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Solar Tracking Systems – A Review

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Abstract

The biggest challenge and concern for the upcoming 50 years is the idea of power generation, by making less use of the fossil fuels. The idea of solar energy as fuel, and the fact that we can convert freely available energy which we receive from the sun into usable energy, is fascinating, and is probably at the highest priority at the moment as compared to other renewable energy sources. Although solar energy as fuel is the go-to form of green energy, it is faced with some problems. The two main problems are, first, it is geographically constrained and second is that it is nearly impossible to collect a hundred percent heat energy from the sun at every single point of the day. This happens because the relative angle of the sun changes continuously with respect to the earth. This leads to a problem. The watts delivered by the solar panels gets reduced. Thus, it gets more challenging to generate power. To overcome this problem, developers and researchers came up with an innovative solution, "Solar Trackers". After a lot of studies and extensive research conducted on this technology, it can staunchly said that solar trackers are the best alternative as compared to static solar panels, for increasing the efficiency. In this paper different types of tracking systems, their setups and comparison in between their performances are reviewed. After carefully analysing and comparing different results obtained from different solar tracking systems, we can say that altitude and azimuth dual axis solar trackers are more coherent, accurate and efficient in collecting the radiation as compared to the traditional static solar panels and the single axis solar trackers. However, we should also consider the fact that the dual axis solar trackers are not pocket friendly and are not feasible to install compared with the single axis solar tracking system.

Keywords: *Azimuth, Latitude, Microcontroller, Static Panels, Solar Energy as Fuel, Solar Tracker*

1.0 Introduction

For any nation to be developed and to progress, energy plays a huge factor in it. The rapid progress in industrialization and urbanization has led to a drastic unbalanced channelization of energy globally. A huge part of energy is withdrawn, administered and enthralled in the global society daily. Fossil fuels are responsible to produce nearly 85 percent of the energy. As we know, fossil fuels are not available in huge amounts, their resources are limited and most importantly, their depletion rate has gone an all-time high, the increasing amount of their usage and consumption is resulting in the rise of the Earth's temperature, which in turn is resulting in a global issue. Global warming. Scientists, researchers, developers, and entrepreneurs have now started to realise the importance of renewable energy sources. Extensive research and study are going on, on how to make the best use of freely available energy sources. Therefore, the demand for solar energy as fuel, geothermal energy, ocean tidal and wave energy has increased. To create a sustainable environment for generations to come, it is important to start using this renewable energy.

Due to the overuse of the already depleting fossil fuels, energy deficiency problems have arisen. Especially the third world countries have started facing energy deficiency problems. This has urged researchers to find an alternative to the fossil fuels which would fulfil its

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demands without leaving any carbon footprints behind. As discussed above, the alternative energy sources include solar, wind, geothermal, tidal, ocean and nuclear. Solar energy as fuel, in simple terms is the energy generated by mobilizing the power obtained from the sun. It is therefore the cleanest source of energy having zero carbon footprints, it is a green energy which does not pollute the environment. Earth acquires around $1.8x10^{12}$ MW of power from the sun, which is very huge in comparison to the utilization of energy for commercial purposes. One of the main issues of solar energy as fuel is that it is geographically constrained. It is because, even in the extreme and arid regions on earth, where the temperature exceeds the normal temperature on earth, the available solar radiation flux seldom exceeds to 1 kW/m^2. This becomes a problem because it is still sparse for most of the technological utilities. Only 18 to 20 percent of the sun's energy which falls on the panels, is converted into consumable energy.

There is another factor which reduces this collected energy furthermore. Light gathering loss. It is fully dependent on the relation of the angle of incidence of the sun to that of the solar panel. Simply speaking, an ideal situation for maximum energy collection is, where the sun's rays are incident to the solar panel's surface at exactly 0 degrees. So, we can say that power generation will be maximum if the panel is facing the sun directly. Let's take a real-life example. Say, a panel is mounted parallel with respect to the ground. Then according to the theory of radiation collection, the panel will collect almost no radiation from the sun at sunrise or sunset, as the angle of incidence in this case will be 90 degrees. Whereas, maximum radiation collection will be done when the sun is perfectly above the panel's surface, that is at midday as the angle of incidence will be approaching to 0 degrees. As the day will progress towards dusk, the increasing angle of incidence will cause the power generation to decrease gradually.

From the above real-life example, we can see that, in order to gain maximum power output from the solar panels, it should always be kept aligned always with respect to sun, that is, the angle of incidence between them needs to be maintained. This can be done by automating the navigation of the solar panels to make them continuously face the sun. Here, a solar tracking system is very useful. This process of detecting the position of the sun and aligning itself with it is known as Solar Tracking. The device is called as a solar tracker.

1.1 Solar Tracking System - Components and Basic Working Principle

For any solar tracker to work, it requires basic components that are mentioned below.

- PV solar module
- LDR sensors
- Servo motors
- PIC Microcontroller
- A voltage regulator
- Battery
- A charge controller

The working of the trackers consists of a Sun tracking algorithm, a control unit, a positioning system, a transmission system, and sensing devices like LDRs. An algorithm is developed to calculate the position of the sun throughout the day. These algorithms may be based on

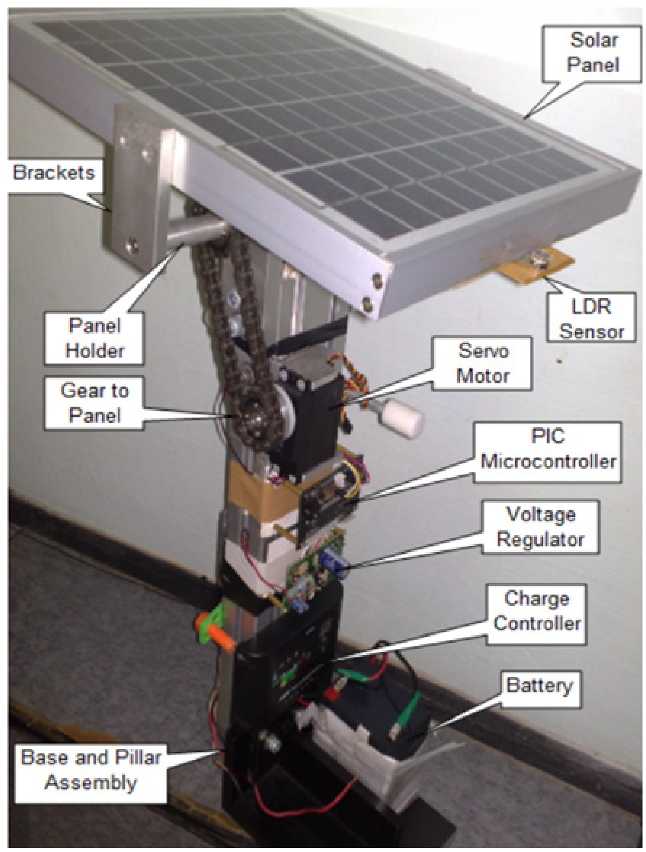

Figure 1. Actual solar tracker design[1]

real time light intensity readings or some are based on astronomical references. For such, the system's algorithm is pre-fed with the data of astronomical positions of sun and various space objects. The control unit applies the algorithm, and it coordinates with the movements of the positioning system. The positioning system helps manoeuvre the trackers or reflectors to face the sun. It can be either electric or hydraulic. The drive mechanism usually consists of mechanical components like actuators, hydraulic cylinders, and gears. It is mainly responsible for the movement of the solar trackers as determined by the positioning system. Sensing devices are used to sense the amount of radiation coming from the sun. They are a group of sensors generally used to monitor ambient condition for pressure, humidity, and temperature[2].

1.2 Different Types of Solar Tracking Techniques

1.2.1 Based on Collectors

a) Flat Plate Photovoltaic Panel (PV)

In flat plate photovoltaic panel tracking system, the main aim is to reduce the angle of incidence between the sun band the earth as much as possible (also known as cosine angle). By doing so, studies have proven that maximum energy could be generated. M. Koussa *et al.,*[3] have studied the effects of various tracking systems on flat plate collectors. They compared the performances of these systems on various days and sky states in region of an arid and hot climate located at Ghardaïa site, in the north of Algeria's desert. The data collected was measured from the year 2004 to 2007 in which 14 clear days, 12 partially clear days characterized by different clarity level factors and 5 cloudy days were taken into consideration. It was found that dual axis solar trackers gave maximum results (45 - 65%) on sunny clear sky state compared to other systems. But on a cloudy day, each system got equivalent results.

b) Concentrated Photovoltaic (CPV)

The optics used in CPVs are responsible to concentrate the amount of incoming sunlight onto the solar panel. Thus, large amount of energy is concentrated on the solar panels, giving a boost in the efficiency of the system. The most common ways to do this is by installing components like lenses and curved mirrors. Muhammad Burhan *et al.* studied and analysed long term performances of 2 CPV prototypes. Parameter which was considered while analysing the performance was electrical ratings in kWh/m[2].

Figure 2. Concentrated photovoltaic panels[4].

The electrical ratings were calculated and then they were compared with the conventional PV systems installed in various parts of Singapore. It was found that the newly developed mini dish Cassegrain type CPV were 86% efficient compared to other PV systems. Also it was found that the CO_2 savings could be achieved using this type[4].

c) Concentrated Solar Power (CSP)

The principle of concentration of solar power was applied by Das *et al.,*[6] They developed an innovative system using a mirror booster which gained them 75% more power from a regular tracking system. They placed the mirror in such a way that more light was reflected on the panels, thus increasing the efficiency of the system. But this comes with a problem. They realised that installing more mirrors will result in generation of greater amount of heat and can thus damage the panel. More or less, this system can be useful if the positioning of the mirror is done in a proper way. Odeh *et al.,*[7] developed a parabolic trough using the same principle of concentrating the radiation, for water heating.

Figure 3. Mounting a mirror on a solar panel system[5].

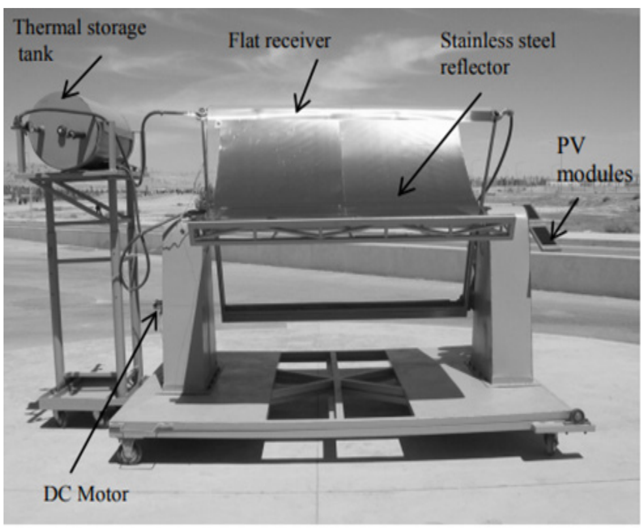

Figure 4. Experimental Setup developed by Odeh *et al.*[7].

To test the experimental setup, a thermal performance test with open loop water flow was carried out during a sunny day. It was observed that the solar irradiation was constant throughout the experiment, but the solar collector efficiency increased at noon. The setup proved to be 60 percent efficient at noon.

1.2.2 Based on the Axis

A) Single Axis Tracker

In simple words, single axis trackers have only one degree of freedom that is they can either move North to South or East to West. They are used most commonly in many tracking systems and are proved to be much more efficient that the traditional static solar panels. Anuraj *et al.,*[8] developed a simple single axis solar tracker using steppe motor. It is made using two photo resistors wherein to meet a normal day light condition AIN0 needs to provide higher voltage than AIN1. Resistance is inversely proportional to the magnitude of sunlight incident on the photocells. The tracker will move to 3.75 degrees every 15 minutes. As only two resistors are used, it reduces the cost, thereby increasing the efficiency to about 20%. The power loss during the process is bare minimum.

i) Horizontal Single Axis Tracker (HSAT)

In this type of tracking system, a single axis is mounted horizontal with respect to the ground. Li *et al.,*[9] developed a mathematical procedure to estimate the daily collection of radiation by the system. He found that East-West sun tracking performed less efficiently (8% increased efficiency) and North-South sun tracking performed more efficiently (around 11-12% increased efficiency), which gained maximum efficiency.

ii) Vertical Single Axis Tracker (VSAT)

In this type of tracking system, the orientation can be North/South or East/West and the system will move in Up/Down motion. They are extremely beneficial in the northern regions where the latitudes range between 40 to 50 degrees[10].

iii) Tilted Single Axis Tracker (TSAT)

The axis of rotation of the Tilted Single Axis Tracker (TSAT) is in between the vertical and horizontal axis. That's why the name. While installing them, it needs to

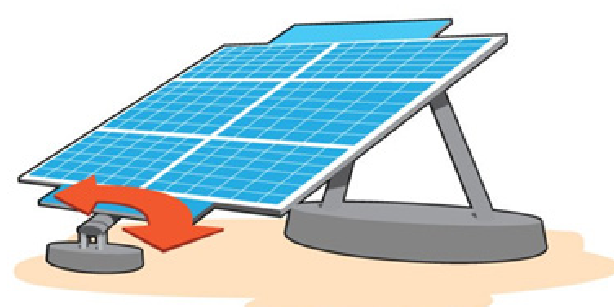

Figure 5. Vertical Single axis solar tracker (VSAT)[11].

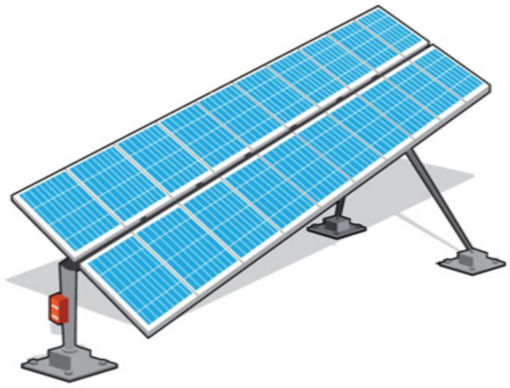

Figure 6. Tilted Single Axis Tracker (TSAT)[12].

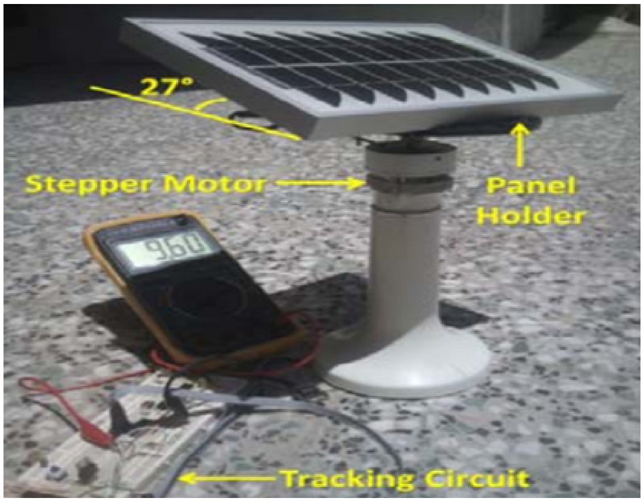

Figure 7. TSAT setup designed by Rezaei *et al.,*[13].

be kept in mind the considerable effect of 'shading'. This should be done in order to minimize energy losses and also to optimally utilize the area of installation[12]. Rezaei *et al.,*[13] developed a TSAT based on microcontroller with a 27-degree angle.

ATMEGA 8 microcontroller was one of the main controlling elements in the entire setup. The setup was tested on 2 different days with different weather conditions. Results show that on sunny day, the power production came out to be 4.18% and on a rainy day, the power production came out to be 4.34%. The entire experiment was carried out in the city of Kerman, Iran. Hence, higher power production.

B. Dual Axis Tracking

i) Azimuth-Altitude Dual Axis Tracker (AADAT)

Figure 8. Dish collector in Shanxi, China[15].

Figure 9. Heliostats in the Dahan concentrating solar power plant in Beijing, China.

It is a two axes-based system. The axis perpendicular to the ground is called the azimuth axis. The second axis – the altitude axis. It is perpendicular to the azimuth axis. When the setup is in working condition, the collector rotates in the direction of the sun. Thus, there is a change in the azimuth angle. When, the system rotates around the altitude axis, there is a change in the altitude angle. One of the applications of the AADAT can be seen in[14]. The simulation of the system was carried out with the help of vectors. The authors came to conclusion that the system increased the electrical gains by 43.87% and the efficiency is 49% compared to static solar panels.

ii) Polar Aligned Dual Axis Tracker (PADAT)

Polar aligned technique is a dual axis tracking technique also called as spinning-elevation tracking. It has 2 axes.

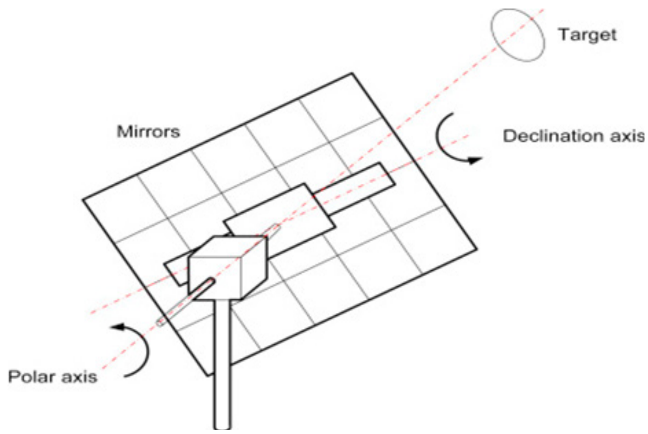

Figure 10. Polar aligned tracker principle.

One axis is pointing towards the north pole (Celestial) and the other is parallel to the earth's axis of rotation. It moves at the same speed of the earth's rotation but in the opposite direction[15].

C) Based on Driver

a) Active Tracker

i) Microcontroller and Electro-optical Sensor Based Solar Tracker

Bingol *et al.,*[16] in his paper put forward a developed version of microcontroller based solar tracker. They have used PIC16C71 microcontroller to keep the setup cheap. They compared a stationary panel's reading with rotary panel. The temperature between 7am to 5:30 pm on stationary panel were 34.9 degree Celsius versus to that of the rotary panels were 43.88 degree Celsius. It was obvious from the results that the rotary panels took greater light density (9 degrees more) compared to stationary panels. 2 main advantages of the proposed system are, first, it is not geographically constrained and second is that, being fully automatic, it doesn't require operator's interference.

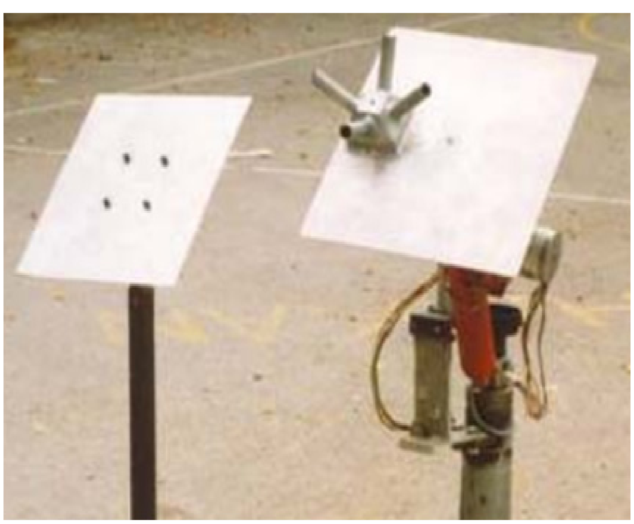

Figure 11. Proposed solar tracker system by Okan Bingol *et al.,*[16].

ii) Auxiliary Bifacial Solar Cell Based Solar Tracker

From the study of Vladislav Poulek *et al.,*[17] it can be seen that bifacial solar cell can double the energy harvest as compared to traditional panels. They can produce 5-20% more energy than monofacial solar module. The main advantage of using bifacial solar cell is that it can collect radiation from the back surface also. From their study, it is proven that the energy gain from back side of the cell could be 2-5% more. Also, bifacial cells have 5 to 6 degrees lower operating temperature, hence, the chances of the frame getting damaged is very less (Degradation of polymer encapsulants of modules). Also, studies show that, using a white tarp below the solar tracker assembly will help the light to reflect on the back side of the panels, more. But it should be noted that these tarps lose their reflectivity by 0.17% per month. Hence, after every 5 years or so, they should be replaced by a new tarp.

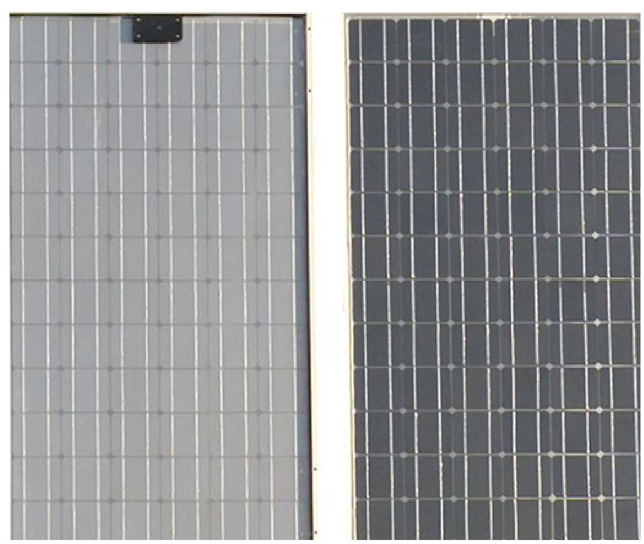

Figure 12. 100W bifacial PV panel[17].

iii) Date, Time and Sensor Based

Anusha *et al.,*[18] developed a Real Time Clock based efficient Solar Tracking System. The basic principle of the system is that, the controller continuously compares the RTC (Real Time Clock) with the stored tabular values. The stored tabular values are positional values of the sun w.r.t to time. They are pre-fed in the controller. If the values match with each other, then the positional values are sent to the PWM generator. This makes the motor rotate precisely towards the direction of the sun. This increases the precision of tracking.

b) Passive Tracker

These trackers are not actively powered by any external power supply, nor do they have motors for movement of the panels. Instead, they have a low boiling point gas. This gas, when exposed to the sun, tends to expand and this results in the activation of the actuators. This is called differential expansion. It tends to move the panels in the direction of the sun. Since they are passively powered, they are not accurate as compared to active solar trackers, but they can prove to be useful in simple and small solar tracker setups (Non-commercial). Other advantages of these type of trackers are that they are more reliable as compared to the complex designs of active/automatic trackers. But their accuracy is not high. They cannot function in lower temperatures. They do not have warning alarms like powered trackers[19].

2.0 Literature Review

A comparison of basic solar tracking systems by the various authors, their setups and the result obtained by carrying out experiments on them has been presented in (Table 1).

Table 1. Comparison of basic solar tracking systems by the various authors

Author/s	Type of Tracking System	No. of Axis	Setup	Performance/Result
Anuraj and Gandhi[8]	Solar Tracking System Using Stepper Motor	1	Photo resistor ATMEGA 16 microcontroller Stepper motor.	20% more efficient compared to static panels.
Rizk, and Chaiko[20]	Improvised using a different setup for 2 solar panels	1	1. Simple triangular set-up of 2 solar cells 2. LDR.	30% more efficient than fixed panels.
Protik *et al.*,[6]	Microcontroller Based Automatic Solar Tracking System with Mirror Booster	1	1. Solar panel 2. Mirror 3. ATMEGA 8 microcontroller 4. DC motor 5. Photodiode 6. LM7805 voltage regulator.	9% more efficient than fixed panels.
Odeh *et al.*,[7]	Design and development of an educational solar tracking parabolic trough collector system	1	1. Parabolic Trough Reflector 2. Solar Receiver 3. Thermal Storage Tank 4. Control box 5. DC motor 6. Photo sensor 7. Gear box 8. 12V battery 9. 2 photovoltaic panels.	60% maximum efficiency observed at noon.
Anusha *et al.*,[18]	Design and Development of Real Time Clock based efficient Solar Tracking System	1	1. LPC2148 board with ADC and RS232 2. 6V 300mA solar panel 3. DC motor 4. 12V battery.	40% more efficient than fixed solar system.

Table 1 Continued

Peter *et al.*,[21]	Arduino Based Solar Tracking System	1	1. 6W solar panel 2. LDR 3. Arduino microcontroller and sensor 4. Proteus software.	35% more efficient than static solar panels, especially at noon from 12am to 1pm.
Saravanan, *et al.*,[22]	Automatic Solar Tracking System	1	1. 70 Wp rating solar panel 2. 3 phase 0.5 hp induction motor 3.VFD 4. 2 contactors 5. LDR 6. Inductive proximity sensor.	25 to 30% more efficient than static panels and also cost efficient than static panels.
Chin[1]	Model-Based Simulation of an Intelligent Microprocessor-Based Standalone Solar Tracking System	1	1. 10W solar panel 2. LDR (NORPS-12) 3. PIC18F4520 Microcontroller 4. Lead acid battery 5. Servo Motor	20% efficient compared to conventional solar panels
Poulek and Libra[17]	New bifacial solar trackers and tracking concentrators	1	1. 2 solar cells 2. Reversible DC motor 3. LDR 4. Microcontroller 5. Flat mirrors 6. 100W bifacial PV panel	15-20% energy boost as compared with monofacial solar panels with almost 10-15% energy gains on the back side of the panel.
Rahmana *et al.*,[23]	Dual Axis Solar Tracking System	2	1. 2 LDRs 2. 2 dual comparator ICs LM1458 3. ATmega32 microcontroller 4. TIP 122 as motor driver IC 5. 2 full gear stepper motors.	52.78% efficient than fixed panels, 52.948 watt gained as compared to 40.7 of static panel.
Shngys[24]	Design and Research of Dual-Axis Solar Tracking System in Condition of Town Almaty	2	1. 2 monocrystalline silicon cells 2. LM324N type operational amplifier 3. TIP41C and TIP42C type transistors 4. 1N5407 type diodes 5. Resistors 6. LDRs 7. Capacitor 8. MCU type amplifiers.	31.3% more efficient than fixed photo module.
Hidayanti *et al.*,[25]	Dual-Axis Solar Tracking System Efficiency for Hydroponics Pump	2	1. Batteries 2. Microcontrollers 3. Solar cells 4. Servo motor 5. LDR sensors.	19.29% more efficient than single axis panels.

Table 1 Continued

Mustafa *et al.,*[26]	Direct and Indirect Sensing two-axis Solar Tracking System	2	1. Arduino UNO controller 2. DC motors 3. Gear box 4. LDR sensor module 5. Angle sensor 6. Timing circuit 7. Bluetooth module 8. Motor driving circuit.	It has been observed that the efficiency of this tracking system was constant throughout the experiment whereas the efficiency of traditional solar panel dropped significantly as the time progressed
Ahammed *et al.,*[27]	Energy Efficient Hybrid Dual Axis Solar Tracking System	2	1. Linear actuator 2. Panel carrier and panel carrier rotator 3. 2 stepper motor (half drive mode ULN2803 used as motor driver IC) 4. Sensor unit comprising of light sensor, position sensor and real time clock 5. ATMEGA32 controller 6. 3W solar panel	25.62% more power gain over static system while 4.2% less average power gain compared to continuous tracking system.
Assaf *et al.,*[28]	Design and Implementation of a Two Axis Solar Tracking System Using PLC Techniques by an Inexpensive Method	2	1. 4 LDRs 2. PLC 3. 2 DC servomotors 4. 3 Relays 5. 5 Limit switches 6 Controlled software designed to control the movement of DC motors.	30 to 40% more efficient compared to the static solar panel system.
Patil *et al.,*[29]	Automatic Dual-axis Solar Tracking System for Parabolic dish	2	1. Solar dish 2. 5 Light Dependent Resistor (LDR) 3. PMDC geared motor (using stromtium ferrite magnet) 4. Hercules lite driver IC 5. Arduino UNO board as a controller.	35% more efficient than single axis solar tracker.
BİNGÖL *et al.,*[16]	Microcontroller based solar-tracking system	2	1. PIC16C71 microcontroller unit 2. LDRs 3.4MHz crystal used as a clock signal generator for MCU 4. 2 stepper motors 5. 8 darlington transistors (TIP22).	It has been observed that this tracking system is geographically not constrained, and it doesn't require operator's interference.
Bose *et al.,*[30]	Low-Cost High Efficient Solar Tracking System Using AVR Microcontroller	2	ATMEGA 16 microcontroller Cadmium Sulphide (CdS) photocell 2 stepper motors 15 cm focal length concave mirror.	Can generate 65% more energy from solar panels. Also consumes very less energy during the tracking process.

Table 1 Continued

Koussa *et al.,*[3]	Sun tracker systems effects on flat plate photovoltaic PV systems performance for different sky states: A case of an arid and hot climate	1,2	1. 2 fixed panel systems 2. 2 single axis tracker systems 3. 1 dual axis tracker system.	(Note: The author compared performances of these tracker systems on different days at different weather conditions and at different time periods). Dual axis generated 45-60% over other trackers. But on cloudy days, each tracker almost performed the same.
Ghassoul[31]	Automatic Solar Tracking System	1	1. Proximity switch 2. PIC 18F452 microcontroller 3. 2 LDRs 4. Power motor.	It is more accurate in energy extraction as compared to the static solar system. Also, no drifts occur while aligning at the time of sunrise or sunset.
Pattanasethanon[32]	The Solar Tracking System by Using Digital Solar Position Sensor	1	1. Photodiode 2. 2 12V DC motors 3. 100W bulb for testing purposes 4. Transistor drivers (Tr1, Tr2, Tr3 and Tr4; 2N 3055) 5. (LED; NEC 1N1134) all resistors (1/4 w 1% error).	System proved to be more efficient with less than 1% error when tracking the angle approach to zenith.
Usta *et al.,*[33]	Solar Tracking System with Fuzzy Logic Controller	-	1. 2 magnets 2. PMDC motors 3. 2 directional light detecting circuits 4. 2 Amplifiers 5. 4 LDR 6. Photodiodes or phototransistors.	By looking at the results we can say that response time increases when we use FLC controller hence the tracking becomes more efficient and faster.

3.0 Results and Discussions

Various papers on various types of solar tracking systems, published by various authors have been analyzed. There is a clear-cut conclusive evidence that the solar tracking technology is far more power efficient than the traditional static solar panel system, From the comparison table above we can say that solar tracking system is indeed a more accurate and efficient way compared to the traditional solar panel static system of tracking the sun's rays and converting it into usable energy. The equipment's used by these researchers are cheaply available and they give optimum results, thus improving the efficiency of the solar tracking system by fairly huge margin.

For example, the LDRs used in these systems are fantastic equipment's that can be used to track the sun's rays accurately. The assembly of almost all of the tracking systems is simple and easy to maintain. Rarely does it require operator's interference. One such example of the usage of the simplest of apparatus that is a 'Mirror' can be seen in Protik Kumar Das's *et al.,* "Microcontroller Based Automatic Solar Tracking System with Mirror Booster" paper[6]. By installing a mirror on the ground, in front of the system and by carefully adjusting its angle with respect to the system, we can see that there is a significant amount of boost in the radiation coming from the sun. Such type of setup can be also called as a concentrated photovoltaic setup.

Another example can be seen in Mostefa Ghasshoul's "Design of an Automatic Solar Tracking System to Maximize Energy Extraction" paper[31]. The author has gone with a hardware viewpoint instead of a software one. He has replaced the software used in the system with a hardware which is a much simpler solution and a greater alternative. He mounted a proximity switch on the panels and a reflector on the PILOT. The author has given PILOT, a name, to a sub-system which detects the position of the sun where maximum energy can be gained. This system is intelligent, simple to make and efficient because it follows the sun, only if there is a possibility of larger energy extraction. Also, the consumption of energy by the motors will be very less as compared to the energy which is extracted. On the other hand, the system is capable of perfectly aligning itself, either on sunrise or sunset. This reduces the chance of any drift. These simple hardware additions can result into a significant increase in the efficiency of the system.

Another excellent development in the setup can be seen in Vladislav Poulek's *et al.,* "New bifacial solar trackers and tracking concentrators" paper[17]. He compared the performance of implementing monofacial panels against bifacial panels. The results were very surprising. As the term, 'Bi-Facial' meaning 'faced both sides'. The panel is so designed, that, it can collect/absorb radiation from the front, as well as from the back side. The amount of light it was able to collect from the back side of the panel was 10-15%, making it a total 15 to 20% more efficient than monofacial panels. The working temperature of these panels was also found to be considerably lower than other panels, thus, it can sustain greater amounts of heat with negligible damage to the assembly/frame.

4.0 Conclusions

Thus, looking at all sorts of tracking systems, comparing their numerical results and efficiencies with traditional and static solar panels, we can say that the extraction of more power from the solar panel will result in decrease of the cost per watt. This will ensure that extracting power using the tracking system will be much more cost efficient than traditional static solar panels.

Thus, we can conclude that, single axis tracking system proves to be more pocket friendly and more flexible in installation as compared with dual axis trackers. But dual axis solar trackers, as we saw in the results column of comparison table above, will fetch greater efficiency than single axis trackers. Nonetheless, introducing simple but effective apparatus into the systems, can greatly enhance the performance of the system, thereby increasing its efficiency over other systems.

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