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Temporal Power Analysis of Ethanol Based Bio-Fuel Cells

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Abstract

The search for reliable, sustainable, and clean energy sources has been an ever challenging question for mankind in these days. Currently, fossil fuels as main energy source to fulfil world's energy demand is depleting very fast. Their waste products are also causing global environmental problems. So our environmental policy is demanding a reduction in greenhouse gases and toxic emissions. A coherent energy strategy is required, addressing both energy supply and demand as well as taking account of whole energy life cycle. One of the solutions is to replace the existing fossil fuel energy systems by the non-fossil fuel energy systems. Bio-fuel is one of the non-fossil fuel sources. Bio Energy derived from bio fuels like isopropyl alcohol ethanol, biodiesel, etc. is converted into electrical energy using a fuel cell. The objective of this paper is to investigate the changes in the output power of a fuel cell with respect to the concentration variation of the bio-fuel

1. Introduction

Due to increasing global energy demands, the number of people affected by energy shortage is likely to increase several folds. Energy shortages would be further exacerbated by fiscal and economic measures, which may be required to mitigate green house gas effects caused by burning fossil fuels. Hydrogen is an energy carrier having considerable relevance in such circumstances, primarily because it may be produced from several renewable resources through a number of technological routes [1]. Several factors regulate the lifetime of bio-fuel cells, which has always been a concern for their practical application [2]. Therefore, bio-fuel based fuel cell system is a good candidate for future usages for generating renewable energy. This energy system is an interesting alternative to provide power in stationary areas or as backup for other renewable energy resources for example solar, wind, etc. However, there are still several challenges even with this system as well [3].

Biological fuel cells (bio-fuel cells) are those fuel cells that rely on enzymatic catalysis for at least some part of their activity [4]. A broader definition would consider bio-fuel cells as those fuel cells which use biocatalysts, which includes systems utilizing non-enzyme proteins as well. In the broadest sense, biological fuel cells are devices capable of directly transforming chemical to electrical energy via electrochemical reactions involving bio-chemical pathways [5]. The term bio-fuels can refer to fuels for direct combustion for electricity production, but is generally used for liquid fuels in transportation sector. The use of bio-fuels can contribute to the mitigation of greenhouse gas emissions, provide a clean and therefore sustainable energy source, and increase the agricultural income for rural poor in developing countries. Today, bio-fuels are predominantly produced from biomass resources. Reliability and lifetime are the most essential considerations in such power sources [6]. Biomass appears to be an attractive feedstock for three main reasons:

(1) It is renewable resource that could be sustainably developed in the future
(2) It appears to have formidably positive environmental properties resulting in no net releases of carbon dioxide and very low sulfur content.
(3) It appears to have significant economic potential provided that fossil fuel prices increase in the future [7].

In terms of modern bio energy ethanol, biodiesel and biogas are the three major bio energy products. Ethanol and biodiesel can be used as transportation fuels, and ethanol is also an important raw product in the chemical industry. Therefore, ethanol production has a particularly important role in transforming petroleum based economies to biomass based sustainable and environment friendly economies [8]. For renewable energy generation, solar based hydrogen energy generation may be difficult during cloudy weather. Hence for uninterrupted energy supply, solar based systems should be supported by alternative mechanism of energy production. So, bio-fuel based systems may help towards this objective.

For the short term electricity generation, because of the abundance of natural gas, the availability of methanol and propane, and the lack of a hydrogen infrastructure, it is expected that hydrocarbon fuels will be the dominant fuels for stationary fuel cell applications. For as long as these fuels are cheaply available, reformation of a hydrocarbon fuel is the most cost efficient method of producing hydrogen. In the reformation of a hydrocarbon fuel however, there is an emission of carbon dioxide. Although carbon dioxide is not considered a pollutant, controversy exists that man-made emissions may contribute to global warming. An approach for micro scale power generation is to scale down electrochemical devices such as batteries and fuel cells where fuel cells directly convert chemical energy into electrical energy [9]. A prototype system relying on short term storage require hydrogen path-consisting of electrolyser, hydrogen tank, and a fuel cell [10]. There are no barriers to the introduction of hydrogen and fuel cells either from a technological perspective or from a safety point. Hydrogen has been produced and utilized in industry for over a hundred years [11]. Bio-fuel can be useful during cloudy weather to demonstrate the functions of renewable fuel cell for electricity production. Bio energy can also be derived from bio-fuels like bio-ethanol, isopropyl alcohol and biodiesel, etc. Isopropyl alcohol is an aliphatic alcohol and miscible in water so that according to Fig. 1, electrical energy generation from isopropyl alcohol bio-fuel may be used to energize small DC load in a short period of time to run different appliances.

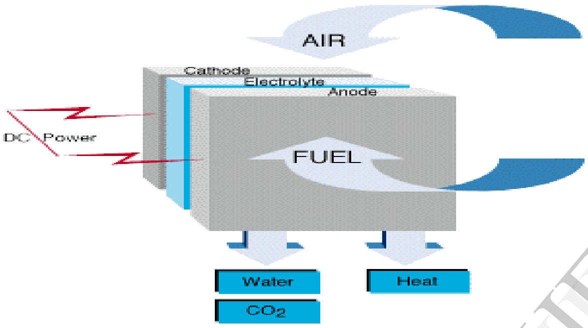

Fig. 1 Bio-fuel based energy production

These new concepts also increase the fuel economy because they avoid burning a part of bio-ethanol, bio-diesel, etc., for producing the reforming reaction. It allows testing of an energy management strategy to best satisfy the power demand. No other energy generating technology holds the combination of benefits that fuel cells offer. Some of the benefits are as follows.

- High energy security due to abundant of fuel source availability
- High supply security due to efficient, modular, and fuel flexible structure
- Physical security due to evenly distributed resources in nature
- High reliability
- High quality power and high efficiency (85%)
- Environmental friendly.

A renewable fuel cell is unique because it can act as both an electrolyser and an electrical power source. When applying an electric current, the device acts as an electrolyser that produces hydrogen and oxygen from de-ionized water. When applying a load, the electrolyser becomes an electrical power source. Polymer electrolyte membrane fuel cells operate at relatively low temperatures, around 80°C (176 F). Low temperature operation allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability.

The use of fuel cells in both stationary and mobile power applications can offer significant advantages for the sustainable conversion of energy. Renewable energy sources are derived from those natural, mechanical, thermal, and growth processes that repeat themselves within our lifetime and may be relied upon to produce predictable quantities of energy when required [12].

The objective of this paper is to investigate temporal power analysis of bio-fuel based fuel cell system. Section 2 explains Polymer Electrolyte Membrane fuel cells along with ethanol fuel cell. The methodology is given in Section 3, results and discussions in Section 4 along with conclusions in Section 5.

2. Polymer Electrolyte Membrane Fuel Cells

Polymer Electrolyte Membrane (PEM) fuel cells also called proton exchange membrane fuel deliver high power density and offer the advantages of low weight and volume compared with other fuel cells. PEM fuel cells are the good candidates for small-scale distributed stationary power generation [13]. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum catalyst. They need only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids like. They are typically filled with pure hydrogen supplied from storage tanks or on-board reformers. Fuel cells could potentially provide energy more cleanly and efficiently than combustion engines [14]. Higher density liquid fuels such as methanol, ethanol, natural gas, liquefied petroleum gas, and gasoline can be used for fuel but the vehicles must have an on board fuel processor to reform the methanol to hydrogen. This requirement increases costs and maintenance. PEM fuel cell uses a thin, permeable polymeric membrane as the electrolyte as shown in Fig. 2. The membrane is very small and light and in order to catalyze the reaction, platinum electrodes are used on either side of the membrane. Within the PEM fuel cell unit, hydrogen molecules are supplied at the anode and split in to hydrogen protons and electrons.

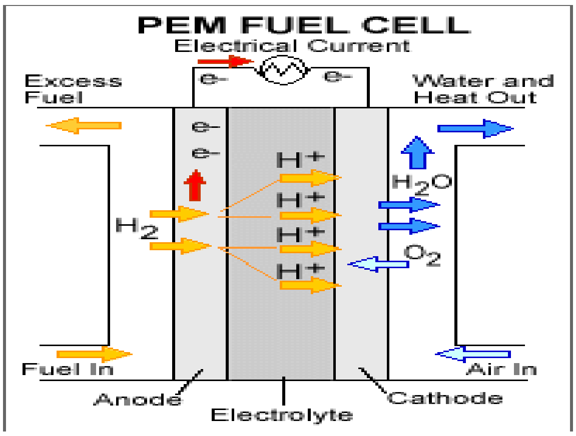

Fig. 2 Proton exchange membrane fuel cell

The protons pass across the polymeric membrane to the cathode while the electrons are pushed round an external circuit in order to produce electricity. Oxygen (in the form of air) is supplied to the cathode and combines with the hydrogen ions to produce water. Compare to other electrolytes which require temperatures up to 10000°C to operate effectively. PEM fuel cells operate at very low temperatures of about 800°C allowing rapid start-up. The efficiency of a PEM unit usually reaches between 40 to 60% and the output of the system can be varied to meet shifting demand patterns. Typical electric power is up to 250 kilo-watts. Generally, there are three main application fields for PEM fuel cells such as transportation, stationary, and portable applications. The development direction of PEM fuel cells in each nation is bound up with their social and industrial environment as well as their structure of energy supply and demand [15]. In addition, PEM fuel cells are often compact and lightweight units. As a result of these characteristics, PEM units tend to be the best candidates for cars, buildings and smaller stationary applications.

However, there are also some disadvantages associated with PEM operation. Although the low operating temperature of the unit is usually seen as an advantage, in some instances temperatures as low as 800°C are not high enough to perform useful cogeneration. Furthermore, in order to achieve the most effective operation of the unit, the electrolyte must be saturated with water. Control of the moisture of the anode and cathode streams therefore becomes an important consideration

Biomass can be converted into bio-fuels such as bio-ethanol, biodiesel and, thermo-chemical conversion products [12]. Bio-fuels that have been identified as potential fuel for fuel cells are landfill gas (LPG), anaerobic digester gas (ADG), biomass gasification (BG), biodiesel, and ethanol, etc. Ethanol (CH3CH2OH) is obtained by the fermentation of the sugar components of biomass, for example from sugarcane. Ethanol is also called ethyl alcohol, pure alcohol or drinking alcohol which is a colourless in nature. Yeast is added to the extracted sugar to run the fermentation process but ethanol can also be produced from cellulosic biomass such as crop wastes (saw dust etc.), municipal solid waste, and recycled newsprint. Cellulosic materials first need to be processed to form sugar that can then be fermented. Ethanol is currently produced from sugar cane and starch containing materials where the conversion of starch to ethanol includes a liquefaction step and a hydrolysis step (to produce glucose). The resulting glucose is then readily fermented [16]. Ethanol is a liquid fuel and a primary alcohol. Compared with LPG, ADG and BG, ethanol is a relatively clean fuel and does not require complex clean-up processes.

3. Methodology

The investigation were carried out on bio-fuel i.e. ethanol using PEM fuel cell for electricity generation. The experimental set up is shown in Fig. 3. Electricity produced from renewable energy sources could be used to make hydrogen by an electrolyser from bio-fuel then hydrogen recombined with oxygen or water in a fuel cell to generate electricity and then generated electricity from bio-fuel cell system applied to the load. Ethanol bio-fuel is mixed with water and then that liquid is applied to the bio-fuel cell system. Chemical reaction takes place between the ethanol solution, water, and oxygen.

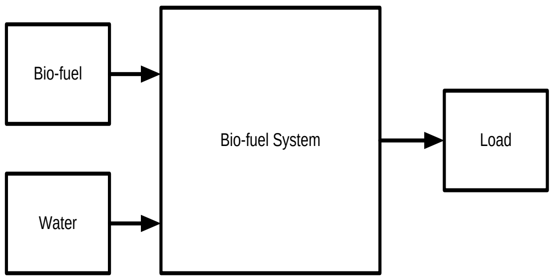

Fig. 3 Experimental setup

Table 1: Estimated power for different levels of concentration

Conc.	Time (min)	Volt (V)	Current (μA)	Power (μW)
E40W10	0	0.635	29.0	18.41
	2	0.648	29.0	18.79
	4	0.658	29.8	19.61
	6	0.664	30.0	19.92
	8	0.671	30.0	20.13
	10	0.677	30.5	20.65
E30W20	0	0.624	28.0	17.47
	2	0.642	29.0	18.62
	4	0.645	29.0	18.71
	6	0.647	29.0	18.76
	8	0.649	29.2	18.95
	10	0.646	29.2	18.86
E20W30	0	0.581	26.0	15.11
	2	0.605	27.1	16.40
	4	0.607	27.2	16.51
	6	0.606	27.2	16.48
	8	0.605	27.1	16.40
	10	0.603	27.1	16.34
E10W40	0	0.589	26.2	15.43
	2	0.589	26.5	15.61
	4	0.594	26.9	15.98
	6	0.594	27.0	16.04
	8	0.594	27.0	16.03
	10	0.593	27.0	16.01
E0W50	0	0.580	26.0	15.08
	2	0.581	26.1	15.16
	4	0.581	26.2	15.22
	6	0.580	26.1	15.14
	8	0.579	26.0	15.05
	10	0.578	26.0	15.03

Investigations were carried out by varying the concentration of ethanol bio-fuel after adding water. Readings were taken after every two minutes using multi-meters at fixed load conditions of 1 kilo ohm. The readings were recorded for a period of 10 minutes after changing the concentration in the input container of the fuel cell.

4. Results and discussion

The reading taken for different concentration of ethanol and water are listed in Table I and plotted in Fig. 4. Here, ExWy means x ml of ethanol and y ml of water. Investigations showed that voltages and currents change according to the concentrations of ethanol alcohol and distilled water. All readings have been taken after every two minutes. Average power for concentration E40W10, E30W20, E20W30 , E10W40 and E0W50 comes as 19.59 µW, 18.56 µW, 16.21 µW, 15.85 µW, and 15.11 µW respectively.

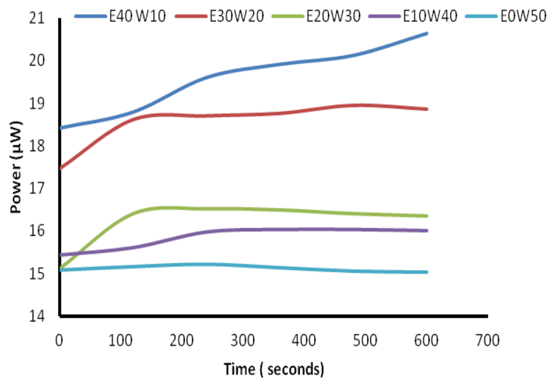

Fig. 4 Variation of power with concentration

5. Conclusion

Investigations were carried out with bio-fuel based fuel cell. It may be concluded from the investigations that the power of the system decrease with the decrease in ethanol concentration. PEM fuel cell provides appreciable stable voltage over time. The waste products from system are not harmful for environment.

During cloudy weather, solar based electricity generation system supplies low output power. So in order to maintain uninterrupted energy supply the bio fuel cell system may be attached to solar system.

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