Asian Journal of Convergence in Technology **Volume V Issue I**
ISSN NO: 2350-1146 I.F-5.11

Power Filters to Reduce Harmonics to Improve Power Quality

Prakash.L.Chavan[1], Aishwarya Patil[2], Pratibha Patil[3], Pranali Dongare[4], Satyawan Surwase[5], Prasad Bhalkar[6] [1, 2, 3, 4, 5, 6] EED-AMGOI-Maharashtra-India-416112
[1]prakash264@gmail.com, [2]aishwaryapatil5626@gmail.com,[3] pratibhapatil1710@gmail.com, [4]pranalidongare04@gmail.com, [5]satyawansurwase3727@gmail.com , [6]prasadbhalkar07@gmail.com

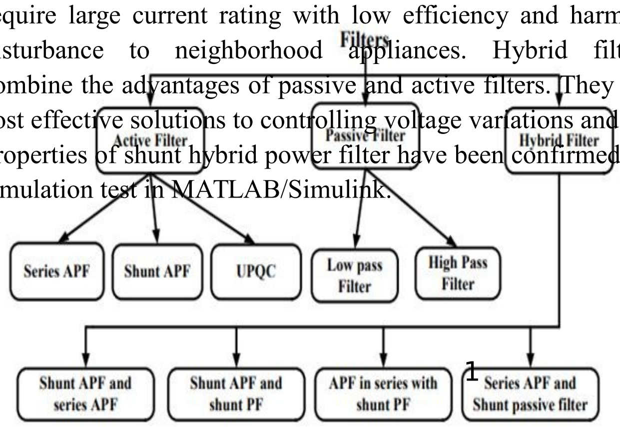
Abstract- This paper focuses towards implementation of hybrid active power filter for compensation of harmonics to improve power quality. Development in smart grid technology created a higher demand for improved power quality. Harmonics are the main constraints for poor power quality. Adjustable-speed drives, switching power supplies, arc furnaces, electronic fluorescent lamp ballasts, lightning strike, L-G fault are the sources of poor power quality. Non linear loads are the major source of harmonics in modern power system. The problems associated with power quality are voltage sags, voltage swells, interruption, sustained interruptions, over voltage, under voltage, long-duration voltage variations, voltage imbalance, and waveform distortion. To overcome these problems motivated to design the hybrid active power filter. For the improvement of power quality hybrid filter amongst other involves the use of both the passive filter and shunt APF in combination are being used to eliminate both higher and lower order harmonics. The p-q method is used for harmonic suppression. The expected properties of shunt hybrid power filter have been confirmed by simulation test in MATLAB/simulink.

I. INTRODUCTION

Now-a-days, due to development in smart grid technology people have a higher demand for improved power quality. However with the increased use of power electronic devices and motor loading, it is becoming more difficult to achieve the goal. Due to rapid increase in the technology especially in electric power sector, the use of non linear loads on a typical distribution system has been increased. These non linear loads are the major source of harmonics in modern power system which is making the system polluted. Modern equipments require clean power for their proper operation. Any of the problems associated with power quality such as voltage sags, swells, interruptions, waveform distortion etc. Causes the sensitive equipment to malfunction. To improve the quality of power several filters are developed. In mid 1940s, passive power filters (PPF) were developed to suppress current harmonics and compensate reactive power. IN 1976, active power filters (APF) were developed to compensation harmonics. HAPFS are more attractive in harmonic filtering than pure APFs from both viability and economical view. To achieve the best performance, the united power quality converter (UPQC), has been developed with an extremely high cost. During 1967~2005, HAPFs are mainly applied to traditional industry, such as steel furnace, ASD, etc.

Effects of voltage sags are- opening of relay affects the relay‟s coil voltage, under voltage sensors on the ac mains operating without need. Voltage swells can affect the performance of sensitive electrical and electronic equipment, causes data errors, produce equipment shutdowns, could cause equipment damage or reduce equipment life. It causes unwanted tripping and deprivation of electrical contacts. Effect of harmonics are overheating of neutrals, transformers, tripping of circuit breakers, voltage distortion, failure of power system, failure of insulation and control system protective devices such as fuse, relays. These power quality problems are mitigated by using different methods, isolation of transformers, passive filter, active filter and special metering. To reduce the harmonics there are many filter topologies like active, passive and hybrid.

Shunt passive power filters, commonly referred to as LC filters, are a conventional solution to eliminating harmonic distortion in a power distribution system. However, these types of filters are incapable of accommodating highly transient conditions where the distortion present in a system is unpredictable. Thus, the conventional passive filter cannot provide a complete solution. Shunt active filter operates by injecting harmonic current into the utility system with the same magnitudes as the harmonic currents generated by a given non-linear load, but with opposite phases. Thus, the shunt APF can be used to compensate current-source non-linear loads. Unfortunately, it cannot compensate voltage-source non-linear loads. The harmonics generated by a voltage-source non-linear load can effectively be suppressed by using a series active power filter. Active power filters have the capability of damping harmonics resonance between an existing passive filter and the supply impedance, but they require large current rating with low efficiency and harmful disturbance to neighborhood appliances. Hybrid filters combine the advantages of passive and active filters. They are cost effective solutions to controlling voltage variations and properties of shunt hybrid power filter have been confirmed by simulation test in MATLAB/Simulink.



distortions as well as suppressing harmonics. They are being used to eliminate both higher and lower order harmonics. The p-q method is used for harmonic suppression. The expected

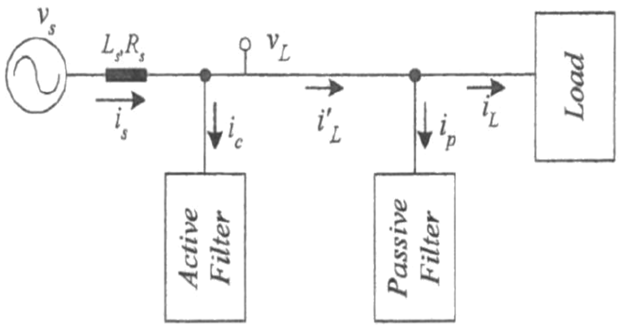


Fig.1 Classification filter

II. LITERATURE SURVEY

A series connected single-phase active power filter (APF) with a control system based on the modified hysteresis method. Waveform from the computer simulation and the waveform from the experimental test of filter operating at limited and unlimited maximum switching frequency [6]. By using FFT analysis Voltage sag and total harmonic distortion (THD) analysis are carried out and confirmed that proposed configuration for series APF has the expected performance [7].Compensation capability of SAPF confirmed by manufacturing a prototype of 15-level inverter based SAPF without using a parallel passive filter (PPF) [8]. To improve the input power factor of a single-phase rectifier with an inductive filter a new technique adopted which consist a two-quadrant active power filter, conventional bidirectional dc–dc converter, connected to the output side of the diode bridge [9]. An adaptive method based on a Kalman filter to obtain the reference compensating current in single-phase shunt active power filters. The method proposed can compensate the phase error in the harmonic components produced by the discrete sampling and the execution time delay associated with digital systems. [10]. the influence of supply-voltage fluctuation on compensation performance of shunt active power filter is analyzed when the dc-link voltage is constant can be concluded that current controller with PI regulator has better performance to suppress the influence of the supply-voltage fluctuation [11].

The structures of HAPFs are discussed in different historical periods, and divided into four developing pattern: parallel active part with parallel element, parallel active part with series element, b-shape, and three-phase four-wire structure. [2]. The performance of proposed series hybrid power filter is successfully utilized to compensate the voltage sag, swell, voltage harmonics, current harmonics and load reactive power demand.[5].Series filters have less attention in the power quality area due to its high cost of compensation, bulky transformers etc. Even though hybrid series active power filters are used in three phase system it is less utilized in single phase system. A novel chattering less sliding mode control algorithm is developed are incorporated with voltage and current control loop which provide source current harmonics elimination coming from voltage fed type of non linear load and other voltage distortions like voltage harmonics, voltage sag/swell initiated through grid. Thus cleaning point of common coupling and enhancing power quality and providing reactive power regulation. Main advantage of the filter is that only less dc voltage is needed for compensation and only small compensation gain is used. Voltage disturbances initiated from power system are obstructed by the compensator and PCC becomes free of

voltage harmonics and protected from voltage sag/swell. [1].The shunt hybrid power filter which consist of a SAPF extended by adding a SPF branch in series with non linear load. The series passive filter is used to block harmonics between the non linear load and the utility side. Consequently the shunt active filter compensates only reactive power and unbalance current.[4].

III. SYSTEM ANALYSIS

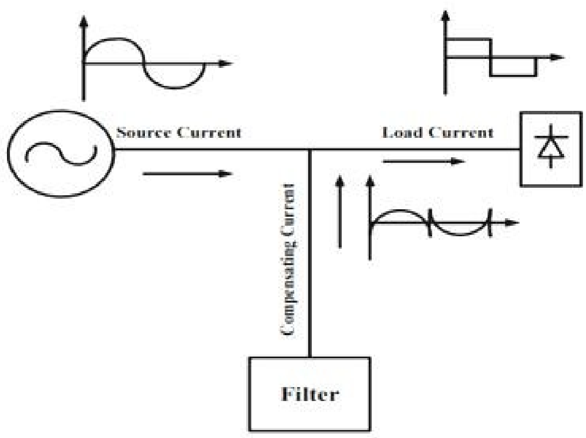


Fig.2 Basic operation of filter

Fig.3 System configuration of hybrid active filter

Fig.2 shows the basic operation of filters, Fig.3 gives the system configuration of the hybrid active power consist a line impedance L, and R, between the sinusoidal ac source and the load side. Load terminal connected with the linear and non linear load. Normally the load current i_L contains lots of harmonics and current amplitude and high order harmonics have low current amplitude. The passive filters with large rated power are shunt-connected at the load side to eliminate low order harmonics such that the current i'_L contains only high order harmonics. Therefore the low rated power of active power filter is adapted in the system to filter out the low order harmonics.

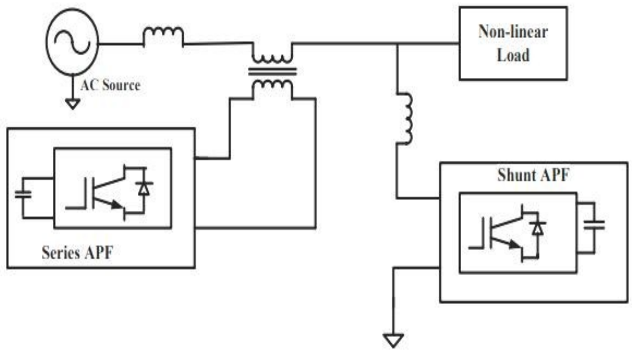


Fig.4 Shunt APF and Series APF combination

The series active filter is connected at the supply side with a coupling transformer which acts as a harmonic isolator to provide very high impedance at harmonic frequencies and forces to load harmonics to circulate in the passive filter. Shunt passive filter are inductance, capacitance and resistance elements configured and tuned to control harmonics are relatively inexpensive. They are employed either to shunt the harmonic currents off the line or to block to flow harmonic current between parts of the system by tuning the passive elements to create a resonance condition. „Notch‟ filter is most commonly used passive filter because of economical and sufficient application. The notch filter is offers low impedance to harmonic current and is connected in shunt with the power system to divert the harmonic currents from their normal flow path on the line through the filter in addition to this Notch filters provides PF correction in for harmonic suppression.

A non-linear load in a power system is characterized by the introduction of a switching action and consequently current interruptions. Provides current with different components are multiples of the fundamental frequency of the system. These components are called harmonics. Some examples of non-linear loads that can generate harmonic currents are computers, fax machines, printers, PLCs, refrigerators, TVs and electronic lighting ballasts.

IV. CIRCUIT CONFIGURATION

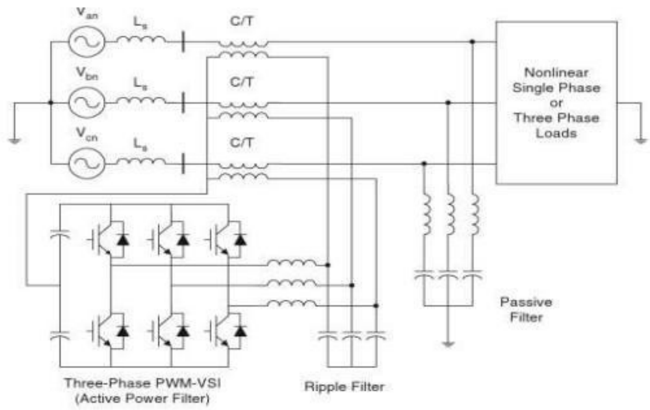


Fig.5 Circuit Diagram of System with Hybrid Filter

The series active power filter used for the PQ improvement is realized as a Voltage Source Inverter (VSI) is connected in series with the source impedance through a matching transformer. The circuit diagram is shown in Fig.5. A capacitor is providing constant input voltage to VSI. A passive filter is connected at the PCC is tuned to eliminate higher order harmonics. A ripple filter is used in series with VSI. The filter parameters are selected such that to reduce the transformer burden.The design criteria is

- XCrf << XLrf, such that at switching frequency the inverter output voltage drops across Lrf
- XCrf << ZS + ZF, to make the voltage divide between Lrf and Crf

Thus, with an efficient control strategy, the active power filter compensates the voltage unbalances and distortion. The control strategy is designed such that the series active power filter together with the passive filter act as a balanced resistive load on the overall system. In a four-wire system, the harmonic currents circulated in the neutral wire are also reduced due to series active power filter.

V. DESCRIPTION OF SCHEMATIC HYBRID ACTIVE POWER FILTER

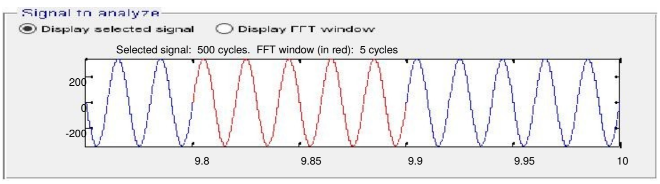
There are many hybrid active power topologies. Some of them are Series association of shunt active filter with passive filter, parallel association of shunt active power filter with passive filter and series active filter with passive filter. In this topology series active filter with passive filter configuration is adopted. The schematic diagram of the proposed Shunt APF and Series APF combination configuration is illustrated in fig.4.

Sinusoidal single phase AC source is given to the non-linear load. Tuned passive filters (TPFs) are connected in parallel with the non-linear load (rectifier fed RL load) which is connected to AC source. The two TPFs are designed to absorb 5th and 7th harmonic currents with the principle of series resonance. The series APF is connected in series with transformer and it compensates remaining harmonics. The Series APF generates compensation voltage (V_f) equal to harmonic load voltage (V_{Lh}) but in opposite phase to it and injects in to the point of common coupling (PCC) through an interfacing inductor. Therefore source voltage (Vs) is desired to be sinusoidal and in phase with the source current (Is) to yield maximum power factor. The Series APF is a VSI and a capacitor connected on the DC side acts as storage element. The function of the IGBT inverter is to support utility fundamental voltage and to compensate for the fundamental reactive power. The MOSFET inverter fulfils the function of harmonic current compensation. Inductors can be used in combination with capacitors, which complement the function of inductors, to form LC filters that can separate the required signals from unwanted ones. Function of coils depends on signal frequencies. Low frequency signals are removed when they pass through the inductor. In power supplies the capacitors are used to smooth the pulsating DC output after rectification so that a nearly constant DC voltage is supplied to the load.

Table.1 System Parameters

System parameter	Range
Source voltage	415V (phase to phase rms)
Line impedance	R=1 ohm L=1 mH
System Frequency	50 Hz
Load 1	Non-linear load (rectifier fed RL load) Active power =1 KW Inductive reactive power = 100 Var
Load 2	Linear load (RL load) Active power = 1 KW Inductive reactive power = 100 Var

Fig.8 Voltage and Current Waveforms of HAPF



IV. SIMULATION RESULTS

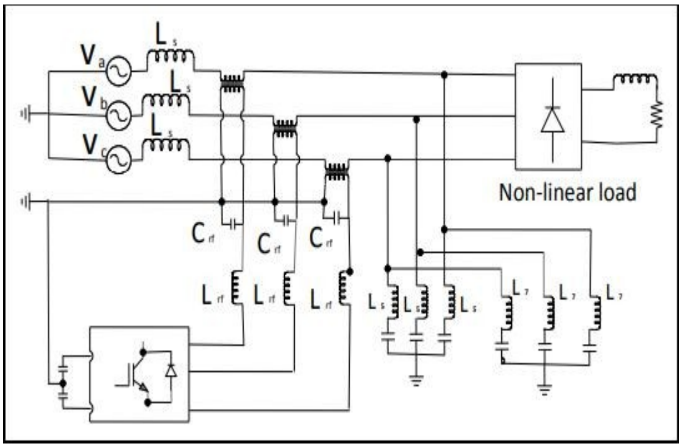


Fig.6 Simulation Diagram With RL Load

A. Hybrid Active Filter

From fig.9 to fig.12 the THD in source current, source voltage, load voltage and load current are found to be 20.33%, 0.00%, 0.73% and 19.15% respectively. From this FFT analysis the lower order harmonics are more effective than higher order harmonics

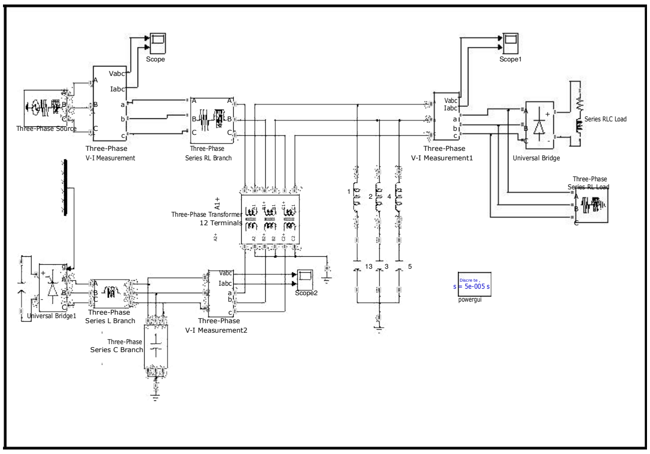
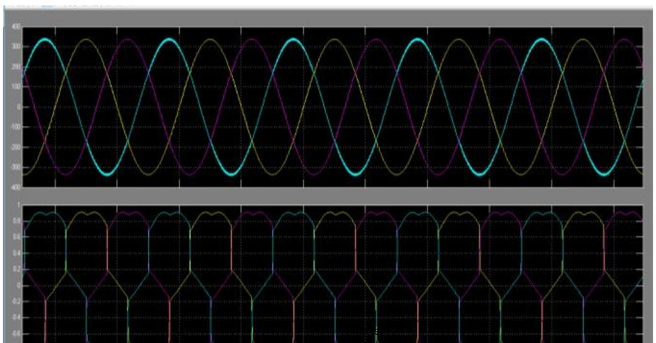
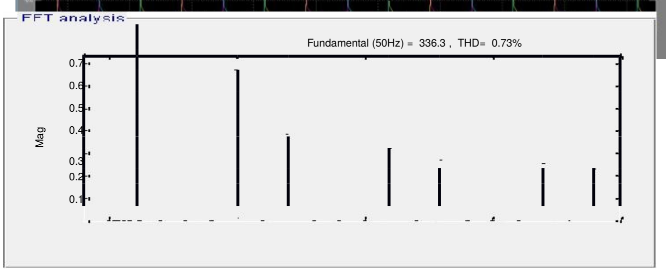
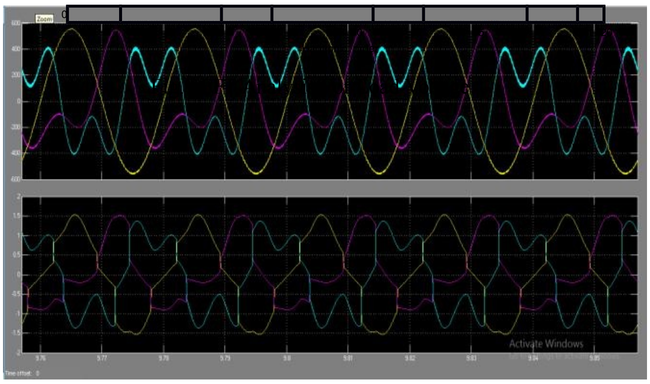


Fig.7 Simulation Model of Hybrid APF







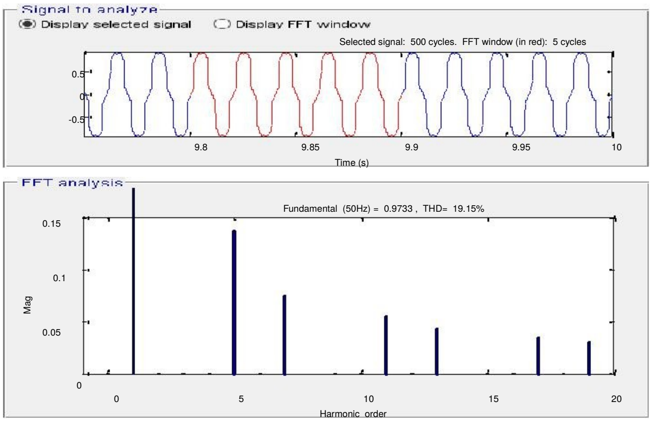


Fig.10 FFT Analysis For load Current

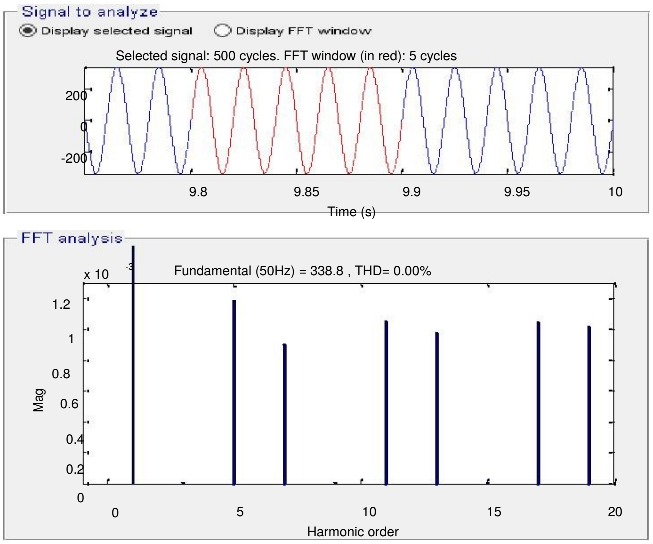


Fig.11 FFT Analysis For Source Voltage

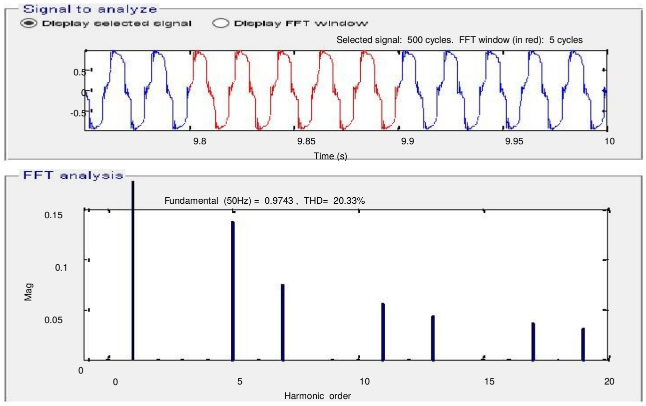


Fig.12 FFT Analysis For Source current

B. HAPF With Induced Harmonics

From fig.15to fig.18 the THD in source current ,source voltage, load voltage and load current are found to be 31.37%, 0.00%, 65.24% and 29.35% respectively. From this FFT analysis the lower order harmonics are more effective than higher order harmonics. From the above all simulations we got result that lower order harmonics i.e. 2nd, 3rd, 5th and 7th are more effective than the higher order harmonics. In HAPF both source current and load voltage harmonics are found to be very less as compared to SAPF and Series APF. The THD comparison for various APFs are shown in table 2

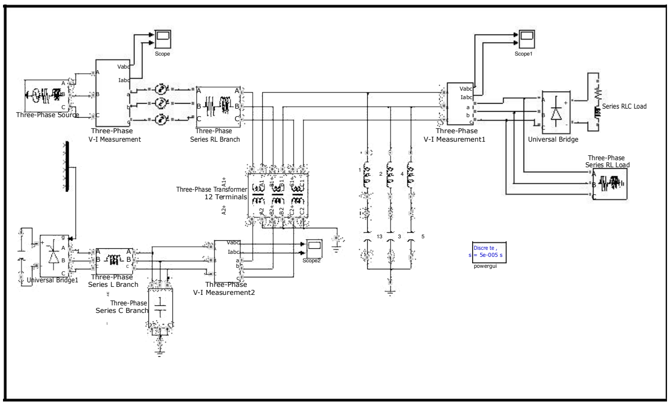


Fig.13 Simulation model of HAP F with created harmonics

Fig.14 Voltage and Current Waveforms of HAPF with induced harmonics

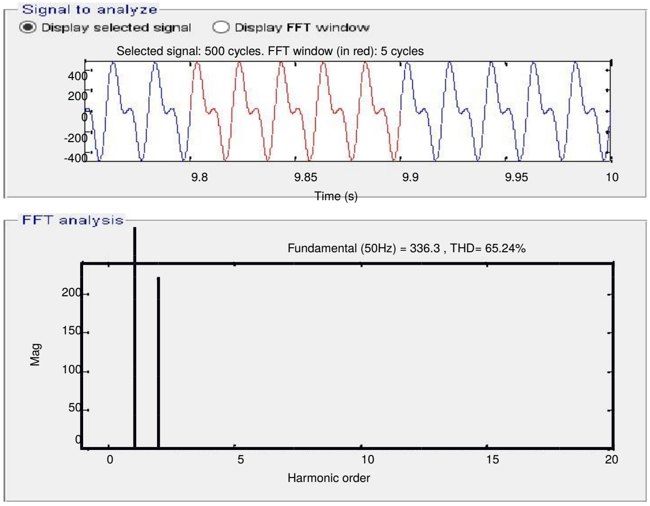
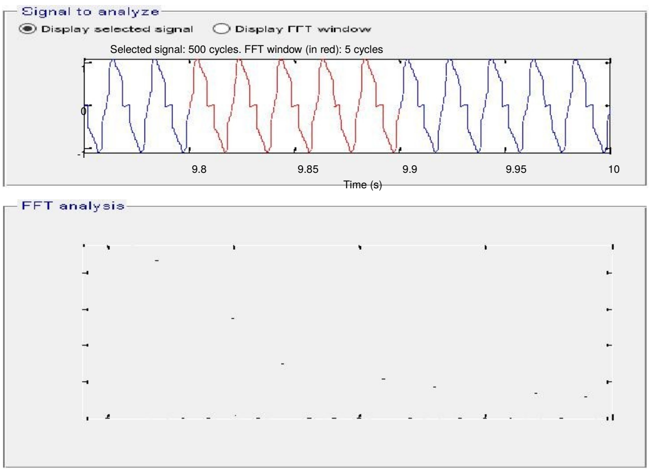


Fig.15 FFT Analysis For Load voltage



Mag

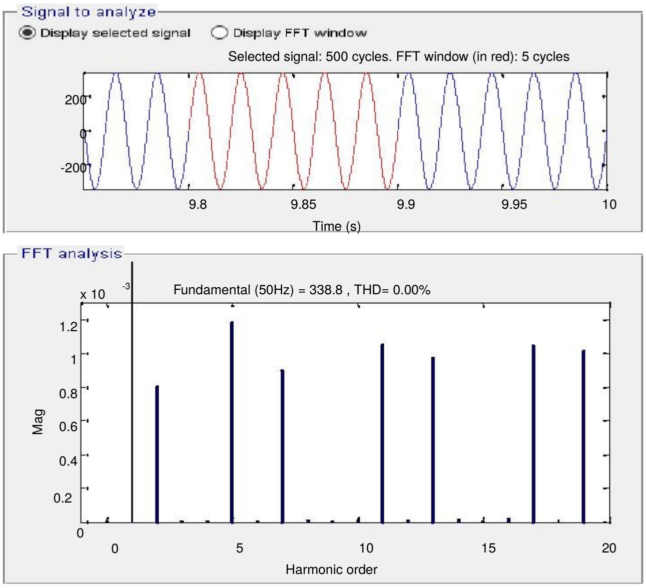


Fig.17 FFT Analysis For Source Voltage

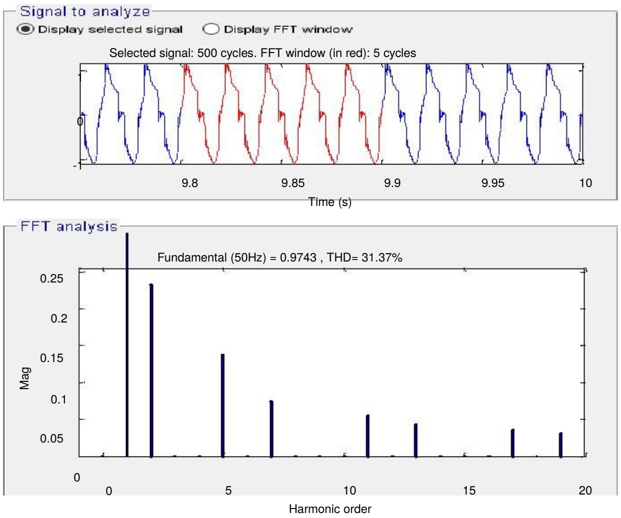


Fig.18 FFT Analysis For Source Current

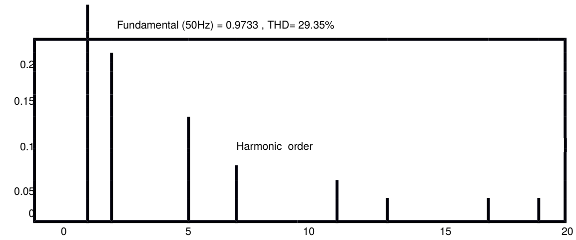


Fig.16 FFT Analysis For Load Current

Table.:2 THD Comparison For Various Active Power Filters

		Series Active Power Filter		Shunt Active Power Filter		Hybrid Filter	
Sourcevoltage	29.50	64.93	0.01	0.01	64.93	0.00	0.00
Sourcecurrent	25.72	74.51	19.0	86.92	74.51	31.37	20.33
Loadvoltage	23.44	122.00	4.56	65.10	0.01	65.24	0.73
Loadcurrent	25.72	74.51	19.0	60.73	19.20	29.35	19.15

CONCLUSION

The shunt APF can be used to compensate current-source non-linear loads but it cannot compensate voltage-source non-linear loads. The harmonics generated by a voltage-source non-linear load can effectively be suppressed by using a series active power filter. Active power filters have the capability of damping harmonics resonance between an existing passive filter and the supply impedance, but they require large current rating with low efficiency. Hybrid filters combine the advantages of passive and active filters. They are cost effective solutions to controlling voltage variations and distortions as well as suppressing harmonics. They are being used to eliminate both higher and lower order harmonics. In HAPF both source current and load voltage harmonics are found to be very less as compared to SAPF and Series APF. From the above all simulations we concluded that lower order harmonics i.e. 2^{nd}, 3^{rd}, 5^{th} and 7^{th} are more effective than the higher order harmonics.

References

[1]. Unnikrishnan S, "Hybrid Series Active Power Filter for Mitigating Power Quality Problems". International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS-2017).

[2]. Yang-Wen Wang, "Historical Review of Parallel Hybrid Active Power Filter for Power Quality Improvement".

[3]. Sushree Diptimayee Swain, "Voltage compensation and stability analysis of hybrid series active filter for harmonic components" 2013 Annual IEEE India Conference(INDICON)

[4]. S.Rahmani , "A Novel Shunt Hybrid Power Filter for the Mitigation of Power System Harmonics" 2007 IEEE Canada Electrical power conference

[5]. Ab.Hamadi, "A New Hybrid Series Active Filter configuration to compensate voltage sag, swell, voltage and current harmonics and reactive power" IEEE International symposium on industrial electronics in July 2009

[6]. Mihail Hr. Antchev, Mariya P. Petkova, "Study of a single-phase series active power filter with hysteresis control".

[7]. Biraja Prasad Nayak, "Reduction of Harmonics and Voltage Sag Compensation by Series Active Power Filter". 2017 International Conference on Data Management, Analytics and Innovation

(ICDMAI) Zeal Education Society, Pune, India, Feb 24-26, 2017,

[8]. Korhan Karaarslan, "Single Phase Series Active Power Filter Based on 1S-Level Cascaded Inverter Topology".2017 4th International Conference on Electrical & Electronics Engineering,

[9]. Silvia Helena Pini, "A Single-Phase High-Power-Factor Rectifier, Based on a Two-Quadrant Shunt Active Filter".IEEE

TRANSACTIONS ON POWER ELECTRONICS, VOL. 26, NO. 11 NOVEMBER 2011 .

[10]. Julio Barros, "An Adaptive Method for Determining the Reference Compensating Current in Single-Phase Shunt Active Power Filters".IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 18, NO. 4, OCTOBER 2003.

[11]. Wu Longhui, "Study on the Influence of Supply-Voltage Fluctuation on Shunt Active Power Filter".IEEE TRANSACTIONS ON POWER DELIVERY, VOL. 22, NO. 3, JULY 2007.