DOI: https://doi.org/10.15407/pmach2019.04.048

UDC 620.91, 536.24, 621.576.5

DEVELOPMENT OF A PERSPECTIVE METAL HYDRIDE ENERGY ACCUMULATION SYSTEM BASED ON FUEL CELLS FOR WIND ENERGETICS

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Hydrogen is one of the most energy-intensive and environmentally friendly energy carriers, which is why its use for the operation of fuel cells (FCs) makes it possible to create efficient autonomous energy supply systems. Power plants based on fuel cells are characterized by high efficiency and environmental safety. Of particular interest are power plants based on low-temperature alkaline FCs with a capacity of 1 to 20 kW, because they can be widely used as autonomous power sources for residential consumers. The location of such autonomous installations is assumed to be in close proximity to the energy consumer, which requires that fuel supply systems be highly safe, reliable and environmentally friendly. These requirements are met by hydrogen storage systems based on reversible metal hydrides (MH), capable of absorbing and releasing hydrogen. One of the main components of an autonomous energy supply system is a multiple-action hydrogen metal hydride storage battery. For the efficiency of the "FC - MH hydrogen storage" system, it is necessary to develop a methodology for determining its main technical characteristics both at the stage of creation and in the process of studying these characteristics. The article presents the developed scheme of a wind power plant with a hydrogen energy storage battery, solves the problem of selecting the FC, and analyses the operation of the fuel cell with the MH hydrogen storage system. The results obtained allowed us to determine the pattern between the amount of heat taken from the FC for hydrogen desorption with its subsequent use to increase the power of the FC, and ensure the characteristics of the consumer network. It is shown that the use of an integrated approach to the study of a perspective scheme of accumulation and use of wind energy will solve the problem of smoothing the irregularity of energy supply from renewable sources.

Keywords: *fuel cells, metal hydride hydrogen storage battery, energy supply.*

Introduction

Since hydrogen is an energy-intensive, environmentally friendly, and technologically flexible energy carrier, its use in fuel cells (FC) makes it possible to create efficient autonomous energy supply systems. Power plants based on FCs are characterized by high efficiency and environmental safety [1–3]. Of particular interest are power plants based on low-temperature alkaline FCs, because these cells are the cheapest in production, and the catalyst on electrodes can be any substance that is cheaper than substances used in the other FCs as catalysts. In addition, alkaline FCs operate at a relatively low temperature, are characterized by high efficiency, noiseless operation, high energy density, specific productivity, and environmental cleanliness.

Power plants based on 1 to 20 kW FCs can be widely used as sources of autonomous and uninterrupted power for such consumers as telecommunication centers, centers of various companies. The location of autonomous installations with a capacity of up to 20 kW is assumed to be in close proximity to the energy consumer, which requires that fuel supply systems be highly safe, reliable, and environmentally friendly.

These requirements are met by hydrogen storage systems based on reversible metal hydrides (MH) capable of absorbing and releasing hydrogen. In these systems, hydrogen is absorbed by MHs during heat removal, and is released during heating, with a rather strong hydrogen equilibrium pressure dependence on temperature arising as a result of a significant thermal effect of the reaction. For low-temperature systems, this pressure changes to values of the order of 10 atm at temperatures from 20 to 80–90 °C, which makes it possible to carry out hydrogen absorption and release processes thanks to the hot and cold water available in the energy supply system, and perform natural compression of gaseous hydrogen with using low-temperature heat.

Problem Formulation

One of the main components of an autonomous energy supply system is a multiple-action metal hydride hydrogen storage battery with a high volumetric hydrogen content (higher than in a cryogenic liquefied state), a wide range of operating pressures and temperatures, pressure constancy during hydrogenation-dehydrogenation, the ability to control the pressure and rate of hydrogen release at different temperatures. Metal hydride hydrogen storage batteries are simple, reliable, safe in operation, noiseless, compact, and emit high-purity hydrogen [4–6].

In order to ensure the efficiency of an "FC – metal hydride hydrogen storage" system, it is necessary to develop a methodology for determining its main technical characteristics both at the stage of its creation and in the process of studying these characteristics. In this regard, the main objectives of the study are to develop a technological scheme of a metal hydride energy supply system based on FCs, select the FC and analyze its operation with a metal hydride hydrogen storage system.

Research Results

To study metal hydride technologies for the accumulation and storage of hydrogen in alkaline FC, a wind power plant scheme was developed (Fig. 1).

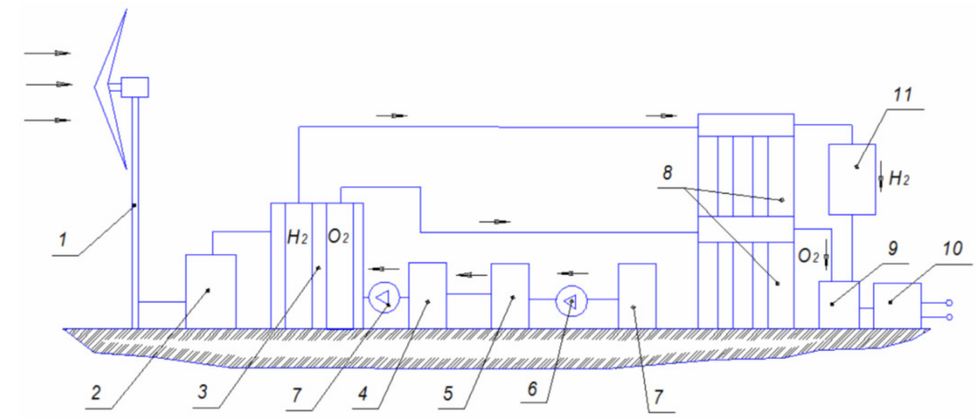

Fig. 1. Scheme of a wind power plant with a hydrogen energy storage system:
1 – wind generator; 2 – control system; 3 – high pressure electrolyzer; 4 – desalinated water tank; 5 – desalination unit; 6 – pumps; 7 – industrial water tank; 8 – balloon gas storage system (H2, O2); 9 – fuel cell module; 10 – inverter; 11 – metal hydride hydrogen storage battery

During the operation of the wind generator, the generated electric energy of the order of 5 kWh, via the control system, is supplied to the high pressure electrolizer. For the operation of the electrolyzer, technological equipment is used, ensuring its continuous and stable operation. In the process of electrochemical decomposition of a liquid alkaline electrolyte, the obtained oxygen and hydrogen are released into the balloon gas storage system whose gases are used to operate the fuel cell module. To convert the resulting constant potential pressure into the variable one, the inverter is used. Then, the converted energy is supplied to the consumer. In the case when the wind generator power is excessive, hydrogen accumulates both in the metal hydride accumulator and gas-balloon storage system.

Thus, wind energy accumulates for subsequent autonomous power supply to consumers. In the case of peak loads (morning and evening time), as well as a sharp enduring decrease in wind velocity, the hydrogen and oxygen from the storage system are spent on extra electricity generation with using an alkaline FC module [7, 8].

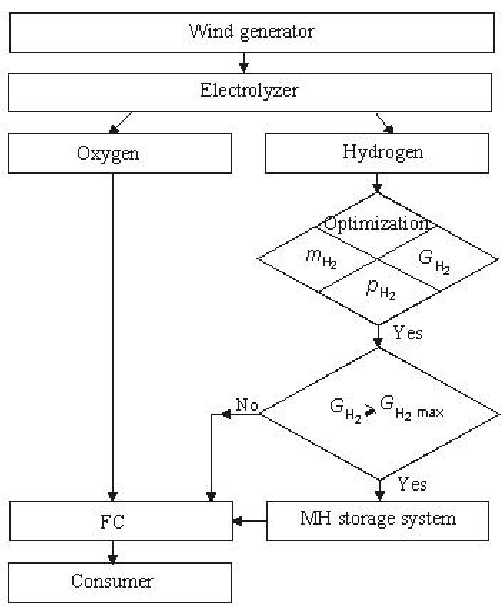

Fig. 2. General scheme of conducting computational studies of an autonomous energy supply system

To carry out computational studies of an autonomous energy supply system, Fig. 2 presents the structure and main stages of its operation.

An important stage in the design of these systems is the determination of hydrogen consumption to provide fuel for FCs. The working material for metal hydride hydrogen storage is LaNi5 whose advantage is low sensitivity to oxygen and moisture impurities, which makes it possible to use either technical or electrolytic hydrogen.

For a wind power plant with a capacity of 5 kWh and a hydrogen flow rate of 1.28 m3/h, we considered and analyzed the alkaline fuel cells presented in the table.

Basic technical characteristics of alkaline FCs [9]

FC	FC capacity, kWh	H_2 pressure, bar	H_2 flux, l/min	H_2 purity requirement, %	Operation time, min.
Dantherm Power DBX 2000	1.676	5.00	25.0	99.95	213
ReliOn E2500	2.500	0.55–0.83	30.0	99.95	180
Dantherm Power DBX 5000	5.000	5.00	72.5	99.95	73

As a result, the ReliOn E2500 FC with a power of 2.5 kWh was selected as providing the specified characteristics of the wind power plant with the hydrogen energy storage system. For the selected FC, the influence of the temperature difference between the temperature of the coolant and environment, ΔT, on the change in both the amount of hydrogen entering the FC (Fig. 3) and its power (Fig. 4) was studied.

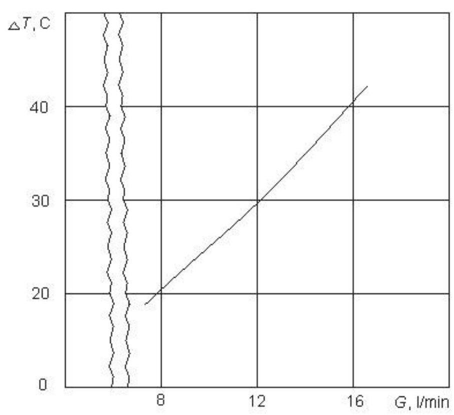

Fig. 3. Influence of the temperature difference between the coolant and environment on hydrogen consumption

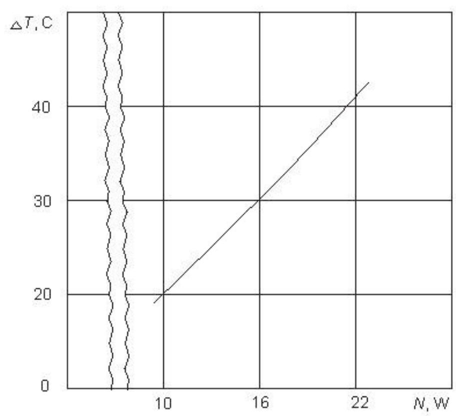

Fig. 4. Influence of the temperature difference between the coolant and environment on FC capacity

The results obtained allowed us to determine the pattern between the amount of heat taken from the FC for hydrogen desorption with its subsequent use to increase the power of the FC, and ensure the characteristics of the consumer network.

Conclusions

A FC was selected for an autonomous energy supply system, and a thermodynamic analysis of the integrated "FC – metal hydride hydrogen storage" system was carried out. It is shown that the use of an integrated approach to study a perspective scheme of accumulation and use of wind energy will solve the problem of smoothing the irregularity of energy supply from renewable sources, and the use of original electrolysis technology as part of a wind energy complex provides the following advantages:

– reduction in energy consumption in the production of target products by 10-15% compared with the existing analogues (specific energy consumption is 3.8–4.1 kWh when 1 m^3 of hydrogen and 0.5 m^3 of oxygen are generated);

– generation of gases with the pressure limited only by the strength of the design of structural components of the electrolyzer;

– increase in the reliability and safety of the system operation in the absence of dividing membranes;

– reduction in the cost of the main equipment due to the fact that rare-earth and platinum group metals are not used in the high-pressure hydrogen and oxygen electrochemical generator, which increases its competitiveness in the market of hydrogen-oriented equipment.

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Received 13 November 2019

Розробка перспективної металогідридної системи енергоакумулювання на базі паливних комірок для вітрової енергетики

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Водень є одним з найбільш енергоємних і екологічно чистих енергоносіїв, тому його використання для роботи паливних комірок (ПК) дозволяє створювати ефективні системи автономного енергозабезпечення. Енергоустановки на базі ПК характеризуються високим коефіцієнтом корисної дії та екологічною безпекою. Особливий інтерес становлять енергоустановки на основі низькотемпературних лужних ПК потужністю від 1 до 20 кВт, які можуть знайти широке застосування як джерела автономного живлення для споживачів комунально-житлового сектора. Розміщення таких автономних установок передбачається в безпосередній близькості від споживача енергії, що вимагає від систем паливозабезпечення високого рівня безпеки, надійності та екологічності. Цим вимогам відповідають системи зберігання водню на основі обернених металогідридів (МГ), здатних поглинати і виділяти водень. Одним з основних компонентів автономної системи енергозабезпечення є металогідридний акумулятор водню багаторазової дії. З метою забезпечення ефективності роботи системи «паливна комірка – металогідридний акумулятор водню» необхідно розробити методику визначення основних її технічних характеристик ще на етапі створення і в процесі дослідження цих характеристик. У зв'язку з цим основними задачами дослідження є розробка *технологічної схеми металогідридної системи енергозабезпечення на базі паливних комірок, вибір ПК і проведення аналізу їх роботи з металогідридною системою акумулювання водню. На основі системного аналізу запропонованого варіанта технічної схеми отримано результати, які дозволили визначити закономірність між кількістю відібраного тепла від ПК під час десорбції водню з подальшим його використанням для збільшення потужності паливної комірки і забезпечення пропускної здатності мережі споживача. Визначено, що застосування комплексного підходу до вивчення перспективної схеми акумулювання і використання енергії вітру дозволить вирішити проблему згладжування нерівномірності надходження енергії від поновлюваних джерел, а використання в складі вітроенергетичного комплексу оригінальної електролізної технології підвищує її конкурентоспроможність на ринку технічних засобів, орієнтованих на отримання водню.*

Ключові слова: *паливні комірки, металогідридний акумулятор водню, енергозабезпечення.*

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