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Design of Unified Power Quality Conditioner (UPQC) To Improve the Power Quality Problems by Using Instantaneous Real & Reactive Power Theory

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Abstract: Paper presents a Design of a Unified Power Quality conditioner (UPQC) connected to three phase four wire system (3P4W). The main aim is to maintain the load bus voltage sinusoidal and at desired constant level in all operating conditions. The neutral of series transformer used in the fourth wire for the 3P4W system. The neutral current that may flow toward transformer neutral point is compensated by using a four-leg voltage source inverter topology for shunt part. The series transformer neutral will be at virtual zero potential during all operating conditions. In this simulation we observe the power quality problems such as unbalanced voltage and current, harmonics by connecting nonlinear load to 3P4W system with Unified Power Quality conditioner. A new control strategy such as unit vector template is used to design the series APF to balance the unbalanced current present in the load currents by expanding the concept of single phase P-Q theory.

Keywords: Unified Power Quality conditioner (UPQC), Active Power Filter (APF) and Shunt (SAPF), Vector Template & PQ Controller

I. INTRODUCTION

To improve the power quality by connecting the series active power filter (APF) and shunt (APF). They 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 simplicity and cost is very low. And so many disadvantages are there, that is resonance problems and filter for every frequency and Bucky. That's we are choosing the active filters. By using active filters the power converter circuit using active components like IGBTs, MOSFETs, etc., and energy storage device (L or C). The advantages are filtering for a range of frequencies and no resonance problems and fast response. But only very few disadvantages are the cost is high. By connecting series active filters the voltage harmonic compensation, high impedance path to harmonic currents these are the main functions. 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.

II. LITERATURE SURVEY

The power electronic devices due to their inherent non linearity 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 [1]. 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 [2]. 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. 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 (SAPF). They are two types of filters one is passive filters and another one is active filters. In passive filters they are using Land C components are connected [3-10]. By connecting passive filters the system is simplicity and cost is very low and so many disadvantages are there, that is resonance problems and filter for every frequency and Bucky. That's we are choosing the active filters. By using active filters the power using active components like IGBTs, MOSFETs, etc., and energy storage device (L or C). The advantages are filtering for a range of frequencies and no resonance problems and fast response. But only very few disadvantages are there that is cost is high. By connecting series active filters the voltage harmonic compensation, high impedance path to harmonic currents these are the main functions. All these non-linear loads draw highly distorted currents from the utility system, with their third harmonics component almost as large as the fundamental [11&12]. 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. 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 3P4Wdistribution system [13].

III. PROPOSED SYSTEM

In proposed system easy expansion of 3P3W system to 3P4W system is possible. The neutral current, present if any, would flow through this fourth wire toward transformer neutral point. This neutral point current can be compensated by using a split capacitor. This neutral current achievement is used the method P-Q theory in UPQC. The extensive use of power electronic based equipment /loads almost in all areas, the point of common coupling (PCC) could be highly distorted. Also, the switching ON/OFF of high rated load connected to PCC may result into voltage sags or swells on the PCC. There are several sensitive loads, such as computer or microprocessor based AC/DC drive controller, with good voltage profile requirement; can function improperly or sometime can lose valuable data or in certain cases get damaged due to these voltage sag and swell conditions. One of the effective approaches is to use a unified power quality conditioner (UPQC) at PCC to protect the sensitive loads. A UPQC is a combination of shunt and series APFs, sharing a common dc link. It is a versatile device that can compensate almost all power quality problems such as voltage harmonics, voltage unbalance, voltage flickers, voltage sags & swells, current harmonics, current unbalance, reactive current. This method is based on the steady state analysis of UPQC during voltage sag and swells on the system. Aim is to maintain the load bus voltage sinusoidal and at desired constant level in all operating conditions. The major concern is the flow of active and reactive power during these conditions, as it plays an important role in selecting the KVA ratings of both shunt and series APF.

IV. SYSTEM CONFIGURATION

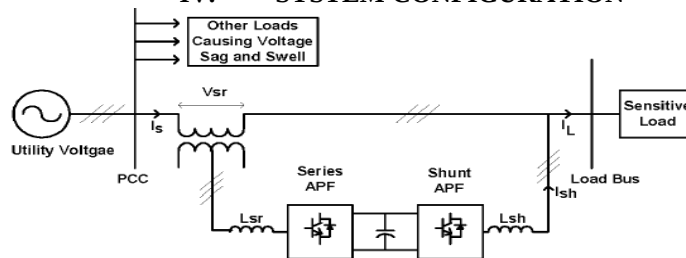


Fig.1: Block Diagram of UPQC

The UPQC is installed in order to protect a sensitive load from all disturbances. It consists of two voltage source inverters connected back to back, sharing a common dc link. One inverter is connected parallel with the load. It acts as shunt APF, helps in compensating load harmonic current, reactive current and maintain the dc link voltage at constant level. The second inverter is connected in series with the line using series transformers, acts as a controlled voltage source maintaining the load voltage sinusoidal and at desired constant voltage level is shown in fig 1.

V. PROPOSED CIRCUIT OPERATION

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 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 DC side capacitor voltage constant. Series active power filter compensate 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 fig 2.

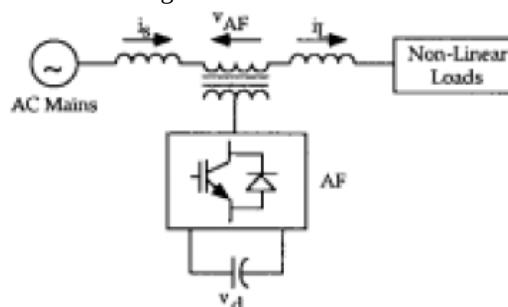


Fig. 2: Line diagram of series active power filter

Implementation of Shunt APF

The active filter concept uses power electronics to produce harmonic current components that cancel the 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 parallel or shunt filter is shown in fig 3.

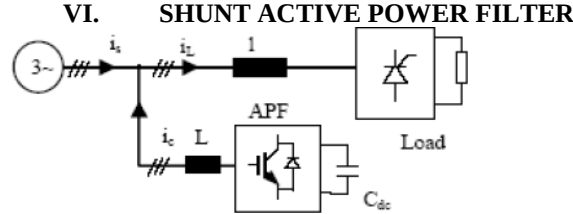


Fig. 3: Line Diagram of shunt active power filter

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. This inverter uses dc capacitors as the supply and can switch at a high frequency to generate a signal that will cancel the harmonics from the non-linear load.

VII. STEADY-STATE POWER FLOW ANALYSIS

The powers due to harmonics quantities are negligible as compared to the power at fundamental component, therefore, the harmonic power is neglected and the steady state operating analysis is done on the basis of fundamental frequency component only. The UPQC is controlled in such a way that the voltage at load bus is always sinusoidal and at desired magnitude shown in fig 4.

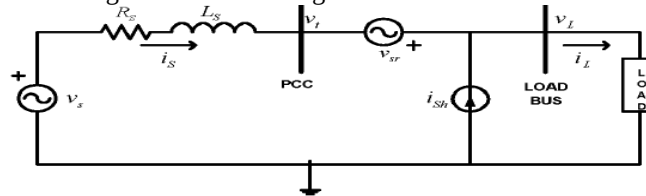


Fig. 4: Equivalent Circuit of a UPQC

The voltage injected by series APF can vary from 0^0 to 360^0 . Depending on the voltage injected by series APF, there can be a phase angle difference between the load voltage and the source voltage. However, in changing the voltage phase angle of series APF, the amplitude of voltage injected can increase, thus increasing the required kVA rating of series APF. The single phase equivalent circuit for a UPQC is shown in the Fig.2. The source voltage, terminal voltage at PCC and load voltage are denoted by v_s , v_t and V_L respectively. The source and load currents are denoted by i_s and i_L respectively. The voltage injected by series APF is denoted by v_{sr} , whereas the current injected by shunt APF is denoted by i_{sh} . The load voltage, V_L , as a reference phase and suppose the lagging power factor of the load is $\cos\phi_L$ then,

$$\bar{v}_L = v_L \angle 0^0 \quad (1)$$

$$\bar{i}_L = i_L \angle -\phi_L \quad (2)$$

$$\bar{v}_t = v_L (1+k) \angle 0^0 \quad (3)$$

Where factor k represents the fluctuation of source voltage, defined as,

$$k = \frac{v_t - v_L}{v_L} \quad (4)$$

The voltage injected by series APF must be equal to,

$$\bar{v}_{sr} = \bar{v}_L - \bar{v}_t = -kv_L \angle 0^0 \quad (5)$$

The UPQC is assumed to be lossless and therefore, the active power demanded by the load is equal to the active power input at PCC. The UPQC provides a nearly unity power factor source current, therefore, for a given load condition the input active power at PCC can be expressed by the following equations,

$$\begin{aligned}
 P_t &= P_L \\
 v_t \cdot i_s &= v_L \cdot i_L \cdot \cos \phi_L \\
 v_L (1+k) \cdot i_s &= v_L \cdot i_L \cdot \cos \phi_L \\
 i_s &= \frac{i_L}{1+k} \cdot \cos \phi_L
 \end{aligned} \tag{6}$$

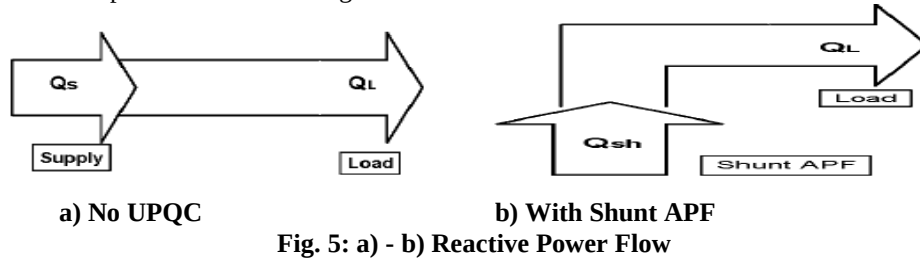
The current provided by the shunt APF, is the difference between the input source current and the load current, which includes the load harmonics current and the reactive current. Therefore, we can write as,

$$\begin{aligned}
 \bar{i}_{sh} &= \bar{i}_s - \bar{i}_L \\
 \bar{i}_{sh} &= i_s \angle 0^\circ - i_L \angle -\phi_L \\
 \bar{i}_{sh} &= i_s - (i_L \cdot \cos \phi_L - j i_L \cdot \sin \phi_L)
 \end{aligned} \tag{7}$$

$$\bar{i}_{sh} = (i_s - i_L \cdot \cos \phi_L) + j i_L \cdot \sin \phi_L \tag{8}$$

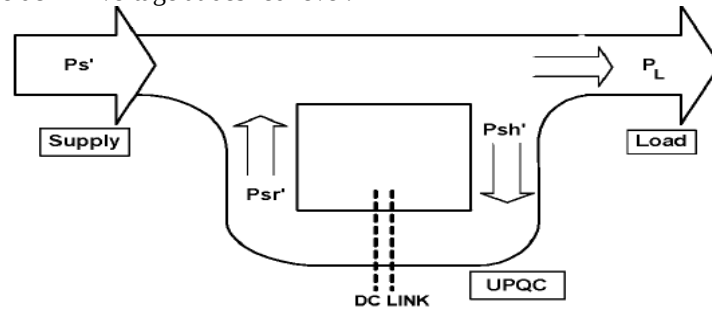
CASE I:

In this condition the reactive power required by the load is completely supplied by the source only. When the UPQC is connected in the network and the shunt APF is put into the operation, the reactive power required by the load is now provided by the shunt APF alone; such that no reactive power burden is put on the mains. So as long as the shunt APF is ON, it is handling all the reactive power even during voltage sag, voltage swell and voltage harmonic compensation shown in fig 5.



CASE II:

If $k < 0$, or $v_t < v_L$, P_s will be positive, means series APF supplies the active power to the load. This condition is possible during the utility voltage sag condition. i_s will be more than the normal rated current. Thus the required active power is taken from the utility itself by taking more current so as to maintain the power balance in the network and to keep the dc link voltage at desired level.



This active power flows from the source to shunt APF, from shunt APF to series APF via dc link and finally from series APF to the load. Thus the load would get the desired power even during voltage sag condition. Therefore in such cases the active power absorbed by shunt APF from the source is equal to the active power supplied by the series APF to the load shown in fig 6.

CASE III:

If $k > 0$, or $v_t > v_L$, P_s will be negative, this means series APF is absorbing the extra real power from the source. This is possible during the voltage Swell condition. i_s will be less than the normal rated current. Since v_s is increased, the dc link voltage can increase. To maintain the dc link voltage at constant level the shunt APF controller reduces the current drawn from the supply shown in fig 7.

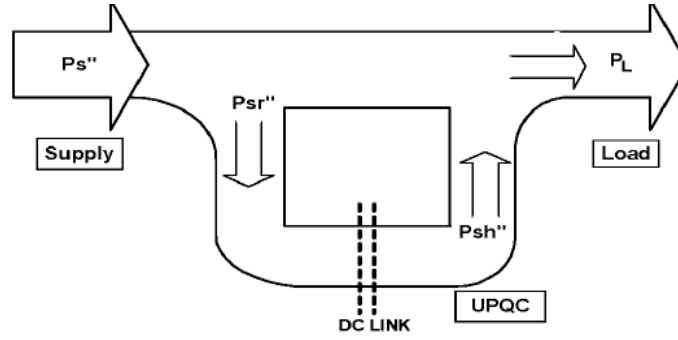


Fig.7: Active Power Flow during Voltage Swell Condition

CASE IV:

If $k = 0$, or $V_t = V_L$, then there will not be any real power exchange though UPQC. This is the normal operating condition shown in fig 8 &9.

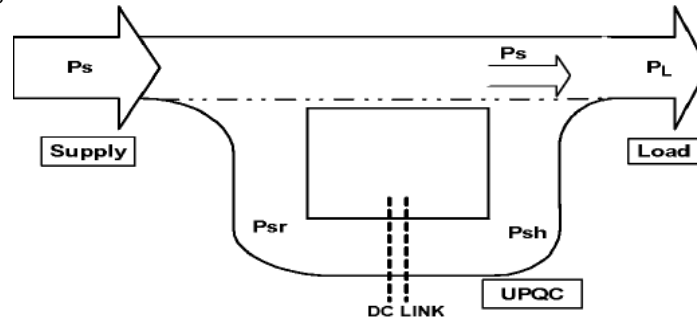


Fig. 8: Active Power Flow during Normal Working Condition

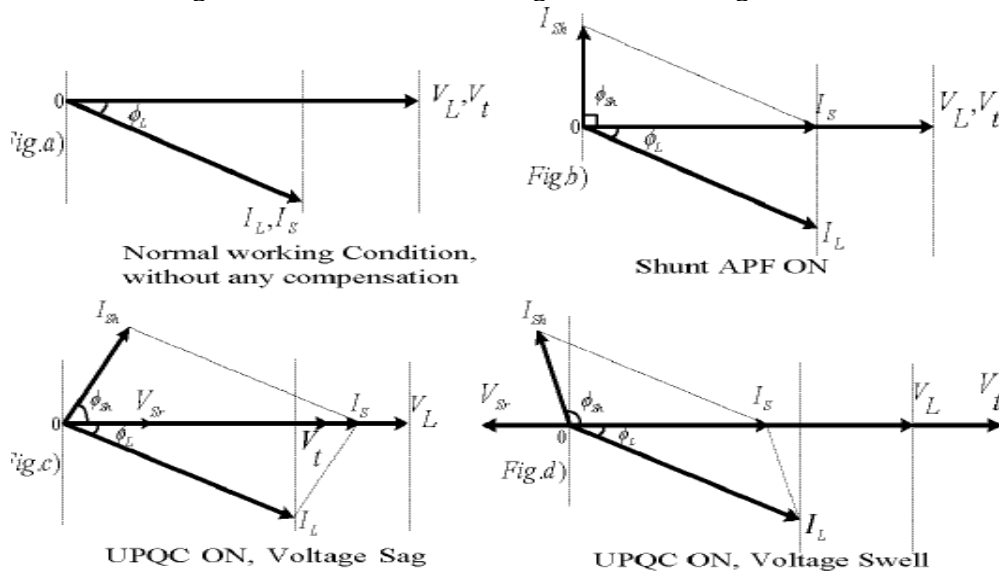


Fig. 9: a)-d) Phasor Representation of all Possible Conditions

VIII. CONTROL TECHNIQUE

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 amplitude. The three phase distorted input source voltage at PCC contains fundamental component and distorted component. To get unit input voltage vectors U_s the input voltage is sensed and multiplied by 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 loop (PLL). With proper delay; the unit vector templates are generated.

$$U_a = \sin \omega t \quad (9)$$

$$U_b = \sin(\omega t - 120^\circ) \quad (10)$$

$$U_c = \sin(\omega t + 120^\circ) \quad (11)$$

Multiplying the peak amplitude of fundamental input voltage with unit vector templates gives the reference load voltage signals.

$$V^* = V_m \cdot U_{abc} \quad (12)$$

The measured load voltages are compared with reference 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 templates 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 this dc link voltage is sensed and compared with reference dc link voltage. The error is then processed by PI controller. The output signal from PI controller is multiplied with unit vector templates giving reference source current signal. The three 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.

IX. EXPERIMENTAL RESULTS

The simulation block diagram of 3P4W system realized from a3P3W system utilizing UPQC is shown in Figure 10-13. Non-linear loads means by connecting power electronics devices to system. The plant load is assumed to be the combination of a balanced three-phase diode bridge rectifier followed by an R-L load, which acts as a harmonic generating load and three different single phase loads on each phase, with different load active and reactive power demands. By using equations (1), (3) and (5) to design the unit vector template of series APF is shown in figure.12 and figure.11 is Series active power filter controller shown in below figures and also shunt APF is Design in fig 10. Finally we compared with the existing load side V-I Output with the proposed output shown in fig 14 & 15.

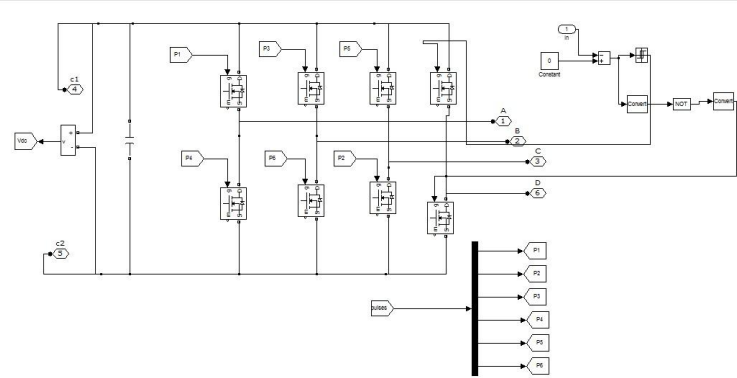


Fig. 10: Simulation Design Block Of Shunt Active Power Filter

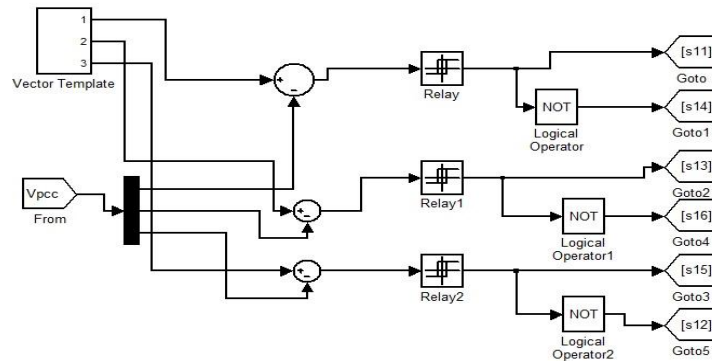


Fig. 11: Simulation Block of Series Active Power Filter

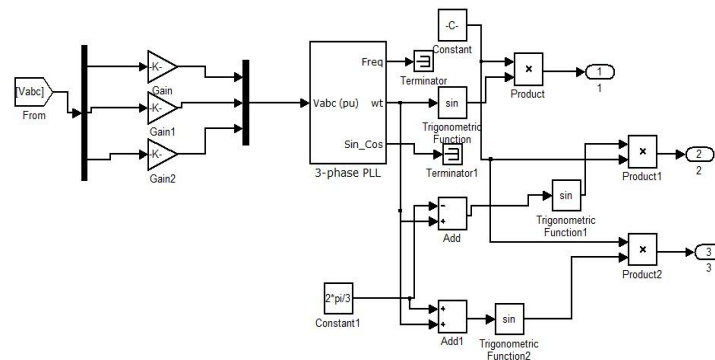


Fig. 12: Simulation Design Block of Vector Template

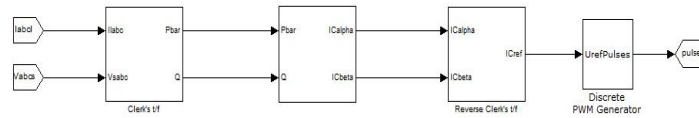


Fig. 13: Simulation Design Block of PQ Controller

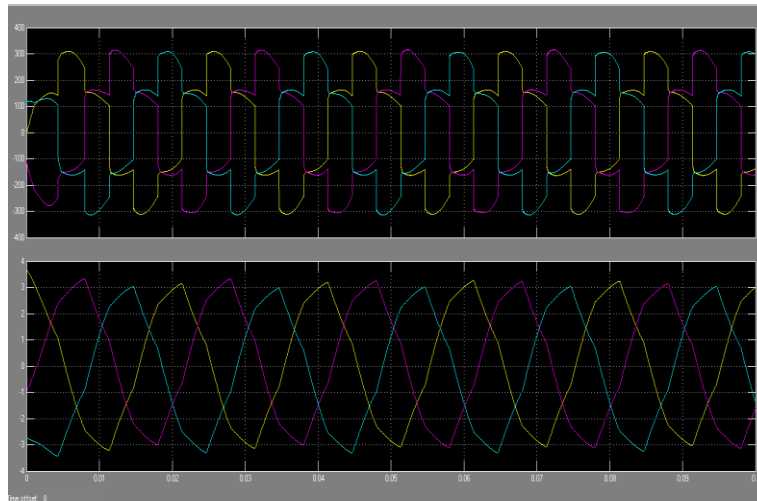


Fig. 14: Existing output of load side Voltage & Current Waveforms

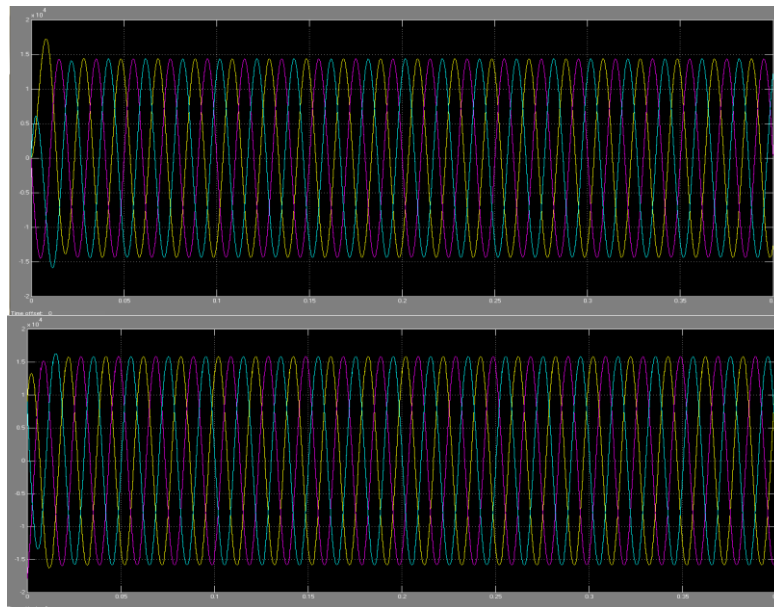


Fig. 15: Proposed output of load side Voltage & Current Waveforms

IX. CONCLUSION

The design of a unified power quality conditioner (UPQC) connected to 3 phase 4 wire distribution system has been presented in this paper. Where upqc is installed to compensate the different power quality problems, which may play an important role in future upqc- based distribution system. The simulation results shows that the distorted and unbalanced load currents seen from the utility side act as perfectly balanced source currents and are free from distortion. Here we can absorb the power quality problems like voltage and current unbalanced and reduced the total harmonic distortion (THD) of 3P4W system utilizing 3p3w system to connect the UPQC.

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