Modelling and Simulation of Shunt Active Filter for Harmonic Reduction

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***Abstract*—In this paper we have used Active filters to improve the quality of the power used in the load side of the power system. This consists of two parts,**

1) **Simulation in which we are adopting the method of hysteresis control method to reduce the third harmonic at the load side.**
2) **Using a model of MOSFET and gate drivers to minimize the third harmonics at the load side.**

The losses from the harmonics at the load side will be high due to usage of the nonlinear loads and due to this the power factor will increases which affect the cost per unit. By applying any of the above method we can minimize the losses as the third harmonics will be too small in this method. The source we are using is less and also the third harmonics reduces to 5% and below. But it can only be applied to small sources and small equipment as it cannot with stand high currents.

Index Terms- Active filters, nonlinear loads, third harmonics.

I. INTRODUCTION

Power quality improvement is the major research topic in modern power distribution system. This is because of the losses involved in it and which can be overcome by few methods. About twenty years ago most of the loads used by the industries and consumers were passive and linear in nature, with a lesser number of non-linear loads. Due to the drastic growth in the technology of power electronics the usage of non linear loads increased due to this rapid growth of power quality management was also required. Non-linear loads draw non-sinusoidal currents, from ac mains and cause a type of voltage and current distortion called a Harmonics.

The voltage source inverter (VSI),based shunt active power filter has been used in recent years and recognized as a viable solution for the harmonic problems .which is simple to apply a method called “hysteresis current controller” method. There are other methods also to control the harmonics like using synchronous detection method

II. PROBLEM DEFINITION

Harmonics

Harmonics are nothing but wave with some frequency. All harmonics are periodic at the fundamental frequency and sum of the harmonics is also periodic at same frequency. These harmonics increases the heating effect in the conductors and may also affect the motors by misfiring invariable speed drives. Mainly the third harmonics produced has the major contribution to the distortion in the main supply.

To improve power quality in power system by reducing harmonics using shunt active power filters. Harmonics refers to an integral multiple of fundamental frequency. The major cause of harmonics is due to energy conversion techniques and control involved in power electronic devices such as rectifier, chopper, cycloconverters etc. Harmonics in power system arises due to wide use of nonlinear loads which produces, distorted voltage waveforms, equipment heating, excessive neutral currents, and low power factor etc.

To minimize the effect of Harmonics in power system two types of filters are used Passive filter and Active filter.

The performance of “shunt active power filter” is designed to improve such harmonics defects and also minimize the cost of electricity per unit which can increase due to drastic changes in power factor due to harmonics.

III. OBJECTIVES

- To discuss effect of harmonics arising due to nonlinear load.
- To study different control strategies already proposed for modeling of 3 phase shunt active power filter.
- To model and simulate single phase active power filter in MATLAB/SIMULINK Environment.
- Design of hysteresis current controller.
- To develop a model of power quality improvement using shunt active filters and by controlling it through gate driver pulses.

IV. METHODOLOGY

There are two types of filters which can be used to compensate the harmonics those are Active power filters and passive power filters.

Passive power filter:

The passive filter requires resistors, inductors, and capacitors and they do not depend upon any type of external power source. By proper selection of *L* and *C*, they are tuned to bypass a particular harmonic component. Multiple numbers of passive filters are connected in parallel to nullify higher order of harmonics Though passive filters were widely used as harmonic improvement and reactive power compensation devices in the power distribution system, their performances is not satisfactory due to following reasons:

- A separate filter is necessary for each harmonic frequency.
- Passive filter must be designed in considering with current provided by nonlinear load.
- Source impedance affects the compensation characteristics of *LC* filters.
- When the content of harmonics in the AC line increases, the filter will be loaded.
- Frequency variation of AC source and tolerances in the filter components will affect the compensation characteristics of *LC* filters. If the system frequency varies in wide range, components required for attaining tuned frequency become impracticable.

So basically, we use active power filter as are of different types to eliminate harmonics and compensate reactive power in the power system.

Active power filters (APF) are constructed using both passive and active elements. For their operation, they need external power source. Presently available APFs are basically of pulse width modulated inverters (current source or voltage source).Current fed PWM inverter act as non-sinusoidal current source to cancel out the harmonic current produced by nonlinear load. Current fed PWM based APF's use is limited to low power application. Voltage source inverter (VSI) is the most popular one for implementing active power filtering. VSI based APFs have high power rating and lower switching frequency. They are connected to AC mains through coupling reactors.

Active power filter can be classified into three categories as per their connection to the PCC, namely

1. Shunt active power filter
2. Series active power filter
3. Hybrid active power filter

And mainly we are using Shunt Active Filter.

Shunt Active Power Filter

SAPFs are widely used in the power system to compensate reactive power and current harmonics. Shunt active power filter compensate current harmonic by injecting complementary current that of produced by non-linear load. By the use of proper control scheme, APF can also improve system power factor. Thus, by the effect of active power filter, voltage sources see the nonlinear load simply as resistor.

Synchronous Detection Method

Synchronous theory can work efficiently under both balanced and unbalance condition. Current is distributed equally among three phases, to estimate the three-phase compensating current to be provided by the active filter. Two assumptions are taken into consideration while calculating three phase reference currents i.e. Source voltage is not distorted and Peak magnitude of source currents are balanced after compensation

Hysteresis Current Controller

The hysteresis band current controller is used to generate pulses for the switching pattern of the inverter. There are numerous current control methods, but quick current controllability and easy implementation make hysteresis current control method much more superior than other current control methods. The properties possessed by hysteresis band current controllers are robustness, excellent dynamics and fastest control with minimum hardware.

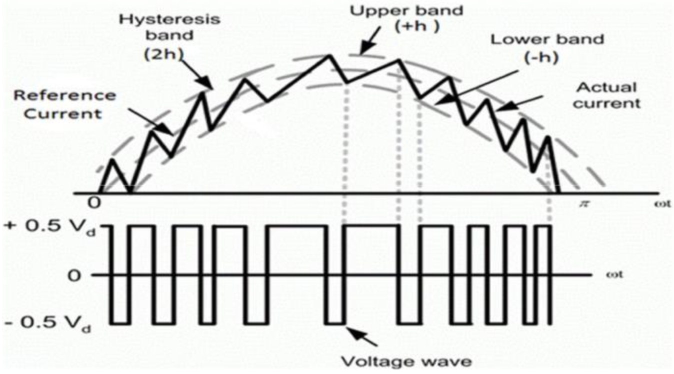

FIG 4.1 HYSTERSIS CONTROLLER

V SIMULATION IN MATLAB

Simulink model with passive elements use of single phase Active power filter(APF) passive elements is build and is simulated in MATLAB/Simulink environment various parameter used for simulation and when the model is run without connecting the APF to PCC power circuit.

The THD observed were around 20%.

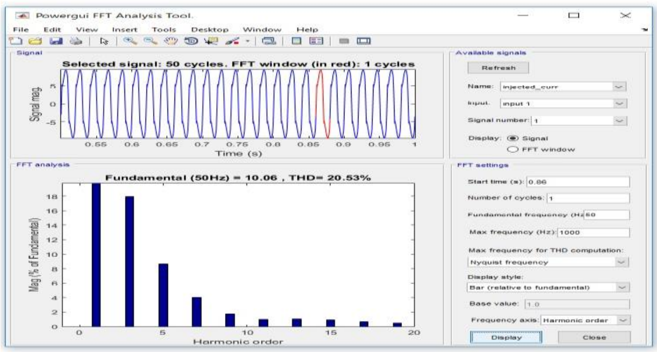

Fig 4.2 FFT ANALYSIS WITHOUT CONTROLLER

When the APF is connected to the circuit then there will be a large inrush of current which is minimized by the DC link capacitor. The controller used is system current controlling the principle is explained by graph when the current should not run the upper or lower bend it should be within reference current.

The THD observed in the single phase APF is shown at the source current and the net current it is referred. To 5% to 2%.When compare to both the THD is reduced by 2-5% is reduced.

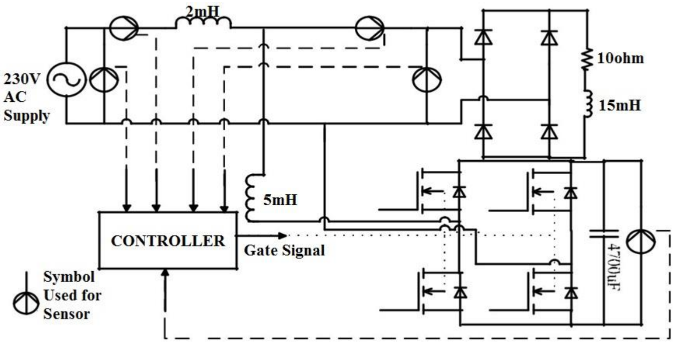

FIG 4.3 BLOCK DIAGRAM OF SIMULATION

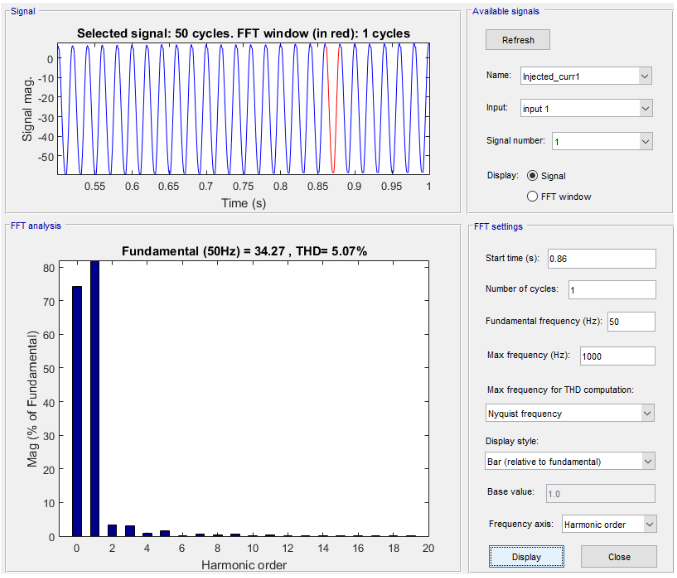

Fig 4.4 FFT ANALYSIS NEAR LOAD

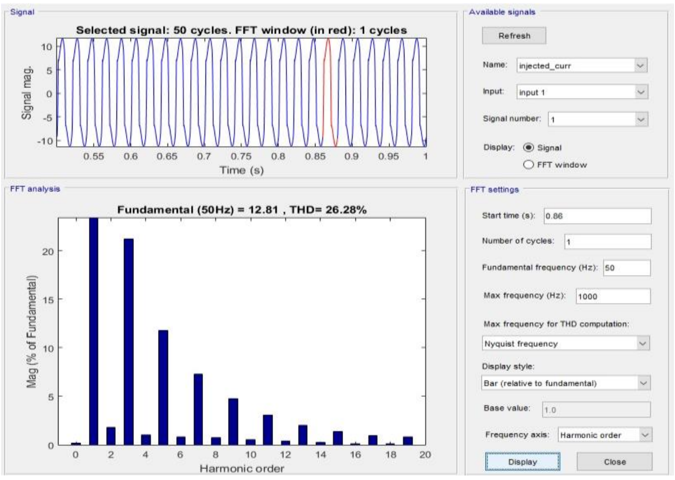

Fig 4.5 FFT ANALYSIS OF INJECTED CURRENT

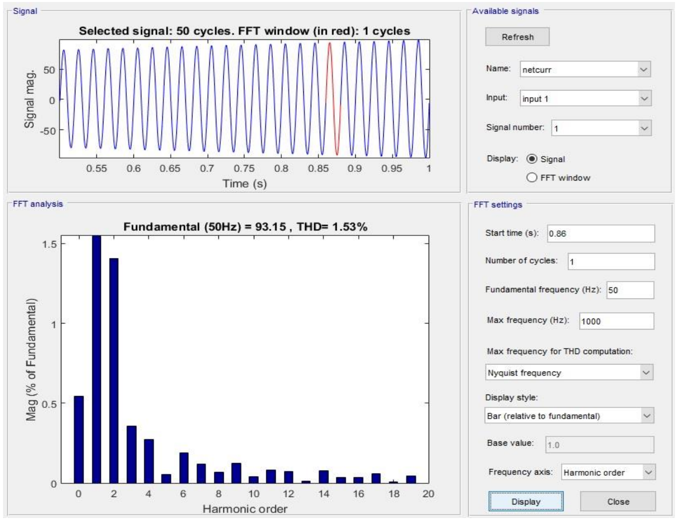

Fig 4.6 FFT ANALYSIS OF NET CURRENT WITH FILTER

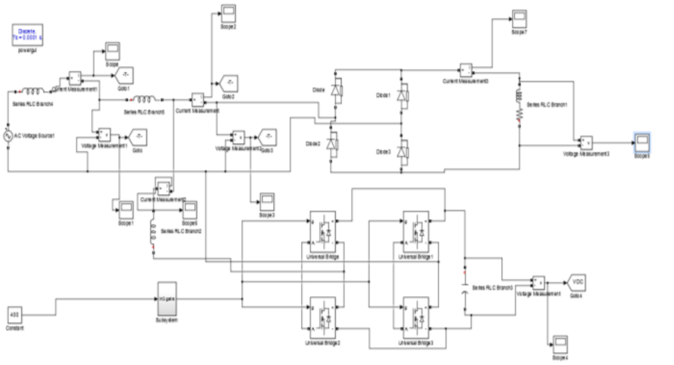

Fig 4.7 MATLAB SIMULATION BLOCK

This is the fig showing the MATLAB simulation block which contains bridge rectifier, MOSFET based VSI and a hysteresis controller as subsystem which control the triggering pulses of the VSI.

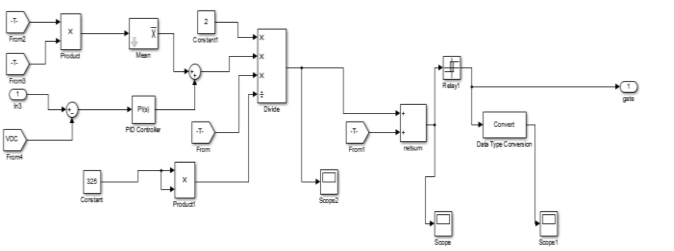

Fig 4.8 MATLAB SIMULATION OF SHUNT ACTIVE FILTER

This is the block diagram showing the controller part which is called as hysteresis current controller it also contains PI controller which has definite values in it.

Table 1. IEEE Std 519-1992 Harmonic Voltage Limits
Voltage Distortion Limits

Bus Voltage at PCC	Individual Voltage Distortion (%)	Total Voltage Distortion THD (%)
69 kV and below	3.0	5.0
69.001 kV through 161kV	1.5	2.5
161.001 kV and above	1.0	1.5

NOTE : High-voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

Table 4.1 IEEE standards of harmonics

This is the table showing the IEEE standards of the harmonic distortion which should be in the limit to maintain the power quality in the system. And in this paper we are getting a net harmonics around 1% so this method improves the quality of the system by reducing the harmonics to around 1%. The total net distortion is around 1% and near the load it is around 5% even there the percentage is maintained at 5% so the distortion is well managed.

THD without active filter in %	THD with active filter in %	THD injected in %	Overall THD in the system in %
20.53%	5.07%	26.28%	1.53%

Table 4.2 THD values of the system

Hardware

A model of the power quality improvement is done which reduces the harmonics at the load side of the current and improves the power quality which in turn gives a quality power factor which keeps the equipment in proper condition and helps to reduce the cost of the electricity per unit. The model is same as the simulation but the controlling method is changed as because the hysteresis control method is bit costly. So we have used gate pulses which give specific pulses and control the injected current. The supply is given to bridge rectifier and then to the load. The MOSFET based VSI is present as part of compensator which is a inverter to oppose the harmonics in the load side given to supply and gate driver of MOSFET which controls the signals to the VSI and a DC link capacitor is also given.

For the gate pulses TLP 250 IC is used. It is MOSFET based gate pulse driver IC it helps to give the specific gate pulses to the inverter which in turns produce the specific pulses to trigger and compensate the main supply. And for the measurement purpose there are two types those are current sensor and voltage sensor in this project there are two current sensors and one sensor of voltage.

Advantages

- DC based loads.
- TRIAC based controller for heating applications.
- High power factor pre regulator.
- UPS based applications

VI. CONCLUSION

The power quality improvement was done in simulation and in hardware which reduces the harmonics mainly third harmonic which is the major concern as it increases the effect of harmonics drastically. And by both hysteresis and by giving gate pulses method we can improve the quality of the power and maintain same quality also

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