Abstract

Wind Plant Penetration is fast approaching 15 to 20 percent in many power systems throughout the world. Because of these high penetration levels, there is a trend towards Transmission Providers holding Wind Plants to the same standards as conventional power plants in terms of reactive power control and voltage ride-through. This paper focuses on coordination of a Doubly-Fed Induction Generator (DFIG, type 3) Wind Plant with STATCOM and shunt capacitor banks to optimize voltage control during steady state operation. The proposal is to design a capacitor switching control to maximize reactive reserve of the DFIG turbines and the STATCOM while maintaining the steady state voltage schedule of a pilot bus. The capacitor switching control may take into account local voltage level, STATCOM reactive power output, and load net wind real and reactive power output and forecast.

Conventional Capacitor Switching Control

Conventional capacitor switching on the transmission system level is done manually by SCADA control. Voltage relays back up manual switching when voltages are out of range.

Conventional capacitor switching is sometimes done automatically based on time of day or local voltage magnitude

Large dead bands are used to avoid excessive switching duty.

Following a fault, switching should be delayed to allow for reclosing, but should happen before ULTCs or distribution voltage regulators act.

Capacitor Switching Control with Wind

Because the reactive capability of a type 3 wind farm varies as its real output varies, Q_{wind} = Q_{load} varies unpredictably.

This unpredictability makes manual cap switching difficult.

STATCOM and synchronous generators compensate for wind reactive power variation while nearby cap banks go unused.

This results in low dynamic reactive reserve and high static reactive reserve - a bad situation.

Proposed capacitor Switching Control

In addition to local voltage signal, the cap switching control will consider:

- STATCOM reactive power output
- Wind Farm real and reactive power output
- Remote signals such as pilot bus voltage, real and reactive power
- P_{wind} - P_{load} and Q_{wind} - Q_{load} forecast

Hierarchical Voltage Control

Primary Voltage Control (PVC) - Control voltage at immediate bus via generator AVR or ULTC transformer. Time constant of seconds.

Secondary Voltage Control (SVC) - Generate set points for regional PVC devices in order to control the voltage of a nearby pilot bus. Also switches of discrete reactive devices such as capacitor banks and reactors.

Coordinated Secondary Voltage Control (CSVC) is a modern form of SVC which uses multivariable optimization to regulate one or more regional pilot buses. Time constant of 10s of seconds to minutes.

Tertiary Voltage Control (TVC) - Optimizes voltage of entire power system by running an Optimal Power Flow. Time constant of 15 minutes.

Voltage Control Resources

- Type 1 and 2 Wind Plants are compensated by shunt capacitors at the generator terminals and by shunt capacitors and a Static Var Compensator or STATCOM at the Point of Interconnection.
- Type 3 Wind Plants have generators which can produce reactive power so they are able to meet reactive power requirements by the use of generators alone. Current research topics include DFIG coordination with STATCOM to improve Low Voltage Ride-through (LVRT) [1] and also integration of DFIG with SVC [2].
- Type 4 generators are capable of producing reactive power and only need additional compensation in the case of extremely weak connections.

Test System

- The Test System above will be used to test a new capacitor Switching Control Methodology.
- A Type 3 Wind Plant is represented as a variable real and reactive power source based on the DFIG capability curve. A STATCOM and capacitor Bank are placed on the low voltage side of the collector substation transformer.
- The pilot bus voltage will be controlled predominantly by the Type 3 generators, STATCOM, and two capacitor banks. It is assumed that the Pilot bus is weakly connected to the rest of the grid (Z1, Z2 << Z3).

References