# Distributed Generation Based Power Quality Control in Grid Connected Wind Farm System

**DR . Dipesh. M .Patel[1] Prof. (Dr.) Karunesh Saxena[2]**

1. Research Scholar – Doctor of Science, Sangam University (Raj.) and Principal and Professor, D.A. Degree Engineering and Technology, Mahemdanad, Gujarat

2. Vice Chancellor of Sangam University, Bhilwara, Rajasthan

*Abstract*-**This paper demonstrated the power quality problems associated with the renewable based distribution generation systems and how the Flexible AC Transmission System (FACTS) device such as Static Synchronous Compensator (STATCOM) play an important role in Power Quality Improvement. First we simulated the wind farm system without STATCOM and after the system simulated with STATCOM. We use the MatLab/Simulink software for Simulation.**

***Key words- Distributed Generation (DG), Satic Synchronous Compensator, Power Quality, Wind Farm, Renewable energy system.***

## I. INTRODUCTION

In the recent years the electrical power utilities are undergoing rapid restructuring process worldwide. Indeed, with deregulation, advancement in technologies and concern about the environmental impacts, competition is particularly fostered in the generation side thus allowing increased interconnection of generating units to the utility networks. These generating sources are called as distributed generators (DG) and defined as the plant which is directly connected to distribution network and is not centrally planned and dispatched. These are also called as embedded or dispersed generation units. The rating of the DG systems can vary between few kW to as high as 100 MW. Various new types of distributed generator systems, such as microturbines and fuel cells in addition to the more traditional solar and wind power are creating significant new opportunities for the integration of diverse DG systems to the utility. Inter connection of these generators will offer a number of benefits such as improved reliability, power quality, efficiency, alleviation of system constraints along with the environmental benefits. With these benefits and due to the growing momentum towards sustainable energy developments, it is expected that a large number of DG systems will be interconnected to the power system in the coming years.

The power quality issues can be viewed with respect to the wind generation, transmission and distribution network, such as voltage sag, swells, flickers, harmonics etc.

However the wind generator introduces disturbances into the distribution network. One of the simple methods of running a wind generating system is to use the induction generator connected directly to the grid system. The induction generator has inherent advantages of cost effectiveness and robustness. However; induction generators require reactive power for magnetization. When the generated active power of an induction generator is varied due to wind, absorbed reactive power and terminal voltage of an induction generator can be significantly affected. A proper control scheme in wind energy generation system is required under normal operating condition to allow the proper control over the active power production. A STATCOM based control technology has been proposed for improving the power quality which can technically manages the power level associates with the commercial wind turbines.

## II. POWER QUALITY IMPROVEMENT

### *A. POWER QUALITY STANDARDS, ISSUES AND ITS CONSEQUENCES*

1) *INTERNATIONAL ELECTRO TECHNICAL COMMISSION GUIDELINES:* The guidelines are provided for measurement of power quality of wind turbine.

The International standards are developed by the working group of Technical Committee-88 of the International Electro-technical Commission (IEC), IEC standard 61400-21, describes the procedure for determining the power quality characteristics of the wind turbine.[4]

The standard norms are specified.

*1) IEC 61400-21:* Wind turbine generating system, part-21. Measurement and Assessment of power quality characteristic of grid connected wind turbine.

*2) IEC 61400-13:* Wind Turbine—measuring procedure in determining the power behavior.

*3) IEC 61400-3-7:* Assessment of emission limits for fluctuating load IEC 61400-12: Wind Turbine performance. The data sheet with electrical characteristic of wind turbine provides the base for the utility assessment regarding a grid connection.

*2) VOLTAGE VARIATION:* The voltage variation issue results from the wind velocity and generator torque. The voltage variation is directly related to real and reactive power variations. The voltage variation is commonly classified as under:

• Voltage Sag/Voltage Dips.
• Voltage Swells.
• Short Interruptions.
• Long duration voltage variation.

The voltage flicker issue describes dynamic variations in the network caused by wind turbine or by varying loads. Thus the power fluctuation from wind turbine occurs during continuous operation. The amplitude of voltage fluctuation depends on grid strength, network impedance, and phase-angle and power factor of the wind turbines. It is defined as a fluctuation of voltage in a frequency 10–35 Hz. The IEC 61400-4-15 specifies a flicker meter that can be used to measure flicker directly.

*3) HARMONICS:* The harmonic results due to the operation of power electronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure the harmonic voltage within limit, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current compared to the line commutated converter, but the output current will have high frequency current and can be easily filter-out.

*4) WIND TURBINE LOCATION IN POWER SYSTEM:* The way of connecting the wind generating system into the power system highly influences the power quality. Thus the operation and its influence on power system depend on the structure of the adjoining power network.

*5) SELF EXCITATION OF WIND TURBINE GENERATING SYSTEM:* The self-excitation of wind turbine generating system (WTGS) with an asynchronous generator takes place after disconnection of wind turbine generating system (WTGS) with local load. The risk of self-excitation arises especially when WTGS is equipped with compensating capacitor. The capacitor connected to induction generator provides reactive power compensation. However the voltage and frequency are determined by the balancing of the system. The disadvantages of self-excitation are the safety aspect and balance between real and reactive power.[5]

*6) CONSEQUENCES OF THE ISSUES:* The voltage variation, flicker, harmonics causes the malfunction of equipment's namely microprocessor based control system, programmable logic controller; adjustable speed drives, flickering of light and screen. It may leads to tripping of contractors, tripping of protection devices, stoppage of sensitive equipment's like personal computer, programmable logic control system and may stop the process and even can damage of sensitive equipment's. Thus it degrades the power quality in the grid.

*B. GRID COORDINATION RULE*

The American Wind Energy Association (AWEA) led the effort in the United States for adoption of the grid code for the interconnection of the wind plants to the utility system. The first grid code was focused on the distribution level, after the blackout in the United State in August 2003. The United State wind energy industry took a stand in developing its own grid code for contributing to a stable grid operation. The rules for realization of grid operation of wind generating system at the distribution network are defined as-per IEC- 61400-21. The grid quality characteristics and limits are given for references that the customer and the utility grid may expect. According to Energy Economic Law, the operator of transmission grid is responsible for the organization and operation of interconnected system.[6]

*1) VOLTAGE RISE (u)*

The voltage rise at the point of common coupling can be approximated as a function of maximum apparent power Smax of the turbine, the grid impedances R and X at the point of common coupling and the phase angle , given in Eq. 1. [7]

$$u = \frac{S_{max}(RCOS\emptyset - XSIN\emptyset)}{U^2} \quad (1)$$

The Limiting voltage rise value is ±2 %

*2) VOLTAGE DIPS (d)*

The voltage dips is due to startup of wind turbine and it causes a sudden reduction of voltage. It is the relative % voltage change due to switching operation of wind turbine. The decrease of nominal voltage change is given in Eq. 2.

$$d = k_u \frac{S_n}{S_k} \quad (2)$$

The acceptable voltage dips limiting value is ± 3%.

*3) FLICKER*

The measurements are made for maximum number of specified switching operation of wind turbine with 10-min period and 2-h period are specified, as given inEq. 3.

$$P_{lt} = C(\varphi_k)\frac{S_n}{S_k} \quad (3)$$

The Limiting Value for flicker coefficient is about ≤ 0.4, for average time of 2 h. [8]

*4) HARMONICS*

The harmonic distortion is assessed for variable speed turbine with a electronic power converter at the point of common connection. The total harmonic voltage distortion of voltage is given as in Eq. 4.

$$V_{THD} = \sqrt{\sum_{n=2}^{40} \frac{V_n^2}{V_1} 100} \quad (4)$$

The THD limit for 132 KV is ± 3%.

$$I_{THD} = \sqrt{\sum_{n=2}^{40} \frac{I_n}{I_1} 100} \quad (5)$$

The THD of current and limit for 132 KV is ± 2.5%.

*5) GRID FREQUENCY*

The grid frequency in India is specified in the range of 47.5–51.5 Hz, for wind farm connection. The wind farm shall able to withstand change in frequency up to 0.5 Hz/s. [9]

## III. STATIC COMPENSATOR (STATCOM)

The STATCOM 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. 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. A STATCOM is a controlled reactive power source. It provides the desired reactive power generation and absorption entirely by means of electronic processing of the voltage and current waveforms in a voltage source converter (VSC). A single line STATCOM power circuit is shown in Fig.1, where, a VSC is connected to a utility bus through a magnetic coupling. In Fig. 2, the STATCOM is seen as an adjustable voltage source behind reactance. This means that capacitor banks and shunt reactors are not needed for reactive power generation and absorption, thereby giving STATCOM a compact design [7].

A STATCOM can improve power system performance as follows: The dynamic voltage control in transmission and distribution systems. The power oscillation damping in power transmission systems.
The transient stability The voltage flicker control, and The control of not only reactive power but also (if needed) active power in the connected line, requiring a dc energy source.

***Principle of Operation***

The exchange of reactive power is done by regulating the output voltage of the inverter VSTATCOM , which is in phase with the mains voltage Vk. The operation can be described as follows.

If the voltage VSTATCOM is below Vk, the current through the inductor is phase shifted in relation to the voltage Vk which provides an Inductive current, then QS becomes positive and the STATCOM absorbs reactive power.

If the voltage VSTATCOM exceeds Vk, the current through the inductor is phase shifted in relation to the voltage Vk which provides a capacitive current, then QS becomes negative and the STATCOM generates reactive power.

If the voltage VSTATCOM is equal to Vk, the current through the inductor is zero and therefore there is no exchange of energy.

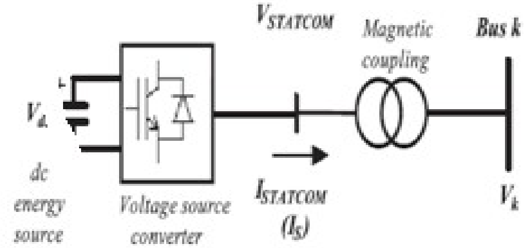


Fig.1 Single line STATCOM Power Circuit

## IV. SIMULATION RESULTS

The case study in this paper consists of a wind farm having six 1.5-MW wind turbines connected to a 25-kV distribution system as shown Fig. 2. The distribution system further delivers power to a 120-kV grid through a 25-km 25-kV feeder. All wind turbines use squirrel-cage induction generators (IG). The stator winding is connected directly to the 60 Hz grid and the rotor is driven by a variable-pitch wind turbine. The pitch angle is controlled in order to limit the generator output power at its nominal value for winds exceeding the nominal speed. Each wind turbine has a protection system monitoring voltage, current and machine speed. Reactive power absorbed by the IGs is partly compensated by capacitor banks connected at each wind turbine low voltage bus. The rest of reactive power required to maintain the 25-kV voltage at bus B25 close to 1 pu is provided by a 3-Mvar STATCOM with a 3% droop setting. The MATLAB/Simulink block diagram is shown in Fig. 3.

As shown in Fig. 4, at t=9.2 s, the voltage bus 25 drops to 0.91 pu, due to insufficient reactive power and consequently the protection circuit of wind turbine 1 disconnects it due to under voltage. After turbine 1 has tripped, turbines 2 and 3 continue to generate 3 MW each as shown in Fig. 5.

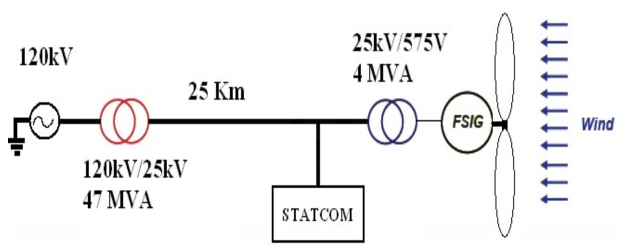


Fig. 2 Single line diagram of system

When the STATCOM is connected at bus 25, the voltage at bus 25 drops to 0.98 pu, due to reactive power support from STATCOM which is shown in fig. 4 and consequently all wind turbines continue to generate power throughout the range of operation without tripping as shown in Fig.

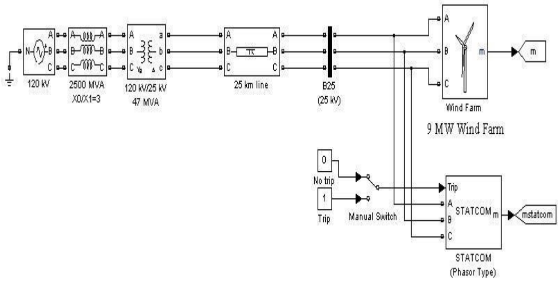

Fig.3. Simulink diagram of grid connected wind farm

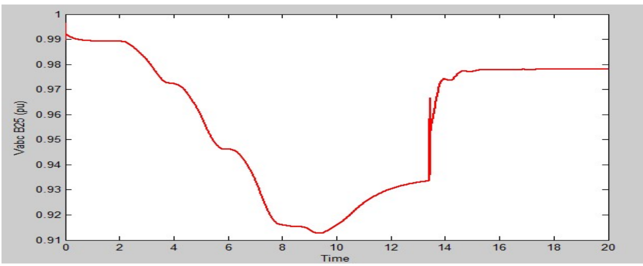

Fig.4. Simulation result of Vabc_B25 V/s Time without STATCOM

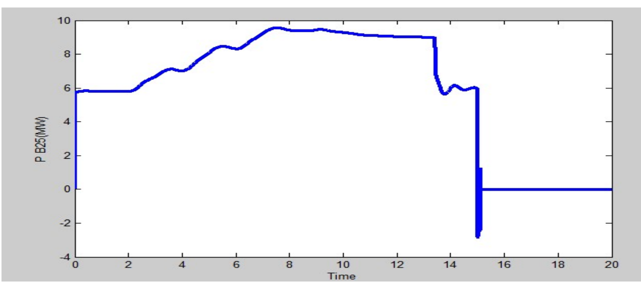

Fig.5. Simulation result of P_B25 V/s Time without STATCOM

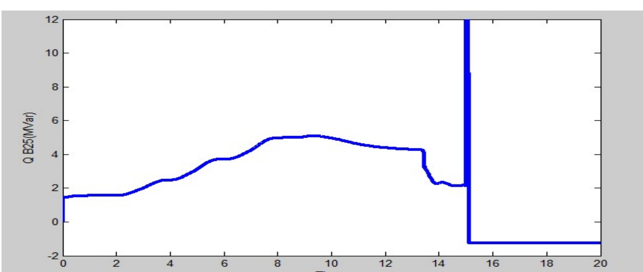

Fig.6. Simulation result of Q_B25 V/s Time without STATCOM

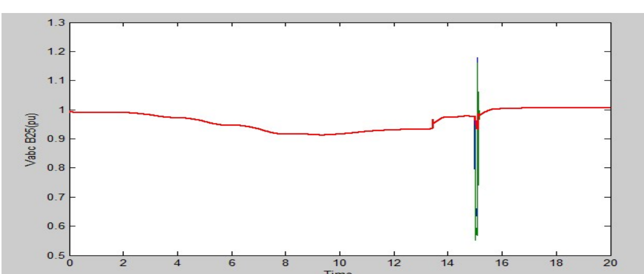

Fig.7. Simulation result of Vabc_B25 V/s Time with STATCOM

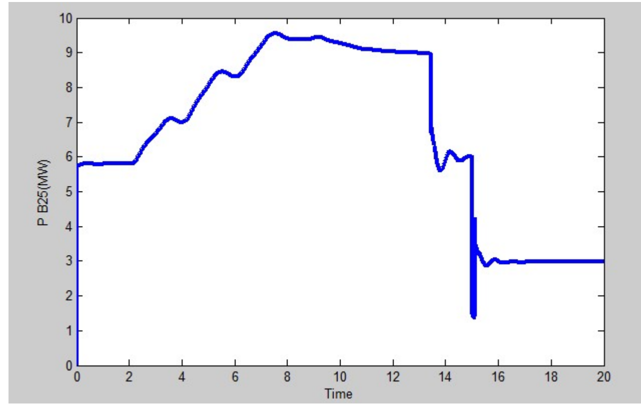

Fig8. Simulation result of P_B25 V/s Time with STATCOM

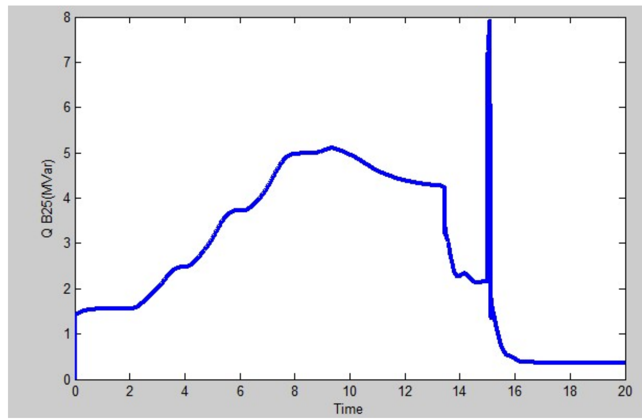

Fig.9. Simulation result of Q_B25 V/s Time with STATCOM

## V. CONCLUSION

In this paper we present the power quality control in distributed generation based on the wind farm system using FACTS device (STATCOM) Flexible AC Transmission System (FACTS) device such as Static Compensator "STATCOM" is power electronic based switch is used to control the reactive power and therefore bus voltages. Results are presented to show that the voltage at bus 25 drops to very low value of 0.91 pu due to insufficient reactive power but this bus voltage gets improved to 0.98when STATCOM is incorporated in the system. Thus the voltage and hence Power Quality Improvement in distributed generation of wind farm system.

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