FPGA Based Sun Tracking System Using Fuzzy Logic.

Snehal P. Hon, M.T. Kolte, Raut Shweta A.

Abstract: Sun tracker is the device that follows the position of the sun throughout the day to harness the output power. Sun tracking increases the output power production by keeping the panel parallel to the sun so that sun radiation makes 90° angle with panel. This paper presents sun tracking system implemented in real time. Sun tracking system composed of fuzzy logic controller implemented on FPGA, sensors, PV panel, stepper motor, input-output interface.

Index Terms: Fuzzy controller, FPGA, Sun tracker.

1 INTRODUCTION

THe Energy is one of the prime issue in today's world. Because of increasing population, energy need and energy cost have increased tremendously in recent year. During the process of energy production, nature gets damaged and global worming type generated. Because of all these aspects solar energy which is the clean source of energy becomes more important. Solar cell converts solar energy into electrical energy. The amount of energy obtain from PV panel is directly proportional to the amount of sun light acquired by that solar panel. As domestic and industrial application of solar energy is increased, that needs to extract maximum power from solar panel. Three factors that affect the efficiency of collection process are; solar cell efficiency, intensity of sun radiation and storage technique. But as because of material used for the manufacturing of solar cell, it is difficult to improve the efficiency of the solar cell, hence it is necessary to improve efficiency of collection process. There are three methods by which efficiency of collection process can be improved and these are: sun tracking, maximum power point tracking method, and both. This paper presents sun tracking technique to harness the output power of PV panel. In the sun tracking system solar trackers are used . A solar tracker is the device that is used to align a single photovoltaic panel or an array of PV modules with the sun, so the tracker can improve the systems power output by keeping the sun in focus for whole day and thus increase the effectiveness of the equipment over the fixed position system. Sun position is mainly depending on two things that are time of the day and season. Output power of the PV panel is high when sun radiations are perpendicular to the PV panel. Solar tracker tracks the position of the sun and rotates the PV panel according to sun position so that PV panel become parallel to sun and sun radiation makes 90° angle with PV panel. So sun tracking system help to improve efficiency of the collection process. Sun tracking is mainly of two types depending on the manner in which path of the sun is determined and that are:

- *Snehal p. Hon, Prof. Dr. M.T. Kolte , Raut Shweta A.*
- *Electronics and telecommunication department of MITCOE, Pune*

Dynamic sun tracking and fixed control tracking. Dynamic tracking system actively searches for sun position at any time of the day. Fixed control tracking does not actively searches for sun position. In dynamic tracking method light sensors are mounted on tracker at various positions. If sun is not facing the PV panel directly means panel is not parallel to the sun then there will be a difference between the outputs of a light sensor compare to another. This principle is used in dynamic tracking .Whereas in the fixed control tracking pre-recorded data of sun position for different time and different season for particular site is used. In this method for given current time, current day and year position of the sun is calculated.

2 SUN TRACKING SYSTEM.

Sun tracking system is composed of stepper motor to rotate the solar panel, sensors controller as shown in Figure 1

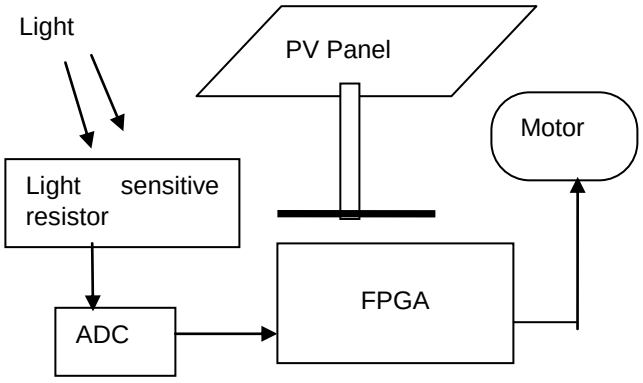


Figure 1. Block diagram of sun tracking system.

Light sensors are mounted on the edge of the solar panel. That sensor determines sun intensity then sensors readings are given to the controller. Controller determine sun position and rotate the stepper motor to align solar panel with sun orientation.

A. SENSOR

Sun tracking system mainly consist sensor named photo sensor.

1. Photo Sensor

LDR is used as photo sensor. LDR means Light Dependent Resistor and here it is used for light sensing. Resistance of LDR varies with the intensity of light. Intensity of light and resistance of LDR having inverse relation means when intensity of light is high, resistance of LDR is low. LDR are

available in different sizes (as shown in figure 2.) but mostly bigger size LDRs are used because bigger size LDR having more sensitivity and required less time to change output when input change.

3 FUZZY LOGIC CONTROLLER

In sun tracking system, to rotate the PV panel according to the sensors output intelligent controller is needed. Hence in sun tracking intelligent controller like PID controller or fuzzy logic controller can be used. Fuzzy logic controller is having advantages over PID controller and these are:

- Mathematical model of the control system is not required.
- Totally depend upon operators experience.
- It deals with nonlinearities of the system.
- Linguistic system definitions can be converted into control rule base or control algorithm.

Fuzzy logic controller can be implemented on the microcontroller, microprocessor PLD, FPGA. Microcontroller is having some disadvantages that is microcontroller is more economical and having problem while dealing with control system because it required high processing speed. FPGA is faster than microcontroller. It is suitable for fast implementation of controller and can be programmed to do any type of digital function. FPGA is more flexible and because of it FPGA have additional function and user interface control and it reduce the requirement of additional external component.

3.1 FLC for Sun Tracking System

Every FLC has three basic parts that are: fuzzification, rule base, Difuzzification. Error and change in the error are the inputs to the fuzzy logic controller. Output of the fuzzy logic controller is fed to the stepper motor driver. FLC for sun tracking system is shown in figure 2, it mainly consist of three basic part and these are discussed as follow:

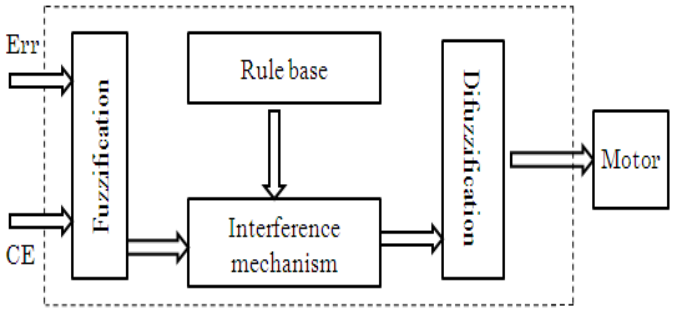


Figure 2. Block diagram of fuzzy logic controller for sun tracking system

Here the inputs Error(Err) and change in the error(CE) come from the sensor. This inputs converted into the fuzzified input and output will get after fuzzification. This output is then fed to the motor to control it. As shown in above figure 3, every fuzzy logic controller have three basic part as mentioned above and these are discussed as follow

3.1.a Fuzzification

Fuzzification is the process that converts numerical values into grades of membership of fuzzy set members. Hence fuzzification block matches the input data with the condition of the rule to determine how well the condition of each rule matches that particular input in-stance.

There is a degree of membership function for each linguistic term that applies to that input variables. Membership functions is of different type like triangular membership function, trapezoidal membership function. For example triangular membership function for error, change in the error and output is shown in the figure 3, 4 and 5 respectively.

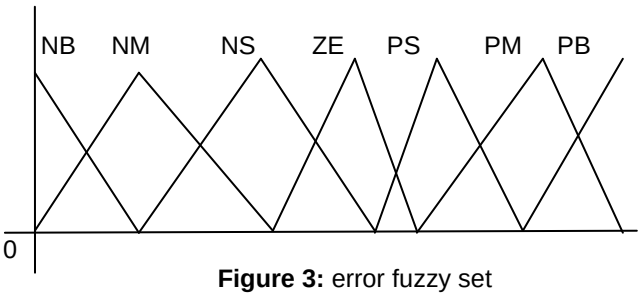


Figure 3: error fuzzy set

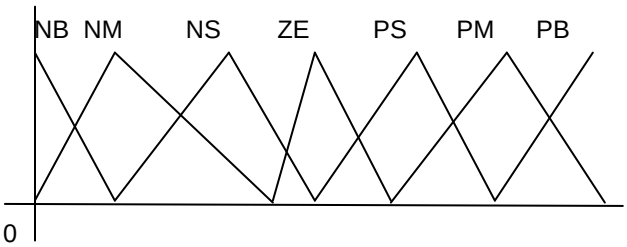


Figure 4: change in error fuzzy set of FLC

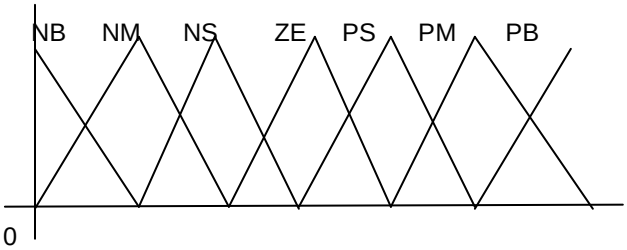


Figure5: Fuzzy set of FLC output entering to stepper motor driver

3.1.b Control rule base

Control rule base depends on the operators experiences. Depending on that experience knowledge base is developed which establish relationship between input and output variables in term of membership function. Structure of the control rule base is as follow:

If ERROR is.....AND CHANGE IN ERROR is.....then OUTPUT will.....

For example:

If ERROR is NB and CHANGE IN ERROR is NM then OUTPUT will be NB.

Er/CE	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PB	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

Table 1: Control rule-base for fuzzy logic controller.

3.1. c Difuzzification

Reverse of fuzzification is Difuzzification. Difuzzification converts fuzzified output into the normal crisp output. Different methods for Difuzzification are available like middle of maxima (MOM), first of maxima(FOM), last of maxima, centre of gravity etc. In this paper centre of gravity method is used for Difuzzification.

4 EXPERIMENTATION

Fuzzy logic controller for sun tracking is implemented on spartan3 FPGA. Here XILINX_ISE 9.1i software is used. RTL schematic diagram of Fuzzy logic controller is shown in following figure 7. And simulation is shown in figure 6 This simulation shows that LDR_1 is having value 8 volt and LDR_2 is having value 26 volts. Here LDR_2> LDR_1 And When intensity of light incident on LDR is maximum, its output is less. Means LDR is having inverse relationship between its input and output. So LDR_1 get maximum intensity of light because of inverse relationship between light intensity and output of LDR i.e. voltage here. Because of that controller rotate motor in anticlockwise direction by giving 1001 bit to it.

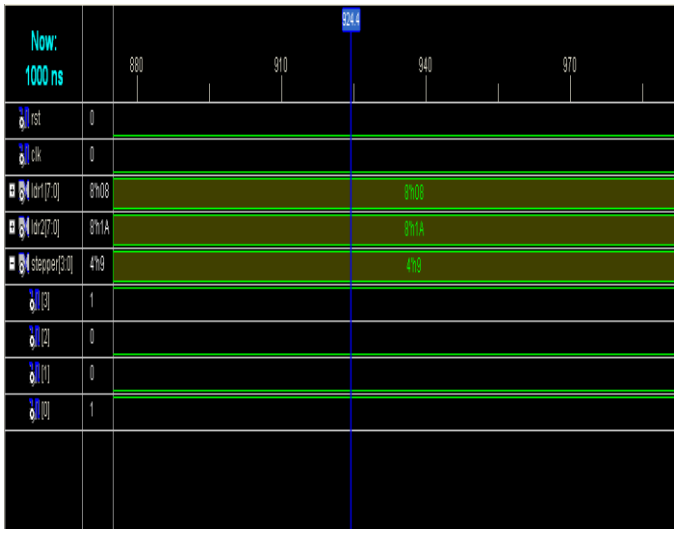
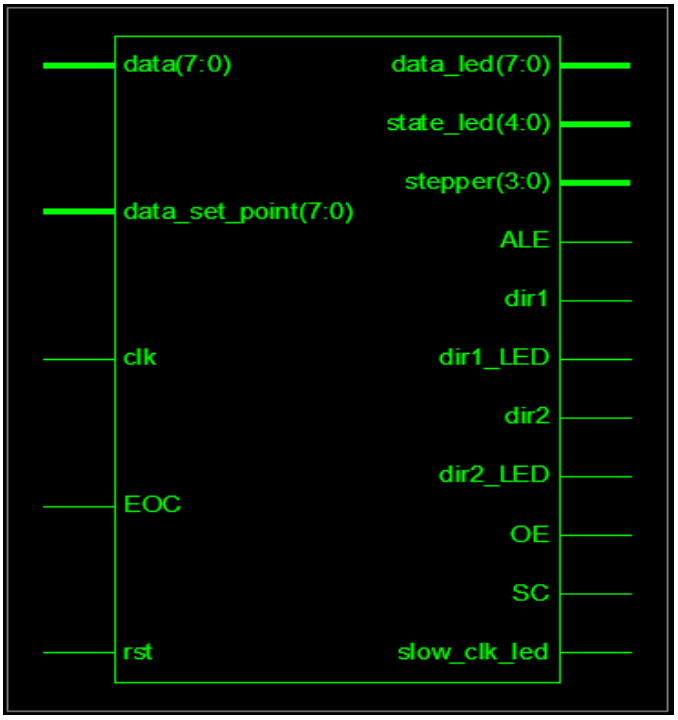
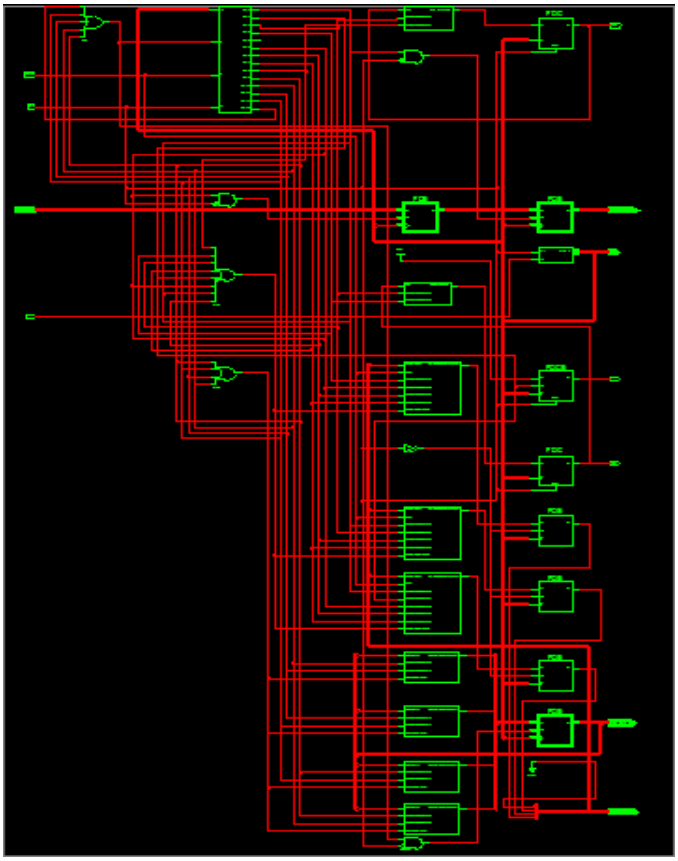


Fig 6: Simulation waveform



(a)



(b)

Fig 7: RTL schematic of the FLC shown in a,b

5 CONCLUSION

Here the main aim behind this paper is improvement in efficiency of PV panel. Efficiency can be increased by developing automatic sun tracking panel. FPGA based sun tracking system track the sun all day and rotate the motor to the sun orientation hence acquires maximum sun radiation throughout the day. Hence sun tracking system is having maximum efficiency than fixed position PV panel.

REFERENCES

[1]. Basil M. Hamed , Mohammad S. EI- Moghany "*Fuzzy Controller Design Using FPGA for Sun tracking in solar array system "*, I. J Intelligent System and Application .2012, 1, 46-52

[2]. Fawzi M. Al-Naima and Bilal R. Al-Taee, "*An FPGA Based Stand-alone Solar Tracking System "*, 2010 IEEE International Energy Conference, 978-1-4244-9380-7/10.

[3]. Y. J. Hung, B. C. Wu, C.Y Chang and T. C. Kuo , " *Solar Tracking Fuzzy Controller Design using FPGA "*, Proceeding of World Congress on Engineering 2009 Vol 1 WEC 2009,July 1-3 ,2009,London, U. K.

[4]. Singh B., Goyal R., Kumar R., and Singh R. (December 2009) Design and VLSI Implementation of Fuzzy Logic Controller (*IJCNS) International Journal of Computer and Network Security*,Vol.1, No.3

[5]. Salma Khan and Prof. Uma Kulkarni "*Design and implementation of Fuzzy logic controller for a DC motor*", International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 8, August 2012)

[6]. Riza ,B. Sheldon,T. (1997). Fuzzy Systems Design Principles Building Fuzzy IF-THEN Rule Bases, *IEEE* PRESS