

Technical University of Denmark



Frequency control in power systems with large scale wind power

Sørensen, Poul Ejnar; Margaris, Ioannis; Zeni, Lorenzo; Rudolph, Andreas Jakob; Münster-Swendsen, Janus

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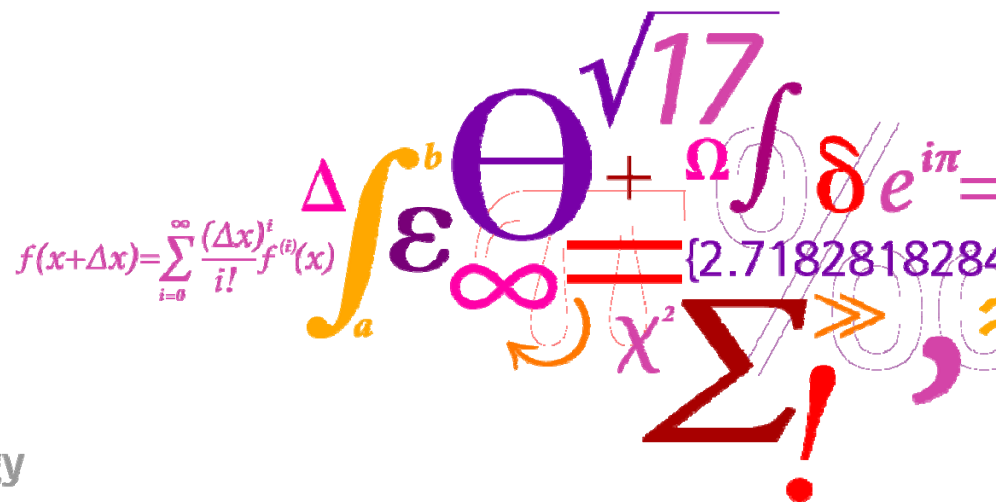
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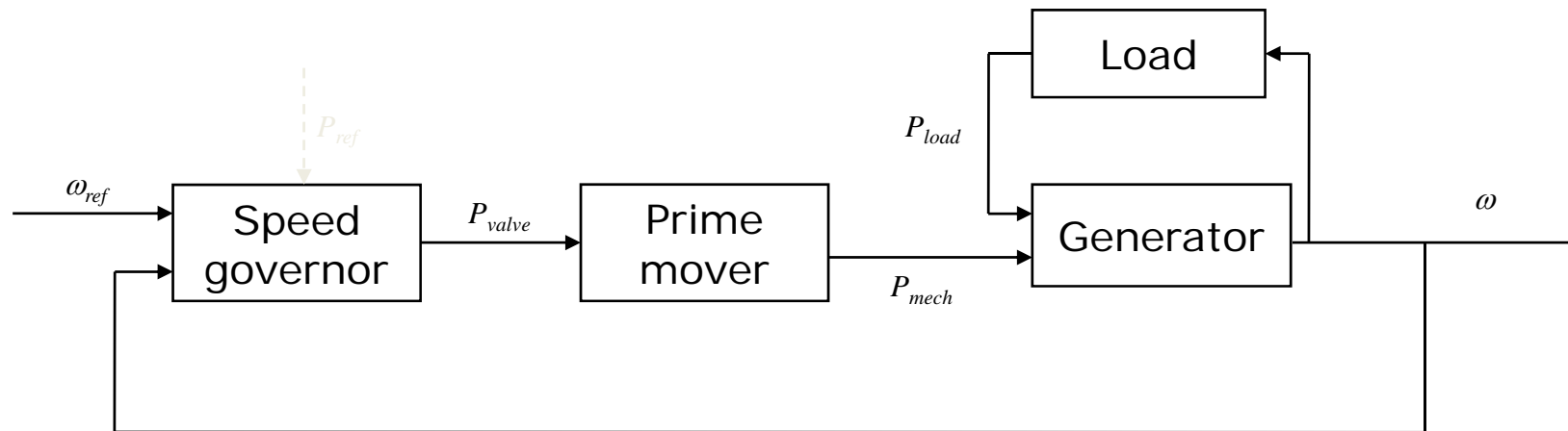
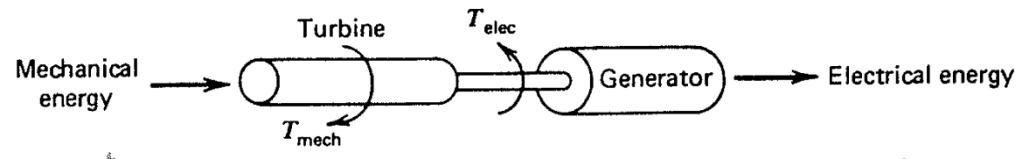
Frequency control in power systems with large scale wind power

Poul Sørensen
Ioannis Margaritis
Lorenzo Zeni
Andreas Rudolph
Janus Münster-Swendsen

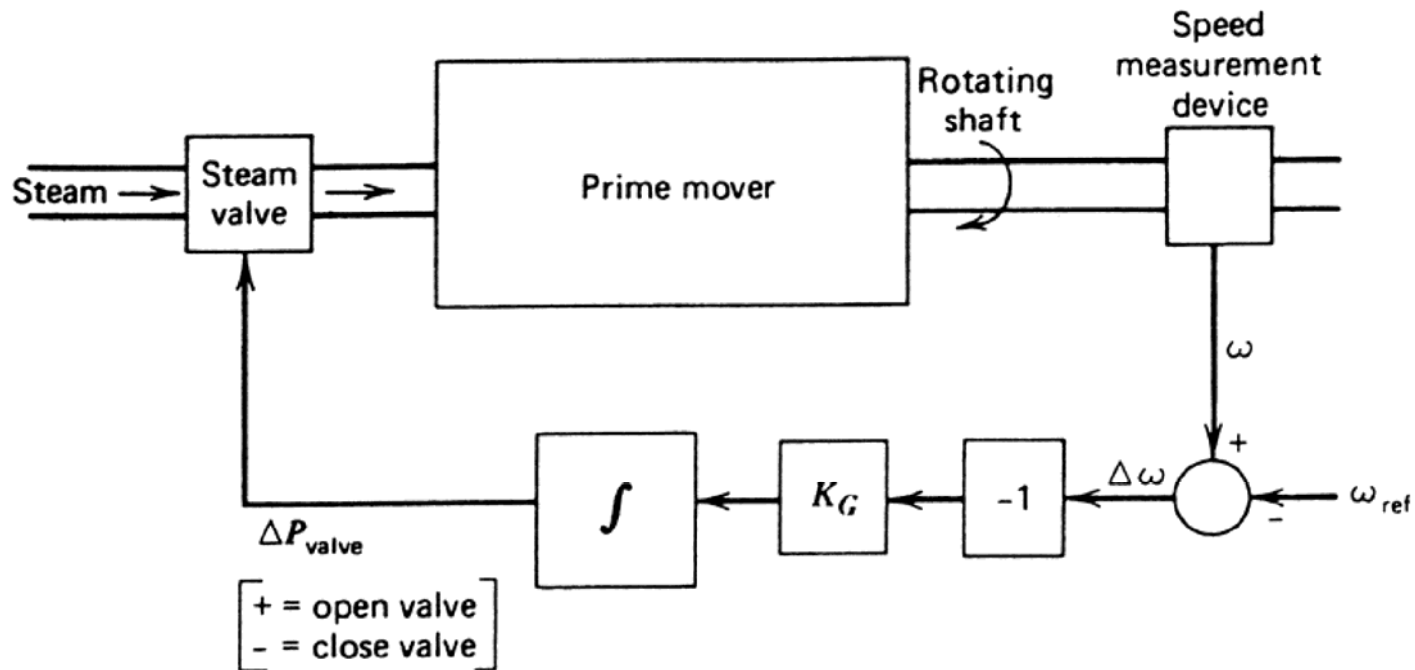
Risø DTU
National Laboratory for Sustainable Energy



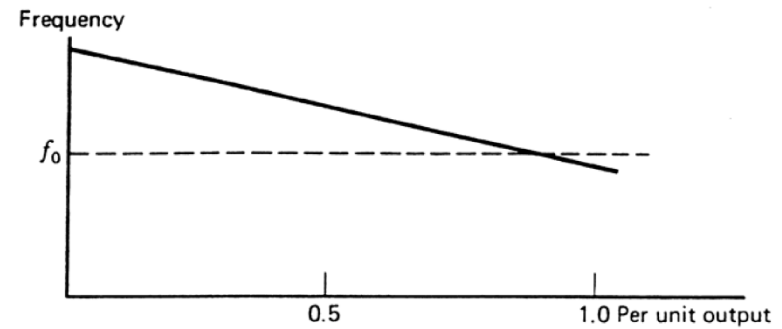
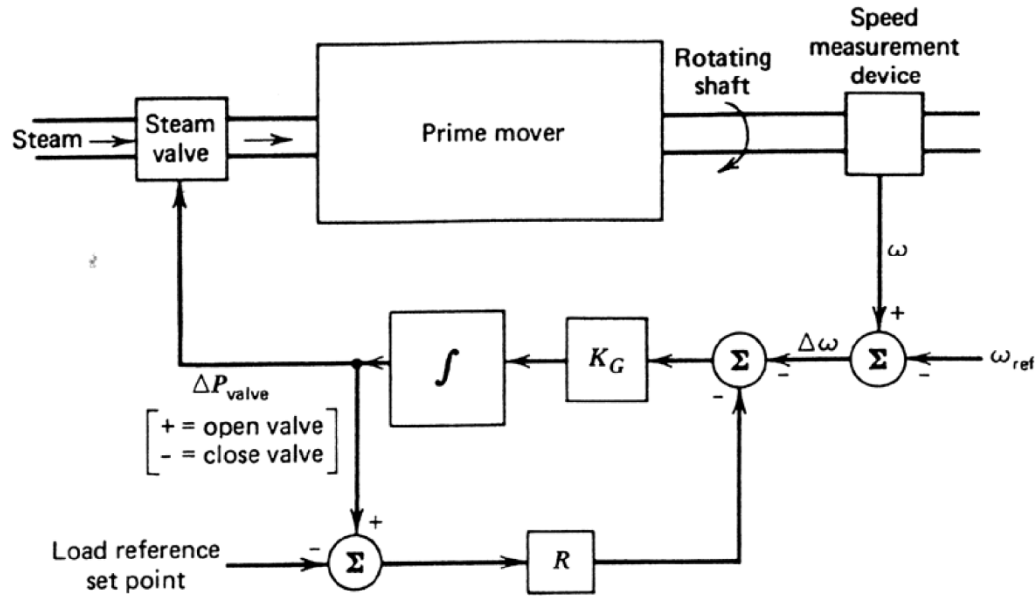
Frequency control of power systems – text book



Isochronous governor – single generator



Speed droop governor – multiple generators



Frequency control example - Nordel

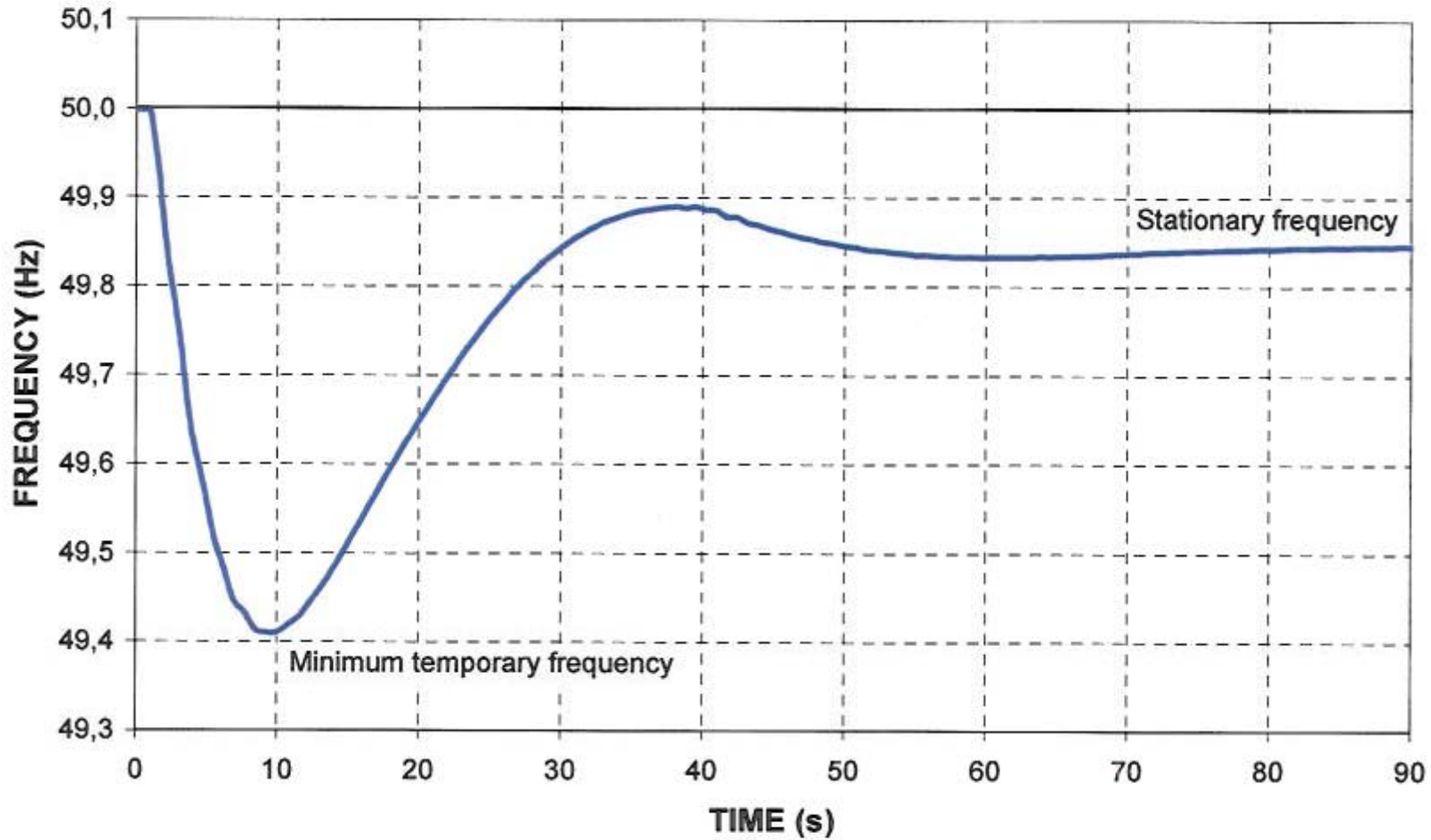


Figure 6 Development in frequency in Nordel following production outage

Why frequency control - Nordel

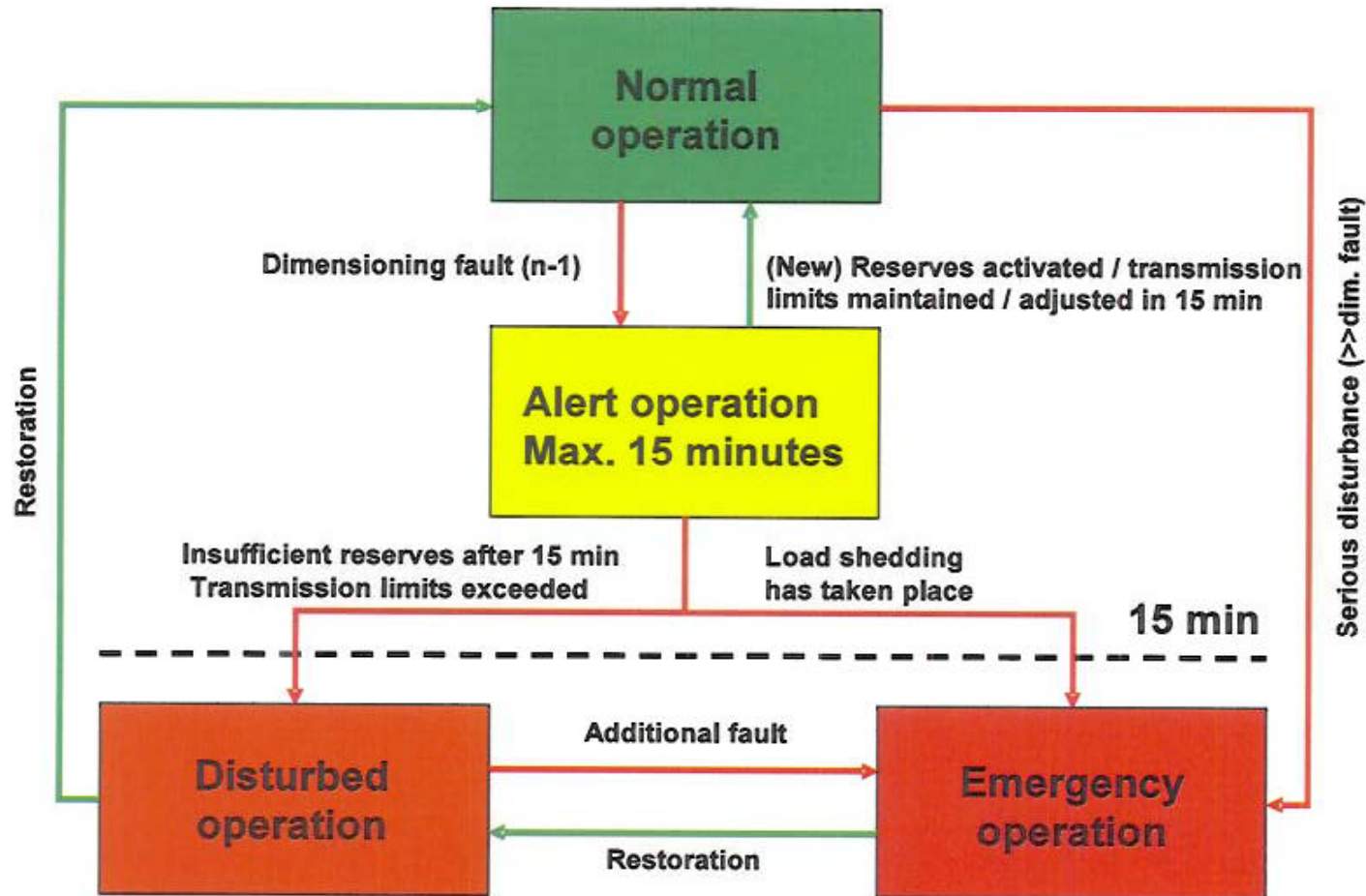


Figure 1 Operational states (network collapse is not specified in the figure).

Frequency controlled actions

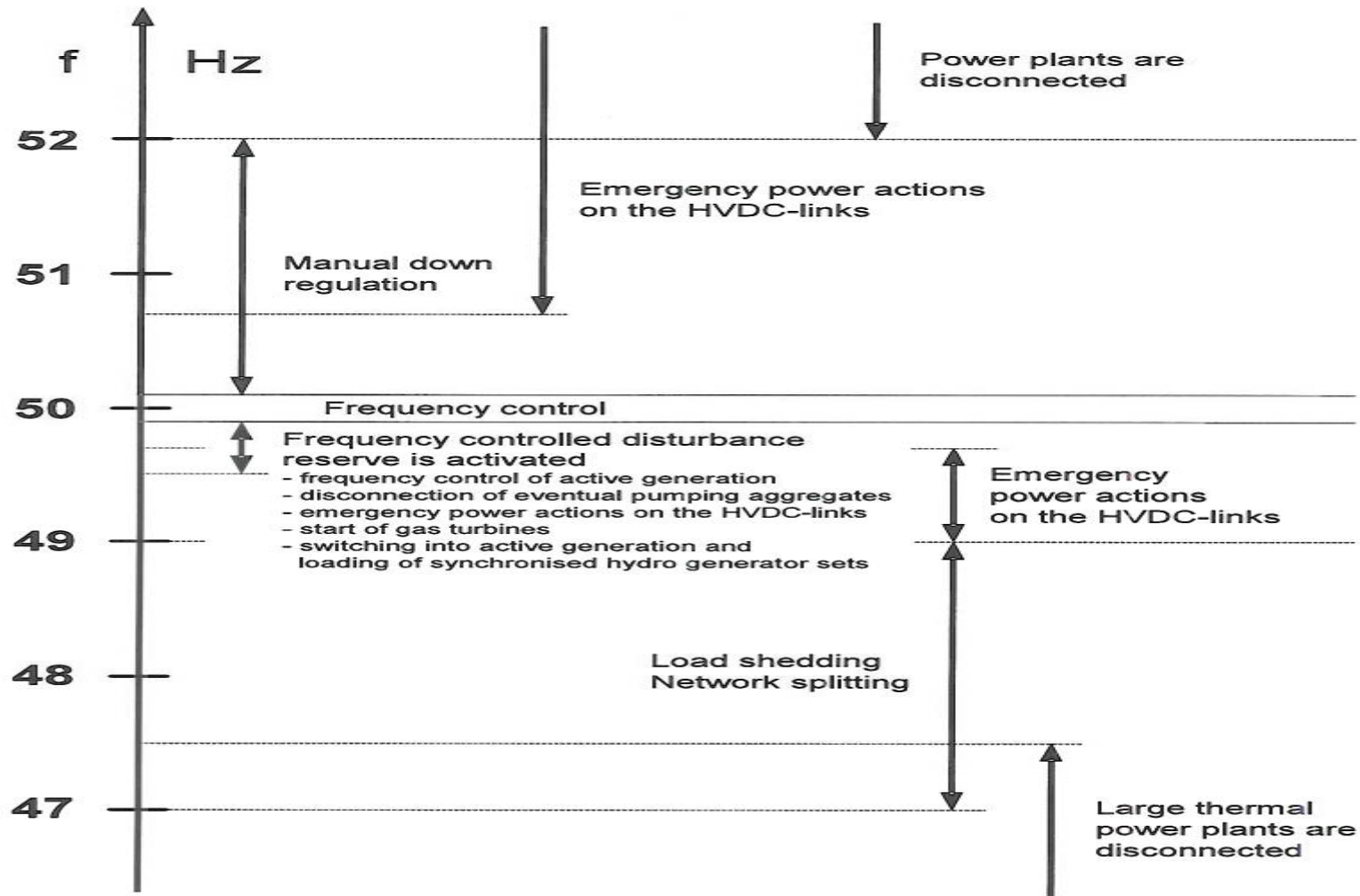
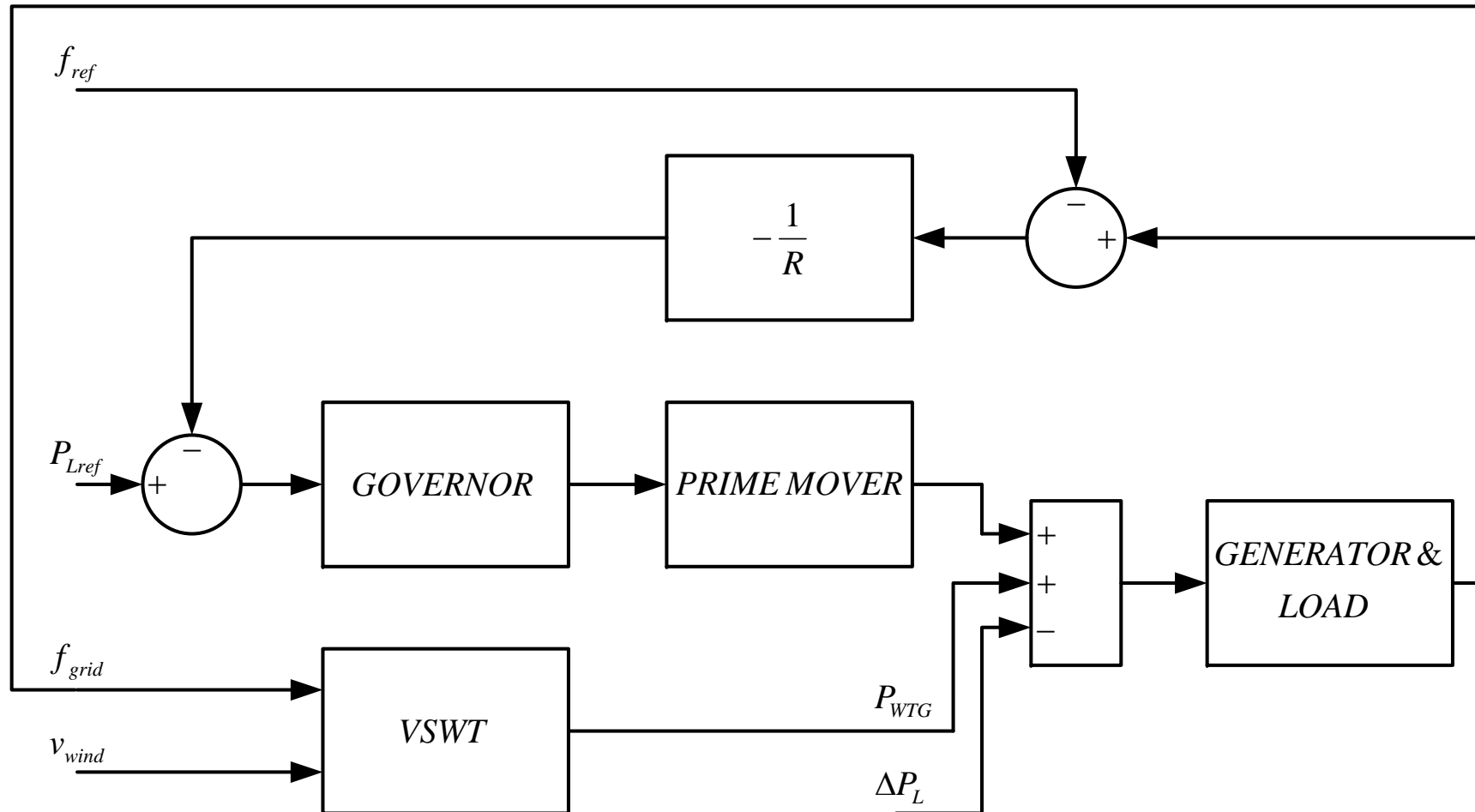


Figure 1 Frequency controlled actions in the Nordel-system

Frequency control model with wind power



Danish grid code for wind turbines

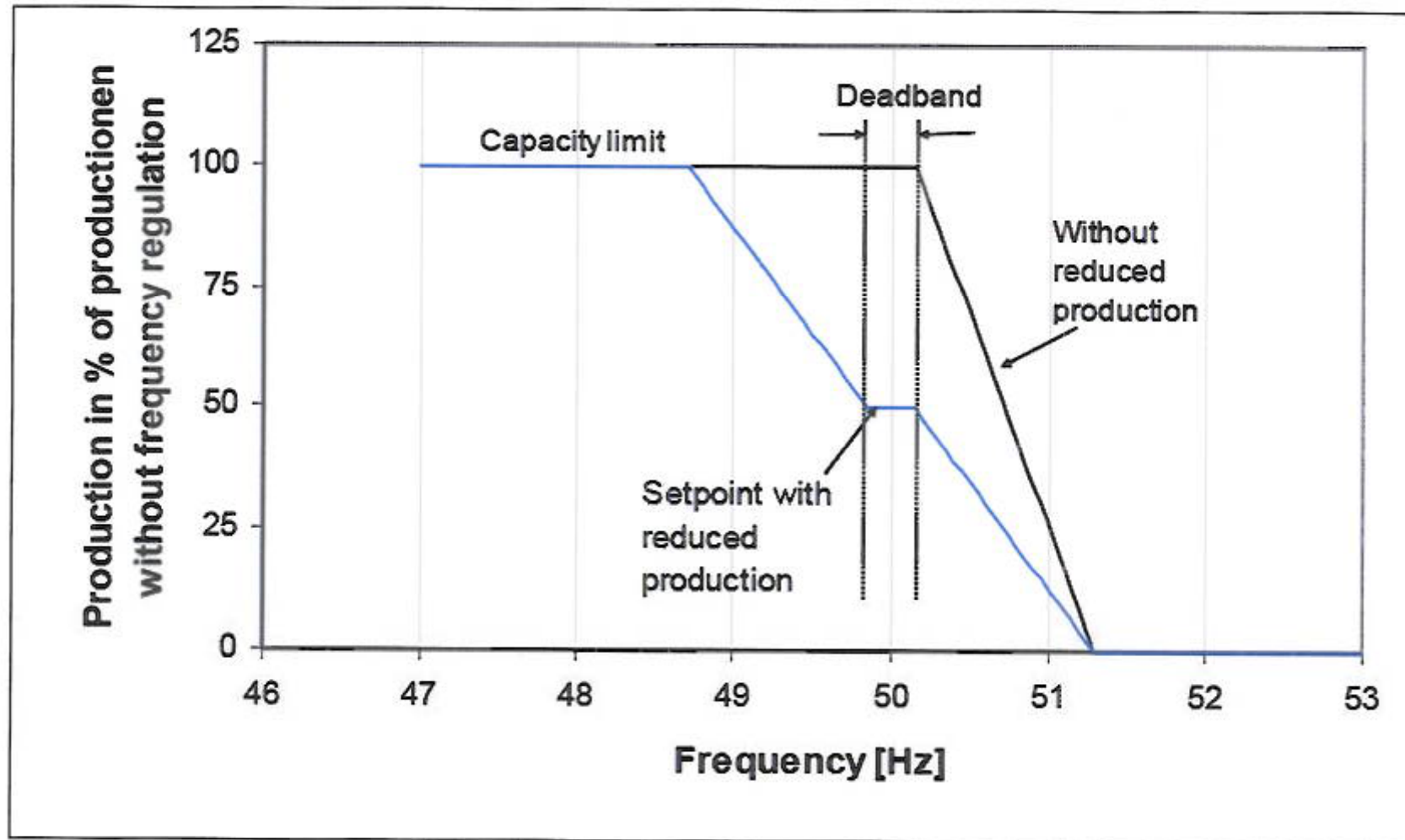
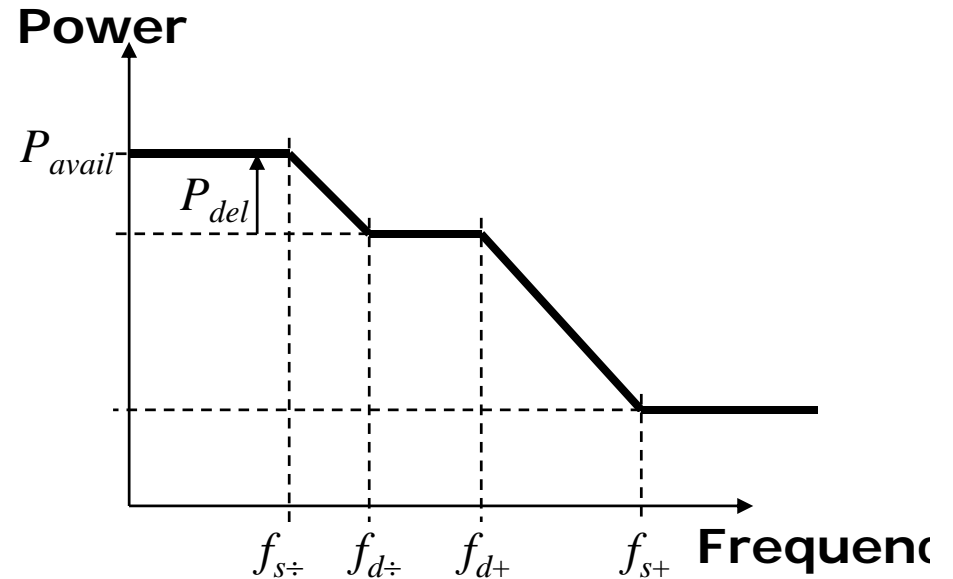
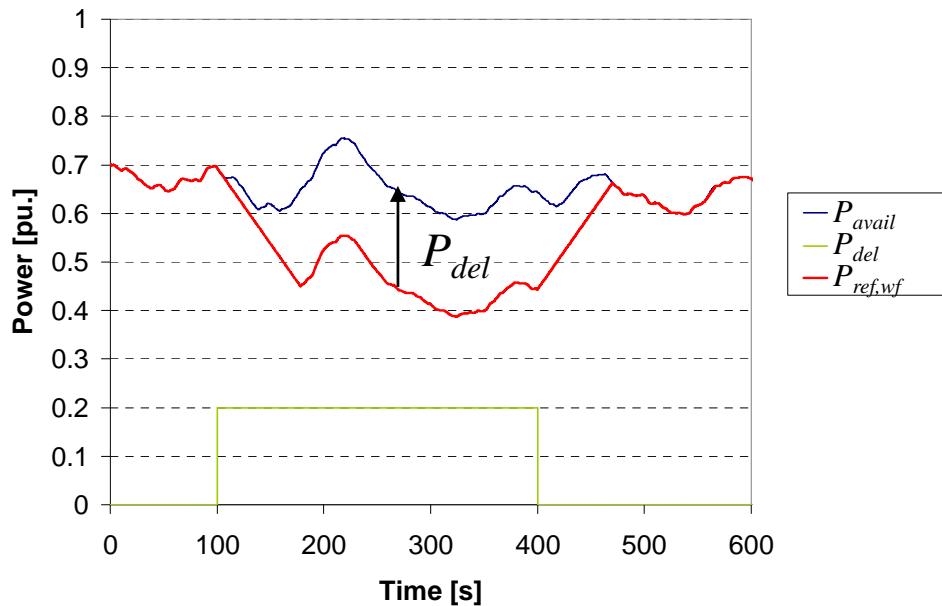


Figure 1 Frequency control based on the default values in Table 1.

Delta control – Danish grid code



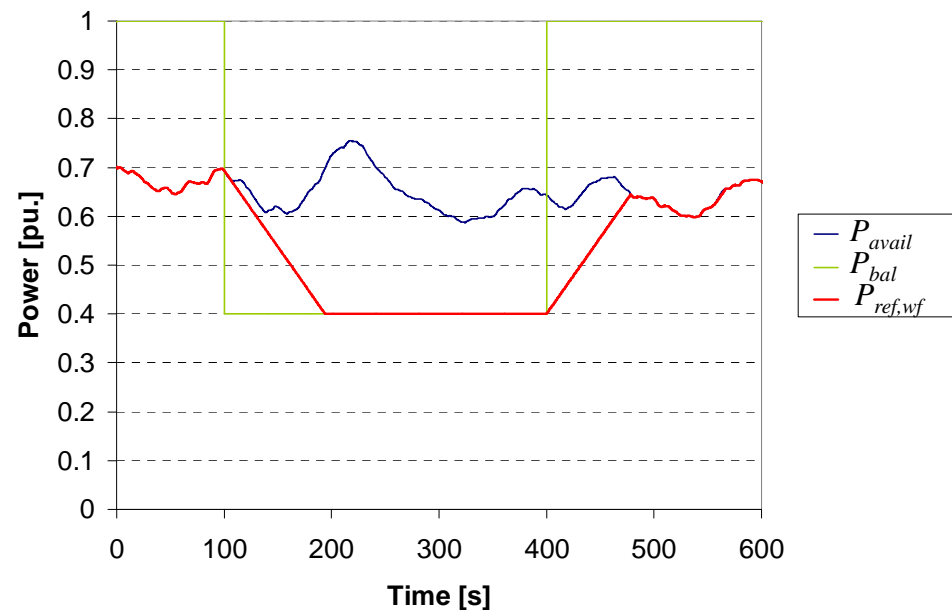
- Delta control provides fixed reserve
- Delta control already implemented in Horns Rev and Nysted
- Reserve can be utilised in frequency control (droop and deadband)



Balance control – Danish grid code



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

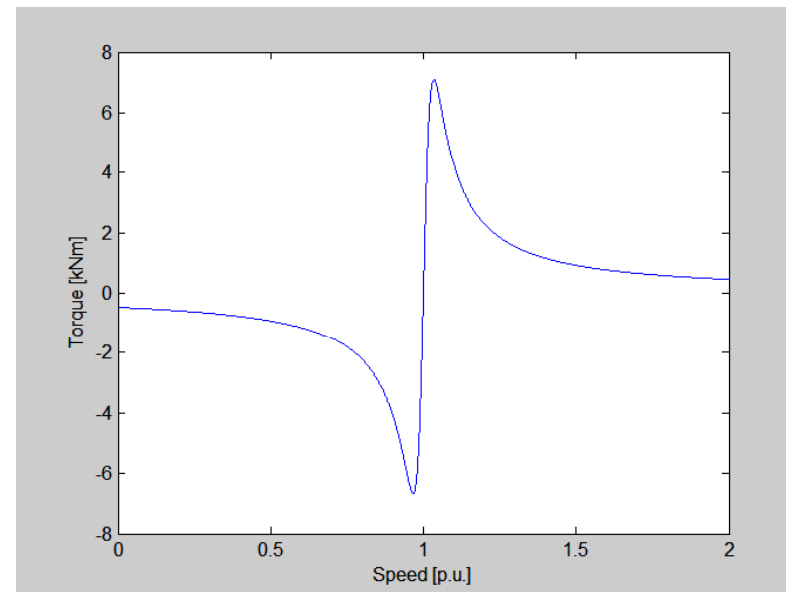
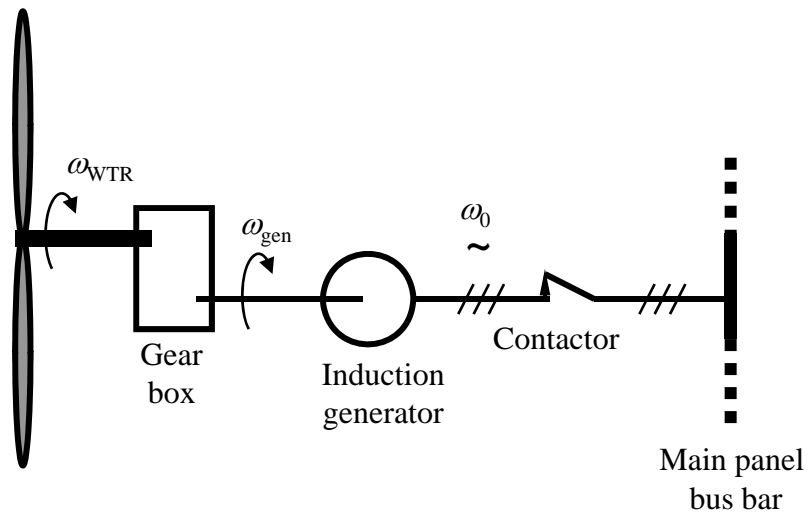


Sustainable Energy Master

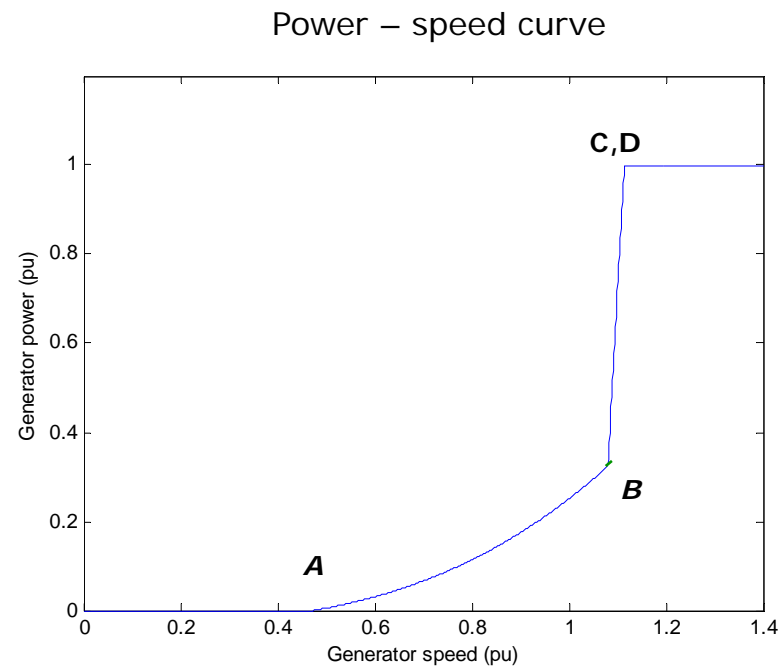
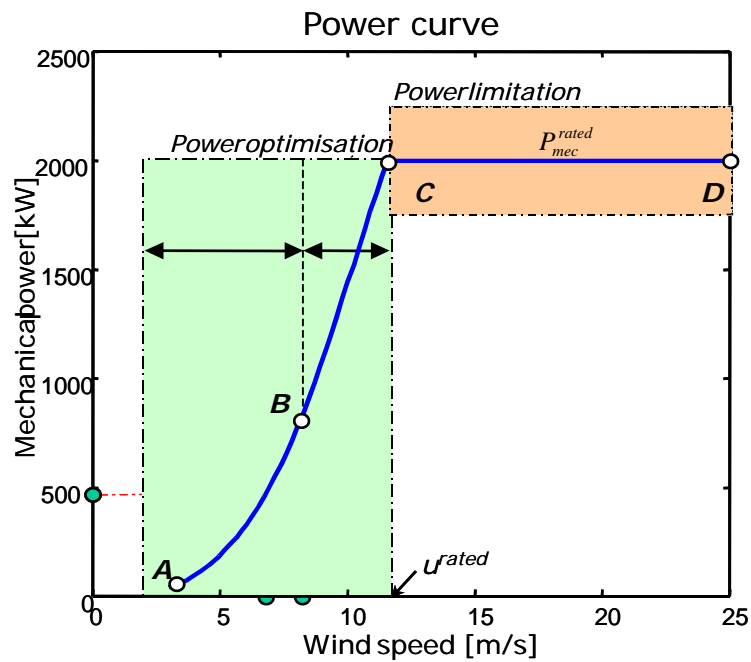


- 45002 Modelling and analysis of sustainable energy systems – 3 final projects on frequency control (1 week work load)
- Impact of wind power fluctuations on frequency control
 - The purpose was to study the impact of wind power fluctuations on the primary frequency control in small island power systems.
- 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.

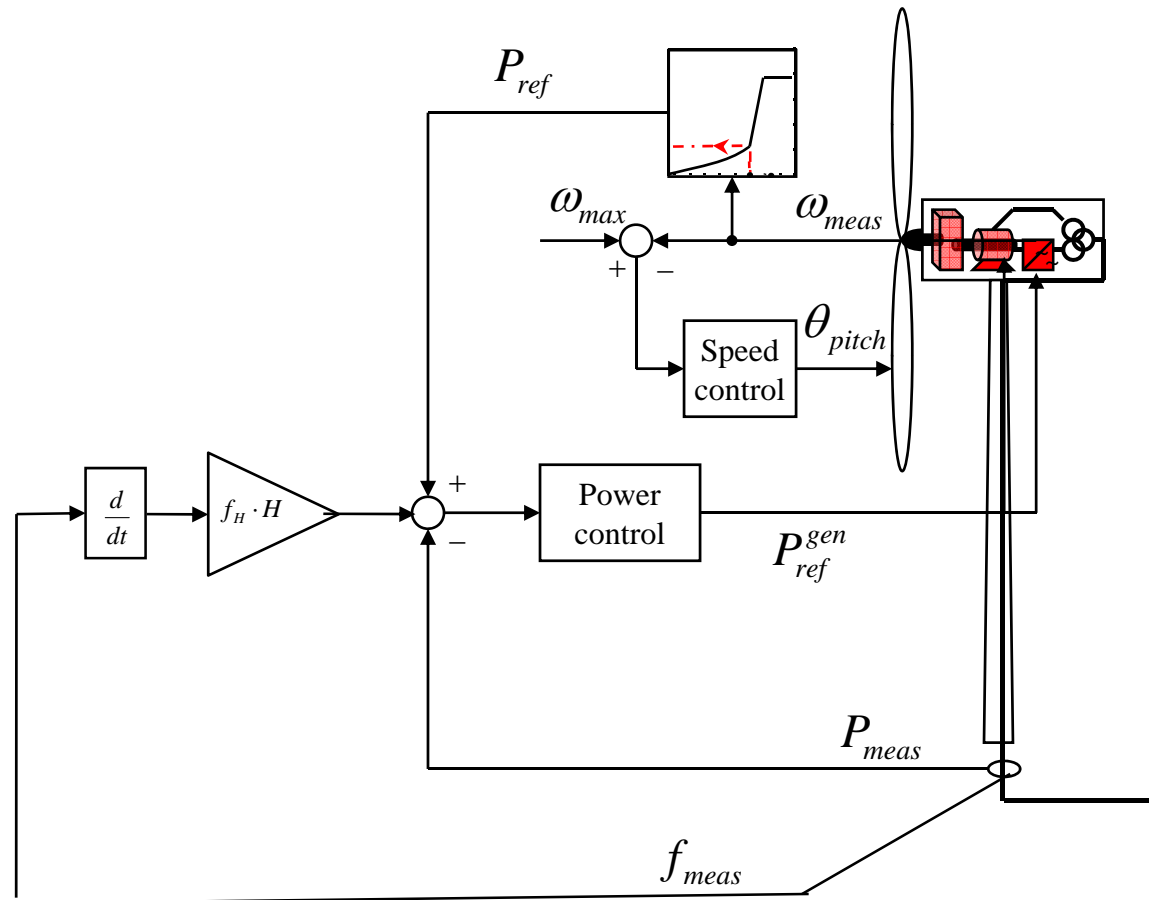
Fixed speed wind turbine "passive control" – natural inertia



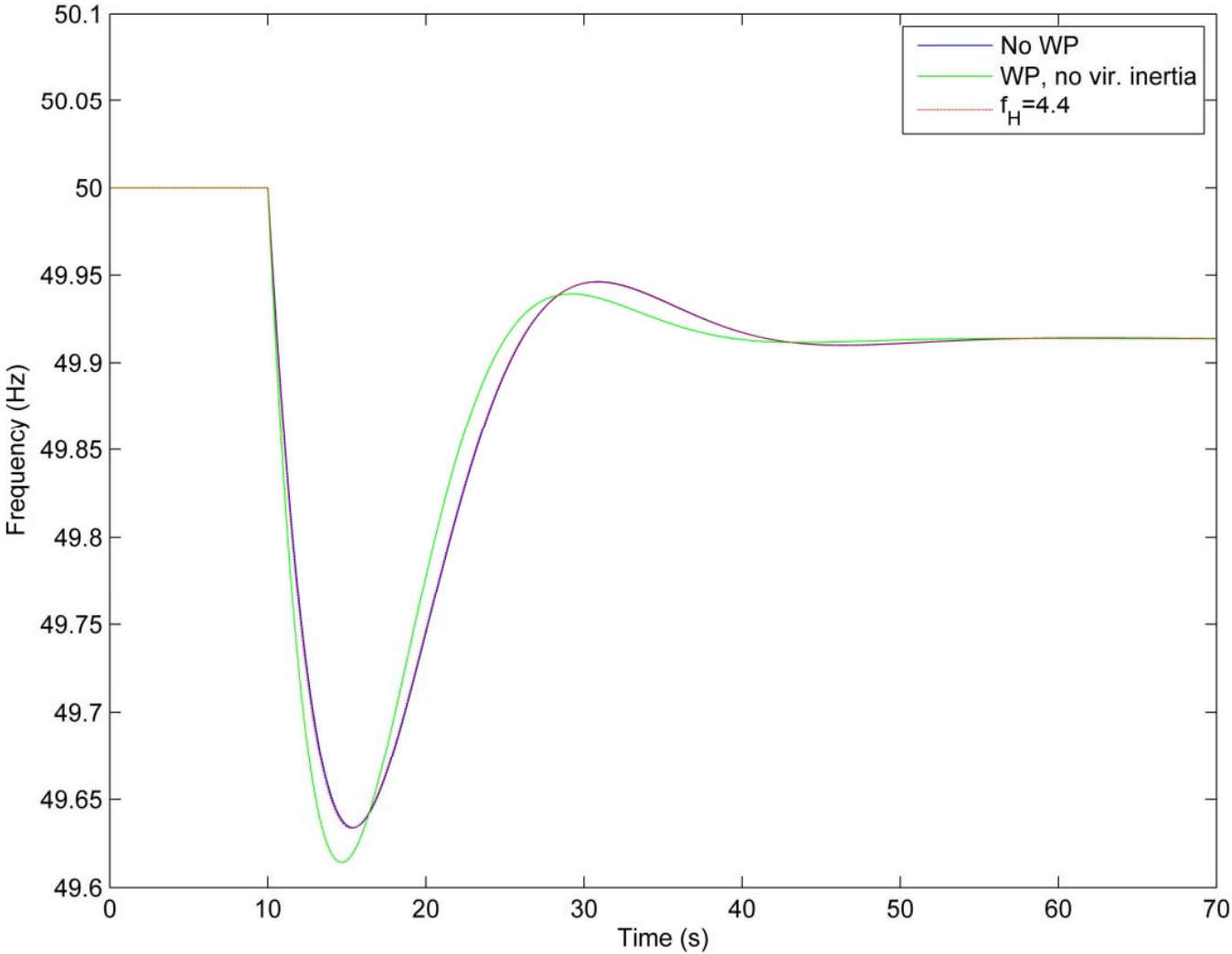
Variable speed wind turbine control strategy



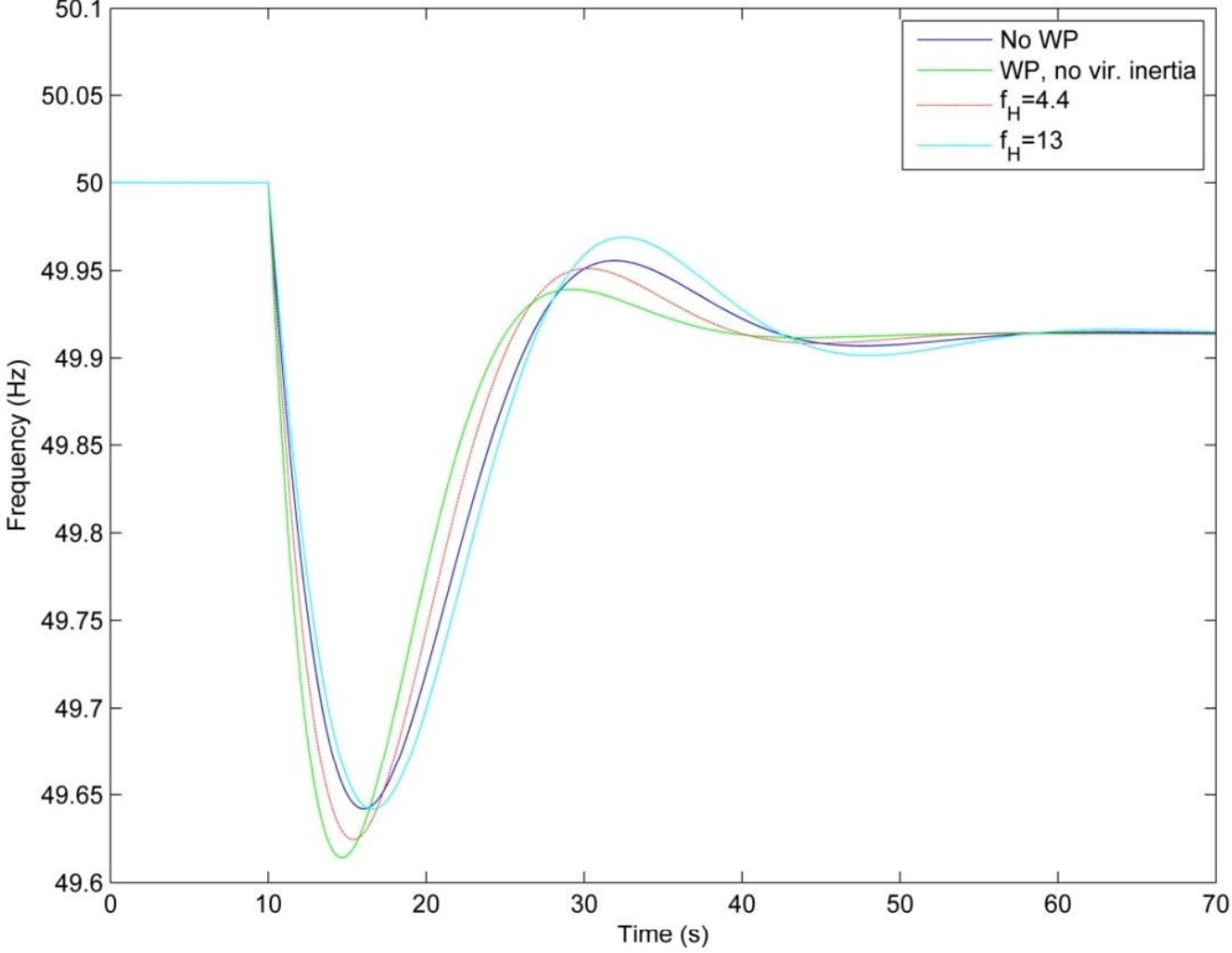
DFIG power / speed control overview



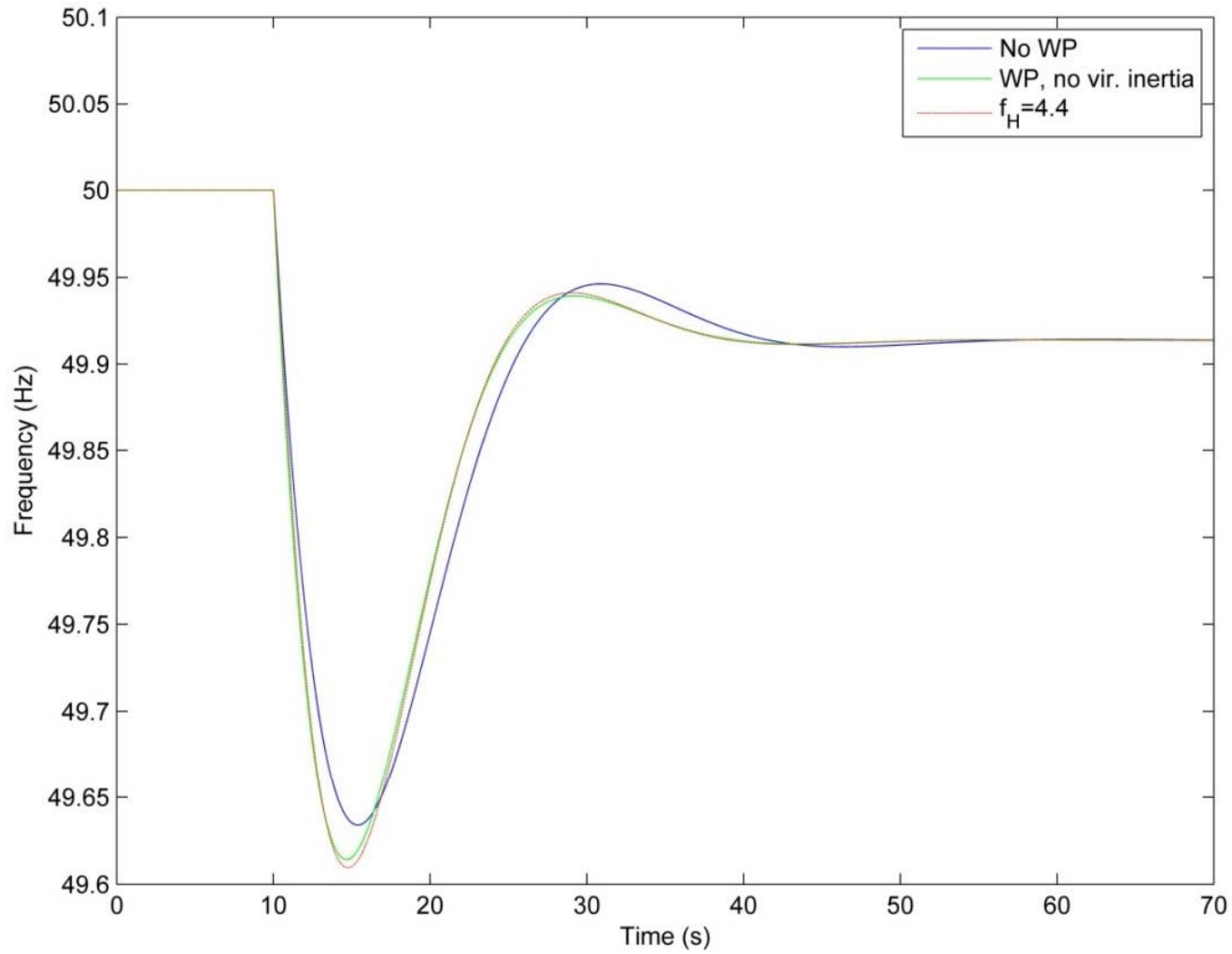
Virtual inertia control – 16 m/s



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