Transient Stability Improvement of Wind Farm Integrated Power System using STATCOM

Mutyala Nagababu, R.S. Srinivas, Polamraju.V.S.Sobhan, M.Subbarao

***Abstract*: The need for Interconnected power system is increasing day by day because of continuous growth of Electrical energy demand and to transmit Electric power to remote places at minimum cost and minimum losses. With the operation of power system in interconnected manner, maintaining the system security is difficult task i.e. whenever a disturbance occurs, the system undergoes stability problems. Even though Conventional energy sources are available, Electrical Engineers prefer Renewable energy sources integration because of Energy crisis and pollution problems related to the former, one such Renewable energy source is Wind power. Wind energy has major share in Renewable energy sources because of its abundant availability in the nature.**

Whenever Wind generators coupled to the power system, the system exhibits drooping voltage characteristics and this situation becomes worse during faults. This condition can be neutralised with FACTS (Flexible AC transmission system) devices, one such FACTS device is STATCOM (static synchronous compensator). STATCOMsupports reactive and real power exchange and also improves Transient stability of the system because of its superior characteristics and quick response.

In this paper a 9 bus Wind farm integrated test power system is taken and stability studies are done. Since, Wind farm is integrated with the system whenever a fault occurs, overall system stability is reduced i.e. the conventional synchronous generators can withstand it, whereas the Wind generators can't. So to enhance the Transient stability of the system, a STATCOM is installed and the system behaviour is observed.

***Keywords* : STATCOM, Wind generator, Transient stability.**

I. INTRODUCTION

Power system dynamics is also called as power system stability. Today's power systems are widely interconnected which results in operating economy and reliability problems. Interconnection of power system leads to stability problems which became a challenging task for the engineers to maintain the system security. So, power system stability has become an important study in system security.

Power system stability is described as the maintenance of synchronism before and after a disturbance in the system. Here, the disturbance in the sense a fault or sudden load change or switching operation. The concept of stability was first discovered in 1920.In 1950's the analog computers were used to simulate the interconnected power system. The first digital computer program of stability was prepared in 1956.

The study of stability problem was concerned with developing the mathematical model of the power system, for this we have to solve the series of non-linear differential and algebraic equations, which doesn't have a unique solution. So, numerical methods are to be adopted for solving them.

In Electrical power generating stations many alternators are connected to the bus having same phase sequence and frequency. So to operate the system in stable, we have to synchronize the bus with all the other incoming lines and generators. So, the power system stability is also referred as synchronous stability i.e. the ability of the system to reach its equilibrium point after the system has undergone some transience [1].

II. LITERATURE SURVEY

Now a days Electrical Engineers are operating the interconnected power system with Renewable energy sources rather than the conventional energy sources because of pollution and energy crisis of later [2]. The availability of wind power is abundant in nature making its share huge in Renewable energy sources. But Wind power integration leads to Reactive power and voltage problems in the system i.e. system exhibits drooping voltage characteristics and because of its controlling difficulties leads to stability problems [3]. Whenever a fault occurs in the system, the conventional generators can with stand it but the wind generators cannot sustain it and thereby reducing the relative stability of the system [4].

With recent developments in Semiconductor technology and the invention of FACTS devices, the problems related to stability, power quality and reactive power can be eliminated [6]. Different FACTS devices like static synchronous compensator (STATCOM), fixed capacitors, TCR (Thyristor controlled reactor), TSC (Thyristor switched capacitor) etc. helps in maintaining voltage stability and improves the power transfer capability. But upon all the shunt FACTS devices, STATCOM gives best results, because of its quick response time, ability of reactive and real power exchange and superior characteristics [5].

This paper presents a Power System Transient Stability analysis on a Wind Farm Integrated Power System (modified from IEEE 9 bus system) and how its Transient stability is improved with STATCOM.The system is used and simulated on MATLAB.

III. TEST AND SIMULATIONS

For testing and simulation in MATLAB two 9 bus wind farm integrated power systems are used. The first system is without STATCOM (Fig.1) and second system is with STATCOM (Fig.2).

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***** Correspondence Author

Mutyala Nagababu, PG Scholar, Department of EEE, ANUCET, Acharya Nagarjuna University, Guntur(dt), AndhraPradesh, India

R.S. Srinivas, Assistant Professor,Department of EEE, ANUCET, Acharya Nagarjuna University, Guntur(dt), Andhra Pradesh, India

Polamraju.V.S.Sobhan, Associate Professor, Department Of EEE, VFSTR, Vadlamudi, Guntur, India

M.Subbarao, Assistant Professor, Department Of EEE, VFSTR, Vadlamudi, Guntur, India

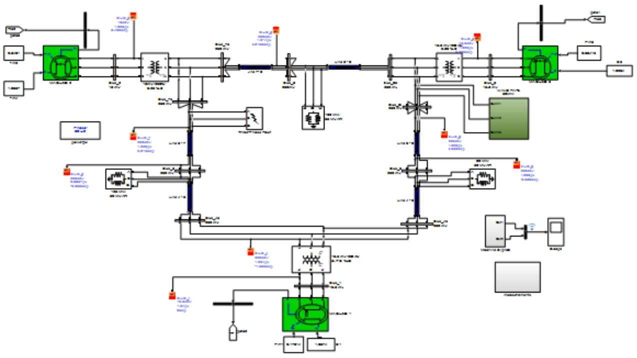

Figure 1: Test system with Wind farm

The above system is modified by installing a STATCOM at bus 9 keeping all the parameters same, as shown in the Fig.2.These models are used to study and compare the behaviour of system with and without STATCOM under transient condition such as three phase fault. The system consists of loads, transmission lines and generators. The above models are the classical representation of power system which are of second order systems. The wind farm is modelled using squirrel cage induction generator [8].

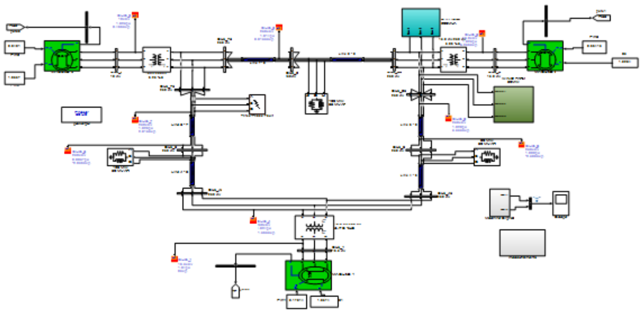

Figure 2: Test system with STATCOM and Wind farm

The following are the data for different elements [7].

Table.1. Generator data

Generator	1	2	3
Rated MVA	247.5	192	128
KV	16.5	18	13.8
Xd(pu)	0.146	0.8958	1.3125
Xd’(pu)	0.0608	0.1198	0.1813
Xq(pu)	0.0969	0.8645	1.2578
Xq’(pu)	0.0969	0.1969	0.25
Xl(pu)	0.0336	0.0521	0.0742
Stored energy at rated speed	2364 MW-s	640 MW-s	301 MW-s

Table.2. Line data

Line	R(pu)	X(pu)	B(pu)
4-5	0.01	0.085	0.088
4-6	0.017	0.092	0.079
5-7	0.032	0.161	0.153
7-8	0.0085	0.072	0.0745
8-9	0.0119	0.1008	0.1045
6-9	0.039	0.17	0.179

Table.3. Transformer data

Transformer	1	2	3
KV	16.5/230	18/230	13.8/230
Z(pu)	0.0576	0.0625	0.0586

Table.4. Load data

Load	A	B	C
KV	230	230	230
P(MW)	125	90	100
Q(MW)	50	30	35

Table.5. Data for SCIG

Variables	Values
KV	13.8
MW	30
Generator inertia	5.04
Stator resistance(pu)	0.004843
Stator inductance(pu)	0.1248
Rotor resistance(pu)	0.004377
Rotor inductance(pu)	0.1791

Table.6. STATCOM data

Variables	values
KV	230
MVA	200
Vref(pu)	1.03
DC link voltage	160KV
DC link capacitance	0.003F

IV. RESULTS AND DISCUSSIONS

The systems in the fig.1 and fig.2 are simulated in the MATLAB.The results obtained from the system with and without STATCOM have been compared to identify the Transient stability enhancement approached using the STATCOM.

Rotor angle deviations of synchronous generators

A three phase symmetrical fault is created at bus 7 to study the power system transient behaviour which is of self-clearing type and lasts for 0.15 sec. from 2 to 2.15 sec. Due to which the rotor starts oscillating from 2 sec. The peak value of first swing of relative rotor angle deviation for the machines 2 & 1 without STATCOM is 47.98° and with STATCOM is 45.66° and for the machines 3 & 1 the peak of first swing has reduced to 30.04° from 36.61°.

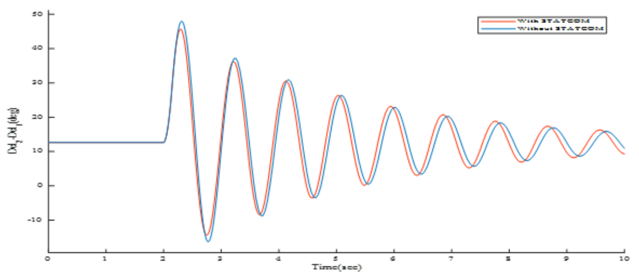

Figure 3.Realative rotor angle deviations of machines 2 & 1

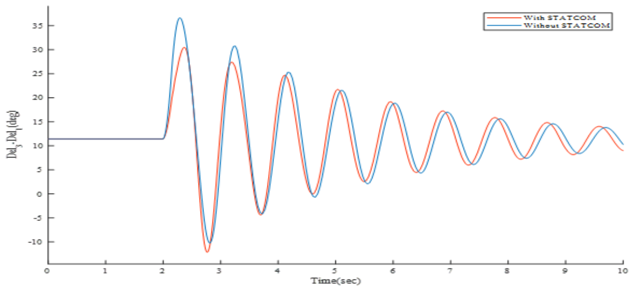

Figure 4. Realative rotor angle deviations of machines 3& 1

Speed deviation of wind generator

With the installation of STATCOM the peak of first swing of rotor speed deviation of wind generator has reduced to 1.01 rad/sec from 1.013 rad/sec. Since the STATCOM is connected at bus 9 which is near to Machine 3, the swing of machines 1 & 3 has reduced more, thereby improving the Transient stability of the overall system.

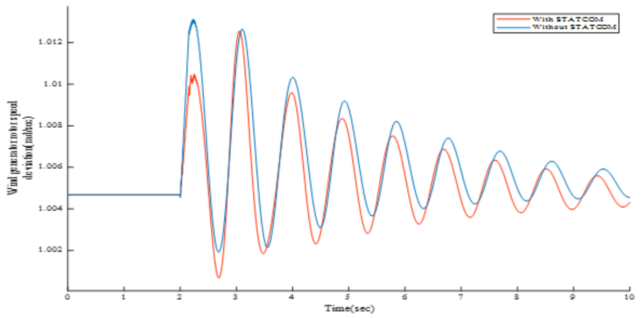

Figure 5.Rotor speed deviation of wind generator

Voltage profile

Since a three phase symmetrical fault occurs in the power system, the voltage magnitude at the bus is reduced. With the introduction of STATCOM the systems voltage profile became flat, thereby making the system to settle quickly i.e. system recovers from fault quickly with the introduction of STATCOM at bus 9.

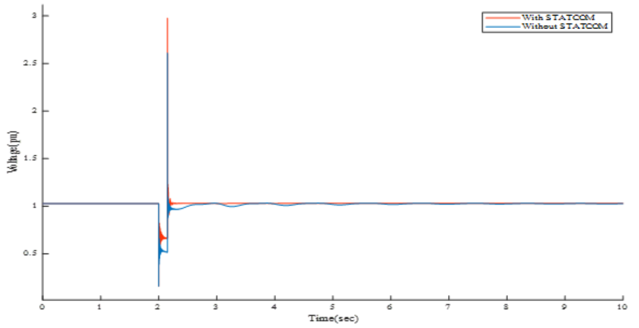

Figure 6.Voltage magnitude profile at STATCOM bus

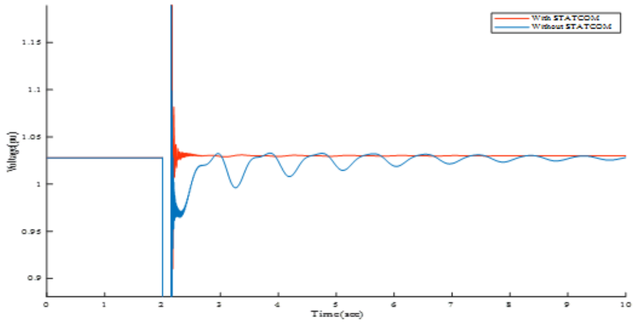

Figure 7.Voltage magnitude profile at STATCOM bus with zoomed Y-axis

Reactive power

The reactive power demand at bus 9 without STATCOM is 0.2904pu, whereas with the introduction of STATCOM the demand has reduced to 0.2866pu.

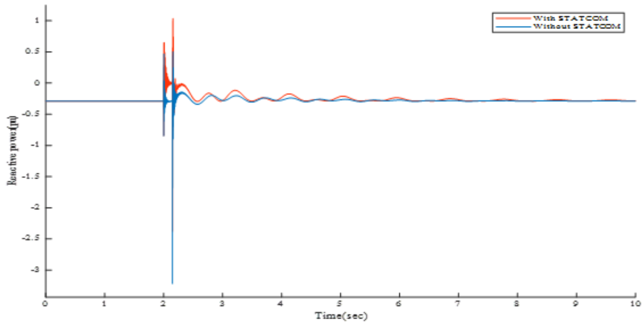

Figure 8.Reactive power at STATCOM bus

V. CONCLUSIONS

It was noticed that Integration of Wind generator to the Interconnected power system leads to the drooping voltage characteristics because of the high reactive power demand by Wind generator and the conventional synchronous generators can with stand the faults without tripping off, but the Wind generators can't with stand the fault, thereby reducing the overall relative Transient stability of the system.STATCOM has the capability of improving the Transient stability of system because of its superior characteristics and quick response time.

This paper investigated how the Transient stability of the Wind farm integrated power system can be improved by installing STATCOM in the system. Simulation studies were done in MATLAB Simulink to denoteand compare the Transient stability of system integrated with Wind farm, with and without STATCOM.

The obtained results show that the system with STATCOM settles quickly and the reactive power demand of the Wind generator was reduced. With the installation of STATCOM, the first peaks of relative rotor angle oscillations of synchronous generators and wind generator were reduced, thereby enhancing the Transient stability of the power system. More over the Voltage profile of the power system with STATCOM is flat when compared to the system without STATCOM.

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