Abstract – This paper presents a control strategy of a three-phase, four-wire Unified Power Quality Conditioner (UPQC) to improve power quality. For the control of series APF, and shunt APF a simple scheme based on the Unit Vector Template Generation (UVTG) is applied. Generally, some topologies applied for 3P-4W UPQC use active compensation for the mitigation of source neutral current along with other power quality (PQ) problems, while the uses of passive elements for the mitigation of source neutral current are advantageous over the active compensation due to ruggedness and less complexity of control. Hence, in this paper a star-delta transformer is connected in shunt near the load for mitigation of source neutral current, while three-leg voltage source inverters (VSIs) based shunt and series active power filters (APFs) of 3P-4W UPQC mitigate the current and voltage based distortions, respectively. In this proposed UPQC control scheme, the current/voltage control is applied to the fundamental supply currents/voltages instead of fast-changing APF currents/voltages, thus reducing the computational delay. The current project will be done by using MATLAB/ Simulink to achieve performance of UPQC.

Keywords: Active Power Filter (APF), Power Quality(PQ), Unit Vector template Generation (UVTG), Unified Power Quality conditioner (UPQC), three phase four wire(3P4W) system.

I. INTRODUCTION

The main objective of electric utility companies is to supply their customers with uninterrupted sinusoidal voltage of constant magnitude. However this is becoming increasingly difficult to do, because the size and number of non-linear and poor power factor loads such as adjustable speed drives, computer power supplies, furnaces and traction drives are increasing rapidly. Due to their non-linear nature, these solid state converters cause excessive neutral currents in three phase four wire systems. Moreover, in the case of the distribution system, the overall load on the system is seldom found to be balanced. In the past, the solutions to mitigate these identified power quality problems were through using conventional passive filters. But their limitations such as, fixed compensation, resonance with source impedance and the difficulty in tuning time dependence of filter parameters have ignited the need for active and hybrid filters. The rating of active filters is reduced through augmenting them with passive filters to form hybrid filters, which reduce overall cost. Also they can provide better compensation than either passive or active filters. If one can afford the cost, then a hybrid of two active filters provides the best solution and thus it is known as a unified power quality conditioner (UPQC) or universal active filter. Therefore, the development of hybrid filter technology has been from a hybrid of passive filters to a hybrid of active filters to provide a cost-effective solution and optimal compensation.

The function of unified power quality conditioner is to compensate supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics. 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 is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage flicker/imbalance. The UPQC consisting of the combination of a series active power filter (APF) and shunt APF can also compensate the voltage interruption if it has some energy storage or battery in the dc link. The proposed control technique has been evaluated and tested under unbalanced load conditions using MATLAB/Simulink software.

II. UNIFIED POWER QUALITY CONDITIONER

The UPQC consists of two voltage source inverters connected back to back with each other sharing a common dc link. One inverter is controlled as a variable voltage source in the series APF, and the other as a variable current source in the shunt APF. Fig. 1 shows a basic system configuration of a general UPQC consisting of the combination of a series APF and shunt APF. The main aim of the series APF is harmonic isolation between load and supply; it has the capability of voltage flicker/imbalance compensation as well as voltage regulation and harmonic compensation at the utility-consumer
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UVTG Control Strategy for Three Phase Four Wire UPQC to Improve Power Quality

III. SYSTEM CONFIGURATION

Fig. 2 shows a 3P-4W UPQC topology, which is feeding a combination of linear and non-linear unbalanced load. The series and shunt APFs are realized using two readily available three-leg VSIs. The dc links of both APFs are connected to a common dc link capacitor. The series APF is connected between the supply and load terminals through a three single phase transformers.

Fig. 3 Control Scheme of Series APF

Three-phase distorted supply voltages are sensed and given to PLL, which generates two quadrature unit vectors. The in-phase sine and cosine outputs from the PLL are used to compute the supply in phase, 120° displaced three unit vectors (ua, ub and uc) using eqn. as

\[
\begin{bmatrix}
  u_a \\
  u_b \\
  u_c \\
\end{bmatrix}
= \begin{bmatrix}
  1 & 0 & \frac{\sqrt{3}}{2} \\
  -1 & \frac{\sqrt{3}}{2} & 0 \\
  -1 & -\frac{\sqrt{3}}{2} & 0 \\
\end{bmatrix}
\begin{bmatrix}
  \sin \theta \\
  \cos \theta \\
\end{bmatrix}
\]

The computed three in-phase unit vectors then multiplied with the desired peak value of the PCC phase voltage (V*lm), which becomes the three-phase reference PCC voltages as:

\[
\begin{bmatrix}
  V'_{ua} \\
  V'_{lb} \\
  V'_{lc} \\
\end{bmatrix}
= V'_{lm}
\begin{bmatrix}
  u_a \\
  u_b \\
  u_c \\
\end{bmatrix}
\]
The computed voltages from reference voltages from eqn. are then given to the hysteresis voltage controller along with the sensed three phase PCC voltages \( v_{la}, v_{lb} \) and \( v_{lc} \). The output of the hysteresis controller is switching signals to the six switches of the VSI of series APF. The hysteresis controller generates the switching signals such that the voltage at PCC becomes the desired sinusoidal reference voltage.

4.2. Shunt Control Strategy:
The control algorithm for shunt APF [1] consists of the generation of three-phase reference supply currents \( (i^*_{sa}, i^*_{sb} \) and \( i^*_{sc} \)) and it is depicted in Fig.4.

\[
\begin{bmatrix}
    i^*_{sa} \\
    i^*_{sb} \\
    i^*_{sc}
\end{bmatrix} = \begin{bmatrix}
    u_a \\
    u_b \\
    u_c
\end{bmatrix}
\]

The computed three-phase supply reference currents are compared with the sensed supply currents and are given to a hysteresis current controller to generate the switching signals to the switches of the shunt APF which makes the supply currents follow its reference values. In this control scheme, the current control is applied over the fundamental supply currents instead of the fast changing APF currents, thereby reducing the computational delay and number of required sensor. In addition to this, no extra control is required for the mitigation of source neutral current. The simulation model of three phase four wire Unified Power Quality Conditioner(UPQC) is shown in fig.5.

![Fig.4 Control Scheme of Shunt APF](image)

Fig.4 Control Scheme of Shunt APF

![Fig.5 MATLAB model of star-delta transformer supported 3P-4W UPQC](image)

Fig.5 MATLAB model of star-delta transformer supported 3P-4W UPQC

V. SIMULATON RESULTS

In this study, the control algorithm for the UPQC is evaluated by using MATLAB/Simulink software under combination of linear and nonlinear load conditions. The simulation results for the proposed 3P4W system realized from a 3P3W system utilizing UPQC are shown in below. Without UPQC load voltages are distorted with voltage THD of 28.28%. The distorted voltage profile is shown in fig.6. The UPQC should maintain the voltage at load bus at a desired value and free from distortion. The plant load is assumed to be the combination of a balanced three-phase diode bridge rectifier followed by an R-L load, and three single-phase loads. The series APF injects the required compensating voltages through series transformer, making the load voltage free from distortion are shown in fig.7. The series APF injected profile is shown in fig.8. Simultaneously, the shunt APF injects the compensating currents to achieve the balanced source current, free from distortion, as discussed in the previous section. With UPQC source current waveform is shown in fig.9.
Load neutral current, transformer neutral current and shown in fig.10 and fig.11. Transformer neutral current is exactly opposite to the load neutral current so that source neutral current reduced to zero. The harmonic spectrums of load voltage without UPQC is shown in fig.13 and it is having a harmonic distortion of 28.28%. After connecting UPQC, load voltage distortion is reduced to 2.81% and it is shown in fig.15. Source current THD is shown in fig.16.
VI. CONCLUSION

UVTG control for a 3P4W distribution system utilizing UPQC has been proposed in this paper. This proposed topology would be very useful to expand the existing 3P3W system to 3P4W system where UPQC is installed to compensate the different power quality problems. The MATLAB/Simulink-based simulation results show that the utility side source currents and load voltages are perfectly balanced and are free from distortion. The star-delta transformer connected near the load effectively compensates the source neutral current. By connecting a star-delta transformer on the load side, the rating of the UPQC is reduced due to elimination of a fourth leg compared to three-phase four-leg VSI based 3P-4W UPQC. In addition to this, no extra control is required for the mitigation of neutral current; hence numbers of current sensors are reduced. Without UPQC the load voltage and source currents are unbalanced but after connecting UPQC those become balanced.
APPENDIX

The system parameters used are as follows:

<table>
<thead>
<tr>
<th>System parameters</th>
<th>values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply voltage</td>
<td>400V (Vrms)</td>
</tr>
<tr>
<td>Linear loads in phases</td>
<td>6kW, 3kVar; 3kW, 900Var; 2kW, 2.5kVar</td>
</tr>
<tr>
<td>a, b and c</td>
<td></td>
</tr>
<tr>
<td>Three phase rectifier load</td>
<td>R=60 Ω and L=5 mH on dc side</td>
</tr>
<tr>
<td>DC link capacitance value</td>
<td>10 mF</td>
</tr>
<tr>
<td>Star-delta transformer</td>
<td>5 kVA ; 231V/231V</td>
</tr>
</tbody>
</table>

REFERENCES


[6]. Yash Pal, A. Swarup, B. Singh “3P-3W UPQC with zig-zag transformer for 3P-4W Distribution System”, International Journal on Electrical Engineering and Informatics Volume 4, Number 2, July 2012