Design Document

DUAL-AXIS SOLAR PANELTRACKING SYSTEM

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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 rest of the world.

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

[1] The link(http://www.imeche.org/knowledge/themes/energy/energy-supply/fossil-energy/when-will-oil-run-out).

[2] This table is taken from the U.S Energy information administration with some edits to the lowest values.

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, the ultimate source is the sun. Building solar farms to harness power are becoming more available and more efficient as the time pass by. The project intended to be build, is aiming toward increasing the amount of sun power to be extracted from the 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 supply power and energy to the traffic light using solar panels rather than grid. With this application, a huge amount of energy would be saved and consequently it would lower the oil production, reserve the oil residue for longer terms, keep the environment as clean as possible and meet the increasing demand for power.

Problem Statement

The application of the solar panels 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 increasing demand of power by two main goals:

a. Increasing the efficiency of solar panels.
b. Use the well-developed and effectual solar panel to feed the traffic lights with solar power.

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 using the system intended to be built:

1. Greener world, using solar radiation as a source of energy is not only infinite, but, it is also the best energy you can think of in terms preserving the environment and keep it clean.
2. Having a successful experiment using renewable energy resource would open the door for other renewable resources like wind, water ...etc.

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, one might think that using the system in a traffic light might be dangerous in case of a system failure and could causes series accidents. However, if the system has a fall safe mechanism, this dangerous aspect can be avoided.

PROJECT SPECIFICATION

Requirement

The system when complete should perform the following:

a. Adjust the Solar Panels to the most efficient angle toward the sun.
b. The system should feed the traffic light with at least 80% 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 switch in case of night or cloudy days.
4. Fall-safe switch in case of an emergency or an error.

Specifications

The system will use a hybrid of an algorithm to track the sun programmed using a high-level language on a microcontroller with the existence of sensors. The system would use the following components to satisfy each of the requirements:

1. Sensors will be used to lower the cost of calculation and adjust the panels more accurately by subtracting the difference between each of the opposite direction.
2. Comparing the angle calculated from the algorithm by using the longitude and attitude to calculate the location of the sun, and accordingly compute the angle and compare it to the one given by sensors to calibrate the system.
3. Using stepper motors to move the panel with high precision (200 steps/revolution) or at least 1.8 degree (preferably more).
4. Battery charging controller used to switch between either solar (normal usage), battery (night or shady) or grid (In case of a system failure).

System Design

Architecture

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

Sub-Function Identification

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

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

System architecture and components

The system architecture as whole will have the following structure:

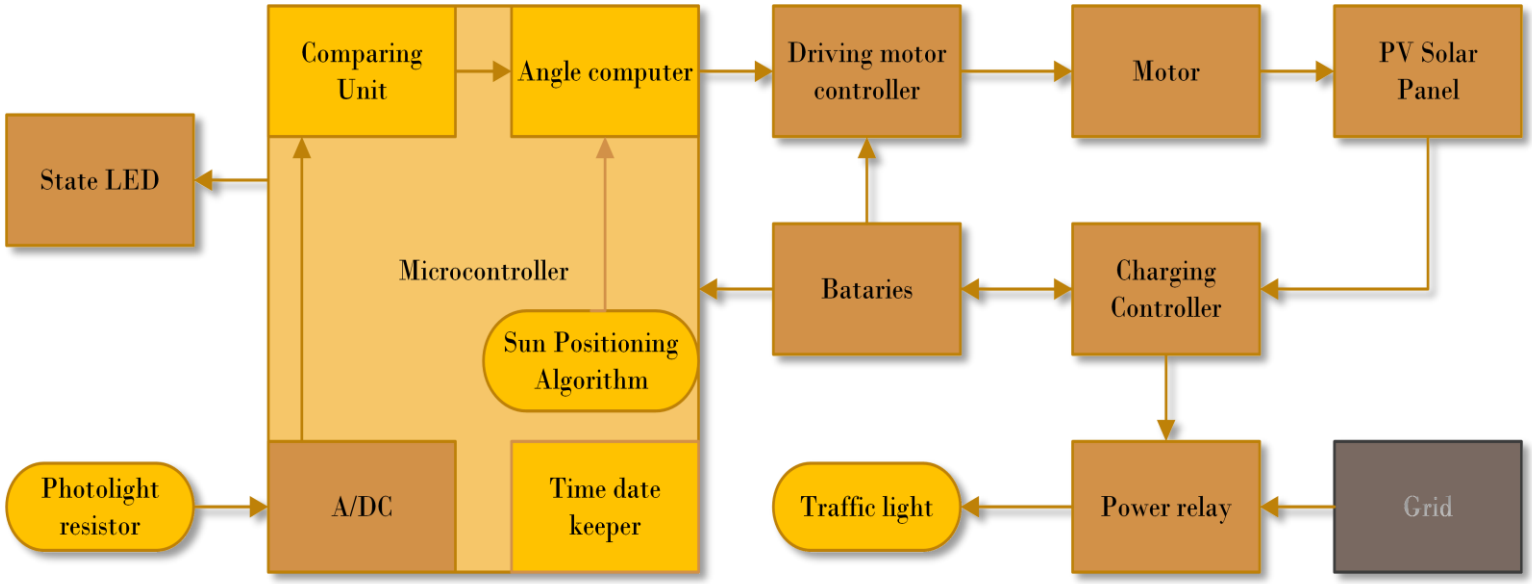

Figure 2 : The system architecture involving the entire component and their relation to each other.

Hardware vs Software Components & Functionality

The following schedule will display the components, whether hardware or software

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

Components	Function
Photo light Sensors	Sensors to detect the light
Batteries	To charge and be used during the unavailability of solar power.
PV Solar Panel	To absorb the sun light and transform into electrical charge 12-24 volts DC
Charging Controller	To increase the life span of the battery and control the charging status.
State LEDs	To indicate the status of the system
Stepper Motors	To control and move the gears towards the direction needed according to the input given by the driver controller
Microcontroller	Including AD/C, Angle Computer, Comparing Unit and Positioning algorithm
Driving Motor Controller	To receive the input from by either the comparing unit Angle computer and transfer it to the motors accordingly
Power relay	To switch between grid and the system
Time-Date keeper	Component responsible of recording and outputting the current time and date to feed it to the positioning algorithm
Positioning algorithm	A software to calculate the position of the sun given the time and date and GPS coordinates to give to
Comparing Unit	A software component to compute the angle given the input from the sensors
Angle Computer	A software to compare the values given by Positioning algorithm and Comparing Unit and decide the course of action

Component Design and Implementation

Ready-used component

a. Two Stepper Motors.
b. Photo-light sensors.
c. PV Solar Panel.
d. Batteries.
e. State LEDs.
f. Driving motor controller.
g. Charging controller.

Customized component

First: Stand to hold the PV Solar Panel

This stand is designed to allow the dual-axis movement with as much smoothness as possible while minimizing the cost of implementation. There are two approaches to build this stand all using two motors and sometime linear actuators. The dual-axis will referred to as ***Up - Down*** and ***left - Right*** (For ease of understanding). The first approach will implement the ***Up - Down*** direction using a gear to move it back and forth (max-angle $\approx 90^0$), while the ***left - Right*** using a rotation of the whole panel (max-angle $\approx 360^0$). The following image illustrate the movement.

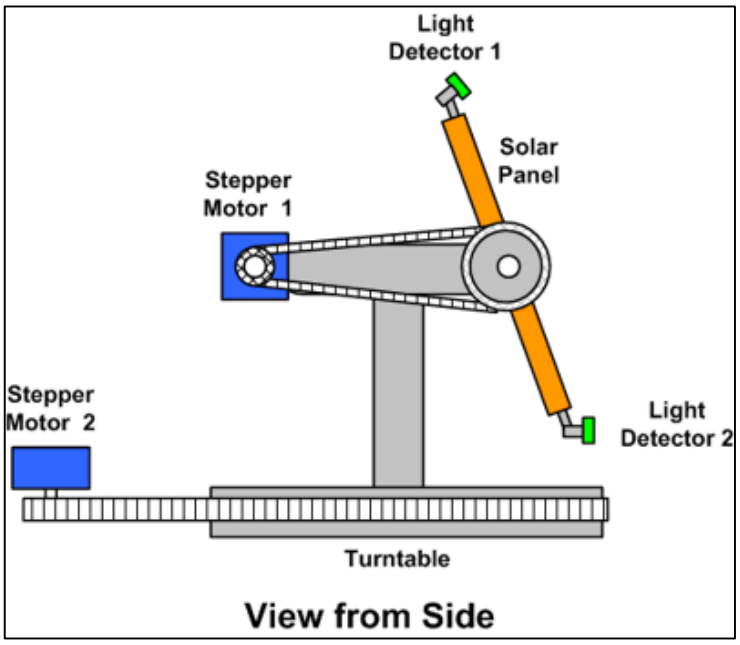

Figure 3 : First approach in designing the Handler (Stand).

Moreover, there is other approach, which uses the dual-axis movement more freely. This approach does not include rotation at all. Using one motor to move ***left - Right*** and linear actuator to move ***Up – Down*** *while keeping the solar panel steady*. Here is a diagram showing the tool used to implement this approach.

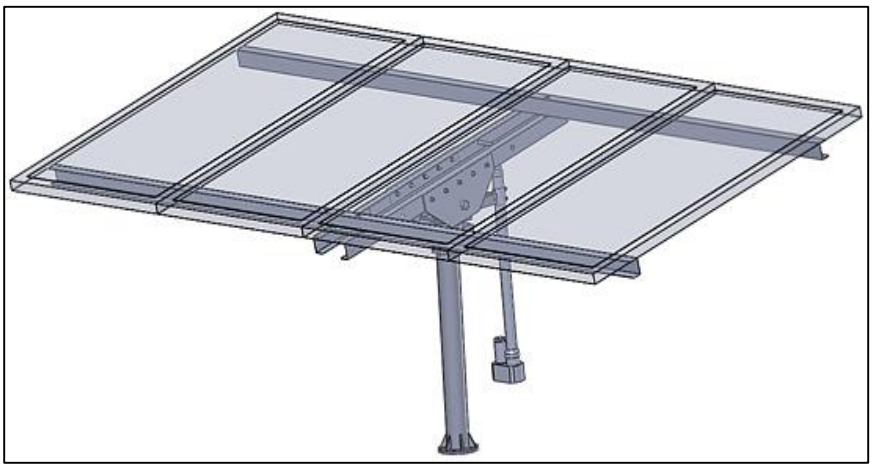

Figure 4: Second approach in designing the Handler (Stand).

Second: Algorithm to track the sun

While the sensors will locate the sun more easily, from a cost-effective point of view, that approach (for a long run) is costly and absorb much of the power given by either solar panels or battery. Thus, an algorithm that take the time, date and GPS coordinates and give the location of the sun computed using a software is a better suited for the job. Indeed the system will still depends on sensors to take reading once every often to calibrate the system, but with this hybrid module the cost is fairly minimized.

Third: Power relay

In order to switch between grid and solar system, a component is placed between them to switch the charge in case of a failure or a sudden blackout.

Implementation & Integration

To implement the system, all components are assembled and connected together. The following represents the actors on the system and their use cases.

Furthermore, for the early stages of system installation, the user has to

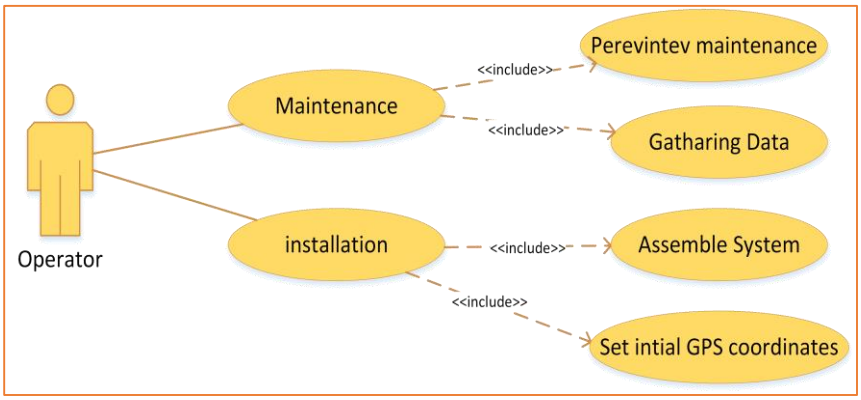

Figure 5: The actors of the system and their use cases.

assemble the system and give the initial GPS coordinates. For the maintenance part, the operator will deal with battery and will collect date every now and then to examine and upgrade the system. Here are the diagrams for the use cases.

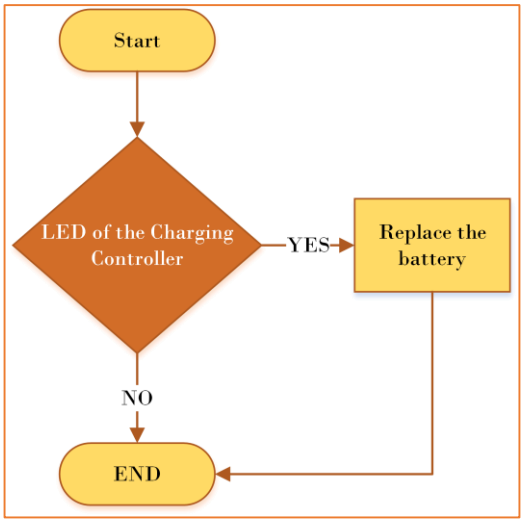

Figure 7: The activity diagram for preventive maintenance use case.

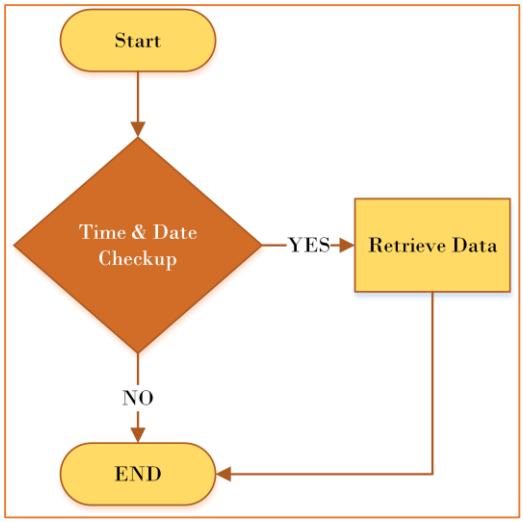

Figure 6: The activity diagram for Gathering Data use case.

Design Decisions

There were many choices to be considered and used in this project. Through a matrix of choices and weights and various reasons and criteria, some of these options was considered not eligible to be included in this project.

First: Stepper Motor vs Servo Motors

Table 3: Showing the matrix used to choose between Stepper vs Servo.

Criteria	Weight	Stepper motor	Servo motor
Cost	0.4	6	4
Power - Continuance feed	0.25	8	2
Accuracy	0.15	6	4
Precision	0.05	4	6
Weight	0.05	5	5
Torque	0.1	7	3
Total	1	36	24
Final score		6.45	3.55

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

Second: Microcontroller vs FPGA

Table 4: Showing the matrix used to choose between Microcontroller 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**.

PROGRESS

Task Schedule

The table below explains in brief what are the task in this project and who did or will do them, add to that the completion percentage per task.

No.	Task	Owner	Description	Timespan	Status (%)
1	Looking for existing innovative solutions	Omar	Searching for similar project and how it been implemented	1 week	100%
2	Investigating the electricity and mechanical aspect of traffic lights	Taha	Looking for traffic light standard in the kingdom and globe	1week	100
3	Looking for a hybrid solution that implement software	Taha & Omar	Experimenting with software that receives GPS coordinates and time-date and outputs the position of the sun.	2 weeks	50%
4	Parts Acquisition	Taha	Acquiring the components needed for the system	2 weeks	20%
5	Stand Design	Omar	Consulting the ME chairmen to develop a dual-axis stand to hold the whole system	2 weeks	10%
6	Implementation	Omar & Taha	Assembling the components and begin building the system as an entity	5 weeks	0%
7	Programming	Omar	Implement the algorithm and experiment with it.	2 weeks	10%
8	Testing and debugging	Taha & Omar	Test the system and debug any error that may occur.	4 weeks	0%

TASK COMPLETED

For the task that has been completed, a variety of solution inspired by previous knowledge has been implemented.

The following tasks were completed:

a. *Looking for innovative solutions*

   The exploration of the solution given by practitioners all around the world was "To say the least" informative and it helped us out plenty in understanding what are the choices available and which ones are the best.

b. *Investigating the electricity and mechanical aspect of traffic lights*

   To further our understanding, we tried to see for our self how much power consumed by a traffic light and is there a possibility for implanting our system on it or not also, the mechanical aspect regarding the position of the solar panel to receive the maximum amount of power.

Some difficulties faced during these tasks:

a. *The lack of a good documentation*

   Indeed we found multiple resources and there were some with good documentation, but some were not well documented which made our search a bit difficult.

b. *The lack of unified and original resources*

   While we were looking for the information regarding the traffic light and its datasheet, there were multiple standards and there is no clear tell which one is used locally to install the traffic light or which company were contracted to install them.