A Project Report

on

Sun Tracking Solar Panel

Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

In

Electronics and Communication Engineering

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(November 2019)

CERTIFICATE

It is certified that the work contained in the project report titled **"Sun Tracking Solar Panel"** by **"Kapil Sharma"**,**"Sanchit Gupta"** and **"Satyam Gupta"** has been carried out under my supervision and this work has not been submitted elsewhere for a degree.

Signature of Supervisor(s)

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DECLARATION

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included ,we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any ideas/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ABSTRACT

The recent demand for renewable form of energy has created a major opportunity in the research of solar power. This project tries to efficiate the solar energy coming from the sun. In this work, we have analyzed the sun's position and moved the tracker accordingly.Solar intensity is a variable phenomenon and varies continuosly over the globe.And using the fixed collector will limit the power generated from the solar energy. Hence, we have used the Tracking-collector which has more exposure to the sun's energy at any given time and more energy is collected from the tracking collector than the fixed one.

ACKNOWLEDGEMENT

We would like to take this opportunity to express our profound gratitude and deep regards to our guide and mentor **Mr. Varun Goel** for his exemplary guidance,monitoring and constant encouragement throughout the course of this project.We owe the success of this project to him and are indebted to him for his blessings, help and guidance.

We would also like to extend our gratefulness to our parents and family for their persistent love and support.

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Chapter 1

INTRODUCTION

1.1 General background

Solar energy is clean and available in abundance. Solar technologies use the sun for provision of heat, light and electricity. These are for industrial and domestic applications. With the alarming rate of depletion of major conventional energy sources like petroleum, coal and natural gas, coupled with environmental caused by the process of harnessing these energy sources, it has become an urgent necessity to invest in renewable energy sources that can power the future sufficiently. The energy potential of the sun is immense.

This project seeks to identify a way of improving efficiency of solar panels. Solar tracking is used. The tracking mechanism moves and positions the solar array such that it is positioned for maximum power output.

Fossil fuels account for around 85 percent of energy that is produced. Fossil fuel resources are limited and using them is known to cause global warming because of emission of greenhouse gases. There is a growing need for energy from such sources as solar, wind, ocean tidal waves and geothermal for the provision of sustainable and power. Solar panels directly convert radiation from the sun into electrical energy. The panels are mainly manufactured from semiconductor materials, notably silicon. Their efficiency is 24.5% on the higher side. Three ways of increasing the efficiency of the solar panels are through increase of cell efficiency, maximizing the power output and the use of a tracking system.

Solar tracking is a system that is mechanized to track the position of the sun to increase power output by between 30% and 60% than systems that are stationary.

There are various types of trackers that can be used for increase in the amount of energy that can be obtained by solar panels. Dual axis trackers are among the most efficient, though this comes with increased complexity. Dual trackers track sunlight from box axes. They are the best option for places where the position of the sun keeps changing during the year at different seasons. Single axis trackers are a better option for places around the equator where there is no significant change in the apparent position of the sun.

The level to which the efficiency is improved will depend on the efficiency of the tracking system and the weather. Very efficient trackers will offer more efficiency because they are able to track the sun with more precision. There will be bigger increase in efficiency in cases where the weather is sunny and thus favorable for the tracking system [1].

1.2 Problem statement

A solar tracker is used in various systems for the improvement of harnessing of solar radiation. The problem that is posed is the implementation of a system which is capable of enhancing production of power by 30-40%. The control circuit is implemented by the microcontroller. The control circuit then positions the motor that is used to orient the solar panel optimally.

1.3 Project justification

The project was undertaken to ensure the rays of the sun are falling perpendicularly on the solar panel to give it maximum solar energy. This is harnessed into electrical power. Maximum energy is obtained between 1200hrs and 1400hrs, with the peak being around midday.

At this time, the sun is directly overhead. At the same time, the least energy will be required to move the panel, something that will further increase efficiency of the system. The project was designed to address the challenge of low power, accurate and economical microcontroller based tracking system which is implemented within the allocated time and with the available resources. It is supposed to track the sun's movement in the sky. In order to save power, it is supposed to sleep during the night by getting back into an horizontal position. There is implementation of an algorithm that solves the motor control that is then written into Python- program on Raspberry PI.

1.4 Objectives

The main objective of the project was to:
Design a system that tracks the solar UV light for solar panels and Prove that the tracking indeed increases the efficiency considerably. The range of increase in efficiency is expected to be between 30 and 40 percent.

1.5 Light Sensor Theory and Circuit of Sensor Used

Light detecting sensor that maybe used to build solar tracker include; phototransistors, photodiodes, LDR and LLS05. A suitable, inexpensive, simple and easy to interface photo sensor is analog LDR which is the most common in electronics. It is usually in form of a photo resistor made of cadmium sulfide (CdS) or gallium arsenide (GaAs). Next in complexity is the photodiode followed by the phototransistor [2].

1.6 Light Dependent Resistor Theory

The simplest optical sensor is a photon resistor or photocell which is a light sensitive resistor these are made of two types, cadmium sulfide (CdS) and gallium arsenide (GaAs). The sun tracker system designed here uses two cadmium sulfide (CdS) photocells for sensing the light. The photocell is a passive component whose resistance is inversely proportional to the amount of light intensity directed towards it. It is connected in series with capacitor. The photocell to be used for the tracker is based on its dark resistance and light saturation resistance. The term light saturation means that further increasing the light intensity to the CdS cells will not decrease its resistance any further. Light intensity is measured in Lux, the illumination of sunlight is approximately 30,000 lux [2].

Normally the resistance of an LDR is very high, sometimes as high as 1000 000 ohms, but when they are illuminated with light resistance drops dramatically. When the light level is low the resistance of the LDR is high.

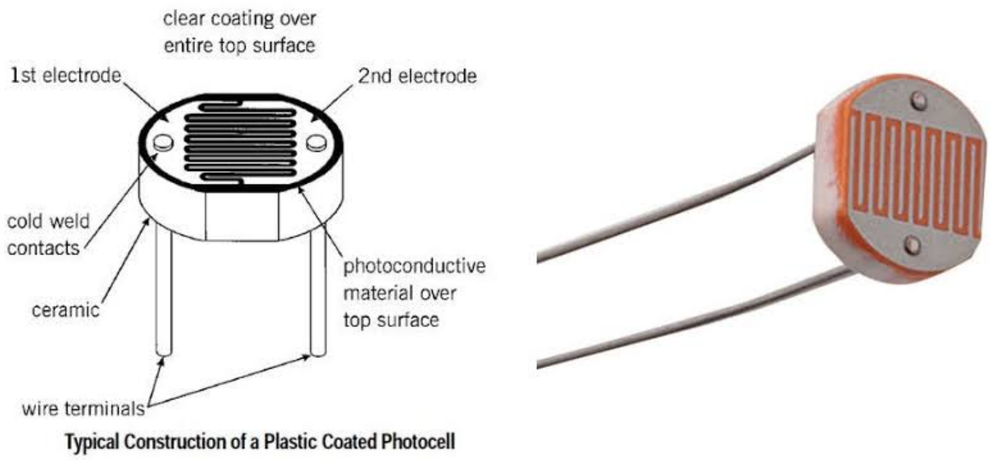

Figure 1.1: LDR construction [2]

This prevents current from flowing to the base of the transistors. Consequently the LED does not light. However, when light shines onto the LDR its resistance falls.

1.6.1 The concept of using two LDRs

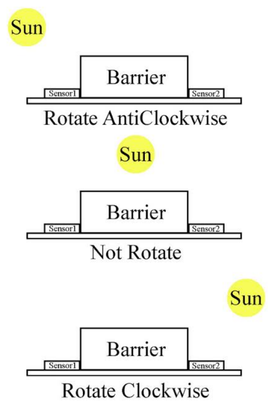

Figure 1.2: Use of 2 LDRs [2]

Concept of using two LDRs for sensing is explained in the figure above. The stable position is when the two LDRs having the same light intensity.When the light source moves, i.e. the sun moves from west to east, the level of intensity falling on both the LDRs changes and this change is calibrated into voltage using voltage dividers. The changes in voltage are compared using built-in comparator of microcontroller and motor is used to rotate the solar panel in a way so as to track the light source.

1.7 Light sensor design

The solar tracker makes use of a Cds photocell for detecting light. There was use of a complementary resistor with a value of 10k. With the resulting configuration, the output voltage will increase with increase in light intensity. The value of the complementary resistor is chosen such that the widest output range is achieved. The photocell resistance is measured under bright light, average light and dark light conditions. The results are listed in the table below.

Table 1.1: Photocell Resistance Testing Data

Measured Resistance	Comment
50 Kilo ohm	Dark light conditions (black vinyl tape placed over cell)
4.35 Kilo ohm	Average light conditions (normal room lighting level)
200 ohm	Bright light conditions (flashlight directly in front of cell)

1.8 DC Motor

The electric motor operated by dc is called dc motor. This is a device that converts DC electrical energy into a mechanical energy.
Structurally and construction wise a direct current motor is exactly similar to a DC generator, but electrically it is just the opposite. Here we unlike a generator we supply electrical energy to the input port and derive mechanical energy from the output port. We can represent it by the block diagram shown below.

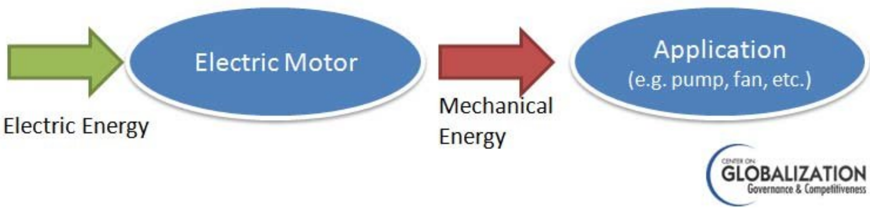

Figure 1.3: Working of DC Motor
[3]

Here in a DC motor, the supply voltage E and current I is given to the electrical port or the input port and we derive the mechanical output i.e. torque τ and speed ω from the mechanical port or output port.
Microcontrollers can't drive the motors directly. So we need some kind of drivers to control the speed and direction of motors. The motor drivers will acts as interfacing devices between microcontrollers and motors. Motor drivers will act as current amplifiers since they take a low current control signal and provide a high current signal. This high current signal is used to drive the motors. Using L293D chip is the easy way for controlling the motor using microcontroller.

1.8.1 Advantages

1. DC Motors gives Increased speed control over a Wide Range. This is not only when it is above the rated speed, but also below the rated speed.

2. DC Motors gives quick control over the motors. Fast and accurate control of motors is required for the immediate start, stop, and reverse operation.

3. DC Motors offer improved speed regulation. DC motors provide much more flexibility in terms of speed regulation when you compare it to AC motors.

4. These are also very convenient for Low Cost operations.

1.8.2 Disadvantages

1. High initial cost.

2. Increased operation and maintenance cost due to presence of commutator and brush gear.

3. Cannot operate in explosive and hazard conditions due to sparking occur at brush .

1.9 Sunlight

Photometry enables us to determine the amount of light given off by the Sun in terms of brightness perceived by the human eye. In photometry, a luminosity function is used for the radiant power at each wavelength to give a different weight to a particular wavelength that models human brightness sensitivity. Photometric measurements began as early as the end of the 18th century resulting in many different units of measurement, some of which cannot even be converted owing to the relative meaning of brightness. However, the luminous flux (or lux) is commonly used and is the measure of the perceived power of light. Its unit, the lumen, is concisely defined as the luminous flux of light produced by a light source that emits one candela of luminous intensity over a solid angle of one steradian. The candela is the SI unit of luminous intensity and it is the power emitted by a light source in a particular direction, weighted by a luminosity function whereas a steradian is the SI unit for a solid angle; the two-dimensional angle in three-dimensional space that an object subtends at a point.

One lux is equivalent to one lumen per square metre:
1 lx = $1 lm \cdot m^{-2}$= 1 $cd \cdot sr \cdot m^{-2}$
i·e· a flux of 10 lumen, concentrated over an area of 1 square metre, lights up that area with illuninance of 10 lux [1].

Sunlight ranges between 400 lux and approximately 130000 lux, as summarized in the table below.

Table 1.2: Range of the brightness of sunlight (lux)

Time of day	Luminous flux (lux)
Sunrise or sunset on a clear day	400
Overcast day	1000
Full day (not direct sun)	10000 – 25000
Direct sunlight	32000 – 130000

1.10 Photovoltaic Cell

A photovoltaic (PV) cell is an energy harvesting technology, that converts solar energy into useful electricity through a process called the photovoltaic effect. There are several different types of PVcells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.

1.10.1 Layers of a PV Cell

A photovoltaic cell is comprised of many layers of materials, each with a specific purpose. The most important layer of a photovoltaic cell is the specially treated semiconductor layer. It is comprised of two distinct layers (p-type and n-type), and is what actually converts the Sun's energy into useful electricity through a process called the photovoltaic effect (see below). On either side of the semiconductor is a layer of conducting material which "collects" the electricity produced. Note that the backside or shaded side of the cell can afford to be completely covered in the conductor, whereas the front or illuminated side must use the conductors sparingly to avoid blocking too much of the Sun's radiation from reaching the semiconductor. The final layer which is applied only to the illuminated side of the cell is the anti-reflection coating. Since all semiconductors are naturally reflective, reflection loss can be significant. The solution is to use one or several layers of an anti-reflection coating (similar to those used for eyeglasses and cameras) to reduce the amount of solar radiation that is reflected off the surface of the cell.
Photovoltaic cell can be manufactured in a variety of ways and from many different materials. The most common material for commercial solar cell construction is Silicon (Si), but others include Gallium Arsenide (GaAs), Cadmium Telluride (CdTe) and Copper Indium Gallium Selenide (CIGS). Solar cells can be constructed from brittle crystalline structures (Si, GaAs) or as flexible thin-film cells (Si, CdTe, CIGS).

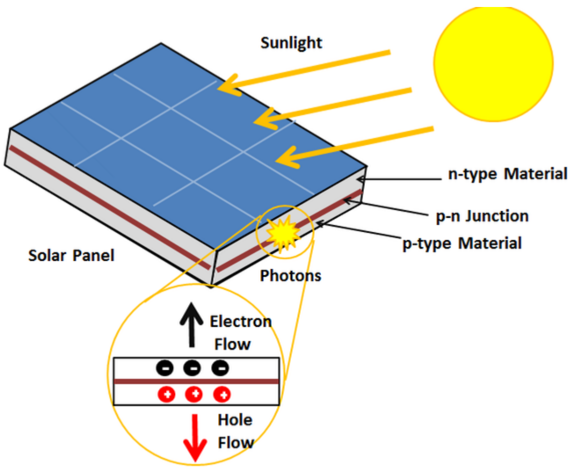

Figure 1.4: Photovoltaic Effect [4]

1.11 Types of solar trackers and tracking technologies

There are various categories of modern solar tracking technologies:

1.11.1 Active tracker

Active trackers make use of motors and gear trains for direction of the tracker as commanded by the controller responding to the solar direction. The position of the sun is monitored throughout the day. When the tracker is subjected to darkness, it either sleeps or stops depending on the design. This is done using sensors that are sensitive to light such as LDRs. Their voltage output is put into a microcontroller that then drives actuators to adjust the position of the solar panel [5]

1.11.2 Passive solar tracking

Passive trackers use a low boiling point compressed gas fluid driven to one side or the other to cause the tracker to move in response to an imbalance. Because it is a non precision orientation it is not suitable for some types of concentrating photovoltaic collectors but works just fine for common PV panel types. These have viscous dampers that prevent excessive motion in response to gusts of wind [5].

1.11.3 Single axis trackers

Single axis trackers have one degree of freedom that act as the axis of rotation. The axis of rotation of single axis trackers is aligned along the meridian of the true North. With advanced tracking algorithms, it is possible to align them in any cardinal direction. Common implementations of single axis trackers include horizontal single axis trackers (HSAT), horizontal single axis tracker with tilted modules (HTSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT) [6].

1.11.4 Dual axis trackers

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to each other. The primary axis is the one that is fixed with respect to the ground. The secondary axis is the one referenced to the primary axis. There are various common implementations of dual trackers. Their classification is based on orientation of their primary axes with respect to the ground.

1.12 Fixed and tracking collectors

Solar energy can be harnessed using either fixed or movable collectors.

1.12.1 Fixed collectors

Fixed collectors are mounted on places that have maximum sunlight and are at relatively good angle in relation to the sun. These include rooftops. The main aim is to expose the panel for maximum hours in a day without the need for tracking technologies. There is therefore a considerable reduction in the cost of maintenance and installation. Most collectors are of the fixed type. When using these collectors, it is important to know the position of the sun at various seasons and times of the year so that there is optimum orientation of the collector when it is being installed. This gives maximum solar energy through the year.
The energy per unit of area for an entire day is:
W= 8.41 kWh/m^2 day

1.12.2 Tracking collectors: Improvement of efficiency

For tracking collectors, theoretical extracted energy is calculated assuming that maximum radiation intensity I=1100W/m^2 is falling on the area that is perpendicularly oriented to the direction of radiation. There is comparison of intensity on the tracking collector and the fixed one. More energy is gotten from the tracking collector than the fixed one.
The energy per unit of area for an entire day is:
W= 13.2kWh/m^2 day

Comparing the theoretical results for the two cases, more energy is obtained from the second case, for the tracking collector. However, as the rays of the sun travel towards the earth, they go through the thick layers of the atmosphere in both of the cases. That notwithstanding, the tracking collector has more exposure to the sun's energy at any given time.

1.13 Efficiency of solar panels

The efficiency is the parameter most commonly used to compare performance of one solar cells to another. It is the ratio of energy output from the solar panel to input energy from the sun. in addition to reflecting on the performance of solar cells, it will depend on the spectrum and intensity of the incident sunlight and the temperature of the solar cell. As a result, conditions under which efficiency is to be measured must be controlled carefully to compare performance of the various devices.
The efficiency of solar cells is determined as the fraction of incident power that is converted to electricity. It is defined as:

$$Pmax = VocIscFF \tag{1.1}$$

$$\eta = Pmax/Pin \tag{1.2}$$

where Voc is the open-circuit voltage,
Isc is the short-circuit current ,
FF is the fill factor
η is the efficiency.
The input power for efficiency calculations is 1 kW/m^2 or 100 mW/cm^2. Thus the input power for a 100×100 mm^2 cell is 10 W.

Project report organization

The project is divided into 4 chapters:

Chapter 1: This is the introduction to the project report that describes the justification for doing the project. The objectives of the work are also described.
Chapter 2: The chapter also includes material studied and which is pertinent to the study.
Chapter 3: The chapter involves the design and implementation of the project.
Chapter 4: This chapter has the discussion, conclusion and recommendations for further work with regard to this project.

Chapter 2

Software And Tools Used

2.1 Microprocessor

Microprocessor is a controlling unit of a micro-computer, fabricated on a small chip capable of performing ALU (Arithmetic Logical Unit) operations and communicating with the other devices connected to it.

Microprocessor consists of an ALU, register array, and a control unit. ALU performs arithmetical and logical operations on the data received from the memory or an input device. Register array consists of registers identified by letters like B, C, D, E, H, L and accumulator. The control unit controls the flow of data and instructions within the computer.

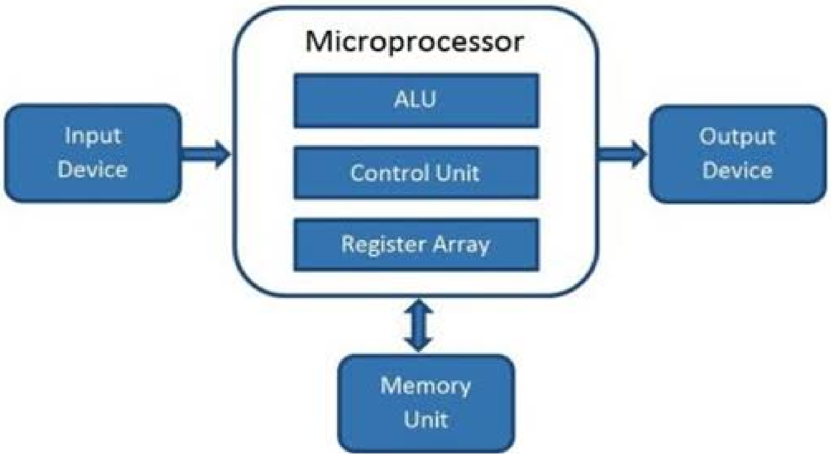

Figure 2.1: Microprocessor Architecture [1]

2.1.1 Raspberry PI

A Raspberry runs an OS, there are quite a few ported already. It has ethernet, USB host, HDMI out, micro USB, an SD card slot and GPIO's. It is a complete computer, connect a keyboard mouse and monitor, use an SD card with Raspbian or another OS and you boot a computer, not so powerful as the Intel and AMD desktops but still. It is used as a media center, streaming video, or to surf the web, as VPN server, NAS or to edit documents. The core of the raspberry pi is an ARM microprocessor. The latest raspberry pi is based on the ARM Cortex-A53, it is a complicated controller, hence we call it a microprocessor.
Raspberry Pi is neither a microprocessor or microcontroller , it is a single board computer which contains a SOC (System On Chip - Has multicore processor,GPU,ROM,I/O Peripherals inside it.),DDR RAM memory, Ethernet port, USB host,micro HDMI on it.

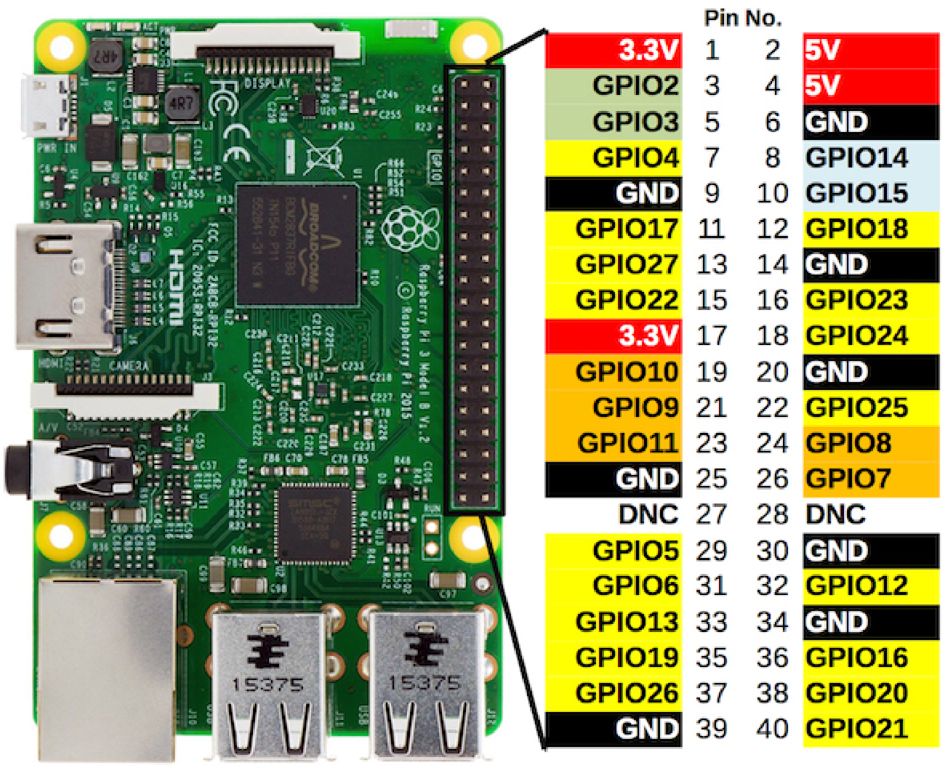

Figure 2.2: Raspberry Pi Pin Diagram [7]

2.2 The design tool

2.2.1 Raspbian software

Raspbian is a Debian-based computer operating system for Raspberry Pi. There are several versions of Raspbian including Raspbian Buster and Raspbian Stretch. Since 2015 it has been officially provided by the Raspberry Pi Foundation as the primary operating system for the family of Raspberry Pi single-board computers.

The operating system is still under active development. Raspbian is highly optimized for the Raspberry Pi line's low-performance ARM CPUs.

Raspbian uses PIXEL, Pi Improved X-Window Environment, Lightweight as its main desktop environment as of the latest update. It is composed of a modified LXDE desktop environment and the Openbox stacking window manager with a new theme and few other changes.

2.2.2 Python

Like shell scripts, Python can automate tasks like batch renaming and moving large amounts of files. It can be used just like a command line with IDLE, Python's REPL (read, eval, print, loop) function. However, there are more useful things you can do with Python. For example, you can use Python to program things like:

- Web applications
- Desktop applications and utilities
- Special GUIs
- Small database
- 2D games

Python also has a large collection of libraries, which speeds up the development process. There are libraries for everything you can think of – game programming, rendering graphics, GUI interfaces, web frameworks, and scientific computing. Many (but not all) of the things you can do in C can be done in Python. Python is generally slower at computations than C, but its ease of use makes Python an ideal language for prototyping programs and designing applications that aren't computationally intensive.

Chapter 3

Project Implementation And Description

3.1 Methodology

The circuit of the solar tracker system is divided into three sections. There is the input stage that is composed of sensors and potentiometers, a program in embedded software in the microcontroller and lastly the driving circuit that has the DC motor. The input stage has two LDRs that are so arranged to form a voltage divider circuit. A Python program loaded into the Raspberry Pi 3B+ forms the embedded software. There is a metallic frame that houses the components. The three stages are designed independently before being joined into one system. This approach, similar to stepwise refinement in modular programming, has been employed as it ensures an accurate and logical approach which is straight forward and easy to understand. This also ensures that if there are any errors, they are independently considered and corrected.

3.2 Flow Chart

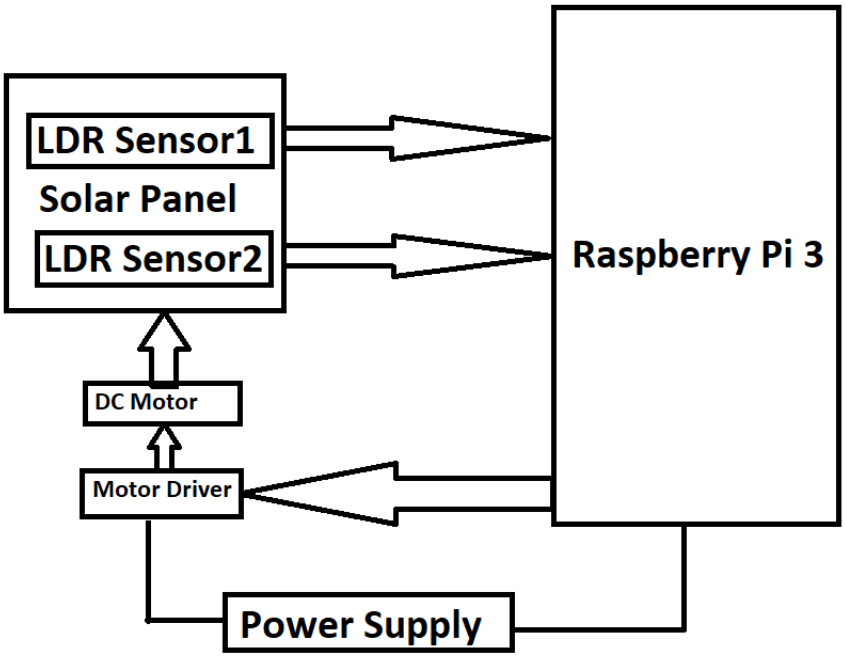

Figure 3.1: Flow Chart

3.3 Algorithm for Motor Control

The algorithm gives the description of the general steps undertaken for the project:

1. There is input of the voltages from the two LDRs.
2. The inputs are taken as analog.
3. The two values are compared and the difference between them obtained.
4. The motor rotates in the direction whose ldr value lesser.

5. If the LDR voltages are the same, the motor stops. Otherwise, the motor rotates until the difference is the same.

The inputs into the system are the two LDR voltages into pins 23 and 24 of the Raspberry pi.The larger of the two signals is sent to the circuit which drives the DC motor to the direction with more light intensity. This has the python code loaded into the raspberry pi that do all the work. The code that was used is shown at the appendix of the report.

3.3.1 Taking Analog Values from the LDR

Unlike some other devices the Raspberry Pi does not have any analogue inputs. All 17 of its GPIO pins are digital. They can output high and low levels or read high and low levels.

It uses a basic "RC" charging circuit which is often used as an introduction to electronics. In this circuit you place a Resistor in series with a Capacitor. When a voltage is applied across these components the voltage across the capacitor rises. The time it takes for the voltage to reach 63% of the maximum is equal to the resistance multiplied by the capacitance. When using a Light Dependent resistor this time will be proportional to the light level. This time is called the time constant :

$$t = RC \tag{3.1}$$

where t is time,
R is resistance (ohms)
and C is capacitance (farads)

So the logic is to time how long it takes a point in the circuit the reach a voltage that is great enough to register as a "High" on a GPIO pin. This voltage is approximatey 2 volts, which is close enough to 63% of 3.3V.

Steps To Be Followed:

• Set the GPIO pin as an output and set it Low. This discharges any charge in the capacitor and ensures that both sides of the capacitor are 0V.
• Set the GPIO pin as an input. This starts a flow of current through the capacitor to ground. The voltage across the capacitor starts to rise. The time it takes is proportional to the resistance of the LDR.
• Monitor the GPIO pin and read its value. Increment a counter while we

wait.
• At some point the capacitor voltage will increase enough to be considered as a High by the GPIO pin.
• Set the GPIO pin as an output and repeat the process as required.

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Appendix A

Setting The GPIO Pins

```
import RPi.GPIO as GPIO

from time import sleep

GPIO.setmode(GPIO.BCM)

value1 = 0
value2 = 0
ldr1 = 17
ldr2=18

def rc_t1(ldr1):
count1 = 0

#Output on the pin for
GPIO.setup(ldr1, GPIO.OUT)
GPIO.output(ldr1, False)
sleep(0.1)

#Change the pin back to input
GPIO.setup(ldr1, GPIO.IN)

#Count until the pin goes high
while (GPIO.input(ldr1) == 0):
count1 += 1

return count1
```

```
def rc_t2(ldr2):
count2 = 0

#Output on the pin for
GPIO.setup(ldr2, GPIO.OUT)
GPIO.output(ldr2, False)
sleep(0.1)

#Change the pin back to input
GPIO.setup(ldr2, GPIO.IN)

#Count until the pin goes high
while (GPIO.input(ldr2) == 0):
count2 += 1

return count2
```

Appendix B

Forward Run

```
def fwd_run():
in1 = 24
in2 = 23
en = 25

    GPIO.setup(in1,GPIO.OUT)
GPIO.setup(in2,GPIO.OUT)
GPIO.setup(en,GPIO.OUT)

    GPIO.output(in1,GPIO.LOW)
GPIO.output(in2,GPIO.LOW)

    a=GPIO.PWM(24,100)
a.start(0)
b=GPIO.PWM(23,100)
b.start(0)

    print("Forward")
a.ChangeDutyCycle(100)

    GPIO.output(en,GPIO.HIGH)

    sleep(1.2)
a.stop(0)
```

Appendix C

Backward Run

```
def back_run():
in1 = 24
in2 = 23
en = 25

    GPIO.setup(in1,GPIO.OUT)
GPIO.setup(in2,GPIO.OUT)
GPIO.setup(en,GPIO.OUT)

    GPIO.output(in1,GPIO.LOW)
GPIO.output(in2,GPIO.LOW)

    a=GPIO.PWM(24,100)
a.start(0)
b=GPIO.PWM(23,100)
b.start(0)

    print("Backward")
b.ChangeDutyCycle(100)

    GPIO.output(en,GPIO.HIGH)

    sleep(1.2)
b.stop(0)
```

Appendix D

Moving the Panel

```
try:
while True:
value1 = rc_t1(ldr1)
value2 = rc_t2(ldr2)
if (abs( value1-value2 )<=60):
print("no move")
print(value1)
print(value2)

    elif ( (value1-value2)>=100):
back_run()
elif ( (value2-value1)>=100):
fwd_run()

    except KeyboardInterrupt:
pass
finally:
GPIO.cleanup()
```