Review of Solar Tracking Techniques

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Abstract— Solar tracking drives can be broadly classified as active or passive. Passive drives are mechanical and active drives are electrical or electronics. In this paper, a review of the some recent published techniques for photovoltaic tracking drives is presented. Based on functionality, the published techniques are compared. Active drives are shown to be more efficient when compared with the passive drives but they required power. However, in terms of flexibility and cost, passive drives are more viable than active drives. The merits and demerits of each drives are concluded.

Keywords: Solar Tracking Techniques, Solar, Wind, Hydro, Fuel Cell (FC)

I. INTRODUCTION

The available renewable energy resources are solar, Wind, Hydro, Fuel Cell (FC) etc. Among these, the solar energy is a pollution free, promising and reliable green source to meet the growing demand. The increasing demand for energy with the concern of depletion in conventional fuels, and protecting the environment from pollution have made the researchers to develop a new solution of utilizing the renewable energy. Further, the consumption of fossil fuels results in the emission of greenhouse gases that increases the global warming. Considering all these factors, the renewable energy is one of the best solutions that will provide sufficient and also a clean energy. It also lessens the greenhouse effect. Power can be extracted from the solar irradiation using the photovoltaic (PV) system. The PV system converts sunlight into electrical power using the principle of photovoltaic effect. Whenever light falls on PV cell, the energy from photon is transferred to the charge carriers. Then the charge carriers split into positively charged holes and negatively charged electrons due to the electric field across the junction. This results in the flow of current if a closed path is provided to the circuit by connecting a load. The basic operation of a PV cell is shown in Fig.1. the total amount of solar energy that consumed worldwide increased exponentially the total capacity, generated, and consumed energy has increased exponentially, and the total growth of solar energy capacity and usage is 29.6%.

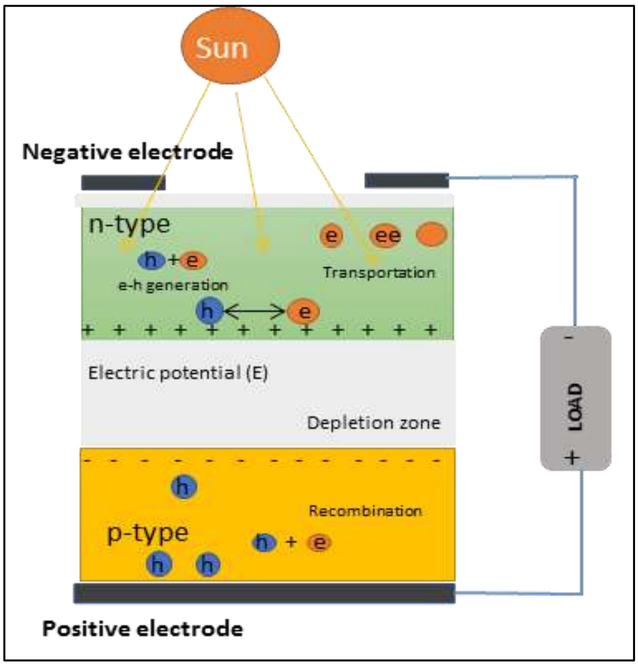


Fig. 1: Solar Tracking System

A. *Need:*

Sun irradiance varies with months, time of day, weather conditions, geographical area, and position of the sun in the sky. So to maintain the maximum irradiance the system called as solar tracker is generally used which can enhances power output by 25%.

Solar tracker systems are designed and developed to increase the amount of solar radiation received by photovoltaic devices and thereby increasing the output of PV module. This process is carried out by maintaining the optimum angle of the solar panel to produce the best power output. Many solar tracking systems have been built and designed to achieve the optimal amount of solar energy, and many models have been proposed to enhance the efficiency of PV module. A solar tracking system tracks the position of the sun and maintains the solar photovoltaic modules at an angle that produces the best power output. Several solar tracking principles and techniques have been proposed to track the sun efficiently. The idea behind designing a solar tracking system is to fix solar photovoltaic modules in a position that can track the motion of the sun across the sky to capture the maximum amount of sunlight. Tracker system should be placed in a position that can receive the best angle of incidence to maximize the electrical energy output.

B. *Type:*

The complexity of a tracking system depends on the number of axes used to move the solar photovoltaic modules i.e. horizontally, vertically, or both. Two main types of solar tracking systems exist. The first one is single axis tracking, which can be used to move the solar photovoltaic horizontally or vertically. The second type is dual axis solar tracking systems, also known as two-axis tracking, which can be used to simultaneously change in both angles of azimuth and tilt angle. In other words the tracker which track sun in only one direction is single axis tracker while if it tracks in both direction the tracker will be called as double axis tracker system as shown in fig.2

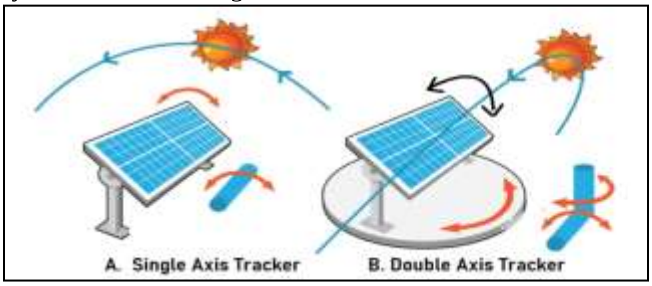


Fig. 2: Magnetization as a function of applied field.

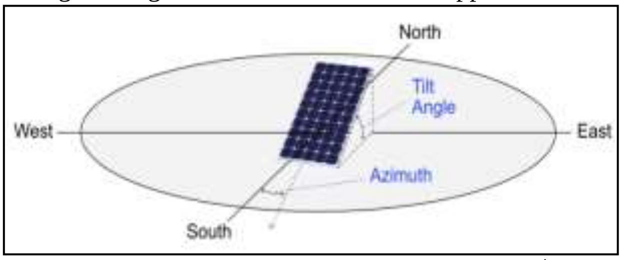


Fig. 3: Solar Tracking Systems Applied Field (10^4 A/m)

Moving solar tracking systems from side to side is equally important as cost of doing so. Therefore solar tracking systems can be manually moved mechanically through the use of cantilevers, gears or motors. The most important point to assist the proposed solar tracking systems is calculating the gained energy compared with the consumed energy by the tracker components. Motors, hardware components, resistors, and the size of photovoltaic panels can affect the gained power.

Solar tracking systems can be mainly divided into two main groups based on the techniques that control the photovoltaic module. These two main groups are active and passive tracking system.

Active tracking systems use some form of electric energy to drive motors and gear trains to direct the panel toward the sun. Passive tracking systems uses the non electric energy such as a low boiling point compressed gas fluid that expands due to energy gain from solar heat or any other phase change material.

C. *Active Tracking*

Active and passive solar tracking are the two main techniques utilized to efficiently track the sun. Active tracker accounts 75% usage in applications while the second most type is the passive solar tracker accounting 7.55%. [1]

In general the tracker uses light detecting sensors like LDR, averages of the signals generated from four LDR's placed at the four corners of a photovoltaic cell. Based on the computed averages, the microcontroller gives instructions to servomotors for rotation of the PV cells towards the direction of maximum incident sun rays as shown in Fig. 2. Their result obtained show a 54.71% increase in the generated output power for the tracking system as opposed to the fixed solar panel [2].

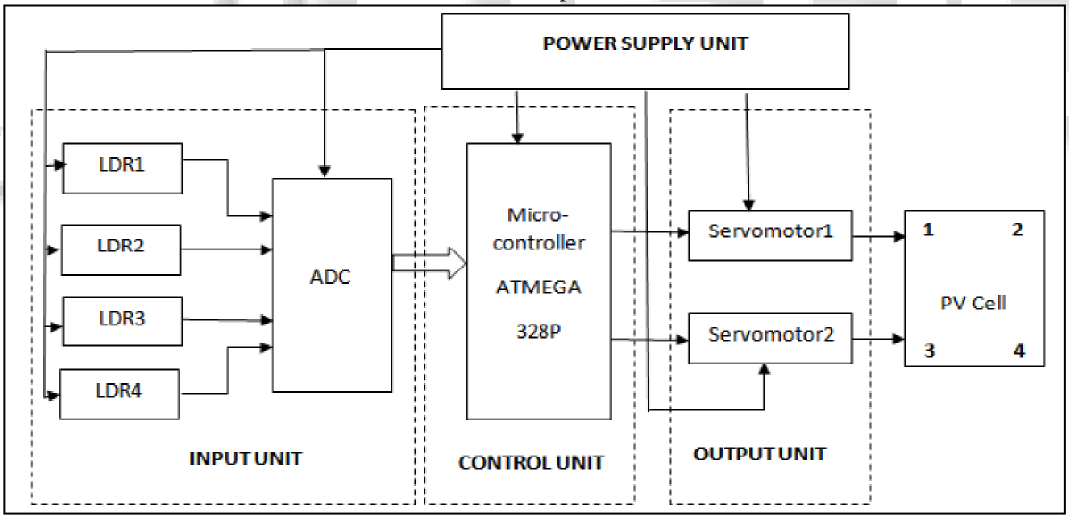


Fig. 4: Controlling configuration block diagram of Active Tracking system

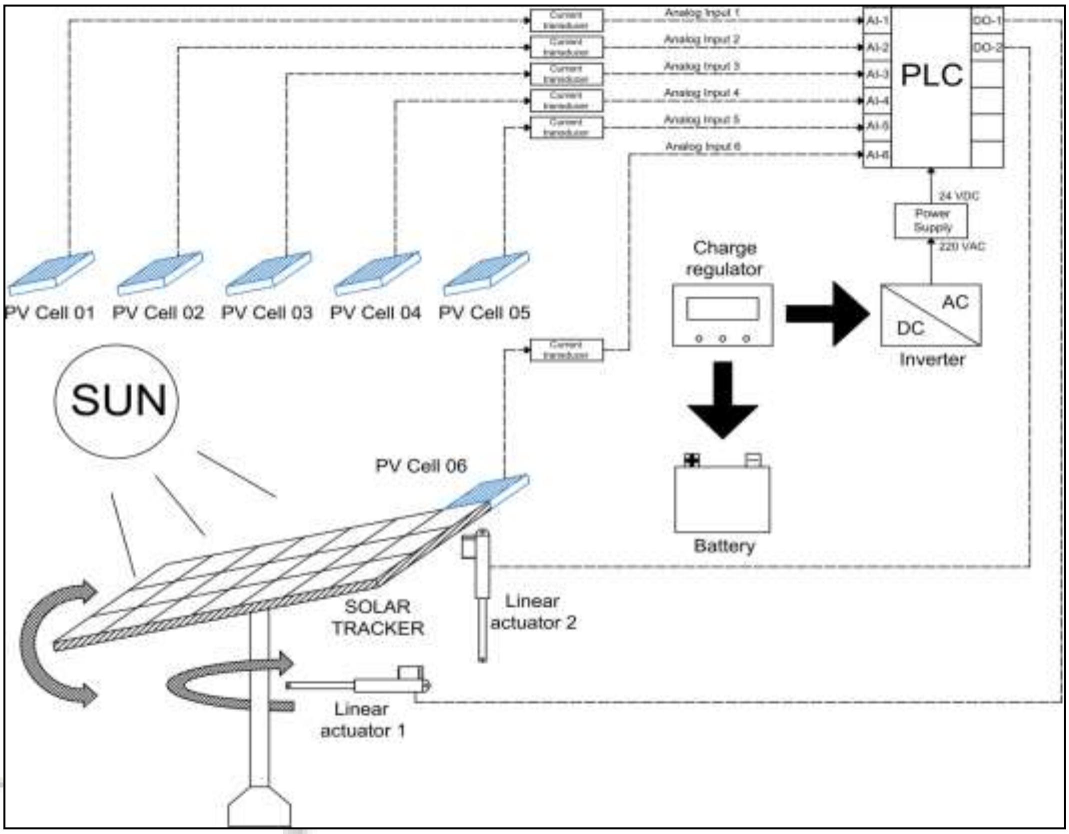


Fig. 5: electrical connections of the solar tracker

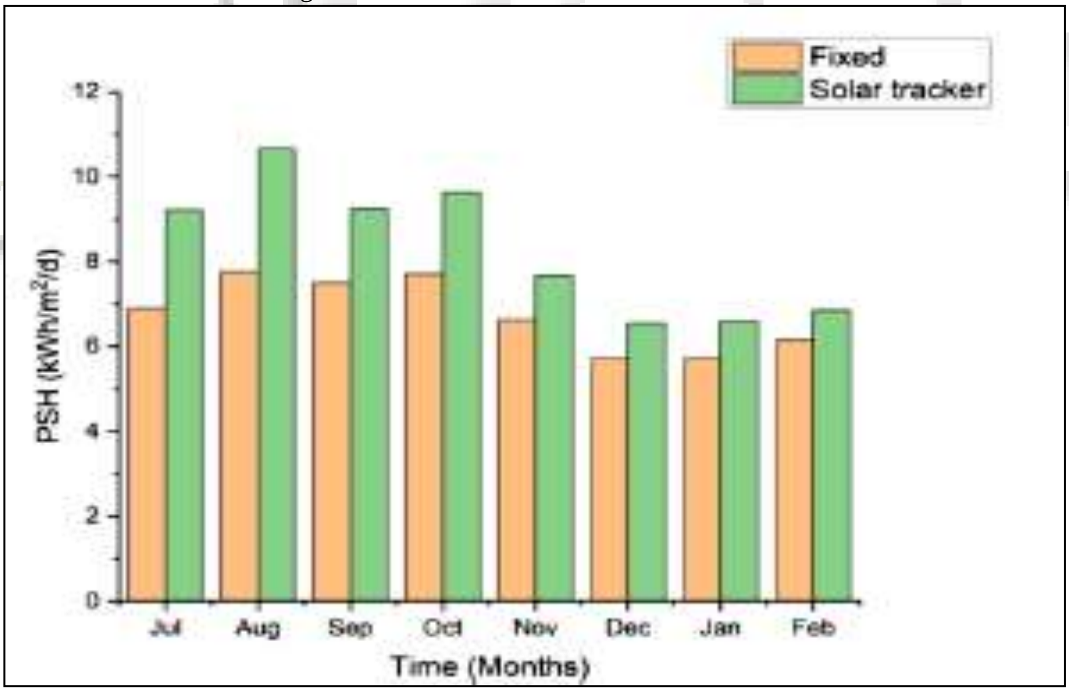


Fig. 6: Monthly energy production of the solar tracker compared to the fixed photovoltaic system

Another Study of 5 PV cells as the input device to controller for photovoltaic performance of a dual-axis solar tracker based on photovoltaic cells with different inclination angles at high altitudes above 3800 m.a.s.l.

A solar tracking system activated by two linear actuators was implemented to automatically follow the trajectory of the sun during the day. As shown in fig.3, Each PV cell measures the solar irradiance independently connected to the PLC; within its programming, the PLC obtains the maximum reference solar irradiance value and compares it with the irradiance of the solar tracker to optimize the range of motion of the axes and find the point of maximum power. It reviles comparison of fixed, single and double tracking system. Tracking sun improves the efficiency of energy conversion up to 24% to 30 % like the dual-axis solar tracker had a maximum monthly photovoltaic yield of 37.63% more than the fixed photovoltaic system and the energy production of 10.66 $kWh/m^2/d$ more than that in the fixed system[3], which produced 7.75 kWh/m^2/d as shown in fig.4.

In contrast, on rainy days with partial cloudiness, the performance of both photovoltaic systems was reduced to 14.38%,[4] but this may not be true all the time considering the availability of sun rays region wise. Efficiency of Fixed Photovoltaics module is 0.4% greater than single Sun Tracker Photovoltaic. In the dry season, Sun Tracker Photovoltaic has 0.5% greater interference than Photovoltaic Fixed Mounting. The maximum efficiency in Photovoltaic Fixed Installation is 12.4%, while the maximum efficiency of Sun Tracker photovoltaic is 13%.[5]

Thus using solar trackers more solar radiation are allowed to capture by maintaining the surface of the module approximately perpendicular to the source for a longer period thereby producing more electric power.

Another studies shows that, Active- single-axis and double-axis solar tracking systems maximize electricity production, increasing the capture of solar radiation and photovoltaic efficiency by between 15% and 45% compared to other fixed photovoltaic systems of equal power [6]; by 19.97% compared with dual-axis systems based on light-dependent resistors (LDR) [7]; by up to 40% compared with other low-cost systems with four and 8 simulated LDRs [8] and by up to 54.39% compared to using a closed circuit control loop[9]. Currently, dual-axis solar trackers have greater photovoltaic efficiency in the production of electricity because they follow the trajectory of the sun in a synchronized movement across the horizontal as azimuth angle and vertical axes.

To control a solar trajectory tracking system, several control strategies are used, including open, closed or combined loops [9], Classic strategies such as ON-OFF, PI and PID controls, control algorithms through a programmable logic controller (PLC). For entering information about the sensors, the sequence of the processes and the output of the actuators that automatically direct the solar tracker software can be used [10]. Therefore, some solar trackers use photo-sensors or photodiodes as the main solar tracking device; however, the normal operation of these sensors depends on clear skies and favorable weather conditions [11]. Others have used low-cost LDRs [12] and photovoltaic panels [5, 13]. In addition, the performance of these solar trackers can be improved by MPPT strategies [14].

The performance of trackers is affected by several factors, such as irregular precipitation, partial cloud cover, seasonality and altitude. To correlate these variables in a scatter plot, performing principal component analysis is used to determine which factor influences the loss of performance [15]. This technique divides the variables into relevant blocks and is very effective for the monitoring and detection of faults.

The study also shows that performance of both type of tracker is function of types of actuators, mechanical components, materials and pay load of solar module and terrain of operation.

II. PASSIVE TRACKER

Other type of tracker system is passive which uses either the phase change material which changes physical properties of fluids as solar energy in tracking the sun or gravitational potential or through mounting spring or integration of wind energy. An early attempt for single axis passive solar tracker based on shape memory alloy (SMA) actuators tested and found useful than bimetallic actuators with higher efficiency [16].On other hand bimetallic laminates of Ni36/Mn75Ni15Cu10 strip for organic cell can be used as main actuator for tracking which changes the shape as it bend and deform due to the influence of temperature depending on the shadow area and the solar cell perpendicular to light as shown in fig.5 and 6. The results hold good feasibility and reasonable in term of stability, deformation process of bistable laminates. The study reviles the deformation capability called as actuation effect which is directly related with tracking efficiency is function of the snap-through temperatures, arrangement of the bimetallic strip on the bistable laminates, thickness of the bimetallic strip tested numerically and experimentally and has reasonably good aggregate[17].

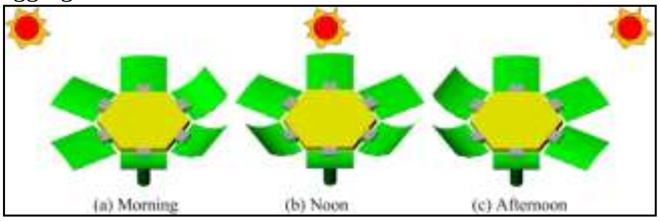


Fig. 7: Application of bimetallic and laminate for solar tracking

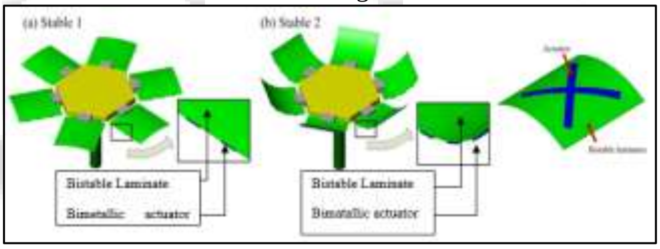
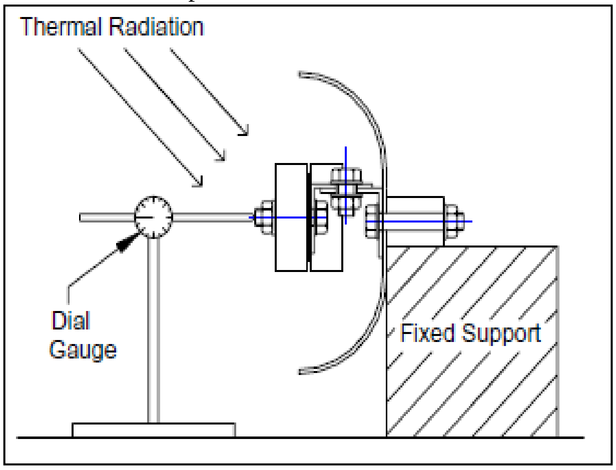


Fig. 8: Actuation effect of laminate and bimetal from stable 1 to 2 and position of actuator and laminate



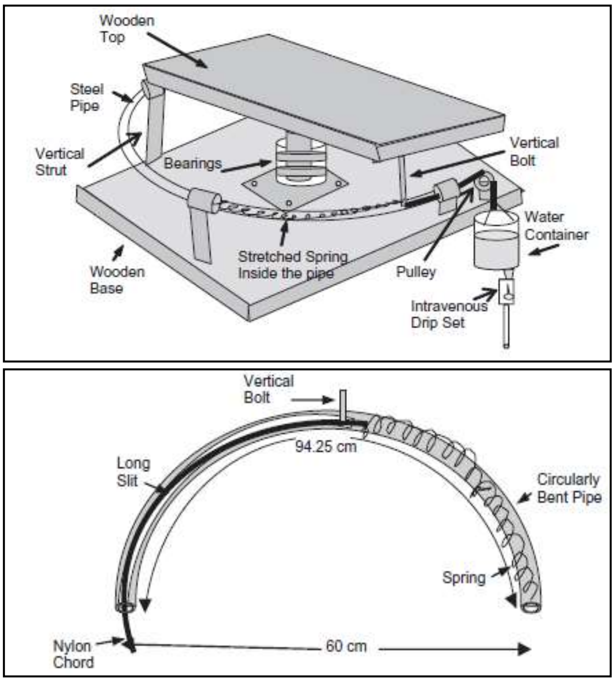


Fig. 8: Gravity based Passive Tracker

Clifford et. al. design a bimetallic strip tracker which consists of two bimetallic strips of aluminium and steel. The bimetallic strips are positioned on a wooden frame, symmetrically on either side of a central horizontal axis such that the strip which is way from the sun absorbs thermal radiation as shown in fig.7 while the other remains shaded. The exposed bimetallic strip gets hotter, the aluminium bends more than the steel due to its higher coefficient of thermal expansion. This bending causes a maximum deflection at the strip midpoint and with the attached mass an unbalanced moment results, which generating movement towards the sun rotates the solar panel along [18].

Another attempt by Suhail Zaki Farooqui et.al.[19] is of making gravity based solar tracker for specially solar cooker. It consists of actuation of stretch spring and mirror as shown in fig.8. Initially Water stored inside a container is attached to a spring through a chord, thus an amount of potential energy stored in the stretched spring and water get discharged at a constant rate from the container, thus the spring slowly returns to its un-stretched position dragging the solar cooker along with it. Further, by increasing the height of the booster mirror attached to the solar cooker fulfills the requirement of tracking along changing solar elevation.

The controlled discharge of water if matched with the rate of change of the solar azimuth, the solar tracking can be achieved. The whole system has been optimized for 6 h of cooking per day, without manual tracking resulted optimum angle of inclination of the booster mirror as 25 degree.

III. Conclusion

Solar tracking systems have very high efficiency and performance compared with fixed or stationary solar photovoltaic systems. The main advantage of solar tracking systems is the increased electricity generation depending on the geographical location of the solar tracker and other variables. However, solar tracking systems possess numerous limitations. Solar tracking systems are more expensive than fixed systems due to the complexity of the technology used and their use of expensive products for their complex operations.

It is observed that active tracker using optical sensor and microcontroller based active drives offer the advantage of high precision tracking and are used widely and also frequently used in comparison with the auxiliary bifacial and time based active drives. However, they have a common disadvantage of low efficiency on cloudy days since the sensors require sunlight to function effectively. Passive drives rely on the changing physical properties of fluids rather than complex and complicated control circuits, motors, gears and sensors used in active drives. This makes them more viable than active drives. Also the factors that affect the energy output of such systems include the photovoltaic material, geographical location of solar irradiances, ambient temperature and weather, angle of sun incidence, and orientation of the panel.

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