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Artificial Intelligent Techniques for Modeling Solar Cell Based on FPGA

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Abstract-- The proposed need to construction of a solar tracking system is to extract the majority of solar energy solar panel. Work includes sports simulation and control of solar tracking system for dual- axis solar panel the program has been implemented using MATLAB. The tracking system can be mounted in areas that were considered rich in solar energy. In this work the design of the solar panel Biaxial characterized by the ability to move in the horizontal and vertical directions. Has been used a fuzzy controller which is dominated by the main portion of the solar tracker positioning of the engines that drives the solar panel to face the sun. Mechanical design consists of rotary joints and two engines. The tracking system makes the solar system more efficient by keeping the face of the solar panel perpendicular to the sun and thus extract the majority of solar energy has led to increased overall efficiency. In this work propos a method to track the sun's rays using sensors solar tracker by the sun and by changing the direction of the solar panel in the vertical and horizontal directions by two engines. Require a sun tracker controller effective. The user is controlled and fuzzy logic controller (FLC). The main idea of this work is to build a digital FLC using fuzzy equations and can be implemented on the FPGA in a practical way, and the advantage of this design is the possibility of FLC used for any other application without changing any part in the main design of the FLC only change the external standard inputs and outputs. Field Programmable Gate Arrays (FPGAs) have been used to implement digital fuzzy logic controller, because of their benefits, as well as the reprogrammability of the FPGAs which can support the necessary reconfiguration to program fuzzy logic controller. A VHDL design of digital fuzzy logic controller is proposed to evolve the architecture FLC circuits using FPGA-Spartan-6. The VHDL design platform creates digital fuzzy logic controller design files using WebPACKTMISE 13.3 program.

Index Terms— Sun Tracker, Fuzzy Logic Controller (FLC), Field programmable gate array (FPGA), DC motor.

1 Introduction

Solar energy is a clean and inexhaustible source of energy in everywhere of our world. It has been identified as an alternative electricity source with respect to the increase in energy demand and cost. Besides, solar energy is environmental-friendly as compared with other energy sources [1]. The PV arrays employed in solar PV systems to convert the received radiation to electricity are either mounted rigidly (resulting in Fixed PV arrays) or mounted on a tilting mechanism (oriented arrays). Orienting a PV module to point towards the sun to maximize the electrical output from the PV modules is called “Sun Tracking” [2]. As the sun is moving, in respect with the PV module surface, the irradiance is changing during the day and the seasons. More energy will be collected by the PV module if it is installed on a sun tracker. Tests have shown that up to 40% extra power can be produced using a variable elevation solar tracker [3]. Fuzzy Logic Controllers (FLC’s) have been widely applied to both consumer products and industrial process controls. In particular, FLC’s are very effective techniques for complicated and imprecise processes for which either no mathematical model exists or the mathematical model is severely nonlinear, because FLC’s can easily approximate a human expert’s control behaviors that work fine in such ill defined environments [4]. Field Programmable Gate Arrays (FPGAs) can be considered as an appropriate solution in order to boost the performance of controllers. These generic components combine low cost development (owing to their reprogrammability), use of convenient software tools, and more significant integration density. For these embedded applications, reduction of the power consumption, thermal management and packaging, reliability and protection against solar radiation are of prime importance. Finally, industrial electrical control systems are also of great interest because of the ever-increasing level of expected performance while at the same time reducing the cost of the control systems. FPGAs have already been used with success in many different electric system applications such as neural network (NN) control of induction motors, fuzzy logic control of power generators, and speed measurement. This is because an FPGA-based implementation

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of controllers can efficiently answer current and future challenges of this field [5].

2 Sun Tracker Design

Solar tracking system uses a dc motor as the drive source to rotate the solar panel. The position of the sun is determined by using a tracking sensor, the sensor reading is converted from analog into digital signal by using ADC, and then it passed to a fuzzy logic controller implemented on FPGA card. The controller output is connected to the driver of the dc motor to rotate PV panel in two axes until it faces the sun. Figure (1) shows flowchart of the sun tracker system. In this work is used proposed design for digital fuzzy logic controller and then download this design on FPGA card by using HDL code on MATLAB package.

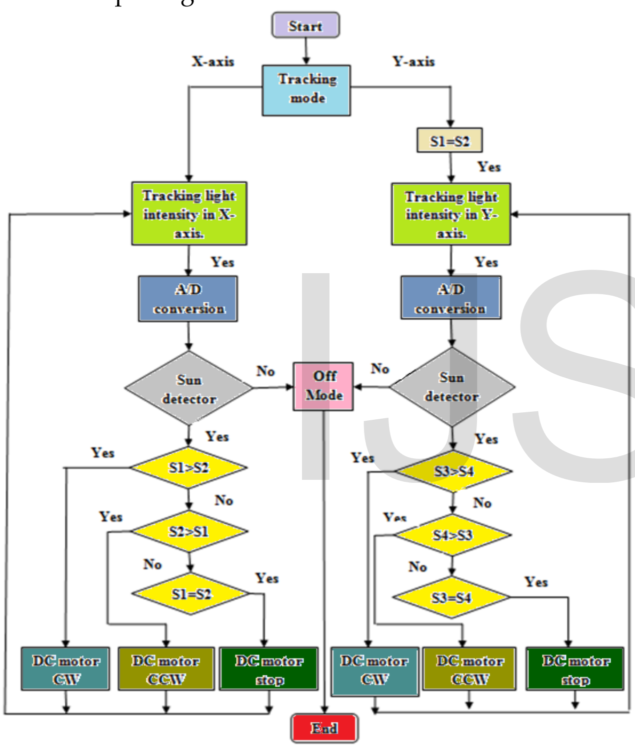

Figure (1): Flowchart for sun tracker system.

3 A proposed Design of Digital Fuzzy Logic Controller

A fuzzy logic based control scheme can be designed using the accumulated experience about the system behavior rather than the availability of the mathematical model. In other words, machines can be provided to give decisions like humans by using fuzzy logic operations. With the use of fuzzy logic approach increases system performance, simplifies application and reduces financial expenses. In this case, system performance is optimized perfectly and a control can be obtained more effective and responsive. A fuzzy logic control is designed to achieve the required tracking. A block diagram of a fuzzy control system is shown in Figure (2).

The first step is to generate a fuzzy membership function for partitioning the input and output spaces into fuzzy subsets. The process of an FLC can be summarized in three steps: Fuzzification, rule based fuzzy processing and defuzzification. Triangular fuzzy membership functions were used in both fuzzification and defuzzification stages.

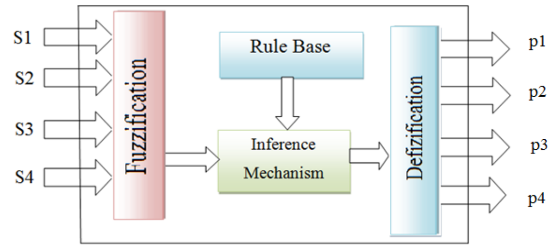

Figure (2): The basic structure of fuzzy logic based controller.

Equation (1) is used to represent the fuzzy triangular membership functions [6].

$$\mu(x) = max\left[min\left(\frac{X-X_1}{X_2-X_1},\frac{X_3-X}{X_3-X_2}\right),0\right] \quad \ldots (1)$$

where x_1, x_2, and x_3 are the crisp parameters used to define the location and shape of the triangle. The input x is the crisp variable whose membership value on this triangle fuzzy subset is the output mu(x). The Simulink model of the triangular fuzzy membership function is shown in Figure (3).

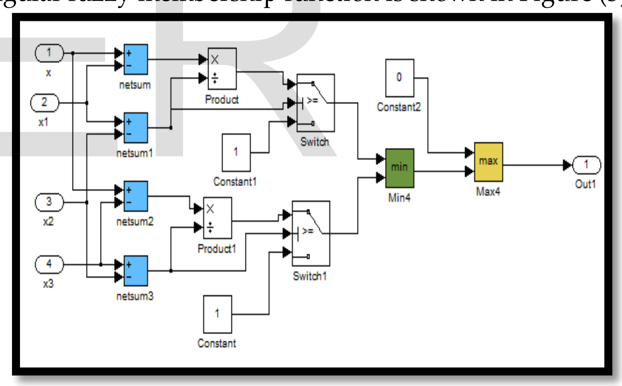

Figure (3): Simulink model of the triangular fuzzy membership function.

The Boolean operator "*min*" is used for the verbal connector "*and*" to simulate the input space of the rules that have the structure as shown in equation (2). The input space of the fuzzy rules used four inputs and four outputs [6].

If S1 is A ***and*** S2 is B ***then*** mu is C. … (2)

Where A, B, and C in equation (2) represent any one of the fuzzy subsets NB, NS, ZE, PS, and PB defined before. The input space in equation (2) is the part that represented by the expression (S1 is A ***and*** S2 is B). The *"min"* operator in Simulink Block Library is used to model the input spaces of 25 rules used by FLC. The outputs of the "*min*" operators indicate the strength (membership degree) of the rules in the output space mu. The implementation of the rule input space is shown in Figure (4).

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obtain the actual operation. The center of area method is given the following equation (3) [6].

$$\Delta U\ (k) = \frac{\sum_{i=1}^{n} \mu_i\ (\Delta u_i).\Delta u_i}{\sum_{i=1}^{n} \mu_i\ (\Delta u_i)} \qquad \ldots (3)$$

where:

ΔU (k): is the defuzzified output.

$\mu_i(\Delta u_i)$: is the aggregated membership function.

Δu_i : is the output variable.

This defuzzification method can also be easily implemented with a digital circuit.

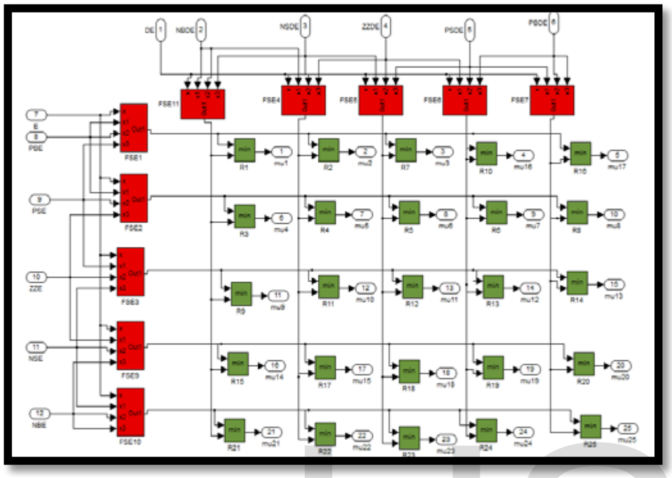

Figure (4): The Simulink model of the verbal expression.

The membership degrees obtained as depicted in Figure (4) are multiplied by the crisp values of each corresponding fuzzy subset in the output space (mu is In) as shown in Figure (5). These crisp values indicate the peak locations of the triangular fuzzy subsets. Actually this multiplication process represents the products in the nominator of defuzzification method called centre of area. Then the sum of these products is divided by the sum of membership values obtained as in Figure (6).

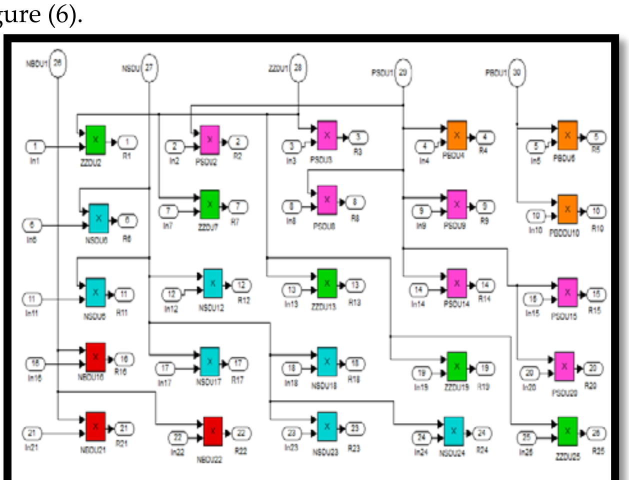

Figure (5): The Simulink model of the fuzzy rules.

A general view of the FLC is given in Figure (7) where the processes from inputs S1, S2, S3 and S4 to outputs p1, p2, p3 and p4 are shown and they are connected to pulse block this block generate one pulse his width its equal to the difference between the sensors. The advantage for this design the user is able to edit and change the parameters of the membership functions on this stage without going into the details of the FLC. The definition parameters of the fuzzy membership functions are problem dependable and must be set accordingly. Once the possible maximum and minimum values of the inputs and output signals are assigned, the other sub values can be placed in between these limits. If the initial settings are to be used, then some gain blocks can be used to match the signals with the predefined membership parameters. Figure (8) shows a proposed design for pulse generated block, where the width of the pulse is change with the output from digital FLC.

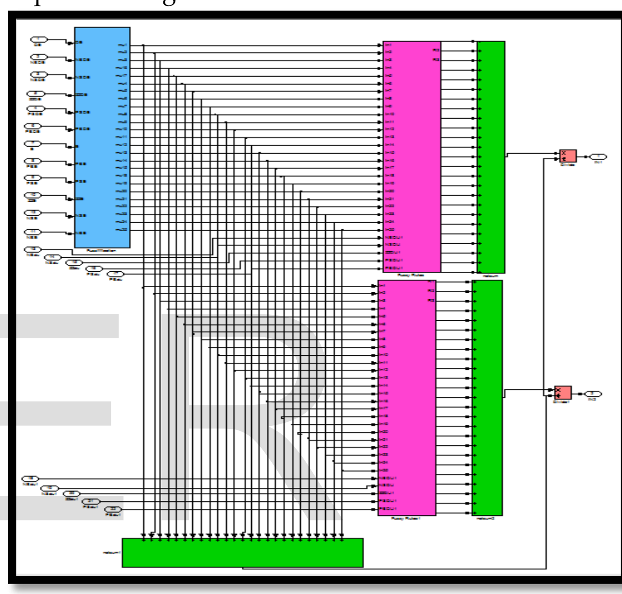

Figure (6): Fuzzy reasoning representing the process from fuzzification to defuzzification.

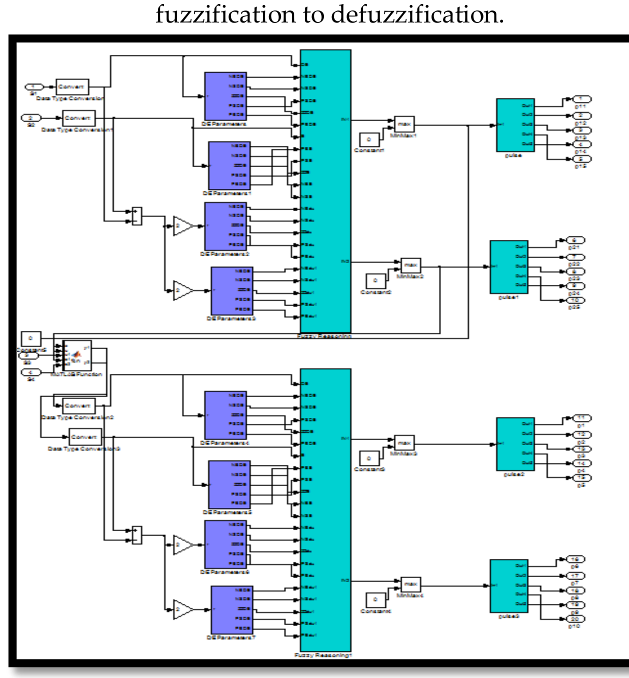

Figure (7): The input and output units of the FLC.

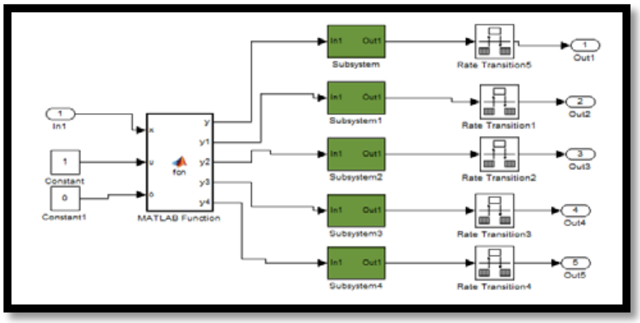

Figure (8): Pulse generated block.

Solar tracking system is simulated using FLC and pulse block. MATLAB/Simulink model block diagram of this system is shown in Figure (9).

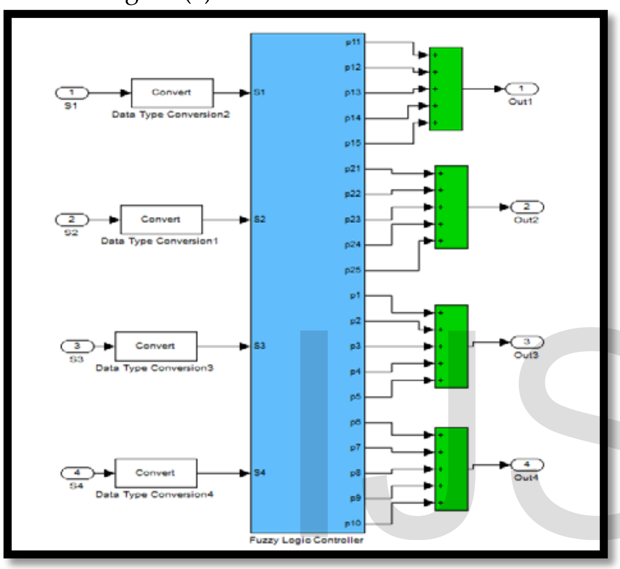

Figure (8): MATLAB/Simulink model for the solar tracking system.

4 FPGA Implementation and Hardware design

The implementation of a proposed fuzzy logic controller using FPGA generally requires a large number of logic gates. It is consists of five steps. The basic step is to collect the information on the number of inputs and outputs to choosing an optimum FPGA, ADC would be required to map from analog to digital, since the plant to be controlled works on an analog domain and the FPGA works on a digital domain. So, the first step is convert the analog signals to digital signals and that will be by 0804 ADCs. The second step is to pass this signals through the FLC which implemented on FPGA card. The third step is to write the rules base, these rules basically instruct the action to be performed for various combinations of inputs. The fourth step is to connect the signal output from FPGA card with the driver of the DC motor, 1 for turn ON the DC motor or 0 for stop the DC motor. The bit stream is downloaded into FPGA chip. The electronic switches in the device opened or closed in response to the binary bits in the bit stream upon completion of the downloading as shown in Figure (9). Xilinx Foundation ISE Design Suite 13.3 is a software tool used to perform FLC for sun tracker recognition on FPGA.

Figure (9): Hardware components for downloading the bit stream into the training kit.

After downloading the bit stream into the kit, the sun tracker signal is generated by using the General Purpose Input Output (GPIO) switch on the FPGA card, where four inputs (LDRs) as Boolean (zero or one) input. After the sun tracker signal generation, it's time is to observe the output and that is by assign the four signal outputs to the GPIO headers as shown in Figure (10). The sun tracker signal can be Real-Time Monitored by oscilloscope as shown in Figures (11) and (12), where logic 1 output from FPGA through GPIO header is equal to (3.3 volts) and logic 0 outputs is equal to (0 volts).

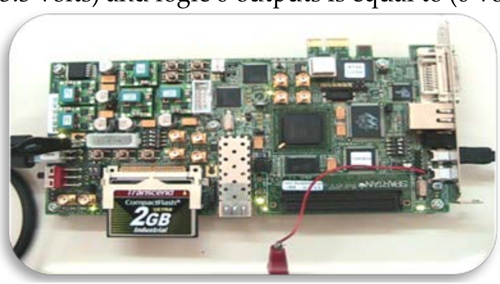

Figure (10): The output from FPGA kit through GPIO headers.

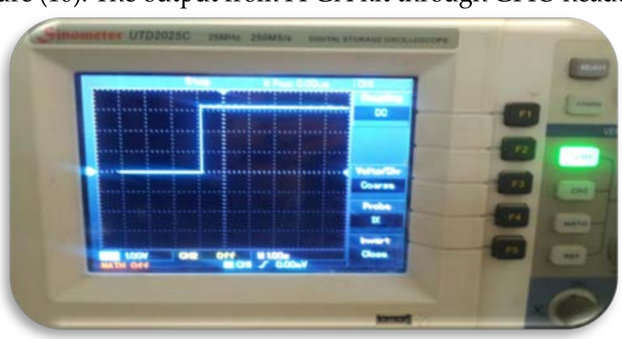

Figure (11): The output from GPIO header when the output is logic 1 (ON).

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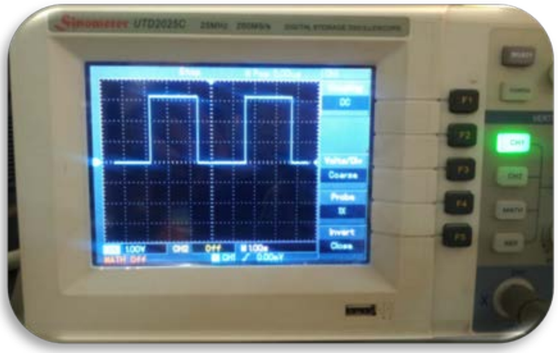

Figure (12): The output from GPIO header when the output is logic 1 (ON) and logic 0 (OFF).

where the practical connected for the a stable 555 IC as shown in Figure (13), the results for this circuit is shown in Figure (14). This circuit 555 IC connects to FPGA card, where the 555 IC represents the external clock for the FPGA card and his time is 1sec.

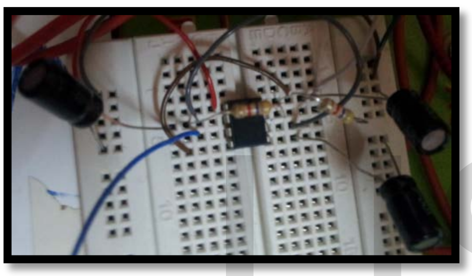

Figure (13): Practical connects the 555 IC.

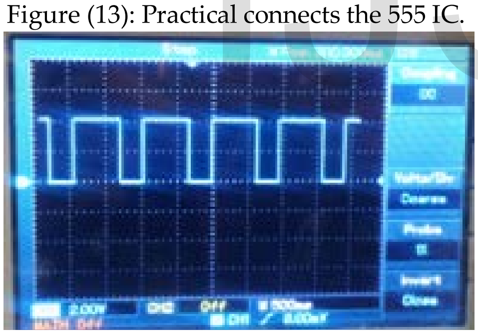

Figure (14): Output signal from 555 IC.

To sense the position of the sun intensity in two axes east/west and north/south, four LDR sensors are mounted on the solar panel and placed in an enclosure as shown in Figure (15). It has a response which is similar to the human eye. The east and west LDR sensors compare the intensity of received light in the east and west. The north and south LDR sensors compare the intensity of received light in the north and south. The light source intensity received by the sensors are different, the system obtains signals from the sensor output voltage in the four orientations. The sensor output voltage value inferred by voltage type A/D converter, in this work is used ADC0804 as shown in Figure (16).

Figure (15): Tracking sensor design.

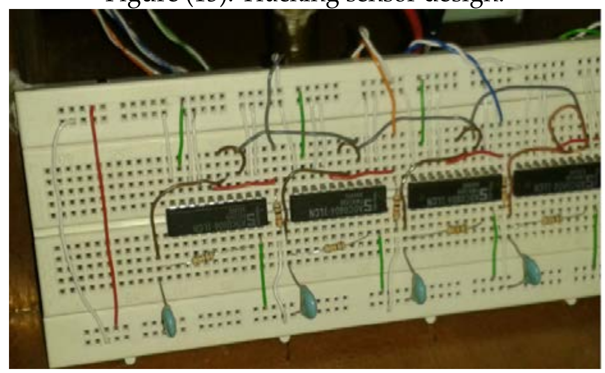

Figure (16): The practical connect for ADC0804.

A motor driver circuit is designed to drive an electromagnetic load. Motors typically require voltages and currents that exceed what can be provided by the analog or digital signal processing circuitry that controls them. In this work, L293D is used as driver for DC motor. The L293D is an integrated circuit motor driver that can be used for simultaneous, bi-directional control of two DC motors, the table below show the state of works the DC motor with L293D.

ENABLE	DIRA	DIRB	Function
H	H	L	Turn right
H	L	H	Turn left
H	L	L	Fast stop

Figure (17) shows the dual-axis solar tracking mechanism. The tracking mechanism is used to support and rotate the photovoltaic panel.

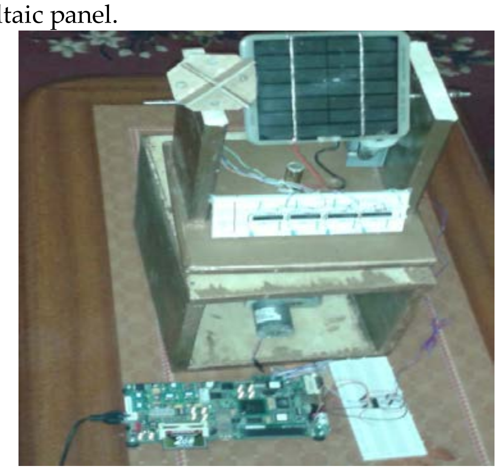

Figure (17): The mechanical system design for dual sun tracker system.

The table below show the output signals from digital FLC which are controlled on DC motor.

S1	S2	S3	S4	DC motor1	DC motor2
0	0	0	0	OFF	OFF
1	0	X	X	ON (CW)	OFF
0	1	X	X	ON (CCW)	OFF
0	0	1	0	OFF	ON (CW)
0	0	0	1	OFF	ON (CCW)
1	1	1	0	OFF	ON (CW)
1	1	0	1	OFF	ON (CCW)

X: don't care (0 or 1).
CW: clock wise.
CCW: counter clock wise.

7 Conclusions

Implementing a sun tracker controlled by digital fuzzy logic controller design by MATLAB/SIMULINK, to keeps the PV panel pointing toward the sun using two DC motors. Two degrees of freedom orientation is feasible, can rotate the solar panel in horizontally and vertically directions. The most important advantage of a proposed digital FLC is the short processing time and the decision making manner, so, increasing the number of membership functions does not affect the processing time since that only one rule from the rule base is used to produce a conclusion. The design for a proposed digital FLC is can used in another application, where the external parameters of the FLC it only change.

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