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Improvement of Power Quality using UPQC in a Non Linear Load

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Abstract—*The efficiency of power system is of utmost importance. Stable power supply is the need of both commercial and domestic consumers. Efficiency of power system get low due to many factors like voltage sag, swell, harmonics, non-linear loads, etc. Power quality enhancement using custom power devices considers the structure, control and performance of series compensating Dynamic voltage restoration (DVR), the shunt Dstatcom and the Unified Power Quality Conditioner (UPQC) for power quality improvement in a distribution system. The UPQC is a combination of both series and shunt controllers. The efficiency in delivering power can be improved to large extent by the use of custom power devices. This paper provides a brief description of power quality improvement, voltage sag in particular, by using UPQC. The relevant simulations are carried out in MATLAB Simulink.*

Keywords*: Custom power devices, Voltage sag, UPQC, Simulink*

1. INTRODUCTION

The power quality has been subjected to various disturbances from power electronic devices as they withdraw harmonics and reactive power from the supply[1]. In a three phase system, power electronic devices can draw neutral currents and can cause unbalance in the system[2]. Poor power quality can be improved by numerous ways. UPQC is one of the many solutions. UPQC (combination of both series and shunt active filters) is an economical and highly effective way to improve quality of power. In order to improve the performance of sensitive and critical loads in a power system, the UPQC is employed in a distribution system to mitigate the disturbances [3]. A Unified Power Quality Conditioner is a multi functioning device, which is use to mitigate voltage and current related problem. The Fig. 1 shows a typical layout of single phase UPQC.

Two IGBT based Voltage source converter (VSC), one shunt and one series cascaded by a common DC link capacitor constitute the parts of a UPQC[4]. Reactive power (VAR) support to load is provided by the shunt converter. UPQC is connected in parallel to loadand controls harmonic currents. During voltage sag, series controller supply the required amount of voltage[5].

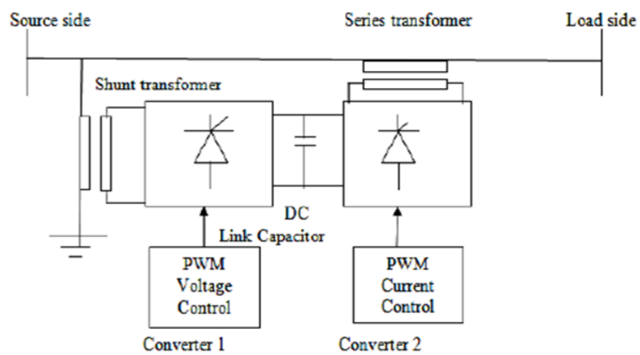

Fig. 1: Block diagram of UPQC

2. CONTROL STRATEGY FOR UPQC.

Parks transformation theory provides active and reactive power control by controlling phase and magnitude of fundamental component. Transformation of three phase line to a two phase reference frame is known a stationary reference frame. Stationary reference frame is further transformed into synchronous reference frame. Synchronous reference frame helps in the control of active and reactive power. The conversion of three phase voltages and currents to dq0 transformation and from dq0 back to three phase transformation is discussed in detail in this paper.

The Instantaneous power at any point on the line is given as:

$$p = V_R I_R + V_B I_B + V_C I_C \quad (1)$$

where,

p is instantaneous power,

V_R, V_C and V_B are the line voltages, and

I_R, I_R and I_R are the phase currents.

Hence, three phase reactive power voltages are a part of three phase voltage set. These three phase reactive voltages can be eliminated at any instant without the alteration of *p*. Vector diagram of the conversion of three phase to two phase is shown in fig.2. Displacement by an angle of 2π/3 is seen among the three phases.

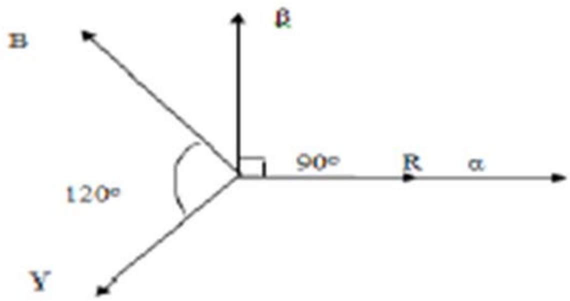

Fig. 2: Frame transformation

The instantaneous voltage and space vector are expressed as:

$V = [V_R\ V_Y\ V_B]$ $\qquad$ $I = [I_R\ I_Y\ I_B]$ (2)

Clarke's transformation helps in converting instantaneous voltage and currents on RYB coordinated into quadrature α and β coordinates which is shown as:

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

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

Where transformation matrix T is:

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

The zero sequence current does not exist as in a balanced three phase system neutral current is zero. And if zero sequence currents are present in a system, they can be eliminated using star delta transformer. Voltages can be further transformed into α-β reference frame.

$$T = \begin{bmatrix} \cos\omega_r & -\sin\omega_r \\ \sin\omega_r & \cos\omega_r \end{bmatrix} \qquad (6)$$

ω_r here denotes angular velocity of dq0 frame.

3. MODELLING OF UPQC IN MATLAB

The MATLAB model of a three phase system is shown in Fig. 3. The UPQC is placed in between load and distribution transformer in order to have efficient output.

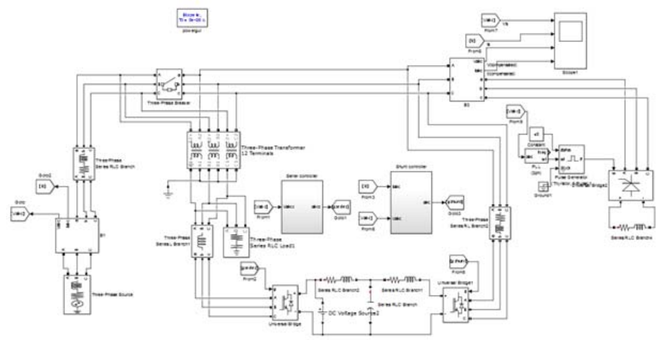

Fig. 3: Matlab model of UPQC.

3.1 Shunt controller

The real and reactive power can be controlled by shunt controller. The shunt controller automatically regulates the reactive power so as to maintain the transmission line voltage to a reference value. The SIMULINK model of shunt controller is shown in Fig. 4. The inner current loop responds very fast, which is approximately ten times faster than outer loop controlling dc voltage[6]. The d-axis reference current is stabilized through PID controller so as to get equivalent d-axis voltage v_d. The actual q-axis current is calculated using q-axis reference current. The error thus obtained is stabilized using PID controller[7]. The equivalent v_{dav} and v_{qav} is obtained by comparing the reference voltages v_d and v_q with actual v_d and v_q voltages. Then, these two voltages are converted into three phase quantities using Clark's transformation. These three phase voltages acts as control signal for PWM modulator as the acts as control switches for the current source rectifiers.

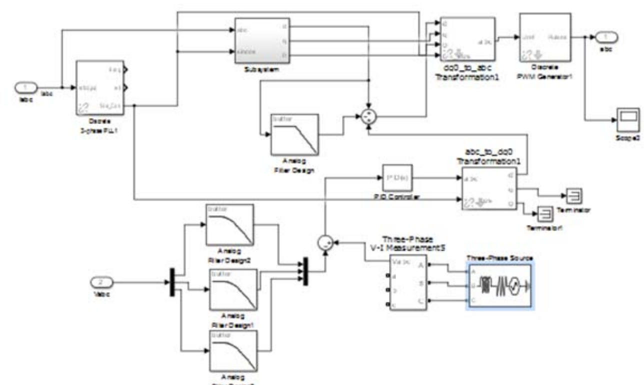

Fig. 4: Shunt Controller.

3.2 Series controller

Series controller is connected in series to power system distribution network. It is simply a voltage source converter. Its main function is to generate a controllable AC voltage. Its components are a phase locked loop (PLL), AC and DC voltage regulators for the desired DC voltages. On the secondary of coupling transformer, voltage source converter is connected. In order to synthesize the voltage v_{con} from a dc voltage source,it uses the forced commutated power electronic devices (such as IGBT, GTO, etc). Harmonics in the system can be reduced to a minimum value by connecting filters at the AC side of the voltage source converter. On varying the modulation index of the PWM modulator, variation in converter voltage v_{con} is observed.

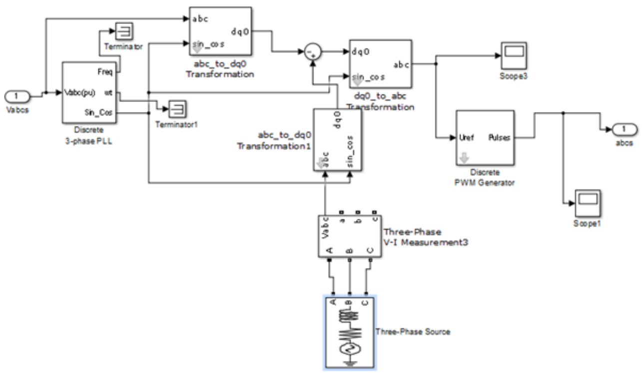

Fig. 5: Series Controller.

4. SIMULATION RESULTS OF UPQC:

An input RMS voltage of 240 volt, 50 Hz frequency is applied to a non linear load. The presence of nonlinear load in the system produces current harmonics. The three phase supply current before compensation is shown in Fig. 6. This waveform is found to be highly distorted due to the presence of non linear load.

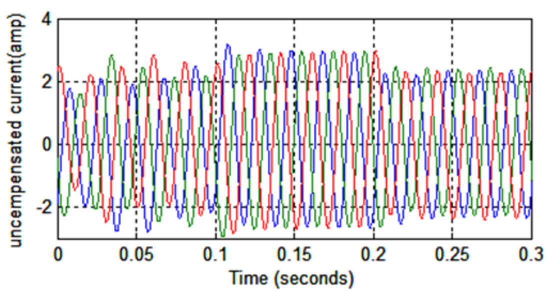

Fig. 6: Uncompensated current waveform.

The load current waveform is found to be more linear as compared to the distorted input waveform as shown in Fig. 7.

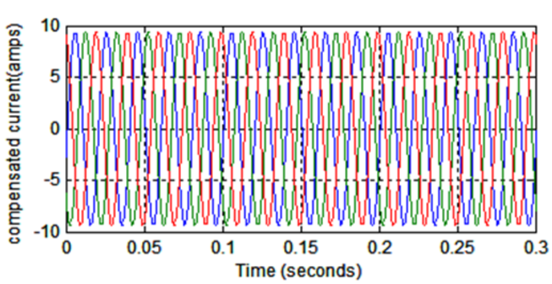

Fig. 7: Compensated load current.

The voltage waveform without compensation is shown in fig.8. Voltage sag is observed from 0.1 sec to 0.2 sec. This voltage sag is due to the presence of a nonlinear load.

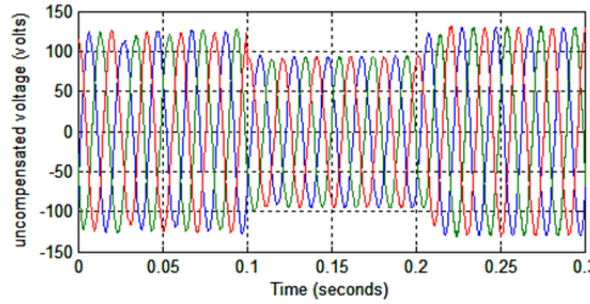

Fig. 8: Uncompensated voltage depicting voltage sag

Finally the output waveform comes out to be a linear and more efficient. Thus, UPQC has compensated for voltage sag in the supply voltage which is seen in Fig. 9.

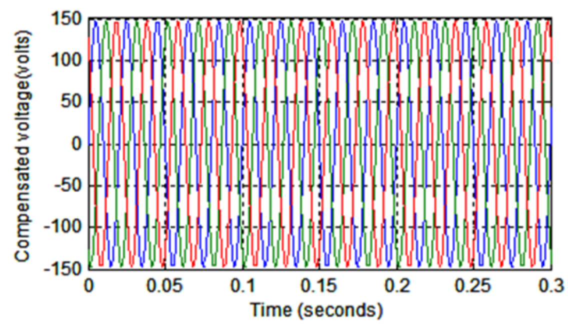

Fig.9: Compensated voltage after removal of sag.

5. CONCLUSION

In this paper, the performance of UPQC has been implemented on a three phase system consisting of nonlinear load. The functions of both series and shunt controller have been described independently. The simulation results show the effectiveness of UPQC for power quality improvement in a three phase system. The uncompensated and compensated load current and voltage waveform have been shown separately.

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