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Design, modeling and testing of a standalone single axis active solar tracker using MATLAB/Simulink

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ABSTRACT

This paper presents the design, modeling and testing of an active single axis solar tracker. The compactness of the proposed solar tracker enables it to be mounted onto the wall. The solar irradiance is detected by two light-dependent resistor (LDR) sensors that are located on the surface of the photovoltaic (PV) panel. The smart tracker system operates at different modes to provide flexibility to accommodate different weather conditions and preference for different users. The PV panel rotates automatically based on the sun irradiance during the day while at night; the system is in 'sleep' mode in order to reduce the energy consumption. A computer model of the standalone solar tracker system is first modeled using MATLAB™/Simulink™. The efficiency over the fixed solar panel, the power generated and the types of PV systems to achieve the required level of efficiency can be determined before actual implementation. The experimental testing shows some agreement with the simulation results.

1. Introduction

Renewable energy resources will be an increasingly important part of power generation in the new millennium. Besides assisting in the reduction of the emission of greenhouse gases, they add the much-needed flexibility to the energy resource mix by decreasing the dependence on fossil fuels [1]. Among the renewable energy resources, solar energy is the most essential and prerequisite resource of sustainable energy because of its ubiquity, abundance, and sustainability. Regardless of the intermittency of sunlight, solar energy is widely available and completely free of cost. Recently, photovoltaic (PV) system is well recognized and widely utilized to convert the solar energy for electric power applications. It can generate direct current (DC) electricity without environmental impact and emission by way of solar radiation. The DC power is converted to AC power with an inverter, to power local loads or fed back to the utility [2]. Being a semiconductor device, the PV systems are suitable for most operation at a lower maintenance costs.

The PV application can be grouped according to the scheme of interaction with utility grid: grid connected, standalone, and hybrid. PV systems consist of a PV generator (cell, module, and array), energy storage devices (such as batteries), AC and DC consumers and elements for power conditioning. The most common method uses the PV cells in grid network. However, to understand the performance and to maximize the efficiency of the irradiation on the PV cells, the standalone PV cells have spurred some interest especially, in the area of solar tracker system.

Over the years, test and researches had proved that development of smart solar tracker maximizes the energy generation. In this competitive world of advanced scientific discoveries, the introductions of automated systems improve existing power generation methods. Before the introduction of solar tracking methods, fixed solar panels were positioned within a reasonable tilted direction based on the location. The tilt angle depending on whether a slight winter or summer bias is preferred in the system. The PV systems would face "true north" in the northern hemisphere and "true south" in the southern hemisphere. Solar tracking is best achieved when the tilt angle of the tracking PV systems is synchronized with the seasonal changes of the sun's altitude.

Several methods of sun tracking systems have been surveyed and evaluated to keep the PV cells perpendicular to the sunbeam. An ideal tracker would allow the PV cells to accurately point toward the sun, compensating for both changes in the altitude angle of the sun (throughout the day), latitudinal offset of the sun (during seasonal changes) and changes in azimuth angle. In the light of this, two main types of sun trackers exist: passive (mechanical) and active (electrical) trackers. The detailed literatures review can be found in [3].

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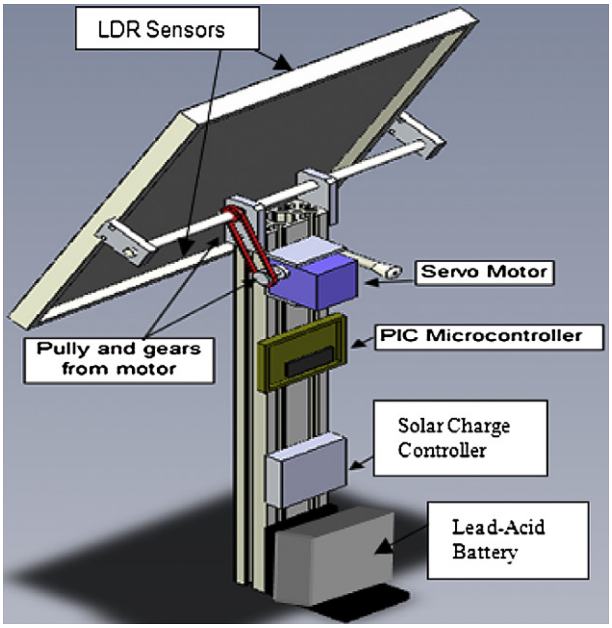

Fig. 1. SolidWork design model.

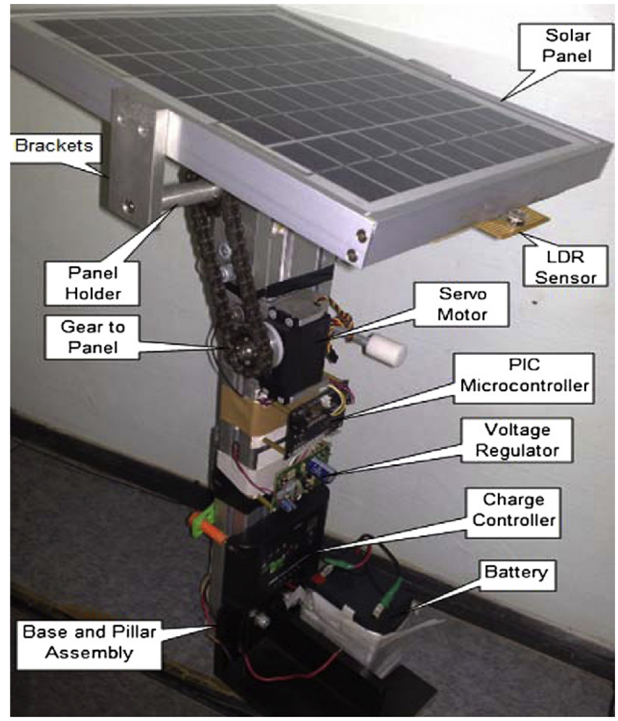

Fig. 3. Actual fabricated design.

One class of the passive solar trackers is the fixed solar panel. It is placed horizontally on the fixed ground and face upwards to the sky. But most of the passive solar trackers are based on manual adjustment of the panel [4], thermal expansion of a shape memory alloys [5]or two bimetallic strips made of aluminum and steel [6]. Usually this kind of tracker is composed of couple of actuators working against each other which are, by equal illumination, balanced. Another passive tracking technology is based on the mass imbalance [6] between both ends of the panel. This group of trackers does not use any kind of electronic control or motor. The sun heats the fluid inside the cylindrical tubes causing evaporation and transfer from one cylinder to another which creates the mass imbalance. Passive solar trackers, compared to active trackers, are less complex but work in low efficiency. Although passive trackers are often less expensive, they have not yet been widely accepted by consumers.

On the other hands, major active trackers can be categorized as microprocessor based, computer controlled date and time based, auxiliary bifacial solar cell based and a combination of these three systems. In the microprocessor based solar tracker systems [7–11], a controller is connected to DC motors. Once the location is selected, the azimuth elevation range is determined and the angular steps are calculated. In this solar tracker design, sensors were often used. For example, a photo-resistor [12,13] was put in a dark box with small hole on the top to detect the illumination or Photosensors called light-dependent resistor (LDR) [11,14] to indicate the intensity of the radiation. The signals were then captured by the microcontroller that provide signal to the motors to rotate the panel.

Whilst in the auxiliary bifacial solar cell [15] systems, the bifacial solar cell senses and drives the tracker system to the desired position. In the design, components such as batteries and driving electronics were eliminated. Hence, it is very simple solar tracker for space and terrestrial applications. In the solar tracking system using the Programmable Logic Control (PLC) [16,17], the required position was calculated and later programmed into the PLC to adjust the PV panel to the sun direction. In another method that uses the combination of microprocessor with sensor and date/time-based system [18,19], the sensors such as pyrheliometers (that measure the direct beam of sun irradiance) send signal to the microprocessor. Using the real-time clock, the data gathered during the day are

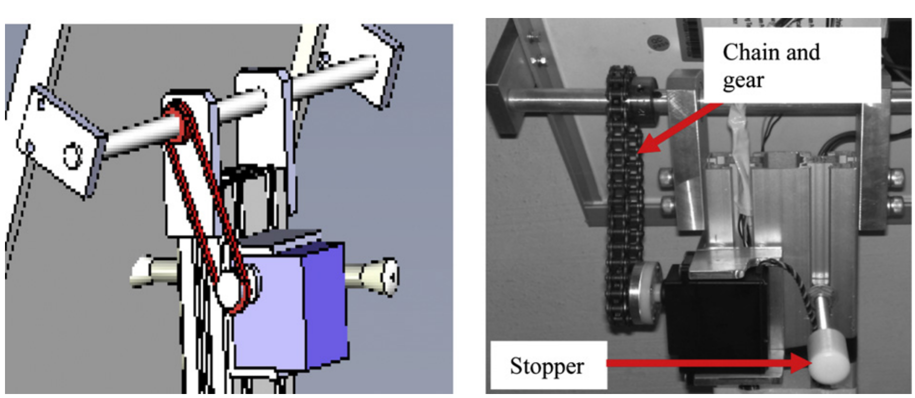

Fig. 2. Transmission system between motor and PV panel holder.