International Journal of Scientific Engineering and Technology (ISSN : 2277-1581)
www.ijset.com, Volume No.1, Issue No.2 pg:128-133 01 April 2012

PLL Based Hybrid Active Filter for Harmonic Suppression Caused by Non-Linear Loads

Kavita More,Prof.Amol Barve

Department of Electrical and Electronics Engineering,L.N.C.T.Bhopal (M.P.) India
kanchanchaturvedi01@yahoo.in

Abstract: As the application of non linear loads are increasing the harmonic distortion is getting more and more serious problem because it causes the poor power factor, heating of the equipments, vibrations in machines reduction in efficiency and is more dangerous for electronic controlling devices such as microcontroller and processor as well as sensing preamplifier which can cause false sensing and unsterilized the complete control system hence the harmonic filtration is getting more attention of designer and many techniques have been already proposed to overcome the problem, in our thesis we are discussing the hybrid filters for suppression of harmonics, the hybrid filters are basically the combination of passive and active filters a combination leads to a better performance, the main concern of the thesis in on active part and we proposed a PLL based technique to control the switching of the active filter so that the harmonic distortion can be minimize furthermore the advantage of the is that it is independent of the topology of the filter weather it is serial or parallel combination which is proved by the simulation results which are obtained by the SIMULINK model.

Keywords: Hybrid Filter, PLL (Phase Locked Loop), Harmonic Suppression.

1. Introduction

Hybrid active filters have been presented as a lower cost alternative to purely active filters for harmonic compensation. Hybrid filters use combinations of passive elements to reduce the ratings of the active element required. The development of hybrid filter topologies has followed a natural progression from purely passive tuned filters which have been used for many years, to simplified passive structures with one active element. These passive structures have been largely based on the original tuned structures [6].

A conventional measure for the compensation of non-sinusoidal currents and/or lagging power factor of a load, is represented by tuned passive filters (PF) connected in parallel to the load. However, their frequency characteristics are unfavorably influenced by a variable grid impedance and here, in reality, the danger of the excitation of resonance exists. However, the variations of the filter parameters occur due to aging, temperature, and other operations conditions. The active power filter (APF) made up of a power converter has been developed to suppress the harmonic currents and improve power factor. The APF may substitute for passive ones in some cases, or serve as an additional tool, together with PF, for improving the harmonic spectra of the load current and supply voltage. The active filters may be also used as voltage stabilizers at the point of coupling or as power flow controllers. Contrary to PF, the function of active filters is influenced substantially neither by ageing nor by changes in the grid impedance. But the main disadvantage for the use APF in large scale is that complex control and cost of power converter become very high thus limiting their applications.

Hybrid power filters (HPF) consisting of dedicated passive and active filters connected in series or parallel has been published in the literature. The tolerances and variations in the hybrid filter are not as serious as those in a passive filter used alone. It is also well known that HPF helps to reduce the active filter rating [4]. Rest of paper arranged as the section 2 presents a brief review of some previous work on similar topics then chapter 3 presents the proposed algorithm followed by simulation results in chapter 4 and at last a conclusion is drawn on chapter 5 on the basis of simulated results.

2. Literature Survey

As discussed that the harmonic compensation is taking more and more intentions of designer as the non linear load are increasing the filters are the first choice of designer to reduce the harmonic distortion since it is an important aspect of system design from a while many researchers are proposed their methods to solve the problem some of which are discussed in this chapter. Mr H. Bouchikha and M. Ghers [1] Proposes a technique by using the "Three Phase Shunt Hybrid Filters" for the Current Harmonics Suppression in their method identification of the supply current was developed as well as simulations and spectral studies for two types of nonlinear loads were made using the software Pspise. Some detail of their work is given below.

A new method of extraction of the current of reference is developed. This method of identification is based on detection of the supply current. The hybrid filter proposed has a very simple control circuit which consists in using two sensors of voltage and only one sensor of current. The advantage of this type of filter is its simplicity of control and its low cost of implementation. They developed an original contribution which consists of a new method of extraction of the current of reference. This method of identification is based on detection of the supply current. The results of simulation show that the hybrid filter proposed effectively cleanses the electrical supply network of the harmonics generated by the nonlinear load. Po-Tai Cheng, Subhashish Bhattacharya, and Deepak M. Divan [2] proposes Control of Square-Wave Inverters in High-Power Hybrid Active Filter Systems in their paper presents a new control scheme for a hybrid parallel active filter (HPAF) system intended for high power applications up to 100-MW nonlinear loads to meet IEEE 519 recommended harmonic standards. The active filter inverter is realized with small-rated (1%–2% of the load rating) square-wave inverters operating at the dominant harmonic frequencies. The proposed system achieves harmonic isolation at desired dominant harmonic frequencies, such as the fifth and seventh, even in the presence of supply voltage harmonic distortions. H. AKAGI [3] presented useful comparison between different types of filters in their paper "Modern active filters and traditional passive filters". This paper deals with general pure active filters for power conditioning, and specific hybrid active filters for harmonic filtering of three-phase diode rectifiers, as well as traditional passive filters. Their paper concludes Active filters based on leading-edge power electronics technology can be classified into pure active filters and hybrid active filters. Jiri Klima, Jiri Skramlik, Viktor Valouch [4] " Analytical Modelling and Implementation of a New Four-Switch Hybrid Power Filter Topology " This paper presents a new three-phase four-switch shunt hybrid power filter with the new circuit topology aimed at compensating reactive power and higher harmonics of the load. A space-vector PWM scheme is adopted to reduce the switching state of power switches. In the proposed control scheme, proper voltage vectors are generated on the ac terminal for drawing nearly sinusoidal line currents with controllable power factor. An original closed-form solution of line currents, based on the mixed p-z approach is presented. The analytical procedure is verified by experimental results to confirm the effectiveness of the proposed control scheme. The scheme with a reduced number of powers switches, improving the filter efficiency. Based on the control algorithm, sinusoidal line currents compensating the non-linear load currents are achieved by the adopted converter. Finally, an original closed-form solution of steady-state line currents, based on the mixed p-z approach is introduced. The analytical results and experiment tests on the component minimized three-phase PWM HPF are shown as well to demonstrate the validity and effectiveness of the proposed control scheme. Jarupula Somlal [5]: "Efficient Hybrid Shunt Active Power Filter for Improvement of Power Factor and Harmonic Suppression" The system of Passive power Filter, Shunt Active Power Filter and the combination of Passive power Filter and Shunt Active Power Filter is proposed in this work. When compared to the three methods the combination of Passive power Filter and Shunt Active Power Filter is efficient for harmonic suppression and power factor improvement. By this method the % of THD can be reduced to 1.95 and the power factor is increased to 0.9554.

3. Proposed Work

Figure 1 shows the model of the proposed filter, implemented with a Controlled voltage source converter. Neglecting the internal power losses of the overall converter, the control & Compensation of the harmonic power is done by adjusting the angle & amplitude of the output voltage V_{MOD} , which can be modified with the PWM pattern as shown in figure 1.

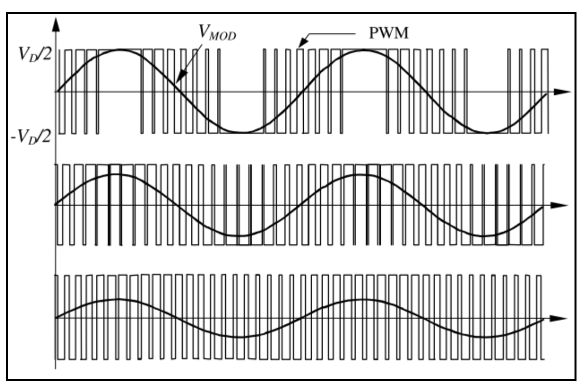


Figure 1: Controlling of generated waves (amplitude and phase of the voltage fundamental component).

When V_{MOD} is larger than the voltage V_{COMP}, the controlled inverter generates reactive power (Figure 2-a) and when V_{MOD} is smaller than V_{COMP}, the compensator absorbs reactive power (Figure 2-b).

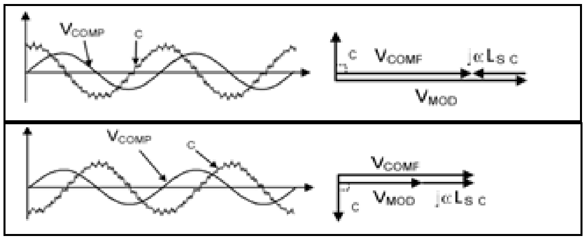


Figure 2-a, b: power exchange control by amplitude.

Also the active power absorbed by the converter and defined by

$$P = \frac{V_{COMP} . V_{MOD}}{X_S} \sin(\delta)$$

Where the δ represents the angle between V_{COMP} and V_{MOD}, X_s is the converter linked reactor.

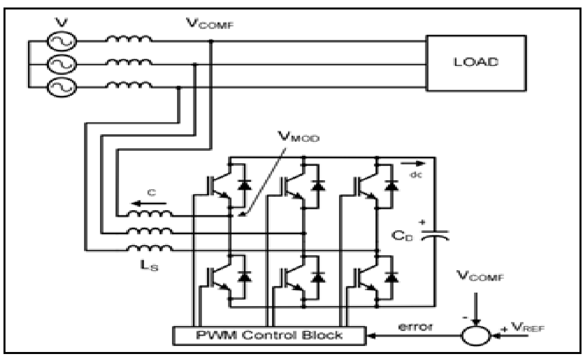


Figure 3: the Example circuit for the proposed algorithm.

The V_{REF} signal is generated by the PLL (Phase Locked Loop)

3.1 Working of PLL

The critical problem of a active filter is to find an algorithm which can obtain an accurate harmonic reference signal for control purpose. Conventional control algorithms, such as using the instantaneous reactive power theory or instantaneous symmetrical components the shunt and series AF currents/voltages are sensed and controlled to match their respective computed reference components there by increasing the number of sensors and computational delays. A PLL (Phase Locked Loop) noise canceling theory is an effective controller used in this thesis for measuring the harmonic components of the nonlinear load current and load voltage is implemented. Let the load current, input frequency and terminal voltage be the input to the PLL. Three phase distorted supply voltages are sensed and given to the PLL which generates sine terms.

The sensed supply voltage is multiplied with a suitable value of gain before being given as an input to the PLL. Here K=1…N, be the gain value assigned for controlling.

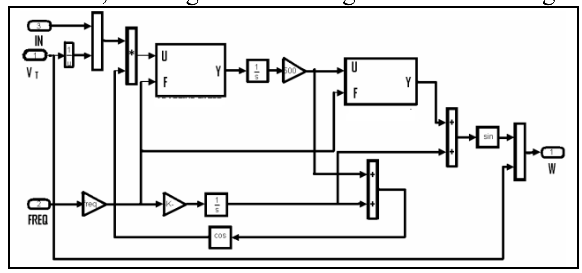


Figure 4: Proposed reference signal generation (PLL)

Here I_L is the load current V_T is the load voltage, ω is the output signal of the adaptive detecting circuit; and f is the fundamental reference frequency which is in phase with ac source voltage. The input sinusoidal reference signal, i.e. the fundamental component of the system voltage has the same frequency and in phase with the desired fundamental components of load current and load voltage, the dc component of the output of integrator will tune accordingly until they are equal in magnitude. The corresponding fundamental real components of the current and voltage are then extracted from the sampled load current and load voltage. Under the action of loop, in steady state the output current I_f and voltage and V_S of detecting circuit have no larger include the fundamental real components, the dc component of the integrator output will keep a constant value, which is in proportional to the magnitude of the fundamental real component of load

$$I_f = I_L - kE_m \sin\omega t(K_0 + 1/\omega RC^t{}_0 I . E_m \sin\omega t$$

$$= I_L - kK_0 E_m \sin\omega t - kK_1 E_m \sin\omega t \quad \ldots\ldots\ldots (1)$$

Where $K_1 = 1/\omega RC\ I_f . E_m . \sin\omega t d\omega t$

$$V_s = V_L - kE_m \sin\omega t(K_0 + 1/\omega RC^t{}_0 V_s E_m . \sin\omega t d\omega t$$

$$= V_s - kK_0 E_m \sin\omega t - kK_1 E_m \sin\omega t \quad \ldots\ldots\ldots (2)$$

where $K_1 = 1/\omega RC I_f . E_m . \sin\omega t d\omega t$

$$I_L = I_P + I_Q + I_H \quad \ldots\ldots\ldots (3)$$

$$V_L = V_P + V_Q + V_H \quad \ldots\ldots\ldots (4)$$

Where I_p is the fundamental active component load current; I_q is the fundamental reactive component of load current; I_h is the harmonic components in load current; V_p is the fundamental active component of load voltage; V_q is the fundamental reactive component of load voltage; and V_h is the harmonic components in load voltage. K_1 is the proportional coefficient and K_0 is the dc component of the integrator output. Then

$$I_f=I_L-k.K_0.E_m\sin\omega T \quad \text{……………. (5)}$$

$$I_f = I_P+I_Q+I_H - kK_0.E_m\sin\omega T \quad \text{……..……. (6)}$$

$$I_F=I_Q+I_H \quad \text{………..…… (7)}$$

$$I_P=k.K_0.\ E_m\sin\omega T \quad \text{……..…….. (8)}$$

The output signal of the adaptive detecting current and voltage are just the reactive power and harmonic components of the nonlinear load voltage and current which are used as reference signal for compensation by inverter.

4. Simulation Results

4.1 Model Description

For the comparison and analysis of the three hybrid filters we develop the MATLAB/Simulink model of each filter and a power system with similar ratings for fair comparison of the performance.

The designed system contains a 230V, 50 Hz, AC source of 10KVA rating with X/R rating of 7, for better transient analysis of system the load is moved to maximum rating in two steps, initially the 5KVA load which is made by equal resistive and inductive ratings is connected and second is connected at 0.3 seconds later and again removed at 0.5 seconds all the switching operation is performed by programmable relay.

Since the main aim of the thesis is to analyze the effects of filters on harmonic distortion the load is designed to behave like non linear this is performed by connecting diodes in series with load hence only positive half cycle conduction is possible.

The active filters is designed by three arm MOSFET bridge with LC components and a proposed controller which generates the appropriate switching pulses to suppress the harmonic components generated by the non linear loads the controller algorithm is explained in detail in proposed algorithm section. The SIMULINK models of the proposed filters with complete system are shown below.

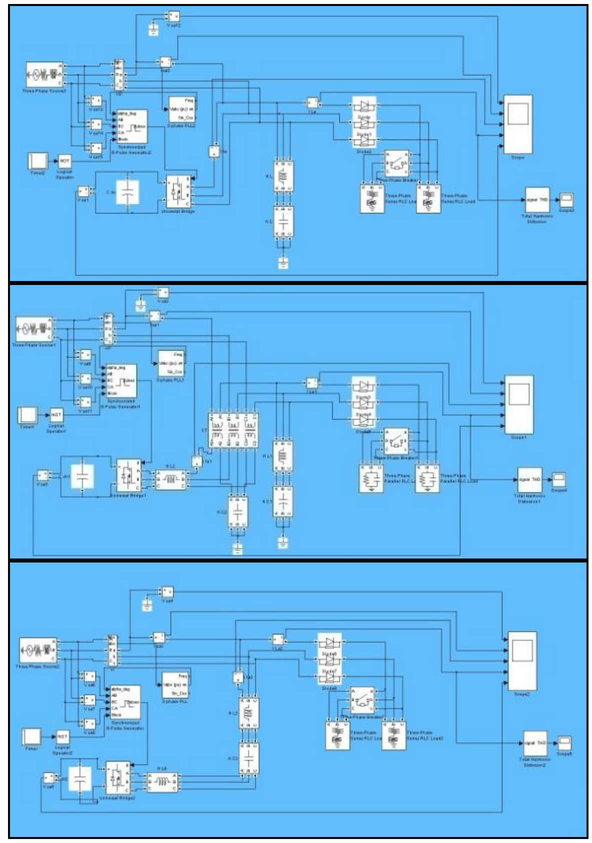


Figure 4: Filters Topologies (1) with shunt LC passive filter in parallel of shunt active filter (top), (2) with shunt LC passive filter in parallel of series active filter (middle), (3) with shunt LC passive filter in series of shunt active filter (bottom).

4.2 Results Analysis

The simulation is perform for 1 second in which during first 0.1 seconds the active filter is turned off be exactly differentiate the performance of passive filter alone this is helpful for showing the improvement added by active filter, then at 0.3 second the second load is turned on by the programmable relay for next 0.2 seconds then it is further disconnected for rest of simulation. After running the simulation for the defined time we can observe waveforms on the main variables scope block to analyze the waveform and harmonic distortion.

Following are the simulated wave forms for different filters.

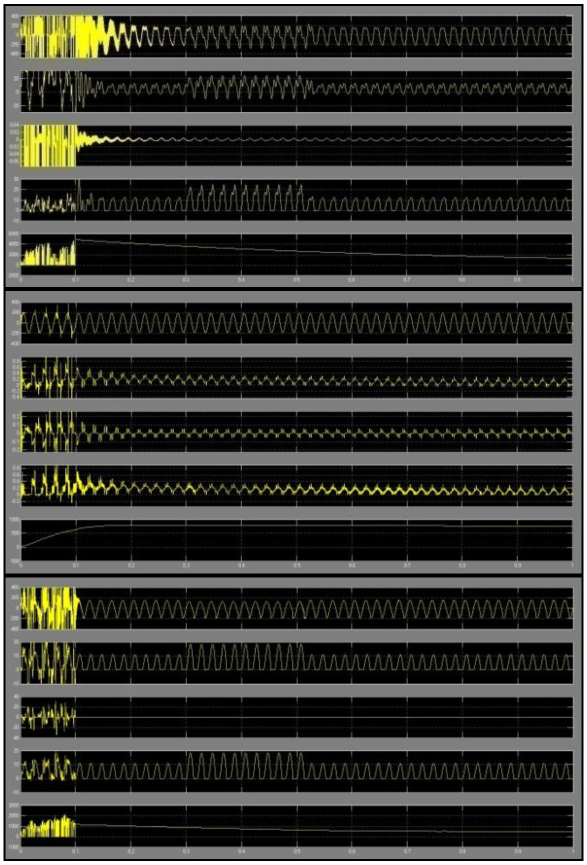
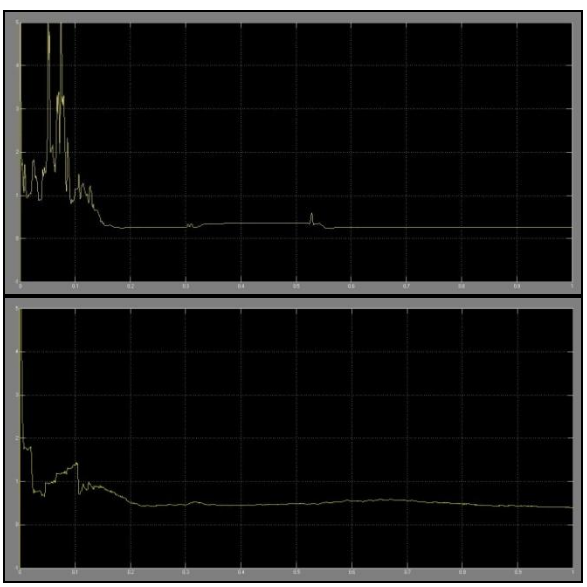


Figure 5: The waveform of all three systems. Wave forms designations are (1) The mains voltage, (2) The source current, (3) The active filter current, (4) The load current, (5) Voltage across capacitor.



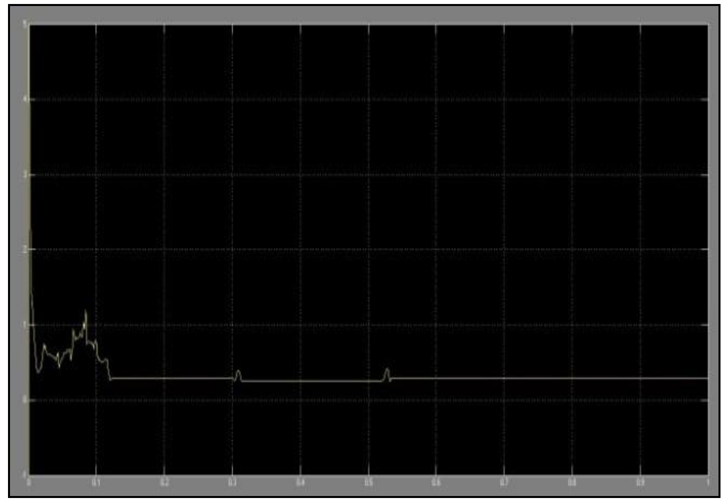


Figure 6: Shows the harmonic distortion of the source current For All three filters.

5. Conclusions

The conclusion can be derived by the simulation results as obtained and discussed above from the above simulated waveform we can see that all filters provides the improvements over the passive filters (reduction in total harmonic distortion THD up to 75%) when the active part is switched on hence it's proved that the hybrid topology gives better performance over passive only filters. When the comparison is performed for three topologies it can be seen that the second topology required a bit more time to settle down which is approximately 0.1 seconds when compared to first which requires 0.75 seconds and the third one which needs only 0.025 seconds, while the sudden load change causes more fluctuations on first topology than second and third here the first topology harmonic distortion increases by 10% and remains for complete switching duration while the second topology holds it for only 0.05 seconds and then come back to previous state and the third topology has further improvement that it come back in only 0.01 seconds also it maintain the smooth control over complete time and not vibrations are shown in power factor waveforms as in previous two.

Finally we it can be concluded third topology is a better solution for harmonic reduction than the other two.

References

[1] Mr H. Bouchikha, M. Ghers "Three Phase Shunt Hybrid Filters for the Current Harmonics Suppression and the Reactive Power Compensation" in European Journal of Scientific Research ISSN 1450-216X Vol.24 No.4 (2008), pp.580-590.

[2] Po-Tai Cheng, Subhashish Bhattacharya, and Deepak M. Divan “Control of Square-Wave Inverters in High-Power Hybrid Active Filter Systems” in IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 34, NO. 3, MAY/JUNE 1998.

[3] H. AKAGI “Modern active filters and traditional passive filters” in BULLETIN OF THE POLISH ACADEMY OF SCIENCES TECHNICAL SCIENCES Vol. 54, No. 3, 2006.

[4] Jiri Klima, Jiri Skramlik, Viktor Valouch “Analytical Modelling and Implementation of a New Four-Switch Hybrid Power Filter Topology”.

[5] Jarupula Somlal “Efficient Hybrid Shunt Active Power Filter for Improvement of Power Factor and Harmonic Suppression using MATLAB“ in Recent Researches in Communications, Electrical & Computer Engineering.

[6] S.Senini, P.Wolfs “Analysis and Comparison of New and Existing Hybrid Active Filter Topologies for Harmonic Current Removal”.