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AUTOMATIC SOLAR TRACKING SYSTEM

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ABSTRACT

The solar energy is a clean, freely and abundantly available alternative energy source in nature. Capturing solar energy from nature is an advantageous task for power generation. Conversion of sun energy into another form is a highly complex phenomenon. For this purpose, Photo-Voltaic (PV) panels are used which convert Sun energy to Direct Current (DC) electrical energy. Conventional fixed type PV panels extract maximum energy only during 12 noon to 2 PM which results in less efficiency. Therefore, building of an automatic solar tracking system is the need of an hour. PV panels have to be perpendicular with the sun for maximum energy extraction which can be fulfilled by automatic tracking. This project includes the design and development of microcontroller based automatic solar tracking system. Light Dependent Resistors (LDRs) are used to sense the intensity of sunlight and hence the sun's position in the sky. Microcontroller AT89S52 is used for controlling the movement of PV panel. The mechanism uses geared DC motors to rotate the PV panel. DC motors are controlled by the microcontroller with respect to signals from LDR. Zigbee transmitter - receiver pair is implemented to receive the data from remote location (plant) i.e. for data acquisition purpose. Liquid Crystal Display (LCD) is used to display the output DC voltage and current on site whereas at the supervising location using Visual Basic (VB) data is acquired, stored and displayed.

INDEX TERMS— LDR, Microcontroller, DC motors, PV panel, LCD Display

INTRODUCTION

Mechatronics system design is an activity in which the designer designs a particular automatic and/or manual system which satisfies the customer's need. For some given requirements, a designer analyses and thinks on various aspects and product design which may be a bit different than the present ones. The design of any electronics/mechanical component needs some parameters such as dimensions, shape, material, load and type of application. The design of a solar tracking system is mainly influenced by factors, such as type of sensors, rotation method, weight upon the motors, type of Photovoltaic panel, type of microcontroller being used, component selection etc. Today every country satisfies its energy needs from a variety of sources that could be categorized as commercial and non-commercial. In the past few years, it is noted that fossil fuel resources are fast depleting and that the fossil fuel era is gradually coming to an end particularly for oil and natural gas. The most serious problem of using conventional energy sources is its harmful effects on the environment. It is also the main contributor to the global warming phenomenon which is now a matter of great concern. According to latest report of the Intergovernmental Panel on Climate Change (IPCC), the global average temperature has increased because of increase in the concentration of methane and nitrous oxide. Therefore, to overcome these challenges the sun energy has to be used more frequently. Solar energy is clean and renewable source of energy which is abundantly available in nature. The sun is a large sphere of very hot gases, the heat being generated by various kinds of fusion reactions. Diameter of the sun is $1.39*10^6$ Km and diameter of the Earth is $1.27*10^4$ Km. The mean distance between them is $1.496*10^8$ Km. Although the sun is large, it subtends an angle of 32 minutes (0.53°) at the earth's surface because of having very large distance. Thus, the beam radiation received from the sun on the earth is almost parallel. The brightness of the sun varies from its center to its edge. The power received by the earth from the sun is approximately $1.8*10^{11}$ MW which is thousands of times larger than the present consumption rate on the earth of all commercial energy sources. So, with the help of solar energy thousands of years could be lived without being dependent upon conventional energy sources such as fossil fuels.[12] India has 3000-4000 sunshine hours per year which can generate an electrical energy which will be hundreds of times greater than the current consumption of energy by the country. For efficient energy extraction/generation from the sun energy the PV panels have to be kept perpendicular to the direction of the sun movement throughout the day. Therefore, the motive behind this project is to design an automatic solar tracking system which could extract maximum amount of sun energy and convert it to electrical energy.[12] The non renewable sources take millions of years to be formed in the crust of the earth by natural processes. Once burned to produce electricity, they are gone forever. Burning fossil fuels create unwanted by-products that pollute our environment which changes the planet's climate and harms ecosystems. On the other hand with 0% polluting agents, solar power is unlimited. Therefore, the problem statement of this dissertation is to control photovoltaic (PV) panel movement in response to the sunlight using Light Dependent Resistors, microcontroller, DC motors to extract maximum amount of sun energy and convert it to electrical energy and acquire each and every data by using ZigBee transmitter and receiver and display and store the same on PCSection 2 of this paper is literature review, which reveals the study of existing work in the solar tracking field and also gives the existing designs of the same. Literature review also reveals different tracking mechanisms which can be used to continuously track the sun. Section 3, highlights the design and development part of the Automatic Solar Tracking System. This chapter also reveals the various types of parts and components used in tracking system. Section 4 discusses about the simulation results obtained in the project. Electronic code development part of the system is elaborated in section 5. In Section 6, the experimental results are stated and Section 7 concludes the project and suggests the future scope of this work.

LITERATURE REVIEW

This literature review reveals the detailed work that has been carried out till date on the topic of Solar Tracking. N. Othman, M. I. A. Manan, Z. Othman, S. A. M. AlJunid have designed a two-axis sun tracking system with the use of five LDRs and an Arduino UNO controller [1]. The objective of this research is to design and construct the automatic dual axis solar tracker for maximum sun energy utilization. The only point of worry is that this system should consume energy as minimum as possible so that the difference between power conversion and power consumption would increase and hence the net profit of the system. Arduino UNO controller has been used and it is programmed in C language. LDRs are used to detect the maximum sunlight position in the sky and the program written performs calculations and drives the servo motors to make PV panels perpendicular to the sun [1]. The sun not only travels from east to west but there is a change of angle in north to south direction also. So the north and south directions should also be taken care of. Dual axis trackers do that. These trackers track the sun on a horizontal as well as vertical axis. Because of this operating ability the dual axis trackers have more output power than the single axis trackers. Light Dependent Resistors are used to find the brightest spot of the sun in the sky. LDRs are connected to Arduino UNO controller which gets to know the position of the sun in the sky and hence rotates the motors towards the sun. Two Servo motors are used for panel rotation which also fulfils the low cost and lightweight criteria [1]. Md. Tanvir Arafat Khan, S.M. Shahrear Tanzil (2010) have designed and constructed a microcontroller based solar tracking system using LDRs to sense the intensity of sunlight and stepper motors to move the Photo-Voltaic (PV) panels in accordance with the sun [2]. Fabian Pineda, and Carlos Andres Arredondo (2011) have designed and implemented a two-axis sun module positioning by sensing the maximum brightness point in the sky. A geodesic dome based sensor has been built for the bright point tracking [3].Authors Salabila Ahmad et al. have designed and constructed an open loop two axes sun tracking system with an angle controller. The hardware is selected such as it will maximize the power collected and minimize the power consumed as the efficiency parameter lies in between these two power parameters [4]. Solar tracking also helps in transmitting sunlight to dark area like basement. Authors Jifeng Song *et al.* have implemented the high precision tracking system based on a hybrid strategy for concentrated sunlight transmission via fibres [5]. Author Cemil Sungur (2008) has presented the multi-axes sun tracking system with PLC control. The azimuth and altitude angles of the sun are calculated for a period of 1 year at 37.6º latitude where Turkey is located. According to these angles, an electromechanical system which tracks the sun according to azimuth and altitude angle is designed and implemented [6]. Authors A.chaib *et al* (2013) have presented the heliostat orientation system based on PLC robot manipulator. It is presented that by mounting certain no. of heliostats and facing them towards central power tower water can be heated and turbines can be driven for energy conversion purpose. By applying MATLAB program for determining the sun's position for heliostat orientation and by using PLC robot manipulator it is presented that maximum amount of energy gets converted from solar to electricity. Concentrated Solar Power (CSP) is used in this experiment [7]. Authors Tao Yu and Guo Wencheng (2010) have introduced automatic sun-tracking control system based on Concentrated Photo Voltaic (CPV) generation. CPV generation works effectively when light panels trace the sun accurately. Stepper tracking control technology is used. This control relies on control circuit with ARM and camera which can provide powerful computational capability [8].

DESIGN OF A TRACKING SYSTEM

In this study, a microcontroller (AT89C52) based Automatic Solar Tracking System is implemented. 4 LDRs are used to sense the intensity of the sunlight. LDR has the property of reducing its resistance as the light falling on it increases. Keeping this principle in mind a microcontroller program is written for tracking purpose. LDRs are connected to Analog to Digital Converter (ADC) because the Microcontroller understands the digital language and the output of LDR is an analog quantity. Three geared DC motors are used to move the solar panels. Out of them two are of 30 Revolutions per Minute (RPM) speed and one is of 10 RPM speed. A temperature sensor LM 35 is also used to keep a track of PV panel output performance with change in temperature. A wireless protocol ZigBee (XBee) is also implemented to transfer the data from the actual place of hardware mounted (plant) to personal computer (PC/ supervising area). Zigbee (XBee) has an advantage of low power consumption and also has range of 10 to 100 meters.

Based on the literature review and current scenario of solar tracking, it was decided to build an Automatic Solar Tracking System as shown in Figure1. In this system, 4 LDRs and one temperature sensor are connected to ADC. Four LDRs are mounted on PV panel. In figure 1, the numbered 1, 2, 3, 4 are the four LDRs. The design and description of the system is such that the PV panel moves towards the direction of LDR which has a lowest resistance compared to the other three. Power supply is given to ADC, Microcontroller and DC motors.

Three DC motors are connected to the microcontroller and then to the PV panel. XBee transmitter receives signals from microcontroller and transmits those signals to the XBee receiver side at the PC end. These signals are each LDR's resistance value, PV panel Output voltage, current and ambient temperature. The transmitted signals by XBee will be received by XBee receiver module and will be displayed on and stored in PC. A single 16*2 Liquid Crystal Display is also used to display the above mentioned parameters.

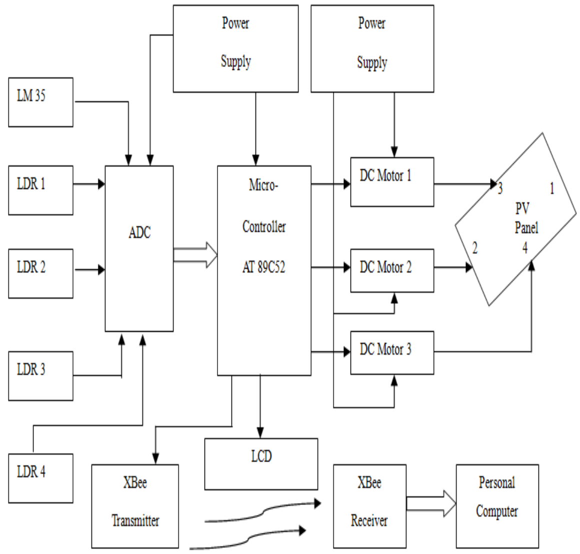

Figure 1: Block diagram of the implemented system

SIMULATION RESULTS

Simulation of the Automatic Solar Tracking System is performed using Proteus software. Simulation process is carried out to judge whether the actual system will perform as per our expectations or not. Simulation process shows the actual connection diagram of each and every circuit diagram. It's an actual circuit diagram implemented in Proteus software.
Figure 3 shows the simulation diagram of the actual system

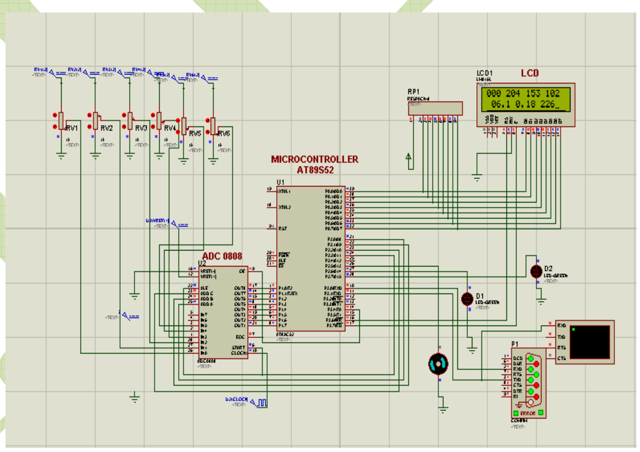

Figure 2: Simulation of Automatic Solar Tracking System.

ELECTRONIC CODE DEVELOPMENT

The software program to control the movement of the PV panel is written using Keil compiler and downloaded in microcontroller using software called Flash magic. The below shown flowchart discusses about the program flow of the actual system. The flowchart is shown in figure3.The program starts with the port initializing part and the serial

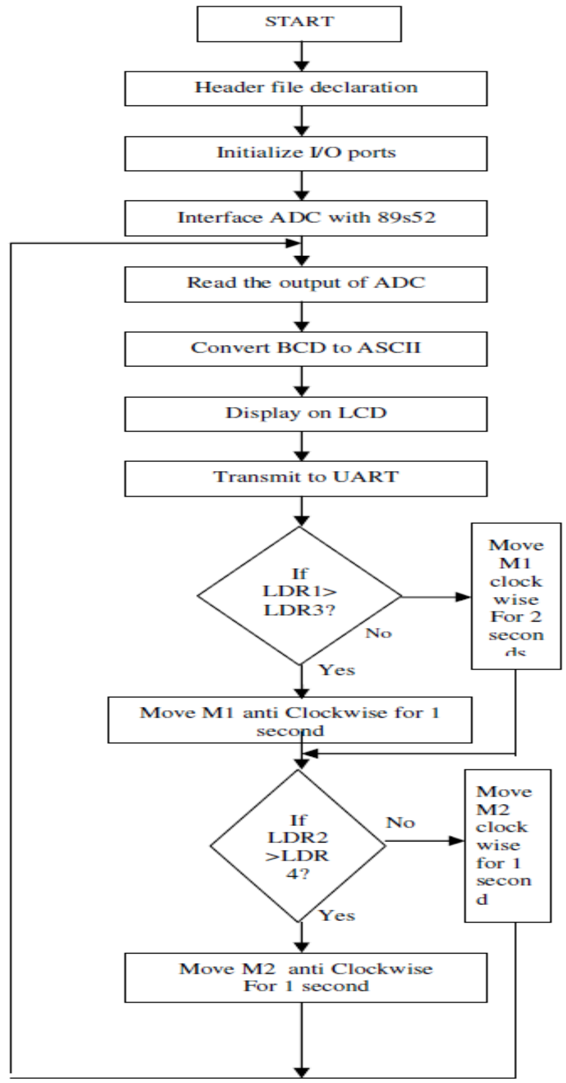

Figure 3: Software flowchart of automatic solar tracking system

Communication initialization. Initialization process is required to carry out because microcontroller has to understand that at which port which component is connected. In this microcontroller, 7 channels are used to detect 4 LDRs, PV panel output voltage, output current and ambient temperature which is sensed using LM 35. The data from channel 0 is read in a variable called S1. Then, this HEX data is converted to Binary Coded Decimal (BCD) to make microcontroller able to calculate and display that data. Further, the data is converted to American Standard Code for Information Interchange (ASCII) code to display it on LCD. The data gets displayed on LCD then. This procedure is repeated for all the 7 channels to sense all the parameters. 1 and 2 are LDRs as shown in figure 1. If LDR 1 detects light intensity more than 2(lower resistance than LDR 2) then the motor M1 will rotate clockwise else anticlockwise. Same is the case for LDRs 3 and 4. If LDR 3 detects light intensity (lower resistance than LDR 4) more than LDR 4 then motor M2 will rotate clockwise else anticlockwise. Hence, as shown in figure 3 the system will continuously be running.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Readings for the automatic solar tracking system are taken on different days in different climatic conditions such as clear and sunny, partly cloudy, cloudy and overcast. The observations and readings taken are as under. The graphs show different readings on different days. With the help of these graphs the project has been concluded.

1. ON A TYPICAL CLEAR AND SUNNY DAY

Table I: Experimental Results Of Automatic Solar Tracking System On A Clear And Sunny Day

Time	LDR1(Ω)	LDR 2(Ω)	LDR 3(Ω)	LDR 4(Ω)	Temperature (°C).	Fixed Panel O/P (W)	Dual Axis O/P (W)
7:00 AM	49	75	159	77	25	2.22	6
8:00 AM	47	77	165	78	26	3.67	7.84
9:00 AM	46	72	171	69	28	6.72	8.34
10:00 AM	47	68	164	68	29	7.35	8.76
11:00 AM	45	55	166	52	29	7.92	8.45
12:00 PM	41	50	42	54	30	8.84	9.58
1:00 PM	48	46	52	48	31	8.87	9.32
2:00 PM	168	161	55	162	32	8.64	9.08
3:00 PM	172	163	57	161	32	8.38	8.86
4:00 PM	170	174	68	176	29	7.33	8.78
5:00 PM	171	168	67	165	28	5.69	8.37
			Average		29	6.875454545	8.489090909

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The experimental results are obtained on various days. The data in the table I shows values of 4 LDRs, ambient temperature and output of fixed PV panel and dual axis panel (automatic solar tracking system). From the data it can be observed that as light intensity increases (sun travels from east to west) each LDR represents different value from each other. This means, falling light intensity upon each LDR is different. From table I, it is observed that LDR 1 offers low resistance from 7:00 AM to 1:00 PM whereas LDR 3 offers moderate resistance from 7:00 AM to 11:00 AM. LDR 2 and LDR 4 offer quite similar resistance from 7:00 AM to 1:00 PM. Fixed panel has maximum output only during 11:00 AM to 3:00 PM. Automatic tracking system panel is 60% efficient at 7:00 AM, 95% efficient at 12 noon, and 83.7% efficient at 5:00 PM. During the clear and sunny day noted average temperature reading was 29ºC.

2. ON A PARTLY CLOUDY DAY.

The readings were obtained after 10 hours of tracking during partly cloudy day. It was observed that the power output almost remains constant throughout the day. Due to partly presence and absence of the sun it was bit of a task for PV panels to convert photon energy to electrical energy. These readings and the average power was less than those readings obtained during the clear and sunny day. From the readings it can also be concluded that the ambient air temperature and the power output of the PV panels have almost the linear relationship. Table II shows the experimental results on a partly cloudy day i.e. 05-jun-2015.

Table II: Experimental Results Of Automatic Solar Tracking System On A Partly Cloudy Day

Time	LDR1(Ω)	LDR2(Ω)	LDR 3(Ω)	LDR 4(Ω)	Temperature (°C).	Fixed Panel power o/p(W)	Dual axis Power o/p (W)
9:00 AM	55	75	182	77	27	1.57	6.6
10:00 AM	53	77	181	78	27	2.59	6.6
11:00 AM	48	72	179	69	28	5.62	6.7
12:00 PM	48	68	179	68	30	6.24	6.8
1:00 PM	47	55	179	52	32	6.27	6.8
2:00 PM	165	50	57	54	32	6.18	6.9
3:00 PM	168	46	57	48	32	5.92	6.4
4:00 PM	171	161	56	162	28	5.21	6
5:00 PM	175	163	55	161	28	4.04	6
6:00 PM	183	174	56	176	27	3.81	5.7
				Average	29.1	4.745	6.45

From table II it is observed that LDR 1 offers low resistance from 9:00 AM to 1:00 PM whereas LDR 3 offers moderate resistance from 9:00 AM to 1:00 PM. LDR 2 and LDR 4 offer quite similar resistance throughout the day. Fixed panel has maximum output only during 11:00 AM to 2:00 PM. Maximum power output of the fixed panel is only 62.7% of the rated power output. Dual axis panel is 66% efficient at 9:00 AM, 68% efficient at 12 noon, and 60% efficient at 5:00 PM. During the partly cloudy day the noted average temperature reading was 29.1ºC.

3. ON A CLOUDY AND OVERCAST DAY

A set of readings are also taken on a typical cloudy and overcast day. The table 6.4 shows the overall the values of fixed panel output, dual axis panel output with respect to temperature and time. During the day, sunlight presence was very low and that is why output of PV panel reduced drastically. Table III shows the experimental results obtained on a cloudy and overcast day.

From table III certain things can be easily concluded such as LDR 1 offers high resistance at 7:00 AM,

Table III: Experimental Results of Automatic Solar Tracking System on A Cloudy And Overcast Day

Time	LDR1 (Ω)	LDR2(Ω)	LDR3(Ω)	LDR 4 (Ω)	Temp(°C)	Fixed Panel o/p (W)	Dual Axis o/p (W)
7:00 AM	210	218	214	221	21	0.726	2.215
8:00 AM	203	198	199	197	22	1.197	2.898
9:00 AM	48	72	179	69	21	2.193	3.073
10:00 AM	48	68	179	85	21	2.397	3.2
11:00 AM	47	78	179	89	23	2.598	3.087
12:00Noon	182	133	112	132	23	2.883	3.47
1:00 PM	187	67	147	115	22	2.898	3.38
2:00 PM	171	161	56	162	24	2.8206	3.297
3:00 PM	175	163	55	161	23	2.733	3.22
4:00 PM	183	174	56	176	23	2.4087	3.199
5:00 PM	237	241	238	227	21	1.848	3.052
6:00 PM	242	239	224	235	21	1.386	3.072
			Average		22.08	2.17403	3.09692

8:00 AM, low resistance for the next three hours and then moderate resistance for the rest of the day. LDR 3 offers high and moderate resistance from 7:00 AM to 1:00 PM. From 2:00 PM to 4:00 PM its resistance reduces drastically. Again at 5:00 and at 6:00 PM the resistance increases. LDR 2 and LDR 4 offer quite similar resistance throughout the day. All LDRs resist in mixed behaviour due to uneven light intensity on this particular day. Fixed panel has maximum output only during 12:00 noon to 2:00 PM. Maximum power output of the fixed panel is only 28.98% of the rated power output. Dual axis panel (Automatic solar tracking system) is 30% efficient at 9:00 AM, 34.7% efficient at 12 noon, and 30.52% efficient at 5:00 PM. During the cloudy and overcast day the noted average temperature reading was 22.08ºC.The conclusion can be made as; during the cloudy and overcast day both the panels i.e. fixed and automatic tracking have less power output than the other days where sunlight or solar irradiation is more.

CONCLUSION

A 89S52 microcontroller based Automatic Solar Tracking System has been implemented using geared DC motors and LCD. From Experimental results it can be concluded that the solar tracking system is more helpful in all senses than the fixed panel system. Different set of readings on different environmental conditions have been taken for experimentation. From the readings the dissertation is analyzed and hence concluded.

- On a typical clear and sunny day, fixed panel has maximum output only during 11:00 AM to 3:00 PM. Automatic tracking system panel is 60% efficient at 7:00 AM, 95% efficient at 12 noon, and 83.7% efficient at 5:00 PM.
- The average power of the automatic solar tracking system leads ahead by 17.45% to that of fixed panel on a typical clear and sunny day.
- On a partly cloudy day, fixed panel has maximum output only during 11:00 AM to 2:00 PM. Maximum power output of the fixed panel is only 62.7% of the rated power output. Dual axis panel is 66% efficient at 9:00 AM, 68% efficient at 12 noon, and 60% efficient at 5:00 PM.
- On a cloudy and overcast day, All LDRs resist in mixed behavior due to uneven light intensity on this particular day. The average power produced by the fixed panel is 2.170 W whereas automatic solar tracking system produces 3.096 W. Fixed and automatic tracking have less power output than the other days.
- From the above conclusions a final conclusion could be made that in any environmental condition the automatic solar tracking system is a way much better implementation than the fixed panel.

FUTURE SCOPE

Automatic solar tracking system offers a prototype for implementing a large array type solar tracker. This will be an expansion of mechanical as well as electronic system
Following additions can be made to the prototype to maximize the power conversion:

- By connecting the solar panels in an array more energy can be extracted.
- Using aluminum type of material for the assembly set up the weight upon the motors can be reduced which will automatically reduce the power consumption of the system.
- With the monocrystalline PV panel in use the efficiency of the project can be increased. Monocrystalline PV panels have also more lifetime than polycrystalline panels.
- In Zigbee transmitter- receiver pair by interfacing range extension modules signal range can be extended up to 10 miles.

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