

# PERFORMANCE ASSESSMENT OF IMPROVED CURRENT CONTROL STRATEGY BASED SHUNT ACTIVE POWER FILTER: A REVIEW

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**Abstract-** The most powerful solution to current harmonics is a shunt active power filter (SAPF). Because of its simple implementation features, the Synchronous Reference Frame (SRF) concept has been commonly used in current harmonics extraction algorithms in its controller. The traditional SRF algorithm, on the other hand, has a significant time delay due to its heavy dependency on slow numerical filters. Furthermore, the algorithm is still thought to have unnecessary features that place an undue computational burden on the controller. Active control filters are commonly used in the power system to reduce harmonics induced by nonlinear loads. The Shunt Active Power Filter (SAPF) injects a suitable compensating current at a line point known as the point of common coupling (PCC) to cancel out the line's harmonics and restore the sinusoidal existence of voltage and current waveforms. As an active filter, a three-phase current-controlled voltage source inverter (VSI) with a DC connection capacitor across it is used. Shunt active power filter (SAPF) is the best solution that minimises the harmonic problems in power systems, but how fast and how effective it is. This paper describes a detailed study about the various types of power quality disturbances and their mitigation techniques and their comparative details.

**Keywords:** Power harmonic filters, Harmonic analysis, Algorithm design and analysis, Active filters, Filtering algorithms, Filtering theory, Current harmonics, DQ theory, Multilevel inverter, Power quality, Shunt active power filter (SAPF).

## 1. INTRODUCTION

Due to the widespread use of frequency and variable speed drives we need robot systems, automated production lines, precise digital control systems, programmable logic control systems, computer data management systems etc. These structures and devices are particularly vulnerable to wave power and various disorders. Non-linear loads and harmonic sources are many of these devices. Any power quality problems can reduce product quality or lead to management uncertainty.

The problem of power quality is not new, but the consumer awareness of these issues has recently increased. For example, for a number of years interruptions that were less than a few minutes were not seen for most consumers as cause of concern. With higher quality customer demands, the term power quality becomes particularly relevant. In many cases, consumers are impacted by poor quality electricity.

The lack of quality power may also affect the health of people by losing productivity and damaging machinery or equipment. Consequently, it is very important to maintain high power efficiency. The long-standing issues of power quality include a number of conventional solutions. However, these conventional solutions use passive elements and do not always respond properly as the power system conditions change. Energy converters are accessible in a range of applications thanks to the rising capacity, controlling and cost-saving capabilities of modern semiconductor equipment. New flexible solutions to various power quality issues have become possible with the help of these power conversion devices. Non-linear devices like electricity converters increase the total reactive power demanded by equivalent load and the distribution grid is fed into harmonic currents. The need for sensitive power reduces the feeder's voltage on and increases the loss. The harmonic currents can result in additional losses and distortion of voltage, which contributes to a poor energy quality. Furthermore, the number of sensitive loads requiring optimum sinusoidal tension for proper operations has increased. Increased use of electronic equipment responsive power fuels in the area of power technology. There is also a need for some kind of compensation to keep the efficiency of the power within the standards. Customer power quality can be improved by using power electronic energy-conditioning systems. Increasing power efficiency, compact in size and better control is achieved with power electronic transformation. However, due to switching operations, such systems are operating as non-linear loads. Therefore, when they are related to the benefit, these systems derive a lagging current from the source. This leads to the weak displacement and distortion of these structures. Therefore, they derive significant reactive voltage amplifiers from the power networks and inject harmonics.

Voltage drops can have implications in the industrial environment including injuries to workers, waste material and long restart times. System troubles, faults, substantial maintenance, expensive service behaviour are caused that reduced quality of production and it may loss of sales or fines under contract. Costs can quickly amount to several hundred thousand dollars, especially in industries like the semiconductor, automotive or chemical industries that are continuously manufactured.

The degree of complexity in industrial automation has reached very high. Many advanced technologies now

house facilities, including vehicles manufacturing plants, chemical plants technology calls for a solid and permanent public grid. However, the grid can differ and interrupt unforeseeably and erratically. If a sensitive charge is part of this network, it needs to be secured for clean and uninterrupted power via a power quality device such as a DVR system or Shunt APF to ensure continued industrial charges can receive a rock-strong, clean and uninterrupted flow of power. Furthermore, the device seems promising to researchers in terms of potential applications in the transport and distribution sectors due to advances in semiconductor technology at higher voltage levels.

Most voltage fluctuations of customers are triggered by power supply faults often caused by overhead power lines such as lightning, wind and ice [5, 13]. Individual consumers may also suffer higher financial losses arising from these short-term incidents than the expense of interruptions. This process need to keep the equipment in service is extremely necessary to prevent large financial losses in automated installation operations. Disruption of production, income and profits will lead directly to downtimes.

Voltage decreases are most common [4] due to various power quality disruptions and contribute to the highest financial losses, as voltage decreases also cause equipment malfunction [5]. The voltage sag occurrence is much more than the number of power breaks. Consequently, financial losses incurred by tension-sag incidents for individual customers can also be greater than the expense of power interruptions. The increased sensitivity and high cost of such incidents are the driving force behind an increased study interest and a reduction of the impacts of conflict sales on customer operations. As voltage sales are important for consumers, the character of voltage sales encountered in their network should be taken into account by power distribution companies.

In addition, the Electric Power Companies should be evaluated to mitigate the disadvantages caused by voltage slips by the impact of alternative device configuration [3]. If such changes are made on the network as well as on the customer side, the voltage drop effect is expected to change.

The effect of the voltage slopes can be seen in terms of financial losses resulting from customer downtime using the methods outlined in this study. Accurate estimates of the loss of voltage drops will encourage power distributors to make their systems more redundant by changing their switching schemes so that the voltage drops would have a less effect on customers connected to their networks. This will help electricity distributors to boost network efficiency and cope with the growing demands of the electricity companies and the consumers that are more demanding.

In Present Scenario, most of the DVR projects are based on compensation for voltage sag. There is growing demand worldwide for power quality and tensile offsetting devices every day. DVR has become increasingly common because the industry is increasingly vulnerable to voltage slumps. Conception and regulation of the complex voltage restaurator integrated with emphasis on voltage dip mitigation in the LV or HV delivery or utilities.

## 2. LITERATURE REVIEW

Problems within the research field and its fields are often resolved in order to learn about potential problems, literature reviews are required. A sound literature review offers valuable research backgrounds. First find out the research problem and select the purpose of the concrete work in order to begin a research work. Researchers identify several protocols and processes to draw clear conclusions for the purpose of analysis.

Power quality is the term used to squeeze all the voltage and current amplitude, phase and frequency functions of the Power Circuit output. Power quality due to temporary conditions in a power train or non-linear loads, power quality is impaired.

Toshifiimi Ise [1] provides numerous examples of power quality definitions based on this description. Power quality can be divided into three groups: reliability of voltage, consistency of delivery and value of voltage.

Such schemes may provide their customers with an interrupted degree of energy stream subject to the contractual scale, frequency and power delivery schedules; the distribution systems have a number of non-linear charges which significantly affect supply quality. Custom power is the use of electronic power controller distribution systems. Custom power supplies improve customers' efficiency and power reliability because customers are constantly demanding higher standards in the power supply of the electrical company.

Comprehensive research by different agencies on customized power equipment, issues with power quality, quality assessments, demands and indices and various approaches to improve power quality from time to time.

Afshin and Ara Lashkar et al. [10] mentioned electronic power plants and technological analysis in different stages of power engineering. In addition, power conditioners are used to solve problems of power quality with strength electronic equipment. Controls of power are occasionally called delivery of the truth (DFACTS). Compare the modes of operation and applications of FACTS operation.

Dixon Juan W. and others [11] gives the Active Power Filters sequences and act as a sinusoidal current source during the power supply process. An error signal regulates the range of the simple current in the series filter. A reference between load voltages has been developed. The quest provides an effective correction of the power factor, harmonic distortion and load voltage regulation.

Devaraju et al. [12] define the presence of power quality issues indicating that non-standard voltage, current or frequency was the result of equipment failures. Sensitive industry loads and supply networks are all exposed to numerous forms of interruptions and interruptions which can cost a large financial loss per incident on the basis of process downtime, loss of production, idle staff and other factors. In these electromagnetic transitory studies two custom power controllers are describing the Distribution Static Synchronous Compensator (DSTATCOM)

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and the Dynamic Voltage Restrautor (DVR).

Singh and Mahesh et al. [13] demonstrate the probability of introducing power quality measures for end user and the scope of the service. The work describes some important measures that can be carried out at the utility level without much disturbance. The models are presented with a custom power supplier to mitigate D-STATCOM and DVR impacts. In the application of a modern PWM power system, the voltage sink is highly prominent. Power capability DSTATCOM was complied with the compensation and voltage control mainly depends on the rating of dc storage devices.

Yun Wei et al. [14] has proposed and implemented a DVR system based on the downstream failure management feature and the model flow charge feedback controller. It would act as a major virtual inductance with the distribution feeder in a defective state. The DC connection protects it from sudden slumps, swells and also reduces stress. Analysis and Compensate the problems of power quality.

Pedro Roncero-Sanchez et [15] launched the two-level DVR with a repetitive controller for tension in sag, harmonic voltage and imbalances of voltage. The specialty of repetitive control systems has been observed as a rapid transient reaction, ensuring a constant zero error, for all sinusoidal inputs and sinusoidal disturbances. For implementing the controller, they use either the stationary frame or rotating frame.

Parag Nijhawan and Rajan Sharma et al. [16] are the focus of improved power performance. DSTATCOM induction engine feeders drive radial, not linear and DTC feeders. The effectiveness of DSTATCOM in distribution networks is compensated in this article. Present load harmonics are discussed and discussed under various conditions of operation and failure Implemented. The IGBT switch pulses are calculated through a PWM current controller based on dqo transformation. The efficiency of DSTATCOM has been established. Present harmonic framework for enhancing reactive power and distribution power.

Nijhawan Parag et al. [17] assessed the carriers' efficiency change in Static pulse-width (PWM) or multi-level (five level) modulation. In relation to the inductive furnace, load synchronous compensator with PWM-based inverter (DSTATCOM) is used. Simulink is Utilized as a model for the multilevel inverter or DSTATCOM inverter based on the induction furnace load in the distributed grid for minimizing harmonic distribution of load current.

Parag Nijhawan and Rajan Sharma [18] give the improvement of DSTATCOM power quality for induction controlled loading motor drives on the basis of field. The task of DSTATCOM in this paper is to improve the quality of distribution network energy. It looks at regular conditions of work and fault. Comparison Analysis of THD for loadings and separated defects of the induction engine under normal conditions. DSTATCOM is also covered in this article, For DSTATCOM, IGBT we will use dqo transformation. IGBT gate pulse turning controller is used with PWM Switch. DSTATCOM can efficiently compensate for existing load harmonics, offset reactive power and increase the power efficiency of the distribution system.

Nijhawan and Parag et al. [19] submitted a request for DSTATCOM in the Induction Furnace Load Network. The load produces the induction oven and possible to distort the harmonic. The output can also influence this harmonic distortion. This is consistent with other computer loads. DSTATCOM is a power improvement unit of custom power and connected in shunt. This is accomplished by creating an electricity grid exchange rate network. This paper includes the Simulink model for the applications. A harmonic distribution network distortion with an induction furnace charge is shown by the PI DSTATCOM controller.

Nijhawan and Parag al. [20] suggested distribution software for static Synchronous Compensator (DSTATCOM) in the supply network induction load furnace. The results were obtained in this paper for the Simulink model. It demonstrates the use of the Fuzzy controller in the furnace-charge-inducting distribution network to reduce the harmonic of DSTATCOM load current distortion.

### 3. STOCKWELL POWER QUALITY MITIGATION

In an ideal power system, power should be transferred from the source to the customer as pure sine waves for voltages and currents. But in practice, that does not happen due to the existence of non-linear loads such as power electronic converters that add a wide range of harmonic distortion into utility grid.

Power electronic converters act as non-linear loads due to the switching operation that occur within them. Inserting these converters lead to generating random harmonics into the utility grid, which causes a poor power quality. Furthermore, using power electronic converters with high inductive loads lead to decrease the power factor level [1], [2]. These poor power quality problems add unnecessary losses to utilities, and can cause electrical hazards in electrical equipment, such as transformers, underground cables and meters.

To mitigate power quality problems, which are mainly high Total Harmonic Distortion (THD) and poor power factor, two main solutions are proposed: (i) passive filters and (ii) active power filters. These filters are still in optimization process and the new trends focus on implementing multilevel inverters in Active Power Filters with different control techniques.

### 4. POWER QUALITY

The purpose of the electricity company is to provide its customers with relatively constant sine voltage and frequency. The power generators are very similar to a sine signal. However, the system has non-linear charges and devices that cause voltage and current signals to be distorted harmonically. The fact that an installation adds more nonlinear loads distorts these waveforms.

Various methods are available for harmonic analysis of different non-linear loads. The distortion of tensile

forces induced by the system's harmonic load is dependent on the system impedance and the amount of harmonic current injected.

The power source uses electricity more, while its generation and transmission occurs on nominally continuous levels with frequencies and voltages that can be regulated. Therefore, the disparity includes certain types of power conditioning or conversion, usually implemented by power circuits that distort voltage and current shapes. If the voltage distortion of the neighboring responsive loads is brought on, harmonically production loads. The distortion of tensile forces induced by the system's harmonic load is dependent on the system impedance and the amount of harmonic current injected. The simple distortion of a particular current does not necessarily imply that other power users suffer disproportionately.

If the equipment impedance is low, the voltage distortion is usually negligible in the absence of harmonic resonances. However, if harmonic resonance prevails, intolerable harmonic tension and currents can be present. Frequency and voltages in a practical power system vary from their defined values. The non-linear features produce the harmonic system in several device components which can decrease signal transmission in nearby telephone lines. As non-linear devices in the system, they generate non-sinusoidal waveforms when the sine voltage source is supplied. The power quality issues arise. The voltages and the currents are harmonically distorted while the instruments are in the electric grid.

Nonlinear loads pose no significant harmonic problem in single steps, but large quantities of such loads can be inappropriately high harmonic voltages and currents leading to an increase in neutral four-wire system currents through the heating and mechanical oscillations of the system distribution in generators and engines. The condenser and failure due to harmonic resonance, erratic behaviour, fast voltage variation and overheating of the transformers are other undesirable effects.

Power quality is defined as a "ever power problem occurring during voltage, current and frequency deviations that lead to failure and normal operation of the end user's equipment", which may be caused by poor power quality either through transient power circuit conditions or the installation of non-linear loads. Due to increasing use of energy-sensitive loads such as computers, industrial drives, communications and medical equipment, the theme of energy efficiency has become increasingly important in the last 20 years.

Today, the quality of power is much more difficult than in the past, because the new cargo not only has a sensitive impact on power quality but also a negative effect on the quality of power supply.

## 5. ISSUE OF POWER QUALITY

For power quality, the main words and definitions are as follows-

- Sag Voltage – The voltage sag is a fall in RMS voltage from 0.1 to 0.9 P.U. often called sag' for more than half a minute of the main loop. This is normally due to malfunction, increased load demand and transitional events like the start of large engines.
- Swell Voltage - RMS voltage rises between 1.1 and 1.8 P.U. via the swelling of the voltage. For over half a major time and less than 1 minute. The machine glitches, load switches and the condenser switching are usually responsible.
- Complete Electric Voltage Loss - Voltage interruption is the total electric voltage loss. Short-term or long-term interruptions (less than 2 minutes) can happen. When a circuit breaker, line release system or fuse is opened, the electric disconnection is usually disrupted.
- Sparkling Voltage - The voltage flicker can be observed as a lamp intensity deviation of the standard bulb by the human eye when the waveform amplitude has been modulated at frequencies less than 25 Hz. The voltage flicker is due to the arcing state of the power system. Filter installation, static armor supply, static compensators can solve problems with flickering.
- Tension Notches – Short cycles from one phase to another phase cause periodic loop transients. The switching stage in a.c., this is typically the product of d.c.converter.
- Voltage Imbalance - It state that does not equal the voltage magnitude of either the three-phase or the phase variations of each phase are not 120° or both.
- Frequency Deviation - This is an over / under-standard frequency variation, usually +0.1% of the nominal distribution frequency.
- Harmonics – a harmonic electrical signal is characterized as a signal content whose frequency is an integral part of the device's basic frequency.

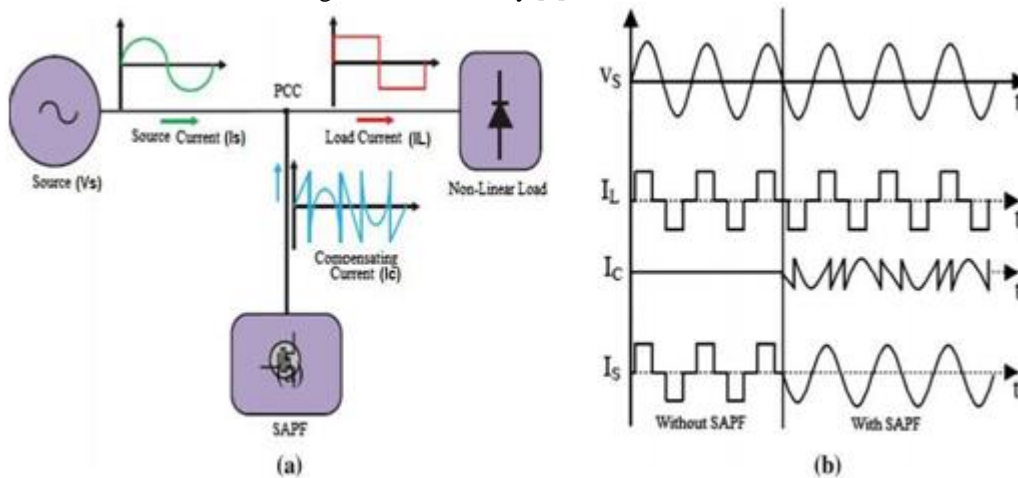
The overall performance and power quality of the electrical system are affected. Real harmonics affect the system, as other frequency waveforms consume energy and do not add power to the load by loading the distribution system.

## 6. MITIGATION TECHNIQUES

### 6.1 Active Power Filter

Installation of various types of power electronic converters and nonlinear loads such as AC/DC rectifiers, variable frequency drives and soft starters, is the major cause of PQ problems (high THD%, poor power factor and different types of transients). Therefore, it is crucial to evaluate new solutions in order to increase the quality of the electrical services by reducing the harmonics distortion, correcting the power factor and reducing the losses.

Recently, a tremendous research focused on delivering real power to the loads, in addition to mitigating harmonics and increasing the power factor up to unity, which may cause problems associated with resonance and stability. APFs become the most effective solution in eliminating different types of harmonics (inter-harmonics and sub-harmonics) due to their advantages such as; fast response to grid variations, ability to compensate random harmonics and high control accuracy [8].



**Fig. 6.1** General working concept of Active Power Filters; (a) block diagram of SAPF and (b) respective waveforms [9]

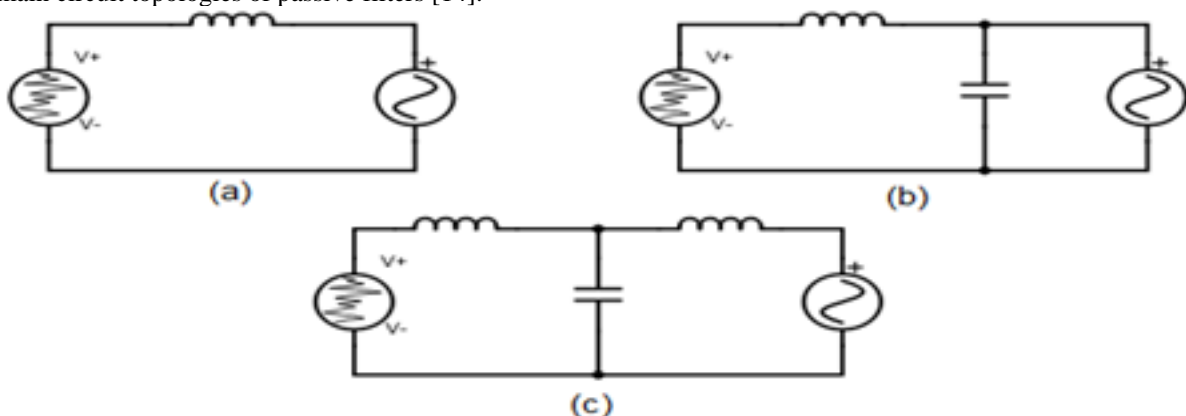
In practice, APF injects a compensating current or voltage into the Point of Common Coupling (PCC) equal but opposite in its direction to the grid's harmonics in order to cancel a wide range of harmonics that affect the system, also it generates / absorbs reactive power into PCC in order to correct grid's power factor (PF). Furthermore, APF keeps the grid system balance and stable with load variations and grid transients. Fig. 2.1 shows the general operating concept of APF [9].

## 6.2 Passive Vs Active Filters

There are three types of filters; passive, active and hybrid filters. Each type has its own classifications as follows:

### 6.2.1 Passive Filter

It is a low pass filter that consists of passive elements (resistors, inductors or capacitors). This type of filter is simple in design and cheap in low power applications. The main drawbacks of this types are tuning difficulties, its inability to compensate the sub-harmonics (harmonics with a frequency below 50 Hz), resonance problems, in addition to its low efficiency, high cost and bulky size in high power applications [13]. Fig. 2.2 shows the main circuit topologies of passive filters [14].



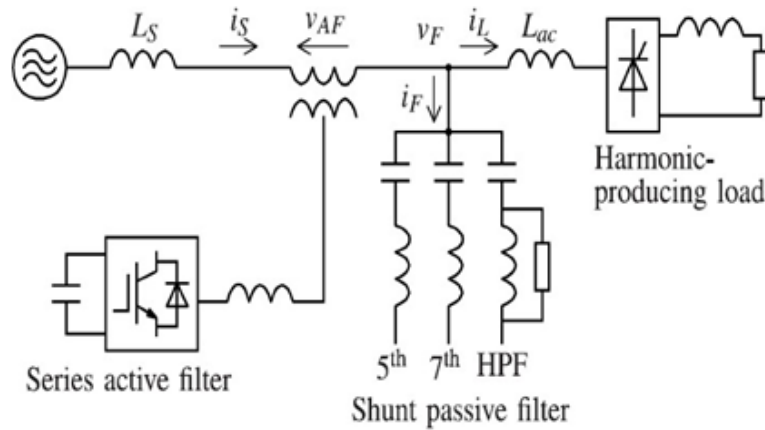
**Fig. 6.2** Main circuit topologies of passive filters; (a) L, (b) LC and (c) LCL types [14].

### 6.2.2 Active Filter

It is an electronic filter that consists of active elements (transistor switches, diodes) with complex control techniques. This type of filters has a high efficiency, more complex in its design, providing an isolation property, accurate in Power Factor (PF) correction, acting as a load balancer, which is used in high power applications and accurate systems, such as airplanes, and it is able to compensate the all types of harmonics [13].

### 6.3 Hybrid Filters

It is a combination between passive and active filters, the main advantage of this type is significantly reducing the rating of active filters in addition to achieving a harmonic isolation between supply and loads in utility grids [13]. Fig. 6.3 shows the main configuration of hybrid filters [13].



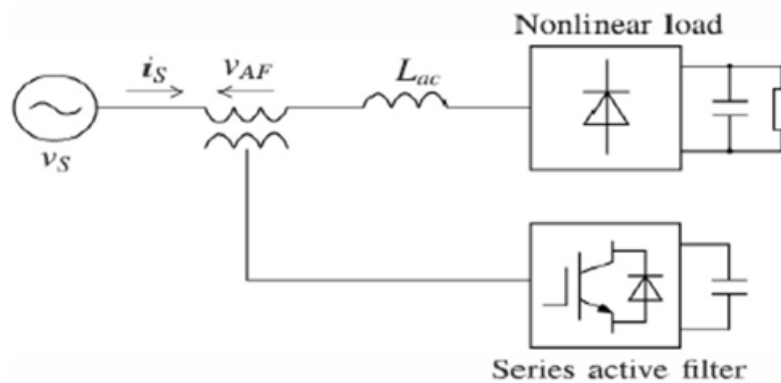
**Fig. 6.3 The main configuration of hybrid filters**

### 6.3.1 Active Power Filters

There are two main types of Active Power Filters (APF); Series Active Power Filters and Shunt Active Power Filters. Each type has its own properties and applications.

### 6.3.2 Series Active Power Filter

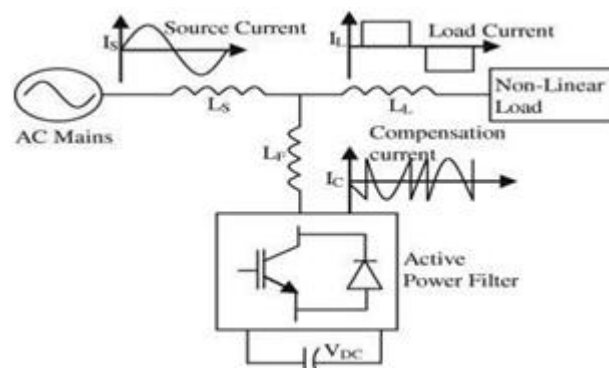
It is a filter used in series with the load and it is designed to mitigate voltage harmonics of the grid by generating negative voltage harmonic in order to cancel the effects of the load voltage harmonics, It keeps the grid's voltage in a pure sine shape against transients such as sag, swell and flicker events in addition to balancing the unbalanced voltage source [6], [15].



**Fig. 6.4 A series Active Power Filter Configuration**

### 6.3.3 Shunt Active Power Filter

It is a filter connected in parallel with nonlinear loads that used to reduce the grid's current distortion, and to increase the utility power factor by injecting negative harmonic currents into the grid in order to achieve a pure sine wave in addition to balancing the unbalanced loads [15]. Fig. 2.5 shows the topology of a Shunt Active Power Filter (SAPF).



**Fig. 6.5 Shunt Active power filters configuration**

The main drawback of the Series APF is that, it has to handle the high load current (handle with the same current rating of the load), which leads to increasing the current rating of this type [15], It might cause.

## CONCLUSIONS

In this article, a detailed study about the various types of power quality disturbances and their mitigation techniques and their comparative details is described. The PWM control is based on parabolic carriers applied successfully in single phase design and Active filter power shunt. It has been demonstrated that the Active shunt

filter proposed can compensate for this sufficiently Harmonic non-linear loading currents. Self-charging PI controller capabilities has also been successful in the SAPF suggested for dc regulation of the voltages of the condenser. But the draught still requires for test results to be validated.

## FUTURE WORK

In the following fields the work presented can be extended:

- Custom power devices can be checked for different loads.
- More sophisticated controllers including the fugitive interface, the artificial neutral network, AUPF, ISCT, AGCT, IGCT, and UPQC can also be used for more efficiency in the system.
- Multi-level converters will examine the efficiency of UPQC.
- The effect of Z-source inverters on different Custom Power devices can be examined.

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