Single Axis Solar Tracker using PIC Microcontroller and Multiple Stationary Positioning Light Dependent Resistors

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Abstract: The use of renewable energy for electricity generation has become increasingly demanding in remote locations and off-grid areas around the globe. Harnessing renewable energy such as the solar radiation from the sun to produce electrical energy enables the decrease in the cost of the energy demands and at the same time, contributes to sustainability and mitigates global warming and its effect. Since sunlight is natural and abundant, focussing on the development of managing the harvesting of this energy is quite imperative. In this paper, we shall present a design that integrates the use of a solar photovoltaic system along with a simple single-axis solar tracking system that aims at improving the energy absorption by the solar panel by aligning the panel perpendicular to the sunlight. The simple design consists of multiple stationary position light dependent resistors (SP_LDRs) used as sensors for sunlight detection and are assembled at fixed positions and a single rotational light dependent resistor (R_LDR) attached to the movable solar panel mechanism to match the sun's position with the stationary position LDRs. The objective scope is to reduce the angle of incidence between the ray of sunlight and the solar panel normal surface. The results show that the proposed single-axis solar tracker presented in this paper is economical and can increase the power output of the solar PV panel. The reduction in power consumption by the rotating motor mechanism is compared directly with the stationary position LDRs. The motor will rotate only a few angles each time once during the duration of the day. This mechanism will and therefore minimized the motor operation throughout the day; thus, less power is used. The model can be projected on a bigger scale and targets domestic electricity production in rural locations. The reduction of the angle of incidence can be reduce to minimum by increasing the number of stationary positions LDRs.

Keywords: solar tracker, renewable energy, microcontroller, real-time light intensity, high-level language, light dependent resistor, stationary position, photovoltaic module

1. Introduction

A system known as the solar tracker utilizes the angle of incidence on the surface of the solar PV panels and the sun's rays through the use of its electro-mechanical mechanism, the stepper motor. It is responsible for minimizing the incident rays from the sun by calibrating the panel to be perpendicular as much as possible. Due to the demand posed by the system to manage RES, especially the harvesting and maximizing the sunlight and converting it into electrical energy, a solar tracking system is considered. Sunlight is only available during the day, and solar panels must be active during those periods. There are other factors as well that are affecting the solar panel efficiency and performance during the day; that is the sun's intensity, cloud cover, heat build-up, and relative humidity. The power output of the solar has an impact on those factors, for example, an increase in the power output and solar energy collection is during the midday when the sun is at its highest or peak intensity. On a cloudy day, there is a decrease in the sunlight collection thus leading to less absorption of the sun's rays by the solar panels.
Moreover, power output is reduced by 10 to 25 percent due to heat build-up when the temperature is higher causing semiconductors to increase their conductivity and reducing the magnitude of the electric field (Wiggins, 2016). Finally, in terms of humidity, the performance of the panel decreases and less amount of power is produced when humidity penetrates the solar panel frame. It can also deteriorate the performance of the panel as well (Wiggins, 2016). However, the solar tracking system is designed to increase the efficiency and performance of the solar PV panel by utilizing its orientation and decreasing the angle of incidence as much as possible. Apart from a dual-axis solar tracker, a single-axis exhibits functionality that enables the rotation in one direction only, either forward or reversed. Moreover, due to the difference in the weather pattern and shading upon the solar PV module at any time of the day, power saving is of note when dealing with a single-axis tracker. Dual-axis may exhibit rotation which may lead to more power consumption due to the difference in terms of dual directions sensing of sunlight that occurs during the day.

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However, careful assessment of the direction of sunrise and sunset needs to be taken into consideration, which allows proper setup for the solar PV profile. Therefore, the rotation would not be affected in other directions except in the single-axis direction. The performance of a photovoltaic (PV) system depends upon the orientation and the site's climatic conditions. Solar PV tracking systems align the modules perpendicular to the incoming solar radiation (Alkaff, 2019).

2. Requirements / Methodology

The main mechanism of the solar tracking system consists of the tracking device, tracking algorithm, control unit, positioning system, driving mechanism, and sensing devices (Racharla, 2017).
The selection of the photovoltaic module and inverter is based on technology and commercial availability. The selection of a PV module is based on its maturity, commercial availability, performance, and reliability. Multi-crystalline silicone modules are known to last over 20 years with a typical cell efficiency of around 15%. The average yearly degradation of the PV module is 0.7% (Alkaff, 2019).
The orientation of the solar PV module can be discussed to establish a comprehensive method for the selection of the tracking phenomena. Figure 1 shows the different types of orientation that can be selected for the design.

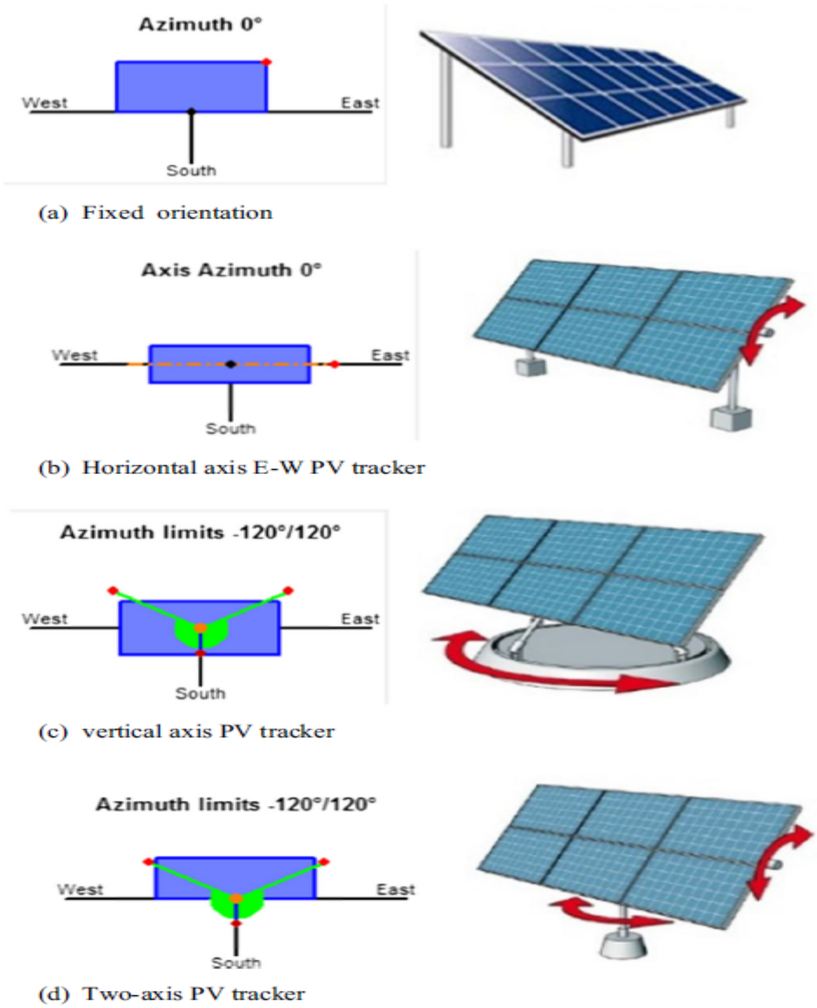

Fig. 1. Illustration of the PV tracker. (a) Fixed mounted orientation, (b) single-axis, horizontal-axis E-WPV tracker, (c) single-axis vertical-axis PV tracker, and (d) two-axis PV tracker (Alkaff, 2019).

For this paper, we select the horizontal axis E-W PV tracker as shown in Figure 1 (b).

2.1. Types of Solar Tracking Algorithms

The tracking algorithm determines the angles which are used to determine the position of the solar tracker. There are two types of algorithms-astronomical algorithms and real-time light intensity algorithms. The astronomical algorithm is a purely mathematical algorithm based on astronomical references. The real-time light intensity algorithm is based on real-time light intensity readings.

The control unit performs the tracking algorithm and manages the positioning system and the driving mechanism. The positioning system operates the tracking device to face the sun at the calculated angles. The positioning system can be electrical or hydraulic. The driving mechanism is responsible for moving the tracking device to the position determined by the positioning system. The sensing devices are a group of sensors and measurements that measure the ambient conditions, the light intensity in the case of real-time light intensity algorithms, and the tilt angle of the tracker utilizing an inclinometer or a combination of limit switches and motor encoder counts (Racharla, 2017).

2.2. Components

This section features the electronics and mechanical components that are required to construct the single-axis solar tracker. Table 1 provides the major components used and their functional descriptions.

Table 1. Functional component for designing single-axis solar tracker

No	Components	Functional Descriptions
1	Light-dependent resistors (LDRs)	Light intensity sensor uses LDRs as a sensing device for light for the design of the single-axis solar tracker
2	LM358 Operational amplifier	Amplify and compute digital signal as input for MCU. It functions by comparing the two inverting input and produces a digital output for further computation in MCU
3	PIC16F877A MCU	The MCU is the central controller that operates a single-axis solar tracking system
4	20x4 LCD	Display interface for information on the position of the solar PV module and the state of light intensity
5	ULN2003 stepper motor driver	Used to accurately control the movement of the stepper motor
6	74LS138 decoder	Used to decode the bits for the position LEDs indications
7	Stepper motor	Used to rotate the PV module. The stepper motor used for the model demonstration is 5V.
8	Light-emitting diodes (LEDs)	Use to indicate the position of the PV module versus the active intensity location.

2.3. Programmer

Microcontrollers are widely used for automation that can be easily embedded with algorithms in the form of programs. These programs can be used to execute instructions that are used to control the operations of a system.

PIC microcontrollers (MCU) are widely used in applications that require automation and specific algorithms for the standalone operation of electronics. For the microcontrollers to fully function as hardware, it requires specific software or integrated development environment (IDE) that is responsible for flashing the instruction into the program memory of the microchip.

The programming of the PIC16F877A microcontroller is shown in figure 2.

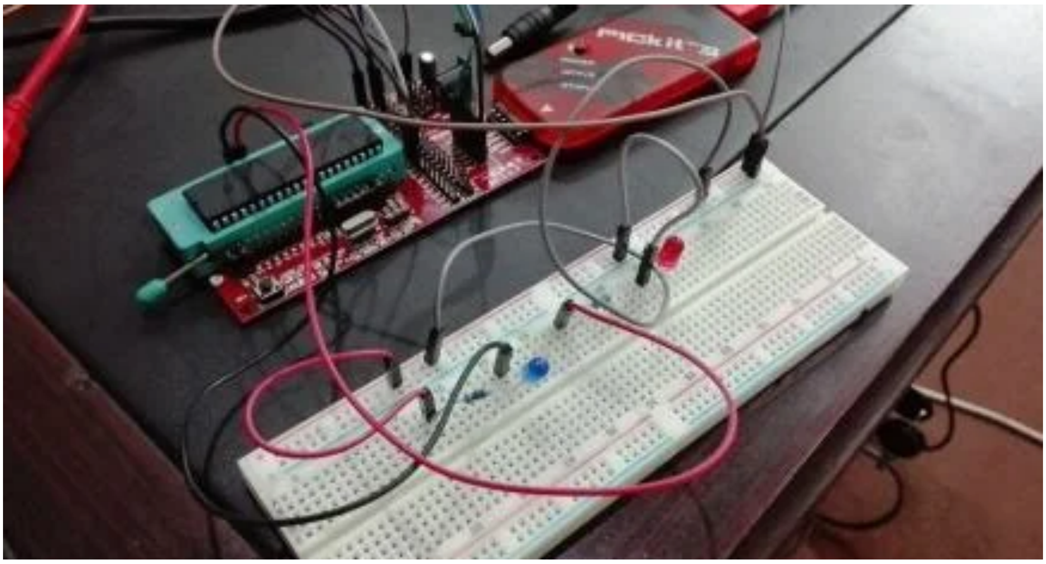

Fig. 2. Programming circuitry of PIC microcontroller (PICKit3, 2024).

The programming software or IDE used in this experiment and prototype is the MikroC Pro for PIC. It uses high-level C++ programming language and is designed to be used with the PIC Kit 3 programmer. The PIC Kit 3 is shown in figure 2.

3. Design

This section provides the design mechanism of the single-axis solar tracking system.
It is responsible for the positioning of the solar PV panel perpendicular to the direction of the sunlight. The single-axis solar tracking system utilizes seven (7) stationary positions each with 30˚ angle apart starting from east to west directions. The circuit diagram shows the PIC microcontroller (MCU) that is associated with sensing and controlling peripherals that operate the single-axis solar tracking system (Sylvester, 2024). The discussion of the design presents four main scopes, which are as follows:

3.1. Control System

The approach for the design of a single-axis solar tracker is achieved through a closed-loop control system. The solar tracker has a feedback system that enables the use of the signal from an LDR to be fed back to the controller. Figure 3 shows the feedback control system of the single-axis solar tracking system.

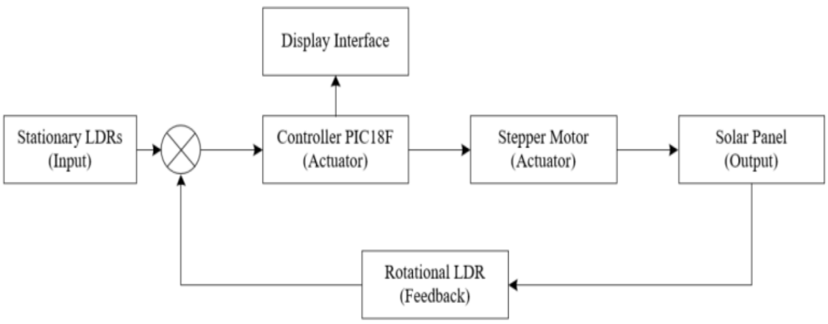

Fig. 3. The control system diagram of the single-axis solar tracker.

3.2. The Circuit Diagram

The circuit diagram includes the necessary components required to facilitate the operation of the single-axis solar tracker. The block diagram design of the proposed single-axis solar tracker is shown in figure 4.

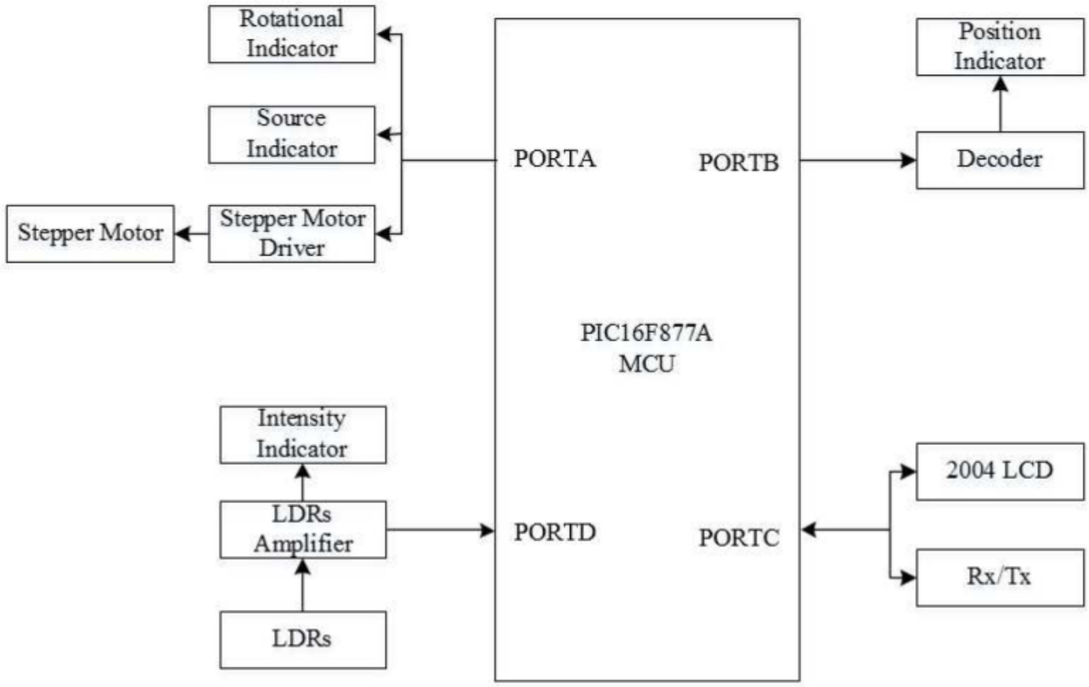

Fig. 4. The proposed circuit diagram and the main component of a single-axis solar tracker.

The PIC16F877A microcontroller consists of mainly 5 ports, from port A – E. PORTA contains 8 pins and is mostly used as analog pins of the microchip. PORTB – PORTD contains 8 pins and is used mostly as digital pins.
As seen on the block diagram in figure 4, PORTA is configured as an output port that provides control bits for the stepper motor driver, a rotational indicator (east or west direction), and a RES selector indicator (solar or other RES). PORTB is also configured as an output port which provides control bits for the decoder to perform indications of the position of the solar panel when at rest. PORTD is configured as an input port for stationary LDRs signals. External circuit design such as an LDR amplifier circuit is used to amplify the LDRs signals to the MCU and at the same time provides an intensity indication of the position that has a higher light intensity. PORTC is configured as an output port that connects the LCD for display. The connection of each peripherals corresponding to the ports and pins can be seen on the circuit diagram in figure 5 using the simulation approach.
The detailed design is done using the Proteus design suite and is presented in section 3.3. It presents the schematic of the design for the overall circuit of the single-axis solar tracker.

3.3. Simulation

The simulation is based on real-time – where the practical application can be seen in section 3.4. The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. The software is used mainly by electronic design engineers and technicians to create schematics and electronic prints for manufacturing printed circuit boards (Wikipedia, 2023).

Figure 5 shows the schematic of the design. It comprises of functional components and is tested in real time using the proteus design simulator.

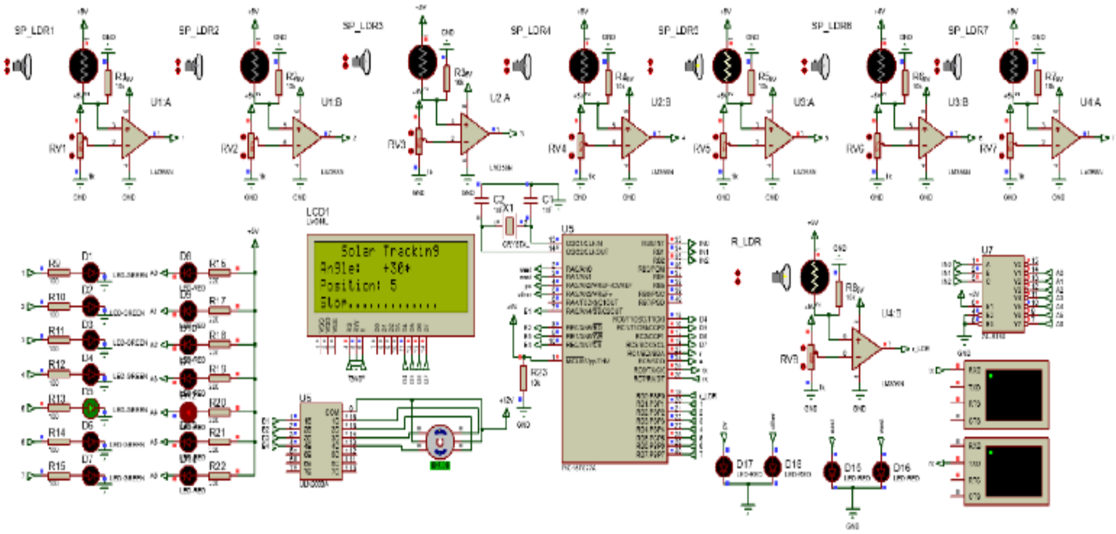

Fig. 5. The schematic diagram of the proposed single-axis solar tracker using Proteus.

The main components associated with the schematic are depicted in table 1, with their descriptions and purposes for use in the design of a single-axis solar tracker. The test simulation was carried out to ensure that the stability was maintained. The proteus software offers a remarkable simulation platform through which the single-axis solar tracker was tested.

3.4. Basic Working Principle

The basic principle of the system in this section clarifies how the system will operation under daylight condition. The angle computation of the x-surface and the line of normal n is computed in equation 2,

$$x^2 + y^2 = 1 \tag{1}$$

$$n = tan\theta = \frac{sin\theta}{cos\theta}, \qquad 22.5° \leq \theta \leq 157.5 \tag{2}$$

where n is the line of normal and θ is the angle between x-surface and the line of normal.

The x-surface correspond to 180°. The line of normal is proportional to the direction of the sunlight and is perpendicular to the solar PV panel. Equation 1 compute half of the unit circle used in the position of the normal.
The solar panel rotation is registered to a fix position based on the seven stationary position light dependent resistors (SP_LDRxx). Table 2 display the stationary position and angle corresponds to the x-surface.

Table 2. Position of stationary light dependent resistor and corresponding angles

Position [i]	**SP_LDRxx**	**Angle (θ)**	**Sunlight Intensity (SP_LDRxx)**	**Sunlight Intensity (R_LDR)**
1	SP_LDR01	22.50	0	0
2	SP_LDR02	45.00	0	0
3	SP_LDR03	67.50	0	0
4	SP_LDR04	90.00	0	0
5	SP_LDR05	112.5	0	0
6	SP_LDR06	135.0	0	0
7	SP_LDR07	157.5	0	0

Initially at night, there are no sunlight to the SP_LDRs and R_LDR. The PIC microcontroller will register '0' bit in the memory respectively.

In the morning, the stationary position (SP_LDR01) = 1, only when the sunlight has high intensity at the light dependent resistor 1. Using the algorithm embedded in the microcontroller, if the previous position of the solar panel registered is in position 7, then the rotation is towards the east. The rotation will stop when R_LDR = SP_LDR01 = 1. The new position registered is [i=1]. Figure 6 shows the position of the sunlight proportional to the surface normal of the solar panel n.

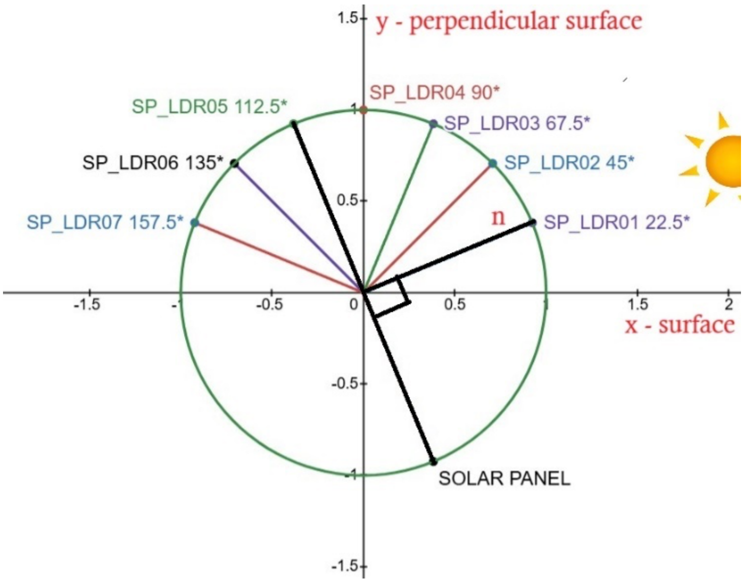

Fig. 6. Positioning of PV module at position 1.

Almost midday, if the sunlight has high intensity at position 3, the SP_LDR03 will register 1. According to the algorithm in figure 10, if SP_LDR03 > [i=1], the rotation is towards the west. When rotation light dependent resistor (R_LDR) = SP_LDR03, the rotation will stop. The new position registered is [i=3]. Figure 7 shows the solar panel at position 3.

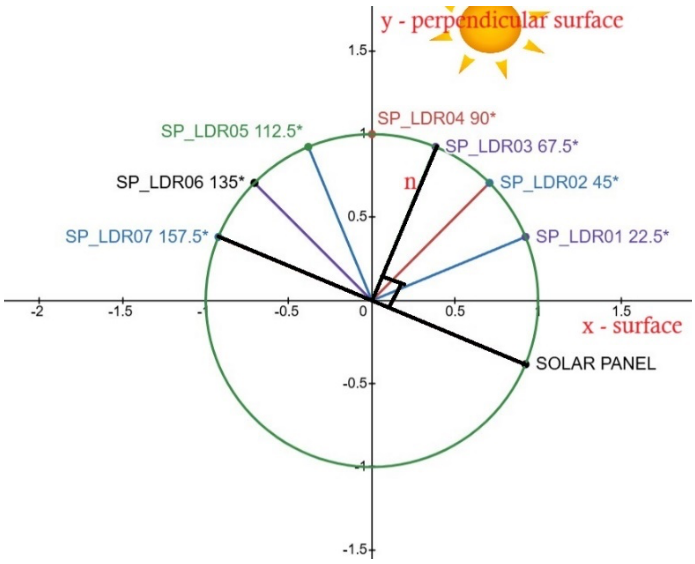

Fig. 7. Positioning of PV module at position 3.

In the afternoon, if the light intensity is high at position 7, SP_LDR06 >[i=3]. According to the algorithm in figure 10, the rotation of the motor and solar panel is towards the west. If R_LDR = SP_LDR06 = 1, the motor rotation will stop. Figure 8 depicts the rotation to position 6. The new position registered is [i=6].

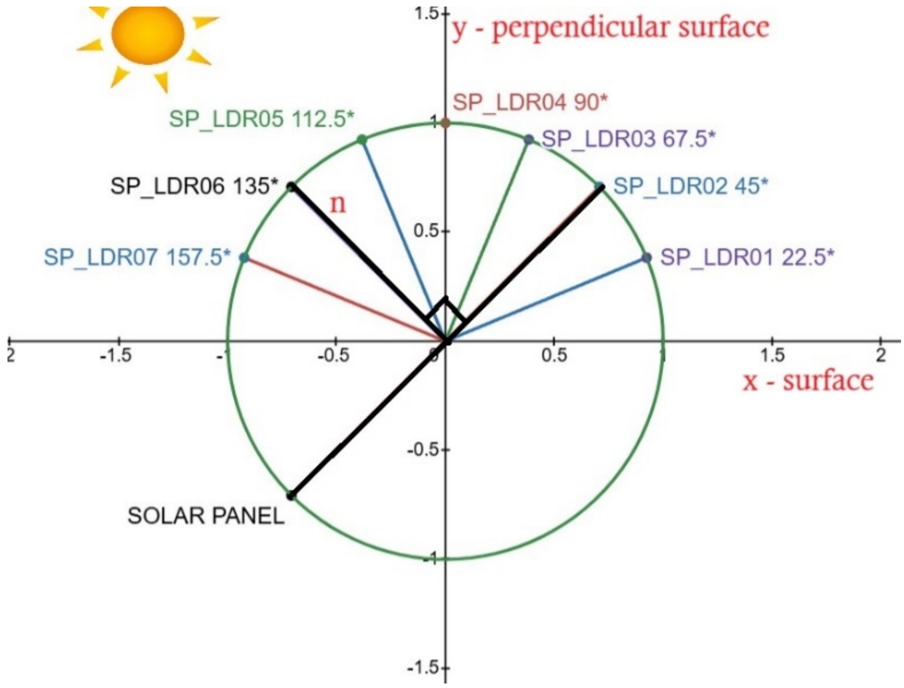

Fig. 8. Positioning of PV module at position 6.

The x-surface that is proportional to the ground surface can be adjusted as well as the angle of incidence of the solar panel. Feasibility study can be done in accordance to the location and alignment of the ground level. This scope of work proposed as describe in this section is mainly to capture the difference between an ordinary single axis solar tracker using light dependent resistor and the introduction to multiple stationary light dependent resistors which is mainly used as a set point to guide the rotation throughout the day by specifying the location and the position with high intensity of light. In this way, we shall minimize the use of the rotational mechanism that guide the solar panel.

3.5. Prototype

The model in figure 9 is used to demonstrate the working of a single-axis solar tracker. It consists of three main components as labeled.

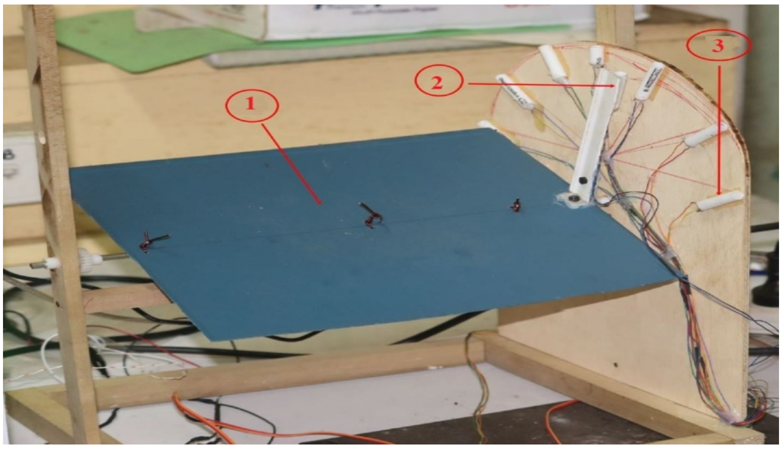

Fig. 9. Model of the single-axis solar tracker.

The physical components used in the model are described in table 3 with their functional descriptions.

Table 3. Descriptions of the model components

Solar Tracker Model Components		
No	**Physical Component**	**Functionality**
1	Solar PV Model (plastic board)	Used as a demonstration in place of solar PV module.
2	Rotational LDR (SP_LDR)	Attached to the solar PV module and to compute the equivalent bits with the SP_LDR while in rotation.
3	Stationary Position LDRs (SP_LDR[7])	Used to detect the position of the sunlight with higher intensity.

3.5.1. Prototype Validation

The prototype in figure 9 is used to test the validation of the algorithm that is embedded in the PIC microcontroller. The component (3) shows the stationary light dependent resistors. A total of seven LDRs is attached to the side of the board as shown in figure 9. Component (2) is the rotational light dependent resistor. It is attached to the rotational mechanism of the solar panel board, and is mostly used to stop the rotation of the motor when it detects light intensity. Component (1) is a plain board that is attached to the rotating shaft that is connected to a stepper motor. The stepper motor is connected at the back of the board.

A torch was used at specific point of the stationary light dependent resistors to test the motion of the rotation. The operation of the prototype and model is described in section 3.4 and section 4.2 respectively. The prototype displays an enormous outcome by guiding the plastic board and the stepper motor rotation throughout each stationary position with high light intensity.

4. Results and Discussions

The single-axis solar tracker has the ability to monitor the light intensity of the sun. The result of the movement of the solar PV for the light intensity is generated experimentally using the prototype that has been designed.

The results have proven that the angle of incidence can be reduced through the use of a solar tracker while power output can be maximized. Unlike a dual-axis solar tracker, a single-axis solar tracker has a minimum power requirement to only control a single stepper motor for rotational purposes and has 7 direct positions to align the PV panel.

4.1. Flow Chart

The flow chart in figure 10 summarizes the operations of the solar tracker concerning the intensity and position of the panel. It portrays the design of programmable instruction sets and the result during the mode of operation.

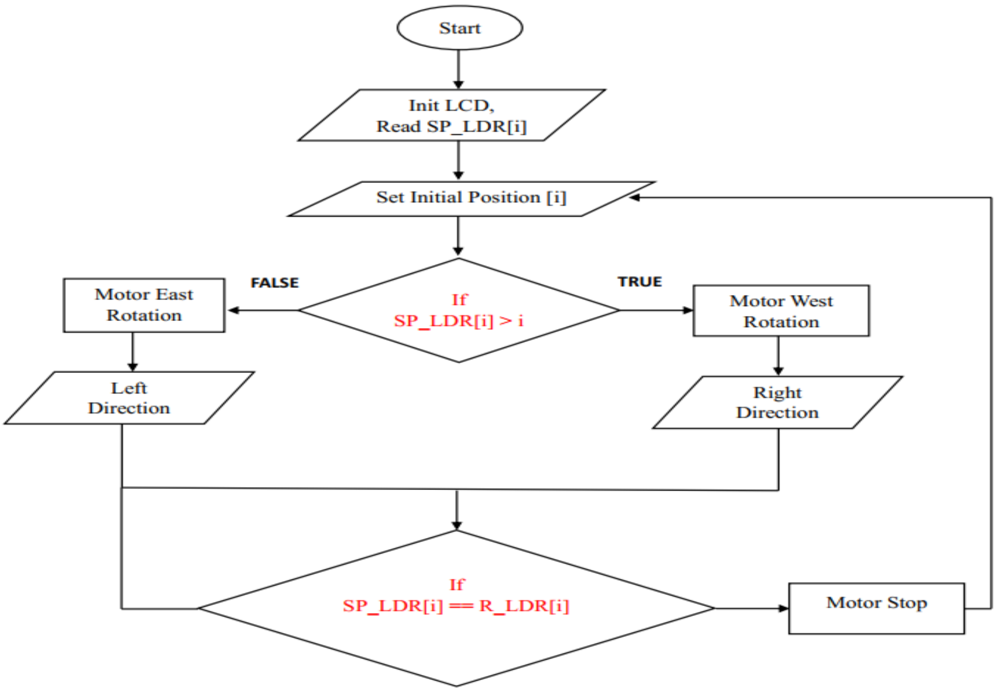

Fig. 10. Programming flow chart of the proposed single-axis solar tracker.

The program codes in the appendix section follows the operation of the flow chart. Specific instructions for light emitting diodes (LEDs) and liquid crystal display (LCD) are also included as per the directive of the flow chart. Specific directive for LEDs such as current position of the light intensity, registered position, rotational directional and stop operation is also included in the algorithm. Similarly, the LCD display the current position, registered position and the current angle of the solar PV module. Those directives can be seen in figure 11 in section 4.3.

4.2. Operation

The sensing mechanism of the sunlight is through the use of LDRs, which is a sensor that has a resistance decrease ability when the sun hits the surface of it. On the other hand, the resistance increases when there is no sunlight detection. The sensor output is amplified to become the input to any MCU digital pins, and from there, further computational approaches are done. Upon the light intensity of any of the LDRs, the MCU sends a command signal to enable the rotation of the stepper motor to the direction of the sensors with the highest intensity. Stepper motor is termed due to its accuracy known as step angle and is used mostly in robotics and industries where accuracy is highly recommended.

The command line in the controller executes the following operation as described by the flow chart. Initially, the controller will monitor the 7 stationary position LDRs (SP_LDR) {ID value 1 to 7 for stationary positions 1 to 7 respectively} which are mounted at a certain position and 22.5-degree angle apart from each other with initial position [i].

The direction of the rotation is based on the position computation of the light intensity in equation 3 below,

$$SP\_LDR[i] > i \tag{3}$$

where the position i=1,2,3,….7.

Initially, if the registered position [i=2] and SP_LDR05 on position 5 has a higher intensity, then position computation [5>2] is true, so stepper motor will rotate the PV module in the right direction (towards west) until the rotation LDR (R_LDR) on the PV module is equal to the SP_LDR05 at position 5 and the rotation will be stopped; thus, a new initial position is set (in that case is 5). If the solar PV panel is at rest at position 7, and there is a higher light intensity at position 1, then the computation (if 1>7) is false, the controller will send the signal to the stepper motor to rotate in the left direction (towards east) until the R_LDR is equal to SP_LDR01 at position 1.

All in all, through monitoring the initial position of the PV module, the operation, and the direction of the rotation depending on the light that triggers the SP_LDR. If the SP_LDR is greater than the initial position of the PV module, the rotation will be in the right direction. On the other hand, if the SP_LDR is less than the initial position of the PV module, the rotation is toward the left direction. The rotation will stop or is at rest when the LDR specified as the SP_LDR equals the R_LDR (specifically the bits). Variables such as the angle, intensity, and position are synchronized in the LCD for on-site monitoring.

4.3. Display

The display circuit consists of a liquid crystal display (LCD) – which shows the angle, position, and mode of rotation of the solar panel, the indicator of the position of the light intensity corresponding to the 7 stationary LDRs, the position of the solar panel corresponding to the rotational LDR.

Figure 11 shows the display panel of the single-axis solar tracker and its operation.

Fig. 11. Display panel of the single-axis solar tracker.

The printed circuit board (PCB) was designed using the schematic in section 3.3. The performance of the PCB along with the status update for the positioning of the solar panel was greatly achieved. The prototype model in figure 6 works such that by shining a light (torch) along each of the stationary LDRs, the steeper motor turns to align the plastic board (solar PV model) and the rotational LDR. The information on the rotation and the direction, as well as the intensity, are well presented and displayed on the display panel as seen in figure 8.

5. Conclusion

The simple solar tracker present in this paper serves as a guide in implementing a reliable and cost-effective system for governing the sunlight that can be used in electricity production. The integration of multiple stationary positioning LDRs along with a single movable LDR provides precise monitoring of the sun's radiation. Most advancement in solar energy harvesting is to utilize and enhance solar tracking mechanisms. This mechanism is therefore suitable for increasing the energy output of the solar panel. This horizontal single-axis solar tracker is fully functional during the daytime. The angle of incidence perpendicular to the surface of the solar panel is deviate by less than or equal to 22.5°. To reduce the angle of incidence more, it is possible to increase the number of stationary positioning LDRs to monitor the sunlight position during the day.

The results present mainly focus on the deliverance of the tracking phenomena and how best will the system respond to the changes in the sunlight position during the day. The algorithm embedded in the PIC microcontroller as programs executes the entire operational description of the horizontal single-axis solar tracker. The program code is provided in the appendix section of this paper.

It is successfully proven through the process of validation and testing using the simulation and the prototype. We assure by using the simple design, we can enlarge the prototype to cater to a huge application that requires more solar PV modules per instalment. It can be portable to rural homes and domestic industries that target solar renewable energy for electric power production. Increasing the use of solar electricity and harvesting the maximum power production will greatly contribute to sustainability and mitigation of global warming and its effects.

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APPENDIX

In this section, the source code used for the design of a horizontal single-axis solar tracker is presented. These program codes are used both in the simulation (section 3.3) and the prototype model (section 3.4) presented in this paper. The flow chart in the result section was derived from the operation instruction of the program code given.

```
/*
 *
 *
 Design of Single Axis Solar Tracker
 MCU: PIC16F877A
 Clcok frequency: 32.00MHz
 Oscillator: 8MHz
 Programmer: Sylvester Tirones
 *
 *
*/

// Lcd pinout settings
sbit LCD_RS at RC4_bit;
sbit LCD_EN at RC5_bit;
sbit LCD_D7 at RC3_bit;
sbit LCD_D6 at RC2_bit;
sbit LCD_D5 at RC1_bit;
sbit LCD_D4 at RC0_bit;

// Pin direction
sbit LCD_RS_Direction at TRISC4_bit;
sbit LCD_EN_Direction at TRISC5_bit;
```

```
sbit LCD_D7_Direction at TRISC3_bit;
sbit LCD_D6_Direction at TRISC2_bit;
sbit LCD_D5_Direction at TRISC1_bit;
sbit LCD_D4_Direction at TRISC0_bit;


int rotation;                    // initialize rotation as integer
int initial_Position;            // initialize initial_Position as integer
int set_Position;                // initialize set_Position as integer
int x;                           // initializs variable x as integer
float read;                      // initialize read as floating values
unsigned char txt[14], data_, P_text[7];          // initialize txt as character
char PV_Pos [7] = "Solar:" ;


#define  LDR1  PORTD.B1
#define  LDR2  PORTD.B2
#define  LDR3  PORTD.B3
#define  LDR4  PORTD.B4
#define  LDR5  PORTD.B5
#define  LDR6  PORTD.B6
#define  LDR7  PORTD.B7

#define  r_LDR  PORTD.B0

#define ON 1
#define OFF 0

#define West PORTA.B0
#define East PORTA.B1

#define PV PORTA.B2
#define Other PORTA.B3



void direction(){

        /*
        if rotation = 1 ----- forward direction
        if rotation = 2 ----- reverse direction
        */

        switch (rotation){

        case 1:                 // forward direction
        Lcd_Out (1,21, "Clockwise");
        East = ~ East;
        West = OFF;
         PORTA.B5 = 1;
         PORTE.B0 = 0;
         PORTE.B1 = 0;
         PORTE.B2 = 0;
         Delay_ms (10);
         PORTA.B5 = 0;
         PORTE.B0 = 1;
         PORTE.B1 = 0;
         PORTE.B2 = 0;
```

```
        Delay_ms (10);
        PORTA.B5 = 0;
        PORTE.B0 = 0;
        PORTE.B1 = 1;
        PORTE.B2 = 0;
        Delay_ms (10);
        PORTA.B5 = 0;
        PORTE.B0 = 0;
        PORTE.B1 = 0;
        PORTE.B2 = 1;
        Delay_ms (10);

       break;

       case 2:                    // reverse direction
       Lcd_Out (1,21, "Anti Clockwise");
       West = ~ West;
       East = OFF;
        PORTA.B5 = 0;
        PORTE.B0 = 0;
        PORTE.B1 = 0;
        PORTE.B2 = 1;
        Delay_ms (10);
        PORTA.B5 = 0;
        PORTE.B0 = 0;
        PORTE.B1 = 1;
        PORTE.B2 = 0;
        Delay_ms (10);
        PORTA.B5 = 0;
        PORTE.B0 = 1;
        PORTE.B1 = 0;
        PORTE.B2 = 0;
        Delay_ms (10);
        PORTA.B5 = 1;
        PORTE.B0 = 0;
        PORTE.B1 = 0;
        PORTE.B2 = 0;
        Delay_ms (10);

        // use hexa number to decide the rotation
        set_Position ++;
       break;

       case 3:                    // stop
       Lcd_Out (1,21, "Stop............");
       break;

       default:
       break;
       }
}



void GUI (){
    IntToStr (Set_position, P_text);
    UART1_Write_Text (P_text);
    Delay_ms (500);
```

```
    UART1_Write (13);
}



void main() {                          // main function
    TRISD = 0xFF;
    TRISB = 0x00;
    TRISA = 0x00;
    TRISC = 0x80;
    PORTD = 0x00;
    PORTB = 0x00;
    PORTA = 0x00;
    TRISE = 0x00;
    PORTE = 0x00;
    ADCON1 = 0x0F;
    ADCON0 = 0xF0;

    UART1_Init (9600);
    Lcd_Init(); // initialize LCD
    Lcd_Cmd (_LCD_CURSOR_OFF);
    //Welcome message
    Lcd_Out (1,1, "Welcome to Smart BMS");
    Lcd_Out (1,21, "Solar Tracking Sys");
    Delay_ms (2000);
    Lcd_Cmd (_LCD_CLEAR);


    Lcd_Out (1,1, "Angle: ");
    Lcd_Chr (1,10, 42);
    Lcd_Out (2,1, "Position: ");

    set_Position = 0;
    initial_Position = 0;

    START:

    if (r_LDR == 0){
         if (set_Position > initial_Position){
           rotation = 1;
           direction();
         } else {
          rotation = 2;
          direction();
         }
         GUI();
      } else {
          rotation = 3;
          initial_Position = set_Position;

          switch (set_Position){

          case 1:
          Lcd_Out (1,7, "-30");
          Lcd_Chr (2,16, 49);
          LDR1 = OFF;
          PORTB = 0x01;
          break;
```

```
case 2:
Lcd_Out (1,7, "-60");
Lcd_Chr (2,16, 50);
LDR2 = OFF;
PORTB = 0x02;
break;

case 3:
Lcd_Out (1,7, "-90");
Lcd_Chr (2,16, 51);
LDR3 = OFF;
PORTB = 0x03;
break;

case 4:
Lcd_Out (1,7, "+60");
Lcd_Chr (2,16, 52);
LDR4 = OFF;
PORTB = 0x04;
break;

case 5:
Lcd_Out (1,7, "+30");
Lcd_Chr (2,16, 53);
LDR5 = OFF;
PORTB = 0x05;
break;

case 6:
Lcd_Out (1,7, "+90");
Lcd_Chr (2,16, 54);
LDR6 = OFF;
PORTB = 0x06;
break;

case 7:
Lcd_Out (1,7, "+120");
Lcd_Chr (2,16, 55);
LDR7 = OFF;
PORTB = 0x07;
break;


default:
break;

}
direction();
Delay_ms (1000);
}

do{

if (UART1_Data_Ready()){
data_ = UART1_Read();

switch (data_){
```

```
case 'A':
Delay_ms (20);
UART1_Write_Text (PV_Pos);
IntToStr (Set_Position, P_text);
UART1_Write_Text (P_text);
Delay_ms (500);
UART1_Write (13);
break;

default:
// do nothing
break;
}

}



if (LDR1 == ON){
set_Position = 1;
GUI();
goto START;
} else if (LDR2 == ON){
set_Position = 2;
GUI();
goto START;

} else if (LDR3 ==ON){
set_Position = 3;
GUI();
goto START;

} else if (LDR4 ==ON){
set_Position = 4;
GUI();
goto START;

} else if (LDR5 ==ON){
set_Position = 5;
GUI();
goto START;

} else if (LDR6 == ON) {
set_Position = 6;
GUI();
goto START;

} else if (LDR7 ==ON){
set_Position = 7;
GUI();
goto START;

}

} while (1);

}
```