STATCOM FOR WIND ENERGY SYSTEMS

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Abstract:

An integrated power system has large wind farms stability and controllers. A thorough study has been needed to identify the initial problems and to develop measures for the mitigate that. And integration of high levels to an existing transmission system has not required a major redesign system and it necessitates additional control and compensates equipment to enable recovery from severe system disturbances.

These paper insights to the purpose of the Static Synchronous Compensator (STATCOM) along with wind farms for the use of stable the grid voltage such as a 3 phase short circuit faults, temporary trip of a wind turbine and load changes. The strategy focuses on a fundamental grid operational requirement is maintain the voltages power system at the point of common coupling by voltage system. The DC voltage for wind turbine (WT) inverters is also stabilized for facilitate operation of wind turbines during disturbances system.

Keywords- STATCOM, DFIG, FACTS, Simulation

I. INTRODUCTION

The wind power penetration has increased dramatically in the past few years, hence it has become necessary to address problems associated with maintaining a stable electric power system that contains different sources of energy including hydro, thermal, coal, nuclear, wind, and solar. One of the major issues concerning a wind farm interconnection to a power grid concern is its dynamic stability on the power system. Voltage instability problems occur in a power system that is not able to meet the reactive power demand during faults and heavy loading conditions. Stand alone systems are easier to model, analyze, and control than large power systems in simulation studies. A wind farm is usually spread over a wide area and has many wind generators, which produce different amounts of power as they are exposed to different wind patterns.

Flexible AC Transmission Systems (FACTS) such as the Static Synchronous Compensator (STATCOM) and the Unified Power Flow Controller (UPFC) are being used extensively in power systems because of their ability to provide flexible power flow control. The main motivation for choosing STATCOM in wind farms is its ability to provide bus bar system voltage support either by supplying and/or absorbing reactive power into the system.

The applicability of a STATCOM in wind farms has been investigated and the results from early studies indicate that it is able to supply reactive power requirements of the wind farm under various operating conditions, thereby improving the steady-state stability limit of the network. Transient and short-term generator stability conditions can also be improved when a STATCOM has been introduced into the system as an active voltage/var supporter.

This paper explores the possibility of enabling wind farms to provide voltage support during normal conditions, as well as under conditions when system voltages are not within desired limits. The transient behavior of wind farms can be improved by injecting large amounts of reactive power during fault recovery. This paper examines the use of STATCOMs in wind farms to stabilize the grid voltage after grid disturbances such as line outages or severe system faults.

Power control is vital for transient and voltage stability during faults and is required to meet the connection requirements of the wind turbines to the grid which vary mostly with the short circuit capacity of the system considered. Reactive power is required to compensate for the additional reactive power demand of the generator and the matching transformers so that the wind power installation does not burden the system. Low Voltage Ride Through (LVRT) is a recently introduced requirement that transmission operators demand from wind farms. A STATCOM is being evaluated for its performance to effectively provide LVRT for wind turbines in a wind farm.

II. WIND TURBINE

The wind turbines (WTs) considered in this paper is Doubly Fed Induction Generators (DFIGs) that are capable of variable speed operation. A DFIG has a power electronic converter by which both real power and reactive power can be controlled. A STATCOM was employed to regulate the voltage at the bus, to help maintain constant DC link voltages at individual wind turbine inverters during disturbances. This feature will facilitate the continuous operation of each individual wind turbine during disturbances, thus enabling the wind farm to participate in the grid side voltage and power control.

The dynamic DFIG model Power has been used for the simulations. The STATCOM with a higher rating capacity was developed based on the study of an available low capacity STATCOM model. The complete power grid studied in this paper is a combined case study of interconnected two wind turbines, a synchronous generator, a STATCOM and a typical load all forming a four bus system.

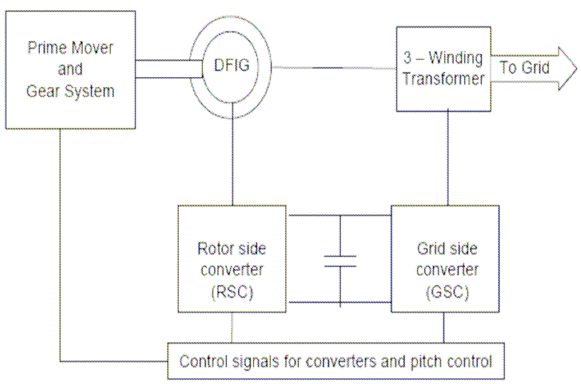

Fig 1. Block diagram of DFIG

A back-to-back converter is connected between the rotor and stator of the DFIG. The main objective of the GSC is to keep the DC link voltage constant. The reactive power supplied by this converter can be controlled by maintaining the power factor of this converter at unity. The GSC works as supplementary reactive power compensation though the reactive power capability of this converter during the fault is limited as it is rated just about 25% of the wind turbine power ratings. RSC controls the stator active and reactive powers. The RSC is also used to control the machine speed and the stator reactive power. The stator of the DFIG is directly connected to the grid and the slip-rings of the rotor are fed by self-commutated converters. The magnitude and phase of the rotor voltage can be controlled using these converters which makes active and reactive power control possible. By controlling the reactive power generated or absorbed by the RSC, voltage or reactive power at the grid terminals can be controlled.

The main components of the DFIG model are: the prime mover consisting of the pitch angle controller, the wind turbine and the shaft, the DFIG, control system regulating active and reactive power of the DFIG through the RSC and a protection system. Crowbar protection is also being increasingly used in wind turbines to short circuit (with small impedance) the rotor side converter in case of faults to protect the RSC from over currents. Crowbar protection is specific to DFIGs and protects the RSC against over currents.

The converter is blocked and bypassed through additional impedance, when the rotor current exceeds the rotor converter current ratings. The additional impedance reduces the amount of reactive power absorbed by the machine and, thus, improves the torque characteristic during voltage sags.

In DFIGs, the size of the converter is related not to the total generated power, but to the selected speed range and, hence, to the slip. As speed range requirements around the synchronous speed increases, the size and cost of the converter increases. Typical high power wind turbine generators are mostly DFIGs that allow more speed control of about 25% synchronous and an effective reactive power control with a small size rotor that is only about 25% of the total power rating of the turbine.

III. PERFORMANCE OF A WT WITH FAULTS ON THE SYSTEM

Generators are the major components in the power system that reacts to system disturbances. The reaction of the conventional synchronous generators to all kinds of grid disturbances has been studied extensively; however wind turbines are generally not equipped with synchronous generators. Wind turbine generators interact differently with the grid when there are faults on the system. The grid voltage has to be controlled inevitably, irrespective of the capabilities with which a wind farm's generators might be equipped.

The most popular type of wind turbines installed today are variable speed wind turbines that feature improved power quality and speed control and reduced mechanical stresses. Under the same circumstances, the power generated by variable speed wind turbines is greater than that generated by the fixed speed wind turbines. Recently developed grid codes require that wind turbines be able to withstand voltage disturbances without disconnection, which is known as the LVRT capability of the wind turbine.

Figure 2 shows the LVRT requirement for wind generation facilities per FERC order 661 and power electronic based FACTS controllers such as STATCOM can be used to hold the line voltage to a specific value to help the WT ride-through the fault. The LVRT requires that a WT does not trip even if the voltage drops to 0.15 per unit for about 0.625 seconds. If due to a fault, the voltage drops below this value, the wind turbine can be tripped until the system restores and the wind turbine can be resynchronized. A WT can take a maximum of 2.375 seconds to restore to about 0.9 per unit voltage after the fault has been cleared. These rules are more stringent for some grids which are derived based on grid reliability requirement.

Details received by FERC (Federal Energy Regulatory Commission), sets specific wind power requirements, namely, low voltage ride through, power factor design criteria (reactive power), and Supervisory Control and Data Acquisition (SCADA) capability. The grid codes are specific to a particular power zone and they vary with respect to the voltage profile requirement during system disturbances.

This paper focuses mainly on the low voltage ride through requirement for wind turbines. Several studies have been performed to understand the behavior of the wind generators, the voltage profile and the reactive power in the system, to various system disturbances. The transient behavior of the wind turbines during and after fault in the presence of different compensation techniques and their dynamic performance has been studied.

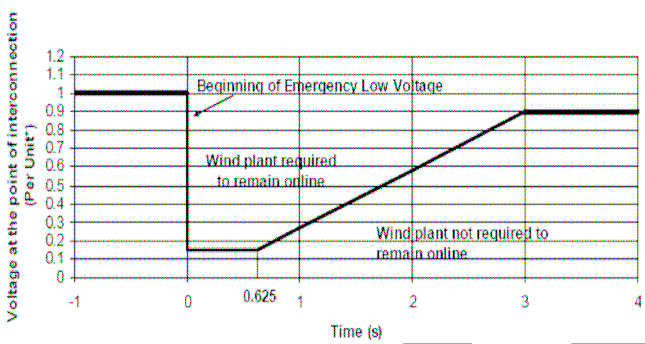

Fig 2. LVRT requirement for wind generation facilities per FERC Order No. 661

IV. THE STATCOM

A. STATCOM model

Figure 3 shows the basic model of a STATCOM which is connected to the ac system bus through a coupling transformer. In a STATCOM, the maximum compensating current is independent of system voltage, so it operates at full capacity even at low voltages. A STATCOMs advantages include flexible voltage control for power quality improvement, fast response, and applicability for use with high fluctuating loads.

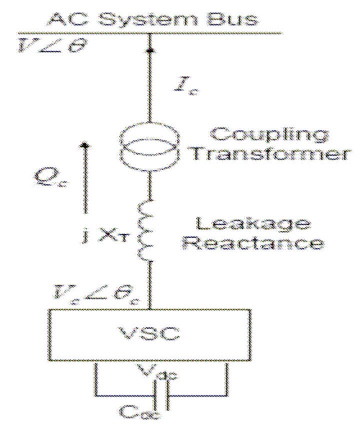

Fig 3. Basic model of a STATCOM

B. Control Scheme

The STATCOM is a static var generator whose output can be varied so as to maintain or control certain specific parameters of the electric power system. The STATCOM is a power electronic component that can be applied to the dynamic control of the reactive power and the grid voltage. The reactive output power of the compensator is varied to control the voltage at given transmission network terminals, thus maintaining the desired power flows during possible system disturbances and contingencies.

STATCOMs have the ability to address transient events at a faster rate and with better performance at lower voltages than a Static Voltage Compensator (SVC). The maximum compensation current in a STATCOM is independent of the system voltage. Overall, a STATCOM provides dynamic voltage control and power oscillation damping, and improves the system's transient stability. By controlling the phase angle, the flow of current between the converter and the ac system are controlled

A STATCOM was chosen as a source for reactive power support because it has the ability to continuously vary its susceptance while reacting fast and providing voltage support at a local node. Figure 4 show the block diagram of the STATCOM controller.

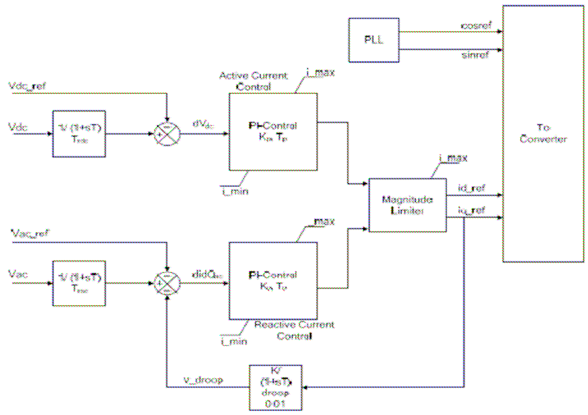

Fig 4. Control scheme of the STATCOM

By controlling the phase and magnitude of the STATCOM output voltage, the power exchange between the ac system and the STATCOM can be controlled effectively.

V. TEST SYSTEM AND SIMULATION RESULTS

A. Test System

Synchronous generators respond immediately to system disturbances while due to their complex control it is difficult to make wind turbines respond in a similar fashion. Hence, additional system equipment is required to help maintain the power grid to be stable during and after a disturbance. The proposed test system has two types of generators - a DFIG and a synchronous generator. Under normal operating conditions, the synchronous generator is not operating at its full capacity to accommodate for power reserve in the system.

The grid represents an external system which is connected to the system of interest through a weak link. The intent to force the generator and STATCOM only, and not the grid to respond to faults in the area of interest. The low short circuit capacity of the connected electric power grid implies that this is a weak grid and thus requires a compensating device of a higher rating. One of the objectives of this thesis is to evaluate the specific needs of the system to restore to its initial state as quickly as possible after fault clearing.

The source of reactive power is always connected as close to the point where it is required and this is the main motivation for connecting the STATCOM at the load bus. This is specifically done to facilitate the effective operation of the STATCOM and to avoid excessive interaction of the connected power system. Also, mechanically switched capacitors are relatively inexpensive and are used for slow changes in the reactive power but ideally reactive power requirement changes continuously and hence a controller is required to adjust the reactive power level.

B. Simulation Results

The effect of a three phase high impedance (X_f=5Ω) short circuit fault at the load bus is studied. The ground fault is initiated at t=0.4 sec and cleared at t=0.6 sec. The system is studied under different conditions at the load bus as shoen below. The study evaluates voltages during the fault, voltage recovery time, voltage overshoot at recovery, and the settling time.

Figure 5 shows the voltage at the load bus or the fault bus for the different operating. Without any compensating device, the voltage takes a long time to recover after the fault has been cleared - a condition that does not meet some stringent grid codes for certain transmission operators. Figure 6 shows the zoomed version of the load bus voltages where it is observed that the voltage during the fault, and overshoot at recovery is the highest in the case of system using 125 MVA STATCOM. It also has the fastest response time.

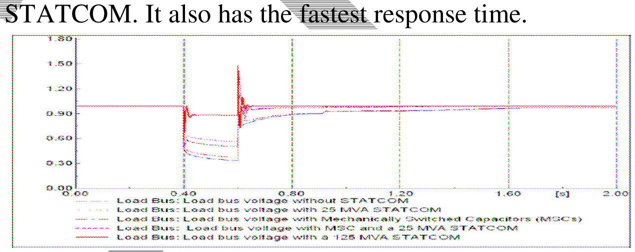

Fig 5. Voltage at the fault bus (Load bus)

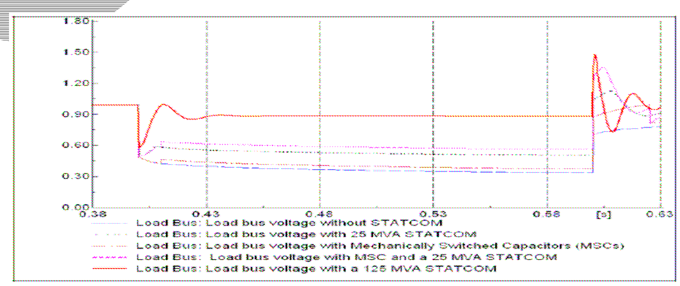

Fig 6. Voltage at the fault bus (Zoomed version)

Figures 5 and 6 shows the synchronous generator bus voltage and its zoomed version respectively under the same distinct conditions. The time that this voltage takes to recover is longer than that of the load bus voltage as it has to supply some reactive power to the system to help stabilize the voltages at different buses of the system. The case with the high rating STATCOM yields the best performance. The DFIG operates normally even during the faulted conditions as the total reactive power demand is provided only by the STATCOM and the system is not overly stressed. In the other cases, the synchronous machine also has to respond to supply some of the reactive power required. DFIG protection is triggered if the rotor side converter currents exceed a threshold value, thus shorting the RSC connections by impedance so that it becomes an induction generator. The rotor protection scheme called "crowbar" protection is removed once the rotor currents return to normal.. It can be observed that there is a voltage overshoot at recovery for every case where a STATCOM is used. The case with only mechanically switched capacitors does not exhibit any overshoot during recovery but they do have a longer recovery time.

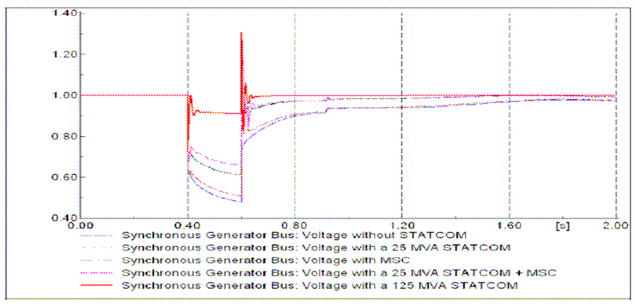

Fig 7. Voltage at the synchronous generator bus

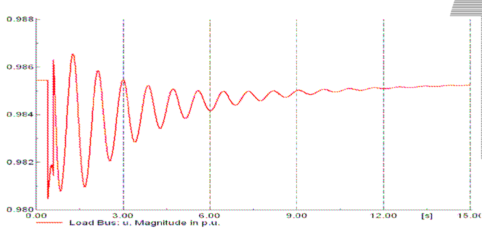

Fig 8. Load bus voltage without STATCOM

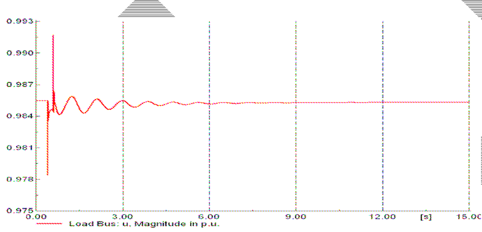

Fig 9. Load bus voltage with STATCOM

VI. CONCLUSION

The dynamic performance of wind farms in a power grid is improved by the application of a STATCOM. The STATCOM helps to provide better voltage characteristics during severe faults like three phase impedance short circuit faults as well. The response of a wind farm to sudden load changes is improved by the use of a STATCOM in the system.

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