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Design and Research of Dual-Axis Solar Tracking System in Condition of Town Almaty.

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Abstract: The solar tracking system is the most common method of increasing the efficiency of solar photo module. This study presents the efficiencies of energy conversion of photo module with solar tracking system and fixed photo module. The proposed sun tracking system uses 4 photo resistors, which are mounted on the sides of the photo module. By these photo resistors the solar tracking system becomes more sensitive and it allows to determining a more accurate location of the sun. A comparative analysis was performed between fixed and dual-axis tracking systems. The results showed that the dual-axis solar tracking system produced 31.3% more power compared with stationary photo module.

Key words: Sun tracking system · Photo module · Microcontroller · Solar energy · Technology · Stationary.

INTRODUCTION

Nowadays, the development of the electricity industry is facing major changes. The progressive development of technology pushes the energy industry to a new level of energy development on the Earth. The mankind always looked for the most available and environmental friendly type of the electric power in the way of development. Since XIX-XX centuries till present time, the basic and almost irreplaceable source of the electric power were hydrocarbons which damage the environment in the form of greenhouse effects. That in turn has led to changes in the climate of the planet. But with the development of techniques and technologies, alternative types of energy, which are cheaper, environmental friendly as well easily accessible wind, sun and water energy, have become available. If, hydrocarbons would be equally accessible to all and are also cheap and environmental friendly to use as alternative energy sources, it may not have had such a high level of development in the field of renewable energy sources. In this regard, the XXI century humanity has linked its further development with green energy and alternative energy sources.

At present the share of solar energy in the energy market is not great, but it is a temporary phenomenon. And the average efficiency of photovoltaic cell varies between 15-22%. Yet in the wake of the development of scientific and technological progress, these figures are not a limit. There are a number of alternative ways to increase those numbers and on which many scientists from different countries are working hard.

In our research, in order to increase efficiency photo module optimization, installing of solar panels on the basis of follow-up was considered, which is designed to track the sun movement. The sun's rays fall on the surface of the panel at an angle of 90° degrees improves production efficiency of PV modules (Fig 1.), therefore the design mentioned above, has been applied.

Efficiency in practice means a ratio of a maximum power P_{max}, which can be removed from the unit area photo module the total solar radiation power W, incident perpendicularly on the surface of the working unit photo module expressed in percentage:

$$W = A * \lambda \cos\theta \tag{1}$$

$$\eta = \frac{P_{\max}}{W} * 100\% \tag{2}$$

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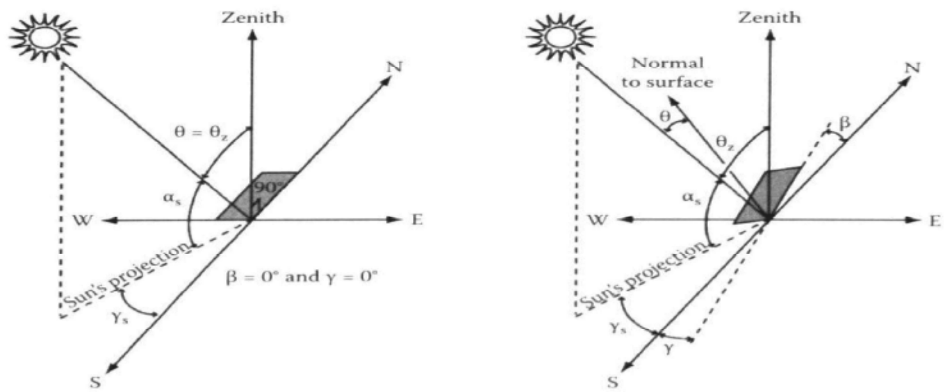

Fig. 1: The angle of incidence of light for the photo module

Here, *A* represents a certain limiting factor in the design of transformation, because they cannot convert 100% of the solar light absorbed into electricity.

To create photon pairs in the semiconductor electron - hole requires a certain energy. In silicon it is 1.12 eV, which corresponds to a wavelength of 1.2 microns. Photons with a longer wavelength have a lower energy and therefore completely useless. The photons with a shorter wavelength can also generate pairs of electron - hole, but efficiency in this case decreases as the excess over the amount of photon energy 1.12 eV is dissipated as heat. It can be shown that the theoretical efficiency element silicon for solar spectrum must be approximately equal to 22 - 23%. Thereby neglecting internal losses and assume that all pairs are used electron - hole formed in the material by light. Real photovoltaics have much lower efficiency since several factors reduce this figure. These factors are quite numerous and they can be divided into two groups. For one of them could be the factors contributing to the imperfection of instruments and to the other - depending on the operating conditions [1].

Many scholars have proposed various methods of tracking the sun. [4,6-9]. Permanently mounted photo module can produce a high percentage of the energy available only in the afternoon, a significant power is available in the early mornings and afternoons in the time interval 8.30-15.00 [5]. Thus, the main benefit of the system is tracking to gather as much solar energy for the longest period of the day with the most accurate alignment. Relying on such an environment, in our research, in the coordinates of N $43°13^{I}50^{II}$ and E $76°46^{I}33^{II}$ data were taken from the PV modules. Stationary photo module was fixed at 23.5° degrees to the optimum relationship of land and photo module with a tracking mode reacts to sun themselves.

Description of Solar Cell: Atoms in semiconductor are excited by the influence of light and extra electron-hole pairs are formed in the *n* and *p* regions of the crystal. The resulting electrons and holes participating in thermal motion start to move in different directions, including towards the *p-n* junction.

Due to the potential barrier of a *p-n* junction will separate the main diffusing to it non-core excess carriers. As a result of this separation excess electrons will accumulate in the *n* region of the crystal, whereas excess holes will accumulate in the *p* region. The accumulation of excess electrons in the *n* region and holes in the *p* region of the photo module will lead to space charge compensation, concentrated at the *p-n* junction, that is, to the creation of the electric field oppositely directed to the field which had already been there. Formed by light electric field positively charges the left layer of *p* type and negatively charges the right layer of *n* type. A photo EMF (Electromotive force) is created between the regions of the plate. The concentration of light formed extra carriers at *p-n* junction and, consequently, the quantity of photo EMF depend on light intensity and the magnitude of the load resistance connected to the external circuit of the photo module.

The following current-voltage characteristic determining formulae were used during the research of real photo module (Fig.2):

$$I_l \approx I_{ph} - I_o\left(e^{\frac{q}{kt}(U_l+I_lR_l)}-1\right) \tag{3}$$

$$U_l \approx \frac{kT}{q}\left(In\left(\frac{I_{ph}-t_l}{I_o}+1\right)\right)-I_lR_{ph} \tag{4}$$

$$P = I_lU_l \approx \xi U_{oc}I_{sc} \tag{5}$$

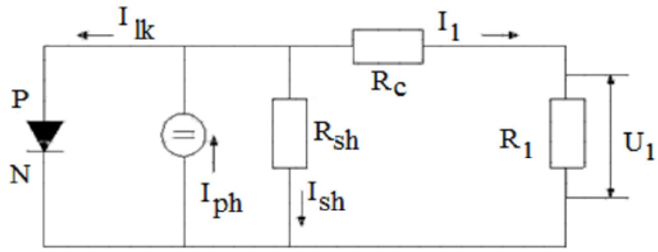

Fig. 2: The real photo module scheme.

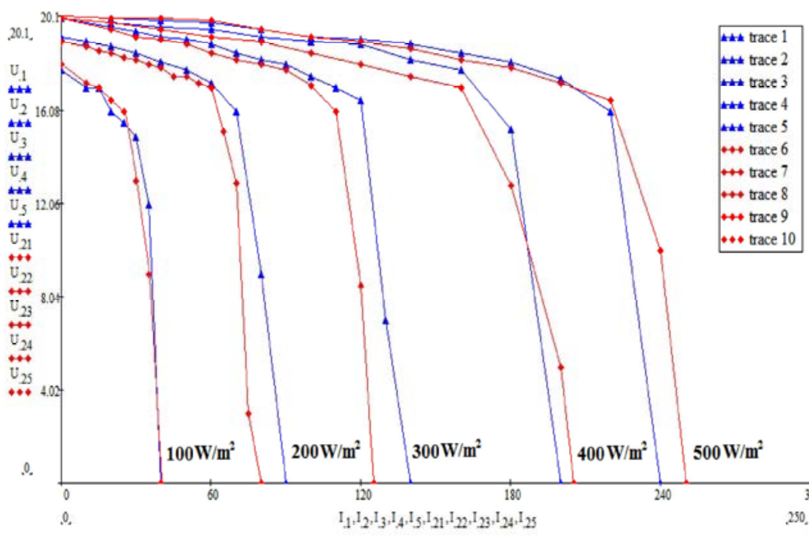

Fig. 3: Current-voltage characteristics of PV modules

I_l = Load current
U_l = Load voltage
I_{ph} = Current from the light
I_{sc} = Short-circuit current
I_0 = Algebraic sum of the hole and electron currents of minority carriers across the *p-n* junction in the dark.
R_l = Load resistance
U_{oc} = Open-circuit voltage
R_{ph} = Resistance photo module
q = The electron charge ($1{,}6*10^{-19}$)
K = Boltzmann constant ($1{,}38*10^{-16}$)
T = Absolute temperature
[*Xi*] = Value, which can be called the fill factor (this ratio shows how much of a power, the product of and U_{oc} and I_{ssc}, is the power taken from photo module; for the good elements the value of [*Xi*] can be up to 0.8) [1-3].

For research were selected two monocrystalline silicon cells with the same characteristics. These cells are made from pure monocrystalline silicon. in these cells, the silicon has a single continuous crystal lattice structure with almost no defects or impurities. The main advantage of monocrystalline cells is their high efficiency, which is typically around 15%. The disadvantage of these cells is that a complicated manufacturing process is required to produce monocrystalline silicon, which results in slightly higher costs than those of other technologies [10].

So initially were compared current-voltage characteristics of PV modules (Fig.3.). And from obtained values of PV modules have been defined difference in 9-13%, which is within the normal range. In laboratory bench PV modules are tested at different illumination.

Designing a System for Tracking the Sun: In this research when choosing a tracking system, several conditions were determined. They are the cheapness of management system, the ease of assembly plan (Fig.3) and the highest precision of the work. Firstly, all the items in the scheme are available and affordable. For example, LM324N type operational amplifier, TIP41C and TIP42C type transistors, 1N5407 type diodes, resistors, adjustable resistor, light dependent resistors (LDR) and capacitor

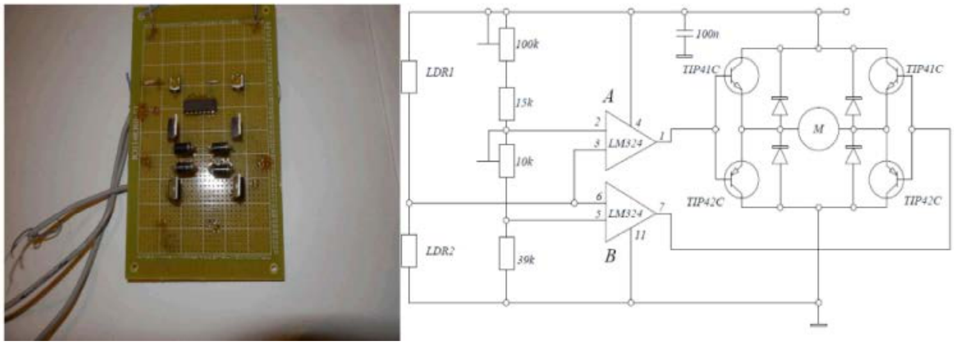

Fig. 4: Wiring diagram of the controller

Fig. 5: Dual-axis tracking system.

Table 1: The action algorithm of controller

Channel A	Channel B	Motor condition
Low	Low	Stopped
Low	High	Forward
High	Low	Backward
High	High	Stopped

totally cost 5-8 U.S. dollars. Secondly, the simplest operational amplifier (MCU) was chosen. Mode of operation depended on the values of photo resistors and LDR. To track the sun, the system should work in closed loop form, the controller needs to sense the light through a light sensor. For this purpose LDR were used. The LDR consists of a disc of a disc of semiconductor material with 2 electrodes on its surface. In the dark or in dim light, the material of the disc has relatively small number of free electrons in it. There are few electrons to carry electric charge. This means that it is a poor conductor of electric current. Its resistance is high. In the light, more electrons escape from the atoms of the semiconductor. There are more electrons to carry electric charge. It becomes a good conductor [7]. If the value of LDR are varied depending on the light, so the device gives out a voltage to one of its outputs, which resulted in the movement of the motor. Thirdly, resistors and photo resistors were calculated and chosen very carefully. Photo resistors had to have the same meaning, which is very important. The trimmer was easily configured according to the output voltage. The motor worked at 12V, but at lower voltages moved very slowly, which was necessary for the smooth tracking of the sun. The simple algorithm of micro scheme and motor work is shown in the table below (Table.1).

RESULTS

The study was conducted in 20.10.2013, in the coordinates of N 43°13ˡ50ˡˡ E 76°46ˡ33ˡˡ. In the 7.00a.m.-18.30p.m. of time period, from both PV modules have been obtained values of current and voltage (Table 2.). In accordance with obtained values was built a comparative graph of powers (Fig.5).

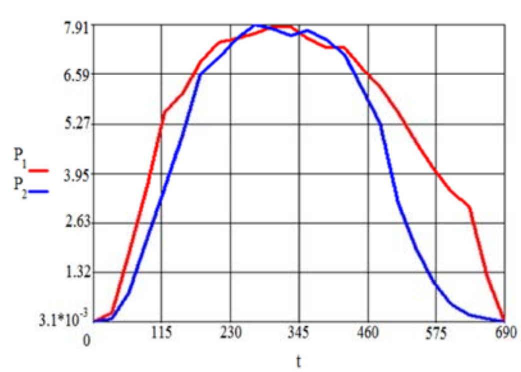

Fig. 5: Graph of the PV cell power for fixed and tracking systems. P1- dual-axis, P2- stationary.

Table 2: Mono crystalline PV modules (20.10.2013)

	Dual-axis			Stationary			Difference between St. and Dual-Axis
Time, hh.mm	U, V	I, mA	P, W	U, V	I, mA	P, W	ç, %
7.00	10.75	0.62	0.0067	10.27	0.55	0.0056	16.48
7.30	18.30	11.80	0.22	15.30	5.55	0.085	61.36
8.00	20.90	87.60	1.83	19.27	41.5	0.799	56.34
8.30	21.50	167.5	3.6	20.80	107.9	2.24	37.78
9.00	21.30	260	5.54	21.0	169.4	3.55	35.92
9.30	20.90	290	6.061	20.90	240	5.01	17.34
10.00	20.90	330	6.89	20.60	320	6.59	4.035
10.30	21.20	350	7.42	20.60	340	7	5.66
11.00	20.90	360	7.52	20.40	370	7.54	-0.27
11.30	20.70	370	7.66	20.30	390	7.91	-3.26
12.00	20.60	380	7.83	20.50	380	7.79	0.511
12.30	21.20	370	7.84	20.60	370	7.62	2.81
13.00	20.90	360	7.52	20.40	380	7.75	-3.1
13.30	20.80	350	7.28	20.30	370	7.51	-3.2
14.00	20.80	350	7.28	20.30	350	7.10	2.47
14.30	20.40	330	6.73	20.10	310	6.23	7.43
15.00	20.80	300	6.24	20.30	260	5.27	15.54
15.30	20.60	270	5.56	19.80	160	3.16	43.16
16.00	20.60	230	4.74	19.20	100	1.92	59.49
16.30	20.30	200	4.06	18.90	56	1.05	74.14
17.00	19.50	178	3.47	18.70	25	0.46	86.74
17.30	19.20	160	3.07	18.10	10.30	0.18	94.137
18.00	18.10	66	1.18	17.50	4.0	0.07	94.1
18.30	10.55	0.54	0.0057	6.80	0.45	0.0031	45.61
						Total	31.3%

CONCLUSION

This article was proposed by the system of dual-axis sun tracking based on type of microcontroller LM324N. This article has shown, the development and implementation of dual-axis sun tracking system with minimal effort. The mechanical structure was very simple and reliable, it has been designed in such a way that the entire controller card should fit into the platform tracking system. The scheme was designed with a minimal number of components to minimize cost and to simplify the assembly have been integrated onto a single board.

The article shows the optimality of the dual-axis sun tracking system compared to a stationary photovoltaic cell. A dual-axis tracking system produces 31.3 % more power than fixed photo module in the coordinates N 43°13^{I}50^{II} E 76°46^{I}33^{II}.

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