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Design of a Solar Tracker System for Panels

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Abstract - Solar energy is fast becoming a very important means of renewable energy resource. By using solar tracking system, it is possible to generate more energy from solar panels since the solar panel can maintain a perpendicular profile to the rays of the sun. Even though the initial cost of setting up the tracking system is considerably high, there are some cheaper methods that can be used to generate more energy. This paper presents the design and construction of a solar tracking system that has a single axis of freedom. Light Dependent Resistors (LDRs) are used for sunlight detection. The control circuit is based on an ATMega328P microcontroller. It is programmed to detect sunlight through the LDRs before actuating the servo to position the solar panel. The solar panels have been positioned to a particular place where it is able to receive maximum light. As compared to other motors, the servo motors are able to maintain their torque at high speed, more efficient with efficiencies in the range of 80-90%. Servos can supply around twice their rated torque for short periods. Performance and characteristics of solar panels are analysed through experimental set up.

Keywords— Solar energy, Tracking system, ATMega328P, LDRs,

I. INTRODUCTION

A solar tracker is a device used for orienting a photovoltaic array solar panel or for concentrating solar reflector or lens toward the sun. The position of the sun in the sky is varied both with seasons and time of day as the sun moves across the sky. Solar powered equipment work best when they are pointed at the sun. Therefore, a solar tracker increases how efficient such equipment are over any fixed position at the cost of additional complexity to the system[1]. There are different types of trackers .extraction of usable electricity from the sun became possible with the discovery of the photoelectric mechanism and subsequent development of the solar cell. The solar cell is a semiconductor material which converts visible light into direct current. Through the use of solar arrays, a series of solar cells electrically connected, there is generation of a DC voltage that can be used on a load. There is an increased use of solar arrays as their efficiencies become higher. They are especially popular in remote areas where there is no connection to the grid.The photovoltaic cell is the basic building block of a photovoltaic system. The individual cells can vary from 0.5inches to 4 inches across[2].

Fig.1.Sloar Panel.

II. Sun Tracking Solar Panel System

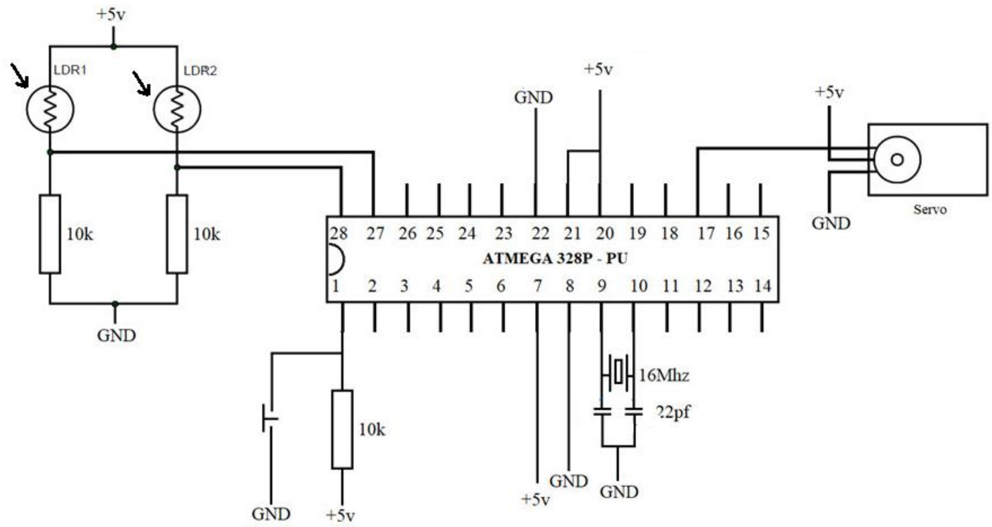

Fig.2 Circuit diagram of solar tracking panel

The Earth: Rotation and Revolution:

The earth is a planet of the sun and revolves around it. Besides that, it also rotates around its own axis. There are thus two motions of the earth, rotation and revolution. The earth rotates on its axis from west to east. The axis of the earth is an imaginary line that passes through the northern and southern poles of the earth [3]. The earth completes its rotation in 24 hours. This motion is responsible for occurrence of day and night. The solar day is a time period of 24 hours and the duration of a sidereal is 23 hours and 56 minutes.

The movement of the earth round the sun is known as revolution. It also happens from west to east and takes a period of 365 days. The orbit of the earth is elliptical. Because of this the distance between the earth and the sun keeps changing. The apparent annual track of the sun via the fixed stars in the celestial sphere is known as the ecliptic. The earth's axis makes an angle of 66.5 degrees to the ecliptic plane. Because of this, the earth attains four critical positions with reference to the sun.

Solar Irradiation: Sunlight and the Solar Constant:

The sun delivers energy by means of electromagnetic radiation. There is solar fusion that results from the intense temperature and pressure at the core of the sun. Protons get converted into helium atoms at 600 million tons per second. Because the output of the process has lower energy than the protons which began, fusion gives rise to lots of energy in form of gamma rays that are absorbed by particles in the sun and re-emitted.

The total power of the sun can be estimated by the law of Stefan and Boltzmann.

$P = 4\pi r^2 \sigma \epsilon T^4$ W [4]

T is the temperature that is about 5800K, r is the radius of the sun which is 695800 km and **σ** is the Boltzmann constant which is $1.3806488 \times 10^{-23}$ m^2 kg s^{-2} K^{-1}. The emissivity of the surface is denoted by **ϵ.** Because of Einstein's famous law $E=mc^2$ about millions of tons of matter are converted to energy each second.

Sunlight:

Photometry enables us to determine the amount of light given off by the Sun in terms of brightness perceived by the human eye. In photometry, a luminosity function is used for the radiant power at each wavelength to give a different weight to a particular wavelength that models human brightness sensitivity. Photometric measurements began as early as the end of the 18th century resulting in many different units of measurement, some of which cannot even be converted owing to the relative meaning of brightness. However, the luminous flux is commonly used and is the measure of the perceived power of light [5].

Elevation angle:

The elevation angle is used interchangeably with altitude angle and is the angular height of the sun in the sky measured from the horizontal. Both altitude and elevation are used for description of the height in meters above the sea level. The elevation is 0 degrees at sunrise and 90 degrees when the sun is directly overhead. The angle of elevation varies throughout the day and also depends on latitude of the particular location and the day of the year.

Zenith angle:

This is the angle between the sun and the vertical. It is similar to the angle of elevation but is measured from the vertical rather than from the horizontal. Therefore, the zenith angle = 90

Degrees – elevation angle

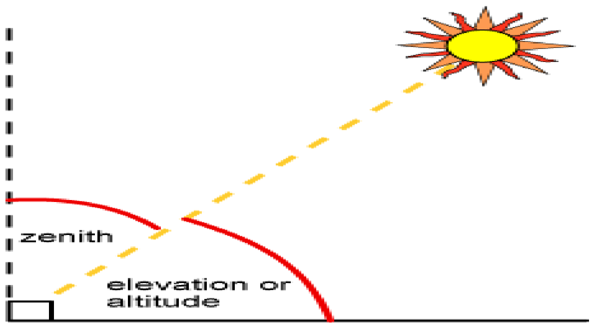

Fig.3 Elevation Angle of Solar system.

Azimuth angle:

This is the compass direction from which the sunlight is coming. At solar noon, the sun is directly south in the northern hemisphere and directly north in the southern hemisphere. The azimuth angle varies throughout the day [6]. At the equinoxes, the sun rises directly east and sets directly west regardless of the latitude. Therefore, the azimuth angles are 90 degrees at sunrise and 270 degrees at sunset.

III. Types of solar trackers and tracking technologies

Active tracker:

Active trackers make use of motors and gear trains for direction of the tracker as commanded by the controller responding to the solar direction. The position of the sun is monitored throughout the day. When the tracker is subjected to darkness, it either sleeps or stops depending on the design. This is done using sensors that are sensitive to light such as LDRs.

Passive solar tracking:

Passive trackers use a low boiling point compressed gas fluid driven to one side or the other to cause the tracker to move in response to an imbalance. Because it is a non-precision orientation it is not suitable for some types of concentrating photovoltaic collectors but works just fine for common PV panel types. These have viscous dampers that prevent excessive motion in response to gusts of wind [7].

Chronological solar tracking:

A chronological tracker counteracts the rotation of the earth by turning at the same speed as the earth relative to the sun around an axis that is parallel to the earths. To achieve this, a simple rotation mechanism is devised which enables the system to rotate throughout the day in a predefined manner without considering whether the sun is there or not.

Fixed collectors:

Fixed collectors are mounted on places that have maximum sunlight and are at relatively good angle in relation to the sun. These include rooftops. The main aim is to expose the panel for maximum hours in a day without the need for tracking technologies. There is therefore a considerable reduction in the cost of maintenance and installation. Most collectors are of the fixed type. When using these collectors, it is important to know the position of the sun at various seasons and times of the year so that there is optimum orientation of the collector when it is being installed. This gives maximum solar energy through the year.

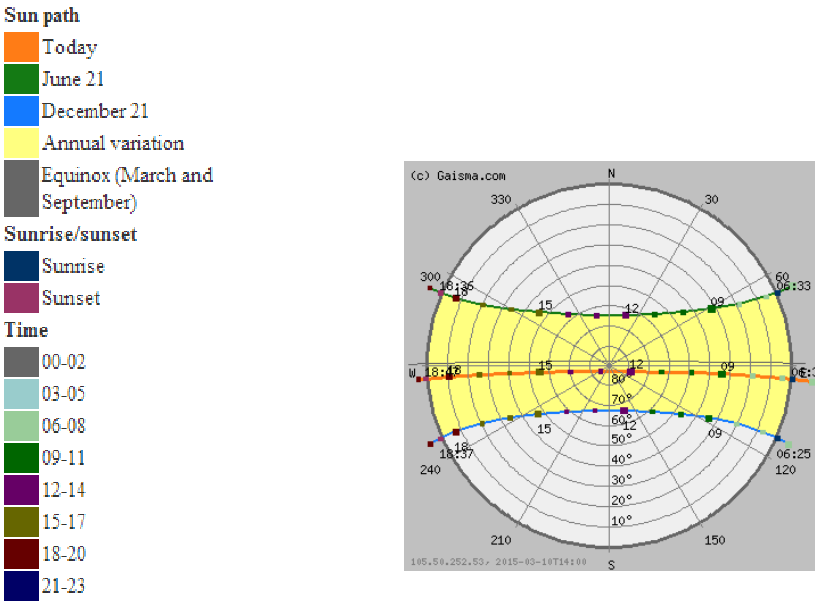

Fig.4 The Sun Chart.

The Collector:

When collectors are fixed, the projection area on the area that is perpendicularly oriented to the direction of radiation is given by S = So cos θ, where θ changes in the interval (-π/2, +π/2) during the day. The angular velocity of the sun as it moves across the sky is given by $\omega = 2\pi/T = 7.27\times10^{-5}$rad/s with the differential of the falling energy given by dW = IS dt. For tracking collectors, theoretical extracted energy is calculated assuming that maximum radiation intensity I=1100W/m^2 is falling on the area that is perpendicularly oriented to the direction of radiation. There is comparison of intensity on the tracking collector and the fixed one. More energy is gotten from the tracking collector than the fixed one.

The Tracking Collector:

For tracking collectors, if atmospheric influence is neglected, the energy per unit of area for an entire day is given by

$W = ISdt = 4.75 \times 10^{-5}$Ws,

That is 13.2kWh/m^2 day.

Comparing the theoretical results for the two cases, more energy is obtained from the second case, for the tracking collector. However, as the rays of the sun travel towards the earth, they go through the thick layers of the atmosphere in both of the cases. That in spite of, the tracking collector has more exposure to the sun's energy at any given time.

Components of the Solar System.

Light Dependent Resistor(LDR)

The simplest optical sensor is a photon resistor or photocell which is a light sensitive resistor these are made of two types, cadmium sulfide (CdS) and gallium arsenide (GaAs). The sun tracker system designed here uses two cadmium sulfide (CdS) photocells for sensing the light. The photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with capacitor. The photocell to be used for means that further increasing the light intensity to the CdS cells will not decrease its resistance any further. Light intensity is measured in Lux, the illumination of sunlight is approximately 30,000 lux.the tracker is based on its dark resistance and light saturation resistance. The term light saturation

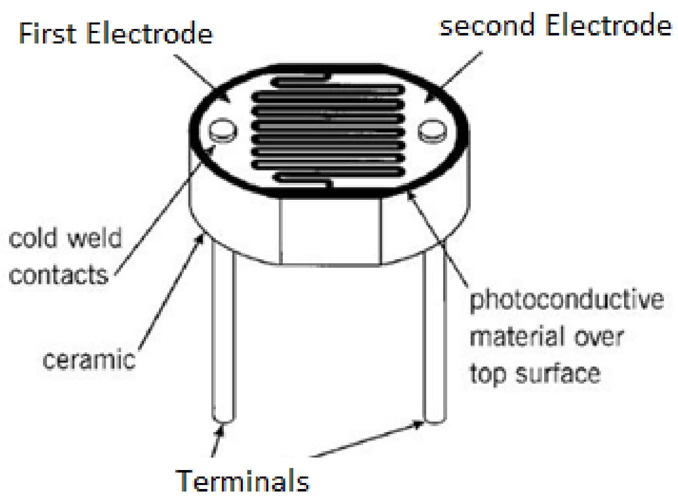

Fig.5. LDR

Microcontroller:

Microcontroller is a single chip microcomputer made through VLSI fabrication and also called an embedded controller because the microcontroller and its support circuits are often built into, or embedded in, the devices they control. A microcontroller is available in different word lengths like microprocessors (4bit,8bit,16bit,32bit,64bit and 128 bit microcontrollers are available today [8].

A microcontroller contains one or more of the following components:

- Central processing unit (CPU)
- Random Access Memory (RAM)
- Read Only Memory (ROM)
- Input/output ports
- Timers and Counters
- Interrupt controls
- Analog to digital converters
- Digital analog converters
- Serial interfacing ports
- Oscillatory circuits

Microcontrollers need to be programmed to be capable of performing anything useful. It then executes the program loaded in its flash memory – the code comprised of a sequence of zeros and ones. It is organized in 12-, 14- or 16-bit wide words, depending on the microcontroller's architecture. Every word is considered by the CPU as a command being executed during the operation of the microcontroller.

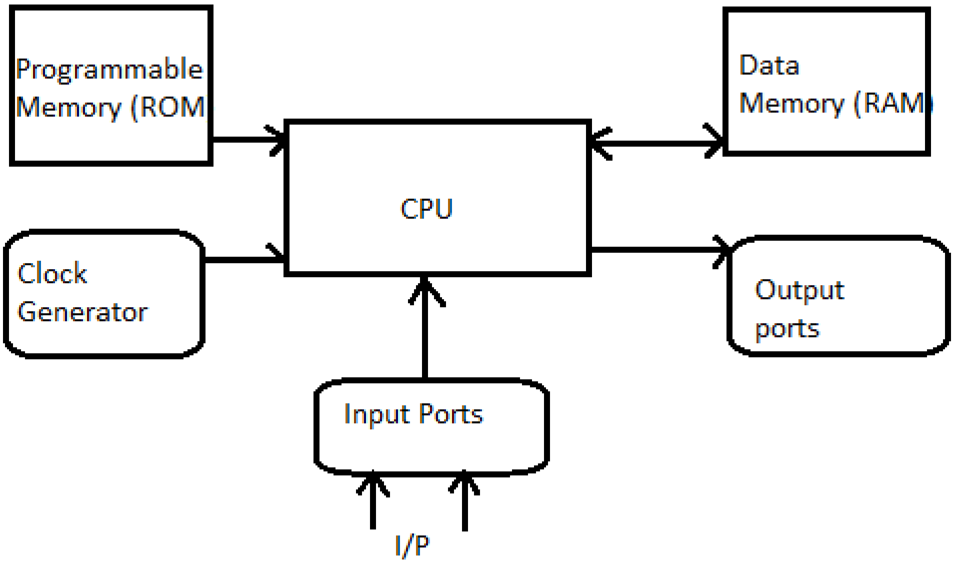

Fig.6. Microcontroller and its operation.

ATmega328P:

The ATmega328P is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega328P achieves throughputs approaching 1 MIPS per MHz allowing the system designed to optimize power consumption versus processing speed. It has 28 pins. There are 14 digital I/O pins from which 6 can be used as PWM outputs and 6 analog input pins. The I/O pins account for 20 of the pins. The 20 pins can act as input to the circuit or as output. Whether they are input or output is set in the software.

The Atmega328 chip has an analog-to-digital converter (ADC) inside of it. This must be or else the Atmega328 wouldn't be capable of interpreting analog signals. Because there is an ADC, the chip can interpret analog input, which is why the chip has 6 pins for analog input. The ADC has 3 pins set aside for it to function- AVCC, AREF, and GND. AVCC is the power supply, positive voltage, that for the ADC. The ADC needs its own power supply in order to work. GND is the power supply ground.

IV. Observations and results:

The Sun tracking solar panel consists of two LDRs, solar panel and a servo motor and ATmega328 Micro controller. Two light dependent resistors are arranged on the edges of the solar panel. Light dependent resistors produce low resistance when light falls on them. The servo motor connected to the panel rotates the panel in the direction of Sun. Panel is arranged in such a way that light on two LDRs is compared and panel is rotated towards LDR which have high intensity i.e. low resistance compared to other. Servo motor rotates the panel at certain angle.

When the intensity of the light falling on right LDR is more, panel slowly moves towards right and if intensity on the left LDR is more, panel slowly moves towards left. In the noon time, Sun is ahead of light with more intensity on both the panels is same. In such cases, panel is constant and there is no rotation.

The results were obtained from the signals of LDRs for the solar tracking system and the panel that has a fixed position. The results were recorded for four days, recorded and tabulated. The outputs of the LDRs were dependent on the light intensity falling on their surfaces. Adriano has a serial that communicates on digital pins 0 (RX) and 1 (TX) as well as with the computer through a USB. If these functions are thus used, pins 0 and 1 can be used for digital input or output. Adriano environment's built in serial monitor can be used to communicate with the Adriano board. To collect the results, a code was written that made it possible to collect data from the LDRs after every one hour. The values from the two LDRs are to be read and recorded at the given intervals.

The LDRs measure the intensity of light and therefore they are a valid indication of the power that gets to the surface of the solar panel A code was written that made it possible to obtain readings from the two LDRs at intervals of one hour. The EEPROM came in handy in this. It is the memory whose values are kept when the board is turned off. The AT mega 328P has 1024 bytes of EEPROM. To get the values at the end of the day, the Adriano board was used to connect the Microcontroller to the computer. The RX and TX pins are used for the connection. The code for reading the values that were recorded is loaded into the microcontroller. The various values are obtained and converted into volts. The Vcc to the microcontroller and the LDRs is 5volts. The At mega 328P has 1024 voltage steps and 5volts. When they are converted into digital values, the values will be in the range of 0-1023.

V. Conclusion

A solar panel that tracks the sun was designed and implemented. It is observed that the instructions pertaining to various actions mentioned in the program worked satisfactorily for the project to work. As a result, tracking was achieved as desired. The system designed was a single axis tracker. While dual axis trackers are more efficient in tracking the sun, with additional circuitry and complexity associated with the system. Dual trackers are most suitable in regions where the sun position changes frequently.

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