

TRACKING CONTROLLER FOR PHOTOVOLTAIC SYSTEMS BASED OF NEURAL NETWORKS

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Abstract: The power delivered by photovoltaic systems it can be increased through its automated tracking after the sun. Utilizing a cheap solution for control required the implementation of an algorithm for orientation, simple and efficient. The best solution was the classic algorithm that generates sun relative movement from Terra. Because the calculus volume of sun position is relative big, it must be necessary to find another solution that described the sun trajectory. The proposed solution it based on a neuronal structure, capable to approximate with a good precision the sun trajectory and to deliver permanently its coordinates.

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

1. INTRODUCTION

Solar energy is the most environmentally friendly source of power imaginable. Solar cells (or more accurately, PV Modules) convert the sun's energy into electricity. PV cells produce DC electricity like a battery. As the light energy (photons) strikes the specially prepared silicone, electrons are knocked free which can flow through an electrical circuit back to the opposite side of the silicone cell to fill the holes left behind. Unlike batteries PV modules cannot store electricity. So long as light continues to strike the panel there is a never-ending supply of electricity, but, when the sun sets so does the power. This problem is overcome through the use of storage batteries that are charged during the day and supply electricity at night or at times when the sunlight is insufficient.

PV modules come in two distinct categories – crystalline silicon and amorphous silicon thin film. Both amorphous and crystalline technologies are commonly used in efficient grid connected and stand alone installations. Mono and poly crystalline modules usually have 36 solar cells in a 9 x 4 matrix connected in series to provide an output voltage suitable for battery charging. Modules can be connected in series or parallel to form an array to provide higher voltage and current outputs as required.

The specific site where a PV system will be located plays a crucial role in the design and performance of the system. The amount of power generated by a solar cell depends upon the intensity of sunlight striking it, and the amount of available sunlight varies with latitude, climate, and local conditions, such as the presence of trees. It is helpful to understand how the sun moves through the sky throughout the year when evaluating your site's solar potential.

There are three factors responsible for variations in the amount and quality of sunlight reaching the Earth. First, the Earth is round. Second, it revolves around the sun in an elliptical orbit. Third, the Earth rotates on a tilted axis. As the Earth is round, sunlight strikes its surface at differing angles ranging from 0° (just above the horizon) to 90° (when the sun is directly overhead). When the sun's rays are perpendicular to the surface of the Earth, they transmit the most energy. When the sun is low in the sky and its rays are at a very low angle, they

must pass through a longer portion of the atmosphere, making the sunlight scattered, diffuse, and reducing its energy.

The effectiveness and efficiency of the system can depend on a series of variables, some of which are listed below:

Location – the amount of sunlight available will affect the amount of energy produced.

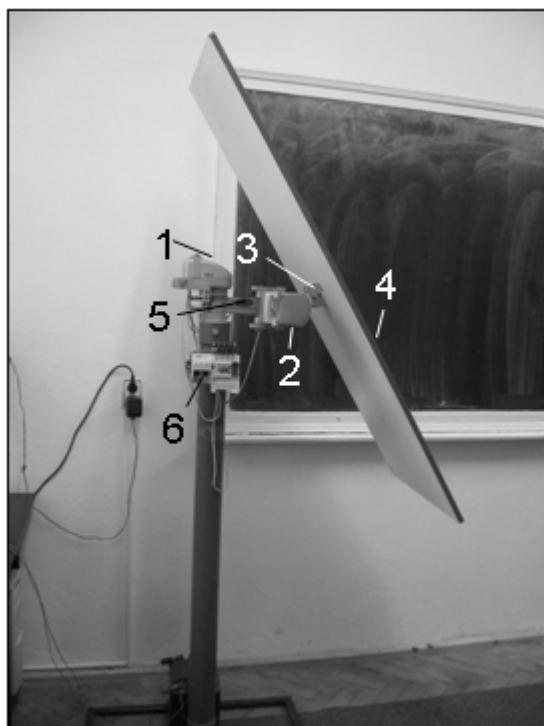
Orientation – the orientation of a building and positioning of solar arrays are vital factors to maximise energy production. In Scotland, and the northern hemisphere, a south facing façade will collect most light throughout the year and so produce the most energy.

Tilt Angle – inclining or tilting solar panels towards the sun can increase the levels of light falling on the surface and therefore cause an increase in electricity output. The appropriate angle of inclination will depend upon the latitude of the proposed site.

The power delivered by the photovoltaic panels can be increased through there automated orientation in two coordinates after the sun. This objective can be realized by utilization of a programmable controller which has implemented a continuous panel positioning program, perpendicular to solar arrays. This paper describe the solution to generate continuously the positioning coordinates beside the two axes, therefore the photovoltaic panel can attend the relative movement of the sun.

2. THE AUTOMATED ORIENTAITION SYSTEM OF PV MODULES

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 1,600x800 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.

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 energy delivered by photovoltaic cells increased with the panels orientation directly on sun. these orientation systems can increased the delivered with 30% -40% in a day time, compared with fixed panels.

The Tracking PV module system realized it is presented in figure 1.

- 1, 2 – continuous current engines with reducers
- 3– Inclinometer module
- 4 – PV module
- 5 – Orientation sensor (compass)
- 6 – Programmable controller PLC

Fig. 1. The Tracking PV module system

The collector orientation command was realized by two continuous current engines with reducers (Diseq H-H engine) 1 and 2 (figure 1). The engine 1 assures the rotation movement of the vertical axe, and the engine 2 afford the inclination regulation of PV module 6.

It was desired that the elected constructive solution be the most simple and the most reliable therefore it can have finally, the best performance-price ratio. The electric energy producing system is made, without photovoltaic panels, with an accumulator and an inverter which have loader controller.

The command system of the photovoltaic panels orientation it was realized by a modular programmable controller, type TWIDO, using a master module TWDLMDA20DRT and a slave module with analogical inputs, TWDAMM3HT.

For the determination of the direction in which must be oriented in one time the panel (the azimuth) it is necessary to measure permanently, the angular displacement beside a cardinal point, in horizontal plan. This was realized by a magneto-electronic sensor type compass, which assure the directional information – controller that can establish the orientation direction. The utilized compass it is an analogical sensor type Dinsmore Sensing Systems no. 1655, technological based on the Hall Effect.

For the controller it is needed a information about the *inclination angle*, to facilitate the lineament in vertical plan. It can be realized by the utilization of a digital inclinometer adjust to a single axe, realized by SmartTool Technologies.

3. CALCULATING THE SUN ANGLES FOR THE SPECIFIED LOCATION, DATE AND TIME

The sun angles consist of two values: the altitude angle and the azimuth angle. The altitude angle (inclination) describes how high the sun is in the sky. It is measured between an imaginary line that represents the sunray that reaches the observer and the horizon. Its value is positive between the sunrise and the sunset. The azimuth informs us about the direction of the sun. It is the angle formed by the projection of a sun ray on the ground and from South direction.

These angles will be calculated by the following astronomic algorithm:

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

$M = M_0 + M_1 * (J - J_{2000})$; where J_{2000} is a constant equal with 2451545.J – the Julian day number

The mean anomaly is utilized to indicate the planet position depending on it perihelion which is measured in grades. M_0 , M_1 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 .

$$v = M + C$$

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

$$C \text{ aprox} = C_1 \sin M + C_2 \sin (2M) + C_3 \sin (3M) + C_4 \sin (4M) \dots$$

To describe the Terra orbit it will be necessary C_1 , C_2 , C_3 , only, where C_1 , C_2 , C_3 are constants.

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)
 $Eq = 23.45$

The ecliptic coordinates

The ecliptically longitude of a planet like it is viewed from the sun is:

$$la = v + le = M + C + le.$$

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

$$La = M + C + le + 180$$

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:

$$\begin{aligned} \sin \alpha \cos \delta &= \sin la \cos eq \cos \beta - \sin \beta \sin eq \\ \cos \alpha \cos \delta &= \cos la \cos eq \\ \sin \delta &= \sin \beta \cos eq + \cos \beta \sin eq \sin la; \\ \alpha &= \arctg((\sin la \cos eq) / \cos la) \\ \delta &= \arcsin(\sin la \sin eq) \end{aligned}$$

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

North latitude: ϕ
 West longitude: lw

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

Th, Th_0, Th_1 are specific constants of the earth

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

$$\sin az \cos h = \sin H \cos \delta$$

$$\cos az \cos h = \cos H \sin \phi \cos \delta - \sin \delta \cos \phi$$

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos H$$

$$H = th - \alpha$$

From this, it can be calculated the formulas which determine the two angles:

$$\begin{aligned} Az &= \arctg(\sin H / (\cos H \sin \phi - \tg \delta \cos \phi)) \\ h &= \arcsin(\sin \phi \sin \delta + \cos \phi \cos \delta \cos H) \end{aligned}$$

4. THE NEURONAL NETWORK PERFORMED TO GENERATE THE SUN POSITION COORDINATES

The calculus volume can be reduced on line using a neuronal network which can be trained with anterior algorithm calculated values for the azimuth and altitude. The network shown in figure 2 permits the calculation of azimuth and altitude for the input informations that refers to geographical position, date and time. If the calculus (positioning) are made for a certain geographic area (i. e. Bacau- Romania, $46,56^\circ$ latitude and $26,9^\circ$ longitude), the neuronal network can be simplified by 2 inputs abandonment. In this case, the training of neuronal network it realized just with calculated dates of that geographical area.

For a very good obtained approximation, the problem can be than separate generating two neuronal networks, one for azimuth (figure 3) and one for altitude.

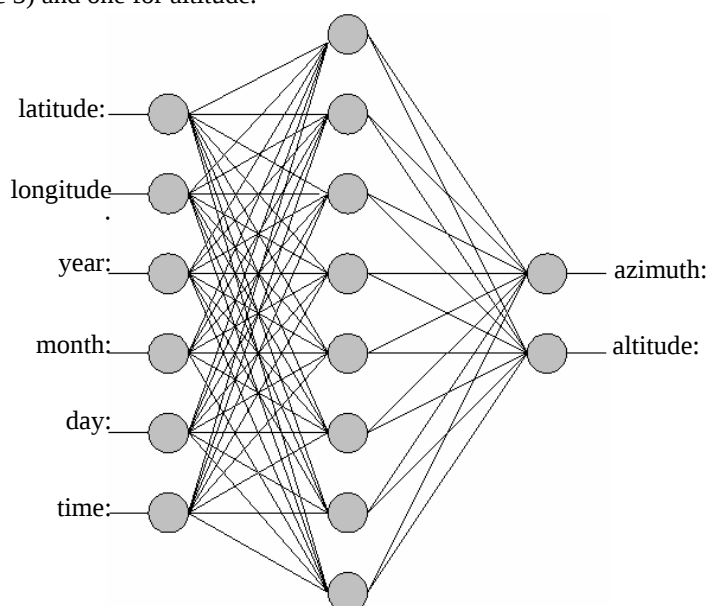


Fig 2 Neural network which calculate azimuth and altitude

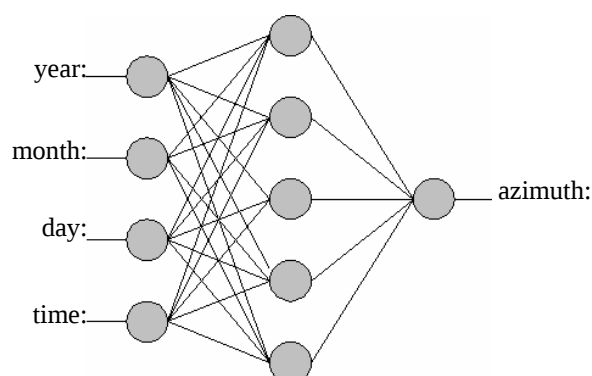


Fig. 3. Neural network which calculate the specific azimuth of a geographic position

The neuronal network shown in figure 3 was realized and tested with help of NeuroSolutions 5.03 program, realized by NeuroDimension. The activation functions utilized were configured according to figure 4.

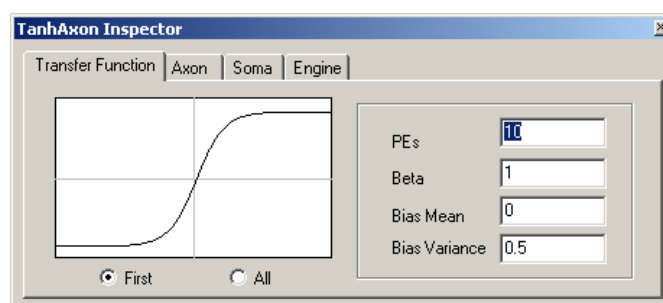


Fig. 4. The activation function

The conceivable network it was trained with calculated dates by a program that has at base, the algorithm that was previous presented. The results obtained for azimuth was satisfactory, because deliver closed values with the desired values (figure 5).

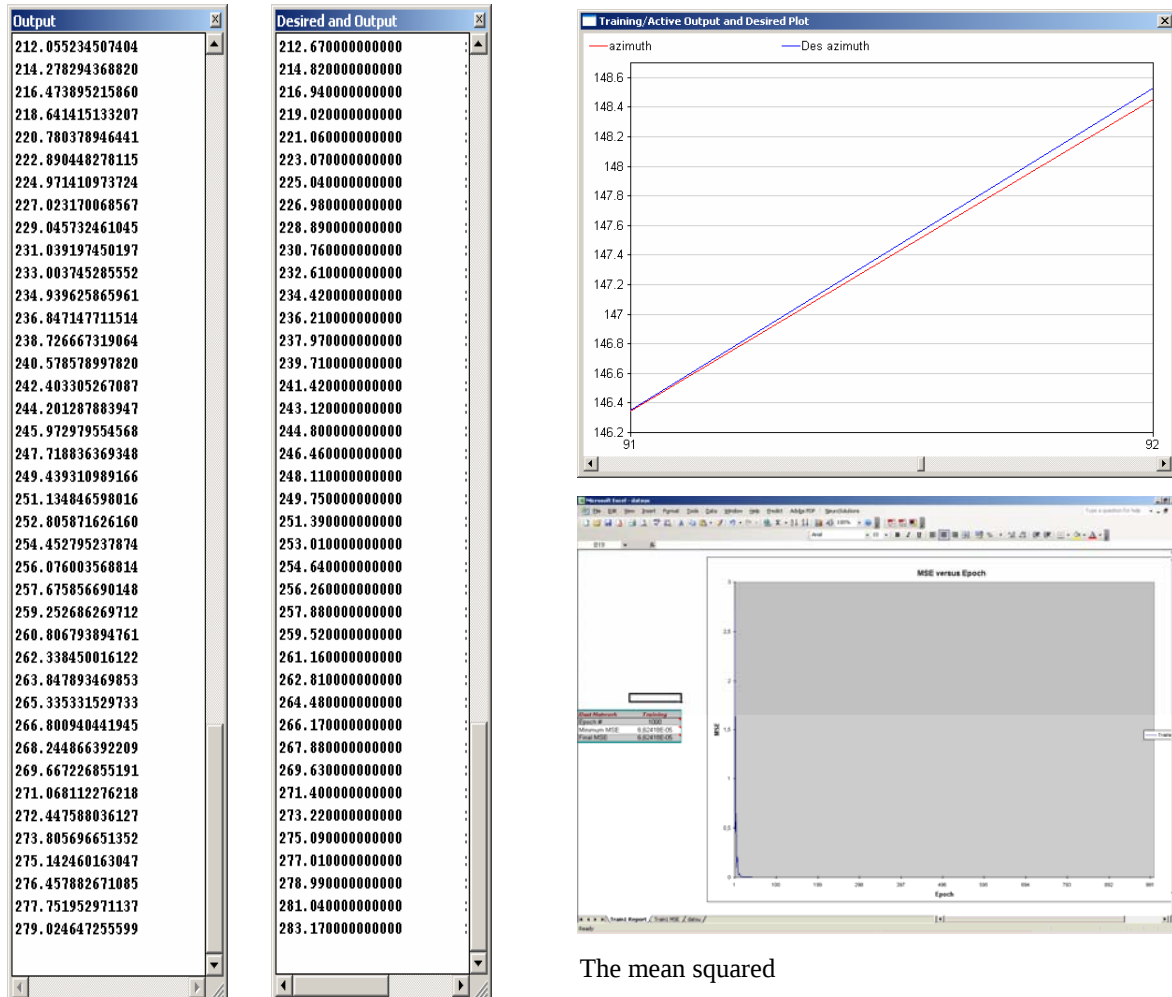


Fig. 5. Comparing the desired azimuth with calculated azimuth and the mean squared.

5. CONCLUSIONS

The trained and simulated neuronal network permits the implementation of a more simple and efficient program for the programmable controller which commands the tracking PV system. Utilizing this solution it can be used less complex controllers, which is a solution for reducing the cost price for the tracking PV module.

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