Laboratory Equipment for Hydrogen Energy Education

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Abstract – **This paper is provided laboratory equipment for experimental work and student laboratory for the study of the production of hydrogen fuel cell type PEMFC.**

Keywords - **student laboratory, energy system, fuel cells.**

I. INTRODUCTION

One of the actual questions today is connected with increasing energy consumption. The nature sources exhaust, the average human life increases, the human population increases. In the front there is the question for environment population using conventional energy sources.

All this wants searching of new possibilities for energy production – more ecology friendly and more economically effective. One of the possibilities in this direction is using hydrogen as a pure fuel.

After burning of hydrogen there is no carbon dioxide (CO_2) or other toxic gases, the only product is water - Table I).

TABLE I
COMPARING CHARACTERISTICS OF AUTO CARS WITH PETROL ENGINES AND ENERGY SYSTEM WITH FUEL CELL

Energy consumption at v = 60 km/h, kWh/100km			
Fuel	Petrol		Hydrogen
	87,2		43,6
Waste products, g/km	CO	2,30	0
	C_nH_m	0,20	0
	NO_x	0,15	0
	CO_2	213,00	0
	H_2O	98,00	117,0

The program for changing of EC countries towards hydrogen energy includes the period 2000÷2050 years. Only in 2003 year 1 million euros are given for hydrogen projects and 1 million euros - for projects, connected with fuel cells. For period 2005÷2015 years - 2.8 billion euros will be invested. The number of the cars using hydrogen should be two million in 2020 year.

As mode of work and laboratory build models exists over 20 types of fuel cells. The most common classification is according to the type of the used electrolyte (membrane). If dictates the temperature range of the fuel cells as well. On this base there are two types of fuel cells – low temperature and high temperature.

Fuel cell is electrochemical current source, in wish there is direct conversion of the energy of the fuel and oxidizer, passing uninterruptible to the electrodes, into electrical energy (Fig. 1). In the two sides of the membrane powder like electrodes are deposited [1], [2]. The hydrogen comes to the anode and oxygen – to cathode. On every electrode different chemical reactions exist (Fig. 2).

In some fuel cells the electrodes are with catalyzer, usually platinum or other precious metals, stimulating dissociation. The anode and cathode are porous for free passing of hydrogen and oxygen.

The protons pass through the membrane, but the electrons are trapped from external circuit. From the cathode site protons and oxygen produce residual product – water, or clear water.

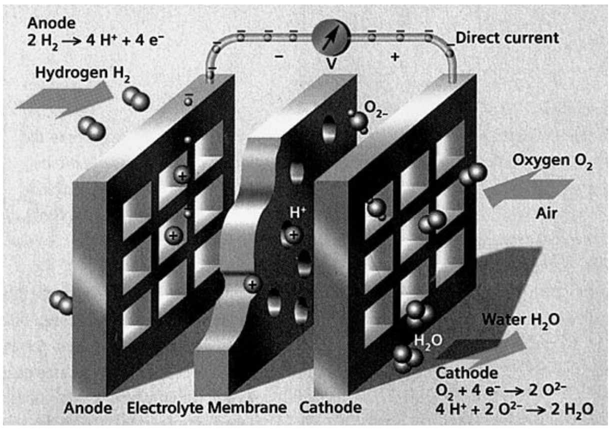

Fig. 1. Fuel cells with polymer electrolytic membrane (PEMFC)

As a difference from galvanic element and the battery, fuel cell do not use electrodes as a spending materials consummated. Hydrogen and oxygen enter in the time of work, but they not charge preliminary. They is way fuel cells can work long time (ten thousand hours).

The additional advantage of the fuel cell are low expense of active materials comparing with conventional electrochemical systems.

The energy from the chemical reaction converts directly in electrical, without forming other types of energy. In this way it could be obtained high values of the yield η -η_{max}=1-T($\Delta S/\Delta H$), where ΔH - enthalpy, ΔS – entropy [3].

For isotherm and reversible process not only chemical energy (-ΔH) convert in the electrical and in the same time the energy from environment heat- Q= T.ΔS, that in why the yield of such source can exceeds 100%.

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The real yield η of fuel cell is 40÷60%, under 100% in the same time the heat is produced and could be used. In fuel cell work used gas (H2, CO, hydrocarbons) and liquid (methanol, formaldehyde) fuels.

Accordingly, a sufficiently high speed can be oxidized only hydrogen in the special fuel cells - the carbon monoxide and methanol.

Fuel cells with polymer electrolytic membrane (PEMFC) effectively produce high density power. PEMFC usually work at low temperatures 60÷80°C, which gives possibility for quick start in comparison with more high-temperature cells [4].

In PEMFC there are not acids and alkalis, that is why for the body construction there is no need of expensive corrosion preventive materials. The sizes are small in the reason of high energy density of the membrane – up to $1A/cm^2$. This makes such type cells compact and suitable for the purpose of this laboratory work.

II. LABORATORY EQUIPMENT WITH POLYMER ELECTROLYTE FUEL CELL H- 20

For creating an educational module for laboratory classes the configuration is proposed, shown in Fig. 2.

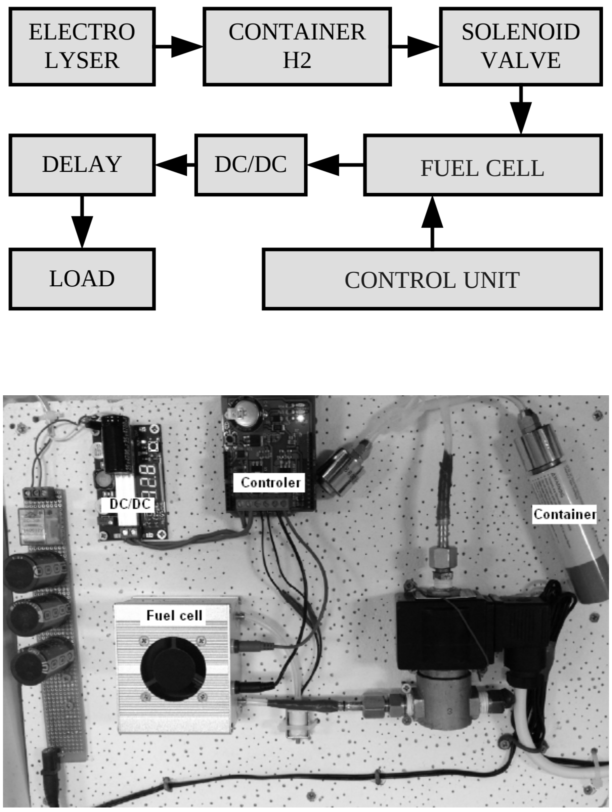

Fig. 2. Block diagram of laboratory equipment

The system uses electrolyser HYDROFILL-FCH-010- "Horizon Fuel Cell Technologies" for hydrogen production. It is a polymer electrolytic reversible fuel cell.

The produced hydrogen is stored in specially designed tanks HYDROSTIK PRO. The body is from aluminum alloy and inside there is an alloy from AB_2 group for hydrogen absorption. There alloys consist titanium, zirconium or hafnium as the base, and metal (nickel, chromium, vanadium) in the lattice structure. They have the possibility to absorb hydrogen, forming hydrides to full saturation, while the process structure expands and releases heat.

Ssolenoid valve is in the "normally open" and acts as a circuit breaker.

The fuel cell model H-12 (H-20) (FCS-B12) company "Horizon Fuel Cell Technologies" is the main component in the system, it is the source of energy. Furthermore, depending on the type of additional components, and how to configure the system.

Fuel cell is a module of the type of fuel cell PEMFC and contains 13 individual cells connected in series with a total capacity 20W.

Since the output voltage of the fuel cell is not stabilized, the system was added to DC/DC step-up converter (input voltage 3~35V, output DC voltage 3.5V~35V, Uout>Uin), has stabilized output adjustable output voltage with a potentiometer.

To disconnect the load from the system provided a scheme that is powered by a control voltage from the mains. The scheme has an adapter (9V, 500mA), relay with normally open and normally closed contact and a capacitor connected in parallel to delay the operation of the relay in case of voltage drop.

To make the scheme energy undependable it uses normally closed contact for closing the circuit, i.e. the load will switch the system on loss of control power.

Since after completion of the power control relay must delay the involvement of the load is used in parallel capacitor 10000 μF, which will provide a delay of the order of 8-10 seconds , sufficient for the smooth start of the cell.

To achieve 20W power in this model fuel cell is better to use command system that will provide optimal working conditions. The main functions of the controller are:

- short circuit - to maintain normal operating mode at a higher consumption without disturbing the balance in the fuel cell required operating mode can be divided into cycles. Electrical terminals of the fuel cell should be given a short time X at the end of each cycle, then the beginning of the next cycle time Y. X and Y depend on the model and the nominal capacity of the stack. Fuel cell model H-12, X=100ms, Y=10s.
- purging the water vapor - implemented using attached to the fuel cell valve, which is controlled by the controller. Upon activation, the pressure in the fuel cell decline. Thus, the source of fresh hydrogen enters the exhaust gas with a small amount of water is discharged through the outlet. The valve is activated for the time X at the end of each cycle Y. For fuel cell H-12 (X=100ms, Y=25s) the load is adjustable with the possibility of change of power in the range 1-30 W.

III. Testing the Laboratory Equipment with Different Load

The work of the proposed equipment was tested using three different values of the consumer – 6, 12 and 20 W. The date obtained are:

- The change of voltage over the load and current through the load;
- The power of the system;
- The change of output voltage of the fuel cell (FC) before DC/DC converter and after that.

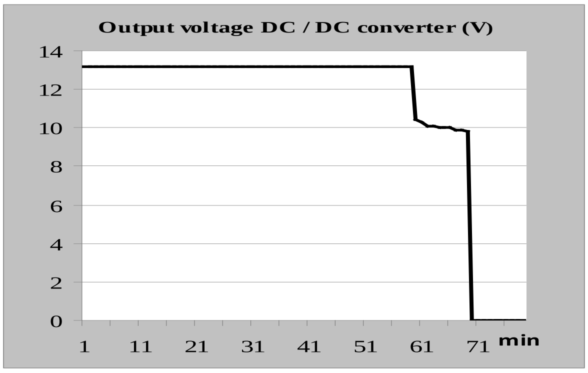

Fig. 3. Change the output voltage(V) DC/DC converter depending on the time

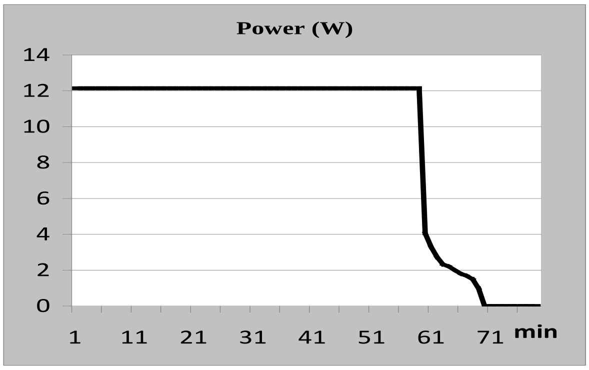

Fig. 4. Change the power (W) depending on the time

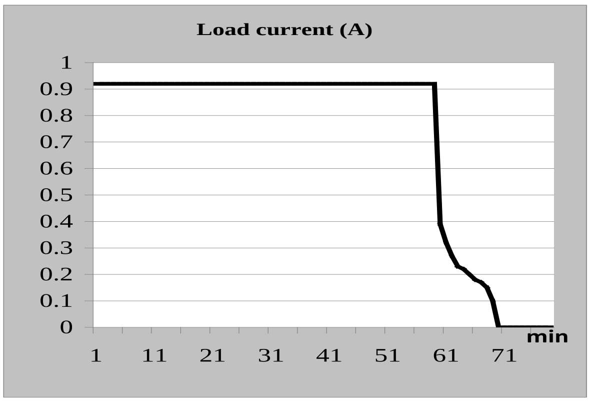

Fig. 5. Change the load current (A) depending on the time

The results obtained from testing the system in continues working cycle in load with power 12 W are shown on Figs. 3-6. The comparable dates for the results in testing the system with consumer power 6, 12 and 20 W are in Table II.

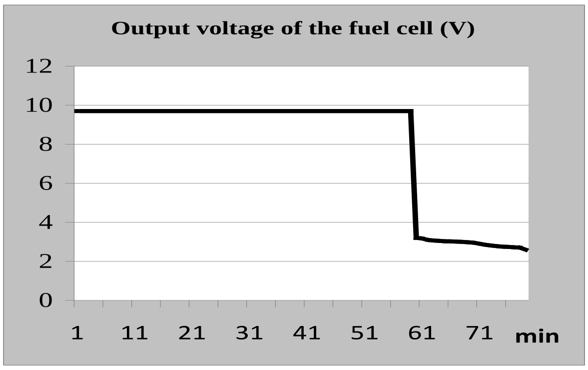

Fig. 6. Change the output voltage of FC depending on the time

TABLE II
TESTING THE SYSTEM WITH CONSUMER POWER 6, 12 AND 20 W

	Power of the consumer (W)		
	6	12	20
Work of nominal power (min)	97	59	26
Inom	0.45	0.92	0.79
Unom	9.9	9.7	9.1
E(Wh)	9.7	11.8	8.6

IV. Conclusion

On the base of the obtained results the next conclusions could be done:

- The work of the system with 12 W load gives the highest energy.
- As a variant for developing of the educational equipment it is supposed the connect the photo-voltaic panel into electrolyser and accumulating the energy – hydrogen in suitable for the purpose container.
- The next step is the system to supply energy saving LED illumination in the classroom.

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