Analysis of Stability Problem in Wind Generator Using STATCOM and SDBR

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Abstract

Now a days, the renewable energy sources such as wind and solar considered as best alternative energy sources. The power from wind generator varies due to the different environmental air velocity conditions. The generated power from renewable energy sources is always fluctuating due to environmental conditions. Because of the asynchronous operation nature, system instability of wind farms based on FSIG (Fixed speed Induction Generator) is largely caused by the reactive power absorption by wind generator Due to the large rotor slip during fault. This paper presents a method to enhance the stability of a grid-connected wind farm composed of a fixed-speed wind turbine generator system (WTGS) using a small series dynamic braking resistor (SDBR) or FACTS devices of static synchronous compensator (STATCOM). The SDBR and STATCOM have active and reactive power control abilities, respectively, and these units paves the way to stabilize the fixed-speed wind farm. In this paper, a centralized control scheme of using an SDBR and STATCOM is focused, which can be easily integrated with a wind farm. Different types of symmetrical and unsymmetrical faults are considered to evaluate the transient performance of the proposed control scheme, applicable to a grid-connected wind farm. Simulation results show that a application of a small STATCOM and with small SDBR is an effective means to stabilize the wind farm composed of a fixed-speed WTGS.

Keywords

Wind Farm, Grid Code, D-STATCOM, Voltage Dips.

I. Introduction

Doubly-Fed induction generator (DFIG) is, currently, the most employed wind generator due to its several merits. One of the advantages is the higher efficiency compared to a direct-drive wind power generation system with full-scale power converters since only about 20% of power flowing through power converter and the rest through stator without power electronics. Another advantage of a wind DFIG is the capability of decoupling control of active power and reactive power for better grid integration. However, by connecting stator windings directly to the power grid, a wind DFIG is extremely sensitive to grid faults. Moreover, wind energy is a kind of stochastic energy, implying that the output of Wind Farm (WF) varies in a certain range due to unstable wind characteristic. Therefore, the operating point of the power system changes from time to time when the wind power is integrated with the power system.

The fixed-speed WTGS that uses an induction machine as a wind generator has the stability problem similar to a Synchronous Generator (SG) [1]. This study focuses on both transient and dynamic stability improvement issues of the fixed speed WTGS. Due to the huge penetration of wind power to the grid, wind farm grid codes have been developed recently in many countries in which Fault Ride Through (FRT) is an important constraint to adopt with [2]. There are different techniques and compensating tools reported in power system literatures to augment the stability of the fixed-speed WTGS [3]. Energy capacitor systems [4], battery energy storage systems, superconducting magnetic energy storage systems [5], and flywheel energy storage systems [6] are very effective tools as having both active and reactive power control abilities.

A static synchronous compensator (STATCOM) is also found to be a potential candidate to stabilize a fixed-speed WTGS [7]. The transient response of a pitch controller is comparatively slow, as reported in [8], compared with the flexible alternating current transmission system (FACTS) devices used in [9]. In addition to these, a dynamic braking resistor (DBR) can be used for wind generator stabilization. As the DBR has only the active power control ability, it is good idea to incorporate a reactive power compensating device along with the DBR. For stability augmentation of a fixed-speed WTGS, a series DBR (SDBR) is more effective than a DBR with a shunt-connected topology. In a simulation analysis is performed using only one fixed speed WTGS that connects the grid. That study is symmetrical to a distributed topology where each SDBR is connected close to the individual wind generators and differs significantly from the centralized topology using only one SDBR installed at the wind farm terminal. Incorporation of an SDBR with a dynamic voltage restorer increases the system cost due to the presence of a transformer and an LC filter.

In earlier works with the SDBR, the effect of other SGs that exist in a realistic power system is not evident. This study focuses on transient and dynamic stability augmentation of a grid-connected wind farm composed of fixed-speed WTGSs using a combination of an SDBR and a STATCOM, the purpose of which lies to reduce the overall cost of the compensating devices. Therefore, centralized SDBR and STATCOM are considered to be connected at the terminal of a wind farm that connects the power system to observe the effectiveness of the proposed system during normal and grid fault conditions, in this study. Instead of a representative wind farm model used in, where the components are expressed using a simple transfer function, realistic component modeling is considered in this study using the laboratory standard power system.

II. STATCOM

Static Synchronous Compensator is made up of a shunt transformer, a voltage source converter (VSC), a DC capacitor, a magnetic circuit, and a controller. STATCOM also known as an advanced static VAR compensator is a shunt connected FACTS device. It generates a set of balanced three phase sinusoidal voltages at the fundamental frequency, with rapidly controllable amplitude and phase angle. A typical application of a STATCOM is for voltage support. The objective of the STATCOM is to regulate the voltage at the PCC rapidly in the desired range and keep its DC link voltage constant. It can enhance the capability of the wind turbine to ride through transient disturbances in the grid. STATCOM is widely used in grid connected wind turbine for power quality improvement.

The VSC converts the DC voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allows effective control of active and reactive power exchanges between the STATCOM and the ac system. The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for three quite distinct purposes: Voltage regulation and compensation of reactive power, Correction of power factor, Elimination of current harmonics. Fig. 1. Clearly describes the basic structure of STATCOM.

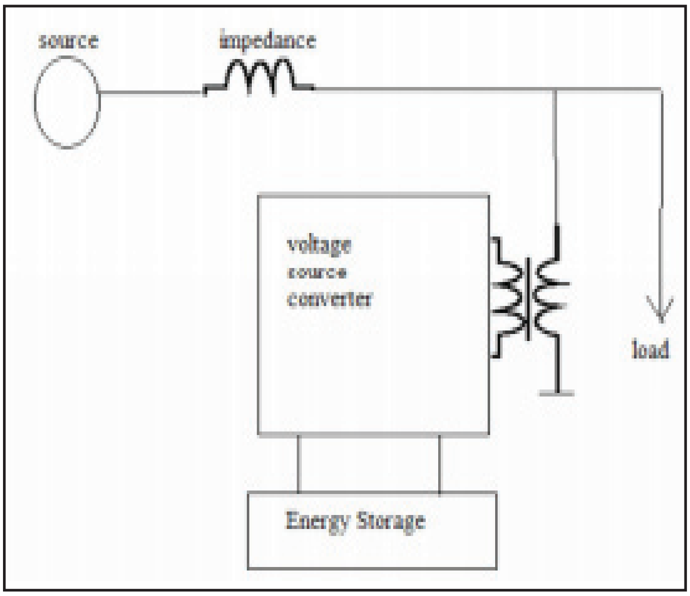

Fig. 1: Schematic Diagram of STATCOM

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The negative sequence effect caused by wind turbine on grid can be eliminated by voltage control capability of STATCOM. PI controller is used as conventional technique and comparison is made with hybrid fuzzy logic controller. Further performance of SVC and STATCOM is compared and STATCOM is found to be better than SVC as it has more switching losses. SVC has the capability to control voltage at each phase under faulty condition. But it has the disadvantage of losses which is caused due to power switches. This can be eliminated in case of STATCOM.

III. Wind Turbine and Electronic Models

The mathematical relation for the mechanical power extraction from the wind can be expressed as follows:

$$P_t = \frac{1}{2} \cdot \rho \cdot \pi \cdot R^2 \cdot V^3 \cdot C_p(\lambda, \beta) \qquad (1)$$

Where Pt is the extracted power from the wind, ρ is the air density [kg/m3], R is the blade radius [m] and Cp is the power coefficient, which is a function of both tip speed ratio, λ and blade pitch angle, β [deg].

In this operating mode, the wind turbine pitch control is deactivated and the pitch angle Beta (β) is fixed at 0°. If the wind speed is above the rated value, the rotor speed can no longer be controlled within the limits by increasing the generator and/or the converter. In this situation, the pitch control is activated to increase the wind turbine pitch angle to reduce the mechanical power extracted from the wind [4]. The Cp-λ curves are shown in fig. 3 for different values of Beta.

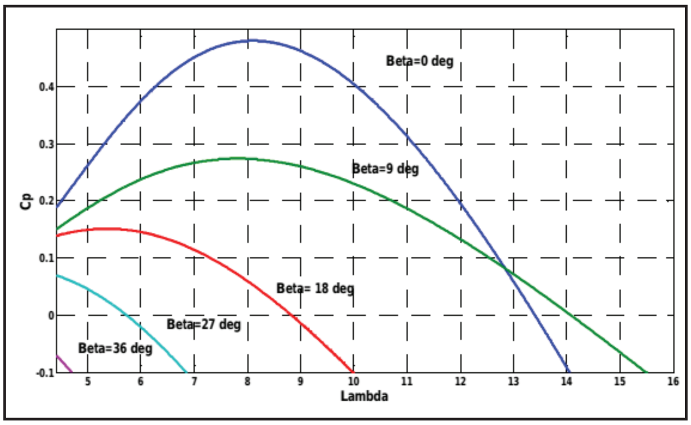

Fig. 2: CP-β Curves for Different Pitch Angles.

In order to generate power the induction speed must be slightly above the synchronous speed but the speed variation is typically so small that the WTIG is considered to be affixed speed wind generator [5].

The basic schematic arrangement of a Doubly Fed Induction Generator (DFIG) coupled to a wind turbine as shown in fig. 3.

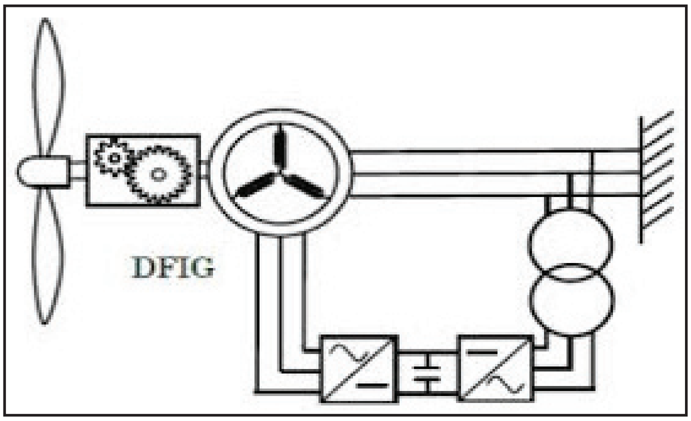

Fig. 3: Wind Turbine and Induction Generator

IV. The Stability of Induction Generator

The normal operating point is obtained when the mechanical torque intersects the electrical torque curve. Assuming generator operating condition, the generator will accelerate during fault in the power system according to the following movement equation:

$$\frac{d}{dt}\omega_m = \frac{1}{2H} \cdot (T_m - T_e) \qquad (3)$$

A typical torque-speed static characteristic of an induction machine is presented in fig. 4.

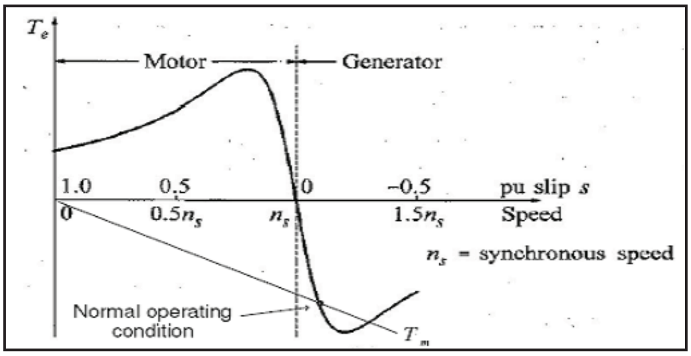

Fig. 4: Typical Torque-Speed Characteristic of an Induction Machine [6].

During the failure event in the power system the mechanical torque Tm is practically unchanged; on the other hand the electrical torque will be reduced since the electrical torque is proportional to the square of terminal voltage. This means that the resulted over speed is a function of the inertia constant H of the generator, the duration of the fault and severity of the fault [6-7]. To improve the transient voltage stability and therefore help the wind during grid faults, an alternative is to utilize dynamic reactive power compensation such as a STATCOM as considered in this study.

V. SDBR

A series dynamic braking resistor directly control the balance of active power during abnormal fault conditions, with the potential to replace the need to use of complex reactive power control devices . It does this dynamically by inserting a series resistors at the terminal of the generator, thereby reducing the power, voltage, and speed instability of the generator, simply by dissipating active power and boosting the terminal voltage up. There are various topologies of SDBR, the insertion of the resistor can be discrete at lower cost simply by just adding the resistance into the line, or it as shown in fig. 5

A. Control of SDBR

The control of SDBR fig. 5 is simply implemented; as the Generator's stator voltage goes below the reference point, it senses the fault and the bypass switch are opened to insert the resistor into the grid, and divert the fault current into the SDBR. The value of the resistance is chosen to be 0.8 pu

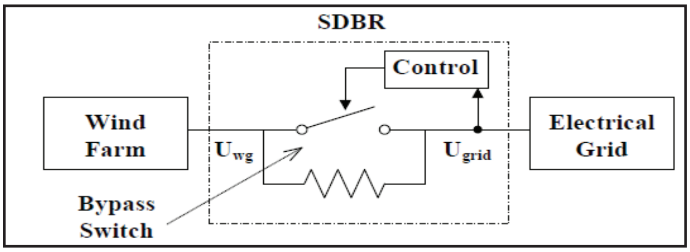

Fig. 5: Control Scheme of SDBR

During the system fault condition, the WTGS terminal voltage, as well as the voltages at individual wind generators, suddenly decreases. The wind farm voltage is compared with the reference voltage VRef (in this study, a 0.8 per unit (p.u.) value is considered as reference), and the SDBR is switched on instantly. The characteristics of the SDBR is that it has a current-squared relationship to the electrical power dissipation, and it quickly restores the wind farm voltage that eventually helps the wind farm to be connected with the power system, fulfilling the FRT requirement of wind farm grid code.

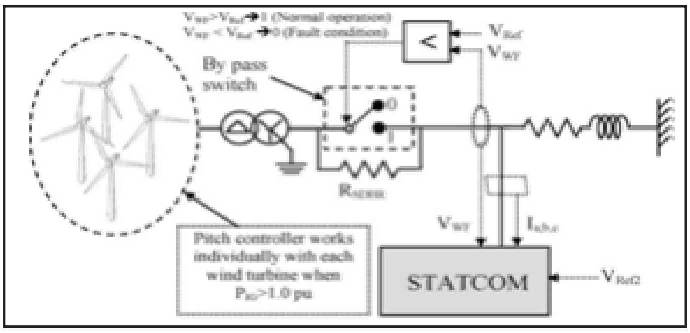

Fig. 6: Proposed Control Scheme for a Wind farm using SDBR/ STATCOM.

VI. Matlab/Simulink Results

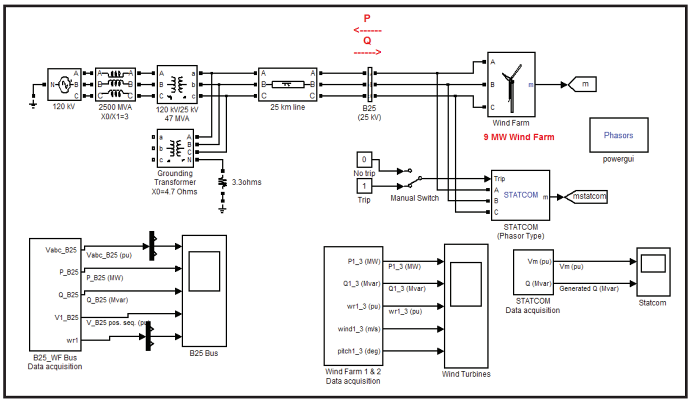

Fig. 7: Matlab/Simulink Model of Proposed Circuit Without STATCOM

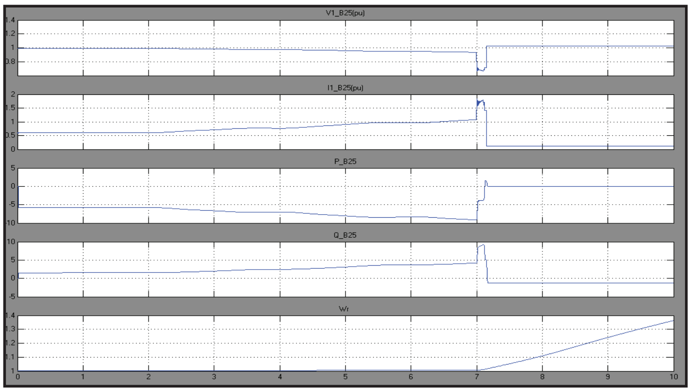

Fig. 8: Shows Voltage, Current, Active Power, Reactive Power, Wind Turbine Rotor Speed Without

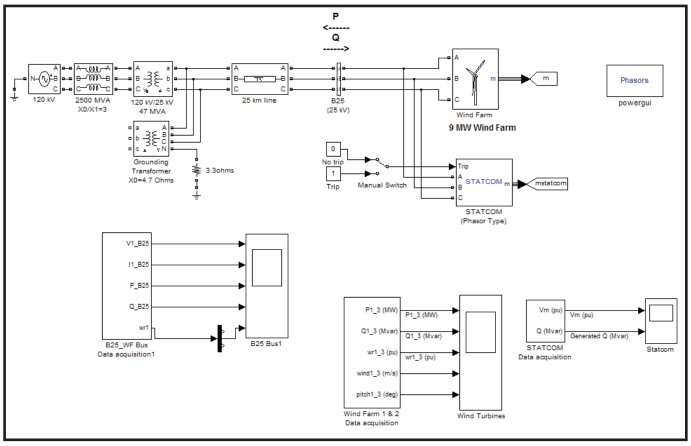

Fig. 9: Matlab/Simulink Model of Proposed 30 MVAR Circuit with STATCOM.

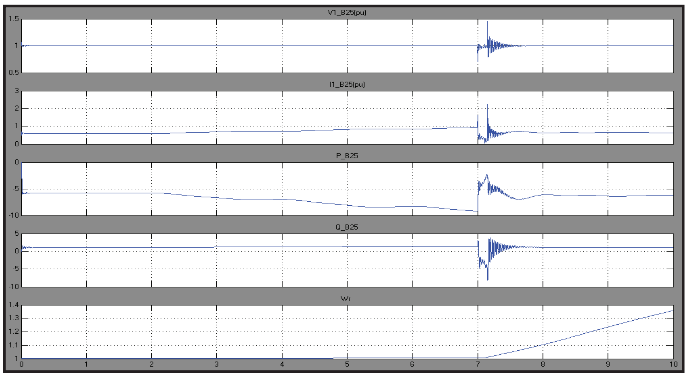

Fig. 10: Shows Voltage ,Current, Active Power, Reactive Power, Wind Turbine Rotor Speed for 30MVAR with STATCOM

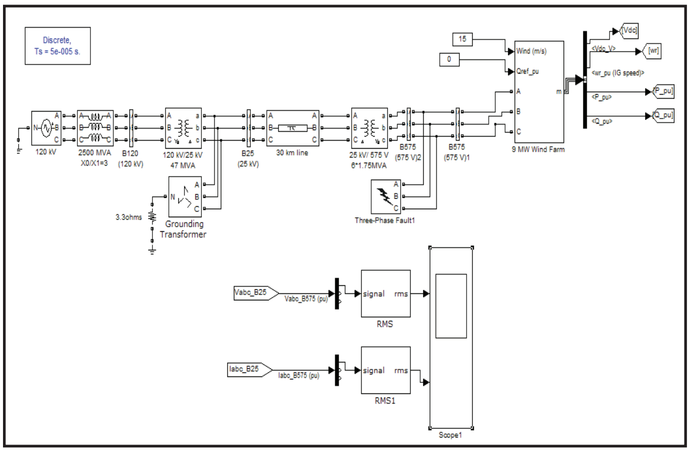

Fig. 11: Matlab/Simulink Model of 9 MW Wind Generator Without SDBR.

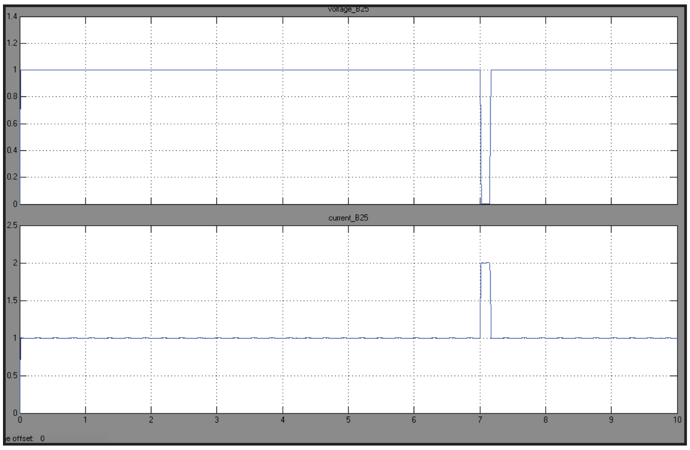

Fig. 12: Voltage and Current Responses on BUS 25 with a 9 MW wind generator without SDBR.

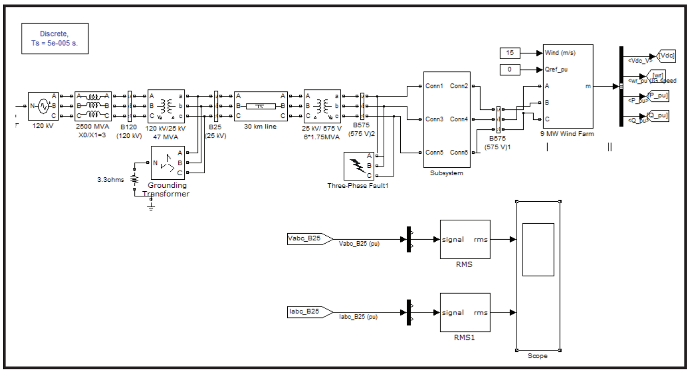

Fig. 13: Matlab/Simulink Model of 9 MW Wind Generator With SDBR.

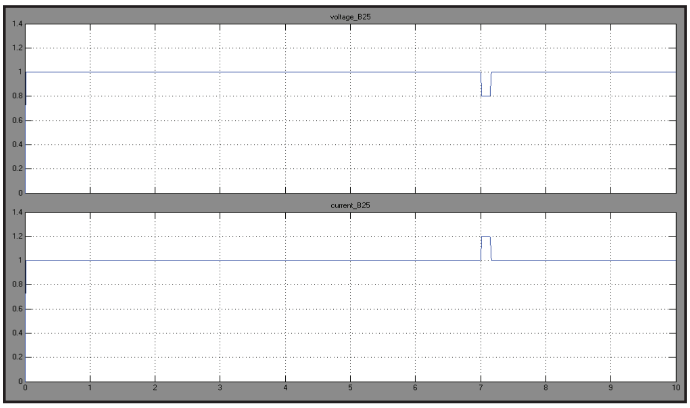

Fig. 14: Voltage and Current Responses on BUS 25 with a 9 MW Wind Generator With SDBR.

VII. Conclusion

It is observed that the proposed WTG system was able to recover from most of the faults as in the case of STATCOM. However the transients in the proposed system are much lower than the STATCOM based system. This proportion is considered for analyzing all types of symmetrical and unsymmetrical fault conditions, and it is found that the wind farm FRT requirement is fulfilled as per recent grid code. It is also investigated the statcom based wind generator system makes the circuit complexity and high cost of the solution which is one of the important observations from this study. Hence to overcome this problem one more technique for stability is proposed by SDBR method through the extensive simulation analysis, few more relevant observations are given below for further study on the SDBR and the STATCOM for stability augmentation of grid connected wind generators.

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