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Modeling and Simulation of Wind Farm with STATCOM in PSCAD/EMTDC Environment

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ABSTRACT
This paper focuses on the modeling and control of WECS (Wind Energy Conversion System) in a grid connected system through PWM converters with DC link. A Wind Power Plant which is comprised of wind turbines are connected to Synchronous Generator with Multimass Torsional Shaft Interface modeled and designed. The output power of the generator is transmitted to Grid bus through PWM rectifier (to convert AC to DC) and a STATCOM based PWM inverter. This multi-level inverter convert DC power into ac power at desired output and frequency through a transformer .Varying the firing angle of converters simulation results show the effectiveness of the STATCOM based PWM converter presented in this paper using PSCAD/EMTDC software.

Keywords
Wind farm, PWM based STATCOM, Firing angle, PSCAD/EMTDC

1. INTRODUCTION
A pressing demand for more electric power coupled with depleting natural resources has led to an increased need for energy production from renewable energy sources such as wind and solar. Wind energy is one of the extra ordinary sources of renewable energy due to its clean character and free availability. Moreover, because of reducing the cost and improving techniques, the growth of wind energy in Distributed Generation (DG) units has developed rapidly.

In terms of wind power generation technology, because of numerous technical benefits (higher energy yield, reducing power fluctuations and improving var supply) the modern MW-size wind turbines always use variable speed operation which is achieved by a converter system [1].In wind power stations, induction machines are often used as generators, but the development of new permanent magnet generators, the improvement of the AC-DC-AC conversion and its advantages for output power quality make other solutions possible. A recent solution is to use a permanent magnet synchronous generator with variable speed and a conversion stage, which is studied in this paper. A STATCOM or Static Synchronous Compensator is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are a number of other uses for STATCOM devices including, wind energy voltage stabilization, and harmonic filtering. However, the most common use is for stability. In this paper, a complete wind farm is modeled with PWM based STATCOM converter to stabilize grid connected synchronous wind generator system A theoretical and simulation study by PSCAD software of wind turbine generation is analyzed by this paper [2-8].

2. SYNCHRONOUS GENERATOR
Synchronous generators are doubly fed machines which generate electricity by the principle when the magnetic field around a conductor changes, a current is induced in the conductor. Typically, a rotating magnet called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. The field cuts across the conductors, generating an electrical current, as the mechanical input causes the rotor to turn. The rotating magnetic field induces an AC voltage in the stator windings. Often there are three sets of stator windings, physically offset so that the rotating magnetic field produces three phase currents, displaced by one-third of a period with respect to each other. The rotor magnetic field may be produced by induction by permanent magnets (in very small machines), or by a rotor winding energized with direct current through slip rings and brushes. The rotor magnetic field may even be provided by stationary field winding, with moving poles in the rotor. Automotive alternators invariably use a rotor winding, which allows control of the alternator generated voltage by varying the current in the rotor field winding. Permanent magnet machines avoid the loss due to magnetizing current in the rotor, but are restricted in size, owing to the cost of the magnet material. Since the permanent magnet field is constant, the terminal voltage varies directly with the speed of the generator.

3. STATCOM
The STATCOM is shunt-connected reactive-power compensation device that is capable of generating and or absorbing reactive power and in which the output can be varied to control the specific parameters of an electric power system. It is in general a solid-state switching converter capable of generating or absorbing independently controllable real and reactive power at its output terminals when it is fed from an energy source or energy- storage device at its input terminals. Specifically, the STATCOM considered as a

Voltage-source converter that, from a given input of dc voltage produces a set of 3-phase ac-output voltages, each in through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor. The VSC has the same rated-current capability when it operates with the Capacitive- or inductive-reactive current. Therefore, a VSC having certain MVA rating gives the ST ATCOM twice the dynamic range in MVAR (this also contributes to a compact design). A dc capacitor bank is used to support (stabilize) the controlled dc voltage needed for the operation of the VSC. The reactive power of a STATCOM is produced by means of power-electronic equipment of the voltage-source-converter type. A number of VSCs are combined in a multi-pulse connection to form the STATCOM. In the steady state, the VSCs operate with fundamental-frequency switching to minimize converter losses. However, during transient conditions caused by line faults, a pulse width-modulated (PWM) mode is used to prevent the fault current from entering the VSCs. In this way, the STATCOM is able to withstand transients on the ac side without blocking. A single-line STATCOM power circuit is shown in Fig.1 where a VSC is connected to a utility bus through magnetic coupling with and coupled to the corresponding ac system voltage [9- 11].

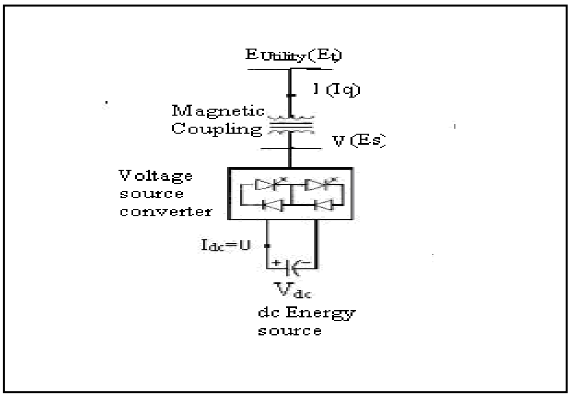

Fig 1: A single-line STATCOM power circuit

4. SIMULATION AND DESCRIPTION

In this PSCAD software simulation a wind turbine connected to a permanent Magnet Synchronous Generator with 100 pole pairs. The connection to the grid is then performed through a full AC/DC/AC converter. The main advantage of this strategy is to allow removing the gear box in the wind turbine. Fig 2 shows the complete wind farm model with STATCOM based voltage source converters connected to grid in PSCAD Environment.

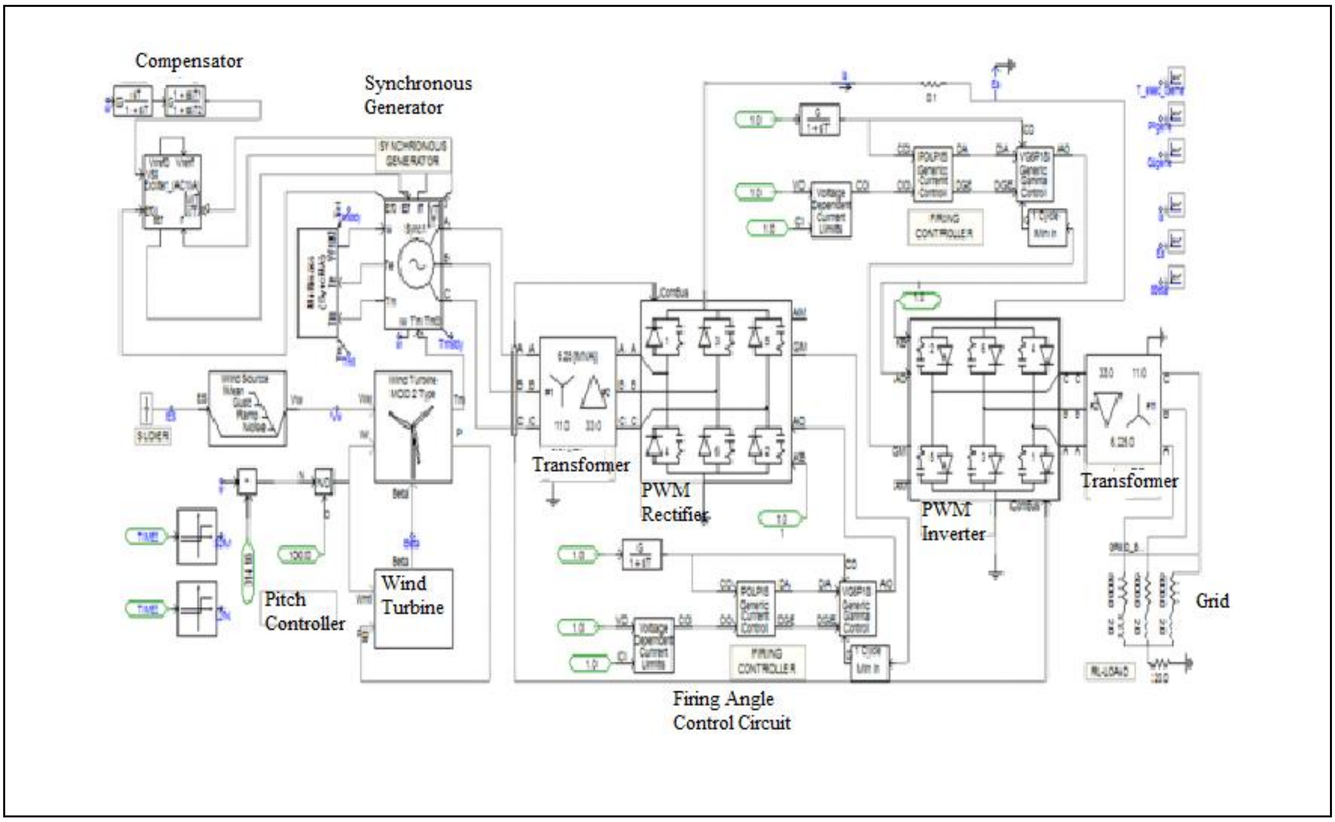

Fig 2: Complete wind farm model with STATCOM based voltage source converters connected to grid in PSCAD Environment

5. RESULTS

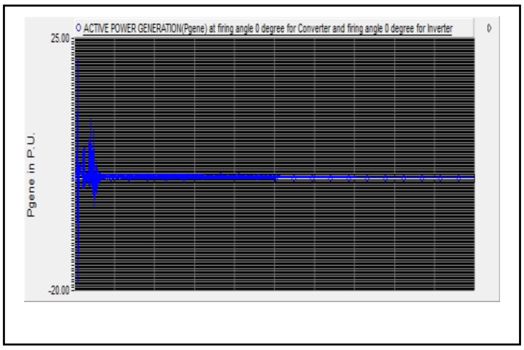

Fig 3: Real power characteristics at 0◦ firing angle

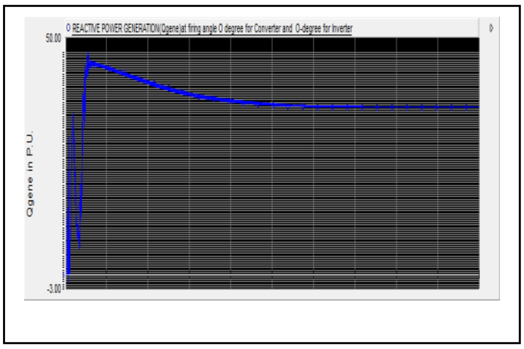

Fig 4: Reactive Power characteristics at 0◦ firing angle

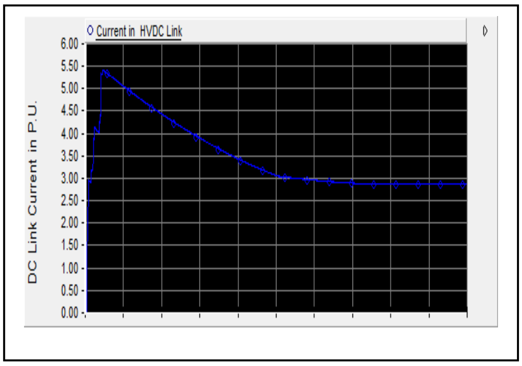

Fig 5: Current characteristics in HVDC link at 0◦ firing angle

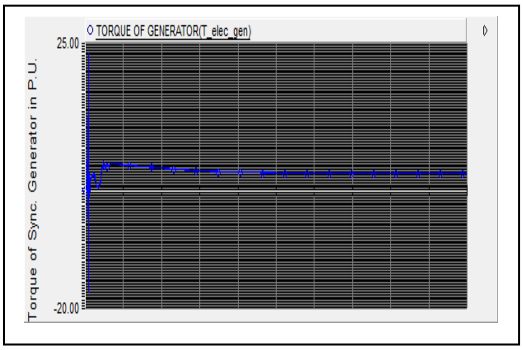

Fig 6: Torque characteristics of Generator at 0◦ firing angle

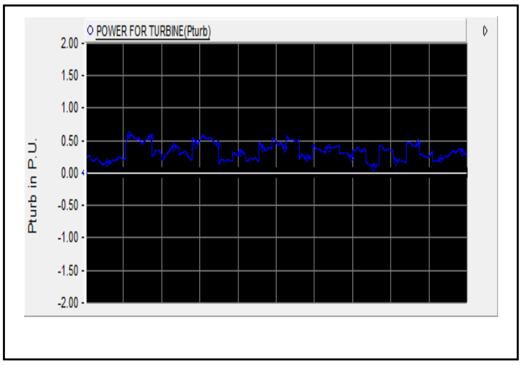

Fig 7: Power characteristics of Turbine

Table 1: Wind farm characteristics at 0◦ firing angle

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	21.130576
2	Qgene(Reactive Power)	46.993557
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.38832

Table 2: Wind Farm characteristics with firing angle at 30◦ for rectifier and 0◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	31.036645
2	Qgene(Reactive Power)	51.356848
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.345187

Table 3: Wind Farm characteristics with firing angle at 0◦ for rectifier and 30◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	21.182593
2	Qgene(Reactive Power)	46.993693
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.38823

Table 4: Wind Farm characteristics with firing angle at 90◦ for rectifier and 0◦ for inverter

Sl No	Variable Name	Generation in Maximum(in PU)
1	Pgene(Real Power)	32.125207
2	Qgene(Reactive Power)	54.93304
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.358674

Table 5: Wind Farm characteristics with firing angle at 90◦ for rectifier and 90◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	32.117243
2	Qgene(Reactive Power)	54.939679
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.358705

Table 6: Wind Farm characteristics with firing angle at 0◦ for rectifier and 90◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	21.148936
2	Qgene(Reactive Power)	46.993788
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.388306

Table 7: Wind Farm characteristics with firing angle at 0◦ for rectifier and 120◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	21.148936
2	Qgene(Reactive Power)	46.993788
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.388306

Table 8: Wind Farm characteristics with firing angle at 145◦ for rectifier and 0◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	32.117243
2	Qgene(Reactive Power)	54.939679
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.358705

Table 9: Wind Farm characteristics with firing angle at 180◦ fo r rectifier and 0◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	32.117243
2	Qgene(Reactive Power)	54.939679
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
6	DC Current	5.358705

Table 10: Wind Farm characteristics with firing angle at 0◦ for rectifier and 180◦ for inverter

Sl No	Variable Name	Generation in Maximum (in PU)
1	Pgene(Real Power)	21.148936
2	Qgene(Reactive Power)	46.993788
3	Pturb(Turbine Power)	0.647227
4	Wmech (Mechanical Speed)	3.1416
5	Tturb (Turbine Torque)	64.748664
7	DC Current	5.388306

6. CONCLUSION

In this paper the performance of Wind Farm is investigated in controlling the flow of power through the PWM STATCOM based Converters. This paper presents real and reactive power flow control by varying the firing angle of both the converters. The model has been implemented using PSCAD/EMTDC software. The simulations performed indicate that the system presents good dynamic characteristics, without any stability problems. PSCAD/EMTDC proved to be a valuable tool in predicting the behavior of the WT, in selecting controller parameters and optimizing in general the control and operation of the machine.

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