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Harmonics Cancellation in Distribution Systems by Using a Hybrid Power Filter

Miss. Prajkta R. Gangurde
M.E Student, SND College of Engineering& RC, Yeola
Savitribai Phule University of Pune, India
prajktagangurde@gmail.com

Prof. M. M. Hapse
HOD SND College of Engineering& RC, Yeola.
Savitribai Phule University of Pune, India
manikhapse@gmail.com

Abstract: This paper presents a proper method to filtering harmonics or cancel out the harmonic in Distribution grid.. The hybrid filter is presented in this paper, the limitation of the active and the passive power filter is overcome by developing the hybrid power filter . In the hybrid power filter the resonant cell is combining with voltage source inverter and this together combination is act as a hybrid power filter. and the rating of voltage source inverter can be increased with increased in dc-link voltage and hence the capability of harmonic mitigation can be increased with dc link voltage . The reactive power control and the improvement in power quality is also presented in this paper. the quality factor is responsible for selecting the frequency of tuning circuit. The MATLAB simulation design give the harmonic reduction in distribution grid or distribution system and in three phase four wire system, this system is most economical.

Index Terms - *Active power filters, hybrid power filters, passive power filters, Distribution network, reactive power control, FFT Analysis*

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1. INTRODUCTION

current harmonics in distribution networks or in distribution grid or in the transition system represent the importance of the problem originated by current harmonics in terms of power quality reliability, and continuity of supply, steady state stability of the system mainly . Current harmonics or the voltage harmonic in distribution grids mostly arises due to use of nonlinear loads. such as personal computer Discharge lamps that is the mercury vapour lamp or the sodium vapour lamp generally used for the street lightning and power electronics based equipments semiconductor devices are the some frequent examples of nonlinear lo ads in residential, commercial, and industrial facilities. Currents harmonics also have a dominant effect on medium-voltage and Low Voltage networks due to the presence of loads such as furnaces, ovens and rectifiers .Three-phase loads generate positive or negative sequence current harmonics in the distribution grid . as a result of this there is generation of resonance condition voltage distortion, overheating of equipment, and increase in transmition and distribution losses, premature ageing of electrical equipments, etc whereas the Single-phase loads load generate the zero sequence current harmonic ,generally the single phase load is connected between the phase and neutral conductors, and the 3rd, 9th, and 15th harmonic order. is generated in the neutral conductor. Harmonics with order of multiple of three is produced from the several single-phase non linear loads and are considered up in the neutral conductor, as a result of this the harmonic current in the neutral conductor is higher than in the phase conductor.

multiple of three order harmonic currents, also causing characteristic problems can give rise to neutral conductor overload, common mode neutral to earth voltages, increase of phase voltage distortion, and transformers overheating generator over heating to avoid this problem the series and shunt connected power filter can be developed , Shunt-connected current power filters can be classified as Shunt passive power filters and shunt active power filter Each one of these shunt filters is designed to offer a very low Impedance path to current harmonics at the tuning frequency. As the harmonic components take a low impedance path major advantages of the Shunt Passive Power Filters are their simplicity and low cost. but the performance of this shunt passive power filter is e dependent on the filtering characteristic on the grid impedance.

The usage of Shunt Passive Power Filter developed the losses at the fundamental grid frequency, and as a result of this there is parallel or series resonances. the Shunt active power filters considered power-electronics-based power converter working in closed-loop mode as a current source. there is one main thing about the Shunt Active Power filter is that this filter can cancel out harmonics and unbalance from the load current, which gives the sinusoidal balanced current at fundamental frequency flowing toward the source side. although the shunt active power filter has better harmonic eliminating capability but it has a relatively higher cost and hence their application in distribution networks or in distribution grid or in trasmition system is less. there is one more possible design of power filter that is the Shunt hybrid power filter. These filters is the combination of passive and active power filters by considering the advantages of both the shunt passive power filter and shunt active power filter so that the Shunt Hybrid power filter developed the good filtering characteristic, which is generally independent of the grid impedance also there is one more advantage of the shunt hybrid power filter is that the cost of a Shunt hybrid power filter is less as compared to the shunt active power filter and the shunt passive power filter.

due to the low power rating of the power converter which is used in the shunt hybrid power filter and shunt passive power filter there is considerable reduction in the cost of the power filter and are conventionally based on simple resonant cells, the resonant cell is the series combination of the capacitance and inductance Therefore, by installing the individual *LC* filters current harmonics should to be canceled out. Shunt Passive Power Filter are not used to cancel out the third-order current harmonic, and the zero sequence current harmonics. as the Shunt passive Power filter was tuned at the

third harmonic, then the resonance frequency of the *LC* resonant cell would be arises and it is closed to the very close to the fundamental frequency, generally 50/60 Hz. there are different method to cancel out the zero sequence harmonic in the distribution system is that the zig-zag reactor and this zig zag reactor has one feature that is this reactor has very low impedance to the zero sequence current harmonic in the distribution grid or in the distribution network.

These hybrid filters act as high impedance blocks to the third-harmonic current. This high impedance limits current which is flowing through the neutral conductor but reduces the phase to neutral voltage . the Active power filter and hybrid power filters are based on power converters, sometimes particular transformer configurations is also used in the active power filter and hybrid power filter.. Power converters allows the effective controlling of the filtering characteristic, making this active and hybrid filter very suitable to efficiently cancel out zero sequence current harmonics. This paper represents an interesting method for filtering current harmonics in three-phase four-wire networks or in distribution network or in distribution grid. The proposed filter that is hybrid filters based on a special topology and characterized by a particular connection of the single-phase inductors and capacitors ,without using any additional controlling device.. The resonant cells are designed to mitigate the 5th-, 7th-, 11th-, and 13th-order harmonics in addition with the mitigation of zero sequence component harmonics that is 3rd, 9th,and 15th current harmonics . this hybrid filter topology can work either in passive mode ,when only passive components are design to mitigate the harmonics In this paper hybrid topology is introduced for three-phase four wire system or for distribution grid or for distribution system, become analyzed and evaluated by both Simulation in MATLAB and experiments. The general structure of the shunt passive power filter is shown in Fig. 1 in the figure 1the positive sequence and negative sequence and the zero-sequence voltage components of the three-phase system that the passive filter is connected is also shown this passive filter topology consists of three phase branches with three identical single-phase impedances and one neutral branch with a fourth single-phase impedance .

In Figure 1, the passive power filter is connected to a three-phase network in which positive sequence impedance is given below

$$Z_{12} = U_{12}/I_1$$

we can write the positive sequence impedance in general as follows

$$= U_{fo}/I_f = Z_f$$, with f = {a, b, c} where the a,b,c are the three phases

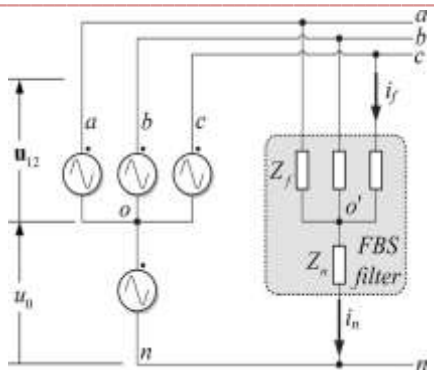

FIGURE1. POWER FILTER WITH BRANCH IMPEDANCES

II. POWER FILTER TOPOLOGY

The three single-phase impedances in three phase and in neutral branches of power filter are the resonant cells nothing but a passive filter, and this possesses several resonance frequencies. According to the connection of the resonant cell power filter gives rise to two groups of resonance frequencies, in which one group for the positive sequence components and another group for the zero-sequence components. This represent that's the shunt passive power filter is capable to perform selective filtering of current harmonics by providing low-impedance paths to current components with specific frequencies and sequences. the resonant cells in the power filter become complex in some particular applications ,when there is a single resonance frequency for such resonant cell then there is good filtering characteristics generally Simple *LC* resonant cells will be considered in the power filter for this paper so the power filter can work as a shunt passive power filter. and this gives the satisfactory performance when the resonant frequency is approximately equal to the grid frequency at this condition the zero sequence circuit would not absorb current at fundamental frequency for a balanced grid voltage. at this condition there is one more point should be considered that the at the resonance frequency the zero sequence component is higher than of the positive sequence component. Hence, due to that filtering capability of positive sequence circuit is higher or more than for zero sequence . also this system has one more advantage that the this system does not used any transformers or special electromagnetic devices, for the filtering design as a result of this is there is lower cost .

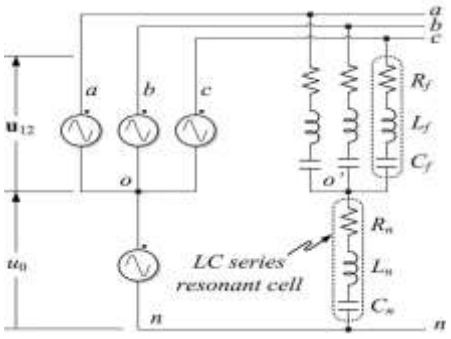

FIGURE.2 POWER FILTER BASED ON SERIES LC RESONANT CELLS

The modified structures of the power filter are shown in Figure 2 and this is represented in the following section. In these power filters, various configuration can be obtain for various application ,there is a inductance and the capacitance is connected in series and this combination is then connected to the three phase and only the inductance is connected in the neutral branch for the application where the zero sequence resonance frequency is lower than the positive nor negative sequence resonance frequency In this power filter implementation, the phase-branch impedances are formed by series *LC* resonant cells, and the neutral branch impedance consists only of a single-phase inductance . Resistances are neglected, in other type of configuration of the passive power filter suitable for those applications where the zero sequence resonance frequency is higher than the positive or negative sequence resonance frequency in this configuration, the phase branches are series *LC* resonant cells, and the neutral branch is constituted by only a capacitor ,there is one more configuration is used for the power filter destined to both compensation of reactive power at the fundamental grid frequency and cancellation of zero sequence current harmonics at zero sequence frequency, in this configuration all three phase branches are constituted by a capacitors only, and the inductance is connected to the neutral branch . then for the application to maintain a reactive power and to give better performance the fourth one configuration is used in this configuration, the phase branches consist of three single-phase inductances only, and the neutral branch is constituted by a single capacitor only.

The resonant cells in phases and neutral branches could be constructed by more complex networks to obtain multiple resonance frequencies using only power filter.

III.LITRAUTRE SURVEY

The electronic filters are constructed using only resistors and capacitors or resistors and inductors. and this filter are known as RC and RL passive filter. With the used of digital signal processing, active digital filters have become common in used where as passive power filter are constructed using the combination of resistors , inductors and capacitors . also passive power filters do not depend upon an external power supply and they do not contain active components such as transistors. The simplest passive filters RC and RL filters, consist only one reactive element, in L type power filter two reactive elements is considered, one is connected in series and one is connected in parallel. Three-element power filters can have a 'T' or 'π' structure also there is various type of power filter such as, a low-pass, high-pass, band-pass, or band-stop.. The high-pass T filter has very low impedance at high frequencies, and a very high impedance at low frequencies similarly, for low-pass π filter, has low frequencies at high impedance and reflecting high frequencies at low impedance. Multiple element filters are simply constructed using a ladder network. the additional elements are needed when it is desired to improve the parameter of the filter. the active power filter can be constructed using combination of passive and active components, and with the help of additional power source. . Digital signal processing allows the cost effective construction of a variety of power filters also the Quartz crystal filters have much higher quality factors as compared LCR filters. Both are very much effective in the harmonic cancellation. Filters are generally electromechanical devices commonly used in radio frequency applications. This hybrid filtering method is also found in an analog filter in the past year their is, linear analog filter design has evolved, in the oldest designs main design criterion was the Q factor of the circuit.. From the 1920s filters began to be designed as the image point of view, mostly being driven by the requirements of telecommunications.

Low order power filters can be designed by directly applying basic network laws such as Kirchhoff's laws to obtain the transfer function. by this kind of analysis typically only simple low order that is 1st or 2nd order harmonic can be mitigate or the cancel out . but there is another approach to in cresed the ability to easily extend to a higher orders. It has the disadvantage that accuracy of responses of filter depends upon image impedance,. The particular element values of the power filter are obtained by continued-fraction or partial-fraction expansions of this polynomial. the Digital filters may be more costly than an equivalent analog filter due to their increased complexity in construction,. Digital power filters are very commonplace and an essential element in electronics such as radios, cell phones, and AV receivers. A different variety of mathematical method may be adopted to analyze the behavior and performance of a digital power filter. Many of these analysis techniques may also be developed the various designs, and often accordingly form the basis of a filter specification.

IV. PROPOSED SCHEME

A previously represented passive power filter can offer a fairly good behavior when applied to cancel out harmonics in three-phase four-wire systems or to cancel out the harmonic in distribution system under considerable operating conditions. However, there is some problem related to the filtering characteristic of the passive power filter is that this passive filter can effectively affected grid impedance; whenever there is presence of resonance, retuning is necessary due to ageing and tolerances. this problem of retuning is solved by integrating a power converter into the passive filter structure. this new structure is known as a hybrid power filters. A perfectly designed and well-controlled power converter can generate any voltage current relationship at its output, and it become inside its operative range. Therefore, such power converter could be introduced a “virtual impedance” into the original structure of the passive power filter. one main advantage of this virtual impedance is that it improves the behavior of the original passive filter by increasing its capability of mitigating the current harmonics at frequencies different from the resonance frequency,. generally the Conventional three-phase three-wire hybrid power filters are used to integrate a three-leg full-bridge

voltage-source inverter to improve the filter performance to cancel out the positive sequence or negative-sequence current harmonics from the distribution grid.

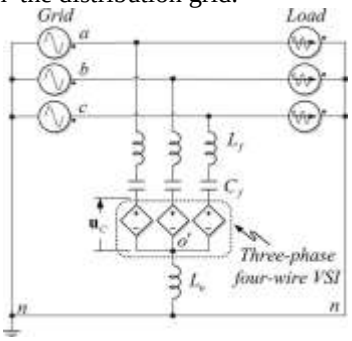

FIGURE 3. IMPLEMENTATION OF HYBRID POWER FILTER

Different connection of hybrid power filters can be achieved depending on both the complexity of the impedances and the topology of the Voltage source inverter Figure 3 represent the implementation of a three-phase four-wire hybrid power filter with the distribution grid that results from connecting the Voltage source inverter to the passive filter that is with the resonant .the figure 3 shows that phase branches are consist of combination of series inductance and the capacitance that is by the *LC* resonant cells, and the neutral branch is consist by an inductor only . two resonant frequencies are developed with this configuration generally named as a positive sequence or negative sequence frequency and the zero sequence frequency. for the simplicity in the network the Resistances of the branches have been intentionally neglected.

The Voltage Source Inverter in hybrid power filter structure can continuously synthesize and monitor both positive sequence and negative sequence and zero sequence voltage .and as result of this there is improvement in the filtering characteristics of the passive power filter. depending on this paper represent the hybrid power filter is an effective solution for canceling out the most dominant positive or negative sequence current harmonics, that is the 5th, 7th-,and 11th-order harmonics, along with the zero sequence third-order current harmonic. Higher the rating of voltage source inverter higher the capacity of controllability and better is the performance of the hybrid power filter, but the implementation of such system is more expensive also the power converter which is used in hybrid power filter is much smaller in size or cost economical than the power converter which is used in the conventional active power filter. Therefore the dc-link voltage of the power converter which is used in hybrid power filter can be significantly reduced in comparison with to the conventional Shunt Active Power Filter, according to the control algorithm the performance of the hybrid power filter can be modified.

The block diagram of hybrid power filter is shown in figure 4 it consist of main five blocks namely the grid current processing blocks and the injected current controller block ,third one is the dc link voltage controller block , fourth one is the modulator block and last that is fifth one is the voltage source inverter and the resonant cell blocks , the function of the grid current processing block is that this block selecting the current harmonics to be filtered from the controlled grid current .the second block is the injected current controller and the function of this block is to sets a reference voltage for the Voltage source Inverter in order to cancel out or to mitigate the selected current harmonics in the distribution grid or in distribution system. third one block is the dc-link voltage controller block and main function of this block is that the, modifies the original reference voltage of the Voltage Source Inverter by adding an extra voltage in order to keep the dc-link voltage at its normal rated value. And fourth one block is the modulator and the function of the modulator is to generate the switching signals of the Voltage Source Inverter from the final reference voltage of the Voltage Source Inverter and last one block is the voltage source inverter and the resonant cell block The resonant cells of the hybrid power filter provide the of very low impedance path to positive and negative sequence and zero sequence currents at the positive and negative sequence resonance frequencies and zero sequence resonance frequency. Hence, a low dc link voltage is necessary in the Voltage Source Inverter to inject into the grid significant levels of harmonic currents.

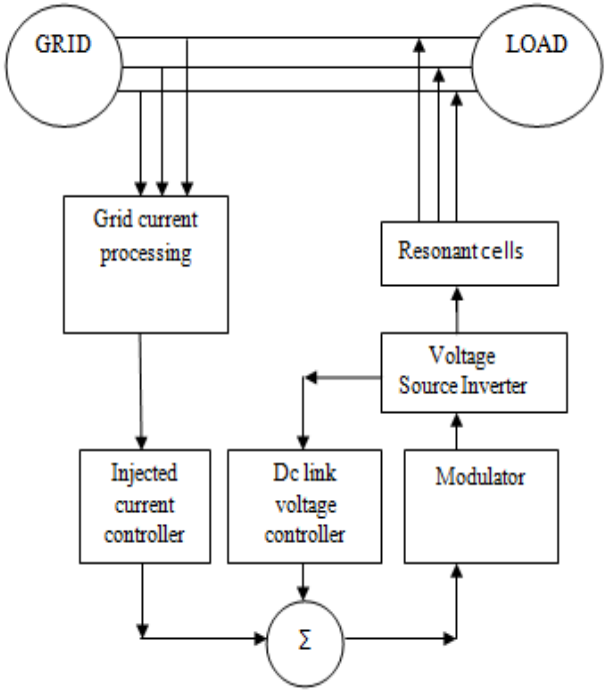

FIGURE . 4 BLOCK DIGRAM OF HYBRID POWER FILTER

If frequency goes far away from the resonance frequency then impedance offered by the resonant is also increases, there is one more important consideration in the hybrid power filter is that it can compensate only a limited range of the positive and negative sequence and zero sequence current harmonics. Hence , the grid current processing block select those individual frequencies that are suitable to be

filtered from the grid current by using any signal filtering methods. As the harmonics compensation range can be increased by increasing the dc-link voltage level of voltage source inverter further this increases the Voltage source inverter rating, and consequently, cost associated to this. The transfer function of the control system which is developed for the hybrid power filter is depends on both the current sensing point and the type of current controller. This current controller can operate in two mode firstly in synchronous or static reference frames,. Interaction between voltage and current generates an exchange of active power between Voltage source inverter and the distribution grid, main purpose of this paper is that to introduces the hybrid power filter for the distribution system.

V. SIMULATION MODEL

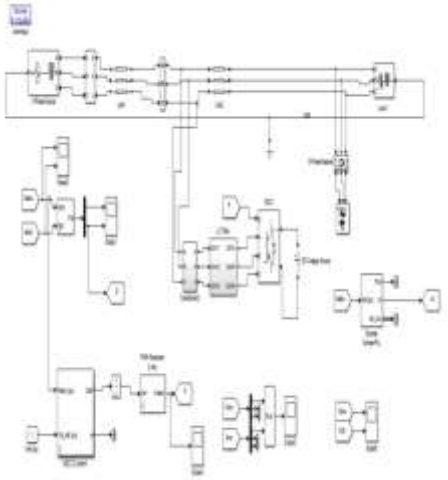

FIGURE .5 SIMULATION MODEL OF HYBRID POWER FILTER

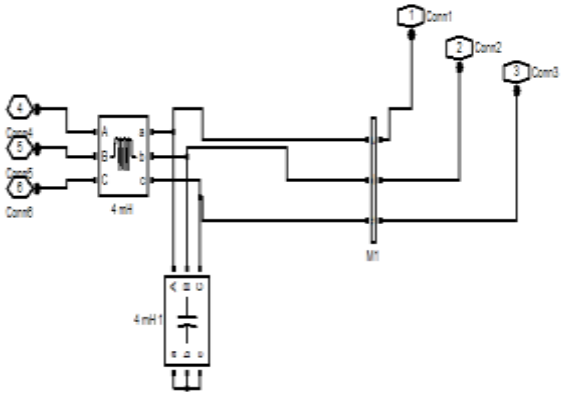

FIGURE .6 SIMULATION MODEL OF LC POWER FILTER

VI. RESULTS AND CONCLUSION

The results of the proposed system is shown below , it consist of Total harmonic distortion of load current and voltage .The active and reactive power is also shown in results.

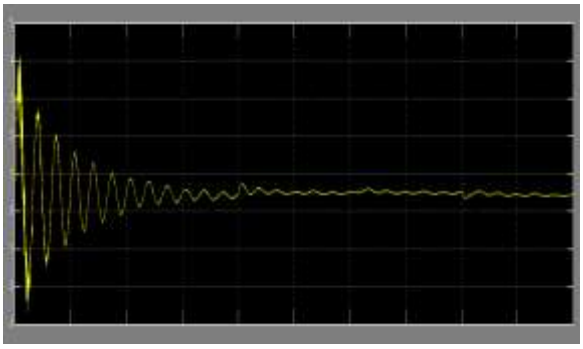

FIGURE7. THE ACTIVE POWER

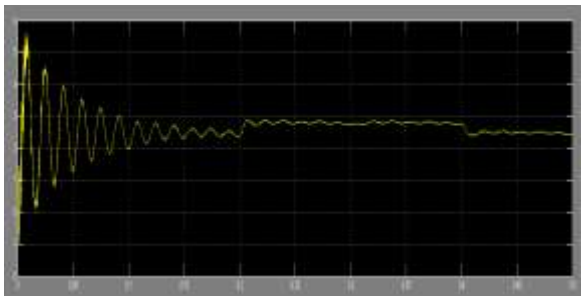

FIGURE 8. THE REACTIVE POWER

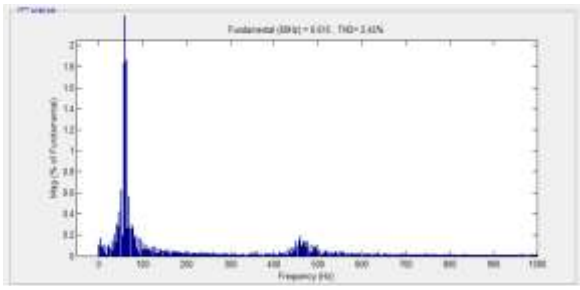

FIGURE 9. THE FFT ANALYSIS

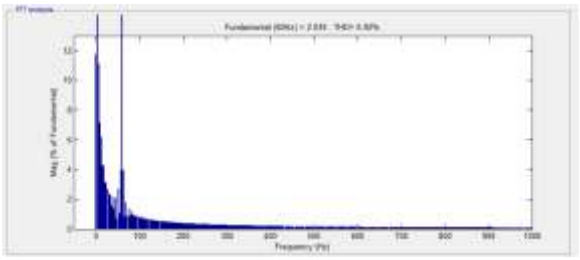

FIGURE 10. THE FFT ANALYSIS

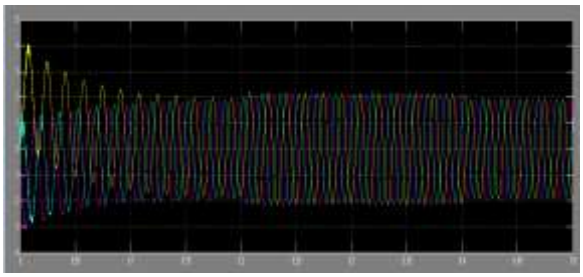

FIGURE 11. Iabc LOAD CURRENT

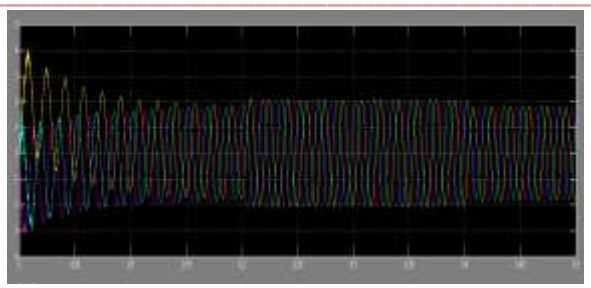

FIGURE 12.Iabc GRID CURRENT

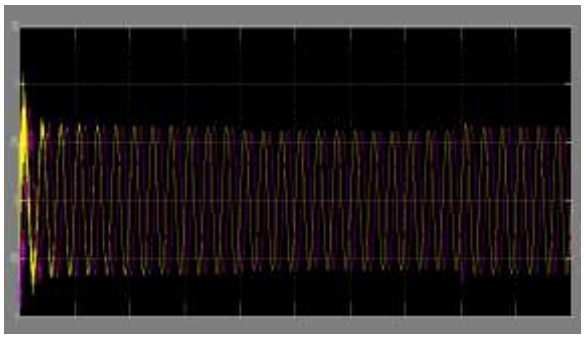

FIGURE 13.Vabc LOAD VOLTAGE

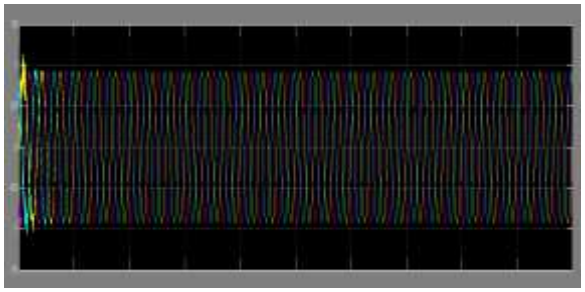

FIGURE 14.Vabc GRID VOLTAGE

The hybrid power filter for the distribution grid or for distribution system is presented in this paper. With development of hybrid filter this power filter is applicable in trasmition system i.e. for the three phase tree wire system as well as for the three phase four wire system The Analysis and simulations give the proper performance of the system
Generally the 5^{th} 7^{th} and 11^{th} order harmonic is or the higher order harmonic is mitigate with the development of the hybrid power filter. So that high power quality, better reactive power control and steady state stability can be maintained of the distribution system. The behavior of the system can be analyzed from the FFT analysis.

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