Dual Axis Solar Tracking System using Verilog

[1]Hardik Modi,[2]Keith Frank,[3]Amtulla Khambhati, [4]Himanshu Patel
[1,4]Assistant Professor, [2,3]Student
[1]V T Patel Department of Electronics and Communication Engineering
[1]Charotar University of Science and Technology, Changa-388421, Anand, Gujarat (India)

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ABSTRACT: : *This paper highlights the design of solar tracking system using FPGA.FPGA's meet demanding timing and performance concern with parallel processing and real-time control application performance, concession the greater system integration and lower development cost. This paper analyzesthe use of astronomical equation.Astronomical equation deals altitude and azimuth angle using this position of the sun can be determined. Main conceptof this design is to develop a solar panel which uses sun rays as energy and generate maximum power effectively. The design of Verilog code has been successfully implemented on SPARTEN 6 FPGA kit. For design entry Xilinx ISE 14.7 software is used,Xilinx simulator used for functionality check. FPGA having advantages of densely parallel data processing, field reprogram ability. Performance gain for software applications and real time application performance, which allowed fast processing and lower development cost.*

Key Words:

Introduction

Solar energy is the energy that is being obtained by occupying heat and light from the sun. Energy from the sun is assigned as solar energy. It is considered as a green technology because it does not exhale greenhouse gases. The use of the renewable energy is more demanding as the world population increases day by day. Nowadays, oil and coal which is main source of energy is about to end up. Solar energy is one and only non-pollutant, reliable and cost-effective source of energy.Solar energy is that the step to the forthcoming associated is an economical and dependable supply of substitute energy [6]. photovoltaic cell becomes strikingly fashionable for utilizing alternative energy and may even be worn to reconcile our electricity requirement through star electrical phenomenon cells (SPV) or photovoltaic cell [16]. photovoltaic cell is associate device that convert radiation straight into electricity by electrical phenomenon impact. The engender electricity will be used exactly or will be reserved within the battery [16]. there are numerous varieties of utilization of alternative energy like producing electricity, transportation, cooking and many more.The solar radiations are accumulated by solar collector.In photovoltaic effect light from the sun is consumed by the p-n type junction and principle momentum of electrons to p-side and holes to n-side of junction. Hence it isconcluded that number of electron-hole pairs are set up which creates the flow of electric current.The figure 1 spectacleevolution of charge shipper as sun light drops on photovoltaic cell. [16]

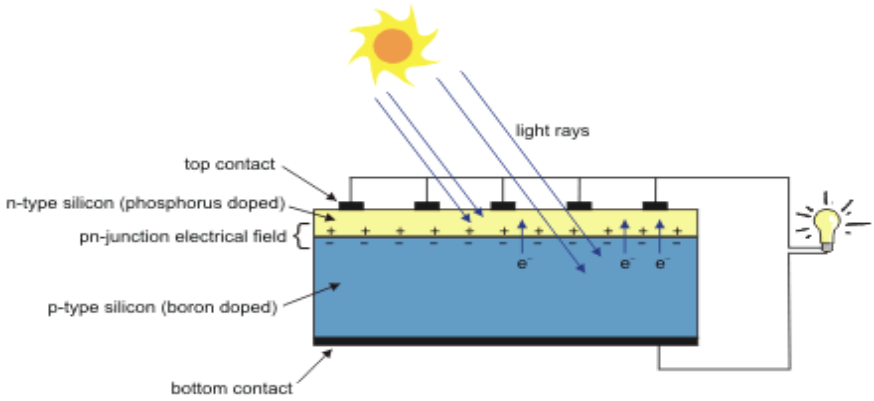

Figure-1Charge generation in a Photovoltaic Cell [8]

Incident radiation is that the most important parameter for the facility deliver the goods by the alternative energy system. The sun location within the sky take issue each with the seasons and time of the day. There

square measure numerous equations matured to forecast the precise location of the sun within the sky at a given date, a given hour and given latitude [16].

FPGA square measure universally used for dangerous prototyping. FPGA's square measure programmable digital logic chips that square measure primarily based abreast of a matrix of configurable logic blocks (CLB's). These CLB's square measure connected via programmable interconnects. FPGA may be reprogrammed to crave application or practicality concern once producing. further practicality and program controls may be enclosed into the FPGA reduces the priority for added peripheral elements thanks to its resilience. [16]

Appraisal of Solar Tracker

As the sun moves across the sky, for receiving the best angle of the sun radiation for collection of energy. Most photovoltaic (PV) solar panels are fitted fixed. Though the sun moves across the sky during the day, this is not an ideal solution. Solar panels are installed in the direction of maximum of radiation of sunlight. Now the problem emerge that the sun is moving so we can't get maximum radiation all time.

To solve this problem a tracking mechanism is usually implemented into the solar panel to keep the panel's face in the direction of the sun. A sun tracker is device over it the solar panels are fitted which tracks the sun movement across the sky make sure that the maximum amount of sunlight strikes on the panels throughout the day. Most of solar radiation is absorb when it strikes perpendicular to the PV panel. By meticulously tracking the sun, efficiency of the power generation can be heightened. There are basically two types of tracker one is passive tracker and the another is active tracker [7]. The passive trackers use a low boiling point gas fluid which is driven and cause to move the tacking system. The liquid is then vaporized by the added heat of the sun and the center of the mass is shifted leading to that system finds the new position. Active tracking mechanism directed the solar panel towards the sun with the help of light dependent resister (LDR). Motors are occupied to direct the tracker towards the sun's direction [4].

Descriptionof Tracker

The sun position within the sky changes with seasons and through the day. There are a unit two styles of trackers area unit being delineated. Mechanism drives the only axis hunter in one direction only. Single axis trailing system increase power management by 18%–27% compared to mounted PV cell panel. Dominance of single axis trackers area unit cheaper and fewer difficult [1][17].

Dual axis tracks the sun entirely. Track the sun each in angle and altitude angles, Capture full path of the sun. twin axis trailing system increase power management by 34% - 37% correlative to mounted PV cell panel. however twin axis trackers area unit slightly additional advanced, very little valuable.

Sun Path

In earth's hemisphere, the sun surge within the east, sets in west and alter across the northern sky. the placement of the sun will by chronicle by 2 angles, the Altitude and also the Azimuth angle [8][17].

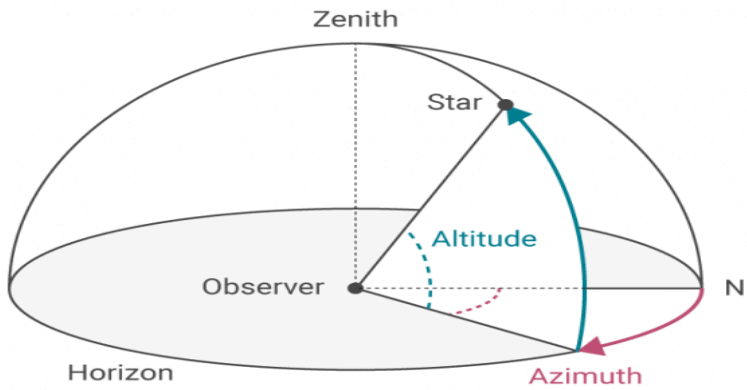

Figure 2 Solar altitudes and azimuth's exemplary behavior of sun path [11]

Azimuth angle (ΘA) is measured right-handed around person's horizon from north. So, associate object N has AZ of 0°, east 90°, south 180° and west 270°.The vector from position of person to the sun position is projected sheer onto a plane suggests that the angle between a reference plane and projected vector. The sun altitude angle (Θz) is that the angle between the road connecting to the sun in conjunction with the horizontal plane. The altitude angle depends on latitude of the world, the declination angle and also the hour angle [3].

$$\textit{Azimuth Angle} = \frac{\cos^{-1}[\sin\sigma\cos\theta - \cos\sigma\sin\theta\cos(ha)]}{\cos\alpha}$$

$$\textit{Altitude Angle} = \sin^{-1}[\sin\sigma\cos\theta + \cos\sigma\sin\theta\cos(ha)]$$

Where, ha is Hour Angle as well as α is the elevation angle, declination angle is σ, latitude is denoted by θ. Declination Angle(6) of the sun is the angle between a line drawn from the center of the Earth to the sun and equator. The declination is maximum (23.450) in the summer/winter.

Declination angle is obsessed as

$$\textit{Declination Angle} = 24.45° \sin\left[\frac{360}{356}(d - 81)\right]$$

Where, d is the number of the day considering the start of the year.

Hour angle can be converted into local solar time (T) into degree. It is given as

$$HRA = 15°(T - 12)$$

Dignity of Solar Energy[21]

- It is a non-conventional fuel energy source.
- The sun is a universal source and it cannot diminish.
- Free from pollution.
- Cost of fuel is free.
- It is a reliable one.

Architecture of Tracking System

In the proposed solar tracking system, FPGA based stepper motor has been used to drive solar panel (PV panel) depends on the position of sun sensed by LDR (Light Dependent Resistor) as shown in figure 3. The position of the sun is decisive by using tracking sensor that's LDR, the sensor reading is in analog so it is converted to digital signal and is transfered to controller implemented on FPGA. The controller output is connected to the driver of the stepper motor to rotate the solar panel (PV panel) until it faces the sun. We used Xilinx 14.7 software to perform solar tarcking system. This design is programmed and uploaded into Waxwing Spartan 6 FPGA Development Board. This dual axis solar tarcking implementation expedite development while maintaining design flexibility, reduces the circuit board costs and simplifies product testing.

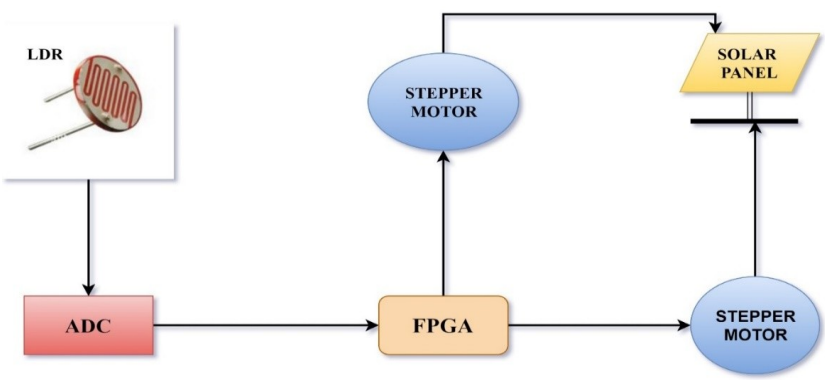

Figure 3 Block Diagram of Solar Tracking System

The figure three shows the diagram of the advanced star pursuit system. The goodish parts of this diagram area unit FPGA Controller, Analog to Digital convertor (ADC), stepper motors for rotating the solar battery. [16]

Light Dependent Resistor

Light dependent resistance (LDR) is employed to construct the device, as a result of it's the foremost reliable device that may be used for lightweight sensing [21]. LDR is essentially a resistance whose resistance diverge with intensity of sunshine;thus, additional intensity offers less resistance. totally different LDR sensors obtainable within the market area unit, the largest size is employed to construct the device as a result of the additional space of the device means that additional its sensitivity or less time taken for output to alter once input changes. Since the device tracks the star lightweight source's direction, choosing the correct trailing device is incredibly necessary [21]

Stepper Motor and Driver

The tracking system consists of two motor, that management the solar array position and an impact circuit to drive these motors.

A stepper motor is controlled by the series of magnetic attraction coils. Series of magnet mounted on the middle shaft, the coils encompassing the shaft area unit given current alternately and generate fields which are a magnet for or repulse the magnet, inflicting motor to rotate. The motors area unit classified into two types unipolar stepper motor and bipolar stepper motor. [5].

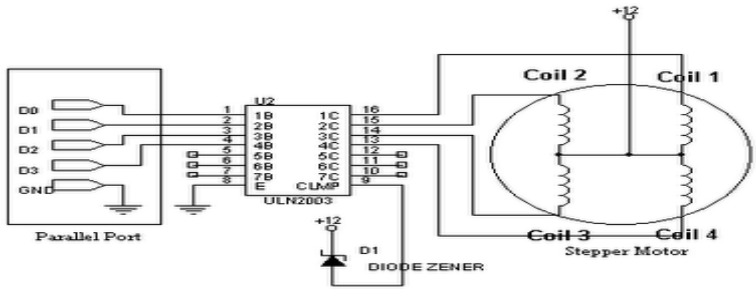

Figure 4Stepper motor with Driver Circuit[20]

The performance of stepper motor is firmly hooked in to the drive electronic equipment. The stepper motor driver electronic equipment regulates this and flux direction within the part windings and type a convenient quantity of current to flow through the windings. It additionally permits short current rise and fall times as possible for higher high-speed performance.
The motor is classified in two types unipolar stepper motor and bipolar stepper motor.

A. Unipolar Stepper Motor

Unipolar stepper motor has five wires, or it may be six also. Power always comes in on this pole, so they are called unipolar stepper motor [10].

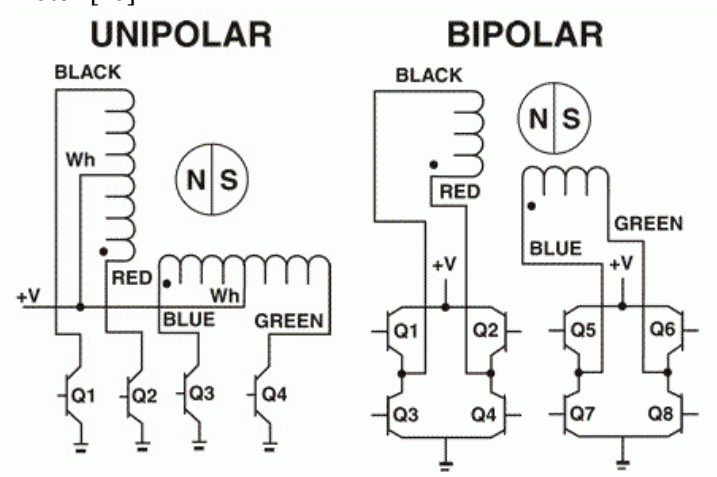

Figure 5 Unipolar Stepper Motor and Bipolar Stepper Motor[19]

B. Bipolar Stepper Motor

Bipolar stepper motor has four wires. Unlike unipolar, bipolar stepper motor has no common connection. They have two separate sets of coils [10]. The sequence is given in table 1.

Table 1Steps of the Stepper Motor

Step	Wire 1	Wire 2	Wire 3	Wire 4
1	High	low	high	low
2	Low	high	high	low
3	Low	high	low	high
4	High	low	low	high

Working Principle of Solar Tracking System

The detector system consists of 4 similar LDR sensors, that area unit situated at the center to find the sunshine supply intensity. At the LDR detector positions, brackets isolate the sunshine from different orientations to attain a camera lens search and quickly confirm the sun's position [21]. To sense the position of sun four LDR sensors area unit mounted on the solar array and placed in an enclosure. The north and

south LDR sensors compare the intensity of received lightweight within the north and south. The east and west LDR sensors compare the intensity of received lightweight within the east and west. once sun's position shifts, the sunshine supply intensity received by the sensors area unit totally different, the system obtains signals from the sensors' output voltage within the two orientations.

The system then determines that detector received additional intensive lightweight supported the detector output voltage understood by voltage sort A/D device (ADC) and ADC0804 device. The system drives the stepper motor towards the orientation of this detector. If the output values of the four sensors area unit equal, the output distinction is zero and therefore the motor's drive voltage is zero, which suggests the system has tracked the present position of the sun.[21]

FPGAProgram Design

For implementing the hardware control circuit, a hardware description language Verilog HDLis used to load the control program. During hardware design, we used the Xilinx 14.7 software to compile the logic circuit of the HDL programs. During software design, we used the Xilinx software development tool and software resources such as synthesis, RTL schematic, Technology schematic, and stimulation to generate and edit application code. Using Xilinx 14.7 software simulation, compilation and analyze, the whole system is tested carefully in every step while designing the system. The integrated steps required for the design of a solar tracker are discussed in following sections

Simulation and Results

In the work, a dual solar tracker axis system has been designed and enforced. The module is intended, verified, synthesized and enforced on FPGA. the planning of the star chase system combines the FPGA star chase system with two ADC and two stepper motor. the highest module of star chase system is shown in figure 6. the full system may be seen from the "RTL schematic" and "Technology schematic" of the Xilinx 14.7 as shown in figure 7 and figure 8. The initial stage interfacing of four LDR sensors and two stepper motor with Spartan six FPGA board. A paradigm of the solar tracker has been created for checking the usefulness of the planning methodology. The initial stage and the actual paradigm enforced on Arduino.

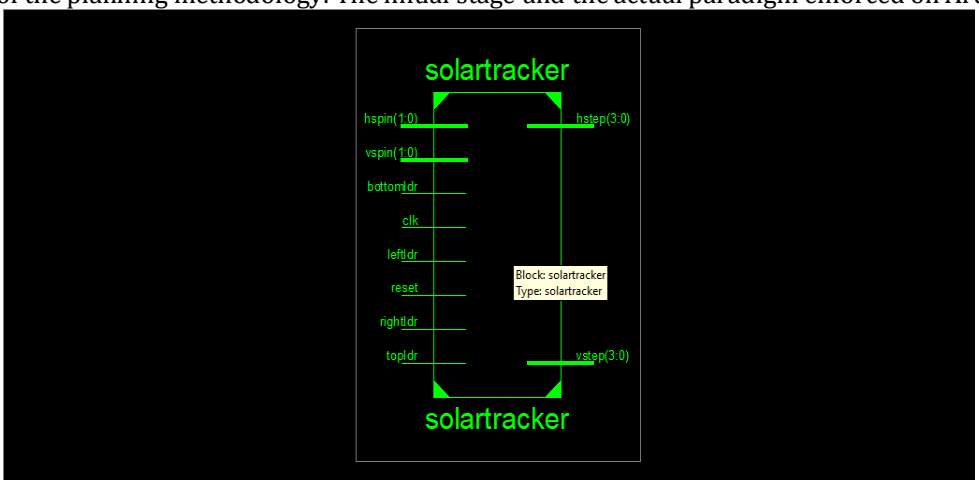

Figure 6Solar Tracker Top Module

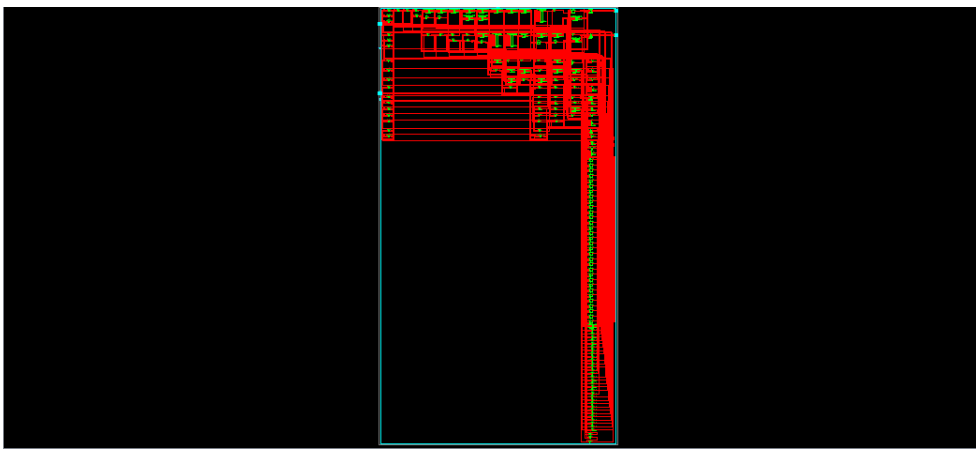

Figure 7Solar Tracker RTL Schematic

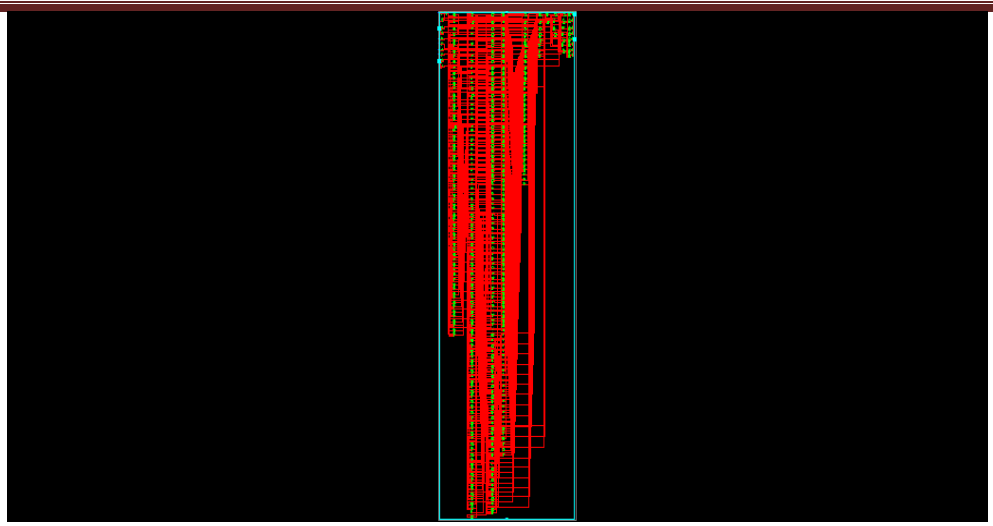

Figure 8Technology Schematic

Conclusion & Future Work

The main aim behind this project is to improve the efficiency of solar panel. FPGA based sun tracking system tracks the sun all day and rotates the motor to the sun orientation hence acquires ultimate sun radiation throughout the day. Hence the designed system can achieve more illumination and energy concentration than conventional fixed solar panel and can improve overall efficiency. The major difference between our design and traditional, single-chip designs (such as the 8051 or PIC device) is that traditional chips cannot write Verilog (VLSI). If traditional devices and discrete components were chosen for the task, external logic circuits were enforced to implement the controller which would increase intricacy in overall implementation. Moreover, in such case, the control system lacks flexibility, difficult to debug or troubleshoot, in cases of error and may be unreliable due to tolerances of components, environmental and aging effects. Alternatively, if an FPGA is used, the control system becomes flexible, programmable and more reliable. The FPGA can be programmed to meet design objectives as demanded by desired application. Moreover, additional functionality and user interface controls can be created into the FPGA minimizing the requirement for additional peripheral components due to its flexibility. The control system has been checked with a prototype solar panel and satisfactory results have been obtained as per as tracking is concerned. The light sensors-based tracking systems may lead to error in cloudy or partially cloudy weather, since there will be less or no striking of light on light sensors (LDR). In such cases, light sensors may not be able to generate required voltage to run the subsequent stages of the tracking system. This can be handled by time-based controlling. However, this research comforts the solar power generating equipment to get the maximum sunlight automatically thereby increasing the efficiency of the system. Moreover, this system can achieve more illumination and energy concentration than stationary solar panel and cut the cost of electricity by requiring fewer solar panels, therefore, it has enormous significance for research and development.

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