ANNOTATION

of dissertation for the Philosophy Doctor (PhD) degree in specialty "6D071900 –Radioengineering, electronics and telecommunications" by Kuttybay Nurzhigit on the topic "**Development of automated photovoltaic systems with wireless monitoring and optimal orientation to the Sun**"

This dissertation paper presents the results of a study of automated single-axis and dual-axis photovoltaic systems with optimal orientation to the Sun with wireless monitoring and control.

Relevance of the dissertation theme.

The orientation of the solar array in space has a decisive influence on the performance of solar panels.When installing a stationary solar battery at an optimal angle to the horizon, depending on the geographical latitude of the location of the solar power plant, the following problems arise: the loss of a large amount of energy at sunrise and sunset, a change in the optimal angle to the horizon during the year, which leads to a decrease in the efficiency of the solar battery. On a clear sunny day, the rays of the visible spectrum fall directly on the surface of the earth without interference. On the contrary, when it is overcast, the rays of light are partially absorbed and partially reflected from the clouds.

In order to effectively solve all these problems, new technologies are being developed using direct and indirect methods. Among them, one of the most common methods is a photovoltaic solar tracking system (solar tracker).

Solar trackers need rotation control systems in various planes. Depending on their design and axes of rotation, solar trackers are classified into two main groups: single-axis trackers (rotate along one axis) and dual-axis trackers (rotate along two axes). Although some scientific studies distinguish types of trackers with a much more complex design, they are not as popular as single-axis and dual-axis trackers, and are more difficult to create. As it turned out, trackers demonstrate greater efficiency compared to stationary photovoltaic systems, depending on control algorithms, time of year, time of day and location.

Most trackers built to date use methods based on photosensors or astronomical calculations of the movement of the Sun in a horizontal reference frame. However, the use of photosensors is possible only in clear weather, since in cloudy weather the albedo of the environment is lower than the albedo of the cloudy sky, and about 90% of the radiation of the visible spectrum is scattered and photosensors are unable to determine the location of the Sun. The second method of tracker control is based on various algorithms and mathematical calculations of the equations of the trajectory of the Sun. Here, navigation devices are used as control sensors. Various random factors (for example, electromagnetic waves) can sometimes lead to a loss of signal of sensors. The solar tracker with this control algorithm works in cloudy weather conditions without deviations. At the same time, the controller must have data on the local time and geographical location of the solar tracker. In case of errors in the

control system or sensors, cumulative errors occur over time, negatively affecting the operation of the system.

In addition to the optimal orientation to the Sun, there is the task of efficiently converting the output power of the solar battery to charge batteries. Traditionally, PWM controllers are used in photovoltaic systems to ensure a stable battery charge. However, during the day, a change in the voltage of the solar battery leads to a shift in the maximum power point (MPP) of the solar array, as a result of which there is a decrease in the efficiency of energy conversion by the PWM controller. The task of tracking the maximum power point (MPPT) is solved by the controllers of the same name. MPPT controllers hold the maximum output power of the solar battery. The problems that arise when creating such systems are as follows: low accuracy of algorithms for determining MPP, low speed of MPP, losses during conversion of electrical energy, low accuracy of current and voltage measuring sensors.

The efficiency of photovoltaic systems directly depends on the continuous monitoring of their operation and the detection of various faults. There may also be a number of problems with the organization of the monitoring system. Most monitoring systems determine the consequences of malfunctions, but cannot determine their cause. Using a wired communication line when transmitting information is ineffective in relation to large power plants due to the large distance between the control center and solar panels. It also becomes necessary to synchronize the date, the exact local time and the angle of rotation of the tracker in both planes for maximum efficiency of the photovoltaic system.

An urgent task today is to study modern systems for tracking the Sun in various weather conditions, the influence of various methods of tracking the Sun, using cloudy weather for single-axis solar trackers. It is also necessary to study the various positions of the solar panel with strong scattering of sunlight in cloudy weather for dual-axis solar trackers and the influence of the MPPT controller on the operation of a single-axis and dual-axis solar tracker in real conditions using a wireless monitoring and control system.

The purpose of the research is to create automated photovoltaic systems with wireless control and monitoring, with one and two axes of rotation, optimal orientation to the Sun and the use of effective MPPT controllers in various weather conditions.

The object of the research.

Automated single-axis and dual-axis photovoltaic systems with MPPTcontroller with wireless monitoring and control system;

The subject of the research.

Improving the efficiency of single-axis and dual-axis solar trackers by optimizing the algorithm and design of the system for use in various weather conditions; efficient conversion of electrical energy using a MPPT controller; improving the reliability of solar trackers using feedback through the use of a wireless monitoring and control system.

Research methods.

To achieve the goal of the study, the following methods were used:

- modeling the design of the tracker rotation mechanism in the Autodesk Inventor development environment;

- simulation of the MPPT controller in the development environment of Matlab, Simulink;

- experimental study of the output power of single-axis and dual-axis solar trackers and MPPT controller in various weather conditions;

- experimental study of the operation of a wireless monitoring and control system to provide feedback.

In order to achieve the above stated goal, it is necessary to carry out the following tasks:

1 Creation of autonomous single-axis and dual-axis solar tracking systems with optimal design of the rotation mechanism;

2 Equipping the Sun tracking system with a control algorithm for optimal orientation to the Sun in various weather conditions and conducting experimental studies in real conditions;

3 Development and experimental study of the effectiveness of the MPPT controller for single-axis and dual-axis solar tracking systems;

4 Development and research of the effectiveness of an optimal monitoring system based on wireless communication, which allows remote monitoring of the overall workflow workflow of a photovoltaic system and automatically correcting errors occurring in the system in real time by establishing feedback.

Scientific novelty of the work.

The novelty and originality of the work are as follows:

1 An increase in the efficiency of a single-axis solar tracker in scattered sunlight has been established using encoders and developed software to determine the angle of rotation in the horizontal plane;

2 Asystem has been developed for determining the optimal position of a dual-axis solar tracker with strong scattering of sunlight using a control tracker;

3 The integrated system of MPPT controller, and single-axis and dual-axis trackers in various weather conditions is investigated;

4 An automated system of wireless monitoring and control with feedback has been developed to improve the reliability of the system.

The main provisions for the defense.

1 The efficiency of a single-axis tracker with control based on astronomical calculations of the coordinates of the Sun and an encoder algorithm higher on average by 4% in cloudy and rainy weather, and higher on average by 2% in partly cloudy conditions, than a similar single-axis tracker with control, based on photosensors, and consumption of the first one is lower by 60% than consumption of the second one;

2 The efficiency of solar tracker with proposed algorithm for determining optimal position of the panel in space is more than 40% in comparison with traditional dual-axis solar trackers in strong scattering of sunlight;

3 The conversion efficiency of the developed MPPT controller integrated with a dual-axis solar tracker is 95%;

4 A two-level check of the position of the photovoltaic module, implemented in the hardware-software control and monitoring complex with wireless feedback

between the control system and the tracker eliminates the deviation of the rotary mechanism.

Practical and theoretical importance of the dissertation.

The results of the research work carried out in the dissertation work have important scientific and practical significance in the design of solar tracking systems. The research results obtained in this paper can be useful in the case of the deployment of both single-axis and dual-axis solar tracking systems in climatic conditions with variable clouds.

In order to optimize and improve the reliability of large photovoltaic systems in which solar panels and the control unit are separated by a large distance, the use of wireless monitoring and feedback control is proposed in this paper.

The reliability and validity of the results is determined by the obtained experimental data. In addition, the results obtained complement the well-known studies of photovoltaic systems. In addition, the reliability and validity of the results achieved in the dissertation work is confirmed by the presence of publications in publications recommended by the Committee for Quality Assurance in the Field of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, in the journals of foreign countries with a non-zero impact factor, and in the proceedings of international conferences.

The personal contribution of the author

The author has completed the entire scope of the dissertation work, which includes the definition of the goals and objectives of the work, the formulation of hypotheses and experimental work, computer modeling and quantitative evaluation of experimental results, analysis and preparation of scientific publications for publication.

Publications.

9 publications have been published on the topic of the dissertation, including 3 papers in the materials of international conferences, 3 papers in scientific publications recommended by CQASESMES RK for the degree of Doctor of Philosophy (RhD), 2 articles in journals included in the international information resources Web of Science (Clarivate Analytics, USA) and Scopus (Elsevier, Netherlands), 1 paper in journal included in the international information resource Scopus (Elsevier, Netherlands).

Approbation of the dissertation. The results obtained in the dissertation were presented and discussed:

– at the International Conference of Students and Young Scientists "FARABI ALEMI" (2019, Al-Farabi Kazakh National University, Almaty);

– at the International Scientific 2019 IEEE international conference on automatic control and intelligent systems (I2CACIS), Shah Alam, Malaysia, 29.06.2019;

Relation of the dissertation theme to the plans of scientific research.

The dissertation work was carried out in accordance with the plans of research work: "Development of an intelligent autonomous system for wireless control and monitoring of street lighting" 2018-2020, IRN AP05132464.

Patent for utility model

Ibraimov M. K., Saimbetov A. K., **Kuttybay N. B.**, Yakubova M. Z., Darayev A. M., Assabayeva R. N., Yakubov Dz. M., Aktayev Ye. T. Solar power plant with automatic control system // Patent for utility model, 2021. № 6043.

Certificate of copyright

Құттыбай Н.Б., Саймбетов А.К., Нұрғалиев М.К., Солнечные трекеры с контроллером отслеживания точки максимальной мощности // Авторское свидетельство, 2022. №25199.

The scope and structure of the thesis.

The thesis consists of an introduction, 3 sections, conclusion and list of references from 112 titles, contains 126 pages of basic computer text, including 93 figures, and 23 tables.