The novel algorithm of dual-axis solar tracker in severe weather condition

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Abstract. Fulfilling the energy demand by using fossil fuel is still heavily dependent. Eco-friendly-based energy like solar energy is being employed. Solar energy possess the potential to adequately fulfil more than ten times of current energy demand, which means it is profitable in terms of energy and environment. Harvesting solar energy using solar cells has issues with its efficiency. The tracking system is believed to enhance the efficiency of solar panels. In other hand, the current system failed when it comes to severe. Global horizon irradiance in severe weather, solar radiation is scattered evenly in the horizontal plane. So, adding the diffused irradiance parameter to the algorithm hopefully tackle the double axis solar tracker (DAST) current issues. This DAST system uses Arduino Uno as the main control. Light dependent resistor (LDR) as a sensor in the DAST system. Servo motor as an actuator is used. Experiment result in sunny day, cloudy day, and rainy day, respectively 59.67Wh, 38.20 Wh, and 2.5 Wh. In other hand, a fixed tilt angle system generates 46.51 Wh on sunny day, 29.84 Wh on cloudy day, and 1.95 Wh on rainy day.

1. Introduction
The Dependency on meeting energy demands is based on the use of fossil fuels. There has been a decline in petroleum reserves. New and renewable energy (NRE) is a solution to this problem in facing the current energy crisis [1][2].

The sun is one of the largest source of energy for the world. Currently, the employment of solar energy through technology development to produce electrical energy is being developed. Utilization of solar energy has been carried out in various parts of the world as an alternative source of renewable energy. Theoretically speaking the energy the earth receives from the sun is more than sufficient to meet the present needs of the whole world. The solar energy through the earth is more than four million exajoules (1EJ = 10180J) which implies more than 10 times the world's energy needs today [3][4].

The extraction of solar energy can be done in many ways. Nature-based-engineering is one of its kind to utilize solar energy. In nature there is a photosynthetic process in which plants are able to convert sunlight into energy. The same thing can be applied in converting sunlight into electrical energy through the photovoltaic effect [1].

The solar power plant (PLTS) installation currently uses a fixed tilt angle system. This system directs the solar panels at a certain angle towards the sun. Meanwhile, solar panels produce maximum energy when perpendicular to the sun. Movement of the sun is from east to west. Based on the path of the sun's passage, the sun is not only moving from east to west but shifting north or south. Current systems only point the solar panels at the sun perpendicularly in a few hours and there are many potential losses of solar energy in this system [5]. The tracking system is a system capable of keeping solar panels...
perpendicular to the sun. There are two types of trackers, single axis solar tracker (SAST) and double axis solar tracker (DAST). SAST is able to increase efficiency by 25-35%, while DAST is capable of up to 40% compared to fixed angle tilt angle systems [6]-[8].

Research conducted by Faiz Mustafa (2018) the DAST system would stop working when the weather is in cloudy or rainy conditions [7]. Research conducted by Salsabila Ahmad (2013) increasing the power output by 15.65% in bad weather conditions compared to the fixed angle tilt system [9].

The global horizon irradiation consists of direct solar radiation and diffuse radiation. The diffuse radiation is scattered or reflected sun light [10]. The diffuse solar radiation is high enough on horizontal surface in severe weather caused by cloud in the atmosphere [10]. So, by adding the diffuse solar radiation parameter in the algorithm of the DAST, it is expected to be able to solve problems in the current DAST system during severe weather conditions.

2. Method
As main control Arduino Uno is used in this DAST. The sensor are used for tracking the sun is four light dependant resistor (LDR). Two servo motors are used as actuators to move solar panels perpendicular to the sun. The method in DAST is divided into three parts, the work system, mechanical structure, and software from DAST.

2.1. The work system
The work system of DAST uses an open loop system, where feedback is not used in adjusting the position of the panel. The DAST system is expected to be able to follow the movement of sun light from sunrise to sunset. The block diagram of DAST is aimed at Figure 1 where the light received by the LDR then the signal issued by the LDR is forwarded to the control unit Arduino to be processed and the processing result in the form of a PWM signal is forwarded to the servo motor as a actuator and the servo will move the solar panel so that it is perpendicular to the sunlight.

The energy produced by the solar panels will go through the ina219 sensor to measure the output voltage and current of the solar panels. The measurement signal generated by the ina219 sensor is forwarded to the Nodemcu module where the measurement result is stored in the webserver. The output power of the solar panels is flowed to the charge controller and battery as the load side.

![Diagram](image)

**Figure 1** Block diagram of proposed DAST
How the DAST system works when the weather is cloudy and rainy is aimed at Figure 2 when the solar irradiation is less than 450W / m², then the digital value generated by LDR will be less than 900 for further processing on a microcontroller which will order the vertical servo motor to move to the 90° position.

![Figure 2 Block diagram of proposed DAST in severe weather](image)

2.2. Mechanical structure of DAST
The mechanical structure is designed to support and move the DAST to work properly. This mechanical structure is made of wood and is shaped according to a sketch as shown in Figure 3 and the specifications are shown in table 1.

![Figure 3 Block diagram of proposed DAST in severe weather](image)

| No | Description            | Value          |
|----|------------------------|----------------|
| 1  | Dimensions             | 54cm x 50cm x 25cm |
| 2  | Vertical movement      | 30°-330°       |
| 3  | Horizontal movement    | 60°-300°       |

2.3. DAST software configuration
The software includes algorithms from the DAST system. This algorithm is using Arduino programming in C language. The algorithm of the DAST system is shown in Figure 4.
Start by making a comparison with the clock whether the clock shows the 15th minute so that the system can proceed. Then the values in the four LDRs are compared whether they are less than the set value (900) or 450W/m² and will drive the vertical servo to the 90° position. If the LDR value exceeds the reference value, then make a comparison between the upper and lower LDR (LDRs) by looking at which part is larger, the vertical servo will move towards the area with the larger value. When the two halves are the same, the vertical servo will stop. The horizontal servo moved by comparing the left (LDRw) and right (LDRe). The process on the left and right is the same as for the vertical servo.

Figure 4 Proposed algorithm of DAST
3. Results and discussions
The test was carried out from March 2020 to June 2020. The test location was in Tangerang at latitude and longitude points as in Table 2, two identical solar panels were also used in this study with panel specifications Pout 10Wp, Vmp 16.5 V, Imp 0.5 A, Voc 21.1 V, Isc 4.23A. One solar panel is connected to fixed tilt angle, while the other is connected to the proposed DAST system. The output data is received by Nodemcu and forwarded to the Web server. Current data, voltage and output power are taken every 15 seconds. The test results are grouped based on weather conditions, sunny or sunny with cloud, cloudy, and rainy.

| Item          | Value            |
|---------------|------------------|
| Latitude      | -6.200076        |
| Longitude     | 106.530006       |
| Latitude DMS  | 6°12'00.3”       |
| longitude DMS | 106°31'48.0”     |
| Altitude      | 22.05 m MSL      |

3.1. Power output during sunny or sunny with cloud condition
In this sunny or sunny with cloud weather condition, the proposed DAST system produces 59.67 Wh of power, while the solar panel on the fixed tilt angle system still produces 46.81 Wh of power as shown in Figure 5. The difference in output power of these two systems because in the morning and late afternoon the solar panel at an angle of inclination still has a large incident angle. This can be seen in the magnitude of the difference in power in the morning at 8am-10am and 2pm-4pm.

3.2. Power output during cloudy condition
The power generated in this cloudy weather is 38.20 Wh for the DAST system while 29.84 Wh is power generated by the fixed tilt angle system. This can be seen in Figure 6 which shows a jagged pattern in cloudy weather conditions. This pattern results in lower output power than sunny weather conditions due to reduced irradiance from the presence of clouds.

![Figure 5 Power output during sunny or sunny with cloud condition](image-url)
3.3. Power output during rainy condition

The power generated depends on the existing weather conditions, when the weather is rainy, the power produced is lowest compared to other weather conditions, this can be seen in Figure 7. This is because the solar irradiance on the surface is extremely low. In rainy weather conditions throughout the day, the power generated is 2.50 Wh for DAST and 1.96 Wh for the fixed tilt angle system.

![Figure 6: Power output during cloudy condition](image)

![Figure 7: Power output during rainy condition](image)

Regarding the comparison of DAST systems with fixed tilt angle systems the overall power generated and consumed in each weather condition is shown in Table 3.

| Weather Condition | Power output DAST (Wh) | Power output fixed tilt angle (Wh) | Gain (Wh) |
|-------------------|------------------------|-----------------------------------|-----------|
| Sunny             | 59.67                  | 46.51                             | 13.16     |
| Cloudy            | 38.2                   | 29.84                             | 8.36      |
| Rainy             | 2.5                    | 1.95                              | 0.55      |
4. Conclusions
In this paper, a novel algorithm of dual-axis solar tracker was presented. The conclusion can be drawn here as follows. The energy generated in sunny or sunny with cloud weather conditions by the DAST system and fixed angle the inclination is 59.67 Wh and 46.51 Wh, respectively or 28%. The energy generated in cloudy weather conditions by the DAST system and a fixed tilt angle is 38.20 Wh and 29.84 Wh, respectively. The energy produced in rainy weather conditions by the DAST system and a fixed angle slope is 2.5 Wh and 1.95 Wh, respectively.

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