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Design of a GPS-Based Solar Tracker System for a Vertical Solar Still

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***Abstract*—Compared with horizontal solar still, vertical solar still has better condensation but lower evaporation. To increase the evaporation, it needs a control system that moves a vertical solar still to follow the azimuth angle of the sun. This paper presents a design of a GPS-based solar tracker system, that can moves the vertical solar still follow the azimuth angle of the sun. Furthermore, to determine the effect of this solar tracker system, research was done by comparing the power of 2 solar cells placed in different positions. The first solar cell was placed upright and rotated with the solar tracker system. The second solar cell was placed horizontally. The result showed that the power generated by the first solar cell is greater than the second solar cell.**

Keywords—GPS-based; solar tracker system; azimuth angle; vertical solar still; solar cell

I. INTRODUCTION

Solar still is a prominent method to produce clean and healthy water from polluted water using solar energy. As a country with abundant solar energy resources, and also because most of the remote areas in Indonesia have not been reached with the electricity supply, it becomes a powerful reeason to implement and develop solar still. The weakness of solar still is the low productivity of resulting water. Many researches are proposed to increase the productivity which can be classified to two main approaches.

The first one and the most conducted approach is enhancement of condensation process. Among these approaches are addition of condenser and reduction of the cover temperature [3,7,8]. The second common method is pre-heating approach. The methods are focused on enhancing the evaporation process. The problem of evaporation is the energy supply. To increase evaporation, the methods exploit approaches which increase energy supply.

A vertical solar still is naturally good in condensation due to the position of its cover. Vertical surface has better convection than horizontal [5]. Wind is also important in reducing the temperature of the cover which enhancing the condensation process. But it is lack in evaporation due to path of the solar rays especially in tropical areas. Therefore it is reasonable to increase the vertical solar still productivity through increasing the energy supply. The simplest approach of increasing energy supply is facing the solar still to the path of solar rays.

To be always faced the solar path, the solar apparatus need solar tracker system. Some mechanisms have been proposed. Most of them are designed for PV, photovoltaic [2,4,6,9,10]. The other are proposed for horizontal solar still. On the other hand discussion of such mechanisms for vertical solar still is very rare. The solar tracker for PV does not consider fluid surface and flow while the solar tracker for solar still consider both. The other situation that should be taken into account is the weight of the apparatus. The solar still naturally is heavier than PV [1].

The vertical solar still has different characteristic operation than horizontal solar still. The most differing threats which are greater than the horizontal solar still are wind and solar path effect. For tropical area, the horizontal solar still gets its abundant energy during middle of the day. The vertical solar still gets its abundant solar rays in the morning and afternoon, when the sun is near the horizon.

A half-sphere coordinate with the apparatus as the center is exploited to define the position of the sun, where the rays arrive from. In such coordinate, a point above the observer (O) is defined as top. The point will be used to define zenith as the angle from the top to horizon. A horizon is boundary of a surface where the center (O) is located and perpendicular to the line from the top to the center. The horizon is circular shape through North, East, South and West position. The azimuth is defined as the angle around the horizon which is counted from the north. The description of the zenith and azimuth is figured on Fig. 1 below.

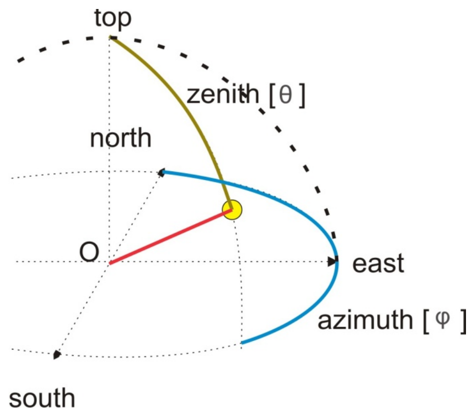

Fig. 1. A half-sphere coordinate for describing zenith and azimuth

Because the solar still here is vertical and it can not be rotated along zenith line, the adjustable position is only azimuth. Therefore, it need to determine the azimuth angle of the sun. The following equation presented herein are taken from NOAA Sunrise/Sunset and Solar Position Calculators, that are based on equations from Astronomical Algorithms by Jean Meeus.

$$\gamma = \frac{2\pi}{365} * (day\_of\_year - 1 + \frac{hour - 12}{24}) \quad (1)$$

$$eqtime = 229.18 * (0.000075 + 0.001868\cos\gamma - 0.032077\sin\gamma - 0.014615\cos 2\gamma - 0.040849\sin 2\gamma) \quad (2)$$

$$decl = 0.006918 - 0.399912\cos\gamma + 0.070257\sin\gamma - 0.006758\cos 2\gamma + 0.000907\sin 2\gamma - 0.002697\cos 3\gamma + 0.00148\sin 3\gamma \quad (3)$$

$$time\_offset = eqtime - 4 * \text{longitude} + 60 * \text{timezone} \quad (4)$$

$$tst = hr * 60 + mn + sc / 60 + time\_offset \quad (5)$$

$$ha = (tst / 4) - 180 \quad (6)$$

$$\cos\phi = \sin(lat)\sin(decl) + \cos(lat)\cos(decl)\cos(ha) \quad (7)$$

$$\cos(180 - \theta) = -\frac{\sin(lat)\cos\phi - \sin(decl)}{\cos(lat)\sin\phi} \quad (8)$$

Here the parameters list of the above equation:

- γ = fractional year (radians),
- eqtime = equation of time (minutes),
- decl = solar declination angle (radians),
- tst = true solar time (minutes),
- ha = solar hour angle (degrees),
- ϕ = solar zenith angle (radians),
- θ = solar azimuth angle (radians).

The azimuth angle of the sun is derived from Equation (8), that is measured clockwise from North. After knowing how to calculate the azimuth angle, then the following is presented the design of a GPS-based solar tracking system for vertical Solar Still.

II. Design and Implementation Process

A. Hardware Layout

As described above, since the Vertical Solar Still can only be rotated along the azimuth line, it requires one actuator only. This condition is favorable, because the control becomes simpler and energy efficient, making it possible to eliminate an additional power supply in the future, and simply relying on the energy supply from the solar cell. The Vertical Solar Still that has been made is shown on Fig. 2 below.

Fig. 2. The Vertical Solar Still with Gearbox to ease rotating the Basin

The Vertical Solar Still is equipped with a gearbox to ease rotating the basin along the azimuth line. The following figure shows a prototype of the solar tracker system.

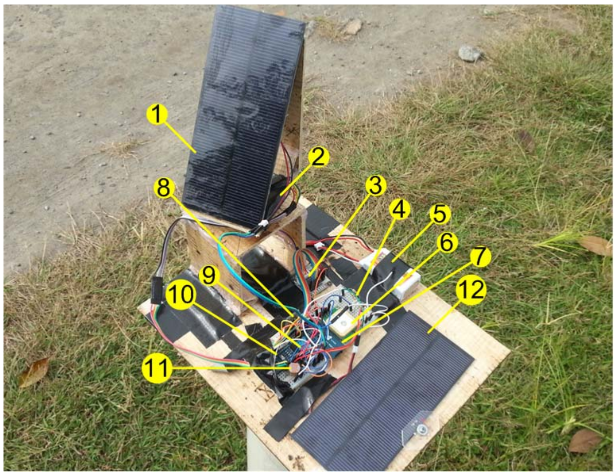

Fig. 3. Prototype of the Solar Tracker System

1	*Solar Cell-1*	*7*	*SD Card Breakout*
2	*Compass Sensor*	*8*	*Bluetooth HC-05*
3	*Stepper Motor + Driver*	*9*	*DHT11*
4	*Voltage Divider*	*10*	*Arduino Nano*
5	*Battery*	*11*	*LDR*
6	*GPS module*	*12*	*Solar Cell-2*

The prototype figure above shows two pieces of solar cells. Both solar cells are used to measure the efficiency of solar energy. The first solar cell was placed in an upright position, slightly tilted, on top of a stepper motor , which will rotate the Solar Cells following the azimuth angle of the sun. The second solar cell was placed on a fixed horizontal position facing up.

B. Control System

The following figure shows the block diagram of the circuit in the prototype of solar tracker system above.

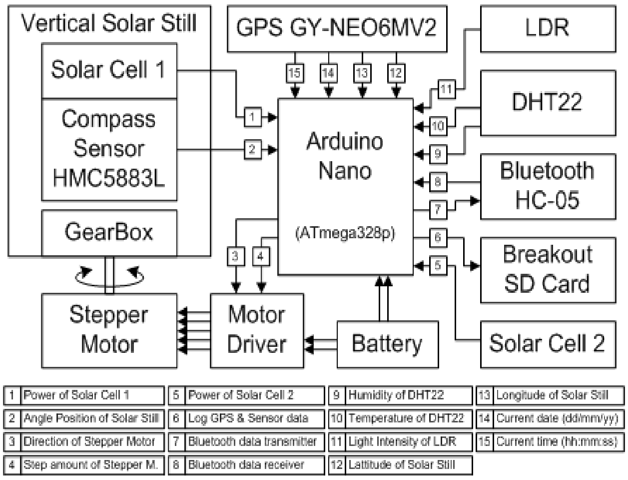

Fig. 4. Block Diagram of the Solar Tracker System

Working principle of the prototype circuit above is as follows: vertical solar still, which is simulated by a solar cell 1, rotated by a stepper motor, which is controlled by Arduino Nano. Arduino Nano was chosen because it is economical, with free programming software. Positioning control of Vertical solar still by Arduino Nano is based on equation of Astronomical Algorithms by Jean Meeus. The equation entering data of lattitude, longitude, date and time that provided by the GPS GY-NEO6MV2. By inserting these values into the equation, the value of azimuth angle of the sun will be obtained. Then the azimuth angle value was compared with the angle value of the compass sensor, which reads the face position of the vertical solar still. When the azimuth angle value is different from the angle value of the compass sensor, the stepper motor will be rotated automatically to minimize this differences.

To determine the effect of control by the solar tracker system, shown in the picture above, we use solar cell 2, which is placed in a fixed position facing upwards. Then Arduino Nano will measure the power generated by the solar cell 1 and solar cell 2, by adding a voltage divider resistor circuit in order to protect Arduino Nano from overvoltage. To determine the environmental conditions, light intensity sensor (LDR), temperature and humidity sensor (DHT22) has been added. Then the data of date, time, lattitude, longitude GPS, azimuth angle, compass sensor angle, power of solar cell 1, power of solar cell 2, light intensity, temperature and humidity, periodically stored in the memory card (8GB micro sd card).

A Bluetooth HC - 05 was added for the purpose of wireless communication with the computer, which will be used for controlling and monitoring solar tracker system from computer using LabVIEW software. The following figure shows control and monitoring whole system from computer wirelessly using LabVIEW software and Bluetooth communication.

Fig. 5. Control and monitoring whole system from computer wirelessly using LabVIEW software and Bluetooth communication

C. Solar Tracker Control and Monitoring System Algorithm

To facilitate the controlling, monitoring and testing of the solar tracker system, a program created using Labview software is used. The program can control the stepper motor, to rotate solar cell 1, manually or automatically based on the calculated azimuth angle and the compass sensor angle.

The following figure shows the display of solar tracker control program using LabVIEW software.

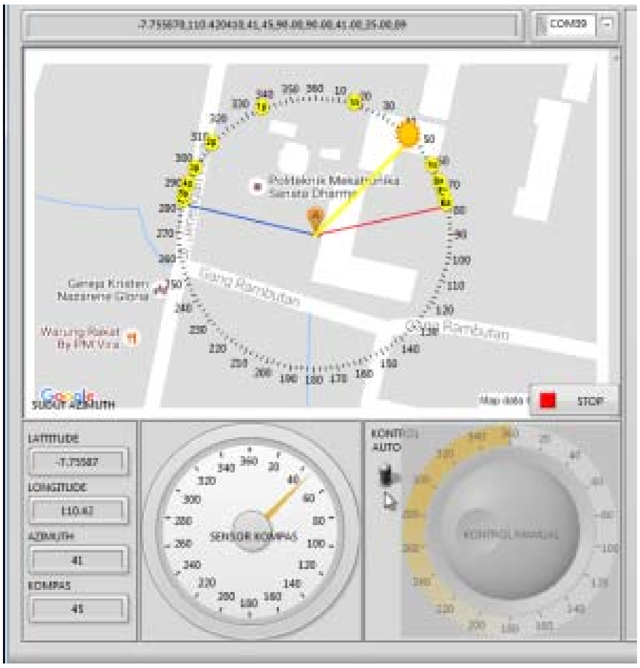

Fig. 6. The display of solar tracker control program using LabVIEW software

The program can also monitor and display the following data in graphical form: data of solar cell 1 power, solar cell 2 power, light intensity, temperature and humidity. The following figure shows the display of sensor data monitoring program using LabVIEW software.

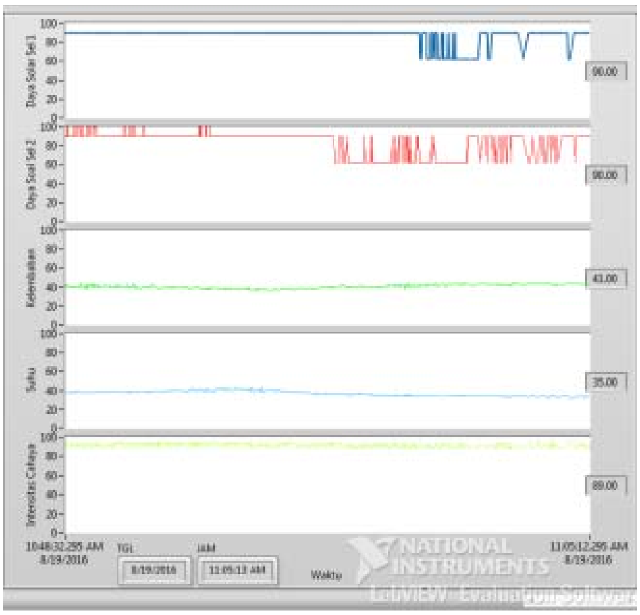

Fig. 7. The display of sensor data monitoring program using LabVIEW

The following figure shows the flowchart of the solar tracker control system using Arduino and control and monitoring whole system using LabVIEW software.

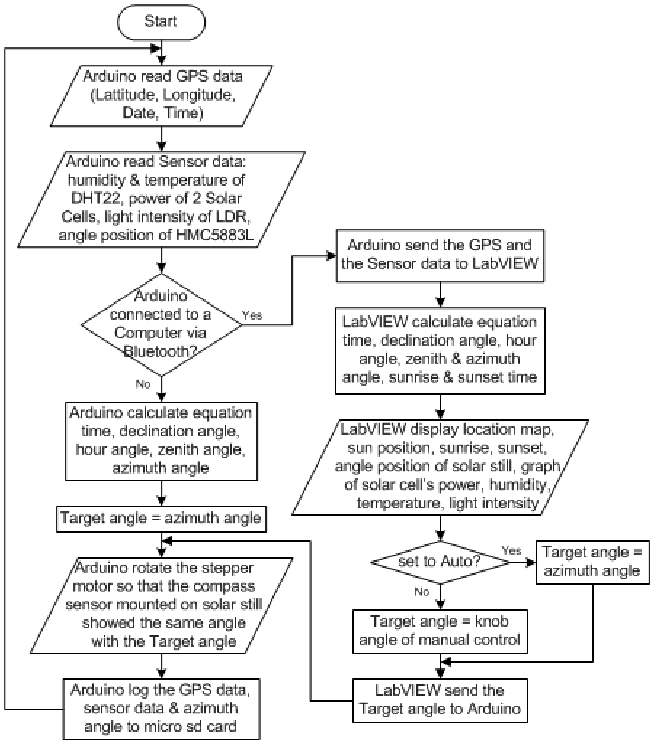

Fig. 8. Flowchart of solar tracker control and monitoring system using Arduino and LabVIEW software

III. Experimental Results and Data Analysis

The performance of the solar tracker system is measured by comparing the power generated by solar cell that controlled by solar tracker system (solar cell 1) with a solar cell placed at a fixed position facing up (solar cell 2). The power generated from both solar cell is recorded in memory card simultaneously for every minute from 6:00 am to 6:00 pm. The following figure shows the graph of recorded data of the power generated by solar cell 1 and solar cell 2.

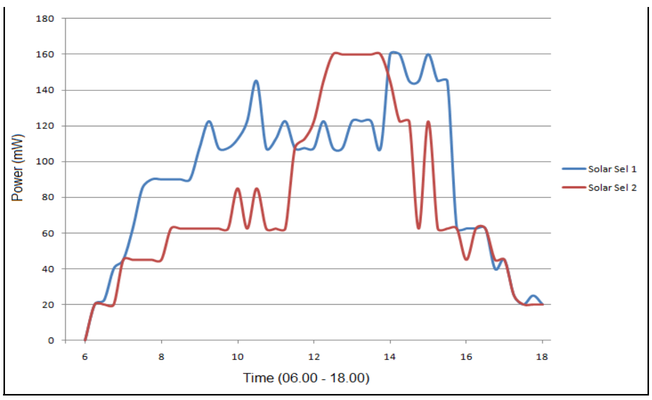

Fig. 9. The graph of the power generated by solar cell 1 and solar cell 2

From the experimental results shown in the graph above, the average power generated by the solar cell 1 is equal to 92.09 mW, while the average power generated by the solar cell 2 is equal to 75.46 mW. From this, it can be stated that the average power generated by solar cell 1 is larger than solar cell 2, which is about 22%.

Based on this experiment, it can be said that the first solar cell, which was controlled by solar tracker system, captures more solar energy than the second solar cell. Furthermore , it can be expected that the evaporation rate on vertical solar still with solar tracker system will be higher than vertical solar still without solar tracker system. Another interesting thing is, with the use of GPS and astronomical calculations, solar tracking systems become faster, because it avoids the scanning and reading of conditions repeatedly, as happens in the solar tracking system using LDR

IV. Conclusion

A prototype of a GPS-based solar tracker system has been proposed and designed to harvest solar energy for vertical solar still as much as possible. Research has been conducted by simulating the vertical solar still with a solar cell, which is mounted upright at a slight angle, which is then compared with another solar cell that placed in a fixed horizontally facing up. The result showed that the first solar cell, that is controlled by solar tracker system can capture more solar energy than the second solar cell, that placed in a fixed horisontally facing up.

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