International Journal of Power Electronics and Drive System (IJPEDS)
Vol. 7, No. 3, September 2016, pp. 996~1003
ISSN: 2088-8694, DOI: 10.11591/ijpeds.v7.i3.pp996-1003

Improvement of Wind farm with PMSG using STATCOM

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Article Info

Article history:

Received Nov 12, 2015
Revised Apr 13, 2016
Accepted May 14, 2016

Keyword:

Dynamic performance
PMSG-FPC
STATCOM
WECS
Wind farm

ABSTRACT

This paper studies about the dynamic performance of the Permanent Magnet Synchronous Generator with Static Synchronous Compensator (STATCOM) for Wind farm integration. A whole dynamic model of wind energy conversion system (WECS) with PMSG and STATCOM are established in a MATLAB environment. With this model the dynamic behaviour of the generator and the overall system has been studied to determine the performance of them with and without STATCOM. Final results portrays that the WECS based PMSG with STATCOM improves the transient response of the wind farm when the system is in fault.

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1. INTRODUCTION

Electric power generation in the mere future rely on renewable and environmentally friendly energy sources such as wind, solar, hydropower, geothermal, hydrogen, and biomass due to the existences of fossil fuels. Among these renewable resources, Wind is considered to be the cheapest and one of the major renewable resources.In recent times, the wind power Industries showing interest towards variable-speed constant-frequency wind energy systems due to the restrictions of fixed wind turbine generators such as their low power quality and efficiency. In recent times, the wind power Industries showing interest towards variable-speed constant-frequency wind energy systems due to the restrictions of fixed wind turbine generators [7]. The most impressive feature of PMSG is its capability to improve the flexibility of the system during random wind speed thereby ensuring the active power output is smooth [1]. The major advantage of PMSG is that it has a capacity to generate wind power at low wind speed by increasing the number of poles of the generator.

The STATCOM by definition, we know that the STATCOM (or SSC) is a 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. Compared to other FACTS devices, it has rapid and continuous response characteristics which provide faster and smoother dynamic voltage control. Therefore, it is more suitable for voltage flicker mitigation at the point of connection of the wind farm [8].

In this paper we study the dynamic performance of the Permanent Magnet Synchronous Generator with the Static Synchronous Compensator (STATCOM) for Wind farm integration. A whole dynamic model of wind energy conversion system (WECS) with PMSG and STATCOM are established in a MATLAB

environment. With this model the dynamic behaviour of the generator and the overall system has been studied to determine the performance of them with and without STATCOM.

2. MODELLING OF WIND ENERGY CONVERSION SYSTEM

The WECS consists of a wind Turbine, Permanent Magnet Synchronous Generator with full power Converter, Static Synchronous Compensator and a RL load. Wind Energy Conversion Systems as shown in Figure 1.

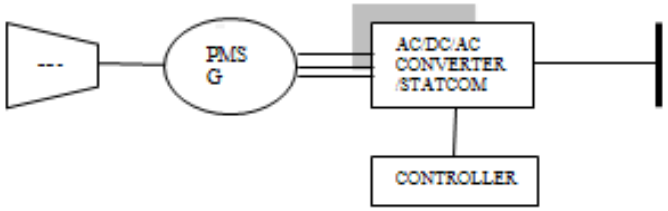

Figure 1. Wind Energy Conversion Systems

2.1. Permanent Magnet Synchronous Generator

The PMSG is a synchronous machine where the DC excitation is provided by Permanent magnet itself which eliminates the field coils, slip rings and brushes. The major disadvantage is that the Permanent magnets are costly which restricts the economic rating of the machine. It offers better performance due to higher efficiency and less maintenance since it does not have rotor current and can be used without a gearbox, which also implies a reduction of the weight of the nacelle and a reduction of the cost.

2.2. Wind Turbine Model

The wind turbine model is designed in MATLAB'12. It has three inputs

1. Generator speed is nothing but the rotor tip speed in per unit of the generator base speed.
2. Blade Pitch Angle in degrees we can get the maximum Performance Co efficient C_p when this angle is zero.
3. Wind Speed in m/s.

The mechanical power output is the product of Performance Co efficient and cube of wind speed in per unit [5]. From this the mechanical torque output is obtained. Wind Turbine Model as shown in Figure 2.

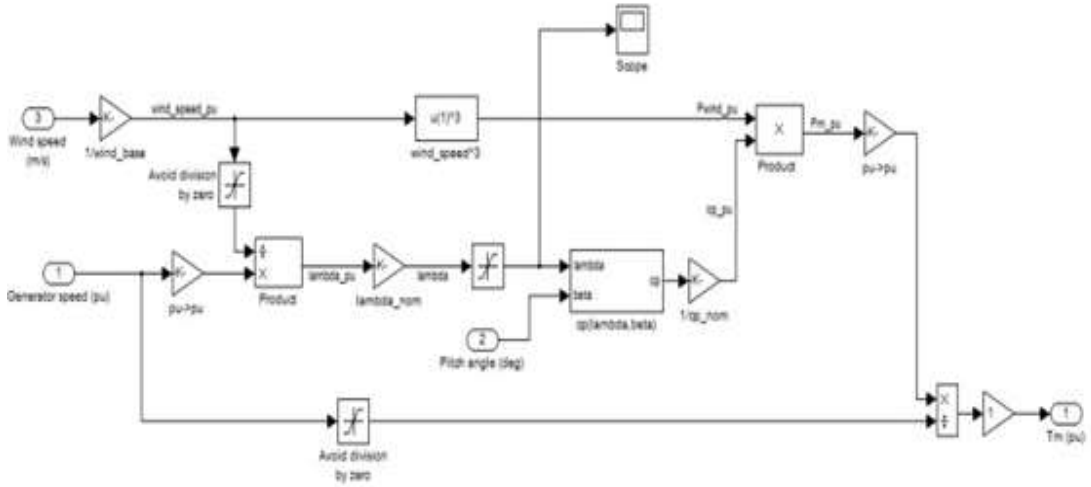

Figure 2. Wind Turbine Model.

2.3. Two mass drive train

The Two mass drive train model implemented in SIMULINK. This is turbine and shaft coupling system. It is suitable for transient stability analysis [4], [5]. Two mass drive train as shown in Figure 3.

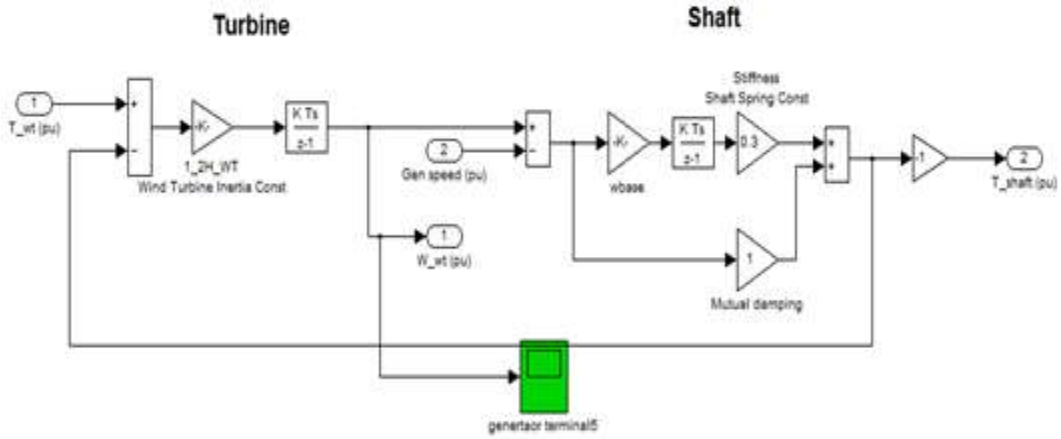

Figure 3. Two mass drive train

3. STATIC SYNCHRONOUS COMPENSATOR

The Static Synchronous Compensator (STATCOM) can provide voltage support to the system as per the requirement level.The Figure 4 shows Static Synchronous Compensator in which the exchange of reactive power between the converter and the ac system can be controlled by varying the amplitude of the 3-phase output voltage, Es, of the converter [15].

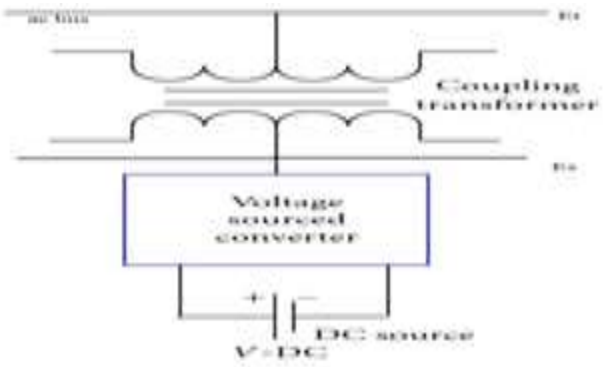

Figure 4. Static Synchronous Compensator

Where, Es - 3-phase output voltage and Et - utility bus voltage.

a. If Es is higher than that of the utility bus voltage, Et, then a current flows to the ac system through the reactance from the converter and the converter generates capacitive-reactive power for the ac system.
b. If the Es is lesser than Et, then the current flows from the ac system to the converter and the converter absorbs inductive-reactive power from the ac system.
c. If the Es equals Et, the reactive-power exchange becomes zero, in which case the STATCOM is said to be in a floating state [15].

STATCOM provide voltage support either by generating or absorbing reactive power into/ from the system and it also has rapid and continuous response characteristics which provide faster and smoother dynamic voltage control [8].

4. SIMULATION MODEL AND RESULTS

The performance of PMSG with and without STATCOM has been analyzed. The wind farm and the power system model are established in the MATLAB/SIMULINK environment.

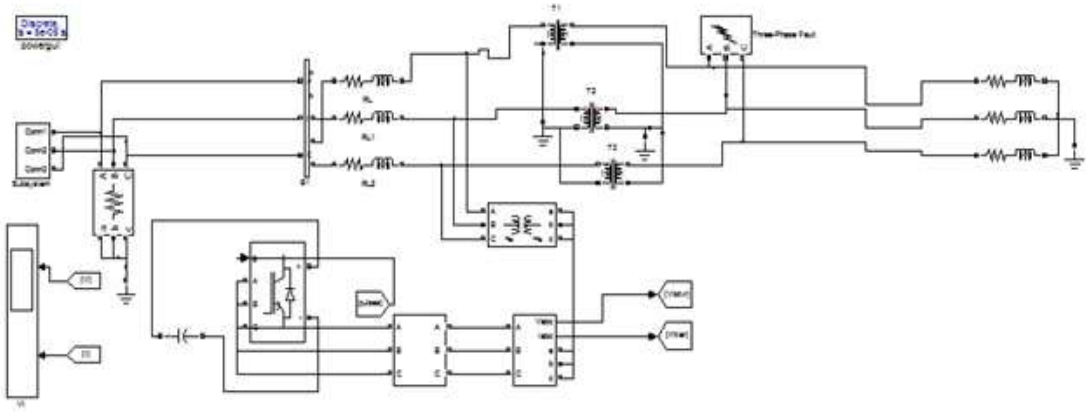

Figure5. Simulation model of PMSG

The whole dynamic model consists of Wind power generation, transmission line, 3 phase fault, compensating device STATCOM and a load. To analyze this, a three phase fault is considered to occur in the transmission line at a time interval of 0.2 to .25 and the generator line voltage, line current, Power and the rotor speed are measured. And the output voltage and current at the PCC is also displayed. Without STATCOM we could witness the distortions in the waveforms at which time the fault has been introduced. The Figures 6-9 shows the voltage dip, distortions so that effective changes in power speed of the generator and the system when a fault is made to occur.

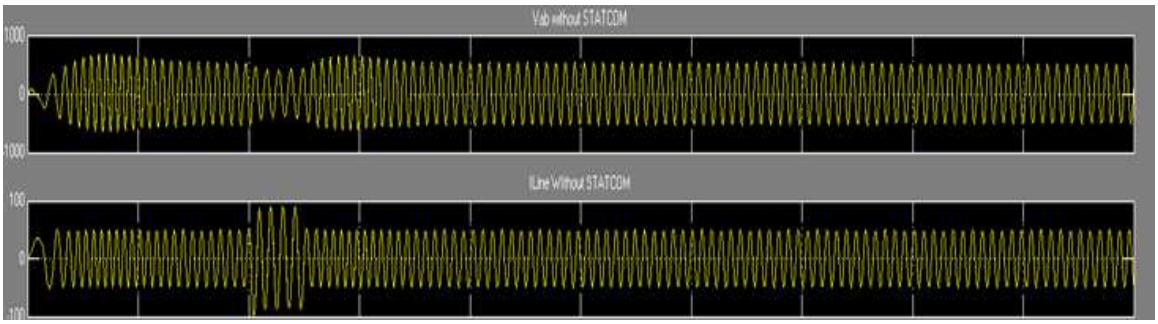

Figure6. Vab and ILine without STATCOM

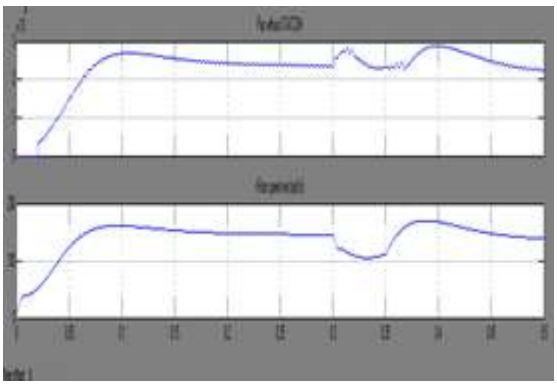

Figure 7. Pac and Rotor speed without STATCOM

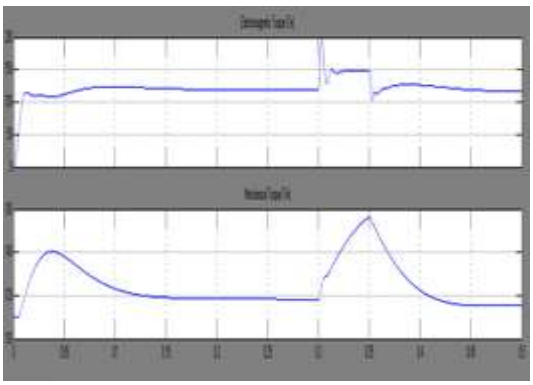

Figure 8. Te and Tm without STATCOM

Now, the improvement in dynamic performance of the generator and the overall system can be achieved by effectively using the STATCOM. To analyze this again a three phase fault is made to occur in the system and the STATCOM provide reactive power support in addition to the generation of reactive power generated by PMSG itself thereby enhancing the system performance when fault occurs.

From the above Figures 10-14, we can see that the wind farm with PMSG using Static Synchronous Compensator, the output voltage of the system has been rebuild rapidly and during the fault the PMSG and STATCOM provides reactive power support to the system and when the fault clears it drops down to zero value. And the Electromagnetic and mechanical torque as well as the generator speed are also maintained.

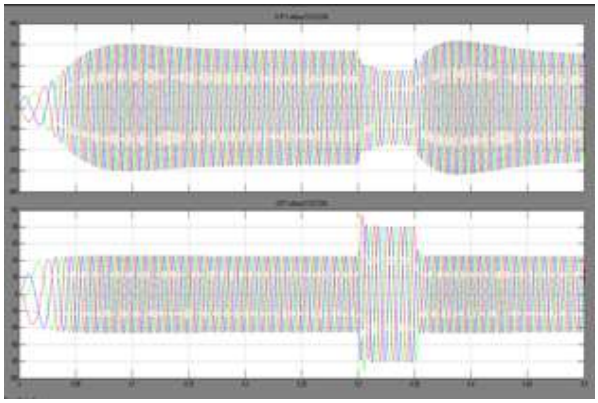

Figure 9. Output Voltage & current without STATCOM

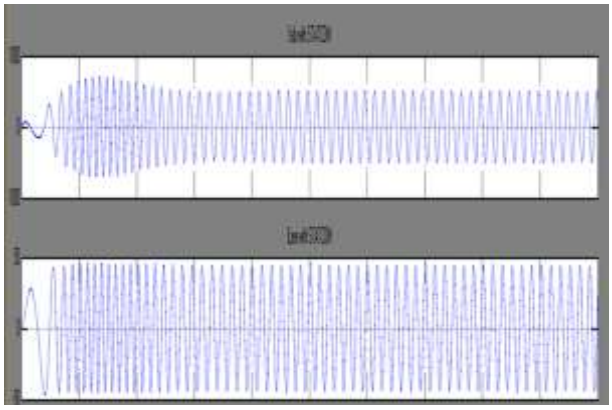

Figure 10. Vab and ILine with STATCOM

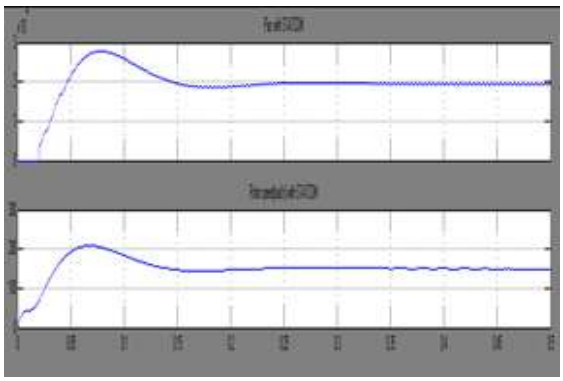

Figure 11. Pac and Rotor speed with STATCOM

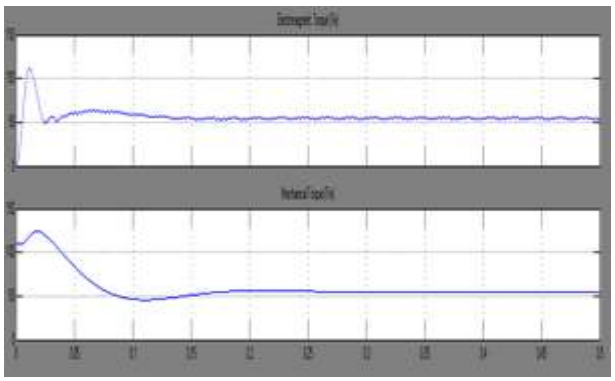

Figure 12. Te and Tm with STATCOM

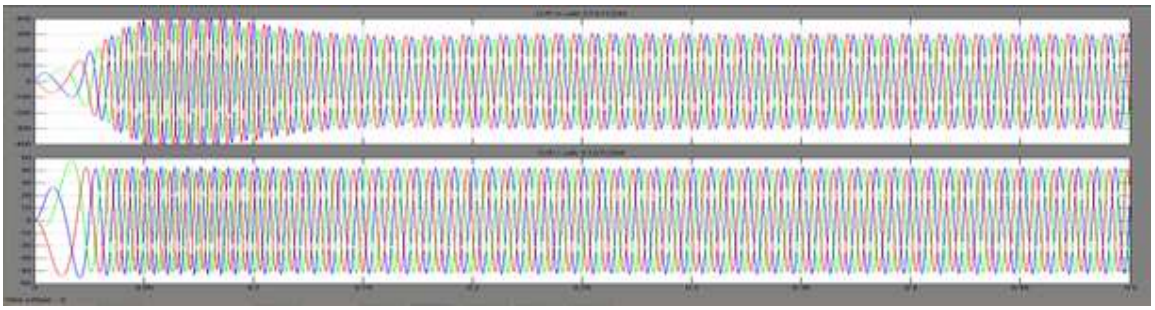

Figure13. Output voltage & Current with STATCOM

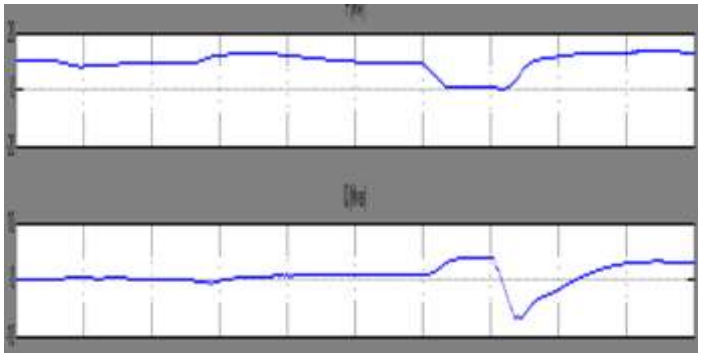

Figure 14. Real & Reactive power with STATCOM

5. RESULTS AND DISCUSSION

The simulation results obtained by running the wind generator with STATCOM model established on MATLAB. Simulation results show that the wind farm with PMSG using STATCOM improves the dynamic performance of the wind farm when system is in fault by providing reactive power support.

ACKNOWLEDGEMENTS

We thank our institute & industry people who helped with the study and analysis of the paper for providing technical assistance. The technical team was made an good approach on this paper by using Static Synchronous Compensator (STATCOM) for Wind farm integration.

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