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OPTIMAL POSITION SENSOR FOR ORIENTATION OF PHOTOVOLTAIC PLANTS

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Abstract: *The produced volume of an electrical energy in non-concentrated, photovoltaic plants may significantly increase if the panel orientation is changing, to follow the optimal position. There are a number of methods and sensors, used to find the PV panel optimal orientation, which depend not only on sun position, but on sky (sun) insulation factors, too. In some cases the diffuse component of the solar radiation produces much more electricity, then direct one. In this article sensor for direct, real time measurement of an optimal PV plant orientation position is proposed. It uses a rotating sensor array, oriented at different tilt angles and scanning the sky. The microcontroller unit performs measurement and control algorithm and allows calculated data through RS485 interface connection.*

Key words: *Solar photovoltaic system, Optimal Position Sensor, Renewable Energy*

1. Introduction

There are different sun following controllers, which provide error signals (normally one signal per following axis). The sun position sensors act as a two axes or four quadrant photocell, giving a mV voltage proportional to the radiation beam position inside the sensor. Sometimes the sensitivity of the sensor phototransistors is raised due to the inclination of the surfaces where they are mounted. Fig.1 presented several sun sensors types [1].

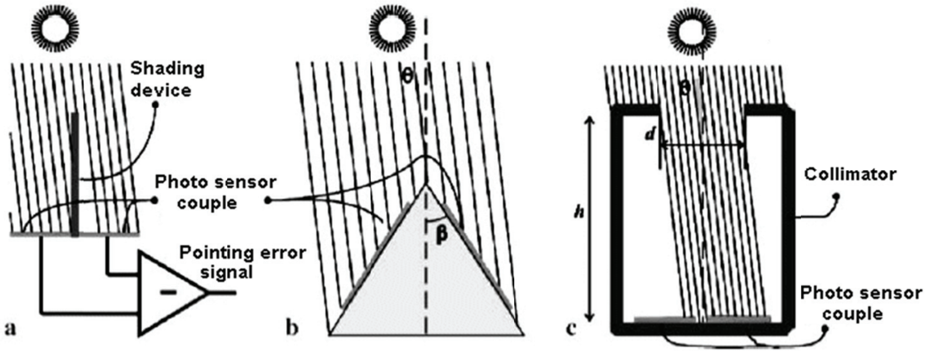

Fig. 1. *Various types of Sun sensors [1]*

Let us consider the classical sensor, which is constructed for one sun position coordinate. There are two phototransistors, which are situated on a pair of surfaces with a slope of 90°. Fig.2 shows the sensor construction [1].

The above mentioned sensors possess two main problems: on the one hand the phototransistors have to be quasi-identically, on the other hand there exists the so called ageing semiconductor effect.

The problems of the classical Sun sensor may be solved by the matrix Sun sensor (MSS).

In the previous solutions, each tracking direction is controlled by using a Sun sensor made by a pair of phototransistors.

This proposal is for a single matrix Sun sensor MSS, which controls both axes of the tracking system. The main advantages of the new solution are the robustness and the economical aspect. The new sensor uses the ancient principle of

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the solar clock. Photo-elements (CdS cells) are employed inside the MSS.

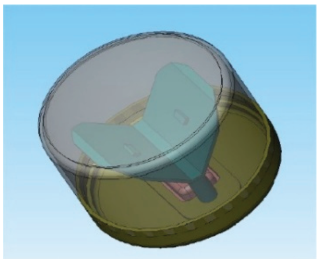


Fig. 2. A classical Sun sensor [1]

Fig.3 presents the position of the photo-resistors [1].

A sensor for measuring the sun position consists of a four-quadrant photodiode (Fig.4). The diagram shows four main zones - north-east (NE), north-west (NW), south-west (SW) and south-east (SE). A beam of light illuminates a part of the four zones through an aperture (Fig.4). When the sensor moves (or the sun's position changes), the beam illuminates different portions of each quadrant and consequently produces different currents in the diode [2].

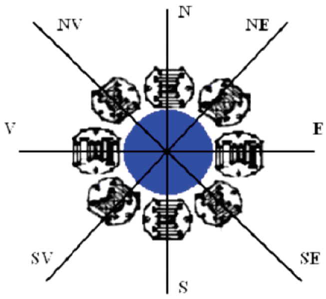


Fig. 3. The photo-resistors matrix [1]

An electronic circuit is used to measure the current from quadrants NE, NW, SW and SE. Error signals for the west–east and north–south axes are obtained by properly summing and deducting the currents [2].

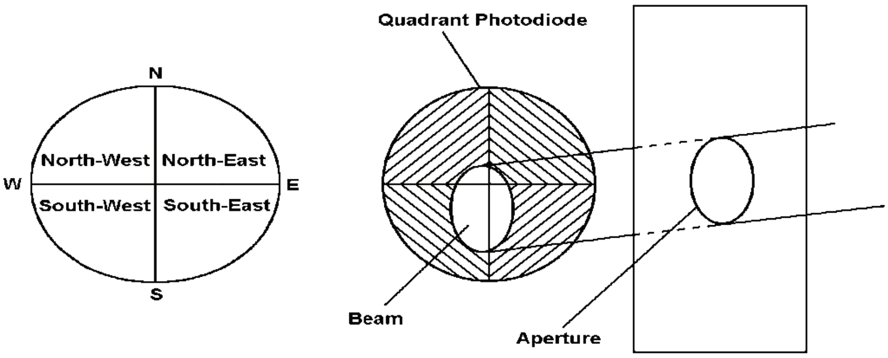


Fig. 4. The four-quadrant sensor [2]

Fig. 5 presents another type of sensor. This sun position sensor acts as a two axes or four quadrant photocell, giving a mV voltage proportional to the radiation beam position inside the sensor. The sensor is intended to keep the radiation beam as near as possible to the (0, 0) position of both axes (Fig. 5).

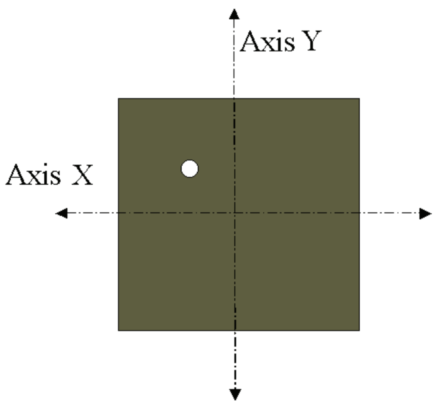


Fig. 5. Sun position sensor [3]

A multicellular photovoltaic sensor uses specific method to direct any installation with solar collectors or PV panels. Its construction is as follows: solar PV cells are situated in several surfaces on a supporting device. The planes have the following angles: 0 °, 15 °, 30 °, 45 °, 60 °, 75 °, 90 °.

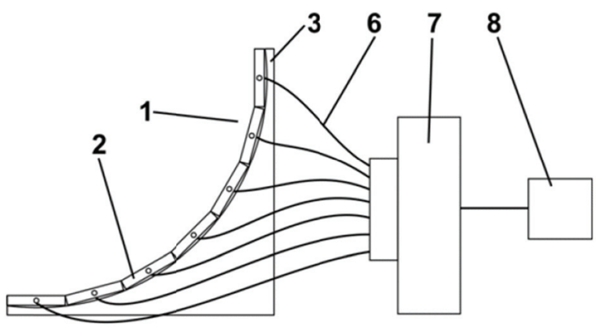


Fig. 6. Sensor with vertical configuration [4]

The role of the solar cells is to find the insolation available in the mentioned surfaces. Another role of the cells is to collect information of the present global solar radiation in the mentioned directions. There are two positions of the sensor - vertical and horizontal. The sensor determines the optimal solar altitude in the first case (Fig.6). The determination of the optimal solar azimuth is done by the second one (Fig.7).

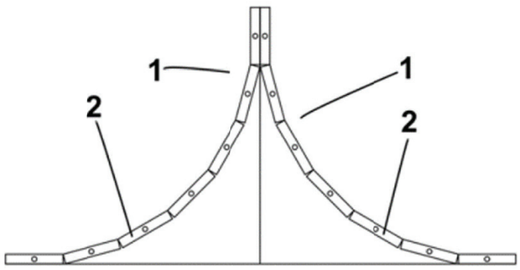
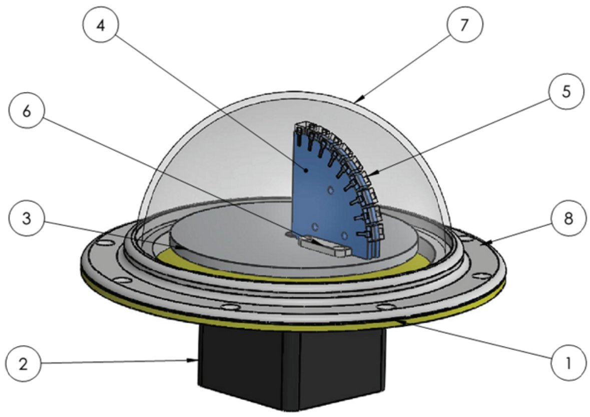


Fig. 7. *Sensor with horizontal configuration [4]*

2. Proposed sensor construction

The proposed sensor principal of operation is based on a full sky scanning procedure, which allows finding, in real time, an optimal PV panel inclination and azimuth angles. The multicellular sensor array 5, mounted on the PCB assemblies 4 (Fig.8) is rotating around the vertical access in 360 degree range, that ensure an real time incoming solar radiation measurement at approximately all possible PV panel orientation positions. The sensor array consists of 9 silicon PV sensors, fixed at different angles (0, 10 20, 30, 40, 50, 60, 70 and 80 degrees) from the horizon. The PCB assembly is fixed on the top of the rotating disk 3 by the PCB support 6. Stepper motor 2 is rotating the disk and the sensor array. The inside area is covered by the quartz glass cover in case to protect sensors by the environment conditions.



ITEM No.	DESCRIPTION	QTY.
1	Stepper Motor Base	1
2	Stepper Motor	1
3	Rotating Disk	1
4	Printed Circuit Board	2
5	Silicon PV Sensor	9
6	PCB Support	1
7	Quartz Glass Cover	1
8	Plastic Ring	1
9	Bottom Cover (Fig.9)	1
10	Level Sensor (Fig.9)	1
11	Sensor Base (Fig.9)	1

Fig. 8. *The mechanical part of the optimal PV plant orientation sensor*

The rotating disk motion begins from the north orientation position and produces a full turn to the same point. The next measurement is performed at an opposite direction turn. This is made by the reason to allow wire signal connection between the rotating and stationary parts of the assembly. The optical start/end position sensor (not showed on the figure) is used to synchronize the movements.

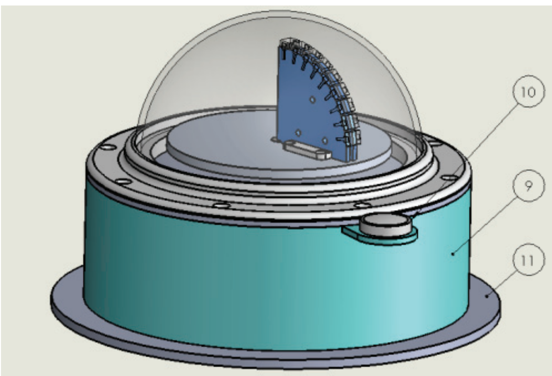


Fig. 9. *The common view of the sensor assembly*

The bottom cover 9 (see Fig. 9) contains an electronic control and measurement PCB and desiccant container, which one is used to avoid wet condensing on the inner surface of the quartz glass cover. The whole sensor is mounted on the sensor base 11, which ensure level screw adjustment, and north direction correction. The actual level is measuring by the liquid level sensor 10.

The optimal position angles (elevation and azimuth) are determined by the comparison of the signal levels, detected from the sensor array in a whole turn data frame. The transimpedance amplifiers are used to gain photovoltaic currents, produced by the silicon sell sensors. Fig.10 shows the schematic diagram of the amplifier section. The 9 identical channels are used to gain signal level to the appropriate value, which may be accurately measured by the microcontroller analog to digital conversion (ADC) section. The inverting amplifiers 9 are producing positive voltages, compatible to the ADC measurement range.

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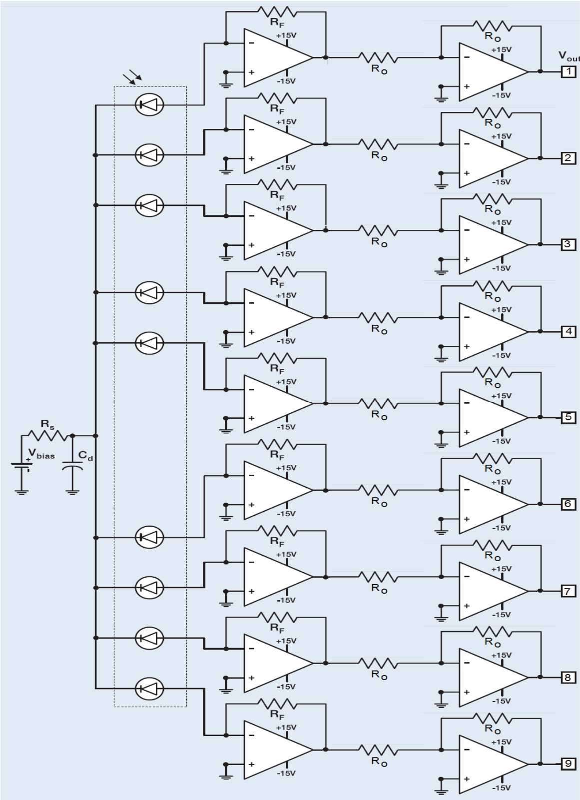

Fig. 10. Amplifier section schematic diagram

The accurate solar radiation level comparison may be performed only if the sensitivities of the 9 measurement channels (sensors and amplifiers) are identical (Fig.10). This is the reason to use a special channel sensitivity calibration procedure. On it the sensor array PCBs, after assembling, are placed on the rotating disk horizontally and the standard sun lite source is situated in front of the assembly. By rotating the disk and measuring the maximal voltage level, produced by the each one channel, the sensitivity coefficients (for all the channels) are determined.

3. Sensor control section

The control unit is based on PIC24FJ128GA010 microcontroller using Microchip's Explorer 16 development board [5]. The board is equipped with various interfaces, including digital I/O, serial UART module, ADC inputs and USB device module. RAM memory is 8K bytes which is sufficient for storing input values from sensors. Processor instruction execution speed of 250 ns allows processing of input data to be done in the given time window (Fig.11).

PV sensor array is connected to 9 channel transimpedance amplifier for amplification and signal level matching and then to analog-to-digital module of the microcontroller. The ADC module is high-speed, pipelined 12-bit A/D converter.

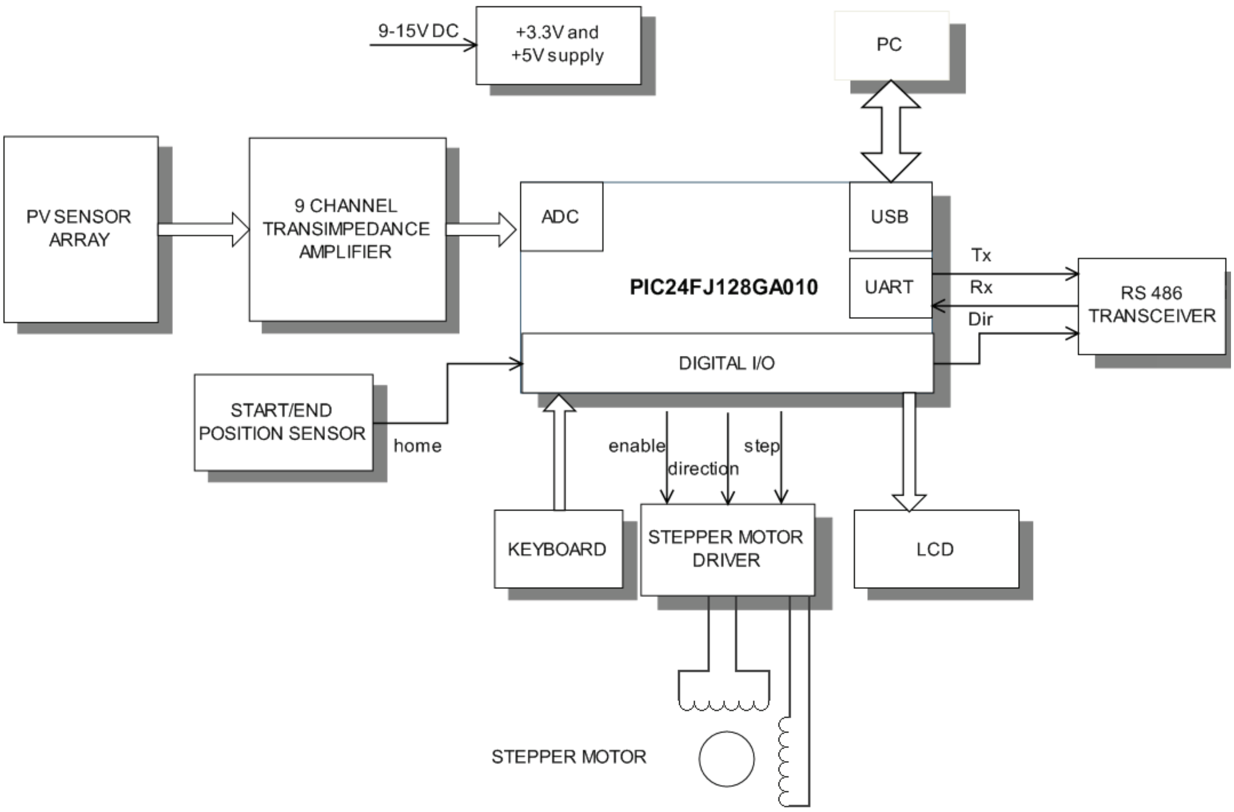

Fig. 11. Control system block diagram

The start/end position sensor is used to indicate start point and the full turn end point in measurement movements. The Texas Instruments DRV8824 [6] provides an integrated bipolar stepper motor driver solution. It has built in micro-stepping indexer and simple step/direction control interface.

The system parameters, such as a scanning time interval, a number of averaged measurement samples, sensor array sensitivity data etc. may be added or changed by using a keyboard and LCD display.

Output data are available through RS485 interface connection. The USB port supports controller program development.

MCU read PV sensors array signals at every step and find the maximum value. At the end of the rotation the algorithm finds the maximum value of all and interpolates with its near sensor value to find the exact optimal angle of elevation. The simplified algorithm diagram for the measurement procedure is presented on Fig.12.

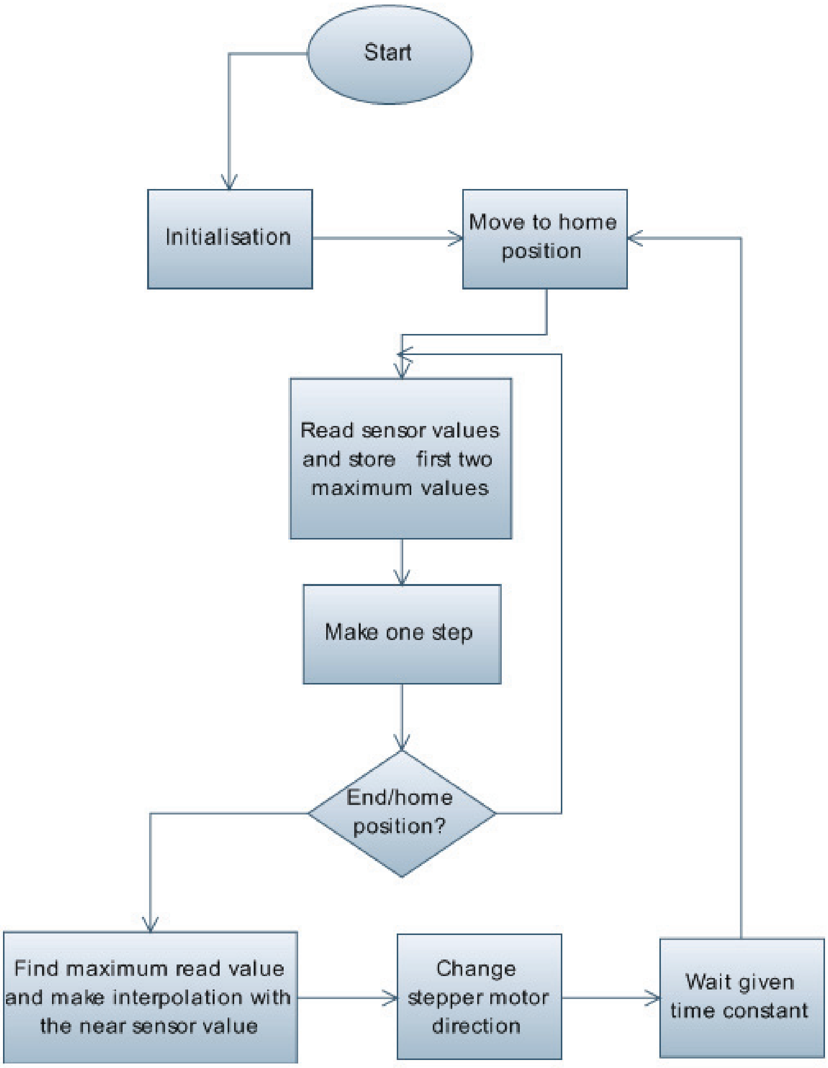

Fig. 12. *The simplified algorithm diagram for measurement procedure*

4. Conclusions

The sensor, proposed in this article, allows the user actual, real time information about the optimal inclination and azimuth orientation of the PV panels, in case to produce maximal electricity power. The obtained data are based on the fast and practically full sky observation procedure. Linear interpolation is used only in elevation access, between two sensors positions, reporting best values. The inclination difference for these two sensors is only 10 degrees.

The azimuth resolution is set to 0,9 degree and match to a half step size of the stepper motor.

For the best results in optimal position measurements, the type of the sensors in photocell array should be the same, as in PV plant panels.

The chosen data interface (RS485) is convenient to cover long distances - up to 1200 m.

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This feature adds flexibility in sensor placement, inside the PV plant arrangement.

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