Interactive Control using Bluetooth for Dual Axis Sun Tracker with Three Light Sensors

Yuwaldi Away\textsuperscript{1*}, Yeni Yanti\textsuperscript{2}, M. Syamsu Rizal\textsuperscript{1}, Andri Novandri\textsuperscript{1}

\textsuperscript{1}Department of Electrical and Computer Engineering, Syiah Kuala University, Banda Aceh, Indonesia
\textsuperscript{2}Department of Informatics Engineering, Serambi Mekkah University, Banda Aceh, Indonesia

Corresponding email: \texttt{*yuwaldi@unsyiah.ac.id}

\textbf{Abstract.} The use of renewable energy from solar panel systems is increasingly being applied, but until now the utilization has not been maximized. The movement of the sun caused by the rotation of the earth should be taken into account to maximize electrical energy in the solar panel (PV). In this study, a concept was proposed to control the movement of the two-axis sun tracker with smartphones using Bluetooth communication. Controlled by rotating two DC motors, two axes are joined together into linear actuators that can extend and shorten, so that the solar panel can move towards the sun. This system uses a light sensor (Light Dependent Resistor) and a gyroscope sensor as input and two DC motors that are placed on each axis as output. The motor driver used is the Monster Moto Shield. Sun tracker that is used based on tetrahedron geometry and uses three light sensors. The light sensor functions to determine the position of the sun while the gyroscope sensor is used to determine the tilt angle of the solar panel. The gyroscope module used is MPU-6050. This system also uses the GY-273 compass sensor which functions to determine the direction of the wind direction. Components of input and output are connected to the ATmega328P microcontroller and wireless communication using Bluetooth. The Bluetooth module used is the HC-05 module. The solar panel movement and the power obtained are then monitored and recorded for analysis.

1. \textbf{Introduction}

Solar energy is a renewable energy that is being popularly developed throughout developed and developing countries, various kinds of research are carried out to improve the performance of solar panels in order to convert light energy into electrical energy, ranging from solar installation to the development of solar panels. Even so, solar energy that can be absorbed by the solar cell is not optimal because the installation only has a certain angle of view. Therefore, sun tracking is being developed as a solution so that the solar panels that are installed can follow the flow of the sun's movements so that more light can be absorbed. Many types of research on sun tracking have been carried out with different methods and installations, rotation arrangements for solar panel modules usually use DC motors because it is easy to adjust motor movements, this setting is also followed by control settings such as PID and fuzzy logic, but in this study using linear actuators which are usually used to drive a satellite dish. This actuator uses a DC motor as a metal rod for longitudinal or shortening conditions.
DC motors rotate 3600 with revolutions per minute (RPM) according to motor specifications, this makes DC motors rather difficult to control at certain angles, unlike servo motors or stepper. In linear actuators, there is a reed sensor which is useful for reading motor rotation when the solar panel moves, so this sensor functions as a microcontroller input to determine the DC motor movement in the solar panel. This DC motor is controlled by using a Monster Motor Shield type motor driver. This shield functions to adjust the direction of motor rotation. Control of sun tracking is divided into two methods, namely manual control using a smartphone through Bluetooth communication. The second method is controlling sun tracking automatically using PID and fuzzy methods [1]. In this study using manual control using bluetooth.

In the solar panel three sensors are installed, namely light sensors (Light Dependent Resistors), gyroscope sensors and compass sensors. Three light sensors are used and geometrically tetrahedron is installed. Its function is to find out where the position of the sun is. The way it works is by looking at the value of the intensity of light received by the three sensors. The gyroscope sensor functions as a reader of the tilt angle of the solar panel so that the movement of the solar panel can be known and controlled. The compass sensor functions as an indicator of the direction of the wind.

Photovoltaic is a device that converts sunlight directly into electricity. The generation of electrical energy in solar cells occurs based on the photoelectric effect, namely the effects that occur due to photons with certain wavelengths, if the energy is greater than the semiconductor threshold energy, then it will be absorbed by electrons so that electrons move from the valence band (N) to the conduction band (P) and leave a hole in the valence band, then two pieces of charge, namely the electron-hole pair is raised. The electron-hole flow that occurs when connected to an electrical load through the conductor will produce an electric current [2].

Linear actuators are mechanical devices to move a system or mechanism. The actuator is activated by using a mechanical arm that is driven by an electric motor, which is controlled by an automatic controller such as a microcontroller. Actuators are elements that convert analog electrical quantities to other quantities such as speed and direction of rotation. In the actuator, a gearbox system is installed to increase mechanical power. Actuators have several types of driving forces including electric power actuators, hydraulic power, pneumatic power, and others and motors commonly used are DC motors, stepper, solenoid, induction motors and synchronous motors [3] [4].

![Figure 1. Linear actuator](image1.png)

The MPU-6050 sensor is a chip that contains a combination of two MEMS (Micro-Electro-Mechanical Systems), namely MEMS Accelerometer and MEMS Gyroscope. Both devices are integrated with each other so that they can work. The physical form of the MPU-6050 sensor can be seen in Figure 2. The data path on the MPU-6050 sensor uses I2C (Inter-Integrated Circuit) communication, which is two-way serial communication using two channels that function to send and receive data. The channel consists of SDL (Serial Clock) and SDA (Serial Data). Serial clock functions as a clock path with a constant signal frequency, while serial data serves as a communication path so that data can be transferred.
Figure 2. Sensor MPU-6050

The motor driver used is the monster motor shield. Moto Shield Monster is a motor driver with two IC VNHS2P30 chips. This motor driver can be used to control the rotation of two DC motors with a maximum current of 30 A. In the VNHS2P30 IC there is an H-bridge MOSFET circuit that is used as a motor controller [5]. The physical form of the Monster Moto Shield can be seen in Figure 3.

Figure 3. Monster Moto Shield

Motor A DC motor is an electric motor that requires a direct current voltage on the field coil to be converted into mechanical motion energy. DC motors have two cables. Positive and negative cable. Motor rotation can be controlled by diverting the flow of electricity to the motor. This transfer of electricity uses a motor driver. This driver will later control the rotation direction and speed of the motor. The physical form can be seen in Figure 4. There are two coils on a DC motor. The first coil is a field coil called a stator. This coil is a part that does not rotate. The second coil is an anchor coil called a rotor. This coil is a rotating part [5].

Figure 4. DC Motor [6]

Light Dependent Resistors or abbreviated as LDR are types of resistors whose resistance value or resistance value depends on the intensity of the light it receives. The value of LDR resistance will decrease when bright light and the value of the resistance will be high if in dark conditions. In other words, the function of LDR (Light Dependent Resistor) is to conduct electric current if it receives a certain amount of light intensity (bright conditions) and inhibits the electric current in dark conditions. Figure 5 is a physical form of LDR. The rise and fall of the resistance value will be proportional to the amount of light it receives. In general, the LDR resistance value will reach 200-kilo-ohms (kΩ) in dark conditions and decrease to 500 ohms (Ω) in bright light conditions.
LDR (Light Dependent Resistor) which is a light-sensitive electronic component is often used or applied in electronic circuits as sensors in street lights, bedroom lights, anti-theft circuits, camera shutter, alarms and so on [7]. GY-273 compass sensor is a module that is used to indicate digital wind direction or also called a digital compass. This module uses the main component in the form of IC HMC5883 which is a 3 axis digital compass IC which has an interface in the form of 2 pin I2C (Inter-Integrated Circuit).

HMC5883 has a high resolution magneto-resistive HMC118X series sensor, plus ASIC with content amplification, automatic degaussing strap driver, offset cancellation and 12 bit ADC that allows the accuracy of the compass to reach 1 to 2 degrees. This module is commonly used for automatic navigation systems, mobile phones, netbooks, and personal navigation devices.

Bluetooth Module (HC-05), HC-05 is a Bluetooth SPP (Serial Port Protocol) module that is easy to use for wireless serial communication that converts serial ports to bluetooth. HC-05 uses V2.0 + EDR (Enhanced Data Rate) bluetooth modulation by utilizing 2.4 GHz frequency radio waves with a maximum range of up to 10 meters. The input voltage used for the HC-05 bluetooth module to work is 3, 6-6 V. There are various types of HC bluetooth modules, namely: HC-03 and HC-05 can be as master and slave, HC-04 and HC-06 only can be as master or slave. The interfaces used are RXD and TXD serial communication. Built-in LED as an indicator of bluetooth connection [8].

2. Methodology
In the initial stage of this research, the system design. This design is the initial design of controlling linear actuators as a solar panel as a sun tracker, which includes hardware design, software and wiring diagrams from the system. Hardware design is a tool design used in this study, the design consists of installing solar panels that use a DC motor as a solar cell drive for four axes and designing linear actuator resources.

![Smartphone](Smartphone) ![Modul Bluetooth Hc05](Modul Bluetooth Hc05) ![Arduino](Arduino)

![Monster Motor Shield](Monster Motor Shield) ![Motor DC](Motor DC) ![Solar Panel](Solar Panel)

**Figure6.** Block diagram of DC motor controller

![Figure7.DC motor control scheme](Figure7)

The initial stages of designing a power system circuit for linear actuators mounted on a sun tracker pole, with controls using a smartphone, the motor power circuit uses a 12V 6AH battery as a motor power, then also uses a VNH2SP30 Monster Motor Shield as a motor driver so can be controlled by Arduino. Furthermore, the pole design and linear actuator position for the sun tracker system can be seen in
Preparation of this software using Arduino IDE, the program created in C language via the Arduino IDE software then compiled (compiled) into the ATmega 328P microcontroller found on Arduino. Controlling the direction of the sun tracker axis movement using a smartphone, the application used is Boarduino that is connected via the Bluetooth HC-05 module, the Boarduino interface can be seen in Figure 8. Linear actuator will extend and move according to the direction of the wind that has been set when getting an order from the smartphone. This Sun tracker uses a type of manual control method that uses a smartphone. The device is connected to the bluetooth module as a tool to move the sun tracker towards the X axis or Y axis according to the direction of the sun's position. The application used is Boarduino, this application has shared Arduino control features via a Bluetooth connection. The form of the Boarduino display interface can be seen in Figure 8.

![Boarduino interface display](image)

Based on Figure 8 it can be seen that this interface has the direction of the four-way control, namely left, right, up and down. The function description of each button can be seen in Table 1.

| Boarduino | PV Direction | North Motor       |
|-----------|--------------|-------------------|
| Up        | North        | *Clockwise*       |
| Down      | South        | *Counter Clockwise* |
| Right     | East         | *Clockwise*       |
| Left      | West         | *Counter Clockwise* |

3. **Research and Discussion**

The result of the system design is a sun tracker that is able to move following the solar light source using manual control via a smartphone so that the power produced by the solar panel can be maximized. The design results of the sun tracker system can be seen in Figure 9.
Figure 9. The results of the photovoltaic system development

The dimension of one solar panel installed is 83.9 cm x 53.7 cm. There are two solar panels installed which are polycrystalline. This system uses two linear actuators which are driven by a DC motor, which functions to regulate the movement of the solar panel into two axes or four compass directions, namely north, east, west and south. The Y motor moves in the Y-axis to the north and south, while the X motor moves in the X-axis to the east and west wind directions. The movements of these motors are controlled by the Arduino microcontroller which is connected to the HC-05 bluetooth module. This module is connected to an Android smartphone with a Boarduino application interface. That way, through smartphones, solar panels can be moved manually according to the position where the sun is located. The results of the power system design for this sun tracker are shown in Figure 10.

Figure 10. Power and control system results

The testing of the sun tracker system aims to find out how the device works so that data can be retrieved and further analysis related to reliability, weaknesses, and limitations of functions.

Bluetooth module testing aims to ascertain whether the module can work well and determine how far the Bluetooth signal range. In this test, it is carried out by controlling the sun tracking via smartphone at certain distances to see how the connection can be achieved by the controller and also the rotation speed of the sun tracking. Illustrations and remote results testing data by smartphones are shown in Figure 11 and Table 2.
Table 2. Bluetooth module testing data HC-05

| No | Testing direction | Distance | Motor condition | Motor Respond |
|----|-------------------|----------|-----------------|--------------|
| 1  | North             | 1 Meter  | Work Well       | Fast         |
| 2  | North             | 2 Meters | Work well       | Fast         |
| 3  | North             | 3 Meters | Work well       | Fast         |
| 4  | South             | 4 Meters | Work well       | Little Slow  |
| 5  | South             | 5 Meters | Work well       | Little Slow  |
| 6  | East              | 6 Meters | Work well       | Little Slow  |
| 7  | East              | 7 Meters | Work well       | Little Slow  |
| 8  | West              | 8 Meters | Work well       | Slow         |
| 9  | West              | 9 Meters | Work well       | Slow         |
| 10 | West              | 10 Meters| Work Well       | Slow         |

Figure 11. Bluetooth testing circuit

Based on the test data, it can be observed that the Bluetooth module connection works well with the smartphone starting from a distance of 1 meter to the maximum radius of bluetooth is 10 meters, the test is done by adjusting the position of the solar panel in the four wind directions. Based on the tests performed, the smartphone can be done manage.

The smartphone can adjust the movement of the solar panel well to the four cardinal directions with a different signal for each wind. Based on these data it can be seen that the motor has a fast response when directed to North, while for the direction of South, East and West the motor response starts slowly, rather slowly to slow. From the observations made, the cause of the difference in response is due to the error of the linear actuator mounting position which is different between the Y axis and the X axis which results in a faster solar panel response when moved to North and South (Y-axis) than when moved East and West (axis X) which has a slow response.

Sun tracker testing aims to determine the position of the solar panel at a certain angle according to the command given. This measurement aims to obtain a voltage value based on angle reading from the gyroscope sensor. At angle $0^\circ$ the position of the solar panel is straight or upright, while the subsequent angles continue to tilt up to an angle of $30^\circ$ which is the maximum angle of the solar panel because it is blocked by the roof of the building from 4 sides. These angles are the sloped boundary for the four cardinal directions. In addition, it also limits the limits of the linear resistance of the metal actuator to the solar panel buffer, so that the slope of the sun tracker is not beyond the linear resistance of the actuator and out of control or damage. Based on the results of testing carried out with all angles and four wind directions, the voltage data generated by the solar panel is obtained as follows.
Table 3. Photovoltaic testing data

| No | Solar panel direction | Time  | Angle | Voltage | Weather Condition |
|----|------------------------|-------|-------|---------|-------------------|
| 1. | North                  | 10:55 | 0°    | 38.1 V  | Cloudy            |
|    |                        | 11:00 | 5°    | 38.2 V  | Cloudy            |
|    |                        | 11:10 | 10°   | 38.3 V  | Cloudy            |
|    |                        | 11:20 | 15°   | 38.8 V  | Cloudy            |
|    |                        | 11:25 | 20°   | 39.3 V  | Cloudy            |
|    |                        | 11:30 | 25°   | 39.4 V  | Cloudy            |
|    |                        | 12:00 | 30°   | 39.6 V  | Cloudy            |
| 2. | South                  | 13:55 | 0°    | 38 V    | Cloudy            |
|    |                        | 14:00 | 5°    | 38.1 V  | Cloudy            |
|    |                        | 14:10 | 10°   | 38 V    | Cloudy            |
|    |                        | 14:20 | 15°   | 38 V    | Cloudy            |
|    |                        | 14:25 | 20°   | 38.2 V  | Cloudy            |
|    |                        | 14:30 | 25°   | 38.1 V  | Cloudy            |
|    |                        | 14:30 | 30°   | 38.2 V  | Cloudy            |
| 3. | East                   | 15:00 | 0°    | 38 V    | Cloudy            |
|    |                        | 15:05 | 5°    | 38.1 V  | Cloudy            |
|    |                        | 15:10 | 10°   | 38.2 V  | Cloudy            |
|    |                        | 15:20 | 15°   | 38 V    | Cloudy            |
|    |                        | 15:25 | 20°   | 38.2 V  | Cloudy            |
|    |                        | 15:30 | 25°   | 38 V    | Cloudy            |
|    |                        | 15:35 | 30°   | 38.2 V  | Cloudy            |
| 4. | West                   | 16:00 | 0°    | 38 V    | Cloudy            |
|    |                        | 16:05 | 5°    | 38.1 V  | Cloudy            |
|    |                        | 16:10 | 10°   | 38.2 V  | Cloudy            |
|    |                        | 16:20 | 15°   | 38 V    | Cloudy            |
|    |                        | 16:35 | 20°   | 38.3 V  | Cloudy            |
|    |                        | 16:40 | 25°   | 38.1 V  | Cloudy            |
|    |                        | 16:50 | 30°   | 38.2 V  | Cloudy            |

4. Conclusion
This study uses wireless bluetooth communication, where the maximum distance between the transmitter and the receiver is 10 meters. The closer the distance is, the faster the response of linear actuator movement on the solar panel. Likewise the opposite, the farther the distance, the slower the response of the linear movement of the actuator. Based on the test data, the angle of the test is between 0° to 30°. This angle movement only affects the change in voltage of 1.5 volts. Due to the wide cross-section of the solar panel, it is 2 x (83.9 cm x 53.7 cm), so that the solar panel can be irradiated in any direction.

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References
[1] Y. Away and M. Ikhsan, “Dual-axis sun tracker sensor based on tetrahedron geometry,” Autom.
Constr., vol. 73, pp. 175–183, 2017.

[2] “Sistem Off Grid, On Grid PLTS,” Solar Surya Indonesia, 2018. [Online]. Available: http://solarsuryaindonesia.com/info/sistem-off-grid-on-grid-tie. [Accessed: 29-Apr-2018].

[3] Soesanto, “Actuator Linear,” 2018. [Online]. Available: http://blandong.com/aktuator-linear/. [Accessed: 04-Apr-2017].

[4] Arduino, “No Title,” 2016. [Online]. Available: https://www.arduino.cc.

[5] A. Kadir, Panduan Praktis Mempelajari Aplikasi Mikrokontroler dan Pemrogramannya Menggunakan Arduino. 2013.

[6] “Zona Elektro,” 2017. [Online]. Available: http://zonaelektro.net/motor-dc/. [Accessed: 04-Apr-2017].

[7] D. Kho, “Pengertian LDR (Light Dependent Resistor) dan Cara Mengukurnya,” 2018.

[8] V. Setiawan, “Bluetooth HC-05.” Politeknik Negeri Surabaya, Surabaya.