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Ancillary services: Research results from wind power plants

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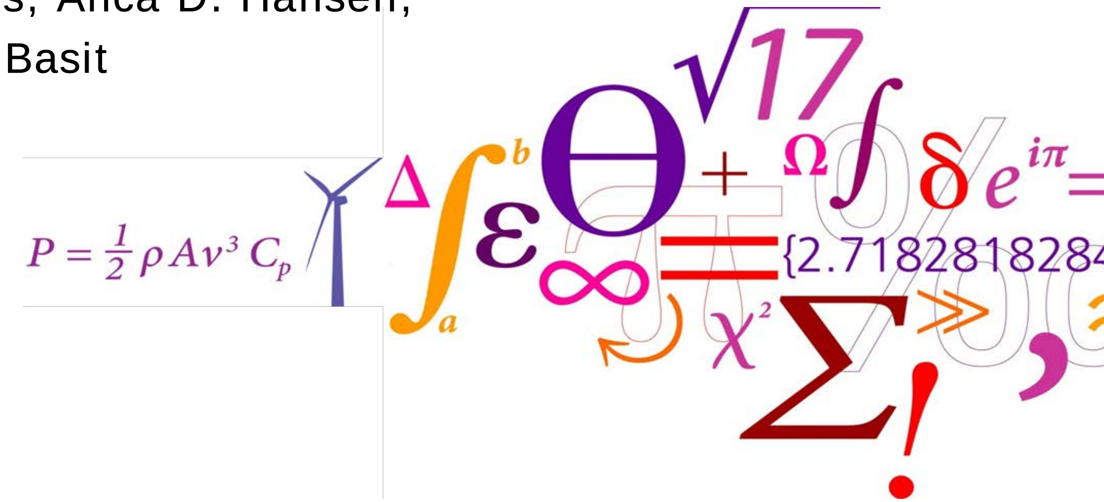

DTU Wind Energy
Department of Wind Energy

Program outline

Ancillary Services: Research Results From Wind Power Plants

- ***Characteristics and requirements*** for ancillary service provision to European power systems - now and in the future

- ***Technical capabilities*** required by wind power plants in order to provide ancillary services - a focus on ***state-of-the-art industry and R&D*** (simulation based) perspectives

- What are the ***economic incentives and barriers*** to providing ancillary services?

- What are the ***next steps*** for researchers, developers, system operators and turbine manufacturers to allow further penetration of wind into European grids?

Definitions of ancillary services

- CIGRÉ report - overview of International Practices
  - ***definitions*** for ancillary services can ***differ significantly*** based on who is using the terms. While some definitions emphasize the importance of ancillary services for ***system security and reliability***, others mention the use of ancillary services to **support electricity transfers from generation to load** and to ***maintain power quality***
- Some TSOs are including ***more specific types*** of ancillary services than others ***because***
  - ***differences in*** the ***definitions*** (above)
  - some of the required properties of the generation plants are ***embedded in conventional power plants*** using directly grid connected synchronous generators.
  - ***new ancillary service products*** seem to pop up in power systems ***with large scale penetration of renewables***.

Requirements for – and types of – ancillary services

- Active power ***reserves*** (using ENTSO-E glossary)
  - Frequency containment reserves (FCR)
  - Frequency restoration reserves (FRR)
  - Replacement reserves (RR)
- Properties required to ***maintain*** power system ***stability*** today (Energinet.dk terminology)
  - Short-circuit power
  - Continuous voltage control
  - Voltage support during faults
  - Inertia
- ***Possible new*** ancillary service ***products*** (research references)
  - Fast frequency response (and inertia support)
  - Synchronising power
  - Power oscillation damping
  - Black-start capability

RESERVICES CONSORTIUM

www.reservices-project.eu

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EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

EPIA
European Photovoltaic Industry Association

3E

VTT

Fraunhofer
IWES

acciona
Energía

UCD
DUBLIN

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EDSO
for smart grids

MAINSTREAM
RENEWABLE
POWER

SMA
SOLAR TECHNOLOGY

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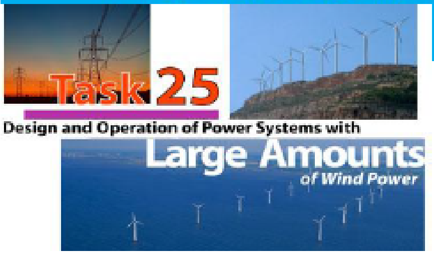


IEA WIND Task 25:
Design and operation of power systems with large amounts of wind power

www.ieawind.org

China has joined the Task from the beginning of 2012. This makes the total number of participants 16 for 2012-14

iea wind

Country	Institution
Canada	Hydro Quebec (A. Robitaille); Manitoba Hydro (T. Molinski)
China	SGERI (Bai Jianhua, Hu Bo)
Denmark	DTU Wind (P. Sørensen); TSO Energinet.dk (A. Orths)
EWEA	European Wind Energy Association (I. Pineda)
Finland	VTT (H. Holttinen, J. Kiviluoma) – Operating Agent
Germany	Fraunhofer IWES (B. Lange); TSO Amprion (A.Gesino)
Ireland	ECAR/UCD (Mark O'Malley); TSO EirGrid
Italy	TSO Terna Rete Italia (Enrico Maria Carlini)
Japan	Tokyo Uni (Junji Kondoh), Kansai Uni (Yoh Yasuda)
Norway	SINTEF (John Olav Tande, Atle Rygg Årdal)
Netherlands	ECN (Jan Pierik); TUDelft (M. Gibescu)
Portugal	LNEG (Ana Estanquiero); TSO REN (Jose Osario); INESC-Porto (J. Pecas Lopes); UTL-IST (Ferreira Jesus)
Spain	University of Castilla La Mancha (Emilio Gomez Lazaro)
Sweden	KTH (Lennart Söder)
UK	DG&SEE (G.Strbac Imperial, O.Anaya Lara Strathclyde)
USA	NREL (M.Milligan); UVIG (J.C.Smith); DoE (C. Clark)

State of the art technical capabilities in industry

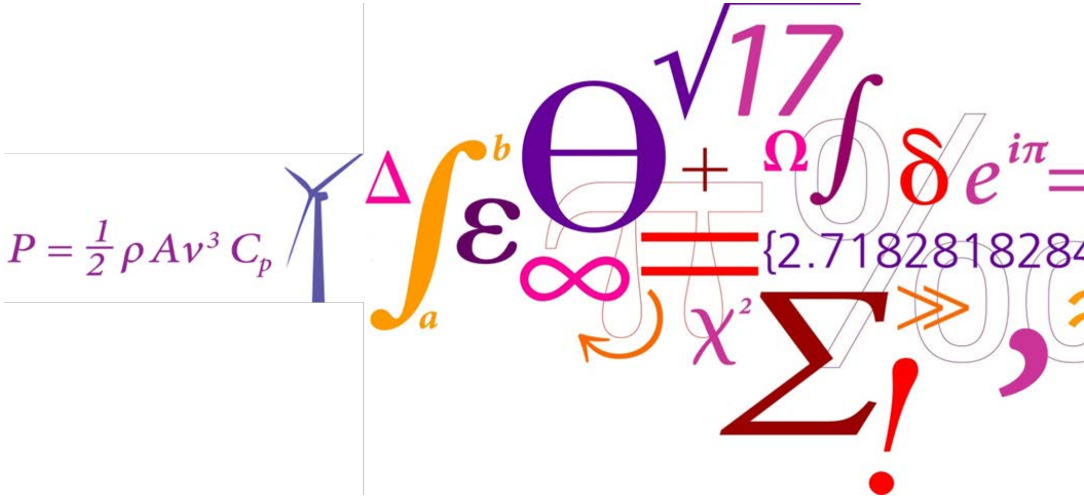
- Horns Rev 2002 (Kristoffersen et.al.) according to first DK technical requirements
  - Primary frequency control
  - Secondary frequency control
  - Reactive power neutral

- Today +
  - Continuous voltage control
  - Voltage support during faults
  - “Inertia” under development – verification?

- REserviceS presentation more details?

Simulation based verification of ancillary services from wind power

Anca D. Hansen, Müfit Altin
DTU Wind Energy



Background

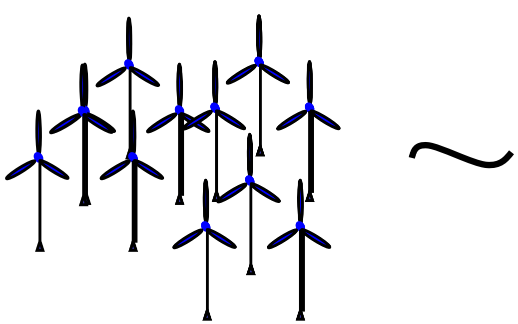
PSO project EaseWind

Enhanced Ancillary Services from Wind Power Plants

Partners: Vestas Technology R&D
DTU Wind Energy
DTU Compute
AAU IET

Objective

to develop technical solutions for enabling wind power to have similar power plant characteristics as conventional generation units.

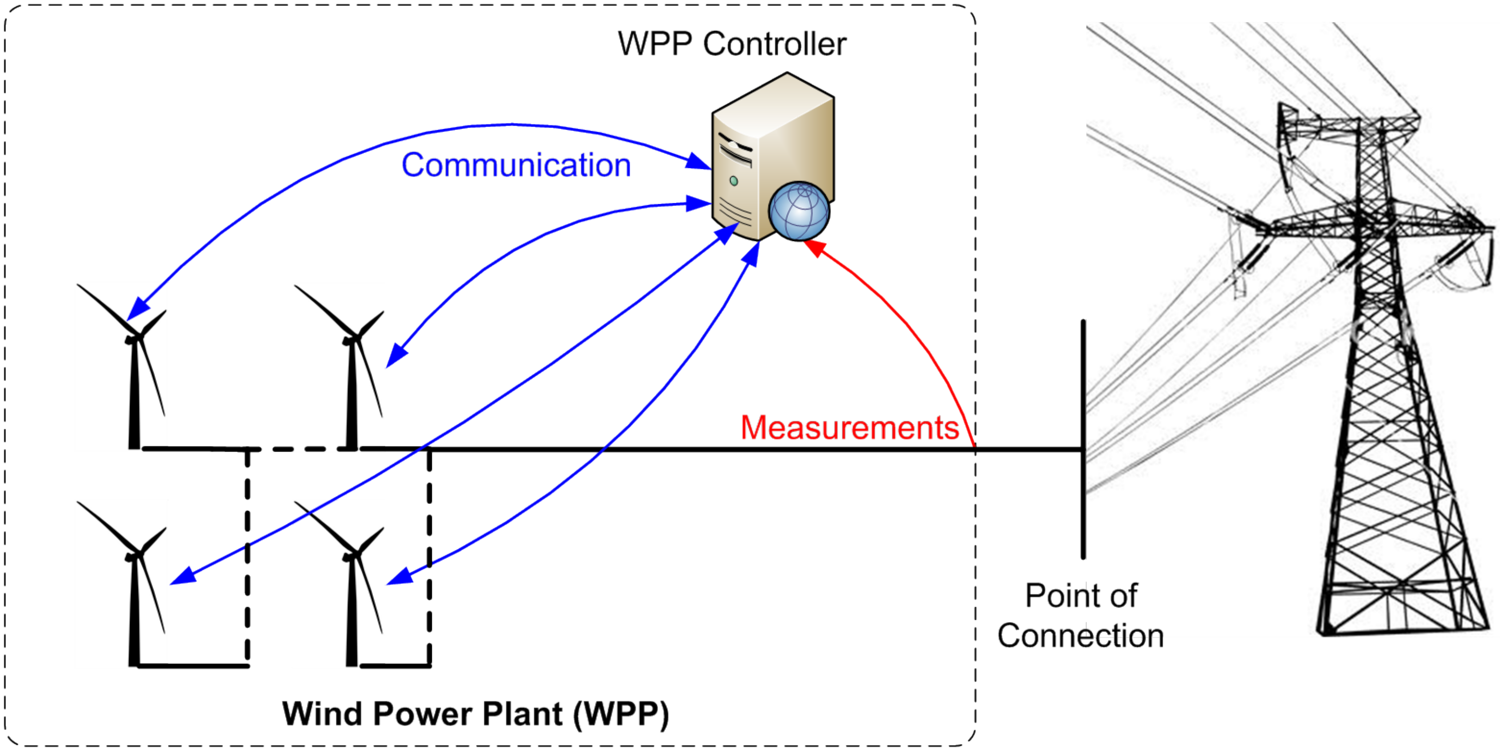


Wind power replacing

conventional power plants!

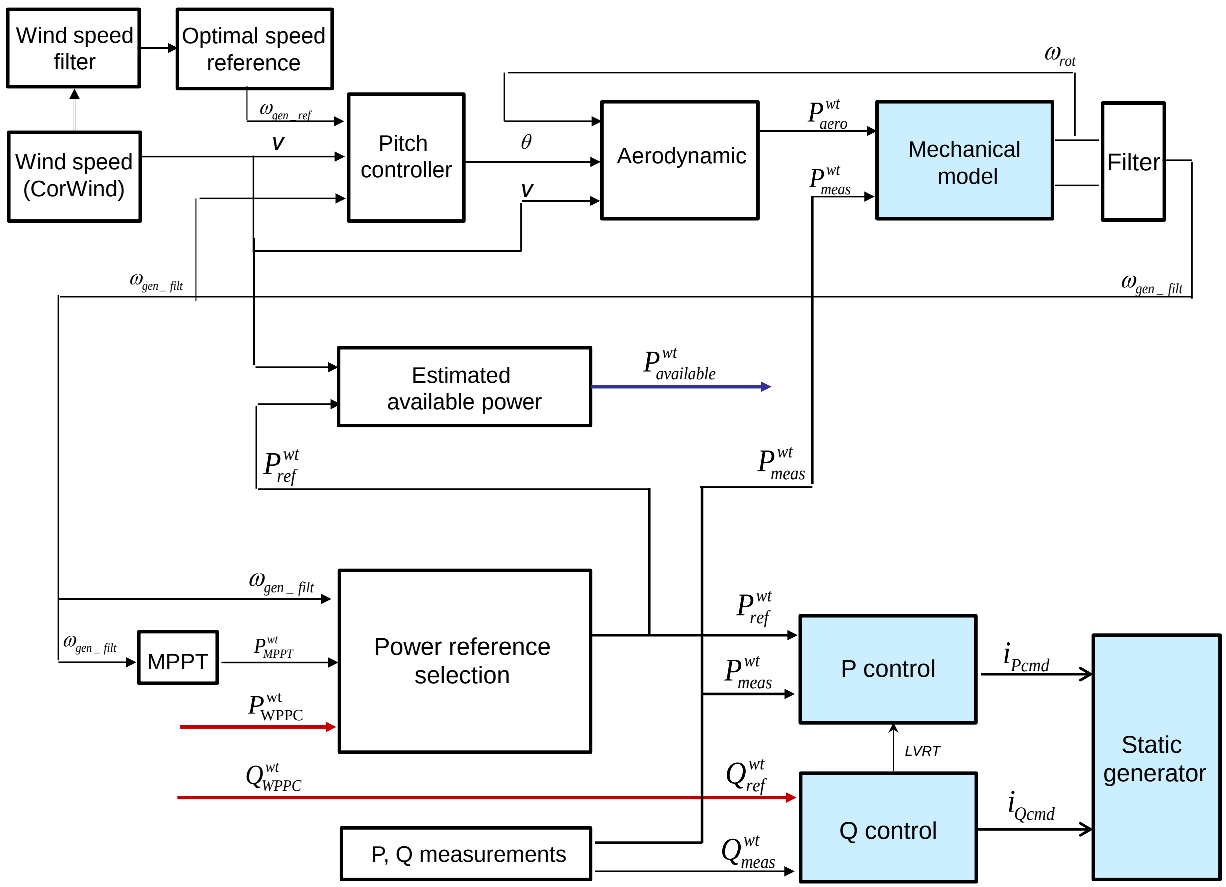
Ancillary services from wind power plants

The ancillary services from wind power plants are ***supported by communication and control*** at the power plant level.

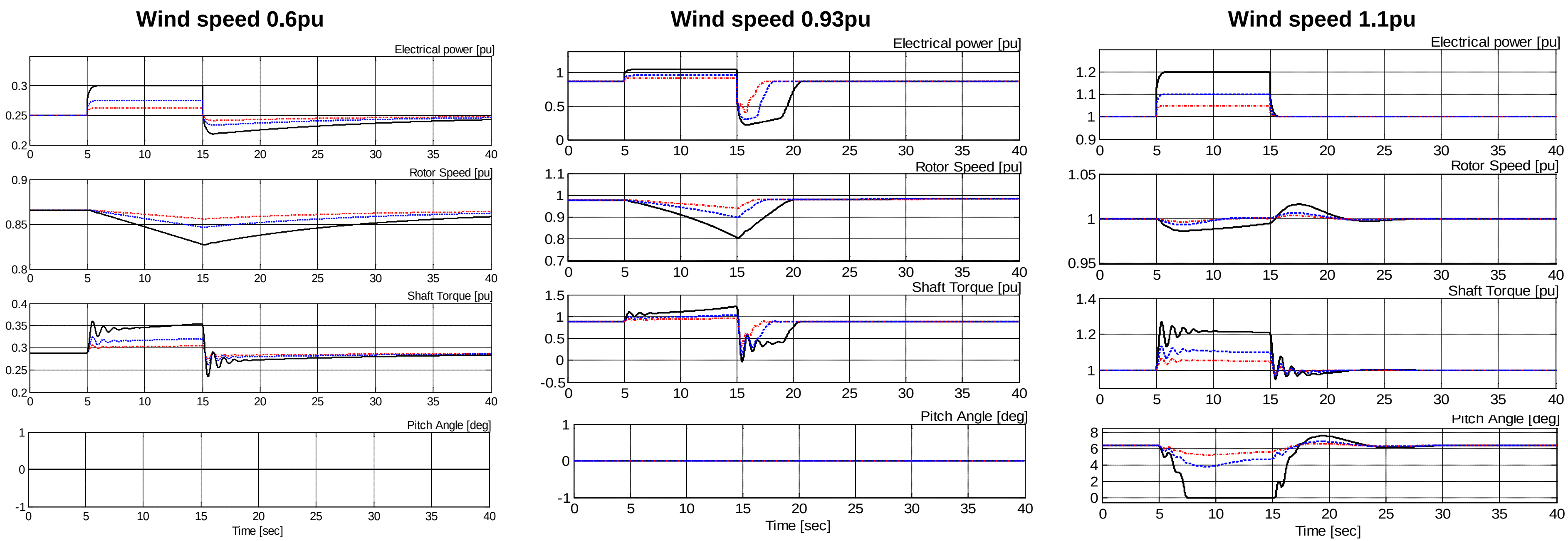


Simple generic wind power plant model

- follows the basic structure of the **IEC standard Type IV** wind turbine model
- includes additional adjustments to reflect the dynamics relevant for active power and grid frequency control capabilities.

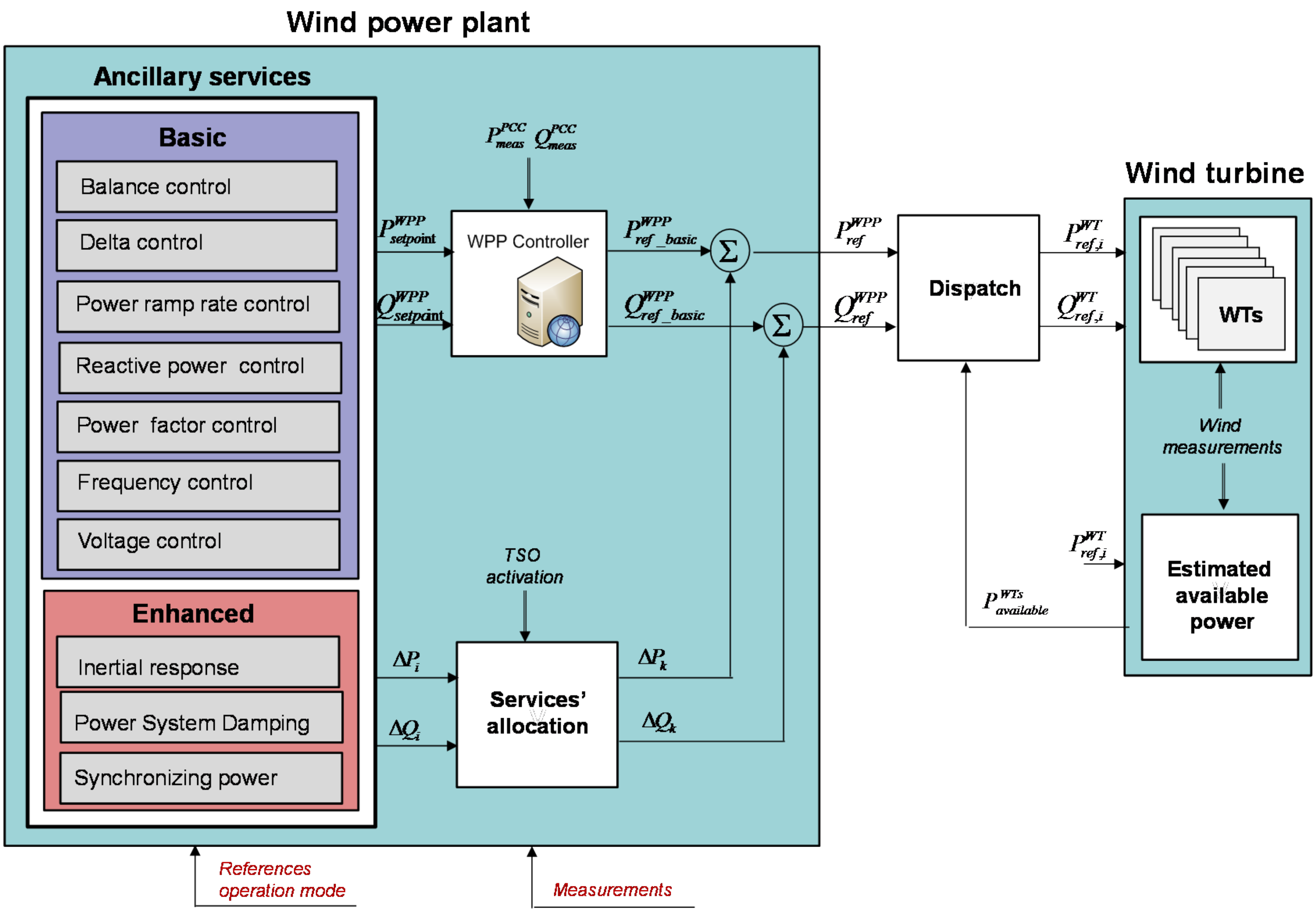


Short-term overproduction capability

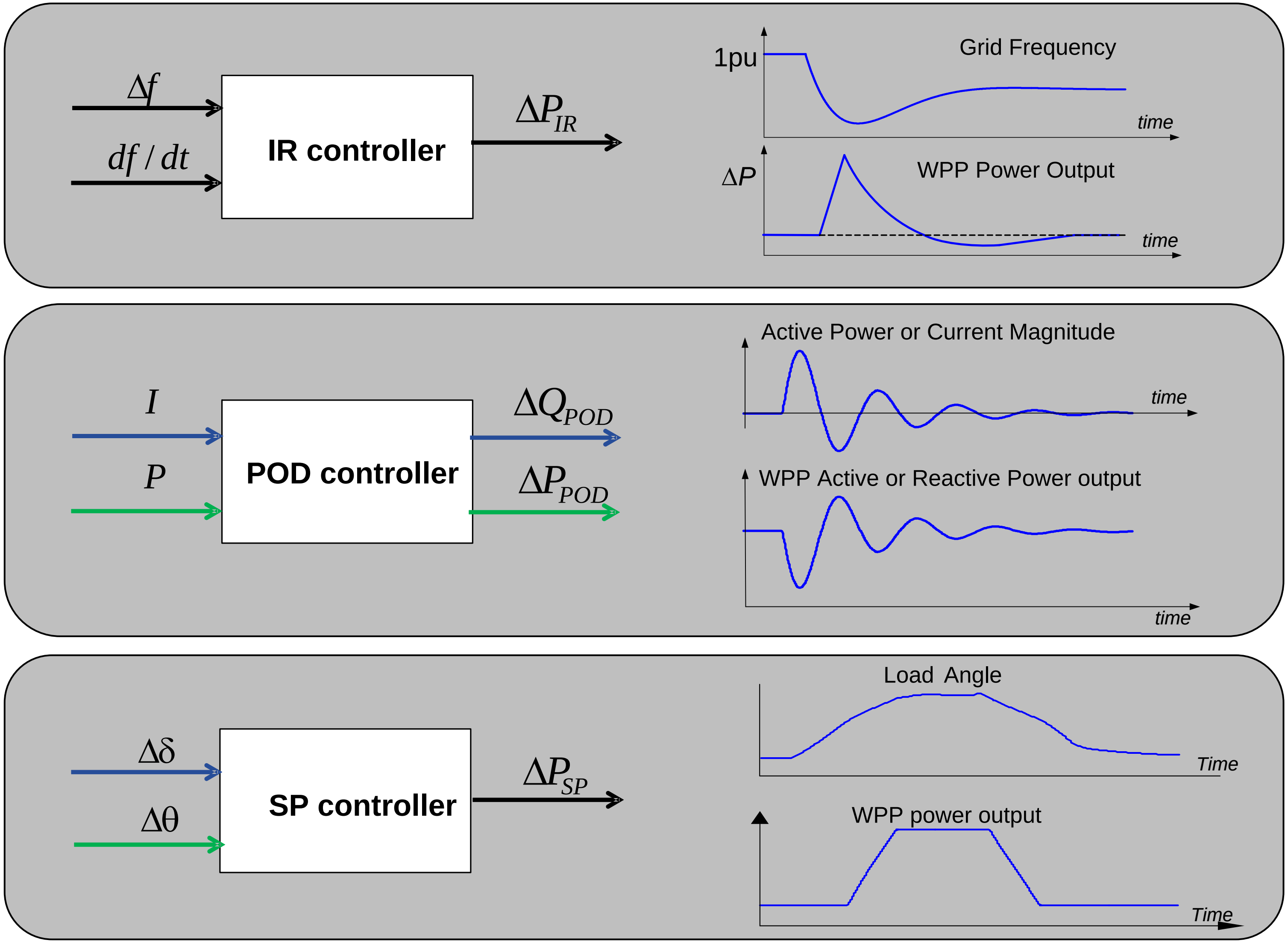


- Below rated wind speed, the overproduction is followed by ***recovery period***
- The higher the wind speed, the ***shorter*** the recovery period
- The higher the overproduction power:
  - the longer the recovery period and the larger the power underproduction -> ***frequency stability*** might be affected
  - the higher the shaft ***torque*** -> high mechanical stress of the turbine
- No power recovery above rated wind speed

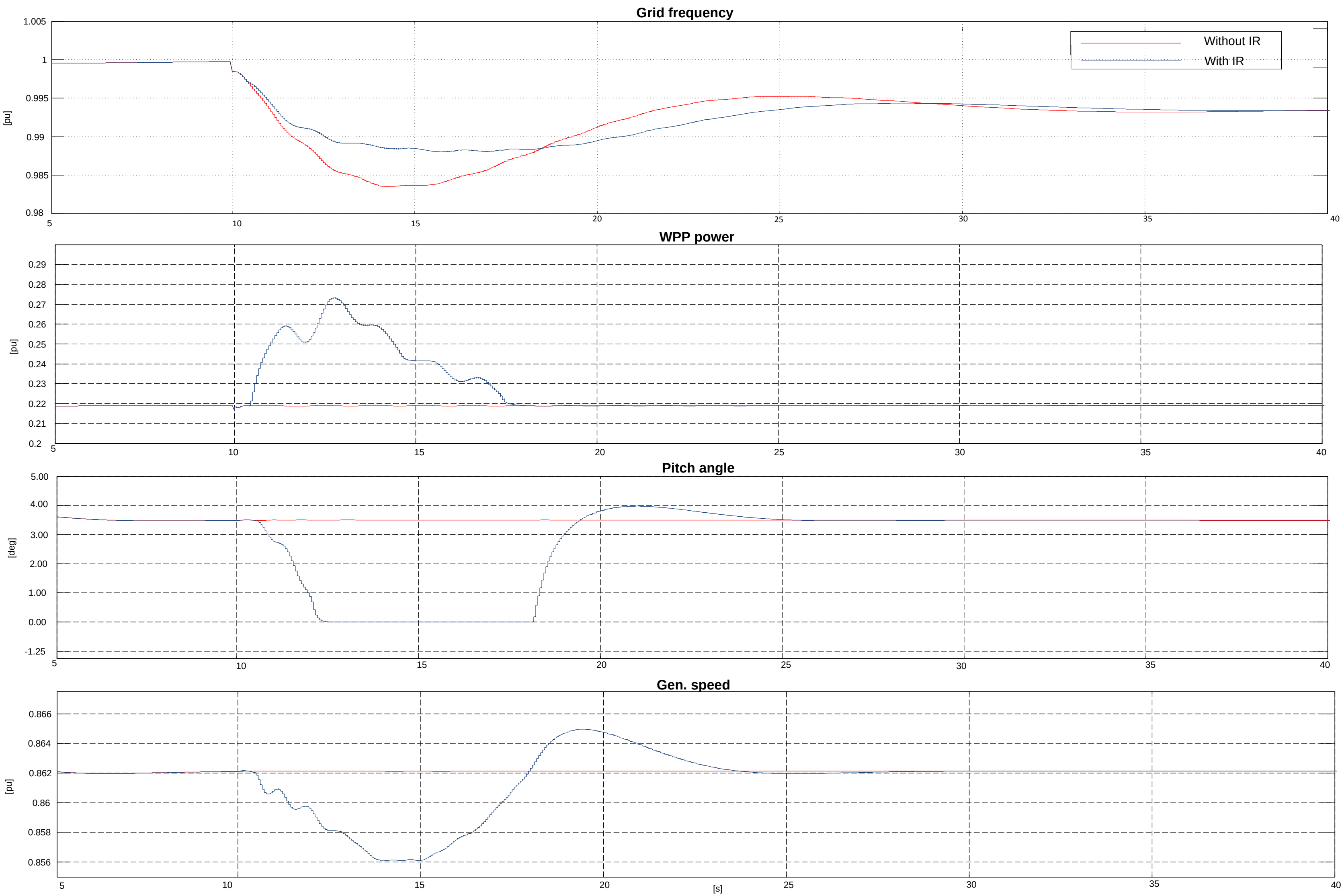
Wind power plant control architecture



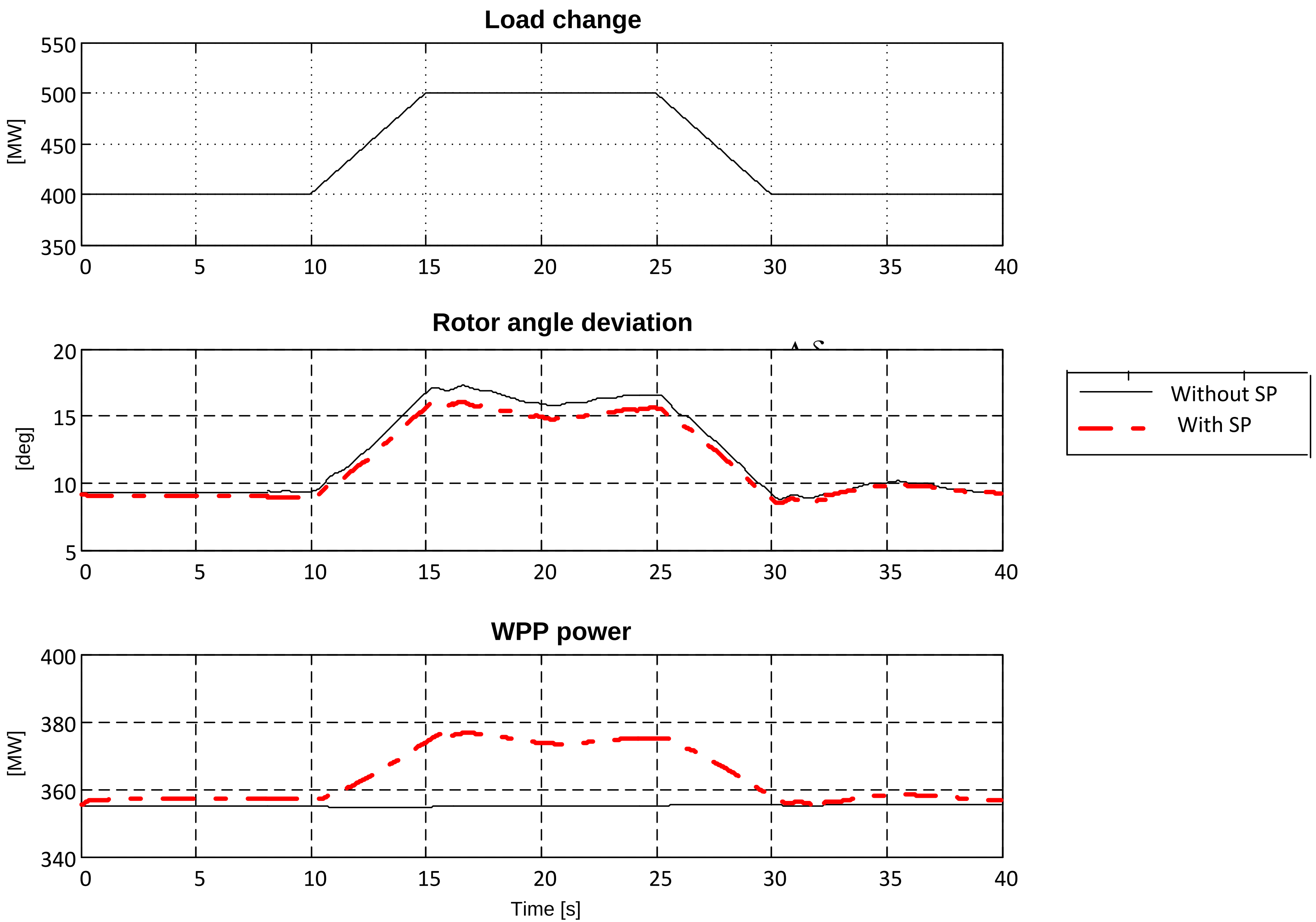
Enhanced ancillary services



WPP Inertial response capability



WPP synchronise power capability



OffshoreDC

OffshoreDC

Nordic Energy Research

WP 3 – Communication and control in clusters of wind power plants connected to offshore HVDC grids

PhD student: Lorenzo Zeni

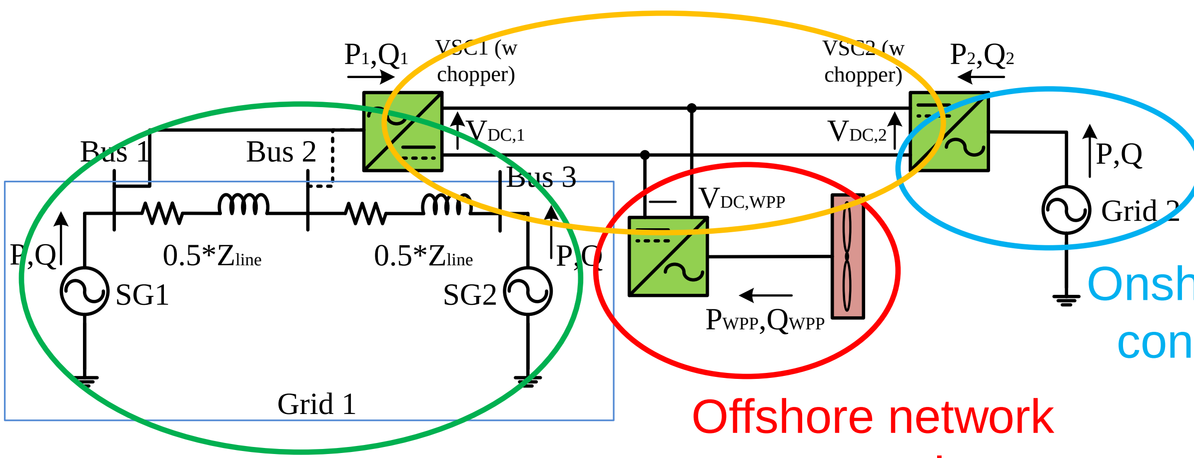
OffshoreDC

Results – status

L. Zeni et.al. From paper in Cigré session 2014

Investigation on system services provision

DC voltage control



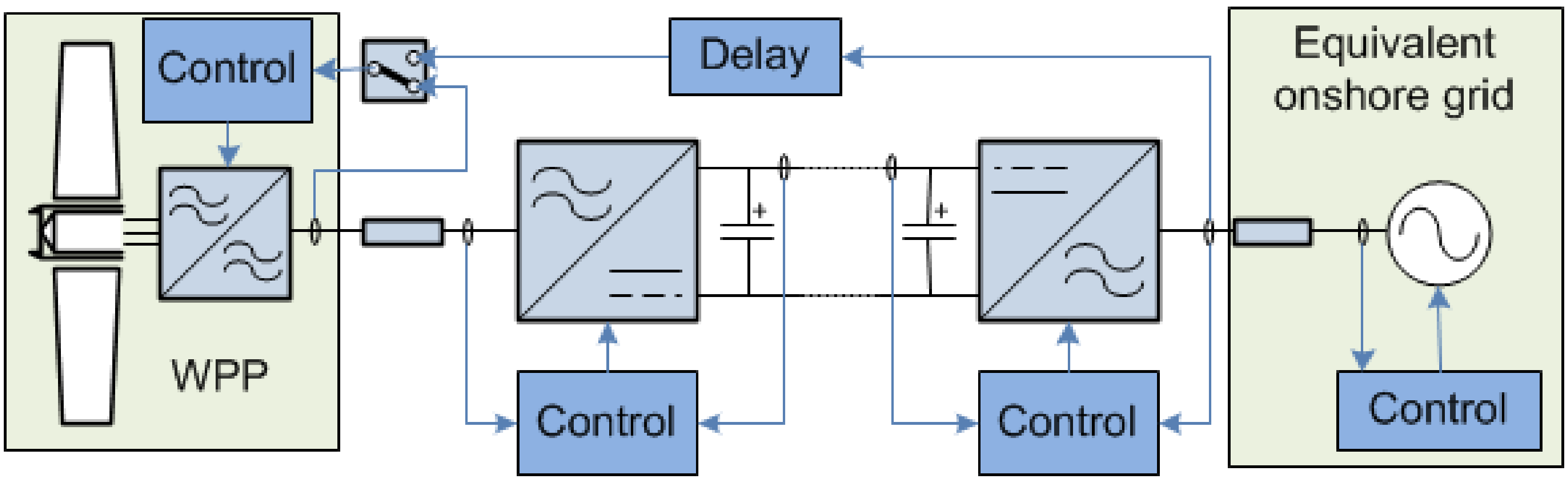
Onshore AC voltage control and LVRT

Offshore network control

Onshore frequency control and power oscillation damping

Important results obtained and lines for future work were drawn.

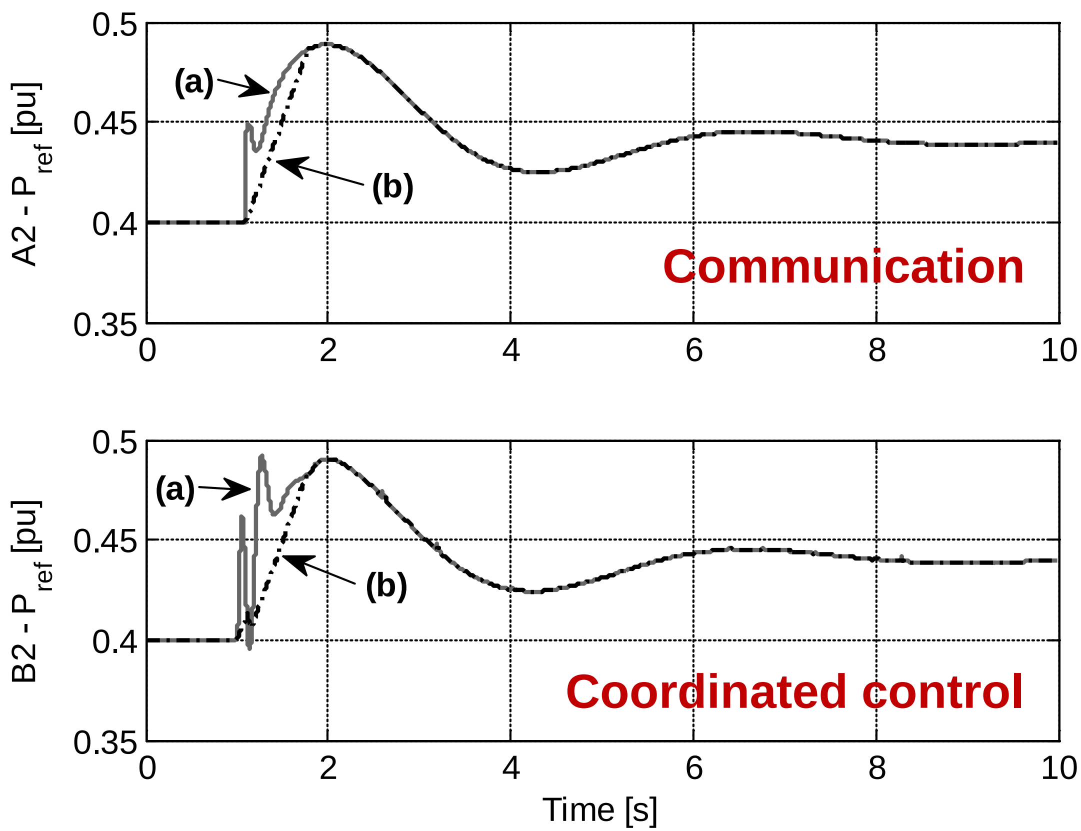
Frequency support through HVDC P2P example



Two strategies are compared:

1. Communication-based control (with communication delay)
2. Coordinated control mirroring the frequency in DC voltage

On the inertial contribution



Power reference to WPP
(a) From controller
(b) Ramp-limited

The initial power support is heavily limited by the ramp limiter (0.1 pu/s):
relaxation of this figure?

Conclusions

- Onshore frequency variations ***can be mirrored*** offshore
- Hence, WPPs can provide frequency control through HVDC with ***communication-less*** scheme
- In a P2P connection, communication-based and coordinated solutions are ***equivalent***, as far as ***frequency control and inertial response*** are concerned
- Fast control actions are inhibited by ***ramp rate limiters*** in the WPP

20 20 Twenties
Transmitting wind

SEVENTH FRAMEWORK PROGRAMME

EUROPEAN COMMISION

Consortium and budget

10 European Member States
1 Associated Country

United Kingdom (2)
ALSTOM GRID
UNIVERSITY OF STRATHCLYDE

France (2)
RTE
EDF

Norway
SINTEF

Denmark (3)
DONG ENERGY
ENERGINET
DTU ENERGY

Ireland
UCD

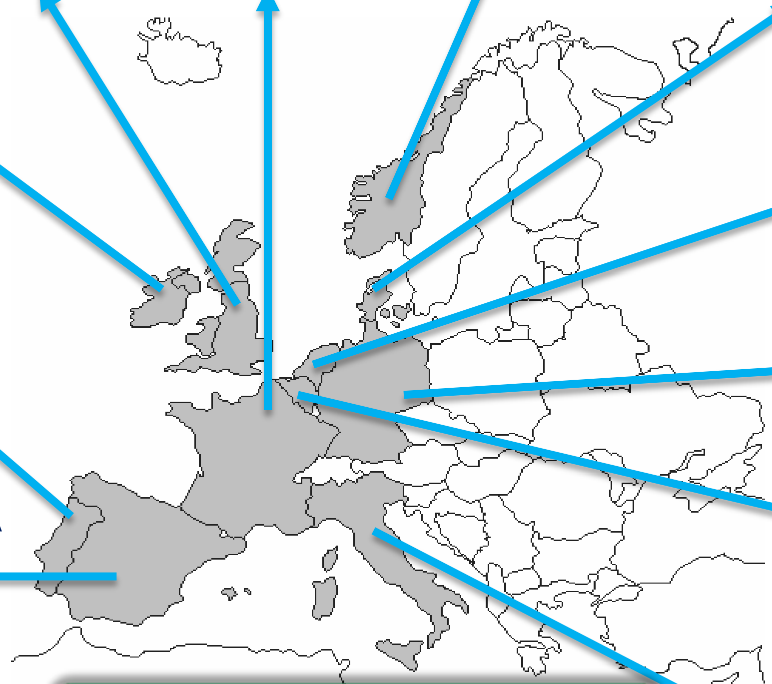
Portugal
INESC-PORTO

The Netherlands
TENNET

Germany (3)
FRAUNHOFER IWES
50 HzT
SIEMENS Wind Power

Spain (5)
RED ELECTRICA DE ESPAÑA
IBERDROLA
ITT COMILLAS
GAMESA
ABB S.A.

Belgium (6)
ELIA SYSTEM OPERATOR
EWEA
CORESO
UNIVERSITY LIEGE
UNIVERSITY LEUVEN
UNIVERSITE LIBRE BRUXELLES

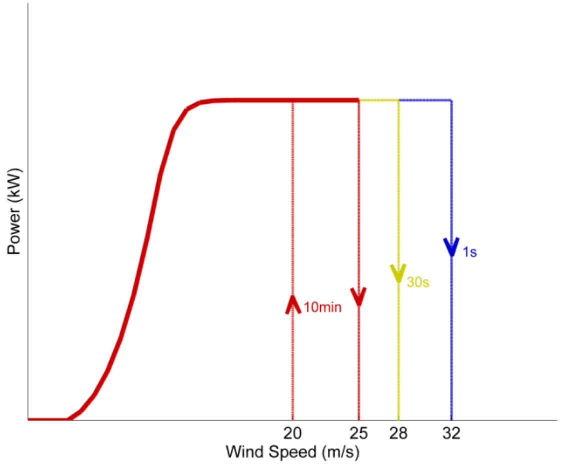


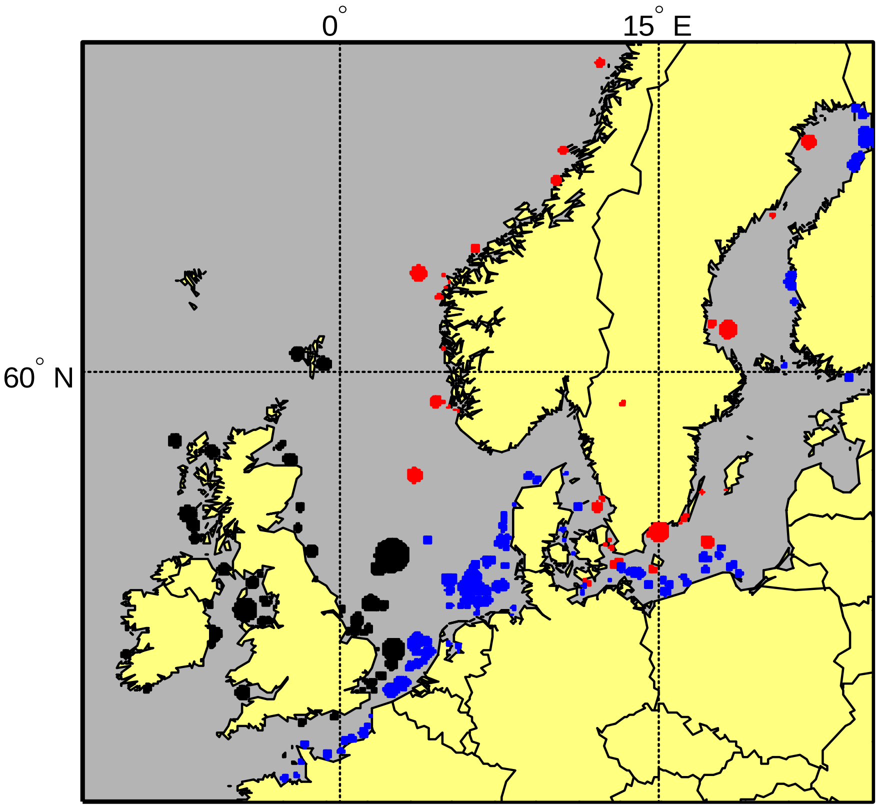
Italy
RSE

Total budget: 56.8 M€
EU contribution: 31.8 M€

Demo 4 - The challenge

Synchronous Area	2020	2030
	MW	MW
Continental	21,421	57,685
Nordic	4,924	14,669
GB	13,711	33,601
Ireland	1,419	3,219



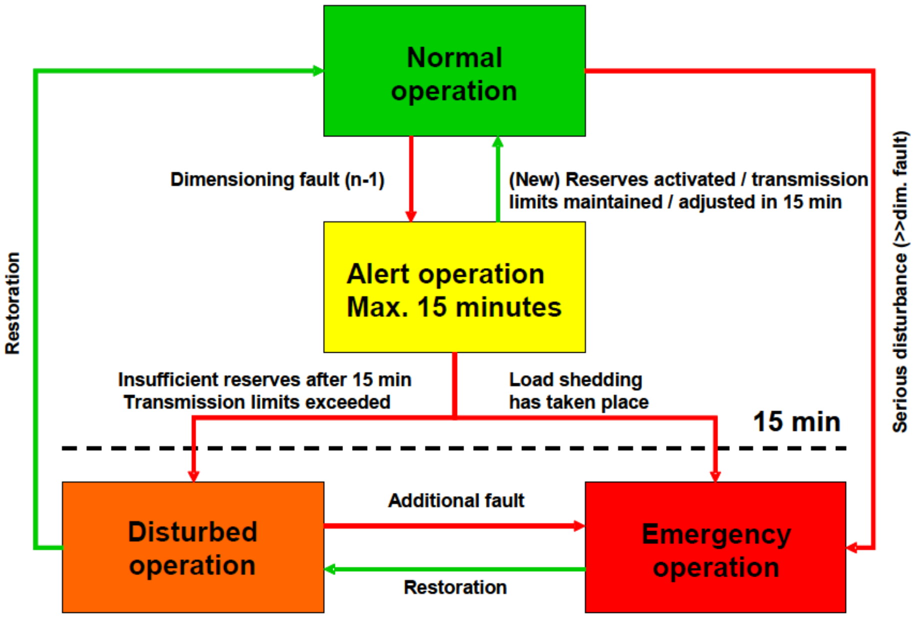


2030 map

Large scale challenge: Adequacy of primary reserves

- There must be sufficient primary reserves in the power system synchronous area to replace lost production corresponding to dimensioning fault
- This brings power system from normal state to alert state
- Frequency restoration (secondary / tertiary) reserves will return system to normal state in 15 minutes
- Larger faults (loss of generation) may bring system into disturbed (or emergency) state
- Therefore, maximum 15 minute wind power forecast errors are essential to esure adequacy of primary reserves

Synchronous Area	Dimensioning faultt
	MW
Continental	3,000
Nordic	1,200
GB	1,800
Ireland	500



Nordic grid code 2007

Upscaling results and conclusion

- Result for ***2020*** indicates that there is ***sufficient primary reserves*** with current dimensioning fault to cover offshore wind power variability in the four main European synchronous areas
- Result for ***2030*** indicates that there is ***not sufficient primary reserves*** with current dimensioning fault to cover offshore wind power variability in Continental and GB synchronous areas
- Current requirements for primary reserves should be revised by 2030 to maintain secure operation

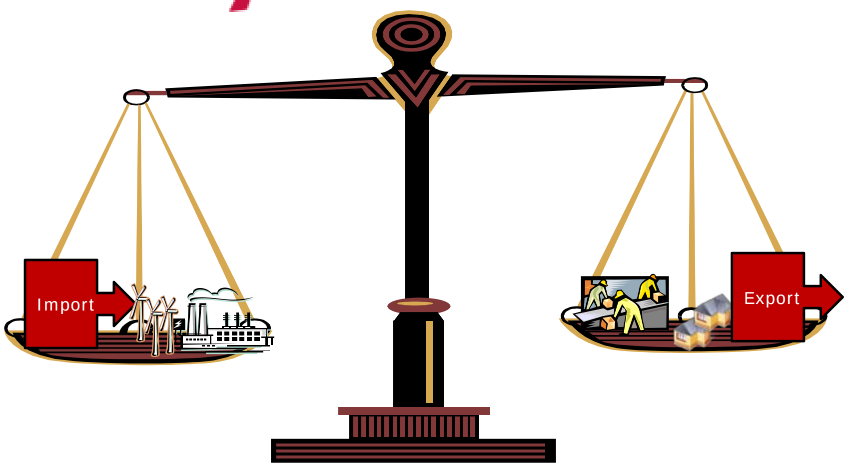
Synchronous Area	HWSD	HWEP	Dimensioning faultt
	MW	MW	MW
Continental	1,661	1,548	3,000
Nordic	480	483	1,200
GB	1,212	1,222	1,800
Ireland	224	224	500

2020

Synchronous Area	HWSD	HWEP	Dimensioning faultt
	MW	MW	MW
Continental	**4,729**	**3,933**	**3,000**
Nordic	**1096**	1082	1,200
GB	**4,418**	4,440	1,800
Ireland	**439**	438	500

2030

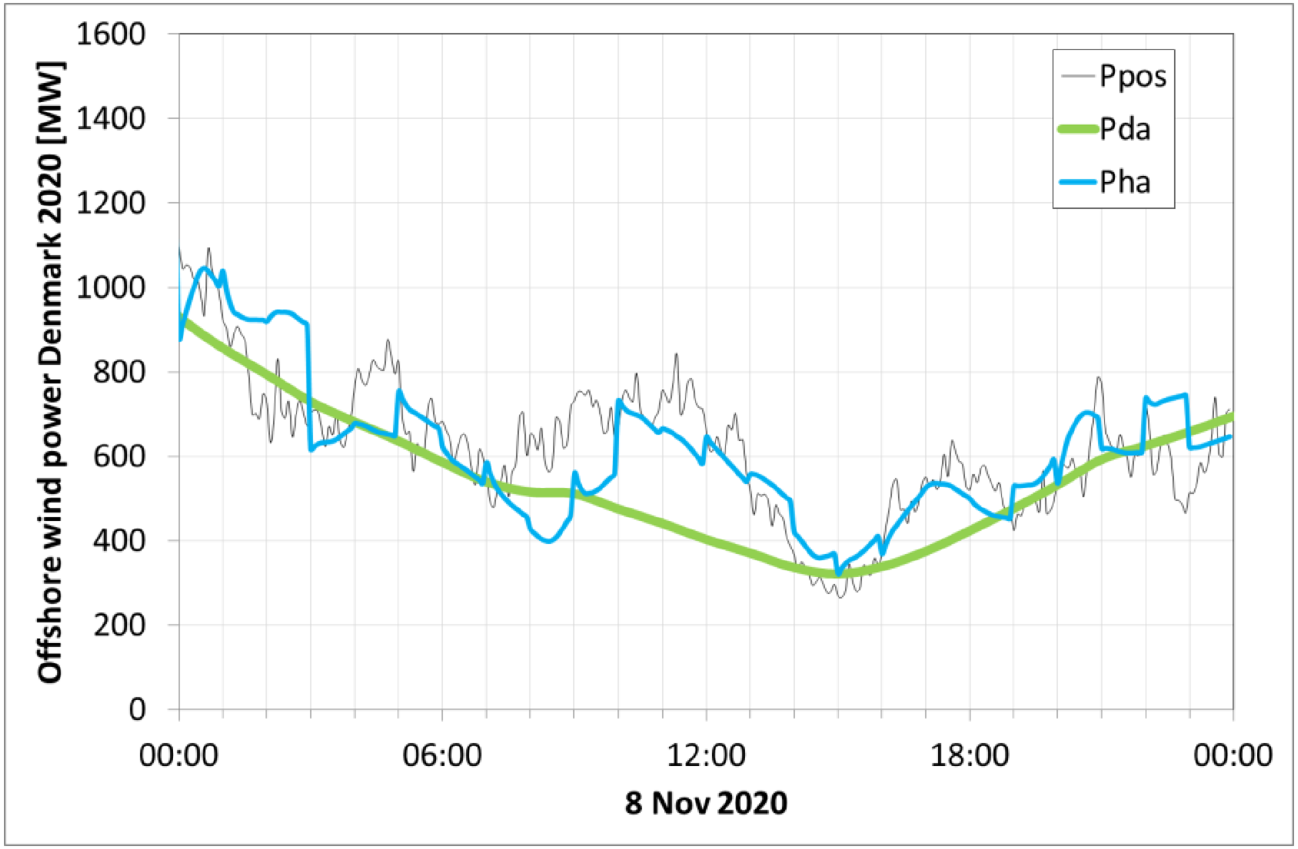
Simulation of balancing (Simba)



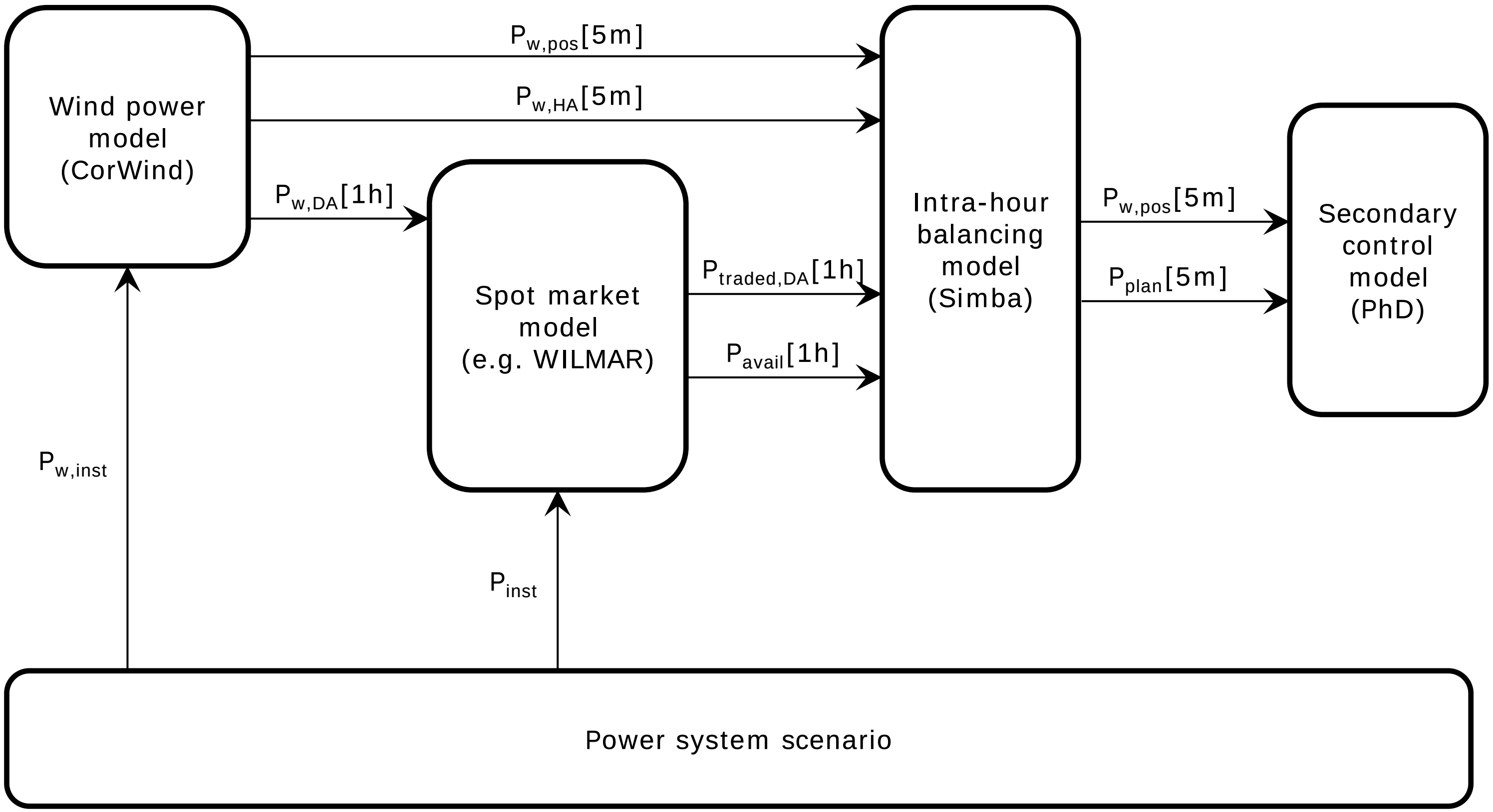
Simulation of Balancing (Simba)

- Simba idea
  - Simulation of intra hour balancing as supplement to day ahead
  - Uses inputs from "day-ahead market model"
  - Main imbalance included today is from wind
- Applications of Simba
  - Planning of investment
  - *Assessment of new market designs (e.g. towards real time)*
  - *Assessment of cost / value of reserves*
  - *Assessment of needs for reserve capacities*
  - *Economic optimisation of system services*
  - Assessment of flexible demand support to system balancing

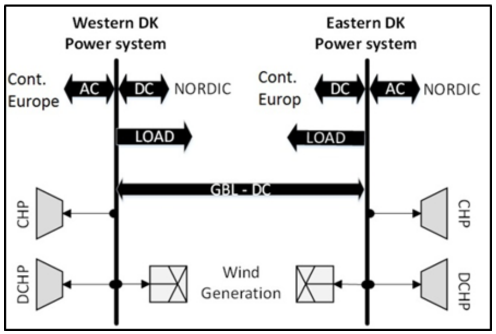
CorWind
Simulation of wind power fluctuations and forecast errors



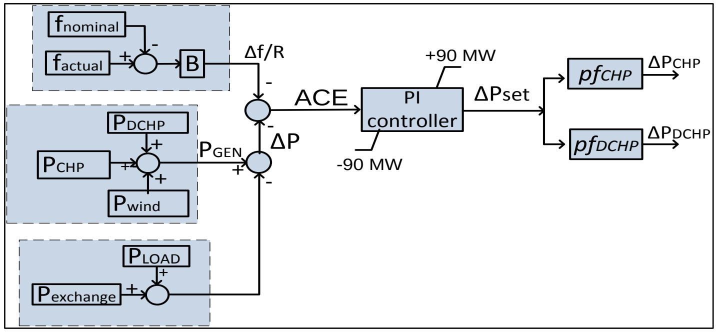
Modelling chain



Automatic Generation Control in a power system with high wind power penetration – Danish case study

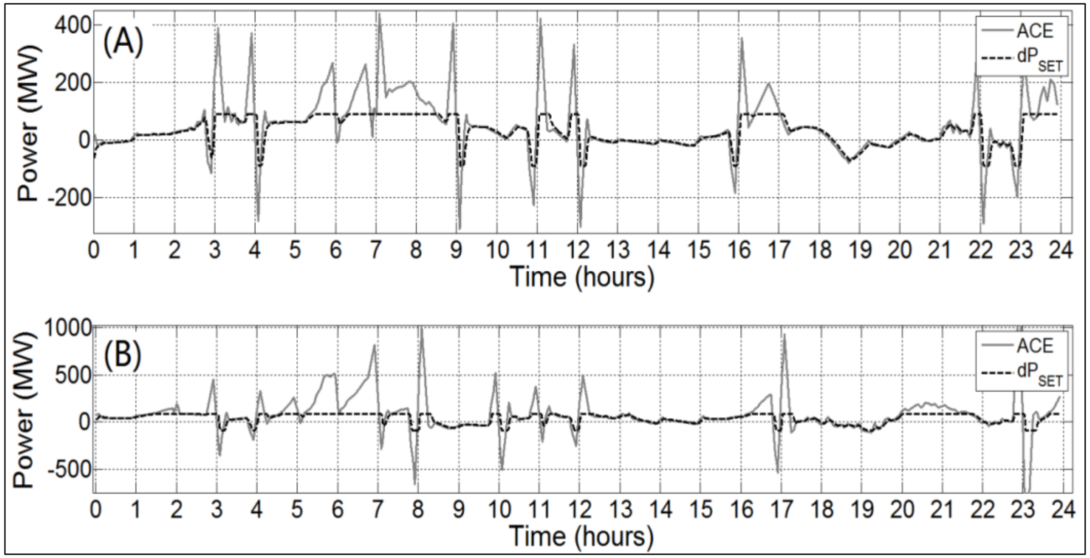


Model overview

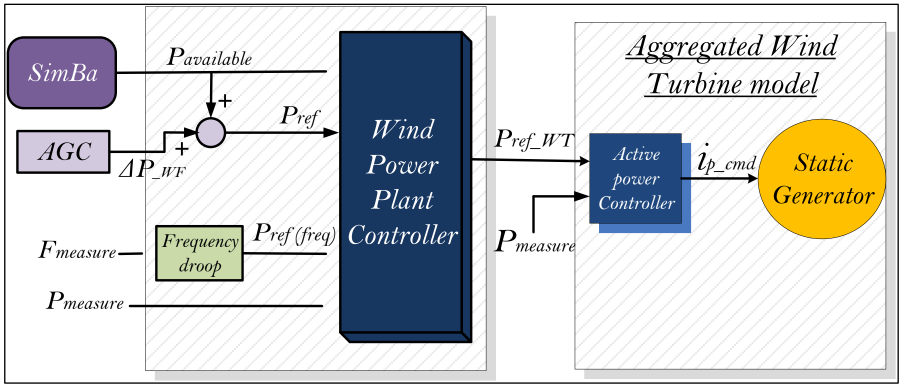


AGC model

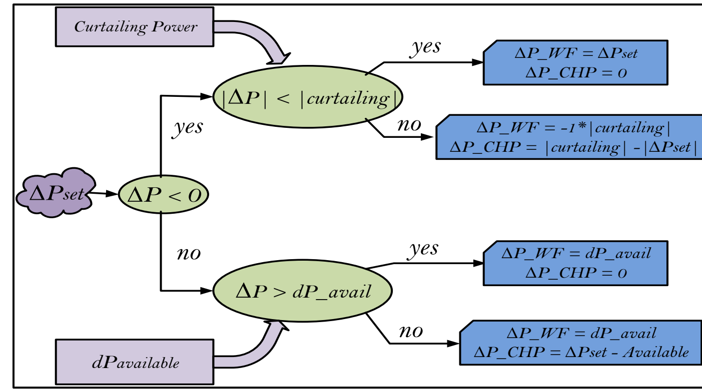
Result: simulated AGC performance



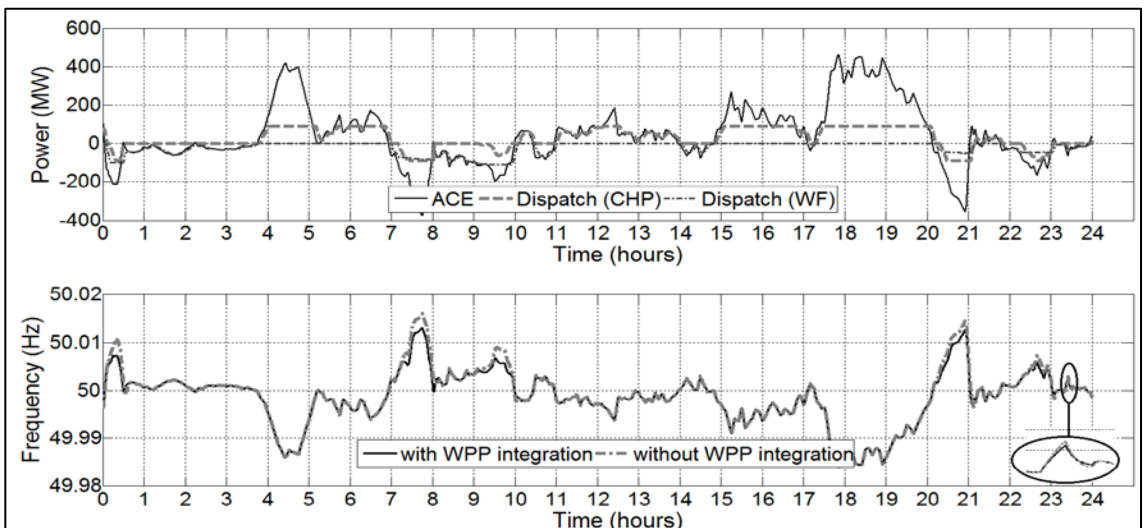
Wind Power integration into the Automatic Generation Control of power systems



Aggregated WPP model



Secondary (AGC) dispatch with wind



Summary and reflections on technical capabilities

- WPPs can provide basic ancillary services and replace conventional power plants
- Also possible to provide enhanced ancillary services – emulating synchronous generators (inertia-like response, power oscillation damping and synchronizing power)
  - ... but is this the optimal solution in future systems?
- Ancillary services can also be provided from HVDC connected WPPs

Economic incentives and barriers

- Incentives:
  - Technical requirements for grid connection!
  - Higher prices for reserves than for power (e.g. low – and even negative power prices)
  - Co-generation with other production technologies (ramp support)
  - Enables higher wind power penetration
- Barriers:
  - Symmetric (up/down) requirement (Spain – TWENTIES)
    - Downwards reserves from WPPs is feasible with high penetration
    - ... loads are more feasible as upwards reserves
  - Length (= prediction horizon) of reserve products
  - Development costs for new products
  - Additional hardware costs
  - Verification needs for new products – costly certifications

TPWind Technology Platform
New strategic research agenda (SRA) / Market deployment strategy 2014

- Issues – very similar to REserviceS
  - Frequency support
  - Voltage support
  - System restoration support
- Research priorities
  - Further ***development of enhanced wind power capabilities*** from wind turbine level up to cluster level, including the related design tools and models;
  - ***Testing and verification*** of frequency and voltage capabilities, and methods of proving compliance of new solutions for advanced capabilities with Grid Codes and standards;
  - ***Harmonisation, standardisation and interoperability*** of methods and technologies for delivering ancillary services with wind power.

Next steps to allow further penetration of wind into European grids?

- Researchers
  - Propose strategies for ancillary services to ensure system strategy – from wind and other sources
    - Special focus on power system security with increasing levels of non-synchronous generation
    - Not necessarily emulation of synchronous generators!!
  - Develop and implement new controls in simulation tools
  - Simulation based validation of ancillary services from wind
  - Develop tools to assess the value of new ancillary services
- Developers / owners
  - Assess the value of new ancillary services
- System operators
  - Propose and verify new strategies to ensure system security
- Turbine manufacturers
  - Develop and implement new ancillary service capabilities in full WPP scale