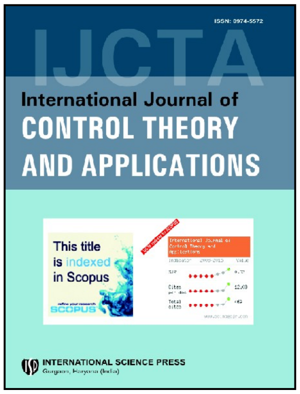

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Power Quality Enhancement in Grid Connected Wind Energy System Using D-STATCOM Based PI Controller

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Abstract: Wind energy is the electrical energy obtained from harnessing the wind. The power generated from the wind turbine is always fluctuating due to its time varying nature results it causing stability problems. This weak interconnection between wind generating source and electrical network affects the power quality as well as the reliability of entire system. Common power quality issues are considered as voltage fluctuation such as voltage sag and swell and reactive power issues and harmonics. In this proposed scheme D- STATCOM based FACTS device is connected at PCC with battery energy storage system to mitigate this power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The proposed control scheme used to improve the power quality in grid connected wind energy conversion system using MATLAB/ SIMULINK. The result gives the source voltage and current in-phase and supports the reactive power demand at PCC in the grid system. The performance of the wind turbine followed according to the guideline specified in International Electro-technical Commission standard, IEC 61400.

Keywords: D-STATCOM (Distribution static Compensator), Power quality, PI (Proportional integral) controller, Voltage Stability, BESS, Harmonics

1. INTRODUCTION

Now a day a price of fossil fuel is increasing heavily. For socio economic development ,the renewable energy expected to play major role.The wind energy is the fastest growing renewable energy .Among the renewable energy sources, wind power occupies a unique place due to technological preparedness and the fact that it is inherently site-specific. Increasing the wind farms across the country represents a need of surrounding wind power and it can able to replace all other forms of electricity generation. However, it will play a important role in the nation’s policy toward helping divert the worst effects of anthropogenic climate change, and to assure energy security in future decades [1].

In recent years, wind energy has become one of the most significant and promising sources of renewable energy, which demands additional transmission capacity and better way of maintaining system reliability. Integration of the renewable energy like wind energy into power system is possible to minimize the environmental impacts. Wind energy conversion systems are the fastest growing renewable source of electrical energy having tremendous environmental, social, and economic benefits [12]. Power quality determines the fitness of electric power to consumer devices. Itis a measure of how well a system supports reliable operation of its loads. A power disturbance can involve voltage, current, or frequency. Power disturbances can originate in consumer power systems, consumer loads, or the utility. Good power quality is benefit to the operation of electrical equipment, but poor power quality will produce great harm to the power system [2]. The power generated from wind energy conversion system is fluctuating due to fluctuation nature of wind. Due to the wind fluctuation, injected power in to the electric grid affect the power quality of entire system.Power quality problems are usually characterized in terms of the effect upon the supply voltage and can be broken down into the following major categories:active power, reactive power, variation of voltage, flicker, harmonics, and electrical behavior of switching operation [4].In this proposed scheme Distribution static Compensator (D-STATCOM) based FACTS device is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues and it provides Reactive Power support to wind generator and load [4]. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The D-STATCOM based current control voltage source inverter, injects the current into the grid in such a way that the source current are harmonic free and there is phase difference with respect to source voltage has some desired value. The D-STATCOM control scheme for the grid connected wind energy conversion system for power quality improvement is simulated using MATLAB/ SIMULINK in power system block set. In this proposed method there will be the analysis of factors which are responsible for the power quality problems and implementation of proper control scheme for power quality improvement in the wind energy conversion system connected to the grid. This paper is organized as follows. The section II introduces the power quality standards, issues and its consequences of wind turbine, the section III describes the topology for power quality improvement and control scheme The section IV describes the control system performance and conclusion respectively.

2. POWER QUALITY ISSUES AND ITS STANDARDS

2.1. IEC Standards

Common guidelines for measurement and rules of power quality of wind turbine are specified in IEC standard 61400 for both manufacturer and buyers. Utilize this standard for better power quality requirement. The standard norms are[10]

- IEC 61400-12 Power performance measurements of electricity producing wind turbines
- IEC 61400-3-7 Assessment of emission for fluctuating load.
- IEC 61400-13:2001 wind turbine measuring procedure in determining power behavior.
- IEC 61400-21:2008 Measurement and assessment of power quality characteristics of grid connected wind turbines.
- IEC 61400-21 part21 power quality characteristics of grid connected wind turbines.

2.2. Power Quality Issues

2.2.1. Voltage Variation

The output variations normally occur due to fluctuation of changes in wind speed in wind turbine, this will leads to voltage variations and flicker effect in normal operation. The voltage variation can occur as a result of load changes and power produce from wind turbines. Normally voltage variations are classified as long duration voltage variation and short duration voltage variations. [8] This variation causes the variation in real and reactive power. The dynamic variation in network caused by wind turbine is described by voltage flicker. The voltage variation frequency is represented in the frequency of 10-34Hz.The flicker level was measured with the help of flicker meter by IEC-61400-4-15 standard. The voltage fluctuation depends on the strength of grid, impedance of network, and power factor and phase angle of wind turbine. [2]

2.2.2. Harmonics

Harmonics are referred as sinusoidal voltage and current having frequencies that are multiples of frequency at which the supply system is designed to operate. Harmonic current are generated at low distortion level in wind turbine. These are the two indices for measuring harmonic content that are total harmonic distortion and total demand distortion [1].Static power converter is the main source of harmonics. Harmonic voltage and current should be in limited as per the IEC-61400-36 guideline. The rapid switching gives a large reduction in lower order harmonic current and higher order harmonics are filtered out by using filters.

2.2.3. Wind turbine location in power system

It is located where the power quality is highly influenced. The operation of wind turbine and its influence on the power system depends on the structure of network.

2.2.4. Consequences of PQ issues

The voltage variation, voltage flickering effect and inducement of harmonic will create much effect in wind turbine which is connected with the grid. This power quality issues which will affect the sensitive equipment connected with grid. Then it will affect the sensitivity of the grid.

3. TOPOLOGY FOR POWER QUALITY IMPROVEMENT

3.1. Grid connected wind energy generating system

The STATCOM based current control voltage source inverter injects the current into the grid will cancel out the harmonics due to load and the reactive part and induction generator current, as a result it improves the power quality. To achieve this goal ,the grid voltages are sensed and are synchronized in generating the current. [8]

The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC), for grid connected system in Fig. 1.

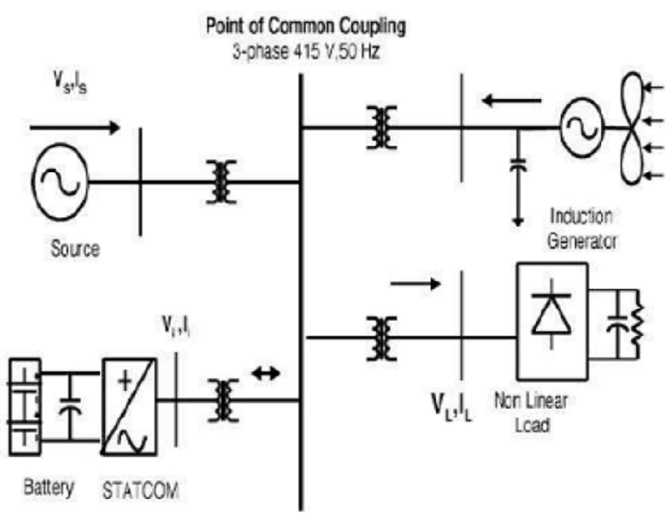

Figure 1: Grid Connected System for Power Quality Improvement

3.1.1. Modeling of wind energy generating system

Available Power from the Wind, The power **P** available in the wind impinging on a wind driven generator is given by:

$$P_{wind} = \frac{1}{2}\rho A V_{wind}^{3} \tag{1}$$

C is Power Coefficient, A is the swept area, ρ is the density of the and**v** is the wind velocity. The power is proportional to area swept by the blades, the density of the air and to the cube of the wind speed. Thus doubling the blade length will produce four times the power and doubling the wind speed will produce eight times the power. [2].

It will not considered all kinetic energy of wind, hence it considered a fraction of power in wind, known as power coefficient C_p of wind turbine, which is given in below equation

$$P_{Mech} = C_p P_{wind} \tag{2}$$

The Cp of a particular wind turbine varies with operating conditions such as wind speed, turbine blade angle, turbine rotation speed, and other parameters. It is a measure of wind turbine's overall system efficiency. The mechanical power formed by wind turbine is specified in below equation

$$P_{mech} = \frac{1}{2}\rho \Pi R^{2} V_{wind}^{3} C_{p} \tag{3}$$

3.1.2. Modeling of DSTATCOM

The D-STATCOM, which is consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. [9]

The VSC connected in shunt with the ac system which can be used for up to three quite distinct purposes Voltage regulation and compensation of reactive power; Correction of power factor; Elimination of current harmonics. Such device is employed to provide continuous voltage regulation using an indirectly controlled converter [17]. A single line diagram of D-STATCOM power circuit [16] shown in fig. (2)

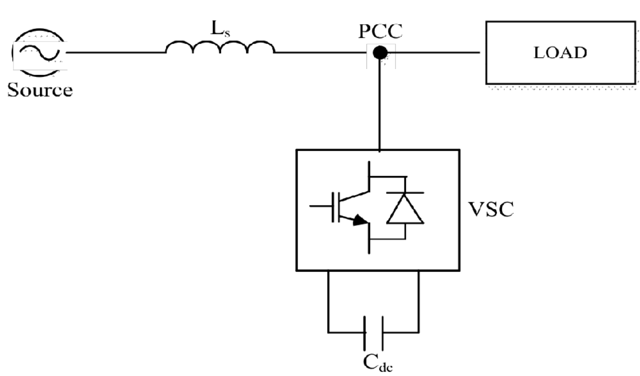

Figure 2: Distribution Static Compensator (DSTATCOM)

3.1.3. Voltage Source Converter

D-STATCOM is a voltage source converter. Voltage source converter is a power electronic device that connected in parallel to the system [19].It generates a sinusoidal voltage with any required magnitude, frequency and phase angle. D-STATCOM output voltage allows effective control of active and reactive power exchange between D-STATCOM and AC grid system [13] .The voltage source converter has AC terminals which are connected to PCC (Point of Common Coupling) through the inductance.It is a controlled reactive power source. It provides desired reactive power generation and absorption entirely by means of electronic processing of voltage and current waveform in voltage source converter. [11]

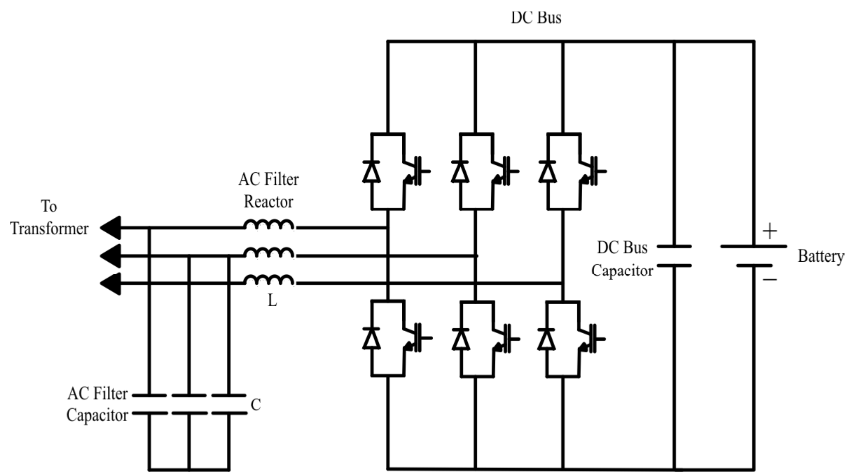

Figure 3: Single line diagram of BESS-DSTATCOM

3.1.4. Battery Energy Storage

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. [6]. It is rapidly injects or absorbed reactive power to stabilize the grid system. It also controls the distribution and transmission system in a very fast rate. When power fluctuation occurs in the system, the BESS can be used to level the power fluctuation by charging and discharging operation.

Various types of energy storage technologies can be incorporated into the dc bus of the DSTATCOM, namely superconducting magnetic energy storage (SMES), super capacitors (SC), flywheels and battery energy storage systems (BESS)[7]. Moreover, BESS can be directly added to the dc bus of the inverter, thus avoiding the necessity of an extra coupling interface and thus reducing investment costs [14] The integrated DSTATCOM/ BESS system proposed in Fig. 3 is basically composed of the inverter , the coupling step-up transformer, the line connection filter, the dc bus capacitors, and the array of batteries.

3.1.5. PI Voltage Regulator

The integral term in a PI controller causes the steady state error to zero. The Proportional Integral (PI) algorithm computes and transmits a controller output signal every sample time to the final control element.[18] The gains of PI controller can be selected by trial and error method. It performs lack of derivative action may make the system steadier in the steady state in the case of noisy data.[PI controllers have two tuning parameters to adjust parameters and integral action enables PI controller to eliminate offset, a major weakness of a P-only controller. [8][15]The STATCOM control block diagram is shown in Fig. 4. The voltage regulator is of proportional plus integral type.

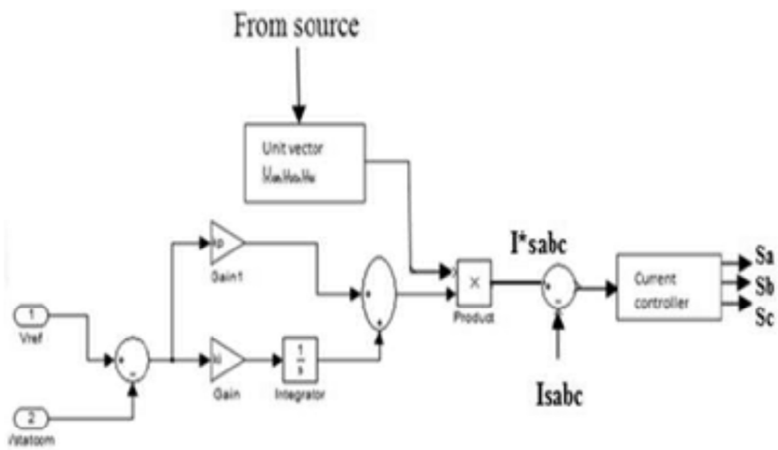

Figure 4: STATCOM model with PI – Voltage Regulator block diagram

4. SIMULATION RESULTS AND DISCUSSIONS

It is observed that the source current on the grid is affected due to the effects of nonlinear load and wind generator, thus purity of waveform may be lost on both sides in the system. The source current waveforms without and with STATCOM are shown in fig. The simulation parameters [7] are tabulated in Table I.

Table I
System Parameters

S.No	*Parameters*	*Ratings*
1	Grid voltage	3Phase, 415V,50Hz
2	Induction generator	3.35KVA, 415V,Hz,P=4,Speed=1440rpm,Rr=0.01O,Rs=0.015O,Ls=Lr=0.06H
3	Line series Inductance	0.05mH
4	Inverter Parameters	DC Link Voltage=800V, DCLink Capacitance=100µF,Switching Frequency=2kHz
5	IGBT rating	Collector Voltage=1200V, Forward Current=50A,GateVoltage=20V, Power Dissipation=310w
6	Load Parameter	Non-Linear Load=25kw

In proposed method the stabilization of wind energy analyzed based on Normal operating condition ,sag condition and swell condition. If generated voltage is same as requiredvoltage, there is no need of DSTATCOM to operate. Due to reduction in short duration rmsvoltage, voltage dip will occur.

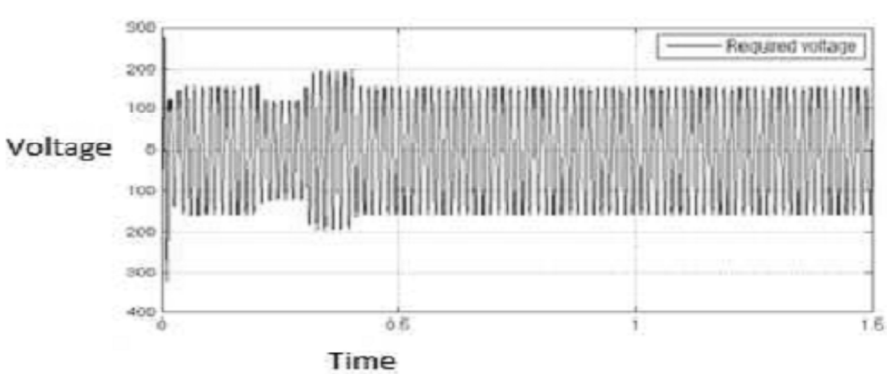

Figure 5: Voltage Required at Sag Condition

Required voltage condition represented in figure 5 and 8.

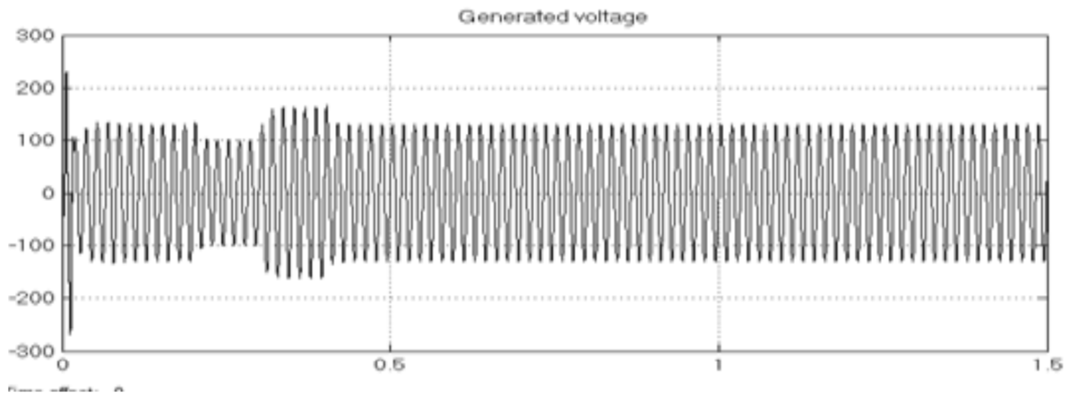

Figure 6: Voltage Generated at Sag Condition

Generated voltage at sag and swell condition represented in figure 6, 9.

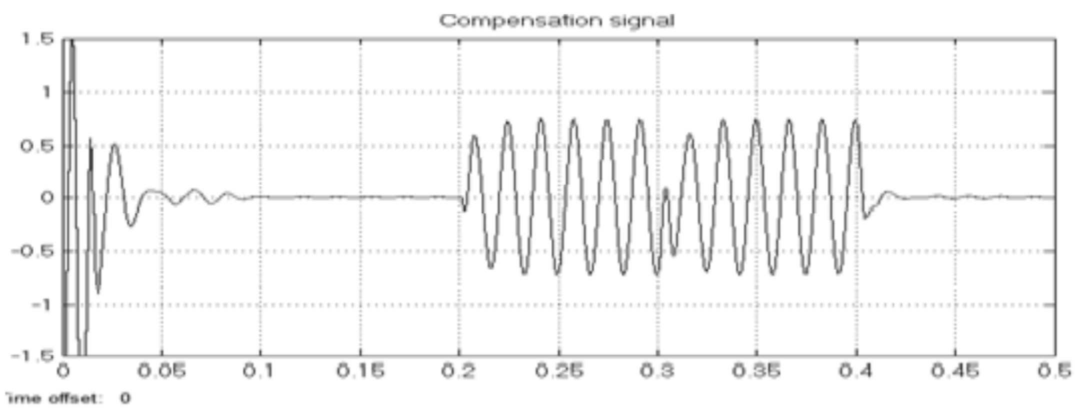

Figure 7: Output of DSTATCOM based on PI at Voltage Sag Condition

Compensated signal generated by DSTATCOM with PI controllerrepresented in figure 8 and 10. It will give better performance than FACTS devices.

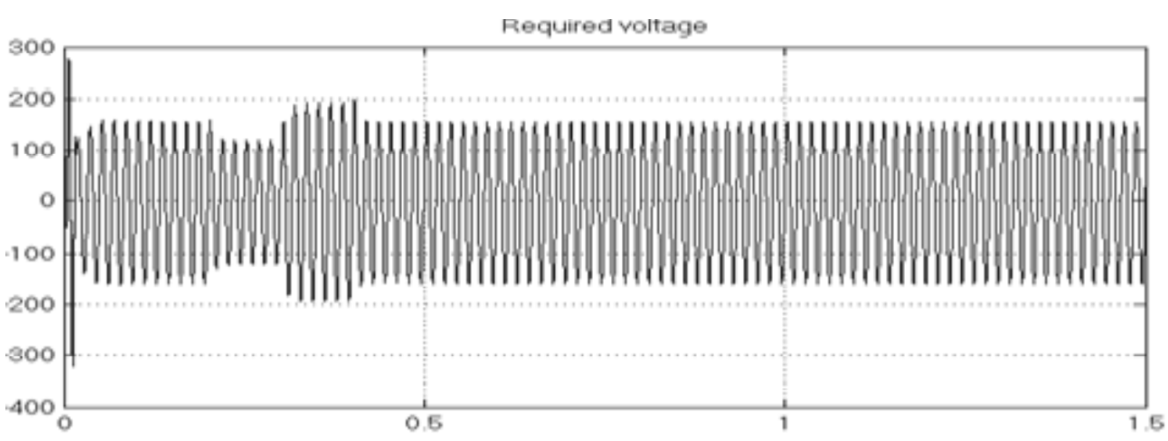

Figure 8: Voltage Required at Swell Condition

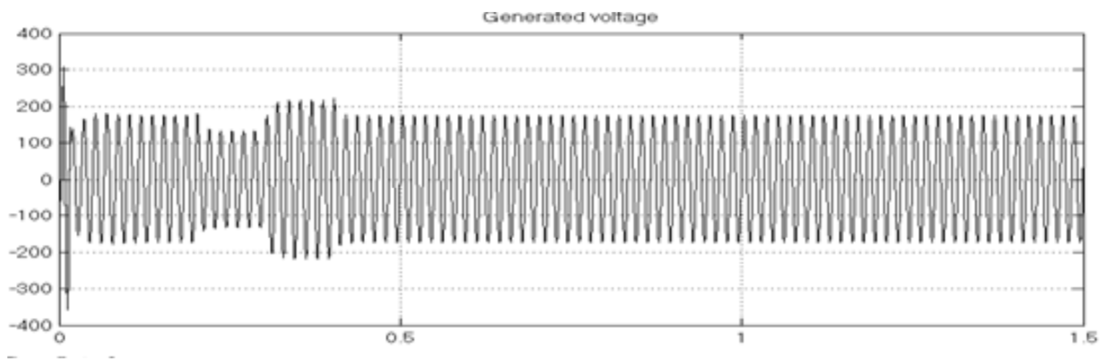

Figure 9: Voltage Generated at Swell Condition

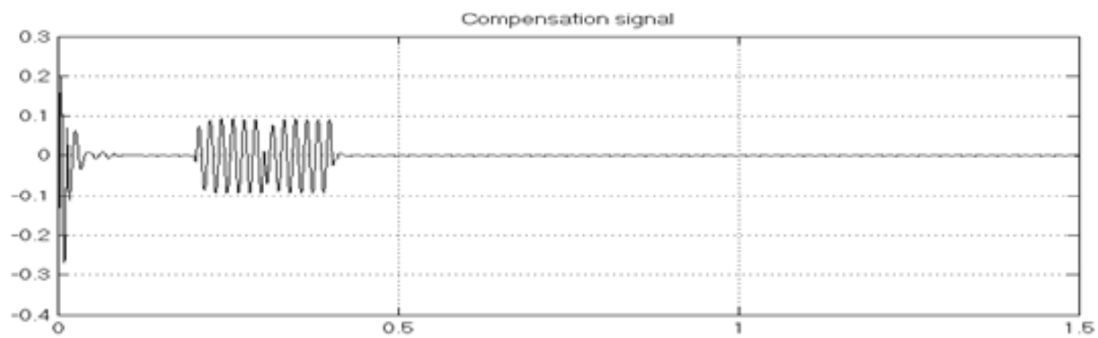

Figure 10: Output of DSTATCOM based on PI at Voltage Swell Condition

5. CONCLUSION

The proposed method discussed STATCOM with PI based control scheme for power quality improvement in Grid connected wind generating system and with nonlinear load. The power quality issues and its effects on the gridand electric utility are enumerated. The proposed PI controller is modelled in MATLAB/SIMULINK for maintaining power quality. The proposed control algorithm effectively compensates the current harmonics by generating equal and opposite compensation signal and 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 the integrated wind generation and STATCOM with BESS have shown the outstanding performance in maintaining the rated voltage stability and harmonic fewer sources current. Thus the proposed PI control scheme in the grid connected system maintains the power quality requirements in compliance with IEEE 519 and IEC 61400-21 standard. [10].

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