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## TABLE OF CONTENTS

**INTRODUCTION**……………………………………………………………………………....5

**CHAPTER I. LITERATURE REVIEW**

1.1.Solar energy system. Development of organic and polymeric photovoltaic…………………………….........................................................................7

1.2. Solar Energy……………………………………………………………………….....8

1.2.1.Solar Cell types and manufacturing methods ………………………………………...12

1.2.2.Solar Cells of The First Generation……………………………………………......12

1.2.3. Solar Cells of The Second Generation…………………………………………....13

1.2.4. Third-Generation Solar Cells……………………………………………………..13

1.3. Solar Panels (Photovoltaic Cells) ………………………………………………..14

1.3.1. Types of Solar Panels……………………………………………………………...15

1.4. Solar Inverter…………………………………………………………………..... ...18

1.4.1. Types of Inverters………………………………………………………………… ...19

1.5. The advantages and disadvantages of using solar energy………………………………...21

1.5.1. Advantages of Solar Energy ……………………………………………………...21

1.5.2. Disadvantages of Solar Energy ………………………………………………...... 22

**CHAPTER II. MATERIAL AND METHODICS OF THE RESEARCH**

2.1. Practical part of the project. Main components of the automatic solar tracker……………..23

2.1.1. Frame and mechanical structure……………………………………………......24

2.1.2. Material Selection…………………..……………………………………....... 26

2.1.3. Mechanical Design………..…………………………………………………... 27

2.1.4. The Ardunio…………………………………………………………………..... 28

2.1.5. Solar energy using Arduino for efficient electrical power generation…………………....29

2.2. Block diagram and purpose of the components…………………………………………….31

2.2.1. Mechanical movement of the structure……………………………………...……32

2.2.2. Arduino UNO…………………………………………………………………......33

2.2.3. The Waveshare 6V-24V Solar Power Manager…………………………………......35

2.2.4. Monocrystal Photovoltaic Module……………………………………………......36

2.2.5. Light Dependent Resistor (LDR) ……………………………………………......37

2.2.6. Servo Motor……………………………………………...……………………..39

2.2.7. Battery…………………………………………………………………………….39

2.3. Working Principle of the automatic solar tracker…...…………………………………….40

**CHAPTER III. THEORETICAL PART OF THE PROJECT**

3.1. Experimental Investigation of an Arduino-Controlled Solar Charger with Automatic Sun Tracking……………………………………………………………………………..............

3.1.2. Smart Solar Charging System with Automated Tracker: Experimental Insights………...44

3.2. Weather condition impacts to the solar tracker…………………………………………...45

3.3. Implement dual-mode solar charger with Arduino…………………………………….. ..47

3.4. Determination of power efficiency of solar panels…………………………………….. ..48

3.5. Types of Automatic Solar Tracker……………………………………………………......49

3.5.1. Methods of Solar Tracking …………………………………………………………….50

3.6. Modes of operation……………………………………………………………………….51

3.7. Calculation of angular and linear speed………………………………………………......52

3.7.1. Calculation of all main parameters……………………………………………………..52

3.7.2. Matlab Simulation of parameters………………………………………………………60

**CONCLUSION**……………………………………………………………………………...62

**REFERENCES**……………………………………………………………………………...64

# INTRODUCTION

Solar power is energy from the sun that is converted into thermal or electrical energy. It's a clean, inexhaustible, and increasingly cost-effective power source compared to fossil fuels.

In our research presents an innovative "Phone Charging Converter with Automatic Solar Tracker" a proficient system engineered to leverage solar energy for efficient and autonomous mobile device charging. The use of wireless automated systems saves labor, time and money, increasing the accuracy of the work performed (N.B. Kuttybay, 2021). The modern surge in electronic device usage, particularly mobile phones, has accentuated the need for sustainable and portable energy solutions.

**Revelance of the topic**: Solar power capacity continues to grow at a record pace. By 2024, global installed solar PV capacity is projected to exceed 1,200 GW. This growth is driven by declining costs, supportive government policies, and the urgent need to address climate change.

Phone Charging Converter with Automatic Solar Tracker is a robust and environmentally conscious solution for device charging. In the research and development phases, slight attention has been given to usability and durability. As the demand for eco-friendly technologies grows, this research stands at the intersection of renewable energy and portable electronics, paving the way for a sustainable future. By embracing the Phone Charging Converter with Automatic Solar Tracker, users not only benefit from a reliable and renewable energy source but actively participate in the global movement toward sustainable living. In our research the graphs were drawn according to the phase, data of the signal taken from the test objects, and their analyzes were made.

**The purpose of the project:** The main feature of the system lies in its integration of a solar panel with an advanced automatic solar tracking mechanism. The automatic solar tracker dynamically follows to the sun’s position, optimizing energy capture throughout the day. This automated tracking ensures a continuous and maximized energy input, addressing the challenge of different sunlight angles. An integral component of the system is the charging converter, which combines cutting-edge power management electronics. This not only simplifies compatibility with a diverse range of mobile devices but also ensures optimal energy transfer efficiency. The system is designed with charging protocols and accommodates different energy demands, providing a versatile solution for charging smartphones and other electronic gadgets.

A phone charging converter with an automatic solar tracker is an innovative device designed to harness solar energy more efficiently for charging mobile phones. This system integrates a solar panel with an automatic mechanism that tracks the movement of the sun across the sky. The primary advantage of this setup is its ability to adjust the panel's orientation throughout the day to ensure it remains in the optimal position for sunlight absorption, significantly boosting the energy capture compared to fixed solar panels.

**The object of the study:** At the heart of this system is the solar panel itself, which captures sunlight and converts it into electrical energy. To make the most of this energy, the system includes a solar tracker that continuously adjusts the panel's angle in response to the sun's position. This dynamic adjustment maximizes exposure to sunlight, leading to more efficient charging.

An essential component of the system is the charge converter or regulator. This part manages the electricity flow from the solar panel to the phone, ensuring that the device receives a steady, safe charge. It prevents issues like overcharging, which can be detrimental to the phone's battery life and overall health.

Some models may also feature a built-in battery, which stores excess solar energy collected during peak sunlight hours. This stored energy can be used to charge the phone during periods of low sunlight, such as on cloudy days or at night, making the system versatile and practical in various lighting conditions.

Overall, a phone charging converter with an automatic solar tracker represents a leap forward in solar technology, offering a more sustainable and efficient way to keep mobile devices powered.

# CHAPTER I. LITERATURE REVIEW

## 1.1. Solar energy system. Development of organic and polymeric photovoltaic.

The discovery of the photovoltaic (PV) effect is commonly described to Becquerel who invented a photocurrent when platinum electrodes, covered with silver bromide or silver chloride, was illuminated in aqueous solution (strictly speaking this is a photoelectrochemical effect) . Smith and Adams made the first reports on photoconductivity, in 1873 and 1876, respectively, working on selenium. Anthracene was the first organic compound in which photoconductivity was observed by Pochettino in 1906 and Volmer in 1913. In the late 1950s and 1960s the potential use of organic materials as photoreceptors in imaging systems was recognized. The scientific interest as well as the commercial potential led to increased research into photoconductivity and related subjects. In the early 1960s it was discovered that many common dyes, such as methylene blue, had semi conducting properties. Later, these dyes where among the first organic materials to exhibit the PV effect. We can say the PV effect was observed in many necessary biological molecules such as carotenes as well as the structural related phthalocyanines (PC). Despite many improvements over the years organic PVs has not yet reached the market place unlike inorganic solar cells (A brief history of the development of organic and polymeric photovoltaics, 2004).

In 1954 the first inorganic solar cell was developed. It was based on Si and had an efficiency of 6%. Over the years the efficiency has reached 24% for crystalline Si solar cells in the laboratory. Today Si-based solar cells are by far the most dominating type of PVs used and account for 99% of all PVs. With increasing efficiency and reduced production costs the world PV-market has increased. In the past 20 years, the demand for solar energy has grown consistently with growth rates of 20–25% per year, reaching 427 MW in 2002. Fifty years of research and innovation has dramatically reduced the price of Si PVs to the level possible using existent technology. However, despite much effort of further reducing the price of Si based PVs, this technology is confined to niches. Thus, semiconductor PVs still account for less than 0.1% of the total world energy production.

Organic semiconductors are a less expensive alternative to inorganic semiconductors like Si. Also, organic molecules can be processed by techniques not available to crystalline inorganic semiconductors. Especially conjugated polymers are attractive in this respect. The superior material properties of polymers (plastics) combined with a large number of cheap processing techniques has made polymer-based materials present in almost every aspect of our modern society.

Solar power is one of the renewable energies which is very cheap compared to other sources of energy generation. According to the International Energy Agency, solar energy systems will become one of the main sources of electricity and contribute at least 17% of global electricity by the year 2050. A photovoltaic system can be considered an alternative power system for several applications. The photovoltaic system could be a backup power system to another system while the system needs maintenance or a fault happened. One of the applications of photovoltaics is the battery charger. Besides, other application of photovoltaics is used on a streetlight. Solar cells are placed on each streetlight to supply each streetlight (Holger Spanggaard, 2004).

## 1.2. Solar energy

Global warming has increasing gradually and leads to requirement of green energy, which is generated by solar system (Abhishek Gupta, 2021). Solar power is a renewable energy source that harnesses sunlight to generate electricity. Photovoltaic cells in solar panels convert sunlight into electrical current, which can be used directly or converted to alternating current using inverters. Solar power systems can be grid-tied or off-grid, with the latter often using energy storage solutions. Solar thermal power is another method, utilizing mirrors to concentrate sunlight for electricity generation. Advantages include sustainability, low environmental impact, and potential cost savings. Challenges include intermittency and initial high costs. Ongoing technological advancements continue to enhance the efficiency and affordability of solar power.

In making a Two-Way Solar Panel Tracker Based on Arduino Microcontroller, there are three main stages that must be done, namely mechanical system design including servo components, electrical system design, and programming design on software (Prawiro Harjono, 2023). The main objective of this project is to develop a free phone charging station with an automatic solar tracking system which will keep the solar panels able to track the sun direction in order to generate maximum the efficiency of the solar system. The originality and novelty of the system come from its modular design, universal applicability, and adaptability, as well as its simplicity, low cost, and scalability (Roland Szabo, 2023). The power generated by the solar tracker system will be stored in the battery for the phone charging purposes. The system is separated into two systems which are solar tracker and phone charger systems. The field of solar energy comprises 11 primary components, ranging from solar panels and inverters to mounting systems, battery storage, charge controllers, solar thermal systems, solar water heating, solar cooling, solar concentrators, grid-tied systems, and off-grid systems (Seng Xiang, 2023).

The European PV Industry Association reports that the total global PV cell production worldwide in 2002 was over 560 MW and has been growing at about 30% annually in recent years (Patel M. R., 2006). Solar energy is a cornerstone of sustainable power generation, fundamentally transforming how we harness and utilize energy. Among the technologies propelling this shift, solar panels and trackers stand out due to their roles in maximizing energy capture and efficiency. Solar panels are devices that convert sunlight into electricity, leveraging the photovoltaic effect. These panels comprise several cells containing a semiconductor material, typically silicon, which absorbs photons from sunlight and converts them into electrical energy. The power thus generated can be used immediately, stored, or fed into a grid. However, the efficiency of solar panels inherently depends on their exposure to sunlight, which varies throughout the day and across seasons. This variability in sunlight exposure brings solar trackers into play. Solar trackers are dynamic systems designed to orient solar panels toward the sun as it moves across the sky. By aligning panels in an optimal position with respect to the sun, trackers significantly enhance the amount of solar radiation received. There are two main types of solar trackers: single-axis trackers, which move according to a single directional axis, and dual-axis trackers, which provide more precise alignment by tracking both azimuth and elevation movements of the sun. The integration of solar trackers with solar panels can result in up to a 25% boost in energy production compared to stationary panel installations. This increase not only improves the economic return on investment by maximizing energy output but also contributes to a more efficient use of space, as fewer panels are needed to produce the same amount of energy (www.kloecknermetals.com, 2024). Moreover, the use of trackers is particularly beneficial in regions with high solar insolation, where the sun’s rays are strongest. However, the benefits must be weighed against the higher initial costs and maintenance requirements associated with moving systems. Advances in technology and manufacturing scale are continually reducing these costs, making solar trackers an increasingly viable option in many solar projects around the world (www.batteryequivalents.com, 2023).

In conclusion, while solar panels are crucial for converting sunlight into usable energy, solar trackers play an essential role in optimizing this conversion process. Together, these technologies are vital components of the renewable energy landscape, helping to increase the efficiency and viability of solar power systems and moving us closer to a sustainable energy future.

Solar trackers represent a pivotal advancement in solar technology, providing a dynamic means to boost the effectiveness of solar energy systems. These devices adjust the positioning of solar panels throughout the day, ensuring optimal alignment with the sun, which significantly enhances electrical output. This exploration delves into the multitude of benefits offered by integrating solar trackers into solar energy projects.

A central advantage of solar trackers lies in their capability to elevate the energy production of solar panels. By continually adjusting the panels to face the sun at the optimal angle, trackers maximize the panels' operational efficiency from sunrise to sunset. Such precision can enhance energy generation by up to 25% over fixed panel setups, with specific gains dependent on the project's geographic context. This efficiency surge not only shortens the investment's payback period but also heightens the overall economic feasibility of solar initiatives.

Efficient utilization of space is another significant benefit provided by solar trackers. As these devices boost the output per panel, fewer panels are required to meet energy production targets, which is particularly beneficial in regions where land is at a premium. The ability to produce more electricity from a smaller installation footprint reduces both the environmental impact and the physical space demands of solar farms.

Solar trackers are versatile and can be seamlessly incorporated into diverse solar projects, ranging from vast utility-scale operations to smaller commercial and residential setups. This adaptability is further supported by technological advancements that enhance the reliability and maintenance ease of trackers.

While the initial investment and upkeep of solar trackers surpass those of static installations, the long-term gains typically offset these initial costs. Enhanced durability and reduced prices, driven by technological improvements and competitive market forces, are making solar trackers an increasingly attractive option for many solar energy projects.

In summary, solar trackers bring forth substantial advantages for solar energy systems, including boosted energy output, improved land efficiency, and better economic outcomes.

With ongoing advancements lowering costs and increasing reliability, solar trackers are set to play a crucial role in the evolution of solar technology, making renewable energy more effective and accessible than ever.

A primary trend driving the future of solar energy is the significant advancement in photovoltaic (PV) technology. Researchers and manufacturers are continuously pushing the boundaries of solar cell efficiency, reducing the cost while increasing the power output of solar panels. Innovations such as perovskite solar cells and bifacial panels, which capture sunlight from both sides, are set to revolutionize the market with higher efficiencies and potentially lower manufacturing costs. These advancements are crucial as they directly translate into more accessible and cost-effective solar solutions for a broader range of applications, from residential to large-scale industrial projects. Another significant trend is the integration of solar power with energy storage systems. As the penetration of solar energy increases, the challenge of variability in solar power generation becomes more pronounced. Energy storage technologies, such as batteries, are becoming more sophisticated and economically viable. This integration helps stabilize the grid and ensures a consistent energy supply, irrespective of sunlight availability, thereby enhancing the reliability and utility of solar energy systems (https://geographicalanalysis.com, 2024).

Furthermore, the decentralization of energy production through distributed generation systems is likely to gain more traction. Solar panels on residential and commercial buildings, community solar projects, and microgrids are examples where solar energy can be generated and consumed locally. This model not only reduces the load on the central grid but also empowers communities by providing energy security and resilience against grid outages.

Global and national policy shifts toward green energy will continue to be a critical driver for the adoption of solar energy. Governments around the world are setting ambitious targets for reducing carbon emissions and are implementing supportive policies such as subsidies, tax incentives, and feed-in tariffs to encourage the adoption of solar technology. As public and political awareness of the climate crisis grows, these policies are expected to become more robust, further accelerating the deployment of solar energy solutions. Lastly, the environmental benefits of solar energy remain a compelling argument for its expanded use. As solar power emits no greenhouse gases during operation, its widespread adoption is key to combating climate change. Additionally, technological improvements in recycling and waste management for end-of-life solar panels are enhancing the sustainability of solar installations throughout their lifecycle.

In conclusion, the future of solar energy looks exceedingly bright, driven by continuous technological innovation, supportive policies, economic feasibility, and a strong environmental imperative. As these factors converge, solar energy is poised to play an increasingly dominant role in the global energy mix, promising a cleaner, more sustainable future for all.

### 1.2.1. Solar cell types and manufacturing methods

Solar energy is the sunlight energy collected and used to provide electricity, heating, cooling homes, businesses or industry. It is a sustainable source in the sense that it does not provide greenhouse gas emissions and proves to be environmental-friendly sources of energy. It is free and maintainable as the sun is here to stay. In 1999 Maycock defines photovoltaic (PV) as the direct conversion of solar radiation into electricity. This is particularly because photovoltaic energy conversion is based on photovoltaic effect. Photovoltaic solar modules convert the sunlight directly into electricity (Matungwa, 2014).

### 1.2.2. Solar Cells of The First Generation

The first solar cell was vertical and revolved in tandem with the solar tracking mechanism. In the meantime, the second solar cell was positioned horizontally. In terms of average output power, the first solar cell produces around 22% more than the second one (Rachedi Mohamed Yacine, 2023). The First Solar Cell Generation Solar cells are predominantly made of semiconductor materials, with crystalline silicon being the most common, accounting for approximately 90% of solar cell production. There are two types of silicon cells used in solar panels: Monocrystalline silicon cells: These cells consist of a single silicon crystal and have an efficiency of converting incoming sunlight into electrical energy at around 17-18%. Polycrystalline silicon cells: Made of various crystals formed by melting silicon and cooling it in graphite molds. These cells represented approximately 48% of global production in 2008, with an efficiency of 12-14%. The process of manufacturing silicon cells typically starts with the production of polysilicon, the primary material used in semiconductors. Polysilicon is cast or hammered into blocks, then cut into thin slices using wire saws, with standardized dimensions. The plates are cleaned and treated with phosphorous to form a layer of negative semiconductors that reduces sunlight reflection. Additional layers of chemicals are applied to reduce reflection and increase sunlight absorption, followed by the use of aluminum testing chips before assembly into solar panels with glass coatings to protect the semiconductors and enhance their absorbency and reduce reflection.

### 1.2.3. Solar Cells of The Second Generation

Second-generation solar cells include morphological cells and thin-film cells, which are more cost-effective than crystalline silicon cells but less efficient. The types of second-generation solar cells are as follows: Amorphous silicon cells: Used in devices like calculators, these cells are made at lower temperatures and have thin silicon layers (up to one micrometer) deposited on plastic 7 surfaces. The efficiency of amorphous silicon cells ranges between 4-8%, and they can operate effectively at high temperatures and under varying weather conditions. Cadmium telluride cells: These cells use a thin coating of cadmium telluride to convert sunlight into electrical energy. The efficiency of these cells ranges between 9-11%. However, environmental concerns due to cadmium toxicity may limit their usage in the solar cell industry. Copper-indium-gallium-diselenide cells: These cells have an efficiency of 10-12% and are manufactured by depositing thin layers of copper, indium, gallium, and diselenide on glass or plastic, with electrodes placed in front and behind the cell to collect electric current. Their high absorption coefficient allows them to effectively absorb sunlight (twi-global.com, 2024).

### 1.2.4. Third-Generation Solar Cells

The third generation of solar cells includes innovative species that are currently in research and development, and have not yet reached commercial industrialization. Examples of third-generation solar cells include: Nano-solar cells: These cells work by producing semiconductor material crystals with microscopic dimensions measured in nanometers, and their efficiency ranges between 7-8%. Polymer-based solar cells: Manufactured from polymeric substances that absorb solar radiation, these cells have an efficiency range of 3-10% and are more cost-effective than silicon solar cells. Dye-sensitized solar cells: Comprising a thin layer of titanium dioxide for the negative semiconductor and a thin layer of nickel oxide for the positive semiconductor, these cells are easy to install. 8 Concentrated solar cells: These cells use multiple mirrors and lenses to generate high thermal energy for heat engines, achieving an efficiency of up to 40% and being thermally stable (Gupta, 2017).

### 1.3. Solar Panels (Photovoltaic Cells)

It is commonly known that energy is needed in practically every field to maintain gadgets in operation. Alternative energy sources are the most efficient and limitless resource of our century, especially when taking prices into account. Solar energy is arguably the most abundant of these endless resources. In our quest to protect the environment, we have discovered a vast array of renewable energy sources; in this case we selected solar energy because the sun is an element that it will always be in most of parts of the world. This energy works when the sun shines onto a solar panel, the energy from the sunlight is absorbed by the PV cells in the panel which creates electrical charges that move in response to an internal electrical field. So many could be benefited by this type of energy even reducing the price in cost production but still not so many people believe on it (López, 2021). Automatic solar tracking system is the possible approach to maximize the solar cell efficiency (Ghazanfar Mehdi, 2019).

The development of active and passive solar systems is the primary contribution of nanotechnology in this field in recent years (Muhammad Irfan Sohail, 2019). Additionally, the tracking system decreased energy output fluctuation, which increased system stability when incorporated into the grid, according to the researchers (Abdul Hameed, 2024).

Solar panels are fundamentally made up of arrays of connected solar cells, each of which is intended to gather sunlight and transform it into electrical energy. When exposed to sunlight, these cells—which are usually composed of semiconductor materials like silicon—use the photovoltaic effect to produce an electric current. The basic idea behind how solar panels work is that sunlight is converted into electricity by the motion of electrons. Electrons in the solar cells are energized by sunlight, which causes them to travel and produce an electric current. An inverter is used to transform this direct current (DC) electricity into usable alternating current (AC), which is then compatible with residential and commercial electrical systems. Solar panel uses are numerous and expanding. They are frequently utilized to provide electricity for cities, towns, and residences in commercial, industrial, and domestic environments. The benefits of solar panels are clear: they may provide clean energy, lessen reliance on fossil fuels, and minimize carbon emissions, which promote environmental sustainability (Photovoltaic Cell, 2024).

Contrary to popular belief, solar energy has been around for a while, but we are just now devoting more work to making it a common energy source. One explanation is that the sun provides us with energy every day. The sun generates about 965 trillion kWh of energy per day (Smith, 2016).

### 1.3.1. Types of Solar Panels

There are several types of solar panels, each with its own characteristics and applications. The most common types include:

1. Monocrystalline Solar Panels:
   - Made using a single crystal structure.
   - Efficiency: Compared to other types, it is generally more efficient.
   - Space Efficiency: Because they are more compact and space-efficient, they are better suited for installations with limited space.
   - Cost: Generally speaking, more expensive than polycrystalline and thin-film panels.
2. Polycrystalline Solar Panels:
   - Formulated from a variety of crystal formations.
   - Efficiency: Not as efficient as monocrystalline panels, but still somewhat lower.
   - Price: Usually less expensive than monocrystalline panels.
   - Appearance: The many crystals give off a blue tint.

**Figure 1.1. Monocrystalline and Polycrystalline Solar Panel**

3. Thin-Film Solar Panels:

- Composition: Constructed from amorphous silicon, copper indium gallium selenide, or cadmium telluride thin layers of semiconductor materials.
- Flexibility: Capable of being applied on curved surfaces, this material is more flexible than crystalline silicon panels.

• Efficiency: Performance has historically been lower, but continuing research is raising it.

• Cost: For some applications and large-scale installations, it may be economical.

• Appearance: Usually more uniform and darker in appearance (Binns, 2024).

Non-silicon thin film shapeless cells are generally high output. A few sorts can reach efficiencies of up to 25%. They are great choices for all control applications, in any case at display they are more costly than other sorts of cells accessible. Either of these types of cells is fine for the construction of solar panels, but if you want to get the most power from a given amount of space, use monocrystalline cells (Hurley, 2006).

**Figure 1.2. Thin-Film solar panel**

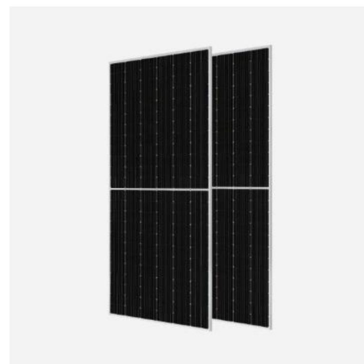

**Figure 1.3. JA Solar 575W Bifacial Solar panel**

4. Bifacial Solar Panels:

• Design: By harnessing reflected sunlight from surfaces like the ground or surrounding structures, these panels may capture sunlight on both the front and rear sides.

• Efficiency: In some situations, particularly when there is a lot of reflected sunlight, efficiency may be higher.

• Applications: Fit for installations that are positioned on the ground and have light reaching the back of the panels.

5. CIGS Solar Panels (Copper Indium Gallium Selenide):

• Composition: Copper, indium, gallium, and selenium are combined in thin-film technology.

• Efficiency: Has room for development and is somewhat efficient.

• Benefits: Compared to certain other technologies, it can be more environmentally friendly, lightweight, and versatile.

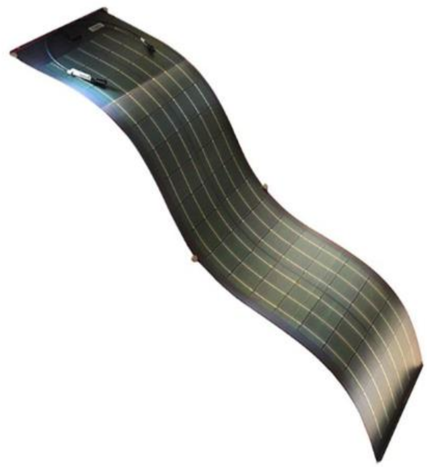

**Figure 1.4. 140W Flexible CIGS Solar module**

**Figure 1.5. Passivated Emitter Rear Cell**

6. Solar panels with passivated emitter rear cells, or PERCs:

- Design: To boost light absorption, the rear surface of these panels is passivated.
- Efficiency: Greater than that of conventional solar cells.
- Performance: greater effectiveness at higher temperatures and in low light

7. HIT Solar Panels (Heterojunction with Intrinsic Thin layer):

- Design: Combines amorphous and crystalline silicon layers.
- Efficiency: Generally higher efficiency and better performance in high-temperature conditions.
- Advantages: Can be more efficient in real-world conditions.

### 1.4. Solar Inverter

An inverter is an essential part of solar power systems that helps transform the direct current (DC) electricity produced by solar panels into alternating current (AC), the type of electricity commonly utilized in homes and businesses. An on- or off-grid inverter is a device that changes direct current into alternating current. The solar PV panel and the solar inverter are directly connected. Maximum power point tracking (MPPT) is a feature that the inverter needs to have in order to achieve high efficiency, particularly in off-grid systems that use solar batteries for electricity. Off-grid converters are utilized on a small scale and don't need much maintenance; they can be adopted based on the needs (Gupta, 2017).

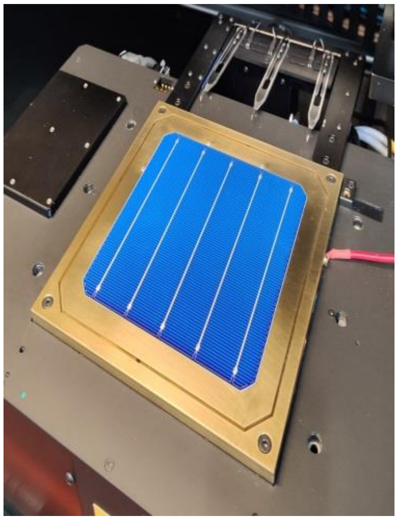

**Figure 1.6. Heterojunction solar cell**

**Figure 1.7. Panasonic 325 watt HIT black solar Panel**

Solar inverters are already being produced in large quantities for use in utility, business, and residential settings. There are now three main types of solar array configurations: string technology, centralized technology, and AC module technology. Consequently, the terms "micro inverter," "string inverter," and "centralized inverter" refer to the inverters used in various configurations (Alsemaan, 2016).

There are some key points about inverters. Direct current (DC) electricity is generated by solar panels. But the electrical grid and the majority of home appliances run on alternating current (AC). The DC electricity produced by solar panels is transformed into AC electricity using inverters. Inverters are necessary in grid-tied solar power systems in order to synchronize the electricity generated by the solar panels with the electrical grid. When the solar panels produce more electricity than is required on-site, this enables the extra electricity to be fed back into the grid. Because inverters are made to synchronize with the electrical grid's frequency, the electricity they generate is always in phase with the power of the grid. The electrical system must operate in synchrony in order to be both safe and effective.


**Figure 1.8. Solar inverter basic diagram**

A key element in determining a solar power system's overall efficiency is its inverter. A higher proportion of the solar energy that the panels collect is turned into usable electricity thanks to the high conversion efficiency that high-quality inverters can achieve. A lot of today's inverters have monitoring features that let customers keep an eye on their solar power system's functioning in real time. Data on energy production, system health, and possible difficulties may be part of this monitoring.

### 1.4.1. Types of Inverters:

String inverters are frequently seen in small-scale business and residential solar installations. An inverter transforms the DC current from every solar panel in a string that is connected in series (What solar inverter to use for shading issues, 2024).

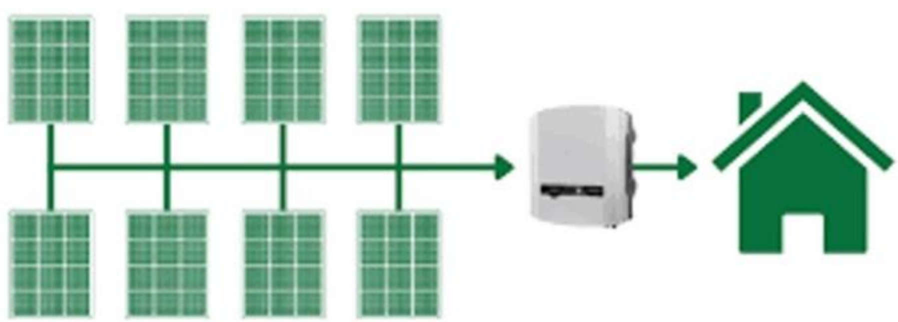

**Figure 1.9. String Inverter basic diagram**

Microinverters: In a system with micro-inverters, every solar panel has a separate inverter. This can minimize the effects of shading or individual panel faults, hence optimizing system performance. In large-scale solar power systems, central inverters are typically utilized. They manage the conversion of DC to AC for several solar panel strings.

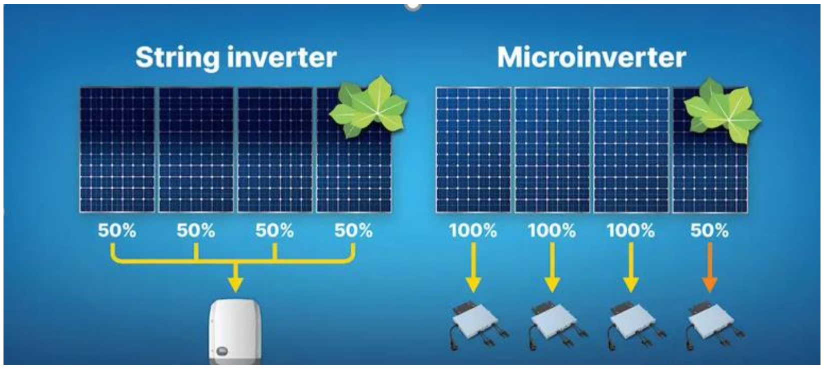


**Figure 1.10. Difference between String and Microinverter basic diagram**

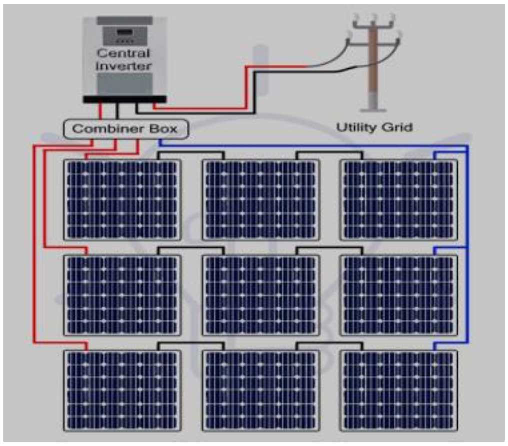


**Figure 1.11. Central Inverter**

Inverters, which enable the conversion of solar-generated DC electricity into the useable AC current required for the majority of applications, are crucial parts of solar power systems. They guarantee the general effectiveness and dependability of solar power installations and aid in the integration of solar energy into the current electrical grids.

### 1.5. The advantages and disadvantages of using solar energy

Solar energy, like other energy sources, has its own set of advantages and disadvantages. Because it doesn't release hazardous emissions or deplete limited resources in the process of generating electricity, solar energy is regarded as a clean and sustainable energy source. It is abundant and freely available, making it a crucial component of efforts to transition away from fossil fuels and mitigate the environmental impact of energy production.

### 1.5.1. Advantages of Solar Energy

Solar energy is abundant and virtually limitless: The sun serves as an infinite energy source, and the amount of solar radiation reaching the Earth exceeds humanity's energy demands by several times. Cost-effective and free to use: Solar energy is available for free, and its usage is primarily limited by the initial investment in solar panels and equipment. No need for extensive transmission and distribution: Solar energy is dispersed globally and reaches everyone without the need for complex transmission and distribution systems. Relatively uniform distribution based on latitudes: Despite variations between the equator and poles, solar energy distribution is generally consistent according to geographical regions, facilitating its study, utilization, and information exchange. Versatile energy conversion: Solar energy can be converted into various forms, including thermal, mechanical, and electrical energy, providing flexibility in its applications. Unique applications in human and plant life: Solar energy finds specialized applications in specific areas like mega projects reliant on water evaporation, photosynthesis, and others. Environmentally friendly: Solar energy is a clean and non-hazardous source of energy, making it environmentally sustainable. Due to the 15% efficiency of photovoltaic panels at the moment, a solar panel can produce between 19 and 56 W/m2, or 0.45 and 1.35 kWh/m2/day (the annual day and night average) (Kruthiventi, 2007).

Utilizing solar energy, a plentiful sustainable energy source, to produce biofuels provides benefits for the environment and the economy. Utilizing this alternative green renewable resource could offer a way to satisfy the world's expanding energy needs. The overall energetics (energy return on energy invested, or EROEI) of the process is greatly impacted by the use of solar thermal energy in the biofuel production process (Betina Tabah, 2017).

### 1.5.2. Disadvantages of Solar Energy

Lower intensity per unit area: Solar energy has a relatively low intensity per unit rooftop compared to other energy sources. Inconsistency during the day: Solar energy is only available for a limited number of hours each day, which can pose challenges for its consistent utilization. Lack of consumer awareness and understanding: The relevance of solar energy might not be well understood by consumers, necessitating educational initiatives to promote its adoption. Potential lifestyle adjustments: The transition to a solar energy system may require significant changes in some societal and lifestyle aspects established by traditional energy systems developed during industrialization (AL-MOHAMMEDAWI, 2023).

## CHAPTER II. MATERIAL AND METHODICS OF THE RESEARCH

In the practical part of the project, we will provide detailed information about each component of the construction separately. Additionally, we will note general information about how the overall block diagram was prepared. We will thoroughly explain why these specific materials were used in our work. We will also describe projects that have been implemented and prepared similar to our work in the past and explain the differences between our project and theirs. Before discussing the materials used and the preparation process, we would like to provide you with general information about projects created using Arduino. The construction of trackers for photovoltaic systems is conditioned by the daily movement of the Sun on the sky on a certain trajectory, from east to west. There are several ways to ensure this movement of the photovoltaic panel (V Boyarchuk, 2022).

### 2.1. Main components of the automatic solar tracker

The use of tracking systems or prediction is not essential to the operation of a PV module; however, without the presence of any, its performance is greatly reduced (Hermes Jose Loschi, 2015). The control strategy of a tracker is basically to generate the trajectory of the tracker in order to perfectly pursue the sun in order to maximize the production (Fatou Dia, 2022). The tracker actively tracks the sun and changes its position accordingly to maximize the power output (v, 2014). In order to make the usage of renewable energy sources like photovoltaics (PV) an alternative for converting solar energy, it will be more beneficial to develop a single axis PV tracker system and an automatic controller system for battery charging. Controlling the voltage drop allows the battery system to function more optimally and support its increased durability. The high motor energy consumption of a number of approaches to optimize solar cell testing using a single axis tracking system then remains suboptimal. Because the sun's arrival angle is not exactly proportional to the solar panel location, PV optimization in flat panel settings is still suboptimal. As a result, the system is made to be a more efficient single-axis solar tracker in order to maximize solar absorption and minimize propulsion energy usage (Habib Satria, Performance of single axis tracker technology and automatic battery monitoring in solar hybrid systems, 2023). In recent years, there has been an increasing inclination towards the installation of photovoltaic (PV) modules over water surfaces, including lakes, reservoirs, and even oceans (Atıl Emre Coşgun, 2024). Let's become familiar with the materials used for our automatic solar tracker and their characteristics in detail.

To harness renewable solar energy, I have designed a phone charging converter with an automatic sun tracker for my project. The project is putting together a phone-charging structure using solar panels, an Arduino, a single motor, and light-sensitive sensors. In order to optimize energy transfer, the architecture aims to guarantee that the solar panel can track the sun's movement throughout the day. In general, the solar cell's layers all absorb light. Except for the absorber layer, all absorption is lost in subsequent layers. The term for it is "parasitic absorption." Furthermore, not all of the light that enters the absorber layer is absorbed because of the layer's restricted thickness. The absorber's restricted thickness causes incomplete absorption, which is an extra loss that reduces the energy conversion efficiency (Olindo Isabella, 2016).

The primary objective is for the panel to continuously react light-sensitively, causing the structure to move and absorb energy as efficiently as possible. Experiments were carried out throughout the project at various times and in varied weather situations to establish the panel's starting, neutral, and final locations as well as to measure its efficiency and energy output.

### 2.1.1. Frame and mechanical structure

The "Phone Charging Converter with Automatic Solar Tracker" concept involves a system that uses solar energy to charge mobile phones. This system comprises two main components: an automatic solar tracker and a converter that transforms solar energy into electrical energy suitable for charging phones. The automatic solar tracker moves the solar panel throughout the day to maintain the most optimal angle towards the sun. This maximizes the panel's exposure to sunlight and, consequently, increases the amount of energy it can generate. The converter part of the system converts the solar energy captured by the panel into electrical energy that can be used to charge mobile phones or other small electronic devices. This usually involves electronic circuits that transform the variable voltage from the solar panels into a stable output voltage. Solar trackers can be classified according to their number of degrees of freedom (Mahery H. Andriamahefa, 2023). There are various type of tracking Solar tracking system is classified by its degrees of rotation.

According to degrees of rotation trackers can be grouped into two primary categories:

- Single Axis Solar Tracker

• Dual Axis Solar Tracker

The single-axis solar tracker uses one axis, horizontal, tilt, or vertical, to orient the PV panel (Mohammed Diykh, 2022). A solar tracker with a single axis keeps track of the sun's movements in both horizontal and vertical directions. This type of tracker appears to have just one axis for rotation, as the name would imply. A dual-axis solar tracker appears to rotate in two directions. It might follow the sun in a vertical or horizontal direction. This kind of tracker ensures optimal efficiency in harnessing solar energy and may be used anywhere in the world. One degree of freedom serves as the rotational axis for single-axis trackers. Single axis trackers usually have their rotational axis oriented along a true North meridian (K, 2016). Dual axis solar trackers are more effective than single axis solar trackers. It is common knowledge that a single axis solar tracker system is unable to collect the whole range of solar energy (Mugachintala Dilip Kumar, 2023).

The mechanical parts of the project are primarily made from light iron and wood. The design being triangular for the construction of an automatic solar tracker simplifies the project even further. For support, 2 triangular-shaped iron legs have been prepared. Additionally, we have joined these with 2 iron lines. At the apex of both triangles, ring-like iron tubes through which an iron line passes have been placed. The iron lines passing through are attached to the frame prepared for holding the panel. With this simple construction, it is possible to induce mechanical movement to the panel by applying any force.

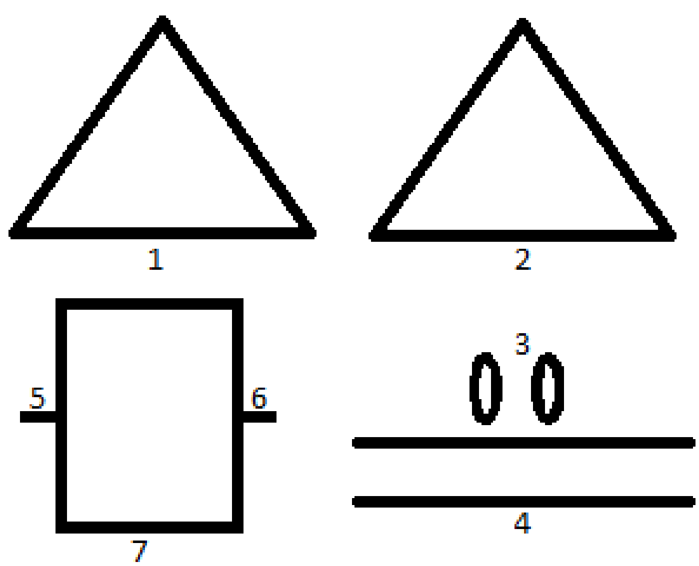


**Figure 2.1. Mechanical parts of the construction**

All mechanical parts are shown in the diagram above. The main parts are as follows:

1, 2 - Triangular-shaped iron legs

3 - Iron tubes

4 - Iron lines

5, 6 - Rotating irons

7 - Frame for holding a panel

### 2.1.2. Material Selection

When preparing any project, it is important that the products available here are of high quality. The materials chosen for our project must be both affordable for a student budget and suitable in terms of quality for use. Therefore, the materials we have used in the mechanical part are mainly wood and iron. The reason for choosing these materials is that they are cheaper in terms of price, more suitable for use, and more appropriate for our project. Each of the selected materials has been efficiently used in the creation of the mechanical part. The lightness of these materials has made it possible to carry the project by hand, which is one of the main advantages of our project.

A solar tracker designed to be portable and light enough to be carried by hand can offer several distinct advantages, especially in specific applications or environments:

1. Flexibility in Location: It can be easily relocated to optimize sunlight exposure throughout the day or year, accommodating changes in the sun's position due to seasonal variations.

2. Accessibility for Small-scale Installations: Ideal for small-scale or personal use, such as for residential properties, small businesses, or educational projects, where permanent installation might not be feasible or desired.

3. Ease of Installation and Setup: Being portable means, it can be set up quickly and without the need for heavy machinery or specialized tools, making it accessible for DIY enthusiasts or for educational purposes.

4. Cost-Efficiency: Portable solar trackers can be more cost-effective, especially for small-scale applications, as they avoid the need for extensive installation procedures and can be moved to maximize efficiency without additional cost.

5. Adaptability to Different Environments: Its portability makes it suitable for use in a variety of locations, from rooftops to ground-level settings, and even in remote or off-grid locations where traditional power sources are unavailable or unreliable.

6. Educational and Experimental Use: Portable trackers are excellent for educational purposes, allowing students and researchers to experiment with solar energy and understand the mechanics of solar tracking in real-time, hands-on settings. These advantages make portable solar trackers an appealing option for many individuals and smaller-scale applications, providing a versatile and efficient solution for harnessing solar energy.

### 2.1.3. Mechanical Design

In this section, we will explain in detail every aspect of the Phone Charging Converter we have developed, including how it was designed. We would like to first note that our project was inspired by other analogous works in this field. The modules that have been developed inspired us to create our own work, and using the resources available to us, we explored how to make a more effective automatic tracker and phone charger in a simple manner. After showcasing analogous works, we will transition to discussing the workings of our own project.

In the construction section, as we have mentioned before, we have utilized materials such as light iron and wood. Initially, we will provide detailed information about how the iron materials were prepared. These are simple iron materials, and we decided to create two triangular-shaped figures for the support legs we needed. These triangular-shaped iron legs are essential for keeping the panel elevated from the ground, and based on the size of the panel, two triangular-shaped legs have been prepared. Subsequently, to more securely join these legs to each other, two iron pieces were connected at their central points from both above and below. We will show you these two centers shortly, and we have prepared a frame to hold the panel, from the central points of which extend iron rods, referred to as rotating irons. These rotating irons will be connected to rings at the apex of the supports, or more precisely, passed through the rings so that the frame can easily move up and down within these rings.

Based on the information provided, the initial version of the construction made solely from iron will be as follows. Each part shown here is made exclusively from iron materials.

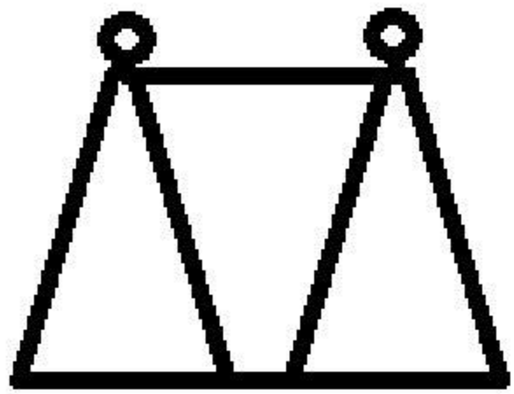

**Figure 2.2. Initial version of iron construction**

### 2.1.4. The Arduino

Arduino is an open-source electronics platform known for its simplicity and accessibility in developing interactive projects that can sense and control objects in the physical world. Its ecosystem comprises a combination of hardware (various models of Arduino boards), software (the Arduino Integrated Development Environment, or IDE), and a vibrant community of users. This article delves into the origins, components, and widespread applications of Arduino, highlighting its significant impact on education, hobbyist projects, and prototyping in the professional sector. Arduino was born in Ivrea, Italy, in 2005, with the aim of providing an inexpensive and easy way for novices and professionals alike to create devices that interact with their environment using sensors and actuators. The project was initiated by Massimo Banzi and David Cuartielles, among others, and it quickly spread beyond its initial context of interaction design education to a global audience. Arduino's philosophy centers around making technology accessible to a wide audience, including artists, designers, hobbyists, and anyone interested in creating interactive projects. The Arduino hardware consists of a microcontroller (MCU) board designed to be easily integrated with a wide range of sensors, actuators, and other electronic components. Over the years, several versions of Arduino boards have been released, catering to different needs. These include:

Arduino Uno: The most popular model, ideal for beginners.

Arduino Nano**:** A compact board suitable for small projects.

Arduino Mega: Offers more I/O pins and memory, suitable for more complex projects

Due: Based on a more powerful ARM processor, supporting more advanced applications.

Arduino boards can be connected to a computer via USB, where they can be programmed using the Arduino IDE. The Arduino Integrated Development Environment (IDE) is the primary software used to write and upload code to Arduino boards. It uses a simplified version of C++, making it easier for beginners to learn programming. The IDE includes a code editor, a compiler, and a mechanism to transfer the compiled code to the Arduino hardware.

Why choosing Arduino Open Source: Arduino is an open-source platform, which means the hardware and software designs are freely available for anyone to use, modify, and distribute. This has resulted in a large community of developers who have created a wide range of projects and libraries that can be easily adapted and reused.

Easy to Use**:** Arduino has a simple and easy-to-learn programming language similar to C/C++. The integrated development environment (IDE) provides a user-friendly interface for writing and uploading code to the board.

Low Cost: Arduino boards are relatively inexpensive, making them accessible to many people. They can be purchased online or at electronics stores for as little as $10.

Versatile: Arduino boards can be used for various projects, from controlling LEDs and motors to building robots and data loggers. They can be easily expanded with shields and other hardware components to add additional functionality. Large Community: The Arduino community is large and active, with many online resources, including tutorials, forums, and libraries. This makes it easy to find help and support for your projects (Muthyala, 2023).

### 2.1.5. Solar energy using Arduino for efficient electrical power generation

While photovoltaic panels directly convert solar energy into electricity, more than 50% of solar radiation is lost as waste heat, diminishing the overall efficiency of the panels (Hua, 2024). Integrating Arduino into solar energy projects for efficient electrical power generation is a brilliant example of how open-source technology can propel renewable energy solutions to new heights. Arduino's flexibility and ease of use make it an excellent tool for enhancing the efficiency and functionality of solar power systems. The operational range of a buck boost converter encompasses the operational zones of both boost and buck converters. Therefore, there is no doubt about the decision to use a buck boost converter to condition the power from the PV panel to match the load requirements (Vidhya S. Menon, 2013). This approach can lead to innovative projects such as solar trackers, smart energy management systems, and automated data collection about solar efficiency. Here's a closer look at how Arduino is being used to optimize solar energy systems for better electrical power generation.

One of the most effective ways to increase the energy output of solar panels is through solar trackers. Solar trackers adjust the position of solar panels throughout the day, ensuring they are always oriented towards the sun to maximize light absorption. An Arduino-based solar tracker uses light sensors to detect the sun's position and motors to adjust the panels' angle.

Implementation:

By programming an Arduino board to analyze inputs from light sensors, it can control motors that tilt the solar panel towards the sun. This continual adjustment can significantly enhance the power output, sometimes by up to 25-40% compared to stationary panels.

*Smart Energy Management Systems*: Arduino can also be employed to create a smart energy management system for solar power. This system can monitor energy production, consumption, and storage, and make real-time decisions to optimize energy use.

*Functionality:* An Arduino board can gather data from solar panels, batteries, and consumption devices, then use this data to efficiently distribute power where it's needed, store excess energy, or even sell it back to the grid. Programming the Arduino to manage these tasks can help in maximizing the utilization of solar energy, reducing waste, and increasing savings.

*Automated Data Collection on Solar Efficiency*: Collecting data on the efficiency of solar panels over time is crucial for maintenance and optimization. Arduino can automate this process, providing valuable insights into the performance of a solar power system.

*Data Collection*: With sensors for temperature, sunlight intensity, and voltage output, an Arduino can log data over time to track the system's efficiency. This information can be used to identify patterns, predict maintenance needs, or optimize the angle and cleaning schedule for the panels. Integrating solar panels with Arduino can improve energy management in urban areas. We evaluate the system's energy generation, battery charging, and consumption management. Additionally, practical ramifications and future development potential are highlighted. This research aims to create a park bench that generates and manages renewable energy using solar panel technology and an Arduino platform. This project attempts to solve the issues of conventional energy use in metropolitan areas through efficient and sustainable solutions. This bench may generate sustainable energy in public settings using solar energy and Arduino technology for intelligent regulation and monitoring. The study hypothesizes that park storage and renewable energy management in urban public places will achieve its goals. A bench with solar panels and an Arduino platform will enable efficient generating. Real-world implementation and performance study of the integrated system will test this notion. Research contributes to sustainable energy use solutions in urban public places. We want to generate, store, and manage renewable energy efficiently and sustainably by integrating solar panel technology with the Arduino platform. The practical design and installation of this solar bench can inspire similar solutions in other metropolitan areas, contributing to the discussion on sustainable energy and environmental improvement (Ain, 2023).

### 2.2. Block diagram and purpose of the components

In contemporary civilizations, solar cells stand as one of the most significant sources of clean energy (Alvaro Rodriguez, 2021). The main objective of our project is to increase the efficiency by tracking the movement of the sun at any given time with a moving construction.This is a logical and effective approach to increase the efficiency of solar panel systems. Tracking systems that follow the sun's movement can significantly increase energy production by utilizing more sunlight compared to fixed systems. In the construction part, the structure has been designed in a triangular shape using iron and wood materials for the frame and supports to hold the solar panel. Using these materials to create a movable construction appears to be the most cost-effective option. This also further enhances the efficiency and essence of our work. In general, the efficiency of movable solar panels is significantly different from that of stationary solar panels. In the project, three positions of the frame have been defined by using just one motor. The amount of energy obtained in the initial, neutral, and final positions will be calculated. The main objective of our work is to ensure that the energy obtained is both transferred to a battery and used for charging phones. Thus, the solar panel becomes self-sufficient. That means it should operate in a movable manner at any time and under any weather conditions, without being connected to any power source. The advantage of our project lies in the fact that the materials used are both simple and inexpensive, it will operate without being connected to an electrical power source, and it will maximize the efficiency of the energy obtained from the sun.

The block diagram shown below is the overall block diagram of our Phone Charging Converter:

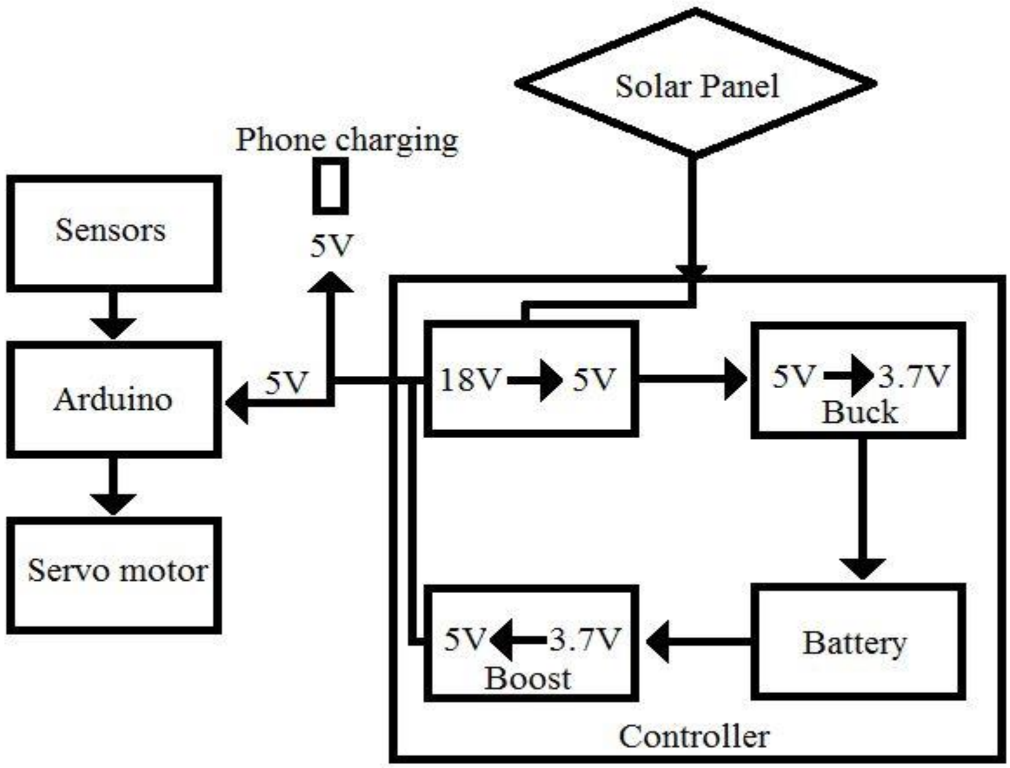


**Figure 2.3 Block diagram of the project**

### 2.2.1. Mechanical movement of the structure

We previously mentioned using a servomotor. To facilitate the attachment of this servomotor, a piece of wood has been affixed at the lower end of the triangular-shaped legs, and the motor’s arm will move on this wood. More specifically, the motor's arm will move across this wooden surface. A nail has been attached to the end of the motor's arm, and this nail is connected to the structure holding the panel. Thus, when the motor receives a signal from the sensors, the arm of the motor moves up and down, thereby moving the nail and, in turn, adjusting the structure holding the panel up and down. There is another piece of wood we have used, which is attached to the underside of the other end of the frame and is referred to as a load. This method is used to keep the nail in tension. That is, if the arm moves upwards, the load will immediately rotate the panel in the opposite direction.

The process of initiating mechanical movement in the structure with the aid of a motor will be possible in this simple manner, that is, by using a counterweight and a servomotor, we can now achieve movement in the structure.

### 2.2.2. Arduino UNO

Arduino Uno is a widely popular open-source microcontroller board based on the ATmega328P microchip. It serves as an easy-to-use platform for developing electronic projects, accessible to hobbyists, students, and professionals alike. Featuring 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button, it provides all the necessary support for a wide range of projects. Arduino Uno boards can be programmed using the Arduino Software (IDE), allowing for simple or complex functions to be executed based on the needs of the project. With a large and active community behind it, resources, tutorials, and project examples are readily available, making it an ideal starting point for those interested in diving into the world of electronics and programming (https://aurorasolar.com/, 2024).

Arduino Uno acts as the backbone for countless projects, from simple household tasks to complex scientific instruments. Its simplicity and open-source nature have cultivated a global community that contributes to an extensive library of code samples, project guides, and tutorials, making it easier for beginners to get started and for advanced users to innovate.

The Uno's programmability through the Arduino Integrated Development Environment (IDE), which supports C and C++, is one of its key strengths. The IDE's straightforward interface simplifies the process of writing code and uploading it to the board. This process fosters learning and experimentation, which is why Arduino is widely adopted in educational contexts, from elementary schools to universities.

Another notable aspect is its connectivity capabilities. While the Arduino Uno itself offers basic digital and analog I/O pins, its functionality can be extended with Shields—additional boards that plug into the Arduino to provide functionalities like WiFi, Bluetooth, GPS, and more. This modular approach enables users to add complexity and functionality to their projects without having to deal with the intricacies of hardware design. The Arduino Uno also benefits from being part of a larger ecosystem, including other boards that offer different capabilities, sizes, and price points, catering to a wide range of projects and skill levels. For instance, the Arduino Mega is designed for projects that require more I/O lines, memory, and processing power, while the Arduino Nano offers a more compact form factor for smaller projects.

In essence, the Arduino Uno has become a fundamental tool in the maker movement, DIY electronics, and education due to its versatility, ease of use, and the vast community support. Whether you're creating a weather station, a robotic project, or an interactive artwork, the Arduino Uno provides a solid foundation to bring your ideas to life.

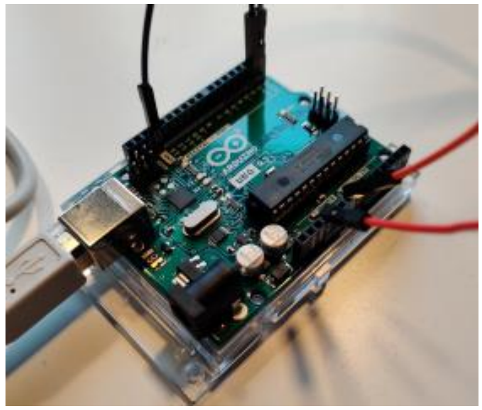

**Figure 2.4. Arduino UNO**

I think there are three major advantages make it so prevalent recently. Firstly, it is a well-configured hardware platform. Arduino Uno is a microcontroller board containing everything that a microcontroller need including 14 digital input/output pins (6 can be used as PWM (Pulse-Width Modulation) outputs), 6 analog inputs, a power jack, a USB connection, a 16 MHz quartz crystal, a reset button and an ICSP (In-Circuit Serial Programming) header. And only with a USB cable, developers can easily connect it to own PC to program and communicate with the microcontroller without worrying about the connections or other interfaces. Secondly, it is an open-source software platform. A simple and integrated IDE (Integrated Development Environment) is introduced by 2005 in which is easy-to-use for developers to write code and upload it to microcontroller board. It is available for almost all platforms including Windows, Mac OS X, and Linux. Besides a number of example codes presented inside the IDE, there are also a large assortment of included libraries decreasing the complexity and difficulty of programming for developers. Thirdly, it is inexpensive. Compared to other microcontroller platforms, Arduino boards are considerably cheaper than others. Hence, the developers allowed to do whatever they want without worrying the price once chips are broken. In addition, engineers, hobbyists and professionals can all work on Arduino Uno due to low price and many communities of working on Arduino emerging on the Internet develop it together (Liu, 2017). The Arduino Uno was the first version to be released amongst their microprocessor catalogue.

This is a microcontroller board that is based on the ATmega328P. There are 14 digital output/input pins and seven analogue inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, ICSP header, a reset button, and a power jack. There is much built-in safety for the controller; the only thing at any real risk is the chip (ATmega328P). This can be easily replaced at a low cost (Andreas Östlin, 2021).

### 2.2.3. The Waveshare 6V-24V Solar Power Manager

This is a module designed for IoT projects and outdoor solar power supply applications. It's an efficient and versatile board capable of managing and regulating power from solar panels to charge batteries and power various electronic devices. Here's a brief overview of its key features and functionalities:

The module can be used with a variety of solar panels because it has a broad input voltage range of 6V to 24V. This range gives you the freedom to select solar panels based on the power needs of your project. It has a circuit for charging batteries that is intended to charge Li-ion or Li-polymer single-cell batteries. In order to optimize charging efficiency, it has MPPT (Maximum Power Point Tracking) capability, which makes sure the solar panel runs at its peak power output level. At present, the active use of renewable energy sources in many developed countries is accepted as a vital, strategically necessary resource that ensures the promising development of the economies of these countries. According to forecasts, the share of renewable energy (solar, wind, tidal, solar energy, etc.) in global energy consumption will increase annually and will reach 30% by 2030, and 50% by 2050 (Aizhan Baidildina, 2023).

**Figure 2.5. The Waveshare 6V-24V Solar Power Manager**

The Solar Power Manager provides multiple output options, including USB output, which is convenient for charging mobile devices or powering USB-powered gadgets. It includes various protection mechanisms such as battery overcharge/discharge protection, output overcurrent/short circuit protection, and solar panel/reverse polarity protection. These features help to safeguard the connected devices and the charging circuitry. Due to its versatility and efficiency, the Waveshare Solar Power Manager is suitable for a wide range of applications, including outdoor solar power projects, IoT applications where power consumption is critical, portable instruments, and any project requiring an efficient power management solution powered by renewable energy sources. If you're planning to use this module in your project, make sure to check the specific model documentation for wiring instructions, configuration details, and best practice s to optimize performance and ensure safety.

### 2.2.4. Monocrystal Photovoltaic Module

A solar panel or module is a group of connected solar photovoltaic cells electrically and mounted on a sustaining structure. A photovoltaic module is a systematical arranged series connection of solar cells (Patel R. , 2014). There are 4 major types of solar panels available on the market today: monocrystalline, polycrystalline, PERC, and thin-film panels. Monocrystalline solar panels also known as single-crystal panels; these are made from a single pure silicon crystal that is cut into several wafers. Since they are made from pure silicon, they can be readily identified by their dark black color. The use of pure silicon also makes monocrystalline panels the most space-efficient and longestlasting among all three solar panel types. However, this comes at a cost — a lot of silicon is wasted to produce one monocrystalline cell, sometimes reaching over 50%. This results in a hefty price tag (Adeleke, 2023).

A solar panel is a device that converts sunlight into electricity through photovoltaic cells. PV cells produce direct current electricity when they are exposed to light, which can then be used to power various devices or stored in batteries. Monocrystalline solar panels generally have high efficiency, meaning their rate of converting sunlight into electricity is higher compared to other types of panels. This implies that they can generate more energy over a limited area. In our project, we have used the URETECH MM-M364-50 Monocrystalline Photovoltaic Module. The reason for using this panel is that it is both cost-effective and lightweight.

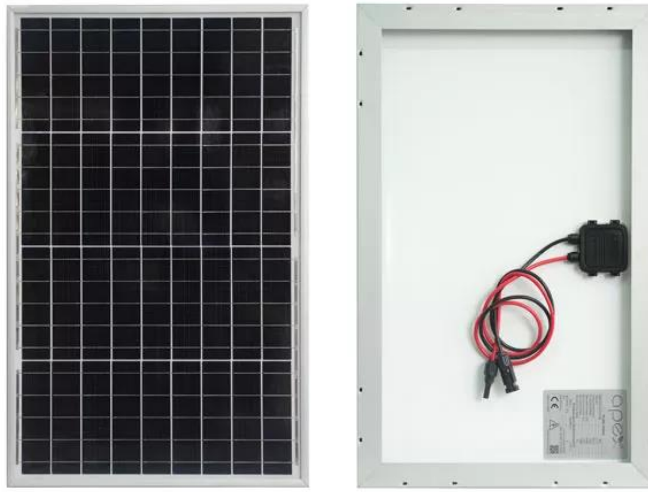

**Figure 2.6. URETECH MM-M364-50 Monocrystalline Photovoltaic Module**

The technical specifications of the product are shown below:

Maximum Power (Pmax): 50W (+/-3%)

Maximum Power Voltage (Vmp): 20.57V

Maximum Power Current (Imp): 2.43A

Open Circuit Voltage (Voc): 24.85V

Short Circuit Current (Isc): 2.57A

Maximum System Voltage: DC 1000V

Dimensions (mm): 675x420x35

Weight (kg): 3

Standard Test Conditions: AM=1.5, Irradiance=1000W/m², Temperature=25°C.

### 2.2.5. Light Dependent Resistor (LDR)

The solar tracker can be controlled automatically with the help of Light Dependent Resistor (LDR) sensors or manually using a potentiometer (Saad Motahhir, 2019). Solar cells are traditionally fixed on rooftop or fixed on ground. As a result, solar cells unable to receive maximum light as position of sun changing varying with time (Shaik Meeravali, 2012). The sun's coordinates are tracked using a Light Dependent Resistor (LDR) (Daryl Anunciado, 2022). The GL5537 is a type of Light Dependent Resistor (LDR), also known as a photoresistor. LDRs are passive electronic components that have a resistance that varies with the amount of light falling on their surface. The GL5537, in particular, is designed to change its resistance with changes in the ambient light level, making it suitable for a wide range of applications where it is necessary to detect or respond to light. In this study, LDR has the property of reducing its resistance as the light falling on it increases. Keeping this principle in mind a microcontroller program is written for tracking purpose (Parasnis N. V, 2016).

Key Characteristics of the GL5537 LDR:

Maximum Voltage: It can handle a maximum voltage of up to 150V DC, which is the maximum voltage limit before the device may get damaged.

Resistance in Light: At 10 lux (a measure of illuminance), the resistance of the GL5537 ranges between 18 KΩ and 50 KΩ. This indicates how sensitive the LDR is in typical lighting conditions found in indoor environments.

Dark Resistance: When in complete darkness, the GL5537 has a very high resistance, typically around 2 MΩ. This high resistance in the absence of light is a common feature of LDRs, allowing them to function effectively as light sensors.

Power: The device is rated for a power dissipation of 100 milliwatts, which is the maximum amount of power it can handle without being damaged, under specified conditions.

During solar tracking, LDRs can be used to determine the sun's location in the sky. LDRs are positioned precisely in these studies to reflect the geographical directions using a variety of techniques. While employing LDRs in this manner makes sun tracking feasible, we previously said that the angular outputs could not be achieved and that the findings are only obtained within specific bounds (Oğuz Gora, 2023). The control circuit is based on an ATMega328P microcontroller. It was programmed to detect sunlight via the LDRs before actuating the servo to position the solar panel (Oloka Reagan Otieno, 2021).

### 2.2.6. Servo Motor

The MG995 is a widely used servo motor known for its high torque and reliability in various applications, including RC (Radio Controlled) vehicles, robotics, and other hobbyist projects. Here's an overview of its main features and specifications:

The MG995 is a digital servo motor that rotates approximately 180 degrees (90 in each direction). It's designed for heavier loads, making it suitable for applications requiring significant movement and strength. The construction of the MG995 typically includes metal gears, which provide better durability and performance compared to plastic gears. The technical specifications of the product are shown below:

Voltage: Operates typically around 4.8V to 7.2V.

Torque: It offers high torque, usually around 10kg/cm (at 4.8V) to 12kg/cm (at 6V), making it powerful for its size.

Speed: The response speed is relatively fast, with typical operation speeds of 0.20 seconds/60° (at 4.8V) and 0.16 seconds/60° (at 6V).

Size and Weight: It is relatively compact, with dimensions around 40.7mm x 19.7mm x 42.9mm and weighs about 55g.

Gear Type: The gears are made of metal, contributing to the servo's robustness and reliability.

Control Type: It is controlled by PWM (Pulse Width Modulation), a common method for controlling servomotors, allowing precise control over the position.

### 2.2.7. Battery

Devices called batteries are made of electrical cells that have the capacity to store electrical energy that cansubsequently be transformed into electricity (H H Rangkuti, 2022). We used Power-Xtra Li-Ion 14500 battery. This compact power source is not just another rechargeable battery; it embodies the intersection of portability and power, fitting a wide range of applications that demand reliability and efficiency. If we want to make the usage of green energy sources like photovoltaics (PV) an alternative for converting solar energy, it will be more beneficial to develop a single axis PV tracker system and a smart controller system for battery charging (Habib Satria, Performance of single axis tracker technology and automatic battery monitoring in solar hybrid systems, 2023). With an 800mAh capacity, the Power-Xtra Li-Ion 14500 battery offers a commendable energy reserve for its size. This capacity indicates how much energy the battery can store, directly impacting how long a device can run before the battery needs recharging. This makes the battery an ideal choice for devices that require a balance between compact size and sustained power output.

## 2.3. Working Principle of the Automatic Solar Tracker

In this section, we will explain in detail every aspect of the Phone Charging Converter we have developed, including how it was designed. A low-cost solar tracker set-up is uniquely set up to act as the solar radiation sensor/detector which is used to rotate the solar panels via the electric motors to position the panels at a specific angle determined by the light dependent resistor of the tracker system (Ayoade, Adeyemi, Adeaga, Rufai, & Olalere, 2022). We would like to first note that our project was inspired by other analogous works in this field. The modules that have been developed inspired us to create our own work, and using the resources available to us, we explored how to make a more effective automatic tracker and phone charger in a simple manner. Upon activating the solar tracker, the microcontroller system will set up the first the servo motor's locations (Anderias Henukh, 2023).

We have provided information about the materials and details used in our project. Now, let's explain the steps related to how this device works. First of all, as we mentioned, we started by combining the used wood and iron materials. The resulting support part prepared the panel for mechanical movement. Two triangular legs were connected to each other and primarily served as the support. We continue with rings attached at the top points. The purpose of these rings is to keep the rotating iron in contact with the support. The rotating iron was then attached to the frame prepared for holding the panel. When we placed the panel inside this frame, everything was ready in terms of appearance and movement. However, this prepared device was not yet automated. It was manually controlled. Later, to automate this, we needed a servo motor. Our main goal was to achieve bidirectional movement using a single servo motor. Therefore, we had to add a wooden piece where we could mount the motor. We attached the wood to the iron legs, and the motor to the wood. By attaching additional wood to the rotating arm on the motor, we increased the length of the rotating arm and thus reduced the load on the motor. This wooden rod was then connected to the frame via a linkage.

Thus, when a signal is sent to the motor, the rotating arm moves and pulls the frame downwards via the linkage. However, there was still an additional problem. Since our goal was bidirectional movement, our project was still not perfect. Therefore, we decided to attach a weight to the other side of the frame. This weight keeps the linkage tense and ensures that when the motor is not in motion, the panel moves towards the opposite side. This allowed us to achieve bidirectional movement. We can explain the overall plan with the following sequence:

**Step 1:** When light falls on the panel, an LDR sensor sends a signal through an Arduino to the motor.

**Step 2:** As a result of the motor's movement, the panel automatically shifts towards the side where the sensor detects more light.

**Step 3:** The energy captured by the sensor is used to charge a battery, power the motor, and also to charge a phone.

# CHAPTER III. THEORETICAL PART OF THE PROJECT

PV panels are supposed to be positioned with their faces perpendicular to the sun. However, because of snow reflection and other considerations, the ideal location for the PV module may deviate somewhat from the astronomical position, which is perpendicular to the Sun (Pandey, 2016). The solar energy is also free and theoretically infinite (Tregambi, 2016). Our goal is to maximize the amount of energy that may be obtained by attempting to maintain the solar panel perpendicular to the sun in order to receive the maximum amount of solar radiation (Serhat Aksungur, 2018). To enhance energy output, the solar tracker moves the solar panel to match the path of the sun. The location of the solar panel is changed because of the weather analyzer's observation of weather patterns. The sun tracker is controlled by microcontroller that receives information from LDR sensors (Shek Md Abrar Faisal, 2023).

## 3.1. Experimental Investigation of an Arduino-Controlled Solar Charger with Automatic Sun Tracking

The quantity of energy harvested from a photovoltaic (PV) panel depends primarily on the instantaneous level of incident sunlight and the ambient temperature (Hussain Attia, 2023). In the pursuit of more efficient renewable energy solutions, the development of an Arduino-controlled solar charger with automatic sun tracking represents a significant technological advancement. This system combines the principles of photovoltaic energy conversion with smart tracking technology to optimize solar energy collection throughout the day. This article provides a comprehensive overview of the experimental investigation conducted to assess the performance and feasibility of such a system.

The increasing demand for renewable energy sources has led to innovative approaches to enhance the efficiency of solar power systems. Traditional stationary solar panels often fail to capture the maximum amount of solar energy due to the sun's movement across the sky. An Arduino-controlled solar charger with automatic sun tracking addresses this issue by adjusting the orientation of solar panels in real-time to face the sun directly, thus maximizing energy absorption.

The system's core comprises a solar panel, Arduino microcontroller, servomotors for panel movement, light sensors for tracking the sun's position, and a charging circuit for energy storage.

- Solar Panel: Converts sunlight into electrical energy.
- Arduino Microcontroller: Acts as the control center, processing sensor inputs and managing panel orientation.
- Servomotors: Enable the precise movement of the solar panel both horizontally and vertically.
- Light Sensors: Detect the most illuminated direction and provide feedback to the Arduino for panel adjustment.
- Charging Circuit: Stores the generated electricity in batteries for later use.

The experimental setup involves positioning the light sensors on the solar panel's edges to detect sunlight intensity. The Arduino microcontroller, programmed with a sun-tracking algorithm, interprets the data from these sensors to determine the sun's position. Based on this information, it commands the servomotors to adjust the panel's angle to maintain optimal alignment with the sun throughout the day.

Performance metrics such as energy output, tracking efficiency, and battery charging rate are measured under various weather conditions. Comparisons are made with stationary solar panel setups to quantify the benefits of sun tracking.

The experimental investigation revealed a significant increase in energy output from the solar charger with automatic sun tracking compared to a fixed-position solar panel system. The tracking system demonstrated an ability to maintain optimal alignment with the sun, resulting in a higher efficiency of solar energy capture and more effective battery charging.

Challenges encountered during the experiment included mechanical wear of moving parts, energy consumption by the tracking system, and the complexity of the tracking algorithm. However, these were mitigated through design optimizations and software improvements.

The development and experimental investigation of an Arduino-controlled solar charger with automatic sun tracking have proven the concept's viability and efficiency. By intelligently adjusting the orientation of solar panels to follow the sun, the system can significantly enhance solar energy capture. This technology represents a promising advancement in solar power, potentially leading to more widespread adoption of renewable energy sources. Further research and development could focus on scaling the system, improving durability, and integrating advanced features such as weather prediction to anticipate changes in sunlight availability (Muhammadqasim, 2023).

### 3.1.2. Smart Solar Charging System with Automated Tracker: Experimental Insights

The transition towards renewable energy sources is imperative in the face of escalating environmental concerns and depleting fossil fuels. Solar energy, abundant and accessible, stands at the forefront of this transition. This article delves into the development and experimental evaluation of a Smart Solar Charging System equipped with an Automated Tracker, emphasizing its efficiency in harnessing solar power. Through meticulous experimentation, we aim to provide insights into the system's operational efficacy, energy conversion rates, and potential for integration into the broader renewable energy ecosystem.

The efficiency of solar panels is significantly contingent upon their orientation relative to the sun. A Smart Solar Charging System with an Automated Tracker innovatively addresses this by dynamically adjusting the panel's angle to ensure maximum solar exposure. This system not only promises an increase in energy output but also incorporates intelligent charging protocols to optimize battery storage and longevity. This paper presents an experimental investigation into the system's design, functionality, and performance metrics.

System Architecture

The system integrates several key components:

- Solar Panel: The primary energy harvesting component, whose efficiency is directly augmented by optimal orientation.
- Automated Tracker: Utilizes light sensors and a control algorithm to adjust the panel's position in real-time, tracking the sun's trajectory.
- Microcontroller Unit (MCU): The brain of the operation, an Arduino board, interprets sensor data and manages the tracker and charging logic.
- Battery Storage: Stores excess energy generated, ensuring a continuous power supply irrespective of solar conditions.
- Charge Controller: Regulates the charging process to protect the battery from overcharging and deep discharging.

The methodology revolves around comparative analysis, contrasting the performance of the Smart Solar Charging System against conventional stationary setups. Parameters such as daily energy output, efficiency of tracking, battery charge levels, and operational durability under various environmental conditions were meticulously recorded.

The Automated Tracker's algorithm was fine-tuned to balance energy consumption (for movement and computation) against the gains in solar energy capture. The system was subjected to a series of tests, ranging from clear sunny days to overcast conditions, to evaluate its adaptability and efficiency.

The Smart Solar Charging System demonstrated a noticeable improvement in solar energy capture, with a 20-35% increase in daily energy output compared to stationary systems. The Automated Tracker efficiently aligned the solar panel with the sun's position throughout the day, maximizing the exposure time and consequently the energy harvested.

Battery charging protocols managed by the MCU ensured optimal charging cycles, significantly enhancing battery life and performance. The system's energy consumption for tracking movements was minimal in comparison to the additional energy harvested, validating the efficiency of the automated tracking approach.

The experimental insights underscore the viability and benefits of integrating automated tracking into solar charging systems. The Smart Solar Charging System not only optimizes energy capture but also incorporates intelligent charging strategies, showcasing a holistic approach to solar energy utilization.

Challenges encountered during experimentation included mechanical wear and tear of moving parts and the system's responsiveness to sudden changes in sunlight intensity. Future work will focus on addressing these challenges, improving the system's durability, and refining the tracking algorithm for even greater efficiency.

The Smart Solar Charging System with an Automated Tracker represents a significant leap forward in solar technology, offering a more efficient and intelligent approach to solar energy capture and utilization. This experimental investigation highlights the system's potential to enhance the performance and reliability of solar power as a key renewable energy source, paving the way for further innovations in the field.

### 3.2. Weather Condition Impacts on the Solar Tracker

Weather conditions play a critical role in the performance and reliability of solar tracking systems. These systems, designed to optimize the orientation of solar panels for maximum solar irradiance capture, are significantly influenced by varying weather patterns. This section explores the impacts of different weather conditions on the functionality and efficiency of solar trackers, offering insights into challenges and potential mitigation strategies.

Solar trackers are an innovative solution to increase the energy output of solar panels by aligning them with the sun's path across the sky. However, their outdoor installation exposes them to an array of weather conditions, from clear skies to severe storms, each affecting their operation differently. Understanding these impacts is crucial for the design, operation, and maintenance of effective solar tracking systems.

Weather Conditions and Their Impacts:

Clear Skies

- Optimal Condition: Clear skies provide the best scenario for solar trackers, allowing them to operate at maximum efficiency with uninterrupted exposure to direct sunlight.
- Challenge: Overheating of system components can occur due to prolonged exposure to direct sunlight without the cooling effect of wind or clouds.

Cloudy and Overcast Skies

- Reduced Efficiency: Solar irradiance is significantly lower on cloudy days, reducing the system's energy output despite optimal tracking.
- Adaptive Tracking: Advanced tracking systems can adjust their operation, minimizing movements to conserve energy when full tracking yields minimal benefits.

Rain

- Cleaning Benefit: Rain can naturally clean the panel surfaces, potentially increasing efficiency by removing accumulated dust and debris.
- Risk of Water Damage: Electrical components and motor systems are susceptible to water damage if not properly sealed.

Wind

- Structural Stress: High winds can exert significant force on solar panels and tracking mechanisms, risking structural damage if not adequately designed to withstand such loads.
- Stow Position: Many solar trackers include a wind sensor to automatically move the panels into a stow position, reducing wind resistance during high wind conditions.

Snow

- Obstruction: Snow accumulation can obstruct sunlight from reaching the solar panels, necessitating manual or automatic clearing mechanisms.
- Weight Concerns: The additional weight of snow on the system can strain mechanical components, requiring robust design considerations.

Mitigation Strategies

- Weatherproofing: Ensuring all electrical and moving parts are protected against water ingress and humidity to prevent corrosion and short circuits.
- Structural Engineering: Designing the system to withstand the maximum expected wind and snow loads in the installation area.
- Energy Management: Incorporating smart algorithms that adjust tracking based on the cost-benefit analysis of energy expenditure versus energy gain under varying weather conditions.
- Emergency Stow Function: Implementing an automatic stow function in response to extreme weather conditions to protect the system from damage.

Weather conditions significantly impact the operational efficiency and durability of solar trackers. By understanding these impacts, designers and operators can implement mitigation strategies to enhance system resilience and performance. Continued innovation in materials, design, and control algorithms will further improve the adaptability and efficiency of solar trackers in the face of changing weather patterns, solidifying their role in the future of renewable energy technology. The solar tracking system collects and stores the output voltage generated by the PV panels in the battery bank (Firas Basim Ismail Alnaimi, 2024).

The objectives of this project are to design and construct a solar tracking system that can track the movement of the sun and adjust the angle of the solar panels accordingly, as well as to integrate a weather forecasting system with the solar tracking system and adjust the angle of the solar panels accordingly (Ahmet Saymbetov, 2020).

### 3.3. Implement dual-mode solar charger with Arduino

The development of efficient solar power management systems is critical for enhancing the viability of renewable energy sources. This paper details the design and implementation of a dual-mode solar charger using an Arduino microcontroller, which optimizes solar energy usage by dynamically switching between direct charging and battery storage modes. The effectiveness of this system in various environmental conditions and its impact on battery health and overall system efficiency are evaluated.

Solar energy systems are increasingly integral to global renewable energy strategies. However, the variability of solar irradiance presents challenges in managing the energy effectively. A dual-mode solar charger, controlled by an Arduino microcontroller, offers a solution by intelligently toggling between charging modes based on solar availability and energy demand, thus maximizing efficiency and extending battery lifespan.

- Improved Efficiency: Preliminary results indicate a 15-25% increase in energy utilization efficiency compared to conventional solar charging systems.
- Battery Preservation: Reduced charge and discharge cycles lead to an extended battery life of up to 30%.
- Adaptive Performance: The system shows robust performance in diverse weather conditions, effectively adapting to changes in solar intensity.

The implementation of a dual-mode solar charger controlled by an Arduino microcontroller represents a substantial improvement in the management of solar energy systems. By optimizing energy use and minimizing wastage, this system not only enhances the efficiency of solar power generation but also contributes to the sustainability of battery resources. Future research could explore the integration of predictive analytics to further refine energy management based on weather forecasts and usage patterns, potentially leading to smarter, more autonomous solar power systems.

This exploration highlights the potential and versatility of Arduino-based solutions in renewable energy applications, demonstrating significant advancements in energy management technologies. In line with this research, in this paper the modeling process and implementation of a single-axis solar tracker is presented (Carlos Robles, 2017).

### 3.4. Determination of power efficiency of solar panels

The power efficiency of solar panels is a crucial factor that directly impacts the effectiveness and viability of solar energy systems. This section discusses the methodologies employed to determine the power efficiency of solar panels, analyzes various factors influencing their performance, and presents experimental results from testing different types of solar panels under varying environmental conditions. As sun is a moving object, this approach is not the best method. One of the solutions is to actively track the sun using a sun tracking device to move the solar panel to follow the Sun (Apoorvi, 2019).

Solar panel efficiency is defined as the ratio of energy output from the panel to the solar energy it receives. Higher efficiency means more energy production from the same amount of sunlight, which is essential for the cost-effectiveness and environmental impact of solar power systems. This study aims to evaluate the power efficiency of different solar panels and understand how environmental factors affect their performance.

Factors Affecting Efficiency:

- Temperature: Solar panels generally become less efficient as they get hotter.
- Angle of Incidence: The angle at which light strikes the panel affects how much energy is absorbed.
- Spectral Composition: Different wavelengths of solar radiation may not be equally converted to electricity.

Data Analysis

- Efficiency Calculation: Efficiency = (Output Power/Input Power) x 100%, where Output Power is the product of voltage and current, and Input Power is calculated from the solar irradiance.
- Comparison Across Types: Monocrystalline panels showed the highest efficiency under STC, but thin-film panels performed better under less ideal conditions due to better temperature coefficients.
- Impact of Environmental Conditions: Efficiency variations were recorded in response to changes in temperature, humidity, and irradiance levels.

### 3.5. Types of Automatic Solar Tracker

Several solar tracking principles and techniques have been proposed to track the sun efficiently (N. Al-Rousan, 2017). There are primarily four types of automatic solar trackers commonly used to enhance the efficiency of solar panel installations by optimizing their orientation relative to the sun. These include:

1. Single-Axis Solar Trackers: These trackers rotate on one horizontal axis, typically oriented from east to west, allowing the panels to follow the sun as it moves across the sky during the day.
2. Dual-Axis Solar Trackers: These offer two degrees of movement, allowing the panels not only to follow the sun from east to west but also to adjust their angle from horizontal to vertical. This adjusts for the sun’s elevation changes throughout the year, providing optimal solar capture.
3. Tilted Single-Axis Trackers: A variation of the single-axis tracker, where the axis of rotation is tilted relative to the ground. This design helps to capture more solar energy in higher latitudes where the sun's angle varies more significantly throughout the year.
4. Vertical Axis Trackers: These trackers rotate around a vertical axis. They are less common and typically used in specific scenarios where space constraints are a significant factor or where shadowing must be minimized.

Each type of tracker has specific applications, advantages, and disadvantages; tailored to various geographical locations, budget constraints, and energy needs. The axis of rotation for vertical single axis trackers (VSATs) is vertical with respect to the ground. These trackers rotate from east to west over the course of the day. Lorenzo (2002) designed the tracking of photovoltaic systems with a single vertical axis. The vertical single axis tracking also called as azimuth tracking is mainly used for the energy gain which can be 40% more compared to tilted static panels (Suneetha Racharla, 2017).

### 3.5.1. Methods of Solar Tracking

There are three methods of solar tracking: active tracking, passive tracking and chronological tracking. The position of the sun is continuously determined by the sensors during the day. The sensor triggers the motion of motor or actuator in such a way so that the solar panel will always face the sun throughout the day.

Passive tracking method does not use sensors like active tracking. Instead of using sensors, a passive tracker moves in response to imbalance in pressure between two points at the ends of the tracker. A chronological tracker is a timer-based tracking system. The structure is moved at a fixed rate throughout the day since the sun moves across the sky at a fixed rate of about 15 degree per hour (Bhagwan Deen Verma, 2020). This technology offers an environmentally friendly and sustainable way to maximize the use of renewable energy sources. By utilizing solar energy, we can reduce the carbon footprint of our energy consumption and charge our mobile devices in an eco-friendlier manner. This technology is particularly significant in areas rich in sunlight or where access to conventional energy sources is limited.

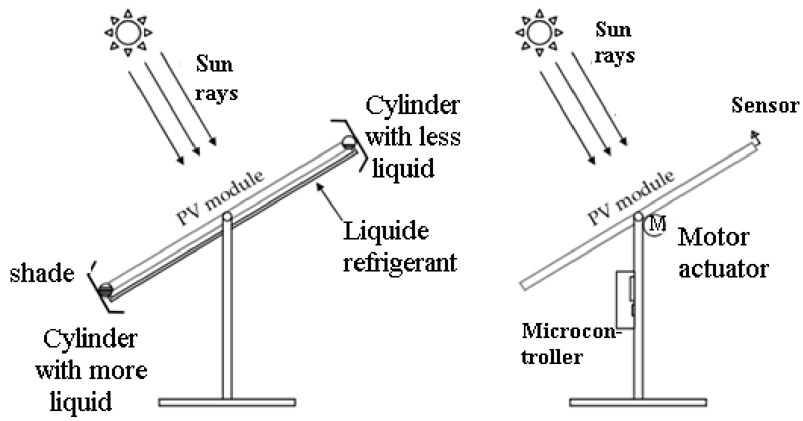


**Figure 3.1. (a) passive tracking system and (b) active tracking system (Sebastijan Seme, 2020).**

### 3.6. Modes of operation

Here, we will define three positions of the solar panel based on the movement of the motor. The solar panel stops in three different positions based on the angle given by the end part of the motor (figure 3.2).

Position 1　　Position 2　　Position 3

**Figure 3.2. Positions of each mode**

The amount of energy obtained in each of these positions has been measured. The motor's arm moves at a 90-degree angle. When the arm is at 0 degrees, the panel is in position 1, at 45 degrees the panel is in the neutral position 2, and when the arm is at a 90-degree angle, the solar panel is in position 3.

### 3.7. Calculation of angular and linear speed

For angular speed by manufacturers datasheet, we know these servo motors spends 2ms for rotation of each degree. Hence, we can calculate angular speed of the motor as below

(Formula 1):

$$\omega = \frac{\theta}{t} = \frac{1^0}{2ms} = 500\frac{degree}{s} \quad (1)$$

As we see 500 degree/s angular speed value is so fast for arm to move. Thus, we have used slow movement system for motor. We set additional 70ms interval for each degree rotation. It means servo motor will spend 72ms for each degree rotation. So calculation of angular speed value for the motor is shown below (Formula 2):

$$\omega = \frac{\theta}{t} = \frac{1^0}{72ms} = 0.014\frac{degree}{ms} = 14\frac{degree}{s} \quad (2)$$

As we know length of the shoulder frame is r=24 cm we can calculate its linear speed as below (Formula 3):

$$\upsilon = \omega * r = 90 * 24 = 2.16\frac{m}{s} \quad (3)$$

#### 3.7.1. Calculation of all main parameters

In the calculation part we have 3 three main modes of operation. And we calculated each mode parameters. Our project operates with 3 modes. Based on the experiments conducted, we have summarized the results and prepared them in a table format. As clearly seen from the table, measurements have been conducted at different times and under various weather conditions for each mode. During these measurements, Voltage, Current, total power, power loss and efficiency were calculated.

It should be noted that all the calculations shown below and the results obtained based on them were gathered on March 19th. The temperature of the air was 5°C at 9:00 AM, 6°C at 1:00 PM, and 9°C at 3:00 PM.

**Mode 1: Battery charging by solar panel**

**1.** V=20.4 V, I=224mA at 09:00

$$P = \mathrm{V} \times \mathrm{I} = 20.4 \times 224 = 4.57\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 20.4 \times 224 = 4.57\mathrm{W}$$

$$P_{out} = V_{bat} \times \mathrm{I} = 4.2 \times 224 = 0.94\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 4.57 - 0.94 = 3.63\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{0.94}{4.57} = 0.2$$

**2.** V=21.12 V, I=245mA at 13:00

$$P = \mathrm{V} \times \mathrm{I} = 21.12 \times 245 = 5.2\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 21.12 \times 245 = 5.2\mathrm{W}$$

$$P_{out} = V_{bat} \times \mathrm{I} = 4.2 \times 245 = 1\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 5.2 - 1 = 4.62\ \mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1}{5.2} = 0.19$$

**3.** V=22.5 V, I=267mA at 15:00

$$P = \mathrm{V} \times \mathrm{I} = 22.5 \times 267 = 6\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 22.5 \times 267 = 6\mathrm{W}$$

$$P_{out} = V_{bat} \times \mathrm{I} = 4.2 \times 267 = 1.12\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 6 - 1.12 = 4.88\ \mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.12}{6} = 0.18$$

**Mode 2: Phone charging by solar panel**

**1.** V=20.4 V, I=203mA at 09:00

$$P = \mathrm{V} \times \mathrm{I} = 20.4 \times 203 = 4.14\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 20.4 \times 203 = 4.14\mathrm{W}$$

$$P_{out} = V_{pho} \times \mathrm{I} = 5 \times 203 = 1\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 4.14 - 1 = 3.14 \mathrm{~W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1}{4.14} = 0.24$$

**2.** V=21.12 V, I=305mA at 13:00

$$P = \mathrm{V} \times \mathrm{I} = 21.12 \times 305 = 6.4\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 21.12 \times 305 = 6.4\mathrm{W}$$

$$P_{out} = V_{pho} \times \mathrm{I} = 5 \times 305 = 1.5 \mathrm{~W}$$

$$P_{loss} = P_{in} - P_{out} = 6.4 - 1.5 = 4.9\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.5}{6.4} = 0.23$$

**3.** V=22.5 V, I=172mA at 15:00

$$P = \mathrm{V} \times \mathrm{I} = 22.5 \times 172 = 3.87\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 22.5 \times 172 = 3.87\mathrm{W}$$

$$P_{out} = V_{pho} \times \mathrm{I} = 5 \times 172 = 0.86 \mathrm{~W}$$

$$P_{loss} = P_{in} - P_{out} = 3.87 - 0.86 = 3\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{0.86}{3.87} = 3$$

**Mode 3: Phone charging by battery**

**1.** V=5 V, I= 250.3mA

$$P = \mathrm{V} \times \mathrm{I} = 5 \times 250.3 = 1.25\mathrm{W}$$

**Table 1. The list of determined parameters for each mode at different time**

| Mode 1: Battery charging by solar panel | | | | |
|---|---|---|---|---|
| Hour | Voltage (V) | Current (mA) | Power (W) | Efficiency (η) |
| 09:00 | 20.4 | 224 | 4.57 | 3.86 |
| 13:00 | 21.12 | 245 | 5.2 | 4.2 |
| 15:00 | 22.5 | 267 | 6 | 4.36 |
| Mode 2: Phone charging by solar panel | | | | |
| Hour | Voltage (V) | Current (mA) | Power (W) | Efficiency (η) |
| 09:00 | 20.4 | 203 | 4.14 | 3.14 |
| 13:00 | 21.12 | 305 | 6.4 | 3.2 |
| 15:00 | 22.5 | 172 | 3.87 | 3.49 |
| Mode 3: Phone charging by battery | | | | |
| Hour | Voltage (V) | Current (mA) | Power (W) | Efficiency (η) |
| 09:00 – 15:00 | 5 | 250.3 | 1.25 | - |

After conducting these experiments, we decided to carry out another check in May, under clearer weather conditions and warmer temperatures. Based on the initial data obtained, we recalculated the main parameters. Thus, the calculations and results from the experiments conducted on May 3rd are presented in the table 2 below.

**Mode 1: Battery charging by solar panel**

**1.** V=21.9 V, I=256mA at 09:00

$$P = \mathrm{V} \times \mathrm{I} = 21.9 \times 256 = 5.6\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 21.9 \times 256 = 5.6\mathrm{W}$$

$$P_{out} = V_{bat} \times \mathrm{I} = 4.2 \times 256 = 1.07\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 5.6 - 1.07 = 4.53\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.07}{5.6} = 0.19$$

**2.** V=22.4 V, I=285mA at 13:00

$$P = \mathrm{V} \times \mathrm{I} = 22.4 \times 285 = 6.3\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 22.4 \times 285 = 6.3\mathrm{W}$$

$$P_{out} = V_{bat} \times \mathrm{I} = 4.2 \times 285 = 1.2\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 6.3 - 1.2 = 5.1\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.2}{6.3} = 0.19$$

**3.** V=22.8 V, I=306mA at 15:00

$$P = \mathrm{V} \times \mathrm{I} = 22.8 \times 306 = 6.9\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 22.8 \times 306 = 6.9\mathrm{W}$$

$$P_{out} = V_{bat} \times \mathrm{I} = 4.2 \times 306 = 1.28\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 6.9 - 1.28 = 5.62\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.28}{6.9} = 0.18$$

**Mode 2: Phone charging by solar panel**

**1.** V=20.4 V, I=219mA at 09:00

$$P = \mathrm{V} \times \mathrm{I} = 20.4 \times 219 = 4.46\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 20.4 \times 219 = 4.46\mathrm{W}$$

$$P_{out} = V_{pho} \times \mathrm{I} = 5 \times 219 = 1.09\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 4.14 - 1 = 3.14\ \mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.09}{4.46} = 0.24$$

**2.** V=20.5 V, I=230mA at 13:00

$$P = \mathrm{V} \times \mathrm{I} = 20.5 \times 230 = 4.7\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 20.5 \times 230 = 4.7\mathrm{W}$$

$$P_{out} = V_{pho} \times \mathrm{I} = 5 \times 230 = 1.15\ \mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 4.7 - 1.15 = 3.55\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.15}{4.7} = 0.24$$

**3.** V=20.9 V, I=244.2mA at 15:00

$$P = \mathrm{V} \times \mathrm{I} = 20.9 \times 244.2 = 5.1\mathrm{W}$$

$$P_{in} = \mathrm{V} \times \mathrm{I} = 20.9 \times 244.2 = 5.1\mathrm{W}$$

$$P_{out} = V_{pho} \times \mathrm{I} = 5 \times 244.2 = 1.22\mathrm{W}$$

$$P_{loss} = P_{in} - P_{out} = 5.1 - 1.22 = 3.88\mathrm{W}$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{1.22}{5.1} = 0.23$$

**Mode 3: Phone charging by battery**

**1.** V=5 V, I= 250.3mA

$$P = \mathrm{V} \times \mathrm{I} = 5 \times 270.3 = 1.35\mathrm{W}$$

**Table 2. The list of determined parameters for each mode at different time in May.**

| Mode 1: Battery charging by solar panel | | | | |
|---|---|---|---|---|
| Hour | Voltage (V) | Current (mA) | Power (W) | Efficiency (η) |
| 09:00 | 21.9 | 256 | 5.6 | 4.23 |
| 13:00 | 22.4 | 285 | 6.3 | 4.25 |
| 15:00 | 22.8 | 306 | 6.9 | 4.39 |
| Mode 2: Phone charging by solar panel | | | | |
| Hour | Voltage (V) | Current (mA) | Power (W) | Efficiency (η) |
| 09:00 | 20.4 | 219 | 4.46 | 2.88 |
| 13:00 | 20.5 | 230 | 4.7 | 3.08 |
| 15:00 | 20.9 | 244.2 | 5.1 | 3.18 |
| Mode 3: Phone charging by battery | | | | |
| Hour | Voltage (V) | Current (mA) | Power (W) | Efficiency (η) |
| 09:00 – 15:00 | 5 | 270.3 | 1.35 | - |

One of the differences in our work is that, unlike classic Solar Converting systems, there is no indirect conversion. A Buck Boost converter has been used.

Generally, the project we prepared operates in 3 modes. As a process, in the first mode, the energy we receive charges the battery. In the second mode, energy is directly transferred to the phone. In the third mode, the battery charges the phone.

During the experiments conducted outdoors, the operational state of the structure is shown in Figure 3.3 below.

**Figure 3.3. The operational state of the structure**

### 3.7.2. Matlab Simulation of parameters

PWM signal view that comes into servo motor is taken by UTD2152 osilloscope. PWM signal at the 3 various position for servo motor is shown in figure 3.4, 3.5, 3.6. There are three main operating modes for our automated tracker. Based on these modes, we attempted to tabulate and automatically generate graphs through Matlab for the consolidated results of the conducted tests and experiments. We had seen similar works that also presented parameters via Matlab. Therefore, we arranged all results obtained through Matlab Simulation according to the angle position in the appropriate sequence and incorporated them into our work. Below, all the results obtained are displayed.Additionally, the signals transmitted to the motor at different angles of movement were measured using MATLAB, and their graphs are shown in Figure 3.7 and 3.8.

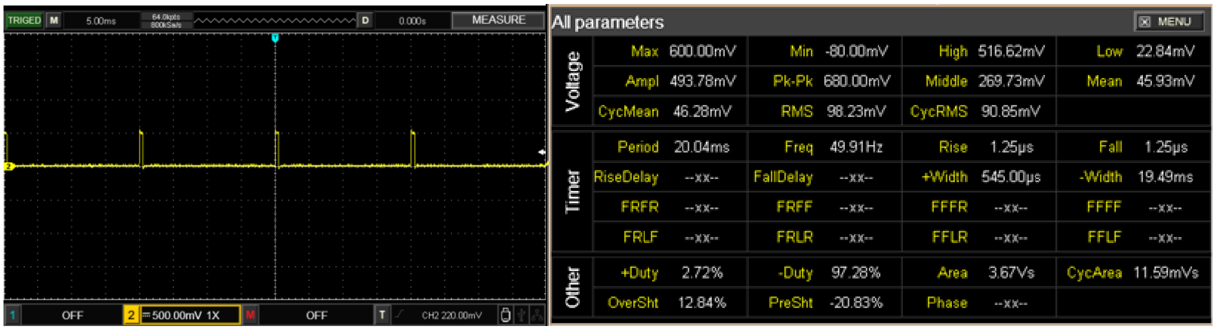


**Figure 3.4. PWM signal view when the angle of the motor is at the 0-degree position.**

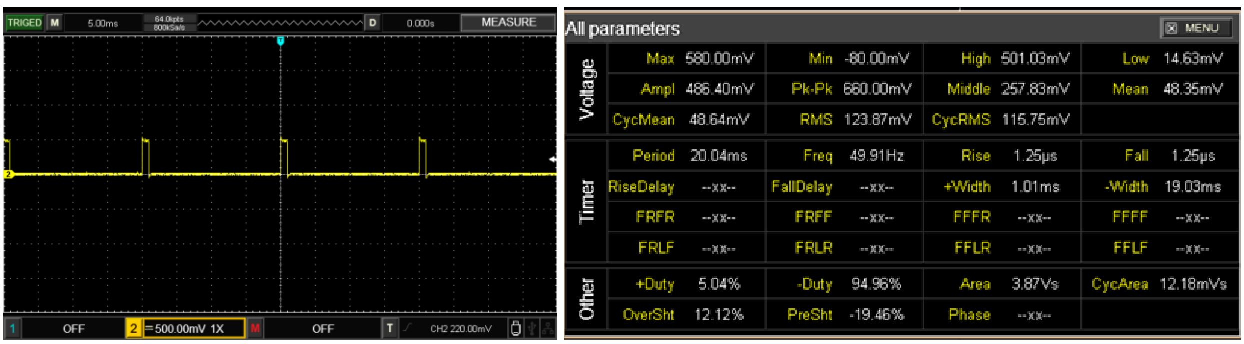


**Figure 3.5. PWM signal view when the angle of the motor is at the 45-degree position.**

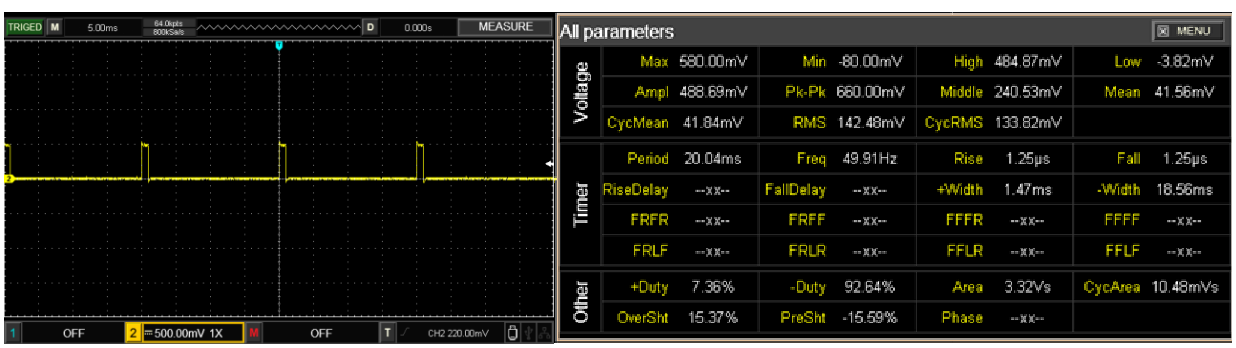


**Figure 3.6. PWM signal view when the angle of the motor is at the 90-degree position.**

Mode 1: Battery charging by solar panel

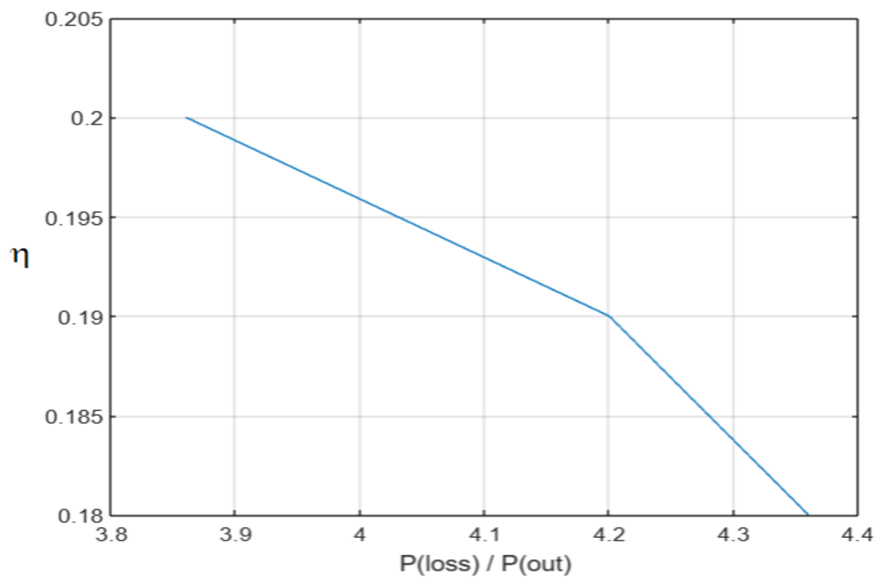


**Fig 3.7. Relationship between efficiency (η) and $P_{loss}/P_{out}$**

Mode 2: Phone charging by solar panel

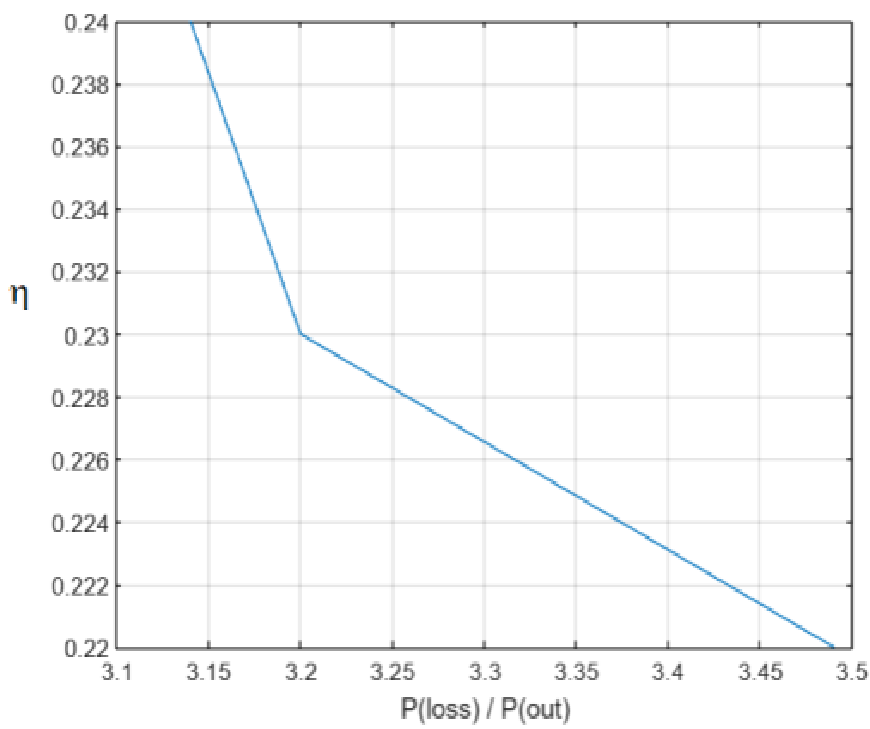


**Fig 3.8. Relationship between efficiency (η) and $P_{loss}/P_{out}$**

## CONCLUSION

As a result, the purpose of our work was to create a tracker for solar panels that could move automatically. By using inexpensive materials, we constructed a design that can power itself with energy. The structure we created can detect the direction of the sun at any time of the day and is used both for aligning the panel accordingly and for charging a phone. Experiments have been conducted both in laboratory and outdoor conditions. The functionality of the structure has been confirmed, and measurements have been carried out accordingly. As you generally know, many projects similar to our work have been prepared before. Although our project is based on similar works, we obtained the results by testing them through real-life experience. The main advantage we can highlight is that it can be prepared at a very low cost. The mechanical part is made at home from just iron and wood materials, which creates a significant difference compared to the costs incurred for similar works. Additionally, being manually portable and small in size is of great importance. Naturally, if a larger panel had been used, more energy could have been obtained. However, for a construction that can move automatically for charging a phone, small dimensions are more beneficial both financially and functionally. Moreover, initially, the construction's operation was checked in a laboratory setting. After confirming the functionality of the features, experiments were conducted outdoors both in March and May under various weather conditions and at different times of the day. Here, the effects of temperature, as well as whether the sky was cloudy or clear, on the parameters are shown in the table placed in the calculation section. The calculations in the section are based on the initial parameters, which change according to the brightness of the sun and the temperature of the air, affecting the results. Generally, we implemented this project through the main 4 setups that were considered and planned before starting the work:

1. Preparation of the construction needed for mechanical movement.
2. Placement of other main parts on the construction.
3. Programming and testing functionality based on experiments.
4. Calculating results under different weather conditions according to the initial data.

As a result, we can say that the single-axis type solar tracker we planned in advance has been created and its automated movement has been ensured. Additionally, its functionality has been tested in both laboratory and outdoor conditions. According to the results obtained in different months and under different weather conditions, we can state that in colder and cloudier weather, the maximum voltage was 22.5 V, and the maximum efficiency was 4.36. In May, which is warmer and clearer, the maximum voltage was 22.8 V, and the maximum efficiency was 4.39.

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