Dynamic Stability Improvement of PMSG-Based Wind Turbine Generators Fed to a Power System Using PID controller Based STATCOM

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Abstract: —

This paper presents the stability-improvement results of four parallel-operated offshore wind turbine generators (WTGs) connected to an onshore power system using a static synchronous compensator (STATCOM). In this project have the fast advance of high-capacity power-electronics technology, large commercial wind turbine generators can be practically employed to contribute high generated power to power systems, where wind PMSGs with full back to-back converters have proven to be good choices for high-power WTGs. Basically, the grid side converter of the PMSG-based WTG can be operated as a STATCOM. Many manufacturers also provide this option even for the case when the WTG is not running. But in a real PMSG-based OWF, It has several PMSG-based WTGs operating together, and it is difficult to control reactive power of all WTGs at the same time to supply adequate reactive power to the system. Hence, to guarantee good power quality (PQ) of the system, an additional VAR compensator is\ required. In this project, a STATCOM is proposed as a VAR compensator. It can be concluded from the simulation results that the proposed STATCOM joined with the designed damping controller can effectively improve the stability of the studied SG-based onshore power system under various disturbanceconditions .The results are obtained from the MATLAB/SIMULINK environment.

Keywords: Dynamic stability; permanent-magnet synchronous generator (PMSG); static synchronous compensator; MATLAB; wind turbine generator (WTG)

I. INTRODUCTION

The renewable energy sources are one of the biggest concerns of our times. High prices of oil and global warming make the fossil fuels less and less attractive solutions. Wind power is a very important renewable energy source. It is free and not polluter unlike the traditional fossil energy sources. It obtains clean energy from the kinetic energy of the wind by means of the wind turbine. The wind turbine transforms the kinetic wind energy into mechanical energy through the drive train and then into electrical energy by means of the generator. Although the principles of wind turbines are simple, there are still big challenges regarding the efficiency, control and costs of production and maintenance.

Some academic researchers have devoted to high-capacity offshore wind turbine generators (WTGs) connected to onshore substations through undersea cables .Currently, wind doubly-fed induction generators (DFIGs) and wind permanent magnet synchronous generators (PMSGs) have been widely used in high-capacity offshore wind farms (OWFs) [1]. From the historical point of view, a direct-coupled, modular PMSG for variable-speed wind turbines was proposed and multiple single-phase outputs were separately rectified to obtain a smooth dc link voltage. The dynamic model based on small-signal stability of a wind turbine (WT) using a direct-drive PMSG with its power converters and controllers was proposed [2].

Regarding the applications of STATCOM to power-system stability improvement, the stability

enhancement of power systems using STATCOMs and the damping controller design of STATCOMs were presented in [9]. A variable-blade pitch of a WTG and design of an output feedback linear quadratic controller for a STATCOM to perform mechanical power control and voltage control under different operating conditions were studied in [10]. Controller design and system modeling for quick load voltage regulation and suppression of voltage flicker using a STATCOM were explored in [11]. A novel D-STATCOM control algorithm for enabling separate control of positive- and negative-sequence currents was proposed in [12]. Dynamic characteristics of a power system with a STATCOM and a static synchronous series compensator(SSSC) through digital simulations were compared in [13]. The application of a STATCOM to damp torsional oscillation of a series-capacitor compensated ac system were shown in [14]. The characteristics of using PSS, static VAR compensator(SVC), and STATCOMfor damping undesirable interarea oscillations of a power system were compared in [15]. These days, with the fast advance of high-capacity power electronics technology, large commercial wind turbine generators can be practically employed to contribute high generated power to power systems, where wind PMSGs with full back-to-back converters have proven to be good choices for high-power WTGs. Basically, the grid-side converter of the PMSG-basedWTG can be operated as a STATCOM. Many manufacturers also provide this option even for the case when the WTG is not running. But in a real PMSG-based OWF, it has several PMSG-based WTGs operating together, and it is difficult to control reactive power of all WTGs at the same time to supply adequate reactive power to the system. Hence, to guarantee good power quality (PQ) of the system, an additional VAR compensator is

required. In this paper, a STATCOM is proposed as a VAR compensator.

This paper focuses on modeling the characteristics of four 5-MW PMSG-based WTGs fed to an SG-based power system to examine the effect of large power penetration to the SG. For improving the damping of the SG of the OMIB system, a STATCOM joined with the designed PID controller connected to the common ac bus of the studied system is proposed.

II. PROPOSED TOPOLOGY – CONTROL STRATEGY

A. Basic diagram of the proposed system:

Fig.1 shows the configuration of the studied system. The right-hand side of Fig.1 represents the synchronous generator (SG)-based one machine infinite-bus (OMIB) system. Two parallel-operated 615-MVA SGs are connected to an infinite bus (or a power grid) through two parallel transmission lines (TL1 and TL2) and a 15/161-kV step-up transformer. Four parallel operated PMSG-based WTGs and a 5-MVAR STATCOM are connected to the common offshore ac bus that is fed to the point of common coupling (PCC) of the OMIB system through a step-up transformer of 23/161 kV and a cable (undersea and underground cables). Each 5-MW WTG is represented by a PMSG with an ac/dc converter, a dc link, a dc/ac inverter, and a step-up transformer of 3.3/23 kV. While the shaft of the wind PMSG is directly driven by a variable-speed WT. the four PMSG-based WTGs, the STATCOM, and a local load are connected to a common ac bus through connection lines and transformers.
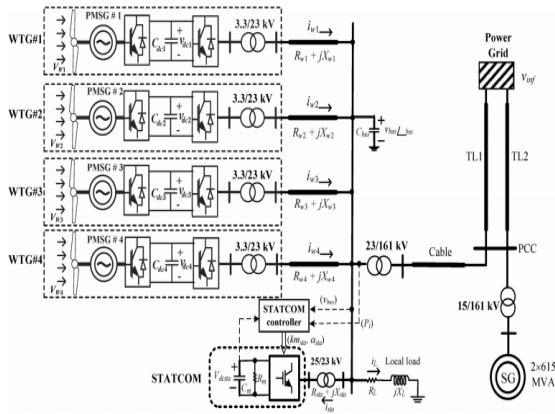
Fig. 1 Configuration of the studied SG-based containing four parallel-operated PMSG-based WTGs with STATCOM

B. Modelling of Wind Turbine:

The blade pitch angle (degrees) are the constant coefficients. The wind speed is modeled as the algebraic sum of a base wind speed, a gust wind speed, a ramp wind , and a noise wind speed. The cut-in, rated, and cut-out wind speeds of the studied WT are 4, 14, and 25 m/s, respectively. When wind speed is lower than 14 m/s, When 14 m/s, the pitch-angle control system activates and increases accordingly. In fig.2 Each WT is directly coupled to the rotor shaft of a wind PMSG.
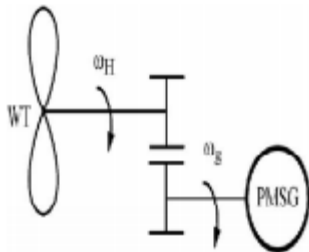

Fig2. Each WT coupled to the rotor shaft of a wind PMSG

A. PMSG and Power Converter :

The power converter of each wind PMSG consists of a voltage source converter (VSC) and a voltage-source inverter (VSI) as shown in Fig. 3. The VSC or the VSI consists of six insulated gate bipolar properly decoupled by the dc- link capacitor. The common dc link with a large capacitor is connected between the VSC and the VSI. Theoperation of the VSC and the VSC is properly decoupled by the dc-link capacitor and, hence, the VSC and the VSI have independent controllers.

A. Modelling of STATCOM :

In order to temporarily avoid the high level of reactive compensation during recovery. In addition to the normal STATCOM control, allows for torque transient alleviation during the recovery process after a grid fault [4]. This is possible to achieve by reducing the voltage reference of the STATCOM control system and, by that, the reactive compensation when stability is ensured after fault clearing but before the grid voltage and the speed of the generator have returned to the prefault values [6]. In this way, the STATCOM can improve the torque capability of the PMSG when this is needed keep the system stable, and once stability is ensured, it can reduce the maximum torque during recovery. The strain on the drive train can thereby be reduced. This is particularly relevant where wind turbines cannot just disconnect from the grid to protect the installation from risk of mechanical damage that might be caused by the cumulative stress of repeated peak torque transients[5] This paper focuses on the recovery process after fault clearing and reactive power compensation .The other main issue related to this concept is that, since the decelerating torque of the generator is limited, the recovery process of the system will be longer than for the case of normal control of the STATCOM with a fixed voltage reference value[8].

III. MATLAB BASED SIMULATION &RESULTS

It is noted that the reactive power exchange between the AC system and the compensator is controlled by varying the magnitude of the fundamental component of the inverter voltage above and below that of the AC system. The compensator control is achieved by small variations in the switching angle of the semiconductor devices, so that the fundamental component of the voltage produced by the inverter is forced to lag or lead the AC system voltage by a few degrees. This causes active power to flow into or out of the inverter modifying the value of the DC capacitor voltage and consequently the magnitude of the inverter terminal voltage and the resultant reactive power. If the compensator supplies only reactive

power, the active power provided by the DC capacitor is zero. Therefore, the capacitor does not change its voltage. With the provision of DC source or energy storage device on its DC side, there can be a little active power exchange between the STATCOM and the electric power system. When the phase angle of the AC power leads the inverter phase angle, the STATCOM absorbs real power from the AC system, if the phase angle of the AC power system lags the inverter phase angle, the STATCOM supplies real power to ACsystem. Without STATCOM is the system they will be a voltage drop. So that when STATCOM is used it will compensate the reactive power either by absorbing or generating in Fig.6&Fig.7 .When voltage is less it whenever fault occurs it can compensate the voltage drop.
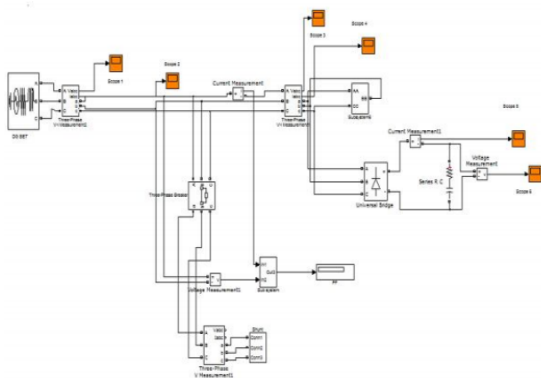

Fig.3. MATLAB based simulation diagram of proposed system with masked diagrams
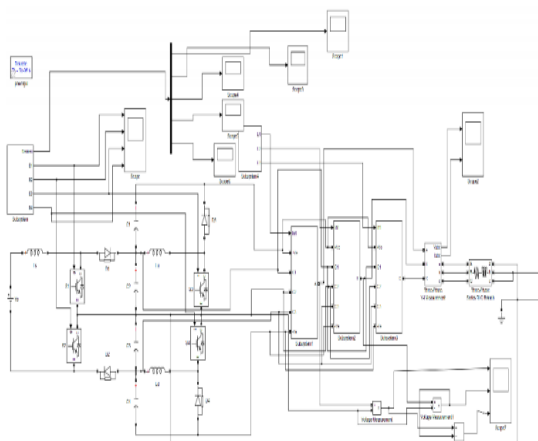

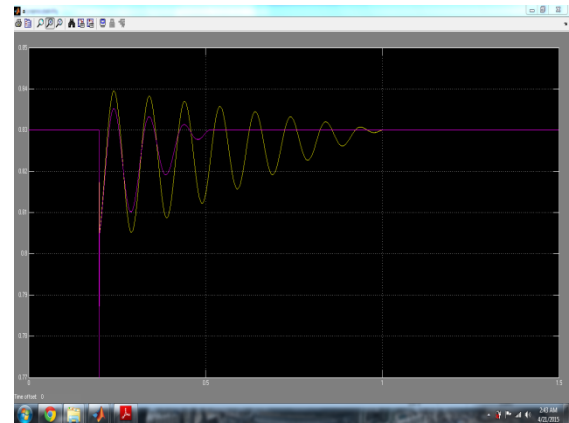Fig.4.MATLAB based simulation diagram of proposed system with masked diagrams

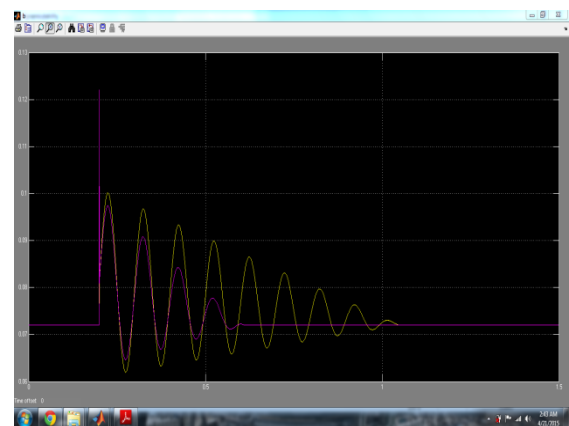Fig.5.MATLAB Based simulation
Of Active power of proposed system

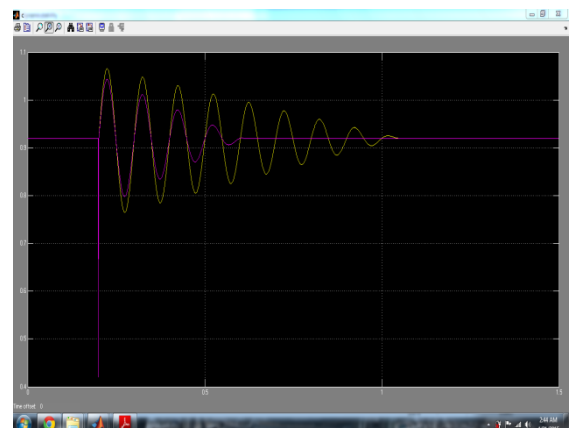Fig.6.MATLAB Based simulation reactive power of proposed system
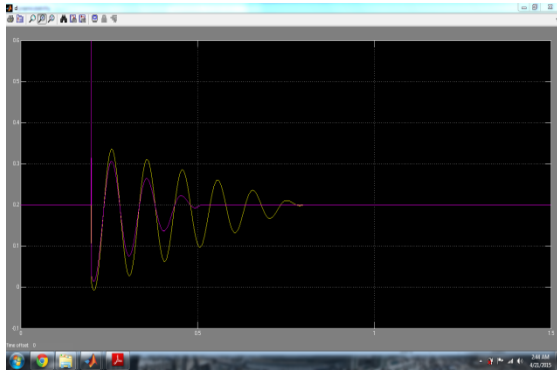

Fig.6.MATLAB Based simulation of Psg

Fig.7.MATLAB Based simulation of Q sg

CONCLUSION

The concept of a new inverter with FACTS capability for small-to-mid-size wind installations is presented. Utilities are a major barrier to increasing the number of smaller distributed renewable installations. One of the ways that renewable can increase their penetration into these systems is by giving additional control to the utilities. This additional control is done with the help of FACTS devices and this will increase the cost of entire system. The proposed system demonstrates the application of a new inverter with FACTS capability in a single unit without any additional cost. Replacing the traditional renewable energy inverters with the proposed inverter will eliminate the need of any external STATCOM devices to regulate the PF of the grid. Clearly, depending on the size of the compensation, multiple inverters may be needed to reach the desired PF. This shows a new way in which distributed renewable sources can be used to provide control and support in distribution systems. The control strategy of system adjusts the reactivepower is controllable by the modulation index m. Usage of SHE method will eliminate lower level harmonics and improves the efficiency of the inverter.

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