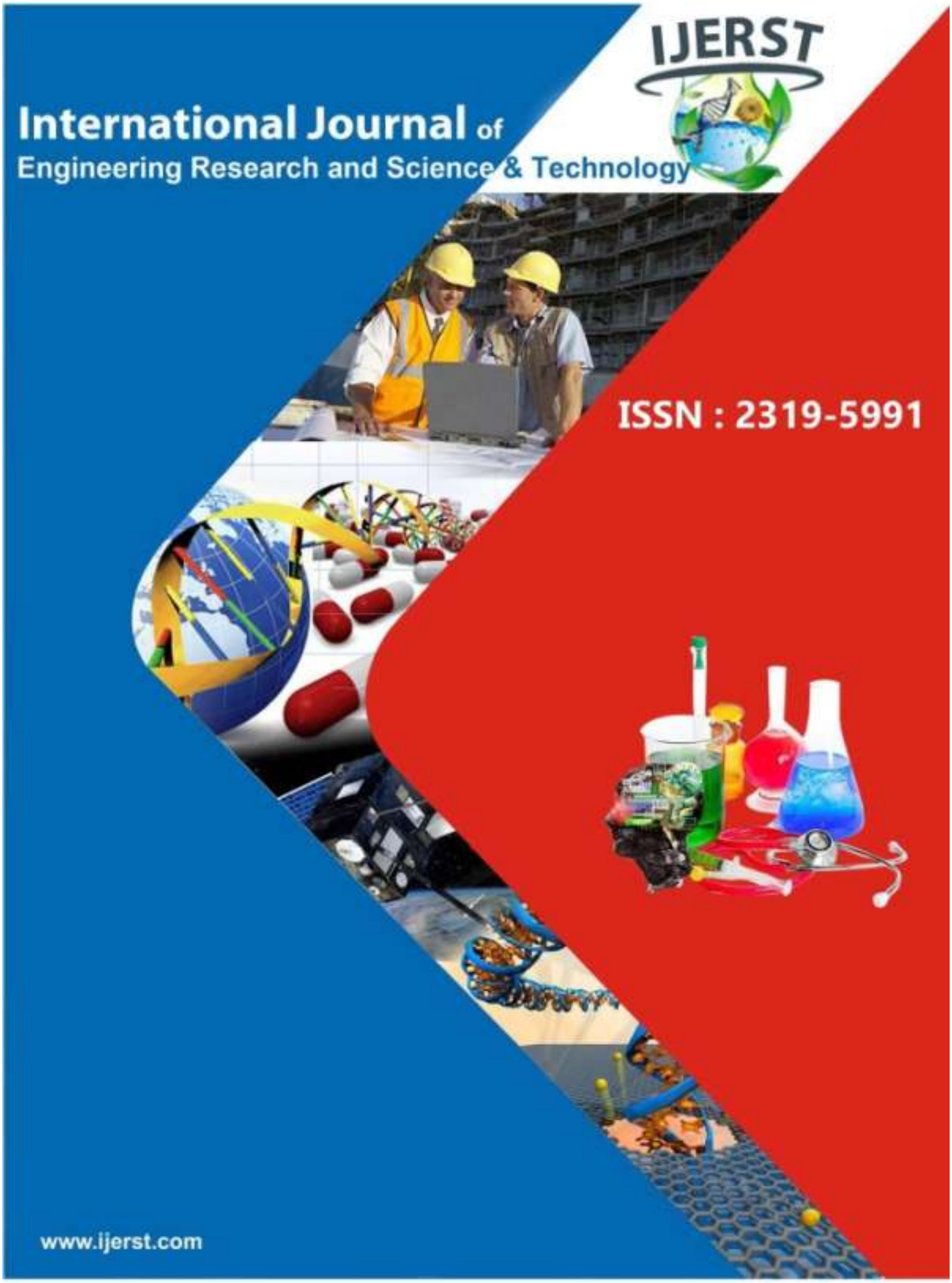

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Fuzzy Logic Controller Based Shunt Connected Three Phase Active Power Filter

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Abstract:Power electronic technology has led to a rise in harmonics in the power system during the last several years. We employed a shunt active power filter to reduce harmonics since they have a negative economic effect on the utilities and the end user (SHAF). SHAF's performance is controlled through PI and FLC techniques, which are based on proportional integrals. To recover the simulated power quality from MATLAB/ SIMULINK, a projected PI with SHAF and a fuzzy with SHAF monitoring structure is set up.

Keywords: DC link voltage (PI controller and FLC) as well as harmonics in Shunt Active Filter (SAF).

1.**INTRODUCTION**

An economic loss has been caused by the widespread usage of non-linear loads such as adjustable-speed gearboxes (e.g., variable-speed drives, traction drives), as well as power converters. The development of devices that might reduce the issue of low power quality is thus vital.

It is described as "any power issue created in voltage, current, or frequency deviation that causes damage, malfunction, or disoperation of the consumer equipment" (PQ [2]). Damages to the system are caused by poor power quality, which has a negative economic effect on the utilities and their consumers. Economic losses due to the usage of highly automated electric equipment are particularly high. Power filters may help decrease or even eliminate harmonic noise. System harmonics have been reduced significantly by the use of Active power filters. Current harmonics are one of the most prevalent and severe power quality issues. Voltage harmonics [1] and issues with power distribution equipment are two examples of current harmonics causing voltage harmonics.

Nonsinusoidal voltage is produced at the power plant. AC machines have a tendency to distort voltage waves due to varying magnetic fields and winding distribution, which causes the voltage to be non-sinusoidal while it's running. Disturbance occurs at the site of creation, although it is quite tiny (between 1 and 2 percent). Voltage harmonics emerge as a result of this deviance from a pure sine wave.

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For any pure AC waveform, the load current drawn is proportional to voltage and impedance. This monitors the coverage of the waveform as a result. They are known as linear loads (loads where voltage and current follow one another without distortion to their pure sine waves)[3].
Linear loads include resistive heaters, incandescent bulbs, and induction motors that operate at a fixed speed. As a result of certain loads, the current varies greatly with respect to the voltage throughout the course of a half cycle. Non-linear loads are those that don't follow a straight line. There are non-linear loads that create current and voltage harmonics. The non-linear effects of the load cause a variety of issues, including EMI, voltage fluctuations in the power system, poor power factor, and low energy efficiency, to name a few. These consequences need compensating. There is a significant increase in THD [4] when the shunt active filter is not used, compared to what is stated in IEEE standard-519 for this application. The THD value should be less than 5% according to this standard. The following is the voltage harmonics THD equation:√($V$2+$V$2+⋯+$V$2

% THD (V) =

2 3
$V$1

n
× 100

(1)

And the THD equation for current harmonics is given by
√($I$2+$I$2+⋯+$I$2

% THD (I) =

2 3
$I$1

n
× 100

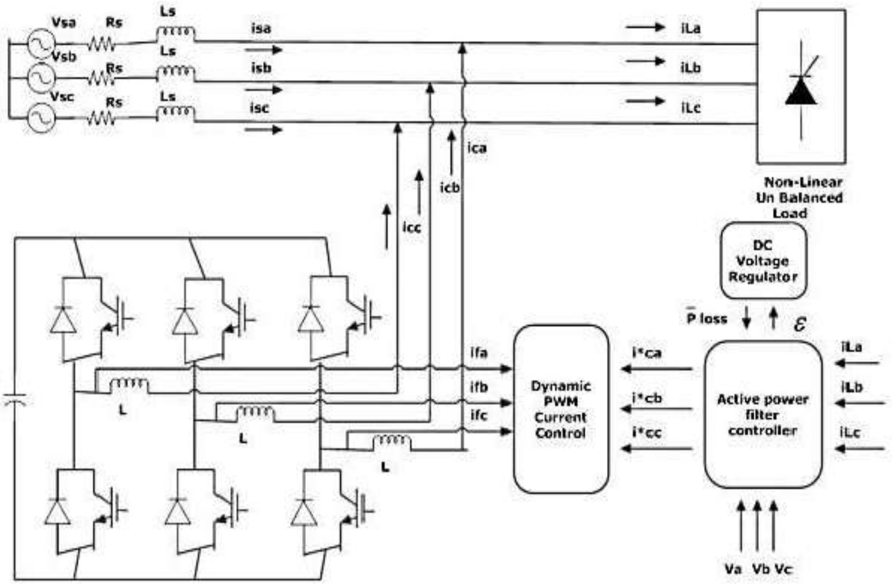


Fig. :

(2)

SHAF [5]-[8] feeding a three-phase, three-wire system and a three-phase non-linear load is shown schematically in Fig. 1. As a result of the non-linear loads, the voltage and current at the source are not maintained at unity power factor. As a result, the power system's unity power factor necessitates the use of shunt active filters.

Compensation current may be injected by the SHAF so that the source current is pure sinusoidal and unity power factor can be achieved with the help of the SHAF. A voltage source inverter (VSI) with three IGBT legs, an interface inductor, and a dc bus capacitor make up the shunt active filter. PI controller and FLC [9, 10] are utilised to regulate the shunt active filter in order to get the optimum performance. A shunt active filter's performance is examined under normal and increased load conditions with balanced and unbalanced source voltage. The FLC-controlled shunt active filter is superior than the PI controller in terms of performance.

There is no difference in compensation when the source voltage is balanced, but when the source voltages are unbalanced, the fuzzy logic controller gives an amazing compensation over the PI controller in terms of the quantity of compensation.

SHOOT THE FILTER ACTIVELY

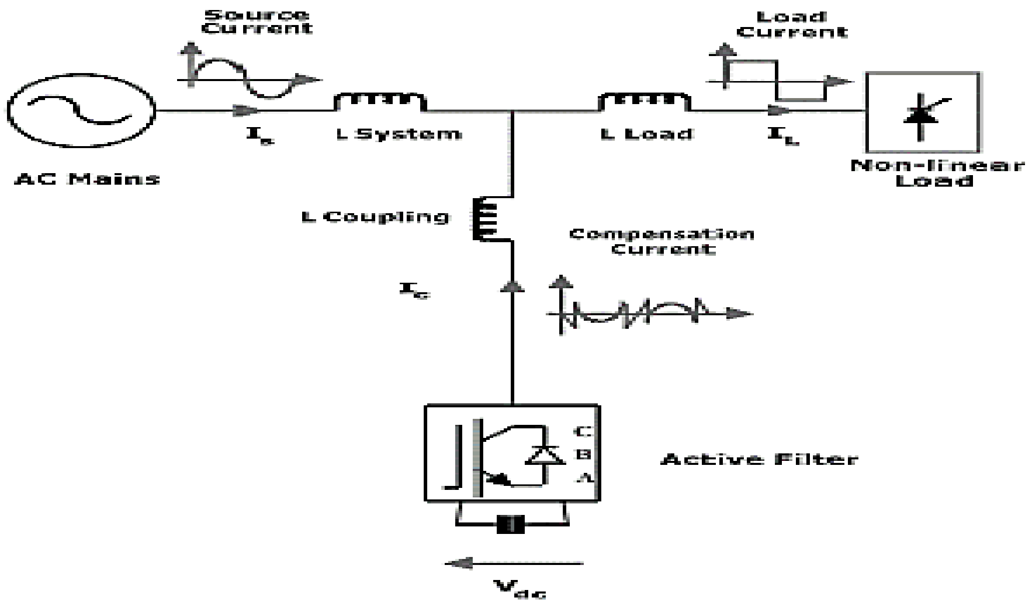
A. Active Power Filter

The harmonics in the electrical systems may be reduced by using power filters. Because of their presence in the power system, harmonics are seen as a source of pollution. Because of its simple construction, simple design, and inexpensive cost, LC filters are utilised here. Passive power filters come in a variety of shapes and sizes. In addition, passive power filters have a number of problems, including resonance, bulkiness, inaccuracy in tuning frequency, and the need for a lot of computations. Active power filters (APF) [6]-[8] were developed to address the shortcomings of passive power filters. Power-electronic devices are used to reduce the amount of harmonics in the power system. Compared to passive power filters, the APF has been shown to be more successful in reducing harmonics. It has the benefit of being smaller and more precise while still overcoming the disadvantages of passive power filters. There are three main types of power filters: series filters, shunt filters, and hybrid filters. These filters are connected in series with the power system to reduce the effects of voltage harmonics on the system's efficiency. In order to reduce the current harmonics in the system, the shunt active filter must be inserted in the system at a common coupling point (PCC). When dealing with harmonic current and voltage distortion, hybrid filters are used. Shunt active filters are a viable option for mitigating current harmonics in this instance, which is why we're considering them.

B. APF Compensation Principle

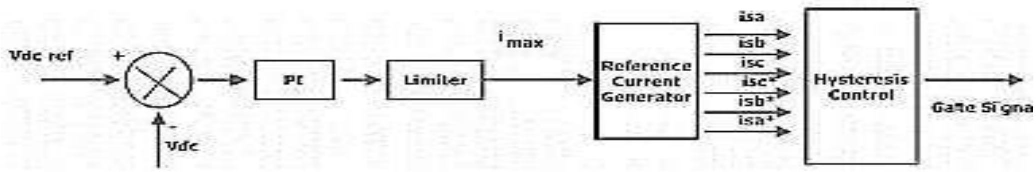
Pi and fuzzy logic controllers were utilised to keep the DC connection voltage constant. – PI In order to compensate for the Active Power Filter, the SHAF is regulated by the PI controller and the Fuzzy Logic Controller FLC. Fig. 2 depicts the SHAF standard. The actual power in the system, i.e. between the mains and the load, fluctuates as the load state changes. The DC link capacitor clears the real power disturbance caused by the system's unbalanced real power, but the voltage across the DC link capacitor drifts away from the reference voltage as a result.

It is necessary to alter the peak value of the reference source current [11] in order to get the best performance from the system. In theory, the actual power provided by the source should be equal again to that consumed by the load if the DC capacitor voltage is recovered and reaches a reference value. Regulating the DC capacitor's average voltage allows the peak current of the reference source to be obtained.



2. **DC LINK VOLTAGE**

A. DC Link Voltage Regulation



The true power going through the system is disrupted if the load situation changes suddenly, and this has to be calmed down. The voltage across the DC link capacitor fluctuates because the DC link voltage is utilised to balance the system's actual power flow. The DC link voltage may be maintained at the required level if the active power flowing into the filter can be managed in such a manner that the losses within the filter are equal to the active power flow. Consequently, the primary function of the active power filter is to maintain the DC link voltage and to provide compensatory current to decrease the current harmonics present in the system.. Active filtering in the shunt configuration

Two kinds of controllers (SHAF) are used.

Controlling linear loads using a PI controller conditional reasoning and fuzziness

controller for a linear load situation

B. PI Controller with SHAF

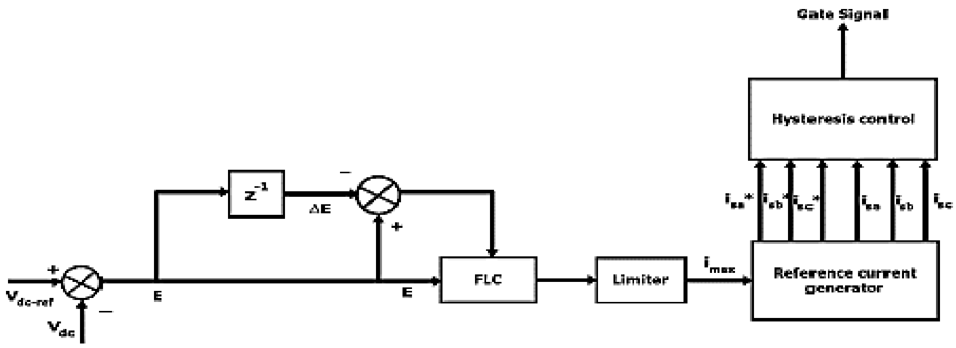
Fig. 3 shows the construction of the controller circuit. System contains of PI controller, limiter and three phase sine wave generator for reference current and switching signals generation [8]. It is known that the real Fig. 3 depicts the controller circuit's design. For the creation of reference current and switching signals, the system includes a PI controller, limiter, and a three-phase sine wave generator [8]. The DC link capacitor voltage compensates for fluctuations in the system's actual power, as is well-known. The PI controller receives a reference voltage and an error signal from the fresh capacitor voltage.

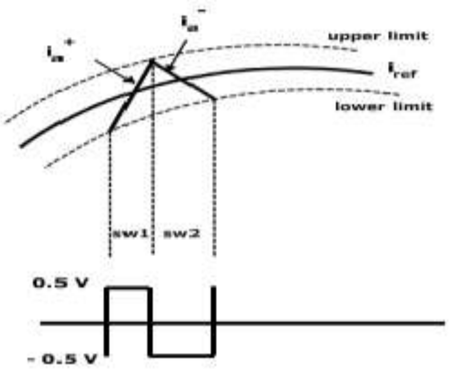
Fig.3 Conventional PI Controller

Errors in the tracking of the reference current signal may then be eliminated by going via a PI controller. In order to maintain a constant average capacitor voltage, the PI controller's output is measured as the peak value of the supply current (Imax), which consists of two components: (a) the basic active power component of the load current and (b) the loss component of the APF. The reference compensating currents are calculated by multiplying the current peak (Imax) with the corresponding source voltages. Error signals generated by the hysteresis band are compared and sensed between the actual current (Isa, Isb, and Isc) and the reference current. current (I*sa, I*sb, I*sc).

(a) Current Wave of Current Controller

(b) Current Controller Waveform Fig. 4 Hysteresis Band





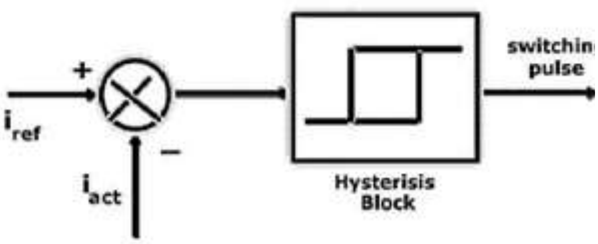


Fig. 4 By comparing two currents, the error signal is formed. In order to provide compensatory current, the gating signal from this hysteresis band is employed to drive the converter switches. In order to monitor the sinusoidal reference current within a specified hysteretic band, the source currents have been pre-prepared. Hysteresis window width, harmonic spectrum and switching frequency of the device are all influenced by the source-current pattern. Each phase of the converter may be separately regulated in this method. Switching down the converter's lower voltage allows it to boost a certain phase's current more easily

current is reduced by turning on the switch corresponding with that phase, while turning off the higher switch of the same phase.

It's time to switch on the phase of the converter. As a result, the PI controller's potential and viability may be shown. [9], [10].

C. Fuzzy controller with SHAF

Fig. 5 Fuzzy Logic Controller

The fuzzy logic controller's control circuit is shown schematically in Figure 5. A three-phase sine wave generator and an FLC serve as the system's reference current and switching signal generators, respectively. The DC link capacitor voltage compensates for fluctuations in the system's actual power, as is well-known.

A reference voltage is used to match the voltage of the new capacitor, and an error signal is then sent to the FLC. Following the FLC processing of the error signal, the tracking of the reference current signal is maintained at zero stable error. The output of the FLC is believed to be the peak value of the supply current (Imax), which is used to create the reference currents and subsequently the gating signals.

The FLC is described in the following manner:

There are five fuzzy sets for every input and output.

2) The use of a never-ending universe of discources for fuzzification.

3) Mamdani's'min' operator is used for implication.

Use of the "centroid" approach for defuzzification.

3. SIMULATIONS

Table 1 System parameters used in Simulink

Syste parameters
Source voltage
DC Link Capacitance
Load impedance
FLC
Sampl Interval
Smoothing Reactance

In order to reduce current harmonics, the three-phase system with a non-linear load features a shunt active filter. Under non-linear load conditions, the PI controller and FLC are employed to regulate the shunt active filter. The source voltage condition circuit's system parameters are shown in Table 1.
MATLAB Model of Compensation Principle of SHAF

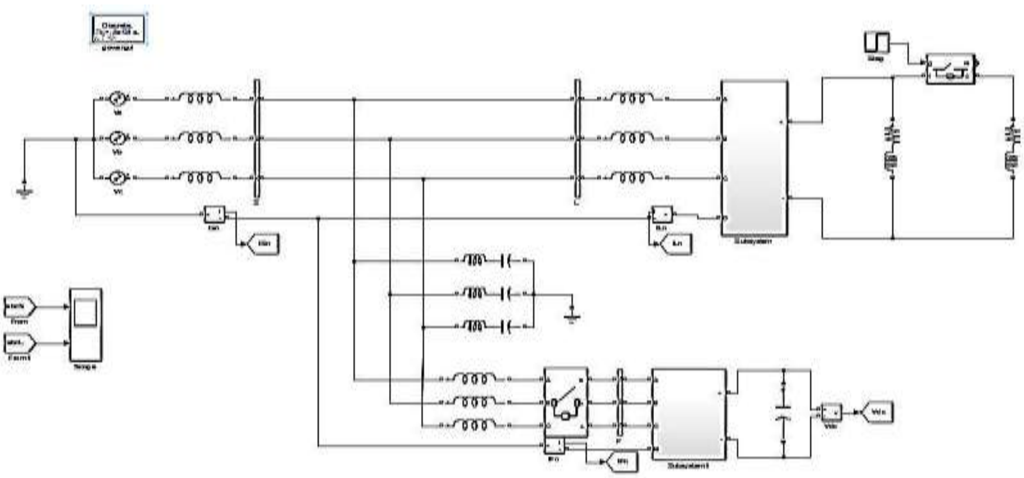


Fig. 6 MATLABModel of Compensation Principle of SHAF

Figure 6 depicts the MATLAB module for the SHAF system's compensating concept. IGBT blocks of eight are utilised to form a three-phase voltage source inverter. The filter's components comprise an inductor, a capacitor, and a resistor. High-order harmonics are illuminated by this filtering method. The state of compensation may be noticed from the scope. The sag voltage is detected and converted into two stationary voltages by the reference generator block. PWM topology pulses are generated by the pulse generator block. Forced may be fired from the block.

IGBTs of the three-phase inverter are commutated devices. The measured voltage pulses are created by a pulsing mechanism.

using a modulating reference signal to compare a repeated waveform against. Choosing hexagonal sectors, calculating switching time, and selecting switching pulses may be used to produce modulating signals. As soon as the sag has been removed,

The reference signal, which appears on one of the feeders, generates pulses for the three-phase inverter. This PWM is pulsing.

The IGBTs' gates are triggered by this. AC signals are generated by the inverter circuit, which transforms DC signals. On the scope labelled as result, the output voltage is measured. A clean sine wave output may be achieved thanks to the LC filter.

A periodic distorted signal's THD may be visually shown via an FFT analysis. When it comes to voltage, the total harmonic distortion (THD) is what's being tracked. The RMS value of the signal's total harmonics is divided by the RMS value of the signal's fundamental signal to get the total harmonic distortion.

4. RESULT AND ANALYSIS

A. Simulation Results for PI Controller with SHAF

Source, load, and remuneration waveforms are shown in Fig. 6.

With a PI controller, the current is maintained.

After 0.06 seconds, the SHAF filter current enters the grid current. When the filter current is injected after 0.06 seconds, the grid current waveform becomes perfectly sinusoidal by utilising a PI controller to regulate the voltage.It is obvious from Fig. 7 that the power factor after adjustment is closer to unity, which is 0.9705. An active filter with a PI controller is installed in the three-phase, three-wire system to reduce current harmonics. It is necessary to do FFT analysis in order to determine harmonic distortion during correction. Every one of these components is displayed, coordinated, and then grasped to replicate the framework THD for the PI model using FFT inquiry, which may be shown in fig. 8.

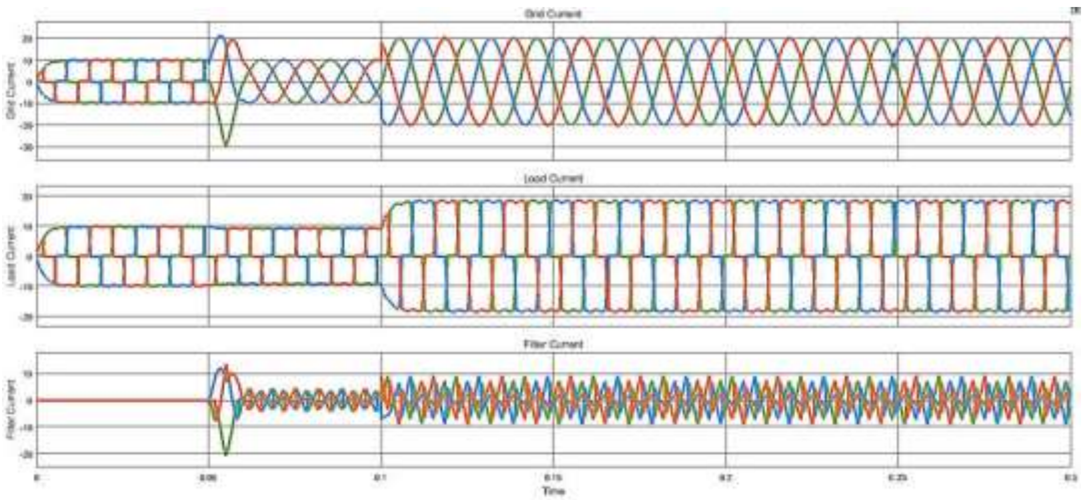
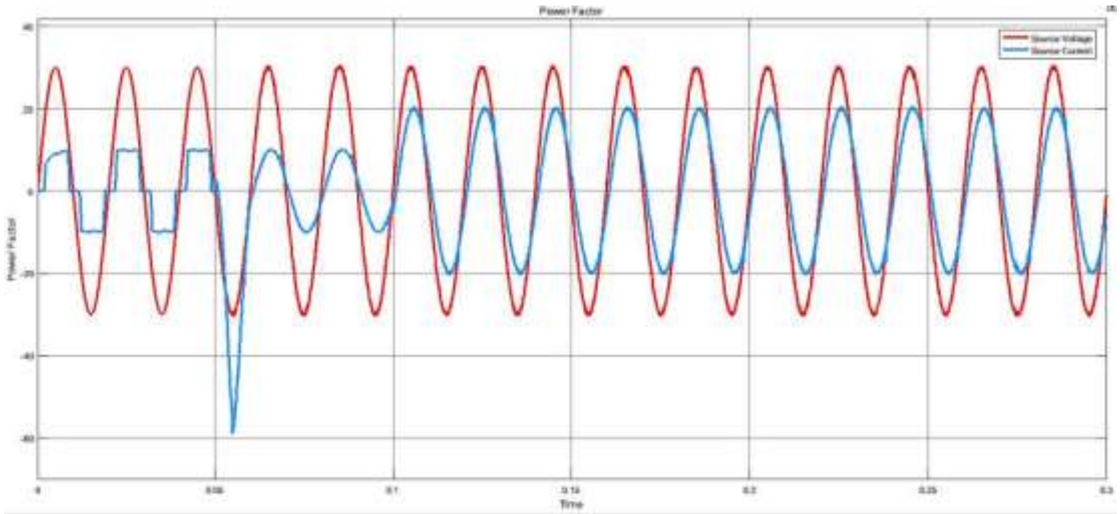


Fig. 6 Waveforms of Source Current, Load Current and Remunerating Current with PI Controller

Fig. 7 Power Factor for APF with Conventional PI Controller



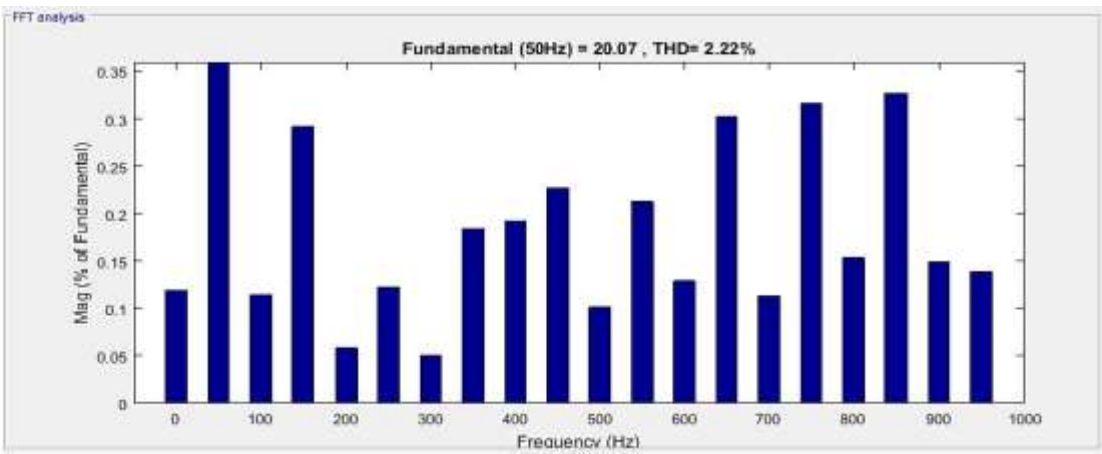


Fig. 8 FFT Source Current with PI Controlled APF

B. Simulation Result for fuzzy controller with SHAF

Source current, load current, and remunerating current waveforms are shown in Fig. 9 using a fuzzy controller. After 0.06 seconds, the SHAF filter current enters the grid current. A fuzzy controller may be used to make the grid current waveform entirely sinusoidal by injecting filter current every 0.06 seconds, and we can see this in the waveform.

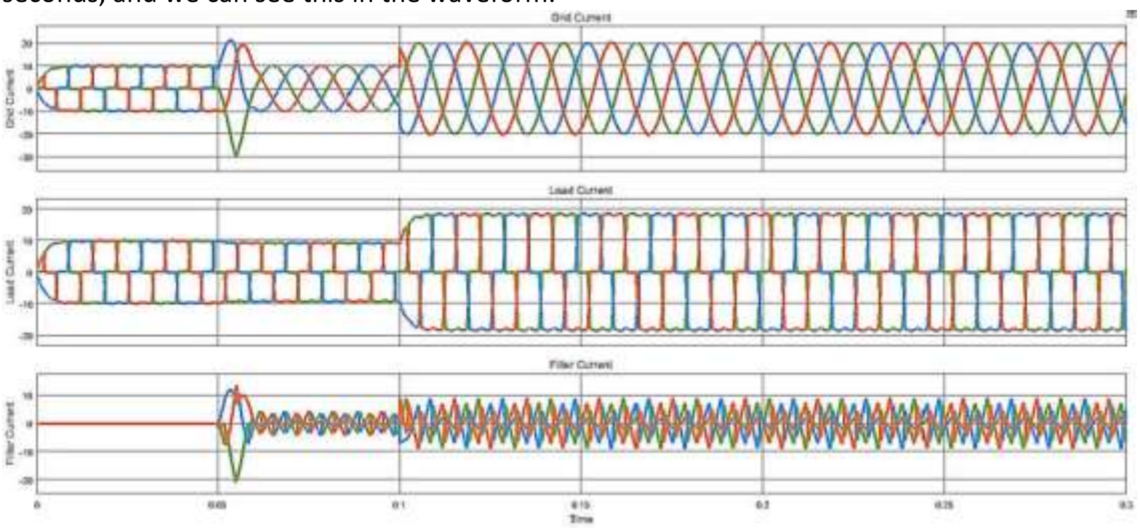


Fig. 9 Waveforms of Source Current, Load Current and Remunerating Current with Fuzzy Controller.

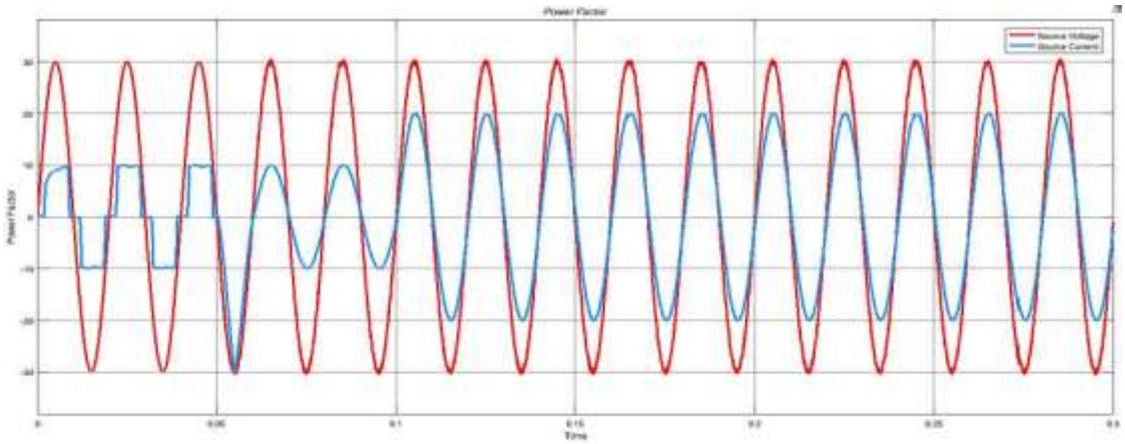
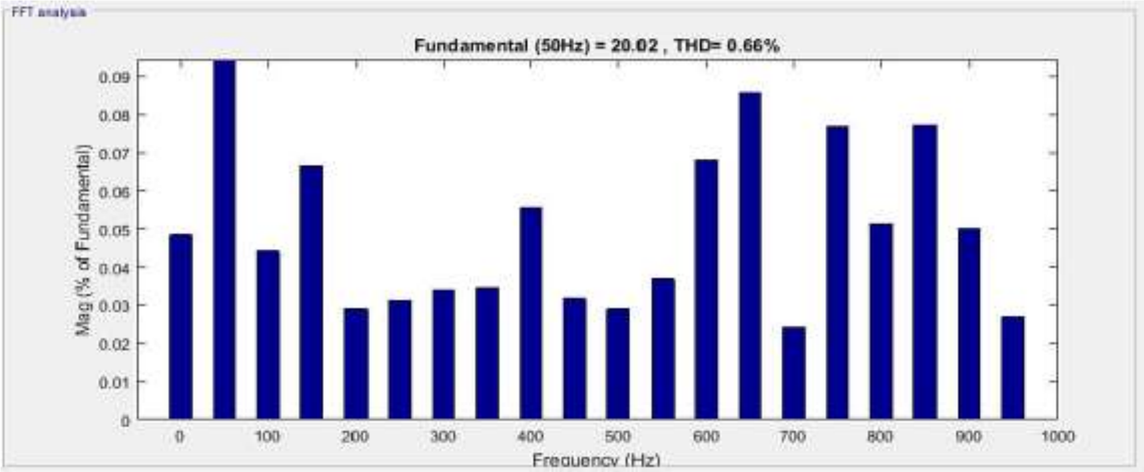


Fig. 10 Power Factor for APF with Conventional Fuzzy Controller

Figure 10 depicts the power factor after adjustment, which is clearly seen to be unity, or 0.9957. Three-phase three-



wire nonlinear load system incorporates a shunt active filter with fuzzy controller to reduce current harmonics.. It is necessary to do FFT analysis in order to determine harmonic distortion during correction. The framework THD for fuzzy model using FFT inquiry is 0.66 percent, as stated in fig 11.

Fig. 11 FFT Source Current with Fuzzy Controlled APF

5. **CONSLUSION**

This system proposes an improvement in power class and relative power correction for renewable power production. The proposed system has a number of benefits, including its ease of use, demonstration and implementation. Comparisons have been made between PI and FLC in terms of their presentation. To ensure the accuracy of the findings, a MATLAB SIMULINK model was built and simulated. In order to correct for the current harmonics, the shunt active filter uses PI controllers and Fuzzy logic controllers. When controlled by FLC, the SHAF's THD is much lower than when utilising a PI controller. As a result, FLC performs better than PI controller in controlling the shunt active filter. Under less-than-ideal circumstances, the SHAF dc bus voltage and power factor are almost maintained at the reference value, confirming the FLC's efficacy.

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