OPEN ACCESS
ISSN: 2249-6645

International
Journal
Of Modern Engineering Research (IJMER)

Power Quality Enhancement of Wind Generators Connected to Grid

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Abstract: *The wind power generation is rapidly growing and the use of wind farms and other distributed power generation systems have drastically increased. According to IEC standard, the power quality is determined from the performance of wind generators. In this paper using a FACTS controller device the power quality enhanced when the wind generators are connected to the grid system. The power quality becomes an issue when wind generators are connected to the grid, due to the interaction between the grid and the wind turbines. The main Impact on the grid by the wind generators, regarding power quality, is related to voltage sag, reactive power, harmonics, power peaks and flickers. The power quality problem arises when the wind generators are equipped with the grid, can be improved by connecting a FACTS controller at a point of common coupling. In this paper, UPFC (Unified Power Flow Controller) control scheme for the wind generators connected grid is used to improve the power quality using MATLAB/SIMULINK in power system block set. Also this UPFC control system that includes both the shunt converter and the series converter has been simulated. In this proposed model, the real and reactive power compensation is the main concern.*

Keywords: *Wind turbine, power quality, FACTS, UPFC, reactive power compensation.*

I. INTRODUCTION

Grid-connected wind generation capacity is undergoing the fastest rate of growth in electricity generation, achieving global annual growth rates of the order 20-30% [1]. Capacity has been doubling every three years for the last decade. Wind power is increasingly being viewed as a mainstream of electricity supply. Its attractiveness as an electricity supply source has fostered ambitious targets for wind power in many countries around the world. Its benefits include[3]:

Emissions of harmful gasses, particularly CO2, Significant economically exploitable resource potential, Significant economically exploitable resource potential, No cost uncertainties from fuel supply price fluctuations, Modular and rapid installation, Opportunities for industrial, economic and rural development.

A grid-connected wind turbine can reduce the consumption of utility-supplied electricity for domestic and industrial applications. If the wind turbine cannot deliver the amount of energy we need, the utility makes up the difference. When the wind system produces more electricity than the individual applications the excess is sent or sold to the utility. With this type of grid-connection, the wind turbine will operate only when the utility grid is available, During power outages, the wind turbine is required to shut down due to safety concerns, Grid integration issues are a challenge to the expansion of wind power in some countries. Solutions such as aggregation of wind turbines, forecasting and modeling have been implemented to facilitate larger market penetration of wind power. [3] Collaborations are increasingly addressing the integration and grid improvement matters. The IEA's 2004 World Energy Outlook estimates that by 2020 global electricity demand will be 25578 TWH(Terawatt hours)

At present, Indian Electricity Grid Code is followed in the transmission system. It specifies the system voltages at Transmission level to be maintained as follows:-

System voltage:
Max Min
RMS
400kV 420kV 360kV
220kV 245kV 200kV
132kV 145kV 120kV

Frequency : The assured frequency of supply is 50 cycles per second with permitted variations of (-) or

(+) 3%. Statutory limits 48.5 to 51.5 HZ CERC standards 49.5 to 50.5 HZ. Integrating renewable into grids to any considerable degree can expose the system to the issues that need attention lest the functionality of the grid be impaired. Such issues can be voltage fluctuations, frequency deviations, and deterioration of power quality. By utilization of FACTS devices [2] such as STATCOM, UPFC and Series capacitors, grid function can be maintained and even improved, enabling increased power transmission capacity over existing lines.

FACTS technologies provide advanced solutions as cost-effective alternatives to new transmission line construction. The potential benefits of FACTS equipment are now widely recognized by the power systems engineering and T & D communities. With respect to FACTS equipment, voltage sourced converter (VSC) technology, which utilizes self-commutated thyristors/transistors, has been successfully applied in a number of installations world-wide. Due to the recent increases in their variety and ratings, an increasing number of high power semiconductor devices are available for power system application; particularly in flexible ac transmission systems (FACTS) apparatus. The unified power flow controller (UPFC) is one of the FACTS devices. The invention of the unified power flow controller has seeded research in two directions. One direction is concerned with its applications. The second direction is concerned with the power electronic realization of the UPFC and its performance characteristics. The UPFC has three independent degrees of freedom, by which the real power through a radial line and the reactive powers at both ends of the line can be simultaneously controlled. It has also the reassuring internal flexibility that its shunt converter can be used as a stand-alone STATCOM its series converter as a stand-alone series capacitor compensator (SSSC) or combinations of the two.

The advantages are Rapid response, frequent variation in output, smoothly adjustable output. The benefits of using facts devices are better utilization of existing system assets, increased system reliability and availability, increased dynamic and transient grid stability and reduction of loop flows, increased quality of supply for sensitive industries, Better utilization of existing system assets.

II. POWER QUALITY ISSUES

A. Voltage SAG

A short –term decrease in voltage lasting anywhere from milliseconds up to a few seconds. Sags cause computer crashes or equipment lock-ups and is usually caused by equipment start-up-such as elevators, heating and air-conditioning equipment, compressors, and copy machines or nearby short circuits, on the utility system. A short term decrease in voltage is not a permanent interruption of electrical power; rather it is a temporary drop below 90 percent of the nominal voltage level. Mostly decrease in voltage does not go below 50 percent of the nominal voltage, and they normally last from 3 to 10 cycles (HZ) or 50 to 170 milliseconds. Voltage sag as defined by IEEE Standard 1159-1995, IEEE Recommended practice for Monitoring Electric Power Quality, is a decrease in RMS voltage at the power frequency for duration from 0.5 cycles to 1 minute, reported as the remaining voltage.

B. Active and reactive power

IEC standard tries to evaluate the capability of the wind turbine concerning the active and reactive powers. The assessment is done by means of different types of tests [4], some of them based on the wind speed and others considering both the wind speed and the wind turbine regulation system.

I) Active Power

For the assessment of the active power three different tests are considered. First, the maximum power is measured from at least 5 time-series of 10min, collected for each 1ms wind speed between the cut-in wind speed and 15ms. The measured power must be transferred to 0.2 s average data and 60s average data by a block averaging [4]:

- PO.2 will be determined as the highest value obtained from 0.2s windows, recorded during the period of 10min.
- P60 will be determined as the highest valid 60s value calculated by averaging the 0.2s values, recorded during the period of 10min.

C. Reactive power

For the assessment of the reactive power two different testes are considered [4]. Both tests must be done considering the regulation system of the wind turbine. The first test tries to assess the capability of the wind turbine concerning the maximum inductive reactive power and the maximum capacitive reactive power. For each of the two settings the measurements must be taken so that at least 30 time-series of 1 min of active and reactive power are collected at each 10% power bin from 0 % to 100%. The sampled data will be calculated as 1 min average data by applying 0.2s block averaging for each 1min period. On the other hand, the reactive power control by set-point value must also be measured, considering two cases: the measurement at a set-point of reactive power at zero and the measurement during the step change of reactive power.

- For the first case, the procedure is the same as that one used to assess the capability of the wind turbine concerning the maximum reactive power.
- For the second case, the test must be of 6min period and the set-point of reactive power must be regulated for 2min intervals corresponding to reactive power of zero, maximum capacitive reactive power and maximum inductive reactive power.
- The active power output, measured as 1 min average values, must be approximately 50% of rated power. The reactive power must be 0.2s average data.
- The results of the test must be the reactive power from 0.2s windows, together with the set-point value of reactive power.

III. TOPOLOGY FOR POWR QUALITY IMPROVEMENT

A Wind Energy Generating System

In the proposed scheme Doubly Fed Induction generator is used because of its simplicity, it does not require a separate field circuit; it can accept constant and variable loads and also doesn't have constraints to reactive power.

B UPFC

The UPFC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and SSSC. UPFC which consists of a series and a shunt converter connected by a common dc link capacitor can simultaneously perform the function of transmission line real/reactive power flow control in addition to UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. The series converter of the UPFC controls the transmission line real/reactive power flows by injecting a series voltage of adjustable magnitude and phase angle. The interaction between the series injected voltage and the transmission line current leads to real and reactive power exchange between the series injected voltage and the transmission line current leads to real and reactive power exchange between the series converter and the power system, Under steady state conditions, the real power demand of the series converter is supplied by the shunt converter. But during transient conditions, the series converter real power demand is supplied by the dc link capacitor. If the information regarding the series converter real demand is not conveyed to the shunt converter control system, it could lead to collapse of the dc link capacitor voltage and subsequent removal of UPFC from operation.

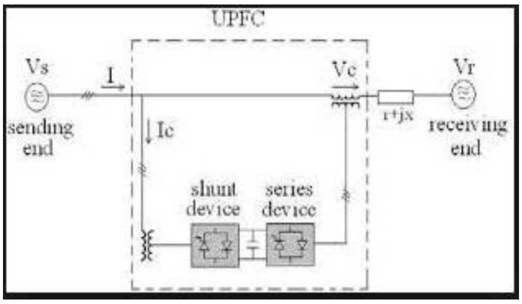

Fig. 1: Basic Functional Scheme of UPFC

The UPFC can provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. It is recognized as the most sophisticated power flow controller. In the proposed scheme to improve the power quality of the system the controller device (UPFC) is connected to the point of common coupling (PCC) as shown in Fig.2. Power injection from gird-connected wind turbines affects substantially the power quality. The wind turbine has to be directly connected to the grid and the measurements of the electrical characteristics have to be made at the wind turbine terminals. The simulation is done and output voltage, current, real and reactive power of the wind turbine is measured using simulink in power system block set as shown in Fig.4

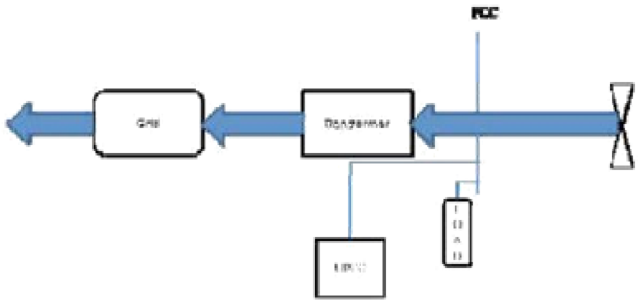

Fig.2: Block diagram for wind generator connected to grid for power quality

IV. SYSTEM PERFORMANCE

The continuous voltage control and reactive power compensation is provided by using FACTS-based device. Among FACTS devices, the Unified power flow controller (UPFC) is chosen due to its versatile regulating capabilities. The UPFC consists of shunt and series branches, which could be interchangeably used. Being located at the point of the wind energy conversion system connection to the distribution network, it is made possible to simultaneously control the WECS bus voltage magnitude and /or series reactive power flow that WECS exchanges with the network.

The wind turbine parameters such as rotor speed, stator voltage, rotor current, torque, power with respect to time are measured using power system simulink block set. The system parameters are shown in Table 1.

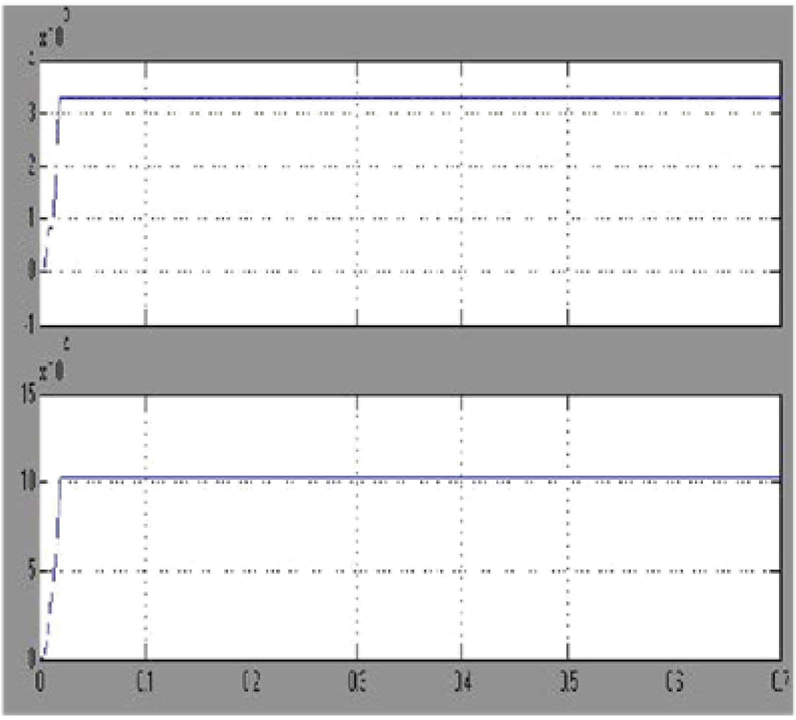

Fig.3: Real and Reactive power without UPFC

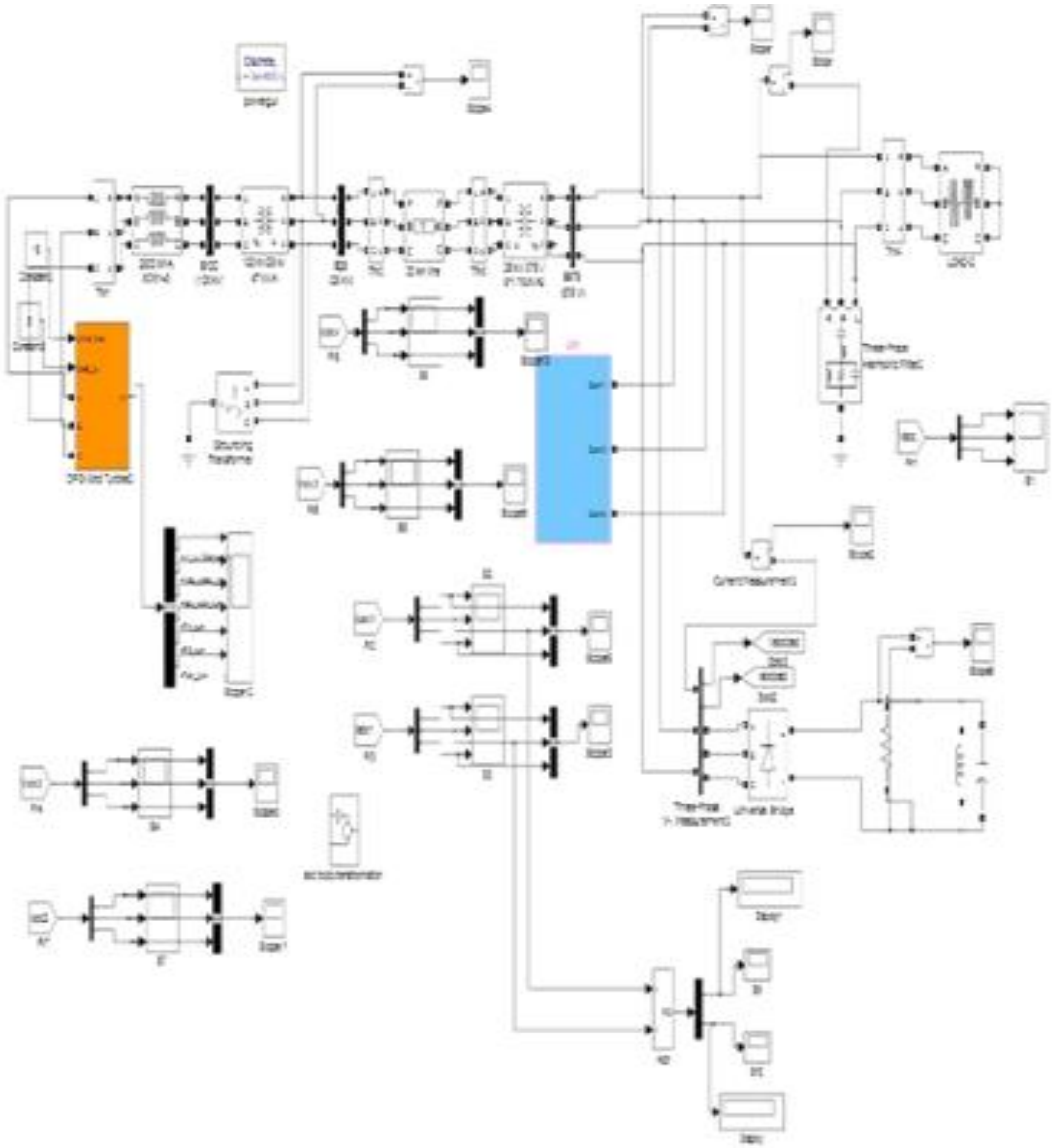

Fig.4. Simulation diagram with UPFC

V. TABLE1: SYSTEM PARAMETERS

S. No.	Parameters	Ratings
1	Grid Voltage	3Phase, 415V,50Hz
2	Doubly Fed Induction generator	1.5KVA,415V, Rs=0.007pu, Rr=0.005pu, Ls=Lr=0.2pu, Speed = 1440rpm
3	Wind Turbine Mechanical output power	$1.5e^6$ w
4	Wind Speed	12 ms
5	Pitch Angle	45 deg

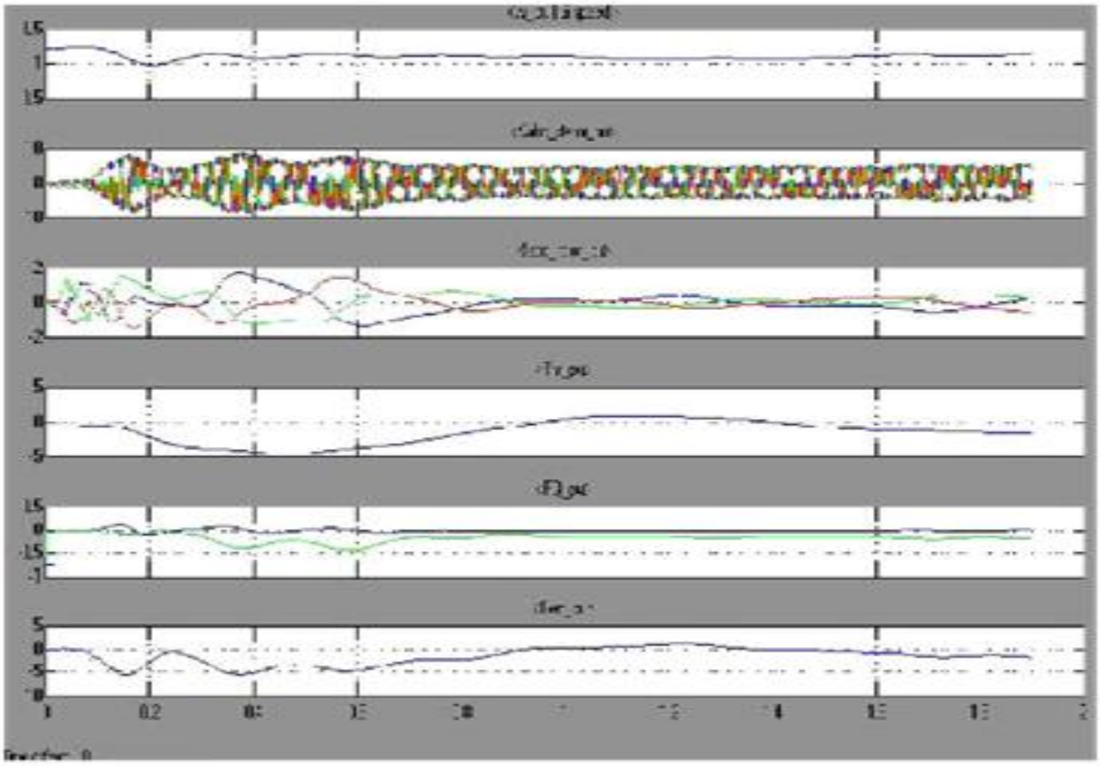

Fig.5 : Characteristics Parameters of Wind Turbine

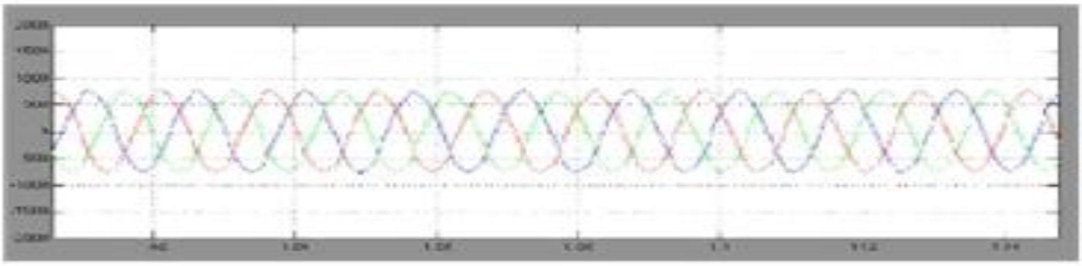

Fig.6: Linear Output Voltage

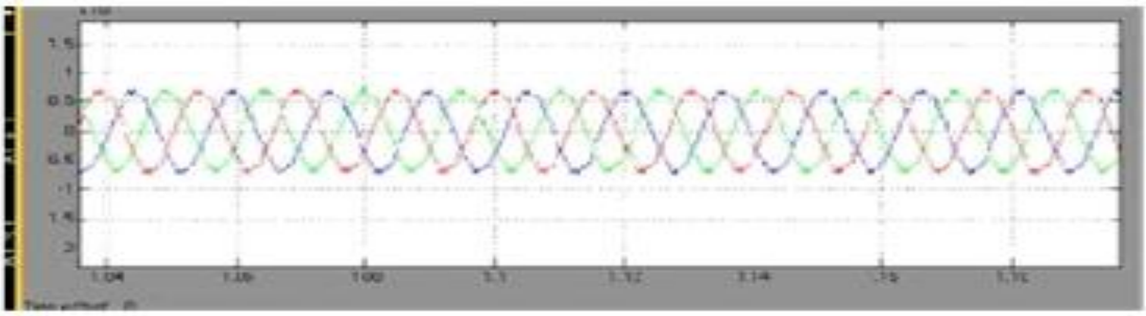

Fig. 7: Linear Output Current

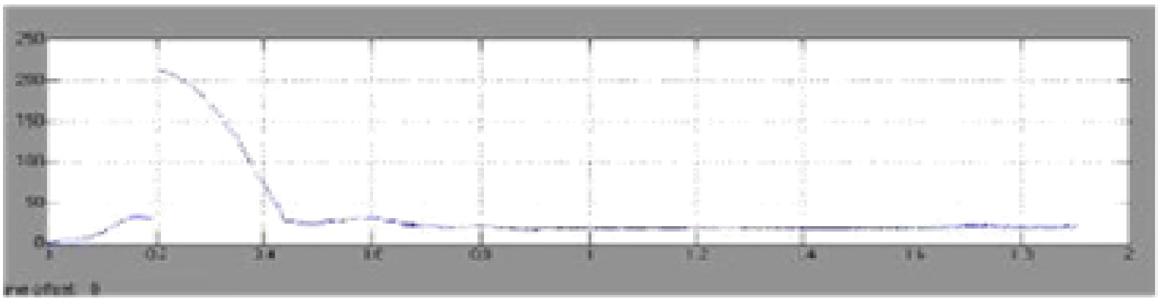

Fig. 8: Non-linear Output Voltage

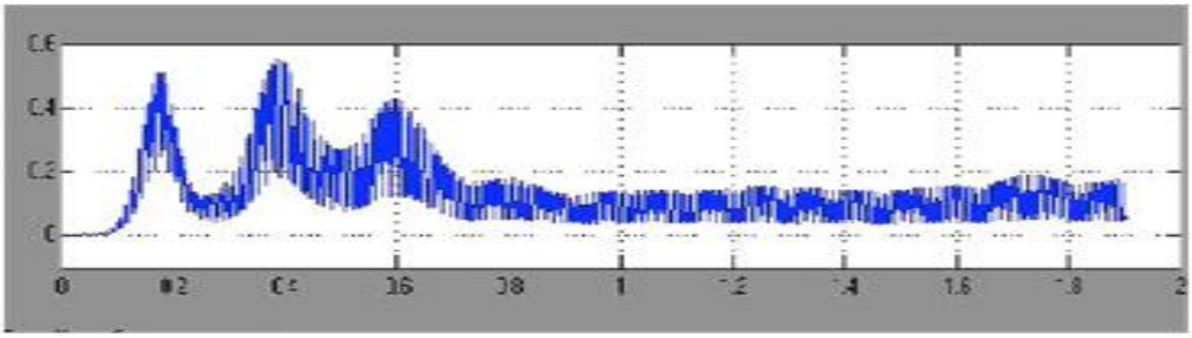

Fig.9: Real Power

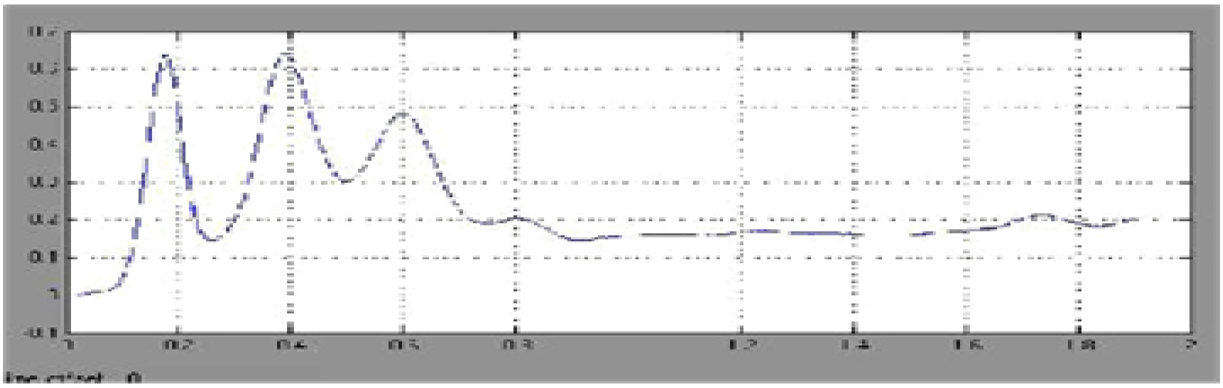

Fig.10: Reactive Power

VI. CONCLUSION

In this paper a control scheme UPFC controller device for power quality improvement in grid connected wind generating system with non linear load is done. The power quality issues, reactive power compensation and its consequences on the consumer and electric utility are presented. The FACTS (UPFC) controller has the capability to cancel out the harmonic parts of the load current improves the reactive power. 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 give an opportunity to enhance the utilization factor of transmission line. Also this paper presents an improvement in the real and reactive power in the grid connected system with UPFC when compared to the system without UPFC.

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