Inertia Response from HVDC connected Full Converter Wind Turbines

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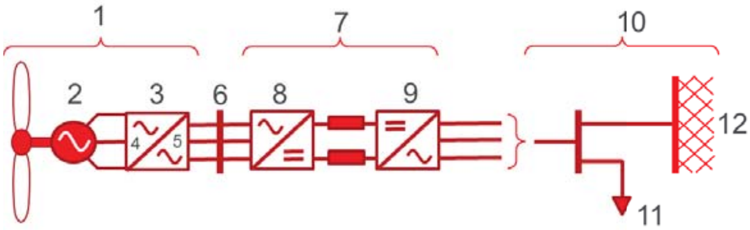
Introduction

The state of art in wind turbine technology features a fully rated frequency converter, allowing the generator side to operate asynchronously from the grid. The Voltage Source Converters, VSC, utilizes extremely rapid switching of semiconductors in order to synthesize the sinusoidal voltage at any frequency. These provide great opportunities with regard to efficiency and flexibility in maximizing power and regulating voltage at the terminals. In addition, VSC-HVDC-links allow the wind parks to be placed offshore, out of sight and in stable wind conditions. A challenge with such installations however, is that the asynchronous operation decouples them from the residual grid, meaning that their equivalent inertia seen from the onshore grid is zero. Adding the fact that power system in general has an increasing amount of distributed power generation (smaller units), the system as a whole has a lower inertia, and is therefore more prone to frequency variations following loss of generation or loads.

System



System configuration and notation:

1. Full Converter Wind Turbine (FCWT), 2. Wind Turbine Generator, 3. Turbine Frequency Converter, 4. Generator Drive Converter, 5. Wind Turbine Grid Converter, 6. Offshore Grid, 7. VSC-HVDC-link, 8. HVDC Offshore Grid Converter, 9. HVDC Onshore Grid Converter, 10. Power system, 11. Load , 12. Residual Grid

The wind turbines are assumed run at optimal power (no reserves) and the system has about 1/3 wind power.

Laboratory set up, National Smartgrids Laboratory at NTNU and SINTEF

Auxilliary control

Principles:

- Energy can be absorbed or supplied by change of rotor speed (kinetically stored)
- Wind turbines must return to its initial rotational speed
- The control should account for lack of primary control (reduced damping)
- Rotational speed drop limits must be kept
- HVDC-voltage limits must be kept

By modifying the reference values of relevant controls in the classical wind turbine converter and HVDC-converter, the frequency deviation of the power system is coupled with the rotational speed of the turbines by electrical qualities, allowing them to contribute with inertia response.

The control design should account for lack of primary control (which dampens the oscillations following a frequency response). This can be explained in two ways; 1. the power flow from the system changes direction when returning to nominal speed (inertial energy can only be lent). 2. The primary control of the residual system must act on a greater mass, its own and the wind turbines.

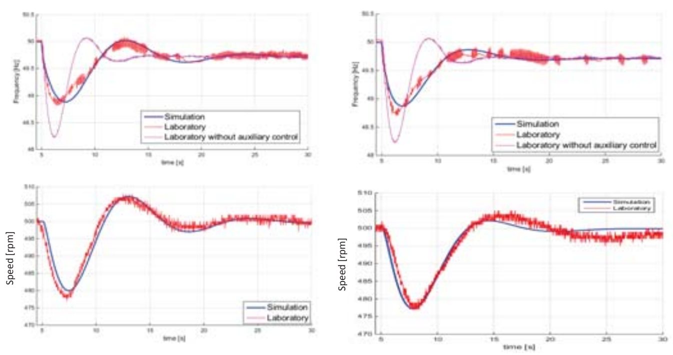
Control: DC-voltage control — Offshore frequency control — Speed control

Measure: Power system frequency — DC-voltage (HVDC) — Offshore grid frequency — Turbine speed

Notation: SDM—Scaled Deviation Mirroring (controller for frequency deviation to be mirrored onto turbine speed), WTS—Wind Turbine Stabilizer (controller for improved damping)

Results

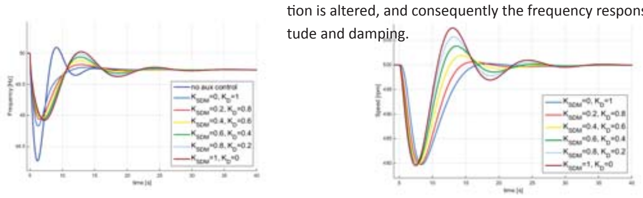
Performance of system with auxiliary controllers. The system is imposed with a 0,0588 p.u. load step in all tests:



Auxiliary Turbine Controllers	Δf [Hz]	Δf-reduction [%]	$\Delta\omega_{WT}$ [rpm]	Overshoot [Hz]	Overshoot reduction [%]	Sustained Oscillations [s]
None	$1.7\ Hz$	-	-	$0.4\ Hz$	-	10 s
SDM	$1.1\ Hz$	35.3 %	$20\ rpm$	$0.35\ Hz$	12.5 %	20 s
SDM and WTS, $K_T = 0.66$	$1.2\ Hz$	29.4 %	$20\ rpm$	$0.15\ Hz$	62.5 %	15 s

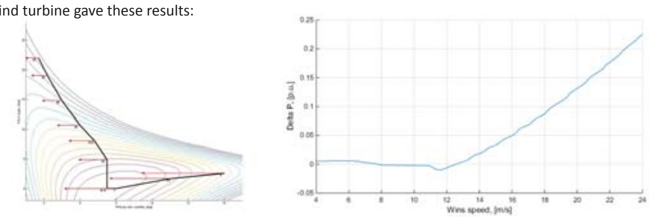
Additional results:

By changing the relative contribution from the SDM and WTS control designs, the timing of the inertial contribution is altered, and consequently the frequency response, amplitude and damping.



Speed-power characteristics of the wind turbine:

Results show a 4% reduction of speed for the wind turbines. Investigation of the aerodynamic performance of a wind turbine gave these results:



Conclusions

The following points have been demonstrated successfully in simulations and laboratory:

- Frequency response can be improved by inertia response from wind turbine control
- Net energy can not be extracted from a governorless power generated unit.
- Added mass in the system, without added primary response, increases oscillations.
- Asynchronous power generation can have its response phase shifted an arbitrary amount, giving possibilities for performance improvement with regard to damping.
- The power coefficient is not critically influenced by the response

The presented material is a selection of the results from the master thesis by Jon Ødegård from NTNU, 2015. The work does not represent Statnett SFs work or research on inertia response, even though it is now Jon Ødegårds current employer and is attending the conference as a representative of Statnett.

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