Research Inventy: International Journal Of Engineering And Science
Vol.4, Issue 10 (October2014), PP 56-62
Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com

GENERATION OF POWER THROUGH HYDROGEN – OXYGEN FUEL CELLS

[1]Ajoko, Tolumoye John and [2]Kilakime, Tari Amawarisenua
Department of Mechanical/Marine Engineering, Faculty of Engineering.
Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

ABSTRACT - *The prominence and sustainability of energy generation is global target which binds together the techno-industrial and socio-economic welfare of any developing country. Study carried out is a test on the proficiency of renewable energy through Hydrogen – Oxygen Fuel Cell to generate useful power supply. It attests that the set-up electrochemical fuel cell with the use of fuel value of hydrogen has the capability of converting the chemical energy involved in the process into electrical energy which generates electricity up to 13.44W with 11.20V making use of a short time duration of 12 – minutes with a small volume of hydrogen gas used (50ml) in the Hydrogen – Oxygen Fuel Cell Test Rig. One advantageous fact is that the end product of the reaction (water) is environmentally friendly, produces no emissions capable of depleting the ozone layer and also can be converted to home use for economical purposes. Obtained results at the test period are displayed on a characteristic curves which shows the relationship of the performance parameters such as electrical energy, power, voltage, electrical charge, etc. Meanwhile, in the process of the experiment; the converted energy was stored in an energy storage device in the test bed which was test run on rotary and lighting load component (Electromotor) in the test rig. Therefore, it is recommended that employing this innovative system in the energy sector will save the environment from decaying, and also as alternative means to the conventional system of energy generation. Thus, sustainability in electrical power generation will drastically improve.*

Keywords - *Current, Electrical Energy, Electrical power, Hydrogen – Oxygen Fuel cell, Test Rig.*

I. INTRODUCTION

The production of an electric power by means of a Synchronous machine operating at a constant synchronous speed at a fixed frequency is most often driven by a shaft power system referred as gas turbine engines. These are natural gas fuelled machineries where chemical combustion takes place in its combustion chamber to enhance its end point performance such as efficient production of thermal power (electricity) for crude oil drills and gas transportation purposes; the production of useful thrust for aero gas turbine applications. Despite the benefits of these natural gas from fossil fuel used as the means of powering this equipment, it also create negative environmental hazard. Its end result depletes the ozone layer with significant increase of atmospheric greenhouse gases (CO, CO_2) by the production of consistent by-products of NO_x, SO_x, etc. Therefore, in remedying this constrains has led to the search of a sustainable alternative energy resources that are readily accessible, environmentally friendly, and cost competitive with fossil fuels. Although, a wide range of study has identify other means of electric power generation from fuel cells and renewable energy from biogas. Meanwhile, the key point of research in this paper is focused on the production of electric power from Hydrogen – Oxygen Fuel Cells which operate quietly and efficiently [1]. Studies unveil that fuel cells are electrochemical devices which is capable of transforming the chemical energy in a fuel to electrical energy or power. It also has the proficiency of having high competence even in small size quantities and are easy to put in place; due to this outstanding features, it have recently been the focus of great interest as a distributed generation [2]. The developmental effort of making fuel cells relevant in the scientific industrial market is the target of every researcher because of its low exhaust emissions, high energy efficiency and variability, energy density, economy friendly, unique operating conditions, planning flexibility and future development potential in comparison with the conventional fuel used in internal combustion engines [1,3,4].

Another advantageous feature of fuel cells is less susceptible to fuel composition changes at high temperature operation range. This is a suitable factor for distributed power generation and integration with other types of bottoming cycles such as gas turbine cycles and cogeneration [2]. Though, the availability of fuel cell technology has not increased much in the industrial market yet research reveals its importance in terms of cost reduction of machine components, maximization of the transient performance and reliability; and the reduction of the size and weight of power components of gas turbines and as an alternative source to be used for combined heat and power (CHP) technology [2,3]. Also the fuel cell downsizing through hybridization system allows reducing the power train cost and volume over the pure fuel cell electric vehicles (FCEV) in which the fuel cell system is made large enough to meet the maximum power requirement [3].

Furthermore, the lower operating temperature of fuel cells requires the use of highly reformed fuels such as hydrogen and prohibits effective utilization of its waste heat for most absorption or water heating technologies [2,5]. However, it is imperative to note that hydrogen is a resourceful energy carrier which can be used to power almost every end users energy needs. Meanwhile, this energy conversion device known as the fuel cells can capture effectively the potentials of hydrogen for necessary energy conversion. A researcher exposed hydrogen fuel cell as stationary fuel cells to be used as power backup processes in power generation plants and cogeneration where excessive heat is released during electricity production which is used as means for other applications [6].

Fuel cells application to power generation systems like the gas turbines is an advancement of technology where a Hybrid Power System exhibits a synergy in which the combination performance far exceeds the gross performance of either system [7]. Fuel cell such as Polymer Electrolyte Membrane (PEM) allows the flow of hydrogen gas through the channels to the anode, where a catalyst causes the hydrogen molecules to separate into protons and electrons. The membrane permits the passage of the protons through it; as it does, the stream of negatively-charged electrons follows an external circuit to the cathode. This movement of electrons causes electricity that can be used to do work [8]. In a likely manner, the reaction of oxygen and hydrogen gases will enhances the procedure of generating the needed electric power. Meanwhile, this reaction leads to the production of water from the system. Thus, the end result is in the form of exothermic reaction which generates useful energy from the fuel cell. Consequently, hydrogen can play key roles in the future by replacing the crude products we use presently in our machineries. Hence, technological philosophy behind these studies is a replacement or an advanced alternative source to the conventional combustion technologies for power generation. Therefore, the development of Fuel cells is under the consideration to replace the traditional technology from the natural crude.

II. STUDY OF HYDROGEN – OXYGEN FUEL CELL TEST BED

The Hydrogen – Oxygen Fuel Cell Rig is a small test bed which is used to experiment and determine the electric power output from hydrogen and oxygen gases. A sample view of the rig is displaced in fig. 1 below. Several tasks are carried out while the polarity at the electrolyser in the test bed was observed and corresponding values recorded accordingly on table 1. In order to measure the volume ratio of the gases produced, the setup of the test bed and a circuit formation of the hydrogen and oxygen gases were arranged in the format presented in fig. 2. This is followed up with the filling of the gas storage up to the 0ml mark point with distilled water. To prevent streaming out of gas from the storage containers, the right connecting sleeves are close with fitting caps. Then, the regulator was adjusted to its maximum so that the volume of hydrogen and oxygen gas could be recorded after waiting for a corresponding reading of 10ml, 20ml, 30ml, 40ml and 50ml of hydrogen is produced respectively.

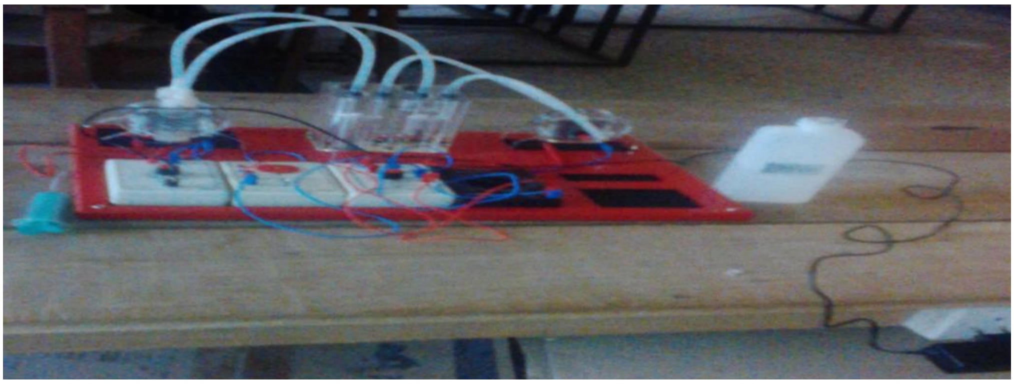

Figure 1- Hydrogen-Oxygen Fuel Cell Rig

The setup is rearranged as shown in fig. 3; this is to enable determine the needed gas volumes produced per time unit in relationship to the setup current of 0.0A to 1.2A with an interval of 0.2A with respect to 0.0sec to 720sec with an interval of 120sec. The essence of this phenomenon is that, some amount of electrical current is expected for the electrolytic breakdown of water into hydrogen and oxygen. At this point, the ampere meter in the test bed is set at the range of 2000mA DC and the voltmeter to the range of 20V DC. Still preventing escape of gas from the gas storage, the pre-determined current value was set and both starting and ending volumes of hydrogen was recorded with their corresponding voltages in table 2. This is to give way for the determination of the electrical energy involved in the process which was converted from the chemical energy from the electrochemical fuel cell with the use of fuel value of hydrogen.

Thus, known that the molar volume of ideal gas at Standard Temperature and Pressure (S.T.P) is given as 22.4136 dm^3Mol^{-1}, where 1 litre = 10^3m^3 ($1dm^3$) [9] with 286KJ/mol. Hence, one mole of hydrogen has a volume of V_m = 22414ml (@ 1 bar and 20°.

In a similar task carried out to estimate the voltage – current characteristic curve; an important characteristic of current producing system is experimented in the test rig. This is shown in fig. 4 where records of experimental data for current and voltage are taken. Meanwhile, setting the voltmeter to 2000m VDC range and a no load voltage with a corresponding current of 0.00A was measured; this is to allow a graphical presentation to start from its origin. Then with connection of the ampere meter, the current through the potentiometer of load 2 is set to start with a high resistance, R with gradual reduction in order to achieve a measuring point roughly for every 0.2A of current to enable have corresponding measured values for voltage, V and electrical power, P. The reason for the high resistance is as a result of the distance between the electrodes [10]. However, measurements from the rig are presented in table 3 for further analysis. Some important fundamental expressions for electrical charge, energy and power were used for the analysis and presented in equations 1-3 below.

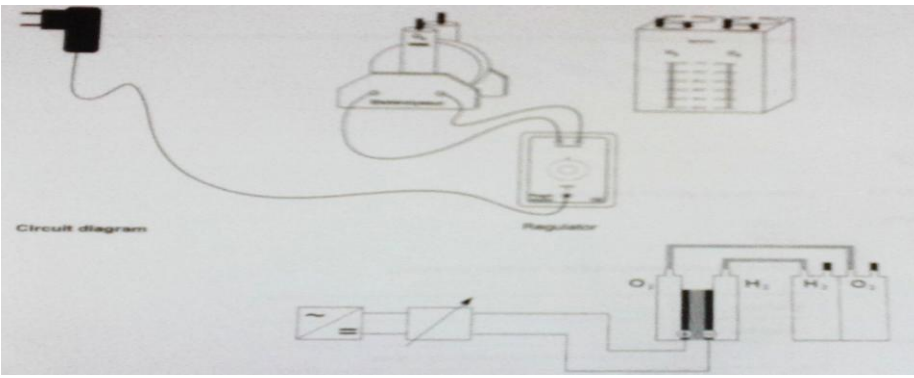

Figure 2 - Setup to measure the volume ratio of produced gas

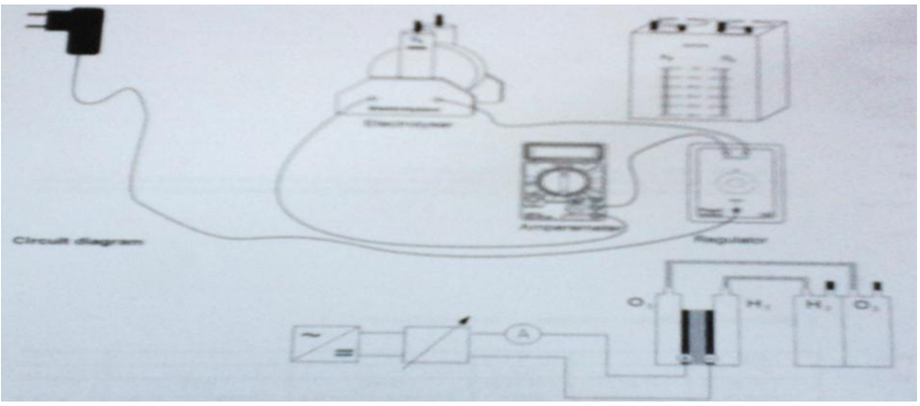

Figure 3 - Setup to measure gas volumes produced per time unit with respect to current

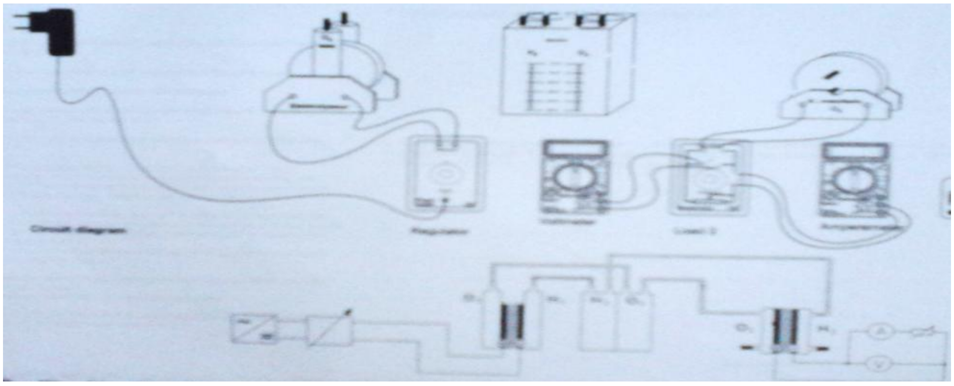

Figure 4 - Setup to voltage – current characteristic curve of the fuel cell

Table 1

Determination of Gas volume Ratio					
Gases	Volume of Gas Produced (ml)				
Hydrogen (H_2)	10	20	30	40	50
Oxygen (O_2)	4.5	9	14	19	25

Table 2

Estimation of Hydrogen Gas with Time						
Current I (A)	Voltage U (v)	Time T (sec)	Electrical Charge Q (C)	Starting Vol. of H_2 (ml)	Ending Vol. of H_2 (ml)	Electri Energ W (J)
0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2	6.5	120.0	24.0	0.0	5.0	156.
0.4	6.8	240.0	96.0	0.0	14.0	652.
0.6	7.8	360.0	216.0	0.0	23.0	1684.
0.8	8.6	480.0	384.0	0.0	30.0	3302.

Table 3

Determination of fuel characteristic Curve				
Current I (A)	voltage U (V)	Time T (Sec)	Electrical Power P (W)	Resistance R (Ω)
0.20	6.50	120.00	1.30	32.50
0.40	6.80	240.00	2.72	17.00
0.60	7.80	360.00	4.68	13.00
0.80	8.60	480.00	6.88	10.75
1.00	10.00	600.00	10.00	10.00
1.20	11.20	720.00	13.44	9.33

$$Q = It \quad (1)$$

$$W = QV \quad (2)$$

$$P = IV \quad (3)$$

Where Q = Electrical charge, W = Electrical energy, P = Electrical power, I = Current, V= Voltage, t = time

III RESENTATION OF RESULTS

Results are presented on hydrogen – oxygen fuel characteristic curves shown in fig. 5 to 8. These are important characteristic of current, energy and power generating systems which examines the fuel cell and relate it to the output performance of the system. Thus, under discussion are the voltage – current, power – current and resistance – current performance star plots in fig. 5; time – electrical energy and resistance – electrical energy curves in fig. 6; current and resistance versus power plot and a general plot of all performance parameters such as voltage, power, electrical charge, resistance and time versus the electrical energy in fig. 7 and 8 respectively. This is a demonstration of how the fuel cell generates its mechanical useful power.

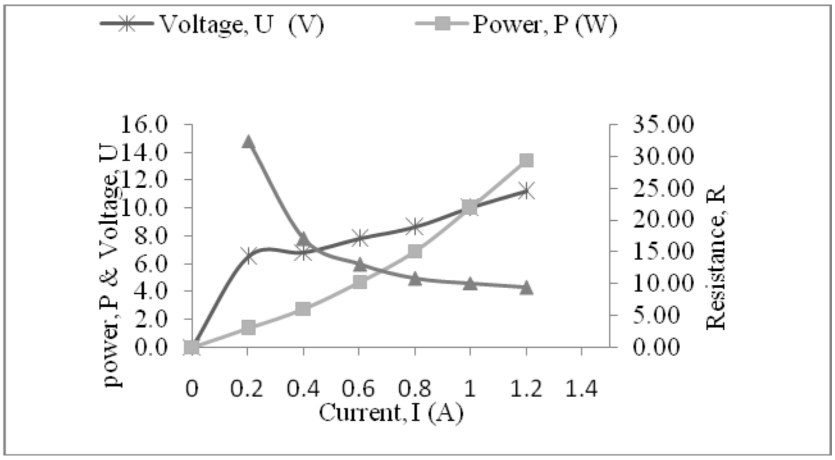

Figure 5 - voltage, power and resistance – current characteristic curves

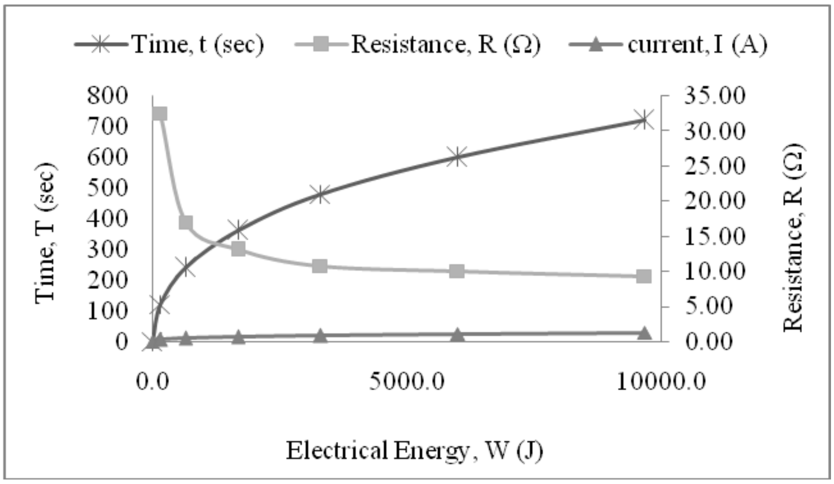

Figure 6 - time and resistance electrical energy characteristic curves

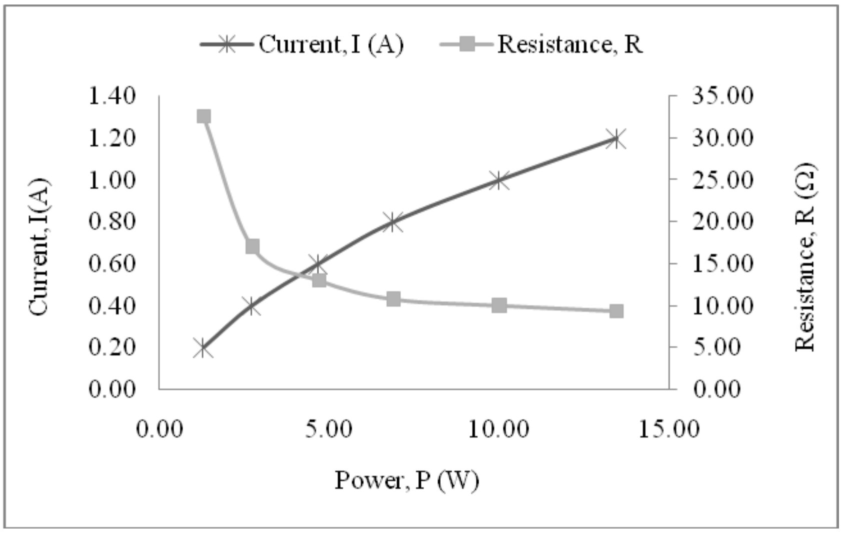

Figure 7 - current and resistance versus power plot

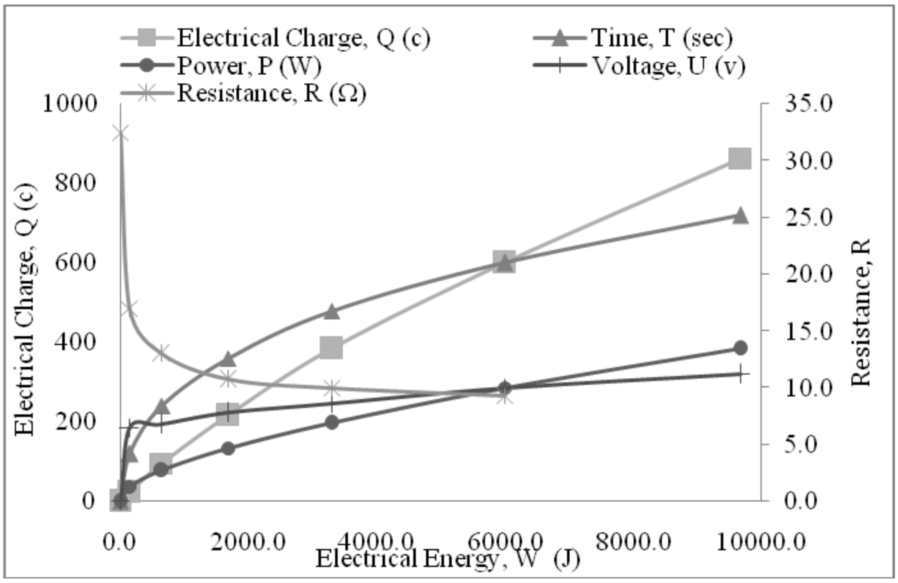

Figure 8 - performance parameters versus the electrical energy

IV RESULT DISCUSSION

The focal point of this study is an experimental test of hydrogen technology on Hydrogen – Oxygen Fuel Cell Rig for the production of mechanical energy such as power. Hence, the test results presented in the figures shows that power generation through fuel cell is possible like its counterpart from the conventional systems. In fig. 5, the power and voltage tends to increase simultaneously as the current is adjusted for every 0.2A in a time interval of 120sec. This was made possible as the resistance is gradually reduced. They both have highest values of 13.44W and 11.20V respectively. A similar scenario happens in fig. 6 in the graphic plot of time, current and resistance against electrical energy with rapid change in status from 0.2 – 1.2A and 120 – 720sec, 35.50 – 9.33Ω amount of current, time and resistance respectively with 156 – 9676.80J worth of electrical energy. This is to certify the mathematical relationship of Joule's law where the electrical energy, W is directly proportional to the square of the current, resistance and time. Again, is the plot in fig. 7 with current and resistance against power; which demonstrates the mathematical relationship of power as the product of the square of current and resistance. The similarity of the curves in fig. 6 and 7 can best be explained from the equations of Joule's law and that of power below.

$$W \propto I^2RT \qquad \text{(iv)}$$

$$P = I^2R \qquad \text{(v)}$$

The right hand side of both equations is one and the same if the sign of proportionality of equation (IV) is changed to equality sign, for instance introducing T as a constant. Then the electrical energy, W is synonymous to power mathematically. The graphical display in figure 8 is a simple test of the gradual increase of all measurable parameters such as power, voltage, electrical charge and energy with respect to time from the test bed of the study.

V CONCLUSION

At each case of the experimental test of Hydrogen – Oxygen Fuel Cell, a chemical action occurs at the electrodes due to the flow of current through the electrolyte. This chemical action thus refers as a chemical energy is converted to an electrical energy in the process. Theoretically, it is calculated from fuel value of hydrogen with $286KJMol^{-1}$, where a mole of hydrogen has a volume 22414ml.However, test results at the end of test period were validated with the use of the energy storage device in the test rig which has the capacity of storing the converted energy. The energy from the storage device was test run on a rotary and lighting load in the test bed and its reliability was confirmed. This is a clear validation that hydrogen – oxygen fuel cell is capable of generating electricity. This branch of renewable energy which is environmentally friendly with useful end product of clean pure water, no percentage production of emissions such as NO_x, CO, SO_x, etc, zero capability of depleting the ozone layer, is a substitute to the conventional fossil fuels. Therefore, massive construction of hydrogen – oxygen fuel cell machine is recommended for the sustainability of the system.

VI ACKNOWLEDGEMENT

Special appreciation and thanks to colleagues and technical staff that assisted in building the test rig for the study.

REFERENCES

[1] E. Fontes and N. Eva, Modelling the Fuel Cell, *American Institute of Physics*, 2001, 14-17.

[2] Z. Florian, L. Yixin, and S. Laura, A solid oxide fuel cell system for buildings, *Energy Conversion and Management*, 2006, 809–818.

[3] L. Xiaofeng, D. Demba, and M. Claude, Design Methodology of Fuel Cell Electric Vehicle Power System, *Proc. of the Int. Conf. on Electrical Machines*, 2008, ID. 1270.

[4] M. Alhassan, and M. Umar Garba, Design of an Alkaline Fuel Cell Leonardo Electronic, *Journal of Practices and Technologies*, 2006, ISSN 1583-1078, 99-106.

[5] G. Luna-Sandoval, C. G. Urriolagoitia, L. H. Hernández, S. G. Urriolagoitia, and E. Jiménez, Hydrogen Fuel Cell Design and Manufacturing Process Used for Public Transportation in Mexico City. *Proc. of the World Congress on Engineering*, London, U.K, 2011, Vol. III

[6] DOE Energy Efficiency & Renewable Energy Information Centre, 2006, http://www.hydrogen.energy.gov, Accessed on 19 August 2014.

[7] S. Scott, Fuel Cell/Gas Turbine Hybrid Systems, *ASME International Gas Turbine Institute*, 2004.

[8] M. Cifrain, and K. Kordesch, Hydrogen/oxygen (Air) fuel cells with alkaline electrolytes, *Handbook of Fuel Cells–Fundamentals, Technology and Applications*, (Chichester, 2003), 267 – 280, ISBN:0-471-49926-9.

[9] U.M.O. Ben, *The SI Units* (Stockwell, London; ISBN 978-199-008-2, 1984).

[10] R. Chris, and S. Scott, Introduction to Fuel Cell Technology, *University of Notre Dame,* Unpublished Course Note for Department of Aerospace and Mechanical Engineering, 2003.