An Innovative Design of a Dual Axis Automatic Tracking Solar Power Generation System with Improved Performance in Different Environmental Conditions

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Original Article

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Abstract

The term solar energy refers to the radiation in light energy and the heat of the sun that is received in a high amount. The solar energy that is received from the sun reaches the surface from the 6 surface layers that travel from the sun to power the environment. Some parts of the solar energy can be converted into electrical energy, and the maximum solar energy is transmitted or reflected in the environment. Solar energy can be converted and used to the fullest extent possible while there is an energy crisis in the world, society, and power companies. In this paper we will discuss the solar energy generation, control of power, tracking of the solar panel, data collection from the SPV power plant, and comparison of the solar tracking data and non-tracking data. The main aims of this research are to reduce the cost and increase the amount of electricity generated for installed PV systems by fabricating a simple control circuit for dual axis solar tracker PV systems. It is possible to design an SPV power plant monitoring system that can be installed along with the solar panels for the generation of electrical energy and can be controlled and monitored remotely. It should be checked frequently to ensure system control and continuous power supply. By implementing both techniques, the cost of a PV power plant can be reduced by increasing the productivity and proper monitoring of the photovoltaic generation system. This paper presents a detailed description of the designed and fabricated electrical circuits used in the tracker PV system and string monitoring system. Reduction in operating cost of SPV dual axis tracking system. Power losses due to control circuits in moonlight are also avoided, as per the design presented by many authors in the past. Energy losses can be detected and corrected by monitoring the operational performance and analyzing the recorded data of PV systems. Monitoring PV systems is pretty helpful in developing white papers and setting benchmarks for the system performance of PV systems. The sun tracker circuit consists of a 12-volt power supply circuit, an LDR-based sensor circuit, an H-bridge circuit, a timer circuit, and a DC motor driving circuit. For transferring the data wirelessly like PV string array voltage, current, and voltage taken by DC motor during the sun tracking throughout the whole day from the remote station to base station, a simple X-bee-based designed circuit.

Keywords: **SPV Power Plant, Operating Cost, Tracking System, Fabricated PV System, Control Circuit, MPPT Techniques, Solar Energy.**

1. Introduction

Solar energy is generated by photovoltaic plants but also it is generated by semiconductor devices, these devices are called solar cells, and a combination of the cells is called solar arrays [1, 2]. The load of the home is taken at the average of 1.7 KW for the power system at run-on maximum load condition. The area approximate area required for the installation of a 1.7 kW SPV system is about 142 square meters, depending on the size and efficiency of the panels, as has been observed; the cost of energy has been a matter of concern. Many researchers are going to meet the demands of solar energy available and produce more energy at a lower cost while taking care of the environment and various government agencies are working to promote alternative sources of energy and its conservation [3, 4].

The main aims of this research are to reduce the cost and increase the amount of electricity generated for installed PV systems by fabricating a simple control circuit for dual-axis solar tracker PV systems. An SPV power plant system is designed for generating solar energy for supplying the load center at the maximum value and it would be controlled by monitoring the system. Regular monitoring of the system reduces maintenance losses of the panel. By implementing both techniques, the cost of the PV power plants can be reduced by increasing the productivity and proper monitoring of photovoltaic generating system [5].

After monitoring the operational performance and analyzing the recorded data of PV systems, energy losses can be detected and corrected. Monitoring of PV systems is pretty helpful in developing white papers and setting benchmarks for the system performance of PV systems. This paper presents a detailed de- description of designed and fabricated electrical circuits used in tracker PV systems and string monitoring systems [6]. The sun tracker circuit consists of a 12-volt power supply circuit, an LDR-based sensor circuit, H- a bridge circuit, a timer circuit, and DC motor driving circuit.

For transferring the data wirelessly like PV string array voltage, current, current, and voltage taken by DC motor during the sun tracking within the whole day from the remote station to the base station, a simple X-bee-based designed circuit also describes in this section. For monitoring the voltage and current of the PV array, a front view has been developed on the dot.net platform. At last, results describe the improved efficiency of SPV systems due to single both dual and single-axis solar tracking systems including different environmental conditions [7, 8].

2. Required Components of Electrical Circuit

Figure – 1: Electrical Subsystem of Fabricated Solar Tracking System (170X3 Watt)

The overall dual-axis sun tracker PV system consists of mechanical and electrical subsystems as given above in Figure – 1. The sun tracker system mainly consists of electrical components like PV cells, an LDR sensor circuit, a power supply to operate the op-amp-based tracker control circuitry, and a simple string monitoring circuit. The sunlight intensity of the sun can be sensed by the LDR sensors and the signal is sent to Op-amp, Operational amplifier compares the voltages coming from the LDR sensors and give the signal to the motor driving circuit of the PV panel to change their position from one point to another point.

The PV cells are nothing but it is electrical transducers that are used to generate electrical energy from the heat energy of the sun. The rating of the solar panel is 170 w for each panel to fulfill the load demand of the center [9]. The solar panel has their specification at the standard test condition (100 mW /Cm^2. at air mass 1.5 and at 250C cell temperature) present in Table – 1.

Specification of the solar panel	72 cells are used within series (12*6) Glass Laminated single Type
Size of the solar panel	1595 (±3) x 790 (± 2) x 50 (± 1) MM
Weight (Kg.)	15 with Anodized Aluminum Frame
O C (Voltage) S C C (Ampere) Operating Voltage Max Power Output	42.00 V 04.86 A 35 V 170.0 W ± 3%

Table – 1: Specifications of 170WP Solar Photovoltaic Modules (L24150 type module)

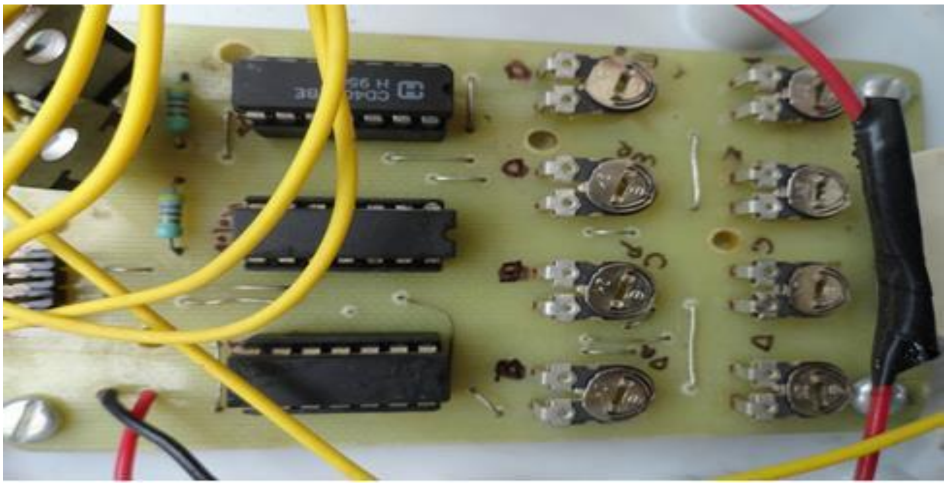


Figure – 2: Basic Circuit of the Solar Tracker Controller at Dual Axis

To track the sun's position during the whole day and the whole year, the tracker control circuit plays an important role. This circuit was designed for dual-axis tracking control. It is connected to the power supply circuit. The fabricated control circuit is shown in Figure – 2. The circuit diagram of the single-axis solar tracker has been represented in Fig 3. In this designed circuit four light-dependent resistors are used [10]. Two LDR sensors are used to rotate the DC motor from the East to west direction and the other two LDR are used to move the tracker from the west to east direction. First, in the fabricated circuit, fixed-resistance of 100 KΩ was used in place of the left side LDR sensor than problem faced on a cloudy day; in the low-intensity sunlight tracker control circuit did not work properly. Because whenever the voltage across the right LDR sensor is lower than the reference value (voltage across fixed resistance) sun tracker fails to track the exact sun position.

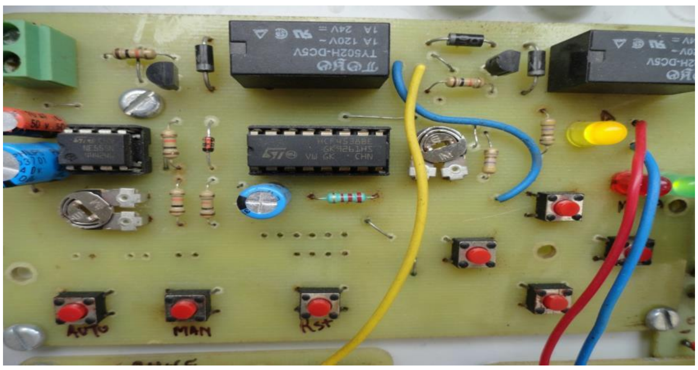


Figure – 3: Fabricated Delay Timing Circuit

For smart tracking, a partition is provided between the left and right side LDR sensors. Whenever the same sunlight occurs on both sides of LDR there will no voltage difference at Op-Amp and the tracker will not move. In the morning time left side sensor receives full light intensity and the right side LDR will come in under shadow due to the partition wall. In this situation, the tracker starts to move from the west to the east direction till both LDRs will not get the same sunlight. A similar concept is applied to east-to-west rotation. The same circuit and concept are used for elevated sun tracking [11].

A Delay timing circuit is used for reducing the power consumed by the tracker control circuit. In the first setup, the solar tracker control circuit was directly connected to a 170-watt solar panel without the use of a delay timing circuit than DC motor continuously take the power from the PV cells, resulting in very much power losses in the tracker control circuit.

To overcome this problem, a Delay timing circuit has been designed. The Delay timing circuit consists of two 555 timers IC, one flip- flop and one ripple counter. In this circuit, a variable pot was used to adjust the on/off timing pulse according to our requirements. With the use of this delay circuit, the power consumed by the tracker control circuit can be reduced by 40%. In the experimental setup, it has been seen. Whenever the circuit timing pulse is on than tracker control circuit takes 0.16 Amp current, while in off position control circuit takes 0.08 amp current. In this circuit, the POT has been adjusted such a way that the timer circuit generates an ON pulse for one minute and an OFF pulse for four-minute [12, 13].

DC Watt-Hour meter has been designed for measuring the power consumed by the tracker control circuit and DC motors. The specifications of components used in fabricated Watt-Hour meter. The fabricated circuit of the DC-watt-hour meter is shown in Figure – 4.

The circuit layout diagram is shown in Figure – 4. In this circuit, the ATMEGA16 microcontroller is used for calculating the power consumed by the dual-axis sun tracker circuits and 24-volt DC motors. An LCD is connected for displaying voltage and current values. The program is used in the microcontroller. It has been measured that the total power consumed by the circuit is 2.13 watts/hour [14, 15]. And the power consumed by the circuit in a whole day is 20 watts. The tracker control circuit is directly connected to the PV panel via a power supply circuit. So, in absence of sunlight, the tracker control circuit will not be operated so the use of a limit switch can be avoided.

Figure – 4: Designed DC Watt-Hour Meter Circuit

3. String Monitoring and Controlling System

It is comprised of X-bee and three hall-effect sensors. The PV string current is measured with the utilization of the Hall Effect current module. The second one is used for the current measurement of the X-motor, taken by the DC motor during the tracker movement from east to west and vice-versa. The third current sensor is used for the measurement of current taken by the Y-motor during elevated rotation. In this work, we used ACS714 Hall Effect Sensors built-in string monitoring units of rating 5 amps to measure the values of DC current, for measuring the value of DC voltage a simple potential divider circuit was mounted on the string monitoring system as shown in the Figure – 5. And also a DC Watt-hour meter. As explained above is connected to this circuit for measuring the DC power consumed by the circuit and DC motor during the dual-axis tracking [16].

4. Results

The performance and power consumed by the motor during dual-axis tracking were analyzed. The values of voltages and currents are recorded within a whole day for both motors. The data have been recorded in different conditions of the environment such as a clear sky day, or a cloudy day may be (fully or partially). Before using the current sensor in the fabricated circuit, a reading was taken in the lab to see the performance analysis of the Hall Effect sensor. The input current level in Ampere is shown in the blue bar and the corresponding out voltage level in mV is shown in a red bar in the presented bar chart, as shown in Figure – 6.

The current and voltage of the PV array can be monitored and calculated, DC motor, a user-friendly front view was designed on the VB.Net platform. So that any user can easily axis, use, and monitor at any time the different parameters and data in terms of current and voltage received from the PV array. Also, a recording option has been implemented so that the data coming from the remote station can be stored in *. xls file. In this front view design, voltage and current values taken by both motors during the dual axis tracking also can be monitored as shown in Figure – 7.

The following results have been obtained as shown in Figures 8, 9, and 10 for the DC motor during azimuthal tracking (X-Motor). Figures 7(a), (b), and (c) shows the variations in power, voltage, and current with respect to time. The data was recorded on date 14-07-2022, under clear sky day conditions. It has been calculated that the total power consumed by X-motor during azimuthal tracking from 11:00 AM to 5:00 PM is 0.127 watts.

Figure – 5: Fabricated Circuit of Plant Level String Monitoring System

To see the variation in Power, voltage, and current with respect to time. The data was recorded on date 16-07-2022, under partial cloudy sky day conditions [17, 18, 20]. These variations are shown in Figures 8 (a), (b), and (c). The power consumed by X-motor on this day is 0.086 watts. This power is calculated for the recorded data from 10:00 AM to 4:00 PM

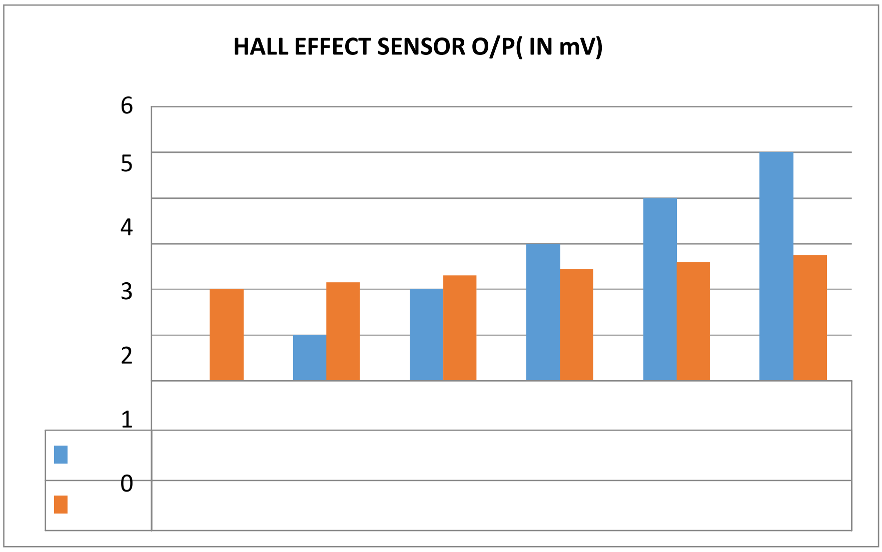
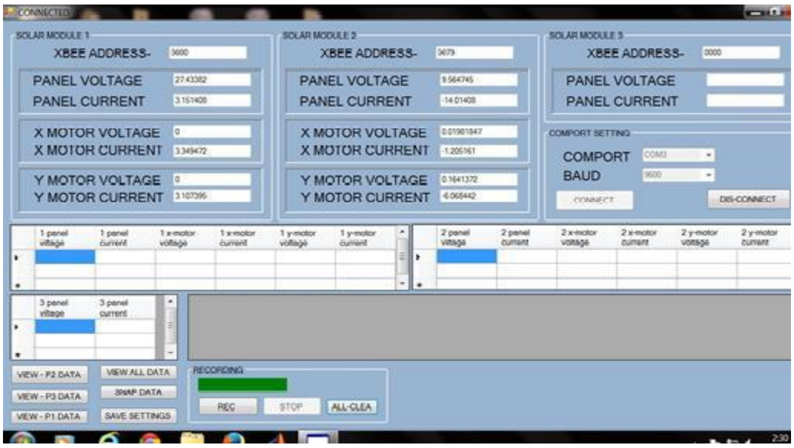


Figure – 6: Bar Chart of Hall Effect Sensor Output (in mVolt)



igure – 7: Front Panel View Designed in VB.DotNet

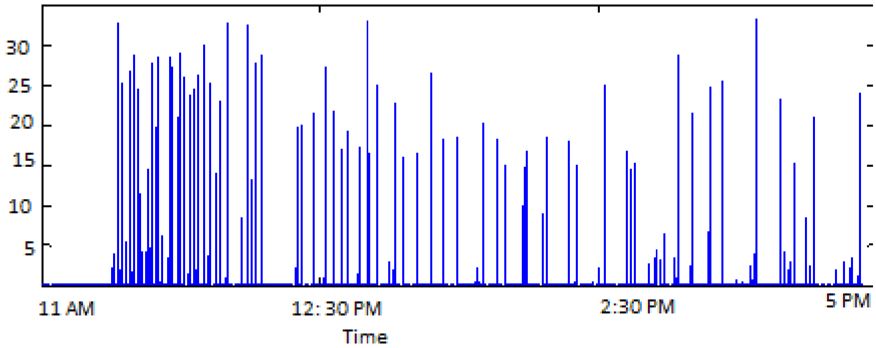


Figure – 7(a): X-Motor Power (watt) Vs Time (sec.)

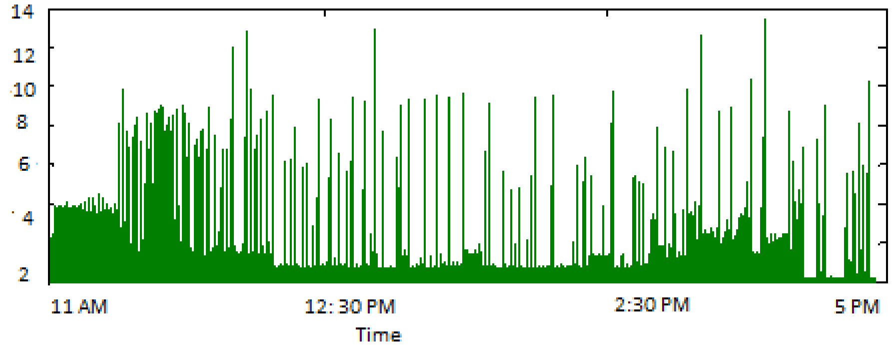


Figure – 7(b): X-Motor Voltage (volt) Vs Time (sec.)

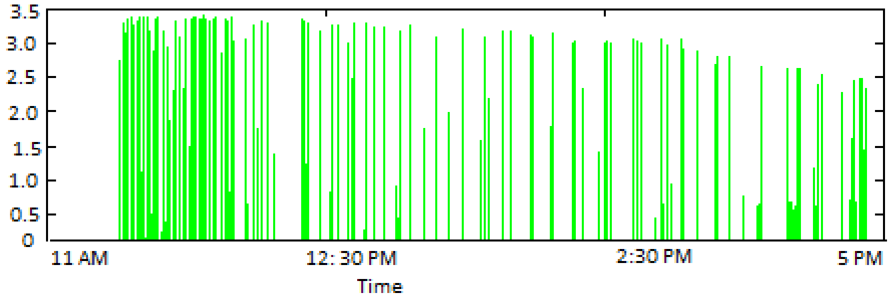


Figure – 7(c): X-Motor Current (amp) Vs Time (sec.)

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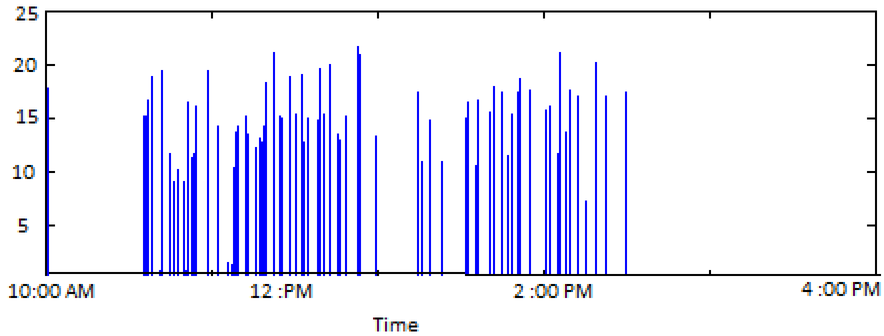

Figure – 8(a): X-Motor Power (watt) Vs Time (sec.)

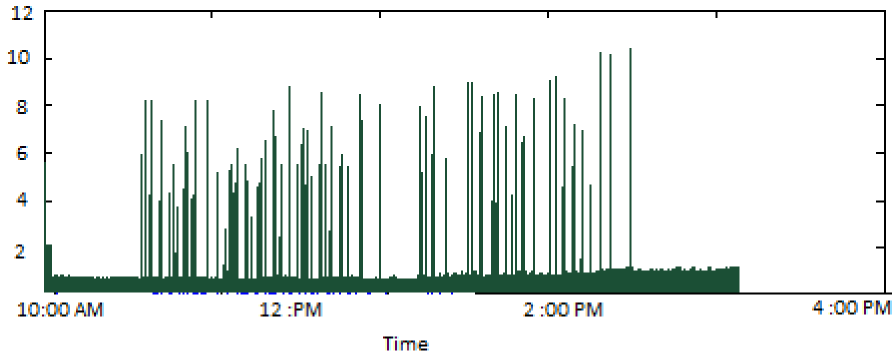

Figure – 8(b): X-Motor Voltage (volt) Vs Time (sec.)

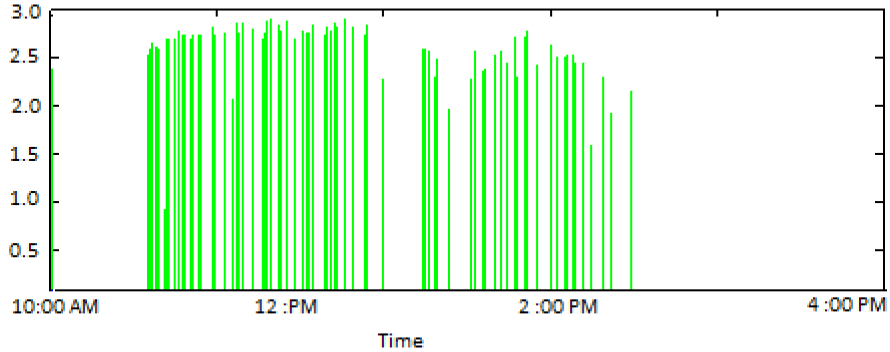

Figure – 8(c): X-Motor Current (amp) Vs Time (sec.)

Figures 9(a) and (b) show the variation in power and voltage in X-motor for the recorded data on the date 19-07-2022, fewer than 60% cloudy day. The total power consumed from 9:00 AM to 4:00 PM by X-motor on this day is 0.195 watts [19].

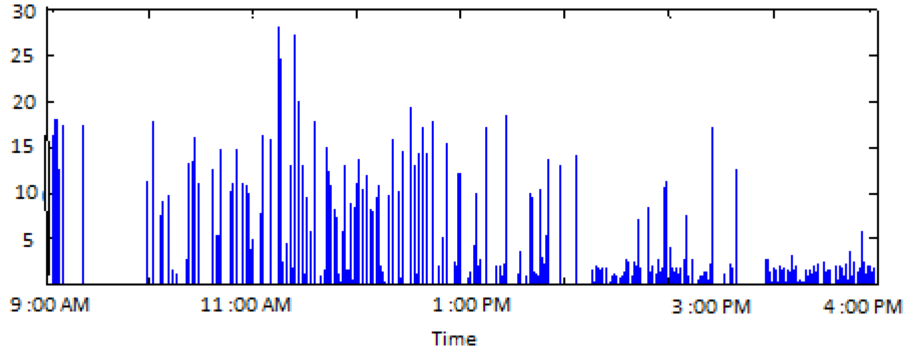

Figure – 9(a): X-Motor power (watt) Vs Time (sec.)

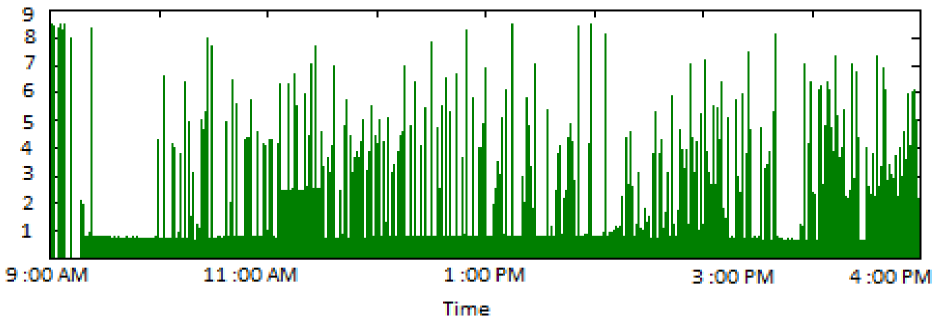

Figure – 9(b): X-Motor Voltage (Volt) Vs Time (sec.)

Figure – 10 shows the different variation in solar radiation on the day fully cloudy or partly cloudy. In this graph relation is given between solar radiation from 100 to 1000 intensity and the time morning to evening 8: 00 AM to 5:30 PM then the intensity of the sunlight change due to the cloudy weather in this way output power depends on the intensity of the solar radiation not the direction of the sun. Figure – 11 provides the relation in the variation of the current consumption at the 1000-watt load with respect to time from morning to evening. Figure – 12 gives the Graphical Representation of the Power Variation of both Systems under a fully Cloudy Day.

S.NO	READING ON DATE : 16-07-2022							
	TIME	TRACKER		**FIXED**		ANGLE		
		Voltage	Current	**Voltage**	**Current**	X (Azimuthal)	**Y (Elevated)**
1	10.15	23.00	13.2	22.50	12.1	010	-10.0
2	10.44	24.00	13.5	23.70	12.2	010	-08.0
3	11.21	24.28	13.7	24.00	12.4	017	-03.0
4	11.35	25.18	13.8	24.61	12.5	020	-01.5
5	11.45	24.92	13.9	24.20	12.6	025	-00.5
6	12:00	25.00	13.5	24.53	12.3	033	00.0
7	12.10	25.20	13.8	24.78	12.6	037	00.0
8	12.20	25.36	13.6	24.82	12.4	045	00.1
9	12.35	23.50	13.5	22.10	12.5	053	00.1
10	12.46	25.80	13.8	24.46	12.6	060	00.1
11	13:00	25.82	13.6	24.72	12.5	068	00.1
12	13.10	24.78	13.4	23.10	12.3	078	00.1
13	13.25	24.53	13.0	22.50	12.3	082	00.1
14	13.55	23.95	12.0	18.10	11.5	095	-06.0
15	14.15	22.15	12.0	17.68	10.0	098	-08.0
16	14.30	25.75	12.5	16.14	10.9	105	-11.0
17	14.40	23.59	12.0	14.72	10.5	107	-13.0
18	14.50	23.28	11.9	13.68	09.7	109	-14.0
19	15:00	19.12	10.5	08.50	09.8	110	-15.5
20	15.10	17.65	12.0	09.42	08.0	112	-17.0
21	15.20	21.32	11.8	08.35	07.5	114	-20.0
22	15.30	12.24	08.7	05.70	06.0	115	-20.0
23	16:00	07.22	06.7	02.65	05.0	116	-21.0
24	16.35	03.57	05.0	00.45	00.0	214	-22.0

Table – 2: Reading for Performance Analysis of Solar 510 Watt Solar Tracker System

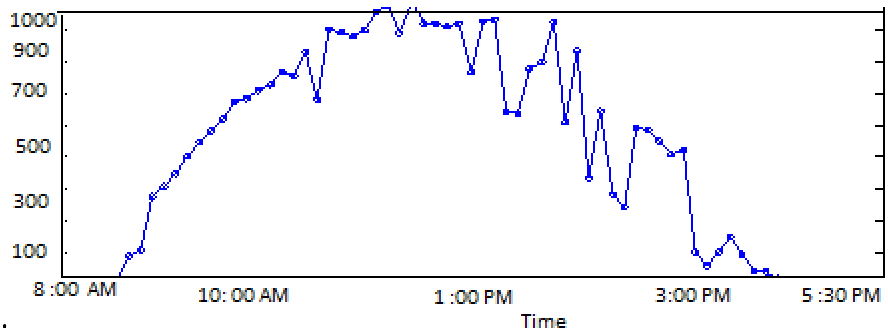

Figure – 10: Variation in Solar Radiation under Cloudy Day

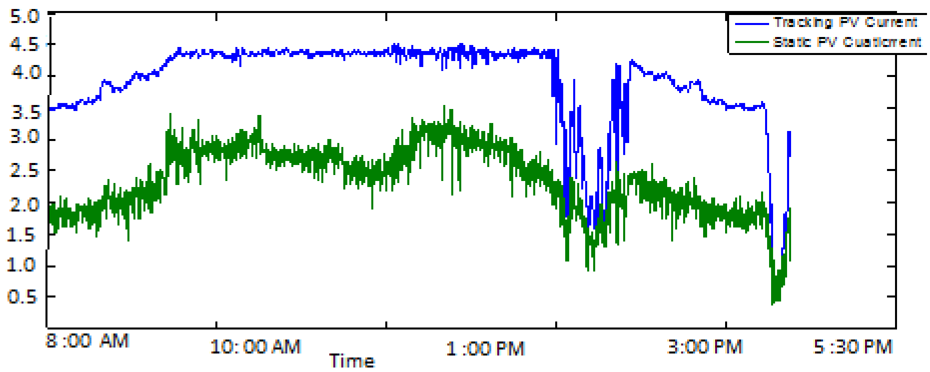

Figure – 11: Variation in Current Consumed by 1000 Watt Load Connected to Both PV Systems

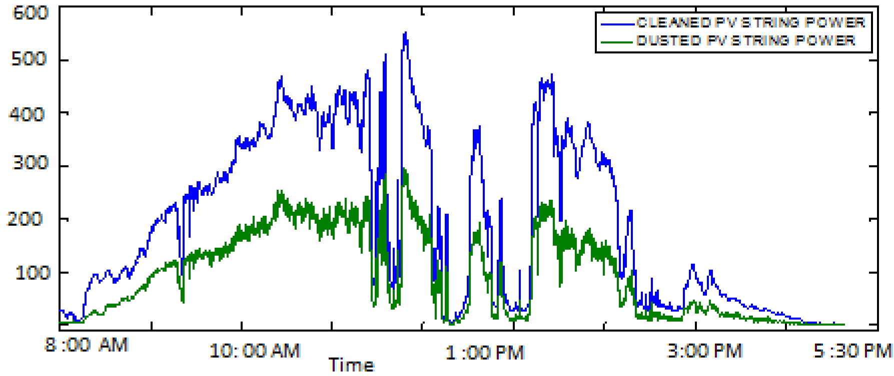

Figure – 12: Graphical Representation of Power Variation of Both System Under Cloudy Day

5. Conclusion

Both PV systems were mounted at 26^0 south-facing from the horizontal axis and the data was collected on the date of 16 -07-2022 on a partial and fully cloudy day The data recording was started from 8:30 AM and recorded till 5:30 PM. Figure – 12 shows the variation in power within the whole day. The total power calculated from the cleaned PV System is 8297508 watts while from dusted PV system is 4977221.7 watts. The efficiency of the cleaned panels PV System was calculated as 66.3% more energy compared to dusted PV System power. From the above results, it is determined that dual-axis tracking systems have 48 % higher efficiency compared to the static solar PV system. The results obtained are also good on cloudy as well as clear sky days.

6. References

1. Kuttybay N, Mekhilef S, Saymbetov A, Nurgaliyev M, Meiirkhanov A, Dosymbetova G, Kopzhan Z. An automated intelligent solar tracking control system with adaptive algorithm for different weather conditions. In2019 IEEE international conference on automatic control and intelligent systems (I2CACIS) 2019 Jun 29 (pp. 315-319). IEEE. Available at: https://doi.org/10.1109/I2CACIS.2019.8825098
2. Mousazadeh H, Keyhani A, Javadi A, Mobli H, Abrinia K, Sharifi A. A review of principle and sun-tracking methods for maximizing solar systems output. Renewable and sustainable energy reviews. 2009 Oct 1;13(8):1800-18. Available at: https://doi.org/10.1016/j.rser.2009.01.022
3. Nadia AR, Isa NA, Desa MK. Advances in solar photovoltaic tracking systems: A review. Renewable and sustainable energy reviews. 2018 Feb 1;82:2548-69. Available at: https://doi.org/10.1016/j.rser.2017.09.077
4. Saymbetov AK, Nurgaliyev MK, Nalibayev YD, Kuttybay NB, Svanbayev YA, Dosymbetova GB, Tulkibaiuly Y, Meiirkhanov AK, Kopzhan ZK, Gaziz KA. Intelligent energy efficient wireless communacation system for street lighting. In2018 International conference on computing and network communications (CoCoNet) 2018 Aug 15 (pp. 18-22). IEEE. Available at: https://doi.org/10.1109/CoCoNet.2018.8476893
5. Alexandru C, Pozna C. 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. 2010 Sep 1;224(6):797-811. Available at: https://doi.org/10.1243/09576509JPE871
6. Koussa M, Cheknane A, Hadji SM, Haddadi M, Noureddine S. Measured and modelled improvement in solar energy yield from flat plate photovoltaic systems utilizing different tracking systems and under a range of environmental conditions. Applied Energy. 2011 May 1;88(5):1756-71. Available at: https://doi.org/10.1016/j.apenergy.2010.12.002
7. Kelly NA, Gibson TL. Increasing the solar photovoltaic energy capture on sunny and cloudy days. Solar Energy. 2011 Jan 1;85(1):111-25. Available at: https://doi.org/10.1016/j.solener.2010.10.015
8. El Kadmiri Z, El Kadmiri O, Masmoudi L, Bargach MN. A novel solar tracker based on omnidirectional computer vision. Journal of Solar energy. 2015 Jan 31;2015:6. Available at: https://downloads.hindawi.com/archive/2015/149852.pdf

9. Khan MT, Tanzil SS, Rahman R, Alam SS. Design and construction of an automatic solar tracking system. InInternational Conference on Electrical & Computer Engineering (ICECE 2010) 2010 Dec 18 (pp. 326-329). IEEE. Available at: https://doi.org/10.1109/ICELCE.2010.5700694
10. Ferdaus RA, Mohammed MA, Rahman S, Salehin S, Mannan MA. Energy efficient hybrid dual axis solar tracking system. Journal of Renewable Energy. 2014 Jul 8;2014. Available at: https://doi.org/10.1155/2014/629717
11. Yazidi A, Betin F, Notton G, Capolino GA. Low cost two-axis solar tracker with high precision positioning. In2006 first international symposium on environment identities and Mediterranean area 2006 Jul 9 (pp. 211-216). IEEE. Available at: https://doi.org/10.1109/ISEIMA.2006.344932
12. Zhan TS, Lin WM, Tsai MH, Wang GS. Design and implementation of the dual-axis solar tracking system. In2013 IEEE 37th Annual Computer Software and Applications Conference 2013 Jul 22 (pp. 276-277). IEEE. Available at: https://doi.org/10.1109/COMPSAC.2013.46
13. Othman N, Manan MI, Othman Z, Al Junid SA. Performance analysis of dual-axis solar tracking system. In2013 IEEE International Conference on Control System, Computing and Engineering 2013 Nov 29 (pp. 370-375). IEEE. Available at: https://doi.org/10.1109/ICCSCE.2013.6719992
14. Jamroen C, Komkum P, Kohsri S, Himananto W, Panupintu S, Unkat S. A low-cost dual-axis solar tracking system based on digital logic design: Design and implementation. Sustainable Energy Technologies and Assessments. 2020 Feb 1;37:100618. Available at: https://doi.org/10.1016/j.seta.2019.100618
15. Abdollahpour M, Golzarian MR, Rohani A, Zarchi HA. Development of a machine vision dual-axis solar tracking system. solar energy. 2018 Jul 15;169:136-43. Available at: https://doi.org/10.1016/j.solener.2018.03.059
16. Yao Y, Hu Y, Gao S, Yang G, Du J. A multipurpose dual-axis solar tracker with two tracking strategies. Renewable Energy. 2014 Dec 1;72:88-98. Available at: https://doi.org/10.1016/j.renene.2014.07.002
17. Jamroen C, Fongkerd C, Krongpha W, Komkum P, Pirayawaraporn A, Chindakham N. A novel UV sensor-based dual-axis solar tracking system: Implementation and performance analysis. Applied Energy. 2021 Oct 1;299:117295. Available at: https://doi.org/10.1016/j.apenergy.2021.117295
18. Barsoum N. Fabrication of dual-axis solar tracking controller project. Intelligent Control and Automation. 2011 Jun 3;2(02):57. Available at: https://www.scirp.org/html/5173.html
19. Motyl B, Baronio G, Uberti S, Speranza D, Filippi S. How will change the future engineers' skills in the Industry 4.0 framework? A questionnaire survey. Procedia manufacturing. 2017 Jan 1;11:1501-9. Available at: https://doi.org/10.1016/j.promfg.2017.07.282
20. Racharla S, Rajan K. Solar tracking system–a review. International journal of sustainable engineering. 2017 Mar 4;10(2):72-81. Availabe at: https://www.tandfonline.com/doi/full/10.1080/19397038.2016.1267816