Enhancement of Power Quality using Unified Power Quality Conditioner withKalman filter

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Abstract:

Unified power quality conditioners (UPQC) used for compensation of current and voltage disturbances that would affect sensitive electrical load while compensating the reactive power. Many control methods have been implemented to measure the instantaneous output voltage of the series active power filter of UPQC but in most of the cases, controllers only can compensate a type of voltage disturbance.This workfocuses a digital controller for UPQCs which allows the harmonics in the load current and reactive power is to be compensated at the grid side while avoiding the effect of voltage dips, over voltages and voltage harmonics at the sensitive loads.The operation and performance of the proposed controller have been evaluated through MATLAB simulation software.

Keywords: UPQC, voltage dips, over voltages, voltage harmonics, current harmonics and reactive power.

I. INTRODUCTION

Unified Power Quality Conditioners have combined series and shunt active power filters for simultaneous compensation of current and voltage disturbances and reactive power. The UPQCs are applicable to distribution system which is connected at the point of common coupling of loads which generates harmonic voltage and currents. Unified Power Quality Conditioner (UPQC) may perform the operations of both DSTATCOM and DVR. The UPQC have two voltage source converters (VSCs) which are connected to a common dc bus. One of the voltage source converter is connected in series with the feeder, the other one is connected in parallel with the same feeder. The dc links of both voltage source converters are supplied through a common dc capacitor. The aim of the UPQC is to maintain the load voltage constant against voltage sag/swell, interruption, and disturbances in the system to protect the Non Linear and sensitive load L_1 and to compensate for the reactive and harmonic components of nonlinear load current.

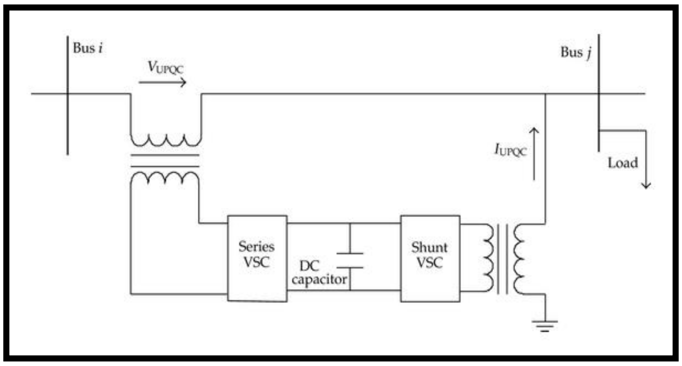

Figure 1 Structure of UPQC

Many topologies has been implemented in literature for UPQCs in single phase mode, that is two IGBT half bridges (Kannan, P., Rajamani, V., 2013) or multilevel topologies (Payaldeshpande, Amitshrivastava et al., 2015), but this work focusing on the commonly employed general structure shown in figure 1. The series converter can compensate the source voltage disturbances such as harmonics, voltage sags or over voltages, which may affects the operation of the load while the shunt converter reduces the unwanted load current components. Moreover the shunt converter controls the dc bus voltage in order to rely the compensation capability of the UPQC. These functionalities can be carried out by applying control strategies which can operate in the time domainor in the frequency domain or both. Time domain methods, such as pq methods, allows the very fast compensation of disturbances but make more difficult in their selective compensation. Here frequency domain techniques are more flexible but their dynamic response is slower.

This work utilizes a new control technique for UPQC based on a Kalman filter. The method to be proposed operates both in the time domain and frequency domains allowing the selective compensation of voltage and current harmonics with fast dynamical responses. Morever the impact of voltage sags and over voltages can be compensated by applying the proposed controller.

II. FUNCTIONAL STRUCTURE OF UPQC

The basic functions and operations of a UPQC controller are mentioned in figure 2. The compensating voltagev_c* and injecting current i_C* are the reference signals required for compensation purposes are evaluated from the measurements of the source voltage v_S, the dc bus voltage v_{dc} and the load current i_L. Reference signals are compared with the measured signals v_1, i_2 and applied to the voltage and current controllers, which in turn ensure that the compensation signals corresponding to the reference signals.

The gating signals of the power converters were obtained by applying pulse width modulators to the controllers. The power converters switching at high frequency signals which can generates a PWM output voltage waveform which must be low pass filtered (L_1, R_1& C_1 in case of series APF and L_2,Y & C_2 for the shunt APF). Switches S_1, S_2, S_3 control the compensation of the UPQC.

The voltage controller can able be implement in three methods. Feedback structures allow a good response while a forward structure generates quick responseduring the voltage transients. The generation of the reference signal depends on the compensation of voltage sags, over voltages or voltage harmonics. The root mean square value of the grid voltage can be measured to identify the voltage sags and over voltages, the PLL used to synchronizing the compensation signal must be same to maintain the previous phase. When the load voltage harmonics are the compensation objective, arepeated controller may be applied to compensate the effect of voltage harmonics. Here the reference signals are generated in the voltage controller.

Different approaches have been pointed for current control of grid connected VSCs. Hysteresis controllers were implemented usingsimple analog circuits but the drawback is the output current is not stabilized, which creates difficulties in the output filter design. Usually PI controllers were used but due to their finite gain at the fundamental frequency they can creates steady state errors. This error can be solved using generalized integrators. Artificial neural networks and fuzzy logic has been also used as current controllers in case of multiple harmonic frequencies in the reference signals.

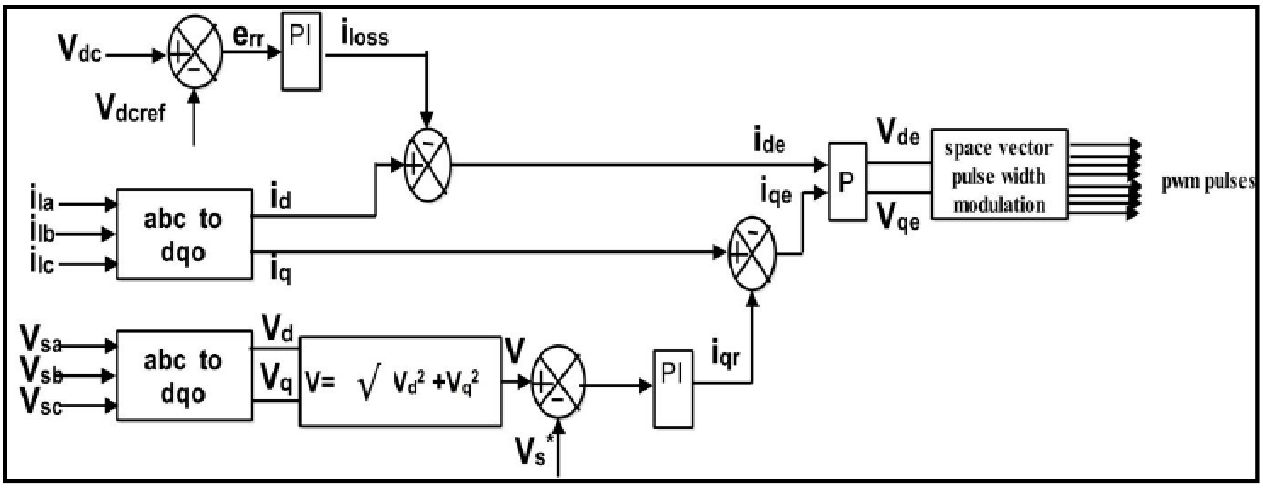

Figure 2 Reference Current Generation

III. PROPOSED TECHNIQUE FOR THE ESTIMATION OF THE COMPENSATION REFERENCE SIGNALS

A. Reference voltage estimation

The structure of the proposed algorithm for estimation of v_{C*} can be seen in figure 2. A stationary frame Kalman filter estimates the instantaneous values of each grid voltage harmonic vi,α (k) (Sairamand Amarnadh et.al., 2011). This voltage harmonic component is used to establish the presence of a voltage disturbance comparing the measured values and the established configuration values. Voltage sag or dips and over voltages are detected using the grid voltage fundamental harmonic component, the amplitude of other measured voltage harmonic components are evaluated to establish the presence of harmonic distortion is to be compensated. If voltage disturbance is detected, the series voltage source converter of the UPQC is switched on using S_1, S_2 and S_3. The reference voltageV_i*(k) at each required frequency is obtained as different of the measured voltage harmonic component and the established configuration value.

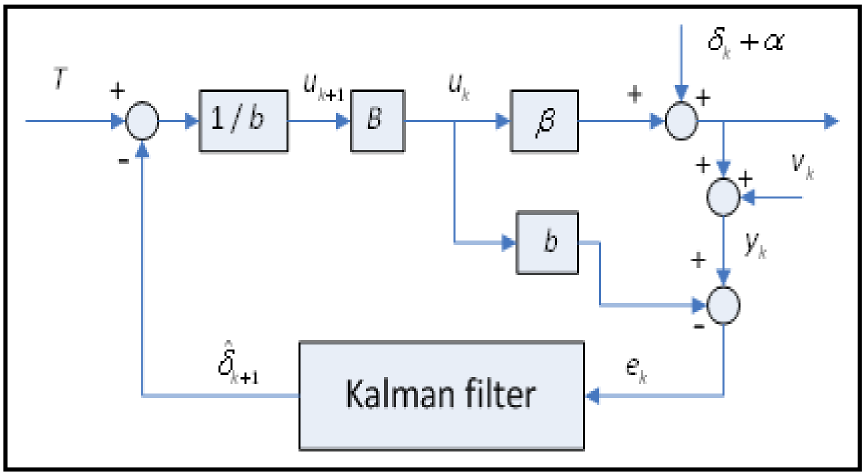

Figure 3 Block DiagramKalman Filter

B. Reference current estimation

The process to obtain reference current is shown in figure2. AKalman filter using a stationary frame is applied toload current i_L in order to obtain its harmonic andreactive components. The estimation of theharmonic reference current is carried out according to the process described in the previous section and, hence, this section only describes the estimation of load currentwhich contributes to the reactive power. The reference currents are obtained via Park transformation.It should be considered that the dc bus voltage is controlled by current consumption at fundamental supply frequency, which amplitude is determined using PI controller and in phase with the source voltage.

IV. SIMULATION RESULTS

The proposed algorithm has been tested in simulation, using the MATLAB Sim Power Systems Block Setaccording to figure 3. The dc reference voltage of the UPQC has been established at 415Vdc, the output filter of the voltage compensator consists of a low pass filter with L_1=3 mH, R_1=1.0 Ω and C_1=230 μF while the current link of the current compensator has been modeled by applying L_2=10 mH and R_2=0.8 Ω. The voltage source contains a 50Hz, 325V signal and a 5th harmonic of 5%. A diode rectifier with a RC load (CL=1000μF, RL=300Ω) has been used as local load. The referenceestimation technique have been applied using T_S=156 μs as sampling time, load current signal has been modeled through the first 10 odd harmonics while 1st, 3rd, 5th, 7th and 9th voltage harmonics has beenconsidered in case of the grid voltage signal.Fig.6 shows the current compensation capabilities.

Table: Simulation Parameters

Parameters	Value
Transformer	12KVA
Lp	0.17mH
Rp	35mΩ
Lm	252mH
Rm	80Ω
Ts	156 Microseconds

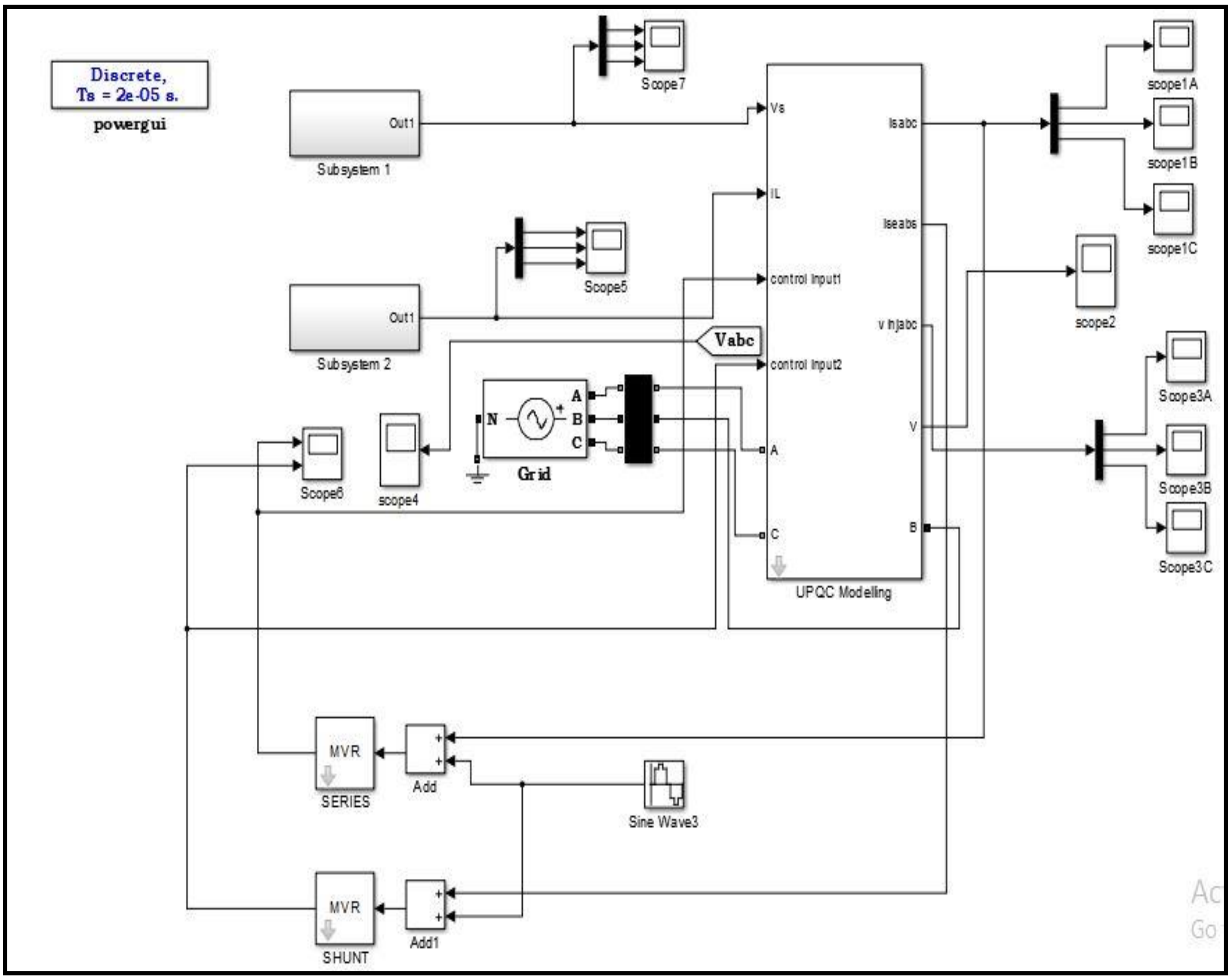

Figure 4 Simulation diagram of UPQC.

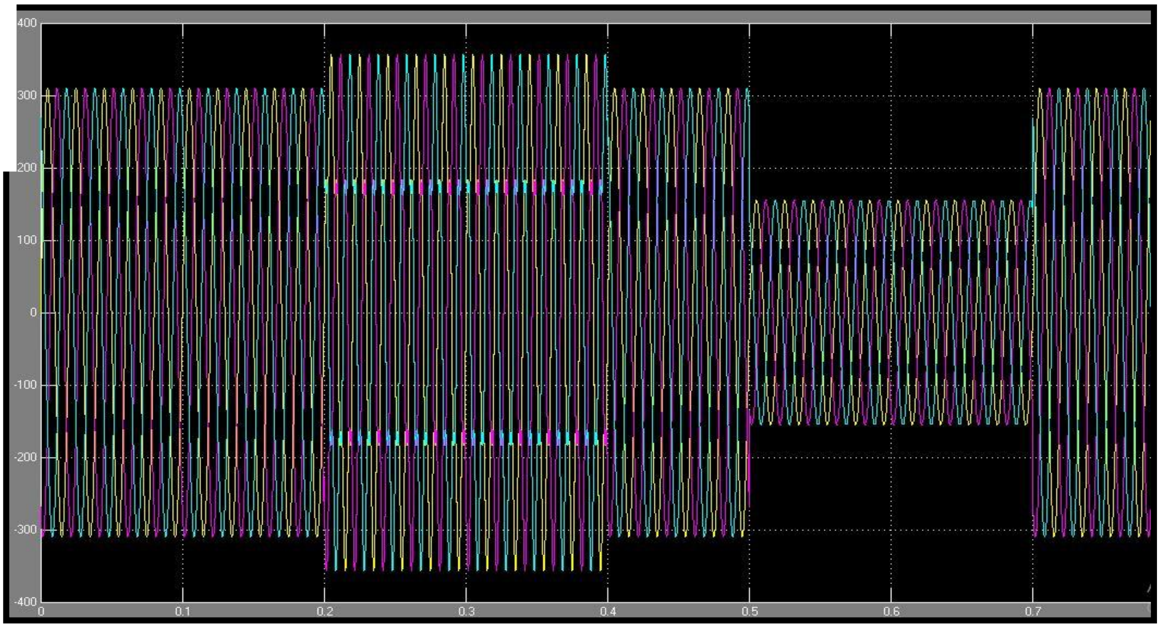

Figure 5 Sourcevoltage with Sag and Swell

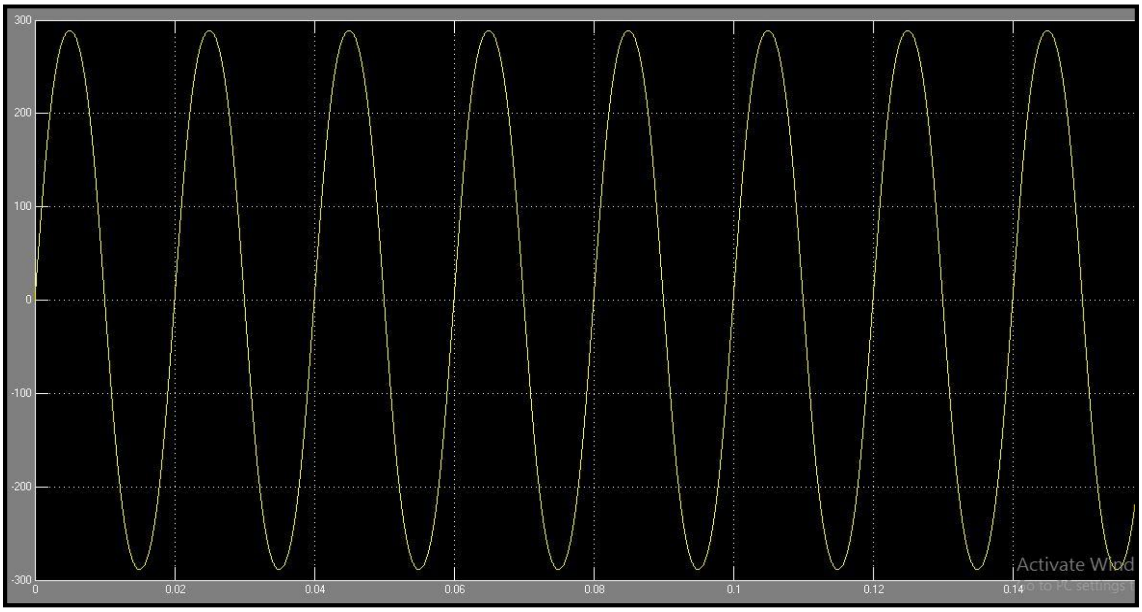

Figure 6 Compensated output

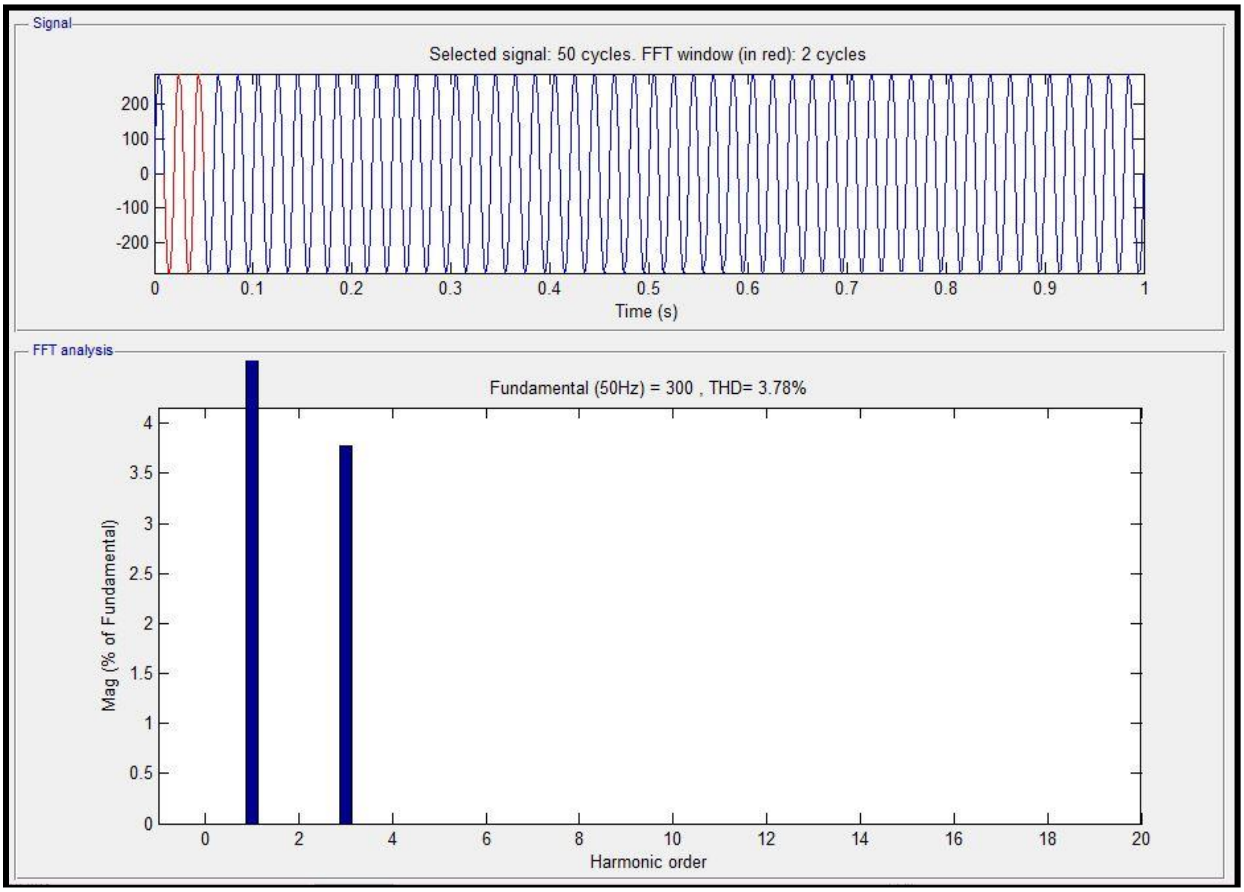

Figure 7 THD output

V. CONCLUSION:

A digital control technique which applied to a discrete Kalman filter to generate the reference compensation signals in UPQC have been presented and tested in MATLAB simulation. The structure of the referencecurrent and voltage estimator allows the compensation of the reactive power at the fundamental frequency, voltage and currents harmonics simultaneously and mitigates voltagesags and over voltages.The THD value of Source voltage 3.78%. Moreover, the disturbancecompensation levels can be configured allowing a more flexible operation. The performance of the controller has been tested through dynamic and steady state simulation tests.

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