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Performance Analysis of Wind Farm PID Controller Based STATCOM Device

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Abstract- In this paper interconnection of wind generating source in the electrical network affects the power quality and reliability. The influence of the wind turbine in the grid system concerning the power quality measurements are the active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation and these are measured according to national international guidelines. The paper study demonstrates the power quality problem due to installation of wind turbine with the grid. The proposed control scheme to mitigate the power quality issues for power quality improvement in the grid connected wind energy generation is simulated using MATLAB/ SIMULINK in power system block set.

Keywords: - PID, DFIG, STATCOM, DFIG, controller, bidirectional inverter.

I. INTRODUCTION

Growing concern for limited fossil fuels reserves and CO2 emission reduction stimulated development of the renewable energy sector. Especially, wind energy sector experienced huge thrust in recent years due to clean and economical energy generation. As an example, in European Union, in 2008 one third of the 23.85GW power generation was from wind turbine generators (WTG).

As induction generator, which is the major source of reactive power, is connected with a wind turbine to generate electricity, the compensation of reactive power is necessary in order to maintain rated voltage in the network. Integration of wind energy into power systems on such a large scale is not straightforward. Power system and its operation were concerned with conventional power plants where synchronous generators were directly coupled to the grid. Wind power plants have different characteristics from the conventional ones.

Thus, because of mismatch of their characteristics grid performance and stability is affected. Therefore, transmission system operators (TSO) were forced to impose New requirements for the connection of Wind Turbine Generators to the power network. This way, TSOs try to that all regulatory actions, which are needed for maintaining grid stability, are still performed on a satisfactory level, when renewable energy is introduced into the system.

On the other hand certain devices like Flexible AC Transmission Systems (FACTS) were developed in order to dynamically control and enhance power system performance. Stability is the key aspect for introducing FACTS devices. Therefore one of the present day concerns is employment of FACTS devices for enhancing wind farm performance with respect to the grid codes and power system stability.

1. Static Synchronous 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.

Specifically, the STATCOM, which is a voltage-source converter which when fed from a given input of dc voltage, produces a set of 3-phase ac-output voltages, each in phase with and coupled to the corresponding ac system voltage through a relatively small reactance (which is provided by either an interface reactor or the leakage inductance of a coupling transformer). The dc voltage is provided by an energy-storage capacitor.

A STATCOM can improve power-system Performance like: 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. Furthermore, a STATCOM does the following: It occupies a small footprint, for it replaces passive banks of circuit elements by compact electronic converters.

A STATCOM is analogous to an ideal synchronous machine, which generates a balanced set of three sinusoidal voltages at the fundamental frequency with controllable amplitude and phase angle. This ideal machine has no inertia, is practically instantaneous, does not significantly alter the existing system impedance, and can internally generate reactive (both Capacitive and inductive) power.

2. Wind Energy Generating System:
The working principle of the wind turbine includes the following conversion processes: the rotor extracts the kinetic energy from the wind creating generator torque and the generator converts this torque into electricity and feeds it into the grid. Presently there are three main turbine types available. They are Squirrel-cage induction generator.

The first one which is the simplest and oldest system consists of a conventional directly grid-coupled squirrel cage induction generator. The slip, and the resultant rotor speed of the Generator varies with the amount of power generated. The rotor speed variation is small, approximately 1% to 2%, and hence this is normally referred to as a constant speed turbine. The other two generating systems are variable –speed systems. In the doubly fed induction generator, a back to back voltage source converter feeds the three phase rotor winding, resulting that the mechanical and electrical rotor frequency are decoupled and the electrical stator and rotor frequency can match independently of the mechanical rotor speed.

In the direct-drive synchronous generator, the generator is completely decoupled from the grid by power electronics, as a converter is connected to the stator winding and another converter is connected to the grid. Thus the total power delivered by the wind power is transmitted by an HVDC link.

3. Doubly-Fed induction generator (DFIG):
It is, currently, the most employed wind generator due to its several merits. One of the advantages is the higher efficiency compared to a direct-drive wind power generation system with full-scale power converters since only about 20% of power flowing through power converter and the rest through stator without power electronics. Another advantage of a wind DFIG is the capability of decoupling control of active power and reactive power for better grid integration [1].

However, by connecting stator windings directly to the power grid, a wind DFIG is extremely sensitive to grid faults. Moreover, wind energy is a kind of stochastic energy, implying that the output of OWF varies in a certain range due to unstable wind characteristic. Therefore, the operating point of the power system changes from time to time when the wind power is integrated with the power system.

Several published papers have discussed how to reduce the negative influences of the power grid on DFIG-based wind farms [2]–[6].

In [2], DFIG-based OWF connected to a power grid through a line-commutated high-voltage direct-current (HVDC) with a damping controller located at the rectifier current regulator of the HVDC link was proposed to contribute adequate damping to the OWF under various wind speeds and different disturbance conditions. But this control scheme was only suitable for the systems having a long distance from OWFs to onshore grids.

In [3], a variable frequency transformer (VFT) was proposed to smooth the fluctuating active power generated by the OWF sent to the power grid and improve the damping of the OWF. These papers, however, just considered a power grid as an infinite bus that is not a practical power system.

II. RELATED WORK

Wind energy are drawing utmost importance in the research arena day by day as one of the renewable energy sources due to the limitation in conventional energy resources. But to stabilize the voltage harvested from wind energy has become a point of major concern. Different methodology is being adopted to mitigate this.

In this study, grid-connected wind farm stability has been upgraded by mitigating voltage Fluctuation and attaining reactive power compensation using Static Synchronous Compensator (STATCOM). Voltage control loop with PID controller has been used to control STATCOM.A Pulse Width Modulation (PWM) method has been adopted as the control strategy of STATCOM.

Different comparative study regarding stabilization of a wind farm has been performed using Different approach (i.e. wind farm with capacitor bank and STATCOM or using STATCOM along with Proportional–integral–derivative (PID) controller) during wind speed change. Comparison of result shows that STATCOM with PID controller offers better performance with enhanced stability.

In the power system, every fault, even when cleared, brings about some oscillations; these oscillations are the so-called low frequency oscillations (LFOs). In this regard, the design of damping controllers will be very useful for the series or parallel compensators. If the controllers are properly designed, they will be able to sufficiently increase the power system stability [6–8].

For this aim, Ref. [6] has addressed the design of damping controllers for the static VAr compensator (SVC) in order to improve the voltage drop resulted from the fault occurrence in a single-machine power system connected to an infinitive bus in the presence of wind farms. The utilized method for the design of SVC controllers was based on an adaptive neural fuzzy network. In a similar way, the researches in [7, 8] have designed the controllers of STATCOM in the single-machine and multi-machine power systems, respectively.

It is worth mentioning that the controllers are only designed for the FACTS devices, and no controller has been considered for the converters of the wind farms. To achieve an acceptable range of stability in a power system, in addition to the use of FACTS devices, it is required to optimally adjust the controllers of the grid-side converters (GSCs) and rotor-side converters (RSCs).

One of the techniques used for reducing the LFOs in DFIGs is to put a feedback control on the active and reactive powers of the converter. The input of this control loop, which is named power system stabilizer (PSS), is the power flowing through the line [9].

The main idea of this work is the application of PSS to the induction generator and tuning its parameters using the fuzzy system. A wide-area damping controller design is employed in [10] to mitigate LFOs. The shaft torsional oscillation, as well as destabilizing the wind turbine generator system operation may also occur as a result of employing these control strategies which are not taken into account in the abovementioned studies. The renewable energy resources had developed its presence in power distribution system for enhancing the interruption in power supply.

III. PROPOSED SYSTEM

Electricity generation, electric power transmission and final distribution to an electricity meter are some of the processes performed in the industry of electric power. Power quality is an important factor to show the wellness of electric power. Due to the changing behavior of power generation in wind systems, more power quality issues may occur.

This paper presents the simulation and analysis of Distribution Static Synchronous Compensator for voltage sag mitigation, harmonic distortion and power factor improvement using the control strategy ,The maintenance of generating power and the fulfillment of customer needs are the main objectives of power system operation.

In some of the unpredictable situations the compensation is provided by additional devices such as distribution generations integrated into the power system. In recent years the inexhaustible energy sources such as wind, solar energy systems are integrated into the power system. Among those

resources the wind energy system has the increasing demand in today's environment.
The reason for increasing willingness is the gratification of renewable energy systems are reduced usage of fossil fuels, reduced cost and reduction of greenhouse gases [37].

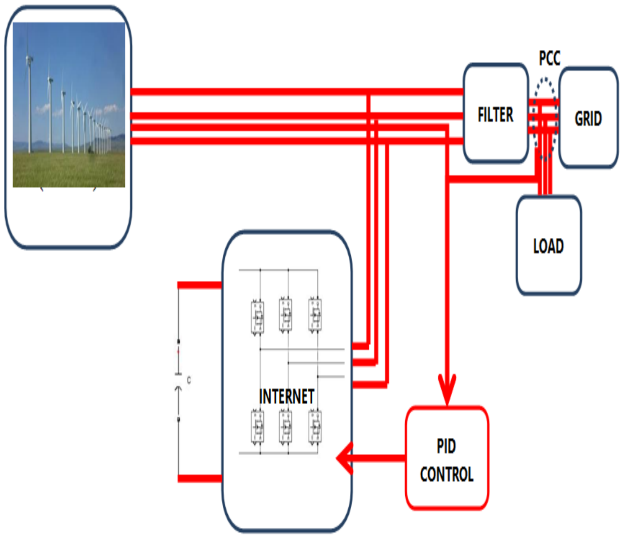

Fig 1. Block Diagram.

The wind energy systems are integrated into the distribution power systems for the continuation of power supply. Likewise one of the promising distribution systems is the wind power distribution system. While the integration of wind systems provides betterment in supplying system power supply at the same time it generates a new problem that is power quality reduction. In the same way the generation of wind energy is oscillating one because of the wind blows.

IV. SIMULATION RESULTS AND DISCUSSION

The proposed control scheme is simulated using SIMULINK in power system block set. The system parameter for given system is given Table I.

The system performance of proposed system under dynamic condition is also presented. The three phase injected current into the grid from STATCOM will cancel out the distortion caused by the nonlinear load and wind generator. The IGBT based three-phase inverter is connected to grid through the transformer. The generation of switching signals from reference current is simulated within hysteresis band of 0.08. The choice of narrow hysteresis band switching in the system improves the current quality and control signal of switching frequency within its operating band.

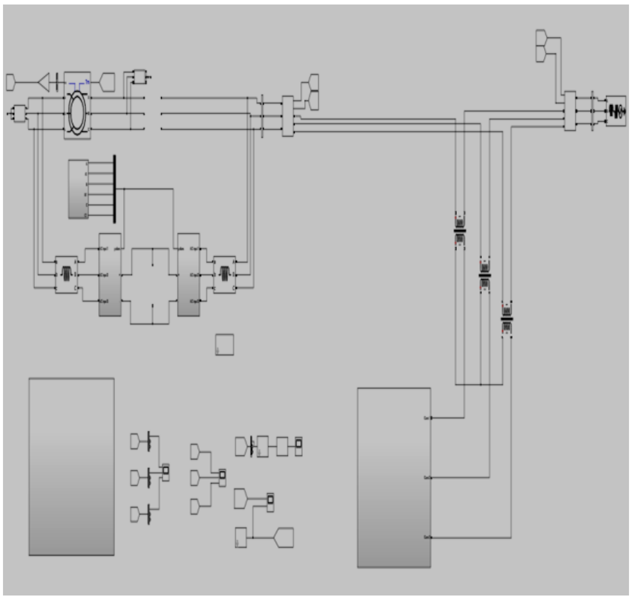

Fig 2. Proposed System Model.

In this paper, Voltage Control System is used both in PID controller and without PID controller. Without PID controller there are voltage fluctuations and the system is unstable. But with PID controller the voltage fluctuations are less and the desired output is gained. This gives a better performance and makes the system stable.

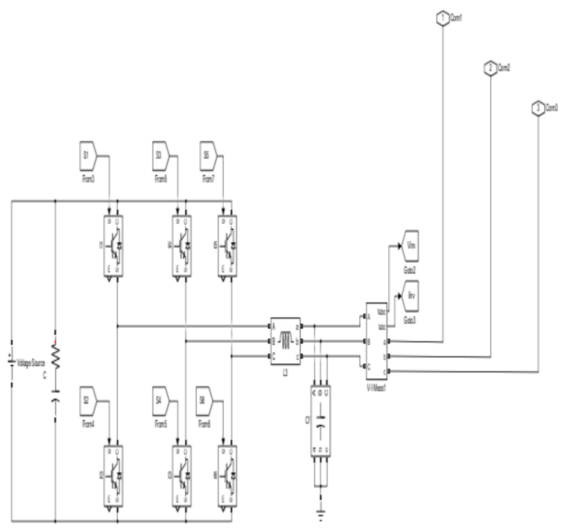

Fig 3. Proposed Control Scheme With STATCOM.

The DC link voltage and Current through capacitor are shown in Fig.6. The source voltage and source current at PCC is shown in Fig.5. The outputs of source current, load current, inverter injected current and wind generator current are shown in Fig 6.

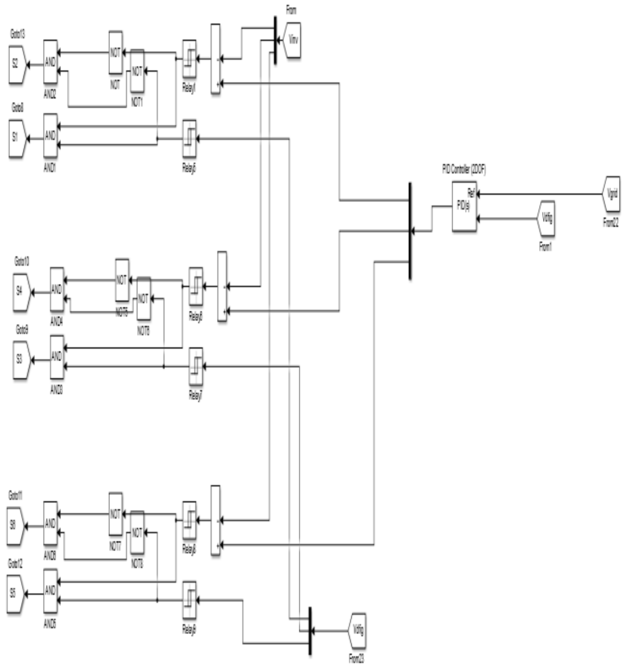

Fig 4. Control System.

The Proportional-Integral-Derivative controller (PID Controller) is a feedback mechanism of control loop system which is mainly used in industrial purposes and continuously modulated control systems

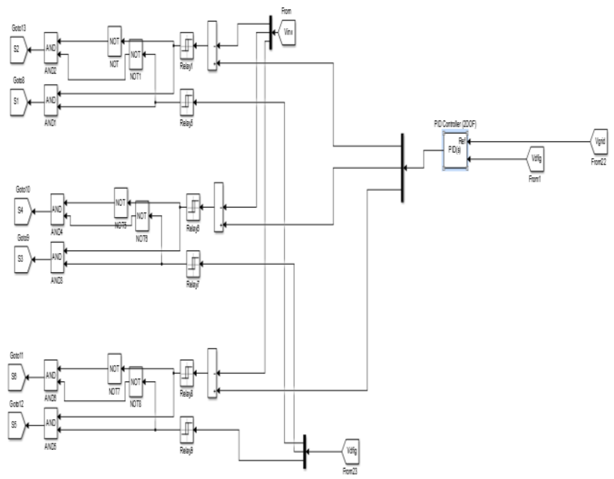

Fig 5. Voltage Control System Using PID Controller.

V. CONTROL STRATEGIES OF STATCOM

STATCOM control strategies are mainly depends on vector control principles [17]. It is connected to the three phase grid-connected systems. As the DC link capacitor creates the voltage source converter, to reduce the converter losses the DC link voltage can be controlled by modulating the converter direct axis current segment. The grid voltage can be controlled by the converter quadrature current segment to adjust the flow of reactive power from STATCOM to the grid[18]. On the ratio of the rated power of the wind farm and short-circuit connection point the minimum fault condition depends on operation [19]. In this paper mainly two types of control Strategies are discussed. One is Voltage Control System using PID controller and another is pulse width modulation.

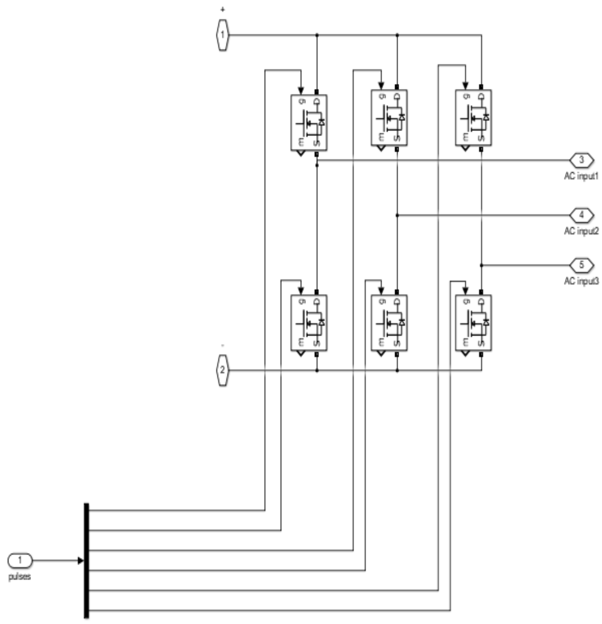

Fig 6. Bidectional Inverter.

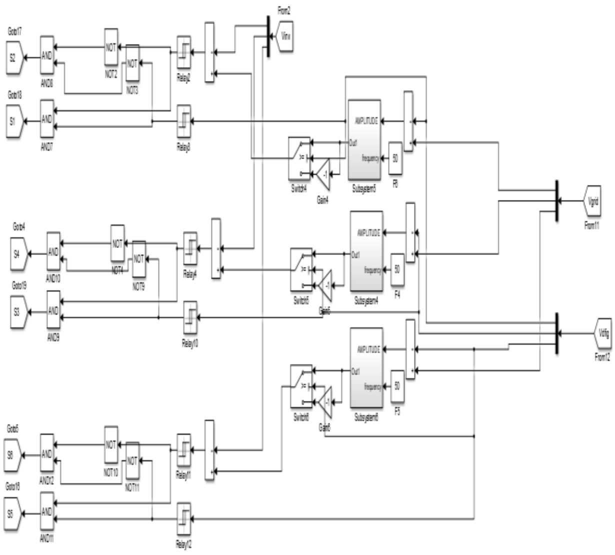

Fig 7. Without PID control scheme.

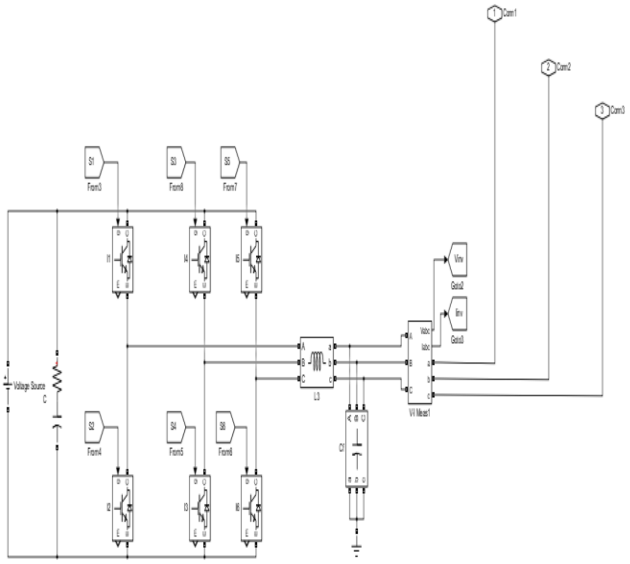

Fig 8. STATCOM without PID Controller.

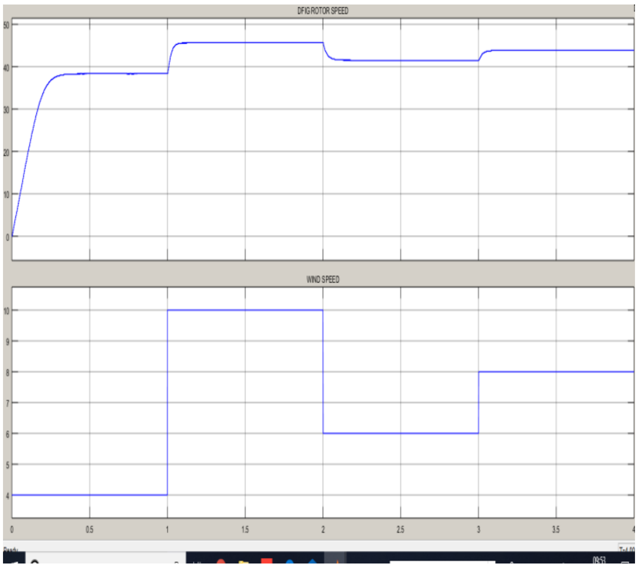

Fig 11. Wind Speed and Dfig Speed with PID.

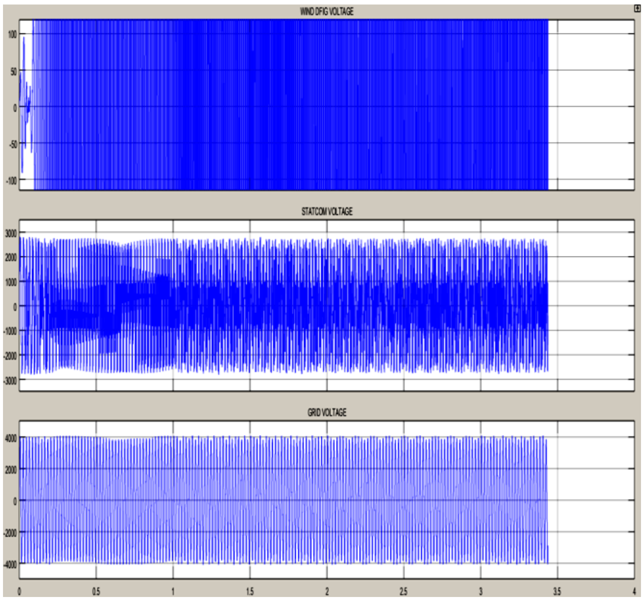

Fig 9. Without PID.

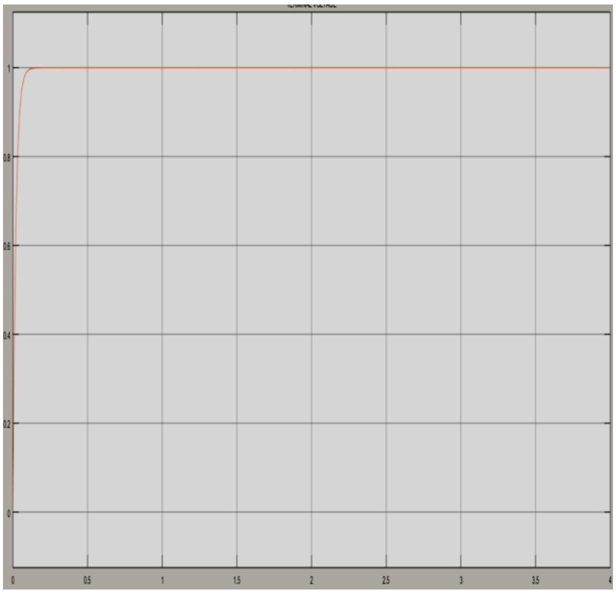

Fig12. Terminal Voltage.

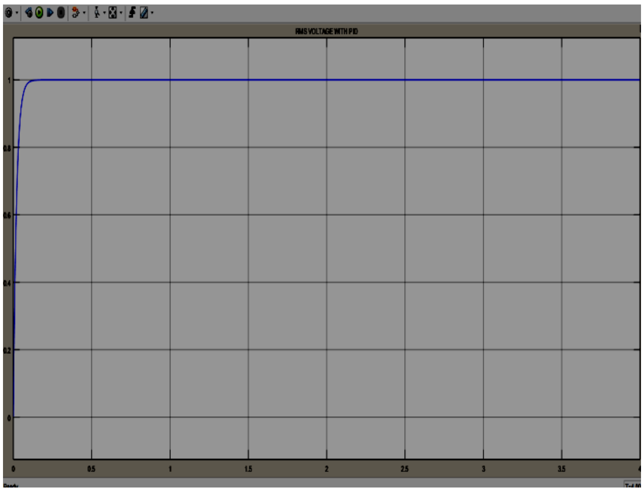

FIG 10. RMS voltage with PID.

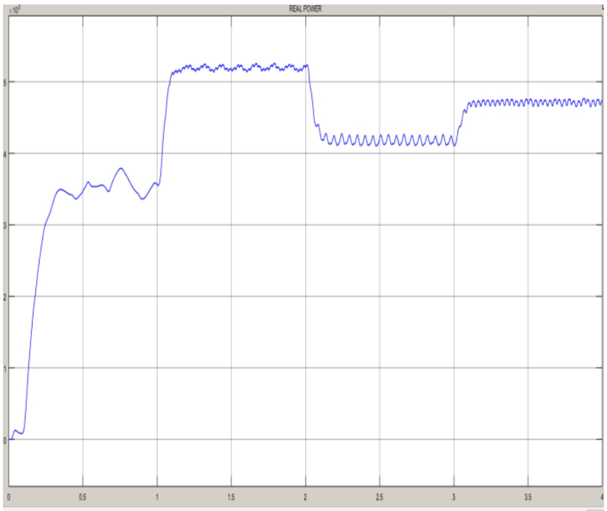

Fig 13. Real Power.

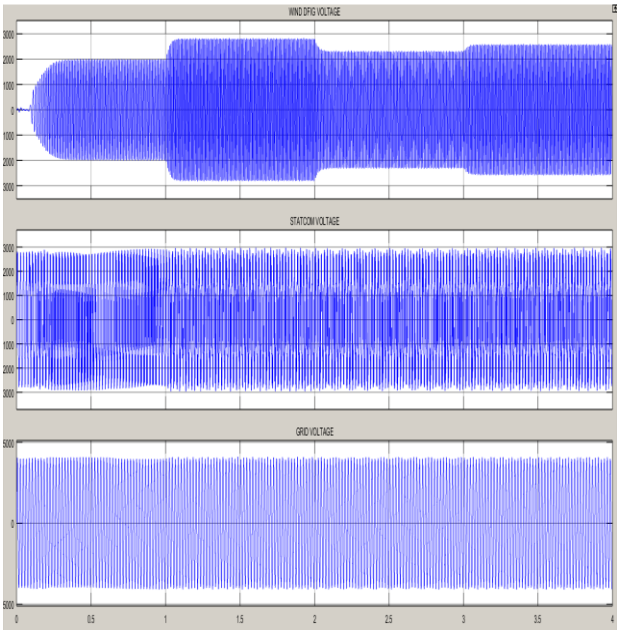

Fig14. Wind Voltage and Grid Voltage without PID.

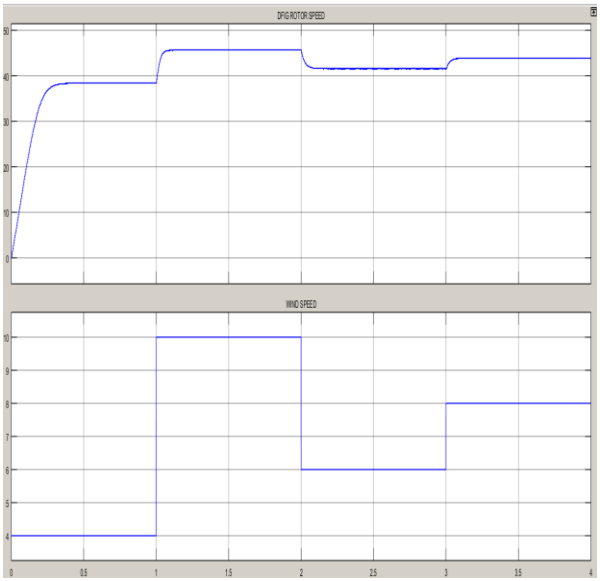

Fig 15. Wind Speed without PID.

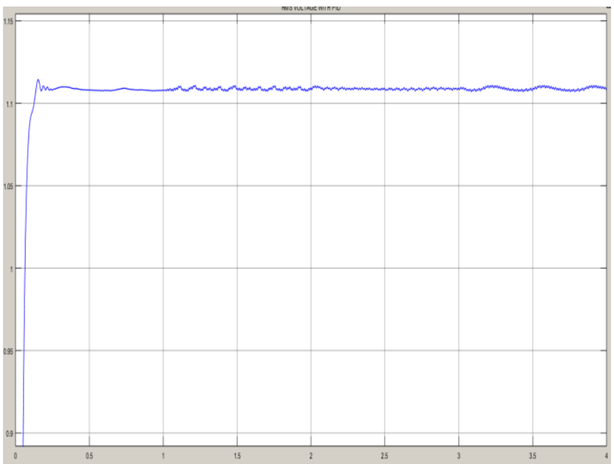
Fig 16. Rms Voltage without PID.

VI. CONCLUSION

The paper analyses the factors which are responsible for the power quality problems in the wind energy conversion system and implementation of proper control scheme for power quality improvement in the wind energy conversion system connected to the grid.

The proposed control scheme for the grid connected Wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK. The control scheme has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the wind generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line.

The results indicate that the STATCOM is more effective to stabilize the RMS voltage and terminal voltage over capacitor bank. STATCOM along with PID controller can effectively stabilize the wind farm voltage more smoothly than capacitor bank by providing sufficient reactive power to the wind farm.

So the STATCOM system is more efficient. Finally, the stability of a grid-connected wind farm has been enhanced by mitigating voltage fluctuation and attaining reactive power compensation using STATCOM and PID controller.

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