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Improvement Of Power Quality By Using Active Filter Based On Vectorial Power Theory Control Strategy On The MATLAB-Simulink Platform

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Abstract

Harmonic current drawn from a supply by the nonlinear load results in the distortion of the supply voltage waveform. Both distorted current and voltage may cause conductors to overheat and may reduce the efficiency and life expectancy of the equipment. So that reduction of harmonics is very important in day today life. For that purpose used filters Active power filters are used to improve power quality by compensating harmonics and reactive power required by a non-linear load. In this paper a Series active with passive shunt filter and hybrid active power filter topology are discussed. The control strategy based on vectorial power theory of instantaneous reactive power, so that the voltage waveform injected by the active filter is able to compensate the reactive power.

1. INTRODUCTION

In recent years both power engineers and consumers have been giving focus on the "electrical power quality" i.e. degradation of voltage and current due to harmonics, low power factor etc. A power quality problem exists if any voltage, current or frequency deviation results in a failure or in a bad operation of customer's equipment. So, for the better performance of the system it should be free from harmonics. For that purpose filters are used. There are so many types of filters such as active filter, passive filter, high pass filter, low pass filter etc. In that high-pass filters present disadvantages due to the resistance connected in parallel to the inductor, which increases the filter losses and reduces the filtering effectiveness at the tuned frequency. Conventionally, Passive LC filters were used to compensation of current harmonics. But, there are some limitations of using only passive filters such as fixed compensation, large size, bulkiness, occurring series and /or parallel resonance problem etc. To overcome these limitations combination of active and passive filters are used. In this paper a Series active with passive shunt filter is discussed. Series active with passive shunt filter topology is implemented with three phase PWM inverter connected in series with power lines and resonant LC passive filter are connected in parallel with power lines.

2. Power quality

Power quality means the physical characteristics of the electrical supply provided under normal operating conditions that do not disturb the customer's processes.

2.1 Power quality problems

Power quality problem exists if any voltage, current or frequency deviation results in a failure or in a bad operation of customer's equipment [2]. Also some power quality problems are like a Voltage sag, voltage swell, voltage imbalance, voltage fluctuation, transient, overvoltage, under-voltage etc. One more problem is harmonics. Harmonics are produced due to non linear load.

2.2 Solution to power quality problems

A flexible and versatile solution to power quality problems are offered by active power filters. There are also three types of active power filter such as series active power filter, shunt active power filter & hybrid active power filter. In that the cost of shunt active power filter is relatively high and they are not preferable for a large scale system. The series active power filters works as a kind of harmonic isolator rather than a harmonic voltage generator. Series active power filters are used to eliminate voltage harmonics, to balance and regulate the terminal voltage of the load or line. Also, it has been used to reduce negative-sequence voltage [4].A new control algorithm is hybrid filter, which is a series combination of an active filter and passive filter which is connected to parallel with the load is quite popular because of the solid-state devices are used in the active series part can be of reduced size and cost. Also the major part of the hybrid filter is made of the passive shunt LC filters are used to eliminate lower order harmonics [4]. It has the capability of reducing voltage and current harmonics at a reasonable cost, and allows the use of active power filters in high-power applications at a relatively low cost. Moreover, compensation
characteristics of passive filters can be significantly improved by connecting a series active power filter at its terminals, giving more flexibility to the compensation scheme [6] and avoid possibility of the generation of series and /or parallel resonance.

3. Series active power filter

Series active power filters compensate current harmonics caused by non-linear loads by imposing a high impedance path to the current harmonics which forces the high frequency currents to flow through the LC passive filter connected in parallel to the load. The high impedance imposed by the series active power filter is created by generating a voltage of the same frequency that the current harmonic component that needs to be eliminated. Current harmonic and voltage unbalance compensation are achieved by generating the appropriate voltage waveforms with the three phase PWM voltage-source inverter (Fig.4).Voltage unbalance is corrected by compensating the fundamental frequency negative and zero sequence voltage components of the system.

4. Hybrid active power filter

The hybrid active power filter topology is shown in Fig. 6 and is implemented with a three-phase pulse width modulation (PWM) voltage-source inverter operating at fixed switching frequency (the active power filter), and connected in series to the passive filter through coupling transformers. Basically, the active power filter acts as a controlled voltage source and forces the utility line currents to become sinusoidal and in phase with the respective phase to neutral voltage by pushing all current harmonics to circulate through the hybrid scheme. In other words, because the active power filter is connected in series to the passive filter through coupling transformers, it imposes a voltage signal at the primary terminals that forces the circulation of current harmonics through the passive filter, improving its compensation characteristic, independently of the variations in the selected resonant frequency or filter parameters. In this way, the compensation characteristic of the passive filter is significantly improved.

5. Instantaneous reactive power theory

The instantaneous reactive power theory is the most widely used as a control strategy for the active power filter. There are five formulations of the instantaneous reactive power theory: p-q original theory, d-q transformation, modified or cross product formulation, p-q-r reference frame and vectorial theory. From the five formulations, only the vectorial one allows balanced and sinusoidal source currents after compensation. The main difference between vectorial power theory and rest of the formulations is that, vectorial formulation need not do any kind of coordinate's translation. It uses the same power variables as the original theory. Among all above theories only vectorial formulation is adequate to establish APLC compensation strategies with any kind of load and any kind of supply.

Defining now the instantaneous real and imaginary power in phase coordinates as follows:

$$p(t) = \vec{v} \cdot \vec{i} = v_1 i_1 + v_2 i_2 + v_3 i_3$$

$$q(t) = \vec{v}_q \vec{i} = \frac{1}{\sqrt{3}} \begin{bmatrix} v_2 - v_3 \\ v_3 - v_1 \\ v_1 - v_2 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix}$$

With

$$\vec{v}_q(t) = \frac{1}{\sqrt{3}} [v_{23} \quad v_{31} \quad v_{12}]^t$$

6. Simulations and results:

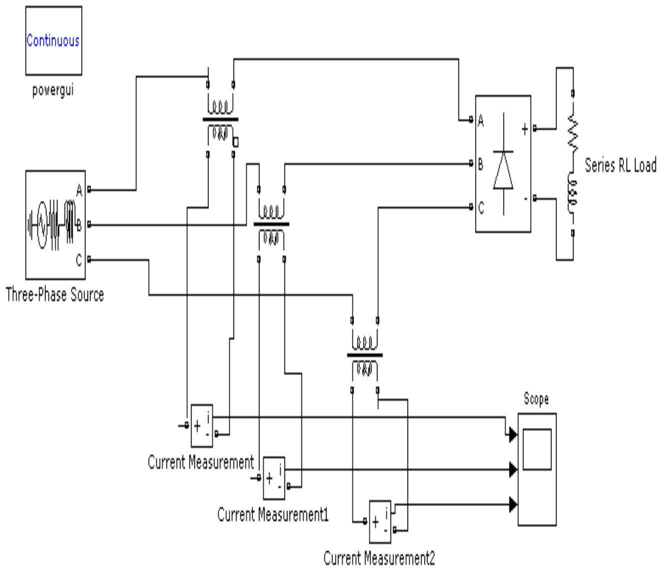

Fig.No.1 Three phase source before using filter

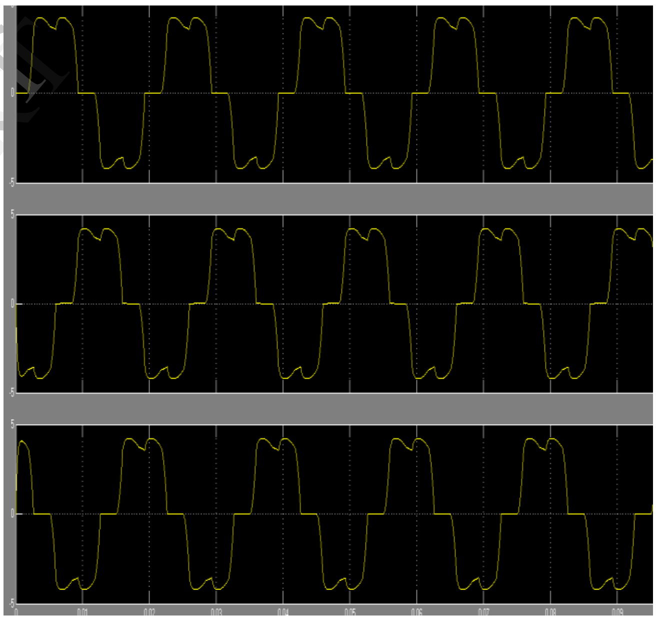

Fig.No.2 Current Waveform before using filter

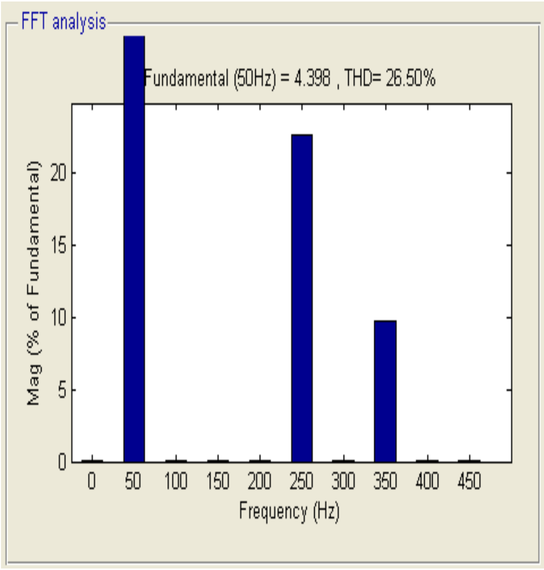

Fig. No. 3 FFT analysis of harmonics.

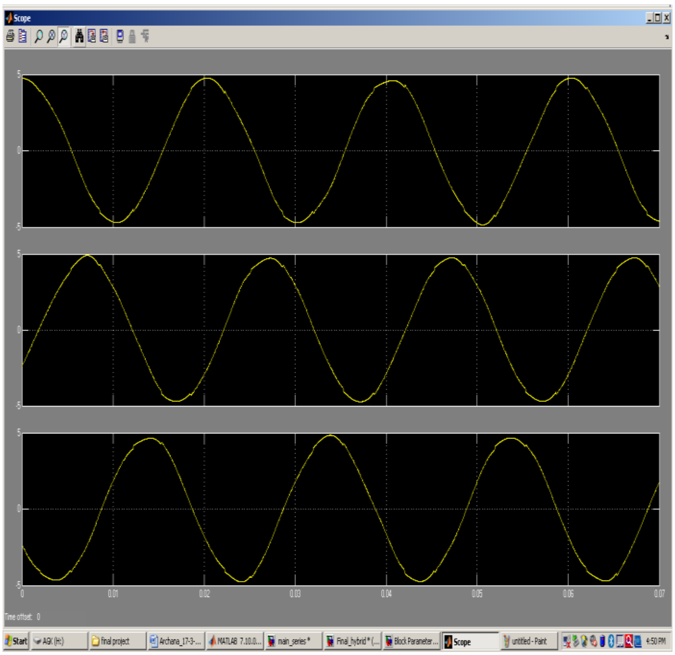

Fig.No.5 Current Waveform after filtration

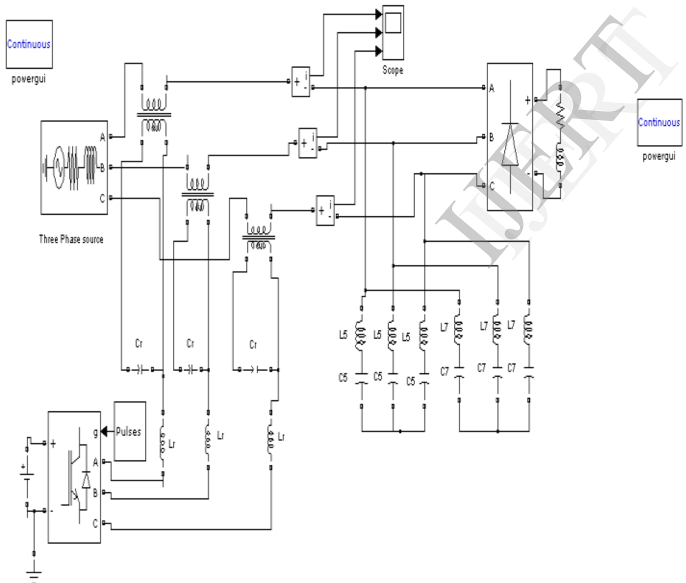

Fig. No. 4 Series active and shunt passive filter topology

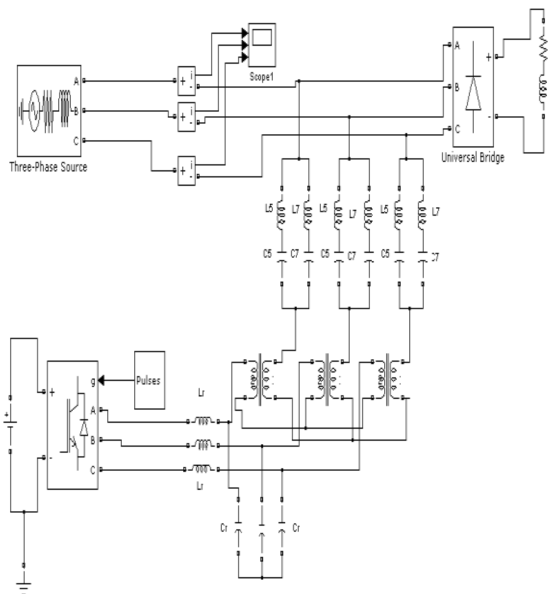

Fig.No.6 Hybrid active power filter

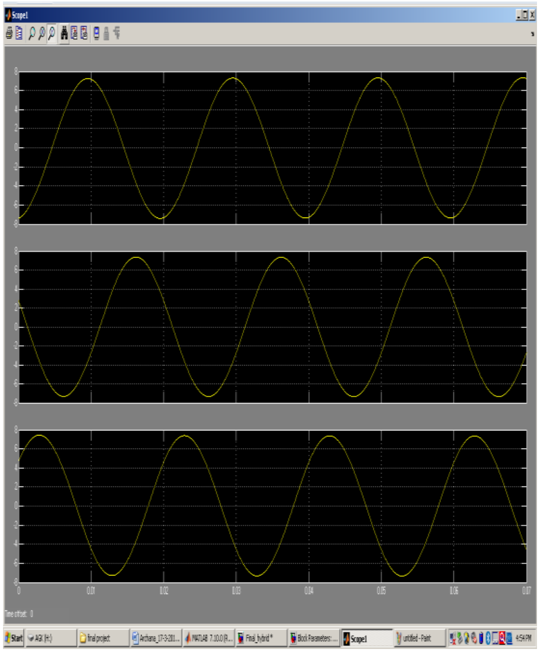

Fig.No.7 Current waveform after using hybrid filter

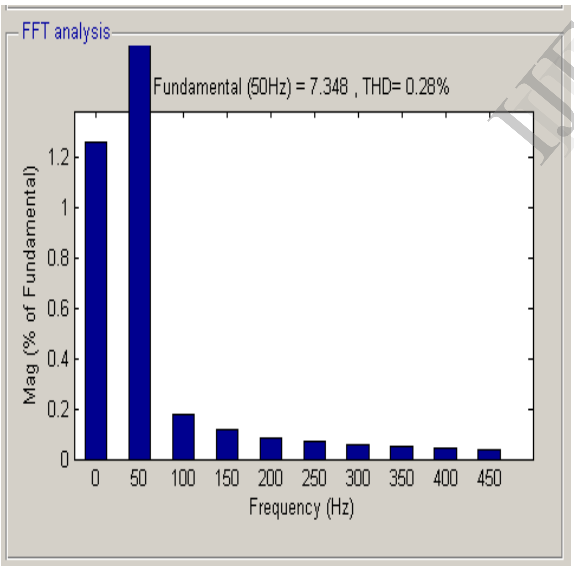

Fig.No.8 FFT Analysis after using hybrid filter

TABLE I.

PASSIVE FILTER VALUES

	For fifth order harmonics	For seventh order harmonics
Passive Filter	L= 13.5mH	L=6.5mH
	C= 30.9µF	C=31.5µF
Ripple Filter	L= 1 mH	C= 633µF

The system shown in Fig. 1, Fig.4 & Fig 6 has been simulated in the Matlab-Simulink platform. Each power device has been modeled using the Sim Power System toolbox library. Fig.1 shows the system without using filter and harmonics are introduced in that system. Fig.2 shows the distorted current waveform without using filter. From distorted current waveform 5th & 7th order harmonics are found by using FFT analysis which is shown in Fig.3. Here we are choosing a fundamental frequency is 50 hertz. As shown in fig 3 bar are display on 250 and 350 hertz frequency. It means 5th & 7th order harmonics are present in our system.

Fig no.4 shows the series active and shunt passive filter topology, in that the PWM voltage source inverter consists of an Insulated Gate Bipolar Transistor (IGBT) bridge. With 200V dc supply are connected in DC side. An ripple filter has been included to eliminate the high frequency components at the output of the inverter. This set is connected to the power system by means of three single-phase transformers with a turn ratio of 1:1. Also passive LC filter are connected in parallel with load to eliminate the 5th & 7th order harmonics. In this case if passive filter is not connected then current harmonics are not eliminated, and rest of the system only regulate the voltage or balance the voltage. Also a ripple filter is connected between the output of inverter and secondary winding of transformer. It is used to avoid induction of the high frequency ripple voltage generated by the PWM inverter switching pattern at the terminal of the primary winding of series transformer. In this way a voltage applied in series with power system corresponds to the component required to compensate the voltage unbalance and current harmonics. The ripple filter must be designed for the carrier frequency of PWM inverter [7]. The selection criteria to fix the ripple filter were, in the case of low frequency components, that the inverter output voltage be almost equal to voltage across capacitor. However, in the case of high-frequency components, the reduced voltage in must be higher than in the capacitor. Furthermore, inductor and capacitor values must be selected so as not to exceed the transformer burden.

Therefore, the following design criteria must be satisfied.

---X crf << X Lrf, to ensure that inverter output voltage drops
across at the switching frequency;

---X crf << Zs + Zf, to ensure that voltage divider is between
Lrf and Crf, where is the source impedance, the shunt passive filter, reflected by the secondary winding.

Calculate value of inductor and capacitor for switching frequency=20-kHz. Fig. No. 5 shows the current waveform of after using series active & shunt passive filter.

Fig No. 6 shows the Hybrid active power filter topology. Fig No. 7 shows the current waveform after using the hybrid active power filter which is becomes a purely sinusoidal. Fig no.8 shows the FFT analysis of after using the hybrid active power filter. In this case all harmonics are eliminated and total harmonic distortion is reduces up to 0.28%

7. Conclusion

Harmonic distortion is a main cause of power quality degradation. For elimination of harmonics active filters are used. Because there is some disadvantages of passive filter. Hybrid active power filter improve the compensation characteristic of passive filter. It eliminates the problems of using only a shunt passive filter. Also it improves the behavior of passive filter. It allows the use of active power filter in high power application at relatively low cost. Compensation characteristic of hybrid active power filter do not depend upon system impedance. It is achieve by using vectorial power theory control strategy. Also it reduces the Total harmonic distortion (THD) significantly.

8. References

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