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A NEW APPROACH FOR CONTROL SYSTEM OF SOLAR PANELS

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ABSTRACT

The cleaning system, cooling system, and auto tracking system are three modification systems for solar panels that can boost the efficiency and output of the system. The goal of this project is to examine prospective techniques of automated cooling, cleaning, and tracking in solar systems, with the goal of getting an appropriate scope in the design, application, and future development of automatic cooling, cleaning, and tracking technologies. The cooling system works by transferring heat from the solar panel body to the coolant (water) within a serpentine-shaped copper tube put at the rear of the solar panel. Cleaning is accomplished with the use of a cleaning brush that travels across the panel's whole surface. Finally, the automated tracking system relies on two major components to move the panel. This study aimed to designing a new system for smart control of solar panels, the new system was established and tested by the authors.

KEYWORDS

PV systems; solar panel; light dependent resistor; mechanical design.

INTRODUCTION

Photovoltaic systems, typically transform solar radiation directly into electrical energy and are designated a renewable energy source, may be used for a variety of applications, ranging from tiny systems powering sensors or domestic aircraft to big systems sending electrical power into the grid. Considering its wide range of applications, the system's fundamental configuration is simple. At the heart of the system is the pv system, which involves the combination of PV modules representing the system's required power capacity. Power conditioning and energy storage systems, arrays installation and support, safety assurance, and system performance assessment are the remaining subsystems.
Photovoltaic (PV) systems transform sunlight into electricity by using semiconductors. Everywhere from calculators and traffic signals to big industrial residential complexes might be powered by PV devices.

The system's performance is influenced by its operating conditions and technical design, which is primarily concerned with energy output in terms of quantity and time. The position of the system, in turn, affects the amount of solar energy received, the ambient temperature, and the operating conditions, as well as other meteorological factors that affect the system's efficacy.

Photovoltaic systems are divided into two categories based on whether or not they are connected to the local power grid.

Grid-connected systems are often built to always deliver the maximum energy production and to aid in the fulfilment of electrical demands, either locally or via the electricity network.

In this case, the system's goal is to deliver the proper amount of electricity to the specified load. Standalone PV systems run independently of the grid and are widely utilized in locations where there is no electricity or where grid connection is difficult.

Solar panels are made up of several different parts. Cells, which are typically constructed of silicon, are stacked on a module, which is then coupled to provide the needed system size. When exposed to sunlight, these cells produce a modest direct current of electricity, and when utilized in a group, they may generate a large amount of electrical power with no moving components, noise, or pollutants.

The electricity is then sent to an inverter, which converts direct current to alternating current, which we use in our houses.

Photovoltaic systems can be built in a variety of ways, including grid-connected or stand-alone, fixed or tracked, flat plate or concentrator operation.

The Egyptian government emphasizes the power of a renewable energy mix in meeting rising demand while also transitioning to a more ecologically friendly and diverse electrical industry. Renewable energy is emphasized in the 2035 Integrated Renewable Strategy, which builds on prior projects. Egypt aims to raise renewable energy generation to 20% of total electricity generation by 2022. By 2035, the figure will have risen to 42%. By 2035, wind energy will account for 14% of total power generation, hydroelectric will account for 2%, and solar will account for 25%. The bulk of this capacity is projected to come from the private sector. [1].

Photovoltaic Panels

A Photovoltaic system is a photovoltaic cell assembly that has been installed in a structure. Solar energy is used to generate direct current electricity in photovoltaic cells. An Array is a collection of Panels, whereas a PV Panel is a collection of PV modules. The arrays of a photovoltaic system supply sun energy to electrical equipment. Grid-connected or stand-alone photovoltaic systems can be built in a variety of designs, including fixed or tracked, flat plate, or concentrator operation.

Fig. 1. PV Panels

PV system method of operation

The antireflective layer efficiently maintains the incident light by improving its propagation to the next layers when solar rays fall on the solar cell. When the negative slice is exposed to sunlight, the photons' energy is passed to the electrons in the valence zone, allowing them to migrate to the negative slice's conducting area. The positive gaps, on the other hand, move to the conduct area of the positive wafer, likely to result in a voltage

distinction between the two surfaces of the double link, which can be connected by an electrical conductor to obtain an electric current in an electrical circuit, where the electrons pass from the first link negative to the positive link in the electrical circuit, so light energy must be converted into electrical energy, [2 - 7].

Structure of the Solar Panel

Plenty of known solar panel producers are 'vertically integrated,' meaning that they supply and manufacture all the major components, including all the silicon ingots and wafers required to produce solar PV cells. Many solar panel producers, on the other hand, build solar panels with elements supplied from other sources, and as cells, polymer back sheets, and encapsulating EVA material. While these companies can be more careful about the components they use, as they do not need to monitor their product quality, they should make sure they select the best suppliers available.

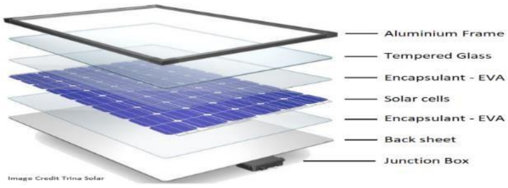

Fig. 2 Structure of the Solar Panel

Photovoltaic Solar cell Classification:

Each photovoltaic (PV) cell is made up of two or more thin layers of semi-conductive material, the most common of which being silicone. Electrical charges are created when a semiconductor is exposed to sunlight, and these charges may be extracted through metal contacts as direct current. Because the electrical output of a single cell is limited, numerous cells are linked together to produce a line that generates direct current.

Monocrystalline silicon PV panels

These are created using cells made from a single cylindrical silicon crystal. This photovoltaic technique is the most efficient, converting roughly 17% of solar energy into electricity. Mono - crystalline silicone manufacture is complex, resulting in somewhat higher prices than equivalent technologies.

Fig. 3 Monocrystalline PV panel [5].

Polycrystalline silicon PV panels

Polycrystalline silicon cells, also known as multi - crystalline silicon cells, are made from melted and crystallized silicon ingots. The flakes are then sawed into ultra-thin wafers, which are then reassembled into entire cells. They are generally less expensive to make than mono - crystalline because to the simpler production procedure, albeit they are considerably less efficient, with approximate efficiencies of roughly 13 percent -16 percent.

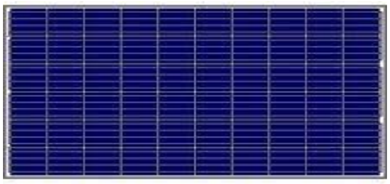

Fig. 4 Polycrystalline PV panel.

Thick-film silicon PV panels

This is a multi-crystalline technological variation in which silicon is continually deposited onto a base material, resulting in a fine-grained, dazzling appearance. Thick-film silicon PV panels, like many other crystalline PV, are coated in a transparent insulating polymer with a tempered glass cover before being assembled into a metal framed module.

Fig. 5 Thick-film PV panel.

Solar Panel types:

Solar power is a sustainable energy technique that uses photovoltaic modules to turn solar energy into electrical energy. The produced power can be instantly stored or consumed, or it can be sent back into the grid or used off-grid.

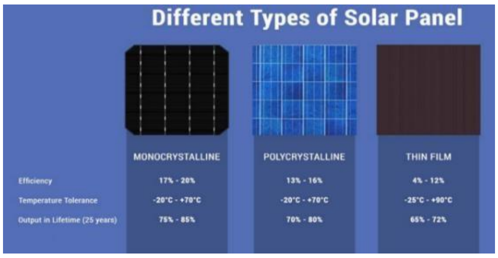

Fig. 6 Different types of solar panel.

On grid system

They are solar energy stations that generate electricity and pump it into the public electricity network. The sizes of these locations range from a kilowatt implemented on the roofs of buildings to several thousand kilowatts built across large areas of land, and they require permits and licenses from the electricity provider to be implemented and plugged. If an unique solar power station is built in a building and plugged, the station's owner consumes what he needs from the solar station's production throughout the day, with any excess injected into the distribution network. The electrical loads of this subscriber are provided with energy from electricity provider throughout the night, and the accounting is done on the basis of the difference between what the solar plant produced and what the network consumed, a method known as net metering.

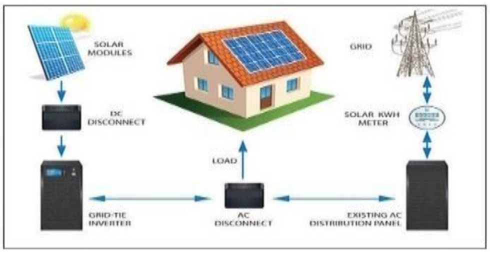

Fig. 7 On grid system, [8].

Off grid system

Because it is not connected to the power grid, an off-grid system requires battery storage. Off-grid solar systems should be designed appropriately to supply adequate power throughout the year and have enough battery capacity to meet the needs of the home, even when sunlight is limited in the winter. Due to the high cost of batteries and off grid inverters, off-grid systems are significantly more expensive than on-grid systems. For this reason, they are usually only required in more remote, off-the-grid locations. However, as battery prices fall, a new market for off grid solar battery solutions, even in cities, is developing.

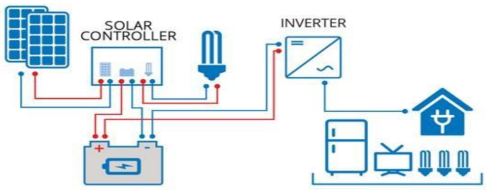

Fig. 8 Off grid system, [7].

Hybrid PV system

Modern hybrid systems combine solar and battery storage into a portable device that is available in a variety of shapes and sizes. As battery storage becomes more inexpensive, systems that are already connected to the power grid can begin to benefit. This refers to the ability to store and use solar energy that is created during the day. When the stored energy runs out, the grid steps in as a backup, giving clients the best of both worlds. In hybrid systems, off-peak electricity may also be used to charge the batteries (usually after midnight to 6am).

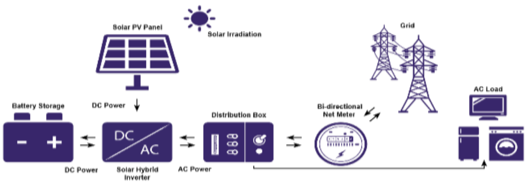

Fig. 9 Hybrid PV system, [8].

Cleaning system

The performance of solar plants degrades when they are dirty. Depending on the amount of dirt, a dirty panel will produce 10% less than a clean panel under the same conditions. Dirt is available in a wide range of forms and sizes. Pollution, dust, bird droppings, oil, or any other airborne particles that cling to the solar panels. Hotspots form when dirty sections of the panel heat up quicker than other parts. These hotspots can accelerate the deterioration of solar panels. Solar panels work by enabling the sun's natural light to 'enter' their solar cells. The more natural light that reaches the panel, the more energy it produces. The following are some compelling reasons to get your house cleaned.

Fig. 10 Dust contaminated solar panel, [3].

The two types of soil shading that may be found on PV modules are hard shading and soft shading. Soft shading happens when certain elements, such as smog, are present in the air, whereas hard shading occurs when a particle, such as collected dust, covers the sunlight. Soft shadowing affects the PV module's current, but the voltage remains constant. When a PV module is subjected to intense shadowing, its performance is determined by whether some or all of its cells are shadowed. If certain cells are shaded, the voltage generated by the PV module will decrease if the unshaded cells receive some solar irradiation.

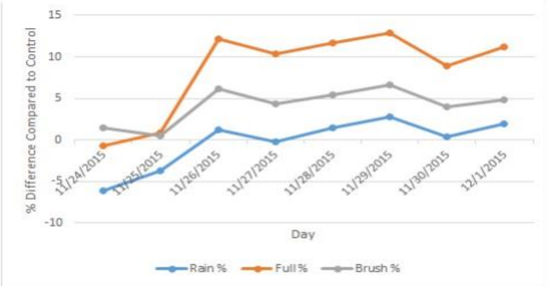

Fig. 11 Improvement in solar energy generation after cleaning, [3].

Is it feasible to eliminate the faeces? Because of their location, solar panels are susceptible to bird droppings. Rain does not, contrary to common perception, wash the droppings away. This lowers the total energy generating output by reducing the amount of light reaching the solar cells. Many solar panel manufacturers also say that the buildup of these droppings will reduce the panel's ability to operate as expected.

To Avoid Collecting Dirt and Dust Natural elements such as dust and filth can obscure the surface of a solar panel, lowering its efficiency. If solar panels aren't cleaned on a regular basis, they won't perform as well as they could, lowering your return on investment and diminishing your energy savings. Furthermore, dust or other particles that have been placed on solar cells for an extended period of time can harm the aluminium strip of the solar panel plate, so we eliminate this damage with this approach, and the solar panel's dependability is increased.

In addition, to improve total energy efficiency regularly maintained solar panels have a considerable boost in efficiency. Studies reveal that when a site's solar efficiency is precisely preserved utilizing typical cleaning facilities, the site's solar efficiency rises by 10 – 30 %. Customers that wash their solar panels on a regular basis have a 25 % greater performance than identical users who do not.

The World Academy of Science, Engineering, and Technology came to this decision, stating that "a decline in the efficiency of a solar PV panel is not wanted." The accumulation of dust on the solar panel is one of the contributing reasons in the loss of efficiency in solar PV panels. In order to get the best performance, dust must be cleaned from the surface of solar PV panels in practice." Finally, keep your panels clean if you want them to work and stay continuing.

Why should you use clean solar panels?
Airborne dust particles, sticky tree and plant sap, smoke, and bird droppings are just a few of the things that might cause debris to build on your panels. As a result of the buildup, sunlight will be blocked from reaching the cells. For solar energy owners and investors, this results in poor system performance, efficiency loss, and a loss of financial return. Regularly cleaning your modules provides optimal performance, protects your warranty, saves you money, extends the life of your investment, and avoids permanent stains.

Technologies for panel cleaning:
Cleaning solar panels is one of the most important and cost-effective concerns that both present and emerging technologies must address. Most solar panel systems now rely on one of the following:
The amount of rain that falls and the speed at which the wind blows are as follows: They are unrestricted but unreliable, and rain is uncommon in arid areas. As a result, the consistency cleaning approach is difficult to use when the stain is strong and rainfall is insufficient to remove the soil, either in quantity or concentration. Following a small rain, substantial performance decreases have been seen in some occasions. Wind may also lessen or eliminate soiling to a certain extent, but for best power generation, water is required to wash the surface.

Manual cleaning: To remove the filth from the surface, brushes with specific bridles are used. This prevents the units from being scraped. Some brushes are also directly connected to a water source, allowing them to clean and brush at the same time. Cost of employment, workplace safety, cleaning efficiency, and quantity are all challenging to achieve.

Robotic systems: technology is used to run the washing work as well as a water storage capacity. To lessen the influence of dust, regular washing cycles are recommended, with weekly washing during dry seasons and daily cleaning recommended for severe dust development.

Cooling system
The Effects of Temperature on Solar Panels The open-circuit voltage declines considerably when the panel temperature goes over 25 ºC, but the short-circuit current increases very little. The temperature coefficient is a mathematical expression that describes how temperature affects photovoltaic performance. As a result, the power output reduces as the temperature rises. When the temperature rises or falls above or below 25 degrees Celsius, the temperature coefficient % shows a change in output. As a result, in order to offset the negative impacts of cell temperature and keep the operating temperature within the manufacturer's stated range, it's necessary to remove heat from the PV with adequate cooling devices.

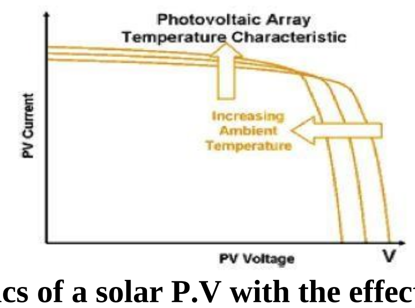

Fig. 12 Characteristics of a solar P.V with the effect of temperature, [4].

Tracking system

Renewable energy control automation systems require automated solar tracking software and solar position algorithms to achieve dynamic motion control using control automation architecture, circuit boards, and hardware. On-axis sun tracking systems, such as altitude-azimuth dual axis or multi-axis solar tracking systems, use sun tracking techniques or ray tracing sensors or software in automated solar tracker applications to ensure the sun's passage through the sky is traced with high precision, all the way through the summer and winter solstices. A high-precision sun position calculator, also known as a Winter solstice and solar equinox calculator.

A computer programmer routine is also employed to align the solar tracker with the sun, and it is an important component of the concept and mechanism of an automated solar tracking system.

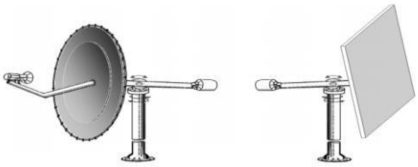

Fig. 13 Tracking system, [4].

EXPERIMENTAL

PV Solar System Component (Test Rig): A photovoltaic Solar system's main components are the PV array, solar charge controller, inverter, watt hour meter, supplementary sources, and loads.

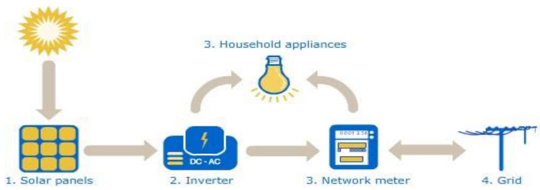

Fig. 14 Major PV Solar System Component.

Figure 15 shows the new PV solar system component Design.

Fig. 15 test rig.

Polycrystalline silicon PV panel

A polycrystalline silicon PV panel is used and shown in Fig. 16.

Fig. 16 Monocrystalline PV panel.

Charge controller for solar panels

Prevents battery overcharging and extends battery life by regulating the voltage and current supplied to the battery from the PV panels.

Fig. 17 Solar charge controller.

Metal chassis

The panel is held in place on the upper frame by a metal framework.

Fig. 18 Main structure.

Water pump

Water circulation on the cooling system is provided by a DC water pump (750 GPH -12 V).

Fig. 19 Water pump.

Linear actuator

The essential element of the Auto tracking system is an actuator for moving the solar panel.

Fig. 20. Linear Actuator.

Arduino

The major job of the Arduino MEGA is to control operations.

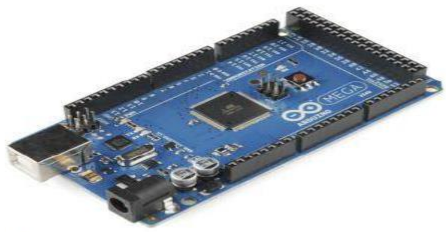

Fig. 21 Arduino.

Relay module

The polarity of a voltage delivered to a load is switched using an electrical circuit.

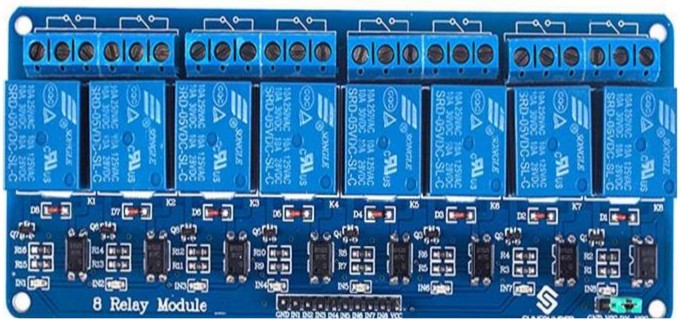

Fig. 22. Relay module.

Sensors

a. LDR Sensors

LDRs (light dependent resistors) are light-sensitive components that are often used to detect as well as measure the intensity of light.

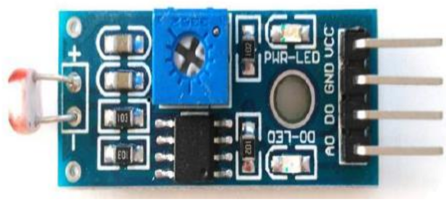

Fig. 23 LDR Sensor.

b. Temperature sensors

Fig. 24. Temperature Sensor.

Battery

Two batteries (12 volts) are used as the power source and storage.

Fig. 25 Battery.

Electrical wires and switches

It is used to control the closing and opening of the circuit as needed.

Fig. 26 Electrical wires and switches.

Cleaning brush

It is used to clean the surface of the panel.

Fig. 27 Cleaning brush.

Cooling serpentine tube

15m copper tube serpentine shaped facing behind the panel.

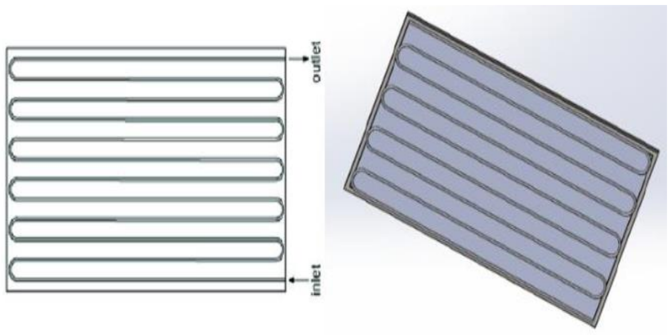

Fig. 28 Cooling serpentine tube.

Mounted bearing
It is used to connect the shaft (which mounted to the plate) to the chassis.

Fig. 29 Mounted bearing.

The linear rail is used to move the cleaning brush over the surface of the plate.

Fig. 30 Linear rail.

RESULTS AND DISCUSSION

The goal of this study was to examine potential ways of automated cooling, cleaning, and tracking in solar systems in the hopes of getting an appropriate scope in the design, use, and future development of these technologies. The acquired power and temperature for four days are shown in Tables 1, 2, 3 and 4. At 12 a.m., the maximum power was attained.

Table 1. Day One

Time	Electric current	Voltage	Power	Temperature
Day 1		Fixed		
6:00 AM	6.9 A	30.1 V	207.69 W	26 C
7:00 AM	7.23 A	30.2 V	218.34 W	26.4 C
8:00 AM	7.5 A	30.3 V	227.25 W	27 C
9:00 AM	7.8 A	30.6 V	238.68 W	27.6 C
10:00 AM	8.2 A	30.8 V	252.56 W	28.6 C
11:00 AM	8.39 A	31.2 V	261.768 W	29 C
12:00 AM	8.45 A	31.4 V	265.33 W	31 C
1:00 PM	8.41 A	31.4 V	264.07 W	32 C
2:00 PM	8.37 A	31.1 V	260.31 W	30.4 C
3:00 PM	8.26 A	30.9 V	255.23 W	30.2 C
4:00 PM	8.11 A	30.7 V	248.9 W	29.6 C
5:00 PM	7.87 A	30.5 V	240.035 W	29.2 C
6:00 PM	7.3 A	30.3 V	219.7 W	29 C

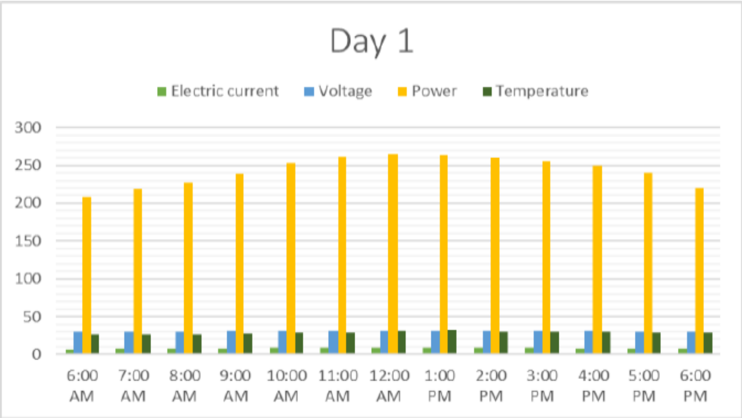

Figure 31: day one

Table 2. day two

Time	Electric current	Voltage	Power	Temperature
Day 2	Tracking			
6:00 AM	7.15 A	30.1 V	215.22 W	28 C
7:00 AM	7.21 A	30.3 V	218.5 W	28.6 C
8:00 AM	7.6 A	30.7 V	233.32 W	29 .4 C
9:00 AM	7.78 A	30.76 V	239.31 W	30 C
10:00 AM	7.92 A	31.11 V	246.4 W	31.5 C
11:00 AM	8.32 A	31 .2 V	259.6 W	32.6 C
12:00 AM	8.47 A	31.6 V	267.7 W	34.6 C
1:00 PM	8.43 A	31.45 V	265.12 W	34.2 C
2:00 PM	8.26 A	31.2 V	257.7 W	33.9 C
3:00 PM	7.96 A	31.09 V	247.5 W	33.5 C
4:00 PM	7.84 A	30.97 V	242.8 W	33 C
5:00 PM	7.63 A	30.67 V	234.01 W	33 C
6:00 PM	7.35 A	30.2 V	221.97 W	31.8 C

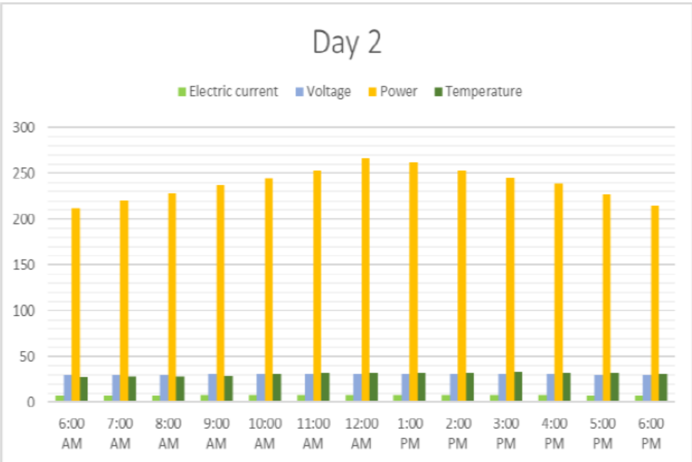

Figure 32. day two

Table 3: day three

Time	Electric current	Voltage	Power	Temperature
Day 3	**Cooling**			
6:00 AM	7.02 A	30.2 V	212 W	27 C
7:00 AM	7.25 A	30.43 V	220.62 W	28 C
8:00 AM	7.43 A	30.68 V	227.95 W	28.5 C
9:00 AM	7.68 A	30.79 V	236.5 W	29.7 C
10:00 AM	7.91 A	30.97 V	244.97 W	31.2 C
11:00 AM	8.12 A	31.23 V	253.6 W	31.9 C
12:00 AM	8.49 A	31.42 V	266.75 W	32.3 C
1:00 PM	8.36 A	31.3 V	261 .7 W	32.6 C
2:00 PM	8.13 A	31.11 V	252.92 W	32.6 C
3:00 PM	7.94 A	30.92 V	245.5 W	32.7 C
4:00 PM	7.76 A	30.74 V	238.54 W	32.4 C
5:00 PM	7.45 A	30.56 V	227.67 W	32.1 C
6:00 PM	7.08 A	30.31 V	214.6 W	31.6 C

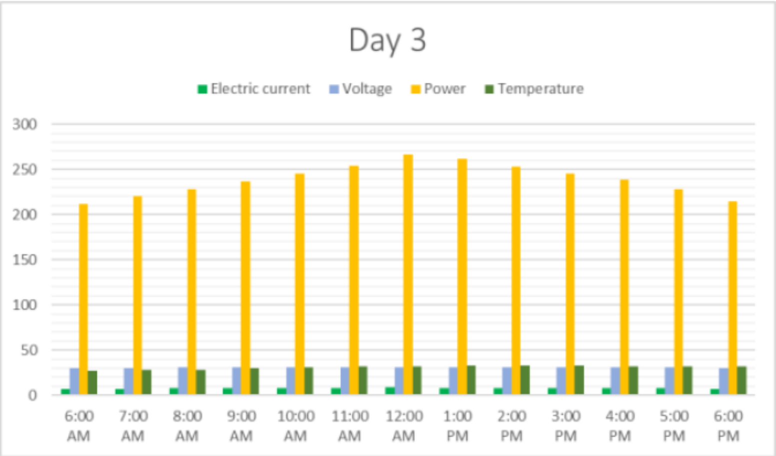

Figure 33: day three

Table 4: day four

Time	Electric current	Voltage	Power	Temperature
Day 4	**Tracking and Cooling**			
6:00 AM	7.1 A	30.2 V	214.42 W	29 C
7:00 AM	7.28 A	30.37 V	221.1 W	29.2 C
8:00 AM	7.34 A	30. 67 V	225.12 W	29.6 C
9:00 AM	7.86 A	30.81 V	242.2 W	30.3 C
10:00 AM	8.17 A	30 .95 V	252,86 W	30.4 C
11:00 AM	8.38 A	31.32 V	262,5 W	30.8 C
12:00 AM	8.55 A	31.49 V	269.23 W	31.4 C
1:00 PM	8.42 A	31.38 V	264.21 W	31.5 C
2:00 PM	8.23 A	31.23 V	257.02 W	31.45 C
3:00 PM	8.1 A	31.01 V	251.2 W	31.3 C
4:00 PM	7.92 A	30.78 V	243.7 W	31.2 C
5:00 PM	7.74 A	30.56 V	236.53 W	31.1 C
6:00 PM	7.26 A	30.24 V	219.5 W	31 C

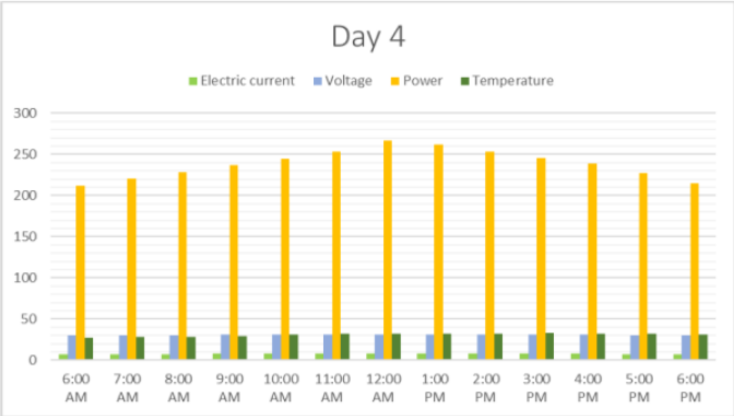

Figure 34: day four

Figure 35 and 36 shows the gained power and current during four days

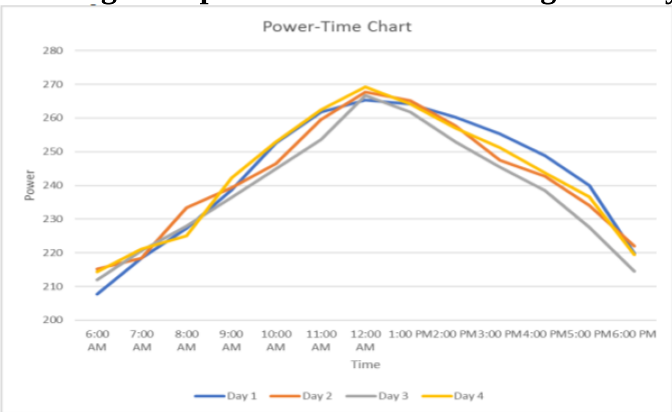

Figure 35: Power against time due to four days

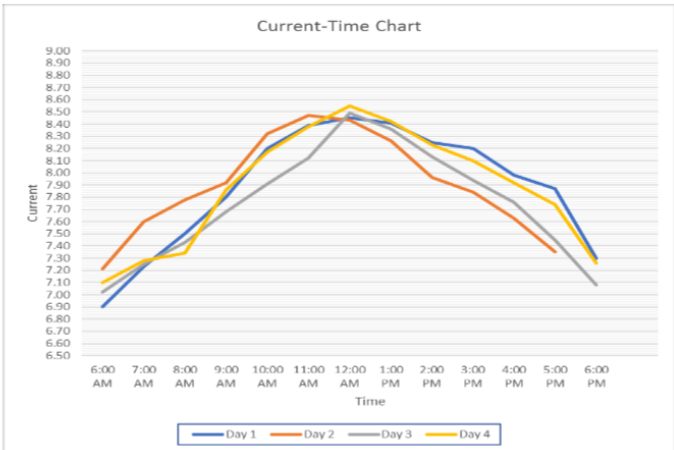

Figure 36: current against time for four days

CONCLUSIONS

1. **Although solar panels are typically self-cleaning, dust and other particles such as bird droppings can build up over time in particularly dry areas or if panel tilt is restricted, limiting the amount of power generated by a module. At this stage, it's possible that the solar panels will need to be cleaned.**
2. **Accumulated dust on solar panels is one of the contributing factors in the reduction of efficiency in solar PV panels.**
3. **Rainfall and cleaning will improve panel production while reducing the amount of dirt on them on average.**
4. **Automated solar tracking increases the efficiency of solar panels by keeping them aligned with the revolving sun.**

5. **Solar tracking systems are used to line solar panels and collectors with the sun's movements during the day, increasing the quantity of solar energy gathered by the solar energy collector and so extending the energy output of the heat/electricity produced.**
6. **Solar panels are normally evaluated at roughly 77 degrees Fahrenheit, with peak efficiency measured between 59- and 95-degrees Fahrenheit.**
7. **Solar panels, on the other hand, may achieve temperatures of 149°F in the summer.**
8. **The efficiency of your solar panels may deteriorate if the surface temperature of your panels reaches to this level. Overheated solar panels are ineffective. Many methods have since been discovered to allow them to cool down and boost their power output.**
9. **When the temperature of solar panels rises over 77°F, they lose efficiency. As a result, a solar panel's efficacy decreases at the rate of its temperature coefficient for every degree of temperature increase.**
10. **As the temperature of the solar panel rises, the output current climbs exponentially, and the voltage output drops linearly; in fact, the voltage drop is so constant that it may be used to accurately monitor temperature. As a result, heat can reduce the solar panel's ability to generate power dramatically.**

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