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Design and Implementation of UPQC and Power Quality Improvement

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ABSTRACT

The Unified Power Quality Conditioner (UPQC) in distributed generation has been presented. Quality of power supply has become an important issue with the increasing demand of distributed generation (DG) system. UPQC is used to mitigate power quality problems like harmonics and sag. The shunt and series active filter performs the compensation of reactive power, harmonic current and voltage fluctuation during the interconnected mode of operation.

Keywords—UPQC, improvement PQ, shunt controller, series controller, harmonics mitigation.

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I. INTRODUCTION

The present power distribution system is usually configured as three-phase three-wire or four-wire structure featuring a power-limit voltage source with significant source impedance, and aggregation of various types of loads. Ideally, the system should provide a balanced and ripple free three-phase voltage of constant amplitude to the loads; and the loads should draw a current starts from the line with power factor(unity), no harmonics, and balanced phases. To four - wire systems, no excessive neutral current should exist. However, with a fast increasing the number of applications of electronics industry connected to the distribution systems today, including nonlinear, switching, reactive, single-phase and unbalanced three-phase loads, a complex problem of power quality emerge characterized by the voltage and current harmonics, unbalances, low power factor (PF). Some active circuits were developed to compensate unbalanced currents as well as limit the neutral current. Voltage-source converter based custom power devices are increasingly being used in custom power applications for improving the power quality (PQ) of power distribution systems. The term electric power quality broadly used to maintaining a nearly sinusoidal power distribution bus voltage at rated magnitude and frequency. In addition, the energy supplied to consumer must be uninterrupted from reliability point of view. Though power quality is mainly a distribution system problem, power transmission system may also have impact on quality of power It can also regulate the voltage of a distribution bus. A DVR can compensate for voltage sag/swell and distortion in the supply side voltage such that the voltage across a sensitive/critical load terminal is perfectly regulated. A UPQC able to perform the functions of both DSTATCOM and DVR. The UPQC consists of two voltage-source converters (VSCs) that are connected to a common dc capacitor. Any one of the VSCs is connected in series with distribution feeder, while the other one is connected in shunt with the same feeder. It is possible to connect two VSCs to two different Feeders in a distribution system and also possible for multi bus/multi feeder system (MC-UPQC).

UPQC TOPOLOGY

Basic Configuration Of UPQC

Fig shows the basic configuration of a general UPQC consisting of the combination of a series active and shunt active filter. Fig 2.1 Inverter 1 (Series Inverter SE) is connected in series with the incoming utility supply through a low pass filter and a voltage injecting transformer. Inverter

2 (Shunt Inverter SH) is connected in parallel with the sensitive load, whose power quality needs to be strictly maintained.

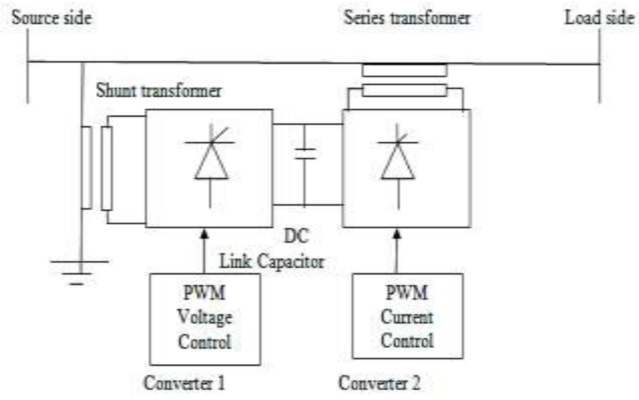


Figure1:

The essential purpose of the series active filter is harmonic isolation between a sub transmission system and a distribution system. In addition the series active filter has the capability of voltage flicker/imbalance compensation and voltage regulation and harmonic compensation at the utility-consumer point of common coupling (PCC). The main purpose of the shunt active filter is to absorb current harmonics, compensate for imaginary power and negative sequence current, and regulate the dc link voltage between both active Filters.

Specification of UPQC

Fig 2.1 shows the configuration of a specific UPQC. The aim of specific UPQC is not only to minimize for the current harmonics, but also to eliminate the voltage flicker/imbalance contained in the receiving terminal voltage VR from the load terminal voltage (VL). The receiving terminal in Fig 2.1 is corresponding to utility-consumer point of common coupling in high power applications. The operation of series active filter greatly forces all current harmonics produced by load into existing shunt passive filter. It also has the capability of damping series/parallel resonance between the supply impedance and the shunt passive filter. The shunt active filter is connected across to the supply by the step up transformer. The only objective of the shunt active filter is to regulate the dc link voltage inbetween both active filters. Thus, dc link is kept at constant voltage level even when a large amount of active power is flowing into or out of the series active filter during the flicker compensation. Although the shunt active filter have that capability of reactive power compensation, the shunt active filter in Fig 2.1 provides no reactive power compensation in order to achieve the minimum required rating of shunt active filter. Therefore, it should be connected downstream of the series active filter acting as a high resistor for harmonic frequencies. In Fig 2.1 the shunt active filter draws or injects the active power fluctuating at a low frequency from or into the supply, while the existing shunt passive filter absorbs current harmonics. To avoid the interference between shunt active and passive filters, the shunt active filter should

CONTROL STRATAGEY FOR UNIFIED POWER QUALITY CONDITIONER .

dq transformation

Its established that the active filter flows from leading voltage to lagging voltage and reactive power flows from higher voltage to lower voltage. Therefore both active and reactive power could be controlled by controlling the phase and the magnitude of the fundamental component of the converter voltage with respect to line voltage..According to the dq control theory three-phase line voltages and line currents are converted in to equivalent two-phase system called stationary reference frame. These quantities further transformed into reference frame called synchronous reference frame. In synchronous reference frame, the current components corresponding to active and reactive power are controlled in an independent manner. This three-phase dq transformation and dq to three-phase transformation are discussed in detail. The outer loop controls the dc bus voltage and the inner loop controls the line currents. The instantaneous real power at any point on line can be defined by:

$$p = VaIa + VbIb + VcIc \qquad (1)$$

And we could define instantaneous reactive voltage conceptually as a part of three phase voltage set that could be eliminated at any instant without altering *p*. Reference frame theory based d-q model of shunt active filter presented in this section. While dealing with instantaneous voltages and currents in three phase circuits mathematically, it is adequate to express their quantities as instantaneous space vectors [10]. Vector representation of instantaneous three phase quantities R, Y and B which are displaced by an angle 2π/3 from each other is shown in Fig.2

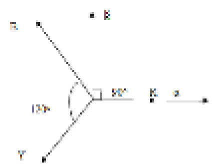


Figure 2 : Frame Transformation (abc to αβ)

The instantaneous current and voltage space vectors are expressed in terms of instantaneous voltages and currents as:

$$v = [\mathrm{Vr\ Vy\ Vb}]\quad I = [IR\ IY\ IB] \qquad (2)$$

Instantaneous voltages and currents on RYB coordinates could be transformed into the quadrature α, β coordinates by Clarke Transformation as follows:

$$\begin{bmatrix} v_\alpha \\ v_\beta \\ v_0 \end{bmatrix} = T \begin{bmatrix} v_R \\ v_Y \\ v_B \end{bmatrix} \qquad (3)$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \\ I_0 \end{bmatrix} = T \begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} \qquad (4)$$

Where Transformation matrix

$$T = \frac{\sqrt{2}}{3}\begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \quad (5)$$

Since in a balanced three-phase three-wire system neutral current is zero, the zero sequence current does not exist and zero sequence current can also be eliminated using star delta transformer. These voltages α-β reference frame could further be transformed into rotating d- q reference frame as Fig.3

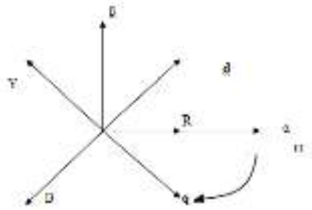


Figure 3 : αβ to dq Transformation

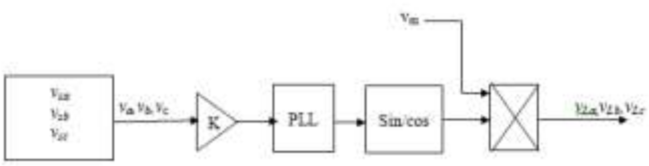
$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = T \begin{bmatrix} v_d \\ v_q \end{bmatrix} \quad (6)$$

$$T = \begin{bmatrix} \cos \omega_r & -\sin \omega_r \\ \sin \omega_r & \cos \omega_r \end{bmatrix} \quad (7)$$

Where ω_t is the angular velocity of the d- q reference frame as shown in Fig. 3 The current components in the d- q reference frame can be similarly obtained using the α-β to d-q transformation matrix *T1*. The unit vector required for transformation is generated using the grid voltage.

Basic Control Function

Its evident from above discussion that UPQC must separate out the fundamental frequency positive sequence components first from the other components. Then it is required to control both series and shunt active filter to give output. The control strategy uses PLL based unit vector template for extraction of reference signal from the distorted input supply. The block diagram of extraction of unit vector template is as given in Fig.4.



The input source voltage at point of common coupling contains fundamental and distorted component. To get unit vector tem-plates of voltage, input voltage is sensed and multiplied by gain to *1/vm*, where *vm* is peak amplitude of fundamental input voltage. These unit vector templates are then passed through a PLL for synchronization of signals. The unit vector templates for the different phases are obtained as follows:

$$Va = \omega t$$
$$Vb = (\omega t - 1200)$$
$$Vc = (\omega t + 1200) \quad (8)$$

MODELING OF UPQC IN MATLAB

The three-phase system shown in Fig.5 considered for verifying performance of UPQC. [9] Three-phase source feeding this system at one end. For the best performance, UPQC is placed at the midpoint of the system as shown in Fig.5 UPQC placed between two sections source and nonlinear load of the transmission line.

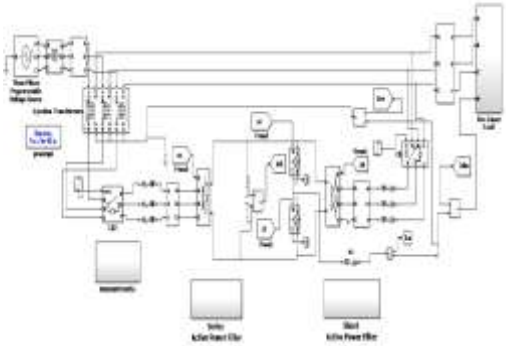


Figure 5: Simulink Model Of UPQC

Shunt Controller/STATCOM Model in MATLAB

The process of control shunt active power filter must estimate the current reference waveform for each phase of the inverter, preserve the dc voltage constant, and produce the inverter gating signals. The compensation effectiveness of an active power filter depends upon the reference signal calculated to compensate the distorted load current with a minimum error and time delay. A new control strategy is proposed to compensate the current imbalance present in the load currents by expanding the concept of single phase PQ theory or instantaneous PQ theory.

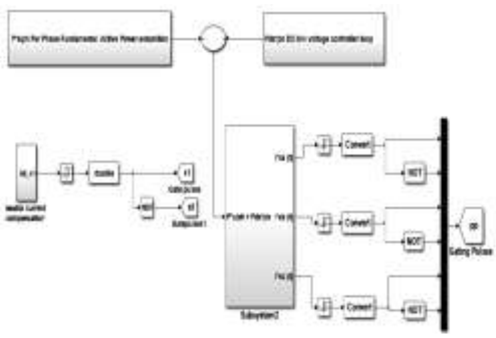
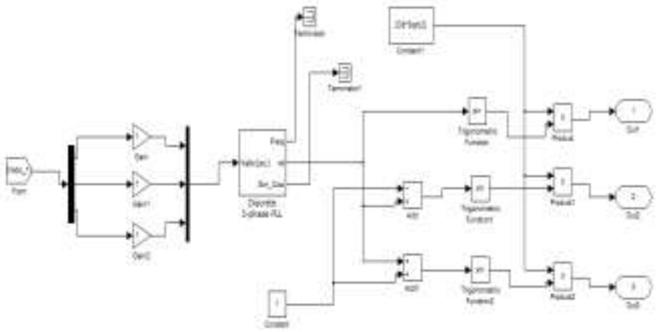


Figure 6.: Simulink Model of Shunt Controller

Series Converter/SSSC Model in MATLAB

The control algorithm for series APF is based on unit vector template generation scheme (UVTG). As the supply voltage is distorted, a phase-locked loop (PLL) is used to achieve synchronization with the supply voltage. Three phase distorted supply voltages are sensed and given to the PLL, generating the reference voltage signal of required voltage magnitude and phase angle by the equation (8) is named as unit vector. This signal is compared with the load voltage, it produce error signal, by the help of error signal and hysteresis technique it generates the switching or gating pulse which is then given to the VSI's to inject the required voltage .The simulation block of Unit Vector Template generation and Series APF controller is shown in figure 8.



UVTG

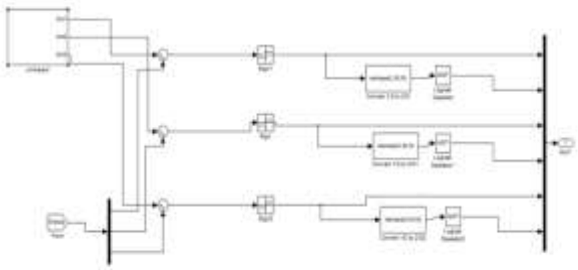
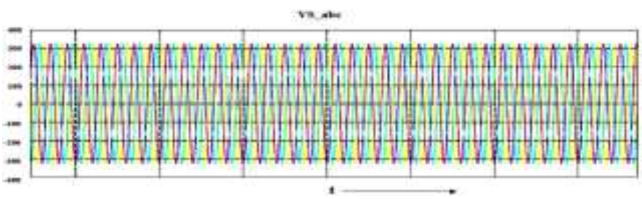
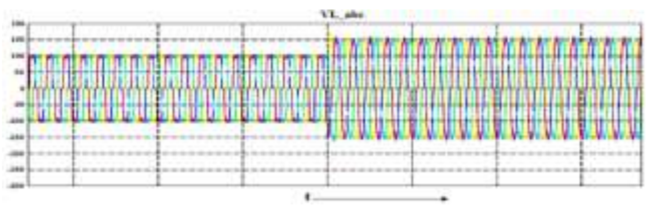


Figure 8 : Series controller Model using PID controller

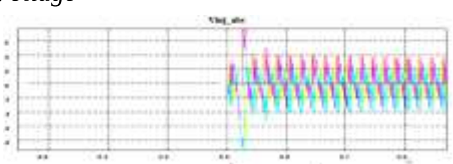
SIMULATION RESULTS OF UPQC USING PID CONTROLLER



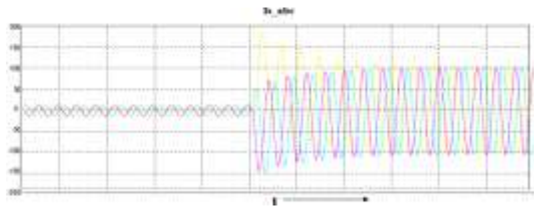
***1**.Source voltage*



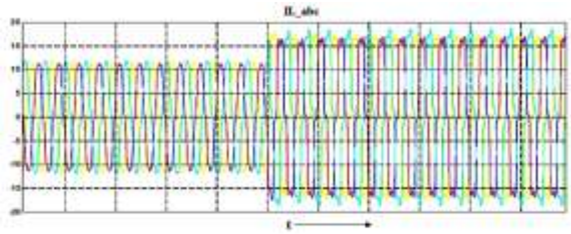
2.Load Voltage



3. Injection Voltage



4. Source current



5. Load Current

CONCLUSION

Power Quality maintenance is assential aspect in economic operation of a system. Various PQ problems may lead to another undesirable problems. Proper mitigation devices like UPQC can be used to maintain the level of power quality as desired.

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