KING FAHD UNIVERSITY FOR PETROLEUM AND MENIALS

COMPUTER ENGINEERING DEPARTMENT

SENIOR PROJECT DESIGN – COE 485

FINAL REPORT

MICROCONTROLLER – BASED DUAL-AXIS SUN TRACKING SYSTEM (MDASTS)

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Contents

LIST OF FIGURES

LIST OF TABLES

1. Introduction

Human in their nature tends to use more if available and suitable for their need, and as the population of the earth increases, theoretical and practical thinkers tend to wonder about the future ahead. Are we going to have sufficient food and energy to survive the upcoming surge in population with the current use of resources, a question that any concerned individual would care to know the answer of. Rather more frequently, the source of energy and power comes to play the main actor of the survival of the human race. As the article labeled ("**When will oil run out?**") written by the institute of mechanical engineers [1] indicate that "There are an estimated 1.3 trillion barrels of proven oil reserve left in the world's major fields, which at present rates of consumption will be sufficient to last 40 years over of consumption will be sufficient to last 40 years.". As the table (Table 1)[2] shown below, the reserves of the oil are in sharp decrease.

Table 1 : Table showing the oil reserves on top 22 countries and the Middle East as a sum and the r e

Crude Oil Proved Reserves (Billion Barrels)	2013	2014
Rest of the World	1645.984	NA
Middle East	802.1571	804.1271
Central & South America	325.9296	326.4106
Venezuela	297.57	297.74
Saudi Arabia	267.91	268.35
North America	213.8981	NA
Canada	173.1052	173.2
Iran	154.58	157.3
Iraq	141.35	140.3
Africa	127.7391	126.7291
Eurasia	118.886	118.886
Kuwait	104	104
United Arab Emirates	97.8	97.8
Russia	80	80
Libya	48.01	48.47
Asia & Oceania	45.35564	45.87487
Nigeria	37.2	37.14
United States	30.529	NA
Kazakhstan	30	30
Qatar	25.38	25.24
China	23.7168	24.3756
Brazil	13.1542	13.2193
Algeria	12.2	12.2
Europe	12.01863	12.43736

Nevertheless, the idea of alternative solutions to provide energy became more popular in the last decade and it is becoming more present in the mind than ever before. While a nuclear planet is a solution to provide energy and power. It is still in the early stages of developing and is still more expensive than oil. Renewable energy is now the main trend toward solving the problem of the energy consumption.

While some countries in Europe depends heavily on wind to generate power, for sunny countries like Saudi Arabia, solar power is the best fit. Related project and researches in building solar farms to harness solar energy are becoming concurrent and efficient as the time pass by [3]. The Solar Tracker project is aiming toward increasing the amount of solar power extracted from sunrays using Dual-Axis solar panels. An application or a proof of concept is applied through attaching that solar panel to a traffic light to feed it with power using solar panels instead of or with the energy supplied from the grid. With this project, the supply of electricity to traffic lights would be solely dependent on solar energy or in the worst case, it would reduce the consumption by half. Consequently it would lower the oil production, reserve the oil residue for longer and better usage, keep the environment green and meet the increasing demand for power.

2. Problem Statement

The proof of concept for the project is traffic lights. To be specific, supplying the traffic light with cost-effective, power-saving solar energy to subsidies and save the power used to feed the traffic light coming from the electricity grid.

This project aims to solve the problem of the increase demand of power by two main goals:

a. Researching in ways to increase the utilization of solar panels.
b. Use the well-developed and effectual solar panel to feed the traffic lights.

As a result of this system being built, many advantages and benefits will occur globally and locally, for a worldwide effect, the following is expected to result from implementing this project:

1. Greener world, using solar radiation as a source of energy is not only infinite, but, it is also the best energy in terms preserving the environment and keeping it clean.
2. Having a successful experiment using renewable energy resource would open the market for cheaper and more realist approaches for this type of energy.

Locally, a number of shifted polices may occur in the country if solar energy became first instead of oil:

1. The energy used to supply traffic lights could be transferred into money and invested in building houses, factories, neighborhood and more.

2. Achieving closed economy in energy needs would be closer to reality than before.

While the idea of developing such a system is indeed excellent and persuasive, the solar energy is actually of use for small application. However, solar energy used to supply houses is a troublesome to manage for electricity companies.

3. Project Specification

3.1. Requirements

The system should perform the following tasks:

a. Adjust the solar panel toward the angle of most power outcome from the sun through a hybrid module that implement two approaches.
b. Feed the traffic light with at least 70% of its daily power.

With the following criteria:

1. Cost-effective solution for mass production.
2. Competent dual-axis tracking system with high degree of precision.
3. Battery operated system charged using solar panel.
//Fall-safe switche in case of an emergency or an error.

3.2. Specifications

The system uses a battery (batteries) charged from the solar panel through a controller to produce 12-24 VDC that will run the application. The solar panel operates in four modes; each mode will test a certain method of applying the harvesting operation. The modes are as follows:

1. **Stationary**: a mode created to test the quantity of energy harvested if the solar panel is fixed.
2. **Sensors**: a mode to examine the amount of power collected from the panel using sensors only.
3. **Algorithm:** an approach modified to asset the quantity of energy gathered if the angle is computed using an algorithm to calculate the position of the sun.
4. **Hybrid:** a method that combines the effort of both sensors and the algorithm to compute the angle.

In addition, to fulfill the application's requirement, a minimal of the following should be harvested to feed the traffic light:

Traffic Light	Need
Power	RED : 6 – 10 watt
	GREEN: 8 – 12 watt
	YELLOW: 8 – 20 watts
Voltage	12 – 24 VDC - 100-277VAC
Current	0.5 – 0.9 amps

4. System Design

This system design and architecture is explained through multipoint view beginning from the architecture ending with the implementation.

4.1. Architecture

To simplify the idea of the architectures of system, the following divisions will be discussed:

4.1.1. Sub-Function Identification

a. Locating: This function is concerned with determining the location of the sun.
b. Computation: This function is designated to take care of angle computation.
c. Adjustment: The function is responsible for adjusting the panel according the computation given by the previous function.

Furthermore, locating is done through the positioning algorithm and sensors. Then, the computation phase for the sensors values and for the difference in degrees between the algorithm and sensors. Finally the adjustment for the solar panel according to the outcome of the difference.

Figure 1: The sub-function identification for the project.

4.1.2. System architecture and components

The system architecture as whole have a structure of hardware components with modules based on software, the system architecture from top to bottom is shown in figure 2 shows from left to right. The structure is divided into two groups:

a. Hardware : Physical component that perform various function (indicated by a brown **color**)
b. Software: program that gather and control the hardware component. (indicated by a yellow **color**)

And the electrical grid as an outer source for power (indicated by black color).

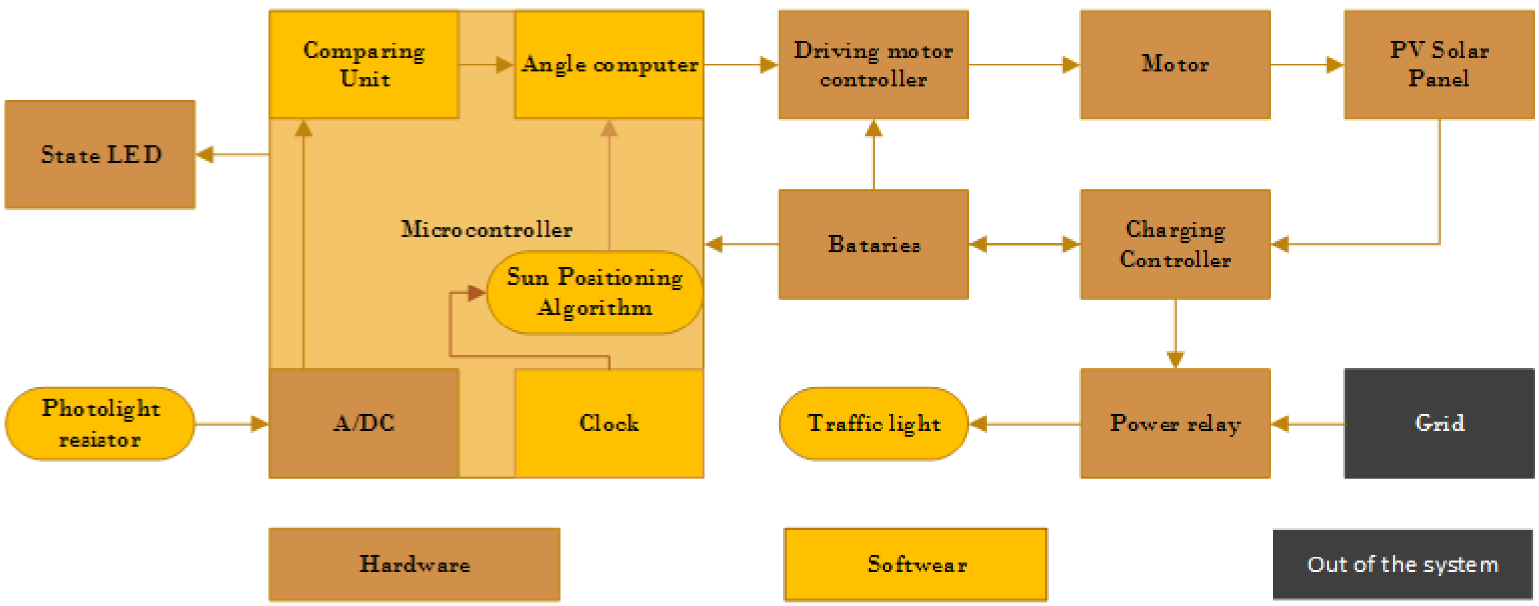

Figure 2 : The system architecture involving the entire component and their relation to each other.

4.1.3. Hardware versus Software Components & Functionality

The design uses both hardware and software component to benefit most from both and get the maximum output with the lowest power consumption. In table 2, a display of the components is shown, beginning with hardware modules then the software ones.

Table 2: Table showing all the hardware components as well as software ones in the system.

Components	Function
Wide-Range light sensors	Specialized light sensors to detect the slightest difference in the photons coming from the sunray.
Batteries	To provide a constant 12-24 DC voltage to be feed to the charger controller.
PV Solar Panel	To absorb the sun light and transform into electrical charge 12-24 volts DC
Charging Controller	To regulate the outcome of the solar panel through batteries, control the operation of charging batteries to increase its life span and provide a constant 12-24 voltage outcome to connect it to the load
State LEDs	To indicate the mode that run the system
Servo Motors	To control and move the gears towards the direction needed according to the input given by the driver controller
Microcontroller	Including AD/C, used as an interface to control the hardware components and run the software modules.
Driving Motor Controller	To receive the input from by either the comparing unit Angle computer and transfer it to the motors accordingly
Time-Date keeper	A software component using the real-time clock of the microcontroller (hardware) to output the time and date to position algorithm.
Positioning algorithm	A software to calculate the position of the sun
Angle Computer	A software component to compute the angle given the input received from the sensors
Comparing Unit	A software to compare the values given by the positioning algorithm and the angle calculator and decide the course of action

4.2. Component Design and Implementation

4.2.1. Ready to use component

a. Servo Motors.
b. Wide-Range light sensors.
c. PV Solar Panel.
d. Batteries.
e. State LEDs.
f. Driving motor controller.
g. Charging controller.

4.2.2. Customized component - Design

4.2.2.1. First: Mechanical aspect

While indeed the project contains a digital in a more relevant aspect, it contains a heavy duty mechanical part that will affect the choices for the digital aspect. To gain the dual – axis movement, there are two designs for the stand "holder", all using motors and in some cases linear actuators. The dual-axis will be referred to as ***Up - Down*** and ***left - Right*** (For ease of understanding), the following are the choices for design.

First: Rotation-based design:

This scheme will implement the ***Up - Down*** direction using a gear to move it back and forth (max-angle 180^0), while the ***left - Right*** using a rotation of the whole panel (max-angle 360^0). Figure 3 illustrate the movement.

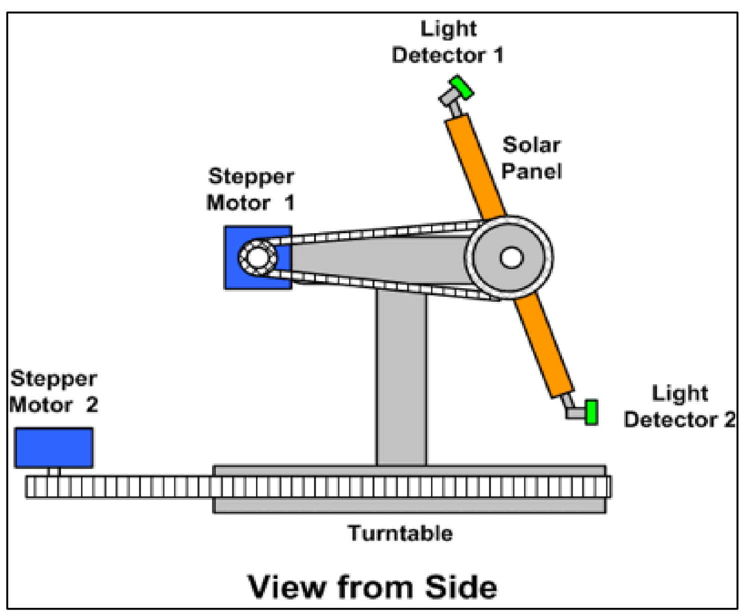

Figure 3 : First approach in designing the Handler (Stand). [4]

Second: Linear actuator- based

The other approach is to use actuator to move the solar panel to both directions. This approach does not include rotation at all. Using one motor to move ***left - right*** and a linear actuator to move ***up – down.*** This approach has more free movement than the first method. Figure 4 displays the component detailed structure.

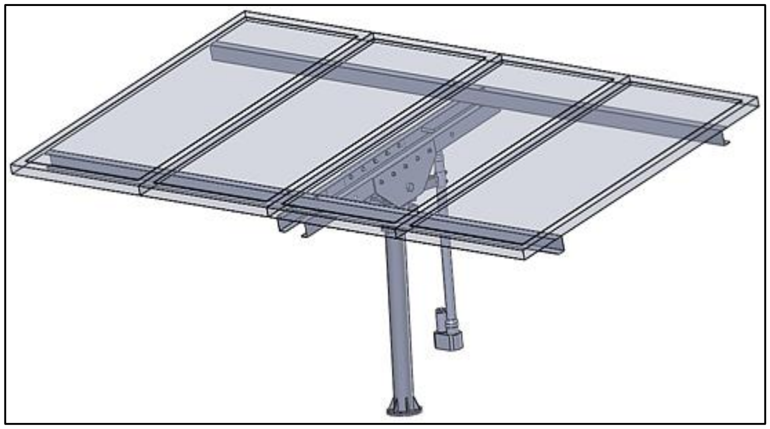

Figure 4: Second approach in designing the Handler (Stand). [5]

These two approaches have their advantages and disadvantage accordingly, in which they rely on various factors, Table 4 shows the different pros and cons for both designs.

Table 3: Two implementation of the dual-axis movement

Design	Advantages	Disadvantages	Notes
Rotation-Based	Easier and more reliable implementation, all based on servo or stepper motors only (cheaper) and more accurate	Difficult and longer configuration time, totally dependent on the stall torque of the motors.	There are tweaks to solve the torque issue
Actuator-Based	Easier in control and movement, easier installation and hydraulics hold the weight of the stand	Expensive, less accurate	DC motors are not expensive, hydraulics are.

4.2.2.2 Second: Algorithm

Sensors are somewhat accurate, but mistakes could happen and the margin for the difference is changing throughout the year. Indeed, the energy used to move the solar panel is small, but at a higher frequency, it could make an effect. Although even with that much error in margin, it would not consume that much of power, but at the level of harvesting and efficiency that this project seeks, it is considered consuming. Thus, a pre-defined algorithm is used to calculate ahead of time the position of the sun and give its location given the time and date. The algorithm uses multiple variables and considers multiple issues to give the most accurate outcome. To illustrate, the algorithm depends on the latitude and longitude along with Greenwich Mean Time (GMT) Time difference to calculate the position of the sun. In contrary to the popular thinking about solar orientation, the sun moves with respect to time two different directions .The resultant of that is three angles, which are the Azimuth, Elevation (Zenith) and Slope.

The sun movement consists of two angles:

a. Azimuth: This angle is concerned with the daily motion of sun that draws an arc from the east to the west, it is called the Azimuth. The red line in Figure 5 representing the Sun's path during the course of day. The Azimuth is as indicated in figure 7 is the observer angle with respect to the sun movement.

b. Elevation (Altitude): In the course of a year, there are changes in the size of the arc and its position in the sky as indicated in Figure 5. The different red lines represent different arc sizes and positions throughout the year. As Figure 6 illustrate the elevation angle is the position of the sun in relevant to horizon an angle toward the middle of the sky.

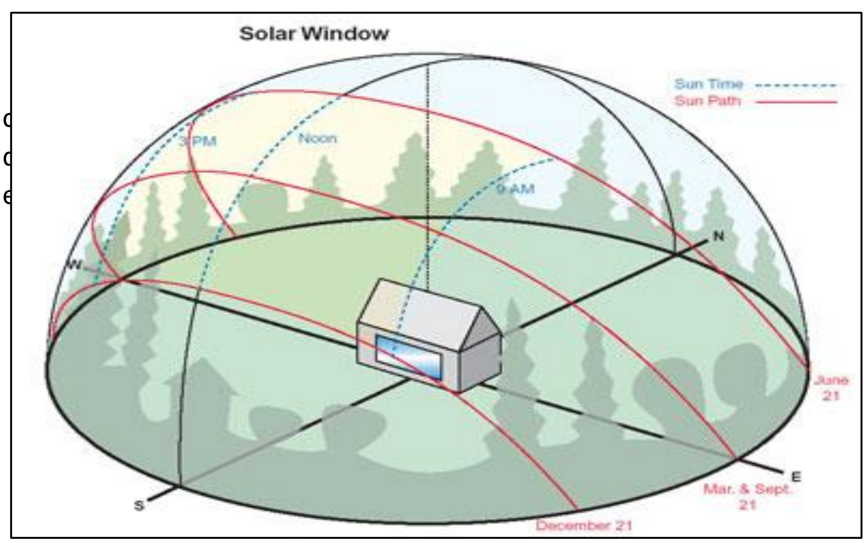

Figure 5: The archaic movement of the sun (Azimuth) [6]

In addition, there is the Slope. Which as figure 6 indicates, the inclination of the solar panel with the respect to horizon vertical line.

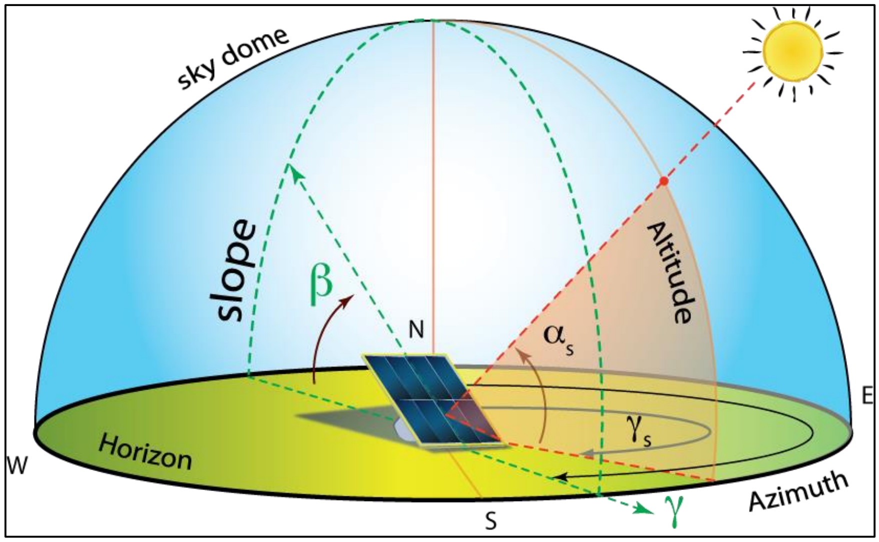

Figure 6: The Azimuth, Altitude and Slope [7]

4.2.2.3 Third: The hybrid module

The hybrid module is an integration of two approaches, sensors and algorithm, to reach the optimal power consumption with at most accuracy, the hybrid module will lower the usage of sensors and increase its dependence on the algorithm to preserve power and to predict the next movement. In table 2.1, the illustration of each approach main advantages and disadvantages:

Table 4: The pros and cons of using every approach for the solar panel.

Approach	Advantages	Disadvantages	Notes
Sensors	Accurate	Power consuming	The power consumption is low in general
Algorithm	Prediction & Power saving	Not precise	More errors means more movement
Hybrid	Accurate and Power saving	Management is difficult	

In general, the hybrid module embed both important advantages of both approaches and add an extra advantage of further flexibility for managing and incorporating more modes of operating inside the system. The hypothesis of applying the hybrid approach is to make use of both sensors and the algorithm to the maximum outcome increasing the accuracy and precision and improving the energy consumed by the motors and circuitry. The hybrid method's efficiency comes from a variable called frequency that determines how many times the calculation is due, and by that reducing the number of occurrences the solar panel has to move. To achieve that, a number of means could be followed. The following are examples of how to achieve the hybrid methodology:

a. Using the algorithm to provide the initial value and using sensors for correction only, provided that a frequency value is modified by more if the correction is high and less if there is no correction or the difference is negligible. As Figure 7 shows, the UML flowchart for the hybrid module.

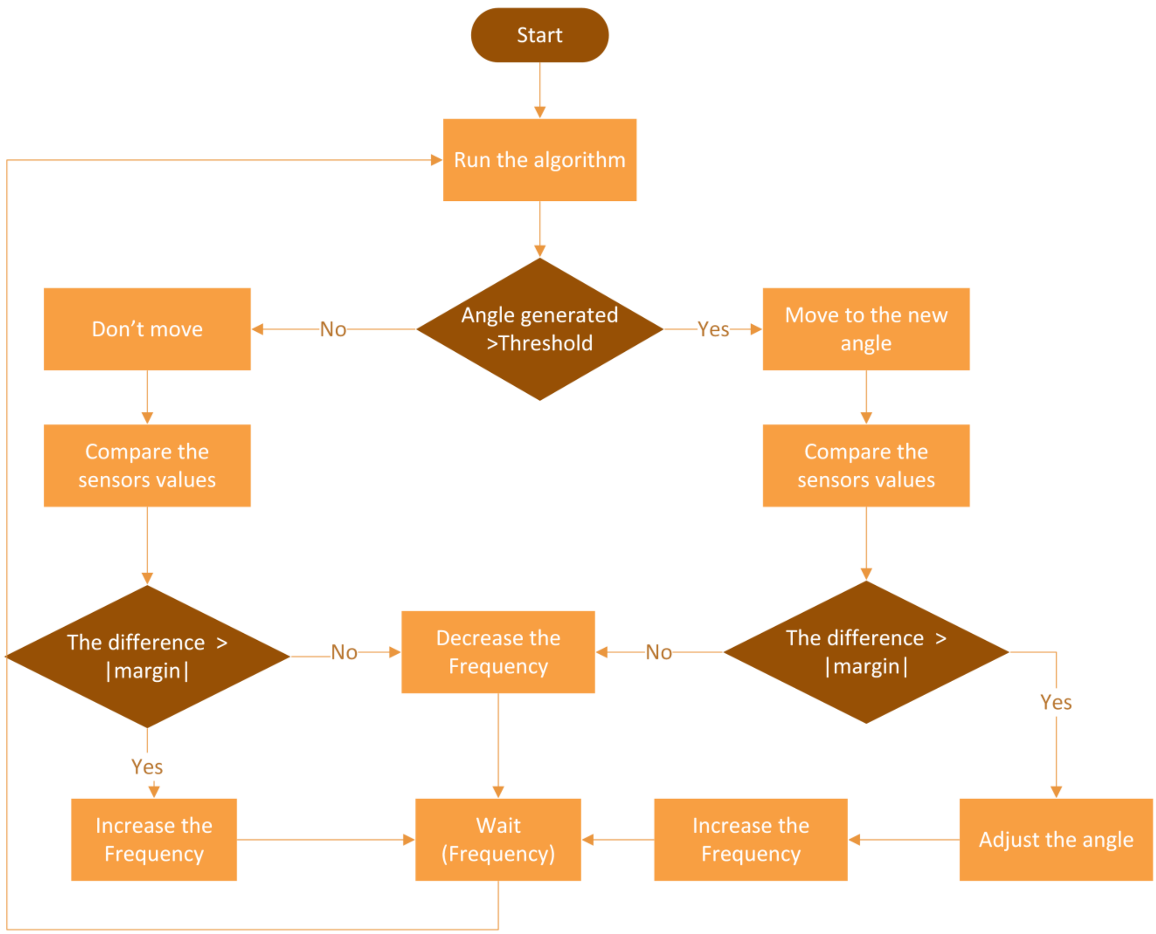

Figure 7: The UML flow chart for the hybrid module.

b. Another approach is using sensors along with the algorithm and calculating the difference between the old and new values of both and compares it to a certain threshold. If the value passes this threshold the solar panel will move accordingly indicated in Figure 8.

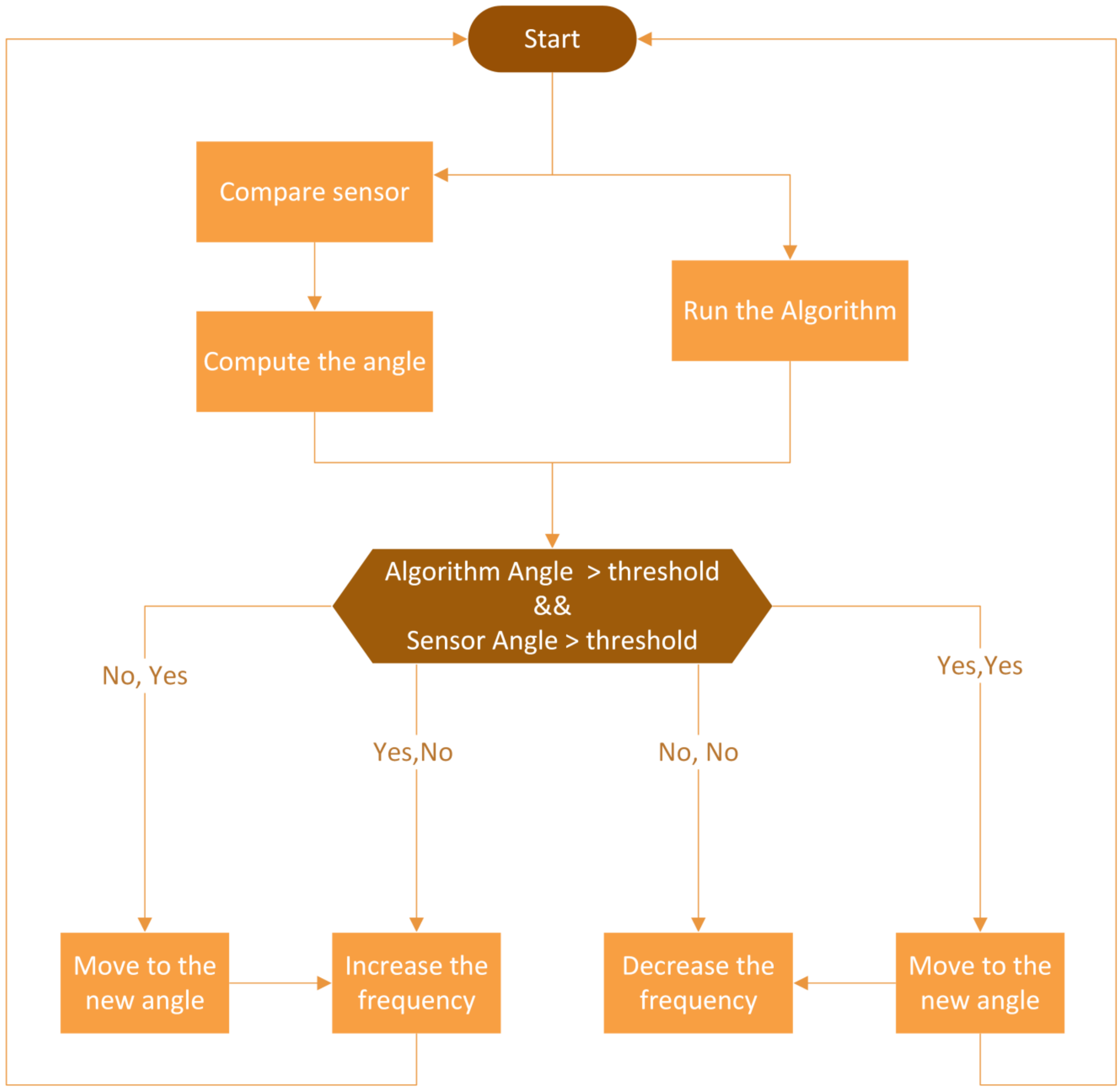

Figure 8: The UML Flowchart for second approach for the hybrid module.

To prove what is the most profitable approach is only done through testing. Thus, these method and more intermediate solution will be applied to further get the best valid outcome.

4.2.3. Customized component – Implementation

This section will detail the process of implementing for each particular customized component and the way it is applied in this project.

4.2.3.1 First: Mechanical aspect

To apply the dual-axis movement stand, the first design (which was the rotation-based) was implemented and made. The mechanical design took a long portion of time to be completed due to the lack of knowledge in Mechanical Engineering. Thus, trial and error was the only approach to apply the design. Starting with the sketches of the design, these are the basic design of each component and its functionality:

a. The Middle Shaft: As illustrated in Figure 8 and Figure 9, the middle shaft is divided into two middle shafts connected with a bearing to facilitate the circular movement. This shaft is responsible for allowing the rotation movement holding the whole design.

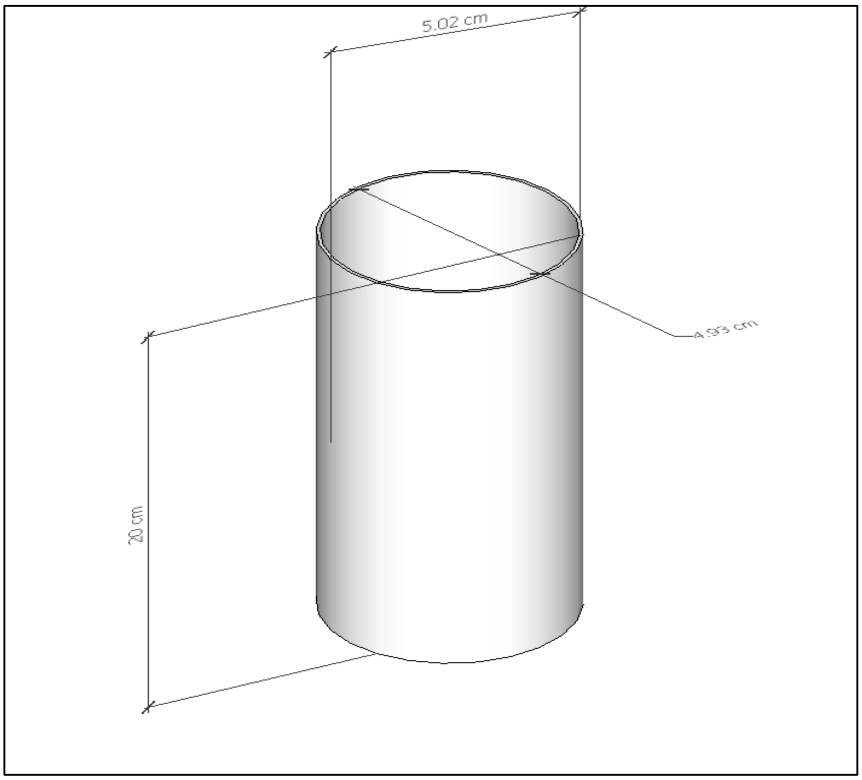

Figure 9: The bigger shaft of the middle shaft.

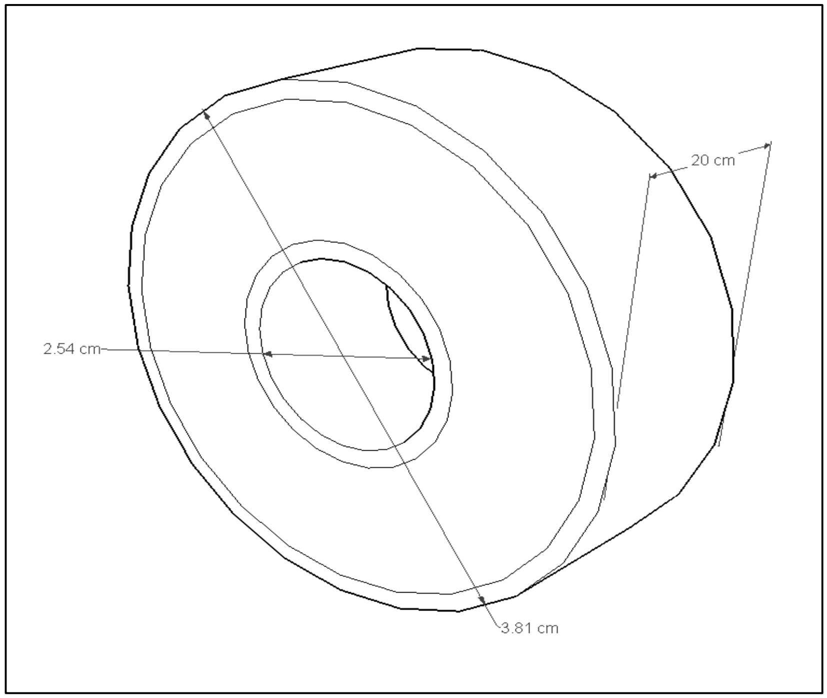

Figure 10: The ball bearing design and dimensions.

b. The Horizontal Shaft: which is the shaft responsible for holding the solar panel and it is wielded with it.

After that, there are two shafts that are connecting the horizontal and vertical one and this is done through wielding.

The design as whole as Figure 9 displays is a simple yet sturdy design to allow the dual-movement with smoothness yet be able to keep the weight of the solar panel.

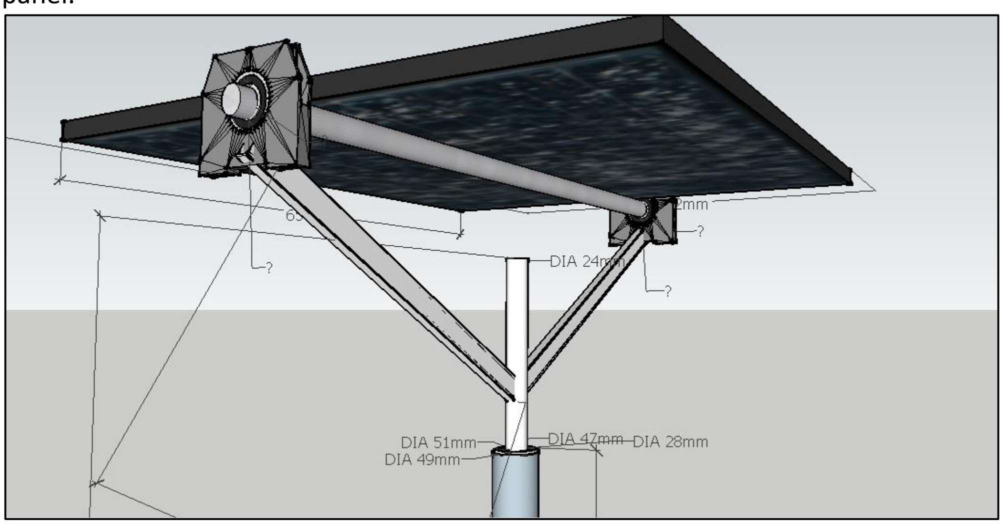

Figure 11 : The solar panel design from a side point of view.

4.2.3.2 Second: Algorithm

Although the algorithm is defined and given by the National Renewable Energy Laboratory (NREL), it needed some modification to be suited to run on a microcontroller. NREL provided the code in a form of a solar calculator [references], without going into too many details (See reference [reference]), the code is written in C language and it is divided into 3 parts:

a. The core code: this part contains all the equation and calculations needed to compute the needed angles.
b. The header file: contains the header of these methods to be called and pointers to these methods (not necessary).
c. The test file: C code written to test the output of the solar calculator.

The header file is there for fast linking and previously for protection of access. In the implementation phase, the algorithm is mounted into the microcontroller and used for computing the angles (Azimuth and Elevation).

4.2.3.3 Third: Hybrid module

The hybrid module implementation leans greatly on software, which include the two approaches that are mentioned in section 4.2.2.3.

4.3. Design Integration

After the integration of all the components of the system, the user will be able to use two modes (if it is set to that mode):

Sensors: that will work automatically and adjust the panel accordingly.

Stationary: This will allow the user to adjust the position of the solar panel manually.

However, both hybrid and the algorithm would not be ready to be deployed unless certain values are given by the user which includes:

a. Latitude: The position of the relative point in respect to the north – south direction.
b. Longitude: The position of the relative point in respect to the east – west direction.
c. Elevation: The height of the point in respect to level of the sea.
d. Slope: The inclination angle for the solar panel in respect of the horizon vertical line.

In addition, the initial time and date values for the internal clock would be given to start counting. After setting all the requirements of the system, the system as default will apply the hybrid method unless set to another mode.

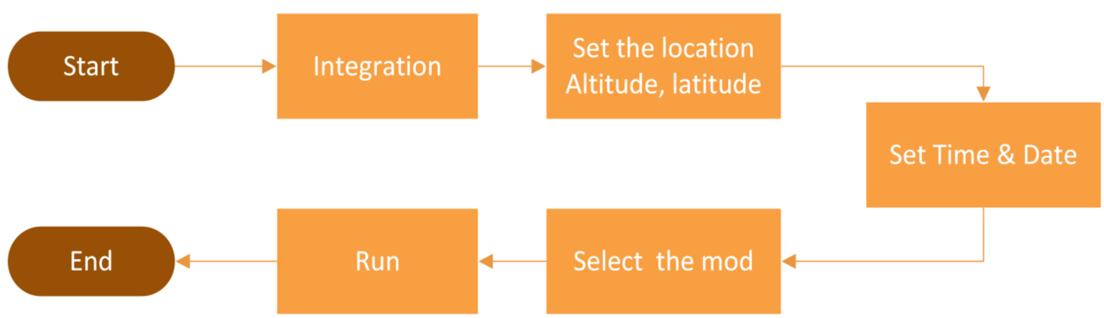

Figure 12: The installment phase.

4.4. Design Decisions

There were many choices to be considered and investigated in this project. Through a matrix of choices and weights and various reasons and criteria, some of these options were considered not eligible to be included in this project. Table 5 and Table 6 are showing an example of a major design decision that required this weight table to reach to a calculated decision.

First: Stepper Motor versus Servo Motors

Table 5: Showing the matrix used to choose between Stepper vs. Servo.

Criteria	Weight	Stepper motor	Servo motor
Cost	0.4	4	6
Accuracy	0.25	6	4
Power	0.15	4	6
Precision	0.05	4	6
Weight	0.05	5	5
Torque	0.1	7	3
Total	1	30	30
Final score		4.85	5.15

Thus, we are going to use the **Servo-Motor**.

Second: Microcontroller vs. FPGA

Table 6: Showing the matrix used to choose between Microcontrollers vs. FPGA.

Criteria	Weight	Microcontroller	FPGA
Cost	0.4	7	3
Power	0.25	4	6
ADC	0.05	4	6
Supported languages	0.1	7	3
Use as hybrid	0.1	8	2
Interfacing	0.1	5	5
Total	1	35	25
Final score		6	4

Thus, we are going to implement the software components using a **microcontroller**.

4.5. Design Evolution

The design initially was only based on sensors and using an FPGA board to interface the system. All that changed through multiple stages, the following are the stages of transition:

First stage: Using sensors only to locate the sun and move the solar panel accordingly.

Second stage: Using the algorithm to locate the sun solely and implementing that on a microcontroller that supports C language

Third stage: Using sensors and the algorithm initial idea were suggested.

Fourth stage: The frequency value were added to determine the frequency of which the solar panel have to move.

Fifth stage: The frequency idea with the hybrid module were fused into one approach and the hybrid module were suggested as a whole.

5. Testing, Analysis, and Evaluation

5.1. Testing

The testing phase uses an outer system that does not interfere with the actual result. The outer system consists of an Arduino Uno board connected with a current sensor that uses INA169 chipset. The current sensor connected between the solar panel and the battery. The sensor value is in voltage. However the conversion process is simple. Every Volt received from the sensor is equivalent to one Ampere. The values could be retrieved by the terminal on a PC. After acquiring the current, the power is calculated by multiplying the current value by 12, which is the average battery volt. After calculating the power at a given instance "second", we divide the current by 1000 to convert it to KW then we accumulate the power values to get KW.Second. Then, that value needs to be converted to KWH by dividing the value of the KWS by 3600. By this methodology the calculation of power gained by the solar panel is completed. The Arduino code is in Appendix A.

The analysis and evolution will be implemented once the system is tested

6 Engineering Tools and Standards

6.1 Available Tools

In the researching for innovative solutions phase of the project and within the scope of the functions that the solar tracker system should perform, a numerous methods and engineering tools posed as a candidate tools to be used for this particular project. To exemplify, for controlling and interfacing the hardware component with the software component (which was discussed earlier in the Design Decisions section), there was a choice between FPGA-Based and Microcontroller-Based project which ended with choosing a microcontroller. For every facet, there were multiple choices and through a selective process depending mainly on cost as the main criteria the optimal selection was made. Table 7 shows the main tools that were considered to be used during the implementation and design phase for the mechanical aspect:

Table 7: Tools for designing the stand of the solar panel.

Tool Name	Functionality	Shortcomings	Strengths
123D Design	3d Modeling & Sketches	Huge and slow, limited functionality	Easy UI, Huge library,
SolidWorks	3d & 2D Modeling & Mechanical Design	Huge and complex	Multiple functionality, professional and supported
SketchUp	3D, 2D modeling, sketches	Basic	Multiple functionality, Huge library and supported, fast

Furthermore, Table 8 shows the boards considered for a microcontroller for the system:

Table 8: Microcontrollers and their shortcomings and strengths.

Board Name	Language Used	Shortcomings	Strengths
Arduino - Uno	Specialized C language	Expensive, difficult implementation for pure C code, simple	Easy UI, Huge library,
LPCXpresso-1549	C language	Not well supported, online compiler, bugs and heating	Support mbed online compiler, multiple channels for AD/C, supports Arduino shields and powerful

Moreover, the LPCXpresso – 1549 provides two environments for the board which are:

a. Mbed: Simple, easy UI, online compiler for the board with extensive support and a huge library.
b. LPCXpresso IDE: Installed, sophisticated program that deals with the board in the register level.

Arduino only uses its program.

6.2 Chosen Tools

Since cost is a main issue, seconded by speed less time consuming to learn and start working, there were only one explicit choice for the mechanical design tool which was Sketch Up, using a huge library that provide for millions of already made designs and allowing for editing and view made Sketch Up the best fit for the case.

For the microcontrollers and their IDE, the selection went to LPCXpresso board for its powerful capabilities, vast memory and support for 12-bit AD/C. In addition, the IDE selected was mbed, fast and quite easy for fast learning, which is suited for the job.

6.3 Standards

The serial link based on the USB standard used for establishing communication between the microcontroller and the PC for receiving initial values for the algorithm and hybrid modes.

7 ISSUES

7.1. ISSUS FACED

The knowledge that is gained in this project and in the experience as whole is quite an accomplishment by itself. Nevertheless, the number of obstacles that occurred and dealt with or ignored were many. Including the mechanical aspect of the project table 7.1 shows all the issues faced in this project and the reason for this issue and the action or the response towards it.

Table 9: Problems faced in this project.

Issue	Reason	Action or response	Notes
Designing the stand	Lack of mechanical knowledge	Learned enough to implement.	The support of ME department was not as ones hopes
Creating the stand			
Interfacing and using the LPCXpresso	First time usage	Learned enough to implement.	Helped by Dr. Ahmad and Dr. Hazam to learn faster
Unavailability of parts – trial and error	No support	Ordered	Took a long time to test and verify

7.2. LIMITATIONS AND CONSTRAINTS OF THE DESIGN

The requirements illustrated in the specification section has a big role in placing some of the limitation for the system, which indeed reflects some of the major constrains that the system at the design phase had to abide by them which include:

a. Cost – effective solution: this constrains lowered the amount of functions that can be integrated in the system to avoid cost inflation.
b. Lower energy consumption: To provide a sustained outcome from the solar panel, everything else should use as low as possible in respect of power consumption.

7.3. LIMITATIONS AND CONSTRAINTS OF THE IMPLEMENTATION

When implementation phase came, many restrictions appeared and slowed the work process. Including the following:

a. Cost of the mechanical part: some detailed parts costs 2000 SR to be exclusively made or manufactured.
b. Size versus watts: To produce such power, the size of the solar panel grew and thus the choice of the solar panel's size was a constraint by itself.

8 TEAMWORK

The project indeed helped improve the ability to work under a team and perform faster with the existence and collaborate to get the tasks done. Table 9 shows the tasks for the project and who was the responsible for accomplishing tasks. In addition, the table will illustrate all the members involvement in a task and the expertise gained.

Task	Member responsible	Other contributors	Expertise gained Taha	Expertise gained Omar
Researching and Looking for available solutions	Taha	Omar	Gained experience and learned from other trials	
Mechanical Design	Omar	Taha	Gained knowledge about basic mechanical terminology and implementation	
Digital Design	Taha	Omar	Get familiar with the ARM-based microcontroller	Revise old concepts about Digital design, experiment with the new and powerful LPCxpresso
Programming – Algorithm	Omar			Revised C language and learned about the solar orientation
Sensors	Taha		Using mbed online compiler and learned how to debug it	
Hybrid module – Design	Omar	Taha	Learned how to reach high accuracy when tracking the sun with lowering the consumption	
Hybrid module – Implementation	Taha	Omar		
Testing	Taha	Omar	Revised some concepts about astronomy	
Debugging	Taha	Omar, Jalal Al-Rkhumi	Learned methodology of debugging through mbed	

The first team member "Taha" is experienced in digital design, 3d design and some of the mechanical aspect. The second team member "Omar" is experienced in the mechanical aspect, documentation and 3d printing.

9 CONCLUSION

9.1 WHAT WAS LEARNED

In this project, various fields were visited for the first time and many others were explored. In addition, old previous knowledge and concepts were revised and practiced through implementation. The following fields were necessary to learn in order to finish the project:

a. Astronomy: Basic knowledge about the solar orientation were acquired to understand the concepts behind the algorithm.
b. Geometry: The angle calculation in the algorithm is based in geometrical computation.
c. Electrical: Increase the utilization of the solar panel and accordingly increase the power produced is the main target for this project. Thus, some concept about power is learned to understand and perform the tasks of this project.
d. Mechanical: The project lay heavily on perfecting the design and the idea of the dual-axis movement. Thus, basic movement knowledge and usage of 3d simulators and designs were accumulated for understanding the movement of the solar panel.
e. Information Computer Science: Used heavily in dealing with the algorithm and performing the interfacing the hardware with the software.
f. Digital Design: Learned for understanding the infrastructure of the microcontroller and use it properly and understanding the circuitry behind it.

Other concepts were researched in the researching phase to implement the mechanical and digital design including:

1. The mechanical aspect of using a bearing.
2. Interfacing stepper motors.

9.2. WHAT WOULD YOU DO DIFFERENTLY IN A SIMILAR PROJECT

Since the project itself was a new experience for both members, there were a lot of trial and error. Hence, there some regrets about some minor mistakes that should have been avoided for the project to succeed completely. Firstly, time was a major issue regarding numerous aspects, but mainly in ordering and finalizing the parts and finishing the mechanical design. The second regret was the time wasted in waiting for the ME department to react and help in the mechanical aspect of the project. Finally, include more members would be the strategy to hence this project is too complicated and handful for two not fully experienced members only.

9.3. Conclusions

In conclusion, the solar power is growing and the prices for its equipment is reducing, which will facilitate the research and the industry growth in that field. Furthermore, the research toward the methods of creating the solar panels is prominent [8].

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APPENDIX A

The following code is used for testing and debugging the hybrid module:

```
/*
 Description:

 This sketch shows how to use the Adafiut INA169 Breakout
 Board. As current passes through the shunt resistor (Rs), a
 voltage is generated at the Vout pin. Use an analog read and
 some math to determine the current. The current value is
 displayed through the Serial Monitor.

 Hardware connections:

 Uno Pin     INA169 Board    Function

 +5V         VCC             Power supply
 GND         GND             Ground
 A0          VOUT            Analog voltage measurement

The other pins Vin+ and Vin- used to major the current across the
lode.
For example: Vin+ connected to the 3.3V and Vin- used to feed the
LED.

 */

// Constants
const int SENSOR_PIN = A0;  // Input pin for measuring Vout
const int VOLTAGE_REF = 5;  // Reference voltage for analog read

// Global Variables
float sensorValue=0;   // Variable to store value from analog
read
float current=0;       // Calculated current value at any time
float power=0;         // Power at any time
float kws=0;           // Energy equivalent to one kilowatt (1
kW) of power expended for one second
float kwh =0;           // ACUMELATED POWER (kilowatt Watt Hour)

void setup() {

  // Initialize serial monitor
  Serial.begin(9600);

}
void loop() {

  // Read a value from the INA169 board
   sensorValue= analogRead(SENSOR_PIN);
  // Remap the ADC value into a voltage number (5V reference)
```

```
  current = (sensorValue  * VOLTAGE_REF)/ 1024;
  // Calculat the power P=I*V wher V is avreged as 12 V
  power = current * 12;
  //  Convert this value to kilowatt for one second
  kws=(power/1000)+kws;
  //  Calculat the power in Hours
  kwh = kws /3600;


// print in the terminal
Serial.print ("Current : ");
Serial.print (current);
Serial.print ("A  Pwoer : ");
Serial.print (power);
Serial.print ("W  Pwoer consumed in KWH: ");
Serial.println(kwh);

  // Delay program for a few milliseconds
  delay(1000);

}
```