# Maximizing the Power of Solar Cells by Using Intelligent Solar Tracking System Based on FPGA


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***Abstract*—The Renewable energy is considered as the one of the cleanest and best energy sources in the world, which is used for different purposes, the solar cell, is one of the Renewable energy sources. This paper proposed a solar tracking system, which maximizes the output signal from the solar cells. It has two intelligent controllers where acts like human brain; each one of them controls the direction of the system depending on the target. These intelligent controllers are trained and tested by MATLAB and ISE design suite 13.3, it is implemented on Spartan 3 FPGA as hardware part. Two DC motors are used and acts like human neck, which is controlled by the intelligent controllers to rotate the proposed system according to the direction of the target. Furthermore, four LDRs sensors are used in the proposed system.**



***Keywords*—Solar tracking system; intelligent controller; FPGA; artificial intelligent; solar cell.**


## I. Introduction

At recent years, the one of the most important problems at the world is the lacking of supplying energy in a continuous way due to the increasing of using devices that depends mainly on the electrical power [1]. In the past, machines, trains and other devices were generally based on the heat as a source of energy which is generated by the coal burning. Later, the main source of supplying energy was the oil, which is being abundant in the ground and has become one of the most important requirements in the world for many years to supply the energy [2]. Whatever, the presence of environmental pollution associated with the dependency on these sources and the possibility of ending this source of energy, results in directed the world to search for a clean and non-enforceable energy. This type of energy is known as ”Renewable Energies”, such as geothermal energy, tidal energy, wind power, solar energy and other available energies [3]–[6]. And one of the easiest sources of energy that can convert the energy directly into an electrical energy is the solar cells which convert the solar energy into the electrical energy. The solar cells depends mainly on the intensity of the light that falls on them to provide the energy [7]; researchers began to find the best ways to increase the intensity of light on the solar cells and there are many research in this era. [8] Presents a small power photo voltaic control system using fuzzy algorithm and FPGA Technology. [9] Presents tracking system using fuzzy logic controller based on FPGA which sends signals to stepper motor for tracking mechanism. [10] Presents solar tracking system based on astronomical equations, at any time the positions of sun is a function of azimuth and altitude angle values. [11] Presents tracking system using fuzzy logic controller and DC Motors; PWM technique is used to control the speed; however, it uses the 555 IC for clock generation instead of using FPGAs cart clock which decreases the accuracy of controlling the speed. [12] Presents intelligent controller for tracking system depending on the signals outs from LDRs sensor without controlling the speeds of motors rotations and implement the hardware part on FPGA.[13] Presents the implementation of Reflex charge control in a dual-axis solar tracking system with maximum power point tracking (MPPT) based on Spartan 3 FPGA. In order to search for the optimum gain constants of the PI controller and the Reflex charging frequency, PSO used for optimization. [14] Presents maximum power point method for maximizing the power generated of solar cells with new algorithm called Flower Pollination Algorithm (FPA). [15] Presented the design of neuro fuzzy controller and implemented using Field Programmable Gate Array (FPGA) board for dual axis sun tracker depending on optical sensors to orient the PV panel by two linear actuators. This paper proposed a solar tracking system which maximizes the output signal from the solar cells using neural logic controller and DC Motors.

## II. MATERIAL AND METHOD

The proposed Solar tracking system acts like human head where four light dependent sensors (LDRs) are used in order to be sensitive to the intensity of the light. These sensors are worked together in such a way like the movements of human eyes which takes into consideration the four movements direction up/down and right/left. The output signals of LDRs sensors are converted to digital signals; then, these digital signals are entered to the intelligent controllers which acts like human brain. It determines the right direction that the proposed solar tracking system must takes to enable the solar cells from facing the sun at all the time. Furthermore, two DC motors are used in the proposed system which acts like human neck. The movement mechanism of rotation and speed of these two

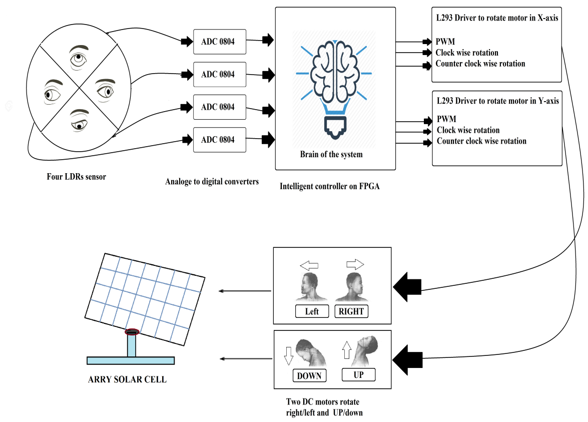



Fig. 1: The Proposed Solar Tracking System.

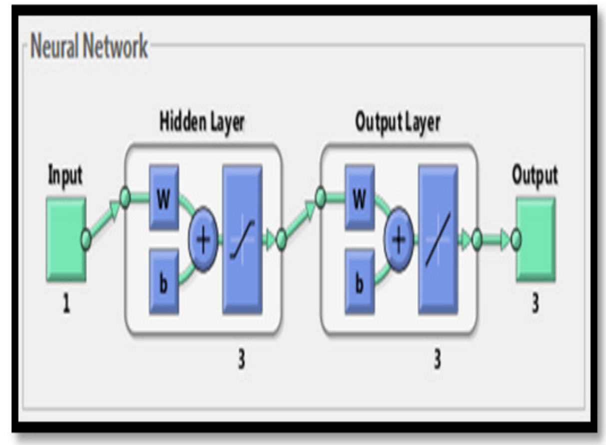



Fig. 2: Neural network with one input neuron, three hidden neurons and three outputs neurons.

DC motors are controlled by the intelligent controllers. Figure 1 shows the proposed solar tracking system.

In this paper, the intelligent controllers (Brain) were downloaded on Spartan 3 FPGA card by using VHDL code based on MATLAB package.

## III. RESULTS AND DISCUSSION

Before All The intelligent controllers of the system (human brain) trained by using MATLAB and supervised feed forward neural network. The activation functions which consists of the number of input layers, hidden layers and output layers are chosen by trial and error. Fig. (2) shows the results of training neural network with one input layer where this input is the subtraction of sensors voltage, 3 hidden layers and three output layers for three outputs (PWM, Clock wise rotation and counter clock wise rotation) respectively, fig. (3) shows the simulation results of training with three hidden layers. Fig. (4) shows the results of training neural network with one input layer where this input is the subtraction of sensors voltage, 15 hidden layers chosen by trial and error and three output layers for three outputs (PWM, Clock wise rotation and counter clock wise rotation) respectively. Fig. (5) shows the simulation results of training with fifteen hidden layers. After training the intelligent controllers of the solar tracking system, the simulation results shows that the supervised feed forward neural network with fifteen hidden layers better than supervised feed forward neural network with three hidden layers. The trained intelligent controllers of the system were converted to the Simulink as shown in fig. (6). As mentioned previously, the proposed solar tracking system have two intelligent controllers. The first one is used to control the neck in X-axis direction to track the sun at this direction by controlling the first DC motor which responsible on the direction of movement around X-axis. The second one is used to control the neck in Y-axis direction to track the sun at this direction by controlling the second DC motor which responsible on the direction of movement around Y-axis.

There are several general states shows the simulation results for the first and second intelligent controllers to be able from tracking the sun. 1) The intensity of the light on

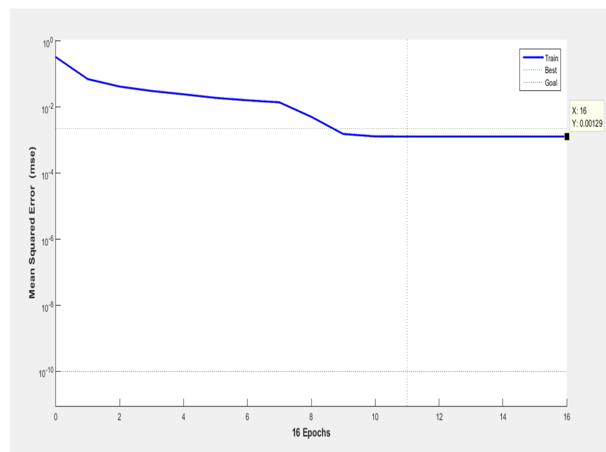



Fig. 3: Simulation results of training.

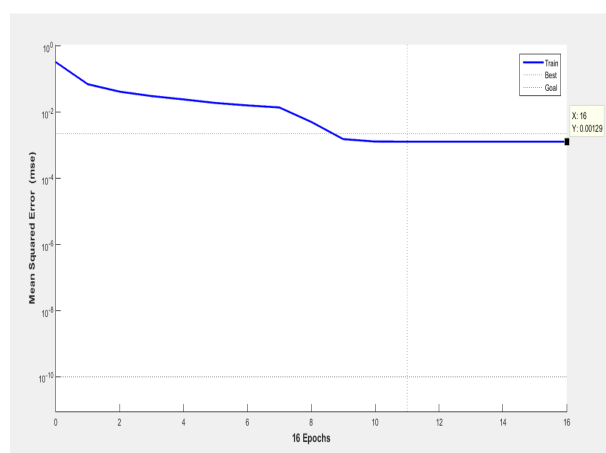



Fig. 4: Neural network with one input layers, fifteen hidden layers and three outputs layers.

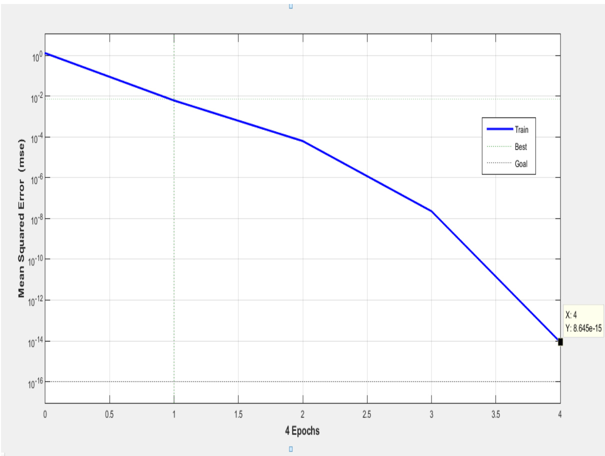



Fig. 5: Simulation results of training.

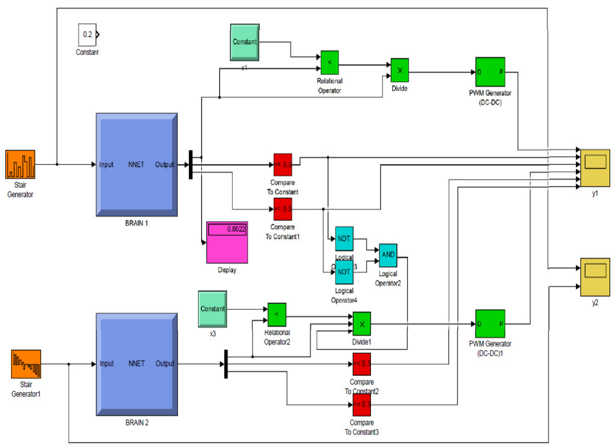



Fig. 6: The trained intelligent controller in Simulink.

the right sensor is greater than the intensity of the light on the left sensor; this state is similar to the human eyes when detecting the target at the right side as shown in fig. (7). , the first intelligent controller will adjust the duty cycle to PWM to control the speed of rotation of motor1 according to the difference between right sensor and left sensor; furthermore, at the same time it will send (1 and 0) signal to the motor drivers pins Clock Wise (CW) and Counter Clock Wise (CCW) respectively. This will result in rotating the first motor in Clock Wise and tracking the sun at the X-axis direction. While the second intelligent controller will send three signals to (PWM, CW, and CCW) respectively to rotate the second motor to track the sun at the Y-axis direction. 2) The intensity of the light on the right sensor is smaller than the intensity of the light on the left sensor; this state is similar to the human eyes when detecting the target at the left side as shown in fig. (8). , the first intelligent controller will adjust the duty cycle to PWM to control the speed of rotation of motor1 according to the difference between right sensor and left sensor; furthermore, at the same time it will send (0 and 1) signal to the motor drivers pins Clock Wise (CW) and Counter Clock Wise (CCW) respectively. This will result in rotating the

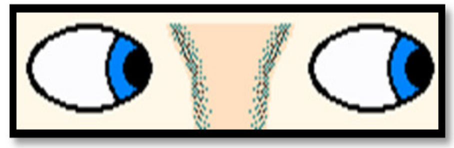


Fig. 7: Intelligent controller detecting target in right side as compared with human eyes.

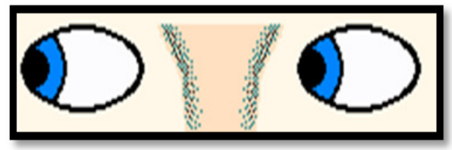


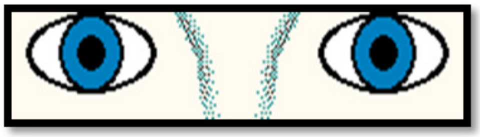
Fig. 8: Intelligent controller detecting target in left side as compared with human eyes.

first motor in Counter Clock Wise and tracking the sun at the X-axis direction. While the second intelligent controller will send three signals to (PWM, CW, and CCW) respectively to rotate the second motor to track the sun at the Y-axis direction.

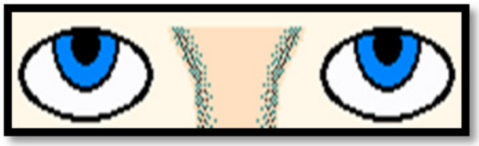
3) The intensity of the light on the right sensor is equal to the intensity of the light on the left sensor; this state is similar to the human eyes when detecting the target at the middle side as shown in fig. (9). The first intelligent controller will send three signals (PWM, CW and CCW) to stop the rotation of the first motor. Now, if the intensity of the light on the upper sensor is greater than the intensity of the light on the lower sensor such as the human eyes when detecting the target at the upper side as shown in fig. (xx). The second intelligent controller will adjust the duty cycle to PWM to control the speed of rotation of motor2 according to the difference between the upper sensor and lower sensor; furthermore, at the same time it will send (1 and 0) signal to the motor drivers pins Clock Wise (CW) and Counter Clock Wise (CCW) respectively. This will result in rotating the second motor in Clock Wise and tracking the sun at the Y-axis direction. 4) The intensity of the light on the right sensor is equal to the intensity of the light on the left sensor; this state is similar to the human eyes when detecting the target at the middle side as shown in fig. (10). The first intelligent controller will send three signals (PWM, CW and CCW) to stop the rotation of the first motor. Now, if the intensity of the light on the upper sensor is smaller than the intensity of the light on the lower sensor such as the human eyes when detecting the target at the lower side as shown in fig. (xx). The second intelligent controller will adjust the duty cycle to PWM to control the speed of rotation of motor2 according to the difference between the upper sensor and lower sensor; furthermore, at the same time it will send (0 and 1) signal to the motor drivers pins Clock Wise (CW) and Counter Clock Wise (CCW) respectively. This will result in rotating the second motor in Counter Clock Wise and tracking the sun at the Y-axis direction.

Fig. (11) shows the differences values between sensors, Fig. (12) shows many state for solar tracking system.

The output signal from the intelligent controllers will be the

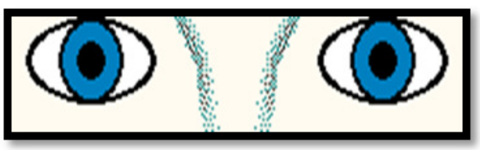


(a)

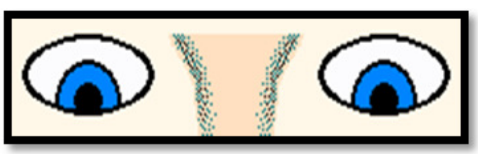


(b)

Fig. 9: A: Intelligent controller fully detected target B:Intelligent controller detecting target in upper side as compare with human eyes.



(a)



(b)

Fig. 10: A: Intelligent controller fully detected target B:Intelligent controller detecting target in lower side as compare with human eyes.

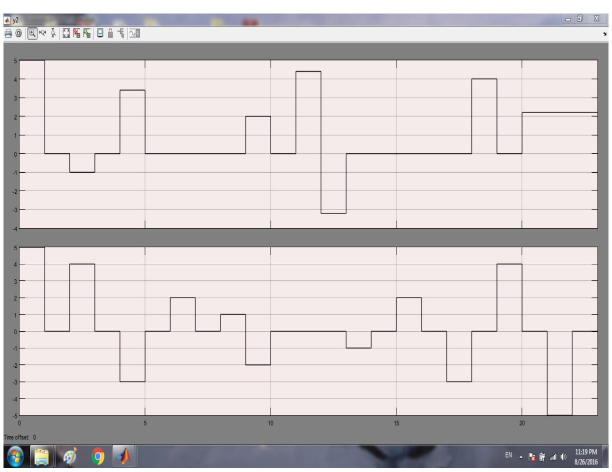


Fig. 11: The differences values between sensors.

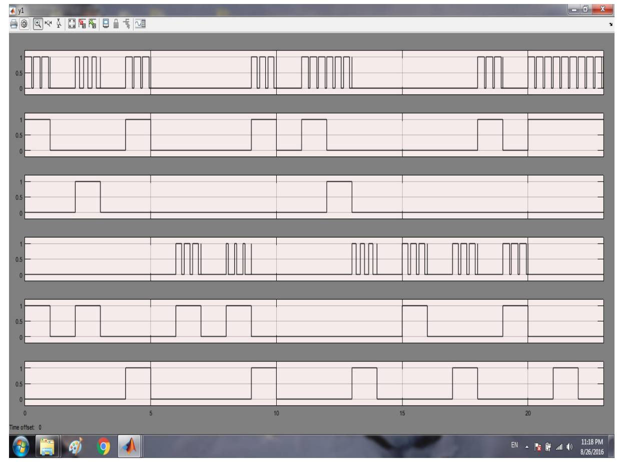


Fig. 12: Many states for solar tracking system.

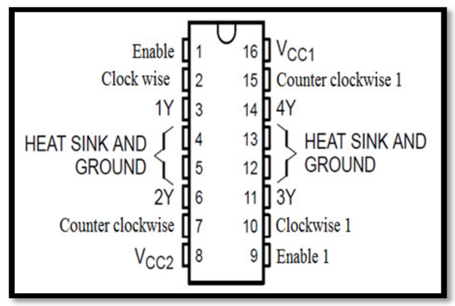



Fig. 13: Pins diagram for L293D DC motor driver.

input to the motor driver IC (L293D) which is used to control the two DC motors . Fig. (13) shows the pin diagram of the L293D IC and fig. (14) shows the simulation results of using it with the two dc motors by using proteus 8 professional. After completing the simulation of the system through using MATLAB and PROTEUS, the results can be converted to the VHDL code to be able from downloading it on the FPGA cart.

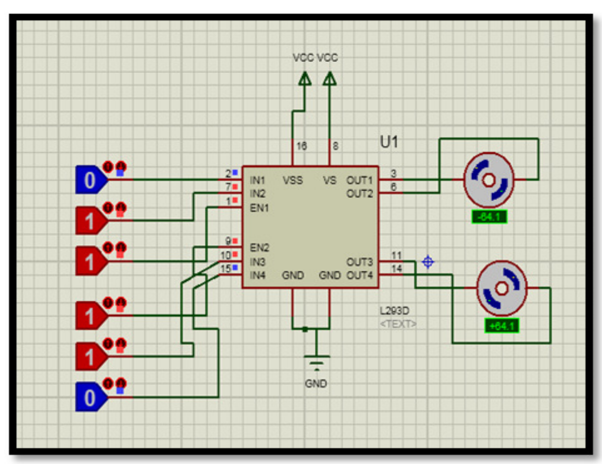



Fig. 14: The simulation results for L293D DC motor driver.

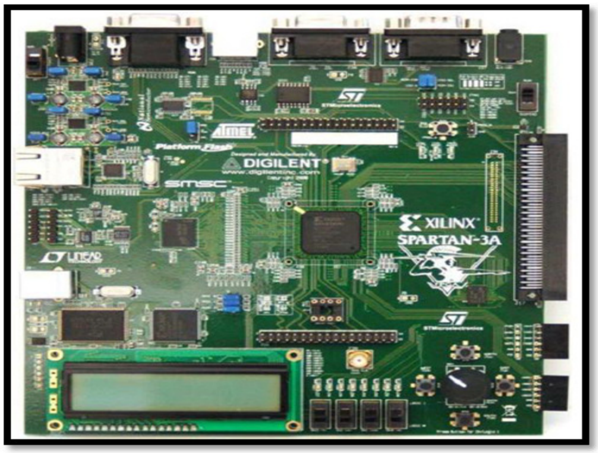



Fig. 15: Spartan 3A starter kit.

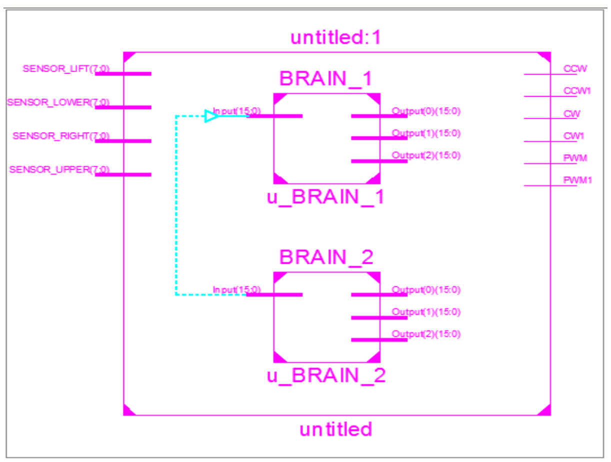



Fig. 16: RTL of intelligent controller.

Spartan 3A FPGA used in the hardware implementation for its speed, simplicity and reprogramming ability which supply the perfect environment for the controller to enhancement its working. Fig .(15) shows the Spartan 3A FPGA and Fig. (16) Shows the RTL of intelligent controllers; also fig. (15) Shows the simulation results of training of intelligent controllers by using ISE design suite 13.3.

## IV. Conclusions

In this paper, an intelligent solar tracking system is used to track the sun that will results in maximizing the power which produced from the solar cell. The proposed solar tracking system acts just like the movement of human head; it tracks the target by the trained neural network to fully control the speed and direction of motors. The sensors are directed in such a way that senses the intensity of the light to move the solar cells towards it which act like human eyes. The simulation results are tested by MATLAB and ISE design suite 13.3.and the hardware results are tested by downloaded the VHDL code on the FPGA cart.

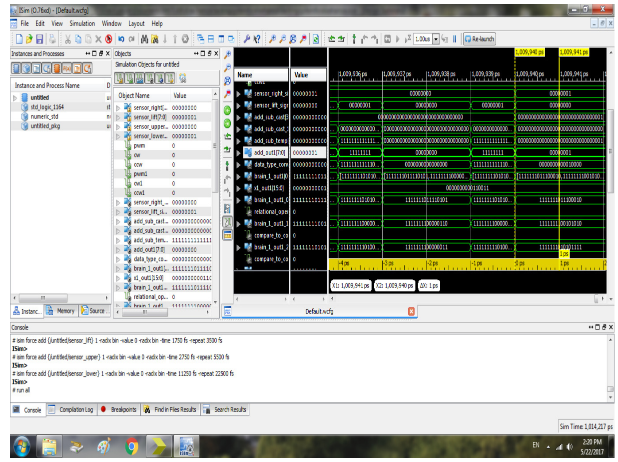


Fig. 17: The simulation results of trained intelligent controller.

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