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Renewable energy: Sun tracking solar power system

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Disclaimer:

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Abstract :

The purpose of this project is to implement the most efficient control algorithm of dual-axis sun tracker. The simulation gives the tracker angles that position the solar panel along the sun's rays such that maximum solar irradiation is absorbed by the panel. The traditional solar panels used in homes and factories ,etc… are fixed with a certain angel, sun-tracking system allow the solar panel to adjust its position according to the position of sun in the sky. A dual-axis sun trackers have 2 degree of freedom, it could rotate both vertically and horizontally, thus they can track sun's entire motion in the sky from east to west and from south to north. LDRs are used to position the sun location in the sky and motors are used to change the panel position/angle on both axis. As the work of the project included hardware design and implementation, it needs software programming for the micro-controller unit of the solar tracker. The system utilized an Arduino to control motion of the servo motors.

The amount of rotation was determined by the Arduino, based on inputs retrieved from the sensors.

The generated power from the solar panel will feed a smart home model (electrical fan, LED, smoke alarm) with energy. Before that the DC wave generated by the solar panel would have been change to another DC wave form which will be suitable to be stored at the batteries connected to the system using DC battery charger. The home system will be supplied with the necessary energy and any excess energy will remain stored in the battery.

An auto-cleaner is added to the panel to clean it from the built dust in order to make sure that the efficiency of the panel is not effected.

The main advantage of this approach that it gives the solar panel a high degree of flexibility, which allows higher energy output.

1. Introduction

The consumption of Conventional energy resources such as fossil fuels in the past decades has cause resources' depletion and has contributed to huge environmental issues such as environmental pollution, This has created the urging need to find substitutes to produce energy. Renewable energy sources such as solar energy, wind energy, geothermal energy, and hydroelectric power, are clean sustainable substitutes. Unfortunately, because the occupation had confiscated huge land spaces and water resources, both wind energy and hydroelectric power aren't a strong option. This turned the eyes toward Solar energy which has been used in factories and home power systems increasingly nowadays.

The problem with the solar panels is that the sun changes its position every hour in the day, so we aren't gaining the maximum energy from it if we're using the traditional fixed solar panel system where the panels are placed fixedly on the floor by angle 38 -here in Palestine- by and it gains the sun's energy only if the sun rays are toward these panels.
The sun moves through the day from east to west and up in the sky till it reaches its highest point in the afternoon then down till sunset.
Our work is to find the best approach to gain maximum possible output from the solar panel. We have designed a sun tracking solar system that moves with sun both ways from east to west and up and down. This solar system will be used to provide a smart home with the necessary power to turn the inside devices on such as light and a fan that both will work if there is a motion inside the home. Also, an alarm that would go on if it detect smoke or gas leak in the home.
The report organization is as this. Chapter 2 discusses the challenges s we faced during our work. Chapter 3 provides quick background regarding solar power, In addition to previous applications. Chapter 4 discusses the methodology and components that are used to build the application. In chapter5 a discussion about the claim that had been made in the report. Finally, discuss a conclusion of the work and possible future work in chapter 6.

2. Constraints:

While working, we have faced a series of problems and challenges that we have fortunately overcome.

One is the differentiation of LDRs reading even if the same light is directed. We have overcome this challenge using a software method which is adding a constant that represent the tolerance, in other words, what is the acceptable difference in reading if the LDRs are under the same light.

Another challenge we had faced, Is the lack of accuracy in the RTC model (Real Time Clock) that we have used to know what is the time. Since it was 6 minutes late the next day after its first use. To solve this we change the used RTC model from DS1307 to DS3231 which provided a higher accuracy.

3.Literature Review

People have been using the sun since the 7th century B.C. They had used the sunlight to create fires using magnifying glass. Later, they had used the solar power to light torches for religious occasions. One another popular yet old use of the sunlight is the concept of "light room" where massive windows are used in building to direct sunlight into the area. In the late 1700s and 1800s, researchers had successful used the sunlight to power ovens and produce solar-powered steamboats.

The era of solar panels, has risen the concept of manipulating the power of the sun. In 1883, Charles Fritts produced the first solar cells made from selenium wafers. Later in 1954, Daryl Chapin, Calvin Fuller, and Gerald Pearson’s created silicon photovoltaic (PV) cell and that was the first instance of a solar technology that could power an electric device. In 1962, The first solar tracker was invented by C. Finster, it was a mechanical system. Finster realized insignificant energy gains though this solar tracker.

Our system is made up of four photo-resistors module -LDRs- Placed up–down and right–left (represent North- south and east-west), those will detect the light intensity, this is system also use the Arduino micro-controller and manipulating the two positioning mechanism through two Servo motors.

4. Methodology

This is a report of a project where a dual-axis sun tracker off grid solar system was implemented to gain energy and supply the other two parts of the project which are: an auto-cleaning system that rinse the panel from dust, the other part is a smart home model that detect motion to turn on fan and light in the home and has an alarm that goes on if detected gas leak So, this project includes 4 parts:

4.1. Off-grid solar system

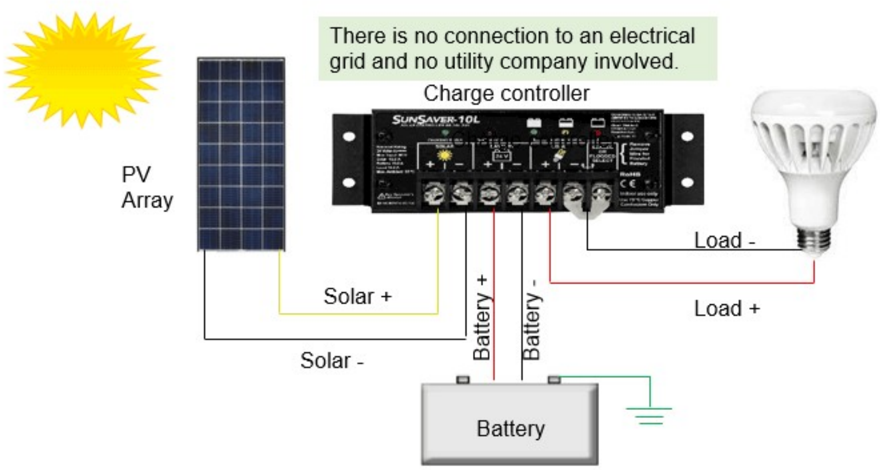


Figure 1: off-grid system

To implement this part we have used :

1. solar panel:

which provide 12 volt as output.

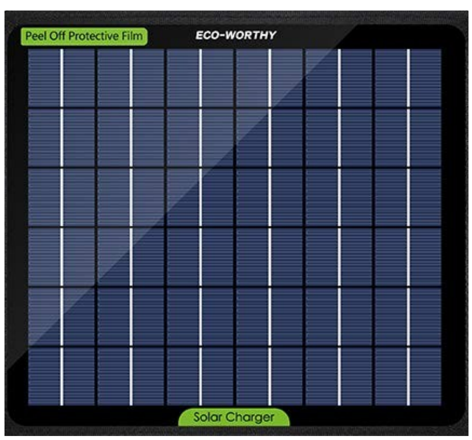


Figure 2: 12 volt solar panel

2. 20A 10A Solar Charge Controller CMTD-A2410/ CMTD-A2420 10 Amp 20 Amp PWM Solar PV Regulator With Current Display

: which generate 12 volt output load.

Figure 3: Solar charge controller

3. 12 volt battery

Figure 4: 12 volt battery

4.2 Sun tracking system

To implement this part, we have used 4 LDRs, 2 servo motors , Arduino Uno and buck convertor

4.2.1 Design the base

The design contain a circular base that moves horizontally controlled by a servo motor. The base contains 2 wooden circles one above the other and between them the servo motor and 3 wheels to smooth its movement. Then two wooden sticks have been attached to the base in order to hold the panel and the motor that holds the panel from one side and responsible of the vertical motion of the tracker.

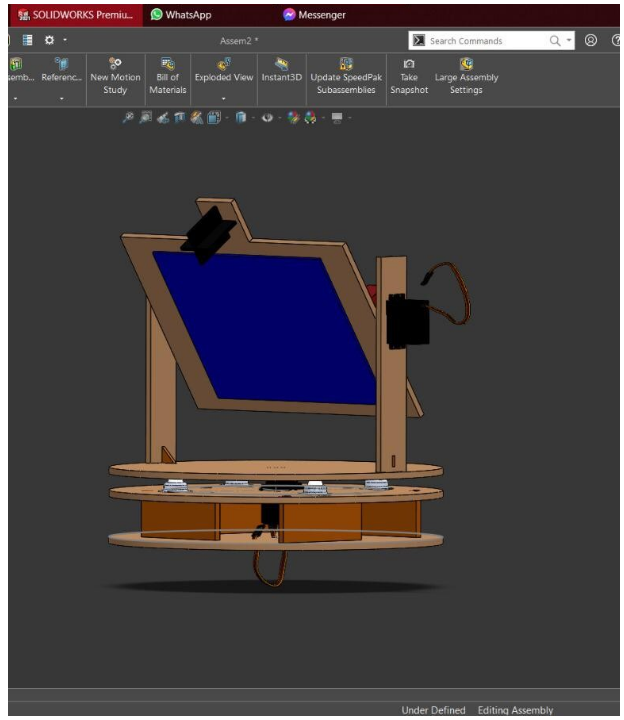


Figure 5: The design

Used components:

1. 2 Servos

Figure 6: servo motor

2. 4 LDRs :

A photo-resistor are used to detect light since its resistance lower when received luminosity is higher.


Figure 7: Photo-resistor

3. 6 Resistors: connected to LDRs

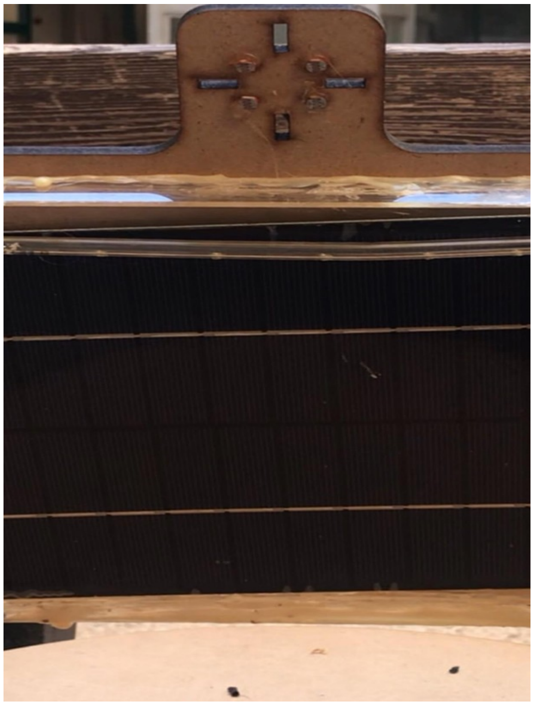


Figure 8: LDRs placement

we will use a + shaped piece between the 4 LDRs

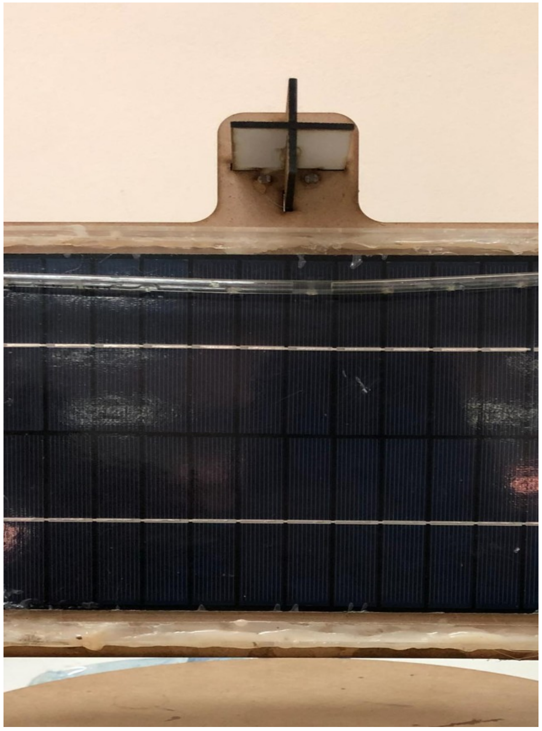


Figure 9: LDRs

4.LM 2596 DC to DC Buck Converter

: Used to power the servo motors with 5 volt and 2 Ampere

, Itself is power using the 12 volt regulator load output.

Figure 10: LM 2596 DC to DC Buck Converter

4.2.2 Implementation

To determine and control sun-tracker motion we will use Arduino Uno micro-controller.

The 4 LDRs are connected to the analog input pins(A0-A3).

While the servo motors' signal wires are connected to 2 digital output PWM pins (~9 and ~10). while their VCC wires are connected to the OUT+ of the buck converter .

The GND of the servos and the OUT- of the buck converter are connected to the GND of the Arduino.

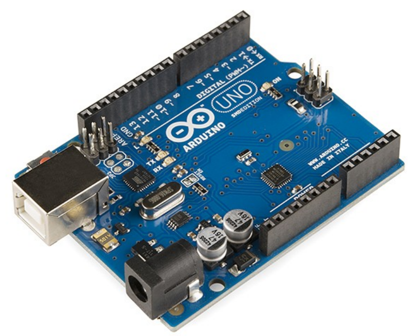


Figure 11: Arduino Uno

There are 4 LDRS : UL (upper-left), UR (upper-right), LR (lower-right) and LL (lower-left). To determine where to move we find the average of the upper ones reading, the average of the lower ones reading, the average of the left ones reading and the average of the right ones reading. Then, we find the difference between both upper and lower to determine the vertical motion and we find the difference between both left and right to determine the horizontal motion.

```
//LDRs
int UL = A3;//brown
int UR = A2;//purple
int LL = A1;//orange
int LR = A0;//blue
//LDRs' reading
//note ldr reading is lower when light hit
int rUL =0 , rUR =0, rLL=0, rLR =0;

int avt=0;//avg top ldrs
int avd=0;//avg down ldrs
int avl=0;//avg left ldrs
int avr=0;//avg right ldrs

int dvert = 0;//diff bt top and down
int dhoriz = 0;//diff bt right and left

int tol=50;//toleranc
```

Figure 12: initializations connected to LDRs

```
rUL = analogRead(UL) ;
rUR = analogRead(UR) ;
rLL = analogRead(LL) ;
rLR = analogRead(LR) ;
avt = (rUL+  rUR) / 2; // average value top
avd = (rLL + rLR) / 2; // average value down
avl = (rUL + rLL) / 2; // average value left
avr = (rLR + rUR) / 2; // average value right
dvert = avt - avd; // check the diffirence of up and down
dhoriz = avl - avr;// check the diffirence og left and rigt
```

Figure 13: LDR data measurement and comparison

4.3 Auto-cleaning system

This system will work on a definite time each day to ensure the cleanness of the solar panel.

4.3.1 Auto-cleaner implementation

The auto-cleaner functionality will be implemented using Arduino Uno , DS3231 RTC module, a water pump and a Motor Controller.

-RTC module:

Used to know what is the time (the hours, minutes and seconds also could be used for the date)

```
DateTime now = rtc.now();
 Serial.print(now.hour(), DEC);
 Serial.print(':');
 Serial.print(now.minute(), DEC);
 Serial.print(':');
 Serial.print(now.second(), DEC);
 Serial.println();
```

Figure 14: DS3231 RTC

-Water pump:

To drive the water pump we need a motor controller, that works on 12v and could drive a 5v water pump

Figure 15: 5v DC water pump

-L298N Dual Motor Controller Module:

To control a water pump using motor controller

- Connect out1 and out2 to the water pump wires
- Connect 12V and GND to the regulator load output + And -
- Connect IN1 and IN2 to Arduino digital output pins.
- To turn the water pump on the 2 pins value should Vary , if one is high the other is low

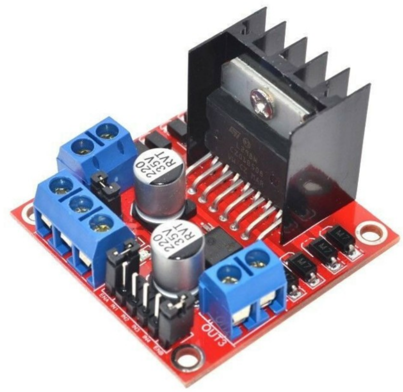
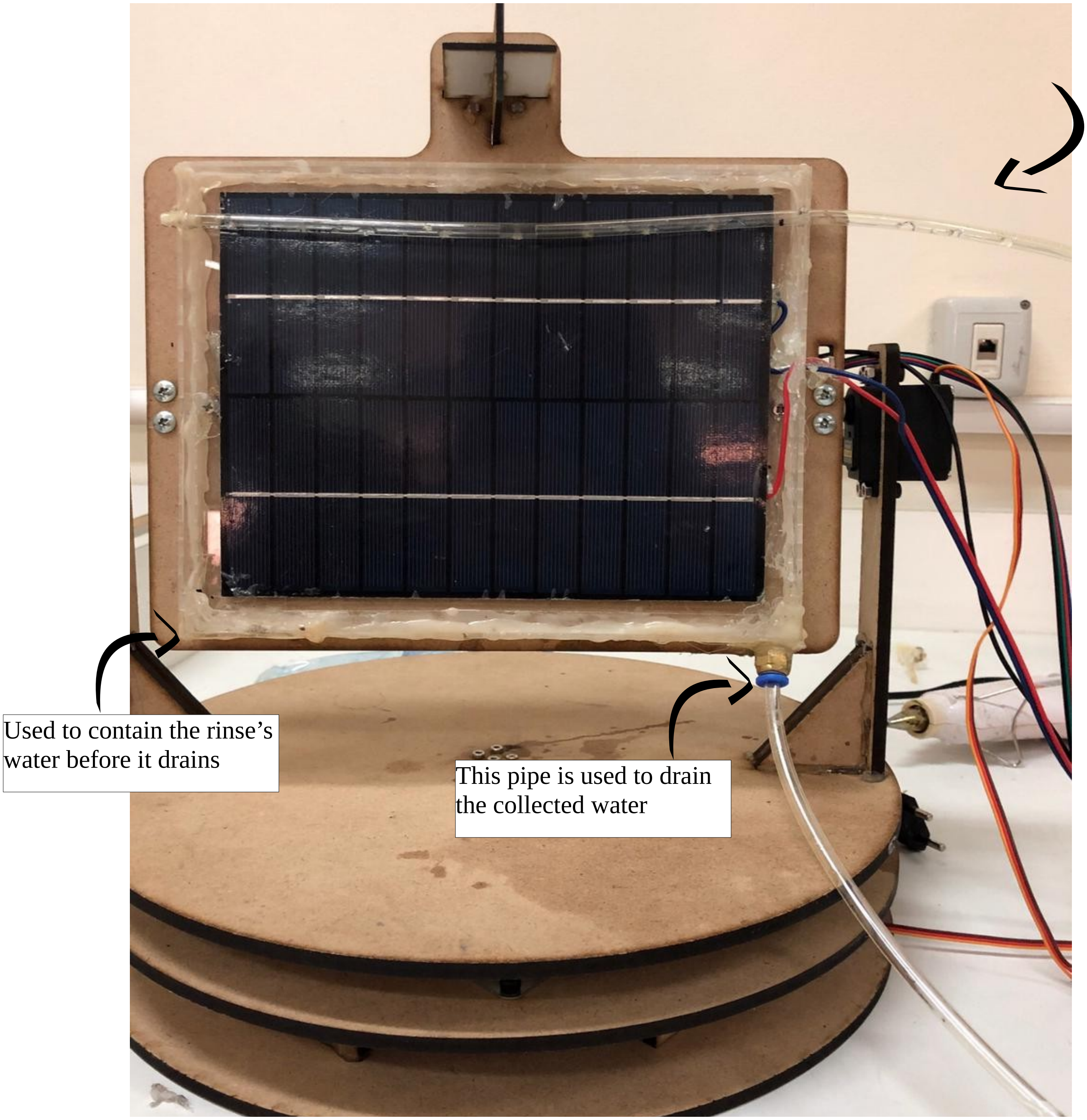


Figure 16: L298N Dual Motor Controller Module

4.3.2 Auto-cleaner design

A pipe with holes to rinse the panel with the pumped water from that water pump that is connected to its end


Used to contain the rinse’s water before it drains
This pipe is used to drain the collected water

4.4 Smart home model

4.4.1 home design

We have designed

A 30x30x20 prototype

for our smart home

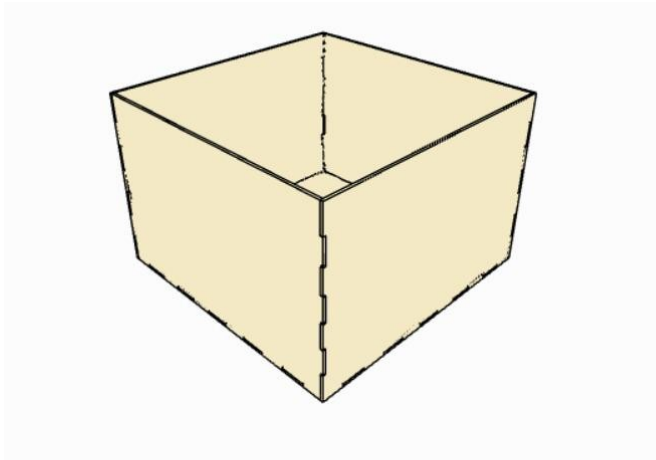


Figure 17: Home design

Figure 18: Home design output

- This home will get energy from the regulator 12v load output. The home will contain number of devices and sensors, which are:

1. 12V Led strip

Figure 19: Led strip

2. 12V fan

Figure 20: 12V fan

3. 5V buzzer

Figure 21: 5V Buzzer

4.MQ2 gas sensor

Figure 22: MQ2 gas sensor

5. PIR Sensor

Figure 23: PIR sensor

4.4.2 Smart home implementation

1. Smoke/ gas leak detection:

Using MQ2 sensor, If there is smoke or gas leak in the house a buzzer will go on.

```
 MQ6digitalValue = digitalRead(mq2);
  if(MQ6digitalValue==LOW){
  tone(buzzer, 1000, 200);
  Serial.println("innn mq2");
 }
 else if(MQ6digitalValue==HIGH){
  noTone(buzzer);
 }
```

Figure 24: smoke/gas detection

2. Motion Detection

Using PIR sensor, if there is someone moved inside the house both led and fan will turn on

```
pirStat = digitalRead(pirPin);
if (pirStat == HIGH) {            // if motion detected
   digitalWrite(ledPin, HIGH);  // turn LED ON
   digitalWrite(fanPin, HIGH);  // turn LED ON
  Serial.println("Hey I got you!!!");
  delay(10000);
}
else {
 digitalWrite(ledPin, LOW);  // turn LED ON
 digitalWrite(fanPin, LOW);  // turn LED ON
 Serial.println("!!!");
 //delay(10000);
}
```

Both fan and led strip need a relay

we used a 5v dual channel relay to drive them

How to connect?

DC+ with Arduino VCC

DC- with Arduino GND

IN1 and IN2 with Arduino digital output pins

(give them high to turn fan/led)

NO1 and NO2 with Fan /Led VCC

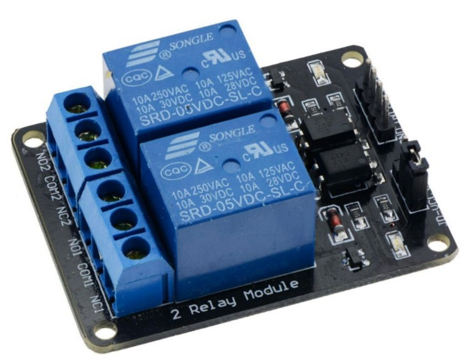


Figure 25: Dual channel relay

COM1 and COM2 are connected to the regulator + 12v load output.

5. Discussion

Is the sun-tracker worth it?

the fixed solar panels are inefficient, they can't get 100% from the sun's energy falling into it, there could be a methods to improve the output from the solar panel such as connectors and reflectors but the may be the best way is to track the sun "solar tracking".

Let's talk about the solar tracking system, there are tow types f solar tracking, single and Dual axis, single can track the sun in horizontal or in vertical movement, in the other hand dual axis can track the sun in horizontal and vertical movement.

The majority uses a fixed in place solar panel, which gives advantages, such as stability and ease to maintenance, but on the other hand the sunshine falling into panels varies to the season and though the day, so fixed panels does affect the maximum output power of the panel.

so in order to know when panels get the maximum energy we have to know what affect the solar panel?

irradiance: the power in watts falling on a surface at any instant in time,

insolation: the power falling on a surface over time,

temperature: solar panels most efficient at 77 degrees F,

orientation: direction pointing – due South for Northern hemisphere, due North for Southern

and tilt angle: location latitude +15 degrees in Winter and -15 degrees in Summer

for the irradiance and insolation, we can't do much except keep the panel clean and not shaded, in additional, for the orientation, if the panel was tilted then the area covered by the same energy is larger, so intensity is less because it spread also for the temperature we can't do anything.

The main 2 factors we can adjust, now to analyze the cost and payback we need to know:

1. installation cost auto-tracking system

2. Total annual energy generated by a fixed solar panel

3. Total annual energy generated by solar panel using auto-tracking

4. The cost per unit (kWh) of electricity in the locality

1. installation cost : an auto-tracking system costs about 30% of the installation cost of the fixed solar panel array, which comes in at approximately $3 per watt. So if the solar panel costs $15000 then the auto tracking system costs $5000.

2. the Annual energy generated by 5kW fixed solar panel

we need a location to calculate this, if we tack South Bend, Indiana, for example and according to GlobalSolarAtlas site the Irradiation value is 1422 kWh/m2 then the annual energy production in kWh is 7110kWh, the average home usage is 10000kWh.

3. Annual energy generated by 5kW solar panel auto-tracker

If we assumed that at least the improvement of auto-tracker over fixed is 30% the energy generated 7110kWh *0.3=9243 kWh, The auto-tracking system will generate 2133 kWh more than the fixed.

4. The cost of electricity per kilowatt hour

As we tack South Bend, Indiana, an example the electricity cost is 10.53kWh

Case study: A 5 kW solar panel system in South Bend, Indiana

Fixed array:

- Installation cost $15000 (-30% after government/state relief) = $10000
- Energy generated (saved) 7110 kWh = $748.68/annum
- Payback period = $10000/$748 = 13.5 years

Sun-tracker:

- Solar array + tracker Installation cost $20000 (-30% after government/state relief) = $14000

- Energy generated (saved) 9243 kWh = $973/annum
- Payback period = $14000/$973 = 14.4 years

In our studied case the payback period is slightly longer, but after this time the annual saving will be grater, calculation doesn't take into account additional maintenance costs of the realistic life of the sun-tracker mechanism, which obviously has moving parts that wear out and need replacing, The active life of the solar panel array will also be shorter due to the extra heat brought by the more focused irradiation. Each extra degree not only reduces solar cell output but also the effective life of the crystals. However, the effect is minor.

Out of the total installation cost of about $3/watt, equipment purchase cost is $1.70. The actual cost of a solar panel per watt is falling every year until in most places in 2021 it's less than $1/watt.

So after these calculations and numbers, many hose owners says it dose not worth it to hassle of installing a complex pieces equipment like a sun-tracker, when they could simply add more solar panels to get the same effect, this can be done only if you have enough space to put the extra panels, to replace the gain from the tracking system and for our example, the needed solar panel power is energy saving / the annual peak-sun-hours :2133/1422=1.5 kW, so 1.5 kW can be connected to give the same effect with life longer and less maintenance.

At the end, if we have a space to place our panels, we can use multiple fixed solar panel, it provides a clear cost advantage no need for regular maintenance, in the other hand if there is no enough space the can use tracker system, with regular maintenance.

6. Conclusions and Future work

At the end of the project we were able to build a prototype of a sun tracker that follow the sun motion during the day, so the solar panel will generate the maximum possible output by collecting most of the sun rise, and we were able to build an auto-cleaning system, that will help the sun tracker to clean itself from the dust. For a future work we can improve our project by adding cooling system to extend the life cycle of the batteries and the solar panel, add a WIFI component, to get information about the output power for the day, battery charge and to control the tracking system remotely.

7.References