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New Opportunities for the Development of Power Supplies for Autonomous Fuel Cell Based Radio Repeaters

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Abstract

The main characteristic of autonomous power systems of radio repeaters is the duration of uninterrupted operation without maintenance. In existing schemes, autonomy is ensured by the use of solar panels, wind generators and batteries or diesel-generators. However, both batteries and diesel-generators in real practice suffer from many shortcomings and their use for autonomous operation is coupled with significant risks. Instead, they began to develop power supply devices for fuel cells. Typical fuel cells are significantly more expensive. But in recent years, solutions have appeared that lower cost, higher efficiency and, compared with diesel generators, greater fuel efficiency. The article describes these new installations and compares their main characteristics.

Keywords: radio repeater, fuel cell, diesel-generators, autonomous, telecommunications, PEMFC, SOFC

I. Introduction

Fuel cells (FC) have significant advantages compared to all other energy technologies: environmental friendliness, noiselessness, high efficiency. Their main disadvantage is the high cost. However, in recent years, the production of fuel cells continues to grow. In 2017 fuel cells generated 30% more energy and produced almost 10,000 more than in 2016 [1]. From 2013 to 2018, the stationary systems sales sector for fuel and energy plants grew 22-fold from $ 1.4 billion to $ 30 billion [2].

Fuel cells for telecommunications are also attracting more and more investments. But the telecommunications market, according to experts, is tough, with conservative buyers who need to be convinced of the advantages of fuel cells [1]. To prove the advantages of fuel cells, it is enough to provide specific data on the duration of battery life. So, in FC the Efoy Pro 12000 Duo used in telecommunications, with an output power of 500W from SFC Energy AG (Germany), two 28-liter fuel cartridges with methanol-alcohol can autonomously supply a device with a power of 25 W for about 15 weeks. The EFOY Pro FC series constantly monitors the state of charge of the battery and automatically charges it. At the same time, diesel-generators can provide only up to 2 weeks of battery life [3].

However, until recently, the price was a deterrent to the large-scale development of fuel cells. The price depends on the type of fuel cell. There are two of the most promising types: PEMFC – Proton-exchange membrane fuel cells and SOFC – Solid-oxide fuel cells. The current average cost per kilowatt of installed capacity is approximately $ 500 for PEMFC [4] and $ 2000 for SOFC [5] and depends on production volumes and plant capacity. At the same time, recent studies open up completely new prospects for the use of fuel cells, both broadly and for telecommunications.

II. Fuel Cell Efficiency Studies In Autonomous Installations For Powering Radio Transmitters

The first experiments on modeling competitiveness and experimental verification of the feasibility of using FCs in remote maintenance-free transmitters were performed in the early 2000s. In 2003, the NREL National Renewable Energy Laboratory (USA) stated that "Recent advances in hydrogen fuel cell and internal combustion engine technologies have allowed the creation of new technologies for delivering electricity to remote, autonomous regions". A

NREL study analyzed the competitiveness of hydrogen FCs compared to the two options. The first is a combination of a photovoltaic and a battery operating on a 350 W transmitter in Oregon, and the second - two 50 kW wind turbines and a battery to complement diesel-generators in Alaska [6].

It turned out that the economically optimal configuration for the radio repeater in this case is the system "PV (photovoltaic battery) – wind – fuel cell – battery". When using inexpensive lead-acid batteries, fuel cells can be competitive with a cost reduction of 25%. For a system with a wind – diesel-battery, fuel cells become competitive while reducing their cost by 40% [6].

Two years earlier, specialists at Humboldt State University (Germany) completed the practical development of an autonomous telecommunications station in Redwood National Park (USA), where the important requirements were the absence of noise and polluting emissions [7–9]. This was the first longest PEMFC FC field test. The experience gained has shown that PEMFCs are a viable alternative to diesel- generators as autonomous standby power for photovoltaic panels without on-site monitoring in specialized applications, such as a telecommunication installation in a park [9].

Subsequently, the efforts of the researchers were aimed at choosing the best configuration of a hybrid power system with the inclusion of fuel cells for powering autonomous telecommunication stations in various climatic conditions. So, one of these works was carried out in 2013 in Nepal, where there was a shortage of wind resources. In this case, the preferred structure of the power system was the following: PV – Fuel Cell – Electrolyser – Battery [10].

III. Ready-Made Commercial Products

In parallel with the beginning of the intensification of work on fuel cells, in 2000 the German company SFC Smart Fuel Cell (the original name, later – SFC Energy AG) was created with the aim of production and distribution of PEMFC fuel cells on methanol. In September 2008, SFC launched its EFOY Pro FC series for professional users and demanding industry applications, primarily telecommunications.

The most powerful product, the Efoy Pro 12000 Duo with 500W FC, was launched in November 2015 (Fig. 1). This fuel cell, if necessary, charges the battery fully automatically, then turns off again – without maintenance and user intervention. Using the principle of modular construction, an increase in power is possible.

Fig. 1. Efoy Pro 12000 Duo, 500W fuel cell for telecommunications applications (photo from SFC Energy AG [11])

Efoy's fuel cells are based on DMFC (Direct Methanol Fuel Cell) technology. They generate energy in a methanol fuel cartridge using oxygen from the air. During the operation of the fuel cell, waste heat and water vapor with a small amount of carbon dioxide are created.

The market success of SFC Energy AG was determined, first of all, by its own patented technological developments. In addition, the choice of fuel also affected. Used methanol is half the price of diesel fuel, convenient in operation, and has a high energy density. Ten liters of methanol contain 11.1 kWh of energy. Four 28 liter tanks provide about 30 weeks of operation on a 25 W device [11].

Despite the many advantages of Efoy Pro products, it cannot be argued that they are a complete replacement for diesel-generators due to low power. Large capacities can be achieved using pure hydrogen as fuel for PEMFC type fuel cells. But the use of pure hydrogen leads to a rise in the cost of telecommunication systems.

In addition to cheap methanol, other fuels were also considered, as well as the use of SOFC technology.

The first SOFC technology project for autonomous work in telecommunication applications was completed in June 2018 by the Israeli company GenCell Energy. Product GenCell A5 (Fig. 2) has been selected for installation at 800 telecommunications stations in Kenya to replace diesel generators. According to reports, its use over the course of 10 years may result in savings on operating expenses of $84 million [12].

Fig. 2. GenCell A5 fuel cell generator From GenCell Energy [13]

Ammonia (NH3) was used as fuel. Its cost is half the cost of diesel fuel.

In order to make such a solution possible, GenCell Energy has developed and patented a number of technologies to reduce capital investments and operating costs. Among these technologies are the use of a non-platinum catalyst, the mechanisms for using ambient air as an oxidizing agent, and anhydrous liquid ammonia. An ammonia tank of 12 tons is sufficient for uninterrupted operation of a 4 kW fuel cell during 24/7 mode. Remote control of fuel cells is optional, but possible using special software [13].

Solution A5 includes 4 key components: 1) ammonia cracker, 2) 4 kW fuel cell generator (see Fig. 2), 3) an energy bridge to adjust the output power, and finally 4) a unit for using the generated heat to dissipate the excess

temperature. Together with the container, the weight of the installation is 3000 kg. Maximum fuel consumption – 2.5 kg/h [13].

Next, for comparison, we present the completed development with a fuel cell for hydrogen telecommunications. The ReliOn E 2500 module with a power of 2500 W for backup power was developed by the Russian company SvyazKomplekt.

The company was founded in 1996 and is a supplier of telecommunication equipment of a wide profile. The E-2500 module is compact and allows you to expand the system to achieve the required power.

The module weighs 51.4 kg, fuel consumption is 30 l/min, the duration of operation on one hydrogen balloon with a capacity of 40 l is approximately 3 hours (Fig. 3) [14].

Fig. 3. ReliOn E 2500 module from SvyazKomplekt company [14].

IV. Unique fuel cell designs for energy purposes

Among the developments of fuel cells for energy purposes, there are installations that, by their characteristics, allow the use of also for autonomous operation of radio repeater.

One of these FCs was developed by the German company Eberspächer. The device is compact, designed to provide auxiliary power to large trucks (Fig. 4).

Fig. 4. Auxiliary power supply for large fuel cell trucks SOFC from Eberspächer [15].

The fuel used is diesel, which is used to fuel the truck. Maximum output power 3 kW, efficiency – up to 40%. The electronic control system automatically adjusts the performance of the installation, limiting the generation of electricity in cases where maximum consumption is not required. As a result, fuel is consumed 50% less [15]; harmful emissions are 90% less than in a traditional diesel-generator. Achieving the unique characteristics of the installation was made possible thanks to the key know-how of the company [16]. The first demonstration of the device took place at the automobile exhibition in Hanover in 2014 [17]. In reports on this development, it is indicated that it can easily be used as a mini-power station for a private house or farm. Obviously, for stand-alone radios it may be too.

Another unique project was proposed by Alexander Lipilin, an employee of the Institute of Electrophysics, Urals Division of the Russian Academy of Sciences (IEP UrD RAS) (Russia). He developed a modified solid oxide fuel cell (SOFC). A key innovation of the invention is in the comb design (Fig. 5).

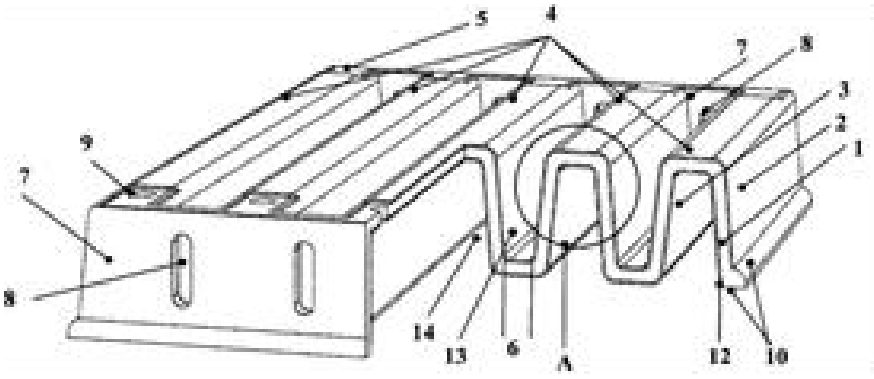

Fig. 5. Scheme of the modified planar fuel cell of A. Lipilin (Fig. from patent - [18]).

Thanks to this solution, the efficiency of fuel cells is significantly increased [18]. Another innovation is the composition of solid electrolyte, the essence of which is reflected in the collective patent of the IEP UrD RAS [19]. The characteristics of this fuel cell exceed, as stated in the description of the project based on it, all existing analogues [20].

FCs using this technology are characterized by high compactness and specific power. With a battery size of SOFC cells of 1 dm3, the power reaches 20 kW, the device's capacity of 1 m3 can be 20 MW. The fuel consumption in SOFC according to this technology for the generation of 1 kW/h of electricity is 3 times lower than that of diesel generators, due to a higher efficiency of 70%. The installation cost – many times less than the traditional SOFC

FC – up to $ 500 per 1 kW of electricity. These fuel cells are characterized by high environmental friendliness and noiselessness. Any hydrocarbons can be used as fuel, including the most economical ones, such as oil and gas waste. The life of these fuel cells is more than 10 years [20].

The main problem of SOFC FCs is the high temperature, about 800 ℃. Redox Power Systems LLC, in collaboration with scientists from the University of Maryland (USA), after extensive research [21], managed to lower the temperature to 650 ℃. Moreover, in the future, the company intends to achieve a further decrease in temperature of less than 500 ℃. The power plant developed at the SOFC FC has a power of 25 kW with a volume of about 1 m3. However, fuel consumption (natural gas) is very intense – 75 l/min. [22]. Such fuel consumption for stand-alone installations is hardly acceptable. However, the advent of temperature reduction technology creates new opportunities for SOFC FC technology in general.

V. Conclusion

Thus, technical solutions to replace diesel-generators with fuel cells in stand-alone radios are already available. Only investment activity is lacking. Affirmations that diesel-generators are currently unrivaled technology are currently untrue. Due to the emergence of the possibilities of using cheap hydrogen-containing fuels, the gap in functionality between the fuel cells for backup operation in the "PV – wind generator – FC" systems and truly autonomous power sources on fuel cells without a combination with renewable energy sources is widening.

New fuel cells used in autonomous radio relay systems are able to independently operate without mandatory maintenance from several months to one year.

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