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The Use of Solar Energy to Operate a Fuel Cell

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Abstract: Many renewable energy-based systems are being used to increase the utilization of renewable energy as they have huge potential nowadays; the investigation of the utilization of fuel cells and solar energy in cars are important where the investigation and understanding of the technical aspects are crucial such as how the flow of electrons creates direct electric current in both fuel cells and photovoltaic systems. In this article, a prototype of a car used hydrogen produced on board by analyzing water. This hydrogen used to operate a fuel cell that generates electricity capable to run a car. The characteristic curves of the fuel cell were measured and evaluated. The results show that this type of cars can be promising in the next few years.

Keywords: renewable energy, fuel cells, solar energy, vehicle

INTRODUCTION

The human activities that have continued for thousands of years by burning fossil fuels have caused harmful effects on air quality [1]. The use of internal combustion engines both in mobile vehicles and in stationary generators had a major impact on the deterioration of air quality more and more [2]. The increasing numbers of people and their concentration in large cities have led to an increase in pollutant concentrations resulting from the burning of fossil fuels in these cities to levels that are harmful to health [3]. Scientists around the world have agreed that the treatment of air quality and accompanying environmental problems is shifting to the use of renewable energies such as wind and solar energy.

Solar energy is a renewable energy that is radiated by the sun in huge amounts and varies in quantity and quality. This solar source can be captured, stored and most importantly converted to heat or electricity. The use of solar energy to generate enough heat to run a power station [4, 5], or a solar chimney where the air is heated to move wind turbines and generate electricity are becoming traditional applications around the world [6]. Photovoltaic cells are also used to generate electricity directly from the sun to run water pumps [7, 8], lighting car parking stations [9], or to produce the electricity needed for a city's requirements with the help of other kinds of renewable or traditional energies [10].

The uses of solar energy in practical life have become numerous and varied. They are used for comfort, air conditioning and ventilation [11, 12], and are used for heating spaces (Trombe wall) [13]. The disadvantage of applications of solar energy is the fluctuation with time, the intensity of solar radiation increases and then decreases, which makes the thermal storage or the production of electrical power directly from them fluctuating and not a single rate. The problem of this energy fluctuation has been solved through the use of energy-intensive materials such as PCM. As most of these materials have low thermal conductivity, which hinders the rapid storage of energy, nanomaterials were added to accelerate and improve this property [14, 15]. Solar cells are also affected by climatic conditions such as temperature, humidity and dust [16, 17]. The researchers found a solution to the impact of solar cells at high temperatures through the use of PVT systems to cool the cell using nanomaterials and also to use the PCM with nanomaterials [18, 19]. The negative impact of the accumulation of dust has studied on the solar cells and found that this effect varies from region to region depending on the physical and chemical properties of dust [20, 21].

Fuel cells convert chemical energy into electrical energy these electrolytic cells have four primary components the node, catalyst, cathode and electrolyte it uses hydrogen and oxygen as fuel to produce electricity and water as waste product; fuel cells continue to operate as long as the fuel and oxidant are supplied [22].

In a fuel cell the reaction is broken into two halves by using a membrane/electrolyte to keep the gasses apart, on one side hydrogen molecules loose electrons to the anode to form H+ which defuse through the electrolyte in the center of the cell; on the other side H+ reacts with oxygen O2 and gain electrons from the cathode to produce water H2O, for this to happen electrons have to flow from the anode to the cathode through in an electric current so a fuel cell works just like a battery with a much higher energy capacity that can be recharged by adding more hydrogen; if the electrons are forced to go in the opposite direction by applying a voltage water can be split back to into hydrogen and oxygen [23].

The concept of polymer membrane electrolyte fuel cells has been known since the early 1960s, and this type of fuel cell is marketed successfully [24]. As the world moves towards renewable energies, there are other hopes for the use of hydrogen to replace oil and natural gas, especially in cars [25]. The use of hydrogen will mean clean, safe and available as long as water is available [26]. Hydrogen, however, needs energy to be extracted from water, and today's focus is on using renewable energies to produce hydrogen, such as solar energy [27]. Recent analyzes show that in 2030 as solar and fuel cells advance, life-cycle costs can be equalized to the cost of traditional gasoline vehicles today. However, Ref. [28] concluded that the best path to future development and the environment is using hydrogen-powered cars powered by solar energy.

A solar car uses photovoltaic cells to transform energy from the sun to charge a battery or to power the vehicle directly. The land speed record for a solar car is 55.2 miles per hour, set on Jan. 7, 2011 by the Sun swift IV with its 55-pound battery removed. Reaching such speeds requires carefully planned aerodynamics and the sacrifice of comfort, according to How Stuff Works [29, 30].

One of the problems of solar vehicles is the fact that they only charge when the sun is shining [31]. Nights and overcast days limit their ability to maintain the power needed to move the car [32]. The addition of a battery adds weight, requiring more power to move the vehicle. However, the addition of a battery allows charging to take place, even when the owner parks the vehicle [33].

This paper aims to evaluate the possibility of using solar energy in producing hydrogen and operating a fuel cell by it. The simple small prototype used was enough to give a practical simulation of this operation.

EXPERIMENTAL SETUP

The main important characteristics are: - The electrolyze characteristic; - The current, voltage and power characteristics on fuel cell; - The efficiency of fuel cell and electrolyze. It is simply, no moving parts and can be used in stack installation to increase power load of the fuel cells systems. The U104 fuel cells are efficient in transport systems, communication and power supply. The hydrogen fuel cells are one of new interesting energy sources. In the last few years the Proton Exchange Membrane (PEM) fuel cells are one of the leaders on a field of fuel cells. Different type fuel cells are used for energy generation. In this project the analysis of characteristics of the U104 fuel cell is presented.

Experiments were carried out on a model of a fuel cell powered by solar energy. This model is produced by h-tech Company. Table 1 shows the specifications of the system used in the experiments. First hydrogen is produced by passing an electric current from the solar cell through the electrolysis and directing the hydrogen produced to the fuel cell. The same cell uses the produced oxygen and the stock to facilitate the utilization of stored hydrogen to form electrolytes. The current is used for the purposes of running the car. Fig. 1 represents the used prototype.

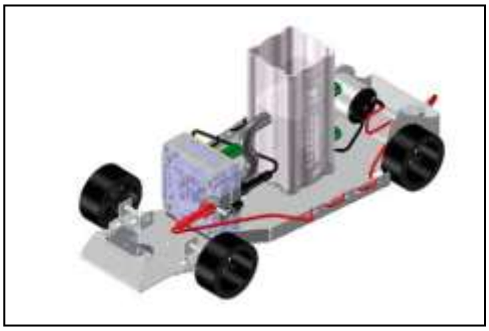

Fig-1: the used prototype in the experiments

Table-1: Technical data of the used prototype

Electrolysis mode	5cm^3/min H_2 2.5cm^3/min O_2	Electric load (car)	150 mA
Fuel cell mode	100 mW	Cable length	250 mm
Gas storage tank	30cm^3 H_2, 30 cm^3 O_2	H x W x D	140x450x380 mm
Solar module	2.0 V/600 mA	Weight	3.5 kg
Battery box	4.5 VDC/0.8 A		

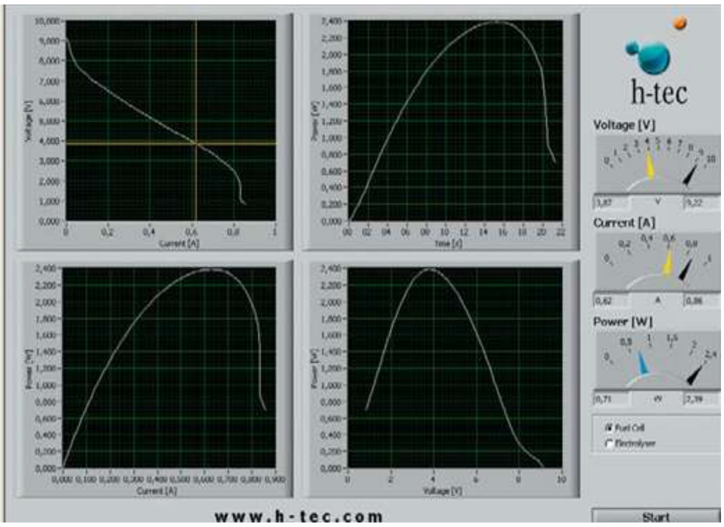

Fig-2: A sample of the characteristic curves of the tested fuel cell

The tests were conducted by recording the characteristics of fuel cell such as voltage, current, and time characteristics, automatically. The fuel cell was connected to the joining sockets of the measuring transformer card, which measures the fuel cell variables. The fuel cell was put in standby mode, and then start button was switched on, so the fuel cell automatically records the characteristic curve of the fuel cell. Figure 2 represent a sample of the produced characteristic curves of the tested fuel cell.

As the curves show in Fig. 2 there are peak points related the variables as voltage-current, time-power, current – power, and voltage power. If the operator of the fuel cell could operate the fuel cell at these points, then maximum power will be gained from this operation mode.

RESULTS AND DISCUSSIONS

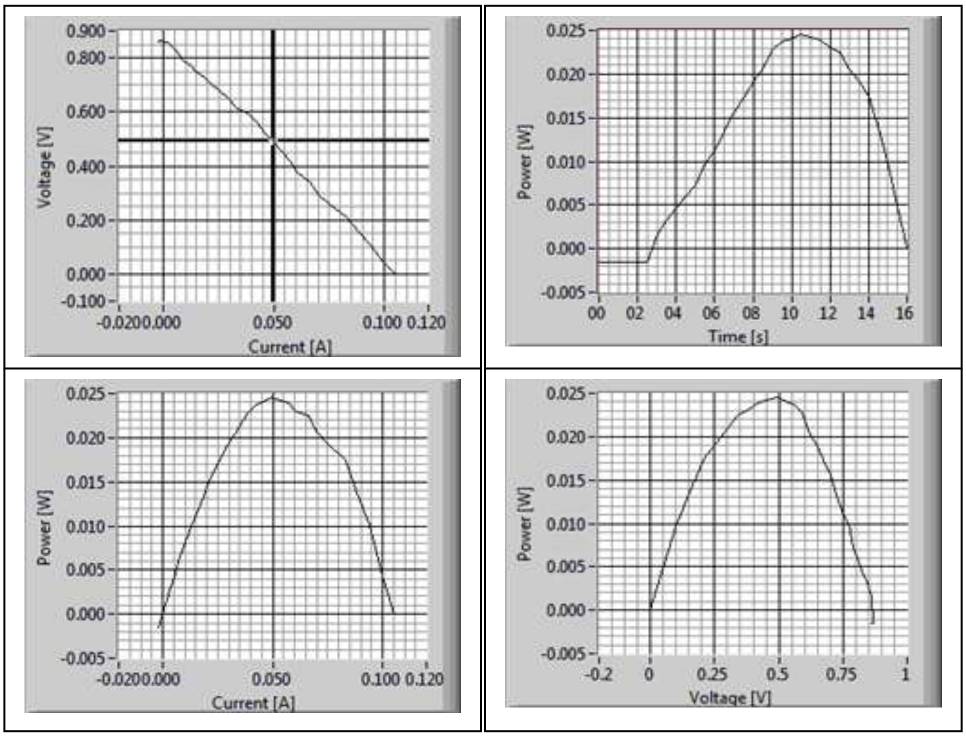

Fig-3: characteristics curves for the tested fuel cell

Fig. 3 represents the characteristic curves of the fuel cell used in the experiments cell using the FCM automatically records. These curves show that the cell voltage reduced linearly with increasing the current, and the power reached its maximum value after 10 sec operation at this mode. Also, the current-power curves shows that the power reached it maximum value at operation mode of current valued 0.05A, and the voltage was 0.5 volt.

All these figure are at the same point that selected by Cursor position for the automatic performance. The curves show that the Cursor position for the mean power point (MPP) is at 0.492 V; 0.050 A. When these values are used to calculated the cell efficiency:

η= (Actual voltage / Theoretical voltage) * 100%
= (0.492 / 6) * 100%
= 16.67%

The power was also calculated using information from Fig. 3 using the equation:

$P = I \times V$

$P = 0.050 \times 0.492 = 0.0246$ W

This power represent the maximum power can be achieved by the fuel cell operation.

Fig. 4 manifests the measured current and voltage through the electrolyze fluid. Electrolysis is the use of electricity to separate water into hydrogen and oxygen. The curve has three main points (or peaks).

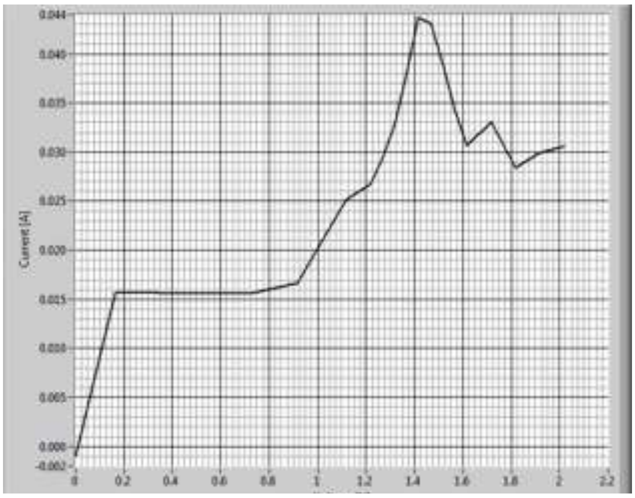

Fig-4: The voltage and current passing through in the electrolyze fluid

At point 1

$P = I \times V$

P= 0.15 * 0.15 = 0.0225 W

At point 2

P=0.035 * 1.4 25= 0.0498 W

At point 3

P=0.31 *2 = 0.62 W

The change in the voltage between the cathode and anode caused variation in the current passing through the electrolyze fluid. As a result the hydrogen production depends on the achieved voltage and current. As illustrated in figure e, at the first period as the voltage increase the current increase as well until the current remains constant as the voltage increase. The curve then fluctuates going up and down. This fluctuation of current is an indication of the separation of water into hydrogen and oxygen.

CONCLUSIONS

The fuel cell can be considered the future of energies in the near term and can be used to generate electricity for homes in addition to the operation of vehicles and other means of transport. The production of hydrogen from electrolysis of water is a very clean way if the electricity used is the result of a renewable source, such as the result of the movement of the wind or the sun.

In this study, the generation of hydrogen was tested from an electrolytic water analysis and immediately transferred to a fuel cell to produce electricity capable of operating a model of a car engine. The cell is connected to the measuring transformer card and analyzed results. The results obtained showed that there are values that can be obtained at the highest capacity and efficiency by directing the car to work in this mode. Also, the electrolyzer solution is affected by the voltages passing between poles and on the basis of which the amount of hydrogen produced is determined. The idea of research on the production of hydrogen locally in the car and use it to operate a fuel cell that moves the car is a promising step, especially in the case of the use of water produced from the reaction of hydrogen inside the cell and recycling it.

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