



## Ancillary Services from Wind Farms

**Hansen, Anca Daniela; Margaris, Ioannis; Zeni, Lorenzo; Sørensen, Poul Ejnar; Cutululis, Nicolaos Antonio**

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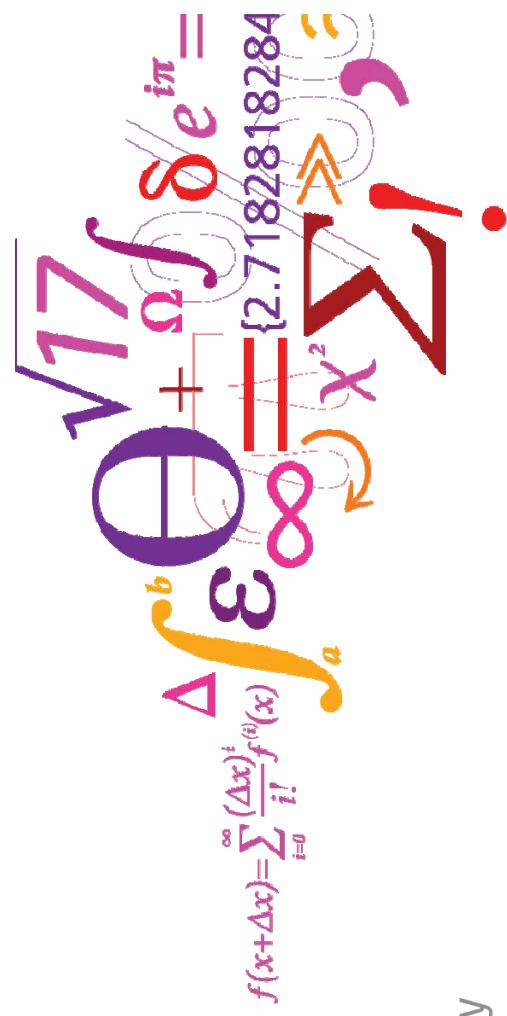
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# Ancillary Services from Wind Farms

Anca D. Hansen  
Ioannis Margaris  
Lorenzo Zeni  
Poul Sørensen  
Nicolaos A. Cutululis (presenter)

$$\int_a^b \mathcal{E}^{\Theta} = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x) = \frac{e^{\Theta}}{2.7182818284}$$


# Ancillary services

**Ancillary Services** are support services in the power system, particularly those which are necessary to support the transmission capacity and are essential in maintaining power quality, reliability and security of the grid

Classification (Alvarado, 1996):

**Real vs reactive power**, time and insurance

Real power: **frequency regulation**, ramping schedules, energy imbalance, loss compensation and unit commitment

Reactive power: **voltage regulation**, capacitor switching and generator scheduling

# Danish TSO requirements

## Danish TSOs requirements:

- Fault Ride Through Capabilities

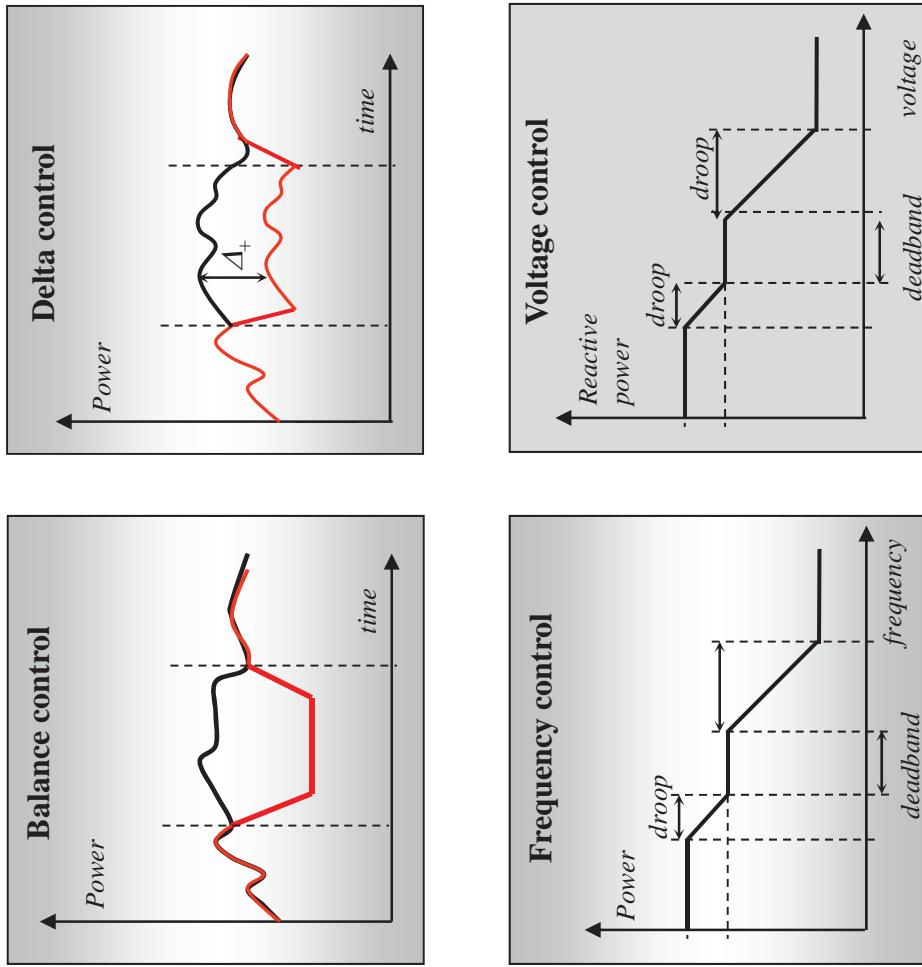
- Power control Capabilities:

- Active power control functions:

- Balance control
- Delta control
- Power gradient limiter
- Automatic frequency control

- Reactive power control functions:

- Reactive power control
- Automatic voltage control



# Wind turbine control

## Traditionally:

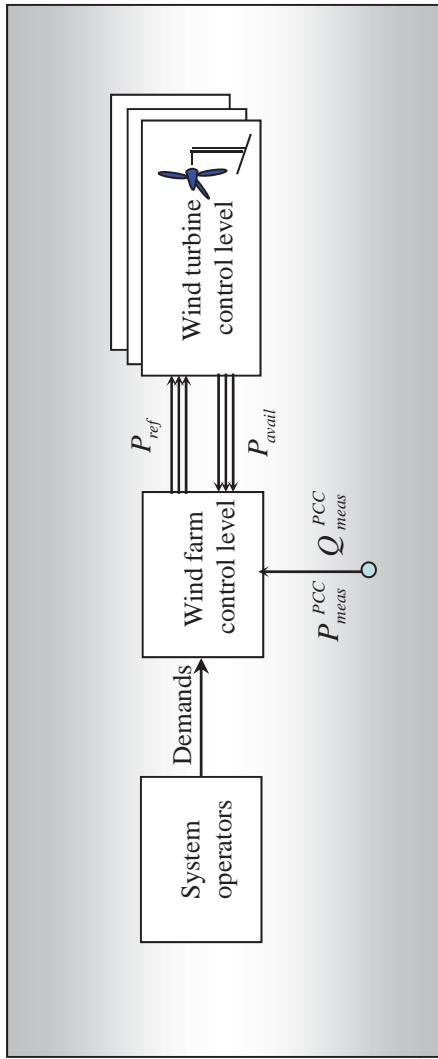
- to produce maximum possible power
- to reduce the structural loads on the mechanical components and thus theirs costs

## Additionally now:

- to optimize the integration of the wind turbines in the power system, in order to secure quality, stability and reliability
- to reduce the required grid connection costs

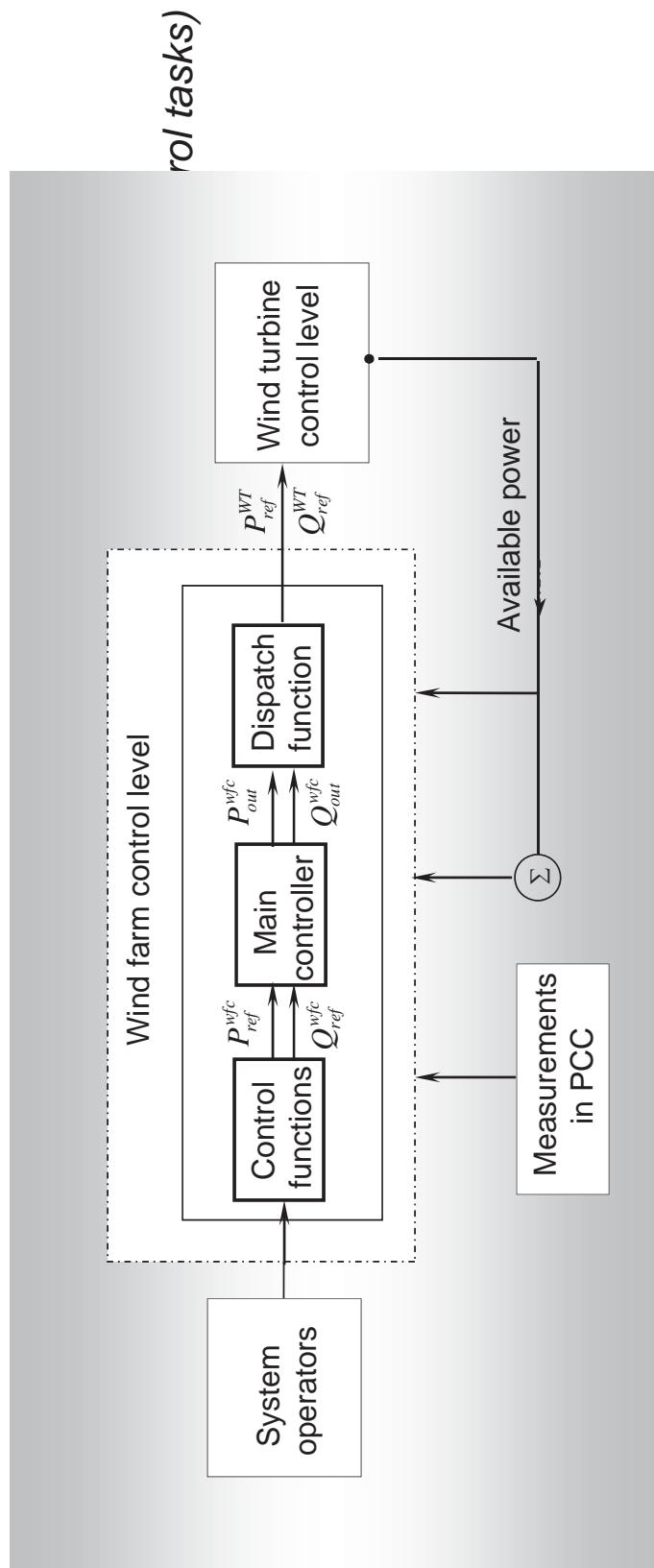


# Wind farm hierarchical supervision

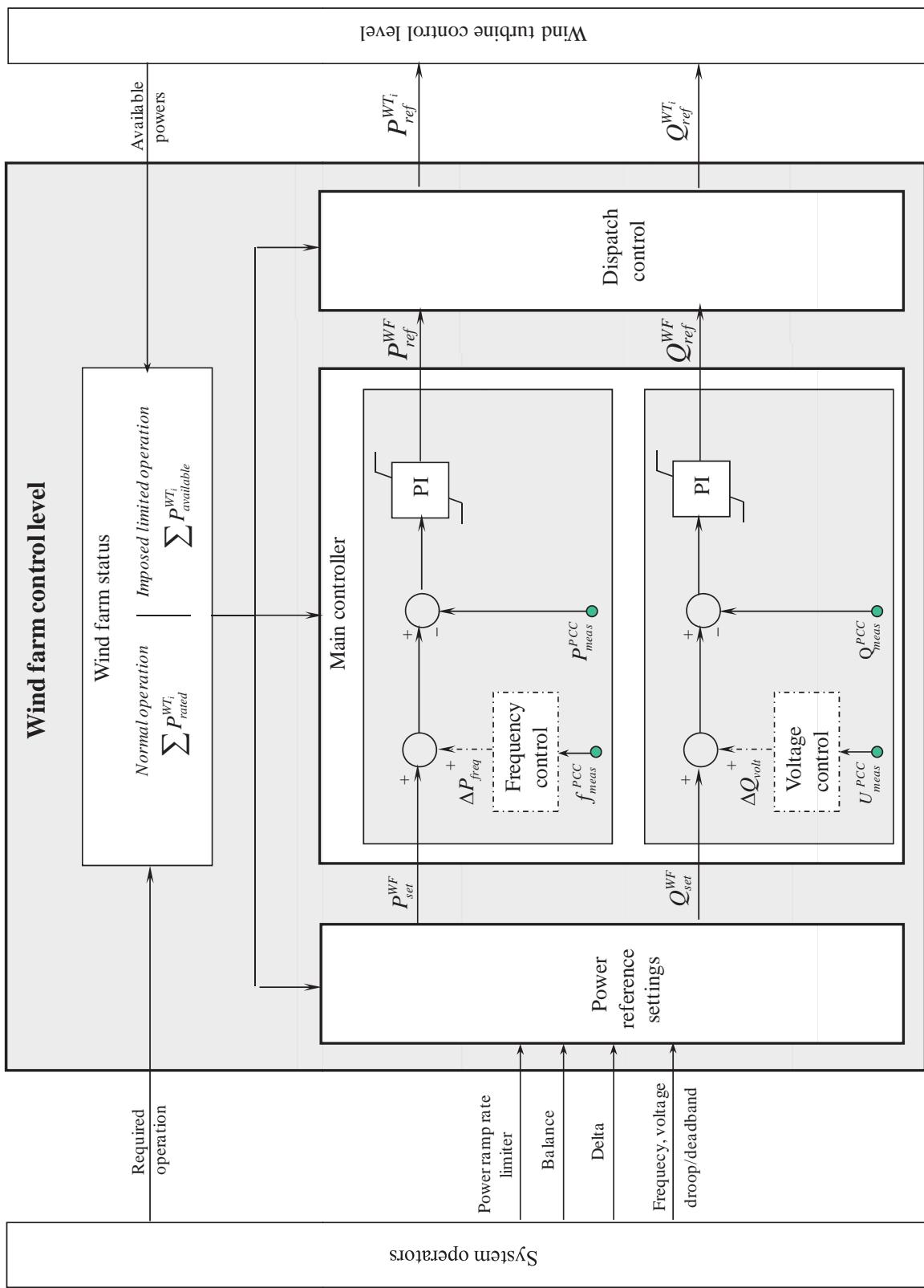


Wind farm controller's goal is to meet grid integration challenges!

System  
•



# Wind farm control level



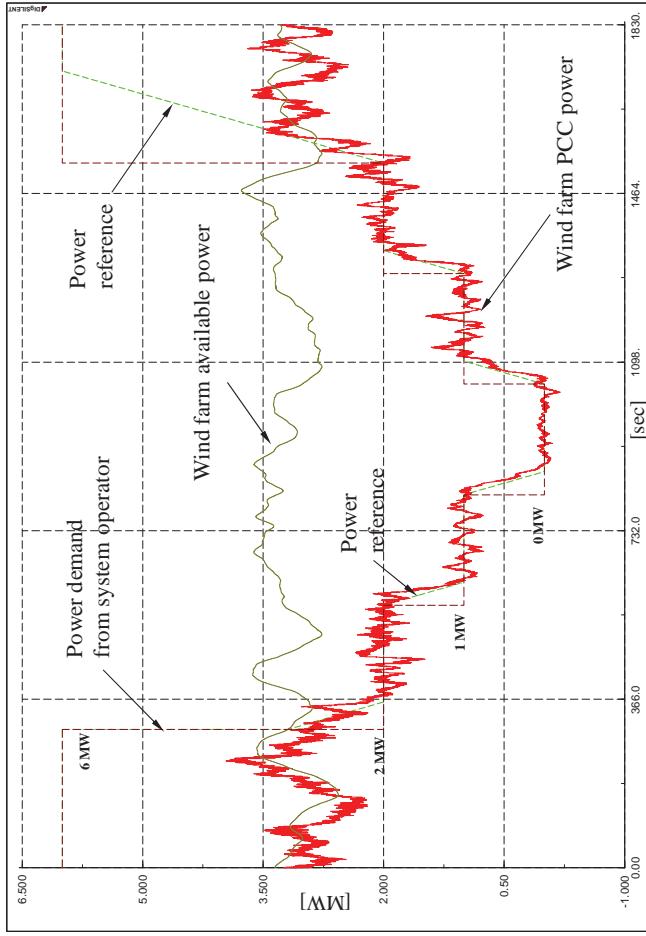
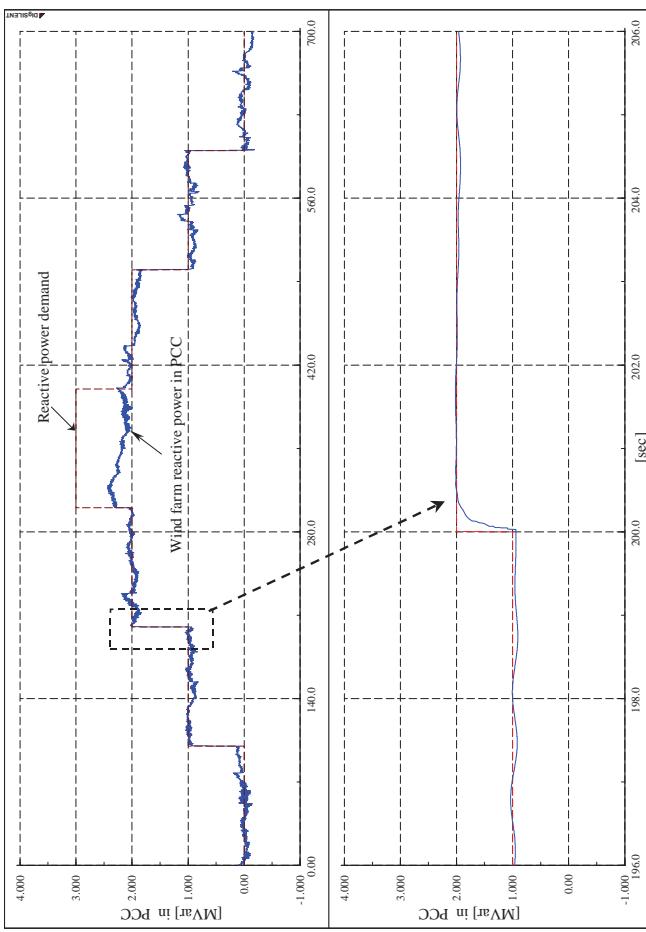
# Power control grid support: ASWT wind farm

## ASWT equipped with appropriate controller:

- can provide a relatively fast response to changes in active power demands.
- new P setpoint reached within a few seconds
- quickly control of voltage

## Dynamic phase control

- immediate response to Q demands  
(*in the limits of capacitor bank*)
  - new Q reference reached in less than 0.5 s.



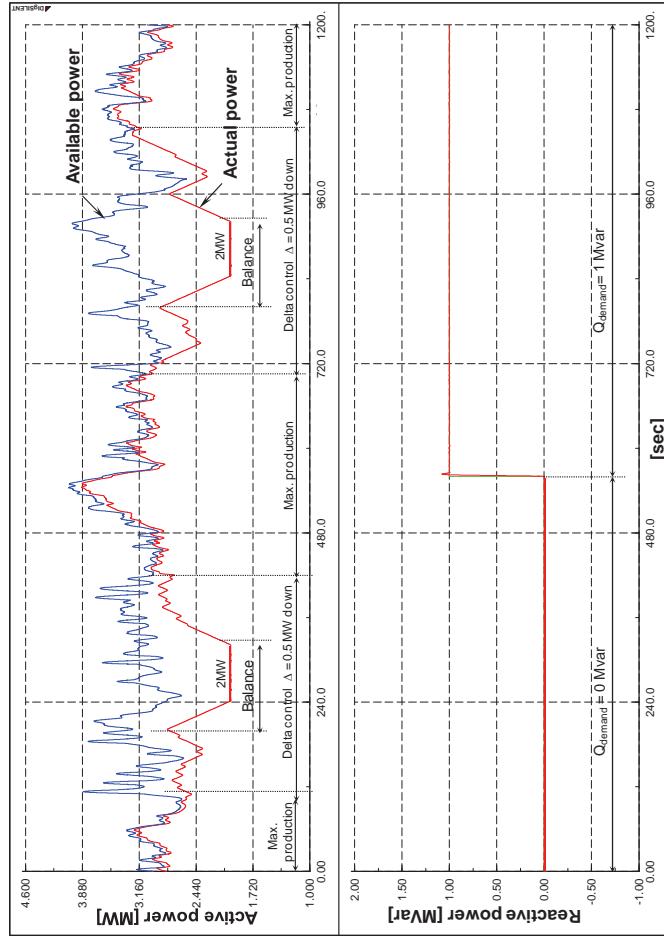
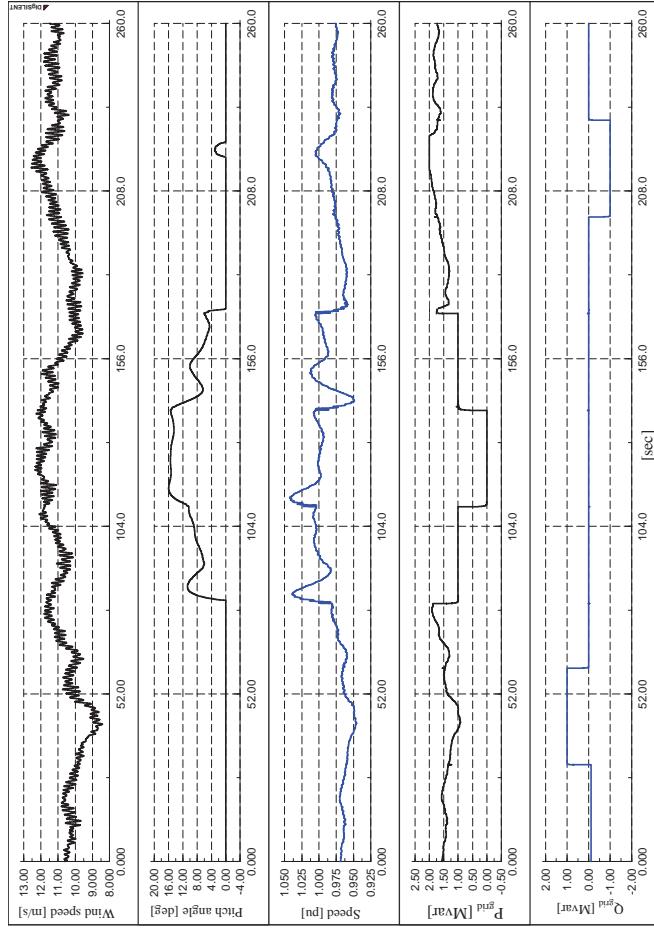
# Power control grid support: DFIG/PMSG wind farm

## Variable speed wind turbines (DFIG or PMSG)

- respond immediately to changes in P and Q demands from power system operator.
- control independently P and Q

## PMSG have better grid support capability than DFIG

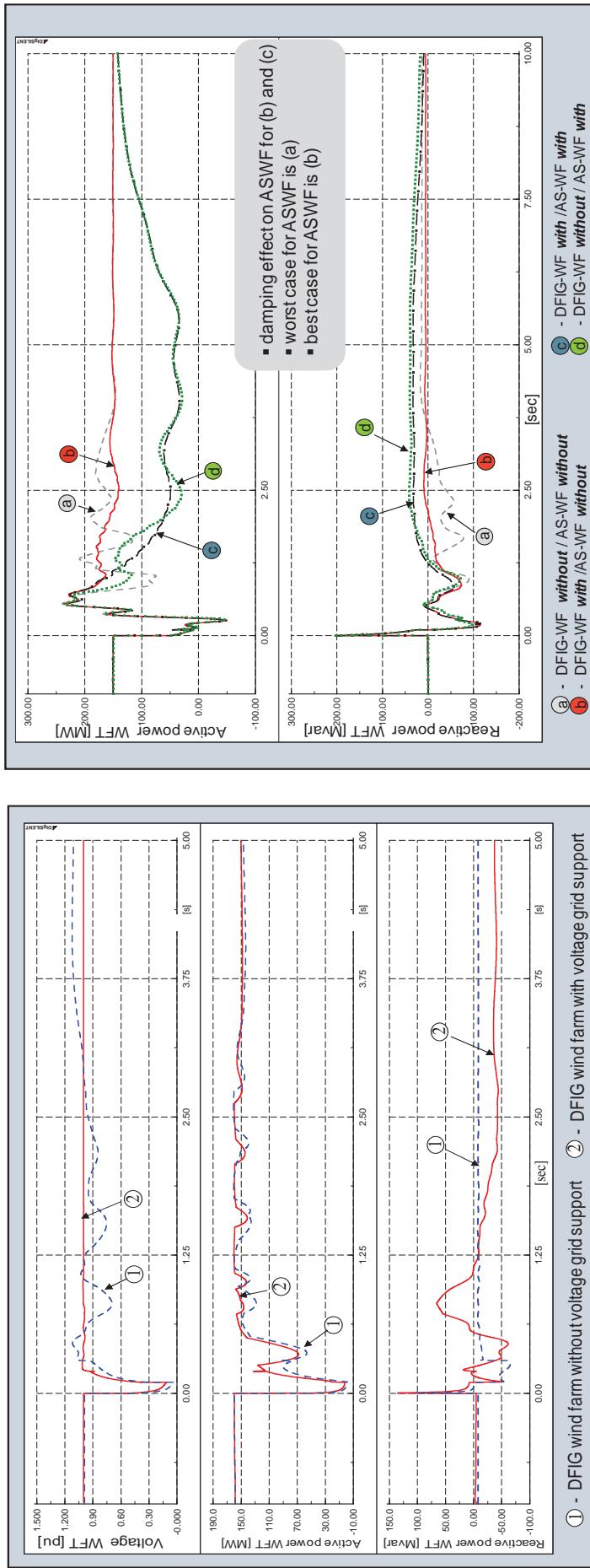
- can provide a higher amount of reactive power
- can support voltage level to a higher level
- recovers faster the voltage



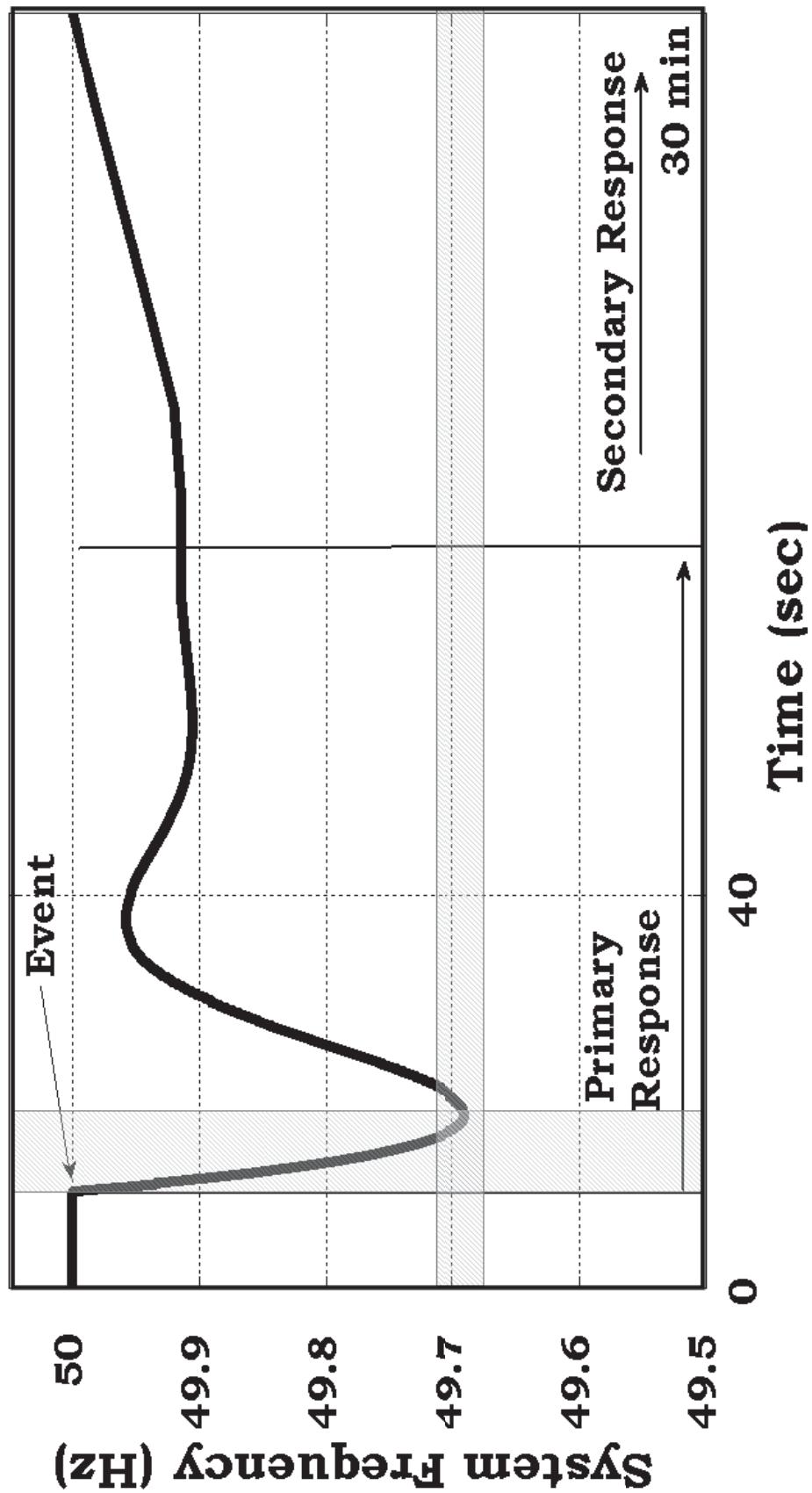
# Voltage control grid support DFIG/PMSC wind farm

## Variable speed wind turbines (DFIG or PMSG)

- participate to properly reestablish the grid voltage during a grid fault.
- can help a nearby active stall wind farm to FRT, without any additional ride through control setup in the nearby active stall wind farm

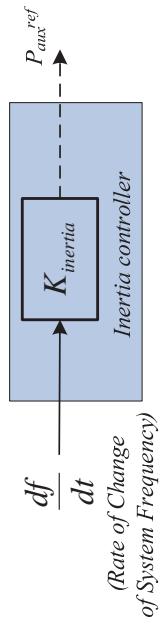


# Frequency control



# Frequency control – primary response

## (i) Inertia Control (“virtual inertia”)



## (ii) Droop Control

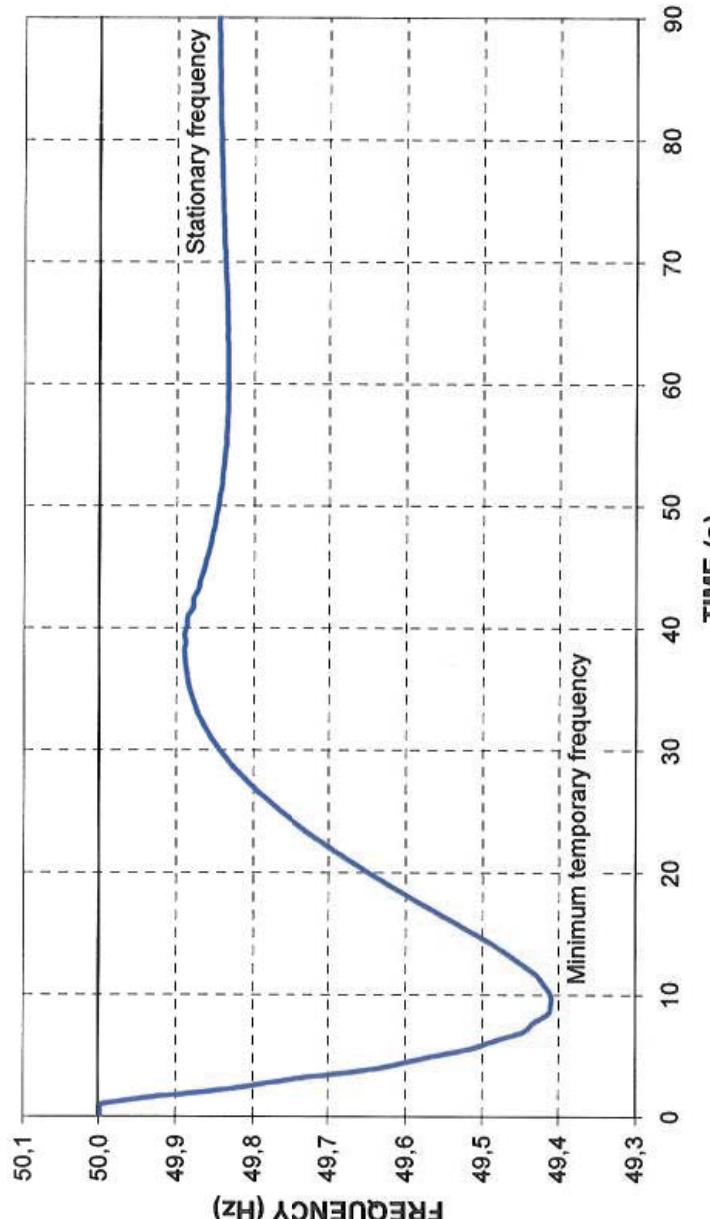
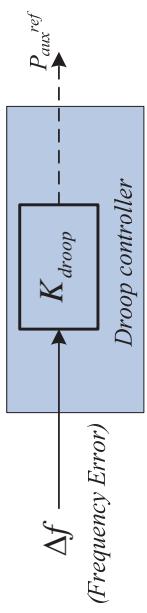
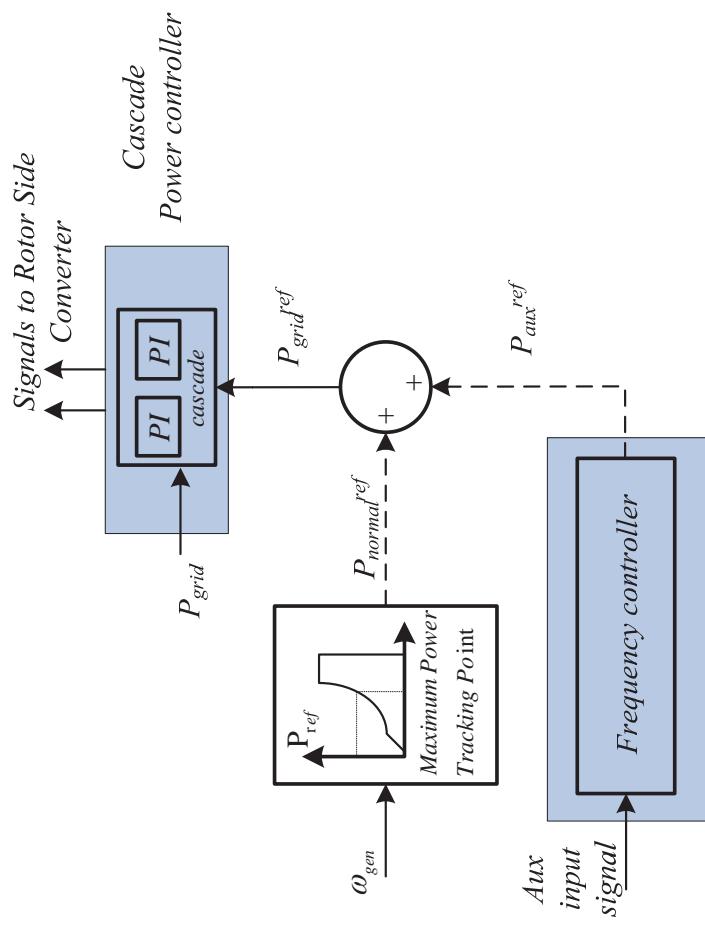


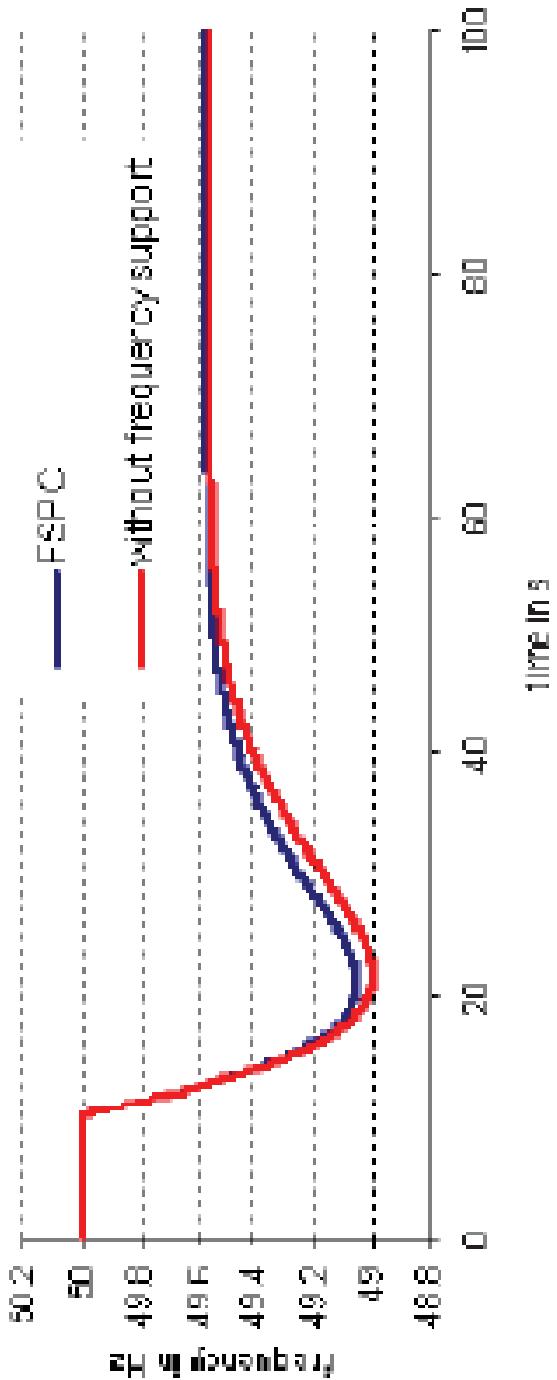
Figure 6 Development in frequency in Nordel following production outage

# Frequency control scheme



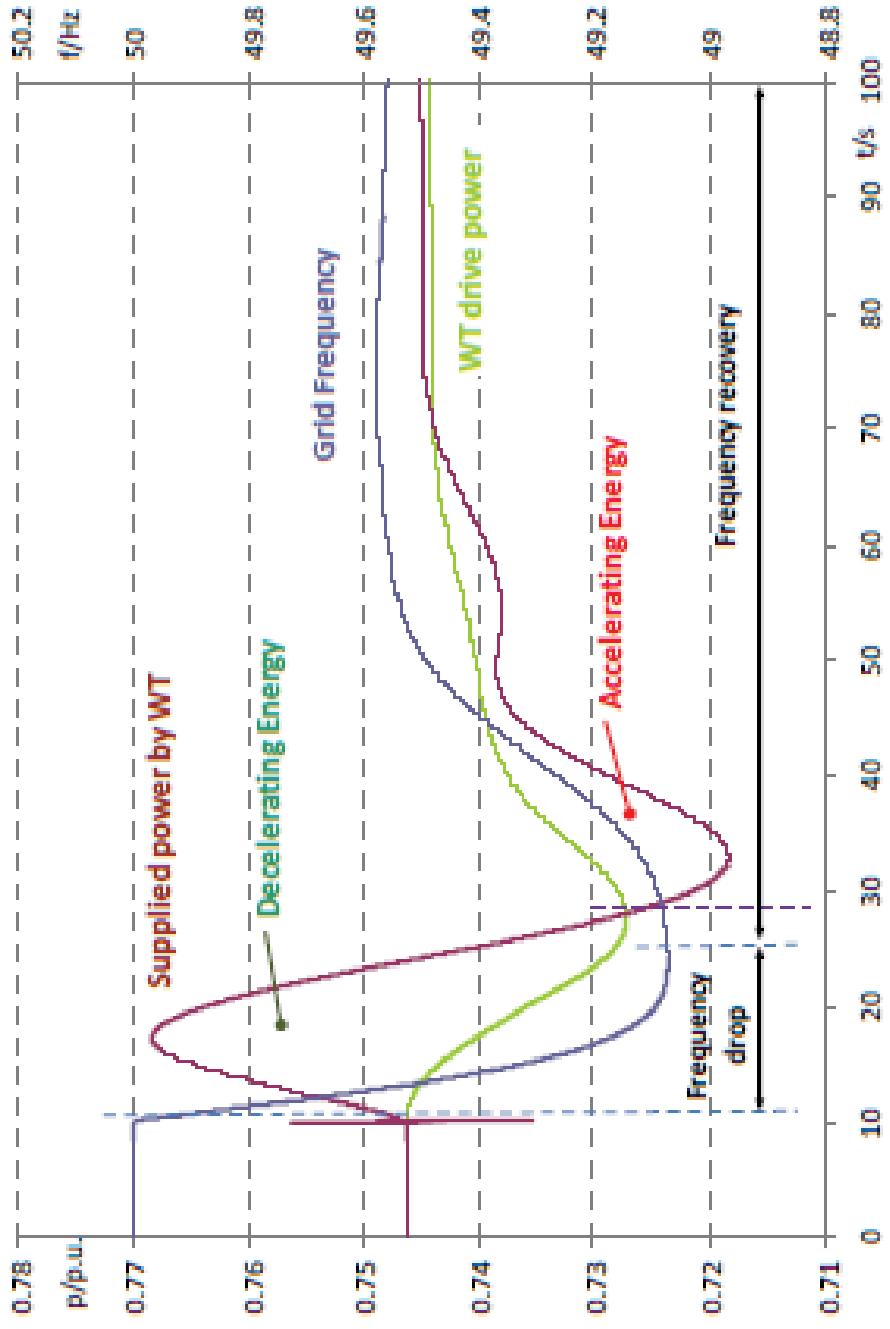
General frequency control scheme

# Droop control



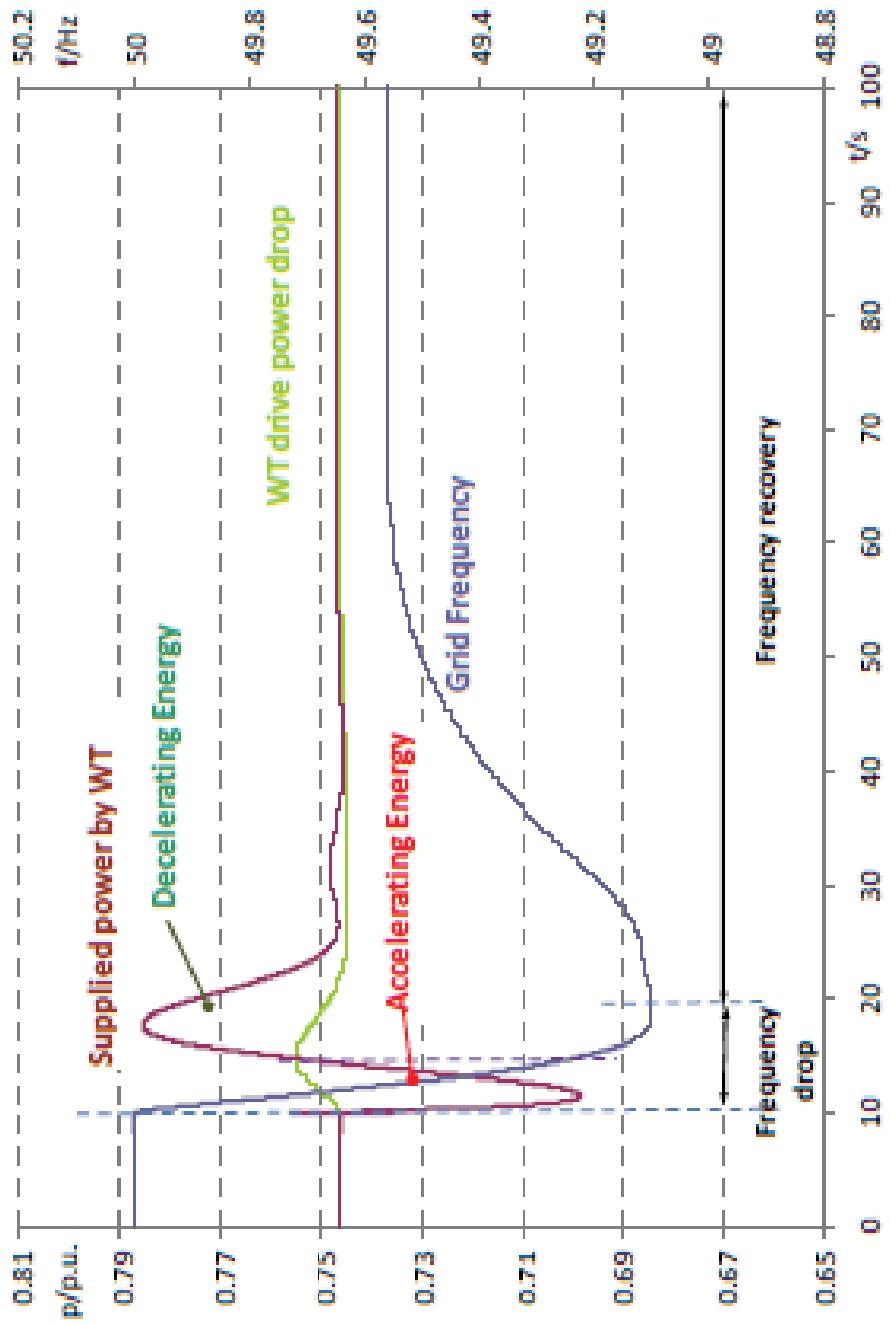
Source : I. Erlich, 2010

# Kinetic energy 1 (virtual inertia)



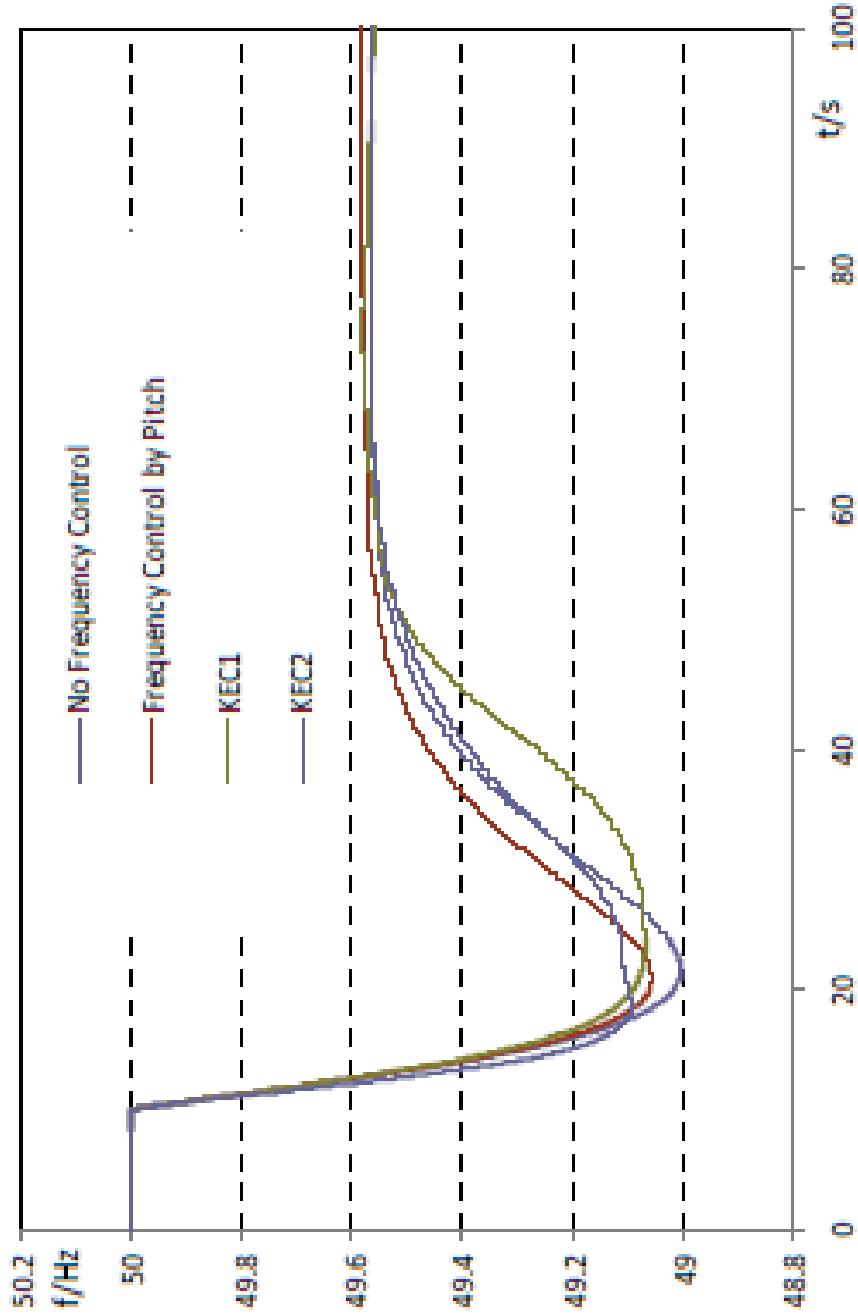
Source : I. Erlich, 2010

## Kinetic energy 2 (temporary droop)



Source : I. Erlich, 2010

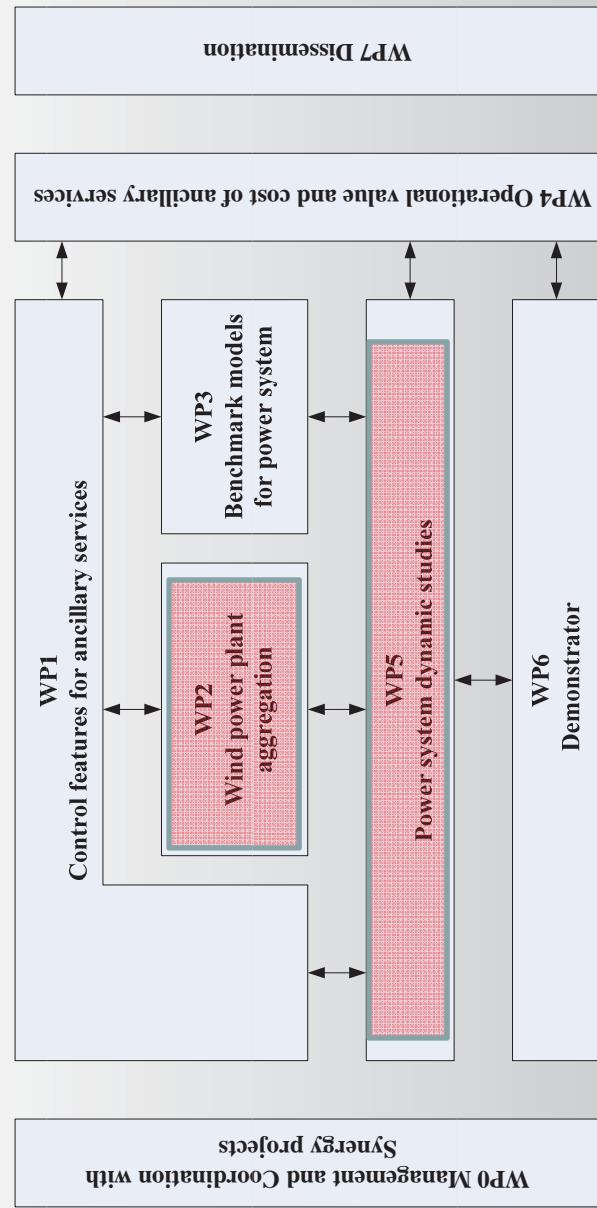
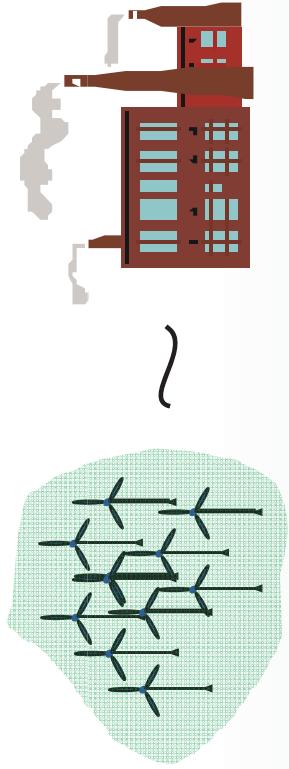
# Frequency control



Source :I. Erlich, 2010

# Enhanced Ancillary Services from Wind Power Plants (EASEWIND)

**To develop, assess and demonstrate technical solutions for enabling wind power to have similar power plant characteristics as conventional generation units.**



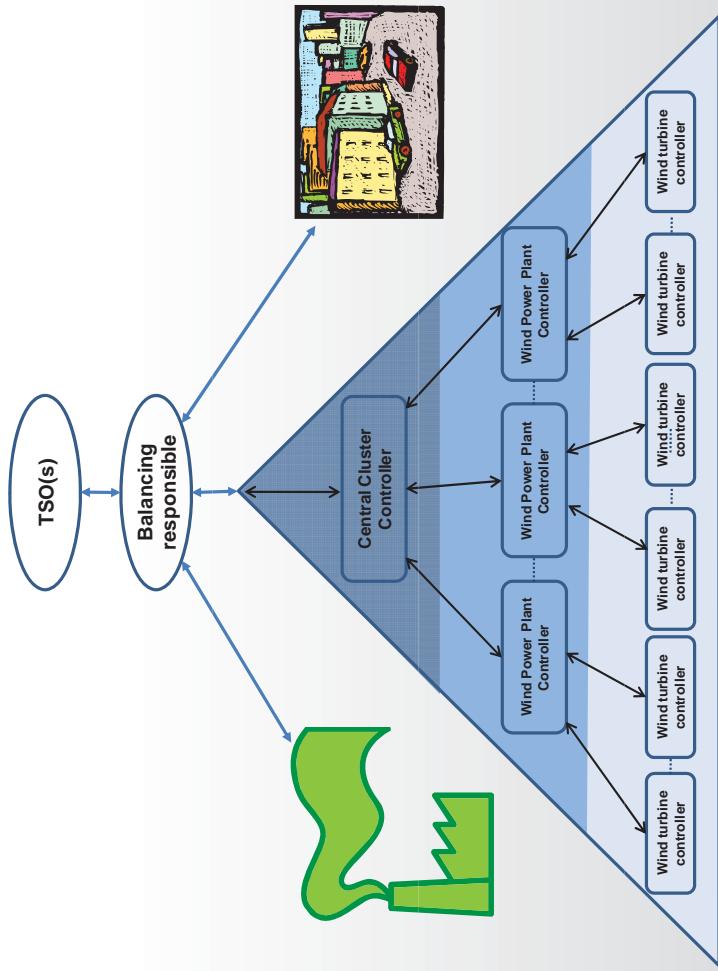
**Partners:**

- Vestas Power Programme
- Risø DTU – VES and IES
- DTU/IMM
- AAU/IET

# DC grids for integration of large scale wind power (OffshoreDC) – [www.offshoredc.dk](http://www.offshoredc.dk)

## Overall objective:

To develop and apply the Voltage Source Converter (VSC) based HVDC grid technologies in the deployment of offshore wind power.



## Partners:

- Risø DTU – VES
- Vestas Technology R&D
- DTU Elektro
- ABB
- DONG Energy
- EnergiNet.dk
- Chalmers University
- SINTEF
- VTT

## Cluster control (Ph.D student):

Communication and control in clusters of wind power plants connected to HVDC offshore grids  
(control system architecture, allocation of control tasks, communication protocol)