Marcin MOCZAŁA[1], Mariusz Piotr HETMAŃCZYK[2*]

[1,2]Institute of Engineering Processes Automation and Integrated Manufacturing Systems,
Faculty of Mechanical Engineering, Gliwice, Poland
[*]mariusz.hetmanczyk@polsl.pl

THE MINIATURE PHOTOVOLTAIC SYSTEM WITH SUN-TRACKING ALGORITHM

Abstract: To the non-renewable energy sources belongs each source which is not subjected to a process of renewal in a short time. This means that theirs consumption is much faster than the replenishment of the stock. According to the laws of power engineering departments the conventional energy source mostly is obtained by the combustion of organic fossil fuels. Due to the limitation of resources appears the necessity of looking for new alternative energy sources, among others wind, solar, hydro, etc. The article presents the model of the miniature photovoltaic system with the Sun-Tracking algorithm.The authors also described the designed mechanical structure, control system, selection of sensory elements, security devices and wiring diagrams.

1. Introduction

The noticeable increase in prices of energy derived from fossil fuels and simultaneous growing environmental demands have contributed to an intensification of work focused on improving usage of renewable energy sources [1].

Advanced systems for converting solar energy into electricity are likely to prevail also in Poland, provided that the technology development will be accompanied by a marked decline in their prices [2]. This effect will allow for significantly increase the profitability of investment in this area [3]. It is estimated that over the next ten years the price of energy produced in the traditional way and by photovoltaic systems will be equal.

The simplest devices used for converting solar into electrical energy are photovoltaic cells. The increase of interest in the world market is caused by first of all by a direct conversion of solar energy into electricity without noise and pollution.

Photovoltaic systems are divided at two basic types, in terms of the energy storage and its conversions, as follows [4-6]:

- OFF-GRID (also called stand-alone or island systems) - photovoltaic systems without direct connection to the electric grid,
- ON-GRID (systems fully integrated with electric grids) - designed to produce alternating current with simultaneous transmission of excess power to the electric grid.

In case of the difference at orientation methods, solar photovoltaic systems are divided into two main groups [7-9]:
- stationary - working at constant, fixed angles of azimuth and inclination to the horizontal direction,
- movable (the Sun-Tracking systems) - enable movement with respect to the horizontal axis (azimuth change, assuming that the module is inclined to the horizontal at a constant angle equals to the latitude of the place where it is installed), about a fixed vertical axis (with elevation changes) and both axes.

2. Structure of designed Sun-Tracking photovoltaic system

The basic premise was realization of structural design of biaxial system allowing positioning of photovoltaic panel surface at right angle to the axis of sunlight (regardless to the time of day and the weather conditions). To the development of a 3D model (Fig. 1) the Solid Edge was used.

The turntable consists of three basic elements:
- supporting structure with housing for mounting of drives and control devices,
- the movable platform for changing orientation of the moving elements (seated on vertical axis) by wheel rim with internal toothing driven by electric motor,
- rail with connector to mounting a photovoltaic panel and toothed bar with external toothing (a movement control in the horizontal axis).

The kinematic structure of designed device (with required mobility of axes at ranges of rotation about the vertical axis 70° and the horizontal axis 355°) allows obtaining high efficiency and (additionally with combination of implemented Sun-Tracking algorithm) an optimum positioning in respect to a direction of sun radiation.
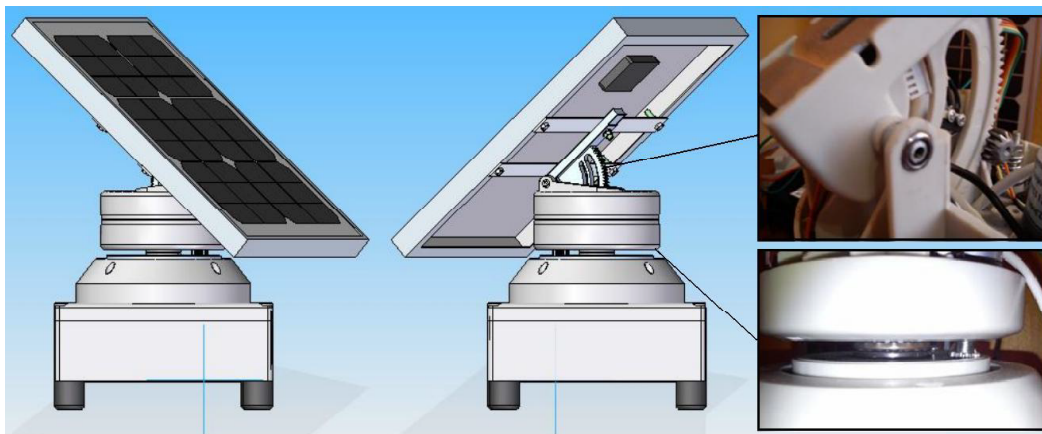

Fig.1. The 3D model view of the mini photovoltaic system with the Sun-Tracking algorithm

For the manual operation the control panel was made.The panel consists of an enclosure, two three-position switches (mono-stable), LED indicators (the voltage emergence at terminals of analog outputs), a two-position switch (selection of automatic or manual modes) and output terminal blocks.

After switching to the automatic mode, the PLC is powered up. An axis control is based on the input values (phototransistors placed on a surface of the photovoltaic module) processed by the algorithm.

All phototransistors were arranged on the circumference of the backplane at 90°. Additionally phototransistors located opposite each other are inclined at angle of 5° to each other.

3. The structure of the sensory subsystem

Sensors (Fig. 2) are powered by the 12 Volts battery, but analog inputs of the PLC unit require voltage in the range between $0 \div 10$ V. In order to protection the voltage regulator was used. By reducing the voltage elaborated system uses almost the whole measuring range of analog inputs of the PLC controller.

Resolution of the PLC controller equals 10-bits, which means that the PLC is able to recognize voltage level greater than or equal to 9.77 millivolts.
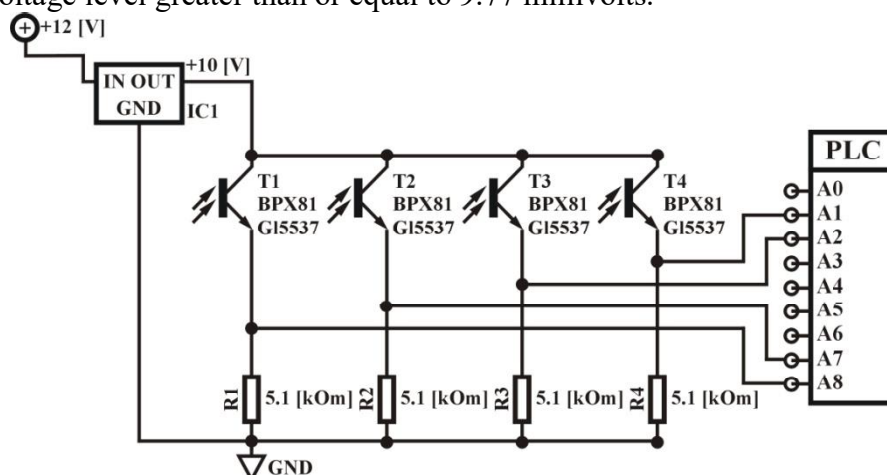

Fig.2. Wiring diagram of the sensory system with the PLC controller

To the analog inputs of the PLC controller four phototransistors have been connected. Other inputs were connected to limit switches which indicate exceeding of permissible values for rotational moves (Fig. 3).

As a result the user can select three methods for control of the orientation of the photovoltaic panel:
- an open system - positioning based on the calculated position of the sun, i.e., the clock algorithm (change in the position takes place at predetermined intervals of time),
- a closed system - positioning based on information from the sensors and the measured position of the photovoltaic cell,
- a hybrid system - a combination of open and closed systems.

For power generation the mono-crystalline solar MH10-10W was used. Selected photovoltaic cell is made up of thirty-six mono-crystalline units placed on a rigid and lightweight composite substrate, protected against damage by the hard antireflective glass. Electric contacts are terminated in a waterproof junction box.

The panels can be connected in parallel (to increase the current intensity) or in series (to increase the voltage). Efficiency of panels drops after 10 years up to 90% power, and after 25 years up to 80% nominal power.
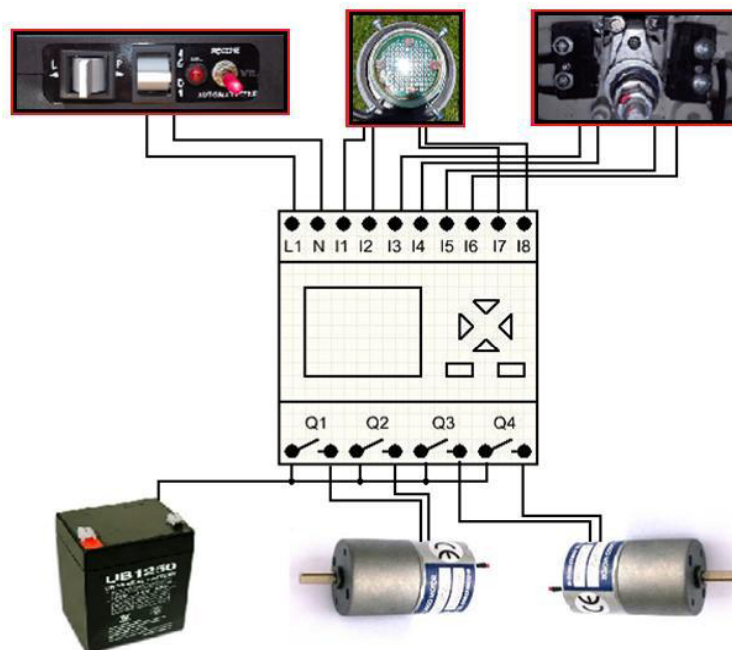

Fig.3. The schematic connection diagram of the PLC controller

The main selection criteria of axis drives can be described in few points: low power consumption, 12 Volts power supply, small overall dimensions and build-in self-locking gear. As the drives were chosen gear motors equipped with DC motors with permanent magnet (type SG-27123000-610k). Small values of the input current intensity caused that control can be realized using low-power transistors, directly from the TTL output as well as with usage operational amplifiers.

4. Practical verification of system operation

The ability to control in automatic and manual modes allows comparison the power yield with usage of stationary and movable (with the Sun-Tracking algorithm) systems (Fig. 4).

In the case of the stationary system the authors adopted the optimum location in a southerly direction at an angle of 35° above the plane of the horizon. Selection of the optimum angle was made by using the interactive PVGIS software (Photovoltaic Geographical Information System).Selected value of angle for the studied geographical coordinates allows for obtaining the greatest efficiency.

On the basis of obtained results the authors elaborate a plot (Fig. 5) illustrating the difference in received power in case of stationary and movable system with the Sun-Tracking algorithm. The difficulties associated with the use of solar energy in Poland are as follows:

- low density of the daily flux of solar radiation, which in Poland does not exceed $100W/m^2$ and its value approximately equals $1000kWh/m^2$ per year,
- existing seasonal and daily variations of solar energy radiation,

- high prices of additional and basic equipment (very high cost of producing photovoltaic cells and batteries).
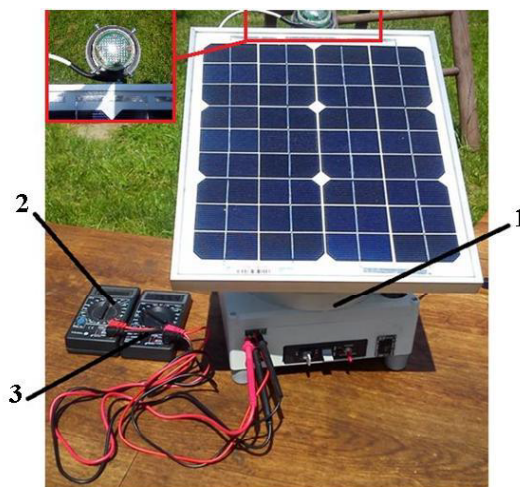

Fig.4. View of measuring stand, where: 1 - tested photovoltaic system, 2 - voltmeter, 3 - ammeter

An additional problem is the operating range, so in the winter the whole control and energy storage systems (batteries) should be kept in a positive temperature. Another important problem is icing of moving parts and stiffening of lubricants manifesting in increased motion resistance of gears.
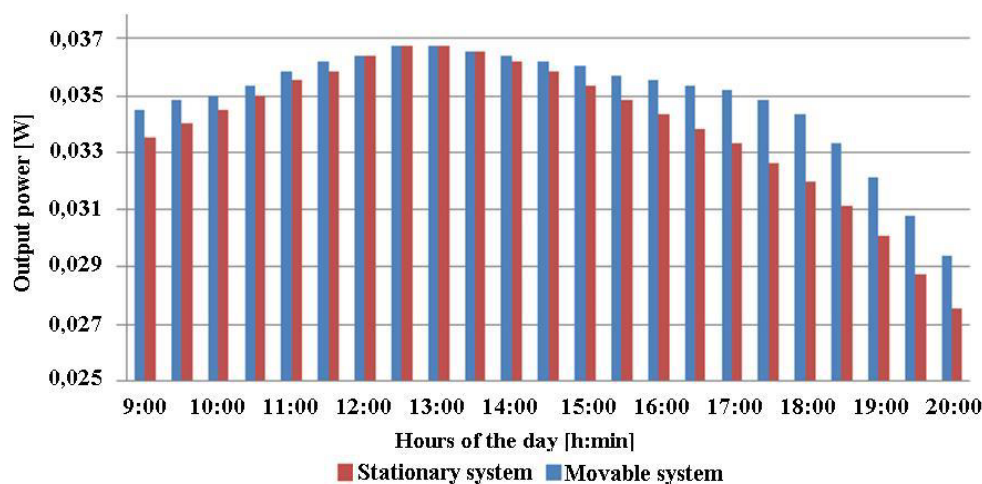

Fig.5. Comparison of results of investigated photovoltaic systems (stationary and movable)

In practice only between 12:30÷13:00 conversion results of the two systems are identical. In other cases values of energy yield are higher in use of Sun-Tracking algorithm.

On the basis of presented case it is difficult to indicate incontestable premises to the use of the Sun-Tracking algorithm. Such situation arises from the fact that within the range of analysed geographic coordinates results of the measurements exhibit only the minimum energy yield. The practical use of solar energy requires estimation of the actual and potential solar energy resources in the area and taking into account the impact of meteorological conditions tailored to the needs of used energy conversion technology.

6. Conclusions

Designed installation despite the proved energy yield, it also has a number of drawbacks in the form of: higher investment costs and the complexity as well as a high failure rate.

The advantages of photovoltaic power plant may include: the autonomous work and the lack of need for an external power supply (production of sufficient energy amount used for reorientation of photovoltaic cell and supply of external devices).

Additionally the installation with the Sun-Tracking algorithm does not require precise alignment of starting position and is characterized by a quick response to changing angle of sunlight incidence [10].

The measured values were obtained during the summer without taking into account the power consumption of other types of electric drives. In the next step should be defined characteristics in negative temperatures, which would determine the efficiency of the system in relation to the entire annual cycle.

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