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Static Compensator for Dynamic Stability during Connection of Wind Turbines to Power System

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ABSTRACT

The penetration of wind power as a one of renewable energy resources to meet load at demand side in power system is greatly increasing. Therefore it is urgent to study the impact of wind power on the dynamic stability of power system. The increasing power demand has led to the growth of new technologies that play an integral role in shaping the future energy market. Keeping in view of the environmental constraints, grid connected wind turbines are promising in increasing system reliability. This paper presents the impact of Static Compensator known as STATCOM on the stability of power systems connected with wind energy conversion systems.

Keywords: *Doubly Fed Induction Generator, Synchronous Generator's, Rotor angle stability, Induction Generator's Rotor speed stability.*

1. INTRODUCTION

The wind generator model considered is a variable speed doubly fed induction generator model. Doubly Fed Induction Generator (DFIG) is widely utilized in large wind power plants. Therefore the dynamic behavior of DFIG wind turbines is necessary to be studied. This research presents the impact of Static Compensator (STATCOM) on the dynamic stability of power system connected to DFIG.

Under grid connected mode, DFIGs not only to contribute active power generation but also to the reactive power independently but due to limited reactive power capability and remote location of wind turbines it cannot provide the sufficient reactive power support without any external dynamic reactive power compensation device. As stated that the problem of voltage instability can be solved by using dynamic reactive compensation. Shunt flexible ac transmission system (FACTS) devices such as the SVC, TCPAR, TCSC, SSSC, UPFC, IFPC, GUPFC, HPFC, and the STATCOM, have been widely used to provide high-performance steady state and transient voltage control at the point of common coupling (PCC) [1-3].

In order to improve the dynamic stability, control parameters of STATCOM device need to be set and control optimally. The stability assessment is made first for a three phase short circuit without STATCOM controller in the power network and then with the STATCOM controller. In this paper we studied on the impact of faults on the performance of induction generators and wind turbines, transient rating of the STATCOM controller for enhancement of rotor speed stability of induction generators and angle stability of synchronous generators.

In [4] the static compensator for maintaining voltage stability of wind farm integration to a distribution network is simulated and analyzed.

Authors in [5] were made active–reactive power, voltage variations, the rotor angle, oscillation damping and power flow control of wind plant in power system which has many generators by using STATCOM and SSSC.

In case of temporary stability, in [6], the STATCOM effects were examined in the wind plants that have induction generators. In [7] the effects of voltage and reactive power characteristics in fixed speed wind plants by were examined using STATCOM [12]. In [8], authors were found in their study were observed slide-moment characteristic in low power wind plant which has induction generator by using STATCOM and SVC. The effects of load changes by the STATCOM in the power system with infinte power bus were examined by [9] and the voltage and reactive power variation in the bus were compared with proportional integral (PI) and fuzzy logic (FL) control methods.

2. DFIG WIND TURBINE

DFIG wind turbine (Fig.1) uses a wound rotor induction generator coupled to the wind turbine rotor through a gearbox [10]. This generator presents the stator winding connected directly to the grid and a bidirectional frequency converter feeding the rotor winding. It is made up of two back-to-back Insulated Gate Bipolar Transistor (IGBT) bridges linked by a direct current (DC) bus. This converter decouples the electrical grid frequency and the mechanical rotor frequency and thus enabling variable-speed generation of the wind turbine. The wind turbine rotor presents blade pitch angle control in order to limit the power and the rotational speed for high winds. Furthermore DFIG presents noticeable advantages such as the decoupled control of active and reactive powers, the reduction of mechanical stresses and acoustic noise, the improvement of power quality, and the use of a power converter with a rated power 25% of total system power.

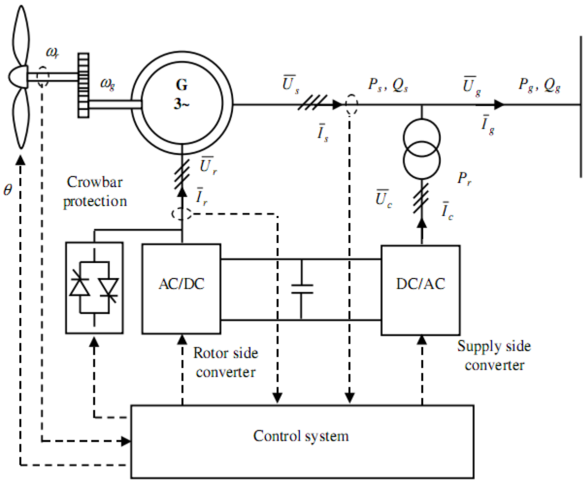

Fig.1. Wind turbine configuration- DFIG

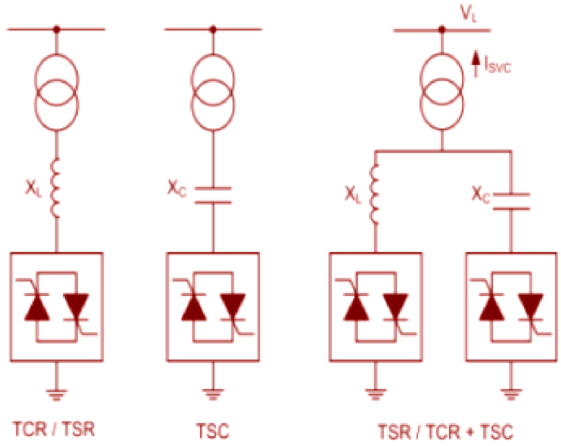

Fig.2.Basic structure of TSC/TCR (SVC)

3. FACTS DEVICE

3.1 Static Var Compensators (Svcs)

Static VAR compensators, commonly known as SVCs and provides an excellent source of rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled reactive devices. An SVC is typically made up of the following major components:

1. Coupling transformer
2. Thyristor valves
3. Reactors
4. Capacitors (often tuned for harmonic filtering)

They consist of conventional thyristors which have a faster control over the bus voltage and require more sophisticated controllers compared to the mechanical switched conventional devices. SVC_s are shunt connected devices capable of generating or absorbing reactive power.

By having a controlled output of capacitive or inductive current, they can maintain voltage stability at connected bus.

Figure 2 shows these configurations: the Thyristor Controlled Reactor (TCR), the Thyristor Switched Reactor (TSR) and the Thyristor Switched Capacitor (TSC) or a combination of all three in parallel configurations. The TCR uses firing angle control to continuously increase/decrease the inductive current whereas in the TSR the inductors connected are switched in and out stepwise, thus with no continuous control of firing angle. Usually SVC_s are connected to the transmission lines, thus having high voltage ratings [9-10]. Therefore the SVC systems have a modular design with more thyristor valves connected in series/ parallel for extended voltage level capability.

3.2 Unified Power Flow Controller (UPFC)

This FACT device is consisted of two converters. As presented in Fig.3 the converter-1 is to supply or absorb the real power demanded by converter-2 at the common dc link to support the real power exchange resulting from the series voltage injection. Converter-1 can generate or absorb controllable reactive power if desired, and thereby provide independent shunt reactive compensation for the line. The superior operating characteristic of UPFCConverter-2 provides the main function the UPFC by injecting a voltage Vpq with controllable magnitude and phase angle ρ in series with the line via an insertion transformer [11].

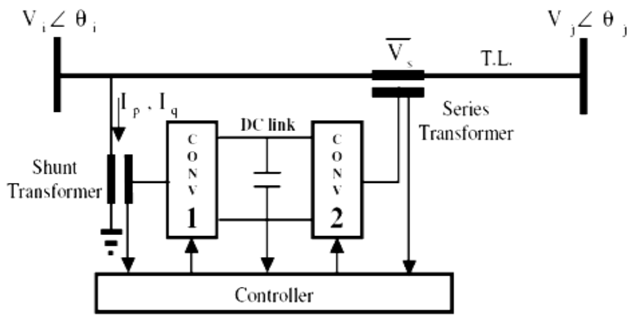

Fig.3.Basic structure of UPFC

3.3 Static synchronous Compensator (Statcom)

Usually, STATCOM is installed at the MV bus in the wind farm. Its aim is to help the wind farm in situations of voltage dips, voltage regulation, power factor control and power flow stabilizing [12]. A general scheme of a STATCOM connected to an AC system has been presented in Fig.4.

If the primary voltage of the inverter side becomes larger than the system side, the current passes the AC power system through the leakage reactance (X) of the transformer, and inverter generates reactive power for the power system (capacitive case). If the secondary voltage of the inverter side becomes larger than the system side, the reactive current passes from AC system to the inverter and inverter observes reactive power.

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The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), as shown in Fig.8. The grid connected system in Fig.8, consists of wind energy generation system and battery energy storage system with STATCOM.

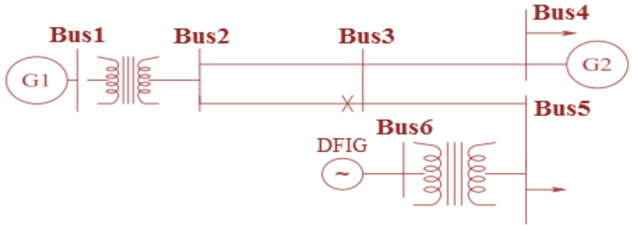

Fig.4. Basic structure of Statcom at grid connected wind turbines

4. REASONS FOR CHOOSING A STATCOM

Capacitors are usually connected to fixed speed wind turbines to enhance the system voltage because they are a sink of reactive power. Mechanically switched fixed shunt capacitors can enhance the system's voltage stability limit, but is not very sensitive to voltage changes. Also, voltage regulated by the wind generators equipped with only fixed capacitors can become higher than the voltage limit of 1.05 pu. Hence, a fixed capacitor cannot serve as the only source of reactive power compensation.

One of the most important advantages of using STATCOM over a thyristor based SVC is that its compensating current is not dependent on the voltage level at the connection point which means that the compensating current is not lowered as the voltage drops [13-14].

The output of the wind power plants and the total load vary continuously throughout the day. Reactive power compensation is required to maintain normal voltage levels in the power system. Reactive power imbalances, which can seriously affect the power system, can be minimized by reactive power compensation devices such as the STATCOM. The STATCOM can also contribute to the low voltage ride through requirement because it can operate at full capacity even at lower voltages.

In this research, a voltage source converter (VSC) PWM technique based STATCOM is proposed to stabilize grid connected DFIG based wind turbines.

5. LOCATION OF STATCOM

Simulation results show that STATCOM provides effective voltage support at the bus to which it is connected to. The STATCOM is placed as close as possible to the load bus for various reasons. The first reason is that the location of the reactive power support should be as close as possible to the point at which the support is needed. Secondly, in the studied test system the location of the STATCOM at the load bus is more appropriate because the effect of voltage change is the highest at this point.

The location of the STATCOM is based on quantitative benefits evaluation. The main benefits of using a STATCOM in the system are reduced losses and increased maximum transfer capability. The location of STATCOM is generally chosen to be the location in the system which needs reactive power. To place a STATCOM at any load bus reduces the reactive power flow through the lines, thus, reducing line current and also the RI^2 losses. Shipping of reactive power at low voltages in a system running close to its stability limit is not very efficient. Also, the total amount of reactive power transfer available will be influenced by the transmission line power factor limiting factors. Hence, sources and compensation devices are always kept as close as possible to the load as the ratio $\Delta V/V$ will be higher for the load bus under fault conditions.

6. MATLAB-SIMULINK BASED SIMULATION AND DISCUSSION

At first the power test system without wind turbines and STATCOM is presented in Fig.5.

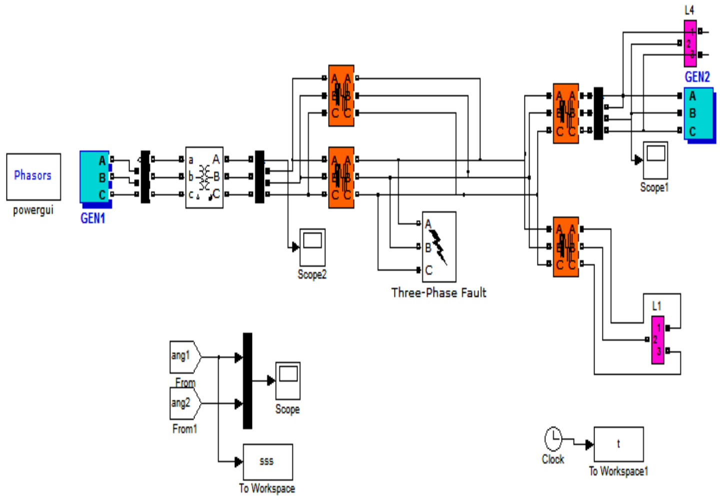

Fig.5. Test system without wind turbine and STATCOM

The proposed strategy based STATCOM for power quality improvement of grid connected wind turbines is implemented on distribution test system as shown in Fig.6.

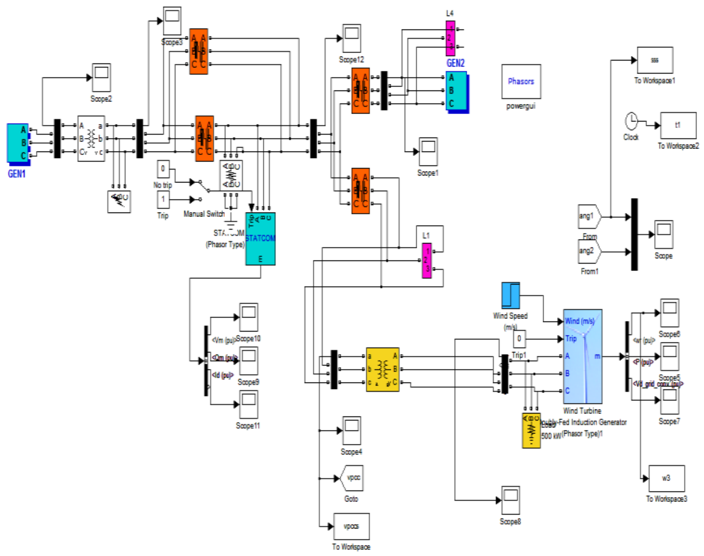

Fig.6.MATLAB/SIMULINK diagram of grid connected wind farm

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The subsystem of simulated system discussed in this paper for data acquisition of analyzed bus and wind turbine is presented as Figs 7-8.

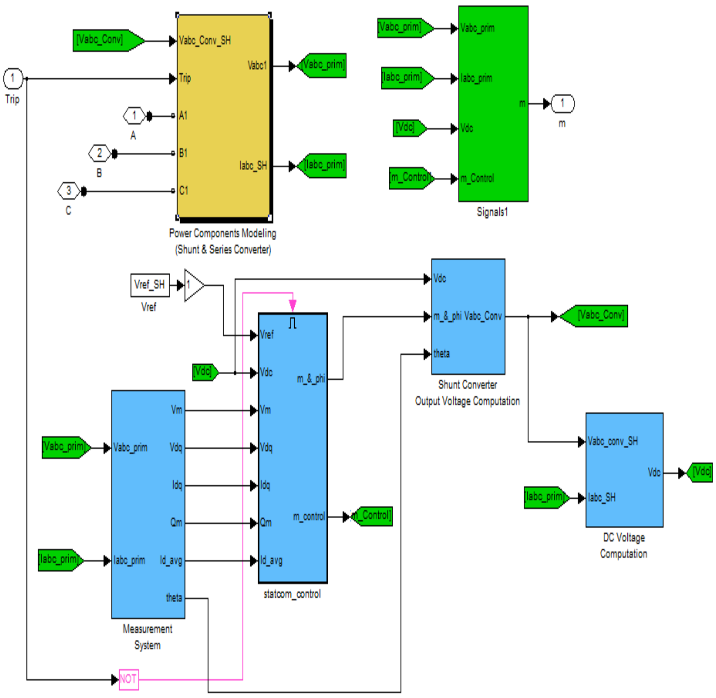

Fig.7.The subsystem of simulated system for data acquisition of analyzed bus

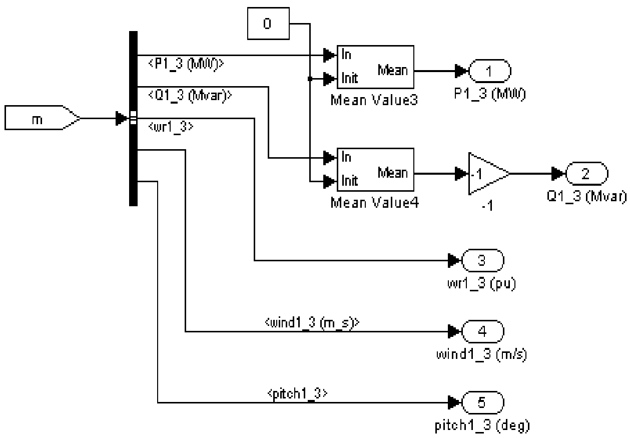

Fig.8.The subsystem of simulated system for data acquisition of wind turbines

All wind turbines use squirrel-cage induction generators (IG). The parameters setting of each of three wind turbines which implanted in this study is shown in Fig.9.

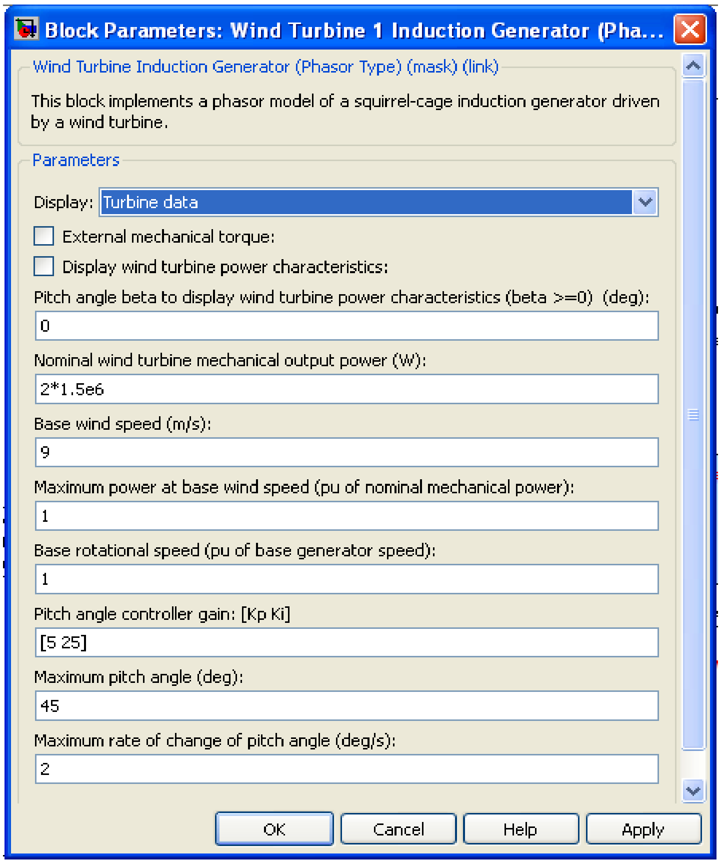

Fig.9. Setting of wind turbine parameters

The rotor angle of generator 1 without wind turbine operation is shown in Fig.10.

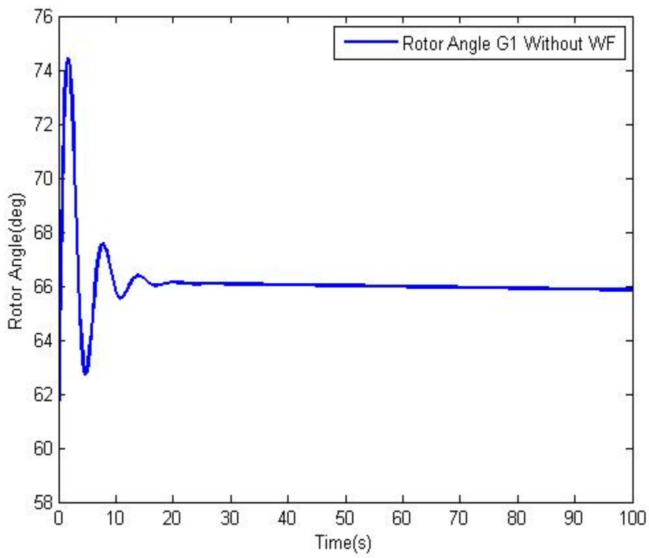

Fig.10. Rotor angle of generator 1 without wind turbine

The effect of wind turbine connection to system without operation of STATCOM is presented as shown in Fig.11.

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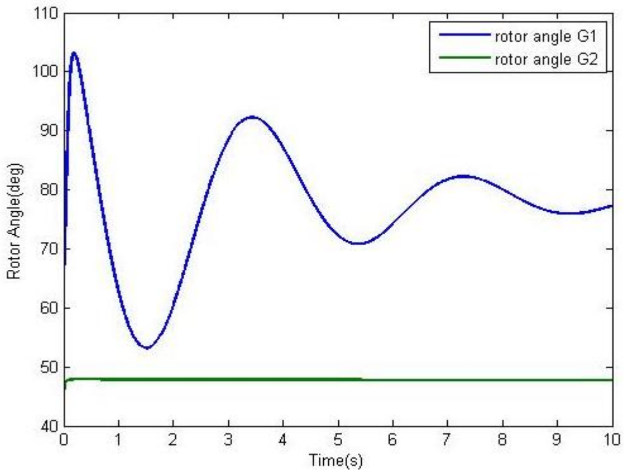

Fig.11.The response of rotor angles of G1 and G2 in presence of wind turbine

When STATCOM is switched to system, the oscillation of rotor angels due to operation of wind turbine, is improved as shown in Fig.12.

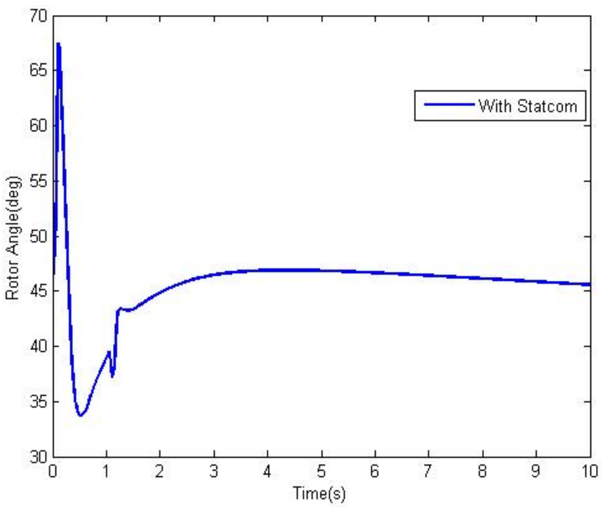

Fig.12.The variation of active and reactive power at Bus 25 of test system with presence of STATCOM

7. CONCLUSION

When integrated to the power system, large wind farms pose stability and control issues. A thorough study is needed to identify the potential problems and to develop measures to mitigate them. Although integration of high levels of wind power into an existing transmission system does not require a major redesign, it necessitates additional control and compensating equipment to enable recovery from severe system disturbances. This paper investigates the use of a Static Synchronous Compensator (STATCOM) along with wind farms for the purpose of stabilizing the grid voltage after grid-side disturbances such as a three phase short circuit fault, temporary trip of a wind turbine and sudden load changes. The strategy focuses on a fundamental grid operational requirement to maintain proper voltages at the point of common coupling by regulating voltage. The DC voltage at individual wind turbine (WT) inverters is also stabilized to facilitate continuous operation of wind turbines during disturbances.

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