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Solar Power Generation Based on Mechatronics System

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ABSTRACT: This paper explores current demands for environmentally friendly, renewable energy sources; sun radiation is changing into progressively enticing. However, while sun radiation is free, non-polluting and, in sensible terms, inexhaustible, there remain significant inefficiencies in capturing it. To draws an idea from the fact that the sun bathers the earth with more energy per minute then the world consumes in one year. The paper proposes a fuzzy algorithm to achieve optimal solar tracking with greater efficiency. The proposed system uses a dc motor and light sensor & fuzzy logic.

Keywords: Solar Cell, DC Motor, Solar Energy, fuzzy-logic, Light Sensor.

I. INTRODUCTION

Extraction of useable energy from the sun made possible by the invention of the Photovolatile device and successive growth of the solar cell. The cell is a semiconductor material that converts visible light into a direct current. By using solar arrays, a series of solar cells electrically connected, a DC voltage is generated which can be physically used on a load. Photovolatile arrays or panels are being used increasingly as efficiencies reach upper levels, and are particularly fashionable in remote areas where placement of electricity lines is not cost-effectively viable. As shown in fig. 1

Fig. 1. Solar arrays stationary setup.

This substitute power supply is always achieving greater popularity especially since the realization of fossil fuels shortcomings. Renewable energy in the form of electrical energy has been in use to some measure as long as 75 or 100 years ago. Sources such as Solar, Wind, Hydro and Geothermal have all been utilized with varying levels of success. The most widely used are hydro and wind power, with solar power being moderately used worldwide. This can be attributed to the relatively high cost of solar cells and their low conversion efficiency. Solar power is being heavily researched, and solar energy costs have now reached within a few cents per kW/h of other forms of electricity generation, and will drop further with new technologies such as titanium oxide cells. With a peak laboratory efficiency of 32% and average efficiency of 15-20%, it is necessary to recover as much energy as possible from a solar power system. As shown in the fig. 2.

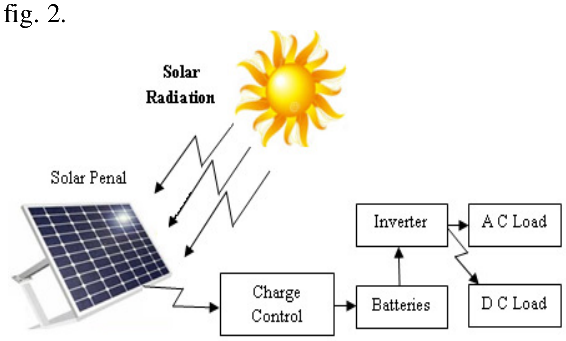

Fig. 2. Block diagram of the solar systems.

II. STATE –OF-ART

The research surrounding solar energy has a brief history of rapid growth. Bell Telephone Laboratories originally created Solar Cells during the 1970s (Nansen, 1995). Utilization of this developing technology may lead to long-term solutions to the growing energy crisis. With the continued damage to the environment and growth of energy demands new sources of energy must be realized for continued prosperity. Experts can all agree that two basic criteria must be observed to be considered a viable option. Energy must be low cost and reliable (Meisen, 2002; Nanson, 1995). Other criteria to be considered are environmental effects (Meisen, 2002; Nanson, 1995) and usability of the type of energy (Aronson, 2009;

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As our current utility systems are based on the burning of carbon fuels environmentalists are studying the effects on the environment. Energy utilities Mechatronics Application to Solar Tracking produce greenhouse gasses. As energy demand rises, the production of greenhouse gasses will also rise. Nuclear power is another alternative that is harmful to the environment. Nansen (1995) said: "Nuclear power uses a depletable resource and also leaves in its wake toxic nuclear waste." "Hydroelectric power is generated by a wonderful renewable source, but there are few rivers left in the world to dam and there is a growing concern over the impact dams have on the fish population (p. 7)." From Nansen's statement we see the implications of hydroelectric power and how its effects the ecosystem in rivers. Rose and Pinkerton emphasize the pollution caused by coal and nuclear power. Rose and Pinkerton (1981): "Solar cells have no known adverse environmental impacts during operation. Another study was conducted by Mohammed S. Al-Soud, E

Ibrahim Sefa, Mehmet Demirtas, and Ilhami Colak (2009) designed a single axis sun tracking system in Turkey. The sun tracking system developed by Sefa and others included a serial communication interface based on Rs 485 to monitor whole processes on a computer and record the data. Feedback data was recorded by two photoresistors. The solar cell was aligned at a fixed 41° facing south (Sefa, et al., 2009). A microcontroller observed and controlled the east-west rotation of the tracker by means of 24V 50W dc motor (Sefa, et al., 2009). The results of the measured energy showed an increase up to 46.46% of collected solar energy (Sefa, et al., 2009). Yusuf Oner, Engin Cetin, Harun Kemal Ozturk, and Ahmet Yilanci (2009) developed a solar tracker utilizing the application of a spherical motor. The motor contains a rotor containing a four pole magnet surrounded by eight individually energized stator poles (Oner, et al., 2009). With the magnet in the middle direction is controlled by the surrounding stator poles (Oner, et al., 2009). This design allows for three degrees of freedom. The degrees of freedom being forward and back tilt, a left and right lateral tilt, and rotation along a z-axis.

III. SOLAR TRACKING CONTROL SYSTEM

An excessive-performance sun tracking system uses two motors as the drive source, conducting an approximate hemispheroidal 3-D rotation on the solar array within a sure quantity of area. This rotary motion allows the system to track the solar in real time to efficiently do photoelectric (PV) conversion and production. The two drive motors are decoupled (i.e., the rotation angle of one motor does not influence that of the other motor), reducing control problems. Additionally, the tracker does not have the problems common to two-axis mechanical mechanisms (i.e., that one motor has to bear the weight of the other motor). This implementation minimizes electricity consumption for the duration of operation and will increase both performance and the whole quantity of energy generated

From the study we are able to know when the temperature is fixed, the stronger the sunlight is, the higher the open-circuit voltage and the short-circuit current are.

IV. SYSTEM BLOCK DIAGRAM

The system architecture of the proposed solar tracking control system using microcontroller MSB430F6438 is shown in Fig. 5. The sun light fed to the solar panel will feed the boost converter directly which stores the electrical energy temporarily in an inductor and then charges the battery. The battery then feeds the load during sunlight hours as well as nighttime. The boost converter is to be operated by a digital controller. The digital controller will be based upon a microcontroller that monitors the voltage and current levels coming from the solar cell and controls the boost converter accordingly. Finally, the charge sensor will keep track of the charge of the battery in order to not overcharge the battery, which may damage some types of batteries. While not shown, all active components such as the digital controller will be getting its power from the solar cell.

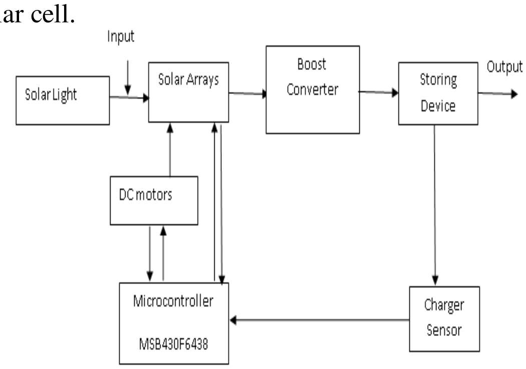

Fig. 5. System architecture of the solar tracking system.

The array solar tracking system architecture contains two motors to drive the platform, conducting an approximate hemispheroidal three-dimensional rotation on the array solar generating power system as shown in Fig. 6. The two motors are decoupled, i.e., the rotation angle of one motor does not influence that of the other motor, reducing control problems. This implementation minimizes the system's power consumption during operation and increases efficiency and the total amount of electricity generated. The flow chart of the tracking is shown in Fig. 7.

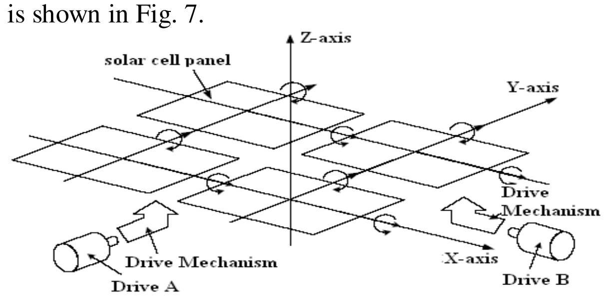

Fig. 6. Sketch of the two-axis array solar cells.

There are two important advantages in the array type mechanism as follows:

(1) High efficiency of light-electricity transformation.

Since the array solar tracking mechanism has a function of rotating like three-dimensional, the array solar tracking mechanism can track the sun in real time. Therefore, the system has high efficiency of light-electricity transformation and has an advantage of large production.

(2) The mechanism is simple and saving power.

The two rotating dimensions of the array solar tracking mechanism are controlled by the two independent driving sources, which do not have the coupling problem and bear the weight of the other driving source. At the same time, the rotating inertia of the rotating panels can be reduced.

The tracking device is composed of two same LDR (Light dependent resistor) light sensitive resistors, which detect light intensity from eastern, western, southern, and northern directions, respectively. In every direction, there is a LDR light sensitive resistor with an elevating angle 90^0 to face a light source. The two sensors are separated each one. One is using LDR light sensitive resistors to be an eastward- eastward direction sensor for comparing the light intensity of eastward and westward directions. When the eastward-westward direction sensor receives different light intensity, the system will obtain the signal according to the output voltages of the eastward-westward direction sensors. As shown in the fig. 7.

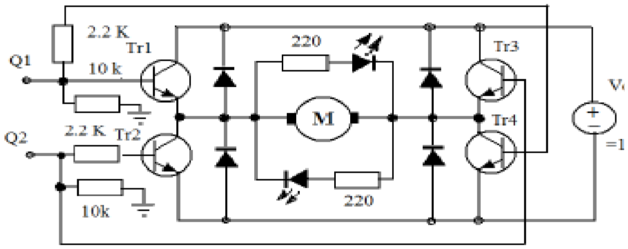

Fig. 7. Motor driver circuit for solar altitude direction.

A voltage type analog/digital converter (ADC0804) can read different output voltages of the sensor and decide which direction has larger light intensity than the other direction. Then, the system will drive the stepping motors to make the solar panel turn to the decided direction. When the output voltages of the eastward-westward direction sensor are equal, i.e., the difference between the outputs of the eastward-westward direction sensors is zero. Then, the motor voltage is also zero. This means that the tracking process is completed in the eastward-westward direction. Similarly for another southern-northern direction sensor, it can be analyzed by the same methodology to track the sun in the Southern-northern direction.

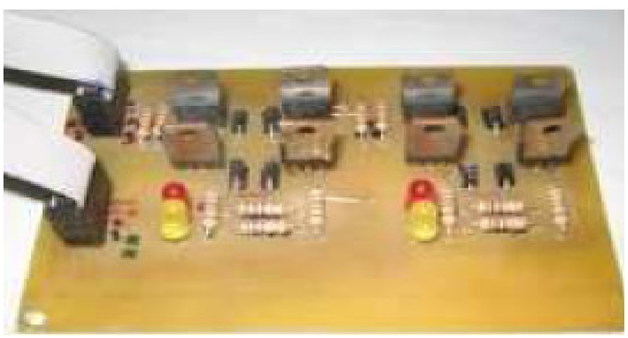

Fig. 8. Print circuit board of motor driver circuit.

Motor driver circuit: This experiment is conducted by the main source of power or motor which functions both altitude and azimuth directions. Two 12 volt direct circuit motors are employed in the device. The motor test from head gear indicates that the motor speed is at 8 rpm. This part is split into two significant parts which are the altitude part and azimuth part. The motor structure is as displayed in the Fig. 8.

V. EXPERIMENTAL RESULTS

The experimental solar cell panels are shown in the fig. 9 (a), (b), (c) and fig. (d). Solar intensity of the light reaching the Earth is dependent on the sun's angle of altitude. Solar radiation is always at highest on a plane that is perpendicular to the sun's ray.

As the horizontal and the altitude angle change throughout the day and the year, the incidence angle of the solar radiation varies constantly on given areas. Orienting panels to keep them facing the sun can achieve significant energy gains in comparison of any fixed position.

Fig. 9. (a) Completed Solar Tracker Prototypes.

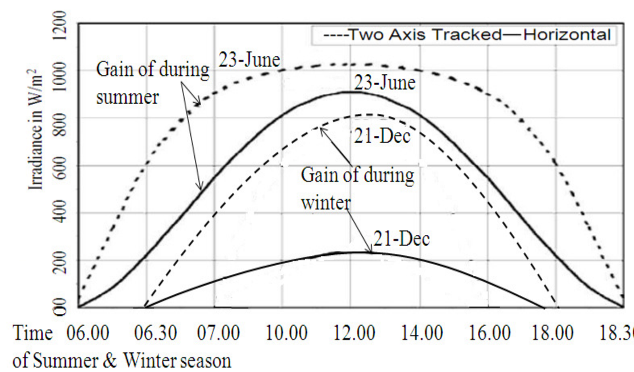

Fig. 9 (b): Difference in irradiance on straight & tracked for sunny days.

Fig. 9 (c): Solar arrays stationary setup.

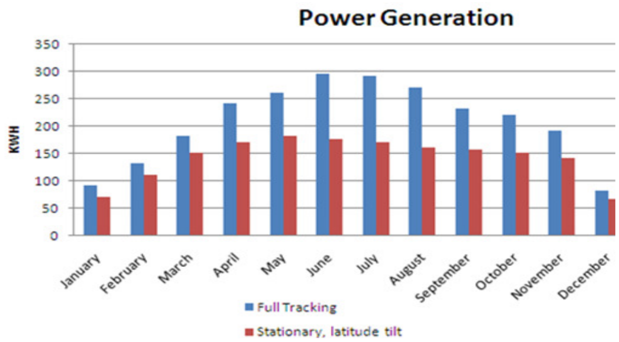

Fig. 9 (d): The power generation comparison of fixed angle type and tracking systems.

Gains of 50% during summer and 300% during winter have been mentioned for a comparison between tracked and horizontal planes. It is interesting to realize that rarely panels will be installed on horizontal plane. An altitude angle near 30^o is normally used in south Indian area. Despite the fact that percentage gains appear lower during summer than winter, the yield increase is predominant during the summer period of the year as shown in Fig. 9 (b). Solar trackers may be solo axis or double axis. Solo axis trackers usually use a polar mount for maximum solar efficiency. Single axis trackers will usually have a manual altitude (axis tilt) adjustment on a second axis which is adjusted on regular intervals throughout the year. Compared to a fixed amount, a single axis tracker increases annual output by approximately 30% and a double axis tracker an extra 6% shown in the fig.12. A tracking device is more expensive than a fixed mounting rack. It requires a modifiable vertical that can withhold larger wind pressure during storms. It can either be equipped with an electric drive. The produce desired output DC voltage and current. Since solar cells are difficult to be produced, every solar cell panel has its own characteristics. In addition, environmental factors such as dust, clouds, etc., may cause different voltages and currents in different sets. Another problem is that some sets may be loads for other sets. In this case, the temperature of set will be risen because of power consumption. When the internal temperature of a solar cell panel is over 85 C ° ~100 C °, the set will be broken. Furthermore, all voltage will be applied in the set, when there are some broken sets in the solar cell array. Therefore, a bypass diode is in a parallel connection to a set for solving the above problem. Thus, a low impedance path of energy dissipation can be provided for each set to overcome a problem of many sets connection.

VI. FUZZY LOGIC CONTROLLER OF SOLAR ARRAYS

The fuzzy sets concept was proposed by Zadeh in 1965. The fuzzy algorithm can make human knowledge into the rule base to control a plant with linguistic descriptions. It relies on expert experience instead of mathematical models. The advantages of fuzzy control include good popularization, high faults tolerance, and suitable for nonlinear control systems.

A fuzzy controller design has four parts, fuzzification, control rule base, fuzzy inference, and defuzzification. The block diagram of the fuzzy control system is shown in fig. 10.

At first, the sun light illuminates on a LDR light sensitive resistor of the solar tracking device. Then a feedback analog signal will be produced and transformed into a digital signal through an analog/digital converter. When the voltage on the eastward-westward direction or the southward-northward direction is different; the differences will be delivered into the fuzzy controller. Then, the fuzzy controller produces pulses to motor drivers and the motor drivers produce PWM signals to control step motors for tuning desired angles. Note that if the differences of sensors are zero, i.e., the sun is vertical to the solar panel, so the fuzzy controller does not work.

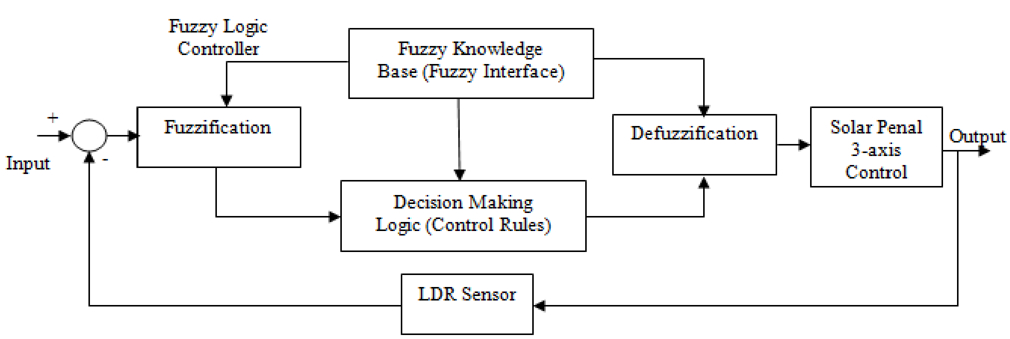

Fig. 10. Solar Penal fuzzy control system structure.

Since the sun moves very slow, the fast rotating speed of the solar tacking device is with high speed rotation not necessary. By fuzzy control, some advantages such as reducing consumption power of step motors and fast and smooth fixed position can be achieved.

Therefore, the fuzzy control algorithm has enough ability to complete this goal.

Since the corresponding LDR light sensitive resistors can operate independently, it can be seen as independent control. For one motor control, the error of output voltages of corresponding sensors can be set as input variables. The rotation time of the stepping motors for clockwise and counterclockwise are output variables. The membership functions are shown in Figs. 11 (a) and (b). Five fuzzy control rules are used, as shown in the following. Fig. 13. shows velocity up after the first movement of the motor on a vertical and horizontal directions Fig. 13 shows that the variation at motor torque for the period of steady operation on an uneven road. It can be seen that fig.12 and fig. 13 while the vehicle running on uneven rood motor torque is high-quality adaptive to rood indirectly speed is constant.

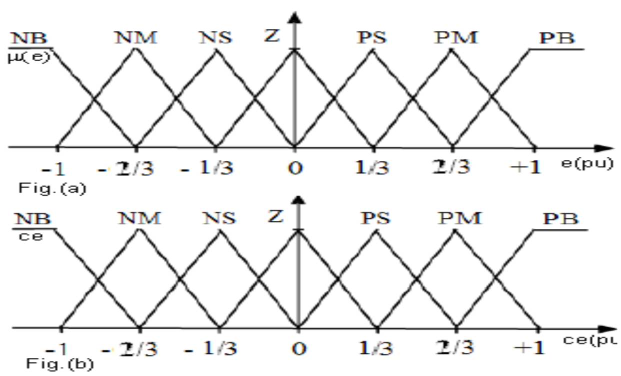

Fig.11. (a) & (b) Membership functions of linguistic variables

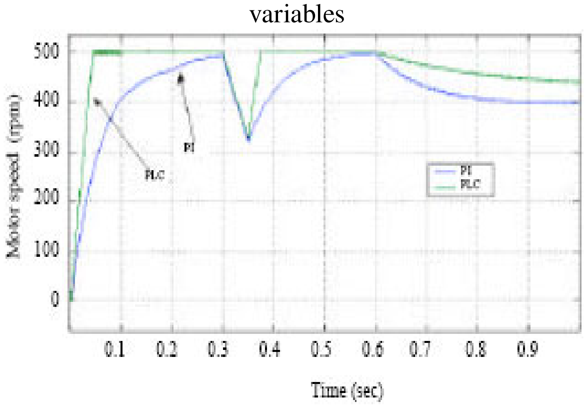

Fig. 12. Velocity up curves against to time of the vertical and horizontal direction.

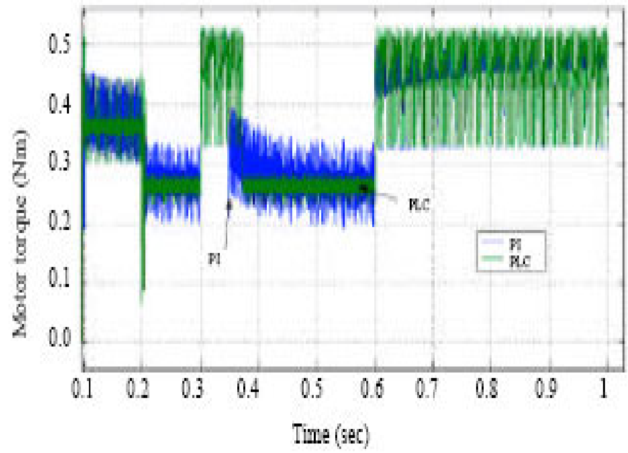

Fig.13. The variation at motor torque for the period of stable operation on a vertical and horizontal direction.

VII. CONCLUSION

The paper presents a solar tracking power generation system. The tracking controller based on the fuzzy algorithms uses a MSB430F6438 microcontroller. A solar tracker is designed by employing the new principle of using small solar cells which functions as self-adjusting light sensors and provides a variable indication of their relative angle to the sun by detecting their voltage output. The said principle helps the solar tracker in maintaining a solar array at a sufficiently perpendicular angle to the sun. The increased power gain over a fixed horizontal array was found to be in excess of 30 to 35% from fixed solar arrays.

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