Stability Analysis of Wind Farm Based on DFIG by STATCOM

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Abstract— The power system defined these days is highly capable and complex so that they can satisfy the demand of the users over the power system. One of the complex forms of power system is wind turbine based systems. These systems having the turbine motor with fixed or the variable speed. With all these power systems, the common problem and requirement is the voltage stability. The stability requirement is more crucial if some fault occur over the system. In such case some dynamic mechanism is required to maintain the steady state of the power system and to achieve the stability over the system so that equalize distribution of power will be done in the defined area. This Paper reviews the various stability of the system with different generating system and stability improvement with the help of various technologies like STATCOM.

Key words: DFIG, STATCOM, SVC, WIND POWER

I. INTRODUCTION

Growing environmental concerns and attempts to reduce dependency on fossil fuel resources are bringing renewable energy resources to the mainstream of the electric power sector. Among the various renewable resources, wind power is assumed to have the most favorable technical and economical prospects. In the last five years, the world wind turbine market has been growing at over 30% a year and wind power is playing an increasingly important role in electricity generation. By 2020, wind power would account for more than 12% of the world's total installed capacity. Modern power systems are characterized by extensive system interconnections and increasing dependence on control for optimum utilization of existing resources. The supply of reliable and economic electrical energy is a major determinant of industrial progress and consequent rise in the standard of living.

The increasing demand for electric power coupled with resource and environmental constraints pose several challenges to system planners. The generation may have to be sited at locations far away from load centers. However, constraints on right of way lead to over loading of existing transmission lines and an impetus to seek technological solutions for exploiting the high thermal loading limits of EHV lines.

This paper review various models of wind energy conversion system and techniques stability improvement technics.Rest of the paper is organized in following ways section 1 gives the detail of the DFIG andlitrature surway of DFIG models model for power system stability. In section 2 analysis, effect, improvement of stability of the wind power system with help of various reactive & active power compensator devices. Conclusion is given in section 3.

II. DFIG IN WIND ENERGY CONVERSION SYSTEM

Wind turbines use a doubly-fed induction generator (DFIG) consisting of a wound rotor induction generator and an AC/DC/AC IGBT-based PWM converter. The stator winding is connected directly to the 50 Hz grid while the rotor is fed at variable frequency through the AC/DC/AC converter. The DFIG technology allows extracting maximum energy from the wind for low wind speeds by optimizing the turbine speed, while minimizing mechanical stresses on the turbine during gusts of wind. The optimum turbine speed producing maximum mechanical energy for a given wind speed is proportional to the wind speed. Another advantage of the DFIG technology is the ability for power electronic converters to generate or absorb reactive power, thus eliminating the need for installing capacitor banks as in the case of squirrel-cage induction generator.

Nowadays, among all the renewable energy sources, wind systems are more economic in comparison with others. Variable wind speed systems deliver 20 to 30% more energy in comparison with the constant speed systems. They also decrease power oscillation and improve reactive power injection. Various technologies are developed for wind systems as their application has developed. During the previous years, permanent magnet synchronous generators (PMSGs) are greatly used in wind turbine applications because of their advantages such as low weight and velocity, high efficiency and gear-less structure.

Efficient control of electric power at the generation has been an important contributing factor for industrial growth in the twentieth century. Bulk of this power is generated and utilized through electromechanical energy conversion. Speed operation of electrical machines enables this conversion of power in a controlled manner. With the availability of power semiconductor devices the efficiency of conversion is high and, if desired, fast dynamic response can also be achieved.

At present, there are mainly three kinds of generators are used in wind power system: squirrel cage induction generator (SCIG), doubly fed induction generator (DFIG.) and permanent magnet synchronous generator (PMSG). While a multi pole synchronous generator connected to a power converter does not need a gear, so it can operate at low speeds. The research focuses on the control strategy of DFIG based wind power system under STATCOM. Through the field-oriented control, the highest efficiency of wind generator can be reached.Yang HAN [4]: They have proposed the control strategies and digital simulation for the double-fed induction generator (DFIG)-based wind generators for transient stability studies. The wind turbine power tracking characteristics and the power flow mechanism of the DFIG-based wind plant are analyzed. The rotor-side converter (RSC) control, grid-side converter (GSC) control and the pitch angle control scheme are presented based on the phasor model of the DFIG system are described.S.Radha Krishna Reddy et al. [5]: In their work they have proposed a Fuzzy logic controller which is applied in nonlinear systems to stabilize it. Double-fed wind turbine induction generator can regulate reactive power in addition to stabilizing the system based on Fuzzy Logic Controller superior to other energy storage technologies for comprehensive performance and Double-Fed Wind turbine Induction Generators substituting for ordinary wind turbine induction generators are proposed .Abdelmalek Boulahia et al. [6]: In this paper direct power control (DPC) strategy is applied to control a doubly fed induction generator (DFIG) based wind energy generation system. An AC/DC/AC converter is controlled by direct power control method. The rotor side converter is controlled by selects appropriates voltage vector based on the instantaneous errors between the reference and estimated values of active and reactive powers and rotor flux position. Also the Grid side is controlled by direct power control based a grid voltage position to ensures a constant DC voltage, Simulation results demonstrate robust, precise, and fast dynamic behavior of system.A.P.deshpande et al. [7]: This paper presents the analysis, design and simulation of a back to back converter for a modern wind energy system. The control strategy for the back to back converter is described with equations and the snapshot of the theoretical scheme and scheme implemented in the real life situation are both shown. The control strategy for the grid-side and rotor-side converter is thoroughly elaborated. Tan Luong Van et al. [8]: In their work they have proposed a function model of back-to-back PWM converters, based on the switching function, is developed for simplified simulation of power electronic application systems. For the function model, the PWM power switches are represented by dependent power sources. By using the proposed function model, the computer memory and the run time required for the simulation of power circuits can be significantly reduced. Seifeddine Belfedhal et al. [9]:In this paper they have illustrated the control of a variable speed wind generator system based on a doubly fed induction generator connected to the network associated to a flywheel energy storage system is considered. Firstly, the doubly fed induction generator is modeled and simulated. A.Babaie Lajimi et al. [10]: Their work has demonstrated a complete mathematical DFIG model is proposed. The rotor is considered fed by a voltage source converter whereas the stator is connected to the grid directly. Output power and electromagnetic torque are controlled using field-oriented control (FOC). Simulation results show the efficiency of the controller in exploiting the maximum power of wind. Christian Wessels et al. [11]: In their work they have proposed an application of a dynamic voltage restorer (DVR) connected to a wind-turbine-driven doubly fed induction generator (DFIG) is investigated. The setup allows the wind turbine system an uninterruptible fault ride-through of voltage dips. The DVR can compensate the faulty line voltage, while the DFIG wind turbine can continue its nominal operation as demanded in actual grid.M. Ebrahim Adabi, et al. [12]: This paper investigates a shaft voltage remediation strategy for a doubly fed induction generator. A three-level back-to-back AC-DC-AC converter has been used in this system. This analysis is based on reduction of the maximum common mode voltage levels by removing related switching vectors from a switching pattern. Applying this technique leads to a 66 percent reduction of the common mode voltage of the rotor side converter which plays the key role in shaft voltage generation of the DFIG .Haisheng Sun et al. [13]: In their work they have illustrated a back-to-back PWM converter which is used as the excitation power supply for the doubly-fed induction generator (DFIG) wind power generation of variable speed constant frequency (VSCF). The mathematical model and control strategy of converter which is connected between rotor and grid is analyzed. Output power of DFlG can be regulated effectively and the maximum wind energy capture is realized.Sundeep Sheri et al. [14]: This paper deals with the modeling and controller for DFIG has been described. Its performance under disturbances has been demonstrated. A reduced order model has been used for ease of calculations and reduced simulation time. The main assumptions in the model used were neglect of stator transients and saturation effects.Hongmei Li et al. [15]: In their work they have demonstrated the effect of electrical parameters of the double fed induction generator on the transient voltage stability of a DFIG to a simple grid; the DFIG model has been developed in the Matlab/simulink tool. The dynamic behavior of a wind turbine connected to a grid is examined. A three-phase fault is applied close to the wind turbine.B.Chitti Babu et al. [16]: They proposed a complete modeling and simulation of wind turbine driven doubly-fed induction generator which feeds ac power to the utility grid. For that, two pulse width modulated voltage source converters are connected back to back between the rotor terminals and utility grid via common dc link. The grid side converter controls the power flow between the DC bus and the AC side and allows the system to be operated in sub-synchronous and super synchronous mode of operation. Duan Qichang et al. [17]: They have proposed a new open-circuit fault diagnosis scheme, which is capable for detecting one or two open-circuit fault of power switches in the back-to-back converter of a DFIG wind power generation system is proposed. A redundant topology for the back-to-back converter is set out enabling reconfiguration of the converter circuit once the faulty device or devices is identified and isolated. A.A. Sattar et al.[18] The paper describes the design of a Doubly Fed Induction Generator (DFIG) connected to the grid through back to- back converters in the rotor circuit. A vector control oriented with the stator voltage is applied for the grid side converter that is responsible for maintaining the DC link voltage constant regardless of the power flow between the rotor and the grid. A field orientation control with the d-axis aligned with the stator flux is applied for the rotor side converter.S. M. Zahim et al. [23]: This paper compares four combinations of PWM techniques through conceptual discussion and based on simulation results. The results show that each combination has its own performance advantages which can give an idea on designing DFIG controller based on desired objectives. Pulse width modulation (PWM) has been widely employed in voltage source converter (VSC) due to its superior output waveforms. PWM types are generally g grouped into continuous (CPWM) and discontinuous (DPWM). Each has its own performance characteristic, which contrasts from the other. M. A. Chowdhury et al. [24]: They have proposed the work which deals with investigating the current research issues in this area (DFIG), research gaps and limitations in previous works to gestate future research options. Considering the inclusion of quantitative research on the impact of DFIG wind energy systems on a power network with dynamic loads. Particularly, transient stability studies will be performed on these networks when unsymmetrical faults occur in the system. These studies may contribute to more accurate simulation results for finding out better strategies for smooth, reliable and uninterrupted operation of power networks with the future penetration of wind energy systems.

III. REACTIVE COMPENSATION SYSTEM FOR WIND POWER

In 1999 the first svc with voltage source converter called STATCOM (static compensator) went into operation. The STATCOM has a characteristic similar to the synchronous condenser, but as an electronic device it has no inertia and is superior to the synchronous condenser in several ways, such as better dynamics, a lower investment cost and lower operating and maintenance costs. A STATCOM is build with thrusters with turn-off capability like GTO or today IGCT or with more and more IGBTS. The static line between the current limitations has a certain steepness determining the control characteristic for the voltage. The advantage of a STATCOM is that the reactive power provision is independent from the actual voltage on the connection point. This can be seen in the diagram for the maximum currents being independent of the voltage in comparison to the svc. This means, that even during most severe contingencies, the STATCOM keeps its full capability.In the distributed energy sector the usage of voltage source converters for grid interconnection is common practice today. The next step in STATCOM development is the combination with energy storages on the dc-side. The performance for power quality and balanced network operation can be improved much more with the combination of active and reactive power.

STATCOMs are based on voltage sourced converter (VSC) topology and utilize either gate-turn-off thyristors (GTO) or isolated gate bipolar transistors (IGBT) devices. The STATCOM is a very fast acting, electronic equivalent of a synchronous condenser. If the STATCOM voltage, vs, (which is proportional to the dc bus voltage vc) is larger than bus voltage, ES, then leading or capacitive vars are produced. If vs is smaller than ES then lagging or inductive vars are produced. The three phases STATCOM makes use of the fact that on a three phase, fundamental frequency, steady state basis, and the instantaneous power entering a purely reactive device must be zero. The reactive power in each phase is supplied by circulating the instantaneous real power between the phases. This is achieved by firing the GTO/diode switches in a manner that maintains the phase difference between the ac bus voltage ES and the STATCOM generated voltage vs. Ideally it is possible to construct a device based on circulating instantaneous power which has no energy storage device (i.e. no dc capacitor).

A practical STATCOM requires some amount of energy storage to accommodate harmonic power and ac system unbalances, when the instantaneous real power is non-zero. The maximum energy storage required for the STATCOM is much less than for a TCR/TSC type of svc compensator of comparable rating.

Several different control techniques can be used for the firing control of the STATCOM. Fundamental switching of the GTO/diode once per cycle can be used. This approach will minimize switching losses, but will generally utilize more complex transformer topologies. As an alternative, pulse width modulated (pwm) techniques, which turn on and off the GTO or IGBT switch more than once per cycle, can be used. This approach allows for simpler transformer topologies at the expense of higher switching losses. Sillparasetti V Kumar [1]: In their work they have prosed the stability analysis of wind generator with help of STATCOM and SDBR and method of stability improvement of wind farm composed of fixed speed wind power generator using a small series dynamic bracking register or by using STATCOM.They statcom and sdbrhave active and reactive power control ability.Archana N, Vidyapriya R, Ashok Kumar [2]: In this paper they proposed power quality improvement in a multy machine system using FACTS based STATCOM device. In this proposed paper STATCOM is connected at the point of common coupling to mitigate the power quality issue.Sharmila , Pardeep Nain[3]: Study include the implementation of FECTS devices in wind farm using squirrel cage induction generator. FACTS devices are used to enhance the voltage stability of wind farm.N. H. Woodley [31-32] explains various power quality problems and the solutions to those problems with solid state switching devices such as: Static VAR Compensator, Static Compensator (STATCOM), Unified Power Flow Controller (UPFC), and Dynamic Voltage Restorer (DVR) in detail. The author also discusses the energy storage systems for voltage sag mitigation. Here author suggested that for the future developments of devices we must consider both of technical and economic aspects to existing problems and their solution techniques.Reference [33-34] describes the techniques of correcting the supply voltage sag in a distribution system by two power electronics based devices called DVR and D-STATCOM. The steady state performance of both DVR and D-STATCOM is determined and compared for various values of voltage sag, system fault level and load level. The minimum apparent power injection required to correct a given voltage sag by these devices is also determined and compared. The maximum voltage sag that can be corrected without injecting any active power into the system is also determined.Reference [35] studied the compensation of frequently time-variable loads by means of STATCOM controllers. An arc furnace is considered as a heavily distributing load. The STATCOM system was used to ensure good power quality at the point of common coupling. Simulation models of the load and two types of STATCOM controllers namely; 12-pulses and 24-pulses are discussed in detail. The simulation results demonstrate the compensation effectiveness.Reference [36] present an overview of power-electronic based devices for mitigation of power quality phenomena. The concept of custom power is highlighted. Both devices for mitigation of interruptions and voltage dips (sags) and devices for compensation of unbalance, flicker and harmonics are treated. The attention is focused on medium-voltage applications. It is shown that custom power devices provide, in many cases, higher performance compared with traditional mitigation methods. However, the choice of the most suitable solution depends on the characteristics of the supply at the point of connection, the requirements of the load and economics.

IV. CONCLUSIONS

In this paper, review on various models of wind energy conversion system, analysis ofSmall signal stability and transient stability and enhancement of stability are given. VariousModels for wind energy conversion system for stability studies are proposed by variousResearchers and reported in [4-18, 23-24]. These models are varied from simple models to reduced order models. Model simplification is important to keep a balance between computation time and result accuracy. In this context, third order, fifth order and sixth order models have beenProposed for the study of stability analysis of wind energy conversion systems.

Various Techniques are discussed by researchers for compensate reactive power and achieve the stability of the wind farm in the faulty conditions. One of the technical is STATCOM. In general case, as the fault occur the voltage, complete voltage distribution over the system is affected and overall voltage in the system set to 0. But in this presented system, the STATCOM based controller is been defined to achieve the voltage stability. Many researcher define stability analysis by Statcom.which is reported in this paper in [1-3, 31-36].

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