Simulation of UPQC using Cascaded Multilevel Inverter & Comparing it with Shunt & Series Active Power Filters

Sureshkumar Sahu, Dr. D. Vijaya Kumar, I. Ramesh

Abstract—Power quality is related to the ability of utililities to provide electric power without interruption. One of the major concerns in electric industry today is power quality problem to sensitive loads. Power quality problems such as sag, swell, harmonic distortion, unbalance, transient and flicker may have impact on customer devices, cause malfunctions and also cost on loss of production. Unified Power Quality Conditioner (UPQC) is a seres element and shunt element connected in the power system. In this paper, a UPQC with cascaded multilevel inverter is proposed. Voltage sag, unbalance in generation system is mitigated using proposed multilevel UPQC. There is no need of using transformer and filter when multilevel UPQC is applied and it is applied and it is one of its advantages. Conventional fundamental switching scheme is used for pulse generation to control the switches in the multilevel inverter. The main objective of this paper is to regulate the voltage at source side against any power quality issues like under voltages, over voltages. The total harmonic distortion was reduced by using multilevel UPQC.

Index Terms— Active power filters, harmonics, power quality, multilevel inverter, UPQC, pq-theory, MATLAB/Simulink.

1 Introduction

BECAUSE of the increased number of nonlinear loads in the power system we need and efficient and cost effective solution to improve the power quality. As the conventional palleve filters fails at resonant condition we can adopt the active power filters to improve the trandient as well as steady state stability of our system [1], [2], [3].

To do this we need voltage and current sources imverters. We can reduce the cost of our system by a proper design and selection of inverter topology from the wide range of available options [5]. The cascaded multilevel inverter is a cost effective solution [11] and it reduces harmonics in the system [4], [10]. The UPQC provides better characteristics than compared to individual series and shunt active power filters [6], [7], [8], [9].

To operation of the proposed UPQC was verified through simulation with MATLAB/Simulink software.

2 Active Power Filter

An active power filter is implemented when orders of harmonic currents are varying. One case is a variable speed drive. Active filters use active components such as MOSFET, IGBT etc., to inject negative harmonics to into the network effectively replacing a portion of the distorted current wave coming from the load. Active filters can be classified based on the connection scheme as: shunt active filter, series active filter and UPQC.

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2.1 Shunt Active Power Filter

An active power filter connected in parallel to the load is known as shunt active power filter. This injects negative harmonic currents into the line to cancel the harmonics generated by the nonlinear load. Fig. 1 illustrates the concept of the harmonic current cancellation so that the current being supplied from the source is sinusoidal.

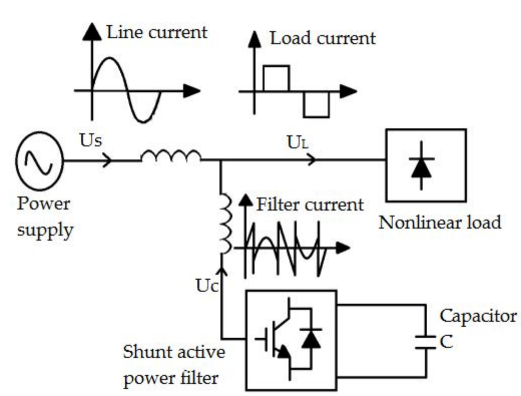

Fig. 1. Circuir connection of shunt active power filter.

2.2 Series Active Power Filter

An active power filter connected in series to the load is known as series active power filter. This works as isolator, instead of generators of harmonics. Series active power filters acts as controllable voltage sources. A voltage source inverter is used as the series active power filter. This is controlled so as to draw or inject a compensating voltage from or to the supply, such that it cancels voltage harmonics on the load side. Fig. 2 illustrates the concept of the series active power filter.

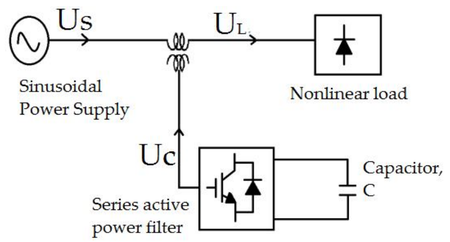

Fig. 2. Circuir connection of series active power filter.

2.3 Unified Power Quality Conditioner (UPQC):

Series and shunt active power filters are connected back to back by the dc link capacitior to form an UPQC. Fig. 3. shows the circuit connection of UPQC.

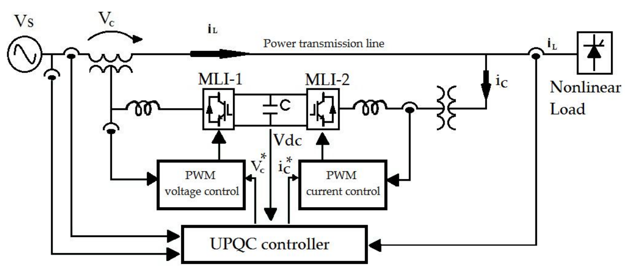

Fig. 3. Circuit connection of UPQC.

3 MULTILEVEL INVERTER (MLI)

Multi level invertes use components of low rating to serve medium rated applications to reduce the overal cost. The performance of an inverter with any switching strategies can be related to the harmonics contents of its output voltage. Based on inverter topology they are devided into three types:

1. Diode clamped multilevel inverter.
2. Flying capacitor multilevel inverter.
3. Cascaded multilevel incerter.

3.1 Cascaded Multilevel Inverter

Cascaded multilevel inverters are based on a series connection of several single phase inverters. This structure is capable of reaching medium output voltage levels using only standard low voltage components. A basic structure of a cascaded MLI is shown in fil. 4.

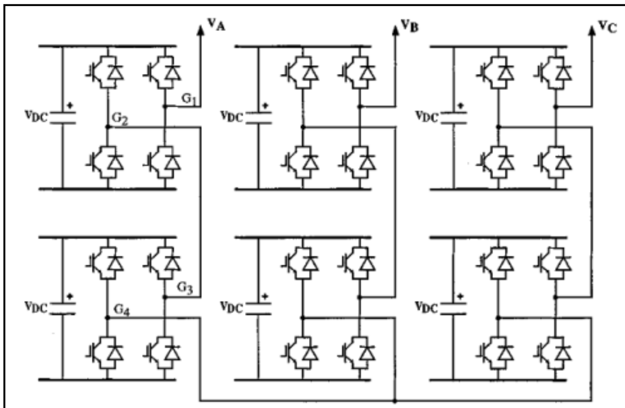

Fig. 4. Three phase H bridge cascaded Multilevel Inverter.

Each inverter used a dc-link voltage to generate a modulated voltage at the output terminals. The total output voltage is obtained by the sum of each individual otput voltage is obtained by the sum of ach individual output voltage. Three phase voltage output from a MLI is shown in Fig. 5.

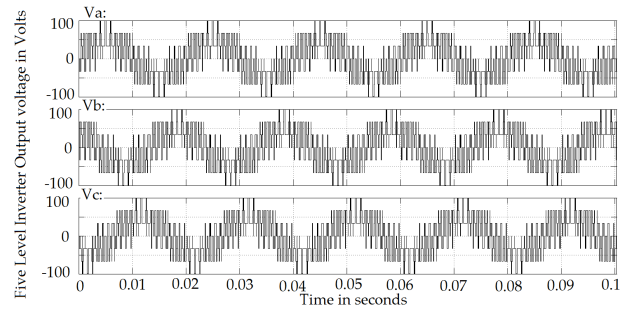

Fig. 5. Multilevel inverter output.

3.2 Phase Shift Carrier PWM Method

A phase shift sinusoidal pulse width modulation (PS-SPWM) switching is proposed for MOSFETs in the MLIs.

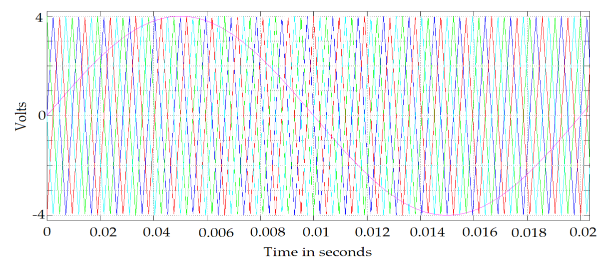

Fig. 6. Phase Shifted Carrier Pulse width modulation.

Optimal harmonic cancellation is achieved by phase shifting each carrier by (k-1) π/n, where k is the kth inverter. Where n = (L-1)/2 is the number of series connected single phase inverters. L is the number of switched DC levels that can be achieved in each phase leg.

3.3 MLI Simulation Diagram

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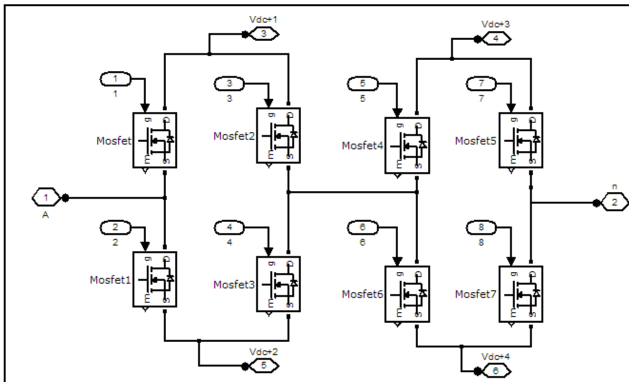

Fig. 7. Simulation circuit of one leg of MLI.

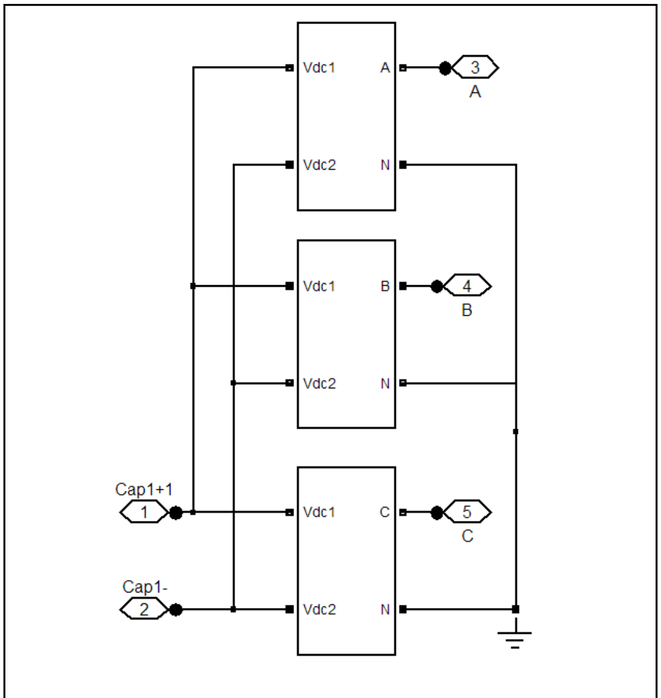

Fig. 8. Three sincle phase inverters to form a thre phase MLI.

4 Instantaneous Reactive Power PQ-Theory

The pq-theory consists of an algebraic transformation of the three phase voltages and currents in the a-b-c coordinates to α-β-o coordinates, followed by the calculations to the α-β-o coordinates, followed by the calculation of the pq-theory instantaneous power components as shown by the following equations:

$$\begin{bmatrix} V\alpha \\ V\beta \\ Vo \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix}, \quad (1)$$

$$\begin{bmatrix} U\alpha \\ U\beta \\ Uo \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} Ua \\ Ub \\ Uc \end{bmatrix}. \quad (2)$$

Instantaneous zero sequence power is given by,

$$Po = VoUo. \quad (3)$$

Instantaneous real and reactive power is given by,

$$\begin{bmatrix} Uc\alpha^* \\ Uc\beta^* \end{bmatrix} = \frac{1}{V\alpha^2 + V\beta^2} \begin{bmatrix} V\alpha & -V\beta \\ V\beta & V\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} - \tilde{p}o \\ q \end{bmatrix}, \quad (4)$$

5 Control Strategy

The parameters required for the control of the compensator are shown in [3]. Let U's are current components ansd V's are voltage components. To obtain the reference compensation currents in a-b-c coordinates to shunt inverter we can write,

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V\alpha & V\beta \\ -V\beta & V\alpha \end{bmatrix} \begin{bmatrix} U\alpha \\ U\beta \end{bmatrix}. \quad (5)$$

$$\begin{bmatrix} Vc\alpha^* \\ Vc\beta^* \end{bmatrix} = \frac{1}{U\alpha^2 + U\beta^2} \begin{bmatrix} U\alpha & -U\beta \\ U\beta & U\alpha \end{bmatrix} \begin{bmatrix} \tilde{p} - \tilde{p}o \\ q \end{bmatrix}, \quad (6)$$

$$Ucn^* = (Uca^* + Ucb^* + Ucc^*). \quad (7)$$

$$Vcn^* = (Vca^* + Vcb^* + Vcc^*). \quad (8)$$

Similarly the reference compensatin voltages in the a-b-c coordinates for the series inverter are,

$$Uco^* = Uo, \quad (9)$$

$$\begin{bmatrix} Uca^* \\ Ucb^* \\ Ucc^* \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Uco^* \\ Uc\alpha^* \\ Uc\beta^* \end{bmatrix}, \quad (10)$$

$$Vco^* = Vo, \quad (11)$$

$$\begin{bmatrix} Vca^* \\ Vcb^* \\ Vcc^* \end{bmatrix} = \frac{\sqrt{2}}{\sqrt{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} Vco^* \\ Vc\alpha^* \\ Vc\beta^* \end{bmatrix}, \quad (12)$$

6 Harmonic Analysis

Percentages of different harmonic components to the fundamental component in the system at different cases are shown in fig. 9 and fig. 10. In the figures THD means total harmonic distortion.

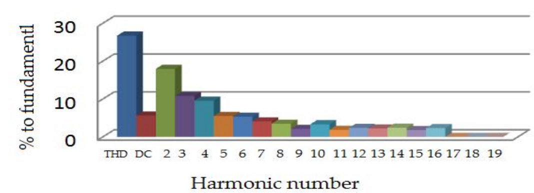

Fig. 9. Harmonics in the system without filter.

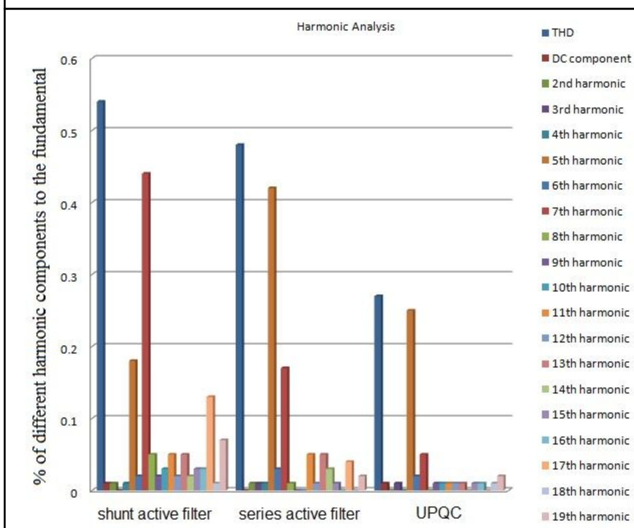

Fig. 10. Harmonic analysis in the system at APFs.

4 Conclusion

In this paper I used a new configuration of UPQC, applying multilevel inverter. From the graphs of harmonics in different systems we can conclude that UPQC reduces harmonics in the system effectively. Voltages sag or swell characteristics due to sudden application or removal of load is compensated. UPQC does this well than that of shunt and series active power filters. Its cost is also less compared to other inverter topologies as praposed in [11]. Also the load power factor tends to uity.

The effectiveness of the proposed UPQC was verified by simulation of multilevel UPQC with MATLAB/Simulink (R2009a).

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