An assessment on enhanced wind farm control design for system operation enabled by digitalisation

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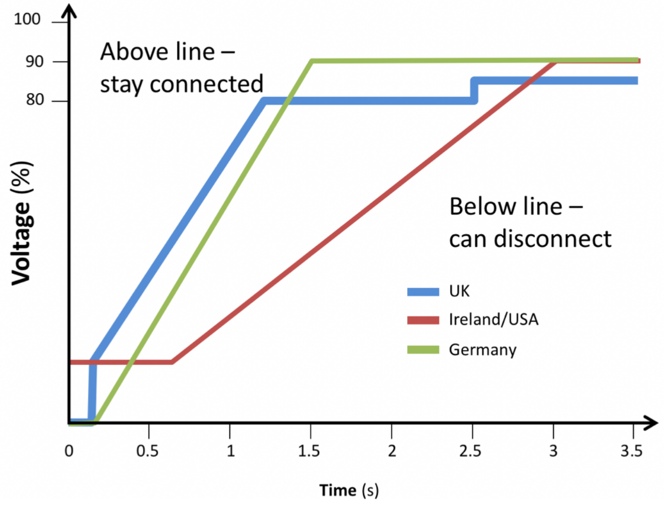
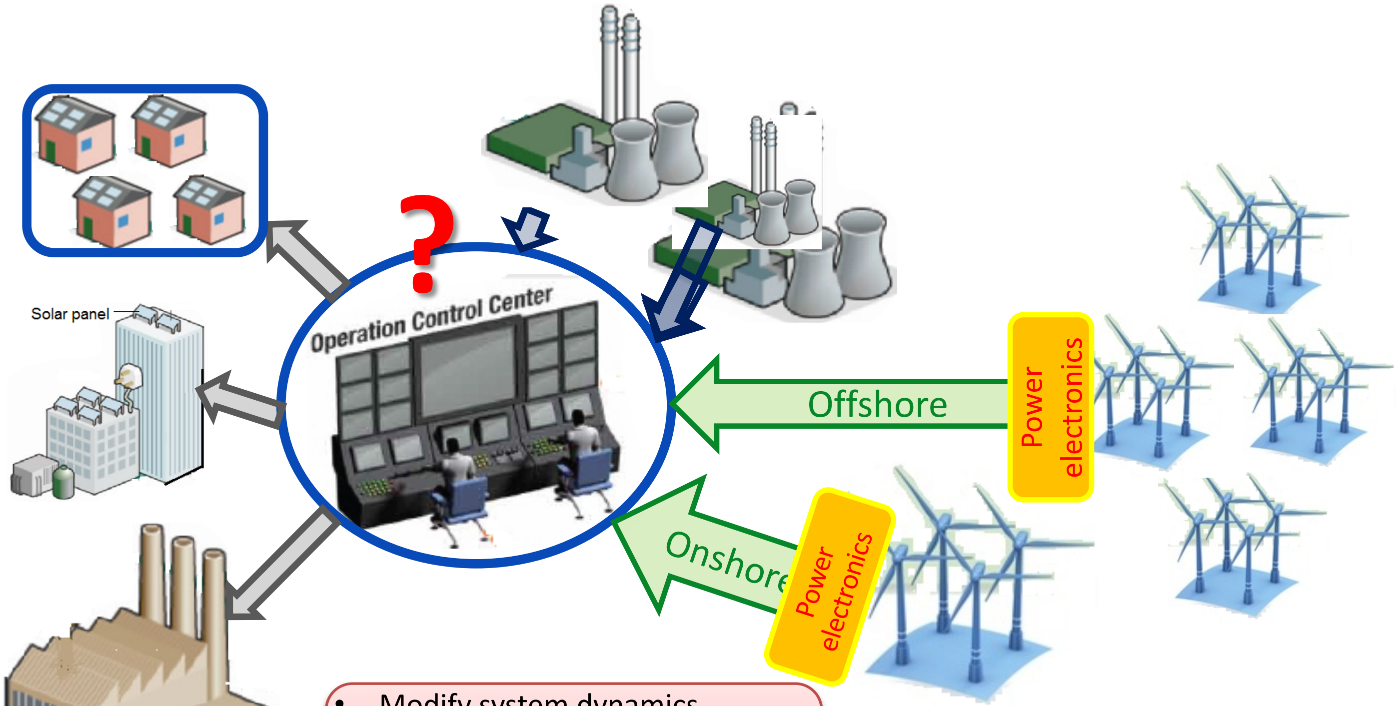
Outline

- Problem definition
- Grid Code compliance and provision of Ancillary Services from large wind power plant
- Control approaches and mechanisms to enable provision of grid services
- Digitalisation solutions to enable wind farms to provide system support efficiently.



Problem definition



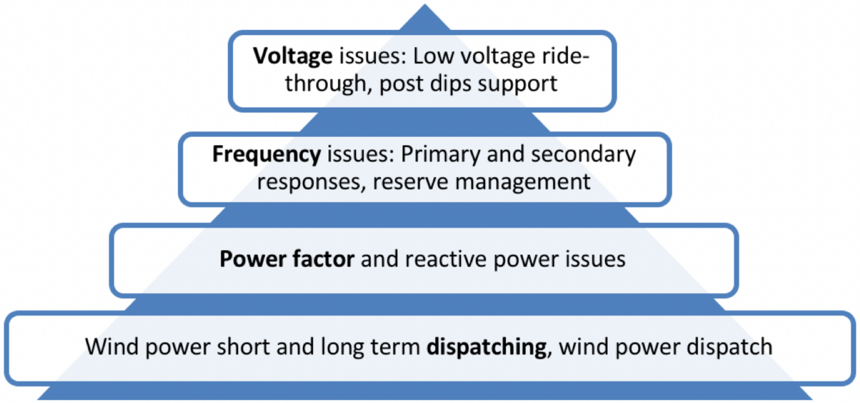
- Modify system dynamics
- Displacement of conventional generation that provides ancillary services

WPP are required to behave as conventional power plants and to provide similar services to maintain grid stability and security

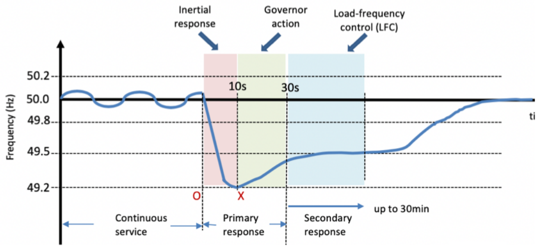
Source: IRPWind – M. Paz Comech, Ayman Attya

Typical control objectives for grid support

- WPPs must comply with Grid Code requirements and provide ancillary services



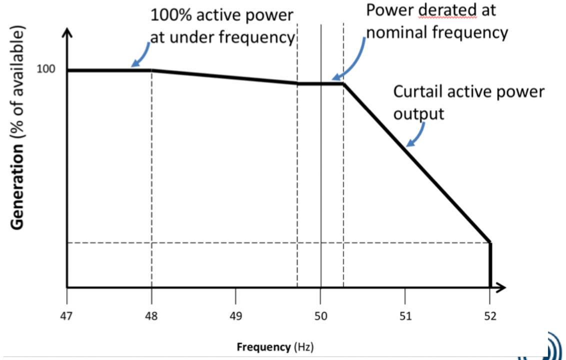
Provision of Inertia and frequency support



Short-term primary response (synthetic inertia)

Other services that could be expected include:

- Black-start capabilities
- System damping (power system stabiliser capabilities)
- Sub-synchronous resonance mitigation
- Grid-forming capabilities



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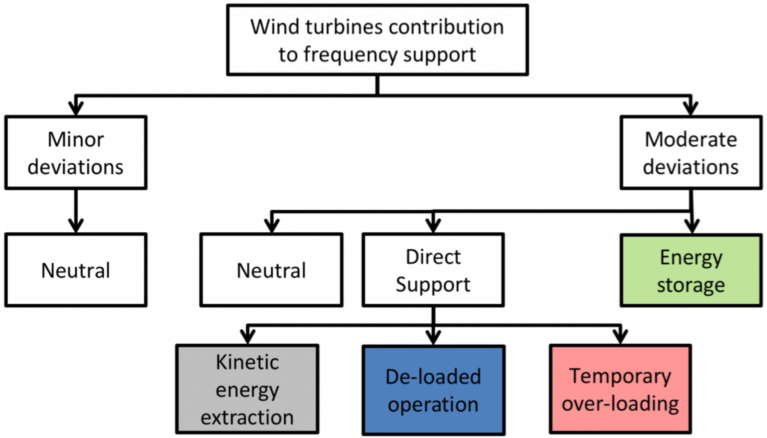
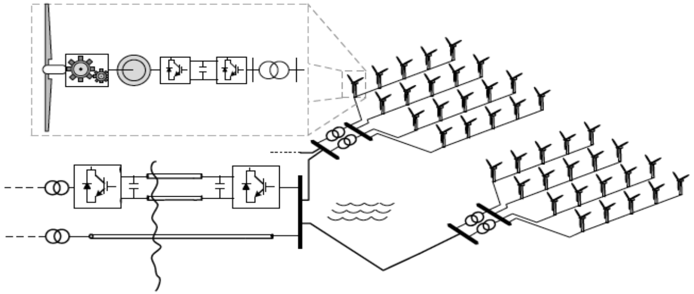
Provision of frequency support



- Additional control loops modify active power setpoint from speed control loop:
  - Inertia control
  - Droop control
  - De-loading



- Frequency support services rely on direct measurements of the power system frequency, which would be prone to high noise and lack of accuracy.
- A number of power converter interfaces between the wind turbine generator and the point of connection
- Communication issues (e.g. delays) can become significant in distant offshore wind farms.

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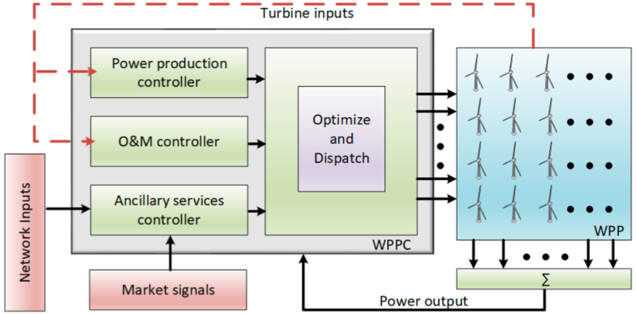
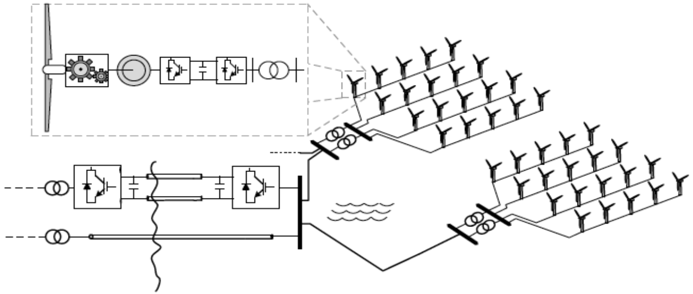
The wind farm controller

The WFC coordinates the response and power contributions of the various wind turbines in the farm and must consider:

- Wake interaction and propagation through the wind farm.
- Wind field turbulence at farm and turbine level.
- Wind turbine dynamics and structural loads.



Hierarchical wind farm controller and typical objectives



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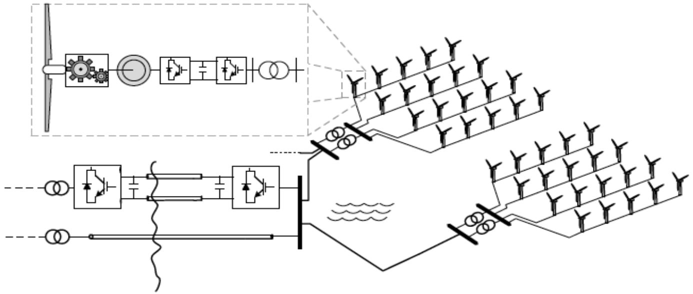
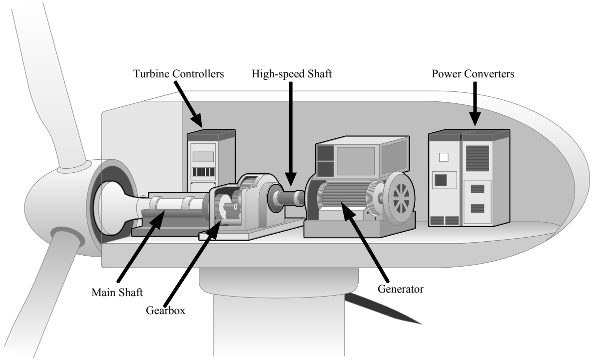
Sensors and actuators for control

- Measurement of external input signal: wind speed (magnitude, directions, etc.)
- Measurement of feedback signals for power production: rotor speed; generator speed and power.
- Measurement of feedback signals for load reduction: blade root bending moment; tower top acceleration.



- Blade pitching motor: changes the *pitch angles* to control rotor speed and power, reduce loads on blades and towers.
- Generator: provides desired *generator torque* or load.
- Yaw motor: provides active yaw control for large wind turbines



(Adapted from: Anaya-Lara, 2018)

- Wind Energy is truly a Big Data industry
- ~500 sensors/"channels" per turbine
- SCADA sampling at 1 reading per second
- Stored in 10 minute averages
- Stored continuously

Digitalisation in the power grid

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Wind farm level

- ✓ Intelligent sensors
- ✓ Digitalised data management
- ✓ Digital Twin
- ✓ Data-driven control approaches
- ✓ Advanced communications (techniques and infrastructure)
- ✓ Cyber-Physical Security

Testing in SYSLAB. (T. Nielsen)

Power system level

- ✓ Digital substation
  - Remote controls
  - Fault detection
- ✓ Planning and operations
  - E.g. short-term weather and wind power forecast
  - Close-to-real time operational planning
  - Remote control of generation
  - Dynamic Line Rating
- ✓ New advanced SCADA
  - WAMS and WAMPAC
  - Grid flows predictions

Frequency support – example

EFCC Project

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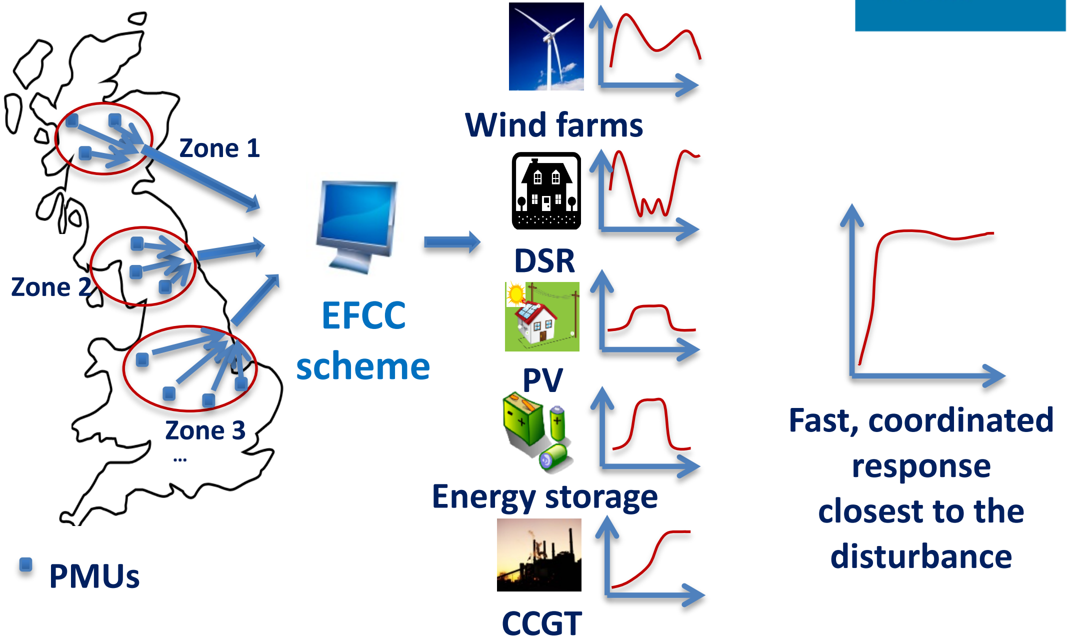
- Fast frequency response using **wide area monitoring and control** techniques.
- Locational impact of disturbance is considered for resource deployment.
- **Coordinated response** from a variety of types, e.g. energy storage, demand side, wind, etc.



Courtesy: Prof. Campbell Booth

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Conclusions

- ✓ Digitalisation can help to integrate wind generation and coordinate with other renewable sources (e.g. PV).
- ✓ Enhanced measurement and communications will be crucial.
- ✓ Stronger interaction/collaboration among experts on digitalisation technologies and wind farm/power system control, operation and stability is necessary.