Power Oscillation Damping Controller for Wind Power Plant Utilizing Wind Turbine Inertia as Energy Storage

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Industrial PhD Project

Participants

- Siemens Wind Power A/S
- Centre for Electric Technology,
  Technical University of Denmark
- National Grid Electricity Transmission,
  TSO England/Wales, Scotland

3 year project – finalized by Apr-2012

Power System Oscillations (I)

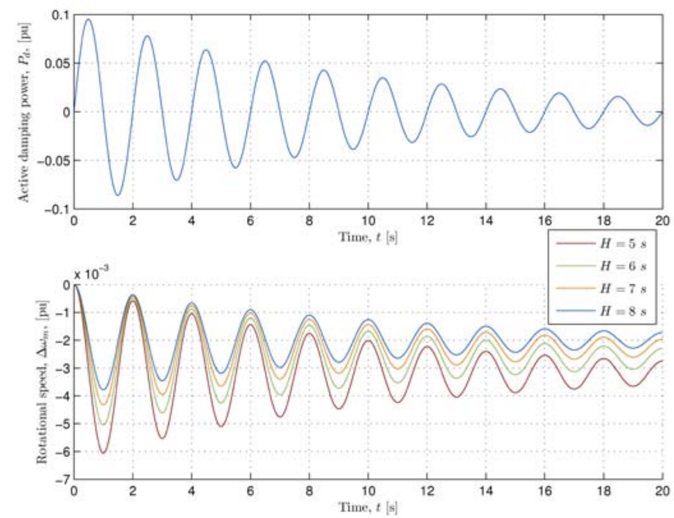
- Behavior well-known for synchronous machines
- Large-scale integration of wind power changes fundamental properties of the power system
- Increasing cluster size change expectation to “power park modules”
- Small-signal stability analysis would have to consider:
  - Large wind power plants are often commissioned in remote areas
  - Increased penetration displace synchronous generation
  - Interfaced through electronic power converters

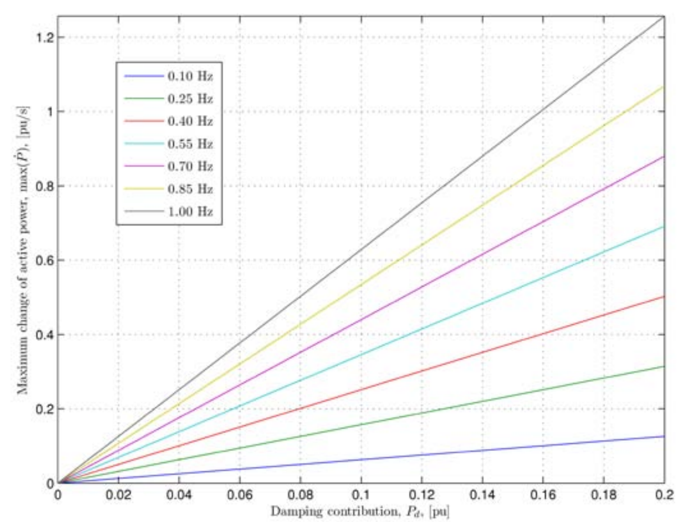
Power System Oscillations (II)

- Wind Power Plant (WPP) Power Oscillation Damping Controller (POD) proposed in literature
- Independent control of both active and reactive power
- Active and/or reactive power modulation

Active Power POD

- Wind is free, produced energy is *not*
- Low energy content in damping signal
- High inertia machine
- POD subject to operational constraint of the WT





Conceptual Study

Better understanding needed of

- WT mechanical resonance
- Interaction with other stabilizing units
- Interaction with WT normal operation
- WPP distributed and modular
- Robustness of WPP POD
- Efficiency of damping control

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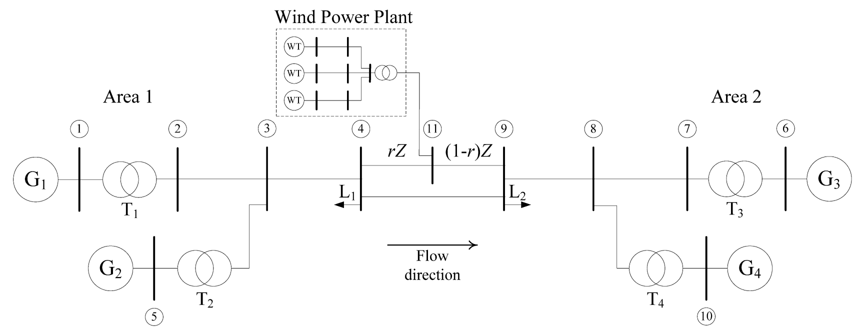
→ is WPP POD practically feasible and favorable?

Study Case

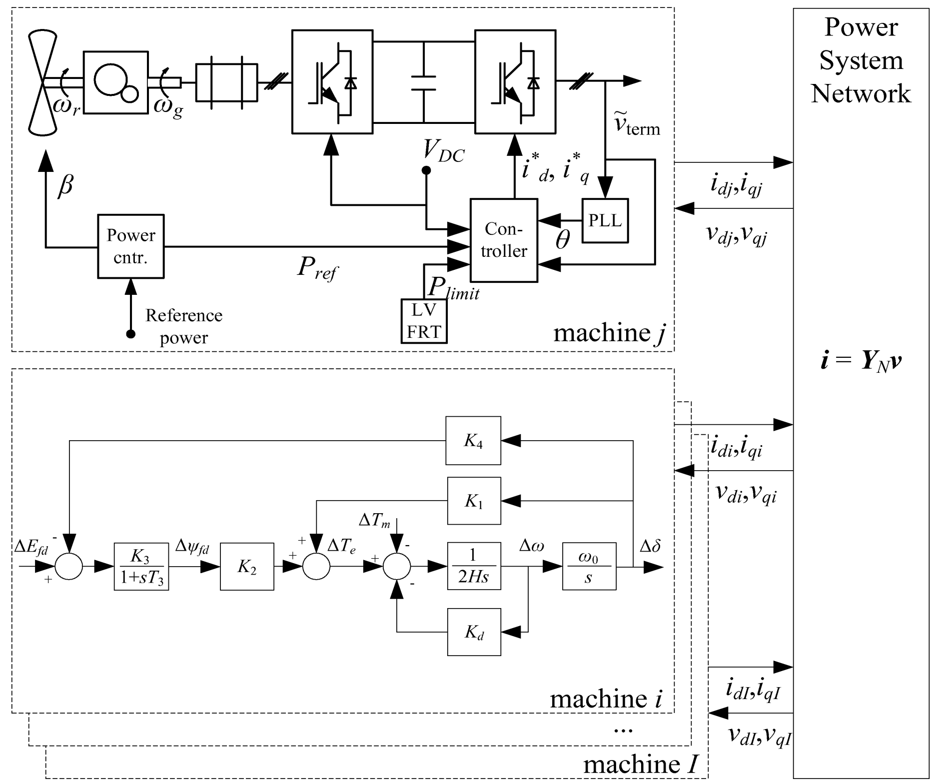
- Location of WPP within inter-area oscillation
- Three aggregate feeders
- 110 3.6 MW WTs
- High and medium wind conditions
- Analyze open loop system with induced torque coefficients (ITC)



$$\frac{\Delta P_{\text{stab}}}{\Delta u} = \underbrace{K}_{Gain} \underbrace{\frac{1}{sT_{lp}+1}}_{\text{Low pass}} \underbrace{\frac{sT_w}{sT_w+1}}_{\text{Wash out}} \underbrace{\frac{1+c_1 s + c_2 s^2 \dots}{1+d_1 s + d_2 s^2 \dots}}_{\text{Phase compensation}}$$

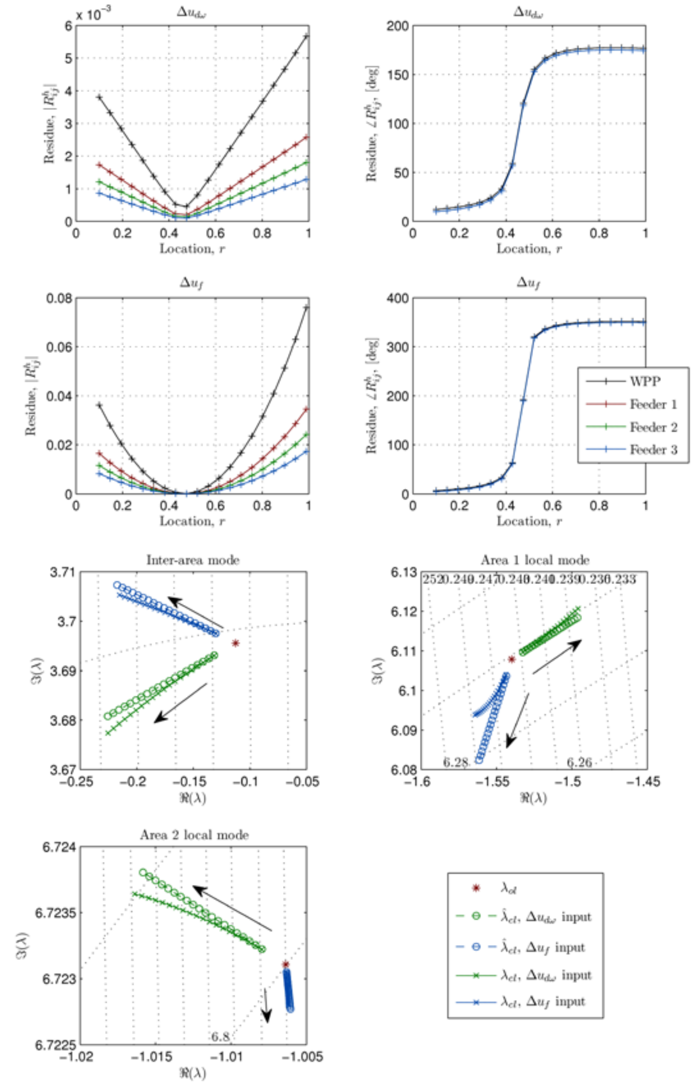
Inter-Machine Interactions

- Low participation of WT mechanical system in system oscillations
- No direct coupling between WT mechanical system and synchronous speed
- WT operation *can* induce a torque on the synchronous generators through the network



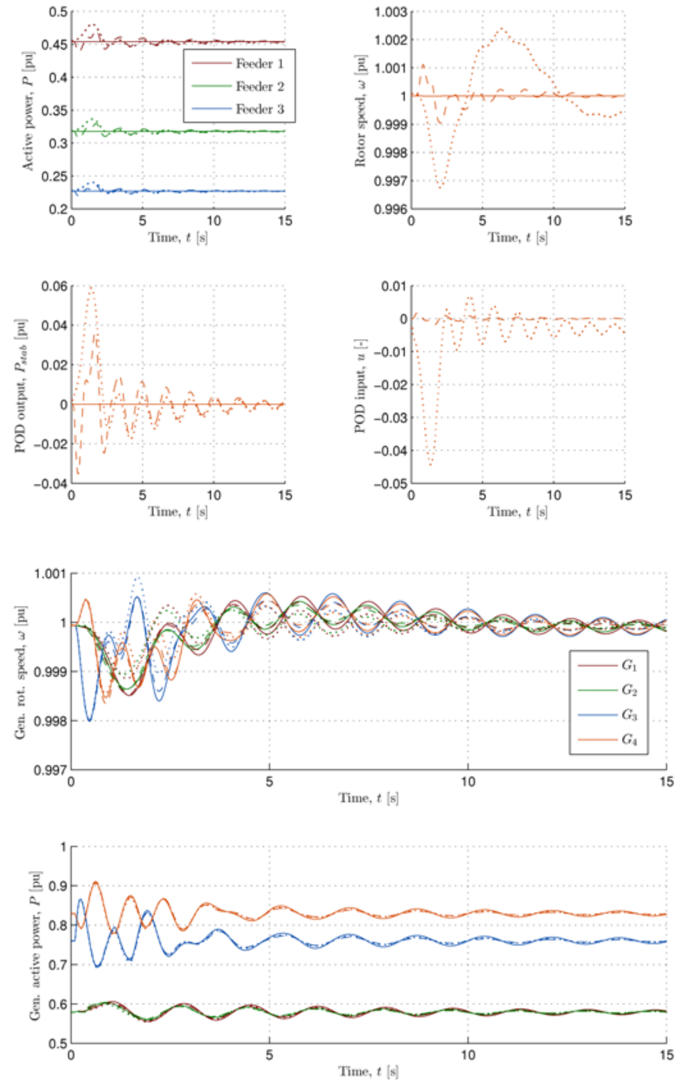
Modal Analysis

- Location of WPP very important for POD efficiency
- Similar residue phase characteristics for each feeder
- ITC predictions match overall behavior



Damping Performance

- Active power output modulated according to POD
- Energy exchange seen i rotor speed
- Increased damping



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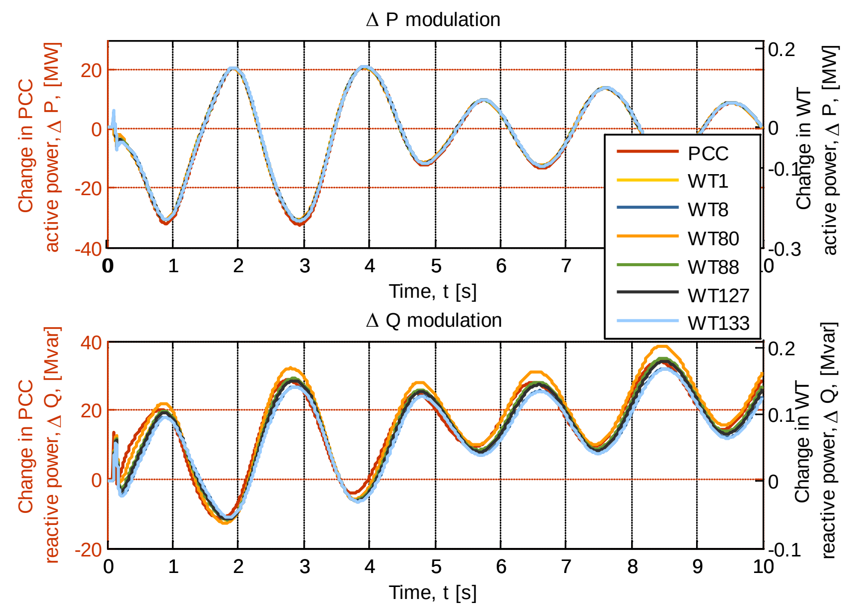
Conclusions

- Concept of using stored kinetic energy as damping power demonstrated
- Positive damping contribution achieved without curtailed operation
- Location of WPP very important for efficiency of damping control
- Predictions from induced torque calculations capture dominant closed-loop properties
- Further work is needed to assess impact, performance, usability, etc. with using WPPs for oscillation damping

Future Work

- Consider modular and distributed nature of WPPs
- Consider more complex power system
- Assess sensitivity to system changes
- Assess efficiency of damping control



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