An Automated Intelligent Solar Tracking Control System With Adaptive Algorithm for Different Weather Conditions

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***Abstract* — The paper considers an intelligent automated solar tracking control system designed to increase the efficiency of solar energy production. The proposed method of detecting cloudiness allows system to adapt to various weather conditions in real time by changing the angle of the solar panel. It is known that in case of strong scattering of solar radiation in cloudy weather panels installed horizontaly are more effective, rather than trackers which precisely oriented to the Sun. Proposed solar biaxial solar tracker equipped with two additional small solar modules. One of the modules is installed in a horizontal position, the second module is also a biaxial solar tracker. The algorithm for determining the position of the solar panel is based on known trajectory of the Sun during whole year saved in memory card and on monitoring the output currents of small solar panels built into the system. When cloudiness increases, the output current of a small solar horizontal module will exceed the current of the module oriented to the Sun. Then the big solar panel goes into a horizontal position. For remote monitoring of the energy characteristics of the solar battery, wireless data transmission based on LoRa AS32 TTL modules were added into the system. Experimental results showed that energy generated in cloudy weather using proposed method exceeds energy collected by biaxial solar tracker by 18%.**

Keywords— solar energy, solar tracking control system, biaxial solar trackers, autonomous intelligent system, wireless monitoring

I. INTRODUCTION

Today there are various ways to increase the efficiency of solar energy conversion. A large number of works are devoted to sun tracking systems [1-6] and their use in various branches of human activity. Depending on the design of the solar tracking system (solar trackers) can be classified as uniaxial and biaxial. Uniaxial solar trackers rotate in a horizontal plane turning in the direction of the Sun using various algorithms. In this case, uniaxial solar trackers do not take into account the change in the height of the Sun during the day. The angle of the solar panel is set equal to the latitude of the area in which the tracker is installed. Biaxial solar trackers have an advantage over uniaxial [7-11], as they take into account the change in the height of the Sun during the day and during the year.

To date, there are many automated biaxial solar trackers working on the basis of various algorithms. Most often, the algorithms of automated solar trackers are based on indications of photosensitive sensors that determine the direction of the maximum intensity of solar radiation, or on the basis of the known trajectory of the Sun moving across the sky in the coordinate system related to the Earth. Using these algorithms, the trackers find the desired position of the solar panel so that the sun's rays fall perpendicular to the surface of the solar battery. If weather conditions change, clear weather is replaced by variable cloudiness and rain, then the panel installed in a horizontal position will produce more power [12-17]. However, sun tracking systems with photosensitive sensors are practically not adapted to cloudy and rainy weather [18-20]. On the other hand trackers working on the basis of astronomical calculations of the daily trajectory of the Sun cannot determine the presence or absence of clouds. That decreases their effectiveness.

Analysis of the modern tracking systems for the Sun, we have come to the development of an intelligent autonomous tracking system of the Sun, which allows us to orient solar panel horizontally in cloudy and rainy weather to increase the output current of the solar panel.

II. STRUCTURE OF ADAPTIVE INTELLIGENT SOLAR TRACKER

Here we are going to look at the structure of an adaptive intelligent solar tracker and the electrical circuit of the control unit. The structure of the solar tracker is shown in Fig. 1. Here 1 is the solar panel; 2 - control unit for horizontal rotation of the panel, consisting of several gears of different size and motor. There is also an electrical system control unit and batteries; 3 - linear actuator that allows us to track the height of the Sun. Small solar panels 4 and 5 are located on an additional platform. Small solar battery 4 is equipped with a biaxial solar tracker, made on the basis of two servo motors 6 and 7 rotating a small solar battery vertically and horizontally. Small solar battery 5 is installed horizontally. The task of small solar batteries is to monitor the current in a horizontal position and with precise orientation towards the Sun.

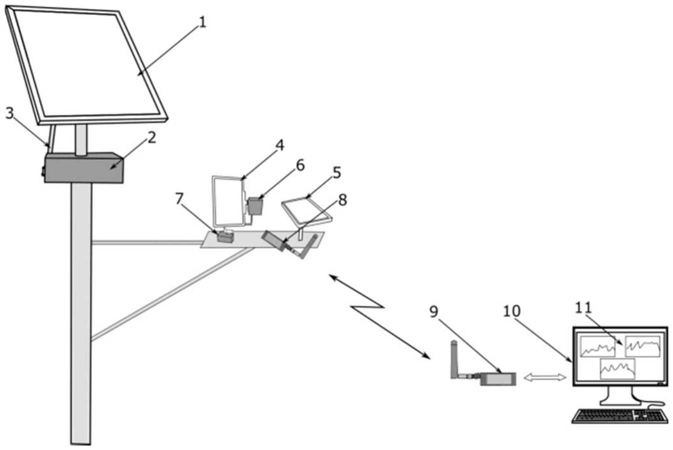

Fig. 1. The structure of an adaptive intelligent solar tracking system

Data transmission over the wireless channel and remote monitoring is carried out using the LoRa AS32 TTL transceiver. LoRa wireless technology works on frequency 433 MHz. It uses linear spread spectrum to increase the coverage area. Thanks to the LoRa modulation it is possible to receive packets even if the power of signal lower then level of noise by 19 dBm. We used model with output signal power 100 mW. This module has coverage area about 3 km in open space. The control of the processing of the received data and sending over the wireless channel is also performed by the electrical control unit 2. Data is received by the second wireless module LoRa AS32 TTL, which is indicated by the number 9. The receiver is connected to the computer 10 via the serial USB port. Dispatch program 11, allows us to monitor whole process in real time. If the current generated by the small tracker is greater than the current generated by the small horizontal battery, the "big tracker" remains in a position turned to the Sun. If the horizontal small battery will generate more current, the "big tracker" moves to the horizontal position. The second case is possible if there is strong scattering of sunlight by clouds.

The control unit of the solar tracker consists of several parts. Fig. 2 shows electric circuit of adaptive intelligent solar tracking control unit. The most important part of the control unit is the ATMega328 controller. The controller is powered by a LM7805 DC-DC converter connected to a battery with a nominal voltage of 12 V. A slot for an SD card is needed to connect a memory card that collects data on the position of the Sun for each day of the year. To obtain the values of voltages on the battery and the solar panel, electronic voltmeters are connected to inputs 1 and 2, 3,4 - inputs for obtaining values of currents of small solar batteries, based on the operation of the sensor INA219, 5 - input for measuring the current of the solar tracker, to which the current sensors INA219 are connected. The most important elements are the real-time clock, which is connected to input 6. Stepper motors are used to rotate the solar panel in space, which are connected to the controller via drivers. Drivers need to be connected to input 7, and input 8 and powered from 12 V power supply. The inputs marked by number 9 are for the LoRa AS32 TTL wireless data module. Stepper motors must be connected to a power supply of at least 12 V through relays and motor drivers to reduce the power consumption of the motors. Inputs 10 are designed to power stepper motors.

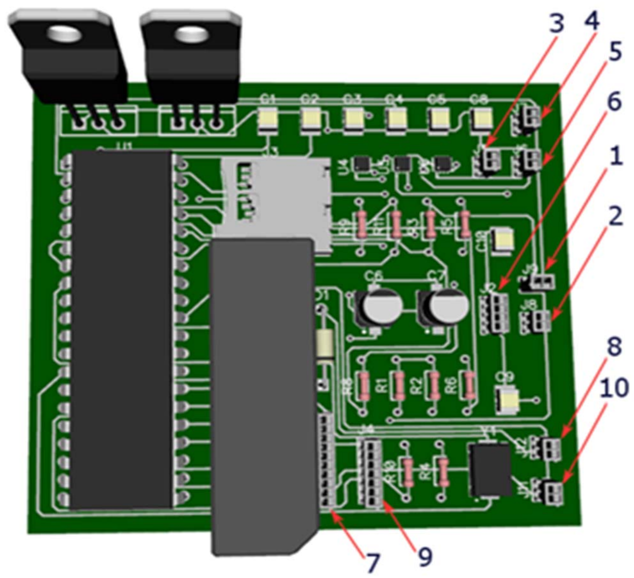

Fig. 2. Adaptive Intelligent Solar Tracker Control circuit

3D electronic circuit of intelligent solar tracking system was constructed in schematic and PCB design software DipTrace. Using constructed circuit we will manufacture control unit to perform the experiment.

III. ALGORITHM OF WORK OF AN ADAPTIVE INTELLIGENT TRACKING SYSTEM FOR THE SUN

The algorithm of the biaxial solar tracking system is shown in Fig. 3. After initialization, the controller turns on the LoRa AS32 TTL wireless module. The next step is, a real-time request is made and inserted in the variable t_C, as well as the coordinates of the Sun at the given time. Then it is necessary to determine the time of sunrise t_{SR} and sunset t_{SS}, in order to reveal the time of active work of the system of tracking the Sun.

If the condition $t_{SR} > t_C > t_{SS}$ is fulfilled, the controller calculates the number of rotations is necessary to bring the tracker to the desired position. Then a stepping motor is set in motion, which rotates the tracker in the horizontal plane. Now, if the current of the small tracker is greater than the current of the small horizontal battery, then the big tracker drives the stepping motor, which changes the vertical position of the panel. If vice versa the current of the small horizontal battery is greater, the big tracker goes into the horizontal position. In this case, clouds appear in the sky. Next, the current and voltage of the battery and big tracker must be measured, to determine the level of its charge, and to calculate the output power of the tracking system of the Sun. The obtained values of currents and voltages are sent over the wireless channel to the dispatcher for data processing and presentation in a convenient form. After a short period of time, the cycle begins anew.

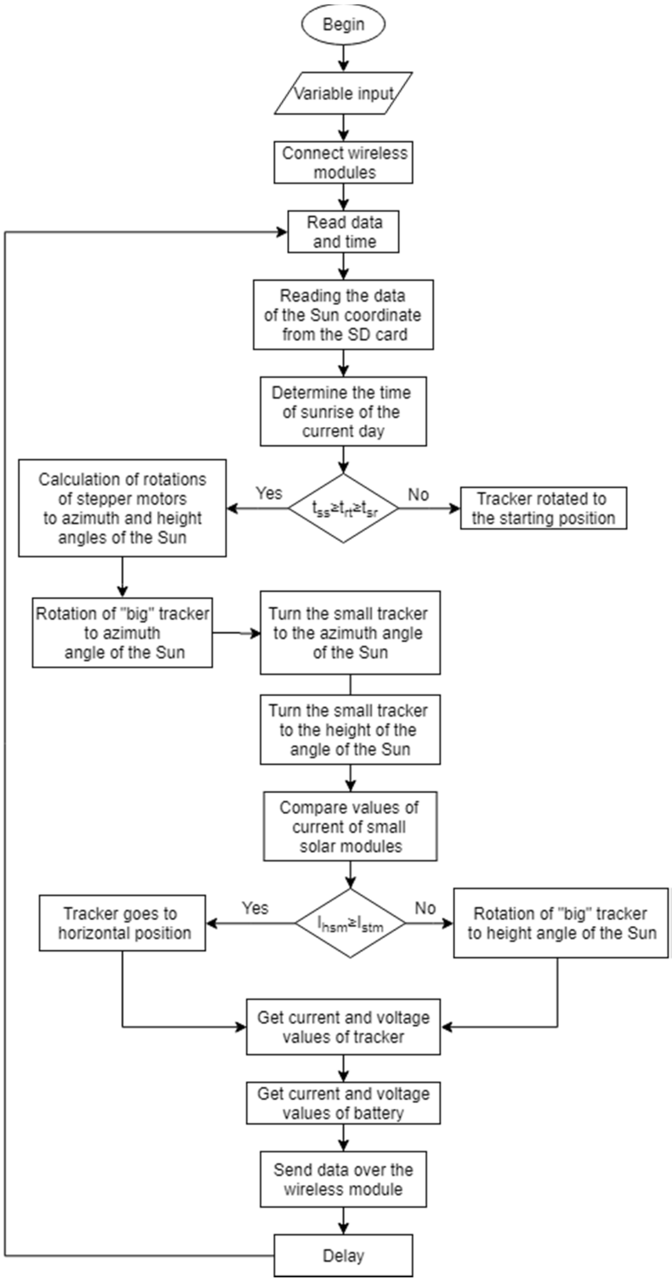

Fig. 3. The algorithm of the adaptive intelligent solar tracking system

IV. EXPERIMENT RESULTS AND DISCUSSION

An adaptive intelligent solar tracker with wireless data transmission using the LoRa AS32 TTL technology was manufactured for the experiment. For the solar tracker a solar battery with a peak current of 2.34 A and peak voltage of 17.1 V, as well as a power of 40 W was used. The developed solar tracking system is shown in Fig. 4.

Fig. 4. The developed adaptive intelligent solar tracking system

The experiment was conducted on the territory of Al-Farabi Kazakh National University in Almaty city on March 30, 2019. On this day, there was an increased cloudiness and light rain. Fig. 5 shows the graphs of the current of a small tracker and a small horizontal solar battery. Sending data over the wireless channel was made at intervals of 15 minutes from 8:00 a.m. until 6:00 p.m.

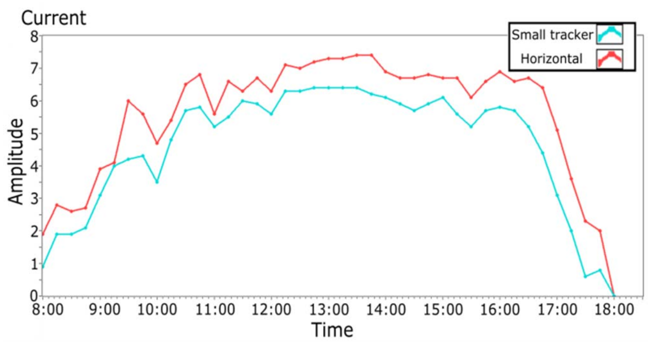

Fig. 5. Comparison of currents of a small tracker and a small horizontal battery on a cloudy day

The graph shows that the current of a small horizontal solar cell lies above the small tracker throughout the day, since the sun's rays are strongly scattered in cloudy weather. So the big tracker was in a horizontal position for the whole day according to the proposed algorithm. Fig. 6 shows a graph of the power of the big solar tracker. The maximum generated power of the solar battery is registered, as it turned out, at 11:00 a.m. with value 2750.4 mW. However, when the Sun was at its highest point, the power of the electric current was lower, 1776.84 mW. The reason for this change is the high density and rain type of clouds. As the Sun approached the zenith, the clouds thickened and began to rain. Where as in the morning the clouds were evenly distributed across the sky.

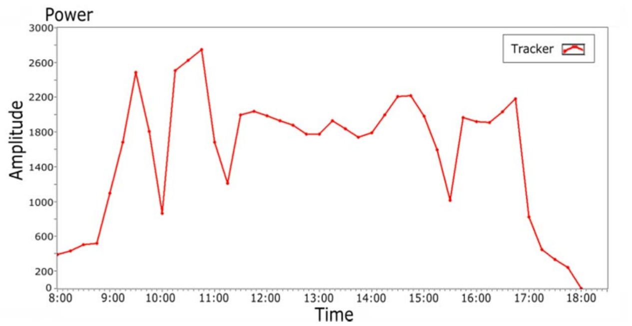

Fig. 6. Power of a big solar tracker on a cloudy day

Reduction the power level of a big tracker corresponds to the reduction of the current strength of a small horizontal panel.

Fig. 7 shows the dispatch program for monitoring the operation of an adaptive intelligent solar tracker created in the LabView graphical development environment. The first line contains graphs of current, voltage and power of a small solar tracker and a small horizontal solar panel, respectively. In the second line current, voltage and power of a big tracker, respectively.

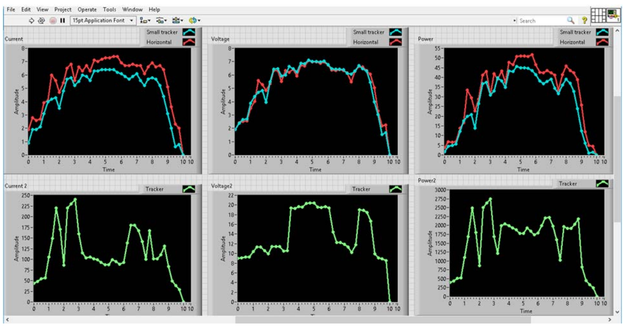

Fig. 7. The dispatch program for monitoring the operation of intelligent solar tracking system

Thus, using this software and proposed adaptive tracking system, it is possible to increase the efficiency of energy generation in rainy and cloudy weather.

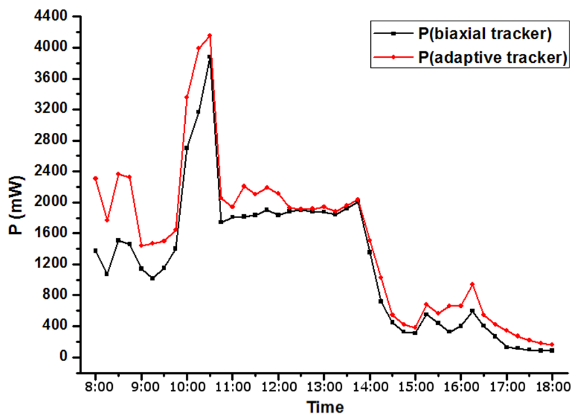

Fig. 8. Comparison of the power of the solar tracker and adaptive tracker in cloudy weather

Fig. 8 shows the power of the proposed adaptive tracker and biaxial solar tracker in cloudy day. These experimental data were taken on April 21, from 8:00 am to 18:00 pm. At the beginning of the experiment, up to 9 am it was foggy and we can see that the energy output of a adaptive solar tracker is much greater than that of a solar tracker. Further, until 10 am the sky was covered with a thick dark cloud, which corresponds to the graph with a decrease in the energy produced by both solar trackers. From 10 am to 11 am the time period clouds became thinner and the power increased. At the time from 12 pm to 14 pm when the Sun was at the zenith covered by thick clouds, the energy output of both systems becomes almost the same. Then, from 2 pm, it was rainy and the output power of the panels decreases. But still the adaptive solar tracking system produces more energy.

Summing up all the data obtained we can find the difference between power generated by adaptive solar tracker and biaxial solar tracker. Energy obtained by adaptive solar tracker exceeded by 18% in cloudy weather.

V. CONCLUSION

As a result of this work, an adaptive intelligent system for tracking the Sun was developed. An algorithm for detecting the presence of clouds for a solar tracker using the difference in current values of small solar batteries has been developed and applied. The architecture of the remote monitoring system and dispatching program based on the LoRa AS32 TTL wireless module has been developed. Experimental data of the system operation using the developed algorithm and the remote monitoring system in cloudy and rainy weather were obtained. Energy obtained by adaptive solar tracker exceeded energy collected by biaxial solar tracker by 18% in cloudy weather. The developed algorithm can be used in industrial installations to improve the efficiency of solar tracking systems.

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