IGBT implementation for time delay reduction and two leg VSIs in place of three leg VSIs in a series active filter for component scaling

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ABSTRACT
Power quality issues such voltage sags, interruptions, voltage swells, and harmonics have been brought on by the presence of power electronic equipment in the power system. Harmonics are the most problematic of these issues for consumers because they lead to a variety of power quality issues, including the breakdown of all electrical equipment connected to the supply. Connecting a device called a filter to the electrical system will solve this issue. The most effective filtering out of harmonics among all the current filters is the active power filter. The simulation model and performance of a three-phase, three-leg voltage source inverter (VSI)-based series active power filter will be presented in this study. This essay also features the work of three phase two leg VSI based series active power filter. The time delay performance of series active power filter using IGBTs and thyristor are also presented in this paper. Both three leg and two leg based active series filters are effective at reducing the distortion level of source current. IGBTs are also effective in reducing time delay between source and load voltage.
Keywords: Harmonic, Total Harmonic Distortion, Active Power Filter, Hysteresis Controller, Pulse width modulation, Insulated Gate Bipolar Transistor. Silicon Controlled Thyristor or simply thyristor, Voltage Source Inverter, Fast Fourier Transform

INTRODUCTION

Power quality is said to be poor when there is a change in supply voltage, current or frequency beyond permissible limits. It causes a range of power quality problems such as voltage sag, swell, inter harmonic, harmonics, interruption, blackout etc. The presence of harmonics in an electrical system is of grave concern as it causes malfunctioning of the electrical equipment connected to the supply, overheating of underground cables, insulation failure etc. Solution to this problem is to connect filters to remove harmonics from the supply. There are two types of filters: passive and active. Passive filters do selective filtering and suffer from other drawbacks such as ageing, resonance etc. To overcome these limitations, active power filters were introduced. Active power filters (APF) have proved to be most efficient in harmonic and reactive power compensation. APFs inject harmonics into the supply at the point of common coupling. The harmonics produced by APF are the same as produced by loads but displaced by 180 degrees. Thus, it cancels out the effect of the harmonic generated by loads smoothening the supply waveform.

LITERATURE REVIEW

Non-linear loads are essential parts of the power system. The quantity of switching components has dramatically increased as a result of advancements in the field of power electronics. These factors worsen power quality, raise losses, and distort supply waveforms [1]. Unreliable power results in decreased output, equipment damage, and an increase in power losses, which interferes with communication lines. In the past, passive filters were employed to reduce the distortion brought on by harmonic current in industrial power systems. However, these devices have a number of shortcomings, one of which being their reliance on system impedance. To ward off such drawbacks active power filters are now used. Shunt APFs inject current harmonics into the supply system while as series APF inject voltage harmonics. This implies that shunt APF is used for harmonic current compensation while as series APF is used for harmonic voltage compensation[2].Active filters use power electronics switches to generate harmonic current that cancel the harmonic currents from the non-linear loads[3]. The series APF is capable of compensating for the dip and

rise in voltage [4]. Shunt APF is a well-known technology for eliminating power quality problems present in both three phase and three wire systems[5]. The combined operation of the shunt APF and the series APF decreases the overall harmonic distortion of the source current and load voltage[6].

METHODOLOGY

Total Harmonic distortion at the point of common coupling can be reduced by using the filters that can prevent currents of frequency above fundamental frequency from passing into the power distribution system. Filters are of two types: Passive filters and Active filters. That filter which is made up of only passive elements is called passive filter. Unlike active filters, it does not consist of any energy source except for the signal. In most of the cases, it consists of one of combination of only four basic passive elements: resistor, capacitor, inductor and transformer. Its major drawbacks are inability to compensate for load variations and introduction of system resonance. Active filter, on the other hand, is a power electronic converter that is specifically designed to inject harmonics into the system. Depending on number of phases, active filters are categorised as single phase or three phase. Single phase filters compensate for poor power quality problems caused by single phase loads while as three phase filters are used with high power non-linear loads. Active filters are can be series type, shunt type or series-shunt type(UPQC). These filters can be combined with passive filters to create hybrid filters. When an active filter is connected in series between the source and the non-linear load, it is called series active filter.

In this work a series active filter is added to a three phase electrical system to reduce total harmonic distortion of source current and IGBTs are used to reduce time delay. The basic compensation principle of series active power filter is shown in Fig 1
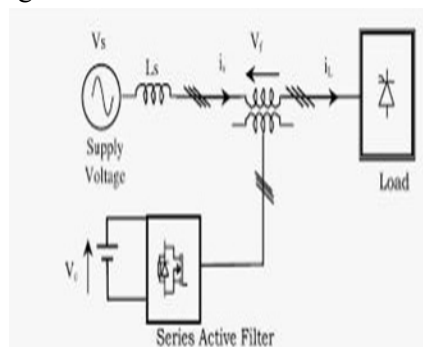

Fig 1:Basic configuration of series APF

A controlled voltage source inverter is used as series active power filter. The components of series active power filter are reference current generator, control circuit, voltage source inverter(VSI) and a transformer. Voltage source inverter changes dc signal into ac signal with variable amplitude and frequency Mid- point of each of the three legs is connected to each phase signal. It is then connected in series with source impedance through a transformer. A capacitor is used at the input side of the inverter to provide constant input to the VSI.

Reference generator is the harmonic extractor. Its job is to estimate the quantity of harmonics the filter should compensate for. It determines all the frequency components present in the current or voltage signal. Its output is the reference signal for controller circuit. Control circuit produces pulses in order to drive the inverter in such a way that it produces compensating signals similar to that produced by reference generator

SIMULATION AND RESULTS

In the simulation model depicted in Fig 2, a non-linear load is connected to a three phase sinusoidal source without the use of any filter.
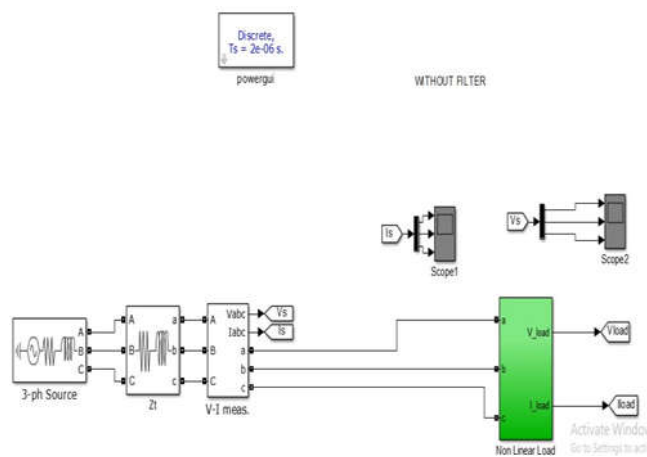
Fig 2: Simulation of three phase source connected to a non-linear load without filter.

To validate the proposed work, a series active filter has been modelled in MATLAB Simulink as shown in Fig 3
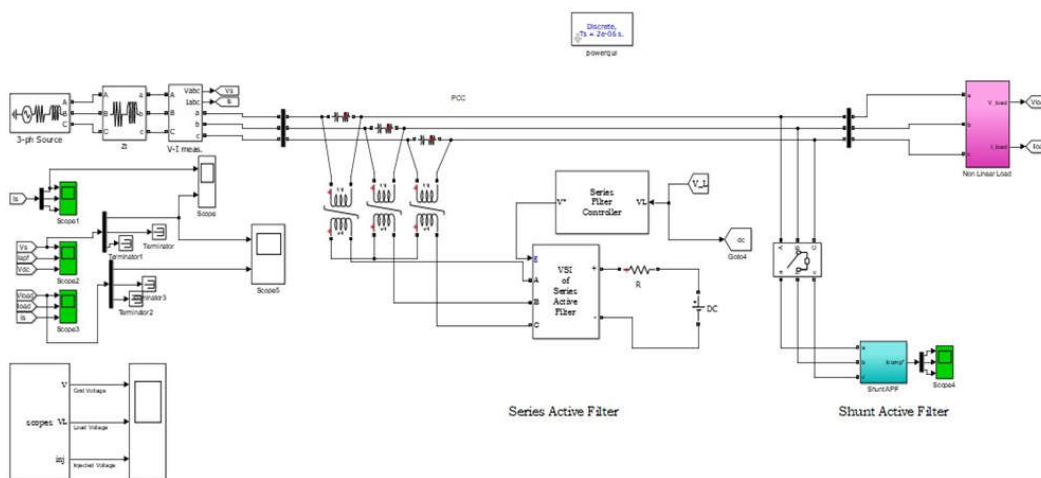

Fig 3: Simulation of series active power filter in MATLAB SIMULINK

Thyristors and IGBTs are used in voltage source inverter as power switches .Simulation is shown in Fig 4 and Fig 5respectively.
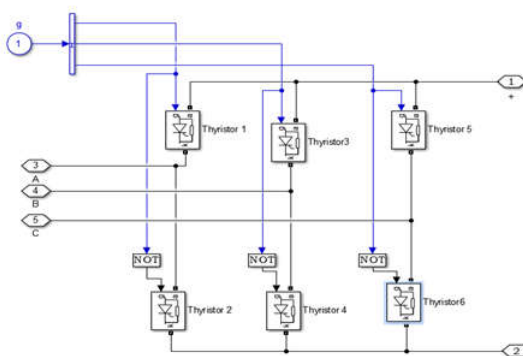

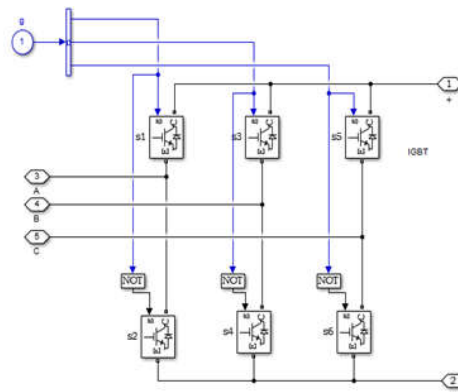Fig 4: Simulation of thyristor based three leg voltage source inverter

Fig 5: Simulation of IGBT based three leg voltage source inverter

The simulation results of Fig 6 show that with thyristor there is a time delay between source voltage and load voltage while as with IGBTs there isn't any time delay. It is clearly shown in Fig 7 that with IGBTs the peaks of source and load voltages overlap meaning their peaks occur at the same time while as Fig 6 shows that with thyristor load voltage lags source voltage by fraction of seconds and thus is a bit delayed.
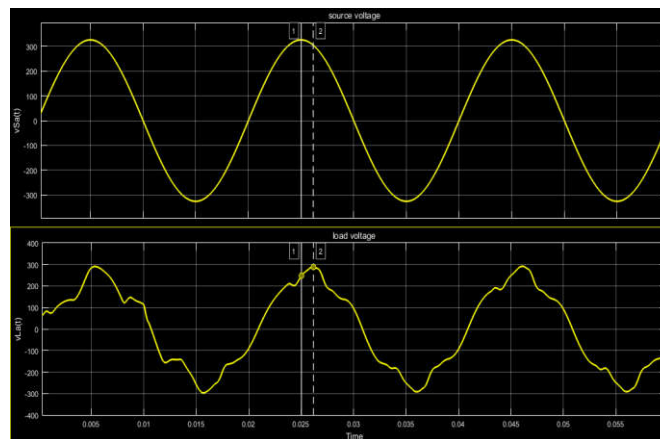

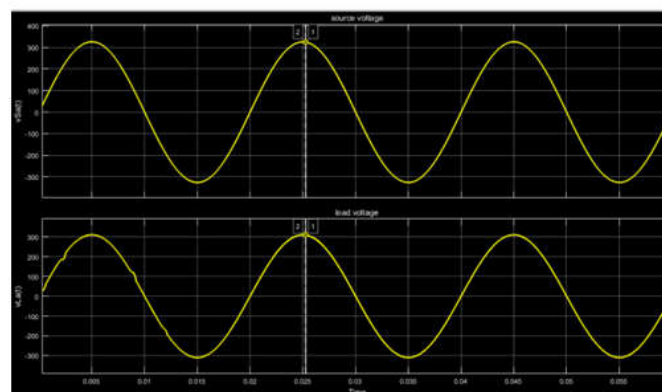Fig 6: Time delay using thyristor

Fig 7: Time delay using IGBT

As non-linear loads are a major source of harmonics these distort the source current waveform. It is clear from Fig 8 thatwithout the use of filters source current is no longer sinusoidal.
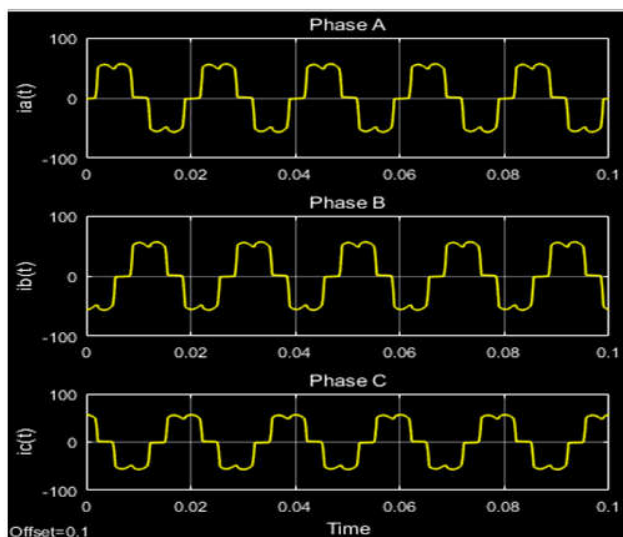
Fig 8: Source current without any filters.

FFT analysis shown in Fig 9 depict that THD level in current waveform in this case is 27.03%. This distorted waveformcauses power quality problems.
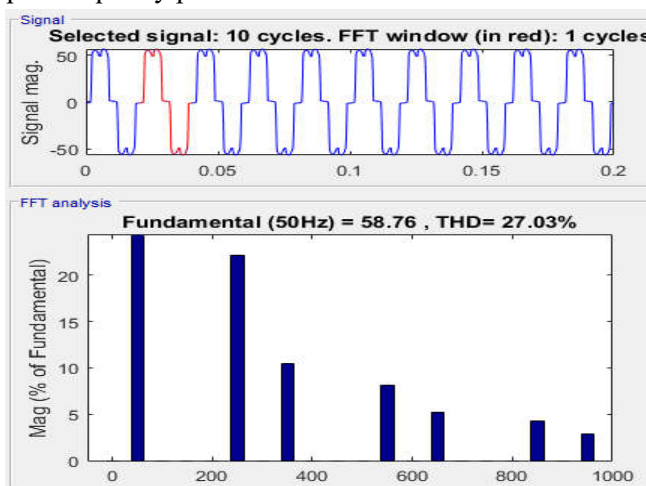

Fig 9: Fast Fourier Transform (FFT) analysis of source current without any filter

To eliminate the distortion a series active power filter is added to this system. Two cases are presented in this paper. In first case, three phase three leg voltage source inverter(VSI) is used in series active filter. The source current waveform obtained using three phase three leg VSI based series active is depicted in Fig 10.
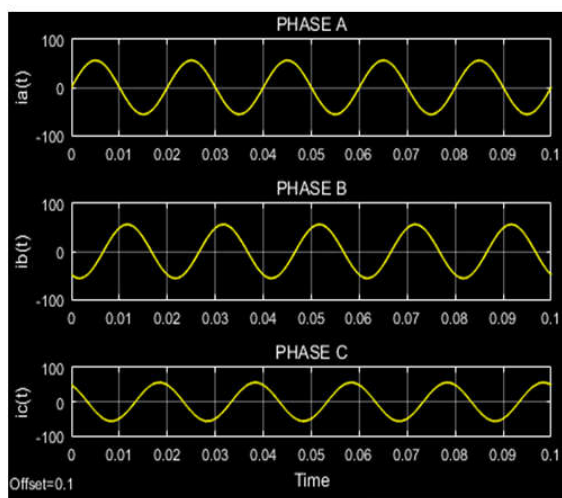

Fig 10: Source current waveform obtained by adding three phase three leg VSI based series active filterFFT analysis shown in Fig 11 depict that THD level in current waveform in this case is 3.34%.
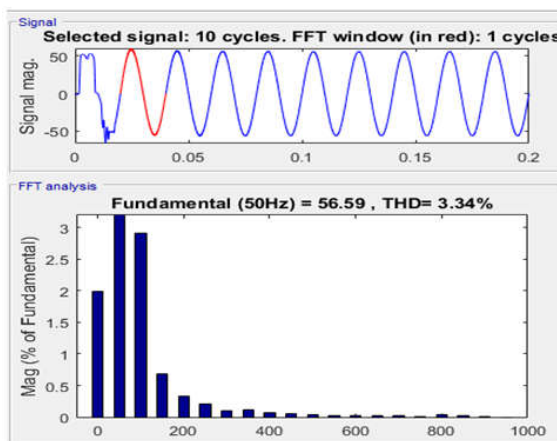
Fig 11: FFT analysis of source current waveform obtained by adding three phase three leg VSI based series active filter

In second case, three phase three leg voltage source inverter is replaced with three phase two leg voltage source inverter.

Fig 12 shows the implementation of three phase two leg inverter in Simulink.
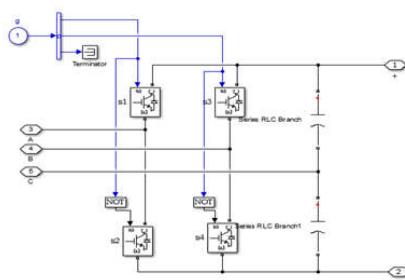

Fig 12: Simulation of three phase Two leg voltage source inverter(VSI)

Source current waveform that was obtained using three phase two leg VSI based series active filter is depicted in Fig 13
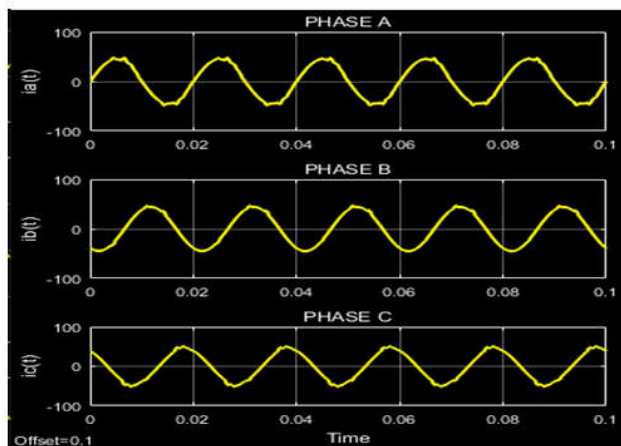

Fig 13: Source current waveform obtained by adding three phase two leg VSI based series active filterFFT analysis shown in Fig 14 depict that THD level in current waveform in this case is 6.04%.
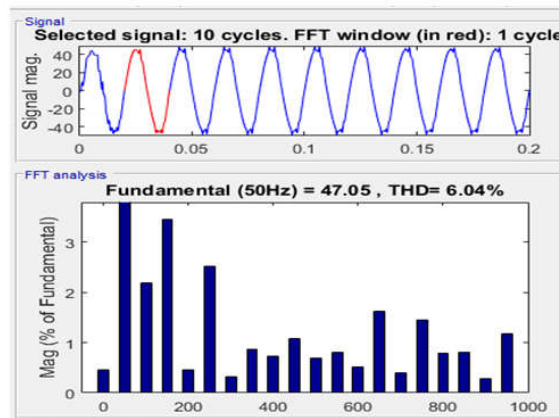
Fig 14: FFT analysis of source current waveform obtained by adding three phase two leg based VSI series active filter Although THD obtained in case of two leg voltage source inverter is a bit higher than that obtained using three leg voltage source inverter but it is preferred to be used in situations where economic constrains are present. It is because the number of power electronic switches and their gate circuitry has been reduced from six to four which reduces the overall cost of the filter.

CONCLUSION

Passive filters can easily be replaced by active power filters. Where the magnitude and angle of the harmonic order change, active power filters are used. By generating equal amplitudes of opposite phase, the active filters cancel harmonics produced by non-linear components and replace the current wave from non-linear loads, minimizing the effects of harmonic current.

In MATLAB Simulink, the concept outlined in this paper was put into practice. Isolated gate bipolar transistors were successfully used to reduce time delays (IGBTs). The source and load voltage peaks for IGBTs happen simultaneously. A series active filter was used to successfully compensate for harmonic current. Total harmonic reduction (THD) calculation of source current using Fast Fourier Transform (FFT) analysis show a significant reduction in THD (from 27.03 % to 3.34% in case of three phase three leg VSI based series filter and to 6.04% in case of three phase two leg VSI based series filter). It is preferred to use two leg VSI based active series filter in cases where budgetary constraints are present.

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