

Modelling and Simulation of Improved Design of Shunt Active Power Filter for Harmonic Mitigation

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ABSTRACT

A Shunt Active Power Filter is the most potent solution to current harmonics (SAPF). The Synchronous Reference Frame (SRF) concept is widely employed in contemporary harmonics extraction techniques in its controller because of its simple implementation advantages. Due to its extensive reliance on slow numerical filters, the classic SRF algorithm, on the other hand, has a large time delay. Furthermore, the method is still regarded to have needless characteristics that burden the controller with extra processing. To reduce harmonics caused by nonlinear loads, active control filters are frequently utilized in the power system. To cancel out the line's harmonics and restore the sinusoidal presence of voltage and current waveforms, the Shunt Active Power Filter (SAPF) injects a sufficient compensating current at the Point of Common Coupling (PCC). A three-phase current-controlled Voltage Source Inverter (VSI) is utilized as an active filter, and a DC connection capacitor is placed across it. The greatest option for minimizing harmonic difficulties in power systems is a shunt active power filter (SAPF), but how fast and effective it is remains a question. It has precise control over its algorithms. The method is employed in a voltage source for current control using Pulse-Width Modulation (PWM) parabolic carrier-based (PWM). A converter based on a single phase Shunt Active Power Filter (VSC). The change the two switches in the phase leg of the converter limits of the present nonlinear parabolic tracking error band is determined by using a pair of PWM parabolas (a Positive and a Negative). The SAPF's dc-bus tension is likewise controlled by the PI controller using self-loading technology. Harmonic currents can be improved by using the SAPF phase. The simulation research Matlab-Simulink is used to validate the suggested SAPF's design concept. To boost mitigation efficiency, a numerical filter might be replaced with a mathematically dependent average identifier, and superfluous characteristics could be removed to reduce algorithm complexity. The proposed algorithm is created and evaluated using MATLAB / Simulink. According on the simulation results, the new approach outperformed the traditional algorithm.

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

1. INTRODUCTION

We require robot systems, automated production lines, accurate digital control systems, and programmable logic control systems, computer data management systems, and so on because of the extensive usage of frequency and variable speed drives. Wave power and other illnesses are particularly dangerous to these structures and gadgets. Many of these gadgets are non-linear

loads and harmonic sources. Any issues with power quality might lower product quality or cause management uncertainty. Although the issue of electricity quality is not new, consumer awareness of it has lately increased. For many years, for example, most consumers did not consider disruptions of less than a few minutes to be a cause for concern. The word power quality becomes more essential as customer demands for higher quality rise. Poor quality electricity has an

influence on consumers in several circumstances. People's health may be harmed by a lack of quality power, which results in lost production and damage to machines and equipment. As a result, maintaining good power efficiency is critical. A number of traditional methods have been proposed to address long-standing power quality issues. These traditional methods, on the other hand, rely on passive parts and do not always respond appropriately as power system circumstances change. Because of the increasing capacity, control, and cost-saving capabilities of modern semiconductor equipment, energy converters are now available in a wide range of applications. With the help of these power conversion devices, new flexible solutions to diverse power quality challenges have become conceivable. Non-linear devices, such as electricity converters, raise the total reactive power demanded by equivalent load, causing harmonic currents to flow through the distribution grid. The requirement for sensitive power lowers the voltage of the feeder and increases the loss. Harmonic currents can cause additional losses and voltage distortion, contributing to poor energy quality. In addition, the number of sensitive loads that require optimal sinusoidal tension for proper functioning has grown. In the field of power technology, increased usage of electronic equipment responsive power fuels. There is also a requirement for some form of compensation in order to keep the power's efficiency within acceptable limits. Power electronic energy-conditioning systems can improve customer power quality. With power electronic transformation, you may increase power efficiency, reduce size, and improve control. Such systems, however, operate as non-linear loads due to switching activities. As a result, these systems draw a trailing current from the source when they are related to the benefit. As a result, these structures are prone to weak displacement and deformation. As a result, they use the power networks to generate significant reactive voltage amplifiers and inject harmonics. In the industrial context, voltage drops can result in worker injury, waste material, and long startup

times. System failures, malfunctions, extensive maintenance, and costly service behavior result in lower production quality, as well as a loss of revenue or contract penalty. Costs can easily add up to hundreds of thousands of dollars, especially in businesses that are constantly manufactured, such as semiconductors, automobiles, and chemicals.

Industrial automation has achieved a very high level of complexity. Many complex technologies, such as automobile manufacturing factories and chemical plants, now require a reliable and stable public grid. The grid, on the other hand, might deviate and disrupt in unpredictable and chaotic ways. If this network contains a sensitive charge, it must be secured for clean and uninterrupted power using a power quality device such as a DVR system or a SAPF to ensure that industrial charges continue to get a rock-solid, clean, and uninterrupted flow of power. Furthermore, due to advancements in semiconductor technology at higher voltage levels, the device appears promising to researchers in terms of prospective applications in the transportation and distribution sectors.

The majority of customer voltage changes are produced by power supply problems, which are frequently caused by overhead power lines such as lightning, wind, and ice [5, 13]. Individual consumers may potentially experience greater financial losses as a result of these brief occurrences than the cost of interruptions. To avoid substantial financial losses in automated installation operations, this method of keeping the equipment in service is critical. Production, income, and profits will all be disrupted, resulting in downtime.

In the current scenario, the majority of DVR initiatives are based on voltage sag compensation. Every day, demand for power quality and tensile offsetting devices grows around the world. Because the sector is becoming more subject to power fluctuations, DVR has grown more prevalent. Integrated complicated voltage restorator conception and regulation with a focus on voltage dip mitigation in LV or HV distribution or utility. The proposed solution should be a solution given by distribution

businesses to consumers who are prepared to pay for value-added power. It is a relatively new product that has not yet done much work. The power quality issues and specialized power devices, in addition to these global considerations, have limited context. This paper will provide a clear context of simulation model and DVR analysis for voltage compensation, as well as SAPF for harmonics mitigation.

2. POWER QUALITY

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. 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. 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. 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 armour 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 characterised as a signal content whose frequency is an integral part of the device's basic frequency.

In other words, 3 times of the basic frequency will be in the third harmonic order. The harmonic waveform components are shown in Figure 1. The phenomenon occurs frequently and distorts the current and voltage waveform continuously. The use of saturable devices, power systems and non-linear consumer loads is typically the result. Depending on the type of loads, sub harmonics are also made. Harmonics are transmitted from source to systems. Impact of harmonics is such as overheating transformers, capacities and engines, malfunctioning of relays and circuit breakers, problems of communication, unsustainable electronic device activity, etc.

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.

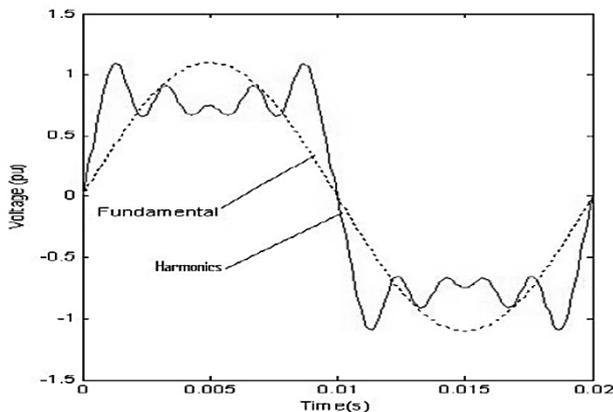


Figure 1: Voltage Waveform Showing Harmonics

It also helps to cause I^2R losses in the system. Tension harmonics are responsible for the current harmonics that distort the waveform of the voltage. These voltage harmonics effect the loads generated by the entire system. Their effect depends on the distance of load from the harmonics power source. In industrial

installations adjustable speed and other electronic power charges may generate substantial quantities of harmonics. Problem due to harmonic distortions is the addition of active or passive load or bus filters or transformative connections that cancel components in zero series. Temporary Shifting of voltage is shorter than slumping or swelling induced by sudden power changes. Transient disorder is a momentary unwanted deviation from the supply or the charging current and it is caused by switching or lightning energy injection.

3. DESIGN OF IMPROVED SHUNT 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].

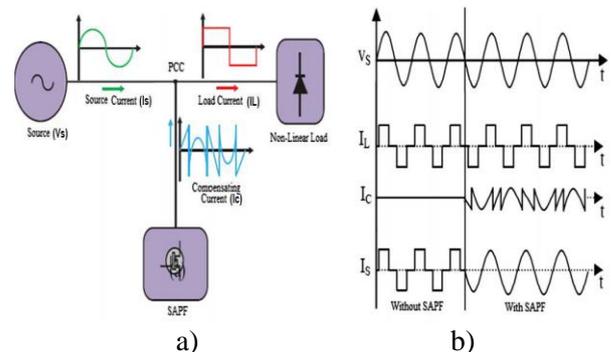


Figure 2: General working concept of Active Power Filters; (a) block diagram of SAPF and (b) respective waveforms

The proposed SAPF for single-phase systems appears in this study. The circuit configuration is shown in Figure 3 and the configuration of the control systems for the filter in Figure.4. The SAPF is positioned at the same time as the non-linear load. Two neutral clamped capacitors are used as DC-bus for a half-bridge voltage source inverter. A R-L branch is used to introduce compensating current into the power system. The sensor for load current, the PCC voltage and the voltage from two DC-Bus condensators will also be measured and supplied into the controller section. One controller output is fed into another controller. It is therefore acknowledged that if any of the controllers becomes unstable the system can be unstable. For SAPF compensation performance the stability of the condenser DC-bus voltage is crucial. The DC-bus voltage should ideally be maintained constantly. Due to numerous factors, such as frequency of offset current, effective value of the source voltage and DC voltage across the condenser, during SAPF, however, a ripple of the DC-bus voltage [3] is created. In order to assure stability of the SAPF, the ripple must be carefully checked. The value value value of the DC-bus capacitance is normally determined based on the permissible voltage ripple range[4]. A typical PI-controller is also utilised to control the DC-bus voltage.

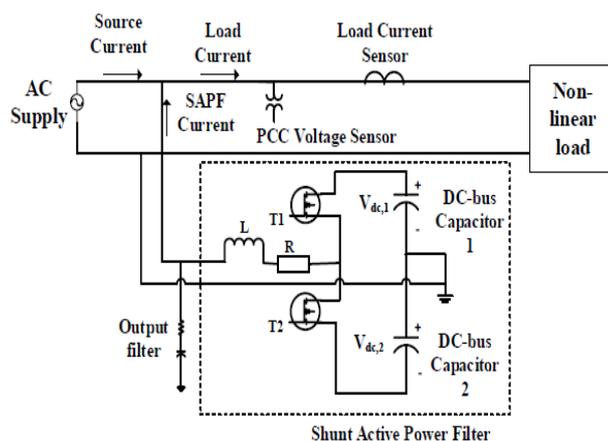


Figure 3: Power circuit of single-phase SAPF.

$$C_{\text{parabolic},+}(t) = K \left[\frac{1}{T_{\text{switching}}} - \left(\frac{1}{T_{\text{switching}}} \right)^2 \right], 0 \leq t \leq T_{\text{switching}} \quad (1)$$

$$K = \frac{T_{\text{switching}}(V_{\text{dc},1} - V_{\text{dc},2})}{2L} \quad (2)$$

$$C_{\text{parabolic},-}(t) = -C_{\text{parabolic},+}(t) \quad (3)$$

Here, the Parabolic PWM-based current controller (PCC) block has an immediate current fault. The output of this block is a signal for the gate to be switched to the T1 power switch gates and the T2 NOT port. If T1 is ON, T2 is OFF and vice versa. T1 and T2 can enter the grid via the R-L branch which can be referred as the grid interface circuit, or absorb power from the DC-bus Capacitors $V_{\text{dc},1}$ and $V_{\text{dc},2}$. The ac source is the power system or grid. The Parabolic PWM current control principle is discussed in depth in [9]. Two parabolic carriers are produced in this controller, one positive and one negative. In comparison to both carriers, the current error is between a reference current signal and a true current. In Figure 4.8, the T1 switch turns to OFF, when the error is increased in the positive direction, and the T2 switch is switched on. This switching operation will reduce the current error in the negative direction and turn the T1 switch on and turn T2 off when colliding with the negative parabola carrier. The PCC method is thus identical to the current control method for the hysteresis-band.

4. RESULTS

The Simulation design and performance assessment of Shunt Active Power Filter has been discussed and simulated for harmonic mitigation and power quality improvement. When non-linear loads are connected (Industrial drives), harmonics are produced in the line of our system. We apply SAPF as indicated in Figure. 5.1 to mitigate these harmonics. The voltage and current plot connected between the output terminals of the resistive load .The load voltage is 296 Volts on average with an eight volt ripple. The current is approximately 2.8 Amps with a 0.32 amp ripple (total power output around 900 Watts). The reason that the voltage is less smooth 3300 μF condenser.

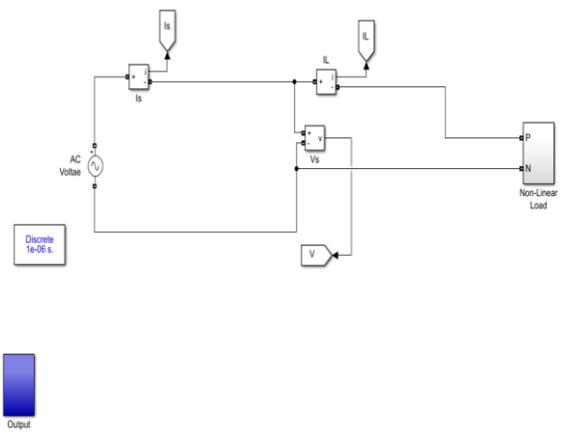


Figure 4: MATLAB/ Simulink Model of Uncompensated Model

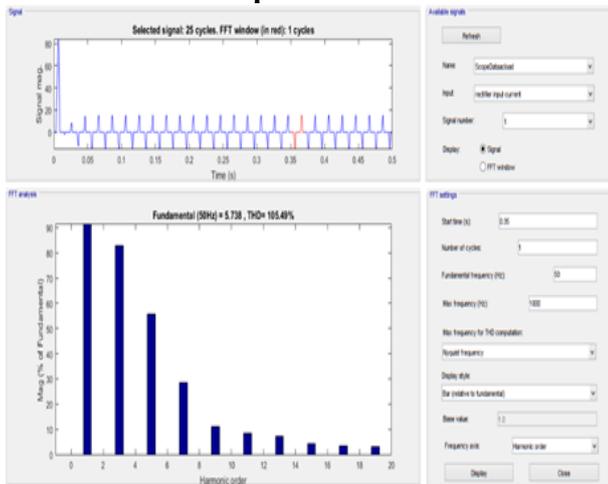


Figure 5: THD Analysis of Uncompensated System

The FFT input analysis is described in Figure. current. The system is set to sample frequency 200 kHz (duration of sampling = 5 μS). THD of input correction Using the powergui fft analysis, current was determined Simulink tool. Tool. THD is calculated at 105.49%. Obviously unacceptable and within limits must be lowered. B. The performance of DC-Bus Voltage Control. The DC-bus has been given a reference voltage of 800 volts. Controller voltage. Positive and negative both DC-bus Initially, 800 volts of the condensers were loaded. Figure. 5.6 shows that the condensers are approaching complete voltage Time of 800 V. This is why the voltage control functions satisfactorily.

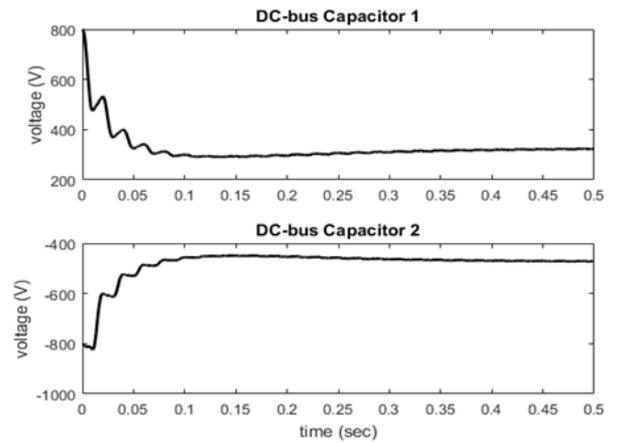


Figure 6: DC Bus Capacitor Voltage of Both Capacitors

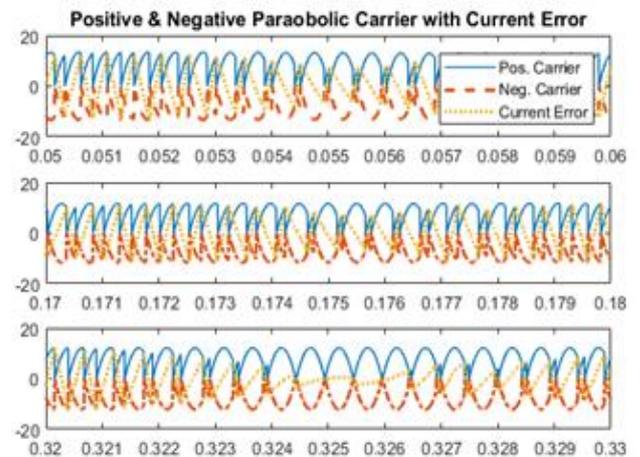


Figure 7: Parabolic- Current-Control Strategy
The current is after the RC output is filtered. The important system variables plot (network voltage, Network current, SAPF current, load current) are presented in Figure. You can observe that the current of the hands is quite sinusoidal. The harmonic content is little. FFT current analyses are Data showing THD of 5.4 percent.

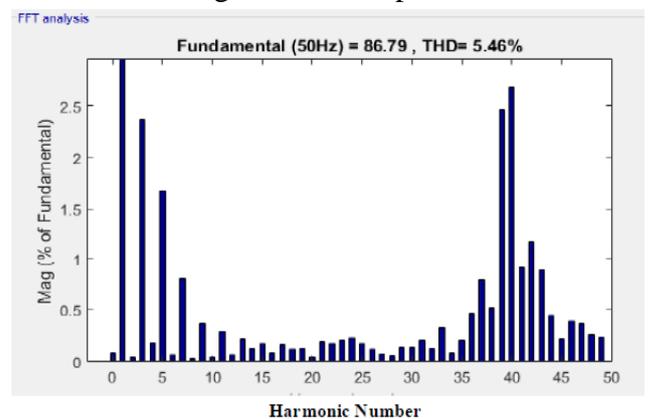


Figure 8: THD Analysis of Output

Compensated System

The method has been successfully implemented for the reduction of harmonics in unbalanced load condition and has been compared with traditional methods, uncompensated and contemporary research for analysis and enhancement. Harmonic analysis of proposed methodology is also shown by Table .1

Table 1: Harmonic Analysis of Proposed Methodology

Methods	%THD
Uncompensated	105
Compensation After Shunt APF	5.4
Percentage Compensation	95.23

5. CONCLUSION

The PWM control was based on parabolic carriers applied successfully in single phase design and simulation It has been demonstrated that the SAPF 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 The voltages of the condenser. But the draught still requires For test results to be validated. This concept, analysis The simulation results serve as a practical basis Shunt active filter hardware implementation .The simulation results show that the fuzzy logic controller performs well in controlling the compensating voltage of the shunt active power filter. The IEEE Std. 519-1992 can be used to calculate the percent Total Harmonic Distortion of voltages at the Point of Common Coupling. There is 95.4 % reduction in harmonic after the implementation of proposed methodology.

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