AUTOMAT SYSTEM FOR THE ORIENTATION OF SUN CAPTURES

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Abstract: The paper present a rentable solution through which it assured a maximum illumination of the solar panels. For a maximum irradiation of the capturing aria, it must be placed perpendicular on the incident light raw. This objective was realized by the orientation of the panel after the relative movement related to earth of the sun. The panel will follow the sun based on an algorithm for positioning, all the time it is in the visibility zone. The selected solution for the orientation of the panels it based on two feedback positioning systems, one for the Elevation angle and one for the Azimuth.

Keywords: solar module, tracking stand, photovoltaic system, inclinometer, compass, PLC

1. INTRODUCTION

The solar energy represents the most impressive and sure source of energy. Since a 20 minute period, the sun deliver the equivalent of the annual mankind energetic consume. In Romanian territory, from a 1 m² horizontal square, it can be capture annual, a 900 to 1450 kWh quantity of energy, certainly depending by the season, too. The daily medium radiation can be 5 time more intense in summer than in winter. In time of an unclouded day, it can be capture 4-5 kWh/m²/day, even in winter time, in condition in which the collected solar radiation it is independent on the environment temperature.

For a maximum irradiation on the energy collecting aria, that must be placed perpendicular on the incident light ray. In practice, it can be utilized both steady and mobile solar panel, which follow the sun movement. The steady solar panel must be placed on the local meridian direction, directed to south and under an optimum inclination angle by the horizon.

This paper presents a solution to realize an automated system of solar panel orientation. This solution can be utilized both for solar panel and for photovoltaic system. The solar panels will follow the sun only in day time, in condition in which it known the relative sun movement.

2. DESCRIPTION OF THE AUTOMATED ORIENTATION SYSTEM OF SOLAR PANELS

The automated orientation system was devised for 1 or 2 photovoltaic panels. It was selected a photovoltaic panel type LPS00236, with a 145W maximum power, 24 V nominal tension, with 1600x800 mm dimension and weight 13,6 kg. The electrical output of solar cell is establishes at Standard Test Conditions (STC), where the irradiance is 1000W/m2 and at a cell temperature of 25°C. With the cell operating at these conditions the open circuit voltage (Voc), short circuit current (Isc), voltage at maximum power point (Vmax) and current at maximum power point (Imax) are recorded.

From this the maximum power delivered by the cell can be calculated as well as the fill factor (FF) – the cell conversion efficiency.

$$FF = \frac{V_{\max} * I_{\max}}{V_{oc} * I_{sc}} \tag{1}$$

and

$$P_{\max} = V_{oc} * I_{sc} * FF \tag{2}$$

Cell operating temperatures have an effect on cell conversion efficiencies – an inverse linear relationship. As cell temperature increases the cell efficiency decreases. The highest temperature of the cell corresponds to the lower efficiency of the cell.

The projected system for panels' orientation is presented in figure 1.

The solar panel orientation command it was realized by two step-by-step motors 1 and 2 (fig. 3). Motor 2 assure a rotation movement 7 of the vertical axel 6, and Motoruk 1 permit the inclination of solar panel adjustment 4. The adjustment of solar panel inclination it was realized by a screw-nut mechanism which permit the variation of the arm 3.

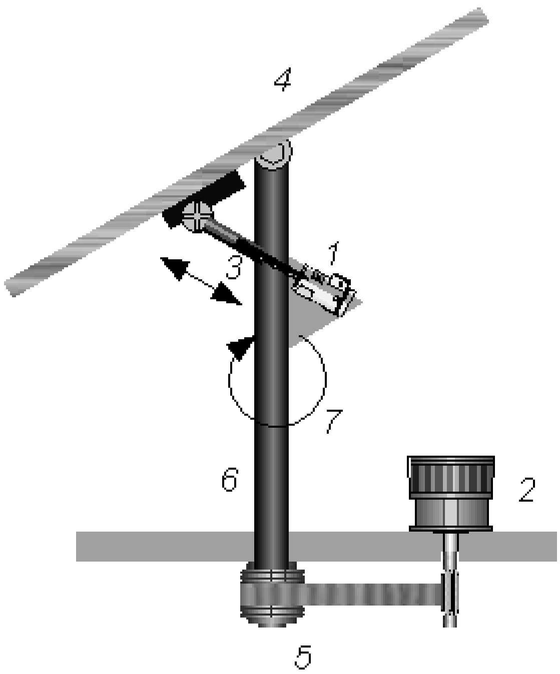


Fig. 1 – The automated system for solar panels

1, 2 – stepper motors
3 – screw-nut mechanism
4 – Photovoltaic panel
5 – Cogged pulleys and belt
6 – Principal axel

The electric energy producing system it made it without the photovoltaic panels, 1-2 accumulators and an inverter with solar charge controller (figure 2).

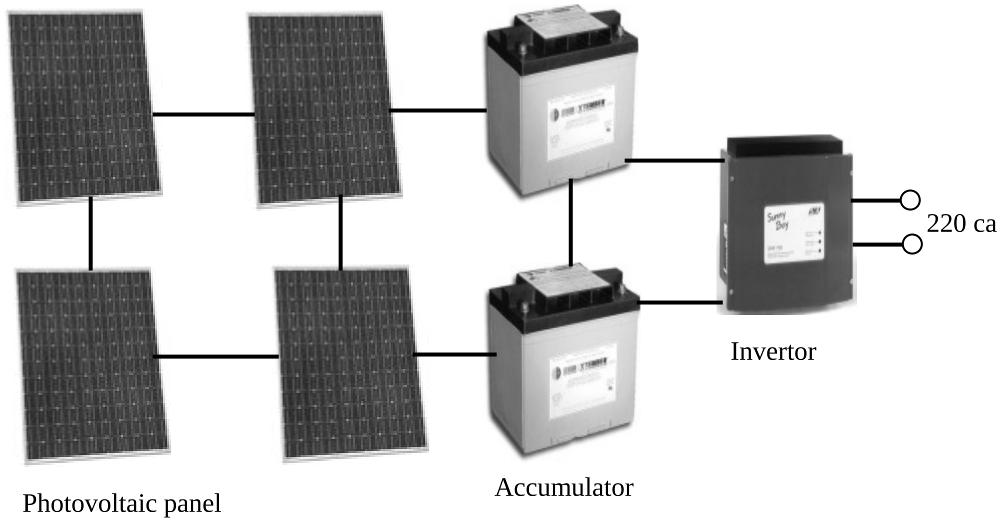


Fig. 2

3. THE SUN POSITION ALGORITHM

In sense that the year cumulate a fractional number of days, around 365.25, and because a day didn't make 24 hours, but less, the time from astronomic algorithms must be calculate by different norms than for Gregorian calendar. Thus, it will be calculated the Julian day number by the following formula, starting from the time of Gregorian calendar:

It will be noted by:

m – number of the month

j – the year

d – the day number of the month

J – the Julian day number

If m < 3 than m = m + 12 and j = j - 1

It must be calculated the expression in which it's make allowance for bisect years

$$c = 2 - |j/100| + |j/400| \quad (5)$$

Than, with help of these the Julian day number J:

$$J=|1461*(j+4716)/4|+|153*(m+1)/5|+dd+c-1524.5 \quad (6)$$

Where, $|x|$ is the integer part of an decimal number (for example: $|123.45|=123$;
$dd = d+h/24 + min/24/60$; where h is hour, min is the minute.

Thus, it can be calculated the Julian day number starting from the normal date and, the hour and the minute selected.

The mean anomaly will be noted by M and it been calculated from formula:

$$M = M0 + M1 * (J - J2000)\text{; where J2000 is a constant equal with 2451545.} \quad (7)$$

The mean anomaly is utilized to indicate the planet position depending on it perihelion which is measured in grades.

$$M0= 357.5291 \tag{8}$$

$$M1= 0.98560028 \tag{9}$$

These are specific constants of Terra.

The center equation

It must be take in consideration the elliptical form of Terra orbit.
One of the parameters of elliptical movement is the true anomaly, notated with v.

$$v=M+C \tag{10}$$

To calculate the C value, it must be resolved the Kepler equations, from which results the approximate solutions, but with accurate values:

$$C \text{ aprox} = C1 \sin M+C2 \sin (2M)+ +C3 \sin (3M)+ +C4 \sin(4M)\ldots \tag{11}$$

To describe the Terra orbit it will be necessary C1, C2, C3, only.

Where C1, C2, C3 are constants which have the following values:

$$C1= 1.9148 \tag{12}$$

$$C2= 0.0200 \tag{13}$$

$$C3= 0.0003 \tag{14}$$

For the following calculations it will be necessary to know the two specific astronomic constants of the planets, namely: ecliptically longitude - le and the inclination of the axe related to obliquity, eq. For Terra, le= 102.9372 (perihelion)

$$Eq= 23.45 \tag{15}$$

Both measured by grades.
The ecliptic coordinates:
The ecliptically longitude of a planet like it is viewed from the sun is:

$$la = v+le=M+C+le. \qquad (!6)$$

To calculate the ecliptically longitude of sun like it is viewed from the planet, it will be utilized the formula:

$$La=M+C+le+180 \tag{17}$$

The ecliptically latitude beta for sun it is insignificantly, therefore it will be considered equal with 0.

The equatorial coordinates

These are related to the rotation axe of the planet: declination, noted by delta and right ascension, noted by alpha. The declination indicate from which place can be viewed the sun, and the right ascension, when is visible the object. Its can be calculated in accordance with the ecliptically coordinates, by the solutions of the following trigonometric equations:

Sin alpha cos delta = sin la cos eq cos beta – sin beta sin eq (18)]

Cos alpha cos delta = cos la cos eq (19)
Sin delta = sin beta cos eq + cos beta sin eq sin la; (20)
Alfa=arctg((sin la cos eq) / cos la) (21)
Delta=arcsin(sin la sin eq) (22)

The sun position algorithm in accordance with the geographic position of the observer

North latitude: phi (23)

West longitude: lw (24)

For the position subsequent determination it is need to calculate the sidereal time:

Th=Th0+Th1*(J-J2000) – lw (25)

Th0=280.1600 (26)

Th1=360.9856235 are specific constants of the earth (27)

Two coordinates are necessary to present the position of an object from the sky:
The high over the skyline – h, which can be>

- from 0 to 90 degrees, for an object visible over the skyline, and
- 0…-90 degrees, for an object visible under the skyline.

The azimuth, az, it is related to the cardinal points, thus:

- equal with 0 for a point put in a position at south from the observer

with 90….to West
180….to North (28)
270…to East

The trigonometric equations utilized to calculate the coordinates of the body are:

Sin az cos h= sin H cos delta (29)

Cos az cos h= cos H sin phi cos delta – sin delta cos phi (30)

Sin h = sin phi sin delta + cos phi cos delta cos H (31)

H=th – alpha (32)

From this, it can be calculated the formulas:

Az=arctg(sin H /(cos H sin phi – tg delta cos phi) (33)

h= arcsin(sin phi sin delta + cos phi cos delta cos H) (34)

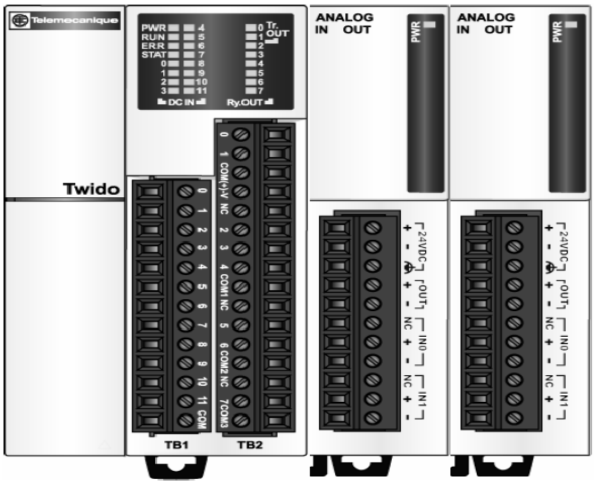
Calculating the azimuth, az and the high, h, it can be calculated by the fact, the celestial coordinates of the sun. It must be take care by the calculus expression of arcsin and arctg functions, to avoid the glaring errors.

4. THE COMMAND SYSTEM BASED ON TWIDO CONTROLLER

To determine the direction that the solar panel is currently pointing, it is necessary to provide directional feedback on the horizontal plane. This is accomplished by means of a magnetic electronic compass which provides directional information to the controller to indicate lateral dish heading. The compass used is a

Dinsmore Sensing Systems Analog Sensor No. R1655 based on Hall-effect technology. The sensor requires a 5V input and outputs a continuous sine and cosine curve pair which is interpreted by the controller as a directional indicator.

The sensor R1655 is constructed to operate in a vertical position with the leads down. The sensor is designed to measure the direction of the horizontal component of the earth's flux field (Compass component). If it is tilted off of vertical, it begins to sense some of the vertical component of the earth's field introducing some error. For practical purposes, up to about 12° tilt is considered acceptable. To facilitate alignment in the vertical direction, the controller requires feedback from the stand to indicate its vertical level. This is accomplished with the use of a single-axis digital inclinometer from SmartTool Technologies. The inclinometer is connected to the controller through a digital input with high speed.
The motors command was realized with programmable TWIDO, utilizing a master module TWDLMDA20DRT and two slave modules of analogical inputs outputs, TWDAMM3HT.



TWDLMDA20DRT TWDAMM3HT TWDAMM3HT

Figure 3 – Hardware structure with TWIDO controllers

TWDAMM3HT module has two inputs and one output with 12 bits resolution.

5. CONCLUSIONS

The automated orientation systems of solar panels increased the power delivered by them. It was tried to find the simplest solution for the orientation system, hence to justify the investment. The adjustment of the panel position was realized utilizing an inclinometer and a compass direction sensor. The mode in which was designed the orientation system permit its installation on mobile platforms (motor vehicles, airplanes), too. These systems, without the fact that offer ecological energy, its can offer the total energetic independence, if it’s correct dimensioned, too.In case of isolated buildings placed at a distance more than 300-400 meters far away from the electric energy network, the alternative energy supply became the most rentable solution.

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