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ENHANCEMENT OF PERFORMANCE ANALYSIS OF POWER CONDITIONING SYSTEM FOR FUEL CELL APPLICATIONS

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Abstract- Fuel cells have been considered as the primary energy source for the distributed power generation as they are highly efficient, modular and clean. The main drawback is that the dc voltage generated by a single fuel cell varies from 0.7V to 1V. Due to the low input voltage in fuel cells, a suitable power conditioner is required to interface to the utility grid or local loads. To meet this requirement, this paper presents the design, development and performance of an inverter. The advantage of the proposed topology is that the modulation, control and protection requirements of each bridge are modular and it requires only a single dc source in each phase leg. A two-level H-bridge inverter using SPWM wave carrier modulation technique has been studied for total harmonic distortion (THD) and switching losses for fuel cell applications. A detailed study of the technique was carried out through MATLAB/SIMULINK for switching losses and THD. The results were verified through simulation.
Keywords: Fuel cells, converter, inverter, PCS, control, SPWM, Simulation, MATLAB/Simulink.

1. INTRODUCTION

The concept of the fuel cell originated in Britain in 1839. Sir William Grove developed the idea of using oxidation reduction equations to produce electricity (r9). However, it was not until over a hundred years later that fuel cells were considered for constructive applications. Fuel cells were used on space missions such as the Apollo and Gemini projects, and were introduced to automotive applications in the mid 1960's. There are several different types of fuel cells, including Proton Exchange Membrane (PEM), Alkaline Fuel Cells (AFC), Phosphoric Acid Fuel Cells (PAFC), Molten Carbonate Fuel Cells (MCFC), and Solid Oxide Fuel Cells (SOFC) (r9). The most common type used in automotive applications is PEM fuel cells. PEMs use a hydrogen rich gas as fuel and oxygen from the air as an oxidizer, whose only by-product is water vapour (r4).

The inverter strategy is a practical solution for reducing harmonics. Various topologies have been reported in the literature. The multilevel inverter with separate dc sources can fit many of the needs of all electric appliances. The fuel cells to generate a nearly sinusoidal voltage waveform. This structure is favourable for high power applications since it provides higher voltage at higher modulation frequencies (where they are needed) with a low switching (carrier) frequency. It means low switching loss for the same total harmonic distortion (THD) .It also improves the reliability by reducing the number of dc sources. Performance of the multilevel inverter (such as switching loss and THD) for the fuel cell PCS is mainly decided by the modulation strategies. Compared to the conventional triangular carrier based PWM, the SPWM carrier has a better spectral quality and a higher fundamental output voltage without any pulse dropping. In order to balance the switching duty among the various levels in inverters, a SPWM carrier based PWM has been suggested and Performance is verified based on simulation results.

2. FUEL CELL PLANT DESCRIPTION

Fuel cells produce DC power, water and heat from the combination of hydrogen produced from the fuel and oxygen from the air. In procedures where CO and CH4 react in the cell to produce hydrogen, CO2 is also a co-product. Reactions in fuel cells depend substantially on the temperature and pressure inside the cell. A system must be built around the fuel cell to supply air and clean fuel, convert the energy to a more usable form such as grid quality ac power, and remove the depleted reactants and heat that are produced by the reactions in the cells [7]. Figure 1 shows the basic structure of a fuel cell. Energy to DC electricity using the stacks of individual fuel cells. Number of stacks used in the power producing section unit depends on the specific power application. Finally, power conditioner converts DC power generated by the fuel cell stacks into the regulated AC or DC power suitable for customer. First stage of a fuel cell power system plant is a fuel processing unit where a conventional fuel (natural gas, methanol, coil, naphtha, or other gaseous hydrocarbon) is purified into a gas containing hydrogen. The following stage converts chemical energy to DC electricity using the stacks of individual fuel cells. Number of stacks used in the power producing section unit depends on the specific power application. Finally, power conditioner converts DC power generated by the fuel cell stacks into the regulated AC or DC power suitable for customer usage.

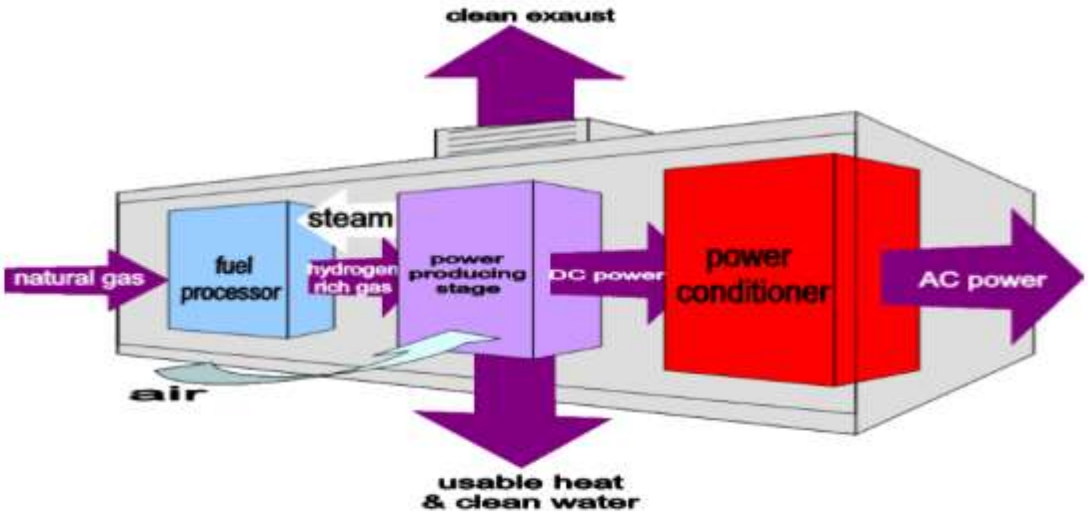

Fig. 2.1 Block Diagram of a Fuel Cell Power System

3. FUEL CELL POWER CONDITIONING SYSTEM

Fuel cells have broad spectrum of applications which require a particular power conditioning system as Shown in figure 2. Majority of conditioning systems include DC-to-DC and DC-to-AC power conversion blocks. Since the DC voltage generated by a fuel cell stack varies widely and is low in magnitude (<60 V for a 5-10 kW system, <350 V for a 300 kW system), a step-up DC-DC conversion stage is essential to generating a higher regulated DC voltage (400 V typical for 120/240 V AC output). The DC to DC converter stage draws power from the fuel cell and should be designed to match the fuel cell's current ripple specifications. Additionally, the DC-DC converter should not introduce any negative current into the fuel cell. Following this stage, a DC- AC inverter is used to supply the AC power at 50 Hz. An output LC filter stage is connected to produce a low total harmonic distortion (THD) AC waveform.

Fig. 3.1 shows a block diagram of a typical residential fuel cell system incorporating an auxiliary energy storage device (ultra capacitor or battery) for sudden load changes or fuel-cell start-up

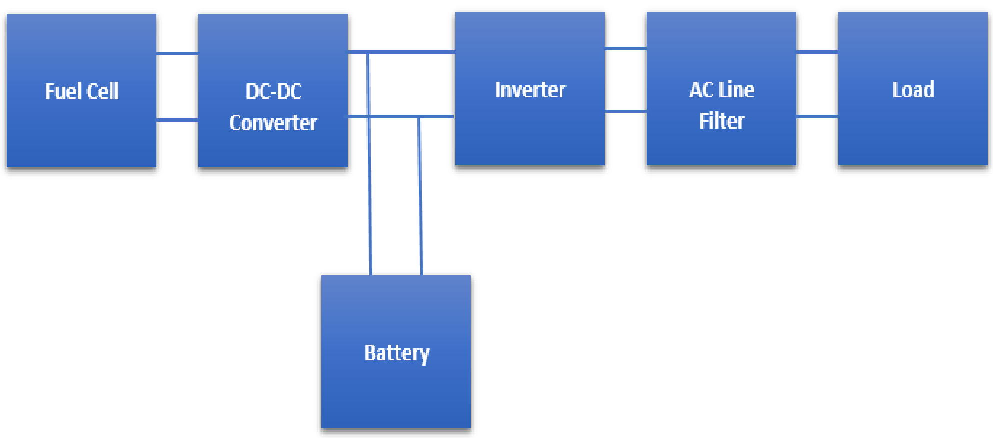

Fig. 3.1 Block Diagram of the Complete System

4. SIMULATION MODELS AND RESULTS

The Simulation is a widely used software package in academia and industry for modelling and simulating dynamic systems. It supports linear and nonlinear systems, modelled in continuous time, sampled time, or a hybrid of the two. Systems can also be multi-rate, i.e., have different parts that are sampled or updated at different rates. Simulink encourages the user to try things out. User can easily build models from scratch, or take an existing model and modify it. Simulations are interactive, so user can change parameters on the spot and immediately see what happens The witching sequence, MATLAB Simulink model and simulation result of single phase inverter system as shown in figs 4.1 & 4.2.

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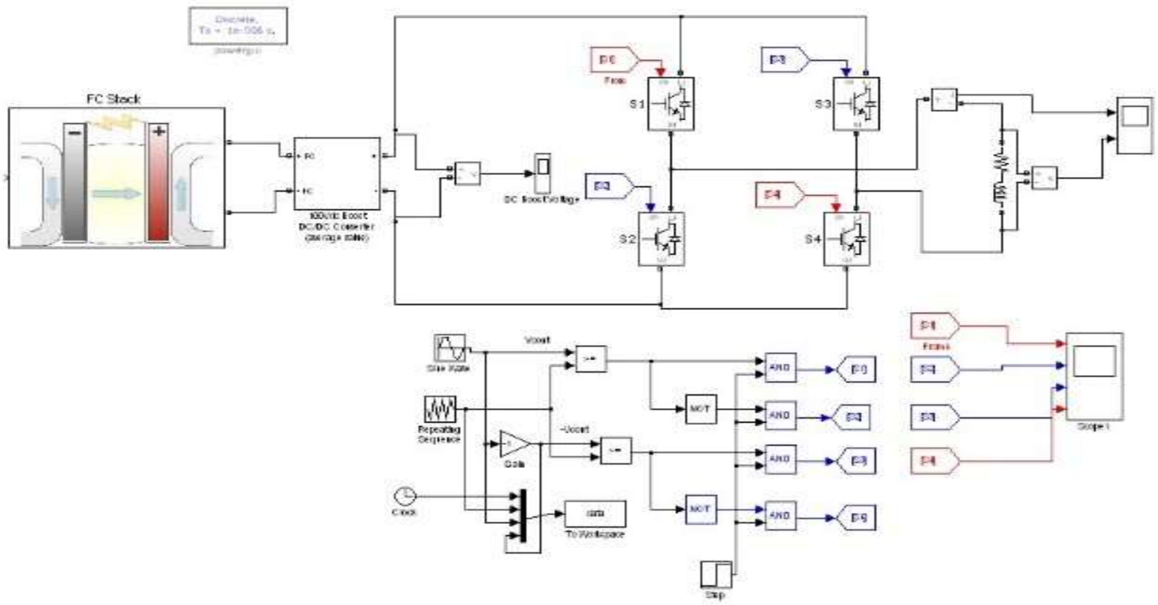

Fig. 4.1 Simulink Model of 1-ph Inverter Fuel Cell System

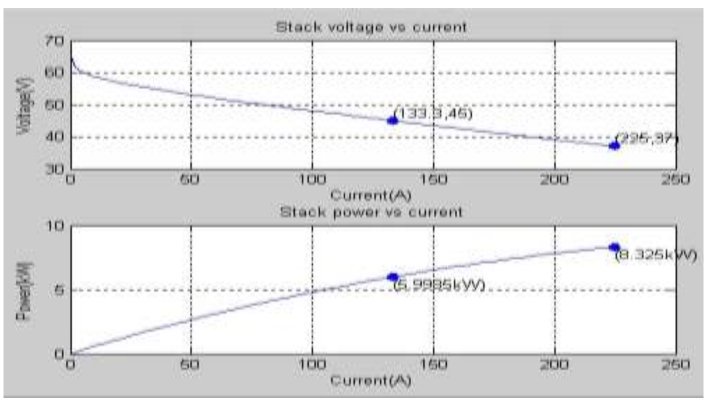

Fig.4.2 Power, Current and Voltage Waveform of Fuel Cell System

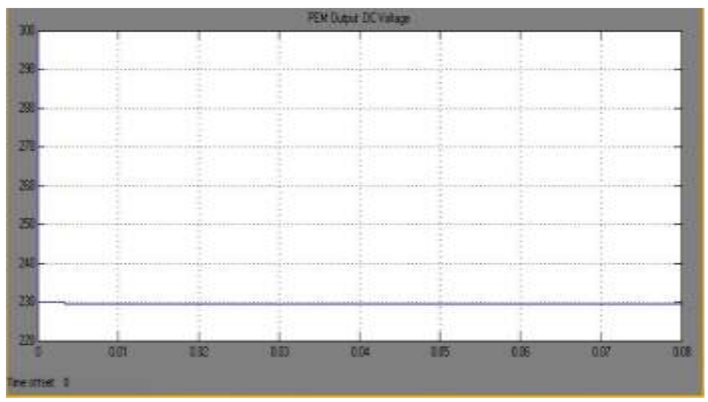

Fig. 4.5 Boost DC Voltage Waveform of Fuel Cell System

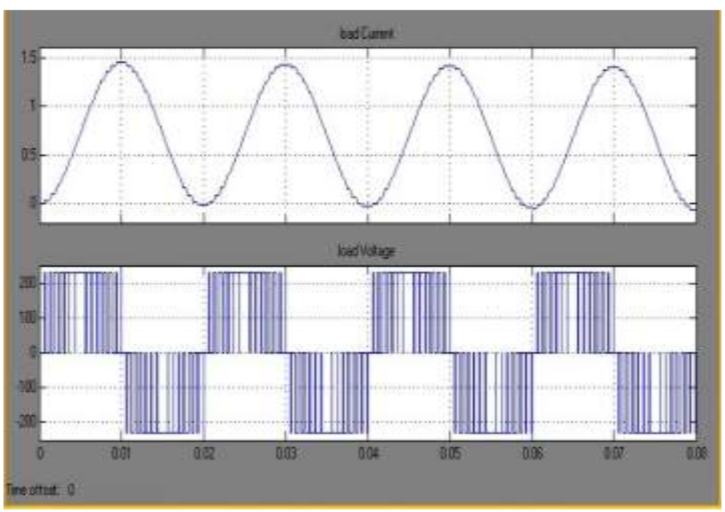

Fig. 4.6 Load Current, Load Voltage Waveform of Fuel Cell System

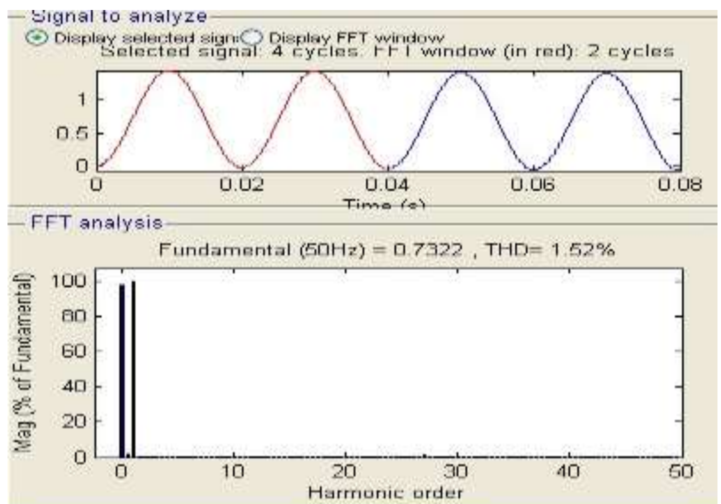

Fig. 4.7 THD Spectrums for Load Current Waveform for Single Phase Fuel Cell System

The MATLAB Simulink model of three phase inverter with SPWM modulation technique without filter and results as shown in figs [9-12].

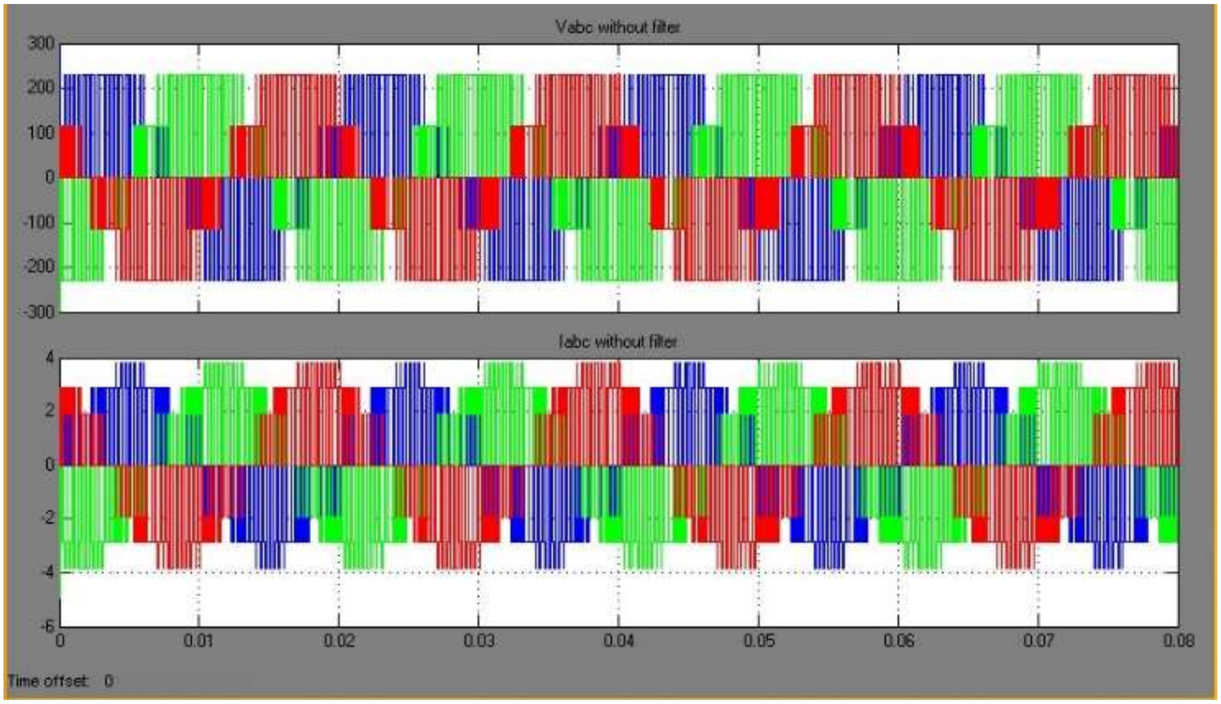

Fig. 4.8 3-ph Load Current, Load Voltage Waveform for SPWM Without Filter

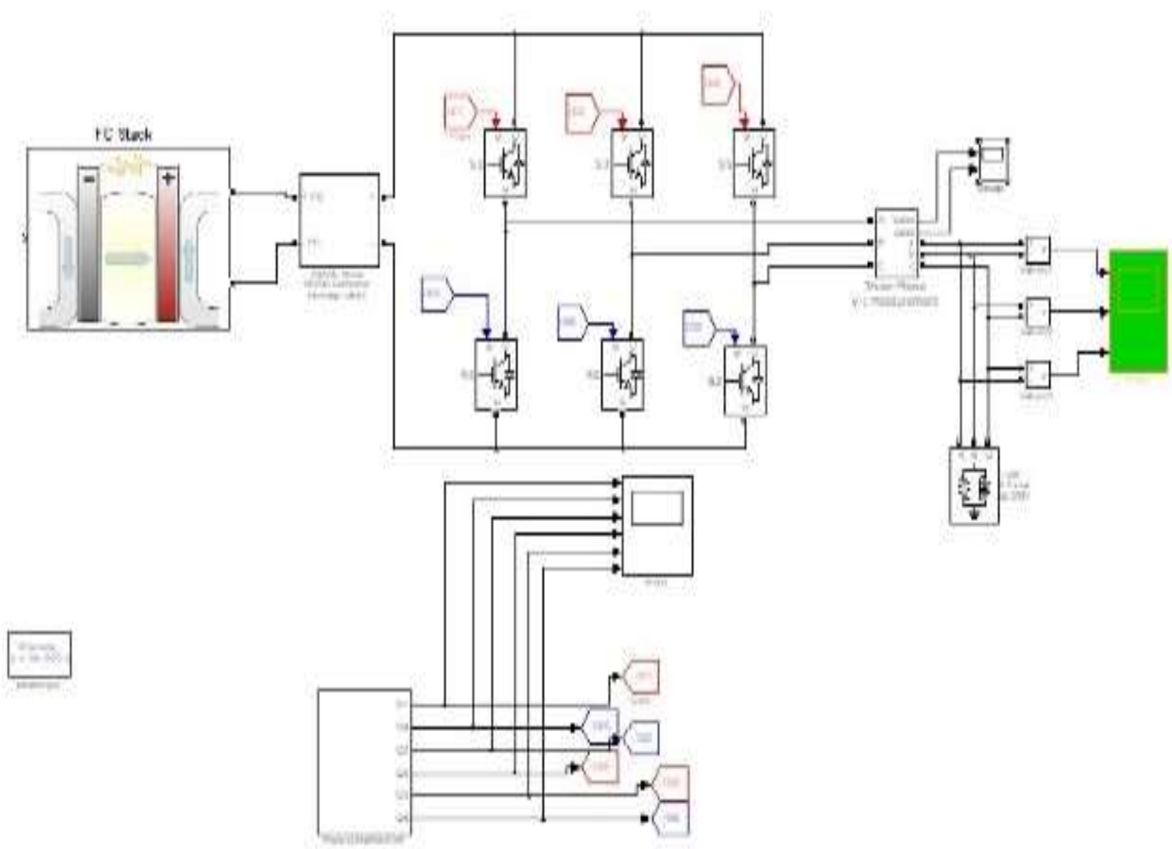

Fig. 4.9 Simulink Model of 3-ph with SPWM Without Filter

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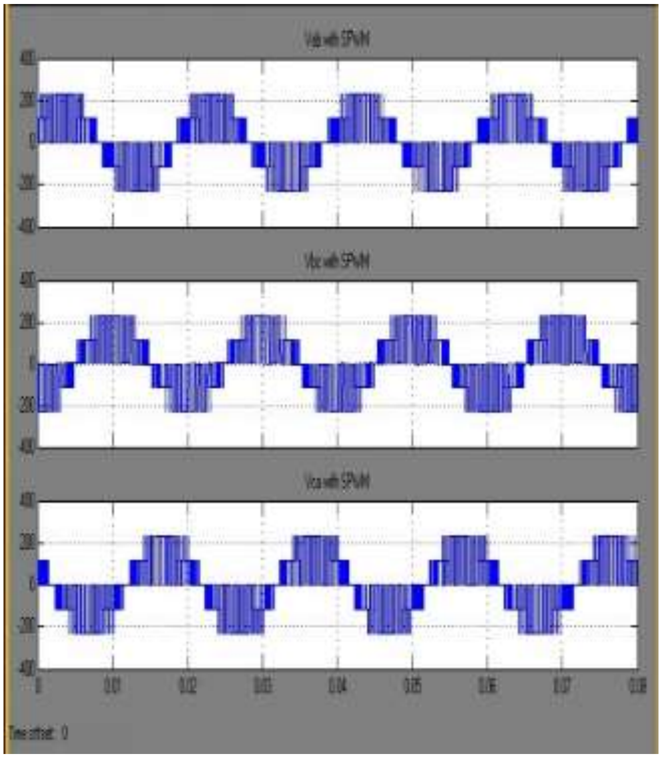

Fig. 4.10 Vab, Vbc and Vca line to line Voltage Waveform for Inverter SPWM Without Filter

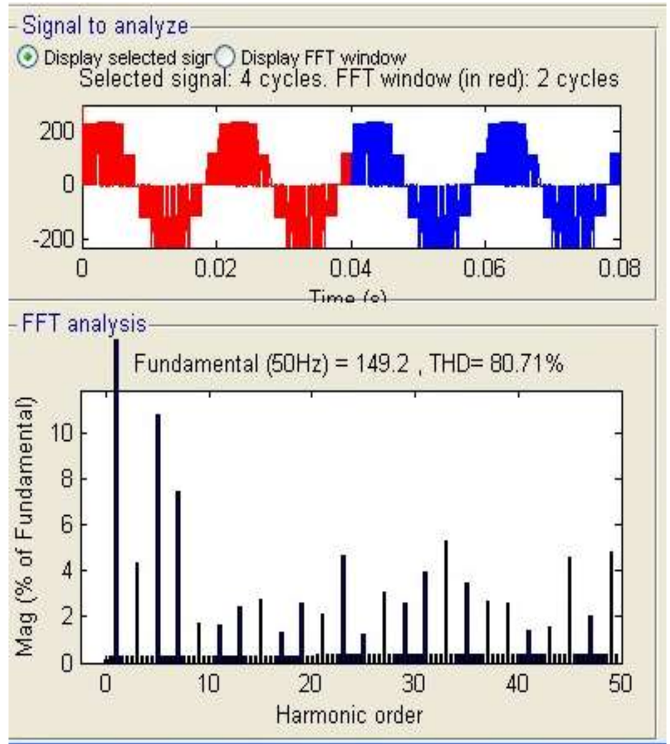

Fig. 4.11THD Spectrums for Load Voltage Waveform for Inverter SPWM Without Filter

The MATLAB Simulink model of three phase inverter with SPWM modulation technique with filter and results as shown in figs [13-17]

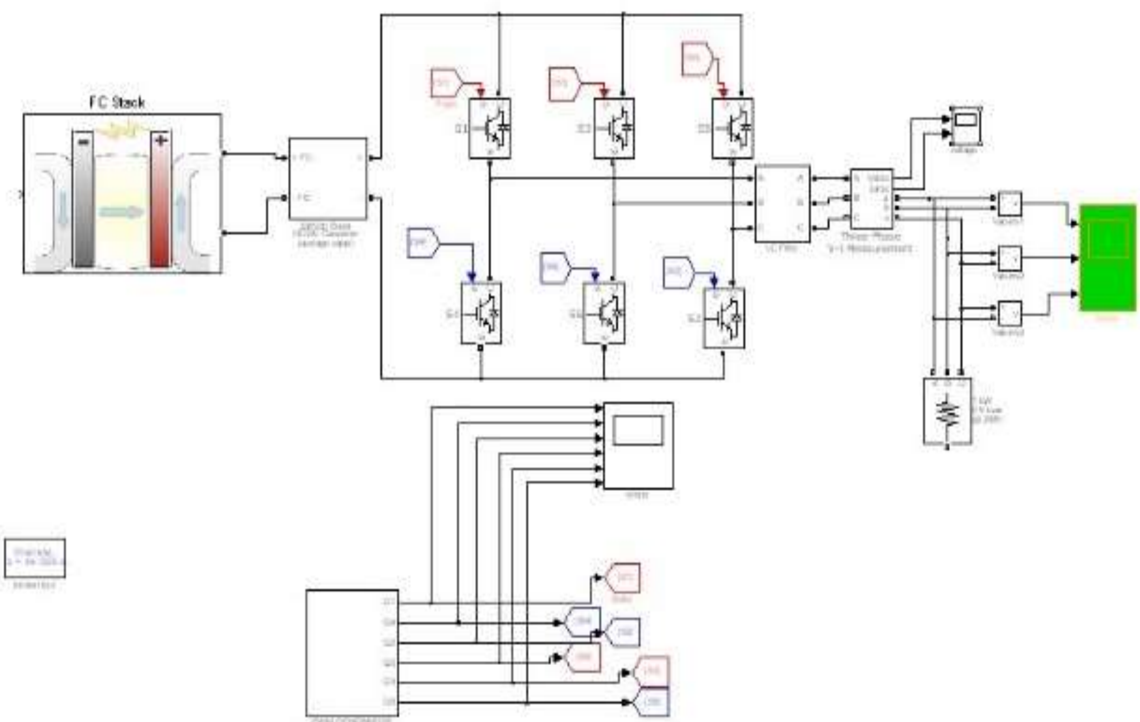

Fig. 4.12 Simulink Model of 3-ph with SPWM with Filter

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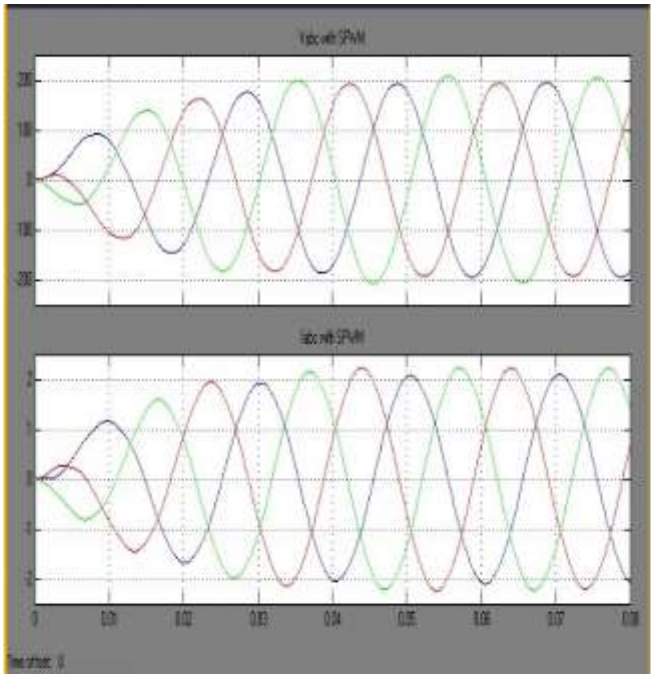


Fig. 4.13 3-ph Load Current, Load Voltage

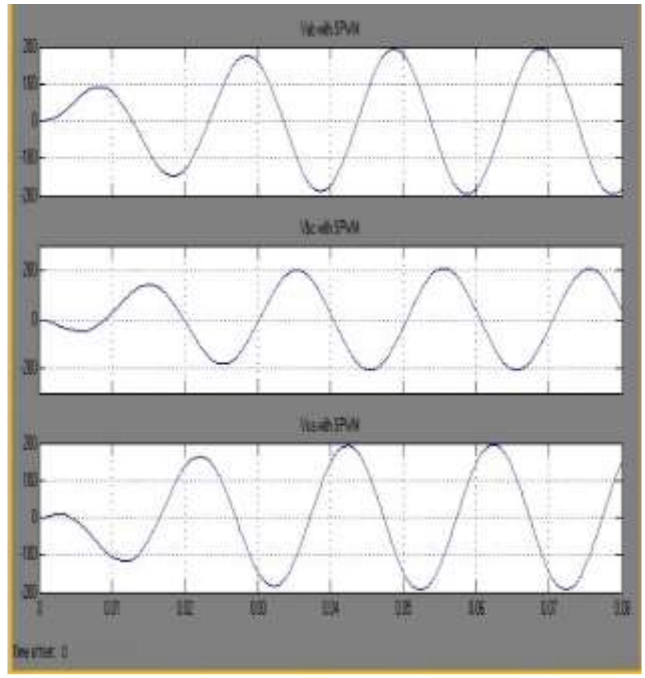
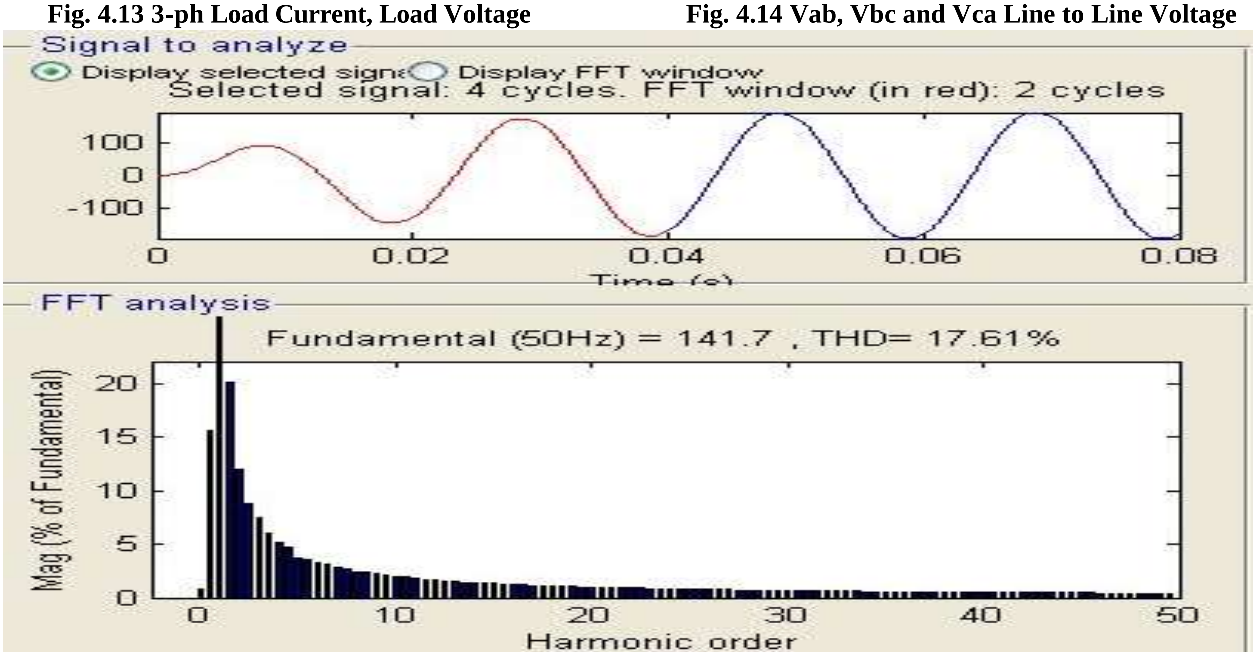


Fig. 4.14 Vab, Vbc and Vca Line to Line Voltage



Waveform for SPWM with Filter **Waveform for Inverter SPWM with Filter**

Fig. 4.15 THD Spectrums for Load Voltage Waveform for Inverter SPWM with Filter

CONCLUSIONS

This work investigates how electricity can be generated from fuel cells with the best integration in energy systems suitable for domestic application. Power electronic converters provide the electrical interface between the sources, storage, and loads, and the availability of reliable, low-cost and efficient. Pressure on fossil fuels will be reduced greatly if the contribution of renewable energy sources can be increased by a great amount. Fuel cell can play an important role in this case. The challenge in front of us is to find a more convenient, more cost effective way to convert the DC power available from the fuel cell to AC & supply it to the grid converters will produce current wave shapes exactly what the grid requires

Those Fuel Cells are preferred which have high voltage ratings and low current profile. This is because at higher current the losses within the fuel cell will be more and hence the efficiency of the system, for which it is known, will deteriorate. But the main drawback of higher voltage fuel cells is that voltage level can be increased only by adding series stacks. This adds to the system cost.

In low power rating fuel cells, low voltage is an issue. Boost converter provides solutions to raise the voltage level of the FC stack. Besides this bi-directional DC to DC converters are also used for boosting and isolation. This increases the bulkiness of the whole application. For AC applications the single phase inverter and three phase inverters are discussed with and without filter and analyzed the THD also.

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