

THE DEVELOPMENT OF INTELLIGENT SYSTEMS FOR SOLAR PANELS STATION AND METHODS FOR DETERMINING THE PRECISION OF THE SOFTWARE TRACKING SYSTEMS , THE USE OF WIRELESS COMMUNICATION DEVICE

SATYBALDIYEVA F.A.^{1*}, BEYSEMBEKOVA R.N.¹, SARYBAEV A.S.², ESENBKOVA G.J.³,

¹Kazakh National Research Technical University named after K.I.Satpayev

² M. Auezov South Kazakhstan State University

³ T.K. Zhurgenov Kazakh National Academy of arts

*Corresponding author's e-mail: feruza201200@gmail.com

ABSTRACT

Use of wireless communication between detectors, transducers and industrial logical controllers in modern optical SPS heliostat control systems is more advantageous than laying hundreds meters of cable.

To provide power supply, it is proposed to equip each heliostat with a self-contained power supply, since heliostat operates when concentrated solar radiation in the receiver is sufficient for steam generation, while the rest of the time it is in the standby mode. That is why use of a solar battery-powered self-contained power supply is more advantageous than use of centralized power supply from the industrial network. As distinct from other measuring informational systems, the described heliostat control system operates only when tracking parameters deviate towards the maximum permitted values.

Presented in article the model of system of automatic control of the heliostats constitutes one of the varieties of measurement and information and control systems. Unlike other measurement systems described control system of the heliostats works only when the deviation of the tracking parameters in the direction of the maximum. The use of modern control systems, heliostats optical system SES wireless connections between sensors, transducers and industrial logic controllers is advantageous compared to laying hundreds of meters of cables.

Key words: *Intelligent Control Systems, Mathematical Model,, Heliostat, Wireless Communication, Power Supply.*

1 INTRODUCTION

Interest in alternative energy sources was the highest in the world in connection with the growing needs of the global economy in energy, limited reserves of hydrocarbon resources has exacerbated the problem of the use of renewable sources. Development of renewable energy sources provides environmental and energy security, environment preservation, clean, preservation of hydrocarbon reserves for future generations and the possibility of their use for other non-energy purposes. The main obstacle in the development of renewable energy sources is the high specific capital costs and, consequently, high tariffs for electricity. However, rising prices for electricity produced in the traditional way, the decline in the price of energy from alternative

sources in the future will make the difference in cost is negligible. Renewable energy sources can be economically justified especially in remote and energy-deficient regions of Kazakhstan. The concept of "green economy" is becoming in the modern world is of great importance, including in a number of areas that are interdisciplinary in nature, combining expertise in Economics, natural Sciences, sociology and philosophy. It is considered that the current economic system is not perfect, because the negative consequences are too great. This deterioration of the ecological and economic situation, as expressed in the desertification of Eco territory, opportunities of climate change for the worse, loss of biodiversity, depletion of natural resources, the lack of fresh water, all-encompassing poverty and misery because of the lack of food that poses

a serious threat to the existence of future generations. Inefficient use of energy is accelerating the depletion of natural resources, which negatively affects the completion of state revenues that could be used for social needs and infrastructure development

Solar cells were invented and then developed in 1960's as power provider in space use. It received focus in 1970's oil crisis in seeking alternative energy sources. Rapidly, the solar cells' advantage of remote use was highly recognized, and in turn, it promoted the development of the whole photovoltaic industry. The solar cell record efficiency increased, and a silicon cell reached up to 20% efficiency milestone in 1985. In the next decade, a 15% to 20% steady growth rate

was seen of the photovoltaic industry, and reached a 38% in 1997. Meanwhile an exponential increase of annual solar power installation has been experienced [1]. Currently, the semiconductor materials mostly used are monocrystalline silicon, polycrystalline silicon, amorphous silicon and cadmium telluride, where crystalline silicon PV systems together have more than 85% of today's market share and thin film technologies (such as CdTe and amorphous silicon) takes most of the rest [1]. The major problem hinders solar cells electricity market share is that solar cell generated electricity lacks economic grid parity with market price. The problem is temporarily addressed by government subsidy and tariff programs, but, the thesis author expects it must eventually be resolved by the technology itself. The Levelled Cost of Electricity (LCOE) is the net present value of total life cycle costs of the project divided by the quantity of energy produced over the system life. Ways to reduce LCOE may be increasing efficiency including good maintenance, reducing cost and lengthening solar cell working lives. One of the ways to increase efficiency is the use of devices and automation devices that collect radiation from continuous tracking of the Sun, increasing the output power and thereby creating an intelligent system for controlling and controlling the elements of the solar panels.

Existing solar energy systems are still very expensive compared to traditional methods of electricity production, due to the material of semiconductors, which are made of PV solar cells (solar cells). Analysis and study of minimizing the prices of PV solar systems show

that the best way is to concentrate the sun's rays. Solar concentrating PV system also require optimization of rates so it is very important to optimize the parameters of solar concentrating PV energy systems, particularly coal misalignment of panels which can be used to create cost-effective solar PV system.

There are several types of support-rotary mechanism (PSM) which distinguishes between a design:

PSM type azimuth (slewing rings rotational movement horizontally;

PSM moves progressively horizontally);

PSM the type elevation (OPU with the rotational movement vertically;

Slewing rings in reciprocating vertical);

PSM the type of azimuth-elevation (OPU rotating horizontally and vertically;

PSM rotary motion horizontal and reciprocating vertically;

PSM translational movement vertically and horizontally)[2].

The system of tracking the movement of the Sun can be divided into three classes:

A system of tracking the Sun's motion on the basis of sensors (light sensors, image sensors, video cameras);

A system of tracking the Sun's motion on the basis of the calculation of coordinates of the position of the Sun in the celestial sphere by the astronomical calendar;

A tracking system positioning.

The objective of accuracy determination in tracking software systems (TSS), just as in optical tracking systems (OTS), is to determine the misalignment angle between the Sun and the optical axis in concentrators or the set direction of reflection in heliostats.

In OTS, this angle is directly recorded by an optical detector (OD) that sends the signal for misalignment angle handling, with OTS also performing drive errors and rotational axes positions compensation due to available feedback. That is, when tracking using OTS, there are practically no requirements for drive errors and rotational axes positions. These sensors controlled the angles of heliostat turning in terms of azimuth and zenith. Field research of the sensors operation was performed. The experimental design was as follows: heliostat was put into the tracking mode using an optical sensor, while turning angles were determined by an angular sensor and further compared in time with the designed angles of turning. TSS

operates as follows. The control program calculates the Sun's angular position in a coordinate system associated with a concentrator (or heliostat) — the Sun's angular coordinates are determined, based on which the software determines the angles of heliostat turning (the angles of concentrator turning are equal to the Sun's angular coordinates in one CS), the drives receive a signal for handling of these angles. That is, TSS cannot “see” the Sun, and thus there is no compensation of drive errors and rotational axes and, accordingly, control algorithm errors. But here we also obviously need control of concentrator turning angles, i.e. feedback is required as well. This task was considered and solved in the course of development of the Big Solar Furnace (BSF) heliostat software control system; the azimuthal and zenithal drive reducers were equipped with angular sensors at a pitch of about 36 arcsec.

2 THEORY AND CALCULATIONS

As is known, solar cell concentrators (heliostats) must turn (keep track) of the Sun with a certain level of accuracy due to its apparent movement.

At the initial approximation, the defocusing leads to a shift of a concentrated spot at the receiver. The methodical task setting (concepts of static and dynamic defocusing modes), as well as experimental and calculation studies of the influence of defocusing, virtually the only ones to the present day, were conducted in [2-5]. In these studies, allowed values for defocusing angles β were identified for energy concentrators. It was found that β must not exceed 16 *arcmin* at the acceptable flow reduction at the receiver by 10% for concentrators of solar power plants. At that, along with concentrator's accuracy characteristics, tracking accuracy is one of the factors influencing the solar radiation concentration, i.e. irradiance variation in the focus and mean concentrations at the receiver. Tracking accuracy, as was determined above, is clearly defined by a defocusing angle β or by an angular deviation of axial solar beams from either optical axis of the concentrator (the concentrator mode) or predetermined direction of solar beam reflection from the heliostat (the heliostat mode). The issue of permissible defocusing angles also becomes relevant due to problems of development of software systems for concentrators (heliostats) to keep track of the Sun. Acceptable values of defocusing angles obtained in [2-5] generally al-

low to make the conclusion on possible requirements for the tracking accuracy, although during the design of tracking systems it is still assumed that the tracking accuracy must not exceed 1 *arcmin*.

Flow densities at the receiver's surface elements and subsequently flows will be determined using the model suggested by Grilikhes V.A. [3]. This model assumes that even if beams are reflected from a non-precise concentrator, the angular dimension of the reflected solar cone will not change; and that concentrator inaccuracies are distributed according to some randomly set rule with the standard angular deviation σ of normal in relation to normal of a precise concentrator. In practice, this integral is defined numerically and actually is replaced by a sum of the following type. For example, when determining the flow on the area S_R of the receiver, it will be as follows:

$$E_A = \sum_{S_R} \sum_{S_C} B(\mathbf{a}) * (\mathbf{n}_M * \mathbf{a}) * (\mathbf{n}_A * \mathbf{a}) * d\omega \quad (1.1.)$$

$$S_R \quad S_C$$

where $B(\mathbf{a})$ is the brightness of the reflected solar beam from the M point (the surface element of the concentrator in the direction of A point of the receiver (the unit vector \mathbf{a}); \mathbf{n}_M and \mathbf{n}_A are M and A area normals; $d\omega$ is the elementary solid angle with a vertex in the A point; S_R, S_C are surface areas of the receiver and the concentrator.

As stated in [2], the surface area of the concentrator S_C and its geometry, specular reflection factor (R_z), coordinates of M and A points, orientation of normal \mathbf{n}_A in the center of the receiver's surface element dS_A , and incident irradiation parameters (for the Sun, it is usually a vector direction of the axial solar beam \mathbf{c} , its angular radius φ_0 and the angular distribution of brightness $f(\varphi, \varphi_0)$ across the solar disk) shall be set in order to determine components of the irradiance integral. Based on these formulas, we developed an algorithm as well as software in C++ for calculation of both the irradiance and the flow from a paraboloid concentrator based on a flat receiver surface, taking into account the possibility to set the concentrator inaccuracies and the defocusing angle in the software.

The following sun spot radius r_p of the precise paraboloid will be used as the size scale, as well as for the purpose of results summarization [3]:

$$r_p = p * \varphi_0 / [(1 + \cos U_0) * \cos U_0] \quad (1.2)$$

where p is the focal paraboloid parameter ($p = 2f$, f is focal length); φ_0 is the angular radius of

the solar disk; U_0 is concentrator's opening angle valid for a circular concentrator and effective for other shapes [4].

Overall influence of the defocusing angle β on irradiance distribution in the focal plane of a precise parabolic concentrator ($\sigma = 0$) on a concentrated spot is shown in Fig. 1.1, where for comparison you may also see irradiance distribution for a non-precise concentrator ($\sigma = 8$ arcmin) for the case of $\beta = 0$. As we can see, assumptions in [1, 10] were confirmed, as sufficiently large defocusing angles mainly resulted in the shifting of spot leaving the irradiance curve's shape unchanged.

Thus, the following typical dimensions of the spot radii may be identified for the given concentrator with $U_0 = 58.7^\circ$ for the area radius r in fractions of the image spot radius of the precise concentrator r_p : I – the focal up to $r/r_p \approx 0.05$, where $C \approx 42,324$ (at $\sigma = 0$) and $C \approx 18,800$ (at $\sigma = 8$); II – the area of high mean concentration, up to $r/r_p \approx 0.25$ where $C \approx 40,440$ ($\sigma = 0$) and $C \approx 18,100$ ($\sigma = 8$); III – the border of sharp drop of the irradiance curve, up to $r/r_p \approx 0.35$ where $C \approx 38,600$ at $\sigma = 0$, while for the non-precise concentrator, it is up to $r/r_p \approx 0.7$ where $C \approx 12,200$ ($\sigma = 8$); IV – the border of a sloping part and the irradiance curve, the radius of which for a precise concentrator is equal to $r/r_p \approx 0.65$ and $C \approx 20,500$ ($\sigma = 0$), while for a non-precise concentrator it is $r/r_p \approx 1$ and $C \approx 8000$ ($\sigma = 8$). That is, even in the case of the non-precise paraboloid concentrator, the average concentrations are quite high within the spot. Moreover, which is important in practice, for the non-precise concentrator the main flow falls into the spot area of the precise concentrator, i.e. in the area of $r/r_p \approx 1$.

For the same concentrator tab. 1.1 illustrates flow changes at these areas depending on the angle of defocusing β for both precise ($\sigma = 0$) and non-precise ($\sigma = 8'$) concentrators. To sum up the results, F_β flows at the receiver are shown in a relative form, as the fractions of flow incident on this area in the absence of defocusing $F_{\beta=0}$, i.e. when $\beta=0$. To allow determination of the $F_{\beta=0}$ flow fraction in the total flow, there are also $F_{\beta=0}$ values given in fractions of the total flow F_P [5] reflected from the concentrator.

Due to the fact that the flow change depending on β is quite minor, requirements for tracking inaccuracy α_C and its impact on reduction of flow $\Delta F / F_{\beta=0} = (1 - F_\beta / F_{\beta=0}) * 100\%$ for the practical case — the non-precise concentrator

with $\sigma = 8'$ — are presented in a tabular form (Table 1). Here we may clearly see the actual difference between the defocusing angle and tracking inaccuracies or the misalignment angle. Thus, in fact, to ensure the required defocusing angle, it is necessary that actuation angles α_a and α_h or projections of misalignment angle α at $\alpha_a = \alpha_h$ in the sensor planes were:

$$\alpha_a = \alpha_h = 0.7\alpha. \quad (1.3)$$

TABLE 1: Flow Reduction ($\Delta F / F_{\beta=0}$, %) At The Receiver Of R/R_p Radius, Depending On The Misalignment Angle α_C And Tracking Inaccuracy $\alpha_A = \alpha_H$ For A Non-Precise Concentrator ($\sigma = 8'$).

$\alpha_C = \beta$, arcmin	$\alpha_a = \alpha_h$, arcmin	area radius, r/r_p			
		0.05	0.25	0.7	1.0
		$\Delta F / F_{\beta=0} = (1 - F_\beta / F_{\beta=0}) * 100\%$			
0	0	0	0	0	0
1	0.7	0	-0.1	-0.1	-0.03
2	1.4	0.6	0.1	0.1	0.08
3	2.1	0.6	0.7	0.6	0.3
4	2.8	0.8	1.5	1.2	0.8
5	3.5	1.4	2.7	2.2	1.3
6	4.2	2.8	4.2	3.4	1.9
7	4.9	4.6	5.9	4.8	2.8
8	5.6	7	8.0	6.5	3.7
9	6.3	8.8	10.0	8.3	4.8
10	7	12	13	10.4	6.0

As Table 1. shows, in the case of tracking inaccuracy $\alpha_C = 2'$ ($\alpha_a = \alpha_h = 1.4'$), almost no reduction of flow and, consequently, concentration C occurs, and reduction of about 1% only occurs when $\alpha_C = 4'$ ($\alpha_a = \alpha_h = 2.8'$). Thus, tracking accuracy may be at the level of $4'$ ($\alpha_a = \alpha_h = 2.8'$) for solar furnaces, while for solar power plants tracking inaccuracy may be up to $7'$ ($\alpha_a = \alpha_h = 4.9'$) for the cases where the receiver radii (r/r_p) are at the level of 0.7-1 with acceptable flow reduction of 3%.

Having determined the software tracking accuracy in the Lab View virtual environment, we considered the model of application of a wireless communication device and self-contained power supply in heliostat units with centralized monitoring and control system.[7,11,12]

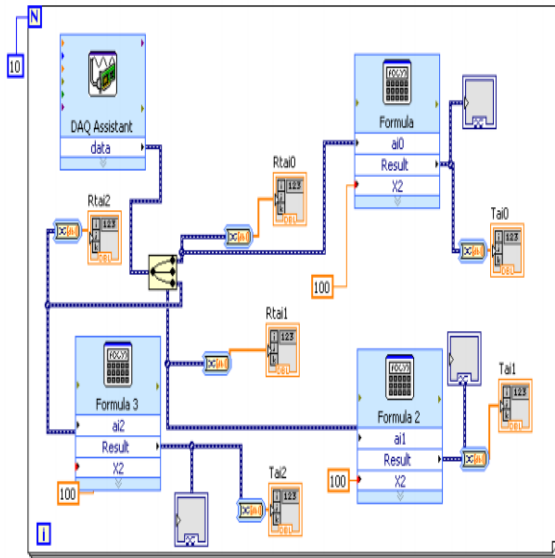


Figure 1. Creates a window of the diagram in Lab View

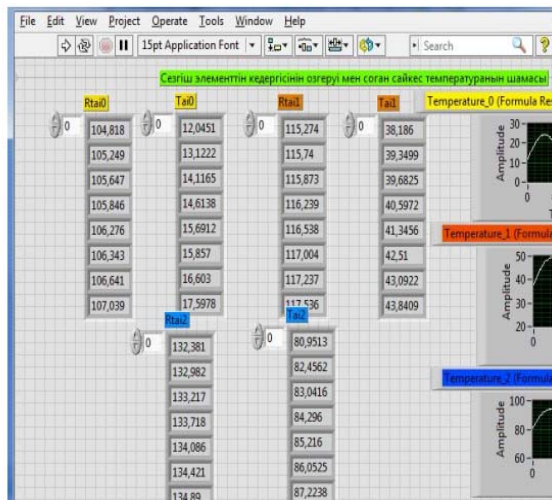


Figure 2. Meteorological Parameters In Labview Format Opened With Graphics Editor National Instruments Labview

3 EXPERIMENTAL MATERIALS AND METHODS

Currently, three types of heliostat automation systems are used, i.e.:

- the individual automatic control system;
- the centralized monitoring and control system;
- the combined monitoring and control system.

The operation concept of the individual automatic control system is that each heliostat

operates individually, independently of each other, and each of them is equipped with tracking, positioning and orientation devices.

The centralized automation system monitors and controls the whole heliostat field from the operator's room.

The combined automation control system includes both of the above control systems [3, 17].

Let us consider the centralized control system for solar power station (SPS) automation. In addition to individual heliostat control system devices, the centralized control system includes centralized control devices with functions of feedback and control of each heliostat's orientation.

When controlling the SPS heliostat field, the control commands (certain codes of analog or digital signals) are sequentially transferred in a group or separately to each heliostat individually: start of operation, movement, stop, end of operation and reset. Control commands (electric signals) are transferred to heliostats via signal cables while power is transferred via power cables. The precise control of a corresponding heliostat is achieved by introduction of a specific system of signal coding and receiver addressing. Accuracy of heliostat control will be mainly determined by accuracy of automatic control system operation.

Figure 3 presents a block diagram of a centralized automatic monitoring and control system, which performs control from the primary system by means of continuous signals or impulses sent at specific time intervals according to the Sun's position on the dome of the sky. At that, the control commands must be generated (formed) in the primary control system.

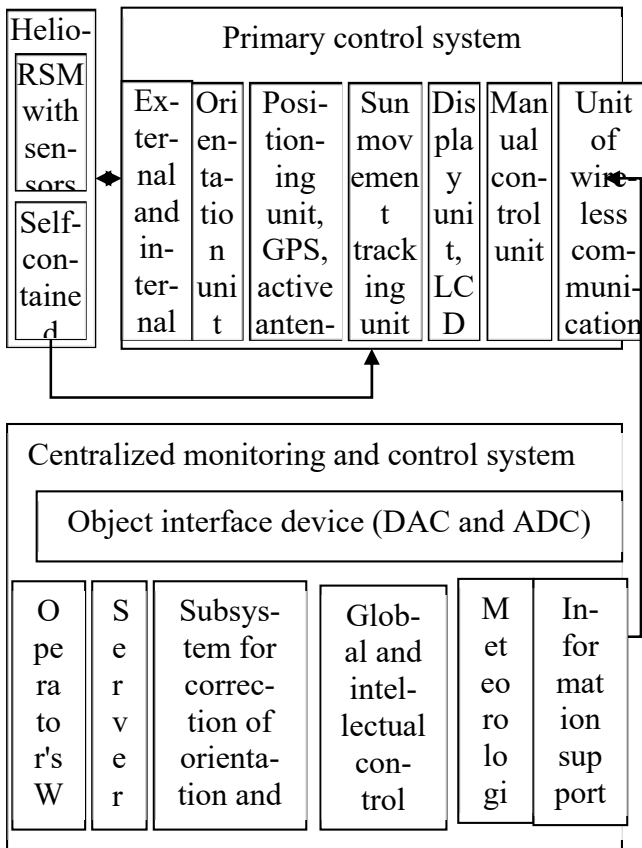


Figure 3- Centralized Monitoring And Control System

In case of use of the above automated control system (ACS) scheme with optical SPSs, each heliostat must be equipped with two electric drives with appropriate reduction gears to ensure zenithal and azimuthal turning and with four position sensors for precise pointing (on each heliostat) [1,8].

The considered automatic heliostat control system is one of types of measuring informational and control systems, which are complexes of measuring instruments and information-processing equipment. Their characteristic feature is that they are designed to obtain information on operating parameters values, which are characterized by the “pointed” or “misaligned” states, directly from the controlled (monitored) object. That is why such control systems must be functionally linked with the controlled object and must receive information directly from the object (from heliostat groups).



Figure 3a- Experimental Device For Control System

The matter of remote information transmission, i.e. communication channels, is of special importance for automated control systems on optical SPSs with a great number of heliostats.

The automatic control unit for all heliostats of an optical SPS system deals with signals transmitting information over a distance via wires (communication channels) [11,14]. Their main objectives are communication effectiveness and reliability, i.e. transmission of the greatest volume of information using the most economical way with the least distortion caused by various disturbances introduced by the communication channels themselves or due to other reasons.

For sequential control of turning of separate heliostat groups, the control signals must be transmitted via the communication channel in a specific sequence. This function may be performed by a multichannel system with time distribution of the channels. When building multichannel systems, the values of controlled variables are usually represented by a uniform parameter, such as DC voltage, resistance, etc. To transmit values via a communication channel,

the uniform parameter is converted to an intermediate parameter, which ensures the least errors caused by instability of communication channel parameters or disturbances. At the receiving point, the intermediate parameter is converted to direct current or other signals allowing to register the values of controlled variables or reproduce them.

4 RESULTS AND ANALYSIS

Thus, analysis of design, technical parameters of heliostats on operating tower-type SPSs, as well as analysis of the composition, functions and operation of automation systems allow us to make the following conclusions [5,9,15]:

- land area utilization efficiency is not high, as heliostats are bulky and, accordingly, the area occupied by a heliostat field is very large;
- the cost of a heliostat with the reflective surface area of 50 m², a tower with height of 80 m or more, equipped with a tracking system, position sensors, electronic positioning and orientation devices is relatively high;
- large overall dimensions and weight of heliostats complicate their control in terms of accuracy of sun rays pointing to a receiver (free play, deformation, etc.);
- coordination of the industrial computer with controlled objects requires a great amount of DAC and ADC inputs and outputs;
- high power consumption by automation devices and the monitoring and control system.

In an optical system of tower-type SPS, the communication with the upper level of the automation system is carried out via a signal cable network. Heliostat power supply is arranged via a power cable network. Power and signal cables are laid in special ducts, trays and trenches. Currently, costs of cables and their laying are rather high, and they comprise 10% of the SPS's total cost.

With development of network and telecommunications technologies, wireless communication between detectors, transducers and industrial logical controllers is widely used in modern SCADAs. These devices are small and may be embedded directly into primary automation facilities. These devices are cheap and their application is more advantageous than laying hundreds meters of cable. That is why, to reduce costs and expenses on purchase and laying of signal cables, we propose to use cheap but effective wireless devices.

This device can transmit both analog and discrete signals over a distance of up to two kilometers. The transmit and receive speed is 10 Mbit/s, the transmitter's operating frequency is 2.8 MHz. power supply is 5 V. The heliostat is equipped with RSM, electronic RSU motor control unit and wireless receiver and transmitter. To provide them with DC power, we propose to equip every heliostat with a self-contained power supply. [11,12,15]

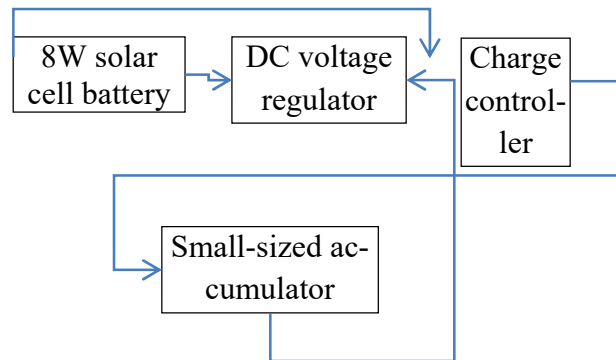


Figure 4: - Block Diagram Of Self-Contained DC Power Supply Composition

This power source (PS) consists of the following units presented in Figure 5.

This PS is cheap and small-sized. The solar panel is installed directly on the heliostat's reflecting surface. Heliostat operates only in weather when concentrated solar radiation in the receiver is sufficient for steam generation, while the rest of the time it is in the standby mode.[15] That is why use of a solar battery-powered self-contained power supply in our opinion is more advantageous than use of centralized power supply from the industrial network. It should be noted that this self-contained PS is designed to supply several adjacent small-sized heliostats.

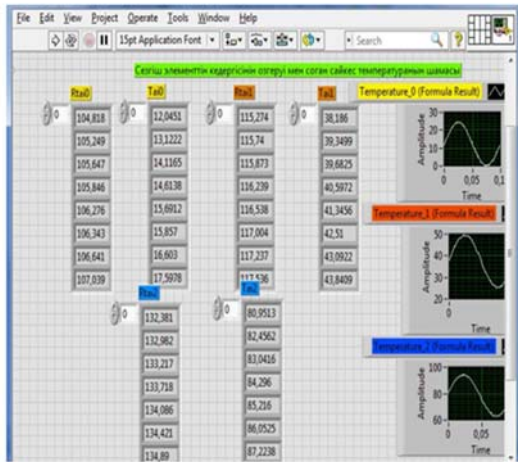


Figure 5: - Window Of Self-Contained DC Power Supply Composition In LW

All the electronic control devices of the five heliostats are connected to the self-contained PS, but all RSM motors are disconnected from PS, and each RSM motor n_i sequentially connects to PS when performing functions of pointing, manual control, reset after maintenance or repair, setting to the next morning position and specific positioning in the period of extreme weather conditions.

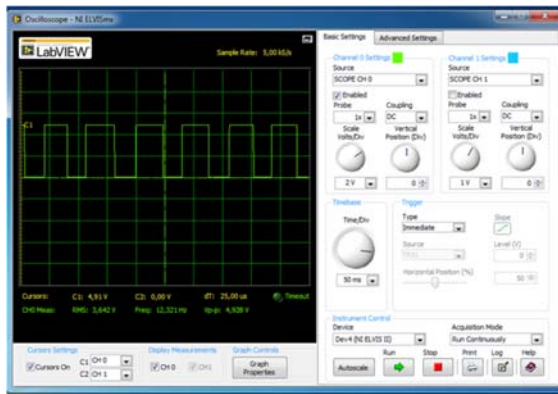


Figure 6: - Calculation Of Parameters Impulse Sensitive Elements Using Virtual Oscilloscope

Thus, the monitoring and control methods fundamentally change when using a self-contained PS.



Figure 7: - Meteor Station And Systems Of Wireless

5 CONCLUSIONS

The use of modern control systems, heliostats optical system SES wireless connections between sensors, transducers and industrial logic controllers. The proposed model is beneficial compared to laying hundreds of meters of cables. For power proposes to implement each heliostat a self-contained power source, since the heliostat works when concentrated solar radiation in the receiver is sufficient to generate steam, and the rest of the time it is in sleep mode. Therefore, the use offline SP solar will be more profitable than using a Central supply from an industrial network. 3. Application of PIC microcontroller with a special subroutine that implements the function of the equation of motion of the object. Development of the electronic scheme of the tracking system based on PIC microcontroller

will allow to adapt and combine the functions of control and surveillance into one whole, which will reduce the ratio of the inertia and lag of the tracking system through the use of a combined tracking system. Software management "constantly ahead of the curve" adjusts the coordinates of the position of the Sun and heliostat and thereby less time spent on search of the Sun in the celestial sphere. [15]

Tracking inaccuracy calculations and available conclusions given us the 15% efficiency factor based on the defined general relation between the defocusing angle β and misalignment angle α in measuring planes of the optical tracking sensor. [19] It was shown that for cases of both concentrator and heliostat modes of tracking, α is always equal to β , although the nature of their changing as well as their projections may vary, and that in practice the actual tracking inaccuracy in the sensor planes must not exceed $\alpha_a = \alpha_n \leq 0.7\beta$. [16]

Common link between the defocusing angle β and misalignment angle α in measuring planes of the tracking optic sensor has been determined, we demonstrated that $\alpha = \beta$ always, both in the concentrator and in the heliostat tracking mode, though the nature of their variation and their projections may differ, and in practice the actual tracking inaccuracy in sensor planes must not exceed $\alpha_a = \alpha_n \leq 0.7\beta$.

As distinct from other measuring informational systems, the described heliostat control system operates only when tracking parameters deviate towards the maximum permitted values. Thus, the considered diagram provides a much simpler way of comparing the obtained parameters against the preset parameters.

In contrast to existing foreign analogues we have developed the automation system has a centralized tracking system, the intelligent part of the system automation performs a logical analysis of the weather condition and independently produces the mode selection optical system. Monitoring and control between the automation system and the optical system is carried out by wireless digital communication.

Simulation Algorithm Design
The simulation is designed using MATLAB®. The model in-takes data at an hourly base for a typical meteorological year; builds up geometric structures of sky dome, ground as reflector, panels and their racking posts; checks the ray blocking and shading due to the geometry; and outputs the annual energy generated by a bi-

facial solar panel under investigation (Figure 8).

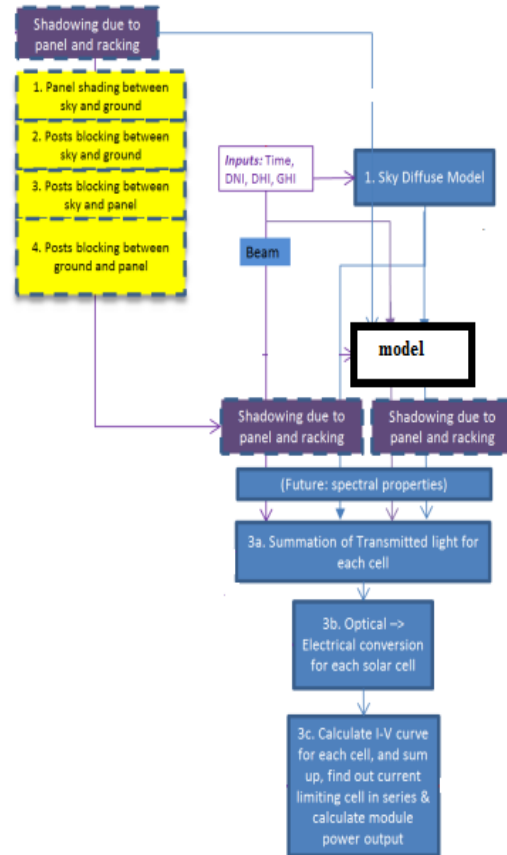


Figure 8 The Top-Layer Scheme Of The Bifacial Solar Panel Simulation Algorithm

First of all, although this simulation intends for South Kazakhstan implementation, it can be applied to anywhere in south hemisphere.

This simulation model set up a complicated scenario model with detailed consideration of various aspects.

More speeches are detailed below:

X Contrary to expectations, the posts of the casting shades of the beam significantly impact the panel annual energy yield.

X Intelligent system boosts about 13% of the annual yield from the mono-facial solar panel of the same quality when set south facing, latitude tilt and 1 meter clearance.

The simulation model may be used as a platform, more analysis may be executed in the future, and also more performance and functionalities may be built upon.

Based on the existing model, further investigation topics may include but not limited to the following:

X A detailed intelligent solar cell model based on

its physics and automatic working principles; X OPU is an important factor in photon absorption thus increase output;

Electricity generation from solar energy has great potential because it relies mainly on abundant and clean source. However, there is a lot of mutable and immutable factors that can drive the PV module efficiency. Dust is one of the environmental factors, location-dependent, which fall under unchangeable factors. This can decrease the efficiency of PV panels, causing physical damage, weakening incoming solar radiation and increase in temperature, which leads to changes in electrical characteristics. In the future continues to develop intellectually clean the panels with a support swivel mechanisms.

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