REPUBLIQUE ALGERIENNE DEMOCRATIQUE ET POPULAIRE

MINISTERE DE L'ENSEIGNEMENT SUPERIEUR ET DE LA RECHERCHE SCIENTIFIQUE

Université de Mohamed El-Bachir El-Ibrahimi - Bordj Bou Arreridj

Faculté *des Sciences et de la technologie*

Département D'électronique

Mémoire

Présenté pour obtenir

LE DIPLOME DE MASTER

FILIERE : **Electronique**

Spécialité : Industrie Electronique

Par

- **Elabed SidAli**
- **Zeghlache Khaled**

Intitulé

Une Commande MPPT(P&O) appliquée a un Filtre Actif Solaire Hybride

Soutenu le : 04/07/2023

Devant le Jury composé de :

Nom & Prénom	*Grade*	*Qualité*	*Etablissement*
Dr. Boukezata Boualam	*MCB*	*Président*	*Univ-BBA*
Pr. Sarra Mustapha	*PROFESSOR*	*Encadreur*	*Univ-BBA*
Dr. Talbi Billel	*MCB*	*Examinateur*	*Univ-BBA*

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Abstract

The hybrid active power filter consists of a parallel active power filter and a parallel low pass filter. This filter works in an ideal way as it combines the advantages of the parallel filter and the passive filter, which means that all impurities in the voltage and current signal can be filtered and all power quality problems in the electrical network can be filtered. In this research, a we used a two-level inverter and series of solar panels with a capacity of 50 kW were used to feed the active filter and provide the electric grid with the effective energy required for the loads. The supply of electrical energy to the grid depends on the value of the load, the frequency of the network, the energy provided by the solar panels, and the power factor at the point of connection of the filter. In this research, the working principle of these filters will be explained with the mathematical analysis of these filters and the mathematical analysis of non-sinusoidal waves. And study the voltage and current in the research elements in different cases. This system has shown a high ability to delete all impurities in the electrical network , in addition to the ideal ability to improve the power factor and support the electrical network with energy generated from solar cells. This system is considered unique due to the accuracy of its work and its ability to overcome obstacles.

Résumé

Le filtre hybride de puissance consiste d’un filtre actif de puissance en parallèle et d'un filtre passive parallèle. Ce filtre fonctionne de manière idéale car il combine les avantages du filtre parallèle et du filtre passive, ce qui signifie que toutes les impuretés dans le signal de tension et de courant peuvent être filtré et tous les problèmes de qualité de l'alimentation dans le réseau électrique peuvent être filtrés. Dans cette recherche, on a utilisé un onduleur électronique à deux niveaux et une série de panneaux solaires d'une capacité de 50 kW utilisés pour alimenter le filtre actif et fournir l'énergie efficace nécessaire pour les charges au réseau électrique. L'alimentation en énergie électrique du réseau dépend de la valeur de la charge, de la fréquence du réseau, de l'énergie fournie par les panneaux solaires et du facteur de puissance au point de raccordement du filtre. Dans cette recherche, le principe de fonctionnement de ces filtres sera expliqué avec l'analyse mathématique de ces filtres et l'analyse mathématique des ondes non sinusoïdales. Et étudiez la tension et le courant dans les éléments de recherche dans différents cas. Ce système a montré une grande capacité à éliminer toutes les impuretés du réseau électrique , en plus de la capacité d'améliorer le facteur de puissance et de soutenir le réseau électrique avec de l'énergie réel à partir de l’énergie solaires. Ce système est considéré comme unique en raison pour la précision de son travail et sa capacité à franchir les obstacles et sa rapidité.

ملخص

يتكون مرشح الطاقة الفعال الهجين من إتحاد مرشح طاقة فعال توازي و مرشح الامرار الحزمي توازي ويعمل هذا المرشح بطريقة مثالية حيث أنه يجمع بين إيجابيات مرشح التوازي ومرشح الامرار الحزمي مما يعني إمكانية ترشيح جميع الشوائب الموجودة في إشارة الجهد والتيار وحل جميع مشاكل جودة الطاقة في الشبكة الكهربائية .في هاذا البحث تم استخدام عاكس إلكتروني ثنائي المستوى و سلسلة ألواح شمسية ب قدرة 50 كيلو وات لتغذية المرشح الفعال وتزويد الشبكة الكهربائية بالطاقة الفعالة الازمة للاحمال يعتمد تزويد الشبكة بالطاقة الكهربائية على قيمة الحمل ومقدار تردد الشبكة و الطاقة الموفرة من الألواح الشمسية ومعامل الطاقة عند نقطة ربط المرشح، وتم تصميم النظام والتأكد من عمله بإستخدام برنامج الماتلاب سيميلينك . في هاذا البحث سيتم شرح مبدأ عمل هذه المرشحات مع التحليل الرياضي لهذه المرشحات والتحليل الرياضي للموجات غير الجيبية .ودراسة الجهد و التيار في عناصر البحث في حالات مختلفة . وقد ابدى هذا النظام قدرة عالية على حذف جميع الشوائب الموجودة في الشبكة الكهربائية ، بالاضافة الى القدرة المثالية على تحسين معامل القدرة ودعم الشبكة الكهربائية بالطاقة الناتجة من الخلايا الشمسية ، ويعتبر هذا النظام فريد من نوعه نظرة لدقة عمله وقدرته على تخطي العقبات بسرعة فائقة.

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List of abbreviations

P: Active power.

AC: Alternative current.

APF: Active power filter.

S: Apparent power.

DC: Direct current.

HAPF: Hybrid active power filter.

IGBT: Insulated gate bipolar transistor.

IP: Integral proportional controller.

LPF: Low pass filter.

MOSFET: Metal Oxide Silicon Field Effect Transistor.

PF: Power factor.

PI: Proportional integral controller.

PAPF: parallel active power filter

PWM: Pulse width modulation.

Q: Reactive power.

RLC: Resistor, inductor, and capacitor.

RMS: Root means square value.

SAPF: Series active power filter.

SVPWM: Space vector pulse width modulation.

THD: Total harmonic distortion.

IEC: International Electrotechnical Commission

Mppt: Maximum Power Point Tracking

Pu: Per unit

IEEE: Electrical and Electronics Engineering

List of tables

General introduction

The increasing use of nonlinear loads and power electronics devices has led to power quality problems, particularly concerning harmonic emissions. The spread of harmonics in power grids adversely affects the normal functioning of connected devices, posing challenges for control system and protection circuits, international electrical committees have introduced standards and regulations to limit harmonic emissions.

Voltage imbalances and sudden changes in grid voltages are significant issues in electrical engineering. To address these concerns, voltage regulators and protective devices are employed to maintain a stable voltage level for connected devices. The activation and deactivation of electric motors contribute to voltage variations, especially when multiple motors start simultaneously.

Various solutions have been proposed to deal with harmonic problems. Passive filters offer a straight forward method of harmonic filtering but are more suitable for stable static systems. Active filters, introduced in the 1980s, dynamically compensate for harmonic currents and voltages, reacting instantly to load and system changes. Active filters provide flexibility in adjusting their behavior based on system parameters [7].

Active power filters can be categorized for voltage regulation, current harmonics reduction, or simultaneous voltage regulation and harmonic current suppression. Series active power filters regulate voltage, while shunt active power filters compensate for current harmonics and reactive power. Hybrid APFs, combining active and passive filters, have been proposed to improve compensation performance.

Overall, addressing harmonic issues requires a comprehensive approach that considers the nature of the load and the dynamic characteristics of the power system. Active filters provide more flexibility and responsiveness compared to passive filters, allowing for effective harmonic compensation in various system conditions [15].

in this work, we propose the use of a hybrid active power filter (HAPF) as a solution to enhance the power quality of a system, The hapf combines the advantages of both apf and passive filters to provide improved flexibility and effectiveness in power quality enhancement, and the instantaneous power method as a control strategy to calculate reference current power to handle power quality disturbances effectively.

The work is divided to three principal chapters:

The first chapter is devoted to the description of current and voltage disturbances that can occur in an electrical network. This chapter also presents traditional and modern depollution solutions.

In the second Chapter of this dissertation, we will study the general structure of the active power filter, control and regulation strategy.

In the third chapter we will discuss about the realized experience in which we simulate the performance of the hybrid active power filter in MATLAB/SIMULINK.

Chapter I

Power Quality disturbances and their solutions

Chapter I: Power Quality Disturbances and their solutions

I.1Introduction

This chapter examines and introduces various issues pertaining to power grids. It addresses the distortion encountered in current and voltage signals and explores the impact that voltage and current distortion have on both power grids and the devices used by consumers. Additionally, it delves into diverse solutions for addressing power grid problems. The discussion encompasses passive, active, and hybrid filters, highlighting their role as power quality conditioners. Furthermore, the advantages and disadvantages associated with these filters are thoroughly examined. The primary objective of this chapter is to present a comprehensive overview of the range of power problems and their respective traditional and modern solutions.

I.2 Problems in the Power Grids

Power grid systems often experience unexpected fluctuations in voltage and current, including voltage sags, swells, interruptions, frequency variations, harmonics, and other instantaneous issues. These problems arise due to the presence of various loads connected to the grids. The starting and stopping conditions of electrical motors and power electronics devices are major contributors to voltage and current problems. The proliferation of power electronic switching devices has increased pollution levels in electrical grids and exacerbated stability-related problems. Consequently, researchers have proposed various methods to address power quality and pollution issues. The following section present and discuss different problems encountered in power grids.

I.2.1 Pure Sine Signal

The pure sine waveform signal, also referred to as a healthy signal in certain publications, represents the ideal waveform for voltage or current. In the case of voltage signals, the ideal frequency is typically 50 or 60 Hz. A pure voltage signal can be mathematically modeled using the equation:

$$\boldsymbol{f(t) = A\sin(\omega t)} \ \#(\mathbf{1})$$

In this equation, the parameters for the voltage signal are defined as follows:

- A represents the amplitude of the signal, which can be set to 1.0.

- f denotes the frequency, such as 50 Hz.

- ω represents the angular frequency, calculated as 2πf in radians per second.

Thus, for a pure voltage signal with an amplitude of 1.0, a frequency of 50 Hz, and an angular frequency of $2\pi \times 50$ rad/s, the equation becomes:

$f(t) = \sin(2\pi \times 50t)$

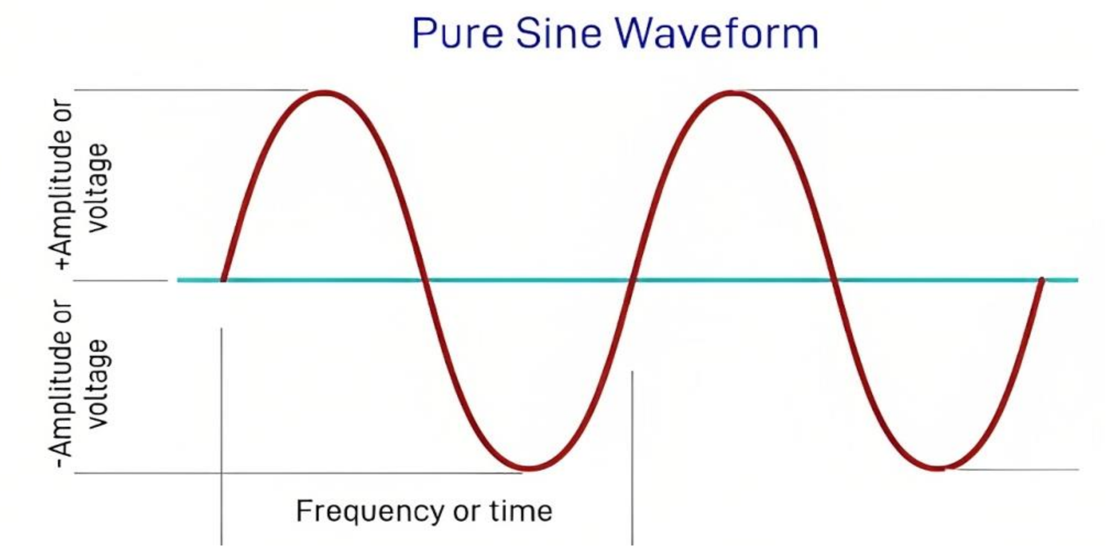


Figure I. 1 : Pure voltage signal

I.2.2 Sag

Sag is a significant Power Quality Disturbance commonly observed in electrical power systems. It is characterized by a momentary reduction in the root mean square (RMS) voltage magnitude, typically ranging between 0.1 and 0.9 per unit (Pu), at the power frequency. The duration of a sag is relatively short, typically lasting from 0.1 to 1 minute, which corresponds to approximately 0.5 to 30 cycles. Short-duration sags typically span from 2 to 5 seconds and are often caused by transient faults. On the other hand, sustained sags, which persist for 1 minute or longer, are predominantly the result of permanent faults. Figure I.2 provides an illustration of a typical sag magnitude and its corresponding duration [9].

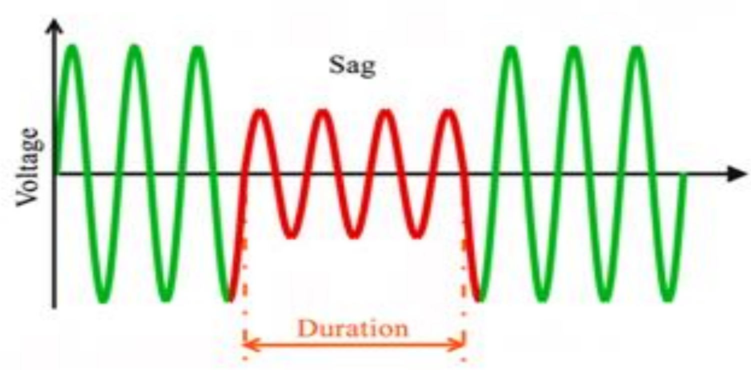


Figure I. 2 : The sag phenomenon

Sags can occur due to various factors, including the starting of large motors, fault clearances, and initial faults. A fault on a feeder can lead to a voltage sag at the substation bus. Additionally, significant changes in loads can cause sags within the system. In the case of induction motors, even their starting process, which involves a slight change in speed, can trigger voltage sags [9].

Voltage sag events can have detrimental effects on electronic devices, particularly those that are highly sensitive. It can result in damage to such devices and may even lead to the loss of synchronized data or system stability. Controllers equipped with fault detection sensors are typically employed to identify sags and initiate load shutdown processes. During a sag event, a reduction in lighting may also be observed.

I.2.3 Swell

A swell disturbance is the opposite of a sag, characterized by an increase in the root mean square (RMS) voltage magnitude. It typically ranges between 1.1 to 1.8 per unit (pu) at the power frequency, with a duration of time ranging from 0.1 to 1 minute, corresponding to approximately 0.5 to 30 cycles. Figure 3 illustrates a typical swell and its duration. In many research publications, the magnitude of a swell is defined when the line voltage exceeds 1.0 pu.

Swell disturbances can be caused by single line-to-ground faults, but they occur less frequently than sags in power systems. They can also be triggered by sudden load dropping, switching off heavy loads, or loose wiring. However, the most common cause of a swell is the switching on of a large capacitor bank.

Swell disturbances can have a significant impact on electrical power systems, leading to failures in electronic devices, computers, and controllers. In severe cases, they can even result in a complete blackout. While power grid components are typically protected against swells, such as through the use of switchgears in the bus bars, they may experience temporary issues if exposed to live swells. Regular swells on capacitor banks can cause individual bulges.

There are various possible solutions for handling voltage swells, including the use of voltage regulators or motor generators set to mitigate swells before equipment is exposed to overvoltage conditions.

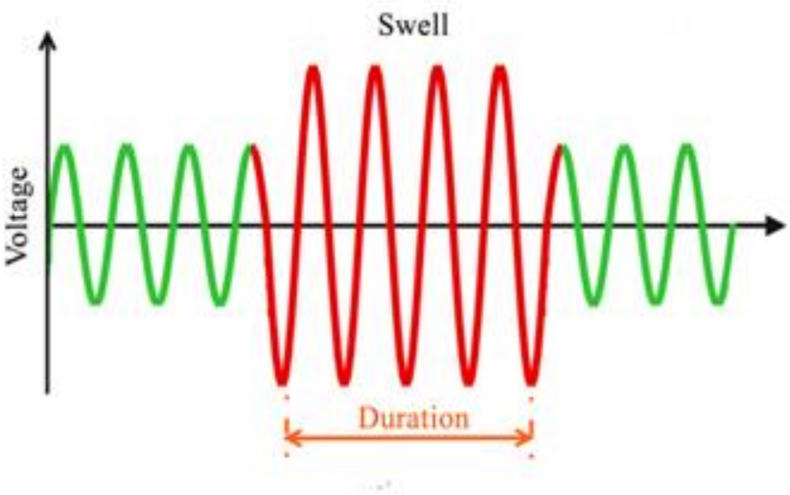


Figure I. 3 : The swell phenomenon

I.2.4 Interruption

An interruption in the context of power systems is defined as a reduction in the root mean square (RMS) voltage to less than 0.1 per unit (pu) for a duration of less than 1 minute. It often occurs following a voltage sag and can be a consequence of a system fault. Interruptions can result from various factors, such as losing connection, control failures, lightning strikes, severe faults that do not clear, equipment failures, and reclosing of circuit breakers. The measurement of interruptions takes into account their duration and magnitude. During an interruption, the voltage drops to a minimum magnitude, which is typically less than 10% or almost zero in most cases, indicating a lack of power in the system. Figure I.4 illustrates a typical interruption event.

In many cases, an interruption event follows the occurrence of a sag in the system or serves as the event between a sag and the operation of protective devices. This means that resolving the interruption relies on the operation of a protective device, typically taking less than 30 cycles.

The impact of interruptions on power systems includes operational disruptions, revenue losses, and production losses. Instantaneous interruptions can disrupt lighting and electronic equipment, resulting in shutdowns or incorrect operations. Electronic equipment, including controllers, computers, and controls for rotating machines, are particularly susceptible to such interruptions. Temporary interruptions or dropouts in operation often affect the performance or functioning of induction motors.

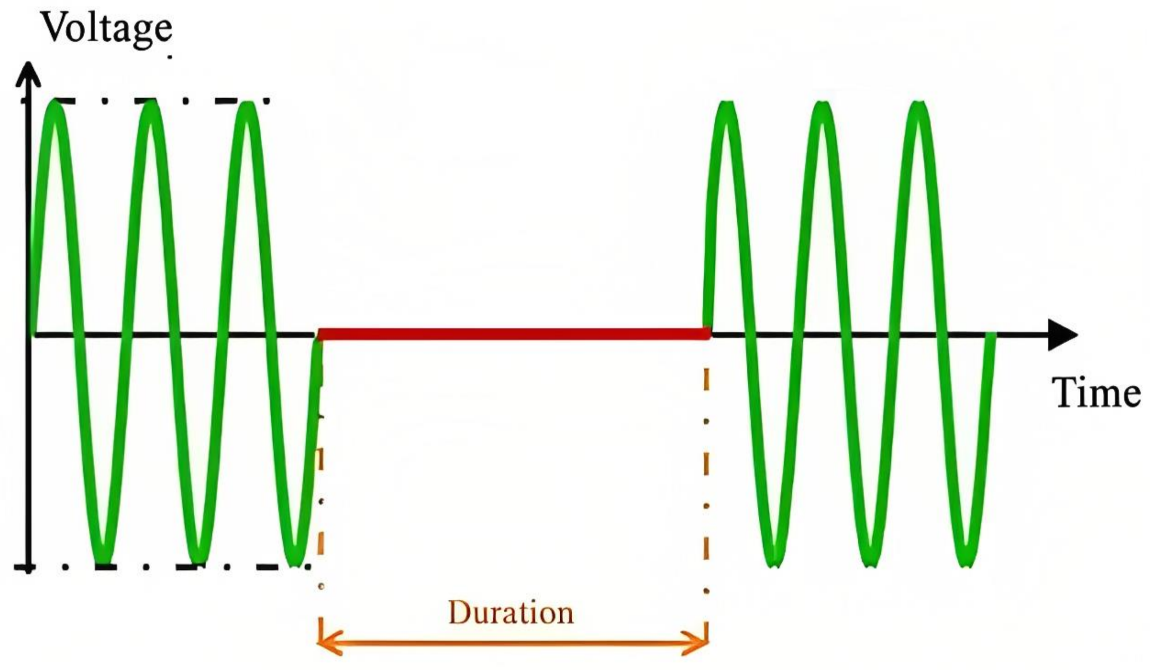


Figure I. 4 : Interruption disturbances

I.2.5 Harmonics

Harmonics can be defined as sinusoidal voltages or currents with frequencies that are integer multiples of the fundamental frequency at which the supply system is designed to operate. Both IEEE and IEC provide definitions of harmonics. In an ideal scenario, the voltage waveform would be a pure sinusoidal wave at the designated fundamental frequency of either 50 Hz or 60 Hz. However, due to the presence of nonlinear loads in power systems, this ideal case is not commonly observed on a daily basis, as depicted in Figure I.5.

There are numerous sources that can generate harmonics, and unfortunately, their prevalence is increasing. The primary source of harmonics in power systems is the usage of electronic devices. These devices introduce harmonics as they act as sources of nonlinear voltages. The current drawn by these electronic devices, acting as loads, injects harmonic currents into the power system. Consequently, voltage disturbances arise due to the presence of these harmonic currents interacting with the system impedance. In modern times, with the widespread use of semiconductor devices and the adoption of modern lifestyles, concerns regarding harmonics have become more prominent across various applications.

Each harmonic distortion level in the complete harmonic spectrum is categorized by its magnitude and phase angle. The magnitude of harmonic distortion is commonly referred to as the total harmonic distortion (THD). THD provides an indication of the level of harmonic distortion present in a system.

The impact of harmonics on electrical power supply is significant. It starts with the injection of harmonic currents generated by customers' loads, which leads to the appearance of harmonic voltages in power systems. Voltage harmonics can cause issues such as overshooting in rotating machines, transformers, and system malfunctions. These problems can result in disruptions or breakdowns in customer processes. Standards and guidelines for harmonics control have been established to assist both electrical power utilities and customers in minimizing such disturbances and their adverse effects [4].

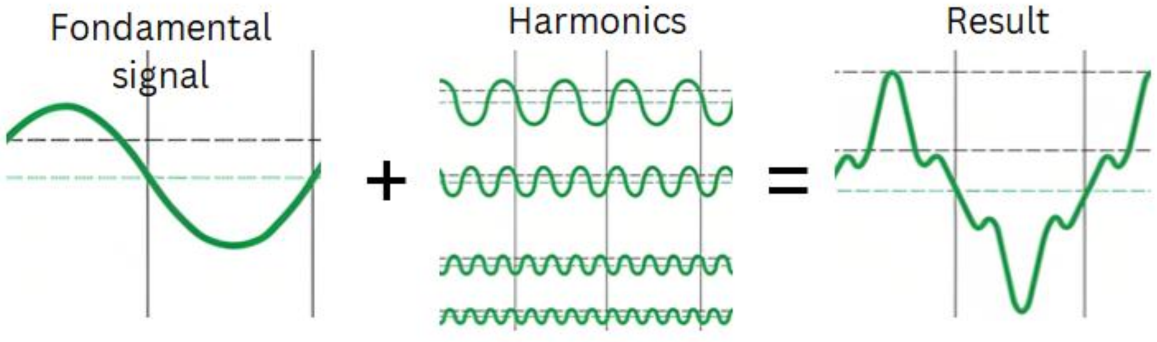


Figure I. 5 : Harmonics in power systems

I.2.5.1 Total harmonic distortion

The total harmonic distortion (THD) is a measure used to quantify the level of harmonic distortion present in currents or voltages. It is calculated as the ratio of the total sum of the squares of all harmonic components to the square of the fundamental frequency component. Harmonic distortion occurs when waveforms at frequencies that are multiples of the fundamental frequency are introduced to the signal by various nonlinear loads.

$$\mathbf{THD}(\%) = \frac{\sqrt{\sum_{\mathbf{i=2}}^{\infty} \mathbf{x_i^2}}}{|\mathbf{x_i}|} \quad \#(\mathbf{2})$$

THD is widely used as a descriptor for harmonics, although it does have limitations. One limitation is that it cannot accurately describe the stresses on capacitors since it is related to the peak values of signals rather than the effective or RMS values. This means that THD may not fully capture the impact of harmonics on capacitor performance.

Despite this limitation, THD remains a commonly used metric for characterizing harmonic distortion in power systems. It provides a valuable indication of the overall level of harmonic content present in a signal.

I.2.5.2 Power factor and harmonics

The power factor is defined as the ratio of the active power to the apparent power in an AC circuit. It represents the cosine of the phase angle between the voltage and current waveforms in a sinusoidal signal. Power factor calculations are applicable to sinusoidal signals.

Improving power factor can be achieved by introducing capacitors to the power grid. These capacitors draw leading currents and provide lagging volt-ampere reactive power to the system. Power factor correction capacitors can be switched in and out automatically or manually as needed to maintain reactive power at minimum levels and for voltage control.

In the case of an ideal sinusoidal signal, the power factor is determined by the ratio of active power to apparent power. A low power factor indicates inefficient utilization of electrical equipment. The apparent power is defined by the equation:

$$\mathbf{S = V_{rms}.I_{rms} = V_{rms}.\sqrt{\frac{1}{T}\int_0^T I_l^2 dt}} \qquad \#(\mathbf{3})$$

And the active power P and reactive power Q are defined as:

$$\boldsymbol{P = V_{rms}.I_{L1}.}\mathbf{cos}(\boldsymbol{\alpha}\mathbf{1})$$

$$\boldsymbol{Q = V_{rms}.I_{L1}.}\mathbf{sin}(\boldsymbol{\alpha}\mathbf{1}) \qquad \#(\mathbf{4})$$

As a result, the power factor will be given as:

$$\boldsymbol{P.F} = \frac{\boldsymbol{P}}{\boldsymbol{S}} = \frac{\boldsymbol{P}}{\sqrt{\boldsymbol{P}^2 + \boldsymbol{Q}^2}} \quad \#(\mathbf{5})$$

I.2.6 Flicker

Flicker refers to the regular variation of the voltage waveform, characterized by a series of random voltage changes. Its magnitude typically ranges between 0.9 and 1.1 pu (per unit) of the nominal voltage, representing a variation of approximately ±10% of the voltage magnitude. Flicker is often observed at the end of distribution loads or can be detected at the input to a customer's building. In the field of power quality, flicker is commonly defined as the perception of unsteadiness in visual sensation caused by fluctuations in luminance or spectral distribution of a light stimulus over time.

There are two main types of flicker phenomena categorized based on their durations: short-term flicker and long-term flicker. A dedicated standard has been introduced to address flicker events.

One of the primary sources of voltage flicker in transmission and distribution systems is arc furnaces. Figure I.6 illustrates an example of a voltage flicker waveform caused by an arc furnace. However, there are various factors that can contribute to flicker disturbances. For instance, loads with significant variations stemming from reactive components can induce flicker. A sudden change in the current load can also lead to voltage flicker.

Voltage flicker is characterized by modifications to the fundamental frequency waveform, determined through RMS measurements of voltage magnitude. This involves separating the waveform frequencies by removing the fundamental frequency and calculating the magnitude of the variation components. Flicker disturbances can result in lighting loss within networks and miss operation of sensitive loads. The extent of these effects, among others, depends on the tolerance of the equipment involved [8].

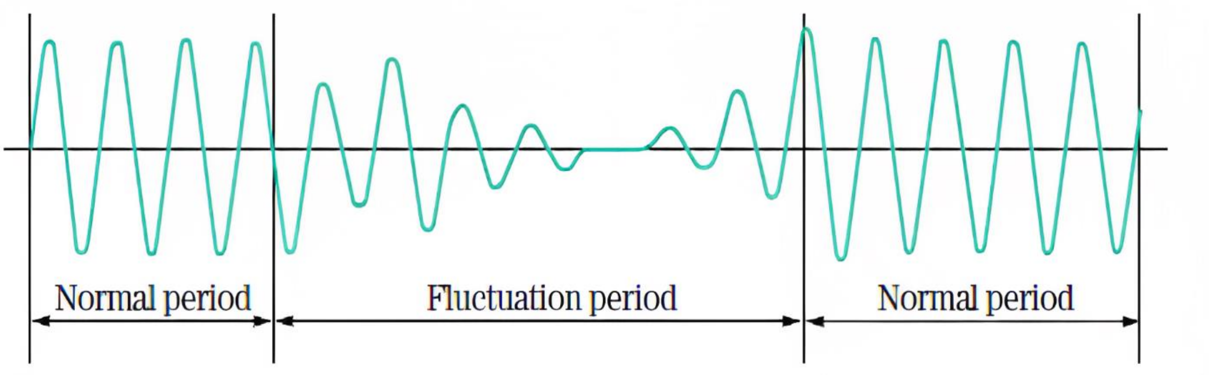


Figure I. 6 : Flicker Voltage phenomenon

I.3. Solution of disturbances

I.3.1 Traditional solution

I.3.1.1 Resonant filter:

The resonant passive filter consists of an inductance (L) connected in series with a capacitor (C), which is calculated based on the harmonic range that needs to be eliminated. This filter has low impedance for the targeted harmonics and high impedance for the fundamental frequency. Therefore, one filter is required for each harmonic range that needs to be eliminated. The equivalent circuit of the resonant filter, including the harmonic source and grid impedance, is depicted in Figure I.7.

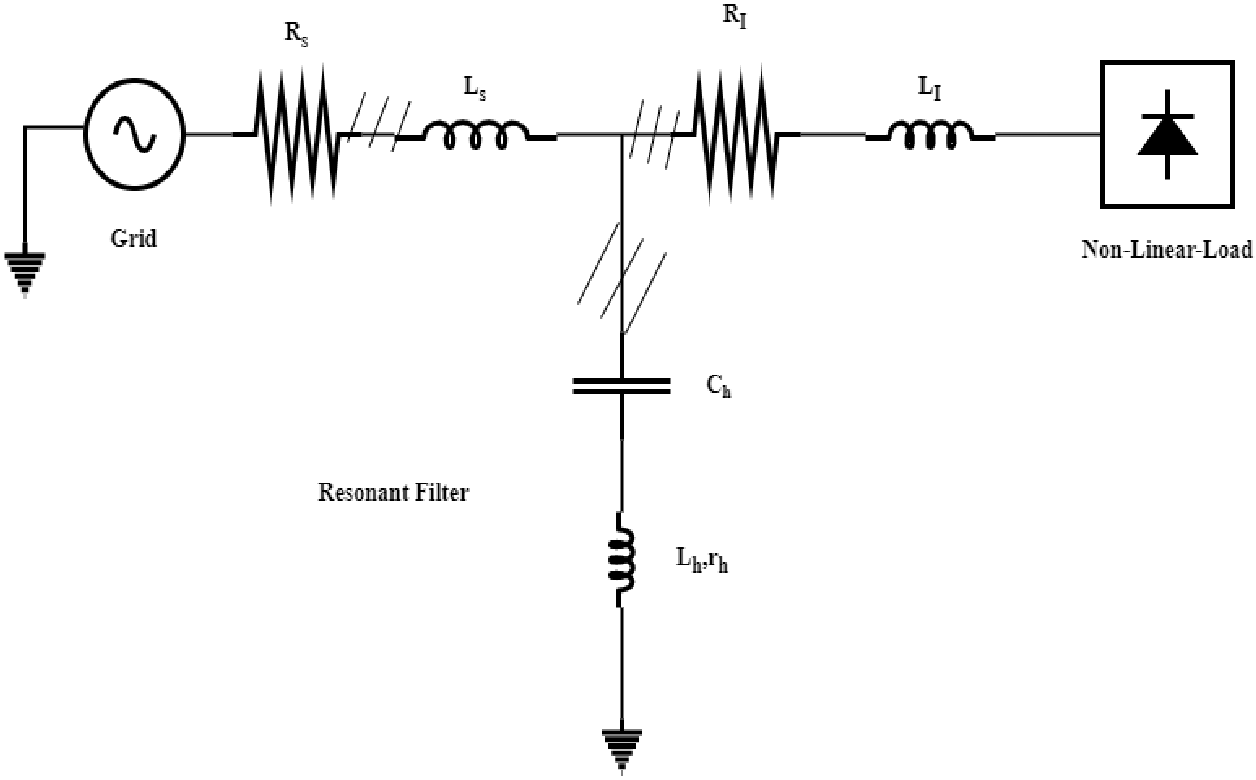


Figure I. 7 : Resonant filter in parallel with non-linear load

I.3.1.2 High pass filter

On the other hand, the high-pass filter incorporates passive elements (RLC) as shown in Figure I.8. This filter is employed to eliminate harmonics over a wide range of frequencies. It is typically utilized for suppressing high-frequency harmonics that are sufficiently far from the fundamental frequency of the system. This ensures that the filter does not affect the fundamental frequency of the system [2].

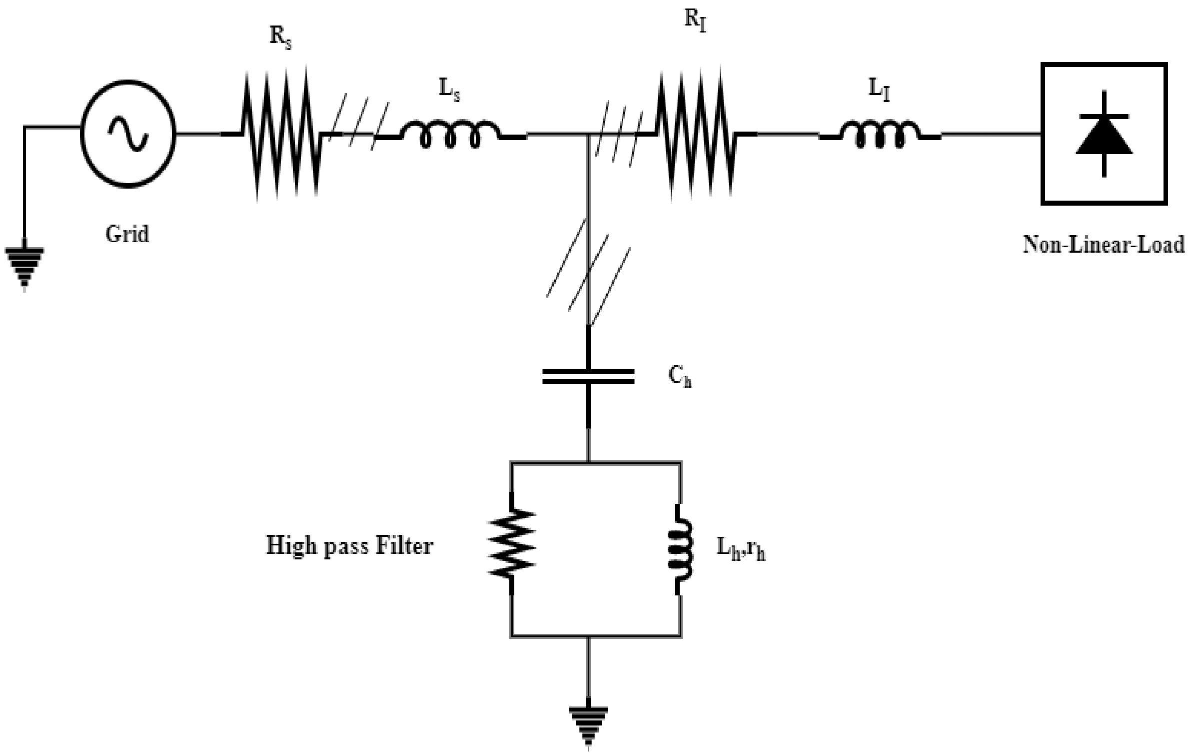


Figure I. 8 : High pass filter in parallel with non linear load

I.3.1.3 Resonant high pass filter

Figure I.9 illustrates the connection of resonant filters for specific harmonic ranges (in this case, the 5th and 7th harmonics) in parallel with a high-pass filter. This combination of filters is used to address multiple harmonic components in the system.

The combined arrangement of resonant filters for specific harmonics and a high-pass filter enables a comprehensive approach to harmonic filtering, addressing a wider range of harmonics in the electrical system [2].

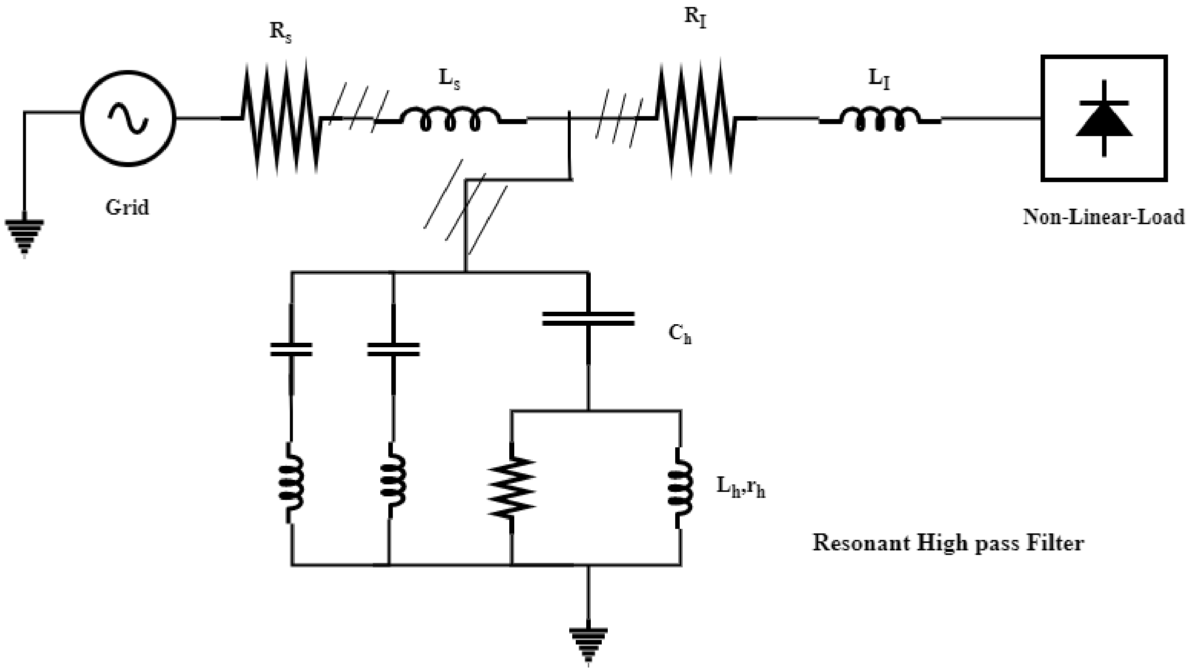


Figure I. 9 : Resonant high pass filter with non linear load

I.3.2 Modern solution

Indeed, the classic passive filter solutions for harmonics reduction and power factor correction have some limitations and challenges. These include the possibility of resonance with certain frequencies, lack of flexibility with load changes, generation of current harmonics by the filters, dependence on the grid parameters and harmonic spectrum, sensitivity to frequency variations, the need for modifications with changes in the grid, risk of consuming active power, and being capacitive for the fundamental frequency [10].

These new solutions provide more robust and efficient methods for harmonics reduction and power factor correction, overcoming the drawbacks associated with passive filters. They are designed to better adapt to changing grid conditions, offer enhanced harmonic compensation, and provide improved performance in mitigating grid harmonics [10].

I.3.2 Active Power Filters

Active power filters (APFs) are designed to generate harmonic currents or voltages in such a way that the grid current or voltage waveforms maintain a sinusoidal structure. They can be connected in series, parallel, or in combination with passive filters to compensate for voltage or current harmonics.

I.3.2.1 Series active power filter (SAPF)

Series active power filters (APFs) are designed to modify the grid impedance locally. They act as a source of harmonic voltages that cancel out the voltage harmonics originating from the grid or those caused by the circulation of harmonic currents into the grid.

In a series APF configuration, coupling transformers are used to connect the APF to the power grid. The APF injects voltages into the grid to compensate for voltage harmonics and disturbances. Series APFs were introduced in the 1980s and primarily function as voltage regulators, separating the loads from the power source. They provide protection to consumers against unexpected supply voltage faults such as high voltages or low voltage sequences. Series filtering is particularly recommended for compensating voltage imbalances and sags in the power supply. Series compensators inject voltages in series with the supply voltage and can be considered as controlled voltage regulators [11].

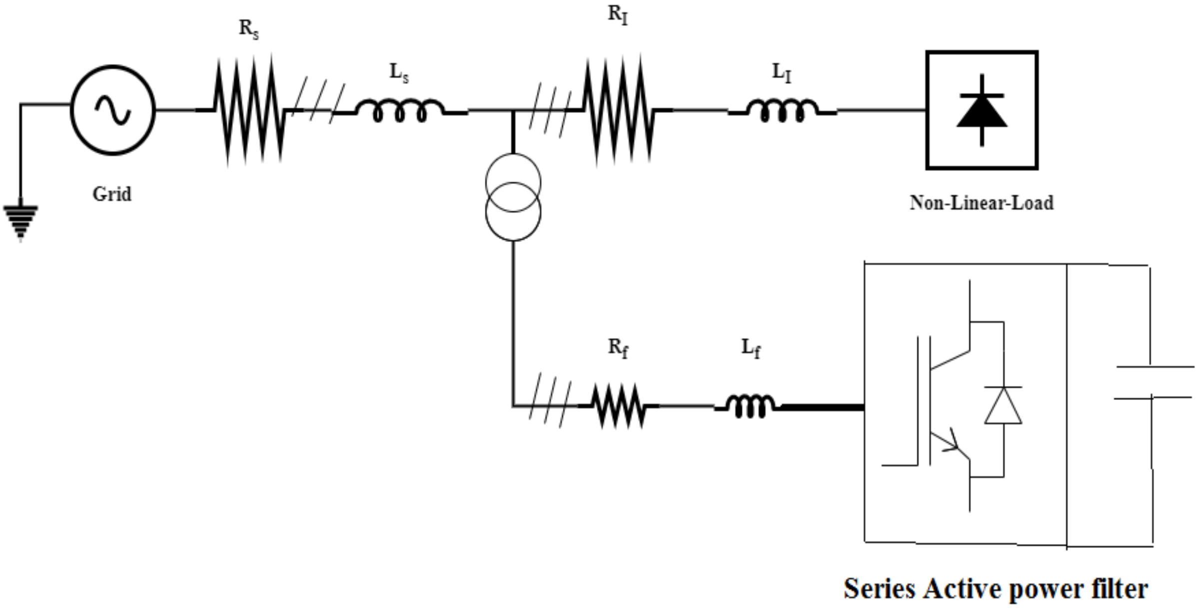


Figure I. 10 : Series active power filter connected to the grid

I.3.2.2 Parallel active power filter (PAPF)

Parallel active power filters (PAPFs) are connected in parallel with the harmonic-emitting loads in order to inject harmonic currents in real time that cancel out the harmonic currents drawn by the loads. The objective is to ensure that the total current flowing through the power mains becomes sinusoidal.

PAPFs continuously monitor the harmonic currents drawn by the loads and generate corresponding compensating currents of opposite phase. By injecting these compensating currents in parallel with the loads, the PAPFs effectively neutralize the harmonic currents, resulting in a sinusoidal current waveform on the mains.

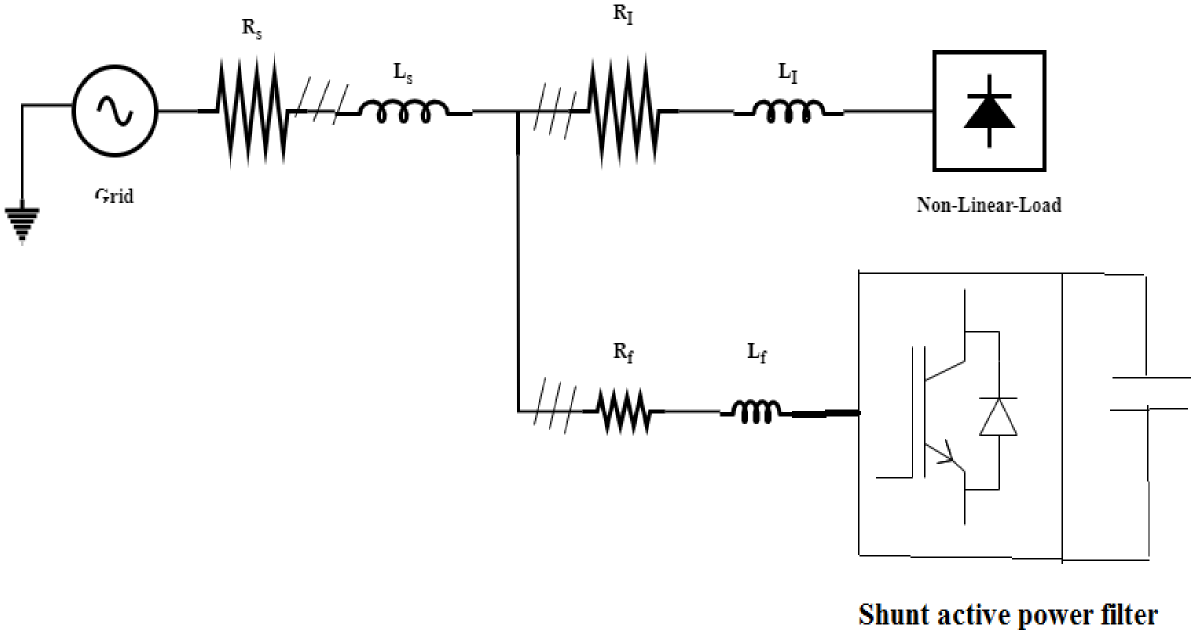


Figure I. 11 : Shunt APF connected in parallel with non-linear load

I.3.2.3 Hybrid filters

Indeed, hybrid filters have emerged as a promising solution for mitigating harmonic currents in power grids. By combining the advantages of both passive and active filters, hybrid filters offer improved performance and cost-effectiveness.

By integrating passive and active filter elements, hybrid filters offer several advantages. They provide selective harmonic compensation, allowing for targeted mitigation of specific harmonic frequencies. This flexibility is beneficial in situations where only certain harmonics need to be addressed [5].

I.3.2.3.1 Series connection of active filter with passive filter

In this configuration the active and passive filters are connected together directly in series. Then the system is connected in parallel with the grid as shown in Figure I.12.

]

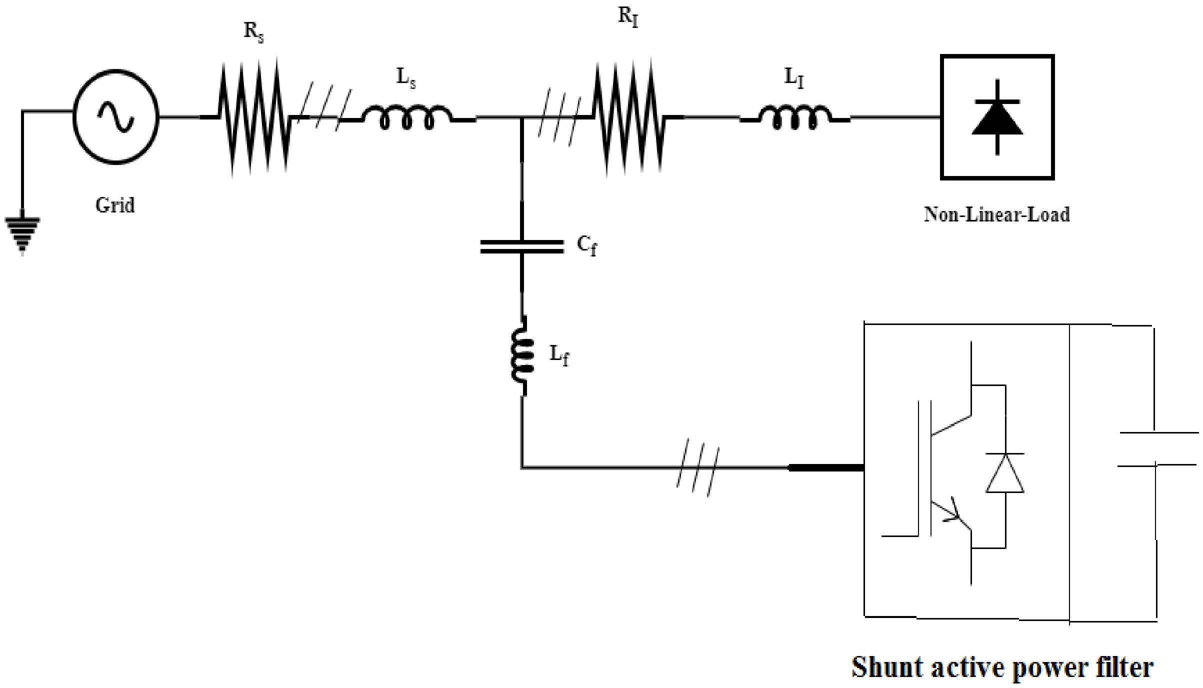


Figure I. 12 : Series association SAPF and passive filter

I.3.2.3.2 Parallel connection of PAPF with passive filters

In the topology shown in Figure I.13, an active filter and a passive filter are connected in parallel and shunted with the load. This arrangement allows for a combined approach to harmonic compensation, with the passive filter addressing specific harmonic ranges and the active filter handling the remaining harmonics present in the grid [5].

By combining the passive and active filters in parallel, this topology takes advantage of the strengths of both approaches.

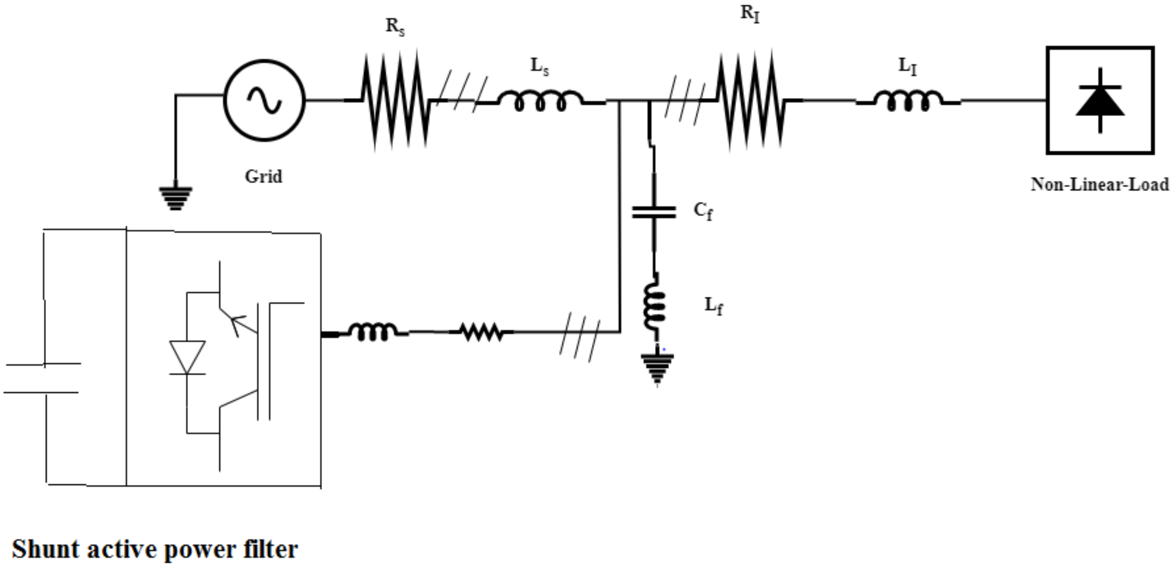


Figure I. 13 : Parallel association SAPF and passive filter

I.3.2.3.3 Series active filter with passive filter

The structure shown in Figure I.14 illustrates a configuration that helps mitigate the risk of anti-resonance between the elements of a passive filter and the grid impedance. In this arrangement, the series active filter serves as a resistance to the harmonic currents, directing them towards the passive filter while keeping the fundamental frequency unaffected [1].

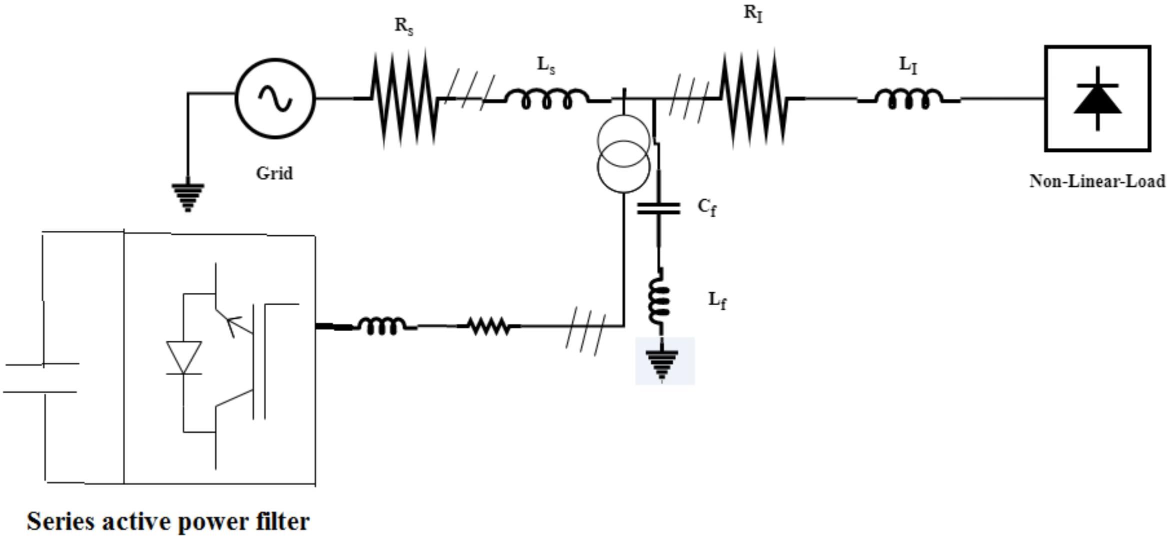


Figure I. 14 : Series active power filter with passive filter

I.4 Conclusion

In summary, this chapter has provided an overview of power grid problems and pollutants, with a specific focus on voltage and current harmonics. The traditional approach of using passive filters was discussed, highlighting their advantages and disadvantages. It was noted that passive filters have limitations in terms of dynamic adjustment to load and grid variations.

The chapter also introduced the concept of active filters, which utilize power electronic devices to actively compensate for harmonics in real time. Active filters offer advantages in compensation and maintain grid current. Hybrid filters, which combine passive and active filter elements, were also presented as a promising solution that leverages the benefits of both approaches.

The different configurations of series and parallel combinations of active and passive filters were explored, emphasizing their characteristics and capabilities. The chapter provided an understanding of the evolving technologies and solutions available for addressing harmonic issues in power grids.

By presenting and discussing these various methods, the chapter aimed to enhance awareness and knowledge about harmonics and their treatment, enabling readers to make informed decisions when it comes to managing power grid pollution and improving power quality.

Chapter II

Control strategy and regulation of Hybrid filters connected to Photovoltaic system

Chapter II Control strategy of hybrid filters connected to PV system

II.1 Introduction

In this chapter, the focus is on active power filters, their structures, and control topologies. The chapter explores various aspects related to active power filters, including their construction, power inverters, and functional principles. It also delves into the discussion of different control methods employed in power inverters used in active filters, namely hysteresis control, pulse width modulation (PWM), providing a comparison of these methods.

Furthermore, the chapter covers the control of active filters using different methods, particularly the active and reactive power methods. The active and reactive power theory is highlighted for its high performance in controlling active filters. Additionally, the chapter incorporates the discussion of PID (Proportional-Integral-Derivative) controllers.

Finally, the chapter delved into the generation of PV cells and provided an overview of their modeling. It also discussed PV systems equipped with MPPT techniques, specifically focusing on the P & O algorithm. The incorporation of a DC-DC boost converter in PV systems was explained, emphasizing its role in efficiently converting the generated power.

II.2 Overview of Active Filters Active filters

In the parallel filter configuration, the filters are designed to inject currents that are exactly out of phase with the harmonics circulating in the grid. By doing so, they effectively absorb the harmonic currents generated by nonlinear loads, preventing them from propagating into the electric grid. This helps to maintain a cleaner and more sinusoidal waveform in the grid.

Parallel filters can be used to compensate for reactive power consumed by inductive or capacitive loads. By providing reactive power compensation, these filters help to reduce the stresses on transformers and transmission lines that result from higher currents consumed by non-pure resistive loads. As a result, when these loads are connected with the parallel filter, they appear as linear loads to the power system.

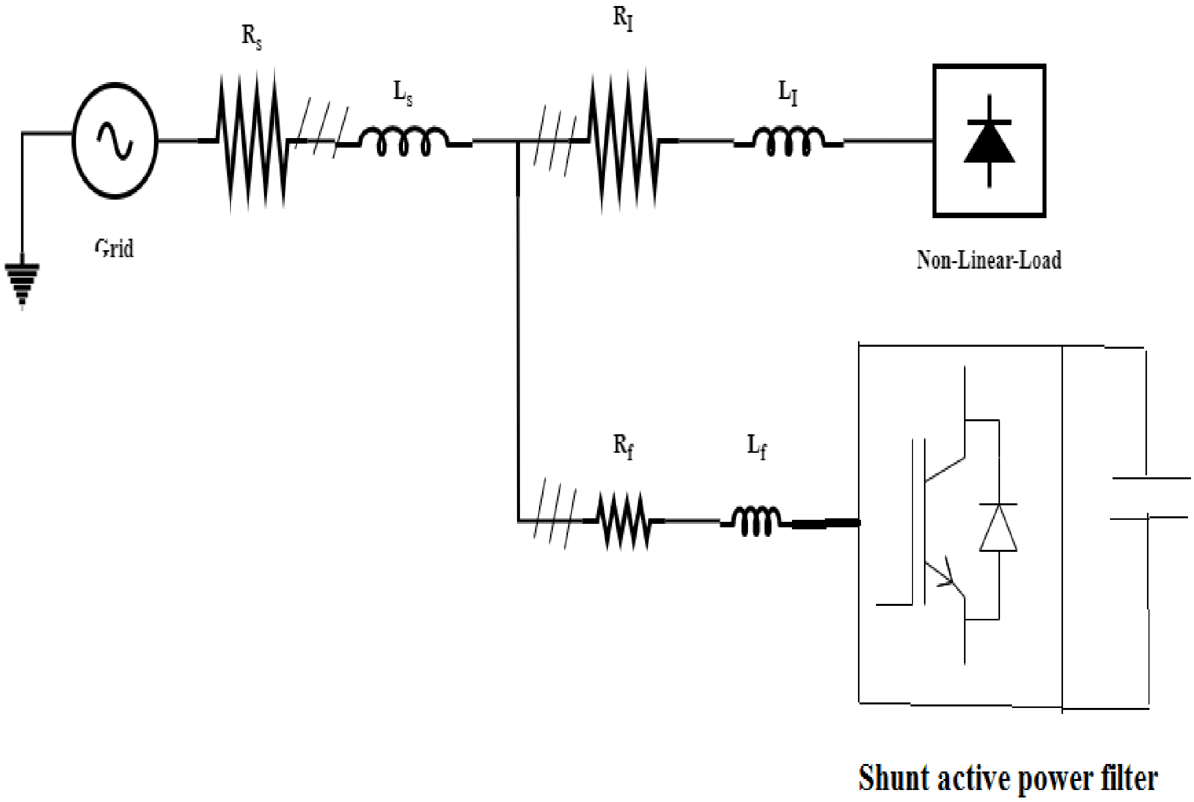


Figure II. 1 : General topology of parallel active power filter

II.3 Construction of Active Power Filter

The active power filter consists of several components: the DC power source, three phase output, the LC filter, and the control circuit.

The active power filter typically uses power MOSFETs or IGBTs as switching devices. These devices are controlled by the control circuit to regulate the current and voltage in different parts of the system.

The DC power source provides the necessary power for the active filter. It can be a bridge rectifier with a DC capacitor connected to the grid, or the DC capacitor of the filter itself, which acts as a battery storing instantaneous energy for the filter, or a DC capacitor connected to a PV array. The control circuit ensures stable transmission of power between the filter and the capacitor, maintaining a constant voltage on the capacitor. This voltage stability is crucial for the overall stability and performance of the filter.

The main function of the active filter is to provide controllable three- or single-phase current or voltage that is injected into the grid.

Overall, the structure and components of an active power filter enable precise control of current and voltage, allowing for effective compensation of harmonics and reactive power in the grid.

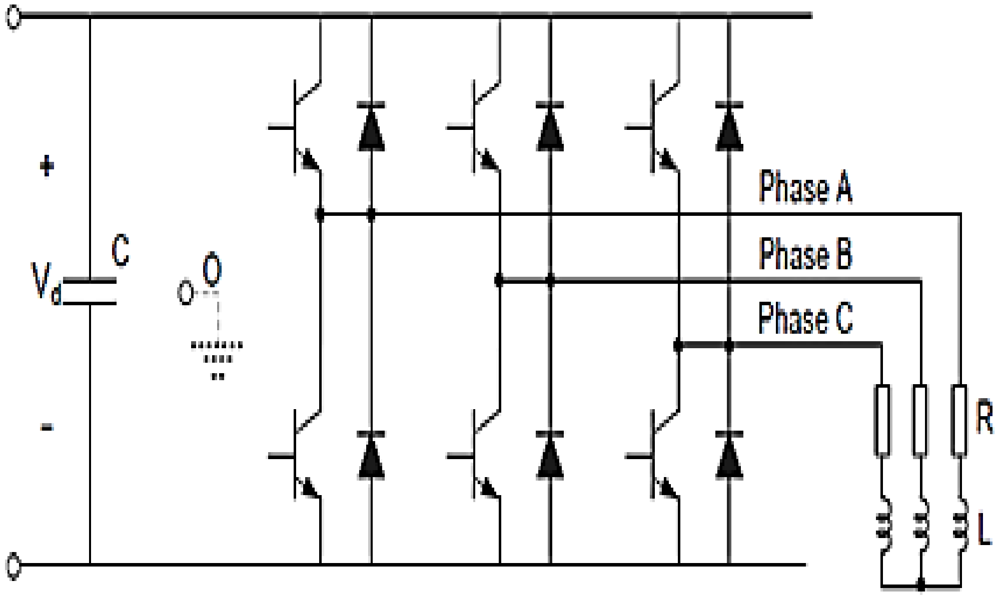


Figure II. 2 : Three phase voltage source inverter

As seen from the figure II.2, it is having three legs, which offers 23 different states. The output of the inverter is defined in function of the different states of switches. The voltage changes between 2/3 and -2/3 of the capacitor’s voltage.

II.4 Control of the Active Filter

The control system of an active power filter is a crucial component responsible for ensuring effective harmonic compensation and maintaining power quality. It involves several parts that work together to generate the appropriate control signals for the active filter. Let's discuss each part in more detail:

1. Calculation Reference

2. Regulation

3 Control of the Filter

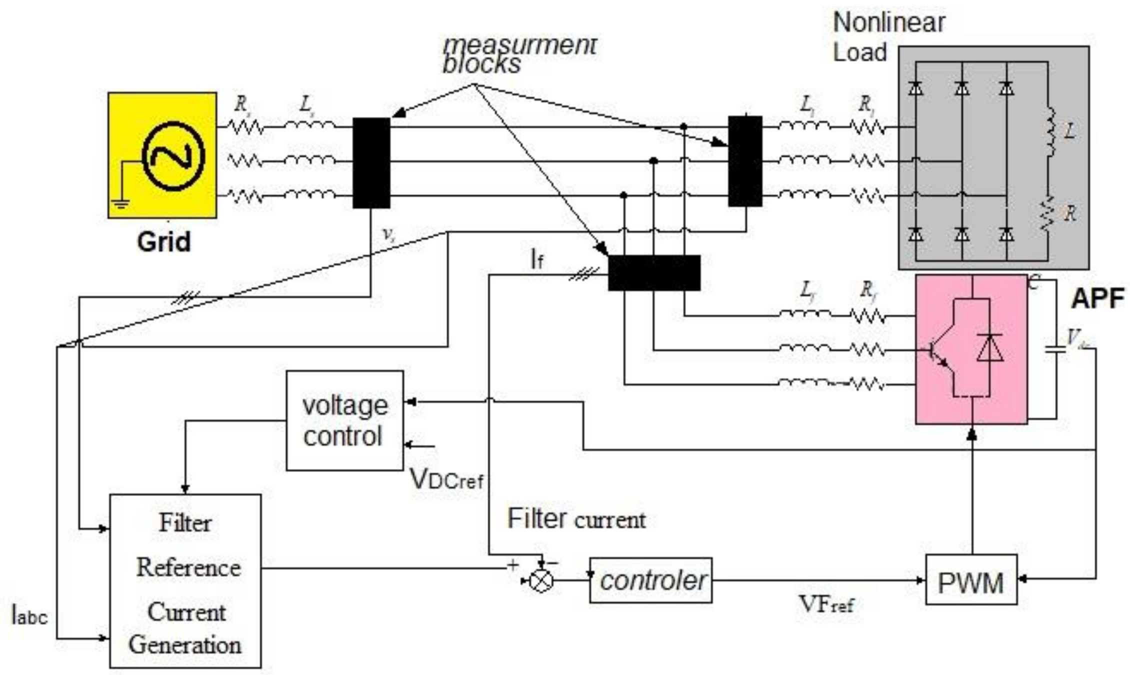


Figure II. 3 : General control of parallel shunt active power filter

II4.1 Reference generation in shunt active power filter

The generation of reference currents is a crucial step in the control of shunt active power filters (APFs) as it lays the foundation for effective filtering. Errors in this stage can lead to malfunctioning of the filter and adversely affect its performance. Various methods are employed for reference current generation, including the Fourier transform, instantaneous active and reactive power theory, and Park transform-based methods.

II.4.1.1 The instantaneous active and reactive power theory:

Introduced by Akagi and others in the 1980s, offers high precision and simplicity in implementation. However, it lacks flexibility when dealing with non-balanced or distorted three-phase voltages. Despite this limitation, most APFs are based on this theory.

The theory involves transforming the three-phase system into a two-phase system using the Park transform or dq transformation. Through this transformation, the active and reactive powers can be calculated instantaneously. The transformed two-phase system allows for filtering out harmonics and enables the recalculation of the original pure or harmonic contents of the current or voltage [4].

The transformation from the three-phase system (Va, Vb, Vc) to the two-phase system (Vα, Vβ) is given by the following matrix equation:

$$\begin{matrix} V_\alpha \\ V_\beta \\ V_\gamma \end{matrix} = \sqrt{\frac{\sqrt{3}}{2}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{matrix} V_a \\ V_b \\ V_c \end{matrix} \quad \#(6)$$

This transformation is also applied to the currents, which may contain harmonics. The powers can then be expressed as functions of the currents and voltages:

$$\mathbf{p(t) = v_\alpha i_{l\alpha} + v_\beta i_{l\beta}} \quad \#(7)$$

$$\mathbf{q(t) = u_\alpha i_{l\beta} - u_\beta i_{l\alpha}}$$

Here, p represents the active instantaneous power, and q represents the reactive instantaneous power consumed by the nonlinear load. Each power component consists of a fundamental part related to the fundamental voltages and currents and a harmonic part associated with the harmonics of the current and voltage.

To extract the harmonic components from the active power components, a high-pass filter or a low-pass filter with feed-forward can be employed. Figure II.4 illustrates the use of a low-pass filter with feed-forward for harmonic extraction. The low-pass filter allows the low-frequency (fundamental) component to pass through while attenuating the high-frequency signals representing the harmonics. The fundamental component is then subtracted from the original signal to obtain the harmonic power.

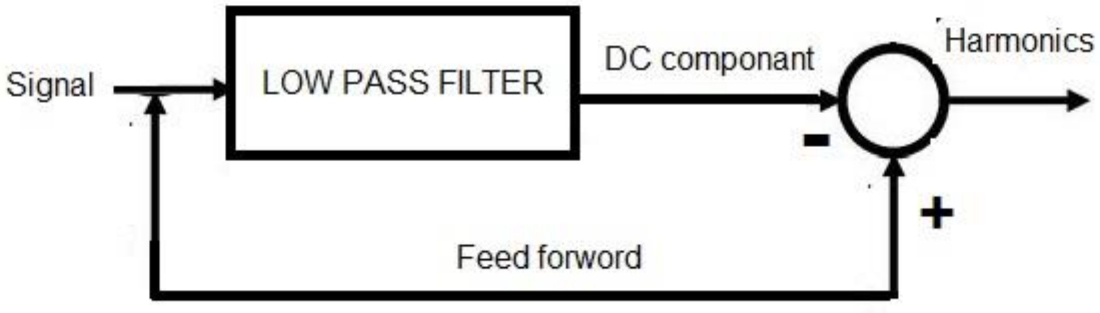


Figure II. 4 : Low pass filter used for harmonics extraction

The harmonic power can be utilized to determine the reference currents. The reference currents in the two-phase system (Iα, Iβ) can be obtained using the following equation:

$$\begin{matrix} i_\alpha \\ i_\beta \end{matrix} = \frac{1}{v_\alpha^2 + v_\beta^2}\begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix}\begin{bmatrix} P_{harmonic} \\ q \end{bmatrix} \quad \#(8)$$

To obtain the reference currents in the three-phase system, an inverse transformation from the two-phase system to the three-phase system is applied:

$$\begin{matrix} i_a \\ i_b \\ i_c \end{matrix} = \frac{\sqrt{3}}{2}\begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad \#(9)$$

Figure II.5 provides a concise overview of the application of the instantaneous active and reactive power theory for reference generation in shunt APFs.

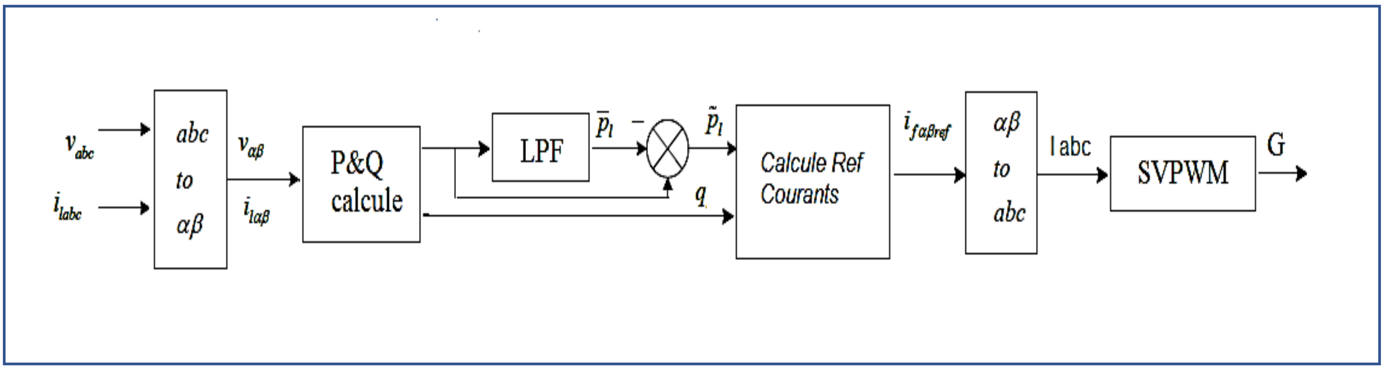


Figure II. 5 : PQ theory principle and its implementation

II.4.2 Regulation

II.4.2.1 PI Controller for DC Voltage

The voltage of the DC side of the inverter or active power filter plays a crucial role in maintaining stable operation and high-quality filtering. Fluctuations in the DC voltage can result in undesired ripples in the injected current to the grid, which can negatively impact the filtering process. To ensure the DC voltage remains constant despite changes in grid and filter parameters, it is common to utilize either a dedicated DC power source or a capacitor.[14]

When a capacitor is employed, its capacitance must be chosen appropriately to support the filter and maintain the DC voltage near a predefined value over short periods of time. The energy stored in a capacitor can be expressed as:

$$E = \frac{1}{2} c_{dc} . V_{dc}^2 \ \#(10)$$

Differentiating this energy expression with respect to time yields the power delivered to or from the capacitor:

$$p = \frac{d}{dt}\left(\frac{1}{2} C . V^2\right) = CV\frac{dV}{dt} = CV\left(\frac{V_f - V_i}{\Delta t}\right) \quad \#(11)$$

To keep the difference between the initial and final capacitor voltages close to zero, the capacitance must be increased. Additionally, it is essential to minimize the time interval (Δt) so that the power gained or lost during a small period can be quickly readjusted to maintain the energy of the capacitor constant.

A proportional-integral (PI) controller can be employed to regulate the capacitor voltage and ensure it remains fixed at the desired reference value. Figure II.6 illustrates the concept of PI control for capacitor voltage.

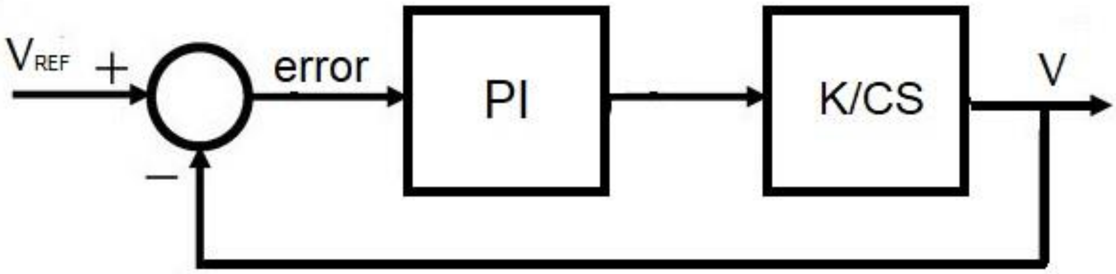


Figure II. 6 : PI Control of a capacitor voltage

By appropriately designing and tuning the PI controller, the voltage of the capacitor can be effectively regulated, mitigating fluctuations and contributing to the stability and performance of the active power filter

II.4.2.2 PI Controller for Filter Currents

For the control of filter currents, a separate PI controller is utilized for each current component. The input to these controllers is the error between the measured filter current and the reference current, which is generated using an appropriate method such as the instantaneous active and reactive power theory or other techniques. The output of the PI controllers determines the required voltage to regulate the filter currents and track the reference values. Considering the transfer function of the inverter, AC filter, and PI controller as a second-order system (1/(LS+R)), the overall system configuration is shown in Figure II.7 [14].

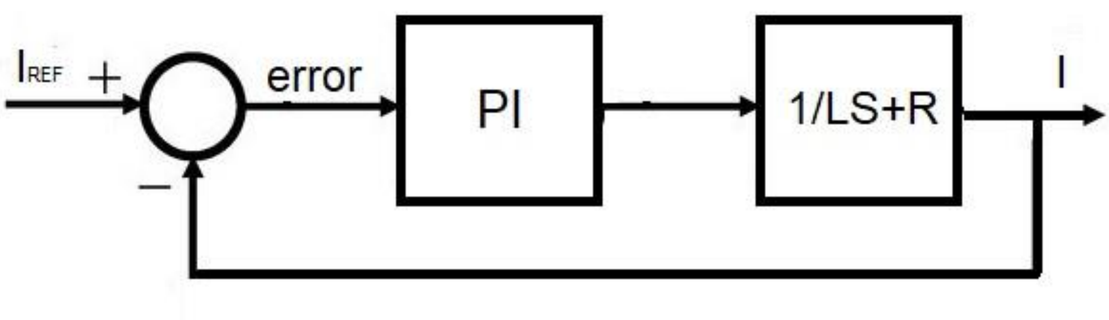


Figure II. 7 : PI Controller for current control

II.4.3 Command of the Filter

In the control of active power filters, various methods can be employed. Two commonly used methods are hysteresis control and PWM control.

II.4.3.1 Hysteresis control involves directly controlling the current by setting a hysteresis band. The current is monitored, and if it exceeds the upper limit of the hysteresis band, the control system reacts by generating a switching signal to reduce the current. Similarly, if the current falls below the lower limit of the hysteresis band, the control system generates a switching signal to increase the current. Hysteresis control ensures fast response and accurate current tracking, but it can result in higher switching frequency and increased switching losses.

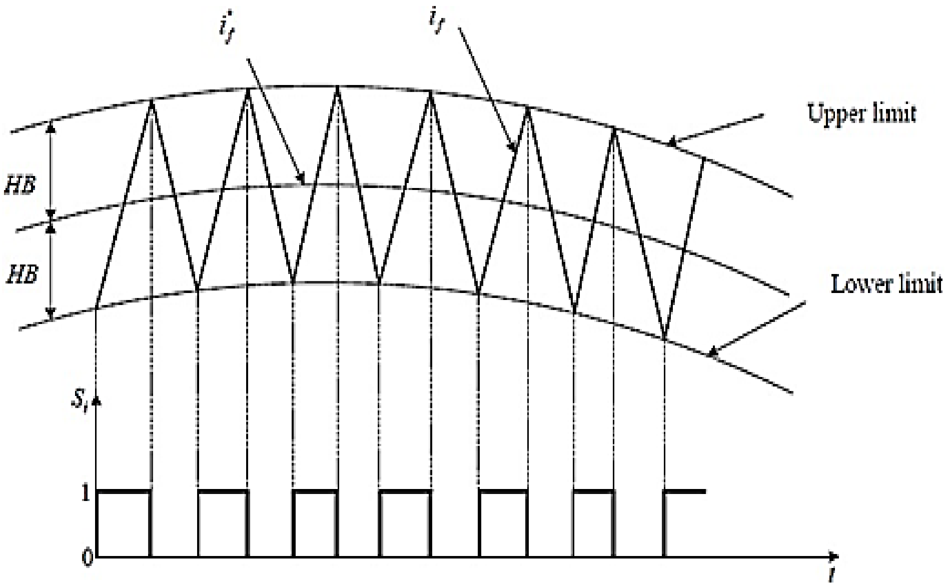


Figure II. 8 : Hysterisis control principle

II.4.3.2 PWM (Pulse Width Modulation) control is another widely used method. It involves comparing the actual current with a reference current and generating a series of pulses with varying widths to control the switching of the power devices. The pulse width is adjusted in such a way that the average value of the current matches the reference current. PWM control offers precise control over the current and allows for flexible adjustment of the modulation index, which determines the ratio of the fundamental component to the harmonic components in the output waveform [14].

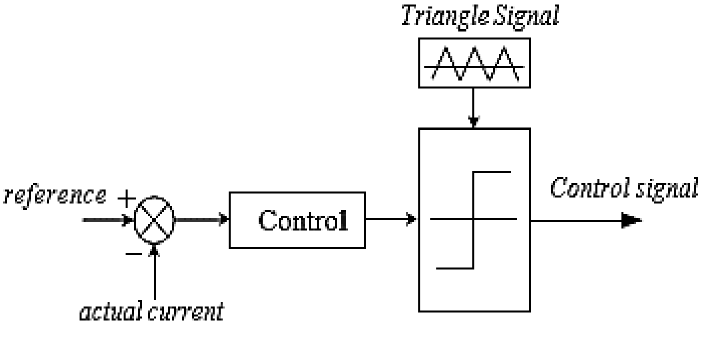


Figure II. 9 : Comparator controller and modulator of PWM

II.5 Photovoltaic System

II.5.1 Photovoltaic Cell Theory.

The solar cell composed from a semiconductor silicon material to form a PN-junction. So, the photovoltaic system builds basely from the PN- junction. A big number of electrons and holes are generated when the light stroked on the flat of PN-junction. Therefore, an electric field generated between the PN-junction terminals and positive and negative terminals are also formed [7].

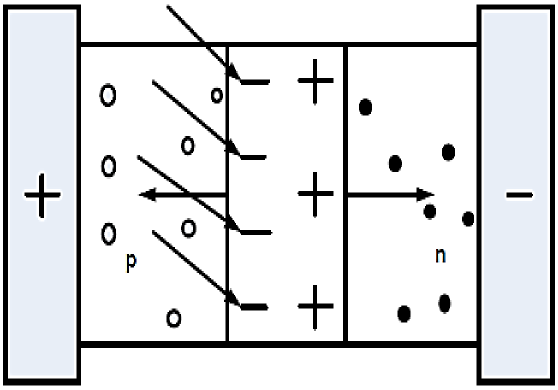


Figure II. 10 : P-N Junction clarification of PV cell

As seen from the above figure II.10, when the junction exposed to the sunlight, a pair of electrons and holes are formed by getting the needed energy from the sunlight. Whereas the P-region is the house of holes and the n-region is the house of free electrons. Hence, positive and negative terminals are created as shown the middle portion of the Figure II.10.

If we put an electrical load between junction terminals, the electrons will travel to P-type part and the holes travel to N-type part. That means, an electrical current motion generated through the PN-Junction and transfers the energy in sunlight to electrical energy.

II.5.2 Photovoltaic Cell, Module or Panel and Array.

The solar cell energy is so low, it is about 1.5 watts for mono crystalline type, so to make it useful, it is needed to get high solar power generation source.

The solar power generation source composed from a big number of series and parallel solar cells and it can be named as solar panel or module then named Array for high power systems.

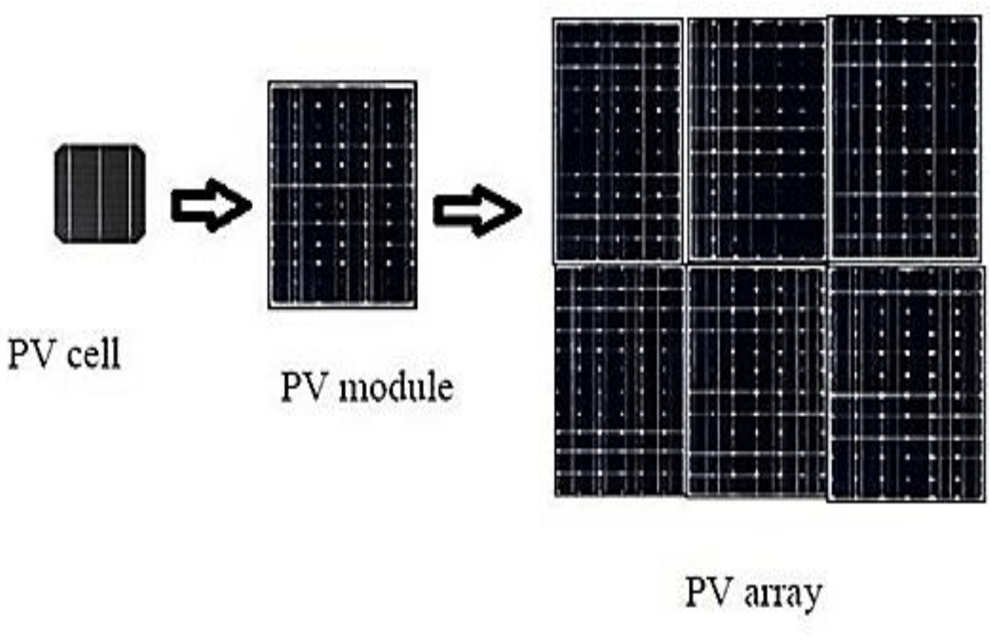


Figure II. 11 : Creation of solar module and solar array

II.5.3 Perturb and Observe (P&O) MPPT.

The P&O algorithm is depending on the “hill-climbing” principle, which relies on moving the operation point of the PV array in the way of maximum power. Hill-climbing algorithms are the top common MPPT methods referred to their ease of implementation and acceptable performance when the irradiation is constant. The advantages of P&O method are the simplicity and low power consumption needed. There are two drawbacks of this technique, the major one is that they can easily lose track of the maximum power point (MPP) if the irradiation changes quickly. The minor disadvantage of P&O method is the unstable voltage and current around the maximum power point (MPP) in the steady state and to overcome these handicaps, we used enhanced P&O method [7].

II.6 Boost Converter

The DC-to-DC converters is necessary for MPPT designing. As in Boost converter, input voltage (DC) is a less than output voltage (DC). That means input PV-voltage is smaller than the output voltage of boost converter. Hence, boost converter is required for the PV system with MPPT technique to boost-up the voltage of the PV system. DC-DC Converters are used for dc-input voltage which is then converted to desired dc-output voltages where the magnitude of the output voltage must differ than the input voltage magnitude. Normally, DC-DC converters are classified into three types namely: buck, boost and buck-boost Converter and here boost converter is preferred as we need to step up the PV output. DC-DC converters are also useful for noise isolation and power bus regulation. The DC-DC boost converter contains an inductor, capacitor, diode and an IGBT as it is a high frequency switch. It produces higher voltage during power supply to the load. Based on the switch duty cycle the output voltage may change. Generally, transformer can step up the voltage, but there may be losses in the transformer. So, to overcome this loss DC-DC Boost converter is used to get desired output voltage [7].

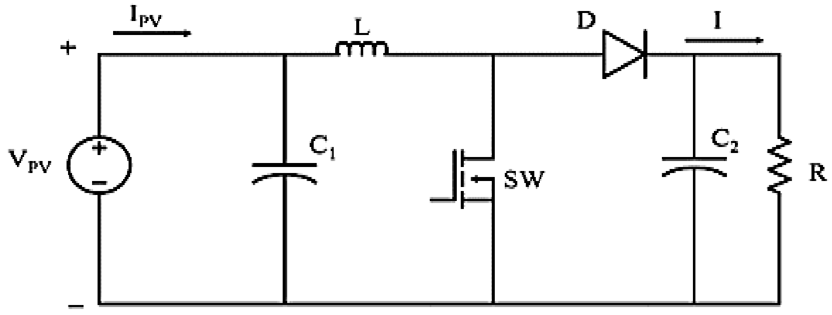


Figure II. 12 : circuit diagram of the converter

The conversion ratio for the boost converter can be determined by assuming the inductor and capacitor having large value that can be enough to take voltages and currents as DC values. The switch can be replaced by an equivalent voltage source having value (1- D). The complementary duty cycle presents the duration during which the diode conducts can be expressed as D' = (1 - D). During this period, it is assumed as an ideal diode, where the intermediate voltage is shorted to VL. The intermediate voltage is shorted to ground during on this condition of the switch. Hence, the average value is equal to (1 – D) Vout.

Since at DC condition, the inductor is short circuited hence,

$$V\text{in} = (1\text{-D})\ V\text{out}$$

The above equation shows that the conversion ratio of the boost converter depends on duty cycle assuming constant-frequency operation. A boost converter can operate with both constant on-time and constant off-time switching. But in both the cases, change in duty cycle results in change in frequency. So here a constant-frequency boost converter is taken.

The duty cycle indicates the duration period for which the diode turns on. It can be expressed as D' = (1 - D). Through this period, it is assumed as an ideal diode, where the intermediate voltage is shorted to $Vout$.

II.7 Conclusion

The chapter introduced the structure and control of parallel filters, highlighting the utilization of PI controllers to regulate their operation. It further explored various methods for harmonic extraction, focusing PQ theory with its configuration.

Furthermore, the chapter delved into the generation of PV cells and provided an overview of their modeling. It also discussed PV systems equipped with MPPT techniques, specifically focusing on the P & O algorithm. The incorporation of a DC-DC boost converter in PV systems was explained, emphasizing its role in efficiently converting the generated power.

In summary, this chapter covered the principles and control mechanisms of active parallel and series filters, harmonic extraction methods, PV cell generation and modeling, as well as PV systems with MPPT and DC-DC boost converters.

Chapter III

Simulation and discussion

Chapiter 3 Simulation and discussion

III.1 Introduction

In order to evaluate the performance and functionality of the proposed system, MATLAB SIMULINK environment was utilized for simulation. The simulation of the hybrid active power filter (HAPF) was conducted to verify the proper operation of all interconnected system components. Furthermore, the performance of the system at each stage was thoroughly examined and will be discussed in detail in the subsequent section.

III.2 System components

The system used in this work consists of several components, as depicted in the provided diagram. The three-stage Hybrid Active Power Filter (HAPF) includes an inverter controlled by the PQ algorithm. The inverter is supplied by a photovoltaic system through a DC/DC converter employing the MPPT algorithm. The outputs of the inverters are connected to the Point of Common Coupling (PCC) , a passive filter which is an LC circuit connected in parallel , The nonlinear charge is generating harmonic currents and consuming reactive power modeled by a bridge rectifier three-phase delivering on a capacitive load (R//C) .

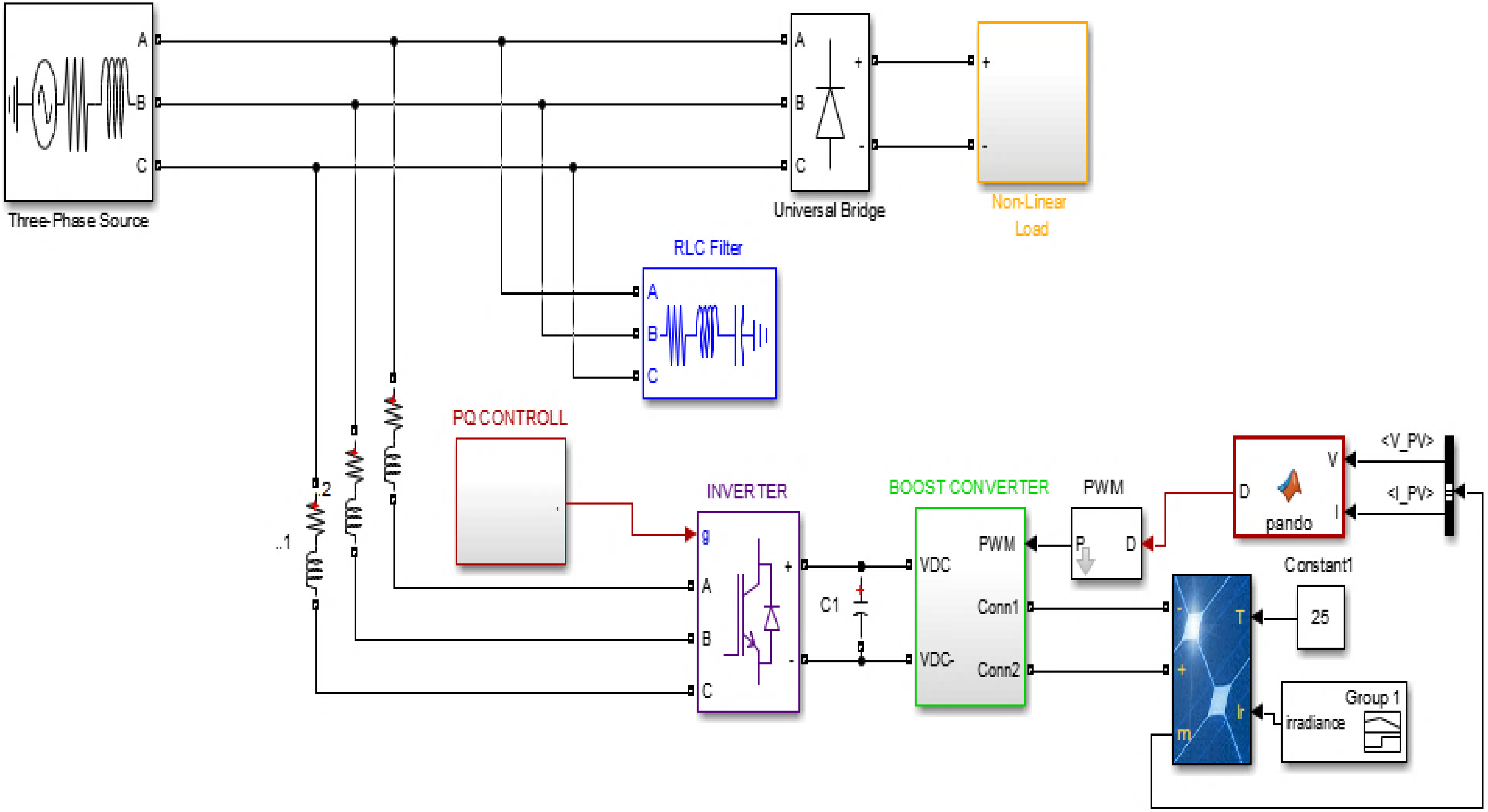


Figure III. 1 : Three stage Hybrid active power filter (HAPF)

III.2.1 PQ method

The PQ method, which is used in this system, is illustrated in the provided diagram. It includes a set of mathematical equations that describe its operation. Furthermore, the simulation blocks for the PQ method in MATLAB Simulink are shown in the accompanying figure (from III.2 to III.7).

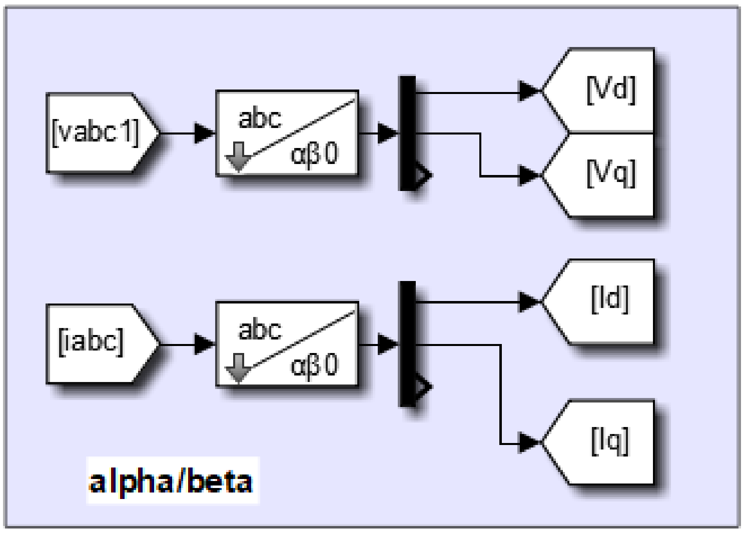


Figure III. 2 : alpha/beta calculation

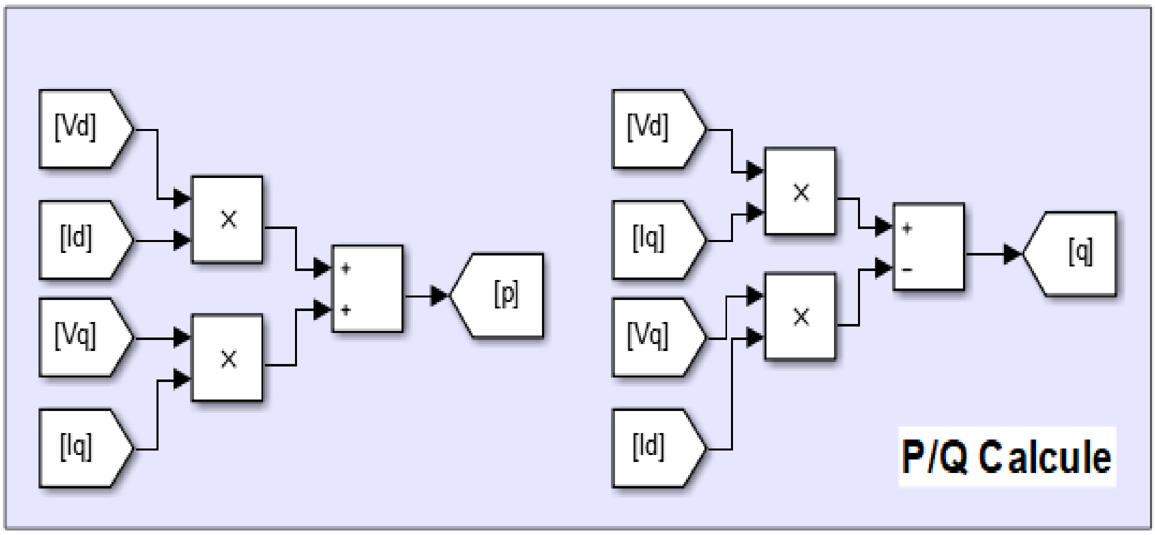


Figure III. 3 : P and Q calculation

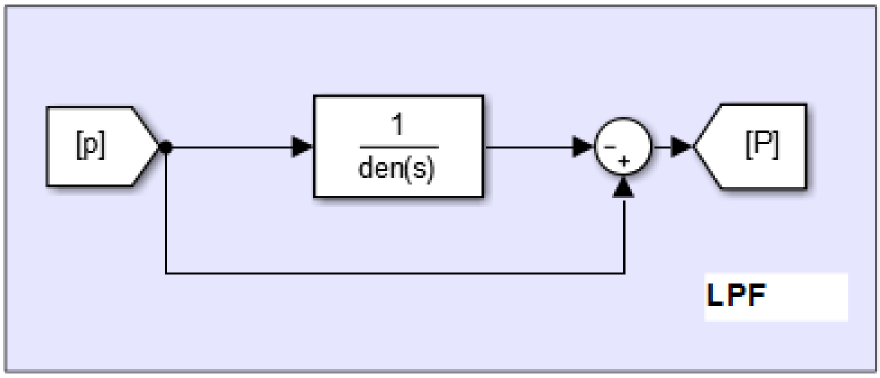


Figure III. 4 : LPF for harmonic extraction

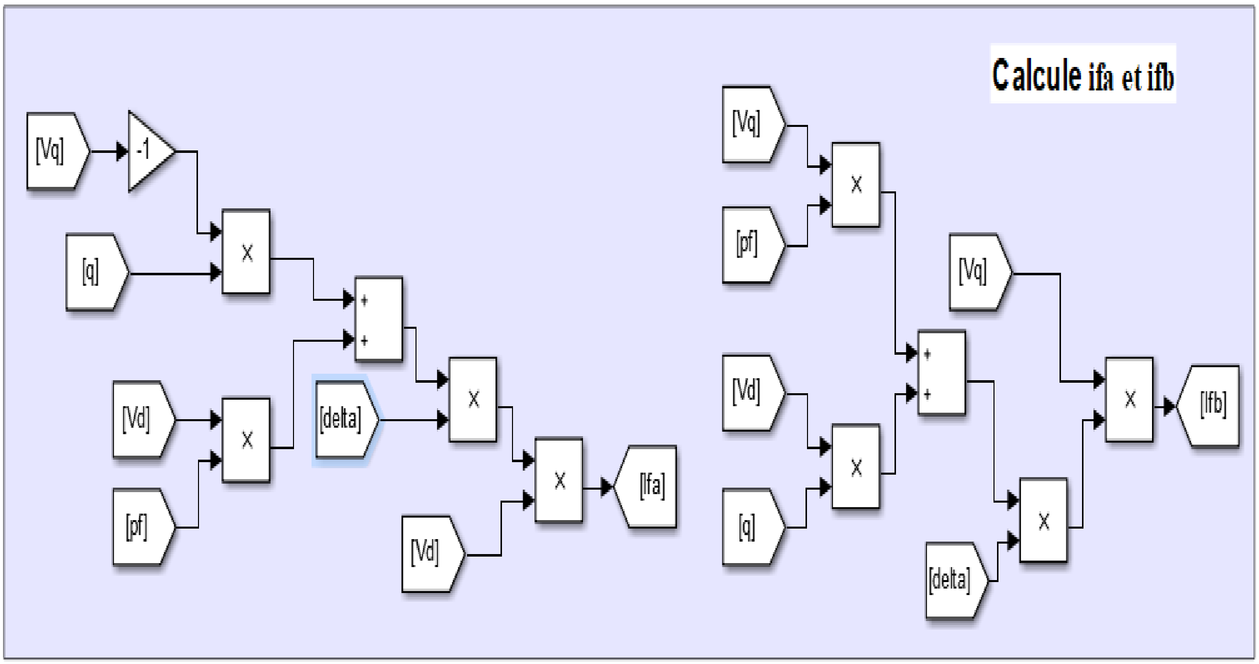


Figure III. 5 : Ifa and ifb calculation

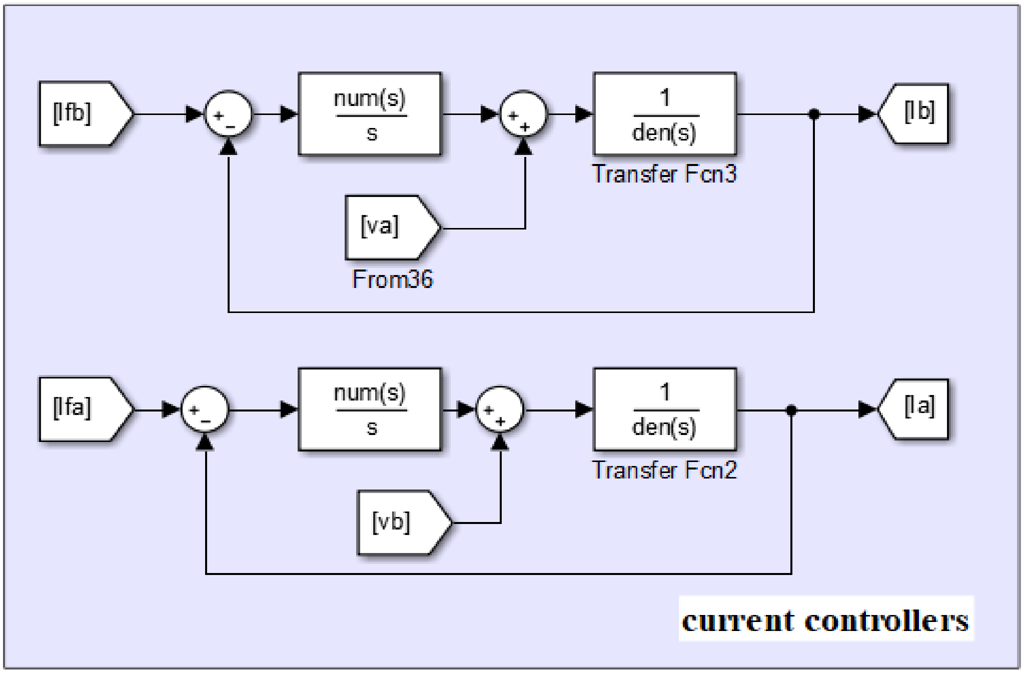


Figure III. 6 : Current Controller

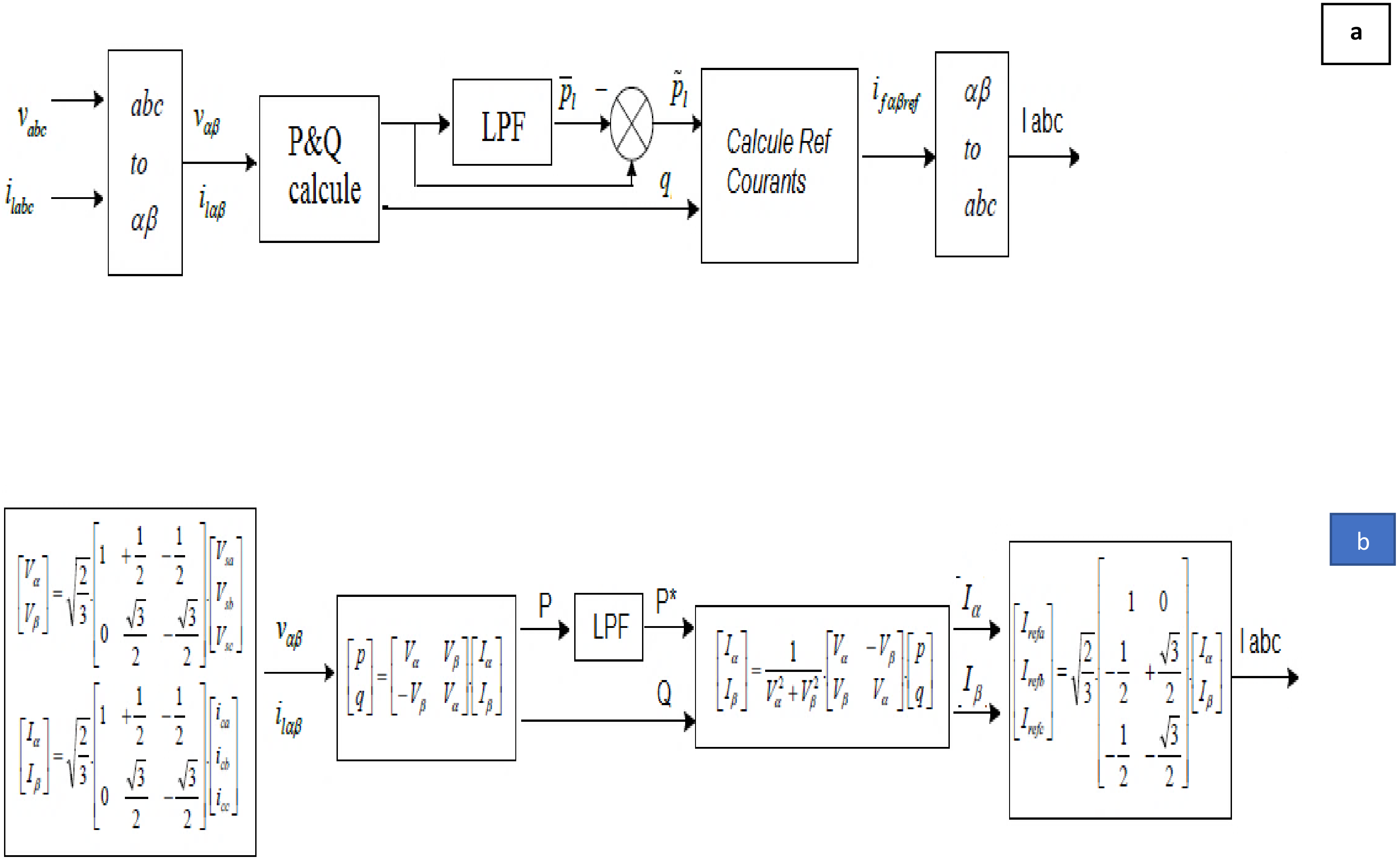


Figure III. 7 : (a) Diagram of PQ method (b) mathematic equation of PQ method

III.2.2 MPPT

The MPPT algorithm specifically the P and O (Perturb and Observe) algorithm, is depicted in the diagram. Additionally, the simulation of the MPPT algorithm using MATLAB functions is shown in the provided figure III.8, III.9, III.10.

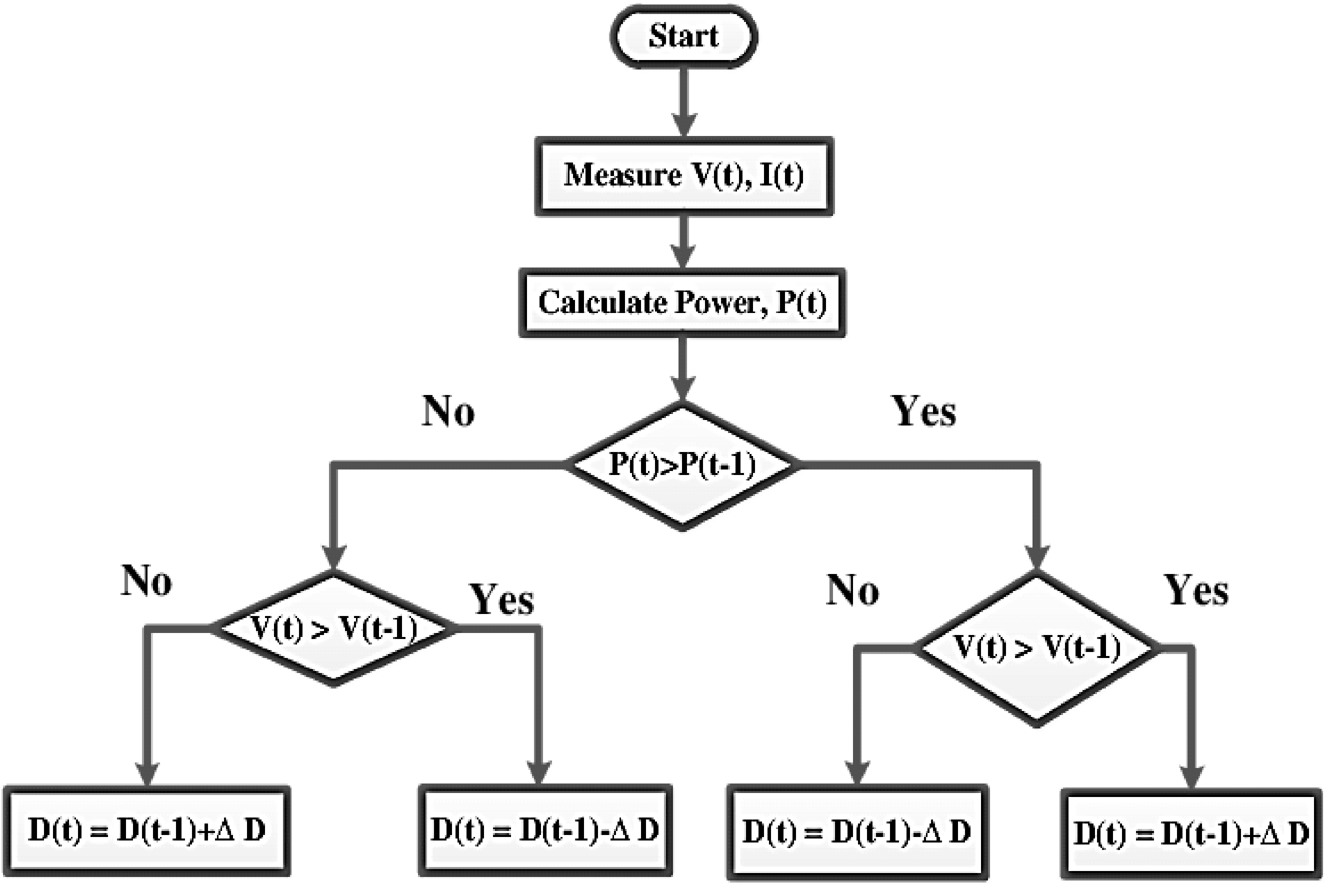


Figure III. 8 : MPPT (P&O) Diagram

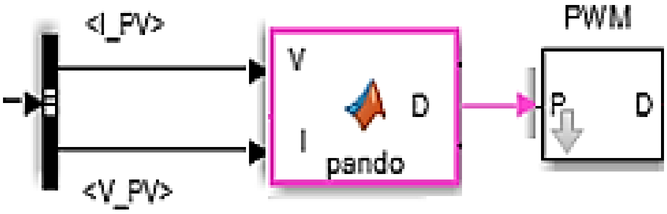
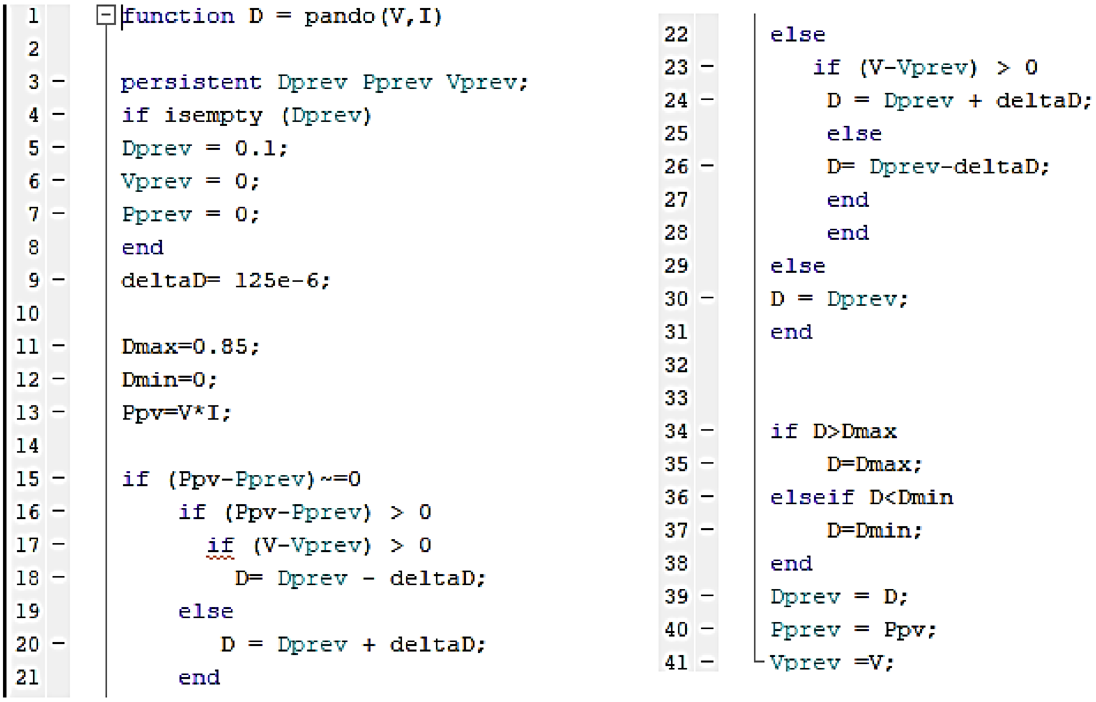


Figure III. 9 : P&O MATLAB function



```
function D = pando(V,I)

persistent Dprev Pprev Vprev;
if isempty (Dprev)
Dprev = 0.1;
Vprev = 0;
Pprev = 0;
end
deltaD= 125e-6;

Dmax=0.85;
Dmin=0;
Ppv=V*I;

if (Ppv-Pprev)~=0
    if (Ppv-Pprev) > 0
      if (V-Vprev) > 0
        D= Dprev - deltaD;
    else
       D = Dprev + deltaD;
    end
else
   if (V-Vprev) > 0
    D = Dprev + deltaD;
    else
    D= Dprev-deltaD;
    end
    end
else
D = Dprev;
end


if D>Dmax
    D=Dmax;
elseif D<Dmin
    D=Dmin;
end
Dprev = D;
Pprev = Ppv;
Vprev =V;
```

Figure III. 10 : P&O script code mathlab function

III.3 Results and discussion

The figure shown below is the result of the parameters we chose for pv system

This section presents the simulation results of the hybrid active filter, focusing on the reduction of current drawn by the active filter and its power. Passive filters are utilized to compensate for low-order harmonics, while the active filter compensates for the remaining harmonics not addressed by the passive filters.

In addition, a nonlinear load in the form of a voltage source is considered, modeled by a diode bridge delivering on a resistor in parallel with a capacitor, Fig III.12 shows current consumed by the load in this simulation.

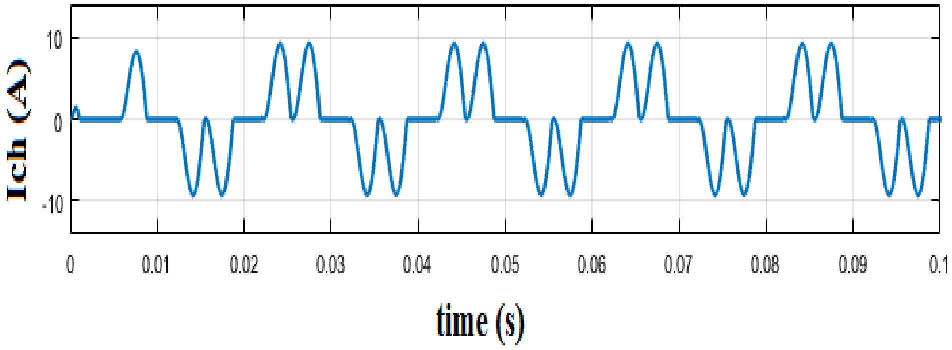


Figure III. 11 : Load current

The solar irradiation curve, is shown in the figure III.13, is custom-designed and created using the Signal Builder block in Simulink.

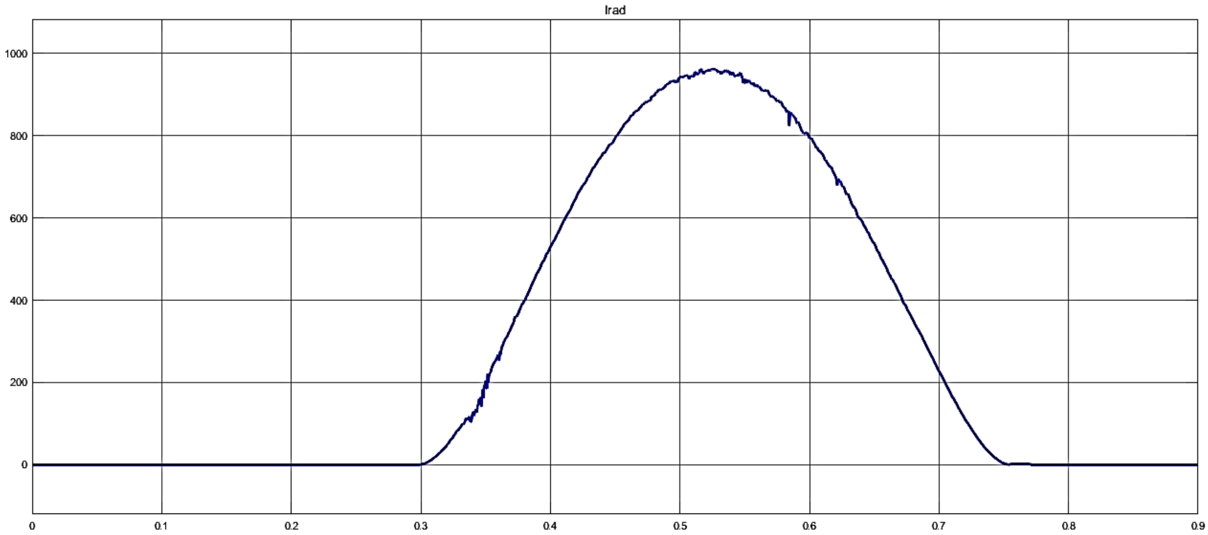


Figure III. 12 : Irradiance curve

The reference voltage Vdc_ref for the DC bus regulation loop is set to a fixed value of 142 V. The figure represents variation of the DC voltage delivered by the photovoltaic system over this experiment.

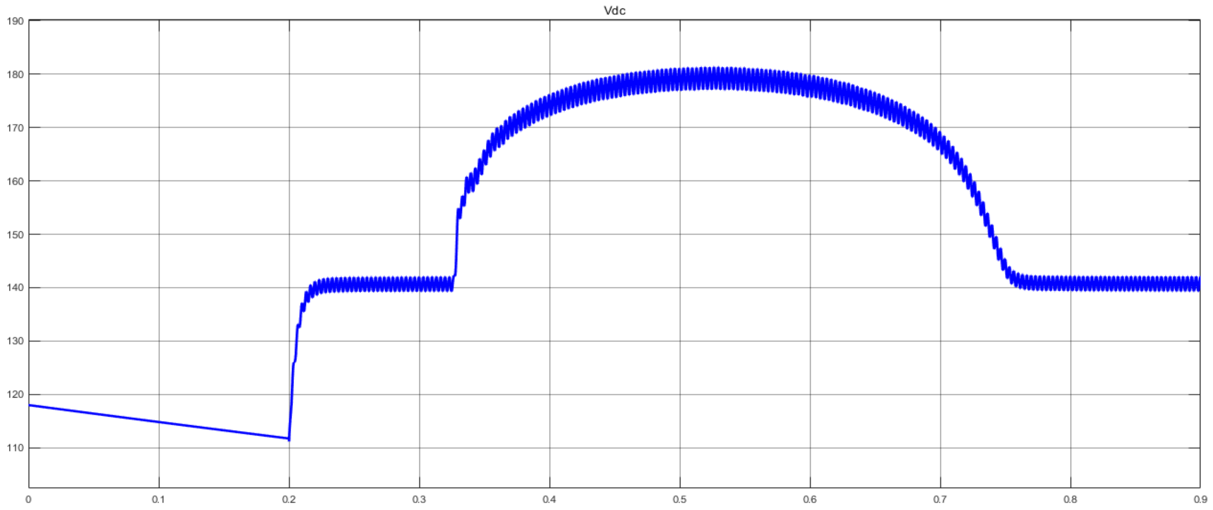


Figure III. 13 : DC bus voltage

The simulation and experimentation parameters used in the study are summarized in the following tables

Tables 01: General parameters of solar panels

Parameter of solar panel (1Soltech 1STH-215-P)	
Series modules PV	5
Parallel string PV	10
Vmax(V)	300
Pmax(W)	11KW
Maximum Power (W)	218.871
Open circuit voltage Voc (V)	36.6
Voltage at maximum power point Vmp (V)	29.3
Cells per module (Ncell)	60
Short-circuit current Isc (A)	7.97
Current at maximum power point Imp (A)	7.47
Temperature coefficient of Voc (%/deg.C)	-0.36101
Temperature coefficient of Isc (%/deg.C)	0.10199

Tables 02: Simulation parameters

PAF Parameter	
C_{dc}	1100 μF
R_s , L_s	0.01 Ω , 50* 10^{-6}
R_f, L_f	0.01 Ω ,110 mH
$R_I, L_I, C_I,$	0.01 Ω , 1.9*10^{-3} h , 110 μF
R_D, C_D	16.15 Ω, 470 μF
V_{DC}^{*}	142 V
Boost converter Parametres	
L_{PV}	3* 10^{-3}
C_{PV}	2200 μF

III.3.1 Simulation

It should be noted that the experiment was divided into three times sections for analysis:

1-Grid with Nonlinear Load without Filters (0s-0.1s): In this section, the system was operated without the active and passive filters. The nonlinear load was connected to the grid, and its behavior was observed.

2-Connection of Passive Filters with the Network (0.1s-0.2s): In this section, the passive filters were connected to the system. The purpose was to compensate for the harmonics of low order generated by the nonlinear load. The performance of the passive filters in reducing the harmonic distortion was evaluated.

3-Activation of the Active Filter for Current Injection (0.34s-1s): In this final section, the active filter begins to inject compensation currents into the system. The active filter aimed to compensate harmonics and approve power quality. The behavior of the active filter and its effectiveness in harmonic mitigation were analyzed.

These three times sections allowed for a comprehensive evaluation of the system's performance under different operating conditions and the contribution of each filter component to harmonic compensation and power quality improvement.

III.3.1.1-part one:

During the time period from 0s to 0.1s, the system consisted of only the grid and the nonlinear load. The simulation results are presented in Figure III.14 and Figure III.15., Based on these simulation results, it can be observed that the current drawn from the grid by the nonlinear load contains a significant number of harmonics. The distortion rate of the grid current is measured to be 75%, indicating a substantial deviation from the ideal sinusoidal waveform. This high distortion rate signifies the impact of the nonlinear load on the power quality of the grid.

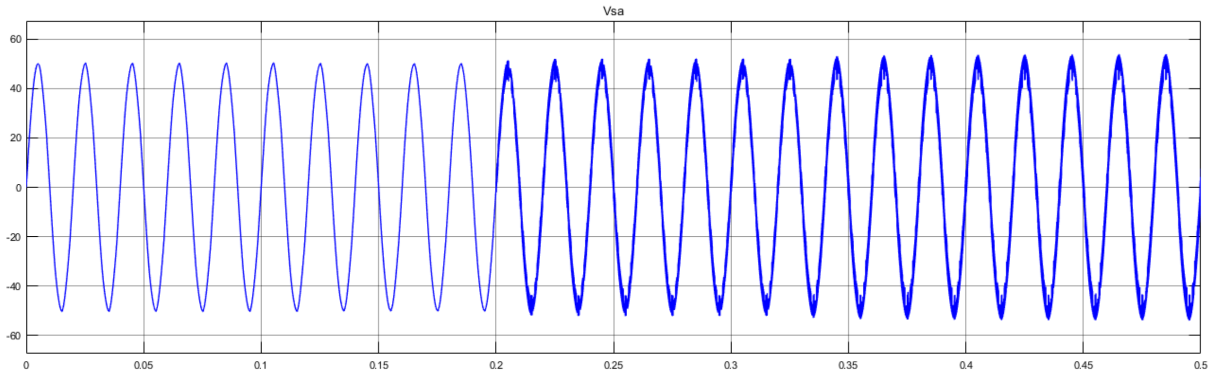


Figure III. 14 : Source voltage

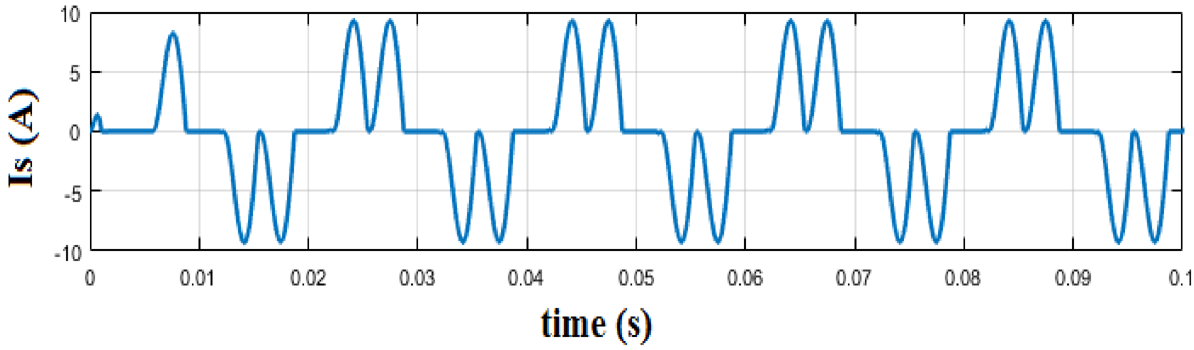


Figure III. 15 : Source current

III.3.1.2-part two:

From 0.1 s to 0.2 the passive filter starts to compensate for the harmonics of low order which are the most significant harmonics in the grid, Figure III.16 presents the grid current waveform with its frequency specter Analyzing the results, we can observe that the passive filter successfully mitigates some of the targeted harmonics from the source current. However, it is important to note that the waveform of the grid current is still not a perfect sinusoid. The distortion rate, measured to be 73.04%, indicates that there is still some residual harmonic content present in the current waveform, further improvements are necessary to achieve a higher quality sinusoidal waveform.

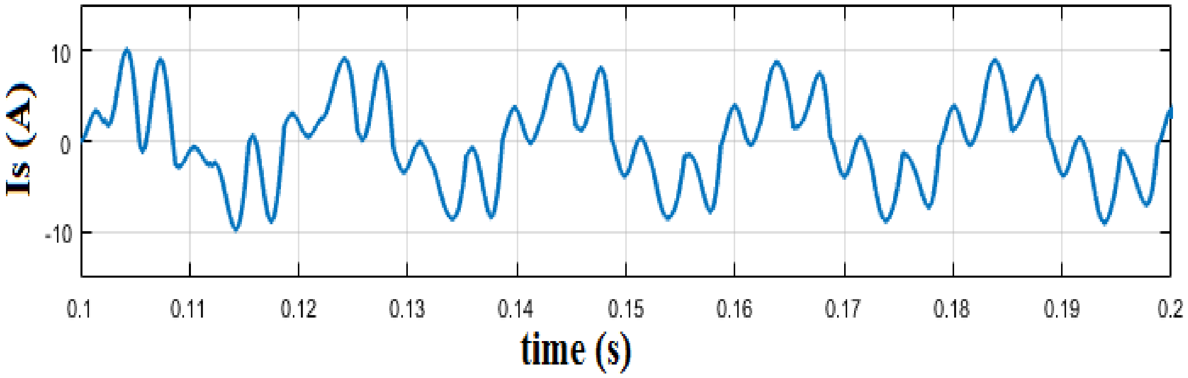


Figure III. 16 : Source current

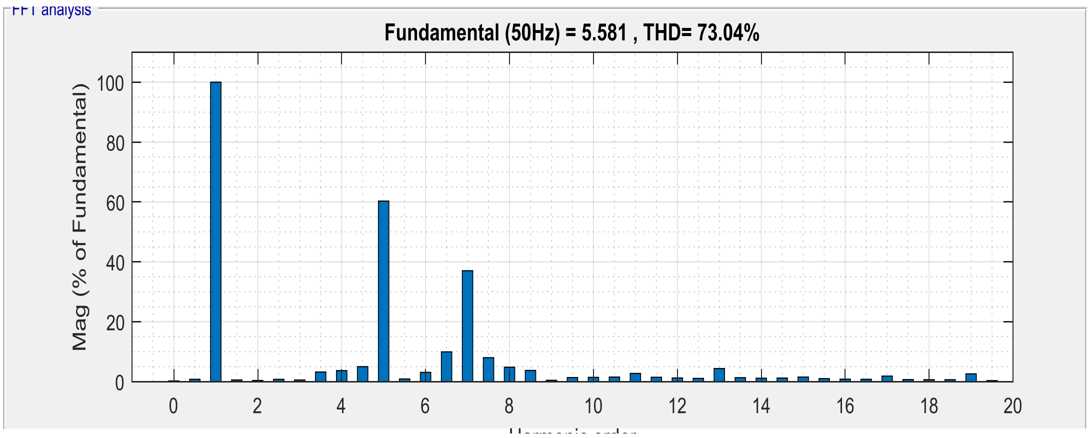


Figure III. 17: Spectre THDI (1)

III.3.1.3-Part three:

In the third part of the experiment (from 0.2s to 1s) the active filter is activated and starts injecting compensating current into the network. Figure III.19 presents the waveform of the grid current along with its frequency spectrum, while Figure III.18 shows the grid voltage.

Analyzing the results, we can observe a significant improvement in the quality of the source current waveform. After 0.22s, the source current becomes pure sinusoidal and is in phase with the corresponding voltages. This indicates that the active filter effectively compensates for the harmonic components present in the grid current, the (THD) of the source current decreases substantially from 73.04% to 5.94%. This reduction in THD signifies a significant improvement in the overall quality of the current waveform, approaching a more ideal sinusoidal shape. Figure III.20 illustrates the current injected by the active filter.

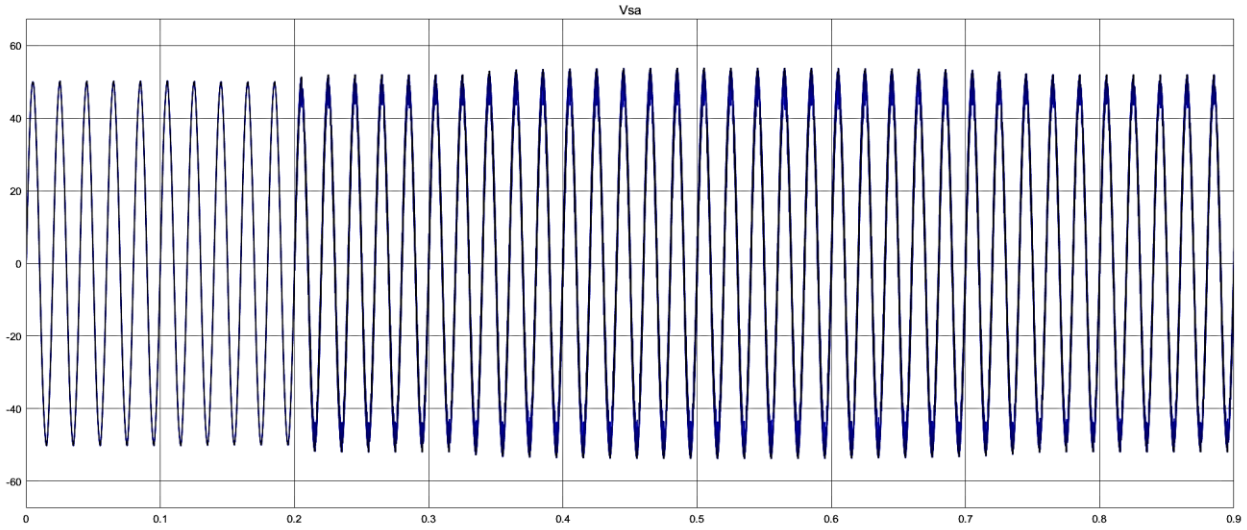


Figure III. 18 : Voltage Source

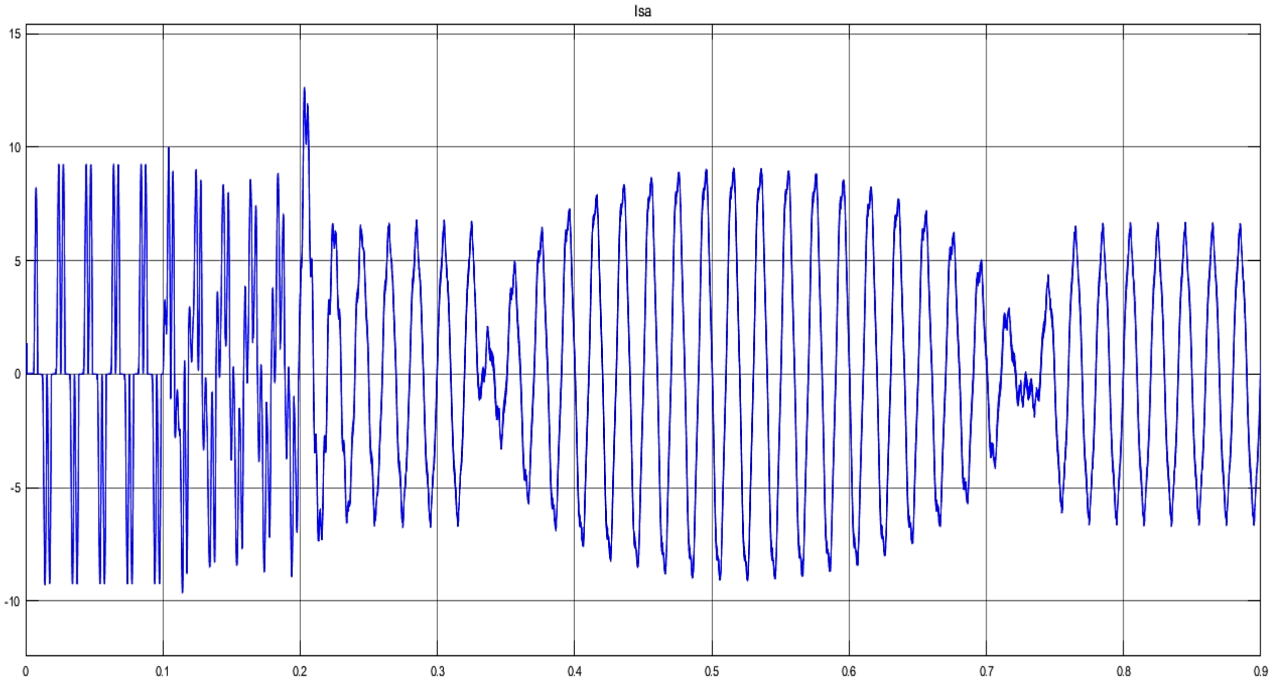


Figure III. 19 : Current source

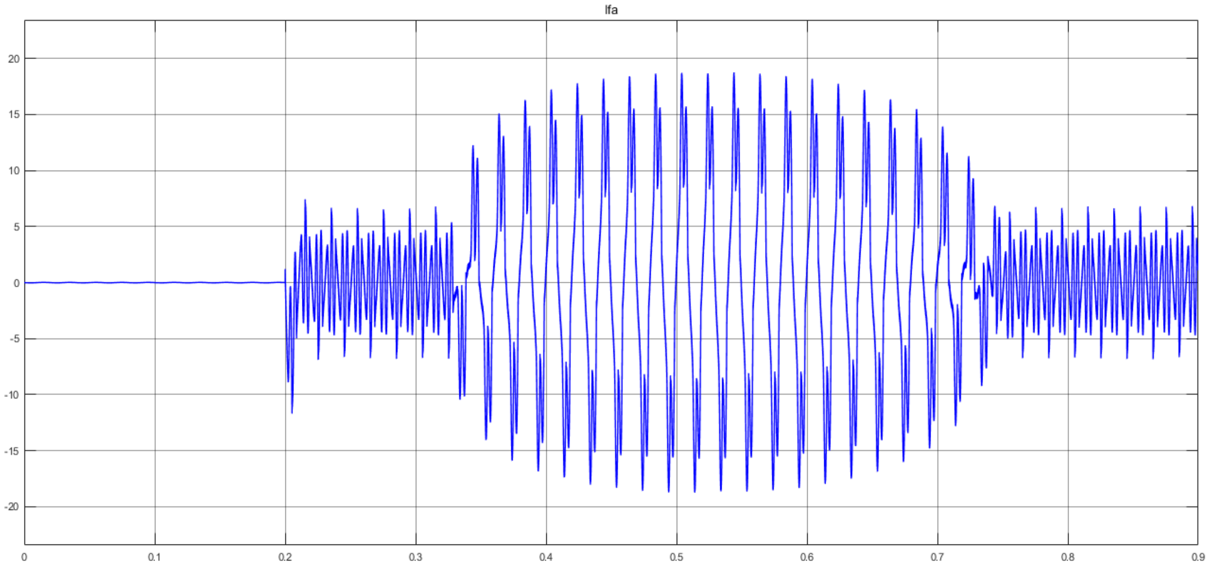


Figure III. 20 : Current injected by the filter

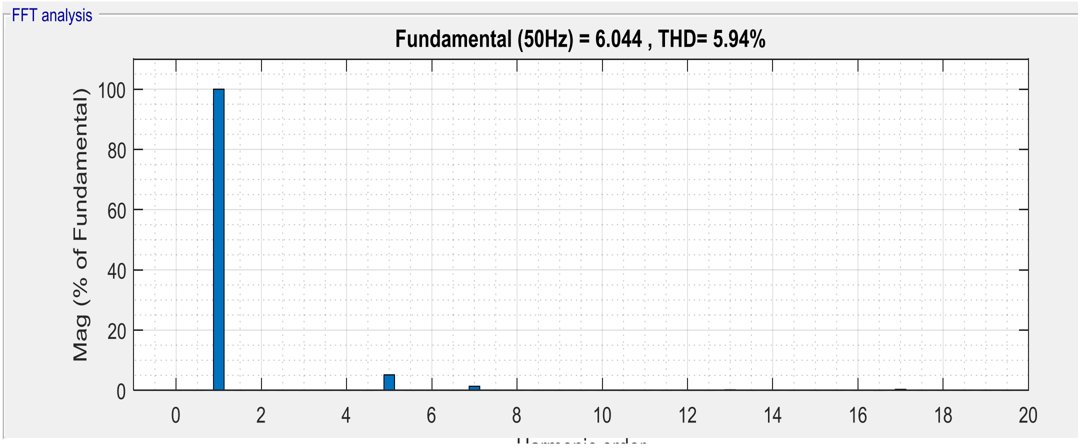


Figure III. 21 : Spectre THDI (2)

Figure III.22 and Figure III.23 provide the waveforms of the instantaneous powers (real power P and reactive power Q) It is observed that at 0.34s, the active filter starts injecting real power into the network and improving the power factor, the reactive power oscillates around zero, indicating effective compensation by the active filter and ensures minimizes the overall power losses in the system.

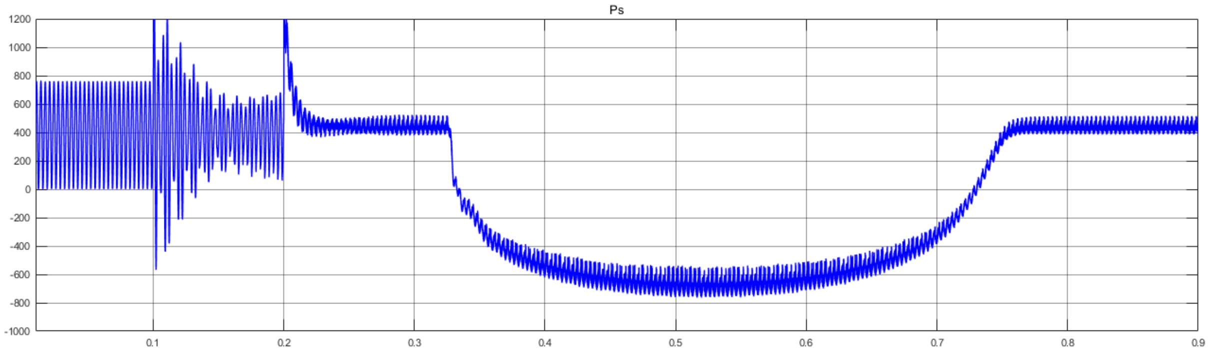


Figure III. 22 : Active power

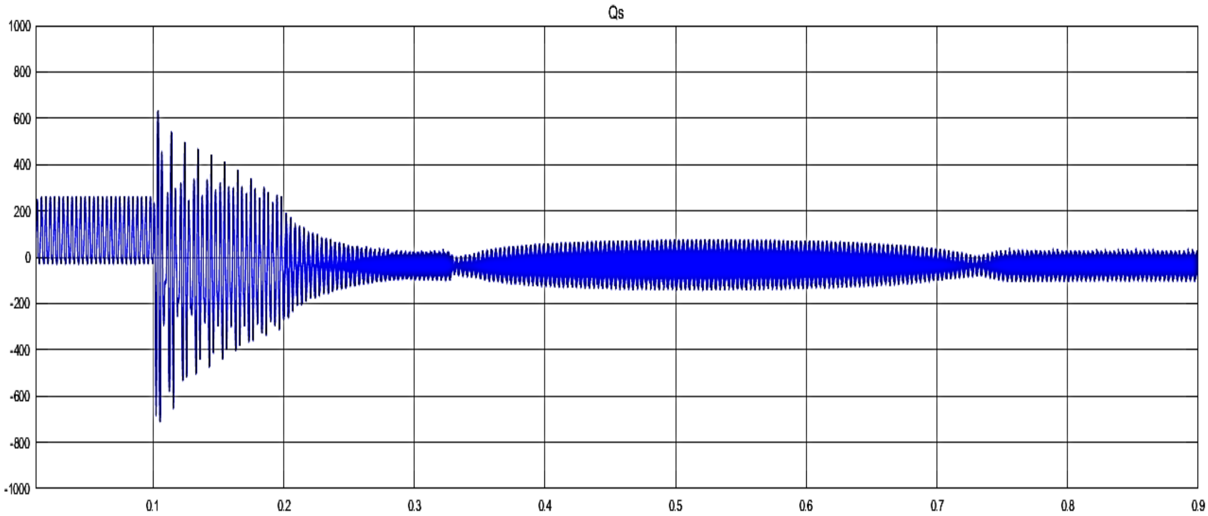


Figure III. 23 : Reactive power

III.4 Conclusion

In conclusion, the implementation of a hybrid active power filter has proven to be effective in enhancing the electric power quality and improving the overall performance of the distribution network. Through its ability to filter out harmonics in both current and voltage, the hapf successfully mitigates power quality issues and ensures a cleaner and more stable power supply.

Overall, the results demonstrate the significant benefits of using a hybrid active power filter in enhancing power quality, reducing harmonics, improving power factor, and injecting real power. The implementation of such a system can greatly contribute to the efficient and reliable operation of distribution networks, leading to improved performance and reduced power-related issues.

General Conclusion

Harmonics are much more prevalent in electrical networks. They degrade the quality of the power delivered. In order to compensate for these harmonics, voltage dips, etc., several methods have been introduced, such as passive and active filters.

This work conducted in this dissertation focused on the study and simulation of a hybrid active filter with power quality (PQ) control. The primary objective was to eliminate disturbances in electrical networks caused by power quality issues.

In the first chapter of the dissertation, the focus was on power problems and exploring potential solutions. The chapter aimed to provide a comprehensive understanding of the challenges associated with power quality issues and to identify suitable solutions to address them.

In the second chapter of the dissertation, an overview of active filters and the proposed hybrid APF solution was provided. The chapter also discussed various control methods, with a particular focus on the PQ algorithm. Additionally, we discussed PV solar systems, and maximum power point tracking (MPPT) control using P&O.

The third chapter presented the experimental validation of the simulation results using MATLAB/SIMULINK. All these simulation and experimental results obtained for the PQ method are very satisfactory and shows the good performance of the hybrid active power filter because of its capabilities of filtering out harmonics and increasing overall stability of the distribution network.

These results demonstrated the superior performance of the hybrid active power filter in terms of filtering out harmonics and enhancing the overall stability of the distribution network. The experimental validation confirmed the effectiveness of the hybrid active power filter in enhancing power quality and stabilizing the distribution networks.

Some facts we have learned in this dissertation:

-The non-linear load consumes non-linear voltage and current from the electrical source, and this affecting the function of end customer equipment.

-To clear the load current harmonics and optimize the power factor a shunt active filter is connected at the PCC which injects the compensating current.

-The shunt active filter can inject real power to the electrical network depending on the status of the system.

-To compensate the voltage harmonics this hybrid active power filter is used.

-The shunt active power filter is controlled based on the “Generalized Theory on the instantaneous Reactive Power in Three Phase Circuits (p-q theory)”, to compensate the load harmonics.

-Simulation of the proposed system show the behavior and the results of a complete simulation results for Hybrid Active Power filter was discussed and analyzed.

-The simulation of complete system verifies the correct operation of the hybrid active power filter for the ability to compensate voltage and current harmonics, inject the real power to the electrical network, and improve the power factor at PCC with taking into account the system status as well as the electrical network stability.

1

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