“The research and development of promising hydrogen technologies in the MPEI for the transition to a hydrogen economy in Russia”

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Today, the development and implementation of hydrogen technologies are one of the key areas of the energy and transport sectors modernization of industrialized countries, including Germany, Canada, the USA, Japan, the Republic of Korea, and China. The reason for this is the possibility of a significant reduction in emissions of harmful substances and greenhouse gases from vehicles and power plants.

The prospects for the formation of two major hydrogen consumption centers in Asia and Europe, combined with the availability of unloaded nuclear and hydroelectric power plants, create serious prerequisites for the development of technologies for the production and transportation of hydrogen in Russia. Therefore the Ministry of Energy has developed and sent to the government a roadmap “Development of hydrogen energy in Russia” for 2020-2024 according to which the goal of Russia is to become a leading producer of hydrogen.

According to expert assessments of the EnergyNet infrastructure center, the implementation of the measures described in the roadmap requires an annual investment of $ 2.2-3.9 billion per year. At the same time, the potential benefit will be $ 1.7 to 3.1 billion per year. It is expected that the first hydrogen producers will be two large energy companies - Gazprom and Rosatom.

A possible plan for the hydrogen economy development in the Russian Federation is proposed by the National Research University "Moscow Power Engineering Institute". Hydrogen production and export are considered as the most promising areas. Europe, China, Japan, and Korea may be the main delivery destinations.

Thus, it is possible to use the existing gas pipeline system to export hydrogen fuel to European countries and China. Export of ecologically safe fuel to Japan and Korea is possible with the establishment of sea transportation of liquid hydrogen.

Wind power plants in the North of Russia can become sources of energy for hydrogen production, and in Northern latitudes it is possible to use the capacities of the Kola nuclear power plant and solar power plants in Yakutia, which are characterized by high insolation. In the East of the country, there is a significant potential for using the capacity of hydroelectric power plants.

The proposed concept of a “hydrogen city” is based on the presence of the following hydrogen consumers: industrial enterprises for oil refining and production of ammonia for fertilizers, for thermal power plants located within the city and cars. At the same time, the transportation of hydrogen can be carried out both through gas pipelines and by freight transport.

The energy complex for the production of hydrogen should include an energy source, a converter, as well as a storage for hydrogen fuel. The development, creation, and operation of such a complex require highly qualified personnel.

The large-scale task of developing a hydrogen economy in Russia should be solved by the joint efforts of industrial enterprises and scientific and educational organizations. An

important problem is the creation of an effective system for training highly qualified personnel who can conduct advanced research and implement innovative solutions directly in production.

To meet these challenges, the Institute of Energy Efficiency and Hydrogen Technologies was formed at the MPEI in 2019 with an aim of personnel training in the next areas: hydrogen production, storage, transportation, and consumption.

The Institute consists of 5 departments and 3 research units. Bachelors are trained in 5 educational program specializations and Masters are trained in 7 educational program specializations. There are two scientific centers for the investigation of hydrogen technologies.

The topics of scientific research conducted at the MPEI on the subject of hydrogen technologies are primarily related to the development of highly efficient energy complexes for the production and consumption of environmentally friendly fuel. In particular, the employees of the Department of Chemistry and Electrochemical Power Engineering, together with the Kurchatov Institute, are engaged in the development of water-alkaline electrolyzers. New polymer diagrams and highly efficient nickel-based composite electrodes were created, which allowed achieving energy consumption for hydrogen production at the level of 4.1-4.3 kWh / m^3.

Two departments at once are engaged in research on ways to integrate hydrogen production plants into the schemes of thermal and nuclear power plants: the Department of Thermal Power Plants and the Department of Innovative Technologies for High-Tech Industries. All developments in this area have an integrated, systematic approach.

Research begins with thermodynamic analysis, the results of which form the requirements for power equipment. Then, using the methods of mathematical modeling and experimental research, the development of design solutions is carried out. The final stage is to assess the cost of new power equipment and the entire power complex.

The slide shows the developed thermal diagram of the hybrid power unit, the distinctive feature of which, in comparison with traditional steam turbine plants, is the presence of hydrogen overheating. When the working fluid temperature at the turbine inlet is 840 °C, the net efficiency of the unit can reach 45.5%.

Additional combustion of hydrogen fuel in intermediate combustion chambers leads to an increase in the flow rate of the working fluid in the flow path. The problem arises of developing ways to increase the capacity of low-pressure turbines.

By joint efforts of the staff of the Department of Steam and Gas Turbines and the Department of Innovative Technologies for High-Tech Industries, the design of a two-tier low-pressure turbine of increased capacity was developed. The structure of the lower tier contains 5 stages and the upper one - 3 stages. In this case, the penultimate blade has a forked shape. The flow capacity of the low-pressure double-deck turbine is 40% higher compared to a traditional low-pressure turbine with a 1200 mm blade.

In the future, the MPEI plans to increase the volume of research on hydrogen topics. In this case, the priority areas will be:

1. The development of effective and low-cost technology for H2 production.
2. Optimization of H2 transportation methods for various energy consumers (gas stations, thermal and nuclear power plants, industrial enterprise).
3. Research of hydrogen storage methods.
4. Research and development of thermal and atomic power plants fired on natural gas-hydrogen mixtures.