Methodological Approach to the Innovative Development of an Isolated Energy

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Abstract. Isolated energy systems serve, as a rule, enterprises of the mining and oil and gas industries with cities and towns. The fight against climate change, which began more than 50 years ago, was marked by the adoption in 2015 of the Paris Agreement on Climate [1] within the framework of the UN Framework Convention [2] and was further developed in Europe - the climate program Fit for 55 was adopted in the European Union [3]. According to the provisions of this program, it is assumed that the climate policy will be toughened by 2030 and 2050. It is planned to achieve zero greenhouse gas emissions into the atmosphere, create an updated system for trading greenhouse gas emissions and introduce cross-border taxes on carbon dioxide emissions starting from 2023 for the supply of goods to the EU countries. Extensive development and lack of modernization of existing isolated energy supply systems will negatively affect the economic attractiveness of the extracted minerals due to increased costs of electricity generated and a tangible cross-border tax on greenhouse gas emissions. The article analyzes methodological approaches to the choice of an innovative way of modernization and the creation of an isolated medium-power power system.

1. Introduction

The remote sparsely populated northern, eastern and arctic regions of the Russian Federation are currently not part of the country's unified centralized energy system. For the autonomous supply of thermal and electrical energy to industrial enterprises of the mining and oil and gas industries, such as mines, open pits and mines in remote regions of Russia, various types and generation systems are used - from diesel generators for low-power systems and medium-power systems of the entry-level to thermal power plants on coal, fuel oil and gas for systems of medium and high power [4]. Regardless of the installed capacity and the type of generation of an autonomous power supply system, it is necessary to control the following properties:

- work in an extremely wide temperature range - from +35°C in summer to -55°C in winter;
- presence in the soil of a multi-meter layer of permafrost;
- the need for quick regeneration of the system after the elimination of force majeure circumstances;
- the highest reliability since the generation object is often available in a single copy.
For local power systems of low power (up to 20 MW), generation based on diesel stationary engines is almost universally used. Outdated diesel engines with low environmental class and high specific fuel consumption are often found in such power supply systems. Diesel fuel for such power systems is manufactured in a special Arctic version, delivered from afar, and due to this is characterized by a very high price.

For isolated power systems of systems of medium (from 20 MW to 200 MW) and large (more than 200 MW) power, classical systems of thermal power plants (TPP) operating on natural gas are used. coal or fuel oil. Very often, the fuel, as in the case of isolated low-power power systems, is imported with a large transport shoulder and a higher price due to this.

The development of new and modernization of existing isolated energy systems should only follow an innovative path since otherwise the extracted minerals will be subject to an additional carbon tax within the framework of the European system of climate laws Fix for 55 [4] and will significantly reduce their competitiveness.

2. Analysis of innovative solutions for isolated power systems

It is possible to increase the ecological class and reduce environmental pollution, which means carbon taxes in diesel generation, not only by replacing an outdated diesel engine with a more modern, high ecological class with low specific fuel consumption. The maximum effect can be obtained in the case of using a combined power supply system. Such a system includes a diesel generator, a buffer battery, an electrolyzer for hydrogen production, renewable energy sources and converters with a control system, connected to a common network. Consumers in such a system are powered by the converter, connected to the battery, the diesel generator turns on only if the battery charge level drops to a certain level and turns off when the battery is fully charged. Renewable energy always works in case of favourable weather conditions, part of the generated energy goes to replenish the battery charge, the surplus of the generated energy goes to the production of hydrogen in the electrolyzer. Hydrogen generated by the electrolyzer is stored in special containers and consumed by the diesel generator together with diesel fuel. The use of fuel cells for direct generation of electricity from the obtained hydrogen in stationary power systems of low power can be considered taking into account the economic feasibility of this type of generation.

It is not advisable to completely transfer such a power supply system to renewable energy sources, since the most common renewable energy sources - solar panels and wind generators - are related to the generation of cyclic action. Interruptions in the generation of these types of renewable energy sources can be so long that they threaten the uninterrupted supply of electricity despite the presence of a buffer battery, since in addition to the standard cyclicality of renewable energy sources based on solar batteries in the Arctic Circle, there are phenomena of the polar day and polar night with a duration of many days. also by the fact that, due to the harsh climatic conditions in winter, it is necessary to spend a significant part of the generated energy for heating not only the wind generator itself or the solar panel to protect it from frost and degradation, but also the buffer battery and control electronics and converters. The operation of small hydroelectric power plants in the remote northern and eastern regions of the Russian Federation also has a seasonal nature of work, since in these regions small and medium rivers freeze completely in winter, and in summer, in the absence of the proper amount of precipitation, periods of low water are possible, which impede the normal operation of the hydroelectric power plant. Therefore, such hydroelectric power plants as a source of additional generation can only be in demand in power systems with the production of hydrogen in the warm, full-flowing season. An additional way to increase the efficiency of this power system is to equip a diesel engine with an exhaust heat recovery system and use the waste gas heat to generate heat or electricity.

In isolated power systems of medium and high power, the main type of generation is a classic thermal power plant (TPP). The most environmentally friendly of all types of power plants are gas and combined cycle thermal power plants. The efficiency of these types of power plants can be increased due to the utilization of waste gas heat by microtube units operating according to the organic Rankine cycle. The use of renewable energy sources in the form of small hydroelectric power plants, wind generators and
solar panels will allow, as in the case of isolated low-power power systems, to improve the environmental characteristics of the power system, reduce greenhouse gas emissions and reduce fuel consumption, usually imported. The maximum use of the energy generated by renewable energy sources is possible when using hydrogen, which is produced by electrolyzers and stored in special containers, as additional fuel for the main generating power plants. Hydrogen, as in the case of isolated low-power power systems, generated in electrolytic cells due to the energy generated by renewable energy sources. The produced hydrogen can also be used as a fuel for self-propelled mining equipment and infield transport. It is possible to radically improve the ecological characteristics of the power system by using hydrogen as the main fuel, which will be produced by cracking methane with separation into hydrogen and carbon without the formation of CO\(_2\). If methane, used as the main fuel in the energy system, is produced at local fields, it is possible to obtain hydrogen directly from the well of a gas field [5]. In this case, steam and catalyst are supplied to the injection well, and a selective membrane is installed into the production well, allowing the only hydrogen to pass outside. In this case, CO\(_2\) will be buried without bringing it to the surface.

All options for innovative creation and modernization of existing local energy systems require certain capital and production costs while allowing to reduce the carbon footprint of mined minerals and reduce the cross-border carbon tax. In this regard, the need to optimize the power system significantly increases due to the choice of the capacity of the electrolytic cell for hydrogen production, its storage systems, as well as the composition and structure of the main generating capacities of the power system.

3. Methodology for choosing the innovative development of an isolated power system

The methodology for determining the optimal composition of a new or modernized isolated power system involves solving the following tasks:

- Assessment of climatic features and potential of RES in the modernized or newly created isolated power system.
- Assessment of the potential for the generation and storage of hydrogen in the modernized or newly created isolated power system.
- Selection of the optimal control algorithm for the combined power system with partial replacement of the main fuel with hydrogen generated by renewable energy sources.
- Assessment of the carbon footprint and cross-border carbon tax on extracted minerals using the existing energy system.
- Assessment of the carbon footprint and cross-border carbon tax on extracted minerals during innovative modernization of an existing or newly created energy system.
- Evaluation of the economic efficiency of the selected innovative option for modernization or creation of a new energy system, taking into account the carbon footprint and cross-border carbon tax.

Evaluation of the economic efficiency of an innovative option for the creation and modernization of existing local energy systems with the replacement of a part of the basic fuel with hydrogen produced from renewable energy sources can be estimated at a minimum of specific discounted costs for generated electricity. Specific discounted costs for electricity generated in an isolated power system \(C_{LHE}\) can be calculated as follows:

\[
C_{LHE} = \frac{\sum_{t=T_0}^{T_B} \left( \sum (C_{itim} + C_{ite} + C_{ith}) \right)}{(1 + d)^{t - T_d}} - \frac{\sum_{t=T_0}^{T_L} \left(W_t \right)}{(1 + d)^{t - T_d}}
\]
• where \( C_{ilm} \) - is the total cost of generating electricity by the main generating capacity.
• \( C_{ite} \) - the total costs of generating electricity from renewable energy sources going to the local energy system.
• \( C_{ith} \) - total costs of hydrogen production by electrolysis, including electricity generated by renewable energy sources
• \( T_e \) - period of use of generating capacities.
• \( T_B \) - the period of the beginning of the use of generating capacities.
• \( T_d \) - the period of bringing the calculations at different times.
• \( T_0 \) - the period of commissioning of generating capacities.
• \( W_i \) - the period of commissioning of generating capacities.
• \( d \) - discount rate.

The following design parameters are taken into account in the total costs \( \sum C_{ilm} \) of the main generating capacities:

• Capital investments in the main generating capacities of the isolated power system.
• Operating costs of the main generating facilities, including the cost of the main fuel of the power system and payment for greenhouse gas emissions (cross-border carbon tax).
• Costs for decommissioning major generating facilities and environmental remediation.

В суммарных затратах \( \sum C_{ite} \) ВИЭ учитывается следующие проектные параметры: The following design parameters are taken into account in the total costs of renewable energy sources \( \sum C_{ite} \):

• Capital investment in renewable energy sources in an isolated power system.
• Operating costs in RES
• Costs of decommissioning renewable energy sources and remediation of the environment.

The total costs \( \sum C_{ith} \) for the production, storage and supply of hydrogen to the main generating capacities take into account the following design parameters:

• The total costs of C for the production, storage and supply of hydrogen to the main generating capacities take into account the following design parameters:
• Operating costs for the generation, storage and supply of hydrogen.
• Costs for decommissioning the electrolyzer, hydrogen storage and supply systems, and environmental remediation.

From several possible options, the optimal innovative option of an isolated power system partially running on hydrogen is selected with the optimal terms of modernization (construction) and maximum economic efficiency.

4. Conclusion
The use of renewable energy sources to generate hydrogen, which is used as an additive to the fuel of the main generating capacities of an isolated power system, makes it possible to reduce the cost of imported fuel, maximize the use of renewable energy, since the capacity of the buffer battery is quite limited, and most importantly, to reduce the carbon footprint and, accordingly, cross-border taxes for greenhouse gas emissions. Of greatest interest is the option of an isolated power system using hydrogen as the main fuel, obtained on-site from methane by cracking with the release of hydrogen and carbon without the release of carbon dioxide. In the case of using gas from local fields, the option proposed in
Skolkovo for producing hydrogen directly from a well by steam cracking of methane in the field and burying CO$_2$ in the field without lifting it to the surface is of great interest.

5. References
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