Research of the hydrogen fuel cell working with electrolyser powered energy from photovoltaic conversion

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Abstract **The work presents a proposal of an analysis of the cooperation of a laboratory hydrogen fuel cell with photovoltaic modules that constitute the power source for an electrolyser. The results of the tests conducted can constitute a substantive teaching basis.**

Keywords **electrolyser, hydrogen fuel cell, photovoltaic conversion, efficiency.**

I. INTRODUCTION

Fuel cells were used as early as during the Apollo space program, where they were used to generate electric energy and warm water on board of a space ship. The growing demand for highly efficient and clean energy sources at the time when fossil fuel sources are quickly depleting led to the rapid development of fuel cells. Nowadays, fuel cells are used to construct the batteries for mobile devices, low and high power generators, stationary power plants, vehicles, etc. [1],[2].

II. FUEL CELLS

A fuel cell is an electro-chemical device which produces usable energy (electricity, heat) as a result of a chemical reaction of hydrogen and oxygen. The by-product of the reaction is water.

PEM (Proton Exchange Membrane) fuel cells are powered with pure hydrogen or with reformate. The membrane of a PEM cell is made of a polymer material (e.g. nafion). A characteristic feature of PEM cells is the high efficiency (35÷65 %) of the conversion of chemical energy into electric energy and the low amount of heat generated. An advantage of a PEM cell is its good tracking performance in systems exposed to varying loads and short start-up time (up to 60 s.); the reaction in the cell takes place in low temperature (60-100°C). The efficiency of fuel cells in terms of the amount of electric energy generated reaches up to 50 %. In the process of co-generation, generation of both electric energy and heat, fuel cells reach the efficiency of up to 85 %.

The hydrogen necessary for the fuel cell can be obtained from water in the process of electrolysis, using alternative energy sources, e.g. solar radiation. Hydrogen can also be obtained from methane in the process of steam reforming whose efficiency reaches about 80 %. The by-product of this process is carbon dioxide. The most common and the most frequently used way to store hydrogen is storing it in containers under the pressure of up to 1000 bar.

III. EXPERIMENTAL RESEARCH

The primary goal of the research is to experimentally verify the knowledge about the functioning of the electrolyser system with a fuel cell powered with energy obtained from photovoltaic modules (PV). What is more, special attention was put on the obtained efficiency levels of the whole system as well as of its individual elements.

Apart from the start-up and determining the operational characteristics (U=f(I) and P=f(I)) of the hydrogen cell examined, the experiment was also focused on determining the efficiency. The efficiency η_1 means the efficiency of photovoltaic conversion of PV modules, η_2 – the efficiency of the process of electrolysis and of the hydrogen cell, and η_3 – the efficiency of the whole process including photovoltaic conversion, according to the following formulas:

$$\eta_1 = \frac{U_{PV} I_{PV}}{ES} 100 \ [\%] \tag{1}$$

$$\eta_2 = \frac{UI}{U_{PV} I_{PV}} 100 \ [\%] \tag{2}$$

$$\eta_3 = \frac{UI}{ES} 100 \ [\%] \tag{3}$$

where: U, I *[V, A]* – voltage and current of the loaded hydrogen cell, U_{PV}, I_{PV} *[V, A]* – voltage and current of the system of PV modules powering the electrolyser, E *[W/m^2]* – irradiance on the surface of PV modules, S *[m^2]* – the area of PV modules.

As a result of the measurements and calculations performed, the results summarized in table I were obtained.

TABLE I
MAXIMAL EFFICENCY LEVELS OBTAINED IN THE EXPERIMENT

η_1 [%]	η_2 [%]	η_3 [%]
4,11	32,40	0,13

IV. CONCLUSION

The results of the experiments make it possible to obtain practical knowledge on the nature of the process of electrolysis, the functioning of a hydrogen cell and the efficiency of the whole system as well as its individual components in the form of: photovoltaic modules, the electrolyser and the hydrogen cell working under load.

V. REFERENCES

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