A Novel Hybrid Three-Phase Shunt Active Power Filter Based On the Adaptive Fuzzy Dividing Frequency-Control Method

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Abstract - Because of quick progression in innovation and gadgets gear number of non-straight loads are expanding exponentially, because the harmonichappen in the power framework. Power quality has transformed into a significant research subject in control appropriation frameworks on account of a basic augmentation of symphonies defilement caused by extension of nonlinear loads, for example, diode rectifiers, exchanging power provided and distinctive sorts of line related power converters etc. The unwavering quality and execution of insect APF framework to a great extent influenced by control calculation it employments. Shunt active power filter is generally utilized as a part of current electrical circulation system and it needs a precise control algorithm that gives robust execution under source and load unbalances. A hybrid three - phase shunt active power filter has been proposed in this work based on the adaptive fuzzy dividing frequency control method. Modeling of proposed model has been done on Matlab and simulation has done on Matlab simulink.

Keywords - Shunt Active Power Filter, adaptive fuzzy control method, Three phase SAPF, Power Quality Control, Nonlinear Load, Harmonics.

I. INTRODUCTION

The increasing use in the industry of non linear loads based on the power electronic elements introduced serious perturbation problems in the electric power distribution grids. Also, regular increase in the harmonic emissions and current unbalance in addition to high consumption of reactive power can be noticed. The flow of harmonic currents in the electric grids can cause also voltage harmonics and disturbance. These harmonic currents can interact adversely with a wide range of power system equipments, control systems, protection circuits, and other harmonic sensible loads. The energy distributers as like as consumers were then concerned by imposing some regulations protecting against the expansion of harmonic problem.

In order to face the problem of harmonics, many solutions have been proposed. These solutions included modifications on the load itself for less harmonic emissions like the case of special structure single phase and three phase rectifier, and PWM rectifiers. Or the connection on the polluted power grids of other traditional or modern compensation systems.

Most of traditional harmonic reduction solutions includes the use of harmonic trapping passive filters based on RLC elements calculated in accordance with the harmonic ranges to be trapped. In addition, these passive filters can be designed to compensate reactive power simultaneously with the desired harmonics. Nevertheless, these solutions are of poor efficiency due to different factors

The three-phase Shunt APF topology for harmonic mitigation in low and medium voltage power distribution systems consists of a VSI based three phase shunt active filter (SAF). It also presents the analysis of synchronous reference frame theorem to estimate the compensation reference current and hysteresis current controller for switching signal generation for SAF.

In a wide variety of industrial applications, an increasing demand exists to improve the quality of electrical system. Besides the reliability and availability of electric power, the power quality is now becoming an important issue. There are many disadvantages caused by the poor electrical power from the failure of the sensitive apparatus until the failure of the utility. The financial losscaused by these failures, in fact, varies according to the industry supported by the power source, but according to the report, there has been millionsof dollars of loss because of the electric power failure.

Many types of APF have been proposed and used in harmonic compensation. Series APF is used for voltage harmonics compensation. Shunt APF was proposed for current harmonics andreactive power compensation. The Unified Power Quality Filter or Conditioner combines the two types Shunt and Series APF in one device responsible for the simultaneous compensation of voltage, current harmonics and reactive power.

Although there are different types of APF, the Shunt APF is still the most famous and used type APF. The main function of Shunt Active Power Filter is to cancel harmonic currents occurring in power grids. The principle of SAPF is to generate harmonic currents equal in magnitude and opposite in phase to those harmonics that circulate in the grid. The non-linear loads absorb non-sinusoidal currents from the grid. Whereas, the SAPF current is generated in a manner that grid current keeps the sinusoidal form.

There are two main structures for the control of Shunt Active Power Filter; these are the direct control and the indirect control of APF. In the direct control the main idea is to generate filter current references using the appropriate methods. The generated reference currents are then to be compared with the measured APF currents.

Shunt active power filter compensates current harmonics by injecting equal-but-opposite harmonic compensating currents into the grid. In this case the shunt active power filter operates as a current source injecting the harmonic components generated by the load but phase shifted by 180°. This principle is applicable to any type of load considered as harmonic source. Moreover, with an appropriate control scheme, the active power filter can also compensate the load power factor. In this way, the power distribution system sees the non linear load and the active power filter as an ideal resistor. The current compensation characteristics of the shunt active power filter is shown in Figure 1.1

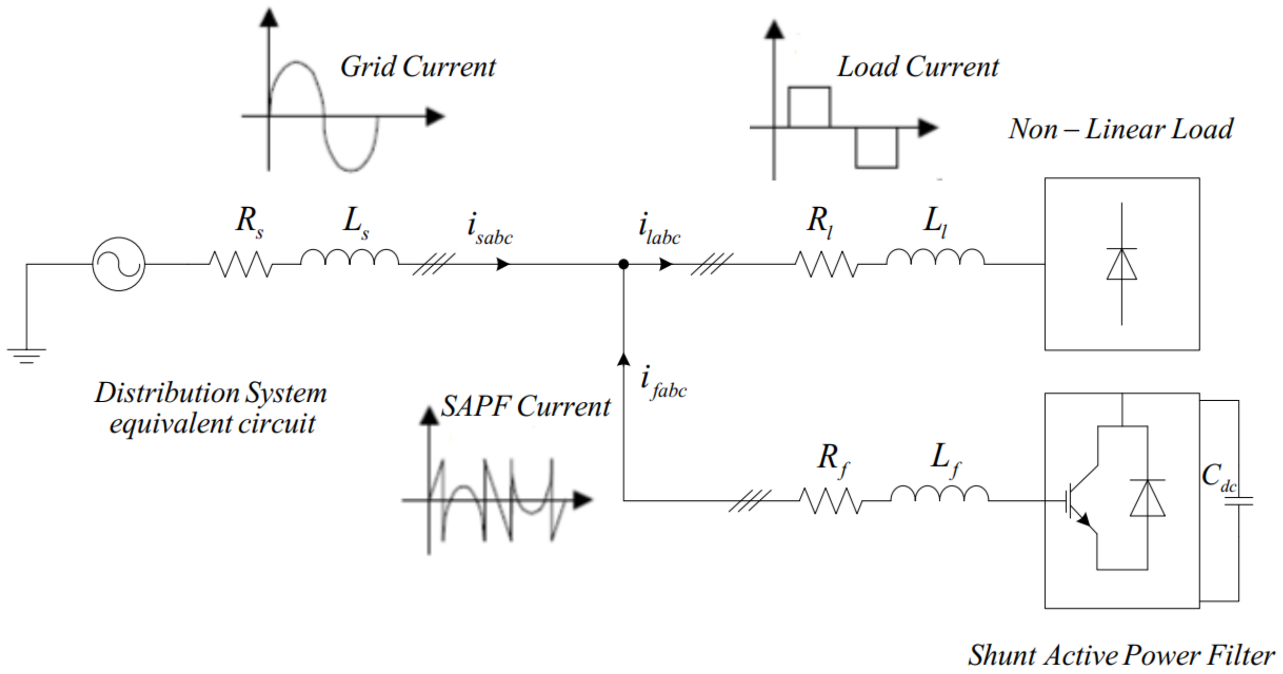

Figure 1.1 Compensation characteristics of Shunt active power filter.

II. ADAPTIVE FUZZY CONTROL DESIGN

Fuzzy Logic Controllers (FLCs) are based on a set of fuzzy control rules which make use of people's common sense and experience. The fuzzy logic used in these controllers is very well defined mathematically and is able to take into account the uncertainty in the knowledge used to develop the rules and the uncertainty in the operating conditions. The initial rules for FLCs come from the experience of people who work with the systems that are to be controlled. This experience is obtained in the form of linguistic rules such as "If the temperature is too low, open the hot water valve" and "If the temperature is too low and going down fast, open the hot water valve very quickly", etc. Pure direct and indirect adaptive fuzzy controls are simple, but they also have disadvantages. Thus, in the later years, it is often that adaptive fuzzy control is combined with other control techniques.

These initial rules are then used to construct a fuzzy control matrix that implements the logic of thecontroller. The initial fuzzy control matrix and other FLC parameters need to be refined using adjustment strategies that are usually based on manual trial and error methods to achieve improved performance.

Several researchers have studied and implemented self-tuning or adaptive fuzzy logic controllers (AFLCs) that improve their performance as they adjust to the controlled process and the environment. The operation of an AFLC relies on past experience that looks at suitable combinations of control strategies (control rules, membership functions, and scale factors) and the effects they produce. A particular feature of AFLCs is that they automatically improve their performance until they converge to a predetermined optimal condition

Direct AFC combined with indirect AFC: propose hybrid direct and indirect adaptive fuzzy control schemes in which the control output is the weighted average of direct and indirect adaptive fuzzy controllers. This combination provides a framework to incorporate both linguistic knowledge describing the plant behaviour and the control actions.

AFC combined with another controller to compensate for approximation error: In general, there exist approximation errors when approximating nonlinear functions by fuzzy systems. These approximation errors may effect and deteriorate the stability and performance of adaptive fuzzy controlsystems. To overcome this problem, previous researchers have proposed combining AFC with another controller.

AFC combined with output feedback control: In many applications, it is impossible or too expensive to measure all the state variables of the system under control. Output feedback control is an approach to overcome this difficulty. The only variable needed to be measured is output of the system.

AFC combined witha supervisory control: An adaptive fuzzycontroller sometime does not adapt fast enough. It leads to the state variables of the controlled system moving outside of a desired constraint set. This problem can be solved by increasing adaptive gains. However, adaptive gains cannot be too large. Increasing adaptive gains increases sensitivity to noise, leading to chattering of control output.

This supervisory control is also a variable structure control term, which is designed using knowledge of the bounds of the unknown nonlinear functions. When the state variables are well inside the constraint set, the supervisory control is zero. When the state variables tend to move outside of the desired boundaries, the supervisory control begins to operate toforce the states to stay in the constraint set.

In general, adaptive fuzzy control combined with other control schemes overcome disadvantages existing in pure direct and indirect adaptive fuzzy control. However, they are more complicated in both theoretical analysis and implementation.

In the theory of nonlinear control, the control of different classes of nonlinear systems has been considered. Different classes of nonlinear systems have different characteristics, and thus require different control techniques. Some well-established techniques are available for different classes of nonlinear systems.

III. PROPOSED MODEL

Implementation and simulation of proposed work has completed on Matlab Simulink. The Simulink Model of proposed work has been shown in figure 3.1. The proposed system has designed in two sub models variable frequency control and adaptive fuzzy control logic. The aim of active power filtering is to compensate the harmonic currents produced by the non-linear loads, and to ensure the sinusoidal form of grid currents and voltages. The first step in active filtering is the harmonic currents extraction to be injected into the grid. The good extraction of harmonics is a keyword for a good active power filtering.

The basic SAF scheme considered is depicted in Fig. 3.1. Practically, it is a three phase converter, where the primary energy storage component is given by the capacitor and the inductors are utilized to control the filter currents by methods for the converter voltages. Then again to the instance of an unadulterated voltage converter, the concentration for such kind of gadget is on the currents injected into the line which need to compensate for harmonics created by nonlinear load.

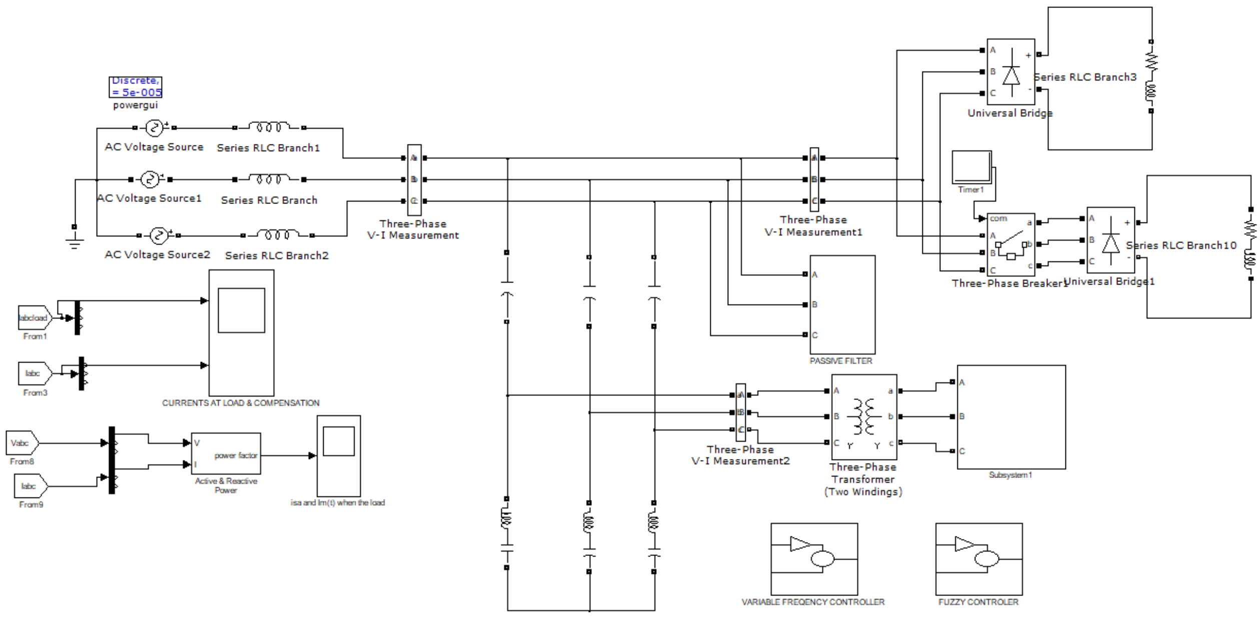

Figure 3.1 Proposed System Model.

The proposed adaptive fuzzy control logic shunt APF is connected with the distribution line at the PCC through an interfacing inductor. This interfacing inductor gives disengagement from the distribution line. A huge interfacing inductor is best since it brings about little switching swell. However, the expansive interfacing inductor restricts the dynamic reaction of the compensation current. Additionally to achieve better results two sub blocks are used along with main model are variable frequency control block shown in figure 3.2 and adaptive fuzzy control logic shown in figure 3.3.

a. Variable Frequency Control

V/f Control is the most prevalent and has discovered far reaching use in modern and household applications in light of its simplicity of-usage. However, it has inferior dynamic execution contrasted with vector control. Along these lines in areas where precision is required, V/f Control is not used.

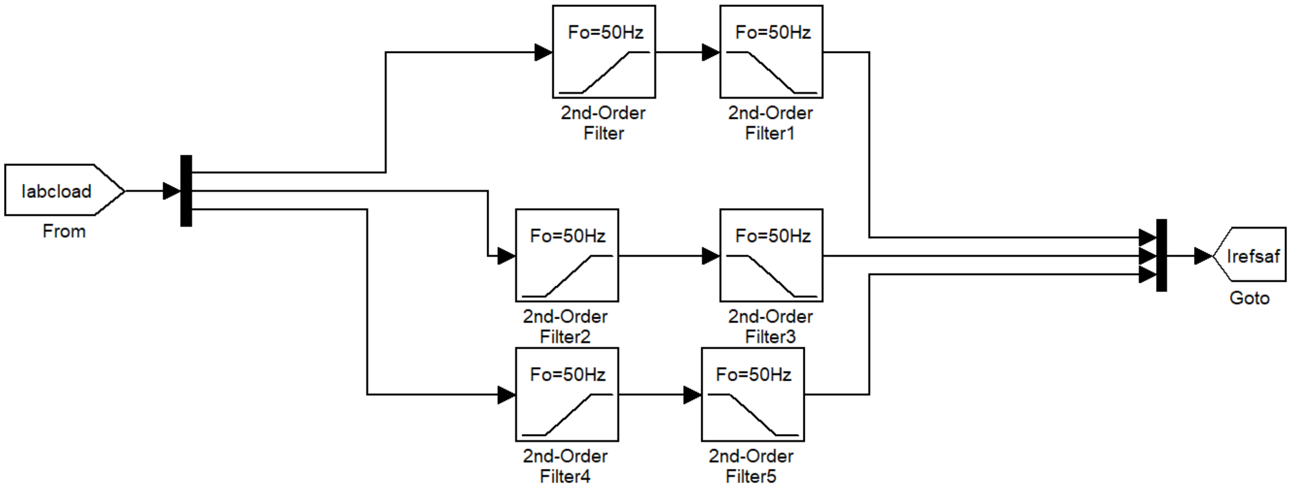

Figure 3.2 Variable frequency control.

In open loop, V/f Control the stator voltage was varied, and the supply frequency was simultaneously varied such that the V/f ratio remained constant. A MATLAB code was developed which asked the user to input different frequencies and then varied the voltage to keep the V/f ratio constant.

b. Adaptive Fuzzy Control Logic

An adaptive fuzzy isolating frequency-control strategy is proposed by examining the bode graph, which comprises of two control units: a summed up integrator control unit and fuzzy adjustor unit. The summed up integrator is utilized for partitioning frequency basic control, while fuzzy logic control is utilized for balancing proportional-integral coefficients timely. The versatile fuzzy isolating frequency control demonstrates the upsides of shorter response time and higher control accuracy.

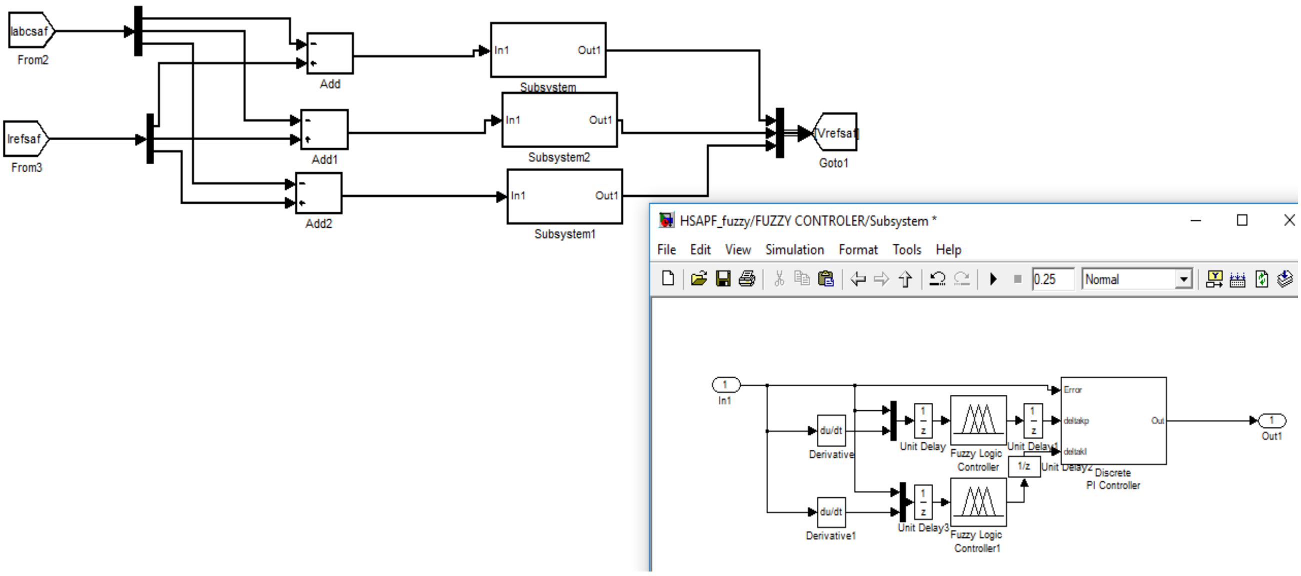

Figure 3.3 Adaptive Fuzzy control logic.

IV. SIMULATION RESULTS

MATLAB/Simulink software was used to simulate a SAPF. MATLAB is widely chosen among researchers due to its powerful computation capabilities and relative easiness to use for non-programmers. Simulink library in MATLAB provides extensive mathematical tools and specific libraries related to electrical and power engineering. Hence, it minimizes research time and effort to run the APF simulation. As mentioned earlier, the simulations will be carried out to compare the performance of the filter with different loads. Two scenarios were considered:

(a)The fridge as the non-linear load; the active filter circuit is represented as an active front end.

(b)All appliances as the non-linear load; the filter is placed on the feeder input (i.e. transformer secondary).Simulink's SimPowerSystems library was utilized to run and test the aforementioned simulations.

Figure 4.1 Three-phase source current waveforms obtained by A, B, C phases.

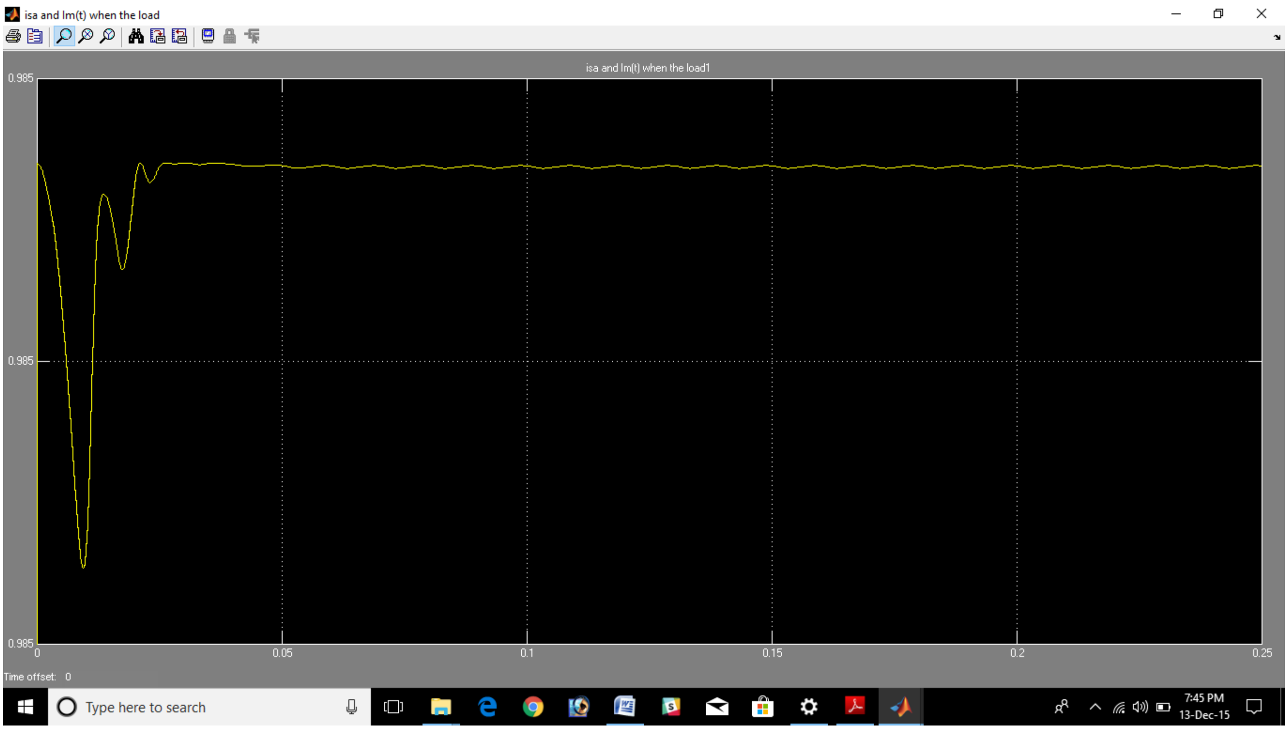

Figure 4.2 Im(t) when load is connected.

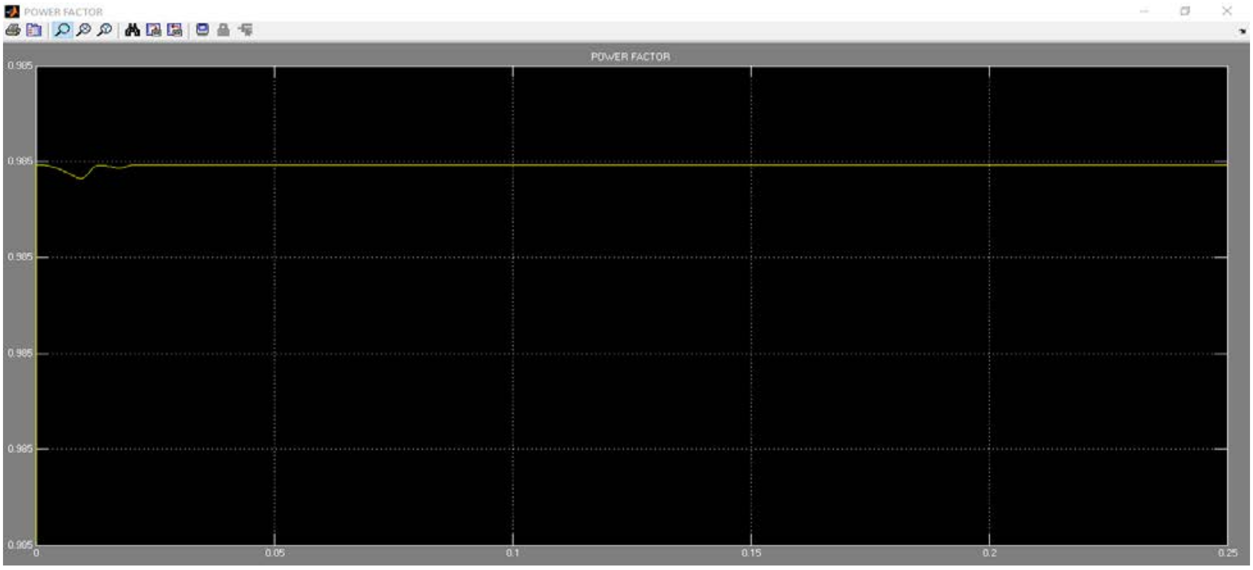

Figure 4.3 Dynamic responses of isa and Im(t) when the load1 is disconnected from PCC (POWER FACTOR).

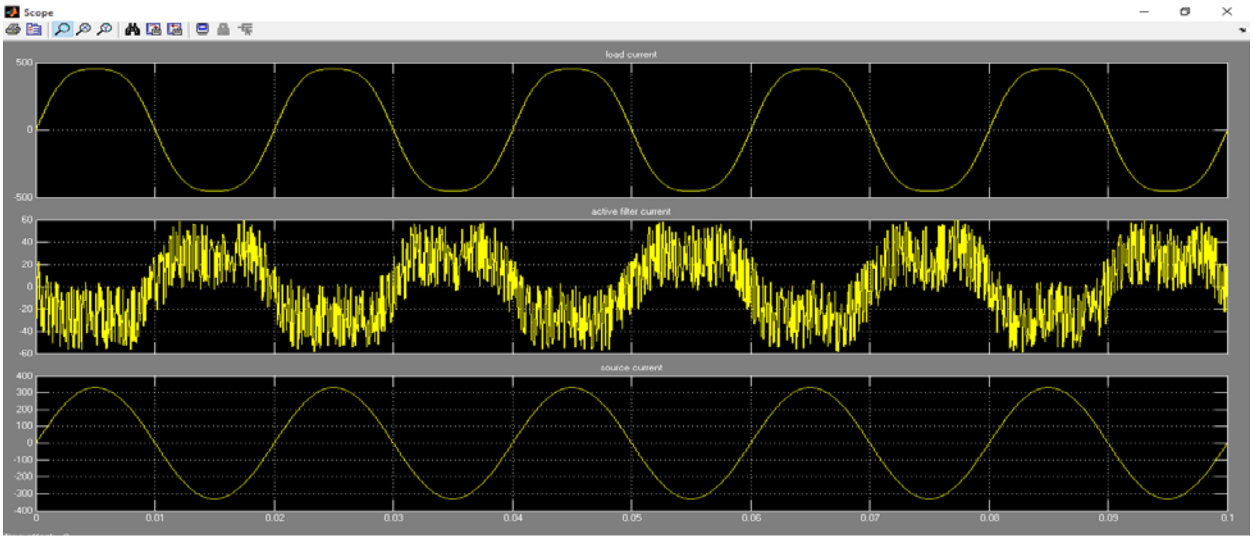

Figure 4.4 Steady-state waveforms of load current, active filter current, source current and spectrums of load and source currents for phase A.

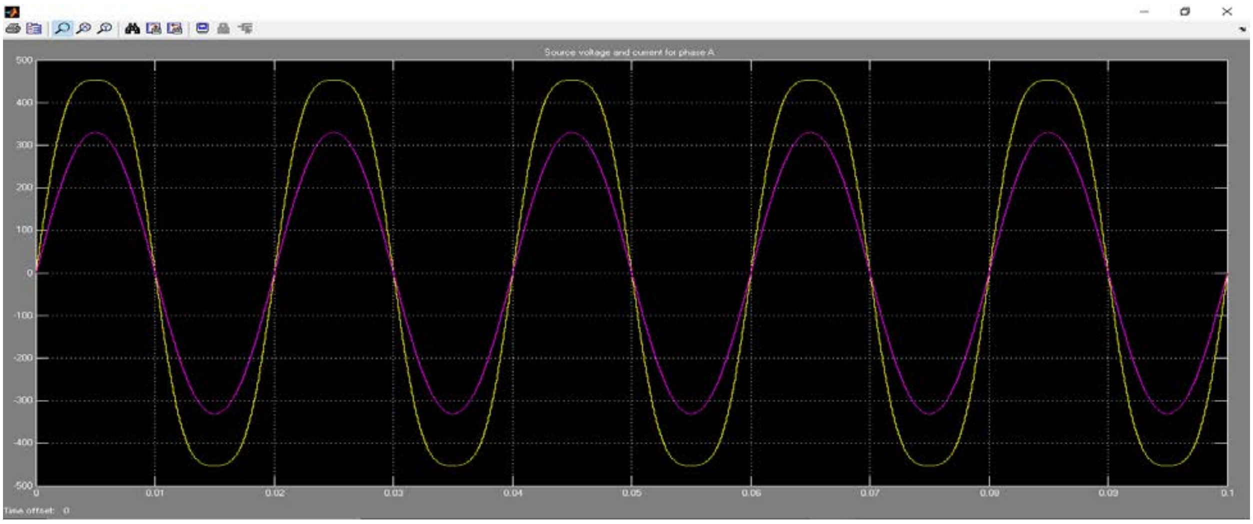

Figure 4.5 Steady-state waveforms of single-phase source currents and source voltage for phase Ab Source voltage and current for phase A (scale: 2 A/div, 20 V/div).

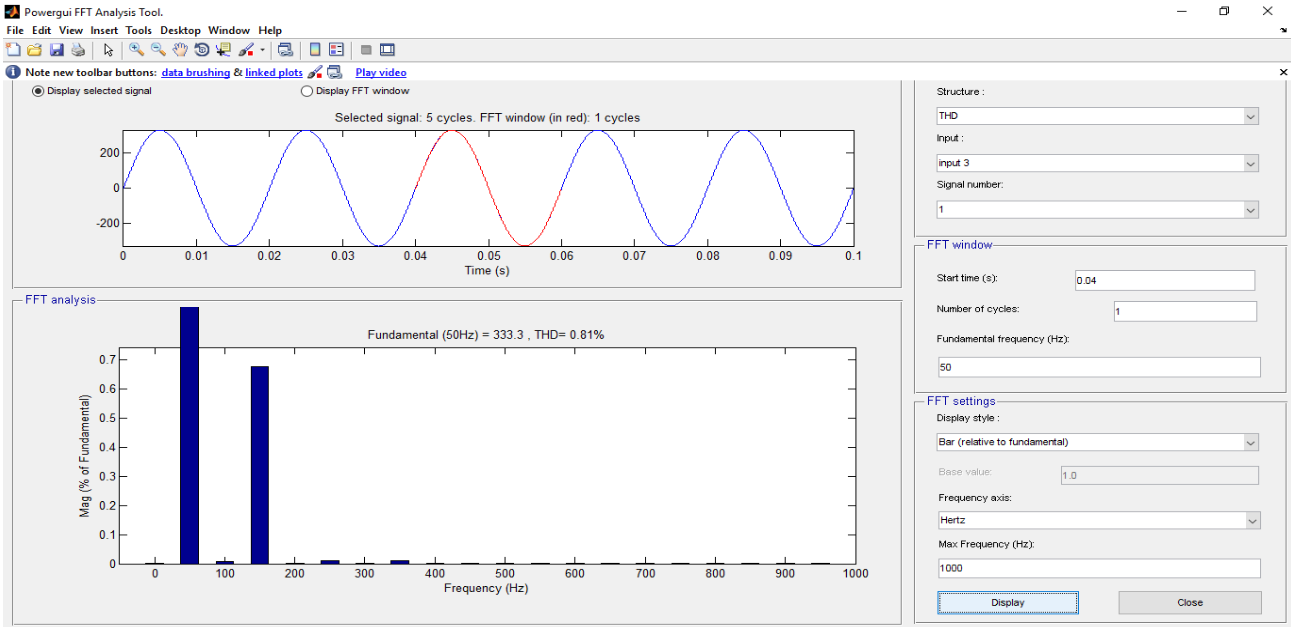

Figure 4.6 THD is 0.81%.

V. CONCLUSION AND FUTURE SCOPES

A design of a three phase hybrid SAPF base on adaptive fuzzy dividing frequency-control method has been proposed, and filter results from simulation have been validated experimentally. SPAF's are capable of significantly reducing the source current THD. A SAPF issimulated using MATLAB/Simulink library. Measured non-linear loads data imported and modeled using the signal builder block of Simulink. The operation of the filter was tested for two scenarios:as an active front end, where the filter compensated for current harmonics for a smart fridge and as a feeder compensator, where the filter compensated for current harmonics for various smart household appliances. The evaluated THD in proposed work is 0.81%.

Further research needs to be conducted to improve the designs of SAPFs. Namely, to design a filter that is able to compensate for various combinations of non-linear loads. It will be challenging to design a variable inductor with many taps/selections, since this will increase the cost of such a device and will impose computational complexity.

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