Bulletin of the *Transilvania* University of Braşov • Vol. 12 (61) No. 1 - 2019
Series I: Engineering Sciences
https://doi.org/10.31926/but.ens.2019.12.61.6

WIRELESS CONTROLLED SYSTEM OF PHOTOVOLTAIC PANELS

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Abstract: *This paper presents a wireless controlled system which gives the photovoltaic panels (PV) orientation towards the sun all year around. It provides the remotely control and monitoring of PV through the GSM network. The system electronic control, the software design and some practical aspects related, are also presented. The proposed system can generates renewable energy for small farms and houses and realizes a maximum of 40% gain in energy.*

Key words: *photovoltaic panel, wireless control, GSM network, battery.*

1. Introduction

The demand in renewable energy sources increases due to a continuous decline of natural resources. In this case, solar energy is some of the most affordable resources of renewable energies, because it uses energy emitted from the sun in order to produce electrical current. To improve the generated electric energy with up to 40%, a best possible orientation of panels twards the sun must be accomplished, [1, 3]. The authors appreciate that, the best results (efficient, and economic) are obtained using a wireless control system with two axis of panel rotation to have optimal light detection. This one could be the best power supply for a stand–alone residential consumer because is totally/partially independent of local/national resources. It provides also the changing in tilt degree and the electrical energy storage in a battery bank, taking into account that the energy depends on the sun local position, orientation and intermittency output.

2. System Description

The sun tracker is a device which provides best orientation of the PV panel on the sun, in order to have sun incident radiation at maximum value during all the day. To have maximum of 40% gain in energy, it is proposed a controlled tracking system with stepper motors based on a previous programming algorithm.

To design the main parts of the system, the following aspects may be considered:

- mechanical design of frame, azimuth gears and elevation mechanism;

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- electronic control design of the system (general diagram, development board, driver of the stepper motors, light detection, interface with GSM network, measuring the battery voltage and the control of photovoltaic panels);
- software design of Arduino graphical interface, checking the battery state of charge (SOC), communication through the GSM network and sending/receiving SMS messages.

To have the sun tracker best orientation it was implemented a programming algorithm based on the local astronomical position coordinates, as seen in Figure 1, [1, 2].

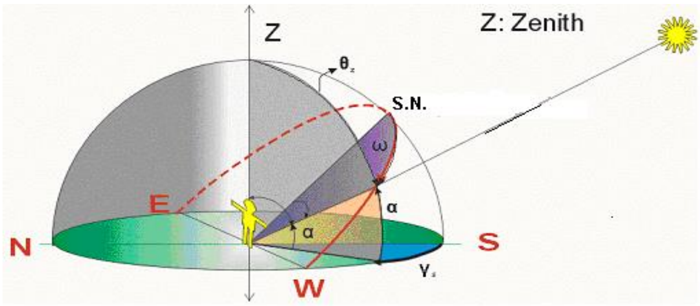

Fig. 1. *Position and coordinates of sun trajectory on the sky*

To establish the real sun position on the sky, are considered the remarkable angles of zenith (θ_z), azimuth (γ_s), declination (δ) and angle zone (ω), calculated as follows:

a) zenith angle (see Figure 1):

$$\cos\theta_z = \sin\varphi \cdot \sin\delta + \cos\varphi \cdot \cos\delta \cdot \cos\omega, \quad (1)$$

where: φ is the latitude of the sun tracker location (constant, for Brașov - Romania is of $45^0 39'$), δ is the declination angle and ω is the angle zone;

b) declination angle (see Figure 1):

$$\delta = 23.45\sin\left[\frac{360}{365}\cdot(284+n)\right], \quad (2)$$

where *n* is the day when the determinations are made;

c) angle zone (which describes the instantaneous sun position):

$$\omega = \frac{\pi\cdot(12-t_{sun})}{12}, \quad (3)$$

where t_{sun} is the solar time.

The angle zone is positive during the a.m. time, negative during the p.m. time and zero during the lunch time (when the sun is situated in the maximum point of the trajectory).

To calculate the solar time, we proceed as follows:

$$t_{sun} = t_{local} + \frac{E}{60} + \frac{long_m - long_{local}}{15}, \tag{4}$$

where t_{local} is the local time, $long_m$ is the longitude of the local standard meridian, $long_{local}$ is the longitude where is located the observer and E is a time correction parameter calculated with the following relation [1], [2]:

$$E = \begin{cases} -14.2\sin\frac{\pi(n+7)}{111}, & 1 \le n \le 106 \\ 4\sin\frac{\pi(n-106)}{59}, & 107 \le n \le 166 \\ -6.5\sin\frac{\pi(n-166)}{80}, & 167 \le n \le 246 \\ 16.4\sin\frac{\pi(n-247)}{113}, & 247 \le n \le 365 \end{cases}. \tag{5}$$

d) azimuth angle (see Figure 1):

$$\cos\gamma_s = \frac{\sin\theta_z \cdot \sin\varphi - \sin\delta}{\cos\theta_z \cdot \cos\varphi}. \tag{6}$$

Taking into account the previous equations, the angle zone corresponding to the sunrise is calculated with the following equation:

$$\omega_s = \cos^{-1}(-\text{tg}\,\varphi \cdot \text{tg}\,\delta). \tag{7}$$

The angle zone for the sunset corresponds for the value of $-\omega_s$.

2.1. Mechanical subassembly

This one consists in a base support plate a mechanical frame and a sustaining tripod which provides a good and stable position of the whole system, as shown in Figure 2.

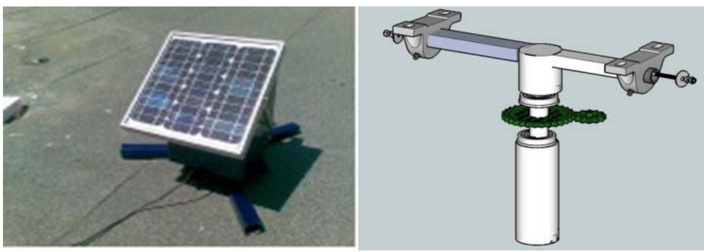

Fig. 2. *Mechanical sustaining support and frame*

At the base of the frame it is mounted the control panel and a metal box which contains the electronic components as well as the battery. The solar panel rotation around its own axis is done by a reducer made out of two gears with straight teeth, [1]. Dimensions and gears geometry are calculated so that the resulting transmission ratio must be as big as possible, using a stepper motor having power of 5 W, a torque of 0.23 Nm and a gear which has 3.7 mm distance between its teeth. The maximum power of the motor is at a speed of 250 steps/s (7.85 rad/s). In order to have a continuous support for the panel of 3 Kg, by acting just the motor, a worm gear could be used, [1].

2.2. Electronic control system

The block diagram of the developed electronic control system is presented in Figure 3.

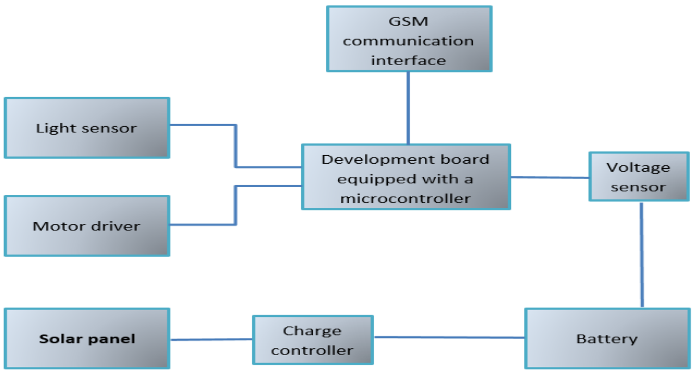

Fig. 3. *Block diagram of the control system*

To develop the control system, the following components are used:

- a development board (Arduino Uno) equipped with an ATmega328 microcontroller having interface with the outside world through 14 digital pins and 6 analog pins. The current is 40 mA at each pin and the input controlled voltage of 6-20 V, [3, 4, 5];
- a *Big Easy* driver, produced by the Spark Fun Company, which is based on Allegro A4988 integrated circuit. It controls the stepping motor providing a current of up to 2 A/phase, through two microcontroller parameters (direction and step) and a motor rotation of 0.11°, [3, 4, 5]. The motor type used is a bipolar stepping one with steps of 1.8°, able to develop a torque of 0.23 Nm at a rated voltage of 12 V. The connection between motor, driver and development board is depicted in Figure 4;
- a light detection system which detects the maximum light intensity. This allows the panel to guide itself in order to obtain the maximum possible efficiency. The degree of illumination is determined by connecting the output of the operational amplifier to an analogic pin on the development board. It is obtained a value between 0 (total darkness) to 1023 (powerful light). This value variation depends on the photo-resistor resistance and on the environment's illumination;
- an interface with the GSM network able to remote control the photovoltaic panel. This one consists in a GSM shield (d-u3G) supplied by the battery and is easily interfaced with the development board, [2, 4, 5]. Control is done by reports at specific time

intervals with information regarding the position of the panel and the battery SOC. Also, it is possible to rotate the panel in a certain position, by sending an SMS with information about the new position;

- a battery voltage measuring unit which prevents the its overcharging and discharging. The unit monitoring is provided by a dedicated controller Steca Solsum 6.6F/12,24V/6A [4, 5].This controller provides battery overcharging protection, voltage control and smooth charging in multiple steps. Also, it prevents the total battery discharge and the reverse losses through the panel during the night.

2.3. System software design

The master piece of the system is the microcontroller. It controls all the system activities, through a dedicated software program included in its memory. This program is developed on a personal computer, in an integrated space called Arduino Software and has the graphical interface presented in [6].

The main steps of the program are the followings:

- initiating the variables and configuring the used pins;
- registering the GSM system interface to the network. It takes a long period of time, in which the microcontroller is in standby mode. If this process is successful, a SMS confirmation is sent;
- sending a message with information regarding the panel position and the battery SOC.

After this process, the information on the degree of illumination is being read from the light sensors and the motors operate until the panel correct position is reached. At regular time intervals (every hour), the battery SOC is checked and if the voltage is not in normal limits, a warning message with the voltage value is sent. Depending on a SMS received and read the system in accordance reacts regarding the panel position and the battery state of charge. If the SMS content cannot be read, a warning message is sent. If the values read by sensors drop below a reference value set for the night time, the panel is rotated in the initial position (azimuth 0°, elevation 0°) and the microcontroller is set of sleep mode for all the night.

The reading process allows the continuous positioning of the panel. It is possible to have both communications of voice and data by using the SMS service. In this situation, the following facilities are provided:

- sending reports, at regular times, regarding the panel position and the battery SOC,
- showing the battery voltage dropping/exceeding values within imposed limits,
- receiving messages in order to implement the photovoltaic panel positioning,
- extracting information about the panel new position from the received message,
- request reports.

3. Experimental Results

The laboratory tests were carried out within Power Electronics laboratory of *Tansilvania* University of Brașov. Main parts of the experimental model are the followings:

- a photovoltaic panel generating an output of over 30 W in good lighting conditions;

- two lead acid batteries of 6 V each, connected in series;
- an ATmega328 microcontroller with a memory of 32 KB and a step down DC to DC converter from 12 V to 5 V;
- a Steca-Solsum 6.6F/12,24V/6A dedicated controller for photovoltaic panel;
- a development board Arduino Uno and a GSM shield d-u3G;
- two bipolar stepper motors with steps of 1.8° and a torque of 0.23 Nm at a rated voltage of 12 V.

In the Figure 4 is presented the laboratory experimental model.

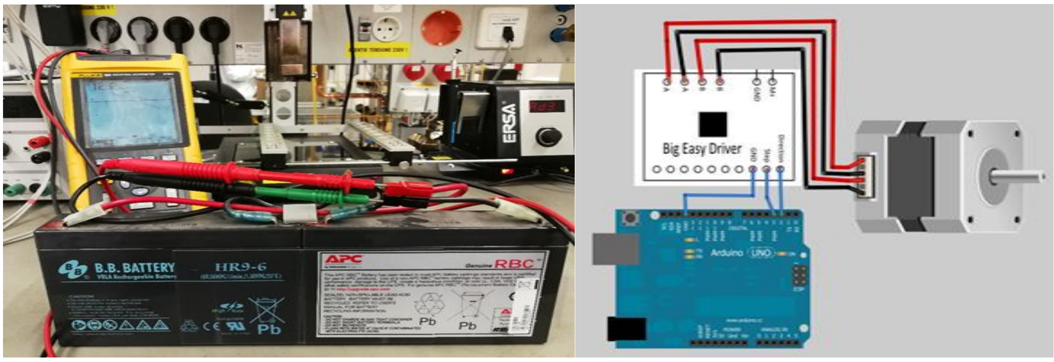

Fig. 4. *Laboratory test bench and motor connection with driver and development board*

4. Conclusion

It was presented a wireless controlled system which orientates by remote control the photovoltaic panels towards the sun all year around. This system is able to monitor the sun tracker through the GSM network. It can be used to generate renewable energy for small farms and houses located in isolated areas. The system electronic control and the software design were taken into consideration in order to obtain a maximum of 40% gain in energy. The authors follow the development of experiments for higher power applications.

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