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Fuel Cell Based Grid Connected Power Generation System

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Abstract *— Uses Of Renewable Energy Sources like a Solar, Pv cells, Wind Energy, Fuel cell etc. In this Thesis We Used Pollution Free Energy source As a Fuel cell For the Decreasing The Green House effect and also Decreasing size or Area of the equipment, also produces almost no Carbon Dioxide. In this thesis we introduced the power electronic interface for grid-connected fuel cell power generation system. Fuel cell and power electronic interface is addition of DC-DC Converter and DC-AC Inverter. Needed Of DC-DC Converter Because of the Fuel cell Voltage Is Low And with This low voltage It can not Applied on any generation equipment that's why A simple Circuit configuration using for the DC-DC converter Because of the high step up gain for boosting out the voltage for the fuel cell lower voltage. Also feeding for the minimizing the current ripple of the fuel cell by controlling dc-dc power converter. DC-AC inverter multilevel topology using for the conversion into AC with feeding into the grid supply system and load for using .A Mathematical Model of the fuel cell in mat lab is introduced in this thesis the result of the output voltage, efficiency and losses of the chemical reaction of the fuel cell. Main purpose of this topology is 1200W load sharing for the household application.*

Keywords*- Fuel cell, Boost Converter, SPWM Inverter, LC Filter, Control system,*

I. INTRODUCTION

The efficiency 90% set for the fuel cell stack for better operation. With using of fuel cell its low output voltage converted into step up voltage because of the high step up gain produced for the residential application. DC-DC converter boosting up voltage than for grid interface 3Φ line using simple inverter topology. DC power converting into AC with using inverter. After that setting up inverter side load and produced desired amount of voltage, current, magnitude, frequency matched up with grid. for filtering L-C component after dc ac inverter. Inverter producing desired voltage for the residential or house hold application. all the result shown in the simulation for better judgment. Power traditionally relies upon fossil fuels. Fuel cells can power anything from a house to a car to a cellular phone. They are especially advantageous for applications that are energy-limited. This is the only renewable energy source which gives the output as water and pollution free gases[1]. Fuel cell and its different topology now widely used in all over world basically in power plant area for the electricity generation, hybrid vehicles, power electronic area. Fuels cells are electrochemical devices used to convert the energy stored within the chemical bonds of a fuel to electrical energy and/or heat. Fuel Cells are unique in that they are the only solid state energy conversion technology capable of electrochemically extracting energy from all the chemical bonds found in biogas, gasoline, natural gas, jet fuel, syngas, hydrogen, or any oxidizable fuel. More importantly, Fuel cell are very efficient in doing this[1]. High electrical and cogeneration (i.e. combined heat and power) efficiencies of 50-60% and 80-90%, respectively.

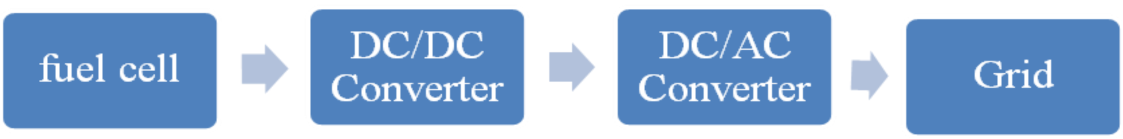
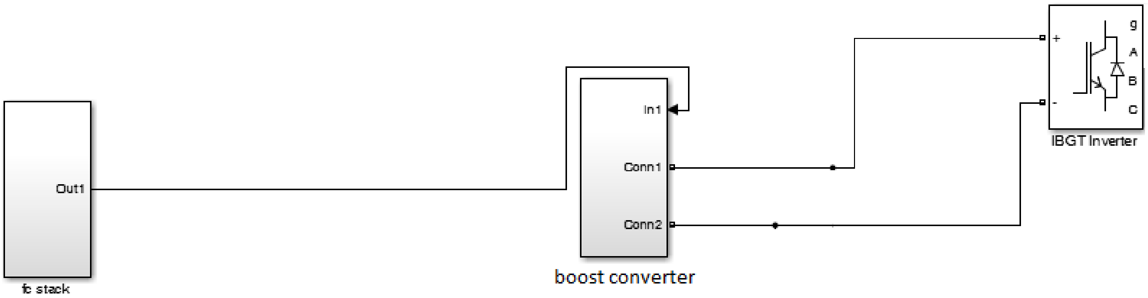


Figure: Block diagram of circuit

This power electronic interface is composed of a DC–DC power converter and a DC–AC inverter. the DC–DC power converter to perform high step-up gain for boosting the output voltage of the fuel cell to a higher voltage. The input current ripple of the fuel cell is suppressed by controlling the DC–DC power converter. The DC–AC inverter is configured by a simple SPWM AC output voltage. The DC–AC inverter can perform the functions of DC–AC power conversion and active power filtration. A fuel cell based distributed power generation system generates electrical power which is injected into the distribution power system.

II. CIRCUIT CONFIGURATION



2.1 Fuel cell

A fuel cell consists of a negatively charged electrode (anode), a positively charged electrode (cathode), and an electrolyte membrane. Hydrogen is oxidized on the anode and oxygen is reduced on the cathode. Protons are transported from the anode to the cathode through the electrolyte membrane, and the electrons are carried to the cathode over the external circuit[1]. In nature, molecules cannot stay in an ionic state, therefore they immediately recombine with other molecules in order to return to the neutral state. Hydrogen protons in fuel cells stay in the ionic state by traveling from molecule to molecule through the use of special materials. The protons travel through a polymer membrane made of persulfonic acid groups with a Teflon backbone. The electrons are attracted to conductive materials and travel to the load when needed. On the cathode, oxygen reacts with protons and electrons, forming water and producing heat. Both the anode and cathode contain a catalyst to speed up the electrochemical processes[1].
A typical PEM fuel cell (proton exchange membrane fuel cell) has the following reactions[1]:

Anode: $H_2(g)\quad 2H^+(aq)+2e^-$

Cathode: 1/2O2 (g) □ □ $2H^+(aq)$ □ □ $2e^-$ $H_2O(l)$

Overall: H2 (g) □ □ 1/2O2 (g) □ H2O (l) □ □ electric energy □ □ waste heat

Reactants are transported by diffusion and/or convection to the catalyzed electrode surfaces where the electrochemical reactions take place. The water and waste heat generated by the fuel cell must be continuously removed and may present critical issues for PEM fuel cells. The basic PEM fuel cell stack consists of a proton exchange membrane(PEM), catalyst and gas diffusion layers, flow field plates, gaskets and end plates as shown in Table 1.2: The actual fuel cell layers are the PEM, gas diffusion and catalyst layers. These layers are “sandwiched” together using various processes, and are called the membrane electrode assembly (MEA). A stack with many cells has MEAs “Sandwiched” between bipolar flow field plates and only one set of end plates.

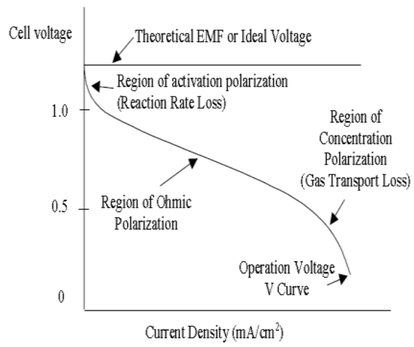
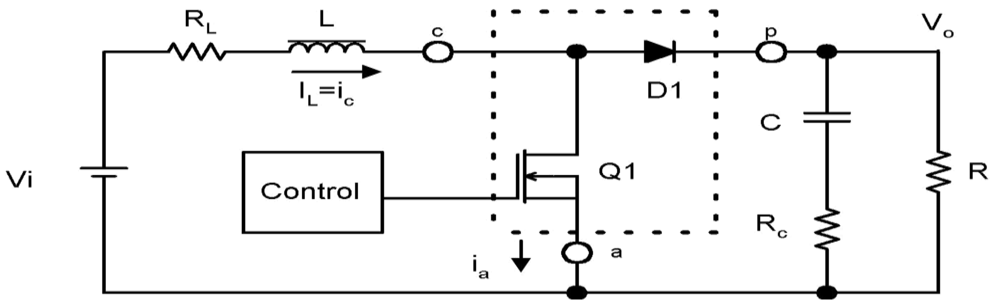


Figure: Characteristics of fuel cell

There are 3 types of losses:
1- **Activation losses**: Due to slowness of reaction inside the cell.(low voltage densities)
2-**concentration losses**: Due to high current densities.

3-**ohmic losses**: leakage of electron that passes through the membrane to cathode instead of flowing through the electric load.

2.2 Boost converter



Boost is a attractive non-isolated power converter topology, sometimes it is called a step-up power converter. Power supply demonstrated choose the boost power converter because the needed output is always higher than the input voltage[20]. It is also used for regulated dc power supplies and for the regenerative breaking of dc motor. When switch is on at that time diode is in reverse biased condition and also output state is also isolating. Here shown also the input passing the energy directly the inductor. When switch is off condition the output receives energy from inductor as well as input.

Figure 3.1 shows a simplified diagram of the boost power converter. In steady state, output filter capacitor is very large to ensure a constant output voltage.

$$V_o(t) = V_o$$

Inductor design equation:

$$I_{omax} = \frac{P_o}{V_o}$$

$$R_{min} = \frac{V_o}{I_{omax}}$$

$$R_{max} = \frac{V_o}{I_{omin}}$$

$$D_{min} = 1 - \frac{V_{in\_max}}{V_o}$$

$$D_{max} = 1 - \frac{V_{in\_min}}{V_o}$$

$$L_{min} = \frac{R_{max} * D_{max}(1 - D_{max})^2}{2 * f_s}$$

Capacitor design:

$$C=\frac{D_{max}*V_o}{f_s*R_{min}*V_r}$$

2.3 SPWM inverter

Sinusoidal pulse width modulation technique directly controls the output voltage and frequency according to the sine function. The PWM inverter has been the main choice in power electronic for decades, because of its circuit simplicity and rugged control scheme. In SPWM techniques, constant amplitude pulses with different duty cycles for each period is generate[3]. The width of these pulses is controlled to control output voltage of the inverter. In SPWM three sine wave and single carrier wave of high frequency is used for generation of gate signal sine wave is called reference or modulation signal, and have phase shift of to each other Frequency of sine signal is selected based on required speed for induction motor. The carrier signal is normally triangular wave with high frequency. For generation of switching pulse, sinusoidal wave is compared with carrier wave. . In following figure sine wave comparison for single phase is shown. The comparator gives switching pulse when sine wave voltage is greater than the triangular voltage, otherwise it being at low state. The switches of same leg cannot be switched on simultaneously, to avoid short in leg. To control the output of inverter voltage, width of switching pulse need to be changed and it is done by changing frequency or amplitude of modulating signal[3].

For SPWM, amplitude and frequency modulation index is,

$$\text{Amplitude Modulation} \quad M_a = \frac{A_m}{A_c}$$

$$\text{Frequency Modulation} \quad M_f = \frac{f_m}{f_c}$$

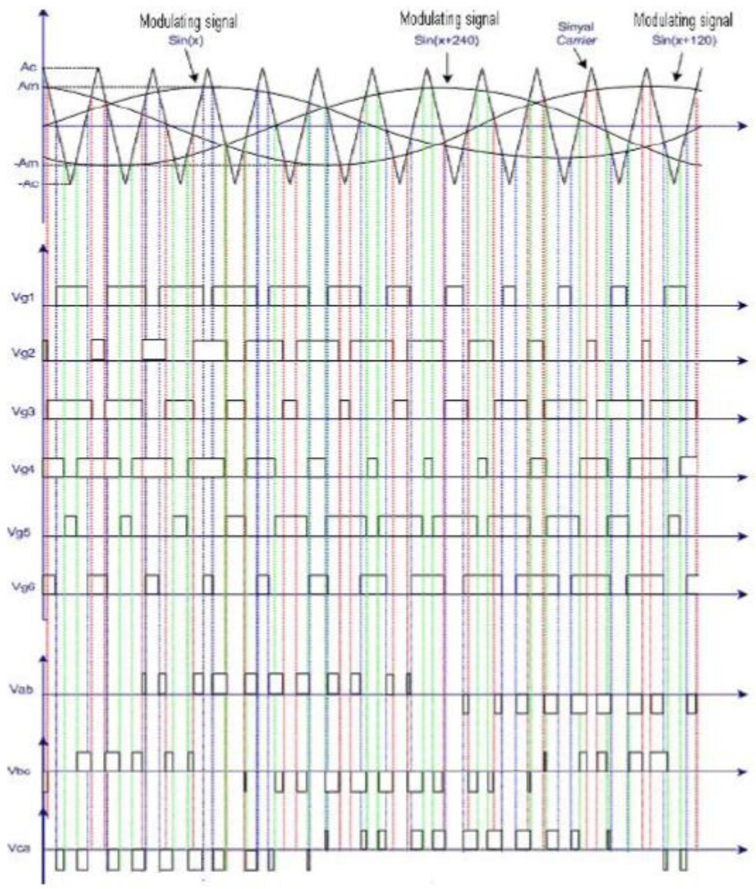


Figure: Conventional SPWM generation technique for three phase voltage source inverter[3]

The inverter output voltage has the following features:

- PWM frequency is the same as the frequency of carrier signal.
- Amplitude is controlled by the peak value of modulation signal.
- Fundamental frequency is controlled by the frequency of modulation signal[3].

III. CONTROL SYSTEM

Control system for boost converter

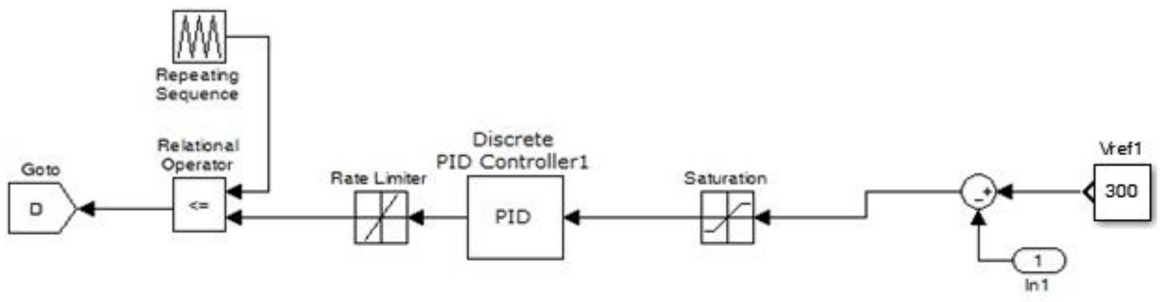


Figure: Close loop system of Boost Converter

Here 3oov reference voltage is applied constant and measured voltage is taken for the compare after that it will applied to the pid controller and it set the value of Kp and Ki. It is given to the relational operator for the limiting the pulses and as per shown in figure repeating sequence also applied for the switching frequency and given to the switch.

3.2 Control system for inverter and synchronization:

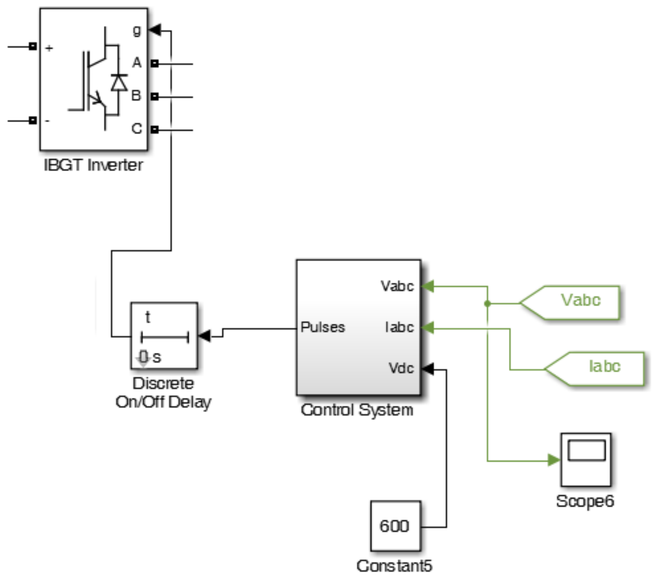
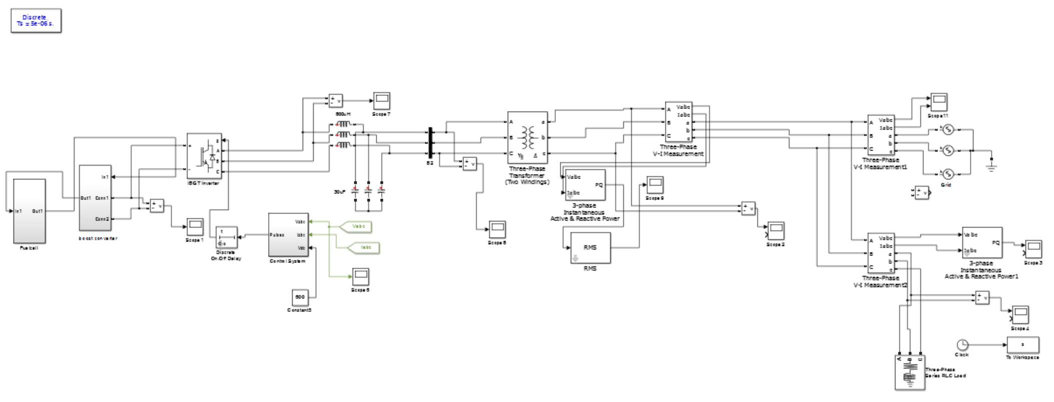


Figure: Control system

It is the control system as well as pulse generator of the inverter and also synchronization system of the inverter and Grid. With using of abc to dq0 reference here to control the grid voltage of Vabc.

IV.SIMULATION RESULTS



Fuel cell different losses mathematical model is presented here for more knowledge. This whole system is in open loop system and value of different system is presented here: fuel cell different chemical reaction particles, hydrogen, oxygen which is shown in following table.

Parameters	value	Parameters	Value
N	**20**	**T_{ref}(K)**	**298.15**

T(K)	323	F(C/mol)	96486.7
P_{H2}(atm)	10	R(J/mol K)	8.314
P_{o2}(atm)	10	£$_1$	-0.9514
(J/mol)	237180	£$_2$	0.00312
A(cm^2)	150	£$_3$	$7.4*10^{-4}$
S(mol K)	-163.15	£$_4$	$-1.87*10^{-4}$
l(μm)	51	C(F)	2.5
B(V)	0.016	J_{max}(A/cm^2)	1.5
Λ	20	R_c(Ω^2)	$3*10^{-4}$

Table: Parameters of FC

Waveform of the Fuel Cell:

Here the output voltage of the FC is 50V. and current of the FC is near about 3A.

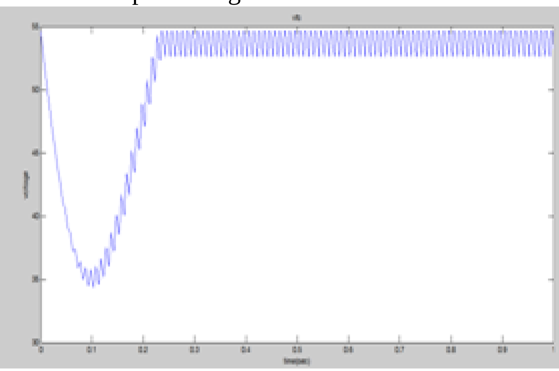


Figure: Output voltage

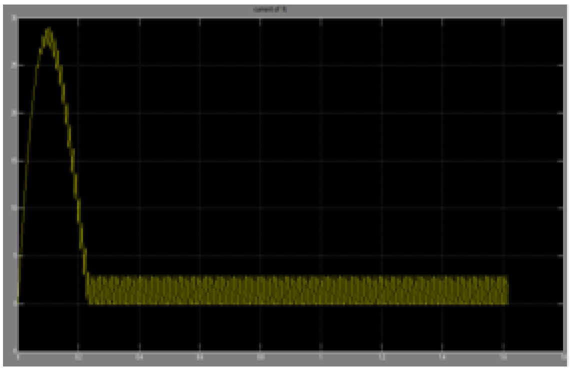


Figure: Output current

Boost converter parameters:

L	C	Duty cycle	Kp	Ki
96.98e-3H	117e-4F	0.83%	0.0005	0.150

Here output of the boost voltage is 265V and this constant dc voltage will be applied to the dc-ac inverter and the following figure shows the waveform for this.

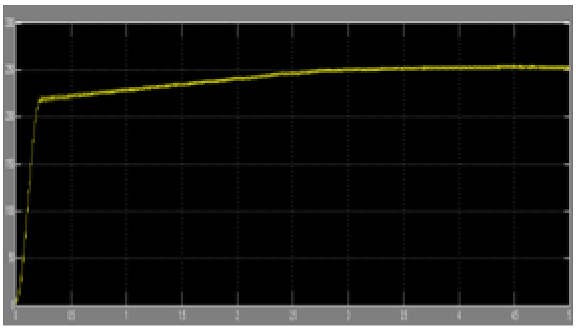


Figure: Boost output voltage

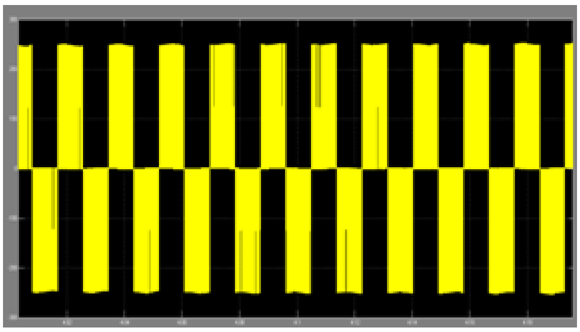


Figure: Inverter output voltage

Figure: showed the filtered waveform of the inverter which is pure sinusoidal and LC filter is using for the LC value is based on trial and error method.
This the wave of the pure sinousidal waveform of LC Filter the value of filter are:

L=800µH

C=30µF

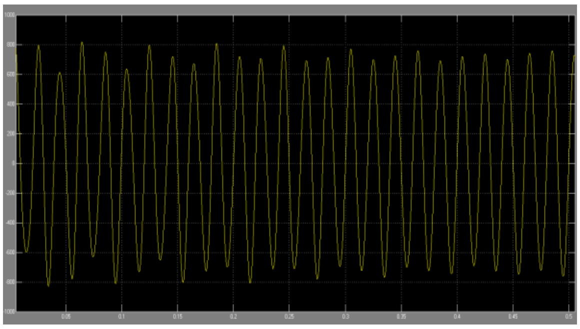


Figure: Filtered output voltage of inverter

Design of the stepup transformer :

Nominal powerVA	Frequency	Winding1	Winding2
6000VA	**50hz**	**415**	**415**

At last this rating applied to the grid and load and show the waveform:

Design of the grid:

Peak voltage = 315v

3phase

F= 50Hz

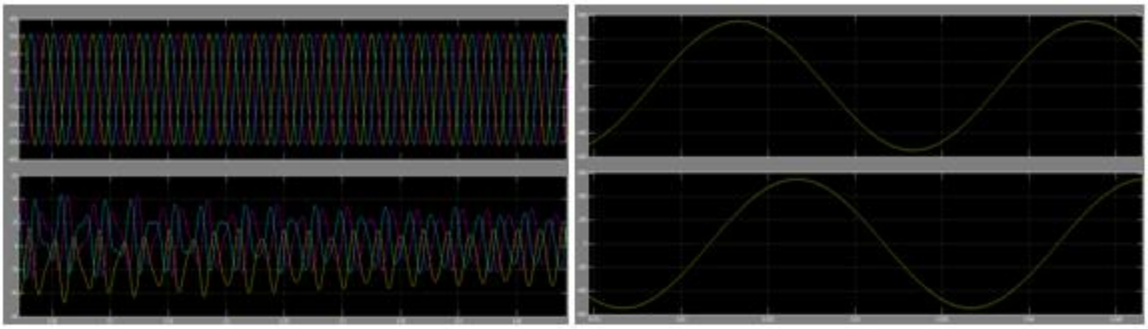


Figure: Synchronization, system+grid

V.HARDWARE IMPLEMENTATION

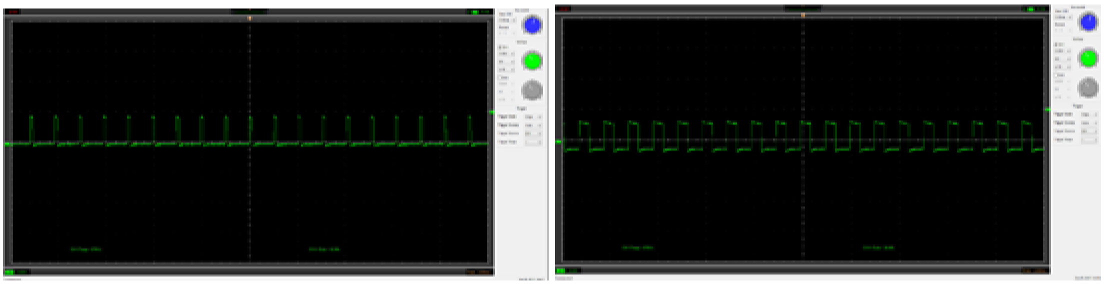


Figure: Gate pulse of buck and boost converter

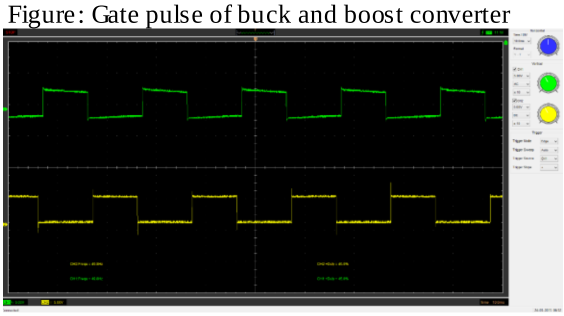


Figure: Gate pulse of inverter

Description:
For the hardware here single phase system is implemented. Main of the hardware is run the 100w load as bulb, CFL. After that 100w is applied to the grid for matching the synchronization. Here, one thing is to be noted that against of fuel cell here as a sources buck converter is used and 230V ac converting using bridge rectifier circuit rating as 348/50V dc supplied to the converter. This 348V dc buck converter reduced as per characteristic near about 210/30V and after that applied to the boost converter which boosting up voltage near about 300Vdc. After that using single phase inverter this voltage converting into ac and after applied to grid and load.

V. CONCLUSIONS

Fuel Cell a Wide Performable Energy source also called as pollution free source using of its higher efficiency, reliability, 5 year working capacity and Siting any area of the power plant. Help of this equipment its lower voltage boosting with boost converter, for the 1.2kw load producing used for residential application and grid connection. SPWM inverter which modulation scheme is easy, also high efficiency converting this Vdc into Vac for the three phase inverter which peak to peak output voltage is approximate 315v. To match this voltage with grid voltage, also its magnitude, and frequency for grid interfacing.

VI. ACKNOWLEDGMENT

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