Chapter 4

Increasing the Energy Efficiency of Photovoltaic Systems Operating Under Conditions of Uneven Illumination:

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ABSTRACT

The presented research was carried out at existing solar power plants and renewable energy sources laboratories, whose purpose was to increase the energy efficiency of photovoltaic installations with parallel and mixed switching of photocells, operating under uneven illumination, parallel voltage arrays of photovoltaic modules due to voltage equalization. Experimental characteristics of photovoltaic installations with the developed device for coordinating the array of photoelectric modules (DCA), realizing a method of selection of electric energy and without its use are given. It is experimentally shown that the use of DCA increases the electrical power of the array with partial shading up to 2.6 times with partial shading. The results of the research can be used to design new photovoltaic installations and upgrade existing ones.

BACKGROUND

Wider implementation of solar power plants prevents a number of reasons, the main ones are: high cost, low efficiency, imperfection of energy storage technologies. Specialists from various countries, including Russia, are working to reduce the impact of the factors outlined. A great contribution in this direction was made by A.F. Ioffe, J.I. Alferov, D.S. Strebkov, G. Rauschenbach, M. Prince, A.P. Landsman, J. Loferensky, V.V. Kharchenko, V.A. Mayorov and others (Kuznetsov P.N., Avdeev D.S. 2017).

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Figure 1 shows a graph showing the dynamics of the unit cost of solar installations and modules with silicon photocells, from which it can be seen that the cost reduction of both plants and modules is rapid due to their technological and technical improvement, which is confirmed by the values of the modules’ efficiency made in different years (Renewable Energy Technologies: Cost Analysis Series. 2012).

One of the main trends in the development of photovoltaics in the world is the creation of new technologies for the manufacture of photovoltaic cells and modules, focused on reducing costs and increasing efficiency.

In the first half of the 20th century, the efficiency of photocells was no more than 1%. Currently, the average efficiency of the most common silicon elements is 14-18%. Elements made based on cascade heterostructures have an efficiency of up to 36.9%, and with the use of arsenide of gallium (GaAs) up to 47.5%. The theoretical efficiency of terrestrial cascade solar cells is 49% (Alferov Zh.I., Andreev V.M., & Rumyantsev V.D. 2004).

At the same time, it should be noted that the cost of such installations is still high, which calls for continuing work in this direction. Moreover, not only photovoltaic modules need to be improved, but also all the additional elements included in the installation - conversion devices, supporting structures, energy storage systems and many others that significantly affect its cost in general. The data of the International Renewable Energy Agency (IRENA) show that the cost of a solar installation can be up to four to five times the cost of the modules.

The improvement of additional elements of photovoltaic plants, in addition to reducing costs, should be aimed at improving the reliability and stability of energy output in the face of changing environmental parameters, or the effects of external factors (shading, pollution, etc.), and achieving maximum energy efficiency. To this end, in recent years a number of new devices and technologies have been created, the main of which are (Kitaeva, 2015; Gevorkian, 2016; Strebkov & Tver’yanovich, 2007):

Figure 1. Dynamics of unit cost of solar installations (blue) and modules with silicon photocells (orange)
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