SIMULATION AND PERFORMANCE ANALYSIS OF THE ACTIVE FILTER AND ANN FOR CANCELLATION OF REFERENCES IN POWER SYSTEM

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
MOTAZ B. A. HAMMOUDA

In Partial Fulfilment of the Requirements for the Degree of Master of Science in Electrical and Electronic Engineering

NICOSIA, 2019

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Approval of Director of Graduate School of

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I hereby declare that, all the information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my parents…

ABSTRACT

Harmonics are created in power systems by non-linear loads; switches, elements and resonance circuits, etc. It has a negative effect on power system quality.

To overcome the influences of harmonics in modern power systems, passive and active filters are used. However, filtering of the harmonics sometimes does not provide the desired results.

In order to increase the quality and amount of filtering, this thesis proposes applying an ANN model with active filters as a solution.

Results of simulation show that the proposed model has more accuracy than the well-known active power filtering methods. It shows the effectiveness of feedback connected ANN model in eliminating harmonics and thus increasing power system quality.

***Keywords*:** Filter, Neural Network, Active power, Harmonics

ÖZET

İletişim sistemlerindeki yeni teknoloji, tüm araştırmacılara hızla ve hızla yayıldığını ve tüm dünyaya yayıldığını kanıtladı. Günümüzde aktif enerji filtreleri alanındaki yeni teknolojinin, özellikle günlük yaşamda sinir ağlarının kullanımında artması ve uygulamalarının sürekli kullanımı da bu kadar genişlemiş, bu uygulamaların en çekici kullanımı harmoniklerin iptali ve etkili sonuçları doğru sonuçlarla bir filtre olarak kullanırlar. Ayrıca, sinir ağlarının filtre olarak kullanılması, istenmeyen harmoniklerin iptal edilmesine yardımcı olmak için yeni olarak kullanılır. Bu çalışma, Yapay Zeka Sinir Ağı olan ve olmayan referanslarını iptal etmek için düşük maliyetli seri aktif güç filtreli çok esnek bir çalışma sunuyor. Serinin referansları ve şant aktif güç dolgusunun filtrelemeden suni istihbarat kullanarak nasıl iptal edileceği ve filtrelemede sıkça kullanılan yöntemler tartışılır. Simülasyon sonuçları elde edilmiş ve önerilen sistemin iyi bilinen yöntemlerden daha doğru olduğunu kanıtlamıştır.

Anahtar Kelimeler: Filtre, Yapay Sinir Ağı, Aktif güç, Harmonikler

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CHAPTER 1
INTRODUCTION

1.1 Overview

In this chapter an investigation about the procedure of how to cancel the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering is discussed.

1.2 Introduction

Harmonics are unwanted higher components which superimposed on the fundamental waveform creating a distorted wave pattern, some examples of harmonic producing loads are electric arc furnaces, static VAR compensators, inverters, DC converters, switch-mode power supplies, and AC or DC motor drives. Harmonics are created by electronic equipment with nonlinear loads and different switching elements. The short pulses because distorted current waveforms, which in turn cause harmonic currents.

1.2.1 Source of Harmonics:

Most of the sounds of worry in electrical conveyance frameworks are brought about by twisting of the regularly

a) Switching devices:

Sinusoidal voltage or current wave because of the exchanging of intensity electronic gadgets. For a long time, the essential such source was the three-stage connect rectifier with an inductive burden. Symphonious Analysis Studies were centered on this gadget and its trademark sounds. Alleviation methods were essentially the fifth symphonious step channel. As PWM engine drives became common the run of the mill symphonious spectra have changed fundamentally, and now and again become a lot more prominent in greatness. Simultaneous with the new PWM drives, new consonant moderation innovation has been grown, for example, BFs including AFs.

b) Reusable circuit:

In an electrical force framework for ordinary working at a solitary essential recurrence with sinusoidal voltage and flows, the framework attributes might be altogether unique for voltages and flows at non-crucial frequencies than at the central. Specifically, arrangement and equal blends of inductive and limits components may make thunderous frequencies which harmonize with, or are near, frequencies of music produced by power electronic hardware. At the point when a thunderous circuit is energized by a symphonious, the outcome is a huge increase of the energizing amount. Resonances in power frameworks can cause over voltages bringing about protection disappointment and short-circuits. Resonances can likewise build flows, normally bringing about capacitor disappointment or the opening of capacitor assurance gadgets, for example, wires. Generally, symphonious remediation has comprised of supplanting capacitor saves money with tuned channels which change the recurrence reaction qualities of the framework to such an extent that voltage and current amplification are disposed of or extraordinarily decreased.

1.2.2 Harmonic Effects on Devices and Loads:

Protection stress (voltage impact): Insulation stress relies upon the momentary voltages, just as its terminating rate.

Warm pressure (current impact): Thermal pressure relies upon the nearness of consonant flows. Consonant flows can cause copper misfortunes, iron misfortunes and dielectric misfortunes in the hardware.

Burden break (anomalous activity): Several electronic gadgets are dependent upon this possibility, on the grounds that their ordinary activity relies upon the presence of an absolutely sinusoidal voltage source. In particular, consonant flows circling in electric machine armatures can create throbbing electromagnetic forces. A distinctive model is a family unit computerized clock that will quickly propel the time within the sight of extra zero intersections from symphonious twisting. Any gadget that synchronizes to the zero-intersections ought to be viewed as defenseless against disturbance by consonant twisting. Partial and sub-sounds can influence video shows or broadcasts. Fragmentary sounds are frequencies that are not whole number products of the central recurrence.

Sub music are frequencies beneath the major recurrence. Partial sounds produce an adequacy tweak of the essential recurrence.

Impact on Transformers: The essential impact of intensity framework music on transformers is the extra warmth produced by the misfortunes brought about by the symphonious substance created by the heap current. Different issues incorporate conceivable reverberation between the transformer inductance and the framework capacitance, mechanical protection.

1.3 Overview of Published Works

Worries because of temperature cycling and conceivable little center vibrations. The essential misfortune segments are the winding I2R misfortunes and winding whirlpool current misfortunes. The misfortunes because of the I2R part are because of conductor warming and the skin impact. It is discovered that, misfortunes from the winding vortex current increment with the square of the recurrence. Early equipment was intended to withstand unsettling influences, for example, lightning, short circuits, and sudden over-burdens without additional use. Current power gadgets (PE) costs might be much higher if the supplies were planned with the same vigor. Contamination has been brought into power frameworks by nonlinear loads, for example, transformers and soaked curls; notwithstanding, annoyance rate has never arrived at the present levels. Because of its nonlinear attributes and quick exchanging, PE makes the majority of the contamination issues. The vast majority of the contamination issues are made because of the nonlinear aspects and quick exchanging of PE. Give or take 10% to 20% of today's vitality is prepared by PE; the rate is evaluated to achieve half to 60% by the year 2010, because of the quick development of PE competence. A race is as of now occurring between expanding PE contamination and affectability, from one viewpoint, and the new PE-based curative mechanisms, which can lessen the issues made by PE, then again (Dixon et al., 1997).

Expand in such non-linearity causes diverse undesirable characteristics like low framework proficiency and poor power variable. It likewise causes unsettling influence to different purchasers and impedance in close-by correspondence systems. The impact of such non-linearity may get sizeable through the following few years. Thus, it is exceptionally imperative to beat these undesirable characteristics (Tarnini, 2009).

Traditionally, shunt uninvolved filters, comprise of tuned LC filters or high inactive filters are utilized to stifle the sounds and power capacitors are utilized to enhance the power component. Anyway, they have the restrictions of altered remuneration, huge size and can likewise oust reverberation conditions (Freitas et al., 2010). Dynamic power filters are presently seen as a suitable elective over the established aloof filters, to repay sounds and receptive power necessity of the non-direct loads. The goal of the dynamic sifting is to tackle these issues by joining with a tremendously diminished rating of the vital aloof segments (Shaik et al., (2012).

The PQ issue is characterized as "any event showed in voltage, current, or frequency deviations that brings about harm, steamed, disappointment, or miss-operation of end-utilization supplies." Almost all PQ issues are nearly related with PE in practically every part of business, down home, and modern requisition. Equipment utilizing power electronic devise are private machines like TV's, Pcs and so forth business and office supplies like copiers, printers and so on. Mechanical equipment like programmable rationale controllers (PLCs), flexible velocity drives (ASDs), rectifiers, inverters, CNC instruments etc. The Power Quality (PQ) issue might be located from one of the taking after a few manifestations depending on the sort of issue included.

- Lamp flicker
- Frequent blackouts
- Locations
- Communications interference
- Overheated elements and equipment.

PE is the most critical reason for music, between sounds, indents, and impartial flows. Equipment influenced by sounds incorporates transformers, engines, links, interrupters, and capacitors (reverberation). Unbiased flows genuinely influence the impartial conductor temperature and transformer capacity. Between music are transformed by static recurrence converters, cyclo-converters, prompting engines & arcing units (Anand et al., 2012). Gear presents diverse levels of affectability to PQ issues, contingent upon the sort of both the supplies and the unsettling influence. Besides, the impact on the PQ of electric force frameworks, because of the vicinity of PE, relies on upon the sort of PE used.

The most extreme worthy qualities of symphonious tainting are specified in IEEE standard regarding aggregate consonant twisting (Mulla et al., 2012). Power hardware has three countenances in force circulation: one that presents significant mechanical and domesticated supplies; a second one that makes issues; and, at long last, a third one that serves to take care of those issues. On one hand, power gadgets and microelectronics have turned into two advances that have significantly enhanced the nature of advanced life, permitting the presentation of modern vitality productive controllable gear to industry and home (Kumar et al., 2013).

Contingent upon the specific requisition or electrical issue to be tackled, animated power filters might be actualized as shunt sort, arrangement sort, or a combo of shunt and arrangement dynamic filters (shunt- arrangement sort). These filters can likewise be joined together with aloof filters to make half breed power filters (Fujita et al., 1998). The shunt-associated animated power filter, with a self-regulated dc transport, has a topology like that of a static compensator (STATCOM) utilized for sensitive force remuneration within force transmission frameworks. Shunt dynamic power filters remunerate load current sounds by infusing equivalent yet inverse symphonious repaying current. Hence the shunt dynamic power filter works as a current source infusing the consonant segments created by the heap yet stage moved by 180° (Tumbelaka et al., 2001).

1.4 The Problem

In this thesis, the problems how to cancel the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering that facing the researchers are investigated and a new model is proposed to solve this problem.

1.5 Motivation

Decrease in the cost of power electronic devices and improvement in the efficiency of both power converters and energy storage components have increased the applicability of new technological solutions such as CP and FACTS Devices. APF is one of the CP devices and can mitigate harmonics, reactive power and unbalanced load currents originating from load side.

In this thesis, a comprehensive review how to cancel the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering that facing the researchers are investigated and a new model is proposed to solve this problem. The thesis also helps the researchers to select the optimum control strategies and power circuit configuration for APF applications.

1.6 Aim of the Study

Investigating the procedure of how to cancel the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering.

1.7 Limitations of the Study

This study has the following limitations:

1- Survey problem areas in the series and shunt active power filer.
2- This study is limited by the period that begins from March till June 2015 depending on the models mentioned in this study.
3- Introduce the selection of the neural network parts and the specifications of each part. Moreover, discusses the features mentioned in the result chapter.
4- Required software for the cancellation and recognition of the proposed system using MATLAB programming software.
5- Optimize the target for the aim of the cancellation process.
6- This study is limited to Middle East countries.

1.8 Overview of the Study

This thesis consists of six chapters and references:

Chapter One: This presents a brief description of the new investigation about the procedure of how to cancel the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering is described, and literature review of the study.

Chapter Two: It presents an overview of different research on series and shunt active power filer.

Chapter Three: It consists of two parts; the first presents an overview of different power filters and introduces the main topic of filters and the neural network. It ends that have a broad introduction of the research area. The second part provides more detail about neural network uses in the aim of a filter to cancel the references of the series and shunt active power filter.

Chapter Four: It discusses the neural network, specifications, used software, and the operation process for each part.

Chapter Five: This chapter describes the proposed simulation scheme simulation results.

Chapter Six: It draws conclusion in the results achieved in the last chapter. What's more, it presents ideas that might profit the reader to undertake future research work in the region.

1.9 Summary

One of the challenge problems in the modern life is how to cancel the references of the series and shunt active power filter without the use of the filtering and the common methods by filtering.

CHAPTER 2
RELATED RESEARCH

2.1 Overview

In this chapter, a review surviving written work on the use of artificial intelligence as a filter in the aim of cancelling the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering.

2.2 Related Work

Dixon et al., (1997) exhibited recreation and tests for power filter and demonstrated that filter keeps the line current practically sinusoidal and in stage with the line voltage supply. Additionally, confirmed that the filter reacts quickly under sudden changes in the heap condition to achieve its consistent state in two cycles.

Tarnini, (2009) proposed another arrangement single stage dynamic power filter dependent upon high input power variable and low harmonics. Tarnini intended to meet the necessities of voltage-sourced harmonic loads that are dependent upon a load current estimation utilizing a DC capacitor voltage of active power filter sensing the load current, and created it so as to characterize new control plans described by basic control calculations and a decreased number of current transducers.

Freitas et al., (2010) portrayed a work that is, no doubt finished in the configuration and execution of an arrangement dynamic power filter for electrical power quality purposes. This sort of filter has the ability to adjust for the accompanying voltage related issues in the power framework: short power outages for a couple of cycles, voltage twisting because of harmonics on a dull groundwork, voltage unbalance in three-phase frameworks, voltage glimmer (sub-harmonics) and transient over or under voltages. Moreover, Freitas, described as a main objective for his work an arrangement active filter regulated by a PC with standard multifunction information obtaining PCI transport card, as a result of its relative minimal effort and flexibility.

This PC based result displays a few troubles since the control of an arrangement animated filter is a sort of requisition which obliges a quick controller which that does not miss examines and where all continuous due dates must be met every single time, or the framework won't work legitimately. These attributes infer that this requisition falls in the "hard real-time" control class.

Shaik et al., (2012) proposed a control algorithm for a series power filter to be constitute by series active filter and shunt passive filter. The control system is dependent upon immediate responsive power hypothesis. So, the voltage wave structure infused by active power filter which has the ability to remunerate the touchy power and the load current harmonics.

Anand et al., (2012) introduced a recreation investigation of Hysteresis Current Controlled, three stage arrangement dynamic force channel to improve power quality by repaying sounds and receptive force required by a non-direct burden, the explanation of exemplary channels might not have acceptable execution in quick shifting conditions. At last, proposed an auto tuned arrangement dynamic channel which keeps up the THD well inside the IEEE-519 norms.

In the area of active power filtering, with an objective to reduce inverter capacity Mulla et al., (2012) presented a simulation study SHAPF in order to eliminate the produced harmonics.

Kumar et al., (2013) proposed an active recompense method is situated in an arrangement active filter utilizing versatile search calculation within the customary Sinusoidal voltage control procedure. Kumar investigated the proposed filter when joined with load of three-phase rectifier arrangement with inductive load and a pure resistance directly.

Fujita et al., (1998) talked about the control technique of the UPQC's. In addition, concerned on the stream immediate active and reactive powers.

Tumbelaka el al. (2001) introduced an arrangement of active power filter with a little arrangement reactor which comprises of numerous non-straight loads as a mixture of harmonic sources for both current and voltage.

Rajasekar et al., (2011) Researched the relief of current harmonics utilizing diverse design of fell multilevel inverter based SHAPF and enhance power magnificence of the framework to have the ability to create and dissect the compensation aspects of cascaded multilevel inverter based shunt hybrid active power filter by utilizing indirect current control calculation.

Singh et al., (1999) presented a comprehensive report on AF configurations, the control strategies, and the number of components.

Litran et al., (2006) stated that the active power filters are based on electronic converter PWM, this system is connected in series with the APF to allow the elimination of harmonics which is caused by voltage source harmonic load. The development in electronic gadgets applications helping the nonlinear burdens in power frameworks on the grounds that the majority of those gadgets include utilizes managed power gracefully including SMPS, Choppers and so forth yet with the non-linearity remembered for the controlling procedure it makes undesired sounds and responsive segments that causes the warming, vibration electromagnetic obstruction and so on. Thus to alleviate these objections numerous techniques are recommended for example utilization of uninvolved LC channels and furthermore other controlled APF with various controlling calculations and geographies.

Chaturvedi et al., (2012) presented a case study and analysis of assorted active techniques useful for suppression of harmonics.

Mahalekshmi, (2010) proposed an improvement to the summed up integrator control so as to improve the presentation of APF. In addition, the computation of the reference current by utilizing dq change. The bountiful utilization of Non-straight loads in dispersion framework realizes power quality issues, the expansion of microelectronics processors in a wide scope of gear, VCRs and computerized tickers to robotized modern mechanical production systems and emergency clinic diagnostics frameworks, has developed the weakness of such hardware to control quality issues. These issues, for example, various electrical unsettling influences, which may begin from numerous points of view and furthermore effectively affect different sorts of touchy burdens.

What were once viewed as minor varieties in power, normally unnoticed inside the activity of customary gear, may now carry entire industrial facilities to stop, Voltage quality issues relates to any disappointment of hardware because of deviations in the line voltage taking a gander at the ostensible attributes, and furthermore the flexibly dependability is described by its sufficiency, security and accessibility. Force quality issues are basic for all intents and purposes in the greater part of business, mechanical and utility systems. Normal wonders, for example, lightning would be the most common main driver of intensity quality issues. Exchanging wonders bringing about oscillatory homeless people inside the electrical flexibly, for example when capacitors are exchanged, likewise contribute generously to control quality aggravations are two systems to the relief of intensity quality issues. The essential methodology is alluded to as burden molding, which guarantees that the rigging is less comprehension of intensity unsettling influences, permitting the activity much under huge voltage bending. Another choice is set up line molding frameworks that stifle or neutralizes the office framework aggravations. Shunt dynamic force channel remunerate current music by infusing equivalent however inverse symphonious repaying current.

kavitaha et al., (2012) described in briefly the shunt active power filter as a case of current source injecting the harmonic components which is generated by the load with phase shift 180^{o}.

Marks et al., (2002) introduced a novel strategy to straightforwardly figure the mean-pivot contribution to the rectifier without separating by utilizing an ANN as an indicator to permit precise estimation of the crossing out to the references of the arrangement and shunt APF which is working under consistent state and transient conditions.

Ravindra et al., (2012) explained briefly the two power quality disturbances to deregulate the electricity industry, increment client requests and the mix of sustainable power sources, all after the presentation of the various phrasings.

Chen et al., (2004) presented all possibilities of control strategies that applied to the active filters which compensate what's more, as the significant job on the improvement of the exhibition and soundness of the APF.

2.3 Summary

In this chapter an overview of the related research is introduced and different research on how to cancel the references of the series and shunt active power filer by using artificial intelligence without filtering and the common methods by filtering is discussed.

CHAPTER 3
THEORETICAL FRAMEWORK

3.1 Overview

In this chapter, the theoretical consideration of the fact that large portions of present-day applications require this sort of dynamic promotions of adjustments for the types of filters and their control are presented.

3.2 Introduction

As of now, there is a major consideration given to an issue of versatile frameworks, in light of the fact that large portions of present-day applications require this sort of a dynamic promotion of adjustment. Topicality of inspected issue compares to change of a chip procedure execution: multi-center processors, field programmable gate array (FPGA). Indeed, low execution of processors was the fundamental restricting component in use of the advanced complex versatile channels. The thought of the adjustment originates from properties of the bioplasm, it has the capacity of living beings to adjust their conduct to changes in a domain they live in, particularly, when these progressions are antagonistic as mentioned in (Martinek et al., 2013). This wonder is ordinarily called learning. To this gathering of frameworks, which are fit for adjustment it can likewise tally mechanical frameworks alongside of those organic ones, then alleged machine learning. The capacity to learn is some of the time considered as a definition for knowledge. So it has honest to goodness that there is a major push to gain such a credit likewise to specialized frameworks. These specialized versatile frameworks are portrayed by the capacity to adjust their parameters as indicated by real data about controlled framework or executed sign. Precisely these capacities are utilized by the writers of this article to foresee the progressions of current in supply arranges which are created by joining of nonlinear burdens. The article is fundamentally centered on frameworks which utilize the blend of fluffy framework systems and the manmade brainpower. Most creators manage utilization of Adaptive Neuro-fluffy Interference framework (ANFIS) in view of control of three-stage force channel for symphonious relief (Shamala et al., 2015).

Dynamic force channels (APFs) are broadly used to control consonant mutilation in force frameworks. They utilize power gadgets converters with a specific end goal to infuse consonant parts to the electrical system that offset the music in the source streams brought on by non-straight loads. Latent LC filters were utilized routinely to lessen the music and for force variable change of the air conditioner burdens, capacitors were additionally utilized (Viswaja et al., 2015).

Be that as it may, a few disadvantages like fixed remuneration, substantial size and reverberation issue are happened in the detached filters. Presently numerous exploration works are done on the APFs for the alleviation of sounds issue. Be that as it may, the control method of dynamic force filter assumes a crucial part in the general execution. Quick recognition of aggravation sign with high exactness, quick handling of the reference sign and high element reaction of the controller are the prime necessities for wanted compensation (Vanus et al., 2015).

3.3 Instantaneous Power Theory

Traditional methodologies of force framework investigation depend mostly on RMS or normal estimations of the variables. With the nonstop advancement of force electronic converters which has fast reaction and infuse high recurrence symphonious segments, one ought to understand that traditional methodologies are not sufficient to perform valuable investigation. Likewise, as a result of the nonlinear way of these consonant sources, time area examination of three stage power frameworks is should have been have the capacity to identify these high recurrence parts progressives, (Shamala et al., 2015 and Kalbat, 2013). Instantaneous theories in power subjects define most sets of powers with time dependent. These theories are classified into two main groups: p-q theory and abc theory. p-q theory is based on the transformation from abc phases of the three-phase system to a three orthogonal stationary reference frame called αβ0 (Kalbat, 2013).

p-q theory uses the αβ0 or Clarke change to guide three stage voltages and streams into αβ0 reference casings utilizing a genuine lattice. A favorable circumstances' percentage of utilizing this hypothesis is that it is legitimate for unfaltering state as well as for transient state which makes it conceivable to utilize it for the recognition of irregularities in the force system flaws, inrush current (Kumar et al., 2013).

Another point of interest is the capacity to apply this hypothesis to three stage frameworks with or without impartial conductor in which the zero-arrangement segments exist. It could be connected to adjusted or uneven frameworks and could be connected to motions with or without sounds. Above all, in light of the fact that its counts principally rely on upon genuine frameworks, it could be effectively executed in these days' accessible processors. p-q hypothesis has the capacity isolate the momentary current and voltage on the αβ pivot into quick dynamic and receptive segments. It is additionally ready to define the three's force stage framework by genuine (p) and nonexistent (q) power as appeared in 1a and 1b, separately. Every one of the beforehand specified force segments genuine and nonexistent are disintegrated into normal force P˜ and q˜ and swaying force P˜ and q˜ (Freitas et al., 2014).

The physical which means of all force parts presented beforehand could be clarified utilizing p-q hypothesis. While the genuine force (p) speaks to the aggregate three stage vitality flow per unit time in the circuit between two frameworks, the fanciful force (q) speaks to the force that is being traded among the three stages without exchanging any vitality. Likewise, the wavering parts of the forces P˜ and q˜ are identified with the sounds' vicinity in the heap current. In this way, by extricating the swaying parts of the force, one could pick up data about the unbalances and the sounds present in the framework under study [3]. This hypothesis shapes the premise for concentrating on force molding gadgets and filters like shunt dynamic force channels which will be discussed.

$$p = \bar{p} + \tilde{p} \qquad (3.1)$$

$$q = \bar{q} + \tilde{q} \qquad (3.2)$$

3.3.1 Shunt Active Power Filter

SAPFs are power conditioning devices that compensate for harmonic currents from a specific nonlinear load and keep tracking of its harmonic contents which makes it to be selective and adaptive in its nature.

In simpler words, it compensates for the harmonic current by injecting another current harmonic at the PCC which have the same magnitude but opposite in phase of the current drawn by the nonlinear loads so once added together they cancel each other (Siva et al., 2014 and El-Habrouk et al., 2000). Unlike passive filters which are tuned to remove specific harmonic components, SAPF could be tuned to compensate for a specific range of harmonic components determined at the designing stages. Although SAPF is more expensive than passive filters, it has the ability to resist overloading by being designed for a specific nonlinear load. SAPFs generally consist of two main blocks which are the power processing block and signal processing block. The power processing block consists of the PWM converter which is responsible for synthesizing the compensating current that should be drawn from the power system. The signal processing is done by the active filter controller which is responsible for calculating the compensating current references which are continuously passed to the PWM converter (El-Habrouk et al., 2000).

There are different control strategies which determine the compensating characteristics of active filters. One possible strategy is constant instantaneous power control strategy which is done by forcing the active filter to compensate for the oscillating real power $\tilde{p}$. Another one is sinusoidal control strategy which is achieved by the active filter compensating for the load current to guarantee that balanced and sinusoidal current drawn from the power system (Peng et al., 1993). In this paper, the second control strategy will be considered. The controller of SAPF which is responsible for generating the compensating current references contains the different transformation matrices which will be discussed here. The controller starts by sensing the line voltages $V_a, V_b \; and \; V_c$ at the point of common coupling of the nonlinear load, power source and the SAPF. It also senses the line currents at the nonlinear load side. Then, the αβ components of the line voltages and current are calculated. The zero sequence c components will be zero throughout this paper because the system that is under study is a three-phase three-wire system. By using the αβ components previously calculated, one could calculate the instantaneous power components p and q. Next step is to decide whether the power component to be compensated for is the average power $\bar{p}$ and $\bar{q}$ or the oscillating power $\tilde{p}$ and $\tilde{q}$.

Since the main objective of this paper is harmonic current compensation, then the compensation should be done for the oscillating power which could be extracted for p and q using high pass filters. After that, the αβ components of the compensating current references I_α^* *and* I_β^* are calculated as shown in 5 where p_c^**and* q_c^* the power components of the compensating reference are current. Finally, the three phase components of the compensating current references I_{Ca}^*, I_{Cb}^* *and* I_{Cc}^* which are passed to the PWM converter. Current errors are created by comparing the three phase components of the compensating current references I_{Ca}^*, I_{Cb}^* *and* I_{Cc}^* to the line currents of the filter. These current error values are used as the gating signals for the PWM converter which in turn create the final compensating currents. By adding the compensating current to the point of common coupling, the harmonics injected by the nonlinear load will be removed from the power system.

1. Clarke Transformation:

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (3.3)$$

$$\begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (3.4)$$

2. Instantaneous Power

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \quad (3.5)$$

3. Selection of the power components to be compensated for.
4. Calculation of the αβ components of the compensating current references:

$$\begin{bmatrix} I_\alpha^* \\ I_\beta^* \end{bmatrix} = \frac{1}{V_\alpha^2+V_\beta^2}\begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix}\begin{bmatrix} -p_c^* \\ -q_c^* \end{bmatrix} \tag{3.6}$$

5. The calculation of the αβ components of the compensating current using the inverse of the Clarke transformation

$$\begin{bmatrix} I_{Ca}^* \\ I_{Cb}^* \\ I_{Cc}^* \end{bmatrix} = \sqrt{\frac{2}{3}}\begin{bmatrix} 1 & 0 \\ -1/2 & \frac{\sqrt{3}}{2} \\ -1/2 & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} I_\alpha^* \\ I_\beta^* \end{bmatrix} \tag{3.7}$$

3.3.2 Shunt Power Active Filter Operation

Conventionally, a shunt APF is controlled so as to infuse symphonious and responsive remuneration flows dependent on determined reference flows. The infused flows are intended to drop the symphonious and responsive flows drawn by the non-straight loads. Be that as it may, the reference or wanted current to be infused must be dictated by broad counts with characteristic deferrals, mistakes and moderate transient reaction (Kesler et al., 2011).

3.3.3 Series Inductance

A key part of this framework is the additional arrangement inductance X as appeared in Figure 3.1, which is practically identical in size to the compelling matrix impedance, ZS. Without this inductance or an arrangement dynamic channel, load consonant voltage sources would create symphonious flows through the network impedance, which couldn't be remunerated by a shunt APF. Flows from the APF don't essentially change the symphonious voltage at the heaps. Hence, there are as yet consonant voltages over the matrix impedance, which keep on delivering symphonious flows. The inductance XL replaces an arrangement dynamic force channel at altogether less expense, giving the necessary voltage decoupling between load symphonious voltage sources and the network (Tarnini, 2009; Mulla et al., 2012; Fujita et al., 1998 & Kale et al., 2005).

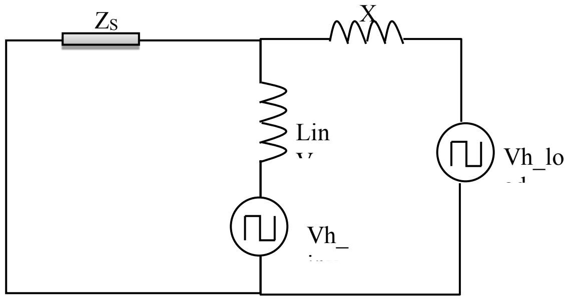

Figure 3.1: Harmonic's Equivalent Circuit

Grid Current Direct Control

As appeared in Figure (3.1) the CC-VSI is worked to specifically control the air conditioner network current instead of it is own current (Serpa et al., 2000).

The framework current is detected and specifically controlled to take after symmetrical sinusoidal reference signals in stage with the lattice voltage. Consequently, by putting the present sensors on the framework side, the network current is compelled to carry on as a sinusoidal current source and the matrix shows up as a high-impedance circuit for sounds (Tumbelaka et al., 2001). By constraining the framework current to be sinusoidal, the APF consequently gives the symphonious, responsive, negative and zero succession streams for the heap, taking after the essential current summation principle:

$$i_{grid} = i_{APF} + i_{load} \quad (3.8$$

Where, the reference signal of the sinusoidal grid current is shown in Equation (3.9)

$$i_{ref} = kv_{grid-I} \quad (3.9$$

Where, v_{grid-I} is the crucial segment of the network voltage, and k is gotten from an external control circle controlling the CC-VSI dc-transport voltage. This can be master by a clear PI control circle. This is a convincing strategy for choosing the necessary degree of dynamic current required, ensuing to any scramble between the necessary weight dynamic current and that being obliged by the CC-VSI would achieve the significant solutions for direct the dc-transport voltage. In the VSI geography used as a piece of the APF, the dc-capacitor voltage must be more unmistakable than the forced air system's peak structure voltage.

3.4 Ramp-time Current Control

The presentation and the adequacy of the channel are improved by the utilization of the incline time current control strategy to control the CC-VSI. The rule activity of incline time current control depends on the idea of ZACE (Tumbelaka et al., 2010; Abdel-Salam et al., 2010 & Daniyal, 2011). In this application, the current error signal is the difference between the actual grid current and the desired/reference grid current waveform. The ramp-time control produces switching instants which result in the current error signal crossing zero at intervals of half the desired switching period (Tumbelaka et al., 2010).

Subsequently the current mistake signal invests a large portion of the energy in exchange sides of zero, bringing about a normal estimation of zero, a nearby after of the reference signal, and an exchanging period and henceforth exchanging recurrence near the ideal worth. As referenced, in this application, the CC-VSI is exchanged in order to control the network current as opposed to it is own current. Controllability is guaranteed by the best possible relative measuring of the inverter channel inductance Linv and the decision of the dc transport voltage with the goal that the two yield PWM states (per stage) will consistently result a comparing inverse extremity current mistake signal incline. The controllability of the air conditioner network current is ensured since the CC-VSI can be developed with the goal that its base di/dt surpasses the greatest di/dt allowed by the inductance XL. This gives the CC-VSI unlimited oversight over the air conditioner network current (Setiadji et al., 2003 and katnal, 2013).

Non-direct loads, particularly power electronic burdens, make symphonious flows and voltages in the force frameworks. These music cause increment of misfortunes, diminishing of influence factor and decrease of framework proficiency. Aloof LC channels can dispose of music utilizing mass detached parts.

Arrangement and equal resonances are the fundamental impediments of aloof channels. Different dynamic force channels (APF) have been created to conquer uninvolved channel issues (Akmaz et al., 2014; Tumbelaka et al., 2009; Devi et al., 2014 and Dehini et al., 2011). Dynamic force channels can stifle the music, make up for receptive force and equalization three stage uneven burdens. A few reports seemed to accomplish receptive force pay and others have been made for responsive force pay and symphonious end (Chandra et al., 2000 and Spro, 2013). A few endeavors have been made for responsive force pay; consonant end and parity three-stage unbalance nonlinear burdens. In any case, the estimation of the current THD is high (4.2%), even it is inside as far as possible, and the force factor is not as much as solidarity and the channel is tried under sinusoidal flexibly voltage just (Zhang, 1998 and Kumar, 2015).

The shunt type APF acts to wipe out the receptive force and symphonious flows delivered by non-straight loads from the source current by infusing remunerating flows which bring about sinusoidal gracefully current with solidarity power factor (Jambulingam, 2014 and Ilakkia et al., 2014). This channel has been demonstrated to be powerful in remunerating symphonious current sources, however it can’t appropriately make up for consonant voltage sources (Babu, 2013).

Numerous electronic machines, for example, switch mode power supplies and electronic counterweights, are consonant voltage sources. A voltage sourcing arrangement dynamic force channel is reasonable for controlling symphonious voltage sources, however it can't appropriately make up for consonant current sources.

Much of the time, non-direct loads comprise of blends of symphonious voltage sources and consonant current sources and may contain noteworthy burden unbalance ex. single stage loads on a three-stage framework. To make up for these blended nonlinear burdens, which create consonant voltages and symphonious flows, a joined arrangement of a shunt APF and an arrangement APF can be viable (Jambulingam, 2014; Ilakkia et al., 2014 & Babu, 2013).

The force inverter of dynamic force channel is controlled to produce a pay current, which is equivalent however inverse to the music current and to take care of the heap with the necessary responsive force so the gracefully current is sinusoidal and in stage with flexibly voltages.

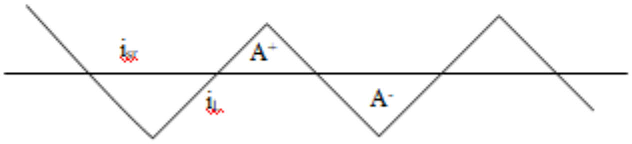

Figure 3.2: Error Signal

The control of the APF is isolated into two phases, the principal stage is to produce the reference flows (i_{ar} , i). The subsequent stage is to produce the inverter exchanging signals. Many control methods, for example, immediate receptive force hypothesis (p-q hypothesis) (Jasmine, 2015; Singhai, 2013; Rojin et al 2014 & Shahbaz, 2013) and instantaneous active and reactive current (i_d-i_{qbr}) controls [10] have been used to generate the APF reference currents. The DC side capacitor voltage was balanced against a reference esteem where the blunder signal is taken care of to a PI controller. The yield of the PI controller is increased by unit sin vectors in stage with source voltages to acquire the references flows. An improved (i, i_{crd}-i_q) control was reported (Sing et al., 1997) to improve the exhibition of the dynamic force channel. The p–q hypothesis and id-I control are broadly utilized in APF control hardware to ascertain the ideal pay current. Nonetheless, they are touchy to bending and unevenness that may happen in the voltage at the PCC (Khalid et al., 2011). The p-q and i_{qd}–i strategies balance three-phase unbalanced loads on the expense of distorting the source current.

The unity power factor (UPF) control method does not work well in presence of zero sequence voltage components. Also, it didn't correct the power factor to unity when the load currents are unbalanced (Sanjuan, 2010; Ng et al., 2004, pp. 43 & Yang et al., 2004, pp. 113). The utilization of DC side capacitor voltage to produce the reference APF current doesn't work at all the conditions. In the event that the DC capacitor voltage is not exactly the pinnacle estimation of the PCC voltage, at that point the remuneration bombs totally (Srikanth, 2013).

Also, the CC-VSI loses its controllability if a certain condition is not satisfied. Q Perfect harmonic cancellation method (PHC) is the best control method to eliminate harmonics, correct power factor and balance three-phase unbalanced currents for all operation conditions (Bharadwaz et al., 2013). Therefore, the use of PHC provides a robust control strategy working at all the loading conditions on the expense of extra cost when compared with the use of PI loop only (Camacho et al., 2011).

Keeping in mind the end goal to produce the inverter exchanging signs PWM current control, hysteresis current control or incline time current control can be utilized (Salem et al., 2014; Sun et al., 2012; Ramesh et al., 2014 and Gawande et al., 2014). The zero normal current control procedure (ZACE) could be utilized with hysteresis or slope time current controls. Incline time like hysteresis current control where the exchanging moments are ceaselessly produced in order to push the present blunder sign back towards zero (Borle, 1995 and Baker et al., 2010). Like hysteresis current control, the present mistake sign invests generally proportionate measures of energy in every side of zero inside of every exchanging period, bringing about zero normal current blunders as appeared in Figure (3.2), where i_{sr} is the reference current and I is the real inductor current.

Dissimilar to hysteresis current control, exchanging moments are L picked with the aim of delivering an altered exchanging recurrence which is missed in hysteresis current control. Incline time current control accomplishes ZACE with altogether enhanced control over the exchanging recurrence when contrasted with hysteresis current control (Abdel-Salam et al., 2010). The execution and the channel's adequacy are upgraded by the incline's utilization time current control method to control the CC-VSI. A shunt dynamic force channel is acquainted with kill sounds; enhance the force element to solidarity and equalization three-stage unequal burdens under sinusoidal and mutilated supply voltage. Slope time current (RT) control and flawless symphonious cancelation (PHC) system are utilized (Abdel-Salam et al., 2010 and Davoodnezhad, 2008).

3.5 Active Power Filter Operation

Figure (3.3) shows major unique power channel piece graph inside non-direct three phase load (uncontrolled rectifier with course of action inductance L and shunt capacitance C for meals sounds supported to the resistive weight R). The shunt dynamic power channel is functioned as a current source corresponding with the nonlinear weight. The APF when everything is said in done involves a three-phase current-controlled voltage source inverter (CC-VSI), smoothing inductor L_f, a DC capacitor C and control circuit (Ramesh et al., 2014 and Patidar et al., 2009).

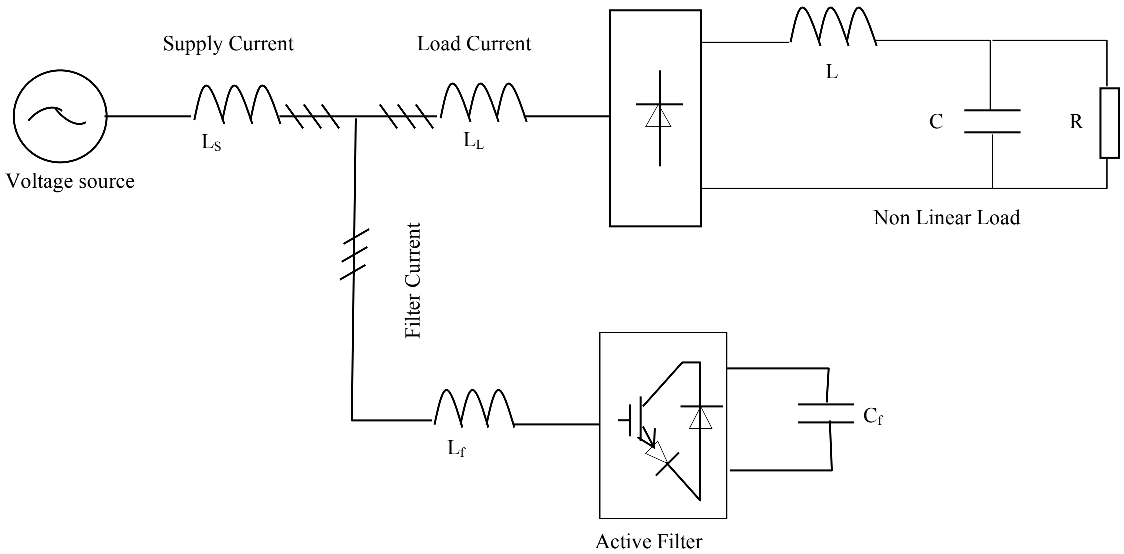

Figure 3.3: Active Power Filter

3.5.1 Active power Filter Control

The PHC technique is utilized here to produce the reference flows for the dynamic force channel. This strategy is utilized before in symphonious relief in regular and propelled airplane electric force framework (Dey et al., 2015 and S. Janpong et al., 2011). Taking into consideration the points of the common coupling (PCC) as V_a, V_b and V_c as the voltages, and the points i_{La}, i_{Lb} and i_{Lc}, as the loading currents. Then the instantaneous power where the load is available will be expressed as:

$$P_L = v_a i_{La} + v_b i_{Lb} + v_c i_{Lc} \tag{3.10}$$

The mean and oscillating values of the given power in equation (3.10) is expressed as

$$P_L = \bar{P}_L + \tilde{P}_L \tag{3.11}$$

Where, the voltage of the capacitor is assumed and fixed to be constant through the process of controlling the power loss in the inverter by using PI to regulate the voltage in the DC capacitor. Leading to determine the total active power that fed by the source voltage as the summation of switching loss as P_{sw} and the power required in the load as P_L. all this, gives the equation of the reference source current as:

$$i_{sr} = Kv^{+1} \tag{3.12}$$

Considering the PCC voltage as V^{+1} for single positive component which is determined from the phase-lock loop (PLL), moreover, the power obtained from the source can be expressed as:

$$P_s = vi_{sr} = Kv^2 \tag{3.13}$$

It is noticed that the low pass filter (LPF) is required in order to determine the mean of the power. This process can be done by dividing the mean load power by the total of the squared positive sequence, which gives the parameter K as:

$$K = \frac{\bar{P}_L}{V_{al}^2 + v_{bl}^2 + v_{cl}^2} \tag{3.14}$$

From equation (3.14) and after calculating the coefficient K, then the source reference currents can be obtained as:

$$\begin{bmatrix} i_{ar} \\ i_{br} \\ i_{cr} \end{bmatrix} = K \begin{bmatrix} v_a^+ \\ v_b^+ \\ v_c^+ \end{bmatrix} \tag{3.15}$$

Determining the reference current as expressed in Equation (3.15), can determine the error as expressed in Equation (3.16)

$$Error = i_L - i_r \tag{3.16}$$

Figure 3.4 shows the complete PHC method to generate the reference currents.

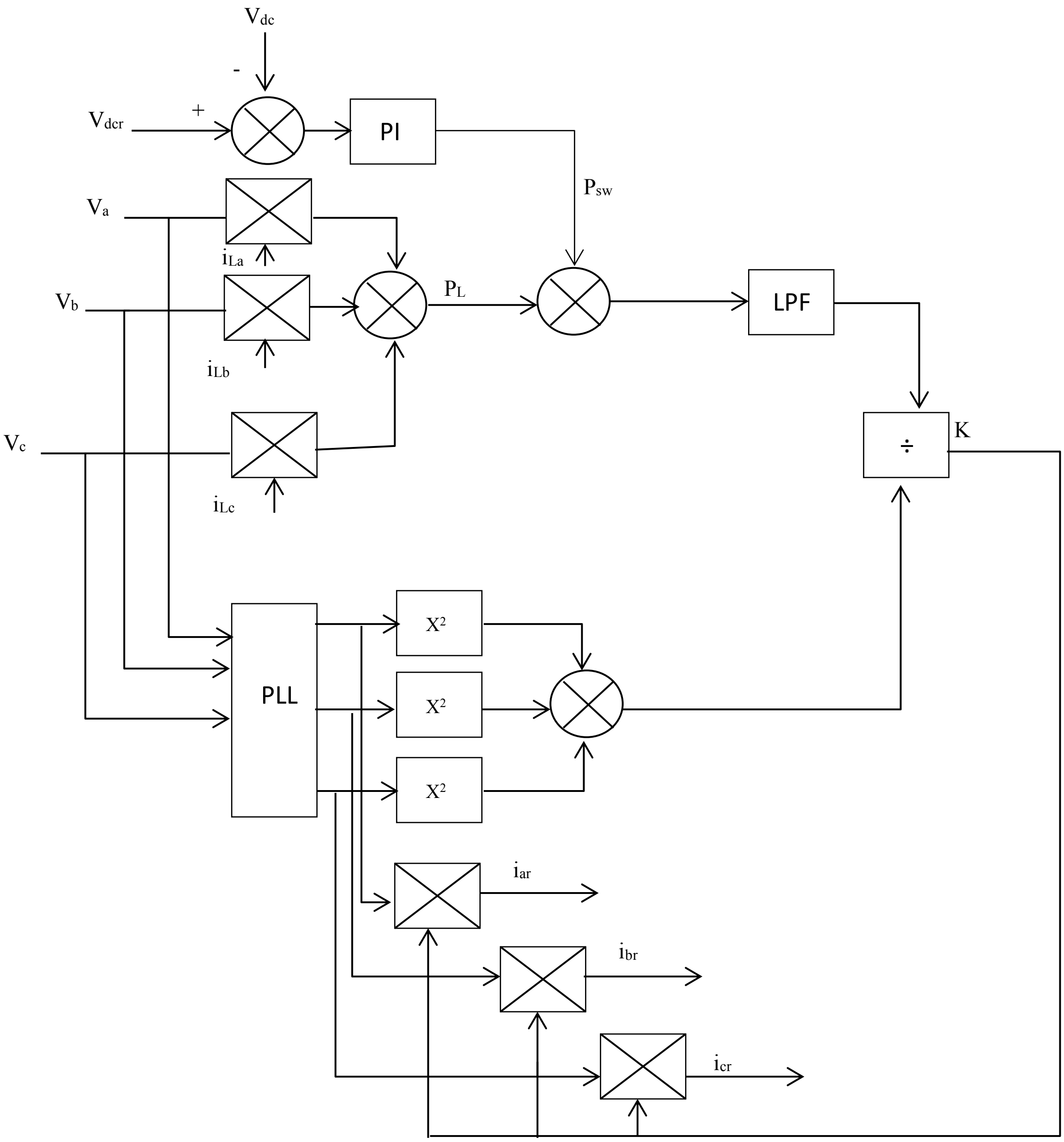

Figure 3.4: Complete PHC method

3.5.2 Control Stage

The use of the Ramp-time is the causing of the current existed in the inductance L_f of the active power filter in order to be in the same desired reference current signal. This can be obtained when the current error signal is zero crossing instants.

Then the Ramp-time can adjust a stabilized and fixed frequency without the dependent on the hysteresis band and clock (Ramchandra et al., 2014).

This gives the results of the error signal to be the contrast between the genuine burden and the ideal gracefully current waveform. The advantage of the Ramp-time is the control which produces the switching instance to make the current error signal crossing zero in the interval of the half of the desired switching points.

When the current error signal exceeds the half of the required time available on the both sides of zero, then the obtained result of the average value is zero, where, the close following the reference signal and the switching interval is very close to the required values.

As shown in Figure 3.5 how the switching signals are obtained for the CC-VSI, where the input to the Ramp-time (RT) is the error signal to be as the reference signal in between i_L and i_r.

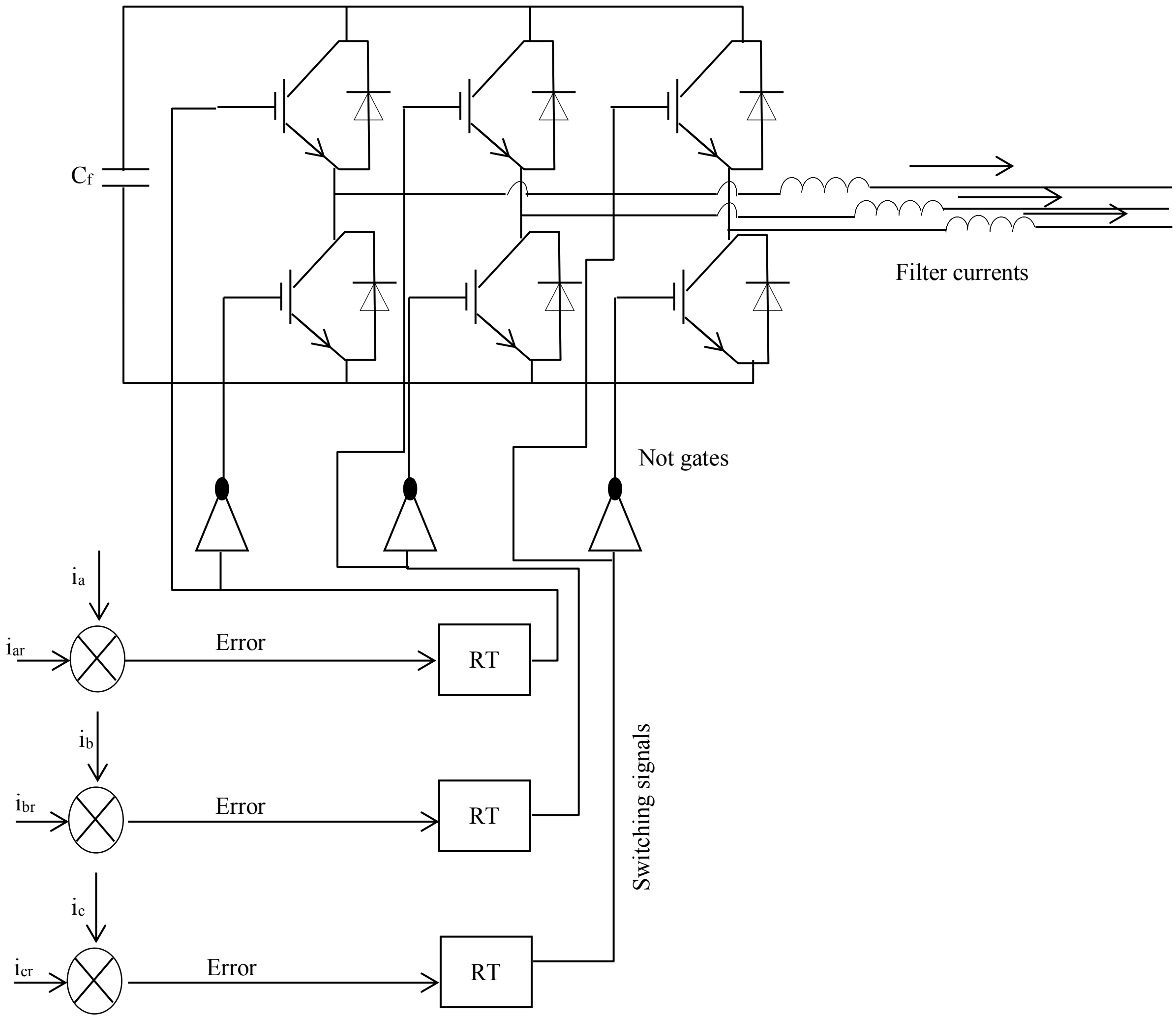

Figure 3.5: APF Switching Signals for the CC-VSI

In this case, the overall performance of the system is dependent on the selection of the switching frequency. Where, the higher performance is the use of higher switching frequency as much as possible except for the drawback, while these switching losses in the inverters and increase proportionally with the selected switching frequency that is f_s. In this case, the switching frequency is mostly selected to be less than 6 KHz in most of the applications. This frequency is most probably chosen in order to decrease the switching losses and get the required performance on the system. These switches are not ideal, the reason of they are not turning ON or OFF instantaneously. For this reason, it is importantly to include a threshold or dead time as illustrated in Figure 3.6 in order to avoid the short-circuit conditions.

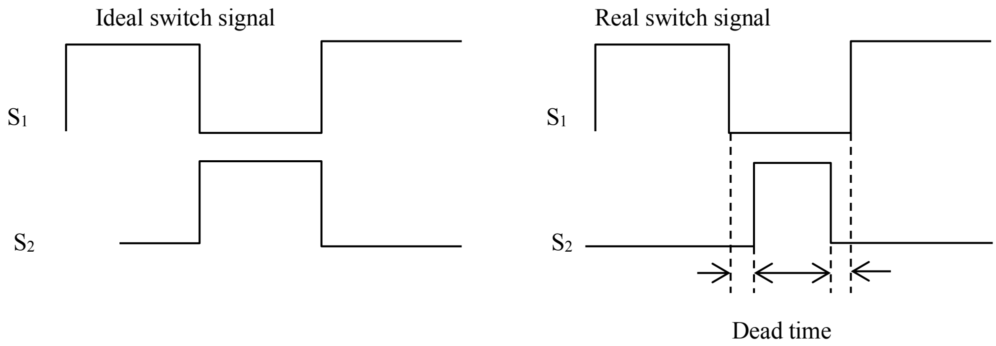

Figure 3.6: Switch pulse comparison with and without dead time

3.6 Active Power Filter

The nonlinear loads and their availability as mentioned in the previous section in the switching converters to control the AC drives and the HVDC, produce harmonics in the load. This gives an idea about the power electronics as a source of harmonics. In this thesis, the idea is to eliminate these harmonics to obtain stability and getting the required improvement in the power. SAPF is found to be the best for these problems, where its effectiveness is depending on:

1. The used process in order to get the reference currents, and
2. The controller types to control these currents.

In this thesis, the currents are generated by the artificial neural network (ANN) in the feedback process to obtain more stability and more efficient results.

The use of this technique is dependent on the improvement of the passive filters used in the past, and the research done about the passive filters and their disadvantages as

1. Large size, and
2. Tuning and risk resonance

The APF is considered as the improvement for the passive filters and the solution of the disadvantages of it. Moreover, APF is considered as the improvement in the semiconductor power devices. One of these improvements is the shunt active power filter for eliminating the harmonics in the reference currents. In these filters, there are three modes for the control process as:

1. Load current detection
2. Supply current detection, and
3. Voltage detection.

From these advantages for the APFs, it can be considered that the series APF to be perfect in the eliminating process of the harmonics in the supply voltage, while parallel power filters (PPFs)can be considered as the perfect filters to eliminate the supply currents. The SPAF is considered as more performance filter in the process of eliminating the unwanted harmonics even, not only in the production of current process. Also, the process of charging the capacitor as required by the Vdc to be suitable transmission of the power for the inverter supplement, this capacitor which absorbs the fluctuation of the power by the compensation process of the reactive power, where the harmonics and the losses of the converter for achieving the proper active control of the power. In this process, the idea is to keep the voltage across the terminals of the capacitor to be constant and stable, calling this voltage as Vdc as a reference voltage which must have minimum double the time of the boost in the DC voltage across the bus with respect to the peak of the phase in the AC voltage as expressed in equation (3.17).

$$V_{dcref} = \frac{2\sqrt{2}}{\sqrt{3}} \frac{V_{LL}}{m} \quad (3.17)$$

While the capability of the energy storage in the DC bus for the AF which should be as sufficient as to keep the disturbances that arise due to the load perturbation.

To determine the DC bus capacitance using equation (3.18) as follows

$$\Delta E_{dc} = \frac{1}{2} c_{dc} \left[\left(V_{dcref} \right)^2 - (V_{dc})^2 \right]$$
$$= \frac{1}{2} c_{dc} \left(V_{dcref} + V_{dc} \right) \left(V_{dcref} - V_{dc} \right) \qquad (3.18)$$

Assuming ΔE_{dc} as the energy that stored in the capacitor.

While the inductance which is used in the APF has important rule in smoothing process for the voltage sources inverter, these inductances are considered according to the carrier signal frequency and the hysteresis bandwidth of the filter current. Then the inverter pole point is expressed as shown in equation (3.19).

$$V_s = R_c i_c + L_c \frac{di_c}{dt} + V_f \qquad (3.19)$$

Assuming that V_f to be the value of the pulse width modulation voltage and V_s to be the instantaneous voltage.

In this process of control, it is used the reference source current and their generation. Where, the inputs are dependent on the p-q theory as mentioned in the previous sections to be

1. The load side harmonics,
2. Source voltages, and
3. Loss components of the current from the DC voltage control.

The conversion equation for the voltages and currents using the p-q theory which consists of the transformation variables as a, b and c as references for the instantaneous power, voltage and current using the αβ frame is expressed in equations (3.20) and (3.21).

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} cos\theta & \cos(\theta - 120) & \cos(\theta + 120) \\ sin\theta & \sin(\theta - 120) & \sin(\theta + 120) \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \qquad (3.20)$$

$$\begin{bmatrix} u_\alpha \\ u_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} cos\theta & \cos(\theta - 120) & \cos(\theta + 120) \\ sin\theta & \sin(\theta - 120) & \sin(\theta + 120) \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} \qquad (3.21)$$

The expression of the active and reactive power also expressed in equation (3.22)

$$\begin{bmatrix} p_l \\ q_l \end{bmatrix} = \begin{bmatrix} u_\alpha & u_\beta \\ u_\beta & -u_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{3.22}$$

Figure 3.7 shows the block diagram of the shunt active power filter including the non-linear load compensation. The circuit is designed so that to cancel the harmonic currents drawn on the non-linear load and producing current to be in-phase with the waveform. This connection is controlled in order to support the compensated current. The result of this circuit is the sinusoidal signal which is obtained from the power system at the coupling of the shunt APF.

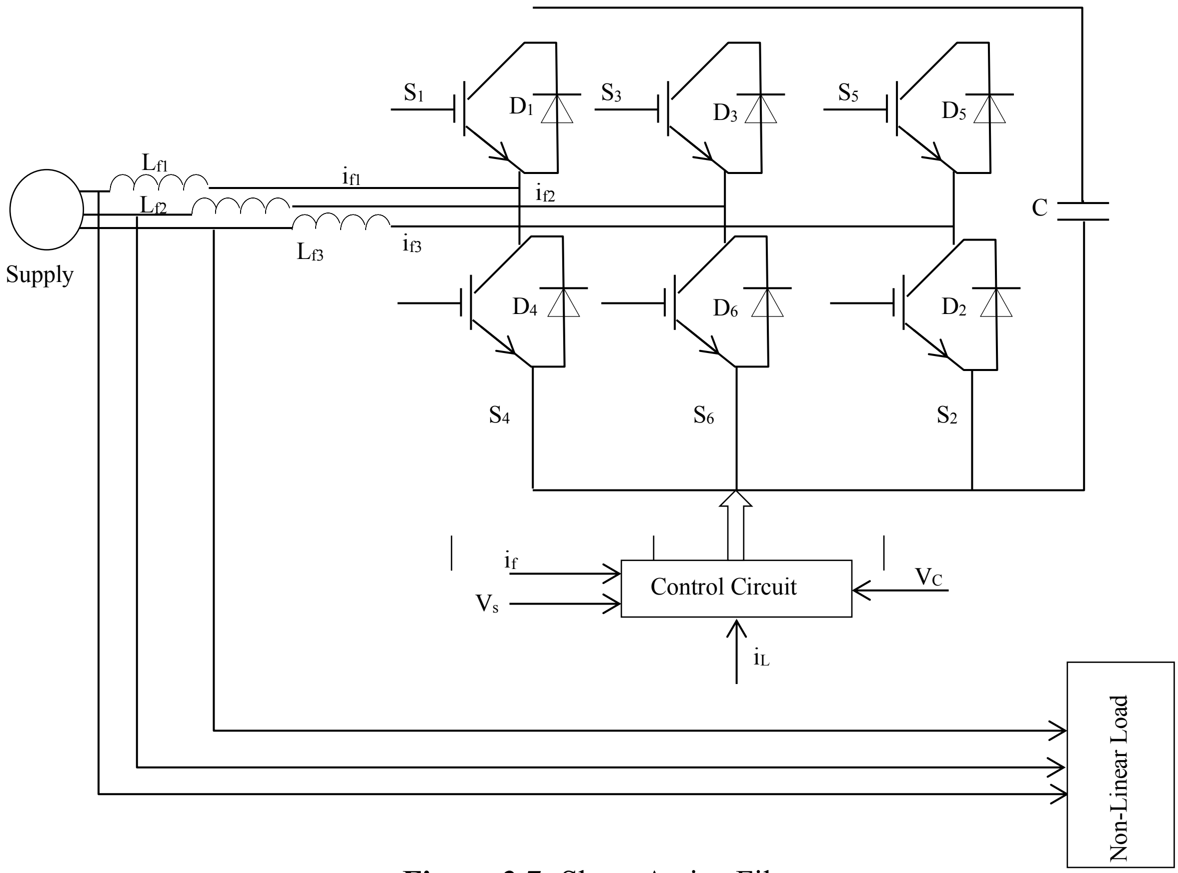

Figure 3.7: Shunt Active Filter

For the control of the shunt active filter is done as:

a. Synchronous method

In this method, in order to eliminate the harmonic currents, using the currents i_a, i_b and i_c and transferring them from 3-phase to 2-phase currents using αβ reference frame as i_α and i_β using equation (3.23) as

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -0.5 & -0.5 \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{La} \\ I_{Lb} \\ I_{Lc} \end{bmatrix} \tag{3.23}$$

By applying the phase locked loop (PLL) algorithm and using the voltage sources v_{sa}, v_{sb} and v_{sc} to generate $\cos(\theta_{est})$ and $\sin(\theta_{est})$. Moreover, the obtained currents from equation (3.23) and using the (d-q) reference to express their currents as shown in equation (3.24).

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \sin(\theta_{est}) & -\cos(\theta_{est}) \\ \cos(\theta_{est}) & \sin(\theta_{est}) \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{3.24}$$

Now applying a LPF to transform the DC quantities to non-DC quantities as expressed in equation (3.25).

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \bar{i}_d + i_d \\ \bar{i}_q + i_q \end{bmatrix} \tag{3.25}$$

Using the expressions for $i_{\alpha\text{-ref}}$ and $i_{\beta\text{-ref}}$ as shown in equation (3.26)

$$\begin{bmatrix} i_{\alpha-ref} \\ i_{\beta-ref} \end{bmatrix} = \begin{bmatrix} \sin(\theta_{est}) & -\cos(\theta_{est}) \\ \cos(\theta_{est}) & \sin(\theta_{est}) \end{bmatrix}^{-1} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \tag{3.26}$$

$$\begin{bmatrix} i_{\alpha-ref} \\ i_{\beta-ref} \end{bmatrix} = \begin{bmatrix} \sin(\theta_{est}) & \cos(\theta_{est}) \\ -\cos(\theta_{est}) & \sin(\theta_{est}) \end{bmatrix} \begin{bmatrix} \bar{i}_d + i_d \\ i_q \end{bmatrix} \tag{3.27}$$

These reference currents can be expressed as

$$\begin{bmatrix} i_{a-ref} \\ i_{b-ref} \\ i_{c-ref} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -0.5 & \frac{\sqrt{3}}{2} \\ 0.5 & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{\alpha-ref} \\ i_{\beta-ref} \end{bmatrix} \tag{3.28}$$

Resulting, the compensation currents can be expressed as

$$i_{ca} = i_{a-ref} - i_{La}$$

$$i_{cb} = i_{b-ref} - i_{Lb} \tag{3.29}$$

$$i_{cc} = i_{c-ref} - i_{Lc}$$

Figure 3.8, shows the scheme of the synchronous references

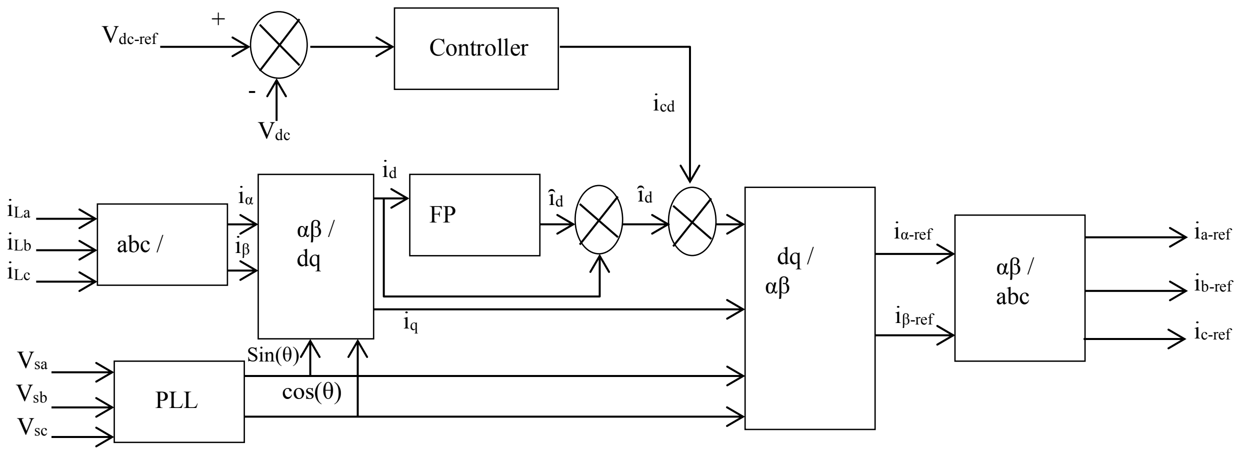

Figure 3.8: Frame detection method

The measuring of the source voltages as V_{sa}, V_{sb} and V_{sc} to control the synchronous currents and this method is expressed by

$$v_{sa}(t) = V_{sm}.\sin(\omega t)$$
$$v_{sb}(t) = V_{sm}.\sin\left(\omega t - \frac{2\pi}{3}\right) \tag{3.30}$$
$$v_{sc}(t) = V_{sm}.\sin(\omega t - \frac{4\pi}{3})$$

Where, the maximum amplitude of the current obtained from the filter as I^*_{smax} can be expressed as:

$$I^*_{s\,max} = I^*_{smp} + I^*_{smd} \tag{3.31}$$

With

$$I^*_{smp} = \frac{2P_{moy}}{3V_{sm}} \tag{3.32}$$

Using this expression I^*_{smd} to express the current that keeps the voltage i.e. the DC one across the capacitor C_{cd}.
The obtained currents are in phase with the supplied voltage, the calculation of the current source can be done by the multiplication of the maximum point of the amplitude.
The used equations can be defined as

$$i_{ua}(t) = \frac{v_{sa}}{V_{sm}}$$
$$i_{ub}(t) = \frac{v_{sb}}{V_{sm}} \tag{3.33}$$
$$i_{uc}(t) = \frac{v_{sc}}{V_{sm}}$$

$$i^*_{sa}(t) = I^*_{sm}.i_{ua}$$

$$i_{sb}^*(t) = I_{sm}^*.\, i_{ub} \quad (3.34)$$

$$i_{sc}^*(t) = I_{sm}^*.\, i_{uc}$$

The compensation currents are i_{ca}^*, i_{cb}^* *and* i_{cc}^* and can be obtained from the difference between the current references and the currents obtained from the load. Moreover, these currents can be expressed as

$$i_{ca}^* = i_{sa}^*.\, i_{La}$$

$$i_{cb}^* = i_{sb}^*.\, i_{Lb} \quad (3.35)$$

$$i_{cc}^* = i_{sc}^*.\, i_{Lc}$$

In figure 3.9, the principle operation of the synchronous currents is explained in details.

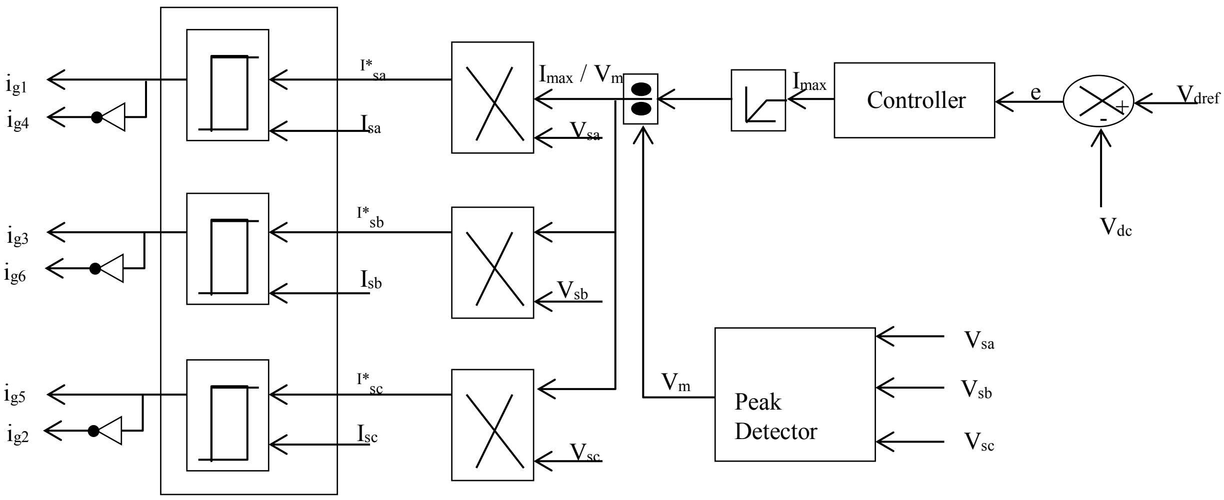

Figure 3.9: Synchronous Current reference detection

For the controller of the DC voltage, the comparison of the measured and the reference voltages as a regulation loop is taken and applying equation (3.36) as:

$$\frac{V_s^2}{(V_{dc-ref}.C_{dc}.s)} \tag{3.36}$$

Using the transfer function of the closed loop with the regulator given by equation (3.37)

$$\frac{V_{dc}}{V_{dc-ref}} = \frac{\frac{K_p+K_i}{s}.\frac{V_s^2}{V_{dc-ref}.C_{dc}.s}}{1+(K_p+\frac{K_i}{s}).\frac{V_s^2}{(V_{dc-ref}.C_{dc}.s)}} \tag{3.37}$$

Re-arranging equation (3.37) to get a second order equation for the closed loop as equation (3.38).

$$S^2 + 2\xi\omega_n s + \omega_n^2 \tag{3.38}$$

3.7 Summary

In this chapter, the theoretical description of the different types of filters and the control process of the currents as reference currents are explained in details. In the next chapter, the proposed model and its simulation results will be explained and discussed in details.

CHAPTER 4
ARTIFICIAL NEURAL NETWORK

4.1 Overview

This chapter explains the theoretical concept of the artificial neural network in details. In machine learning and psychological science, artificial neural networks (ANNs) are a group of models enlivened by organic neural systems the focal sensory systems of creatures, specifically the cerebrum and are utilized to gauge or surmised capacities that can rely on upon a substantial number of inputs and are by and large obscure. Manufactured neural systems are for the most part exhibited as frameworks of interconnected neurons which trade messages between one another. The associations have numeric weights that can be tuned in view of experience, making neural nets versatile to inputs and fit for learning.

4.2 Introduction

The most advantage of the passive filters is that the passive filters are used for the elimination process of the harmonics with simple and costless. Where, the passive filters have so many disadvantages and some of these disadvantages are: large size, tuning and the risk of the resonance and its problems. In some issues, the improvements done for the power semiconductor devices are the consideration of the active power filters (APF). For the most popular filters to be considered, the shunt active power filter (SAPF) for the performance got in the mitigation of the harmonic in the current. The control process has three types as:

- Load current detection,
- Supply current detection, and
- Voltage detection.

For the compensation process of the harmonics elimination in the supply voltage, the series active power filter (SAPF) is the most suitable filter to be considered.

Moreover, the parallel active power filter is considered to be the most suitable filter in order to compensate the harmonics in the supply current.

As mentioned in the previous chapter, the shunt active power filters (SAPFs) have the most performance to eliminate the harmonics, and the best control process to produce currents, as much as to recharge the capacitor by V_{dc} to be exactly and perfect transmitted of the required power to supply the inverter.

Where, the capacitor which is called the storage capacitor absorbs the fluctuated power by the compensation of the reactive power, as much as the harmonics and finally the losses of the converter for the control process of the active power. In these mentioned cases, the average voltages available across the terminals of the capacitor are kept at a constant value. Also, the PI controller is sometimes used in order to regulate the voltages, in other cases and while the variation process for the load perturbations and the non-linear conditions makes the detection process of the PI parameters to be difficult and consuming time as a disadvantage. Moreover, another disadvantage which is the un-ability to improve the transient response of the power controls. For this reason, the artificial neural network (ANN) became more famous in these applications for its learning structure, ability of learning, higher speed of recognition and the adaptation for any system applied with.

4.3 Artificial Neural Network

As known about the ANN to be a mathematical model for simulating the structure and the functionalities of any biological system, where, the basic structure of the ANN is an artificial neuron, which can be considered as a mathematical function. This model consists of three sets:

- Multiplication,
- Summation, and
- Activation.

Where, at the input edge of the neural network, the input system is multiplied by the individual weight, while in the center port of the neural network consists of the summation function, which sums all the input ports including the weights and the bias.

The summation process for the bias and the weighted inputs are at the exit points of the neural network to be the activation function, which is called the transfer function as shown in Figure 4.1.

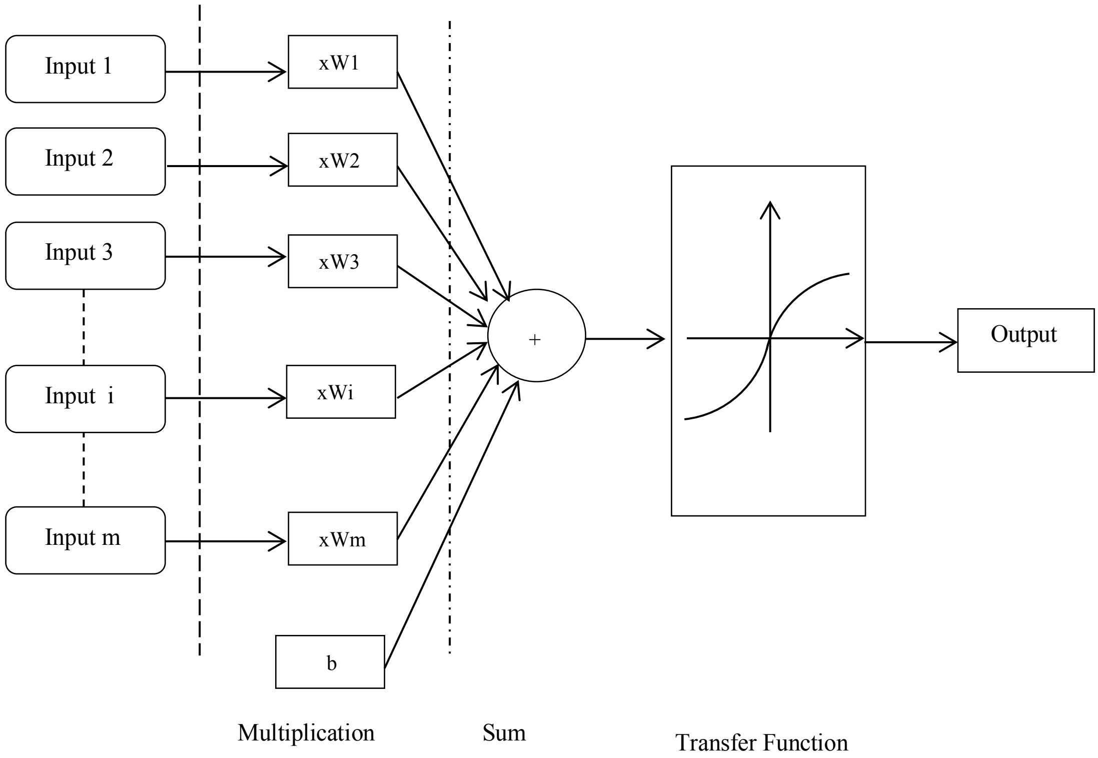

Figure 4.1: Artificial Neural Network General Block Diagram

Where, the simplest set of rules for the NN and its shape as shown in Figure 4.2, the ANs can use the simplest facts in order to merely simple and few rules.

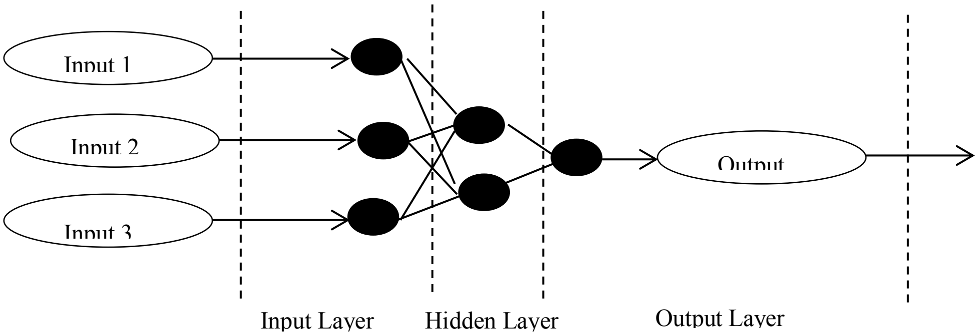

Figure 4.2: Simple ANN

4.4 Artificial Neuron

The artificial neuron (AN) is the main consideration of the ANN. The basic functions of the AN came from the biological neuron which is the main concept of the biological NNs that has the brain, spinal cord and the peripheral ganglia which can be shown in Figure 4.3.

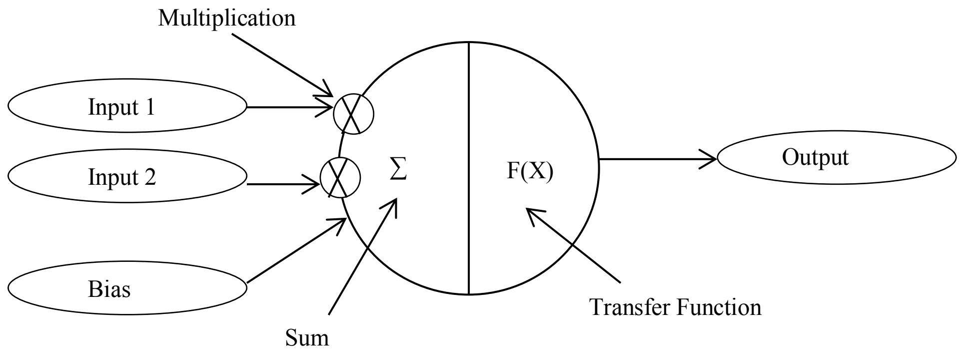

Figure 4.3: AN Shape

Where, Figure 4.3 shows the AN with all its components as the inputs, weights, transfer function, bias and the output. Moreover, the body of the AN represented by the multiplication for the inputs with the weights, then the summation and then the transfer function to obtain the output. The benefit of the AN system is the simplicity in the mathematical operations as expressed in Equation (4.1).

$$y(k) = F\left(\sum_{i=0}^{m} w_i(k).x_i(k) + b\right) \tag{4.1}$$

As shown in the mentioned above and in the equation (4.1), the only unknown which is the transfer function. The transfer function which represents the properties of the AN and as shown it is represented as a mathematical formula. This can be solved by selecting the transfer function as the basis for the neural network (NN) to solve it, this function is selected from the set of functions as:

a. Step function,
b. B. linear function and
c. Non-linear function.

Where, the step function is considered as a binary one which has just one or zero as a result. This depends on the specification of the threshold which is expressed in Equation (4.2). This means that if the output meets the required value which is called the target value in the NN, then the result will be one. While, if the output does not meet the target, then the obtained result is zero.

$$y = \begin{cases} 1 & if\ w_i x_i \geq threshold \\ 0 & if\ w_i x_i < threshold \end{cases} \quad (4.2)$$

This type of function, when it is used in the NN, then it is called perceptron. This type of function is used for the solution of the classification problems which exists in the end layer of the NN. This type of solution is the simplest type as it is called the linear transfer function, because the NN is processing the simplest linear transformation including the summation of the weights multiplied with the inputs and the bias is added to their multiplication results. In the case of non-linear function, then the sigmoid function is the used function. The sigmoid function (SF) has its importance in the calculation for the weights and the updates of the weights in the ANN.

4.5 Artificial Neural Network and its Types

The meaning of the artificial neural network (ANN), is the combination of more than one AN. The reason of combining the AN, is to have the ability to solve any complicated problem. This came from the disadvantage of using only one AN. The use of AN alone, has so many disadvantages, and the most commonly one, which is the usefulness of solving real life problems. The ANN which is the combination of more than two or more of the AN has the ability to solve the real-life problems as a nonlinear, distributed and local methods. The combination of the AN is called topology, architecture of the ANN. The combination of the AN to be ANN is called:

a. Feed-forward neural network (FNN)
b. Recurrent neural network (RNN)

These names and their connections are expressed in Figure 4.4.

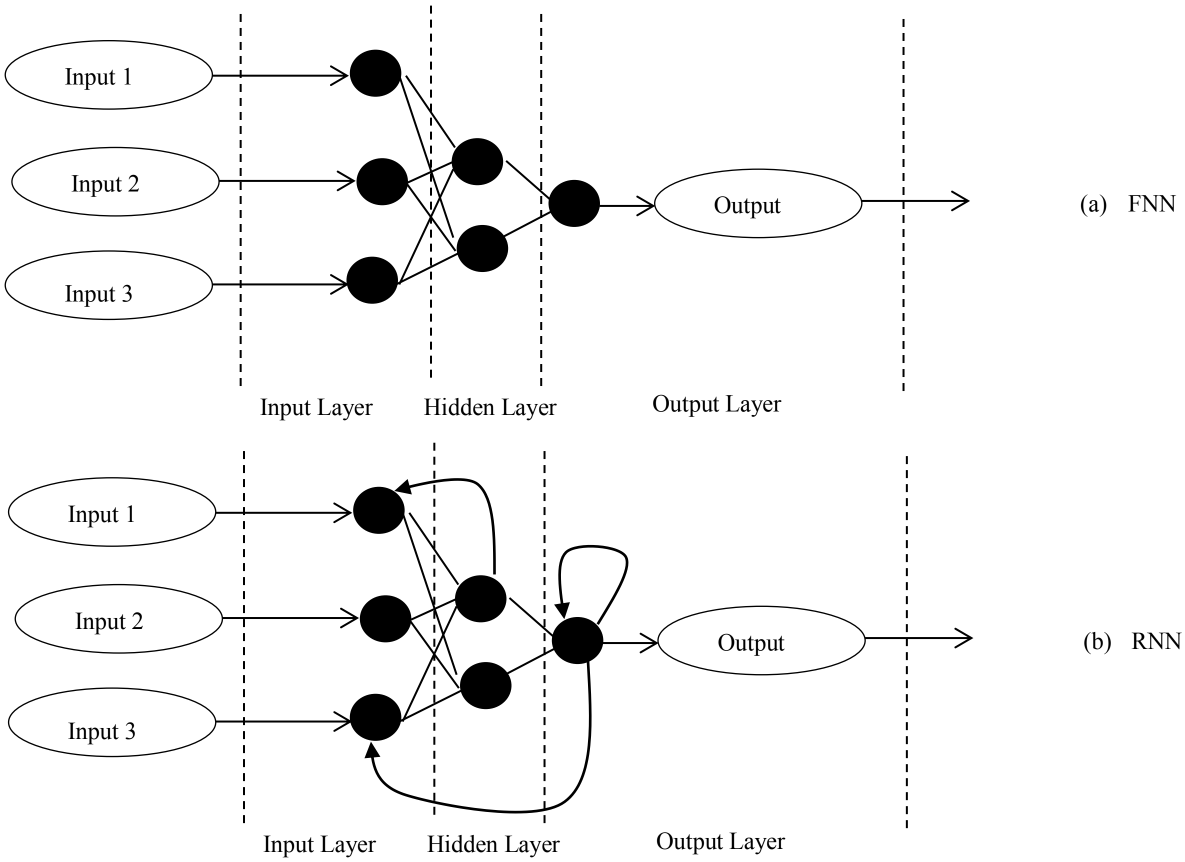

Figure 4.4: Artificial Neural Network Topologies: (a) FNN and (b) RNN

4.5.1 Feed Forward Artificial Neural Network

When the information passes from the input part to the output through the multiplication process between the input and the weights adding the bias to the function then to the output in one direction without any back loop, then it is called feed forward neural network (FNN) as shown in Figure 4.5. In the FNN, there are no limitations used in the number of inputs, also in the number of weights to the function. Where, the simplest FNN is the one including only one perceptron which has the ability of learning linear problems. This kind of ANN is for the purpose of the analytical explanations.

The mathematical description is shown in Equations (4.3), (4.4) and (4.5).

$$n_1 = F_1(w_1x_1 + b_1)$$

$$n_2 = F_2(w_2x_2 + b_2)$$

$$n_3 = F_2(w_2x_2 + b_2) \tag{4.3}$$

$$n_4 = F_3(w_3x_3 + b_3)$$

$$m_1 = F_4(q_1n_1 + q_2n_2 + b_4)$$

$$m_2 = F_5(q_3n_3 + q_4n_4 + b_5) \tag{4.4}$$

$$y = F_6(r_1m_1 + r_2m_2 + b_6)$$

$$y = F_6\begin{bmatrix} r_1\big(F_4[q_1F_1[w_1x_1 + b_1] + q_2F_2[w_2x_2 + b_2]] + b_4\big) + \cdots . \\ +r_2(F_5[q_3F_2[w_2x_2 + b_2] + q_4F_3[w_3x_3 + b_3] + b_5]) + b_6 \end{bmatrix} \tag{4.5}$$

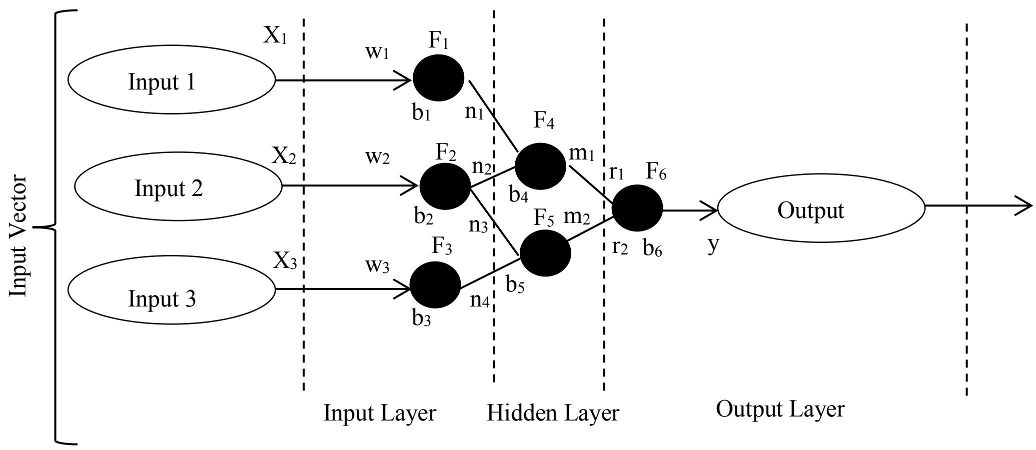

Figure 4.5: Feed Forward ANN

4.5.2 Recurrent Artificial Neural Network

In the recurrent artificial neural network (RNN), the only difference between RNN and the FNN is the back loops, otherwise all are same even with the unlimited number of inputs and weights are same. In the RNN, the information is not transmitted in only one direction; also, it is transmitted in the backward. Moreover, this behavior of backward, gives the system to create an internal case for the network to use the internal memory for the processes of any sequence of input as shown in Figure 4.6. In the case of RNN, the ANN is fully functionally; in this case all blocks are connected directly to every building block and in all directions. RNN has many other types as:

a. Hopfield,
b. Elman,
c. Jordan and
d. Bidirectional.

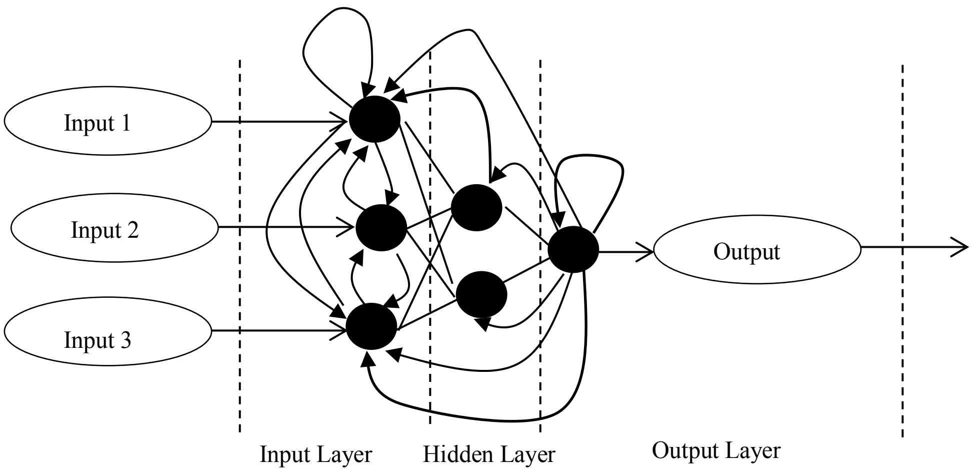

Figure 4.6: RNN block diagram

4.5.3 Hopfield Artificial Neural Network

As mentioned above, Hopfield artificial neural network (HANN) is a type of RNN, where in the HANN has the ability to store more than one target as an output vector. Moreover, these stable vectors are used as memory for the system to be recalled for comparison when provided with almost or same vector.

In this system of HANN, the binary system unit only has two values when they exceed the assigned threshold values as 1 or -1, and 1 or 0. The mathematical representation of this system is expressed in Equations (4.6) and (4.7).

$$a_i = \begin{cases} -1 & if \sum_j w_{ij} s_j > \theta_i \\ 1 & otherwise \end{cases} \quad (4.6)$$

$$a_i = \begin{cases} 0 & if \sum_j w_{ij} s_j > \theta_i \\ 1 & otherwise \end{cases} \quad (4.7)$$

In this type of ANN, the weights are adjusted so that the symmetric requirements are obtained; this reason is used to maintain the guarantee the decrease of the energy function monotonically in the activation regulations. If there are anon symmetric cases, then the NN will exhibit a periodic behavior. The HANN is shown in Figure 4.7.

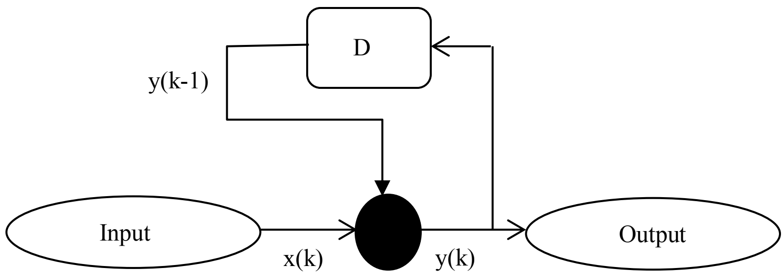

Figure 4.7: Hopfield Artificial Neural Network

Elman and Jordan Artificial Neural Network

Another type of RNN in its simple form is the Elman network. The difference in this type is that the first layer has only the RNN. This type is simple with three layers ANN with a backward in the hidden layer to the input layer. This type has the ability of detecting and generating the time-varying pattern. The Elman ANN has a sigmoid AN in the hidden layer, as much as a linear ANs in the output. This gives this type of ANN the accuracy just in a case that there are an enough ANs in the hidden layers.

When it has an enough layer in the hidden part, then it will get the ability to store the information and generate a temporal pattern as well as spatial patterns as shown in Figure 4.8. While in Jordan network, it is the same as the Elman networks, just in one difference which are the context units which are fed from the output layers not as the Elman networks getting fed from the hidden layers as shown in Figure 4.9.

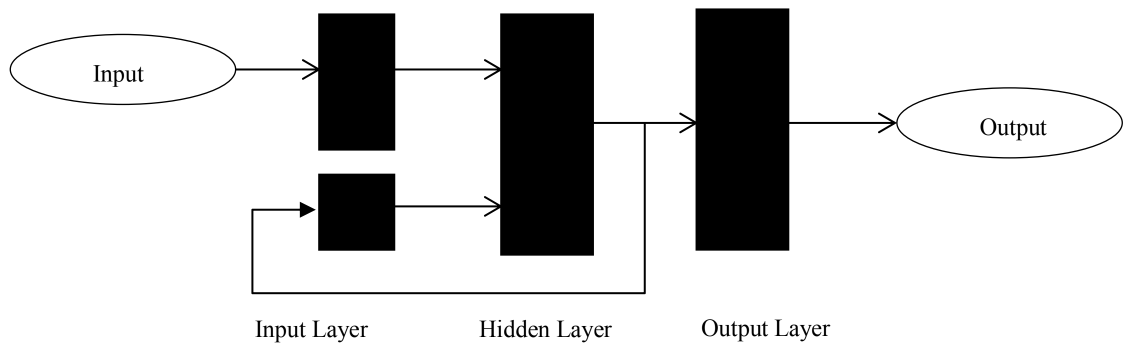

Figure 4.8: Elman Artificial Neural Network

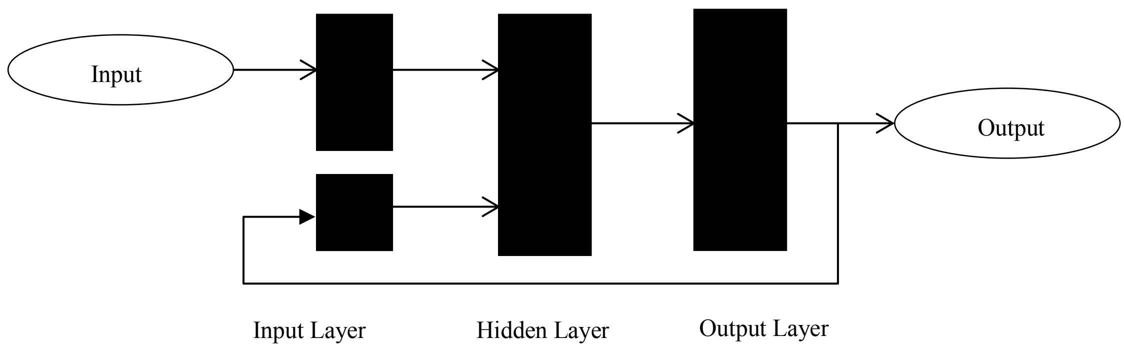

Figure 4.9: Jordan Artificial Neural Network

Long-Short Term Memory

Another type of the RNN which is the long-short term memory, this topology has the ability of learning from its experience of the process, as much as the ability to classify and predict the time-series with a long time for the unknown sizes in the important events. This gives this type of topology the name long-short term memory in order to outperform the other RNNs as the hidden Markov topologies in the learning sequences.

This type of NN has the ability to remember values for any length of time. This procedure is done by gates which determine when the input layers have the significant enough remembering it and when to transfer them to the output layer. This type of topology is shown in Figure 4.10 and as shown, the input layer has the sigmoid units.

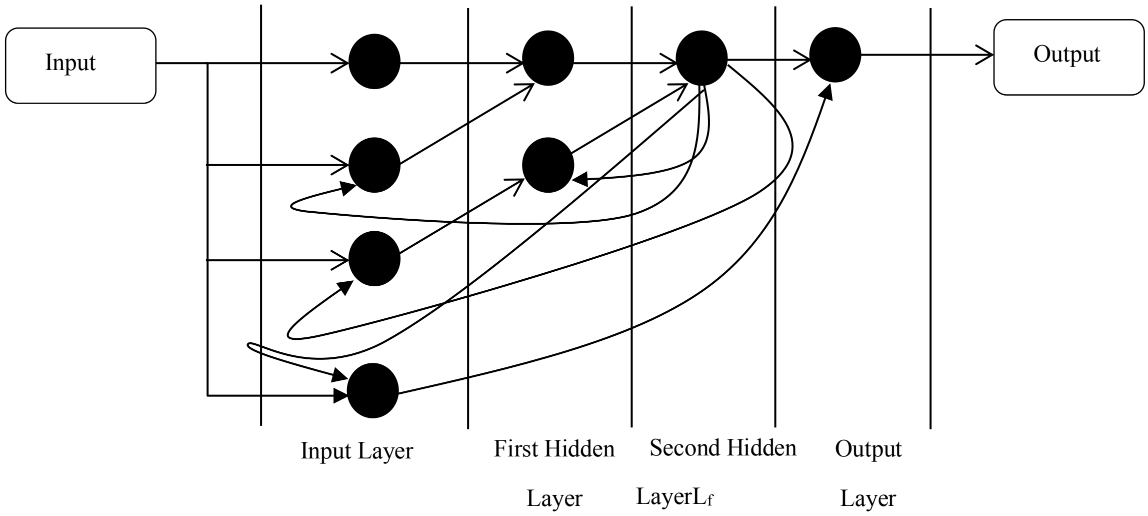

Figure 4.10: Long-Short Term Memory

Bidirectional Artificial Neural Network

This type of topology is an extension of the RNN, where it is designed for the prediction of the complex time series. This type has two directions of operations, the first direction is the direct and the second one is the inverse, for this reason it is called bidirectional transformation. The interconnection of the AN via sub networks is obtained by the two dynamic ANs to be able to remember the internal state. This kind of connection, increases prediction of the time series, this type of topology has the ability to connect the future and the past values of the signals. Moreover, this gives the ability to have two phases of learning, one for teaching the neural network and the second for the prediction process for the past history as shown in Figure 4.11.

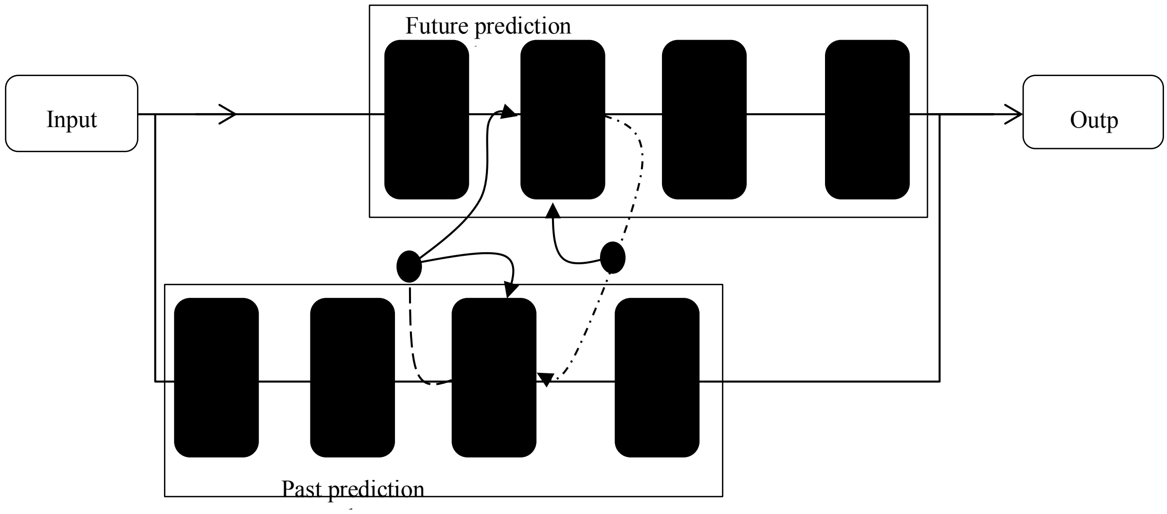

Figure 4.11: Bidirectional Artificial Neural Network

4.6 Summary

In this chapter, a theoretical concept about artificial neural network is explained in details, while the next chapter will explain in complete details about the proposed system simulation and the obtained results.

CHAPTER 5

SIMULATION RESULTS

5.1 Overview

This chapter explains the simulation concept of the proposed system in details. Taking into consideration the machine learning and psychological science, artificial neural networks (ANNs) which are a group of artificial neural networks (ANNs), moreover, manufactured neural systems are for the most part exhibited as frameworks of interconnected neurons which trade messages between one another. The associations have numeric weights that can be tuned in view of experience, making neural nets versatile to inputs and fit for learning.

5.2 Series Active Filter

In the real life, in order to perform the parallel active power filter, it is promoted to be according to the voltage source (Dey et al., 2013). Also, it has accurate achievement in the case of high voltage with multilevel inverters. In this thesis, for three-phase voltage, it is desirable to use the active filter as parallel connection as shown in Figure (5.1).

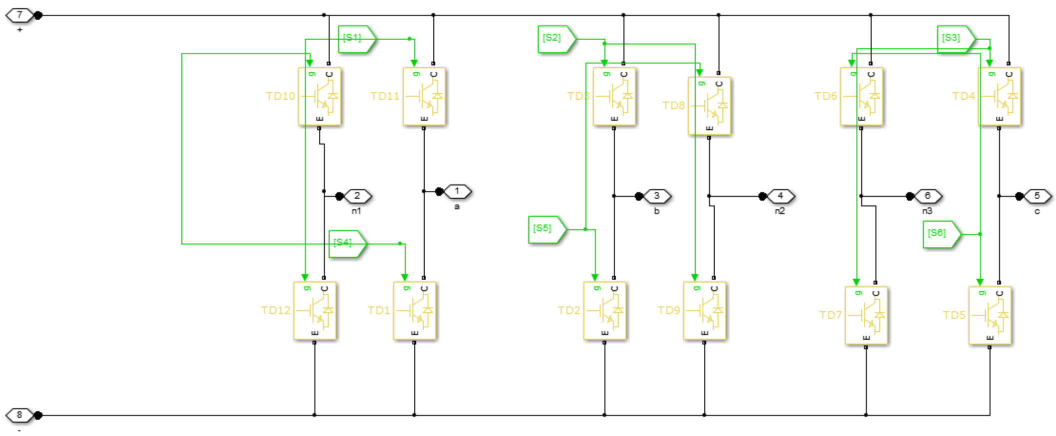

Figure 5.1: Active Power Filter

In this case, the filter produces current in each connection point for the following reasons:

- Minimizing or even cancelling the harmonics
- Correcting the power factors to be suitable with the required frequency
- Regulating the magnitude of the voltage
- Balancing the load

For this reason, the distribution of the AC models is done by the active fundamentals in the current available in the load. Where, the regulation of the voltage is a synchronous case as much as the power factor, for their dependent on the reactive current. Also, this is effective in the real time for any control process that has the flexibility in order to be shaped. The filter in this case can be controlled with any other method for the most important two cases:

- Voltage
- Current

In the proposed model, as a three-phase system as shown in Figure (5.2).

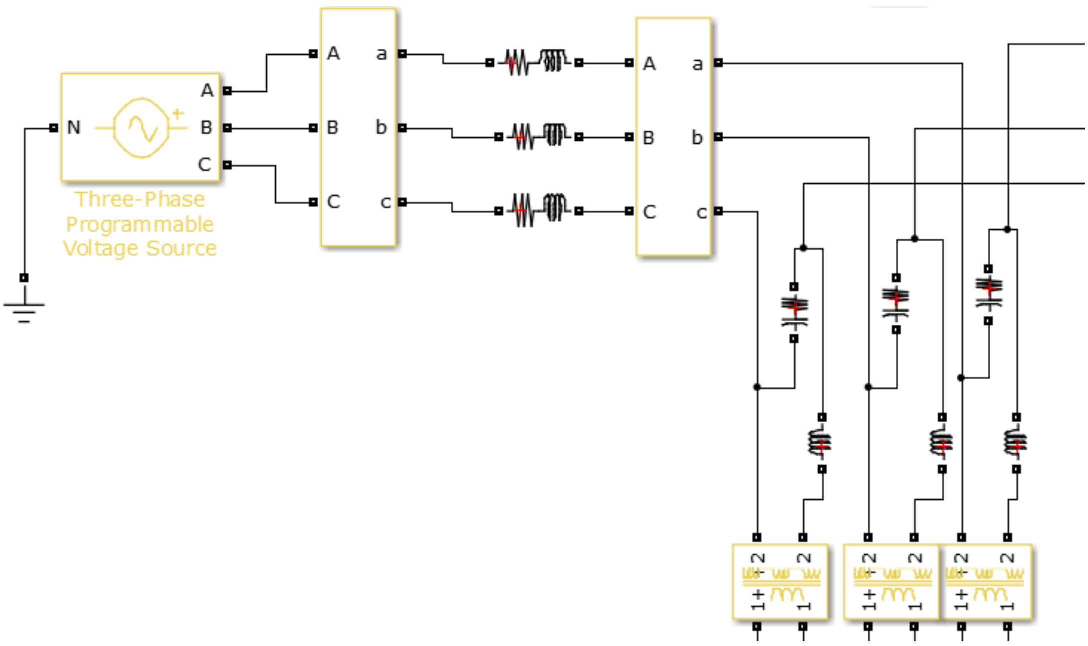

Figure 5.2: Input system (Three-phase)

5.3 Three-Phase V-I Measurement

Using the three-phase V-I block as shown in Figure (5.3) in order to measure the voltage and current in the circuit. The connection of this block is in series with all elements to obtain one of two cases:

- Phase to ground
- Phase to phase

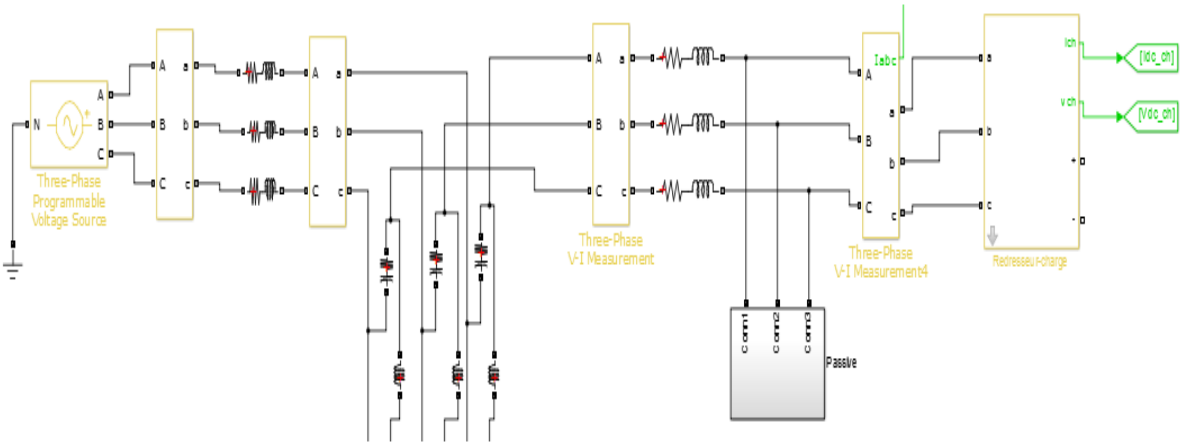

Figure 5.3: Three-Phase V-I Measurement

For calculating voltage as Phase to ground, then using Equation (5.1)

$$V_{abc}(pu) = \frac{V_{phase\ to\ ground}(V)}{V_{base}(V)} \tag{5.1}$$

Where, $V_{base} = \frac{V_{nom}(V_{rms})}{\sqrt{3}}.\sqrt{2}$

As Phase to phase, then using Equation (5.2)

$$V_{abc}(pu) = \frac{V_{phase\ to\ phase}(V)}{V_{base}(V)} \tag{5.2}$$

Where, $V_{base} = V_{norm}(V_{rms}).\sqrt{2}$

As a current measure, using Equation (5.3)

$$I_{abc}(pu) = \frac{I_{abc}(A)}{I_{base}(A)} \tag{5.3}$$

Where, $I_{base} = \frac{P_{base}}{V_{norm}} * \frac{\sqrt{2}}{\sqrt{3}}$

The adjustment in MATLAB simulation block diagram is shown in Figure (5.4). The obtained result is shown in Figure (5.5)

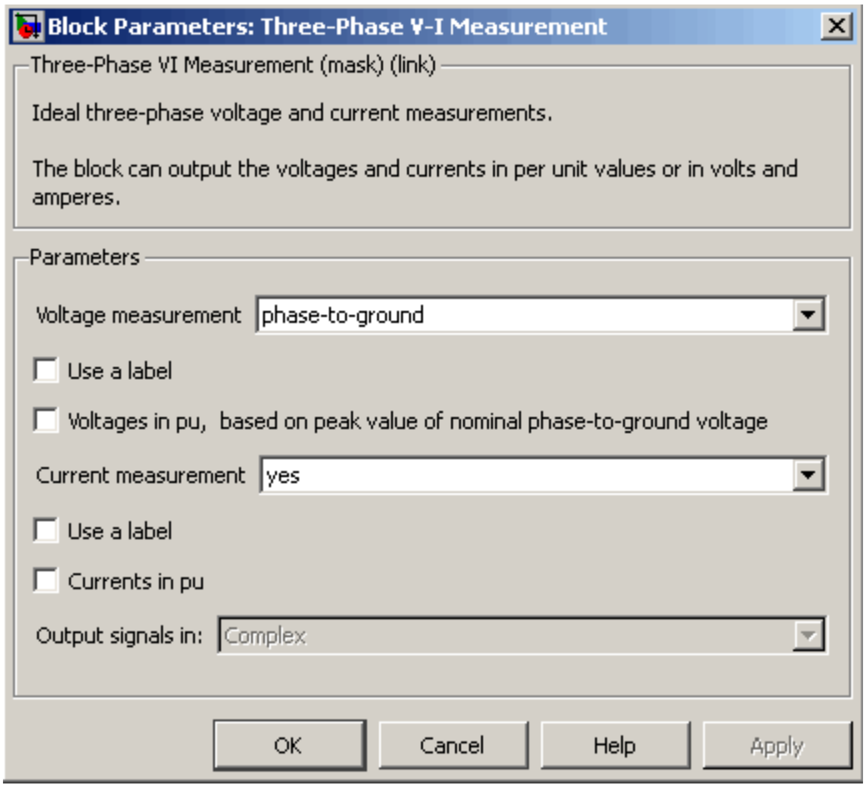

Figure 5.4: Voltage selection box

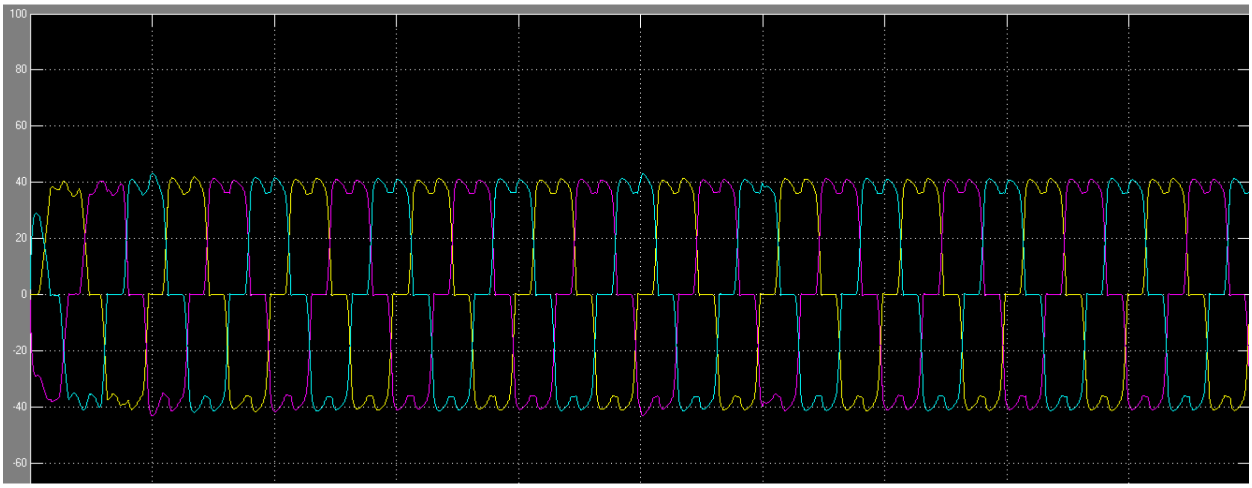

Figure 5.5: Obtained Result for I_{abc}

The selection process is controlled as shown in Figure (5.6)

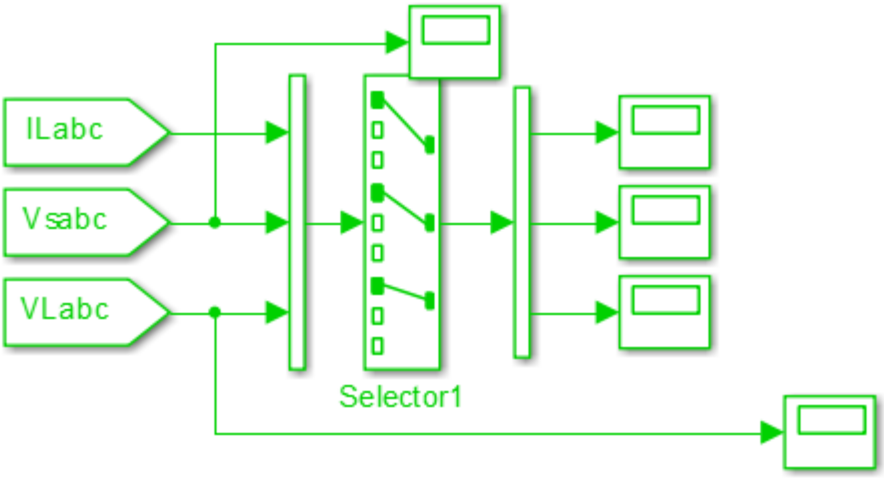

Figure 5.6: Voltage selection control box

While current control box is shown in Figure (5.7)

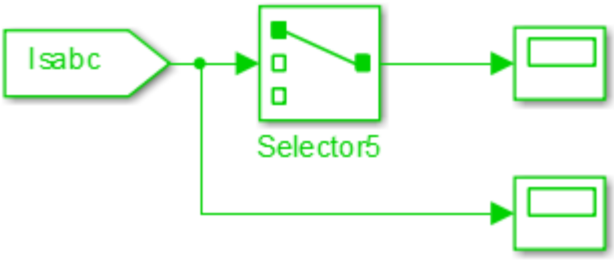

Figure 5.7: Current selection box

According to the obtained results from the above boxes are as follows:

1. First selection (I_{Labc}) is shown in Figure (5.8)

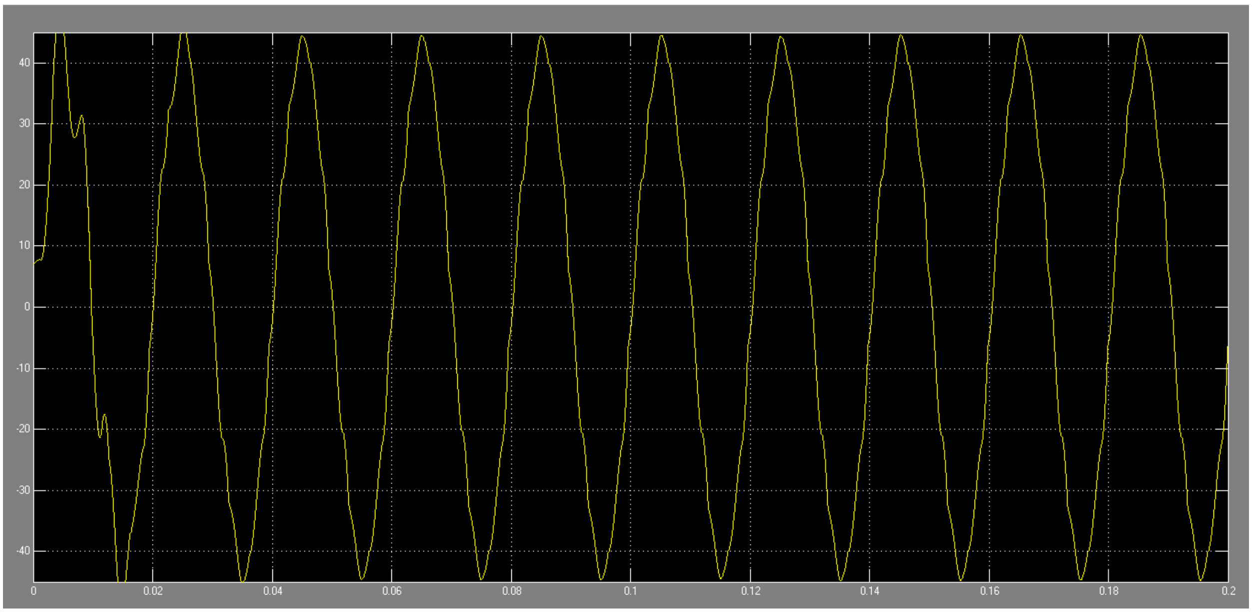

Figure 5.8: First Selection

2. V_{Sabc} selection is shown in Figure (5.9)

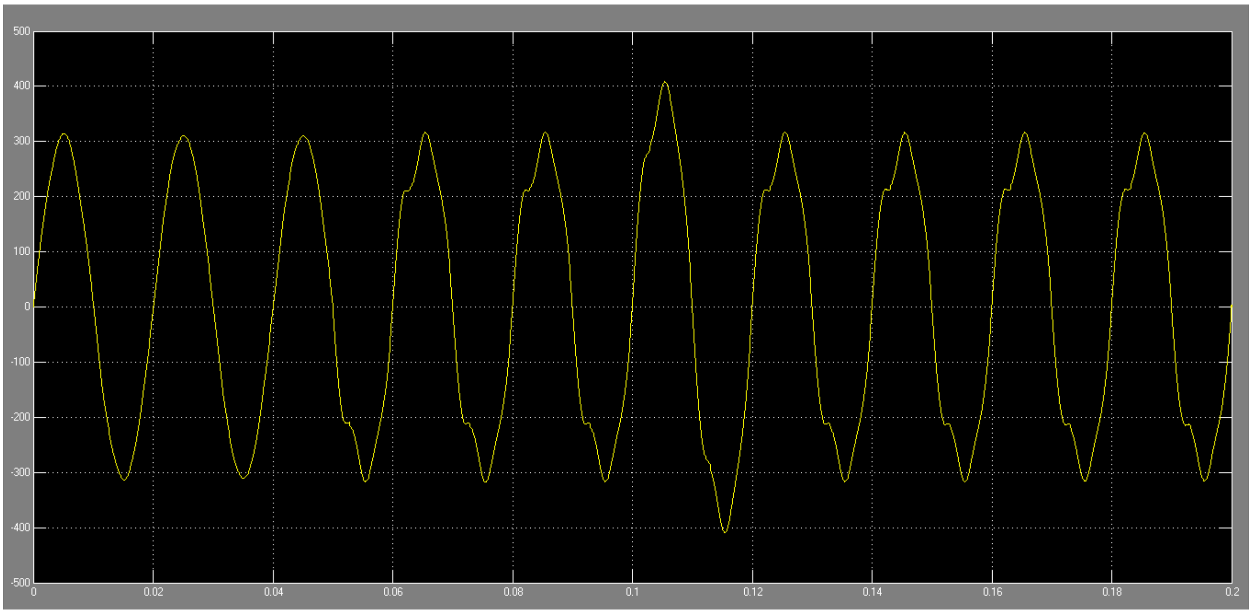

Figure 5.9: Second Selection

3. V_{Labc} selection is shown in Figure (5.10)

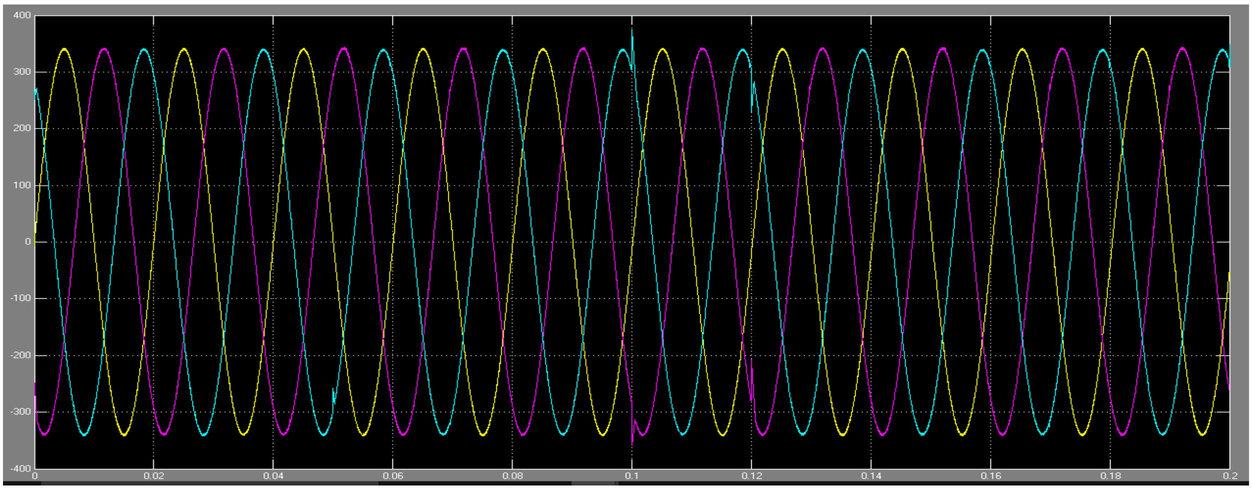

Figure 5.10: V_{Labc} selection

In the case of I_{Sabc} has two cases, the first case which is the result obtained by the selector is shown in Figure (5.11).

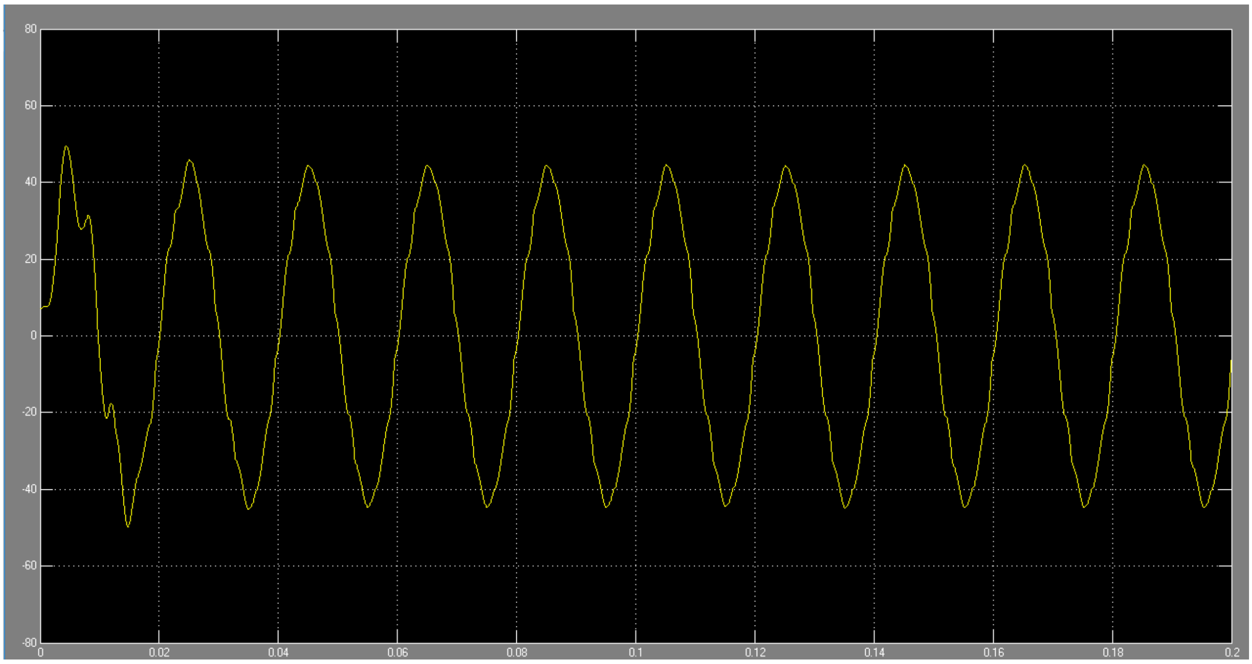

Figure 5.11: Obtained after the Selector

Without the selector, the obtained result is shown in Figure (5.12)

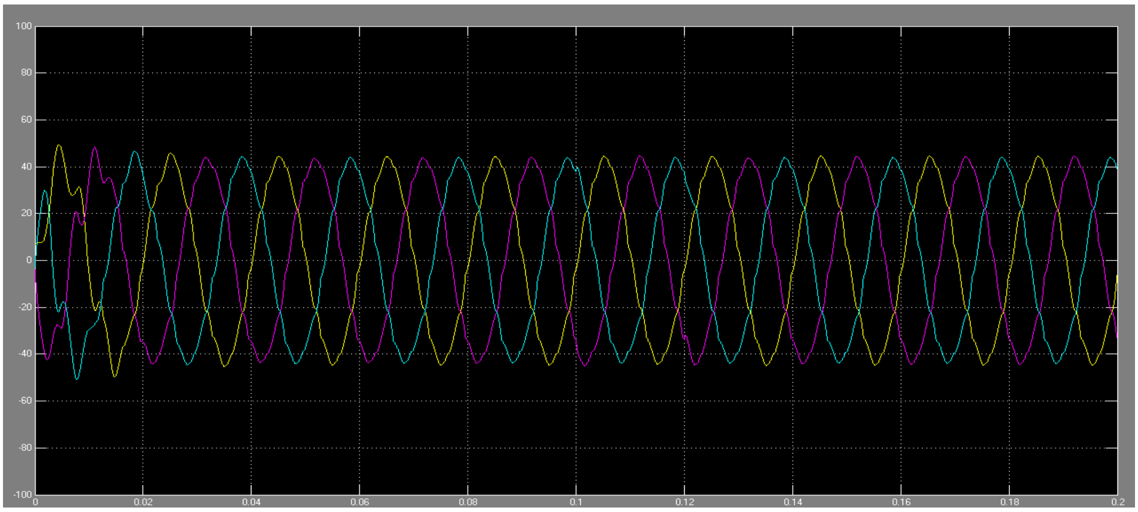

Figure 5.12: The obtained result without the selector

5.4 Neural Networks for cancelling Harmonics

In this work, the neural network is used to work as a harmonic cancellation process; the used network, including PWM is shown in Figure (5.13).

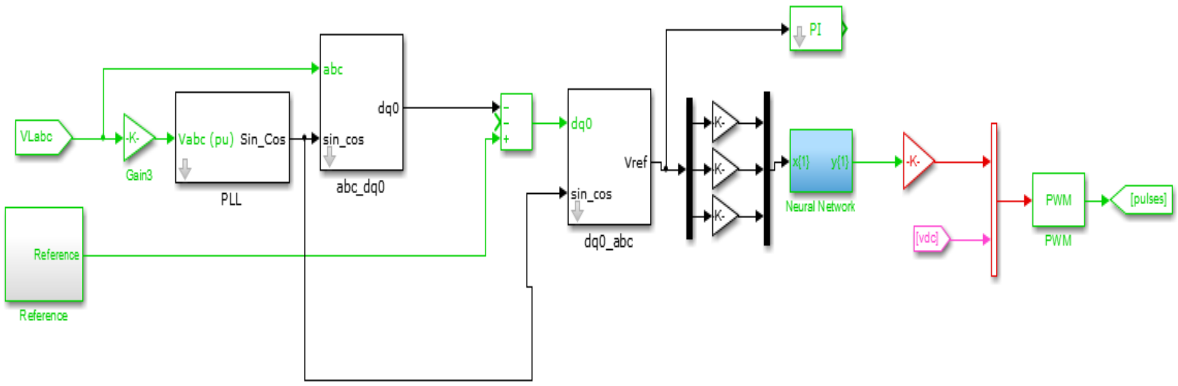

Figure 5.13: Neural Network

The importance of using neural network as a feedback to cancel the unwanted harmonics is implemented and proved its performance more than any other method. Moreover, using the neural network in the shunt active power filter is unique so that the proposed methods excluding the neural network have the same applications with some disadvantages as:

a. Existence of unwanted harmonics
b. Complicated models
c. Higher order filters

While using the proposed model has the following advantages as:

a. Almost zero unwanted harmonics
b. So simple model
c. A lower order filters

As shown in Figure (5.14), the output signal obtained by the series active filter with its distortions

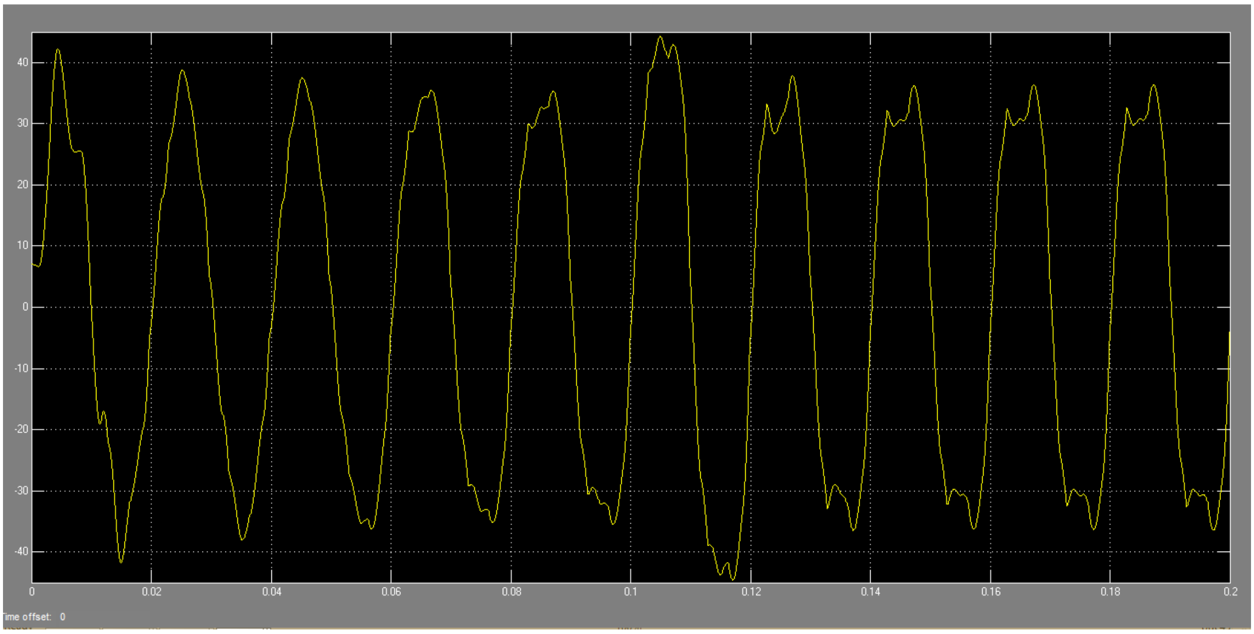

Figure 5.14: Output Signal of the Series Active Filter

While Figure (5.15) shows the output, signal obtained by considering the neural network

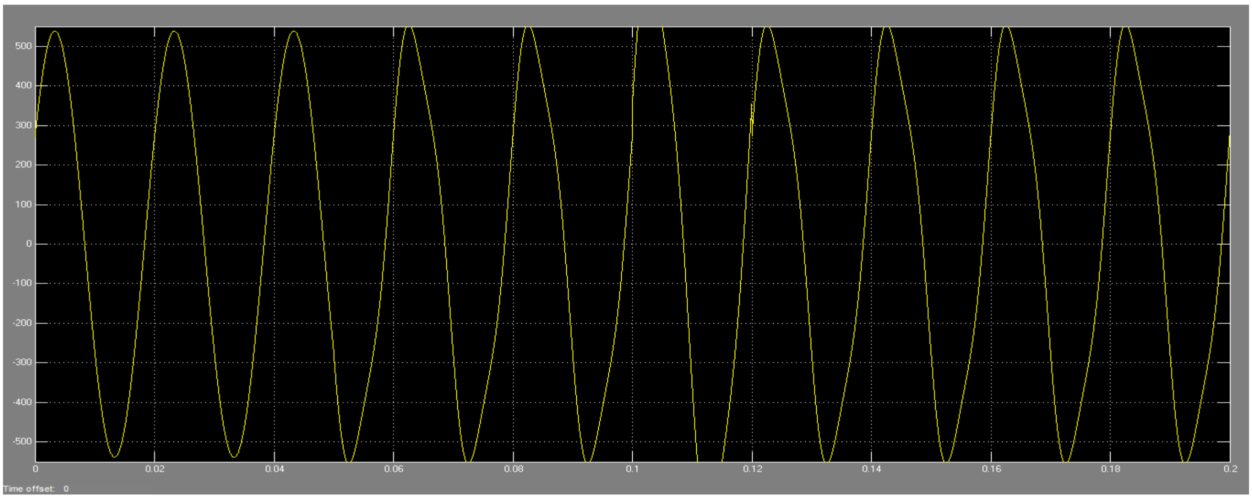

Figure 5.15: Neural Network Obtained Signal

A comparison done between the two outputs, one of the series active filters and the other by using neural network, the results are shown in Figure (5.16).

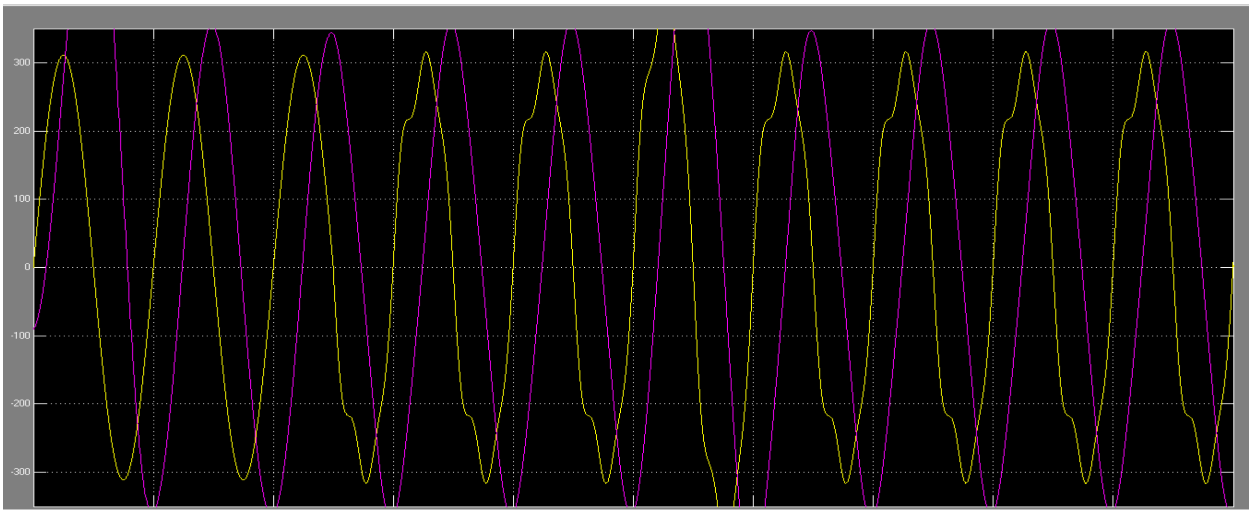

Figure 5.16: Comparison process

5.5 Discussion

5.5.1 Without the Artificial Neural Network

The proposed model proved that the use of artificial neural network as a feedback filter in order to eliminate the unwanted harmonics as shown in Figure (5.17).

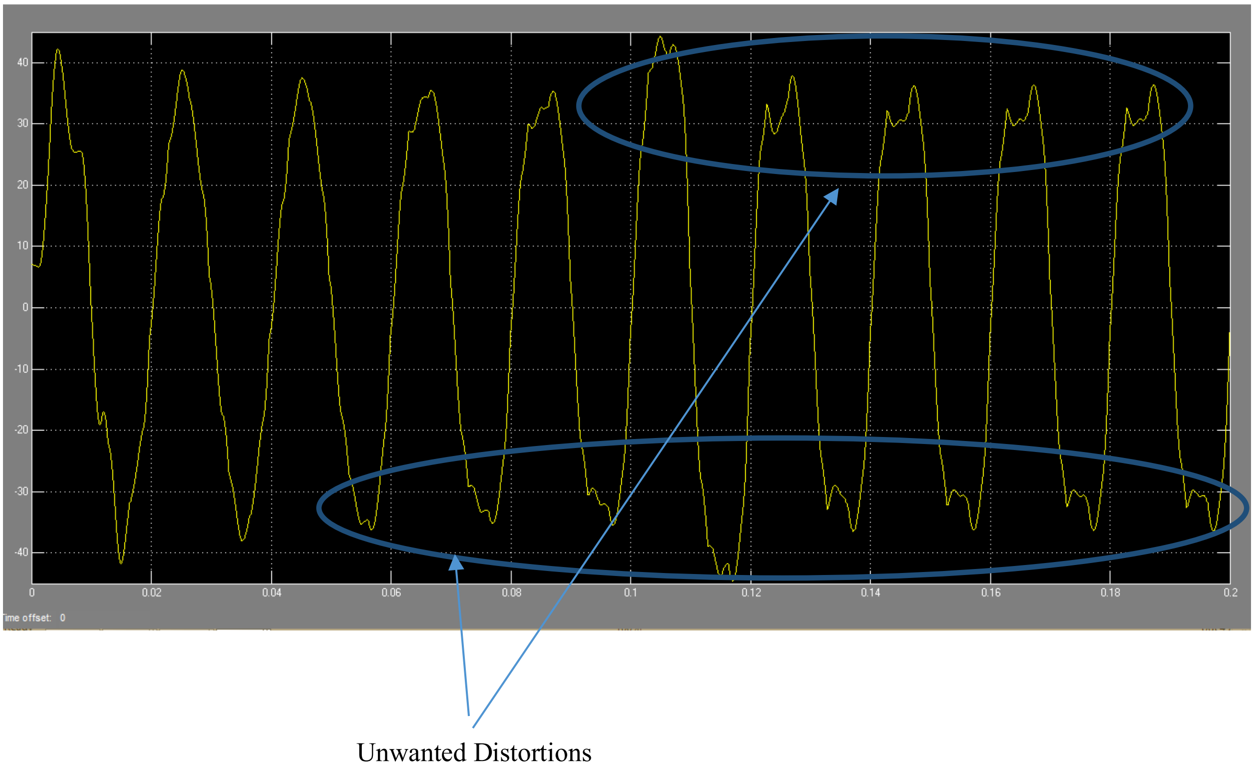

Figure 5.17: The obtained results without the use of Artificial Neural Network

As shown in Figure (5.17), the effectiveness of the artificial neural network as a filter to vanish the unwanted harmonics is so important, faster and lower in cost than the dependence on the normal filters only. The absence of the artificial neural network in the proposed model, the obtained results are affected by distortion in the output signal, so that it is necessary to increase the order of the filter in order to eliminate the unwanted distortions. Finally, the obtained results without the use of Artificial Neural Network is limited by 24% in the positive axis and 17% in the negative axis.

5.5.2 With the Artificial Neural Network

The proposed model while including the Neural Network obtained the results shown in Figure (5.18).

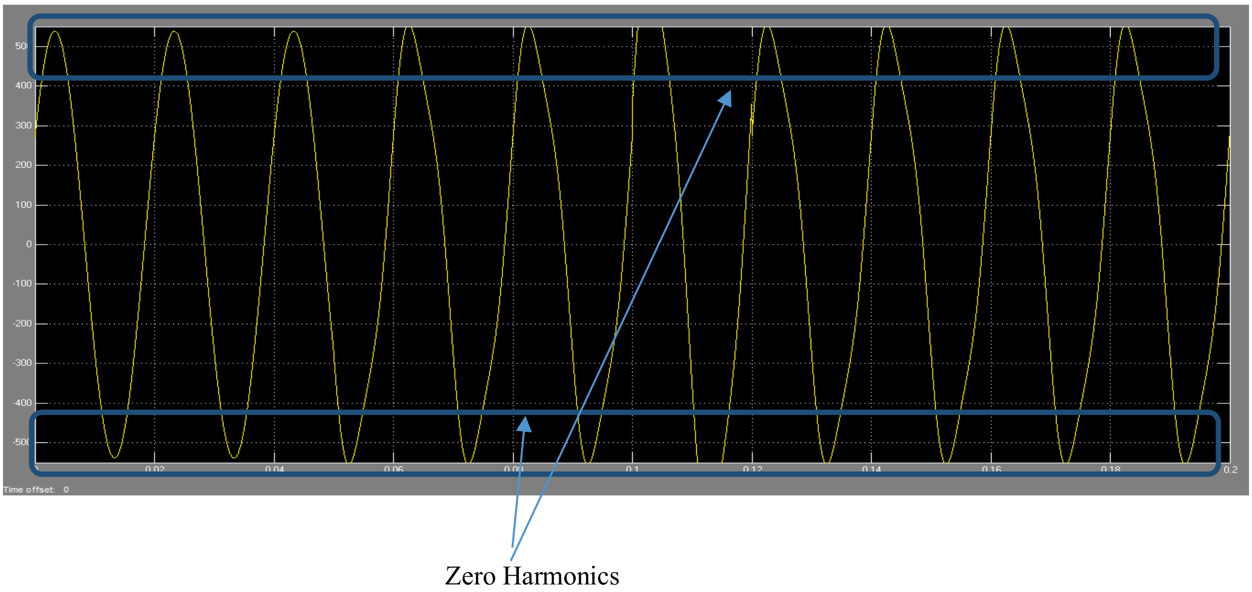

Figure 5.18: The obtained results with the use of Artificial Neural Network

In this thesis, Artificial Neural Network is proposed in order to identify the reference currents and cancel the unwanted harmonics, the proposed model showed perfect performance. The performance of the proposed model is related to the quality of the reference currents. The proposed model accepts the harmonic currents and the power compensation at the same time. Moreover, the obtained results by using the artificial Neural Network that the obtained current and the voltage are all in phase as shown in Figure (5.19).

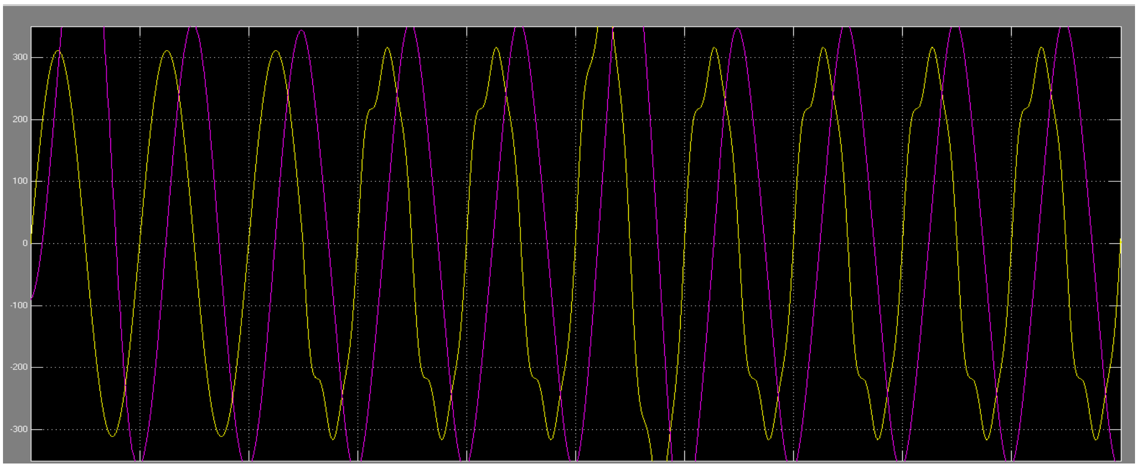

Figure 5.19: DC Capacitor voltage and source current

As shown in Figure (5.19), the obtained results show that the dc-side capacitor voltage is nearly constant with small ripple and the source current waveform purely sinusoidal after filtering

5.6 Summary

In this chapter, the simulation blocks and the obtained results are discussed briefly, also the effective of using the neural network as a cancellation process for the harmonics is proved and the obtained results show the effectiveness of the neural network to be connected as a feedback for the cancellation process.

CHAPTER 6

CONCLUSION

6.1 Conclusion

Early equipment was intended to withstand unsettling influences, for example, lightning, short circuits, and sudden over-burdens without additional use. Current power gadgets (PE) costs might be much higher if the supplies were planned with the same vigor. Contamination has been brought into power frameworks by nonlinear loads, for example, transformers and soaked curls; notwithstanding, annoyance rate has never arrived at the present levels. Because of its nonlinear attributes and quick exchanging, PE makes the majority of the contamination issues. The vast majority of the contamination issues are made because of the nonlinear aspects and quick exchanging of PE. Give or take 10% to 20% of today's vitality is prepared by PE; the rate is evaluated to achieve half to 60% by the year 2010, because of the quick development of PE competence. A race is as of now occurring between expanding PE contamination and affectability, from one viewpoint, and the new PE-based curative mechanisms, which can lessen the issues made by PE, then again. In this work, a developed system suitable for cancelling the unwanted harmonics in three phase system for AC voltage and current using artificial neural network to cancel the references of the series and shunt active power filter by using artificial intelligence without filtering and the common methods of filtering is developed and checked. The obtained results proved that the proposed system is more accurate than any other system.

REFERENCES

Fujita, H. and Akagi, H. (1998). The unified power quality conditioner: the integration of series- and shunt-active filters. *IEEE Transactions on Power Electronics*, 13(2), 315-322.

Chauhan, A., & Thakur, R. (2016). Power Quality Improvement using Passive & Active Filters. *International Journal Of Engineering Trends And Technology*, *36*(3), 130-136. doi: 10.14445/22315381/ijett-v36p225

Dixon, J., Venegas, G. and Moran, L. (1997). A series active power filter based on a sinusoidal current-controlled voltage-source inverter. *IEEE Transactions on Industrial Electronics*, 44(5), 612-620.

Grid Tied Solar Power Generation with Active Power Filter for Nonlinear Loads. (2015). *International Journal of Science and Research (IJSR)*, 4(12), 1606-1610.

Khalid, S., Kumar, N. and Mishra, V. (2014). Application of Adaptive Tabu Search Algorithm in Sinusoidal Fryze Voltage Control based Hybrid Series Active Power Filter. *International Journal of Energy Optimization and Engineering*, 3(2), 59-75.

Litrán, S., Salmerón, P., Herrera, R. and Vázquez, J. (2008). Control of series active power filter by state feedback. *Renewable Energy and Power Quality Journal*, 1(06), 535-540.

Mahalekshmi, T. (2010). Current Harmonic Compensation and Power Factor Improvement by Hybrid Shunt Active Power Filter. *International Journal of Computer Applications*, 4(3), 14-19.

Mendonça, P. and Amorim, F. (2016). Environmental Benefits from the Use of Vegetable Materials in Building Construction: Case Study in the South of Portugal. *International Journal of Environmental Science and Development*, 7(6), 431-435.

Mendonça, P. and Amorim, F. (2016). Environmental Benefits from the Use of Vegetable Materials in Building Construction: Case Study in the South of Portugal. *International Journal of Environmental Science and Development*, 7(6), 450-459

Ortuzar, M., Carmi, R., Dixon, J. and Moran, L. (2006). Voltage-source active power filter based on multilevel converter and ultracapacitor DC link. *IEEE Transactions on Industrial Electronics*, 53(2), 477-485.

Pandey, R., Purwar, V. and Sharma, N. (2017). Hysteresis Current Control Based Shunt Active Power Filter for Six Pulse Ac/Dc Converter. *International Journal of Engineering Research and Applications*, 07(02), 26-30.

Rajasekar, S., Senthilkumar, A., Shasi Kumar, Y. and Ajay-D-VimalRaj, P. (2012). Power quality enhancement using cascaded multilevel inverter based shunt hybrid active power filter. *International Journal of Engineering, Science and Technology*, 3(9).

Reduction and Elimination of Harmonics using Power Active Harmonic Filter. (2019). *International Journal of Recent Technology and Engineering*, 8(2S3), 178-184.

Singh, B., Gairola, S., Singh, B., Chandra, A. and Al-Haddad, K. (2008). Multipulse AC–DC Converters for Improving Power Quality: A Review. *IEEE Transactions on Power Electronics*, 23(1), 260-281.

Tumbelaka, H., Borle, L. and Nayar, C. (2005). Analysis of a series inductance implementation on a three-Phase shunt active power filter for various types of non-linear loads. *Australian Journal of Electrical and Electronics Engineering*, 2(3), 223-231.

Appendix 1: Ethical Approval Latter.

YAKIN DOĞU ÜNİVERSİTESİ

ETHICAL APROVAL DOCUMENT

Date: 30/01/2020

To the **Graduate School of Applied Sciences**

The research project titled **''SIMULATION AND PERFORMANCE ANALYSIS OF THE ACTIVE FILTER AND ANN FOR CANCELLATION OF REFERENCES IN POWER SYSTEM''** has been evaluated. Since the researcher(s) will not collect primary data from humans, animals, plants or earth, this project does not need through the ethics committee.

Title: **Prof. Dr.**

Name Surname: Fahreddin SADIKOĞLU

Signature:

Role in the Research Project: Supervisor

Appendix 2: Similarity Report.

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