ANALYSIS OF TECHNICAL AND ECONOMIC INDICATORS OF SOURCES OF OWN GENERATION OF ENERGY ON RAILWAYS

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ABSTRACT

The stages of the system analysis of technical and economic indicators allowing to compare the efficiency of renewable solar energy equipment are described. It is shown that the introduction of solar installations as an additional source for a power supply system for non-traction and non-transport consumers (for equipment of information and computer complexes of railways) will make it possible to reduce energy costs and reduce construction of power transmission lines. The authors of the article are sure that the situation in the energy pricing policy makes an objective assessment of the energy payback of the solar installation construction particularly important.

Keywords: railway, system analysis, solar energy, solar installations, energy payback.

Background. *In order to reduce the cost of energy supply and improve the quality of electricity in rail transport, it is envisaged to develop its own generation of energy for non-traction needs: to provide power to non-traction and non-transport consumers by using non-traditional renewable energy sources. Depreciation of fixed assets of electric grids is 40 %. It is only for this reason that the introduction of renewable energy sources (RES), independent of electrical networks, is actual. For regions of Siberia and the Far East with a high level of solar insolation, it is advisable to use solar RES.*

In our article, we will consider RES with solar installations (SI), which convert solar energy into electrical energy for the equipment of information and computer complexes (ICC) of railways.

Objective. *The objective of the authors is to analyze technical and economic indicators of sources of own generation of energy on railways.*

Methods. *The authors use general scientific and engineering methods, mathematical calculations, evaluation approach, comparative analysis.*

Results. *Provision of ICC for industrial and transport purposes with sources of additional/reserve and, if necessary, autonomous power supply should be carried out taking into account the requirements for their guaranteed inclusion in work, qualified maintenance and improvement of the environment, availability of ready-to-use mobile computing modules (with power installations) in case of accidents and emergency situations [1, 2]. In this regard, the task arises of a technical and economic assessment of RES equipment with solar installations for the reliable operation of ICC.*

The limiting theoretical efficiency of the photoelectric conversion (PEC) exceeds 90 %, therefore, the actual task of increasing the efficiency of PEC is up to 50 % and more as a result of optimizing the structure and parameters of PEC and SI. Solar installations with concentrators capture 40 % more solar energy [3, 4]. On the basis of experimental data obtained at Stanford University [5], it can be concluded that when using PEC on gallium arsenide and gallium nitride with a concentration of solar radiant energy and combining two principles of conversion of sunlight into electricity – thermodynamic and light – the efficiency is increased by 26 % (an average of 40 % compared with the current average of 14 %). The thermodynamic conversion is based on the use of thermoelectric and thermionic processes. The light conversion (direct conversion of photons into a current by means of a semiconductor) is based on the methods of photoelectric, photovoltaic and photoemission transformations. The specific cost of energy production by means of SI can be reduced not only by increasing the efficiency of the installation and its components, reducing the cost of managing it, but also by using SI as an additional source of power and supplying electricity to the public network for a fee guaranteed by the government.

The main components in the cost structure of SI are described by parameters which values characterize the level of technology used. The cost of a solar watt depends primarily on the cost of semiconductor material in the photoelectric converter, as well as on the efficiency of PEC (rub./W):

$$S_{\mathrm{PEC}} = \frac{S_{\mathrm{sc}} d \rho}{E_{\mathrm{av}} \eta_{\mathrm{PEC}} Y_1 Y_2}, \qquad (1)$$

where S_{sc} is the cost of the semiconductor [rub.]; d is thickness of the plates used [µm]; ρ is semiconductor's density [kg/m^3]; E_{av} is average value of solar illumination for a day taking into account evening and morning hours and climatic conditions in different seasons [W/m^2]; η_{PEC} is efficiency of PEC; Y_1 and Y_2 are technological coefficients characterizing the yields of the processes of processing semiconductor's crystals in plates and plates into solar cells.

It follows from relation (1) that the larger is the area of solar panels, the higher is the cost of a semiconductor. The current uncertainty in the state pricing policy on energy carriers makes the objective assessment of the energy payback of SI facility especially important. The cost of accumulator batteries (AB), which are electrochemical energy storage units (ESU), is the most significant part of the total cost of solar electrical installations. High short-term power can be obtained only with a very high capacity of AB, which determines the large size and mass of the storage unit. Other drawbacks of AB include low cyclic stability and, therefore, a limited service life, as well as the presence of acid, lead, cadmium and other environmentally hazardous materials.

Payback period of SI depending on its unit cost [years]:

$$T_{\mathrm{PP}} = \frac{S_{\mathrm{SI}}}{E_{\mathrm{SI}} S_{\mathrm{T}}}, \qquad (2)$$

where S_{SI} is cost of SI [rub.]; E_{SI} is annual amount of electricity generated by SI [kW•h/year]; S_T is cost of energy from a traditional power installation [rub./ kW•h].

For solar installations to be cost-effective, it is necessary to almost halve the cost of solar energy. Preliminary estimates of the use of concentration of radiant energy of the Sun [6] by combining two principles of conversion of sunlight into electricity – thermal and quantum efficiency [5], the use of PEC of solar cascade elements in the photovoltaic cell [1], reducing the cost of controlling SI using a follower electric drive (FED), implementing the step-by-step regime of tracking the Sun [7], indicate that at the present stage of the development of the SI, a significant reduction in the cost of the solar watt becomes real while ensuring the quality of production electricity at the required level [8].

Economic profit through the ability to perform additional functions can be derived by generating additional energy from SI. It is advisable to realize additional energy only when the cost of the replaced electricity of a traditional power system is equal to or greater than the cost of electricity generated by SI. If support is provided at the governmental level for introduction of solar installations, the cost of electricity to be replaced should remain exactly this, taking into account the deduction of «emission quotas» by reducing carbon dioxide emissions [9]. Accordingly, we write down the following inequalities [rub.]

$$S_T \geq S_{SI} / E_{SI} \text{ or } S_T \geq S_{SI} / (E_{SI} - S_{QU}), \quad (3)$$

where S_{QU} is emission quota.

***Conclusions.** A technical and economic assessment of the energy optimization of RES renewable energy sources with solar installations has been developed. In order to make the use of solar installations profitable, it is necessary to almost halve the cost of solar energy received from them. With the participation of the state or without it, but the fulfillment of this task is the main condition of economically viable projects related to the introduction of non-traditional types of energy.*

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Article received 31.03.2016, accepted 04.09.2016.