Reactive Compensation Systems for Large Wind Farms

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Overview of Presentation

- Background to the need for reactive compensation
- Overview of reactive power requirements for large wind farm interconnections in North America
- Overview of the reactive power capabilities of various types of wind turbine generators
- Composition of typical reactive compensation equipment
- Case study on a typical compensation system for a large wind farm

Background to the Need for Reactive Compensation

- Power flow causes voltage drops due to impedance of lines & cables
- System loads change daily and seasonally
- Motor loads and wind plants without reactive power capability consume reactive power
- Transmission lines and cables provide capacitive reactive power under light load conditions
- Reactive power can be used to control bus voltages to desired levels

Overview of Reactive Power Requirements for Wind Farms

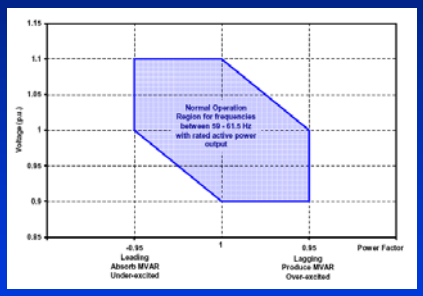
- Requirements for wind parks similar to those of conventional synchronous generators
- Reactive power required for voltage control on the utility system
- Grid codes/interconnect agreements specify reactive power requirements
  - FERC 661-A in USA
  - Provincial requirements in Canada

Overview of Reactive Power Requirements for Wind Farms

- FERC 661-A specifies that large wind farms must maintain a power factor within the range of 0.95 leading to 0.95 lagging, measured at the POI as defined in the LGIA, if the Transmission Provider shows in the system impact study that they are needed to ensure the safety or reliability of the transmission system
- Provision for the wind farm to provide sufficient dynamic voltage support in lieu of the power system stabilizer and automatic voltage regulation at the generator excitation system associated with conventional synchronous generators if the system impact study shows this to be required for system safety or reliability

Overview of Reactive Power Requirements for Wind Farms

- Canada: Manitoba Hydro
  - Generator to maintain power delivery at continuous rated power output measured at the generator intermediate bus at a power factor within the range of 0.95 overexcited (leading) to 0.95 underexcited (lagging) if the facility is rated larger than 10 MW



Wind Turbine Generator (WTG) Reactive Power Capabilities

- Wound rotor induction generators with external resistors
    - Power factor correction capacitors
- Doubly-fed induction generators with rotor converter
    - Dynamic power factor control
- Simple induction generator with full power converter
    - Dynamic power factor control

Reactive Power Compensation Systems for Wind Farms

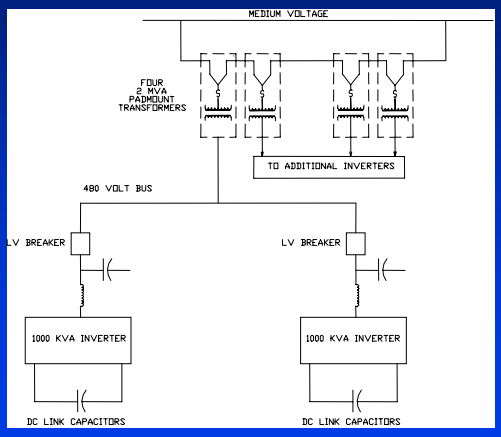
- Collector substation-based reactive power compensation systems
  - Mechanically-switched capacitors (MSC) and reactors (MSR)
  - Static Var Compensators (SVC)
  - Hybrid compensators
    - Inverter-based dynamic component
    - MSCs and MSRs

Inverter-Based Dynamic Compensators

- Inverter-based dynamic component
  - 1/1.2 MVAR modules
  - 250 to 330% of continuous rating short-time capability for 2 to 4 seconds
    - LVRT support
    - Dynamic range requirement
  - Connects to collector bus via 480 V/34.5 kV padmount transformer

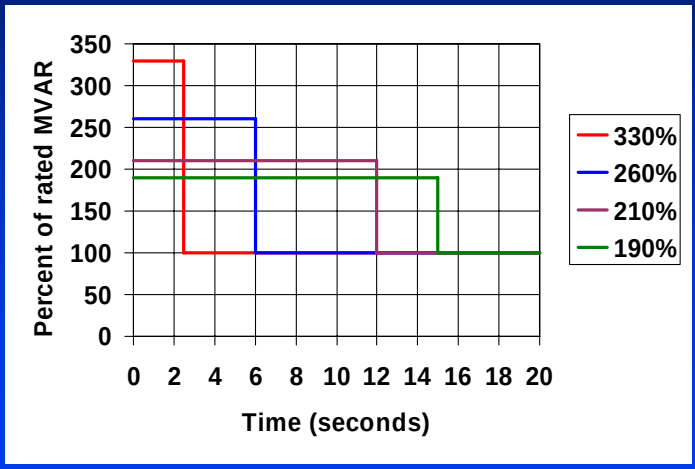
Inverter-Based Dynamic Compensators

Typical configuration



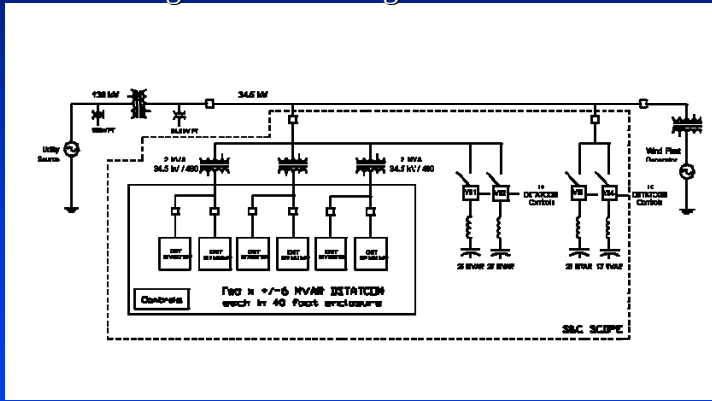
Inverter-Based Dynamic Compensators

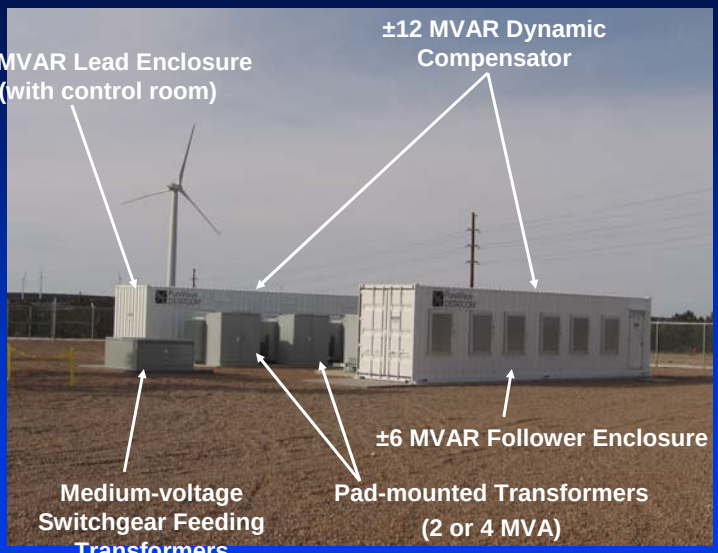
Short-time capability



Case Study: Typical Compensation System for a Large Wind Farm

±12/40 MVAR DSTATCOM on 90 MW Wind Farm controlling 4 MSCs totaling 91 MVAR





±12 MVAR Dynamic Compensator for Wind Farm

Conclusions

- Interconnect requirements or grid codes on reactive power compensation for large wind farms can generally be met by the reactive power capabilities of the WTGs and an external reactive compensation system
  - Extent to which the WTGs can contribute towards the overall reactive power requirements is dictated by the type of WTG
- MSCs or hybrid compensation systems consisting of inverter-based dynamic compensator and multiple switched capacitor banks used in most cases to meet overall reactive power requirements for large wind farms