Design and Analysis of Dual (Twin) Axis Solar Tracker System with the Improvement of Photovoltaic Efficiency

Venkatesh KumarS[1], Dr. Kathirvel C[2], Dr. Sebastian Vindro JudeP[3]& Mohan Kumar R[4]

[1,2,3,4]Sri Ramakrishna Engineering College, Coimbatore, Tamilnadu, India

[1]venkateshkumar.s@srec.ac.in, [2]kathirveleee@srec.ac.in, [3]jude.panimayam@srec.ac.in, [4]mohankumar.r@srec.ac.in

Abstract

Now-a-days, there is a significant demand in power generation therefore the usage of both renewable and non-renewable resources has increased rapidly. In general, the solar panel power system is immobile this means; the solar panel will not always be facing towards the orientation of the sun, due to which the intensity of sunlight absorbed by the panel is not maximum thus reducing the efficiency of the solar photovoltaic system. In order to overcome this imperfection "Dual Axis Solar Tracking Systems" are proposed. The annual energy efficacy of dual (twin) axis solar tracking system is of about 36.504% which is high when compared with single axis solar tracking system. The proposed model comprises Arduino UNO to control the entire system, Light Dependent Resistors (LDR) to detect the intensity of light and transmit the data to the Arduino UNO and DC motors to mobilize the solar panel. The solar tracker continuously monitors the suns orientation and modify the position in line with suns position to increase the output power.The surface of the solar photovoltaic panel should be cleaned periodically to prevent the system from getting damaged and also to improve its efficiency. This can be done by using wiper control mechanism. The proposed cleaning system operates by spraying an amount of water on the surface of the photovoltaic panel and then actuating the wiper using a DC motor. This design is highly effective in improving the efficiency ofthe photovoltaic system.

Keywords: Dual Axis Solar Tracking System,Solar Panel, DC Drives

1. INTRODUCTION

These days, there is a significant demand in power generation therefore the usage of both renewable and non-renewableresourceshasincreasedrapidly.Theexhaustionof thefossilfuelsandconcernovertheenvironmentalproblems has brought the generation of electric power using solar photovoltaicsystemsintolimelight.Currently,thereisahigh requirementofthesolarphotovoltaicsystemsassolarenergy is a renewable resource. UV region of suns radiation fall on the surface of solar panel. The radiation from the sun will be absorbed with the help of using solar panels which is used to transform solar radiation into electric power. Solar photovoltaic panels are fixed to towards the sun to get more absorption. For feasible solar energy generation, it is mandatory to increase the conversion efficiency which results in emerging of various solar tracking methods which helps to improve the way of tracking of suns direction.There are two major radiations in sunlight. They are the direct beam (beam radiation) and diffuse beam (diffused radiation). Direct beam radiation is the suns radiation which will not be scattered. This radiation carries almost 90% of the solar energy to the earth. The remaining 10% energy is carried to the earth surface by the diffuse sunlight. [1][2].Theaddition of beam radiation, diffused radiation and reflected radiation aremeasured as global radiation in the earth surface. In order to get maximum energy form the solar panel, it is mandatory to track the direct beam radiation continuously.

Due to the development in the technology, the efficiency of the solar cell has been increased and automatic solar tracking system was evolved which overcomes the traditional fixed solar PV system. In the conventional solar PV system, the solar panels are fixed to a constant position towards the north-south direction. In solar PV tracking system, based on the azimuthal angle and the geometrical capacity, the position of the solar panels are continuously changed with help of electro-mechanical system in order to get maximum exposure to the sun light [3]. In this research in order to increase the efficacy of solar photovoltaic panel, the system is designed to follow the sun's movement. In general, the sun's rays are upright to the solar PV panel. Here the stationary photo module was fixed at an angle of 23.5º to the optimal connection of the land and photovoltaic module with a tracking system[4].In the year 1962, C. Finster invented the first solar tracking system based on the mechanical arrangements. Initially, this results in less improvement of energy gains. But over a period of time, modern technology leads different way for the improvement of solar tracking system with high efficiency [5]. For a developing country like India, there is vast need of electrical energy. So the renewable resources are used for energy generation. This will leads to the implementation of solar powered electricity generation for the public sector and commercial buildings. With the use of dual axis tracker, these solar panels are tracked regularly to increase the efficiency.

2. PROPOSED SYSTEM

Asolartrackerhashugeapplicationsinpowergeneration but, the solar photovoltaic systems have few drawbacks. The first one is that the energy conversion rate of solar PV system is about 12% to 42%. The second drawback is the solar power produced by the solar cell is based on non-linear conditions like solar irradiation, partial shading conditions, change in temperature level, and charging infrastructures. In this regard, the solar power generated from photovoltaic cells depends on various non-linear parameters, so this made it mandatory to track the solar power incident on the panel to get the maximum efficiency. The aim of this proposed work is to make sure that the radiations from the sun is to fall perpendicularly on the solar PV panel. This arrangement makes the system to absorb more solar energy and convert into electric energy with maximum efficiency. In order to increase the energy conversion efficacy, it is proposed to track the relative motion of the sun by dual axis system to maximize the output power[6]. Dual axis solar tracker circuit diagram as shown in below figure.1.

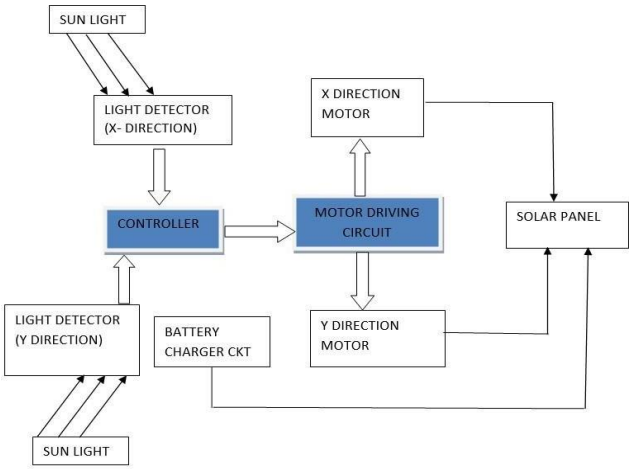

Figure 1:Dual Axis Solar Tracking System Block Diagram

The tracking operation of suns radiation is performed by using DC motors. DC motors and stepper motors are used in this operation. The suns linearity is tracked by using DC motor in the upper PV panel holder. The parabolic displacement of the sun is tracked by using stepper motor at the base of the PV panel. These DC motors are along with the sensors are interconnected to the controller. The controller gives the tracking signal to the DC motors based on the inputs from the sensors[7]. The light energy from the sun is sensed by using LDR and it send signal to the controller. The Arduino gets the signals from LDR and based on that the turning of the DC motor is decided. From the block diagram, it is clear that LDR forwards the signal to controller after sensing the light energy. Suppose the sun changes its location from eastern to western direction, itwill made the light-intensity to be dissimilar in first sensor when likened with the additional sensor. Depending on the change in light intensities of the sensors, the controller gives the control signal to the driver circuits of DC motor[8]. As the outcome, the proposed method will be able to absorb high amount of suns radiation which in turn improves the solar energy conversionefficiency of the system[9].

3. LIST OF COMPONENTS AND SPECIFICATIONS

The proposed prototype consists of photovoltaic panels, microcontroller, comparator, motor driver, gear motor and other components. The components and their description are as follows;

3.1 PhotovoltiacPanels

Thephotovoltaicpanelsaremadeupofphotovoltaiccells that are connected together. The solar panel absorbs the sun's radiation and to convert it into electrical energy. The electric power generated from the solar PV panels is most widely used for domestic and commercial equipment's.

3.2 Arduino Uno

The Arduino UNO is one of the type of microcontroller circuit. It contains digital and analog input and output pins which canbeinterfacedto externalcircuits.Itcomprisesof14 digital I/O pins and six analog I/O pins. The Arduino IDEsoftware is used to programme the Arduino UNO.

3.3 MotorDriver

The DC motors requires high current signal to operate tracking system. This high current signal is obtained from the motor driver circuit which amplifies the small current signal from the controller board. In this system, L293N is used to drive the DC motors which can be able to drive two DC motors in parallel.

3.4 GearMotor

The speed of the motor is adjusted by the principle of the gear motor which leads the motor to operate at a certain speed. As the gear head functions as a torque multiplier and allows small motors to generate higher speeds, the gear motor has the ability to deliver high torque at low speeds.

3.5 Light DependentResistor

A Light Dependent Resistor (LDR) will becalled as photo-resistor or a cadmium Sulfide (CdS) cell or a photo conductor. LDR is known as photocell which is based on the working principle of photo-conductivity. The value of resistance of the Light Dependent Resistors decreases when the intensity of light decreases.

Table 1: List of Components and Specifications with Estimated Cost

S. No	Name of the Component	Specifications	Quantity	Cost (Rs)
1	Photovoltaic panel	20W	1	300
2	Arduino	UNO	1	300
3	Motor Driver	IC L293N	2	40
5	Gear Motor	60RPM,12 V DC,6MM	2	400
6	Light Dependent Resistors	-	4	10
7	Resistors	10k ohms	4	20
8	Resistors	1k ohms	4	8
9	Power Supply	12 V	1	250
10	Jumper wires	M-M	20	20

4.PROTOTYPE MODEL

The dual axis solar tracker consists of two parts, one is the sensing part and the other one is the comparing part. In the proposed system, the prototype model consists of four LDRs, two stepper motors, solar panel, motor driver and Arduino[10]. The intensity of the light absorbed is sensed by the LDR and the signal is given to the Arduino as shown in Figure 2. The LDR output signal is observed when the sun light is perpendicular to any LDR. The LDR output signal compares with the reference voltage and output is given to the IC L293N motor driver[11].

The gear motor is connected with the controller asshown inFig2.Inthis,theL293Nisusedasthe motordriver,based on the signals received by the LDR; the comparator selects the rotational direction of the gear motors. In order to rotate the stepper motors; C language program is implemented and executed using Arduino IDE Software. The controller sends the control signal to the driver circuit of DC motor which enables the gear motor to move in respective track[12] [13].

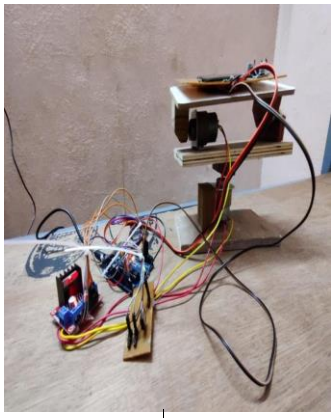

Figure 2.

The light intensity depends on incident angle of the sun to the surface of solar PV panel. During morning and evening sessions the angle of incidence is nearly 0°. In this angle, the light absorption ability of the solar panel will essentially be zero resulting in no output[14]. At noon, the angle of incidence approaches to 90 degree which results in steady increase until maximum power is achieved. In order to receive maximum output from the panel the angle of incidence should be maintained to be nearly 90 degree. This can be achieved by tilting the solar panel to continuously face the sun[15].

4.1 Flowchart

The program flow chart is shown below;

- ✓ The intensity of the light is first sensed by the LDR.
- ✓ The signal is converted from analog to digital.
- ✓ The signal is then sent to the comparator and then it compares it with the reference voltage.
- ✓ The resistance of LDR1 is higher than that of LDR2, if LDR2 has more light intensity than LDR1. This makes the voltage at CH-1 is lower than that of CH-2 which results to rotate the gear motor of solar PV panel in the forwarddirection[12].
- ✓ If light intensity of LDR1 and LDR2 are equal then a stable position is obtained.

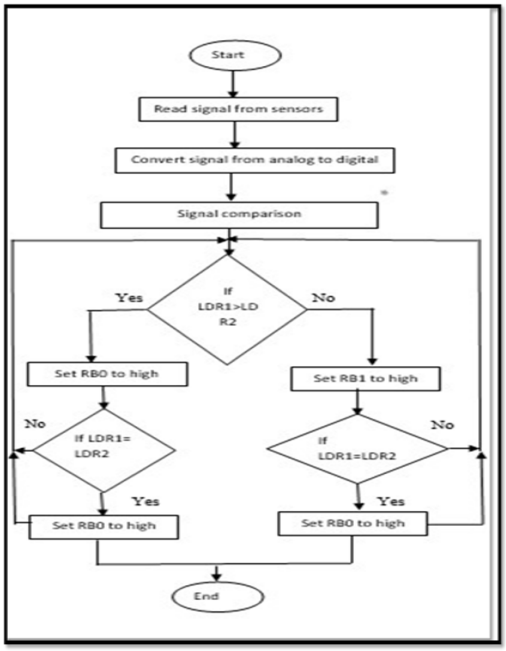

Figure 3. Program Flow Chart

5 RESULTS AND DISCUSSIONS

The solar power absorbed by the twin (dual) axis solar tracking system is maximum when the entire trackingperiod of timeand it alsoimproves the solar energy transformationinto electric power output. The output voltage is 1.8 to 2V has been generated by the proposed prototype model. The proposed system is cost effective. This prototype model will increase the energy by about 40%.

The twin (dual) axis solar tracking system perfectly tracking the direction of the light energy from the sunwith high competent way and gives the maximum output power. It improves 40% of additional power from each solar PV panel. While to achieve the same output power by using single axis solar panel tracking requires more number of panels and frames. On the other side, we may use the same number of panels and generate 40% more electricity and revenue with the same number of panels. The use of gears rather than linear actuators improves the overall tracker's efficiency.

6 CONCLUSION AND FUTURE SCOPE

The direction of the sun has been traced by the proposed prototype due to which the intensity of the sunlight absorbed by the panel is maximum. Therefore, this implemented design has confirmed to be highly effective in increasing the conversion efficiency of the photovoltaic systems. At present this type of energy generation is being used as secondary source, but in the foreseeable future solar tracking systems might become

the main source for energy generation. In future, using high powerful motors to tracking the solar radiation with maximum capability and also lifespan shall be improved, but comparatively at higher cost. Dual-axis solar trackers will helpful to accomplish the optimum solar energy level for implementing this technique. In forthcoming this twin axissolar collector tilting techniques can also be implemented in the huge solar plants and it can be functioned spontaneously.

7 REFERENCES

[1] Alexandru, C., and C. Pozna. "Simulation of a Dual-Axis Solar Tracker for Improving the Performance of a Photovoltaic Panel", Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy 224(6),pp.797-811, Sep 2010. [DOI:10.1243/09576509JPE871]

[2] Almonacid, G., E. Muñoz, F. Baena, P. Perez Higueras, J. Terrados and M.J. Ortega, "Analysis and Performance of a Two-Axis PV Tracker In Southern Spain", Journal of Solar Energy Engineering, 133 (1),011004-7,2011. [https://doi.org/10.1115/1.4003297]

[3] Abdul-Lateef and Kais I, "A Low Cost Single-Axis Sun Tracker System using PIC Microcontroller", Diyala Journal of Engineering Sciences 5(1) pp. 65-78, Jun 2012.

[4] Sadyrbayev, ShyngysAlmakhanovich, AmangeldiBekbaevichBekbayev, SeitzhanOrynbayev and ZhanibekZhanatovichKaliyev, "Design and Research of Dual-Axis Solar Tracking System in Condition of Town Almaty", Middle-East Journal of Scientific Research 17(12), pp. 1747-1751,2013.[DOI:10.5829/idosi.mejsr.2013.17.12.12363]

[5] Batayneh, Wafa, AbdelrahmanOwais, and MutasemNairoukh, "An Intelligent Fuzzy Based Tracking Controller for a Dual-Axis Solar PV System", Automation in Construction 29, pp.100-106, Jan 2013. [DOI:10.1016/j.autcon.2012.09.006]

[6] Bhote, Visha, and Jaikaran Singh., "Implementation of Dual Axis Solar Tracker Model by using Microcontroller", International Journal of Engineering Research and General Science, 2 (4), pp.780-784, Jun 2014.

[7] SadashivKamble, Sunil Kamble, VaibhavChavan, AnisMestry and NileshPatil, "Dual Axis Solar Tracking System", IJIERT - International Journal of Innovations in Engineering Research and Technology, 2 (4), pp. 2394-3696,2015.

[8] Praveen Kumar B,SasankaJonnalagadda, SrihariM and Haji Bonothu, "Dual-Axis Solar Tracker" International Journal of Recent Scientific Research, 8, pp.15598-15603,2017. [DOI: 10.17148/IARJSET.2021.86141]

[9] Vikash Kumar andSanjeev Kumar Raghuwanshi, "Design and Development of Dual Axis Solar Panel Tracking System for Normalized Performance Enhancement of Solar Panel", Proceedings of International Conference on Sustainable Computing inScience,Technology and Management (SUSCOM), Amity UniversityRajasthan, Jaipur, India, Feb 2019.

[10] Mpodi, Emmanuel Karabo, ZeundjuaTjiparuro, and OduetseMatsebe, "Review of Dual Axis Solar Tracking and Development of its Functional Model", Procedia Manufacturing 35, pp. 580-588, Jan 2019.[DOI:10.1016/j.promfg.2019.05.082]

[11] Amadi, HachimenumNyebuchi, and Sebastián Gutiérrez, "Design and Performance Evaluation of a Dual-Axis Solar Tracking System for Rural Applications", European Journal of Electrical Engineering and Computer Science 3, (1), Jan 2019.[DOI:10.24018/ejece.2019.3.1.52]

[12] S.Gomathi"Enhancement of Modified Multiport Boost Converter For Hybrid System" Scopus Indexed by IEEE Explore ISBN 978-1-6654-3521-5

[13] Saeedi, Mahdi, and Reza Effatnejad. "A New Design of Dual-Axis Solar Tracking System with LDR Sensors by using the Wheatstone Bridge Circuit," IEEE Sensors Journal 21(13) pp. 14915-14922, Apr 2021.[DOI:10.1109/JSEN.2021.3072876]

[14] Putra, Dimas FajarUman, Aji Akbar Firdaus, Riky Tri Yunardi, Machrus Ali, Andrea PrajaRosalino, and Novian Patria Uman Putra, "Real-Time Monitoring of Dual-Axis PV System Based on Internet of Things" In IEEE International Seminar on Intelligent Technology and Its Applications (ISITIA), pp. 349-353, Jul 2021.

[15] Bouzakri, Hicham, Ahmed Abbou, ZakariaAbousserhane, and Rafika El Idrissi, "Control of a Bi-axial Solar Tracker by Observing the Power Supplied by the MPPT", In International Conference on Digital Technologies and Applications, pp. 836-844. Springer, Cham, 2022.

Biographies

Mr. S. Venkatesh Kumar is currently working as Assistant Professor (Senior Grade) in the Department of Electrical and Electronics Engineering at Sri Ramakrishna Engineering College, Coimbatore. He completed his B.E in Electrical and Electronics Engineering from Sri Subramanya College of Engineering and Technology, Palani(Anna University, Chennai) in the year 2008. He completed his M.E in Applied Electronics from Dr.Mahalingam College of Engineering and Technology, Pollachi (Anna University, Coimbatore) in the year 2010. He has 10 years of teaching experience. His research area of interest includes Renewable Energy Systems and Electrical Machines. He is a life member of ISTE and IAENG.

Dr.C.Kathirvel, has completed his Ph.D in Electrical Engineering from Anna University, Chennai in the year 2014. He has completed his M.E.,(Applied Electronics) degree from Coimbatore Institute of technology, Affiliated to Anna University, Chennai in the year 2004 and has received his B.E., (Electrical and Electronics Engineering) degree from Bharathiyar University in the year 2000. He joined as a Lecturer in the year 2004. He is currently working as Professor& Head in EEE Department. He has more than 15 years of teaching and industrial experience. He has published more than 50 research papers in International, National Journals and conferences. He has organized many conferences and chaired several technical sessions in national and international conferences. His area of interests includes Renewable Energy systems, Soft computing and Controllers for Hybrid energy systems. He is a life member in ISTE and a certified ISO internal auditor.

Dr.P.SebastianVindro Jude is currently working as Assistant Professor (Selection Grade) in the Department of Electrical and Electronics Engineering at Sri Ramakrishna Engineering College, Coimbatore. He completed his B.E in Electrical and Electronics Engineering from Government College of Engineering, Bargur (Madras University) in the year 2001. He completed his M.E in Energy Engineering from National Engineering College, Kovilpatti (Anna University, Coimbatore) in the year 2006.He completed Ph.D in Electrical Engineering (Anna University) in the year 2020. He has 15+ years of teaching experience. His research area of interest includes Renewable Energy Systems and Electrical Machines. He is a life member of ISTE and IAENG.

Mr. R. Mohan Kumar is the Assistant Professor (Sr.G) in the department of Electrical and Electronics Engineering. He has 12 years of teaching experience. He completed his Under Graduate in Electrical and Electronics Engineering branch from Sri Ramakrishna Institute of Technology, Coimbatore and his Post Graduate degree in Information and Communication Systems (Applied Electronics) from Anna University of Technology, Coimbatore. He is currently pursuing his Ph.D under Anna University, Chennai in the area of Renewable Energy Systems.His area of interest is Electrical Machines and Renewable Energy Systems. He is a Life member of ISTE and IAENG.