Solar Tracking System Based on FPGA

Dayana Garzón Vergara[1], Aldair Soledispa Carrasco[2]
Escuela Superior Politécnica del Litoral, ESPOL
Facultad de Ingeniería en Electricidad y Computación,
Campus Gustavo Galindo Km 30.5 Vía Perimetral, P.O. Box 09-01-5863, Guayaquil, Ecuador
{dtgarzon[1], aldasole[2]}@espol.edu.ec

***Abstract*— This paper describes the design and development of an angular position control based on FPGA that aims to capture light signals to know the position in which the photovoltaic panel should move. Also, it consists of an embedded system which will handle the processing times of the CPU and memory being used. For this, a system that compares the values of each of the sensors will be implemented to obtain the position of the light and that the photovoltaic panel can move in the direction of the light. In addition, a web server will be implemented in which there will be a visual interface that allows displaying the values obtained by the system.**

Keywords— Solar Tracking system, FPGA, machine learning, web server, embedded

I. INTRODUCTION

Since ancient times, the human being has needed to have light to be able to carry out activities or works such as the sun goes down, for these problems he has looked for the way to keep illuminated the place where he is, he started with the natural energy of the fire and then evolved getting the electric power, but this led to another problem. In order to use electric power, it was necessary to store it in a container if it required to be taken to another distant site or to have connections to the power plant, many scientists realized that they could convert solar energy into electrical energy and to be able to carry out this discovery they proceeded [1] to create solar panels. Although this led to another dilemma, since the solar panels remained static they lost a lot of solar energy during the day [2]. We are going to describe a system which will allow moving a solar panel to the position that keeps the lightest, so you can get all the solar rays throughout the day without having the loss of energy when the sunlight changes position, you will also have the ability to compare the values of the sensors to be able to have a better result in movement of the panel allowing it to capture all possible sunlight.

II. RELATED WORKS

To the best of our knowledge, some algorithms have been used to achieve the tracking of solar rays working with a programmable door matrix that is applied to design the controller so that solar cells are always pointing to the sun's rays most of the day [4].

In order to maximize the power of solar cells by; some studies indicate that the use of machine learning improves the behavior of the automated system by providing the best positioning of the solar panel to capture the greatest amount of solar energy. This allows us to make a solar tracking system which maximizes the output signal from the solar cells using intelligent controllers that act as a human brain; each of them controls the direction of the panel depending on the position of the solar cells at the time. [5]

Fuzzy logic controllers have been implemented in some works with two systems for solar tracking effectively, implemented in FPGA, sensors, motor and an input and output interface. For better monitoring of the solar panel, a system was implemented with an engine that allows the panel to rotate, but not only this also adds the use of light sensors to detect the solar rays that the panel will have for periods of time and in this respect the efficiency of the panel rotation will increase, when PV panel reaches at its edge value, then controller stops the motor and prevents it from rotating in same direction to avoid it breakage problem. At night sensor are in very dark night so the outputs of the sensors are very big, then controller goes in night subroutine and rotate panel in starting position [6].

The position of the photoresistors will depend on the amount that will be used. They can be placed along a curved base when more than one photoresistor is used; or they can be placed at the outer end of the axis of rotation, as we will do in the present work since only two photoresistors will be used. [7]

Some works have used a field programmable gate matrix (FPGA) with a Xilinx Spartan-3 FPGA to implement Reflex load control in a dual-axis solar tracking system with maximum power point tracking (MPPT). One of the important points about the document is how they charge a battery and in turn control and regulate the wear of energy by managing the temperature values. [8].

In this work, we are going to implement an Embedded System based on FPGA with the ability to move a photovoltaic panel by performing a process of adjusting the proportional, integral and derivative parameters of the PID controller and be able to store the readings of two photoresistors in Double Data Rate 3 Synchronous Dynamic Random-Access Memory (DDR3-SDRAM). The system will have as output a visual interface in a web application deployed in a web application server running in a Linux operating system with ARM processor where the light intensity values obtained by the two photoresistors will be shown in real time. the error between these values, which will represent the error to be corrected by angular displacement.

III. DATA SET

The dataset consists in two files, one for training and the other for prediction; with sampling frequency of 50Hz, with the recording of angular position of the solar panel, its direction by a binary value: 01 left and 10 right and the LDRs values. The samplings were collected at the time of every 0.1 s while performing a rotational movement tracking the light source.

The dataset will be used to detect the behavior and extract the characteristics of the plant, in order to create a neuronal network that will predict the direction of the panel and it will allow us to control it; so, in that way it is always perpendicular to the sun and capture the greatest amount of solar energy.

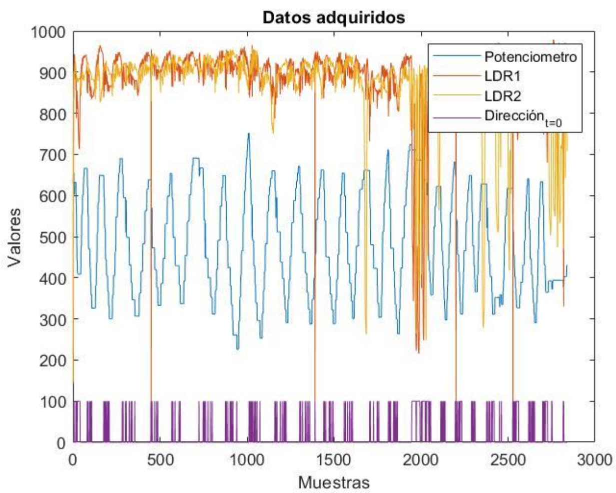

Illustration 1. Presentation of data acquired in Arduino

IV. EXPERIMENTAL DESIGN

The data acquisition system was based on a model consisting of a main structure in which an Arduino was responsible for collecting data from the potentiometer, the direction and LDRs values to anticipate the behavior of the system.

For sampling to be continuous; a DC motor with gearbox was used; which allowed the open-loop movement of the solar panel and also a potentiometer was used to determinate the angular position and define the limits of the rotation range to limit the movement of the panel and that it only rotates 90 degrees; 45 degrees on each side when the solar panel is completely horizontal.

As the panel moves from one limit to another following the light source, Arduino was collecting the data in a local file.

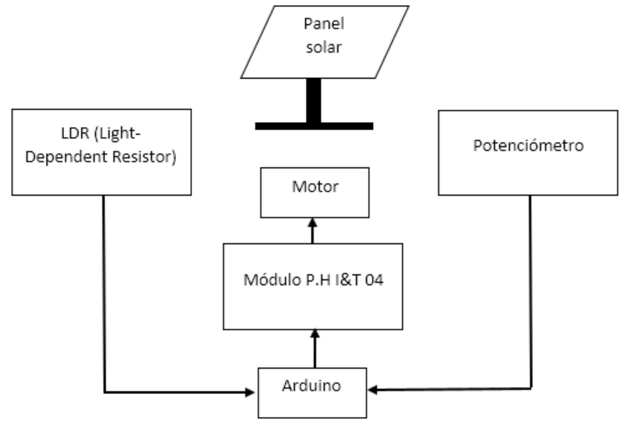

Illustration 2. Experimental Design

V. METHODOLOGY

When obtaining the results of the LDR values, two channels were used to acquire the data that would serve to show how much light is present on the solar panel with their respective direction. The result of the readings gave inconsistent and out of range values, so it was decided to use a formula which did not present values within the range of our dataset and with these could be used:

$$LRD = \frac{(ldr * 3.3) * 100}{4095 * 3}$$

Equation 1. Data converter at set range.

The use of pointers was carried out and the memory addresses that were placed in the "system.h" file, located in the. bsp directory of the eclipse project, were established. From this address, the data obtained in our system is written. After acquiring the data, we proceeded to take them from memory, process and send them to a neural network, which determines and predicts the direction in which the panel should move to obtain the greatest amount of light present.

In addition, the absolute value or subtraction is calculated to determine the panel position error. When this value is below a certain limit, it indicates that the LDR values are approximately equal and the engine will stop running. Otherwise, when the value is above that limit, the panel will continue moving until the error is acceptable.

$$error = \left|LDR_{Derecha} - LDR_{Izquierda}\right|$$

Equation 2.Total Engine Position

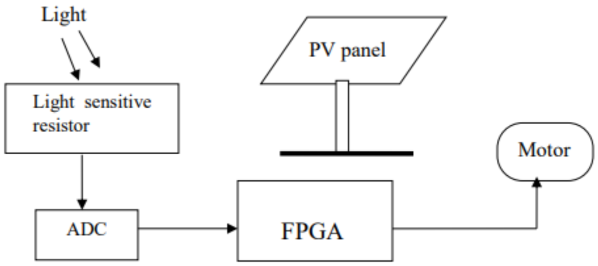

Illustration 3.Block Diagram of sun tracking system

A neuronal network with 3 layers was implemented. An input layer with the LDRs data, angular position and the direction; a hidden layer whose neurons analyze the behavior of the system, and finally the output that predicts the direction of the panel after 10 samples.

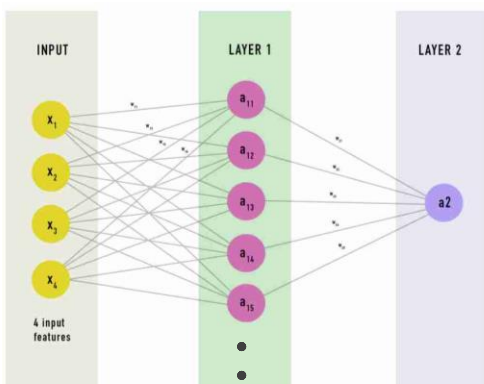

Illustration 4. Diagram of the function of neural net

For the training and validation of the natural network, two different files where used. The data recollected from the two LDRs, angular position and direction by the Arduino connected to the FPGA is processed by the NN. Finally, the output obtained is direction of the solar panel in t+1 as shown in the following illustration.

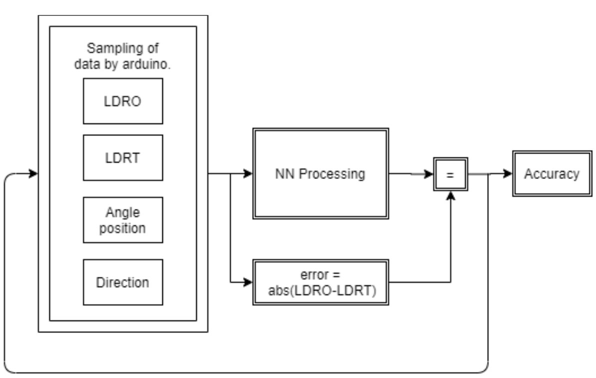

Illustration 5. Block Diagram of data processing in FPGA

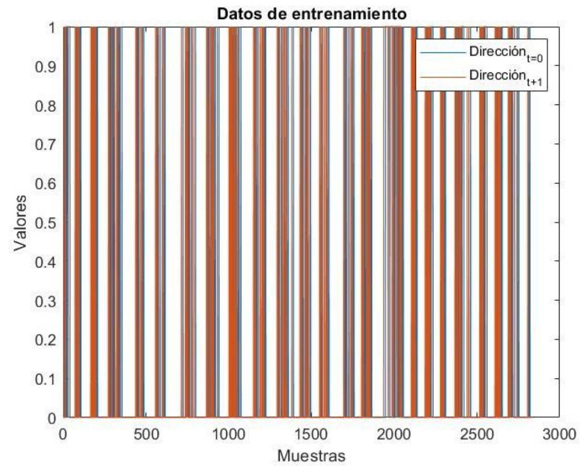

Illustration 6. Data Training

A. Hardware Architecture

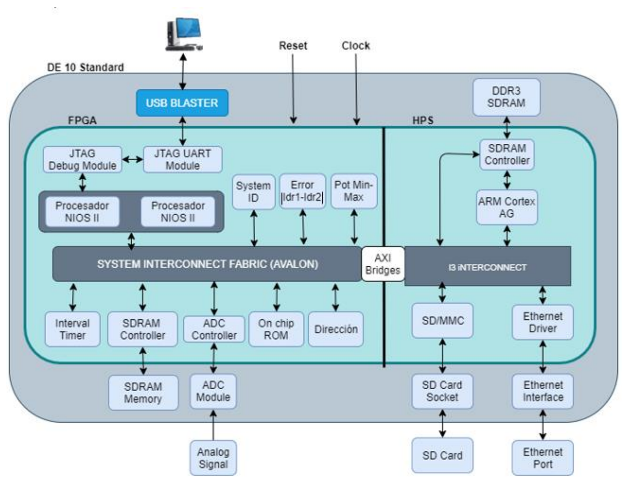

Illustration 7. Block diagram based on the NIOS ii Processor

VI. RESULTS

Several samples of data were observed while the training of the neural network was performed with tests of 1000 data and with a waiting time of 100 milliseconds, 20 layers were established to obtain fully accurate values to be able to predict with certainty the value of the direction the engine should take. Once the predictions were obtained and sent to the engine, a problem was noticed that the engine did not stop moving, so it was necessary to make a comparison of the LDR values and thus be able to stop the engine and in turn move it, but this led us to a question of why the use of a neural network and it was established that the behavior that the motor will have is going to be altered not only in the comparative values of the LDR but also it was very necessary to have the prediction of its direction, since it improves the behavior of the system and saves resources.

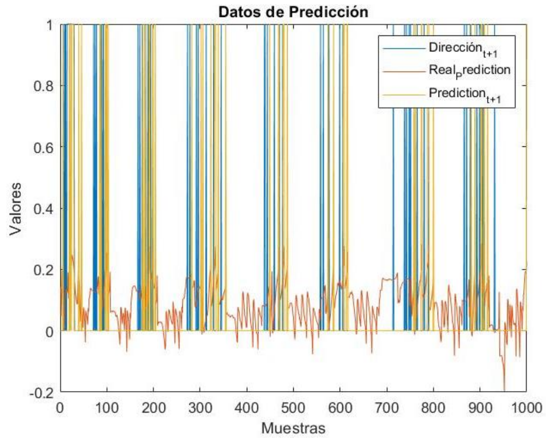

Illustration 8. Neural network prediction

The direction, real prediction and prediction can be observed directly in illustration 7. The address value is the value that was taken from the sampling of data in which several tests were carried out on the panel which turned on the light and the panel moved giving its direction, the real prediction is how the neural network gave us values that they simulated the direction, but since they were not correct values, respective changes were made in the coding of the neural network in order to give way to a totally correct value, showing as such the prediction direction.

VII. DISCUSSION AND CONCLUSIONS

The use of FPGA is not only limited to making use of a specific section, since, this card has many functions that can open the way to new tools or work solutions. In order to solve problems or provide a faster and more efficient response to the use of the FPGA, a system was implemented which was worked in HPS with which motor control functions and acquisition of the LDR values were carried out for Be displayed on a web server.

VIII. REFERENCES

[1] Tableau, «Tableau,» [En línea]. Available: https://www.tableau.com/es-mx/learn/articles/business-intelligence-examples.

[2] L. J. Herráiz, «AteneoEscurialense,» [En línea]. Available: http://www.ateneoescurialense.org/Archivos/Adjuntos/Contenidos/Historia_de_la__ELECTRICIDAD.pdf. [Último acceso: 30 11 2019].

[3] M. S. A. S. M. B. Shaikh Mohamadsaied Rubab, «Irjet, » 10 2017. [En línea]. Available: https://www.irjet.net/archives/V4/i10/IRJET-V4I10247.pdf. [Último acceso: 30 11 2019].

[4] Y. J. Huang, Member, IAENG, B. C. Wu, C. Y. Chen, C. H. Chang, and T. C. Kuo, Member, "Solar Tracking Fuzzy Control System Design using FPGA", Proceedings of the World Congress on Engineering 2009 Vol I WCE 2009, July 1 - 3, 2009, London, U.K.

[5] A. Hamza Omran, Y. M. Abid, A. S. Ahmed, H. Kadhim, Ruqaia Jwad, "Maximizing the power of solar cells by using intelligent solar tracking system based on FPGA", 2018 Advances in Science and Engineering Technology International Conferences (ASET).

[6] Snehal P. Hon, Prof. Dr. M.T. Kolte, "FPGA Based Standalone Solar Tracking System", International Journal of Scientific and Research Publications, Volume 3, Issue 10, October 2013 1ISSN 2250-3153.

[7] C. M. Sánchez, M. A. Cruz, R. S. Ortigoza, J. C. Herrera-Lozada, "POSITION CONTROL OF A SOLAR CELL VIA AN FPGA", National Polytechnic Institute, CIDETEC. Mechatronics area. Professional Unit Adolfo López Mateos. C.P. 07700, México, D. F., MÉXICO.

[8] Jui-Ho Chen, Her-Terng Yau and Jin-Han Lu, "Implementation of FPGA-Based Charge Control for a Self-Sufficient Solar Tracking Power Supply System", 2 February 2016.