Power Quality Solutions for Voltage dip compensation at Wind Farms

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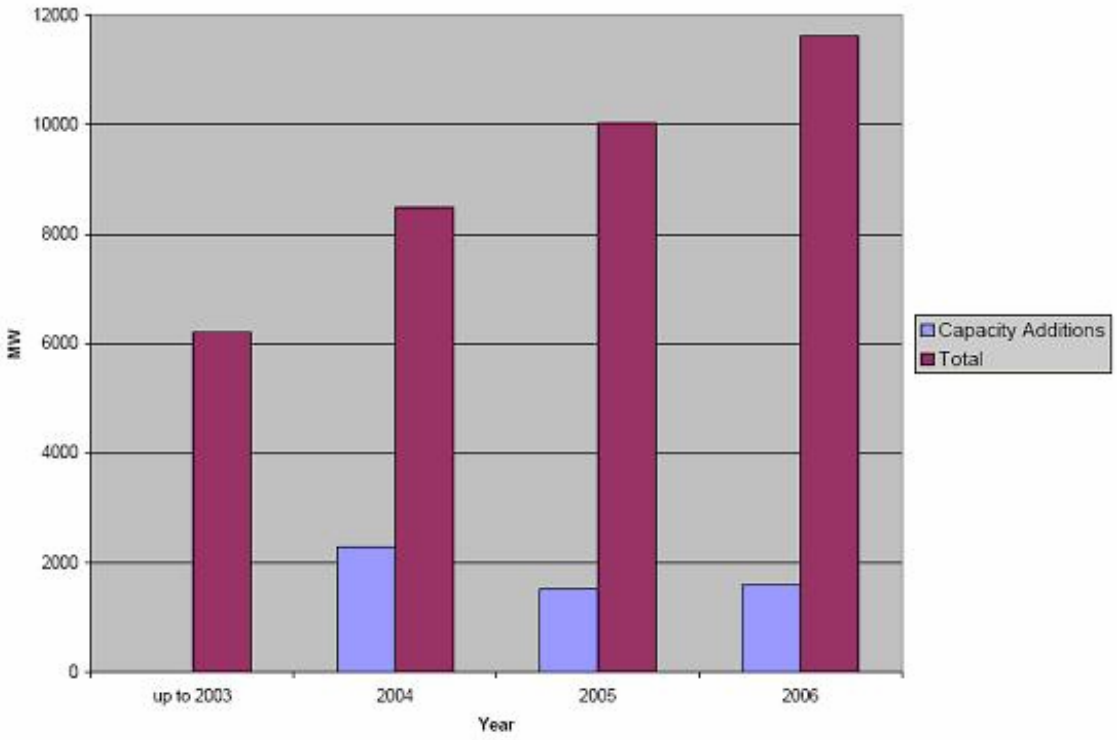
Agenda

- 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



Installed wind capacity in Spain

Sources:

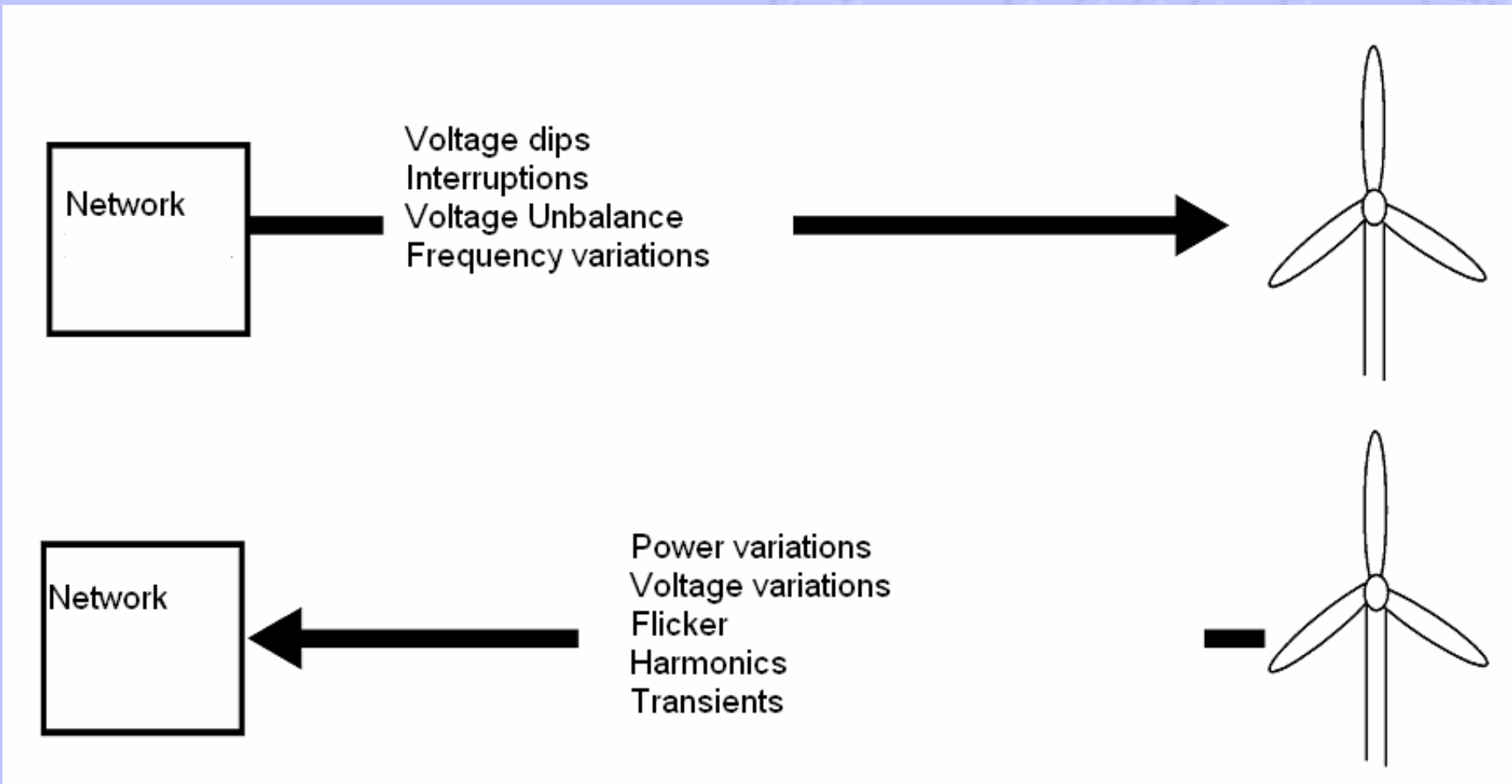
Global Wind Energy Council. "Global Wind Energy Markets Continue To Boom – 2006 Another Record Year." 2007.

- 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.

Basic Technologies

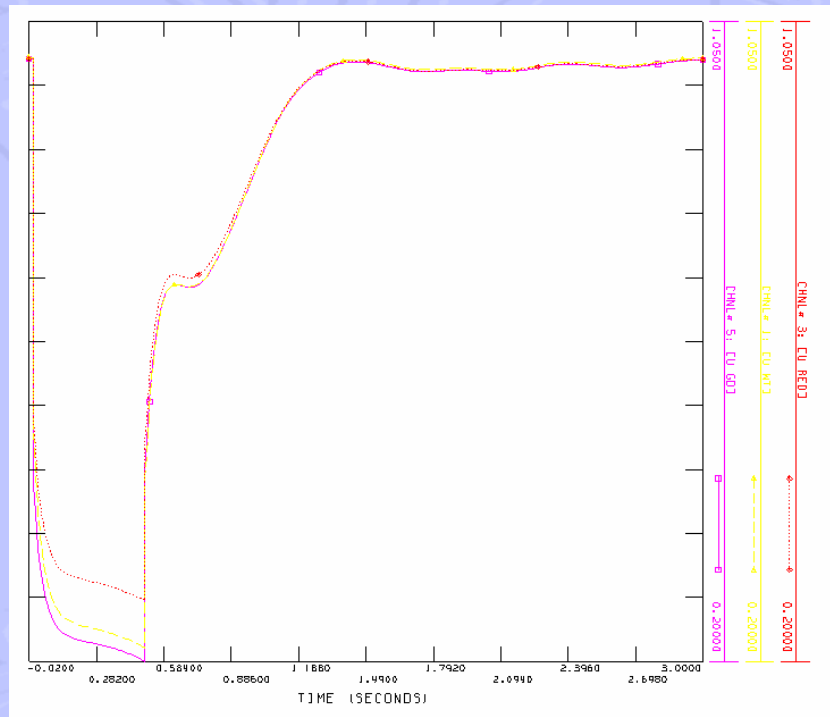
- Fixed speed
  - Induction generator with capacitor bank
  - Induction generator (two-generator principle) two pole pairs
  - Induction generator rotor resistance control
- Variable Speed
  - Doubly-fed induction generator DFIG (wounded rotor)
  - Full power converter:
    - Squirrel cage induction generator –full power converter
    - Synchronous generator- external magnetized
    - Synchronous generator Permanent magnet

Power Quality from wind turbines



Voltage dips at wind farms

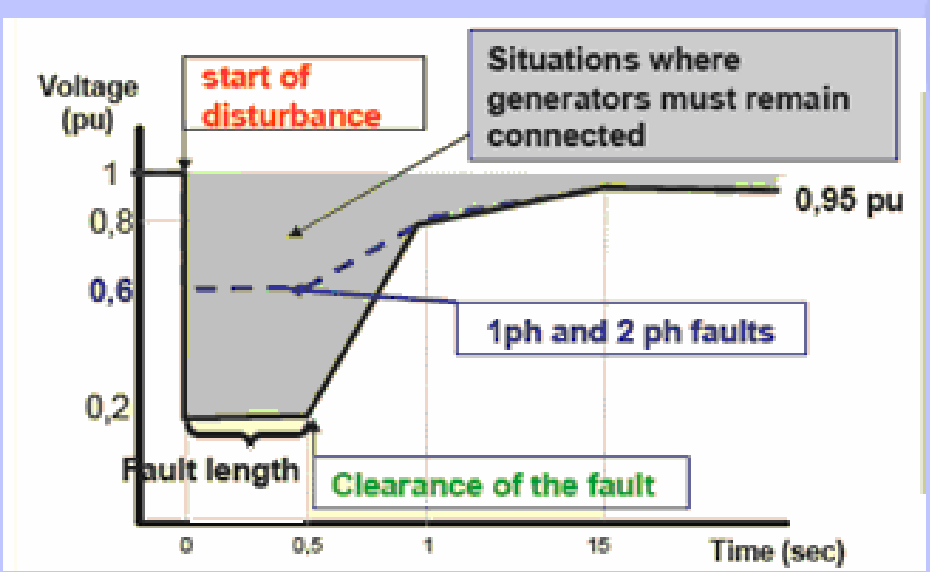
Spanish Regulations established in 1985 require that all wind turbines automatically trip off-line if the grid voltage drops below 85% of the required voltage.

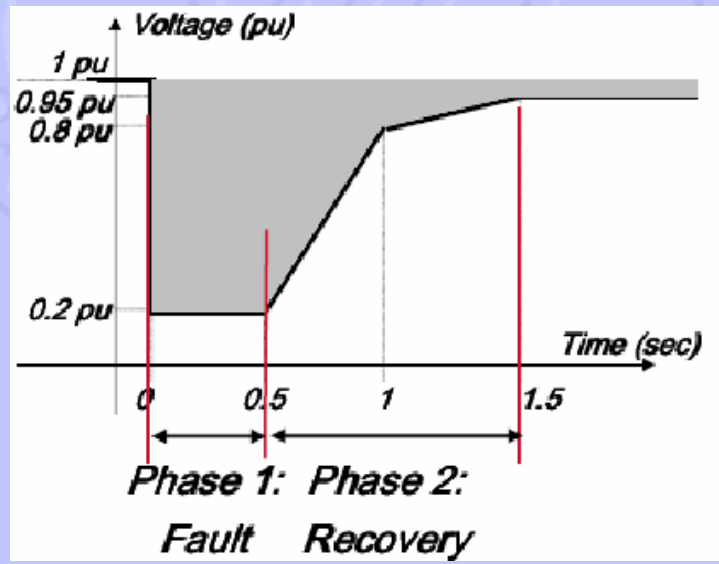


Simulation PSS/E fixed-speed wind farm

Risks Stability Problems!!

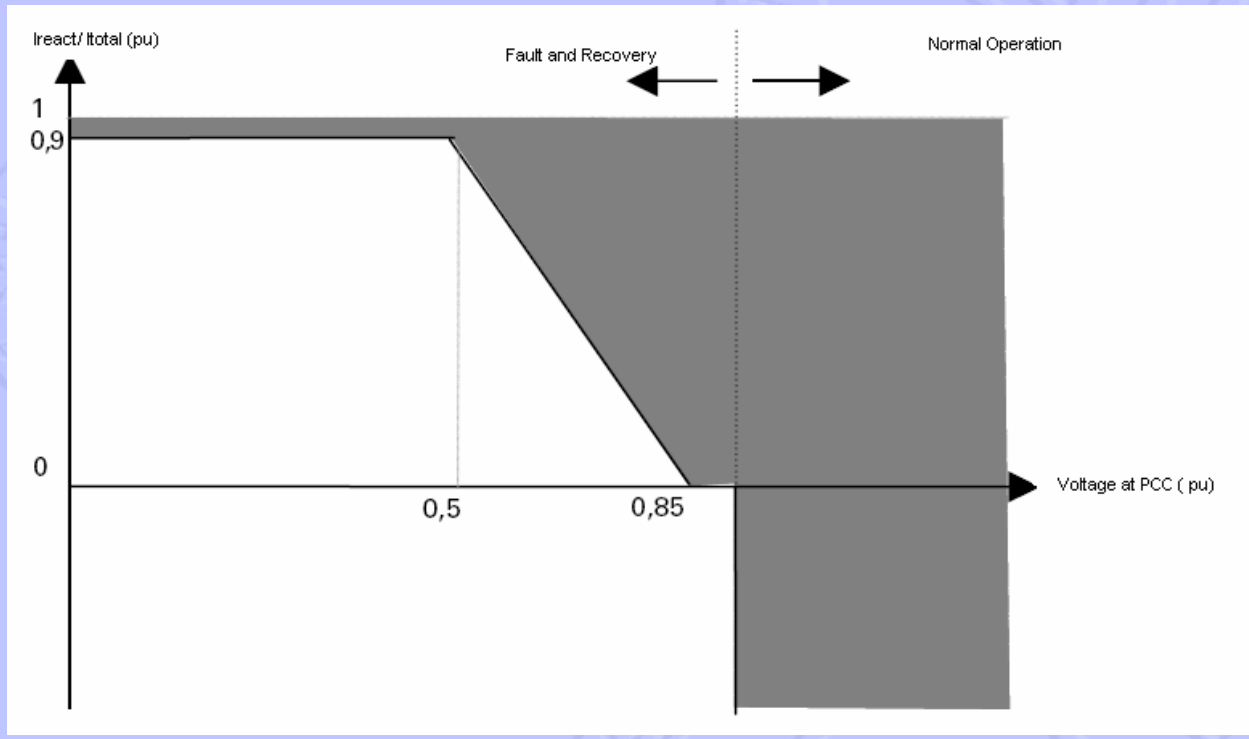
Grid code requirements





- 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



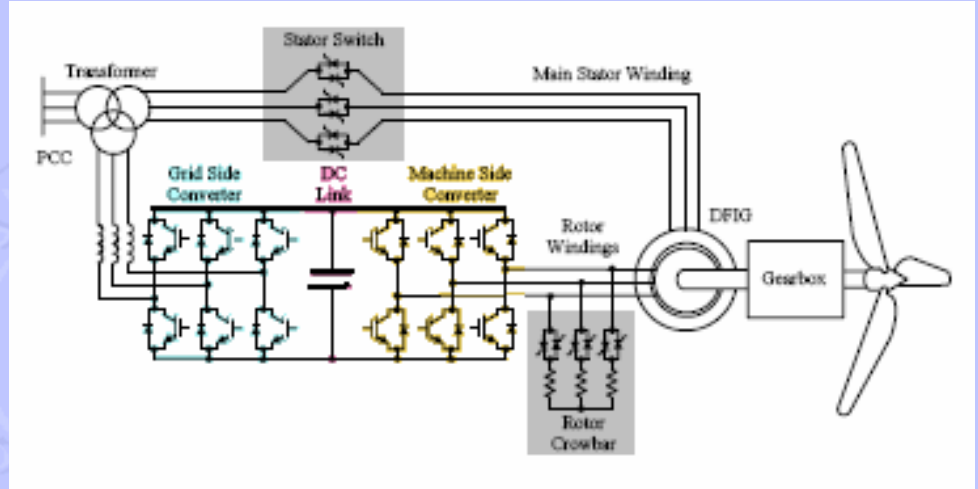
voltage stability by utilizing **reactive** power **injection** capability of variable speed **wind turbines**.

Wind Power requirements

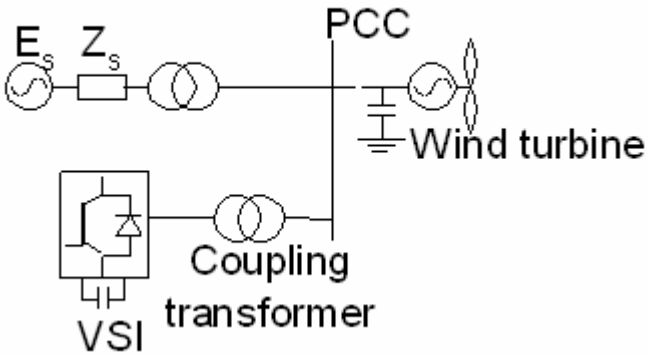
- The capacity to meet these requirements depends on the wind turbine technology
  - Variable speed wind turbines using synchronous generators with a power electronic converter connected to the grid can provide this facility with minimum modifications.
  - Fixed-speed induction generators require additional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

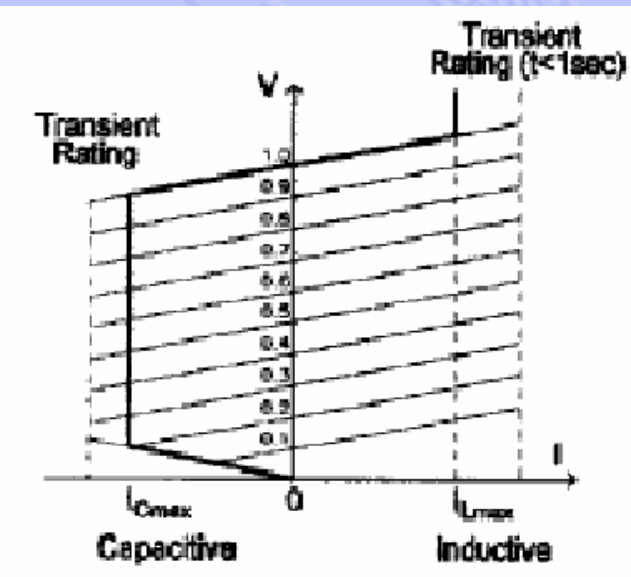
      DFIG+ Crowbar

      DFIG+ Crowbar and stator switch



D-STATCOM

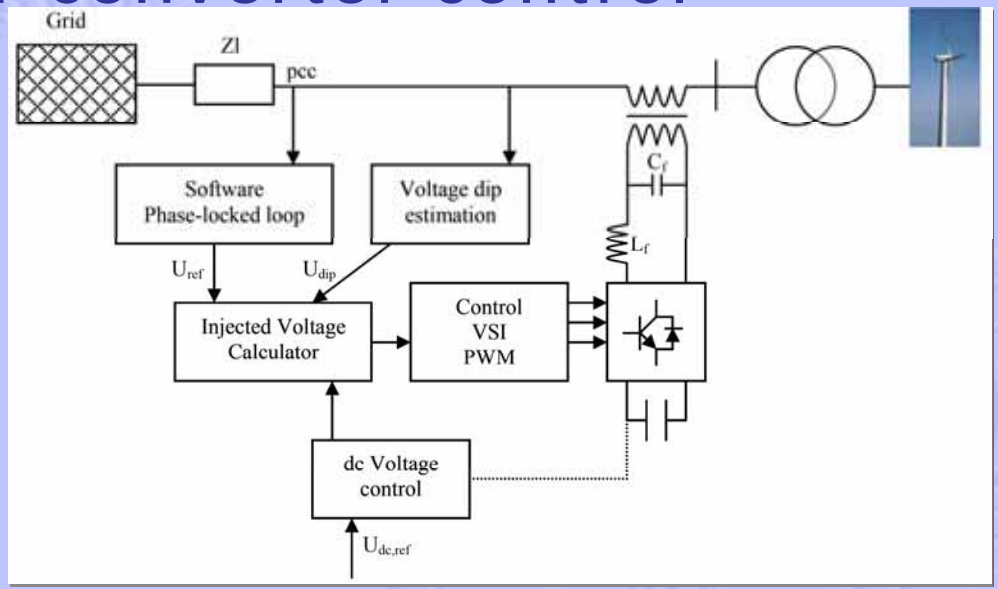




- Based on Voltage Source Inverter (VSI)
- Operating range is wider than a classic SVC
- Control functions is based on the adjustment of voltage through power electronics
- The capability of the STATCOM to operate at low voltage allows it to contribute to the low voltage ride through requirement

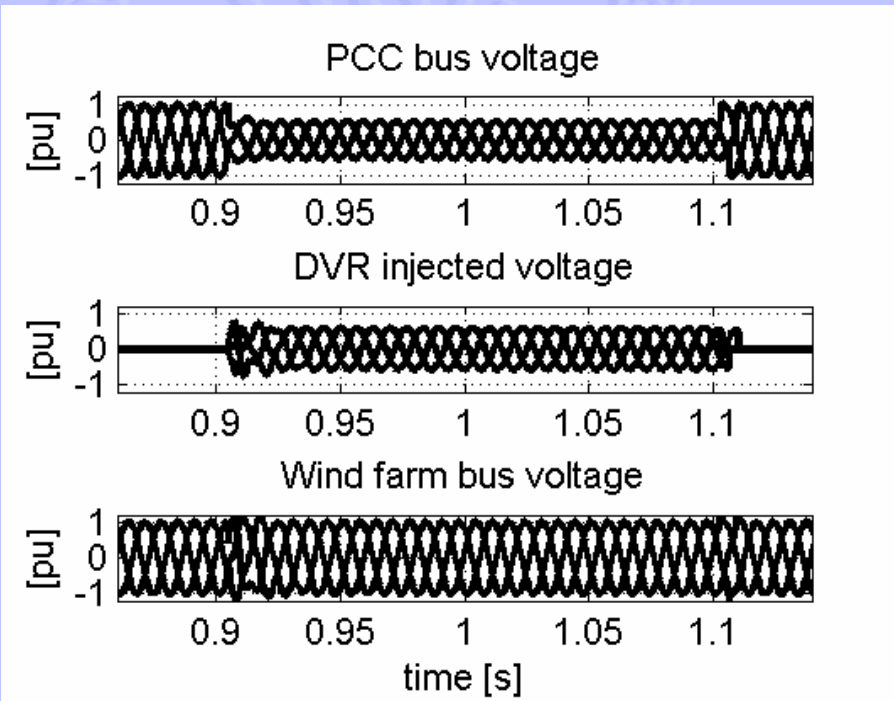
Case Study: DVR AT PCC

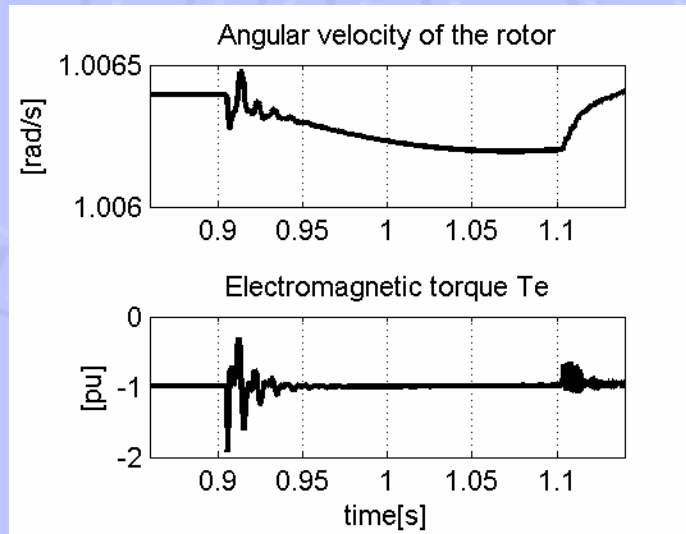
- DVR control structure includes:
  - Voltage dip **detection**.
  - **reference generation and compensation** strategy.
- DC voltage control
- IGBT power converter control

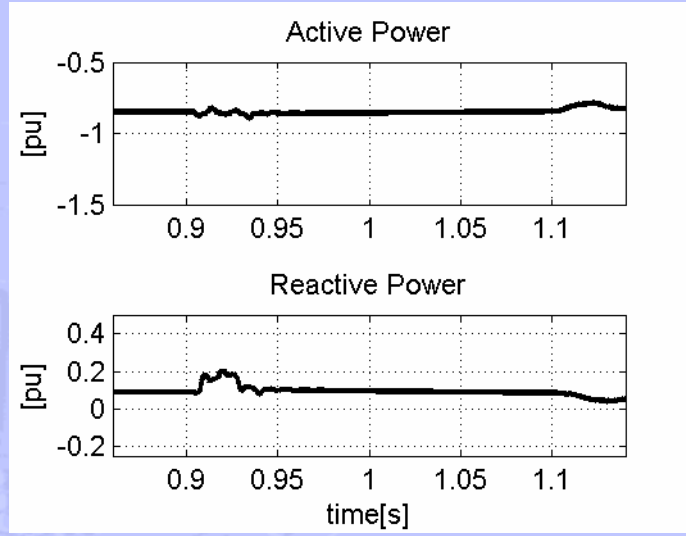


Simulation results (I)

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

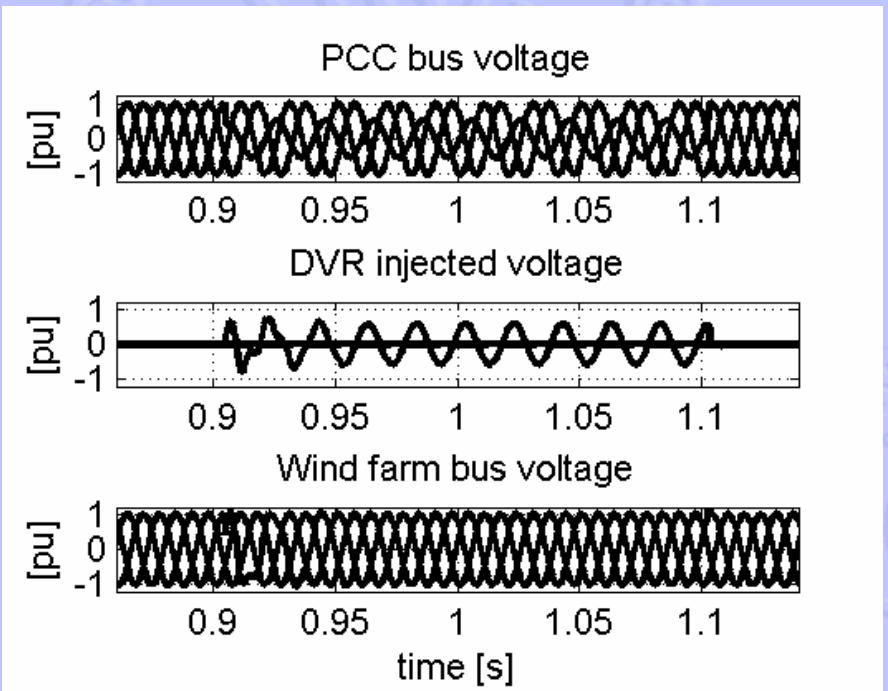


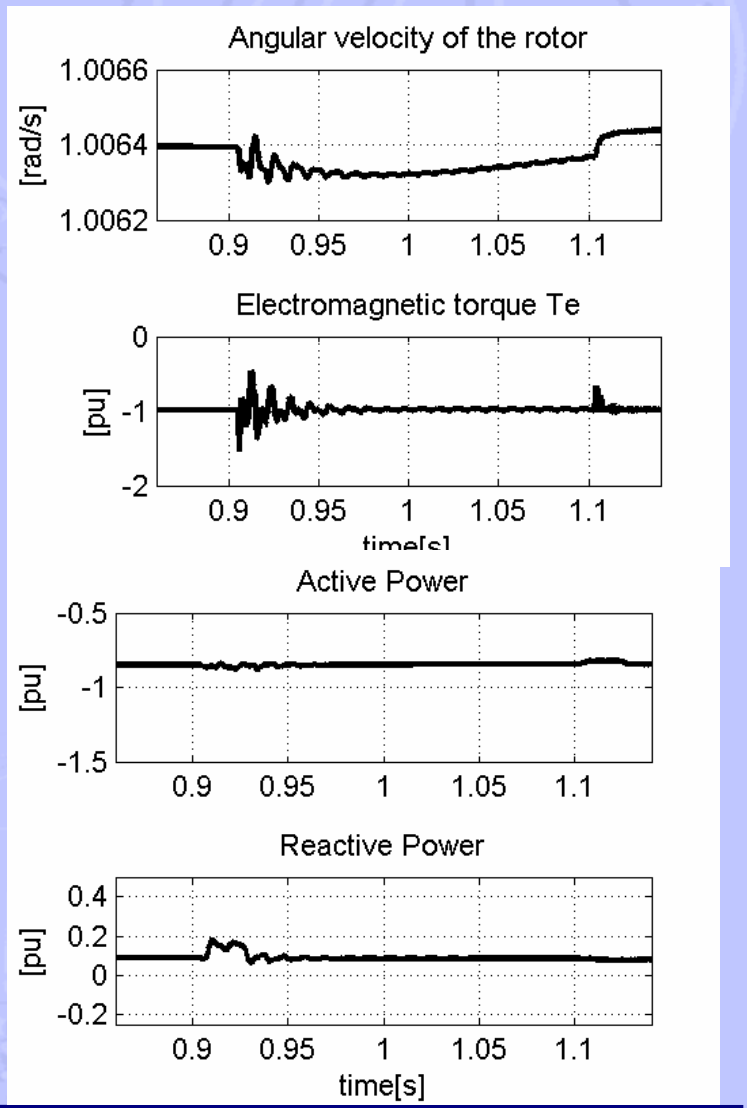




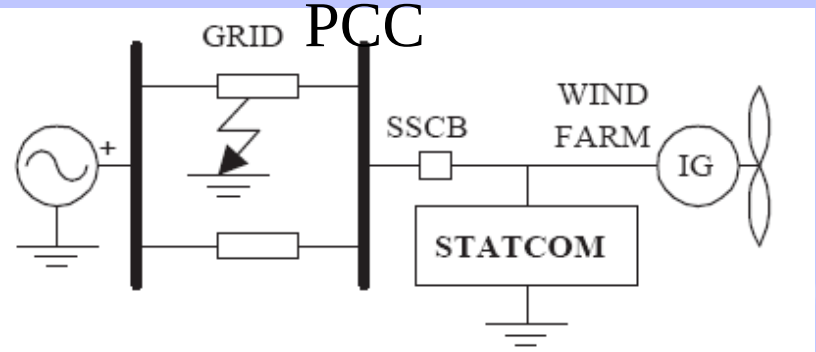
Simulation results (II)

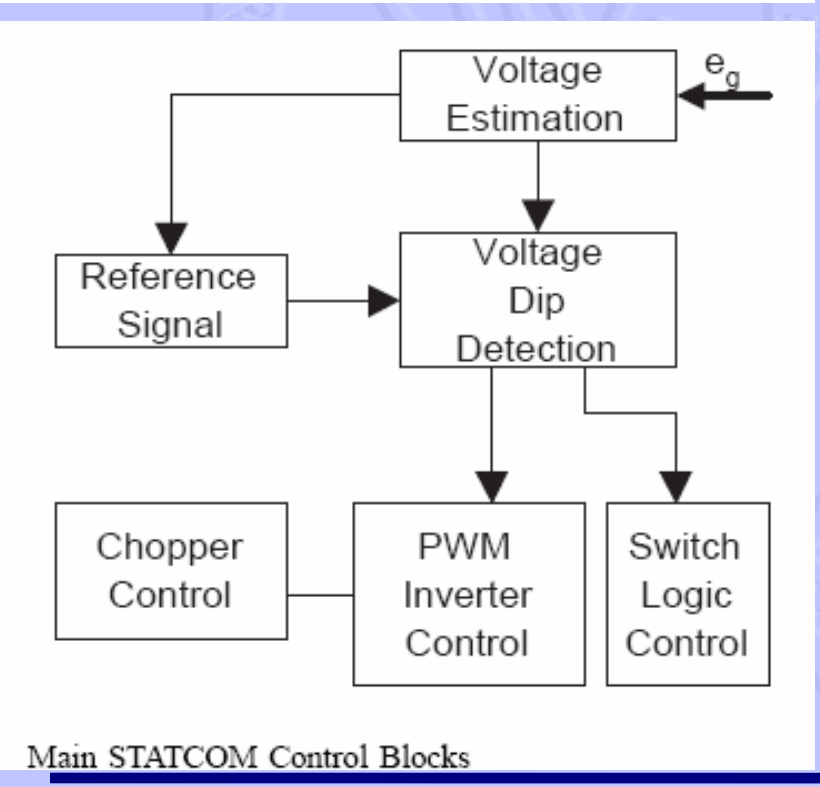
- Wind turbine performance under single-phase to ground fault with DVR.





CASE STUDY: STATCOM AT PCC



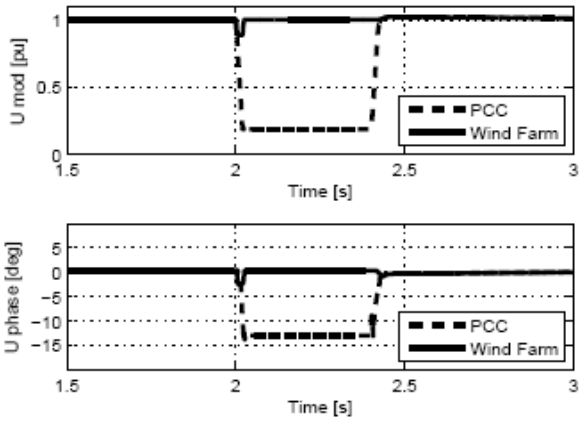


Main STATCOM Control Blocks

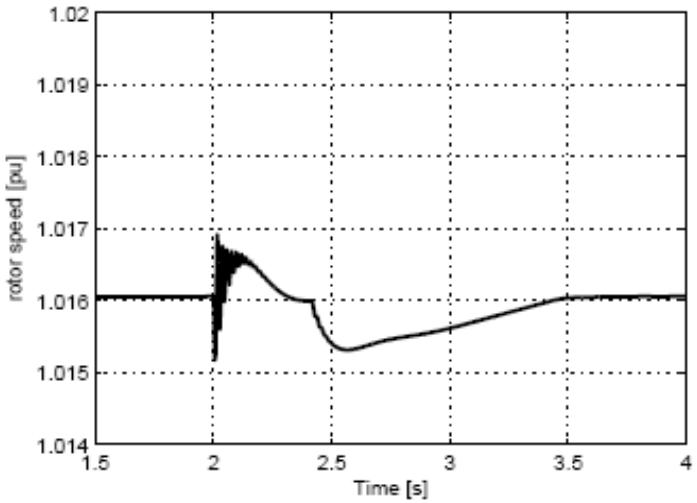
Objective of the simulation

- 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.

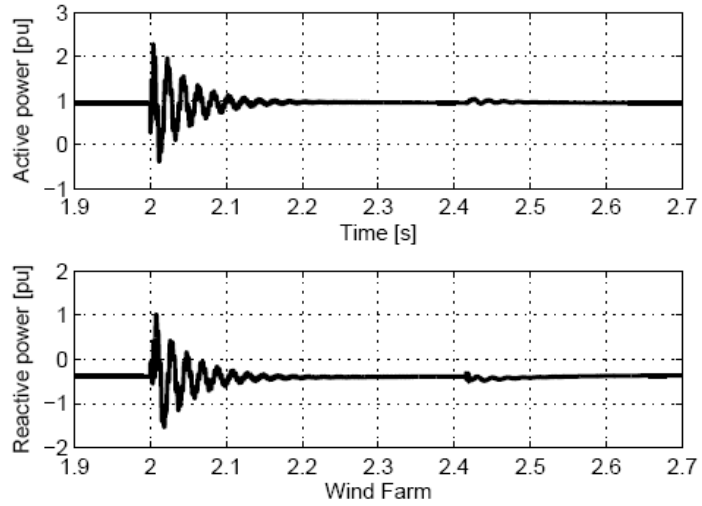
Simulation results: STATCOM at PCC



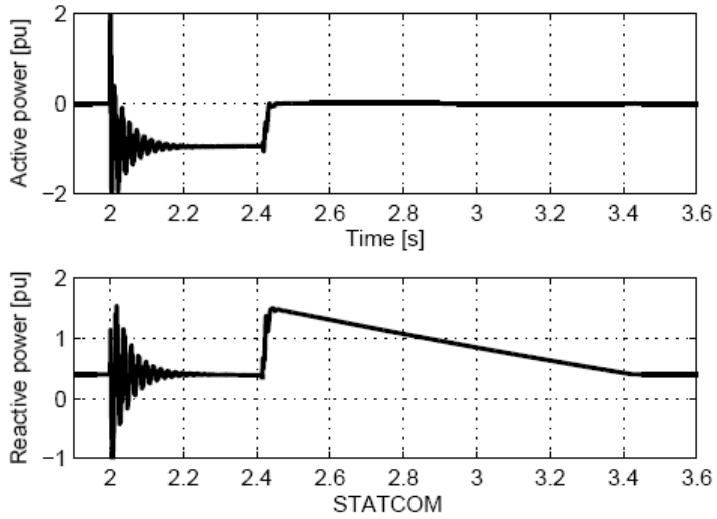
Magnitude and phase voltage at PCC and wind farm during the dip



Rotor speed evolution during the dip

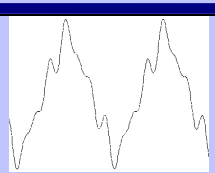
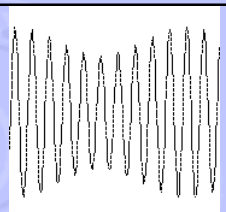
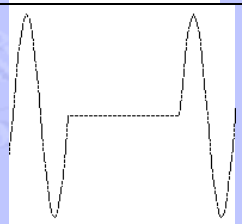
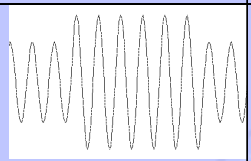
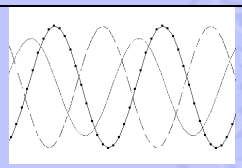


Injected active and reactive power from the wind farm



Active and reactive power supplied by the STATCOM

Conclusions

Harmonics		-Active filters	-Good
Flicker		-D-STATCOM -DVR -UPQC	-Good -Not used -Good
Voltage dips and short interruptions		-D-STATCOM -DVR -UPQC	-Limited by the capacitor -Good -Good
Voltage fluctuation		-D-STATCOM -DVR -UPQC	-Low -Good -Good
Voltage Unbalance		-D-STATCOM -DVR -UPQC	-Difficult control -Good -Good

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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