Laboratory Equipment for Energy Accumulation from Renewable Sources

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Abstract – **The goal of this work is to analyse the system for energy production using renewable energy sources. One of the main aspects is education of students. The method of work is based on production of hydrogen, accumulation and reverse transformation using photovoltaic and fuel cell.**

Keywords – **Photovoltaic, Fuel cells, Hydrogen, Electrical energy, Renewable energy sources.**

I. INTRODUCTION

The supply of electrical energy for the users can be successfully realized with the complex use of the energy from renewable energy sources (RES) and energy accumulation. This gives additional possibilities for developing of renewable energetics, particularly – nuclear stations.

The accumulation of the energy is not a new idea in energetics. The fossil sources (petrol, coal, etc.) are effective accumulators with high density of energy. As a fact, of shortage of the traditional energy sources and increasing of their price it is necessary to reach other method for accumulation.

One of the methods is production and accumulation of renewable fuel. One variant is chemical accumulation. The energy could be stored in the chemical connection.

Hydrogen energy is one of the important directions in the developing of renewable energetics. The main priorities touch dissolving of problems connected with the use of hydrogen as a energy carries and accumulators.

The hydrogen could be derived using hydrolyze of a water and as a gas could be kept, transported and used for energy. The only residual product of burning of hydrogen is water, there is no environment pollution.

The storage of hydrogen in big quantities is not easy process, even using high pressures and this requires significant volumes [1-5, 8].

Gas hydrogen is stored in balloons (in high pressure) and transported via pipes from special materials with high prices.

The direct used of hydrogen as a gas could be realized using hydrating process. Thus it could be stored for a long time and to be used in the traditional engines. In the last years there are intensive works on creating new materials for hydrogen storage.

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As a perspective method for storage of hydrogen, is its adsorption in hydride metals (up to 3%) and in inter metals (up to 5%).

Hydride metals are compounds, type Me-H. The energy of destruction of the connection for same metals is low and lots of them - Ni, Cr, Co, Ti are destructed in the temperature 150÷250 ^{0}C.

High accumulating capabilities have noble metals – Pt and Pd but they are very expensive.

The practical accumulating of the hydrogen have elements from IV period group, but lots of them (from Se to Ni) form hydrides with very low concentration of hydrogen.

The modern accumulating systems based on metals give possibility to keep the hydrogen as a hydride of the metal in the ratio 1:10 by weigh.

Good results is reached with MgH_2–0,07 kg H_2/1 kg metal [3].

TABLE I
MATERIALS FOR STORAGE OF HYDROGEN

Material	Composition	Working interval	
		T, ^oC	P, atm.
Metals	Mg	300-400	1-10
	V	0-200	1-200
	Ti	500-600	1-10
Alloys	Mg-Ni	250-400	1-10
	V-Cr-Mn	0-200	1-150
	Ti-Al-Ni	200-600	1-10

When store the hydrogen in a type of a hydride the volume of the systems decreases about three times compared with the volume of the balloon, transportation simplification and no expenses for liquefaction.

The best materials for use are low temperatures (working temperature: -20÷100 ^{0}C) hydride of intermetallic compounds as a type AB5 (A–La, Ce; B–Ni, Co, Fe, Cu, Mn, Al), AB2 (A–Ti, Zr; B–Mn, Cr, Fe, V), AB (A–Ti, Zr; B–Fe, Co) and compounds based on Vanadium which have high volume concentration of hydrogen, but not sufficient capacity as a mass (less than 3% mass.).

In Table I the data for same perspective materials are shown [6].

The base advantages of metal hydride systems are high volume density of hydrogen, good interval of working pressure and temperatures, possibility for regulation of pressure and speed of hydrogen derivation, high purity and etc.

Including in the energy system of hydrogen accumulators of energy (complex of electrolizer of water, contained for hydrogen and oxygen and accumulator for fuel cell) appears to be useful (Fig. 1).

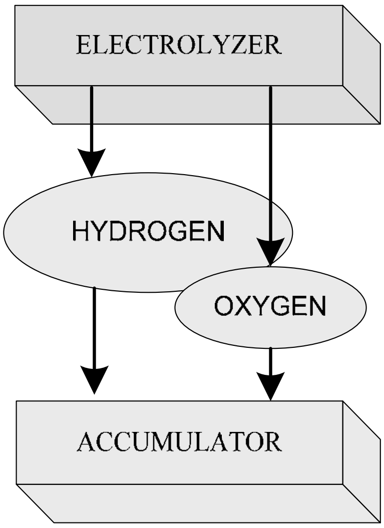

Fig. 1. Functional working diagram of fuel cells with reservoir, supplied by electrolizer.

Such technical decision will insure creating of equipment for long time keeping of energy practically without losses. This leads to additional decreasing of system price.

Using of fuel cells in energy systems increase working capability.

The fuel cells have low toxic, low noise, variety of fuel wide interval of power (Fig. 2).

Still now the price of the energy is very high and relative low resource. The best resource, have polymer materials as PEM FC - 2÷5000 h work.

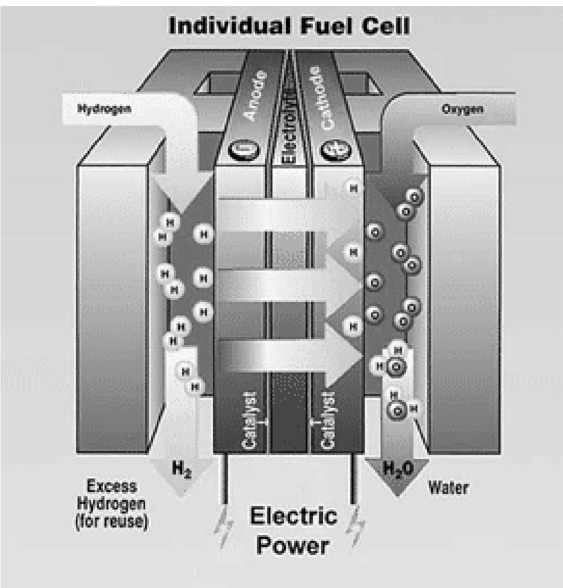

Fig. 2. Fuel cell.

The accumulating of energy with the use of hydrogen can be realized in energy system with renewable sources (wind, sun, hydro energy).

The technology for hydrogen production from primary sources includes the use of electrolyzing equipment []. The main work of such type systems is converting of electrical energy from renewable sources into chemical energy of hydrogen.

This energy can be used as a type of electrical or thermal energy depending on the need of the user.

The base element of the accumulating system is the equipment for hydrogen production. It is connected principally with the power of the renewable energy sources.

The use of the system electrolizer – fuel cell gives the possibility to realize significant accumulating effect.

The problem in RES is the fact, that energy production depends on the meteorology conditions and it could not be planed.

The fuel cell (FC) is a electrochemical energy current source, in which the direct transforming of energy from fuel and oxide.

This process is a result of uninterrupted supply of fuel to the electrodes (Fig. 2).

In hydrogen fuel cell the distribution is as follows: hydrogen to anode, oxygen to cathode.

Fuel cell with proto reaction, rapidly reach to the maximum working power and they generate current with high density – $2A/cm^2$.

They have high dynamic range – after turning on FC immediately come in the nominal power from several microwatts to hundred wats.

II. Investigation the possibilities for hydrogen production using PV-energy

1.1. Experimental equipment.

The investigation of the possibilities for accumulating an energy using system electrolizer – fuel cell was done in the laboratory of Faculty of computer science and engineering, Burgas Free University (BFU).

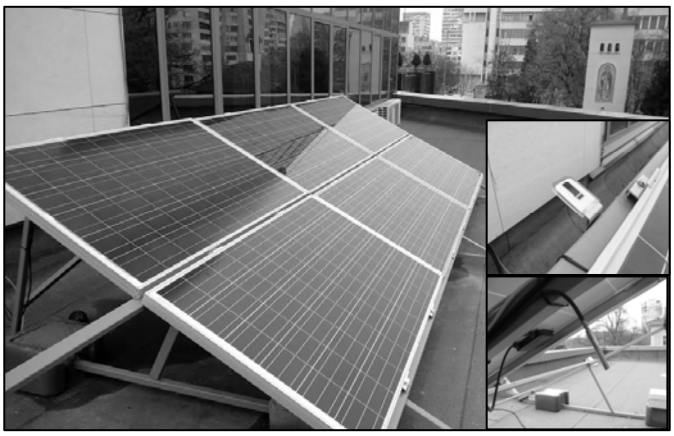

Fig. 3. PV-central on the roof of BFU.

This laboratory has different equipment as follows:

- PV-central (Fig. 3), mounted in the roof of the university with six photovoltaic panels and total installed power 1428 Wp (6x238 Wp).
  The roof space gives the possibility 50 PV-panels to be installed. The central can work in two modes: as a direct sublayer of electricity for the needs of BFU building or for hydrogen production;
- Meteostation - BFU-METEO, system for monitoring the parameters of sun radiation, temperature, wind in real time [7].
  The system has possibilities for writing, storage and analyzing of data received from the sensors.
  The diagrams and graphs are used; file exportation of data for the concrete period of time is supported.
- Electrolizer – model HYDROFILL-FCH-010 from the company "Horizon Fuel Cell Technologies". It is polymer electrolyte fuel cell with reverse action [9-11].
  The produced hydrogen is kept in special reservoir–cylinders from alloy type AB2 for hydrogen absorption.
  Represent a group of AB2 alloys containing titanium, zirconium or hafnium as a base and a metal (nickel, chromium, vanadium) in the lattice structure. Has the ability to absorb hydrogen to form hydrides full and saturation. The internal pressure of fully loaded cartridge remains 30 Bar (435 pounds per square inch-PSI).
  The electolizer is supplied from PV, then the system is fully autonomous.
- Fuel cell, model H-12 (H-20) (FCS-B12) from the company "Horizon Fuel Cell Technologies".
  It is a module of fuel cells type PEM FC and includes thirteen serial connected single cells with total power 20 W [9].

1.2. Investigation the yield of hydrogen using electrical energy from PV central.

With the help of meteostation BSU-MS the experimental data for sun radiation for seven months were received (Table 2).

TABLE II
MONTHLY VALUES OF SUN RADIATION

Sun radiation (kWh/m^2)	BFU-MS	PVGIS
August	187,15	211,73
September	135,17	163,8
October	84,62	123,38
November	36,43	82,5
December	36,31	59,52
January	63,85	66,34
February	75,65	82,04

The data were compared with the information automated system PVGIS gives for a point with geographical coordinates of Burgas Free University.

On the base of received data for the intensity and duration of sun radiation in the time of investigated period the theoretical values of generated energy were determined.

On Fig. 4 the radiation data for chosen day with the biggest intensity (19 august) are shown.

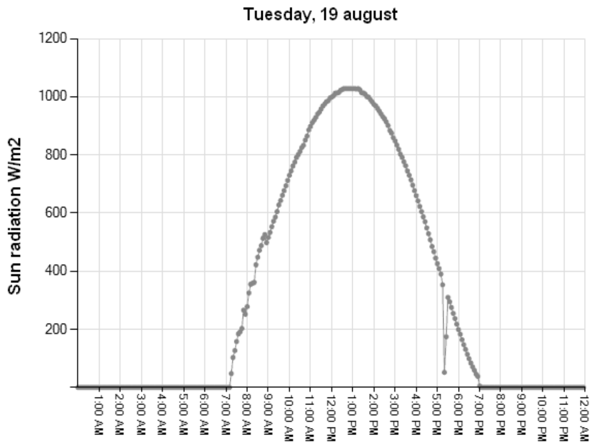

Fig. 4. The radiation data for chosen day with the biggest intensity.

TABLE III
GENERATED ELECTRICAL ENERGY (KWH) PER MONTH

Month	Number of panels			
	1	6	10	50
August	22,271	133,625	222,709	1113,543
September	16,085	96,511	160,852	804,262
October	10,070	60,419	100,698	503,489
November	6,069	36,415	60,692	303,462
December	6,049	36,295	60,492	302,462
January	10,637	63,824	106,374	531,871
February	12,603	75,620	126,033	630,165

The quantity of the energy, which could be received from the panels was determined using Eq.1.

$$W = \left(k \times P_w \times N\right) / 1000 \quad (1)$$

Where:

- W – produced electrical energy (W/h);
- k – coefficient reading the power losses as a result for photovoltaic heating, as well as and angle change of sun beams dropping onto the photovoltaic during

the day. For winter months the value is 0,7; for summer the value is 0,5;

- Pw – power of the panel;
- N – number of panels.

The received results are shown in Table III.

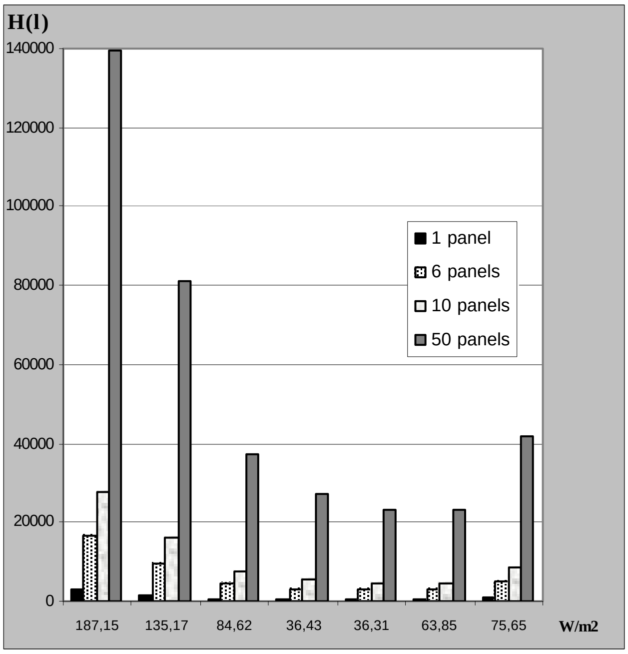

Fig.5. Data for hydrogen in liters, produced by different number PV panels depending on sun monthly radiation.

Theoretical calculation for quantity hydrogen, which can be produced using electrolizer were done.

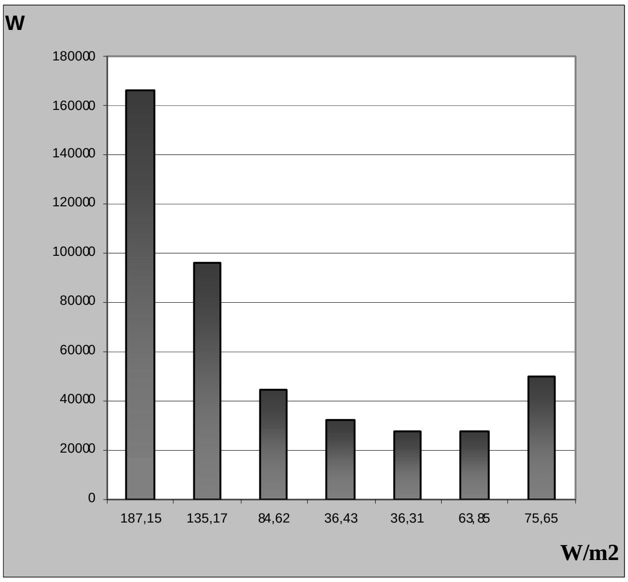

Fig. 6. Quantity electrical energy from the accumulated hydrogen.

The choice of the electrolizer power is in connection with the quantity electrical energy produced for one hour from PV.

The data for hydrogen which can be produced with different number of panels for months with experimental data for sun radiation are shown on Fig. 5.

The accumulated hydrogen could be used for production of electrical energy with the help of FC.

Data for quantity electrical energy which can be received from the accumulated hydrogen are shown on Fig. 6.

III. Conclusion

So proposed complex systems, is suitable for practical student (laboratory) classes.

It gives the possibility to follow and analyze a cycle of technological processes – production of electrical energy from renewable energy sources, accumulation and reverse converting in electrical.

The other advantage of the proposed system is the possibility the produced electrical energy to be used for the needs of university building.

Independently that the effectiveness of transformation hydrogen into electricity is not high, the received energy successfully could be used in emergency switch off of power supply – for supporting of servers, emergency light etc.

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