

## International Journal of Innovative Research in Science, Engineering and Technology

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# A Study of Unified Power Quality Conditioner in Wind Energy Conversion System

Subhasmita Baral<sup>1</sup>, Chakrapani Ghadai<sup>2</sup>, Diptimoyee Bhuyan<sup>3</sup>, Devidarshinee Pradhan<sup>4</sup>

M.Tech Scholar, Department of Electrical Engineering, CET, Bhubaneswar, India<sup>1,3,4</sup>

Assistant Professor, Department of Electrical Engineering, CET, Bhubaneswar, India<sup>2</sup>

**ABSTRACT:** Wind energy is one of the most efficient as well as cost effective renewable energy resources for generating electricity compared to other conventional types of energy resources. When wind energy source is integrated to the existing power system, various power quality issues arise at different level of power system. To overcome these problems, here a unified power quality conditioner (UPQC) in wind energy conversion system (WECS) is used. In Unified Power Quality Conditioner (UPQC) a series active filter and a shunt active filter are connected in a back-to-back configuration to simultaneously compensate the problems due to voltage distortion, voltage unbalances and to compensate harmonics produced due to current.

**KEYWORDS:** Unified power quality conditioner (UPQC), wind energy conversion system (WECS), Power quality

### I.INTRODUCTION

Due to the increasing demand various renewable energy sources are connected to the existing power system. Wind energy source is extensively used as it is cost effective, eco friendly as well as an efficient energy source. One of the most efficient wind energy conversion systems is permanent magnet synchronous generator based wind energy conversion system with fixed pitch angle. When wind energy source is integrated to the electric grid it affects the power quality [1]. Therefore, various power electronic devices used in integration of wind energy conversion system into the electric grid. The series active power filter is generally used for compensation of voltage harmonics and voltage sags [2]. The shunt active power filter is used to mitigate harmonics produced due to current. The UPQC, which has two active power filter connected back to back with a common DC link capacitor, can compensate the voltage sag and swell, the harmonic current and voltage, and control the power flow and voltage unbalance [3]. A versatile device like UPQC can be a universal solution to various grid integration issues of wind energy conversion system and a more reliable operation of wind generators can be achieved. The block diagram of proposed system is given below in the figure 1.

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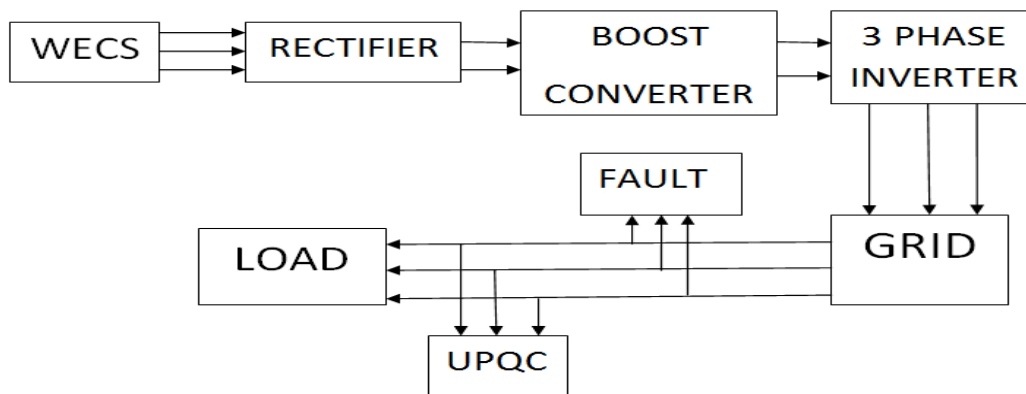


Figure 1 Block diagram of UPQC with WECS

## II. WIND ENERGY CONVERSION SYSTEM (WECS)

The wind energy conversion system (WECS) converts wind energy into electrical energy. A wind energy conversion system consists of a wind turbine, generator, and Power electronics converter connected to the grid [4]. The block diagram of WECS is given in the figure 2. The wind turbine system takes the kinetic energy of wind as input and provides mechanical power as output, and then it is fed to the electrical generator to produce three phase electrical power as output. Then ac to dc converter converts three phase ac voltage to dc voltage. After that dc to dc converter converts the unregulated dc to a fixed dc. Lastly a dc to ac converter is used to convert dc voltage to required three phase voltage which is synchronized with the grid. In this way the kinetic energy of the wind is converted to the electrical energy in the wind energy conversion system.

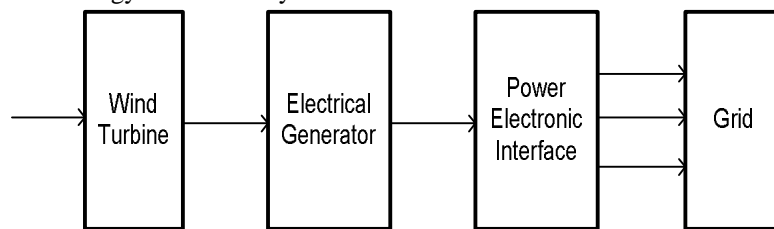


Figure 2 wind energy conversion system

The output power of the wind turbine is given by,

$$P_{\text{mech}} = \frac{1}{2} \rho A_r C_p(\lambda) w^3 \quad (1)$$

Where A is the swept area of wind turbine rotor. The power coefficient  $C_p$  as a function of  $\lambda$  &  $\beta$  is expressed by equation (2).

$$C_p(\lambda, \beta) = 0.5176 * (116 / (1 / (\lambda + 0.08 * \beta) - 0.035 / (\beta^3 + 1))) - 0.4 * \beta - 5 * \exp(-21 / (1 / (\lambda + 0.08 * \beta) - 0.035 / (\beta^3 + 1))) + 0.0068 * \lambda \quad (2)$$

The tip-speed ratio is given by the expression,

$$\lambda = \frac{\Omega_r R_r}{w} \quad (3)$$

Where w is the wind speed,  $\Omega_r$  is the rotor speed,  $R_r$  is the rotor plane radius,  $\rho$  is the air density. In general,

$$P_t = T_t W_m \quad (4)$$

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Combining eq<sup>n</sup> (2) ,eq<sup>n</sup>(3), eq<sup>n</sup> (4) , the expression for torque developed is expressed as,

$$T_t = \frac{1}{2} \rho A_r \frac{C_p(\lambda)}{\lambda} W^2 \quad (5)$$

The power extracted from the wind is maximum when the power coefficient is at its maximum. This occurs at a defined value of the tip speed ratio (TSR). Hence, for each wind speed; there is an optimum rotor speed where maximum power is extracted from the wind. Therefore, if the wind speed is assumed to be constant, the value of  $C_p$  depends on the wind turbine rotor speed. Thus, by controlling the rotor speed, the power output of the turbine is controlled.

### III. UNIFIED POWER QUALITY CONDINTIONER (UPQC)

The Unified power quality conditioner consists of following components

- **Series APF**-It is connected to the transmission line with the transformer. It is used to compensate the problems arises due to voltage distortions and voltage unbalances. The series APF injects a compensating voltage so that the voltage will be balanced and regulated.
- **Shunt APF**- Shunt APF is used to compensate for distortions & harmonics which are produced due to current. Due to non- linear load there is harmonics in load current, so shunt APF is used to keep source current completely sinusoidal and distortion free.
- **Series Transformer**-The necessary voltage which is generated by series APF so that the voltage at load side is perfectly balanced and regulated is injected into the transmission line with the help of series transformers.
- **DC link capacitor**-The two voltage source inverters are connected back to back through a DC capacitor. DC capacitor is provides a DC voltage for working of both the inverter. The DC capacitor also provides a real power difference between source and load during the transient period and also acts as a energy storage elements.

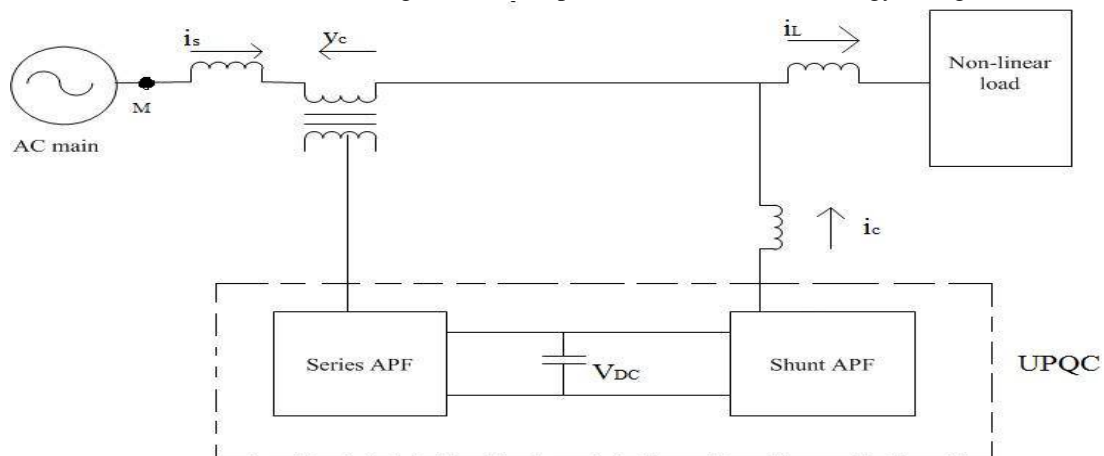


Figure 3 Configuration of UPQC

Operation of UPQC -

As given in the figure3,  $v_s$  is source voltage,  $v_c$  is series compensation voltage,  $i_s$  =source current and  $i_l$  is load current. The source voltage contains a positive, negative and zero, and also the harmonic components. The voltage at M is written as

$$V_s = v_{1n}(t) + v_{1p}(t) + \sum_{k=2}^{\infty} V_k(t) \quad (1)$$

Equation (1) can also be written as

$$v_s = v_{1n}(\sin(\omega t + \theta_{1n})) + v_{1p}(\sin(\omega t + \theta_{1p})) + \sum_{k=2}^{\infty} V_k(k\omega t + \theta_k) \quad (2)$$

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Here  $v_{1n}$ ,  $v_{1p}$  are fundamental frequency of component of negative sequence and positive sequence,  $v_k$  is the harmonic component, and  $\theta_{1n}$ ,  $\theta_{1p}, \theta_k$  are phase angle of voltages. Generally, UPQC can be configured in two ways by connecting the unit to terminal voltage  $v_t$  at point of common coupling (PCC).

## IV.SIMULATION OF TEST SYSTEM AND RESULTS

### (A) Simulation of Test System with Fault

Figure 4 shows the test system with fault. Here a three phase to ground fault is occurred during a period of 0.4 sec to 0.6 sec. The fault block is simulated using the MATLAB software.

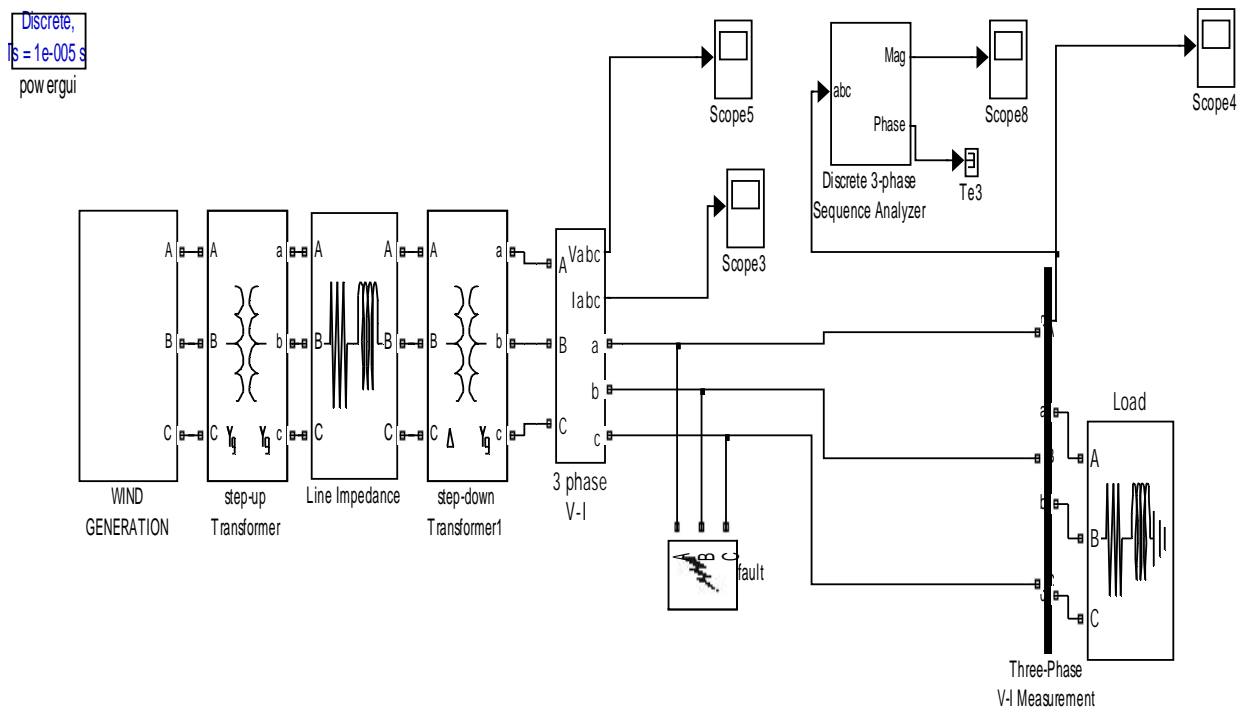


Figure 4 MATLAB Simulation of Test model with fault

### (B) Simulation of Test System with UPQC

The series compensating device is used to mitigate the power quality issue occurred due to the three phase to ground fault. But due to switching action of compensator switch there is a distortion of voltage due to the harmonics. So the THD level of the wave is increased. For reducing the voltage level a shunt compensating device is required. So a hybrid model of shunt compensator and series compensator which is aggregately termed as UPQC is implemented with the test model by using MATLAB software. The Simulink model of the test system with UPQC is shown in figure 5

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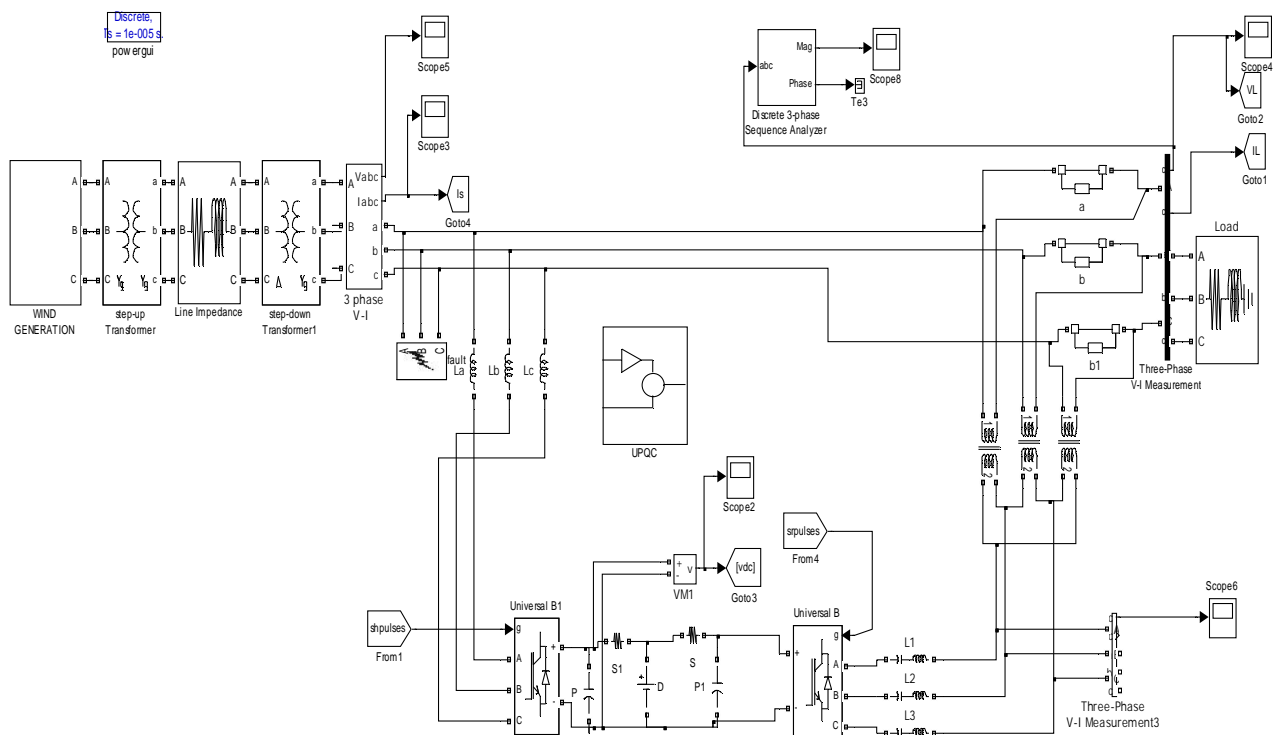


Figure 5 Simulation model of test system with UPQC

Results of the test model is given below

### (A) Results of the test system with fault

When fault is applied to the system, voltage sag occurs in the source voltage. The effect of fault on source voltage and the magnitude of source voltage is given in below figure 6 and figure 7.

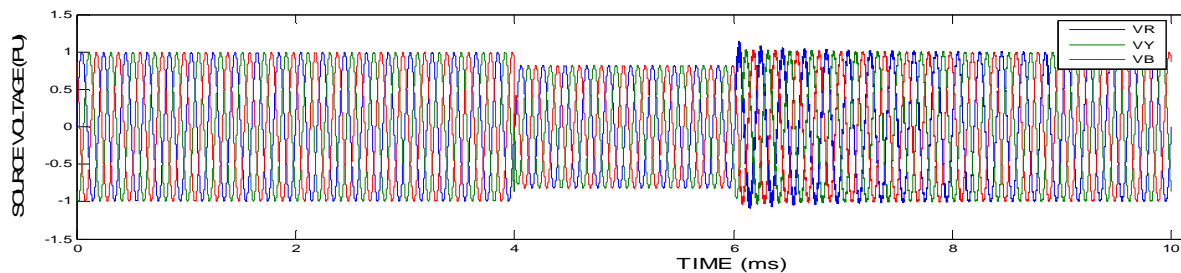


Figure 6 Source voltage of test model with fault

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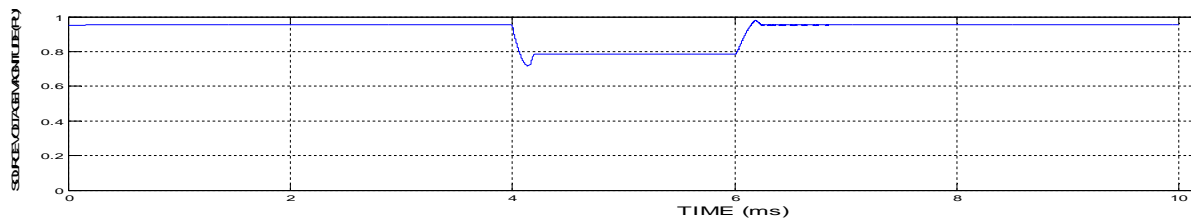


Figure 7 Source voltage magnitude of test model with fault

The effect of fault on load voltage and in the magnitude of load voltage is shown in bellow figure 8 and figure 9

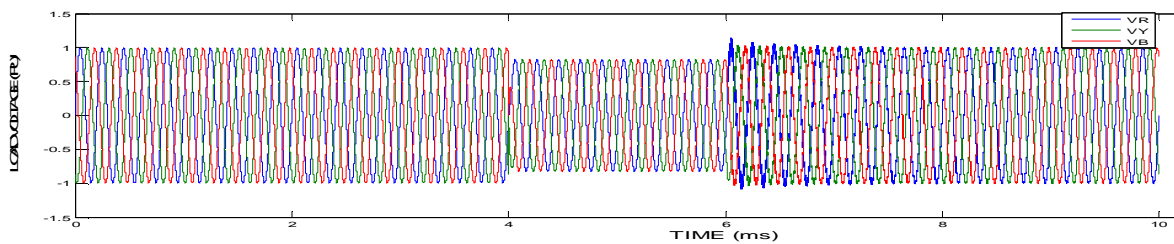


Figure 8 Load voltage of test model with fault

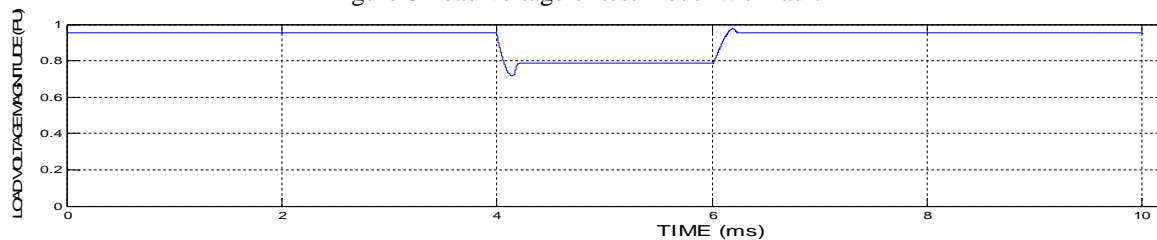


Figure 9 Load voltage magnitude of test model with fault

**(B) The output result of test system with UPQC is shown in figure 7**

When UPQC is connected to the system, the voltage sag and harmonics are mitigated. The source voltage and the magnitude of source voltage are shown in figure 10 and figure 11.

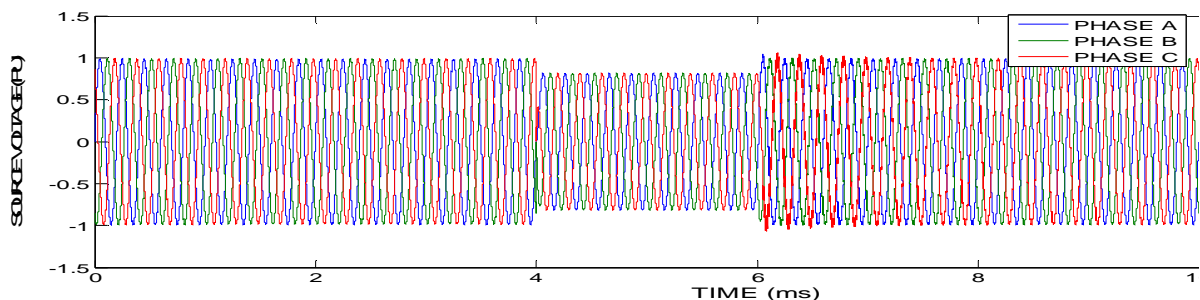


Figure 10 Source voltage of test model with UPQC

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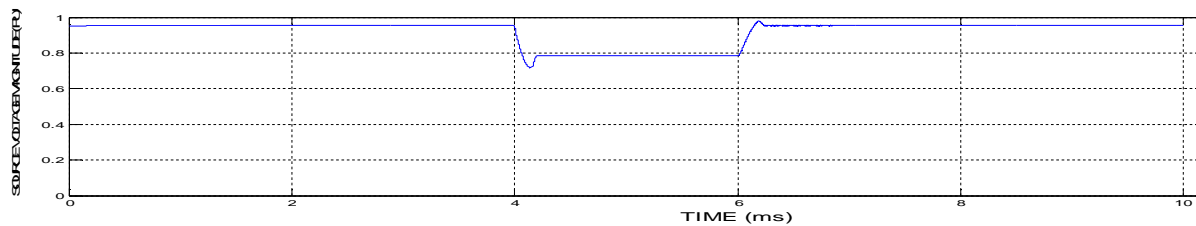
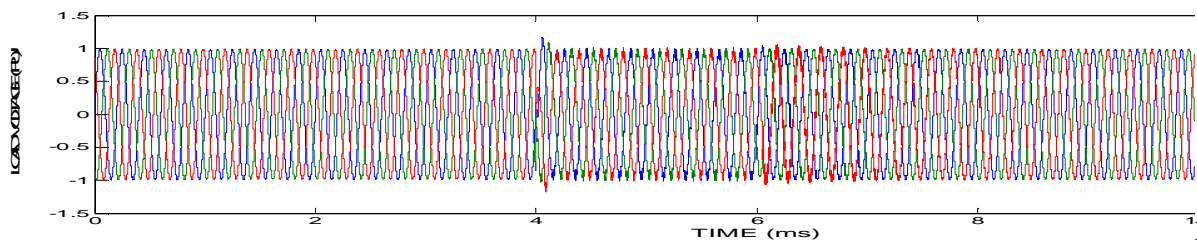


Figure 11 Source voltage magnitude of test model with UPQC

The voltage sag in load voltage is compensated completely, when we used UPQC in the system. The load voltage and the load voltage magnitude is shown in below figure 12 and figure 13.



12 Load voltage of test model with UPQC

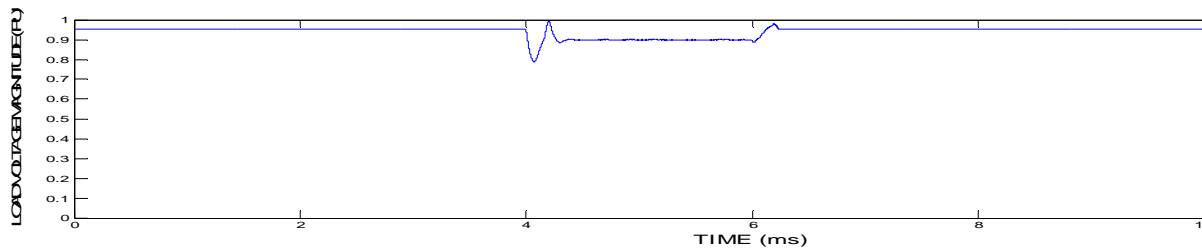


Figure 13 Load voltage magnitude of test model with UPQC

## V. CONCLUSION

When UPQC is used in WECS, the voltage sag is mitigated and load voltage is perfectly balanced. Also the harmonic distortion is compensated. The total harmonic distortion with series compensator is 11.70% and with UPQC it is reduced to 6.12%.

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