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Mitigation of Voltage Sag in Grid connected Wind System by using STATCOM

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***Abstract* - Now days renewable energy sources are very important for electrical power generation. In that condition wind power generation plays an important role in power system especially under integration of high penetration level of wind to grid, but at grid location having power quality problems like voltage sag, voltage swell, voltage fluctuations. As we know that most of the generator is induction generator (IG), so it requires more reactive power (VArs) from grid. In this paper according to aerodynamic aspects of wind farms, the major power quality problem that is voltage sag is mitigated by STATCOM .Wind turbine connected to squirrel cage induction generator(SCIG) is modeled by using MATLAB simulation with a fault condition to mitigate voltage sag and where STATCOM inject reactive power to increase power system stability.**

Index Terms— Renewable energy, Power Quality, STATCOM, VArs, Squirrel Cage Induction Generator SCIG.

I.INTRODUCTION

RENEWABLE energy is the most effective alternative energy resource is introduced in our power system. In that wind power is the fastest growing renewable source of electrical energy. The latest technological advancements in wind energy conversion and an increased support from governmental and private institutions have led to increased wind power generation in recent years.

Now days wind power penetration according wind velocity into the grid increases very fast and that influences created power quality issues and is becoming very important. This wind power penetration creates the major impact on power system stability. Therefore an adequate model is required to facilitate the investigation of impact of wind farm on the dynamic of power system to which it is connected.

So in order to avoid this problem the detail model is of wind farm along with ten to hundred wind turbines and their interconnections. If the network is weak this situation will cause a voltage collapse to occur in the transmission system.

This condition can be dynamically supported by a STATCOM to improve voltage stability and to improve recovery from network faults and mitigate voltage fluctuations. The wind farms are generally connected to a weak system and located far from major load point or centres. That’s why it introduced short circuit ratio (SCR) of inter operation of wind farms. To overcome this situation reactive power plays an important role in today’s condition. So for that an induction generator is the best option that already introduced in wind farms for energy conservation.

They utilized the principle of induction generator that is consuming reactive power in order to generate real power. This reactive power is utilized fo r minimizing the transmission and distribution losses, Issue related to fixed speed wind turbine equipped with squirrel cage induction generators is the fault ride through capability. When connected to a weak power grid and during a grid fault, the over speeding of the wind turbines can cause voltage instability. Therefore at this condition utilizes directly disconnect the wind turbine from the grid. Also continues wind velocity variation affects the total electricity generation and voltage sag, voltage fluctuation take place. With the rapid increase in penetration of wind power in power grids, tripping of many turbines in a large wind farm during grid faults may begin to influence the overall power system stability

India had a record year and was the fourth largest market globally both in terms of cumulative capacity and annual additions last year. 3,612 MW of new wind power was added to reach a total of 28,700 MW at the end of December 2016.But India has a weak grid network and it creates major power instability problems.

In this paper use of more intelligent controller for STATCOM and its interface to wind farm mitigates the voltage sag problems effectively. It was found that STATCOM considerably improves the stability during and after disturbances especially when network is weak. By using PI controller STATCOM mitigates the voltage sag problems connected with wind farm and grid.

The remaining paper is structured as follows. Firstly, utilization of STATCOM for voltage sag improvement is presented in Section II. A detailed

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description of method used to control is discussed in III. Section IV shows the simulation and results. The paper is concluded in Section V.

II. UTILIZING STATCOM FOR VOLTAGE SAG IMPROVEMENT

A. STATCOM Technology and Principle

The STATCOM operates according to the voltage source converter principle (VSC), which together with PWM (Pulsed Width Modulation) switching of IGBTs (Insulated Gate Bipolar Transistors) gives it unequalled performance in terms of effective rating and response speed.

The STATCOM ratings are based on many parameters which are mostly governed by the amount of reactive power the system needs to recover and ride through typical faults on the power system and to reduce the interaction of other system equipment that can become out of synchronism with the grid. Although the final rating of the STATCOM is determined based on system economics, the capacity chosen will be at least adequate for the system to stabilize after temporary system disturbances.

The type of faults that the system is expected to recover from also determines the size of the STATCOM. For example, a three phase impedance fault of low impedance requires a very high rating STATCOM while a high impedance short circuit fault needs a lower rating device to support the system during the fault and help recover after the fault. The converter current ratings and the size of the capacitor also decide the capability of the STATCOM.

STATCOM having property to operate in an inductive mode as well as in capacitive mode for reactive power utilization to mitigates voltage sag.

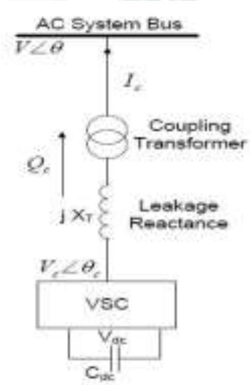

Fig. 1 Single line STATCOM power circuit

The shunt inverter, transformer and connection filter are the major components of a STATCOM. The control system employed in this system maintains the magnitude of the bus voltage constant by controlling the magnitude and/or phase shift of the voltage source converters output voltage. By properly controlling iq, reactive power exchange is achieved. The DC capacitor voltage is maintained at a constant value and this voltage error is used to determine the reference for the active power to be exchanged by the inverter.

The power system performance can be improved by employing STATCOM as given below:

- The power oscillation damping in power transmission systems.
- Maintain transient stability.
- Quickly inject and absorb reactive power.
- The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

STATCOM is capable of compensating either bus voltage or line current. It can operate in two modes based on the parameter which it regulates. They are-

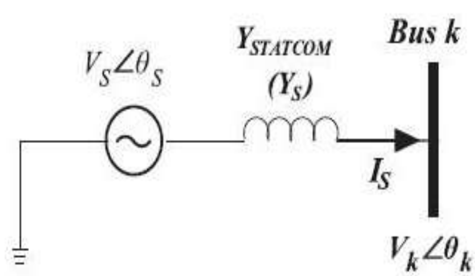

Fig.2. Equivalent circuit

• If the voltage VSTATCOM is below Vb the current through the inductor is phase shifted in relation to the voltage Vk which provides an Inductive current, then Qs becomes positive and the STATCOM absorbs reactive power.

• If the voltage VSTATCOM exceeds Vb the current through the inductor is phase shifted in relation to the voltage Vk which provides a capacitive current, then Qs becomes negative and the STA TCOM generates reactive power.

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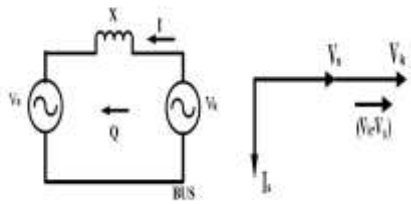

Fig. 2(a) Inductive Mode of Operation

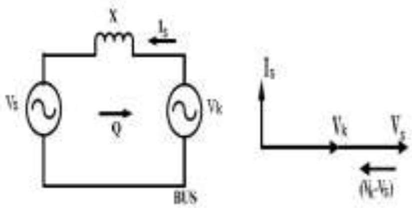

Fig. 2(b) Capacitive Mode of Operation

From the above figures i.e. fig. 2(a) and fig. 2(b) shows that STATCOM can work with two modes of operation to observe or inject the reactive power respectively. Also If the voltage VSTATCOM is equal to Vb the current through the inductor is zero and therefore there is no exchange of energy.

III. METHODOLOGY

A. Control Diagram of the proposed scheme

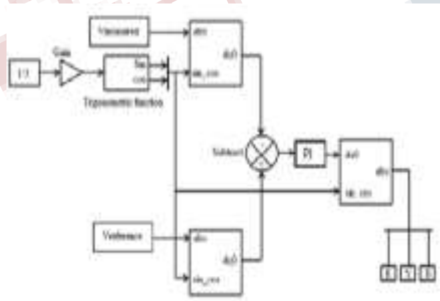

Fig. 3 Control Diagram of the Proposed Scheme

Three phase instantaneous currents are transformed using abc to dq0 transformation. The d-axis component id and q-axis component iq are regulated by two separate PI loops. Id reference is calculated from the control of DC link voltage and Iq reference is calculated from the control of reactive power. Therefore, instantaneous current tracking control is achieved by using four PI loops. Dq0 to abc transformation and a Phase Locked Loop (PLL) is used to find the voltage reference for the switching patterns.

B. P-I controller

P-I controller is mainly used to eliminate the steady state error resulting from P controller. PI Controller is a feedback controller which drives the plant to be controlled with a weighted sum of the error and the integral of that value. The proportional response can be adjusted by multiplying the error by constant KP, called proportional gain. The contribution from integral term is proportional to both the magnitude of error and duration of error. The error is first multiplied by the integral Gain, Ki and then was integrated to give an accumulated offset that has been corrected previously.
The contribution from the integral term is proportional to both the magnitude of the error and the duration of the error. The integral in a PI controller is the sum of the instantaneous error over time and gives the accumulated offset that should have been corrected previously. The accumulated error is then multiplied by the integral gain (Ki) and added to the controller output.

C. Active and Reactive Power in d-q frame

The voltages Vabc are transformed to d-q components such that with an added advantage of d-q theory the voltage axis is aligned in with the d-axis such that the component along the q or quadrature axis will be zero. So Vd=|V| and Vq=0 The same transformation applied for currents Iabc such that the vector I makes an angle Ɵ" where Ɵ refers to phase angle. Such that following figure shows Id= IcosƟ and Iq=IsinƟ So, active power control indirectly means controlling of Id component and reactive power control indirectly means controlling of Iq component. Fig 3 shows that active and reactive power in d-q frame.

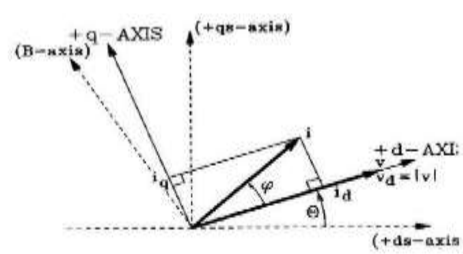

Fig.4 Active and Reactive Power in d-q frame

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IV. SIMULATION RESULTS AND DISCUSSION

A wind farm consisting of six 1.5MW wind turbines is connected to a 25kV distribution system exports power to a 120kV grid through a 25km 25kV feeder. The 9MW wind farm is simulated by three pairs of 1.5 MW wind turbines. Wind turbines use squirrel cage induction generators (IG).The stator winding is connected directly to the 60 Hz grid and the rotor is driven by a variable pitch wind turbine.

The pitch angle is controlled in order to limit the generator output power at its nominal value for winds exceeding the nominal speed (9 m/s). In order to generate power the IG speed must be slightly above the synchronous speed. Speed varies approximately between 1 pu at no load and 1.005 pu at full load. Each wind turbine has a protection system monitoring voltage, current and machine speed.

The turbine mechanical power as function of turbine speed is displayed for wind speeds ranging from 4 m/s to 10 m/s. The nominal wind speed yielding the nominal mechanical power (1pu=3 MW) is 9 m/s.

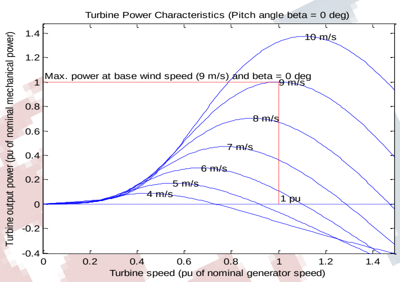


Fig. 5 Wind Turbine Power Vs turbine Speed

Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus (400 kvar for each pair of 1.5 MW turbines). The rest of reactive power required to maintain the 25kV voltage at bus B25 close to 1 pu is provided by a 3Mvar STATCOM with a 3% droop setting.

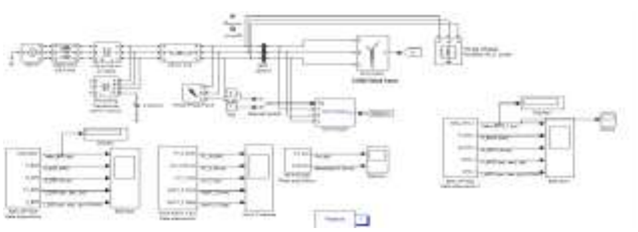


Fig. 6 Simulation of proposed control scheme.

Three phase impedance ground fault: The effect of three phase impedance short circuit fault at the bus is studied. The ground fault initiated at t=0.4sec and clear at 13.5sec.

Fig. 7 shows that the voltage at the bus or without any compensating device, the voltage take a long time to recover after fault has been cleared a condition that does not meet some grid code for certain transmission operation.

From fig. 8 Observed on B575 bus scope that because of the lack of reactive support, voltage at bus 25 now drop to 1.82pu. This low voltage condition results in on overload of IG of Wind Turbine 1 and it tripped at t=13.70 sec

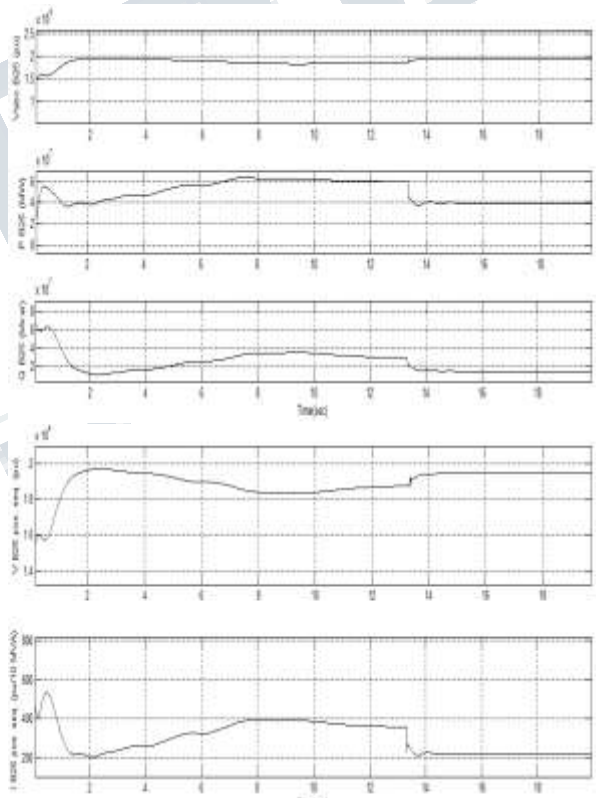


Fig. 7 The voltage, the current, active power and reactive power at bus B25 without using STATCOM

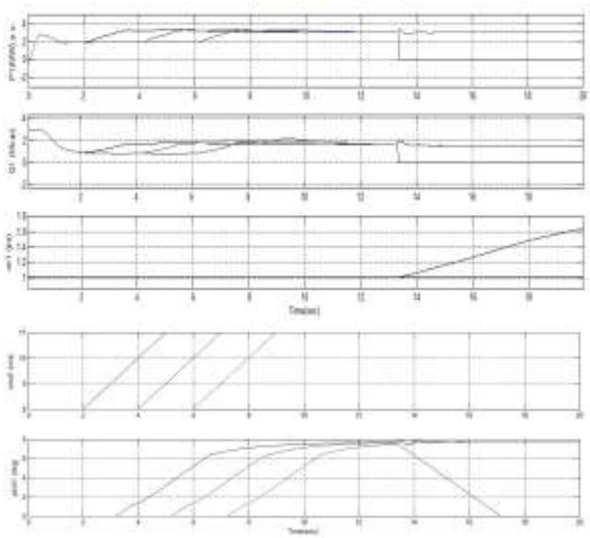


Fig. 8 Active power, reactive power at buses B575 (1, 2, 3), Speed of SCIGs and pitch angles without STATCOM

Now, observing the same scope monitoring by connecting STATCOM, for a 11m/s wind speed, the total exported power measured at the B25 bus is 6.4 MW and the STATCOM maintains voltage at 0.984 pu by generating 1.32 Mvar

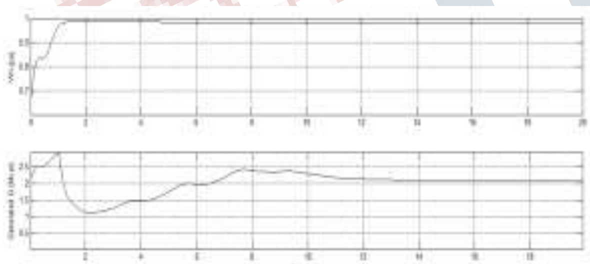
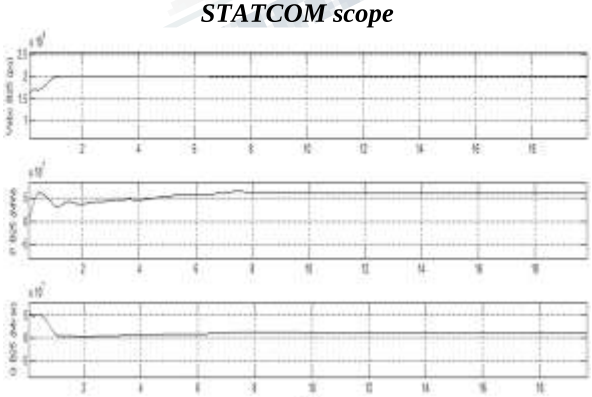


Fig. 9 Voltage (p.u) and generated reactive power at STATCOM scope



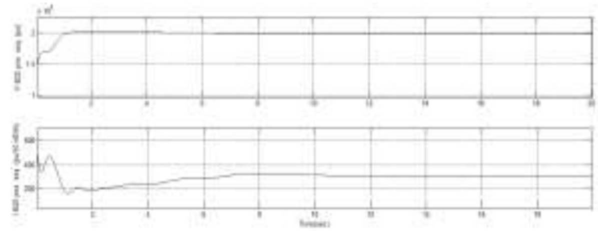


Fig. 10 The voltage, the current, active power and reactive power at bus B25 after using STATCOM

By utilizing STATCOM, all turbines will be stable as shown in fig.11

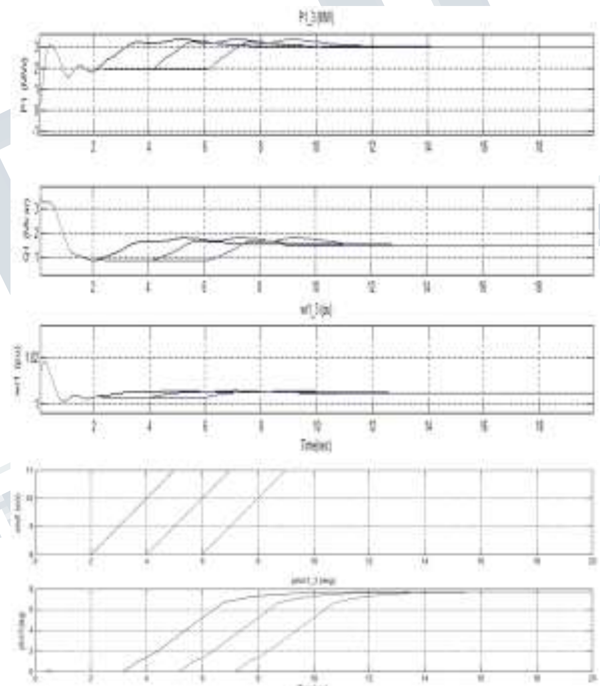


Fig. 11 Active power, reactive power at buses B575 (1, 2, 3), Speed of IGs and pitch angles after using STATCOM

This simulation results represents the solutions to mitigate the voltage fluctuations caused by the aerodynamic aspects of a wind farm in a power system by utilizing a Static Compensator (STATCOM).

V. CONCLUSION

From this paper the simulation results shows that it is clear that the FACTS device (STATCOM) -based control scheme for power quality improvement in grid connected wind generating system. Flexible AC Transmission System (FACTS) device such as Static Compensator STATCOM is power electronic based switch is used to control the reactive power and therefore bus voltages. Results are presented to show that the voltage at bus B25 drops to very low value of 0.91 pu due to insufficient reactive power but this bus voltage gets improved to 0.98 pu when STATCOM is incorporated in the system.

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