ANNOTATION

dissertations for the degree of Doctor of Philosophy (PhD) in the specialty 6D072300 – "Technical Physics"

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"Development of a hardware and software system of optimize the search and selection of maximum output power from solar panels of spacecraft and ground-based solar stations"

General characteristics of the work The dissertation work presents the results of the development of a hardware and software complex for optimizing the search and selection of maximum output power from solar panels of spacecraft and ground-based solar stations.

Relevance of the research topic. The number of satellites in low Earth orbit is growing every year and will reach 100,000 satellites by 2030. The size of satellites is decreasing due to the development of technologies in the field of electronics, but the energy needs of spacecraft are growing due to the increase in the flight task. There is also a growing number of radar satellites that use an active payload, and their consumption is significantly higher than that of optical spacecraft. Satellites in a sun-synchronous orbit have a limited amount of time on the sunny side, so the task is to accelerate the battery charge during the passage of the illuminated part of the satellite's orbit.

The limitation for spacecraft of remote sensing of the Earth in low orbit for the time spent on the solar side does not allow to increase their energy capacity and, accordingly, their shooting performance. An increase in energy capacity by increasing the area of solar panels leads to an increase in mass and significant changes in the design of the spacecraft.

The most acceptable solution for increasing the energy efficiency of remote sensing spacecraft is seen in the development of a hardware and software complex to optimize the search and permanent location (maximum power point tracking) MPPT from the solar battery spacecraft based on the use of "smart" MPPT controllers, which will increase the amount of electricity taken from solar panels and increase the overall performance of spacecraft by reducing the battery charging time.

This dissertation presents solutions to increase the energy capacity of remote sensing spacecraft by reducing the battery charging time.

The connection of the topic with government initiatives and research plans - The research was carried out in accordance with the approved research plan, the Ministry of the Republic of Kazakhstan and within the framework of the scientific project PCF - BR05336483 "Optimization of technical parameters and

methodological approach to the use of remote Earth data of domestic KazEOSat-1,2 spacecraft" (2018-2020).

The object of the study is the location of the MPPT from the solar panelof spacecraft and ground stations.

The subject of the study is the hardware and software system for optimizing the search and finding MPPT.

The purpose of the study:

The development of the hardware and software complex to ensure the selection of maximum power from the solar panel of satellite power system well as power plants by using various algorithms.

To achieve this goal, it is necessary to solve the following tasks:

development of technical specifications for the development of engineering models of the hardware and software complex for power take-off control with solar panel of spacecraft and ground plant;

development of mathematical and simulation models of the functioning of various photovoltaic converters;

development of methods, algorithms and the hardware and software complex for solving optimization problems of determining the MPPT;

Design, assembly and testing of engineering models of the hardware and software complex for power take-off control with solar panel.

The way to achieve the goal:

Formation of technical specifications for the creation of engineering models of the hardware and software complex for power take-off control with solar panel of spacecraft and ground plant. Development of mathematical and simulation models of the functioning of various PV and solar panel;

Creation of methods, algorithms and software mathematical complex for solving optimization problems of determining the MPPT;

Developed, assembled and tested engineering models of the hardware and software (HS) complex power take-off control with solar panel.

Results of the study:

Engineering models of the (HS) complex have been created to ensure the permanent location of MPPT from solar panel of satellites and ground plants.

In addition, the following have been developed: software and mathematical support for solving the optimization problem of finding MPPT with solar panel; engineering models of (HS) complex for power take-off control with solar panel, development, assembly and testing of engineering models of (HS) complex for power take-off control with solar panel were also carried out.

The scientific novelty of the dissertation research is that for the first time in Kazakhstan, a scientific study of the process of finding MPPT with solar panel was conducted to ensure a constant maximum battery charge. For this purpose, a mathematical model, algorithmic and optimization software and mathematical support have been developed. Design documentation and prototypes of a hardware and software complex in the form of an MPPT controller have also been developed, which will constantly find the point of maximum power with high

accuracy, which will ensure that more than 10% of electric energy is additionally received from solar panels.

The main provisions submitted for protection:

1. The developed hardware and software package for finding the maximum power point makes it possible to find the maximum power 50% faster than the standard scanning method for determining the maximum power in conditions of failure of a part of the photo converters or their shading.

2. The developed complex for measuring the electric power generated by photovoltaic converters using a space standard microcontroller (TMS 470) and physical modeling of the process of obtaining the volt-ampere characteristic of a solar battery contribute to obtaining up to 10% additional power from solar panels compared with traditional devices and methods.

3. The developed device for determining the point with the maximum power in the conditions of shading of the solar battery allows you to find the global maximum power, unlike existing traditional methods and leads to a reduction in battery charge time by 10 %.

The significance of the research on a national and international scale lies in the fact that the results of the work performed can be used in almost all Kazakhstani and international projects in which it is necessary to obtain MPPT from PV and other renewable energy sources.

In addition, the global trend towards miniaturization of spacecraft leads to a decrease in their weight and cost, which contributes to an increase in their number. The hardware and software complex planned for development does not require significant changes to the design of spacecraft and ground-based solar power plants.

Scientific and technological needs (economic and industrial interests).

In Kazakhstan, the specific energy capacity is at a low level and amounts to 4 MWh/person, whereas in Russia it is 6.7 MWh/person, in the USA it is 14 MWh/person, in China it is 35 MWh/person. This indicator indicates that for the further development of the industry, it is necessary to increase electricity generation. These data show that there is a social, economic and industrial interest in significantly increasing electricity generation in Kazakhstan.

In addition, it should be noted that the results of the proposed work will significantly increase the extraction of electricity from the solar panels of spacecraft. In particular, for remote sensing spacecraft located in solar synchronous orbits, there is a need for fast charging of batteries, and the use of "smart" MPPT controllers will increase the amount of electricity taken from solar panels and reduce battery charging time, i.e. technological and scientific needs are covered.

The impact of the results on the development of science and technology and the expected social and economic effect

As already noted above, the use of the MPPT controller hardware and software complex will significantly improve the technological parameters of the spacecraft power supply system without additional significant capital investments.

The use of "smart" MPPT controllers for ground-based power plants (solar and wind) also makes it possible to significantly increase the electrical output of solar panels and wind units without significant capital investments.

The results of the study

The results have been introduced into the educational process of the L.N.Gumilev Eurasian National University with laboratory work with students and staff of this university, training seminars will be held with specialists of Galam LLP. This will allow you to visually present the results of scientific research in the form of a hardware and software package for monitoring the charge and discharge of batteries.

At the moment, point tracking with maximum power - MPPT in spacecraft is implemented in hardware.

The hardware and software complex can also be used for ground-based solar stations in order to optimize the search for MPPT from the solar panel, for example, in the form of a charge and discharge controller, which is able to prevent a number of negative consequences for batteries. Uncontrolled charging current (and/or voltage) from solar panels, which may exceed the critical value for this type of battery, which will accelerate chemical processes that may cause the battery to collapse.

In this paper, algorithms have been developed for cases where partial shading of solar cells occurs on a solar panel or one or more elements fail, so standard methods for finding maximum power are not suitable.

Approbation of the work. The main results and conclusions obtained during the study, as well as suggestions and recommendations based on these results, were discussed and verified at national and international conferences, as well as published in scientific journals included in the Scopus list and the CCSON of the Ministry of Education and Science of the Republic of Kazakhstan. All these publications fully reflect the results of this research related to the topic of the dissertation. The results were presented by the author at international conferences held in Istanbul (Turkey), Moscow (Russian Federation), Samara (Russian Federation), Minsk (Belarus), in appendices.

A list of published works. The research results are reflected in the following scientific papers, including:

Scientific publications with a high impact factor included in the international database Scopus and Web of Science

1. Algorithm for finding maximum power point tracking when shadowing or failure of solar panel photo cells on satellites using low orbits, Syzdykov A.B., Baktybekov K.S., Messerle V.E., Komarov F. F., Askaruly R, Zilgarinov D., Murat A, ISSN 1811-1165 (Print); 2413 -2179 (Online) Eurasian Physical Technical Journal, 2023, Vol.20, No.1 (43)

Scientific publications recommended by the the Ministry of the Republic of Kazakhstan for the publication of the main results of scientific activity

1. Particle swarm optimization with individually biased particles for reliable and robust maximum power point tracking under partial shading conditions, Baktybekov K., Kurmanbay A., Sakhanov K., Syzdykov A., Mukhamediyev A. ISSN 1811-1165 (Print); 2413-2179 (Online) Eurasian Physical Technical Journal, 2020, Vol.17, No.2 (34)
2. Evaluation of wind power potential in shelek corridor (Kazakhstan) using weibull distribution function, Zh. Baizhuma, S.A. Bolegenova, R.K. Manatbayev, K. Baktybekov, A. Syzdykov, International Journal of Mathematics and Physics 9, №2, 86 (2018)
3. Definition of the basic geometric parameters of a control of a corousel type turbine its technological solution, R.K. Manatbayev, N. Kalasov, B. Bektibai, Ye. Nurymov K. Baktybekov, A. Syzdykov, E.M. Zulbukhanova, International Journal of Mathematics and Physics 10, №1, 82 (2019)

Publications in collections of abstracts of reports on the results of International scientific conferences

1. Optimization of series-parallel connection of PV array to mitigate negative influence of partial shading conditions, A Kurmanbay, K Baktybekov, K Sakhanov, A Syzdykov and A Mukhamediyev18th International Conference "Aviation and Cosmonautics" (AviaSpace-2019) IOP Conf. Series: Materials Science and Engineering 868 (2020) 012001 IOP Publishing doi:10.1088/1757-899X/868/1/012001

The author's personal contribution consists in the independent planning and execution of the experimental part of the study, as well as the interpretation and processing of the data obtained, the development of algorithms and mathematical models, and a hardware and software complex. The author also worked with scientific consultants to set goals and discuss the results of the study.

The structure and scope of the dissertation. The dissertation consists of 145 pages and an introduction, 3 sections, a conclusion, a list of sources used (94 titles) and 8 appendices. The paper contains 127 tables and 79 figures.