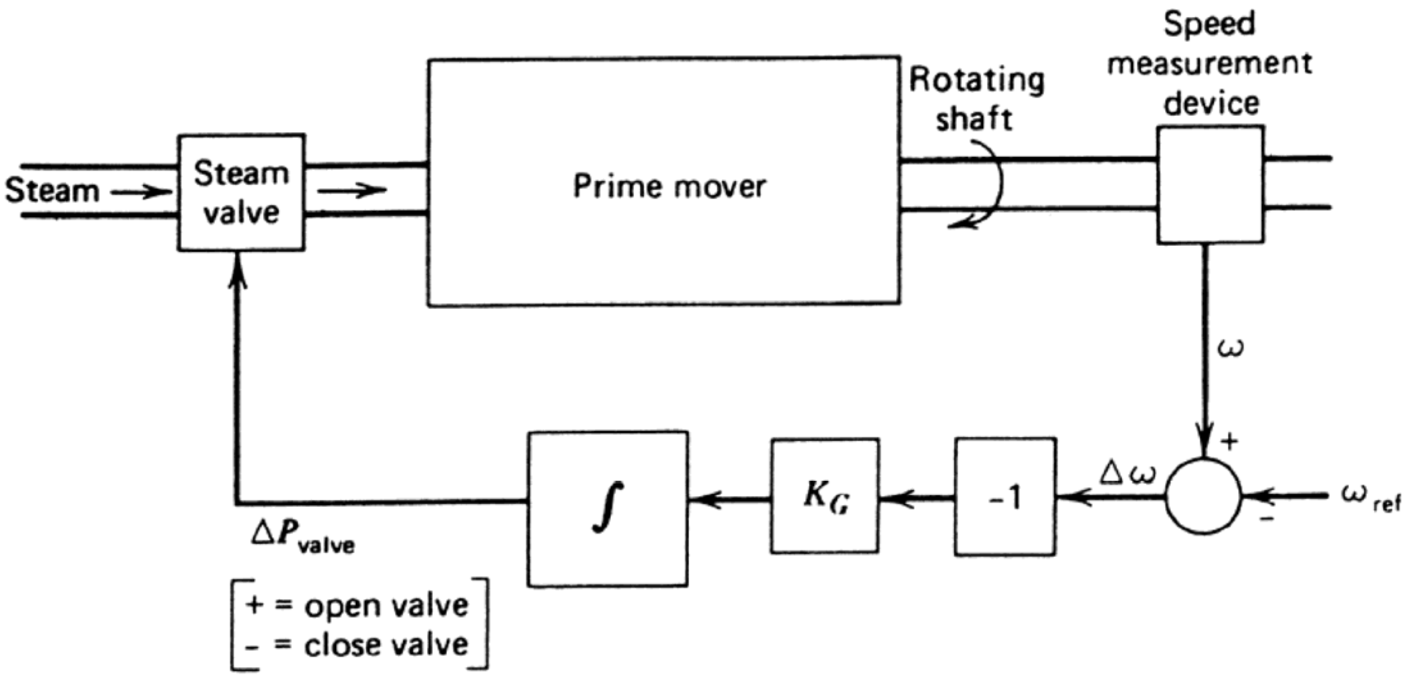
Risø DTU
National Laboratory for Sustainable Energy

Frequency control of power systems – text book

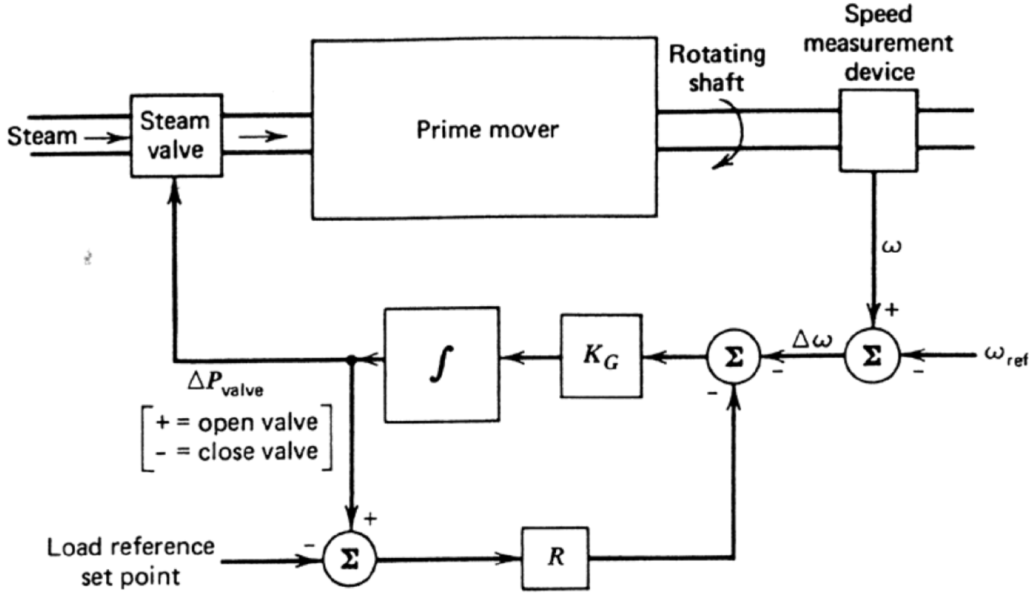


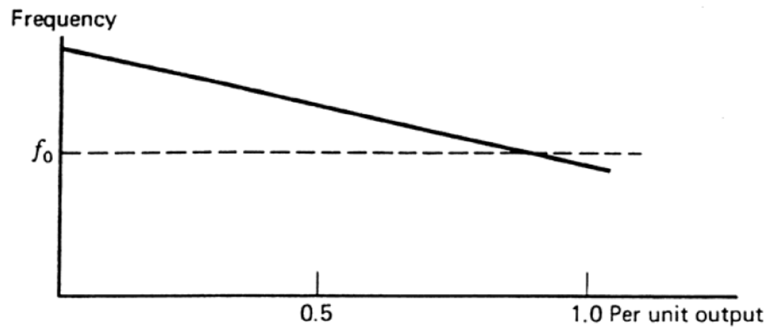


Isochronous governor – single generator



Speed droop governor – multiple generators





Frequency control example - Nordel

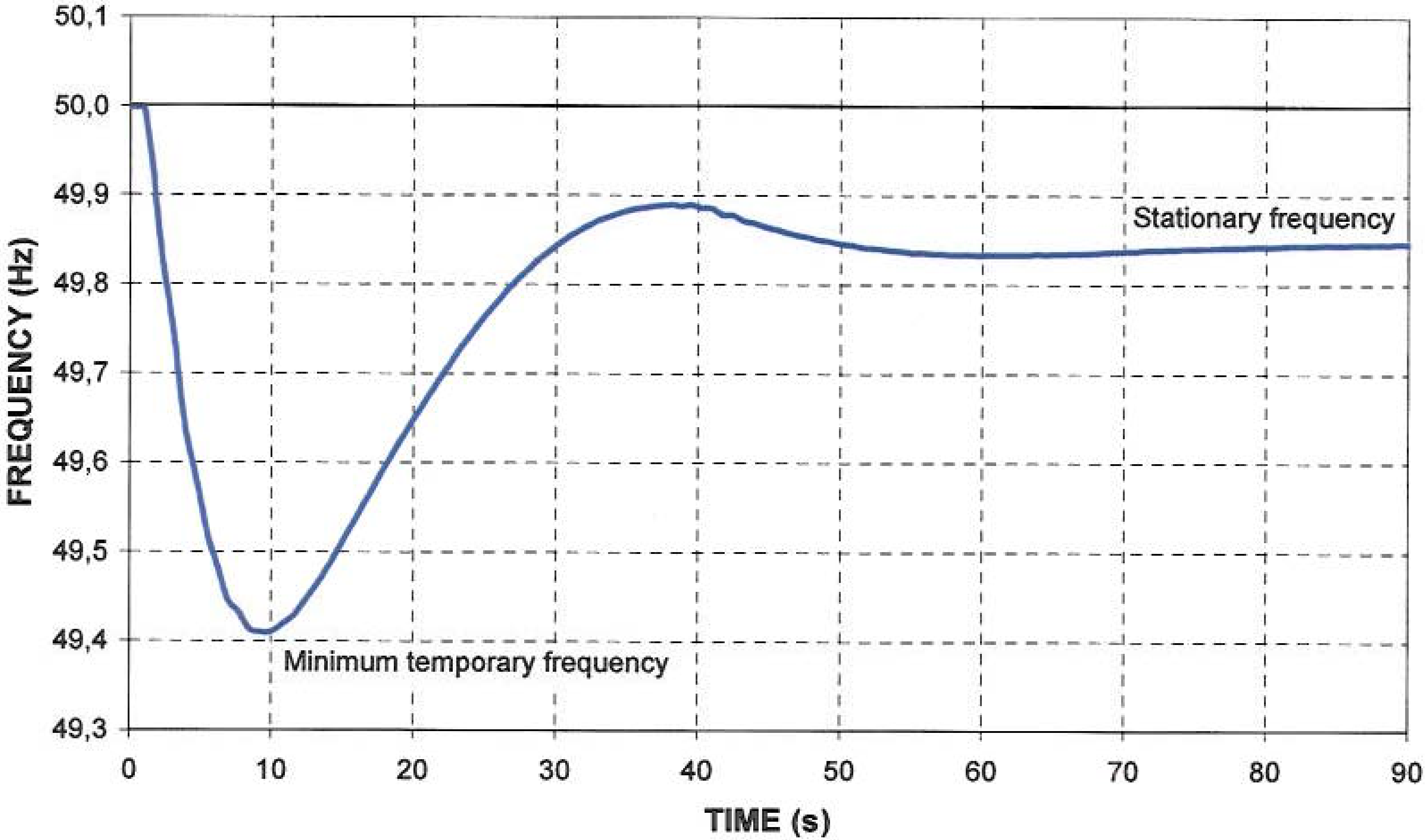


Figure 6 Development in frequency in Nordel following production outage

Why frequency control - Nordel

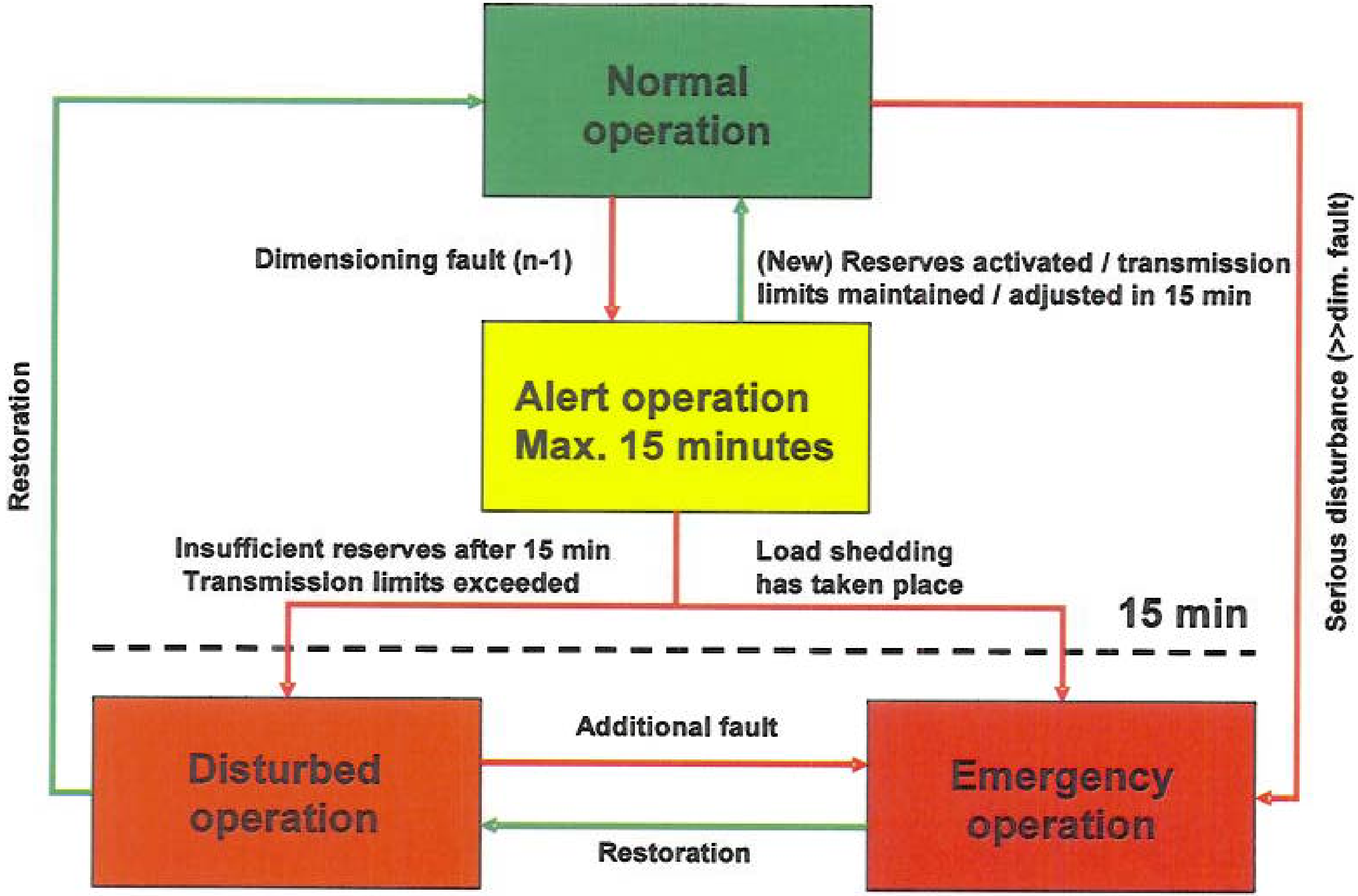


Figure 1 Operational states (network collapse is not specified in the figure).

Frequency controlled actions

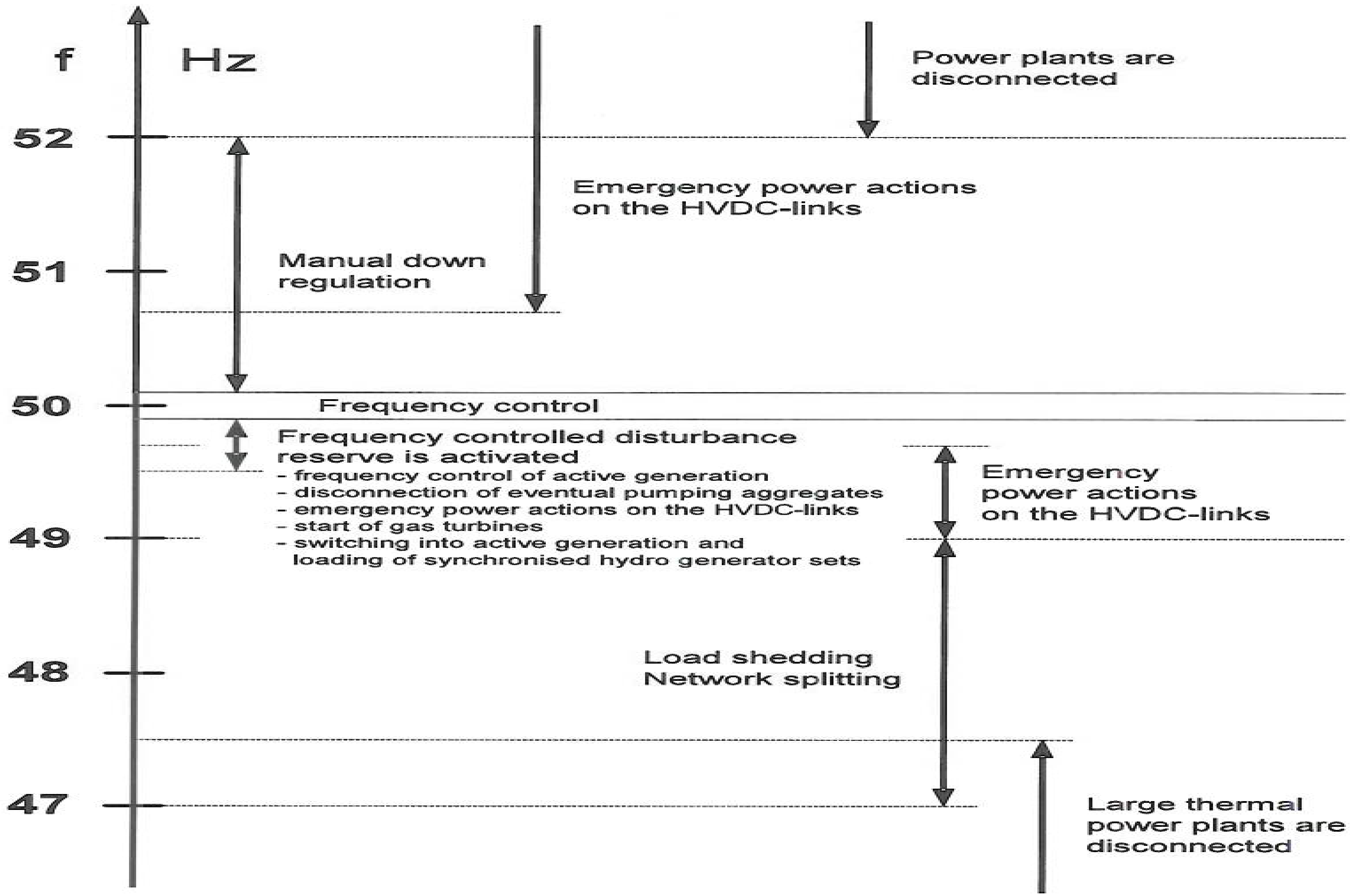
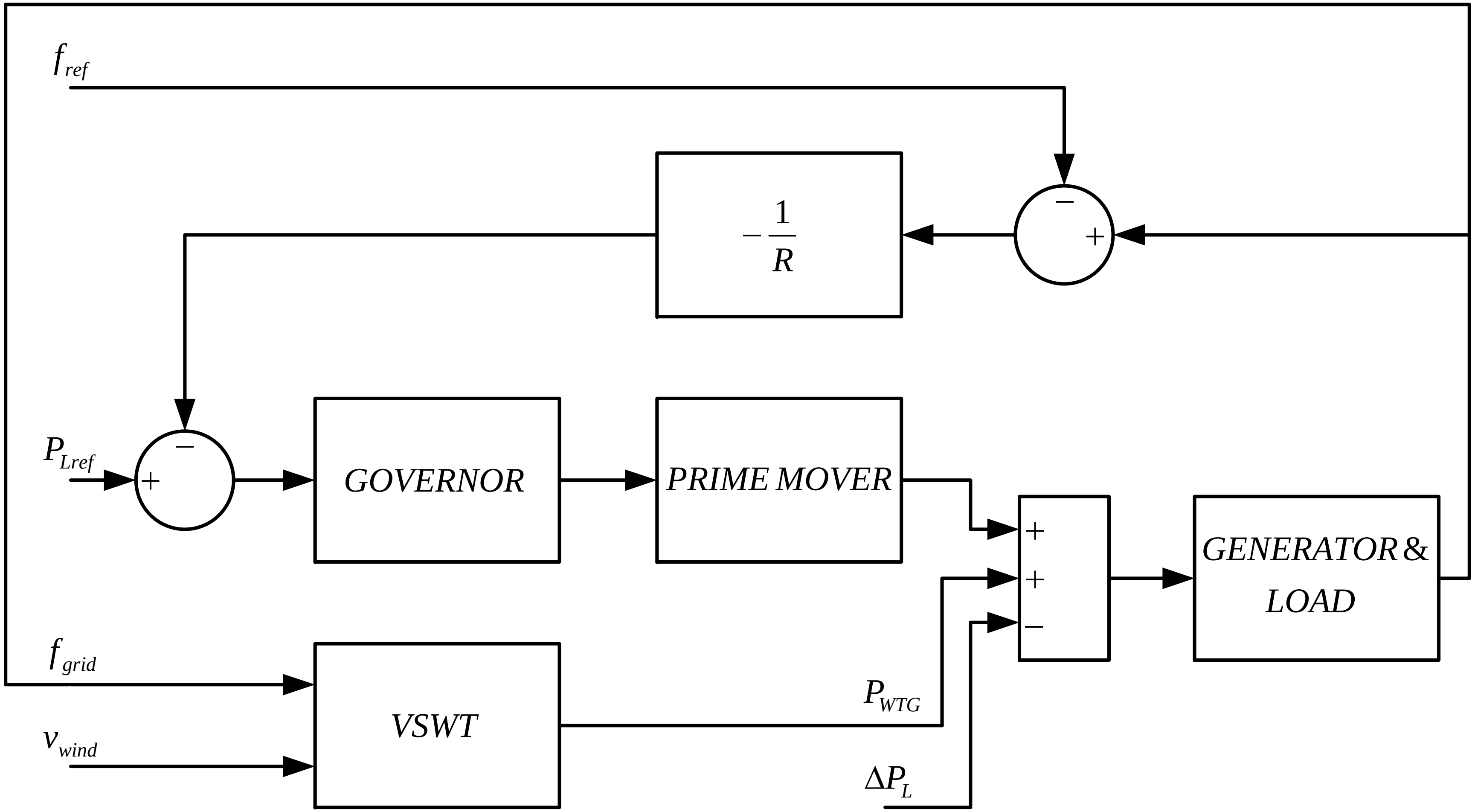


Figure 1 *Frequency controlled actions in the Nordel-system*

Frequency control model with wind power



Danish grid code for wind turbines

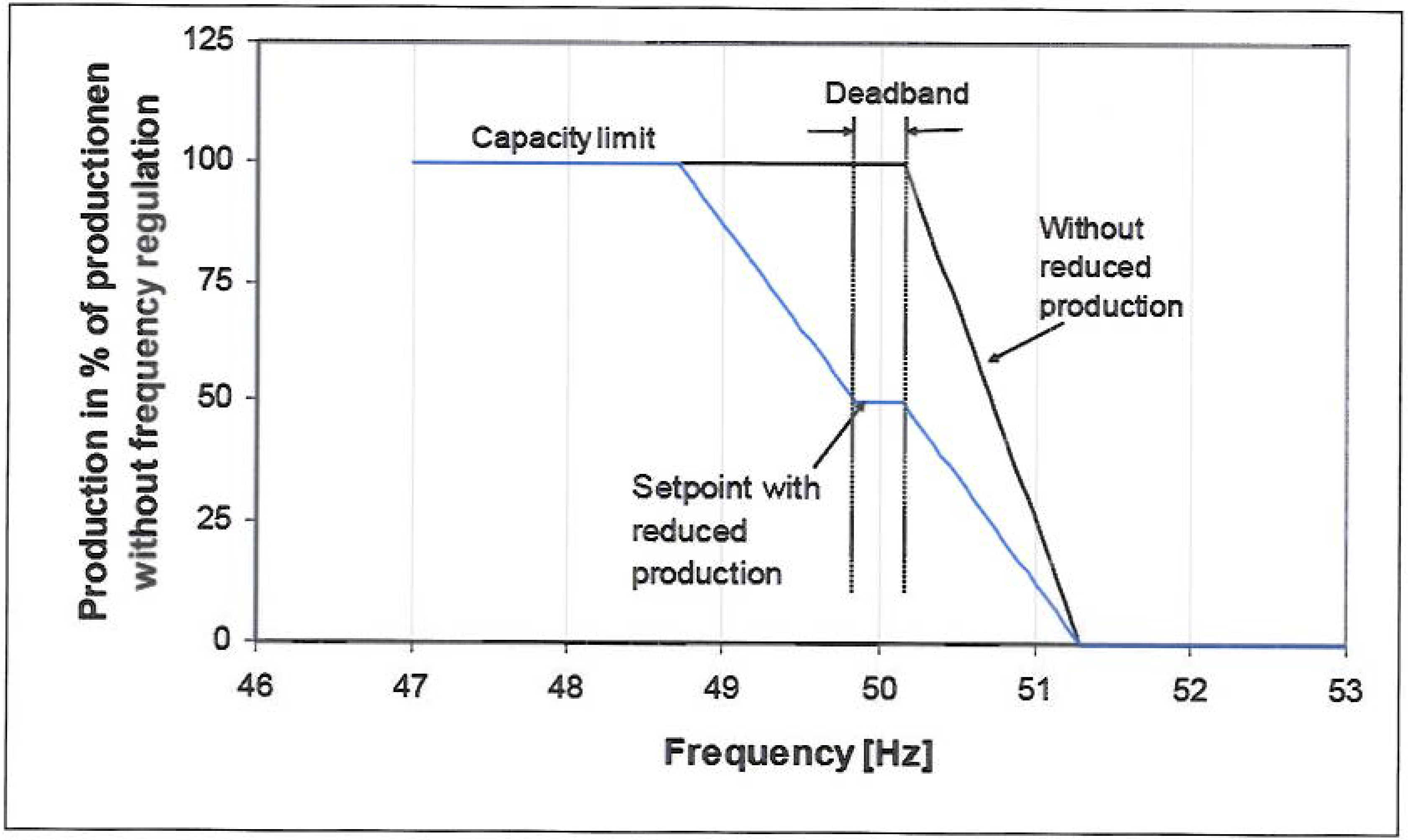
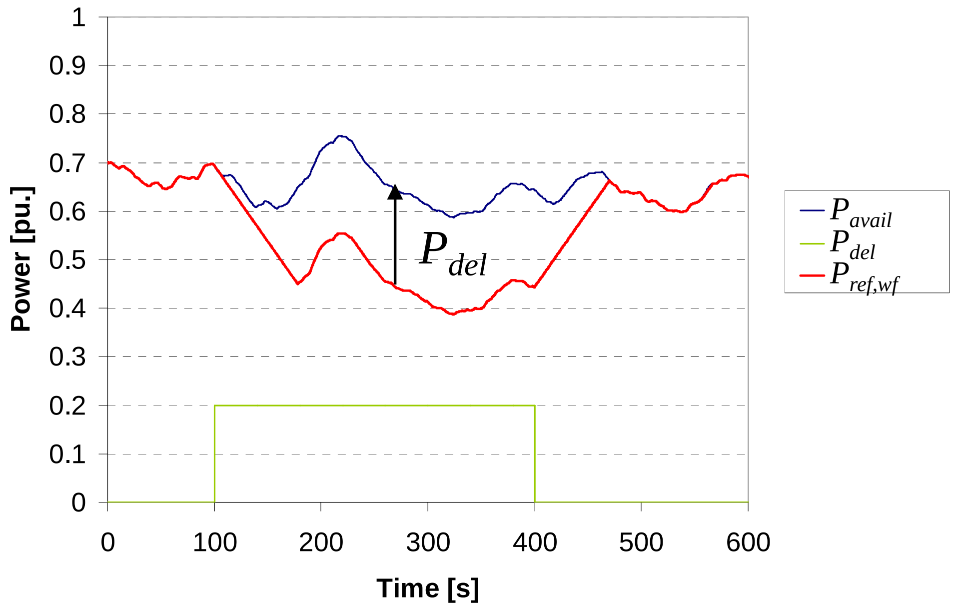


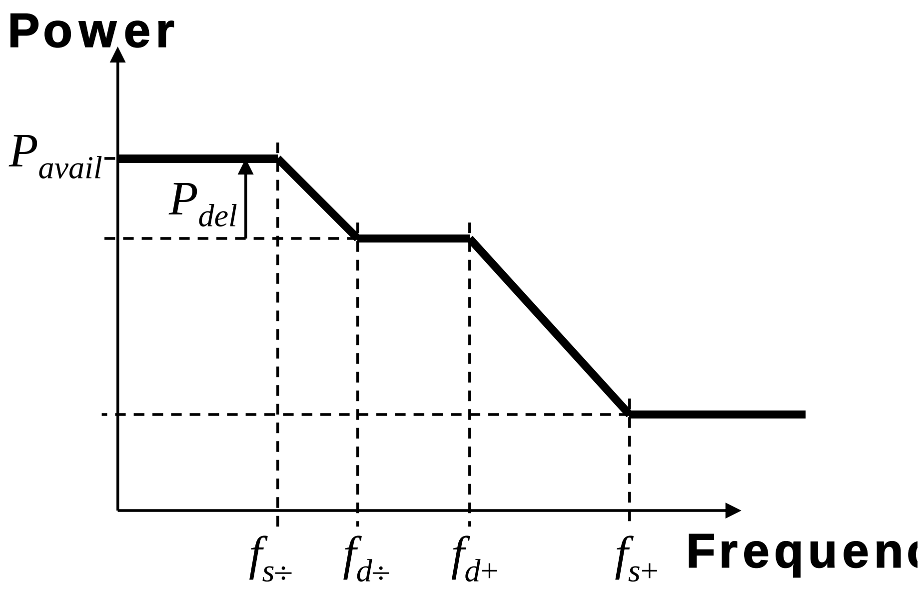
*Figure 1 Frequency control based on the default values in **Table 1**.*

Delta control – Danish grid code

- Delta control provides fixed reserve
- Delta control already implemented in Horns Rev and Nysted

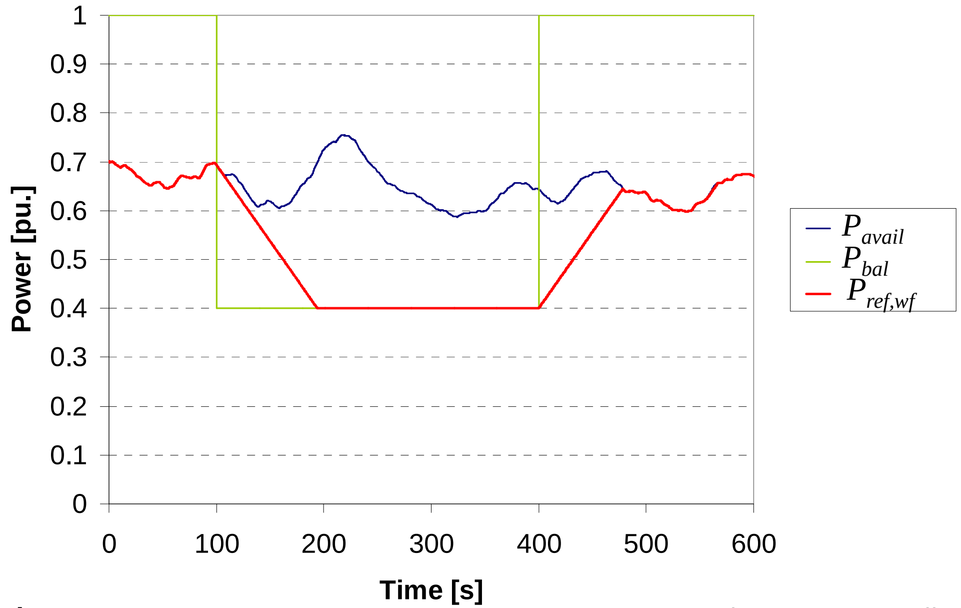
- Reserve can be utilised in frequency control (droop and deadband)





Balance control – Danish grid code

- Balance control provides
- Balance control already implemented in Horns Rev and Nysted



Sustainable Energy Master

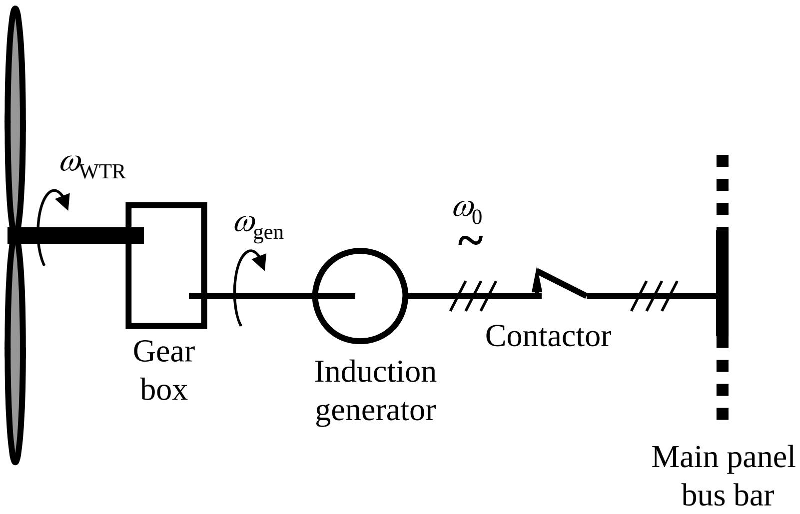
- 45002 Modelling and analysis of sustainable energy systems – 3 final projects on frequency control (1 week work load)

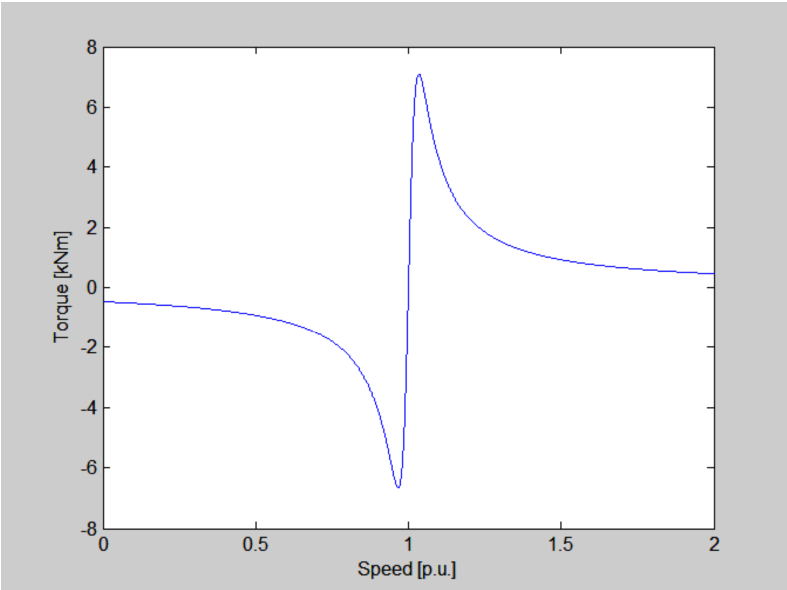
- Impact of wind power fluctuations on frequency control
  - The purpose was to study the impact of wind power fluctuations on the primary frequency control in small island power systems.

- Wind power frequency droop control
  - The purpose was to develop and implement a frequency droop control for a fixed speed wind turbine and show how this control feature can contribute to the power system frequency control.

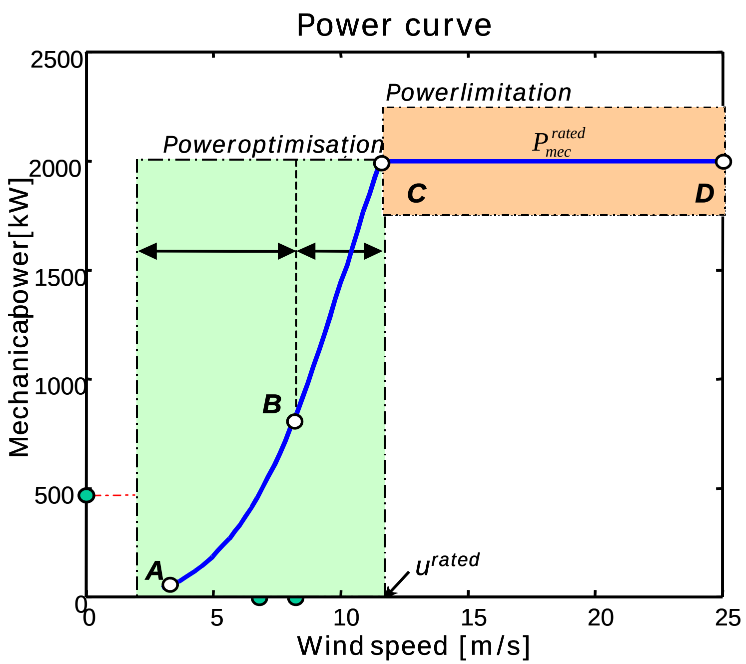
- Variable speed virtual inertia
  - The purpose was to develop and implement a virtual inertia control for a variable speed wind turbine and show how this control feature can contribute to the power system inertia.

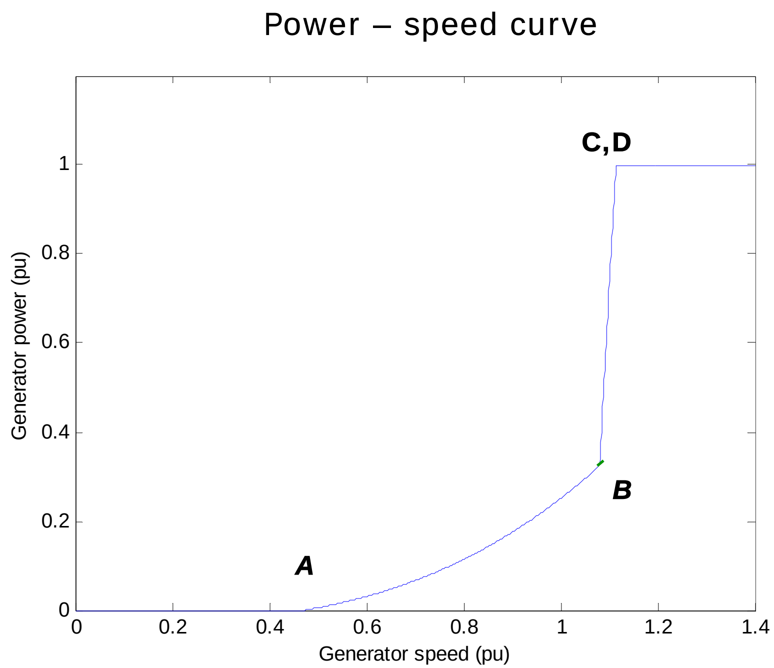
Fixed speed wind turbine
”passive control” – natural inertia



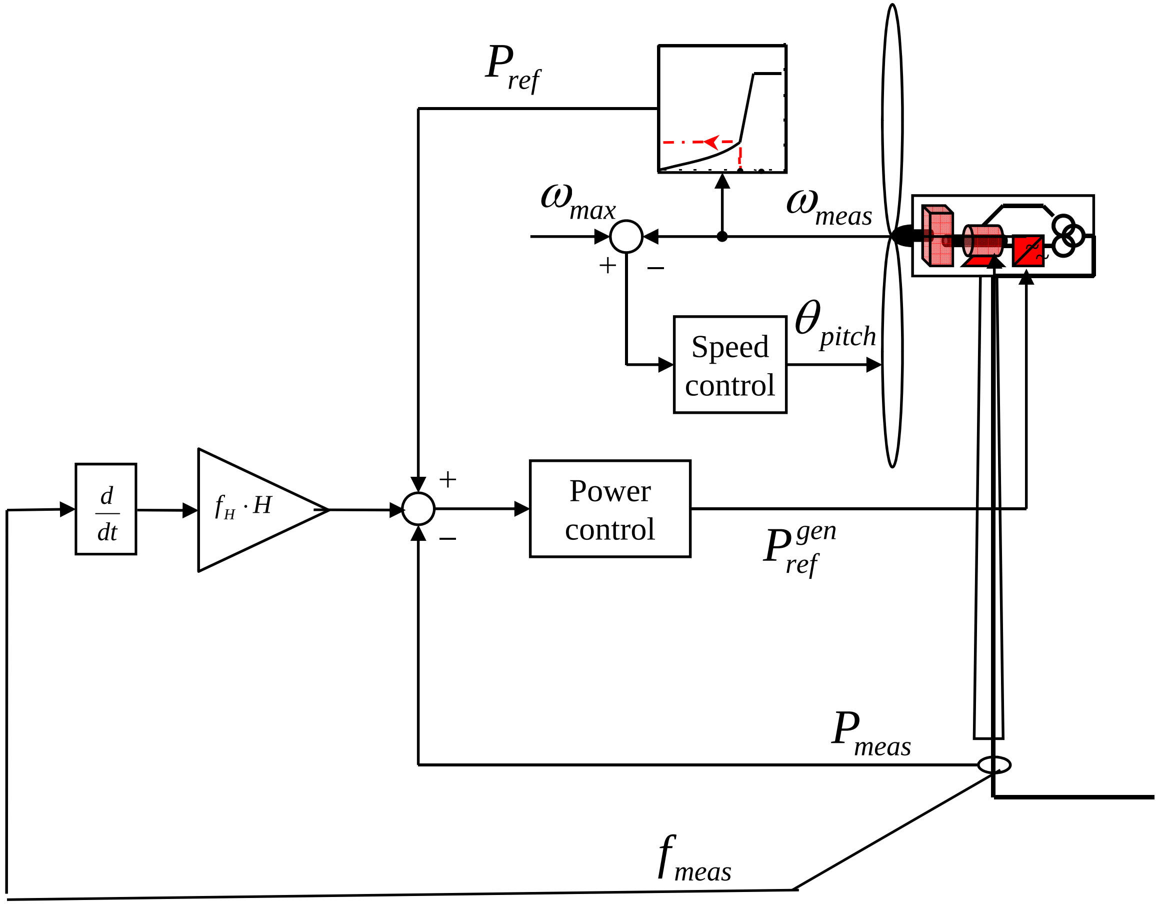


Variable speed wind turbine control strategy

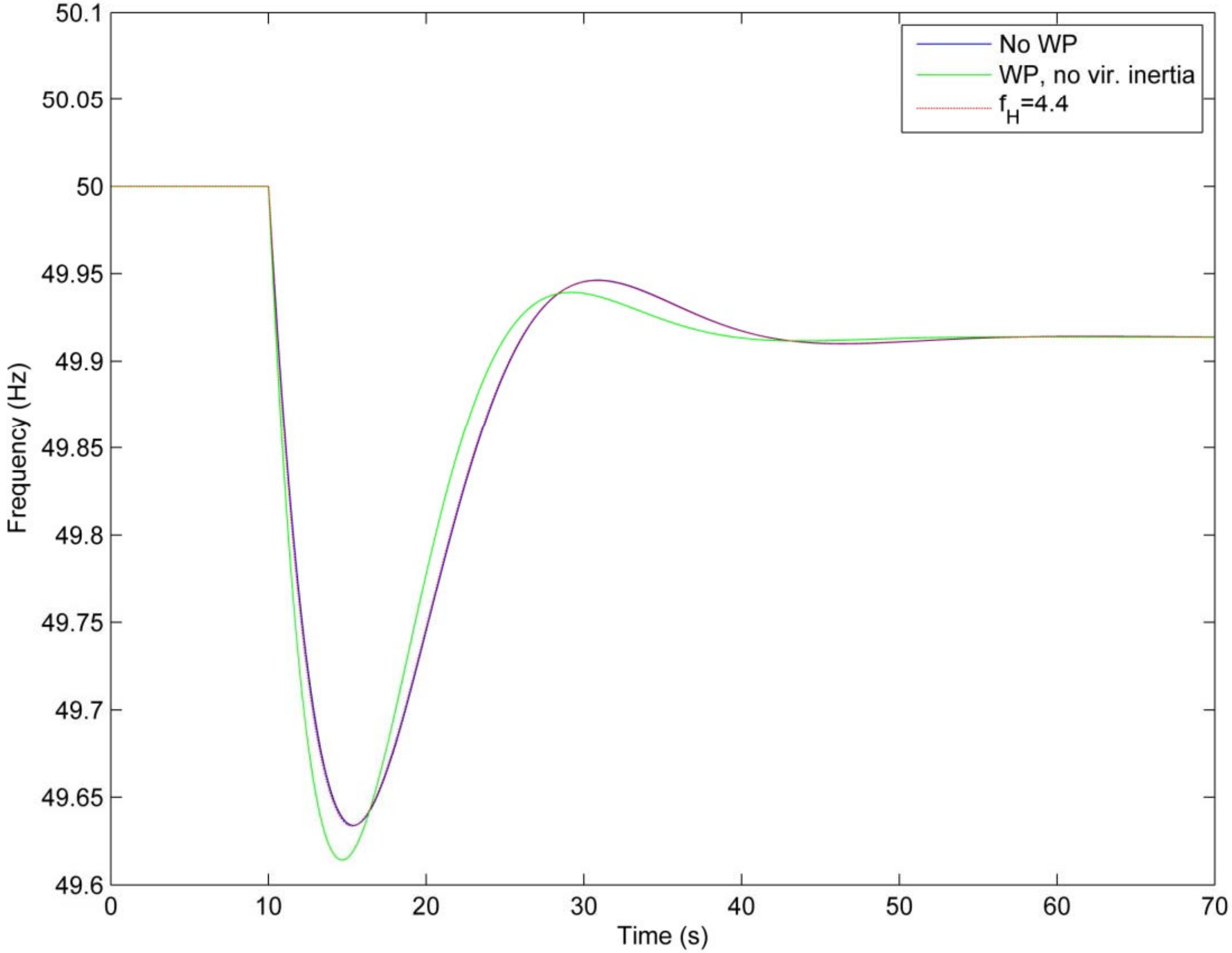




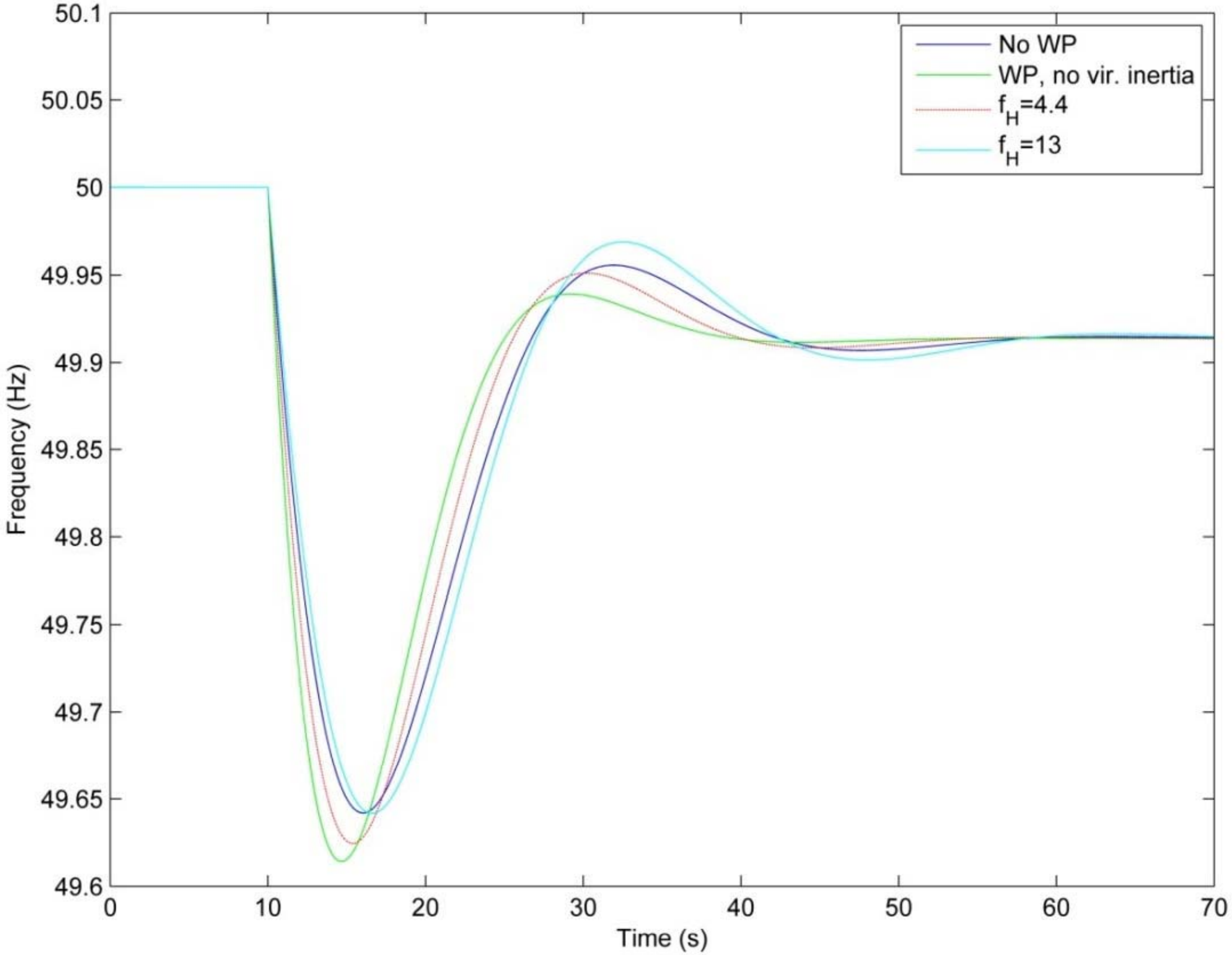
DFIG power / speed control overview



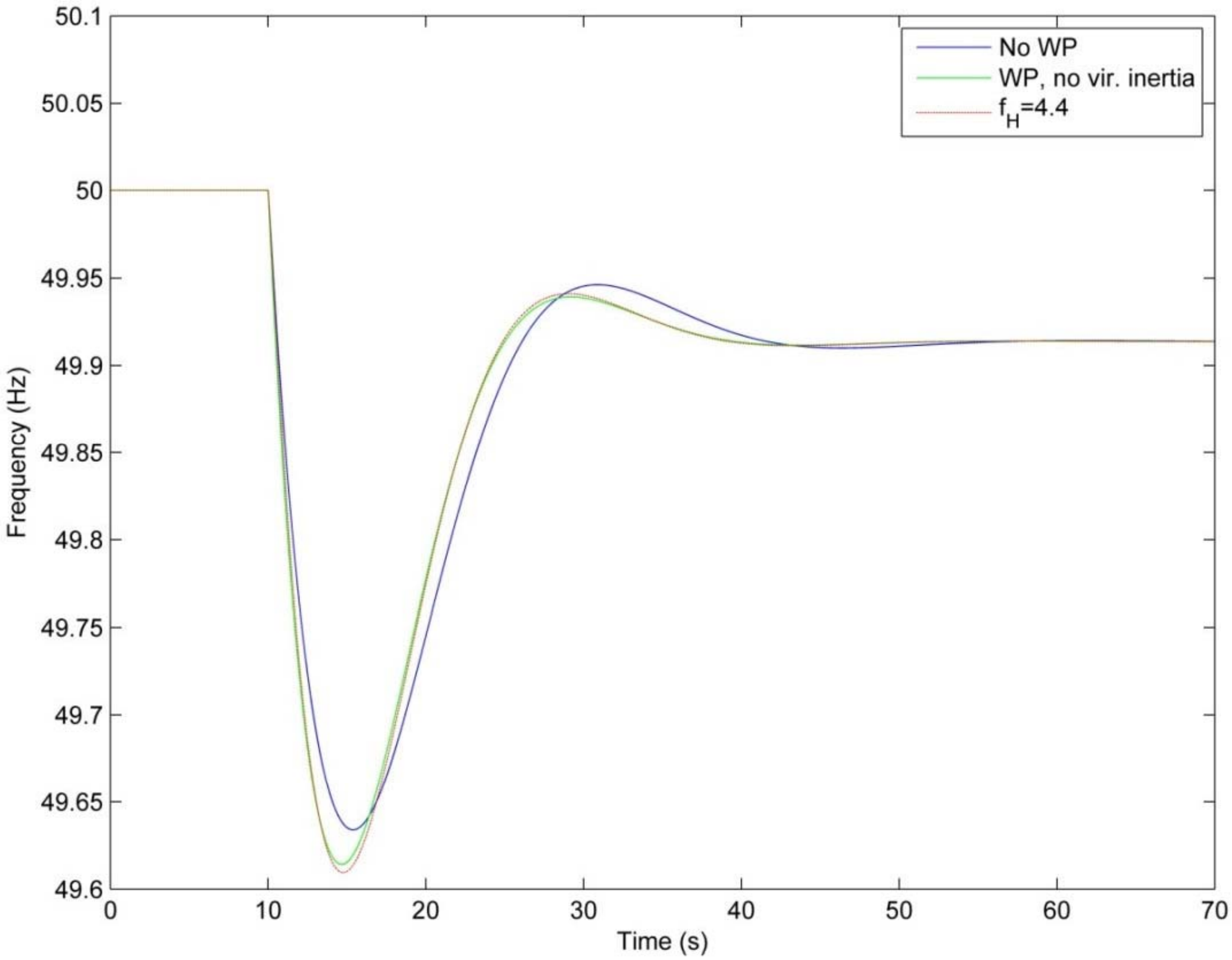
Virtual inertia control – 16 m/s



Virtual inertia control – 8 m/s



Virtual inertia control – 12 m/s



Conclusions on wind turbines provision of frequency control

- Wind power can contribute to frequency control
  - Inertia
  - Droop (automatic, primary)
  - Regulating power (secondary or tertiary reserves)

- Virtual inertia control can be provided without loss of wind power, positive reserves (droop or secondary) cost significant loss of wind power

- Simple virtual inertia control add-on does not work properly with standard speed – power lookup control algorithm
  - Power limitation region (CD) works perfect
  - Power optimisation – no speed limit region (AB) works partly
  - Power optimisation – speed limited region (BC) works very poorly.

- Alternative control algorithms should be able to solve this problem