# Solar Tracker of Two Degrees of Freedom for Photovoltaic Solar Cell Using Fuzzy Logic

Gustavo Ozuna, Carlos Anaya. Diana Figueroa. Nun Pitalua

*Abstract*— **This paper proposes and evaluates mathematical simulation, a solar tracking controlled by fuzzy logic in order to achieve the correct positioning of a photovoltaic solar cell and get as much sunlight during the day and therefore produce the most electricity. The results of the first phase of the research show the behavior of direct current motors with respect to the proposed sensors to carry out this function.**

## I. Introduction

THIS paper is a result of the research project " Solar tracker of two degrees of freedom for photovoltaic solar cell, using fuzzy logic" this propose it’s a mechanism for more efficient solar energy capture by positioning a solar cell tracking to the sun during the day, in which its first phase is represented mathematically with fuzzy logic, this assure the correct positioning of the PV panel during the day, The control algorithms position the panel from east to west along the apparent path of the sun and north-south positioning in the changing seasons of the year, as shown in Figure 1.

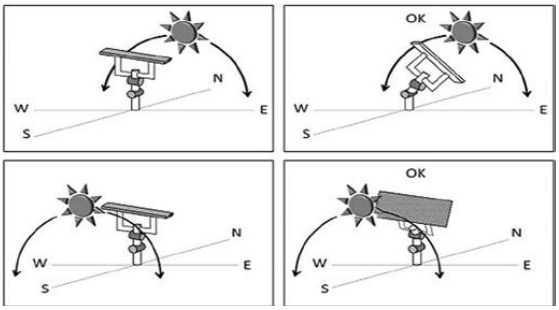


Figure 1. Positions of the sun and solar panel

## II. Problem

Today we see a number of disciplines that seek to develop sustainable systems of energy transformation and addressing the problem from several points view to achieving cleaner production. Photovoltaic solar cells that we see in the city are still installed and capture most of the rays of the midday sun. Also on the market alternatives are tracking photovoltaic solar cells as global positioning system, using programmable logic controllers and by computer using LabView, the proposed prototype is intended as a low cost alternative.

Manuscript received March 9, 2011; revised March 31, 2011.
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## III. Prototype

In the system shown in Figure 2 is needed to position both motors to ensure proper tracking of the solar panel in any position of the sun with respect to the East-West or North-South. The 2 motors are used direct current, with the following application:

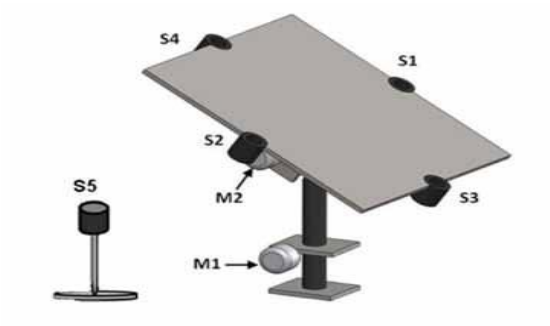


Figure 2. Solar tracker sensors

Motor 1: Horizontal position (North-South, South-North)

Motor 2: Vertical position (East-West, West-East)

These are modeled mathematically using the following equations: [4] [5]

$$\frac{di}{dt} = \frac{Vapp}{L} - \frac{R}{L} i - \frac{K\Phi}{L}$$

$$\frac{d\omega}{dt} = \frac{K\Phi}{J} - \frac{b}{J}\omega$$

Vapp is the applied voltage, R is the electrical resistance, L is the inductance, b is the friction, J is the moment of inertia for the motor and it counts KΦ is the electromagnetic field represented in Figure 3.

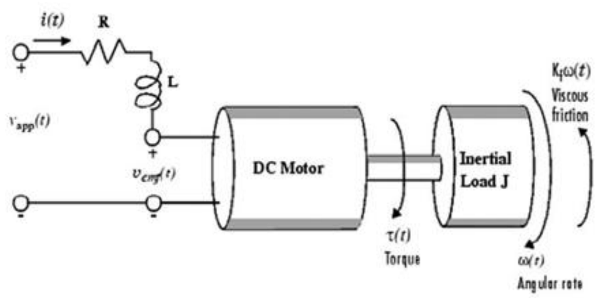


Figure 3. DC Motor

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

In addition, for the system under consideration 5 sensors coded as follows:
S1: East
S2: West
S3: South
S4: North
S5: Day or Night

These photo resistive sensors only allow passing a given voltage ranging from 0 volt to the 5 volts depending on the amount of sunlight that reaches them, thereby achieving continuous values. The fifth sensor S5 it's a pyrometer.

## I. CONTROL

To control is proposed using fuzzy logic because it emulates human acceptable reasoning and could make decisions based on inaccurate data [2]. This uses a microcontroller in which fuzzy rules are scheduled and so able to position the solar panel in the four cardinal points as shown in Figure 1.

The equations of the DC motor and voltage inputs from the sensors were simulated using MATLAB and Simulink which is represented in Figure 4. For control system using input devices S1 and S2 for position control system for motor 1, S3 and S4 to the position control system of the motor 2 and also the S5 sensor that detects sunlight and controls the other four sensors. The Microcontroller (simulated) performs the comparison of the sensors S1, S2 and S3-S4 to calculate the error and then send the signal to the motor 1 to motor 2, which is constantly fed back, by comparing the input voltage sensor for precise positioning of the photovoltaic panel, appropriate if the error is zero when the sensors S1 and S2 are receiving the same voltage.

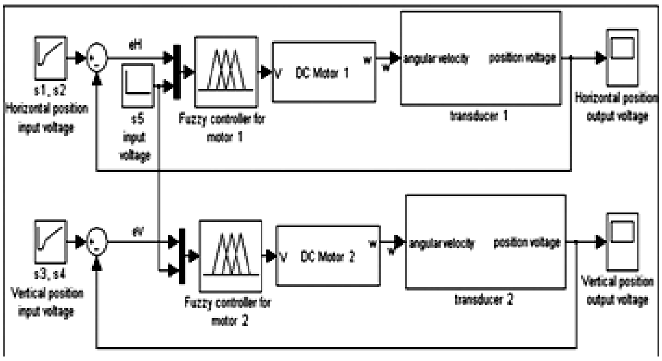


Figure 4. Position control in Simulink.

S3 and S4 sensors work the same way. The position is determined by the information set out in the fuzzy inference tables (Tables 1 and 2), where each rule makes the comparison between the sensor and the horizontal error S5 (mv) in the case of motor 1 and the vertical error (eV) for the motor 2. Membership functions used for fuzzy tracking system are represented in Tables 1 and 2:

| eH/S5 | ON | OFF |
|---|---|---|
| NEG | EO | OK |
| Ok | OK | OK |
| POS | OE | OK |

Table 1. Fuzzy inference table for horizontal position.

| eV/S5 | ON | OFF |
|---|---|---|
| NEG | SN | OK |
| Ok | OK | OK |
| POS | NS | OK |

Table 2. Fuzzy inference table for vertical position.

In Figure 5 we see the representation of the fuzzy set resulting voltage eH, where each voltage value [-5 5], corresponds to a range [0 1] as its membership. When the system is stabilized on "OK", the monitoring system at its input receives the same amount of voltage between the sensors and thus the photovoltaic cell is positioned properly on the path East West. Besides the fuzzy set to eV is similar to that used in Figure 5 because the behavior of the errors are similar, because both input voltages control systems from sensors with the same voltage range.

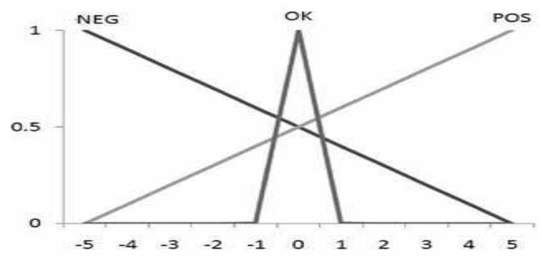


Figure 5. Input fuzzy set for both position errors (eH, eV)

Output fuzzy sets shown in figures 6 and 7, are similar for the other 1 and 2, since both share the same mechanical and electrical properties in addition to receiving information from sensors with the same behavior.

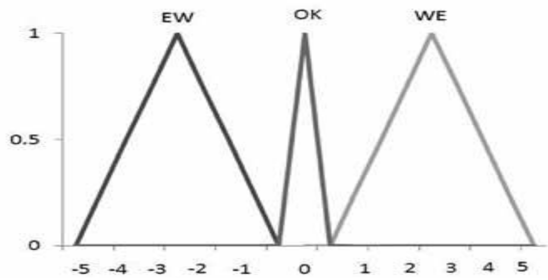


Figure 6. Output fuzzy set for fuzzy controller of the motor 1

Figure 7 shows the input fuzzy set of sensor S5 which is a pyrometer and its function is to detect solar radiation. This is located outside the system, which could handle multiple diffuse solar tracking systems at once. When it's daytime S5 is set ON, so that other sensors will start to seek the maximum sunlight and when the sensor S5 is OFF, the other sensors stop looking, but panel sensors detect another kind of light, for example, lamps or other light sources will not be taken into account because it is only sensitive to sunlight, thus avoiding energy losses during the night at rest. Table 3 show the fuzzy control rules for the system both horizontally.

| | FUZZY RULES |
|---|---|
| 1 | If (eH is NEG) and (S5 is ON) then (M1 is EW) |
| 2 | If (eH is ok) and (S5 is ON) then (M1 is OK) |
| 3 | If (eH is POS) and (S5 is ON) then (M1 is WE) |
| 4 | If (eH is NEG) and (S5 is OFF) then (M1 is OK) |
| 5 | If (eH is ok) and (S5 is OFF) then (M1 is OK) |
| 6 | If (eH is POS) and (S5 is OFF) then (M1 is OK) |

Table 3. Rules for the fuzzy control horizontal position

ISBN: 978-988-19251-4-5
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

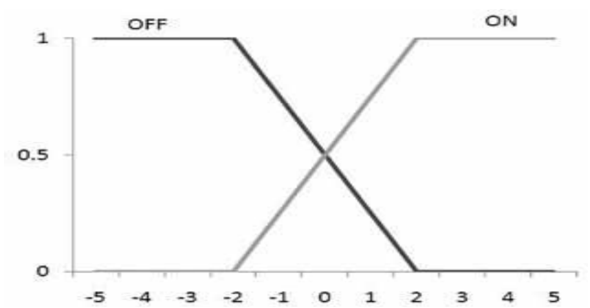


Figure 7. Output fuzzy set of sensor 5

## II. SIMULATION

For the simulation, the voltage represented through 5 vectors as input to the sensors S1, S2, S3, S4 and S5 in the system shown in Figure 4 by means of SIMULINK software MATHLAB belonging to the platform. Figure 8 shows the behavior of the motor 2 which controls the position of the solar cell, in the WE-EW (West-East East-West), where the position of the panel begins in the WE and then in the direction of EW For directions to the peak of EW and then return to the WE zone ending at the peak of WE.

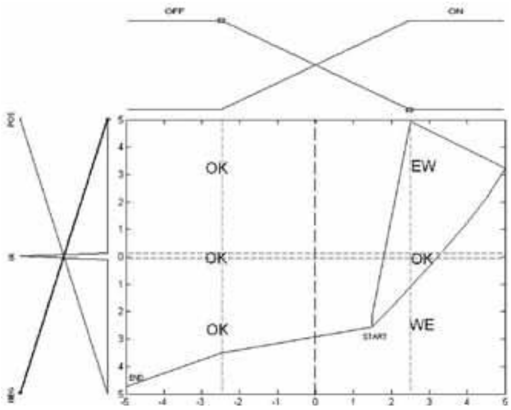


Figure 8. Linguistic path to the horizontal position of the solar panel

Likewise, Figure 9 shows the behavior of motor 1, and the position of the panel during the day and in the NS-NS (North-South South-North). The graph starts in the NS the behavior of this vector is always kept in the range of [5 - 5] which indicates that the path will exchange for NS-NS areas. This shows the linguistic path through areas of activation in a period of 1hrs. The Figures 10 and 11 shows angular velocity of motor 1 horizontal and vertical angular velocity of motor 2 in a period of 12 hrs. [1].

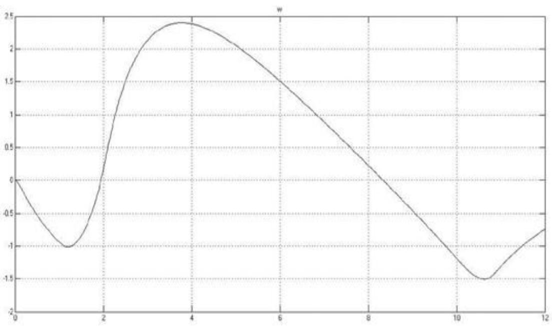

Figure 9. Horizontal angular velocity over a period of 12 hrs

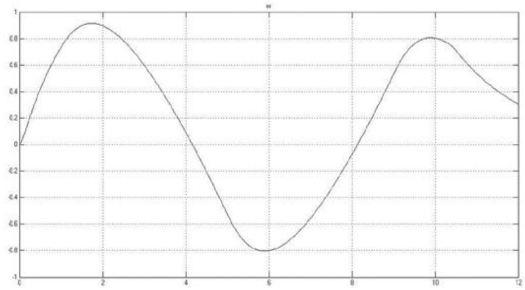

Figure 10. Vertical angular velocity over a period of 12 hrs.

## III. ELECTRONIC PROPOSAL

After carrying out tests simulating the behavior of the engines with respect to the sensors and obtaining the simulated system is stable, the research team developed the electronic proposal, which is shown in Figure 11. This circuit uses the PIC 16F628A microcontroller which will have programmed the fuzzy rules and is a popular low-cost microcontroller.

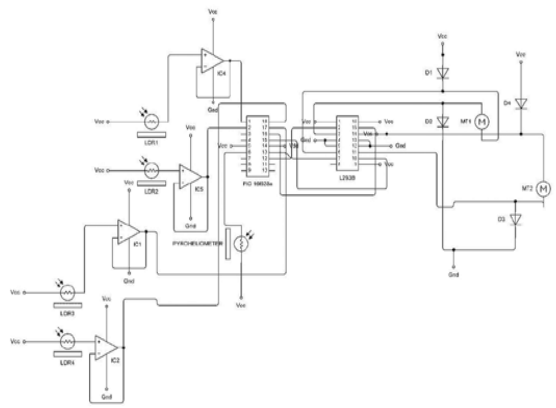

Figure 11. Electronic proposal for solar tracker

## IV. MECHANIC PROPOSAL

The proposed mechanical design modeling the transmission in Solid Works software for a prototype solar tracker includes a worm gear with a ratio of 1:40, the mechanical system provides the motion that puts the tracker South - North - North - South and east -west - west –east, This proposed mechanism is its practicality and simple operation represented in the figure 12 and figure 13.

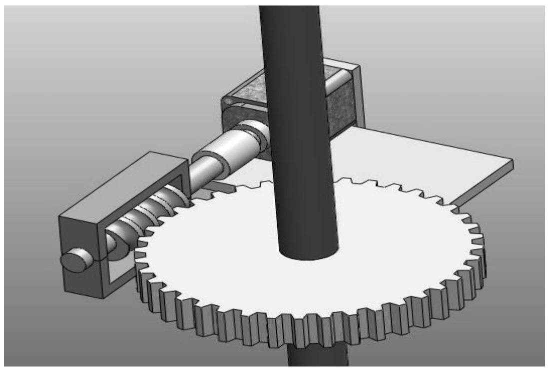

Figure 12. Worm gear motion north– south – south - north

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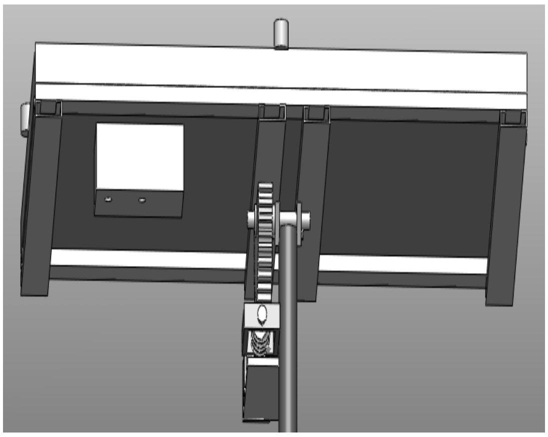

Figure 13. Worm gear motion west – east – east - west

## V. CONCLUSIONS

The search new alternatives for conversion solar energy at the University of Sonora, contributes to the achievement of a sustainable university committed to the environment. The proposed system is an economical alternative in the medium power generation to meet electricity demand in the classroom, household or rural communities.

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ISBN: 978-988-19251-4-5
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