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Design, Construction and Effectiveness Analysis of Hybrid Automatic Solar Tracking System for Amorphous and Crystalline Solar Cells

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***Abstract:* -** This paper concerns the design and construction of a Hybrid solar tracking system. The constructed device was implemented by integrating it with Amorphous & Crystalline Solar Panel, three dimensional freedom mechanism and microcontroller. The amount of power available from a photovoltaic panel is determined by three parameters, the type of solar tracker, materials of solar panel and the intensity of the sunlight. The objective of this paper is to present analysis on the use of two different material of Solar panel like Amorphous & Crystalline in a Solar tracking system at Stationary, Single Axis, Dual Axis & Hybrid Axis solar tracker to have better performance with minimum losses to the surroundings, as this device ensures maximum intensity of sun rays hitting the surface of the panel from sunrise to sunset.

***Keywords:* -** *Solar Tracker, Three way of rotating freedom mechanism, Amorphous & Crystalline Solar Panel, Microcontroller.*

I. INTRODUCTION

At present, there is a great interest towards solving the energy problems facing the world. This has led to research on alternative energy source that would complement the conventional fossil fuel. The alternatives energy sources include solar, nuclear and wind, but in this research work we focused on solar energy. Solar energy is the energy generated by the power of the solar radiation. It is the cleanest source of energy whose use can contribute to saving exhaustible energy sources. Photovoltaic panels convert the suns radiation to electricity. The amount of power available from a photovoltaic panel is determine by three parameters first, the type of tracking system, material of the solar panel and the intensity of the sunlight. In this research the review in the use of two different material Solar panel like Amorphous & Crystalline in a Solar tracking system at Stationary, Single Axis, Dual Axis & Hybrid Axis solar tracker to have better performance with minimum losses to the surroundings. As this device, solar tracker ensures maximum intensity of sun rays hitting the surface of the panel from sun-rise to sunset.

II. THEORY

A solar panel must be able to follow the suns movement to produce the maximum possible power. This is achieved through the designed and implementation of the tracker system, that maintains the panel orthogonal position with the light source. The device is implemented by integrating it with Amorphous & Crystalline solar panel, three dimensional freedom mechanism and microcontroller connected with the computer to accumulate the data. The construction of the tracker is made up of three segments, the mechanical, computer Science and electronics & electrical part respectively. The mechanical system consists of the DC motors, worm gears and the frame that housed the entire system. The electrical & electronic system consists of PV sensor, a comparator circuit and a microcontroller and at last to connect the complete system with computer by software to accumulate data & data base.

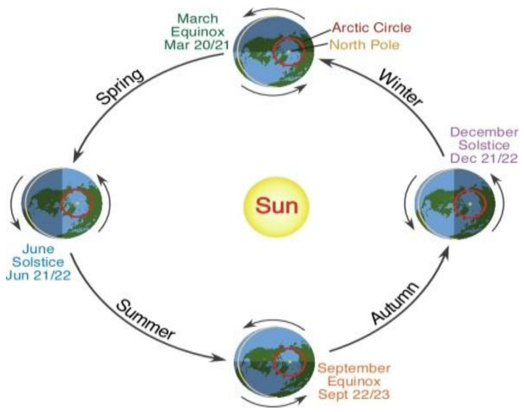

Fig 1 (a) Earth revolution around the Sun.

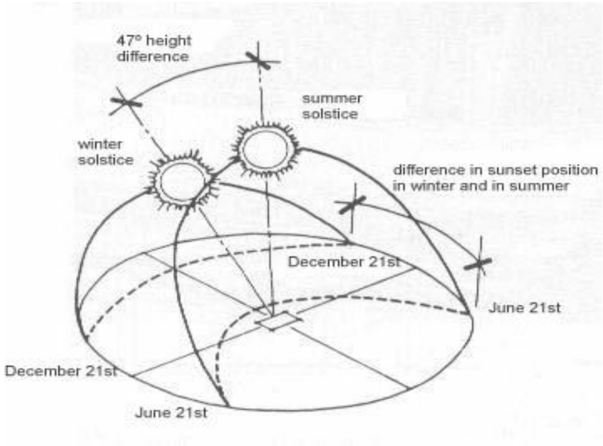

Fig 1 (b) Position of Sun with respect to Earth.

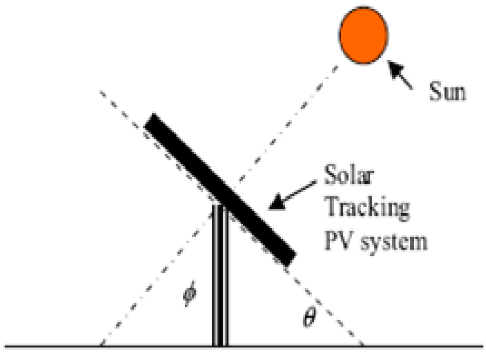

Fig2. Tilt Angle θ of a PV Array.

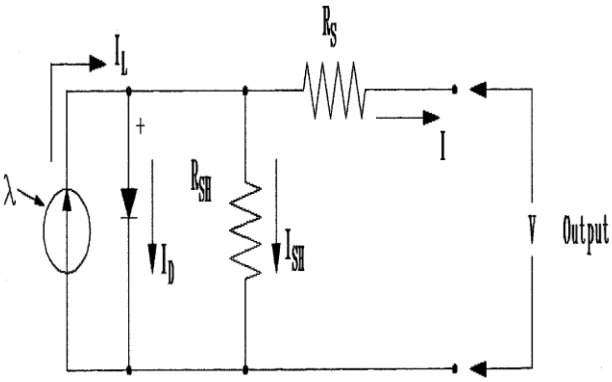

Fig. 3. Equivalent electrical circuit of PV module

For many years, several energy companies and research institutions have been performing solar tracking for improving the efficiency of solar energy production. The current work shows that a comparable system can be designed at a lower cost particularly for academic institutions.

Before the advent of solar tracking, fixed solar panels have been positioned within a reasonable tilt range based on the latitude of the location. A rule of thumb is to select a tilt angle of within ± 15° of the latitude depending on whether a slight winter or summer bias is preferred in the system. The PV array would face "true south" in the northern hemisphere and "true north" in the southern hemisphere. Solar tracking is best achieved when the tilt angle of the tracking PV array system is synchronized with the seasonal changes of the sun's altitude and with the geographical insolation level for optimized solar tracking during the day

As depicted in Fig 1(a), the position of the sun with respect to that of the earth changes in a cyclic manner during the course of a calendar year. Tracking the position of the sun in order to expose a solar panel to maximum radiation at any given time is the main purpose of a solar tracking PV system. The normal to the cell is perpendicular to the cell's exposed face.

Fig2. The sunlight comes in and strikes the panel at an angle. The angle of the sunlight to the normal is the angle of incidence (h). Assuming the sunlight is staying at a constant intensity (k), the available sunlight to the solar cell for power generation (W) can be calculated as-

$$W = A\ k\ \cos\theta \qquad (1)$$

Here, A represents some limiting conversion factor in the design of the panel because they cannot convert 100% of the sunlight absorbed into electrical energy.

Equivalent electrical circuit of pv module, showing the diode and ground leakage currents.

$$Voc = V + I\ R_{sh} \qquad (2)$$

The diode current is given by the classical diode current expression:

$$I_d = I_D\ [QV/AKT-1] \qquad (3)$$

Where I_D = the saturation current of the diode
Q = electron charge = $1.6 \cdot 10^{-19}$ Coulombs
A = curve fitting constant
K = Boltzmann constant = $1.38 \cdot 10^{-23}$ Joule/°K
T = temperature on absolute scale °K

The load current is therefore given by the expression:

$$I = I_L - I_D \left[e^{Q\,V_{oc}/AKT} - 1\right] - V_{OC}/R_{sh} \quad (4)$$

PV CELL TECHNOLOGIES

In making comparisons between alternative power technologies, the most important measure is the energy cost per kWh delivered. In PV power, this cost primarily depends on two parameters, the photovoltaic energy conversion efficiency, and the capital cost per watt capacity. The continuing development efforts to produce more efficient low cost cells have resulted in various types of pv technologies available in the market today, in terms of the conversion efficiency and the module cost. The major types are discussed in the following sections:

(a) Single-Crystalline Silicon

The single crystal silicon is the widely available cell material, and has been the workhorse of the industry. In the most common method of producing this material, the silicon raw material is first melted and purified in a crucible. A seed crystal is then placed in the liquid silicon and drawn at a slow constant rate. This results in a solid, single-crystal cylindrical ingot. The wafers are further cut into rectangular cells to maximize the number of cells that can be mounted together on a rectangular panel.

(b) Amorphous Silicon

In this technology, amorphous silicon vapour is deposited on a couple of µm thick amorphous (glassy) films on stainless steel rolls, typically 2,000-feet long and 13-inches wide. Compared to the crystalline silicon, this technology uses only 1 percent of the material. Its efficiency is about one-half of the crystalline silicon at present but the cost per watt generated is projected to be significantly lower.

III. EXPERIMENTAL SETUP

The experimental setup comprises of different element used for three dimensional freedom mechanisms for tracking the maximum intensity of sun rays. Mechanical Arrangement for movement in three direction i.e. Horizontal axis, Vertical Axis & hybrid Axis is mentioned below.

<u>Horizontal Axis</u>

To rotate the panel along with the sun in horizontal Axis is mounted in a shaft of 1x35inches & clamped by aluminium strips.

Gear Arrangement of three Spur Gear of 72, 16 & 36 teeth respectively with Single start Worm gear connected with Stepper Motor 18°/pulse, 12 Volt, 6Ω has been done for rotating the panel to horizontal axis. (Fig 6)

<u>Vertical Axis</u>

Similar as horizontal axis here too the gear arrangement is with Spur Gear of 72 teeth assembled with the Single start Worm gear connected with Stepper motor 18°/pulse, 12 Volt, 6Ω with Simply supported two wheel bearing. (Fig 5)

<u>Hybrid Axis</u>

For moving the panel to hybrid axis a stud of 10 mm is assembled with Spur gear of 42 teeth & Single start worm gear connected with Stepper motor 18°/pulse, 12 Volt, 3.9Ω. (Fig 7)

<u>Micro Controller</u>

The Micro Controller used in the solar tracking system is P1C16F877A (Fig. 8) contains number of element which performs different work to control the panel & to prepare the data base of the analysis the same was connected with the desktop with Terminal Software. The element of microcontroller is listed below

- IRs detects the sunlight intensity. When consume high sunlight intensity resistance is decreased and supply high current trough it.
- The motor controller IC MAX 232 drive the DC motor by the direction of microcontroller
- LCD JHD162AC is mounted on the micro controller to represent the current Voltage & Current for both the material i.e. Amorphous & Crystalline.
- Amplifier T1P122 used to amplify the data of micro controller 7 provide the input to Stepper motor.

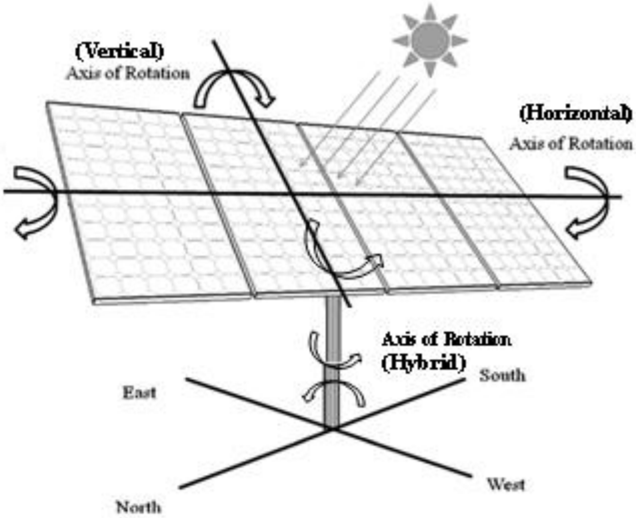

Fig4. Structural view of three ways rotating freedom solar tracker.

In the system shown in Figure 4, a solar panel is mounted over the supporting arm with consisting three direct current motor with gear mechanism, four IR (Infra Red Sensor) sensors and a control box. The light detecting system consists of four Infra Red Sensor (IR) which are IR 1, IR 2, IR 3 and IR4 mounted on the solar panel and placed in an enclosure. The sensors are setup in a way that IR 1 and IR 2 are used to track the sun horizontally for drive the horizontal positioning motor while IR 3 and IR 4 are use to track the sun vertically for drive the vertical positioning motor. The all operations are operated by control box where microcontroller and motor control ICs processes whole detection and control system. So that, all the three motors vertical, horizontal& hybrid movement to ensure proper tracking of the solar panel in any position of the sun with respect to the East-West or North-South.

Solar panel should be directly perpendicular to the sunlight so that radiation of sunlight is highest. But, position of the sun is not same place during the whole day. Therefore, direction of the sun radiation is not same and its changes during the course of the day. So, if we can use solar tracking system it would give maximum solar efficiency.

The dimension of Solar panel used in the setup is 49x15inchs for Amorphous & 30x12inchs for Crystalline. The picture of setup along with the Hybrid Tracking Mechanism is shown in Fig. 9

Fig 5. Gear Mechanism for Vertical Axis

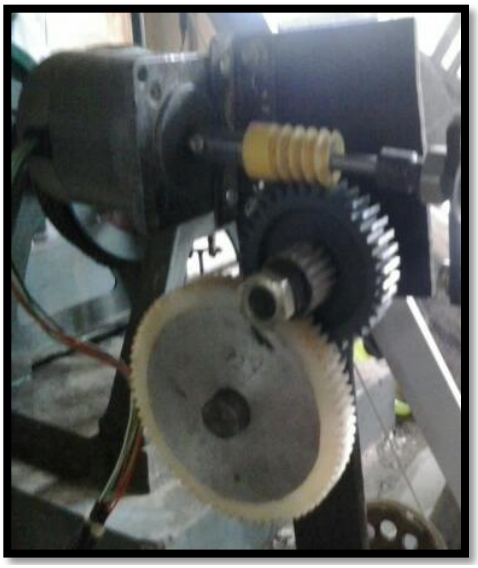

Fig 6. Gear Mechanism for Horizontal Axis

Fig 7. Gear Mechanism for Hybrid Axis

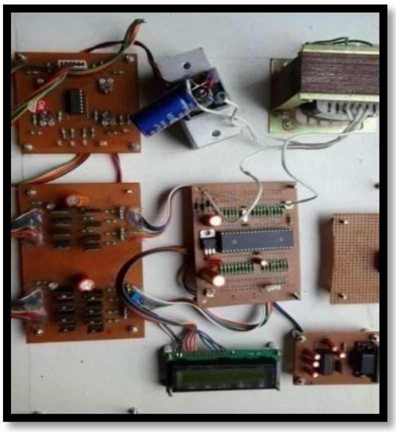

Fig 8. Microcontroller

IV. METHODOLOGY

The complete methodology used in the construction & design of the Hybrid Automatic Solar Tracking system is drawn below (fig. 10) with the help of block diagram. The construction of the tracker is made up of three segments, the mechanical, computer Science and electronics & electrical part respectively.
The key component of the system under above three segments is clearly mentioned in the block diagram used to convert solar energy into electricity.
Here SP1 is Solar Panel 1st for Crystalline,
SP2 is Solar panel 2nd for Amorphous.

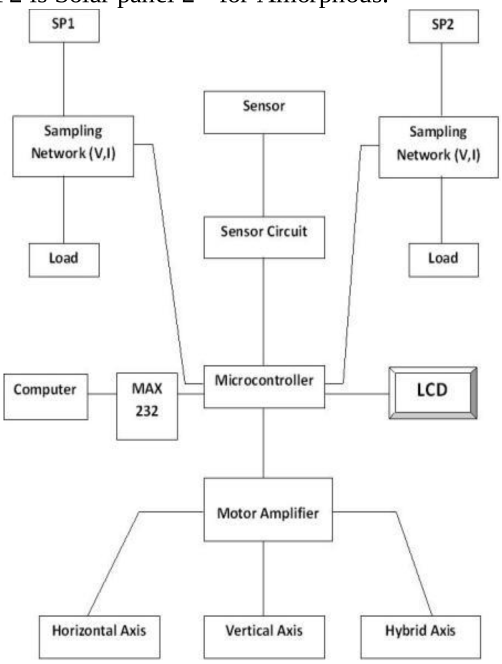

Fig. 9 Schematic view of Hybrid Automatic System.

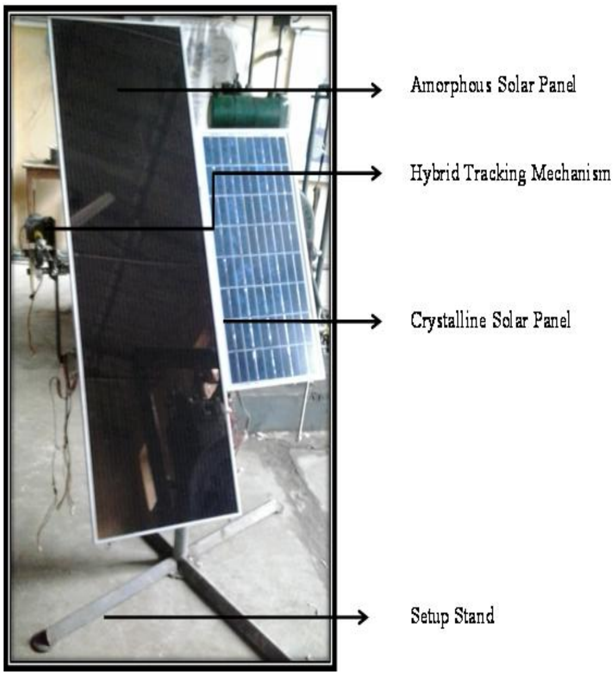

Fig.**10 Block diagram of Hybrid Automatic Solar Tracking Solar Tracking System.**

V. RESULTS & DISCUSSION

The performance assessment of Amorphous & Crystalline Solar panel at different positions are discussed below-

1. Stationary Tracking System.

The power generated by Amorphous & Crystalline Solar Panel at Stationary position that is 23.5°with the horizontal & other two axis are fixed is maximum at 12:00 noon & drop with respect to the time.(Fig 11)
The maximum power generated by Crystalline Solar panel is 13.2W where the power generated by Amorphous Solar panel is 11.9W at 13:00PM

Table1. Amorphous & Crystalline PV Module

Amorphous Solar Panel different position of Solar panel							
Time	Pw of stationary (W)	Pw of single-axis (W)	Pw of dual axis (W)	Pw of hybrid (W)	% difference between St and DA	% difference between SA and DA	% difference between SA and hybrid
10:00	8.85	8.92	8.95	8.98	1.16	0.34	0.66
11:00	10.94	10.96	10.98	12.50	0.44	0.25	14.09
12:00	11.50	14.50	15.90	16.40	38.26	9.66	13.10
13:00	11.90	15.10	16.10	16.10	35.29	6.62	6.62
14:00	10.50	13.84	13.88	16.70	32.14	0.29	20.71
15:00	9.30	12.37	12.39	12.40	33.18	0.15	0.24
16:00	7.90	8.24	8.27	8.29	4.66	0.29	0.55
Average percent difference between 10:00 and 16:00					**21.98**	**3.03**	**8.87**

Crystalline Solar Panel different position of Solar panel							
Time	Pw of stationary (W)	Pw of single-axis (W)	Pw of dual axis (W)	Pw of hybrid (W)	% difference between St and DA	% difference between SA and DA	% difference between SA and hybrid
10:00	9.30	12.30	9.50	9.61	2.15	29.47	21.87
11:00	12.80	12.80	13.70	13.80	7.03	7.03	7.81
12:00	13.20	14.90	17.15	18.50	29.92	15.10	24.16
13:00	12.50	16.20	17.60	18.10	40.80	8.64	11.73
14:00	12.10	15.30	16.15	17.90	33.47	5.56	16.99
15:00	11.10	14.90	15.50	15.90	39.64	4.03	6.71
16:00	10.30	10.90	13.50	13.90	31.07	23.85	27.52
Average percent difference between 10:00 and 16:00					**26.81**	**5.96**	**10.17**

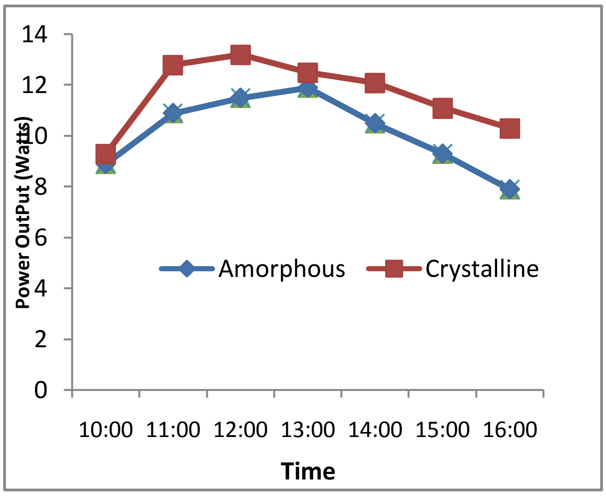

Fig 11.Performance assessment at Stationary Solar Tracking System

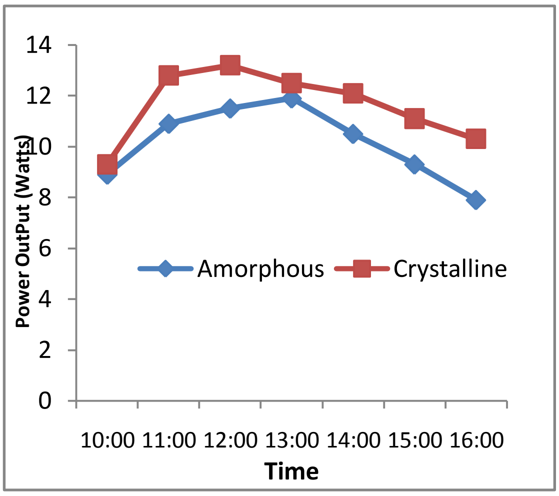

Fig 12.Performance assessment at Single Axis Solar Tracking System

2. Single Axis Tracking system.

As its name implies the panel in single axis tracking system is rotated in one direction that is the horizontal axis to track the sun & ensure maximum sun rays hitting the surface of the panel. The amount of Power generated by the Crystalline Solar Panel is 16.2W & for Amorphous it is 15.1W. (Fig 12)

3. Dual Axis Tracking system.

In dual axis tracking System two of the axis of solar tracker is moving along with the suns direction one is the horizontal axis & second is the vertical axis. The maximum power generated by Crystalline & amorphous in Dual axis tracking system is 17.6 & 16.1 respectively. The curve shows that the maximum power is generated in between 12:00-13:00 PM when the intensity of sunrays is highest. (Fig 13)

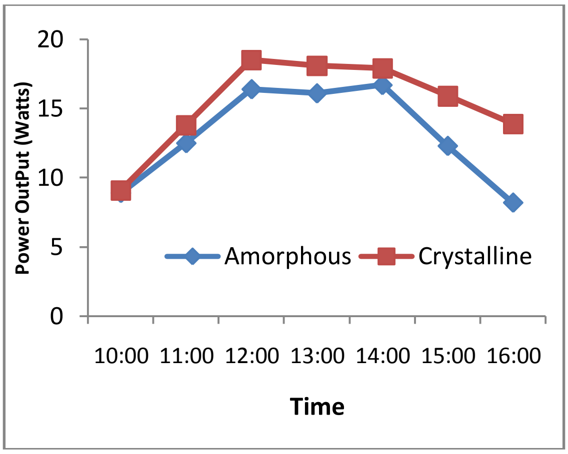

Fig 13.Performance assessment at Stationary Solar Tracking System

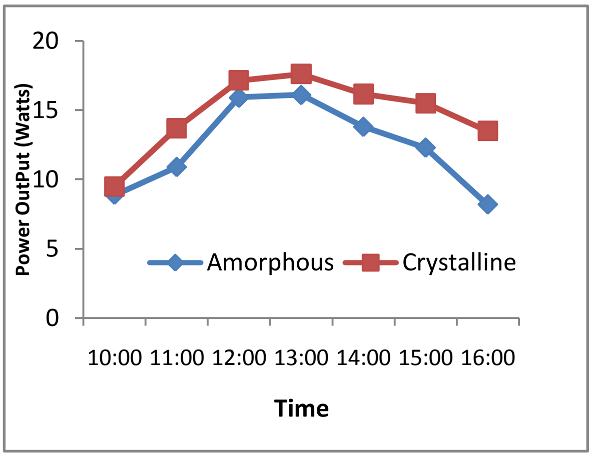

Fig 14.Performance assessment at Hybrid Axis Solar Tracking System

4. Hybrid Tracking System.

In this system the panels are capable to rotate in all the three direction for tracking the sun to have the maximum intensity of solar radiation over the year from sun rise to sun set. The results of hybrid tracking system are as it produces power output 18.5W by Crystalline Solar panel & 16.4W by Amorphous Solar panel. (Fig 14)

VI. CONCLUSION

In this paper, it has been presented a solar-tracking system which is an efficient system. It can be utilize anywhere such as house-hold activities in office even in industrial purposes. Today's world is facing acute power crisis. We need to find new resource and also need to boost efficiency for the production of power from other renewable energy sources.

We also need a better power system to give service to those people who live in remote area. Under this circumstance, this type of project can give a good result when energy crisis is one of the most vital issues in the world.

A comparative analysis was performed using four systems, i.e., hybrid tracking, dual-axis, single-axis, and stationary. The results showed that the use of the dual-axis tracking system produced 17.87% gain of power output, compared with a single-axis tracking system. The gain of output power with the hybrid tracking system was much higher (52%) when compared with a stationary system inclined at 23.5 deg to the horizontal.

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