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Enhancement of Power Quality With Hybrid-Fuzzy Based Active Compensation Scheme for Grid Connected-Hybrid Power Generator

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Abstract

A hybrid control system which combines the fuzzy logic system features and conventional PI controller features in improving the power quality of supply in distribution network when grid is connected with Renewable energy sources . voltage as feedback is used in the control strategy proposed for improving the performance of Active Power Filter under various dynamic conditions. A 4-leg voltage-source inverter(VSI) with prescient control plan is utilized as a dynamic power channel. Harmonics generated by non-liner 3-phase and single loads and unbalanced currents also compensated by using a Voltage source inverter with four legs. Dynamic channel scientific demonstrating with the thought of force framework identical impedance is utilized to outline the prescient control calculation. Under different conditions performance of the hybrid controller system with APF for improving the power quality in grid connected DG sources is verified by MATLAB/SIMULINK.

Keywords

Hybrid Fuzzy Logic Controller, Distribution Generation(DG), , current control, Fuzzy Controller, Active power filter(APF) and Power Quality(PQ), PI Controller.

1 Introduction

Modern power system with distributed generation (DG) which includes photovoltaic (PV), wind turbine ,fuel cell and micro hydro turbines are introduced at the distribution level due to emission of various toxic pollutants by the conventional energy sources such as thermal and nuclear counterparts. By the deep penetration of DGs in distributed networks made the management of the grid so complex. Due to which power quality is affected a lot and also making very difficult to meet the standards of power quality. But Renewable Energy Sources use power electronic converters.

Among Various RES, the solar/wind and hybrid power plants is more reliable source of utility. Almost in all RES battery bank is used to store and extract maximum power from it. But, due to chemical pollution and high initial cost of batteries made to think about direct connection of RES to the grid. To interconnect RES to the grid system, many problems which are to be taken care like power quality, Protection, Stability and Reliability issues. But all these problems are overcome with the advances in technologies. After many years of extensive research they come out with a solution which addresses the power quality problem mainly by shunt active filter. Instead of using extra hardware equipment for shunt active filter features, The RES interfacing inverter[1] to grid itself will play the role of shunt active filter is proposed in this paper. The grid voltages may not be balanced and not pure sinusoidal always, linear loads are affected by these poor conditions and may supply harmonics into it. By use of Shunt active filter will overcome the problems due to distorted and unbalanced grid conditions. Simulation of the control system is required under these several conditions [2].

The two important tasks has to be done by controller is extraction of required reference current from the distorted line current and generation of switching patterns by PWM-current controller. Similarly to extract the harmonic components various control strategies are proposed, Though conventional PI controller is easy but its performance under parameter variations and disturbances its performance is degraded. Another disadvantage with the PI controller is that the gains are chosen randomly. These problems are overcome by using Fuzzy Logic Controllers (FLCs).Now a days these controllers are used extensively in various power electronic applications. The main advantages of Fuzzy controllers are they can handle nonlinearities and simple in design. They don't require any accurate mathematical model.

To control the DC-link voltage[3] and to reduce the THD proposed hybrid fuzzy-logic controller serves as a intelligent controller. The design Procedure and the operation of predictive control scheme is clearly explained with mathematical modelling of the 4L-VSI.Reference current generation is also explained with mathematical modelling.. Finally, the performance of the proposed APF in terms of THD is explained under different conditions with MATLAB/SIMULINK.

2 Shunt Active Filter

Many types of non-linear loads may inject current harmonics to the grid source side parameters gets distorted, Due to that sensitive loads connected at the pcc may be damaged. These currents increases losses when they flown through transformer and even decreases the efficiency of overall system[8-9].Due to its low cost and simplicity in design Passive LC filters are used for reducing current harmonics. But, passive filters have so many demerits like Resonance problems, tuning and big size. On the other side by the use of Active power filter as shown in Fig.1 will solve the load current balancing, reactive power supply, current harmonics better option than the conventional passive LC filter.

So, To compensate current harmonics and improve the performance shunt active filter is connected as shown in Fig.1. Reference currents are generated by control strategy in the operation of shunt active filter in the first stage of two steps and in the second step these currents are compared with the inverter output currents and according to that pulses are generated. In the final Stage these pulses are used to synthesize the reference currents.

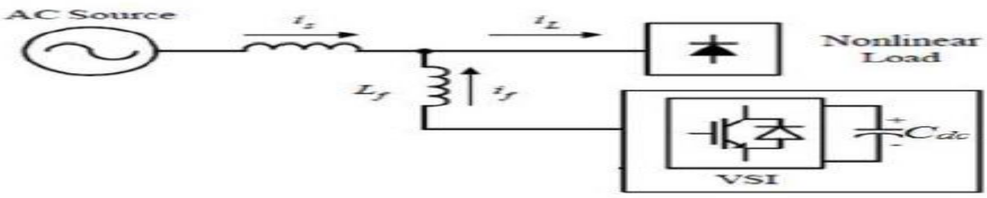

Fig.1 Basic circuit diagram of Shunt active filter

3 4-Leg Shunt Active Power Filter(APF)

Two kinds of Voltage source inverter(VSI) topologies are used in 3-phase 4-wire systems like 3-leg inverter and 4-leg inverter in which for compensation of zero sequence (neutral) current 1-leg in 4-legs is exclusively used. Though in 3-leg inverter switching devices are less control circuit design is difficult and large capacitors in DC-link are introduced and also to keep the voltage across capacitor constant is main problem. where as in the 4-leg shown in Fig.3 is used for compensation of neutral current and also this scheme use DC-link voltage effectively so it don't require much DC-link capacitance .

The Main block diagram of a 4-leg shunt APF with different loads commonly shown as Z_L is shown in Fig.2.By using filter inductor at middle part each branch is connected to power system. In 4-leg VSI with APF[10-13], 3-legs are used to compensate 3-ϕ currents and for neutral current compensation remaining leg is used. An Energy storage capacitor with 8 IGBT Switches in a 4-leg VSI with hysteresis current controller is used to create pulses for each inverter branch . RC high–pass channel is utilized to take out the higher request current harmonics created by the IGBTS of the PWM Inverter.

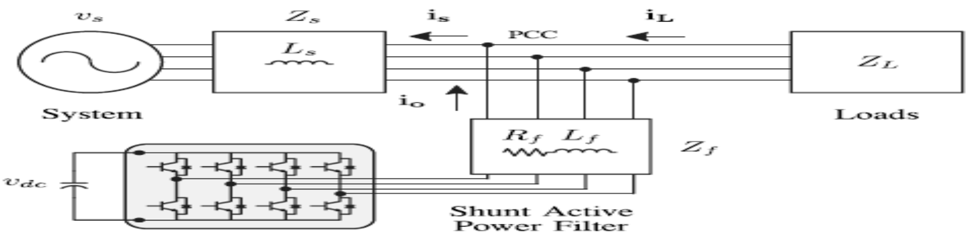

Fig. 2. Equivalent circuit diagram of the proposed shunt APF

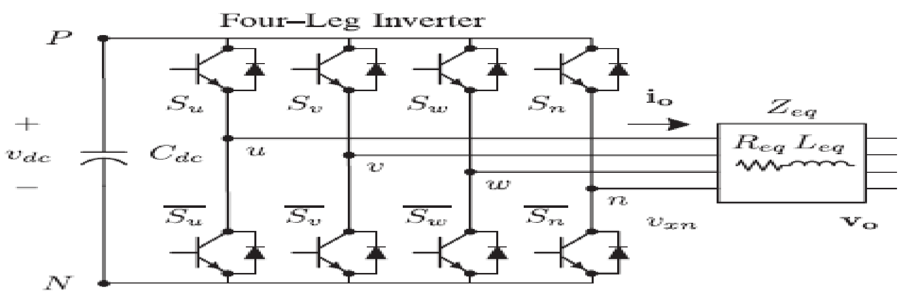

Fig.3. Four-leg converter with PWM-VSI topology

The voltage across any leg of the converter with respect to neutral point (*n*), is expressed in terms of switching states, as follows:

$$v_{xn}=S_x\text{-}S_nV_{dc},x=u,v,w \quad (1)$$

By using equivalent circuit mathematical model derived from the figure shown in Fig.3 is

$$v_o = v_{xn} - R_{eq} i_o - L_{eq} \frac{d i_0}{dt} \quad (2)$$

Where R_{eq} and L_{eq} are the 4Leg-VSI output parameters are obtained from Thevenin's impedances Z_{eq} at the converter output terminals . Therefore, the Thevenin's equivalent impedance is calculated by and a parallel arrangement between the system equivalent impedance Z_s and the load impedance Z_L with the ripple filter impedance Z_f in series is given as follow

$$Z_{eq} = \frac{ZsZL}{Zs+ZL} + Z_f \approx Z_s + Z_f \quad (3)$$

4 Reference Current Generation Scheme

In this method, the error due to the deviation between the reference voltage and DC link voltage is controlled with the help of PI controller. Trial and error method is used to tune the parameters of PI controller. By modifying the proportional and integral gains outputs of the controller are observed. When satisfactory settling time and overshoot are obtained those gains are fixed. After sensing the 3-phase currents from system they converted to d-q reference frame. To synchronize the circuit with the grid voltage a PLL is used. Active current and reactive current are represented as I_d and I_q respectively. By the use Low pass filter the fundamental components of I_d& I_q are obtained, from that harmonic components are found. To suspend harmonics components it is multiplied by -1.The result of PI controlled DC link voltage controller is added with the d axis component of the current, which gives the required reference currents . These are converted to required abc frame and given as input to current controller. For generating pulses to inverter switches most commonly Hysteresis Current Controller is used by comparing actual and reference currents [4-6].

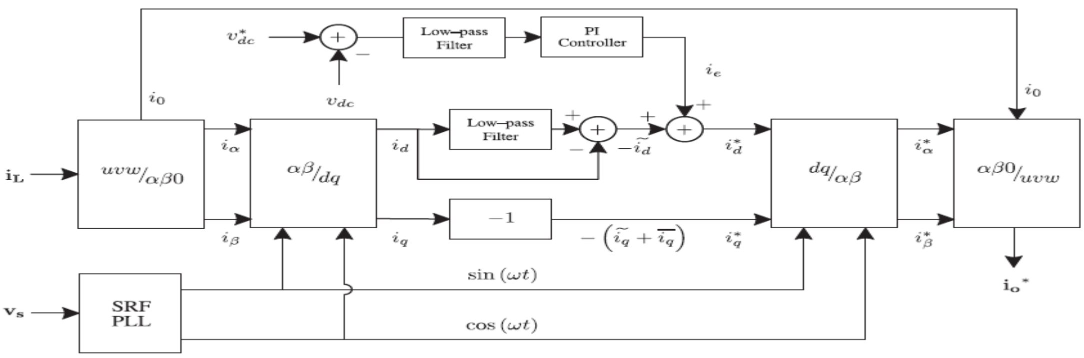

Fig. 4. Circuit model of dq-based current reference generator.

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \sin\omega t & \cos\omega t \\ -\cos\omega t & \sin\omega t \end{bmatrix} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{Lu} \\ i_{Lv} \\ i_{Lw} \end{bmatrix} \quad (4)$$

The current flowing through the neutral of the load is compensated by injecting the same value obtained from the phase-currents and phase-shifted by 180°, as shown below.

$$i_{on}^* = -(i_{Lu} + i_{Lv} + i_{Lw}) \quad (5)$$

5 Dc Link Voltage Control

The voltage over the electrolytic capacitor dynamic reaction does not influence transient reaction of the current. Because of that, for the dc-voltage control PI controller[7-9] might be a straightforward and viable arrangement. The dc-voltage remains steady until the dynamic influence devoured by the converter diminishments to a level where it can't compensate for its adversities. The dc-voltage Vdc is measured and a short time later differentiated and a consistent reference regard V*dc. The error(e) is made zero by PI controller, The augmentations Kp and Ki are Selected by the Required component response. Fig. 5 demonstrates that the simple block diagram of the PI controller is used to the dc-voltage exchange work G(s) which is given by a first order system..

6 Hybrid Fuzzy Logic Controller

Application of intelligent control Techniques to power system[15] is quickly developing now a days. The main quality of fuzzy logic controllers (FLCs) is that the control strategy is designed by expressing the rules in terms of linguistic terms which describe the behavior of the controller. In addition to that, FLCs are relatively easy to design and simple in implementation. Furthermore, dynamic performance of a system is obtained by the design of hybrid fuzzy logic controller for small signal and large signal model to meet the desired objectives.

.7 Matlab Modeling And Simulation Results

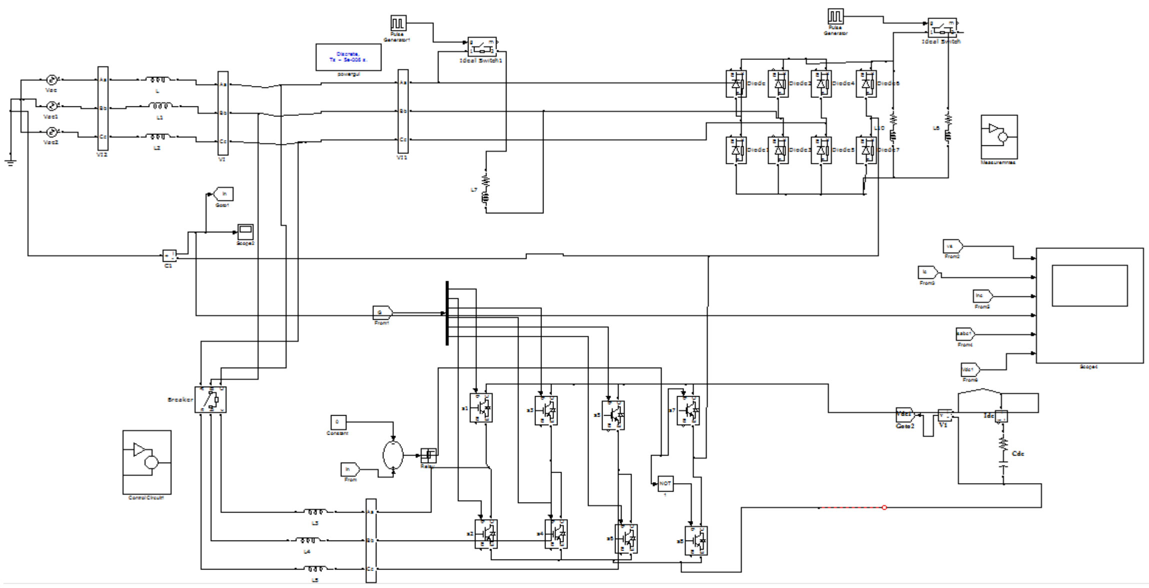

Fig.6 Matlab/Simulink Model of Proposed RES Fed 4-Leg APF system with formal PI & Intelligence Controllers

Case 1: Proposed RES Fed APF with Conventional PI Controller

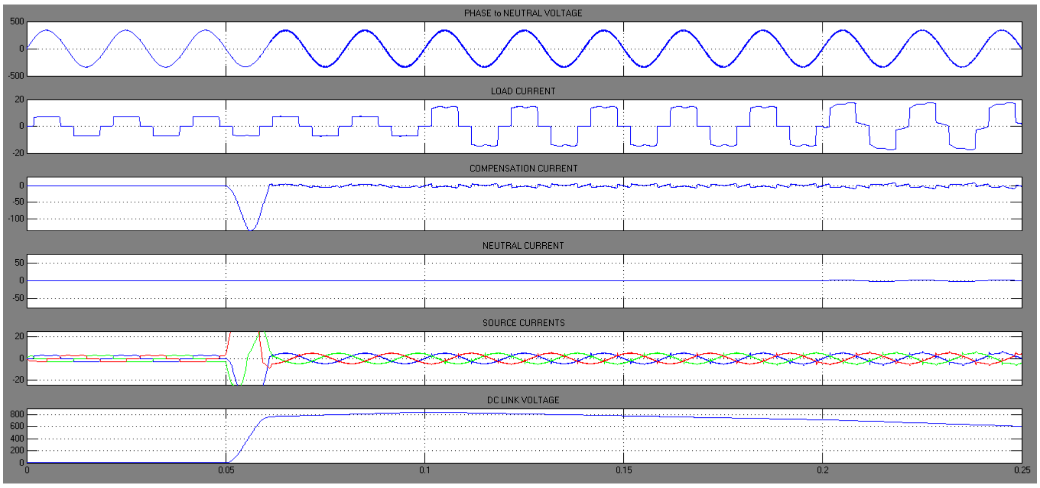

Fig.7. Simulation results for APF with PI Controller
(a)) Source Voltage(V_s). (b)) Load current(I_L). (c) Compensator Current(I_S).
(d) Neutral Current(I_n), (e) Source Current(I_s) (f) DC Link Voltage.

Fig.7. Simulation results for APF with PI Controller (a) Source Voltage(V_s). (b) Load current(I_l). (c) Compensator Current(I_c), (d) Neutral Current(I_n), (e) Source Current(I_s), (f) DC Link Voltage. Here compensator is turned on at 0.05 seconds, before we get a few music originating from non-straight load, then misshapes our parameters and get sinusoidal when compensator is in on.

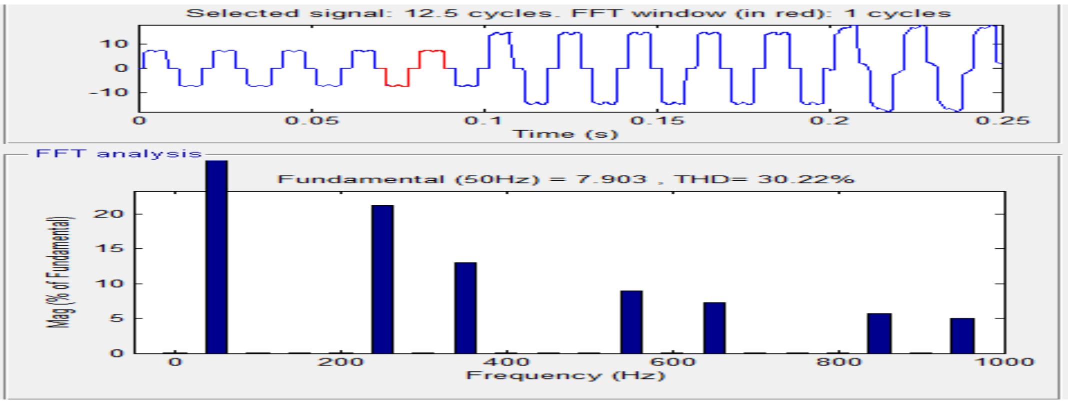

Fig.8 Phase-A Source Current FFT Analysis for without compensation scheme

Fig.8 demonstrates the Phase-A Source Current FFT Analysis without any compensation, here we end with 30.22%.

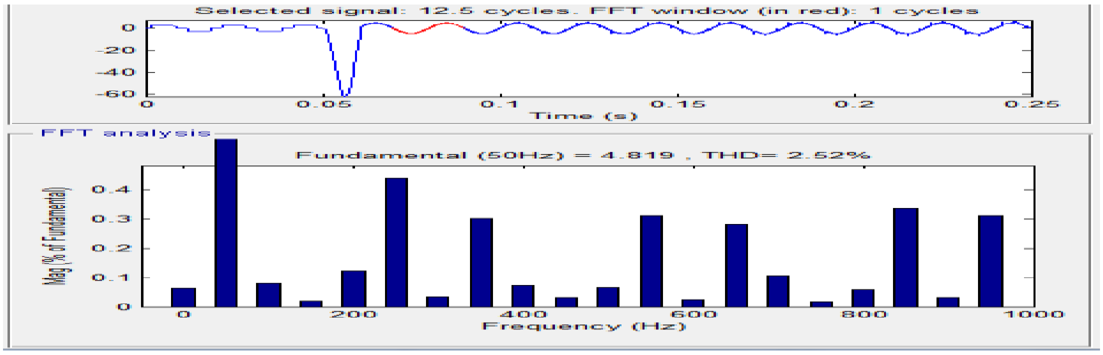

Fig. 9 Phase-A Source Current FFT Analysis with PI Controlled APF

Fig.9 demonstrates the Phase-A Source Current FFT Analysis with PI Controlled APF, here we get 2.52%.

Case 2: Proposed APF with Intelligence based Hybrid Fuzzy Controller

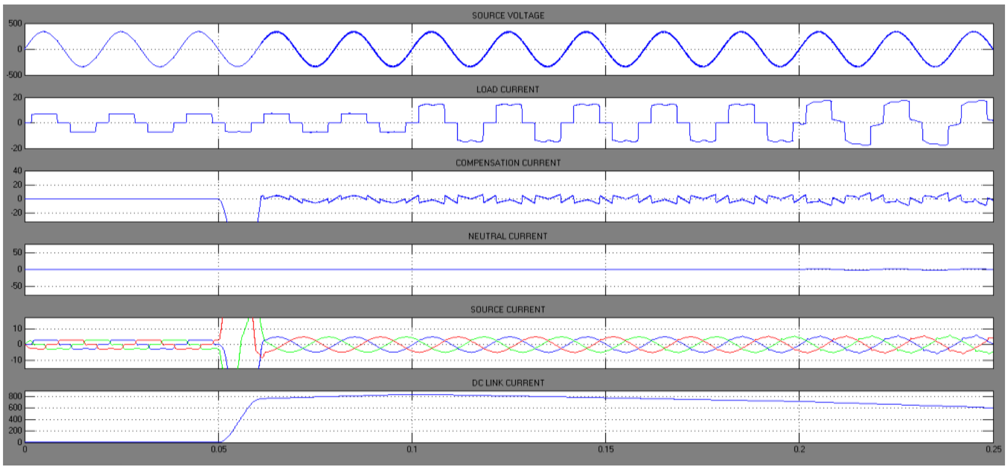

Fig.10 Simulation results for APF with Hybrid Fuzzy Controller
(a) Source Voltage(V_s). (b) Load current(I_l). (c) Compensator Current(I_c).
(d) Neutral Current(I_n).(e) Source Current(I_s).(f) DC Link Voltage.

. Fig.10 Simulation results for APF with Hybrid Fuzzy Controller (a) Source Voltage(V_s). (b) Load current(I_l). (c) Compensator Current(I_c), (d) Neutral Current(I_n), (e) Source Current(I_s), (f) DC Link Voltage. Here compensator is operated at 0.05 seconds, before we get some harmonics coming from non-linear load, then distorts our parameters and get sinusoidal when compensator is in on

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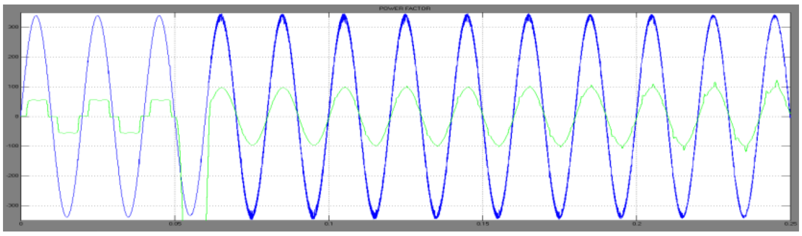

Fig.11 Power Factor for APF with Hybrid Fuzzy Controller

Fig. 11 demonstrates the power factor , it is clear from the figure after use of powerfactor variable is solidarity.

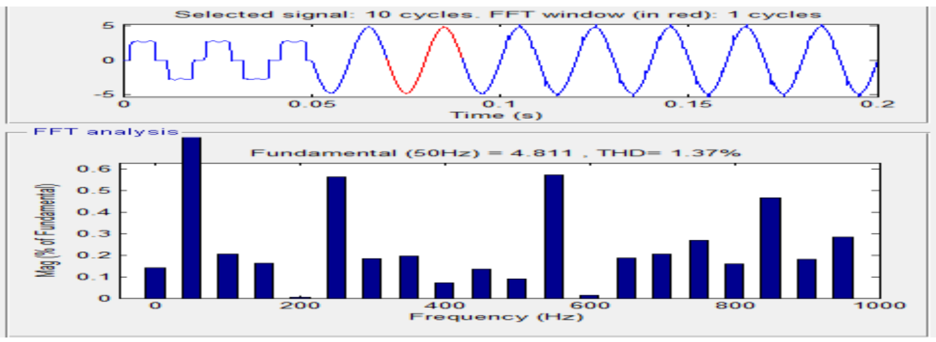

Fig. 12 Phase-A Source Current FFT Analysis with Fuzzy Controlled APF

Fig.12 shows the Phase-A Source Current FFT Analysis with Fuzzy Controlled APF, here we get 1.37%.

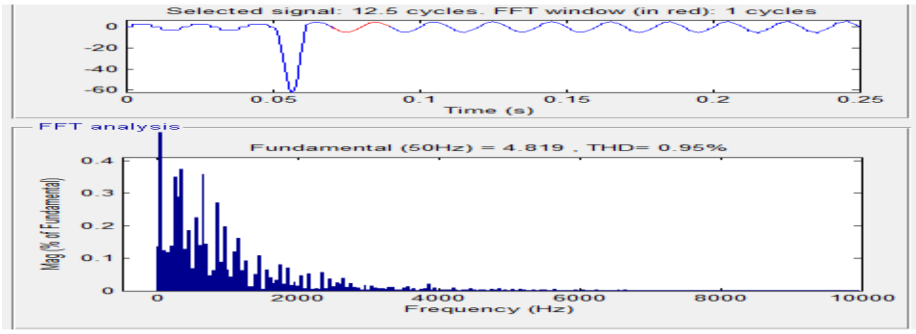

Fig. 13 Phase-A Source Current FFT Analysis with Hybrid Fuzzy Controlled APF

Fig.13 shows the Phase-A Source Current FFT Analysis with Hybrid Fuzzy Controlled APF, here we get 0.95%.

Conclusion

A Hybrid Wind-Solar is interconnected to GRID using grid interfacing inverter and DC-DC converter. The Inverter is operated according to the requirement like as a grid interfacing unit and as active filter. So the grid interfacing inverter has additional feature such as power quality improvement device in distribution system which is cost effective. Simulations are done in MATLAB Simulink by connecting Non linear loads to the system supplied with Renewable Energy sources using Conventional controller, Fuzzy Controller and Hybrid-Fuzzy controller. It has been watched that the APF with half and half fluffy controller have better execution in terms of THD incentive than different controllers.

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