Grid Connected Wind Generator

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Abstract: Injection of wind power into an electric grid affects the power quality and reactive power issues at the connected electric network. Power quality problems such as voltage sag and swell are some major concern. In this paper these issues are analyzed. Wind turbine connected to squirrel cage induction generator is modeled using PSCAD simulation software to analyse the said issues where STATCOM is introduced as an active voltage and reactive power supporter to increase the power system stability. STATCOM unit is developed to inject reactive power for mitigation of power quality problems and to get stable grid operation.

***Keywords** - Squirrel Cage Induction Generator (SCIG); PSCAD; Wind Turbine Generator (WTG); Static Synchronous Compensator (STATCOM); Power Quality.*

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1. Introduction

As the wind power penetration into the grid is increasing quickly, the influence of wind turbine on the power quality is becoming an important issue. Wind power penetration is the impact on power system stability. In order to avoid the necessity of developing a detailed model of a wind farm with tens or hundreds of wind turbines and their interconnections, aggregated wind farm models are needed [1]. From each generating station the probability of the total generating capacity not exceeding a given power level. This gives a measure of the reliability of the system [2].If the network is weak this situation will cause a voltage collapse to occur in the transmission system. The process can be dynamically supported by a STATCOM to improve voltage stability and to improve recovery from network faults and mitigate voltage flicker [3]. Frequently wind parks are connected to weak systems, as they are typically located far from major load centres and central generation. This reflects itself in the short circuit ratio (SCR) of the interconnection. For weak systems the SCR will usually be less than 6 having over speed of generator [4].Reactive power is the most important aspect in today’s condition. Reactive power consumption in a Wind farm is mainly due to the use of induction generators for energy conversion. The basic principle of induction generator is that they consume reactive power in order to generate real power. The magnetizing currents drawn by step up transformers also contribute to reactive power consumption to some extent. This reactive power consumption leads to increased T & D losses, poor voltage profile over loading of T & D equipment and blocked capacity and over loading and reduction in life of T & D equipment [5]. As a result, utilities typically disconnect the wind turbines immediately from the grid when such a contingency occurs. With the rapid increase in penetration of wind power in power grids, tripping of many turbines in a large wind farm during grid faults may begin to influence the overall power system stability [6].

Considering the increasing share of wind generation interfaced to grid it is necessary to study an overall prospective on various types of existing wind generator systems and possible generator configuration, critical power quality issues, problems related with grid connections [7].Use of more intelligent controller for STATCOM and its interface to large power systems addressing various issues such as security, stability, and voltage profile improvement and power quality [8].It was found that STATCOM considerably improves the stability during and after disturbances especially when network is weak [9].FACTS devices provide an effective means of dynamic voltage control of wind farm, dynamic power control of the transmission lines, improving power oscillations damping and transient stability [10].As the speed during induction generator operation is not synchronous, it is also called an asynchronous generator. Variation in “δ” changes both active power and reactive power flow at the SEIG terminals there by simultaneously changing both terminal voltage and frequency of the Self Excited Induction Generator [11].The use of STATCOM shall be considered for stability improvement as well as improvement of power quality taking considering techno economic aspects [12].

2. Wind farm modelling

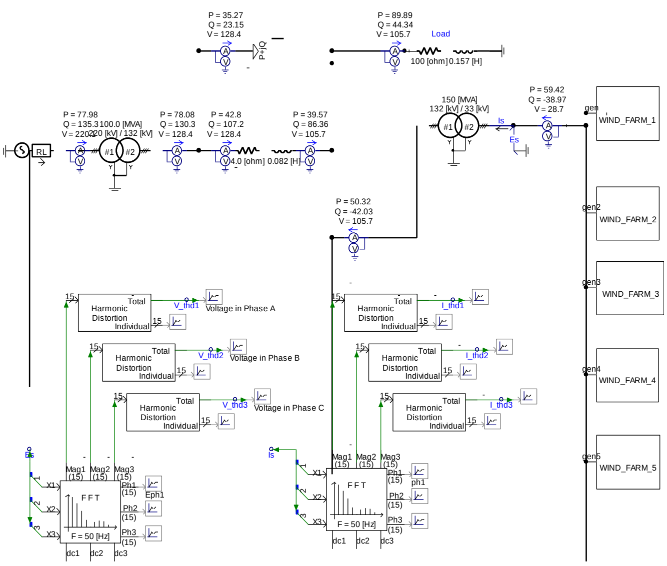

Fig.1. Large scale wind farm

A wind farm typically consists of a large number of individual wind turbine generators (WTGs) connected by an internal electrical network. To study the impact of wind farms on the dynamics of the power system, an important issue is to develop appropriate wind farm models to represent the dynamics of many individual WTGs. The major issues considered for the work for grid connected wind turbine generators (WTGs), equipped with squirrel cage induction generators (SCIGs) are sag/swell during three phase fault condition. The model is developed and compared by simulation studies in the PSCAD/EMTDC environment under different wind velocity and fluctuation conditions to obtain the reactive power burden on grid.Wind generators are primarily classified as fixed speed or variable speed. With most fixed speed units, the turbine drives an induction generator that is directly connected to the grid. For the studies carried out in this paper, it focuses on modeling the fixed speed unit. In this case study, large scale wind farm with squirrel cage induction generator having capacity 75 MW is connected to 33/132 kV substation to 220 kV electric grid system is modelled by PSCAD as shown in figure 1.

3. Power quality issues

Although the main issues of power quality are common to grid connected induction generator system are as voltage sag, swell.

3.1 Voltage Sag: Sag is a decrease to between 0.1 and 0.9 p.u. rms voltage and current at the power frequency for duration from 0.5 cycles to less than 1 minute.

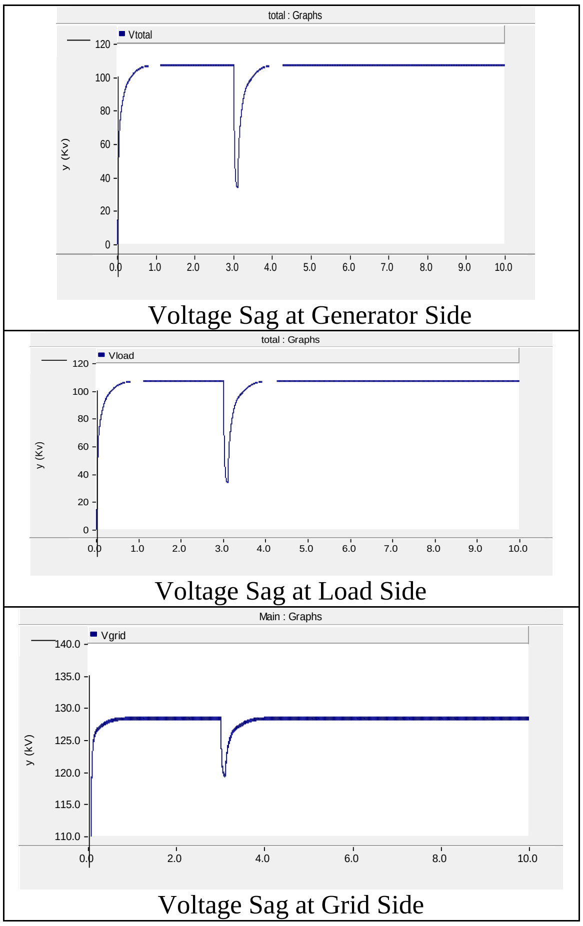

Fig.2. Voltage sags at different locations.

Fixed speed wind turbines have a high sensitivity to voltage sags due to the fact that a generator is directly connected to the main grid.

In case of a voltage drop, resulting from a fault on the main grid, the electromagnetic torque of the generator reduces significantly while mechanical torque is still applied. This leads to the unbalanced torque, accelerating the rotor, which may, in turn, result in the rotor instability.

In this case study, voltage sag is developed due to symmetrical & unsymmetrical fault at different location. As per Math J. H. Bollen seven types of sag are analysed. Voltage sag is developed at generator, load & grid side due to faults are shown in figure 2.

Table 1: % Sag & I_{sc} /I_L at different location

Fault Location: Near to Generator		
Location	% Sag	I_{sc} /I_L
After Generator Transformer	68.35	5.34
Before Generator Transformer	52.91	20.3
Load	66.85	0.28
After Grid Transformer	10.80	3.19
Fault Location: Near to Load		

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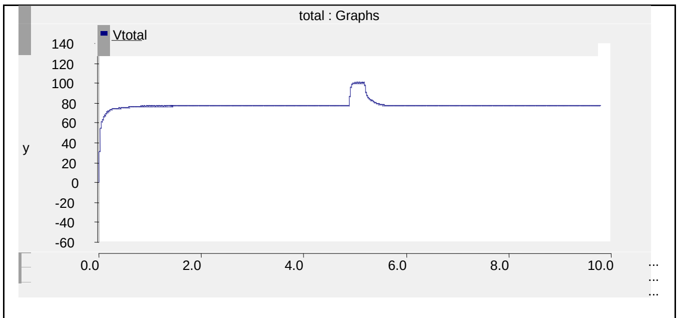
491 – 495

After Generator Transformer	9.98	1.67
Load	10.80	3.0
After Grid Transformer	1.78	1.71
Fault Location: Near to Grid		
After Generator Transformer	66.62	6.16
Load	59.83	0.4
After Grid Transformer	90.88	2.2
Before Grid Transformer	54.47	19.2

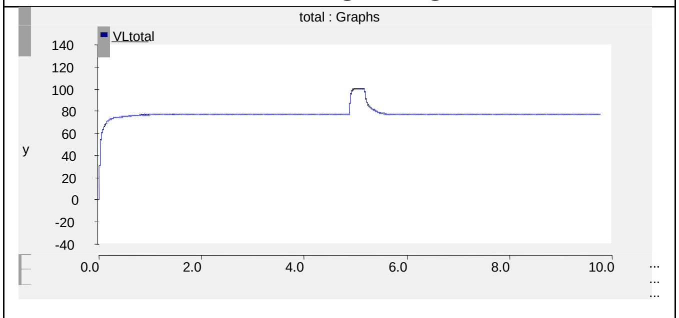
Table 1 indicates fault location, percentage Sag & I_{SC}/I_L at different location. If any fault developed near to generator, it also affects voltage profile of load as well as grid and vice versa.

3.2 Voltage Swell

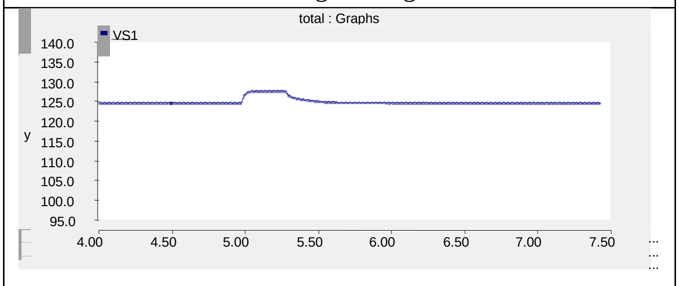
Swell is an increase to between 1.1 and 1.8 p.u. rms voltage or current at the power frequency for duration from 0.5 cycles to less than 1 minute.In this case study, voltage swell is developed due to symmetrical fault at different location. Voltage swell developed at generator, load & grid side due to faults are shown in figure 3.



Generator Voltage during Swell



Load Voltage during Swell



Grid Voltage during Swell

Fig.3. Voltage Swell at different locations

4. Static synchronous compensator (STATCOM)

The Static Synchronous Compensator (STATCOM) is a shunt connected reactive compensation equipment which is capable of generating and/or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of the electric power system. It consists of VSC connected in shunt to a bus through a coupling transform. The objective of the STATCOM is to provide fast and smooth voltage regulation at the point of common coupling. In this paper, the VSC is modelled as a six-pulse IGBT converter with a dc-link capacitor. The static compensators are devices with the ability to both generate and absorb reactive and active power, but the most common applications are in reactive power exchange between the AC system and the compensator. 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 developed voltage is higher than system voltage the STATCOM will supply reactive power like a rotating synchronous compensator and improve the voltage and conversely if lower it will remove reactive power. Figure 6 indicates large scale wind farm with SQIG connected to the grid with STATCOM is modelled.

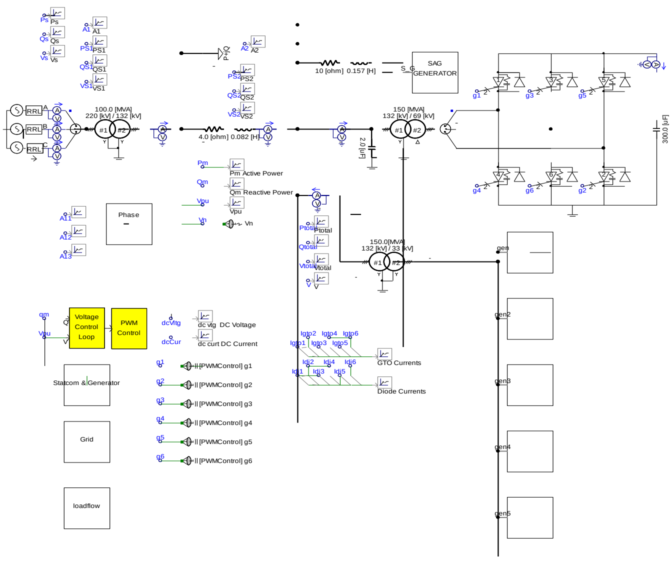


Fig.4. Large scale wind farm connected by STATCOM.

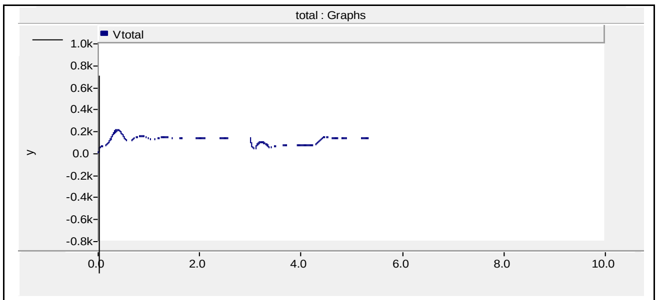
4.1 Voltage Sag Mitigation

Figure 5 indicates the voltage profile with STATCOM connected. The DC side capacitor charges to higher value to compensate reactive power requirement during sag and to maintain system stability.

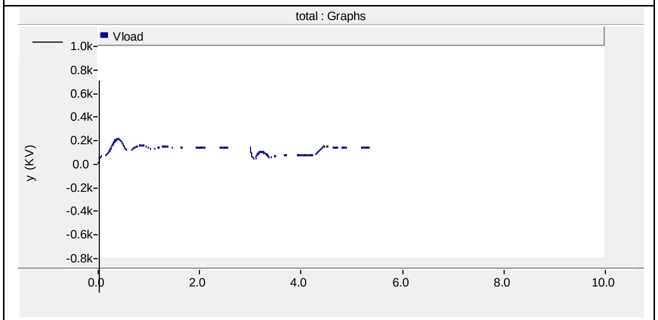
Table 2 : % Sag Mitigation by using STATCOM

% Sag	Generator Location	Load Location	Grid Location
After STATCOM	54.71 %	43.00 %	10.02 %
Before STATCOM	68.35 %	66.85 %	10.80 %
Reduced after STATCOM	13.64 %	23.85 %	0.78 %

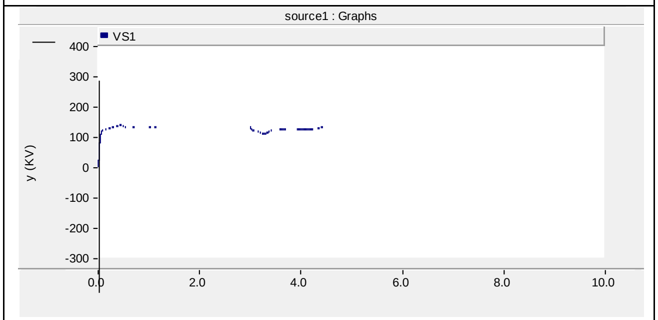
Table 2 indicates how sag is reduced by using STATCOM at different fault location.
From the simulation results, the designed wind farm with STATCOM responded well in mitigating voltage sag caused by symmetrical and asymmetrical fault.



Voltage Sag Mitigation at Generator Side



Voltage Sag Mitigation at Load Side



Voltage Sag Mitigation at Grid Side

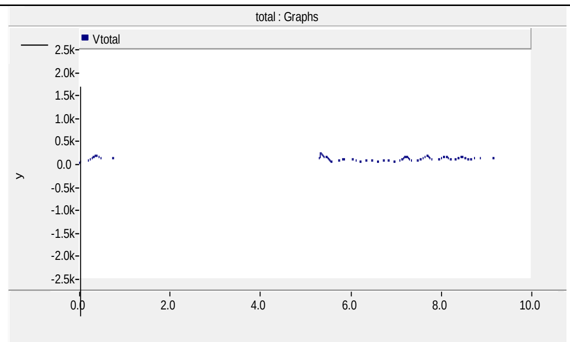
Fig.5. Voltage sag mitigation by STATCOM.

4.2 Voltage Swell Mitigation

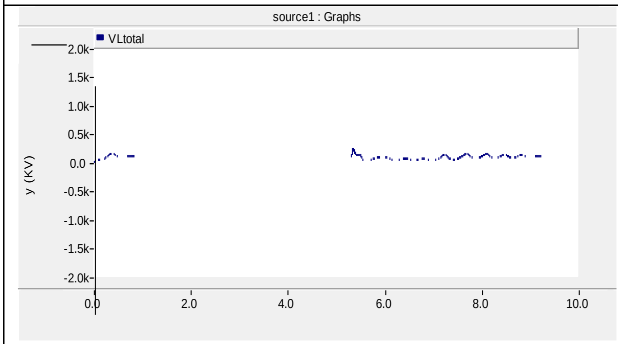
From the simulation results, the designed wind farm with STATCOM responded well in mitigating voltage swell caused by symmetrical fault which is shown in figure 6.Table 3 indicates how swell is mitigated by using STATCOM at different fault location.

Table 3: % Swell mitigation by using STATCOM

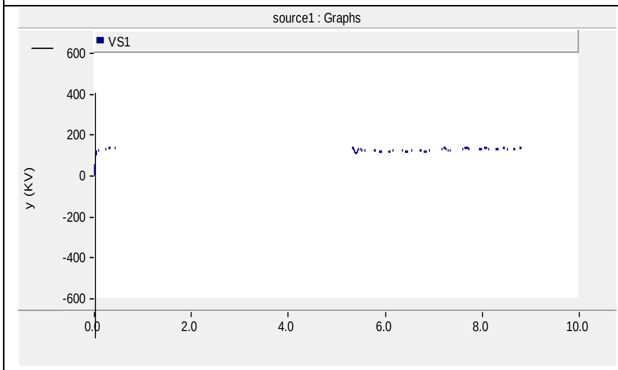
% Swell	Generator Location	Load Location	Grid Location
After STATCOM	112.53 %	119.02 %	103.39 %
Before STATCOM	131.67 %	131.34 %	131.67 %
Reduced after STATCOM	19.14 %	12.32 %	28.28 %



Generator Swell Voltage Mitigation



Load Swell Voltage Mitigation



Grid Swell Voltage Mitigation

Fig.6. Voltage swells mitigation by STATCOM.

5. Conclusion

This paper has investigated the application of STATCOM to wind farm equipped with Squirrel Cage Induction Generators to study reactive power supporter during wind variation and symmetrical & unsymmetrical fault condition. A simulation on model of large scale wind farm is designed in PSCAD software to study the voltage sag & swell mitigation using STATCOM. The study has demonstrated that an additional active voltage/var support produced by a STATCOM can significantly improve the recovery of wind turbines from fault since this device can make a faster restoration of the voltage, improving the stability limit conditions of the induction generators.

The simulation results provide a clear qualitative verification of transient margin increase in the wind energy conversion system with STATCOM when compared to the system without the STATCOM support.

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Prof. Kadam D.P graduated in Electrical Engineering from Govt. College of Engineering, Amaravati in 1997, Master's Degree in Electrical Engineering from Walchand college of Engg., Sangli, Shivaji University, Kolhapur with Power System and Ph.D (Electrical) from Savitribai Phule Pune University, Pune in 2015. He is working as a Professor at Sandip Foundation, SIEM, Nashik, Maharashtra, India. His research area includes Power Quality, Optimization of Reactive Power & FACTS. His total experience spans over 16 years.