Design and Implement of Two Axes Automatic Sun Tracking with Fuzzy Controller

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Abstract

The solar energy is widely used in Thailand. Most of all are fixed on the roof or ground. To increase efficiency of harvesting energy, two axes solar tracking is designed and constructed. The position of the sun is detected by using four LDR sensor. Those sensors are divided by partition in order to know the light direction of the sun. Those data from the sensor are sent to micro-controller to determine the motion by fuzzy controller. The rule of controller is designed to be concerning of energy consumption. Two linear actuator is applied to rotate solar panel. Both of actuator is decoupled. Fifty watts of solar panel is applied to collect the energy. The solar tracking of this research can gain more energy than fixed panel 14 percent. The experimental results are presented and compared.

Keywords: two axes tracking, fuzzy controller, solar energy, LDR sensor

I. INTRODUCTION

Nowadays, much renewable energy is wildly used such as solar, wind, geothermal, biomass and hydropower energy. In Thailand, about sixty percent of the energy source is from natural gas and only seven percent from renewable energy [1]. The solar energy is the third of the sources used after bio-mass.

The sun is the biggest sources and clean energy. The solar panel is used to harvest energy from the sun. The solar panel system can be divided into two types. The passive solar panel is fixed tilt (cannot move following the sun) another type is the active solar panel (the panel can track the sun). The harvesting light is dependent on the angle of incident on sun's light to the solar panel. To get high power from solar panel, the incident angle should be close to zero [2] (perpendicular to the solar panel's surface).

There are many researchers focus on sun tracking system. Soteris A. Kalogirou [3] is designed and build the one-axis sun tracking by using three lights-dependent resistor (LDR). Those of sensor separate works; the first is checked focus of the collector, the second is for detecting day or night and the last sensor is cloud cover. Two LDRs is implemented for solar tracking in one-axis [4]. By output voltage comparing between both LDRs. Both sensor are placed along east to west direction, the output voltage will be difference when the sun rotate all day. From many previous research, [2] presents the active solar panel (one-axis) can increase average 30 percent of fix panel. To increase high efficiency of solar panel, two axis tracking is implemented by [5-8]

Two axis solar tracking is controlled by PLC program [5]. The idle time of the system will be 15-35 min and work for few second. By this concept of idle time. The system can save working energy of the actuator. [6] is implement and controlled by micro-controller. By tracking sensor, four LDRs is fixed inside the hallow cylinder tubes. One pair of LDR sensor detects movement in azimuth angle and another pair detects tilt angle. Both pairs of sensor are comparing the voltage value and try to balance it by moving solar panel. Chong, K [7] is applied mathematics to calculate the movement of actuator (open-loop control). And last previous work is P.R.Kaware [8] presents the closed-loop control with four LDR with a cylindrical shade. [9] applied only on-off control to track the sun.

In this paper, the active solar is designed and implement control algorithm. The solar panel is two-axis sun tracking in order to increase efficiency. To reduce the actuator power, Fuzzy algorithm is applied to control the system.

II. HARDWARE DESIGN

A. Structure Design

Due to movement of the sun are composed of azimuth angle (ψ) and tilt angle (α), then every day the sun path is always changing. By this information, the designer of sun tracking have to two degrees of freedom in order to cover the movement.

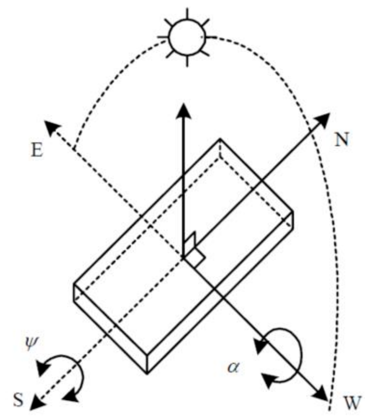

Fig. 1 two axis of sun tracking [6]

The system consist of hardware structure, solar panel, controller board and motor actuator. Those components of sun tracking system are present in Fig.2

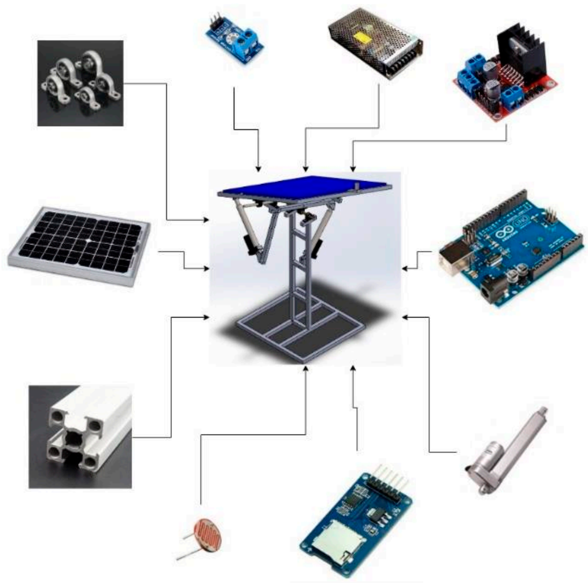

Fig. 2 The sun tracking component

To rotate the solar panel, the linear motor is applied and design to rotate the panel. The advantage of linear actuator is useful in designed structure. The first advantage is self-locking mechanism. The sun is moving slowly in each time period, so if the system is always working in those periods, it will consume more energy to keep track. By this effect of self-locking, the system cannot always tracking all time to maintain position. The second advantage is high power. Due to the weight of solar panel, the torque efficiency of linear motors is higher compared with sizing. The solar tracking mechanism is presented in Fig.3

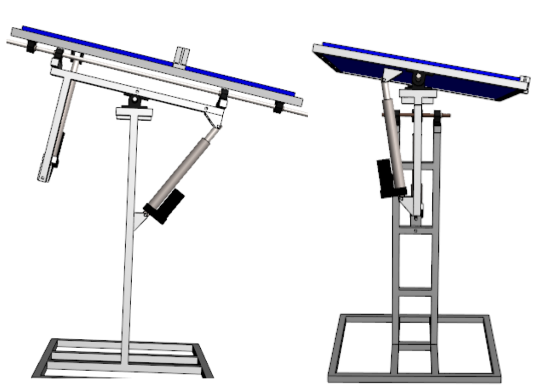

Fig. 3 The solar tracking mechanism

The disadvantage of linear motors is decreasing of working space. Then the panel cannot normal to sun in the morning period (sun rise).

The solar panel angle (ψ, α) can be controlled by the length of linear motor by following equation (1)

$$\psi, \alpha = cos^{-1}\left(-\frac{L^2 - x^2 - y^2}{2xy}\right) \quad (1)$$

when

- ψ is azimuth angle
- α is tilt angle
- L is Length of linear motor
- x is length from Pivot point to linear motor in x direction
- y is length from Pivot point to linear motor in y direction

B. Sensor Design

The main sensor to design sun tracking is the light dependent resistor (LDR). [10] can divide the concept of LDR sensor designing into three types. The first type is placed on a flat surface with shading device. The second is added to tilt surface and the last is in collimating tube. Three concepts shown in Fig. 4.

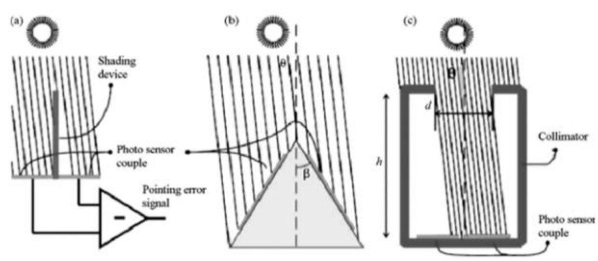

Fig. 4 Tracking concept with LDR sensor [10]

This research combines the first and the second concept of [10]. By combination of both concept, the sensor set can precisely separate direction of sunlight. Four LDR is placed in the corner of partition in this research. And the partition will divide each LDR to four zones, the LDRs sensor present in Fig.5. The working concept of LDRs is balancing the voltage output of each LDR. By rotating the LDRs sensor normal to the light source, the voltage signal will be equaled.

When the sun rise, the LDRs is presented in block_ A as show in Fig.6. Only left side of the LDR can detect light, the actuator will be rotating the LDRs to block B position. This position both LDRs will get equal light value.

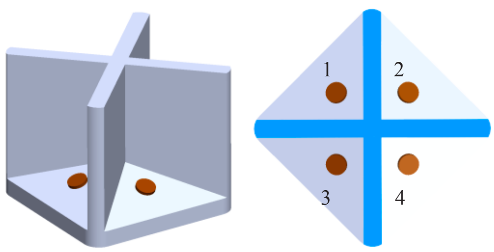

Fig. 5 the LDR assembly sensor

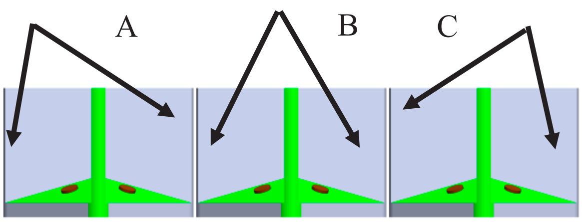

Fig. 6 the working concept of LDRs

C. Implementation of sun tracking

The prototype of two axis sun tracking is implemented to test and control by LQRs sensing. The main structure is made of 20x20 aluminum profile. 100 mm. and 300 mm. of linear motor rotate the solar panel. The Arduino UNO R3 is the main controller to receive data from sensor, calculate control rule and drive command to linear motor. 50 Watts of solar panel is designed to collect power. The sun tracking hardware is presented in Fig.7

III. FUZZY CONTROL OF SUN TRACKING

Two axis sun tracking is designed and built. Both of the axis are decoupling control. The data output of the LDRs sensor (see Fig.4) no.1 and 2 are added together and compared with summing data from sensor 3 and 4 to detected sunlight in azimuth angle. And also no.1 and 3 compares with 2 and 4 to detect the tilt angle.


Fig. 7 sun tracking hardware

The Fig.8 shown the concept to control sun tracking by Fuzzy control. And to design and implement control algorithm, Fuzzy control block in Matlab program is applied to design the control rule. The mandani is fuzzification of this solar tracking. The Matlab block setting is presented in Fig.9

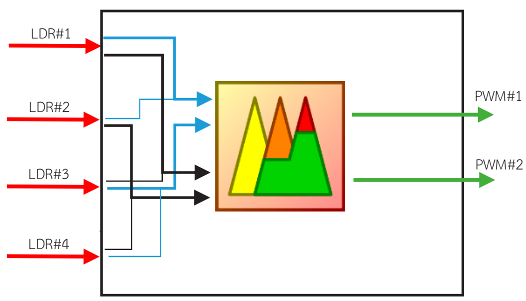

Fig. 8 Fuzzy control block diagrams

The Fuzzy control algorithm is designed to control the sun tracking. By applying fuzzy control, the system can manage tracking error with inaccurate data and working as human reasoning. Then the control rule can be designed by ourselves.

The LDRs sensor is the input of the solar tracking system. The triangular and trapezoidal is applied to the input and output of membership functions. The input and output can be divided to three membership function. Those of membership functions are present in Figs.10 and 11. And Mamdani is the Fuzzy inference between input and output.

There are three rules to manage sun tracking system:

1. If(sensor_Error is Negative_Error) then (%PWM is Shrink)
2. If(sensor_Error is Neutral_Error) then (%PWM is No Movement)
3. If(sensor_Error is Positive_Error) then (%PWM is Stretch)

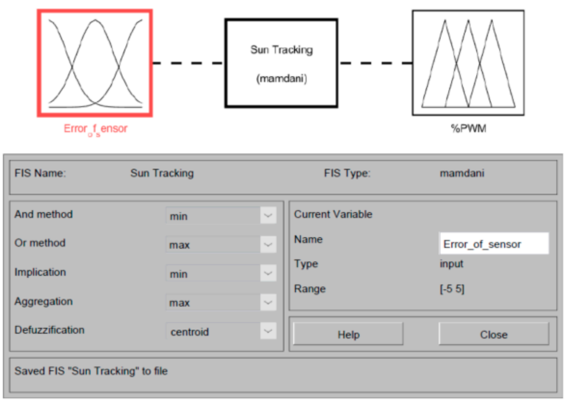

Fig. 9 Fuzzy control setting

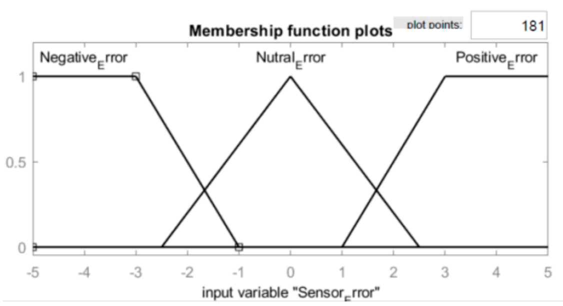

Fig. 10 input membership function

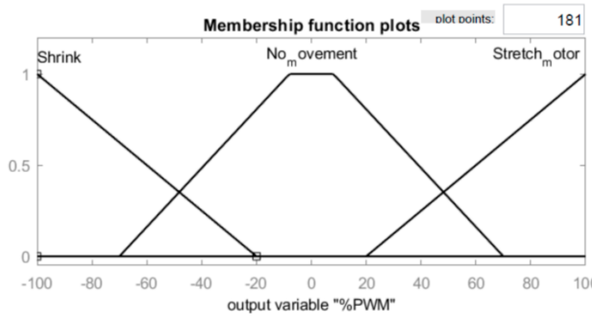

Fig. 11 output membership function

By adding a fuzzy rule to control algorithm, the solar panel can be tracked the sun. The design of the control rule of sun tracking is designed by a gap of both sensor error to activate actuator.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The last session of this research is an experiment. The voltage output from the solar panel from fixed and tracking are conducted and compared. And also present effect of Fuzzy control algorithm. By adding LDRs sensor tracking and Fuzzy algorithm, the solar panel can track the sun and harvest energy. The setting of fixed solar panel is 15 degree fixed and east direction. The data collected is starting in 9.00 to 17.00. The experimental results are presented in Fig.12.

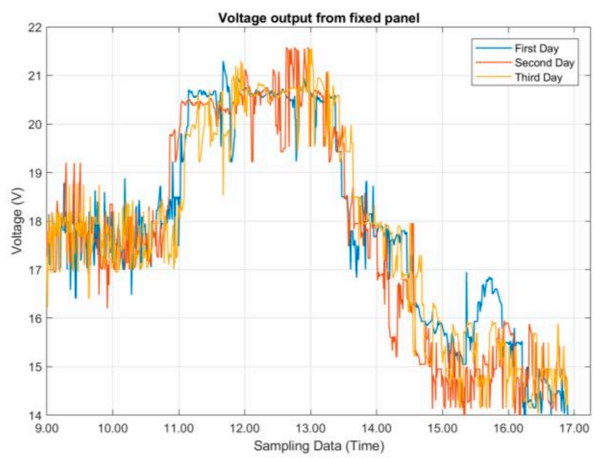

Fig. 12 voltage output from fixed panel

The voltage output from fixed panel can be divided to three zones. The first zone is 9.00 am to 11.00 am, the morning light can produce voltage about 17.5 V. Since the incident angle is not normal to solar panel, then the voltage output is dropped. The noon light is start from 11.00 am to 13.00 pm. This period can produce highest output voltage about 21 V. And the last period is after noon, the output is lower than other period.

After applying fuzzy control algorithm to micro-controller in order to track the sun, the solar panel can move and track the sun by comparing LDRs sensor. The data collected is starting in 9.00 to 17.00. The experimental results are presented in Fig.13.

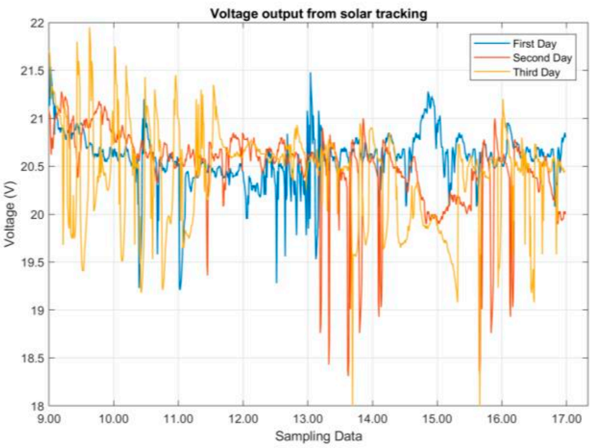

Fig. 13 voltage output from tracking panel

From the experimental result, the output voltage from the solar panel quite stable in each period about 19-21 V. because of the incident angle of the sun is always perpendicular to the solar panel. By tracking the sun, the output voltage is obtained higher than the fixed panel. The results are compared in table1.

Table 1 Output Voltage comparison

Period Time	Average Output Voltage		Voltage compared (V)
	Fixed (V)	Tracked (V)	
09.00-10.00	17.613	20.475	2.862
10.00-11.00	18.914	20.422	1.508
11.00-12.00	19.724	20.289	0.565
12.00-13.00	20.324	20.689	0.365
13.00-14.00	18.952	20.820	1.868
14.00-15.00	17.203	20.301	3.098
15.00-16.00	16.945	20.270	3.325
16.00-17.00	14.745	20.428	5.683

The solar tracking by fuzzy controller can track and harvest energy from the sun with 14% higher than fixed panel and voltage output quite stable.

The output voltage from tracking solar panel by Fuzzy control algorithm and linear controller (PID) is quite similar because the sun rotates from east to west very slow and the sun radiation is very large. Then the benefit of the fuzzy control algorithm is decreasing consumption of tracking power. The power consumption input of two actuators result shown in Figs.14 and 15.

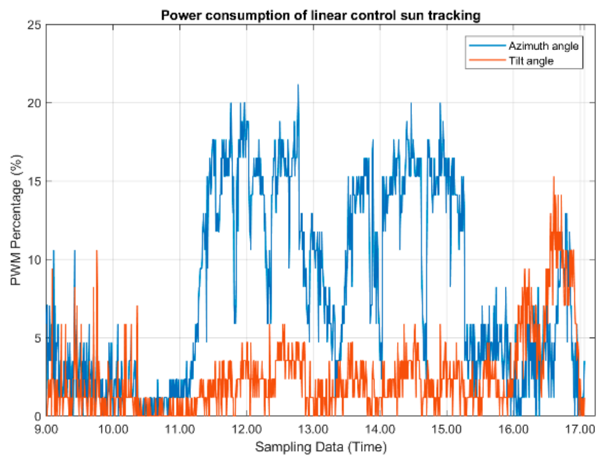

Fig. 14 the power consumption of linear control sun tracking

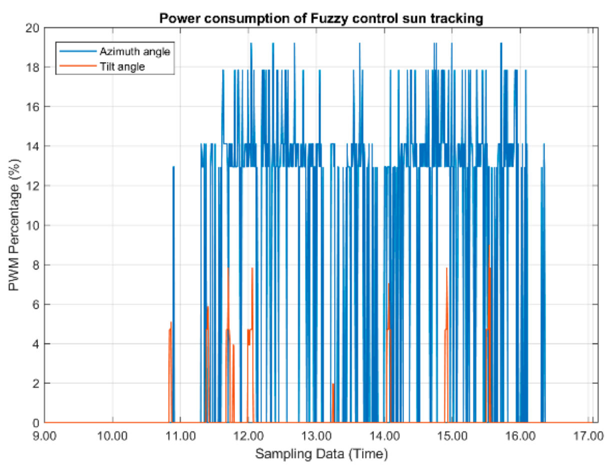

Fig. 15 the power consumption of Fuzzy control sun tracking

From the results of power consumption, the Fuzzy control can track the sun and also lower consume energy than linear controller. Because we can design the control rule, design the non-active zone of actuator.

The problem of the solar tracking is the cloudy condition. The LDRs sensor cannot get the direction of light when cloudy condition. To solve this condition, the equation of motion of the sun can handle.

V. CONCLUSION

To harvest greatest energy from the sun, the incident angle of the sun has to perpendicular to the solar panel. The two axis solar tracking is designed and implement fuzzy control to track the sun. The fuzzy controller can control two linear motors. Four LDR sensor can detect the position of the sun by comparing detecting voltage. The output voltage from solar tracking is stable and higher performance than fixed panel 14 percent.

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