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Power Quality Improvement Using Hybrid Filters for the Integration of Hybrid Distributed Generations to the Grid

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Abstract: ***Power quality improvement is an important parameter in power system. Not only is to meet the demands, but also the quality power a major goal of power system. Distributed Generations such as Solar and Fuel cell integration solves the problem of power demand. Power quality is improved by using Hybrid Filter. The model of the solar and fuel cell integration to the grid with the help of hybrid filter is modeled in MATLAB. Hysteresis Controller is used to supply the controlled gate pulses for the switches in filter. Total Harmonic Distortion is measured using Fast Fourier Transform in MATLAB. Reactive power demand and load current harmonics are compensated by using hybrid filter. In this paper two cases are considered Active power filtering mode when no power from solar and fuel cell and also the case when solar and fuel cell supplying power to grid.***

Keywords: DG(Distributed generation),HF(Hybrid filter),PV array (Photovoltaic array),FFT(Fast Fourier Transform),PWM(Pulse Width Modulation).HC(Hysteresis Controller).THD(Total Harmonic Distortion)

1. Introduction

Power system includes Generation in which power is generated by means of renewable and non renewable resources. Nowadays renewable resources are becoming more popular because of pollution free and easily available in nature. Renewable resources can be generated nearer to the load and it can be made available for the customers in easy means. Even though there are some demerits such as uncertainty of power, hybrid DGs can be used to overcome this problem. [1] Passive power filter in power system has some problems such as, source impedance affect the characteristics of filter and system impedance. So as to overcome these problems hybrid filters are used. [2]Controllers of different types are known as nonlinear loads which draws sinusoidal current with some distortion from the mains. For many considerations hybrid filters play a important role in improving the power quality. [3]In the case of dispersed generation power quality is the major problem due to the uncertainty of power. These problems can be solved using hybrid filters. [4]New type of hybrid filter is designed with varying inductance in the passive side for the power quality improvement. This new type of filter is used to compensate current harmonics and unbalanced load. [5]Shunt active filter and shunt passive filters are used to filter the higher order harmonics. The Total Harmonic Distortion is well within the limits according to the power quality standards (IEEE-519). [6]Fuzzy logic controller based filtering arrangements are made, which also do the role of damping, load balancing, reactive power control, power factor correction, voltage regulation, and voltage flicker reduction. The filtering arrangements are made for three phase system. [7] Distributed power generation system with hybrid filter is used for different configurations are presented. Adaptive signal processing controller is proposed. Simulation is done using MATLAB. [8]A Hybrid Filter is modeled not only to compensate the harmonics but also to compensate the positive and negative sequence reactive power.[9]This paper deals with the power quality improvement using hybrid filters. Compensation strategies based on PQ theory is modeled.

2. Proposed Model

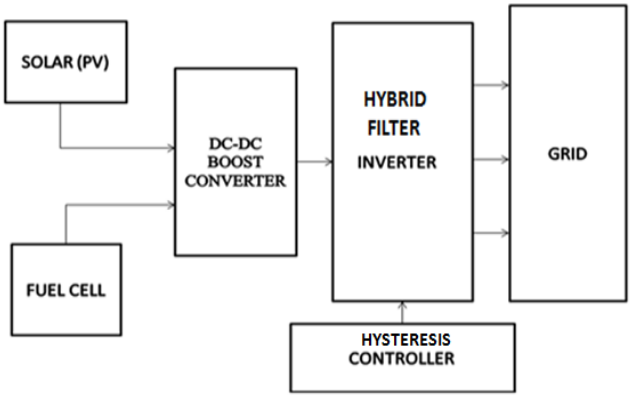

Figure 1: Block diagram of the proposed system

Hybrid solar and fuel cell model is connected to the Grid via boost converter and Hybrid filter. The gate pulses for Hybrid filter is controlled using hysteresis controller. Reference current for Hysteresis Controller is generated using Synchronous Reference Frame Theory. Total Harmonic Distortions is found using Fast Fourier Transform in MATLAB for two cases. With solar and Fuel cell and without solar and fuel cell (Active power filtering mode).Real and reactive power is also measured with and without Hybrid Filter. Block diagram of the proposed model is as shown in Figure1.

3. Solar Photovoltaic

3.1 Solar Cell

Solar energy is available as nature's gift. We don't need to pay anything for the fuel cost. It's also pollution free and environment friendly. Photovoltaic effect is the important factor that makes solar energy attractive. Photovoltaic cells consists of a direct transformation, sunlight is directly converted into electricity by solar panels. Solar panel is made up of solar cells. These arrangements are called as Distributed Generations which can be connected directly to the grid or can be standalone supplying power to domestic customers. Maximum Power Point Tracking system is available to extract maximum power from the sun. Photovoltaic solar cell can be modeled in MATLAB and can be connected to the grid as a model. Number of cells can be connected in series or parallel to form the module. Modules can be connected to form the array. In case these modules are connected in series, their voltages are added with the same current. Nevertheless, when they are connected in parallel, their currents are added while the voltage is the same. The equivalent circuit of a PV cell is shown in Figure 2. It includes a current source, a diode, a series resistance and a shunt resistance.

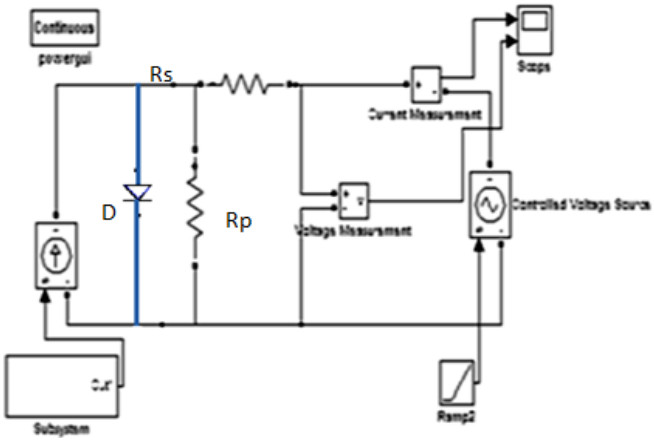

Figure2: Equivalent circuit of solar cell

This model consists of a photocurrent source i_{ph}, a nonlinear diode, series resistance Rs which represents the internal losses and shunt resistance, Rsh in parallel with diode to take into account leakage current to the ground. The I-V characteristic of the ideal photovoltaic cell depends on the internal characteristics of the device (Rs, Rsh) and on external influence such as irradiation level and temperature. The amount of incident light directly affects the generation of charge carriers and consequently the current generated by the device. In practical devices the series resistance is low and the parallel resistance is high.

4. Fuel Cell

Fuel cells convert chemical energy such as hydrogen fuel to electrical energy. Hydrogen is an odourless and colourless gas. It has the simplest and lightest atom with one proton and one electron. The only byproduct of hydrogen is water. It is the most commonly used industrial gas. There are many types of fuel cells.

a. Phosphoric Acid Fuel Cell
b. Polymer electrolyte membrane fuel cell
c. Molten Carbonate Fuel Cell
d. Solid Oxide Fuel cell

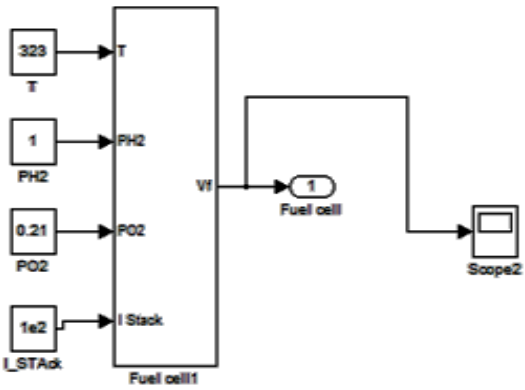

Figure 3: Simulation representing the Fuel cell

Fuel cell is similar to a battery. A Fuel cell has number of cells, each cell has an anode, a cathode and an electrolyte. Cells combine to form the fuel cell stack. When hydrogen gas enters the fuel cell it combines with oxygen to produce current heat and water. Fuel cell supplies electricity as long as fuel is supplied.Figure 3 represents the simulation model with stack. Fuel cell differs from batteries in only one way they need continuous supply of fuel. Although there are different types of Fuel cells each is well suited for different applications. In this work Proton Exchange membrane fuel cell is considered.

4.1 Proton Exchange Membrane Fuel Cell

The Proton Electrolyte membrane fuel cell has two electrodes anode and cathode. Nickel acts as negative electrode. Silver acts as the positive electrode. Platinum is used as the catalyst. Polymer membrane such as Polystyrene Sulphonic acid acts as electrolyte. Air which we use should be free from corbondioxide, because corbondioxide combines with potassium hydroxide to form potassium carbonate, which Increases the Electrical resistance of the cell. This decreases the output voltage. Proton Electrolyte membrane fuel cell is also known as Polymer Electrolyte Membrane fuel cell

It has some of the properties such as high ionic conductivity, Non Permeable to reactant gases such as hydrogen and oxygen, Low degree of electro osmosis, High resistance to dehydration, High resistance to oxidation or hydrolysis, High mechanical Stability. On the positive electrode the coolant tubes run through the ribs of current collectors. The fuel cell can operate up to 200 degree Celsius.

4.2 Principle of Operation

At the anode side it is catalytically split into protons and electrons as shown in equation 1.
At the Anode:

$$H_2 \longrightarrow 2H^+ + 2e^- \quad (1)$$

At the cathode side oxygen molecules react with the protons permeating through the polymer electrolyte membrane and

the electrons arriving through the external circuit to form water molecules as shown in equation 1.

At the cathode:

$$O_2+4H^{+}+4e^{-} \longrightarrow 2H_{2o} \quad (2)$$

Overall reaction:

$$O_2+2H_2 \longrightarrow 2H_{2o} + Heat + Electricity \quad (3)$$

Hydrogen and oxygen combines to form water, heat and Electricity.

5. Boost Converter

The output of the controller is used to control the gate pulse of the switch in converter, so that the output voltage follows the reference value. The output from the boost converter is given to the shunt active power filter before connecting to the grid for harmonic analysis. The boost converter has higher efficiency and requires less components as compared to other DC-DC converter topologies like push pull, half bride and full bridge, etc., which could possibly be used to interface the hybrid system to the grid.

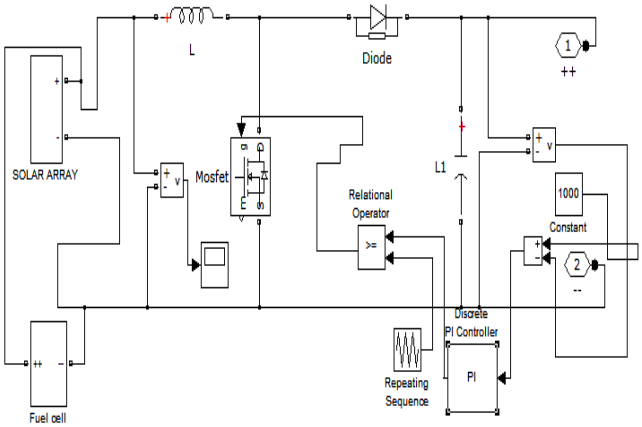

Figure 4: Boost converter with PI controller

A boost converter is a dc to dc voltage converter with an output dc voltage greater than input dc voltage. This is an SMPS containing at least two semiconductor switches a diode which act as freewheeling diode two ensure a path of the current during the off state of other switch and a transistor connecting in series of the source voltage. Filters made of capacitor and inductor is used to reduce the ripple in voltage and current respectively, is used at the output stage of the converter. The basic operating principle of the converter consists of the two distinct states, in on state, switch is closed, resulting in an increase in the inductor current. In off state, switch is open, resulting in decrease in the inductor current.

Hybrid Filters

Hybrid Filters are of different types, in this paper combination of shunt active power filter and passive filter acts as hybrid filter. Hybrid filter ensures the compensation of source current harmonics. Series and Parallel resonance are eliminated by this hybrid arrangement. Active and Passive filters are connected in Series and the arrangements are connected parallel to the grid as shown in Figure 5. Hybrid Filter can suppress the series and parallel resonance. By using this Hybrid Filter harmonic currents due to nonlinear loads are very much reduced.

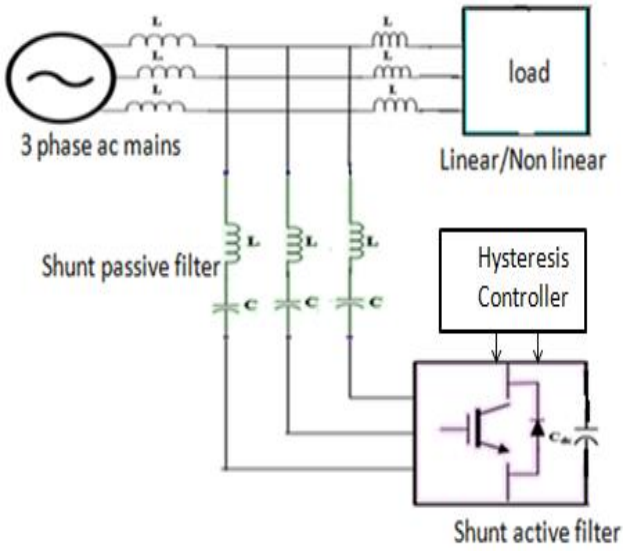

Figure 5: Hybrid Filter Integration to grid

6. Controllers

6.1 Hysteresis Current Control Method

Hysteresis Current control Method is used to supply pulses for the Switches in the inverter which is also used as filter. The hysteresis control method has best accuracy, and stability to the system. It is usually for current controlled inverters. Hysteresis current control technique is used for pulse generation in current controlled Voltage source inverters. It consists of a hysteresis band surrounding the generated error current. The current error is obtained by subtracting the actual filter current from the reference current. The reference current used here is obtained by the Synchronous Reference Frame method.

6.2synchronous Reference Frame Theory

There are different control methods for the calculation of reference current namely, Instantaneous Reactive power theory, One Cycle Control, Synchronous Reference power theory, Unity Power Factor Method, And Fast Fourier Method ect.

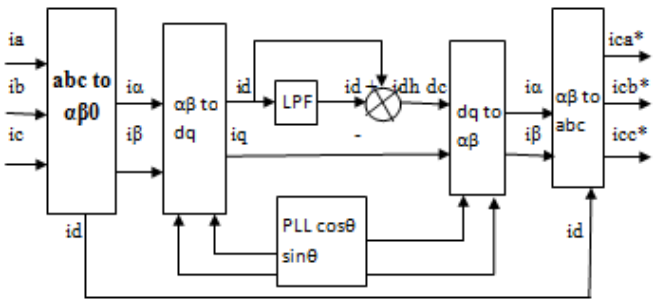

Figure 6: Block diagram of Synchronous Reference Frame Theory

Synchronous reference frame theory is used to extract the reference current for active power filter. Figure 6 shows the block diagram which explains the synchronous reference

frame theory.In this method the source current ia,ib,ic are first transformed into two phase stationary frame αβ.So now the two phase currents iα ,iβ are transformed into two phase synchronous frame.Synchronous reference frame is the d-q axis,cosθ and sinθ represents the synchronous unit vectors which is generated using phase locked loop. The d-q currents consists of AC and DC parts. DC component represents the fundamental component of current. AC represents the harmonic component.The harmonic component can beextracted using a filter.The d axis current is a combination of fundamental current and load current. The fundamental current rotate in synchronism and thus its DC. The AC component idh can be obtained by the difference in id and the total d-axis current,which leaves behind the harmonic component. Inverse transformation is performed to transform the dq synchronous frame to two phase αβ.Finally the two phase stationary frame Finally the current from two phase stationary frame αβ is transformed to three phase abc,and thus ica,icb,and icc are obtained. Figure 7 depicts the simulation model of Synchronous reference frame theory for reference current generation.

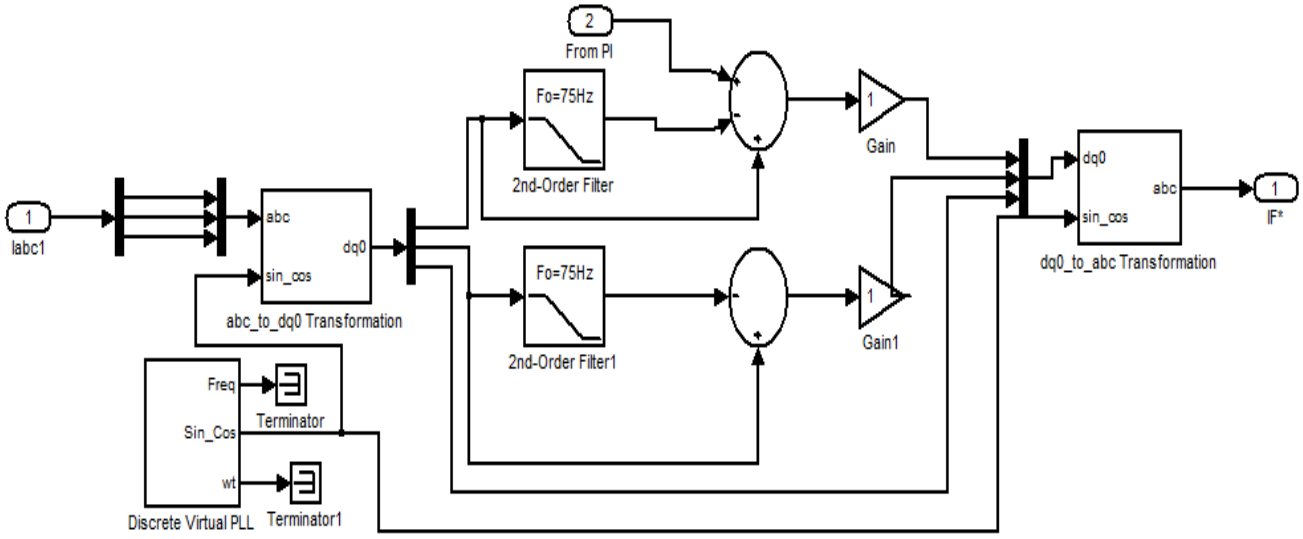

Figure 7:Simulation model of Synchronous Reference Frame Theory

7. Simulation Diagrams

Simulation diagrams for the proposed model using Hysteresis controller with sources and Active power filtering mode is shown in fig8 and fig 9.

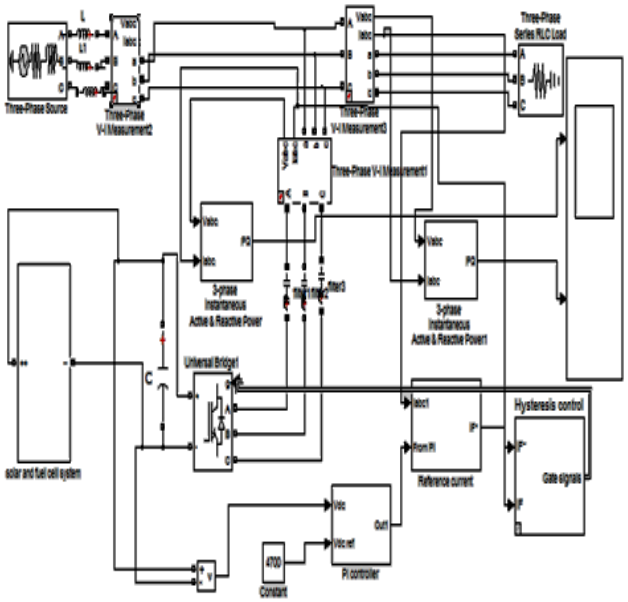

Figure 8: Simulation diagram of the proposed model with hysteresis controller to find the reactive power with linear load

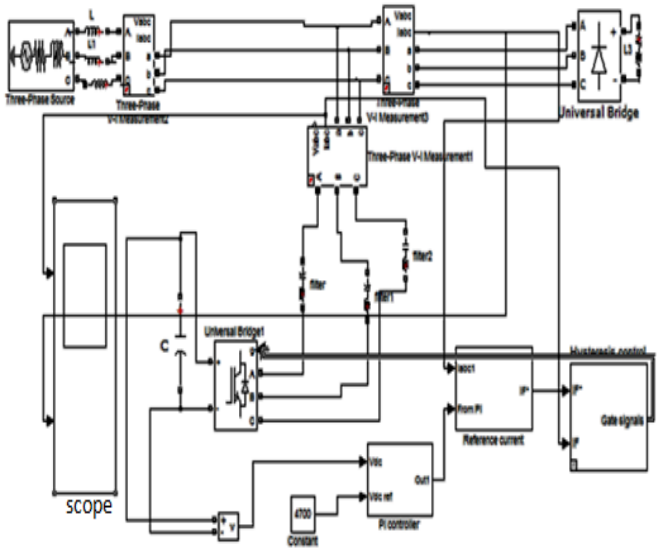

Figure 9: Active power filtering mode with hybrid filters to find the harmonics with nonlinear load

The Solar/Fuel cell is supplying power to the grid and the load. Thus, the inverter is also injecting active power from DG to the Point of common coupling apart from working as a Filter. Solar/Fuel cell supplying power is given to the boost converter. The stepped up voltage is given to the Hybrid Filter for mitigating the harmonics. The output from the Hybrid Filter is fed to the grid.

Thus the Hybrid Filter compensates the non sinusoidal source current.The Hybrid Filter compensates the phase difference between the grid voltage and grid current. The DC-link voltage is maintained so as to supply the power in the case of active power filtering mode. Total harmonic analysis is done in MATLAB using Fast Fourier Transform and the results are as shown in Figure 13 and 16, Output current and output voltage of the three phase source and load for two cases are as shown in Figure 10 and 14. Hybrid Filter output current and voltage are as shown in Figure 11 and 15.Real and Reactive power before and after compensation by Hybrid Filter for the two cases are as shown in Figure 12 and 17.

8. Simulation Results

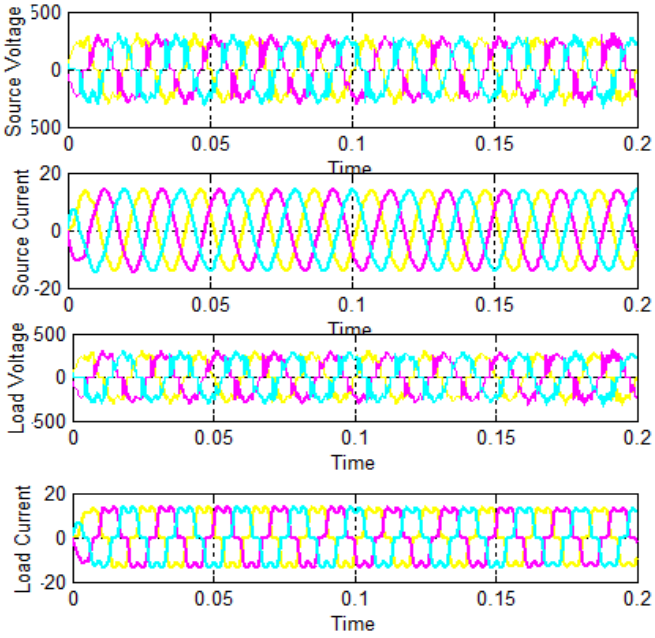

Figure 10: Output Voltage and Current of Three phase Source and Load connecting the Grid with Solar and Fuel cell.

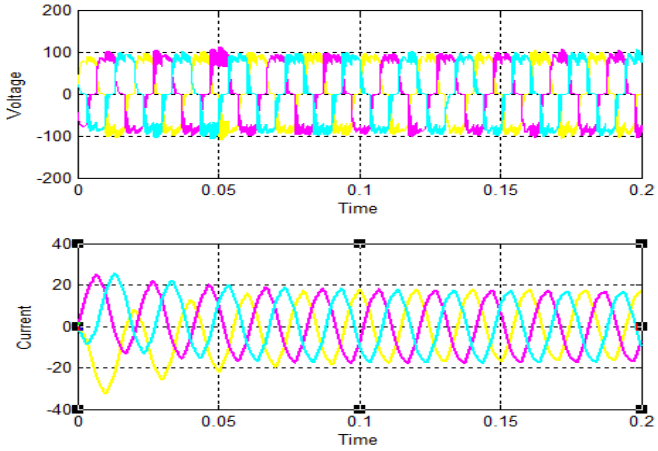

Figure 11: Hybrid Filter output Voltage and Current with Solar and Fuel cell connected .

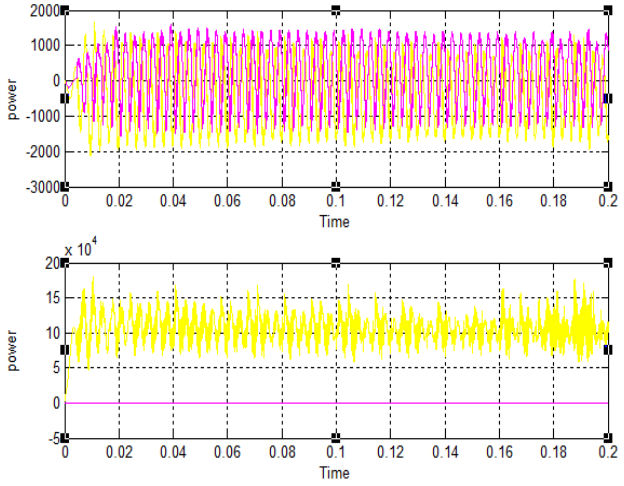

Figure 12: Active and Reactive power before and after the placement of filter with Solar and Fuel cell

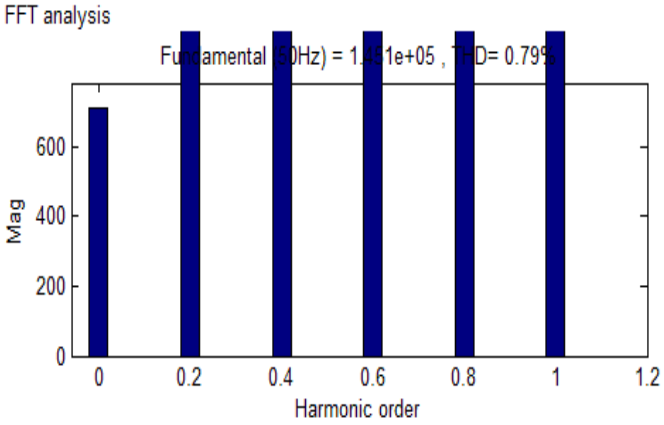

Figure 13: THD analysis using Hysteresis controller without solar and fuel cell.

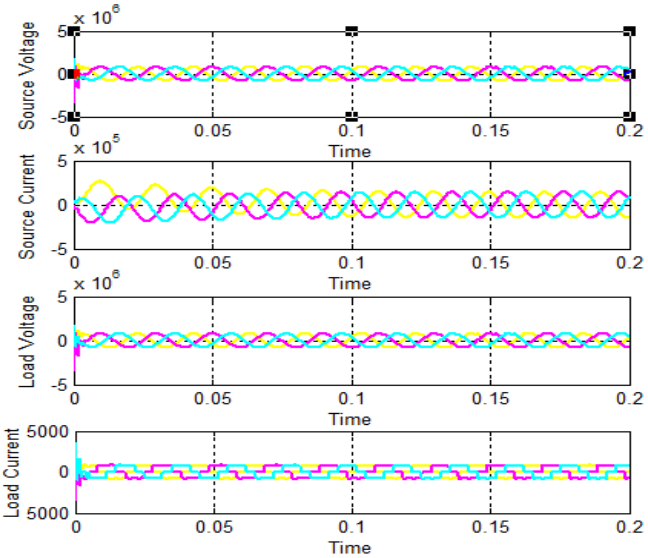

Figure 14: Output Voltage and Current of Three phase Source and Load connecting the Grid in active power filtering mode

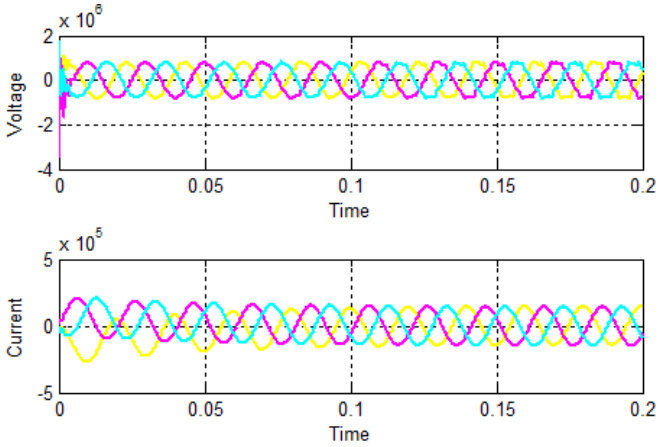

Figure 15: Hybrid Filter output Voltage and Current in active power filtering mode

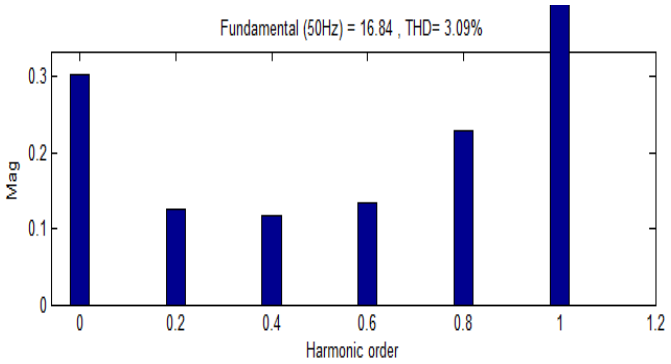

Figure 16: THD analysis using Hysteresis controller with solar and fuel cell

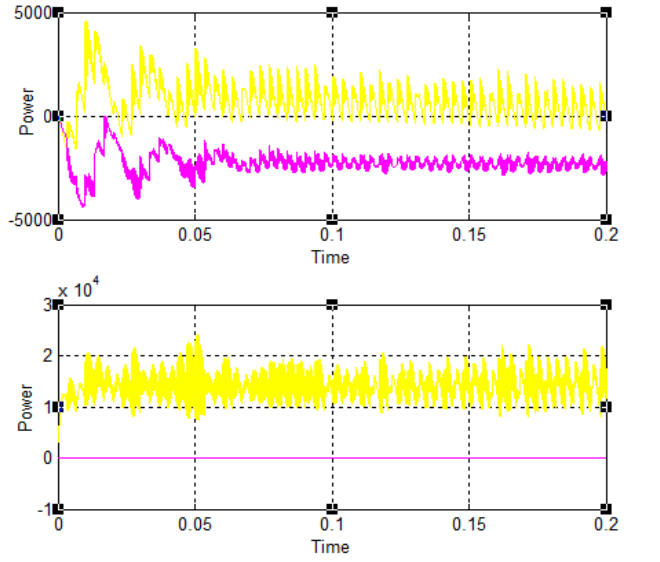

Figure 17: Active and Reactive power before and after the placement of filter without Solar and Fuel cell

9. Conclusion

The Solar and Fuel cell integration to the grid is modeled using MATLAB. Hybrid Filter which has both Shunt Active Power Filter and Passive Filters are used for compensating Harmonics, Real and Reactive power. Total Harmonic Distortions are found using Fast Fourier Transform analysis in MATLAB. Hysteresis current control technique used for the switching pulse generation was found to be effective and its validity is proved based on simulation results. Thus Hybrid Filters has been proved to be effective for two cases to keep the harmonic content in power lines within the permissible limit.

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