Modelling and Simulation of Unified Power Quality Conditioner (UPQC) for Mitigation of Power Quality Problems

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Abstract

A power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mal-operation of end use equipment. With shifting trend towards distributed and dispersed generation, the issue of power quality is taking new dimensions. The concept of custom power was introduced to distribution systems for improving the system performance. The aim therefore, in this work, is to identify the prominent concerns in the area and thereby to recommend measures that can enhance the quality of the power, keeping in mind their economic viability and technical consequences. The Unified power quality conditioner (UPQC) is an effective custom power device for the enhancement of power quality due to its quick response, high reliability and nominal cost. A Unified power quality conditioner is used to compensate distortion in source current. It is efficiently capable of protecting sensitive loads against the voltage variations or disturbances//. The MATLAB software is used to simulate the 415 Volt system comprising of Non-linear load which injects harmonics in supply current and the supply voltage is Non-ideal. The Developed system in MATLAB using SRF (Synchronous reference frame) method.

Keywords: Harmincs Distoration, Powe Quality, Unified power quality conditioner, DVR, SRF

Nomenclature

DVR - Dynamic Voltage Restorer
APF - Active Power Filter
THD - Total Harmonic Distortion
UPQC - Unified Power Quality Conditioner
SRF - Synchronous Reference Frame
PLL - Phase Locked Lo

1. Introduction

Power Quality (PQ) has become an important issue to electricity consumers at all levels of usage. The PQ issue is defined as "Any power problem manifested in voltage, current, or frequency deviations that results in failure or mal operation of customer equipment." The development of power electronic based equipment has a significant impact on quality of electric power supply. The switch mode power supplies (SMPS), dimmers, current regulator, frequency converters, low power consumption lamps, arc welding machines, etc. are some out of the many vast applications of power electronics based devices. The operation of these loads/equipment generates harmonics and thus, pollutes the modern distribution system. The growing interest in the utilization of renewable energy resources for electric power generation is making the electric power distribution network more susceptible to power quality problems. In such conditions both electric utilities and end users of electric power are increasingly concerned about the quality of electric power.

Many efforts have been taken by utilities to fulfil consumer requirement; some consumers require a higher level of power quality than the level provided by modern electric networks. This implies that some measures must be taken so that higher levels of Power Quality can be obtained. Active power filters (APF) have been proposed as efficient tools for power quality improvement. Active power filters can be classified as series or shunt according to their system configuration. The series APF generally takes care of the voltage-based distortions, while shunt APF mitigates current based distortions. The combination of series and shunt

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active power filter is called the unified power-quality compensator (UPQC). UPQC mitigates the voltage and current based distortion simultaneously as well as independently. In this thesis the main focus is on UPQC .

The paper [6] presents the enhancement of power quality for a micro grid system at distribution level using Shunt active power filter. The main objective of this paper is to identify a suitable controller technique for obtaining a better compensation capability of shunt active power filter. The compensation capability of the device is mainly depends on the regulation of DC link capacitor voltage. Conventionally this voltage regulation is achieved by the closed loop operation of PI controller. To raise the performance of shunt active power filter, Unit Vector Template Generation (UVTG) has been proposed [7].

2. Unified Power Quality Conditioner (UPQC)

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system. Fig. 3.1 shows the system configuration of a single-phase UPQC[15]. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage Source Converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor .

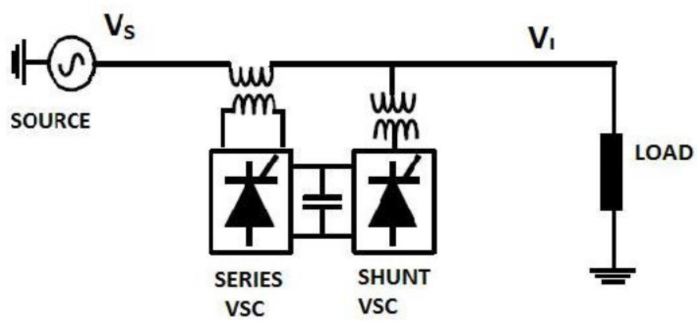

Fig.1. Block Diagram of UPQC

2.1 Series APF

In a transmission line series APF is generally connected in series. It is connected to the transmission line with the transformer. Series APF is a voltage source inverter connected in series with transmission line. It is used to compensate or mitigate the problems which comes due to voltage distortions and voltage unbalances. The series APF injects a compensating voltage so that load voltage will be perfectly balanced and regulated. Controlling of series inverter is done by PWM (pulse width modulation) techniques [14]. Here we used Hysteresis band PWM techniques as it implementation is easy. Also its response is fast. Its details are explained in subsequent sections.

2.2 Shunt APF

In a transmission line shunt APF is generally connected in parallel. Shunt APF is used to compensate for distortions & harmonics which are produced due to current. Due to non- linear load there are harmonics in load current, so to keep source current completely sinusoidal and distortion free, we uses Shunt APF[16]. Shunt APF injects compensating current so that the source current is completely sinusoidal and free from distortions. Controlling of Shunt APF is done by hysteresis band PWM techniques. In hysteresis band PWM techniques output current follows the reference and current and is within the fixed hysteresis band .

2.3 Synchronous Reference Frame (SRF) Technique

The series active filter based on SRF method can be used to solve the voltage related power quality problems such as, voltage sag, voltage swell and voltage harmonics. The SRF method is used in series active filter for generating reference voltage signal[17].

To implement the SRF method and for reference voltage calculation the phase locked loop (PLL) is used to generate the transformation angle (ωt) which presents the angular position of the reference frame. This transformation presents is known as park transformation. Figure 3.10 Shows the Control block diagram of SRF theory for generating voltage reference signal in Series APF. The source voltages from a-b-c coordinates are transformed to d-q-0 coordinates. Then the d axis component is passed through low pass filter to obtain the reference source voltage in d-q coordinates. [13].

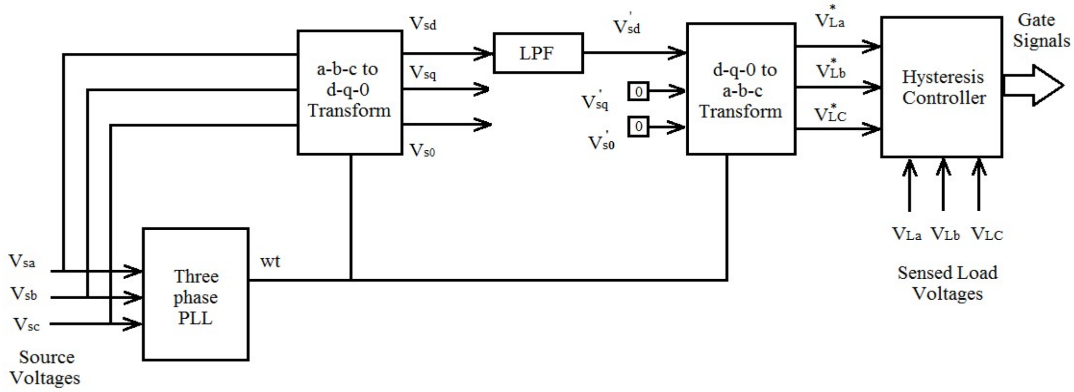

Fig. 2. Control Block Diagram of Series APF Using SRF

3. Simulation Results of Series APF with SRF

Series APF is used to mitigate all problems related to voltage unbalance and disturbance. It mitigate the voltage unbalance in source voltage i.e. voltage dip/rise so that the load voltage become perfectly balanced and regulated. Table-1 shows system parameters of series APF.

Table 1. System parameters used for series APF

Supply Voltage	415 V
Line Frequency	50 Hz
Line impedance	R = 0.01Ω & L = 0.01 mH
Load impedance	R = 50Ω & L = 1 mH
Series Transformer turns ratio	1:1
DC Voltage	415 V

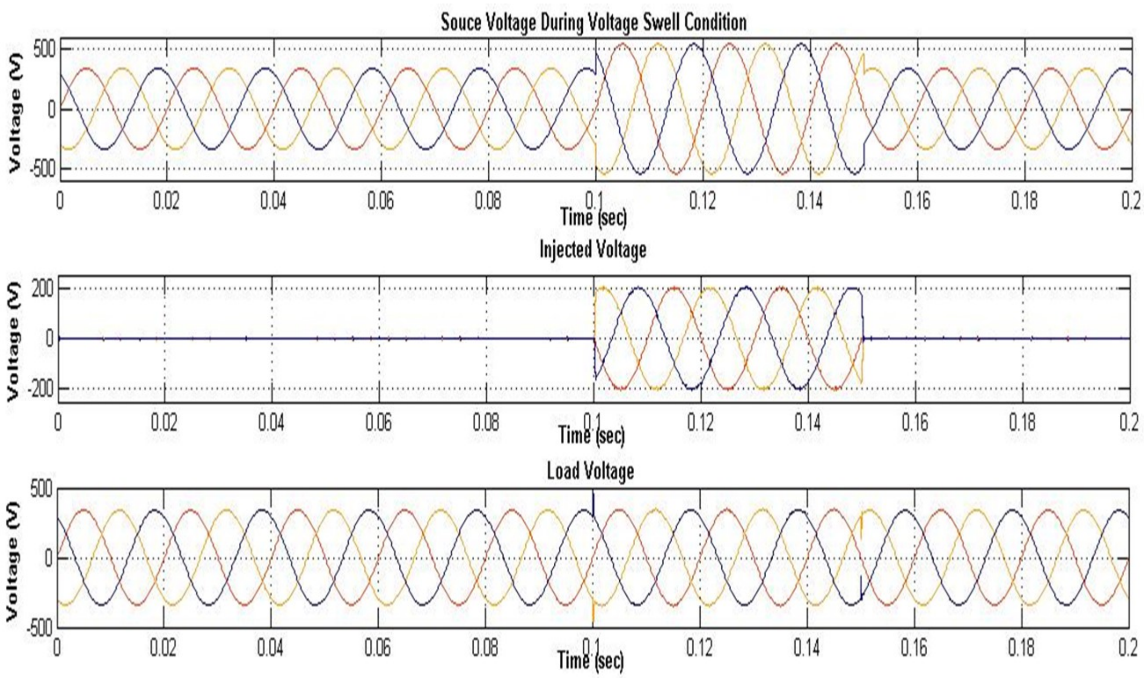

Fig.3. Voltage Waveforms of Series APF during Voltage swell

As given in Fig.3 it is the source voltage and load voltage during sag and swell condition with SRF theory. Sag time interval is 0.02 sec to 0.04 sec and swell time interval is 0.06 sec to 0.08 sec. The sag is due to voltage unbalance that may be caused due to faults and swell may be due to faults or capacitor switching. During the periods of voltage sag and voltage swell the voltage is injected in series with the line during 0.02 to 0.04 sec and 0.06 to 0.08 sec. In Fig.3 the load voltage of series APF during sag and swell is given. Due to operation of series APF the voltage sag from time interval 0.02 sec to 0.04 sec and voltage swell from 0.06 sec to 0.08 sec are removed and the load voltage becomes completely balanced. Now the voltage is completely balanced in whole interval of time.

2.4 Simulation Results of Shunt APF with SRF

Shunt APF is used to remove problems due to current harmonics. So it makes current drawn from source completely sinusoidal which is affected by load current harmonics. In Table-II system parameters of shunt APF are given

Table 2. System parameters of Shunt APF with SRF

Supply Voltage	415 V
Line Frequency	50 Hz
Source impedance	R = 0.01Ω & L = 0.01 mH
Load impedance	R = 50Ω & L = 1 mH
DC Link Voltage	800 V
DC Capacitor	2200 μF

As shown in fig.4.8 the waveform of load current of shunt APF is given and they are not sinusoidal due to presence of non-linear loads. This is non-linear waveform. They are Non-linear due to presence nonlinear loads like diode etc. Fig. 4.8 also shows source current of shunt APF with SRF. The source current waveform is sinusoidal after the operation of shunt APF.

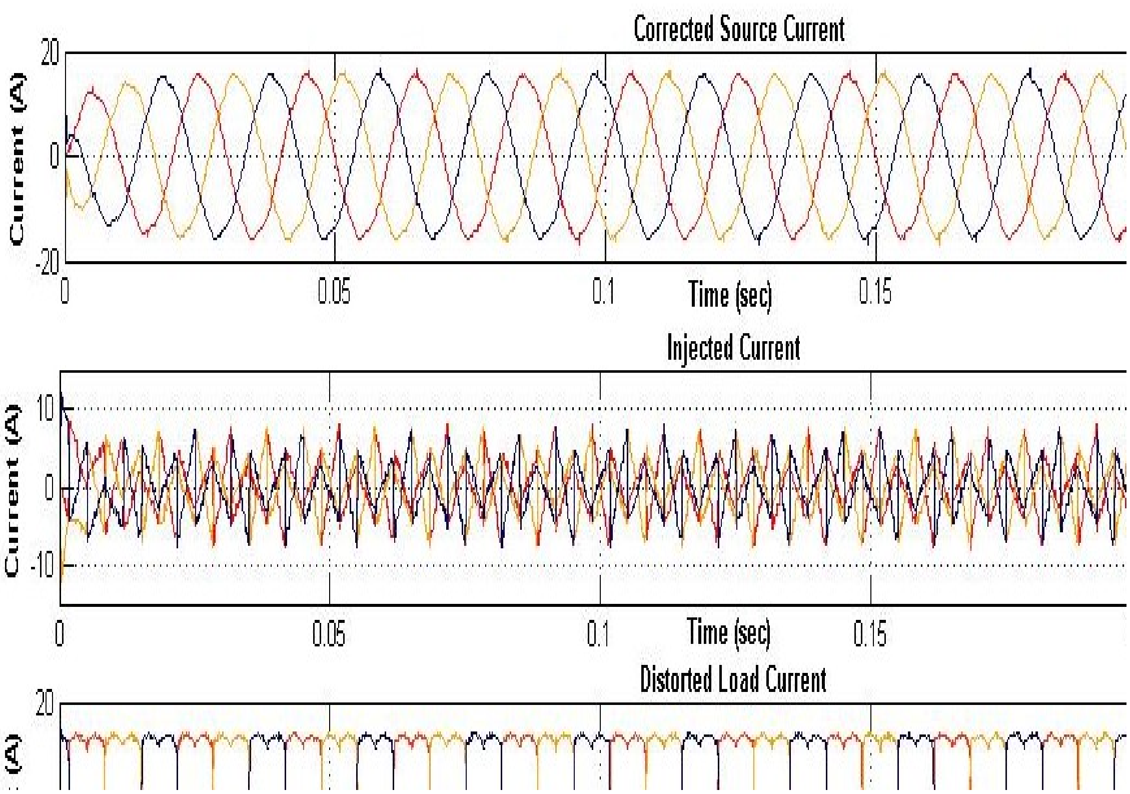

Fig. 3.1 Current Waveforms of Shunt APF during Only Nonlinear load connected

As shown in Fig.3.1 capacitor voltage is given. The shunt APF starts operating and PI controller compares the reference DC voltage and actual DC voltage of capacitor and always try to follow reference DC voltage which is 800 V.

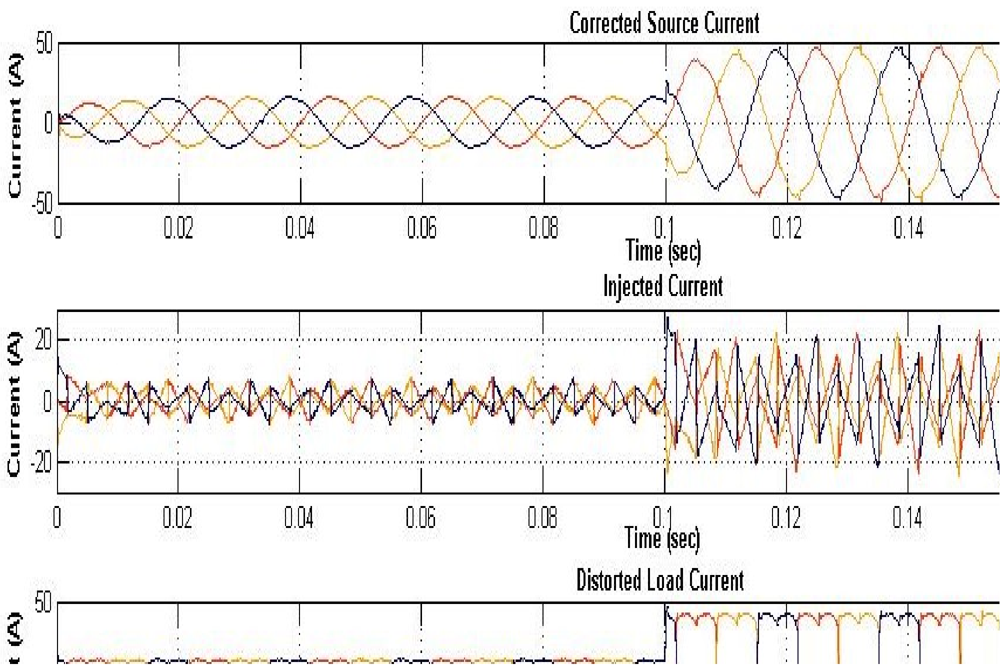

Fig. 3.2 Current Waveforms of Shunt APF during Only Nonlinear load connected

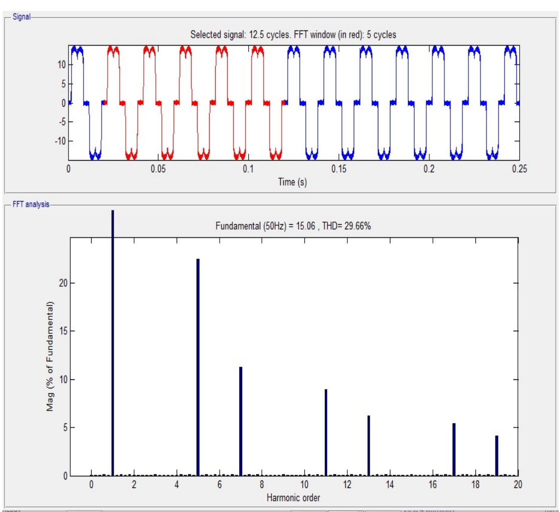

Fig. 3.3 THD of load current (A phase) using SRF

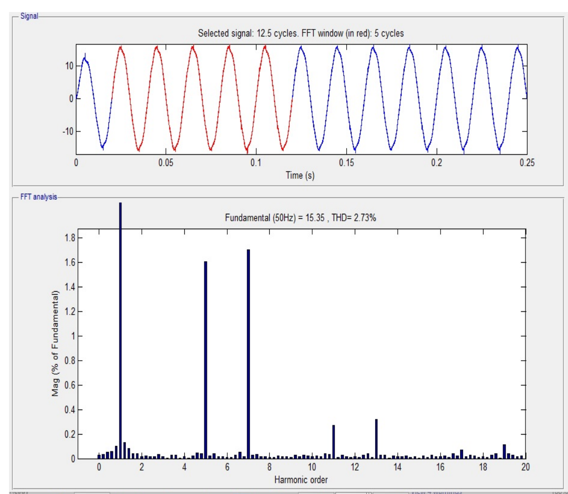

Fig. 3.4 THD of Source current (A phase) using SRF

The % THD of load current of A phase was 30.53% and after operation of shunt APF the % THD of source current is reduced to 2.12 %. The % THD of load current of B phase was 30.57% and after operation of shunt APF the % THD of source current is reduced to 2.14 %. The % THD of load current of C phase was 30.53% and after operation of shunt APF the % THD of source current is reduced to 2.07 %.

4. Conclusion

Unified quality conditioner was studied and investigated in this paper for power quality improvement. UPQC is a type of advance hybrid filter which uses series APF for removal of voltage related problems like voltage sag and swell, fluctuation, imbalance and shunt APF for removal of harmonics in current harmonics.

Series APF model is developed using Synchronous reference frame (SRF) Theory and controlling techniques used are hysteresis voltage controller. The simulation is done and source voltage sag and swell are mitigated and load voltage is made completely balanced.

Shunt APF model is developed using Synchronous reference frame (SRF) Theory and control techniques used here is hysteresis current controller. The simulation is done and current harmonics are eliminated and current drawn from source is completely sinusoidal. The THD of source current is within the limit that is 5%.

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