ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

Performance Analysis of a Hybrid Filter Composed of Passive and Active Filter with Active Damper Controller

[1] Shruti Meshram, [2] Krupali Sur, [3] Bhavik Dhabale, [4] Nikhil Khobragade
Department of Electrical Engineering,
K.D.K. College of Engineering, Nagpur, India

***Abstract*: -- This Paper Deals with the Reduction of Harmonics in Transmission System. Harmonic frequencies in power system are the frequent cause of power quality problem, hence it is very essential to eliminate the harmonic content in the system this paper so for the removal of harmonic content using various combination of Active and passive Filter controlled by Active Damper Controller. The main harmonic source is the non-linear load which takes discontinuous current and injects harmonics further causing unnecessary losses in the transmission network. The results show that the active damper can become a promising approach to stabilizing the future power electronics based power systems, the simulation work is also carried out in MATLAB to compare the result without or with hybrid filter.**

***Index Terms:* - Power Quality, harmonic mitigation, total harmonic distortion, passive tuned filter, active harmonic filter..**

I. INTRODUCTION

IN RECENT years, harmonic propagation has become a serious problem in power distribution systems. It consists in harmonic-voltage amplification due to resonance between li ne inductances and shunt capacitors installed for power factor correction. Harmonics are created by electronic equipment with non-linear loads drawing in current abrupt short pulses. The short pulses cause distorted current waveforms , which in turn cause harmonic currents to flow back into other parts of power systems result in increased heating in the equipment and conductors, misfiring in variable speed drives, and torque pulsations in motors [1].

Due to the non-linear load characteristics and switching action of power electronic devices, various power quality issues such as increased harmonics and reactive power components of current from ac mains, low system efficiency and a poor power factor are created in power system, which can disturb the other loads connected at the point of common coupling of the distribution network.

The main effects of ac harmonics in a power system are usually,

1) Losses in ac filter capacitance, ac machine, transformer etc.
2) Ac voltage harmonic cause additional heating of machine such as synchronous generator , induction motor .
3) Shunt capacitor and shunt reactors are heated due to harmonics.

One of the major effects of power system harmonics is to increase the current in the system. This is particularly the case for the 3rd harmonic, which cause a sharp increase in the zero sequence current, and therefore increases the current in neutral conductor.

Table I shows a comparison in unidentified and identified sources between harmonic pollution and air pollution

TABLE I

Comparison between Harmonics pollution and air pollution[2]

Source	Harmonic pollution	Air pollution
Unidentified	TV sets and personnel computers, adjustable speed and heat pump	Gasoline Fuelled vehicles &and diesel power vehicles
Identified	Bulk rectifier and cycloconverters	Chemical plant coal and oil station

In order to damp out the harmonic propagation active damper controller is to detect the resonance from power system, we take the voltage from PCC point the PCC voltage are phase log by PLL then resonance detected by LMS based ,[3] ANF's are introduced for the active noise cancelling which are later applied to enhance the phase detection of PLL and generate a retrieval of sinusoidal signal in noises[4]-[5].

Today in modern age fashion of electronics load increased rapidly. These electronics component are very much responsible for change in the electrical characteristics which are if when analyzed with analyzer become the evident of change of line voltage & line current waveform from pure sinusoidal to some other signal form, this distortion in waveform is given as Harmonic Distortion.. Today most of

All Rights Reserved © 2018 IJEREEE

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

load act non linear because of load is deal with power electronics devices the power electronics devised perform switching operation so the most of reactive power in the system gain by load , therefore the reactive power in the system is unbalanced.

II. HARMONICS

In the past most loads were linear (e.g. induction motors, heaters, light bulbs), which means when connected to a sinusoidal voltage these devices create a sinusoidal current. Today most loads act non-linear (e.g. power electronics like rectifiers, frequency converters, switched mode power supplies, electronic lamps etc.), which means that when connected to a sinusoidal voltage these devices create non-sinusoidal currents (Fig. 1). These currents are not only consisting of the fundamental current, but also of currents with higher frequencies that distort the sinusoidal waveform. Voltage harmonics are mostly caused by current harmonics. A non-linear load will not directly cause voltage harmonics unless it is injecting power[6].

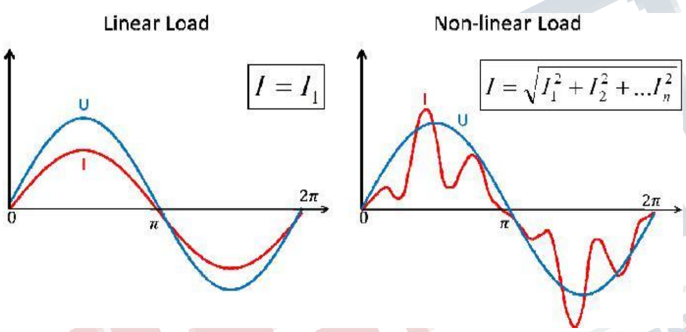


Fig.1. Comparison between a linear load and a non-linear load in time domain

If the source impedance of the voltage source is small, current harmonics will cause only a small voltage harmonic distortion. The total harmonic distortion or THD is a common measurement of a signal defined as the ratio of the sum of all harmonic components to the value at fundamental frequency.
In the case of power systems, as it is shown in Eq. 1 for current (similar representation for voltage, power or other type of measurement as in Eq. 1)[6]

$$THDi = \frac{I_{harmonic}}{I_{fundamental}} \cdot 100\% \qquad (1)$$

Expanding the Eq.1, it could be rewritten as Eq. 2:

$$THD_I = \frac{\sqrt{\sum_{j=2}^{\infty} I_j^2}}{I_1} = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + I_5^2 \cdots I_n^2}}{I_1} \qquad (2)$$

In Eq. 2 where in is the RMS voltage of the n-th harmonic and j = 1 is the fundamental frequency. Therefore, the THD can be decrease by either decreasing $I_{harmonic}$ by increasing $I_{fundamental}$

III. GENERAL STRUCTURE

Recently, wide applications of nonlinear and time-varying devices has led distortion of voltage and current waveform in ac networks. Active power filter are flexible and versatile solution to voltage quality problems. Improvement of technologies devoted to induction machine drives in particular, realization of fast electronic switches has developed the use of active filter for harmonic and power factor compensation. Several work on active compensator based on synchronous reference frame transformation are implemented.
Classification of filter according to configuration Following data described about the classification of filters according to series and shunt connections. Shunt active filter used alone: Fig. 1 shows the connection of active filter in shunt with the system. In this circuit diode rectifier plays the role of non-linear load. Active filter consist of IGBT switch and capacitor is provided to supply the energy to IGBT switches. Series active filter used alone: Fig.2 shows the connection of active filter in series to the system with the help of transformer so that it should be able to compensate the harmonics problem.
Hybrid active and passive filter: Fig.3&4 or Fig5 shows combine connection of active as well as passive filter .As in the single circuit both active and passive filters are used hence this can also be called as hybrid filter. The very important reason behind the hybrid connection is the reduction in initial cost and increased efficiency. Also hybrid filter have more advantages than the filters used alone hence alone filters are replaced by the hybrid filters.

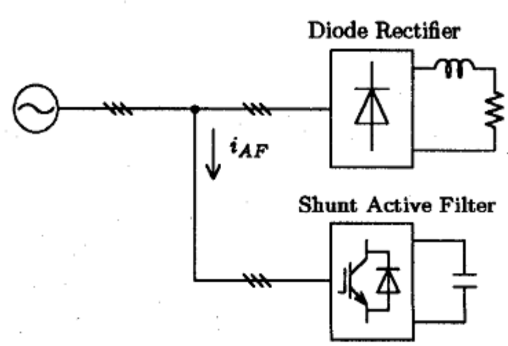


Fig.1 Shunt Active Filter (alone)

All Rights Reserved © 2018 IJEREEE

IFERP
connecting engineers... developing research
ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

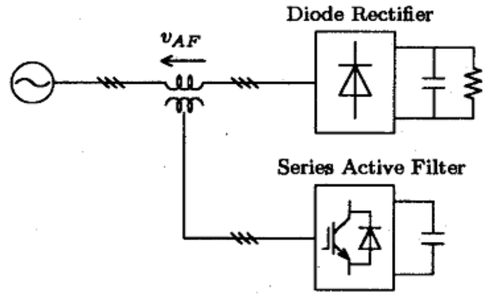


Fig.2 Series Active Filter (used)

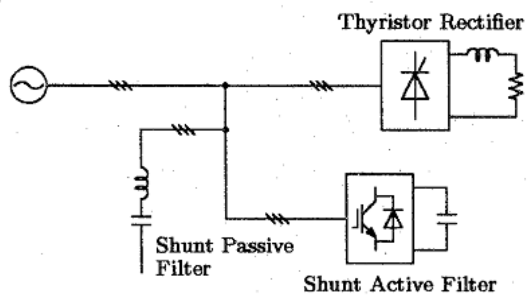


Fig.3 Combination of Shunt Active and Shunt Passive Filter

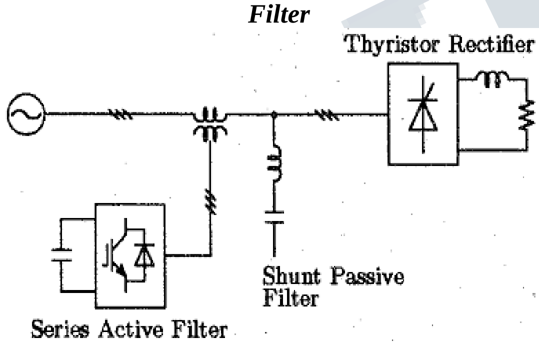


Fig.4 Combination of Series Active and Shunt Passive Filter

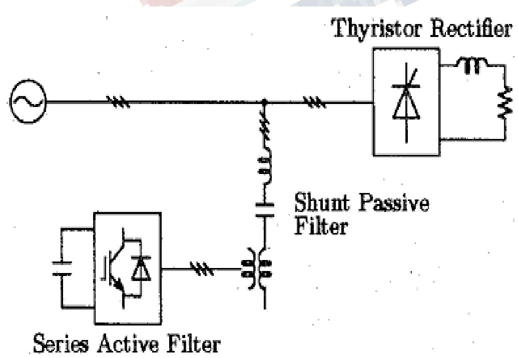


Fig.5 Combination of Active filter in series with Shunt Passive Filter

IV. ACTIVE DAMPER

Active damper that can suppress the multiple resonances with unknown frequencies. A cascaded Adaptive Notch Filter (ANF) structure based on the multiple ANFs and Frequency-Locked Loops (FLLs) is proposed to detect the resonance frequencies. The performance of the active damper is validated by applying it for a three-phase grid-connected inverter through the long power cable. Active damper provides an effective way to suppress the resonance propagation along the power cable and the output filter of inverter[3].

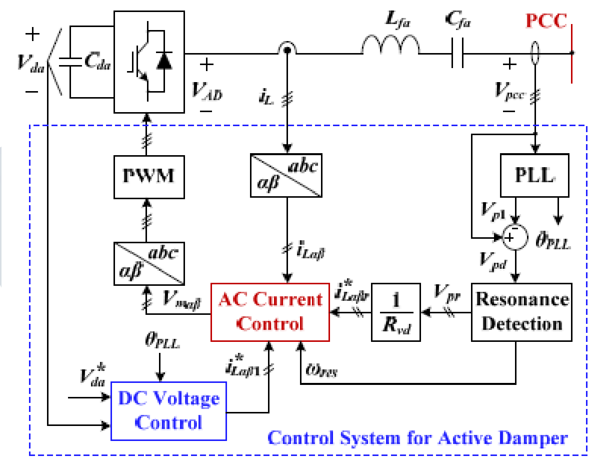


Fig .4 Control block diagram of the active damper

Above fig4. Control of active damper controller there the dc link include dc voltage control and ac current control while detecting resonance frequency from PCC point and it compare with reference value after that convert into in a-b-c transformation and applying gate pulse to IGBT using PWM[7].

a) DC-Link Voltage Regulation

DC-link voltage regulation of the damper involves both the DC Voltage Control and AC Current Control blocks shown in Fig. 4. Their purpose is to keep voltage Vda across the dc-link capacitor Cda constant. Detailed diagram of the DC Voltage Control is given in Fig. 4(a). where a proportional-integral (PI) controller has been included for enforcing zero dc voltage error in the steady state. The PI controller output is an active current command iLq* that the damper draws for compensating losses[7], Reactive current command iLd* is included too, but is set to zero[8] since the damping converter is generally not able to produce a sizable reactive power. Reactive power generation is instead dominated by filter

All Rights Reserved © 2018 IJEREEE

IFERP connecting engineers... developing research
ISSN (Online) 2395-2717
International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

capacitor Cfa, whose voltage is higher while carrying the same series current. The active and reactive current commands can next be brought to the stationary α-β frame by performing the necessary "dq-to-αβ" transformation. A Phase-Locked-Loop (PLL) is needed, as shown in Fig. 2, for generating the phase angle ϕPLL synchronized to the PCC voltage [9].

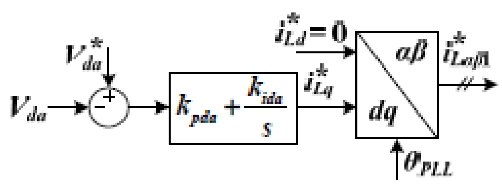


Fig. 4(a). DC voltage and control

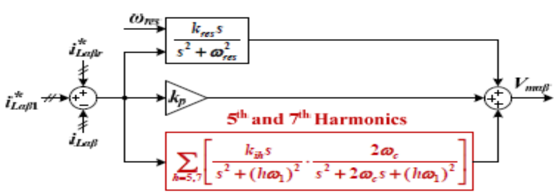


Fig. 4(b). AC Current and control block of the active damper

The same explanation has been mentioned in [9] for a series-LC- APF, but because of its simpler single-loop implementation, an important stability concern has not been clarified. This related concern can be explained by referring to Fig. 5 (a), where the assumption made for performing "dq-to-αβ" transformation has been illustrated pictorially. It clearly shows that with the voltage across capacitor Cfa assumed in phase with the PCC voltage, The resulting sum of voltages across Cfa, Lfa and the damping converter does not lead to the PCC voltage. It is thus not realizable in practice, but merely an approximation made for simplifying analysis. The more likely phasor diagram is shown in Fig. 5(b), where it can be seen that the actual active current flowing through the series filter and damping converter cannot be exactly along the q-axis.

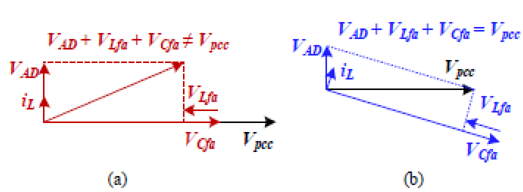


Fig. 5. (a) Assumed and (b) actual phasor orientations of the active damper

It is therefore not possible for the actual active current to track its command earlier placed along the q-axis. Common practice of adding a controller for enforcing zero steady-state current tracking error must thus not be applied to avoid destabilizing the system. Hence, only a proportional gain kp is used with the ac current controller for the dc-link voltage regulation, as shown in Fig. 4 (b). Besides the proportional current controller, the AC Current Control block also comprises a second-order resonant controller for system stabilization and a fourth-order resonant controller proposed.

For grid disturbance rejection. They are explained in the following:-

b) RESONANCE DETECTION AND DAMPING-

Fig. 3(b). A Frequency-Locked Loop (FLL) based on a Pre-filtered Adaptive Notch Filter (P-ANF) is used to detect the resonance component from the PCC voltage [10]. The basic principle underlying this detection scheme is the Least Mean Square (LMS) adaptation algorithm [11]. Differently from the Second-Order Generalized Integrator (SOGI)-based FLL used for grid synchronization [12], the GI with a sixth-order Taylor series approximation is applied to the ANF for a more accurate estimation of the high-frequency resonance component [13].

To further remove the low-frequency disturbances, two ANFs are cascaded to form a pre-filtered structure

c).GRID DISRUBANCE REJECTION-

It is common for the grid voltage to be disturbed by the 5th and 7th harmonics, located lower than most system resonances. Rejection of these grid voltage harmonics is not trivial for the proposed active damper, owing to its predominantly capacitive filter characteristic at those frequencies. Usual synchronous integral and stationary resonant controllers will therefore not work. Instead, a fourth-order resonant controller is proposed and shown in Fig. 3(b), where ω1 is the fundamental frequency, ωc is the cut off frequency, and kih is the controller gain. The purpose of this controller is to re-shape the predominantly capacitive "control plant", which in the worst case, can be represented by an equivalent capacitance Ceq[7].

TABLE II

Controller Parameter Of Active Damper

Symbol	Meaning	Value
T_{s_AD}	Sampling period of active damper	50μs
K_{pda}	Proportional gain of dc-link voltage controller	0.5
K_{ida}	Integral gain of dc-link voltage controller	0.01
R_{vd}	Virtual damping resistance	0.2 Ω
K_p	Proportional current controller	15
K_{res}	Resonance damping controller	600
K_{ih}	Proposed resonant controller gain	4*10^5
ω_c	Proposed resonant controller cut-off frequency	250 rad/s

All Rights Reserved © 2018 IJEREEE

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

For illustrating the intended re-shaping, the forward transfer function of grid disturbance rejection path is written as,

$$G_R(s)\cdot G_{re-P}(s)=\sum_{h=5,7}\left\{\frac{k_{ih}s}{s^2+(h\omega_1)^2}\cdot\frac{2\omega_c}{s^2+2\omega_c s+(h\omega_1)^2}\right\}\cdot sC_{eq}$$

$$=\sum_{h=5,7}\left\{\left[\frac{k_{ih}s}{s^2+(h\omega_1)^2}\right]\cdot\left[\frac{2\omega_c s}{s^2+2\omega_c s+(h\omega_1)^2}\cdot C_{eq}\right]\right\} \quad (1)$$

Where GR(s) is the usual resonant controllers placed at the 5th and 7th harmonic frequencies, and Gre-P(s) is the re-shaped "plant". The re-shaped "plant" becomes a band-pass filter with a common gain of Ceq placed at the 5th and 7th harmonic frequencies. In other words, the re-shaped plant behaves like a resistor at those considered frequencies, hence allowing GR(s) to perform the necessary control without being burdened by stability and dynamic concerns [7].

d) THD

In power system Total harmonic distortion is an important factor and it should kept as low as possible, (THD) is an important figure of merit used to quantify the level of harmonics in voltage or current waveforms. Two different definitions for THD may be found in the literature. According to one definition, the harmonic content of a waveform is compared to its fundamental. By the second definition, the harmonic content of a wave-form is compared to the waveform's rms value [3]. Hence with the use of this filter we get better output and efficiency. The simulation result of this filter is described in conclusion. The below table show that %THD while using single filter or hybrid filter.

TABLE III

Comparison of %THD of different types of filters

Type of Filter	%THD
Shunt Active Filter	4.81%
Series Active Filter	10.71%
Combination of Shunt Active and Shunt Passive Filter	2.23%
Combination of Series Active and Shunt Passive Filter	4.11%
Active filter in Series with Shunt Passive Filter	8.98%

From the table III combination of Shunt Active and Shunt Passive filter have the better THD results compare to other filters.

V. MATLAB SIMULATION

A. simulation model with series active filter:-

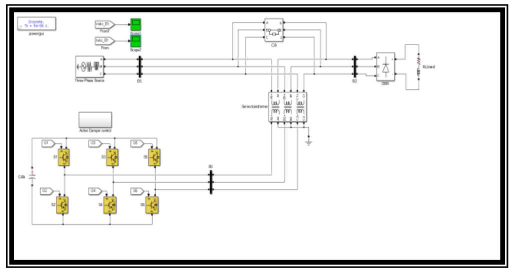


Fig.5. MATLAB simulation on model of series active filter

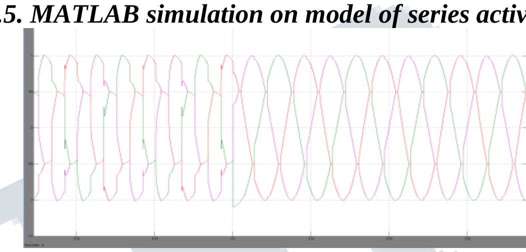


Fig .6. MATLAB simulation result of rectified voltage waveform using series active filter

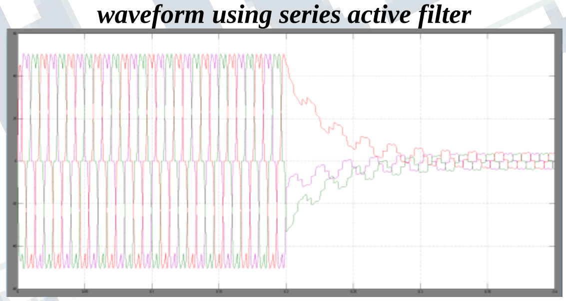


Fig .7. MATLAB simulation result of rectified voltage waveform using series active filter

B. MATLAB simulation model with shunt active filter:-

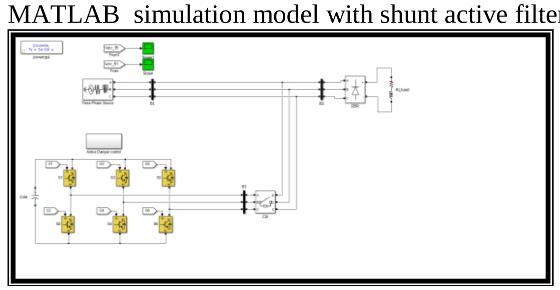


Fig.8. MATLAB simulation Model with Shunt

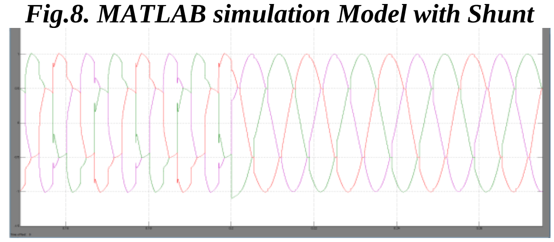


Fig.9. MATLAB simulation result of rectified voltage waveform using shunt active filter

All Rights Reserved © 2018 IJEREEE

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

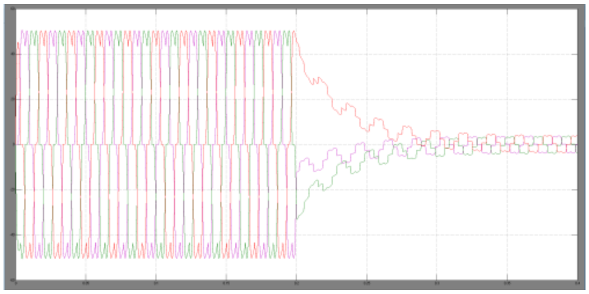


Fig.10. MATLAB simulation result of rectified current waveform using shunt active filter

C. MATLAB simulation model with shunt active and shunt passive filter:-

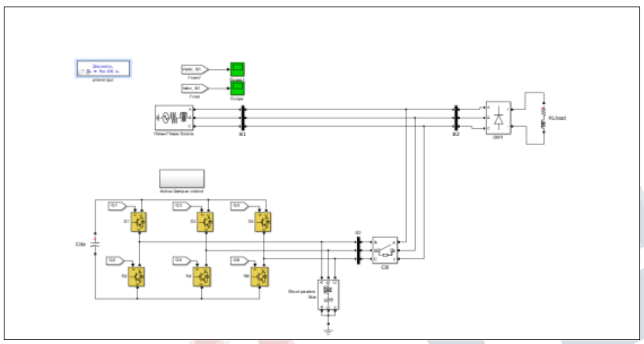
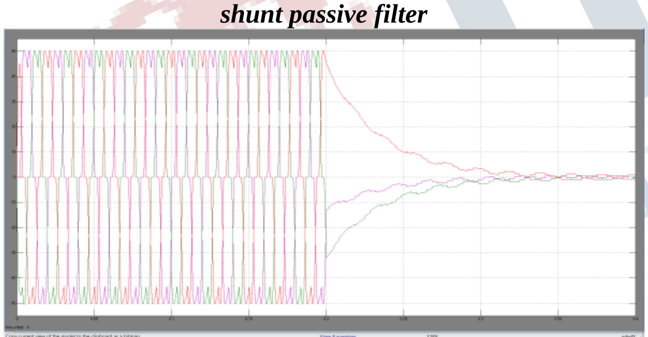


Fig.11. MATLAB simulation model with shunt active and shunt passive filter



Fig,12. Current waveform of MATLAB simulation model with shunt active and shunt passive filter:-

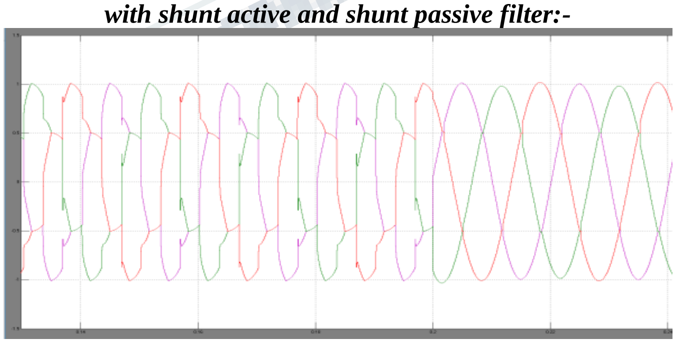


Fig.13. Voltage waveform of MATLAB simulation model with shunt active and shunt passive filter

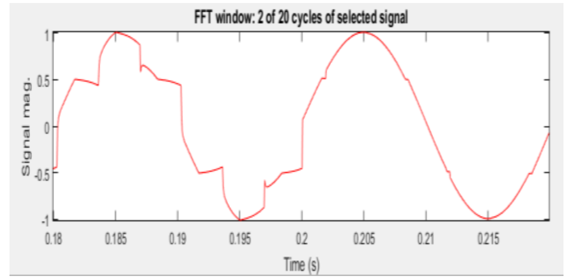


Fig.14.FFT Analysis of MATLAB simulation model with shunt active and shunt passive filter.

VI. CONCLUSION

This paper has discussed harmonic current filtering and resonance damping. The %THD values are taken before the connection of filter and after the connection of filter for that the circuit breaker is used in the system. Normally when filter is not connected in the system, the %THD value in between 20% to 30% or even more but when the filter come into existence, the %THD value is below 20%. Hence we can say that the series Active & passive Filter or hybrid filter is use for harmonic compensation. A Active Filter in which it is connected in series & parallel with the help of transformer for series connection to the nonlinear load similarly a Hybrid filter also simulates. Active damper control plays very important role, it provides gate pulse to IGBT of active filter and it can operate in low voltage and it allows faster switching operation which makes the series Active Filter to operate in low voltage condition. Series active filter itself acts as a voltage source and with the use of series Active filter we can able to achieve the following objectives such as:

1. Voltage imbalance compensation
2. Reactive current
3. Harmonic compensation

REFERANCES

[1]. Rubén Inzunza, , and Hirofumi Akagi to be presented at "IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 20, NO. 4, JULY 2005

[2]. Hirofumi Akagi " New trend in Active filter for power conditioning " to be presented at the IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL 32, NO 6, NOVEMBERDECEMBER 1996

[3]. Xiongfei Wang, Frede Blaabjerg, and Marco Liserre Department of Energy Technology, Aalborg University, Aalborg, Denmark to be presented at IEEE2014

All Rights Reserved © 2018 IJEREEE

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 4, Issue 3, March 2018

[4]. J. G. Mark, J. R. Steele, and C. C. Hansen, "Residual mode phase locked loop," U.S. Patent 4 495 475, Jan. 8, 1982

[5]. J. Matas, M. Castilla, J. Miret, L. G. Vicuna, and R. Guzman, "An adaptive prefiltering method to improve the speed/accuracy trade off of voltage sequence detection methods under adverse grid conditions," IEEE Trans. Ind. Electron., vol. 61, no. 5, pp. 2139-2151, May 2014.

[7], Xiongfei Wang and Ying Pang, Poh Chiang Loh, and Frede Blaabjerg "A Series-LC-Filtered Active Damper with Grid Disturbance Rejection for AC Power- Electronics-Based Power Systems" . I E E E Transactions on Power Electronics, 30(8), 4037-4041. 10.1109/TPEL.2014.2382477.

[8]. R. N. Beres, X. Wang, F. Blaabjerg, C. L. Bak, and M. Liserre, "Comparative evaluation of passive damping topologies for parallel grid-connected converters with LCL filters," in Proc. IEEE IPEC 2014, pp. 3320-3327.

[9]. R. Inzunza and H. Akagi, "A 6.6-kV transformerless shunt hybrid active filter for installation on a power distribution system," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 893-900, Jul. 2005.

[10]. X. Wang, F. Blaabjerg, and M. Liserre, "An active damper to suppress multiple resonances with unknown frequencies," in Proc. APEC 2014, pp. 2184-2191.

[11]. B. Widrow, J. R. Glover Jr., J. M. McCool, J. Kaunitz, C. S. Williams, R. H. Hearn, J. R. Zeidler, E. Dong Jr. and R. C. Googlin, "Adaptive noise canceling: principles and applications," in Proc. IEEE, vol. 73, no. 12, pp. 1692-1716, Dec. 1975.

[12]. P. Rodriguez, A. Luna, R. S. Munoz-Aguilar, I. Qtadui, R. Teodorescu, and F. Blaabjerg, "A stationary reference frame grid synchronization system for three-phase grid-connected power converters under adverse grid conditions," IEEE Trans. Power Electron., vol. 27, no. 1, pp. 99-112, Jan. 2012.

[13]. A. G. Yepes, F. Freijedo, O. Lopez, and J. Gandoy, "High-performance digital resonant controllers implemented with two integrators," IEEE Trans. Power Electron., vol. 26, no. 2, pp. 563-576, Feb. 2011.

All Rights Reserved © 2018 IJEREEE