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Design Dual-Axis Solar Tracker using Microcontroller

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ABSTRACT

Renewable energy solutions are becoming increasingly popular, solar power is one of the most powerful renewable energy. Maximizing power output from a solar system is desirable to increase efficiency. In order to maximize power output from solar panels, one needs to keep the panels aligned with the sun. In this paper, a prototype for a microcontroller-based dual-axis multi-function solar tracking system is designed, which will keep the solar panels aligned with the sun in order to maximize the power generation. This system is designed using micro-controller, light dependent resistors, and servo motors. This tracking system has multi-functions such as cloudy day assist, auto alignment during night time, it works in automatic mode.

Keywords : Solar Tracker, LDR (Light Dependent Resistors), Dual –Axis Tracking, Servo Motor.

I. INTRODUCTION

THE solar tracker, a device that keeps photovoltaic or photo thermal panels in an optimum position perpendicularly to the solar radiation during daylight hours, can increase the collected energy by up to 50%. Commercially; single-axis and two axis tracking mechanisms are available. Usually, the single axis tracker follows the Sun's East-West movement, while the two-axis tracker follows also the Sun's changing altitude angle. Sun tracking systems have been studied with different applications to improve the efficiency of solar systems by adding the tracking equipment to these systems through various methods [1]–[7]. A tracking system must be able to follow the sun with a certain degree of accuracy, return the collector to its original position at the end of the day and also track during periods of cloud over. The aim of this work is to design a microcontroller operated two-axis Sun tracker which works efficiently in all weather conditions regardless of the presence of clouds for long period and also to investigate the effect of using two-axis sun tracking systems on the electrical generation of a flat photovoltaic system (FPVS), an experimental study is carried out to evaluate its performance under local climate.

Theoretical calculation of the energy surplus in the case of tracking collectors is as follows: Assume, the maximum radiation intensity is $I=1100 \text{ W-m}^{-2}$ falling on the area which is oriented perpendicularly to the direction of radiation. It is assumed, the day lengths $t=12\text{h}=43000\text{s}$ as well as the daylight length and it is compared, the tracking collector which is all the time optimally oriented to the sun with the fixed collector which is oriented perpendicularly to the direction of radiation only at noon. For fixed collector, The projection of the sun beam on the PV Cell, which is oriented perpendicularly to the radiation direction, is equal $S = S_0 \cos\Phi$ and the angle Φ is changing in the interval $[\pi/2, -\pi/2]$ during the day where S_0 is the collector area. The angular velocity of the sun moving cross the sky is equal $\omega = 727 \times 10^{-5} \text{ s}^{-1}$ and the differential of

the falling energy is equal $dW = IS dt$. When it doesn't consider the atmosphere influence and can calculate the energy, which is fallen on the collector area $S_0 = 1\text{m}^2$ during one day.

II. SOLAR CELL DESCRIPTION

The solar cell is composed of the semiconductors of the P-N

junctions [10-11]. It can convert light into electric energy. Therefore we can assume that electricity produced using sunlight shining on the solar cell can be used like common electricity. 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 nonlinear impedance of the P-N junction. D_j is a P-N junction diode, R_{sh} and R_s represents 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_0 represents the external load. I and V represent the output current and the voltage of the solar cell, respectively. From the equivalent circuit, and based on the characteristics of the P-N junction, (1) presents the connection between the output current I and the output voltage V :

$$I = n_p I_{ph} - n_p I_{sat} \left[\exp \left(\frac{qV}{kTA n_s} \right) - 1 \right]$$

Where n_p represents the parallel integer of the solar cell; n_s represents the series connected integer of the solar cell; q represents the contained electricity in an electro ($1.6 \times 10^{-19} \text{ C}$); k is the Boltzmann constant ($1.38 \times 10^{-23} \text{ J / } ^\circ\text{K}$); T is the temperature of the solar cell (absolute temperature $^\circ\text{K}$); and A is the ideal factor of the solar cell ($A = 1 \sim 5$). The current I_{sat} in (1) represents the reversion saturation current of the solar power. Further, I_{sat} can be determined by using the following formula:

$$I_{sat} = I_{rr} \left(\frac{T}{T_r} \right)^3 \exp \left[\frac{qE_{Gap}}{kA} \left(\frac{1}{T_r} - \frac{1}{T} \right) \right] \quad (2)$$

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 is the E_{Gap} energy needed for crossing the energy band gap for the semiconductor materials.

From the study we are able to know that when the temperature is fixed, the stronger the sunlight is, and the higher the open-circuit voltage and short-circuit current are. Here we can see the obvious effects of illumination on the short-circuit current, rather than the open-circuit current.

Therefore the solar cell can provide higher output rate as the sunlight becomes stronger, i.e. solar cell facing the sun.

III. DESIGN OF DUAL-AXIS SOLAR TRACKER MOUNT

The model of dual axis tracking is introduced in order to track the sun both in north-south axis as well as in east-west axis. This is possible by constructing the solar panel mount to rotate over both the axis, in this prototype the mount base is made to rotate in north-south direction and the head of the mount is made to rotate in the east-west direction, the rotation is shown in the fig.1.

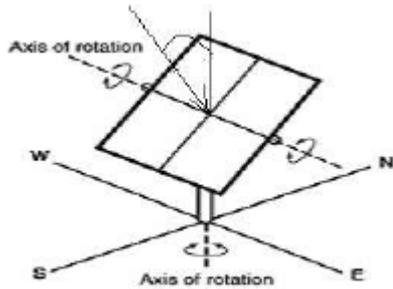
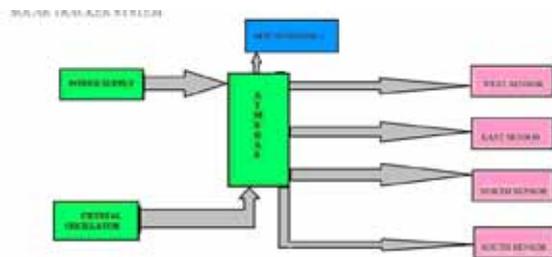


Fig.1. Dual Axis solar tracker

The mount has two stepper motors, one at the base and other at the head. The stepper motor at the base is used to rotate the solar panel over north-south axis and the other stepper motor is used at the head of the mount, which is used to rotate the panel over east-west axis. The mount has gear system at both the stepper motor arrangement to fix it and rotate the panel.

IV. SYSTEM DESCRIPTION

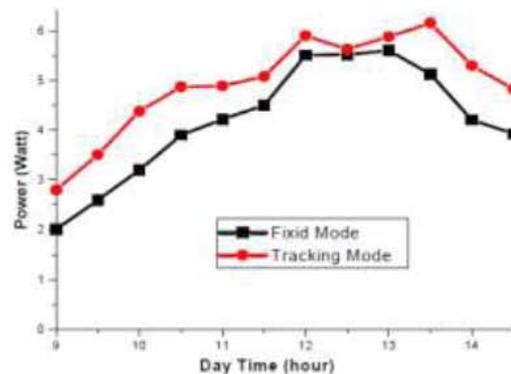
This solar tracking system designed to rotate in dual axis, which will keep the solar panels aligned with the sun in order to maximize the power generation. The tracking model is implemented using single mount flat solar panel, this system consist of a solar panel, solar mount, two servo motors, four LDR (Light Dependent Resistors) and a control unit. The four LDR are attached on four sides of the solar panel, so when the panel is aligned with the sun then all the sensors will get the light, if the sun moves then corresponding LDR can get light so the controller will switch the servo motor accordingly to make the solar panel align with the sun. X-axis (east-west) sensor will give the data for the panel alignment in the east-west direction similarly the Y-axis (south-north) sensor will give the data required to align the panel in south-north direction. in this system all program is made for automatic when light come on LDR its automatic rotate



The micro-controller will read all the four sensor values if all the four sensor value is are equal or higher than the average it will stay in steady mode. The sensor will first read the north and south sensor values and compare it, if the north and south sensor values are equal then no alignment is required else if the south sensor is less than the north the controller should switch the servo motor to rotate in the clockwise direction, else if the south sensor is greater than the north the controller should switch the servo motor to rotate in the anti-clockwise direction. After the north south alignment the micro-controller will read the east and west sensor values, if the east and west sensor values are equal then no alignment is required else if the east sensor is less than the west the controller should switch the servo motor to rotate in the clockwise direction, else if the east sensor is greater than the west the controller should switch the servo motor to rotate in the anti-clockwise direction.

V. EXPERIMENTAL

Measurements on the PV system with and without sun tracking at various local climatic conditions are shown in Figure.



From the experimental results of variation of intensity with day time characteristic it is seen that solar intensity increases with day time up to 13 PM and then decreases but there is some fluctuation of intensity due to flow of some cloudy sky and abnormal atmospheric condition. The experimental measured variables are compared with that at fixed axis. The results (figure 4) indicate that there is an overall increase of output power about 30-45% for the dual axis Sun-tracking system compared to the fixed PV system. The tracking mechanism is capable of tracking the Sun according to the direction of beam propagation of solar radiation and there has a provision in the software for adjustment of the system in case of seasonal variation if necessary. Moreover the motor (operate by only 6V DC) also consumes a small amount of energy because it rotates only for a fraction of a minute at every interval of time. The software control circuit faces the panel always perpendicular to the Sun's incident rays with greater accuracy. The tracker is able to withstand available wind load and temperature and aims at the sun with greater than ±0.1 degree of accuracy. It is possible to face the panel always perpendicular to the Sun's incident rays by the software control circuit. So, it has greater flexibility and accuracy.

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