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Harmonics Cancellation in Three-Phase Four-Wire Systems by Using a Filtering Topology

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Abstract: This paper presents harmonics mitigation in distribution system .in this the single phase inductance and capacitance are used to develop the four-branch star filter topology ,this filter topology does not required any type of transformer and electromagnetic device .Via this hybrid filter two resonance frequencies is obtain one for positive or negative sequence component and other for zero sequence component. This filtering topology can be used in hybrid or passive mode ,in passive mode only capacitance and inductance is used to mitigate the harmonic in distribution system or in hybrid mode the capacitance and inductance is used with voltage source inverter .The analysis and simulation designed provide better solution to mitigate the harmonic in Three phase four wire system i.e.in distribution system . This hybrid filter topology provides the better power quality and significant reactive power control.

Index Terms - *Active power filters, hybrid power filters, passive power filters, power line filters, power system harmonics, reactive power control. Total Harmonic Distortion, power quality.*

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1. INTRODUCTION:

High quality power supply is necessary now days .There is generation of harmonic is due to wide used of non linear load such as UPS , electronic devices ,power electronic devices ,PC etc. This harmonic generation due to such devices causes adverse effect on power system such as heating of various equipment ,voltage sag ,voltage fluctuation. Also there is generation of the reactive power so avoid this undesirable effect on power system or to compensate reactive power the passive and hybrid filter is used but the passive filter is only the combination of the single phase inductance and the single phase capacitance and this passive filter is not that much effective to mitigate the harmonic in the power system. As compare to this the hybrid filter can effectively reduce the harmonic in the power system This project develop the hybrid filter to mitigate the harmonic in distribution system trough the MATLAB simulation.

A) Need of Harmonic reduction:

There is generally two type of load that is linear and non linear load. The linear load means that the load which draws the current which is proportional to the applied voltage for example the all resistive loads incandescent lamp etc . And the non linear load mean the load in which the voltage and current are not proportional and sinusoidal for example computers, variable frequency drives, discharge lighting ,power electronic devices, electronic component etc, These non-sinusoidal nature arises due to presence of harmonic in current which can cause the distortion in voltage waveform also the voltage fluctuation and voltage sag ,various power system equipment heating . voltage distortion that can affect both the distribution system equipment and the loads connected to it. Power electronic devises include the converters and this convert uses the power semiconductor devices for conversion of power from AC to DC, DC to AC ,DC to DC, AC to AC and considered the large non linear load to electric power system. The converters are used in the industry for various purpose, such as adjustable speed drives, uninterruptable power supplies, switching mode etc. A nonlinear load draws distorted current from the supply, which distorted current passes through all of the impedance between the load and power source. This non sinusoidal current when passes through the system impedance which causes the voltage sag and the voltage fluctuation .the power factor correction are used in various industry that is the capacitor is used to improve the power factor in the industry and the harmonic current is interact with this capacitor which can over heat the plant and damage the plant and equipment. Due to harmonic the bus bars and cables may prematurely age. Fuses and circuit breakers will not give the proper performance to protect the system equipment. as a result of this there is nned of harmonic mitigation.

B) Active Power Filter:

The active power filter is consist of both active and passive element also the active power filter is an electronic filter and it consist of amplifiers so the behavior and performance can be improved with the help of amplifier. Hence the active filter can remove the current harmonic in the power system also remove the voltage and current distortion also control the reactive power in the power system. the voltage fluctuation and the voltage sag can be considerably avoided with used of active filter1.The figure shows the connection of non linear load with the power source and the connection of the active power filter with the system. This active power filter is shunt connected.

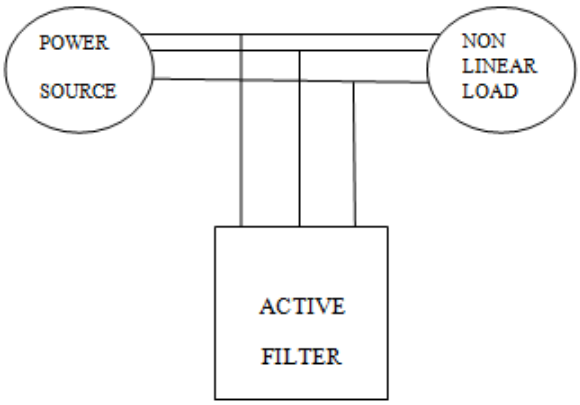

Figure 1 SHUNT ACTIVE POWER FILTER

As the name suggested the shunt active power filter means the active power filter is connected in parallel to the system. The main function of this shunt connected active power filter is to cancel out the current harmonic and the improve the power quality .the shunt active power filter generally used the IGBT to compensate the harmonic component of the load current. The block diagram of the arrangement of shunt connected active power filter is shown in.1 the series active filter means the multilevel converter along with the LC passive component, and this series active power filter can inject the active power to compensate the voltage sag and voltage disturbances..

*C) **Passive Power Filter**:*

The passive power filter consist of the series parallel connection of the passive element such the inductor ,capacitor, resistor . the passive power filter can provide low impedance path or low resistance path to the harmonic current. Hence harmonic current is pass through this low resistive path and harmonic current is diverted through passive filter network and system become free from the distortion and current harmonics. Also the system is free from voltage waveform distortion. For bypassing the current effective means of connection is connecting the passive filter in parallel with the load. Different variety of passive filters such as single tuned, double tuned, high pass and low pass filter, c-type filters are used for current harmonic mitigation purpose. but out of this the most commonly used filter in the passive filter is the single tuned filter. In the passive power filter the series combination of capacitance and the inductance provide low impedance path for tuned harmonics .although passive filters doesn't eliminate harmonics to a greater extent yet it is used due to some additional feature.

Figure 2 shows the block diagram of a passive shunt connected power filter connected in which the power source is connected to the non linear load it can also used the six pulse ac-dc converter with R-L load This is one of the most commonly used configuration or arrangement of shunt connected passive power filters it can operate as a low pass filter and high pass filter the shunt connected low pass filter can eliminate the 5^{th} and 7^{th} harmonic and the shunt connected high pass filter can eliminate the 11^{th} harmonic frequency .

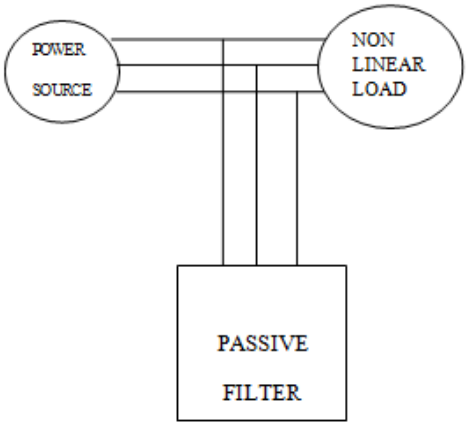

Figure 2 SHUNT PASSIVE POWER FILTER

This shunt connected passive power filter can more dominantly eliminate the 5th and 7th and other higher order harmonics and thus avoid to them to enter into the ac mains. The diversion of the harmonic current in the passive power filter is mainly due to the impedance available in system. The higher value of source impedance means better performance of the passive power filter. Like a passive shunt connected filter the passive series filter is considered as a potential solution for harmonic mitigation. Block diagram of series connected series active power filter is same as that of the shunt connected passive filter .in this the branches of passive filter is connected in series with source and the load. It can also mitigate the 5^{th} and 7^{th} and 11^{th} harmonic frequency Here, the performance of the series passive filter is not much dependent on the source impedance. But there is one drawback of this is that there is reduction in dc bus voltage

II.LITRAUTRE SURVEY

he harmonic is the integral multiple of the fundamental component ,there are several electronic filters, that is the passive analog linear filters, this passive filter is constructed using only resistors and capacitors or resistors and inductors. As due to the connection of inductance and capacitance their named suggested as RC and RL single-pole filters the complex multi pole LC filters is also developed in resent ,the Hybrid filters are also developed by combining the passive filter or the resonant cell with the voltage source inverter in that the 12 pulse or 18 pulse voltage source inverter can be used. With the availability of digital signal processing, the active digital filters have become common. in used where as the implementations of the passive are based on the combinations of resistors (R), inductors (L) and capacitors (C) These types are called as passive filters, because they do not depend upon an external power supply and also the passive filter do not contain any active components such as transistors Inductors where as this component is generally used in the active power filter.

In passive filter as the signal passed through the inductor this provide the less attenuation to low-frequency signals than high-frequency signals and is therefore a filter. and when the signal passes through a capacitor, or has a

path to ground through an inductor, then the filter presents less attenuation to high-frequency signals than low-frequency signals and therefore is a high-pass filter.

Also in passive filter the inductors and capacitors are the reactive elements of the filter. The number of elements determines the order of the filter. LC tuned circuit filter being used in a band-pass or band-stop filter is considered a single element even though it consists of two components,.. Historically, the design of linear analog filter has evolved through three major approaches. the design of the linear analog filter is mainly depend on the Q factor that is quality factor of the. the quality factor measure the frequency of the tuning circuit. in 1920 the design of filter has been developed, as the requirements of telecommunications.

The Kirchhoff's law is used to developed the transfer function which is used in the design of the Low order filters. This kind of analysis is usually developed only to carried out for simple filters of 1st or 2nd order. This approach analyses the filter sections from the point of view of the filter being in an infinite chain of identical sections. there is some advantage of such design is that the simplicity of approach and the ability to easily extend to higher orders. but is has some disadvantage that is the accuracy of predicted responses relies on filter terminations in the image impedance, which is usually not the case. The analysis of network synthesis approach starts with a required transfer function and then expresses that as a polynomial equation of the input impedance of the filter.

The actual element values of the passive and active and also the hybrid filter are obtained by continued-fraction or partial-fraction expansions of this polynomial. Unlike in the image method, there is no need for impedance matching networks at the terminations as the effects of the terminating resistors are included in the analysis from the start sources must be power electronic based to provide the required flexibility to insure operation as a single aggregated system. A variety of mathematical techniques or method is employed to analyze the behavior of a given digital filter. Many of these analysis techniques may also be employed in designs, and often form the basis of a filter specification. Typically, the design is depend on one characteristics filters by calculating how they will respond to a simple input such as an impulse. this paper represents a combined system of a passive filter and a small rated active filter ,both connected in series or parallel with each other. and the passive filter is integrated with voltage source inverter to developed the hybrid filter The passive filter remove low order the load produce harmonic just as a conventional one does. On the other hand the hybrid filter plays a role in improving the filtering characteristics of the passive filters. As results of this there is great reduction of the required rating of the active filter and in eliminating all the harmonics and the limitation faced by using only the passive filter, by considering a practical and economical aspect of the system.

III. PROPOSED SCHEME

the all ready existing passive power filter can offer a fairly good behavior when it is used to to cancel out current harmonics in three-phase four-wire systems . However, the filtering characteristic of the passive power filter, active power filter and the hybrid filter is affected by typical problems of any passive filter, it consist of its filtering capability depends on the value of the grid impedance; as there is a resonance is occur then, retuning is necessary due to ageing and tolerances. this problem with passive hybrid filter is overcome in this paper by developing the hybrid power filtering topology the hybrid filter consists of integrating a power converter that is the voltage source inverter into the filter structure. and the structure id obtain is known as a hybrid power filters. A properly designed and well-controlled power converter that is the voltage source converter can generate any voltage current relationship at its output, by considering such topology power converter could be introduce a "virtual impedance" into the of the passive filter. by This virtual impedance the performance and the behavior of the passive power filter can be improved, and this also damping oscillations due to resonance phenomena. the filter characteristic for pn-seq current harmonics can be improved by using the conventional three phase full bridge voltage source inverter. the Different implementations hybrid power filters and the passive filter can be achieved and can be depending on both the complexity of the branch impedances and the topology of the Voltage source inverter. Fig.3 represent the whole block diagram of specific implementation of a three-phase four-wire hybrid power filter that is the combination of voltage source inverter and the passive filter that is the resonant cell and the passive power filter. all the phase branches are constituted by *LC* resonant cells, where as the neutral branch is constituted by an inductor only. from this circuit the Resonance frequencies and for the positive sequence and zero sequence component is obtained. Resistances of the branches have been intentionally neglected..

The Voltage source inverter can continuously maintain the both positive sequence and zero sequence voltages at its output and due to this there is improving in both the pn-seq and the z-seq passive filter characteristics at the same time. this paper present the hybrid power filter as an effective solution for canceling out the most dominant positive and negative sequence current harmonics, that is the the 5th, 7th-,and 11thorder harmonics along with with the zero sequence third-order current harmonic. as the higher the voltage range for the Voltage source inverter, the higher the controllability ,behavior and the better the response of the hybrid power filter, but there is one more drawback with this system is that the more expensive the implementation. It should also be noted that the power converter of the hybrid power filter is generally much smaller and inexpensive that is cost effective than power converter of a conventional active power filter. This is due to the fact that the power converter in an hybrid power filter ideally does not generate any voltage at fundamental frequency because the grid voltage at fundamental

frequency drops across the capacitors of the *LC* resonant cells which is in series with voltage source inverter.

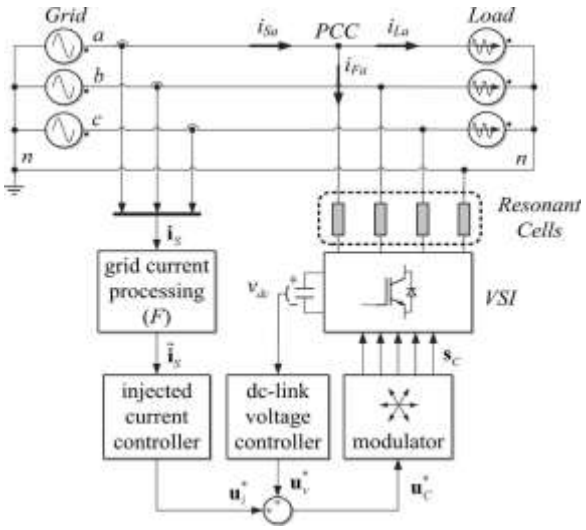

Figure 3 CONTROL DIAGRAMOF THE FBS HYBRID POER FILTER

Therefore, this hybrid power filter topology is exclusively used to generate only those harmonic voltages that are necessary to inject the desired harmonic currents into the grid. Therefore the dc-link voltage of the power converter in an hybrid power filter can be significantly reduces as compared to the shunt active power filter. the main aims of this paper is only to present the main characteristics of the filtering topology as shown in figure 3The control system of the hybrid power filter is consist of the four main 4blocks namely: 1) the grid current processing block (*F*), which is selecting current harmonics to be filtered from the controlled grid side current ;2) the second block represent the injected current controller, which sets a reference voltage for the voltage source inverter in order to cancel out the selected current harmonics in the tree phase four system; 3)the block represent the dc-link voltage controller, which modifies the original reference voltage of the Voltage source inverter by adding an extra term in order to keep the dc-link voltage at its nominal value; and 4) and the fourth block represent the modulator, which generates the switching signals of the Voltage source inverter from the final reference voltage of the Voltage source inverter The resonant cells of the hybrid power filter of Figure 3provide the very low impedance to positive sequence and negative sequence currents at the tuning frequencies

Therefore, a low dc link voltage only about 5- 10% of the grid voltage is necessary in the Voltage source inverter to inject into the grid significant levels of harmonic currents at positive and negative sequence frequencies However, impedance offered by the resonant circuits increases as frequency goes far away from the resonance ones. As a positive consequence, the current ripple injected by the hybrid power filter into the grid at the switching frequency is very low. However, this also implies that the hybrid power filter can only compensate a limited range of the positive and negative or zero sequences current harmonics. For this reason, the grid current processing block (*F*) extracts those individual frequencies that are suitable to be filtered from the grid current by using any signal filtering technique. this is one of the better solution for increasing the limit of the hybrid power filter As previously mentioned that the harmonics compensation or harmonic mitigation range can be extended by increasing the dc-link voltage level, which increases the rating of the Voltage source inverter and consequently, its cost. Currents signals at the input of the current processing block can be sensed at the point of common coupling between the power filter and the grid. The transfer function of the control system depends on both the factor that is the current sensing point and the type of injected current controller .This current controller can work on either synchronous or static reference frames using either as a conventional synchronous PI that is the proportional integral or stationary resonant controllers, The dc-link voltage controller generates a reference voltage in phase with the grid current at the fundamental grid frequency flowing through the Voltage source inverter. by the Interaction of both voltage and grid current generates an exchange of active power between Voltage source inverters and as a result of this the grid intended to keep the energy stored into the dc-link stored energy and so the dc-link voltage close to its nominal rated value .however the aim of this paper is to only introduce the filtering topology and some of its main applications, the control diagram of Figure 3can be analyzed and is implemented by using algorithms,. Hence, the grid current processing block (*F*) consists of three very narrow notch filters one per phase canceling out the fundamental frequency component of the grid and load current harmonics to be compensated by the filter. also the modulator can provide the pulses to the voltage source inverter and due to this the voltage source inverter can be generate the output voltage .

IV. SIMULATION MODEL

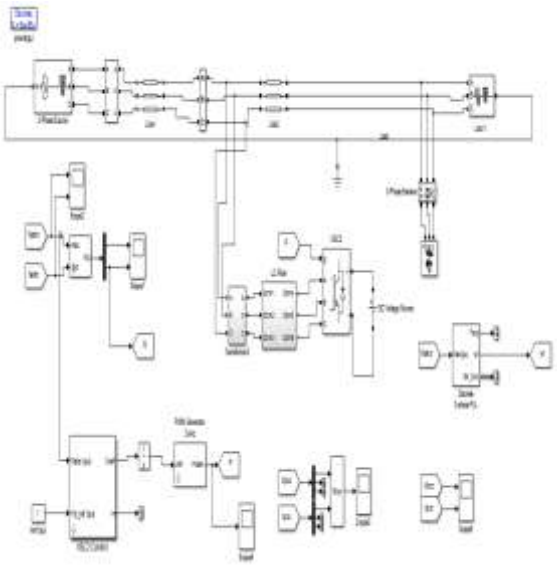

Figure 4 SIMULATION MODEL OF THE HYBRID POWER FILTER

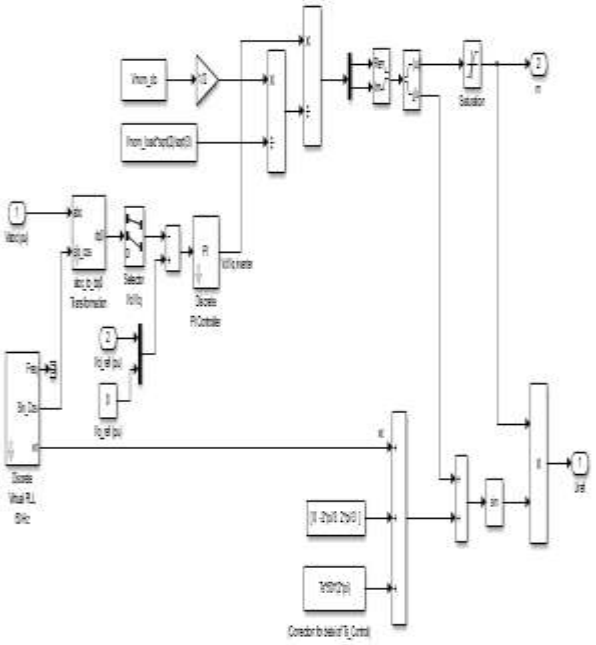

Figure 5 CONTROLLER SIMULATION MODEL

V. RESULTS AND CONCLUSION

The results of the proposed system is shown below, it consist of FFT Analysis it also shows the controller performance bode plot.

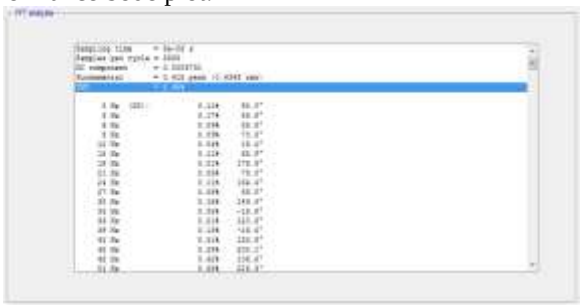

Figure 6 The FFT Analysis for voltage

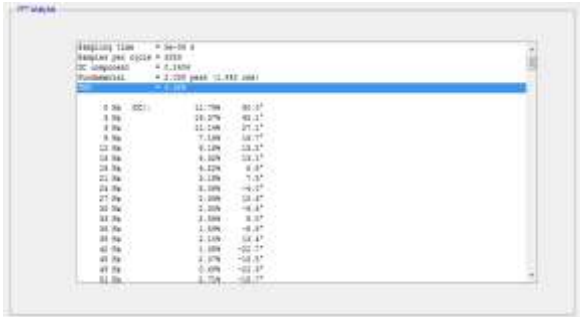

Figure 7 The FFT Analysis for current

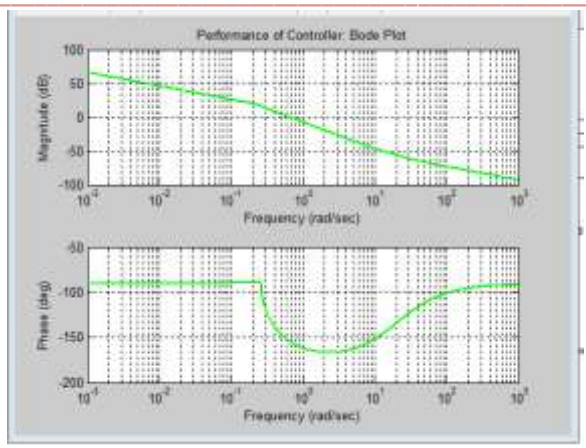

Figure 8 The performance of Controller: Bode plot

A Passive and Hybrid filtering topology is presented in this paper. The harmonic mitigation is achieved through the simulation in MATLAB. the analysis and simulation give effective solution for harmonic mitigation in three phase four wire system the connection of inductance and capacitance that is the passive filter decide the impedance for the given current harmonic .both the passive and hybrid system provide better performance to mitigate the harmonic in three phase four system to improve the power quality. Hence the overall efficiency of the power system is increased.

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