POWER QUALITY ENHANCEMENT USING HYBRID ACTIVE POWER FILTER UNDER NON-LINEAR LOAD CONDITION

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Abstract - *The concern generated by the quality of power is capacitor banks failure, over voltages voltage failure, and excessive current due to resonance and so on. The power quality issues under transient type include most of the phenomena which is of transient nature such as voltage sag/dip, swell, noise and fluctuations of voltage. The steady state type difficulty includes flicker, harmonics current at load and unstable load currents .The utilization of active , passive , hybrid filters in series , shunt or combination of both for various configurations such as single phase two wire , three phase three wire , three phase four wire has aided for balancing of linear and nonlinear loads along with the mitigation of harmonics. For the eradication of harmonics current in non- linear loads the shunt active power filters proves to be cost effective. This paper presents the active shunt and passive shunt topology of hybrid active power filter, active series and passive shunt along with instantaneous reactive power theory as the control algorithm for the deprecation of harmonics and improvement of power quality. With the aid of simulation and results of experiment the constructiveness of the topology and control scheme is validated.*

Key Words: THD (Total Harmonic Distortion), harmonics, hybrid power filter, IRPT (Instantaneous Reactive Power Theory)

INTRODUCTION

Primarily passive filters were used to reduce harmonics and for power factor correction capacitors have been employedBut because of the heavily dependence on the system parameters , fixed compensation , problem of resonance with impedance of system and also their limitation of filtering out a particular frequency active power filters are considered to overcome their drawbacks . Active filters are in use since 1970's for the compensation of reactive power and negative sequence current.
Active filters undergoes various drawbacks which can be listed as follows :-

- Increased rating of the filter which can reach out to 80% of the load
- Costlier option for power quality improvement at times because of high rating
- In the presence of both voltage and current based power quality issues they do not provide a complete solution
- Increment in losses

Therefore, to mitigate the drawbacks of the active and passive filter HPFs(hybrid power filter) is evolved which seems to be more cost effective for the compensation of non-linear loads .

1.1 HYBRID POWER FILTERS

The combination of both active and passive filter is known as hybrid power filter . They have got the advantage of both active and passive filter. Hybrid filters are combination of both shunt passive and series passive filters, it overcomes the drawbacks of the filters which they possess when utilized individually [1].
Under varying loads these hybrid filters provide superior filtering characteristics.
The hybrid active filter is the combination of active and passive filters which aids in overcoming the demerits of the active and passive filter when utilized individually for reactive power compensation and mitigation of harmonics. [2-5].
This paper presents the comparison of two topologies of hybrid filter namely hybrid filter as a combination of series active and shunt passive filter and hybrid filter as a combination of shunt active and shunt passive filter along with control algorithm of instantaneous reactive power theory

1.2 Configurations of Hybrid Active Power Filters:-

Hybrid 1: Combination of Series Active and Shunt Passive Filter

This combination of hybrid filter comprises of active filter connected in series with passive filter connected in shunt as shown in fig (1). It is a cost effective solution for the elimination of harmonics for voltage fed loads. The series combination of active filter and passive filter connected in shunt depicts this filter configuration. The harmonic current produced by the load is suppressed by passive filter while the active filter helps in improving the filter characteristics of passive filter. By constraining the harmonic current the series connected active filter let the harmonic current to sink in the passive filter [7-9]

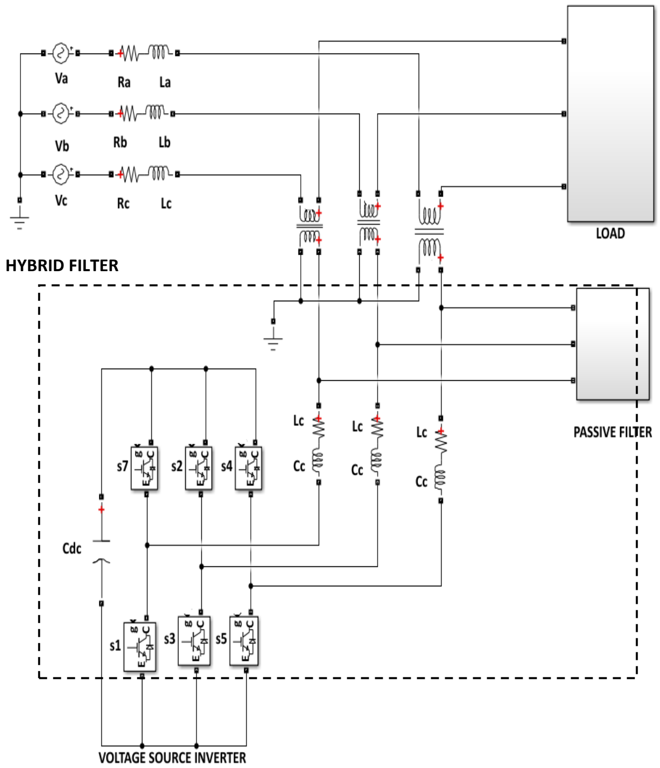

Fig -1: Hybrid Filter with Combination of Series Active and Shunt Passive Filter

Hybrid 2: Combination of Shunt Active and Shunt Passive Filter

The order of frequencies that is needed to be filtered out decides the rating of the active power filter. Thus, the active filter will be of reduced size and cost which filters lower order harmonics this is the basic idea used in the designing of this filter. The higher order harmonics is filtered out by the shunt connected passive filter and the lower order harmonics is filtered out by the shunt connected active power filter.[10].

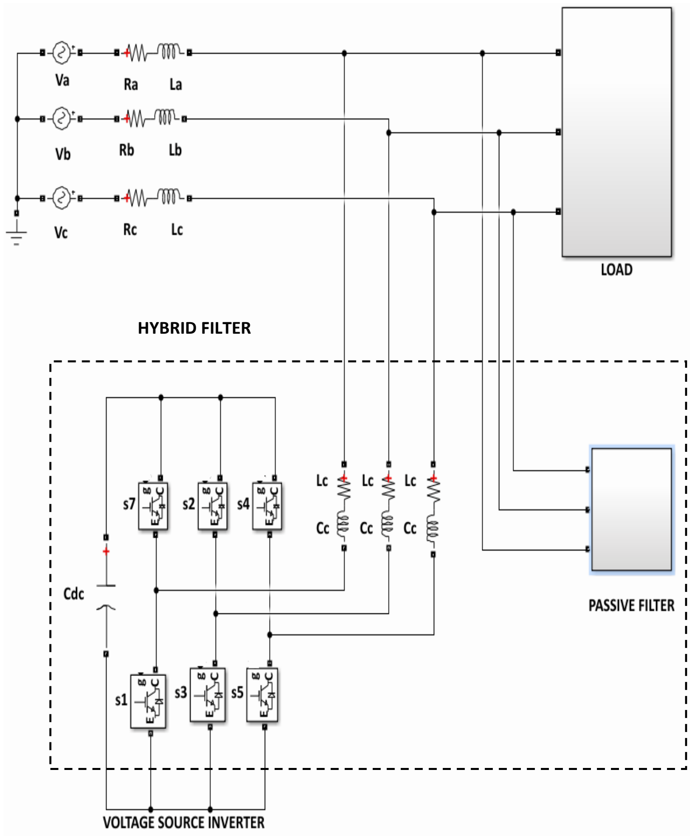

Fig -2: Hybrid Filter with Combination of Shunt Active and Shunt Passive Filter

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2. CONTROL STRATEGIES

The mitigation of power quality problems based on the current is the main objective of DSTATCOM. Reactive power, unbalanced currents, neutral current and harmonics are mitigated by DSTATCOMs which are the most common power quality based problems which are based on current and it also with the aid of DC bus of the voltage source inverter based DSTATCOM it aid in the supply of balanced sinusoidal current.

There are different control strategies which aids in the generation of gating pulses for inverter action. [8]. The control strategy proposed in this paper is instantaneous reactive power theory.

3.1 Instantaneous Reactive Power Theory

The block diagram of instantaneous reactive power theory is shown in fig 3.

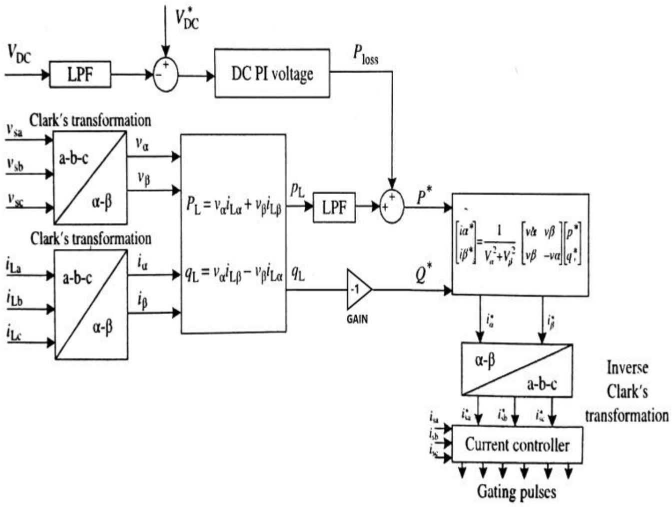

Fig -3: Instantaneous Reactive Power

Instantaneous active and reactive power are calculated by sensing load currents(three phase) and voltage at point of common coupling. For the elimination of ripple contents the point of common coupling voltages(three phase) are sensed and processed by the Butterworth filter(a type of low pass filter).[11]

Clark's transformation is used for the transformation of filtered three phase load voltages into two phase α-β orthogonal coordinates given as(v_0, v_α, v_β).

$$\begin{pmatrix} v_\alpha \\ v_\beta \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{pmatrix} \qquad (1)$$

Similarly, the transformation of three phase load currents (i_{La}, i_{Lb}, i_{Lc}) is done into two phase α-β orthogonal coordinates which can be given as $(i_{L\alpha}, i_{L\beta})$.

$$\begin{pmatrix} i_{L\alpha} \\ i_{L\beta} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{pmatrix} \qquad (2)$$

Load side instantaneous active power can be given as:-

$$p_L = v_\alpha i_{L\alpha} + v_\beta i_{L\beta} \qquad (3)$$

And the load side instantaneous reactive power can be given as:-

$$q_L = v_\alpha i_{L\alpha} - v_\beta i_{L\beta} \qquad (4)$$

The estimation of the reference three phase current (supply current) $(i_{sa}^*, i_{sb}^*, i_{sc}^*)$ is given as below:-

$$\begin{pmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & 0 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{pmatrix} \begin{pmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{pmatrix}^{-1} \begin{pmatrix} p^* \\ q^* \end{pmatrix} \qquad (5)$$

In this configuration of instantaneous reactive power theory the reference current $(i_{sa}^*, i_{sb}^*, i_{sc}^*)$ are compared with the source current (i_{sa}, i_{sb}, i_{sc}) for the generation of gating pulses of voltage source inverter.

4. SIMULATION RESULTS

Three topologies of hybrid filter are simulated using MATLAB simulation and the results are compared. The various design parameters for the system are as follows:-

Source voltage (per phase) =240 volts.

The passive filter parameters for hybrid configuration of active series and passive shunt filter is as follows:-

Table -1: Passive Filter Parameters

	Passive Filter Parameters		
	Resistance (ohms)	Inductance (mH)	Capacitance (µF)
5th order harmonics	0.02	16	24
7th order harmonics	0.02	8	24

The passive filter parameters for shunt active and shunt passive hybrid filter is:-

Table -2: Passive Filter Parameters

	Passive Filter Parameters		
	Resistance (ohms)	Inductance (mH)	Capacitance (µF)
5th order harmonics	0.01	2.5	40
7th order harmonics	0.01	3.3	30

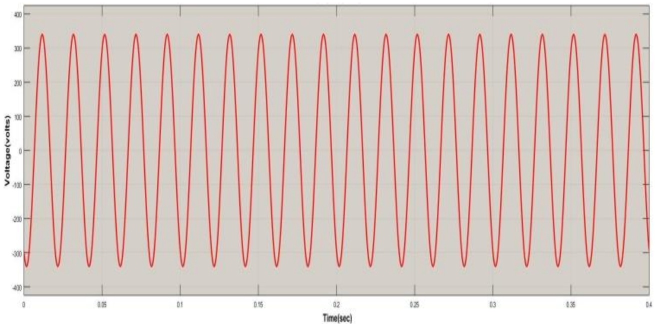

Fig -4: Source voltage waveform

Configuration 1: Series active shunt passive based hybrid filter

The source current and source voltage of series active shunt passive filter without compensation is shown in fig (5). The control strategy used is instantaneous reactive power theory.

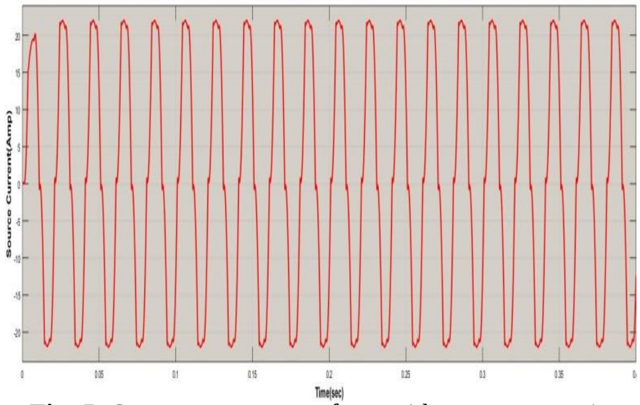

Fig -5: Source current waveform without compensation

To eliminate these harmonics filters are being used. when hybrid filter which is combination of both passive and active filter is used the THD becomes 4.45%. The source current waveform when hybrid filter is used is shown in fig (6).

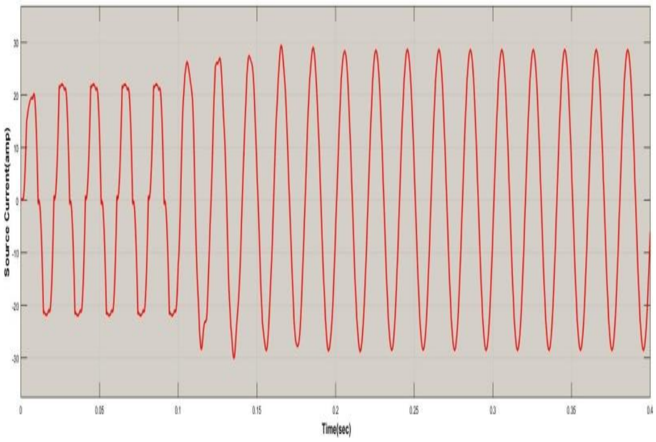

Fig -6: Source current waveform with Hybrid active power filter compensation

Configuration 2: Shunt active and shunt passive based hybrid filter

The source current waveform without compensation is shown in fig (7).

Thus to mitigate the harmonics of the source current the hybrid filter is used. The THD of the system with hybrid filter is 4.23% .The source current waveform after compensation fig (8).

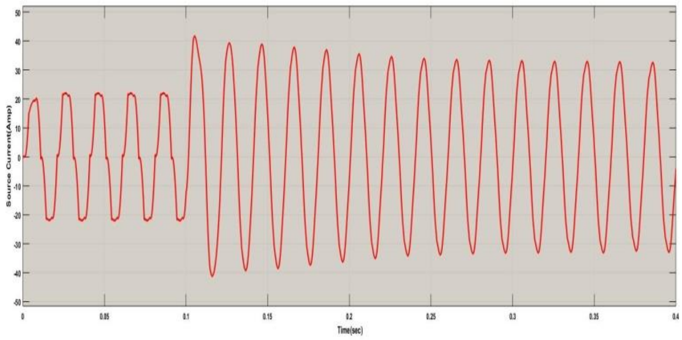

Fig -7: Source current waveform without Hybrid active power filter compensation

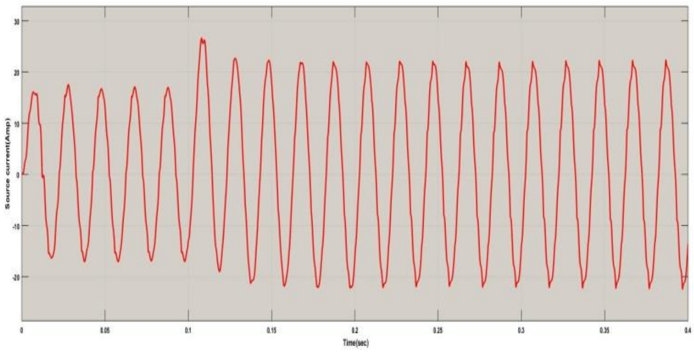

Fig 8: Source current waveform with hybrid filter compensation

The DC link capacitor voltage is shown in figure 9.

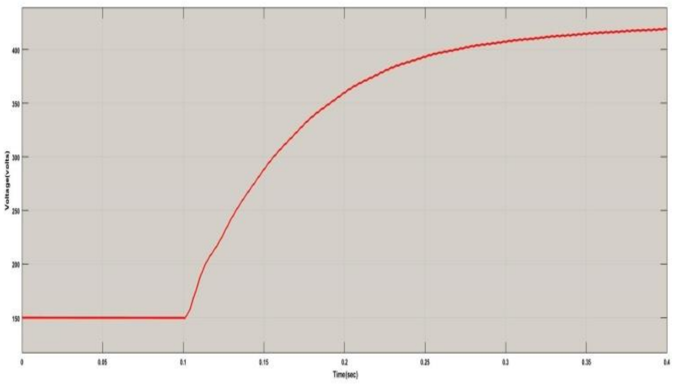

Fig -9: DC link capacitor voltage

5. CONCLUSIONS

The increment of non-linear loads in system has increased to a great extent with the utilization of electronic switches. The increase in non-linear loads causes the %THD to increase to a great extent. With the increase in %THD the equipment failure problems also increases. Various hybrid filter topologies and their control strategies are explained. From the comparative study of these topologies it is found that active series and passive shunt combination of hybrid filter is found efficient as it improves the system performance with mitigation of harmonics to a great extent. Therefore, with the proposed control algorithm the harmonic compensation feature of the passive filter is improved along with the power factor of the load.

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