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# Unified Power Quality Conditioner in the Compensation Study of Wind Generation

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## ABSTRACT

*An electrical power system consists of wide range of electrical, electronic and power electronic equipment in commercial and industrial applications. The quality of the power is effected by many factors like harmonic contamination, increment of non-linear loads, large thyristor power converters, rectifiers etc., the problems are partially solved by passive filters but they cannot solve the random variation. So active filters can solve the problems, by using the combination of shunt and series Active Power Filters (APF) like Unified Power quality Conditioner(UPQC) aiming low cost for effective control. The quality of power worsens when the load changes drastically producing disturbances in the PCC voltage and stability in the wind farms when connected to weak grid. This situation occurs when the moderated power generation is connected through medium voltage distribution lines. In this paper is proposed a compensation strategy based on a particular Custom Power devices technology (CUPS) device, the Unified Power Quality Compensator (UPQC). The internal control strategy is based on the management of active power filters and the exchange of power between converters through UPQC DC–Link. This approach increases the compensation capability of the UPQC with respect to other custom strategies that use reactive power only. Simulations results show the effectiveness of the proposed compensation strategy for the enhancement of Power Quality and Wind Farm stability.*

***Keywords: Active Power Filters(APF), Point of Common Coupling(PCC), Power Quality(PQ), Unified Power Quality Conditioner(UPQC), Wind Farm(WF).***

## I. INTRODUCTION

Electric supply systems in today's world are widely interconnected. This is done for economic reasons to reduce the cost of electricity and to improve its reliability. These interconnections apart from delivering the power from pool power plants and load centres in order to pool power generation and reduce fuel cost. Thus they reduce the overall number of generating sources, but power transfer improves. The power system become increasingly complex to operate and it may lead to large power flows with inactive control, excessive reactive power and large dynamic swings between parts of the system. It is very difficult to control such transmission of power in such systems. Most of the controllers designed in the past were mechanical in nature. But mechanical controllers have numerous intrinsic problems. These problems paved the way to design power electronic controllers. These power electronic controllers are all grouped in a category called flexible AC transmission controllers or FACTS

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controllers[1]. FACTS allow flexible operation of AC transmission systems without stressing the changes in the system[2],[3]. FACTS controllers are used to regulate power flow inn critical lines and ease congestion in the electrical networks.

The injected harmonics due to the use of power electronic devices, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor. In addition to this, the power system is subjected to various transients like voltage sags, swells, flickers etc.[4]. Power Quality (PQ) mainly deals with issues like maintaining a fixed voltage at the Point of Common Coupling (PCC) for various distribution voltage levels irrespective of voltage fluctuations, maintaining near unity power factor power drawn from the supply, blocking of voltage and current unbalance from passing upwards from various distribution levels, reduction of voltage and current harmonics in the system and suppression of excessive supply neutral current [5],[6]. These all can be done by UPQC using control techniques which are used to maintain DC link capacitor voltage constant.

In recent years, the technological development of high power electronics devices has led to implementation of electronic equipment suited for electric power systems, with fast response compared to the line frequency. These *active compensators* allow great flexibility in: a) controlling the power flow in transmission systems using Flexible AC Transmission System (FACTS) devices, and b) enhancing the power quality in distribution systems employing Custom Power System (CUPS) devices. The use of these active compensators to improve integration of wind energy in weak grids is adopted in this paper. In this paper we propose and analyze a compensation strategy using an UPQC, for the case of SCI G–based WF,

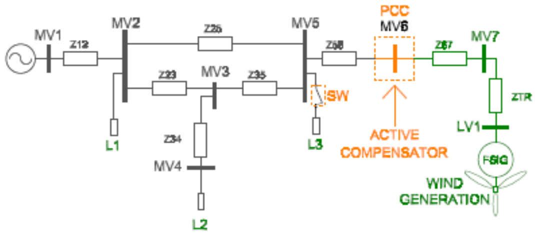


Fig. 1 Study case power system

The UPQC is controls and regulates the WF terminal voltage and mitigates the voltage fluctuations at the PCC, which is caused by the sudden load changes and the pulsating power generation. The voltage regulation at WF terminal is conducted using the UPQC series converter, by voltage injection "in phase" with PCC voltage. On the other hand, the shunt converter is used to filter the WF generated power to prevent voltage fluctuations, requiring active and reactive power handling capability. The sharing of active power between converters, is managed through the common DC link.

## II. SYSTEM DESCRIPTION

### 2.1 System Description

Fig. 1 shows the power system under consideration for the case study for the simulation of UPQC in the compensation study [7]. The WF is composed by 36 wind turbines using squirrel cage induction generators, adding up to 21.6MW electric power. Each turbine has attached fixed reactive compensation capacitor banks (175kVAr), and is connected to the power grid via 630KVA 0.69/33kV transformer.

### 2.2 Model of generator

For the squirrel cage induction generator the model available in Matlab/Simulink Sim Power System libraries is used. It consists of a fourth–order state–space electrical model and a second–order mechanical model [8].

### 2.3 Compensator Model

The compensation of voltage variations is conducted by injecting voltage in series and active–reactive power in the MV6 (PCC) bus bar; this is accomplished by using an unified type compensator UPQC . In Fig.2 we see the basic outline of this compensator; the bus bars and impedances numbering is referred to Fig.1. The operation is based on the generation of three phases.

voltages, using electronic converters either voltage source type (VSI–Voltage Source Inverter) or current source type (CSI– Current Source Inverter). VSI converter is preferred because of lower DC link losses and faster response in the system than CSI [9]. The shunt converter of UPQC is responsible for injecting current at PCC, while the series converter generates voltages between PCC and U1, as illustrated in the Phasor diagram of Fig.3. The main function of compensator is the operation of both converters is by sharing the same DC-bus voltage, enabling the active power exchange.

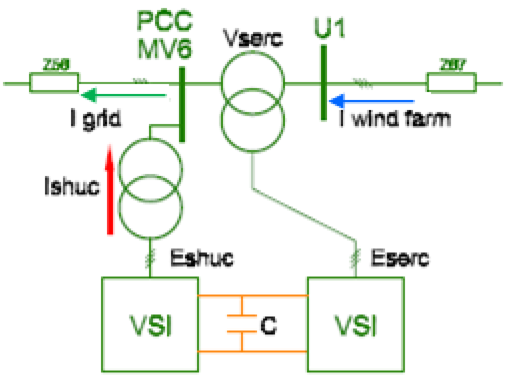


Fig. 2 Block diagram of UPQC


Fig. 3 Phasor diagram of UPQC

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## III. UPQC CONTROL STRATEGY

The main operation is dependent on the generation of the three phase voltages and currents, using the electronic converters either voltage source converters (VSI) or current source converters(CSI)[9]. In this paper VSI are preferred due to lower DC-link losses and it has faster response for the power variations system then CSI. The voltage and currents are measured from the three phase VI measurements of the system. The control strategy shown in Fig. 4 generates the reference signals for both the series and shunt APFs of UPQC, an approach based on the closed loop PI controllers for the shunt APF utilization and other strategy Unit Vector Template(UTT) is exploited to get the reference voltage signals for the series APF.

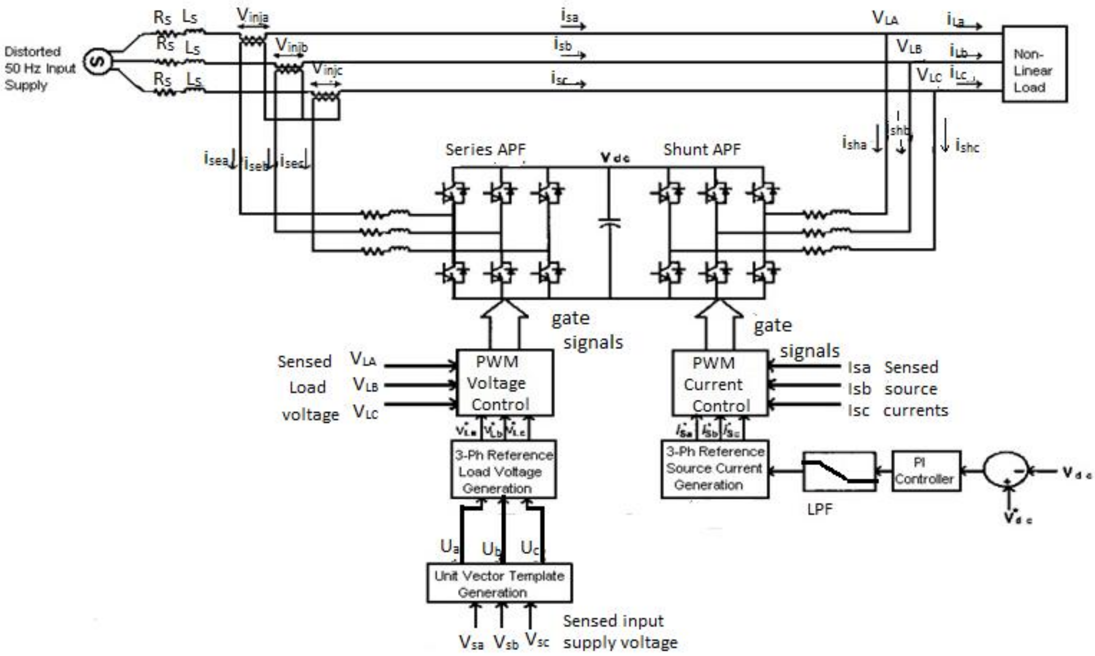


Fig. 4 Basic Circuit Model of UPQC

The control strategy is basically the way to generate reference signals for both shunt and series APF of UPQC [10]. The compensation effectiveness of the UPQC depends on its ability to follow with a minimum error and unit delay to calculate to reference signals to compensate the distortions, unbalanced voltages or currents or any other undesirable condition. In the following section an approach based on Unit Vector Templates Generation is explained to extract the reference voltage and current signals for series and shunt active power filters respectively.

The first term is the load reference currents and voltages are generated using Phase Locked Loop (PLL).The control strategy is based on the extraction the Unit Vector Templates from the distorted input supply. These templates will be then equivalent to pure sinusoidal signal with unity (p.u.) amplitude. Fig. 5 shows the extraction of Unit Vector Templates (UTT) and 3-Ph reference voltage generation. Multiplying the peak amplitude of fundamental input voltage with unit vector templates of equation gives he reference voltage signals.

$$V^*_{abc} = V_m . U_{abc} \quad (1)$$

Where $U_{abc}$ =input voltage vectors.

$V_m$ = peak amplitude of input voltage.

` $V^*_{abc}$= line voltages

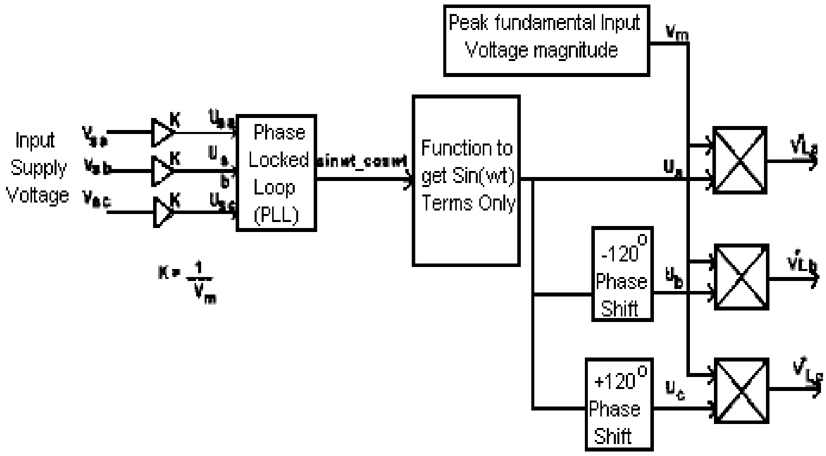


Fig. 5 Extraction of Unit Vector Templates And 3-Ph Reference Voltage.

The error generated is then taken to a PWM controller to generate the required gate signals for series APF. The extractions of three phase voltage reference signals are based on vector template generation. A phase Locked Loop (PLL) is used to extract the pure sinusoidal signal at fundamental frequency. The PLL gives signal in terms of sine and cosine functions. Here only sine terms are considered. As we know the supply voltage peak amplitude in advance. We can generate the unit supply voltage vector the terminal voltage are sensed and multiplied by a inverse of peak amplitude of fundamental terminal voltage. These unity voltage vectors are then taken to PLL. Thus the output of PLL is equal to the unity terminal voltage of fundamental frequency only. With proper phase angle shifting the unit vector templates for three phase are generated. We also know the desired voltage level at the wind farm $V_{WF}$ with UTT the signals are passed to the series compensator controller through the series transformer. The control of the UPQC, will be implemented in a rotating frame dq0 using Park's transformation (eq.2-3)

$$T = \frac{2}{3}\begin{bmatrix} \sin(\theta) & \sin\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) \\ \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} f_d \\ f_q \\ f_0 \end{bmatrix} = T \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix} \quad (3)$$

Where $f_i$=a, b, c represents either phase voltage or currents, and $f_i$=d,q,0 represents that magnitudes transformed to the dqo space. This transformation allows the alignment of a rotating reference frame with the positive sequence of the PCC voltages space vector. To accomplish this, a reference angle _ synchronized with the PCC positive sequence fundamental voltage space vector is calculated using a Phase Locked Loop (PLL) system. In this work, an "instantaneous power theory" based PLL has been implemented. Under balance steady-state conditions, voltage and currents vectors in this synchronous reference frame are constant quantities. This feature is useful for analysis and decoupled control.

The shunt APF is used to compensate for current harmonics as well as to maintain the dc link voltage at constant level. To achieve the things the dc link voltage is sensed and compared with the reference dc link voltage. A PI controller then process the error. Fig 6 shows the PI controller. After extracting the reference voltage and current signals for series and shunt APF, the next step is to force the inverters to follow the reference signals. This is done by switching the inverter IGBT's in a proper manner. To have the required gating signals, the modulation technique is used and the control technique is based on the PWM strategy.

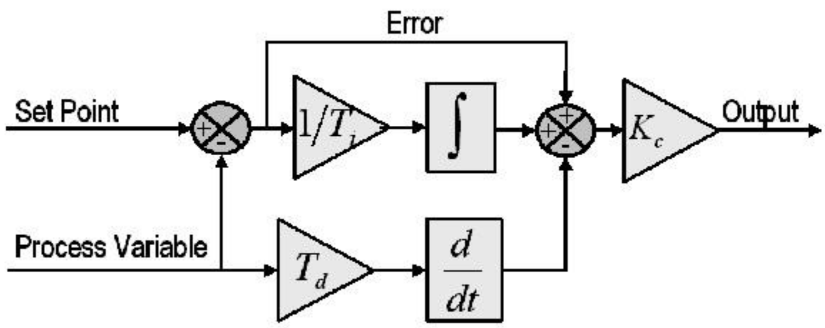


Fig. 6 PI controller.

## IV. SIMULATION RESULTS

The model of the power system scheme illustrated in Fig.1, including the controllers with the control strategy in detail was implemented using Matlab/Simulink software. Numerical simulations were performed to determine and the compensate voltage fluctuation due to wind power variation, and voltage regulation problems due to a sudden load connection. The simulation was conducted with the following chronology:

- At t=0.0" the simulation starts with the series converter and the DC-bus voltage controllers in operation.
- at t=0.5" the shadow effect starts
- at t=3.0" the Q and P control loops(See Fig. 5.5.) are enabled .
- at t=6.0" L3 load is connected.
- at t=6.0" load is disconnected.

- At t=0.5 " begins the cyclical power pulsation produced by the tower shadow effect.

**4.1 Compensation for voltage fluctuation :**

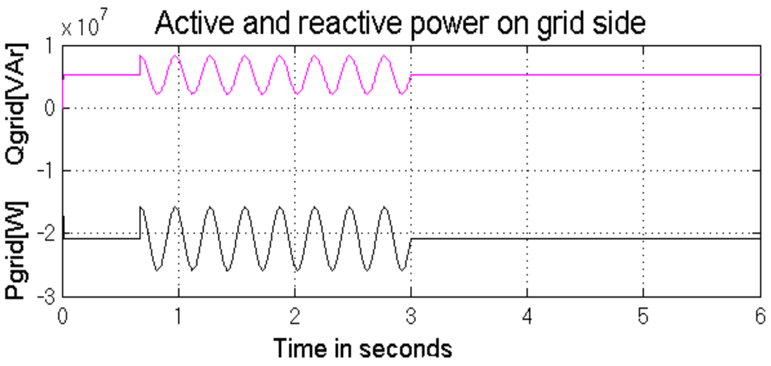


Fig.4.1 Active and reactive power demand at power grid side.

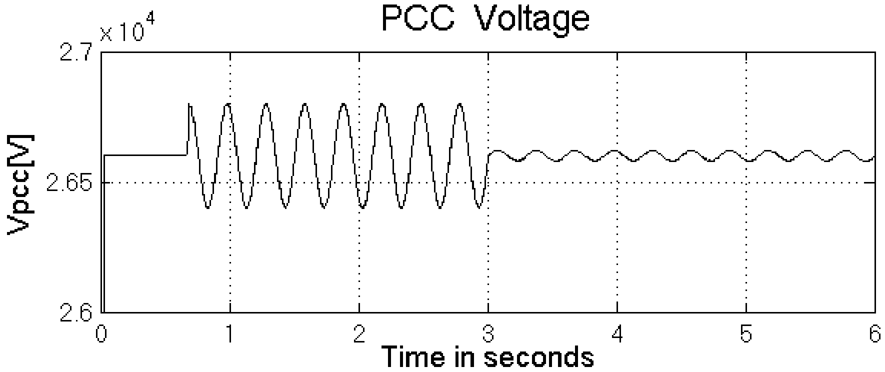


Fig. 4.2 PCC voltage.

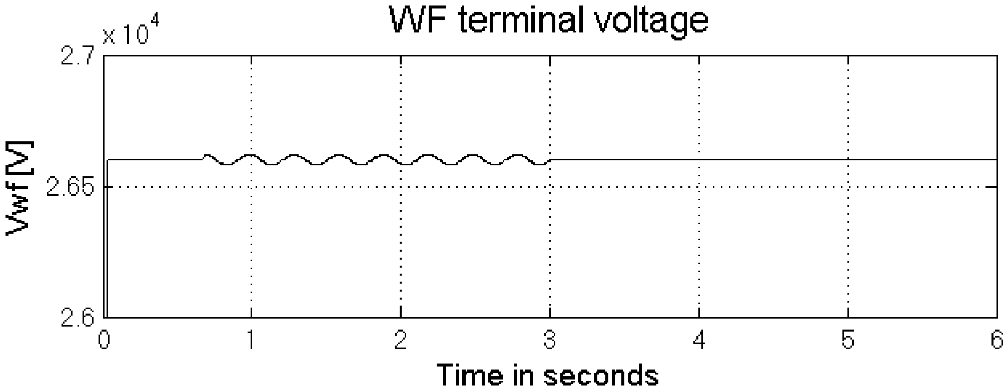


Fig. 4.3 Wind Farm terminal voltage.

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### 4.2. Voltage regulation:

The UPQC can also be operated to maintain the wind farm terminal voltage constant, rejecting PCC voltage variations, due to events like sudden change in connection/ disconnection of loads, power system faults, etc. A sudden connection of load is performed at t = 6'', by closing L3 switch in fig. 4.4 and is disconnected at t = 10''.

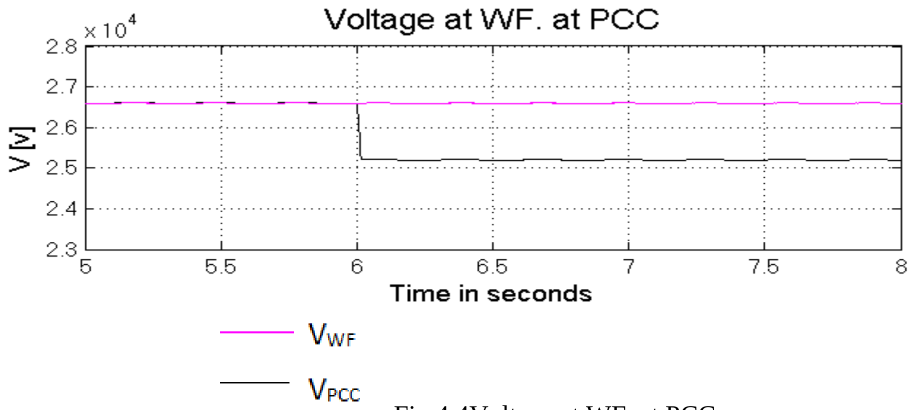


Fig.4.4Voltage at WF, at PCC.

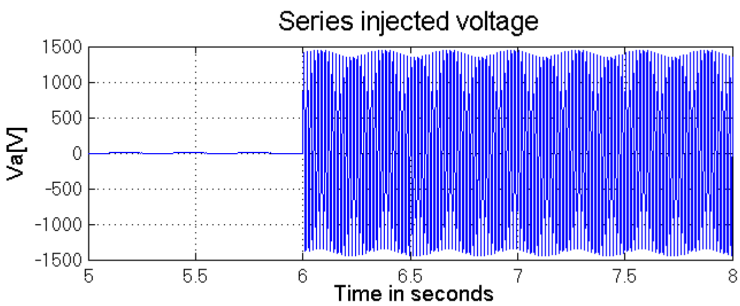


Fig. 4.5 Series injected voltage at 'a' phase.

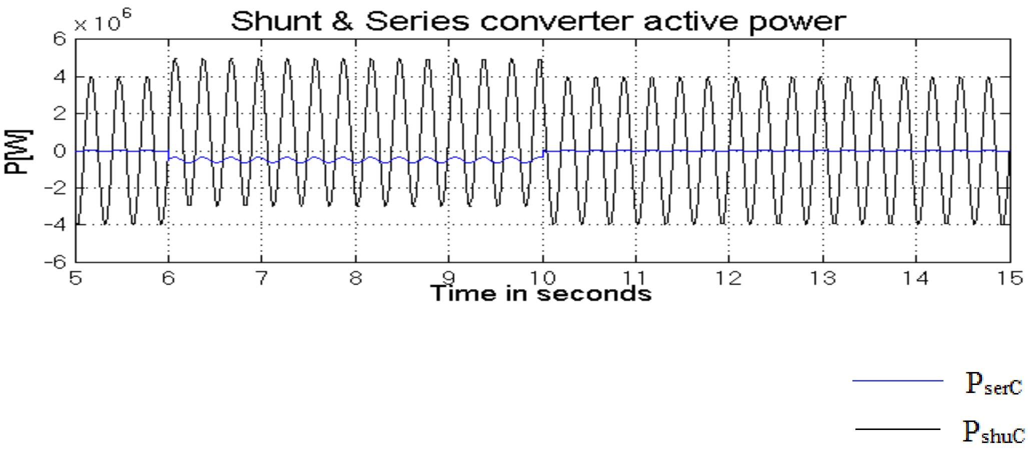


Fig. 4.6 Shunt and series converter active power.

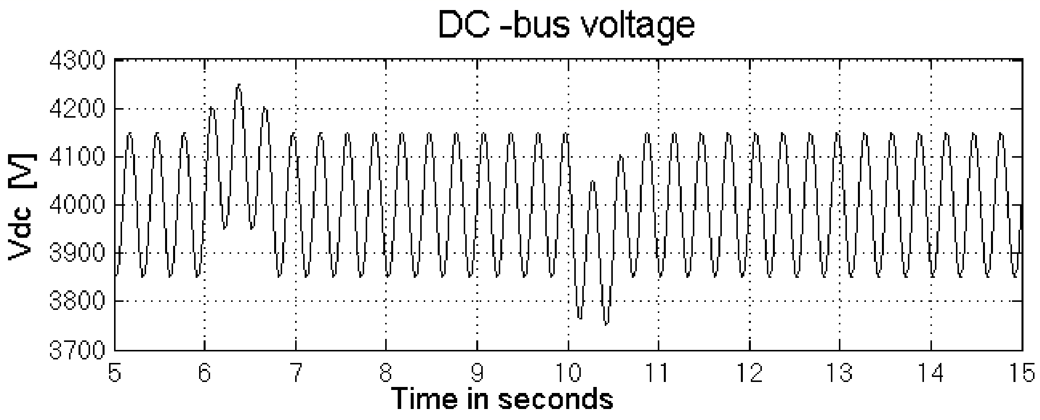


Fig. 4.7 DC-bus voltage.

Fig. 4.6 shows the shunt and series converter active power behaviour. The mean power injected (absorbed) by series converter is absorbed(injected) by shunt converter, because of the DC voltage regulation loop action. So, the step in series converter active power is the same but opposite sign, that shunt converter power. Fig. 4.7 shows the DC-bus voltage and the $V_{DC}$ control action. $V_{DC}$ mean value is maintained at its reference level, while ripple is not rejected.

## V CONCLUSION

In this paper, a new compensation strategy implemented using an UPQC type compensator was presented. The proposed compensation scheme enhances the *system power quality*, exploiting fully DC–bus energy storage and active power sharing between UPQC converters, features not present in DVR and D–Statcom compensators. The simulation results show a good performance in the rejection of power fluctuation and the regulation of voltage due to a sudden load connection. So, the effectiveness of the proposed compensation approach is demonstrated in the study case. In future work, performance comparison between different compensator types will be made.

## REFERENCES

[1] N. G. Hingorani and L. Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, New York: Institute of Electrical and Electronics Engineers Press, 2001 edition.

[2] K.R.Padiyar, *FACTS Controllers in POWER TRANSMISSION AND DISTRIBUTION* New age international publishers, 2011 edition.

[3] Yong Hua Song and Allan T Johns *Flexible ac Transmission Systems (FACTS),* The Institution of Electrical Engineers, IEE POWER AND ENERGY SERIES 30.

[4] Math H.J.Bollen – '*Understanding power quality problems*'.

[5] Ewald F. Fuchs and Mohammad A.S. Masoum *Power Quality in Power systems and Electrical Machines,* March 2008 edition.

[6] J.B.Dixit and Amit Yadav, '*Electrical Power Quality*', University Science Press.

[7] M.F. Farias, P.E. Battaiotto, M.G. Cendoya, '*Wind Farm to Weak-Grid Connection using UPQC Custom Power Device*', 2010 IEEE.

[8] P. Kundur "Power System Stability and Control" McGraw Hill ISBN 0-07-035958-X.

[9] C.K.Sundarabalan, P.Satishbabu, '*Unified Power Quality Conditioner for Enhancement of Power Quality and Hybrid Power Generation Injection to Grid*', International Journal of Modern Engg, Research (IJMER), VOL. 2, Issue 2, Mar-Apr 2012 pp. 493-499 ISSN : 2249-6645.

[10] Yash Pal, A.Swarup, *Senior Member IEEE*, and Bhim Singh, '*A Control Strategy Based on UTT and ISCT for 3P4W UPQC*', International Journal of Electrical and Electronics Engineering 5-3 2011
Fuel Level Sensor".IEEE 2000.