



POWER QUALITY ENHANCEMENT IN DOMESTIC NON-LINEAR LOADS WITH SINGLE PHASE SHUNT APF

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Abstract

The realization of the standards and guidelines such as IEEE-519-1992/ IEC 61000 has attracted the attention of both utility and consumer to share their responsibilities, to keep the harmonics contamination within acceptable limits and provide quality power to the consumer. Harmonic mitigation can usually be done by the use of conventional active filters. Conventional passive filters, namely LC passive filters, possess the merits such as the simple structure, low cost and can compensate reactive power along with harmonics elimination. But PF based on resonant principle have many disadvantages, such as large size, fixed compensation, tuning problems etc. To overcome aforesaid problems, active filters came into picture to provide appropriate solution best suited to the compensation necessities under dynamic load conditions. This paper presents the study and simulation of Shunt Active Power Filter using hysteresis current controller for different non-linear loads.

Keywords: APF; THD; Harmonics;

1 INTRODUCTION

In a modern power system, increasing of loads and nonlinear equipments have been demanding the compensation of the disturbances caused for them[12]. These non-linear loads may cause poor power factor and high degree of harmonics. Active power filter (APF) can solve problems of harmonic and reactive power simultaneously. APFs consisting of voltage source inverters and a dc capacitor have been researched and developed for improving the power factor and stability of transmission systems. APF have the ability to adjust the amplitude of the synthesized ac voltage of the inverters by means of pulse width modulation or by control of the dc-link voltage, thus drawing either leading or lagging reactive power from the supply. APFs are an up-to-date solution to power quality problems. Shunt APF compensate the current harmonics and unbalance, together with power factor correction, and can be a much better solution than conventional approach (capacitors and passive filters). The simplest method of eliminating line current harmonics and improving the system power factor is to use passive LC filters. However, bulk passive components, series and parallel resonance and a fixed compensation characteristic are the main drawbacks of passive LC filters.

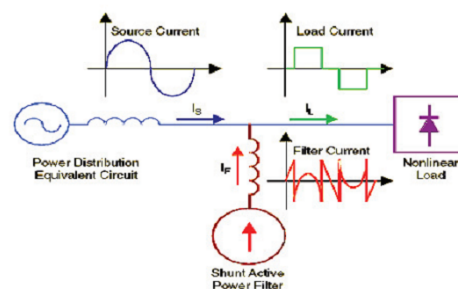


Figure 3.6 Basic Compensation Principles

2 CONTREOLLERS

Here using two control techniques

- a. Fuzzy logic controller

b. PI controller

A. Fuzzy logic controller

Fuzzy logic is all about the relative importance of precision. Fuzzy logic is a super set of Boolean logic. It adds degrees between absolute true and absolute false. Some propositions may be truer than others. In recent years, the number and variety of applications of Fuzzy Logic (FL) have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. To understand why use of Fuzzy Logic has grown, it must be first understood as what is meant by Fuzzy Logic.

Fuzzy logic can be viewed as an alternative form of input=output mapping. Consider the input premise, x , and a particular qualification of the input x represented by A_i . Additionally, the corresponding output, y , can be qualified by expression C_i . Thus, a fuzzy logic representation of the relationship between the input x and the output y could be described by the following:

R1: IF x is A_1 THEN y is C_1

R2: IF x is A_2 THEN y is C_2

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.....

R $_n$: IF x is A_n THEN y is C_n

where x is the input (state variable), y is the output of the system, A_i are the different fuzzy variables used to classify the input x and C_i are the different fuzzy variables used to classify the output y .

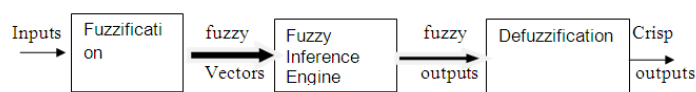
i.e. the set U for a particular system could be comprised of Negative Small (NS), Zero (ZE) and Positive Small (PS). Thus, in this case the set U is equal to the set of [NS, ZE, PS]. For the system described by the above equation, the linguistic universe for

the input x would be the set $U_x = \{A_1, A_2, \dots, A_n\}$. Similarly

TABLE 5.1 Fuzzy and linguistic variables

Linguistic Variables		Fuzzy Variables (Linguistic Qualifiers)	
Speed error	(SE)	Negative large	(NL)
Position error	(PE)	Zero	(ZE)
Acceleration	(AC)	Positive medium	(PM)
Derivative of position error	(DPE)	Positive very small	(PVS)
Speed	(SP)	Negative medium small	(NMS)

the linguistic universe for the output y would be the set $U_y = \{C_1, C_2, \dots, C_n\}$.



Fuzzy inference system basic block diagram

B. PID controller

PID (proportional integral derivative) control is one of the earlier control strategies. Its early implementation was in pneumatic devices, followed by vacuum and solid state analog electronics, before arriving at today's digital implementation of microprocessors. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. Since many control systems using PID control have proved satisfactory, it still has a wide range of applications in industrial control. PID control has been an active research topic for many years. Since many process plants controlled by PID controllers have similar dynamics it has been found possible to set satisfactory controller parameters from less plant information than a complete mathematical model. Fuzzy logic is a method of rule-based decision making used for expert systems and process control that emulates the rule-of-thumb thought process used by human beings. Due to these properties, fuzzy logic can be used to control a process that a human can control manually with expertise gained from experience. The linguistic

control rules that a human expert can describe in an intuitive and general manner can be directly translated to a rule base for a fuzzy logic controller

These equations show the relationships:

$$P \text{ (Proportional)} = 100/\text{gain}$$

$$I \text{ (Integral)} = 1/\text{reset (units of time)}$$

$$D \text{ (Derivative)} = \text{rate} = \text{pre-act (units of time)}$$

Depending on the manufacturer, integral or reset action is set in either time/repeat or repeat/time. One is just the reciprocal of the other. Note that manufacturers are not consistent and often use reset in units of time/repeat or integral in units of repeats/time. Derivative and rate are the same. Choosing the proper values for P, I, and D is known as PID Tuning.

3 SIMULATION RESULTS

A. *Simulation parameters*

The Performance of the Single-phase shunt active power filter for controlled rectifier as non-linear load is evaluated through MATLAB in order to program and test the system under non-linear load conditions. The system parameters values are

$$\text{Peak source voltage} = 324 \text{ V}$$

$$\text{System frequency (f)} = 50 \text{ Hz}$$

$$\text{DC-Link Capacitor} = 800$$

$$\text{Reference DC Voltage} = 650 \text{ V}$$

$$\text{Interface Inductor} = 5.12\text{mH and } 0.01\Omega$$

$$\text{Full bridge rectifier load} = 40 + j0.05\Omega$$

B. Simulation of APF using HCC for Rectifier as a non-linear load

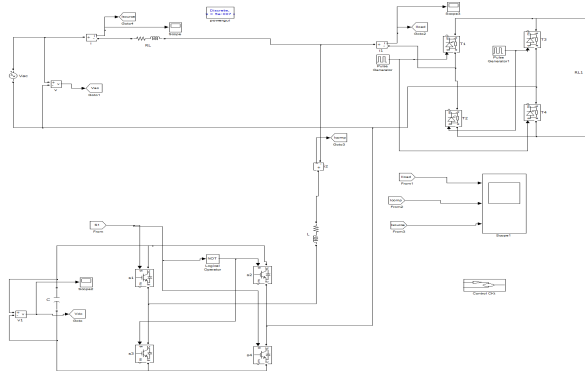


Figure 6.1 Simulink Model of APF using HCC for Rectifier as non-linear load

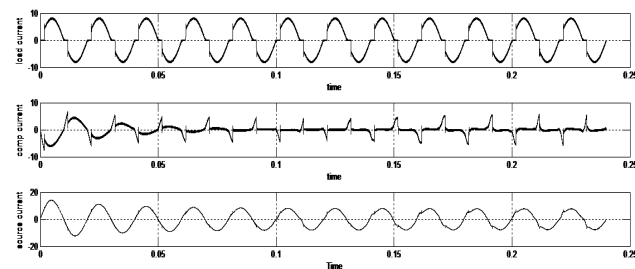
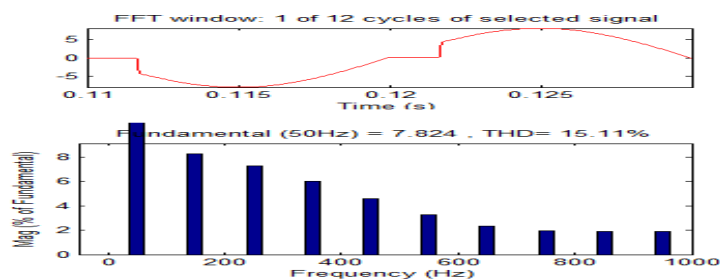
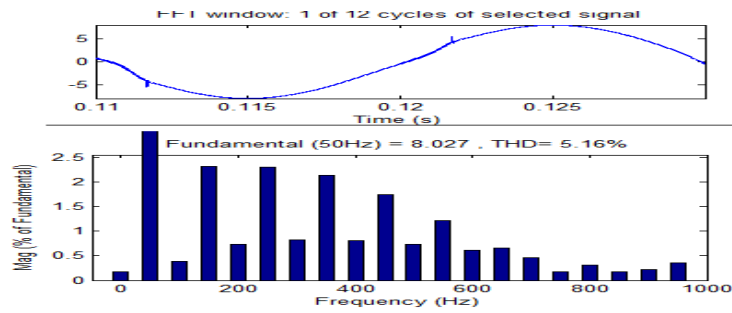


Figure 6.3 Load ,Compensation and Source Current for $\alpha = 30^\circ$



(a)Source Current without APF



(b)Source Current with APF
Figure 6.4 FFT Analysis of Source current for $\alpha = 30^\circ$

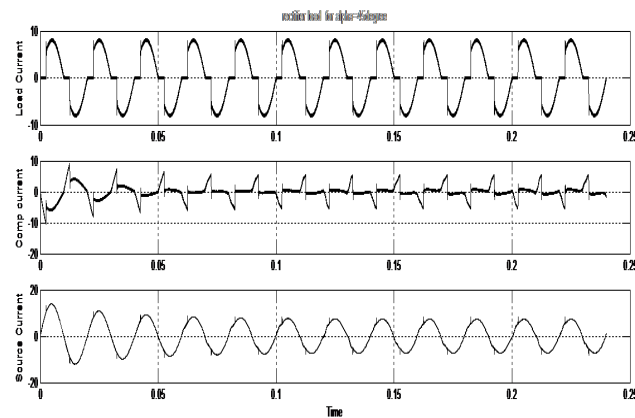
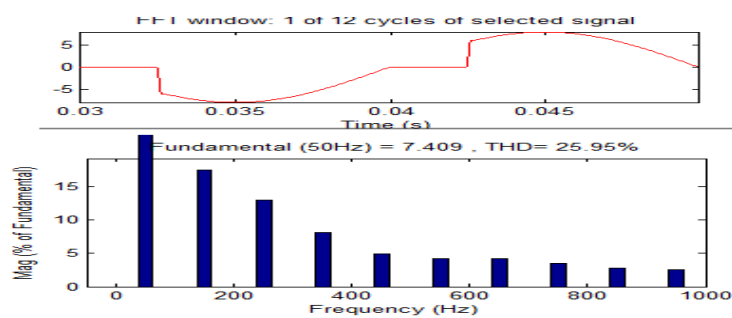
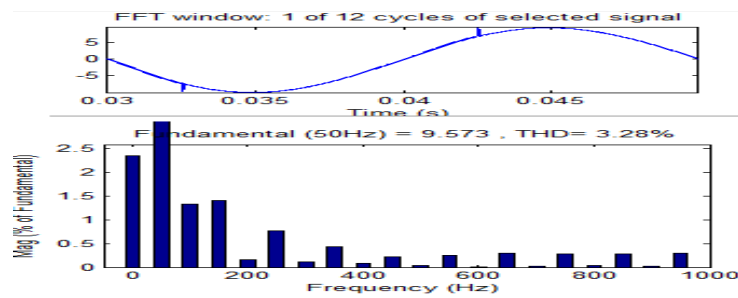


Figure 6.5 Load ,Compensation and Source Current for $\alpha=45^\circ$



(a)Source current without APF



(b)Source current with APF

Figure 6.6 FFT analysis of source current for $\alpha = 45^\circ$

C. Simulation of APF using HCC for different non-linear loads

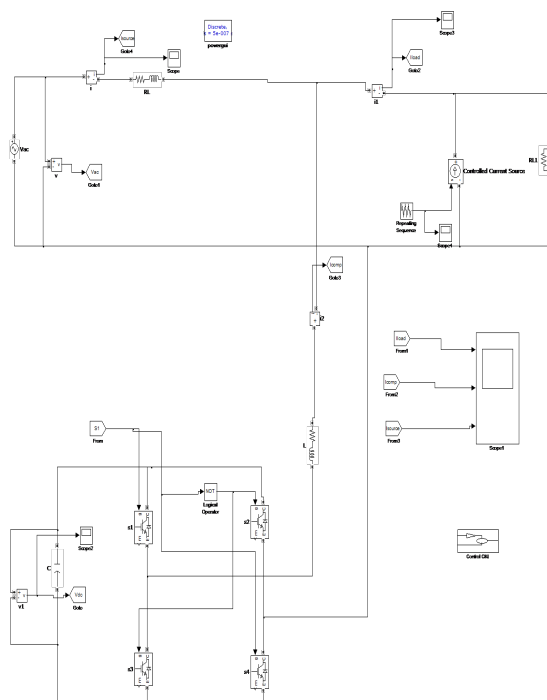


Figure 6.7 Simulink model of APF using HCC for different non-linear loads

a. CFL(Compact Fluorescent Light) as non-linear load

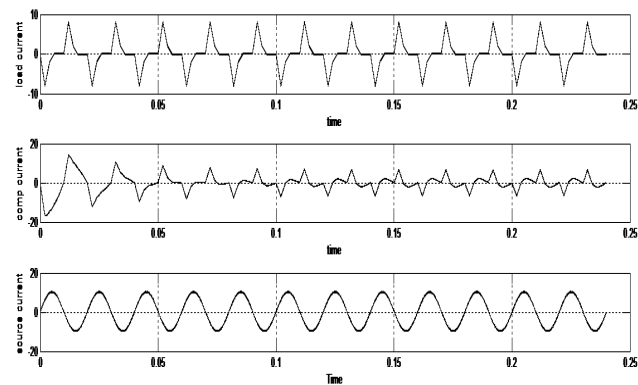
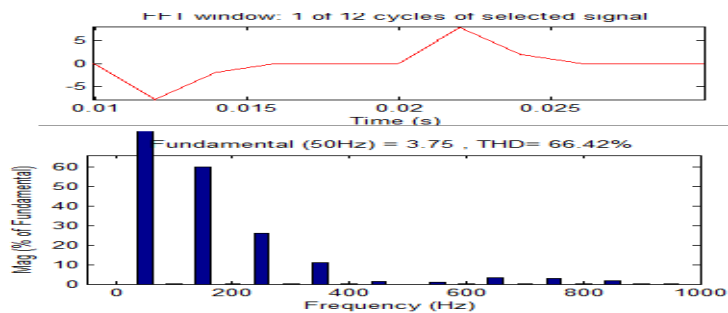
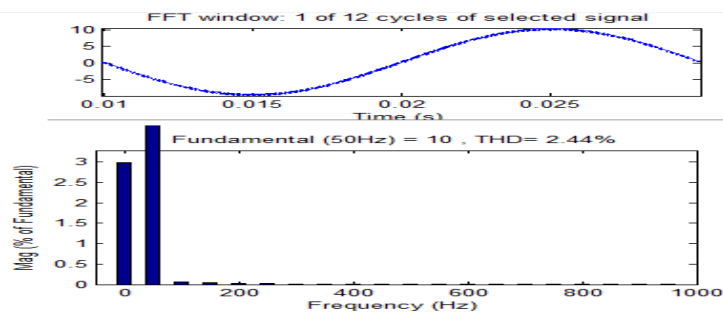


Figure 6.8 Load, Compensation and Source currents of CFL load



(a)Source current without APF



(b)Source current with APF

Figure 6.9 FFT analysis of source current for CFL

D.Oven as non linear load

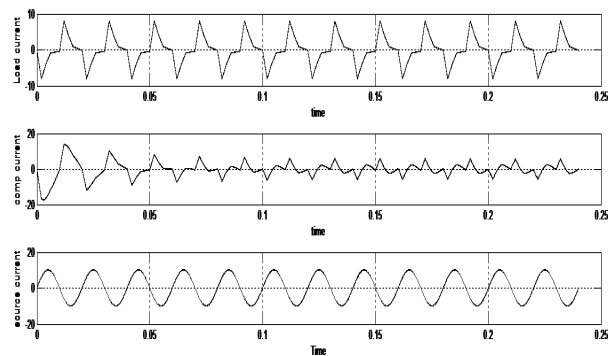
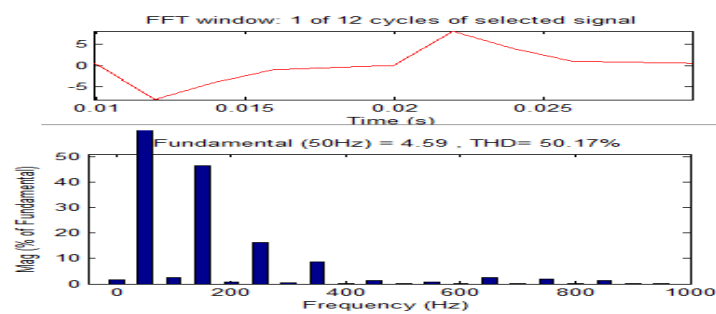
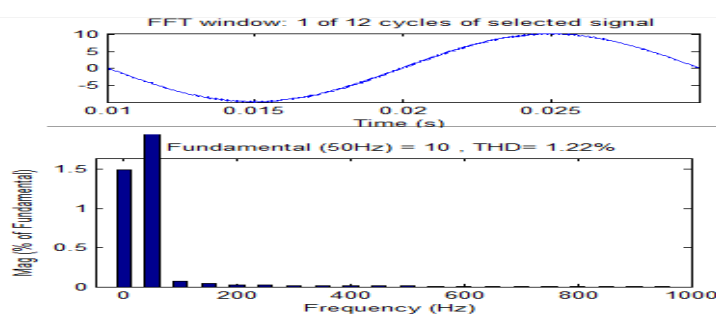


Figure 6.10 Load, Compensation and Source currents of Oven



(a)Source current without APF



(b)Source current with APF

Figure 6.11 FFT analysis of Source current for Oven

E. Refrigerator as non linear load

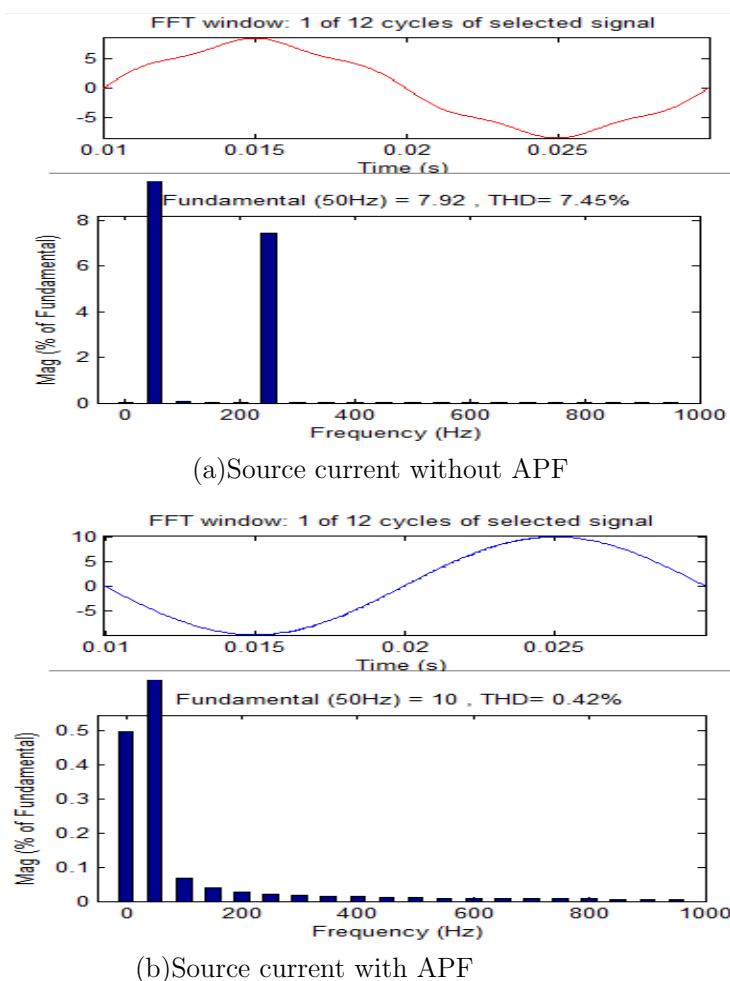


Figure 6.13 FFT analysis of source current for Refrigerator

The harmonics produced in the power system by different non-linear loads are eliminated by connecting the single phase shunt active power filter at the point of common coupling. The total harmonic distortion of the source current is reduced for each non-linear load when shunt active power filter is connected. The results are shown in the tale 6.1

Table 6.1 Comparison of THD with and without APF for different non-linear loads

Load	THD without APF	THD withAPF
Rectifier ($\alpha = 30^\circ$)	15.11%	5.16%
Rectifier($\alpha = 45^\circ$)	25.95%	3.28%
CFL	66.42%	2.44%
Oven	50.17%	1.22%
Refrigerator	7.45%	0.42%

Table 6.2 Comparison of THD over PI andFuzzy controller for different non-linear loads

Load	THD without APF	THD withAPF (PI Controller)	THD with APF (Fuzzy controller)
Rectifier ($\alpha = 30^\circ$)	15.11%	5.16%	0.75
Rectifier($\alpha = 45^\circ$)	25.95%	3.28%	0.91
CFL	66.42%	2.44%	1.22
Oven	50.17%	1.22%	0.82
Refrigerator	7.45%	0.42%	0.10

4 CONCLUSION

The presented single-phase Shunt Active Power Filter has demonstrated to be able to compensate the harmonic currents and the

power factor produced by loads, making the current at the source side to become almost sinusoidal and in phase with the system voltage. This current compensation can also prevent voltage harmonics. APF simulation using MATLAB Simulink is proven to be very useful for studying the detailed behavior of the system for harmonic and unbalance compensation, under steady state and transients. The total harmonic distortion of source current is reduced when shunt active power filter is connected to the power system at the point of common coupling.

Although the PI controller is the most satisfied control strategy earlier, as it does not recognize the parametric variations and system disturbances, there is a need to prefer an intelligent controller. Fuzzy logic controller is designed and implemented for each case of non-linear load for control of compensation current to eliminate the harmonics. The total harmonic distortion of source current for each case of non-linear load is reduced noticeably.

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