IRP BASED SHUNT ACTIVE POWER FILTER

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Abstract - **The paper discusses a theory called p-q theory, which can be used to analyze and control the power in electrical systems. The paper proposes using this theory for Shunt Active filter Reactive Power compensation and compensation in a three-phase system. The paper uses a mathematical approach called the Clarke transformation to convert the system into a two-phase system and then back into the original three-phase system. The paper also conducted simulation studies using MATLAB to support their results. In summary, the paper presents a theoretical and simulation-based analysis of using p-q theory for compensation in a three-phase system. Harmonic is also a big problem in the system which is generated due to nonlinear load. Continuous research is going on in this filed for improvement.**

keywords - **P-Q Theory, Shunt filter, Reactive Power, Harmonic, Nonlinear Load**

I. INTRODUCTION

Today, the use of powerful electronic equipment has increased industrial application level (ie switching power supply, uninterruptible electrical systems, inverters and high frequency lighting, etc.). These charges are non-linear in nature. Because of these types of loads, the current waveforms are non-sinusoidal in nature and contains high total harmonic distortion (THD). harmonious current distortion represents the current waveform as a distortion factor in the sense of a pure sine wave. Therefore, several harmonics are injected into the mix input system. This creates a more serious problem for the power grid.

Passive LC filters have traditionally been utilized to eliminate these harmonics, including the current one. However, these load-dependent, fixed, and bulky passive LC filters are Additionally, they may result in system resonance issues. Active power filters (APFs) have been developed and utilized to mitigate these issues to address them.

Various control algorithms have been suggested for the management of shunt active power filters, but many of them are intricate and difficult to execute. However, this study presents a simplified approach based on instantaneous reactive power theory, which employs three current sensing devices, two voltage sensing devices, and a DC link voltage measurement device to control the APF. The proposed method is easy to use and reduces the overall implementation expenses

II. ACTIVE POWER FILTER

Active filters are considered the most effective tools for mitigating harmonic distortion and compensating for reactive power, load imbalances, voltage regulation, and flicker regulation on power lines. With the rapid development of modern electronic technology, active filter implementations have become an increasingly crucial component of power grids.

Since the early 1980s, technological advancements and significant trends in consumer and industrial power electronic equipment have put tremendous pressure on utility companies to provide high-quality and reliable supplies. Nonlinear loads, such as computers, printers, fax machines, fluorescent lights, and most office equipment, generate harmonics by drawing current in rapid, short pulses instead of smooth sine waves. Nonlinear loads are known to cause severe overheating and insulation damage when powered with harmonics. To mitigate this predictable problem, active filters are installed at each nonlinear load in the power grid. Although not cost-effective presently, active filters are widely used to address power quality issues in distribution grids, including harmonic current compensation, reactive current compensation, voltage drop compensation, voltage flicker compensation, negative sequence current compensation, etc. Overall, the deployment of active filters ensures a contamination-free system with improved reliability and quality, addressing the growing demand for high-quality and reliable power supply in today's power grids.

An active shunt power filter is employed to mitigate the negative effects of line harmonics caused by nonlinear loads. This filter consists of an active line filter that is connected in parallel with the nonlinear load. The active line filter utilizes a pulse width modulated voltage source inverter to function as a current controlled voltage source. To compensate for current harmonics in the shunt active power filter, compensation currents with the same magnitude and opposite phase (180 degrees out of phase) are injected. By doing so, the line harmonics are cancelled out, resulting in a sinusoidal line current that is in phase with the line voltage. To generate the switch control signal, a control strategy is implemented to produce a reference signal. This reference signal is then compared with the source current, which enables the system to regulate the switch control signal.

III. P-Q THEORY

The theory related to instantaneous power can be broadly divided into two groups:

αβ0 reference frame theory: This theory defines power on the αβ0 reference frame, which is based on abc to αβ0 transformation. It is mainly used to analyze the power flow in three-phase systems.

This theory was introduced in 1983 by Akagi, Konazawa, and Nabae, and is also called the "Instantaneous active and reactive power theory." It defines a set of instantaneous powers in the time domain, which allows for the behavior of voltage and current to be analyzed without restriction. The p-q theory is applicable to three-phase systems with or without a neutral conductor, and it is valid in both steady state and transient state conditions. This theory considers the three-phase system, rather than as a sum of three single-phase circuits. It is commonly used in power conditioning applications because it provides flexibility in designing control strategies and implementing them in controllers. The p-q theory is particularly useful for generating reference currents for reactive power compensators, as it defines power clearly.

The real and imaginary power (P and Q) of the load can be split into its average and fluctuating components. The undesirable parts of the real and imaginary power drawn by the load that require compensation can be chosen. These power portions are denoted by -Pc and -Qc, where the negative sign highlights the need for the compensator to produce a compensating current that exactly counteracts the unwanted power drawn by the non-linear load. The current from the source is the sum of the load current and the compensating current, following conventional current conventions. The αβ to abc transformation is then employed to determine the instantaneous values of the three-phase compensating current references, namely ica, icb, icc.

The entire process of generating compensating currents is illustrated in the diagram presented below. Firstly, the 3-phase voltages and currents are converted into αβ axes using the Clarke transformation. Next, the instantaneous powers are computed, followed by the determination of compensating powers. This leads to the calculation of iα and iβ. Subsequently, the inverse Clarke transformation is conducted to obtain the compensating currents (i_{ca} , i_{cb}, i_{cc}).

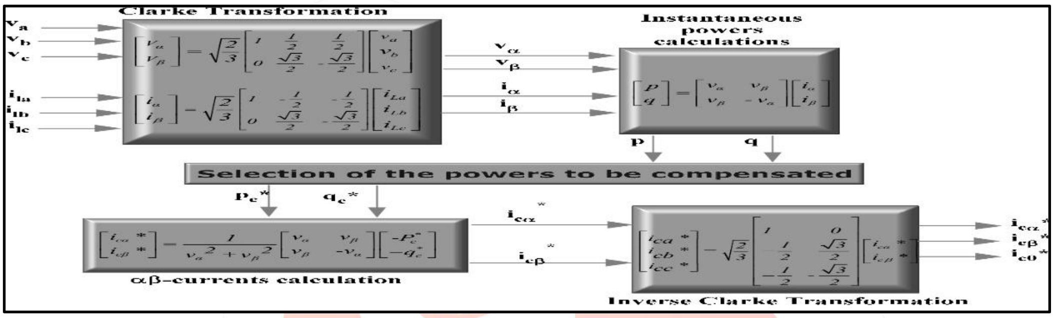


Fig.1 IRP theory lay out block diagram.[2]

IV. P-Q THEORY MATLAB SIMULATION

The p-q theory has an important practical use in mitigating unwanted currents. In cases where a non-linear load is being supplied by a source and compensated by a shunt compensator, the compensator can act as a three-phase current source under control, capable of drawing a specified set of reference current. Figure-13 demonstrates a general control method for the shunt compensator's controller. By utilizing the p-q theory, the real and reactive power of the load (P and Q) can be divided into their average and oscillatory components. The undesirable components of the load's real and reactive power that require compensation can be identified and selected. The power that needs to be compensated is represented by -Pc and -Qc.

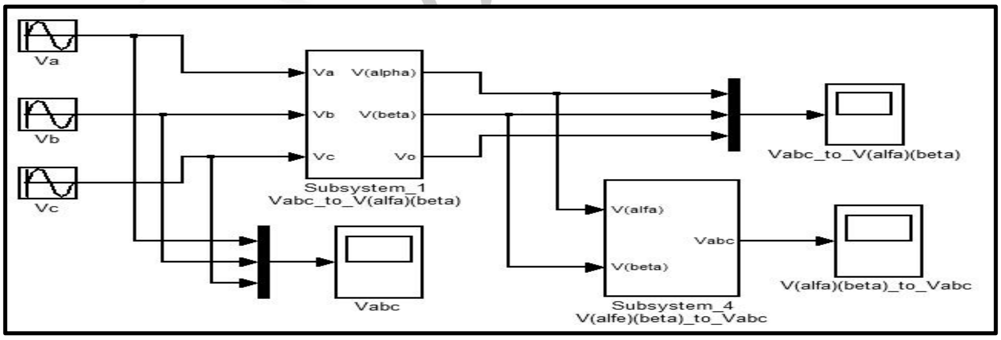


Fig.2 Simulation of Three Voltage Phase to α β

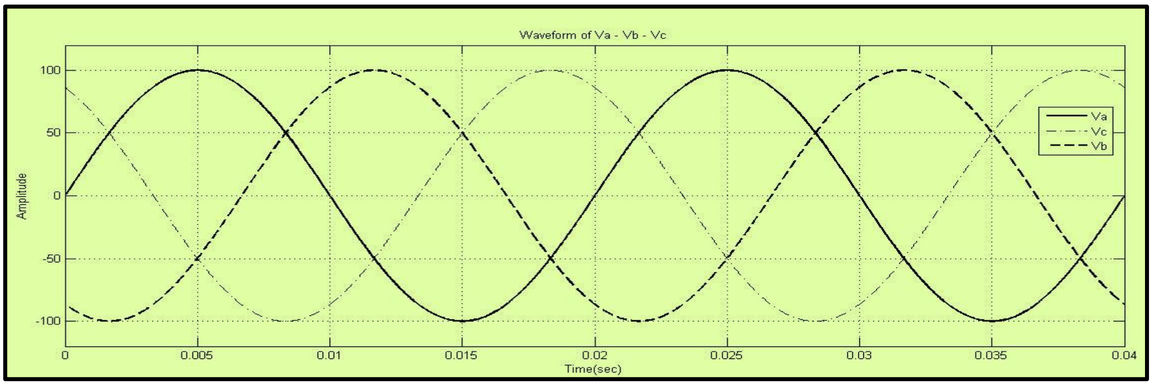


Fig.3 Three Phase Voltage Waveform

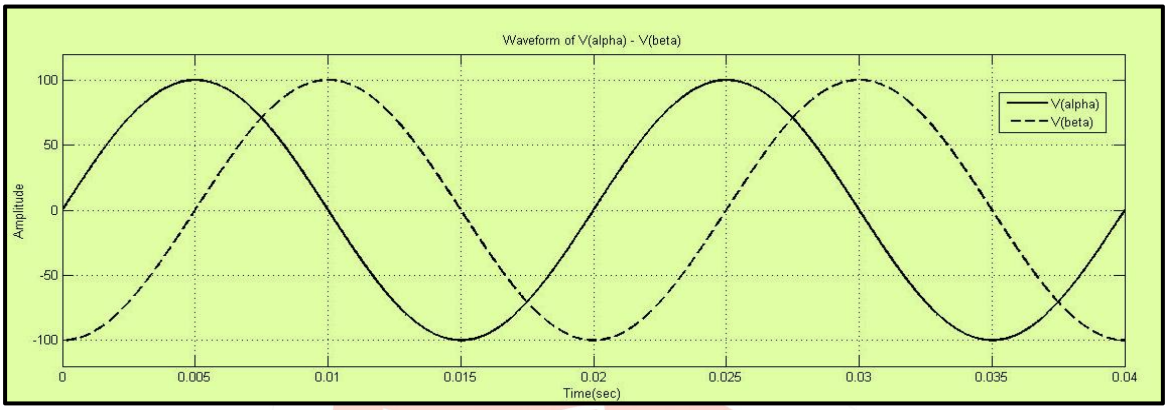


Fig.4 Alpha & BetaVoltage Waveform.

V. SIMULATION AND RESULT

A simulation model using MATLAB SIMULINK has been created to simulate the operation of SHAPF (Shunt Active Power Filter) utilizing the instantaneous power theory.

In this project, our objective is to simulate the designed Active filter on the system and evaluate its performance by analyzing the Total Harmonic Distortion (THD) generated by the filter when loaded. Our target is to achieve a THD value below 5% or as close to 5% as possible while ensuring that the Inter Harmonic Distortion (IHD) is compliant with the IEEE standard.

We will be carrying out the simulation first on 7KW & 192 KW load on a nonlinear load. As per below load data

LOAD	Kvar	KW	THD Before Filter	THD After Filter
7 KW	680var	6.8	28.32%	3.75%
192 KW	120	190	10.52 %	4.12%

A- 7KW Load Simulation

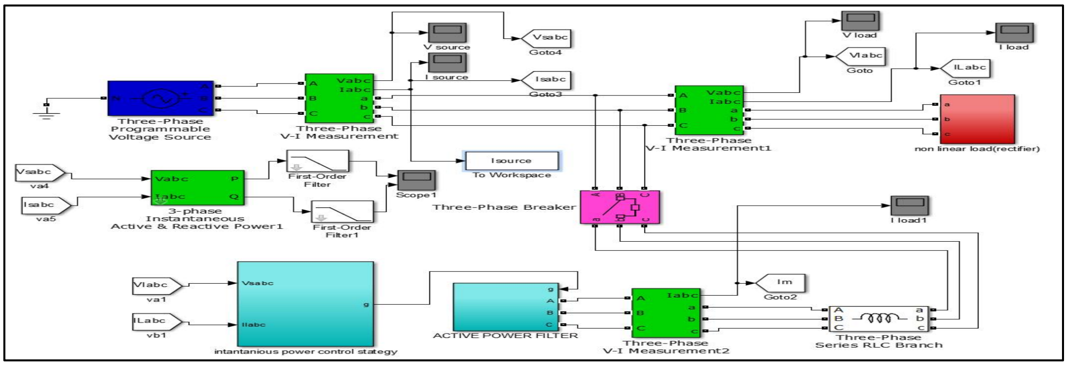


Fig.5 Filter Simulation on 7 KW & 192 kw load.

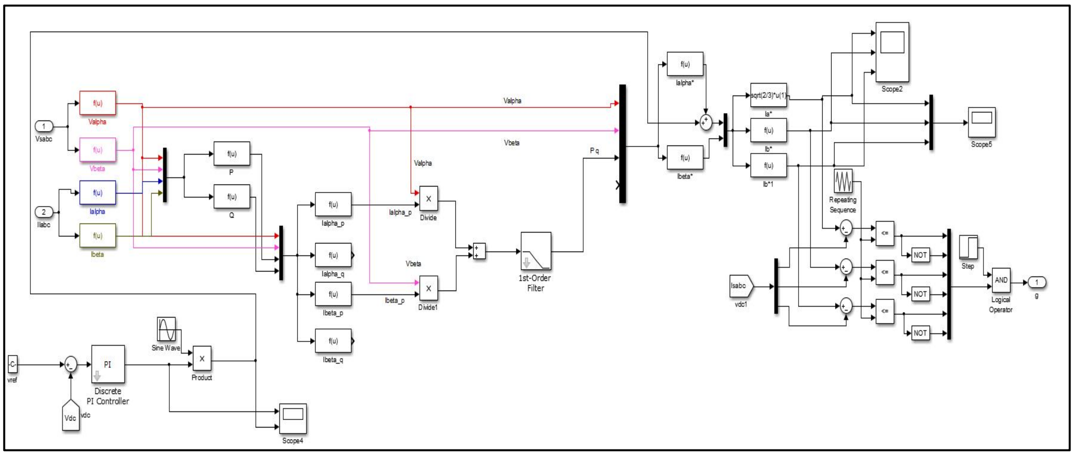


Fig.6 Sub System (P-Q Theory)

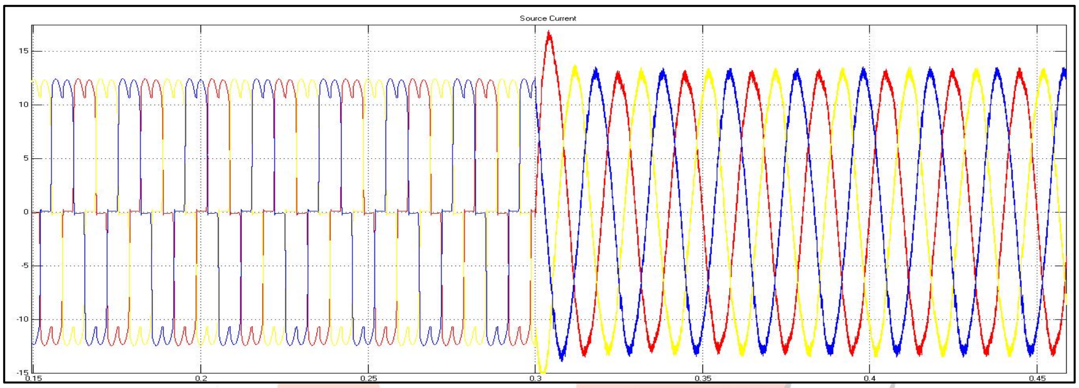
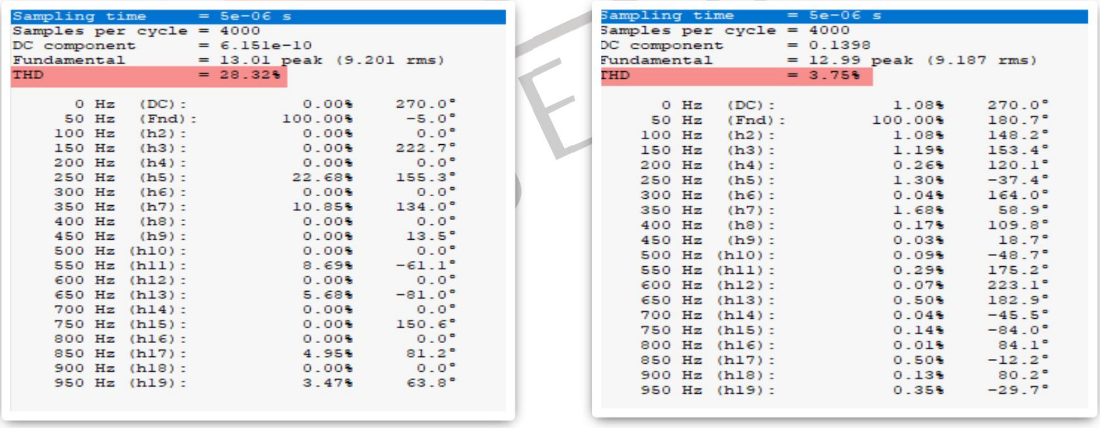


Fig.7 Source Side Current after Filtration.



```
Sampling time       = 5e-06 s
Samples per cycle = 4000
DC component        = 6.151e-10
Fundamental         = 13.01 peak (9.201 rms)
THD                 = 28.32%

     0 Hz   (DC):          0.00%     270.0°
    50 Hz   (Fnd):       100.00%      -5.0°
   100 Hz   (h2):          0.00%       0.0°
   150 Hz   (h3):          0.00%     222.7°
   200 Hz   (h4):          0.00%       0.0°
   250 Hz   (h5):         22.68%     155.3°
   300 Hz   (h6):          0.00%       0.0°
   350 Hz   (h7):         10.85%     134.0°
   400 Hz   (h8):          0.00%       0.0°
   450 Hz   (h9):          0.00%      13.5°
   500 Hz  (h10):          0.00%       0.0°
   550 Hz  (h11):          8.69%     -61.1°
   600 Hz  (h12):          0.00%       0.0°
   650 Hz  (h13):          5.68%     -81.0°
   700 Hz  (h14):          0.00%       0.0°
   750 Hz  (h15):          0.00%     150.6°
   800 Hz  (h16):          0.00%       0.0°
   850 Hz  (h17):          4.95%      81.2°
   900 Hz  (h18):          0.00%       0.0°
   950 Hz  (h19):          3.47%      63.8°
```

```
Sampling time       = 5e-06 s
Samples per cycle = 4000
DC component        = 0.1398
Fundamental         = 12.99 peak (9.187 rms)
THD                 = 3.75%

     0 Hz   (DC):          1.08%     270.0°
    50 Hz   (Fnd):       100.00%     180.7°
   100 Hz   (h2):          1.08%     148.2°
   150 Hz   (h3):          1.19%     153.4°
   200 Hz   (h4):          0.26%     120.1°
   250 Hz   (h5):          1.30%     -37.4°
   300 Hz   (h6):          0.04%     164.0°
   350 Hz   (h7):          1.68%      58.9°
   400 Hz   (h8):          0.17%     109.8°
   450 Hz   (h9):          0.03%      18.7°
   500 Hz  (h10):          0.09%     -48.7°
   550 Hz  (h11):          0.29%     175.2°
   600 Hz  (h12):          0.07%     223.1°
   650 Hz  (h13):          0.50%     182.9°
   700 Hz  (h14):          0.04%     -45.5°
   750 Hz  (h15):          0.14%     -84.0°
   800 Hz  (h16):          0.01%      84.1°
   850 Hz  (h17):          0.50%     -12.2°
   900 Hz  (h18):          0.13%      80.2°
   950 Hz  (h19):          0.35%     -29.7°
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Fig.8 THD is improved from 28.32 % to 3.75% following IEEE Standard.

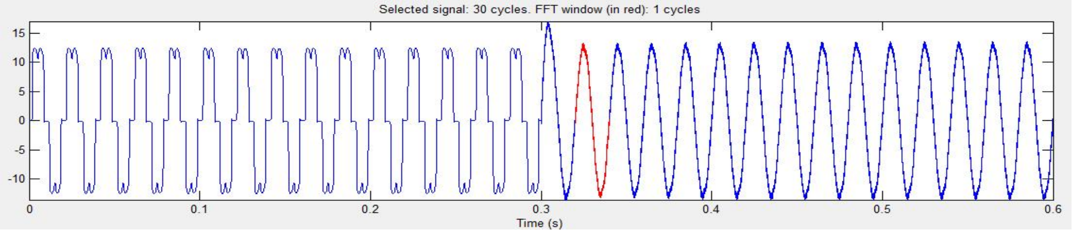


Fig.9 Filtration from Red Line.

B-192 KW Load Simulation.

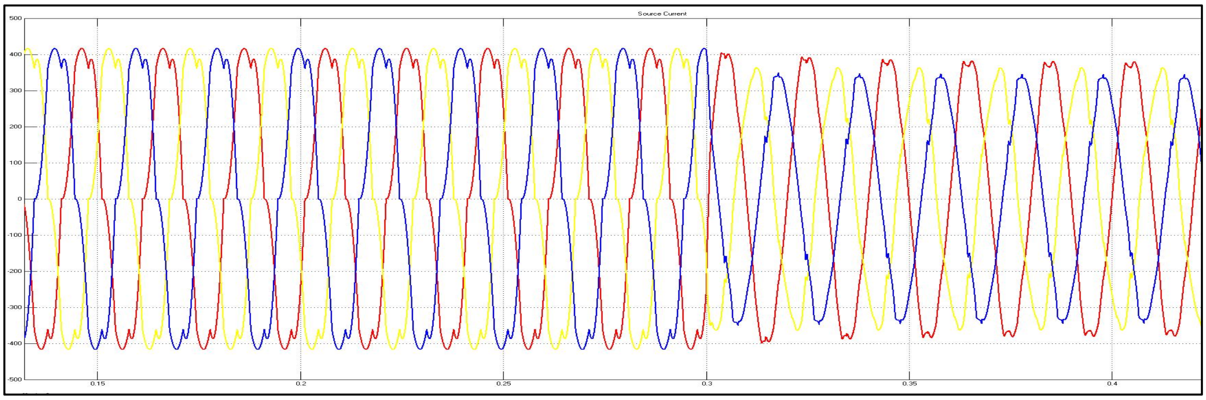
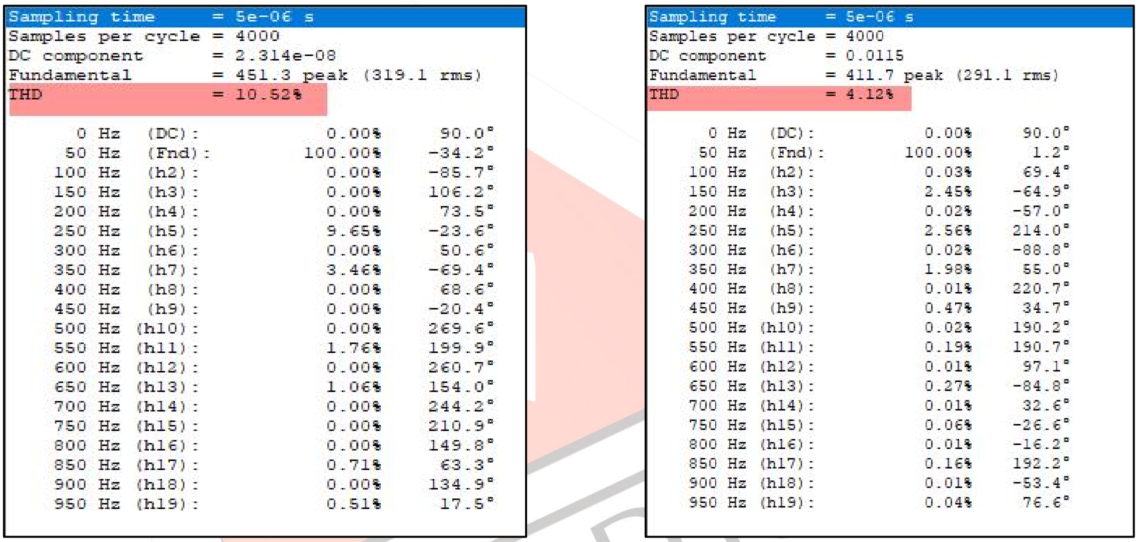


Fig.10 THD is improved from 28.32 % to 3.75% following IEEE Standard



```
Sampling time      = 5e-06 s
Samples per cycle = 4000
DC component      = 2.314e-08
Fundamental       = 451.3 peak (319.1 rms)
THD               = 10.52%

   0 Hz  (DC):          0.00%     90.0°
  50 Hz  (Fnd):       100.00%    -34.2°
 100 Hz  (h2):          0.00%    -85.7°
 150 Hz  (h3):          0.00%    106.2°
 200 Hz  (h4):          0.00%     73.5°
 250 Hz  (h5):          9.65%    -23.6°
 300 Hz  (h6):          0.00%     50.6°
 350 Hz  (h7):          3.46%    -69.4°
 400 Hz  (h8):          0.00%     68.6°
 450 Hz  (h9):          0.00%    -20.4°
 500 Hz (h10):          0.00%    269.6°
 550 Hz (h11):          1.76%    199.9°
 600 Hz (h12):          0.00%    260.7°
 650 Hz (h13):          1.06%    154.0°
 700 Hz (h14):          0.00%    244.2°
 750 Hz (h15):          0.00%    210.9°
 800 Hz (h16):          0.00%    149.8°
 850 Hz (h17):          0.71%     63.3°
 900 Hz (h18):          0.00%    134.9°
 950 Hz (h19):          0.51%     17.5°
```

```
Sampling time      = 5e-06 s
Samples per cycle = 4000
DC component      = 0.0115
Fundamental       = 411.7 peak (291.1 rms)
THD               = 4.12%

   0 Hz  (DC):          0.00%     90.0°
  50 Hz  (Fnd):       100.00%      1.2°
 100 Hz  (h2):          0.03%     69.4°
 150 Hz  (h3):          2.45%    -64.9°
 200 Hz  (h4):          0.02%    -57.0°
 250 Hz  (h5):          2.56%    214.0°
 300 Hz  (h6):          0.02%    -88.8°
 350 Hz  (h7):          1.98%     55.0°
 400 Hz  (h8):          0.01%    220.7°
 450 Hz  (h9):          0.47%     34.7°
 500 Hz (h10):          0.02%    190.2°
 550 Hz (h11):          0.19%    190.7°
 600 Hz (h12):          0.01%     97.1°
 650 Hz (h13):          0.27%    -84.8°
 700 Hz (h14):          0.01%     32.6°
 750 Hz (h15):          0.06%    -26.6°
 800 Hz (h16):          0.01%    -16.2°
 850 Hz (h17):          0.16%    192.2°
 900 Hz (h18):          0.01%    -53.4°
 950 Hz (h19):          0.04%     76.6°
```

Fig.11 THD is improved from 10.52 % to 4.15% following IEEE Standard

VI. CONCLUSION

The purpose of the research on the three-phase Shunt Active Power Filter is to mitigate the impact of harmonic currents and power factor generated by loads, thereby enabling the current on the source side to approach a sinusoidal waveform and be in phase with the system voltage. The simulation outcomes presented in this study demonstrate that Shunt Active Power Filters can be a viable solution for a wide range of applications, including residential loads, modern office equipment, and specific industrial loads with lower to medium power ratings. By utilizing the proposed control technique, the simulation results show that the APF is capable of compensating for a vast range of load harmonics within the limits defined by IEEE 519 standards.

VII. ACKNOWLEDGMENT

I am writing to express my sincere gratitude for the invaluable guidance and support you have provided me during my work. Your expertise and dedication have been instrumental in helping me carry out my tasks efficiently and effectively.

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VIII. REFERENCE

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