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HYBRID POWER ENERGY SOURCE BASED ON PEM FUEL CELL/SOLAR SYSTEM

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Abstract— **The paper presents an overview of existing technologies by presenting the idea of using a system based on fuel cells and solar systems as an energy source. Fuel cells have the ability to reverse actions. The process of electrolysis is used to produce hydrogen and the reverse process, the chemical reaction of hydrogen and oxygen made the production of electricity. To produce electricity to be used in the process of electrolysis can use solar module and thus achieve full use of alternative renewable energy as energy source.**

Keywords-fuel cells; hybrid; solar energy;

I. INTRODUCTION

The conversion of various forms of energy into electricity has been known for decades. One of the more recent times is often mentioned the energy of hydrogen, which, through an element known as the fuel cell, converts into electrical energy, and as a by-product, the product has thermal energy and technical water. It can be said that this type of conversion is environmentally acceptable in relation to the use of oil and oil derivatives for this purpose. The paper analyzes the model of one type of fuel cell and its current voltage characteristics, and the possibilities of integration of the system based on fuel cells and systems based on photovoltaic technology. One of the most commonly used types of fuel cells are PEM fuel cells (Semi-permeable membrane-based fuel cells).

II. PEM FUEL CELLS

PEMFC (Proton Exchange Membrane Fuel Cell) is a fuel cell with a polymer membrane as the electrolyte. The fuel is hydrogen and the charge carrier is the hydrogen ion (proton), and as the oxidant can be used pure oxygen or oxygen from air [1,2].

In the fuel cell anode separation process takes place on the molecules of hydrogen ions of positive hydrogen and electrons. Ions pass through the membrane to the cathode, and electrons pass external electrical circuit to the cathode. Warm-up article that accompanies the reaction of air from the atmosphere is regulated and stops at approximately 80 °C so as submitted porous polymer membranes. At this temperature water occurs, which pushed the air stream leaving the cell, partly liquid and partly as a couple. It is noteworthy that this reaction is very slow if you ran electrolytic membrane does not in itself would have a platinum catalyst. This precious metal is not oxidized, so for this type of chemical reaction, the catalytic properties and excellent resistance to the influence of oxygen, is ideal. Electrolyte membrane is a product high technology, and best-known material that is made is Nafion [3].

The anode reaction occurs very fast dissolution of the hydrogen molecule into two single atoms that are connected to two platinum atoms and then released by an electron conductor that flowed to the consumer. Hydrogen ion (proton) is free to do with the platinum atom and is continuing the porous electrolyte membrane to the cathode where the reaction takes place the second part [4].

The output electrodes generates the potential difference and if the consumer is connected, electric current will flow. The output voltage value is influenced by various factors. The ideal value of voltage at the output if the input is used for pure hydrogen and oxygen, at a temperature of 25^0C is up to 1.2 V per cell.

This output voltage drops due to the impact of three primary factors that are often referred to polarization in the literature, such as [5]: activation polarization, omsk polarization, concentration polarization.

The theoretical value of the fuel cell output voltage can be calculated using the expression for Gibbs free energy [2]:

$$E = \frac{-\Delta \overline{g_f}}{2 \cdot F} \tag{1}$$

Where is: E - electromotive force at the ends of the fuel cell, Δg_f - Gibbs free energy per mole, F - Faraday's constant F=96485C.

Equation (1) is the fundamental equation of the open circuit voltage for a fuel cell with hydrogen as a fuel.

The maximum possible electrical energy obtained is equal to the change in Gibbs free energy and the maximum efficiency is known as the "thermodynamic efficiency". Voltage at the output of the unit fuel cell ranges from 0.98 V to 1.23 V [6].

Besides the temperature effect on the value of the electromotive force of impact and value of the partial pressures of hydrogen, oxygen and water. From equation (2) is visible in the partial pressure effect on the value of the electromotive force [2].

$$E = E^0 + \frac{R \cdot T}{2 \cdot F} \ln \left(\frac{\frac{P_{H_2}}{P^0} \cdot \left(\frac{P_{O_2}}{P^0} \right)^{1/2}}{\frac{P_{H_2O}}{P^0}} \right) \tag{2}$$

where is: E - electromotive force at the ends of the fuel cell, E_0 - emf at standard pressure, P_{H2} - hydrogen pressure at the entrance of the fuel cell, P_{O2} - pressure of oxygen, pressure of weather, P_0 standard atmospheric pressure, usually assumed to be 1bar, R = 8,314$JK^{-1}mol^{-1}$ universal gas constant, T - fuel cell temperature, F - Faraday's constant.

III. ACQUISITION PROCESS HYDROGEN ELECTROLYSIS

Apparatus for electrolysis using electrical energy to perform chemical separation of water molecules (H_2O), molecules of hydrogen (H_2) and oxygen molecules (O). The function of these devices is the opposite of a function of fuel cells. The basic theory of chemical unfolding process is the same as in fuel cells, except that the chemical reactions going in the opposite direction [6]. Figure 1 shows the sheme of the device electrolysis [2].

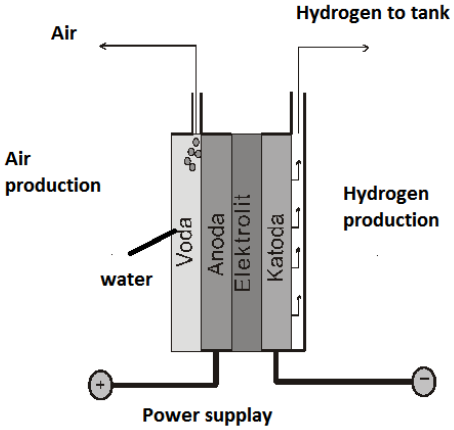

Figure 1. Principal scheme of the device for electrolysis

The basic principle of the device for electrolysis is reflected through the progress of chemical reactions on the negative and positive electrode [4].

One of the major reasons for the success of PEM electrolysis unit is reflected in the fact that no additional devices for cooling and ventilation. Appliance efficiency electrolysis can be defined as [2]:

$$\eta = \frac{1,48}{V_c} \tag{3}$$

where: η - efficiency of the electrolysis device, V_c - the mean voltage of a cell in a series of fuel cell, constant of 1,48 was chosen in relation to the upper heating value.

For the production of one mole of hydrogen energy must be expended [2]:

$$\Delta W = n \cdot R \cdot T \cdot \ln \left(\frac{P_2}{P_1} \right) \tag{4}$$

where: n number of moles of hydrogen, R universal gas constant, T temperature, P_2 desired compression pressure of hydrogen, P_1 standard pressure of hydrogen is usually 1bar (101325 Pa).

IV. ELECTRICAL CHARACTERISTICS OF PEM FUEL CELLS

For the analysis of electrical properties of the fuel cell can be very useful knowledge of current voltage characteristics of fuel cells. It has already been mentioned above that the value of the output voltage is influenced by factors that are divided into three main groups. The effect of each parameter is reflected in the voltage drops from the effects of activation polarization, ohms, and at the end of concentration polarization [6]. Taking into account the impact of these factors for a mathematical model of voltage-current characteristics can be written [2]:

$$V = E_{oc} - i \cdot r - A \ln(i) + m \cdot e^{(n \cdot i)} \tag{5}$$

where: E_{OC} real practical value of the open circuit voltage, and output power density fuel cell, r the specific resistance of the surface of the fuel cell, A slope factor of the curve, m constant, n is a constant.

Last member of the form (5) was obtained empirically [2].

For the practical value of the open circuit voltage E_{OC} can be written [2]:

$$E_{oc} = E + A \ln(i_0) \tag{6}$$

where: E electromotive force defined by the form (1), i_0 current density at which the output voltage begins to fall.

A factor is defined by the form [2]:

$$A = \frac{R \cdot T}{2 \cdot \alpha \cdot F} \tag{7}$$

where: F the Faraday constant, R is the universal gas constant, α the charge transfer coefficient. The value of this coefficient varies depending on which electrode materials have been made and could be in the range of 0.1 to 1. The most common value is 0.5.

The form (5) can be abbreviated to write [2]:

$$V = E - \Delta V_o - \Delta V_a - \Delta V_t \tag{8}$$

where: ΔV_o voltage drop due to polarization or ohms resistance fuel cells, the voltage drop due ΔV_a activation polarization, the voltage drop due ΔV_t concentration polarization.

The voltage drop at the exit of the fuel cell effect as previously mentioned three main groups of parameters. The first sharp decline caused by activation losses, ohmic and concentration and in the end. The default value of individual fuel cell voltage output is 0.6 V. By attaching more cells are obtained the necessary voltage levels.

Using the software package Maple can be simulated in the mathematical model for the form (5) voltage-current characteristics obtained fuel cell. Figure 2 shows the voltage-current characteristics using the following data: E_{OC} = 1.031 V, r = 2.45·10^{-4} kΩcm^2, A = 0.03 V, m = 2.11·10^{-5}V, n = 8·10^{3}cm^{2}mA^{-1} [2].

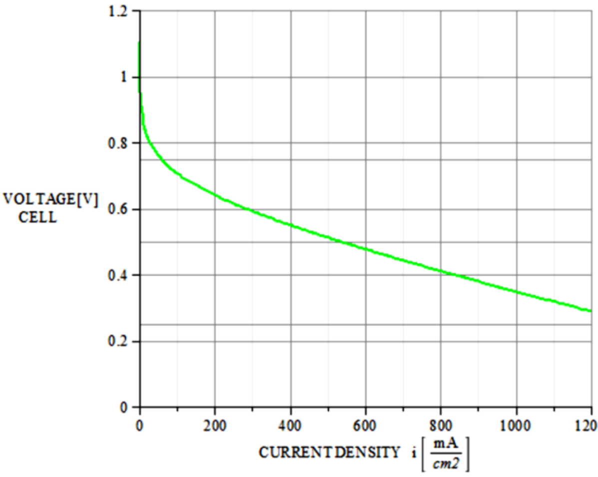

Figure 2. Voltage-current characteristics of fuel cells

According to a study conducted in the literature [7] for voltage losses in a fuel cell can be written [7]:

$$L=\frac{R\cdot T}{\alpha\cdot n\cdot F}\cdot\ln\left(\frac{i+i_n}{i_0}\right)+r\cdot\left(i+i_n\right)-\frac{R\cdot T}{n\cdot F}\cdot\ln\left(1-\frac{i+i_n}{i_L}\right) \qquad (9)$$

where: α the charge transfer coefficient, n is the number of electrons transferred in reaction, i_n the internal current density related to the internal power losses, limiting current density i_L-related losses due to changes in the concentration of hydrogen.

On the basis of the form (9) can be written by analogy to the form (5) the expression for the value of the electromotive force of the fuel cell output:

$$V=E_{oc}-A\cdot\ln\left(\frac{i+i_n}{i_0}\right)-r\cdot\left(i+i_n\right)+B\cdot\ln\left(1-\frac{i+i_n}{i_L}\right) \qquad (10)$$

where: B constant B = 0.05 V.

Based on the data: E_{oc} = 1,031V, r = 2,45·10^{-4} kΩcm^2, A = 0,03V, B = 0,05V, i_n = 3mAcm^{-2}, i_0 = 0,04mAcm^{-2}, i_L = 1000mAcm^{-2} with simulation in Maple software package, show in Figure 3 a voltage-current characteristics on the basis of theoretical models of the form (8).

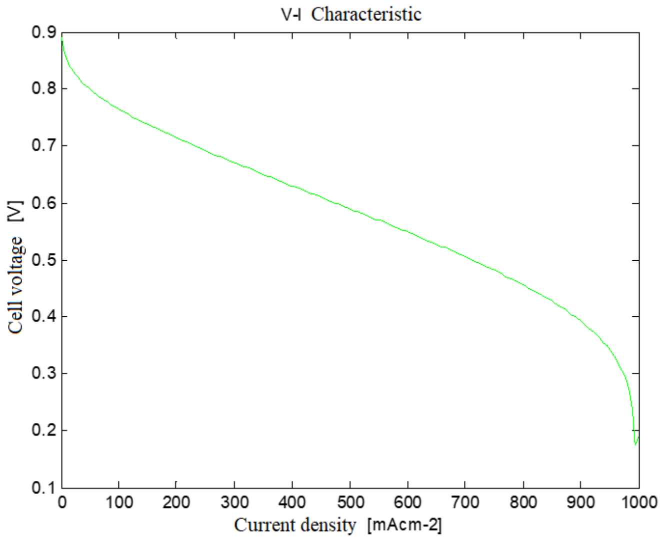

Figure 3. Voltage-current characteristics of fuel cells based on model form (8)

Figure 4 shows along the voltage current characteristics obtained by mathematical models for forms (5) and (10).

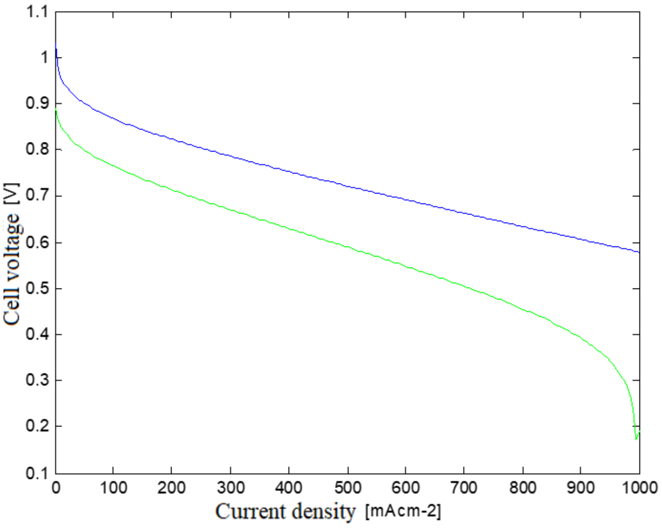

Figure 4. Comparative review of V-I characteristics of two mathematical models

V. HYBRID ENERGY SOURCES BASED ON FUEL CELL/SOLAR

Electrolysis unit is installed in hybrid devices, and by using photovoltaic module for power generation. In figure 5 is shown an independent energy source consisting of a photovoltaic generator which is used for power generation, system control and management controls of battery charging and control spending [8].

For the simulation of PV system was chosen photovoltaic module H250 which is power 25Wp. Mentioned module dimensions 55cm x 45cm so it is possible to assemble on the roof of small house or on electric car. The maximum voltage of the photovoltaic module is V_{MP} = 21V and maximum current in the I_{mp} =1.6 A. To operate the device for electrolysis it is necessary to provide a power of approximately 2W. Figure 5 shows the motion of the movable block diagram of an independent hybrid energy sources:

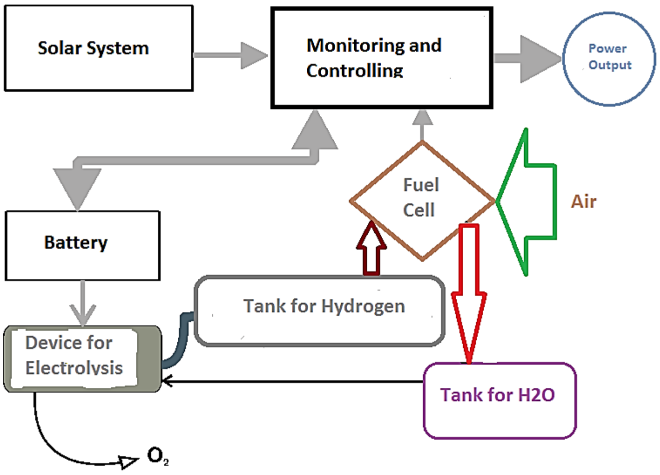

Figure 5. Block diagram of the hybrid system

The observed system will work during sunny days standstill and thereby the energy produced by photovoltaic systems placed in the battery. Energy from the battery will power the device for electrolysis to produce hydrogen that is left in the tank. Starting system includes a devices for control of fuel cells that take the form of hydrogen fuel and convert it into electricity, heat and water. The resulting water is returned to the electrolysis system. Electricity used to run electric loads. Thermal energy in the winter months can be used to heat the interior of the house [8].

In Figure 6 shows the results of the simulation work of PV system in software package Matlab.

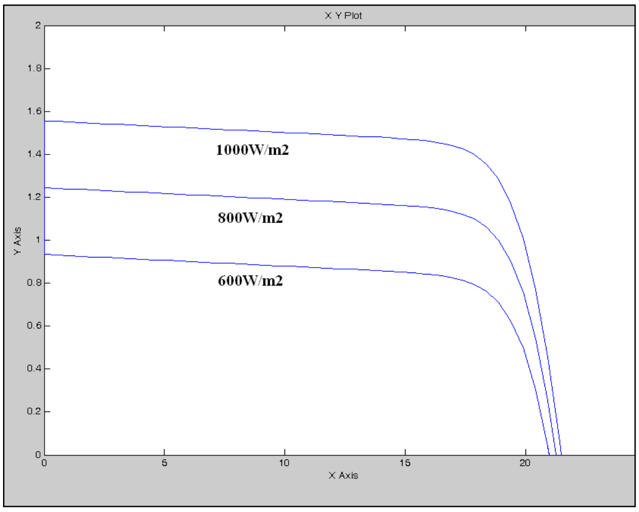

Figure 6. I-V characteristic of photovoltaic module H250 for different solar radiation intensities

The picture 7. is show simulated PV system in software package PVsyst for different sunlight intensity.

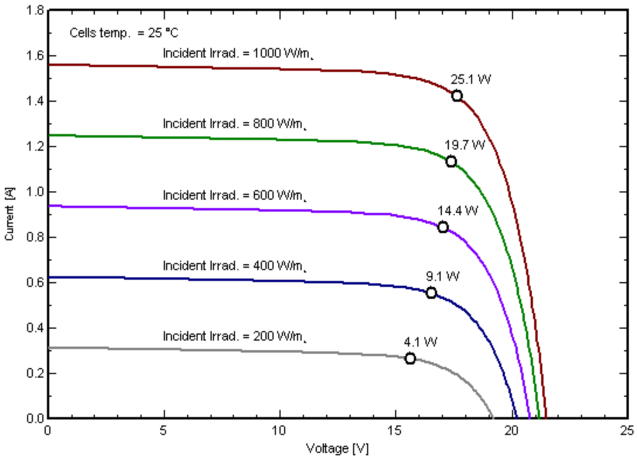

Figure 7. I-V characteristic of module H250 for different solar radiation intensity

VI. CONCLUSIONS

The paper presents a way to use hybrid power systems based on photovoltaic and fuel cells. Simulations are shown along the voltage current characteristics for two different models of fuel cells. The present system is a block diagram that describes the basic components that comprise it.

Finally the simulation of a photovoltaic system with the results produced and the energy needed to operate the device for electrolysis.

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