Use of Solar Tracking System for Extracting Solar Energy

Gagari Deb and Arijit Bardhan Roy

***Abstract*—The increasing demand for energy, the continuous reduction in existing sources of fossil fuels and the growing concern regarding environment pollution, have pushed mankind to explore new technologies for the production of electrical energy using clean, renewable sources, such as solar energy, wind energy, etc. Among the non-conventional, renewable energy sources, solar energy affords great potential for conversion into electric power, able to ensure an important part of the electrical energy needs of the planet. This paper deals with the design and execution of a solar tracker system dedicated to the PV conversion panels. The proposed single axis solar tracker device ensures the optimization of the conversion of solar energy into electricity by properly orienting the PV panel in accordance with the real position of the sun. The operation of the experimental model of the device is based on a Stepper motor intelligently controlled by a dedicated drive unit that moves a mini PV panel according to the signals received from two simple but efficient light sensors. In this paper mechanism of building an efficient solar tracking system with the help of Labview software is discussed and also discussed about the control strategy of the stepper motor. From the study it is found that the motor will move the solar array according to the light intensity of the sun.**

***Index Terms*— Light intensity, lab view, stepper motor, solar tracker.**

I. Introduction

In today's hi-tech technology, energy is the main inspiration for socio-economic development. But due to incremental rate of environmental concern renewable energy provide a significant interest in INDIA. This alternative power source is continuously achieving greater popularity especially since the realization of fossil fuels shortcomings. Renewable energy in the form of electricity has been in use to some degree as long as 75 or 100 years ago. It is the energy comes from sun, wind, rain etc. Among the non conventional, renewable energy sources solar energy affords great potential for conversation into electric power, able to ensure and important part of the electrical energy needs of the planet. Renewable power generators are spread across many countries. The main forms of renewable energy are- wind energy, hydro energy, biomass, geothermal energy, solar energy [1].

Large solar energy plants with rated power of MW are becoming more and more popular as they are non-polluting. The solar energy is the energy coming from the sun. Sun is the ultimate source for all forms of energy. The conversion principle of solar light into electricity is called photo-voltaic or PV conversion which is one of the most promising and challenging energetic technologies, in continuous development, being clean, silent and reliable, with very low maintenance costs and minimal ecological impact. Solar energy is free, practically inexhaustible and involves no polluting residues or green gases emissions. The knowledge of the quality and quantity of solar energy available at a specific location is the prime importance for the development of a solar energy system. However the amount of electrical energy which is obtained is directly proportional to the intensity of the sun light that falls on the photovoltaic panel. The solar energy can be broadly classified in two categories on the basis of use – Solar Active and Solar Passive. In case of Solar Active energy is directly converted in the application form, and in case of solar passive the energy is put into use by incorporating appropriate designs. Solar Active category is also classified in two categories- Solar thermal and Solar Photovoltaic. The largest solar energy generating plant in the world produces a maximum of 354 mega watts of electricity and is located at Kramer junction in California. Due to simple construction and low maintenance cost solar energy systems are mainly used for generation purpose [1].

In order to obtain solar energy as much as possible, the study of the efficiency for PV systems has attracted many researchers and engineers attention. In general, there are three methods to increase the efficiency of PV systems. The first method is to increase the generation efficiency of solar cells; the second one is related to the energy conversion system included maximum power point tracking(MPPT) control algorithms; and the third approach is to adopt solar tracking system to obtain maximum solar energy input from the sun[2].

In 1975, one of the first automatic solar tracking systems was presented by McFee, in which an algorithm was developed to compute total received power and flux density distribution in a central receiver solar power system [3].

In this paper solar tracking system is developed by the Labview software which is a graphical programming language that uses icons instead of lines of text to create applications. In contrast to text-based programming languages, where instructions determine program execution, Labview uses dataflow programming, where the flow of data determines execution. The output of the Labview program is indicated by the LEDs .The LED of the east direction will glow if the light intensity in that direction is higher and the LED of west direction will glow if the west light intensity is higher and the motor will rotate the solar array accordingly.\

II. Solar Tracking System

Solar energy is the oldest primary source of energy. It is clean, renewable and abundant in every part of the world.

Manuscript received October 22, 2011; revised January 23, 2012.

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Almost all energies are derived from solar energy. However it is possible to convert solar energy into mechanical or electrical energy with adequate efficiency. Sun tracking systems are designed in a way to track the solar azimuth angle on a single axis or to track the solar azimuth and zenith angles on two axes. For the purpose of clarity, the east-west of the tracker will be called the “horizontal tracking” while the angular height tracker will be referred to as “vertical tracking”. In the literature based on the previous studies, it was observed that sun tracking systems provided a significant increase in the amount of energy produced (Zogbit and Lap laze, 1984) [4].

The most commonly used system in sun tracking systems is controlling the motor that moves the panel by evaluating the signals received from the photo sensors placed on the PV panelends through several control systems (Abdalah, 2002).Based on the tracking principles, we can classify the controlling process into three processes namely passive control unit, microprocessor control unit and electro –optical control unit. Passive control unit is basically a system conducted without any electronic device. The microprocessor control unit is more accurate .Electro optical control unit tracks the sun by a solar detecting device that is sensitive to solar radiance Photosensors that are found on PV panel ends produce a signal relative to the sun light that falls on them. Changes according to the movement of the sun occur in the signals produced by photosensors. These different signals, which reach the control system, are evaluated and the required instruction signal is sent to the motor, which moves the PV panel. The panel moves according to this control signal and the movement of the PV panel stops at the position where it directly faces the sun, when the signals from both photosensors reach the same value. In these photosensor systems, unstable states may exist under overcast and partly cloudy weather conditions when the photosensors do not see the sun [5]-[6].

According, it is anticipated that PV systems will become one of the main energy recourses to fulfill the global energy requirement by the end of this century. Solar panels are usually set up to be in full direct sunshine at the middle of the day facing south in the Northern Hemisphere or north in the Southern Hemisphere. Therefore morning and evening sunlight hits the panels at an acute angle reducing the total amount of electricity which can be generated each day [7].

Solar cells are systems that are composed of semiconductor materials and which convert solar energy directly into current. The amount of electrical energy which will be obtained is directly proportional to the intensity of sun light that falls on the photovoltaic (PV) panel.When light falls on the device the light photons are absorbed by semiconducting material and electric charge carriers are generated. The relation between incident photon energy and frequency is W= h.ν, where h= Planck constant and ν= frequency. Silicon is the most abundant element available on the earth surface and mostly of the solar cells fabricated using them. The equivalent circuit of the solar cell is shown in Fig. 1. The current supply I_{ph} represents the electric current generated from the sun beaming on the solar cell. R_j is the non-linear impedance of the P-N junction. D_j is a P-N junction diode, R_{sh} and R_s represent the equivalent lineup with the interior of the materials and connecting resistances in series. Usually in general analysis, R_{sh} is large, and the value of R_s is small. Therefore in order to simplify the process of analysis, one can ignore R_{sh} and R_s. The symbol R_o represents the external load. I and V represent the output current and the voltage of the solar cell, respectively [8].

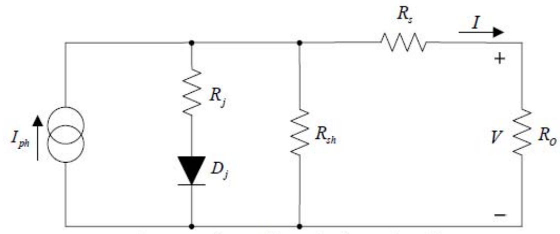

Fig. 1. Solar cell equivalent circuit.

From the equivalent circuit, and based on the characteristics of the P-N junction, equation (1) presents the connection between the output current I and the output voltage V:

$$I= npI_{ph} - npI_{\mathrm{sat}}[\exp(qV/kTA\ ns)-1] \qquad (1)$$

where np represents the parallel integer of the solar cell; ns represents the series connected integer of the solar cell; q represents the contained electricity in an electro (1.6×10− 19

Columbic); k is the Boltzmann constant (1.38×10− 23 J / K); T is the temperature of the solar cell (absolute temperature K); and A is the ideal factor of the solar cell (A = 1 ~ 5). The current $I\ sat$ in equation (1) represents the reversion saturation current of the solar power. Further, I_{sat} can be determined by using the following formula:

$$I_{sat}=I_{rr}[T/T_r]^3\exp[qE_{Gap}/KA(1/Tr-1/T)] \qquad (2)$$

where T_r represents the reference temperature of the solar cell; I_{rr} is the reversion saturation current at the time when the solar cell reaches its temperature T_r ; and E_{Gap} is the energy needed for crossing the energy band gap for the semiconductor materials[8].

A solar tracker is basically a device on to which solar panels are fitted which tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the panels throughout the day. After finding the sunlight, the tracker will try to navigate through the path ensuring the best sunlight is detected. It was observed that at 37.6 degrees latitude 32.5% more energy is obtained from the PV panels which tracks the sun. The sun tracking PV systems are more economical and they will decrease the investment costs. The systems which were implemented in this study can easily be used in sun tracking systems of the PV panels. However, when it is considered to increase the sensitivity of the tracking system, it will be more feasible to use high-bit analog modules. Sun tracking can increase the power output for PV solar power plants by about 25% to 40%, depending on the geographic location. A single axis tracker will increase power output by 26%, while a dual axis tracker increases power by 32%. Single axis trackers follow the sun from east to west, while two axis trackers also track the sun altitude (up/down) Since the sun moves across the sky throughout the day, in order to receive the best angle of exposure to sunlight for collection of energy, a tracking system is often incorporated into the solar arrays to keep the array pointed towards the sun [9].

To build an efficient solar tracker system sensor, Lab view software, motor and PV panels are required. The sensor is used to measure the temperature of two directions (East and West). The Light Dependent Resister (LDR) and Photo-diode can be used as a sensor. Second is the Lab view software where the system is modeled. Third is the motor which moves the panel connected to it and lastly the PV panel which is coupled mechanically with the shaft [10].

III. Modeling of Solar Tracking System

Nowadays, there are many types of solar trackers in the market such as single axis, dual-axis, active and passive trackers. In order to sustain in the market, these trackers must be designed to meet the user's requirement. Basically, there are four factors that must be taken into consideration in building a desired solar tracker. These factors are (1) Cost; (2) Reliability - Material and structure design; (3) Efficiency - Mechanism and circuit design and (4) Accuracy- Sensor positioning. Generally, cost will be the main component that is to be considered for the commencement of a project. In order to produce a low cost solar tracker, material being used must be appropriate for structure design that will lead to higher reliability and life span of the tracker. Besides these the tracker must have good response of time and higher efficiency. Lastly, the sensor must be placed at the proper location on the tracker to increase the accuracy and the tracker will be facing to the light source perpendicularly at all times. To build an efficient solar tracking system at first it is essential to built an efficient algorithm which operates the whole system accurately [11].

A. Algorithm

The main objective of the Solar Tracker Algorithm is to quickly determine to the best angle of exposure of light from the sun. A pair of sensors is used to point the East and West of the location of the light. Fig. 2 shows a flow chart of Solar Tracker Algorithm.

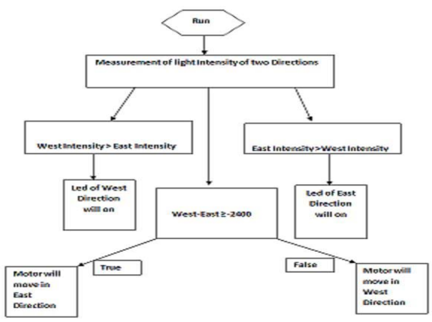

Fig. 2. Algorithm of the solar tracking system.

At first two sensors are set which measure the temperature of two directions and then supply the data to the Labview program which is running in particular logic. At first the output of the thermometer is multiplied by a numeric value 2400. Light intensity = 2400 × Vo lux This is done because human eye is a very poor instrument for measuring light intensity, because the pupil can adjust constantly in response to the amount of light it receives[9].

After that two intensities are comparing with each other. If intensity of the light of one direction is greater than the other direction of light then the Led which represented the higher intensity of light will glow. The second part of the algorithm is, o intensity of one direction is subtracted from the other intensity and compares with a constant value -2400 which decide the movement of the machine in particular direction. The output of the program will control the movement of stepper motor. A PV panel is connected to the shaft of the stepper motor which is perpendicular to the direction of the sun. Stepper motor is mainly used in this work because Stepper motors have a wide range of applications. Some applications require that a stepper motor should rotate continuously or periodically with a constant speed or a variable speed; some applications also require that it should position a device at the right time to a certain position according to a program and it consumes low power with respect to other machines [9],[12]-[14].

B. Working Principle of the Circuit

The circuit of the solar tracking system is dived into two parts. First part is dealing about sensors and other logical blocks which control the stepper motor and second part is nothing but a design of stepper motor, which moves the panel in appropriate position. Fig. 3 represents the logical unit of solar tracking system and 4 is represents the design of stepper motor. And the working principle of the circuit is discussed below:

- In this circuit the source of solar energy is assumed as numeric value in Lab view software.
- Two sensors are placed in two directions are joined with the input values with the help of wire. Here two thermometers are used as a sensor.
- The outputs of the thermometers are connected to meters which show the intensity of two directions.
- The output of the thermometer is multiplied with a value of 2400.
- After measuring the intensity of two directions, it is necessary to compare each other.
- First the comparison is made between east intensity of the light and the west intensity of light with the help of comparison component Less (<).
- After that the output is connected to the LED which is available in the front panel of the Lab view software.
- If the condition is satisfied then the Led connected to it is automatically on otherwise it will turn off.
- The second part of the logical unit is as same as the first part of the circuit but only difference is that in case of Less (<) a Component Greater (>) is used.
- In the circuit it is seen that the intensity of the east light intensity is subtracted from the west light intensity and it is compare to the numeric value -2400.
- If the condition is true then the motor will move in east direction and if the condition is false then the motor will move in west direction.
- The two parts of the circuit is joined with the help of merge signal block which merges two or more signal into a single output.
- By comparing the two intensities the resultant output is send to a stepper motor.

- The motor will move either clockwise or counter clockwise direction depending upon the intensities.

The whole circuit is built in the while loop which is found in the Lab view functions with the help of it repeats the sub diagram inside it until the conditional terminal, an input terminal, receives a particular Boolean value .When it place this while loop on the block diagram, a stop button also appears on the block diagram and is wired to the conditional terminal.

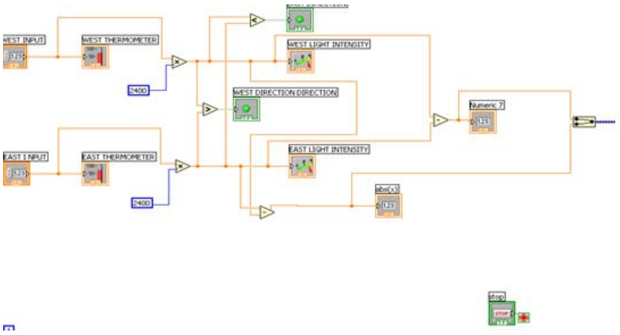

Fig. 3. Logical part of the solar tracking system.

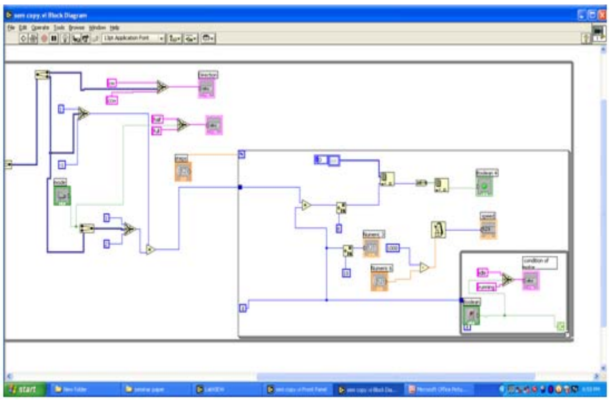

Fig. 4. Design of the stepper motor.

IV. Results

The result is seen in the front panel of the Lab view software. In the front panel three types of results are found at first west intensity is greater than east intensity second is west intensity is smaller than east intensity and the third will be the two intensities are same. The three types of results discussed below.

A. West light Intensity is Greater than East light Intensity

When the West light intensity is greater than east light intensity then the west position LED will glow and the machine will moves in clockwise (cw) direction. The other LED is remaining in off position.

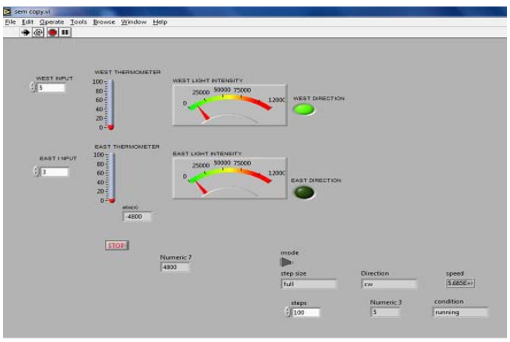

Fig. 5. West intensity is greater than east intensity.

B. East light Intensity is Greater than West Light Intensity

When the East light intensity is greater than West light intensity then the East position LED will glow and the machine will move in counter clock wise (ccw) direction. The other LED is remaining in off position.

Fig. 6. East intensity is greater than west intensity

C. When two Intensities are Same

When the two intensities are same then all the LEDs are connected to the circuit will not glow and the machine is remaining in steady state position. It indicates that two intensities of two directions are same.

Fig. 7. When two intensities are same.

V. Discussion

The result is shown on the front panel of the Lab view software. In this result three conditions are observed on the front panel. From the Lab view program it is seen that when the West light intensity is greater than East light intensity, the LED which is in the West position will glow and the machine moves in West direction which is indicated by small LED. When the East light intensity is greater than West light intensity, the LED which is in the East position will glow and the machine moves in East direction. If the two light intensities are same all the LEDs connected in the circuit will not glow. It indicates that two intensities of two directions are same so the machine will not move and remain in steady state position.

VI. Conclusion

By using this circuit the solar array can be rotated in required direction following the sun path to get maximum energy from the sun. With the help of this Labview program the efficiency of the solar panel would be increased. Again use of this technique can capture large amount of solar energy. For this reason the use of the non conventional energy will increase which is very fruitful incident of our future power sector. It is the main contribution that once the simplicity of solar energy system design is understood, engineers and manufactures will provide new system designs that will expand the solar market worldwide.

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