International Journal of Electrical and Electronics Engineering (IJEEE)
ISSN(P): 2278-9944; ISSN(E): 2278-9952
Vol. 3, Issue 3, May 2014, 1-10

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

IMPROVEMENT OF POWER QUALITY IN AN A INDUCTION GENERATOR BASED WIND POWER GENERATING SYSTEM CONNECTED TO GRID BY USING UPFC

K. E. CH. VIDYA SHEKAR[1] & R. K. SHARMA[2]

[1]M.Tech Student, Department of Electrical Engineering, Lovely Professional University, Punjab, India

[2]HOD, Department of Power Electronics and Drives, Lovely Professional University, Punjab, India

ABSTRACT

This paper study about power quality improvement of the wind energy system connected to grid. For the power quality improvement we used UPFC. UPFC is a versatile FACTS (Flexible AC Transmission Systems) device that is the most sophisticated and complex power electronics equipment and has emerged for control and optimization of power flow and also to regulate the voltage in the electrical power transmission system. This project propose the real, reactive power and voltage control through a transmission line by placing UPFC at the sending end using MATLAB simulation. The control scheme has the fast dynamic response and hence is adequate for improving transient behavior of power system after transient conditions. When no UPFC is installed, real and reactive power through the transmission line cannot be regulated. A control system which enables the UPFC to follow the changes in reference values like AC voltage, DC voltage and angle order of the series voltage source converter is simulated. In this control system, a generalized pulse width modulation technique is used to generate firing pulses for both the converters. Simulations will be carried out using MATLAB/SIMULINK software to check the performance of UPFC.

KEYWORDS: FACTS, Reactive Power, Real Power UPFC

INTRODUCTION

At present years wind power generation has experienced a very fast development in the whole world. As the wind energy power penetration into the grid is increasing quickly, the influence of wind turbines on power quality is becoming an important issue. Flicker is induced by voltage fluctuations, which are caused by load flow changes in the grid. Grid connected wind turbines may have considerable fluctuations in output power, which depend on the wind power generation technology applied [1].

The flicker emission produced by grid connected wind turbines during continuous operation is mainly caused by fluctuations in the output power due to wind speed variations, the wind gradient and the tower shadow effect [1]. Regarding to variable speed wind turbines, which have the ability to reduce power fluctuations, flicker emission is quite different from that generated by fixed speed wind turbines. Variable speed operation of the rotor has the advantage that the faster power variations are not transmitted to the grid but are smoothed by the flywheel action of the rotor. Variable speed wind turbines fed induction generators, the most popular installed variable speed wind turbines worldwide, are the main research interest here [1]. Even' though variable speed wind turbines have good performance with respect to flicker emission, flicker mitigation becomes necessary as the wind power penetration level increases. Flicker mitigation can be realized by appropriate reactive compensation.

The most commonly used devices for flicker mitigation is the STATCOM and SSSC. However, UPFC has received much attention recently. Compare with STATCOM and SSSC, UPFC as overall superior functional characteristics, better performance, faster response and capable of providing both active and reactive power. UPFC is a combination of separate shunt and series elements. That means combination of STATCOM and SSSC. So the it has combine features of STATCOM and SSSC[2]. STATCOM is a shunt controller it inject current into the system at the point of combination. As long as the injected current is in phase with the line voltage, the shunt controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well [2] [3].

SSSC is a Series controller inject voltage in series with the line. As long as the voltage is in phase with the line current, the series controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well[4]. UPFC is a combination of separate STATCOM and SSSC controllers, which are controlled in a coordinated manner, or a unified power flow controller with series and shunt elements. In principle, combined shunt and series controllers inject current into the system with shunt part of the controller voltage in series in the line with the series part of the controller. However, when the shunt and series controllers are unified, there can be a real power exchange between the series and shunt controllers via the power link. Whenever we connect a UPFC to the grid of the wind power generating system it regulates the voltage and power flow in a grid. By connecting of UPFC voltage unbalance and harmonics are reduce. So we can increase the power penetration level of wind energy system.

POWER QUALITY PROBLEMS IN WIND POWER GENERATING SYSTEM CONNECTED TO GRID

- **Voltage Unbalance**

According to the electricity board, the variation in the steady state voltage is in the range from + 5% to –15% at the wind turbine terminals in the wind farms [8]. For low voltages, the no load losses decrease slightly due to reduced iron losses, whereas the full-load losses (i.e. losses at rated power) increase due to increased currents in the generator windings and also reduce the power reduction. Too low voltages can cause the relay protection to trip the wind turbines.

- **Voltage Flicker**

Voltage flicker describes dynamic variations in the network voltage. Traditionally it was of concern when the connection of large fluctuating loads (e.g. arc furnaces, rock crushing machinery sawmills, etc.) was under consideration. However, it is of considerable significance for wind farms, which: (i) often use relatively large individual items of plant compared to load equipment; (ii) may start and stop frequently; (iii) may be subject to continuous variations in input power. Flicker produced during continuous operation is caused by power fluctuations, which mainly emanate from variations in the wind speed, the tower shadow effect and mechanical properties of the wind turbine. Flicker due to switching operations arises from the start and shut down of the wind turbines [6][7].

- **Frequency Range**

According to electricity boards and manufacturers, the grid frequency in India can vary from 47 to 51.5 Hz. Most of the time, the frequency is below the rated 50 Hz. For wind turbines with induction generators directly connected to the micro grid, frequency variation will be very considerable. Frequency variation is directly affected by the power production of wind mill [8].

- **Harmonics and Inter Harmonics**

The emission of harmonic and inter harmonic currents from wind turbines with directly connected induction generators is expected to be negligible. But Wind turbines connected to the grid through power converters however emit harmonic and/or inter harmonic currents that contribute to the voltage distortion. Inverters based on new technologies have a limited emission of harmonics at lower frequencies compared to the converters used in the first generation of variable speed wind turbines. Instead they produce inter harmonics at higher frequencies. Due to this harmonics the wind turbines generator affects [6]

- High System Losses
- Generator Overheating
- Low Power Factor
- Electronic Protective Device Malfunction
- High Telephone Interference Factor
- Increased generator Vibration
- **Transients**

Transients, commonly called "surges," are sub-cycle disturbances of very short duration that vary greatly in magnitude. When transient occur, thousands of voltage can be generated into the electrical system, causing problems for equipment down the line [6][7].

Causes: Lighting; equipment start-up and shutdown; welding equipment

Effects: Processing errors; computer lock-up; burned circuit boards; degradation of electrical insulation; equipment damage.

POWER QUALITY IMPROVEMENT BY FACTS CONTROLLER UPFC

The FACTS device are based on power electronic controllers that enhances the capacity of the transmission line.

These controllers are fast and increases the stability operating limits of the transmission systems when their controllers are properly tuned. FACTS devices are mostly used to regulate voltage and schedule power flow through some lines. FACTS device has the potential to operate the more flexible and economic way. For the power quality improvement of wind energy system we have used UPFC.

Operation of UPFC

A UPFC (unified power flow controller) is the the most versatile FACTS controller for regulation of voltage and power flow in a transmission line. It consists of two voltage sources converters (vsc) one shunt connected and the other series connected. The dc capacitors of the two converters are are connected in parallel as show in figure 1 [9]. If the switches 1 and 2 open, the two converters work as STATCOM and SSSC controlling the line reactive current and reactive voltage injected in the shunt and series respectively in the line. The closing of the switches 1 and 2 enables the two converters to exchange real (active) power flow between the two converters. The active power can be either absorbed or supplied by the series connected converter, the provision of a controllable power source on the DC side of the series connected converter, results in the control of both real and reactive power flow in the line (say, measured at the receiving end of the line). The shunt connected converter not only provides the necessary power required, but also the reactive current injected at the converter bus. Thus, a UPFC has 3 degrees of freedom unlike other FACTS controllers which have only one degree of freedom (control variable) [2].

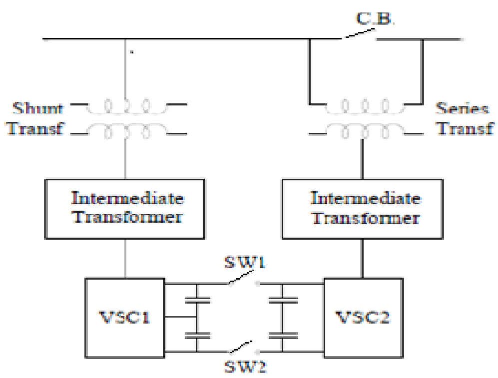


Figure 1: Basic UPFC Schematic

Operating Modes of UPFC

The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, into the transmission line. This current consists of two components with respect to the line voltage: the real or direct component, which is in phase or in opposite phase with the line voltage, and the reactive or quadrature component, which is in quadrature. The direct component is automatically determined by the requirement to balance the real power of the series inverter. The quadrature component, instead, can be independently set to any desired reference level (inductive or capacitive) within the capability of the inverter, to absorb or generate respectively reactive power from the line [10].

- **VAR Control Mode**

The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the VAR reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, Vdc, is also required [10] [11].

- **Automatic Voltage Control Mode**

The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways [10] [11].

Direct Voltage Injection Mode: The reference inputs are directly the magnitude and phase angle of the series voltage.

Phase Angle Shifter Emulation Mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.

Line Impedance Emulation Mode: The reference input is an impedance value to insert in series with the line impedance.

Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

Operation Principle of UPFC

The UPFC consists of two voltage source converters; series and shunt converter, which are connected to each other with a common dc link. Series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line, while shunt converter or Static Synchronous Compensator (STATCOM) is used to provide reactive power to the ac system, beside that, it will provide the dc power required for both inverter. Each of the branches consists of a transformer and power electronic converter. These two voltage source converters shared a common dc capacitor [10][16].

The energy storing capacity of this dc capacitor is generally small. Therefore, active power drawn by the shunt converter should be equal to the active power generated by the series converter. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system. Figure 2 shows the schematic diagram of the three phase UPFC connected to the transmission line. Control of power flow is achieved by adding the series voltage, VS with a certain amplitude, VS and phase shift, φ to V1. This will gives a new line voltage V2 with different magnitude and phase shift. As the angle φ varies, the phase shift δ between V2 and V3 also varies. Figure 3 shows the single line diagram of the UPFC and phasor diagram of voltage and current.

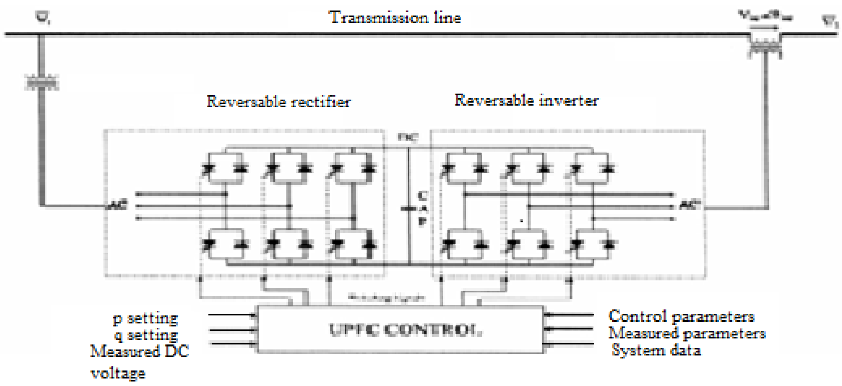
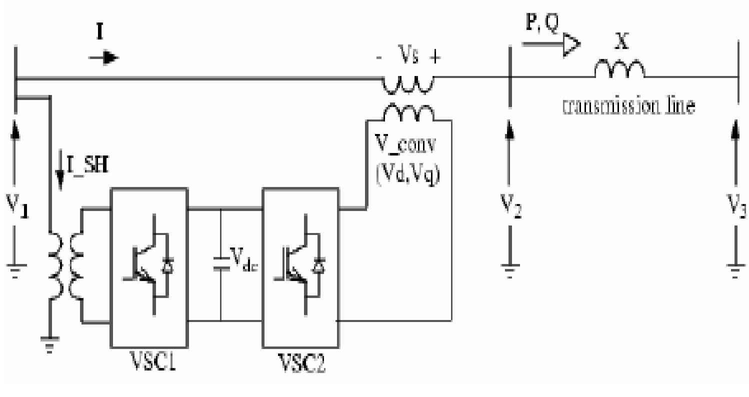


Figure 2: Schematic Diagram of 3 Phase UPFC Connected to Transmission Line



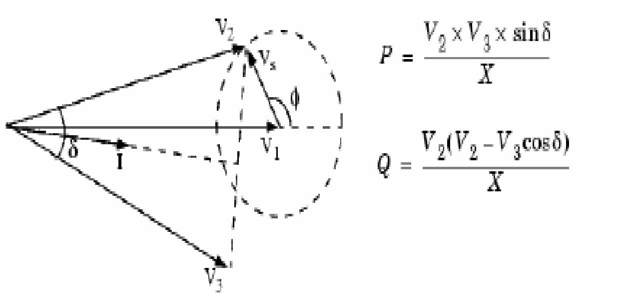


Figure 3: Shows the Single Line Diagram of the UPFC and Phasor Diagram of Voltage and Current

MATLAB/SIMULATION WITH RESULTS

A unified power flow controller (UPFC) is used to control the power flow in a 125kv/25kv grid connected transmission system. The model of induction generator based 9Mw wind frame connected with UPFC is modeled and simulated using MATLAB/SIMULINK.

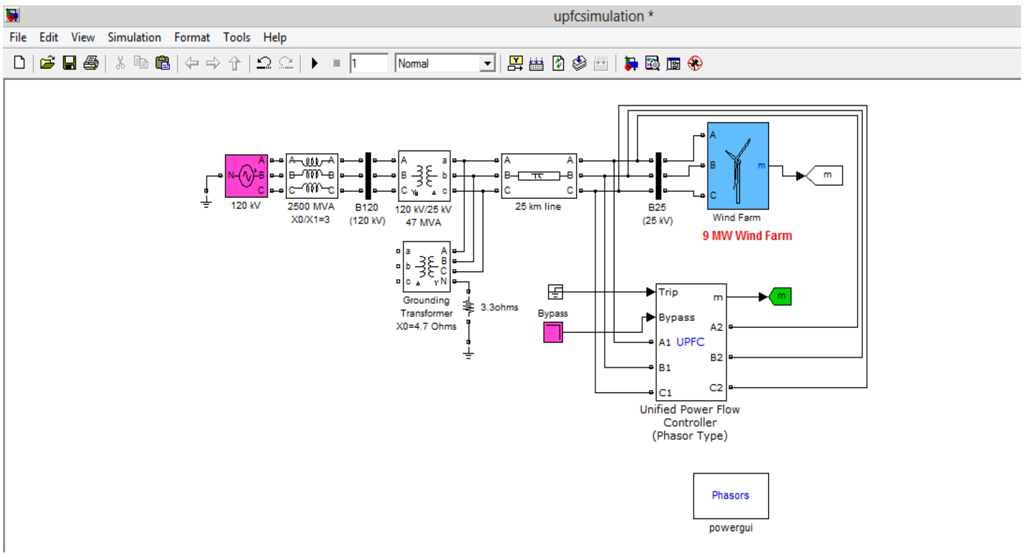


Figure 4: Induction Generator Based Wind Power Generating System with UPFC

The UPFC is connected to the line of 25kms at bus 25 and the bus 120 is used to control the real and reactive power flowing through bus B25, UPFC can be operated in three modes, first mode is when the shunt and series converters are inter connected through the dc bus. Second mode is static synchronous compensator (STATCOM) controlling voltage at bus B1. Third mode is static synchronous series capacitor (SSSC) inject voltage while keeping injected voltage in phase with current.

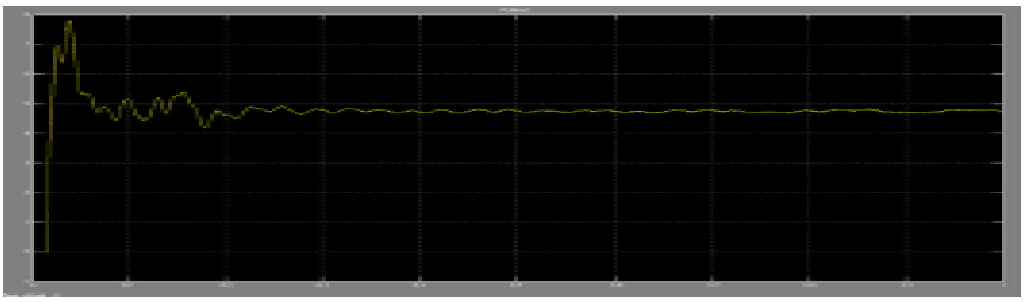


Figure 5: Wind Turbine Real Power (MW)

When two converters are operated in UPFC mode the shunt converter operates as a STATCOM. It controls the bus B120 voltage by the absorbed or generated reactive power while also allowing active power transfer to the SSSC through dc bus.

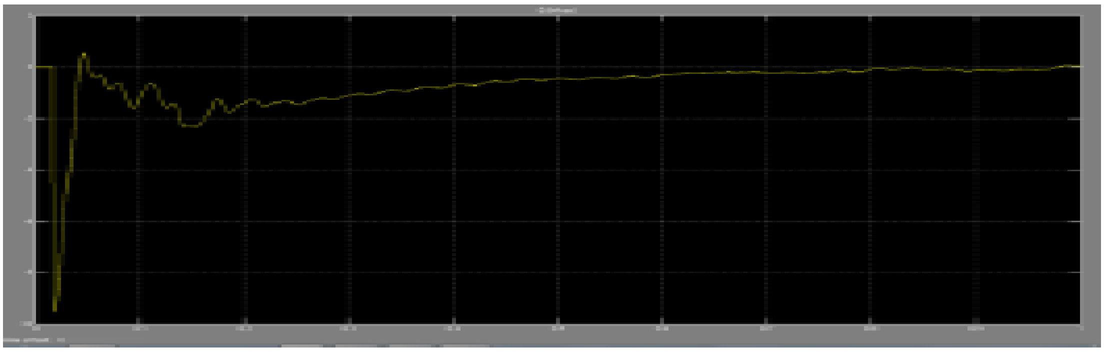


Figure 6: Wind Turbine Reactive Power (MVAR)

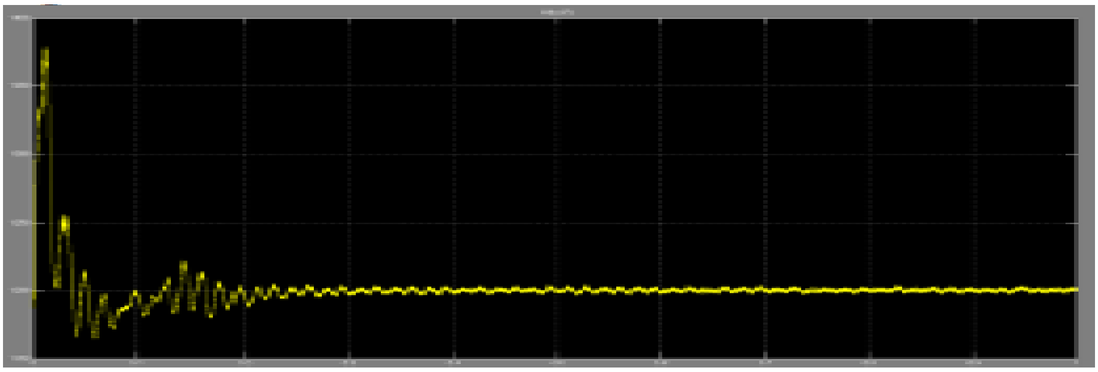


Figure 7: DC Link Voltage (Vdc)

Figure 8: The Voltage and Current at Busb25 without UPFC

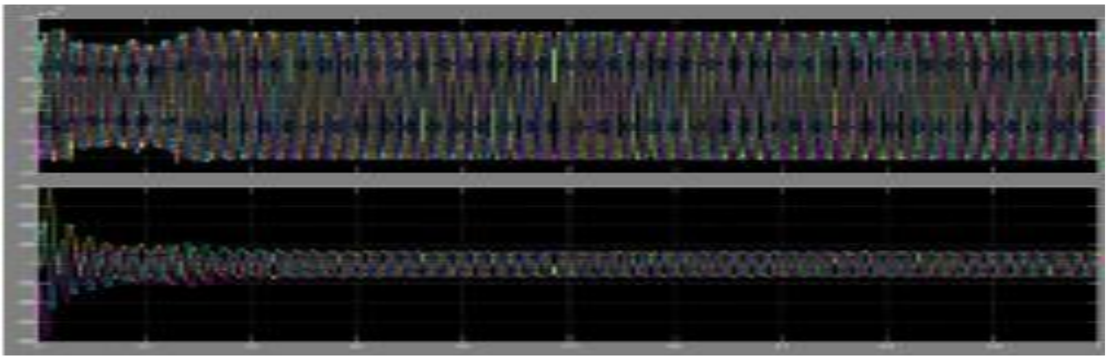


Figure 9: The Voltage and Current at Bus B25 with UPFC

The power quality analysis in induction based wind power generating system is done by using the FFT tool of the powergui, to find the decrease in the total harmonic distortion (THD) of the current injected in the system. The FFT of Iabc_25 without UPFC controller is show in figure 10, and the FFT of Iabc _25 with UPFC controller is shown in figure11.

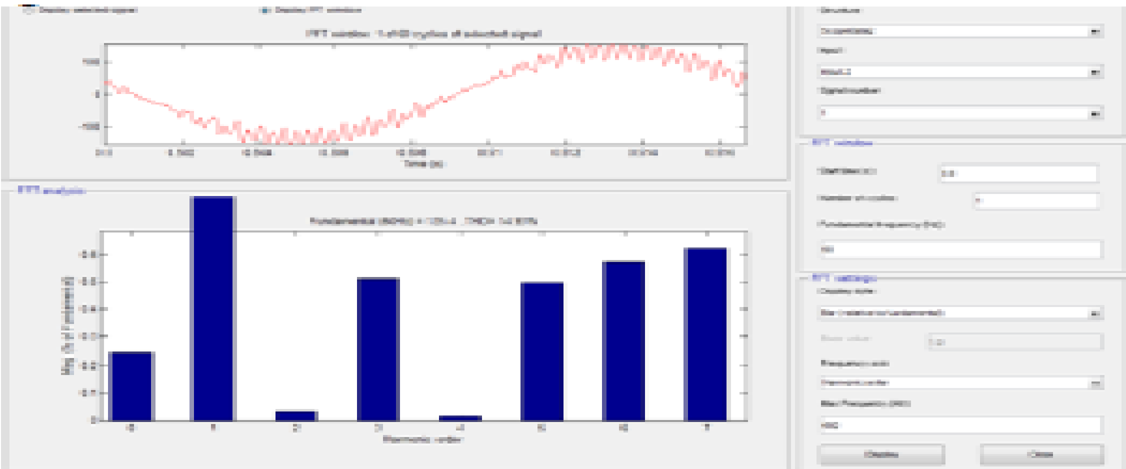


Figure 10: The FFT of Iabc _25 without UPFC

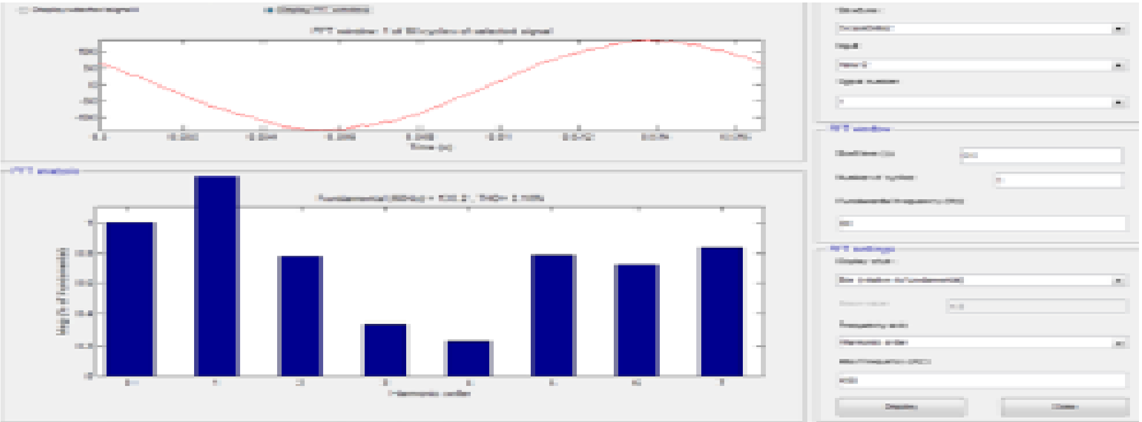


Figure 11: The FFT of Iabc _25 with UPFC Controller

The total harmonic distortion in FFT analysis at Vabc _B25 without UPFC 12.15%, with UPFC 1.88%. and at Iabc_B25 without 14.93%, with UPFC 1.90%

From the figures it can be observed that the UPFC controller mitigates the harmonic distortion that caused by the nonlinear load where all values of THD for voltage and current at BUS_25 are decreased to values are under IEEE standards.

CONCLUSIONS

In this work, power quality issues such as voltage fluctuation, harmonics are analyzed with respect to wind power generator connected to grid. The modeling and the simulation techniques of a wind power generating system connected to grid had been analyzed by using MATLAB/SIMULATION. From this analysis, it is found that voltage fluctuation occurs frequently due to synchronization problem associated with connection of wind generator to grid. Hence UPFC was used to inject reactive power to maintain voltage level within the limits and also eliminates power fluctuations and this confirms the excellent performance of the proposed system for power quality improvement. It was proved that UPFC is the combination of shunt and series voltage source converter which is used to eliminate the harmonics generated in the system.

REFERENCES

1. C. Carrillo, A. E. Feijoo & J. Cidras, Power fluctuations in an isolated wind plant, IEEE Trans. on Energy Conversions, Vol. 19, No. 1, 2004, 217-221.
2. N. G. Hingorani and L. Gyugyi, Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems, New York: IEEE, 2000.
3. Sharad W. Mohod, *Member, IEEE*, and Mohan V. Aware Sharad IEEE SYSTEMS JOURNAL, VOL. 4, NO. 3, SEPTEMBER 2010
4. F. Wang, “Design of SSSC Damping Controller to Improve Power System Oscillation Stability, “0-7803-5546-6/99/$10.00 © 1999 IEEE.
5. K. S. Hook, Y. Liu, and S. Atcitty, “Mitigation of the wind generation integration related power quality issues by energy storage,” *EPQU J.*, vol. XII, no. 2, 2006.
6. Power Quality issues standards and guide lines‖, IEEE, Vol-32, May96
7. J. J. Gutierrez, J. Ruiz, L. Leturiondo, and A. Lazkano, “Flicker measurement system for wind turbine certification,” *IEEE Trans. Instrum. Meas.*, vol. 58, no. 2, pp. 375–382, Feb. 2009.
8. K. C. Divyaa; P.S. Nagendra Raoa Effect of Grid Voltage and Frequency Variations on the Output of Wind Generators” Electric Power Components and Systems, Taylor & Francis no36: vol 6, 2008.pp 602 — 614.
9. K. Shanthini, Dr. N. Verappan Power Quality Enhancement of Wind Generators Connected to Grid *978-1-4673-4634-4/12/$31.00* ©2012 IEEE
10. T. T. Nguyen and V.L. Nguyen,” Dynamic Model of Unified power Flow Controllers in load flow analysis”, IEEE1- 4244-0493-2/06, 2006.
11. S. Muthukrishna and A. Nirmalkumar, “Enhancement of power quality in 14- bus system using UPFC”. Research Journal of Applied sciences, Engineers and Technology 2(4). Maxwell scientific organization, 2010.
12. Sen, K. K and A.J.F. Keri, 2003. “Comparison of field results and digital simulation results of Voltage-Sourced Converter-based FACTS controller”. IEEE Trans. Power Del., 18(1): 300-306.