A Novel to Reduce Harmonics using Conventional Control of Active Shunt Power Filter

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Abstract

The aim of this work is to explain the effects of Harmonics in the Power System and steps to reduce the effects of Harmonics. This thesis will also explain how Harmonic distortion is one of the critical problems associated with power quality and creates several disturbances to the Power System. It includes the Harmonic reduction techniques to improve the power quality and it also includes the simulation for the same. In this work an effective and efficient method of minimization of the harmonics is done using the concept of PI logic controller and results has been compared with the conventional power circuit response.
Keywords: PI control, Active Power Filter, Total Harmonics Reduction, FFT, Harmonic Compensation

I. INTRODUCTION

In recent years with the development of modern power electronics devices which particularly consists of non linear loads ie load which takes current not proportional with the voltage. These loads create current distortion and voltage distortion at the (PCC) point of common coupling. For this purpose Active shunt power filter is used which is based on fuzzy logic controller and thus analyze the Total harmonics distortion (THD) produced in the line current. The objective is done by developing a control system for generation of the waveform which is in opposite phase with the distortion and nullifies the harmonic components of waveform

II. PROBLEM AREAS

Modern power electronic devices are main contributor of the harmonic generation. Harmonic pollution of the utility supply is a growing concern across the high power consumers like Datacenters, Process and Automation industry, Hospitals, Commercial buildings, Retail malls etc. The high harmonic distortion affects the power usage, reduces productivity, components life & can even damage the equipment's. They also affect performance of Transformers, cables and switchgears and causes great drain of the power supply.

Presence of harmonics even causes heating of cables, transformers and raising the neutral current beyond the cable capacity etc. In order to get rid of this problem there were devices like Digital Active Power filter which dynamically eliminates the harmonics from the power sources and improves the power factor nearer to unity

Although a complete power quality survey is beyond the scope of the normal infrared inspection, the load data for thermal problems during your survey will indicate whether harmonic distortion exists in the circuit supplying the defective component.

III. TYPES OF HARMONIC FILTER

Harmonic filters are used to eliminate the harmonic distortion caused by nonlinear loads. Specifically, harmonic filters are designed to attenuate or in some filters eliminate the potentially dangerous effects of harmonic currents active within the power distribution system. Filters can be designed to trap these currents and, through the use of a series of capacitors, coils, and resistors, shunt them to ground. A filter may contain several of these elements, each designed to compensate a particular frequency or an array of frequencies.

A. Passive Filter:

Passive filters are generally constructed from passive elements such as resistances, inductances, and capacitances. The values of the elements of the filter circuit are designed to produce the required impedance pattern. There are many types of passive filters, the most common ones are single-tuned filters and high-pass filters. This type of filter removes the harmonics by providing a very low impedance path to the ground for harmonic signals.

- Shunt passive filter
- Series passive filter
- Hybrid passive filter

B. Active Filter:

The active filter concept uses power electronic equipment to produce harmonic current components that cancel the harmonic current components that cancel the harmonic current components from the nonlinear loads. Active filters have the advantage of being able to compensate for harmonic without fundamental frequency reactive power concerns. This means that the rating of the active power can be less than a comparable passive filter for the same non-linear load and the active filter will not introduce system resonances that can move a harmonic problem from one frequency to another.

- Shunt active filter
- Series active filter
- Hybrid active filter

IV. BASIC CONFIGURATION OF APF

The main purpose of active power filter is to compensate the harmonics produced due to non linear loads. It mainly consists of dc link capacitor which is connected in parallel with the PWM bridge inverter .The switching frequency of this bridge inverter decides the maximum frequency that the inverter will produce. The main objective is to control the switching of the bridge converter by monitoring the voltage across the dc link capacitor

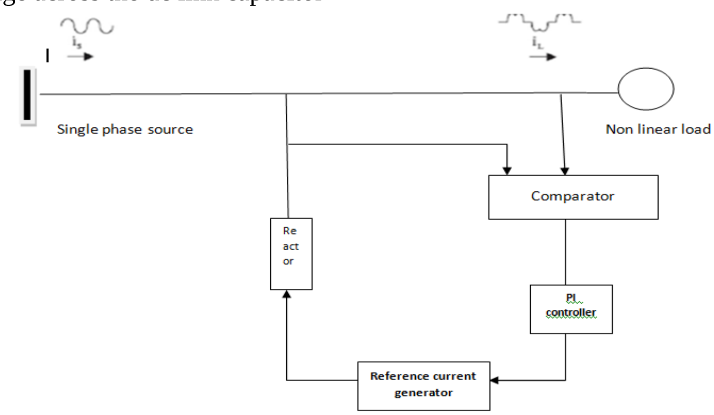

Fig. 1: Basic Configuration of APF

V. PI CONTROL ALGORITHM

The PI control scheme involves regulation of the dc bus to set the amplitude of reference current for harmonic and reactive power compensation. Assuming no power losses in the compensator, the dc-link voltage remains constant if no real power is drawn from it. However, practically, there are switching losses in the APF that increase with the increase in the reactive power demand of the load. These losses are supplied by the capacitor, and its voltage drops. The capacitor also has to supply active power during transient states when the real-power demand of the load increases. Thus, in either case, the capacitor voltage drops. Similarly, the capacitor voltage will increase if the reactive/real power demand of the load decreases. Hence, by monitoring the capacitor voltage, the real power supplied by the APF can be estimated and the amplitude of the fundamental active component of the supply current was estimated indirectly using the real-power balance theory. The control is on the supply current directly. Only one sensor is required to sense the supply current and there is no delay in the compensation process. A PI control algorithm is used to regulate the dc link voltage of the shunt APF. This method is preferred because the reference current is generated without calculating either the load current harmonics or the load reactive power. This results in an instantaneous compensation process and the associated hardware is simple to implement, thereby increasing system reliability.

VI. HARMONIC DETECTION AND EXTRACTION

A shunt active filter acts as a controllable harmonic current source. In principle, harmonic compensation is achieved when the current source is commanded to inject harmonic currents of the same magnitude but opposite phase to the load harmonic currents. Before the inverter can subtly inject opposing harmonic currents into the power system, appropriate harmonic detection strategies must be implemented to efficiently sense and determine the harmonic current from the nonlinear load.

A. *Types of harmonic detection strategies*

There are 3 different types of harmonic detection strategies used to determine the current reference for the active filter. These are:

1) Measuring the load harmonic current to be compensated and using this as a reference command.
2) Measuring source harmonic current and controlling the filter to minimize it.
3) Measuring harmonic voltage at the active filter point of common coupling (PCC) and controlling the filter to minimize the voltage distortion.

VII. STRUCTURE OF APF

The control variables used by the PI control algorithm are the dc bus voltage, supply current and supply voltage. In the control scheme investigated here, a sample-and-hold circuit is used to take capacitor voltage samples at every 10 ms for a supply frequency of 50 Hz.

The error input to the PI controller and the amplitude of the supply current provided by the controller are thus made available at zero crossing only and the supply current is maintained constant for the entire period of one cycle. Hence, the correction action is achieved every half cycle. [1]The ripple in the capacitor is eliminated with this technique and there is no need to use a low pass filter. The dc capacitor voltage has to be maintained at more than twice the peak supply voltage for proper operation of the shunt APF system. This is taken as the reference dc-link voltage (Vref) and compared with the actual voltage of the capacitor (Vdc).

The resulting error Ve (n) at the nth sample instant is expressed as

$$Ve(n) = Vref(n) - Vdc(n) \tag{1}$$

The compared result is fed to a PI controller and the output of the PI controller is given by

$$Vo(n) = Vo(n-1) + Kp \{ Ve(n) - Ve(n-1) \} + Ki\, Vo(n) \tag{2}$$

Where Kp and Ki are proportional and integral gain constants of the voltage regulator. Vo(n-1) and Ve(n-1) are the output of the controller and voltage error at the (n-1)th sampling instant. This output Vo(n) of the controller is limited to a safe permissible value depending on the rating of the APF switches, and the reference supply current Is* for harmonic and reactive power compensation. The phase information is obtained by a unit amplitude sine wave derived from the mains voltage. The reference current so obtained is compared with the actual supply Is and fixed frequency PWM is used to generate the switching signals for the APF converter. The switch control applies +Vf or –Vf on the ac side, forcing the compensation current to track the reference current.

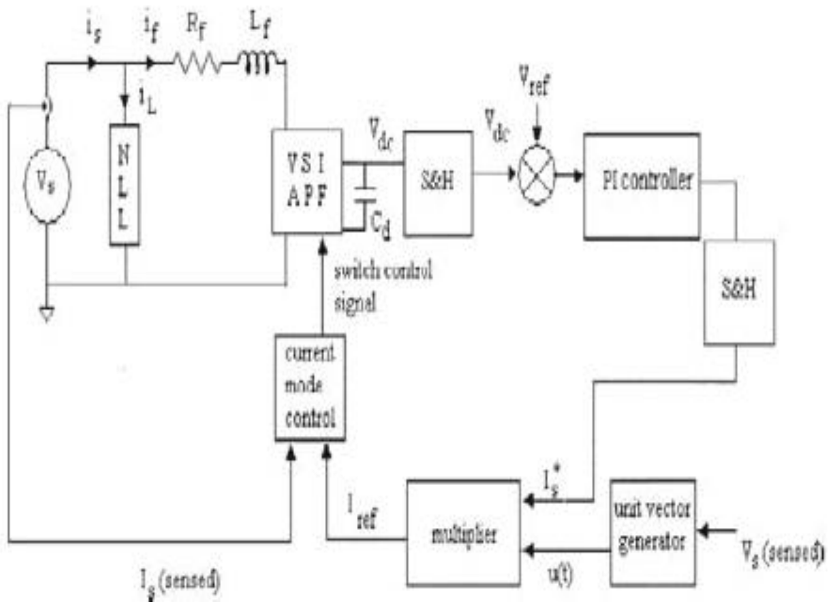

Fig 2: Block diagram of PI based APF

Table 1
Parameters

PARAMETER	*VALUE OF PARAMETER*
Inverter DC voltage	$V_{DC=}$ *650 V*
Inverter side inductance	*L= 2mH*
Capacitors	*C1= C2= 1100uF*

VIII. SIMULATION BLOCK

The SIMULINK model of active shunt power filter using PI control and the feedback control strategy is given

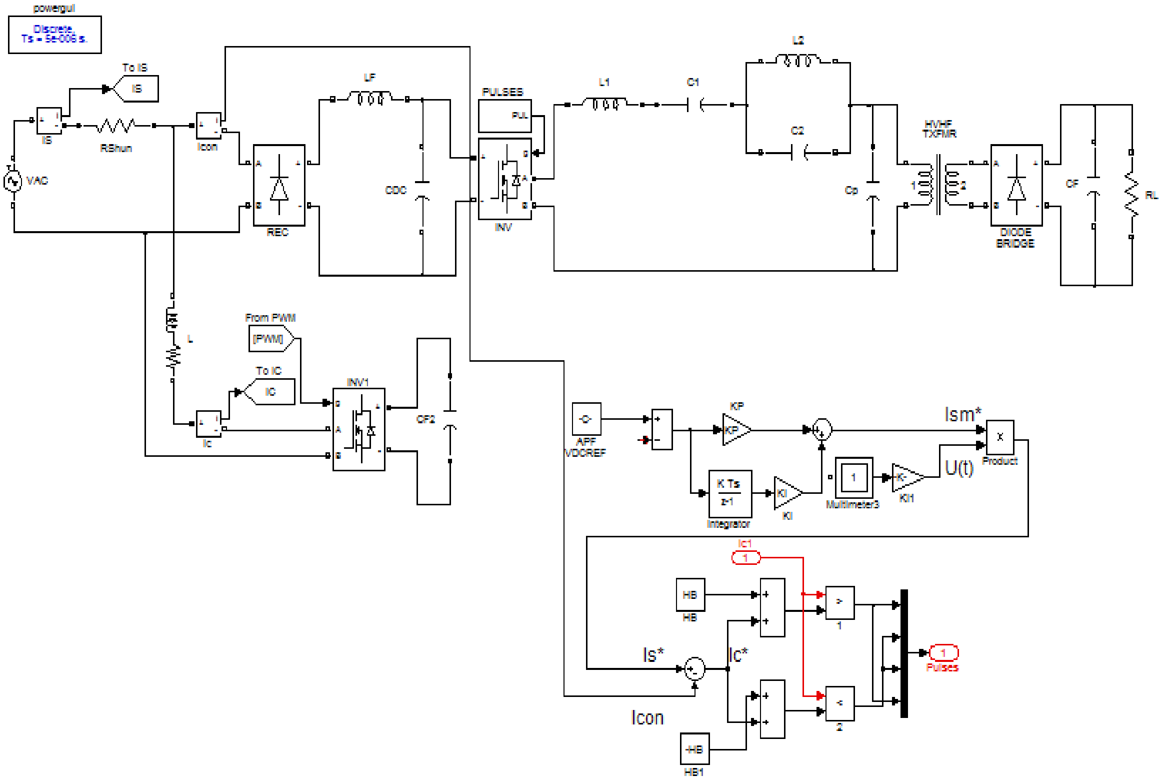

Fig. 3: Simulink Diagram of PI Active Filter

IX. SIMULATION RESULTS

A. Response of a Conventional Power Circuit

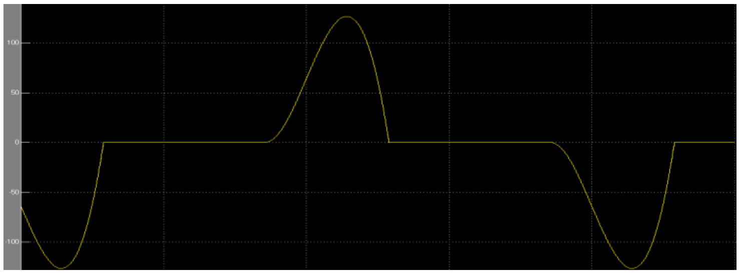

Fig. 5: Plot of source current Vs Time (Conventional Circuit)

B. Response of PI controller based APF

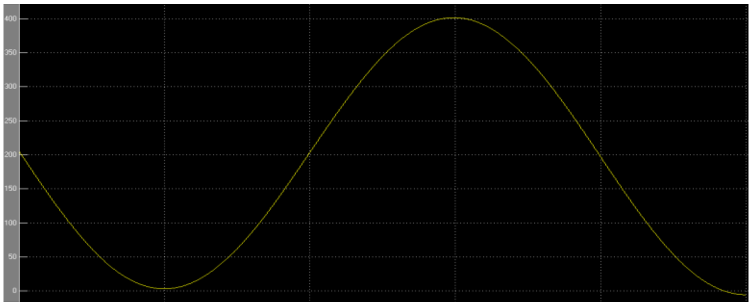

Fig. 6: Plot of source current Vs Time (Circuit)

C. FFT Analysis of Source current (Conventional power circuit)

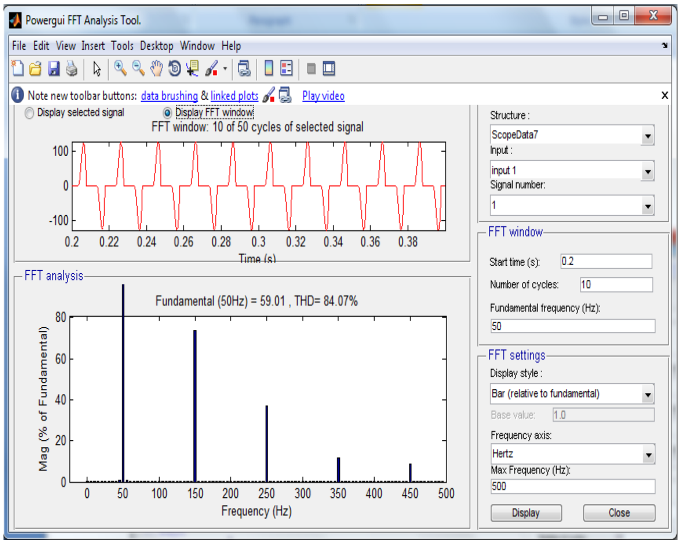

Fig 7: FFT Analysis of source current (Conventional power circuit)

D. FFT Analysis of Source current (Active power Filter)

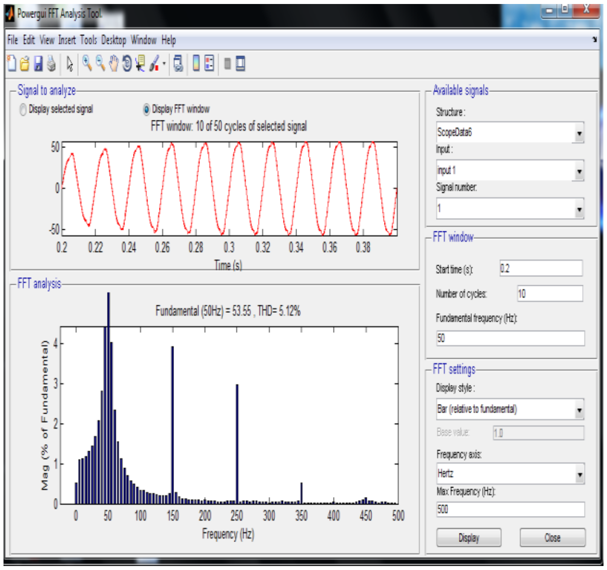

Fig 8: FFT Analysis of source current (Using PI controller)

Table - 2
Comparison between different control strategies

Parameters	Conventional power circuit	APF with PI controller
THD%	84.07%	5.74%

X. CONCLUSIONS

The Proposed method provides an efficient method of achieving better utilization and control of active power filter dealing with harmonic and reactive current compensation. Non-model based controllers designed around PI controller were applied to control the switching of the active power filter and provide much better response under varying load conditions and supply conditions. The control of an active power filter using PI controller is simulated in MATLAB 7/Simulink and the simulation results are compared with the conventional active filter based on instantaneous reactive power theory. The results show that the PI controller based shunt active filter has better performance which has improved harmonic profile and system performance.

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