Performance Evaluation of Fuzzy-IRP Controlled Shunt-APF for Power-Quality Improvement

[1]P. Prabhu Kumar, [2]S. Karthik, [3]K. Kiran Kumar, [4]D. Nagaraju, [5]M. Bhargavi, [6]K. Venkata Sai Kumar
[1]M.Tech, Assistant Professor, [2,3,4,5,6]UG Student
[1,2,3,4,5,6]Department of Electrical & Electronics Engineering
[1,2,3,4,5,6]DVR & Dr. HS MIC College of Technology, Kanchikacherla, Krishna (Dt); Andhra Pradesh, India.

ABSTRACT

In this work, the proposed shunt active filter is used for compensating harmonic current distortions, reactive-power control, load balancing and power-factor correction, etc in a three-phase distribution system without use of additional devices. The performance of proposed shunt active power filter is verified for compensating the harmonics and enhancing the PQ issues by using Instantaneous Real-Power (IRP) theory. Additionally, regulation of DC capacitor voltage at a desired level using a PI controller is not suitable for enhanced PQ features. But, this controller is unpopular due to tuning issues of current controller; the above-mentioned issues are regulated by using novel intelligent based Fuzzy-Logic controller achieving good performance features. This work compares the performance of SAPF with classical PI and intelligent Fuzzy-Logic controller in PQ enhancement. The proposed Fuzzy controlled SAPF provides compensates all current-related disturbances like current harmonics, reactive power control, power-factor correction, unbalanced current and reduction in Total Harmonic Distortion, so on. The performance of proposed SAPF is verified in balanced non-linear loads by using classical PI and proposed Intelligent Fuzzy controller based IRP for attaining good compensation features. The proposed system is verified by using Matlab/Simulink tool; results are presented.

Keyword: - *Active Power Filter, Fuzzy-Logic Controller, Instantaneous Real-Power Theory, Power-Quality Improvement, Total Harmonic Distortion.*

---

1. INTRODUCTION

Power delivery to the load point is expected to be utmost clear in nature with accuracy. Any deviation of power network parameters from the ideal form is annoyance in power system. Poor power quality makes system to experience stalled production, increased energy consumption, reduction in production pace, malfunctioning of equipment, reduced efficiency, reduction in life time of equipment. One of the main responsibilities of a utility system is to supply electric power in the form of sinusoidal and currents with appropriate magnitudes and frequency for the customers at the points of common coupling (PCC) [1]. Although the generated voltage of synchronous machines in power plants are nearly sinusoidal ,some undesired conditions such as lightning and short circuit faults and nonlinear loads cause steady state error or transient voltages and current disturbances. For example, electric arc furnaces cause voltage fluctuations, power electronic converters generate current harmonics and distort voltage waveforms, and short circuits faults result in voltage sags and swells.

The above-mentioned issues are alleviated by using many ways such as passive and active compensation schemes developed as filtering techniques which includes passive filters and active filters. Passive filters with low circuit arrangement can mitigate harmonics. But passive filters can fix only fixed harmonics for which the particular passive filter is tuned leaving out remaining harmonics in the system. Also as order of harmonics is low, size of the passive filter increases as passive filter parameters are inversely proportional to tuned frequency. On other-hand, Shunt Active Power Filter (SAPF) injects a current component which is connected in shunt with the distribution system, thus compensating the current harmonics, reactive-power, load balancing and power-factor correction. The main function of a shunt-APF is the protection of sensitive loads from harmonics; short-circuit faults, coming from the non-linear loads [2].

It mitigates the current-related issues like current harmonics, reactive-power, load balancing and power-factor correction, etc., in any power system network. It sustains the load-voltage as constant at a defined magnitude and phase quantities attained at PCC point. So as to compensate current related issues, Shunt-APF administers the respective voltage and current with a suitable phase and magnitude in shunt with the network/line. Typically, SAPF can be opted for low and/or medium voltage ranges, as well as it is developed as 3-phase 3-wire and 4-wire systems and single phase systems. As usual, the SAPF power-circuitry comprised of DC-AC inverter, DC-link capacitor, LC filter units. During current harmonics, SAPF provides required load power to PCC/load for optimal compensation through DC-link based conditioner, sustains the load-voltage and current as sinusoidal, balanced and linear. The optimal selection and ratings of SAPF topology is totally related with distribution level voltage, investment cost, outage cost, etc [3].

The DC-AC inverter is the heart of the SAPF, among VSI plays a vital role and converts the DC energy to AC energy and injects required load current through filter units. This filter unit minimizes the dominant harmonized sequences generated by VSI for getting RMS quantity of voltage wave-shape and injects in-phase current components [4]-[6]. By using inverter side filtering scheme, it is more advantageous because being nearer to harmonic values thus higher order harmonized values are intercepted. Coming to control schemes of SAPF includes, SRF theory, Instantaneous PQ theory, Artificial intelligent techniques, Sliding-mode control technique, etc. The reference signals helps to furnish the optimal switching states of the VSI, to obtain mitigation strategy. Additionally, regulation of DC capacitor voltage at a desired level using a PI controller is not suitable for enhanced PQ features. But, this controller is unpopular due to tuning issues of current controller; the above-mentioned issues are regulated by using novel intelligent based Fuzzy-Logic controller achieving good performance features. This work compares the performance of SAPF with classical PI and intelligent Fuzzy-Logic controller in PQ enhancement. The proposed Fuzzy controlled SAPF provides compensates all current-related disturbances like current harmonics, reactive power control, power-factor correction, unbalanced current and reduction in Total Harmonic Distortion, so on. The performance of proposed SAPF is verified in balanced non-linear loads by using classical PI and proposed Intelligent Fuzzy controller based IRP for attaining good compensation features. The proposed system is verified by using Matlab/Simulink tool; results are presented.

2. SHUNT-ACTIVE POWER FILTER FOR PQ IMPROVEMENT

In a modern power system, increasing of loads and nonlinear equipment's have been demanding the compensation of the disturbances caused for them. These non-linear loads may cause poor power factor and high degree of harmonics. Active power filter (APF) can solve problems of harmonic and reactive power simultaneously. APF's consisting of voltage source inverters and a dc capacitor have been researched and developed for improving the power factor and stability of transmission systems. APF have the ability to adjust the amplitude of the synthesized ac voltage of the inverters by means of pulse width modulation or by control of the dc-link voltage, thus drawing either leading or lagging reactive power from the supply [7]. APF's are an up-to-date solution to power quality problems. Shunt APF's allowed the compensation of current harmonics and unbalance, together with power factor correction, and can be a much better solution than conventional approach (capacitors and passive filters). The simplest method of eliminating line current harmonics and improving the system power factor is to use passive LC filters. However, bulk passive components, series and parallel resonance and a fixed compensation characteristic are the main drawbacks of passive LC filters.

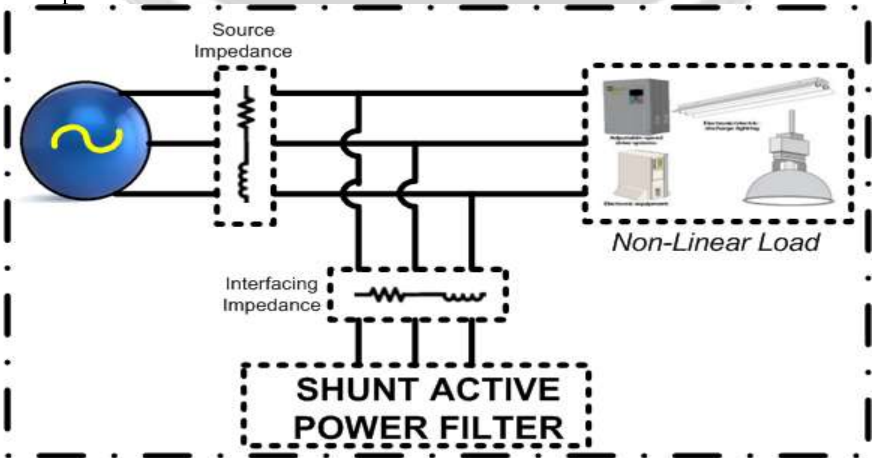


Fig.1 Block diagram of APF

Harmonic compensations have become increasingly important in power systems due to the widespread use of adjustable-speed drives, arc furnace, switched-mode power Supply, uninterruptible power supply, etc. Harmonics not only Increase the losses but also produce unwanted disturbance To the communication network, more voltage and/or current Stress, etc. Different mitigation solutions, e.g., passive filter, Active power line conditioner, and also hybrid filter, have been Proposed and used. Recent technological advancement of switching devices and availability of cheaper controlling devices, E.g., DSP-/field-programmable-gate-array-based system, Make active power line conditioner a natural choice to compensating the harmonics. Shunt-type active power filter (APF) is used to eliminate the current harmonics. The dynamic performance of an APF is mainly dependent on how quickly and how accurately the harmonic components are extracted from the load current. Many harmonic extraction Techniques are available, and their responses have been explored. In this project a new concept is proposed that is IRP algorithm in three-phase 3-wire shunt active power filter to compensate the harmonics. In APF design and control, instantaneous reactive power theory was often served as the basis for the calculation of compensation current. In this theory, the mains voltage was assumed to be an ideal source in the calculation process. However, in most of time and most of industry power systems, mains voltage may be unbalanced and/or distorted. Under such scenarios, this theory may not be valid for application. The *IRP* theory, since its proposal, has been applied in the control of three-phase active power filters. However, power system voltages being often non-ideal, in distorted voltage systems the control using the *IRP* theory provides good performance [8].

3. INSTANTANEOUS REAL POWER (IRP) THEORY

Among the several methods, IRP theory or p-q theory is one of the most common and probably it is widely used method. This section is organized as to describe succinctly the PQ method. The nonlinear load considered is a three-phase diode bridge rectifier. Fig.2 shows the basic configuration of p-q theory. The load current signals are transformed into the conventional rotating frame d-q. If theta is the transformation angle, the transformation is defined by:

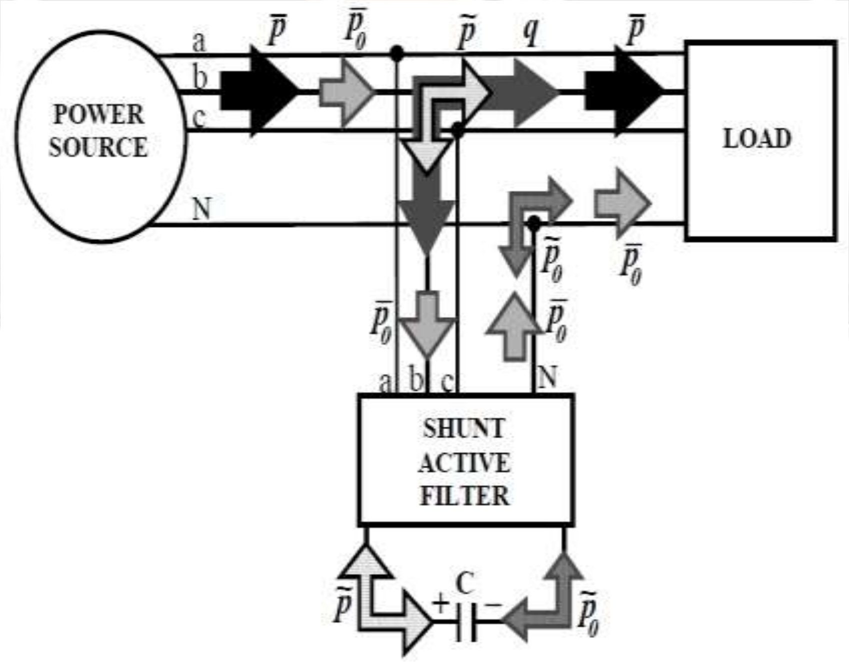


Fig.2 Basic principal of p-q theory

The control scheme of the shunt active power filter must calculate the current reference signals from each phase of the inverter using instantaneous real-power compensator. The block diagram as shown in Fig.3, that control scheme generates the reference current required to compensate the load current harmonics and reactive power. The PI controller is tried to maintain the dc-bus voltage across the capacitor constant of the cascaded inverter. This instantaneous real- power compensator with PI-controller is used to extracts reference value of current to be compensated. The proposed instantaneous real-power (p) theory derives from the conventional p-q theory or instantaneous power theory concept and uses simple algebraic calculations. It operates in steady-state or transient as well as for generic voltage and current power systems that allowing to control the active power filters in real-time.

The active filter should supply the oscillating portion of the instantaneous active current of the load and hence makes source current sinusoidal [9], [10].

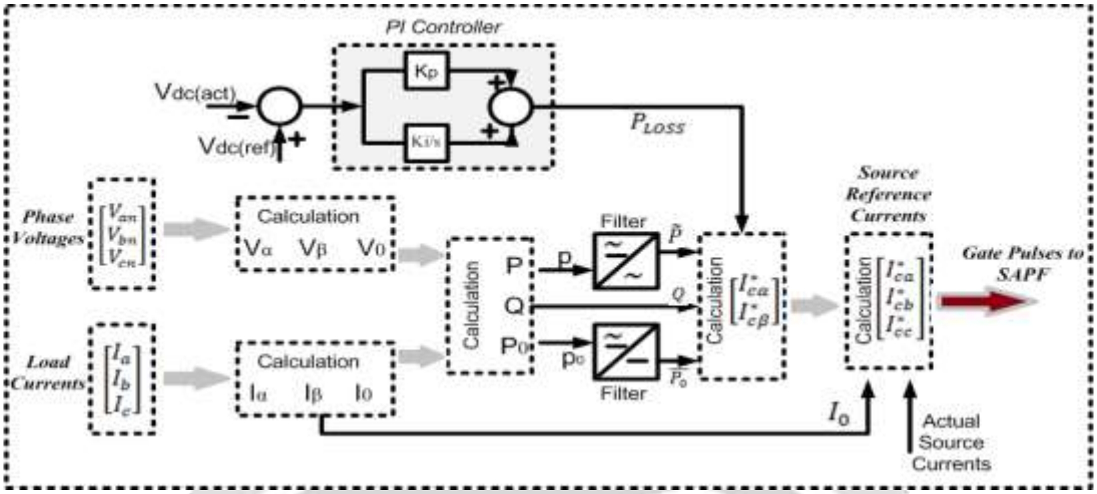


Fig.3 Reference current generator using instantaneous real-power theory

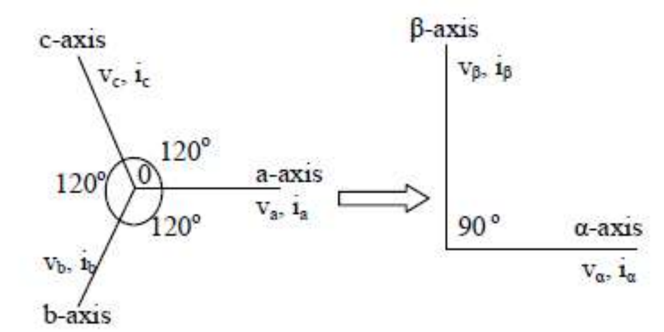


Fig.4: α-β coordinates transformation

The p-q theory performs a Clarke transformation of a stationary system of coordinates $a\ b\ c$ to an orthogonal reference system of coordinates α β . In $a\ b\ c$ coordinates axes are fixed on the same plane, apart from each other by 120o that as shown in Fig.4. Instantaneous reactive power theory is based on set of time domain instantaneous powers. Instantaneous reactive power theory involves algebraic transformations called Clarke's transformation of three-phase balanced voltage/current quantities to balanced two-phase quadrature quantities. The balanced three-phase voltage and current signals are transformed (using Clarke's transformation) to stationary quadrature signals using equations (1) and (2).

$$\begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} I_0 \\ I_\alpha \\ I_\beta \end{bmatrix} = \sqrt{2/3}\begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \tag{2}$$

The three-phase instantaneous active power component can be illustrated as in (3)

$$P_{3\emptyset} = V_0 I_0 + V_\alpha I_\alpha + V_\beta I_\beta \tag{3}$$

If the power components are to be separated with respect to their average and oscillating components:

$$\text{Zero-sequence power, } P_0 = \overline{P_0} + \widetilde{P_0} \tag{4}$$

$$\text{Real power, } P = \bar{P} + \tilde{P} \tag{5}$$

$$\text{Reactive power, } Q = \bar{Q} + \tilde{Q} \tag{6}$$

The loss component of the power is estimated by comparing the actual and reference DC-Link voltages. The power loss component along with the estimated power components signals (4), (5) and (6) are processed to obtain reference source current signals as (7) and the reference source current signals in α-β components are processed through inverse Clarke's transformation to obtain reference source current signals in a-b-c components as in (8).

$$\begin{bmatrix} I_{c\alpha}^* \\ I_{c\beta}^* \end{bmatrix} = \frac{1}{\sqrt{V_\alpha^2+V_\alpha^2}} \begin{bmatrix} V_\alpha & V_\beta \\ V_\beta & V_\alpha \end{bmatrix} \tag{7}$$

$$\begin{bmatrix} I_{ca}^* \\ I_{cb}^* \\ I_{cc}^* \end{bmatrix} = \frac{\sqrt{2}}{3} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_{c0}^* \\ I_{c\alpha}^* \\ I_{c\beta}^* \end{bmatrix} \tag{8}$$

The generated source reference currents are compared to actual currents to generate trigger pulses to switches of SAPF for harmonic compensation. Fig.5 illustrates Proposed system configuration with IRP Control theory for SAPF.

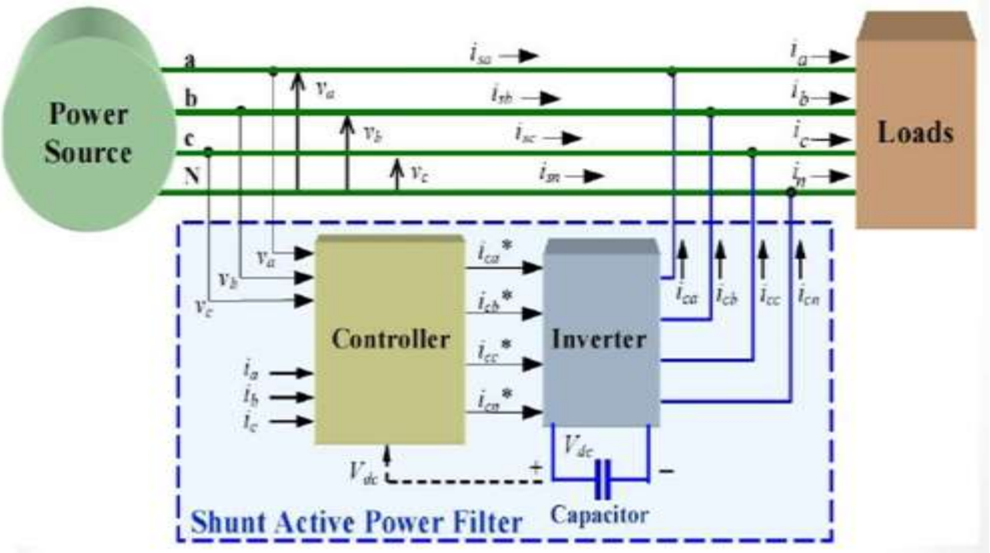


Fig.5 Proposed system configuration with IRP Control theory for SAPF

4. PROPOSED FUZZY-IRP CONTROL SCHEME FOR SAPF

The proposed fuzzy controller has been used extensively for many applications in control engineering, automation which is related to associate problems is designed easily. By utilizing the fuzzy evolution method which is relative functions of qualities work for designing the real time control objective. The fuzzy system in the process/plant is reflected by the control action of the design capabilities in both experience as well as intuitive specific functioning manner. It is mostly commanded for the control scheme of resembled on efficient mathematical plant model [11]. The fuzzy control strategy uses the linguistic information which has many advantages may include the high robust performance, greater strength, model free, attain the universal approximation theorem with rule based algorithm has been selected.

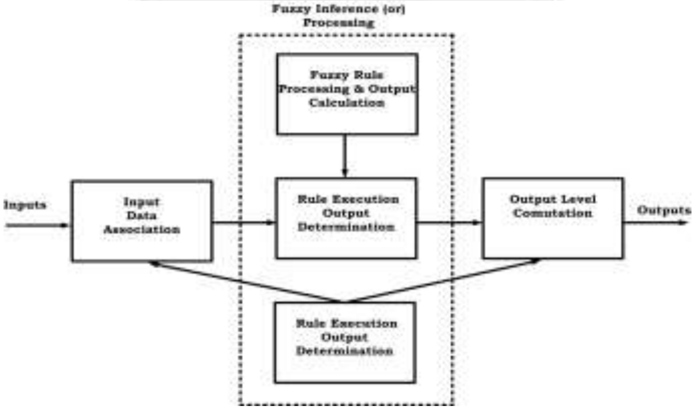


Fig.6 Configuration of Fuzzy Logic Inference Control Objective

For instance, designing the controller can takes place to attain definite performances by using bode/nyquist, these plots requires the significance of more time & analysis. Characterization of fuzzy logic controller (FLC) is mainly depends by its capability of adaptive nature. Such adaptive characteristics by pushing the system to generate the robust appearance with various variations that is more uncertain. The creation of input information with the evaluation of the IF....THEN rules which are produced by the several linguistics logics. After the fuzzification process the rule processing stage reaches at the point of outcome summary, de-fuzzification process is started. The de-fuzzification process is carried during the final stage; the coming inferences are transformed to real data output by fuzzy enhancer. Hence, data is utilized as interfaced module for the need of processing [12]. The configuration of fuzzy logic inference control objective is depicted in Fig.6. The proposed fuzzy-logic controller membership functions are depicted in Fig.7 and the rule base is illustrated in Table.1.

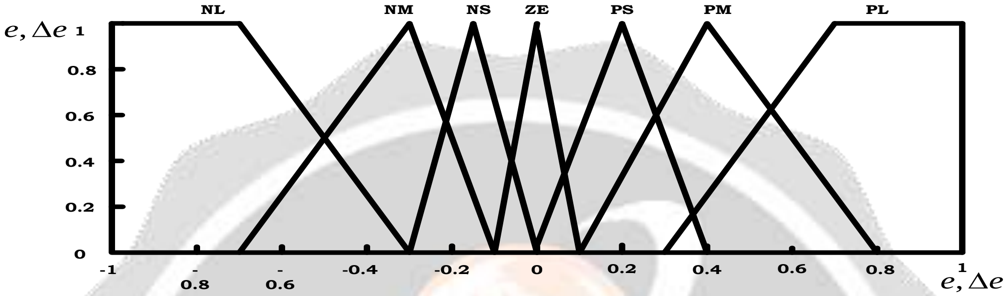


Fig.7 Fuzzy Logic Membership Functions

Table.1 Fuzzy Logic Rules

	NB	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	NM	NS	ZE	PS	PM	PB

The operational logics of the fuzzy logic control objective have been illustrated by linguistic nature is differentiated from the mathematical notations. In spite of linguistic terms delivers the derived methods that are most enhanced and feasible operational characteristics. This fuzzy logic control objective belongs to the symbolic nature control action that regards to a special class. The block diagram of proposed Fuzzy-IRP control scheme is illustrated in Fig.8.

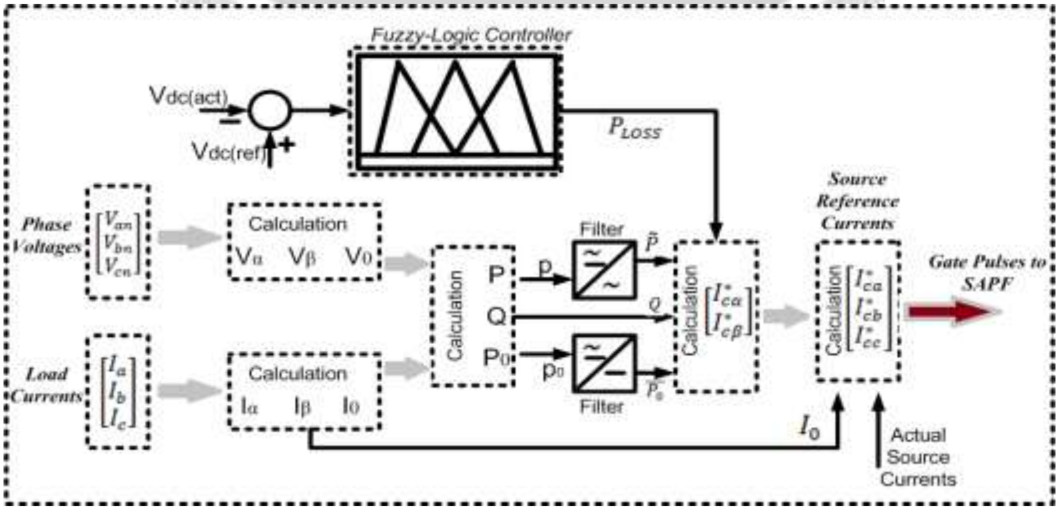


Fig.8 Block Diagram of Proposed Fuzzy-IRP Control Scheme

5. MATLAB/SIMULINK RESULTS & ANALYSIS

The performance of Shunt-Active Power Filter for Power-Quality Improvement Using Classical PI-IRP Control Scheme and Proposed Fuzzy-IRP Control Scheme is verified by using Matlab/Simulink modelling tool. The simulation results are carried based on various cases such as described as below and system specifications illustrated in Table.2.

Table.2 System Specifications

S. No	Parameter	Value
1	Three-Phase Programmable Voltage Source	Vrms-415V, Fs-50Hz
2	Load Impedance	R_L-20 Ω, L_L-20mH
3	DC-Link Capacitor	Vdc-880V, C_{dc}-1500µF
4	Line Interfacing Filter	R_f-1Ω, L_f-100 µH
5	PI Controller	Kp-0.1, Ki-2

5.1 WITHOUT SHUNT-ACTIVE POWER FILTER

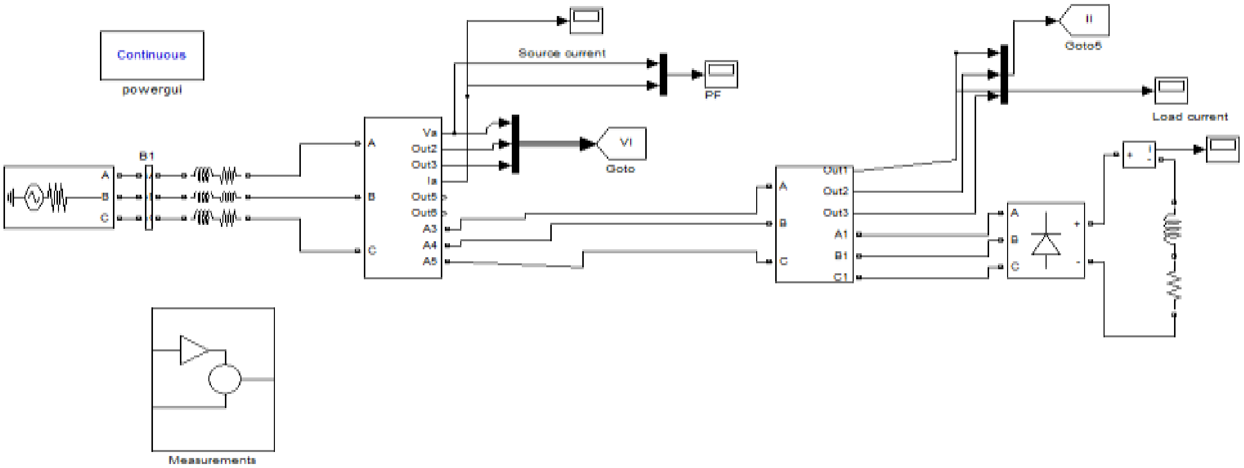
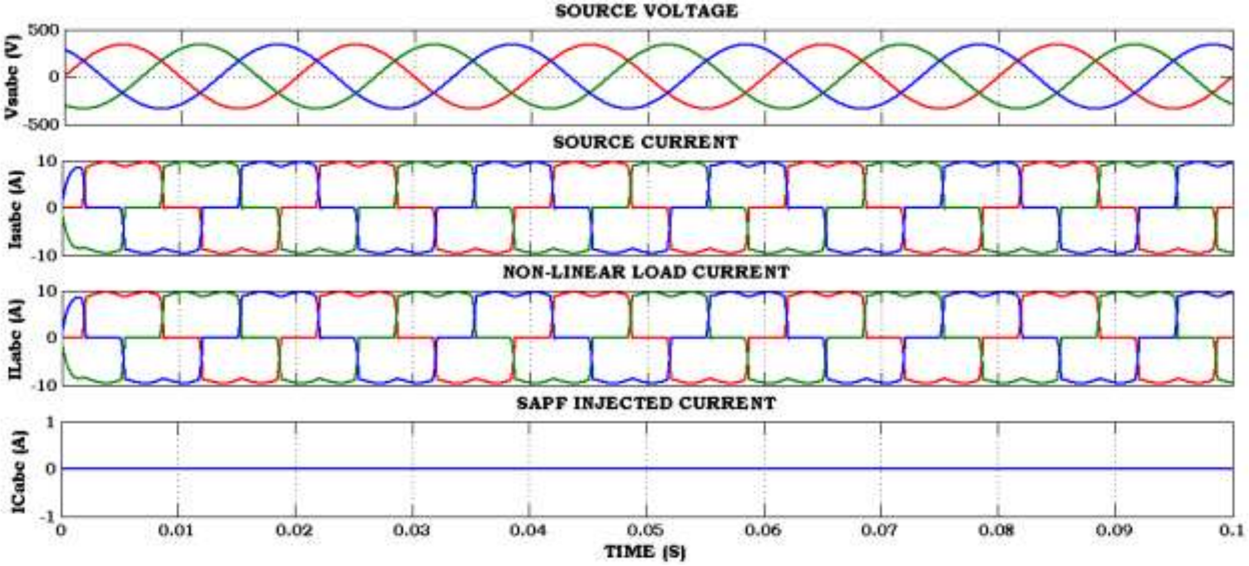
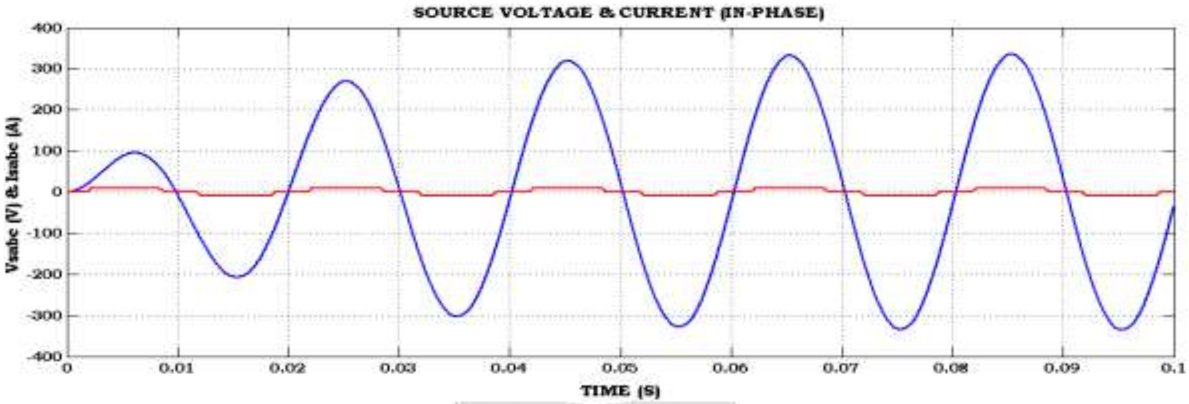


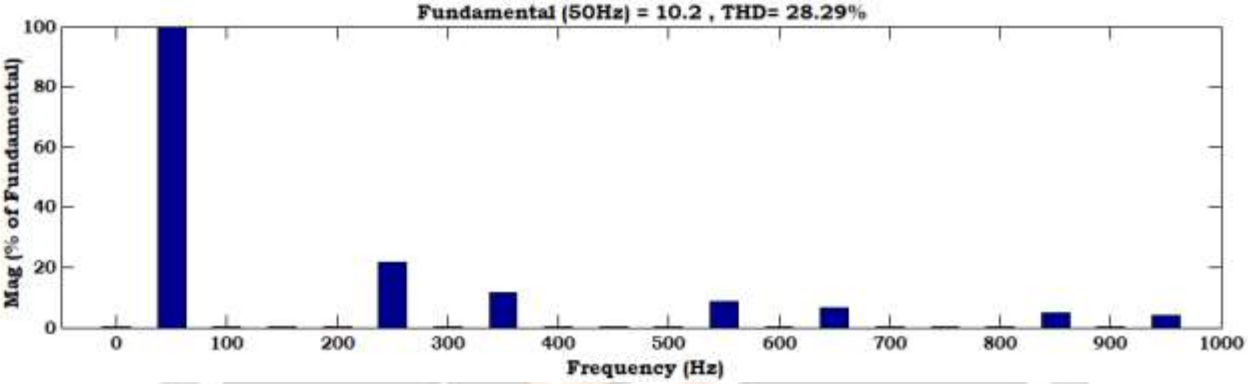
Fig.9 Matlab/Simulink Model of Power Distribution System without SAPF under Balanced Non-Linear Load



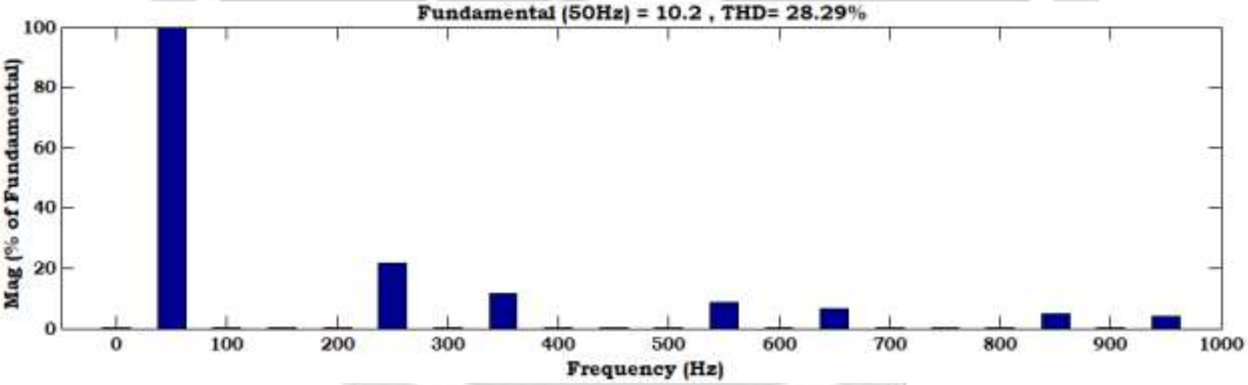
(a) Source Voltage, Source Current and Load Current and SAPF Injected Current



(b) Source Voltage & Current (Non In-Phase Condition)



(c) THD of Source Current



(d) THD of Load Current

Fig.10 Simulation Results of Power Distribution System without SAPF under Balanced Non-Linear Load

The Matlab/Simulink Model of Power Distribution System without SAPF under Balanced Non-Linear Load is depicted in Fig.9.The Simulation Result of Power Distribution System without SAPF under Balanced Non-Linear Load is depicted in Fig.10. It includes, (a) Source Voltage, Source Current, Load Current, (b) Source Voltage & Current (Non In-Phase Condition), (c) THD of Source Current, (d) THD of Load Current, respectively. The non-linear loads is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices, the source or PCC current as harmonized and affecting the specifications in power distribution system. In this case, there is no presence of SAPF compensator; the source current is same as load current and no current injection into the system. Then, the source current is non in-phase to the source voltage which represents the non-ideal power factor at PCC of the ditribution system due to presence of harmonized distortions. Thus, The THD of source current and load current is same and not happening any compensation which is measured with a value of 28.29%.

5.2 THE PERFORMANCE OF SHUNT-ACTIVE POWER FILTER FOR POWER-QUALITY IMPROVEMENT USING CLASSICAL PI-IRP CONTROL SCHEME

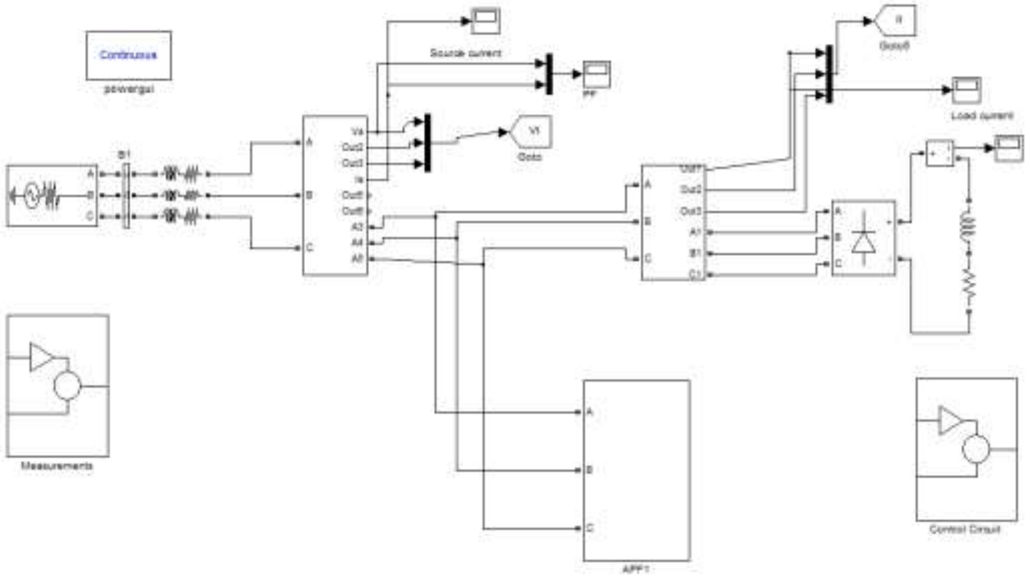
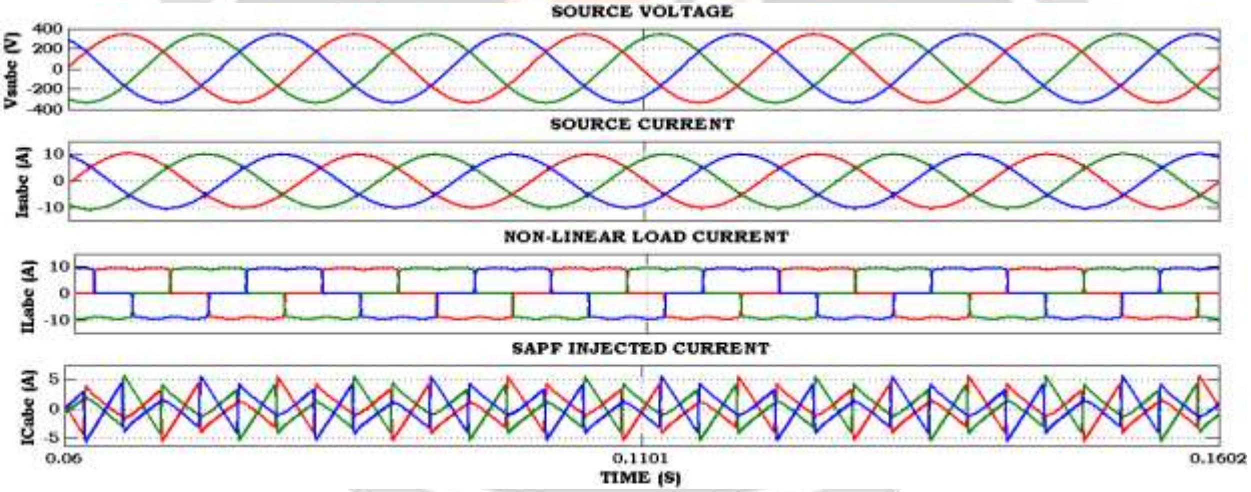
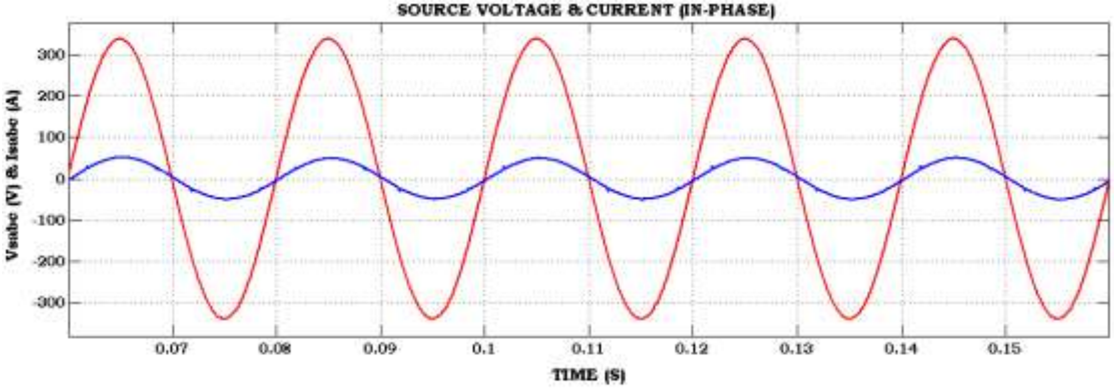


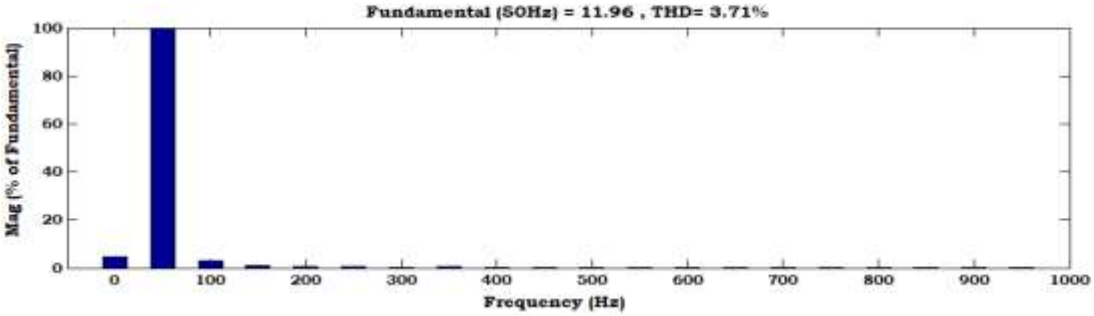
Fig.11 Matlab/Simulink Model of Shunt-Active Power Filter for Power-Quality Improvement Using Classical PI-IRP Control Scheme



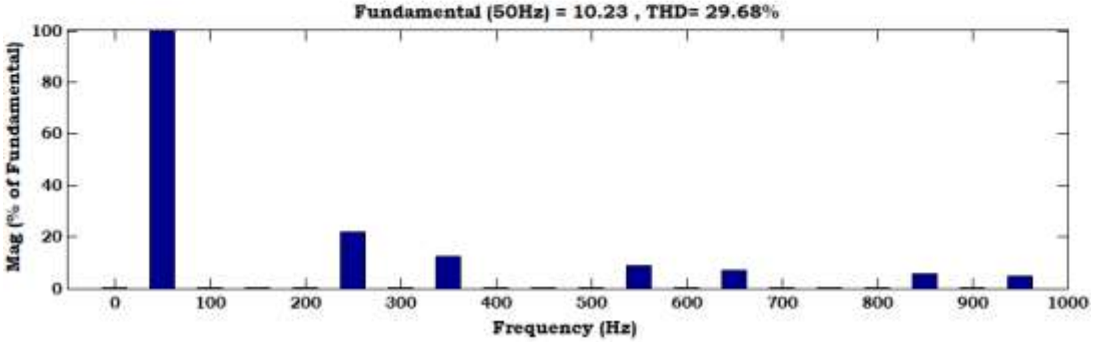
(a) Source Voltage, Source Current and Load Current



(b) Source Voltage & Current (In-Phase Condition)



(c) THD of Source Current

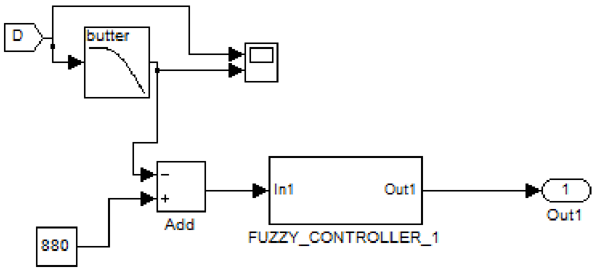


(d) THD of Load Current

Fig.12 Simulation Results of Shunt-Active Power Filter for Power-Quality Improvement Using Classical PI-IRP Control Scheme

The Matlab/Simulink Model of Shunt-Active Power Filter for Power-Quality Improvement Using Classical PI-IRP Control Scheme is depicted in Fig.11.The Simulation Result of Shunt-Active Power Filter for Power-Quality Improvement Using Classical PI-IRP Control Scheme is depicted in Fig.12. It includes, (a) Source Voltage, Source Current, Load Current, (b) Source Voltage & Current (Non In-Phase Condition), (c) THD of Source Current, (d) THD of Load Current, respectively. The non-linear loads is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices, the source or PCC current as harmonized and affecting the specifications in power distribution system. In this case, the Classical PI-IRP Controlled SAPF compensator is used to compensate the harmonics coming from non-linear Diode-Bridge rectifier; the source current is compensated and attains sinusoidal, linear and balanced nature compared to load current. Then, the source current is sinusoidal and in-phase to the source voltage which represents the ideal power factor at PCC of the ditribution system. The THD of source current and load current is measured with a value of 29.68%. The THD of source current is measured with a value of 3.71% by using PI-IRP controlled SAPF device; it is complying with IEEE standards.

1.6.3 THE PERFORMANCE OF SHUNT-ACTIVE POWER FILTER FOR POWER-QUALITY IMPROVEMENT USING PROPOSED FUZZY-IRP CONTROL SCHEME



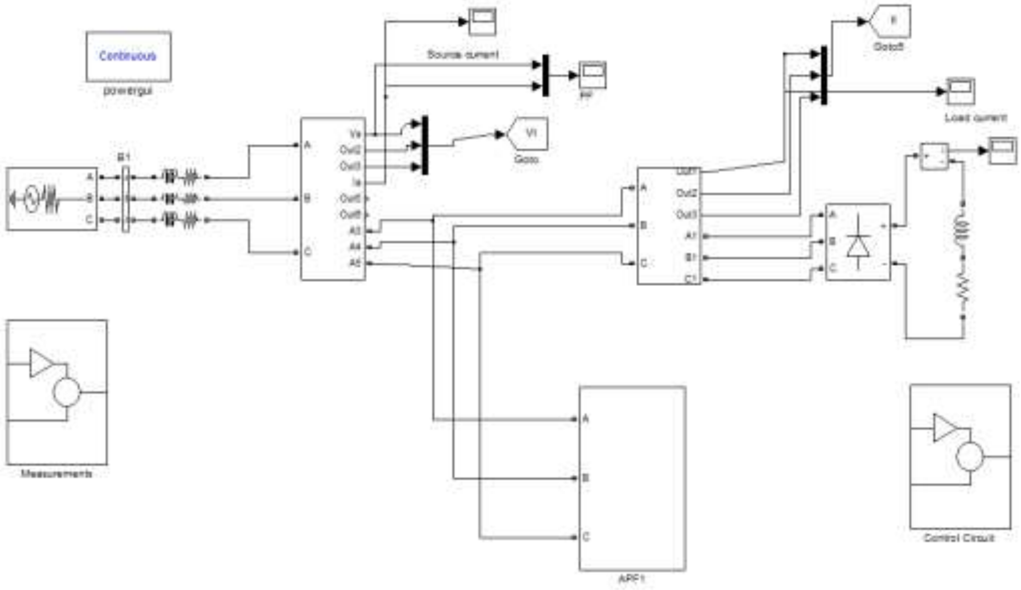
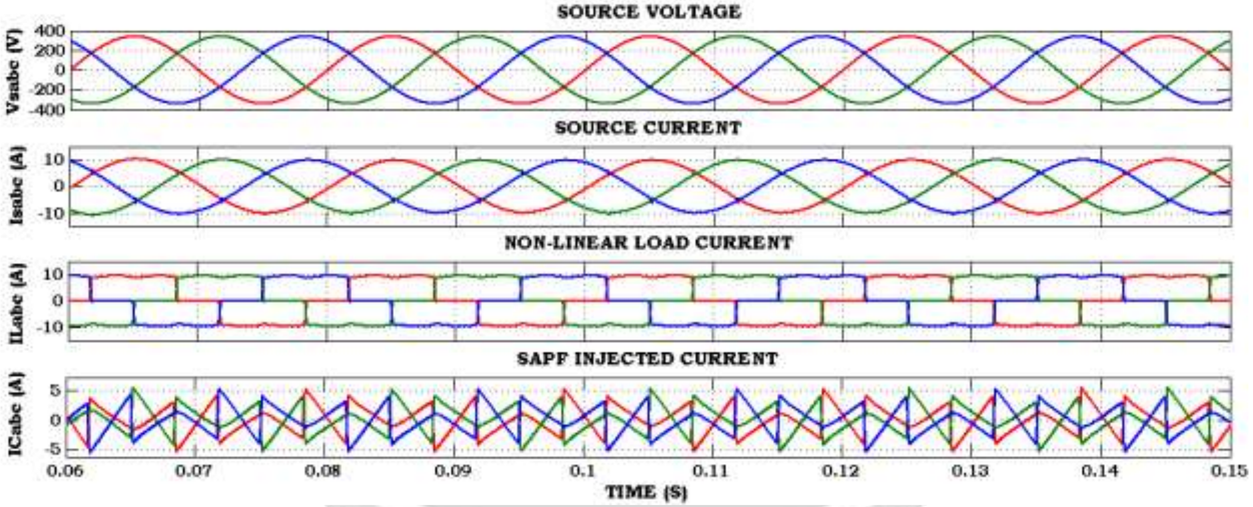
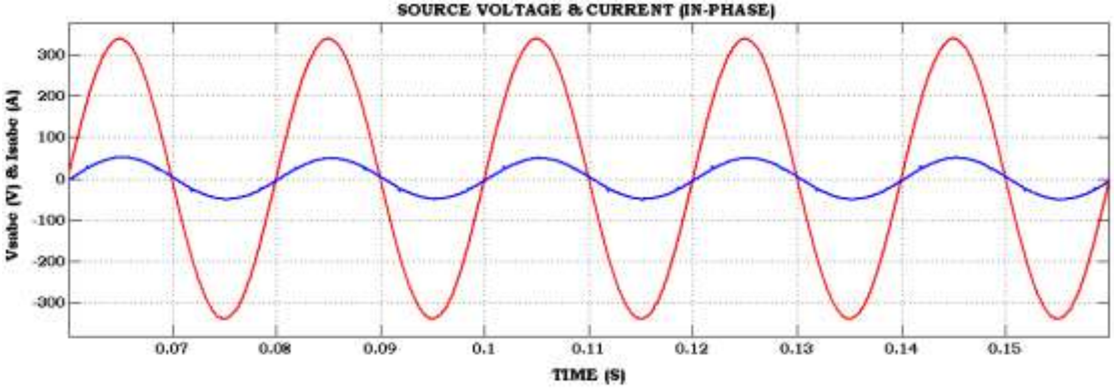


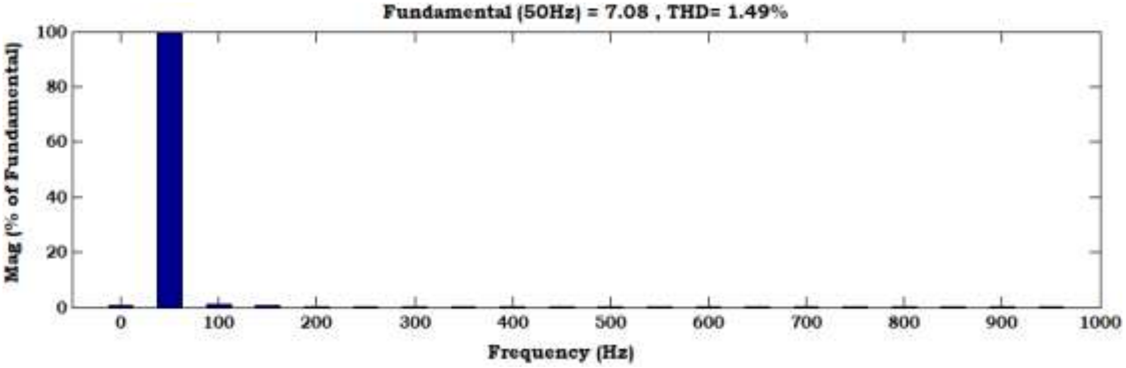
Fig.13 Matlab/Simulink Model of Shunt-Active Power Filter for Power-Quality Improvement Using Proposed Fuzzy-IRP Control Scheme



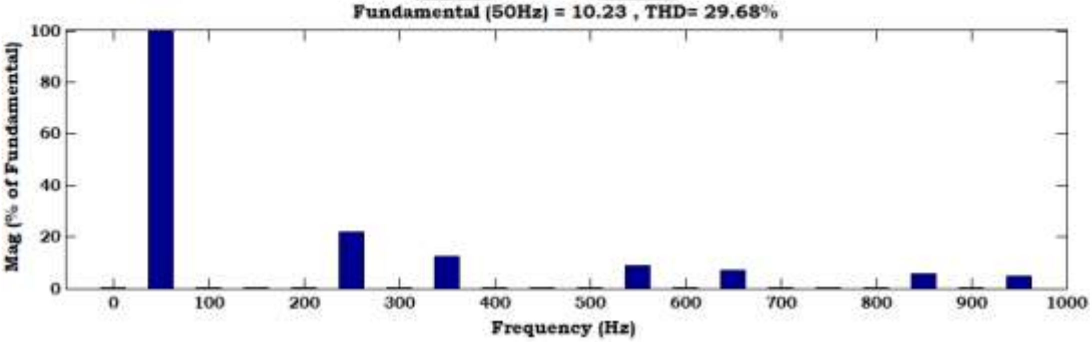
(a) Source Voltage, Source Current and Load Current



(b) Source Voltage & Current (In-Phase Condition)



(c) THD of Source Current



(d) THD of Load Current

Fig.14 Simulation Results of Shunt-Active Power Filter for Power-Quality Improvement Using Proposed Fuzzy-IRP Control Scheme

The Matlab/Simulink Model of Shunt-Active Power Filter for Power-Quality Improvement Using Proposed Fuzzy-IRP Control Scheme is depicted in Fig.13.The Simulation Result of Shunt-Active Power Filter for Power-Quality Improvement Using Proposed Fuzzy-IRP control scheme is depicted in Fig.14. It includes, (a) Source Voltage, Source Current, Load Current, (b) Source Voltage & Current (Non In-Phase Condition), (c) THD of Source Current, (d) THD of Load Current, respectively. The non-linear loads is powered by three-phase AC distribution system through three-phase Diode-Bridge rectifier with a value of 415V, 50Hz. Due to these non-linear devices, the source or PCC current as harmonized and affecting the specifications in power distribution system. In this case, the proposed Fuzzy-IRP controlled SAPF compensator is used to compensate the harmonics coming from non-linear Diode-Bridge rectifier; the source current is compensated and attains sinusoidal, linear and balanced nature compared to load current. Then, the source current is sinusoidal and in-phase to the source voltage which represents the ideal power factor at PCC of the ditribution system. The THD of source current and load current is measured with a value of 28.29%. The THD of source current is measured with a value of 1.49% by using Fuzzy-IRP controlled SAPF device; it is complying with IEEE standards. The THD analysis with classical PI-IRP and Proposed Fuzzy-IRP Control Scheme is illustrated in Table.3.

Table.3 Harmonic Analysis

	THD in Source Current	THD in Load Current
Without SAPF	28.29 %	28.29 %
With Classical PI-IRP Controlled SAPF	3.71 %	29.68 %
With Proposed Fuzzy-IRP Controlled SAPF	1.49 %	29.68 %

5. CONCLUSION

The proposed instantaneous p-q power theory along with Fuzzy-Logic controller is found to be an effective solution for power line conditioning by using shunt-APF. Shunt APF with the proposed controller reduces harmonics and provides reactive power compensation for non-linear load currents; as a result sinusoidal source current(s) and unity power factor are achieved under both transient and steady state conditions. The proposed Fuzzy-IRP controller uses reduced computation for reference current calculations compared to conventional PI-IRP control approach. As evident from the simulation studies, the THD of the source current after compensation is 1.49% which is less than *5%*, the harmonic limit imposed by the IEEE-519 standard. The Fuzzy-IRP controlled SAPF produces better compensation features over the classical PI-IRP and maintain PCC/source as sinusoidal, balanced and linear nature. During both controllers, the THD of source current is well within IEEE-519 standards which imply the enhanced PQ features in distribution network.

6. REFERENCES

[1] R.N. Beres, X. Wang, M. Liserre et al., "A review of passive power filters for three-phase grid-connected voltage-source converters", IEEE J. Emerg. Sel. Top. Power Electron, vol. 4, no. 1, pp. 54-69, 2016.
[2] A. P. Panchbhai, N. N. Prajapati and S. R. Parmar, "Shunt Active Filter for Harmonic And Reactive Power Compensation Using P-Q Theory", IEEE international Conference On Power and Embedded Drive Control, 2017.
[3] Sango Ravindra, Dr. V. C. Veera Reddy,Dr. S. Sivanagaraju, Devineni Gireesh Kumar; " Design of Shunt Active Power Filter to eliminate the harmonic currents and to compensate the reactive power under distorted and/or imbalanced source voltages in steady state :;" IJSER, Volume 3, Issue 1, January-2012 ISSN 2229-5518.
[4] K. Steela and B. S. Rajpurohit, "A survey on active power filter control strategies", Conf. IEEE 6 th India International Conference on Power Electronics, pp. 1-6, 2014.
[5] Amin Talebkhah, Milad Samady Shadlu and Seyyed Majid Fatemi, "Control Strategy of a Single Phase Active Power Filter with Adjustable DC Link Capacitor Voltage for THD Reduction in Nonlinear Loads", Power Electronics Drive Systems and Technologies Conference (PEDSTC) 2019 10th International, pp. 606-611, 2019.
[6] L. Motta and N. Faúndes, "Active / passive harmonic filters: Applications challenges & trends", Proc. 2016 17th International Conference on Harmonics and Quality of Power (ICHQP), pp. 657-662, 2016.
[7] G. Satyanarayana, K. Lakshmi Ganesh, C. Narendra Kumar, M. Vijaya Krishna, "A critical evaluation of power quality features using Hybrid Multi-Filter Conditioner topology", Green Computing Communication and Conservation of Energy (ICGCE) 2013 International Conference on, pp. 731-736, 2013.
[8] M. Jauhari, D.C. Riawan and M. Ashari, "Design of Digital Controller for Active Power Filter Based on P-Q Theory", proceeding of International conference on engineering and natural scienc (ICENS), pp. 39-42, 2016.
[9] B. Harshithananda, S. Priyashree and H. A. Vidya, "Mitigation of harmonics using hysteresis control technique of VSI based active power filter", Conf. Int. Conf on Smart grids Power and Advanced Control Engineering, pp. 258-261, 2017.
[10] M. Jauhari, D.C. Riawan and M. Ashari, "Control Design For Shunt Active Power Filter Based On P-Q Theory In Photovoltaic Grid-Connected System", International Journal of Power Electronics and Drive Systems, vol. 9, no. 3, pp. 1064-1071, 2018.
[11] G. Satyanarayana, K. Lakshmi Ganesh “Tuning a Robust Performance of Adaptive Fuzzy-PI Driven DSTATCOM for Non-Linear Process Applications” is Published in Springer LNCS Series-8947, ISSN-0302-9743, pp.523-533, July 2015
[12] G. Satyanarayana, K.N.V. Prasad, G. Ranjith Kumar, K. Lakshmi Ganesh, "Improvement of power quality by using hybrid fuzzy controlled based IPQC at various load conditions", Energy Efficient Technologies for Sustainability (ICEETS) 2013 International Conference, pp. 1243-1250, 2013.