Simulation of Shunt Active Power Filter to Improve Power Quality in Grid System

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ABSTRACT

Renewable Energy Sources (RES) based Distributed Power Generation use Power Electronic Converters for grid interfacing. This paper deals with a multi objective control strategy for a current controlled three phase Distributed Generation (DG) inverter. The DG inverter incorporates active filter functionality in forward and reverse power flow modes when connected to a nonlinear load. The multifunctional grid connected inverter (MFGCI) can compensate for load current harmonics, load unbalance and load reactive power demand with closed loop active power control. The proposed closed loop power control scheme achieves accurate power tracking with zero steady state errors under ideal and non-ideal supply conditions. A hysteresis band current controller is used to generate the switching pulses for the interfaced inverter. Extensive simulation studies are done in MATLAB/Simulink software to validate the effectiveness of the proposed control strategy.

INTRODUCTION

In recent years Distributed Generation (DG) based on Renewable Energy Sources (RES) has undergone tremendous development globally. Due to the increasing energy demand, reducing fossil fuels and clean energy concepts more and more DG units are connected to the grid at the distribution level. Microgrids which integrates RESs, energy storage devices and local loads are a solution to the present-day energy crisis. Power quality is a major issue in a conventional distribution system in the presence of increased usage of nonlinear loads and power electronic based equipments. Poor power quality is a big challenge for the stable, effective and economic operation of an inverter dominated microgrid. Soon electricity will be a commodity marketed by judging its quality in a competitive environment. Several active power filtering techniques have been developed to mitigate the traditional distribution system harmonic issues. The basic structure of an active filter is like that of a DG inverter and the primary function of these grid interfacing inverters is to inject active power to the grid. The DG inverter may not operate at its full capacity at all the time due to the stochastic nature of the renewable energy sources like solar and/or wind. If controlled properly the unused capacity of DG inverters can be effectively used for providing ancillary services like harmonic, reactive power compensation and unbalance mitigation of the power distribution system. Such an inverter can be called as a multifunctional grid connected inverter (MFGCI). With the recent developments in microgrid technology power quality enhancement using flexible control of MFGCI is an interesting research topic. Use of MFGCI eliminates the necessity of additional compensating devices and results in a cost-effective system.

Voltage Source inverters are used as the interfacing converters in most of the DG systems. Normally these inverters operate in current controlled mode (CCM) during grid connected operation due to its superior harmonic compensation capability when compared to the voltage-controlled mode (VCM). Various control strategies and techniques for enhanced power quality in a grid connected system have been reported recently. During harmonic compensation of the nonlinear load current, the fundamental DG current supplied by the interfacing inverter must be calculated based on the active and reactive power reference. A control technique with power quality improvement features for the integration of DG systems to the grid is discussed. In this strategy generation of fundamental DG current component assumes a stiff voltage source at the grid side and does not consider non ideal supply conditions. An open loop power control strategy for optimal power quality compensation in Microgrid using multifunctional grid connected inverters is proposed. An electrical distribution system is subjected to power fluctuations and uncertainties which cause the voltage at the point of common coupling (PCC) to be unbalanced. The interaction between the DG inverter nonlinear current and distorted PCC voltages may contribute power control errors in the steady state. Hence a closed loop power control Strategy is necessary for accurate power tracking in the case of distorted voltages at the PCC. In a closed loop power control strategy for single phase inverters with active harmonic filtering in stationary frame is proposed for harmonic compensation.

Classification According to Power Rating and Speed of Response in Compensated System:

The block diagram shown in figure 1 shows the classification based on this criterion.

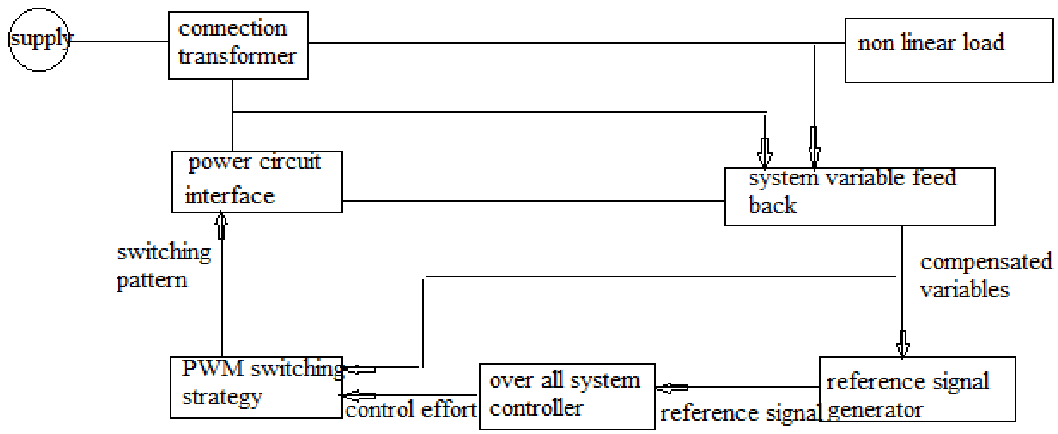

Figure: 1 generalized block diagram for active power filter.

The size of nonlinear loads plays a major role in deciding the way different control methods are implemented. The filter required for compensation must be practical for the load and this decision affects the speed of response. In general, a reciprocal relationship exists between the costs of a system to the required speed of response.

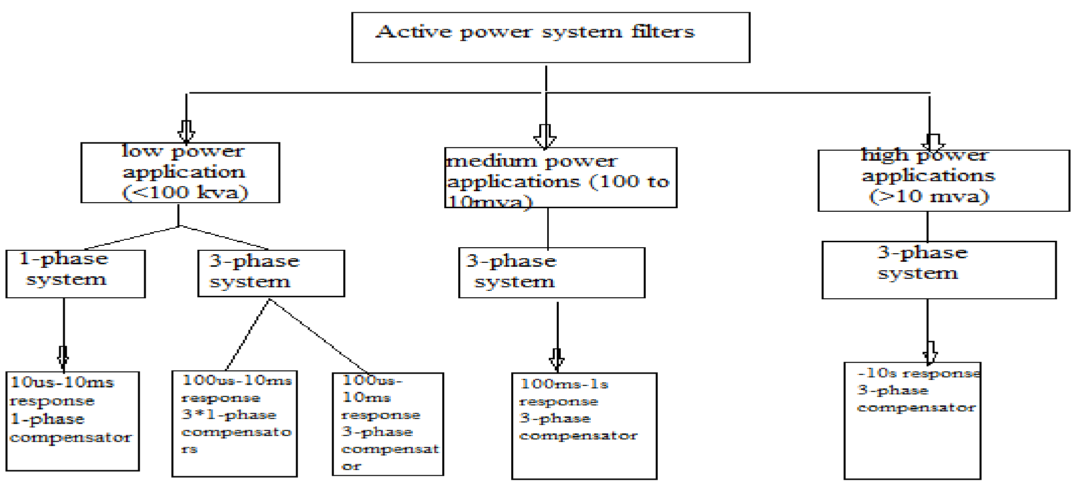

Figure: 2 Subdivisions of active filters according to speed response and power rating.

Classification According to Power Circuit, Configurations and Connections

The choice of power circuit chosen for the active filter greatly influences its efficiency and accuracy in providing true compensation. It is therefore important that the correct circuit configuration is chosen. Figure 3 classes' three major types of filter structures along with the relevant power circuit.

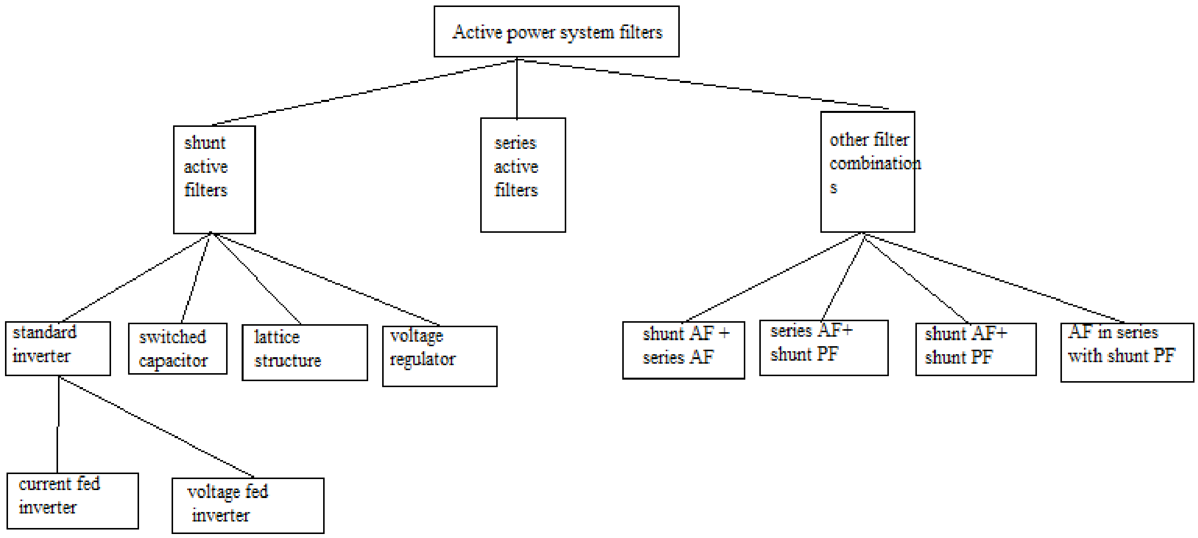

Figure: 3 Subdivisions of power system filters according to power circuit configurations and connections

HARMONIC SOURCE

TV RECEIVER	DIODE/THYRISTOR CONVERTER	STATIC VAR COMPENSATOR
FLUROCENT LAMP	ELECTRIC FURNACE	TRANSFORMER
ELECTRONIC DEVICE	DISCHARGE LAMP	-
DOMESTIC	INDUSTRIAL	CONTROL
-	-	-

Figure.4: Harmonic source

Harmonic Sources from Commercial Loads

Commercial facilities such as office complexes, department stores, hospitals, and Internet data centers are dominated with high-efficiency fluorescent lighting with electronic ballasts, adjustable-speed drives for the heating, ventilation, and air conditioning loads, elevator drives, and sensitive electronic equipment supplied by single-phase switch-mode power supplies. Commercial loads are characterized by many small harmonic-producing loads. Depending on the diversity of the different load types, these small harmonic currents may add in phase or cancel each other. The voltage distortion levels depend on both the circuit impedances and the overall harmonic current distortion.

Since power factor correction capacitors are not typically used in commercial facilities, the circuit impedance is dominated by the service entrance transformers and conductor impedances. Therefore, the voltage distortion can be estimated simply by multiplying the current by the impedance adjusted for frequency. Typical nonlinear commercial loads are single-phase power supplies, fluorescent lighting and adjustable speed drives for HVAC and elevators.

PROPOSED WORK

The multifunctional APF cleans the current drawn from the utility and similarly to a Dynamic voltage restorer (DVR) the point of common coupling (PCC) and utility smart meters will be protected from voltage distortions to avoid wrong computation of power and energy balance. This compensator could inject or absorb active power during grid voltage variations to ensure high quality supply along with complete decoupling from polluted loads.

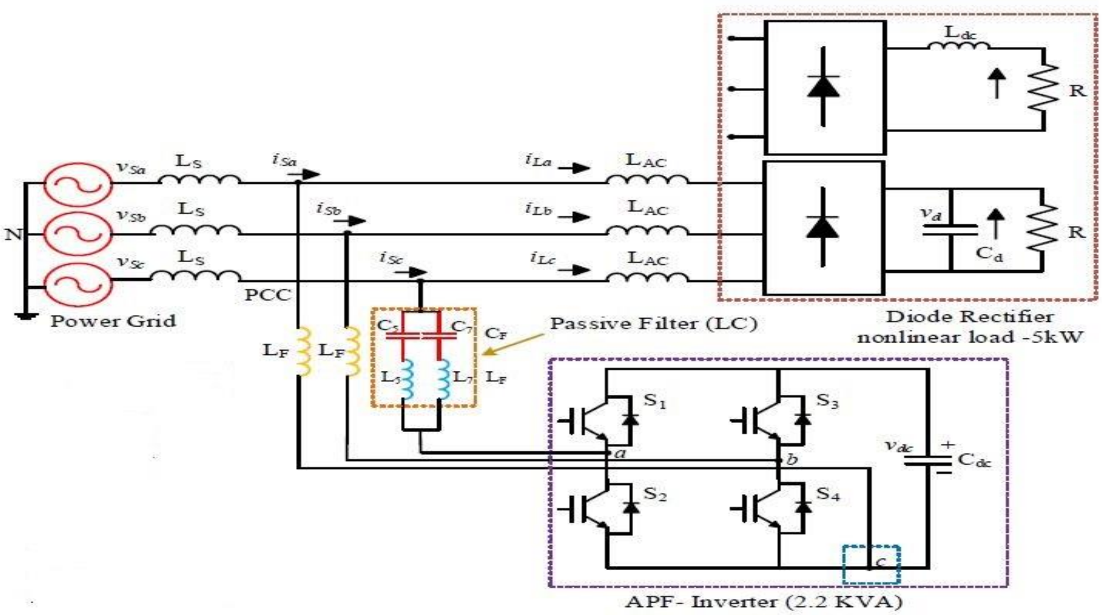

Fig. 5 Proposed transformer less APF system [1]

The proposed design mainly aims to provide superior compensation capability and less complex structure without increasing the number of power switching devices for three-phase applications. The series ac-coupling inductors overcome the fixed reactive power compensation by limiting the use of PFs. The new topology provides superior overall performance as compare to the dc-bus midpoint connection configuration in terms of harmonic compensation capability owing to the balanced current and voltage. Therefore, less complex structure and straightforward connection between the transmission line and the terminal of the dc-bus reduce the constraint of voltage balancing across the dc-link capacitor.

This configuration also eliminates the need of extra controller and transformer in between the LC PF and the filter inverter for preventing magnetic saturation. As a result, the design configuration presents less cost, volumetric size, and lightweight structure. The proposed SAPF is composed of the three-phase two-leg bridge version of the four-switch inverter, as shown in Fig.5. It comprises a two-arm bridge structure, four switches, coupling inductors and sets of LC PFs. The adopted modulation strategy in this study is the sinusoidal PWM (SPWM) for a proper switching scheme. The carrier signal is compared with the comparators with single modification to pattern the reference signals [1]. The third leg of the three-phase VSI is removed by eliminating the set of power switching devices, thereby directly connecting the phase with the negative terminals of the dc-link capacitor. The elimination of single phase-leg generates the dc-link voltage imbalance or voltage fluctuations issues [1]. Therefore, this problem can be solved by connecting the removed leg terminal with the negative terminal of the dc-bus PWM-VSI to stop the unbalance charging of the dc-link capacitors. Furthermore, to stop the flow of decoupling power ripples, the ac film capacitor stores the power ripples [1], to provide the balanced output currents and voltages.

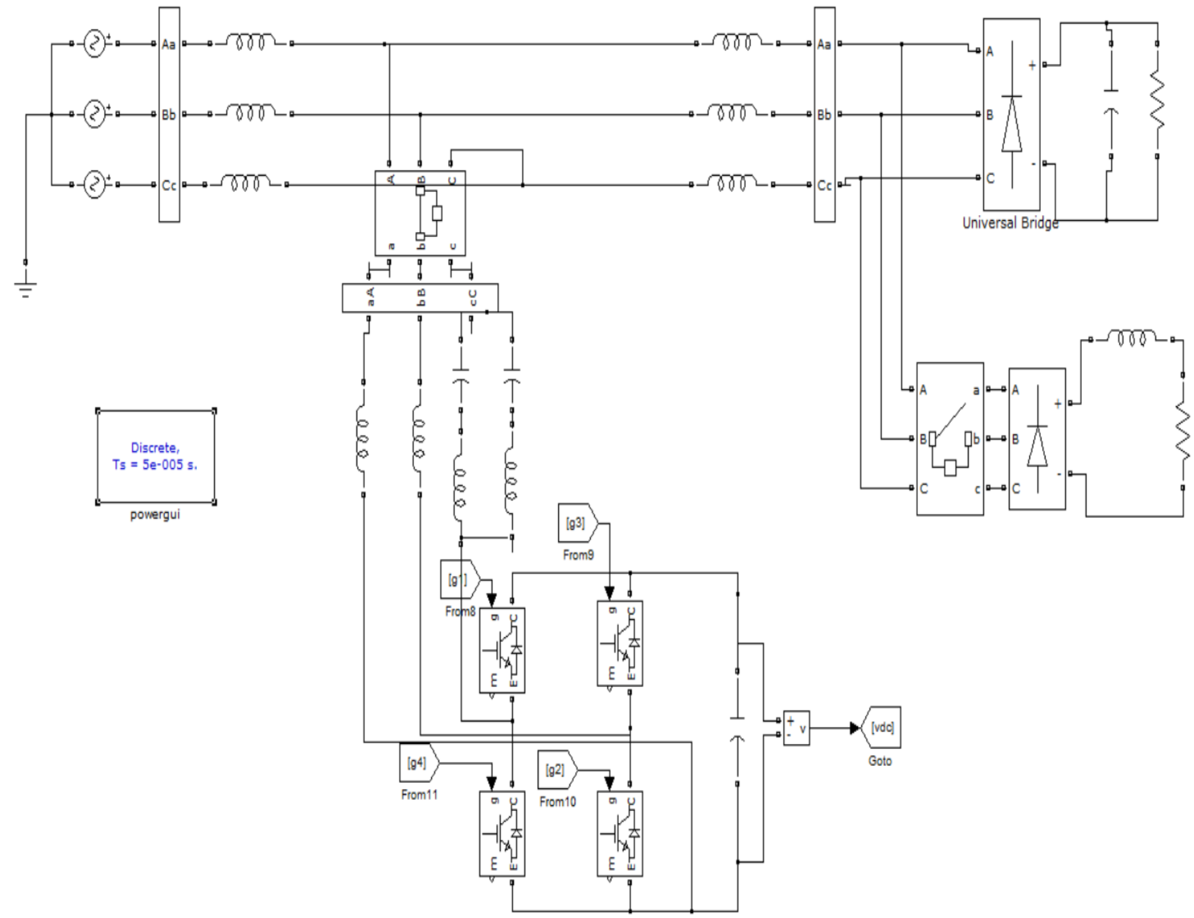

Fig.6- Matlab simulation of Transformer less SAPF

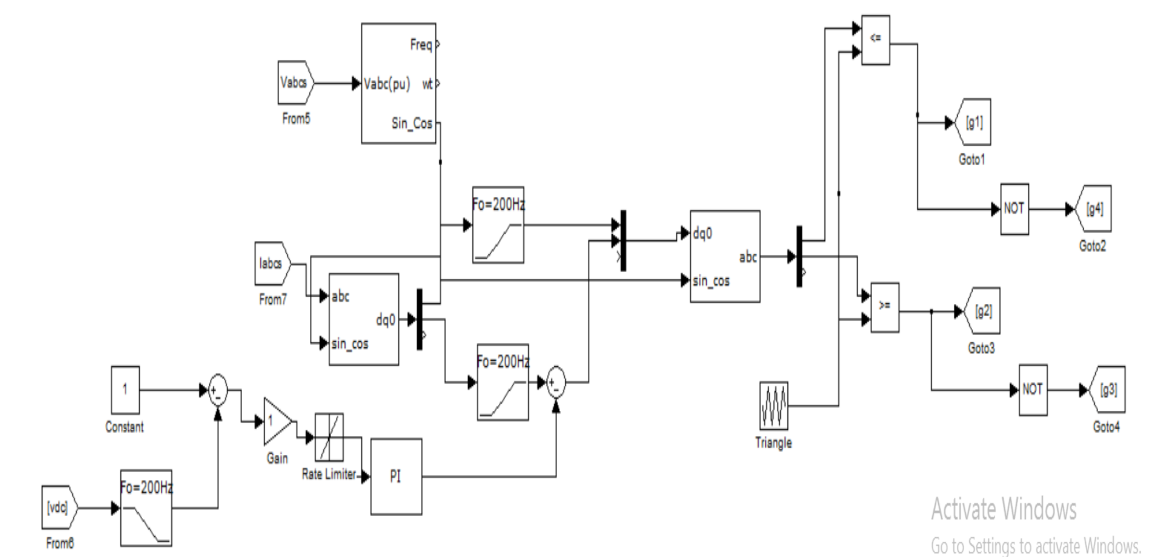

Fig.7- Matlab simulation of Transformer less SAPF control system

SIMULATION RESULTS OF TRANSFORMERLESS SAPF

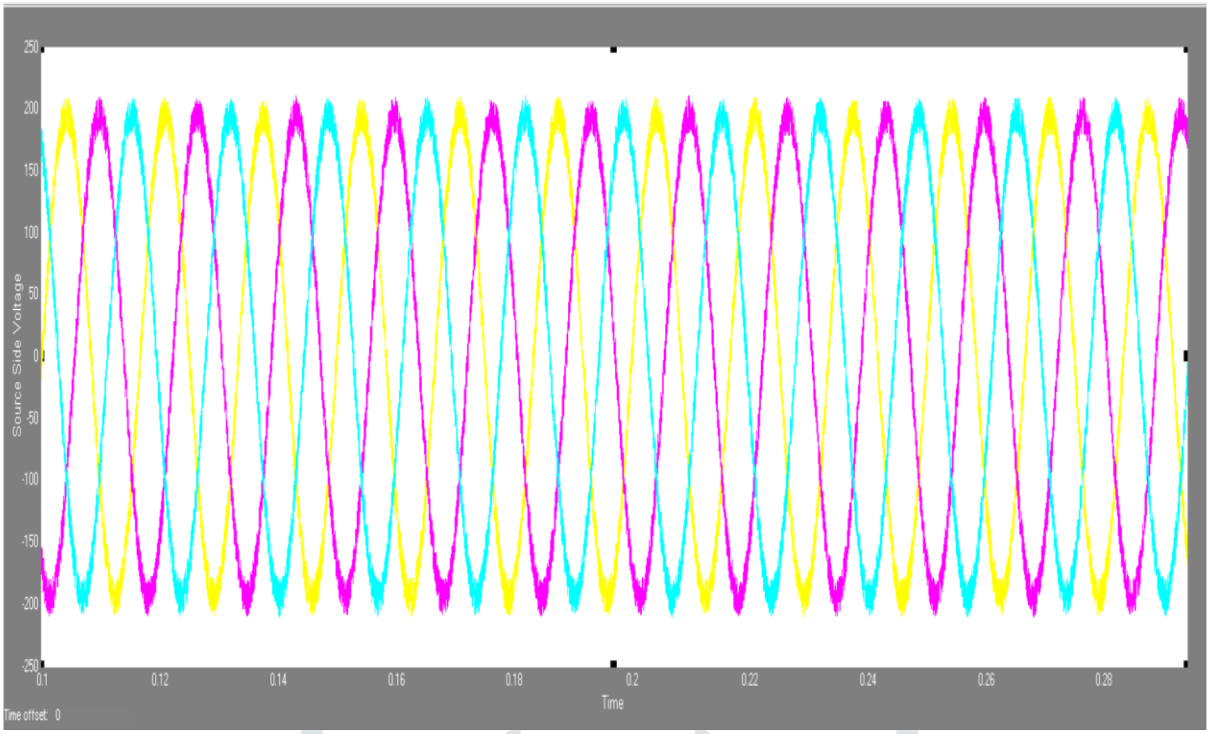

Fig.8- Source Side Voltage Waveform

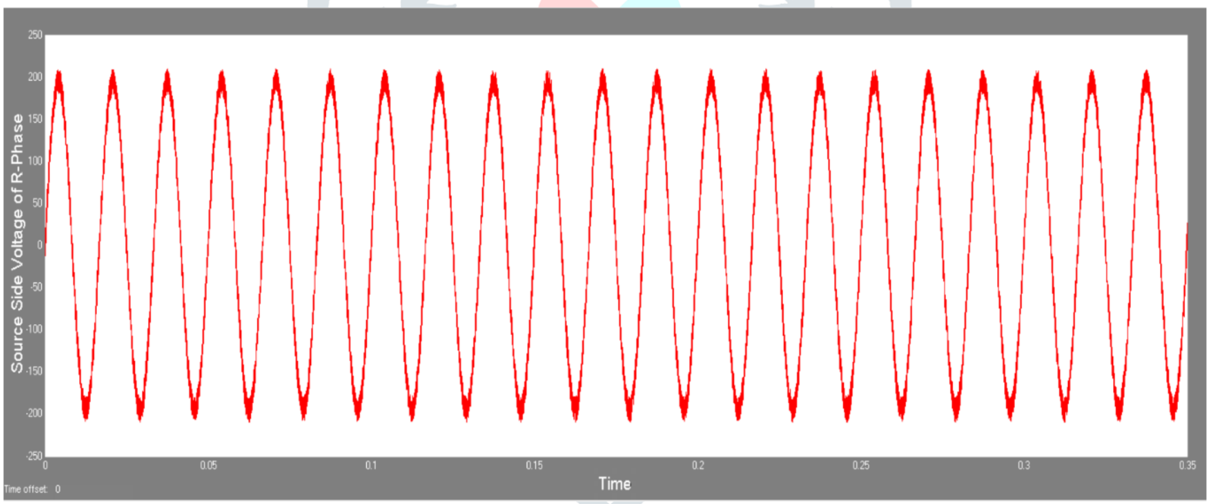

Fig.9- Source Side Voltage Waveform Phase-R

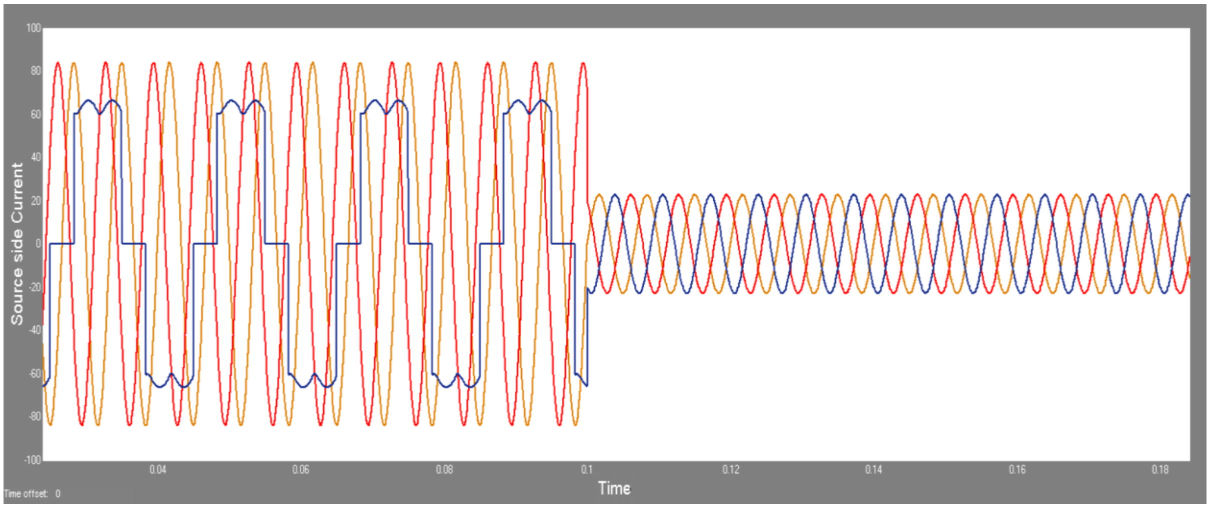

Fig.10- Source Side Current Waveform

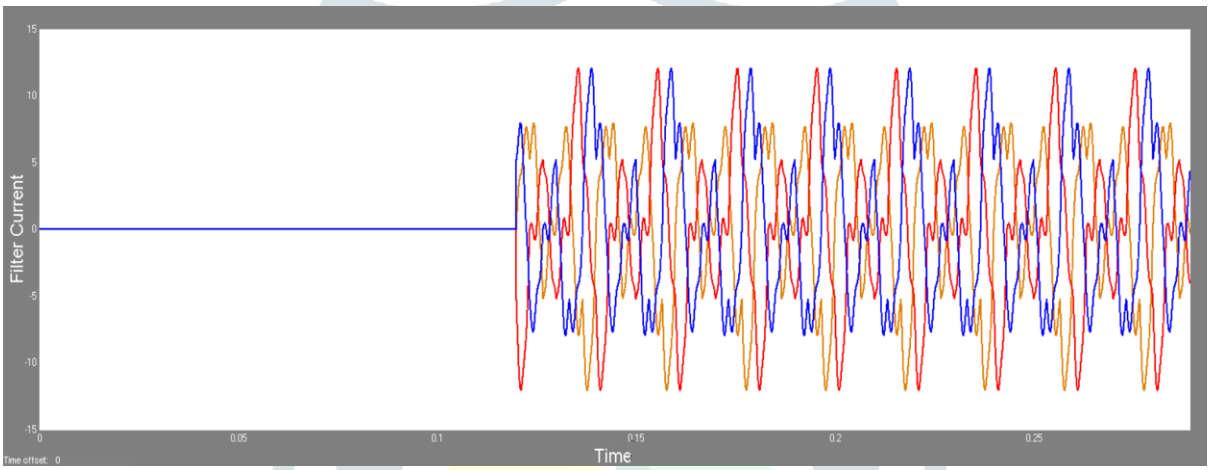

Fig.11- Filter Side Current Waveform

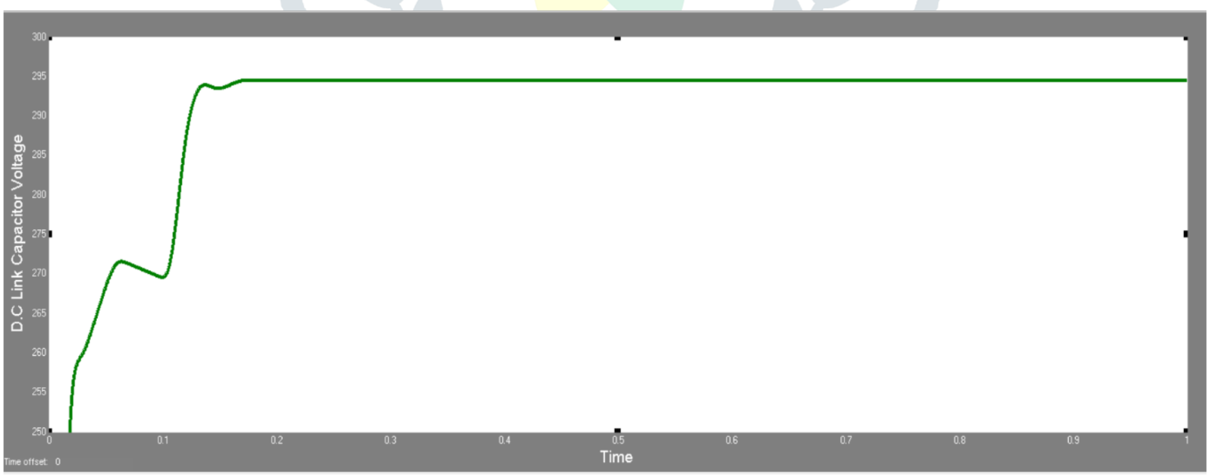

Fig.12- Common D.C Link Capacitor Voltage Waveform

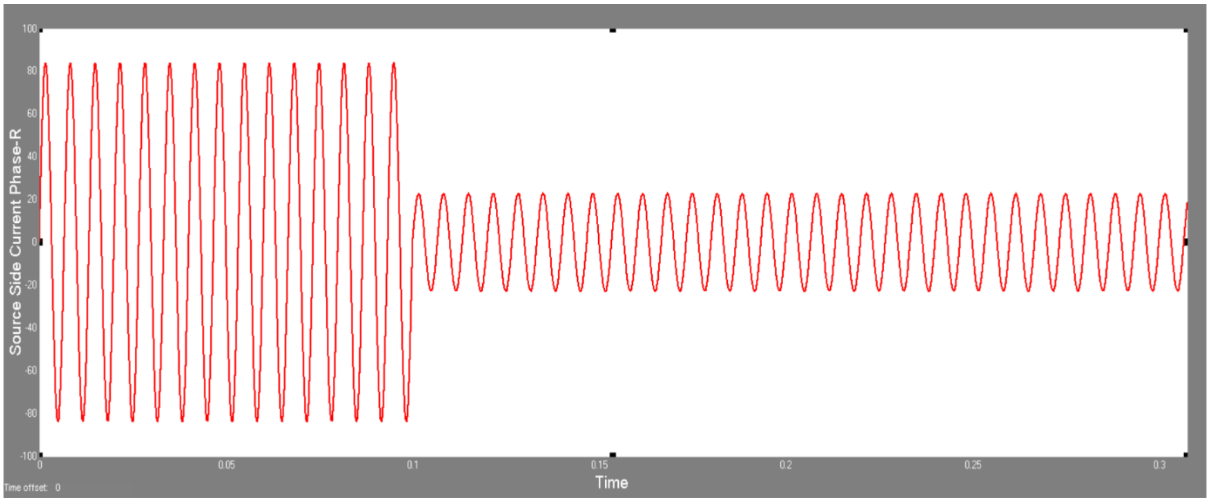

Fig.13- Source Side Current Waveform Phase-R

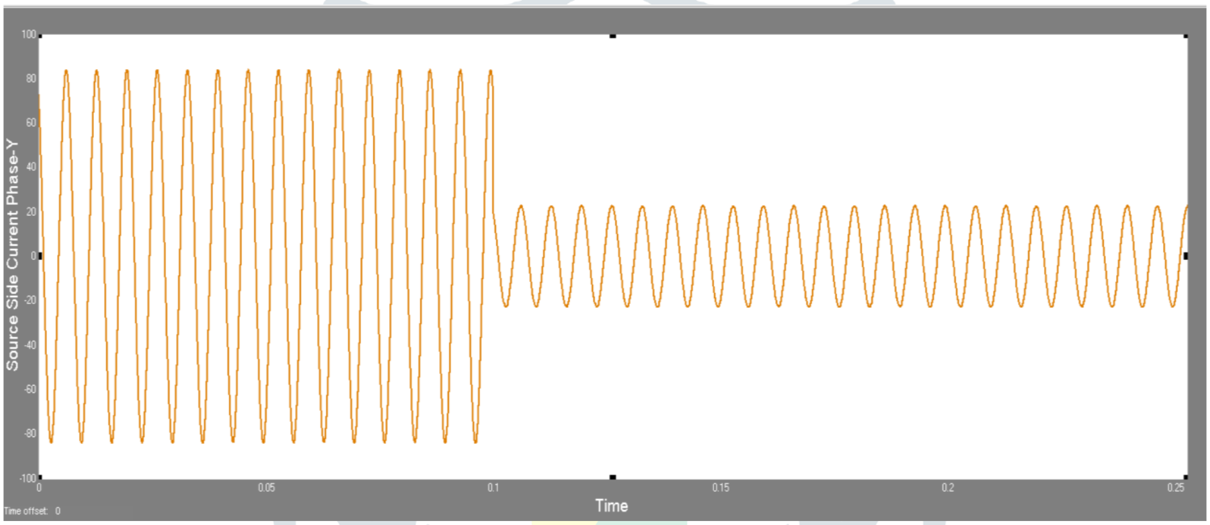

Fig.14- Source Side Current Waveform Phase-Y

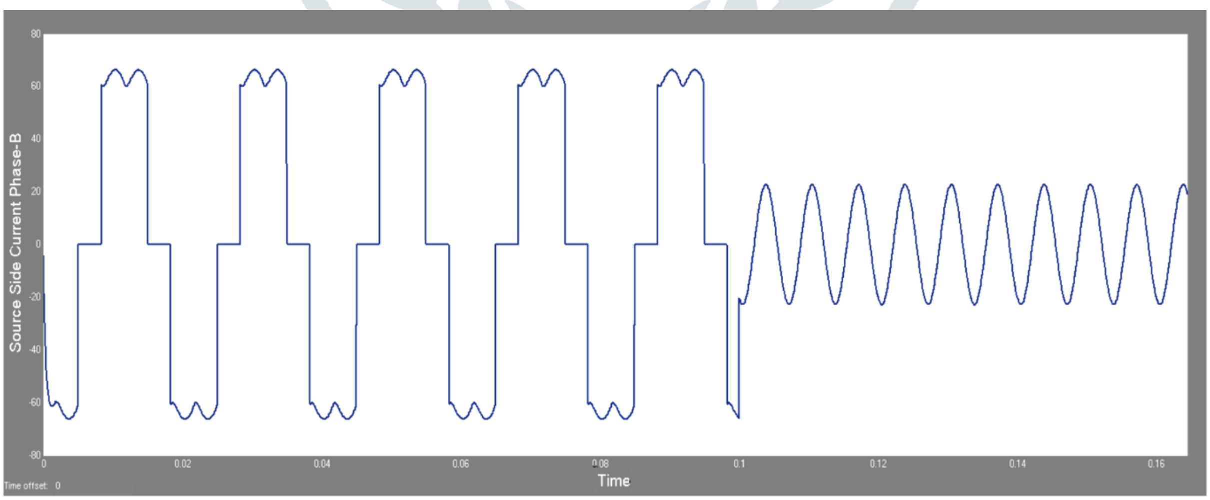

Fig.15- Source Side Current Waveform Phase-B

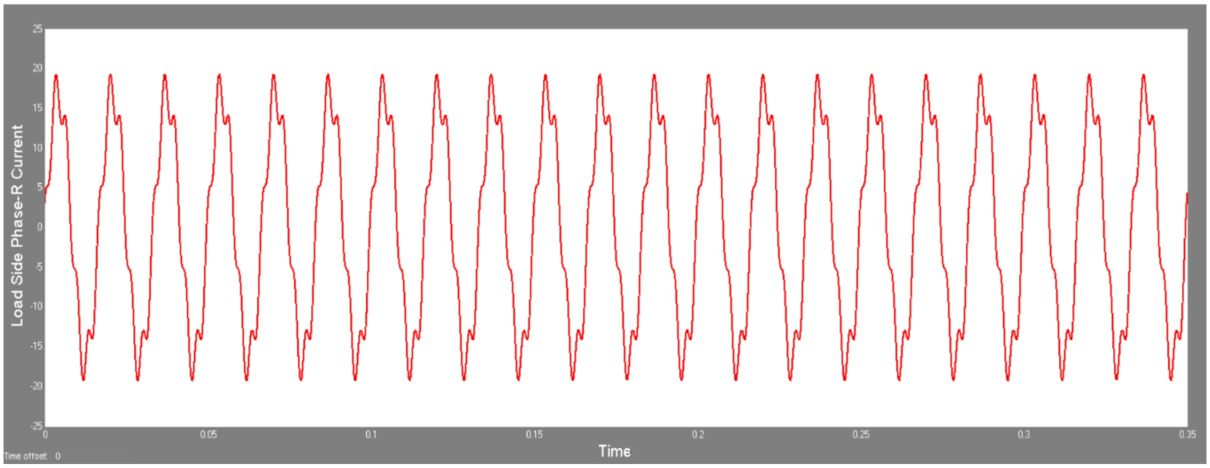

Fig.16- Load Side Current Waveform Phase-R

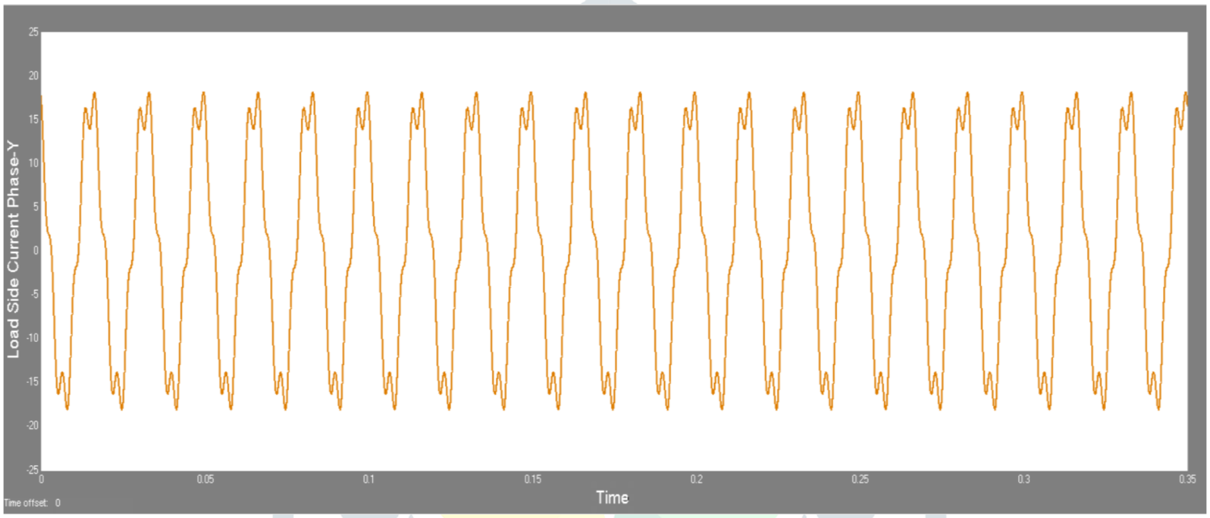

Fig.17- Load Side Current Waveform Phase-Y

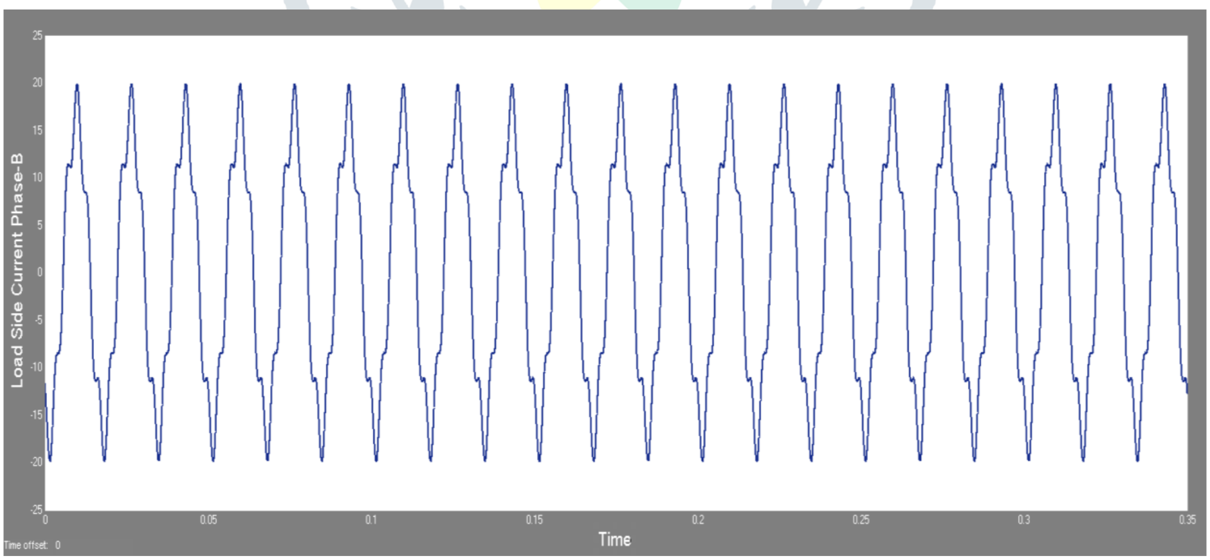

Fig.18- Load Side Current Waveform Phase-B

CONCLUSION

In detail study about our topic we can conclude that the increased use of static power converter and static power capacitors can set up system condition to cause power quality problems like harmonics in power system. In detail study about our topic we can conclude that the increased use of static power converter and static power capacitors can set up system condition to cause power quality problems like harmonics in power system. The proposed filter can compensate source currents and adjust itself to compensate for variations in non-linear load currents, maintain dc link voltage at steady state and helps in the correction of power factor of the supply side adjacent to unity. In this project we have design the Matlab simulation of Series APF for Voltage waveform improvement.

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