Power Quality Solutions for Voltage dip compensation at Wind Farms

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Agenda

• Introduction
• Basic technologies
• Power Quality from wind turbines
• Voltage dips at wind farms
• Spanish Grid Code requirements
• Power electronic solutions
• Case Study: DVR and STATCOM at wind farms
• Conclusions
Introduction

- Plan for the promotion of renewable energy (1999) in Spain
  - Goal of meeting 12% of the total energy supply and 29% of electricity with renewable by 2010.
- The strongest growth in renewable energy comes from the wind sector, which is already at 70% of the Plan’s goal for installed capacity of 13,000 MW by 2010.
- In 2004, the Spanish government raised the renewable energy target to 20 GW by 2010.

Sources:
Basic Technologies

• Fixed speed
  • Induction generator with capacitor bank
  • Induction generator (two-generator principle) two pole pairs
  • Induction generator rotor resistance control

• Variable Speed
  • Doubly-fed induction generator DFIG (wounded rotor)
  • Full power converter:
    • Squirrel cage induction generator – full power converter
    • Synchronous generator - external magnetized
    • Synchronous generator Permanent magnet
Power Quality from wind turbines

Network

- Voltage dips
- Interruptions
- Voltage Unbalance
- Frequency variations

Network

- Power variations
- Voltage variations
- Flicker
- Harmonics
- Transients
Voltage dips at wind farms

Spanish Regulations established in 1985 require that all wind turbines automatically trip off-line if the grid voltage drops below 85% of the required voltage.

Risks Stability Problems!!

Simulation PSS/E fixed-speed wind farm
In October 2006, Spain adopted a grid code that requires a windfarm to stay connected to the system for voltage dips (on any or all phases) above the heavy black line.
Reactive power capability

voltage stability by utilizing reactive power injection capability of variable speed wind turbines.
Wind Power requirements

- The capacity to meet these requirements depends on the wind turbine technology
  - Variable speed wind turbines using synchronous generators with a power electronic converter connected to the grid can provide this facility with minimum modifications.
  - Fixed-speed induction generators require additional equipment at the PCC.
    - DFIG VARIATIONS:
      - DFIG+ Crowbar
      - DFIG+ Crowbar and stator switch
D-STATCOM

- Based on Voltage Source Inverter (VSI)
- Operating range is wider than a classic SVC
- Control functions is based on the adjustment of voltage through power electronics

- The capability of the STATCOM to operate at low voltage allows it to contribute to the low voltage ride through requirement
Case Study: DVR AT PCC

- DVR control structure includes:
  - Voltage dip detection.
  - reference generation and compensation strategy.
- DC voltage control
- IGBT power converter control
Simulation results (I)

- Wind turbine performance under three-phase fault conditions with DVR.

![Graphs showing PCC bus voltage, DVR injected voltage, Wind farm bus voltage, Angular velocity of the rotor, Electromagnetic torque Te, Active Power, and Reactive Power over time.](image-url)
Simulation results (II)

- Wind turbine performance under single-phase to ground fault with DVR.
CASE STUDY: STATCOM AT PCC

Objective of the simulation

- To keep wind farm stable and wait for failure recovery and voltage restoration when faults occurs at distribution network.
- A solid state circuit breaker (SSCB) opens in case of fault at the PCC and closes once in normal situation.
Simulation results: STATCOM at PCC

Magnitude and phase voltage at PCC and wind farm during the dip

Injected active and reactive power from the wind farm

Rotor speed evolution during the dip

Active and reactive power supplied by the STATCOM
## Conclusions

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<th>Harmonics</th>
<th>Flicker</th>
<th>Voltage dips and short interruptions</th>
<th>Voltage fluctuation</th>
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- **Harmonics**: Active filters are good.
- **Flicker**: All methods are good except D-STATCOM is not used.
- **Voltage dips and short interruptions**: Limited by the capacitor.
- **Voltage fluctuation**: All methods are good.
- **Voltage Unbalance**: Difficult control.
Conclusions

- Custom Power Systems (D-STATCOM, DVR) helps wind turbines to withstand voltage drops without disconnection.
  - Reliability, stability and quality of supply.
Thank you!

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