ME 366

Electro-mechanical System Design & Practices

Project title : Dual Axis Rotating Solar Tracker with Cleansing Facilities

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Abstract

Renewable energy is one the most crucial topic in today's world. Solar energy is an everlasting energy resource[3] and desirable for it's free, practically inexhaustible, and involves no polluting residues or greenhouse gases emission[5]. It offers a vast opportunity to reduce carbon emissions and cut electricity costs. Bangladesh has the biggest off-grid solar power program in the world, which offers encounters and exercises for different nations to extend admittance to spotless and moderate power. By outfitting solar power, the program has empowered 20 million Bangladeshis to get to power. Solar tracker originates a viable approach for maximizing the solar panel efficiency. Most of the solar panel converts sun radiation to electric energy without considering the cosine error caused by the changing direction of sun. There is an ample scope of harnessing electricity from solar energy in the dessert. The great Sahara Desert obtains almost 36,000 hours of daylight annually. But the deposition of dust on the solar panels is an eminent problem in harvesting electricity from solar energy. Our project proposes a design of dual axis solar tracker with cleansing facility. The cleaning part can be performed automatically by a mobile app. The adequacy of this tracker is researched by contrasting the energy tackled and without the tracker. The investigation uncovers that the proposed solar tracker is worth as far as cost and gotten electrical energy.

Acknowledgement

We would like to offer our most profound thanks to our respected course teacher, Dr. Md Aman Uddin (Assistant Professor, Department of Mechanical Engineering, BUET), Musanna Galib (Assistant Professor, Department of Mechanical Engineering, BUET).

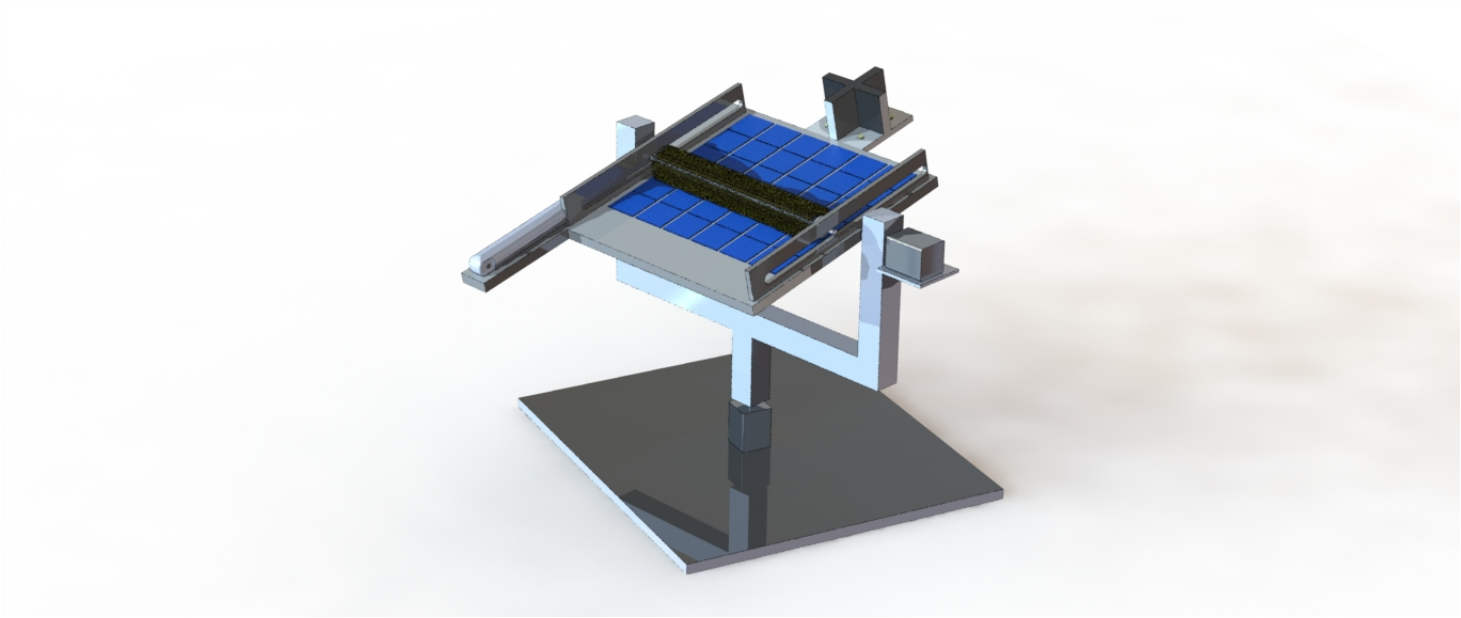


Figure : 3D view of the complete Project

Contents

1 Introduction

1.1 Overview

Energy sources can be broadly classified as renewable and non-renewable. Knowing the dreadful fact that non-renewable sources will eventually deplete, the importance of renewable sources cannot be underestimated, perhaps the most mainstream source. It's right now an interesting issue among the scientists, as it's particularly accessible in the warm countries. There are numerous procedures which are being utilized currently to convert solar energy into other forms of energy and among these strategies, the most mainstream one is by utilizing a "Photo-Voltaic cell" commonly known as a solar panel. Many projects have been done on the "Photo-Voltaic (PV) cells" for collecting solar radiation and converting it into electrical energy. But most of the projects did not consider the difference of the sun angle of incidence by installing the panels in a fixed orientation which influences highly the solar energy collected by the panel. So our goal is to improve a conventional Photo-Voltaic cell, that will track the sun by a rotary mechanism.

1.2 Aim of The Project

• The first & foremost aim is to introduce an automated rotary mechanism in a conventional fixed axis solar panel so that it can rotate by tracking the position of the sun.
• Then the target is to include an automated cleaning mechanism over the solar system.
• Afterwards, the goal is to incorporate a smart system so that the overall procedures can be maintained by a user friendly mobile app.
• Finally, the objective is to accomplish a higher rate of electricity generation from a conventional solar panel in an exceptionally effective manner.

1.3 Scopes & Intended Applications of The project

As solar energy is turning out to be more mainstream as a sustainable source lately, working on the effectiveness of a solar panel has assortment of degrees in different fields. Solar power generation in Bangladesh has been increased up to 300 MW in 2020, which was just below 50 MW in the year of 2010.[1] So, If we can generate higher energy contrasted with the traditional solar panels that are presently on the lookout, we may have an extent of introducing it instead of those fixed axis axes solar panels. In an energy inadequate nation like Bangladesh, where power generation is expensive, solar energy is the best substitute method for power generation. So, we may have a chance to incorporate our project among the mass people, which will decrease the power demand from the national grid & eventually will result in a great effect on our economy. As solar panels are broadly utilized in the field of agriculture, transportation, electrical gadgets etc., we may have a tremendous extent of utilization of our venture in these fields.

1.4 Approach

Our initial approach was to introduce a tracking system into the solar system. A solar tracker can be of 2 kinds – single axis solar tracker & dual axes solar tracker. Single axis solar tracker can rotate just along one axis while the dual axes solar tracker can rotate along both of the horizontal axis & vertical axis. So, for higher accuracy & efficiency, we selected our solar tracker to be of dual axes.

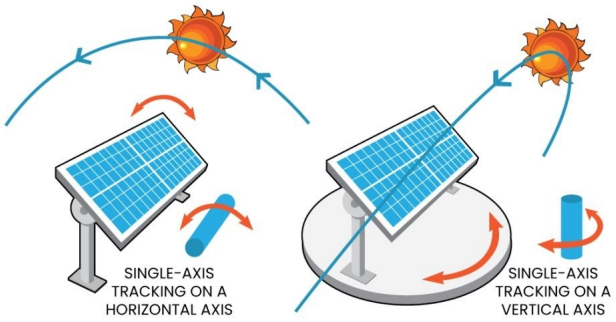


Fig. - Single axis solar tracker [2]

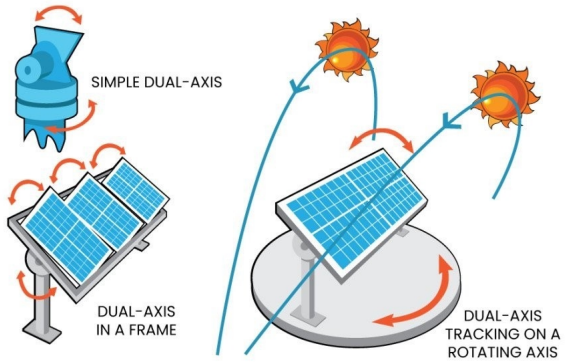


Fig. - Dual axis solar tracker [2]

At first, we made such a structure, that will carry the entire solar panel over it. Then this structure was joined with 2 motors e.g., vertically & horizontally, so that these motors can give rotary motion to the structure along it's both axes i.e., the solar panel will rotate. Hence, the motor will get command to rotate a particular angle from a microcontroller which will be associated with 4 LDRs (Light Dependent Resistors). Here the LDRs will sense the light intensity around the solar panel & give those value of light intensity to the microcontroller. Also, we introduced a dry-cleaning process by adding a roller brush over the solar panel, which will be directly controlled by an external mobile app.

1.5 Assumption

However, our solar tracker has a higher precision and productivity rate than the fixed axis solar panel, it cannot add a significant improvement of power generation in the rainy days as the sun will be covered by cloud at that period. So our solar tracker is assumed to work in just sunny

days & the overcast condition isn't taken into our records to improve overall result. Also, the possible errors due to multiple sensors used in the project have been ignored for simplification.

1.6 Summary

For the most of the time, solar cells run at an efficiency of around 20% which means that they can only capture the 20% of the incident solar radiations. It is just not a significant percentage for our daily uses. To generate more power from a solar panel, we either need to improve the efficiency of the PV panel board or have to find ways of getting more energy from our current solar panels somehow. As the first process is quite hard & not feasible enough to implement, we have to go through the second process i.e., a tracker system for the automated rotation of the solar panel towards the position of the sun. Most of the panels we see in our day-to-day life is installed in a fixed position, most likely facing south at a 45-degree angle, while this approach is extremely simple as well as convenient too. Also, by a automated cleaning process, we clean the dusts over the panel & thus the ability of a solar panel to grab more energy can be increased too.

2 Literature Review

Since the invention of photovoltaic cell, researchers are aspiring to enhance the efficiency of solar panel. Today's commercially available solar panel efficiency is generally about 15-20%. Rizwan et al.[7] showed that Concentrated Photovoltaic technology (CPV) using optics such as mirrors and lens can improve the efficiency up to 32%. Jafari et al.[9] investigated the temperature effect on the efficiency of photovoltaic cell. The ambient temperature for desirable output can be calculated from their study. Air cooled heat sinks can maintain the optimum temperature which has been showed by Catain and Sebastian [6]. Fahmid and Ahsan[8] remarked that the use of solar tracking can increase the electricity generation up to 40%. From the study of Piotr et al.[4] can be stated that ultrasonic cleaning system can amend the efficiency of solar panel working in a dessert condition.
Based on the above literature survey, both solar tracking system and cleaning facilities are not studied extensively. The present project aims at improving the efficiency of solar panel by using both dual axis tracking and dry cleaning system.

3 Design & Methodology

3.1 CAD modeling

In the CAD design, all types of constraints are undertaken to overcome. The solid structure can move 360° in the vertical axis of the lower stepper motor. Correspondingly, the solar panel can be revolved around the horizontal axis, but it was ensured that the solar panel constraints it's movement between 30° and 320° with respect to the vertical axis. These LDRs are separated by black walls fabricated with cork sheet so that the light intensity of one side can not interfere with the other side. An actuator is added to the CAD design which moves the roller brush linearly along the solar panel. Adequate place is considered at the bottom of solar panel. The roller brush is retained in the place when it is stationary.

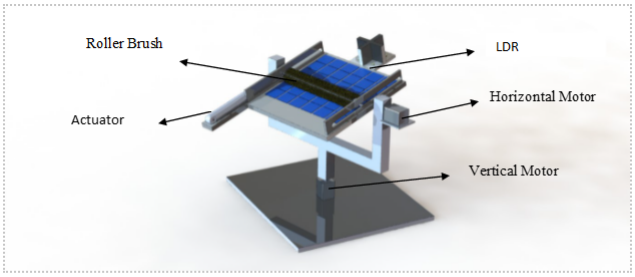


Fig – Isometric view of the solidworks model with labeling

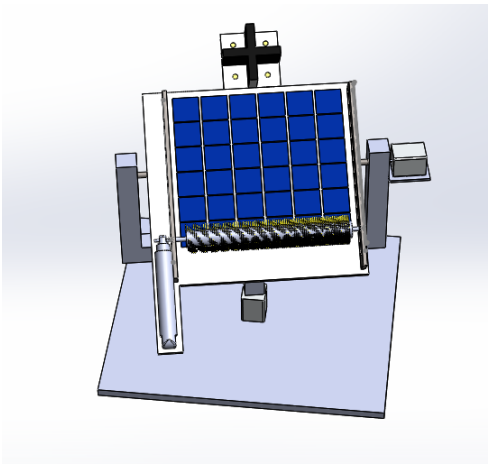


Fig: The Roller Brush Is Set In The Resting Place Without Hindering The Energy Production

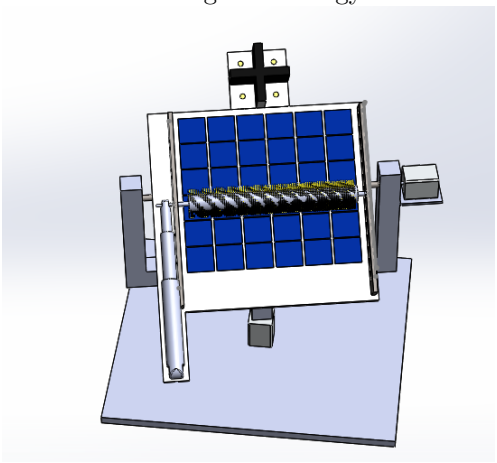


Fig: Actuator Linear Motion While Cleaning

3.2 Algorithm

LDRs operate as the bridge between the environment and our solar system. Four LDR are attached at the top of the solar panel to sense the light intensity. The two Nema 17 stepper motors and actuator are the main driving force

in this project. The stepper motors rotate the solar panel both horizontally and vertically and the actuator imparts linear motion to the cleaning brush. A threshold value termed as tolerance is imparted. The two motors do not rotate until the average of any two LDR exceed the tolerance value If the average value of the top two LDRs is greater than the mean value of the bottom two LDRs, the horizontal motor relocates the panel accordingly to tilt the panel about the horizontal axis. Similarly, the stepper stirs the panel vertically after the comparison between the mean value of right and left side. The code developed in the Arduino IDE is based on this working principle.
A user-friendly app is developed to clean the solar panel by an actuator. The solar panel does not need to be cleaned constantly. One tap on the mobile screen can scrub the solar panel instantly. By this approach, the surface of the photovoltaic cell can be cleaned only if the user wants to. A flowchart is given in the below:

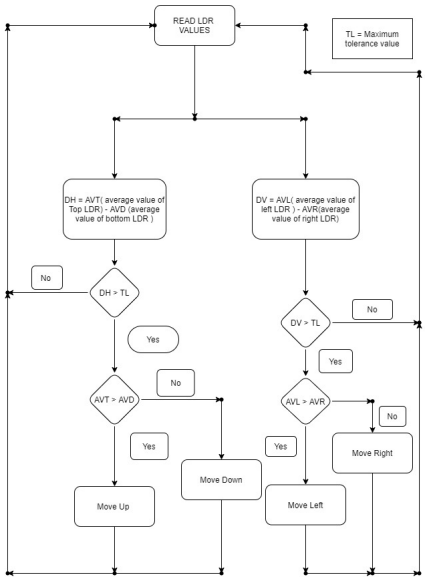


fig - Flowchart of our algorithm

3.3 Circuit Design

A microcontroller i.e., ARDUINO MEGA, a breadboard, 4 LDRs, 4 resistors, 2 L298N motor drivers, 2 NEMA 23 stepper motors, 2 DC power sources i.e., 12V 1800 mAh LIPO battery & jumper wires have been used in this circuit connection. At first the LDRs are connected to the 5V pin of the ARDUINO board through resistors & the other side is joined to a common node. This common node was connected to the analog pins of the ARDUINO board individually and to the ground pin. The input pins of the L298N motor drivers are connected to the digital pins of the ARDUINO board. Both motor drivers are connected with 12V DC power source i.e., LIPO battery. Then the motor drivers are enabled by connecting to the 5V pin of the ARDUINO & the two pins SENSA & SENSB are grounded. Then the two stepper motors are paired with the output pins of the motor drivers. These two stepper motors will help the structure to rotate along vertical & horizontal axes. Later, this circuit connection was checked through simulation in PROTEUS & the motor rotated successfully. Here a schematic of the circuit diagram & a demonstration photo of our physical circuit connection are shown –

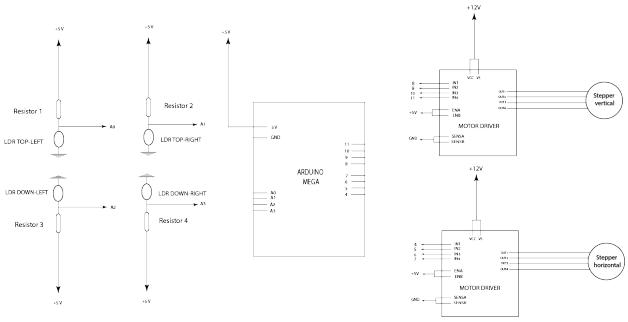


Fig. - Schematic diagram of the circuit

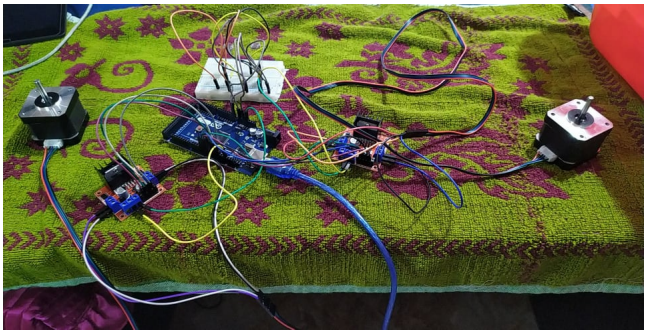


Fig. - Physical circuit connection

3.4 Mobile App Development

3.4.1 Introduction

The main aim for the android app section was to develop a mobile app which would aid the user to use the solar panel more conveniently. Because normal solar panel is cheaper and needs little to no care at all in servicing, our goal was to use the mobile app to bridge up this gap and make our project more appealing to the end users. MIT app inventor environment is utilized to build the app. Our mobile app will help the user to clean the solar panel easily at any convenient time whenever he wants to. Also, the dual axis solar panel will automatically clean its self twice every day. As research study shows, cleaner solar panel can create up to 50 V and 3.5 A current where normal solar panel, as days go by, dust accumulates on it and can only create 41 V and 2.6 A current. Moreover, Live LDR's data is also featured in our app to check if all sensors are working well. So, these steps were taken to make our product is more user friendly and usable by people of all ages.

3.4.2 Components

• HC05 Bluetooth module • 4 LDR • L298 Motor Driver • 12 V DC motor • 12 V Battery • Arduino Mega • Breadboard • Jumper wires The 12 V DC motor is linked with the two output pin of the L298N motor drivers. We connected the enabA and two input pins of the motor driver to

the digital pins(22-24) of Arduino to give the instructions from the code to motor driver when needed. The HC05 Bluetooth module was connected to the Arduinos 0 1 pin for Tx and Rx and connected to the ground and 5 V to respective pins in the Arduino.

3.4.3 Physical Circuit Design

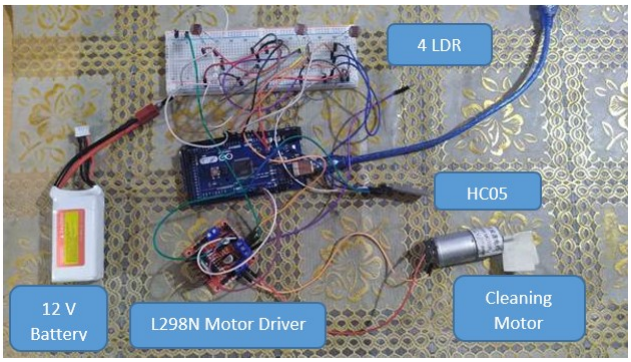


Fig - Physical Circuit Design

3.4.4 Code for The App

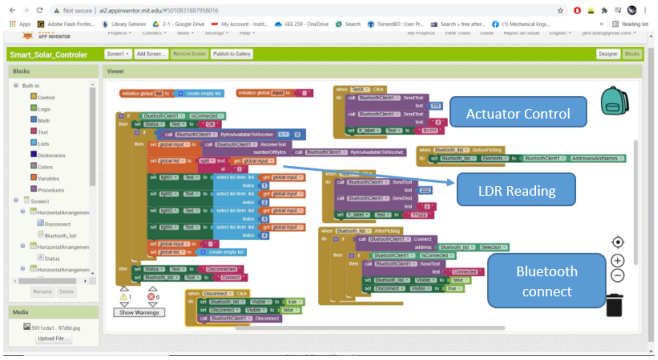


Fig - Code For The App

For the mobile code to run as expected, the mobile app is needed to coupled with Arduino. So, the corresponding code for pairing was written at first, Bluetooth list before picking is used to load up all the available Bluetooth device in the range and after picking part is used to connect it to HC05 when selected and change the Disconnected status to Connected in the app. Then an empty list was created to collect the LDR reading and collected values are separated it by the sign by '—' so the mobile app can know all the separated reading of the 4 LDR and show it in the app respectively. It can be seen in the 'Set light1 text to' section in the code. Now the other feature of the code is that it can control the cleaning motor which is done here by the "When TextX click" and "When TextY click" section which will send 111 and 222 number to the Arduino when it is clicked and Arduino will rotate the actuator anti-clock wise and clock-wise respectively, thus cleaning the solar panel. The app is called "Solarometer". The interface of the app will be like this as shown below-

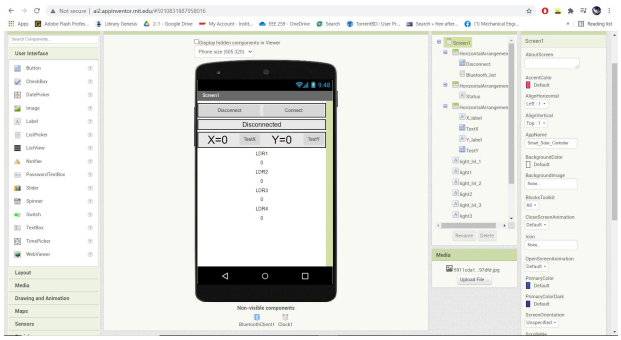


Fig - Mobile App Interface

4 Calculation & Results

There are 4 conditions that can happen in this 4 LDR combination as the top 2 LDR's average becomes top avg value, same for bottom, left and right average too. Now, the tolerance value has been set to 100 in the code. So, difference of 100 would not impart any rotation in the system. There are 2 stepper motors in the system which rotate the solar panel horizontally and vertically. Top and bottom LDR's are responsible for the horizontal movement. Left and Right LDR's are responsible for the vertical movement. If, the top 2 LDR's value are 832 and 920 respectively and bottom 2 LDR's values are 532 and 320. The calculation in the Arduino code will be:
Top Avg. = (832 + 920)/2 = 876
Bottom Avg. = (532+320)/2 = 426
So, the difference will be (876 – 426) = 450 which is greater than the tolerance value 100, so the horizontal stepper motor will run anti clock wise and will run the motor until the difference value come between the tolerance range andotherwise motor will run clock wise.
If, the left 2 LDR's values are 932 and 836 and the right 2 LDR's values are 345 and 550. The calculation in the code will be:
Left Avg. = (932 + 836)/2 = 884
Right Avg. = (345 + 550)/2 = 448
So, the difference becomes (884 – 448) = 436 which is also greater than the tolerance value 100, so the vertical stepper motor will run anti clock wise and will run the motor until difference value come between the tolerance range and otherwise, motor will run clock wise.

5 Data Analysis

An extensive study was conducted by Prof. Ahsan and Fahmid[8]. Their fabricated single axis solar tracker was operated from 8 AM to 5 PM and the voltage was taken at hourly interval. Another solar panel with identical specification is set at a fixed position. After measuring data from the two solar panels, it was evident that the single axis solar tracker power output was 10% more than the fixed one. With dual-axis solar tracker system better performance than the single axis solar tracker can be achieved.

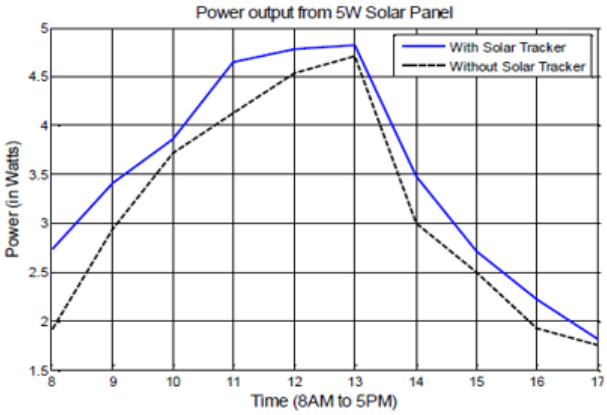
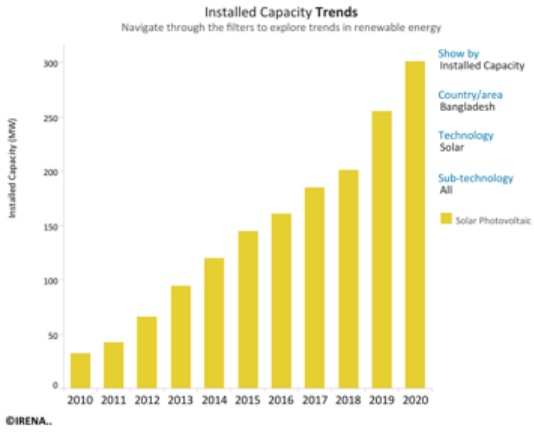


Fig - Hourly solar power output with & without solar tracker



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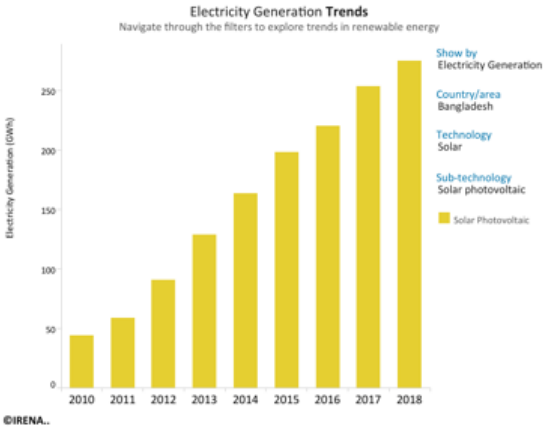

[1]

It is not very economical to use cleaning system in the countries with enough rainfall annually. But the case is different for desert. This barren region has high potential for solar energy. Nevertheless, excessive deposition of sand particle hinders from it's potential to harvest solar energy. Qdah et al. [6] found that in medina the efficiency loss due to dust is more than 5%.

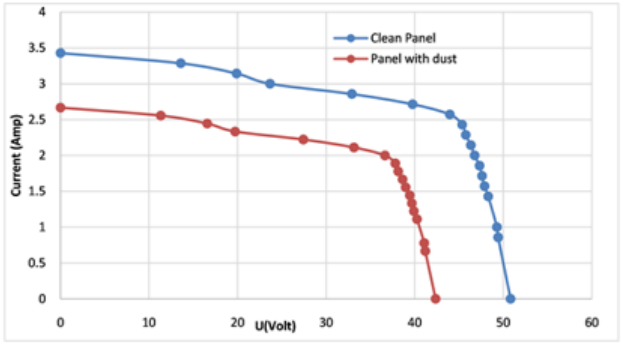

Fig - Measured I-U characteristics for clean vs dusty panel

6 Discussion

A 73 MW solar panel plant is supplying electricity to the national grid. Bangladesh solar energy consumption is growing more and more over the years. With a smart solar system, people can use the solar system more efficiently and conveniently. A user friendly solar system can drive more into this renewable source.

7 Reflection on Learning

From this project, our knowledge in hardwares like Arduino, L298N motor driver, HC05 Bluetooth module, Nema 17 stepper motor etc has been enriched and also in the case of software like Proteus, Tinker Cad, Solid works, MIT App Inventor. Arduino IDE and MIT app development environment are now familiar with us. Besides, a lot of research papers to collect data were studied thoroughly which helped our knowledge about research paper writing, reading and publishing too. Practical knowledge in this sector will help us in depth of knowledge of going more deeper about those components. This knowledge of app development can be beneficial in future app development. This knowledge can be used in completing this project and making it a reality. This knowledge will help to publish conference paper in future and also publishing research paper, now knowing where to collect the data and use it effectively and also hardware knowledge will help in the upcoming future projects too.

8 Future Works

For the future, the first and foremost task will be the completion of the whole project and make a fully functional dual axis solar panel. The next step will be conducting

more research into this topic. Some research works were also published by our teacher which will strong our knowledge more robustly. Further studying research paper and gathering knowledge and data to have concrete expertise on the solar tracker system. Moreover, to improve electricity output by further reducing the power input is our next target that may be done by reducing the stepper motor number and using gears to move the parts more efficiently. Furthermore, introducing the machine learning into the project will further boost the efficiency rate, as the plan is to use it to develop a sunshine pattern for that specific solar panel in that specific environment. The system can automatically detect when it needs to be cleaned with the various data that will be feed into the system over the years. Dry cleaning process in the solar panel is used for now but it may be further improved by introducing ultrasonic cleaning system. In the desert, this type of facility may be a huge advantage in attaining electric energy more efficiently. The huge cost of using an actuator can be omitted also. Additional improvement in app needs to be done by making it more user-friendly and adding more features into it such upgrading it from Bluetooth to Wi-Fi with the aim of controlling the system from home. Also, introducing live energy monitoring system could be a valuable feature in the app. With these further improvements, if the output result is satisfactory, our project could be published in a conference proceeding.

9 Appendices

To get all the simulation videos & the arduino code, click

here & go through "View on GitHub"

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