INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN: 2278 – 0211 (Online)

Generalized UPQC System With An Improved Control Method Using PV Array For Reduction Of Harmonics

Jyothir Mai
M.Tech Student, Department of EEE, TKRCET, JNTUH, Hyderabad, A.P, India
V. Swarupa
Associate Professor, Department of EEE, TKRCET, JNTUH, Hyderabad, A.P, India

Abstract:
Power quality has become an important factor in power systems, for consumer and household appliances with proliferation of various electric and electronic equipment and computer systems. The main causes of a poor power quality are harmonic currents, poor power factor, supply-voltage variations, etc. A technique of achieving both active current distortion compensation, power factor correction and also mitigating the supply-voltage variation of the load side, is compensated by unique device of UPQC. In this paper UPQC with the photovoltaic system is presented. The proposed system consists of a series inverter, a shunt inverter, and a photovoltaic array connected in the DC link through the boost converter. This paper presents a modified synchronous-reference frame (SRF) -based control method to Shunt active filter and instantaneous PQ (IPQ) theory based control technique for series active filtering to compensate power-quality (PQ) problems through a three-phase four-wire unified PQ conditioner (UPQC). The proposed system can improve the power quality at the Point of Common Coupling (PCC) on power distribution systems. The performance of the proposed system was analyzed using MATLAB/SIMULINK.

Key words*: Active power filter (APF), harmonics, Modified phase locked loop (MPLL), power quality(PQ), synchronous reference frame (SRF), unified Power-quality (PQ), conditioner (UPQC), PVArray, Hysteresis controller, Boost Converter*

1.Introduction

The increasing applications of electronic equipment that cause electromagnetic disturbances or that are sensitive to these phenomena, has heightened the interest in power quality in recent years. The quality of the power leads to a direct economic impact on utilities, their customers, and suppliers. The power electronic devices due to their inherent nonlinearity draw harmonic and reactive power from the supply. In three phase systems, they could also cause unbalance and draw excessive neutral currents. The injected harmonics, reactive power burden, unbalance, and excessive neutral currents cause low system efficiency and poor power factor. The use of the sophisticated equipment/loads at transmission and distribution level has increased considerably in recent years due to the development in the semiconductor device technology. The equipment needs clean power in order to function properly. At the same time, the switching operation of these devices generates current harmonics resulting in a polluted distribution system. Custom power devices including power electronic interface can be the effective solution for increasing power quality problems because they can provide fast response and flexible compensation. 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. Therefore, the UPQC[5] is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance. Usually, series and shunt inverter integrated device is called UPQC. There have been several control schemes of UPQC and the instantaneous power theory is a well-known effective scheme that it has been used herein. The UPQC has the prominent capability of improving the quality of voltage and current at the point of installation on power distribution systems or industrial power systems. Therefore, UPQC is expected to be one of the most powerful solutions to the load which is considered as very important or sensitive to supply voltage disturbances; however, UPQC cannot supply large active power to customers steadily due to the limitation of power storage. While, the opening of the energy market under deregulation brings about the interest in Dispersed Generation (DG) because it can provide independence and flexibility to the customer in planning and developing the installation and can give economic benefits in many cases. Photovoltaic (PV) arrays are one of the favourable DGs and being increasingly used to tap into the huge resource of the sun and will play key role in future sustainable energy systems. They offer consumers the ability to generate electricity in a clean, quiet and reliable way. However, PV can cause the negative effects on the existing power systems. That is, some potential problems might be occurred such as voltage variation, protection, harmonics, and personnel safety.

The photovoltaic arrays are interfaced in the AC and DC distributed system by using power electronic circuits. Conventional DC-DC converters, such as push-pull, half bridge and full-bridge converters can be used to boost the low voltage of the photovoltaic to the required level. However, the transformers in these converters have considerable turns ratios (such as 1:20) and hence, high leakage inductances, which results in low energy efficiency and difficulty in control of DCDC converter. Thus, DC-DC boost converters are usually used to convert the DC output voltage of photovoltaic arrays to a higher output voltage. The advantages of this converter are its simple configuration, fewer components, lowest cost and higher efficiency. This paper proposes a combined operation system of UPQC and photovoltaic arrays, which is connected to the dc link through a Boost converter. The advantage of the proposed system over the UPQC is to compensate the voltage interruption, as well as the voltage sag, voltage swell, harmonics, and reactive power. The operation of the proposed system was verified through simulations with MATLAB/SIMULINK.

2.UPQC System With PV Array

The UPQC [1] control algorithm has ability to compensate both harmonics and reactive power of the load. The control strategy uses only minimum measurement like loads and mains voltage measurements for series APF based on the modified PLL with synchronous reference frame theory. The instantaneous reactive power theory is used for shunt APF control algorithm by measuring mains voltage, currents and capacitor voltage. But the conventional methods require measurements of the load, source and filter voltages and currents. The advantage of structure for UPQC as is shown Figure1, where, PV is connected to DC link [6] is voltage interruption compensation and active power injection to grid. Also, this proposed system has higher efficiency and functioning ability compared with other common PVs and cause reduction in system’s total cost.

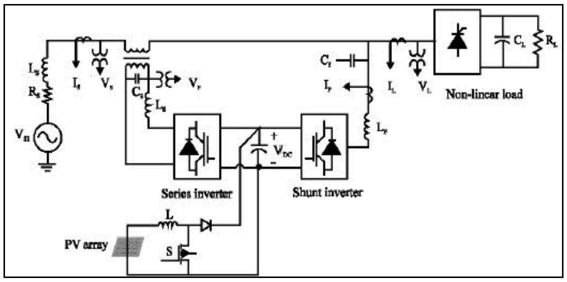

Figure1: Configuration Of UPQC With PV Array And Boost Converter

2.1.Basic Configuration Of UPQC

Generally, UPQC [4] has two voltage-source converters as shown in Figure (3).

Series coveter is a voltage-source converter connected in series with the AC line and acts as a voltage source to mitigate voltage distortions. It is used to eliminate supply voltage flickers or imbalance from the load terminal voltage and forces the shunt branch to absorb current harmonics generated by the nonlinear load. Control of the series converter output voltage is usually performed using sinusoidal pulse-width modulation (SPWM). The gate pulses required for converter are generated by the comparison of a fundamental voltage reference signal with a high-frequency triangular waveform.

Shunt converter is a voltage-source converter connected in shunt with the same AC line and acts as a current source to cancel current distortions, compensate reactive current of the load, and improve the power factor. It also performs the DC-link voltage regulation, resulting in a significant reduction of the DC capacitor rating. The output current of the shunt converter is adjusted using a dynamic hysteresis band by controlling the status of semiconductor switches so that output current follows the reference signal and remains in a predetermined hysteresis band.

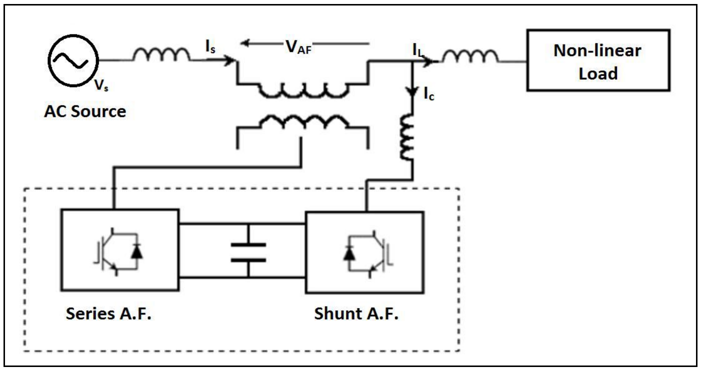

Figure 3: Configuration Of UPQC

3.PV Array

PV arrays are built up with combined series/parallel combinations of PV solar cells, which are usually represented by a simplified equivalent circuit model as shown in Figure 4. A photovoltaic array (PV system) is a interconnection of modules .The power produced by a single module is seldom enough for commercial use, so modules are connected to form array to supply the load. The connection of the modules in an array is same as that of cells in a module. Modules can also be connected in series to get an increased voltage or in parallel to get an increased current.

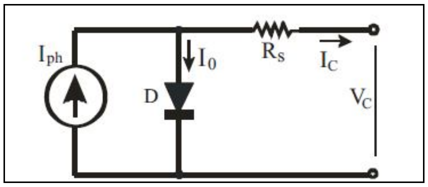

Figure 4: Simplified Equivalent Circuit Of Photovoltaic Cell

A photovoltaic system simulation model is developed using basic circuit equations (Lorenzo mathematical model) of the photovoltaic solar cells including the effects of insulation and temperature changes as shown in Figure 5. The block called PVA model for GUI [2] is the last stage of the model. This block contains the sub models that are connected to build the final model. A diode (D1) is connected in series with the load circuit to prevent the reverse current flow. A filter is connected before the load to maintain a stable voltage. The filter contains a series R-L and parallel C elements. The PVA consists of 8 PV cells all connected in series to have a desired voltage output. Depending on the load power required, the number of parallel branches can be increased to 2 or more. The effects of the temperature and solar irradiation levels are represented by two variables gains. They can be changed by dragging the slider gain adjustments of these blocks named as variable temperature and variable solar irradiation. Since the main objective is the development of the PVA functional model for the Simulink environment, the other parts of the operational block diagram given in Figure are not going to be explained in full detail. However, just to describe the main diagram, as it can readily be seen, the system is modelled to supply power to both dc and ac loads. The dc load is directly coupled while the ac load is fed through a three-Phase inverter and a transformer with turn ratio 1.

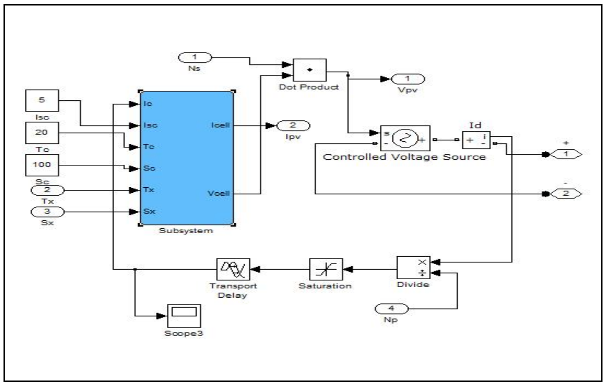

Figure 5: MATLAB-SIMULINK Model Of PV Array

4.Test Distribution System

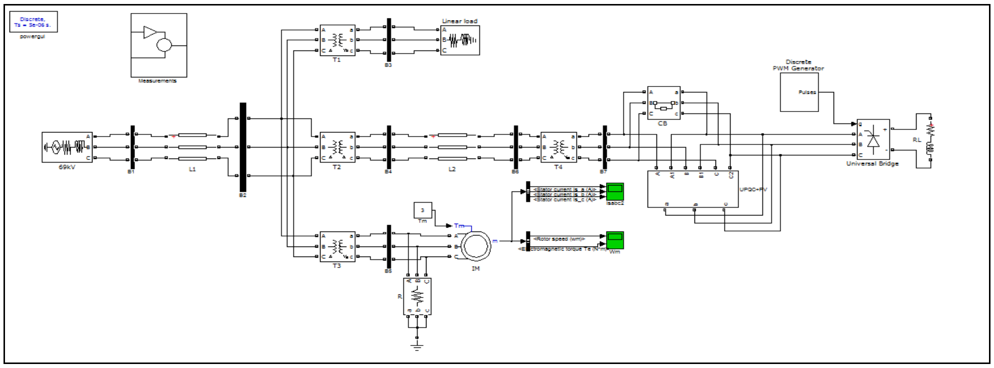

Figure 6: Test Distribution System

The test system is a 13.8KV distribution system as shown in Figure 6. The 69KV source voltage is sent through the line of 50km length. At Bus 2 the voltage is stepped down to 13.8KV. At Bus 2 three transformers are connected T1, T2 and T3. At Bus 3 a linear load is connected. At Bus 5 an Induction Motor is connected. A non linear load is connected at Bus 7. The proposed system (UPQC+PV) is installed at the secondary side of the distribution transformer as shown in figure. As the non linear load is connected at bus 7 the proposed system will reduce the harmonics due to non linear load.

Nominal Voltage(V_{rms})	13.8KV
Stator Resistance (R_S)	5Ω
Stator Inductance (L_s)	0.05974H
Rotor Resistance (R_r)	3Ω
Rotor Inductance (L_r)	0.012H
Mutual Inductance (L_m)	0.2037H

Table 1: Parameters Of Induction Motor

5.MATLAB-Simulink Model

5.1.UPQC

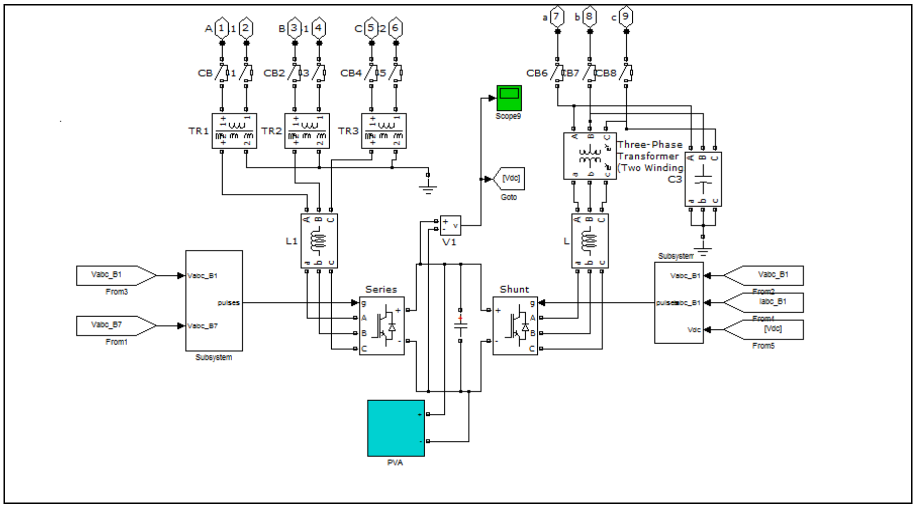

Figure 7: MATLAB Simulink Model Of The UPQC System With PV Array

The Generalised UPQC system as shown in Figure 7 consists of a series AC filter and shunt AC filter and PV Array connected to DC link [3] . The Series and shunt APF's are described briefly in sections B and C. The UPQC is connected to the test distribution system at BUS 7 through series and shunt Transformers.

5.2.Series APF

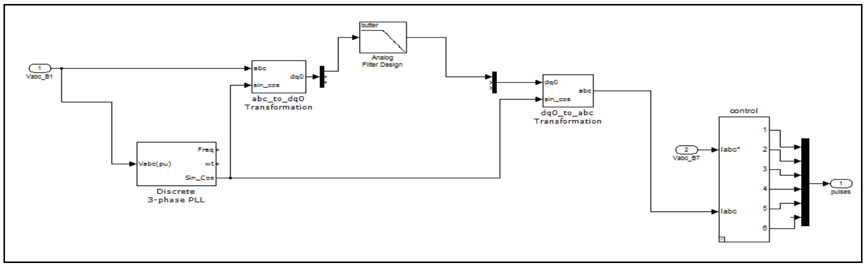

Figure 8: MATLAB Simulink Model Of Series APF

A simple algorithm is developed to control the series filter as shown in Figure (8). The series filter is controlled such that it injects voltages which cancel out the distortions and/or unbalance present in the supply voltages thus making the voltages at the PCC perfectly balanced and sinusoidal with the desired amplitude. Since the supply voltage is unbalanced and or distorted, a phase locked loop (PLL) is used to achieve synchronization with the supply. Three phases distorted/unbalanced supply voltages are sensed and given to the PLL which generates two quadrature unit vectors [5]. The sensed supply voltage is given to d-q transformation block and the output of d-q transformer is given to a low pass filter and inverse d-q transformation is done. The transformed supply voltages are compared with the reference load voltages and given to a hysteresis controller. The output of the hysteresis controller is switched signals to the six switches of the VSI of the series AF. The hysteresis controller generates the switching signals such that the voltage at the PCC becomes the desired sinusoidal reference voltage. Therefore, the injected voltage across the series transformer through the ripple filter cancels out the harmonics and unbalance present in the supply voltage.

A.C Line Inductance	800µH
Resistance	0.2Ω

Table 2: Parameters Of Series APF

5.3.Shunt APF

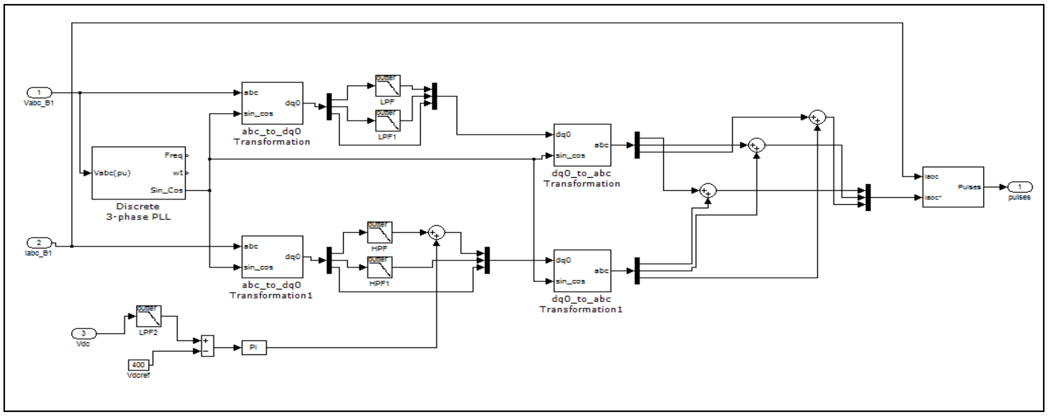

Figure 9: MATLAB Simulink Model Of Series APF

A simple algorithm is developed to control shunt filter as shown in Figure(9).If the load connected to the PCC is non-linear or unbalanced or the combination of both, the given control approach also compensates the harmonics of load current. The actual dc-link voltage is sensed and passed through a first-order low pass filter (LPF) to eliminate the presence of switching ripples on the dc-link voltage. The difference of this filtered dc-link voltage and reference dc-link voltage is given to a discrete-PI controller to maintain a constant dc-link voltage under varying generation and load conditions. The three phase source voltages and currents are given to the PLL to achieve synchronization with supply. The voltages and currents are transformed from abc to dq0 to generate the reference currents. The reference grid currents are compared with actual grid currents to compute the current errors. These current errors are given to hysteresis current controller. The hysteresis controller then generates the switching pulses (P1 to P6) for the gate drives of the shunt inverter.

A.C Line Inductance	800µH
Resistance	0.1Ω

Table 3: Parameters Of Shunt APF

6.Results And Discussion

The UPQC+PV system is switched on at the time instant 0.1. The Figure 10 shows the current waveform of PHASE “A” at BUS 7 so the waveform shows the difference in currents at BUS 7 before and after adding the UPQC+PV system. Rom the time instant 0 to 0.1 the waveform contains harmonics. At time instant 0.1 UPQC is switched on and a pure sine wave is obtained.

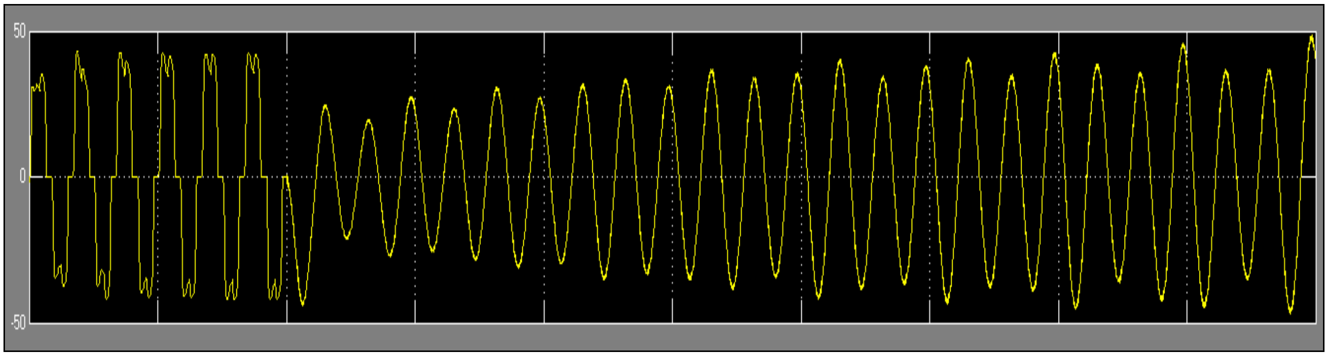

Figure 10: Simulation Result Of The IBUS 7 I_{b7}(Phase A)

The THD of the current waveform at bus 7 for PHASE A after connecting UPQC with PV Array has reduced to 0.27% as shown in FIGURE 11. Before connecting the UPQC+PV system the THD was 10.57% . From 10.57% it has reduced to o.27%.

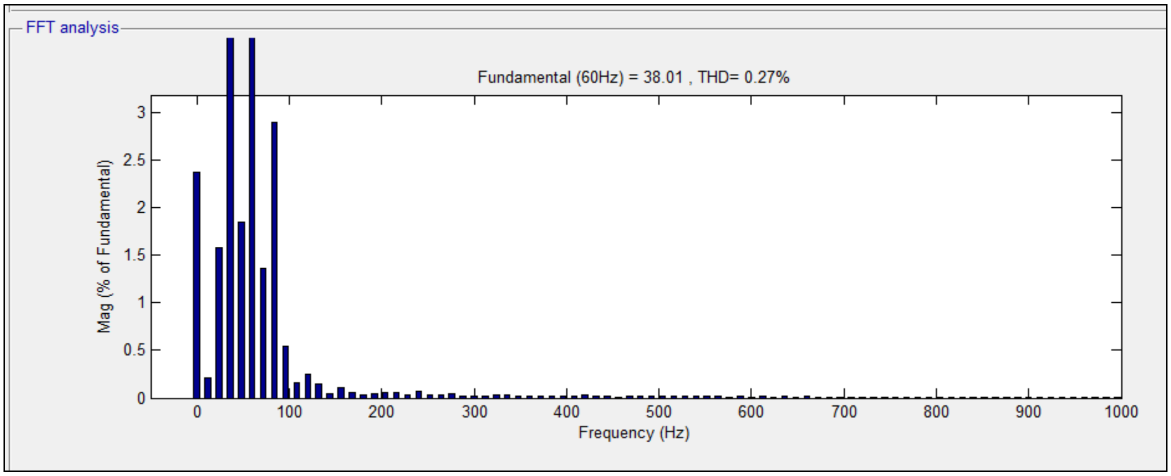

Figure 11: THD Of IBUS 7(Phase A)

The UPQC+PV system is switched on at the time instant 0.1. The Figure 12 shows the current waveform of PHASE "B" at BUS 7 so the waveform shows the difference in currents at BUS 7 before and after adding the UPQC+PV system. Rom the time instant 0 to 0.1 the waveform contains harmonics. At time instant 0.1 UPQC is switched on and a pure sine wave is obtained.

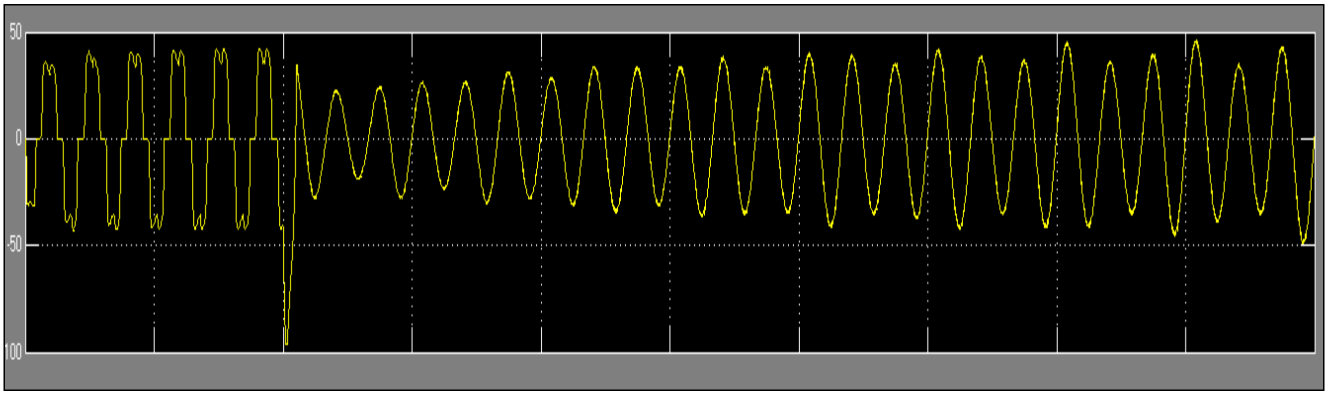

Figure 12: Simulation Result Of The Current At BUS 7 I_{b7}(Phase B)

The THD of the current waveform at bus 7 for PHASE B after connecting UPQC with PV Array has reduced to 0.2% as shown in FIGURE 13. Before connecting the UPQC+PV system the THD was 15.98%. From 15.98% it has reduced to o.2%

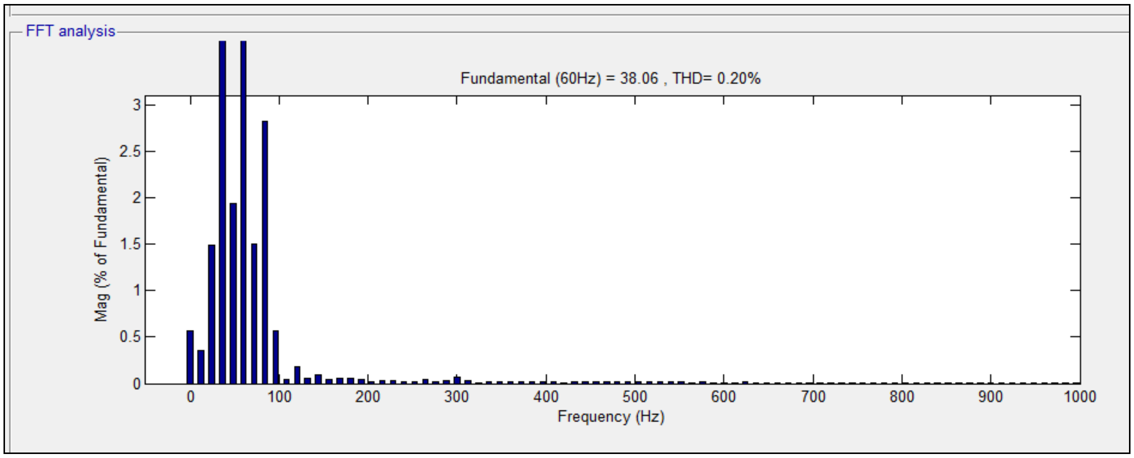

Figure 13: THD Of IBUS 7(Phase B)

The UPQC+PV system is switched on at the time instant 0.1. The Figure 14 shows the current waveform of PHASE “C” at BUS 7 so the waveform shows the difference in currents at BUS 7 before and after adding the UPQC+PV system. Rom the time instant 0 to 0.1 the waveform contains harmonics. At time instant 0.1 UPQC is switched on and a pure sine wave is obtained

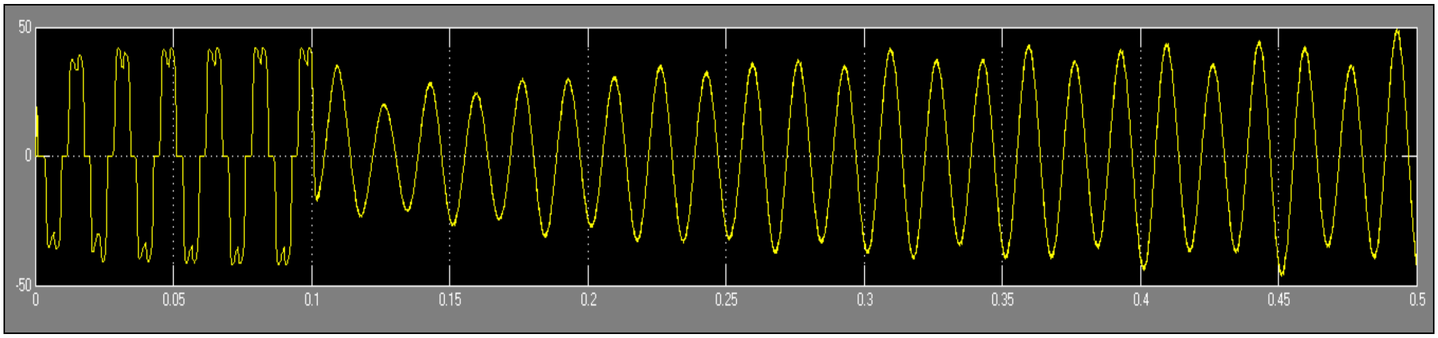

Figure 14: Simulation Result Of The Current At BUS 7 I_{b7}(Phase B)

The THD of the current waveform at bus 7 for PHASE C after connecting UPQC with PV Array has reduced to 0.33% as shown in FIGURE 13. Before connecting the UPQC+PV system the THD was 17.97%. From 17.97% it has reduced to o.33%

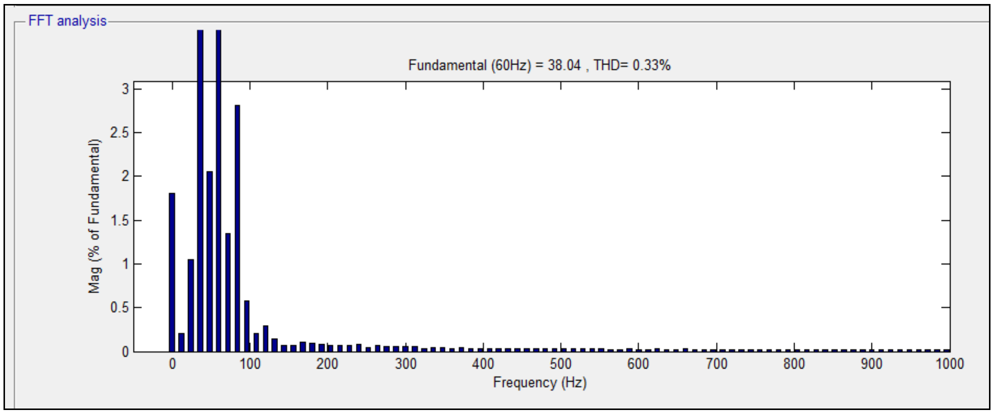

Figure 15: THD Of IBUS 7(Phase B)

7.Conclusion

The proposed control strategy uses only minimum measurement like loads and mains voltage measurements for series APF based on the modified PLL with synchronous reference frame theory. The instantaneous reactive power theory is used for shunt APF control algorithm by measuring mains voltage, currents and capacitor voltage. But the conventional methods require measurements of the load, source and filter voltages and currents. The simulation results show that, when unbalanced and Nonlinear load current or unbalanced and distorted mains voltage conditions, the above control algorithms eliminate the impact of distortion and unbalance of the load current on the power line, making the power factor unity. Meanwhile, the Series APF isolates the loads voltages and source voltage, the shunt APF provides three-phase balanced and rated currents for the loads. This paper proposed a system which is a powerful tool for power reliability and power quality improvement in distribution networks due to versatile compensation functions. Moreover, it integrates all needed compensation characteristics that can be achieved by a device that is made up from UPQC and Photovoltaic Array connected in the dc link through Boost Converter.

8.References

1) Fujita, H and H. Akagi, 1998. The unified power quality conditioner. The integration of series and shunt active filters. IEEE Trans. Power Elect, 13: 315-322.
2) Alkas, I.H. and sharaf, A.M., 2007, A Photovoltaic Array simulation model for Matlab – simulink GUI environment, clean Electrical power, ICCEP’07 – International conference PP 341 – 345.
3) V. Khadkikar, A. Chandra, "A New Control Philosophy for a Unified Power Quality Conditioner (UPQC) to Coordinate Load-Reactive Power Demand Between Shunt and Series Inverters, " IEEE Trans. on Power Delivery, vo1.23, no.4, pp. 2522-2534, 2008.
4) L. F. C. Monteiro, M. Aredes, and L. A. M. Neto, "A control strategy for unified power quality conditioner," in Proc.IEEE Int. Symp. Ind. Electron, Jun. 2003, vol. I, pp. 391-396.197
5) H. Akagi, E. H. Watanabe and M. Aredes, Instantaneous Power Theory and Applications to Power Conditioning. WileyIEEE Press. April 2007.
6) Han, B. Bae, B. Kim, H. Baek, S. “Combined operation of unified power-quality conditioner with distributed generation”. “Power Delivery, IEEE Transactions” vol. 21, Jan. 2006, pp330- 338.