Article

Voltage Stability by Injecting Reactive Power using STATCOM for Wind Turbine Squirrel-Cage Induction Generator System during Fault

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Abstract

Reactive power limit of the system affects it's Voltage stability. The wind driven self excited induction generator during faults and heavy loading condition, lacks in supplying reactive power to the system. FACTs devices improve the reactive power flow in the system thereby improving voltage stability. This paper concludes the effect of STATCOM on the voltage stability. voltage stability is improved through the ability of the STATCOM FACTs devices help to increase the load ability margin of the power network.

Keywords: Voltage Stability, Wind Turbine, Squirrel-Cage Induction Generator, STATCOM, Point of Common Coupling.

Introduction

Power system stability is defined as the ability of a power system that enables it to remain in stable operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance [1]. A criterion for voltage stability is that, at a given operating condition for every bus in the system, the bus voltage magnitude increases as the reactive power injection in the same bus is increased. The power system voltage is stable if voltages after disturbances are close to voltages at normal operating conditions. A power system becomes unstable when voltages uncontrollably decrease due to outage of equipment, sudden increment in load. Voltage stability is generally a local problem, but the consequences of voltage instability have significant impact on the power system. The result of this impact is voltage collapse and a blackout. The voltage stability of the system mainly depends on generator reactive power limits, load characteristics, transmission lines. For efficient and reliable operation of power system, the voltage and reactive power control must properly done to make voltage at all the buses within the acceptable limits [2, 3]. Voltage stability has been the major reason for several major blackouts that have occurred throughout the world including the recently Northeast Power outage in North America in August 2003 [4]. As the load varies, the reactive power requirements of the transmission system also vary. Since the reactive power cannot be transferred over long distances and losses also increases. It is important that voltage control has to be done by locating proper compensating devices.

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The proper selection and location of compensator for controlling reactive power and voltage are major challenges of power system. In this paper, we are proposed to identify the suitable location for compensator to improve the voltage stability in the power system not only in normal loading condition and also in maximum loading condition.

Statcom

A static synchronous compensator (STATCOM) is an electrical device for providing fast acting reactive power compensation on high-voltage electricity transmission networks. Static Synchronous Compensator (STATCOM) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids. It is also called STATCON (Static Condenser). The STATCOM regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive) [5]. When system voltage is high, it absorbs reactive power (STATCOM inductive). STATCOM comprises of voltage source converter (VSC).

A STATCOM can improve power-system performance as:

1. The dynamic voltage control in transmission and distribution systems.
2. The power-oscillation damping in power-transmission systems.
3. The transient stability.
4. The voltage flicker control.
5. The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source. A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the existing system impedance, and can internally generate reactive (both capacitive and inductive) power.

Principle of Operation

STATCOM is a reactive-power, controlled source. It supplies the required reactive-power and ingestion wholly according to what electronic processing of the voltage and current waveforms in a voltage-source converter (VSC). In Fig. 1(a), VSC is placed with the bus. In Fig. 1 (b), a STATCOM is working as adaptable voltage source. It all shows that the any of the reactive power compensation through the capacitor and reactors are not required at the same time. amplitude of the 3-phase output voltage, *Es*, of the converter, as shown in Fig. 1(c) is used to control the power flow between the ac system and converter. Current flows over the reactance from the converter to the ac system and the converter produces capacitive-reactive power for the ac system [6] only if the amplitude of the output voltage is increased more than that of the bus voltage, *Et* and vice-versa.

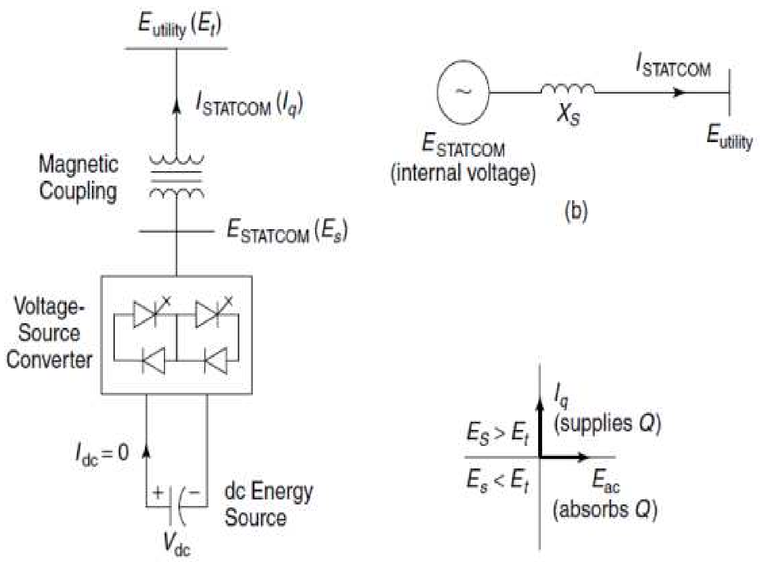

Figure 1.(a) Power circuit of STATCOM (b) Equivalent circuit of STATCOM (c) Power exchange.

Adjusting the phase shift between the converter-output voltage and the ac system voltage can similarly control real-power exchange between the converter and the ac system. In other words, the converter can supply real power to the ac system from its dc energy storage if the converter-output voltage is made to lead the ac-system voltage. On the other hand, it can absorb real power from the ac system for the dc system if its voltage lags behind the ac-system voltage.

STATCOM provides the required amount of reactive power as a conversion the continuous reactive power among the phases of the ac system. A converter basically joins the three output terminals so that the reactive-output currents flow smoothly between the phases. Continuous sinusoidal current from the ac system is sapped from the voltage source converter as staircase wave, which causes small fluctuations in the converter's output power waveform. The amount of needed reactive power by the system defines the rating of the converter to be configured with in the system [7].mA number of VSCs are combined in a multi-pulse connection to form the STATCOM. In the steady state, the VSCs operate with fundamental-frequency switching to minimize converter losses. However, during transient conditions caused by line faults, a pulse width–modulated (PWM) mode is used to prevent the fault current from entering the VSCs. In this way, the STATCOM is able to withstand transients on the ac side without blocking.

Power Exchange

The maximum attainable transient over current in the capacitive region is determined by the maximum current turn-off capability of the converter switches. In the inductive region, the converter switches are naturally commutated, therefore, the transient-current rating of the STATCOM is limited by the maximum allowable junction temperature of the converter switches.

In practice, the semiconductor switches of the converter are not lossless, so the energy stored in the dc capacitor is eventually used to meet the internal losses of the converter, and the dc capacitor voltage diminishes. However, when the STATCOM is used for reactive-power generation, the converter itself can keep the capacitor charged to the required voltage level. This task is accomplished by making the output voltages of the converter lag behind the ac-system voltages by a small angle (usually in the 0.18–0.28 range). In this way, the converter absorbs a small amount of real power from the ac system to meet its internal losses and keep the capacitor voltage at the desired level. The same mechanism can be used to increase or decrease the capacitor voltage and thus, the amplitude of the converter-output voltage to control the var generation or absorption [8].

The reactive- and real-power exchange between the STATCOM and the ac system can be controlled independently of each other. Any combination of real power generation or absorption with var generation or absorption is achievable if the STATCOM is equipped with an energy-storage device of suitable capacity, as depicted in Fig. 2. With this capability, extremely effective control strategies for the modulation of reactive- and real-output power can be devised to improve the transient- and dynamic-system-stability limits.

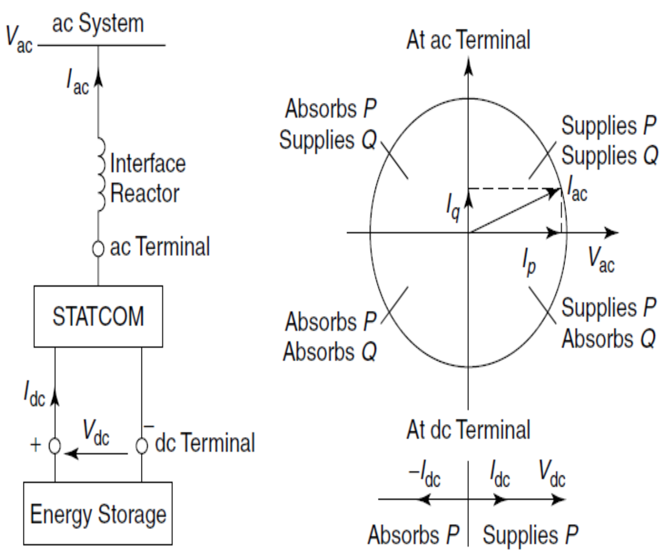

Figure 2.The Power Exchange between the STATCOM and the AC system.

System Configuration and Simulation

Simulation is done in MATLAB 2012 Power-Sim with per unit quantities. System under consideration includes two set of wind turbine driven self excited squirrel-cage induction generators of 3e6/0.9 VA, 575 volt and 50 Hz each as shown in fig. 3. The output of the generators are stepped up to 25e3 volt using two separate transformer and then joined as a common bus. At the same point another bus coming from the separate source acting as grid is also joint to form a common coupling point. Now to this common coupling point the STATCOM is connected.

Behavior of the system and the usefulness of the system is considered during different phase to ground faults at different points in the system. One fault near the generating ends of self excited induction generator each and third fault at the point of common coupling of the system. System is in per unit values so the voltage must be 1 P.U.

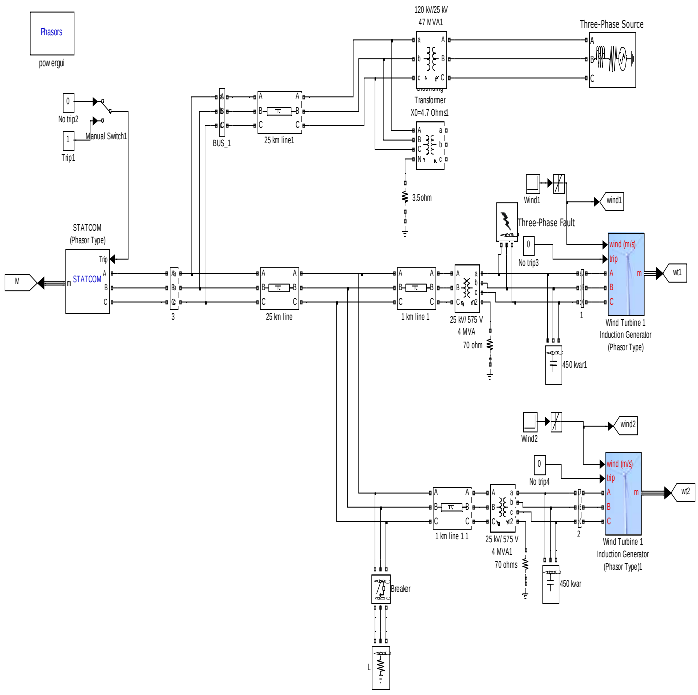

Figure 3.Simulation diagram for the system under consideration.

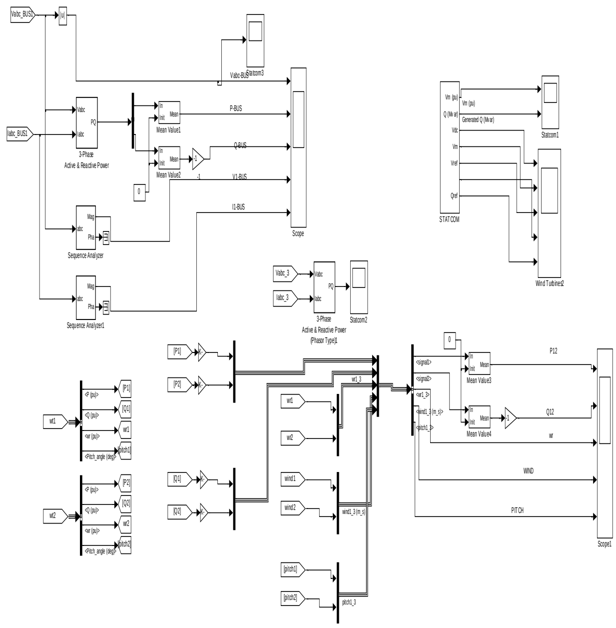

Figure 4.Measurements

Results

With the prime objective to bring the bus voltage to 1 P.U, STATCOM is implemented in the system under consideration. Simulation is completed and the results are evolved by using the phasor solver. First fault occurs at 1sec and will continue to 1.1 sec., Second fault occurs at 1.3 sec. and cleared at 1.4 sec. third fault comes in to existence at 1.5 sec. and got cleared at 1.6 sec. Figure 6.1 shows the result without STATCOM. Figure 5 Shows the inactivity of the statcom as it is feeding zero active and reactive power. Figure 6 shows that the voltage at BUS-1 is below the 1 P.U value i.e. drop in the system voltage and Figure 7 shows the increased reactive power and decrease in active power.

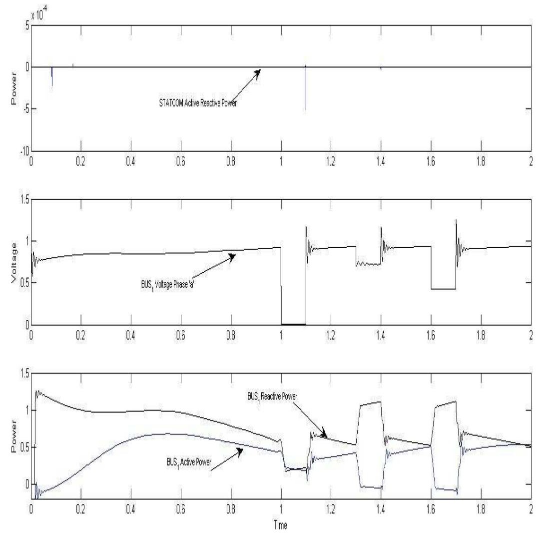

Figure 5.System Voltage and Active –Reactive Power without STATCOM at Bus-1 duringfaults

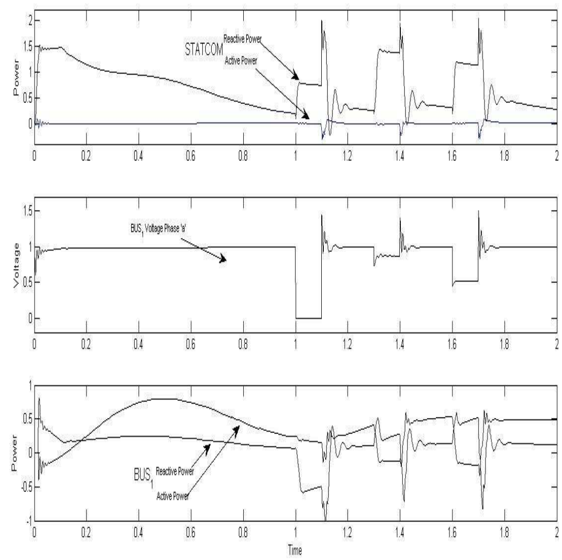

Figure 6.System Voltage and Active –Reactive Power with STATCOM at Bus-1 during faults

Figure 6.2 shows the effect of STATCOM during the faults to maintain the voltage to 1 P.U. In 6.2(a) the upper line shows the reactive power and lower line represents the active power supplied by the STATCOM. During faults STATCOM supplies the required reactive power which in turn maintains the voltage to 1 P.U. and can be clearly seen from the 6.2(b). In 6.2(c) upper line is Active power which is increased and lower line of reactive power which is decreased after STATCOM operation. Figure 6.3(a, b, c) clearly shows the difference in Bus-1 voltages with and without STATCOM during faults.

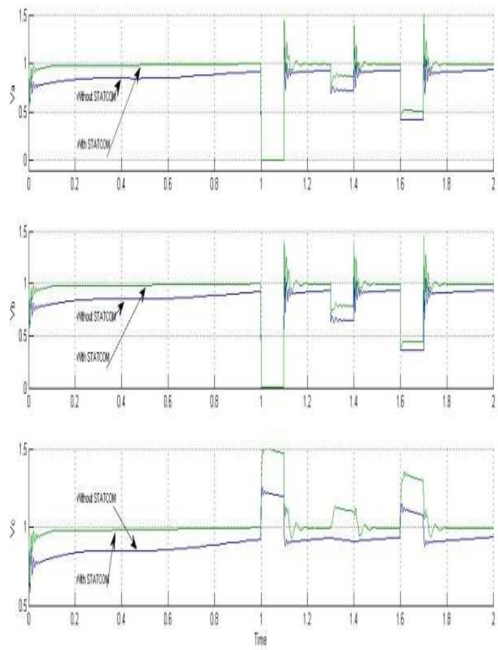

Figure 7.System Voltages with and without STATCOM at Bus-1, during faults

Conclusion

From the results, it is observed that the bus-1 voltage magnitude has been improved and fixed to 1 P.U. before and just after the clearance of the fault by providing the reactive power support through the STATCOM application. It is clearly seen that the STATCOM increases the static voltage stability margin and also improve the power transfer capability of the system. But as compared to the shunt capacitors these controllers are expensive.

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