Multiple Axis Solar Photo Voltaic (SPV) Tracker

Vilas S. Bugade[1], Ganesh H.Patil[2], Ajit Nandawadekar[3]
[1]Associate Professor, [2, 3]Assistant Professor, Department of Electrical Engineering,
Dr. D.Y. Patil Institute of Technology, Pune, Maharashtra, India

***Abstract*–SPV energy is rapidly gaining importance as an energy resource. To make solar energy more viable, efficiency of solar panel systems must be maximized. The position of the sun is not stationary so the angle of incidence also changes with time, thereby performance of the solar panel is not efficient. If the panel is made to align itself perpendicularly to sun rays, maximum efficiency can be achieved. This procedure is called solar tracking. A feasible approach to maximize the efficiency of solar panel systems is sun tracking. A solar panel receives the most sunlight when it is perpendicular to the solar irradiance. This paper presents the design and construction of an inexpensive active dual - axis solar tracking system for tracking the movement of the sun so as to get maximum power from the solar panels as they follow the sun. It uses Light Dependent Resistors to sense the position of the sun which is communicated to an Arduino microcontroller which then commands a set of two servo motors to re-orient the panel in order to stay perpendicular to the sun rays.**

Keywords – **Microcontroller, LDR, Solar PV, Servomotor.**

I. Introduction

SPV energy is the most democratic of renewable energy resources. It is available everywhere on the earth in qualities that vary only modestly. The role of solar energy is indeed going to be predominant. Because solar energy is available free at any place on the earth. Solar energy is renewable and will not deplete within the next several billion years [1].

The demand for electricity is increasing continuously which has the effect of depletion in the fossil fuels reserve. The power produced by the SPV is intermittent in nature as the output depends on the solar irradiance and temperature. The SPV can be used in standalone mode or it can be connected to grid. The controllers should be designed in such a way that it should synchronize with the grid to maintain system stability, and provide proper load management ensuring voltage and frequency at desired values. [2]

The single stage conversion incorporating the voltage and current control techniques and the stability is discussed in [3]. However, the paper doesn't discuss the issue related to reactive power control through the converter. The reactive power control will help in operating the SPV at desired power factor. In [4], a Feed Back Linearization (FBL) based control scheme is used for the PV system. Here, the reactive power control of the SPV is addressed. In [5], the control of real power supplied to the utility grid is achieved by controlling the phase angle difference between the inverter output voltage and the Point of Common Coupling (PCC) voltage. The control obtained the voltage which can produce the maximum power from the SPV for a particular irradiance at a particular temperature. In [6], a control algorithm is developed for the MPPT and the reactive power support to the grid through SPV converter. The comparison of various type of MPPT technique is discussed in [7]. In this paper, perturb and observe (P & O) based MPPT algorithm is used, as it is simple to implement.

Usable electricity from the sun was made possible by the discovery of the photoelectric mechanism and subsequent development of the solar cell - a semi conductive material that converts visible light into a direct current. There are two main ways to make solar cells more efficient, either by improving the actual energy conversion technique, or by installing the solar system on a tracking base that follows the sun, a two axes solar tracker system can increase the energy conversion by 40% by keeping the panels pointing towards the maximum sun radiation during the entire day, being a suitable solution to increase the electrical energy output. The objective of the project was to develop a dual axis tracking system, based on an open loop system where the tracker operates based on mathematical calculation according to the sun's geometry to predict the exact apparent position of the Sun. Solar also become an effective renewable energy source. The output of the solar panels mostly depends on the intensity of sun rays and the angle of incidence. As the sun is always moving the angle of incidence always changes. The output will be maximized whenever sun rays fall perpendicular to the panel [8-9]. In initial days scientist used to arrange the solar panels in stationary position at a particular angle, such that the panel faces the sun most of the time. After the advanced experiments on the sun's path, scientists introduced one manual method, changing the solar panel tilting angle for every 3 months to improve output. Nowadays one best practice has come into the solar world that is solar tracking. A solar tracking is a method of orienting a PV panel toward the sun automatically. Solar tracking decreases the angle of incidence of solarradiations on the panel. This maximizes the output power from a fixed amount of installed power generator. Tracking can be classified into two types: Dual Axis and Single Axis. In Single axis solar tracker, solar panel moves in one direction (using single motor) where as in dual axis solar tracking panel moves in two directions (using two motors) [10]. The single axis tracker isvery useful when the solar path is stationary but as the solar path changes with season.

The Dual axis tracker, which follows the sun aligned to its path, is very efficient. In tracking system, the surface of the module tracks the sun throughout the day. In order to ensure maximum power output from PV cells, the sunlight's angle of incidence needs to be constantly perpendicular to the solar panel. This requires constant tracking of the solar apparent daytime motion, and hence develops an automated sun tracking system which carries the solar panel and positions it in such a way that direct sunlight is always focused on the PV cells. Moving to automatic tracking, this can be around either one or two axes. Single axis tracking is generally adequate for non-concentrating systems and for systems using low to medium concentration. Many systems including large power plants are based on flat plate PV modules and use tracking without any concentration. In this paper a sun taking systems is proposed. The system controls the movement of a solar panel so that it is constantly aligned towards the direction of the sun. The solar tracker designed and constructed in this paper offers a reliable and affordable method of aligning a solar panel with the sun in order to maximize its energy output. The sun tracker system is a hybrid hardware and software prototype designed around Programmable Intelligent Computer (PIC), which automatically provides best alignment of solar panel with the sun.Cadmium Sulfide (CdS) photoresistors are used to sense the light intensity. The CdSphotoresistor is a Light Dependent Resistor (LDR),it is basically a photocell that is sensitive to light. Software will be developed which would allow the microcontroller to detect and obtain its data from the CdS or LDR cells (sensor A and sensor B) and then compare their resistances. The two sensors will be positioned in such a way, so that if one of the two comes under a shadow, the microcontroller will detect the difference in resistance and thus actuate the motor to move the solar panel into a position where the light upon both sensors is equal.

The aim of our project is to design an active, Dual Axis Solar Tracker that will have a minimum allowable error [11].

II. METHODOLOGY

The main component is Arduino Uno 382P; single-board microcontroller. It has an open source physical computing platform and a development environment for writing software for the board and is inexpensive. The other main components are Light Dependent Resistors (LDR's), servo motor and solar panel.

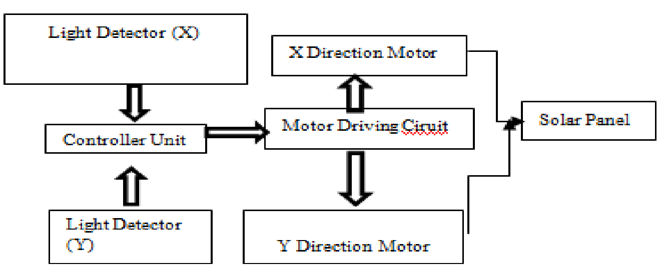


Fig 1: Block Diagram of Hardware Implementation of Dual Axis Solar Tracker

Fig 1 depicts the methodology adopted. The solar tracking system is done by Light Dependent Resistor (LDR). Five LDR are connected to Arduino analog pin A_O to A_4 that acts as the input for the system. The analog value of LDR is converted into digital (Pulse Width Modulation) using the built-in Analog-toDigital Converter. The values of PWM pulse are applied to move the servo-motors. The maximum light intensity captured by the one of the LDR's input will be selected and the servo motor will rotate according toset-up in the programming.

There are three points of motor rotation: 0, 90 and 180 degrees. The positions of LDR are divided into five positions: which are centered, right, left, up and down. The 5 positions allow the highest intensity of sunlight to be can be detected. The microcontroller gets an analog input from the Light Dependent Resistor (LDR) which is then converted into digital signal by Analog-to-Digital converter. The movement of the solar panel is determined by the output given to the servo motor.

A. Hardware Implementation

Fig 2 shows Fritzing diagram, the layout of the hardware components and their interconnections.

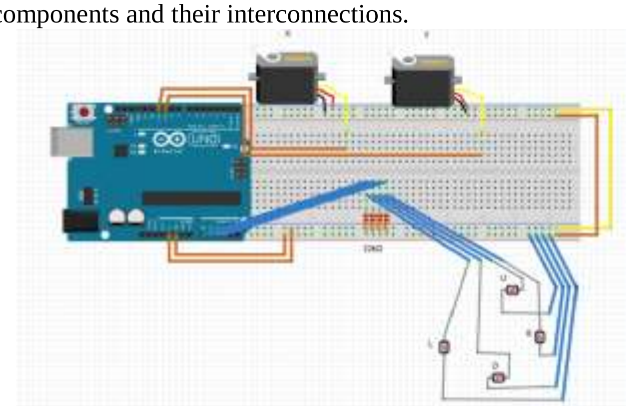
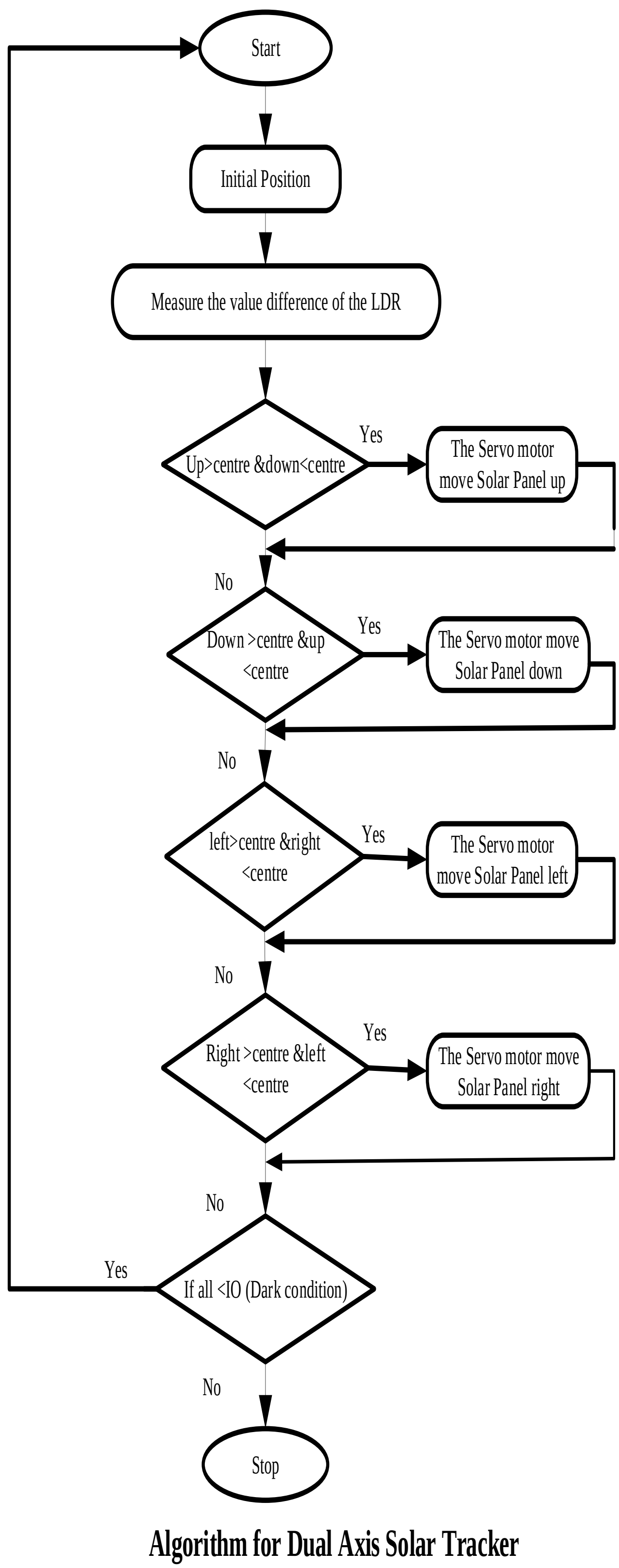


Fig 2: Fritzing Diagram

B. Software Implementation

The software part consists of a programming language that is constructed using C programming. The codes are targeted to Arduino Uno 328P to be compiled and uploaded. Fig. 3 shows the flowchart describing algorithm which is used to develop Arduino code.

Fig 4: Dual Axis Solar Tracker (Module)



.

Fig 3: Algorithm for Dual Axis Solar Tracker

The above hardware and software is implemented and integrated to design and develop the complete system Dual Axis Solar Tracker. Fig 4 shows the developed Dual Axis Solar Tracker.

Sr.No	Component	Specification	Quantity
1	Microcontroller	Arduino Uno 328P	1
2	Solar panel	5V; 200 mW	1
3	Servomotor	MG995 180 degrees	2
4	Light Dependent Resistor	LDR 5 mm	4

Table 1: Main components used for the designing and implementation

III. EXPERIMENTAL CONFIGURATION

The proposed system tracks the sun both azimuth and altitude angles. Two motors were actuated with the help of electromagnetic relays to provide azimuth and elevation angles based on the received sensor data connected to analog pins A1, A2, A3, A4, and A5 of Arduino. The working algorithm for the proposed dual axis tracking systems was as follows:

i. LDR sensors detect the light intensity of the sun. Arduino compares the analog output values of LDR's. When A1 value is greater than A2, digital pin 4 of Arduino becomes HIGH. This actuates relay 1 which in turn energizes motor 1. There by motor 1 rotates the panel in the forward direction by a given angle in azimuth direction.

ii. Whereas, when A2 value is greater than the value of A1, digital pin 5 of Arduino becomes HIGH. This actuates relay 2 which in turn energizes motor 1. There by motor 1 rotates the panel in the reverse direction by angle in azimuth direction.

iii. Arduino compares the analog output values of A3 and A4 from LDRs when A3 value is greater than A4, Digital pin 6 of Arduino becomes HIGH. This actuates relay 3 of relay card. The motor 2 rotates the solar panel in the forward direction by a given angle in altitude direction.

iv. When the value of A4 is greater than the value of A5 digital pin 7 of Arduino becomes HIGH. This will actuates relay 4 of relay card. Motor 2 rotates the solar panel in the reverse direction by a given angle in altitude direction.

v. Whenever LDRs unable to detect the suns position due to cloudy daystimer gets activated automatically& control the tracking as per the time instant.Thus the solar panels are made to align them self perpendicularly to sun rays to maximize the output energy.

A. Importance of timer in tracking

Dual axis tracker output is tracking 36% more than non-tracking solar panel. As LDR cannot detect the solar position on cloudy day, tracking mechanism has to stop. That means, in that period it just works as a non-tracking solar system. So 36% of output will be loosed because of the cloudy atmosphere.

Average rainy days in a year =18

Energy lost because of failure of LDR system per day

= 18 * 36 * non tracking output

= 18 * 36 * 146396

= 94864737kWh

Average power lost per day = 18 * 36 * (non-tracking output/day)

= 18 * 36 * 146396/365

= 259903 kWh

Because of the failure of LDR's tracking mechanism approximately 260000 kWh of energy has been lost.

Main drawback of LDR sensor tracking detect is its inability to solar position on a cloudy day. It has been solved by adding automatically activated timer. This just costs 500 rupees more than conventional dual axis solar tracker. It's reducing cost per kW power and improving the performance of tracking system.

IV. EFFICEIENCY

Dual axis solar tracker improves the panel output by 36% which might not be useful in case of small panels but very useful in large capacity panels.

Table 2: **Energy Generation at 100 kW solar plant**

100 kW Solar Plant	Number of units/year in kWh	Average Number of units/month in kWh
Without tracking	146396	12200
With single axis tracking	184262	15355
With dual axis tracking	199654	16638

Efficiency improvement in single axis tracking

= [(Single axis output-Fixed tilt output)/ (Fixed tilt output)]*100

= [(15355-12200)/12200]*100 =26%

Efficiency improvement in dual axis tracking

= [(Dual axis output-Fixed tilt output)/ (Fixed tilt output)]*100

= [(16638-12200)/12200]*100 =36%

V. CONCLUSION

On one side, we have been seeing the improving in requirement of electrical energy, on the other hand improving pollution. In this situation solar energy is a good choice to produce power. Increasing its efficiency is very essential. In this paper, the efficiency of the system has improved significantly by using dual axis LDR sensor mechanism and Timer. Proposed solar tracking system is economical, efficient, and easy to implement. The running efficiency of the solar PV panel can be further enhanced by developing an automatic dust sensor wiper for maintaining absorption of solar radiations by the solar PV panel.

ACKNOWLEDGEMENT

For this research we received research funding from SavitribaiPhule Pune University, Pune, Maharashtra, India, under proposal no. 15ENG002505 for the years 2016–2018. Also thanks to **Shubham Koshti, Prasad Pawar; and Sandeep Chauhanunder** graduate students from Department of Electrical Engineering at Dr. D. Y. Patil Institute of Technology, Pimpri, Pune, India for their contribution while performing testing of said analysis.

REFERENCES

[1]. Kais I. Abdul-lateef "A LOW COST SINGLE-AXIS SUN TRACKER SYSTEM USING PIC MICROCONTROLLER" University of Technology, Control and systems Eng. dep., Iraq-Baghdad Vol. 05, No. 01, pp.65-78, June 2012.

[2]. Vilas S. Bugade, Dr. Pradeep K. Katti paper on "DESIGN WITH INTEGRATED ACTIVE CONTROL OF GRID CONNECTED THREE PHASE INVERTER FOR MULTIPLE RES USING DSP' in International Journal of Latest Trends in Engineering and Technology, april 2018 Vol.(10)Issue(2), pp.143-149

[3]. Yazdani, A.; Di Fazio, A.R.; Ghoddami, H.; Russo, M.; Kazerani, M.;Jatskevich, J.; Strunz, K.; Leva, S.; Martinez, J.A., "Modeling Guidelines and a Benchmark for Power System Simulation Studies of Three-Phase Single-Stage Photovoltaic Systems," in Power Delivery, IEEE Transactions on , vol.26, no.2, pp.1247-1264, April 2011.

[4]. Huijuan Li; Yan Xu; Adhikari, S.; Rizy, D.T.; Fangxing Li; Irminger, P., "Real and reactive power control of a three-phase single-stage PV system and PV voltage stability," in Power and Energy Society General Meeting, 2012 IEEE , vol., no., pp.1-8, 22-26 July 2012.

[5]. Mastromauro, R.A.; Liserre, M.; Dell'Aquila, A., "Control Issues in Single-Stage Photovoltaic Systems: MPPT, Current and Voltage Control," in Industrial Informatics, IEEE Transactions on , vol.8, no.2,pp.241-254, May 2012.

[6]. Delfino, F.; Denegri, G.B.; Invernizzi, M.; Procopio, R., "A control algorithm for the maximum power point tracking and the reactive power injection from grid-connected PV systems," in Power and EnergySociety General Meeting, 2010 IEEE , vol., no., pp.1-7, 25-29 July 2010.

[7]. Esram, T.; Chapman, P.L., "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," in Energy Conversion, IEEE Transactions on , vol.22, no.2, pp.439-449, June 2007.

[8]. LwinLwinOo Hardware Technology Department Computer University (Lashio) Myanmar, Nang KaythiHlaing Hardware

Technology Department Computer University (Pinlone) Myanmar "Microcontroller-Based Two-Axis Solar Tracking System".

[9]. Tarlochan Kauri, ShraiyaMahajan, ShilpaVerma, Priyanka, and JaimalaGambhir. Electrical Engineering Department, PEC University of Technology, Chandigarh,India; "Arduino based Low Cost Active Dual Axis Solar Tracker" 1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES-2016)

[10]. Dr. Eyad Ibrahim, Dr. wasif al saluos, Faculty of Engineering Technology, Electrical Engineering Department, Zarqa University Supported by Zarqa University "Dual Axis Solar Tracking System Using Pic Microcontroller". IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 11, Issue 3 Ver. III (May. – Jun. 2016), PP 51-56

[11]. S.B.Elagib, N.H.Osman "Design and Implementation of Dual Axis Solar Tracker based on Solar Maps" 2013 IEEE INTERNATIONAL CONFERENCE ON COMPUTING, ELECTRICAL AND ELECTRONIC ENGINEERING (ICCEEE), August 26-28, 2013, PP. 119 – 124.