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Review Article

A Review on Solar Tracking System: A Technique of Solar Power Output Enhancement

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Abstract: The renewable energy is a source of energy that does not deplete with time, because of this most of the research focused on this source of energy. Solar energy is among the renewable energy that is free in nature and clean from pollution, but harnessing this energy has limitation due to some environmental conditions. To solve this problem, solar tracking is used. This paper intended to review different solar tracking system that increases the solar power output. The result revealed the solar system with tracking is more efficient compared to that fixed solar system. Furthermore, dual axis tracking system is also more efficient than single axis tracking system due to the fact that dual axis tracking system have ability to track the solar irradiant on both axes. Finally, it is not recommended to use solar trackers with small PV arrays because of the energy consumption of the driving systems, which vary from 2% to 3% of the energy increase delivered by the solar trackers.

Keywords: Photovoltaic (PV), Solar Tracker, Azimuth Tracking, Light-Dependant Resistor (LDR), Microcontroller

1. Introduction

Nowadays, the world researchers are always finding sources of energy that are clean, renewable, pollution free and have no effect on global warming. Solar energy is among the sources of energy that contains all the above qualities. Moreover, solar energy is abundantly available almost worldwide, so far the efficiency of generating electric energy from solar radiation is low, because solar beam used to change direction with respect to time a day and also based on the season. Thus, increasing the efficiency of generating electric energy from the solar radiation becomes very important issue.

The photovoltaic panels are usually mounted on the roof of the house or at a near open area to face the sun. The custom is to fix these solar modules position angle to the country latitude angle. If possible, seasonally some people try to adjust the module's direction manually towards the sun [1]. To produce the maximum amount of energy, a solar panel must be perpendicular to the light source [2]. Because the sun moves both throughout the day as well as throughout the year, a solar panel must be able to follow the sun's movement to produce the maximum possible power. The solution is to use a tracking system that maintains the panel's orthogonal position with the light source.

Solar tracking is a system that is mechanized to track the position of the sun to increase power output by between 30% and 60% than systems that are stationary [3, 42]. It is a more cost effective solution than the purchase of solar panels.

There are many tracking system designs available including passive and active systems with one or two axes of freedom [4]. Dual axis trackers are among the most efficient, though this comes with increased complexity. Dual trackers track sun light from both axes. They are the best option for places where the position of the sun keeps changing during the year at different seasons. Single axis trackers are a better option for places around the equator where there is no significant change in the apparent position of the sun.

The level to which the efficiency is improved will depend on the efficiency of the tracking system and the weather. Very efficient trackers will offer more efficiency because they are able to track the sun with more precision. There will be bigger increase in efficiency in cases where the weather is sunny and thus favorable for the tracking system [5].

2. Theoretical Fundamentals

2.1. Solar Tracking System

A solar tracking system is a system used for orienting a solar photovoltaic panel toward the sun beam direction, especially in solar cell applications require a high degree of accuracy to ensure that the concentrated sunlight is directed precisely to the powered device. This system can be electrical or mechanical system, the main objective of the system is to find the maximum solar power output.

2.2. Classification of Solar Tracking System

Solar tracking system can be classed into two categories namely:

2.2.1. Classification Based on Nature of Motion

This is further divided into passive and active solar tracking systems:

A. Passive (Mechanical/Chemical) Solar Tracking System: This system uses the idea of thermal expansion of materials or a low boiling point compressed gas fluid driven to one side or the other as a method for tracking. Typically a chlorofluorocarbon (CFC) or a type of shape memory alloy is placed on either side of the solar panel. When the panel is perpendicular with the sun, the two sides are at equilibrium. Once the sun moves, one side is heated and causes one side to expand and the other to contract, causing the solar panel to rotate. A passive system has the potential to increase efficiency by 23% [6]. These systems are cheaper than active systems, but are not commercially popular [4]. And also, these have viscous dampers that prevent excessive motion in response to gusts of wind [7].

B. Active (Electrical) Solar Tracking System: These systems make use of motors and gear trains for direction of the tracker as commanded by the controller responding to the solar direction. The position of the sun is monitored throughout the day. When the tracker is subjected to darkness, it either sleeps or stops depending on the design. This is done using sensors that are sensitive to light such as LDRs. Their voltage output is put into a microcontroller that then drives actuators to adjust the position of the solar panel [7]. There are three main types of active tracker systems: auxiliary bifacial solar cell system, electro-optical system, and microprocessor/computer system.

2.2.2. Classification Based on Freedom of Motion

This class is also subdivided into two viz:

A. Single Axis Tracking System: These trackers have one degree of freedom that act as the axis of rotation. The axis of rotation of single axis trackers is aligned along the meridian of the true North. With advanced tracking algorithms, it is possible to align them in any cardinal direction. Common implementations of single axis trackers include horizontal single axis trackers (HSAT), horizontal tilted single axis tracker (HTSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT) [8].

B. Dual Axis Tracking System: These systems have two degrees of freedom that act as axes of rotation. These axes are typically normal to each other. The primary axis is the one that is fixed with respect to the ground. The secondary axis is the one referenced to the primary axis. There are various common implementations of dual trackers. Their classification is based on orientation of their primary axes with respect to the ground [3]. Azimuth-altitude and tilt-roll (or polar) solar trackers are the most popular two-axis solar tracker employed in various solar energy applications.

The figure 1 below shows the classification of solar tracker system broadly.

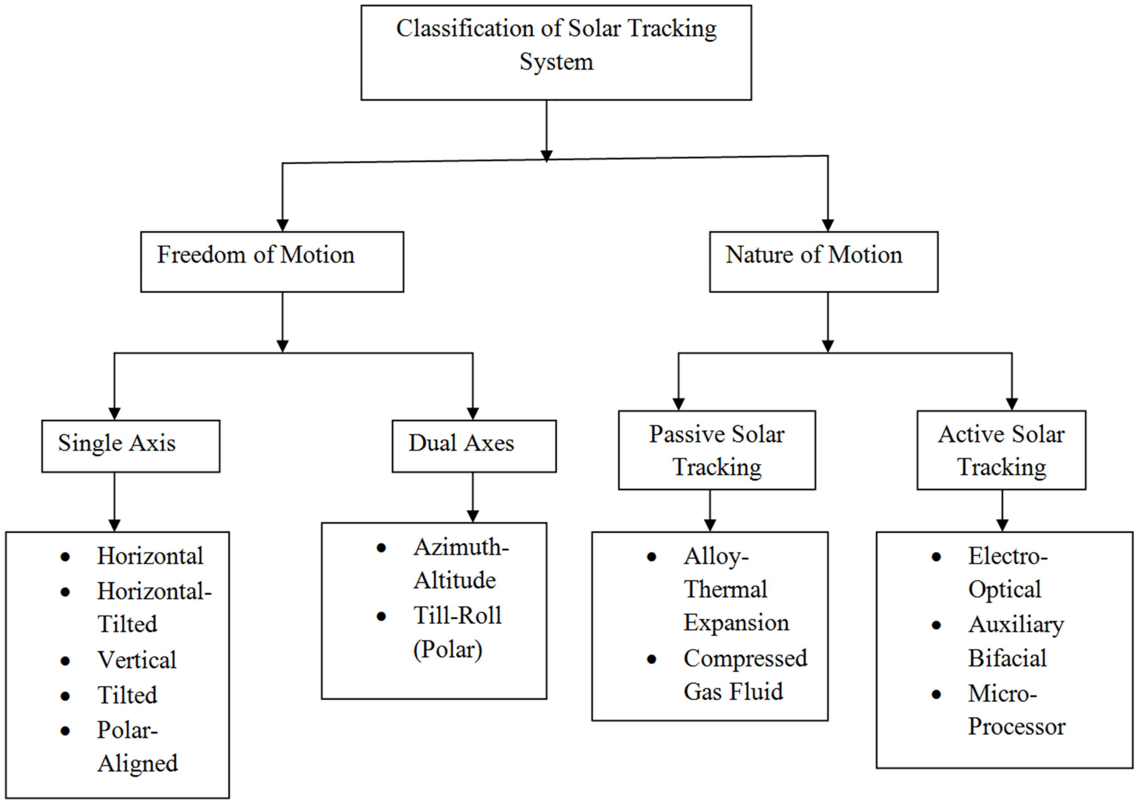


Figure 1. *Classifications of Solar Tracking System.*

2.3. Components of Solar Tracking Systems

The main components of a solar tracking system are the tracking device, the tracking algorithm and thermal or electro-optical for non-algorithm, the control unit, the positioning system, the driving mechanism, and the sensing devices.

a) The algorithm is a tracking control scheme that calculates the angles that are used to determine the position of the solar tracker. There are two types of algorithms: astronomical algorithms and real-time light intensity algorithms. The astronomical algorithm is a purely mathematical algorithm based on astronomical references to calculate the solar angles. The non-algorithm thermal control scheme uses differential thermal expansion of a working fluid to exert torque to move the tracker. The non-algorithm electro-optical control scheme uses differential optical signal to exert torque on the tracking device to follow the sun [9].
b) The positioning system is the system that moves the tracking device to face the sun at the calculated angles. The positioning system can be electrical or hydraulic.
c) The driving mechanism is the mechanism that is responsible for moving the tracking device to the position determined by the positioning system.
d) The sensing devices comprise a group of sensors that measure the ambient conditions (such as ambient temperature, relative humidity, amount of rain, and other ambient measurements), the light intensity (in the case of real-time light intensity algorithms), and the tilt angle of the tracker. The latter is accomplished by means of an inclinometer or a combination of limit switches and motor encoder counts [10].

3. Review of the Past Work on Solar Tracking System

As mentioned early, solar tracking system can be passive or active solar tracking systems, these tracking systems can track the sun beam in one direction (single) axis tracking or two directions (dual) axis tracking. The following are past researches on solar tracking system:

3.1. Passive (Mechanical/Chemical) Solar Tracking System

In 1994, Poulek [11] designed and tested a single axis passive solar tracker with Shape Memory Alloy (SMA) actuators. The actuator can easily be deformed at low temperature under 70^0C and works as a heat engine. It returns back to its original shape when heated above a certain specific temperature. It was concluded that the efficiency of these actuators is almost 2% and is approximately two orders of magnitude higher than that of bimetallic actuators (theoretically).

Clifford and Eastwood [12] design a novel passive tracking system for equatorial regions with an efficiency gain of 23% over traditional fixed PV modules. The design of passive tracking mechanism incorporates two bimetallic strips (bulkheads) made of aluminum and steel, positioned on a wooden structure, symmetrically on both sides, with a central horizontal axis as shown in the Figure 2. The bimetallic strips are shaded so that the strip further from the sun absorbs solar radiation while the other strip remains shaded. They compared the computer model and experimental results of deflections of the bimetallic strip due to the effects of thermal radiation (in mm) and time taken for the solar tracker to reorient from W–E (in second). Both results (computerize and experimental) showed very similar to each other. The designed solar tracker had the potential to increase solar panel efficiency by up to 23%.

In 2006, Mwithiga and Kigo [13] designed and constructed a dryer with limited sun-tracking capability that operated manually. The dryer consisted of a gauge 20 mild steel flat absorber plate formed into a topless box. The drying unit was bolted onto a shaft which in turn was mounted on to a stand so as to face E–W direction. A selector disc on the stand allowed the tilt angle that the drying unit made with the horizontal, to be easily adjusted in increments of at least 15^{o}. This way, the collector plate could be intermittently adjusted in order to track the sun during the day. Four dryer settings for tracking the sun were created. The dryer was set at an angle of 60^{o} to the horizontal facing east at 8.00 a.m. They adjusted the angle of the dryer made with the horizontal either one, three, five or nine times a day when either loaded with coffee beans or under no load conditions. The results showed that the solar dryer can be used to successfully dry grains. Drying of coffee beans could be reduced to 2–3 days as opposed to sun drying without tracking system, which takes 5–7 days and the temperature inside the chamber could reach a maximum of 70.48°C.

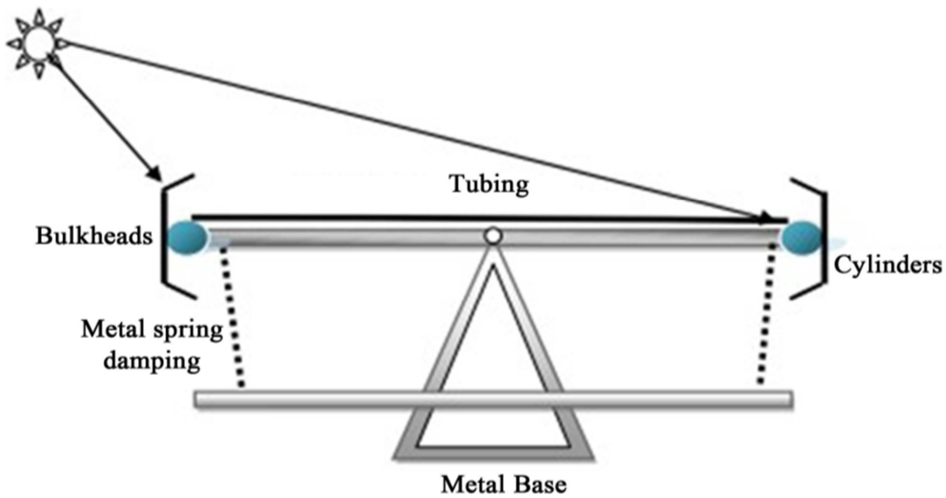


Figure 2. *A tracking system using two identical cylinders, connected by a tube, filled with a fluid under pressure [12].*

In another development, Castaneda [14] in 2011 presents a new tracking system using a pressurized fluid (ethoxyethane), also known as diethyl ether, for being a substance of highly volatility. His work shows clearly the benefits of the tracking system, emphasizing the application of diethyl ether and comparing it with other fluids by conducting field tests with the other proposed substances.

3.2. Active (Electrical) Solar Tracking System

An active tracking system can either be single or dual axis tracking system. Therefore this section is divided into single axis and dual axis tracking system.

3.2.1. Single (One) Axis Active Solar Tracking System

In 1996, Kalogirou [15] presented a one-axis sun tracking system utilizing three light-dependent resistors (LDRs). The first LDR detected the focus state of the collector, while the second and third LDRs were designed to establish the presence (or absence) of cloud cover and to discriminate between days and night respectively. The output signals from the three LDRs were fed to an electronic control system which actuated a low-speed 12V DC motor in such a way as to rotate the collector such that it remained pointed toward the sun.

In the same year, Ibrahim [16] constructed an electronically one-axis concentrating collector with an electric motor for forced circulation. The collector was hinged at two points for its tilt adjustment with a tightening screw to continuously track the sun from east to west through a range of 180^{o}. The collector efficiency was measured for different values of mass flow rates. It was concluded that the collector efficiency increases (reaching the maximum value of 62%) as the mass flow rate increases.

Khalid *et al.* [17] constructed single axis automatic solar tracking system and demonstrated a novel method which will automatically track the sun's position and accordingly change the direction of the solar panel to get the maximum output from the solar cell with the help of IC LM339N, Sensor (LDR) and DC geared motor.

Nowshad A. *et al.* [18] develop low cost single axis automated sunlight tracker design for higher PV power yield. As a result, for the LDRs that are separated by a short distance, the solar panel can be rotated according to the three difference angles as 55° (left LDR), 52° (midpoint of panel) and 47° (right LDR) for the solar panel to trace the light source but the panel is unable to face accurately towards light source. Minimum components cost acquisition for the tracker structure design is achieved by using programming codes instead of mechanical switches for mechanical safety control of the tracker. The unique design and positioning of only two LDR sensors realize the single axis sunlight tracker for PV applications. This tracker is realized within the cost range of around 1/50 (one fiftieth) of its kinds as a noteworthy achievement.

A single axis tracking of the solar PV module was implemented along with the automated cleaning mechanism by Ravi and Chetan [19] in 2010. For tracking the sun, the module was made to rotate 360^o angle in a day, i.e. one rotation in 24 hours. The module starts its rotation from vertical position at the time of sunrise facing towards east and rotates at the rate of 15° per hour. The automated cleaning mechanism was implemented using brush, rod and sliding wheels. The brush was fitted in the rod and the rod was fitted with the wheels at both the ends, which are fitted in the channel in which they rotate. When panel comes in a vertical position at 6am and 6pm the brush fitted on the rod rotates on the panel from upwards direction due to gravity and cleans the panel two times in a day. In this way the cleaning mechanism works. This automated system was implemented using 8051 microcontroller which controls the stepper motor coupled with the gear box (40:1 ratio) as shown in figure 3 below.

In 2011, Ponniran *et al.,* [20] develop an automatic solar tracking system which will keep the solar panels aligned with the sun in order to maximize in harvesting solar power. The system tracks the maximum intensity of light. When the intensity of light is decreasing, this system automatically changes its direction to get maximum intensity of light. LDR light detector is used to trace the coordinate of the sun. While to rotate the appropriate position of the panel, a DC geared motor was used. The system was controlled by two relays as a driver and a microcontroller as a main processor. Figure 4 shows the constructed designed of a single axis sun tracking solar system.

M. Ghassoul [21] presents the design of a solar tracking system driven by a microchip PIC 18F452 micro controller. The system is based on two mechanisms. The first one is the search mechanism (PILOT) which locates the position of the sun. The second mechanism (intelligent PANELS) aligns itself with the PILOT only if maximum energy possible could be extracted. On top of that the main advantage of the technique is that the rotation only takes place, if the energy obtained in the new position is higher than that consumed by the panels during the transition. So there are two mechanisms, one for the search which is mounted on a miniature motor and consumes only small amount of energy. Its role is to locate the best position for maximum energy extraction. The second one is the panel mechanism which rotates to the position when energy extraction is optimal.

In 2014, Kamala and Alex [22] developed fully automated environment sensitive solar tracking system to maximize solar energy harvesting economically and efficiently. The Mechanical system with gear wheels assembled on a frame for maximum efficiency, friction must be minimum for the interlink gear wheels, which is fixed to the frame using 10mm ball bearings. The worm gear is fixed to frame using 10mm ball bearing block. Solar panel is fixed on two ends of the shaft fixed with 20mm ball bearing blocks. To minimize the maintenance of the system, sealed bearings are used otherwise periodic lubrication is required for proper working of the system. Controller power consumption is derived from battery or from the solar panel directly. This system is used to charge 12V, 100Ah battery.

Mechanical Solar Tracking System was developed to enhance the utilization of solar energy with maximum possible efficiency by R. Agarwal [23]. The gear train operating system with the help of potential load is employed to rotate the solar concentrator with the movement of the sun. The comparison between the 'Mechanical Solar Tracking System' and 'Electro-Mechanical Solar Tracking System' shows that it consumes zero energy from the produced energy and thereby, increasing the overall efficiency by 5 to 8%. It can be concluded that "Mechanical Solar Tracking System" is more efficient than "Electro-Mechanical Solar Tracking System". "Mechanical Solar Tracking System" can be cheaper, require unskilled worker, easy to maintain and can be placed at hilly areas, remote or dusty or rainy place to develop electrical energy or to produce heat energy for different applications.

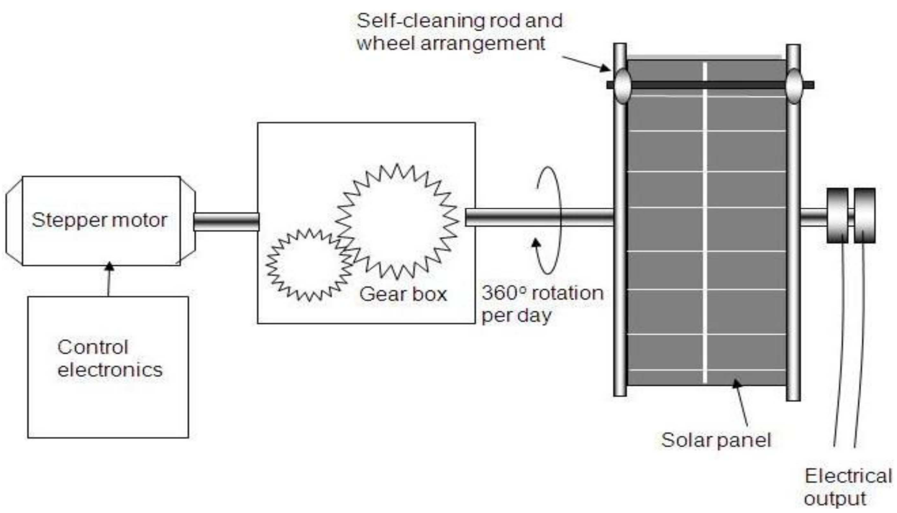


Figure 3. *Schematic diagram of Sun tracking and automatic cleaning of solar PV [19].*

Figure 4. *Constructed designed of a single axis sun tracking solar system modules [20]. 3.2.2. Dual (two) axis Active Solar Tracking System.*

In 1992, Agarwal [24] presented a two axis tracking system consisting of worm gear drives and four bar-type kinematic linkages to facilitate the accurate focusing of the reflectors in a solar concentrator system.

In 1995, Mumba [25] developed a manual solar tracking system for a PV powered grain drier working in two positions. A 12V, 0.42A, DC suction fan powered with PV was placed in the air inlet. To improve collector module efficiency, the sun was tracked 30^o from the horizontal. Mumba investigated the performance under four cases: PV fan-off without sun-tracking, PV fan-on without sun-tracking, PV fan-off with sun-tracking and PV fan-on with sun-tracking. In the sun tracking cases the collector module angled manually eastward at 8.00 a.m. and westward at 2.00 p.m. while the collector module was tilted 15^o from the horizontal to match the sun's elevation. It was concluded that from uniform air temperature point of view, the fanon sun-tracking case was the best, giving a temperature of 60.8^oC. From uniform energy gain point of view, the sun-tracking cases performed superior to that of non-tracking ones. It was concluded that a solar air heater with manual sun-tracking facility can improve the thermal efficiency up to 80%.

Park and Kang [26] designed and an implemented two axes sun tracking system for the parabolic dish concentrator built in Korea. Sun tracking mechanism is composed of 1/30000 speed reduction gear (3 stages) and 400W AC servomotor for each axis. The nominal tracking speed of each axis is ±0.6o/sec and the system has driving ranges of 340o and of 135o in azimuth and elevation tracking axis respectively. Sun tracking control system consists of sun tracking sensor, environmental and working condition measurement system, AC servomotor control system and PC as a master controller. Sun tracking sensor detects the sun located within ±50° measured from the sun tracking sensor normal direction. PC computes the sun position, sunrise and sunset hours. It also makes a decision of whether the system should follow the sun or not based on the information collected from the sun tracking sensor, environmental and working condition measurement system.

Urbano *et al.* [27] Urbano *et al.* [27] presented a 5 Watt-PV module for a stand-alone solar tracking system with a capacity of 2.6 kW. The tracking system was designed to follow the position of the sun autonomously in the altitude and azimuth directions and was driven by two 12 V DC motors, each with a power consumption of 36 W and both fed by a single electrolytic condenser charged by the PV module.

In 2004, Abdallah and Nijmeh [28] developed an electro-mechanical, two-axis tracking system in which the motion of the sun tracking surface was controlled by an open-loop control algorithm implemented using a PLC unit. The proposed system incorporated two separate tracking motors, namely one motor to rotate the sun tracking surface about the horizontal north-south axis, i.e. to adjust the slope of the surface and the other to rotate the sun tracking surface about the vertical axis, i.e. to adjust the azimuth angle of the surface. The experimental results indicated that the two-axis tracking system increased the total daily energy collection by approximately 41.34% compared with that obtained from a fixed surface tilted at 32^otowards the south.

In 2010, M.Serhan and L. El-Chaar [1] designed designed two axes sun tracking system. The system tracks the sun autonomously in altitude and azimuth. Two AC motors move and 80watts panel mounted on the mechanical structure. It requires no human interface where four attached sensors are continuously updating a PIC microcontroller which in return controls the rotations of the motors. The horizontal axis rotates the panel from east to west and the vertical from south to north, thus the system has two degrees of freedom. The hinges facilitate the revolution of the axes. The frame is designed to hold the desired solar panel and the base support the whole rigid body.

A cylindrical solar cooker with two axes sun tracking system was designed, constructed and operated by E. Abdallah *et al.* [29]. The mechanical system which consists of two parts, one for altitude tracking and another for rotating around vertical axes was based on driven motors as shown in figure 5.

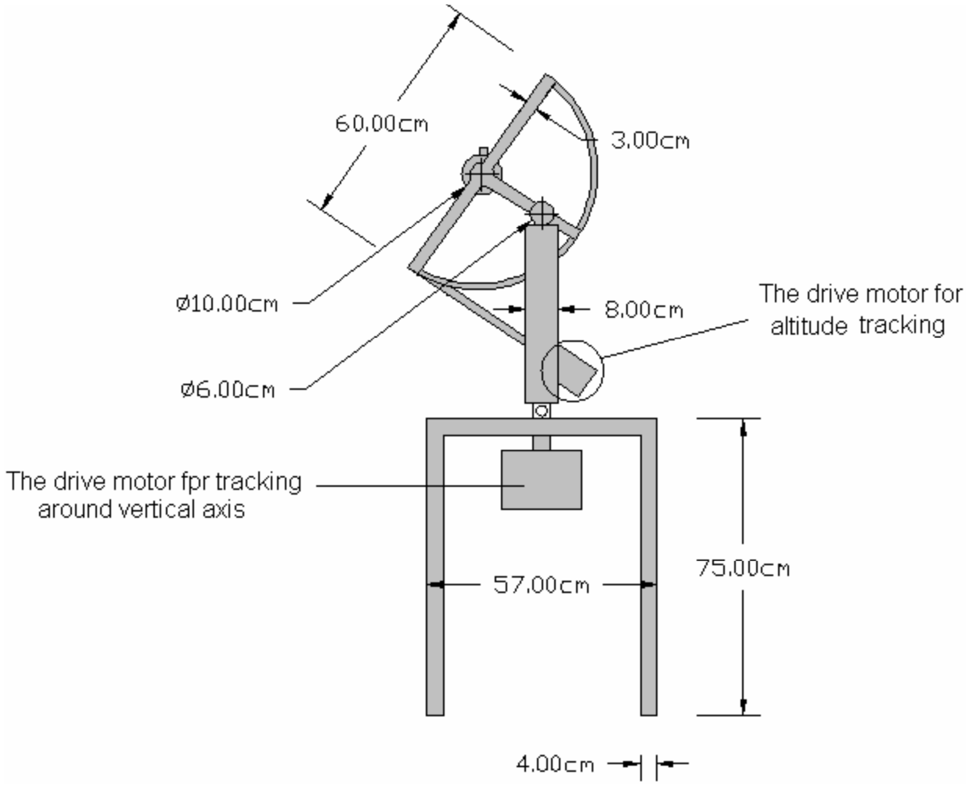


Figure 5. *Cylindrical Solar Cooker Side View [29].*

In another innovative study of M. R. I. Sarker *et al.* [30] in 2010, presents the design, construction and also investigates an experimental study of a two axis (azimuth and Polar) automatic control solar tracking system to track solar PV panel according to the direction of beam propagation of solar radiation. The designed tracking system consists of sensor and Microcontroller with built in ADC operated control circuits to drive motor with control software, and gear- bearing arrangements with supports and mountings. A digital program operates the designed Sun tracker in the control system. Two steeper motors are used to move the system panel, keeping the sun's beam at the center of the sensor. The results indicate that the energy surplus becomes about (30- 45%) with atmospheric influences. In case of seasonal changes of the sun's position there is no need to change in the hardware and software of the system.

In 2012, Yogesh and Suraskar [31] designed and fabricated the manually track parabolic solar disc for in-house cooking. Manual sun tracking arrangement is designed to track both the axis by using the wire ropes and pulleys. Two rotating drivers are provided to which the wire ropes are attached as shown in figure 6. Out of two one rotating driver is for adjusting or setting primary reflector as per the solar altitude angle and another one is to adjust azimuth angle. The operator has to rotate these two rotating drivers to set the orientation of primary reflector normal to the sun once in 10 to 15 minutes.

Ray *et al.* [32] designed two ways of rotating freedom solar tracker using ADC of microcontroller. The structural view of the system is shown in figure 9.The solar panel is mounted over the supporting arm with consisting two direct current motor with gear mechanism, five LDR (light depended resistor sensor) sensors and a control box. The light detecting system consists of five light depended resistors (LDR) which are LDR_1, LDR_2, LDR_3, LDR_4 and LDR_5 represent as S_1, S_2, S_3, S_4 and S_5 respectively mounted on the solar panel and placed in an enclosure. The sensors are setup in such a way that LDR_1 and LDR_2 are used to track the sun horizontally for drive the horizontal positioning motor while LDR_3 and LDR_4 are used to track the sun vertically for drive the vertical positioning motor. The LDR_5 is use to detect it is day or not because only day session system will be the working mode. This sensors information is processes by using fuzzy logic because it emulates human acceptable reasoning and could make decisions on inaccurate information. All the operations are operated by control box where microcontroller and motor control ICs processes whole detection and control system. So that, both motors vertical and horizontal movement to ensure proper tracking of the solar panel in any position of the sun with respect to the East-West or North-South.

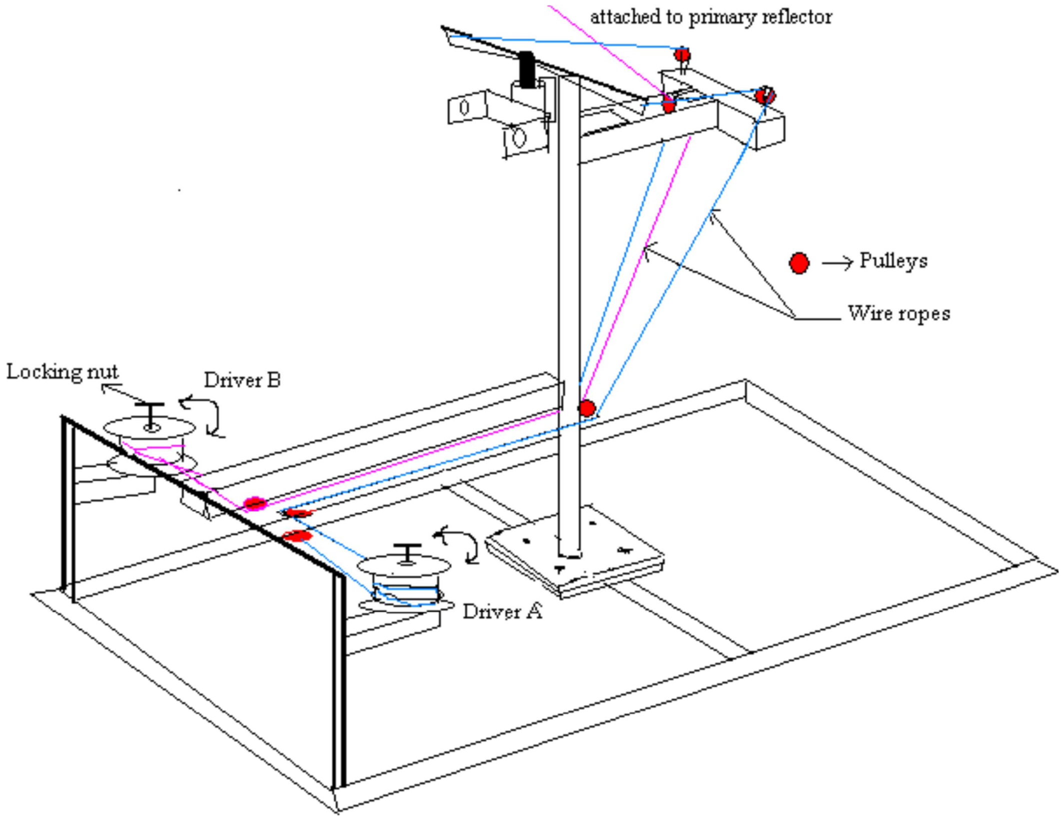
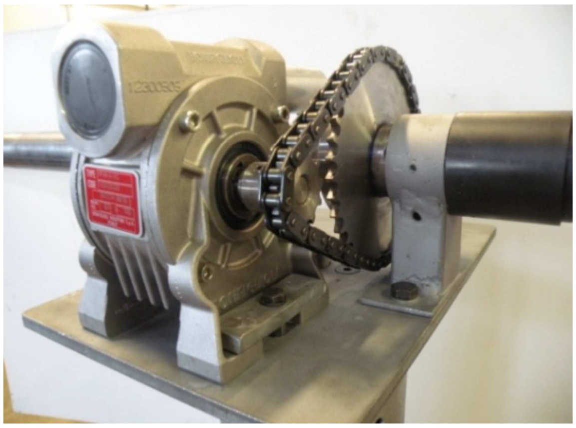
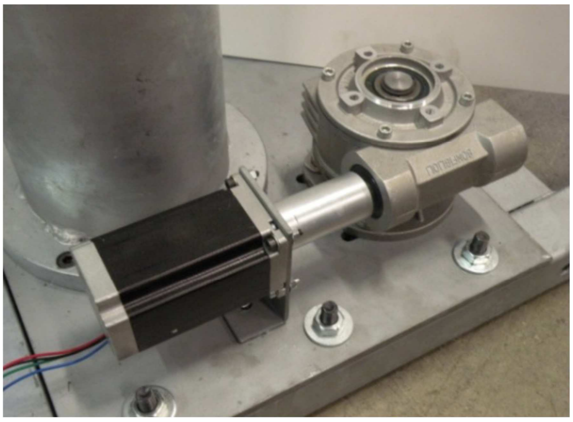


Figure 6. *Mechanical structure of manually track parabolic solar disc for cooking [31].*

Bortolini *et al.* [33] presented a hybrid strategy for altitude-azimuth sun tracking system applied to solar energy conversion plants. The tracking mechanisms are placed in two different positions. For altitude axis of motion the system was located on a plate on top of the pillar and was directly coupled with the shaft that supports the reticular frames containing the lenses and the receivers (Figure 7a). On the contrary, azimuthal chain drive system was close to the bottom of the vertical pillar and the transmission of motion was made thanks to a vertical shaft coaxial to the pillar and placed inside it (Figure 7b).



(a)



(b)

Figure 7. *(a) Altitude tracking mechanism [33], (b) Azimuthal tracking mechanism [33].*

This study performed by M. Mehratash *et al.* [34] on investigating the performance of photovoltaic (PV) systems with different types of solar trackers in Northern climates. To this end, four PV systems were simulated; horizontally fixed, inclined fixed, azimuth tracking, and a dual-axis tracking. The simulations have been carried out by use of PVSOL Pro for daily, monthly, and annual periods. The analyses have been done for climate conditions prevailing in Montreal, Canada. Annual analyses show an increase of solar irradiation upon a tilted system, azimuth tracker system, and dual axis tracker system as compared to the horizontal system. This yearly increase is 16.8%, 50.1% and 55.7% respectively. The results indicated that a dual-axis tracking array is the optimum system if it goes to the horizontal position in overcast condition.

Shrishti [35] developed automatic dual axis solar tracker system is a design and implementation of a polar single axis solar panel tracker. It has a fixed vertical axis and an adjustable horizontal motor controlled axis. This set-up is similar to an office swivel chair. The tracker actively tracks the sun and changes its position accordingly to maximize the energy output. To prevent wasting power by running the motor continuously, the tracker corrects its position after 2 to 3 degrees of misalignment. The sensors compare the light intensities of each side and move the panels until the tracker detects equal light on both sides. Additionally, it prevents rapid changes in direction that might be caused by reflections, such as cars passing by. A rear sensor circuit is also incorporated to aid in repositioning the solar panels for the next sunrise. The gear motor has overturn triggers to prevent the panel from rotating 360° and entangling wires. The motor control and sensing circuitry runs on batteries charged by the solar panel. This system uses three small 10W solar panels of approximately 15 inches by 10 inches to model larger panels used in industries.

In an advanced study, a two-axis sun tracking system with PLC controlled is described and a combinative tracking method is used to control the motion of the solar collector by X. Jin *et al.* [36]. The hardware and software of the system are design and constructed. The designed accuracy of the tracking system is 0.1°. It is certain that the device can operate under many circumstances without manual operation. Stepper motors and reducer gearboxes are employed in this design for the high driving force and accuracy demand.

In 2015, S. Lo *et al.* [37] present the design, operation, and performance evaluation of a unique cable-operated 6.24 kWp commercial-size solar tracking system called iPV dual-axis tracker or iPV DAT with a position detector to gain the maximum power from the sunlight. The operating method of the 6.24 kWp iPV DAT follow a simple pull and release of the steel cables connecting the corners of the PV module frame to the electric motors and directed by an electronic control system. The steel cables attached to the corners of the module frame also provide an extra stability in the event of high wind of up to 220 km/h. The accuracy of the tracking effect is managed by an astronomical algorithm that enables a full 360° azimuth rotation and altitude tilt of −40° to 40° (0 = horizontal). The controller algorithm also includes backtracking capability that allows optimization of ground cover ratio. Performance evaluation of the iPV DAT installed and operated in Taiwan for 12 months is compared with a fixed-tilt PV system. An average electricity gain of 30.1% and performance ratio of 93% are realized using iPV DAT.

T. C. Cheng *et al.* [38] in their paper, solar tracking system was designed for solar-thermal applications with an electromechanical and biaxial-type concentrated. In the tracking system, the sunlight was concentrated by the microstructure of Fresnel lens to the heating head of the Stirling engine and two solar cells were installed to provide the power for tracking system operation. In order to obtain the maximum sun power, the tracking system traces the sun with the altitude-azimuth biaxial tracing method and accurately maintains the sun's radiation perpendicular to the plane of the heating head. The results indicated that the position of heating head is an important factor for power collection. Moreover, the results also revealed that the temperature decrease of the heating head is less than the power decrease of solar irradiation because of the latent heat of copper and the small heat loss from the heating head.

A. Ozturk *et al.* [39] present an experimental performance comparison of a 2-axis tracking system with a fixed panel in a solar renewable energy system was performed in Duzce, Turkey. The comparison provides a quantitative analysis to calculate the time required to payback if a tracking module is used instead of fixed module. It was found that, under the same conditions, the tracking module harvests 35% more energy from the sun compared to the fixed module, and the tracking system amortizes itself in 16 years.

In 2015, M. Yilmaz and F. Kentli [43] performed increasing of electrical energy with solar tracking system at the region which has turkey's most solar energy potential. Both systems were mounted in the same place to compare two-axis tracking system's efficiency with fixed system's efficiency fully and used the same breed panels, charge regulator, measurement device and battery as shown in figure 8. It was observed that Two-axis motion system efficiency was more than fixed system 31.67% over an annual average. This efficiency was measured on some days up to 70% during the winter months and up to 11% during the summer months.

Figure 8. *View from the roof top systems [43].*

4. Conclusion

Both solar thermal and solar photovoltaic systems are simple to develop, but they produce lower power and less energy without tracking mechanisms. The use of solar tracking systems can boost the collected energy from the sun by 10% to 100% at different times of the year and under different geographical conditions [9].

From the review work done in this paper, the solar tracking system can either be passive or active solar tracking system, among which active can track the sun trajectory either in one (single) axis or two (dual) axes. The result revealed the solar system with tracking is more efficient compared to that fixed solar system. Furthermore, dual axis tracking system is also more efficient than single axis tracking system due to the fact that dual axis tracking system have ability to track the solar irradiant on both axes. Finally, it is not recommended to use solar trackers with small PV arrays because of the energy consumption of the driving systems, which vary from 2% to 3% of the energy increase delivered by the solar trackers [4, 40, 41].

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