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Power Quality Improvement By UPQC Using ANN Controller

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Abstract

Any 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, due to the increment of non-linear loads, such as large thyristor power converters, rectifiers, voltage and current flickering due to arc in arc furnaces, sag and swell due to the switching of the loads etc. Since most of the electronic equipment is nonlinear in nature these will induce harmonics in the system, which affect the sensitive loads to be fed from the system. These problems are partially solved with the help of LC passive filters. However, this kind of filter cannot solve random variation in the load current wave form and voltage wave form. Active filters can resolve this problem. However, the cost of active filters is high. They are difficult to implement in large scale. The Unified Power Quality Conditioner (UPQC) device combines a shunt active filter together with a series active filter in a back-to-back configuration, to simultaneously compensate the supply voltage and the load current or to mitigate any type of voltage and current fluctuations and power factor correction in a power distribution network, such that improved power quality can be made available at the point of common coupling. In this paper the compensation principle and different control strategies used are based on PI & ANN controller of the UPQC.

Key words - ANN controller, Harmonics, power quality, Series active power filter, Shunt active power Filter, three-phase four wire system (3P4W), unified power quality Conditioner (UPQC).

1. Introduction

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 design of shunt active filter is described in [3]. 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. The power-electronics-based devices have been used to overcome the major power quality problems [1], [2]. A 3P4W distribution system can be realized by providing the neutral conductor along with the 3 power lines from generation station. The unbalanced load currents are very common and an important problem in 3P4W distribution system. To improve the power quality by connecting the series active power filter (APF) and shunt (APF).There are two types of filters one is passive filters and another one is active filters. In passive filters they are using L and C components are connected. By connecting passive filters the system is simple and cost is very low but, so many disadvantages are there, that is resonance problems and require filter for every frequency and bucky. So active filters are chosen. The advantages are filtering for a required range of frequencies, no resonance problems and fast response. But these are achieved with an increased cost. By connecting series active filters the voltage harmonic compensation and high impedance path to harmonic currents is achieved. All these non-linear loads draw highly distorted currents from the utility system, with their third harmonics component almost as large as the fundamental. The increasing use of non-linear loads, accompanied by an increase in associated problems concerns both electrical utilities and utility customer alike [3].

2. The 3p3w Distribution System Utilizing Upqc

Generally, a 3P4W distribution system is realized by providing a neutral conductor along with three power conductors from generation station. Figure.1 shows the 3P3W system is connected to UPQC. Maintaining the Integrity of the Specifications if we want to upgrade the system now from 3P3W to 3P4W due to installation of some single-phase loads and if the distribution transformer is close to the plant under consideration, utility would provide the neutral conductor from this transformer without major cost involvement.

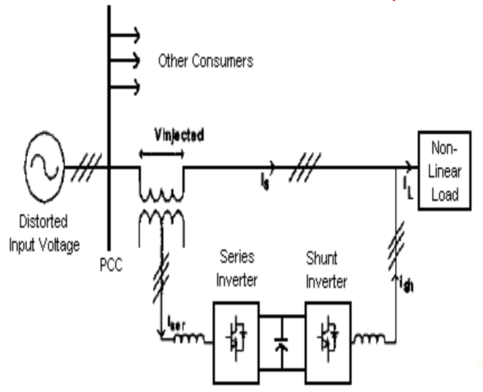


Figure.1: Block diagram of UPQC

In recent cases, this may be a costly solution because the distribution transformer may not be situated in close vicinity. Recently, the utility service providers are putting more and more restrictions on current total harmonic distortion (THD) limits, drawn by nonlinear loads, to control the power distribution system harmonics pollution. At the same time, the use of sophisticated equipment or load has increased significantly, and it needs clean power for its proper operation. As shown in Figure.1 the UPQC should necessarily consist of three-phase series transformer in order to connect one of the inverters in the series with the line to function as a controlled voltage source. If we could use the neutral of three-phase series transformer to connect a neutral wire to realize the 3P4W system, then 3P4W system can easily be achieved from a 3P3W system .The neutral current, present if any would flow through this fourth wire toward transformer neutral point. This neutral current can be compensated by using a split capacitor topology [4], [5], [6] or a four leg voltage source inverter (VSI) topology for a shunt inverter [4], [7].The four-leg VSI topology requires one additional leg as compared to the split capacitor topology.VSI structure is much easier than that of the split capacitor. But here the UPQC design by using ANN and PI controller is connected to 3P4W system. Thus, the structure would help to realize a 3P4W system at distribution load end. This would eventually result in easy expansion from 3P3W to 3P4W systems. A new control strategy to generate balanced reference source currents under load condition is also proposed in this paper and also UPQC design by using ANN controller is also explained in the next section.

3. Design Of Upqc Controller

3.1. Description of Implementation of Series APF

In series APF the Inverter injects a voltage in series with the line which feeds the polluting load through a transformer. The injected voltage will be mostly harmonic with a small amount of sinusoidal component which is in-phase with the current flowing in the line. The small sinusoidal in-phase (with line current) component in the injected voltage

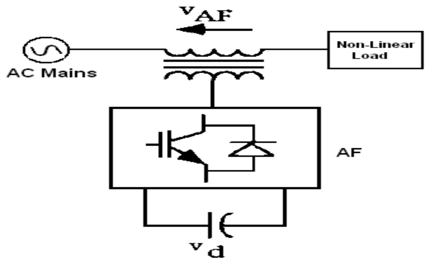


Figure.2: Line diagram of series active power filter.

Results in the right amount of active power flow into the Inverter to compensate for the losses within the Series APF and to maintain the D.C side capacitor voltage constant. Obviously the D.C voltage control loop will decide the amount of this in-phase component. Series active power filter compensates current system distortion caused by non-linear load by imposing a high impedance path to the harmonic current. The line diagram of series active power filter is shown in below Figure.2.

3.2. Description of Implementation of Shunt APF

The active filter concept uses power electronics to produce harmonic current components that cancel the harmonic current components from the non- linear loads. The active filter uses Power electronic switching to generate harmonic currents that cancel the harmonic currents from a non-linear load. In this configuration, the filter is connected in parallel with the load being compensated .Therefore the configuration is often referred to as an active

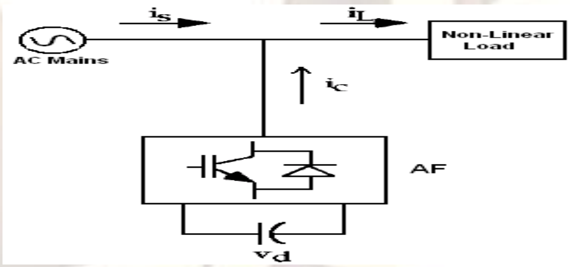


Figure.3: Shunt Active Power Filter.

parallel or shunt filter. Figure.3 illustrates the concept of the harmonic current cancellation so that the current being supplied from the source is sinusoidal. The voltage source inverter used in the active filter makes the harmonic control possible [13]. This inverter uses dc capacitors as the supply and can switch at a frequency to generate a signal that will cancel the harmonics from the non-linear load. The control algorithm for series APF is based on unit vector template generation scheme [8].Where as the control strategy for shunt APF is discussed in this section. Based on the load on the 3P4W system, the current drawn from the utility can be unbalanced.

3.3. Reference generation (Phase Locked Loop)

Reference currents and voltages are generated using Phase Locked Loop (PLL). The control strategy is based on the extraction of Unit Vector Templates from the distorted input supply. These templates will be then equivalent to pure sinusoidal signal with unity (p.u.) amplitude. The extraction of unit vector templates is shown in the Figure. 4.

The 3-phase distorted input source voltage at PCC contains fundamental component and distorted component. To get unit input voltage vectors U_{abc}, the input voltage is sensed and multiplied by gain equal to $1/V_m$, where V_m is equal to peak amplitude of fundamental input voltage. These unit input voltage vectors are taken to phase locked lo
op (PLL). With proper phase delay, the unit vector templates are generated.

$$U_a = \mathrm{Sin}\,(wt)$$
$$U_b = \mathrm{Sin}\,(wt-120) \qquad (1)$$
$$U_c = \mathrm{Sin}\,(wt+120)$$

Multiplying the peak amplitude of fundamental input voltage with unit vector templates of equation (1) gives the reference load voltage signals,

$$V^*_{abc} = V_m.\, U_{abc} \qquad (2)$$

In order to have distortion less load voltage, the load voltage must be equal to these reference signals. The measured load voltages are compared with reference

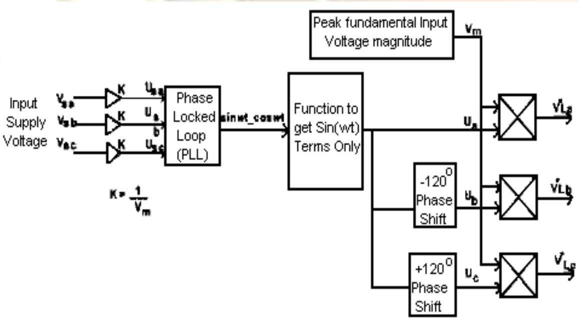


Figure. 4: Extraction of Unit Vector Templates and 3-Ph Reference Voltages

load voltage signals. The error generated is then taken to a hysteresis controller to generate the required gate signals for series APF. The unit vector template can be applied for shunt APF to compensate the harmonic current generated by non-linear load. 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 above mentioned task the dc link voltage is sensed and compared with the reference dc link voltage. A PI controller then processes the error. The output signal from PI controller is multiplied with unit vector templates of equation (1) giving reference source current signals. The source current must be equal to this reference signal. In order to follow this reference current signal, the 3-phase source currents are sensed and compared with reference current signals. The error generated is then processed by a hysteresis current controller with suitable band, generating gating signals for shunt APF.

3.4. Modulation method (Hysteresis Control)

The UPQC uses two back-to-back connected three phase VSI's sharing a common dc bus. The hysteresis controller is used here to control the switching of the both VSI's.

3.4.1. Hysteresis control law for Series APF:

If $(V_{act}) > (V_{ref} + HB)$ upper switch of a leg is ON and lower switch is OFF.

If $(V_{act}) < (V_{ref} - HB)$ upper switch of a leg is OFF and lower switch is ON.

3.4.2. Hysteresis control law for Shunt APF:

If $(i_{act}) > (i_{ref} + HB)$ upper switch of a leg is ON and lower switch is OFF.

If $(i_{act}) < (i_{ref} - HB)$ upper switch of a leg is OFF and lower switch is ON.

where HB is the hysteresis band.

4. Implementation

The matlab/simulink models of 3P3W are shown in Figure 5.without UPQC and Figure 6 shows with UPQC. The load is realized by using a diode bridge rectifier followed by a RL load. The distortion in the supply voltage is introduced by connecting a 5^{th} (20% of the fundamental input) and 7^{th} (10% of fundamental input) harmonic voltage sources in series with the utility voltage. Both the series and shunt APF's are realized by six IGBT switches each, sharing a common dc link.

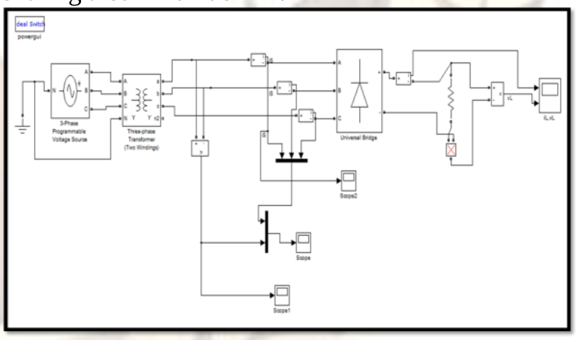


Figure. 5: Matlab/Simulink Model without UPQC

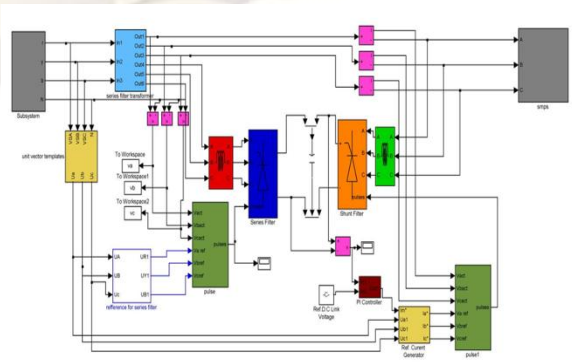


Figure. 6: Matlab/Simulink Model with UPQC

5. Simulation Results

To verify the operating performance of the proposed UPQC, a 3-phase electrical system, a PLL extraction circuit with hysteresis controlled UPQC is simulated using MATLAB software.

The simulation results are shown in the Figure7 and Figure8. The matlab/simulink model for APF is shown in Figure9. Both the series and shunt APF's are put into the operation at different time instant. First series APF put into the operation at a simulation time of 0.1 sec. At time 0.2 sec. shunt APF is put into the operation, such that both series and shunt APF's are operated as UPQC.

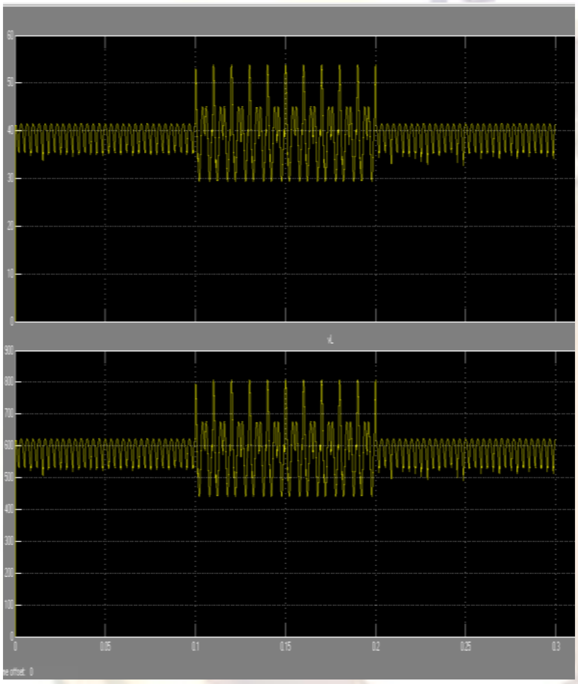


Figure.7: Load voltage and Load current waveforms without UPQC

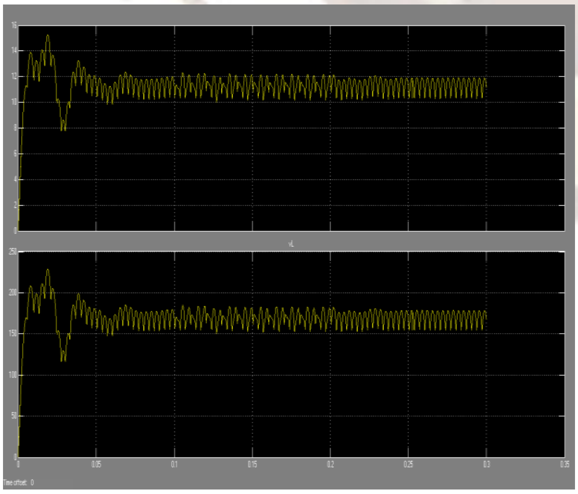
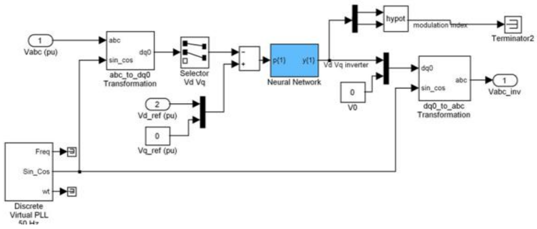
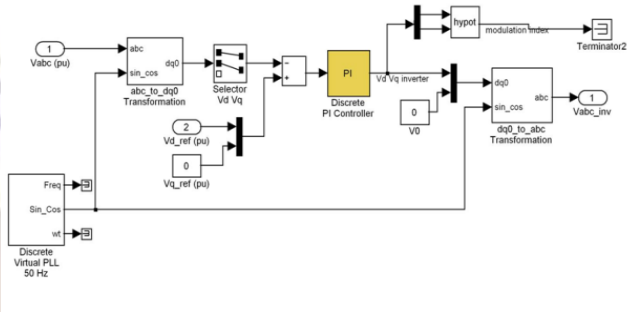


Figure.8: Load voltage and Load current waveforms with UPQC.



(a)

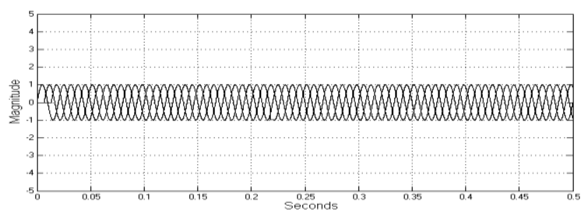


(b)

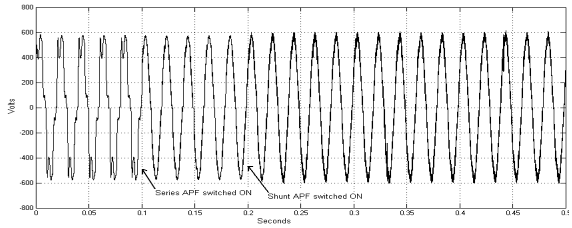
Figure.9: Matlab/simulink model of APF (a) APF with ANN controller. (b) APF with PI controller.

It should be noted that, in spite of distorted voltage at PCC, the unit vector template is pure sinusoidal because of use of PLL. Initially both APF's are not in operation the load voltage is equal to the distorted input voltage deliberately consisting of 5th and 7th order voltage harmonics. As soon as series APF is put into the operation at instant ' 0.1 sec.', immediately it starts compensating the load voltage by injecting sum of 5th and 7th harmonic voltage through series line transformer, such that the load voltage is perfectly sinusoidal, as shown in the Figure 10(b). The voltage injected by the series APF is shown in the Figure10(c), which is nothing but the sum of 5th (20%) and 7th (10%) harmonic voltages in the supply.

Assuming the dc link capacitor is initially charged at 1110V, when series APF starts compensating the load voltage, the dc link voltage starts going down from instant '0.1 sec' to '0.2 sec'. In order to maintain the dc link voltage at required constant level, the shunt APF is put into the operation at instant '0.2 sec'. With in the very short time period the shunt APF maintained the dc link voltage at constant level. In addition to this the shunt APF also helps in compensating the current harmonics generated by the nonlinear load. The load current waveform is shown



(a)



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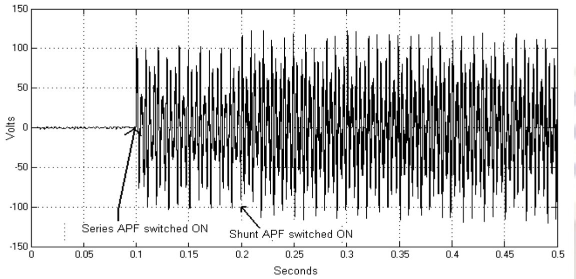
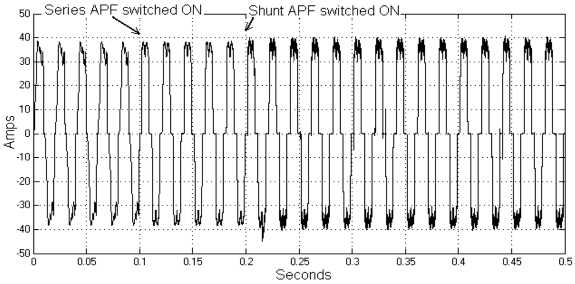


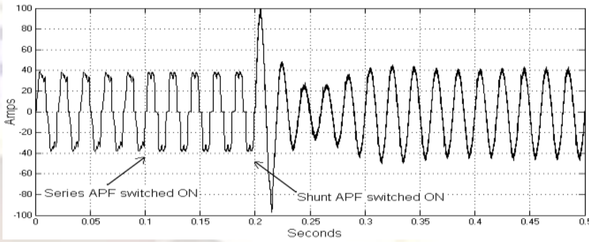
(c)

Figure.10: series APF performance (a) Unit Vector Templates (b) Load Voltage (c) Voltage Injected by Series APF

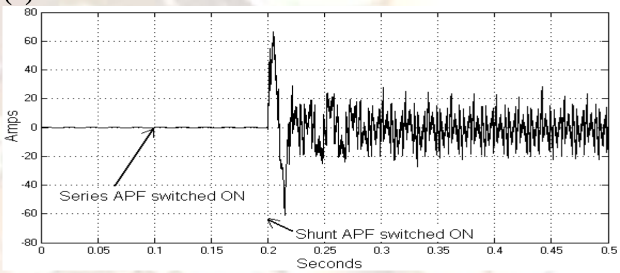
in Figure 11 (a). It is evident that before time '0.1 sec', as load voltage is distorted, so the load current. As soon as the series APF put in to operation at '0.1 sec' the load current profile is also improved. The source current waveform is shown in Figure 11(b). Before time '0.2 sec', the source current is equal to load current. But after time '0.2 sec', when shunt APF starts maintaining dc link voltage; it injects the compensating current in such a way that the source current becomes sinusoidal. Current injected by the shunt APF is shown in Figure 11(c). Source Voltage and Current are shown in Figure 11(d).Voltage and current harmonics (THD's) with and without UPQC are given in Table I.



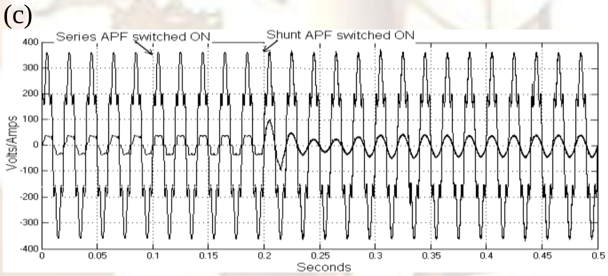
(a)



(b)



(c)



(d)

Figure 11. Shunt APF Performance (a) Load Current (b) Input Source Current (c) Current Injected by hunt APF (d) Input Source Voltage and Source Current

TABLE I
VOLTAGE AND CURRENT HARMONICS (THD'S) OF UPQC

Order of harmonics	WITHOUT UPQC utility side voltage	WITHOUT UPQC utility side current	UPQC with pi controller utility side voltage	UPQC with pi controller utility side current	UPQC with ANN controller utility side voltage	UPQC with ANN controller **Utility side current**
3rd &5th	**4.2**	**24.2**	**2.99**	**2.99**	**1.2**	**1.2**
5th & 7th	**4.2**	**24.6**	**3.42**	**3.42**	**1.19**	**1.19**
7th &9th	**4.2**	**24.6**	**2.18**	**2.18**	**1.3**	**1.3**

6. Conclusion

Custom power devices like DVR, D-STATCOM, and UPQC can enhance power quality in the distribution system. Based on the power quality problem at the load or at the distribution system, there is a choice to choose particular custom power device with specific compensation. Unified Power Quality Conditioner (UPQC) is the combination of series and shunt APF, which compensates supply voltage and load current imperfections in the distribution system.

A simple control technique based on unit vector templates generation is proposed for UPQC. Proposed model has been simulated in MATLAB. The simulation results show that the input voltage harmonics and current harmonics caused by non-linear load can be compensated effectively by the proposed control strategy. The closed loop control schemes of direct current control, for the proposed UPQC have been described. A suitable mathematical model of the UPQC has been developed with different shunt controllers (PI and ANN) and simulated results have been described which establishes the fact that in both the cases the compensation is done but the response of ANN controller is faster and the THD is minimum for the both the voltage and current which is evident from the plots and comparison table1.

REFERENCES

[1] C. A. Quinn and N. Mohan, “Active filtering of harmonic currents in three-phase, four- wire systems with three-phase and single phase nonlinear loads,” in *Proc. 7th IEEE APEC*, 1992, pp. 829– 836.

[2] M.Aredes, K.Heumann, and E.h.Watanabe, “An universal active power line conditioner,” *IEEE Trans. power Del*., vol.13, no.2, pp.542-551,Apri.1998.

[3] R. Faranda and I. Valade, “UPQC compensation strategy and design aimed at reducing losses,” in *Proc. IEEE ISIE*, 2002, vol. 4, pp. 1264–1270.

[4] G. Chen, Y. Chen, and K. M. Smedley, “Three-phase four-leg active power quality conditioner without references calculation,” in *Proc. 19th IEEE APEC*, 2004, vol. 1, pp. 829–836.

[5] V.Khadkikar, A. Chandra, A.O.Barry, and T.D.Nguyen, “Application of UPQC to protect a sensitive load on a polluted 2012 International Conference on Computer Communication and Informatics (ICCCI -2012), Jan. 10 – 12, 2012, Coimbatore, INDIA distribution network,” in *proc.IEEE PES General Meeting. Montreal, QC, Canada*, 2006, 6 pp.

[6] J.M.Correa,S.Chakraborty,M.G.Simoes,and F.A.Farret, “A single phase high frequency AC micro grid with an unified power quality conditioner.

[7] H.Akagi, Y.kanazawa, and A. Nabae, “Instantaneous reactive power compensators comparing switching devices without energy storage components,” *IEEE Trans. Ind.Appl.*, vol IA- 20,no.3,pp.625-630,may/Jun.1984

[8] L.H.Tey,P.L.So and Y.C.Chu,“Unified power quality conditioner for improving power quality using ANN with Hysterisis control,” *IEEE Tran. Power Electronics*,vol.9,no.3,may 1994,pp.1441-1446

[9] Moleykutty George,karthik Prasad Basu, “ Three-phase Shunt active power fliter” *American journal of applied sciences*,5(8):909- 916,2008.