State of the art and technology trends for offshore wind farm grid integration

Results of CA-OWEE work package 2.2

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Introduction

EU Concerted Action - Offshore Wind Energy In Europe

- EU targets require large scale offshore wind energy,
  eg. 10000 MW by 2010
  (=25% of White Paper on RES targets)

➡ Grid Integration = Limiting Factor ?

Grid Integration Issues - Overview

- Production/Consumption Inbalance
- Power Quality
- Power System Stability and Control
- Grid Access Requirements
- Technology Trends

Production/Consumption Imbalance 1

- Short-Term and Long-Term Variability of Wind Power Production
  - Spatial Correlation vs. Cross-Border Transport Limitations
    - Equalising effect on distance of > 1500 km
      But : Limited Cross-Border Transmission Capacity !
- Fast Power Gradients (Storm Fronts)
  - Availability of rapidly dispatchable power ?
  - Feasibility of control by wind farm control system ?

Production/Consumption Imbalance 2

- Compensating Measures for short-term variability:
  - Demand Side Management (tariff signals, ..)
  - Electricity Storage :
    Regenerative Fuel Cells, Pumped Hydropower, Hydrogen, ..
  - Improved Short-Term to Medium-Term Forecasting Tools
    Suitability for balancing requirements vs. trading requirements
  - Increased Flexibility of other (coventional) power plants
    But : Decrease of efficiency

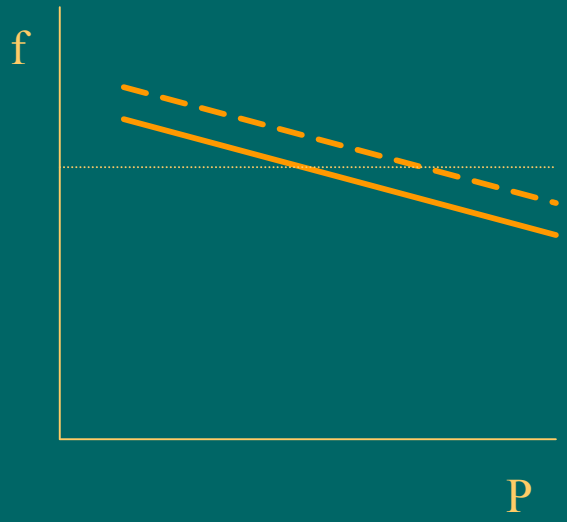
Power Quality

= Voltage/Current Phase Shift (cos phi),
Voltage Variations (incl. Flicker), Harmonics

- Power Quality may be an issue for weak grids,
  BUT : Technical Solutions are available (eg. VSC converters)
- Flicker is not considered a limiting factor for offshore wind energy, due to :
  - low flicker emission level of modern wind turbines
  - equalising effect in large wind farms
  - connection at high voltage level (hence high Scc at PCC with grid)

Power System Stability and Control

- Static Stability / Dynamic Stability (eg. After fast power gradients)
  - Assesment : Load/Flow Analysis + Dynamic Grid Simulation Codes
- Power/Frequency Control :
  - Primary Control
    (automatic adjustment of power to freq.)
  - Secondary Control
    (power setpoint imposed by grid operator)
- Voltage Control
  - Voltage Regulation and Reactive Power Capability



Grid Access Requirements

- Technical Requirements !!!
  - Protection (of People and Property)
  - Power Quality
- Grid Support Requirements ???
  - Contribution to Power System Control
  - Robustness against incident conditions
    - increased sensitivity due to power electronic converters !
    - 'reconnect in flight' capability after transient faults ?
    - stable islanding behaviour ?

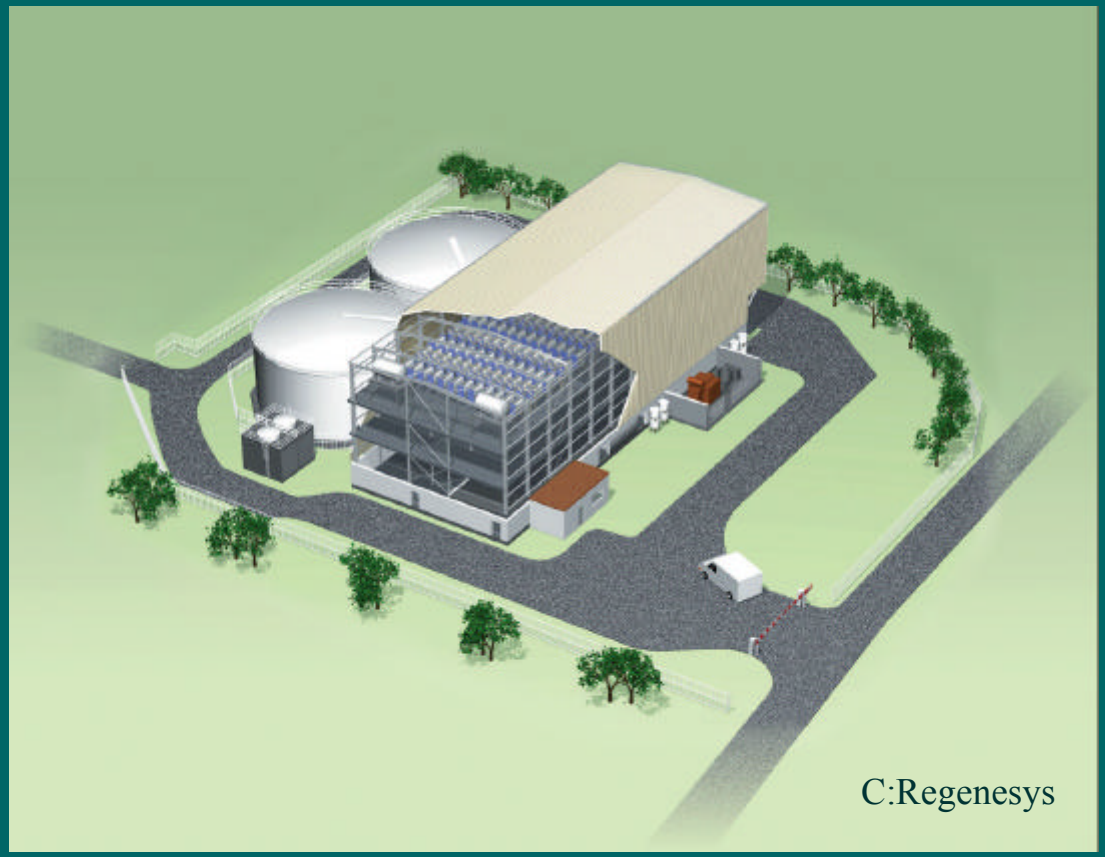
Impact of Power System Deregulation

Alternative options :

- *All generators* provide grid support on an *equal* basis
- *Wind Energy exempted* from grid support
  - BUT Burden on other generators will increase
- *Free market* for grid support (ancillary services market for reactive power, primary control, secondary control, …)
  - Easier for wind energy project developers,
    BUT total cost of electricity will comprise cost of ancillary services
  - Ancillary Services provided by offshore wind farms have market value !

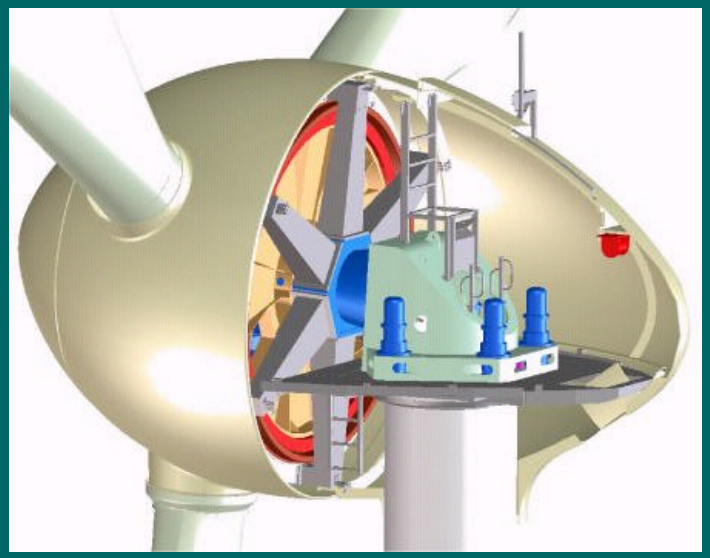
Technology Trends : Energy Storage

- Example : Regenerative Fuel Cell Technology



Technology Trends : New Wind Turbines

- Variable Speed Wind Turbines
  - Generator Types :
    - double-fed asynchroneous generator
    - direct-drive synchroneous ring-generators
    - direct-drive permanent magnet generators
    - cable wound high-voltage generators
  - + VSC Power Electronic Converters !



- ➡ Improved Power Quality
- ➡ Improved Control Capabilities

Technology Trends : HVDC Transmission

- HVDC - classic
  - thyristor based
  - grid commutated
  - too large for offshore ?
- HVDC - light / HVDC - plus
  - transistor based (IGBT)
  - self commutated
  - compact -> possible for offshore

Critical Issues

- Based on ranking by OWEE-members (expert opinion)
- Critical Issues
  - have significant impact on possibility of large-scale development of offshore wind energy (10000 MW target !)
  - are not easily manageable with existing technology
  - are important in the short-term (before 2010)
- ➡ Critical Issues and State-of-the-Art Review are used to define Critical Research Needs

Critical Research Needs

- Increase accuracy and reliability of wind power forecasting tools
- Develop wind turbine models for dynamic grid analysis codes
- Improve robustness of wind farms
- Improve wind farm contribution to power system control
- Analyse cost of increased control requirements on other power plants
- *(Assess spatial correlation of wind power vs. cross-border transmission capacity)*
- *(Improve electricity storage technology)*

Is Grid Integration a Limiting Factor for Offshore Windenergy ???

- **NO** for current 100 .. 200 MW projects
- **YES** for future large scale deployment (10000 MW)
  UNLESS critical issues are solved