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FFT Analysis of Flying Capacitor Multilevel Inverter Based Shunt Active Power Filter

Ameer Hamza Siddiqui, Muhammad Farzam Zaman
Department of Electrical Engineering, Mehran University of Engineering and Technology
Corresponding author e-mail: (ameerhamzasiddiqui1@gmail.com)
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Abstract: **In this paper, the simulation models, output waveforms and FFT analysis of flying capacitor multilevel inverter based shunt active power filter are presented. The main advantage of this topology as compared to the conventional inverter and other multilevel inverter topologies is that it has low switching losses, voltage stresses, better total harmonic distortion performance, and low dv/dt and EMI. The multi carrier PWM technique in order to switch the multilevel inverter, reference generation algorithm is based on instantaneous PQ reactive power theory to generate the compensating currents which feed to the inverter to generate 180 degrees out of phase voltages which inject into the system to mitigate the harmonics and reduce the total harmonic distortion. The FFT analysis algorithm is used to analyze the performance of the design which give the successful reduction in the harmonics which is 8% without shunt active power filter and after using this filter the harmonic distortion reduced to 2%.**

Index Terms— **APF, FFT, THD, Multilevel inverter, Flying Capacitor topology.**

I. INTRODUCTION

The term power quality defined the quality of electrical power A.C mains at all level of electrical system e.g. generation, transmission, distribution and utilization. Power quality of the system can be polluted by natural as well conventional means. The natural means that affect power quality are flashover, lightning or equipment failure etc. where else conventional means are voltage distortion, notches or the customer equipment as they draw non sinusoidal current and behave like a nonlinear load. Since the power quality is the important issue in terms of voltage, current and frequency of the supply system which may result in failure or mall operation of the customer equipment. Major issues are occurred due to the degradation of power quality such as losses in electrical machines, noise, vibration, voltage sags, voltage swells, voltage unbalance, flickers, excessive currents due to resonance, negative sequence current in generators and motor, especially rotor heating, degradation of cables, dielectric breakdown, interference with communication system, interference with the motor controller and digital controller and many more. In terms of the economic design these issues are creating major deficit loss for the industries. Hence these problems are the major concern for industries in order to reduce the economic losses[3]. Moreover, the industry has also become more conscious for loss of production. The increased use of solid state controller in a number of equipment with other benefit such as decreasing the losses, increasing overall efficiency and reducing the cost of production has resulted in increased harmonics levels, distortion, notches and other power quality problems. For a power system to run smoothly there are four quality problems to fulfill: i) Purity of sine wave ii) continuity of supply iii) Voltage within permissible limits iv) Frequency within permissible limits. Scientist, Engineers have designed many techniques in order to solve issues faced due to power quality problems and standard organization IEC, IEEE have also set standard to minimize the consequences arising due to power quality problem which aware the customer as well as utility to tackle the power quality problem. In the presence of harmonics in addition to other power quality problems, a very vast series of passive and power filter mitigation techniques are designed based on different methods and algorithms and different configuration of both single phase two wire, three phase three wire and three phase four wire. The best configuration of the filter is decided depends upon the nature of load. In this paper discussion is about the shunt active power filter improved technique for harmonic filtration.

II. SHUNT ACTIVE POWER FILTER.

Active power filter is one of the better technique for harmonics mitigation in the power system. There are number of topologies and algorithms for active power filtration are designed and discussed and improving day by day. On the basis of implementation technique there are three types of active power filter i) series active power filter connect in the series with the system ii) shunt active power filter connect in parallel to the system iii) hybrid active power filter. This paper is concerned with the shunt active power filter. The main objective of the shunt active power filter is to mitigate most of the current quality problems, such as reactive power, unbalanced current, neutral current, harmonics and the fluctuation present in the consumer nonlinear load or otherwise in the system and provide sinusoidal balanced currents[1]. There are different control techniques and inverter configuration used in the shunt active power filter. The control algorithms a generate reference currents which feed to the inverter switching technique to generate the output of inverter which is injected into the system to mitigate harmonics. Shunt APF suppresses the current harmonic by injecting the harmonic into the line of same amplitude and frequency but in opposite polarity i.e. at 180 degrees out of phase to the harmonic. As the shunt APF bidirectional inverter so it charges the capacitor from line and injects the power in line hence the resultant power remains zero[2]. The intelligent controller in shunt APF observes the current of the line and compares with the reference constantly and generates the gating signal for the inverter at the moment it gets the harmonic sensation. Different methods and techniques are adapted to generate the reference signal in the controller. The power is injected through coupling inductor into the line at PCC to remove the current harmonics[4]. The paper described the shunt active power filter by using multilevel inverter topology.

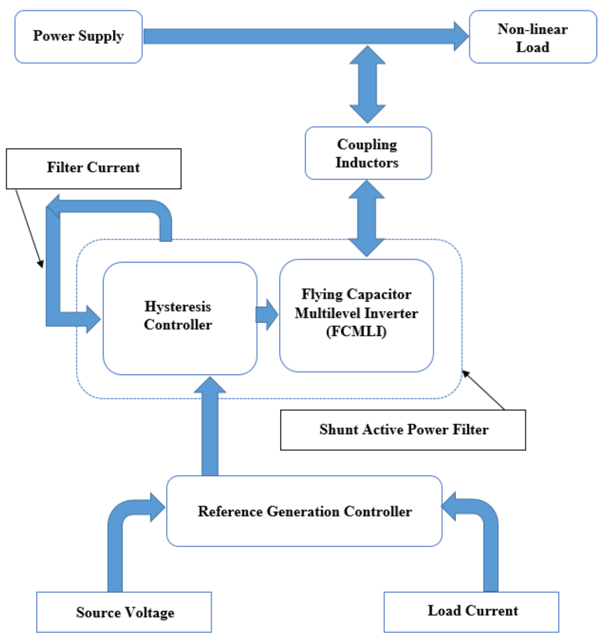

Figure 1 General Block diagram of Flying Capacitor based shunt Active Power Filter

III. METHODLOGY

MATLAB has been used for the simulation of the flying capacitor MLI based shunt APF. The design parameters are:

Parameters	
Coupling Inductance	25mH
Source Voltage/frequency	220 volts/50 Hz
Load	(10+j1e-3)Ω
Inverter capacitors	2200uF

A. General Performance Parameters.

The performance parameters of the system is the FFT analysis which should lie within the permissible limit of IEEE. FFT analysis algorithms compute Discrete Fourier Transform (DFT) of a sequence. The analysis done by the MATLAB analysis FFT done by the MATLAB analysis FFT tools operate with the help of power GUI block.

IV. MULTILEVEL INVERTER

In the Multilevel Inverter topology (MLI), many DC voltage levels are added together to create a smoother output waveform[6]. The acquired output waveforms have decrease harmonic distortions and dv/dt. The circuit design is more complicated with the increase in voltage levels due to addition of the valves and complex control circuit is also required.

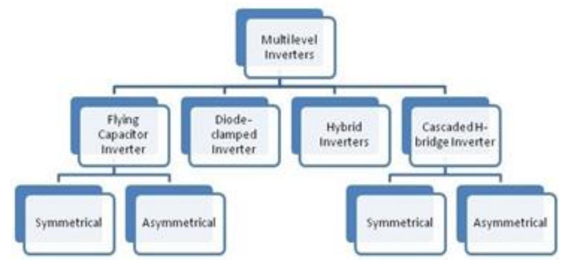

Figure 2 Classification of Multilevel inverters

This particular topology of the multilevel inverter for the design of shunt APF is flying capacitor topology. The main advantage of multilevel inverter over conventional inverter is low THD, low switching frequency hence reduced switching losses, high voltage level can be produced and low dv/dt and EMI[5].

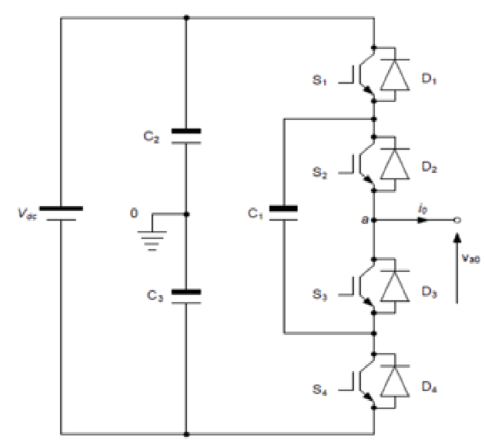

Figure 3 Circuit diagram of Single Phase Flying Capacitor Multilevel Inverter

V. SYSTEM DESIGN

Shunt APF consist of reference current generation system, multicarrier PWM control and multilevel inverter. Reference generation system generate compensating current which feed to the multicarrier PWM control of inverter which generate the 180 degree of harmonics which feed in the system through coupling inductor in order to cancel the harmonics of the system.

A. *Instantaneous PQ Theory*

Reference current generated by instantaneous pq theory which perform Clarke transformation which convert three phase voltages and currents into αβ co-ordinates then feed to the algorithm based on the equation

$$\begin{bmatrix} v\alpha \\ v\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} va \\ vb \\ vc \end{bmatrix} \qquad (i)$$

$$\begin{bmatrix} i\alpha \\ i\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} ila \\ ilb \\ ilc \end{bmatrix} \qquad (ii)$$

$$p = v\alpha\ i\alpha + v\beta\ i\beta \qquad (iii)$$

$$q = v\beta\ i\alpha - v\alpha\ i\beta \qquad (iv)$$

$$\begin{bmatrix} i\alpha* \\ i\beta* \end{bmatrix} = \frac{1}{v\alpha^2 + v\beta^2}\begin{bmatrix} v\alpha & v\beta \\ v\beta & -v\alpha \end{bmatrix}\begin{bmatrix} -pc* \\ -qc* \end{bmatrix} \qquad (v)$$

$$\begin{bmatrix} ica* \\ icb* \\ icc* \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3} \\ -1/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i\alpha* \\ i\beta* \end{bmatrix} \qquad (vi)$$

The compensating current generates through theses equation are feed to the PWM multicarrier switching system of the inverter then the inverter produces180 degrees out of phase harmonics.

VI. SIMULATION RESULTS

The simulation model is prepared in MATLAB (Simulink) environment[7]. This model consists of three phase supply, rectifier, load, reference generation system and flying capacitor multilevel inverter injects its output in the system through coupling inductor.

A. *Source Voltage Waveform without APF*

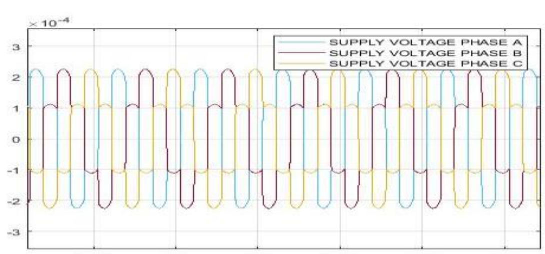

Figure 5 Voltage waveform without Active power filter

B. Compensating Currents of APF.

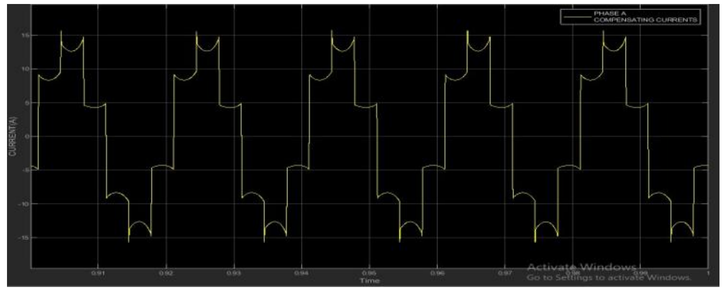

Figure 6 Phase A compensating current

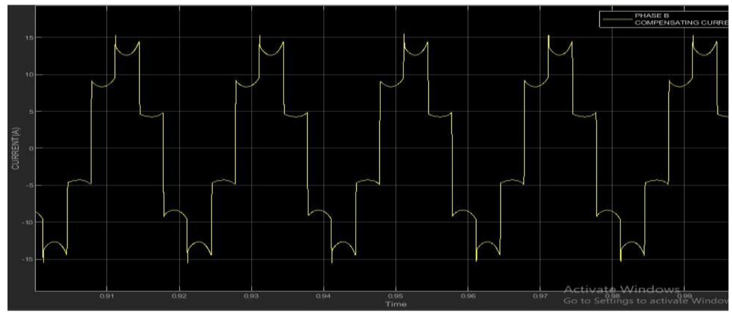

Figure 7 Phase B compensating current

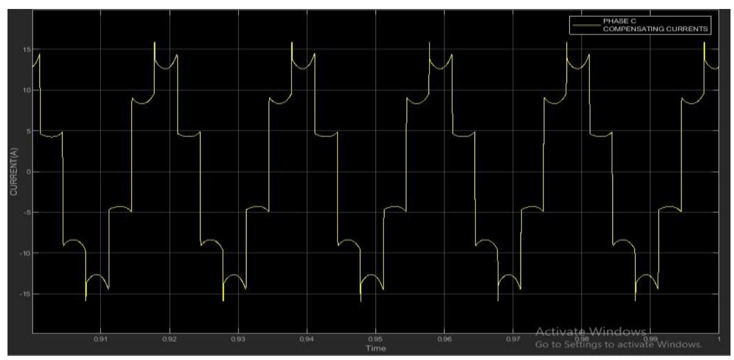

Figure 8 Phase C compensating current

C. *SWITCHING SEQUENCE OF INVERTER*

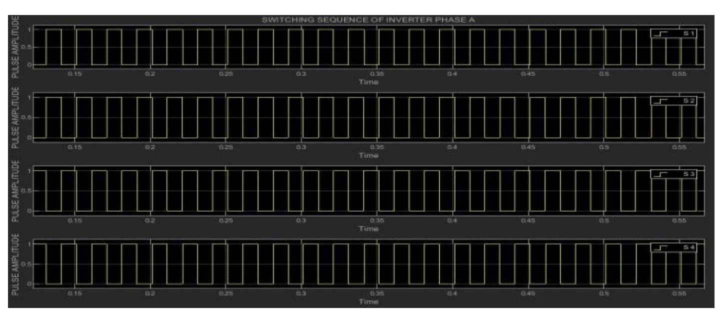

Figure 4 Switching Sequence of Inverter Phase A

Figure 9 Switching Sequence of Inverter Phase B

Figure 10 Switching Sequence of Inverter Phase C

D. Total Harmonic Distortion Analysis

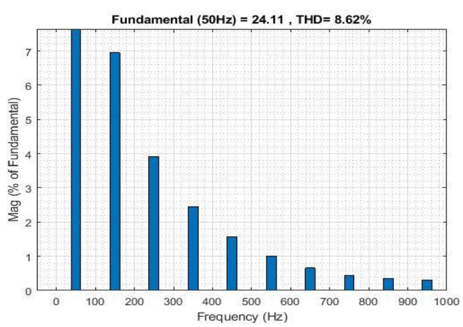

Figure 11 THD analysis without Shunt APF

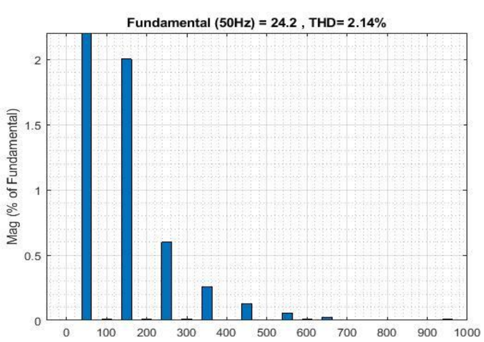

Figure 12 THD analysis with Shunt APF

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VII. CONCLUSION

The paper presents the design, analysis and desired output waveforms of shunt APF with flying capacitor multilevel inverter topology. MATLAB/Simulink software was used to simulate the design and to observe the performance of the system. MATLAB FFT analysis tool is used to calculate and analyze the THD performance of the design. The design project is based on three level multilevel inverter for the future work we can increase the levels of the inverter in order to enhance the system performance further. The THD performance with filter is 8% which is reduced to the 2%.

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