*Global Science and Technology Journal*
*Vol. 4. No. 1. September 2016 Issue. Pp. 20 – 31*

# Development of an Automatic Solar Heat Tracking Parabolic Heliostat Panel System

Nahin Bahar Chowdhury[1], Mohammed Liaket Ali[2], Bikash Kumar Bhawmick[3] and Md. Mahbubul Alam[4]

*Solar power is the flow of energy from the sun. It is one of the effective forms of renewable energy. The primary form of solar energy are heat and heat. Solar cells, referred to as photovoltaic cells, are devices or banks of devices that use the photovoltaic effect of semiconductors to produce electricity from sunlight. The solar tracking system is generally used in drastically changing environments in the tropical countries like Bangladesh. Due to this types of environment, solar panel doesn't always get the absorbable maximum sunlight without any kind of automations system. It also reduces the power generation capacity of the solar panel. The purpose of this project is to automation of a parabolic solar tracker system which changes the angle of 36° in multi dimension and different time depending on sunlight by using sensors(LDR) to produce sufficient electricity and reduce the power crisis of our country*.

**Keywords**: Mechatronics, Renewable Energy, Fluid mechanics.

## 1. Introduction

A solar tracker is a kind of device that directs a payload towards the sun. Here payloads can be lenses or other optical devices, reflectors, photovoltaic panels. In case of flat panel photovoltaic, the main objective of the trackers is the minimization of the angle of incidence between the photovoltaic panel and the incoming sunlight. For a flat-panel solar collector the effective area of collection changes with the cosine of the misaligned panel with the sunlight. Sunlight has two main components, one is the "direct beam" which carries approximately 90% of the solar energy, and the other is the "diffuse sunlight" that carries the remainder. As the direct beam contains majority of the solar energy that's why for the maximization of collection, the panels are required to be exposed to the sun as long as possible. The collectors that cannot move are not suitable because of the complicated motion of the sun across the sky, and the degree of accuracy required to be correctly aimed at the sun's rays onto the target. A heliostat mirror is usually mechanized with a dual axis tracking system, where at least one axis is mechanized. Mirrors may be flat or concave according to the applications. Trackers can be classified with respect to the number and orientation of the tracker's axes. In comparison with a fixed solar panel, a single

1. Nahin Bahar Chowdhury, Department of Mechanical Engineering, Chittagong University of Engineering and Technology (CUET), Bangladesh, Email-nahin.me@gmail.com
2. Mohammed Liaket Ali, Department of Mechanical Engineering, Chittagong University of Engineering and Technology (CUET), Bangladesh, Email-malicuet@gmail.com
3. Bikash Kumar Bhawmick**,** Department of Electrical and Electronics Engineering, Chittagong University of Engineering and Technology (CUET), Bangladesh, Email-anjan.13@outlook.com
4. Prof. Dr. Md. Mahbubu lAlam, Department of Mechanical Engineering, Chittagong University of Engineering and Technology (CUET), Bangladesh,Email-malam@cuet.ac.bd

axis tracker enhances total annual output by approximately 30%, and a dual axis tracker enhances an additional 6%.

Photovoltaic trackers can be grouped into two types: concentrated photovoltaic (CPV) trackers and standard photovoltaic (PV) trackers. As a developing country Bangladesh has many problems, Power crisis is one of them. The development of a country depends on electricity. There are two types of power plants. One type is thermal power plant and another is hydroelectric power plant at Kaptai in Chittagong. This power plant cannot provide sufficient amount of electricity. In thermal power plants we use coal to produce electricity but the cost is very high. Our primary fuel is gas. But the stocks of them are limited. Installation cost of a nuclear power plant is also very high that we can't afford. So we should think about an alternate fuel such as renewable energy. The form of renewable energy is water, wind, geothermal and biomass. Using the renewable energy to produce heat or electricity is not a new idea. Solar tracking is necessary for most of the solar systems to collect maximum amount solar radiation. Concentrators need a higher degree of accuracy to ensure that the reflected sunlight is directed towards the absorber, which is at the focal point of the reflector. Sun tracker can help to increase overall efficiency of a solar installation by over 40%. Usually the automated solar tracker systems increases power generation to a limit when this automation is applied to a concentrated system it leads the system to a great efficiency which made us to do this. We tried to utilize the local stuffs to automate a solar panel system with an increase in power generation in minimal cost so that local people can have it as per requirement in a low margin price rate.

The paper is organized as follows. Section 1 presents the introductory basic things about the solar energy, solar tracker system, its basic functions, emerging possibility of alternate energy source and some review on this issue. Section 2 describes the literature review on solar energy converters. Section 3 discusses the basic methodology of the system (how the solar tracker tracks). Section 4 presents how the system is designed and fabricated along with its different units. Section 5 depicts the overall setup of the system. Section 6 shows the collected data in a table. Section 7 presents the comparative graph and the final outcomes. Section 8 concluded the paper with its limitation and future aspects.

## 2. Literature Review

The Swiss scientist Saussure (1767) is credited with inventing the world's first solar collector or "solar hot box". The photovoltaic effect was first discovered by French physicist Becquerel (1839). The French scientist Mouchot (1861) made his solar engine. At that time, the primary uses of solar technologies ranged from cooking food and distilled water to pumping water for irrigation. Adams and Day (1876) discovered that electricity is produced when selenium is exposed to light. In the United States, Kemp (1891) was considered as the father of solar energy. He patented the world's first solar water heater. His invention was marketed then in the California, where in it became so popular that about 30 percent of the houses in Pasade used that water heater. However Fritts(1883) built world's first solar cell and coated the semiconductor selenium. An extremely thin layer of gold is used for coating to create the junctions. Albert Einstein wins the Nobel prize for his theories explaining the photoelectric effect. Modern solar cell was patented by (Ohl 1946) U.S. patent 2,402,662, "Light sensitive device". The sensitivity of an accurately prepared silicon wafer to sunlight, and the "solar cell" was developed. U.S. space satellites (1950) used PV cells as power source, and they continue to be the prime power source for both manned and unmanned space projects today.

## 3. Research Methodology

The sun is a prime source of renewable energy that emits energy as electromagnetic radiation from the center of the solar system at an extremely large and relatively constant rate, 24 hours per day of the year. This emitted radiation is captured by the solar panel and converted into energy. For utilizing maximum sunlight it is necessary to determine the power loss. Most of the power loss is due to misalignment of the solar panel. The energy that comes by the direct beam decreases with the cosine of the angle between the panel and the incoming light. But the angle of incidence that is up to around 50°, the reflectance is said to be constant, below it reflectance decreases rapidly.

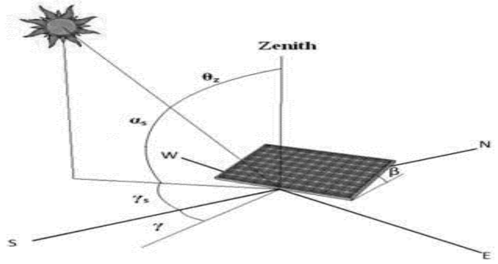
**Table 1: Power Loss (%) Due to Misalignment (Angle i)**

| i | Lost = 1 - cos(i) | i | Hours | Lost |
|---|---|---|---|---|
| $0^0$ | 0% | $15^0$ | 1 | 3.4% |
| $1^0$ | 0.015% | $30^0$ | 2 | 13.4% |
| $3^0$ | 0.14% | $45^0$ | 3 | 30% |
| $8^0$ | 1% | $60^0$ | 4 | >50% |
| $23.4^0$ | 8.3% | $75^0$ | 5 | >75% |

A tracker with an accuracy of ± 5° can deliver more than 99.6% of the energy produced by the direct beam and add 100% of the diffused light. The sun travels through 360 degrees east to west per day, but we can see 180 degrees during a half day from a fixed reference location. Local horizon makes the effective motion about 150 degrees. A fixed solar panel thus according to the table above, will lose 75% of the energy in the morning and evening. Some losses can be recovered by the rotating panels to the east and west. The sun also moves through around 46 degrees south and north with a year. If the panels set at the midpoint between the two poles it will see the sun moving 23 degrees on either side and it will cause losses of 8.3%. A tracker that accounts for both the daily and seasonal motions is known as a dual axis tracker. On one day every year the sun is comes above our planet's equator. On this day, the angle between a line that points to the sun and a line that points straight up exactly matches the latitude of the place. At this position in the middle of the day the sun will be at 0º from the vertical. At 40º of the equinox the sun will be 40º to the south from the vertical. The sun's position on the equinox is the average location of the sun throughout the year. In the summer, the sun appears higher in the sky and increases the duration of sunlight seen in a day. But in the winter it appears lower and decreases the length of sunlight. The sun is

23.45º higher than on the equinox, or at 40 - 23.45 = 16.55º to the south of vertical at summer. In winter the sun is 23.45º lower than on the equinox, or at 40 + 23.45 = 63.45º to the south of vertical. In northern hemisphere at latitude higher than 23.45º the sun will never shine from the north at solar noon.

**Figure 1: Solar angles used in power calculations for PV panels**



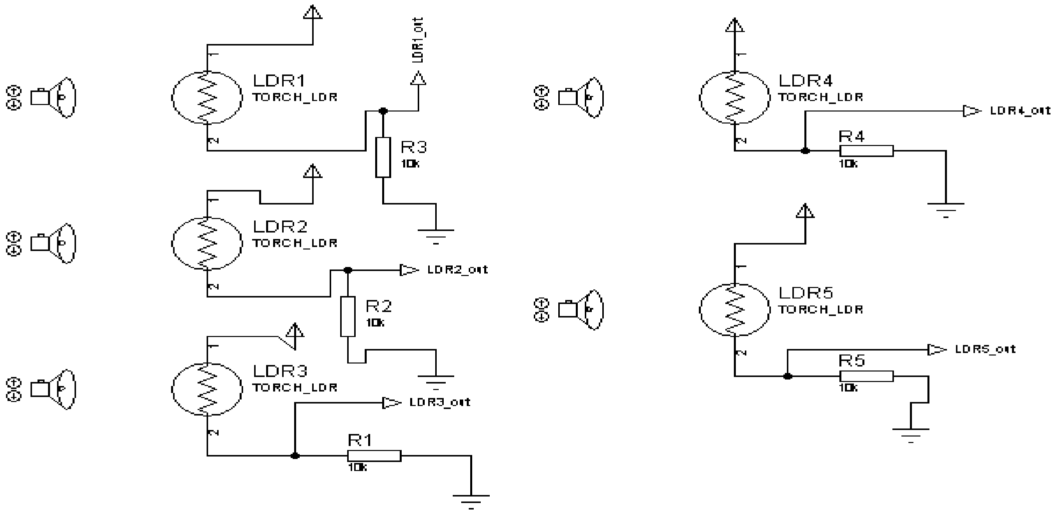

## 4. System Design and Fabrication

Five light-dependent-resistors (LDR) are placed on each side of a parabolic designed paper to track the sun. In a way that when the panel is directly facing the sun, they will be getting equal amounts of light. I put each LDR at 30 degrees from the solar panel. In theory, when identical LDRs get the same amount of light, the temperature of the water is increased which measured by a temperature measuring sensor and is shown in the display. On the other hand, another temperature measuring sensor measures the normal temperature of water which is also shown in the display. The differences between the two temperatures are the resulting output of solar tracker automation. In the very beginning of the day, the sun light detects by the first light-depending-resistor. After the rotation of 30 degree angles of the sun the light is detects by the 2 no LDR of the model and the servo motor rotates the parabolic tracker at that fixed angle.

### A. Sensor Unit

In our project we used 5 light dependent resistors (LDR).The outputs of these LDRs are fed to the op-amps (operational amplifier). The signals given by the LDRs are very random and this fluctuating output is not desirable. That’s why op-amps are used to stabilize the signal and to make the analogue signal into digital. Here LDRs are used for the purpose of following the sun’s motion. This Light Dependent Resistor (LDR) has a resistance which varies according to the amount of light falling on its surface. The temperature of the water in the vessel will increase only when identical sensors get equal amounts of light.

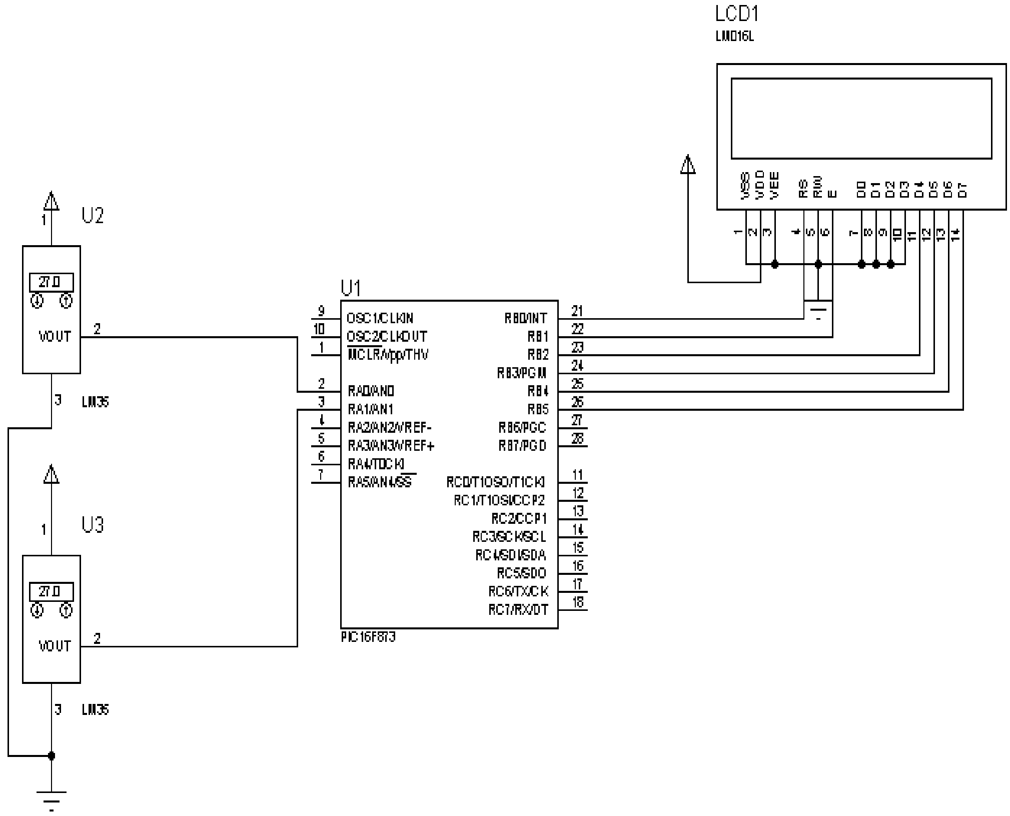
**Figure 2: Sensor Unit**




### B. Temperature sensing unit

Two LM35 temperature sensors are used. One is used to measure the temperature of normal water and the other is temperature of the heated water by the PV panel. Lm35 can measure temperature more precisely than a thermistor. It is a sealed circuit so no question of oxidation. It produces a higher output voltage compared with thermocouples and don't required an additional voltage amplifier. This temperatures are shown in the LCD screen.

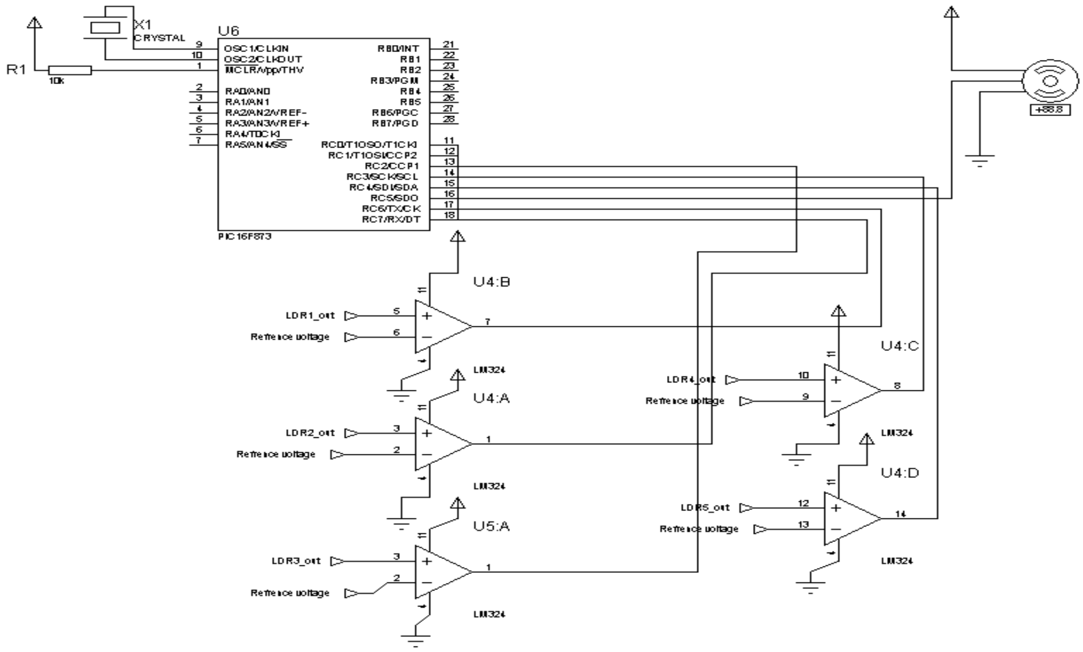
**Figure 3: Temperature sensing unit**




## C. Motor control unit

Two servo motors are used in our prototype project. This motor is controlled by a PIC16F73. Input signals are fed by the Op-amps. Initially first LDR detects the sunlight and when the second LDR detects the sunlight that means sun is moved by an angle 30 degree as all the LDRs are positioned in a 30 degree spaced pattern. This signal is supplied to the microcontroller and it will rotate the servo motor by a 30 degree angle. That means solar panel will be faced towards the sun.

**Figure 4: Motor control unit**




## 5. Overall Setup

In these systems circuits with operational amplifier, voltage comparator, light dependent resistor are used to generate pulses, which are fed to a DC motor for tracking of solar PV panel. DC motors are coupled with gears (Servo motors) for Tracking PV panel.

**Figure 5: Setup of parabolic solar tracker**

## 6. Data collection

**Table 2: Output of photovoltaic panel**

| Time of the day | Day 1 | | Day 2 | | Day 3 | |
|---|---|---|---|---|---|---|
| | Temperature without solar tracker (°C) | Temperature with solar tracker (°C) | Temperature without solar tracker (°C) | Temperature with solar tracker (°C) | Temperature without solar tracker (°C) | Temperature with solar tracker (°C) |
| 10.00 AM | 24 | 26 | 23 | 24.5 | 23 | 24.5 |
| 11.00 AM | 25 | 33 | 24 | 31 | 24 | 31 |
| 12.00 PM | 28 | 39 | 26 | 34 | 26 | 34 |
| 1:00 PM | 29.06 | 46.94 | 28 | 36 | 28 | 36 |
| 2.00 PM | 29.29 | 45.56 | 29 | 42.5 | 29 | 42.5 |
| 3.00 PM | 29 | 46 | 29.33 | 44 | 29.33 | 44 |
| 4.00 PM | 28 | 44 | 27 | 43 | 27 | 43 |

The table 7.1 shows that, the temperature of the solar tracker at different times of 3 days. It refers that, temperature with solar tracker is high than without tracker.

## 7. Results

The recorder temperatures of the water for 3 days are plotted against time in the graphs. Those data are taken in two steps. Once with solar tracker and another time without solar tracker.

Figure 6: Temperature Vs Time curve (with and without tracker) of day-1.

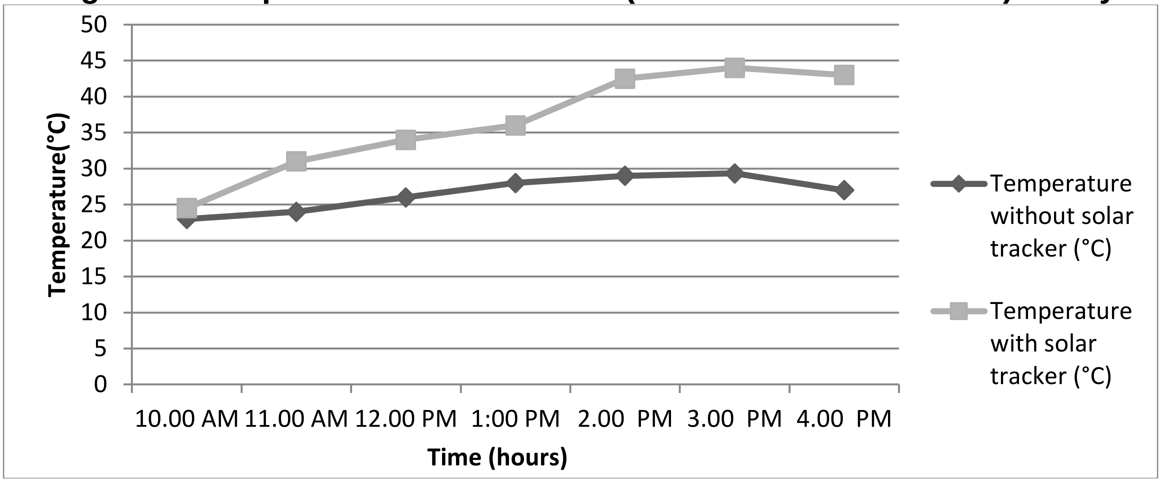



Figure 7: Temperature Vs Time curve (with and without tracker) of day-2.

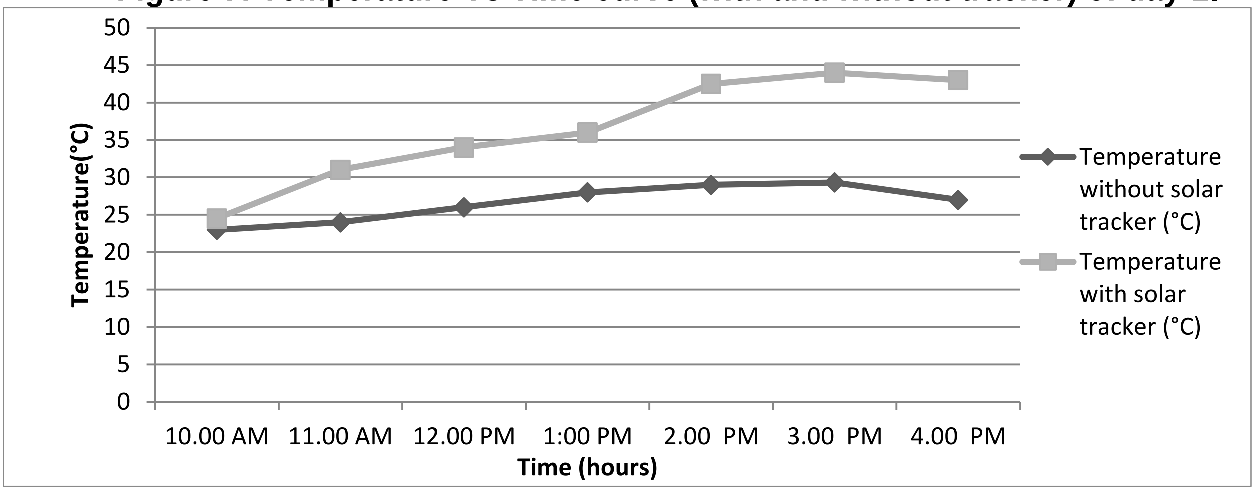
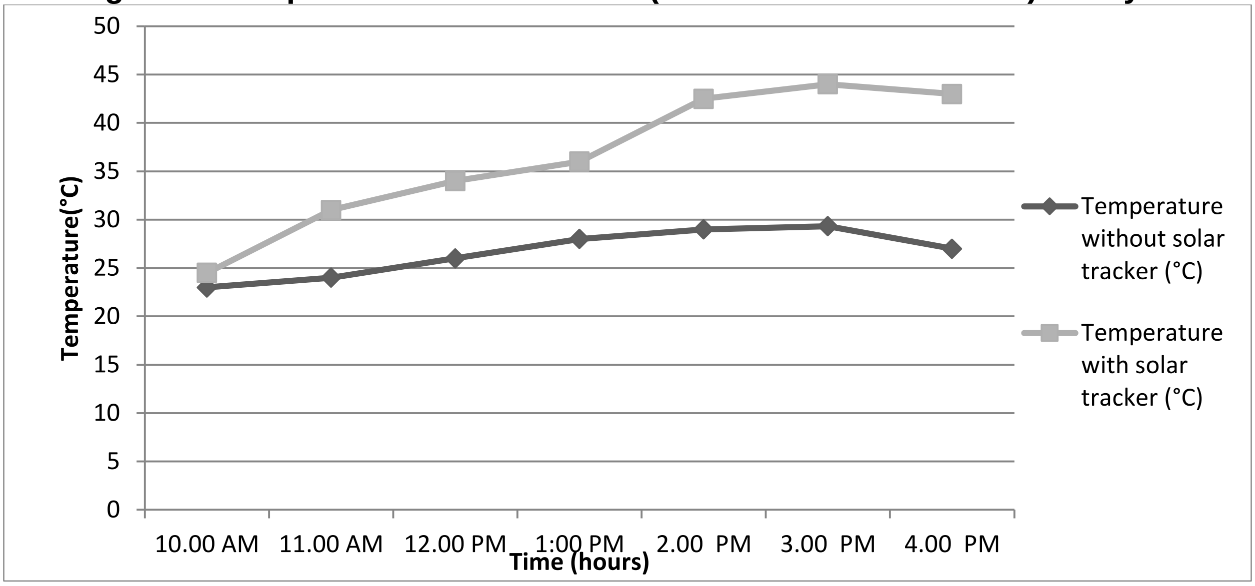


**Figure 8: Temperature Vs Time curve (with and without tracker) of day-3**.




**Efficiency calculation:**

**Table 3: Voltage and Current Output the Solar Panel**

| Time of the day | Without Solar tracker | | With Solar Tracker | | Power | |
|---|---|---|---|---|---|---|
| | Voltage(V) | Current(A) | Voltage(V) | Current(A) | Fixed | Tracker |
| 10.00 | 16.50 | .57 | 16.81 | .72 | 9.41 | 12.11 |
| 11.00 | 16.65 | .61 | 16.95 | .77 | 10.16 | 13.10 |
| 12.00 | 16.40 | .65 | 17.10 | ,81 | 10.66 | 13.86 |
| 1.00 | 16.50 | .75 | 16.84 | .79 | 12.55 | 13.40 |
| 2.00 | 16.70 | .76 | 16.20 | .82 | 12.70 | 13.30 |
| 3.00 | 16.23 | .63 | 16.75 | .93 | 10.33 | 15.57 |
| 4.00 | 16.12 | .62 | 16.50 | .88 | 9.86 | 14.52 |

Power calculation, $P = V \times I$

Total power consumption by the solar cell without tracker is, $P_f$ = 75.67 W.

Total power consumption by the solar cell with tracker is, $P_t$ = 95.86 W.

Now the percentage of power consumption increased by using tracker is,

= (95.86 – 75.67) / 75.67

= 0.2668 or 26.68 %

Here the results shows comparison between the power generation by the solar cell with tracker and without tracker and the final percentage calculation shows that an increase of 26.68% in the power generation is happened when an automatic solar heat tracking parabolic heliostat panel system is introduced.

## 8. Conclusion

The tracking mechanism is capable of tracking the solar panel according to the position of the sun to keep the solar panel perpendicular to the Sun's incident rays with greater accuracy. So, now we can conclude that by using the tracker we can make the maximum use of the day light. Designed simplicity, low cost and material availability make this tracking system different, more effective and acceptable in the market than any other tracking system. This tracking system is simple and easier than any other tracking system with minimum cost because only simple sensor (LDR) and driver circuit (op-amp) are used which are available with low in cost. This features make this system unique as in the developing countries people used to prefer affordable utilities with maximum output. With this Sun Tracker, it is possible to get substantially more power from each PV panel on collector and this increase in power results in lower cost per watt. In this project, output power without solar tracker is 75.67 W and with solar tracker is 95.86 W. increases amount of power is 26.68%. As the world is moving to renewable energy more and more where Photovoltaic cells are most used method to conserve solar power this type of technology can add a great efficiency to the total power generation. This tracking system is just single axis and have to adjust the total system according to the position of the sun but azimuthal mothion of the tracker do not have this types of problem and will certainly produce greater power.

## References

Abu, MR, Abdallah, S, and Muslih, LM 2011, 'Design, construction and operation spherical solar cooker with automatic sun tracking system', *Energy Conversion and Management,* Volume 52, Issue 1, Jan., PP 615-620

Al-Soud, MS, Abdulla, E, Akeylah, A, Adallah, S and Hrayshat, ES 2010, 'A parabolic solar cooker with automatic two axes sun tracking system', *Applied Energy*, Volume 87, Issue 2, Feb., PP 463-470

Batayneh, W, Owais, A and Nairoukh, M 2013, 'An intelligent fuzzy based tracking controller for a dual-axis solar PV system'*, Automatic in Construction*, Volume 29, Jan., PP 100-106

Benling, S 1999, 'rush DC servomotor implementation using PIC 17C756A', Microchip Technology Inc.

Bucella, T 1997, 'Servo control of a DC brush motor', Teknic Inc

Cliford, MJ and Eastwood, D 2004, 'Design of a novel passive solar tracker', *Solar Energy*, Volume 77, Issue 3, Sept., PP 269-280.

Charais, J 2002*, 'RC model aircraft motor control'*, J.,microchip technology Inc. 1st ed pp 44-88.

Floricica, A 2008, 'Low power capacitive sensing with the capacitive sensing module', Application AN1103, Microchip Technology

Ferme, T 2007, 'Software handling for capacitive sensing', Microchip Technology.

Ghassoul, M and Radwan, F 'A programmable logic system to control a solar panel to pump water from a well', *5th IEEE TEM,* KFUPM Dhahran, pp 67-70

Ghassoul, M 2009, 'Design of an intelligent solar tracking system using PIC18F452 micro Controller', *International conference on Industrial Electronics,Technology & Automation 2009,* Bridgeport University, December, pp 4-12.

Hession, PJ and Bonwick, WJ 1984, Experience with a sun tracker system, *Solar Energy*, Volume 32, Issue 1, pp 3-11

Huang, BJ, Ding, WL and Huang, YC 2011, 'Long-term field test of solar PV power generation using one-axis 3-position sun tracker', *Solar Energy*, Volume 85,Issue 9,Sept., pp 1935-1944

Maximum power solar converter, 2008, Application AN1211, Microchip Technology, visited 9/23/2015, 7:27PM, http://solarnavigator.net/solar_power.htm.

Par, EA 1996, *Programmable logic controllers,* Newnes, pp-76-98.

Peatman, JB 2003, *Embedded design with the PIC18F452 microcontroller*, Pearson Education, Inc.

Yedamale, P 2002, 'Speed control of three phase induction motor using PIC 18 Microcontroller', Microchip Technology Inc,