Development of Dual Axis Solar Tracker System

Vivek Prajapati[1] Prof. Rakesh Patel[2]
[1]M.E. Student [2]Assistant Professor
[1,2]Department of Electrical Engineering
[1,2]GCET, V.V. Nagar, Gujarat, India

Abstract—The energy extracted from solar photovoltaic (PV) or solar thermal depends on solar insolation. For the extraction of maximum energy from the sun, the plane of the solar collector should always be normal to the incident radiation. The diurnal and seasonal movement of the earth affects the radiation intensity received on the solar collector. Sun trackers move the solar collector to follow the sun trajectories and keep the orientation of the solar collector at an optimal tilt angle. Energy efficiency of solar PV or solar thermal can be substantially improved using solar tracking system. In this work divided into two stages, which are software and hardware development. In software development, we have to simulate dual axis solar tracker by using four LDR sensor in hardware development, an automatic solar tracking system has been designed and developed using LDR sensors and DC motors on a mechanical structure with gear arrangement. Two-axis solar tracking (azimuth angle as well as altitude angle) has been implemented through active solar tracker based comparator logic. Performance of the proposed system over the important parameters like solar radiation received on the collector, maximum electrical power per day, efficiency has been evaluated and compared with those for single axis tilt angle solar collector.

Key words: Dual Axis, LDR Sensor, DC Motor, Altitude and Azimuth Angle

I. INTRODUCTION

Solar energy is rapidly advancing as an important means of renewable energy resource in many applications like thermal energy storage systems and electric power generation systems. Such systems use collectors in the form of optical reflectors or photovoltaic (PV) modules to collect the solar energy. The average solar energy intercepted by a fixed collector, during the whole day, is less than maximum attainable. This is due to the static placement of the collector which limits their area of exposure to direct solar radiation. More energy can be extracted in a day, if the solar collector is installed on a tracker, with an actuator that follows the sun like a sunflower.

Usually, the single-axis tracker follows the sun's east-west movement while two-axis tracker also follows the sun's altitude angle. Experimental studies have been performed to investigate the performance of various types of solar tracking system, including both open-loop and closed-loop type of schemes. For the open-loop tracking system, the tracker will perform calculation to identify the sun's position and determine the rotational angles of the two tracking axes using a specific sun-tracking formula in order to drive the solar collector towards the sun [1-3]. However, this automated system will stay operational even if the weather is cloudy and there is no sun visible to track, thus spending stored energy without any gain. The same issue arises when a clock mechanism is used for solar tracking with the help of stored parameters to compute the sun position angles. The angles are transformed to coordinates that drive the tracker [4]. Another alternative is to have a database for the correct angle of incidence for the solar rays at a location stored and this stored data sets the solar collector position round the clock. Usually such systems are expensive and complex based on the requirement for the database storage media and clock accuracy. The open loop type is simpler and cheaper but it could not compensate for disturbances in the system and has low accuracy.

On the other hand for the closed-loop tracking, the sun tracker normally sense the direct solar radiation falling on a photo-sensor as a feedback signal to ensure that the solar collector is tracking the sun all the time and keep the solar collector at a right angle to the sun's rays for getting the maximum solar insolation [5-10]. The closed-loop tracking mechanism has lower tracking error than open-loop tracking mechanism. However, closed-loop tracking mechanism is not reliable under foggy and cloudy weather conditions. Various researchers have proposed the use of numerical optimization schemes for the development of accurate solar tracking systems. Typical examples of such schemes include fuzzy logic algorithms and adaptive neuron-fuzzy control scheme.

The closed loop tracking mechanism and overcome the issues related to (cloudy, rainy) weather conditions using ac antenna motors, and power electronic control circuit to convert DC into AC. However, it causes more losses in the system. In the present work, two axis automatic solar tracking system has been designed and built using three LDRs (Light Dependent Resistors) and two DC motors. A sophisticated closed loop tracking control algorithm has been implemented using PIC16F887 microcontroller on a simple and cheaper mechanical structure. Performance of the proposed two-axis tracking system has been evaluated for important parameters like solar energy received by the collector, maximum output power per day , efficiency gain , short circuit current (Isc), open circuit voltage (Voc) maximum power per day and efficiency have been compared with those for fixed tilt angle solar PV module and improvements have been justified through the experimental result analysis.

II. DESCRIPTION OF AUTOMATIC SOLAR TRACKER SYSTEM

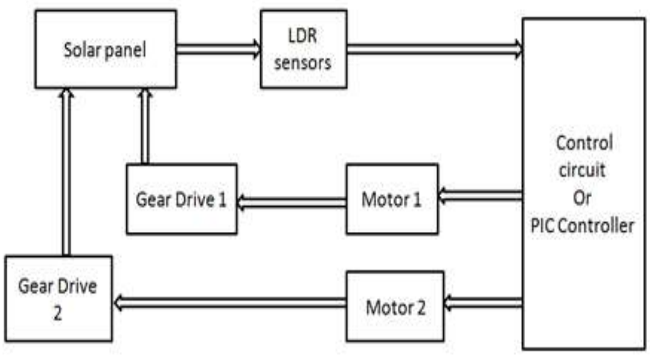

Fig. 1: Block Diagram of Dual axis solar tracker system

A. Schematic Arrangement:

Two-axis tracking system changes both azimuth (horizontal) and altitude (vertical) degrees of solar panel. Schematic block diagram of the proposed solar tracker is shown in Fig. 1. Four LDR sensors are used to feedback from DC motors. LDR1 and LDR2, LDR3 and LDR4 are taken as pairs (please see Fig. 2). Control circuit for tracker is shown in Figure 3.If one of the LDR in a pair gets more light intensity than the other, a difference will occur on node voltages sent to the respective ADC channels of the microcontroller. The microcontroller calculates those node voltage differences and compares them with the respective set values. After that it generates necessary logic signals to actuate the DC motors in such a directions that light intensities on LDR in each pair are equal. LDR is greater or less than a predefined value, microcontroller will send logic signal to drive the DC motors.

B. Simulation of Solar Tracker

Solar tracker simulation is done in proteus software. In simulation, we have to used Four LDR sensor or variable resistor, DC motor and PIC16F887 microcontroller. Sensor 1 and sensor 2 is used for control the altitude angle and sensor2 and sensor4.

Block diagram of solar tracker is shown in figure 2are used for control azimuth angle. (figure4) four channel is taking form sensors. Output of this channel is given to micro controller. Microcontroller is compare channels, if difference between two channels occur at that time micro controller give to signal to drive motors. In microcontroller, input port take as RA and Output port take as RD. channel 1 to 4 is connected to input port RA0,RA1,RA2,RA3 respectively and output port RD0 & RD1 is connected to motor 1 and same way RD2 and RD3 is connected to motor 2. Output waveform for motor 1 and motor 2 is shown in figure5.

Fig. 2: LDR Sensor Pair

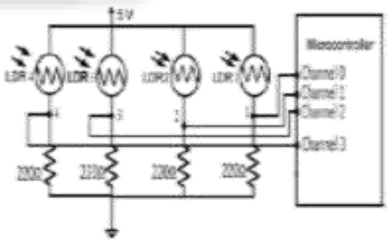

Fig. 3: Sensor Circuit

C. Flow Chart of Controller

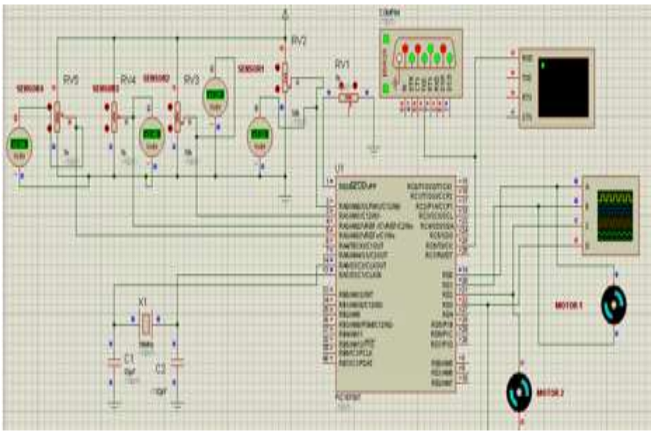

Fig. 4: Solar Tracker Simulation

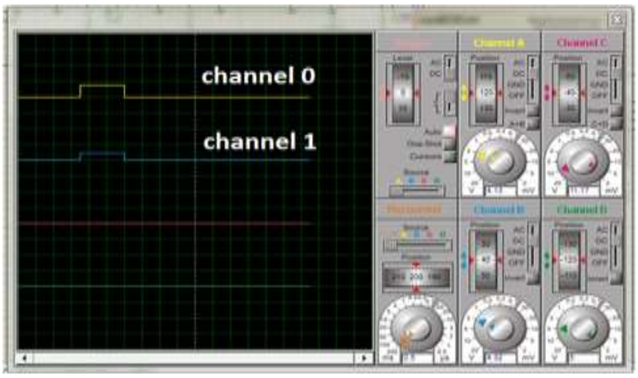

Fig. 5: waveform of channel 0 and 1

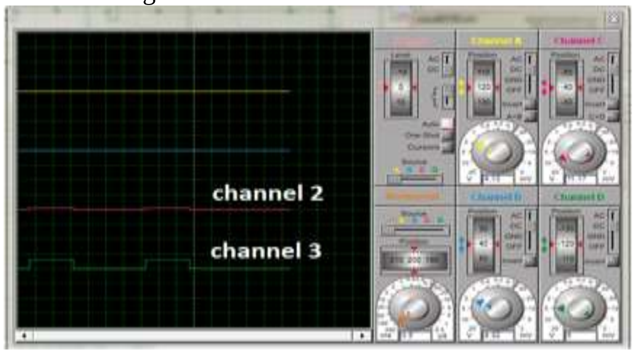

Fig. 5: waveform of channel 2 and 3

D. Flowchart of Control Circuit

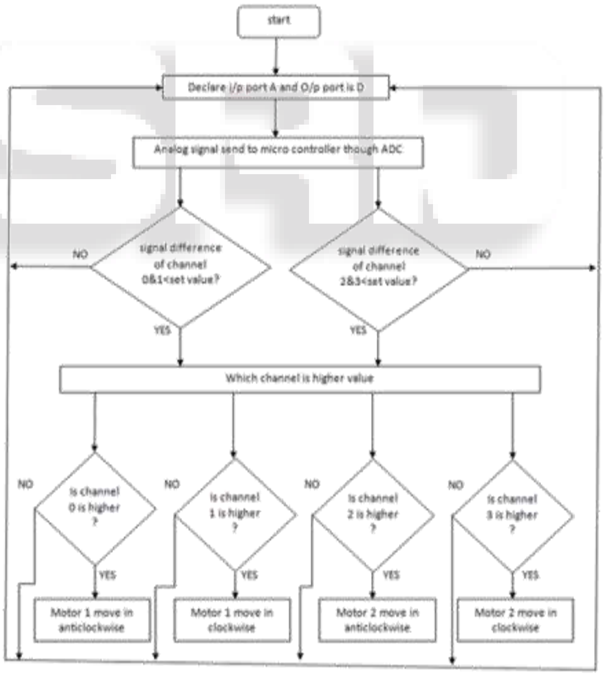

Fig. 5: Flowchart of Control Circuit

III. DEVELOPMENT OF HARDWARE

A. Solar Panel Description

In table 1, 12V,75 W panel description is given . here we have used 14 solar panel connect in series so we have 1000W solar system. solar panel is place onto frame and which is movement by DC motor.

B. LDR Sensor Circuit

Light dependent resistor (LDR) is a resistor whose resistance decreases with the increase of light intensity falling onto it. If light falling on the device is of high frequency, photons absorbed by the semiconductor gives enough energy to bound electrons to jump into the conduction ban d. The resulting free electron conducts electricity, thereby lowering the resistance [14]. To track the sun, an electro-optical sensors are needed. Using Four LDRs and their algorithm for the sun tracking is based on utilization of four LDRs for tracking the azimuth and altitude angle and the other two for sensing the day and night . In our work, only four LDRs have been used. The sensors are used both for tracking on azimuth and altitude angle and sensing the day and night. These sensors are placed on the frame of the PV panel by 90° apart. Each LDR is connected in series with a resistor of 220_ and a Wheatstone bridge circuit is formed using all four LDRs and four resistors. Wheatstone bridge in Fig. 3. A voltage divider circuit is formed at the node 1, 2, 3 and 4 between LDR and a series resistor of 220ohm.

	Type and Model	Description
1	Total module dimension	1207x530x42
2	Total number of cells in the module	36
3	Voc	21
4	Isc	5.3
5	Vmp	17
6	Imp	4.45
7	Pmax (WP)+5%	75
8	Weight (kg)	8
9	Operating module temperature	-48 to 80 C
10	Short circuit current temp. coefficient	0.017%/K
11	Open circuit voltage temp. coefficient	-0.34%/K

Table 1: Type and model

C. *Control Circuit*

In this tracking, we have used two LDR, LM324 (comparator IC), NPN (T1, T3) and PNP (T2, T4) transistor, BLDC motor, four Diode, Resistor (figure 6)

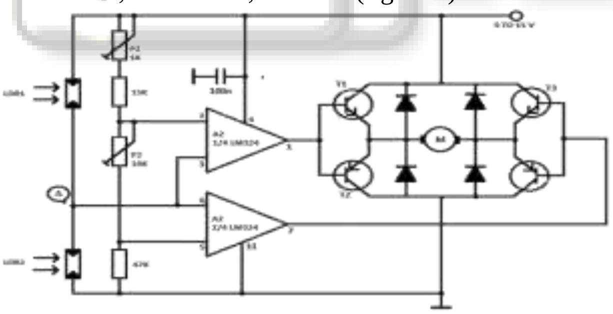

Fig. 6: Control Circuit

The solar tracker circuit uses a window comparator to maintain the motor in a idle state as long as the two LDRs are under the same illumination level. In this case, half the voltage is applied to the non-inverting input of A1 and to the inverting input of A1. When the sun position is changing so does the illumination level on the LDRs and the input voltage for the window comparator is no longer half of the supply voltage thereby the output of the comparator generates information for the motor that rotates the panels for tracking the sun. P1 and P2 are adjusted in such way that the motor stands still when the LDRs get the same amount of solar light. If less light reaches LDR2 than LDR1, the voltage in point A increases to more than half of the power supply voltage. As a result the output of A1 is HIGH and T1 and T4 transistors conduct. In this situation the motor is starting.

If the angle of the solar light is changing again and the voltage in point A decreases at less than power supply voltage, the output of A2 goes HIGH and T3 and T2 transistors conduct. As a result the motor is rotating in opposite direction.

IV. RESULT AND DISCUSSION

We have develop dual axis solar tracker and tested. first at date 5-04-2015, we can taken reading of dual axis solar tracker. second at date 6-04-2015, we can taken reading of single axis tracker in which we can remove sensor 1 and 2 pair and set tile angle 30 degree.

Reading of dual axis solar tracker voltage, current and power result (5-04-2015) shown in table 2

Reading of single axis solar tracker voltage, current and power result (6-04-2015) shown in table 3.

We can take reading for single axis at 7-04-2015 and dual for at 6-04-2015.

Figure is show comparison between single and dual axis solar tracker system.

We can see that from time 7:00A.M to 18:16 dual axis tracker get maximum power compare to single axis solar tracker. Single axis tracker total power per day is 24080W and dual axis tracker total power per day is 31081W. Dual axis tracker has 23 % higher power than single axis.

Sr No.	Time	Solar Amp. ()	MAINS VOL ()	Power (watt)	Sr No.	Time	Solar Amp. ()	MAINS VOL ()	Power (watt)
1	6:19	0	48.25	0	26	13:04	17.61	51.22	901.9842
2	6:35	0	48.56	0	27	13:21	17.67	49.97	882.9699
3	6:51	0.21	48.56	10.1976	28	13:37	17.3	50.83	879.359
4	7:08	0.57	48.33	27.5481	29	13:53	17.04	52.08	887.4432
5	7:24	2.23	49.19	109.6937	30	14:09	17.1	51.53	881.163
6	7:40	7.87	50.67	398.7729	31	14:26	16.79	51.85	870.5615
7	7:56	12.07	51.07	616.4149	32	14:42	16.73	50.52	845.1996
8	8:13	13.83	51.69	714.8727	33	14:58	16.53	50.13	828.6489
9	8:29	15.02	52.24	784.6448	34	15:14	16.32	50.75	828.24
10	8:45	15.7	52.16	818.912	35	15:30	15.85	50.52	800.742
11	9:01	16.32	52.39	855.0048	36	15:47	15.65	47.47	742.9055
12	9:17	16.48	52.24	860.9152	37	16:03	15.28	48.33	738.4824
13	9:34	16.53	52.32	864.8496	38	16:19	14.56	52.32	761.7792
14	9:50	17.15	52.08	893.172	39	16:35	13.99	53.1	742.869
15	10:06	17.3	51.3	887.49	40	16:51	13.37	52.94	707.8078
16	10:22	17.36	50.6	878.416	41	17:08	11.81	52.86	624.2766
17	10:39	17.51	51.69	905.0919	42	17:24	10.05	52.55	528.1275
18	10:55	17.41	51.46	895.9186	43	17:40	8.13	52.24	424.7112
19	11:11	17.56	50.83	892.5748	44	17:56	5.34	51.46	274.7964
20	11:27	17.67	49.35	872.0145	45	18:13	2.02	51.14	103.3028
21	11:43	17.77	50.91	904.6707	46	18:29	0	49.66	0
22	12:00	17.93	51.3	919.809	47	18:45	0	49.5	0
23	12:16	17.82	50.75	904.365	48	19:01	0	49.74	0
24	12:32	17.67	51.38	907.8846	49	19:18	0	49.5	0
25	12:48	17.61	51.3	903.393					**31081.9961**

Table 2: dual axis solar tracker reading

Sr No.	Time	Solar Amp. ()	MAINS VOL ()	Power (watt)	Sr No.	Time	Solar Amp. ()	MAINS VOL ()	Power (watt)
1	6:07	0.05	48.95	2.4475	26	12:52	16.22	57.56	933.6232
2	6:23	0	48.72	0	27	13:08	17.15	50.52	866.418
3	6:39	0.21	48.8	10.248	28	13:24	17.1	50.52	863.892
4	6:55	0.73	49.42	36.0766	29	13:41	15.59	50.44	786.3596
5	7:12	1.45	49.66	72.007	30	13:57	16.06	49.19	789.9914
6	7:28	2.28	50.28	114.6384	31	14:13	15.02	49.89	749.3478
7	7:44	3.57	50.44	180.0708	32	14:29	14.04	48.8	685.152
8	8:00	4.92	51.3	252.396	33	14:46	13.73	49.5	679.635
9	8:16	6.22	51.22	318.5884	34	15:02	12.9	48.09	620.361
11	8:49	8.55	52.47	448.6185	35	15:18	10.93	48.25	527.3725
12	9:05	9.69	52.39	507.6591	36	15:34	10.67	48.48	517.2816
13	9:21	11.19	53.1	594.189	37	15:50	9.69	48.17	466.7673
14	9:37	11.81	53.8	635.378	38	16:07	7.98	48.09	383.7582
15	9:54	13.21	54.98	726.2858	39	16:23	6.84	51.69	353.5596
16	10:10	14.3	55.05	787.215	40	16:39	5.23	51.53	269.5019
17	10:26	14.71	54.9	807.579	41	16:55	4.2	51.61	216.762
18	10:42	15.54	54.74	850.6596	42	17:11	2.43	51.14	124.2702
19	10:59	15.75	55.21	869.5575	43	17:28	0.78	51.3	40.014
20	11:15	16.11	53.72	865.4292	44	17:44	0	50.67	0
21	11:31	17.51	50.91	891.4341	45	18:00	0	50.67	0
22	11:47	17.82	50.52	900.2664	46	18:16	0	50.05	0
23	12:03	16.94	51.22	867.6668	47	18:33	0	50.05	0
24	12:20	17.67	52.32	924.4944	48	18:49	0	49.74	0
25	12:36	16.16	58.57	946.4912	49	19:05	0	49.58	0
					50	19:21	0	49.66	0
									24080.9036

Table 3: single axis solar tracker reading

Graph of table 2 is shown in figure 7(power vs time)

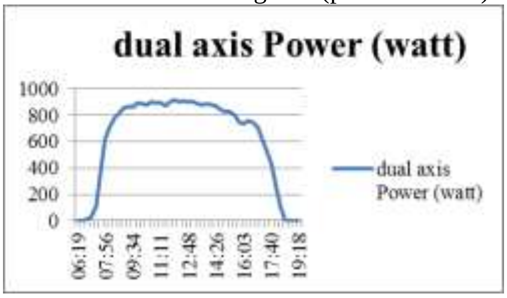

Fig. 7: power vs time (dual axis)

Fig. 8: power vs time (single axis)

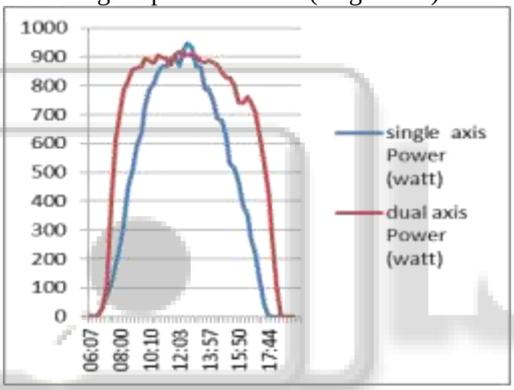

Fig. 9: power vs time (dual axis and single)

V. Conclusion

The performance of a single axis solar module facing south at a tilt angle of 30˚ has been compared with the same solar module on a two-axis automatic tracking system. The automatic solar tracking system has been designed and developed on simple mechanical structure with intelligent control. Performance of the active based tracking system has been analyzed over several parameters like solar radiation received on the collector, maximum electrical power per day. Parameters performance analysis has established the significant improvement in the output of the solar PV collector with the proposed tracking system in comparison to the single PV system. The average gain in the maximum power and efficiency obtained with two-axis PV tracking system is 7001 W per day and 23 % respectively compared to the single axis PV system.

References

[1] J. A. Beltran, J. L. S. Gonzalez Rubio and C. D. Garcia-Beltran, “Design, manufacturing and performance test of a solar tracker made by embedded control electronics,” Conference on robotics and automotive mechanics, pp. 129-134, 2007.

[2] K. K. Chong and C. W. Wong, “General formula for one-axis sun tracking system and its application in improving tracking accuracy of solar collector,” Solar Energy, vol. 83, pp. 298-305, 2009.

[3] A. Marinescu and C. Marinescu, “Control Optimizing Algorithm for Soft Sun- Trackers,” IEEE International conference on Automation, Quality and Testing, Robotics, pp. 54-57, 2006.

[4] A. B. Manish, “Perfomance of a self-aligning solar array tracking controller,” Photovoltaic Specialists Conference, IEEE, vol. 2, pp. 864-869, 1990.

[5] N. Barsoum, “Implementation of a prototype for a traditional solar tracking system,” Third UKSim European Symposium on Computer Modeling and Simulation, pp. 23-30, 2009.

[6] A. Huang, D. Tien and J. Or, “A microcontroller based automatic sun tracker combined with a new solar energy conversion unit,” International Conference on Power Electronics Drives and Energy Systems for Industrial Growth, vol. 1, pp. 488-492, 1998.

[7] M. Rebhi, M. Sellam, A. Belghachi and B. Kadri, “Conception and Realization of Sun Tracking System in the South-West of Algeria, ”Applied Physics Research, vol. 2(1), 2010.

[8] O. Stalter, B. Burger, S. Bacha and D. Roye, “Integrated solar tracker positioning unit in distributed grid-feeding inverters for CPVpower plants,” IEEE International Conference on Industrial Technology, pp. 1-5, 2009.

[9] R. Zogbi and D. Laplaze, “Design and construction of a sun tracker,” Solar Energy magazine, vol. 33(3-4), pp. 369-372, 1984.

[10] M. Hossein, K. Alireza, J. Arzhang, A. Karen and S. Ahmad, “A Review of principle and sun-tracking method for maximizing solar system output,”Renewable and Sustainable

[11] S. R. Bull, “Renewable energy today and tomorrow,” *IEEE Proc.*, vol. 89, no. 8, pp. 1216-1226, 2001

[12] S. Rahman, “Green power: what is it and where can we find it?” IEEE Power and Energy Magazine, vol. 1, no. 1, pp. 30-37, 2003

[13] S. K_vrak, “Passive Trackers”, Renewable Energy Winter School Presentation, Afyon Kocatepe University, 2012.

[14] R. Zogbi and D. Laplaze, “Design and construction of a sun tracker,” Solar Energy magazine, vol. 33(3-4), pp. 369-372, 1984.

