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Hydrogen economy and the prospects of its development

The paper studies the problems of conventional power engineering and the prospects of its development related to the use of hydrogen as energy carrier. The role of hydrogen economy and power supply systems on the basis of hydrogen fuel cells in the context of Russian power engineering has been specified. The promising use of fuel cells as alternative sources of electric energy in power supply systems has been described. The proposals for improvement of strategic hydrogen economy management and implementation of the tools for public stimulation of the use of hydrogen fuel and fuel cells to supply consumers in various industries and major sectors have been developed.

Keywords: *alternative energy, greenhouse gas emissions, hydrogen, hydrogen economy, hydrogen fuel, hydrogen fuel cells, tools for public stimulation.*

NOMENCLATURE

FC	Fuel cell
FEC	Fuel and energy complex
GDP	Gross domestic product
NHEA	National Hydrogen Energy Association
MPEI	National Research University «Moscow Power Engineering Institute»
PGS	Power generation system
RES	Renewable energy sources
SAPE	Small alternative power engineering

1. Introduction

Today, reliability improvement of industrial complexes and geographically distributed consumers complying with requirements of regularity and environmental safety of electric energy production processes and transportation is a crucial task of the development of Russian industry and social service.

It is not always possible to meet the required performance and reliability goals of power supply under energy consumption growth conditions due to substantial depreciation of production capital funds of energy systems, 65% on average (50% is for power grid, 65–70% is for generation; and up to 70% is for power grid distribution system). This results in increase in the number of emergency situations as well as in decline in energy and ecological efficiency along with the reliability of power and other energy sources supply chains. For example, fractional power loss during electric energy transmission through Russian power grid is 13–15%, while in the opinion of international experts the loss factor of 4–5% and less is considered to be satisfactory [1]. These features of conventional power engineering reduce the competitiveness of Russian industry and generate a need for reducing oil, natural gas and coal consumption as well as for switching to environmentally safe, cost effective and reliable energy sources [2].

In recent years alternative energy has become a promising development trend of electric energy systems, which allows solving the problem of reliable power supply. The issues of environmental protection and improvement in power supply of industrial enterprises and social facilities as well as the necessity for developing international cooperation in expansion of innovative technologies have been reflected in the State Program of RF «Energy Efficiency and Energy Sector Development», approved by Russian Government in April, 2014. The program has set the target of increase in electric energy production on the basis of renewable energy sources (RES) up to 4.5% by 2020. And hydrogen fuel is something special among renewable energy sources.

2. Theoretical study

Hydrogen is an environmentally friendly energy source, and nature reserves of hydrogen are practically inexhaustible. The increased use of RES, hydrogen fuel cells (FC) and nuclear power systems is considered in the project of Russian Federal Hydrogen Energy Program by 2050 as a factor in the balanced socio-economic development of the country [3]. The expanded use of hydrogen fuel allows increasing the capability of small-scale power generation systems (PGS), located near electric energy consumers. According to the forecasts of the

[1] Mikhailov S. A. the Strategic management of energy saving in industry. – M.: Finance and statistics, 2010.

[2] The government of the Russian Federation from December, 27th, 2010 № 2446-p «On approval of the state program of the Russian Federation «energy Saving and energy efficiency for the period till 2020».

[3] Kuzyk B. N., Yakovets Yu. V. Russia: strategy of transition to hydrogen energy. M.: Institute for economic strategies, 2007.

scientists, hydrogen could be the major energy carrier in the nearest future [4]. This is due to the sustained decline in the cost of hydrogen with an increase in prices of conventional energy sources, as well as to hydrogen unique properties which determine hydrogen efficiency (hydrogen engine efficiency is 1.5–1.7 times higher than petrol engine) and environmental safety. Moreover, the concept of hydrogen production on the basis of RES is seemed to be economically attractive as energy produced here could be directly integrated into the existing power supply system. Plans have been made in this connection for the share of hydrogen fuel in energy consumption structure of Russia to be increased of 3% by 2020, of 10% by 2030 and of 25% by 2050. It is suggested thereupon, that relative saving of exhaustible energy sources and reducing of greenhouse gas emissions of 3% by 2020, of 10% by 2030 and of 25% by 2050, as well as the increase of the share of hydrogen economy in GDP average annual increase of 0.5% by 2020, of 10% by 2030 and of 20% by 2050 could be provided [5].

At the same time, there are some complexities related to the development of hydrogen economy, which are the following:

- hydrogen economy is considered for now as a means to improve energy efficiency of isolated facilities only, but not as an alternative to the conventional power engineering;
- hydrogen fuel market and hydrogen-fueled systems market haven't been developed yet;
- high prime cost of hydrogen economy, as hydrogen is a secondary energy carrier;
- there is no long term public program for the development of hydrogen economy in Russia.

Among hydrogen-fueled systems of small alternative power engineering (SAPE), FC and electrolyzers have been perfectly developed as alternative sources of electric energy at present. The major advantages of systems with hydrogen FC are the following: high efficiency, long term life cycle, ecological compatibility, high fire and explosion safety, as well as the capability to operate under the extreme conditions. The use of power supply systems on the basis of hydrogen FC has become quite a topical subject which meets specific requirements to the environmental safety of energy sources, considerable remoteness of the consumers from power grid, and insignificant amount of total energy consumption.

[4] Kuzyk B. N., Yakovets Yu. V. Russia: strategy of transition to hydrogen energy. – M.: Institute for economic strategies, 2007.

[5] Drozdova N. In. The mechanism of strategic management of small alternative energy based on fuel cells // Scientific notes of the Russian Academy of entrepreneurship. – 2013. – Vol. XXXVII. – P. 44–48.

Today, hydrogen fuel cell technologies have the following development trends: stationary electric power plant on FC for centralized and decentralized power supply, vehicle propulsion systems, mobile power supplies etc. The promising trend of FC application is its combined use with RES, for example, with photovoltaic panels or wind turbines, which could allow preventing atmospheric pollution completely. The content of the 3rd stage of transition of Russia to hydrogen economy is associated with hydrogen production using RES (as predicted, the share of RES in global electric energy production could be increased to 18–20% by 2020) and processed coal partially [6]. Hydrogen FC and RES values for modern power engineering could be defined as follows (Figure 1).

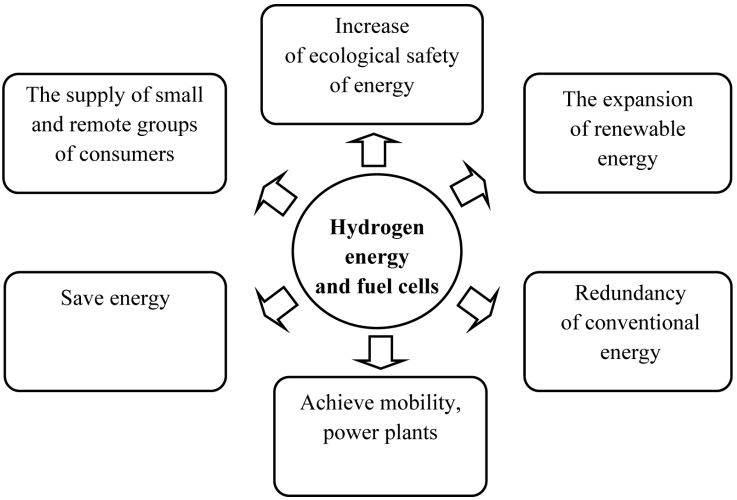

Figure1. The role of hydrogen economy and fuel cells in Russian power engineering

3. Problem statement

The analysis of research papers published by Russian and foreign scientists has shown that management tools for energy systems on the basis of SAPE systems don't consider the particular potentialities of the use of hydrogen fuel and hydrogen FC, which doesn't allow garnering complex effect (economic, social, ecological) of capital investment projects for implementation and use of RES [7].

[6] Kuzyk B.N., Yakovets Yu.V. Russia: strategy of transition to hydrogen energy. – M.: Institute for economic strategies, 2007.

[7] Mikhailov S.A. the Strategic management of energy saving in industry. – M.: Finance and statistics, 2010.

So, a shift would need to occur in the conventional energy mix intended to reduce above-standard energy losses and the consumption of oil and coal.

Hydrocarbon resources of modern power engineering amount to 90%. The development and widespread use of FC technologies may result in structural changes in power engineering, transport and other economic sectors. According to the long-term forecasts made by the experts at the Institute for Economic Strategies, Moscow, decentralized systems based on the use of hydrogen FC and solar energy converters mainly would supply most nearly 50% of market demand for electric energy including hydrogen FC share of 38% by the end of the 21st century [8]. Final consumption of energy sources would be represented mainly by electric energy and hydrogen which could be the major energy carrier and have 49% of market share. The development of FC technologies which could be used in industry, transport, and even in domestic use would promote the expected changes. However, current problems related to hydrogen transportation and storage [9] as well as to hydrogen infrastructure development should be solved in order that hydrogen economy and FC could be widely used, which is possible if the appropriate measures focused on stimulating the development of hydrogen economy as an autonomous branch of the national fuel and energy complex (FEC) [10] would be imposed by the government and business community. To accomplish this, the development of new national standards related to the use of hydrogen as fuel is required, which is described in the paper of A.Yu. Ramenskiy «Hydrogen as Fuel: Subject and the Objectives of Standardization» [11]. The concept of a Hydrogen Civilization of the future with a distinct program character developed by the National Hydrogen Energy Association (NHEA) could be also considered as a significant organizational prerequisite for ensuring hydrogen economy development. According to the concept, the humankind could avoid the environmental disaster and save the biosphere only by shifting from hydrogen energy to hydrogen economy and hydrogen civilization [12].

[8] Kuzyk B.N., Yakovets Yu.V. Russia: strategy of transition to hydrogen energy. – M.: Institute for economic strategies, 2007.

[9] Koroteev A.S. prospects of introduction of hydrogen in energy and transportation in Russia. The state and problems // Alternative energy and ecology. – 2006. – No. 7(39): p. 15.

[10] Kuzyk B.N., Yakovets Yu.V. Russia: strategy of transition to hydrogen energy. – M.: Institute for economic strategies, 2007.

[11] Ramenskaya, A. Yu., Hydrogen as fuel: the object and purpose of standardization // Alternative energy and ecology. – 2015. – No. (1): pp. 33–44.

[12] Goltsov V.A., T.N. Veziroglu, Goltsova L. F. the basics of the new concept of move about the hydrogen civilization of the future // Alternative energy and ecology. – 2006. – No. 5 (37): pp. 42 to 53.

4. Suggestions

The mentioned problems of conventional power engineering on the one hand, as well as the complexities and at the same time great opportunities of hydrogen economy on the other hand, are responsible for the urgency to develop proper tools for strategic management of power supply systems for industrial and domestic energy consumers, based on hydrogen fuel and hydrogen FC in particular. The development and implementation of effective strategies for the use of hydrogen FC to support power supply the continuity and the environmental safety for geographically-distributed consumers.

As the incentive mechanisms of hydrogen economy haven't ensured an adequate development yet, it is necessary to develop appropriate measures at the federal level. The prime tools which could be used in the interests of economic entities [13] are presented in Figure 2.

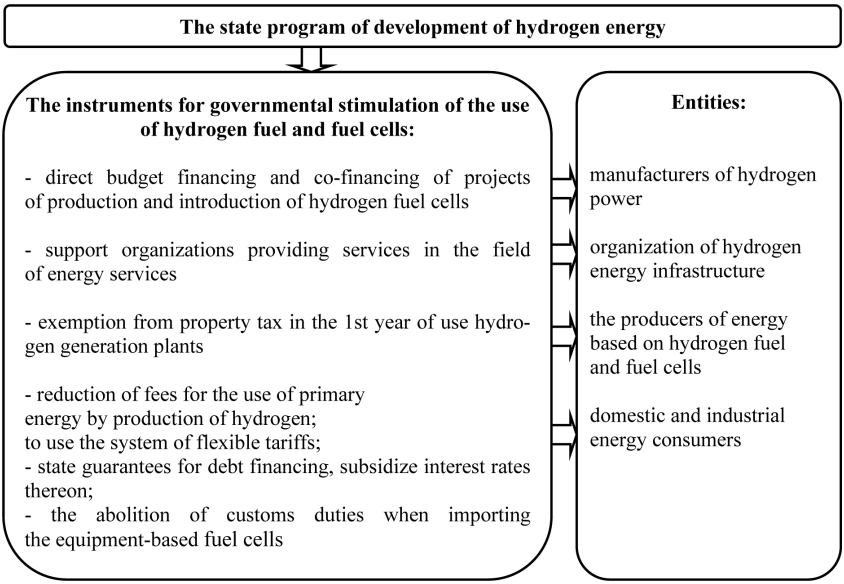

Figure 2. Tools for stimulating the development of hydrogen economy and FC

So, the system control of the use of hydrogen fuel intended to support economic interests of energy sources producers, consumers and the country overall, as well as to improve the environment. While managing the projects of

[13] Drozdova N. In. The mechanism of strategic management of small alternative energy based on fuel cells // scientific notes of the Russian Academy of entrepreneurship. – 2013. – Vol. XXXVII. – P. 44–48.

hydrogen economy development, it seems useful: to establish entities which could ensure complex service support for using FC technologies; to improve public and municipal programs for strategic development and hydrogen economy management as a significant branch of FEC.

Considering the abilities of hydrogen economy and FC in relation to the objectives and high priority tasks of socio-economic development of the regions, there could be possible the following electric energy system development strategies: improvement of energy system economic efficiency (high efficiency FC); reliable power supply (redundancy of conventional power plants by power plants which could operate totally independent of the kind of energy); environmental safety (replacement of conventional power plants which level of pollutant emissions is higher than the contamination standards by FC); energy saving (introduction of hydrogen power plants at the entities with the highest energy intensity); social responsibility (introduction of FC at the consumers including unprofitable).

5. Conclusion

Strategies and tools for hydrogen economy development should be reflected in proper public programs at the federal and regional levels and anchored within the regulatory and legal framework. This would allow implementing a comprehensive approach to managing innovation development of regional energy systems considering economic, ecological and social aspects of power engineering as well as the interests of various electric energy consumer groups.

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5. Koroteev A. S. prospects of introduction of hydrogen in energy and transportation in Russia. The state and problems // Alternative energy and ecology. – 2006. – No. 7(39): p. 15.
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