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Compensation of SequenceVoltages by STATCOM Integrated With PV

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***Abstract*—In conventional generation, the contribution of wind power is increasing nowadays. The wind plants with induction generator exhibit a different behavior than the conventional synchronous generators. The stability of fixed speed induction generator (FSIG) wind turbines can be improved by Static Synchronous Compensator STATCOM. A STATCOM control with the capability to coordinate the control between positive and negative sequence voltages, and thus compensating the reactive power and torque oscillations respectively are evaluated by means of simulations a for three phase fault.**

***Index Terms*— wind energy, STATCOM, Reactive power contol, positive sequence voltage.**

I. Introduction

For the sustainable growth of the economy energy conservation is essential. It can be achieved by meeting the energy demand using the fossil fuels in the cleanest possible way and maximize the utilization of renewable energy sources like wind, biomass, solar, hydro etc. The integration of wind energy into the existing power system causes many power quality issues like voltage variations, frequency variations, voltage transients, flickers.

There has been an extensive growth and quick development in the wind power industry in recent years[1]. There is only one way of generating electricity from wind energy, which is to use wind turbines that can convert the energy contained in flowing air into electricity. Fixed speed wind turbines utilize squirrel cage induction generator directly connected to the grid to produce the electricity[3]. Under faulty conditions, these induction generators draw large amount of reactive power. This reduces the electrical output power and terminal voltage, but the rotor speed eventually increases. So after fault clearance, the terminal voltage is to be recovered by supplying reactive power by the network itself. But this further reduces the voltage and hence the terminal voltage cannot be recovered by itself. Moreover, the unbalanced load at the distribution line leads to unbalanced voltage conditions[4]. While the voltage is small, the negative sequence current is large and this current causes unbalanced heating in the winding resulting in the degradation of induction generator [5]. The squirrel cage induction generator needs the support of an external device (FACTS) in order to remain connected during voltage dips. The STATCOM is one of these types that deliver reactive power required to accelerate the voltage restoration.

II. Effect Of Unbalanced Voltages

In a weak power system network, an unbalanced load at the distribution lines can cause unbalanced voltage conditions. While the unbalanced-phase voltage is small, the negative-sequence currents is large due to low negative-sequence impedance of an induction generator. The negative-sequence currents vary with the size of negative-sequence voltage almost linearly. If an induction generator is connected to this unbalanced voltage, the resulting stator current will be unbalanced. These large currents eventually causes unbalanced heating (hot spots) in the machine windings. The heat may increase the winding temperature, which degrades the insulation of the winding, i.e., the life expectancy of the winding. Unbalanced currents also create torque pulsation on the shaft resulting in audible noise and extra mechanical stress

III. Power System Description

The general layout of a power system which was simulated for study is drawn in Fig. 1 below. The simulations were carried out by power system modelling tool called SIMPOWER SYSTEM in the SIMULINK environment of MATLAB software. The power system consists of a wind farm containing 50 MVA, FSIG based wind turbines, and the induction generator connected with the turbine operates at a power factor of 0.9. For reactive power compensation a shunt capacitor has been connected at the generator terminals. Two step-up transformers of 100 MVA have been connected between the wind farm and rest of the grid.

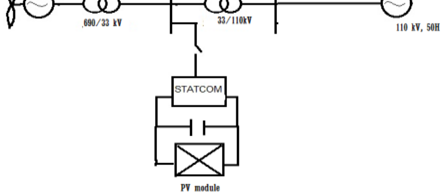


Fig. 1. Single line diagram of studied system

The wind turbine model used is a variable pitch turbine but for the given case it is run at a constant pitch of 0 degrees at a base wind speed of 12 m/s. The wind turbine is coupled with an induction generator squirrel cage type[1]. The stator of generator is connected with the grid directly and rotor is driven by the wind turbine. The wind power captured by the turbine is converted into electrical power by the induction generator and is transmitted to the grid through the stator windings. The pitch angle of turbine is fixed or in a way the pitch angle control has been disabled to run it at a constant mechanical power output. In order to generate power the generator rotor speed must be slightly higher than its synchronous speed. Since the speed variation of squirrel cage wind generator is very less hence they are called fixed speed wind generators. The reactive power absorbed by the induction generator during transients is provided by the grid or by some devices like capacitor banks, SVC & STATCOM.

IV. Mathematical Modelling Of Few Power System Components

A. Wind Turbine Model

The model of wind turbine used for the purpose of simulation is a per unit model based on the steady state power equation of a wind turbine. The gear train used for coupling the generator with the grid is assumed to have infinite stiffness while the friction factor component and the inertia of the turbine is aggregated with these quantities of the electric generator coupled with the turbine.

$$P_m = C_p(\lambda\ \beta)\ \rho\ AV^3{}_{wind} \qquad (1)$$

Here P_m= mechanical power developed by the wind turbine, Cp= power coefficient of the turbine, ρ is the density of air striking the turbine blades (kg/m^3), A is the swept area of the rotor blades of the turbine (m^2), λ is the tip-speed ratio, β is the pitch angle (degrees).

B. STATCOM Model

A STATCOM (Fig. 2) consists of a three phase inverter (generally a PWM inverter) using IGBTs, a dc capacitor which provides the dc voltage for the inverter, a link reactor which links the inverter output to the ac supply side, filter components to filter out the high frequency components due to the PWM inverter. From the dc side capacitor, a three phase voltage is generated by the inverter. This is synchronized with the ac supply. The link inductor links this voltage to the ac supply side. This is the basic principle of operation of STATCOM[2].

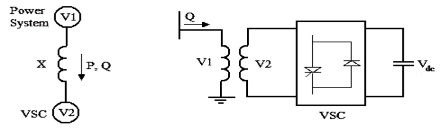


Fig. 2. A Statcom

V. Approach Used For Stability Enhancement By Statcom In Given System

In the simulated power system represented in fig.1, a transient condition i.e. a three phase fault was simulated in the power system. In order to analyze the performance of STATCOM in improving the transient stability margin of the given power system three parameters of the power system were monitored during a fault for a time duration from 0.5 sec to 1 sec. These parameters are the voltage and reactive power at the point of common coupling (PCC) and electromagnetic torque. A relative comparison of voltage recovery time at PCC the simulation when the power system is supported with and without STATCOM.

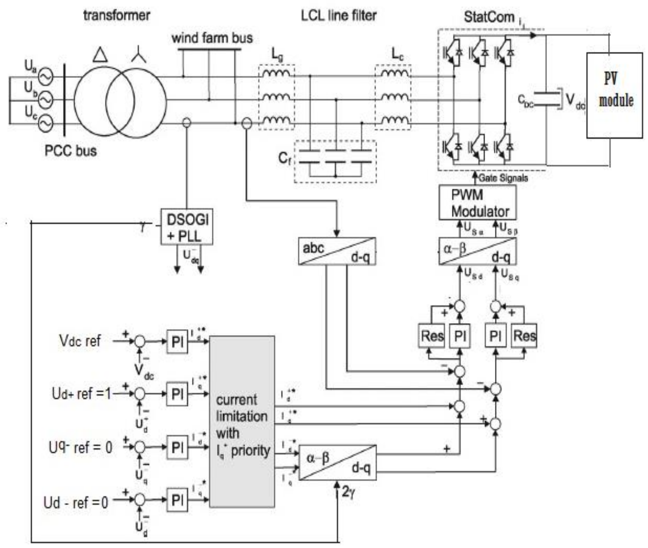
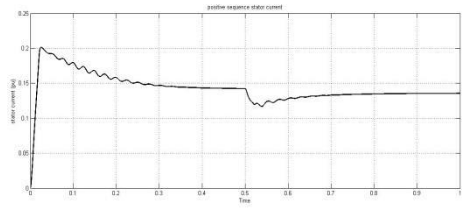


Fig. 3 Control structure of STATCOM

The StatCom control structure is based on the voltage oriented vector control scheme [26] as usually applied to three-phase grid-connected converters. It is a cascade control structure with inner proportional integral (PI) current controllers in a rotating dq reference frame. Resonant controllers (Res) tuned at 100 Hz in the same positive dq reference frame are added to realize the negative sequence current control. The dc voltage for the STATCOM is supplied from the PV array.



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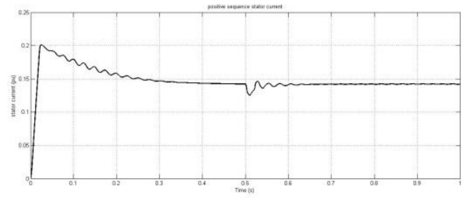

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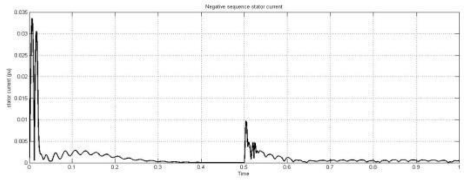

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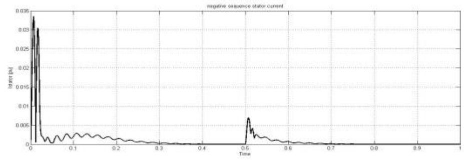

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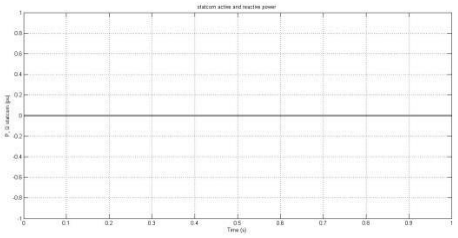

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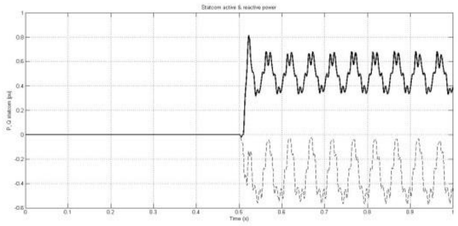


C

Fig.4 Positive Sequence (a), Negative Sequence (b) Stator Voltages and P,Q of STATCOM (c) without and with compensation during fault from 0.5s to 1 s

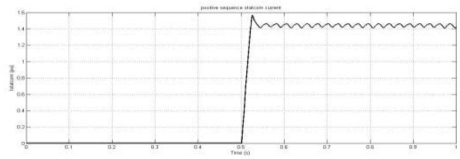
The positive and negative sequences of the voltage at the connection point of the StatCom. The separation of the measured voltage into positive- and negative sequence components is necessary performed based on dual second-order generalized integrators (DSOGI-PLL).

The current references of the four outer controllers must be limited to the maximum STATCOM current with the priority to positive-sequence reactive current Iq^+. Thus, the STATCOM ensures the maximum fault-ride-through enhancement of the wind farm. If there is a remaining STATCOM current capability, the STATCOM compensates the negative-sequence voltage and reduces the torque ripple during the grid fault. The positive- and negative-sequence current references are added. The negative-sequence current references must be transformed into the positive rotating reference frame by a coordinate transformation with twice the grid voltage angle.

VI. Simulation And Results

The first parameter to be monitored is the stator current at PCC. It can be observed from Fig.4 during the fault, the positive sequence stator current is dipped to 0.13pu. By using a dynamic reactive power support like STATCOM, the positive sequence stator current is improved to 0.15pu. This stability is achieved by injecting positive sequence STACOM current.

Similarly, comparing the negative sequence stator current at PCC in the power system it can be observed that the negative sequence stator current at PCC during the fault is near to .1 pu . The STATCOM helps in bringing the negative sequence Voltage to a lower value, almost near to0.5 pu. Here the compensation is done by giving more priority to the positive sequence. Hence improves the voltage stability.



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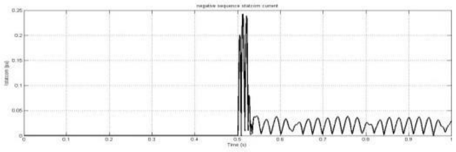

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Fig. 5. Positive (d) and Negative (e) sequence STATCOM current

VII. CONCLUSION

The effects of fault on the behavior of wind farm interconnected during different fault types are studied. Also, the impact of Static Synchronous Compensator STATCOM with the ability to compensate the sequence voltages, on the stability of the system is also analyzed. The wind farm terminal voltage and reactive power are monitored in steady state and fault states are analyzed. STATCOM is a power electronic device that is capable of improving the power system transients' performance and the quality of power. Whenever a fault occurs, the positive sequence voltage compensation leads to voltage stability and the negative sequence voltage compensation leads to reduction of torque ripple. The reactive power compensation is also performed by the STATCOM during the fault.

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