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POWER QUALITY ASSESMENT AND IMPROVEMENT BY REDUCING TOTAL HARMONICS DISTORTION USING HYBRID FILTER

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ABSTRACT

The significant use of power electronics in power systems, such as rectifiers and inverters, results in serious problems with power quality. The generation of current and voltage harmonics is one of these problems, as it can result in equipment overheating, voltage dips, load waveform distortion, and other problems. Furthermore, the presence of non-linear loads in the power system, including speed drives, UPSs, and SMPSs, causes current harmonics to be produced. By extracting the reactive power components of the current from the AC mains, they produce disturbances to the supply current waveform. As a result, THE dc link capacitor voltage management largely determines the device's ability to compensate. There has been use of the conventional fixed hysteresis current control technique. Here, the performance of the shunt active power filter has been enhanced through the development of an adaptive hysteresis current control technique. The performance of the recommended technique has been verified under different operating situations using the MA TLAB/SIMULINK model platform. To stop the impacts of harmonics, the electrical utility system's harmonic component needs to be corrected. Among other techniques, a shunt active power filter (SAPF) is one of the most efficient ways to eliminate harmonics in a power system among other method. In this publication, the performance is described in depth.

Keywords: Power quality, hybrid filter, PI controller, total harmonic distortion (THD), harmonics, hysteresis current controller, shunt active power filter(SAPF) and harmonics.

INTRODUCTION

These days, power electronic gadgets are used in both industrial and residential settings. These devices have increased the amount of harmonics current in distribution networks and have a significant impact on the quality of the voltage that is supplied. They are causing various types of consequences on the power system's equipment and customers, including low efficiency of customer sensitive load, measurement errors, overvoltage and shunt capacitors, a rise in overhead and underground wires, generators, and rotating electrical equipment, or complications with protection system operation.[3]

Industrial power systems have long employed passive filters to reduce distortion brought on by harmonic current. However, they have a number of shortcomings, including a resonance issue, a performance dependence on the system impedance, and harmonic current absorption.

SHUNT ACTIVE POWER FILTER (SAPF)

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Whenever the harmonic issue is detected, shunt active power filter, or SAPF as they is known as, are connected along with to an electrical transmission line. The primary purpose of this device is to eliminate the harmonic and non-sinusoidal current that the presence of a nonlinear load in the electricity network causes. It accomplishes this through generating a current that is shifted in phase by 180 degrees away from the harmonic current, yet still similar as the harmonics present. SAPF usually uses an electrically controlled voltage source inverter (IGBT inverter) to maintain a sinusoidal source current waveform and adjust for the harmonic element on the transmission line present [1].

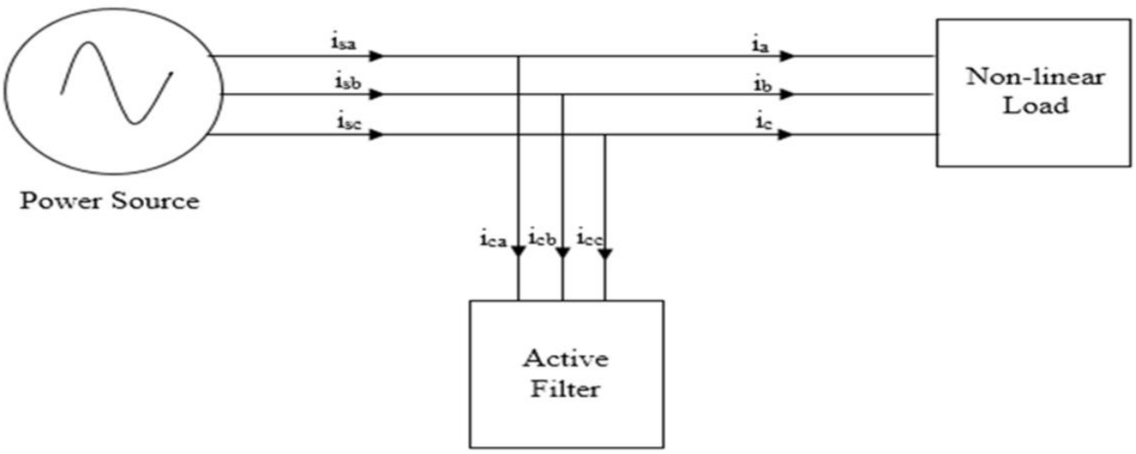

Figure:-1 Shunt active power filter

SAPF are widely used in the power system to compensate for current and reactive power harmonics. Shunt active power filters compensate for current harmonics by injecting complementary current produced by a nonlinear load. By using a suitable control method, APF can also boost system power factor. Because of the active power filter, electrical sources see the asymmetrical load as a simple resistor.[2]

HYBRID POWER FILTER

A passive filter with a small resistance at the prominent frequency ranges were used to reduce the harmonics while accounting for hardware costs. There are a few issues with these circuit configurations, though. Passive filters with preset compensation characteristics cannot filter the current harmonics. Series or parallel resonance does happen between the passive filters and the system impedance [12].

Research has been done on the advancements and uses of active filters as a result of growing concerns about power quality on the consumer or distribution side. By eliminating harmonic current using a switching mode power converter, active filters transcend the limitations of passive filters. Shunt active filters are made to lower harmonic currents and adjust with electrical reactive power at the same time. As a source of current, the active shunt purifiers are operated in combination with the not linear load. [13] The power converter of the active filter is controlled to deliver a compensation current that is distinct from the inactive and sinusoidal currents generated by the uncertain load, but identical to them. In this case, the mains supply is sinusoidal and synchronized with the primary potential.

S. Nathaniel al. [14], explains that passive filters set to the 5th and 7th order fundamental frequencies 50 in a hybrid active power filter reduce smaller harmonics.while higher order harmonics are filtered out by the active component. Shunt active and passive filters work together to drastically lower the price and size of active power filters.

By combining the two control strategies—source current and load voltage detection the performance of the series combination is significantly increased when employing the hybrid control strategy. The outcomes of the Matlab so hare simulation show how effective reactive power correction and harmonic filtering are. The system is capable of compensating for source voltage distortion in addition to source current distortion brought on by load harmonic voltage.

HYSTERESIS CURRENT CONTROLLER

The hysteresis current control technique gives the IGBT inverter a correct gating pulse and sequence by comparing its present fault signal its assigned hysteresis range. As seen in figure 2, the error signal is sent into the band of hysteresis corporator and compared with the Hysteresis range. After that, the resultant data from the compactor is sent via an active power filter, which creates the desired compensatory current that tracks the waveform of the reference current. Because of the synchronous control of the inverter switches, the inductive current fluctuates within the specified hysteresis range. The current ramps up as a result of the failure signal and current being continuously compared. Because of its higher dynamic performance and robustness, this technique is used [4].

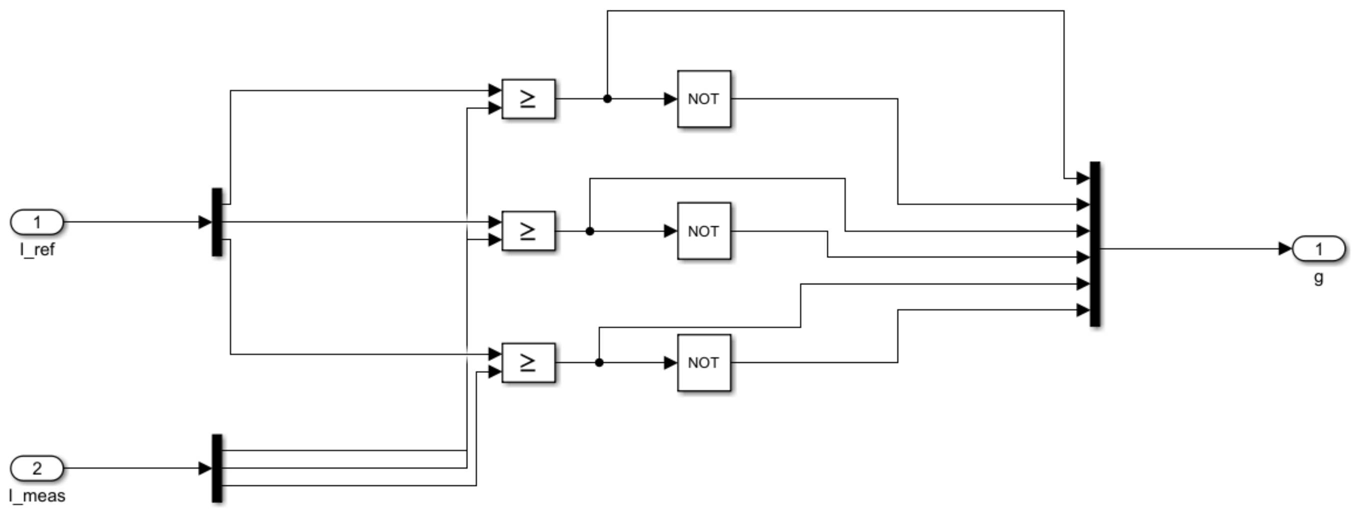

Figure:2 Simulation diagram of hysteresis current controller

HARMONICS MITIGATION

Three categories of harmonic mitigation systems exist following types of harmonic filters: passive, active, and hybrid. Series reactors, converter circuits with more pulses per cycle, and tuned harmonic filters are examples of passive filters. The two fundamental components of this method are an inductor and a capacitor. In accordance with IEEE standard 1459–2010, Chang Song's research investigates the efficacy of harmonic distortion power for the detection of harmonic sources[8]. Harmonic filters come in three varieties: hybrid, active, and passive. Passive filters include tuned harmonic filters, series reactors, and converter circuits with more pulses per cycle. This method consists of two primary parts: an inductor and a capacitor. In his research, Chang-Song examines the value of harmonic distortion power as described in IEEE Standard

PI CONTROLLER

The non-integrating process—that is, the process that yields the same output with the same disturbance and input—is handled by PI controllers. The ideal controller for a non-integrating process is the PI controller. Numerous controller blocks, including limiters, sine wave generators, and switching signal generators, are included in the control system. The maximum value of the initial current will be regulated by the DC link. This capacitor's voltage is measured and contrasted with the preset reference voltage.[6] The reference current is created by the PI controller using the variation of the voltage used as a reference and the actual capacitor voltage as input. The PI controller's output is the maximum value of the system current (I max).

The output of the PI controller consists of two components:

1. The principal active power component of the load current.
2. The losses of the active power filter.

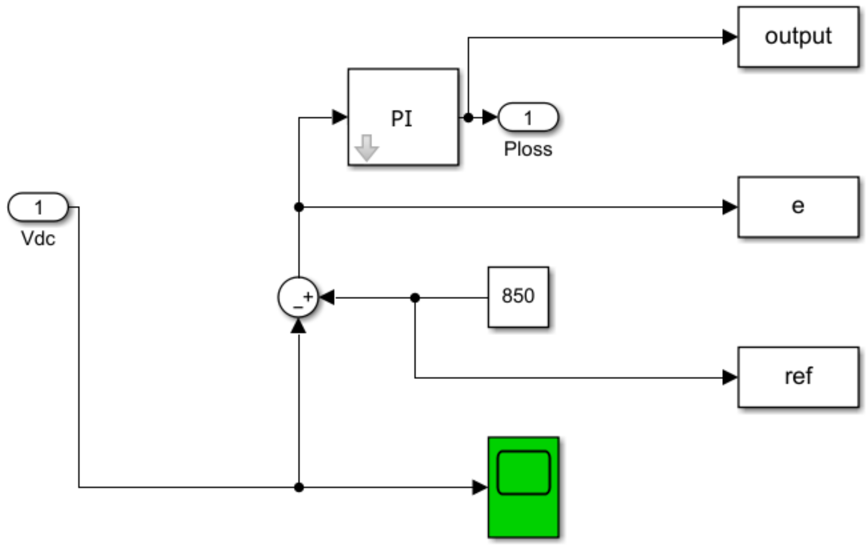

Figure:4 Simulation diagram of PI Controller

To keep the voltage across the capacitor constant, the PI controller's output is employed as the system current's peak value. To create the compensatory current, multiplying I max by the unit vector in phase with the matching source voltage is done.

TOTAL HARMONICS DISTORTION

The ratio of the root mean square harmonic content to the fundamental is a common way to represent total harmonic distortion or THD which is a measure of harmonic pollution. A harmonic signal or wave has a frequency that, when stated as a whole number, is an integral multiple of a reference signal or wave. The relationship between a signal or wave's frequency and that of the reference signal or wave can also be described using this phrase.[7]

PROBLEM IDENTIFICATION

Determine and examine the many kinds of loads—both linear and non-linear—that are attached to the electrical system. Harmonic distortion can be introduced by non-linear loads like computers, switch-mode power supply, and variable frequency drives (VFD).Harmonics are produced when nonlinear loads pull non-sinusoidal current waveform from the power source. These harmonics have the ability to change the voltage waveform, which raises the system's Total Harmonic Distortion (THD) levels and causes voltage distortion.Electrical systems and appliances that draw current in excess of the applied voltage are known as nonlinear loads. Nonlinear loads have nonlinear voltage-current characteristics as opposed to linear loads, which have linear current and voltage changes. Appliances with induction heating, arc furnaces, and air conditioners are examples of nonlinear loads.

1. Non-linear loads

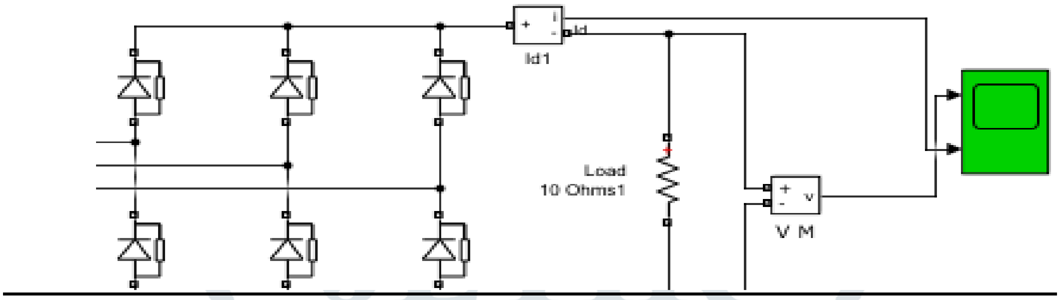

Figure.:5 Non Linear Load connected in the Matlab simulation

When the frequency of the harmonic wave is an integral multiple of the fundamental frequency steady state aberrations, and degradation in the original voltage and current waveform harmonics are typically referred to as periodic in power systems. Nonlinear loads have an impact on power distribution.These days, electrical systems, energy efficiency, and are relatively common. We looked at a transmission line with nonlinear loads to see how nonlinear loads affected a power system. The imbalanced loads were linked to it by the Matlab simulation.

2. Unbalanced resistive loads in three phases

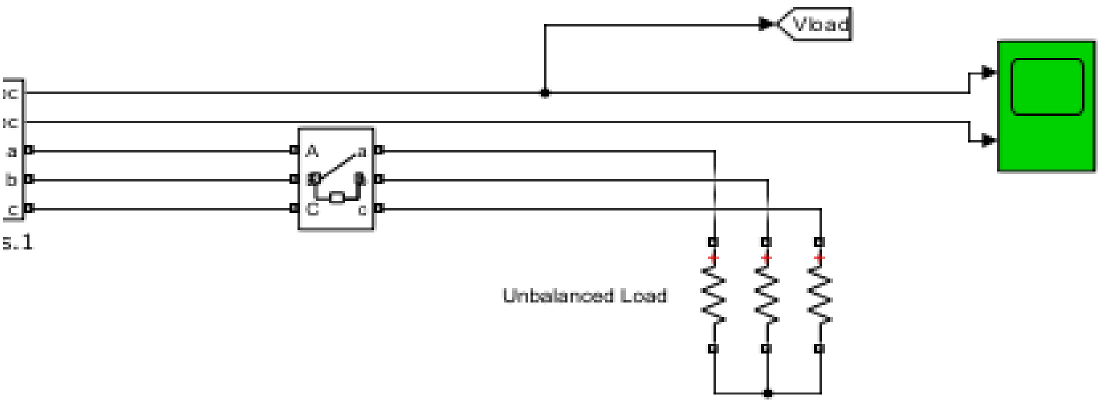

Figure:6 Three phase unbalanced resistive loads connect in Matlab simulation

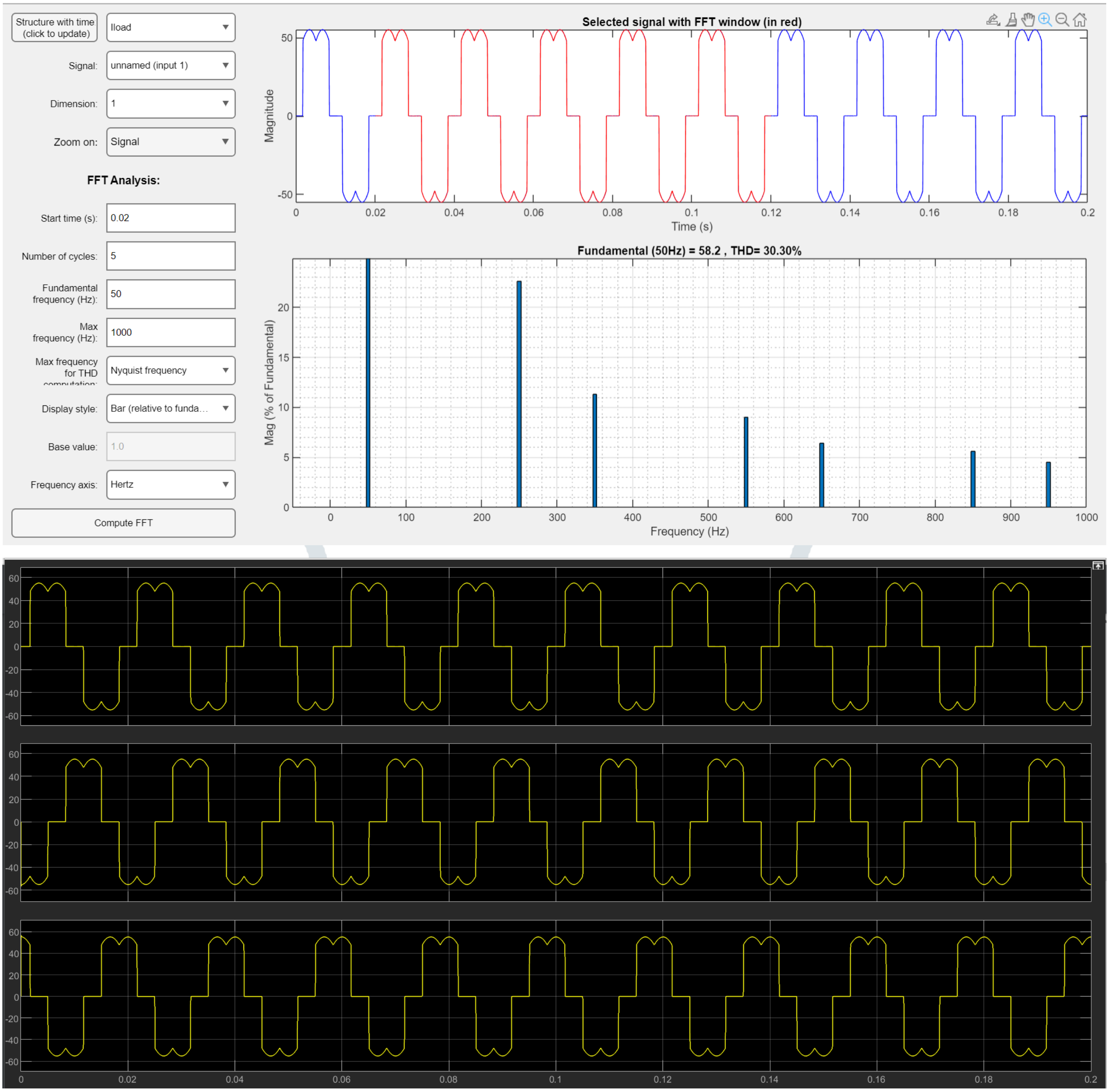

Figure:7 obtained waveform containing harmonics distortion

PROPOSED METHODOLOGY

Our asynchronous motor's integrated load is a specific type of nonlinear load that has evolved over time due to loads in both residential and commercial settings. Both nonlinear and three-phase unbalanced loads are typically present in the system. Variable frequency driving, or nonlinear loads, can lead to the power quality problems such as noise, and voltage swings. Power losses, electric device heating, insulation issues, communication system interference, or in the most severe situations, low-voltage distribution networks' harmonic distortion is the reason behind all electrical power system failure.[9]

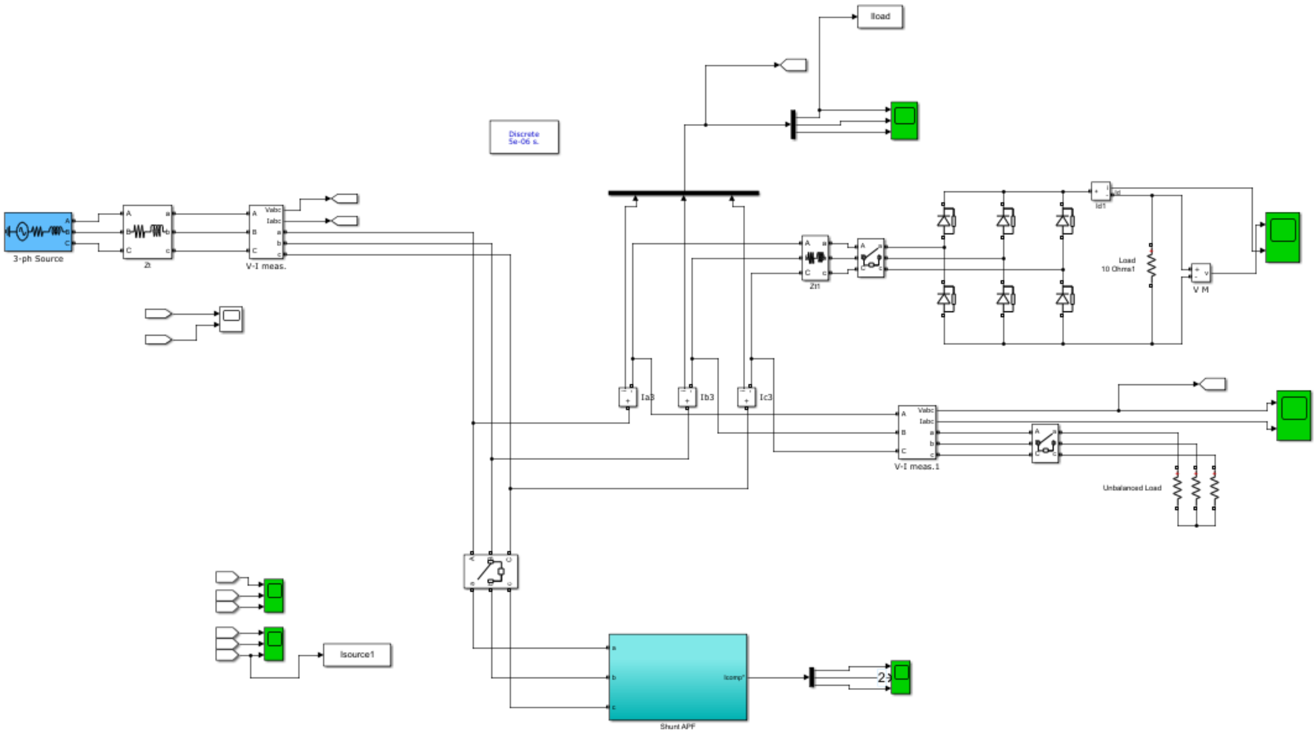

Figure: 8 Proposed Model with Shunt APF for Power Quality Improvement

The massive size, stiffness, and resonant resonance with load impedance or utility impedance instability are the disadvantage of passive power filter .. However, the active power filter (APF), which employs a voltage source inverter and offers a number of advantages like enhanced removing precision, quick variable response, and adaptability, is the best option for managing power quality issues. Because it primarily depends on the compensation management algorithm and the reactive power and current harmonic monitoring technique, shunt active power filter's(SAPF) harmonic mitigation is noteworthy.[11]

The power circuit and control circuit make up a shunt active power filter. The necessary compensatory current must be produced by the power circuit . In addition to DC voltage, it uses a voltage source inverter (VSI) with pulse width modulation (PWM) and a DC link capacitor to store and manage energy.

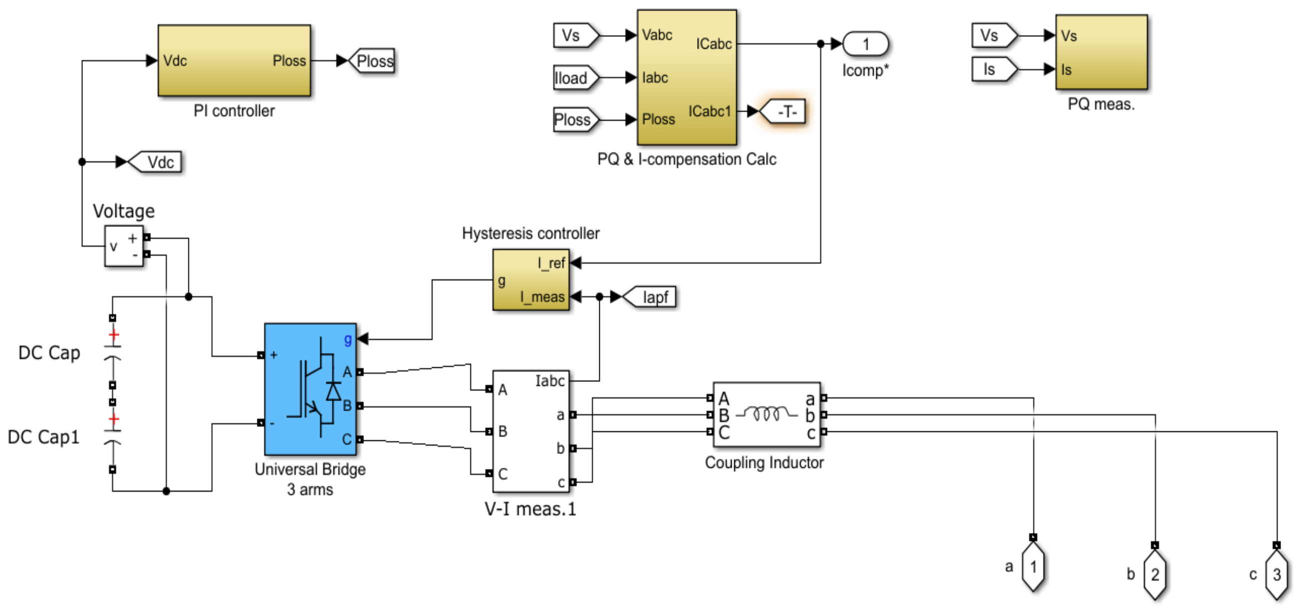

Figure:9 Proposed Matlab model of shunt APF

P-Q MATHEMATICAL METHOD

Equations 1 and 2 illustrate how Clarke's transformation relates the load current and voltage of a three-phase power system to the orthogonal coordinates (α-β-0) system.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} \ldots\ldots\ldots (1)$$

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

By simply multiplying the instantaneous current by the corresponding instantaneous voltage in an orthogonal coordinate system, one can determine the instantaneous power. Since the three phase coordinate system (a, b, and c) in this instance is mutually orthogonal by nature, we may get the instantaneous power using equation 3.

$$p = v_a i_a + v_b i_b + v_c i_c \ldots\ldots\ldots\ldots (3)$$

The instantaneous active and reactive power in matrix form can be expressed as follows using the equations above:

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} V_\alpha & V_\beta \\ -V_\beta & V_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \ldots\ldots\ldots\ldots (4)$$

The instantaneous reactive power cancels the harmonic component in the line current by creating an opposite vector with a 180° phase shift. Equation 5 can be obtained from the equations above.

$$\begin{bmatrix} i_{s\alpha}^{*} \\ i_{s\beta}^{*} \end{bmatrix} = \frac{1}{V_{\alpha}^{2}+V_{\beta}^{2}} \begin{bmatrix} V_{\alpha} & -V_{\beta} \\ V_{\beta} & V_{\alpha} \end{bmatrix} \begin{bmatrix} P_{o} + P_{loss} \\ 0 \end{bmatrix} \ldots\ldots \text{(5)}$$

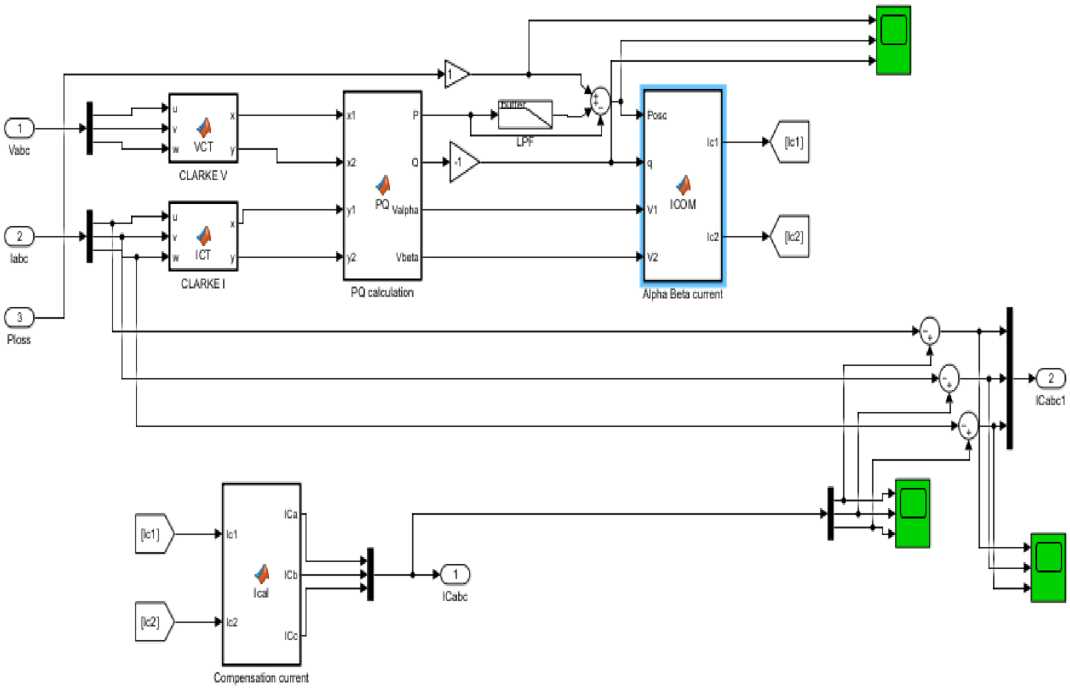

Figure: 10 Proposed Model of p-q Calculation Method

Equation 6 illustrates how to use the inverse Clarke transformations to obtain the compensating current for each phase after determining the α-β reference current.

$$\begin{bmatrix} i_{ca}^{*} \\ i_{cb}^{*} \\ i_{cc}^{*} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} \ldots\ldots\ldots \text{(6)}$$

RESULT

The compensating and reduce the total harmonics distortion from current is seen in the waveform below: When the proposed Shunt APF is coupled in a shunt configuration to at the point of common coupling (CCP), the load , it generates waveform of filtered source and load current. The addition of the Shunt APF resulted in a reduction in the system's Distortion of Total harmonic (THD) as the FFT analysis shows.

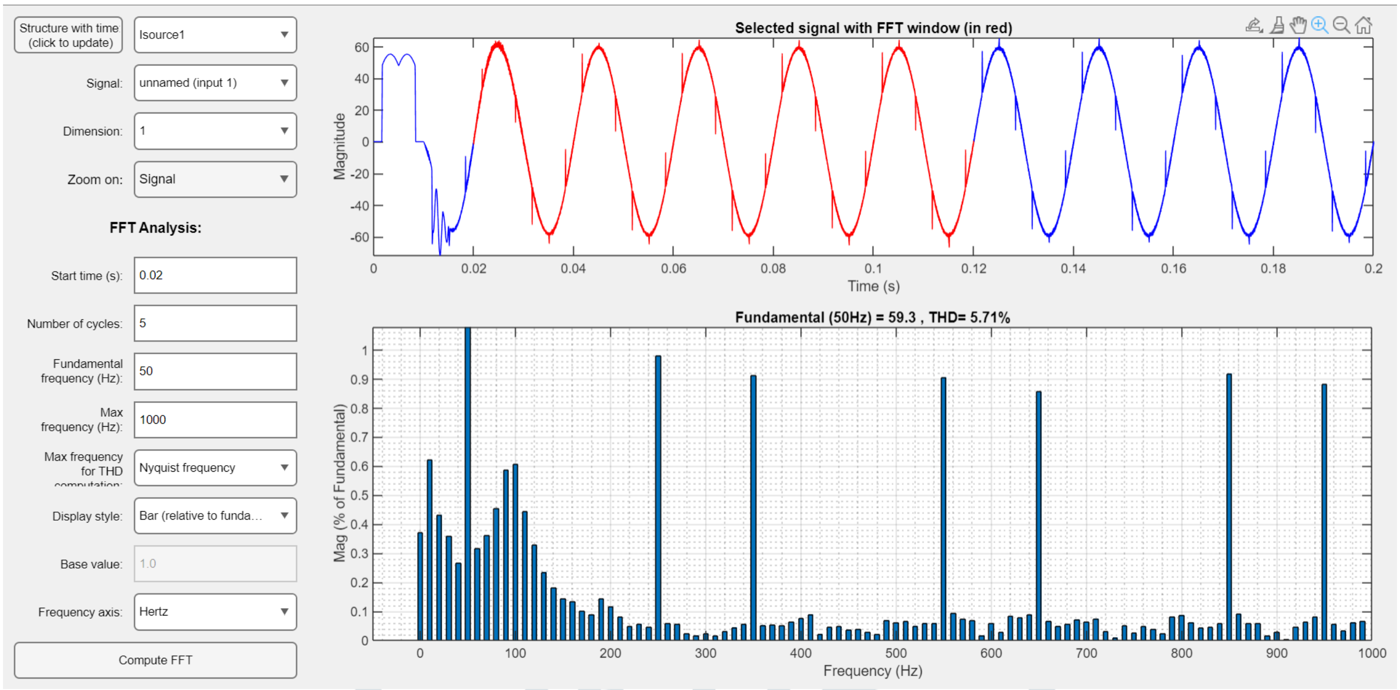

Figure:11 waveform of compensation current

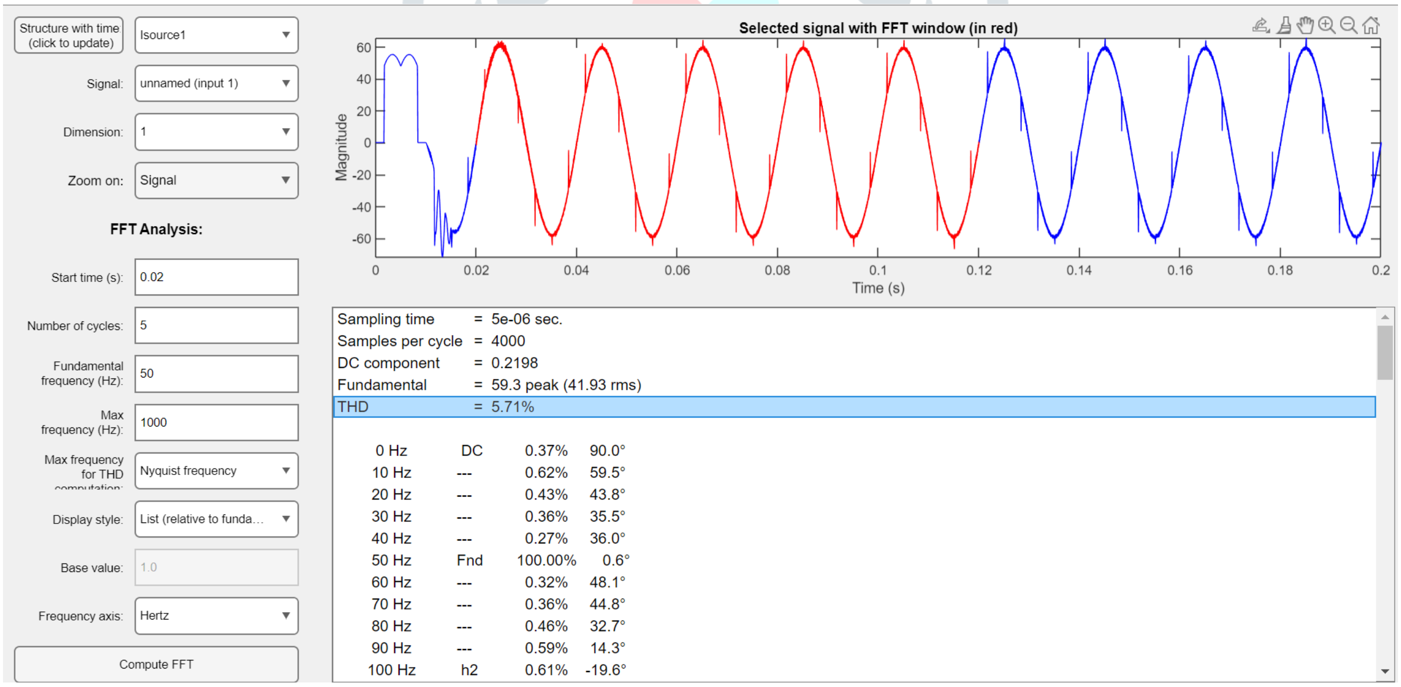

Figure:12 Analysis using the FFT to show harmonics in proportion to the fundamentals

The THD was decreased from 30.30% to 5.79% of the basic value by adding the shunt active power filter When the system was compared to the baseline, the THD dropped by 92.0%. Additionally, each harmonic component was reduced by The increases from the beginning values of the fifth, seventh, and eleventh harmonics were 92%, 93%, and 94%, respectively.

CONCLUSION

FFT analysis shows that the influence of balanced and unbalanced non-linear loads (rectifier and unbalanced three-phase resistive load) lowered the THD from 30.30% to 5.79%, a 92% reduction from its starting value. The system's 93% efficiency rating suggests that it can successfully remove low-order harmonics. and 93% mitigation in the 5^{th} and 7^{th} harmonic of the main harmonics, respectively. components responsible for the subpar power quality.

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