ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

MODELLING, SIMULATION AND CONTROL OF A NON CONVENTIONAL FUEL CELL POWER GENERATION SYSTEM BY VARYING OXYGEN PRESSURE USING MATLAB

Sougata Sen[1], Indrajit Koley[2], Pritam Chowdhury[3], Dr.Pradip Kumar Saha[4], Dr.Gautam Kumar Panda[5]

PG Student, Dept. of Electrical Engineering, Jalpaiguri Govt. Engg.college,Jalpaiguri, India[1]

PG Student, Dept. of Electrical Engineering, Jalpaiguri Govt. Engg.college,Jalpaiguri, India[2]

PG Student, Dept. of Electrical Engineering, Jalpaiguri Govt. Engg.college,Jalpaiguri, India[3]

Professor, Dept. of Electrical Engineering, Jalpaiguri Govt. Engg College ,Jalpaiguri, India[4]

HOD & Professor, Dept. of Electrical Engineering, Jalpaiguri Govt. Engg.College,Jalpaiguri, India[5]

ABSTRACT: Energy from the ground that has limited supplies, either in the form of gas, liquid or solid, are called non renewable resources. They cannot be replenished, or made again, in a short period of time. Examples include: oil (petroleum), natural gas, coal and uranium (nuclear). Oil, natural gas and coal are called “fossil fuels” because they have been formed from the organic remains of prehistoric plants and animals . In present scenario the hole world is tollay dependable on these types of energy. But the problem is that these types of energy sources continuously decreasing .Therefore a huge shortage in energy bank. Thats why we have to find some new energy source which is renewable source of energy and also environment friendly. Fuel cell is a source of energy. Where we use hydrogen and oxygen as a fuel. Basically the pressure of hydrogen is constant, only flow of oxygen pressure is varied. Our aim is that what will happen if we varies oxygen pressure and the corresponding change on load voltage . here we also design filter for better output.

KEYWORDS: Filter , Fuel cell ,Inverter , load, voltage regulator .

I. INTRODUCTION

Research and development of fuel cell system for various applications has been increased in past few years. PEMFC(Proton Exchange membrane Fuel cell) system is the most promising and accepting system in fuel cell technology. PEM fuel cells are environment friendly since they use Hydrogen as fuel. Hydrogen can be obtained from Hydro carbons, biomass, Necular energy or from cleaner sources such as water electrolysis.PEM fuel cells consists of a solid polymer electrolyte and operates low temperature (50^0-100^0C).They do not pollute the environment which is due to only by product is water. When Hydrogen passes through anode and Oxygen passes through Cathode PEM fuel cell produces electrochemical power. Between the anode and cathode there have a a electrolyte which exchanges of electrical charge .Due to flow of charge through electrolyte and electrical current flows. If we connect an external electrical circuit then current will flow. A single cell produce approximately 1.23V under normal operation conditation. For higher requirement of power several cells should be connected in series forming a stack.Ideal output voltage ENernst . ENernst is the electrochemical thermodynamic potential of the cell and it represents its reversible voltage , which is an ideal output voltage. E Nernst can be calculated by a modified version of the equation of Nernst, with an extra term to take into account changes in the temperature with respect to the standard reference temperature 25^{o}C. Using the standard pressure and temperature (SPT)values, we can get a simplified equation as:

$$E = E0 - 0{,}85.10^{-3}\,(T - 298{,}15) + \frac{RT}{2F}\, IN\left(\frac{PH2\;\;PO2^{0.5}}{P_{H2O\;P^{0.5}}}\right) \quad V$$

When we get the water production in the form of steam, 1.229 should be replaced by 1.18. Usually, the fuel stack will be controlled by changing the oxygen pressure , so we can assume that hydrogen pressure is constant. When we compare the two parameters T and PO2 we can find -0.85×10-3T changes “faster” than 4.31×10-5Tln(PO2), because with the parameter x the function f(x)=ln(x) is always smaller than f(x)=x. So, T will mainly determine the ENernst value. By the help of MATLAB, we can get the result .

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

II. FUEL CELL

A fuel cell is a device that uses hydrogen as a fuel to produce electrons, protons, heat and water. Fuel cell technology is based upon the simple combustion reaction given

$$2H2 + O2 = 2H2O \qquad (1)$$

The electrons can be harnessed to provide electricity in a consumable form through a simple circuit with a load. Problems arise when simple fuel cells are constructed Simple fuel cells have a very small area of contact between the electrolyte, the electrode, and the gas fuel. Simple fuel cells also have high resistance through the electrolyte as a result of the distance between the electrodes. Therefore, as a result of these problems, fuel cells have been designed to avoid them. A design solution includes manufacturing a flat plate for the electrodes with an electrolyte of very small thickness between the two electrodes. A very porous electrode with a spherical microstructure is optimal so that penetration by the electrolyte and gas can occur. This design gives the maximum area of contact between the electrodes, electrolyte and gas thus increasing the efficiency and current of the fuel cell.

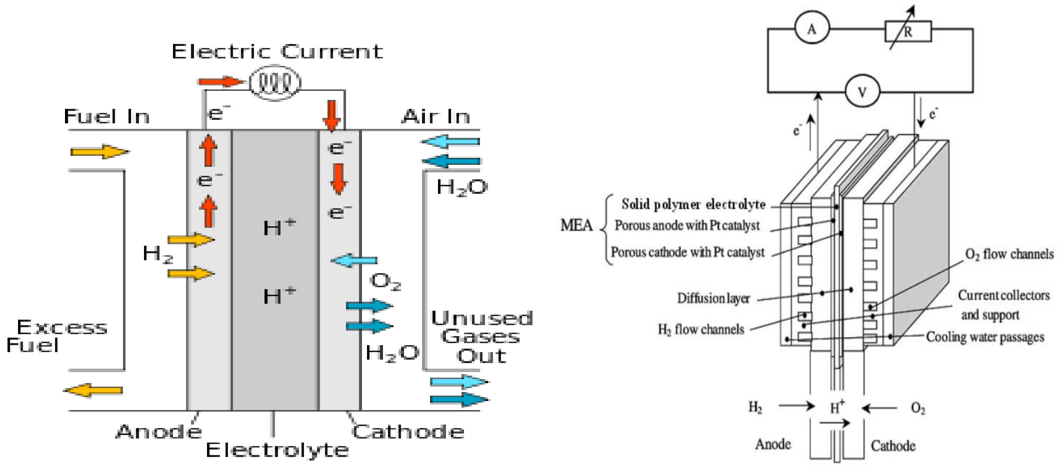

Figure 1. Basic Fuel cell component

III. FUEL CELL WORKING PRINCIPLE

The fundamental structure of a PEM fuel cell can be described as two electrodes (anode, cathode) separated by solid membrane acting as an electrolyte. Hydrogen fuel flows through a network of channels to the anode, where it decouples into protons that in turn flow through the membrane to the cathode and electrons that are collected as electrical current by an external circuit join the two electrodes. The oxygen flows through a channel to the cathode where the oxygen combines with the electrons in the external circuit and the proton flowing through the membrane, which producing water. The chemical reaction occurs the anode and cathode of PEM fuel cell are as follows,

Fuel cell technology is base on a simple combustion-like chemical reaction as shown :

2H2 + O2 == 2H2O + electricity + heat

The whole electrochemical process can be divided into two parts as below:

Anode: H2 - 2e == 2H+

Cathode: O2 + 4H+ == 2 H2O

Based on this structure, the protons can pass the membrane but not the electronics. If a load is connected to the electrodes with wires, when the reaction has been started, the electrons produced by the anode reaction (1.2) will generate electric-current. The oxygen is consumed with the protons and electrons and the product, liquid water, is produced with residual heat on the surface of the catalytic layer.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

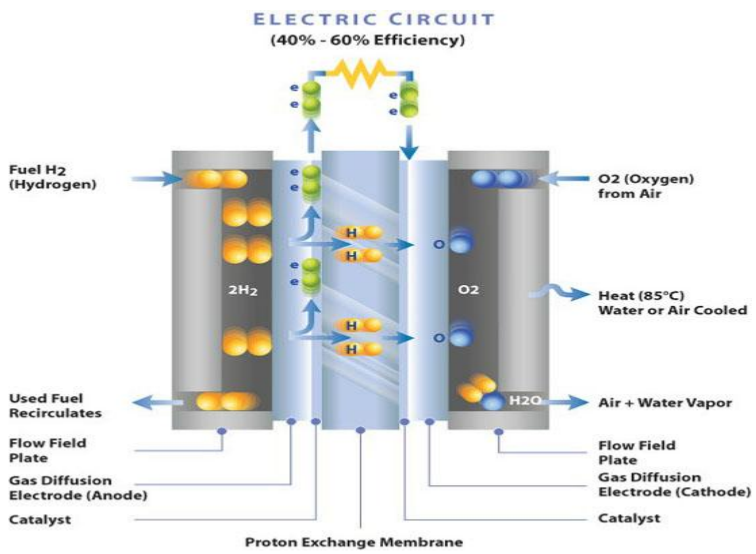

Figure 2. Basic reaction process

IV. MATHEMATICAL MODEL OF PEM FUEL CELL

ENernst is the electrochemical thermodynamic potential of the cell and it represents its reversible voltage , which is an ideal output voltage. ENernst can be calculated by a modified version of the equation of Nernst, with an extra term to take into account changes in the temperature with respect to the standard reference temperature 25^{O} C. Using the standard pressure and temperature (SPT) values, we can get a simplified equation. When we get the water production in the form of steam, 1.229 should be replaced by 1.18. Usually, the fuel stack will be controlled by changing the oxygen pressure P*O*2 , so we can assume that hydrogen pressure is constant. When we compare the two parameters T and PO2 we can find -0.85×10-3T changes "faster" than 4.31×10-5Tln(PO2), because with the parameter x the function f(x)=ln(x) is always smaller than f(x)=x. So, T will mainly determine the ENernst value. The Nerst equation gives the open circuit cell potential (E) as a function of cell temperature (T) and the reactant partial pressures ;

$$E = E0 – 0,85.10^{-3} (T – 298,15) + \frac{RT}{2F}\ IN\left(\frac{PH2\ \ PO2^{0.5}}{P_{H2O}\ P^{0.5}}\right) \quad V$$

E0 represents the reference potential at unity activity, R is the universal gas constant and P is the total pressure inside the stack.

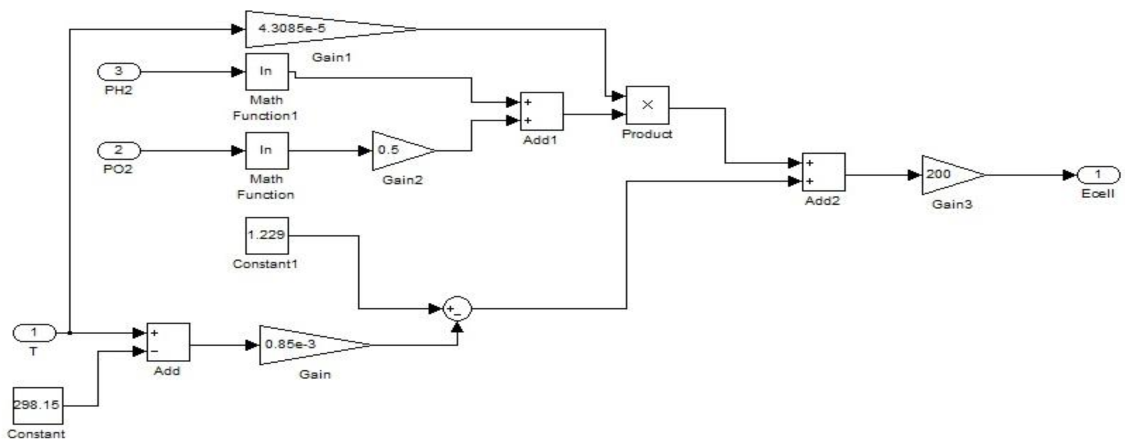

Figure 3. Nernst model of fuel cell

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

The different voltage waveform of fuel cell at different oxygen pressure .Hydrogen pressure is constant,that is 2atm

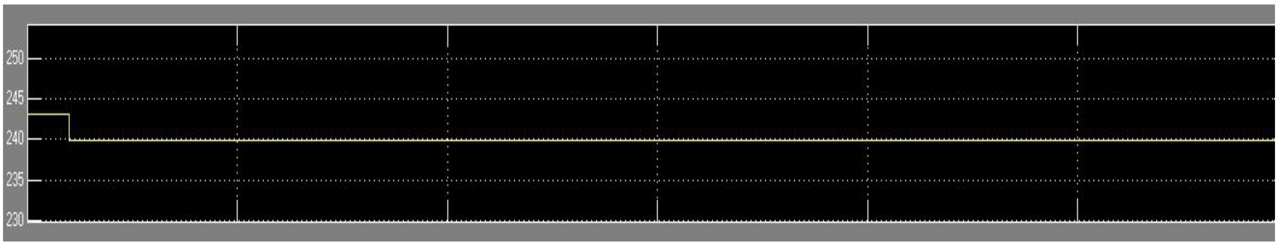

Figure 4. Cell output voltage (At oxygen pressure 5atm, hydrogen pressure 2atm, temperature 340K)

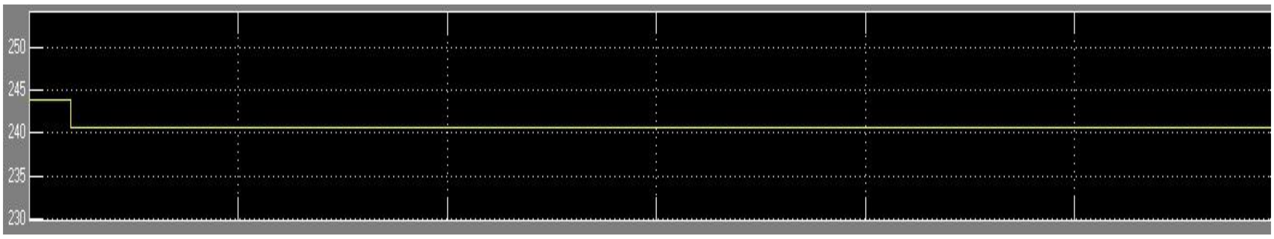

Figure 5. Cell output voltage (At oxygen pressure 8atm, hydrogen pressure and temperature constant)

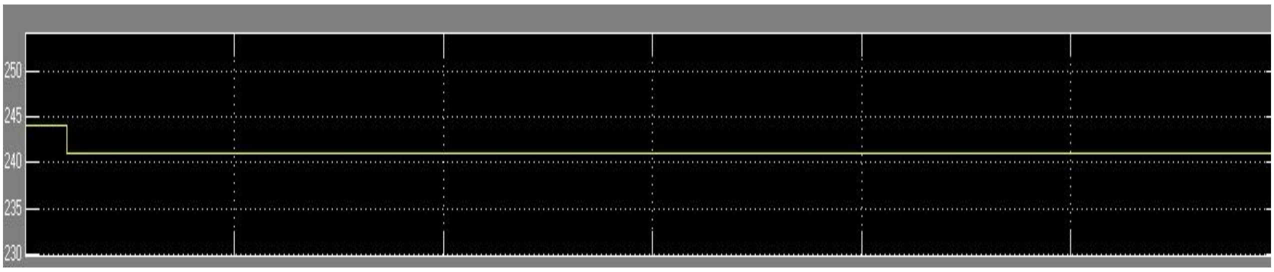

Figure 6. Cell output voltage (At oxygen pressure 10atm, hydrogen pressure and temperature constant)

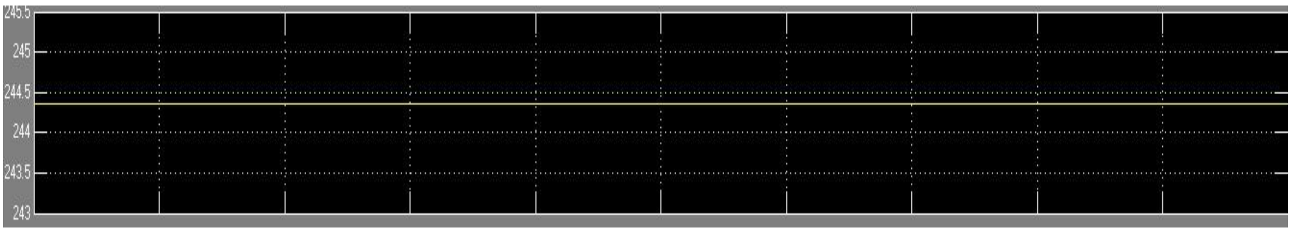

Figure 7. Cell output voltage (At oxygen pressure 12atm, hydrogen pressure and temperature constant)

By comparing all the waveforms at different oxygen pressure (hydrogen pressure and temperature are constant) we can see the voltage output of the fuel cell has varying approximately 1 to 1.5 volt by increasing oxygen pressure 2atm.

V. METHODOLOGY OF INVERTER TRIGGERING

Inverters that take DC and produce a constant amplitude sinusoidal output have been studied and designed for many years. Initially, most inverter technology used silicon controlled rectifier (SCR) devices and a transformer coupling to approximate a sine wave via line commutation. As power transistors became More feasible, most low to medium power inverter systems replaced the SCR with the MOSFET or the IGBT. These new transistors lead the way for force-commutated inverters that can be classified in terms of their output waveform. A summary of the basic types of line-commutated inverters. Significant research and development in the area of pulse width modulation (PWM) has been done in attempt to reduce the passive filter size and create a better sinusoidal output, thus reducing harmonics.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

Here we take the inverter input dc voltage from fuel cell output. Voltage regulator is taken for comparing and controlling the inverter triggering pulse with the given reference voltage. The input of the voltage regulator is taken from the output of the inverter (V_{abc} line voltage). After that a reference signal which is passes through a discrete PWM generator and get the pulses for inverter triggering. That is inverter triggering is controlled by the line voltage.

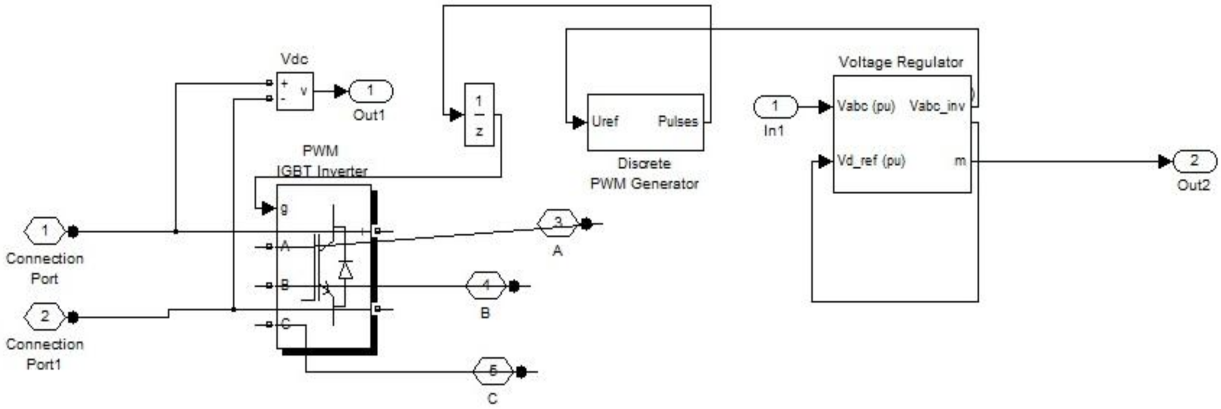

Figure 8. Dc-Ac inverter control

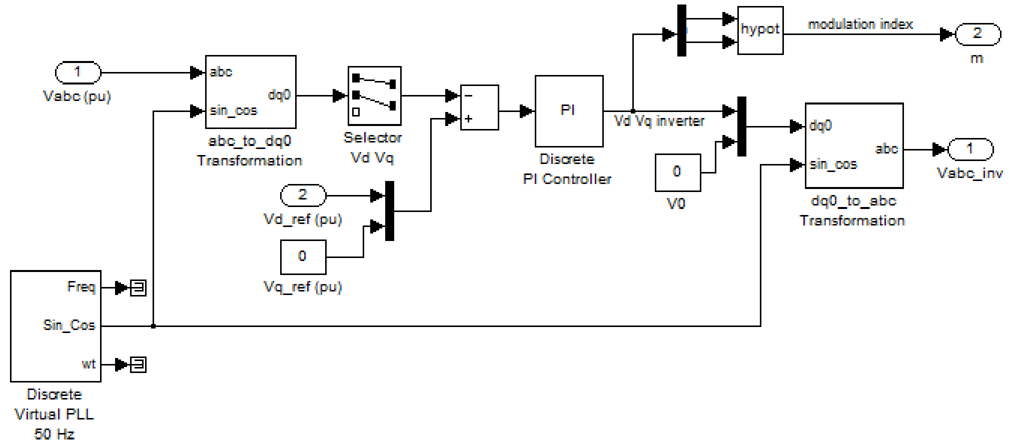

Figure 9. Voltage regulator

VI. FUEL CELL CONNECTED THROUGH FILTER, LOAD

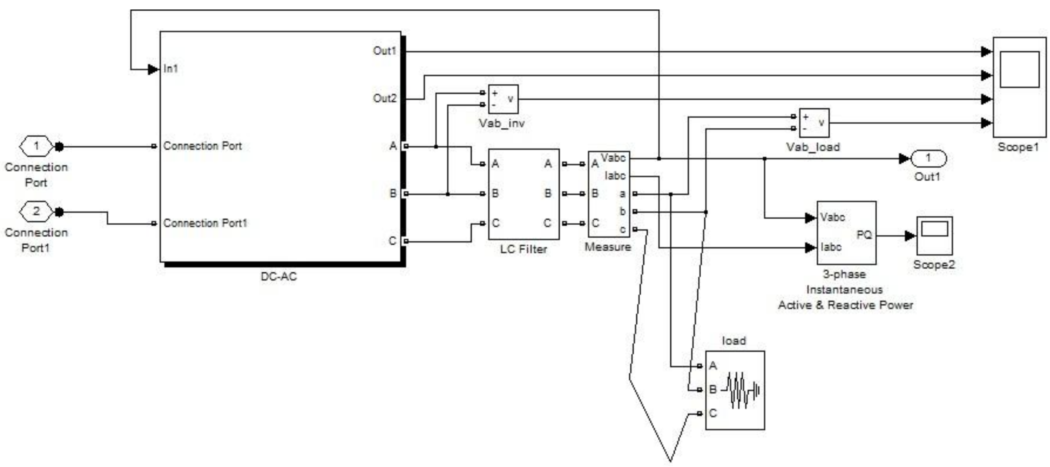

Fig . 10

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

VII. OVERALL MODEL

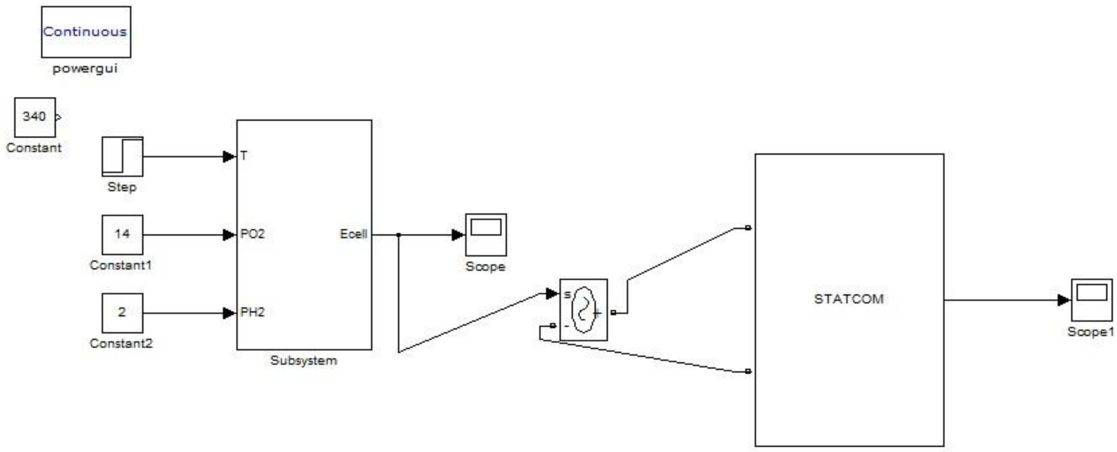

Fig . 11

VIII. SIMULATION GRAPH

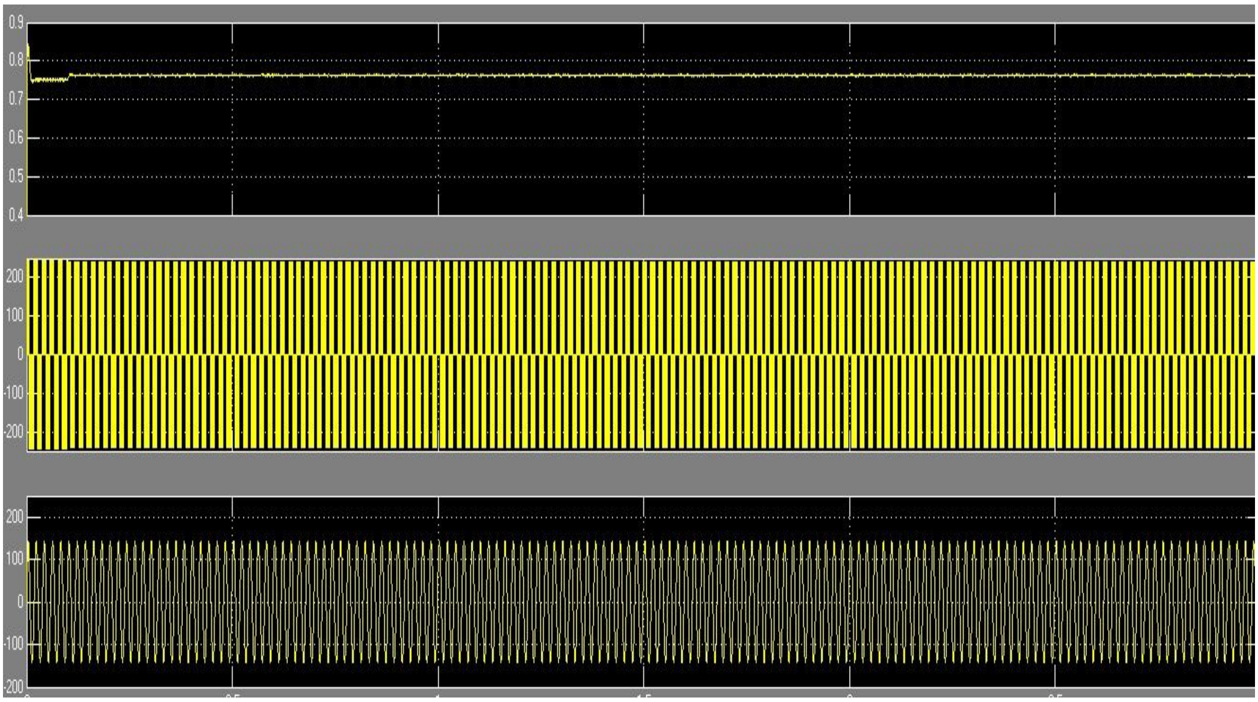

Fig 12 modulation index , Inverter output voltage , load voltage at oxygen pressure at 5 ATM with connected load.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

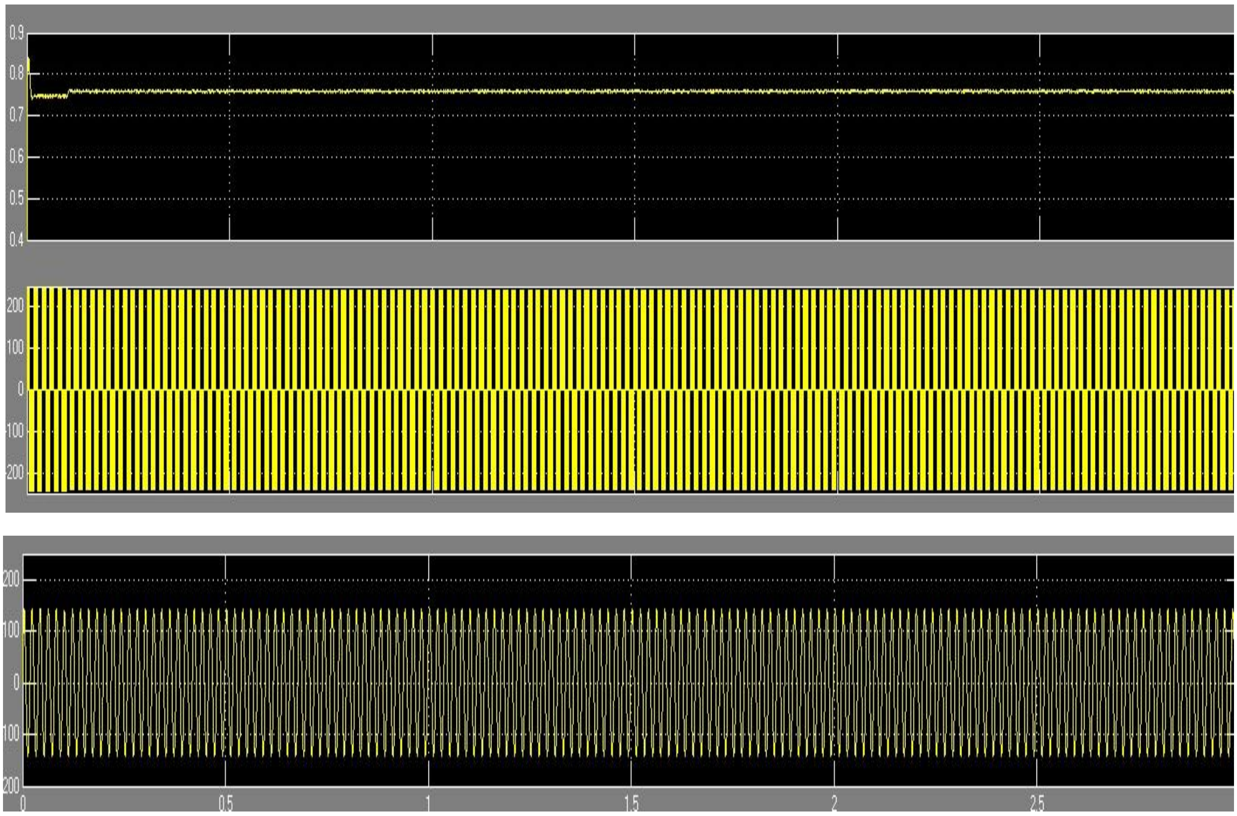

Fig 13. modulation index , Inverter output voltage , load voltage at oxygen pressure at 10 ATM with connected load.

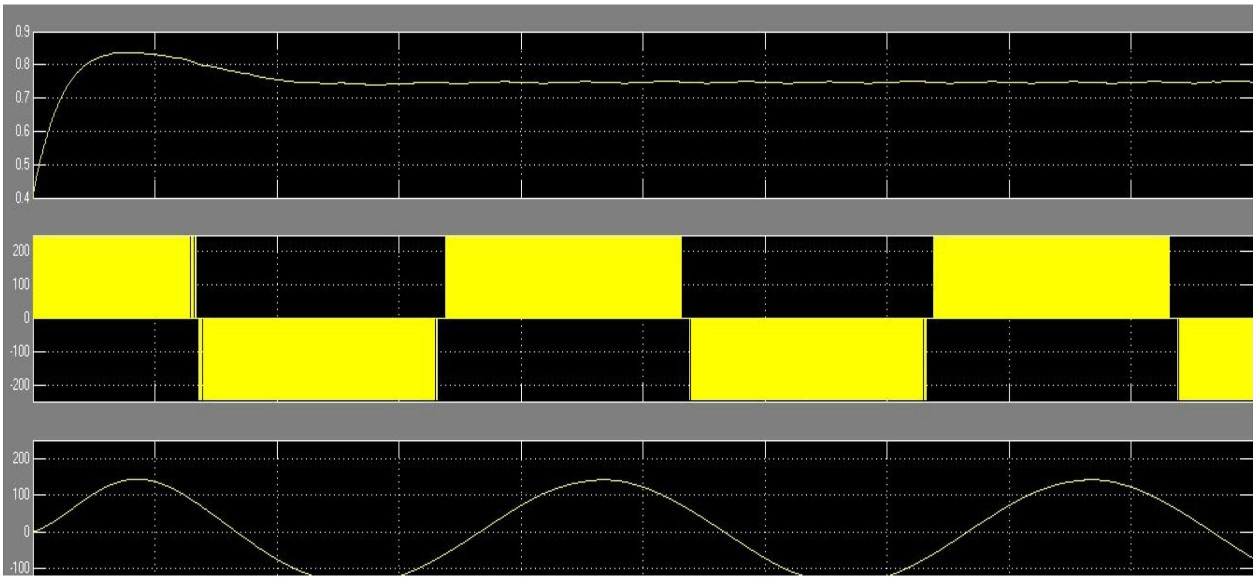

Fig 14. modulation index , Inverter output voltage , load voltage at oxygen pressure at 12 ATM with connected load.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 4, April 2013

IX.GRAPH OF ACTIVE ACTIVE POWER IN DIFFERENT OXYGEN PRESSURE

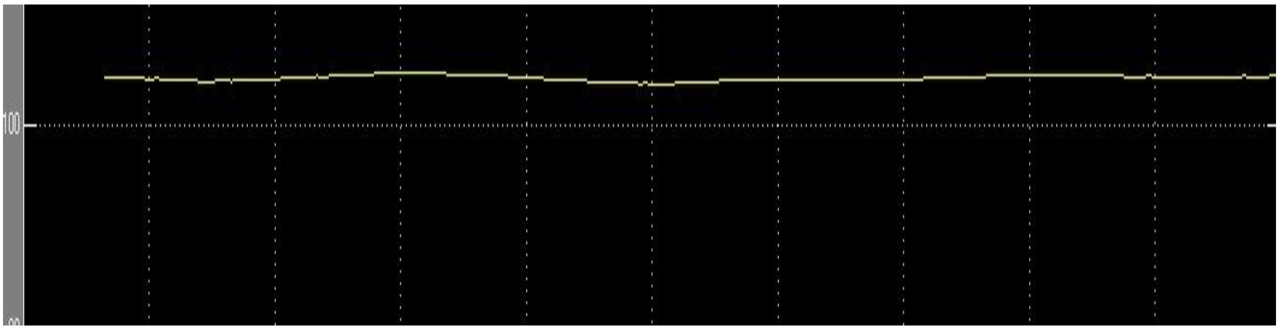

Fig 15. At 5atm

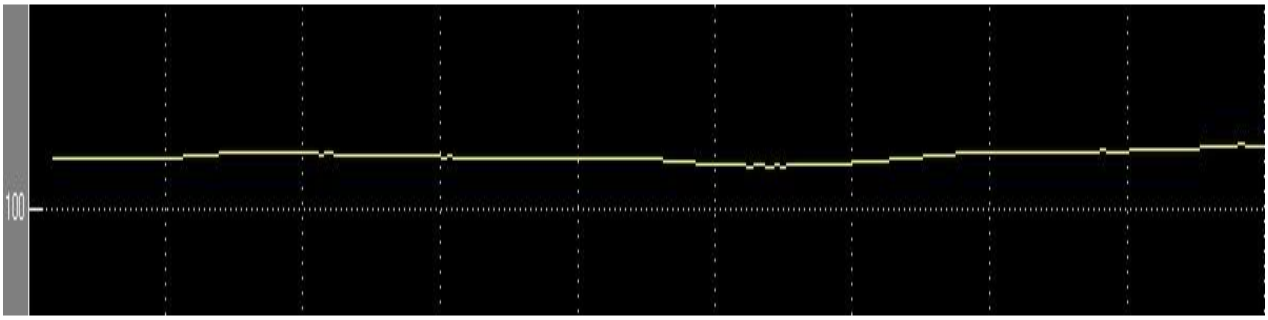

Fig 16. At 10 atm

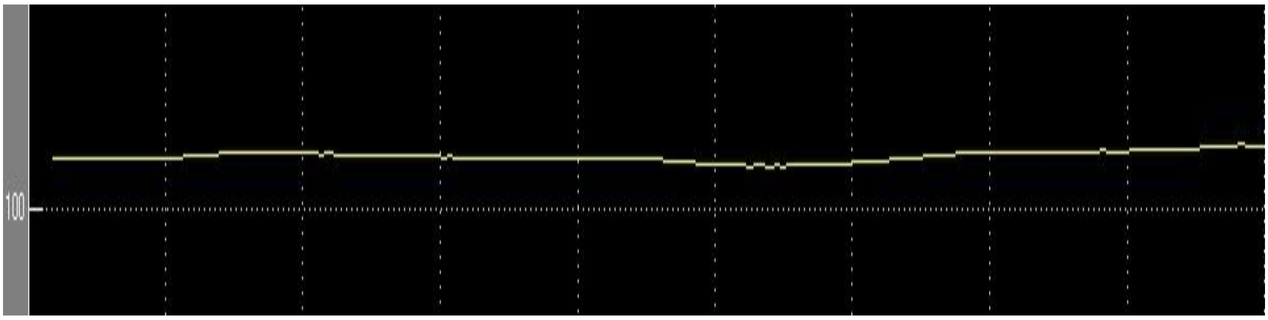

Fig 17. At 12 atm

X. SIMULATION PARAMETER

NO OF CELL SERIES	200
E0 REPRESENTS THE REFERENCE POTENTIAL AT UNITY ACTIVITY,	1.229
REFERENCE TEMPARATURE	298K
INDUCTANCE OF FILTER	2 mh
CAPACITIVE REACTIVE POWER	3 KVAR
PROPORTIONAL GAIN	.4
Vrms OF LOAD	242 V
ACTIVE POWER	5KW
MAXIMUM TEMPARATURE	360 K
CAPACITIVE REACTIVE POWER OF LOAD	0W

XI. CONCLUSION

Here we made a simple fuel cell block by using MATLAB . More members of cell can be connected to get higher voltage. Mainly we are using inverter which is mainly used for DC TO AC and as per inverter gate triggering the output voltage will be varied. There have a feedback control for sense the inverter output voltage which is the input of voltage regulator and the voltage regulator makes the corresponding pulse. This is mainly a PWM pulse generator. From the above simulation we can see by changing oxygen pressure the output voltage of the cell is changing. we can see the voltage output of the fuel cell has varying approximately 1 to 1.5 volt by increasing oxygen pressure 2atm. Also, we can change the working characteristic simply by changing the working pressure of the stack. If we need the stack supplying a higher power, expediently, it seems that raising the oxygen pressure can be a good choice, which can be realised by increase the blower frequency etc. But, we must notice that the simulation parameters are ranged from 0.001 atm up to 20 atm. By 20 atm, it means you may need a more powerful blower to get 2 Mpa pressure, and that will cost more power . The pressure difference between oxygen and hydrogen must be on a reasonable range. Otherwise the membrane will effected . Fuzzy logic controller and more new controllers can be used to improve efficiency. The paper presented to this point clearly demonstrated the ability to implement a simple and cost effective control strategy on a medium power fuel cell inverter system. However the system is far from perfect. The chosen topology is not necessarily the be stone and the power stress design albeit sufficient, was not optimized completely.

REFERENCES

1 . PEM Fuel Cell System Evaluation Using Operational Data and Updated Matlab/Simulink Simulation Tools Naxakis Ioannis Marinis Andreas, Nakis Stavros, Pyrgioti Eleftheria and Ioannis Milias-Argitis High Voltage Laboratory, University of Patras, Patras 26500, Greece Laboratory of Production, Transportation and Distribution of Electric Energy, University of Patras, Patras 26500, Greece Received: February 24, 2012 / Accepted: May 09, 2012 / Published: December 31, 2012.
2. Dynamic Model of Proton Exchange Membrane Fuel Cell and Implementation , Ming, LIU In IISB Fraunhofer, Germany.
3 .Dynamic Simulation of a Pem Fuel Cell System, Zehra Ural1*, Muhsin Tunay Gencoğlu2 and Bilal Gumus3 1,3 Dept. of Elec. and Electr. Eng., Eng. and Arch. Fac., Dicle University, Diyarbakır, TURKĐYE 4. Control Strategies for Load-Following Unbalanced MicroGrids Islanded Operation,Supervisors:Prof. Joao Peças Lopes, INESC Porto, Portugal Dr. Rachid Cherkaoui,
4 .Mathematical Models of PEM Fuel Cells Zehra Ural, Muhsin Tunay Gencoglu
5. Power Controller Based Grid Connected Fuel Cell Author: Siva Ganesh Malla, IIT Bhubaneswar, India.
6. grid connected fuel cell system by pdn.com
7. Y. Wang and C.-Y. Wang, "Transient analysis of polymer electrolyte fuel cells," Electrochimica Acta, vol. 50, no. 6, pp. 1307–1315, 2005.
8. Um, C.-Y. Wang, and K. S. Chen, "Computational fluid dynamics modeling of proton exchange membrane fuel cells," Journal of The Electrochemical Society, vol. 147, no. 12, pp.4485–4493, 2000.
9. J. T. Pukrushpan, A. G. Stefanopoulou, S. Varigonda, L. M. Pedersen, S. Ghosh, and H. Peng, "Control of natural gas catalytic partial oxidation for hydrogen generation in fuel cell applications," IEEE Transactions on Control Systems Technology, vol. 13, no. 1, pp. 3–14, Jan.2005.