Recent Developments in Real Time Clock Based Multilevel Sun Tracking Solar Panel System

A Thesis Submitted to the

Department of Electrical & Electronic Engineering of BRAC University

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DECLARATION

We do hereby declare that the thesis titled —"Real time clocked based multilevel solar system"submitted to the Department of Electrical and Electronic Engineering of BRAC University in fulfillment of the Bachelor of Science in Electrical and Electronic Engineering, is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

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ABSTRACT

Solar energy has been considered as a feasible source of renewable energy over the past few decades as it has been and is still being used to power up our industrial and domestic applications and gain desired national production. Bangladesh, like some other third world countries, demand of energy is higher than the production met by the power sector, even after considering only 70% of the population who are hitherto under electricity coverage of national grid. The result of this shortage is load-shedding, and the people of urban areas suffer the most from it because of their dependency on electricity for daily activities. Although solar energy can be used to reduce the energy crisis of Bangladesh, the limited space for setting enough photovoltaic (PV) panels to meet the demand of city dwellers emerges as a constraint in implementing solar energy system in densely populated urban areas. A modified structure equipped with a rotating and sliding mechanism holding three solar panel has already been implemented. The panels are stacked one above another in a rack to minimize floor area, and track the sun using sun tracking system to maximize power generation. Now, the thesis will focus on collecting data using an automated data logger and verify the claims of the proposed system by analyzing those data. Also we include multilayer reflector to enhance the output power. The reflector is equipped with actuator to measure the right angles depending on the latitude and longitude depending on the seasons and locations. We hereby compare the reflector taken data. The implementation has been done by constructing a physical structure equipped with servo motors controlled by microcontroller to rotate the panels on a horizontal axis. The panels are supported by a metal rod fixed at a tilted angle equal to the latitude among north-south direction facing south (23°). The panels rotate throughout the day from sunrise to sunset through servo motors controlled by microcontroller. It allows rotation of the three panels on a fixed horizontal axis to track the sun at hourly intervals and maximize power generation. The entire position of the three panels is changed by the actuator after midday when the sun moves from east to west. The microcontroller determines the appropriate position of maximum power absorption for a particular time using a real time clock and a set of equations. The data of current and voltages of each panel will be collected using a data logger device developed for this purpose. The collected data will then be analyzed, which will show a high level of conformity to the theoretically calculated values. The projected system will give a worthwhile solution to electricity problems in urban areas where space is inadequate.

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Thesis organization:

The thesis is based on recent developments on real time based multilevel solar panel system. The report is categorized in six different sections.

Chapter 1 composes of introduction and basic overview about the thesis. **Chapter 2** describes the overall system description as well as the reflector design and implementation. **Chapter 3** composes of experimental setup where the system implementation and mechanical construction of the solar system. **Chapter 4** describes the result and calculations of the data which has been taken on different time on different aspects. **Chapter 5** shows the algorithm that is used to run the system as it needs to run from dawn to dusk being in the sunlight. At last **Chapter 6** composes of future optimization of the reflector and the system as well as the conclusion within it. Moreover we have the code in appendix section.

CHAPTER 1

Introduction

1.1 Motivation:

Solar power is energy from the sun that is converted into thermal or electrical energy. Solar energy is the cleanest and most abundant renewable energy source available around the world. Modern technology can harness this energy for a variety of uses, including generating electricity, providing light or comfortable interior environment as well as heating water for domestic, commercial or industrial use. In rural Bangladesh, especially the coastal southwest, it is common to see tiny solar panels embedded even in humble thatch-roofed huts. This is mostly the work of Infrastructure Development Company Limited, a government-backed Bangladeshi energy and infrastructure group that claims more than 90 percent of the country’s booming home solar market. Since 2003, IDcol has installed solar panels in 3.95 million off –grid homes, reaching 18 million people. In terms of individual units served Bangladesh has become one of the world’s largest markets for home solar systems. Solar energy is considered to play an instrumental role in the infrastructure of a country as a distributing source. Country like Bangladesh which has added several natural grids to the national power grids but still that is not enough. In 2015, despite the requirement of 10000 MW on an average, the installed capacity has reached to 12071 MW of which only 75% is available. In addition to this solar energy has become a lifeline for low income Bangladeshis, a great many of whom the grid does not reach. Although its big cities seem bright and bustling, just 25 percent of the population of 160 million has reliable electricity. The position of Bangladesh is between 20.30 - 26.38 degrees north and 88.04 - 92.44 degrees east which indicates an ideal location for solar energy consumption and also the availability of maximum radiation in summer is 4 to 6.5 KWh per square meter. Therefore our climate conditions and the geographical position are very favorable for solar power installation and testingour system efficiently.

1.2 Project outline:

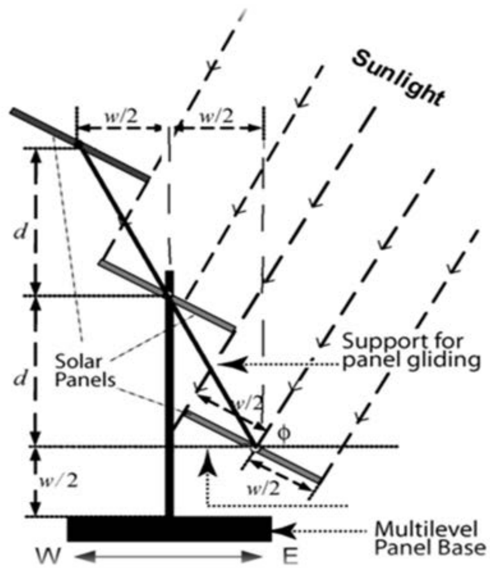


Fig. 1.1: 2-D Physical structure of the rack of solar panels

The system of this project is constructed in such a way that axiomatically converts solar energy while tracking sun from sunrise to sunset. Each of the three panels consists of a servo motor that is controlled by the microcontroller in the Arduino. In our system, we have used both Arduino Mega and Arduino Uno microcontroller boards. Arduino Uno is based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The Arduino Mega board is based on the ATmega1280. It has 54 digital input/output (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.Pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. A simple side view of the proposed system is depicted in figure 1 where three identical panels are supported by a bar with a mechanism so that the panels can rotate on a horizontal axis. This bar along with the panels is mounted on another vertical bar fixed to a base in such a way that the former bar can rotate around a certain pivot. In order to maximize the average solar irradiance on the panels further throughout the year, the panels are tilted by an angle equal to the latitude along north-south direction facing south. Here also used mini maestro software which gives power to the servo motors and also the panels can be fixed to different positions and angles by it. Maestro also helps to achieve the consistent acceleration throughout operation and the code is set such a way that servo motors will run smoothly. The servo motors give updated information of existing position of the panels and hence we can compute the states. Once the system starts it automatically detects the sunlight and panels moves accordingly to get maximum output, and when the sun rises the gliding bar will come into the initial position by the actuator and the panels will be inverted.

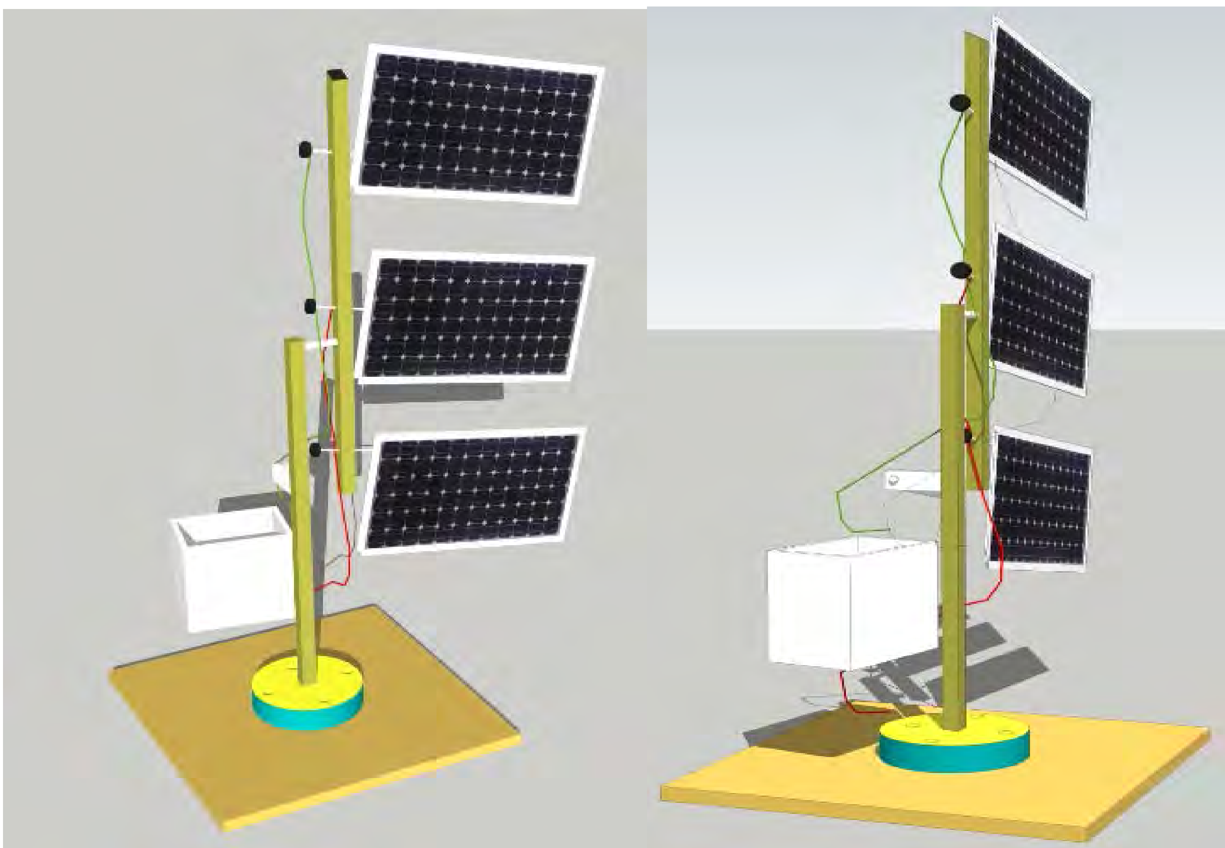


Fig 1.2: 3D design of the multi-layer panel.

At morning the panels will be in east direction where distance between top and middle panel is equivalent to the width of a panel. Hence the gliding bar will create an angle of 67.5 degree. Soon the system starts the panels need to change their position as time flows. So the top panel moves to east and bottom panel moves to west direction by the actuator so that the panels can get maximum sunlight. There has to maintain a certain angle to rotate the panels so that no shadow can fall on the panels as well as the top and middle panels get their position changed by the actuator and vice versa. The gliding process will allow the top and bottom panels to rotate throughout noon but the middle panel will stay vertically stationary from 1 hour before the midday till 1 hour after the midday so that shading over the bottom panel can be eradicated.

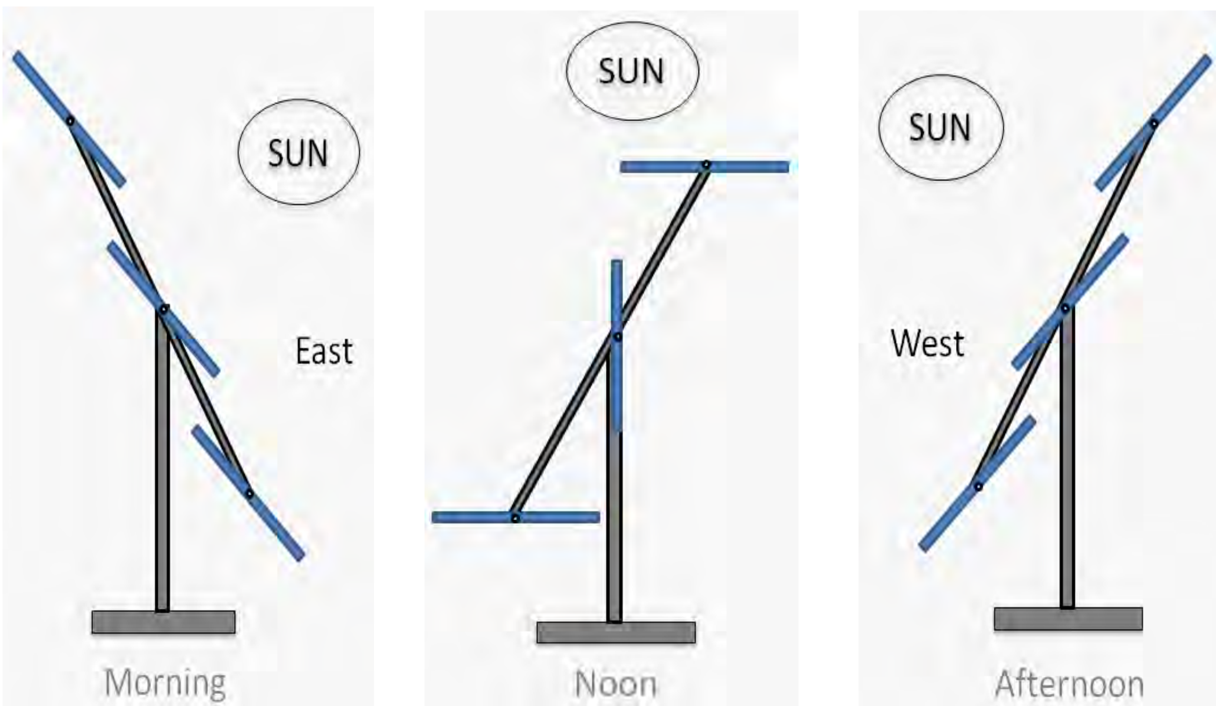


Figure 1.3: Positions of the solar panels throughout different times of the day

Here according to the theory, the consecutive distance between two panels has to be 1.5 times of the width of a panel so that shading over top and bottom panel can be eradicated also this will allow the panels to get maximum exposure. Total height of the system will be (1.5+1.5+0.5) or 3.5 time the panel width.

We hereby use a reflector to enhance the output and we use multilayer reflector for the solar system. The reflector panel is made of aluminum foil paper and the whole body is of stainless steel. The reflector will be placed beside the gliding bar so that maximum sunlight can fall onto the panels. Also the angles can be changed by the actuator so that we will get an advantage to set the dedicated angle for different season depending on the location. Moreover here we use a solar calculator to measure the correct angles of the location and could set the angles so that maximum power can be received.

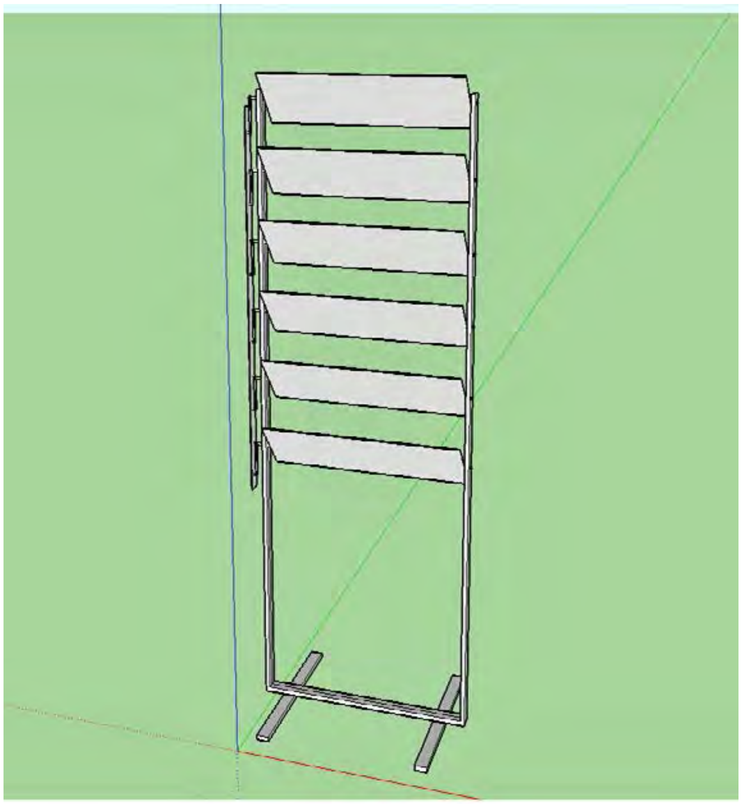


Fig 1.4: 3D design of reflector

In our thesis, we build the reflector to measure the comparison of power and energy between the solar panel with reflector and solar panel without reflector. The reflector has a triangular-square base so that strong wind cannot push it and its placement is necessary since the sunlight falls on the reflector at a measured angle.

1.3 Scope of the project:

As it was already been proposed to construct a prototype multilevel solar panel and it has already been constructed. The next plan is to prove that it is actually efficient and make it more efficient as much as possible. For that we are using the same component that we have used for constructing this solar panel and which includes Arduino, Mini Maestro (motor shield), RTC(Real Time Clock), Relay Break out board, 12V actuator and battery for power supply.

1.4 Project objective:

A developing country like Bangladesh that is facing the shortage of electricity where only 62 percent people are somehow been sheltered under the shade of electricity and in the meantime where there is a big shortage of space. The consumption of energy is growing everyday as the technology is developing day by day. Hence adequate sources of electricity are necessary for ultimate living standard and well-being of a country. At present power generation in Bangladesh is not enough to meet the growing consumers demand. So it is impossible to guarantee an endless supply of electric power to all consumers throughout the country. The sun can deliver us with unlimited solar energy. It is big task and matter of wisdom, that how we can make the efficient use of solar energy. The sun is providing with solar energy every hour in same amount and the entire nation is using that. So we could use this huge amount of resources by employing solar photo-voltaic systems. But the conventional PV modules are less efficient and they require a lot of floor space. A developing country like Bangladesh which is facing the scarcity of electricity where only 62 percent people are somehow been sheltered under the shade of electricity and in the meantime where there is a big shortage of space. It is such a big questions that where and how we can implement the idea of setting a solar panel. So plenty space is a chief issue for establishing solar PV modules in cities where rooftop space is less and that is why our project and paper shows and depicts the way that how we can set up systems built on photovoltaic in a modern and scientific way.

Chapter: 02

System Description

2.1 Introduction

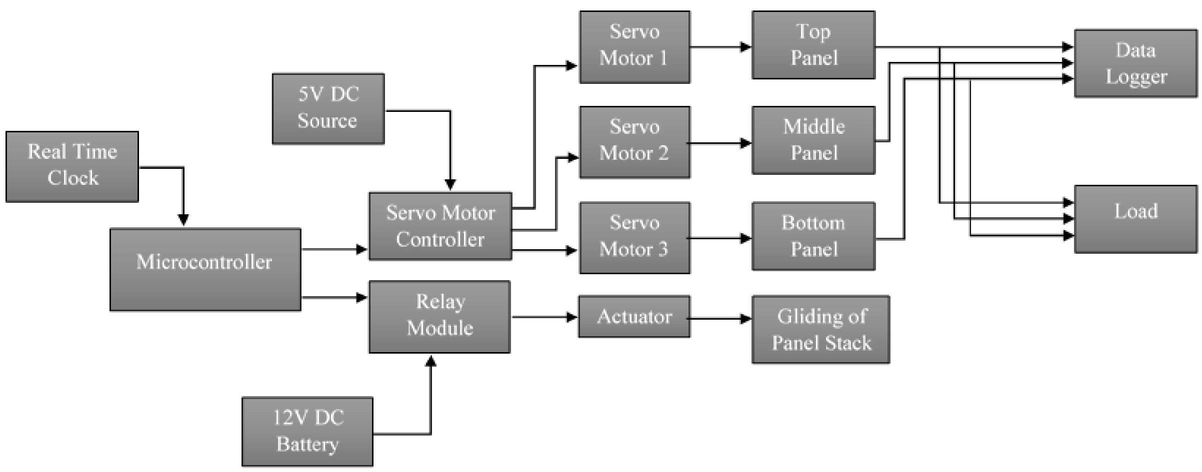


Figure 2.1: Block diagram of the System

The figure shows the block diagram of the overall multilevel solar panel system. In the existing physical system, three solar panels are stacked one above another which moves synchronously along with the direction of the sun. The rotation of the panels and the gliding of the panel stack is controlled by three servo motors and an actuator respectively. The servos and the actuator is controlled by a control unit consisting of a real time clock governing all the steps synchronously with time.All the electrical energy generated by the solar panels are accumulated in a battery from where load can draw the required power. The current and voltage generated by the panels are passed through voltage and current sensors of a data logger designed to record the values in a memory card.

A multi-layered reflector panel is also constructed to reflect back the few passing away sun rays back to the panels and thus increasing the output of the panels.

The prime objective of this paper is to analyze the efficiency of the sun tacking solar panel and also reconstruct and improve the efficiency level of the existing solar panel system.

2.2 Photovoltaic Technology

Solar energy is known to be the most suitable and available renewable energy till this date. Solar panels are used to capture, store and use this energy.

A solar panel is comprised of photovoltaic cells or PV cells. PV acquires its name from the process of converting light (photons) to electricity (voltage), which is known to be photovoltaic effect. The word "photo" means light and the word "voltaic" means producing electricity. So, photo voltaic process means "producing electricity from sunlight" and in this case, the Sun is the source of light. The output power of a solar or photovoltaic cell is dependent on the amount of projected light on it. Factors such as, time of the day, season, position and alignment of the cells affect output power as well.

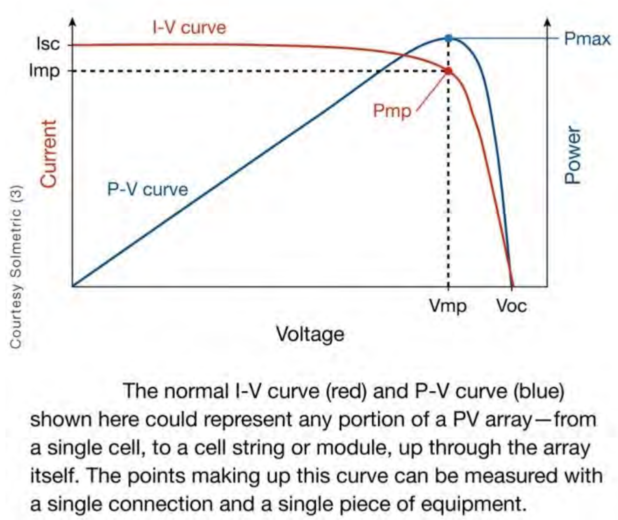


Figure 2.2: I vs. V and P vs. V curve

The figure above shows the relation between Current (I), Voltage (V) and Power (P) of a photovoltaic cells.

2.3 Solar Panel

Solar panels are devices designed to absorb the sun's rays as a source of energy to generate electricity. It is called solar panel because the most powerful source of light available Sun, called Sol by astronomers. Some scientists call them photovoltaic which, basically, means "light-electricity". A solar cell is a form of photoelectric cell which is defined as a device whose electrical characteristics, such as current, voltage or resistance, differ when subjected to light. When a number of photovoltaic cells are connected together, a solar module is formed which will be able to produce electric power from sunlight. A solar panel is a combination of multiple PV cells in one plane. The efficiency of most solar panel varies from 11–15 percent. The efficiency rating denotes what percentage of sunlight striking a panel gets converted into electricity that can be used. The higher the efficiency, the smaller surface area is required in solar panel to produce the desired output electricity. Though the average percentage maybe very small, we can easily fit a typical roof with enough panels to cover energy needs. There are a number of different types of panels with variations in properties among these panels as well. The three most common categories of solar panels are:

1. Mono-crystalline Silicone Solar Cell
2. Polycrystalline Silicone Solar Cell
3. Thin-Film Solar Cells (TFSC) (Amorphous Silicon Solar Cells)

Figure 2.3: (a) Monocrystalline Silicon Solar Cells (b) Polycrystalline Silicon solar cells (c) Thin-Film Solar Cells (TFSC) (Amorphous Silicon Solar Cells)

Monocrystalline solar cells are made out of silicon ingots, which are cylindrical in shape. To optimize performance and lower costs of a single monocrystalline solar cell, four sides are cut out of the cylindrical ingots to make silicon wafers, which is what gives monocrystalline solar panels their characteristic look. Being made out of the highest-grade silicon, monocrystlline solar panels have the highest efficiency and are also space efficient. Although performing the best among other categories of panels, they are the most expensive of all. Since cost efficiency is one of the major issues to be taken to consideration, it does not make it appropriate for the system to be designed.

The first solar panels based on polycrystalline silicon, which is also known as polysilicon (p-Si) was first introduced to the market in 1981. Raw silicon is melted and poured into a square mold, which is cooled and cut into perfectly wafers. The process used to make polycrystalline silicon is simpler and costs very less and also, polycrystalline solar panels tend to have slightly lower heat tolerance than monocrystalline solar panels.

Depositing one or several thin layers of photovoltaic material onto a substrate, such as glass, plastic or metal, is the basic gist of how thin-film solar cells are manufactured. Since the output of electrical power is little, solar cells built using amorphous silicon have usually only been used for small-scale uses, example- calculators. But, new advances have made them more attractive for few large-scale uses too. By using amorphous silicon, mass production is easy but amorphous solar panels are usually not very beneficial for maximum residential sites. These Panels are very low-cost but at the same time, they also need enormous space and the efficiency of amorphous modules to produce sunlight to electricity is half polycrystalline and half mono crystalline .Therefore, this will be not a sensible decision to choose the amorphous silicon.

The current benefits that have been presented in polycrystalline solar panel have made it more preferable in termsof efficiency as we get in monocrystalline panels. Among all advantages, it is the only one that has one special advantage and that is its output is not affected by any sort of shadows. So, for our usage, as we will attempt to use our panels in urban areas like Dhaka city, it is highly advised to use polycrystalline solar panel because of its efficiency.

2.4 Servo Motor-MG 99

Servo motor (or servos) are self-contained electric devices (as shown in Figure 2.4 below) that rotates or drive parts of a machine with great accuracy. A servo is a small device that uses a two wire DC motor, a gear train, a potentiometer, an integrated circuit, and an output shaft. Of the three wires sticking out from the motor casing, one is for power, one is for ground, and one is a control input line. The rating of a servo is 6 volts and delivers 66.7 oz-in. of maximum torque at 70r/min. They are fitted with a servo mechanism for accurate control of angular position. The RC servo motors typically have a rotation limit from 90° to 180°. Few servos do have rotation limit of 360° or more. But servos do not rotate continually. Their rotation is limited in between the fixed angles. Three servo motors are used in our system which consequently rotates the upper, middle and bottom panel as time goes on. The Servo motors are not directly connected to the arduino but to the polulu mini maestro 12. The polulu runs the three servo motors of of system.

Features:

- Voltage: 4.8 – 6.0 Volts
- Torque: 45.8 to 66.7 oz-in (4.8/6.0V)
- Speed : 60 to 70 r/min (4.8/6.0V)
- Rotation: 360°
- Dual Ball Bearing
- 4 Plastic Gears + 1 Metal Gear
- 25T Spline
- Rest point adjustments

Figure 2.4: Servo Motor MG995

Servo controllers have three wires- Brown, Red and Orange. Brown connects to the ground of the Arduino. Red connects to the 5V on the Arduino. Orange connects to the I/O pin on the Arduino,

In this case digital pin 9. Jumper wires are used to connect between the female connectors on the servo cable and Arduino headers.

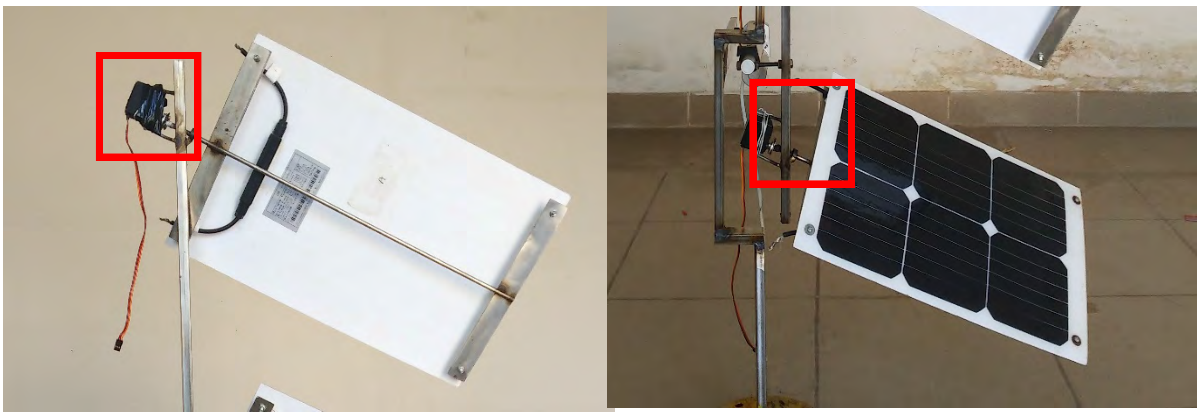


Figure 2.5: Attachment of servo motors to the solar panels in the system

In this planned project servo motors are used to rotate the panel. Sun rises in the east and sets in the west. So our panels will start rotating from east to the west. At the initial period all the panels are oriented and faced towards east, it will then start rotating from east by 15 degree towards west and it will take total 12 steps to complete the whole rotation part.

2.5 Servo Controller (Polulu Mini Maestro)

The Mini Maestros or servo controllers are highly adaptable servo controllers and general-purpose I/O boards. They support three control methods:

1) USB for direct connection to a computer
2) TTL serial for use with embedded systems and

3) Internal scripting for self-contained, host controller-free applications. The channels can be configured as servo outputs for use with radio control (RC) servos or electronic speed controls (ESCs), as digital outputs, or as analog/digital inputs.

A free configuration and control program is available for Windows and Linux, making it simple to configure and test the device over USB, create sequences of servo movements for animatronics or walking robots, and write, step through, and run scripts stored in the servo controller.The Mini Maestros’ 8 KB of internal script memory allows storage of up to approximately 3000 servo positions that can be automatically played back without any computer or external microcontroller connected.

There are number of Pololu’s servo controllers with different number of channels such as:

1. Micro Maestro 6
2. Mini Maestro 12-Channel USB Servo Controller
3. Mini Maestro 18-Channel USB Servo Controller
4. Mini Maestro 24-Channel USB Servo Controller

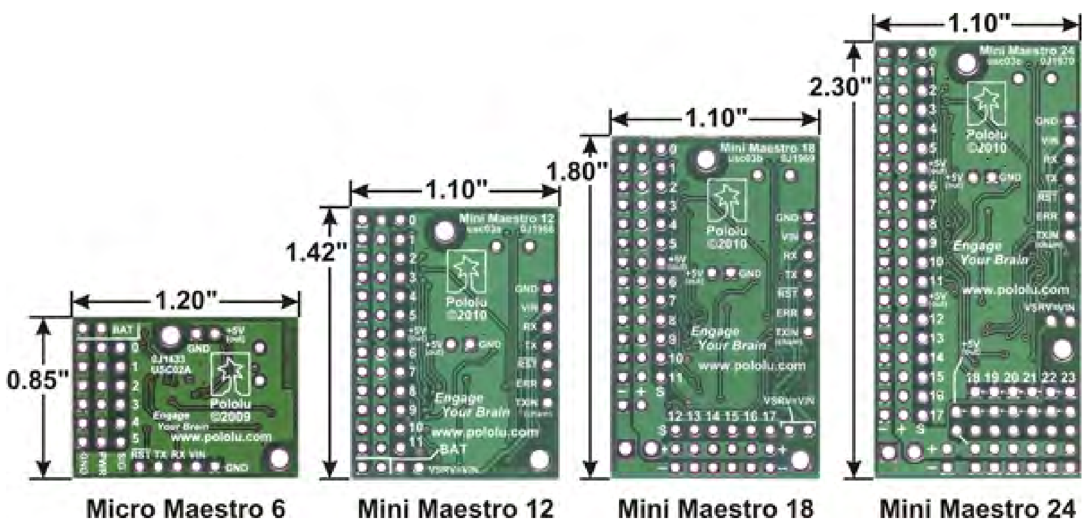


Figure 2.6: Different types of servo controllers of Polulu

For our system, we’ve chosen Mini Maestro 12 Channels USB controller which can run 12 servo motors at once. In our system, there are a total 3 panels and thus three servo motors have been used for the construction. Hence, Mini Maestro has been used. High current flow is to be supplied to run the servo motor which is provided properly by the Mini Maestro. Otherwise, if arduino was used directly with the servo motors, it would damage the servo motors.

Moreover, the usage of Mini Maestro makes the wiring of the system much simple and is much easier to program the code just by putting exact pin numbers in the program of that specific servo motor.

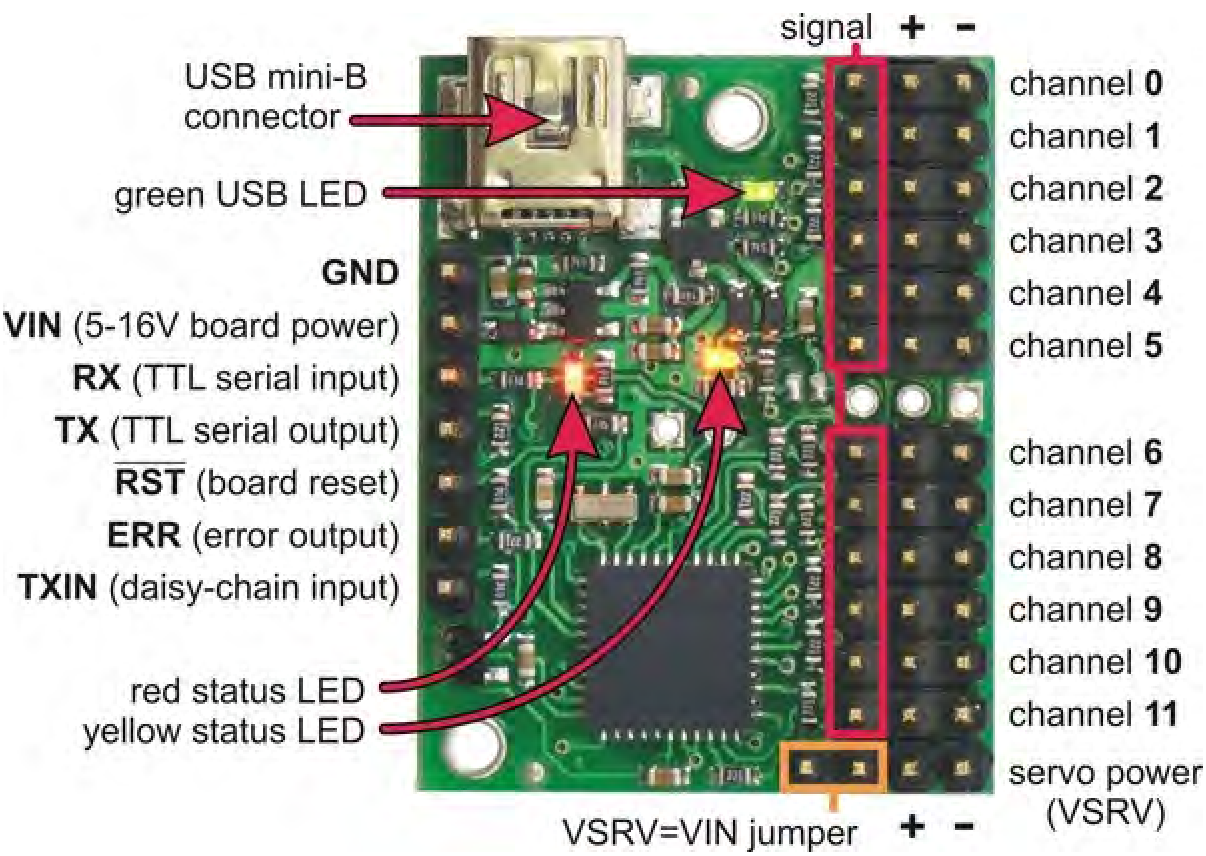


Figure 2.7: Mini Maestro 12-channel USB servo controller (fully assembled) labeled top view

2.6 Arduino

For constructing electronics projects, we use an open-source platform which is known as "Arduino". It can be used to write and upload computer code to the physical board. The board consists of all the components that a miniature microcontroller requires to run. Arduino contains a physical programmable circuit board (often referred to as a microcontroller and a piece of software, or IDE (Integrated Development Environment) that runs on our computer. A very significant feature of the Arduino is the typical way that connectors are all visible, which permits the CPU board to be linked to different interchangeable add-on modules which is termed as shields. Certain shields communicate with the Arduino board directly over several pins, but numerous shields are separately addressable through an I²C serial bus, letting many shields to be arranged and used.

There are generally two types of Arduino for this sort of system:

1. Arduino UNO
2. Arduino MEGA

2.6.1 Arduino UNO

Arduino/GenuinoUNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button.It simply consists of everything required to support the microcontroller. It can be powered by attaching it to a computer using USB cable or by connecting it to an AC-to-DC adapter or by simply connecting it to a DC battery.

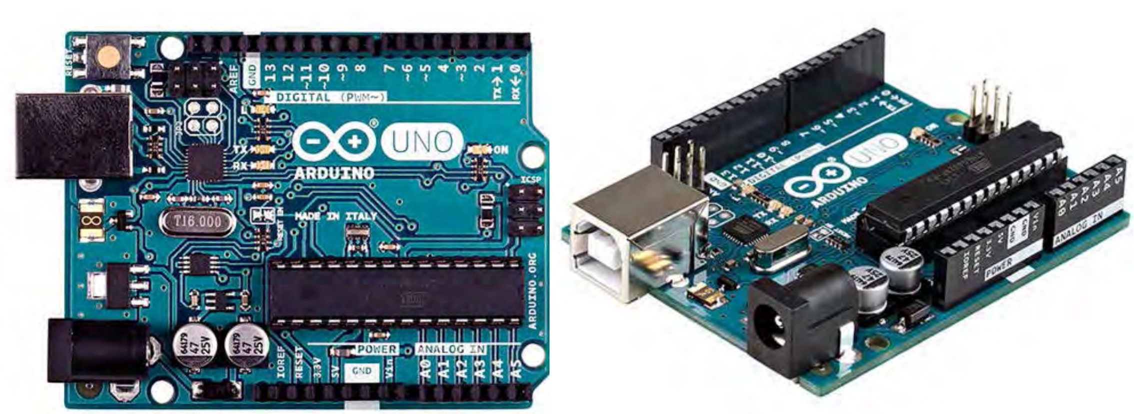


Figure 2.8: Arduino UNO.

2.6.2 Arduino MEGA

The Arduino MEGA is a microcontroller board based on the ATmega1280. It has total 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains each and everything that are needed to support the microcontroller; simply we need to connect it to a computer with a USB cable or attach it with an AC-to-DC adapter or a battery to power it up.

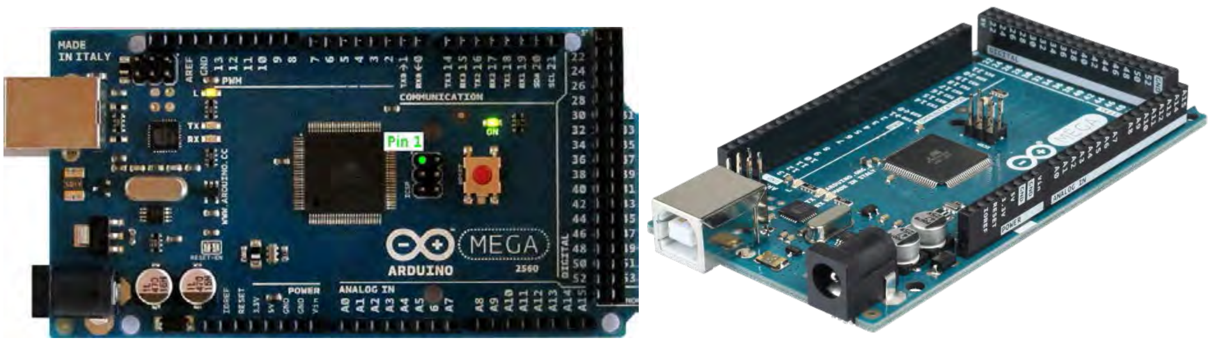


Figure 2.9: Arduino MEGA

Application Ideas:

- LED display / LCD controller
- Pulse width modulation driver
- Robot controller
- Data acquisition systems
- Alarm systems
- Programmable logic controllers
- Embedded web servers
- Control systems

At present, the Arduino hardware platform has the power and reset circuitry setup as well as circuitry to program and transfer data over USB. Moreover, the I/O pins of the microcontroller are already provided out to sockets/headers for very easy access (This can differ a little bit with the particular model). Arduino and 8051 is almost similar. This is because, one is a microcontroller and while the other one is an improvement platform. Arduino runs (quite originally) on Atmel's AVR microcontroller series. The main variations are the major variations in the architecture of the controllers. Thinking from the perspective of user, AVR is richer in peripheral. It consists of in-built ADC and numerous timer based peripherals. It is very easy to program when compared to microcontroller. Thinking from the software side, Arduino does offers numerous libraries making the microcontroller programming easier. The easiest of these are functions to regulate and read the I/O pins rather than having to use the bus/bit masks generally used to interface with the ATmega I/O (This is a slight problem).

More suitable are factors such as being able to set I/O pins to PWM at a particular duty cycle using a single command or performing serial communication. The greatest benefit is to have the hardware platform already set up, especially the circumstance that it permits programming and serial communication over USB. This saves the problem of having to do PCB (which costs more than an Arduino) or bredboarding. The main benefits are the speed as well as ease of development. The open source nature of Arduino has caused the accessibility of various “shields" (i.e. daughter cards) that promote advantages, such as, as Internet access, wireless networking, data logging and device control. Another big benefit is the Arduino IDE which permits software development on every main platform (Mac, PC, and Linux) with an easy-to-use subset of C/C++.

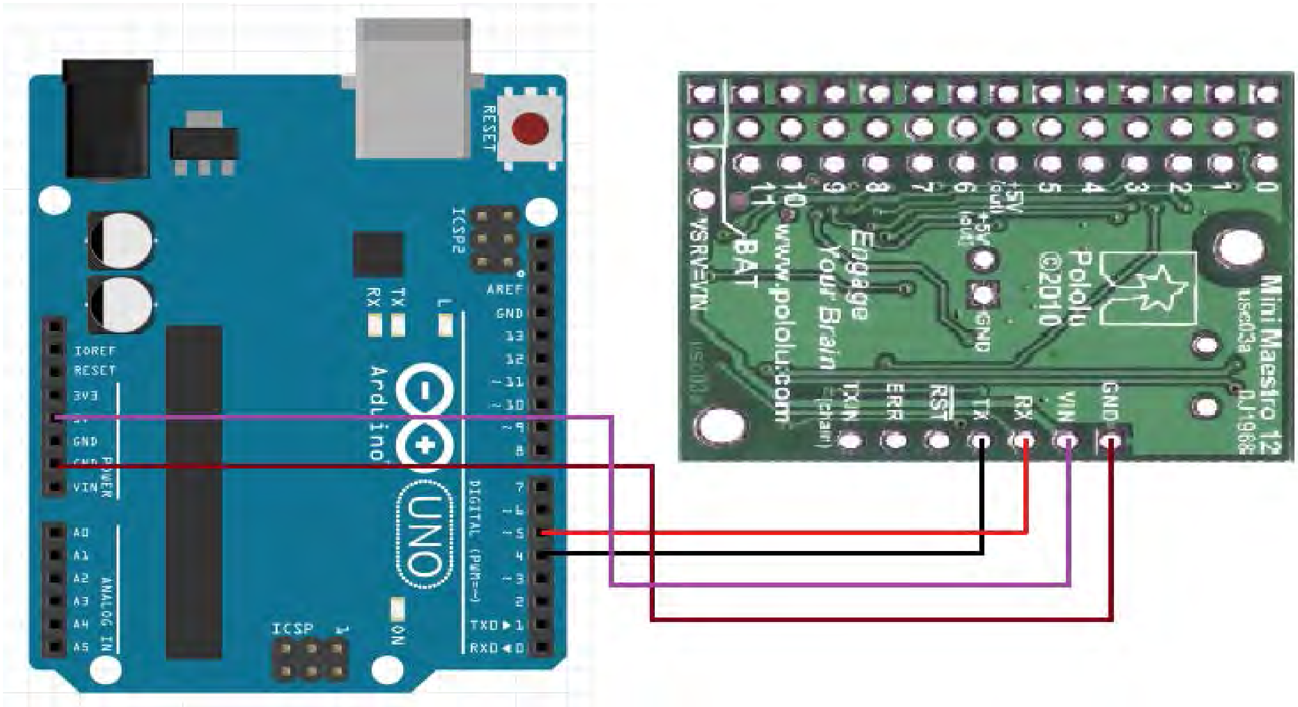


Figure 2.10: Connection of Arduino UNO with Polulu Mini Maestro 12

2.7 Real Time Clock (DS3231)

The component which allows microcontroller to keep track of time even if it is reprogrammed, or its power is disconnected, is known as RTC (Real Time Clock). The RTC is ideal for different purposes, such as-

1. Data logging
2. Clock-building
3. Time stamping
4. Timers
5. Alarms, etc.

The DS3231 is a low-cost, extremely accurate I²C (Inter-Integrated Circuit) real-time clock (RTC) with an integrated temperature-compensated crystal oscillator (TCXO) and crystal. The device incorporates a battery input, and maintains accurate timekeeping when main power to the device is interrupted. The integration of the crystal resonator enhances the long-term accuracy of the device as well as reduces the piece-part count in a manufacturing line. The DS3231 is available in commercial and industrial temperature ranges, and is offered in a 16-pin, 300-mil SO package.

The RTC maintains seconds, minutes, hours, day, date, month, and year information. The date at the end of the month is automatically adjusted for months with fewer than 31 days, including corrections for leap year. The clock operates in either the 24-hour or 12-hour format with an active-low AM/PM indicator. Two programmable time-of-day alarms and a programmable square-wave output are provided. Address and data are transferred serially through an I²C bidirectional bus.

A precision temperature-compensated voltage reference and comparator circuit monitors the status of VCC to detect power failures, to provide a reset output, and to automatically switch to the backup supply when necessary. Additionally, the active-low RST pin is monitored as a pushbutton input for generating a µP reset.

DS3231 has been chosen because of its convenient characteristics compared to its nearest competitor DS1307. While using DS1307, the external temperature can affect the frequency of the oscillator circuit which drives the DS1307's internal counter. This will usually result with the clock being off by around five or so minutes per month. The DS3231 is much more accurate, as it has an internal oscillator which isn't affected by external factors – and thus is accurate down to a few minutes per year at the most.

Key Features:

- Highly Accurate RTC Completely Manages All Timekeeping Functions
    - Real-Time Clock Counts Seconds, Minutes, Hours, Date of the Month, Month, Day of the Week, and Year, with Leap-Year Compensation Valid Up to 2100
    - Accuracy ±2ppm from 0°C to +40°C
    - Accuracy ±3.5ppm from -40°C to +85°C
    - Digital Temp Sensor Output: ±3°C Accuracy
    - Register for Aging Trim
    - Active-Low RST Output/Pushbutton Reset Debounce Input

- Two Time-of-Day Alarms
- Programmable Square-Wave Output Signal

- Simple Serial Interface Connects to Most Microcontrollers
    - Fast (400kHz) I^2C Interface
- Battery-Backup Input for Continuous Timekeeping
    - Low Power Operation Extends Battery-Backup Run Time
    - 3.3V Operation
- Operating Temperature Ranges: Commercial (0°C to +70°C) and Industrial (-40°C to +85°C)
- Underwriters Laboratories® (UL) Recognized

Figure 2.11: DS3231 (RTC)

2.7.1 Wiring RTC up with the Arduino

- SCL pin of DS323 is to be plugged into A5 port of Arduino Uno
- The SDA pin plugs into the A4 port
- The VCC pin plugs into the 5V port of the Arduino
- GND plugs into the GND port

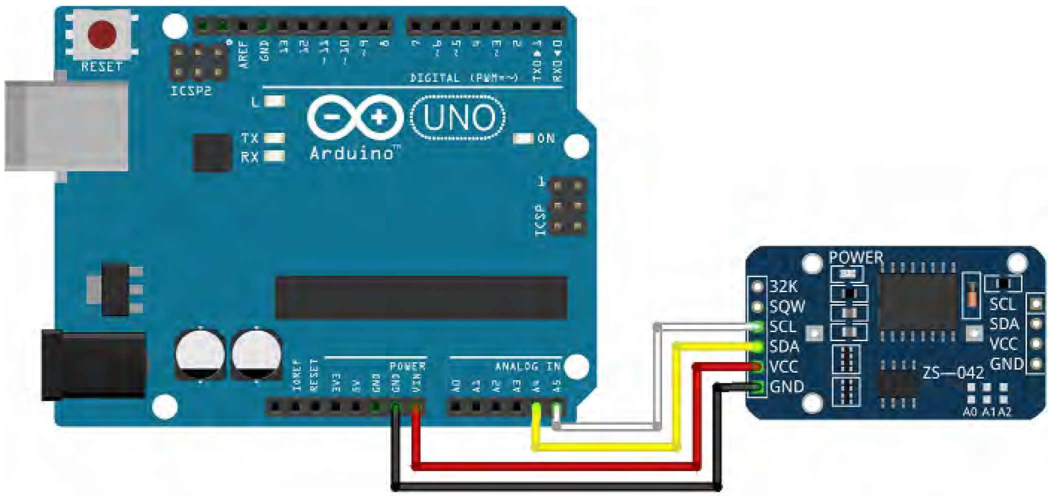


Figure 2.12: RTC DS3231 connectedto Arduino

2.7.2 CR2032 Lithium Battery

Specification of CR2032 battery is given below:

Item	Performance Characteristics
Nominal Voltage	3 V
Nominal Capacity	220 mAh
Continuous Standard Drain	0.2 mA
Diameter	20 mm

Height	3.2 mm
Approx. Weight	2.9 g
Operating temperature	-30 to 60 degree C

2.8 Actuator

An actuator is one type of motor that plays an important role for controlling and moving a structure. It normally functions by the influence of an energy source, for example- electric current, hydraulic fluid pressure, or pneumatic pressure, and converting the input energy into motion. An actuator is the device by which a control system acts depending on the surrounding. The control system can be very simple. It can be software-based, a human, or any other input. There are different categories of actuators .Example- Mechanical actuators, Hydraulic actuators, Pneumatic actuators, Electro-mechanical and Linear motor etc. In our multilevel sun tracking solar panel, we have used linear actuator because of the fact that, motion is created in a straight line in linear actuator, compared to the circular motion of a conventional electric motor.

Advantages and Disadvantages of different types of actuators:

Actuator type	Advantage	Disadvantage

1.	Linear actuator	A linear actuator moves a heap, which can be a gathering, segments, or a completed item, in a straight line. It changes over vitality into a movement or drive and can be fueled by pressurized liquid or air, and in addition power.	Low to medium force.
2.	**Pneumatic Actuators**	Pneumatic actuators create exact straight movement by giving exactness, for instance, inside 0.1 inches and repeatability inside .001 inches.	Pressure losses and air's compressibility make pneumatics less efficient than other linear-motion methods.
3.	**Hydraulic Actuators**	Water driven engines have high pull to-weight proportion by 1 to 2 hp/lb more noteworthy than a pneumatic engine.	Hydraulics will leak fluid. Like pneumatic actuators, loss of fluid leads to less efficiency. Hydraulic actuators require many companion parts, including a fluid reservoir, motors, pumps, release valves, and heat exchangers, along with noise-reduction equipment.
4.	**Electrical Actuators**	Electric actuators can be networked and reprogrammed quickly. They offer immediate feedback for diagnostics and maintenance.	Electrical actuators are not suited for all environments, unlike pneumatic actuators, which are safe in hazardous and flammable areas
5.	Mechanical actuators	Modest, repeatable, no need of force source, independent, comparable conduct developing or withdrawing.	Operated manually. No need of automation.

The principle part of the actuator in our framework is to move our entire framework forward and backward in a day. At first the actuator stays dormant from the morning to the twelve. When it is twelve the actuator gets to be distinctly dynamic and movements the entire framework to simply inverse arrangement contrasted with its underlying position. At first the boards stay in such a position to catch greatest daylight so the actuator operation is not required here. At twelve when the sun is exactly at the highest point of the framework the boards don't get much vitality so the actuator needs to move the framework towards its inverse course to get the full presentation of the daylight to the boards.

Figure 2.13: Actuator used in the system

The actuator in our system will be provided with power from a battery source rather than a power source because the power rating of the actuator is huge which is 12V compared to the power rating of other components used. It is seen that when the actuator is getting power supply from the power source the ongoing check in our framework gets reset. The constant clock gets its energy from a lithium battery and is grounded to a typical point where every one of the parts are grounded. The ongoing clock gets reset since its energy rating is little and when this immense power moves through it constant clock gets reset. At the point when the actuator in dynamic it makes attractive flux around it so the obstruction between the attractive flux and the electric flux additionally reset the continuous clock and this impedance likewise makes issues other hardware of the framework so the whole actuator operation and hardware is isolated from the entire framework.

2.9 Relay Breakout Board

Relays are switches that open and close circuits electromechanically or electronically. Relays control one electrical circuit by opening and closing contacts on other circuits. The relay's switch connections are usually labeled COM (POLE), NC and NO. The operating voltage of relay is 6v.

COM/POLE= Common, NC and NO always connect to this; it is the moving part of the switch.
NC = Normally Closed, COM/POLE is connected to this when the relay coil is not magnetized.

NO = Normally Open, COM/POLE is connected to this when the relay coil is MAGNETIZED and vice versa.

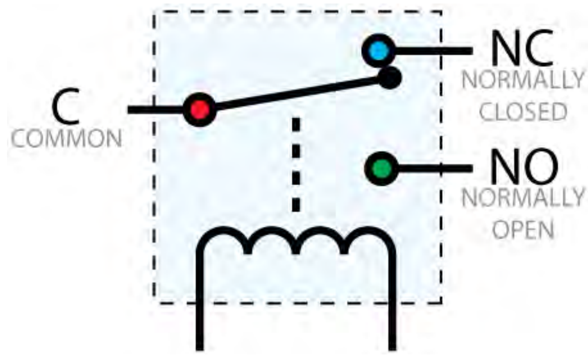


Figure 2.14: Relay and its symbols

There are 5 Pins in a relay. Two sticks A and B are two finishes of a loop that are kept inside the hand-off. The loop is twisted on a little bar that gets charged at whatever point current goes through it.COM/POLE is constantly associated with NC (Normally associated) stick. As present is gone through the curl A, B, the post gets associated with NO (Normally Open) stick of the hand-off. In our framework, we utilized a 2 transfer module.

Figure 2.15: Relay Module

The two relays are used to toggle the positive and negative power to the actuator in order to determine the direction of piston travel. 12V power supply is given to the NC pin and the NO pin is grounded when the actuator is inactive. When NC pin is grounded and NO pin is given 12V the relay switch is pressed and the code reads the current position, and then determines which direction to drive the piston to reach the goal position. Once the goal position is reached, it shuts off the power to the motor.

2.10 Sun Tracker

Solar tracker is a device which follows the *movement of the sun* as it rotates from the east to the west every day. **Solar tracker**s are used to keep solar collectors/solar panels oriented directly towards the sun, as it moves through the sky every day. Using Solar Trackers increases the amount of solar energy which is received by the solar energy collector and improves the energy output of the heat/electricity which is generated. Solar Trackers can *increase the output of solar panels by 20-30%,* which improves the economics of the solar panel project.

2.10.1 Requirement of Sun tracker

Every day, the sun ascends in the east, moves over the sky, and sets in the west. At whatever point the sun is sparkling on us, it is sending vitality toward us. We can feel the warmth from the sun, and we can see questions that are enlightened by the light from the sun as it moves over the sky. However if we use solar trackers it will generate more electricity than their stationary counterparts due to an increased direct exposure to solar rays. If we are located in the tropics, we see that the sun appears to follow a path that is nearly directly overhead. Be that as it may, for areas north or south of the tropics (e.g., scopes more prominent than 23.5 degrees), the sun never achieves a position that is straightforwardly overhead. Rather, it takes after a way over the southern or the northern piece of the sky.

2.10.2 Solar tracker fundamentals

A solar tracker is a device that is used to align a single P.V module or an array of modules with the sun. Although trackers are not a necessary part of a P.V system, their implementation can dramatically improve a systems power output by keeping the sun in focus throughout the day. Efficiency is particularly improved in the morning and afternoon hours where a fixed panel will be facing well away from the sun’s rays. P.V modules are expensive and in most cases the cost of the modules themselves will outweigh the cost of the tracker system. Additionally a well-designed system which utilizes a tracker will need fewer panels due to increased efficiency, resulting in a reduction of initial implementation costs.

2.10.3 Types of tracking

Passive trackers:

Passive trackers use a low boiling point compressed gas fluid that is driven to one side or the other (by solar heat creating gas pressure) to cause the tracker to move in response to an imbalance. As this is a non-precision orientation it is unsuitable for certain types of concentrating photovoltaic collectors, but works fine for common PV panel types.

Active trackers:

Active trackers utilize engines and apparatus trains to coordinate the tracker as summoned by a controller, reacting to the sunlight based bearing. Since the engines devour vitality, one needs to utilize them just as vital.

Open loop trackers:

Open loop trackers determine the position of the sun using computer controlled algorithms or simple timing systems.

Altitude trackers:

Utilize galactic information or sun position calculations to decide the position of the sun for any given time and area. Tracker area, date and time are utilized by a microcontroller to settle the position of the sun. Once the position has been figured, the modules are moved utilizing servo engines and the position is measured by encoders incorporated with the tracker outline. There are many sorts of sun oriented trackers, of fluctuating costs, complexity, and execution.

2.10.4 Types of solar tracker

There are many solar trackers which can be divided among single single and double axis tracker and that is:

Single axis trackers:

Single axis trackers have one degree of freedom that acts as an axis of rotation. The axis of rotation of single axis trackers is typically aligned along a true North meridian. It is possible to align them in any cardinal direction with advanced tracking algorithms. There are several common implementations of single axis trackers. These include horizontal single axis trackers (HSAT), vertical single axis trackers (VSAT), tilted single axis trackers (TSAT) and polar aligned single axis trackers (PSAT).

Horizontal single axis trackers (HSAT):

Single pivot level trackers might be situated by either inactive or dynamic instruments. In these, a long level tube is bolstered on direction mounted upon arches or edges .The pivot of the tube is on a north-south line. Boards are mounted upon the tube, and the tube will pivot on its hub to track the obvious movement of the sun as the day progressed. Since these don't tilt toward the equator they are not particularly viable amid winter late morning (unless situated close to the equator), but include a generous of profitability amid the spring and summer seasons when the sun based way is high in the sky. These gadgets are less successful at higher scopes .The essential favorable position is the intrinsic power of the supporting structure and the effortlessness of the instrument. Since the boards are level, they can be minimalistic ally set on the pivot tube without threat of self-shading and are additionally promptly available for cleaning.

For dynamic instruments, a solitary control and engine might be utilized to impel numerous columns of boards.

Vertical single axis trackers (VSAT):

A single axis tracker may be constructed that pivots only about a vertical axle, with the panels either vertical or at a fixed elevation angle. Such trackers are suitable for high latitudes, where the apparent solar path is not especially high, but which leads to long days in summer, with the sun travelling through a long arc.

Polar single axis trackers:

This method is scientifically well known as the standard method of mounting a telescope support structure. The tilted single axis is aligned to the polar star. It is therefore called a polar aligned single axis tracker (PASAT). In this particular implementation of a tilted single axis tracker, the tilt angle is equal to the site latitude. This aligns the tracker axis of rotation with the earth's axis of rotation.

Tilted single axis trackers:

All trackers with axes of pivot amongst level and vertical are viewed as tilted single hub trackers. Tracker tilt edges are frequently constrained to diminish the wind profile and abatement the hoisted end stature. Field designs must consider shading to dodge superfluous misfortunes and to improve arrive usage. With backtracking, they can be stuffed without shading opposite to their pivot of turn at any thickness. Be that as it may, the pressing parallel to their tomahawks of revolution is restricted by the tilt edge and the scope. Tilted single hub trackers commonly have the substance of the module arranged parallel to the hub of turn. As a module tracks, it clears a barrel that is rotationally symmetric around the pivot of revolution

Dual axis trackers:

Dual axis trackers have two degrees of freedom that act as axes of rotation. These axes are typically normal to one another. The axis that is fixed with respect to the ground can be considered a primary axis. The axis that is referenced to the primary axis can be considered a secondary axis.

Tip-tilt dual axis tracker (TTDAT):

A tip-tilt dual axis tracker has its primary axis horizontal to the ground. The secondary axis is then typically normal to the primary axis. The posts at either end of the primary axis of rotation of a tip-tilt dual axis tracker can be shared between trackers to lower installation costs.

Field layouts with tip-tilt dual axis trackers are very flexible. The simple geometry means that keeping the axes of rotation parallel to one another is all that is required for appropriately positioning the trackers with respect to one another. In addition, with backtracking, they can be packed without shading at any density. The axes of rotation of tip-tilt dual axis trackers are typically aligned either along a true north meridian or an east-west line of latitude. It is possible to align them in any cardinal direction with advanced tracking algorithms.

2.10.5 REFLECTOR

2.10.5.1 Introduction:

A solar reflector is a substance, designed to achieve concentrated reflection factor for solar energy systems. These panels are a great source to generate electricity but sometimes they can be expensive. Here we use sun tracking system to keep solar panel facing towards sunlight to get maximum intensity. The reflector rotates through actuator following the course of the sun and focusing its light on the one point throughout the year. Depending on the seasons, the reflector is configured to the angle of the sun at two levers very simply by hand and also the system is transportable.

The solar panels have several advantages, such as pollution-free during the process of conversion of solar energy into electrical power and low maintenance costs. It is also beneficial since sunlight has the highest power density compared to other renewable energies. However, the price of solar panel device and installation are quite expensive, so it costly for the initial investment.

For those reasons, user needs optimization on solar panel performance to generate electric power as much as possible. The greatest electrical power that can be produced by a solar panel indicates the optimal performance of the solar panels. Increasing solar radiation will also make the power output of solar panels increase. The amount of solar radiation at solar panel can be increased by reflector. It produces reflected light that will be exposed to the solar panel.

2.10.5.2 Background:

Research on the use of reflectors in solar panels has been conducted previously by other researchers. Tabaei and Ameri, for example, investigated that aluminum foil and stainless steel reflectors can increase power output around 8.5%-14% of polycrystalline solar panel (Tabaei, 2012). They hereby claimed that the output radiation can be increased up to 40%. Hereby in our thesis purpose we use the aluminum foil paper to check the increased percentage of radiation, which further results in generating electricity.

Fig 2.16: Solar panel Reflector

Parameters and calculation:

The parameters of solar panel are maximum power output (PMPP), voltage when PMPP is reached (VMPP), current when PMPP is reached (IMPP), short circuit current (ISC), open circuit voltage (VOC), characteristic resistance (RCH).

Equation for I-V curve of the solar cell is

$I=I_L-I_O\ [\exp(\frac{qv}{nKT})-1]$

Where,

IL: light generated current (Ampere)

q: 1.602 × 10-19 Coulomb

I0: dark saturation current (Ampere)

V: voltage (Volt)

I: current (Ampere)

n: ideality factor

T: temperature (Kelvin)

K: Boltzmann's constant

I_{SC} is current when the voltage across the solar cell is zero. ISC, same as IL during the resistance of solar panel, is less than 10 Ωcm2 (Bowden &Honsberg, 2013). V_{OC} is voltage when the current across the solar cell is zero. Equation for VOC is,

$$V_{oc}=\frac{nKT}{q}\ln\left(\frac{I_L}{I_0}+1\right)$$

The short-circuit current and the open-circuit voltage are the maximum current and voltage respectively from a solar cell. However, at both of these operating points, the power from the solar cell is zero.

Equation for the power from the solar cell, *P* is

$$P = I \times V$$

ISC depends linearly on sunlight radiation at solar panel whereas VOC increases logarithmically with sunlight radiation at solar panel level as shown in the equation below (Bowden &Honsberg, 2013).

$$V_{OC}=\frac{nKT}{q}\ln\left(\frac{XI_{SC}}{I_O}\right)=\frac{nKT}{q}\left[\ln\left(\frac{I_{SC}}{I_O}\right)+\ln X\right]=V_{OC}+\frac{nKT}{q}\ln X$$

X is an increase in sunlight radiation at solar panel level. FF is defined as the ratio of the maximum power from the solar cell to the product of VOC and ISC. The FF is illustrated below.

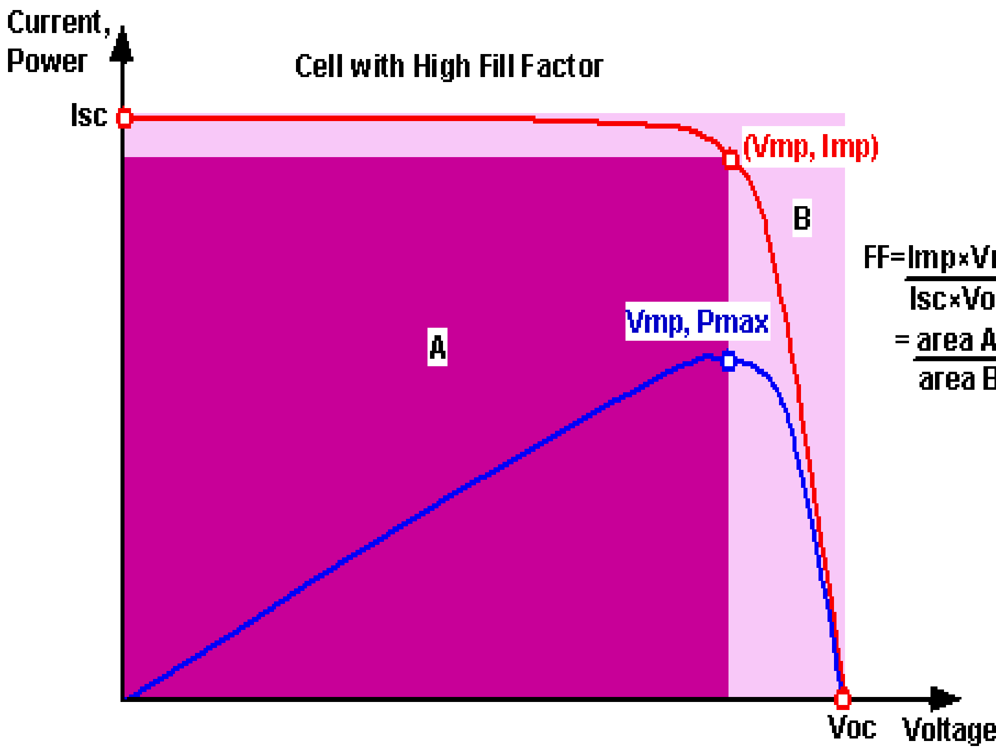


Fig: Fill Factor (Bowden &Honsberg, 2013)

Equation for FF is,

$$FF=\frac{P_{MPP}}{V_{OC}\times I_{SC}}=\frac{V_{MPP}\times I_{MPP}}{V_{OC}\times I_{SC}}$$

R_{CH} is the output resistance of the solar cell at its PMPP. If the resistance of the load is equal to the characteristic resistance of the solar cell, then the PMPP is transferred to the load. It is a useful parameter in solar cell analysis, particularly when examining the impact of parasitic loss mechanisms. The characteristic resistance is shown in the figure below.

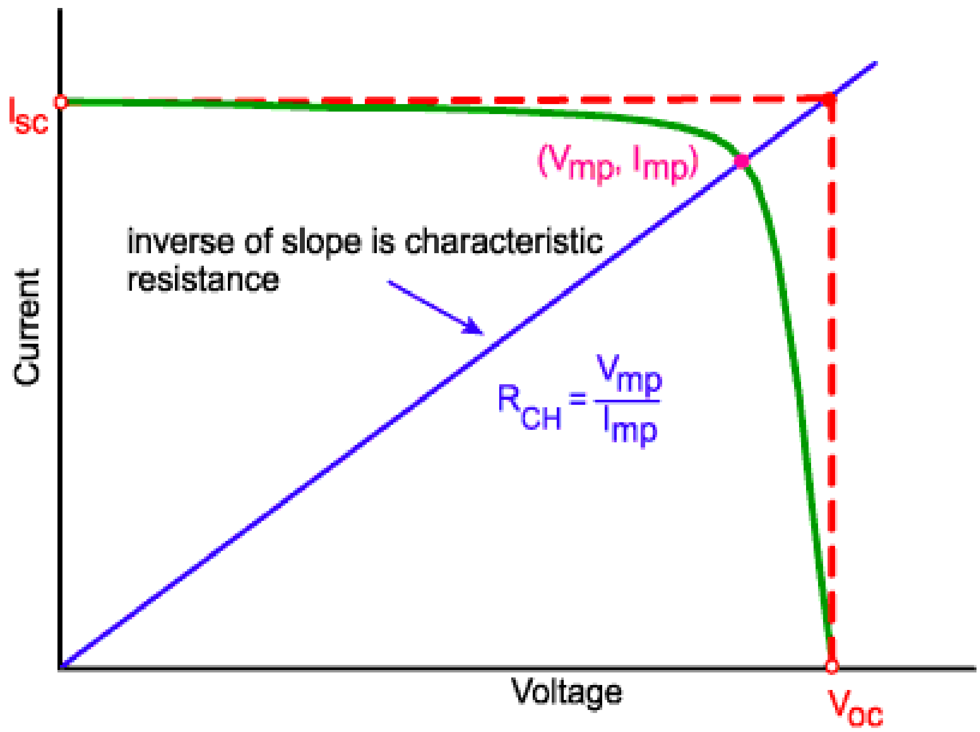


Fig: Characteristic of resistance (Bowden &Honsberg, 2013)

Equation for RCH is,

$$RCH = \frac{V_{MP}}{I_{MP}}$$

Where;

V_{MP} = Maximum peak voltage

I_{MP} = Maximum peak current

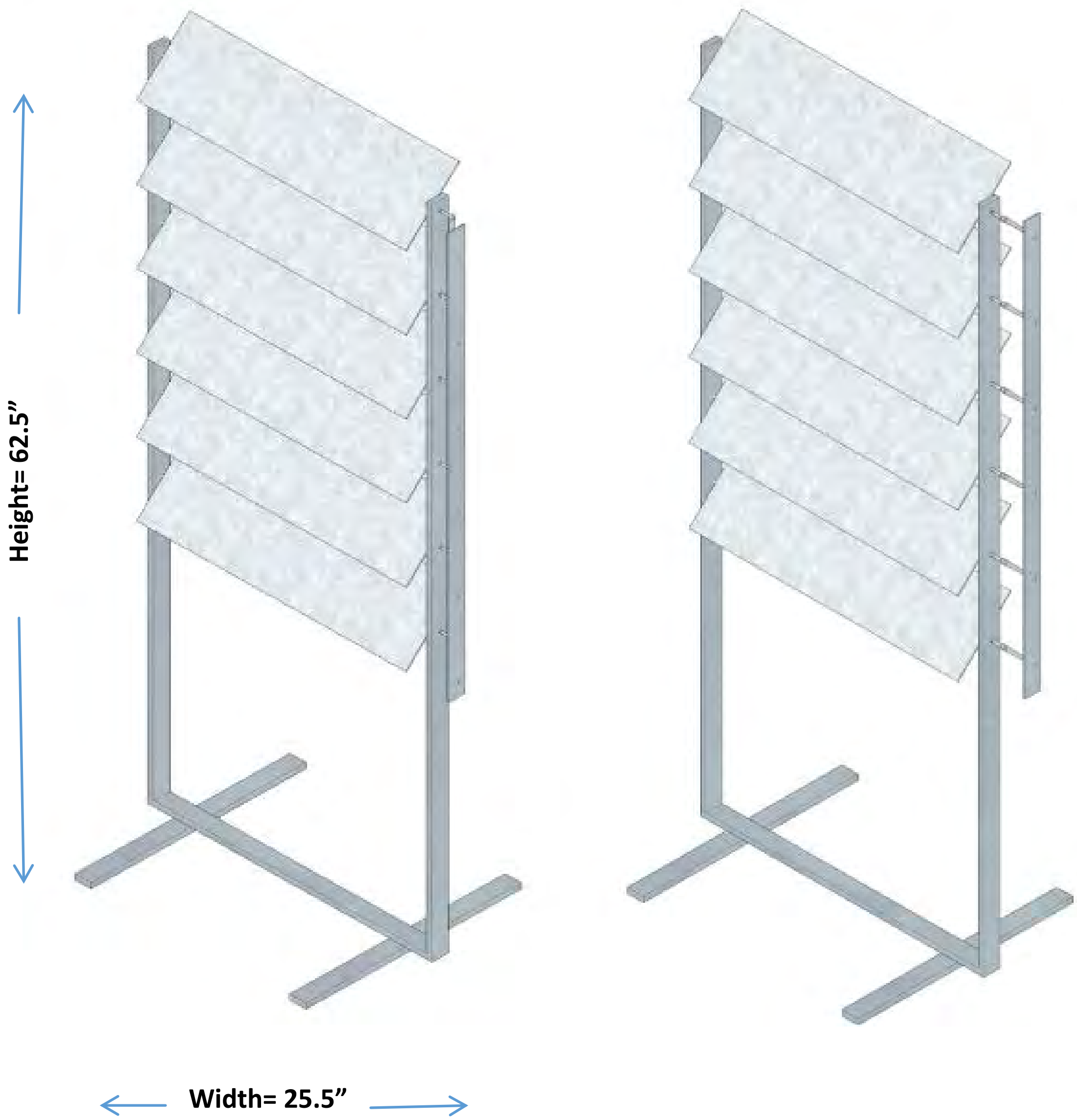


Fig 2.17.1: 3D design of a reflector (Tilt view)

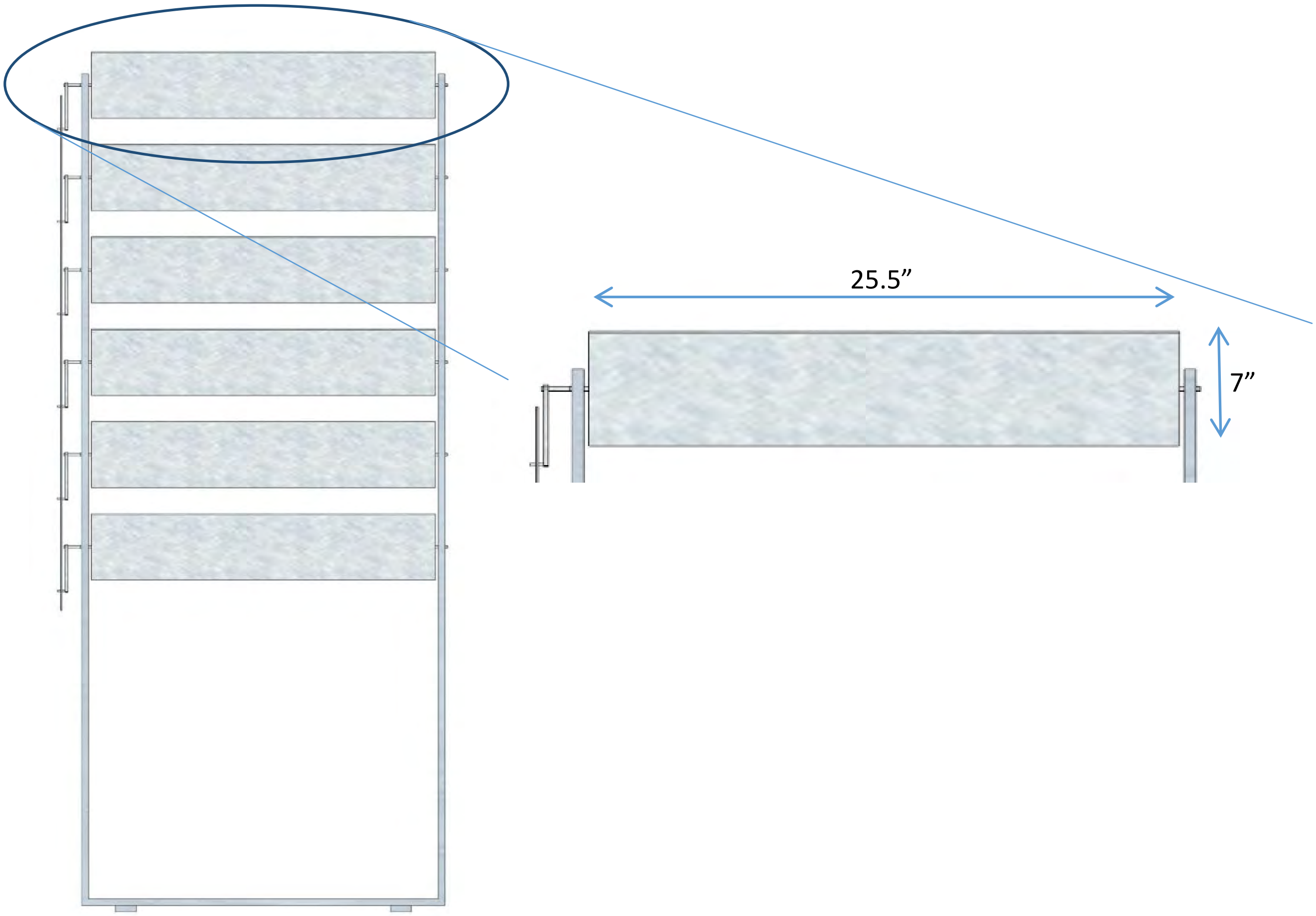


Fig 2.17.2: 3D design of reflector (Front view)

2.10.5.3 Methodology:

In our thesis purpose, we use multilayer reflector for the solar system. The reflector panel is made of aluminum foil paper and the whole body is of stainless steel. Its panel width is 7 inch and length is 25.5 inch. The length of whole system is 62.5 inch and panel gap from one another is 20 cm. it is arranged in such a way that there will be no shadow on the panel and hence it is placed beside the system. The reflector panel therefore can be altered in angles by actuator. Here is the measurement diagram;

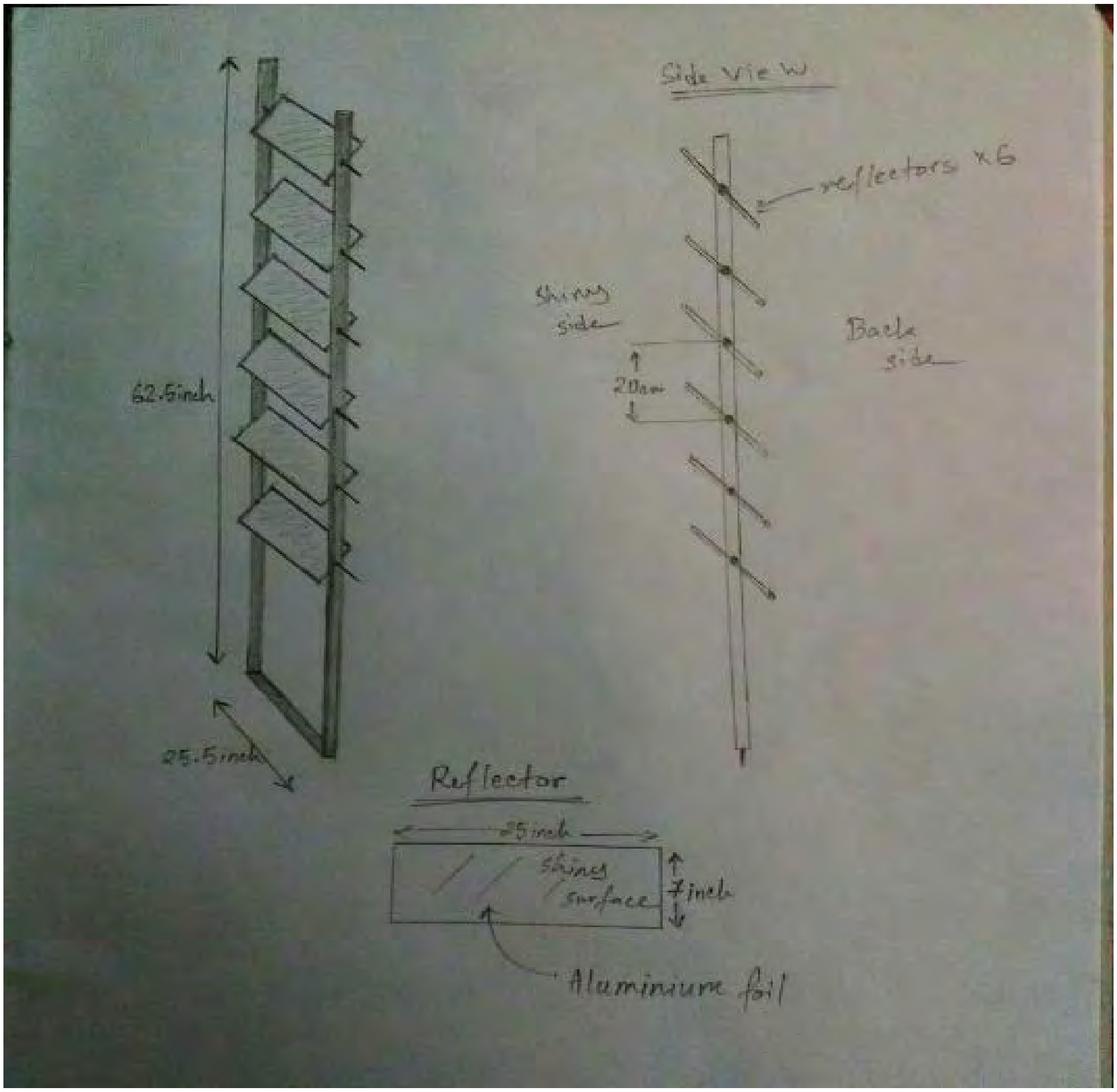


Fig 2.18: Measurement of the reflector

The angles are determined by the location and depending on season as well. In our thesis, we build the reflector to measure the comparison of power and energy between the solar panel with reflector and solar panel without reflector. We hereby place the reflector beside the system to have maximum reflection. The actuator helps to get the necessary and right angle for reflection which is processed by manual input. The angles are determined by solar calculator, it shows the optimum angle for the solar panel. Here is an example of the calculation about how we can measure the optimum angle,

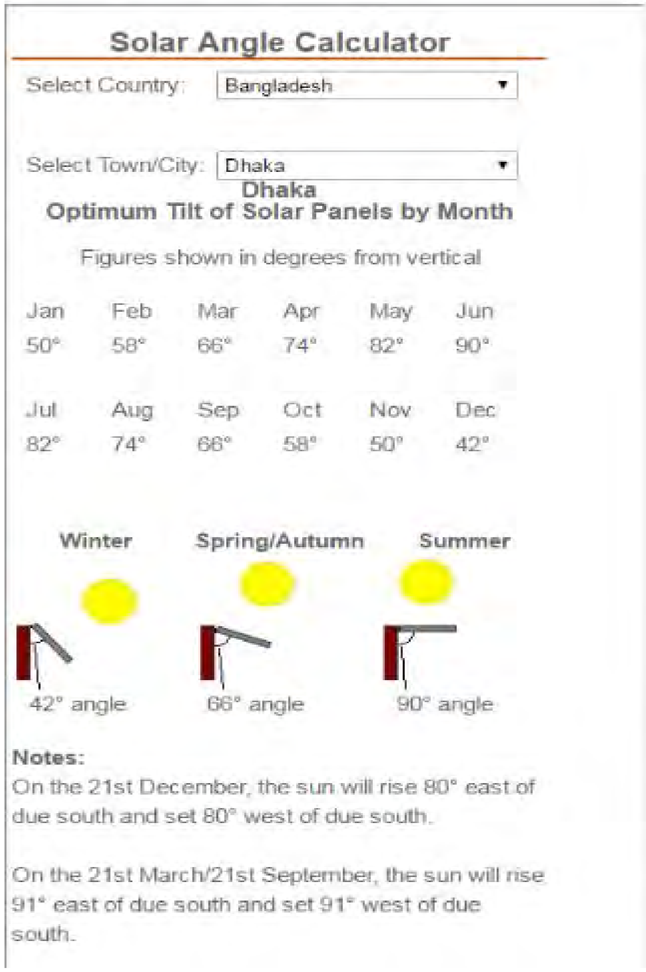


Fig 2.19: Calculation of Solar optimum angle

We did all the necessary calculation and made the reflector. The reflector hereby enhances the reflection and the output power is increased while taking the data. Also it has a triangle-square base which strengthens its position so that it can be strong enough to heal against the wind. All in all it enhances the sun rays and we measured the data.

CHAPTER 3

Experimental Setup

3.1 Introduction

IN this chapter basically we focused on our research and design of our prototype of the sun tracking system. After an extreme research and data collection on the available techniques and components, to meet the requirements of the system and to satisfy the objective of our project we have used suitable methods and implemented it through electrical circuits. We have a control circuit that is controlled by the microcontroller, Arduino. ARDUINO sends signal to the mini maestro which revolves the panels with the help of the servo motor. The mini maestro also calculates and compares the time with the help of RTC. We also made a multi-layer reflector and a fixed reflector for the panels.

3.2 Mechanical Construction

An iron bar was connected vertically with heavy weight iron base through gas wielding, the stack that contains the solar panels is made of SS bar (stainless steel) and is connected to the vertical bar through ball bearing. It helps the panel easily rotate along a horizontal arc with the operation of the linear actuator.

We have drilled the bar and made three holes on the SS bar to connect the panels and 3 inch iron rods were mounted on the SS bar through those holes with small ball bearing to which help the iron rods easily rotate around the horizontal axis. The iron rods are mounted on the main stack in such manner that they are bit tilted downwards and each of the rods contains two rectangular sized long iron plate in transverse manner so that the flexible solar panel can easily be attached to these iron rods. The remaining iron rod on the other side of the ball bearing is connected with servo motors and we have used servo horns for a better grip on them throughout the whole day. Theoretically it has been proposed that the distance between two consecutive holes containing iron rods is 1.5 times of the width of the solar panel.

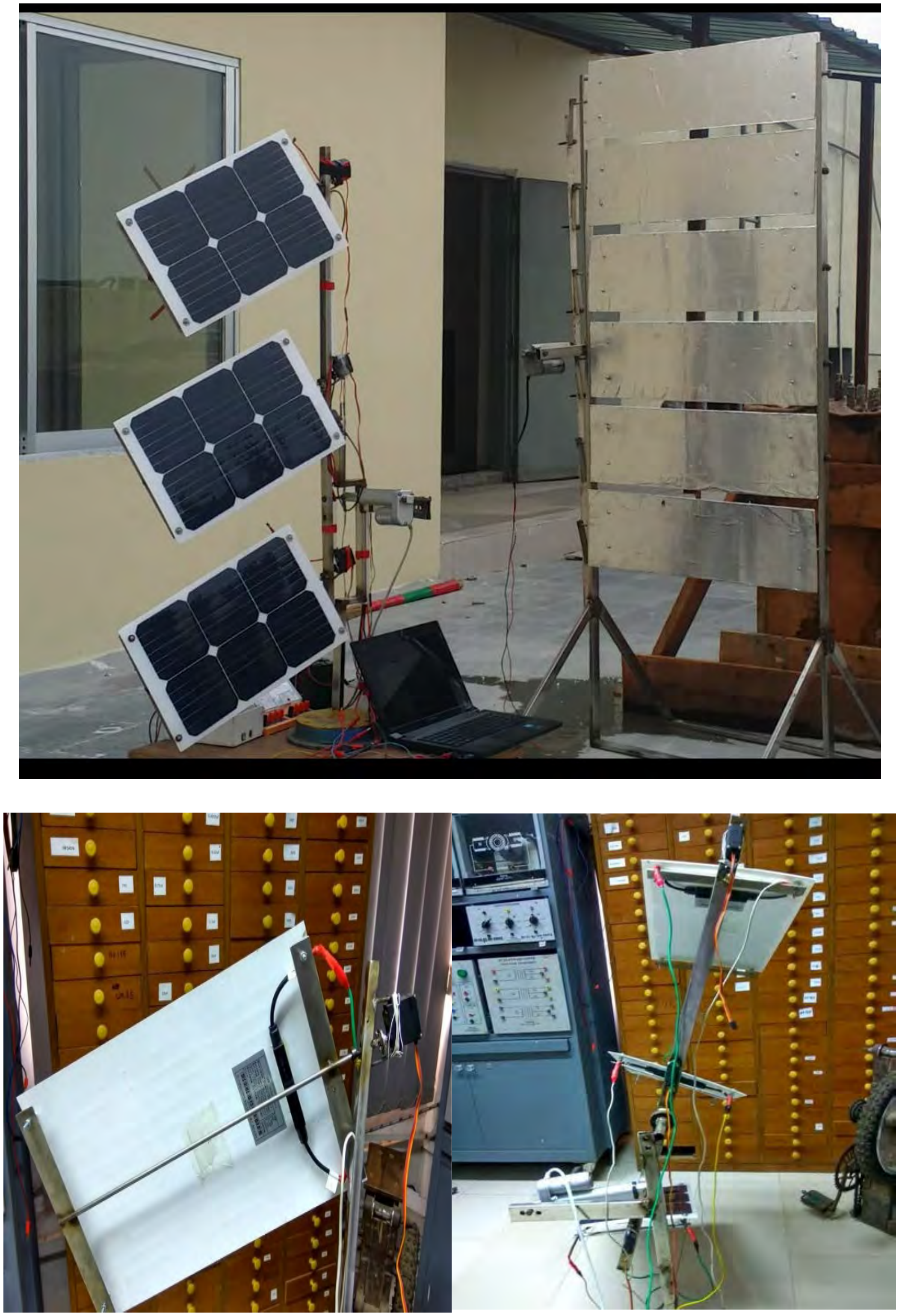


Fig 3.1: Mechanical Construction

3.3 Control Circuit Diagram

We have implemented our circuit by using one ARDUINO Mega, one ARDUINO Uno , three MG995 Servo Motors, two RTC(real time clock), One 12V Actuator for the panel and One Actuator for the reflector, a 2 Relay Module ,one 3V Lithium battery, one Polulu Mini Maestro 12 and a number of male to male and male to female connectors.

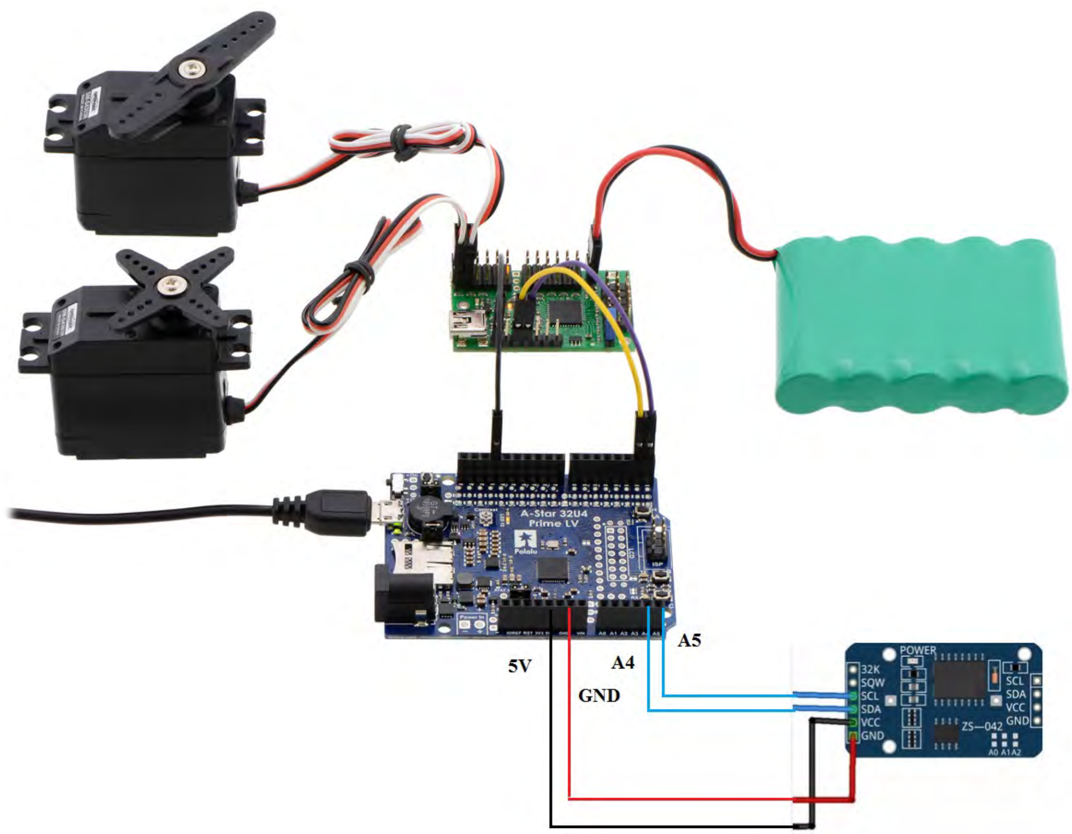


Figure 3.2: The control circuit diagram

So Arduino is connected to the PC or Laptop via an USB cable which gives power to all the other components we have used except the actuator and relays. Arduino supply fixed 5V power to all the components. The Polulu mini maestro is connected in pin number 10 and 11 of the Arduino via its RxD and TxD for transmission and reception of the signals. The RTC which gets its power supply from 3V lithium battery is connected in pin SCL and ground through pin number 5 and 6.

As there is interference between the electric field and the magnetic field produced by the actuator, that's why the actuator is fully separated from the above circuit. The actuator is 12V and the interference cause a lot of problems. The first one is the real time clock gets reset as it cannot tolerate the huge power of the actuator and the second one is that there's a possibility of the other components to get burn or damage because of the huge power. That's why the power is provided to the actuator extremely via a battery.

3.4 States of the sun tracking solar panels throughout the daytime

The tracking process of this multilevel solar panel system works with the help of both the servo motors and the actuator. The servo motors rotates the panel and the actuator that moves the iron bar in a horizontal arc. In this there are 12 positions for the panels. With the help of Real Time Clock and other components the system tracks the sun throughout the whole day and sends signals to the motor driver and relay for the proper alignment of the panels. All these positions are distinguished from one another by the positive angles created by the panels because of their rotation and positions.

The states have been described below:

1. State '1': This state begins at 6:00 am in the morning when all the servo motors start working and they take the panels at an angular distance of +7.5°from the vertical line by rotating their shaft connected with the panels. At the beginning the linear displacement of the actuator shaft is kept 0mm as the iron stack carrying the solar panels remain tilted towards the east till 12pm.

2. State '2': This state begins at 7:00am and the angular distances of the panels from the vertical line goes up to +22.5°.

3. State '3': This state begins at 8:00am and the angular distances of the panels from the vertical line goes up to +37.5° .

4. State '4': This state begins at 9:00am and the angular distances of the panels from the vertical line goes up to +52.5°.

5. State '5': This state begins at 10:00 am and the angular distances of the panels from the vertical line go up to +67.5°.

6. State '6': This state begins at 11:00 am and the angular distances of the top and bottom panel increases up to +82.5° but the middle panel is taken to a position of -180 ° angular displacement with the vertical line and this position is maintained up to 12:00pm for avoiding it's shading over the bottom panel and again this middle panel cannot convert solar energy efficiently during this period due to the shading of top panel over it as the sun radiates energy from the angular position of approximately 90°with the horizon during this time span.

7. State '7': This state begins at 12:00 pm when the 10mm linear movement of actuator shaft tilts the iron stack carrying the solar panels towards the west. In this state, the angular displacement of top and bottom panels with the vertical line reaches +97.5° and the middle panel goes through a rotation of 180 ° comparing to its previous position for avoiding further shading.

8. State'8': This state begins at 1:00pm and all the three panels get aligned at an angular displacement of +112.5° with the vertical line.

9. State '9': This state begins at 2:00pm and all the panels get aligned at an angular displacement of +127.5° with the vertical line.

10. State'10': This state begins at 3:00pm when all the panels get aligned at an angular displacement of +142.5° with the vertical line.

11. State'11': This state begins at 4:00pm when all the panels get aligned at an angular displacement of +157.5° with the vertical line.

12. State'12': This state begins at 5:00pm and continues till 6:00pm. In this state all the panels get aligned at an angular displacement of +172.5° with the vertical line. According to the seasonal daytime length of this country, this system will stop working at 6:00pm and it will again get back to the state '1' in the next morning.

Note: During each state the generalized angular displacement is +15°, which has been determined by the calculations of some parameters related to the motor driver for the convenience of the system.

3.5 Connections of the panels

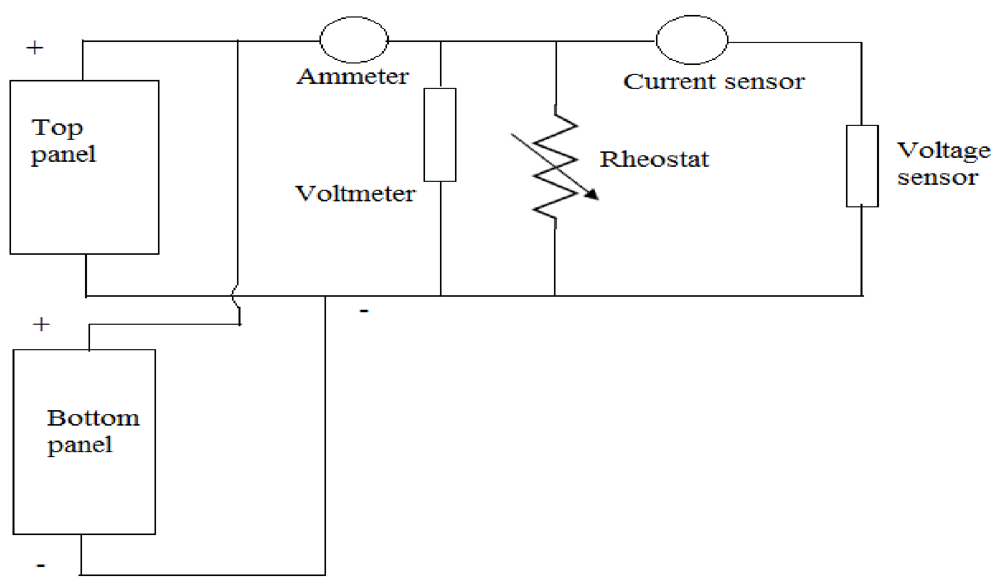


Figure 3.3(a): Arrangement of top and bottom panel in parallel with ammeter, voltmeter, rheostat, current sensor and voltage sensor

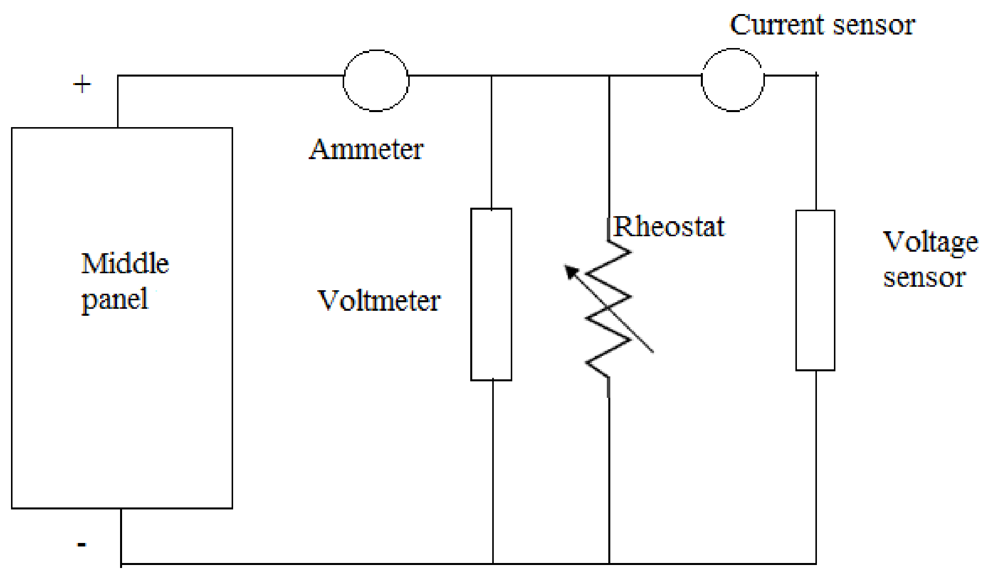


Figure 3.3(b): Arrangement of middle panel with ammeter, voltmeter, rheostat, current sensor and voltage sensor

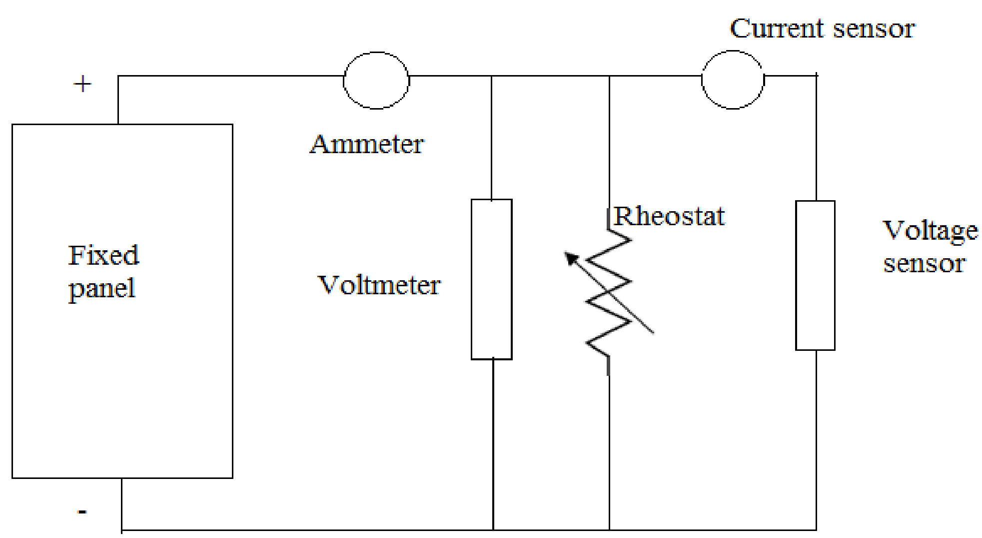


Figure 3.4: Arrangement of fixed panel with ammeter, voltmeter, rheostat, current sensor and voltage sensor

Top, middle and bottom panel will be rotating in similar fashion and they were connected in parallel. We have to compare the efficiency with respect to the rotating panels and that's why there was a fixed with which we can compare the efficiency with respect to the rotating panels.

3.6 Data logger:

A data logger is an electronic instrument that records measurements at set intervals over a period of time. Depending on the particular data logger, measurements can include air temperature, relative humidity, AC/DC current and voltage, differential pressure, time-of-use (lights, motors, etc.), light intensity, water temperature, water level, dissolved oxygen, soil moisture, rainfall, wind speed and direction, leaf wetness, pulse signals, room occupancy, plug load, and many more.

Data loggers are typically compact, battery-powered devices equipped with an internal microprocessor, data storage, and one or more sensors. They can be deployed indoors, outdoors, and underwater, and can record data for up to months at a time, unattended. A data logger may be a single-unit, stand-alone device with internal sensors, which fits in the palm of a hand, or it may be a multi-channel data collection instrument equipped with one or more external sensors.

How the data logger works:

The figure below shows the system overview of the data logger, where we can see that the top and bottom solar panels are connected parallels to the same current and voltage sensors as they remain in the same alignment throughout the day for tracking the sun. Again the middle panel is connected to the second pair of voltage and current sensors and the third pair of voltage and current sensors is used for reading a standard fixed panel. The microcontroller reads the data from the voltage and current sensors through its analog input pins and aligns them with the receiving time taken as input from the Real Time Clock. Then the microcontroller records the data in a memory card which has been connected with it through the digital output pins.

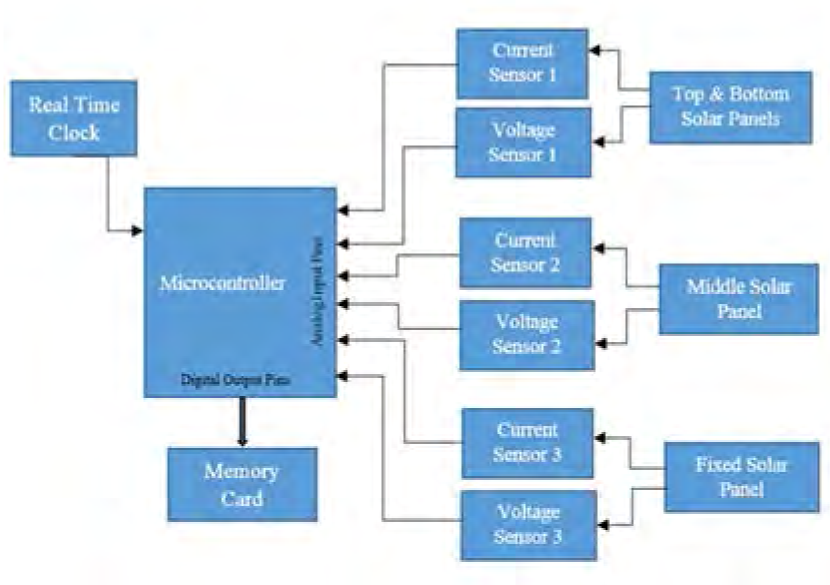


Fig 3.5: Block diagram of data logger

3.6.1 Current sensor:

A current sensor is a device that detects and converts current to an easily measured output voltage, which is proportional to the current through the measured path.

When a current flows through a wire or in a circuit, voltage drop occurs. Also, a magnetic field is generated surrounding the current carrying conductor. Both of these phenomena are made use of in the design of current sensors. Thus, there are two types of current sensing: direct and indirect. Direct sensing is based on Ohm’s law, while indirect sensing is based on Faraday’s and Ampere’s law.

In this information data logger "**ACS714 Current Sensor**" has been utilized for detecting the changing current which is a Hall impact based straight current sensor that works at 5V and has a yield affectability of **185 mV for every Ampere** .The sensor requires a supply voltage of 4.5 V to 5.5 V to be associated over the Vcc and GND sticks in the Figure 1. The ACS714 yields a simple voltage which is straightly relative to the info current. At the point when Vcc is 5 V, this yield voltage is focused at 2.5 V and changes by 185 mV for each amp of info current, with positive current expanding the yield voltage and negative current diminishing the yield voltage [1].

A Hall Effectsensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications. In its simplest form, the sensor operates as an analog transducer, directly returning voltage.

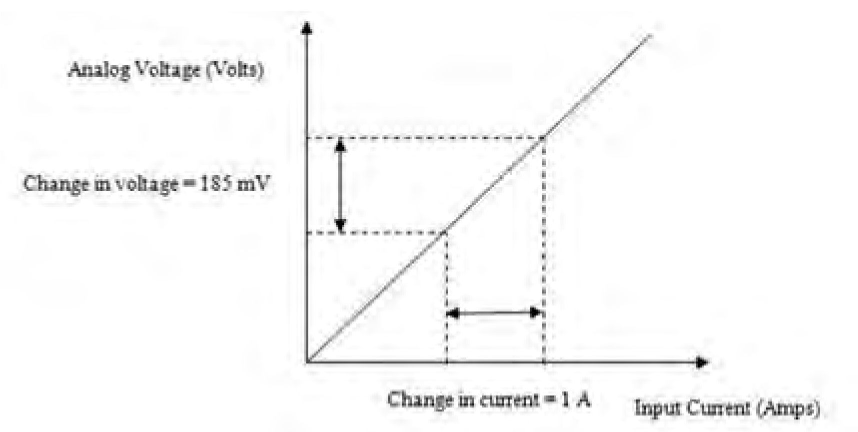


Fig 3.6: Relationship between Analog voltage and input current (when input current is increasing)

The current sensor board feature:

- Bidirectional measurement from -5 to 5 V (though the robust sensor IC can survive up to five times the over current condition).
- The sensor's conductive path internal resistance is typically 1.2 mΩ (just over 1/1000 of an ohm), and the PCB is made with 2-oz copper, so *very little* power is lost in the board.

- Use of a Hall Effect sensor means the IC is able to electrically isolate the current path from the sensor's electronics (up to 2.1 kV RMS). This means it can be used anywhere along the current path, and still offers good electrical isolation!
- 80 kHz bandwidth that can optionally be decreased by adding a capacitor across the board pins marked "filter".
- High accuracy and reliability. With a typical total output error of 1.5% (at room temperature with factory calibration), an extremely stable output offset voltage, and almost zero magnetic hysteresis.
- Automotive grade operating temperature range of -40°C – 150°C [1].

Note: This current sensor should be used below 30V.

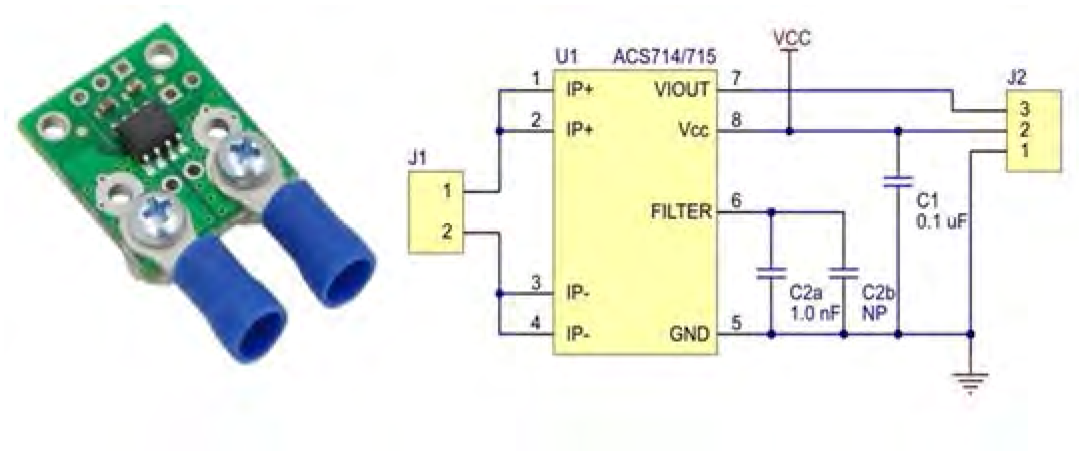


Fig 3.7: ACS 714 current sensor's pin diagram

Vout stick from ACS 714 ought to be associated with Analog input (A0, A1, A2, A4 or A5). In Figure 3 Vout from ACS 714 is associated with Analog information A3 of Arduino Controller.

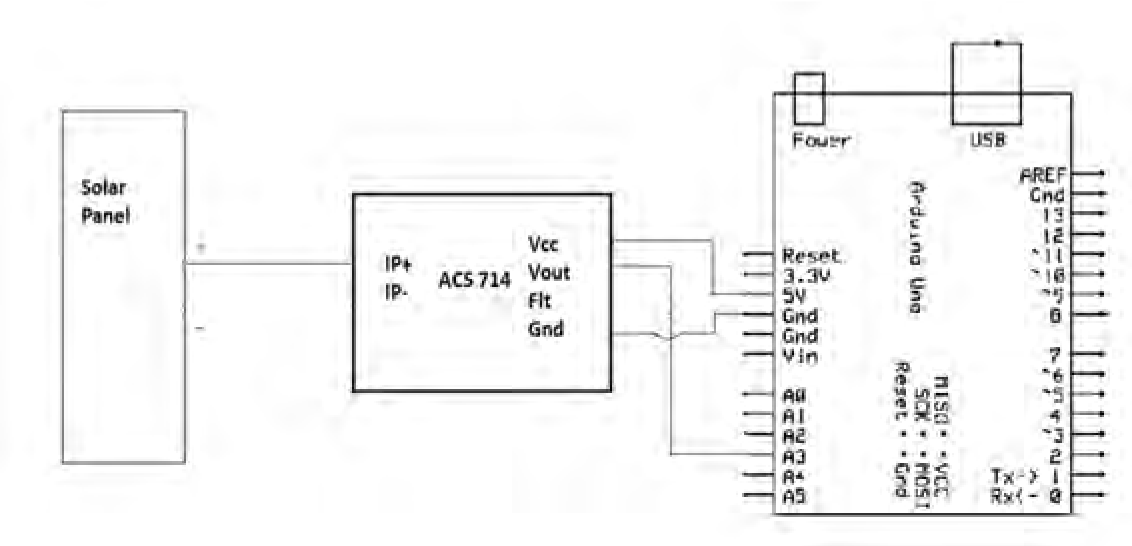


Fig 3.8: Connection of ACS 714 with Arduino Controller

3.6.2 Voltage sensor:

A voltage sensor is going to be able to determine and even monitor and measure the voltage supply. It is then able to take those measurements and turn them into a signal that one will then be able to red. The signal will often go into a specialized electronic device for recording, but sometimes an observer will be present to manually read the sensor output. We used SEN-00101 as voltage sensor for our data logger.

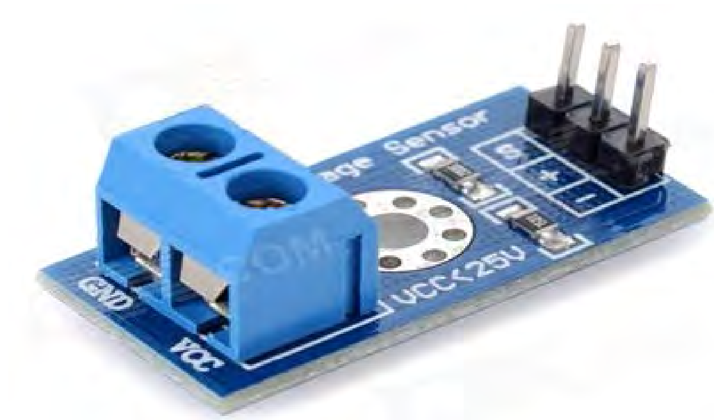


Fig 3.9: 25V Voltage Sensor

The Vout pin from Voltage Sensor can be connected with Analog input (A0, A1, A2, A4 or A5). In Figure 5 Vout pin from Voltage Sensor has been connected with Analog input pin A1.

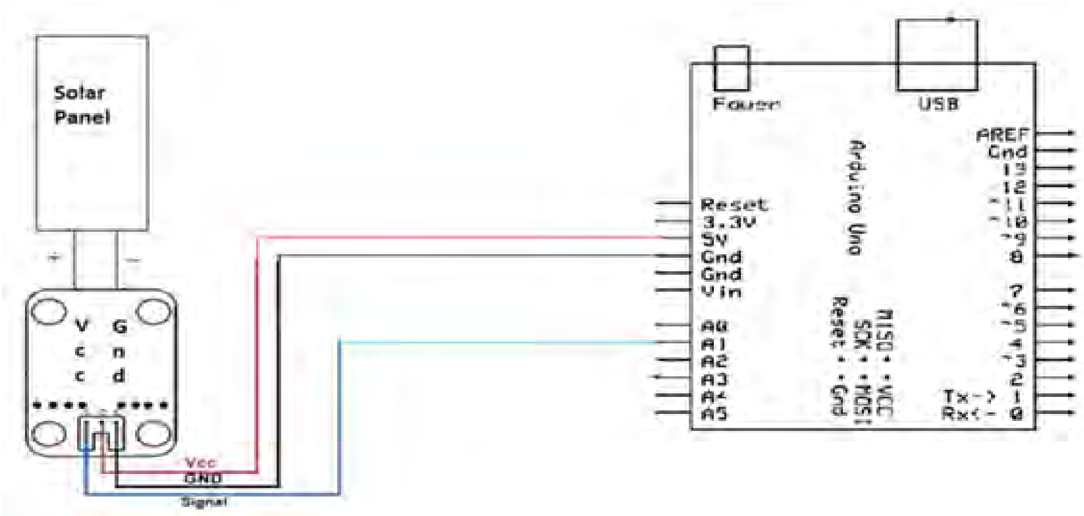


Fig3.10: Connection between voltage sensor and Arduino Controller

Note: We have used three current sensors and three voltage sensors. The top and bottom panel shares a common current sensor and voltage sensor. The other two current sensors and voltage sensors is for our middle panel and fixed panel.

Equation for output reading of Voltage and Current sensors:

$I=0.028496*(v)-14.629$

$V=0.023647*(v)-1.0186$

Here, v is the output parameter bits from arduino MCU ranging from 0 to 1023.

3.6.3 SD card slot for saving data:

The card slot that has been used in our data logger is known as Arduino SD card slot, which has been shown in Figure 6.

Fig 3.11: SD card slot

The correspondence between the microcontroller and the SD card utilizes Serial Peripheral Interface bus, which happens on digital pins 11, 12, and 13 (on most Arduino boards) or 50, 51, and 52 (Arduino Mega). Moreover, another pin must be utilized to choose the SD card. This can be the equipment SS pin - pin 10 (on most Arduino boards) or pin 53 (on the Mega) [2].

The associations have been appeared in Figure 7, where we can see that Digital pins of MCU have been associated with the SDCS, MOSI, SCK and MISO pins of the SD card sold. The space holds an 8GB miniaturized scale SD card for sparing our framework's information.

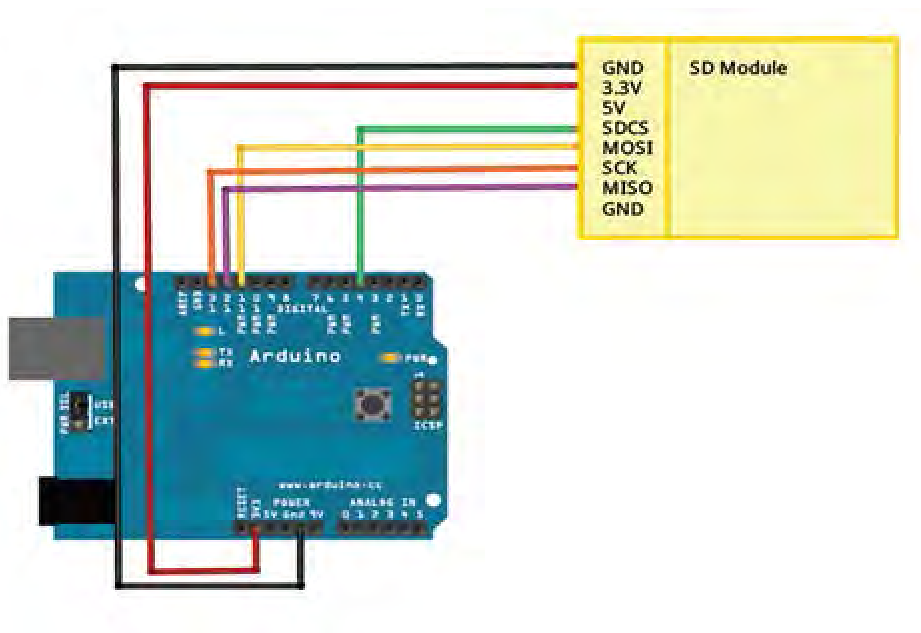
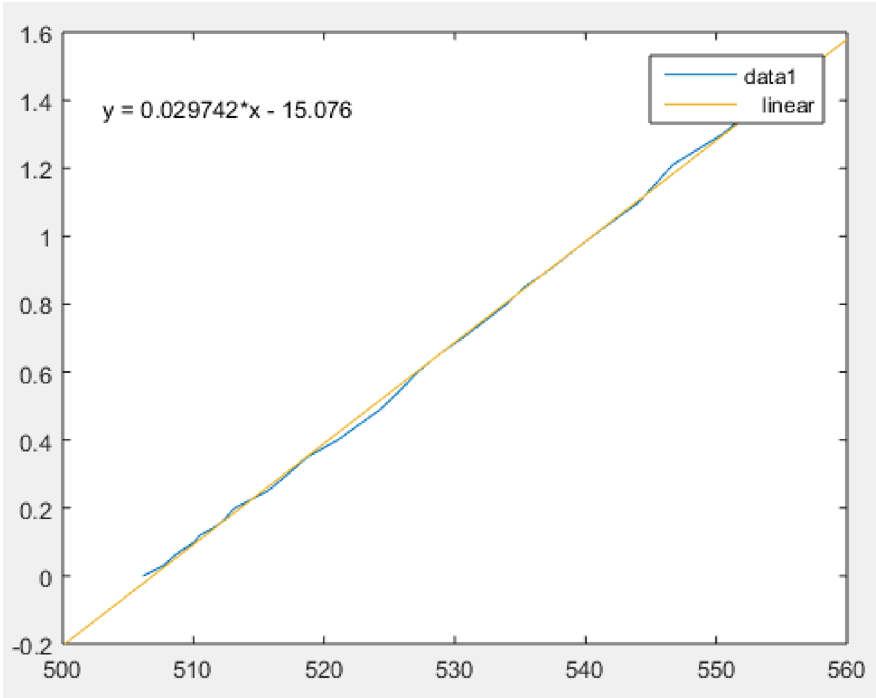


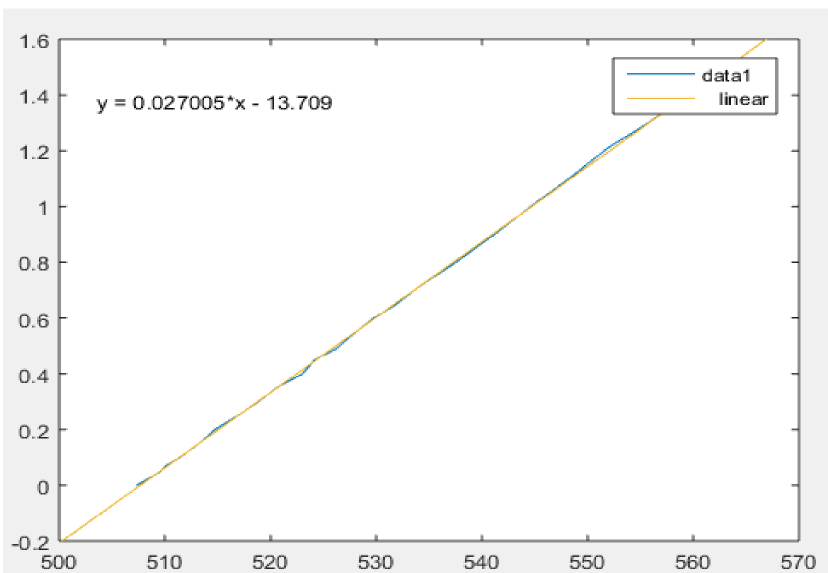
Fig 3.12: Connection between Arduino and sd card slot

3.6.4 Data Logger Calibration and the Plots of the current and voltage sensors

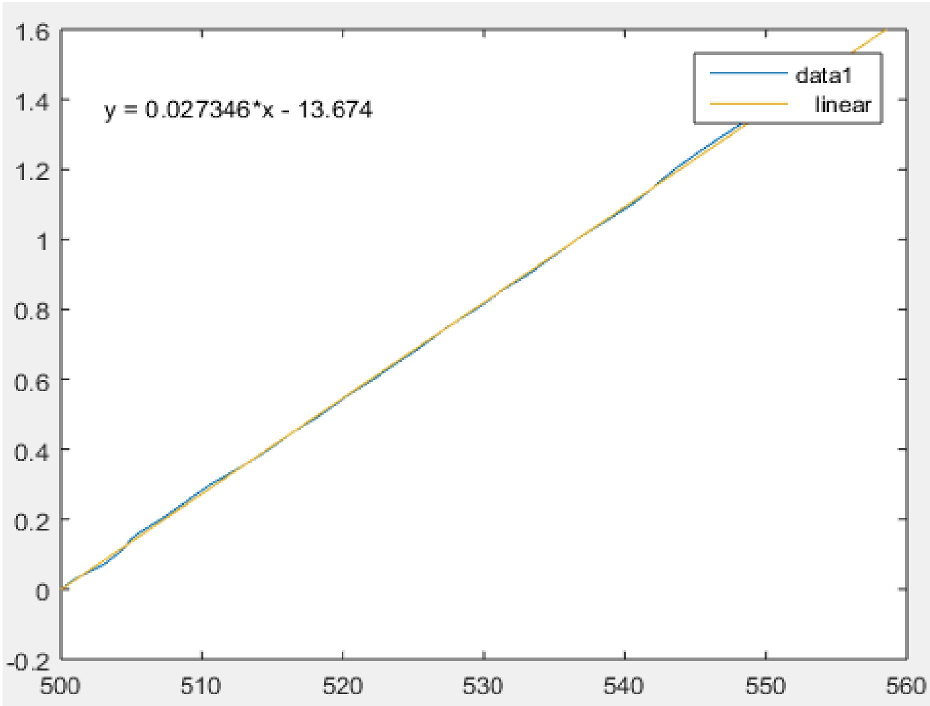
Current Sensor 1



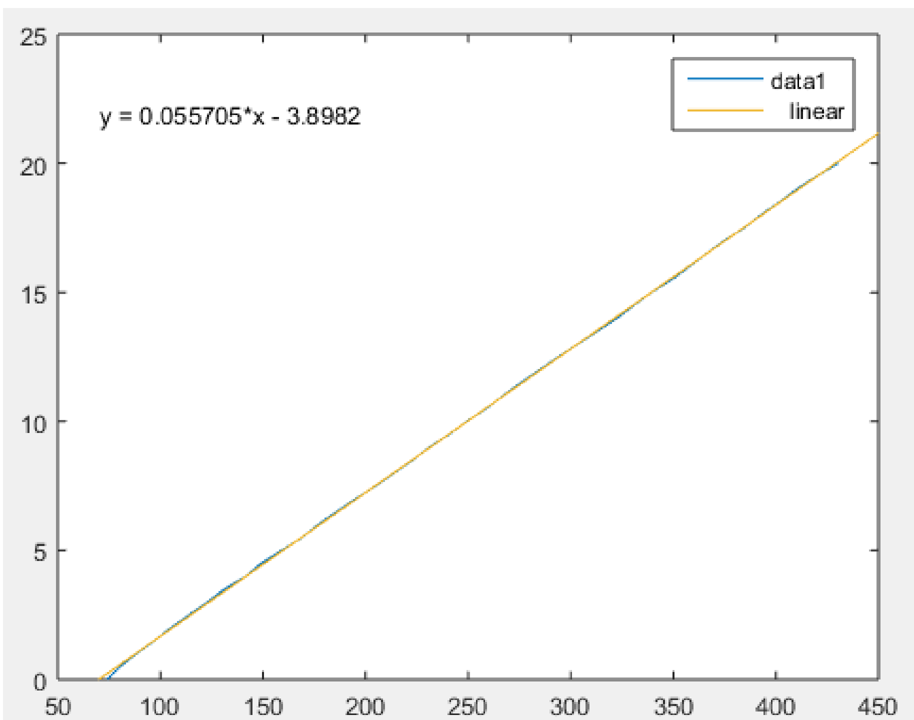
Current Sensor 2



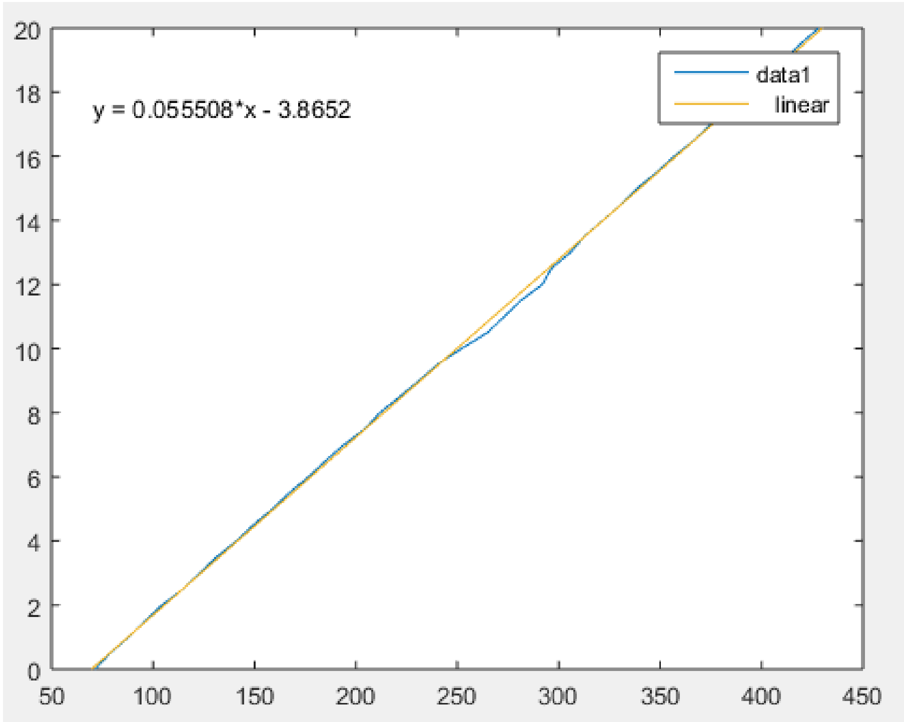
Current Sensor 3



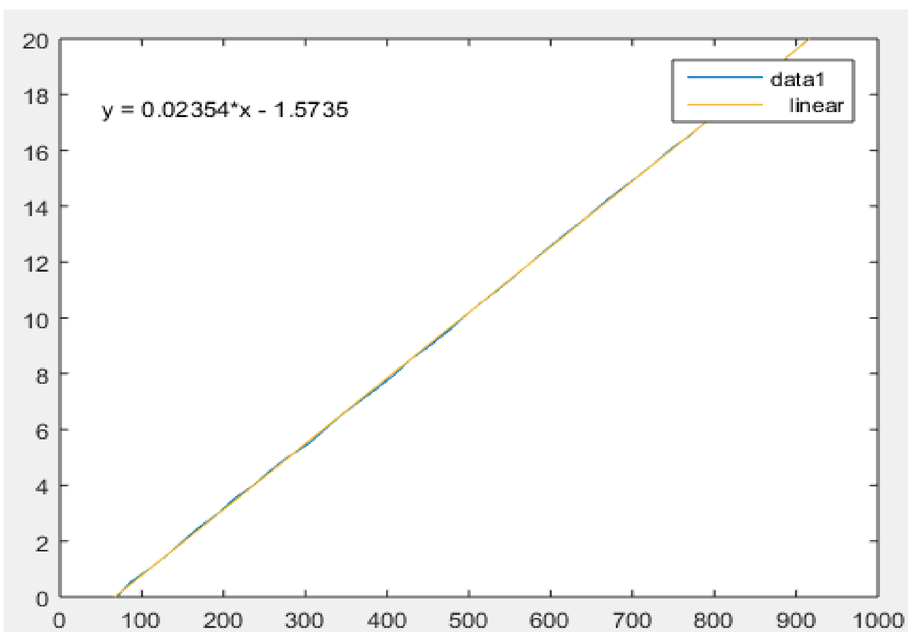
Voltage Sensor 1



Voltage Sensor 2



Voltage Sensor 3



Chapter: 04

Result and Discussion

4.1 Introduction

Once the mechanical construction and modification of the multilevel sun tracking solar panel is done, it was set up on a rooftop to collect data to be analyzed during the months of February, March and mid-April. The collected data later enabled us to analyze the energy and power generation characteristics of the system during the days of spring.

4.2 Circuit configuration of the system for data collection

In the constructed system, the top and bottom panels are connected in parallel to each other as these two panels have the same rotational movement and alignment throughout the day as shown in the Figure 4.1 below. For measuring the voltages and currents, we mainly depended on the conventional instruments like the ammeters and voltmeters along with the current and voltage sensors of the data logger.

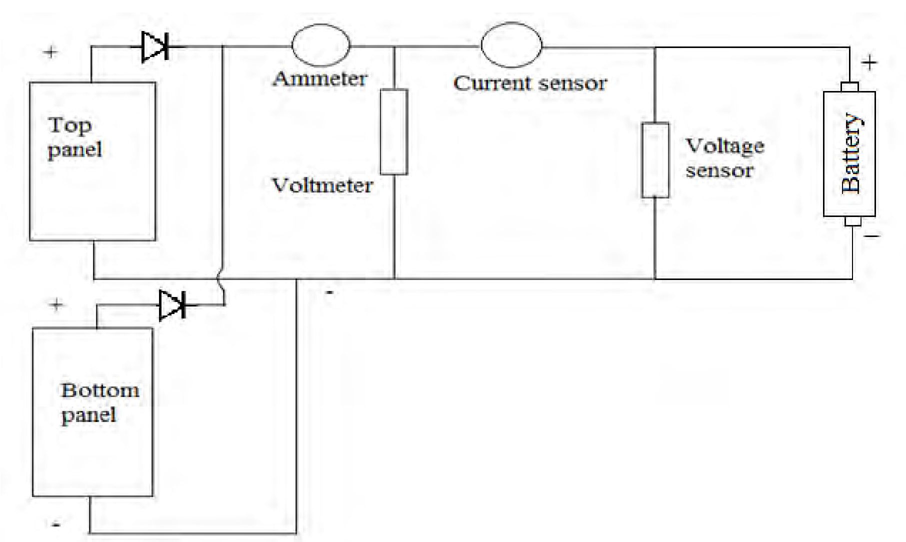


Figure 4.1: Parallel connection of the top and bottom panels for data collection

The middle panel is connected with a single set of ammeter and voltmeter and a single pair of current and voltage sensors as it rotates irrespective of the of the top and bottom panel and remains disabled throughout the midday.

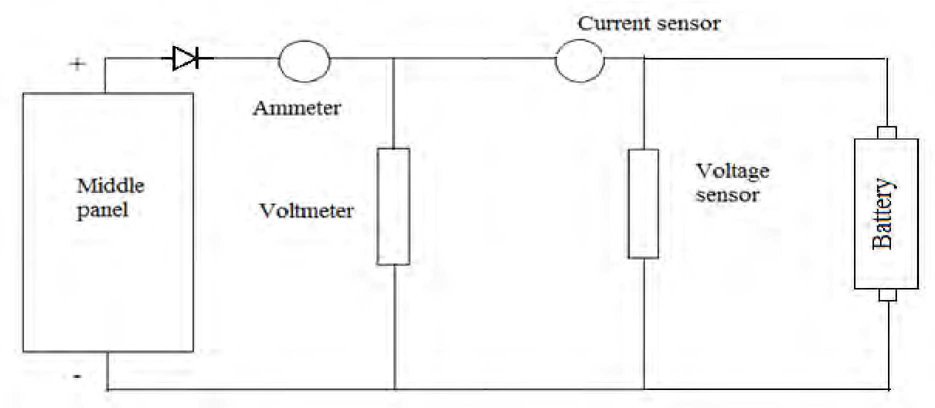


Figure 4.2: Connection of the middle panel in the system

For comparing the system's data with the single level solar system, we used a fixed PV panel with the same characteristics and size for generating same parameters.

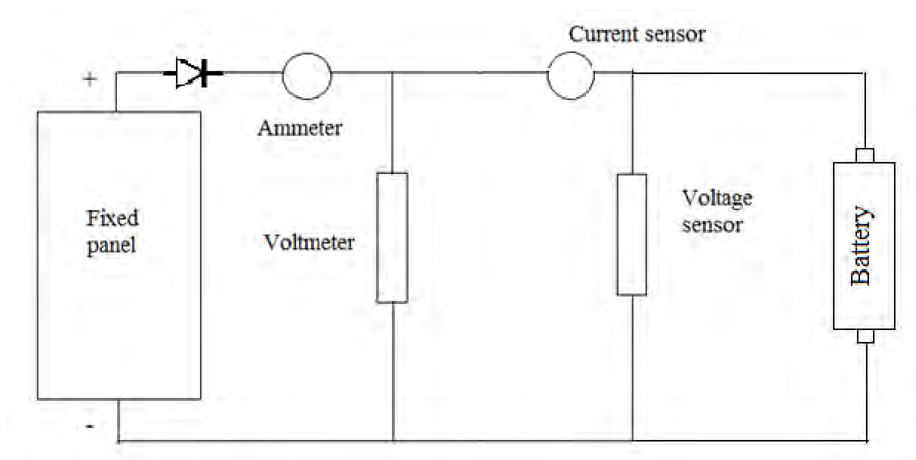


Figure 4.3: Connection diagram of the fixed panel

4.3 Data Analysis and Plots

Date: 9-February-2017 1

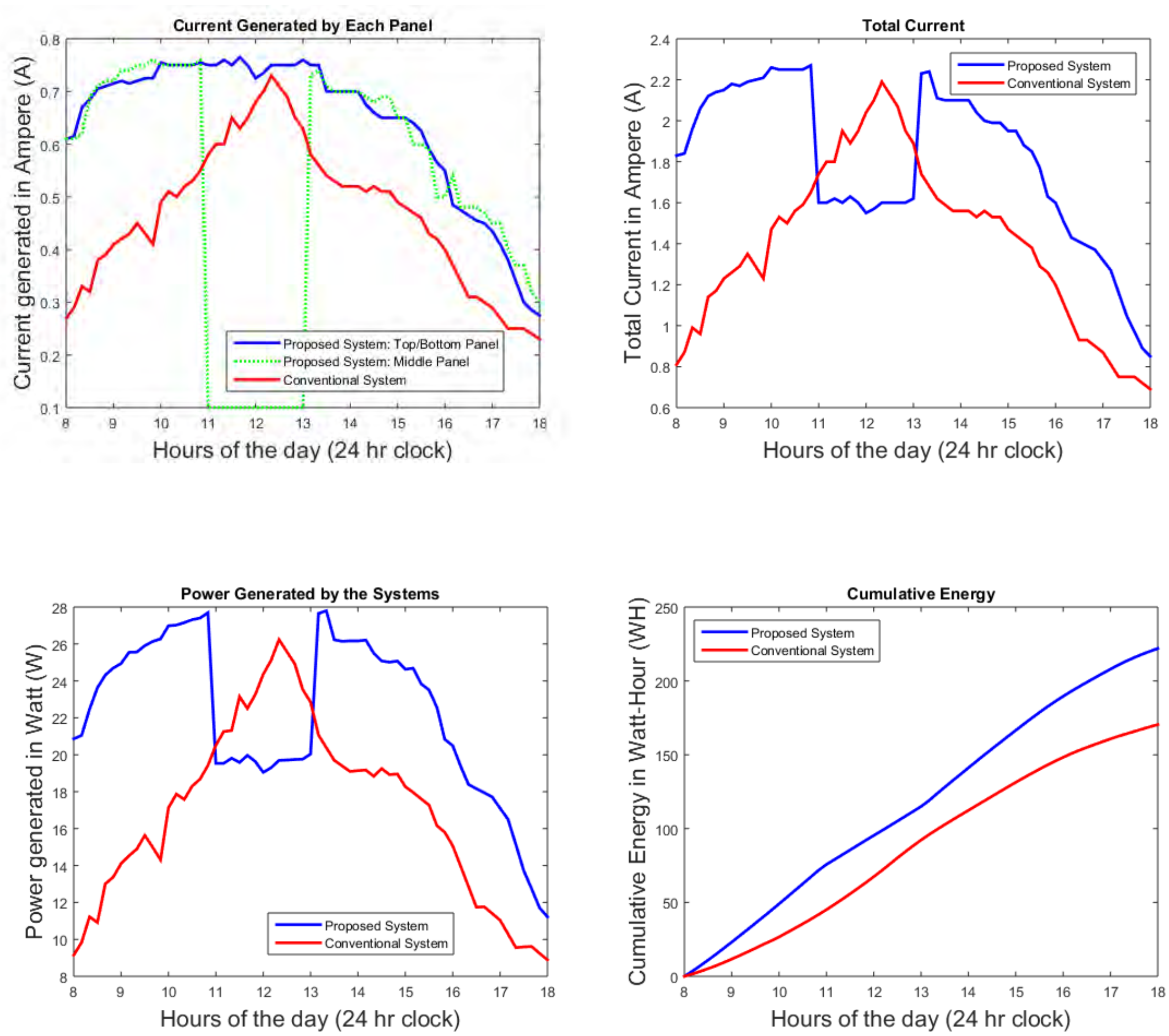


Figure 4.4: Current, Power and Cumulated Energy Plots and comparison for the data taken on 9-February-2017

Date: 14-February-2017 2

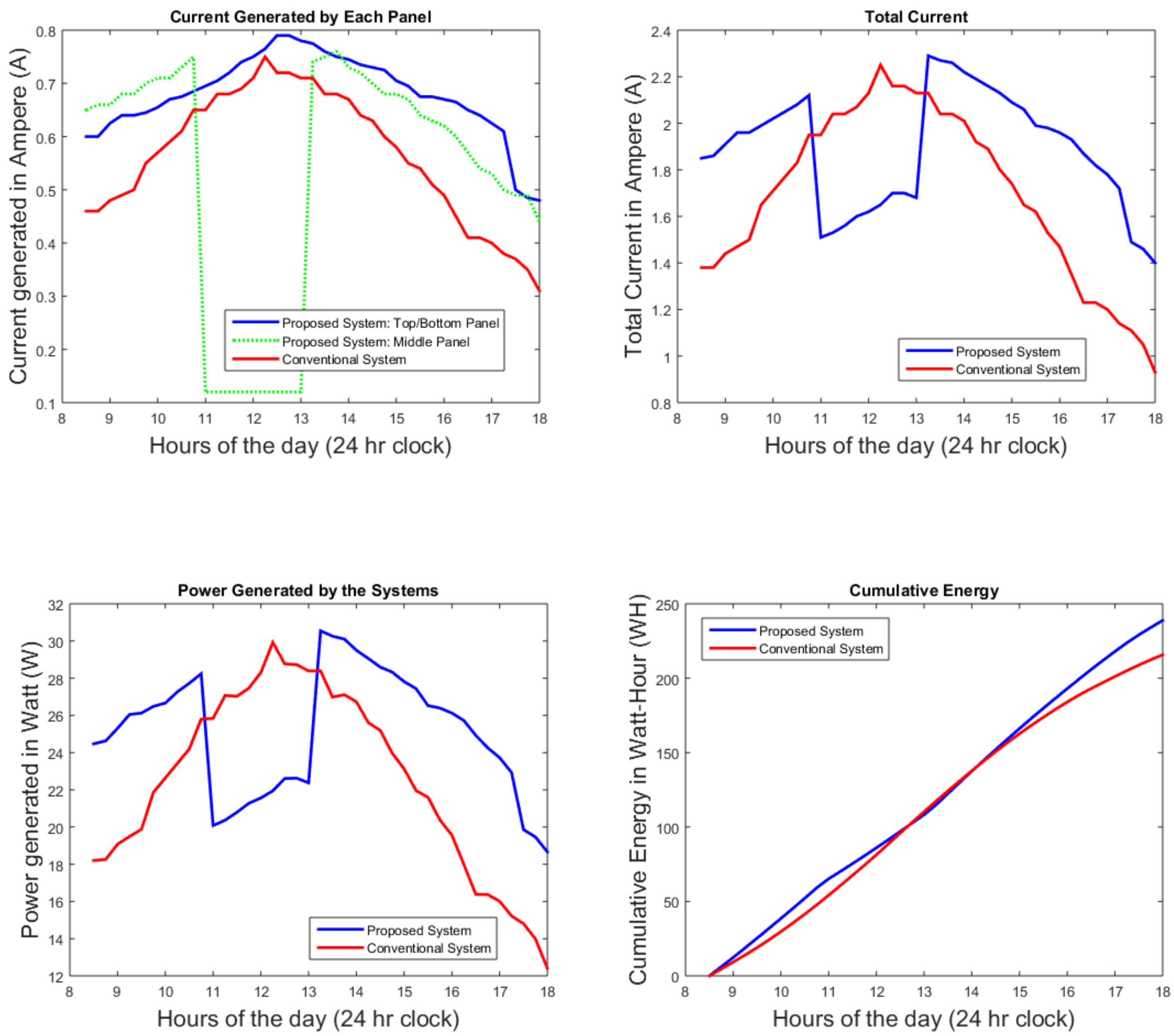


Figure 4.5: Current, Power and Cumulated Energy Plots and comparison for the data taken on 14-February-2017

Date: 23-February-2017 3

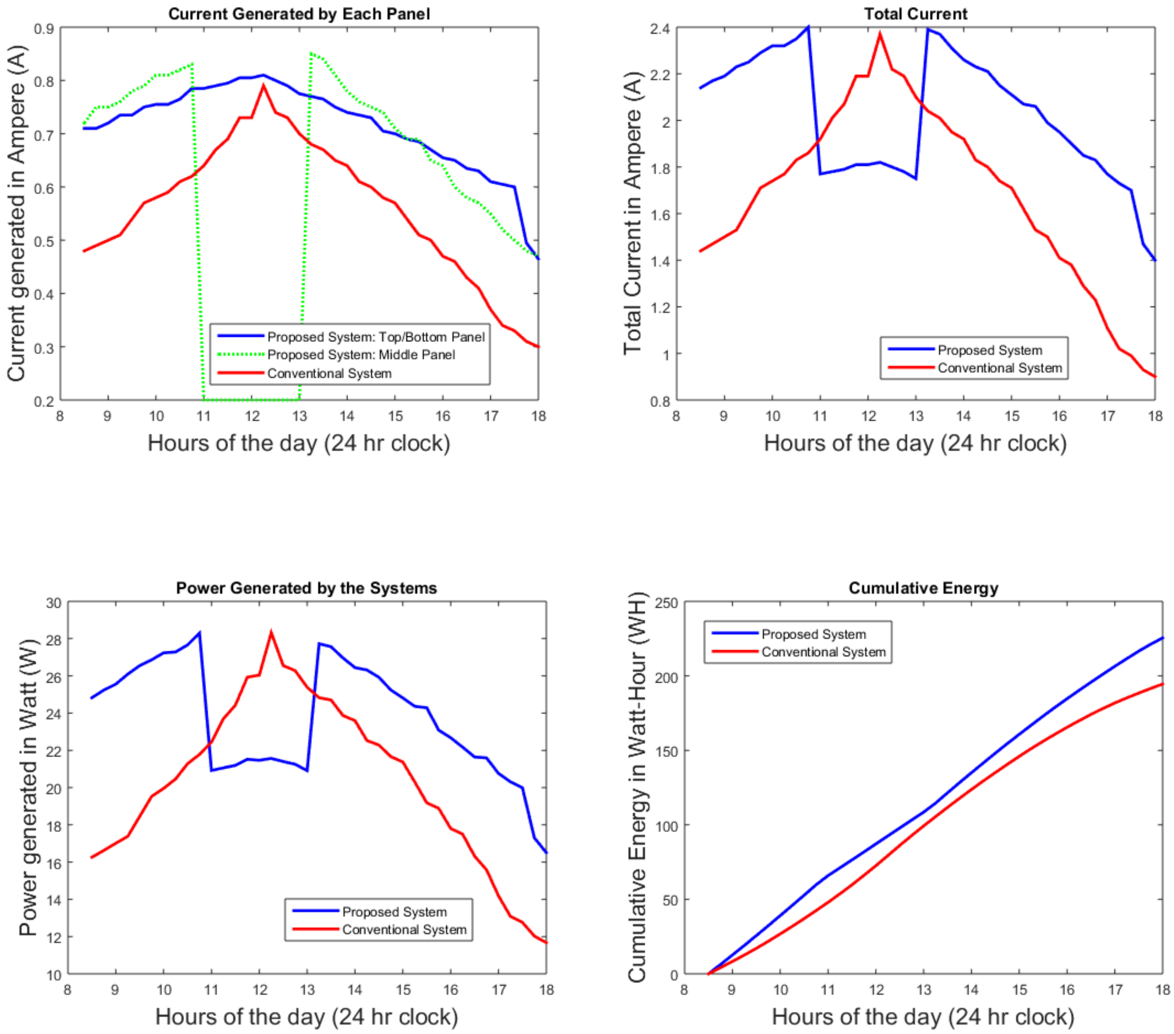


Figure 4.6: Current, Power and Cumulated Energy Plots and comparison for the data taken on 23-February-2017

Date: 25-February-2017 4

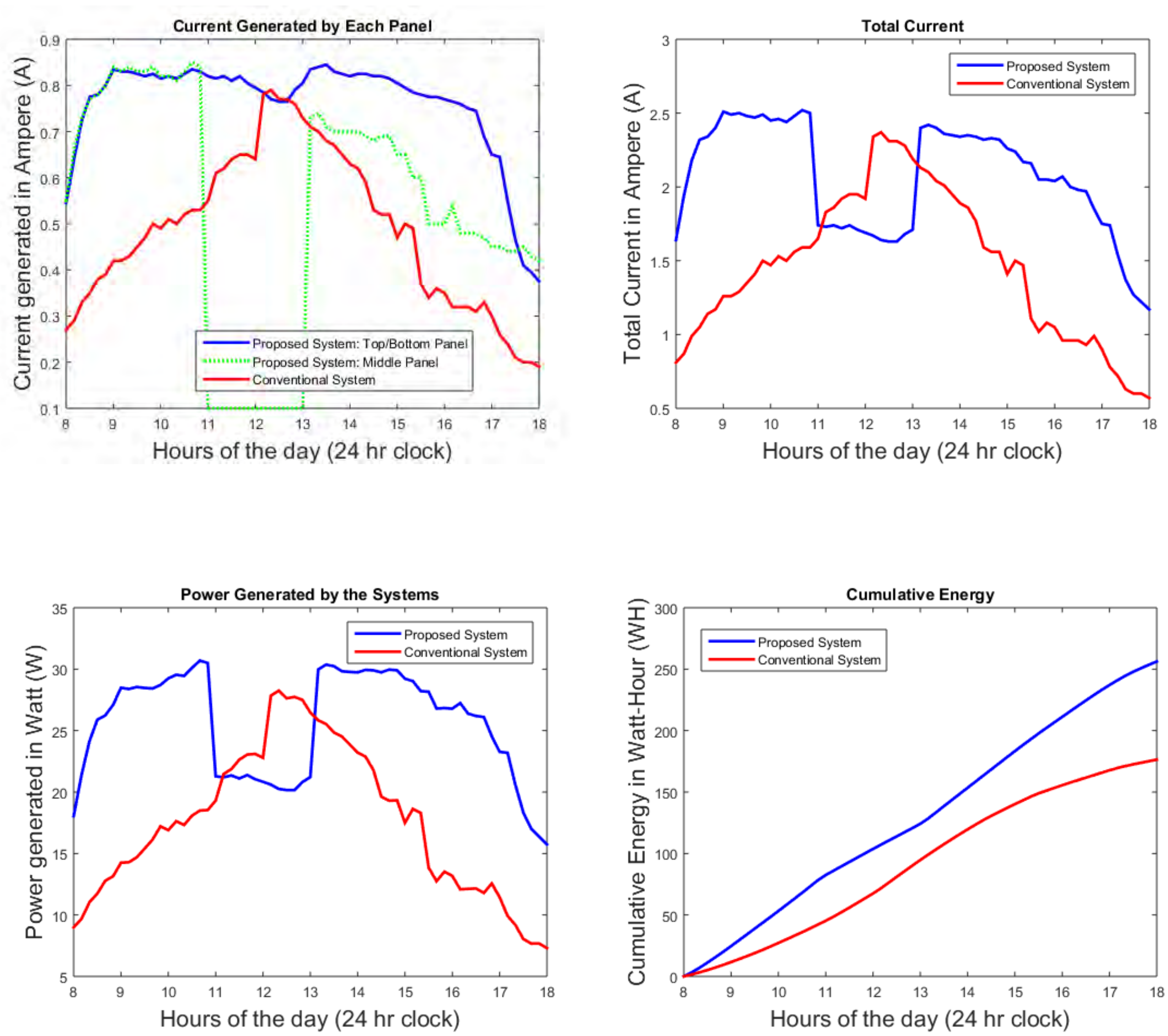


Figure 4.7: Current, Power and Cumulated Energy Plots and comparison for the data taken on 25-February-2017.

Date: 27-February-2017 5

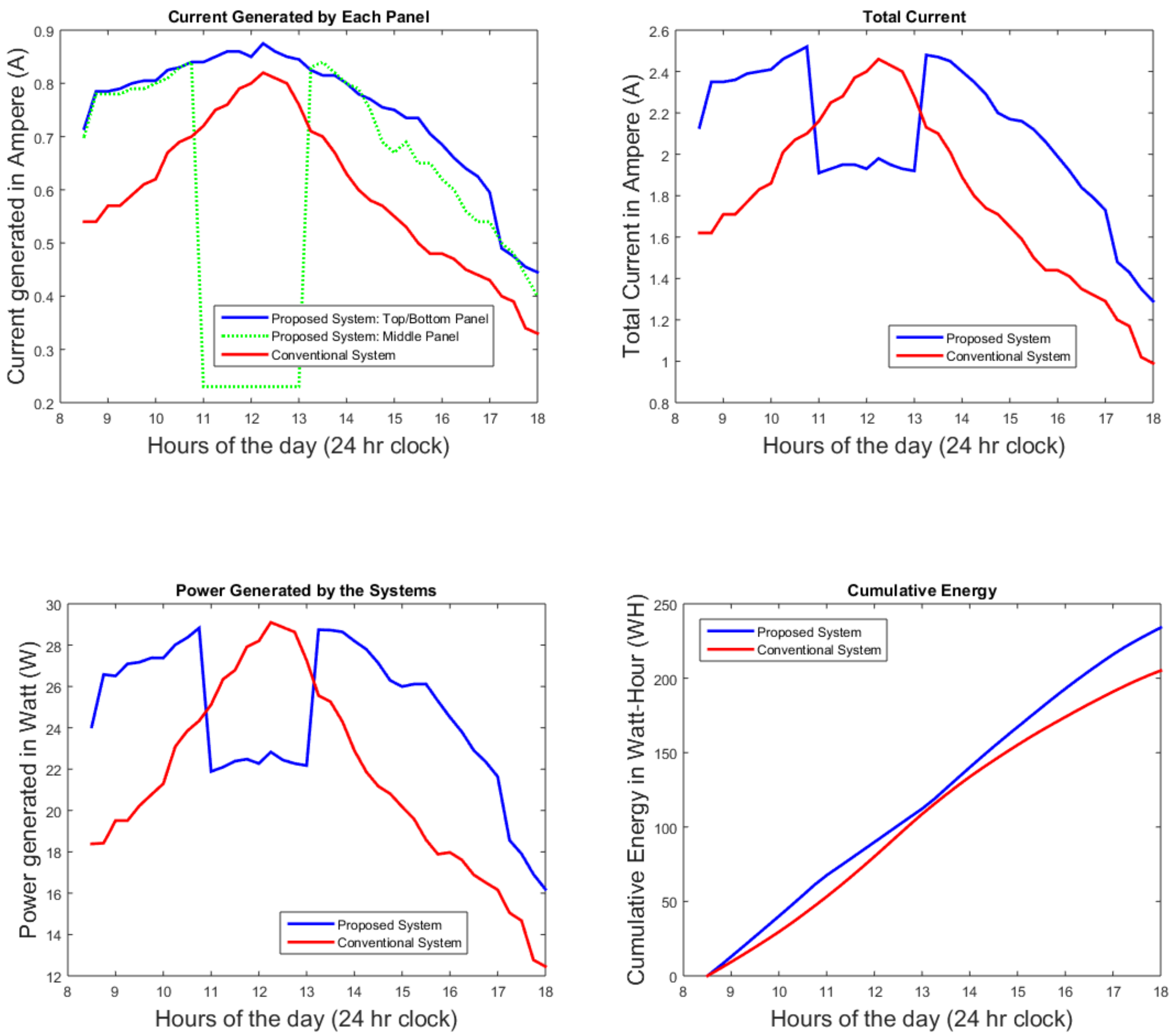


Figure 4.8: Current, Power and Cumulated Energy Plots and comparison for the data taken on 27-February-2017.

Date: 3-March-2017 6

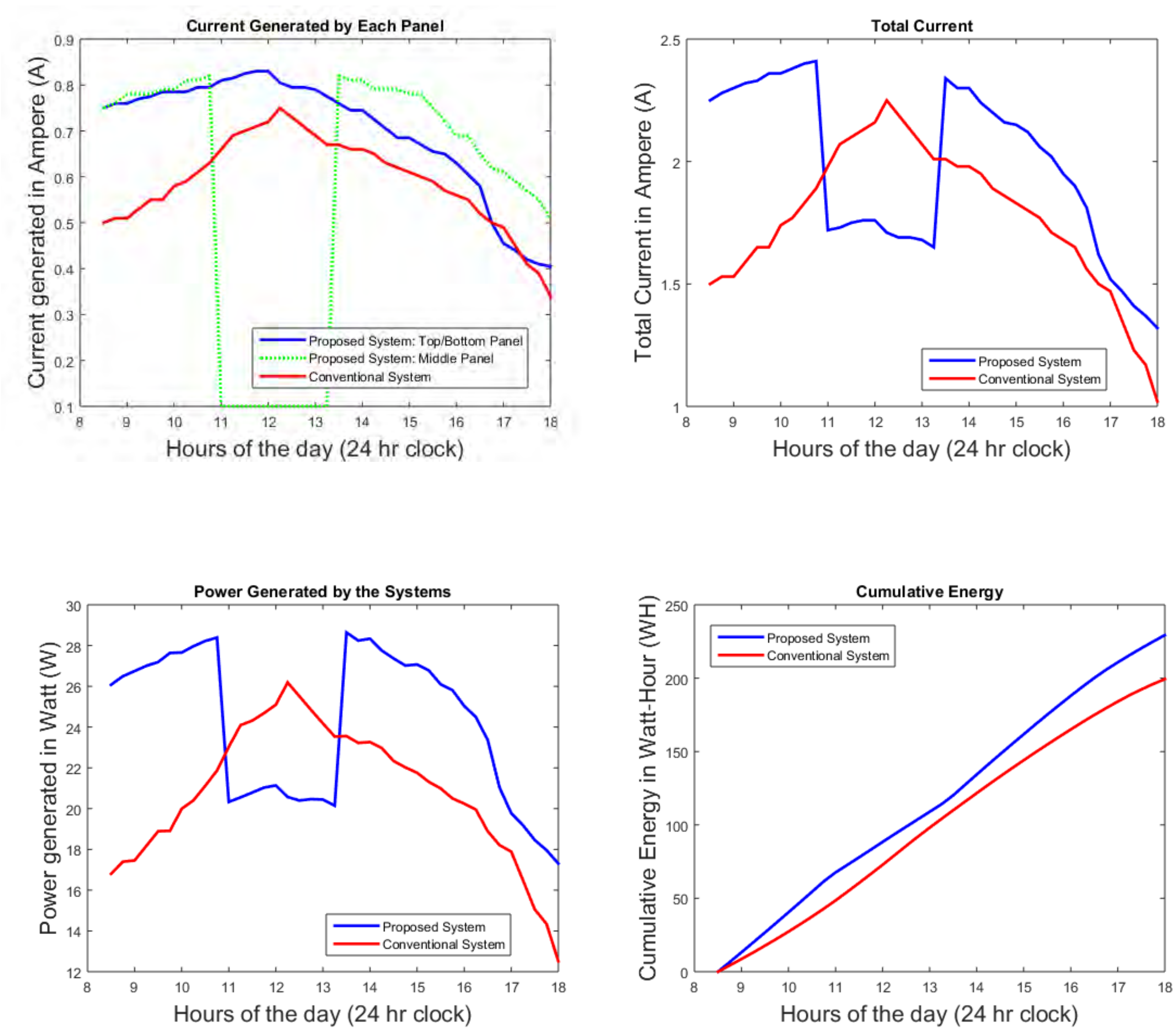
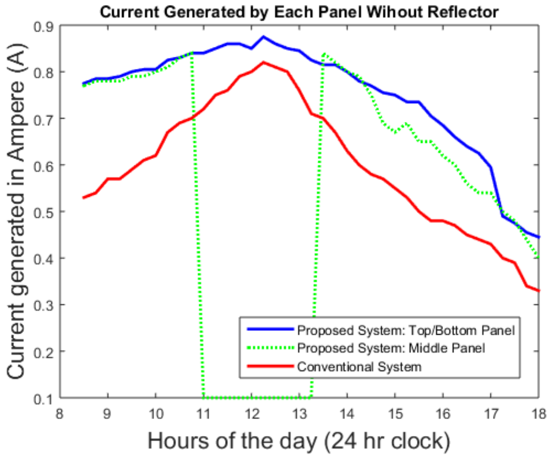
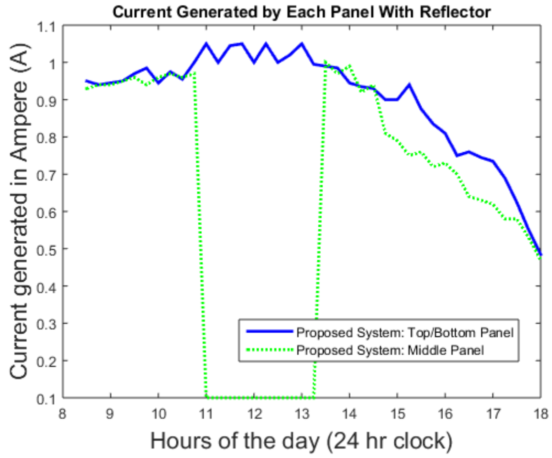
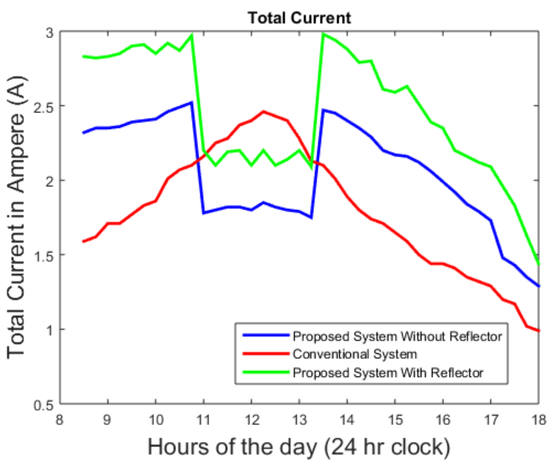


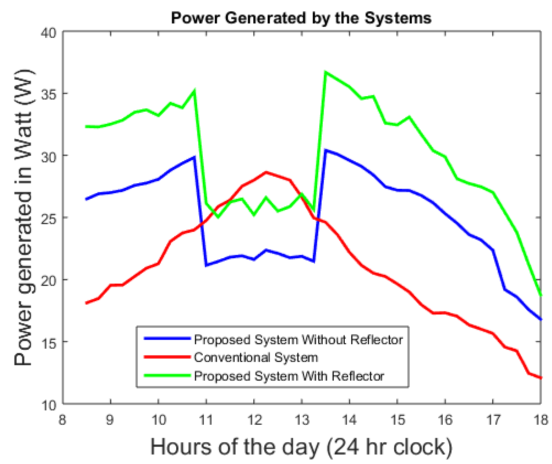
Figure 4.9: Current, Power and Cumulated Energy Plots and comparison for the data taken on 3-March-2017.

Date: 7-March-2017 7









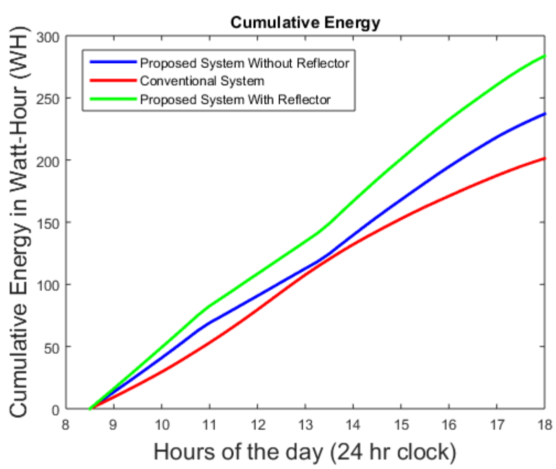
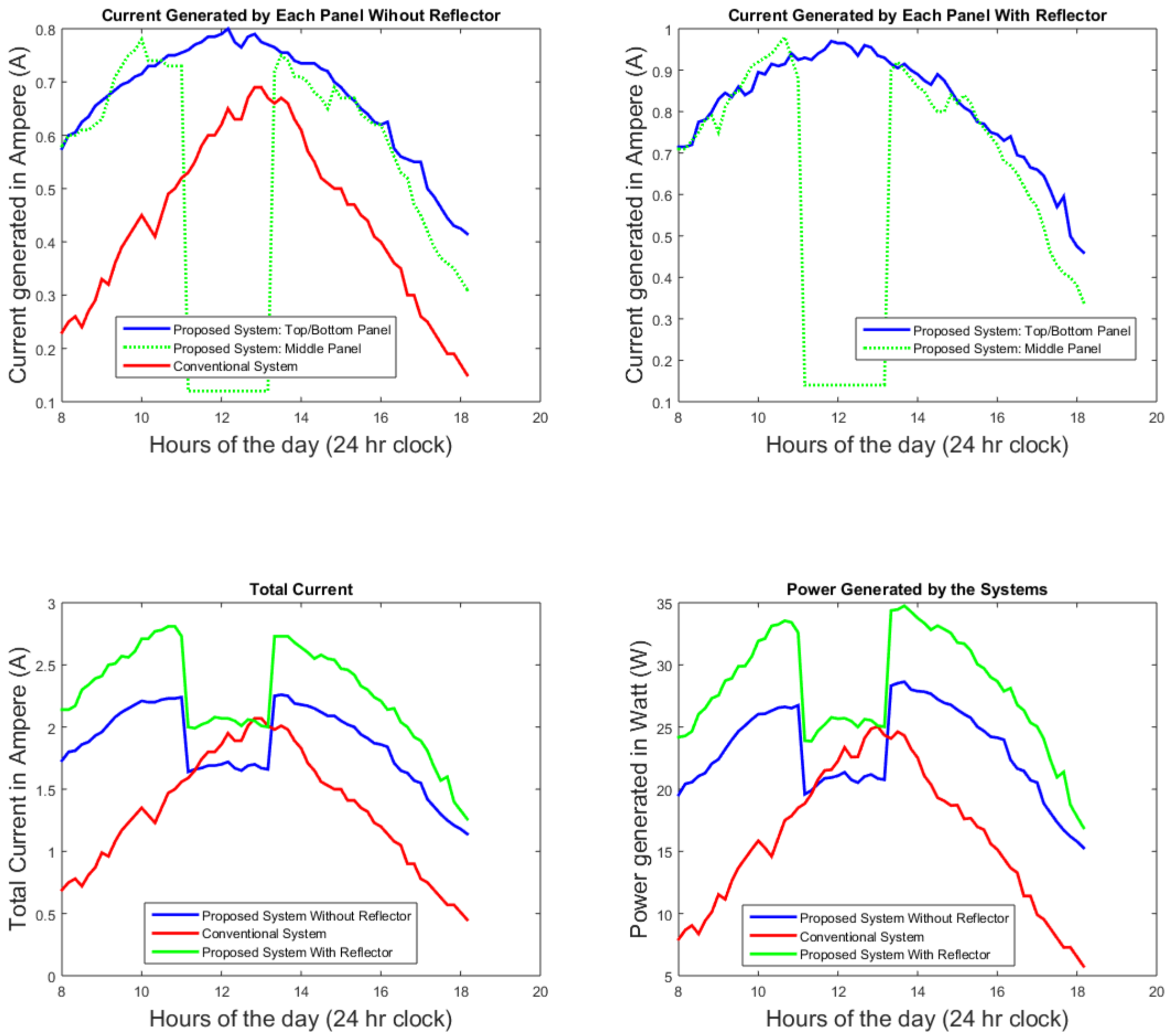


Figure 4.10: Current, Power and Cumulated Energy Plots and comparison for the data taken on 7-March-2017 with reflector.

Date: 15-March-2017 8



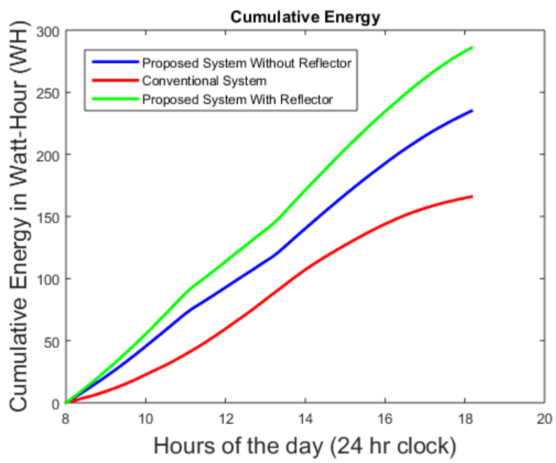
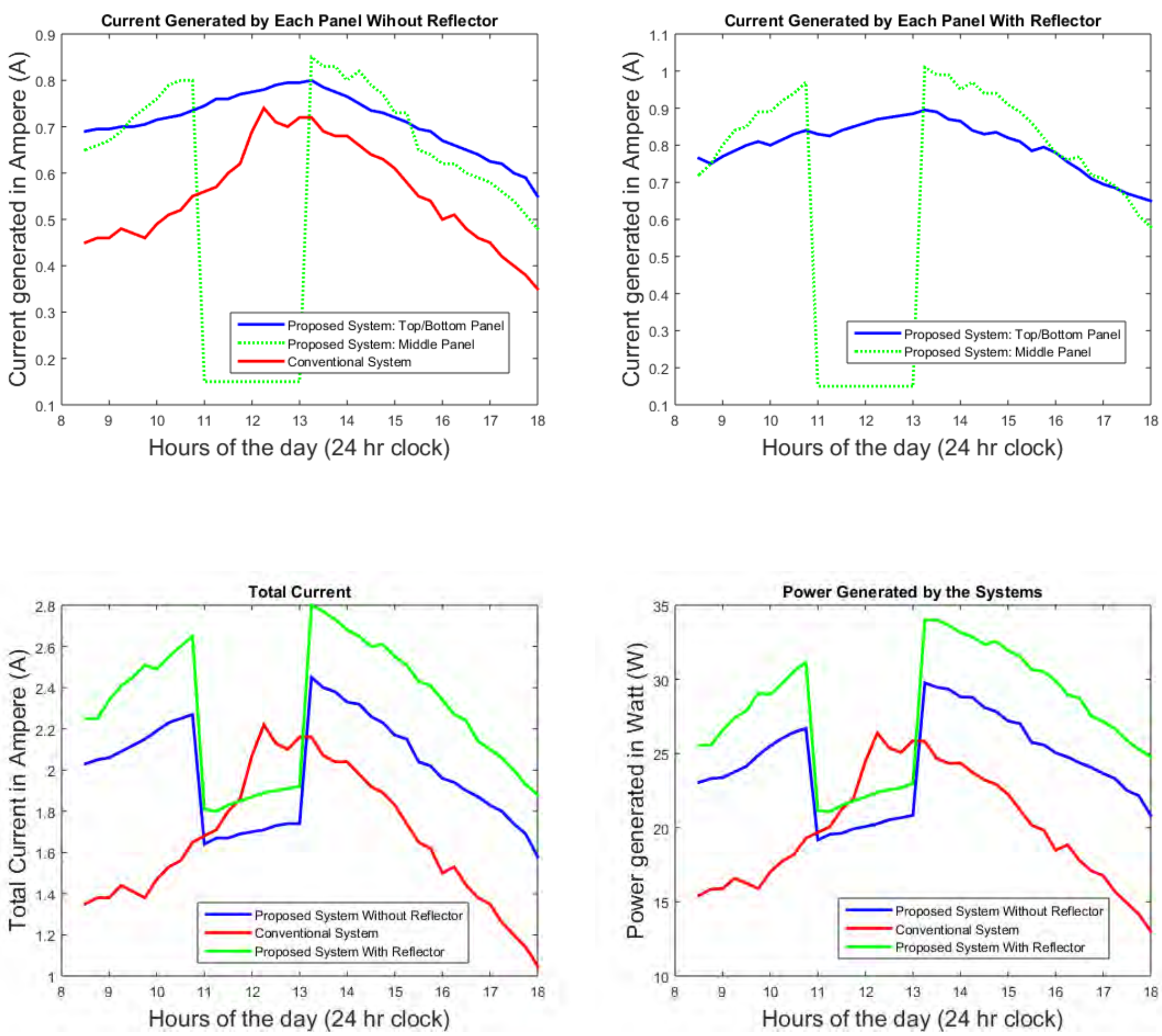


Figure 4.11: Current, Power and Cumulated Energy Plots and comparison for the data taken on 15-March-2017 with reflector.

Date: 17-March-2017 9



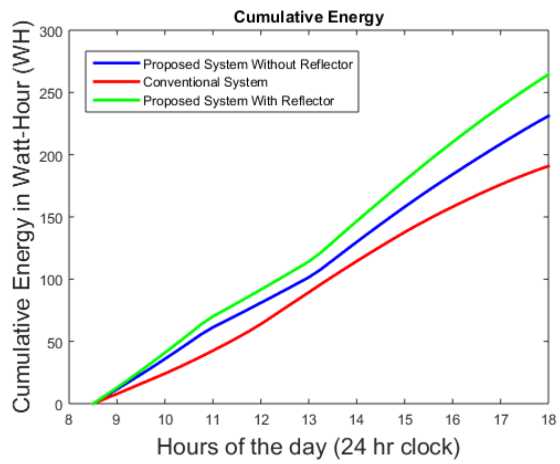
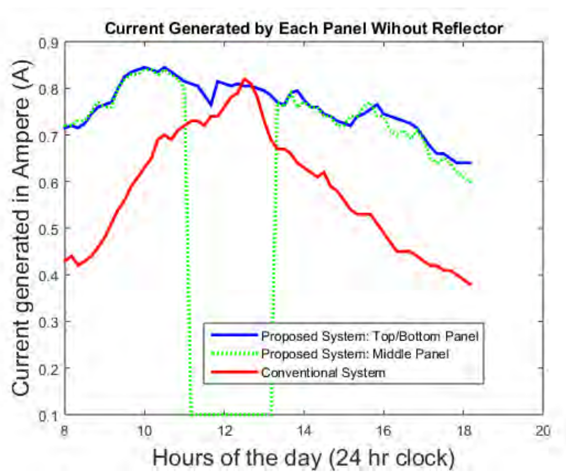
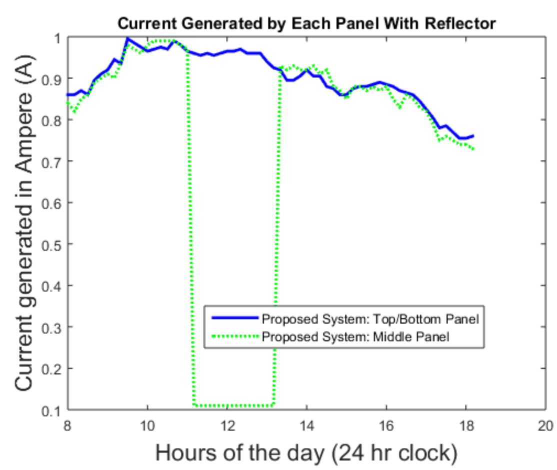


Figure 4.12: Current, Power and Cumulated Energy Plots and comparison for the data taken on 17-March-2017 with reflector.

Date: 27-March-2017 10





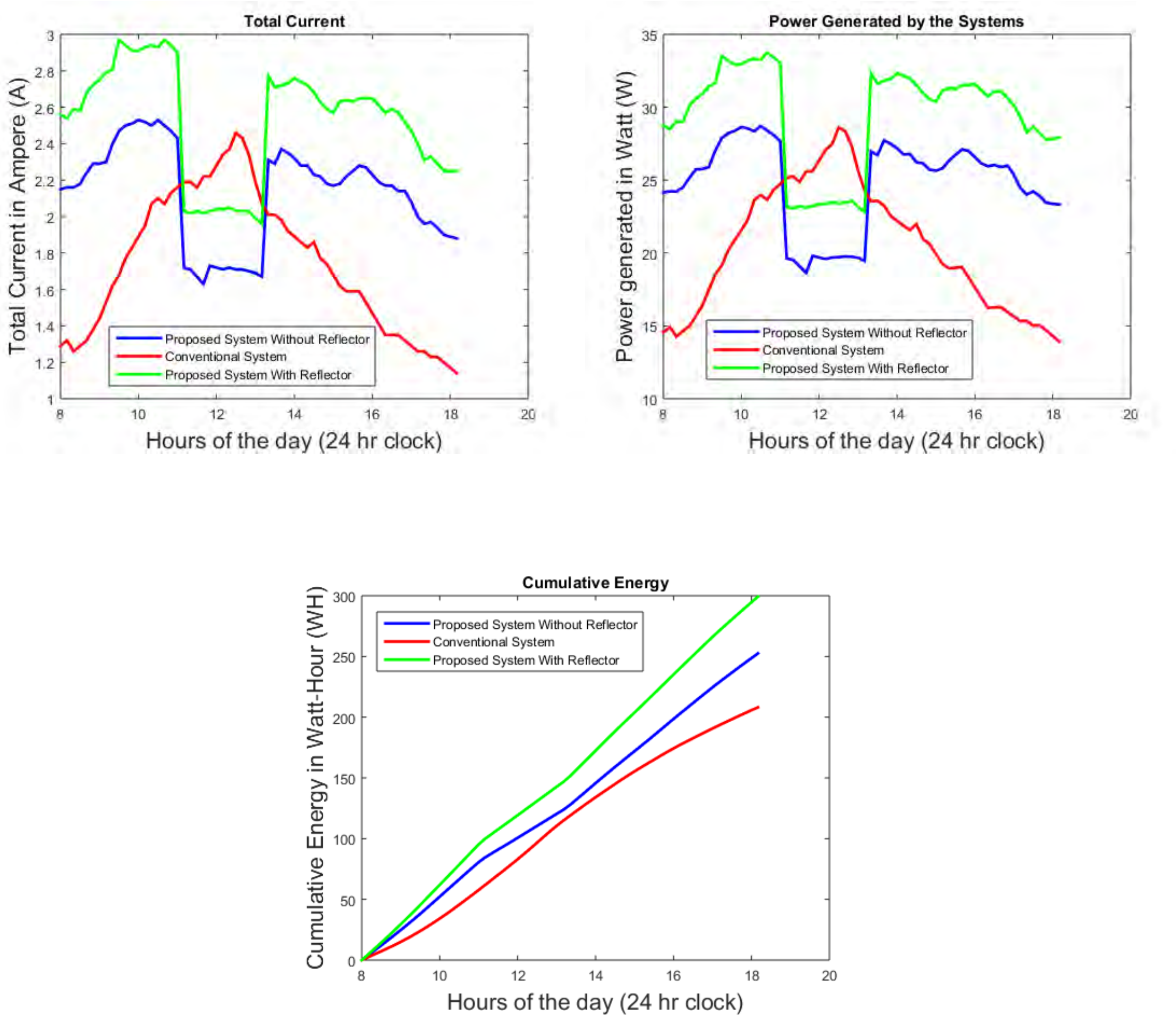


Figure 4.13: Current, Power and Cumulated Energy Plots and comparison for the data taken on 27-March-2017 with reflector.

Date: 2-April-2017 11

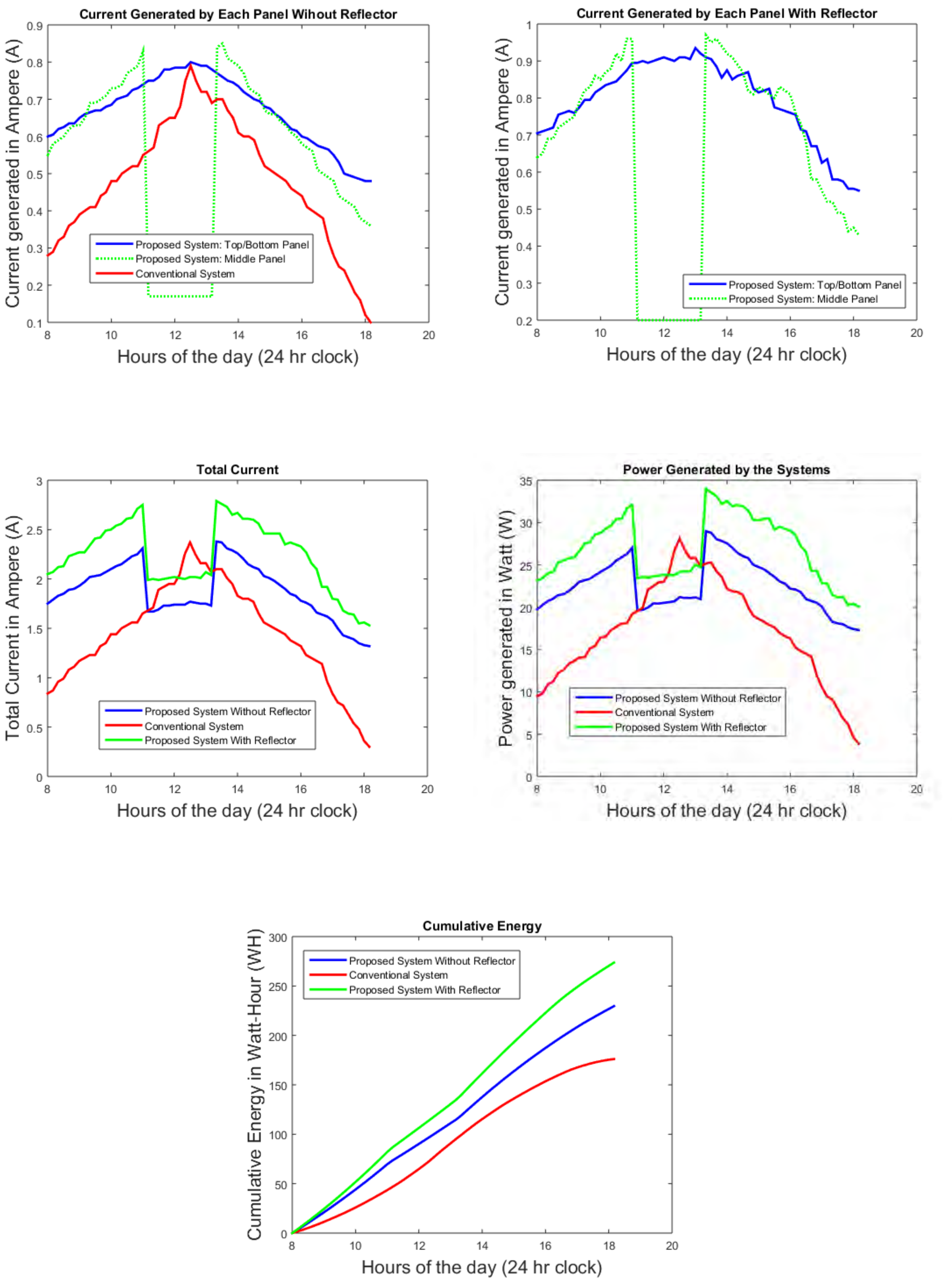


Figure 4.14: Current, Power and Cumulated Energy Plots and comparison for the data taken on 2-April-2017 with reflector.

Date: 8-April-2017 13

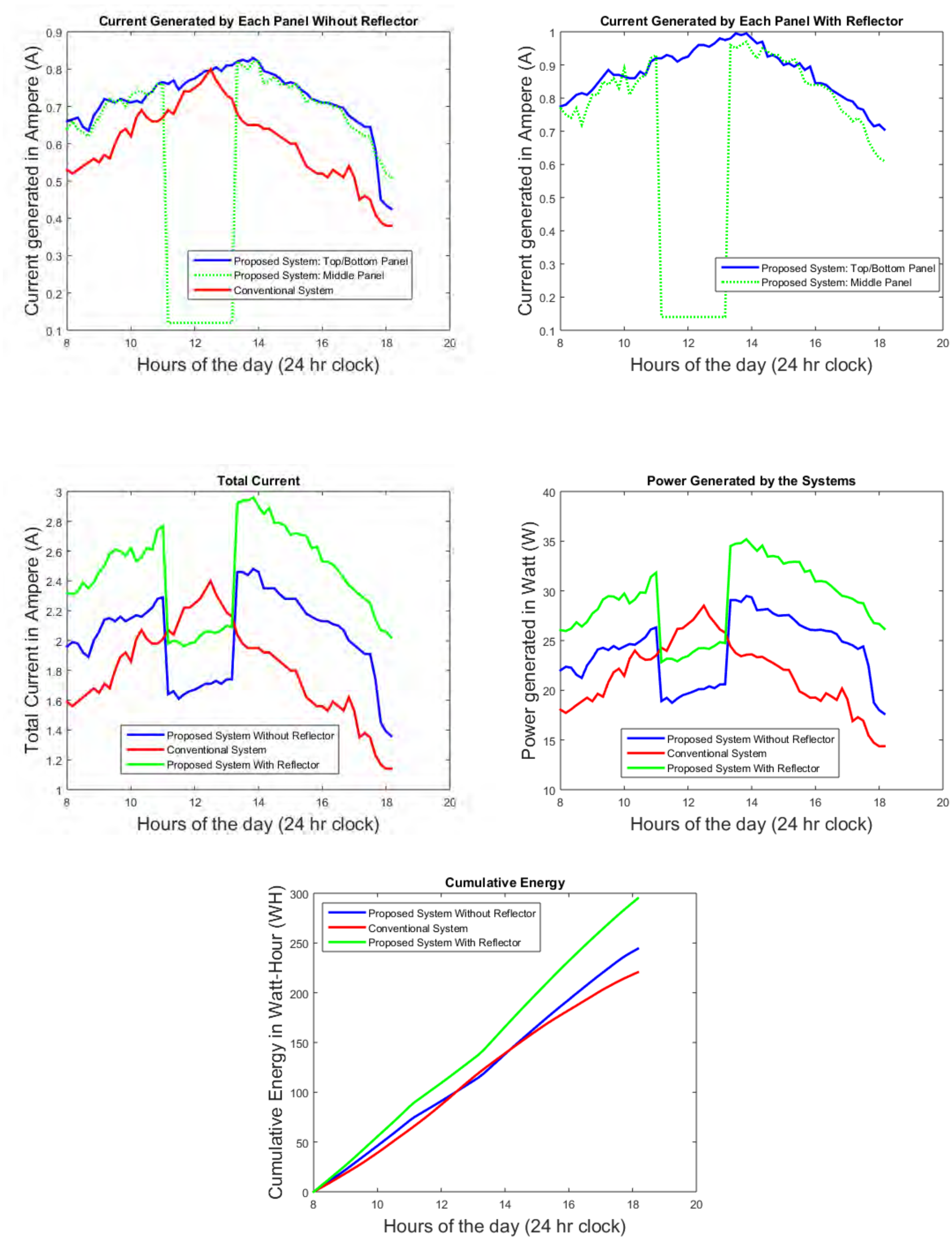


Figure 4.15: Current, Power and Cumulated Energy Plots and comparison for the data taken on 8-April-2017 with reflector.

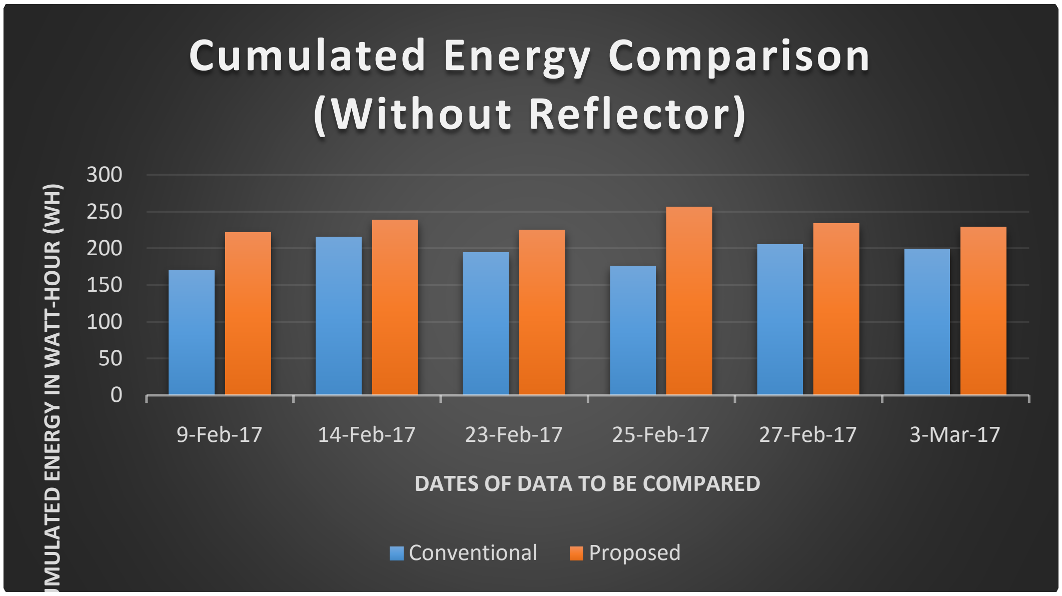
Tables showing the accumulation of energy:

Date	Conventional (WH)	Proposed (WH)	% Difference
09-Feb-17	170.4	221.9	30.22%
14-Feb-17	215.7	238.8	10.70%
23-Feb-17	194.5	225.5	15.94%
25-Feb-17	176.4	256.2	45.24%
27-Feb-17	205.1	234	14.09%
03-Mar-17	199.3	229.3	15.05%

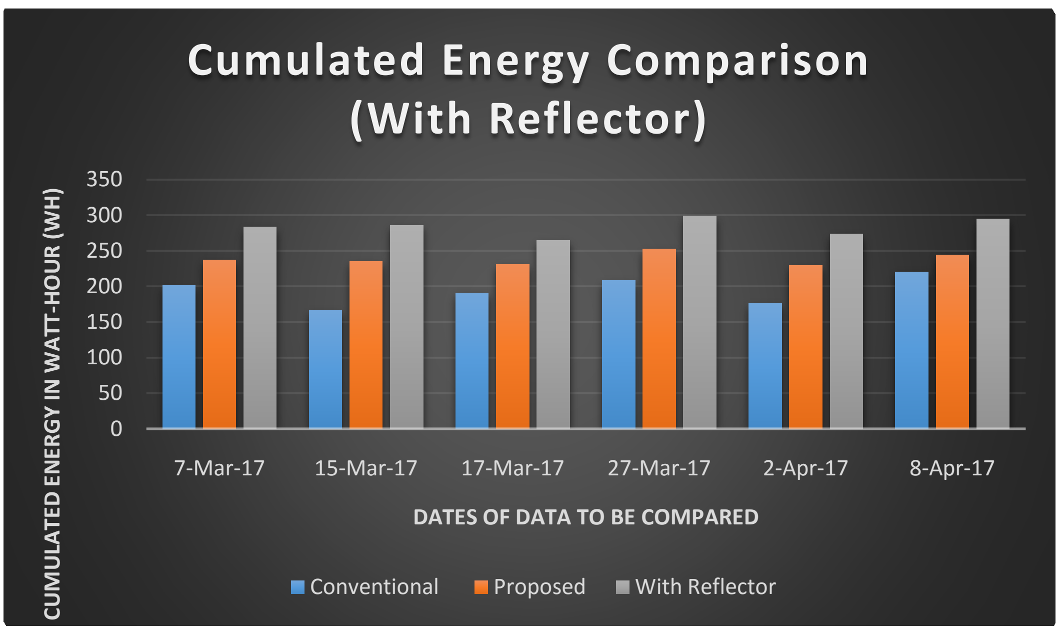
Table 4.1: Accumulation of energy of the Conventional System and the System without Reflector

Date	Conventional (WH)	Proposed (WH)	With Reflector (WH)	% Efficient (With reflector-Proposed)	% Efficient (With reflector-Conventional)
07-Mar-17	201.3	237.1	283.7	19.65	40.93
15-Mar-17	165.9	235	285.8	21.62	72.27
17-Mar-17	190.9	231.1	264.5	14.45	38.55
27-Mar-17	208.1	252.5	299.2	18.5	43.78
02-Apr-17	176.1	229.7	273.7	19.16	55.42
08-Apr-17	220.6	244.3	294.9	20.71	33.68

Table 4.2: Accumulation of energy of the Conventional System, System without Reflector and the System Equipped with Reflector



(a)



(b)

Figure 4.16: (a) Cumulated energy comparison between the fixed panel and the proposed multilayered system. (b) Cumulated energy comparison between the fixed panel, the proposed multilayered system and proposed system with reflector.

As demonstrated in the above graphs, it can be clearly stated that RTC based multilevel Sun tracking solar panel system, if implemented and maintained properly, it can work efficiently in a country like Bangladesh.

The whole period three months of data collection was dived in two. First half, for the data collection of the system without reflector and second half for the data collection of the system equipped with reflector. Figure 4.4 - Figure 4.9 shows the current, power and cumulated energy plots of the data taken during this period. By looking at the figures, it can be deduced that the proposed system is much more efficient and calculations also show that the proposed system has an average efficiency in terms of accumulated energy by 20% approximately.

Figure 4.10 - 4.15 shows the current, power and cumulated energy plots of the data taken during the second half of the period. The graphs demonstrate the current, power and cumulated energy plots of the conventional system, the proposed system and the proposed system equipped with a reflector panel. The plots enable us to get a visual idea about how the current and power varies with time throughout the period of a day. When compared to the proposed system without reflector, the system equipped with the reflector panel has an average efficiency of approximately of 19% in terms of the accumulated energy. When compared with the conventional system, the system equipped with the reflector has an accumulated energy efficiency of 47% approximately. Which is more than double of the efficiency calculated between the proposed system without reflector and the conventional system.

Thus, it can be stated that, a reflector panel used with the proposed system can prove to be very effective in terms of increasing efficiency in a cost effective way.

Chapter 05

Software Implementation

5.1 Software used for programming

For our proposed system, we've used Arduino version 1.6.7. This is an open source project that allows writing and debugging of codes efficiently which is also immensely supported by vast library files. The library files assists in designing algorithms from a sketch book and example's directory. Verification and compilation of error is smooth and easily accessible. By opening Arduino UNO sketch book we can select specific board and upload programming codes.

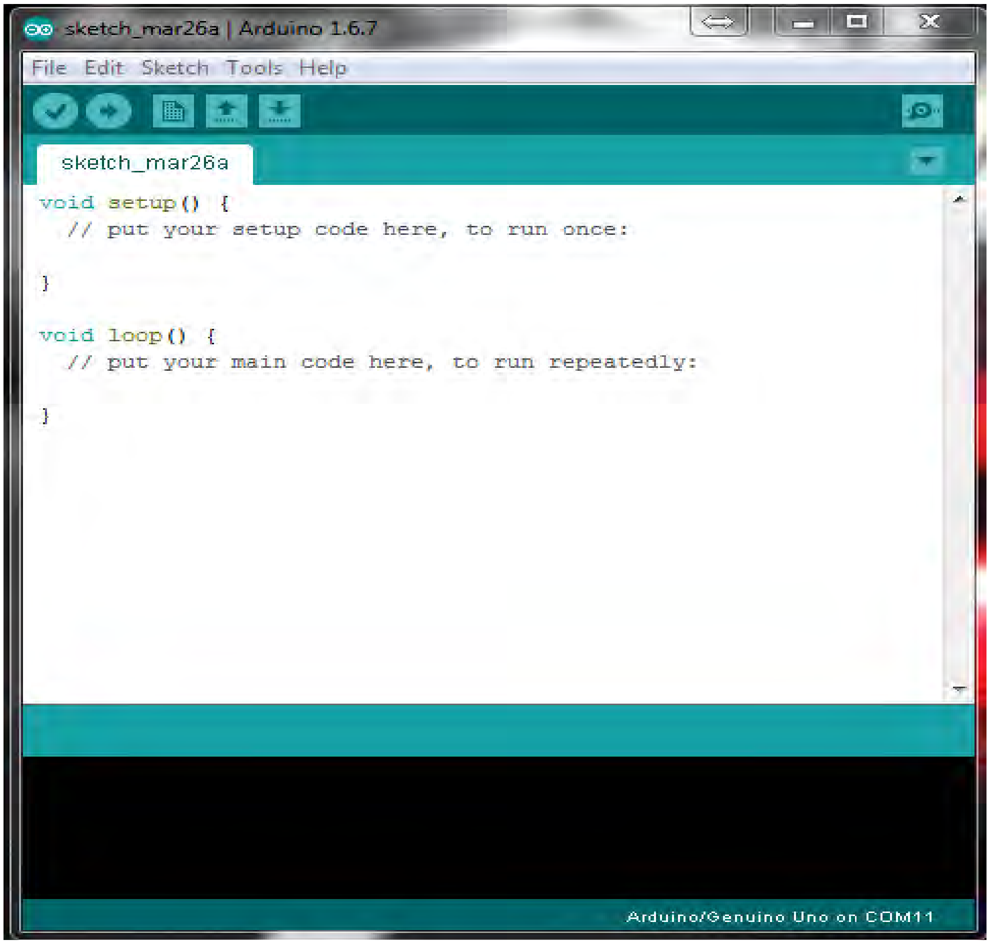


Figure 5.1: Empty sketchbook from Arduino version 1.6.7

5.2 Algorithm for coding

The flow chart in figure 5.2 shows the algorithm used in the micro-controller programming to control the horizontal gliding and rotation motion of the panels to track the sun. The microcontroller reads the real time t and nth day from the real time clock (RTC) and determines the sunrise (T_{SR}) and sunset (T_{SS}) times using the set of Eq. (10)-(14). Then, it calculates the time interval $\Delta T = (T_{SS} - T_{SR})/12$ at which the panels should be rotated.

The panels are rotated at every instance $t = T_{SR} + N.\Delta T$, where N is the number of instances the panels should be rotated and varies from 1 to 12.

When $t = T_{\varphi}$, the time that corresponds to the maximum position of the sun in the sky until which lower panels get full sun exposure, the middle panel is turned in vertically upright position and deactivated until $t = T_{SS} - T_{\varphi}$.

At $t = T_{SR} + (T_{SS} – T_{SR})/2$, i.e. at noon, the upper and lower panels are glided and realigned.

At $t = T_{SS}$, the sunset time, the panels are reset to their original position and angle.

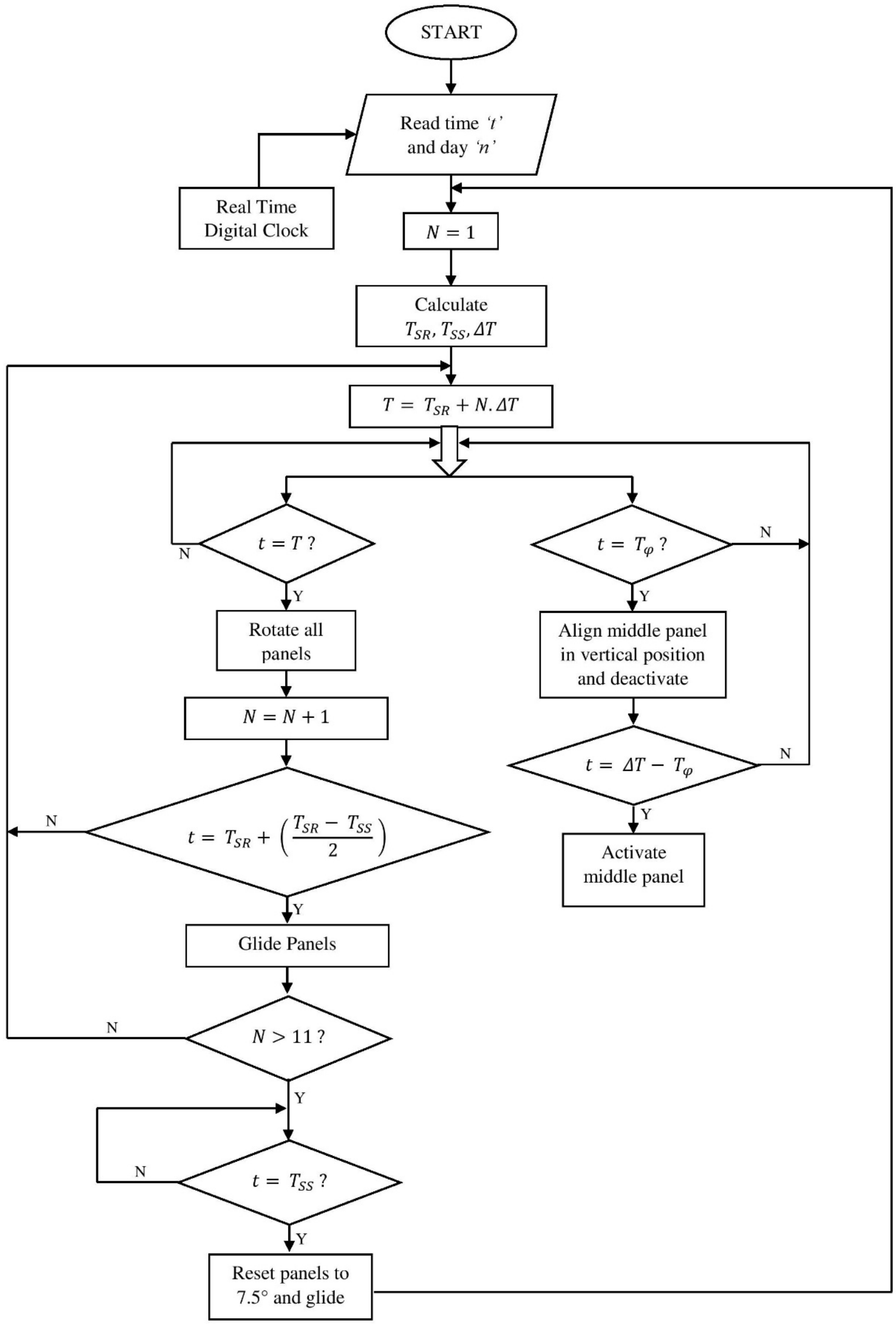


Figure5.2: Flow chart of the algorithm used in the microcontroller programming to control the horizontal gliding and rotational motion of the panels to track the sun

Chapter 6

CONCLUSION

The thesis has presented detailed sun tracking solar system technology and its principle of operation its efficiency and sources of losses to how to mitigate the losses and how to make it more efficient using reflector.

The proposed system consists of three panels mounted in a rack one above another at a fixed distance from each other to minimize the floor area while shifted horizontally from each other by half the panel width to avoid shading of the lower panels. In the proposed system, the panels will be fitted with a tracking system to track the sun to maximize the energy collection. Further, a gliding mechanism is perceived for the panels that will enable the panels glide both ways and realign as the sun moves from east to west to avoid shading. Initial calculation, done for January to April shows that the proposed multilevel three panel system can harness up to 23% more energy than the three conventional fixed panel systems with 33% less area. Instead of continuous tracking, the developed system rotates the panels only 12 times a day, in a step of 15° in each rotation .The proposed system will be useful for large urban city dwellers, especially in third world countries, where not only electricity is in short supply, availability of roof top space toinstall solar panels is also very limited. The sun based power sun following framework is more effective in light of the fact that sun oriented radiation can be a limitless well spring of sustainable power source in our nation as it is arranged close to the equator. In the event that the possibility of this sun following framework can be actualized, the framework will significantly diminish the power issue of our nation.

Future Work

- The bar that holds the panels is not strong enough and not so heavy. So have to ensure the stability.

- We can change the data logger box and the sensors. Hereby we can also use updated sensors for better performance and we can also change the servo motors.

- This system can be an off grid solution if we use obvious glass made huge homes to preserve masses of these solar trackers and control all of the sun trackers using a central server supported by using international climate update and GPS system. This configuration can supply electric power to the national or neighborhood grid additionally.

- If we use glass panel instead of aluminum foil paper, the reflector will be more efficient.

- We can also update the reflector angle measurement system by changing the mechanical construction.

- To get better output, we can use nine reflector panels (aluminum foil) instead of six panels. It can also reduce the panel gap in the existing reflector.

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Appendix

Codes used in Arduino:

Code for the system running:

```
#include <Wire.h>
#include <Time.h>
#include <DS1307RTC.h>
#include <PololuMaestro.h>
#include <SoftwareSerial.h>

SoftwareSerialmaestroSerial(5, 4);

MiniMaestromaestro(maestroSerial);
//These variables are used to scroll LCD, change
//the value of sn to adjust the scroll level
intsn = 14,si=0,sl=0;

//tm stores time and date information for RTC
tmElements_t tm;


//seconds,minute,hour,day,month,year
ints,mi,h,d,mo,y;

//day Number
int N;
int actuator1 = 8;
int actuator2 = 9;

doublepanPos = 0;
intnewPos = 0;
intactst = 0;

//SRT = Sun rise time, SST= Sun set time
double SRT, SST;
```

```
double longitude = 90.35;
doublelattitude = 23.7;
const float pi = 3.14159265359;
void setup() {
pinMode(actuator1, OUTPUT);
pinMode(actuator2, OUTPUT);
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
actst = 0;
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);
Serial.begin(9600);
while (!Serial) ; // wait for serial
delay(200);
maestroSerial.begin(9600);
maestro.setSpeed(0, 2);
maestro.setSpeed(3, 2);
maestro.setSpeed(6, 2);
maestro.setAcceleration(0, 127);
maestro.setAcceleration(3, 127);
maestro.setAcceleration(6, 127);
}
void loop() {
if (RTC.read(tm)) {
updateTime();
numberOfDay();
sunriseTime();
sunsetTime();
rotatePanels();
  } else {
if (RTC.chipPresent()) {
Serial.println("The DS1307 is stopped.  Please run the SetTime");
Serial.println("example to initialize the time and begin running.");
Serial.println();
    } else {
```

```
Serial.println("DS1307 read error!  Please check the circuitry.");
Serial.println();
    }
delay(9000);
  }
delay(1000);
}

void print2digits(int number) {
if (number >= 0 && number < 10) {
Serial.write('0');
  }
Serial.print(number);
}

voidupdateTime(){
  s = tm.Second;
mi = tm.Minute;
  h = tm.Hour;
  d = tm.Day;
mo = tm.Month;
  y = tmYearToCalendar(tm.Year);
print2digits(h);
Serial.print(":");
print2digits(mi);
Serial.println();
}
voidnumberOfDay(){
int N1 = floor(275 * mo / 9);
int N2 = floor((mo + 9) / 12);
int N3 = (1 + floor((y - 4 * floor(y / 4) + 2) / 3));
  N = N1 - (N2 * N3) + d - 30;
}
voidsunriseTime(){
double del = 23.45*sin(360*pi/180/365*(N+284));
doubleWs = acos(-tan(lattitude*pi/180)*tan(del*pi/180))*180/pi;
```

```
double AST = 720-Ws*4;
double LSTM = 15*round(longitude/15);
double D = 360*pi/180*(N-80)/365;
double ET = 9.87*sin(2*D)-7.53*cos(D)-1.5*sin(D);
  SRT= AST-4*(LSTM-90.25)-ET;
  //SRT = 13*60+55;
}
voidsunsetTime(){
double del = 23.45*sin(360*pi/180/365*(N+284));
doubleWs = -acos(-tan(lattitude*pi/180)*tan(del*pi/180))*180/pi;
double AST = 720-Ws*4;
double LSTM = 15*round(longitude/15);
double D = 360*pi/180*(N-80)/365;
double ET = 9.87*sin(2*D)-7.53*cos(D)-1.5*sin(D);
  SST= AST-4*(LSTM-90.25)-ET;
  //SST = 14*60+19;
}

int stat[] = {0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0};

voidrotatePanels(){
doubledelT = (SST-SRT)/12;
doublecurrentTime = h*60+mi;
if(currentTime-SRT>=0){
if (currentTime == SRT+5.5*delT){
panPos = 5.5;
}else if (currentTime == SRT+7.5*delT){
panPos = 7.5;
}else{
panPos = (currentTime-SRT)/delT+1;
    }
if(panPos>12){
panPos = 0;
    }
}else{
panPos = 0;
```

```
  }
Serial.print("State Number: ");
Serial.println(panPos);
if (panPos<=5){
newPos = (int) panPos;
}else if(panPos == 5.5){
Serial.println("Now 5.5");
newPos = 6;
}else if(panPos<=7){
newPos = (int) panPos + 1;
}else if(panPos == 7.5){
newPos = 9;
}else {
newPos = (int) panPos + 2;
  }
if(!stat[newPos]){
reposPanels(newPos);
  }
if (newPos>14){
newPos = 0;
  }
}

voidreposPanels(intpanPos){
double top, bottom, middle;
switch (panPos) {
case 0:
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);
actst = 1;
Serial.println("no state");
top = 848*4;
middle = 2224*4;
```

```
bottom = 2304*4;
break;
case 1:
top = 848*4;
middle = 2224*4;
bottom = 2304*4;
if(actst == 0){
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);

delay(15000);
      }
actst = 1;
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);

delay(5500);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);

Serial.println("state 1");
break;
case 2:
if (actst == 0){
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
delay(5500);
      }

digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);
actst = 1;
top = 955.5*4;
```

```
middle = 2043.25*4;
bottom = 2162.25*4;
Serial.println("state 2");
break;
case 3:
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);
actst = 1;
top = 883.75*4;
middle = 2101*4;
bottom = 2196.25*4;
Serial.println("state 3");
break;
case 4:
if (actst == 0){
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
      }
actst = 1;
top = 1079.00*4;
middle = 1952.5*4;
bottom = 2032.5*4;
Serial.println("state 4");
break;
case 5:
if (actst == 0){
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
```

```
digitalWrite(actuator2, HIGH);
      }
actst = 1;
top = 1247*4;
middle = 1762.25*4;
bottom = 1977*4;
Serial.println("state 5");
break;
case 6:
if (actst == 0){
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
      }
actst = 1;
top = 1247*4;
middle = 624*4;
bottom = 1977*4;
Serial.println("state 5.5");
break;
case 7:
if (actst == 0){
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
      }
actst = 1;
top = 1396.75*4;
middle = 624*4;
bottom = 1848.5*4;
Serial.println("state 6");
break;
```

```
case 8:
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
delay(15000);
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, HIGH);
actst = 1;
top = 1984*4;
middle = 2224*4;
bottom =1220*4;
Serial.println("state 7");
break;
case 9:
top = 1984*4;
middle = 1113.75*4;
bottom = 1220*4;
Serial.println("state 7.5");
break;
case 10:
top = 2077.25*4;
middle = 1113.75*4;
bottom = 1118*4;
Serial.println("state 8");
break;
case 11:
top = 2350.5*4;
middle = 919.25*4;
bottom = 1004*4;
Serial.println("state 9");
break;
case 12:
top = 2437*4;
middle = 802.75*4;
bottom = 865.5*4;
Serial.println("state 10");
break;
```

```
case 13:
if (actst == 0){
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
delay(15000);
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(5000);
      }
actst = 1;
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);

top = 2349.25*4;
middle = 802.75*4;
bottom =1006.5*4;
Serial.println("state 11");
break;
case 14:
if (actst == 0){
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, HIGH);
delay(15000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);
      }
actst = 1;
digitalWrite(actuator1, LOW);
digitalWrite(actuator2, LOW);
delay(5000);
digitalWrite(actuator1, HIGH);
digitalWrite(actuator2, LOW);

top = 2528*4;
middle = 624*4;
bottom = 768*4;
```

```
Serial.println("state 12");
break;
  }
stat[newPos] = 1;
if (!newPos){
stat[12] = 0;
}else{
stat[newPos-1] = 0;
  }
maestro.setSpeed(0, 2);
maestro.setSpeed(3, 2);
maestro.setSpeed(6, 2);
maestro.setAcceleration(0, 2);
maestro.setAcceleration(3, 2);
maestro.setAcceleration(6, 2);
maestro.setTarget(0, top);
maestro.setTarget(3, middle);
maestro.setTarget(6, bottom);
delay(2000);
maestro.setTarget(0, 0);
maestro.setTarget(3, 0);
maestro.setTarget(6, 0);
Serial.print("Top Panel: ");
Serial.println(round(0.029532*(top)-90.407));
Serial.print("Middle Panel: ");
Serial.println(round(0.029532*(middle)-90.407));
Serial.print("Bottom Panel: ");
Serial.println(round(0.029532*(bottom)-90.407));
}
```

Code for data logger:

```
#include <SPI.h>
#include <SD.h>
#include <Wire.h>
#include <Time.h>
```

```
#include <DS1307RTC.h>
File myFile;

int currentSensor1 = A0;
int currentVal1;
int voltageSensor1 = A1;
int voltageVal1;
int currentSensor2 = A2;
int currentVal2;
int voltageSensor2 = A3;
int voltageVal2;
int currentSensor3 = A4;
int currentVal3;
int voltageSensor3 = A5;
int voltageVal3;
intchangeFile = A6;
double sumV1, sumV2, sumV3, sumI1, sumI2, sumI3;
int c;
double pc1, pc2, pc3, pv1, pv2, pv3;
void setup() {
  // put your setup code here, to run once:
Serial.begin(9600);
Serial.println("Current sensing started!");
Serial.print("Initializing SD card...");

if (!SD.begin(53)) {
Serial.println("initialization failed!");
return;
  }
Serial.println("initialization done.");
  sumV1 = 0;
  sumV2 = 0;
  sumV3 = 0;
  sumI1 = 0;
  sumI2 = 0;
  sumI3 = 0;
```

```
  c = 0;
  pc1 = 0;
  pv1 = 0;
  pc2 = 0;
  pv2 = 0;
  pc3 = 0;
  pv3 = 0;
}

void loop() {
tmElements_t tm;

  // put your main code here, to run repeatedly:
while(c<200){
    currentVal1 = analogRead(currentSensor1);
    voltageVal1 = analogRead(voltageSensor1);
    currentVal2 = analogRead(currentSensor2);
    voltageVal2 = analogRead(voltageSensor2);
    currentVal3 = analogRead(currentSensor3);
    voltageVal3 = analogRead(voltageSensor3);

    sumI1 += currentVal1;
    sumV1 += voltageVal1;
    sumI2 += currentVal2;
    sumV2 += voltageVal2;
    sumI3 += currentVal3;
    sumV3 += voltageVal3;
c++;
delay(10);
  }

double result = round(sumI1/c);
double current1 = floor((0.028496*result - 14.629)*1000);
result = round(sumV1/c);
double voltage1 = 0.023647*result-1.0186;
```

```
result = round(sumI2/c);
double current2 = floor((0.026189*result - 13.463)*1000);
result = round(sumV2/c);
double voltage2 = 0.056733*result-1.7727;

result = round(sumI3/c);
double current3 = floor((0.029002*result - 14.601)*1000);
result = round(sumV3/c);
double voltage3 = 0.055008*result-1.5791;
if ((pc1!=0 && abs(current1-pc1)>0.02)|| (pv1!=0 && abs(voltage1-
pv1)>0.05)||
      (pc2!=0 && abs(current2-pc2)>0.02)|| (pv2!=0 && abs(voltage2-
pv2)>0.05)||
      (pc3!=0 && abs(current3-pc3)>0.02)|| (pv3!=0 && abs(voltage3-
pv3)>0.05)){
    //Serial.println("Broken");
}else{
RTC.read(tm);
Serial.print(tm.Hour);
Serial.print(":");
Serial.print(tm.Minute);
Serial.print("     ");
Serial.print("c1: ");
Serial.print(current1);
Serial.print("     ");
Serial.print("v1: ");
Serial.print(voltage1);
Serial.print("     ");
Serial.print("c2: ");
Serial.print(current2);
Serial.print("     ");
Serial.print("v2: ");
Serial.print(voltage2);
Serial.print("     ");
Serial.print("c3: ");
Serial.print(current3);
```

```
Serial.print("     ");
Serial.print("v3: ");
Serial.println(voltage3);
myFile = SD.open("data.txt", FILE_WRITE);
RTC.read(tm);
if(myFile){
myFile.print(tm.Hour);
myFile.print(":");
myFile.print(tm.Minute);
myFile.print("    ");
myFile.print("c1: ");
myFile.print(current1);
myFile.print("    ");
myFile.print("v1: ");
myFile.print(voltage1);
myFile.print("    ");
myFile.print("c2: ");
myFile.print(current2);
myFile.print("    ");
myFile.print("v2: ");
myFile.print(voltage2);
myFile.print("    ");
myFile.print("c3: ");
myFile.print(current3);
myFile.print("    ");
myFile.print("v3: ");
myFile.println(voltage3);
    }
myFile.close();
  }

  c = 0;
  sumI1 = 0;
  sumV1 = 0;
  sumI2 = 0;
  sumV2 = 0;
```

```
  sumI3 = 0;
  sumV3 = 0;

  pc1 = current1;
  pv1 = voltage1;

  pc2 = current2;
  pv2 = voltage2;

  pc3 = current3;
  pv3 = voltage3;
}
```