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Experimental Study of the Characteristic of a PEM Reversible Fuel Cell

Dimitar Gugov[1], *Marin* Todorov[1], *Maik* Streblau[1] *and Tatyana* Dimova[1]

1 – Technical University of Varna, Department of Electrical Engineering, 9010, 1 Studentska Str, Varna, Bulgaria

Corresponding author contact: streblau@tu-varna.bg

Abstract. *Renewable energy sources are the proper way to protect and preserve the natural resources of the only planet we inhabit. The fuel cell is an interesting solution in the field of renewable energy sources. These devices convert the chemical energy from hydrogen and oxygen into electrical and thermal energy. The present paper, therefore, focuses exclusively on their ability to generate electricity, their energy efficiency, quiet mode of operation, and environmental compatibility. The polymer electrolyte membrane fuel cell coverts the energy at high density of power. The weight and cost of this cells are lower than the other kind of fuel cell. A reversible proton exchange membrane fuel cell is a kind of PEM fuel cell. It can operate in two modes - fuel cell mode and electrolyzer mode. Presented in the current paper are the experimental studies conducted into the operation of the fuel cell in electrolyzer and fuel cell mode. The relevant parameters and characteristics obtained from experiments are analyzed in relation to the mode of operation.*

Keywords: fuel cell, mode, proton exchange membrane, electrolyze, polymer electrolyte membrane

1 Introduction

Renewable energy sources are the proper way to protect and preserve the natural resources of the only planet we inhabit. The development, improvement and increase of the reliability of the systems for production of electricity from renewable energy sources will remain a topical issue, constantly evolving and ever-changing. The diversity of design solutions and the combined sharing of different types of renewable energy sources is undoubtedly immense. An interesting solution in the field of renewable energy sources are fuel cells. From their invention in the 19th century to the present, their design solutions have undergone many changes (**Mitzel et al, 2021**). Until recently, the cost of producing fuel cells was too high to be widespread. Of course, all this is gradually changing in recent years, when new developments of fuel cells with cheaper and more practical design have appeared.

Fuel cells are devices that convert chemical energy directly into electrical and thermal energy. The present paper focuses exclusively on their ability to generate electricity, their energy efficiency, quiet mode of operation, and environmental compatibility.

Recognised, so far, despite the ongoing extensive research, are more than 20 types of fuel cells (**Giap et al, 2022**), (**Mitzel et al, 2021**), (**Ou et al., 2021**), (**Sharaf & Orhan, 2014**) and the most popular and widespread, in view of their technical parameters, are (**Akinyele et al., 2020**) – polymer electrolyte membrane fuel cell (PEMFC), alkaline fuel cell (**Gülzow & Schulze, 2008**), phosphoric acid fuel cells (**Fuller & Gallagher, 2008**), solid oxide fuel cells (**Alaswad et al., 2022**), molten carbonate fuel cells (**Rexed et al., 2015**) and direct methanol fuel cells (**Joghee et al., 2015**).

The polymer electrolyte membrane fuel cell converts the energy at high density of power. The weight and cost of these cells are lower than the other kind of fuel cells (**Kui & Xianguo, 2011**), (**Munroe & Cheddie 2006**), (**Peng et al., 2007**).

A reversible proton exchange membrane fuel cell (PEM RFC) is a kind of PEM fuel cell. It can operate in two modes - fuel cell mode and electrolyzer mode (**Rabih et al., 2008**). In the fuel cell mode, an PEM FC generates electrical and thermal energy from hydrogen and oxygen and produces water according to the following chemical equation:

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$$2H_2 + O_2 = 2H_2O + energy \quad (1)$$

In the electrolyzer mode, a fuel cell absorbs energy to divide water into hydrogen and oxygen, according the following equation:

$$2H_2O + energy = 2H_2 + O_2 \quad (2)$$

The aim of the paper is to conduct a detailed study into the PEM RFC. Fully examined, to that effect, is the operation of the fuel cell in two modes – electrolyze mode and fuel cell mode. The parameters and characteristics of the device are analyzed in respect to the operation mode.

2 Experiment

The experiment was realized with the PEM Reversible Fuel Cell shown in Figure1. The technical specifications of the cell are given in Table 1.

Fig.1. PEM Reversible Fuel Cell

Table 1. Technical Data of PEM Fuel Cell.

Fuel Cell	Input Voltage	Input Current	Output Voltage	Output Current	Power
RFC	1.8-3V	0.7A	0.6V	0.360A	0.210 W

The experiment was conducted in two modes – electrolyze and fuel cell mode.

The first part of the experiment was performed in the electrolyze mode. The supply voltage for the electrolyze process was ensured with stabilized DC source PSP1405. It can be observed that the voltage changes in 1.8-3.0V range. For every step of the voltage range the electrolyze process produce 10ml H_2 and 5ml O_2. The block diagram for the electrolyze mode is shown in Fig.2.

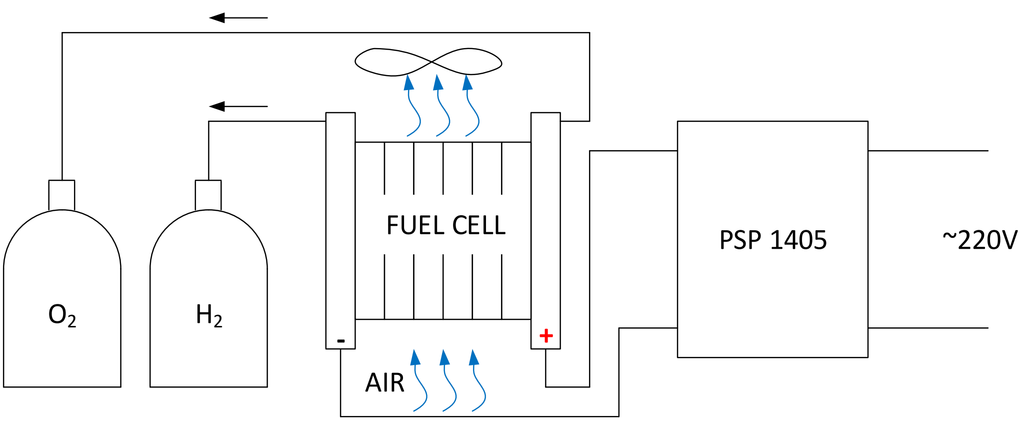

Fig.2. Electrolyze mode block diagram.

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In order to calculate the total efficiency of the electrolyzer, it is measured and reconciled by the parameter **MMW** (**Streblau et al., 2014**), which describes the volume of produced gas in milliliters per time in minutes and the power needed for the production in watts. Formula (3) represents the equation applied.

$$MMW = \frac{V}{t.P} \quad (3)$$

The second part of experiment was performed in fuel cell mode. The generated electricity was insured with the produced oxygen and hydrogen from the electrolyze mode. The block diagram for the electrolyze mode is shown in Fig.3. The process is finished when the fuel cell converts 4ml H_2 and 2ml O_2. The amount of converted gases in electricity is relative to the possibility of extracting the gases from the containers back into the cell.

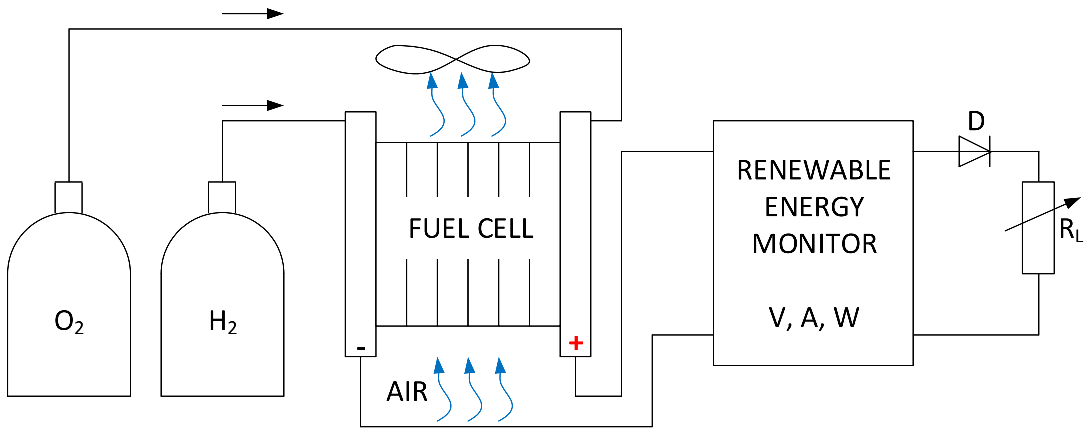

Fig.3. Fuel cell mode block diagram.

3 Experimental Results

Described in the figures below (Fig, 4,5,6,7) are the characteristics for the electrolyze and fuel cell modes. For the electrolyze mode the following characteristics are analyzed– duration of electrolysis process, the electrical power and energy, and MMW with regard to the supply voltage of the cell.

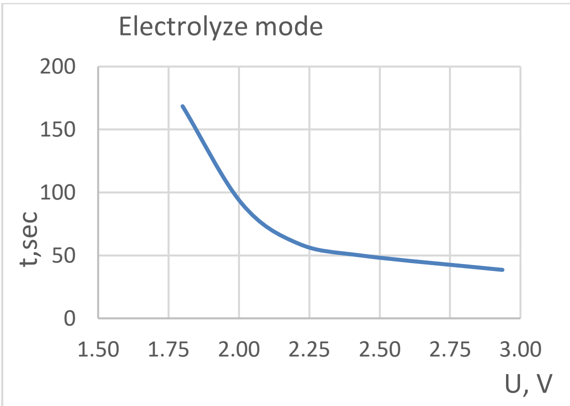

Fig. 4. Electrical Energy as to the supply voltage in electrolyze mode

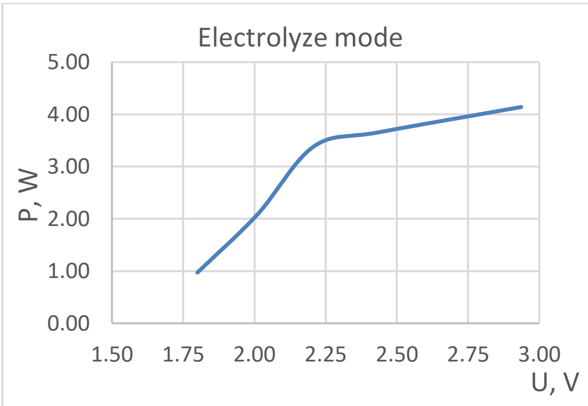

Fig.5. MMW as to the supply voltage in electrolyze mode

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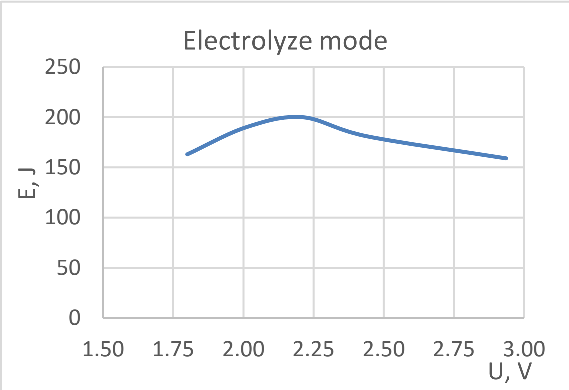

Fig. 6. Electrical Energy as to the supply voltage in electrolyze mode

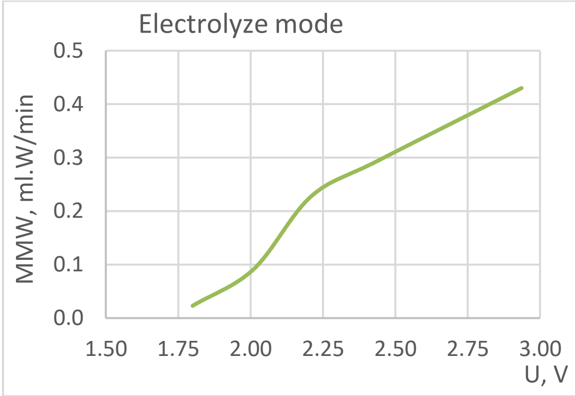

Fig.7. MMW as to the supply voltage in electrolyze mode

The starting supply voltage of the cell in electrolyze mode is 1.8V, which, in turn, defines the initial point for supply voltage range. Clearly, from the characteristics obtained, the higher the voltage, the shorter the duration of the process. Correspondingly, an increase in the electrical power triggers a decrease in the electrical energy.

Explored, as for the fuel cell mode, are the electrical voltage, electrical current, the electrical power and electrical energy relative to the duration of the fuel cell mode (Fig.8,9). The maximum energy change is noticed at 2.21V. The MMW increases throughout the entire range of the voltage and its maximum is obtained at the end of that range.

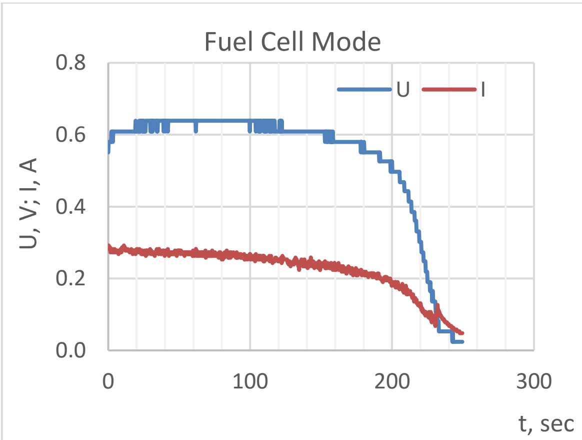

Fig.8. Variation of voltage and current.

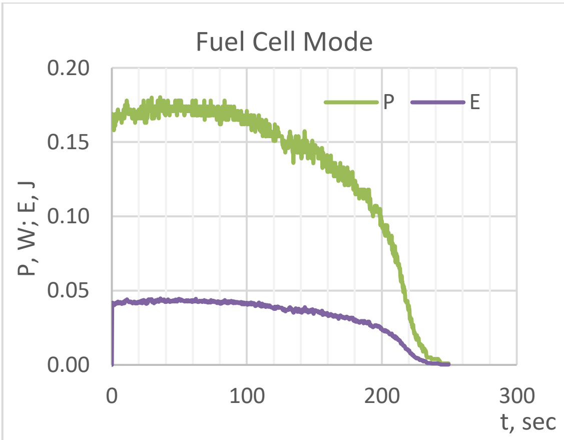

Fig.9. Variation of electrical power and energy.

4 Conclusions

The study of the PEM RFC, proposed hereto, is conducted in two modes – electrolyze and fuel cell mode. The electrolyze mode is capable of producing a certain amount of gas. The characteristics obtained refer to the electrical power and energy, the electrolyze process duration and the efficiency of the process. The efficiency of the process is defined by the MMW parameter.

The fuel cell mode is realized with the oxygen and hydrogen produced from the electrolyze mode. Account is taken of the following characteristics – voltage variation, current variation, electrical power variation and energy variation with the process of duration being determined by the part of the produced gases. It has been found, however, that the consumption of the entire amount of gases obtained in the electrolyze mode is practically unfeasible due to the pressure exerted on the gas cylinders. The average fuel cell mode efficiency is 14% based on the consumed energy from the electrolyze mode.

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