SOLARLY

PV - TRACKING

Product requirements

TABLE OF CONTENTS

1. INTRODUCTION

According to Encyclopædia Britannica, “Studies have shown that the angle of light affects a solar panel’s power output. A solar panel that is exactly perpendicular to the Sun produces more power than a solar panel that is not perpendicular.”

Generally, PV modules are fixed at the optimum angle for their specific latitude. However, this is the angle optimized over the course of a year, and (depending on latitude) can vary by 30° as the sun appears lower or higher in the sky “according to Azimuth-latitude”. Fixing PV modules at the optimum angle typically yields an improvement of around 15% compared with simply laying them flat.

Trackers, on the other hand, adapt to both the daily passage of the sun and potentially the changing seasons too. If placed in the right corresponding rotational angle, the tracking system can generate up to 33 % efficiency in electrical power generated from solar energy- Which is a significant amount of increased efficiency- and that’s according to a study published by ASME (American Society of Mechanical Engineer). Therefore, Trackers are a necessity to maximize the energy output from very expensive solar modules

Solarly tracking system should follow three main principles: Reliability, cost-efficiency, and compatibility. Therefore, this document provides a comprehensive understanding of the requirement of the desired product that should be designed and manufactured in order to satisfy the industry standards and requirements.

Intended audience

This document is considered as reference for Solarly team, to guide the product design and development, and serves as reference point for future. This product is also used to test product after development to improve and validate it.

Berytech is an intended audience and can use this product to understand the scope of the product and assess the engineering discipline followed by the team.

Sponsors can use this document to understand the scope of this product and have a reference of the intended product.

2. SCOPE

This document is a 5 hour work, it details minimum requirements in order to quickly design and develop a prototype for the intended product. This document is concise, and should minimize the complexity of the design, and allow the team to deliver the work within the timeframe and resources constraints, based on high-priority, high-impact, and lowest effort.

3. REFERENCES

The content of this document is based on the research we have done on the solar tracking devices, and sun trajectory and tracking.

The purpose is to have a unique reference that guides our work, its not intending to replicate information. Therefor we gathered and analyzed information, from the internet, and from conducting four condensed meetings with industry experts and technology experts, to build this requirement document.

Reference Title	Author	Source/location
Sun Tracker Performance Analysis for Different Solar Module Technologies in an Alpine Environment	ASME American society for Mechanical Engineers	https://asmedigitalcollection.asme.org/solarenergyengineering/article-abstract/136/3/031005/379594/Sun-Tracker-Performance-Analysis-for-Different?redirectedFrom=fulltext
Encyclopædia Britannica	Britannica	https://www.britannica.com/

4. MARKET ASSESSMENT

This product targets new users who are looking to acquire PV solar system, and wanting to increase the efficiency, to generate more power in an efficient way that has high return on investment. Also provide resellers of PV panel with the opportunity to convince pragmatic users about acquiring a PV panel, because the solar tracking device will upgrade the product to become more valuable and with higher return on investment.

5. OVERALL DESCRIPTION OF THE PRODUCT

Solarly PV system is a tracking system that transforms a static solar panel into dynamic, at the lowest cost possible, to harness most of the solar energy.

The product should be compatible with the existing PV system, to minimize intervention, and therefore minimizing cost on the users.

It should adjust the initial position of the solar panel, and move the panel using a compatible mechanical system, and in the best efficient rotation angle.

Basically, it is a system that upgrades the PV system, to achieve higher efficiency and increase the value generated from the same solar panel and therefore taking the best out of its lifecycle.

1. Operating environment

This product will be placed outdoor, it is exposed to wind, sun, and rain.

It should be placed on the existing chassis, and linked to the solar panel border, so it should consider compatibility with the existing platforms, “According to the third principle adopted: compatibility”

This system should have an interface and application that reflects data to the user, to assess performance of the solar panel, and potentially: outside temperature.

2. Design and implementation contraints

This document is delivered to Berytech as part of the E-hackathon Cleanergy, due to the type of the challenge, there is time constraint that should be respected and managed. There is also resources constraints due to the timebound and because of the challenge of importing some parts, due to the lockdown and the economic problem in Lebanon.

There is also the purchase power in Lebanon that is a constraint and should be taken into consideration and therefore design a cost-efficient system. There is also the purchase power in Lebanon that is a constraint and should be taken into consideration and therefore design a cost-efficient system.

6. ASSUMPTIONS AND DEPENDENCIES

We are assuming we can drill in the ground to fix the bottom extreme of the system that hinges a beam pushing the solar panel to tilt along the tilted single axis.

We are also assuming that all the solar panels have the same type of support

Based on research and industry experts, we are assuming the product generates 27 to 32 % efficiency if tilted in single axis.

7. TESTING ENVIRONMENT AND QUALITY

To test the assumptions, the development team should contact industry experts, to validate these assumptions, before going to development.

After development, In order to test this product, to validate assumptions and to approve quality, the testing environment should be as following: comparing two PV systems next to each other, one being fixed on its chassis and the other dynamic using Solarly product. A test should be conducted for one-week period minimum, and record results on cloud, using micro-controllers such as: Node-MCU. The results should be compared and generate conclusion about increase in efficiency generated by the solar tracking device developed locally by Solarly.

An electronic circuit test should be conducted too, to measure performance of the motor while elevating the panel, reading the current consumed by the motor, and analyze it to come up with a conclusion that will provide feedback on the motor used, and if there should be an increase in motor capacity, or vice-versa.

8. REQUIREMENTS FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS TO DEVELOP A LOCAL SOLAR TRACKER

These requirements have been gathered by Solarly team, through research, conference calls with industry experts, and technical experts.

Functional Requirements	General	Req 1	Must track the sun position and control the solar panel using low cost actuators.
	Hardware	Req 2.1	The mechanical system must be reliable, that means substantial maintenance span
		Req 2.2	Hardware design should be easy to maintain when needed.
		Req 2.3	Most of the resources should be available in Lebanon, with lest import.
	Electrical	Req 3.1	The system must be able to identify the sun position in the sky, using reliable light sensors.
		Req 3.2	The tracking of the sun position in the sky should be accurate.
		Req 3.3	The system actuators must be able to move the solar panels to assure a perpendicular angle with sun.
		Req 3.4	The tracking system must consume least amount of energy to move the panel.
	Control	Req 4.1	The system components must be enclosed to sustain under diverse environmental conditions.
		Req 4.2	The system must be able to carry out a weight of 20 kilograms and allow for a safety factor of 1.5
		Req 4.3	The control system should behave based on state estimation algorithms, not on live instantaneous data to prevent system overshoot.
		Req 4.4	The controller dynamics must be smooth, such as PID.
		Req 4.5	The controller must have an accurate steady-state error
		Req 4.6	The controller must be placed in a safe environment
		Req 4.7	The motor must withstand harsh environments and should have an IP rate of 5 or 6.
		Req 4.8	The motor must provide high torque to provide safe environment for the movable chassis.
	Configuration	Req 5.1	The mechanical system must be configurable on existing chassis, to reduce cost of implementation.
		Req 5.2	The system must be easy to maintain; parts are assembled in a way that is easy to de-assemble and fix.
	Usability	Req 6.1	The user must be able to access his PV system' Data and read the performance generated by the panels

Non-functional requirement	Performance	Req 7.1	System must be reliable to protect the sensitive PV system
			The product must be built and operated with minimum energy
			Must be tested in a systematic and engineering way, to assess performance with and without a solar tracking, and validate the 20 to 30 % increase in efficiency of solar radius
	Safety	Req 7.2	The system must be equipped with many redundancy plans, to protect the system from failure
		Req 7.3	The system must report problems to the user, and/or product engineer, to track and fix the product

9. EXTERNAL ENVIRONMENT AND USER INTERFACE

The hardware should be easily broken to many pieces, to facilitate maintenance.

The software user interface must provide graphs that summarize the performance of the panel throughout the week, on the month, or both. To compare the performance to a static panel, and to quantify the energy generated using the solar panel.

The user interface should display error messages to facilitate reporting and maintenance call center.

A light sensor must be placed in the system to track solar energy and change panel tilt to become perpendicular to the sun and generate more energy.

The sensory system must store data and conduct analysis to identify next decision type: to move the axis left or right, based on the data stored and analyzed, and therefore the system will move in a steady and efficient way across the day with the different position of the sun.

10. DESIGN

In this section, we will discuss the why of the design.

First, solar tracker direct solar panels or modules toward the sun, these devices change their orientation throughout the day to follow sun trajectory to maximize electricity generation.

They mainly comes in two shapes:

- Single axis
- Dual axis

Because solar tracking implies moving parts and control systems that tend to be expensive, single-axis tracking systems seem to be the best solution for small PV power plants. A single-axis solar tracking system uses a tilted PV panel mount and one electric motor to move the panel on an approximate trajectory relative to the Sun's position. The rotation axis can be horizontal, vertical, or oblique. Also dual axis tracking system offer a measly 6% additional efficiency to the single axis, making its cost-benefit ratio less than 1. In

Figure 1 we can see the sun's path and PV panel orientation, current fixed installed PV panel are installed in such a way that they will be perpendicular with the sun at 12 noon (PV panel will be facing south).

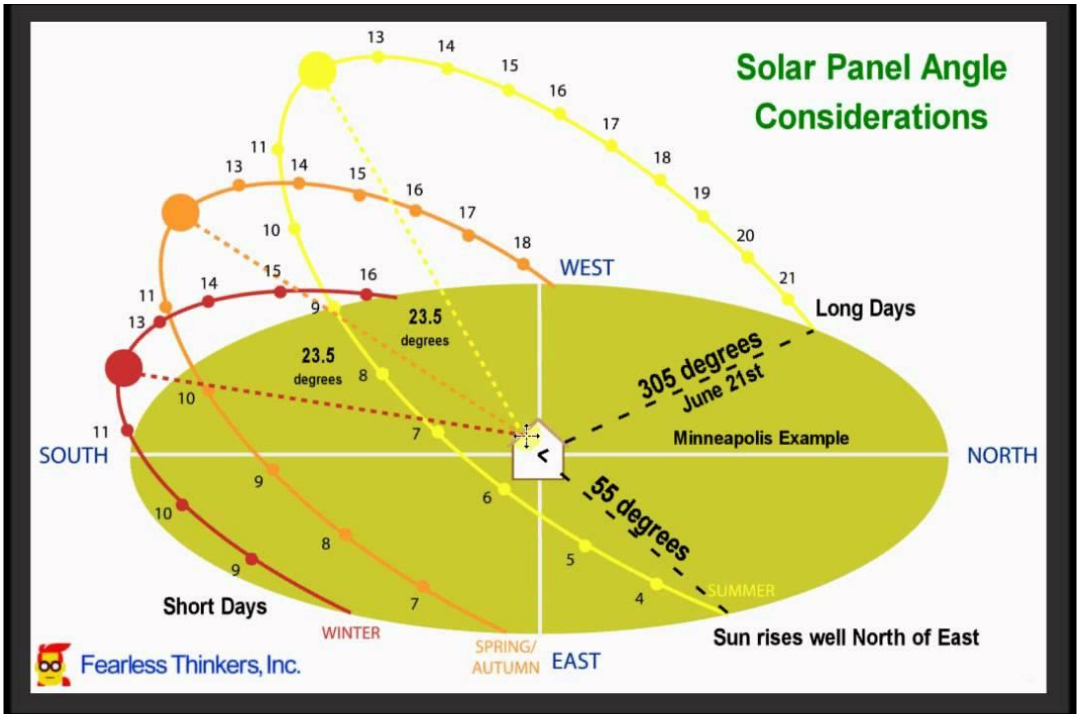

Figure 1: Solar panel trajectory path

After picking single axis tracker, it was time to decide its axis of rotation and based on the literatures published by ASME (American Society of mechanical engineering) we found that the best single axis system is called Tilted single axis tracker (TSAT for short) Figure 2.

The tilt angles of the trackers are often limited so as to decrease the wind profile and reduce the elevated end's height from the ground. The field installations need to make consideration for the effect of shading so as to avoid unnecessary losses and also optimize area utilization. Using backtracking, they can be packed with no shading perpendicular to their own axis of rotation at any density. Yet, the parallel packing to the axis of rotation is limited by the latitude and the tilt angle. Tilted single axis trackers usually have the module's face oriented parallel to the rotation axis. As a module tracks the sunlight, it moves in a cylindrical motion that is symmetric around the axis of rotation.

TSAT is a great way for users looking to increase their system efficiency, while at the same time the cost of manufacturing TSAT is getting lower, and at the same time their efficiency is getting higher, this is why we picked such a powerful design to base our product on. And in 2017 a market research concluded that the global sales volume of solar tracker systems hit a record 14.5. This represented a 32 percent year over year growth, with an equal or higher growth expected with the increasing development of the large-scale solar deployments. However our design will be applicable to homes that own Solar PV which is a niche that no one explored yet.

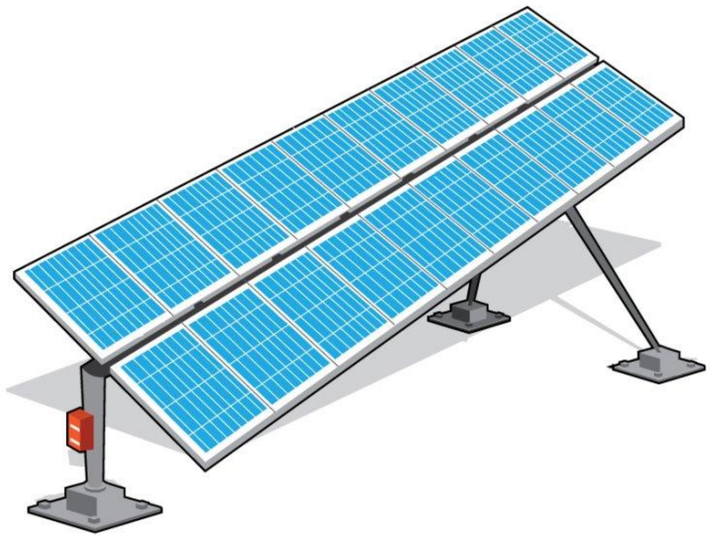

Figure 2: Tilted Axis Solar Tracker

11. HIGH LEVEL DIAGRAM

In this section, the WHAT of this design will be discussed?

First of all, the inclination angle varies along the day by a specific mechanical mechanism which take its flexibility from a simple motor that can controlled by changing the input voltage across its terminals, which takes place through motor driver. This last one, is controlled via an Arduino controller that generates a PWM (Pulse Width Modulation) signal for it, hence, its output voltage will varies according to PWM variation.

In addition, light sensors are connected along with solar panel as a light feedback. The main role of these light sensors is to find the error between the desired and current inclination; thus, this error is important for control system improvement which inform the controller continuously.

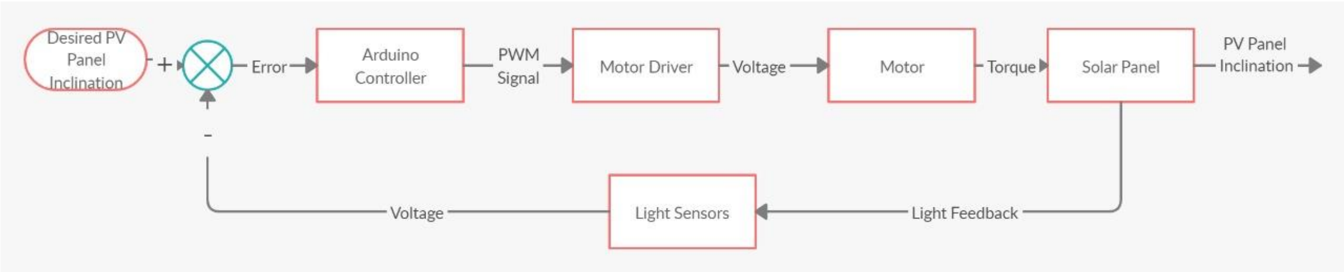

Figure 3: High level Diagram

12. 3D CAD MODEL

In this section, a 3D CAD model will be presented for better understanding. We modeled everything using Fusion 360 Software to be able to prototype later on better design using the fast 3D Printing Technology.

Figure 4: Front view

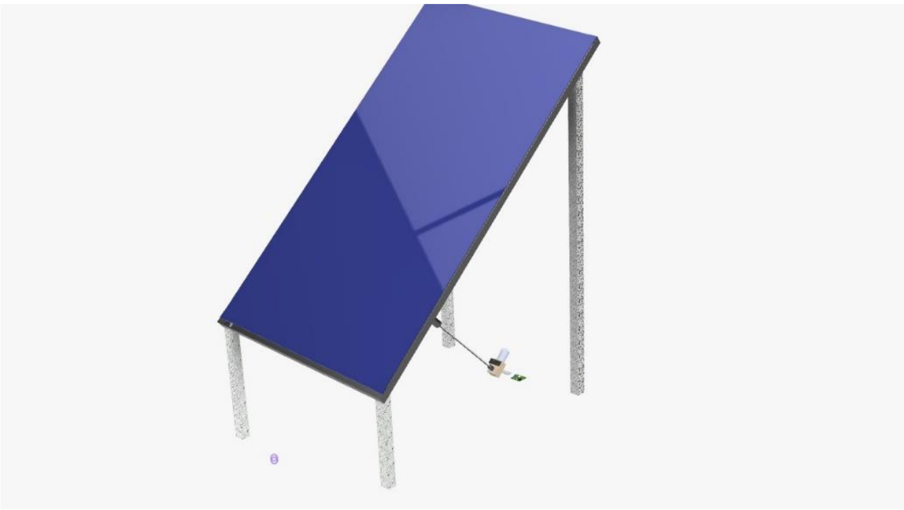

Figure 5: Front- Right Side View

Figure 6: Side View

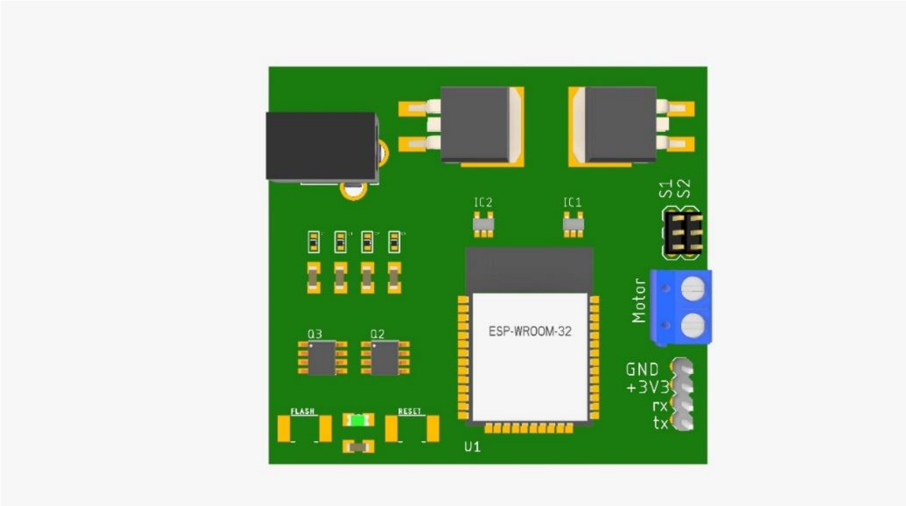

Figure 7: Circuit Board

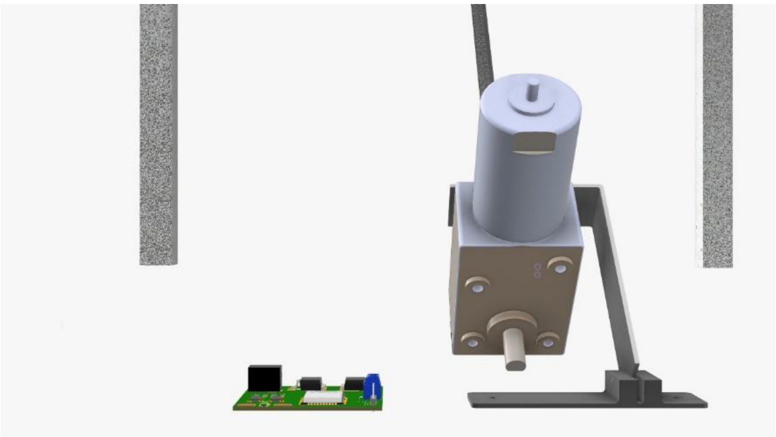

Figure 8: DC motor View (under the panel)

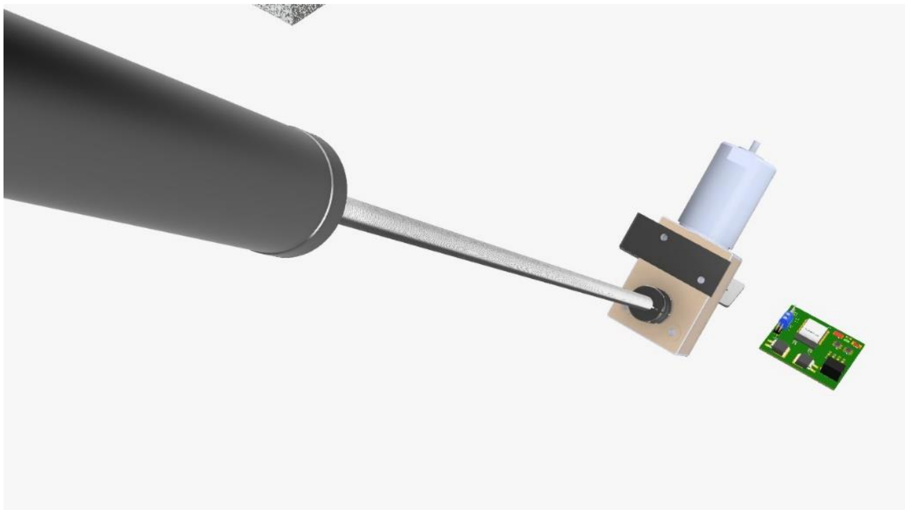

Figure 9: Mechanical arm that moves the panel

13. ELECTRICAL DESIGN

The electrical part of our product consists from esp32 wroom as a micro-controller, Motor driver (direction and speed control), DC motor.

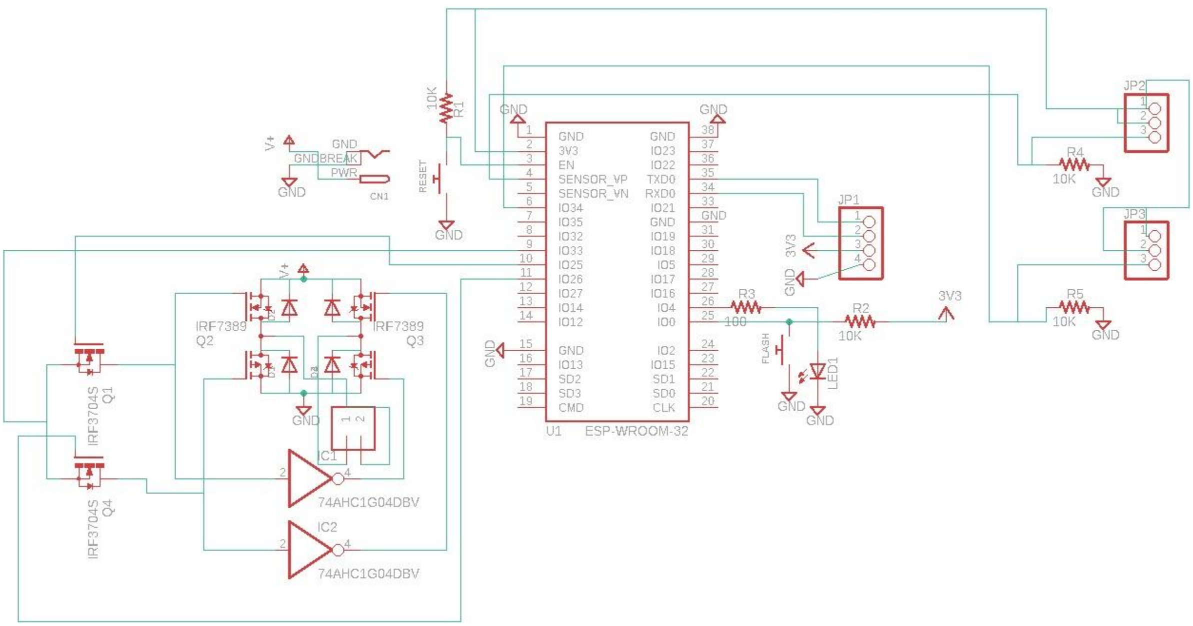

Figure 10: Circuit Schematic

14. PROTOTYPE

In this section, a simple prototype will be presented, and you can find a video we uploaded to YouTube detailing this prototype Here

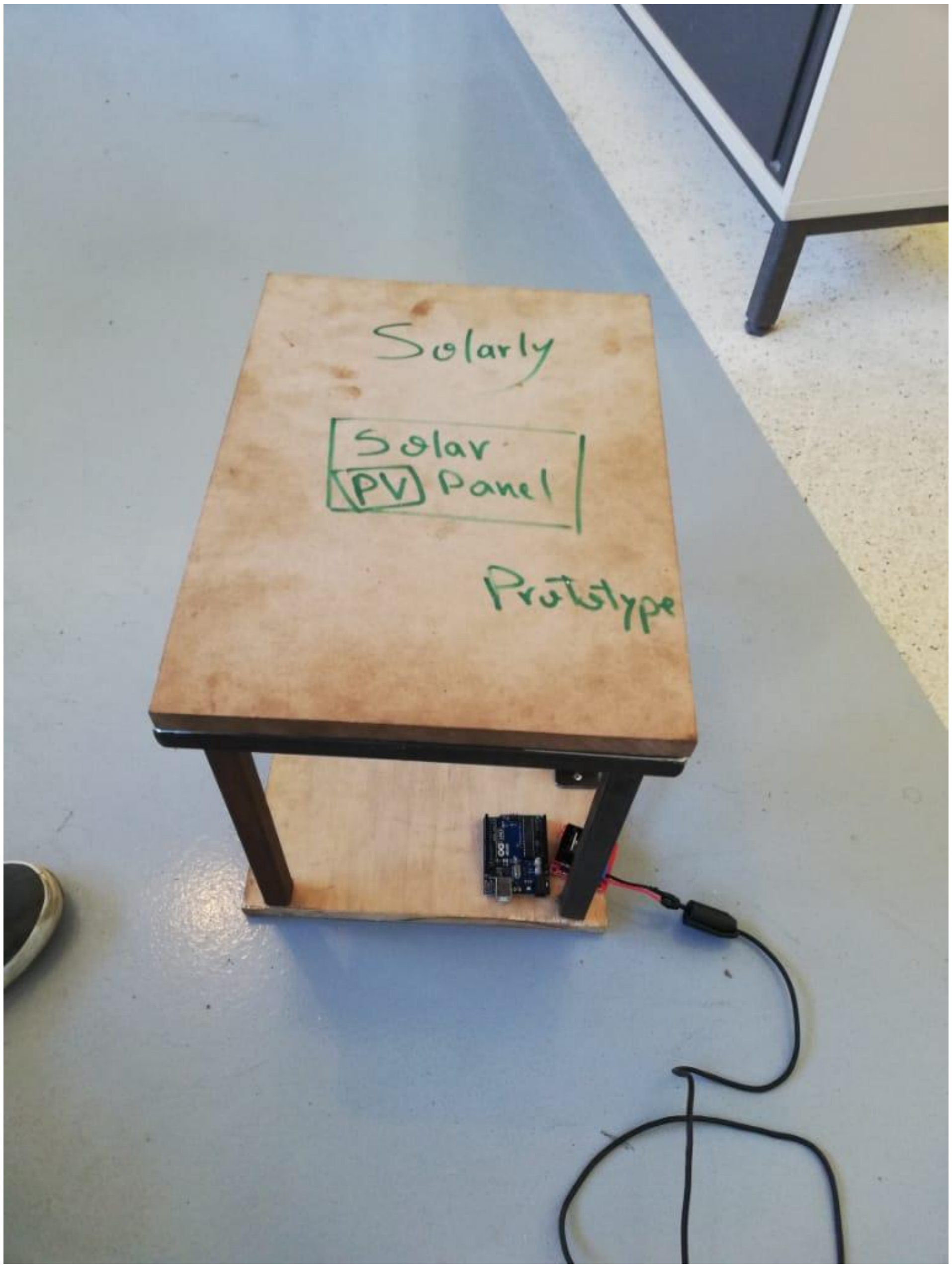

Figure 11: Prototype Top View

Figure 12: Mechanism that moves the Panel

Figure 13: Prototype side view

Team Members:

Mohammad Hosni

Alaa El Dine Ghanem

Raja Murad

Nour Krayem

The team at AECENAR