International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Investigation of Loading Effect on Fuel Cell

Ramandeep Singh[1], Randhir Singh[2], Jyoti Lalotra[3], Parveen Lehana[4,#]
[1, 2]Sri SAI College of Engineering & Technology, Punjab, India
[3, 4]Dept. of Physics & Electronics, University of Jammu, Jammu, India
[#]Email address: [1]pklehanajournals@gmail.com

***Abstract*—**Portable devices rely on battery systems that contribute largely to the overall device form factor and delay portability due to recharging. Fuel cells combine the advantages of batteries and diesel generators, and eliminate some of their significant disadvantages. They can work as long as they are supplied with fuel via a simple and efficient electrochemical reaction and at the same time they are quiet, produce no emissions and require minimum maintenance. Experiments are carried out with hydrogen fuel cell to estimate power delivery efficiency of the cell. Two different loads were connected to the fuel cell and power dissipated across the load is estimated.

***Keywords*—** Fuel cell; power; hydrogen; flow.

I. Introduction

Renewable Energy Sources produce a small amount of greenhouse gases, and there is plenty of energy coming from the sun, rivers or geothermal waters to cover human needs. There are, however, also some problems and limitations connected with these sources – the sun does not shine every day and its strength is different depending on location, wind does not blow with the same strength during the year and there is limited accessibility for hydro and geothermal power depending on the location. An energy carrier is needed to store the electricity during excess production so that it is ready to be used when the peak comes.

Hydrogen seems to be a good candidate for such a carrier. It has higher gravimetric energy density than oil (lower volumetric, that is why it has to be compressed, liquefied or stored in a metal as metal-hydride), it has no emissions and can be converted efficiently into electricity in a fuel cell. Although hydrogen is the most abundant element in the universe, it does not exist on Earth as a gas it has to be obtained from hydrocarbons; for example by means of methane steam reforming, or water electrolysis, which uses electricity to split water into hydrogen and oxygen. However, only electrolysis makes it possible to produce hydrogen in a clean way, on the condition that the energy source is renewable, such as wind, sun or hydropower. Having hydrogen is one thing, but it is also necessary to convert its chemical energy into a state that is more convenient to use. The most efficient and clean way is to use it in a fuel cell, which converts the energy from hydrogen into electricity in the presence of oxygen. This method is more efficient than burning the hydrogen in a combustion engine, because it is not limited by Carnot‘s Law. It is also more environment friendly than conventional combustion engines due to the fact that the only by-product of this process is water.

There are many applications in which hydrogen fuel cells can be used. They are scalable, so they can be used in mobile electronic devices such as cell phones or laptops as a power source, replacing batteries. At the same time there are types that can work as power plants providing power to the grid. Many car producers consider hydrogen fuel cells as a future power source for cars.

The big advantage of fuel cells is that they can work off-grid, in hard accessible places, for instance as a backup power for communication towers. Another, similar application is to use a fuel cell as the power source in an uninterruptible power supply (UPS) for use with digital equipment such as a personal computer (PC), or in hospitals in case of power failure to provide power for life-sustaining equipment. An ideal high-performance UPS system should provide a clean and regulated sinusoidal output voltage with low total harmonic distortion (THD) for both linear and non-linear loads, a fast transient response to sudden changes of the input voltage or load, on-line operation with zero switching time from normal to backup state and vice-versa, high power density, high reliability, high efficiency and low maintenance. The primary purpose of using a fuel cell instead of a battery as a power source is the fuel cell‘s high energy density, and therefore, the ability to operate the system for a very long period of time during utility grid failure.

Fuel cells are future energy systems with a high potential for efficient, environmentally friendly energy conversion that can be used in stationary, mobile and portable applications. A fuel cell is defined as an ―electrochemical cell which can continuously convert the chemical energy of a fuel and an oxidant to electrical energy by a process involving an essentially invariant electrode-electrolyte system‖. In other words, a fuel cell is like a small ―factory‖ that takes fuel and produces electricity and heat (Fig. 1). There are similarities between fuel cells and primary batteries. Both systems have two electrodes separated by an electrolyte, and electrical energy can be withdrawn from the cell reaction. Unlike batteries, in a fuel cell the reactants are supplied from an external source and it operates as long as it is supplied with fuel and oxidant. Viewed this way, a fuel cell is similar to a combustion engine, which also takes the chemical energy stored in the fuel and transforms it into useful mechanical or electrical energy. The difference is that in a fuel cell there is no combustion as an intermediate step, so it is not limited by thermodynamic limitations of heat engines such as the Carnot

Ramandeep Singh, Randhir Singh, Jyoti Lalotra and Parveen Lehana, "Investigation of loading effect on fuel cell," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 3, pp. 9-12, 2016.

efficiency. These are the key benefits of a fuel cell over a battery and conventional combustion engine.

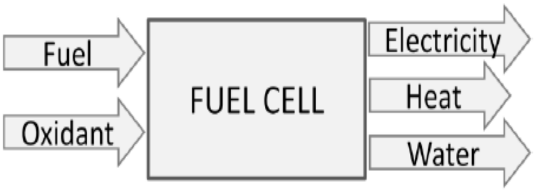

Fig. 1 Basic concept of fuel cell.

The physical structure of all fuel cells consists of an electrolyte layer sandwiched between an anode and cathode electrodes. This configuration is called the Membrane Electrode Assembly (MEA). The electrolyte allows the passage of ionic charge between the electrodes, blocks the passage of electrons, and provides a physical barrier to prevent the direct mixing of the fuel and the oxidant. The specific type of material depends of the type of fuel cell. The main types are briefly described in a later part of this chapter. A porous electrode is used to deliver a fuel or oxidant, and to maximize the three-phase interface between the catalyst, electrolyte and the fuel (gas or liquid). The picture below (fig. 2) exhibits the basic structure and operation of a simple hydrogen-oxygen fuel cell. Fuel is fed continuously to the anode (negative electrode) and an oxidant (often oxygen from air) is fed continuously to the cathode (positive electrode). The electrochemical reactions take place at the electrodes. Hydrogen molecules are split on the anode into protons and electrons. The electrons move from highenergy reactant bonds, through an external circuit, to low-energy product bonds. This creates electric current that performs work on the load. The protons travel through the electrolyte membrane to the cathode, where oxygen, protons, and electrons combine to form water. Heat, as a by-product, is also created.

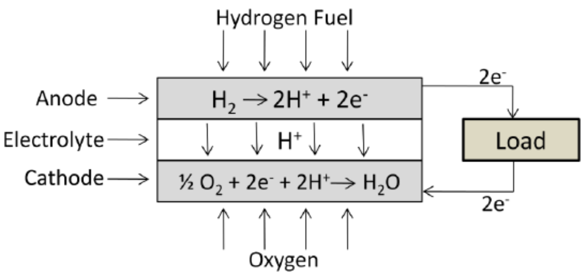

Fig. 2. Fuel cell basic operation.

II. Experiment

Research work is carried out to estimated the power delivering capability of hydrogen fuel cell. In a proton exchange membrane fuel cell (PEMFC) the fuel used is hydrogen and the byproduct of the PEMFC is clean water. The fuel cell used in the experiment is shown in fig. 3. The first step to using this unit as a fuel cell is to electrolyze water. This creates the fuel. Caution: Hydrogen is flammable, so keep the fuel cell and hydrogen storage tank away from sparks. Set up the hydrogen and oxygen storage tanks exactly as described in the operating instructions manual. Switch the empty battery pack to the "off" position, remove its screw, and insert the two AA batteries. Make sure to connect the batteries in the correct polarity. Now get the timer, digital multimeter, and resistor ready for measurement. Use the alligator clip cables to hook the battery pack (which should be switched off), resistor, and reversible fuel cell in a circuit, as shown in fig. 4. The experiment was carried out with various load combinations.

Fig. 3. Fuel cell used in experiment.

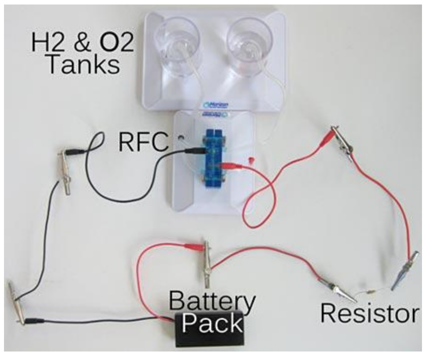

Fig. 4 Fuel cell setup

TABLE I. Electrical parameters across 10 KΩ load resistance.

Voltage (V)	**I (μA)**	**Power (μW)**
1.3	1.26	1.638
1.3	1.19	1.547
1.2	1.14	1.368
1.0	1.07	1.07
1.0	1.03	1.03
1.0	0.99	0.99
1.0	0.96	0.96
1.0	0.93	0.93
1.0	0.90	0.90
1.0	0.89	0.89

III. Result and Discussion

Investigations were carried out with various load resistance and system is run for 15 sec in each iteration. Table I shows the voltage, current reading for resistance (R = 10 KΩ). It is observed from the reading as the supply of fuel decreases the power output also decreases. Figure 5 to figure 7shows the graphical representation of voltage, current, and power across load resistance at various instance of time. It is observed that the voltage drop across the load resistance shows some fluctuation at the beginning and then shows constant behavior.

Ramandeep Singh, Randhir Singh, Jyoti Lalotra and Parveen Lehana, "Investigation of loading effect on fuel cell," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 3, pp. 9-12, 2016.

Current flowing through the resistor decreases with increase in system running time.

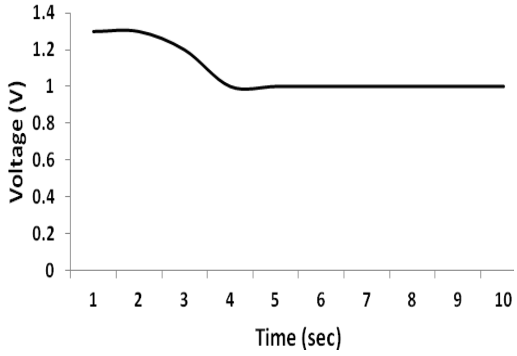

Fig. 5. Output voltage across the load resistance.

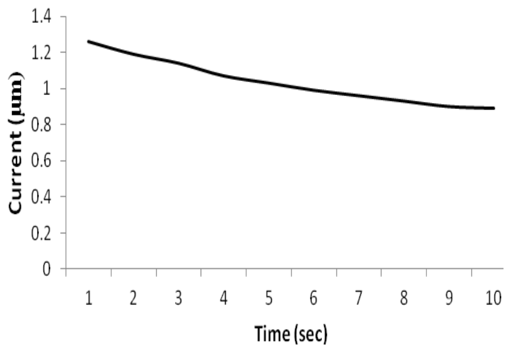

Fig. 6. Current flowing through the load resistor.

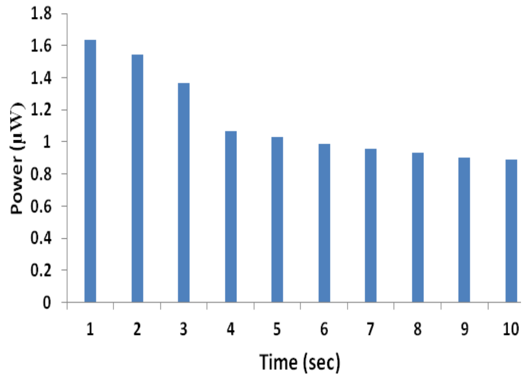

Fig. 7. Output power at different interval of time.

TABLE III. Electrical parameters across 5 KΩ load resistance.

Voltage (V)	Current (μA)	Power (μW)
1.3	0.33	0.429
1.2	0.30	0.360
1.2	0.28	0.336
1.2	0.27	0.324
1.2	0.26	0.312
1.1	0.25	0.275
1.1	0.25	0.275
1.1	0.24	0.264
1.1	0.23	0.253
1.1	0.23	0.253

Table II shows the voltage, current reading for resistance (R = 5 KΩ). It is observed from the reading as the supply of fuel decreases the power output also decreases and after sometime attains constant value. Figure 8 and Figure 10 shows the graphical representation of voltage, current, and power across load resistance at various instance of time. It is observed that voltage shows step down behavior in the output voltage and after 6 sec it stabilizes.

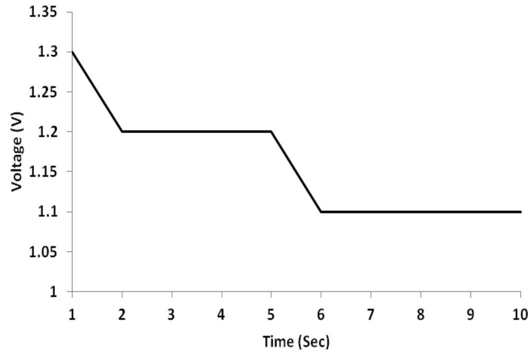

Fig. 8. Output voltage across load resistance.

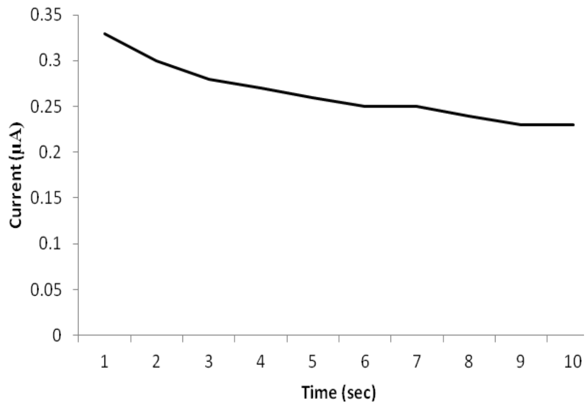

Fig. 9. Current flowing through load resistance.

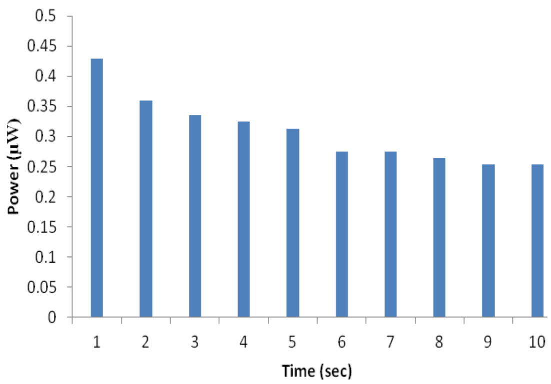

Fig. 10. Power at different interval of time.

IV. Conclusion

Availability and reliability of the power source are the core aspects of energy security. Experiments were carried out with 10 KΩ and 5 KΩ load resistance. Maximum power across load resistance is 1.638 μW and 0.429 μW respectively. Minimum

Ramandeep Singh, Randhir Singh, Jyoti Lalotra and Parveen Lehana, "Investigation of loading effect on fuel cell," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 3, pp. 9-12, 2016.

power load resistance is 0.89 µW and 0.253 µW respectively. The system delivers power efficiently.

REFERENCES

[1] J. M. Andujar, F. Segura, "Fuel cells: History and updating. A walk along two centuries," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 2309-2322, 2009.

[2] A. Bıyıkoglu, "Review of proton exchange membrane fuel cell models," *International Journal of Hydrogen Energy*, vol. 30, pp. 1181-1212, 2005.

[3] S. Bose, T. Kuila, T. X. H. Nguyen, NN. H. Kim, K. Lau, and J. H. Lee, "Polymer membranes for high temperature proton exchange membrane fuel cell: Recent advances and challenges," *Progress in Polymer Science*, vol. 36, pp. 813-843, 2011.

[4] F. R. Brushette, R. S. Jayashree, W. P. Zhou, and P. J. A. Kenis, "Investigation of fuel and media flexible laminar flow-based fuel cells," Electrochimica Acta, vol. 54, pp. 7099-7105, 2009.

[5] Z. Chen, D. Higgins, A. Yu, L. Zhang, and J. Zhang, "A review on non-precious metal electrocatalysts for PEM fuel cells," *Energy and Environmental Science*, vol. 4, pp. 3167-3192, 2011.

[6] S. Ferrigno, A. D. Stroock, T. D. Clark, M. Mayer, and G. M. Whitesides, "Membraneless vanadium redox fuel cell using laminar flow," *Journal of the American Chemical Society*, vol. 124, pp. 12930-12931, 2002.

[7] S. K. Kamarudin, W. R. W. Daud, S. L. Ho, U. A. Hasran, "Overview on the challenges and developments of micro-direct methanol fuel cells (DMFC)," *Journal of Power Sources*, vol. 163, pp. 743-754, 2007.

[8] A. Kamitani, S. Morishita, H. Kotaki, and S. Arscott, "Microfabricated microfluidic fuel cells," *Sensors and Actuators B: Chemical*, vol. 154, pp. 174-180, 2011.

[9] A. Kirubakaran, S. Jain, and R. K. Nema, "A review on fuel cell technology and power electronic interface," *Renewable and Sustainable Energy Reviews*, vol. 13, pp. 2430-2440, 2009.

[10] A. Kundu, J. H. Jang, J. H. Gil, C. R. Jung, H. R. Lee, S. H. Kim, B. Ku, Y. S. Oh, "Micro-fuel-cells-current developments and applications," *Journal of Power Sources*, vol. 170, pp. 67-78, 2007.

Ramandeep Singh, Randhir Singh, Jyoti Lalotra and Parveen Lehana, "Investigation of loading effect on fuel cell," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 3, pp. 9-12, 2016.