Coordinated control between wind and hydro power systems through HVDC links

by

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Introduction

- Demonstrate secure power system control using hydro power plants in Norway to balance storm shut down of a wind farm in Denmark
- Three control systems applied to different part of the power system
  - Wind farm
  - HVDC cables
  - Hydro power units
- Coordinated control to improve system dynamic performance
Model description

- Nordic synchronous power system: Norway, Sweden, Eastern Denmark, and Finland
- Continental European synchronous system: West Denmark and rest of UCTE
- Aggregated generation and load
- UCTE denoted by a single bus
- Primary control: 6% droop and ±0.2 Hz
- Wind farms are modeled as a negative load
- Initial power flows on the HVDC lines are taken from NordPool data from 11 November 2010
Storm Controller

- Implemented in each wind turbine
- Delay ramping to zero
- Shut down is modelled with power production change $\Delta P$ and time span $\Delta T$
- Average wind speeds above 25 m/s
HVDC Controller

- Same basic control topology as the original structure
- Constant current control mode

- The central controller has an additional input $\Delta P$
  - compensate for a given power imbalance
  - $\Delta P$ signal comes from Ramp Following Controller (RFC)
Ramp Following Controller (RFC)

- Two inputs: frequency deviation and power flow deviation
- Gets signal from ACE in two interconnected areas, change in load, change in production or flow on HVDC
- HVDC cable track changes in wind power production
Load Frequency Controller (LFC)

- Area control error (ACE) shared among several generators
- Generators contribute according to their ratings
Studied Cases (1)

- Two cases
  - Case A: Horns Rev 2 ⇒ ΔP=209 MW
  - Case B: Six (planned) offshore wind farms ⇒ ΔP=2000 MW

- Initial power flow
  - German-Danish border
  - HVDC links: from West Denmark to the Nordic system

- Shut down from full production to zero production in 15 minutes

- Studied results
  - Power flows on German-Danish border and HVDC links
  - Nordic frequency
  - Generating units in Denmark and Norway
Studied Cases (2)

- **LFC in Danmark:**
  - ± 90 MW capacity
  - Three largest thermal generators
  - Monitor the German-Danish border flows

- **LFC in Norway**
  - ± 375 MW capacity
  - 3 aggregated hydro power plants
  - Monitor the AC-transmission with Sweden and HVDC connections with Denmark
Simulation Results (1)

Case A ⇒ $\Delta P=209 \text{ MW}$

- RFC-HVDC-control and LFC in Denmark removes German-Danish border imbalance
- Nordic frequency deviation can be avoided by using LFC controllers in Norway

LFC in Denmark

HVDC control + LFC in Denmark

HVDC control + LFC in Denmark + LFC in Norway
Simulation Results (2)

Case B ⇒ ΔP=2000 MW

- Excess power observed in the Western Danish power system
- Reversing the power flow on SK3 reduces the steady state imbalance at the German-Danish border
- Nordic frequency deviation remains within allowed limits

- HVDC control + LFC in Denmark + LFC in Norway
- HVDC control, SK3 reversed + LFC in Denmark + LFC in Norway
Conclusion

- Coordination between the controllers either removes (Case A) or significantly reduces (Case B) the power imbalance.
- Nordic frequency deviations can be avoided/reduced by using LFC in Norway.
- Reversing power flow on Skagerrak3 helps in reducing the German-Danish border imbalance but increases the frequency deviation in the Nordic synchronous system.
- Exporting the imbalance to Norway is feasible and advantageous to the West Danish power system.
- The presented balancing actions require reservation of capacity on HVDC links and hydro generation units in Norway if they were to be implemented in the real system.
Thank You for your attention!

Questions?