Designing a Dual Axis Solar Tracker For Optimum Power

First A. AASHIR WALEED **Second B. DR. K M HASSAN**
University of Engineering and Technology, Lahore
G.T. road Lahore, +923338076638, ashir.waleed@gmail.com , kmhasan@uet.edu.pk

Third C. UMAR SIDDIQUE VIRK
University of Engineering and Technology, Lahore
G.T. road Lahore, +923143132032, umarvirk179@gmail.com

***Abstract*— Sustainable energy systems are necessary for the economic growth and a healthy environment. Pakistan is currently suffering from an economic slump and acute fuel shortage. To overcome these issues the use of renewable energy resources needs to be enhanced manifold. The main purpose of this paper is to present a control system which will cause better alignment of Photo voltaic (PV) array with sun light and to harvest solar power. The proposed system changes its direction in two axis to trace the coordinate of sunlight by detecting change in light intensity through light sensors. Hardware testing of the proposed system is done for checking the system ability to track and follow the sunlight in an efficient way. Dual axis solar tracking system superiority over single axis solar tracking and fixed PV system is also presented.**

***Keywords*— solar, tracker, irradiance, dual axis, Light depending resistor (LDR), Stepper motor, single axis**

I. INTRODUCTION

In the last few decades world has seen a boom in renewable energy systems because of depleting resources of fossil fuels. The depleting sources of fossil fuels have caused world to pay attention to renewable energy systems. Global energy demand will almost triple in next three decades. Depleting fossil fuels will be able to provide energy only for next two centuries [1]. Solar energy is one of promising resource for tomorrow's energy. Fortunately, Pakistan lies in such region of world where solar energy is abundant and sun light is present almost thought the year. Yearly sum of global irradiance is shown in Figure 1. It can be seen that in Pakistan yearly sum of global irradiance is quite high i.e., approximately 2000kWh/m2. Most of the cities of Pakistan receive between 2,200 and 2,500 hours of sun [3]. To fulfil the energy needs of a country like Pakistan there is a need to devise efficient solar systems which could capture maximum power.

There are two possible ways to enhance output power from solar energy based systems. One of them is to use different efficient materials in manufacturing Photo voltaic (PV) cells or to use a solar tracker to follow the sun. To use a fixed PV array system is not a suitable method as sun keep on changing its position and trajectory during a day. A Solar tracker is an automated solar panel which actually follows the sun to get maximum power [2].Different solar tracking systems have been designed so far. A low profile single axis tracker is presented in [4]. The tracking system [4] has disadvantage of tracking in one axis only as sun varies its position in sky both with seasons (elevation) and time of the day as sun moves across the sky. Although single axis solar tracker enjoys superiority over fixed PV array for solar energy conversion but it does not perfectly aligns the sun's path in an accurate way. To improve the solar conversion we use dual axis solar tracker. A computer tracking system based on picture processing is designed in [5]. Tracking through picture processing [5] is not so acute method and involves complex calculations and accuracy level is low. In [6] different types of sun-tracking systems are reviewed and their cons and pros are discussed.[6] gives different topologies for active and passive trackers. A robust fuzzy-neural-network (FNN) control system is implemented to control a dual-axis inverted-pendulum mechanism that is driven by permanent magnet (PM) synchronous motors in [7]. However furzy logic based control has disadvantage as fuzzy logic rules are not very direct. Fuzzy logic and neural networks based controls use estimation approaches.

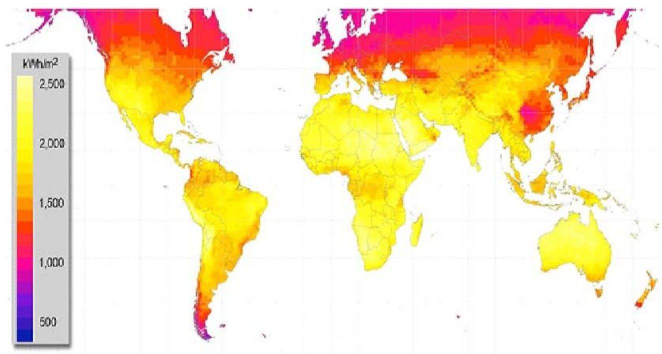

Figure 1: Yearly sum of Global Irradiance

Research work in [8] is doing dual axis using pic microcontroller and DC geared motors. The proposed system in this research incorporates stepper motors which provide more torque at low speeds and provide better control for dual axis tracking purpose. In [9] PIC microcontroller is being used for controlling the PV panel in single axis. Performance analysis of a single axis solar tracker is performed in [10] and work is presenting a control topology for tracker in single axis. M. Serhan [11] proved the dual axis superiority over single axis solar tracked and fixed solar PV arrays.

The main objective for this purposed research model is to design a dual axis solar tracking system with a view to assess the improvement in solar conversion efficiency and to get optimum power. This research work also makes a comparison of this proposed dual axis solar tracker with single axis tracker and fixed PV array.

The proposed system model is explained in experimental setup section. Block diagram and control algorithm for dual axis tracking is elaborated with the help of suitable figures. We have implemented purposed system model on hardware and hardware equipment specifications and hardware designing is explained in hardware implementation section. Hardware testing results of proposed system is described in experimental results section. Conclusions section make a comparison between dual axis and other tracking system and also giving details of efficiency improvement. Future possible work for dual axis solar tracking is also described.

II. Experimental Setup

The proposed tracking system does tracking of sunlight more effectively by providing PV panel rotation in two different axis. In dual-axis tracking system optimum power is achieved by tracking the sun in four directions. In this way we can capture more sun rays. Movement in two axis is explained with the help of figure 2 which is explaining basic idea behind dual axis tracking.

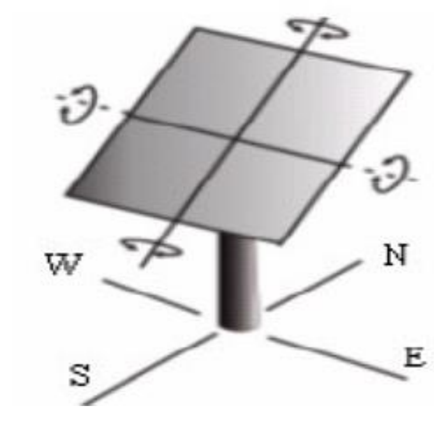

Figure 2: Dual Axis Tracker

The dual-axis solar tracker follows the angular height position of the sun in the sky in addition to following the sun's east-west movement [12]. The dual-axis working is similar to single axis but it captures the solar energy more effectively by rotating in the horizontal as well as the vertical axis. The proposed model for dual axis tracker is shown in figure 3.

The tracker model is composed of four LDR sensors, two stepper motors and PIC microcontroller. One set of sensors and one motor is used to tilt the tracker in sun's east - west direction and the other set of sensors and the other motor which is fixed at the bottom of the tracker is used to tilt the tracker in the sun's north-south direction.

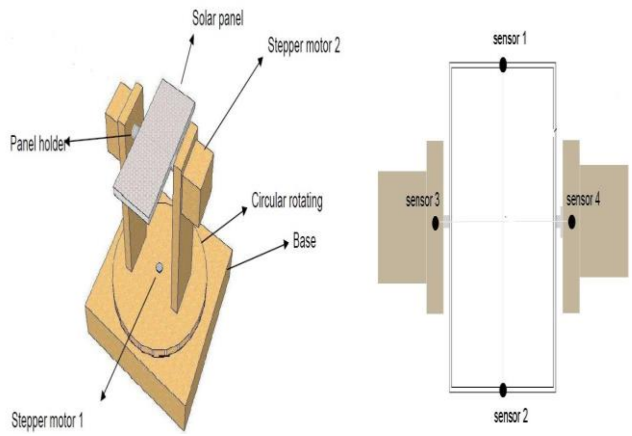

Figure 3: Proposed Model for Dual Axis Tracker

The stepper motors are basically performing function of sun tracking. Upper panel holder stepper motor tracks the sun linearly and base stepper motor tracks the parabolic displacement of sun. These stepper motors and sensors are interfaced with a microcontroller which is controlling stepper motors on the basis of sensor's input. LDR sensors sense the light and sends signal to microcontroller. Microcontroller is doing comparison of signals received from LDR sensors and on the basis of stronger signal it is deciding rotation direction of stepper motors. Dual Axis tracker control is explained with the help of block diagram shown in figure 4. The bock diagram is showing that LDR sensors after sensing the light forward the signal to Microcontroller. Microcontroller is intelligent device which is taking actions on the basis of sensor input and activating the motor driver's circuit accordingly.

Now suppose if sun changes it location and moves from east to west, it will cause light intensity to be different on one sensor as compared to other one. On the basis of light intensity difference on sensors, controller activates driver circuits and moves stepper motors to new positions where light falling on sensor pairs is same. The same process will keep on with change in sun’s location in the sky. As a result this proposed model is able to capture more sun rays and system’s solar energy conversion capability is greatly enhanced.

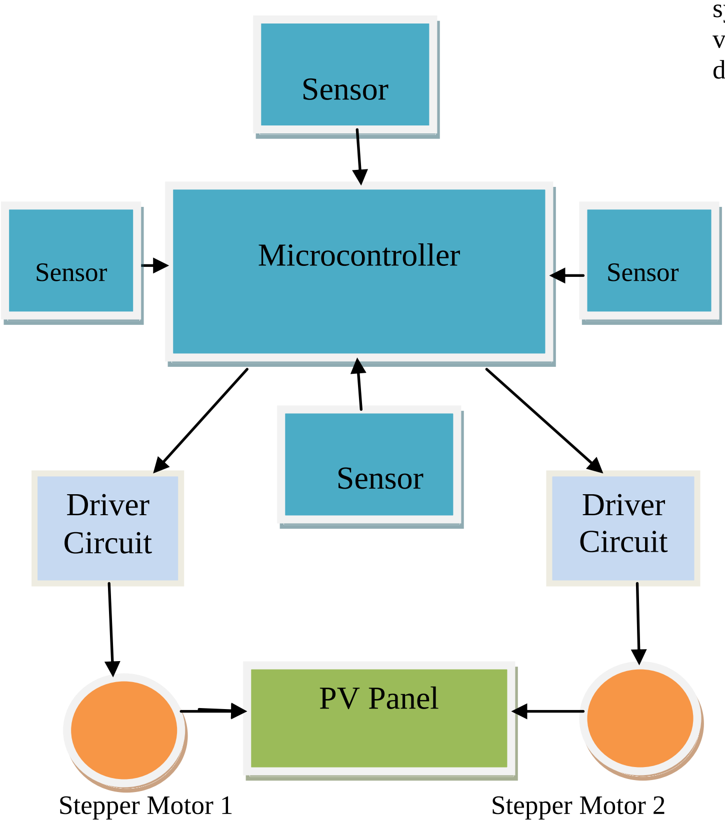

Figure 4: Block Diagram

Controller is performing signal comparison and is the main deciding element. Control algorithm for controller is shown in figure 5.

Algorithm starts with taking data from sensors. Sensors output is analogue which is converted to digital signals. This task is performed using analogue to digital converter (ADC). Digitized signals are forwarded to microcontroller. After collecting digitized signals, it decides about the movement direction and step angle of stepper motors. Controller algorithm is showing that microcontroller drives stepper motors only if sensor light sensing is not equal to each other and if sensor signals are equal. It goes to start of algorithm.This process is repeated until light falling on sensor pairs is equal and PV panel is adjusted in a position for optimum power.

The voltage generated by solar panel is varying and needs to be regulated. A regulator can be used after the solar panel which may regulate the voltage coming from solar panel. Tracker circuitry requires power supply for its working and for this purpose supply is provided by generated solar energy. There is no need to provide external power supply which makes our system economical and cost effective too. The purposed model can also e used as a standalone system by introducing battery storage and proper control of storage system. Battery storage is controlled on the basis of generated voltage. Charging and discharging events for storage are decided on the basis of generated voltage.

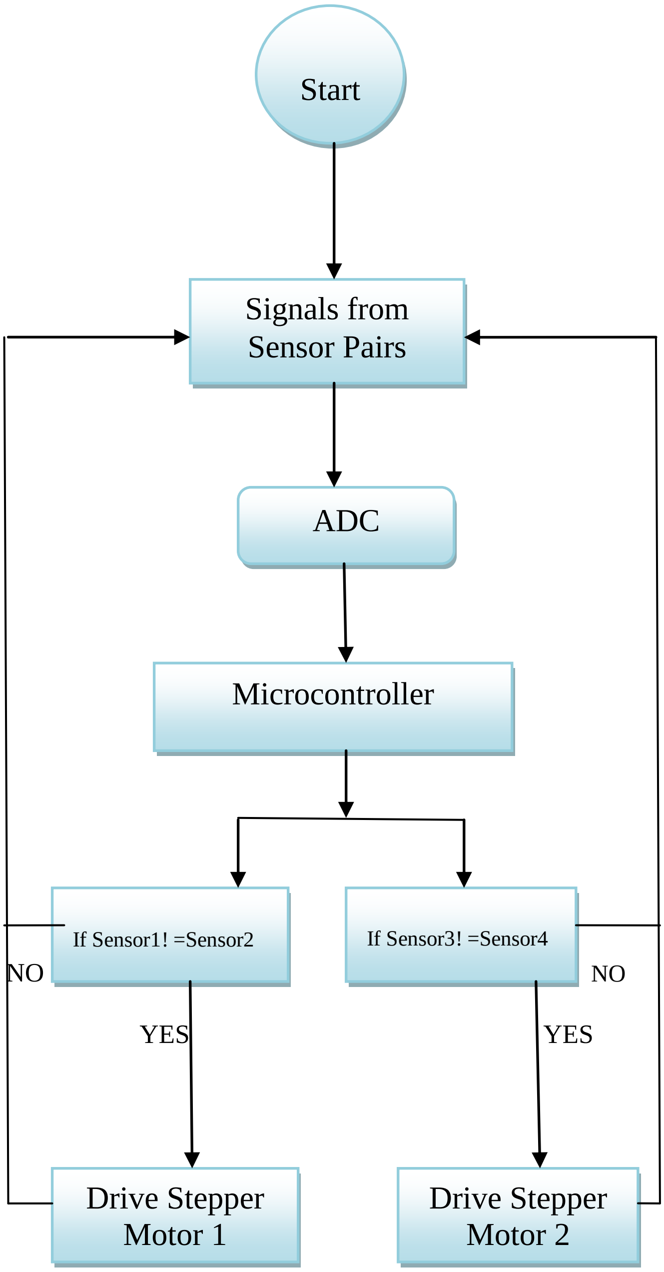

Figure 5: Control Algorithm

III. HARDWARE IMPLEMETATION

In previous section details of control algorithm and block diagram of proposed dual axis were described. Now we come to the hardware implementation of the proposed model.

We have implemented the proposed system practically and final hardware model is shown in Figure 6. Details of PV Panel ratings, LDR sensors and motor ratings for our hardware design are enlisted in Table I.

Figure 6: Final Hardware Design

For supporting of the hardware we devised a support model which is shown in figure. This support model is of 2 feet height. For better control of tracker elevation of panel can be increased and it must be installed in open air environment.

PV panel used for hardware implementation is of 35 watt and it is of mono crystalline type. Two stepper motors of permanent magnet types are used. Stepper motor moves in steps and is best suited for accurate position control. PIC microcontroller is used for controlling purpose which is easier to use as compared to microcontroller ATMEL family.

TABLE I
COMPONENTS RATINGS

Component Name	**Component Ratings**
PV Panel Dimension	16×16 inches square
PV Panel Rating	35 Watts
PV Panel Material	Mono crystalline
Stepper Motor Rating	6v, O.6 A Permanent Magnet stepper motors
Controller	PIC 16877
LDR	GM 9516

IV. EXPERIMENTAL RESULTS

Experiments results were performed by placing the designed system in open air. Table II, III & IV show the output power for PV systems (stationary module, Single axis tracking and dual axis tracking). These observations were performed on 14, 15 and 16 April, 2013 for three cases. The output power data is collected during 8:00 A.M. to 6:00 P.M. In Table V comparison of output power is shown in tabular form for three cases.

TABLE III
STATIONARY MODULE

Time	**Voltage(v)**	**Current(A)**	**Power(watt)**
8:00	7.49	.01	0.074
9:00	8.68	0.09	0.7812
10:00	15.04	1	15.04
11:00	17.04	1.16	19.766
12:00	17.14	1.12	19.196
13:00	17.70	1.14	20.178
14:00	17.68	0.89	15.735
15:00	17.77	0.94	16.7038
16:00	15.02	0.52	7.8104
17:00	6.31	0.12	0.757
18:00	6.3	0.1	0.63

TABLE IIII
SINGLE AXIS TRACKER

Time	**Voltage(v)**	**Current(A)**	**Power(watt)**
8:00	4.57	.001	.0045
9:00	8.97	0.73	0.5481
10:00	14.7	1.32	19.404
11:00	16.45	1.30	21.385
12:00	14.27	1.35	19.262
13:00	16.47	1.62	26.68
14:00	15.15	1.15	17.42
15:00	15.83	1.13	17.88
16:00	15.85	1.18	18.703
17:00	13.47	0.60	8.08
18:00	5.3	0.16	0.848

TABLE IVV
DUAL AXIS TRACKER

Time	Voltage(v)	Current(A)	Power(watt)
8:00	9.16	0.1	0.92
9:00	16.52	1.15	18.99
10:00	21.12	1.44	30.41
11:00	21.78	1.47	32.01
12:00	22.00	1.51	33.22
13:00	22.05	1.64	34.16
14:00	21.39	1.35	28.87
15:00	20.56	1.30	26.72
16:00	20.45	1.26	25.76
17:00	19.52	1.21	23.61
18:00	11.45	0.61	6.98

Table V is making comparison of converted solar energy for all three cases.

TABLE V
GENERATED POWER FOR THREE CASES

Time	Fixed Array	Single Axis	Dual Axis
8:00	0.074	.0045	0.92
9:00	0.78	0.54	18.99
10:00	15.04	19.40	30.41
11:00	19.76	21.38	32.01
12:00	19.19	19.26	33.22
13:00	20.17	26.68	34.16
14:00	15.73	17.42	28.87
15:00	16.70	17.88	26.72
16:00	7.81	18.70	25.76
17:00	0.75	8.08	23.61
18:00	0.63	0.84	6.98

Table V provides a comparison between output powers for three cases. We performed graphical comparison for three cases by plotting three power curves for three cases with the help of data provided in Table V. Collected data was simulated in MATLAB and graphical curves are plotted with the help of MATLAB. Graphical comparison of output power for three cases is shown in Figure 7.

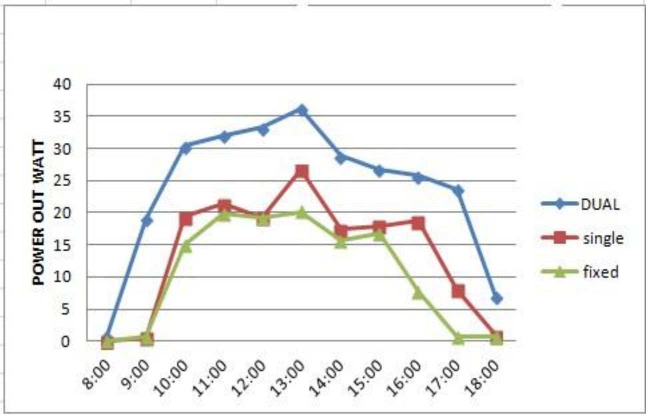

Figure 7: Graphical Comparison

Graphical comparison is clearly showing the improved solar energy conversion for dual axis tracking case. Although single axis solar energy conversion curve is higher above the fixed PV array system but dual axis is showing higher efficiency as compared to single axis. Dual axis system high power capturing property is clear from the graphical comparison.

V. Conclusions

Dual axis tracker perfectly aligns with the sun direction and tracks the sun movement in a more efficient way and has a tremendous performance improvement. The experimental results clearly show that dual axis tracking is superior to single axis tracking and fixed module systems. Power captured by dual axis solar tracker is high during the whole observation time period and it maximizes the conversion of solar irradiance into electrical energy output. The proposed system is cost effective also as a little modification in single axis tracker provided prominent power rise in the system. Through our experiments, we have found that dual axis tracking can increase energy by about 40% of the fixed arrays. With more works and better systems, we believe that this figure can raise more.

VI. Future Work

Commercially, two axis sun tracking is still rare even in countries where a significant part of electricity is being generated by solar energy as they claim that single axis tracking is doing the job. But dual axis tracking can significantly increase the efficiency. For our research work we have implemented this system on a low power PV panel. Cost effectiveness and proposed system efficiency can be observed on commercial level.

We have used mono crystalline PV panel for our research study. However a poly crystalline material based PV panel can also be used for this purposed model and a material based comparison of both systems can be done.

We performed our observations for three days only for spring season. In order to better estimate system's effectiveness observations needs to be taken for long span of time. There is a need also to check system's ability to track in cloudy weather

VII. ACKNOWLEDGEMENTS

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