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Power Quality Enhancement in Grid with Interconnection of Hybrid Power System

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ABSTRACT

Scarcity of power has been one of the nightmare issues for mankind in the modern age. Renewable Energy Sources (RES) working parallel with conventional power plants are playing a lead role in narrowing the difference between supply and demand. Among all the available renewable energy sources wind-solar hybrid systems are the most popular one. Due to their natural advantage of being complimentary to each other, they are assuring reliability to the utility. Power quality issues arising due to the usage of non-linear loads at the point of common coupling are addressed with the help of power electronic device interfacing RES to the grid. The work presented in this paper consists of Modeling and Simulation of wind-solar hybrid energy system and interfacing it to the grid through the interfacing inverter. A suitable control strategy which will add shunt active filter functionality to the RES interfacing device to the grid is also undertaken.

Keywords-Active power filter (APF), distributed generation (DG), distribution system, grid interconnection, power quality (PQ), renewable energy.

I .INTRODUCTION

Fossil fuels are our main source of energy and they are depleting. Fossil fuels are non renewable and environmentally damaging. Due to increasing air pollution, global warming concerns, diminishing fossil fuels and their increasing cost have made it necessary to look towards renewable sources as a future energy solution. There are many Renewable Energy Sources (RES) such as wind, solar, tidal power, biomass etc. Solar energy has great potential to supply energy with minimum impact on the environment, since it is clean and pollution free. In finding solutions to overcome a global energy crisis, the Photo Voltaic (PV) system has attracted significant attention in recent years. The government is providing incentives for further increasing the use of grid-connected PV systems. Conventionally, grid connected Photo Voltaic energy conversion systems are composed of an inverter.

Renewable Energy Sources are increasingly integrated at the distribution level due to increase in load demand which utilize power electronic converters. There is a disturbance in the electrical network due to the extensive use of these power electronic devices. The disturbances are due to the use of non-linear devices. These will introduce harmonics in the power system thereby causing equipment overheating ,damage devices ,EMI related problems etc[1],[2]. Harmonics is considered as one of the most essential problems in electrical power systems. Harmonics in power distribution system are current or voltage that are integer multiples of fundamental frequency. For example if the fundamental frequency 50Hz, then 3rd is 150Hz, 5th is 250Hz. Ideally, voltage and current waveforms are perfect sinusoids. However, because of the increased popularity of electronic and non linear loads, these waveforms become distorted. This deviation from a perfect sine wave can be represented by harmonic components having a frequency that is an integral multiple of the fundamental frequency. Thus a pure voltage or current

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sine wave has no distortion and no harmonics and a non sinusoidal wave has distortion and harmonics. Several methods are described in various papers to solve these problems. There are standards that determine the maximum allowable level for each harmonic in the Alternative Current (AC) system [IEEE Std. 519, 1981].

When excessive harmonic voltage and current are generated, filters are usually installed to reduce the harmonic distortion. There are two functions to connect harmonic filter to the lines in distribution systems as listed below.
1. To reduce the harmonic voltage and current in the AC system below the permitted levels.
2. To provide some of the reactive power absorbed by the converter system. [IEEE Std. 519, 1981]
Conventionally, passive filters have been used to eliminate harmonic problems [3]. This filter mainly consists of common devices such as inductance and capacitance. These devices are tuned to the frequency of the harmonic to be removed. However it has the following limitations
1. A separate filter is necessary for each harmonic frequency.
2. As both the harmonic current and the fundamental frequency current flow into the filter, the capacity of the filter must be decided by taking into account both currents.
3. The filter will be overloaded when the content of the harmonic in the AC line increases.

Other methods of harmonic reduction are considered such as current injected by Active Power Filter (APF) to overcome the above limitations. The APF filter concept uses power electronic switching to generate harmonic components to cancel the harmonic components of the nonlinear loads. It means that in these devices, Direct Current (DC) is converted to form the harmonic currents out of phase of the load which is then injected into AC line, thereby preventing the harmonic currents flowing into the supply. The suitable device in developing the APF is utilizing Pulse Width Modulation (PWM) inverter by using power semiconductors devices such as Insulated Gate Bipolar Transistor (IGBT) or Metal Oxide Field Effect Transistor (MOSFET). The PWM is used because it can be easily adjusted in order to control amplitude harmonic current injection and frequency switching. Following are the reasons APF had been used to minimize harmonic pollution in the distribution line system compared with passive filter.
All the harmonics presented in AC line system can be compensated by using single equipment.

- The maximum order of harmonic to be suppressed has no limitation and is determined by PWM switching
- Even the existing harmonic components change in magnitude and frequency in line it can be accommodated by control adjustment by triangular and voltage reference circuit rather than equipment changes from time to time.
- It is not designed to filter out one harmonic component only, but is intended to attenuate several harmonics in one time.

Compared with passive filter methods, the harmonic current injection into the power network by applied a high frequency switching inverter able to offers suppress harmonic as much as possible adequate with low cost.

In this work, that the existing PV inverter acts as Shunt Active Power Filter (SAPF) that is capable of simultaneously compensating problems like current unbalance current harmonics and also of injecting the energy generated by RES. Shunt Active Power Filter attempts to compensate the current harmonics .The shunt active filter is a voltage source inverter (VSI), which is connected in parallel with load. Shunt Active Power Filter has the ability to keep the mains current balanced and sinusoidal after compensation for various Load conditions.

II. RENEWABLE BASED DISTRIBUTED GENERATION SYSTEM

The proposed system is Three Phase Four wire which consists of Photovoltaic system connected to the dc-link of a grid-interfacing inverter as shown in Fig.4.1. The voltage source inverter is a key element of a PV system

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as it interfaces the renewable energy source to the grid and delivers the generated power. The Photovoltaic system is connected to grid with an inverter coupled to dc-link. The dc-capacitor decouples the Photovoltaic system from grid and also allows independent control of converters on either side of dc-link.

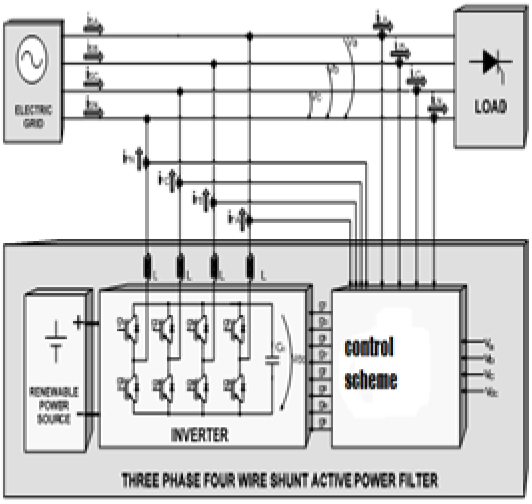

Fig .1: Proposed Three Phase Four Wire System

2.1 VOLTAGE SOURCE CONVERTER (VSC)

A voltage-source converter is a power electronic device that connected in shunt or parallel to the system. It can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. It also converts the DC voltage across storage devices into a set of three phase AC output voltages. It is also capable to generate or absorbs reactive power. If the output voltage of the VSC is greater than AC bus terminal voltages, is said to be in capacitive mode. So, it will compensate the reactive power through AC system. The type of power switch used is an IGBT in anti-parallel with a diode. The three phase four leg VSI is modeled in Simulink by using IGBT.

Voltage source converters are preferred over current source converter because it is higher in efficiency and lower initial cost than the current source converters. They can be readily expanded in parallel to increase their combined rating and their switching rate can be increased if they are carefully controlled so that their individual switching times do not coincide. Therefore, higher-order harmonics can be eliminated by using converters without increasing individual converter switching rates.

2.2 CONTROL TECHNIQUE USED FOR INTERFACING INVERTER TO ACT AS SHUNT APF

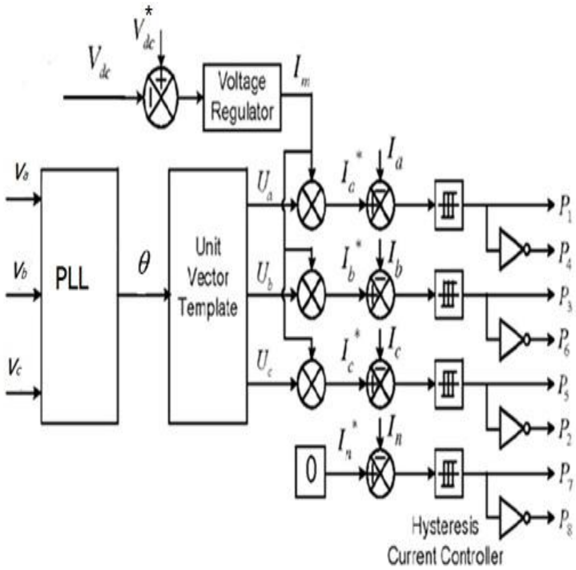

Fig 2: Control scheme

The turn on and turn off instants of inverter switches should be such that the load and the connected RES could appear as balanced load to the system. The dc link voltage, Vdc is sensed at a regular interval and is compared with its reference counterpart Vdc*. The error signal is processed in a PI-controller. The output of the pi controller is denoted as Im.

The reference current templates (Ia*, Ib*, and Ic*) are obtained by multiplying this peak value (Im) by the three-unit sine vectors (Ua, Ub and Uc) in phase with the three source voltages. These unit sine vectors are obtained from the three sensed line to neutral voltages. The reference grid neutral current (In*) is set to zero, being the instantaneous sum of balanced grid currents. Multiplication of magnitude Im with phases (Ua, Ub, and Uc) results in the three phase reference supply currents (Ia*, Ib*, and Ic*).

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The grid synchronizing angle (Θ) obtained from phase locked loop (PLL) is used to generate unity vector template as

$$U_a = \sin\theta \qquad \{1\}$$

$$U_b = \sin\left(\theta - \frac{2\pi}{3}\right) \qquad \{2\}$$

$$U_c = \sin(\theta + \frac{2\pi}{3}) \qquad \{3\}$$

The instantaneous values of reference three phase grid currents are compute as

$$I_a^* = I_m * U_a \qquad \{4\}$$

$$I_b^* = I_m * U_b \qquad \{5\}$$

$$I_c^* = I_m * U_c \qquad \{6\}$$

The neutral current is considered as

$$I_n^* = 0 \qquad \{7\}$$

The reference grid currents(I_a*, I_b^*, I_c^* and I_n^*) are compared with actual grid currents(I_a, I_b, I_c and I_n) to compute the current errors as

$$I_{aerr} = I_a^* - I_a \qquad \{8\}$$

$$I_{berr} = I_b^* - I_b \qquad \{9\}$$

$$I_{cerr} = I_c^* - I_c \qquad \{10\}$$

$$I_{nerr} = I_n^* - I_n \qquad \{11\}$$

These errors are given to hysteresis current controller then generate the switching pulses for six IGBTs of the grid interfacing inverter.

2.3 HYSTERESIS CURRENT CONTROL

The hysteresis current control (HCC) is the easiest control method to implement; it was developed by Brod and Novotny in 1985. The shunt APF is implemented with three phase current controlled VSI and is connected to the ac mains for compensating the current harmonics. The VSI gate control signals are brought out from hysteresis band current controller

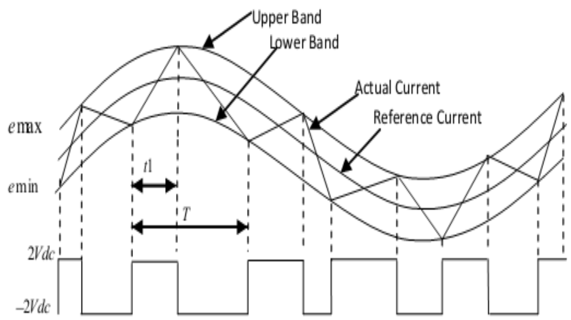

Fig:3 Waveform of Hysteresis current controller

A hysteresis current controller is implemented with a closed loop control system and waveforms are shown in Fig 4.4. An error signal I_{aerr} is used to control the switches in a voltage source inverter. This error is the difference between the desired current I_a^* and the current being injected by the inverter I_a . If the error exceeds the upper limit of the hysteresis band, the upper switch of the inverter arm is turned off and the lower switch is turned on. As a result, the current starts decaying. If the error crosses the lower limit of the hysteresis band, the lower switch of the inverter arm is turned off and the upper switch is turned on. As a result, the current gets back into the hysteresis band. The minimum and maximum values of the error signal are e_{min} and e_{max} respectively. The range of the error signal $e_{max} - e_{min}$ directly controls the amount of ripple in the output current from the VSI.

2.4 SIMULINK MODEL OF HYSTERESIS CURRENT CONTROL

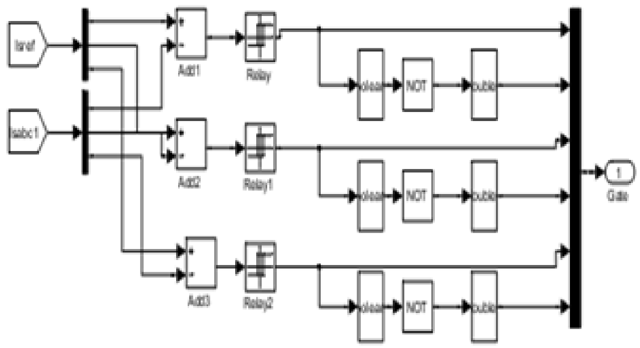

Fig. 4: Simulink Model of Hysteresis Current Control

2.5 MATLAB /SIMULINK MODEL OF PI CONTROL

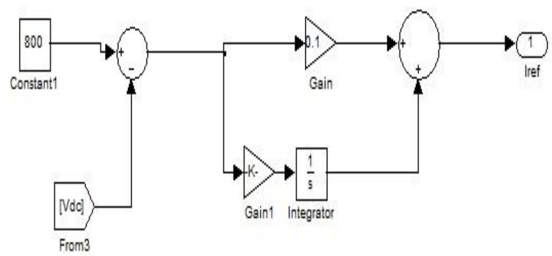

Fig.5: MATLAB Simulink model of PI control

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III. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experiences. It is natural proof that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. These biologically inspired methods of computing are thought to be the next major advancement in the computing industry. Even simple animal brains are capable of functions that are currently impossible for computers. Computers do rote things well, like keeping ledgers or performing complex math. But computers have trouble recognizing even simple patterns much less generalizing those patterns of the past into action of the future.

Now, advance in biological research promise an initial understanding of the natural thinking mechanism. This research shows that brain stores information, as patterns. Some of these patterns are very complicated and allow us the ability to recognize individual faces from any different angles. This process of storing information as patterns, utilizing those patterns, and then solving problems encompasses a new field in computing. This field does not utilize traditional programming but involves the creation of massively parallel networks and the training of those networks to solve specific problems. This field also utilizes words very different from traditional computing, words like behave, react, self-organize, learn, generalize, and forgot. An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. In more practical terms neural networks are non-linear statistical data modeling tools. They can be used to model complex relationships between inputs and outputs or to find patterns in data. A neural network is an interconnected group of nodes, akin to the vast network of neurons in the human brain.

3.1 ARTIFICIAL NEURONS AND HOW THEY WORK

The fundamental processing element of a neural network is neurons. This building block of human awareness encompasses a few general capabilities. Basically, biological neurons receive inputs from other sources, combine them in some way, perform a generally nonlinear operation on the result, and then output the final result. Fig 6.1 shows the relationship of these four parts. Within humans there are many variations on this basic type of neurons, further complicating man's attempts at electrically replicating the process of thinking. Yet, all natural neurons have the same four basic Components. These components are known by their biological names – dendrites, soma, axon, and synapses. Dendrites are hair-like extensions of the soma which act like input channels. These input channels receive their input through the synapses of other neurons. The soma then processes these incoming signals over time. The soma then turns that processed value into an output which is sent out to other neurons through the axon and the synapses

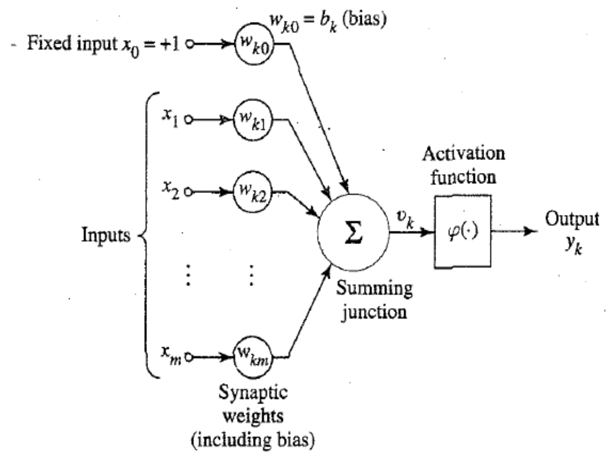

Fig 6: Artificial Neural Networks.

Where x1, x2…..Xm are the m inputs

Wk1 , Wk2,…. Wkm are weights attached to the input links

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For the above model

$Uk = \sum_{j=1}^{m}(Wkj\ Xj)$ (6.1)

$Vk = Uk + bk$ (6.2)

The bias bk has the effect of increasing or lowering the input of the activation function.

$yk = \varphi(Uk + bk)$ (6.3)

The weighted output signal vk is passed through an activation function and compared. If the output is greater than the activation function then vk is passed to the cell body(system) which is used to perform the required activity

IV. SIMULATION DESIGN

A simulation design open loop system as shown in **Fig.7** is implemented in MATLAB SIMULINK

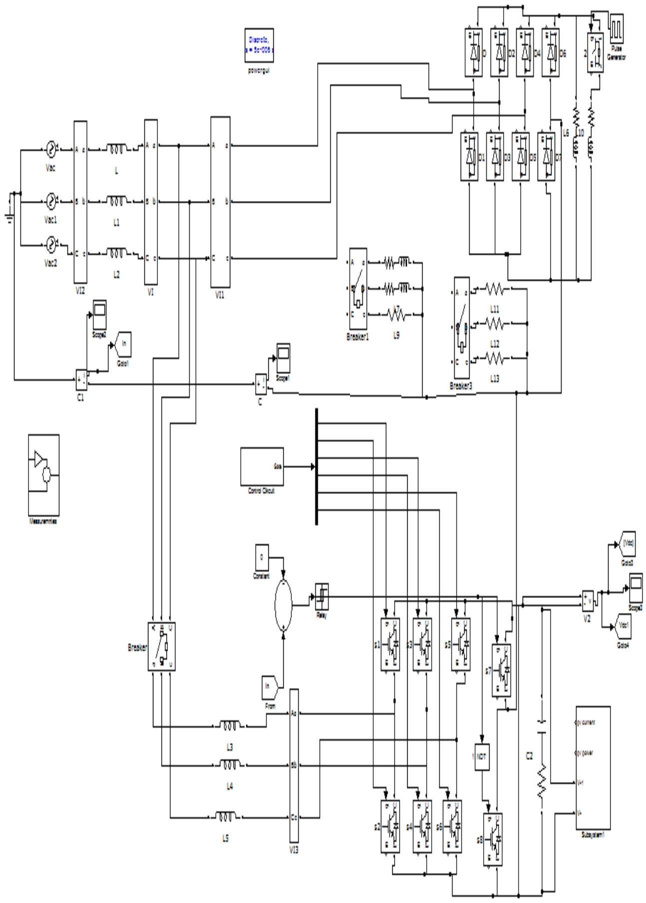

Fig 7. Matlab Implementation

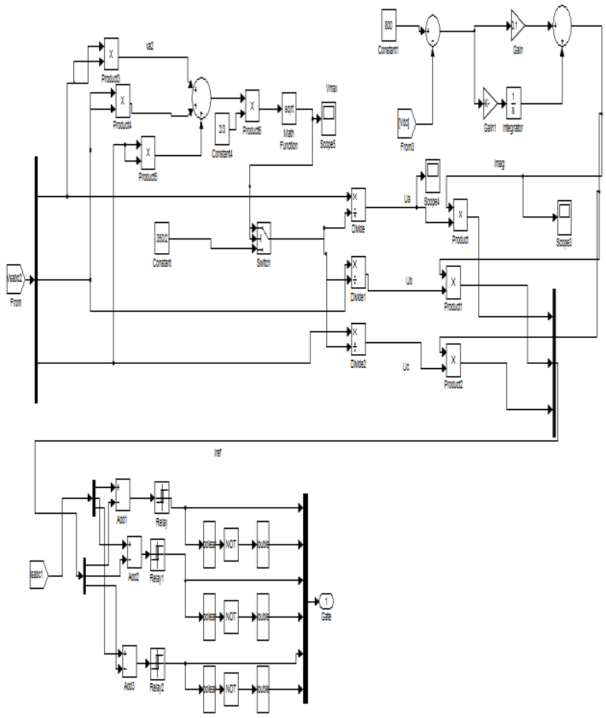

Fig 8. Hysteris With Pi Controller

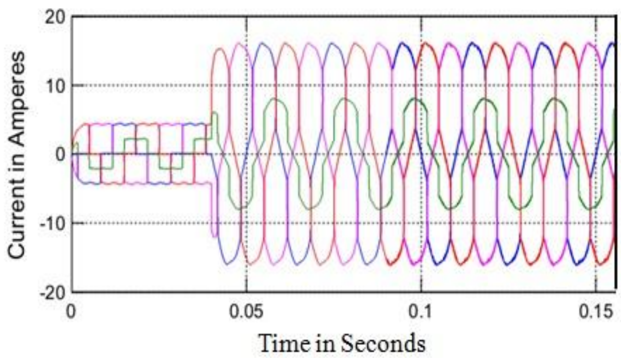

Fig 9. Source Current Due To Non Linear Load

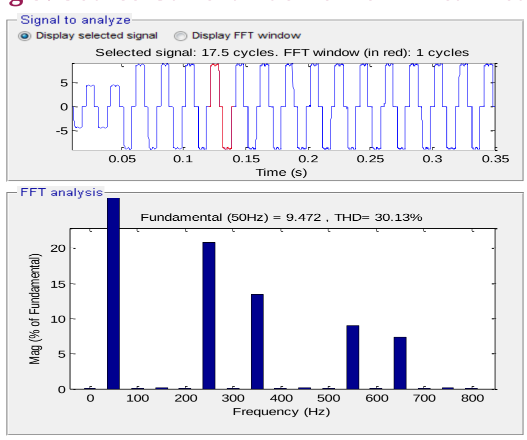

Fig 10. THD Of Source Current Before Compensation

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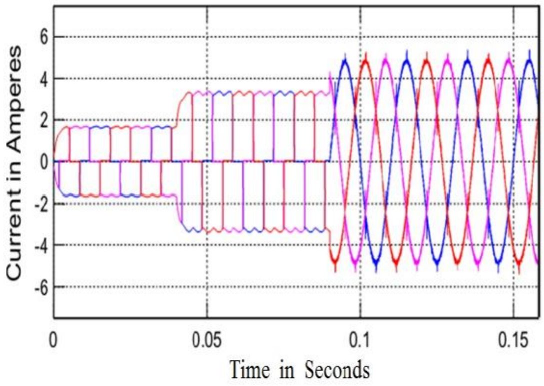

Fig 11. Source Current With Filter

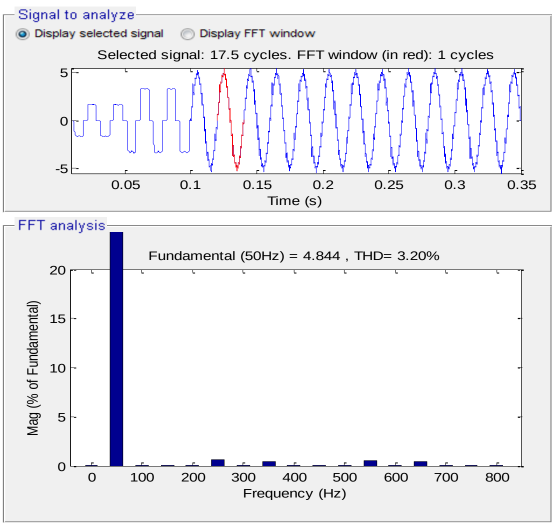

Fig 12 Thd Of Source Current After Compensation

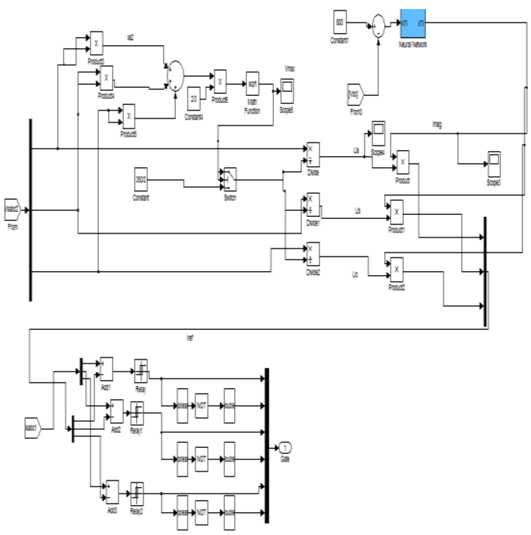

Fig 13 Inverter With Neural Networks

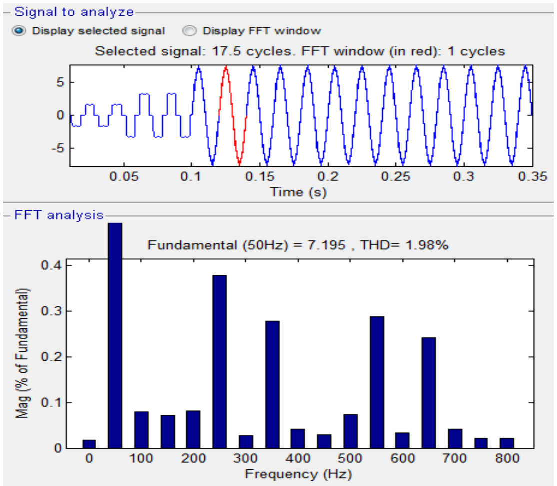

Fig 15 THD Of Source Current With ANN

S.NO.	Source Current THD Without Inverter	Source Current THD With Inverter(PI Controller)	Source Current THD With Inverter(ANN Controller)
1	10	28.63	3.18

Table 1: Comparison Of THD's

V. CONCLUSION

The photovoltaic panel is modeled and connected to three phase four wire distribution system through an inverter. From the results, it can be concluded that the grid interfacing inverter is functioning as a conventional inverter as well as an Active Power Filter.It can also be concluded that the grid interfacing inverter is maintaining sinusoidal source current by reducing THD in supply under various load conditions. Pi controller and ann controllers are used for Inverter current control. It is better to use ann controller by replacing pi controller.

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