Design and Analysis of Solar Photovoltaic System to Charge Three Wheeler Mahindra Treo Electric Vehicle

By

Guta Dibaba Begi

A Thesis Submitted to

Department of Mechanical Engineering

School of Mechanical, Chemical, and Materials Engineering

Presented on Partial Fulfillment of The Requirement for Masters of Science In Automotive Engineering

Office Of Graduate Studies

Adama Science And Technology University

June 2023

Adama, Ethiopia

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DECLARATION

I **Guta Dibaba** declar that this thesis titled “Design and Analysis of Solar Photovoltaic System to Charge Three Wheeler Mahindra Treo Electric Vehicle” and the work presented in it and Submitted to Adama science and technology University, Department of Mechanical engineering is my own work and has been generated by me as the result of my original study. It was not submitted else where for the award of any degree or any other publication

Name of student	Signature	Date
<u>Guta Dibaba Begi</u>	______________	______________

RECOMMENDATION

I, the advisor of this thesis , herebycertify that I have read the revised version of the thesis entitled “Design And Analysis Of Solar Photovoltaic System To Charge Three Wheeler Mahindra Treo Electric Vehicle” prepared under my guidance Guta Dibaba Begi submitted in partial fulfillment of the requirements for masters of science in automotive engineering Therefore, I recommend the submission of revised version of the thesis to the department following the applicable procedures.

Advisor	Signature	Date
Dr. Ramesh Babu Nallamothu	_______________	_____________

APPROVAL PAGE

I, the advisor of the thesis "Design and Analysis of Solar Photovoltaic System to Charge Three Wheeler Mahindra Treo Electric Vehicle" developed by Guta Dibaba Begi, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Guta Dibaba Begi have read and evaluated the thesis entitled "Design and Analysis of Solar Photovoltaic System to Charge Three Wheeler Mahindra Treo Electric Vehicle" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of a Master of Science in Automotive Engineering.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

W	*Watt*
h	*Hour*
m	*Meter*
V	*Voltage*
I	*Current*
KW	*Kilowatt*
KWh	*Kilowatt-hour*
P	*Power*
L	*Length*
A	*Area*
^{o}C	*Degree centigrade*
N	*Number of the day in a year*
α	*Angle between Sun and horizon.*
η_{pv}	*Solar cell efficiency*
ηe	*the maximum power point tracer coefficient*

ABBREVIATION

PPV	*Photovoltaic power*
PV	*Photovoltaic*
MPPT	*Maximum power point tracking*
DC	*Direct current*
AC	*Alternating current*
STC	*Standard test condition*
PSH	*peak sun hours*
NP	*Number of panel required*
A_E	*Effective area needed on the top roof of the car*
A_p	*Area of single panel*
Wp	*Requirement power*

GREEK SYMBOLS

η	*Efficiency*
δ	*Declination angle*
θ	*Incident angle of solar radiation*
β	*Tilt angle of Solar panel*
θz	*zenith angle*
ω	*Hour angle*
ϕ	*latitude*
τ_b	*The atmospheric transmittance for beam radiation*
τ_d	*The atmospheric transmittance for diffuse radiation*
I_d	*diffuse radiation*
I_b	*beam radiation*

SUBSCRIPTS

MPP - *maximum power point*

oc - *open circuit*

sc - *short circuit*

d - *diffuce*

b - *beam*

E - *effective*

ABSTRACT

Security of the energy supply and global warming have recently posed challenges to all nations in terms of environmental damage and the global economy. One of the main contributors to human-caused greenhouse gas emissions and fossil fuel usage is transportation. Due to CO_2 emissions, air pollution from automobiles contribute to concerns including adverse effects on human health and worldwide environmental challenges like climate change. Therefore, the idea of future transportation should be focused on the usage of electric vehicles that use alternative renewable energy sources and emit no emissions or pollutants. Since the globe currently agrees to use solar energy widely in many energy applications due to its abundance, solar energy is favored for an electric vehicle. The goal of this research was to develop a rooftop solar photovoltaic system that could power a "Mahindra Treo Electric Vehicle". Data gathered from NASA, PVGIS, and the Ethiopian Metrology Agency. The sun produces an average daily solar radiation of 5.57 kWh/m^2/day. This study used a variety of data sources, including the Ethiopian metrology agency, NASA, PVGIS, and calculation. solar photovoltaic module-equipped roof. According to the findings, a 4 m^2 solar roof may generate at least 0.6 kW and up to 1.1 kW of electricity each day, resulting in a significant annual savings of grid energy. The analysis's findings indicated that an off-grid solar PV array with a surface area of 4 m^2, a battery with a capacity of 80 Ah at 12 V, a controller with a capacity of 80 A at 120 V, and an inverter with a capacity of 3 kW were needed to meet the need for charging an electric vehicle. The thesis attempted to increase the system's stability and efficiency in order to provide greener answers to the world's energy demands.

KEYWORDS: *Renewable Energy, Electric Vehicle, Solar Pv, and Zero-Emission***.**

CHAPTER ONE

INTRODUCTION

1.1. Background

Security of the energy supply and global warming have recently posed challenges to all nations in terms of environmental polution and the global economy. The population of the world has been growing at an accelerating rate since the turn of the 20th century. The need for energy exists across the world, and it is sourced from various places. The majority of energy sources, including fossil fuel, are pricy, inefficient, and challenging to transport. The majority of energy sources, such as wind energy, solar energy, biogas, etc., are environmentally beneficial. In order to combat the problems of energy security and climate change and to promote local economic growth, renewable energy solutions are being researched. Due to its proximity to the equator and high average daily solar radiation of 5.57 kWh/m^2/day, Ethiopia has a large potential for solar energy. (Mengistu, M. G., Simane, B., Eshete, G., & Workneh, T. S.) (Mekonnen, S. A. July, 2007).

One of the main contributors to human-caused greenhouse gas emissions and fossil fuel usage is transportation. Due to CO_2 emissions, air pollution from automobiles contribute to concerns including adverse effects on human health and worldwide environmental challenges like climate change. Therefore, the idea of future transportation should be focused on the usage of electric vehicles that use alternative renewable energy sources and emit no emissions or pollutants. Renewable energy sources, such as solar, wind, tidal, hydropower, and biomass, are some of the alternatives. Solar energy is the preferable source of energy for an electric car because it is widely used in various energy applications and because it is abundant. Solar-generated direct current electricity powers solar photovoltaic (PV) systems. Santanu Kumar Parida and D.M. 2018).

PV is a cost-effective option when compared to diesel fuel power generation in particular, especially in developing countries where diesel and energy prices are frequently high. PV systems require planning to provide the load and have a significant initial investment cost. In order to match the right sun-based system components with the user's power requirements, the design did this. (2010) (W. Wode-Ghiorgis).

The photovoltaic system serves a variety of purposes, particularly in the modern day.

- Solar home energy solutions for many types of homes.
- For the operation of telecommunications infrastructures.
- For the function of rural electrification.
- Call boxes for emergency situations on highways and college campuses.
- Network-related electricity supply and road lighting.

Solar-generated direct current electricity powers solar photovoltaic systems. It contains several primary parts, including a PV module, charge controller, battery bank, inverter, etc., that work together to convert solar energy into electrical energy (Luis Castafier and Tom Markvart, 2016).

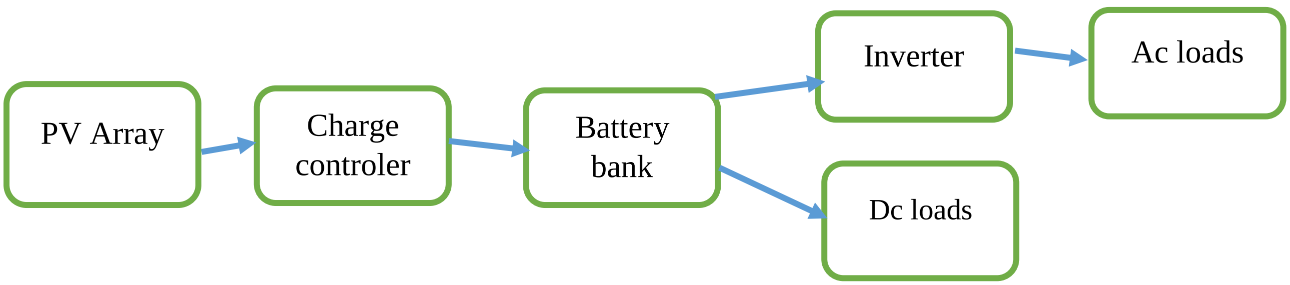


Figure 1.1. Rooftop PV System mode (Tom Markvart and Luis Castafier, 2016.)

Using semiconductor materials, photovoltaic (PV) systems convert solar energy into electrical current. Cleaner, dependable, and compatible power without the need for additional sources is only one benefit of PV systems. PV may also be used in a wide variety of applications. (2003) (M.A. Green).

Grid-tied, hybrid, and off-grid solar PV systems are the three basic varieties. (https://www.deegesolar.co.uk).

Solar-powered on-grid system: A solar PV system that is directly connected to the National Grid is referred to as being on-grid or grid-tied. A solar or micro inverter connects an on-grid solar system directly to the National Grid without the need for a battery storage device.

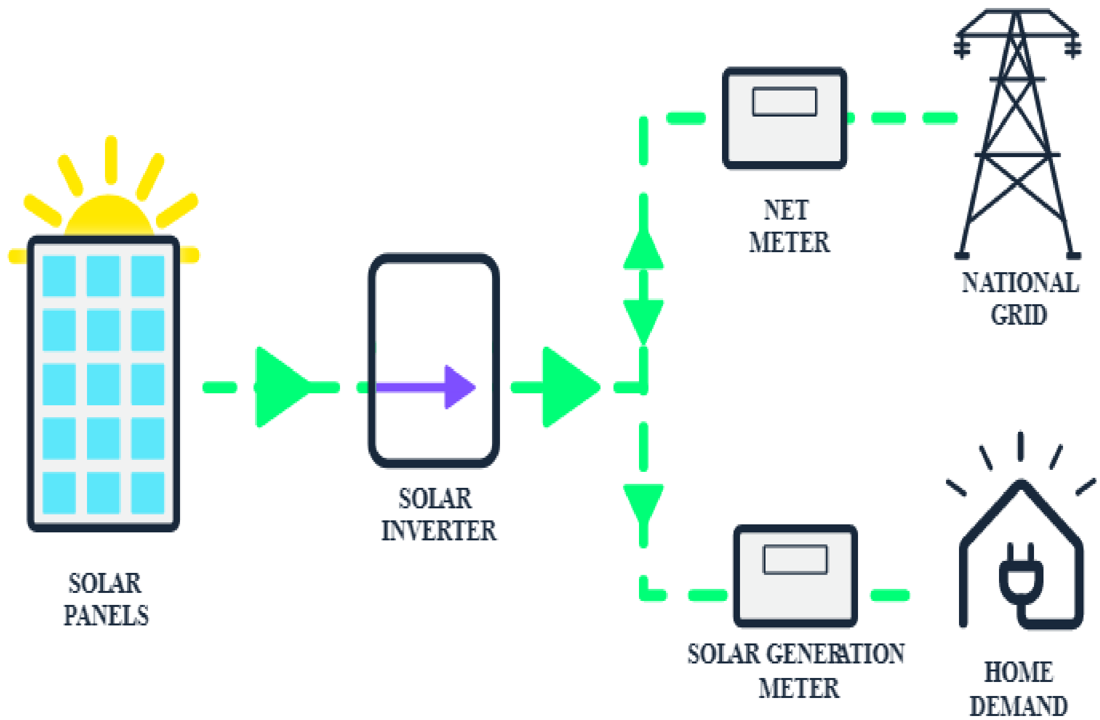


Figure 1.2. On-Grid Solar System (https://www.deegesolar.co.uk).

Hybrid Solar System: Hybrid Solar systems combine solar panel and battery technologies to produce a green energy solution that offers a source of energy as a backup. The National Grid is still connected to a hybrid PV system, but any solar energy generated is first stored in a house battery system before being sent to the grid.

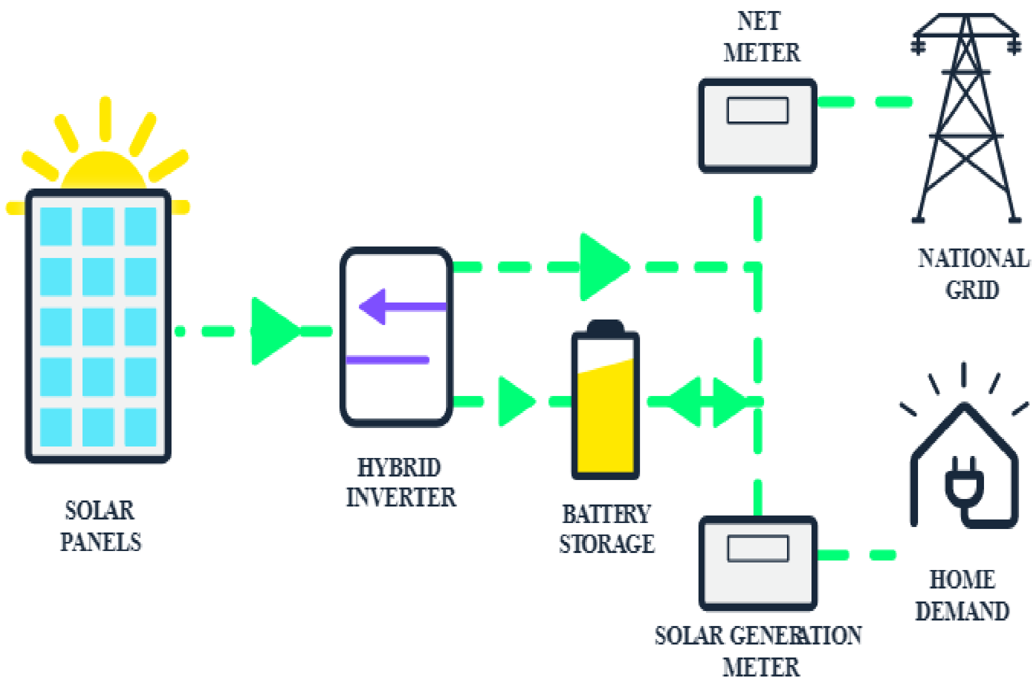


Figure 1.3. Hybrid Solar System (https://www.deegesolar.co.uk).

Off-Grid Solar System: In contrast to an on-grid system, an off-grid system is completely independent of the power grid. Making it appealing to people who find it difficult to connect to the grid or who want to remain energy independent. Off-grid systems frequently include backup batteries and other renewable energy sources to guarantee that your battery is fully charged all year long. Even the most isolated regions can have electricity thanks to off-grid solar installations. You may become energy independent with an off-grid solar system, ensuring a constant source of power wherever you choose to dwell. In order to charge EVs for this thesis, rooftop solar and off-grid solar systems are used.

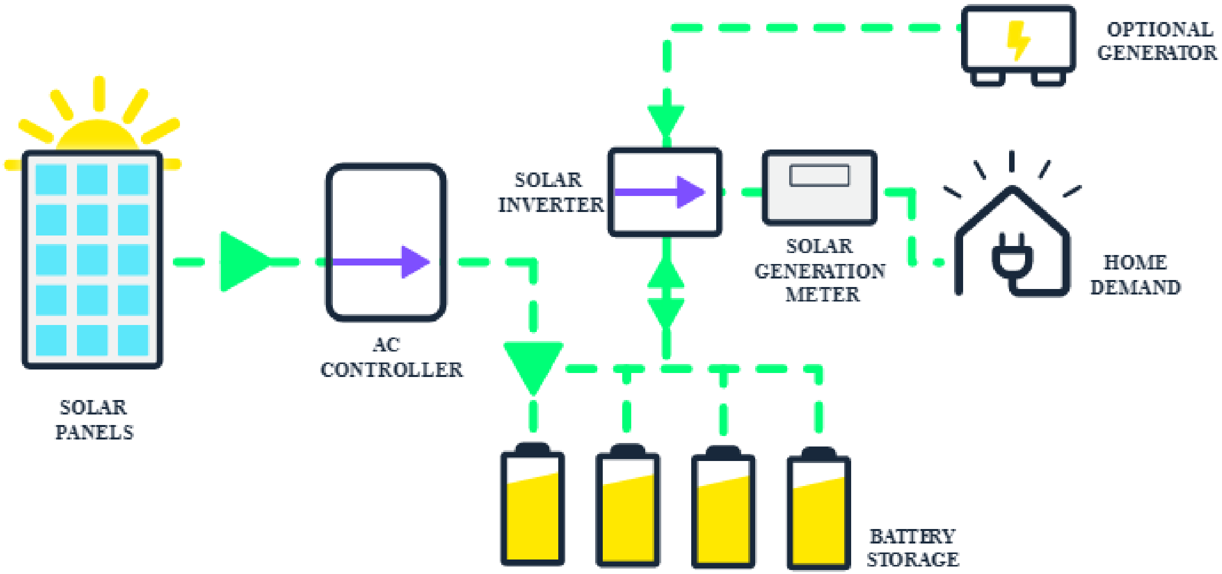


Figure 1.4. Off-Grid Solar System (https://www.deegesolar.co.uk)

1.2. System Architecture

The thin, semi-flexible structure of the solar panels makes it simple to attach or put them on top of the car. The sun's energy will be captured by the solar panels and transformed into useful electrical energy, which will then be stored in the batteries and used to power the engine as needed. A charge controller that is attached to the batteries will maintain their long life by preventing overcharging and overdischarging. The charge controller has a microcontroller that is programmed to detect voltages at the battery terminals and/or solar panel terminals and determine the appropriate charging current that the battery requires. The charge controller must have an additional input that can be used to charge the batteries from an AC power source (just by plugging it in), as this is a crucial component. Due to fog, clouds, or rain, the solar charging system will also have a plug-in charging system for use when there is not enough sunlight. The vehicle's total utility will rise thanks to this provision for an external plug-in system to charge the batteries using a regular AC power source (Keshav Parajuly, D. T. 2020).

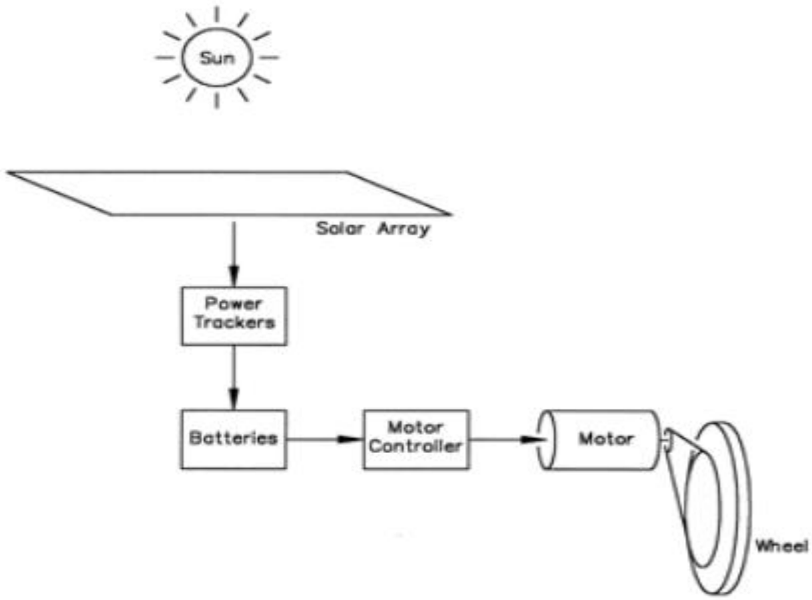


Figure 1.5.Working Principle (Source; Solarcarchallenge.org)

The battery that powers the vehicle's engines would then be fueled by the electricity thus produced. As a result, we would be able to drive an electrically powered vehicle that runs on "free" energy, emits no harmful gases, operates at all speeds at full capacity, and has very low operating costs.

1.3. Statement of the Problem

The lack of charging infrastructure, long charging times, and driving distances are some of the biggest problems with electric vehicles. There isn't a direct comparison between gas stations and charging stations at the moment. For many, charging at home is an option. An electric car's full recharge can take several hours. The only option we have when an electric vehicle runs out of power in an area without charging infrastructure is to load /take over/ it to another vehicle and take it to a charging station. To address this issue, it should be advised to drive at least a specific distance while the batteries are being charged with solar energy.

1.4. Objectives

1.4.1. General Objectives

Designing a solar power system to meet the electric demand needed to recharge the Mahindra Treo electric three-wheeler is the overall goal of this thesis.

1.4.2. Specific Objectives

The precise goals of this project are to:

- Gather and compare location data from various sources.
- Calculating, predicting, and assessing the amount of electricity needed to charge an electric battery.
- Creating a computer simulation of the solar energy system using the MATLAB and PVSYS programs.
- Calculate your energy needs as well as other design parameters and economic analysis.
- Pick the battery kinds that will be applied.

1.5. Significance of study

The most common issue regarding electric vehicles is the lack of charging stations and infrastructure. The Possible solution for this challenge is to charge the batteries additionally with solar energy. As more and more electric vehicles are appearing on the road; to recover and conserve the energy used by electric vehicles may appear. One way to achieve this is to use the renewable energy available from the sun. Thus, the result of this study can serve as a launching aim to work on harnessing solar energy with a solar panel mounted on top of the vehicle.

1.6. Scope

The scope of this project is not relatively new. There are plenty of similar projects which talked This project's scope is not particularly recent. Numerous more efforts that addressed the same topic are comparable. The first electric vehicle's invention has never been easy to attribute to a single person. In addition to an electric car charging station, this study concentrates on solar vehicle charging. This is due to the fact that there are no infrastructure or charging stations for electric vehicles in our nation, but PV solar panels can provide us with the energy needed to power them.

The Mahindra Treo, which has a modern lithium-ion, 48V battery with an installed capacity of 7.37 kWh, is the anticipated vehicle for this investigation. With a torque of 30 Nm and a direct drive gearbox, the charging period from 0 to 100% in normal circumstances is 3 to 4 hours. The study's findings can be applied to future adoption of electric cars by trucks and public transportation vehicles.

1.7. Limitation

This study was conducted on only three weller Mahindra Treo, but other vehicle need to be studied and analyzed. Due to limited time, and lack of data for other vehicles was not considered.There was also a shortage of literature review and data concerning on area.

1.8. Organization of study

Five chapters make up the thesis. The study's background, the issue statement, the objectives, significance, scope, and constraints are all introduced in the first chapter. The second chapters cover thorough literature evaluations on solar systems and electric vehicles. The third chapter discusses the foundational resources and procedures that were employed in this research. The raw data and numerical designs are also examined. The fourth chapter addresses numerous parallels with earlier efforts and how the results have been interpreted. The fifth chapter's final remarks include a summary of the investigation's major results, a suggestion, and potential directions for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

Global trends suggest that recent years have seen exponential growth in both the EV and solar industries. For instance, the USA has about 500,000 solar rooftops and about 250,000 electric vehicles, and both businesses are still expanding enormously. Government regulators and auto manufacturers are looking into the viability of solar energy-based electric vehicle charging systems, despite the obstacles that stand in the way of their widespread adoption.

since a result, the combination of solar energy and electric vehicles (EV) is mutually advantageous, since each one can create new opportunities for the other to flourish while simultaneously dramatically lowering its environmental impact. Additionally, the PV-EV synergy is anticipated to soon bring up new economic opportunities across the value chain while upholding the commitment to clean energy.

Green Tech Ethiopia is the second company to formally enter the Ethiopian market for electric cars after Marathon Motors, which has been producing them there for the past few months. It is stated that the vehicles Green Tech Ethiopia is importing have the ability to run on solar energy in addition to electricity. According to reports, the popularity of electric and solar cars has increased over the past several years. Massive corporations like Tesla have been actively seeking to monopolize the market for electric vehicles. https://newbusinessethiopia.com/.

Six versions of imported rechargeable solar and electric-powered cars are being introduced by Green Tech Ethiopia with the goal of promoting renewable energy in the nation. The business purchased the vehicles from Chinese automaker Dongfeng Motor Corporation and intends to open an assembly plant for automobiles soon.

Although some cars already have solar panels on their roofs, these only supply enough power to run a few of the car's appliances. For instance, some cars feature a tiny solar panel on the roof that charges the engine's starter motor. In other instances, a tiny solar panel might power a fan that keeps a car's interior cool on hot days. An complete car cannot be powered by these solar panels. They have only ever been used to power a few parts, though.

2.1.1. Charging Electric Car with a Solar Panel Rooftop

It's no longer a pipe dream to be able to charge an electric vehicle while driving with a solar panel roof. Around the world, a growing number of startups and significant automakers are concentrating on solar innovations in this field. Many automakers intend to develop solar-powered automobiles and associated advancements.

2.1.2. Developments in the Automotive Industry for Solar EV Roofs

The world is anticipating a future of sustainable mobility more than ever. Lightyear, a Dutch startup, is getting ready to introduce its solar-powered electric vehicle with a phenomenal 450-mile range. Lightyear has teamed with the research-focused business Royal DSM in an effort to increase the uptake of electric cars with integrated solar roofing. In order to remain competitive in the fight for sustainable green transportation, Hyundai Motor Company, another industry innovator, unveiled its first solar-powered electric vehicle (EV).

Leading Japanese manufacturer Toyota also collaborated with NEDO and Sharp Corporation in July 2019 to evaluate the effectiveness of solar-powered electric vehicles (EVs) on the road. The CEO, Elon Musk, has specifically stated that Tesla's all-electric Cyber truck would soon feature a solar rooftop that will be able to provide enough energy to travel about 15 miles per day on a single charge.

2.1.3. Preparing for the Revolution in Green EVs

In many nations, demand for solar-powered electric vehicles is rising quickly in response to the growing desire for a cleaner environment. The early response makes it abundantly evident that solar roof technology will be in great demand as the automobile industry continues to be revolutionized by electric vehicles. Solar roofs for electric cars may end up becoming a standard feature on all makes and models as the green EV movement gains steam.

An excellent method to lessen your carbon impact and perhaps save money is to get an electric or plug-in hybrid vehicle. We may fully charge our electric vehicle using the sun by building a home solar PV system and an EV charger that is solar-compatible. Electric vehicles and solar panels are a match made in eco-heaven.

2.2. Previous works

EVs are being developed quickly to keep up with changing customer demands and legislation aimed at reducing emissions and climate impact. It also makes an effort to fill the gap left by conventional automobiles as the supply of fossil fuels declines and the demand for continued private transportation increases. (2021, Jonathan Welling).

Electric vehicles (EVs) move by converting electrical energy to kinetic energy through an induction motor. They have a battery unit on board for energy storage. Different configurations of energy sources could provide the electricity required to charge EV batteries and power the EV's motor, which also helps to identify the type of EV. K. Parajuly and C. Fitzpatrick 2020.

The commercialization of sola technology will enable it to displace other non-renewable energy sources, such as fuel. Applications for solar technology include solar heaters, solar chargers, solar recycling compactors, and many more. Additionally, as solar technology can produce electricity instead of using other resources' air emissions, it can protect the environment. According to (Tabassum, M., Bin, S., Kashem, A., Chowdhury, M. E. H., & Khandakar, A. 2020).

Electric vehicles fueled by solar energy are safe since they lack hot exhaust systems or flammable fuel. They are odorless, smokeless, noiseless, zero-emission automobiles. They are easier to maintain, have fewer or no moving parts, are more dependable, and can be efficiently charged almost anywhere. Anuraj P., Mohan H. M., Nair A. M., Chandran A. B. *2019).*

Only solar-powered vehicles, which do not use hybrid technology, can be built with a highly efficient solar cell, such as concentrated solar PV, amorphous silicon hydrogen (a-Si: H) cells, multi-junction solar cells, etc., which are predicted to have an efficiency of more than 30%.(2018) by M. Srivalli, Debashish Mishra, and Santanu Kumar Parida.

By 2030, IRENA predicts that 160 million EVs will be required globally to create the circumstances necessary for them to significantly improve electric power networks and variable renewable generation. (IRENA, 2017).

The use of solar energy, and specifically solar cars, would represent a remarkable development in technology. They would permit unrestricted accessibility and unfettered travel. They would permit unrestricted accessibility and unfettered travel. They would make travel free and less polluting.

Being able to run without consuming fossil fuels makes solar-powered vehicles a potential solution to the world's energy issue. (2015) (V. V. Prathibha Bharathi).

The planet's ability to support the growing human population is currently reaching its limitations. However, the demographic census predicted that within the next century, the current level of global population will surely increase by roughly 2-3 times. Natural resources like petroleum and coal are facing a challenging time keeping up with the rising demand. According to statistics, the transportation industry is dominated by the number of cars, all of which depend on gasoline. (2015 T.S. Portal).

When considering a solar-powered car, the solar panels serve as the primary energy source for the entire machine to run. The effectiveness of the solar panels that were employed for the solar vehicle must therefore be fully verified. Solar panels use light photons, which are the sun's radiated energy, to transform that energy into electrical energy. (2013 Samet Bakrc, Adem Alşkan, and H. S. Soyhan*)*.

2.2.1. Electric vehicle

The United States' first viable electric vehicle In 1890, Morrison Electric was constructed (on a wagon). William Morrison, a chemist with a passion for electricity, created Morrison Electric. He employed 24 of his self-improved storage batteries, providing a 4 HP motor with an electric output of 112 A and 58 V. These batteries required 10 hours to recharge and were heavy EVs that used induction motors to transform electrical energy into kinetic energy. Different combinations of energy sources could provide the power required to drive the EV's motor and charge its batteries. With the introduction of rechargeable batteries, EV use increased. The lithium-ion formula is currently used in the EV industry, and LIBs are anticipated to overtake other battery types technology. (Keshav Parajuly, Daniel Fernald, Ruediger Kuehr 2020).

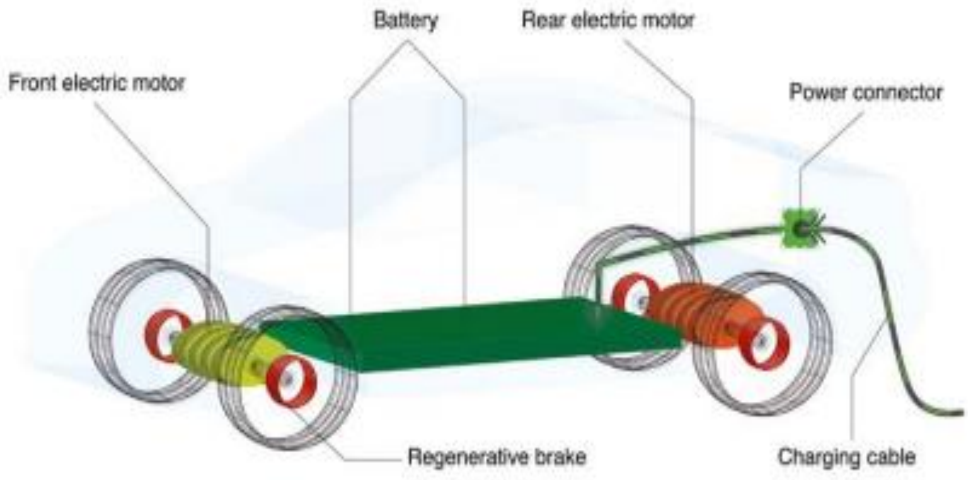


Figure 2.1. Schematic diagram of a battery-electric (Keshav Parajuly, Daniel Fernald, Ruediger Kuehr 2020)

2.2.2. Solar Vehicle

William G. Cobb created the first solar vehicle, known as the "Sun Mobile," in 1955. It was a modest 15-inch working model that was initially shown to the public on August 31st. A solar car is an electric vehicle that is powered by photovoltaic (PV) cells that absorb sunlight. The PV cells use solar energy, which is converted into electricity, to charge the batteries. However, E. W. Brown (1988) noted that although solar cars are currently not sold as viable options for daily transportation, they show promise in the future. Solar energy is produced from the sun's heat and light. (Mujahid Tabassum, S. B. 2020).

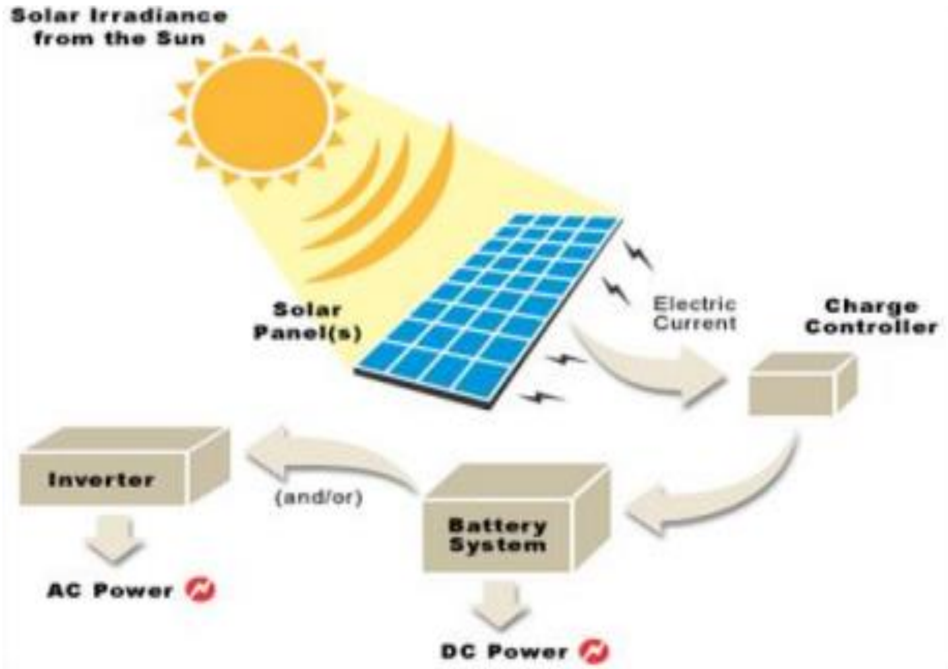


Figure 2.2. Basic Process of Solar Vehicle (Mujahid Tabassum, S. B. 2020).

2.3. Solar Energy

The sun's energy is referred to as solar energy. It is the radiant heat and light from the Sun that has been captured utilizing a variety of constantly developing technologies, including solar architecture, solar heating, solar photovoltaic, solar thermal power, and artificial photosynthesis. (2003 Goetz Berger A).

Nuclear fusion, which transforms hydrogen into helium, generates energy in the sun during the proton-proton chain (P-P) chain of processes. The fusion of around 99% of the Sun's mass only allows the core to produce a significant quantity of heat. Nuclear fusion is the process through which hydrogen nuclei in the core of the sun combine to produce helium nuclei and release energy. Every year, the sun converts about 120 million tons of stuff, primarily hydrogen, into helium.. (N. A. Basharat Jamil, Abid T. Siddiqui, 2018).

A lot of current research in the energy sector is focused on overcoming the wasteful elements of sun-powered control frameworks. Sun-oriented energy is a free, unlimited, and clean source of energy. The energy that the sun provides in a single hour is equivalent to what the earth needs in one year. Sun is like a radiator for a dark body. Its 5800 K surface temperature results in an energy density over the atmosphere of 1367 W/m2. The first factor should be researched and taken into account when designing PV systems.. (Reda, I., & Andreas, A. 2004).

2.3.1. Review of Solar Cell Physics in Semiconductor Devices

Similar to crystalline silicon-based solar cells, solid-state semiconductor p-n junction solar cells use the photovoltaic effect to turn sunlight into direct-current power. were primarily used to deploy electrical power for satellites in space. (N. A. Basharat Jamil, Abid T. Siddiqui, 2018).

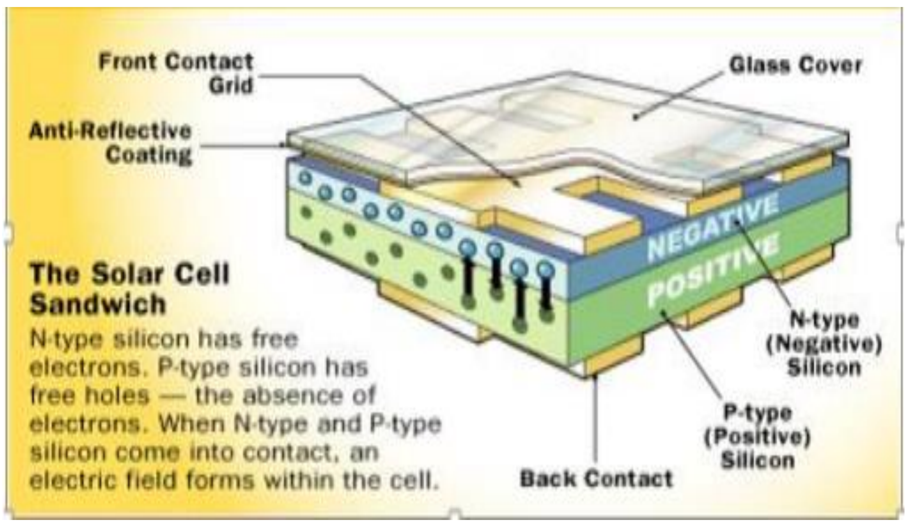


Figure 2.3. Solar cell structure (N. A. Basharat Jamil, Abid T. Siddiqui, 2018)

2.3.2. Photovoltaic module

An assembly of photovoltaic cells installed in a framework for installation is known as a PV module. Solar energy is harnessed by photovoltaic cells to produce direct current power. A system of PV Panels is known as an Array, and a collection of PV modules is referred to as a PV Panel. A solar system's arrays provide electricity to electrical appliances.

Rooftop electricity generation systems that can connect a number of modules are the most prevalent application of solar energy collection. As a result, the benefit of a PV system is added to an existing system when necessary because the modular design makes it easy to do so. (M.A. Green, 2003).

Advanced PV innovations are used to create a variety of PV modules. The following are listed: thin-film silicon (thin film-Si), copper indium diselenide (CIS), undefined silicon (a-Si), and cadmium telluride (CdTe). The first commercial technology is amorphous silicon, however it is not as efficient as the other three, which were introduced more gradually but received much more market acceptance. (R. C. ‘S.R.Wenham, M.A.Green, M.E.Watt, 2019).

The monocrystalline module is chosen for this study because this review aids in choosing the best advanced module for the design based on efficiency, tolerance (below or above-rated capacity that is positive tolerance), lifetime, and cell temperature.

2.3.3. Module performance

A photovoltaic module's power output is a function of its operating current and output voltage. An I-V Curve, which displays the current and voltage output characteristics of the module cell, is a performance curve that demonstrates the basic properties of a PV module.

I-V curves are shown for a cell temperature of 25 °C (77 °F) at 1000 watts per square meter of solar light. 'Peak Sun' is typically defined as 1000 watts per square meter. The I-V curve contains three crucial terms. (Tom Markvart and Luis Castafier, 2016).

1. A location where power is at its greatest is known as the Maximum Power location (MPP). The Vmp and Imp on the I-V curve can be seen in MPP. The MPP voltage (Vmp) and MPP current (Impp) are multiplied together to form the MPP power. A point at the operating point where maximum output power has been attained is known as the maximum power point. The figure below demonstrates this idea in vivid detail.
2. The difference in electrical potential between two terminals of a solar cell when it is not connected to a circuit is known as the open circuit voltage (Voc). There is no linked load. Between the terminals, there is zero electric current flow. If you prefer, you can think of the open-circuit voltage as the voltage that must be provided to a battery or solar cell in order to halt the current. The open-circuit voltage (VOC) displayed in figure

$$V(\text{at } I=0) = VOC.$$

3. The Short Circuit Current (Isc) is an electrical phenomena that enables a current to flow without resistance along an unanticipated path. As a result, the circuit experiences an excessive current flow,

$$I \text{ (at } V=0) = ISC,$$

which reaches its maximum current value. This maximum current value for an ideal cell represents the overall current generated by photon excitation in the module cell.

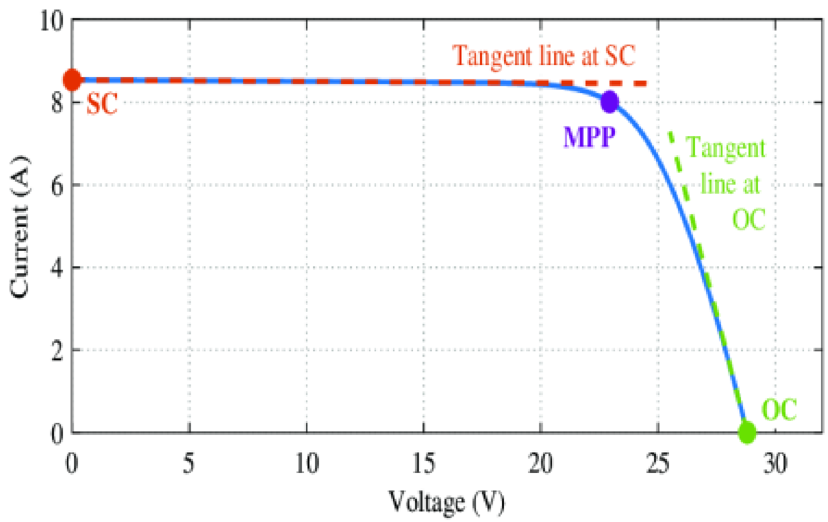


Figure 2.4. Sample Current Voltage graph of a Photovoltaic cell (D. King,2017)

2.3.4. The element that affects the performance of photovoltaic cells

1. Load Resistance—The voltage at which the PV will operate is determined by the load. The battery begins to charge when the module operates at a slightly higher voltage than the battery. The current versus voltage graph at which the PV panel may operate close to the maximum power point must meet the load resistance of the module in order to obtain high module efficiency. As a result, our load may operate at high voltage since, as we know, the EV charging module's internal resistance matches.
2. Sunlight Intensity - The output power of a photovoltaic array is directly correlated to the amount of solar radiation to which it is exposed. Ethiopia is compatible since it is located on the equator and has the higher intensity of sunlight that is required to provide superior module output power.
3. Cell Temperature - A crucial factor in determining how well a photovoltaic module performs is the cell temperature. The efficiency of the module reduces as cell temperature rises. Additionally, as cell temperature rises, the operational voltage also drops. Therefore, convective airflow is used to control this temperature.. (D. King,2017).

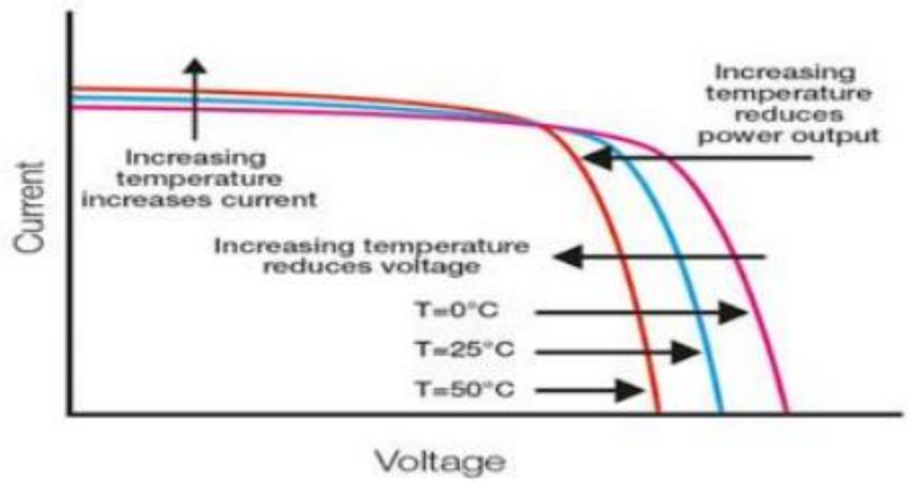


Figure 2.5. Effects of Temperature on module cell (Tom Markvart and Luis Castafier, 2016)

4. Shading: Cell shadowing has an impact on the solar modules as well. PV modules lose power when they are shaded. The output of the module can be reduced by as much as 80% by one completely shaded cell. As a result, analyzing the shadowing effect is crucial for this study because the vehicle is stationary and cannot be moved..

3.3.5. Photovoltaic cell

The cell is a crucial part of the solar module. Cell material develops an electric charge when sunlight strikes the module surface. The photovoltaic cell is constructed from a wafer, which is a semiconductor material such as silicon or germanium, however silicon is frequently used due to its widespread availability. (2003) (M.A. Green).

Due to its semiconductor qualities, silicon is employed in solar cells. Boron and phosphorus are doped into the material to change its electric characteristics by causing an imbalance in the molecular charge.

2.3.6. Photovvoltaic string

In our scenario, one module can only provide a modest amount of power to power the necessary load for EVs, so the module is connected using a series or parallel configuration known as an array. The PV module generated direct current electricity, thus most arrays utilize an inverter that is connected to the already-existing one to give alternating current to the load. In a photovoltaic module, the modules in a PV array are connected in a series arrangement to achieve the desired voltage, and in a parallel arrangement to achieve the desired current. Thus, the output power of solar systems is expressed in watts, kilowatts, or even megawatts.

2.3.7. PV module electrical properties

All PV modules are tested and distinguished from one another according to the manufacturer standard known as Standard Test Conditions (STC). This study takes into account one of the four key considerations when constructing a solar system in STC. The following is a discussion of certain parameters. (M.A. Green, 2003).

1. Radiant power received by a surface per unit area is known as irradiance (sunlight intensity). The watt per square meter (1,000 Watts/m2) serves as the SI unit of irradiance.
2. Air Mass, which expresses the direct optical path length through the Earth's atmosphere as a ratio to the vertical upward path length. The average air mass is 1.5.
3. Cell temperature is the actual temperature of the solar cell; it is different from ambient temperature, which is different from the temperature of the surrounding air. Cell temperature is 25 C^o at STC.
4. Efficiency (η) is calculated by dividing the PV cell's electrical power output (Pout) by its electrical power input (Pin). Pout is based on sun intensity since it runs at its highest level, allowing PMAX to produce the most power with the greatest efficiency

$$\eta = \frac{Pout}{Pin} \quad \eta\text{max} = \frac{Pmax}{Pin}$$

The pin, which is measured in suns (1000 W/m^2) at the solar cell secure area (m^2), is a multiplication of the incident light's irradiance. The efficiency can vary depending on a number of factors, including the surrounding environment's temperature, thus a straightforward test is not the only indicator of a module's performance. The current versus voltage characteristics are followed by the highest efficiency (max). (2003) (M.A. Green). Consequently, a monocrystalline module is chosen for this investigation.

Table 2.1. PV Module Characteristics for Standard Technologies

PV	η_r(%)	0(^{0})	*βp (% /o)*
Mono-cry	16.9	45	0.4
Mono-sl	13.0	45	0.4
Poly-si	11.0	45	0.4
Si	5.0	50	0.11
Cd Te	7.0	46	024
CIS	7.5	47	0.46

2.3.8. Photovoltaic system benefits and disadvantages

A. Benefits

Reliability- Solar power systems are preferable for loads that operate continuously in order to prevent power outages in the event that a continuous power source with minimal maintenance is required. So, one of the benefits of a photovoltaic system is its dependability.

Cost- Photovoltaic systems require just periodic inspection and minor critical maintenance, which makes them less expensive to operate than fuel- or grid-powered systems.

Universal Applications: Of all renewable energy technologies, solar photovoltaic systems are favoured because of their adaptability and capacity to produce electricity in almost every situation, even overcast situations.

Dual-use Solar panels can be used for both covering a structure's top and producing power at the same time. This feature is known as dual usage. The strength of a vehicle construction will be tested in this study using a solar panel that is mounted on the roof.

Environmentally safe: Because solar power systems don't produce any emissions or noise, they are safer energy sources. The best technology for both urban and rural applications is solar power systems.

B. Disadvantages

Cost: Solar photovoltaic systems are more expensive to install than other types of technology. Each solar assembly needs to be weighed against available alternatives and evaluated economically.

Variability of Available Solar Radiation - Since solar systems rely on solar energy, they will lose power if there is no sunshine.

Energy Storage: The photovoltaic system requires energy storage in order to store energy for use when there isn't enough sunlight to power the load. Thus, the system's price and size went up.incre

2.4. Batteries types and specifications

When solar energy is lost at night and electricity is required to replenish a loaded battery, an electric battery serves as an electrochemical cell that converts chemical energy into electricity. Because a module's output varies during the day and according to the season. It's crucial to have an energy storage system to deliver electricity that is essentially constant. Even when there is no sunlight or when maintenance is taking place, the energy comes from the isolated module. (Ponnusamy, M., Manimekalai, P., Harikumar, R., & Raghavan, S., 2013).

There are numerous sorts of batteries, each with a distinct design and set of performance characteristics. They have a variety of uses, the solar system being only one of them. Each battery has a unique set of qualities, and depending on how those features are built, each battery also has strengths and weaknesses. Lead-acid batteries are the most popular battery type used in photovoltaic systems because they are inexpensive and widely accessible in a variety of sizes and capacities. They also do the best when measured against others. Nickel-cadmium batteries are the second most popular form of battery nowadays, however most solar systems didn't employ them because of their high cost. There is no perfect battery for a solar system, so the job is to select a better battery type dependent on the load. The two categories of electrical storage are primary batteries and secondary batteries. Ponnusamy, Manimekalai, Harikumar, and Raghavan (2013).

Primary Batteries: Unlike secondary cells (rechargeable batteries), which are intended to be used just once before being discarded, primary batteries are only intended to be used once. Since the electrochemical reaction taking place in the cell is typically irreversible, the cell cannot be recharged. Chemical reactions in the battery consume the power-generating chemicals when a primary cell is used; if they are depleted, the battery stops producing electricity. Because primary batteries cannot be recharged, they are not used in PV systems.

Secondary Batteries: In a secondary battery, the process can be stopped by renewing the chemical reactants by pumping current into the cell via a battery charger. Small household equipment like flashlights and portable radios can be powered by primary cells, which are available in a variety of standard sizes. In PV systems, lead-acid batteries are frequently employed..

2.5. Charge Controllers

In most photovoltaic systems, charge controllers are used to protect the batteries from overcharging. Overcharging produces heat that heats the electrolyte inside the battery and causes the failure of the battery. When the battery is discharged it will cause permanent battery failure and it also causes damage to the load. Therefore, the charge controller is the basic equipment of the photovoltaic system. (Dakkak, M., & Hasan, A. 2012).

To safeguard battery charging and discharging, charge controllers have various features. The controller manages the battery charge state and turns off the module current once the battery has reached its state of charge and is fully charged. If the controller has a low voltage disconnect feature, it will disconnect all loads when the battery is completely empty and at its maximum depth of discharge before charging it. (Dakkak, M., & Hasan, A. 2012).

The controller measuring device examines the battery voltage to determine the status of charge. By monitoring battery temperature, it also enhances battery performance. The controller's voltage must match the nominal system voltage in order to extend battery life and performance, and it must be able to handle the maximum current generated by the PV module. (Dakkak, M., & Hasan, A. 2012).

2.5.1. Classification of controllers

There are several types of charge controllers, some of which are listed here.

Shunt controller: it diverts the charging current away from the battery in order to function. These controllers use a heat sink to dissipate extra current. Shunt controllers are utilized for systems with lesser currents up to 30 amps.

Series controllers halt charging current by creating an open circuit. The switching controller manages this controller current in order to switch the direct current.

When the store hits its maximum voltage level, single-stage controllers are employed to isolate the module.

Multistage controllers: This controller has a higher charge level efficiency than others. As the battery gets closer to being charged to capacity, it permits various charging currents. The battery must be in a fully discharged state in order to increase internal resistance. (James P. Dunlop, 2017).

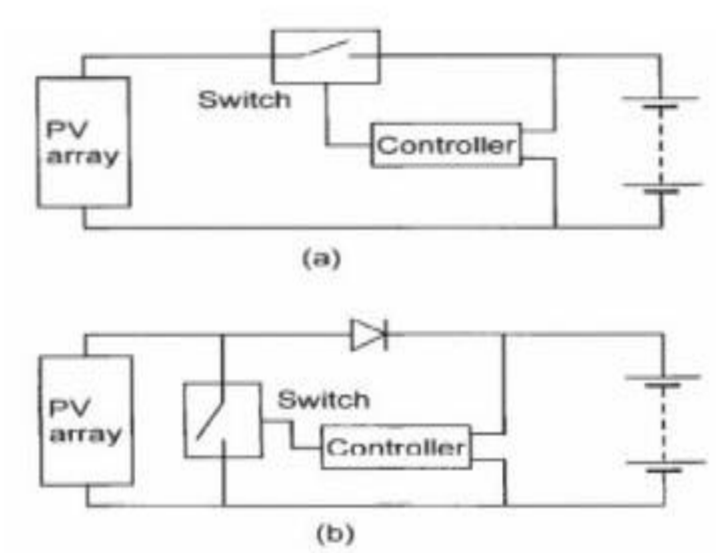


Figure 2.6. (a) Series Controller (b) Shunt Controller (Dakkak, M., & Hasan, A, 2012).

2.6. Inverters

Power conditioning units are another name for inverters. For a rooftop solar system, it is crucial to understand how direct current and alternating current were once converted. The system inverter makes a decision based on the direct current operating voltage.

All aspects of the AC load needs, including power, voltage variation, frequency, and waveform, should be taken into account while choosing the inverter. DC voltage, surge capacity, and allowable voltage variation must all be taken into account for the module output. It's crucial to consider a variety of factors while selecting the finest inverter for solar panels.

The selection of an appropriate inverter is crucial for ensuring the performance and dependability of a PV system. Inverters for rooftop solar systems work with 12, 24, 48, or 120 volts of DC input to produce 120 or 240 volts of AC at 50 Hertz. Waveform is a key factor that divides inverters into distinct groups, including Square Wave, Modified Sine Wave, and Sine Wave. An essential consideration when choosing the inverter input voltage is DC voltage.. (Rina, Z. S., 2017).

2.7. Review Summary

Natural resources are becoming scarce as a result of the manufacturers and traders' suppression of them. Additionally, these resources are potentially contributing to global warming in a negative way. In order to support the population, it is crucial to conduct fresh research on sustainable and renewable energy. A resource is available there in front of us. Solar energy is a reliable, affordable, and limitless source of energy.

The finest pollution-free technique is the solar car, which provides solutions to a variety of environmental issues. Solar cars do have several drawbacks, such as a limited speed range and a high starting cost. Additionally, the energy conversion rate, which is only 17%, is unsatisfactory. However, by undertaking additional study in this field, it will be possible to easily overcome these drawbacks. The issue with solar cells can be resolved by employing extremely efficient solar cells that provide roughly 30–35% efficiency. (Afgan, K. E. (2018), (Arsie I., C. M. 2006)' (Arulious Jora A., E. D. (2021).

Utilizing clean and renewable energy has become more and more important as global environmental issues become more serious. Vehicles are a necessary part of contemporary society's transportation system, but they are also one of the biggest producers of pollution. It is practically impossible to reduce the number of automobiles because of their status. The electric vehicle is one way to reduce emissions. Overall, compared to a car that runs on fossil fuels, an electric vehicle is more energy-efficient, environmentally friendly, and clean. (Keshav Parajuly, D. T. 2020).

Vehicle-integrated photovoltaics' objective is to make it possible for EVs to recharge continuously. Solar cars can continue driving, in contrast to conventional EVs that must stop sometimes to recharge batteries when on a long road trip. Photovoltaic cells integrated inside electric vehicles allow sunlight to be converted into electrical energy. By storing solar power in batteries, they can function normally at night or when there isn't direct sunlight. (Abinesh, D. 2016).

2.8. Research Gap

The assessed literary works are efforts to provide a reliable and perhaps workable method of the energy recovery strategy. However, some literary works have research on direct solar drive-by soles and electric charge. However, in this study, an electric car was designed with a solar panel on top so that the battery could be charged both while driving and when parking.

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1. Introduction

The procedures and the layout of the solar system used to recharge an electric car are described in this section. The best equipment is chosen and created by researching the necessary features. The methodologies employed in this thesis are based on many literature, as shown in Figure 3.1.

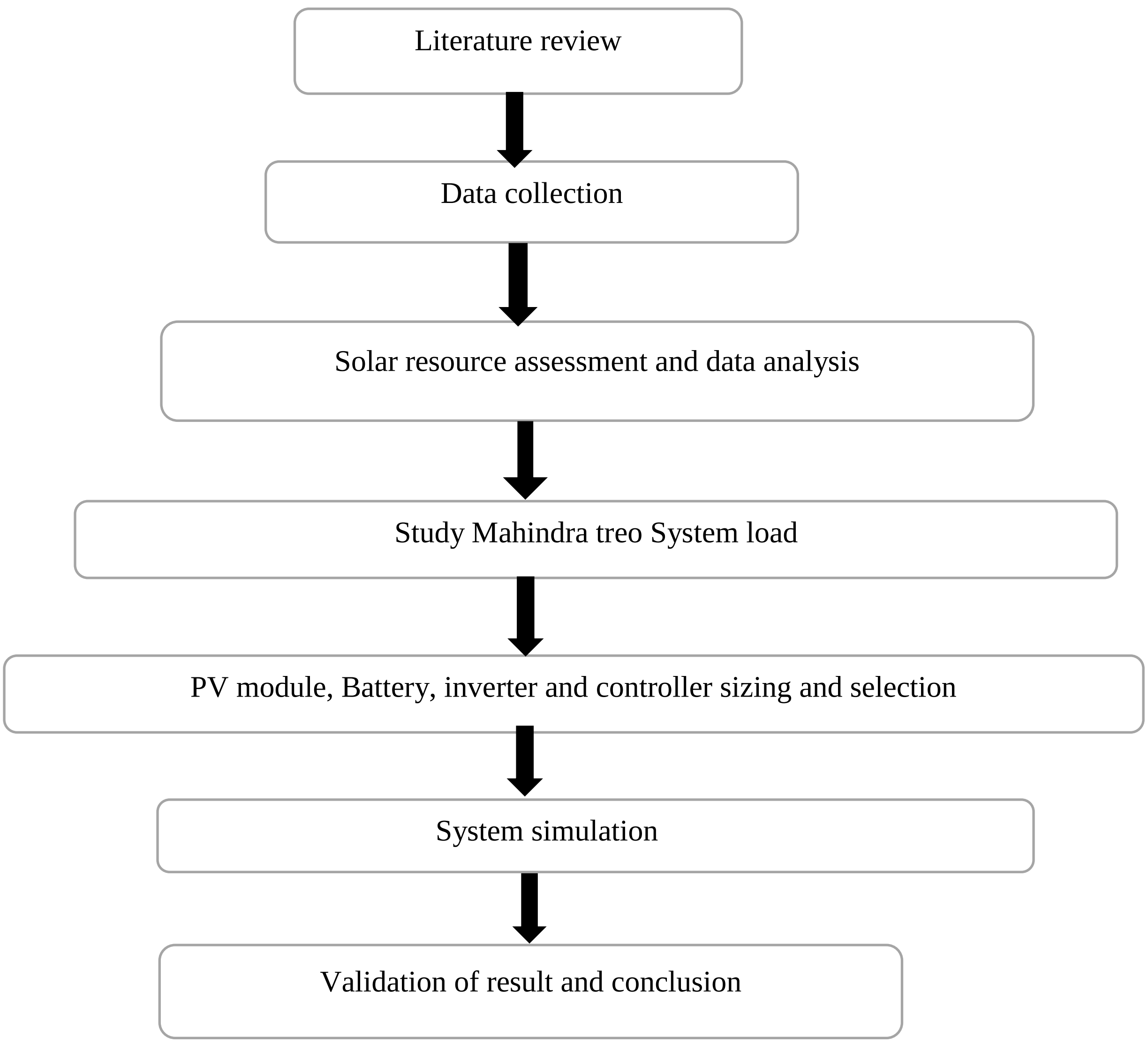


Figure 3.1. Methodology Flow Chart

Also explained are the design specifications and the metrology data. PV system sizing, Solar Radiation Data Collection and Analysis, PV Sizing by PVsyst Software, Size of the PV Modules, Size of the Solar Charge Controller, Size of the Solar Inverter, Size of the Batteries, Size of the Cables, and Layout Design of PV Module on the Roof of the Vehicle are done in addition to the Electric Vehicle Charging Load.

The new Mahindra Treo line of electric three-wheelers is groundbreaking. The Mahindra Treo offers greater savings, better ride quality, and best-in-class interior space thanks to innovative Lithium-ion technology. Mahindra Treo Ev is depicted in Table 3.1 for design consideration. *(Mahindra-Treo.pdf*.)

Table 3.1. Summary of Mahindra Treo Ev for design consideration

Variant	Mahindra Treo
Vehicle Category	L5M – Auto
Seating Capacity	D + 3 Seater
Vehicle roof type	Weather-resistant flex canopy
Vehicle Dimensions and Weight	
Dimensions – Length x Width x Height – mm	2769 x 1350 x 1750
Wheel Base – mm	2073
Ground Clearance – mm	142
Turning Radius – m	2.9
Vehicle curb weight – kg	377
Battery	
Battery Type, Voltage	Lithium-ion, 48V
Battery Capacity (Installed) – kWh	7.37
Charging Time 0-100% @Standard Conditions	3 h 50 min

3.1.1. Solar PV systems are used for EV charging.

Today's electric vehicle solar panel charging installations can be roughly divided into:

- Mobile solar charging systems include rooftop solar panels used to charge an electric vehicle's battery.
- Fixed solar-powered charging installation, a grid-based or off-grid ground-based installation that includes direct charging installations/devices accessible at EV charging stations.

The technology of mobile solar charging stations is discussed in this paper. The photovoltaic energy from solar panels is converted by a solar energy charging system from DC to AC electrical energy, which is then supplied to the batteries of EVs.

3.2. Selection of the PV system design

This chapter outlines the design of solar panels used to generate electricity for EV charging and then selects the best option based on the correct design process for PV systems.

Data gathering and analysis for solar radiation

Solar Resource Assessment of Selected Site: The sun radiation data for Adam is collected in this section from meteorology, PVGIS, and NASA satellite data by adding the necessary parameter as indicated on Figure 3.2.

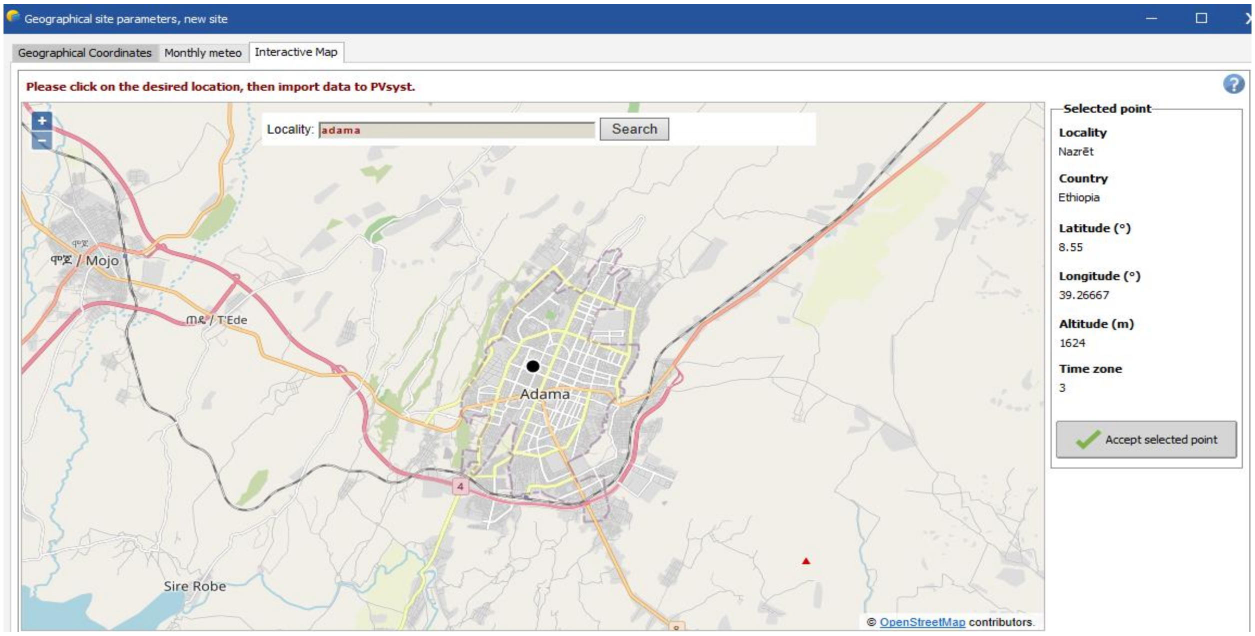


Figure 3.2. Adama PVGIS Solar radiation data

PVGIS estimates for the location parameter presented in Table 3.2 for solar electricity generation. Location: Ethiopia, Adama,

Latitude 8.55° N,

Longitude 39.2667° E,

Elevation/altitude/ 1624 meters above sea level

Solar radiation database used: PVGIS-TMY

Table 3.2.PVGIS estmates solar electricity generation

Month	Hd
January	6.16
February	7.36
March	7.65
April	6.75
May	7.04
Jun	6.37
July	5.56
August	5.96
September	6.53
October	6.66
November	6.70
December	6.61
Yearly average	6.61

H_d: Daily global irradiation that inters to the panel of the given system (kw/m^2 /day).

NASA Latitude 8 / Longitude 39 site data were used, and their elevation information is given as 1624 meters; NASA SSE satellite data; Table 3.3 displays the northern boundary 9, western boundary 40, eastern boundary 41, and southern boundary 9.

Table 3.3. Monthly solar radiation data from NASA

Month	Hd
January	6.08
February	6.57
March	6.52
April	6.31
May	.36
Jun	5.77
July	5.23
August	5.36
September	5.84
October	6.31
November	6.27
December	6.08
Yearly average	6.05

The average daily global irradiation in horizontal and tilt surface for global, diffuse, and beam radiation is derived using data on sunshine hour duration from the Adama metrology agency's 2013 to 2017 G.C. recording. Hourly global radiation and diffuse radiation data are also calculated using the tilt surface reach. The values for global and diffuse radiation are calculated for January 5, 2017, and July 5, 2017. Table 3.4 shows the five-year average for sunshine hours (Venkatachalam, Samuel, & Solomon, 2019).

Table 3.4 Five years average sunshine hour duration

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average (2013-2017)	8.73	9.25	9.0	8.4	8.23	7.96	6.8	6.86	7.32	8.9	9.38	9.35

Solar PV system sizing: The photovoltaic system is sized in the worst possible operating circumstances. The lowest monthly sun irradiation is used in this method to calculate the solar data for the solar PV system design. During its yearly cycle, the Sun's declination angle,, ranges from - 23.5° to + 23.5°. Calculating the declination angle is possible.

$$\sigma = 23.45 sin[\frac{360}{365}(284 + N)] \quad .....3.1$$

Since July has the lowest solar irradiation, as indicated in table 3.2, it is assumed that July 17, which is several days later and equals 212, will be used for PV sizing. Equation 3.1 then uses this number to compute the declination angle, which yields a result of 18.17^o.

Assume 1:15 PM the hour angle ω is calculated by using solartime.

$$\omega = (ST - 12) \times 15^0 \quad ....3.2$$

The local solar time (LST) in the equation above is expressed in hours. LST can be converted from hours to minutes.

$$\omega = 15^0 \times (\frac{LST(in\ min)}{60} - 12)$$

Using the equation above the rough estimate hour angle gives 18.75^o this angle value used to calculate zenith angle.

For the surface, the zenith (θz) can be calculated using equation 3.3. and gives 20.1^0 by latitude ϕ of aproximately 9^o.

$$Cos\,\theta z = cos\,\phi \times cos\,\delta \times cos\,\omega + sin\,\delta \times sin\,\phi \quad .....3.3$$

The angle of incidence of surfaces sloping due north or due south must be calculated for this particular design using the value of (ϕ − β), where is the slope of the panel and has the same angular relationship to beam radiation. Since the vehicle structure is not normal and has a 9^o

inclination, the slope angle for this research is equal to the latitude of the site. Additionally, choosing a slope larger than the latitude is not advisable for the vehicle due to the stability of the vehicle structure.

$For\ summer\ \beta\ =\ \phi\ -(100-150\ )and for\ winter\ \beta\ =\ \phi+(100-150)$……3.4

$$cos\ \theta_z = \ cos\ \delta\ \times\ cos\ \omega\ \times\ cos\ (\phi\ -\ \beta)\ +\ sin\ \delta\ \times\ sin\ (\phi\ -\ \beta)\ \ldots.3.5$$

Where Where: δ: is the declination (°) calculated from equation 1, ϕ: is the latitude (°), θz: is the zenith angle (°), θ: is the angle of incidence (°), ω: is the Hour angle (°), β: is slop.

Solar Radiation: There are two types of solar radiation that reach the surface: beam radiation and diffuse radiation. Solar radiation that enters the surface is known as beam radiation (Ib). The solar radiation that is reflected by various air molecules is known as diffuse radiation (Id), but it is also referred to as direct radiation. There is no specific direction to diffuse radiation. Global radiation (I) is the sum of the two types of radiation, diffuse radiation and beam radiation.

Calculation of Total Radiation on a Surface - A clear sky is one in which the diffuse radiation reaching the surface of the earth is less than or equal to 25% of the total radiation in the universe.

On a sunny day, there is a method for calculating the transmittance of beam radiation. The following formula is used to determine how much diffuse radiation can pass through a sunny day, a beam, and diffuse radiation**.**

The beam radiation on the earth's surfuse is:

$$I_b = \ In\ \tau b\ cos\ \theta z\ \ \ldots\ldots\ldots 3.6$$

Where: In =Isc [1 + 0.033 cos (360 N/365)], where Solar Constant (Isc) = 1367 W/m^2

= 1327 W/m^2

$\tau b = a_o + a1\ e^{(-\ k/\ \cos\ \theta z)}$

ao = ao × ro, 1 = $a1$ × $r1$, k = k × rk

Where $a_0 = 0.4237 - 0.00821(6\text{-}A)^2$

$a_1 = 0.5055 + 0.00595\ (6.5\text{-}A)^2$

$k = 0.2711+0.01858\ (2.5-A)^2$

Summer at mid-latitudes has r_0 = 0.97, r_1 = 0.99, and r_k = 1.02. A - is the height of the region in kilometers above sea level, τb - beam radiation's atmospheric transmittance, τd -The atmospheric transmissionbeam radiation, In - extraterrestrial radiation (radiation incident to the surface tangent to the outer surface of the atmosphere) Ib - beam radiation, and Id - diffuse radiation

$$I_b = 837\ \mathrm{W/m}^2$$

The deffuse radiation is:

$$Id = I n \tau d \cos \theta z \text{.....3.7}$$

$$Id = 86\ \mathrm{W/m}^2$$

Therefore, the radiation from a surface under a completely clear sky is computed as follows.

$$It = I b + Id \text{ ....3.8}$$

Thus, totally clear sky radiation on a horizontal surface is 923.37 $\mathrm{W/m}^2$

Peak sun hours

The minimum monthly solar irradiation is used to calculate the peak sunshine hours for the solar PV system design. Solar PV system design typically necessitates this strategy (planning for the worst-case scenario).

The peak sun hours of the application's location have a significant impact on the performance of the solar PV system. The available solar irradiation of a location is calculated based on the peak sun hour(s) of the region. Equation 3.9 relates the peak solar hours and total irradiation.

$$PSH = \frac{I}{PSI} \quad \text{..........3.9}$$

Where: PSI peak solar irradiation (923.37 W/m2) and I - irradiation (4576 Wh/m2/day)

The peak sun hour is 4.956 hours per day (this PSH occurs in July), according to equation 3.9. After comparison, Ethiopian metrology agency, NASA, and PVGIS take the minimum sun radiation. Equation 3.9 can be used to determine the number of peak sun hours using data from Table 3.5 below regarding the minimum monthly solar irradiation in July, which was 4.956 kWh/m2/day.

Table 3.5 Average summarize data

Months	No of days	δ(d)	PSH
January	31	-17.8	6.17
February	59	-8.67	6.713
March	90	3.62	6.946
April	120	14.6	6.455
May	151	21.9	6.632
Jun	181	23.2	5.557
July	212	18.17	4.956
August	243	8.1	5.262
September	258	0.096	5.523
October	304	-15.1	6.028
November	334	-22	5.874
December	365	-23.1	5.804

3.3. PV Design by PV syst software

It is possible to determine the peak sun hours by using the location's irradiance to describe the energy loss factor on the solar array. The PVSYST computer program's inputs for this task include latitude, elevation, time zone, longitude of a location, types of PV boards with different power requirements, etc.

$$Ppv = Pd \times D \times PSH \; .....3.10$$

Where PSH is peak sun hour (4.956 ±0.25), Pd is the power obtained from the PV panel each day (0.6kW), Ppv is the power produced from the PV panel annually (kWh), and D is a day of the year (365). Therefore, based on equation 3.10, the annual energy generated by PV panels is 1330 kWh.

Length of a vertical object shadow: This straightforward computation provides the vertical object shadow length for the given day and location. The algorithm used in the computation to determine sun altitude employs the Sun's position. As a result, it calculates shadow length using this formula..

$$L = h/tan(\alpha) \text{ .....3.12}$$

Where; α is the angle between the Sun and the horizon and h is the height of the item.

3.3.1. PV module design

The total daily energy in Watt-hours (E), the average sun hour per day (PSH), and the system's dc voltage (VDC) must all be calculated before the array can be sized. We proceed to the sizing process once these elements are made available. To obtain the necessary energy Er, losses must be taken into account by dividing the entire power demand in Wh.day-1 by the sum of all system component efficiencies. The amount of energy needed for an electric car determines how powerful a solar panel is required to be.

Details of the PV Model: The SUNTECH STC 330, 72 cell PV model was chosen for this project based on the power requirements. 1960 x 992 x 40 mm and 330 W are the dimensions of the chosen module, respectively. The SUNTECH PV model, which has a 16.9% overall efficiency, is used in this system and provides the most power generation during peak hours. Ideal for distant and off-grid power installations. The module offers a 25-year warranty and a good working efficiency even under a range of demanding circumstances. For the module to completely utilize and absorb sunlight and provide the highest amount of usable power per square meter of a solar array, a special textured cell surface and bypass diode design are essential. [Appendex A].

The solar panel's area would be determined using the following flow: For electric vehicles, 0.6kW of electricity must be obtained, and the site's minimum solar radiation is 4.956 kWh/m2. The module's efficiency at its maximum power point is 16.9%, and that of the electronics is between 80% and 90%. Choose a $1.944m^2$ standard PV panel to produce 330 W depending on the available space.

$$Wp \times PSH = Ae \times I \times \eta\, pv \times \eta e \quad .....3.12$$

$$Pd = \frac{A\, e\, x\, I \times \eta\, pv\, x\, \eta e}{PSH} \quad ....3.13$$

The area available on a vehicle's roof is 1.35 m x 2.769 m = 3.74 m2 = Ae, and the Pd calculated from the 3.13 is 0.6 KW. The formula below is used to determine how many panels are needed.

$$NP = Ae\ /Ap \quad ....3.14$$

As a result, there are two 3.888 m^2 panels needed. Where NP = Required Number of Panels Ae stands for the car's effective area on the top roof; Ap denotes the single panel's area; PV stands for photovoltaic cell efficiency, I for solar radiation ($kW/m^2/day$), Pd for the power needed to charge electric vehicles, and PSH for the area where the system would be deployed. The highest power point tracker coefficient, e, is assumed to be 0.90.

The PV modules must provide the calculated total Watt-hours produced each day: To determine the overall daily energy use, multiply the Wattage of all appliances by the number of hours in a day. Eight hours a day of operation and 0.6KW of electricity are needed.

$$Er\ = \frac{daily\ average\ energy\ consuption}{product\ of\ component's\ efficiencies} = \frac{E}{\eta overall}$$

$$Er = \frac{600 \times 8}{0.9 \times 0.8 \times 0.95} = 7017.5Wh$$

The previous result is divided by the average number of sun hours per day for the location PSH in order to determine the peak power.

$$Pp\ = \frac{daily\ energy\ requirement}{minimum\ peak\ sun\ hours\ per\ day} = \frac{Er}{PSH}$$

$$Pp = \frac{7017.5}{(4.956\ \pm 0.25)} = 1348\ Wh/Day$$

Divide the peak power by the system's DC-voltage to get the total current required.

$$Idc \ = \frac{peak\ power}{system\ DC\ voltage} = \frac{Pp}{Vdc}$$

$$Idc \ = \frac{1348}{24} = 56Ah$$

$No\ of\ module\ required = Idc\ /\ Imp$ = 56 Ah / (8.81×4.956) = 1.28 ≈ 2.

3.3.2. choosing a solar charge controller

The heart of a solar-powered system is a solar panel charge controller, which converts solar energy into electricity to power the system's battery or inverter. It's crucial to choose a solar regulator that offers dependable load control, diversion regulation, and solar battery charging. As a result, the controller size for this design is:

$$C.C \ = \ Np \times \ Imp \ \times \ 1.3 \quad ...1.15$$

Where; C.C is a charge controller, Imp is the module current, and Np is the number of modules..

3.3.3. Inverter selection

A solar inverter is the only device that supplies power to the EVs load. The load power rate has to be at least the inverter power rate. Manufacturers state that inverters release higher power for a short time, which is double of load power and it is higher than the rated power. As manufacturers stated the Inverter peak power is in watts. But this power is fed to resistive loads with a unity power factor only.

For compressors and motors the power factor is low, thus looking for the surge current of the inverter is very important. The inverter current is an important factor that must be considered. The starting power is typically 3 to 8 times higher than the operating power (to handle surge current during starting) and with it the current. Therefore starting current must be considered when selecting an inverter.

Inverter sizing = 0.6 kW x 5 = 3 KW

3.3.4.Battery selection

When comparing solar battery options, there are certain criteria to consider, such as how long the solar battery will last or how much power it can supply. Depth of discharge (DOD): Most solar batteries need to retain some charge at all times due to their chemical composition. If we use 100% of a battery's charge, its useful life will be significantly shortened so the best DOD is important. When compared to lead-acid batteries, they also have a greater DOD and a longer lifespan. The cost of lithium-ion batteries is higher than that of lead-acid batteries, nevertheless. Lithium-ion batteries with storage (80Ah, 12V), cycle life to 80% depth of discharge (DOD), are therefore appropriate for this system. Charge efficiency is chosen at 20% discharged.

$$BC = \frac{P}{Vs} \text{........................} 3.16$$

Where; BC is the battery's capacity (Ah), which is 60Ah, and P is the equipment's power.

3.3.5. Cable selection

Voltage drop in photovoltaic systems (120 V) ≤ 5% = 6V.

$$Vdrop = IR = \frac{I(\rho L)}{A} \text{......................} 3.17$$

Where; I is the system current and is the copper wire's resistivity (40 10-8). A: cross-sectional area; L: length.

3.4. Layout design of PV module

The figure 3.3. below depicts the coach's roof from the front. 330 W-rated and 9°-inclined monocrystalline PV modules can be used to cover the vehicle's roof. One module on the right side and one on the left side with electrical setup can be mounted along the axis of symmetry. Batteries and inverter charge controllers are set up away from moving vehicles.

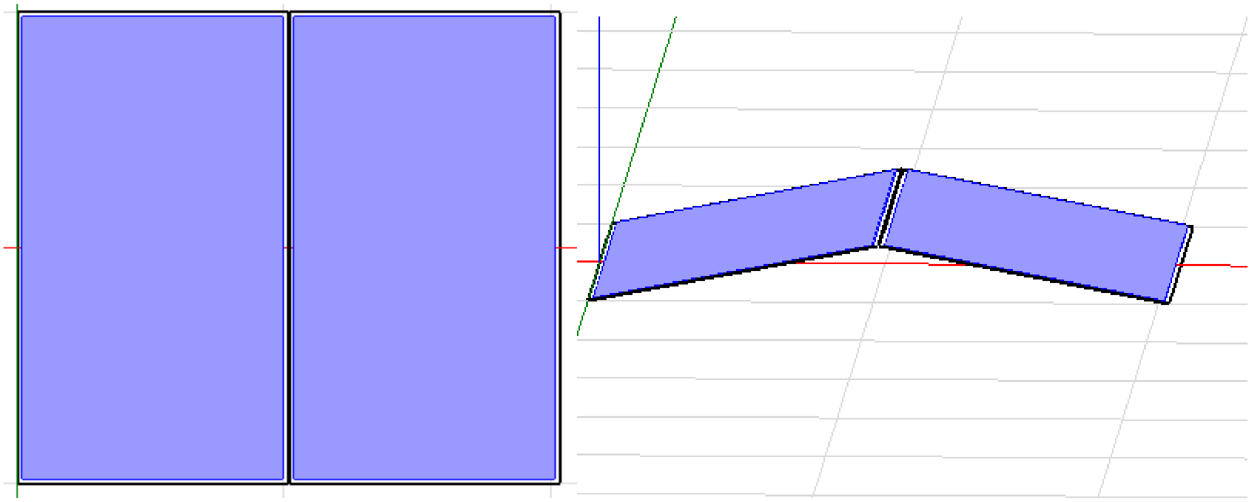


Figure 3.3. Layout design of a PV module

1.3. Economic analysis

Table 3.6. The initial cost for Ev charging Unit powered by the PV system (https://www.mustpower.com) .

Description	Quality	Unit price	Total cost
PV modules, mono-crystalline	2	9000 birr	18000birr
Structure cost	-	-	4000 birr
Batteries	1	12000 birr	12000 birr
Cables	4 m	330 birr	1320 birr
Inverters and Charge controller	1	95600 birr	95600 birr
Others	-	-	2000 birr
Total			46,880 birr

According to Table 3.6, the final cost is 46,880 Birr, while ongoing operating expenses total 0 Birr and battery replacement costs of 12,000 Birr every five years.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1.Results of the PVsyst software's solar PV sizing

Zenith angle, incidence angle, declination angle, peak sunshine hour, and irradiation are required as input parameters for the design. The computed values of these input parameters are shown in (Table 4.1) based on the equations described in Chapter 3 before. The PV system's size has been determined using July 17, which has the lowest solar irradiation of 4.57 kWh/m^2/day (Table 3.5).

Table 4.1. a list of the calculated parameters from the PVsyst software's input

Parameters	Value
Declination angle	18.17^o
Hour angle	18.75^o
Zenith angle	20.1^o
Incident angle	20.1^o
Beam radiation	837 W/m^2
Diffuse radiation	86 W/m^2
Total radiation	923 W/m^2
Peak sun hour	4.956 h/day

Figure 4.2 presents the outcomes based on the aforementioned inputs. The graph in the figure 4.2 clearly displays the annual average power and energy outputs for each month. From January to March, energy levels ranged between 7.15 and 6.45 kWh/m2/day; these levels have since dipped to 4.78 kWh/day. The value was 3.6 kWh/m2/day at the very least in July and August. It began to climb back to its peak value of 6.84 kWh/m2/days in September and has been steadily increasing

since then. At minimum irradiance, a solar-powered car may generate roughly 0.6 kWh of power, as is explored in more depth as the irradiance of the area increases.

Equation 3.10 is used to determine the annual power generated by PV panels. 1330 kWh/year of energy from PV panels are produced annually. The annual energy production is nearly identical to the annual energy output depicted on the PVSYST figure. As a result, the diagram for the entire year is accurate.

Vertical object shadow length: For this case study, the building's shadowing effect is minimal. However, as can be seen from the data below, there is some fluctuation in sun irradiation depending on the design of the vehicle.

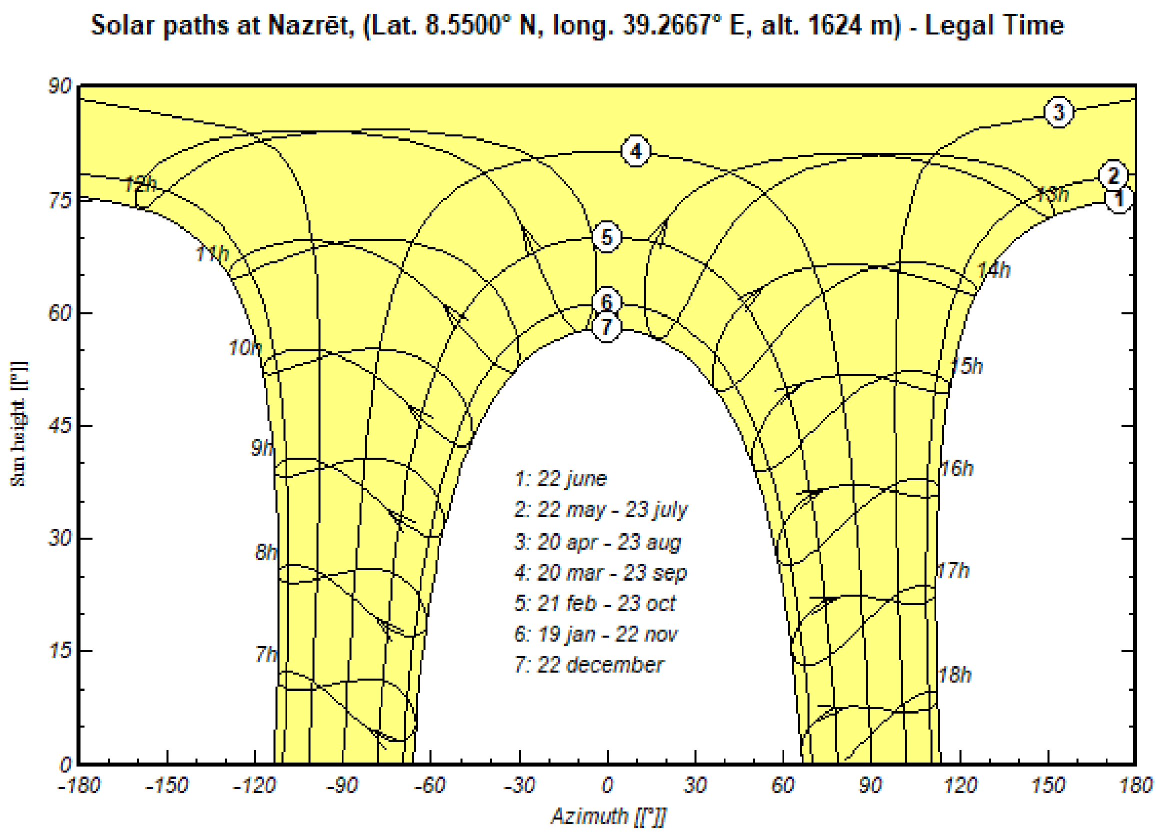
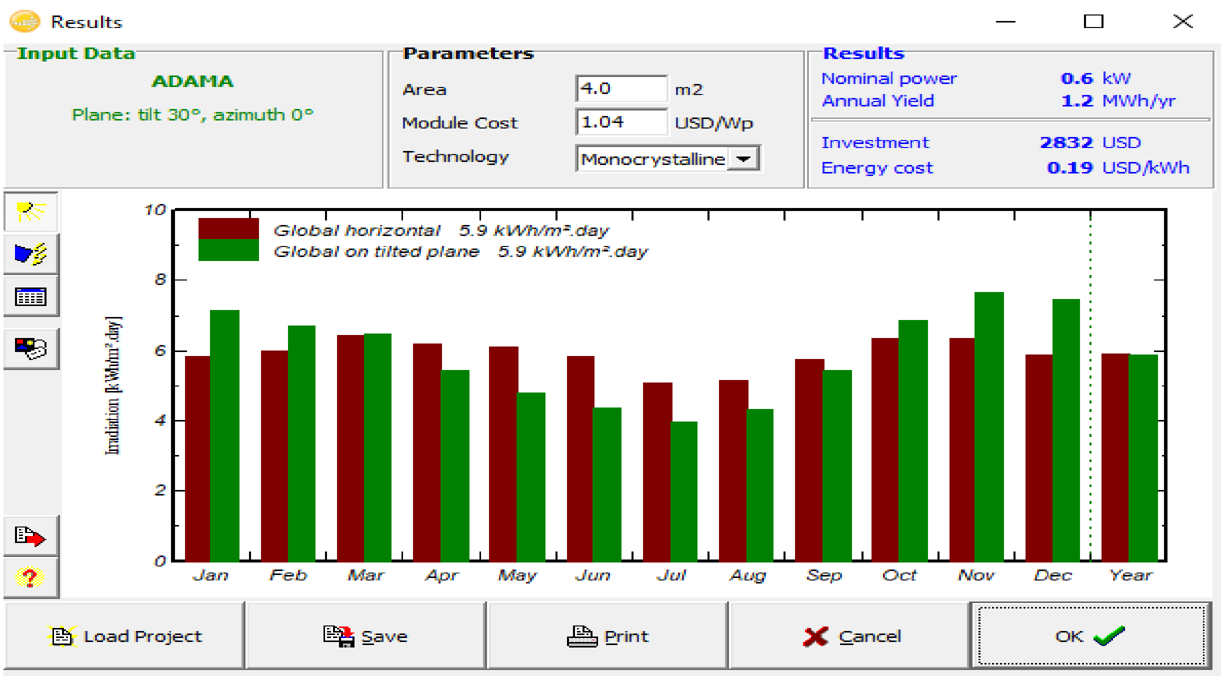


Figure 4.1. Solar paths at Adama

Figure 4.2 below illustrates how the monocrystalline module type can provide nominal power of 0.6 kWh from the horizontal plane that will be put on the vehicle's roof. This indicates that we can generate 1200 kWh of system output energy each year and 1.2 MWh of annual energy from the average 5.22 kWh/m^2/day global irradiation. We can drive for one to two hours using the power obtained at minimal and maximum irradiation.



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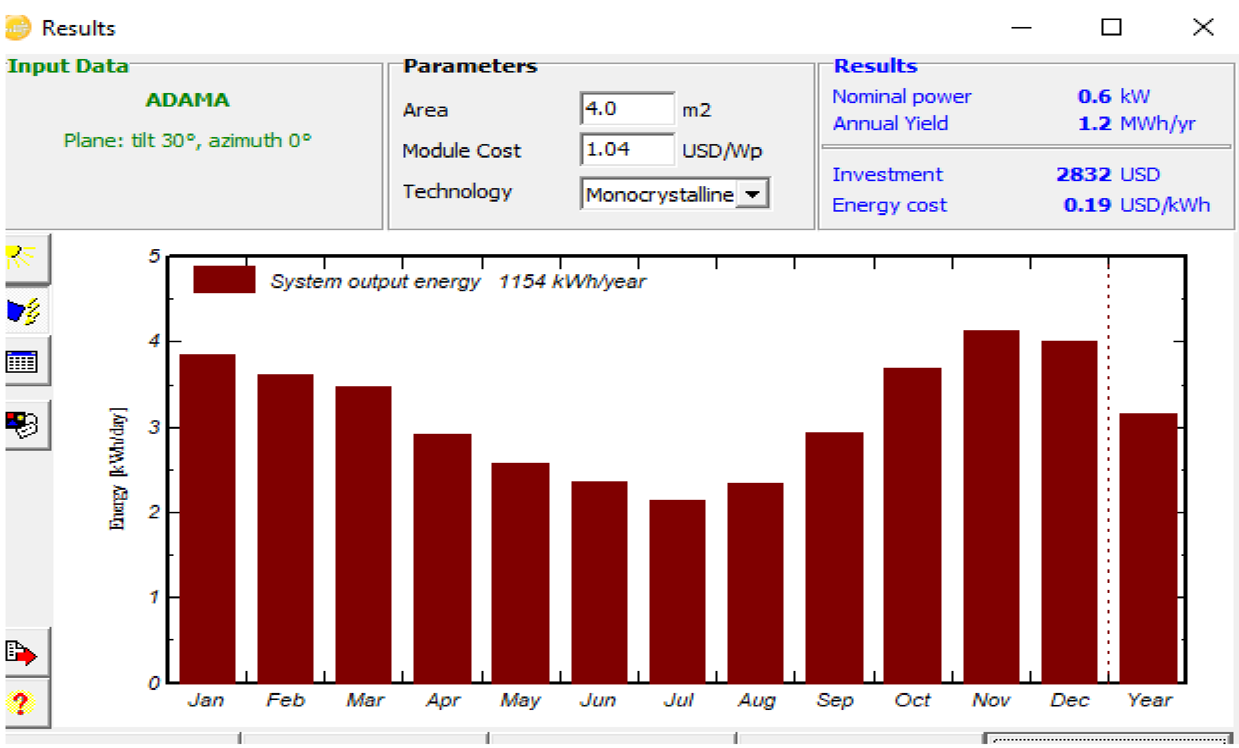

Figure 4.2. Results of output power simulation using PVSYST

4.2. Choosing PV Modules

The area of the solar panel would be estimated as follows: the panel's area is determined from equation 3.13. Depending on the calculated area, pick a 1.944 m^2 standard PV panel, which has a 330 W output. The chosen PV panel is capable of generating the aforementioned electricity. As a result, the design is secure. One car's roof space is 1.35 m x 2.769 m, or 3.74 m^2, although this space is the entire space available.

Equation 3.14 is used to get the number of panels needed for an effective available area of 4 m^2:

$$Np = 4 \text{ m2} / 1.944 \text{ m}^2 = 2$$

Solar charge controller sizing result: Solar charge controller C is required by equation 3.15.

$$C = 1*8.81 *1.3 = 11.45 \text{ A} \approx 20 \text{ A, } 120\text{V}$$

Results of inverter sizing: According to manufacturer data, the max power in watts for the entire inverter is 0.6 kW; however, to handle surge current during startup, the inverter must have three times the required power. Switching power inverters are the kind of inverters that convert DC to AC with a 95% efficiency rate. The 3kW MUSTPOWER inverter is chosen.

Size of inverter: 0.6 kW five, Size of inverter is 3 KW

Battery sizing result: For this study, storage batteries with a cycle life of 80% depth of discharge (DOD) (80Ah, 12V) were chosen as the battery. Charge efficiency is chosen at 20% discharged. Battery capacity is therefore given by Battery Capacity (Ah) = 60Ah from equation 3.16.

Energy needed from batteries: 60 Ah/DOD: 60 Ah/0.8 = 75 Ah; .

Number of batteries: 75 / 80: 0.94 = 1

The car is operated from 1 to 11 o'clock. LT assumes we will install an 80A, 12v battery, resulting in a battery backup time of 8 hours and a charging time of 3.5 hours.

cable sizing: outcome Using equation 3.17 as a guide, the cable size for this study is 35mm^2. Everything is made by MUSTPOWER.

4.3. MATLAB simulation results

The short circuit point, which occurs when the current in the module is at its maximum and when the voltage over the module is zero, is a requirement to observe the performance and characteristics of the module. The open circuit point, which occurs when the voltage in the module is at its maximum and when the current over the module is zero, is the other characteristic performance. The final characteristic performance is the maximum power point, which occurs when the current in the module is at its maximum and when the voltage over the module is zero.

The module's datasheet lists three points at standard test conditions (STC) as (Isc, 0), (Voc, 0), and (Imp, Vmp). However, the primary objective of this design is to determine the precise value of these points under the chosen conditions. The PV module functions as a current source in the event of a short circuit and as a voltage source in the event of an open circuit.

The current vs voltage graph simulation results are shown in Figs. 4.3 and 4.4. As solar irradiance changes, the current on the graph likewise changes. Similar to how the output power (Pm) grows with an increase in solar irradiation.

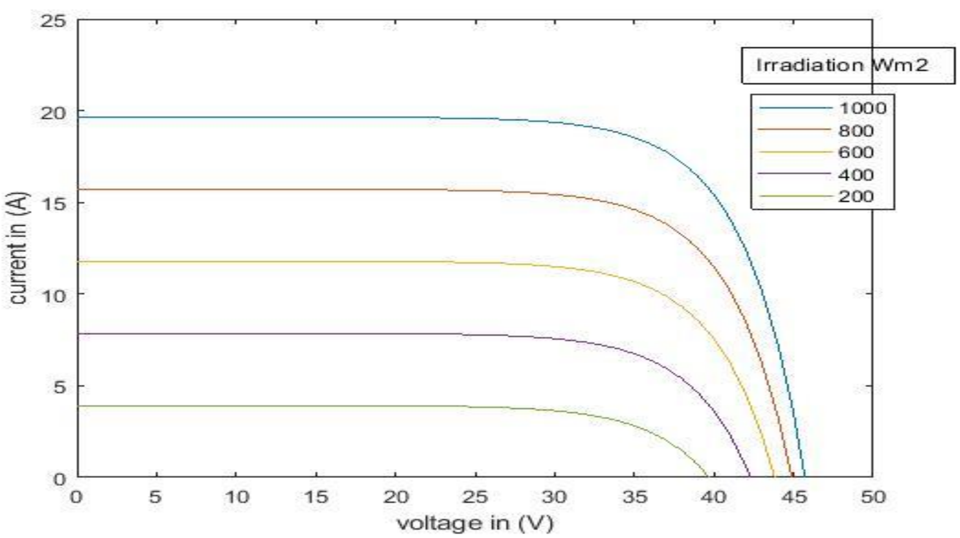

Figure 4.3. I-V graph of a solar PV module under various sun irradiations

Solar irradiation actually varies as a result of environmental change. When sun irradiation rises, solar input into the solar module likewise rises; as a result, the power generated by the module rises for a given voltage value.

The voltage at zero current values rises with an increase in sun irradiation. Because of how the sun strikes the solar cell, a larger level of energy-created electron excitation resulted in a higher level of electron mobility, which leads to a higher power output.

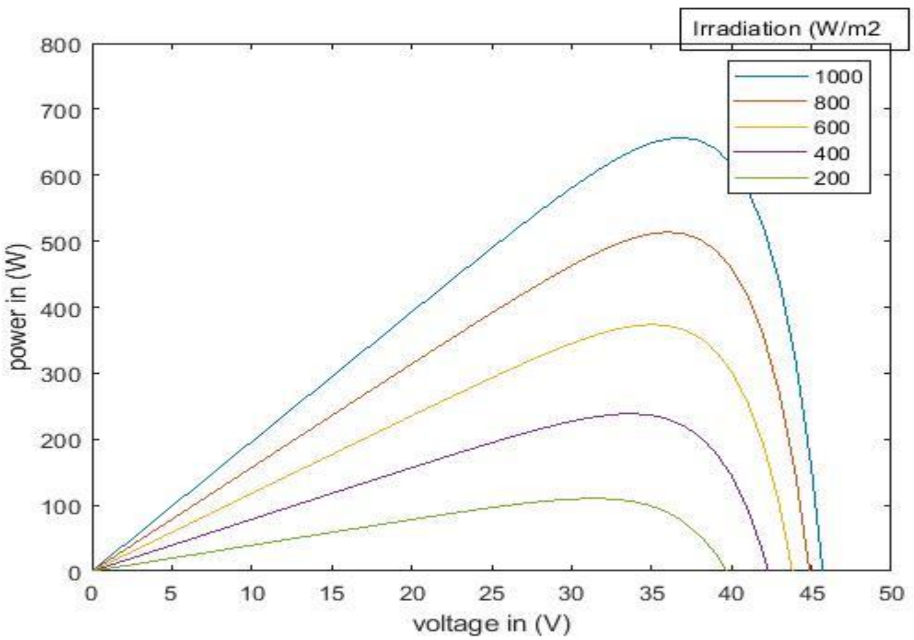

Figure 4.4 shows the P-V graph of a solar PV module under various solar radiation conditions.

After examining the site's solar statistics and coming to the conclusion that the data are reliable, a figure was created to support the model mentioned above. As a result, the supplied simulation data is used to validate the results. The expected outputs of the solar data are shown in the created figures above along with the temperature and irradiation of the photovoltaic panel. These numbers clearly show that my numerical model accurately predicted the power output. Additionally, because this model assumes a fixed axis, it is unable to account for tracking.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The finest pollution-free technique is the solar car, which provides solutions to a variety of environmental issues. In order to lessen our reliance on fossil fuels, we must use them. Solar cars do have several drawbacks, such as a limited speed range and a high starting cost. The system was designed with a total load of 0.6 kW while taking into account all of the factors. In order to supply this load, the system requires a total of 2 solar panel, each rated at 330W, and certain features are also assumed to be known about the PV system. Using PVSYST and MATLAB, researchers were able to determine the electrical equivalent, IV characteristic curve, and variables that influence PV cell output.

The minimal sun irradiation in Adama is 4.8 kWh/m^2/day on average. This study used many data sources, including NASA, PVGIS, calculations, and an Ethiopian metrology agency. The installation of solar photovoltaic modules on a roof. Based on the findings, it is predicted that a solar roof measuring 4 m^2 can provide at least 0.6 kWh and up to 1.1 kWh of electricity per day, resulting in a significant annual reduction in grid energy. We can drive for one to two hours using the power obtained at minimal and maximum irradiation.

The analysis's findings indicated that in order to meet the need for charging an electric vehicle with a peak load of 0.6 kW, an off-grid solar PV array with a surface area of 4 m^2, a battery with a capacity of 80 Ah at 12 V, a controller with a capacity of 80 A at 120 V, and an inverter with a capacity of 3 kW will be needed.

A charging capacity of 0.6 kW will therefore give a general notion of how to design and install the system with sufficient electrical energy supplied to it for the electric vehicle. The article attempted to increase the system's stability and efficiency in order to provide greener answers to the world's energy demands.

In general, it is reasonable to draw the conclusion that the energy output from the vehicle's top roof can supply a sizeable portion of the needed energy for charging. As a result, it lowers the cost of grid investments and promotes the efficient use of renewable energy across the nation.

5.2. Recommendation

It is advised that the solar-powered vehicle option be used in Ethiopia as a prototype solar system to promote future full usage. The installation of solar panels on the top roof of the solar energy system for Ev power supply demonstrates the capability of producing a significant amount of electrical energy.

Therefore, it is advised that Ethiopian power providers and the transportation sector take a number of steps to promote energy security, sustainable development, and reduce environmental harm. The desired output results will be produced by modeling PV solar systems at their peak performance in reality. The research region will test the actual system implementation at a few chosen sites. This research needs further and in-depth analysis because it was conducted under several restrictions.

5.3. Future Work

According to the aforementioned research, a single three-Weller car can produce as little as 0.6 KW/day, which can replace the load, and as much as 1.1 KW/day, which can replace more than the required load of the total power utilized by the vehicle.

Therefore, if a suitable solar design is made, the rooftop of a vehicle can supply a lot of loads for future work. Additionally, a two-axis tracking mechanism is preferable than a manual tracking mechanism for obtaining the ideal sun direction. The sun charging electric car system can be modeled in vehicle areas in addition to simulating this system utilizing other energy sources. The alternative suggestion is to use different solar equipment, such as an MPPT solar charge controller, which is a charge controller integrated with an MPPT algorithm to maximize the amount of current flowing into the battery from the PV module and the aerodynamic effect of the moving air at the top surface.

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GreenTech Africa (greentecafrica.com) https://greentecafrica.com/

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APPENDIX

Appendix A - Solar Module Specification

Electrical Characteristics

STC	STP330-24/ Vfw	STP325-24/ Vfw	STP320-24/ Vfw
Maximum Power at STC (Pmax)	330W	325 W	320 W
Optimum Operating Voltage (Vmp)	37.5V	37.3V	37.1 V
Optimum Operating Current (Imp)	8.81A	8.72A	8.63A
Open Circuit Voltage (Voc)	46.2V	45.9 V	45.6 V
Short Circuit Current (Isc)	9.38A	9.26 A	9.14A
Module Efficiency	17.0%	16.7%	16.5%
Operating Module Temperature	-40 °C to +85 °C		
Maximum System Voltage	1000 V DC (IEC)		
Maximum Series Fuse Rating	20 A		
Power Tolerance	0/+5 W		

STC: Irradiance 1000 W/m², module temperature 25 °C, AM=1.5;
Best in Class AAA solar simulator (IEC 60904-9) used, power measurement uncertainty is within +/- 3%

NOCT	STP330-24/ Vfw	STP325-24/ Vfw	STP320-24/ Vfw
Maximum Power at NOCT (Pmax)	243.5W	240.0W	235.0W
Optimum Operating Voltage (Vmp)	34.3V	34.2V	33.9V
Optimum Operating Current (Imp)	7.10A	6.99 A	6.94 A
Open Circuit Voltage (Voc)	42.5V	42.2V	41.9 V
Short Circuit Current (Isc)	7.60A	7.49A	7.40 A

NOCT: Irradiance 800 W/m², ambient temperature 20 °C, AM=1.5, wind speed 1 m/s;
Best in Class AAA solar simulator (IEC 60904-9) used, power measurement uncertainty is within +/- 3%

Temperature Characteristics

Nominal Operating Cell Temperature (**NOCT**)	45±2°C
Temperature Coefficient of Pmax	-0.41 %/°C
Temperature Coefficient of Voc	-0.33 %/°C
Temperature Coefficient of Isc	0.067 %/°C

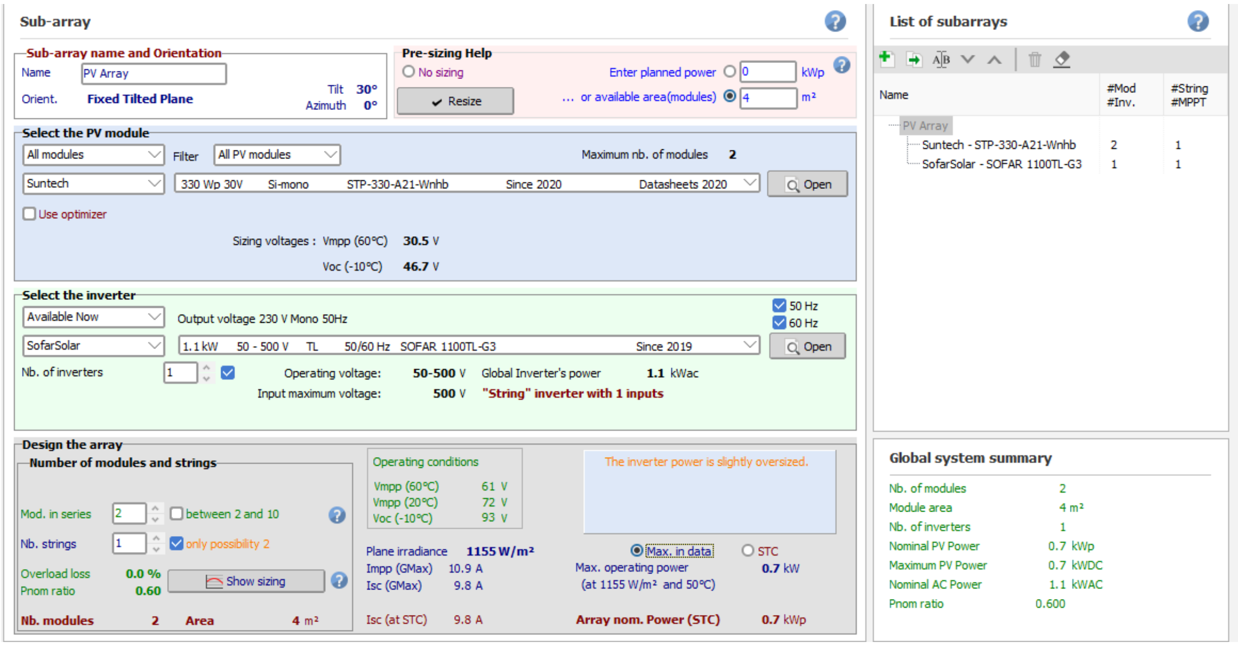
Mechanical Characteristics

Solar Cell	Polycrystalline silicon 6 inches
No. of Cells	72 (6 × 12)
Dimensions	1960 × 992 × 40mm (77.2 × 39.1 × 1.6 inches)
Weight	22.1 kgs (48.7 lbs.)
Front Glass	3.2 mm (0.13 inches) tempered glass
Frame	Anodized aluminium alloy
Junction Box	IP68 rated (3 bypass diodes)
Output Cables	4.0 mm² (0.006 inches²), symmetrical lengths (-) 1100mm (43.3 inches) and (+) 1100 mm (43.3 inches)
Connectors	Genuine MC4

Packing Configuration

Container	20' GP	40' GP	40' HC
Pieces per pallet	26	26	26
Pallets per container	5	12	24
Pieces per container	130	312	624

Appendix B- PV design by PVsyst software



Appendix C- MATLAB for PV system

Editor - C:\Users\Guta\Documents\MATLAB\Untitled.m

```
clear all
close all
%Declearing variables
T=320;
Tr=300;
ki=0.00023;
Iscr=9.82;
Irr=0.000021;
A=2.15;
Eg0=1.166;
alpha=0.473;
beta=636;
S=[1000 800 600 400 200];
k=1.38065*10^(-23);
q=1.6022*10^(-19);

Eg=Eg0-(alpha*T*T)/(T+beta)*q;
Np=2;
Ns=63;
v0=(0:1:300);
%finding values for all 5 vaslues of sun
for i=1:5
    Iph=(Iscr+ki*(T-Tr))*((S(i))/1000);%phase current
    Irs=Irr*((T/Tr)^3)*exp(q*Eg/(k*A)*((1/Tr)-(1/T)));%Current through shunt resistor
    I0=Np*Iph-Irs*(exp(q/(k*T*A)*v0./Ns)-1); % output current
    P0=v0.*I0; %output power
    figure(1)%voltage vs current plot
    plot(v0,I0);
    axis([0 50 0 25]);
    xlabel('voltage in (V)');
    ylabel('current in (A)');
    hold on;
    figure (2) % voltage vs power plot
    plot(v0,P0);
    axis([0 50 0 800]);
    xlabel('voltage in (V)');
    ylabel('power in (W)');
    hold on;
end
```