Design and Implementation of Solar Tracker in Solar Energy Conversion Systems

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Design and Implementation of Solar Tracker in Solar Energy Conversion Systems

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***Abstract*.** **The most commonly used energy resources nowadays are non-renewable resources such as oil and gas which are limited in quantity. Recently, scientists have begin to use and develop renewable resources which allow electricity production in a clean way with no emission of dangerous gasses. One of renewable resources such as solar energy, which converts sunlight energy to electricity by using solar cell technology. Most installations of solar panel are fixed and less effective when the direction of the incoming light is not at right angle to the panel plane. The effectiveness can be increased by positioning the panel for better light exposure in order to collect more solar energy, which in turn will produce more electrical energy. Such system was designed and implemented in this research. By using this system to guide the solar panel, a larger amount of electricity is produced. The result is an energy resource system with better effectiveness and efficiency.**

Keywordssolar panel; solar tracker; renewable energy

I. INTRODUCTION

Indonesia has rich solar energy resources. Its solar energy potential has a high daily solar radiation of up to 450 Langleys/day or 4,64 kWh/m^2 [1] obtained using conversion factor 1 Langleys/day = 0,0116 kWh/m^2. This solar energy is a rich renewable source of energy, unlimitted and free, but its utilization is currently still not optimum yet.

The usage of solar energy for electrical power source can be implemented using photovoltaic cells. The produced energy depends on the efficiency and the area of solar cell panels, and the amount of light energy reaching semiconductor layers forming the solar cells.

Fixed installation of solar cell panels on the roof has its limitation. Output of the solar cell panel will be maximum when the direction of the incoming light is perpendicular to the solar panel plane. This dependencies on the amount of solar energy exposed on the panel is one of the weaknesses of photovoltaic solar energy source. This problem can be fixed by positioning the panel to face the direction of the solar ray so that a maximum exposure is obtained. Maximum exposure in turn will allow the solar panel to produce maximum electrical energy.

II. DESIGN OBJECTIVE

The objective of the design is automating the movement of the solar panel tracking the direction of the incoming solar ray by detecting the highest received intensity to maximize the output power of the system using the tracker.

III. DESIGN SPECIFICATIONS

The solar tracker designed and implemented in this solar energy conversion system has the following specifications:

a. Using Light Dependent Resistor (LDR) for detecting solar ray intensity.
b. Using ADC integrated circuits for analog data to digital data conversion.
c. Two DC motors are used for driving horizontal and vertical movements of the panel.
d. DC power generated by the solar panel is used for charging the battery.

The solar panel used in this research has a power rating of 10 Watt-peak.

IV. DESIGN DESCRIPTION

The solar position tracker consists of panel driver construction, microcontroller, DC motor driver, light sensors, ADC, solar panel, panel movement limiter and charger, interconnected and work together with the microcontroller as the system brain. The system will be active when it detects solar radiation that is sufficient to generate electrical power for charging the battery.

A. Block Diagram

A complete block diagram of the complete designed system is shown in Figure 1.

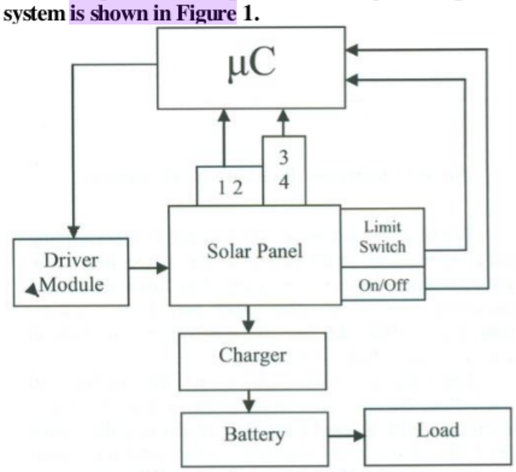

Figure 1. System block diagram

B. System Operation

The sun is assumed to rise and has sufficient radiation power effectively starting from 6 am until sunset at 6 pm. This assumption may be different depends on the actual weather condition that may cause insufficient sunlight radiation on the panel for charging the battery. The solar panel output will still be produced at the load output, regardless it is charging the battery or not, with power limitation depending on the sun light radiation.

A light sensor detects whether it is daytime or night time. If the intensity received is sufficient, then the solar panel and the driver circuit will be activated. The light sensors on the panel will detect the amount of sun light intensity that reached the solar panel parts in the form of electrical voltages. Analog voltages from these sensors are converted to digital data by the ADC of the microcontroller. The microcontroller processes these data to determine whether the solar panel position matches the optimum direction of the incoming sun light while in the sensor reading range. The position determination is performed by a position determination algorithm which continuously moving the two DC motors until the panel position matches the light input received by the sensor. The solar panel output is then read by the charger block and if it is sufficient then it is used to charge the battery. Two solar panels were used with two different conditions. The first one used the solar position tracker and the second one used fixed panel position. The outputs of the two panels were compared in terms of speed and capability to produce electrical power required to charge the battery.

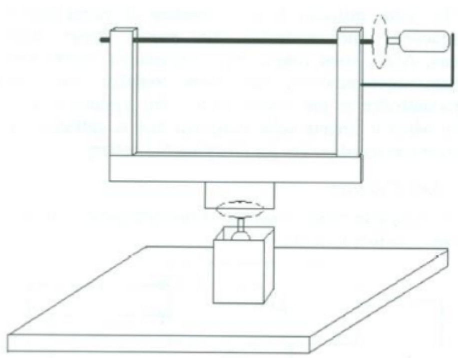

Figure 2. Solar panel driver mechanical construction

The driver construction part is capable of performing panel movements with half-spherical range limit. The construction consists of two parts. The lower part is for horizontal movement. The upper part is for vertical movement. The design of the driver mechanical construction is shown in Figure 2.

The microcontroller block is the center for controlling the whole operation of the system. An Atmel microcontroller is used here. The microcontroller reads the LDR sensor and controls the solar panel movement to face the direction which gives the highest light intensity by driving the DC motors.

V. TEST RESULTS

The DC motor driver block provides the power for driving the two DC motors, horizontal and vertical. The movements follow the instructions from the microcontroller.

The light sensor block reads the light intensity using LDRs. The reading is performed using five LDRs comprising three groups, i.e. horizontal, vertical and day/night time. The horizontal and vertical groups consists of two LDRs each, having a separator between the two in each group, while the third one is positioned at the edge of the driver at a position much higher compared to others. The latter LDR tells the system whether it is day time or night time.

The panel limiter block limits the panel movements so that they do not exceed the range limit of the panel movement. The movement limitation is implemented on both horizontal and vertical movements. These limiters also prevent mechanical damage on the panel construction and system.

The charger controls and limits the charging voltage and current of the battery. The charger module in this system uses two IN 4007 diodes connected to the rechargable 6V battery. The charger module is able to charge the battery when the output of the solar panel is larger than 7 V.

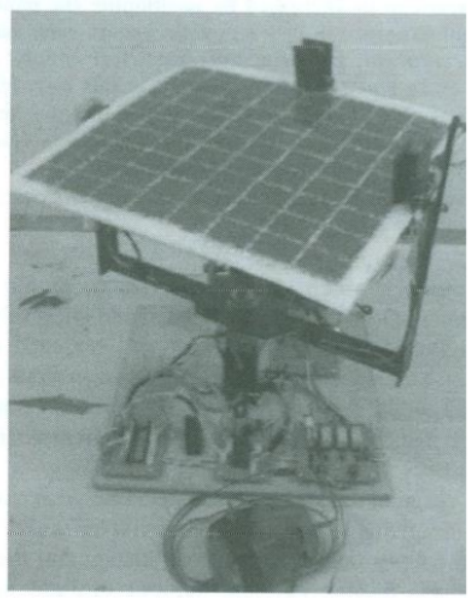

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Figure 3. Photograph of complete system

The test is performed by comparing two systems, with and without the solar tracker. The result is shown in Table I and Table II. Table I shows the result of solar panel test without the solar tracker system, while Table II shows the result of solar panel test with the solar tracker system.

Based on the results shown in the two tables, the comparison is done using the following calculations:

ply (328265-2.34839315) x100% = 39.78281% 2.34839315

The difference in performance (cliff) obtained when the test is performed four times at different times of the day a relatively significant result is obtained. The condition depends on location, time of day and wheather at the time.

Table III shows the result of motor movement response to the light hitting the LDR sensors and the effect of limit switch. The results on the table show motor movement reaction to the light coming into the panel.

The motors will be activated accordingly to the incoming light input when the On/Off LDR sensor is active, in this case the lighting condition is currently morning/midday/afternoon. The three conditions is considered sufficient by panel in order to actively producing output. If the incoming light hit the H R sensor, then the horizontal motor will move the panel to the right, and so is the reverse. If the middle limit switch is active, the motor movement direction is reversed.

TABLE I. TEST RESULT WITHOUT THE SOLAR TRACKER SYSTEM

Time of Day	Output without Solar Tracker			
	V_{oc} (Volt)	I_{sc} (mA)	I_{charge} (mA)	P_{charge} (Watt)
Early morning (7 am)	15.01	16.56	14.58	0.248
Morning (Jam 09.00)	17.61	48.70	42.5	0.858
Midday (12 am)	20.10	210.00	205.00	4.221
Afternoon (3 pm)	17.68	230.00	210.00	4.066
		Average Power		2.348

TABLE II. TEST RESULT WITH THE SOLAR TRACKER SYSTEM

Time of Day	Output with Solar Tracker			
	V_{oc} (Volt)	I_{sc} (mA)	I_{charge} (mA)	P_{charge} (Watt)
Early morning (7 am)	16.92	30.00	26.20	0.508
Morning (Jam 09.00)	18.90	180.00	173.00	3.402
Midday (12 am)	20.10	210.00	205.00	4.221
Afternoon (3 pm)	20.00	250.00	245.00	5.000
		Average Power		3.283

The change is done so that the panel movement is able to stay matched with the direction of light. It needs to be done since the panel position changes while motor reaction to the incoming light logic stays the same. Thus detection is done at the middle position of the panel so that the panel movement can still be responsive.

The test result shown on the table assumes the data nature is only digital (0 or 1) to simplify motor movement logic, while in the actual test a light intensity comparison of more accurate LDR sensors is performed so that the motor movement resolution would be higher.

TABLE III. MOTOR MOVEMENT RESPONSE TO LDR SENSOR INP AND LIMIT SWITCH SETTINGS

Limit Switch Input					LDR Sensor Input					Motor Movement	
LS T	LS L	LS R	LS U	LS D	H L	H R	V U	V D	On/ Off	H	V
0	0	0	0	0	0	0	0	1	0	N/M	N/M
0	0	0	0	0	0	0	1	0	0	N/M	N/M
0	0	0	0	0	0	1	0	0	0	N/M	N/M
0	0	0	0	0	1	0	0	0	0	N/M	N/M
0	0	0	0	0	0	0	0	1	1	N/M	CW
0	0	0	0	1	0	0	0	1	1	N/M	N/M
0	0	0	0	0	0	0	1	0	1	N/M	CCW
0	0	0	1	0	0	0	1	0	1	N/M	N/M
0	0	0	0	0	0	1	0	0	1	R	N/M
0	0	1	0	0	0	1	0	0	1	N/M	N/M
0	0	0	0	0	1	0	0	0	1	L	N/M
0	1	0	0	0	1	0	0	0	1	N/M	N/M
1	0	0	0	0	0	0	0	1	1	N/M	CW
1	0	0	0	1	0	0	0	1	1	N/M	N/M
1	0	0	0	0	0	0	1	0	1	N/M	CCW
1	0	0	1	0	0	0	1	0	1	N/M	N/M
1	0	0	0	0	0	1	0	0	1	L	N/M
1	0	1	0	0	0	1	0	0	1	L	N/M
1	0	0	0	0	1	0	0	0	1	R	N/M
1	1	0	0	0	1	0	0	0	1	R	N/M

VI. CONCLUSIONS AND SUGGESTIONS

A. Conclusions

The following are some conclusions can be drawn from the result of this research:

1. The solar tracker is able to respond to light intensity changes and always looking for better position in order to get better exposure.
2. The solar panel with solar tracker produces larger output compared to one without solar tracker. Based on test results a difference in output of up to 39,78% can be obtained.

B. Suggestions

Some suggestions for improvement and further research are given as follows:

1. Better resolution should be used in controlling both horizontal and vertical movement, using better gear ratio for example.
2. The system should be implemented on larger solar panels to get larger output and better efficiency.

3. The battery charging should use better charging circuit and method with charging indicator and limiter circuit in order to prolong the life of battery.

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