

## **POWER QUALITY IMPROVEMENT IN GRID CONNECTED WIND ENERGY SYSTEM USING UPQC**

**S. RAJESH RAJAN**

Assistant Professor, Lord Jegannath College of Engineering and Technology, Ramanathichanputhur, Tamil Nadu, India

### **ABSTRACT**

Injection of the wind power into an electric grid affects the power quality. The performance of the wind turbine and thereby power quality are determined on the basis of measurements and the norms followed according to the guideline specified in International Electro-technical Commission standard, IEC-61400. This paper demonstrates the power quality problem due to installation of wind turbine with the grid. In this proposed scheme Unified Power Quality Conditioner (UPQC) is connected at a point of common coupling with a battery energy storage system (BESS) to mitigate the power quality issues. The battery energy storage is integrated to sustain the real power source under fluctuating wind power. The UPQC control scheme for the grid connected wind energy generation system for power quality improvement is simulated using MATLAB/SIMULINK in power system block set. The effectiveness of the proposed scheme relieves the main supply source from the reactive power demand of the load and the induction generator. The development of the grid co-ordination rule and the scheme for improvement in power quality norms as the grid has been presented.

**KEYWORDS:** International Electro-Technical Commission (IEC), Power Quality, Wind Generating System (WGS)

### **INTRODUCTION**

The causes of power quality problems are generally complex and difficult to detect when we integrate a wind turbine to the grid. Technically speaking, the ideal AC line supply by the utility system should be a pure sine wave of fundamental frequency (50/60Hz). We can therefore conclude that the lack of quality power can cause loss of production, damage of equipment or appliances or can even be detrimental to human health. It is therefore imperative that a high standard of power quality is maintained. This project demonstrates that the power electronic based power conditioning using custom power devices like P-STATCOM can be effectively utilized to improve the quality of power supplied to the customers.

Power quality and reliability cost the industry large amounts due to mainly sags and short-term interruptions. Distorted and unwanted voltage wave forms, too. And the main concern for the consumers of electricity was the reliability of supply. Here we define the reliability as the continuity of supply. The problem of distribution lines is divided into two major categories. First group is power quality, second is power reliability. First group consists of harmonic distortions, impulses and swells. Second group consists of voltage sags and outages. Voltage sags is much more serious and can cause a large amount of damage. If exceeds a few cycle, motors, robots, servo drives and machine tools cannot maintain control of process.

Transmission lines are exposed to the forces of nature. Furthermore, each transmission line has its load ability limit that is often determined by either stability constraints or by thermal limits or by the dielectric limits. Even though the power quality problem is distribution side problem, transmission lines are often having an impact on the quality of the power supplied. It is however to be noted that while most problems associated with the transmission systems arise due to

the forces of nature or due to the interconnection of power systems, individual customers are responsible for more substantial fraction of the problems of power distribution systems.

## UPQC

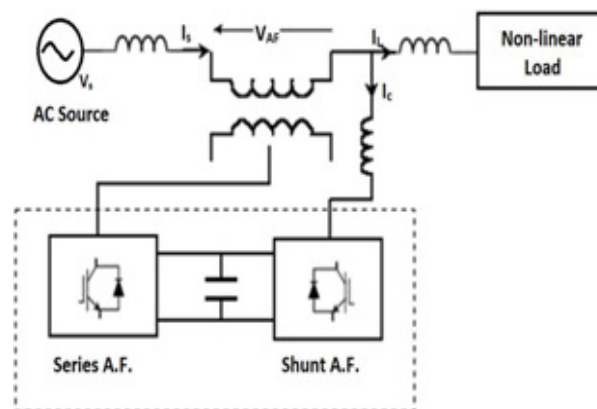
The best protection for sensitive loads from sources with inadequate quality, is shunt-series connection i.e. unified power quality conditioner (UPQC). Recent research efforts have been made towards utilizing unified power quality conditioner (UPQC) to solve almost all power quality problems for example voltage sag, voltage swell, voltage outage and over correction of power factor and unacceptable levels of harmonics in the current and voltage. The basic configuration of UPQC is shown in figure 1

The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics [14]. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected as one of the most powerful solutions to large capacity sensitive loads to voltage flicker/imbalance.

Unified Power Quality Conditioner (UPQC) for non-linear and a voltage sensitive load has following facilities:

- It eliminates the harmonics in the supply current, thus improves utility current quality for nonlinear loads.
- UPQC provides the VAR requirement of the load, so that the supply voltage and current are always in phase, therefore, no additional power factor correction equipment is necessary.
- UPQC maintains load end voltage at the rated value even in the presence of supply voltage sag.
- The voltage injected by UPQC to maintain the load end voltage at the desired value is taken from the same dc link, thus no additional dc link voltage support is required for the series compensator.

The UPQC consists of two three phase inverters connected in cascade in such a manner that Inverter I is connected in series with the supply voltage through a transformer inverter II is connected in parallel with the load. The main purpose of the shunt compensator is to compensate for the reactive power demanded by the load, to eliminate the harmonics and to regulate the common dc link voltage. The series compensator is operated in PWM voltage controlled mode. It injects voltage in quadrature advance to the supply voltage (current) such that the load end voltage is always maintained at the desired value. The two inverters operate in a coordinated manner.



**Figure 1: Unified Power Quality Conditioner (UPQC)**

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load [1]. It is a type of hybrid APF and is

the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system. Figure 1 shows the system configuration of a single-phase UPQC. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply [2]. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor.

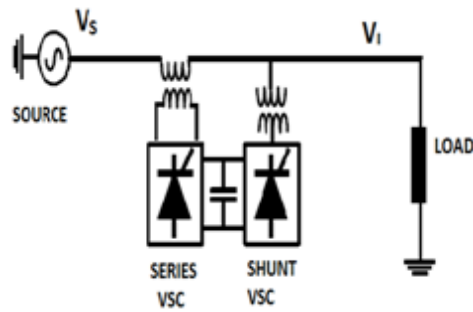


Figure 2: Block Diagram of UPQC

**TOPOLOGY FOR POWER QUALITY IMPROVEMENT**

The 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 their phase-angle with respect to source voltage has a desired value. The injected current will cancel out the reactive part and harmonic part of the load and induction generator current, thus it improves the power factor and the power quality. To accomplish these goals, the grid voltages are sensed and are synchronized in generating the current command for the inverter. The proposed grid connected system is implemented for power quality improvement at point of common coupling (PCC).

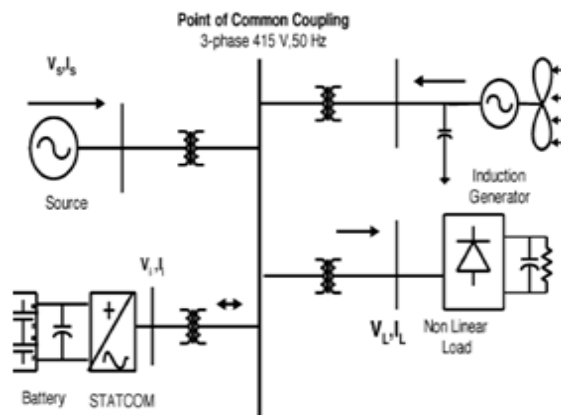


Figure 3: Grid Connected System for Power Quality Improvement of Proposed System

The grid connected system in Figure 3, consists of wind energy generation system and battery energy storage system with UPQC

**Wind Energy Generating System**

In this configuration, wind generations are based on constant speed topologies with pitch control turbine. The induction generators used in the proposed scheme because of its simplicity, it does not require a separate field circuit, it can

accept constant and variable loads, and has natural protection against short circuit. The available power of wind energy system is presented asunder the equation,

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

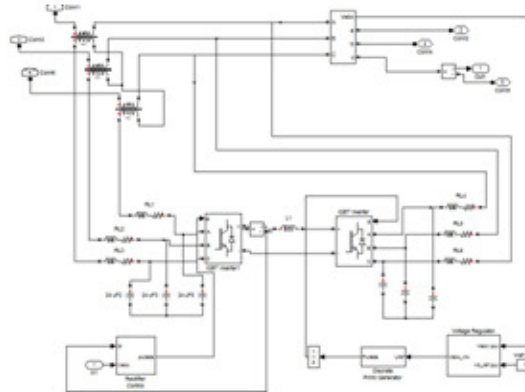
It is not possible to extract all kinetic energy of wind, thus it extract a fraction of power in wind, called power coefficient  $C_p$  of the wind turbine, and is given in eq

$$P_{mesh} = C_p P_{wind}$$

### BESS-STATCOM

The battery energy storage system (BESS) is used as an energy storage element for the purpose of voltage regulation. The BESS will naturally maintain dc capacitor voltage constant and is best suited in STATCOM since it rapidly injects or absorbed reactive power to stabilize the grid system. It also control 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. The battery is connected in parallel to the dc capacitor of STATCOM.

The STATCOM is a three-phase voltage source inverter having the capacitance on its DC link and connected at the point of common coupling. The STATCOM injects a compensating current of variable magnitude and frequency component at the bus of common coupling.



**Figure 4: System Operational Scheme in UPQC**

The shunt connected STATCOM with battery energy storage is connected with the interface of the induction generator and non-linear load at the PCC in the grid system. The STATCOM compensator output strategy, so as to maintain the power quality norms in the gridsy stem. The current control strategy is included in the control scheme that defines the functional operation of the STATCOM compensator in the power system. A single STATCOM using insulated gate bipolar transistor is proposed to have a reactive power support, to the induction generator and to the non linear load in the grid system.

## SIMULATION RESULTS

### Simulation Model

Wind generation using wind turbine, pitch control, Induction Generator. Here we are using the induction generator as generating machine due to its advantages over other machines for its simplicity and economical factors. The pitch angle controller makes the angle of the turbine blade to adjust in such a way that the speed of rotation at every velocity of the wind is maintained constant. And the parallel capacitive bank is to supply the reactive power to the IM

running as the generator. Here we considered the per unit values in the closed loop that can be seen from the Figure 5. The rms values of the current and voltage generated is taken and the power is being calculated at every sampling time interval and the wave form is being traced in the scope. A timer is used in figure for assigning the wind velocity at 3 different states which will be linearise after some loop operations.

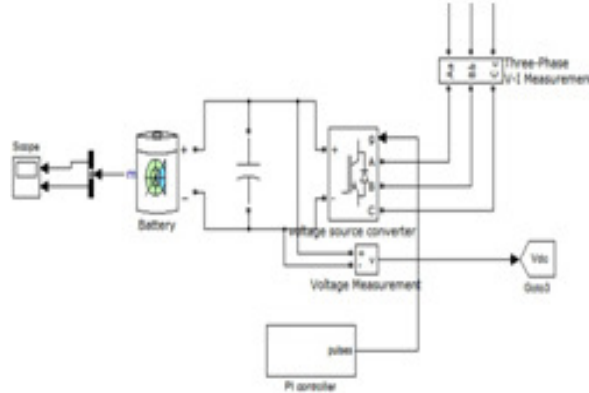


Figure 5: Voltage Source Inverter with Battery and Controller

**Parameters**

Grid voltage	415 V.
Operating frequency	60 HZ.
Induction generator	3.35KVA, 415V, 60 Hz.
Speed	1440rpm,
Rr	0.01Ω,
Rs	0.015Ω,
Ls=Lr	0.06H.
Inverter - DC Link Voltage	800V,
DC Link Capacitance	100μF,
Switching Frequency	2 kHz.
Non linear load	25 KW.

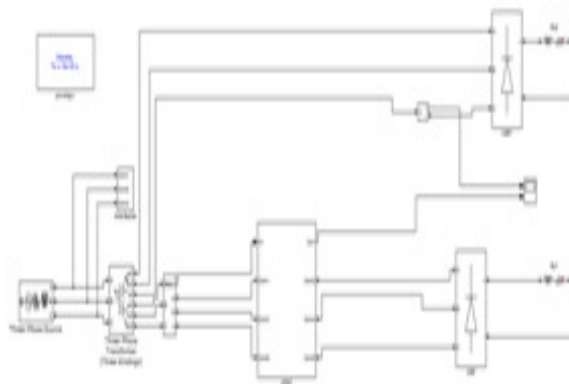
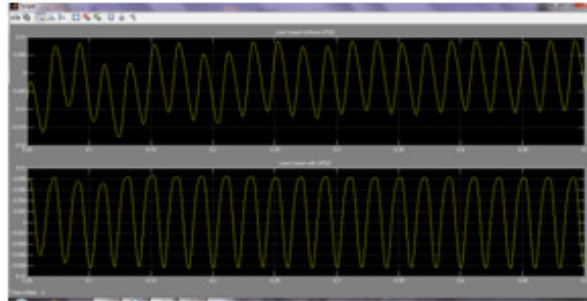
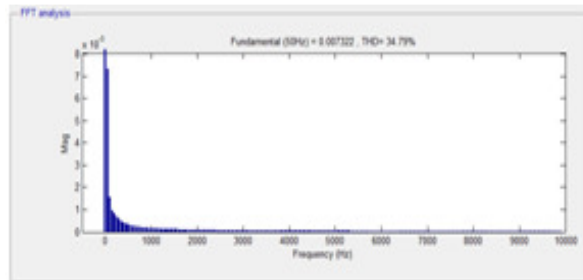


Figure 6: Over all Circuit Diagram in Simulink with UPQC

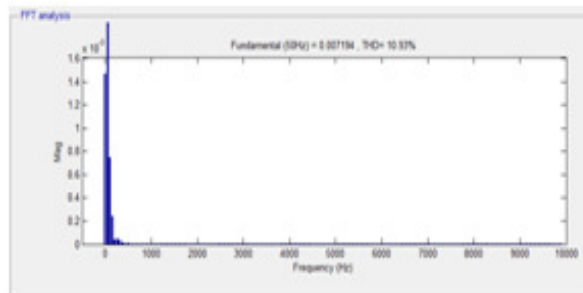
## RESULTS



**Figure 7: Line Current**



**Figure 8: Without UPQC**



**Figure 9: With UPQC**

## CONCLUSIONS

In this paper we present the FACTS device (UPQC) -based control scheme for power quality improvement in grid connected wind generating system and with nonlinear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the UPQC in MATLAB/SIMULINK for maintaining the power quality is to be simulated. It 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.

Thus the integrated wind generation and FACTS device with BESS have shown the outstanding performance in maintaining the voltage profile as per requirement. Thus the proposed scheme in the grid connected system fulfils the power quality requirements and maintains the grid voltage free from distortion and harmonics.

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