POSITIONING SYSTEMS FOR SOLAR PANELS PLACED IN ISOLATED AREAS

Laurentiu ALBOTEANU, Gheorghe MANOLEA, Florin RAVIGAN

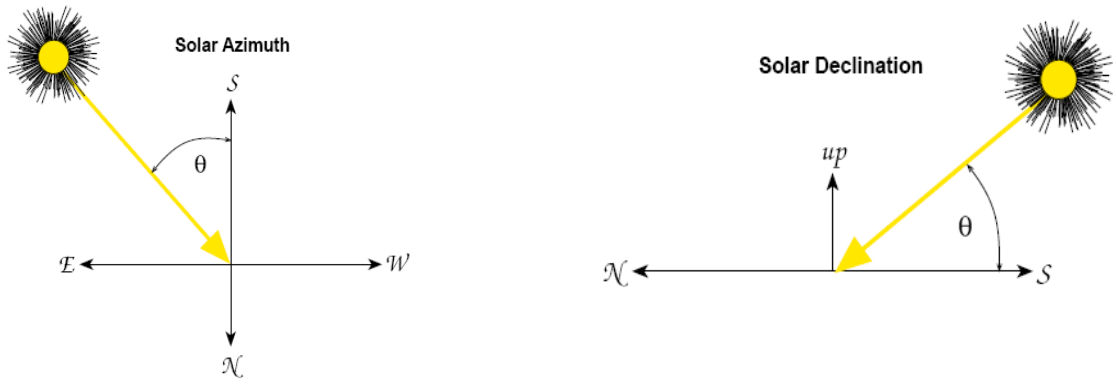
Faculty for Electromechanical Engineering, University of Craiova 107, Decebal Bl., 200440, Craiova, Tel.0251 435 724, Fax. 0251 435 255 ,
e-mail: lalboteanu@em.ucv.ro; ghmanolea@gmail.com; ravigan.florin@gmail.com

***Abstract* – This paper presents some considerations concerning the positioning systems for solar panels as to obtain the maximum energy that these can furnish.**

***Keywords*:** *solar panels, solar energy, solar motion, positioning system.*

1. INTRODUCTION

The photovoltaic (PV) modules work by converting sunlight directly into electricity. The sunlight is the necessary and efficient ingredient. The PV modules work at a maximum efficiency, when the incoming Sun rays are perpendicular to their cells. The adjusting of the static structure PV modules may have as a result more yearly power from 10% to 40%. Maintaining the module perpendicular to the incoming sunlight means that the module intercepts the maximum amount of sunlight [1].
The problem is that the Sun constantly moves being related to the static PV module. Actually, the apparent motion of the Sun is due, to the Earth's motion, but for our purpose here this celestial fact is mere trivia. Even if we place a module so that it may be perpendicular to the Sun at the solar noon, it is not perpendicular in the morning and in the evening. This daily motion from East to West is called the solar azimuth. The apparent height of the Sun in the sky also changes it self being related to the change of the season from winter to summer. This yearly North to South solar motion is called solar declination.
If the PV module is to be kept perpendicular to the daily motion of the Sun from East to West (azimuth), then a device called a tracker is used. A tracker follows the daily motion of the Sun and furnishes more power anywhere from 25% to 35% which is absorbed from the hitchhiking on its back.
If one adjusts by manual the position of the PV panel accordingly to the North-South solar motion, the power broadcast by the PV modules increases whit 10%. The diagrams on the figure 2 present all the necessary data for the achieving of the adjusting, North/South, PV panel position. The calculation of the panel angle (A) is based on the supposition that the panel will be perpendicular to the incoming Sun rays at solar noon. Solar noon (the local time) is the time when the Sun is highest in the sky. This is the time when the angle between the plane of the horizon and a line drawn from the site to the Sun is greatest.
This calculation involves two parameters. These parameters are the latitude of the site (L) and the declination of the Sun (D). The declination of the Sun is the latitude at which the Sun is directly overhead at solar noon. This varies from 23.5° North latitude on the summer solstice (June 21) to 23.5° South latitude on the winter solstice (December 21).
These latitudes are known as the Tropic of Cancer and the Tropic of Capricorn. During the equinoxes (March 21 and September 21) the declination of the Sun is 0°, so that it is directly over the Equator at solar noon.



a) b)

Figure 1: The angles for Sun; a) Solar Azimuth; b) Solar Declination

The equation of the declination (D) for any day is:

$$D = 23.5^0 \sin\left((T/365.25)*360^0\right) \quad (1)$$

where T is the number of days to the day in question as measured from the spring equinox (March 21).
The panel angle (A), the angle between the panel and the horizontal plane, is then calculated from the equation:

$$A = L - D \quad (2)$$

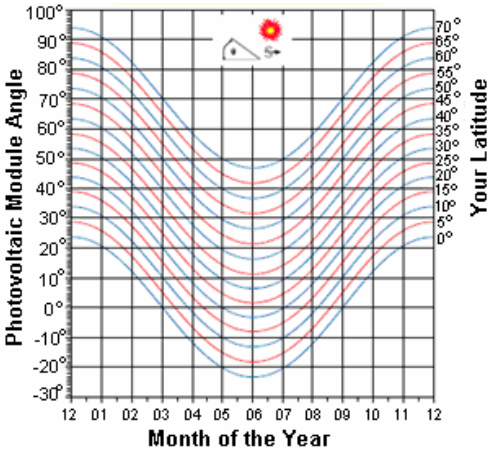


Figure 2: Solar panel angle for various latitudes

2. POSITIONING SYSTEMS FOR SOLAR PANELS

Various positioning structures of the PV panels can be built from a variety of materials and in a variety of styles. Almost all designs can be made to be seasonally adjustable. All commercial produced PV panels have a virtual and difficult seasonally adjustment because they are made to work at a wide range of latitudes

2.1 Single-axis positioning systems

These have a single axis for the rotation of the PV panel; the East-West motion. This system is a little complicated it need only a simple motor and a control system that turns the solar array from East to West each day. This maintains the panel in a close proximity to the Sun.

2.2 Dual-axis positioning systems

These use both East-West and South-North axes for positioning the solar panel. During a year, the dual axis system will produce the most amount of power, because one can fallow the changing of the Sun trajectory every season. At the same time, this structure is more expensive, more complicated for being designed, constructed and maintained.

2.3 Passive positioning system

These trackers follow the Sun without having any motors to drive them [2]. The trackers are carefully balanced. The tubes on each side of the tracker are filled with a gas. As the Sun heats the gas on one side, the gas expands and flows into the other side of the tracker. This shifts the delicate balance, and the solar panels automatically tilt toward the Sun.
The Zomeworks tracker has no motor. It is a passive tracker in which the shifting weight of DuPont Freon refrigerant tips the tracker to follow the Sun. The Freon moves to the cooler of two side canisters, which because of the position of the shades, causes the rack to follow the Sun. This simple yet elegant and cost-effective system demonstrates that even modest solar panel installations can benefit from commercial Sun trackers, as long as the increased efficiencies justify the added cost.

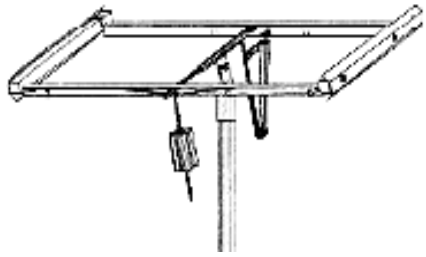


Figure 3: Passive positioning system "Zome works"

3. THE APLICATIONS WITH PV PANELS PLACED IN INSULATED AREAS

3.1 The solar lamps for the lightening of the roads

The lamps supplied by solar power source, are more and more frequently used in different ways for the roads lightening. They work following an easy and simple principle. The light of the day is transformed in electricity by a solar panel, which, in its turn, is stored in a storage battery. The energy from this storage battery is transform again into the light by an economical bulb during of night. The solar lamp is commanded by a little light sensor of which automatically start and stop the lamp. The light power is directly dependent on the power of the solar panel, the storage battery and the economical bulb.

3.2 Water pumping systems supplied by the solar power source

The water supplied has always been a problem particularly during the time when the electrical power was not available. The water pumping systems using the solar panels have always been efficient solutions [3]. The individual irrigation systems which use this technology, showed us to be the ideal solution and they are more and more frequently used in

agriculture. These systems used the submerged pumps or the above surface. In these applications it is essential that one uses the DC pumps, which work at a very high level, the water pumping a very little amount of electrical power. The block scheme of such a system is presented in figure 4.

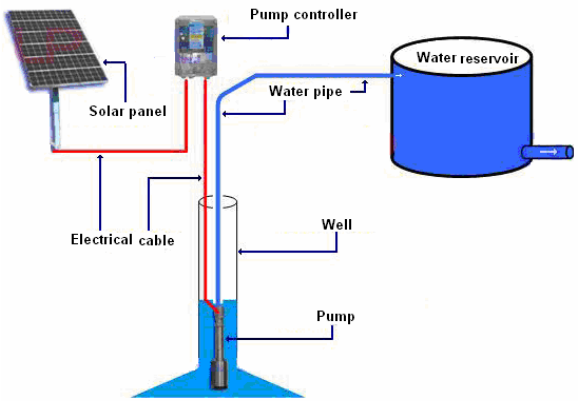


Figure 4: The water pumping system supplied by the solar power source

3.3 The isolated telecom system supplied by the solar power source

The accuracy of the electrical power supplying of an important telecommunication device, is essential. A new application of the alternate energy is supplied by power energy belonging to a telecom system for having access to the net, situated in a site with no access to the network. For this application one may choose for the supplying the use of the PV panels. Many times the camera-man of television through cable (CATV), or the net delivers (ISP) have had great technical difficulties for the installation of some equipment in places with no access to the network, or where the costs of the installation is very high.

3.4 Solar energy system for little space of production

One of the most common applications of the solar energy is the power supply for a little space of production, being found in a place without access to the public network. For this type of applications one may choose for the power supply source by using the compound systems from the PV panels, wind installations, diesel generator and also by using solar panels for obtaining some warm water.

4. THE POSITIONING SYSTEM STRUCTURE WITH DC MOTOR

In the industrial applications it is more often necessary the accomplishment of a precise and accurate position in a very short time [5]. By the type of the used energy, and a power element which assure motion of de charge, such a system may be: hydraulically, pneumatically and more often, electrical. For having a large view on such a positioning system let us consider a very short case, presented in figure 5.

The analyzed system is composed from a transducer of position (T), a regulator (REG), an electrical machine (ME) and a charge machine (ML).

The ideal equilibrium of system corresponds to the situation in which the position of the charges machine is the some with the one imposed, particularly, the output signal is identical with the command signal, situation in which the output tension of the position transducer, u_p, is zero, the supplying tension of the motor is null, and so, the whole structure remain static. At the arrival of a command signal at the output transducer of position appears a signal which is proportionally with the difference between the input size and the output size which, amplified and applied to the motor, it command to bring the charge a after a while in a new position of equilibrium [6].

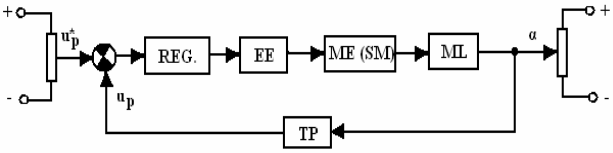


Figure 5: The classical structure for positioning system

5. THE ANALYSE OF THE COMMAND VARIANTS FOR POSITIONING SYSTEMS FOR SOLAR PANELS PLACED IN ISOLATED AREAS

5.1 The command of the positioning systems for solar panels using the astronomical data method

As we have already seen, one generally needs the position of the solar pursuing the apparent motion of the Sun, for obtaining some high energetically performances. Because one requires a high precision for following the Sun, the panel drive installation is more complex and expensive. That is why, the choosing a drive system, is the result of a compromise between the required performances of the PV installation and it cost.

In the system having an equatorial mounting (after a single axis) a rotation axis is parallel to the word axis, and the other axis is perpendicular on the first.

The motion around the first axis is done for the orientation following the hour angle of Sun (H) with a constantly angular speed.

$$\Omega_H = \frac{dH}{d\tau} = 360^0 / 24h = 15[deg/h] \quad (3)$$

In this paper we'll insist on the positioning systems with equatorial mounting, for the azimuthally mounting (after the dual axis) one will do a seasonal adjustment to tilt of angles the solar panel.
Using the astronomical data, one can graphically represent the local time (T_{local}) corresponding to each month of year.

Taking into account the local time one achieved the command positioning system algorithm based on the astronomical data method (see Fig. 6). This algorithm may be implemented on in a microcontroller structure.

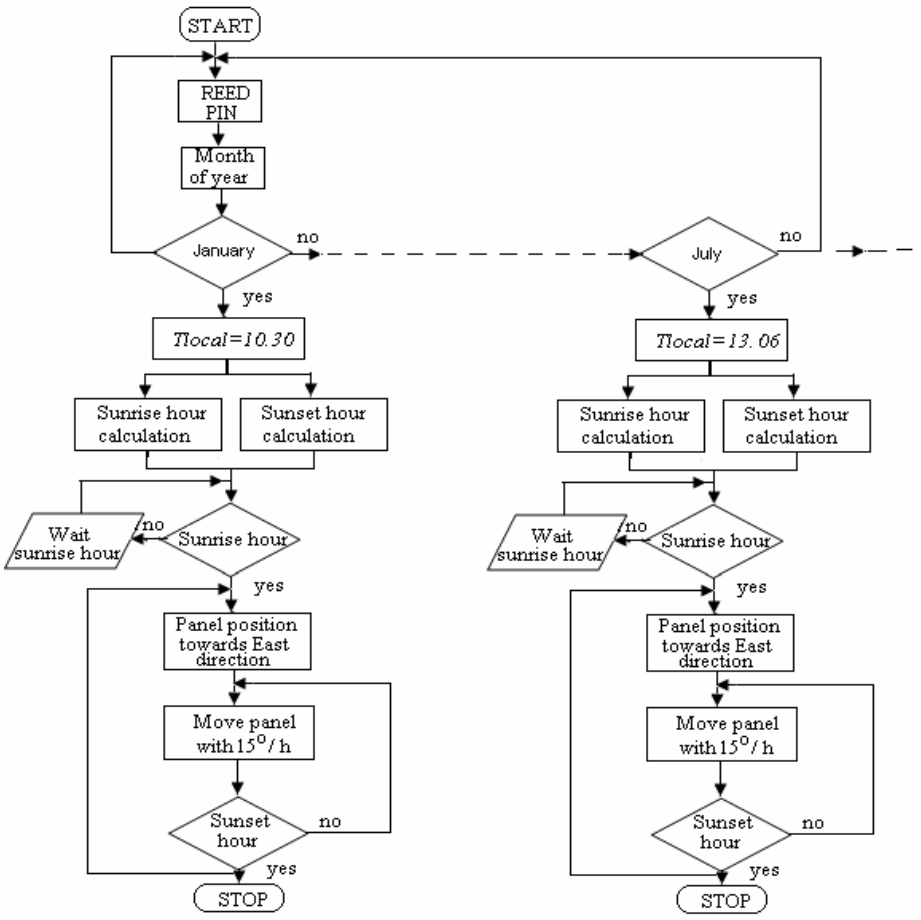


Figure 6: The algorithm of positioning system based on the astronomical data method

5.2 The command of positioning systems for solar panels using maximum power point tracing or the tracing of the Sun method

One experimentally, observed that the PV cell present the great oscillations of output electrical power according to the solar radiation intensity and to the meteorological conditions. In addition, when they debited on the electrical charge on can observe certain problems, and power transferred to the charge, rarely correspond to the maximum power transferred by PV panel.
This method is called Maximum Power Point Tracing (MPPT) and it forces the PV system operates in the maximum power point
When a power source is connected to a charge, the work point is found to the intersection between (I-V) characteristics. This point is permanently modified, because of the power source or the charge is modified permanently. For this reason, it does not work in MPP, and the power furnish to the charge is less than maximum power which could be emitted.
The principles of the regulators MPPT are frequently based on the Power-Volts (P-V) characteristic "the elbow"[7]. It's a method based on explore, as we can see in figure 7. Being in a certain point on the curve (X_1), one can see if the power value in the next point is higher or not than first one. If "yes", the work point is moved in next point (X_2), until the next value (X_n), become lower than the previous one value (X_{n-1}). In this moment one take into account the smaller interval between the known and specified points and one can also start again going on from

(X_{n-1}) until the MPP is reached. When the radiation intensity is modified, from E_1 to E_2, with $E_2>E_1$, the P-V characteristic modified by it self. The point (X), which has been MPP until now, becomes an untrue work point in the new conditions as one can see in figure 8. Another point is MPP, noted (X'). As in the linear regulator case, the control is based on an adjusting system which has the input output variable (X_i) respectively (X_o) (figure 9).

In the most of the adjusting systems, one needs only a measurement for finding out the report between X_o and X_i. This one isn't available any more in an individual system in which this report depends on the time.

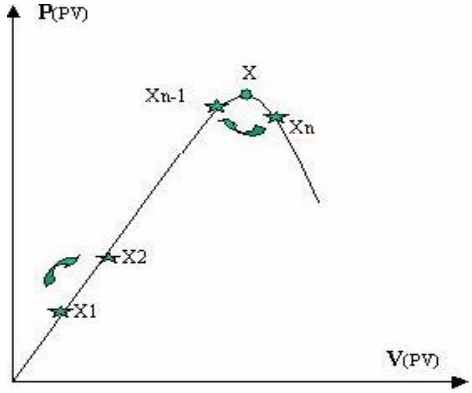


Figure 7: The principle MPP search

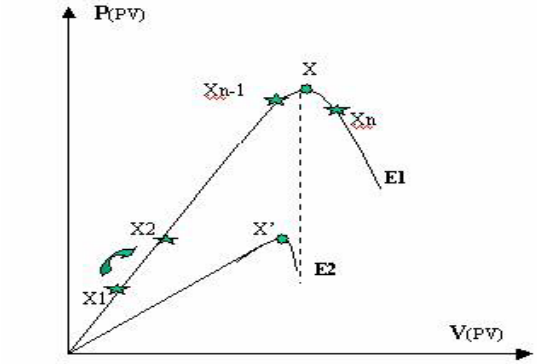


Figure 8: The resultants solar radiation modified about MPP

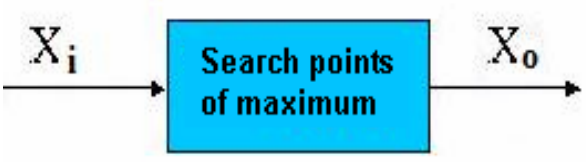


Figure 9: Classical scheme of MPP regulator

The modification points can be assimilated with a perturbation in the maximum adjusting control system. As a consequence, if one knows the derivate sign X_o and if this one show that X_o deviates from the maximum, the regulator is changes the sign and direction of X_i for finding out once again maximum. This permanently evolution of X_i determines some permanent oscillations around the maximum value.

6. SIMULATION RESULTS

The simulink model of the positioning system is presented in figure 10. This model contain of the subsystem block for DC motor model and subsystem block for motor control model [8], [9], [10].

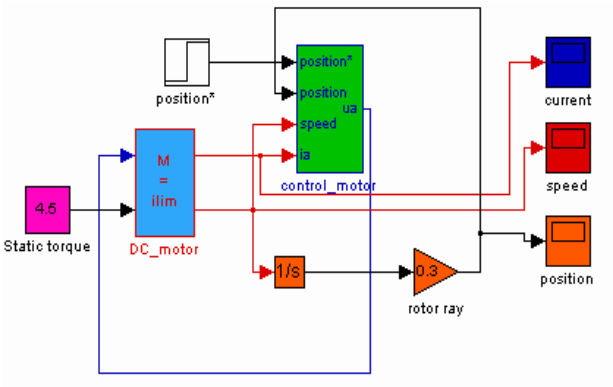


Figure 10: Simulink model of the positioning system

The control bloc for DC motor (Fig. 11) it achieves with PI regulator which have of a the current limitation value to 15 Amperes, and the output Relay block having the signification of the static contactor command in inclusion of the chopper.

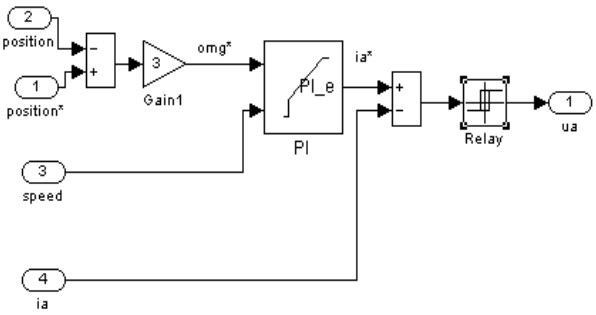


Figure 11: The block mask for control motor

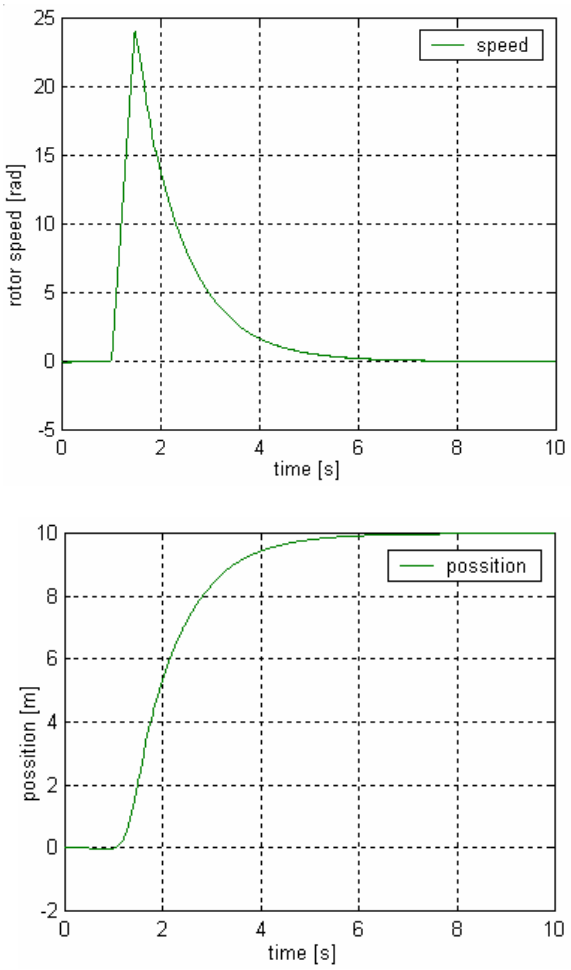


Figure 12: Simulation results

7. CONCLUSIONS

By using an open-loop control system (the astronomical data method) it lacks the mechanism for self adjustment, therefore, it can only deliver a desired output if the process is well understood and all conditions affecting the process are constant.
In a closed-loop control system (the maximum power point tracing method) provides automatic adjustment of a process by collecting and evaluating data and responding to it accordingly, with the aim of maintaining the desired output under changing conditions.
We propose the command strategy by using the combination of the both methods.
The results of simulink model propose are relative good (see Fig. 12), for a linear position prescribed (10 meters), the system had reached this position, without any oscillations.

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Appendix

The parameters of the DC motor:

Rated power	P_N= 2kW;
Rated voltage	U_N=220V;
Rated speed	n_N= 1500 rot/min;
Rotor resistance	Ra=1.64 Ω;
Total inductance	Lt=0.0237H;
Total inertia ratio	J=0.21kgm^2;
Constant torque	KΦ=1.39Wb