Microcontroller-Based Application for Solar Energy Collection Optimization

Dr, Mostafa B. Abuitbel[1], Khaled A. Madi[2], Mohammed M. Aburazizar[2]
[1] Dept. of Electrical and Electronic Enginerring, Azzaytuna University
Dept. of Electronic Enginerring, Engineering Academy Tajoura

Abstract:

This paper describes an investigation into a complete design of a self-rotated single-axis solar tracking system based on microcontroller for maximum solar energy collection. The energy collection can in general be optimized through the use of an efficient tracking system which rotates the solar panel. Through photovoltaic cells, solar panel energy output is maximized when the panel is directly facing the sun direction. In addition to practical implementation, two major activities are presently described, the first being the hardware design and the second being the software development. The work undertaken involves the use of light dependent *photo-resistors where the tracker responds to the sensed sun light intensity to situate the panel in an optimal location to capture solar rays efficiently. Then by implementing a programmed microcontroller and a DC motor, the designed system precisely aligns itself in the direction of the maximum solar intensity throughout the day. For low-cost implementation, a real-time controlled tracking system has successfully been developed to increase the overall efficiency of solar harvesting and practically verified to prove the solar energy utilization.*

Keywords: *Solar tracker, LDR sensors, DC motor, microcontroller*.

I. Introduction:

Although sun is a very abundant source of power, only a fraction of this entire plentiful energy is efficiently exploited. Generally, about 30% of solar energy is reflected back to the space and 19% is absorbed by the atmosphere and clouds while the rest strikes the earth surface. Because only 33% of the sun's energy is theoretically converted to electricity, there is a great potential which needs further research investigation. Therefore, solar energy is rapidly gaining the focus as an important means of expanding renewable energy uses. Renewable energy eventually will replace the conventional energy sources such as from fossil fuels. The resources of the fossil fuels are limited and their use results in global warming due to emission of greenhouse gases. Developed countries are hardly trying to reduce their greenhouse gas emissions and make an efficient use of any available form of a clean and unlimited energy.

To provide a sustainable power production and safe world to the future generation, there is a growing demand for energy from renewable sources like solar, wind and others [1]. Renewable energy can also provide a source of alternative energy for periods when the main power grid is occasionally offline. Moreover, the sun's position in the sky varies both with the seasons and time of the day [2].

Because the sun moves across the sky from east to west and only certain geographic regions can provide sufficient periods of direct sunlight, it is advantageous to have an effective mechanism to capture maximum sun light for maximum power generation. One of the possible solutions is to use solar panels aligned with sun position at all time. Solar panel or photovoltaic (PV) cell is considered to be as a transducer which converts solar energy into useful electrical energy for domestic and other applications. The output power of a PV cell depends on the amount of light projected on the cell, the time of day, season, panel position and orientation[3].

Moreover, fixed angles solar panels are rarely used as they have limits on their area of exposure to the sun during the course of the day and as a result their average solar energy is not always maximized [4]. Thus, the design and implementation of non-stationary solar trackers in this regard have gained massive research investigations for several years [5, 6 and 7].

These previous studies have shown that self-rotated solar trackers are among the most appropriate and proven technology to increase the efficiency of the solar panels. The aim of the current work is to design a complete tracking system based on hardware and software integration to move the tracking base in a horizontal plane according to the sun direction and catch maximum sunlight to increase the output power of the solar panel by taking the advantage of the full amount of the fallen sun energy.

II. Design Methodology:

A. Hardware Description:

The proposed tracking and controlled system is an electromechanical setup and in addition to control programming, the components required for system construction are: microcontroller (Arduino Uno type), power supply, DC electric motor, H-bridge (L298D), designed analog conditional circuit and two light dependent resistors (LDRs) or light-sensitive sensors. The given components are connected in as shown in the Fig.1. This configuration offers the possibility to fulfil the design objectives. The objectives are the ability to precisely follow the sun changing position for maximum power supply and accurately dealing with some weather variations if possible.

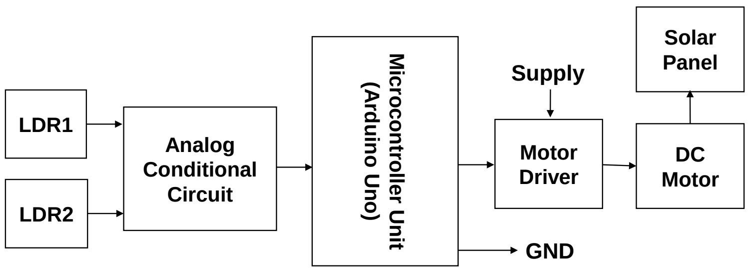

Fig. 1 Block diagram the proposed solar tracking system

B. Theoretical Implementation:

Two LDRs are fixed separately inside hallow cylindrical tubes and positioned on both sides of the solar panel for better light capturing and sensing the amount of fallen light. LDRs have the property to change their resistances according to intensity of light. The higher the light intensity the less is the corresponding resistance of the sensor and vice-versa [8]. Hence, in this case each LDR works as a variable resistor. The sensors are interfaced with the microcontroller. To convert the varying values of the LDRs resistors into something measured on Arduino's analog inputs, they need to be converted into voltage. The simplest way to do that is to combine them with fixed resistors forming a potential divider passing the measured voltage signals to the microcontroller, where the sensors are placed in a series connection with the resistors and the output taken at a point in between. As a result, higher voltage passes through whenever there is high-intensity of light and passes low voltage whenever it is dark.

Furthermore, other signal conditional is used for sensors and microcontroller compatibility. After the microcontroller unit reads the changes of light intensity measured by both sensors, it calculates the difference between the readings. Based on the difference of the readings, the direction of the sun can be determined. This difference could be less than or higher than or even equal to a specified tolerance or threshold value which is being used as a control signal for the desired location. If the difference is higher than the tolerance value, the microcontroller generates a control signal either for LDR1 direction (east) when it catches more light or in LDR2 direction (west) otherwise. However, if the difference becomes zero or equal to the tolerance value, the microcontroller generates no signal. No signal generation indicates that the solar panel is facing the sun and the light intensity falling on the LDRs are uniform or both in dark where no mechanical movement or rotation is occurred [4].

Moreover, the precisely programmed microcontroller is interfaced with a DC motor using a voltage/current driver, because the amount of current required to drive the motor is higher than the current provided by the microcontroller. A solar panel is attached to the motor through a shaft, which allows the panel to be rotated in the direction where sunlight is maximum. The motor rotates as long as it receives a control signal. Finally, a reverse rotation to a specified position is possible for new tracking process. The flowchart given in Fig. 2 simplifies the tracking cycle.

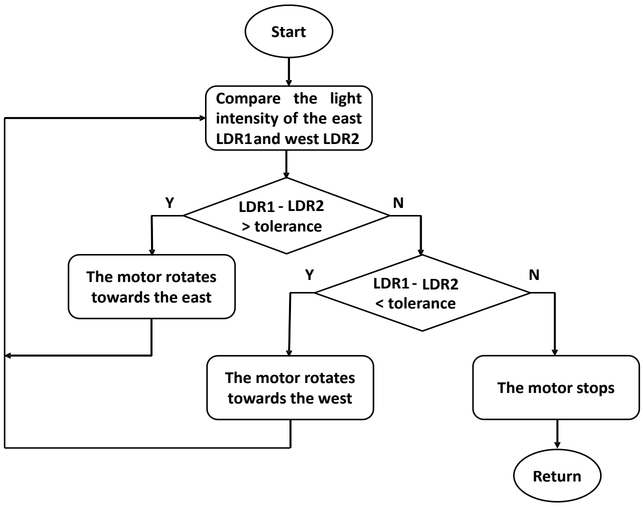

Fig. 2 Flowchart of unidirectional tracking system

C. Software Development:

Programming the microcontroller is developed to provide the required signal processing. The written and loaded code consists of a main module and few subroutines to provide the expected behavior of system operation and to systematically control the hardware operation. Carefully programming the microcontroller prevents the use of extra hardware circuitry to accommodate the possible light intensity changes due to weather condition. This overall automated mechanism is opposed to stationary systems which cannot increase the power generation when the sun is not perfectly aligned with the system and do not obtain the optimum amount of sunlight throughout the day.

III. Practical Implementation:

The hardware previously described is practically designed and experimentally verified to track the position of the sun and controls the movement of the solar panel. Fig. 3 illustrates the real-time designed system along with the corresponding electronic circuitry. For testing, initially, the involved hardware components are operated using a 12V battery where they will be operated afterwards from the solar panel are connected to. It is to be considered to use as little power as possible since any energy consumed here will be subtracted from the total energy the solar cells can provide to any connected load.

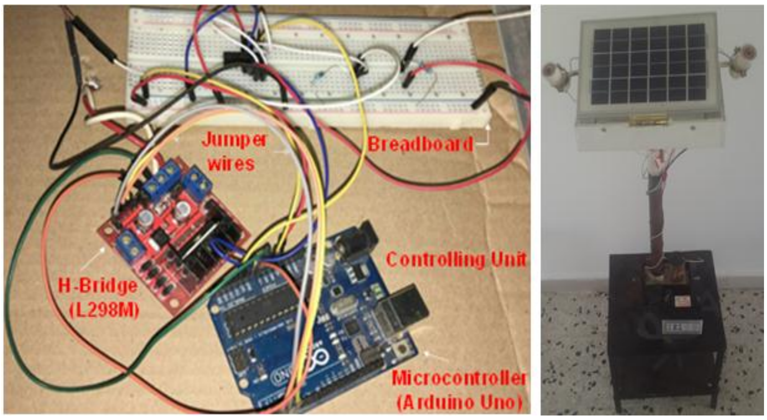

Fig. 3 Prototype of the designed single-axis solar tracker

IV. Experimental Results:

The designed tracker is tested experimentally indoor and outdoor. This is to check that the tracker is performing properly and to determine the panel output power. Thus, for a fixed elevation angle and for 12 hours of a day, the system verification was done in both fixed and auto-tracking case. Taking into consideration the weather condition on the measurement day and the panel size, the corresponding results are given in Fig. 4.

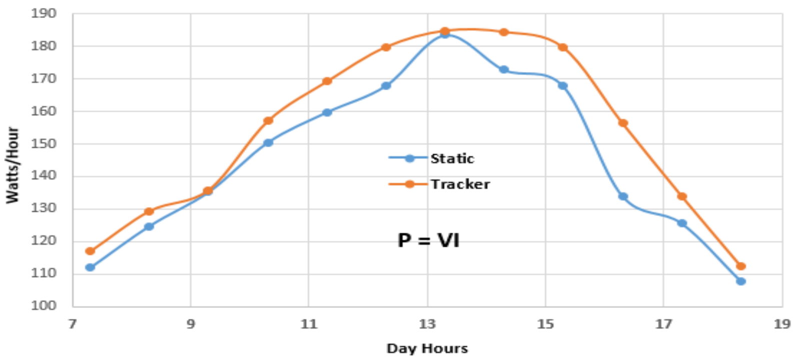

Fig. 4 The measurement results

Generally, the PV modules are used in small and large scale installations, where they can be wired or connected together in series or parallel or both combinations together to increase the voltage or current capacity of the solar array. The voltage increases in series connection and current increases in parallel connection. The electrical power in watts generated by these different PV combinations is still be the product VI. Thus, the field performance of the panels is characterized by measuring the relationship between panel's voltage, current and power output under different environmental conditions and panel orientation.

V. Tracker Expected Utilization:

The obtained readings are direct current (DC) which have higher values for the auto-rotation than for the fixed case. As the electric power used in home and industry is an alternating current (AC), an inverter will be used to convert the generated DC into AC whenever it is needed. Moreover, the primary disadvantage of solar power is that it obviously cannot be created during the night and will be reduced during the cloudy weather. Therefore, a possible set of battery banks can be used to store the energy in day time to be utilized nightly especially for low power appliances. The practical setup for the tracker utilization is simplified in Fig.5.

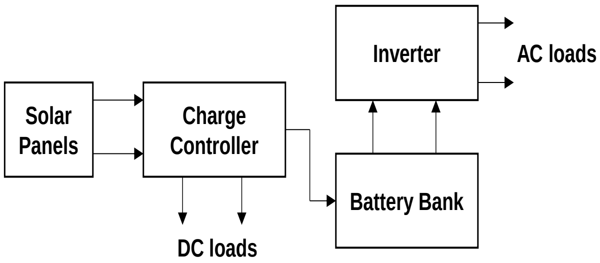

Fig. 5 The principles of solar energy utility

VI. Conculsion:

Energy is an essential factor for the development of any nation. Worldwide countries are taking advantages of solar energy to improve their overall electricity generation. They have employed solar panels to generate clean energy from sun and eventually contributing less environmental pollution. The sun is an enormous and convenient source of permanent energy. The process of sensing and following the position of the sun is known as solar tracking. Therefore, it is desirable to have the ability to track the sun as it moves across the sky. The tracking systems will move the panels to be positioned perpendicular to the sun for maximum energy conversion at all times. Presently, a microcontroller-based automated sun-tracking system has been designed and experimentally tested. As the plane of the panel is always kept normal to the direction of the sun, a maximum energy is guaranteed. The successful real-time practical measurements obtained are compared favourably with the theoretical expectations. Furthermore, as no heavy mechanical or other complicated parts are included, the total construction cost of the proposed tracker was considerably low, where it can be commercially available at an affordable rate. However, some of natural phenomena such as rain and dust may cause erroneous results and under these circumstances, the system may not show a satisfactory performance where a periodic monitoring is required to prevent the system deficiency. Finally, to enhance the tracking capability, the designed system is to be modified and a two-axis tracker can be further investigated for future research activity.

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