Power Flow Simulation of a 6-Bus Wind Connected System and Voltage Stability Analysis by Using STATCOM

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ABSTRACT: FACTS devices have become significant tools for power flow study now-a-days. It has widely improved the power system reliability, operation capability and safety. It has also improved the robust control of power system. FACTS devices are generally made of power electronics devices and circuits. That's why FACTS devices have appeared as the most outstanding innovation in the era of power electronics and power system. FACTS devices are of many types: TCSC, SVC, UPFC, IPFC, STATCOM etc. Among all the devices STATCOM has become one of the most important power system components for reactive compensation of power and Voltage stabilizing capability.
In this paper we have a 6 BUS power system with a variable speed wind generator connected to a BUS. For the stochastic nature of the wind the BUS voltage becomes degraded. With the help of STATCOM, corresponding BUS voltage has been improved significantly which has been studied and simulated in our paper. We have simulated the whole system with MATLAB PSAT environment and analyzed the voltage response, rotor angle response, eigen values, participation factor etc.

KEYWORDS: Flexible AC Transmission System Device (FACTS); Participation Factor; Static Synchronous Compensator (STATCOM); Eigen Values.

I. INTRODUCTION

At present the robust control of power system is the most significant issues to be concerned with. Day by days the system is becoming complex and stability issues are becoming vulnerable. This power system issues must have to be combated with the most reliable devices or equipment. For that reasons FACTS devices have appeared as the most reliable sources of fighting against instability issues of power system. Among all the stabilities such as frequency stability and voltage stability, voltage stability is the most vital one for the power system. Voltage instability issues generally increase as the various stochastic energy sources like solar, wind etc are incorporated to the system. These types of contingencies can easily be solved by the efficient use of FACTS devices. Due to the advancements of power electronics, robust control of FACTS devices and thus power system automation have become immensely outstanding. For our research purpose we have taken IEEE 6 BUS system with a wind generator connected to BUS number 3. Due to connection of wind voltage at bus 3 has been degraded. So we have incorporated a STATCOM (Static Synchronous Compensator) to the bus to improve voltage profile at that bus. The whole system has been simulated using MATLAB Simulink software PSAT (Power System Analysis Toolbox). PSAT has the building block of all FACTs devices. We have taken the STATCOM model from that window. PSAT also has the building block of wind turbine model and wind model. It have constant speed Induction generator, variable speed wind turbine with doubly-fed induction generator and direct drive synchronous generator.

II. POWER SYSTEM STABILITY

Power system stability may be demarcated as the characteristics of power system which makes it to sustain in a condition of acting stasis under natural operating conditions and when disturbance occurs the system can regain its equilibrium an acceptable level. When the force of restoration and the force of disturbance are equal to or greater than a state of equilibrium occurs and this is called stability especially in case of power system [4]. When the restoring force is sufficient to continue the machines in synchronism with others then the system or machines are stable. On the contrary when one machine loses the synchronism with other machines it becomes out of step or synchronism and

instability occurs in it. If proper measures are not taken timely then all the machines can be negatively affected. In that case generator's cascaded failure can be occurred which lead to devastating blackout. Another important criterion to be considered is the low frequency oscillations. We know that, power system encounters generally four types of low frequency oscillations [1]. These are called electromechanical modes of oscillations. These oscillations can be inherent to the power system and create significant havoc to the power system if it is not properly handled. Those are below:

- ➢ Local mode oscillation
- ➢ Inter area mode of oscillation
- ➢ Control mode oscillation
- ➢ Torsional mode oscillation

III. FACTSDEVICES

For AC transmission of electrical energy FACTS are generally composed of some static power electronics devices. There are a lot of FACTS devices to be used in practical. They are STATCOM, SVC, UPFC, IPFC, TCSC etc.At present technology to control the system has been developed. Actually these have become possible due tothe emergence and advancement of modern power electronics [2]. FACTS devices are the major contribution of that power electronics. FACTS devices can easily be controlled due to power electronics which have significantly improved its power transfer capability and the stability of the system. Some of the advantages are illustrated below:

- ➢ Transient Stability and dynamic stability can be enhanced
- ➢ No environmental hazards are observed due to the installation of FACTS devices.
- ➢ Power transmission capability can be enhanced and also dependability and availability are ensured.
- ➢ Power quality can be ensured for the large and enormous industrial application where power quality is one of the major issues.
- ➢ Power system transmission can be utilized more.

IV. FACTS DEVICES FEATURES

There are a lot of criteria to be considered during installing FACTS devices. Among them the following three factors imperative.

- Device type
- Requirement of capacity.
- Suitable location for the optimization of device function.

Voltage limiting problems can be easily be solved by incorporating FACTS devices [2]. Problems can be addressed for the following cases:

- Applications of steady state system should be addressed
- Addressing short circuit leveling problems.
- Addressing thermal limiting problems.
- Problems regarding sub-synchronous resonance type should be addressed.

V. MATLAB PSAT FEATURES

PSAT (Power System Analysis Toolbox) is incorporated in MATLAB as a toolbox. It is a Graphical User Interface (GUI) where every kind of power system analysis can be performed. PSAT has the excellent features to simulate in GUI. It can perform the following analysis [3,6]. These are as follows.

- ➢ Continuation Power Flow (CPF).
- ➢ Optimal Power Flow (OPF).
- ➢ Small-signal stability analysis.
- ➢ Time-domain simulations.

Apart from the above analysis PSAT can perform participation factor and eigen value analysis. PSAT Graphical User Interface (GUI)is completely user friendly. Power system single line diagram can easily be drawn through this. The Data file can be converted from one form to another.

VI. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM is known as the static synchronous compensator which is one of the most important FACTS devices to be mentioned. It is used on AC circuits for power transmission network. STATCOM is generally voltage source converter type source or sink. It is generally used for improvement of power factor and voltage regulation. It is a significant device for voltage stability issues. Capacitor connected to STATCOM acts as the DC source, so STATCOM can provide reactive power as per requirement and can also provide reactive power when needed. That's how STATCOM compensate the reactive or voltage dip in the power system. Both STATCOM and SVC are suitable for reactive power compensation. Generally wind, solar etc. various types of renewable energy sources show stochastic nature. When these sources are connected to the grid, due to environmental problem these sources can severely degrade the voltage profile of the grid causing impairment of power quality and voltage dip. In those cases, STATCOM can play vital role to compensate for the voltage stability problem.

VII. PSAT SIMULATION

The following table is about the PV generators' data which are connected to Bus 2 and Bus 4. In Bus 1 the slack bus or swing bus is connected.

Table-1: PV generator data

Bus	MVA	Voltage (KV)
2	50	11
3	30	11
4	100	11

In MATLAB PSAT simulation environment, we have taken IEEE 6 BUS system. In which one slack bus, two PV generators connected in Bus2 and Bus4. One wind turbine which has constant speed synchronous generator output is connected in Bus3. The four loads are connected in buses 2,3, 4, 5 and 6.

Table-2: The following table is about the Load data:

Bus	MVA	Voltage	Real power(p.u)	Reactive power(p.u)
2	400	11	0.8	0.6
3	100	11	0.8	0.6
4	200	11	0.8	0.6
5	100	11	0.8	0.6
6	300	11	0.8	0.6

Wind Generator Data:

We have used 20MVA, 11KV, 50HZ for wind turbine which is connected to Bus 3. It has the following specifications:
Nominal wind speed=15 m/s
Air density=1.225 Kg/m^3
Filter time constant=4 sec.
Pole = 4
Gear ratio= 1/89

Blade length =17m
Blade numbers =3
After simulation we have got the following results:Voltage at different bus:

Table-3: Voltage output before STATCOM using

Bus No.	Voltage in per unit
1	1
2	1
3	0.8647
4	1
5	0.81299
6	0.67769

Voltage Profile:
Three dimensional voltage profiles has been shown in Fig. 1
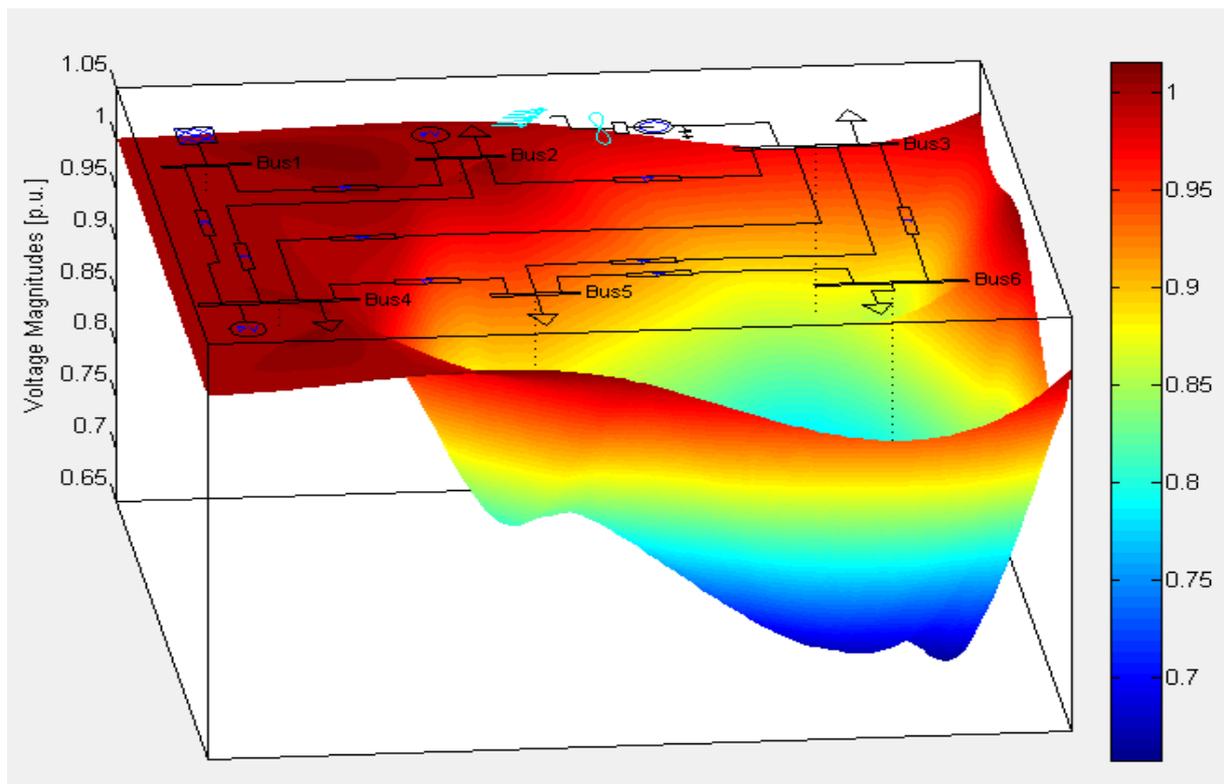
Fig. 1: Three dimensional voltage profile before adding STATCOM

Simulation after Adding STATCOM

The following fig. 2 is the single line diagram after adding STATCOM to Bus 3 to improve the Bus voltage profiles.
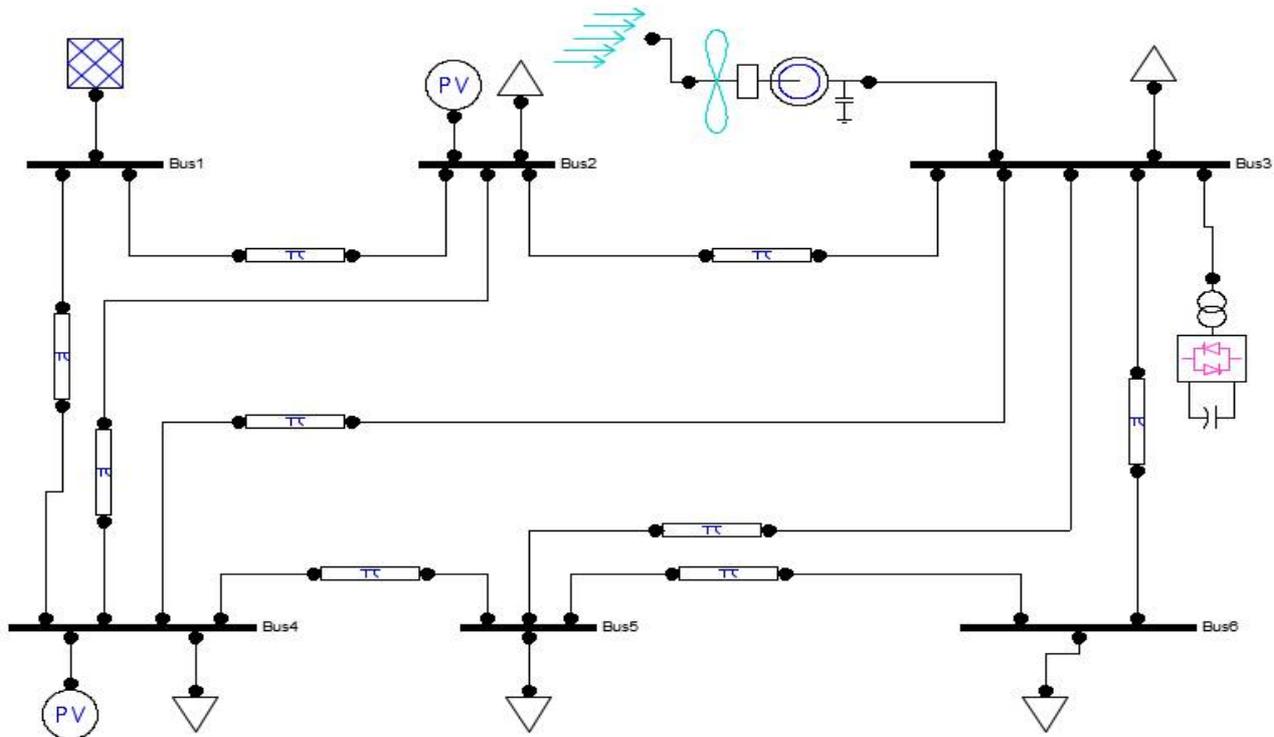
Fig. 2: One line diagram after connecting STATCOM

STATCOM Data:

MVA rating=2MVA
Voltage rating =11KV, Frequency = 50Hz
Gain, K_r=50
Time constant, T_r=0.1
The following voltages have been obtained after adding STATCOM.

Table-4: Bus Voltage after adding STATCOM

Bus No.	Voltage in per unit
1	1
2	1
3	0.99882
4	1
5	0.99705
6	0.9945

After adding STATCOM we can see that there is no voltage dip in the figure. The voltage profile has been improved. Three dimensional voltage profile after adding STATCOM has been shown below:
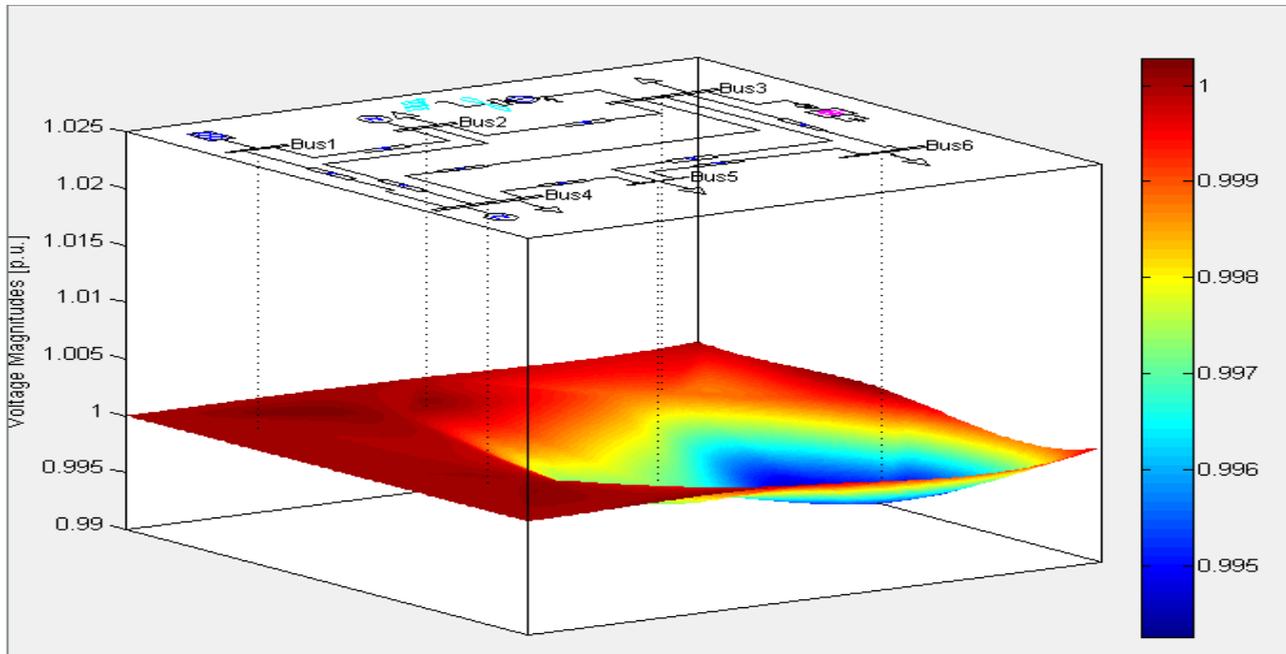
Fig.3: Three dimensional view of the system after adding STATCOM

VIII.CONCLUSION

If we carefully scrutinize the scenario, we can easily presume that the bus voltages have been significantly improved due to incorporating STATCOM in Bus 3. Not only the voltage magnitude in Bus 3 has been improved, but also in all three buses the voltage magnitudes have been improved. Through the above discussion we easily understand the contribution and significance of FACTS devices specially STATCOM in power system voltage stability improvement.

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BIOGRAPHY

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