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Research Paper

SIMULATION OF RIGHT SHUNT UNIFIED POWER QUALITY CONDITIONER

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The proliferation of power electronic based equipment has produced a significant impact on the quality of electrical power supply. Unified Power Quality Conditioner (UPQC), which consists of double converters connected through a DC capacitor. With each other has high potential because of its high controllability. UPQC connected can insert a virtual inductance on the line and, at the same time, its shunt inverter can compensate the line voltage on SVG. The power quality variations are classified as either disturbance or steady state variation. In this paper Left Shunt Unified Power Quality Conditioner (L-UPQC) is proposed to improve the quality of the power delivered to the load. The role of UPQC is to convert the feeder (source) current to balanced sinusoids through the shunt compensation and converter load voltage (VL) to balanced sinusoids through the series compensator and also regulate it to a desired value. The performance of the left shunt (L-UPQC) is tested under different operating condition based on proposed controller to improve power quality of a single feeder distribution system. The simulation results and performance of both UPQC technologies is implemented on MATLAB/SIMULINK platform.

Keywords: Unified power quality conditioner, Power quality, Power factor correction

INTRODUCTION

With the increasing application of non-linear load, the appearance of power quality problem is inevitable like voltage sag interruption distortion and harmonics. The many harmonic sources are single-phase load, such as florescent compact lamp, copier's printer and other home and of electronic equipment. In addition to this the power factor of a load are generally poor. The left shunt unified power quality conditioner(L-UPQC) is one of the key custom power devices, which compensate both current and voltage related problems. In construction a (L-UPQC) connected to a single feeder distribution system which supply a sensitive critical non-linear load are shown in Figure 1. The shunt compensator, VSC_1 which operate as a controlled current source is used

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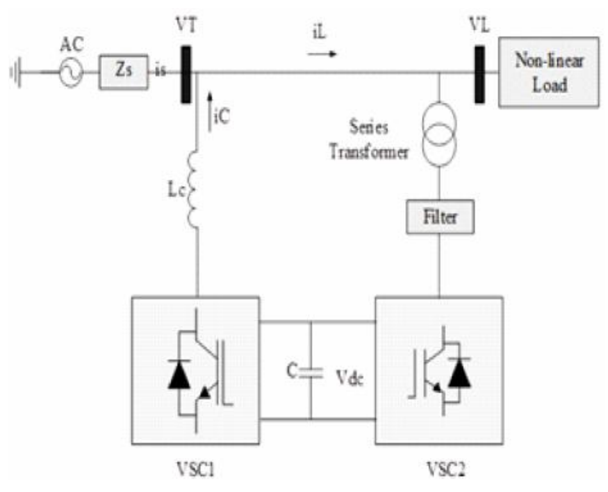
Figure 1: Left Shunt UPQC



into compensate load current harmonics, to provide the reactive power required by the load and to support the real power required by the series compensator to maintainDC link capacitor voltage desired level. The series compensator VSC_2 is used as controlled voltage source to protect the sensitive/non-linear load again input supply voltage importations. The main purpose of a (L-UPQC) is to compensate for supply voltage power quality issues, such as sag, swell, unbalance, dc offset, flicker, harmonics and for load current power quality problem such as harmonics, unbalance, reactive current and neutral current Figure 1. A single feeder distribution system.

The key component of this system is as follows:

1. Two inverter-one connected across the load which act as a shunt APF and other connected in series with line as that of series active power filter.
2. Commutation reactor Lc is used interface the shunt inverter to the network. It also helps in smoothing the current wave shape.
3. A common dc link that can be formed by using a capacitor or an inductor. In Figure 1 the dc link is realized using a capacitor which interconnects two inverter and also maintain a constant self-supporting dc bus voltage across it.
4. AnLc filter that serves as a passive Low Pass Filter (LPF) and help to eliminate high frequency switching ripples on generated inverter output voltage.
5. Series transformer that is used to connect the series inverter in the network. A suitable turn ratio is obtained considered to reduce the current or voltage rating of the series inverter.

Now on the basic configuration, it is divided into two parts (a) Left shunt Unified Power Quality Conditioner (L-UPQC), (b) Right shunt Unified Power Quality Conditioner (R-UPQC).

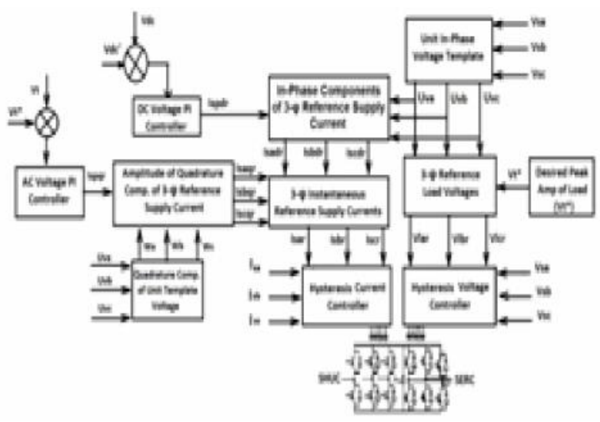
CONTROL STRATEGY OF L-UPQC

The proposed control strategy to generate to reference signal for both shunt and series active power filters of L-UPQC. An approached based out is exploited to get reference voltage signal for the series active filter,whereas the control strategy for shunt active power filter utilized to closed loop PI-controller. The reference voltage generation for series and shunt active active power filter Figure 2.

Reference Voltage Signal Generation for Series APF

The extraction of the three phase voltage reference signal for series active filter is based on unit vector template generation, achieved with the help of unit vector templatesgenerator.

Figure 2: Control Strategy of Left Shunt UPQC



Three phase in-phase unit templates (U_{va}, U_{vb}, U_{vc}) are derive form the three phase supply (V_{sa}, V_{sb}, V_{sc}) three unit vector templetes are multiplied with desired peak amplitude ($V*_t$) of load voltage to reference load voltage denoted by V_{lar}, V_{lbr} and V_{lcr}.

$$V_{lar} = V_t^*(U_{va})$$

$$V_{lbr} = V_t^*(U_{vb})$$

$$V_{lcr} = V_t^*(U_{vc})$$

Reference Current Signal Generation for Shunt APF

The control strategy for shunt APF utilized to closed loop PI controller. One controller is used to get the amplitude of the in phase components of the reference supply current (I_{spdr}), while the other PI controller is exploited to calculate the amplitude of the quadrature component of reference supply current (I_{spqr}). The first PI controller is realized on the sensed and reference value of DC bus voltage back to back VSI capacitor of UPQC, while the second PI controller is on sensed and reference peak value of load voltage ($V*_t$). To regulate the load voltage, three phase reference supply current two components. The first components of reference supply current in phase with the source voltage . It is required to the feed active power to load and losses of UPQC. The second component is in quadrature with the source voltage. This component is used to feed reactive power load and to compensate voltage regulation. In the supply current should load the supply voltage for voltage regulation while the supply current should be in-phase with the supply voltage for unity power factor operation.

The multiplication of amplitude of the in-phase component of reference supply current (I_{spr}) with in-phase unit current vector (U_{va}, U_{vb}, U_{vc}) result in the in phase component (I_{sadr}, I_{sbdr} and I_{scdr}) of three phase component (I_{sadr}, I_{sbdr} and I_{scdr}) of three phase reference supply current. The quadrature components (I_{sadqr}, I_{sbdqr} and I_{scdqr}) of three phase reference supply current are obtained by multiplication of amplitude of the quadrature components of reference supply currents (I_{spqr}) with quadrature unit current vector (W_a, W_b and W_c). The algebraic sum of the in-phase and quadrature components resulting the three phase reference current supply current (I_{sar}, I_{sbr} and I_{scr}) of shunt APF for voltage regulation while, for unity power factor in-phase component (I_{sadr}, I_{sbdr} and I_{scdr}) are three phase reference supply current of the shunt APF.

Computation of In-phase Component of in Phase of Reference Current

The amplitude of in-phase components of reference supply current (I_{spdr}) is computed using PI controller over the average value of the DC bus voltage of the back to back connected VSI of the UPQC and its reference contribute

$I_{spdr}(n) = I_{spdr}(n–1) + K_{pd}\{V_{de}(n) – V_{de}(n–1)\} + K_{id}v_{de}(n)$

where $V_{de}(n) = V_{dcr} – V_{dca}(n)$ denoted the error in V_{dc} calculated error reference value of V_{dc} and average value of K_{pd} and K_{id}

Is proportional and integral gain of the DC bus voltage PI controller. To obtain the three phase in-phase component of the reference supply current (I_{eper}), is multiplied with in-phase unit current.The amplitude of in phase components of reference supply current is computed as:

$I_{sadr} = I_{spdr}(U_{va})$

$I_{sbdr} = I_{spdr}(U_{vb})$

$I_{scdr} = I_{spdr}(U_{vc})$

Computation of Total Reference Current

Three phase instantaneous reference supply current are computed by algebraic sum of in-phase and quadrature component as for equation given below:

$I_{sar} = I_{sadr} + I_{saqr}$

$I_{sbr} = I_{sbdr} + I_{sbqr}$

$I_{scr} = I_{scdr} + I_{scqr}$

A carrier-less hysteresis current controller is employed over the reference and sensed supply current to generate the gating pulse of IGBT's of shunt APF and similarly carrier-less hysteresis voltages controller is employed over the return and sensed source voltage to generate gating pulsed of IGBT's of series APF. In this control scheme, the current and voltage control is applied over the fundamental component instead of the fault changing apf current/voltage, thereby reducing the computational relay and number of required sensor.

SIMULATIOM AND RESULTS

A single machine infinite bus system with nonlinear load is considered for test case, as shown in Figure 3 model for non-linear load is presented in Figure 3. For test case the system has modeled with the voltage rating of 100 V, 60 Hz and 10 kΩ load. Simulation is carried out with the help of MATLAB/Simulink for system with UPQC and without UPQC and harmonic distortion is considered for analysis. Figure 4 shows the MATLAB/Simulink model for the proposed system with UPQC. In the proposed system PI controller is used to regulate the error voltage and current values. Using instantaneous power theory the required reactive power injection values are obtained.

Current harmonics is injected with the help of non-linear load. Figures 5-11 show the

Figure 3: MATLAB/Simulink Diagram for Single Unit Infinite Bus System

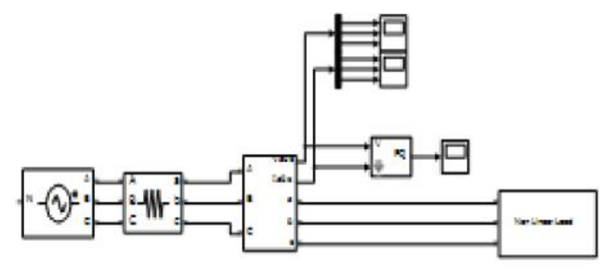


Figure 4: MATLAB/Simulink Model for Single Unit Infinite Bus System with UPQC

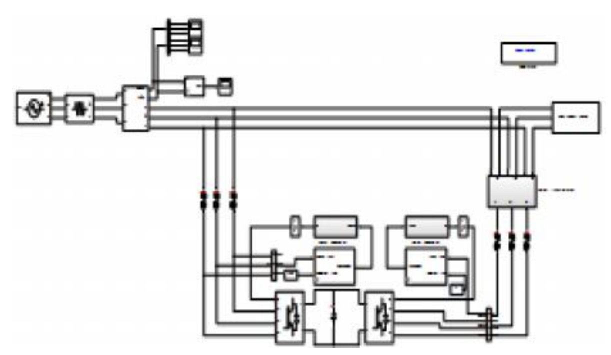


Figure 5: Simulated Voltage Response of Grid Voltage Without UPQC with Non-Linear load

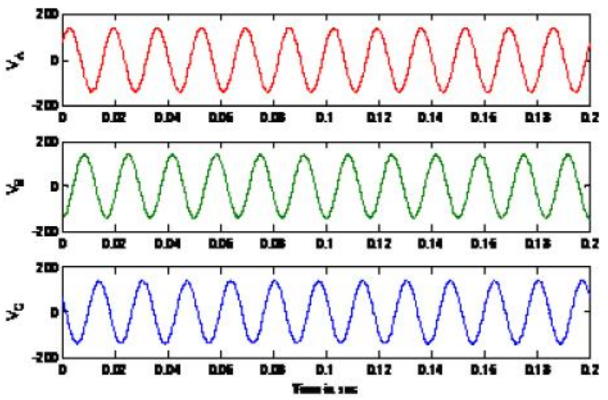


Figure 8: Simulated Reactive Power Response of Grid Without UPQC with Non-Linear Load

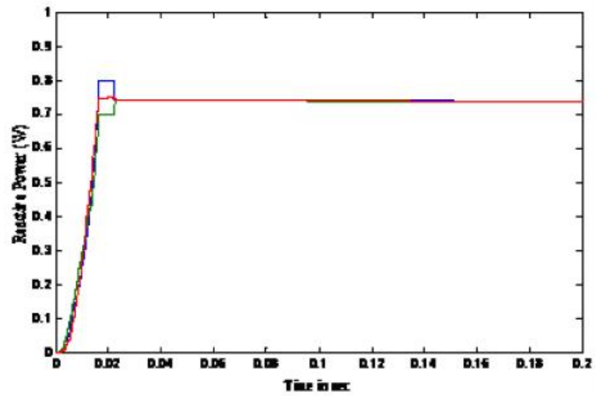


Figure 6: Simulated Current Response of Grid Without UPQC with Non-Linear Load

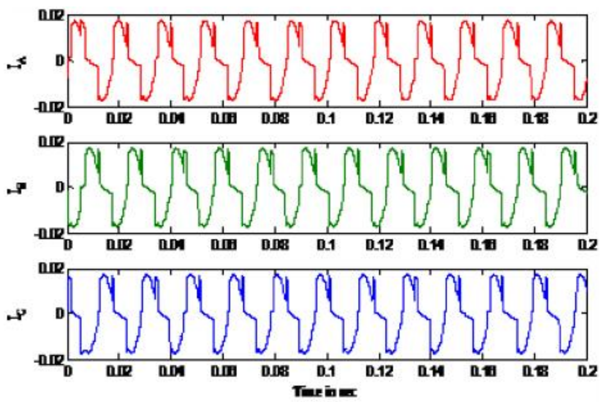


Figure 9: Simulated Voltage Response of Non-Linear Load Connected to the System Without UPQC

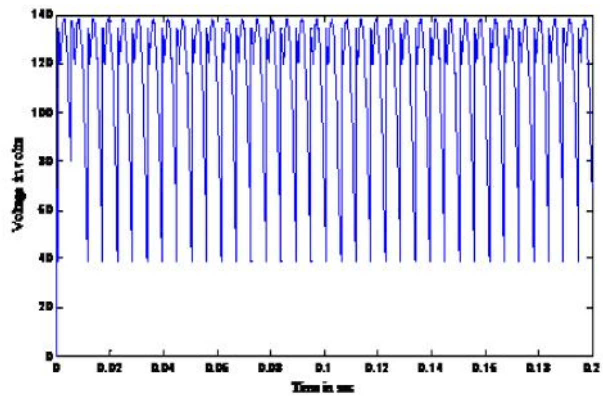


Figure 7: Simulated Real Power Response of Grid Without UPQC with Non-Linear Load

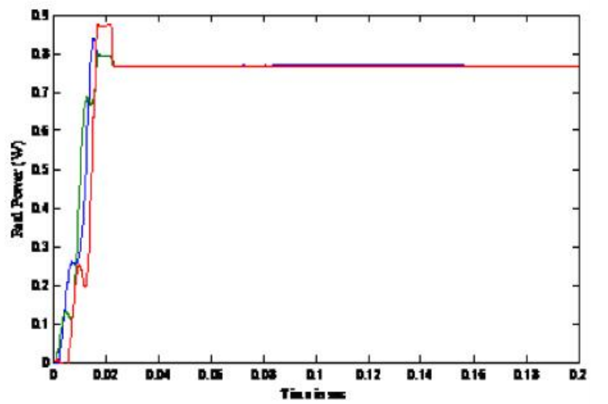


Figure 10: Simulated Current Response of Non-Linear Load Connected to the System Without UPQC

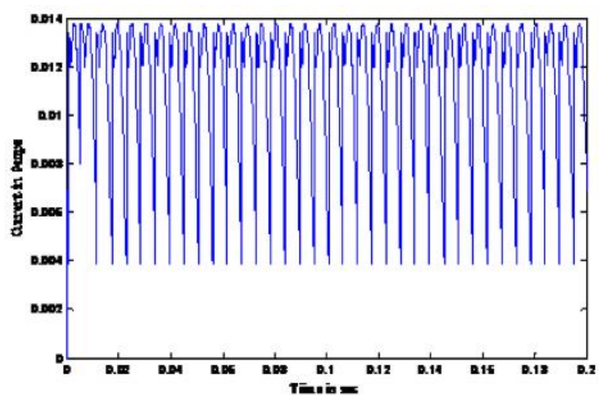
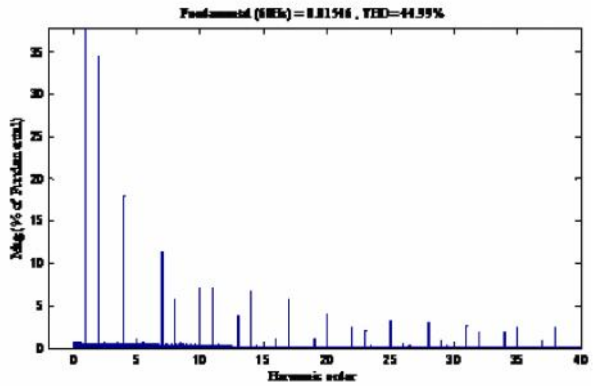


Figure 11: THD Analysis of Grid Current Without UPQC with Non-Linear Load



responses of the system without UPQC and Figures 12-16 show the responses of the system with UPQC. Figures 5 and 12 show the voltage response of system without and with UPQC device. Figures 6 and 13 show the current response of grid without and with UPQC, from these figures it's observed that harmonics present in the system is reduced. Figures 7, 8, 14 and 15 show the real and reactive power response of the system without and with UPQC, from this figure it's observed that real power of the system has improved from 0.8 to 13 units approximately using UPQC. Using FFT, harmonics presence in the grid current is analyzed and shown in Figures

Figure 12: Simulated Voltage Response of Grid with UPQC with Non-Linear Load

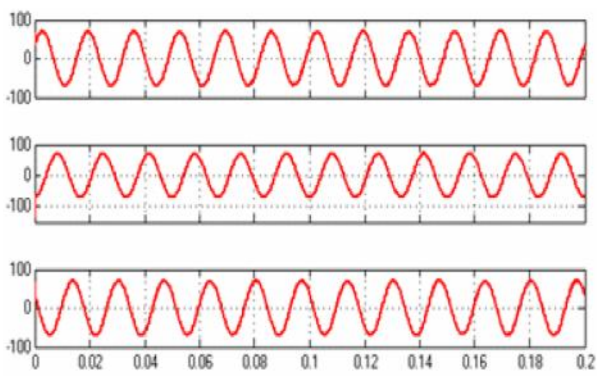


Figure 13: Simulated Current Response of Grid with UPQC with Non-Linear Load

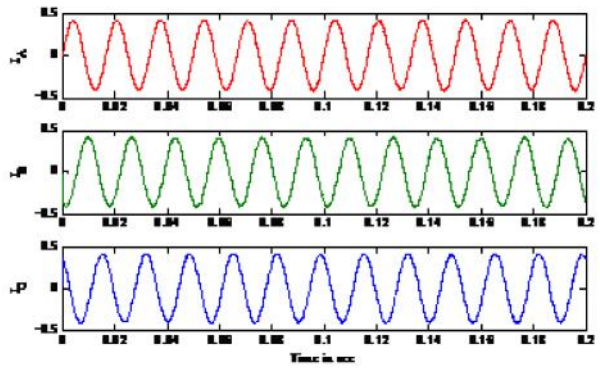


Figure 14: Simulated Real Power Response of Grid with UPQC with Non-Linear Load

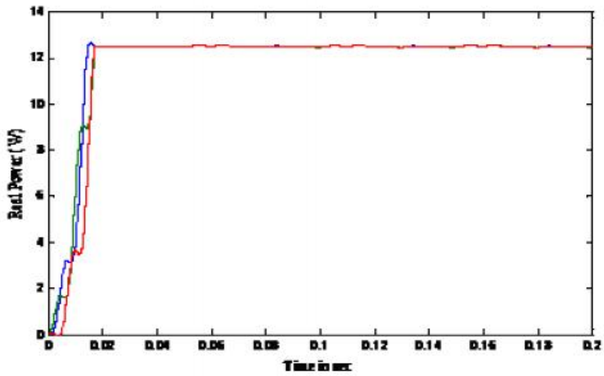
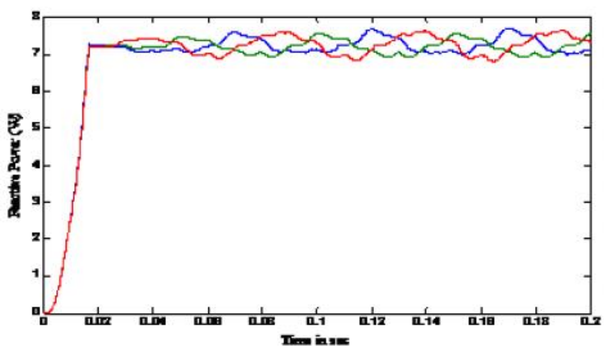
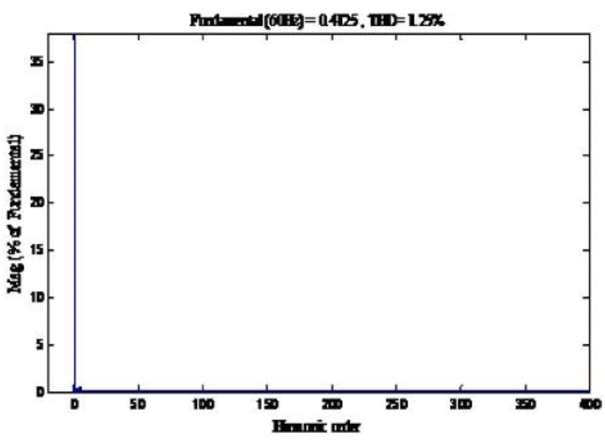


Figure 15: Simulated Reactive Power Response of Grid with UPQC with Non-Linear Load



11 and 16 for without and with UPQC device. From Figures 11 and 16 it is observed that the Total harmonic distortion has improved from 44.99% to 1.25%.

Figure 16: THD Analysis of Grid Current with UPQC with Non-Linear Load



CONCLUSION

In this work L-UPQC based on new series compensation controller to compensate voltage and current harmonics. The compensation performance of UPQC is established by the simulation results on a single feeder distribution system. It is found that the L-UPQC topology only has the capability of operating in zero power injection/absorption modes. It is observed that L-UPQC provided better compensation by reducing the THD of load voltage and source current. However, the UPQC topologies provided compensation performance to mitigate voltage harmonic and minimize oscillating reactive power component based on proposed series compensator controller.

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