Reduction of Harmonics in Grid Interfacing Hybrid Renewable Energy Sources at the Level of Distribution

K.Durga priyanka[1], T.Sridevi[2], J.Ramu[3]

Professor[1], Professor[2], professor[3]
Department of Electrical & Electronics
Swathi college of Engineering, Near ramoji film city, Hyderabad, Telangana, India

Abstract *— In power systems Renewable energy resources plays an important role. These renewable resources reduce the production of greenhouse gases and also it causes the environmental pollution. Renewable energy sources (RES) includes solar and wind, hydro energies. The nonlinear loads causes power quality problems like harmonics in source current, sag in voltages and swell in voltages etc. The main and important objective of the proposed project is to reduce source current harmonics and improve Total Harmonic Distortion (THD) in grid interfacing hybrid renewable energy conversion system (HRECS). The Voltage Source converter (VSC) will be perform multiple functions. The VSC (voltage source converter) can be operated as: 1) It injects power that is generated from RES (Renewable Energy Sources) to the grid, and 2) shunt APF (Active Power Filter) to compensate source current harmonics. All of the two main functions may be completed either individually or instantaneously. And also in this project fuzzy logic controller (FLC) will be implemented to decrease the harmonics of Hybrid Renewable Energy conversion system integrated on the power grid. When the hybrid renewable energy system (HRES) is combined to the grid, due to DC to AC conversion in solar and AC to DC conversion in wind and also due to variation in solar power intensity, the also differences in wind speed, the electrical utility experiences undesired harmonics, so that it will affect the quality of power. To improve THD (Total Harmonic Distortion) in grid interfacing hybrid energy system a fuzzy logic controller (FLC) will be employed to control VSC (Voltage Source Converter). The complete simulation and modelling will be carried out in MATLAB/SIMULINK to validate the proposed analysis.*

Keywords *— Shunt active power filter(SAPF), distribution system, renewable energy, grid interconnection, fuzzy logic controller (FLC).*

I. INTRODUCTION

Now a days users of electric power energy and electric utilities are gradually more day by day. Seventy percent of worldwide energy is distributed by the fossil energies. but resent days due to increasing global heating and sound pollution, air pollution and budget also one of the main reason to think towards unconventional sources like renewable energy sources (RES) as a upcoming resolution for energy. Meanwhile the past years, so many other countries concentration in renewable energy (RES) to generate the electric power. And whenever the renewable energy sources is associated to the grid is can introduce the harmonics it may cause several power quality problems [1]. This is one of the most common difficult is in renewable energy sources (RES) that are associated to the grid. Because of this it must contains one interface element between RES and grid.

Whenever the load that is nonlinear load is associated to electric grid then the reactive power (Q) will be improved because of that the losses in power also improved in the power system. And also the nonlinear loads rises the current harmonics in transformers, transmission lines, and also in rotating parts.so to overcome this problem by using shunt active power filter(SAPF),it helps to reduce the harmonic currents.This paper presents a new technique it contains of shunt active power filter (SAPF) it can concurrently decrease the complications like harmonics in current, power factor and current imbalance and also it can be introducing the power produced by the renewable energy source (RES) with low THD (Total Harmonic Distortion).

If there is no energy or power existing from the renewable power source (RES) that means when no wind and no sun is there. The shunt active power filter (SAPF) can still activate, at the same time it will improve the power quality of the electric grid. A dc-dc power converter is used because to regulate the voltage output value of the renewable energy sources (RES) to the voltage value in dc side capacitor of shunt active power filter (SAPF). Then the obtainable energy is accomplished by the shunt active power filter controller (SAPFC) [2].

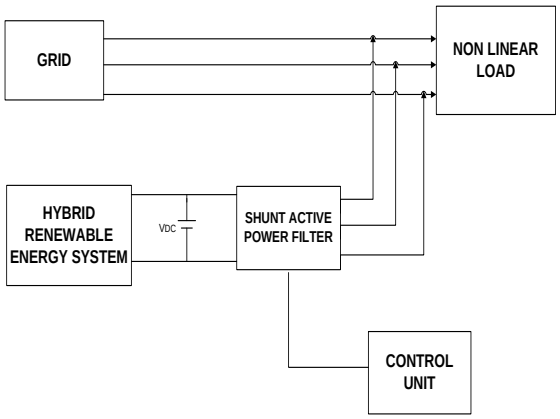


Fig. 1 Block diagram of the proposed system

From the block diagram shown above the grid connected DG (distributed generation) interface it consists of renewable energy sources like as a solar (PV), wind and nonlinear load, voltage source inverter (VSI).

II. GRID CONNECTED DISTRIBUTION GENERATION SYSTEM

Renewable energy sources (RES) are included at the distribution level is termed as DG (Distributed Generation). The voltage source inverters (VSI) are used to connect the renewable energy sources (RES) in the distributed system. In this suggested method no requirement of external hardware scheme to the active power flow control, the grouping of renewable energy generation units with active power filter (SAPF) plays a significant role in organization of power quality in upcoming power systems. And in this paper, the distributed generation (DG) is connected to the electric grid with the help of SAPF (Shunt Active Power Filter).

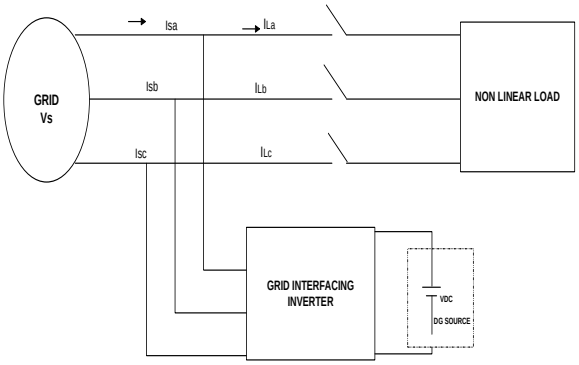


Fig. 2 Grid connected DG interface

The diagram shown above the three-phase grid connected distribution generation (DG) connection Where IS and VS are the grid currents and grid voltages respectively and load current IL [3].

A. Non-linear load

To generate the current harmonics is the main nature of the nonlinear loads that means alterations waveforms in current and this disturbances also effects the voltage waveforms that means distortion of voltage waveforms is also possible. Odd harmonics produced by the nonlinear loads. Basically they are two types leading and lagging loads. In nonlinear loads the impedance rate changes with the supply voltage at the time when changing the current due to impedance that strained by the nonlinear load. And it not a sinusoidal wave even it associated to the sinusoidal voltage. Non sinusoidal current contains harmonics and also voltage alterations that disturbs both loads and apparatus of distribution system. Examples of nonlinear loads are like refrigerators, TV, computer, rectifiers, etc.

III. SHUNT ACTIVE POWER FILTER

In recent years, the power electronics are broadly used in manufacturing and also domestic applications to the power flow control. The advantages of the power converters is developments of power electronics which disturb from the harmonic currents and reactive power (Q) from the supply. The shunt active power filter (SAPF) is very standard technique for cancel the harmonic currents in power system, and also the choice of APF (Active Power Filter) for a particular application is very tough and essential assignment for the end users and application engineers. Three-phase and single-phase, three-phase four wire systems are several applications and are essential for voltage compensation and current compensation. The size and cost of the Active power filter (APF) depends on harmonics and reactive power to be compensated.

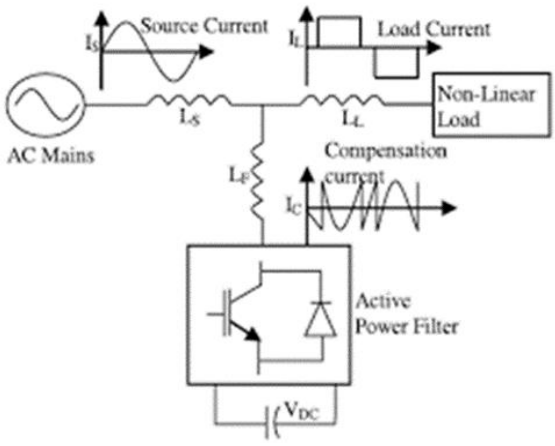


Fig. 3 Shunt active power filter

From the figure shown above is the basic principle of shunt active power filter (SAPF).From the figure we can realize that SAPF (shunt active power filter) draws the current since the load then that current

containing opposed harmonics.so because of that the source current remains sinusoidal and accurate. They are two leading components in the shunt active power (SAPF) filter is the power converter and the control unit [4]. Now this paper recommended a control algorithm for SAPF (shunt active power filter) to decrease the harmonics and maintain equal alteration in the compensated current.so nonlinear loads performs like linear loads and resultants source current have the similar waveforms like supply voltage.so that harmonics are compact and reactive power is compensated.

IV. CONTROL METHODOLOGY

The main resolution is the method of control, means to give accurate gate pulse to the voltage source inverter (VSI) to draw the current that having opposed harmonics. In this paper shunt active power filter (SAPF) dc link capacitor voltage is detected and also compared with the reference value and from the error and rate of change of error fuzzy controller (FLC) gives a reference command. So that power to be measured for the shunt active power filter (SAPF) to the reference current. By applying instantaneous active and reactive power theory (p-q theory) to the current controller. The reference current generator produces a reference current with the support of load current source voltage. The hysteresis current controller (HCC) compare the reference value produced from fuzzy with the active power filter current and give gate pulses to the voltage source inverter (VSI). The output of the voltage source inverter goes through the filter of inductor to the line and draw the harmonics. By this process harmonics in source current are compact and reactive power compensation also the power factor improvement [5].

A. Fuzzy Logic Controller

Fuzzy logic unlike Boolean logic or crisp logic, and also this fuzzy logic deals with the problems like uncertainty, imprecision or vagueness and it uses membership functions with variable values between 0&1 (zero and one).And for the control system it proven that an outstanding excellent for many applications. First the capacitor voltage is compared with the reference set value then the error signal is produced from the fuzzy controller (FLC). Fuzzy set are selected Based on the dc link voltage error. In that we have consider 7*7 (seven*seven) membership functions. That seven membership functions are equal for the input and output. The seven membership functions are {Negative big (NB), Negative medium (NM), Negative small (NS), Zero (ZE), Positive small (PS), Positive medium (PM), Positive big (PB)} used for the program flexibility. [6][7] In a fuzzy logic controller (FLC) a rule base is created to control the output variables, fuzzy logic rule is a simple IF-THEN rule with condition and a conclusion. The control rules table is shown below.

ΔE / E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

Table 1: control rule base table

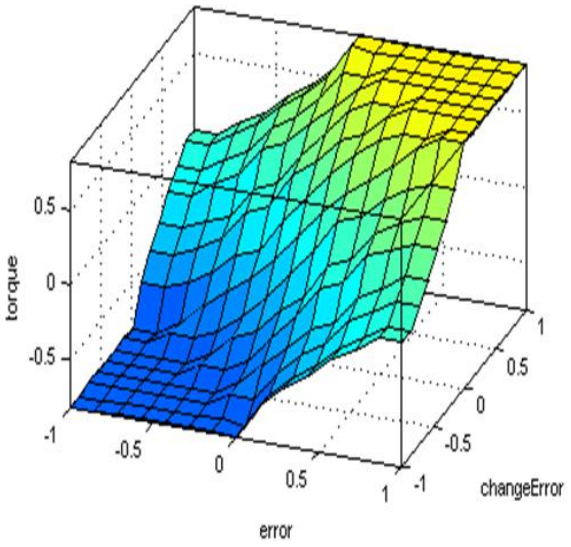


Fig. 4 Surface view of applied fuzzy rules

B. Reference Current Generator

The active power filter (APF) performance be influenced by many aspects, but essentially on the selected system that is reference generation scheme. The filter current is similar as that reference current, then the active power filter (APF) objective is satisfied. There are so many other techniques, but here instantaneous p-q theory (active and reactive power theory) is used [8]. There are mainly five steps to produce the reference current. 1) Clarke transformation, 2) instantaneous p-q calculation and also 3) selection of compensating power, 4) reference αβ calculation and 5) inverse Clarke transformation. The p-q theory (Active and Reactive power theory) definite by using the αβ0-transformation, it contains a real matrix and that converts 3φ voltage and 3 phase currents into αβ0-stationary reference frame current and voltage.

The below equation shows the Clarke transformation:

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (1)$$

As per our topic its only deals with three phase three wire system that's why we can neglect or eliminate zero sequence voltage and current.so v_0 can be neglected from the equation shown above and the current equation also same for generalization. Then after eliminating the zero sequence current and voltages the equations will be shows below.

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (2)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} \quad (3)$$

From the equations in the above (2)&(3) by using Clarke transformation the voltage and currents in the frame of α-β. Now by using V_α and V_β , i_α and i_β calculate the instantaneous active and reactive power (p-q power).

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

$$\begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} = \frac{1}{V_\alpha^2 + V_\beta^2} \begin{bmatrix} V_\alpha & V_\beta \\ V_\beta & -V_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (5)$$

The reference α-β axis currents are considered by using inverse transformation. The reference abc frame currents for the active power filter can be establish. And finally the the inverse Clarke transformation is

$$\begin{bmatrix} i_\alpha^* \\ i_b^* \\ i_c^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_\alpha^* \\ i_\beta^* \end{bmatrix} \quad (6)$$

C. Hysteresis Current Controller

HCC is used to track the reference current, because voltage source inverter (VSI) need accurate gate pulses that is given only to the current controller that is hysteresis controller.

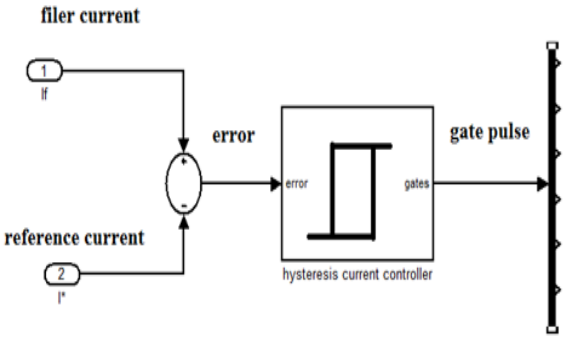


Fig. 5 Hysteresis current controller

Here hysteresis current controller is used to the power converter's gate pulse control. The most important source current is observed instantaneously, and then it also compared to the reference currents that currents are produced by the suggested algorithm. To get the perfect control, IGBT (insulated gate bipolar transistor) switching device should be approaches to zero, then that provides fast response. The hysteresis current control (HCC) is good accuracy, and very fast response. And also the reference current is compared with the actual current, if it beats the upper limit of the hysteresis band, the voltage source inverter arm upper switches is turned off and the lower switches is on. Then the current starts to decline and the procedure is vice versa then if current crosses lower limit of the hysteresis band then current back into the hysteresis band. In this method the actual current is compulsory to track the reference current with in the hysteresis band [9].

V. SIMULATION RESULTS AND ANALYSIS

To checked the functioning of the recommended shunt active power filter (SAPF) under the nonlinear load mat lab simulations was studied by using advanced continuous simulation language (ACSL), and also simulation tools.

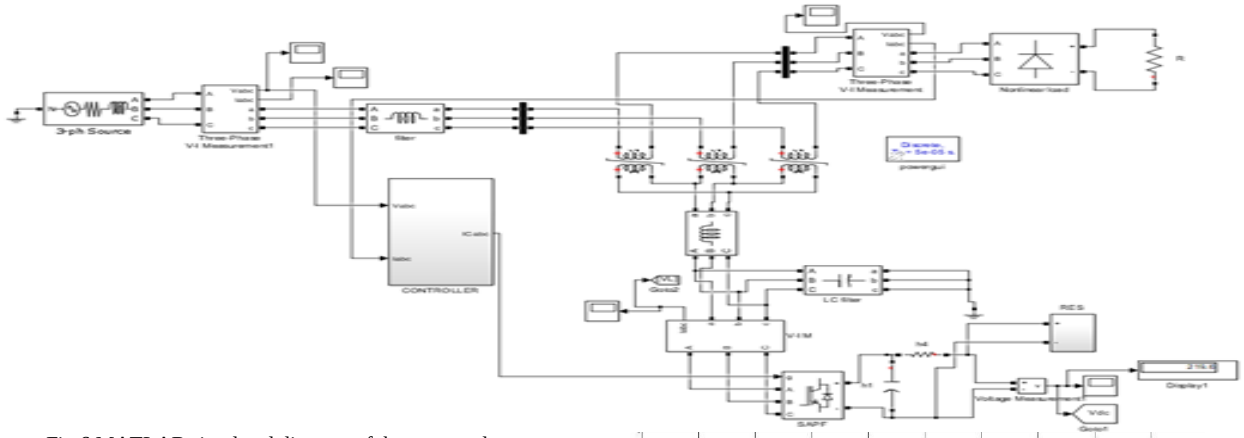


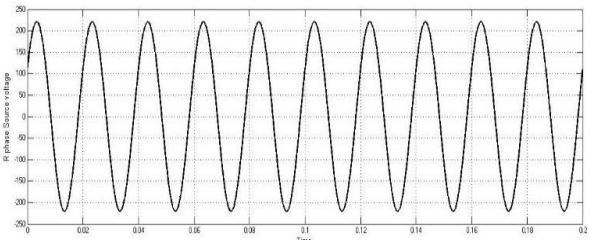
Fig 6 MATLAB simulated diagram of the proposed system

The below table shows the system parameters

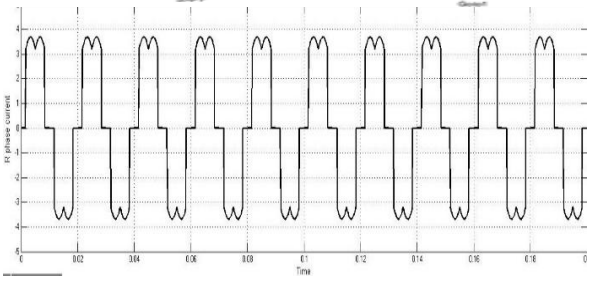
Line-to-line grid RMS voltage	156V
Grid frequency	50HZ
3-phaseNonlinear load	R=60Ω
DC Capacitor	1000μF
DG Voltage	0-220V
DG Resistor	10Ω

Table 2: Shows parameters of the system under unbalance load

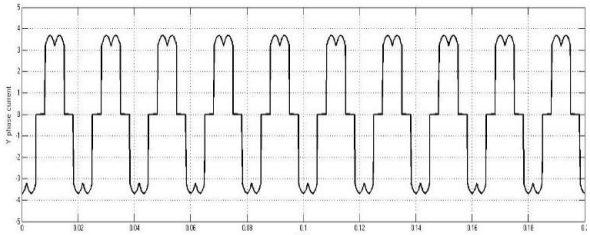
Mostly we know that whenever linear load is associated to electric grid the source voltage and source current is sinusoidal that means there is no disturbances so we don't need any compensation to reduce the disturbances. But when the nonlinear load is linked to power grid there is some changes in source current that means non sinusoidal means some harmonics are produced so some compensation methods are required to get the source current into sinusoidal.First consider nonlinear load is connected to power grid condition without any compensation, the experimental results will be obtained is shown below, that non-sinusoidal source voltage and current is shown in the figure 7,



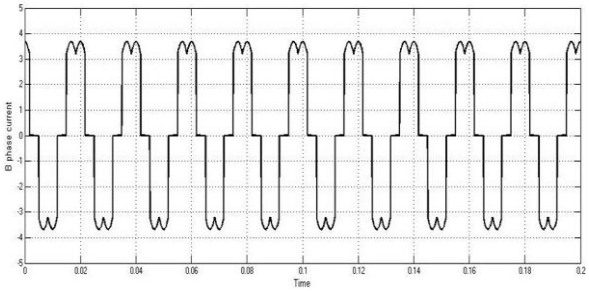
(a)



(b)



(c)

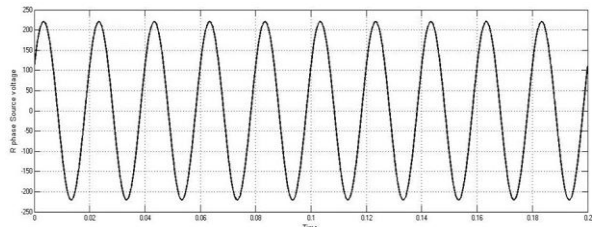


(d)

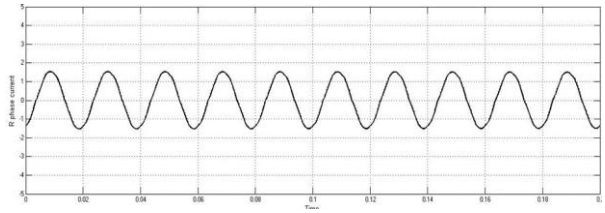
Fig. 7 when nonlinear load connected to grid

(a). R phase grid voltage, (b). R phase grid current, (c). Y phase grid current, (d). B phase grid current

Then now consider nonlinear load connected to electric grid with shunt active power filter (SAPF) to decrease the source current harmonics and the mat lab simulation results observed from the figure 8,



(a)



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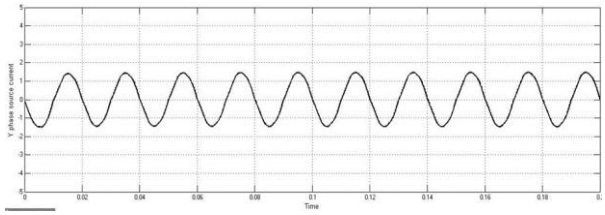
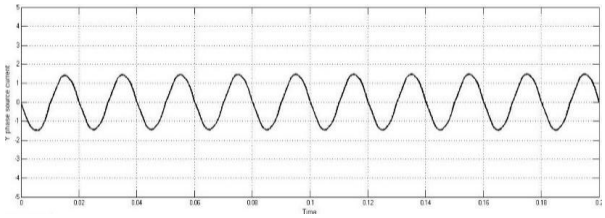
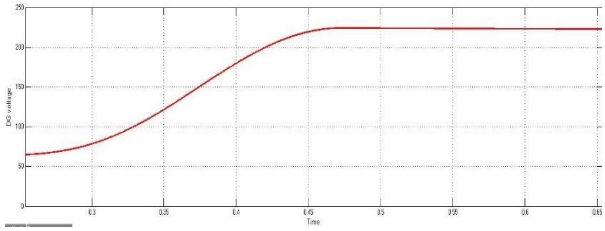


(c)



(d)



(e)

Fig. 8 SAPF response of nonlinear system

(a). R phase grid voltage, (b). R phase grid current, (c). Y phase grid current, (d). B phase grid current, (e) DC link voltage.

The SAPF (shunt active power filter) decreases the harmonics in source current and the THD (total harmonic distortion) value of current from 30% to 2.44% in the nonlinear load condition.

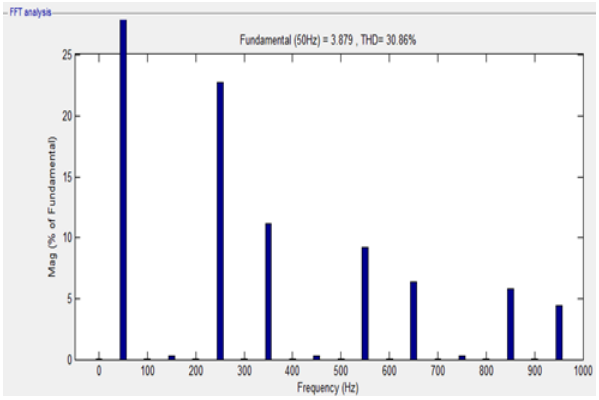


Fig.9 Before compensation

Fig.9 shows before compensation the source current harmonics are very high, and THD value also very high 30%.

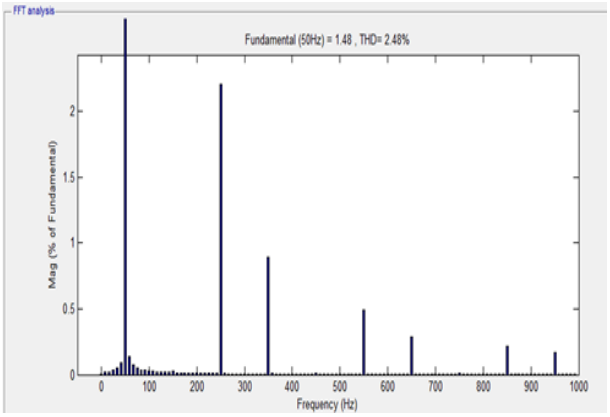


Fig.9 After compensation

Fig. 10 shows using SAPF (shunt active power filter) here the source current harmonics are reduced and also with low THD that is 2.44%.

VI. CONCLUSIONS

This paper existing a new model control of grid interfacing voltage source inverter (VSI) to reduce power quality issues and increase the power quality. And also the grid interfacing voltage source inverter can be efficiently used for power conditioning without disturbing the transfer of real power. The proposed method can be used to;

1) Generated the power from renewable energy system (RES) and injects that power to the grid, and

2) Operate as a shunt active power filter (SAPF) to eliminate the current harmonics.

The shunt active power filter has ability of injecting currents is in sinusoidal and also with low THD (total harmonic distortion), and reduce the problems like current harmonics, power factor, and unbalance. This procedure reduces the necessity for extra power conditioning apparatus for power quality improvement. MATLAB/Simulink simulation results

shows that the grid-interfacing voltage source inverter can be used as a multi-function scheme.Therefore, the multifunction performance of other power electronic compensators to rise the performance of the distribution system. Because of using these projected method, source current means grid current into sinusoidal current and in phase with grid voltage. The mat lab simulation and operation results shows that SAPF (shunt active power filter) works feasibility and perfectly of the suggested control strategy to satisfy the objectives.

The authors are presently researching for any other switching techniques to the voltage source inverter of shunt active power filter (SAPF), to increase the performance of power by decreasing the noise inserted in the electric grid.

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