Improved efficiency study of single axis tracking model compared to static photovoltaic system

Neeraj Tiwari*, Sanjeev Kumar** and Vikas Pratap Singh***

This paper presents the performance study of single axis tracking system compared static PV system. To increase the efficiency of PV System. We designed a simple and cost effective 170W sun tracking system for the experiment. The whole experimental setup has been implemented in Simulink^{TM} platform for the analysis of improved efficiency. The objective of this paper to optimize the solar energy receivers. In this paper, a Simulink model of the static PV system and Tracking PV system has been presented. In the fabrication of real sun tracker system we used a 24 VDC motor and a simple LDR based control circuit for the tracking purpose. The block diagram with detailed description and performance of the tracking system are presented.

1.0 INTRODUCTION

The Sun is an abundant source of solar energy. The total amount of energy received from the sun on the Earth planet – around 10^{17} W. The value of the solar constant is 1000 W/m^2 at sea level on a clear day. While In cloudy sky, there could be a small component of direct radiation and a substantial component of diffuse radiation [1-4].

In order to optimize the efficiency of PV system, Solar tracker is invented because generated power of any PV system is directly dependent on irradiance value and the static PV system disables to move toward the sunlight when the sun moves from east to west. In a past days much research was done in this field. The existing sun tracking techniques is classified in two types (a) passive tracking system (b) active tracking system. In passive tracking system, mechanical techniques are used to track the sun position while in active tracking system electrical and mechanical concept are used. Passive tracking system is cheaper than active tracking system. Hession and Bonwick [5] designed a photo-transistor based sun tracker system.

Ayala, J. Kenneth [6] presented, Microprocessors based tracker system. For experimental setup a simple, low cost tracker system was designed. to track the position of the sun a 24 V DC motor was used and the motor is connected to a PV cells via simple tracking control circuit. we avoid the use of battery for the tracking purpose. This paper also presented a SIMULINK^{TM} model of Tracking PV system as well as Static PV system.

According to Gupta and Mirakhur [7] a single axis tracker increases annual output by approximately 30%, and a dual axis tracker an additional 6%. The Simulation results shows, the accuracy of designed tracking system is much greater than the previous presented tracking system.

*Neeraj Tiwari,Dayalbagh Educational Institute (Deemed University), Agra Email: neerajtiwari.1407@gmail.com Mobile No:09411984649
**Sanjeev Kumar, Hindustan College of Science and Technology, Mathura Email:sanjeev.85ee@gmail.com
***Vikas Pratap Singh, Central Power Research Institute Bangalore Email:vpscpri@gmail.com

2.0   REQUIREMENT OF SUN TRACKER

Solar energy is radiated uniformly in all the direction the spectrum of this radiation lies in the visible and infrared part of the EM (Electromagnetic) wave. The luminosity of the Sun is about 3.86×10^{26} W. The distance of the sun from the earth is 150 million kms and the earth radius is 63×10^3 kms approximately. The solar power we received at the earth surface is approximately 1370 W per square meter is called solar constant. It is varies by +/- 3% because of the Earth's slightly elliptical orbit around the Sun as

The Earth rotate in elliptical orbit around the sun and also around in own axis known as polar axis, mathematically declination angle (∂_z) can be expressed as [10] and shown in equation. 1.

n_d = day of the year.

$$\partial_z = 23.45^0 . \sin\left[\frac{360.(n_d - 180)}{365}\right] \qquad ...(1)$$

If θ_z is the zenith angle

Then: $\theta_z = \varphi - \partial$.

Where $\varnothing$ = latitude angle.
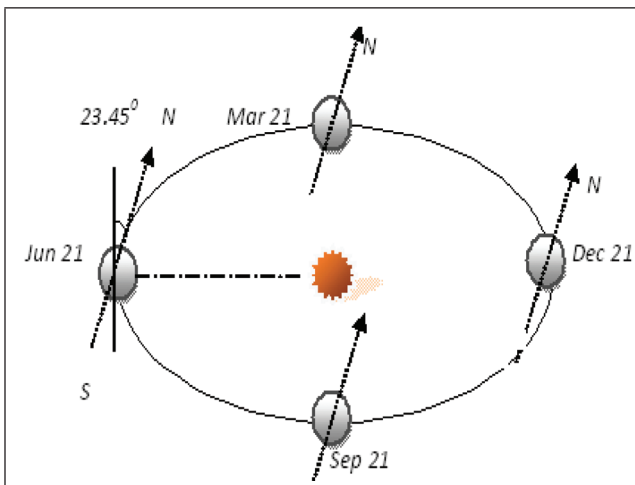
∂_z = declination angle.

Solar Event	Date
Vernal equinox	Mar-21
Summer solstice	June-21
Autumnal equinox	Sep-23
Winter solstice	Dec-21

The azimuth angle is zero at solar noon and increases toward the east. The angle about the vertical axis is called the azimuthal angle and is 0 at due south and becomes positive as you start to point east. The angle about the horizontal axis is called the altitude and is 0 level to the horizon and becomes positive as you point towards the sky.
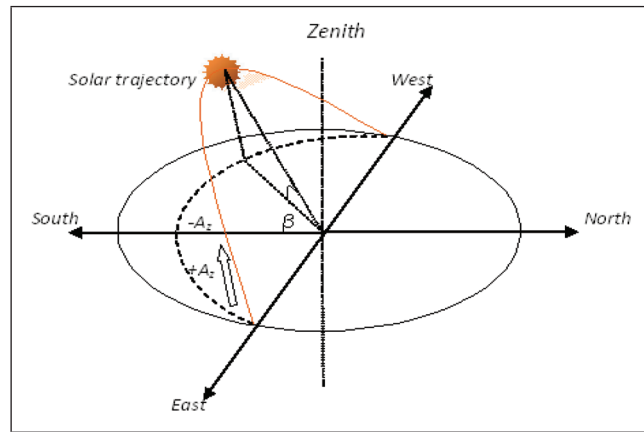

FIG. 2   SOLAR TRAJECTORY

3.0   SOLAR TRACKING PV SYSTEM.

The position of sun in the sky varies in both directions azimuthally as well as elevated direction in the whole day and throughout the year. The block diagram of experimental setup has been presented in Figure 1 and Figure 2-3 shows the actual fabricated solar tracker PV system.
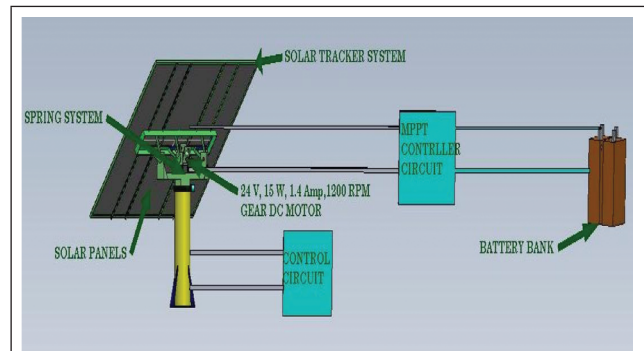

FIG. 3   BLOCK DIAGRAM OF SOLAR PV SYSTEM

FIG. 1   POSITION OF EARTH WITH RESPECT TO SUN

FIG. 4   DESIGNED SOLAR TRACKER PV SYSTEM

Figure 4 shows the designed dual axis solar tracker system. In this system two 24 V DC motor was used to track the Sun position azimuthally (East-West) as well as elevated. for the performance analysis of tracking PV system and DC motor the system has been developed in Simulink platform.

4.0   SPECIFICATION

DC-motor specification:

For the dual axis tracking, Two 24 V each DC motors was used in the designed solar tracker PV system because we avoid the use of battery for the tracking purpose. These motors was directly connected to 170 W PV module. In equation 2 show the DC voltage for the armature circuit is:

$$V = I .R_a + K.\omega \qquad ...(2)$$

Where: Ra is the armature resistance. Increasing R_a The back emf is $E = K \cdot \omega$ where: K is the constant, and ω is the angular speed of rotor in rad/sec.

The specification of DC motor is: 2-POLE permanent magnet Lap wound dc motor. DGM-3440-24V, 15 W, 1200 rpm, 1.5 A geared.

Solar Panel specification:

TABLE 1	
SPECIFICATIONS OF SOLAR PHOTOVOLTAIC MODULES	
Configuration	Single Glass Laminated Type With 72 Cells (12 × 6) In Series
Overall Size	1595 (± 3) × 790 (± 2) × 50 (± 1) mm
Weight	15 kg (Typical)
Module Frame	Anodized Aluminum
Typical Electrical Characteristics of L24150 type module (170 Wp)	
Open Circuit Voltage (V_{oc})	42.0 V
Short Circuit Current (I_{sc})	4.86 A
Operating Voltage	35 V
Max Power Output	170.0 W ± *3%*

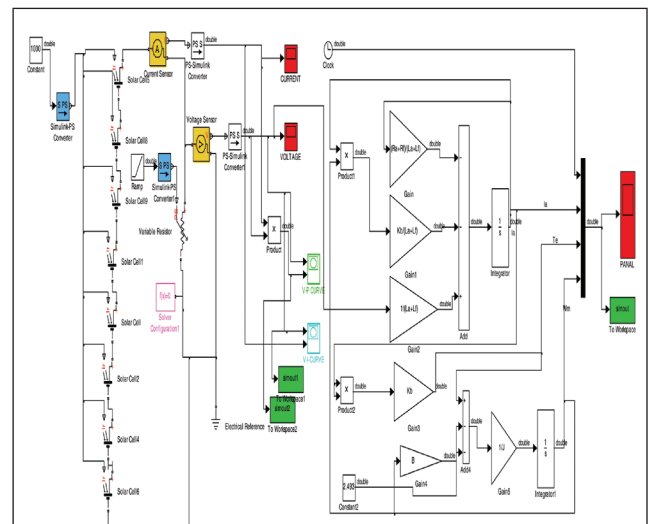## 5.0   SIMULINK MODEL

DC Motor:

FIG. 5   DC MOTOR DIRECTLY CONNECTED TO PV MODULE.

As shown in Figure 3. The DC motor is directly connected to PV module the simulation & results are presented in Figure 5-8.
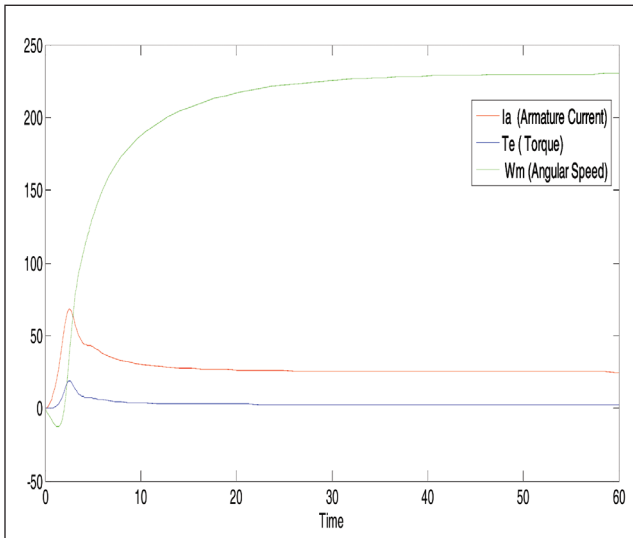
FIG. 6   SIMULATION RESULT OF DC MOTOR CONNECTED TO PVMODULE

Static PV system:

FIG. 7   STATIC PV SYSTEM MODEL IN SIMULINK

Tracking PV system:

FIG. 8   TRACKING PV SYSTEM MODEL IN SIMULINK

For the Simulation Purpose Real time recorded data of temperature and irradiance value was used. Because obtained data was discrete in nature therefore we fitted a spline curve for getting the data in a continuous form. Figure 9-10 shows the variation in temperature and Irradiance value with respect to time respectively.
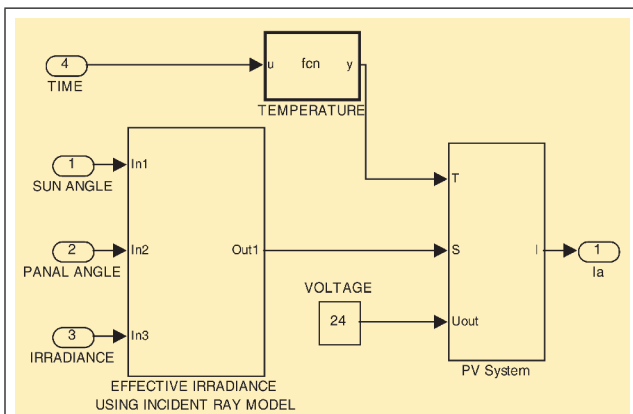

FIG. 9   ACTUAL TEMPERATURE RECORDED ON DATE: 13-08-2014

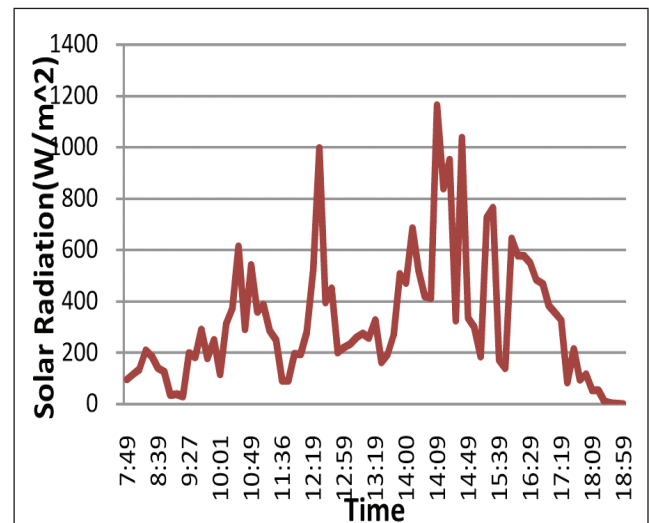FIG. 10   SOLAR IRRADIANCE DATA RECORDED ON 13-08-2014

6.0   EXPERIMENTAL RESULTS

These data were taken in the month of August-13, 2014. Table 2 represents the recorded data of fixed PV system and Tracking PV System. Figure 11-12 shows the graphical representation of fixed & tracking system power output.

| TABLE 2					
FIXED SYSTEM AND TRACKING SYSTEM					
TIME	Static PV System			Tracking PV System		
	Voltage (V)	Current (A)	Power (W)	Voltage (V)	Current (A)	Power (W)
7.00am	0.816	1	0.816	0.941	0.2	0.1882
7.30am	1.180	2	2.36	1.350	1	1.35
7.45am	1.168	2.5	2.92	2.040	1	2.04
8.00am	2.200	3	6.6	1.189	1	1.189
8.15am	3.485	4	13.94	1.010	2	2.02
8.30am	4.750	5.5	26.125	6.60	3	19.8
8.40am	7.35	6.5	47.775	14.50	10.5	152.25
8.55am	9.18	7.0	64.26	16.02	11	176.22
9.05am	10.41	7.52	78.2832	16.82	11.40	191.748
9.20am	12.51	8.40	105.084	17.87	11.70	209.079
9.36am	14.48	9.10	131.768	18.95	12.0	227.4
9.50am	16.21	9.6	155.616	19.80	12.40	245.52
10.05am	18.35	10.4	190.84	19.93	12.50	249.125
10.20am	19.28	10.6	204.368	20.12	12.50	251.5
10.40am	21.70	11.4	247.38	20.80	12.60	262.08
10.54am	22.45	11.6	260.42	21.02	12.60	264.852
11.10am	23.22	11.9	276.318	21.04	12.75	268.26
11.25am	23.45	12.0	281.4	20.85	12.90	268.965
11.45am	23.87	12.0	286.44	20.69	12.75	263.7975
12.00am	23.86	12.0	286.32	20.23	12.50	252.875
12.15am	23.91	12.1	289.311	19.53	12.50	244.125
12.40pm	23.04	12.1	278.784	20.34	12.45	253.233
1.00pm	23.91	12.1	289.311	20.35	12.40	252.216
1.10pm	23.90	12.1	289.19	20.45	12.50	255.625
1:25pm	23.81	12.0	285.72	20.71	12.50	258.875
1:44pm	22.90	12.0	274.8	20.37	12.60	256.662
1:55pm	22.83	11.9	271.677	20.03	12.60	252.378
2.10pm	21.51	11.7	251.667	19.87	12.50	248.375
2.25pm	20.70	11.5	238.05	17.85	12.00	214.2
2.35pm	21.22	11.4	241.908	19.04	12.10	230.384
2.50pm	18.70	10.9	203.83	17.26	11.80	203.668
3.00pm	17.90	10.5	187.95	17.06	11.50	196.19
3.05pm	15.65	10	156.5	14.66	11.00	161.26
3.21pm	14.98	9.6	143.808	14.16	10.90	154.344
3.44pm	10.22	7.5	76.65	10.07	9.00	90.63
4.00pm	9.70	7.5	72.75	10.38	9.00	93.42
4.22pm	6.90	6.5	44.85	7.93	8	63.44
4.35pm	5.64	6.1	34.404	6.62	7.5	49.65
4.40pm	5.05	6	30.3	5.26	7	36.82
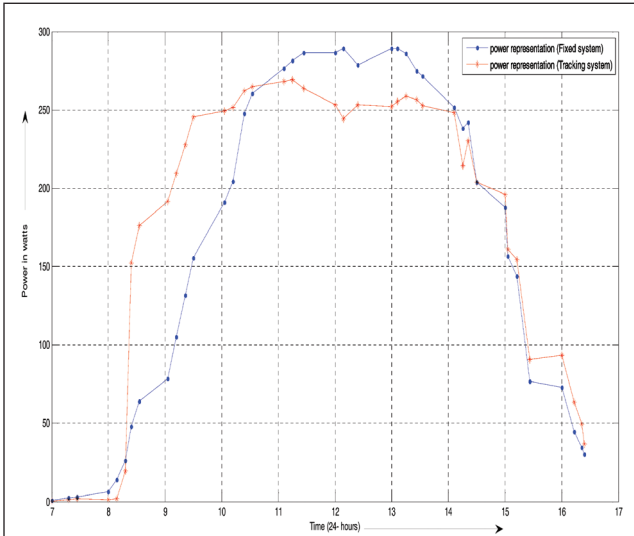
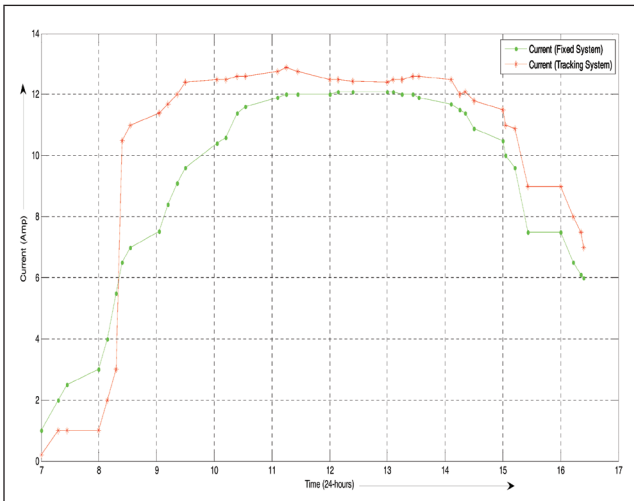FIG. 11   GRAPHICAL REPRESENTATION OF POWER

FIG. 12   GRAPHICAL REPRESENTATION OF CURRENT
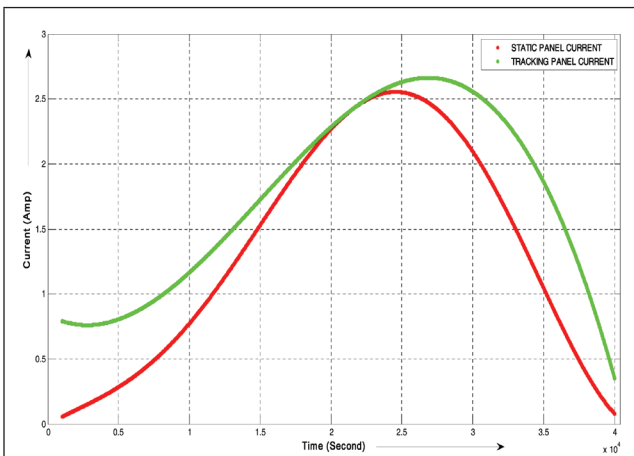
SIMULATION RESULTS

A.

FIG. 13   SIMULATION RESULT OF TRACKING AND
STATIC PANEL CURRENT VS TIME

Figure 13 shows the current values of tracking system and static PV system with respect to time. The variation in efficiency is shown in figure 14.
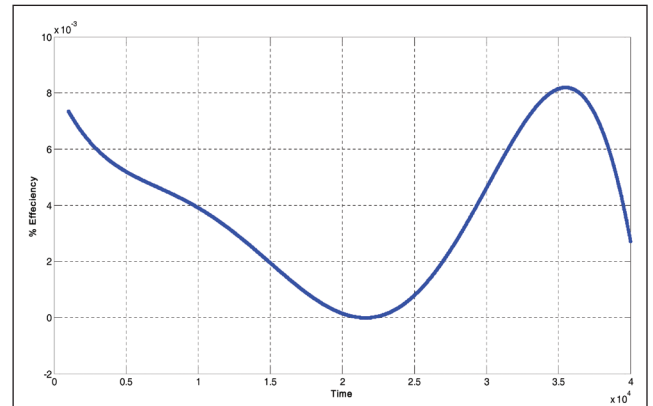

FIG. 14   SIMULATION RESULT OF EFFICIENCY VS TIME

7.0   CONCLUSION

Simulation results show that the improved efficiency of Solar PV system with tracker in azimuthal direction is 36 % compared to static PV System. While in the experiment, the improved efficiency is 38 % compared to static PV system.

REFERENCES

[1]   E C Kern Jr, E M Gulachenski, G A Kern, "Cloud effects on distributed photovoltaic generation slow transient at the gardner, Massachusetts photovoltaic experiment", IEEE Transactions On Energy Conversion, Vol. 4, No. 2, June 1989

[2]   J H R Enslin, M S Wolf, D B Snyman and W. Swiegers, "Integrated photovoltaic maximum power point tracking converter", IEEE Transaction On Industrial Electronics, Vol. 44, No. 6, December 1997

[3]   R Mukaro, X F Carelse, A microcontroller-based data acquisition system for solar radiation and environmental monitoring", IEEE Transaction On Instrumentation And Measurement, Vol. 48, No. 6, December 1999

[4]   E Koutroulis, K Kalaitzakis, N C Voulgaris, "Development of a microcontroller -based, photovoltaic maximum power point tracking control system",   IEEE Transactions On

Power Electronics, Vol. 16, No. 1, January 2001

[5]   P J Hessian, and W J Bonwick, "Experience with a Sun Tracker System," Solar Energy, Vol. 32, No. 1, pp. 3-11 (1984)

[6]   Ayala, J Kenneth, The 8051 Microcontroller Architec-ture, Programming and Applications, 2nd Ed., Penram International Publishing Private Limited, India (1996)

[7]   K C Gupta, P K Mirakhur, and A P Sathe, "A Simple solar Tracking System," SUN Proc. Int. Solar Energy Soc. ,New Delhi , India

[8]   B S William, G Michael, "Power from the Sun", June , 2006

[9]   R Zogbi, and B Laplaze, "Design and construction of sun tracker," Solar energy, Vol.33, pp. 369-372. (1984)

[10] K C Gupta, P K Mirakhur, and A P Sathe, "A Simple solar Tracking System," SUN Proc. Int. Solar Energy Soc., New Delhi , India

[11] K S Karimov, J A Chattha, M M Ahmed et al., Journal of References, Academy of Sciences of Tajikistan, Vol. XLV, No.9, 2002; pp. 75-83