DESIGN OF A MOBILE 1.5 KVA SOLAR POWER STATION WITH A CHARGE CONTROLLER

BY

IYENGUNMWENA NOSAKHARE EMMANUEL (PG/ENG 1819005)

DEPARTMENT OF ELECTRICAL/ELECTRONIC ENGINEERING

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IN PARTIAL FULFILMENT FOR THE AWARD OF MASTER OF ENGINEERING (M.ENG) IN ELECTRICAL/ELECTRONICS ENGINEERING (ELECTRONICS AND TELECOMMUNICATION)

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DECLARATION

I, **IYENGUNMWENA, Nosakhare Emmanuel**, with Registration Number PG/ENG 1819005, declare that the work contained in this thesis, "Design of a Mobile 1.5 kVA Solar Power Station with a Charge Controller," was completed by me, that it is unique to me, and that it has not previously been presented in whole or in part for the award of a degree by this institution or any other.

________________________________ ____________________

IYENEGUNMWENA NOSAKHARE EMMANUEL **Date**

(PG/ENG1819005)

CERTIFICATION

This is to confirm that IYENEGUNMWENA NOSAKHARE EMMANUEL (PG/ENG1819005) completed this project for the University of Benin, Benin City's Masters of Engineering (M.Eng.) in Electrical/Electronic Engineering (Electronics/Telecommunications).

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DR. K.O OGBEIDE	**PROF. (MRS) P.E. ORUKPE**
Supervisor	Head of Department
Date	Date

DEDICATION

This research celebrates the One and Only God, who gave us life and enabled us to make great strides in our academic endeavors. Glory belongs only to Him.

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First and foremost, My Deepest Gratitude goes to My Lovely Family, who has been my source of inspiration and motivation throughout this program.

Our Sincere and profound gratitude goes to our project supervisor Engr. DR. K.O OGBEIDE, whose immense contributions gave good focus to this work. It was a great privilege and honor to study under his guidance. We are also grateful to our lecturers, who were outstanding in their lectures during the course of the program. Also included in the list are all the staff of Electrical/Electronic Engineering.

Finally, I sincerely thank my fantastic friends and coworkers who have helped me grow and develop.

ABSTRACT

This abstract describes a mobile 1.5KVA solar power station, designed to provide an efficient and reliable power supply in remote locations without access to electricity. The power station consists of a portable device with an array of batteries, an inverter, a charge controller, auxiliary connectors, and a foldable solar panel module. The solar module's primary function is to collect solar energy, transform it into electrical power, and store it in the battery bank for later use. The portable unit has AC and DC power outlets for operating and charging various gadgets, including smartphones, tablets, laptops, and other electrical appliances. The station is lightweight, compact, and easily transportable, making it ideal for camping, outdoor events, and emergency situations. It has a robust built and can withstand harsh weather conditions. In conclusion, the mobile 1.5KVA solar power station offers a sustainable and cost-effective solution to meet the growing need for reliable and clean energy supply in remote areas.

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LIST OF ABBREVIATIONS

ABD	Abnormal Battery Drain
AC	Alternating Current
AGM	Absorbed Glass Mat
A.H.	Ampere Hour
BSC	Battery Charging Station
CSP	Concentrated Solar Power
DC	Direct Current
EV	Electric Vehicle
HOMER	Hybrid Optimization Model for Electric Renewables
KVA	Kilo Voltage Ampere
MPPT	Maximum PowerPoint Tracker
PCU	Power Conditioning Units
PSH	Peak Sun Hours
P.V.	Photovoltaic
PWM	Pulse with Modulation
RASS	Reserve Absorber Shallow Solar
RMS	Root Mean Square
SBCS	Solar Battery Charging Station
V	Voltage

CHAPTER ONE

INTRODUCTION

1.1 Background

Most people's living standards have risen due to modern civilization, as has the demand for fossil fuels and energy. In general, all machines and apparatus require energy as an input. (Staton and Harding, 2000).

Since the beginning, people have used solar energy to dry agricultural goods, ventilate homes, and other things. Two thousand years ago, Heron of Alexandria invented a portable solar-powered water pump, while in 214 B.C., Archimedes of Syracuse used to focus sun mirrors to set Roman ships on fire. There are two ways to transform sunlight straight into usable energy. Rankine cycle-based conversion of solar energy into power and photovoltaic (P.V.) effect-based conversion of the sun. The Rankine cycle is the process by which sunlight is absorbed into a surface that has turned dark, converting it into heat. This heated surface will continue to heat up if air or water is moved over it. This makes it possible to transfer heat energy from one place to another. The light that strikes the solar cells is immediately converted into direct current electricity in photovoltaic conversion. There are observable numbers of solar-thermal and photovoltaic installations in use all over the world. In aerospace applications, the primary power source for every satellite is a photovoltaic solar power source. Off-grid and on-grid solar photovoltaic applications include solar street lights, solar water pumps, electrification of rural settlement, industrial power projects, and renewable building technologies.

Most households can no longer buy petroleum products due to the high cost of contemporary drilling techniques and the depreciation of the currencies of most developing nations, including Nigeria. The rise of contemporary civilization has raised most people's living standards while also growing demand for fossil fuels and electricity, raising their prices. Population growth has increased the demand for fuel used to produce electricity. (Abdulkarim et al., 2016).

In recent times, technological advancement has put devices in our pockets that seemed alien a couple of years ago. Smartphones have changed from restricted platforms with only applications installed by default to open outlets with various third-party applications, primarily social media and entertainment apps. These smartphones consume more energy since they have more durable hardware and complex software than feature phones. (low-end cell phones with limited functionality). Unfortunately, due to this expansion, problems with abnormal battery drains (ABD) on smartphones have rapidly risen. Research and development have been done to create an effective energy source that will equal the efficiency of our devices. Many computers can quickly deplete a standard battery from a full charge.

Nigeria is the largest and most populous country in West Africa, with an estimated population of almost 200 million. It currently struggles with an irregular and epileptic electricity supply. This is because at least 60% of the populace needs more or no access to reasonably priced electricity. As a result, the country's energy problem must be resolved. Nigeria's population growth has led to a rise in demand for power without a consistent supply to keep up with demand. Exploring renewable energy sources has become necessary due to the lack of electricity in this nation, particularly in rural areas with insufficient or no grid systems. This proves that in rural regions without access to electricity, stand-alone photovoltaic (P.V.) system configurations provide an affordable alternative to the pricey grid extensions. Solar energy can be produced on a small scale at a reasonable price and used for remote lighting systems and phone charging.

Many rural households in developing nations lack access to electricity, forcing them to use dry cell batteries for their electronic devices or candles and paraffin lamps for domestic illumination. Some people use car batteries for their entertainment and lighting devices, which are charged in stations.

Battery charging stations (BSC) may be feasible for providing energy in areas not yet electrified and where incomes are inadequate to pay for solutions such as solar home systems. Furthermore, in electrified areas, grid-based BCSs can provide access to electricity to those who do not have a direct link to their house, allowing them to benefit indirectly from the electricity infrastructure. Solar battery charging stations (SBCS) built in rural areas are an alternative option for providing energy for the local population's basic requirements while reducing travel time and costs.

Solar power is becoming more popular as an alternative to fossil fuels due to the abundance of technical expertise and solar resources. As an environmentally beneficial solution for power generation, it has several advantages over energy sources that are not renewable such as petroleum, coal, nuclear energy, and so on, much like all of the other forms of renewable energy. Anywhere there is sunlight, it can generate energy and is reliable and non-polluting. Renewable resources will stay supplied for a while is another significant benefit. It has some technical and environmental advantages over other sources. Power is generated using solar panels, which do not need substantial mechanical components like wind turbines. These mechanical parts can fail, require expensive upkeep, and are quite noisy. Solar panels practically eliminate these problems. Furthermore, the solar cells that comprise the solar panel can last for decades without needing to be replaced.

The solar power system has a drawback, too, in that it can only function when sunshine is available. To solve this problem, backup rechargeable batteries are paired with solar panels since they can store surplus energy generated during times of availability. They can be used to power devices without sunlight. The systems demand a circuit for charging for the battery that recharges and voltage regulation of the source voltage from the solar panels. This is so that the phone and rechargeable battery may be charged, as the solar panel typically generates a voltage at the output (D.C.) larger than necessary. Voltage regulation is therefore required.

Solar power can thus be used easily in residential areas, particularly for charging phones and powering electronic devices and lighting systems during the night hours.

The project will be designed with readily available and affordable components, with the need to optimise the system.

1.2 Statement of the Problem

Due to the country's never-stable and never-always-available power supply situation, uninterruptible power supply units are everyday electrical items found in most private and commercial structures in Nigeria. These units, however, still need to provide the required reliable, efficient, and adequate power supply. Even if flawed, these units are not readily available in rural areas. According to a survey of the duration of electrical power available during the day and night in rural areas of Nigeria, a large number of domestic and household electronic users, particularly in rural and urban areas with no or limited access to utility electricity, are forced to spend hard-earned money to power their electronic appliances using a 750VA petrol-powered generator. This adds up to a significant investment over time, particularly for a poor rural dweller; thus, the need for rural residents to have a power supply to do the essentials, such as charging phones, presented a problem, especially during the hours of the day when sunlight is available.

As a result, there is a need to create a solar power station that uses solar energy to recharge its built-in battery, which is relatively cheap and abundant.

1.3 Aim and Objectives

1.3.1 Aim

This project aims to build a 1.5KVA mobile solar power station that controls the voltage and amperage delivered to the load in an energy-efficient manner.

1.3.2 Objectives

The following objectives have been set for this project:

(i) To carry out various studies to determine the best possible configuration and set-up for the electrical system.

(ii) To carry out various calculations and sizing of the individual electrical components based on the required load.

(iii) To design the 1.5 kVA mobile solar station with a charge controller based on the results and designed criteria.

(iv) To simulate the design to ascertain the functionality.

1.4 Methodology

The followings are the techniques and procedures that would be used to accomplish the project's objective:

(i) A theoretical approach will be employed to determine the various components that would be used in the design of the station.

(ii) Load analysis calculations would then be carried out to determine the specifications of the solar panel, charge controller, and battery capacities that will be used for the optimal design of the system.

(iii) The design will be simulated using Homer pro software application

(iv) Testing for voltage, current, open circuit, closed circuit and output signal quality will be carried.

1.5 Significance of the study

The various advantage which would be derived as a result of the outcome of this work include:

i. It would provide a reliable source of power for domestic and household use in the absence of conventional and on-grid power supplies.

ii. It would save time and money spent on fuel for power generation from the generator set.

iii. Due to its compactness and mobility, it can be made available at any location where there is a need for it.

iv. It will provide a base for the development of other solar projects for domestic, commercial and industrial usage.

1.6 Project scope

This project is limited to the design, simulation of the designed output and selection of the components of a 1.5kVA mobile solar power station with a charge controller. The physical implementation of the system was not be carried out.

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Framework

Our solar system's existence depends on the sun's energy. The sun provides enough energy to the planet in one hour to satisfy its energy needs for nearly a year (Okoye and Oranekwu-Okoye, 2018). Solar energy must be converted to electricity before it is used to power electrical equipment. Photovoltaic (P.V.) energy conversion is the process through which solar energy is transformed directly into electricity. With fossil fuel supplies projected to run out very soon, photovoltaic systems provide a different method of supplying energy to the developing globe without relying on a secure fuel supply. Over 1.4 billion people lack appropriate access to energy worldwide today. Sub-Saharan Africans comprise about 42% of the population, with more than 76 million living in Nigeria, 69 million in Ethiopia, and the remaining people living across developing Asia (Mas'Ud et al., 2016). In addition, rural areas are home to 85% of this population. An independent decentralized stand-alone photovoltaic solar power expansion is suggested to improve remote Nigerians' access to energy. A Stand-Alone Solar system relies entirely on photovoltaic technology and is not linked to the grid. While a battery bank is utilized to store energy for later use, the systems operate the direct current output of the solar modules to power direct current loads.

2.2 Solar Energy Potential and Utilization in Nigeria

Nigeria has a plethora of renewable energy sources with tremendous promise. There are countless options to employ these energy sources to generate enough electricity, even though only a small part of them have been used to do so throughout the country. Since it depends on the majority of other renewable energy sources, either directly or indirectly, solar energy is the most important hydroelectricity, wind power, and biomass are examples of renewable energy sources. (Aderoju et al., 2017).

Nigeria has significant solar energy potential, with an average of 19.8 MJm2/day of evenly distributed solar radiation and an average of 6 hours of sunlight each day. Concentrated solar power and photovoltaic production are estimated to have a combined capacity of around 42,700 MW. Calculations indicate that 5% of the land in central and northern parts of Nigeria might be set aside for solar thermal generation, yielding a potential capacity of 42,700 MW. In July 2016, PPAs for 14 Greenfields independent photovoltaic (P.V.) power projects comprising 1,125MW were signed by the Federal Government-owned NBET. The Energy Commission of Nigeria (ECN) is primarily in charge of overseeing and utilizing solar energy in the country with support from the National Agency for Science and Engineering Infrastructure (NASENI), the National Centre for Energy Research and Development (NCERD), the Energy Research Center (SERC), and NASENI Solar Energy Ltd. One of SERC's significant scientific accomplishments is using solar power for pumping water, drying, and heating (Mas'Ud et al., 2016). To meet Nigeria's rising electricity demand, it is crucial to properly evaluate the possibilities of solar energy technology.

Through various applications, including photovoltaic (P.V.) and concentrated solar power (CSP) for electricity generation, the development of solar energy technology can significantly boost the nation's social and economic conditions. It is generally accepted that solar energy encourages equity by reducing the cost of electricity in towns and cities without grid connections. (Bondio et al., 2018). Solar energy has thus been touted as the most economical method of reducing the lack of access to electricity in developing nations like Nigeria. (Shahsavari, and Akbari, 2018). Aside from energy production, developing and applying solar energy technologies would boost the country's economy by generating jobs across many industries.

Geographically near to the equator, Nigeria is in a region with abundant sunlight, which increases its capacity to produce electricity using solar energy. (Abdullahi et al., 2017). A lot of research has been done to figure out Nigeria's solar energy possibilities. Estimates show that Nigeria's surface of the ground receives 25.2 MJ/m2 of solar radiation in the north and 12.6 MJ/m2 in the coastal regions daily. Nigeria's total geographical area reportedly gets an average of 17,459 billion M.J. of solar energy daily. (Giwa et al., 2017). In an additional study by Ohunakin, O.S. et al., daily mean solar insolation in the coast or southern region was calculated to be 3.5 kWh/m2 day. It was estimated to be 7.0 kWh/m2 per day in the northern part. In conclusion, there are usually seven to nine hours of daylight every day across the country. Riti and Shu (2016) estimate that solar panels could provide 1.85 106 GWh of electrical energy annually if installed on just 1% of the country's land area. This yield is anticipated to be over 100 times greater than the country's current energy distribution network.

Similarly, according to Giwa et al. (2017), only 3.7% of the country's landmass is suitable for solar farms that can produce enough solar energy to meet the country's electrical needs. The potential for solar energy in Nigeria was also assessed by Okoye et al. (2016). Lagos, Onitsha, and Kano were evaluated in the assessment due to their sizable populations and thriving economies. The investigation revealed that the solar resources in Lagos (South-West) and Onitsha (South-East) are almost identical, at 4.42 kWh/m2 and 4.43 kWh/m2, respectively. In the North-West geopolitical region, Kano City consistently has the most excellent mean daily global solar resource (6.08 kWh/m2). The distribution of solar radiation is even in Nigeria.

The results of evaluating the solar energy potentials over the vast territory of Nigeria were released (Olatomiwa et al., 2016). The researchers concluded that each of the country's six geopolitical zones had a highly concrete potential that was excellent for various purposes, including solar energy. Although the sunlight varies depending on location, it is often higher towards the country's north. The best places for large-scale solar ranches are in the northern area, especially in the geopolitical regions of the north, notably the northeast and northwest. Solar energy production has a lot of promise in these regions.

2.3 Classification of P.V. Solar System

Categorization of the PV Solar System

Different types of solar systems exist based on the technology's intended use. (Faranda and Leva, 2008.). Solar PV devices can be divided into the following three groups:

- Grid-connected (or grid-tied)
- Off-grid (or stand-alone or autonomous).
- Hybrid

2.3.1 Grid-Tied (Grid-Connected) Solar System

Utility-interactive or grid-connected photovoltaic systems are created to function alongside and close to the power utility grid. An essential component of solar systems connected to the grid is inverters, commonly referred to as power conditioning devices. (PCU). By converting the D.C. power generated by the solar panels into A.C. energy that satisfies the utility grid's criteria for voltage and power quality, the PCU automatically shuts off the electrical supply when the electrical grid is not powered. A bidirectional interface is established between the solar system, the alternating current output circuits, and the electricity distribution network at an on-site distribution panel or service entrance. When the PV system's output exceeds the demand for on-site power, the alternating current electricity from the PV system can power on-site electrical loads or back-feed the grid. The electric utility delivers the excess energy required by the loads at night and when the electrical demands exceed the PV system's production capacity.

All photovoltaic systems linked to the grid must have this safety component. It ensures that when the utility infrastructure is offline for maintenance or repair, the photovoltaic system won't keep operating and will feed back into it. The associated Figure 2.1 illustrates this. (Abdel-Salam et al., 2011)

Figure 2. 1: Block Representation of Grid-connected solar system.

2.3.2 Stand-alone Solar System

Standalone solar power systems are typically created and scaled to supply specific D.C. and A.C. loads and are intended to function independently of the electrical grid. These systems can run alone on solar cells or photovoltaic cells without the assistance of the wind, a power plant, or municipal electricity. The most fundamental kind of standalone photovoltaic system is a direct-coupled system. A solar panel or array's direct current output is directly connected to a direct current load. (Figure 2.2). Although direct-coupled systems need electrical energy storage (batteries) and the load only runs during the day, they are appropriate for typical applications like ventilation fans, pumps for water, and small circulation pumps for thermal solar water heating systems. The electrical load's impedance must match the P.V. array's maximum power output to create a high-performance direct-coupled system. The maximum power point tracker (MPPT), an electronic D.C. converter, is employed between diverse and specific loads, such as positive-displacement water pumps, to maximize the array's overall power output. (Abdel-Salam et al., 2011).

Figure 2. 2: Direct-coupled PV system

In freestanding photovoltaic systems, batteries are typically used as energy storage devices. Figure 2.3 shows a typical standalone PV system for powering AC and DC loads.

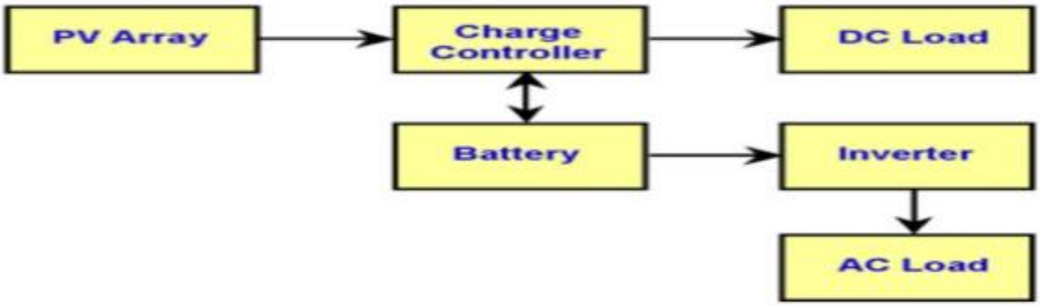

Figure 2. 3: Block Representation of stand-alone solar system with battery storage

2.3.3 Hybrid Solar System

The benefits of both grid-connected and standalone solar systems are combined in a hybrid photovoltaic system. They enable the selling of surplus energy and are connected to the grid. Energy storage and the capacity to disconnect from the grid while still supplying electricity to the home are two features of hybrid system topologies. In Figure 2.4, a hybrid photovoltaic system is shown. (Abdel-Salam et al., 2011)

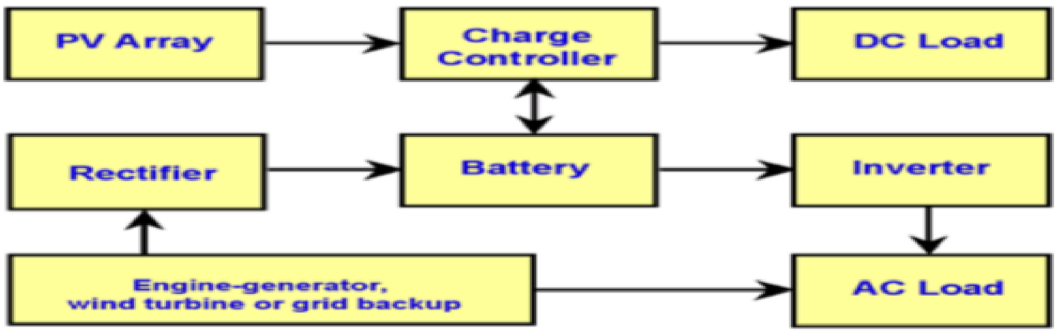

Figure 2. 4: Block Representation of a hybrid solar system

2.4 Review of the Components of a P.V. System

2.4.1 Photovoltaic Panels (P.V. Panels)

Informally, a solar panel refers to a photovoltaic (P.V.) module. A photovoltaic (P.V.) module is an array of solar cells installed in a framework ready for installation. Direct current electricity is generated by photovoltaic cells using sunlight as their energy source. A variety of solar cells is a collection of panels, while a photovoltaic (P.V.) The board is a collection of P.V. modules. Electrical equipment receives solar energy from photovoltaic arrays. (Wikipedia, 2020).

Figure 2. 5: P.V. module assembly

Solar photovoltaic cells, referred to as P.V. cells, are made from crystalline silicon wafers that are the same wafers used to make silicon chips and computer processors. Several methods are used to create silicon wafers, with the Czochralski process being the most used. Although this approach produces monocrystalline cells that are more effective, it is also more expensive and energy-intensive. The production of polycrystalline cells, which are less effective, uses a less complicated and more affordable casting method. A less expensive way of creating monocrystalline cells utilizing a process identical to that of polycrystalline cells, known as "cast mono silicon" or the "cast mono manufacturing process," has recently gained favor. Contrarily, cast-mono cells are less efficient than pure mono cells. (Cleanenergyreview, 2020).

• Monocrystalline silicon cells have the most excellent efficiency but the highest cost.

• Monocrystalline silicon cast cells with high efficiency and cheap cost

• Polycrystalline silicon cells have lower efficiency and expense.

2.4.2 Solar Modules

Since the evolution of solar panels systems, different manufacturers have designed several photovoltaic panels which are utilized according to environmental specifications.

The following are the different types of P.V. cells available in the market:

i. Monocrystalline P.V. Cells

ii. Polycrystalline P.V. Cells

iii. Hybrid P.V. Modules

iv. Amorphous P.V. Panels

2.4.2.1 Monocrystalline P.V. Cells

They are highly efficient, cost-effective, and dependable photovoltaic cells made from a single silicon crystal. Often referred to as the workhorses of the photovoltaic market due to their dependability and effectiveness. The efficiency rating is 800 kWh/kWp.

Figure 2. 6: Monocrystalline P.V. Cells

They are typically dark blue or black and have a uniform appearance.

2.4.2.2 Polycrystalline P.V. Cells

Polycrystalline PV cells are low-cost, low-performance photovoltaic cells made from multifaceted crystalline silicon and characterized by their crystalline structure. When compared to monocrystalline panels, they produce less energy. The efficiency is estimated to be 750kWh/kWp.

Figure 2. 7: Polycrystalline P.V. Cells

2.4.3.3 Hybrid P.V. Cells

These modules comprise amorphous and crystalline cells, providing the finest overall performance. Although the initial cost is higher than for other technologies, hybrid PV panels produce more kWh per year and thus have a shorter payback time. Its efficiency is 900 kWh/kWp.

Figure 2. 8: Hybrid P.V. Cell

2.4.3.4 Amorphous P.V. Panels

Amorphous PV has the lowest efficiency but excellent performance; however, it takes up much more room to produce the same comparative output as other technologies. As a result, they cost more and have an efficiency of 850 kWh/kWp.

Figure 2. 9: Amorphous P.V. panel

The solar module is the brain of a photovoltaic device. The producer wires numerous photovoltaic cells collectively to create

2.5 Inverter

Four (4) fundamental power conditioning duties that inverters carry out are:

- Ensuring that the A.C. cycles occur at a cadence of 50 cycles per second
- Converting the D.C. power from the P.V. modules or battery bank to A.C. power
- Minimizing voltage fluctuations.
- Making sure that the AC wave's shape is suitable for the system it is being used in, such as a grid-connected system's pure sine wave.

Direct current (D.C.) from batteries is converted to alternating current by solar inverters, which is used to power the majority of conventional electrical loads. Inverters are classified into two broad categories: string inverters and central inverters. String inverters are compact and ideal for medium-sized installations, whereas central inverters require a substantial installation. In comparison to string inverters, central inverters demand a great deal of room (Guizani and Ammar, 2015). Two types of waveforms are generated by an inverter.

- Square wave inverter
- Sine wave inverter

2.5.1 Square Wave

This represents one of the basic waveforms an inverter can make and may be applied to many situations. They are capable of running simple appliances without difficulty, but not much beyond. A basic oscillator can simply create square wave voltage. The produced square wave voltage may be converted into a value of 230Volts A.C. or greater using a transformer. Fig. 2.10 illustrates a typical square waveform.

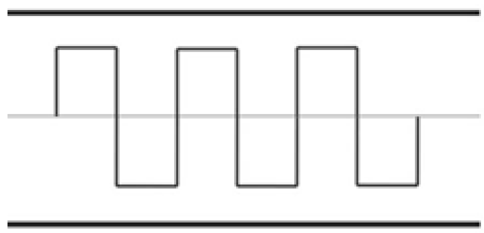

Figure 2. 10**:** Square waveform.

While the oscillator of square wave inverters is relatively straightforward to construct, the ratio of peak to RMS voltage is much different from that of a sine wave. Motors and transformers, in the example, will frequently draw considerably more current than they are rated for, causing them to overheat and die prematurely. However, the majority of switch-mode power switches will happily function from a square wave input. Interference suppression capacitors will be strained due to the square wave's rapid rising time. Peak and RMS values are the same for a square wave. If the voltage is decreased to correct the RMS voltage, many electronic power supplies will experience a significantly reduced input voltage because many filter capacitors charge to the voltage's peak. Certain loads will fail to turn on if the voltage is too low (Guizani and Ammar, 2015).

2.5.2 Sine Wave Form

A sine wave inverter is a power converter that produces an alternating current waveform with numerous steps or a smooth sinusoidal waveform. Manufacturers commonly use the term "pure sine wave inverter" to distinguish them from "modified sine wave" (three steps) inverters.

Nearly all consumer-grade inverters that advertise themselves as "pure sine wave inverters" provide a less choppy output than square wave (one step) and modified sine wave (three steps) inverters. The terms "pure sine wave" or "sine wave inverter" are deceptive to the customer. This is not a significant concern, given how efficiently most electronics manage output. Pure sine wave converters can precisely replicate the alternating current supplied by a wall outlet. Because of the extra electronics, sine wave inverters are frequently more expensive than modified sine wave generators. This cost is mitigated by its ability to power all alternating current electronic devices, accelerate and quiet inductive loads, and reduce audible and electric noise in audio equipment, TVs, and fluorescent lights. The sine a (sinusoidal) signal's waveform is shown in the histogram in Figure 2.11 (Guizani and Ammar, 2015).

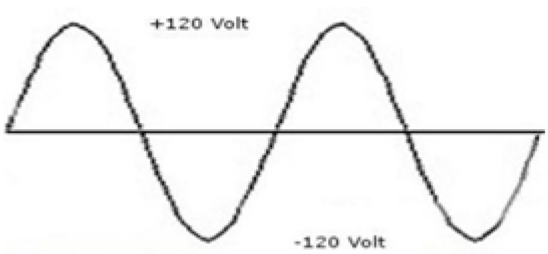

Figure 2. 11: Pure sine wave form

2.6 Battery Bank

A battery is a collection of numerous parallel or series-connected electrochemical cells capable of producing direct current energy via a chemical reaction between two electrodes and a chemical substance. A form of the energy storage device is a battery. Batteries do not produce energy; instead, they store and discharge it. Their voltage (V) and charge capacity ($Q = It$ in Amp-hours (Ah)) are measured. A battery's voltage rating indicates the maximum electromotive force (EMF in Volts) that it can provide. In contrast, its capacity means the amount of power (in Coulombs (C)) it can discharge under normal circumstances. Secondary cells and primary cells (non-rechargeable) are standard classifications for batteries—

(rechargeable). While the electrical energy in secondary batteries can be replenished by passing a direct current through the storm, the chemical energy in primary batteries cannot be recovered once used. (i.e., Recharging the battery). Because of their flexibility and ability to be reused multiple times throughout their useful lives, rechargeable batteries are frequently used for long-term uses. (Femia et al., 2008).

Electrical energy is stored or released when the battery's chemicals charge. This technique can be performed multiple times with rechargeable batteries. Batteries are only partially efficient since some energy is lost as heat during charging and discharging (due to internal resistance in the battery). If a battery is used at 1000 watts, it may require 1050, 1250, or more watts to recharge it completely. Internal resistance is responsible for some, if not most, of the losses involved with charging and discharging batteries. Because this energy is converted into heat, batteries become heated during filling. The lower a storm's internal resistance, the better. Charging and discharge speeds that are slower are more efficient. A battery with a 180 amp-hour capacity for six hours of use may have a 220 amp-hour ability for twenty hours and a total capacity of 260 amp-hours for 48 hours. Because of more excellent internal resistance, this efficiency loss occurs at higher excellent amperage rates. Under ideal conditions, genuine deep-cycle AGMs (such as Concorde and Genus) could achieve 98%. When sizing batteries and battery banks, accounting for a ten percent to twenty percent total power loss is critical. In photovoltaic systems, the following battery types are commonly utilized:

- ❖ Lead-acid batteries
    - Flooded (Liquid vented)
    - Sealed (Valve-Regulated Lead Acid)
    - Absorbent glass mat
    - Gel cell

- Alkaline batteries
    - Nickel-cadmium
    - Nickel-iron

2.6.1 Lead Acid Batteries

Lead-acid batteries are the most common form used in solar systems, whereas sealed lead-acid batteries are the most common in grid-connected systems. Sealed batteries are resilient to liquids and do not require routine maintenance. Although flooded lead-acid batteries are typically the cheapest, they need distilled water to be used at least once a month to replace the water lost during regular charging. The two types of encased lead-acid batteries are AGM and gel cell batteries. AGM lead-acid batteries have become the industry standard owing to their ease of maintenance and suitability for grid-connected equipment where batteries are typically kept at full charge. Even though gel-cell batteries are designed to withstand freezing temperatures, they are frequently a bad option because overcharging them can permanently damage the battery. (Femia et al., 2008).

Almost all big rechargeable batteries are made of lead acid. At full charge, lead-acid batteries generally contain 30% sulfuric acid and 70% water, with an efficiency of 85-95 per cent. Almost all batteries used in photovoltaic and backup systems are lead-acid. They continue to give the finest price-to-power ratio even after over a century of usage. Maintenance-free (valve-regulated) AGM deep-cycle batteries are used in stand-alone solar systems.

2.6.2 Alkaline Batteries

Alkaline batteries are only advised in extreme temperatures (-50ft or less) or for specialized commercial or industrial applications where the benefits over lead-acid batteries are required. This is due to their relatively high cost. These advantages include being fully discharged or overcharged without suffering damage, resistance to extreme cold and heat, low operating temperatures, and minimal maintenance requirements. Alkaline batteries typically have an efficacy of 65%. (Femia et al., 2008).

2.6.3 Battery Lifespan

A deep cycle battery's lifespan will differ significantly depending on how it is used, charged and maintained, the temperature, and other factors, and it can vary drastically in extreme circumstances. The batteries listed below should perform as expected (minimum-maximum) when used in deep cycle applications.

- Industrial deep cycle: ten to twenty years.
- NiFe (alkaline): five to thirty-five years.
- NiCad: one to twenty years.
- Starting: three to twelve months.
- Marine: one to six years
- Gelled deep cycle: two to five years
- Deep cycle (L-16, etc.): four to eight years.

2.6.4 Amp-Hours Rating of Batteries

Amp-hours are the unit of measurement for every deep cycle battery. One amp-hour equals one ampere for an hour, ten amperages for one-tenth of an hour, etc. The "20-hour rate" refers to the widely accepted endurance of batteries utilized in solar electric and emergency power systems. (And for almost all deep-cycle batteries). (Some, such as the Concorde AGM, use the 24-hour rate, which is likely a more accurate representation of real-world performance.) This implies that the battery is drained to 10.5 volts over twenty hours while the actual amp-hours provided are measured. Ratings at the six-hour and one-hour rates are occasionally added for comparison and various uses. Frequently, industrial batteries are charged at a 6-hour pace.

2.6.5 Battery Aging

Battery care must evolve as the batteries age. Consequently, charging time is extended, and the completion rate increases. (higher amperage at the end of the charge). In general, older cells necessitate more frequent watering. (for vented maintenance batteries). Furthermore, as their rate of self-discharge increases, their capability decreases. (Ali et al., 2012).

This project's battery bank was built with deep cycle rechargeable AGM lead-acid batteries to ensure that the batteries' energy can be provided during the day via solar panels and the energy stored can be used at night, as well as for longevity and maintainability.

2.7 Charge Controller

Charge controllers, also known as photovoltaic controllers or battery chargers, are required exclusively in systems with battery backup. A charge controller's principal role is to prevent batteries from being overcharged. Additionally, a low voltage disconnect must be included to prevent batteries from being over-discharged. Furthermore, charge controllers prohibit charges from being returned to solar modules during the night. Maximum power point tracking is a feature of some modern charge controllers that increases the output of the photovoltaic array and, consequently, the quantity of energy produced. For the charge controller's D.C. input voltage to function optimally, the standard voltage of the solar panel array and the battery bank must coincide with calculating how much current should be fed to the battery bank. Although there are many other charge controllers, the most popular ones are PWM (Pulse Width Modulation) and MPPT (Maximum PowerPoint Tracker). Both charge controllers adjust charging rates in reaction to the battery's charge level, enabling charging closer to the battery's total capacity while simultaneously keeping an eye on the battery temperature to prevent overheating, which is preferred to extend the life of the battery bank. (Ali et al., 2012).

Figure 2. 12: PWM charge controller

2.8 Disconnects

Wiring and components are shielded from electrical surges and other device malfunctions by automatic and manual safety disconnects. They also guarantee that components of the system are capable of being safely removed for maintenance and replacement. The system's power sources and energy storage components must all be turned off. The following is a description of the numerous disconnects.

- **Array DC disconnect:** For reasons of repair and maintenance, the solar-based D.C. electric disconnect, also known as the "P.V. disengage," is used to stop the electricity flowing from the solar P.V. panels safely.

- **Inverter DC disconnect:** The inverter D.C. electric disconnect is used with the inverter A.C. electric disconnect to effectively and safely disconnect the Inverter from the solar system. The Inverter's direct current disconnect is the array's quick recent break.

- **Inverter A.C. disconnect:** The primary purpose of the inverter A.C. electric disconnect is to disconnect the solar electric P.V. system from the building wiring and the electric utility infrastructure for a grid-connected P.V. system. The A.C. electric disconnect is typically located inside the electrical panel of the building. A second A.C. electric disconnect is employed and placed close to the inverter, if not near the building's board.

- **Battery disconnects:** In a standalone solar PV system, the battery bank D.C. electric disconnect is responsible for safely and securely removing the battery bank from the photovoltaic (PV) system.

Other System Components applicable to all types of P.V. solar systems are discussed below.

2.9 Array Mounting Racks

Most often, arrays are installed on roofs or steel poles anchored into concrete, and they could be mounted on building walls or ground level, depending on the purpose Roof-mounted PV arrays are generally positioned on a fixed rack that runs parallel to the rooftop and is elevated a few inches above the roof to enable ventilation while keeping the solar panels as quickly as possible.

2.10 Grounding Equipment

Grounding equipment provides a clear, low-resistance path from the PV system to the ground to protect it from current surges produced by lightning strikes or equipment breakdowns. Additionally, grounding gives a common reference point and stabilises voltages. Typically, the grounding harness is situated on the roof.

2.11 State of the Art Literature Review

Any research project driven by the wish to fill a research gap identified in a specific topic area must include a literature review as a critical component. Numerous research papers utilizing different research findings have been published in the realm of renewable energy and the development and implementation of solar systems. As a result, this study shows several important research projects in photovoltaic (P.V.) systems for power production and renewable energy systems.

To explore how a semiconductor material used in a photovoltaic cell might affect how well the solar cell performs under various conditions, including temperature, weight, and other variables, Britt and Wiedeman (2012) published experimental research. The authors have conducted several experiments to create novel methods and equipment for fabricating semiconductor thin-film layers. (Britt, and Wiedeman, 2012). Multi-layer materials and the direct conversion of solar energy to direct current electrical power are included in the broad field of photovoltaics. The primary mechanism underlying this conversion is the photovoltaic Effect. In a conventional solar cell, P-type and N-type semiconductors are sandwiched together, with the N-type semiconductor material displaying many electrons on the opposite side and the P-type semiconductor material depicting numerous holes, each representing the absence of an electron. (Britt, and Wiedeman, 2012).

Solar cell efficacy has been a goal of Frank and Milton's (1995) research. They found that the photovoltaic cell can be improved by changing the semiconductor material combination because the efficacy of solar cells varies between 15% and 22%. The researchers thoroughly evaluated the semiconductor material's characteristics and created a cascaded cell configuration that allows for more than 23% overall efficiency. (Frank and Milton, 1995). The material for a solar cell with an N-Type and P-Type Gallium Arsenide busy junction has previously been suggested to be either Germanium or Gallium Arsenide. Developing solar cells that effectively use the broadest range of sunshine is still underway. Given that it is transparent to light with energy from photons over the band gap, the material that makes up the semiconductor in the solar cell needs to have a small band gap to absorb as many protons as possible.

Solar energy collectors with concentrators were studied by Bareis et al. They claimed in their study that there are two kinds of solar collectors: concentrating and non-concentrating. (non-concentrating type). As a concentrating solar energy receiver, a primary parabolic reflector with a fixed point, a highly reflective surface on the concave side, a fixed axis extending from the open side of the glass, and a conversion module with a reception surface were all developed. The parallel, unfocused rays from the sun are intercepted by non-concentrating solar collectors using a collection of photovoltaic cells. The primary function of the array is the result. (Bareis et al., 2004).

The performance of a solar energy conversion system is influenced by several elements, including the quantum of radiation, intensity, direction, collector tilt angle, and temperature, according to Zhao's 2009 research on solar energy collection and utilization devices. (Zhao, 2009.). The apparatus comprises a paraboloidal mirror, a solar light collector, a solar energy storage and conversion mechanism, and solar energy monitoring equipment. The feasibility of deploying solar power systems to influential rulers and residential areas in Iran was evaluated by the author of (Sadati et al., 2010). They argued that solar energy is the most plentiful type of energy and that it is a resource that can be used cleanly and sustainably if the appropriate technology is in place.

Oko and Nanchi's research determined the ideal collector tilt angle at low latitudes. (Oko and Nanchi, 2012). On the Earth's inclined and horizontal surfaces, clouds, dust, and shadow all impact how solid solar radiation from space is. When designing solar equipment, the design engineer must prioritise capturing as much insolation as possible for the equipment to function effectively.

Nataraj et al. (2012) researched the application of circuit models to energy conversion devices. (Nataraj et al., 2012). Solar energy is directly transformed into electrical power without using any electrical components when a system of photovoltaic cells is used. The solar system's conversion effectiveness technology ranges from 15% to 25%, primarily because D.C. energy is converted to A.C. power via battery bands. A failure occurs on average every four to five years in working photovoltaic systems, with inverters accounting for 63% of losses, modules for 15%, and other components for 23%. (Nataraj et al., 2012). Reduce the failure rate of inverters and other crucial elements to lower the failure rate of solar systems.

Njoku and Ekechekwu (2011) investigated the thermal efficiency and modelling of a reverse absorber shallow solar pond. Two reverse absorbers shallow solar pond (RASS) configurations—one with the top insulated and the other with the top exposed—are offered for theoretical thermal analysis and simulation of their performance. The intended outcome parameters are found by solving the related model equations. They conduct simulation trials and provide visual explanations of the planned research project. Several studies are being conducted to determine how to integrate these solar system applications with specific changes. An example of a "Collection-Cum-Storage" water heater is a shallow solar pond (as opposed to larger non-convictive salt gradient solar ponds). Typical solar ponds reach temperatures of less than 1000 degrees Celsius. (Njoku and Ekechekwu, 2011).

2.12 Review of Existing Systems

Over the years, numerous methodologies have been used in several evolutionary solar system studies. The following paragraphs will examine the merits and shortcomings of each design to separate one work from another completely.

On a human scale, renewable energy is typically produced from resources that naturally replenish themselves, such as sunshine, wind, rain, tides, waves, and geothermal energy.

Renewable energy replaces conventional fuels in four areas—electricity manufacturing, air, and water heating/cooling, fuel for vehicles, and remote (off-grid) energy services.

Ibrahim and Victor's (2016)'s Figure 2.1 shows how an evacuated-tube collector, a latent thermal storage system, and a backup electric heating source were used to build a hybrid indirect solar-powered cooker with latent heat storage. In this system, energy was provided in two different ways: first, by a fluid that transfers heat to the cooking pot, and second, by electrical means. The thermal storage unit received the heat transfer fluid from the evacuated tube collector, fed by natural convection. The phase-changing substance uses heat from the fluid that operates to cook food during the day and at night using a heat exchanger. The thermosyphon phenomenon causes the hot working fluid to move upwards. Due to the vacuum created by the evacuated tube collector, the tube can act as both a barrier and a super-greenhouse. This design has the disadvantage that the thermal transfer fluid needs to be changed periodically to keep the process going. It also helps to keep food warm until late at night.

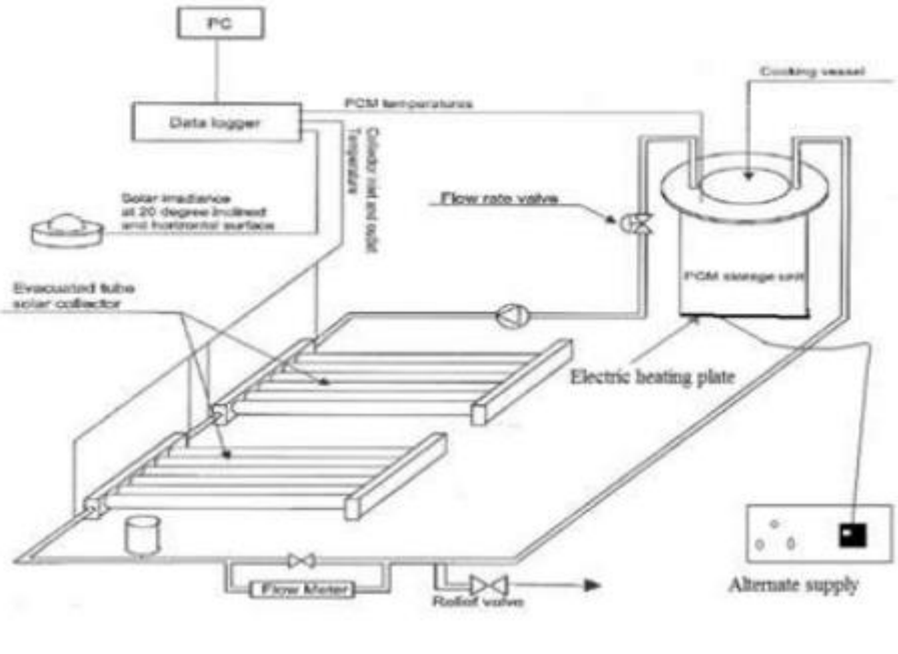

Figure 2. 13: Hybrid solar cooker with latent heat and alternative supply

(Roslan et al., 2019) They have developed a portable solar storage (PSS) system that packs an off-grid solar station's components into a small, mobile, handheld case. Outdoor enthusiasts who need a portable power source for charging their gadgets while participating in their hobbies, such as hikers, campers, and climbers, are the target audience for the PSS. A solar panel's input current and voltage were tested over two weeks. Solar energy produces electricity on 12-volt and 18-volt solar panels, which is then stored on a 98-Watt energy storage system underneath the solar panel. When the stored energy was tested, it was discovered to recharge devices with as much as ten thousand mAh of capacity.

Figure 2. 14: Portable solar storage device

(Gawali and Papade, 2015) They created a solar oven using reflectors and a direct current heater, as shown in Figure 2.15. The apparatus consists of a thermal power storage tank where sensible heat from the sun's thermal energy is stored using a variety of oils. A battery and solar panels are also used to power an additional D.C. heater installed inside the tank. Solar energy is concentrated at a focal point on a thermal storage tank by a solar collector using a parabolic reflector. Figure 2.3 depicts the layout of the thermal storage tank. A heat-storing fluid is heated to its maximum temperature based on several characteristics, such as collection area, emissivity, absorptivity, reflectivity, and boiling/smoking temperatures. Because the density of the heated oil near the focal point diminishes, it rises in the thermal storage tank, taking up space that was previously filled by cold oil. By utilising the natural circulation occurrence, the entire amount of oil that is present in the tank is heated in this manner. When the sun's intensity decreases, insulation is introduced to the tank to prevent heat from leaking into the sky.

Once more, the device uses an auxiliary D.C. heater that is submerged in oil. The batteries that power this warmer are recharged using solar power. The usage of oil, which must be changed regularly because heating oil reduces its heating capacity with use, is a crucial disadvantage of the system.

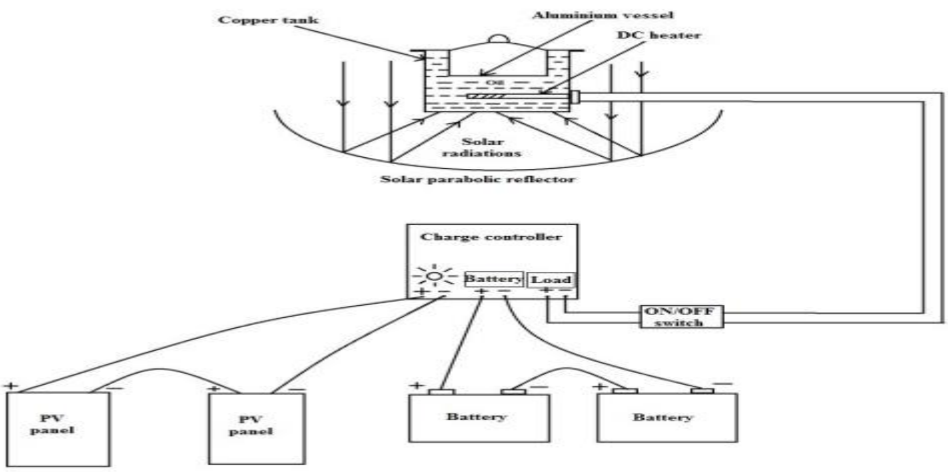

Figure 2. 15: Solar cooker using heating oil

(Dharmaraj et al, 2020) They developed an affordable mobile-based multi-purpose monitoring system to provide solar energy while tracking climate and air quality. The main parts of the monitoring station were built with an Arduino Mega 2560, an MQ135 gas detector, and a PV solar panel.

On the other hand, the program was made in C utilizing the Arduino IDE. Statistic data on environmental temperature, harmful gas concentrations, and alternating current voltage are gathered from monitoring the station. According to several test findings, the projected voltage, temperature, and air quality ppm ranges were eleven to thirteen Volt, 27.31 to 28.13 0C, and 70 to 83 ppm, respectively. These results support earlier studies and demonstrate that the solar-powered gadget can reliably send voltage, temperature, and air quality data. The Blynk cloud server allows remote access to the data from the monitoring station. It can be positioned anywhere for long-term monitoring because it is portable and powered by itself.

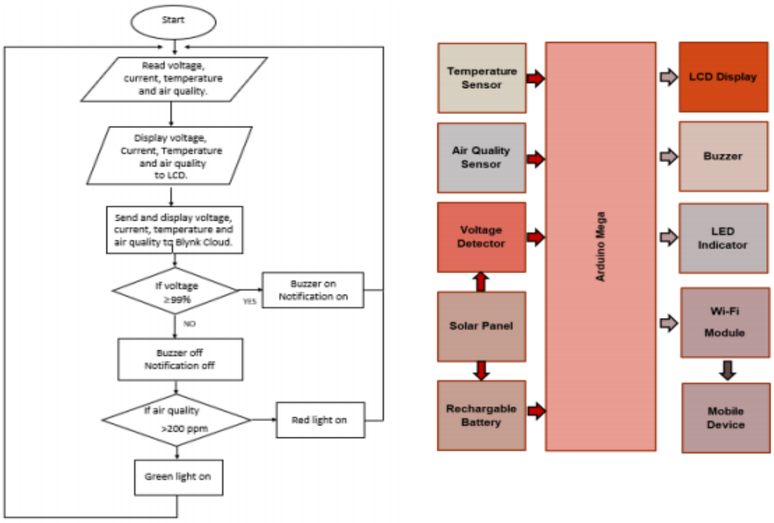

Figure 2. 16: Proposed system design of Mobile Solar Power Monitoring Station Powered by IoT.

Figure 2. 17 Mobile Solar Power Monitoring Station Powered by IoT.

(Kattimani et al, 2020) They created a 'Solar Powered Portable Electrical Vehicle Charging Station' on a hybrid power system. The solar energy is converted to electricity and used to fill the lead-acid battery, which charges the batteries of the electric vehicles (EVs) connected to this station. Energy from the power grid is utilized when solar-generated energy is insufficient to meet demand. This station has several features this station has features, such as amusement, WiFi connectivity, cloud storage, and the Thingspeak platform, to make the design more user-friendly. They could be placed in hotels, clubs, retail stores, train stations, shopping malls, universities, colleges, airports, and other public places.

Figure 2. 18: Solar-powered portable electrical vehicle charging station.

CHAPTER THREE

MATERIAL AND METHOD

3.1 Conceptual Factors

The approach used in this project is modular. To better understand the project objective, each stage of the design analysis is addressed separately. The following elements of the design will be taken into consideration before moving on to the design analysis.

3.2 Planning/System Sizing

To satisfy the load requirement for domestic and household appliances at deployed locations, a mobile 1.5 kVA solar power station is proposed. The suggested system's block diagram is displayed in Fig. 3.1. The P.V. module, Charge Controller, Battery, Inverter, and A.C. inputs comprise the system. The photovoltaic (P.V.) modules convert solar radiation from the sun into direct current (D.C.). This current is then used to power A.C. loads through an inverter and to fill batteries through a charge controller. The battery is a storage device and powers the burden when there is little solar radiation.

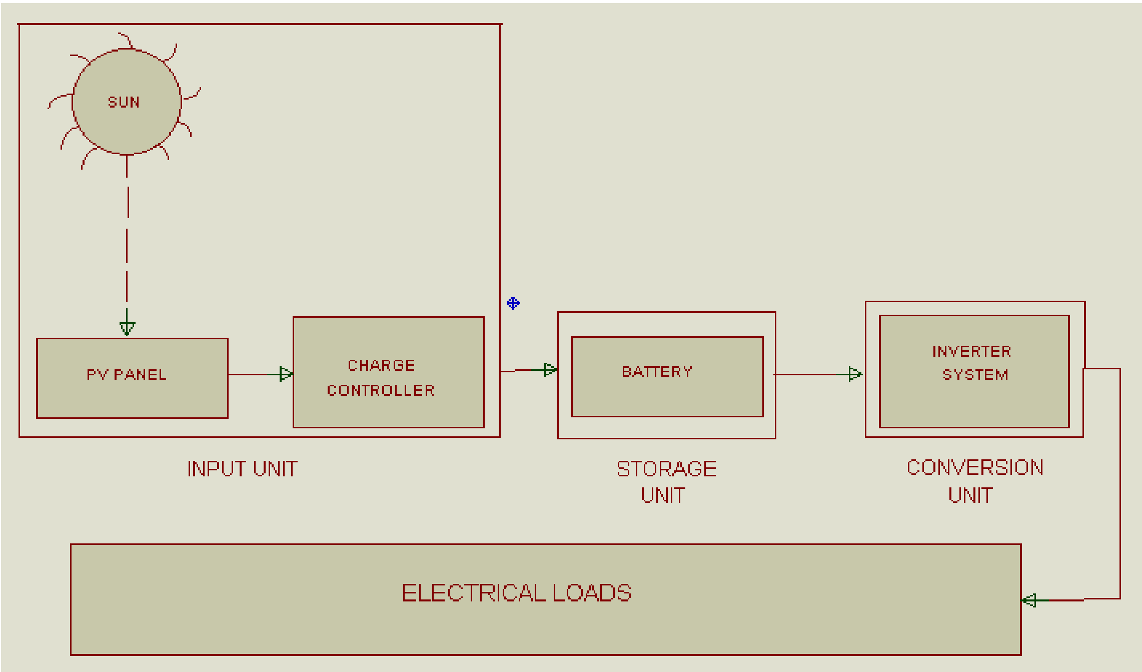

Figure 3. 1: Block Diagram of Proposed Mobile Solar Power Station.

3.2.1 Solar panel selection

The output of solar energy calculation

A hypothetical sphere's surface area is given by:

$$A_s = 4r_S\pi^2 3.23$$

$A_E = 4\pi r_E^2$ Considering that the sun's typical distance from Earth is 1.5×10^8 km

Now, taking into account a sphere with a radius of 1.5×10^8 km and has the sun as its center

Let A_s = hypothetical sphere's surface area

A_E = Earth's cross-sectional area

r_S = The sphere's radius,

r_E = The earth's radius

Where;

$r_E = 6.4 \times 10^6$ km

$r_S = 1.5 \times 10^{11}$ km

$A_E = 4\pi r_E^2 = 3.142\ (6.4 \times 10^6)^2 = 1.287 \text{ x } 10^{11}$ m^2

$A_S = 4\pi r_S^2 = 4 \text{ x } 3.142\ (1.5 \times 10^{11})^2 = 2.828 \text{ x } 10^{23}$ m^2

Percentage of Sun's output is given by:

$$\frac{A_E}{A_S}\ X\ 100$$

Therefore,

$$\left[\frac{1.287 \text{ x } 10^{11}}{2.828 \text{ x } 10^{23}}\ X\ 100\right] = 00000000455\%$$

The inference is that 00000000455% of the energy from the sun is received by the Earth.

Extraterrestrial radiation detection in Nigeria

(Folaranmi, 2009) Given that solar radiation differs by location, extraterrestrial solar radiation in Nigeria can be calculated using the following equation:

$R_x = I_{XC} A_{CL} 3.26$

Where;

R_x = Extraterrestrial radiation,

A_{CL}= Continental area,

I_{XC} = Solar constant

Given their equivalent as;

R_x = 1.262 × $10^{15} W/m^2$

I_{XC} = 1353kWh

A_{CL} = 932768 x 10^6

Assuming an annual average of 9 hours of sunshine per day

R_x = 1353 x 10^3 x 932768 x 10^6 x 3.26

R_x = 1.262 × $10^{15} W/m^2$

R_x = 1262 × 10^{15} x 366 x 9

Therefore,

R_x = 4.157× 10^{18} Wh/year

Since only 47% of interplanetary and terrestrial radiation reaches the earth's surface in Nigeria, a clearness index of 50% is used. (Folaranmi, 2009).

Establishing,

R_x = [(50/100) ×4.157 ×10^{18}] = 2.079 × 10^{18} Wh/year

To determine the direct radiation that strikes the surface of the earth as a function of location (γ), angle of declination (δ), and time of day (t).

Let,

Z = Zenith angle,

γ = Latitude of location,

δ = Declination angle,

t = Hour angle of the sun.

Iz = direct solar radiation,

I_{XC} = extraterrestrial solar radiation constant,

I_h = horizontal radiation

Additionally, the climate visually determined constants x and c, are provided.

Zenith angle is determined by

$\cos z = \sin \gamma \sin \delta + \cos \gamma \cos \delta \cos t$ 3.27

$= \sin 14^0 \sin 0 + \cos 14^0 \cos 0^0 \cos 0^0$

$= 0.2192 \times 0 + 0.970291 \times 1 = 0.97029$

$Z = \cos^{-1} (0.97029) = 14^0$

After passing through the atmosphere, the solar radiation is thus:

$I_Z = I_{XC}\ ^{eC\ (secz)\ x} = 1353e^{-\ 0.357\ (1/cos14)\ 0.678}$

Therefore,

$I_{.Z.\ =}$ 940 w/ m^2

I_Z is the highest incidence value. Only a system automatically checks the radiation from the sun and can obtain direct radiation on a steady surface

Table 3. 1: Solar Panel Parameters

Technical description	**Specification**
E	1000 w/m^2
T.C.	25^0C
Maximum power (Pmax)	150 W
Output tolerance	$\pm$5%
Current at peak (Imp)	8.57 A
Voltage at Pmax (Vmp)	17.5 V
Short - Circuit Current (Isc)	9.60 A
Open - Circuit Voltage (Voc)	22.05 V
Maximum System Voltage	1000 V
Maximum Series Fuse Rating	10 A

3.2.2 Selection of charge controller and battery

In the selection of the charge controller, in addition to selecting a controller with a wide voltage range, the following features were taken into consideration.

i. Clock timing function

ii. Regulatory mechanism for temperature compensation

iii. Ultra-Low Power Consumption

iv. Built-in solar data monitoring interface

v. LCD Display with backlight

vi. Good heat dissipation effect with less noise

vii. Light and Time control mode.

viii. Reverse protection, short circuit protection

Also, the MPPT charge controller suitable had the following Protection features:

i. Photovoltaic array short circuit.

ii. Over-discharge Protection.

iii. Discharge voltage protection.

iv. IP21 Mechanical protection.

v. Load overload protection.

vi. The input low voltage protection.

vii. P.V. Lightning protection.

viii. Battery reverse polarity.

Figure 3. 2: Maximum Power Point Track Charge controller

The extraterrestrial solar radiation landing on the panel and the battery used on the system, as shown in Figure 3.7, influenced the charge controller selection.

Table 3. 2: Charge Controller and Battery specifications

Technical description	Specification
Rated Voltage	12 V/24 V/48 V
Rated Current	30 A
Max PV Voltage	160 V
Max PV Input Power	780 W
Battery Voltage	12 V
Battery Current	200 AH

3.3 Design Calculations

The Mobile Solar Power station design will be implemented as depicted in Fig. 3.2

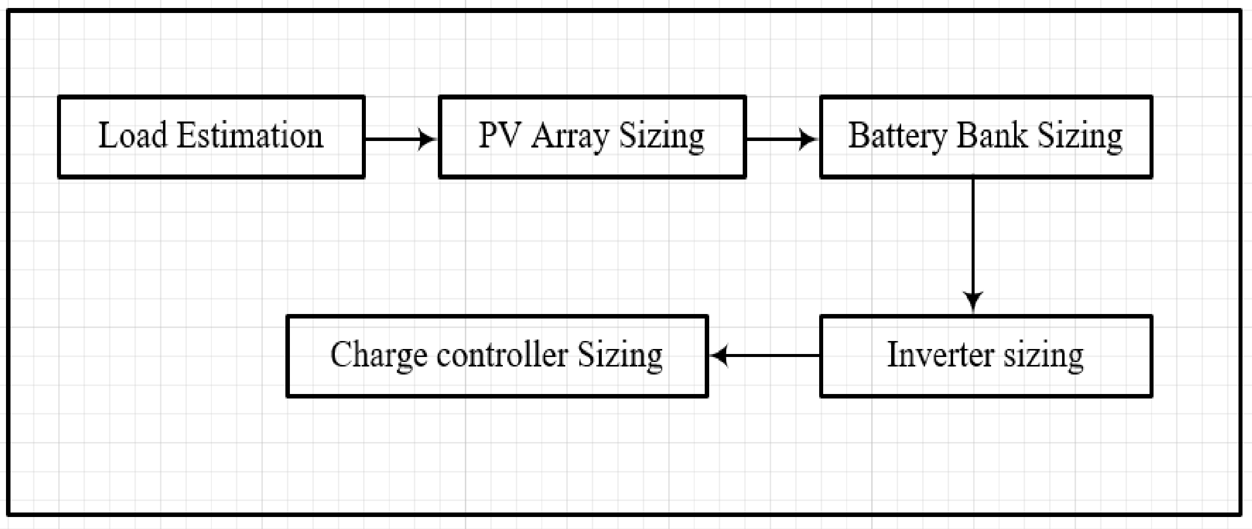

Figure 3. 3: Block Diagram of the Design Steps

3.3.1 Load Estimation

The 1.5KVA Mobile solar Power station will be deployed for the charging of mobile phones, and thus the power factor is negligible. But for a more robust and efficient system, a power factor of 0.85 is adopted. The power rating of a typical modern smartphone ranges from 5W to 20W. Also adopting an overall system efficiency of 80%, the maximum load that can be supplied by the system is computed as follows

$$Solar\ power\ plant\ capacity = 1.5kVA$$

Converting to watts by a power factor of 0.85 we have

$$Solar\ power\ plant\ capacity = 1.5kVA \times 0.85 \times 0.8 = 1020W$$

Hence the Mobile solar power station will be designed to power a maximum A.C. load of 1KW

Total Daily Ah Demanded by the Load From the Storage System

Typically, it takes between 2h to 4h to charge a Mobile Phone from 0 to 100%. Thus, the total energy demand per day is;

$$Total\ Energy\ Demand = 1kW \times 4h$$

$$= 4kWh$$

$$\text{Total Ah demand from Storage/day} = \frac{\text{Total Wh demand/day}}{\text{Battery bus voltage}} \quad (3.1)$$

$$= \frac{\text{4000Wh/day}}{\text{12V}} = 333.33\text{Ah/day}$$

Hence the total daily Ah demanded by the load from the storage system is 333.33Ah.

3.4 Components Sizing and Selection

This section presents the design steps followed to arrive at the size and number of the system components required for the Mobile Solar Power Station.

3.4.1 PV Specification and Sizing

The Solar P.V. array is the main component of a stand-alone P.V. system. It is a combination of solar modules. The following data for a typical 300W mono crystalline solar panel are used for the P.V. array sizing.

Table 3. 3: P.V. Array Size to Meet Design Requirements

PARAMETERS	PANELS
P_{pv}	300W
V_{pv}	24 V
Solar Irradiation (G)	800
V_{oc}	33 V
V_{max}	27.5 V
PSH (Nigeria)	6h
Efficiency (%)	80
I_{sc}	10.99

$$N.(Panels) = \frac{Total\ Load\ Energy}{P.S.H \times P_{PV} \times \eta_{system}} \quad (3.2)$$

Where: η_{system} is the total efficiency of the overall system

PSH is the calculated peak sun hour for the study site

$$N.(Panels) = \frac{4000}{6 \times 300 \times 0.8} = 2.77$$

The P.V. array of the system consists of 3 panels in parallel.

Nominal Rated Array Output

The nominal rating of a P.V. module is the power rating as indicated on its nameplate. For the P.V. module selected, the nominal power rating of one module is 300W. Hence the nominal rating of the array of 3 modules is computed as:

$$Norminal\ \ Rating = Total\ No.of\ modules \times nominal\ rated\ P.V.module\ output$$

(3.3)

$$= 3 \times 300 = 900 \text{ W}$$

Nominal Rated Output Current of the Array

$$I_{pv} = \frac{Nominal\ power\ output\ of\ array}{System\ D.C.voltage}$$

(3.4)

$$I_{pv} = \frac{900}{12} = 75A$$

3.4.2 Battery Bank Specification and Sizing

For sizing the Battery Bank subsystem, certain parameters which include Battery Voltage ($V_{Battery}$), Battery efficiency ($\eta_{Battery}$), and The A.H. rating of the battery is acquired from the manufacturer's data sheet for the chosen battery. The total quantity of batteries needed for the design is as follows:

$$AH_{Total} = \frac{Total\ Load\ Energy \times AD}{DOD \times \eta_{Battery} \times V_{bus}} \quad (3.4)$$

Where:

$Total\ A.H.$ = Total ampere-hour required to meet the design requirements.

A.D. = Days of autonomy to be decided based on design requirements

DOD = Depth of discharge to be selected based on batteries specifications a DOD of 60% is sufficient for most designs.

V_{bus}= Bus Voltage and is taken as a standard voltage close to or equal to the open-circuit voltage of the P.V. panel

$$AH_{Total} = \frac{4000\times1}{0.8\times0.8\times12} = 520.83$$

$$N.(Parallel\ branches) = \frac{AH_{Total}}{AH_{Battery}} \quad (3.5)$$

$$N.(Parallel\ branches) = \frac{520.83}{200} = 2.60$$

The number of batteries in each parallel branch is computed from equation 3.7

$$N.(batteries\ in\ each\ branch) = \frac{V_{bus}}{V_{Battery}} \quad (3.6)$$

$$N.(batteries\ in\ each\ branch) = \frac{12}{12} = 1$$

The total number of batteries required to meet the design requirements can be obtained from equation 3.7

$$N.(Batteries_{Total}) = N.(Parallel\ branches) \times N.(batt.in\ each\ branch) \quad (3.7)$$

Hence a total number of three (3) 200AH batteries is required to meet the energy requirements of the mobile solar power station.

Table 3. 4: Battery Bank Size to Meet Design Requirements

Parameters	**Batteries**
$V_{battery}$	12V
Autonomy	1
DOD	80%
V_{bus}	12V
Efficiency	85%
Total AH	520AH
Battery AH	200AH
N. (Parallel branches)	3
N. (Batteries/ branches)	1
N. (Batteries)	3

Charging Time of Battery Bank

$$Charging\ time = \frac{Total\ Ah\ capacity\ of\ battery\ bank}{Charging\ current} \quad (3.8)$$

$$Charging\ current = \ 10\%\ of\ total\ battery\ Ah \quad (3.9)$$

$$Charging\ current = \ 10\%\ of\ 900Ah = 90A$$

Practically, 40% of losses are considered during battery charging.

Hence, total battery bank Ah capacity

$$= (900 \times 0.4) + 900 = 1260A\text{h}$$

$$Charging\ time = \ \frac{1260Ah}{90A} = 14\ hours$$

Hence the total time required for the battery bank to charge fully is 14 hours

3.4.3 Inverter Sizing

For sizing the Inverter, equation 3.11 is adopted.

$$Rated\ Capacity = \frac{Load\ Power \times Safety\ Factor}{PF} \quad (3.10)$$

Where: *P.F.* is the power factor.

A safety factor of 1.25 will be adopted for this design.

$$Rated\ Capacity = \frac{1000 \times 1.25}{0.85} = 1470\text{VA}$$

Hence, a power inverter rated at 1.5KVA will meet the design requirements

3.4.4 Charge Controller Sizing

For sizing the Charge Controller, equation 3.12 is adopted.

$$I_{\min} = \frac{Total\ NO\ of\ Panels \times P_{PV}}{V_{bus}} \quad (3.11)$$

Where: $I_{\min}$ is the minimum charging current of the MPPT Charge Controller?

$$I_{\min} = \frac{3 \times 300}{12} = 75A$$

As a result, a Maximum Power Point Tracking (MPPT) charge controller rated at 75A or higher fulfills the design requirements.

3.5 Summary of Component Sizing

Table 3. 5: Summary of component selection and sizing

S/N	Component	Description	Result
1	A.C. load	Maximum A.C. power demand	1000W
1	Load estimation	Total load estimation	4000Wh/day
		Total Ah demand/day	520/day
2	P.V. arrays	Array output/day	$5400Wh/day$
		Total number of modules	3 modules
		Nominal array output	900W
3	Battery bank	Battery bank capacity	$600Ah$
		Total number of batteries	3 batteries
		Charging time of the battery	14 hours
4	Charge controllers	The capacity of the charge controller	75A
		Total number of charge controllers	1 controller

3.6 Hardware Design/Development

The system components as presented in Table 3.3 will be used for the implementation of the mobile solar power station. The circuit diagram for the hardware design/development is presented in Fig. 3.3

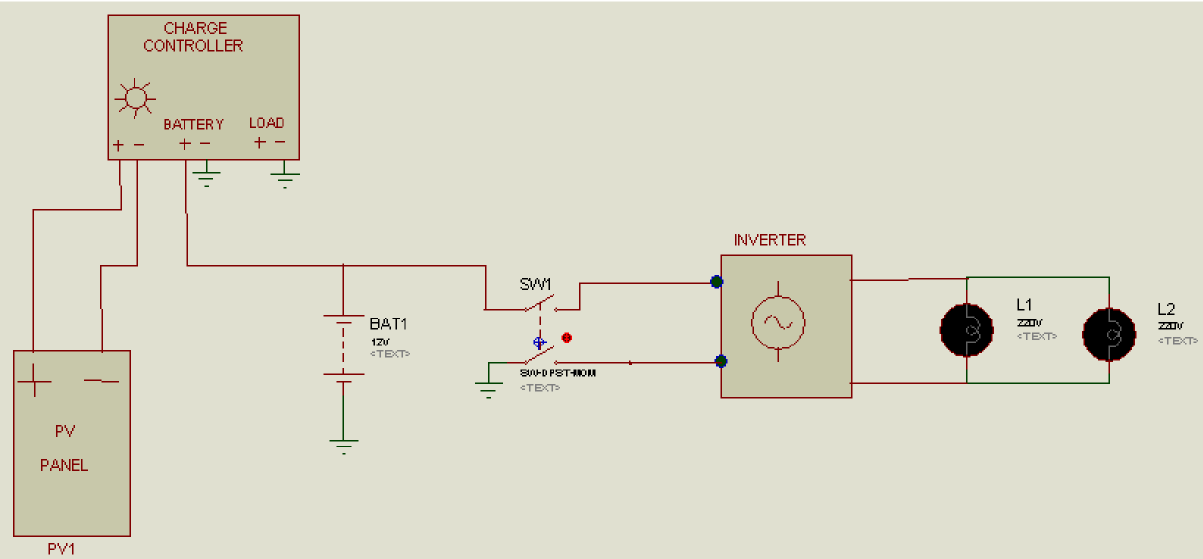

Figure 3. 4: Circuit Representation of the mobile solar power station

3.7 System design simulation

The solar mobile charging station design and simulation considered in this project design was based on data collected within Benin and its environs. The solar mobile charging station was analyzed using HOMER software. Analytical methods which included load flow and power flow analysis within the grid was considered for assessing the impact of synchronizing and controlling the power system network. The execution of this project design started with a collection of data from NASA prediction of worldwide energy resources POWER database, national renewable energy laboratory database on BENIN monthly average wind speed data, solar global horizontal irradiance data, and temperature data. Furthermore, the solar mobile charging station connections with the solar panel details, charge controller details, battery details and schematic diagram showing how each component are interconnected within the system considered for synchronization was obtained. The synchronization model in this research study is simulated using HOMER software and the electrical load profile, monthly electrical production and cost of energy saved were provided. The HOMER pro micro grid software was chosen for this project design because it is a global standard software for optimizing micro grid design in all sectors. The figures below show the monthly average temperature data for BENIN, and monthly average solar horizontal irradiance from NASA prediction of worldwide energy resources power database and national renewable energy laboratory data base respectively.

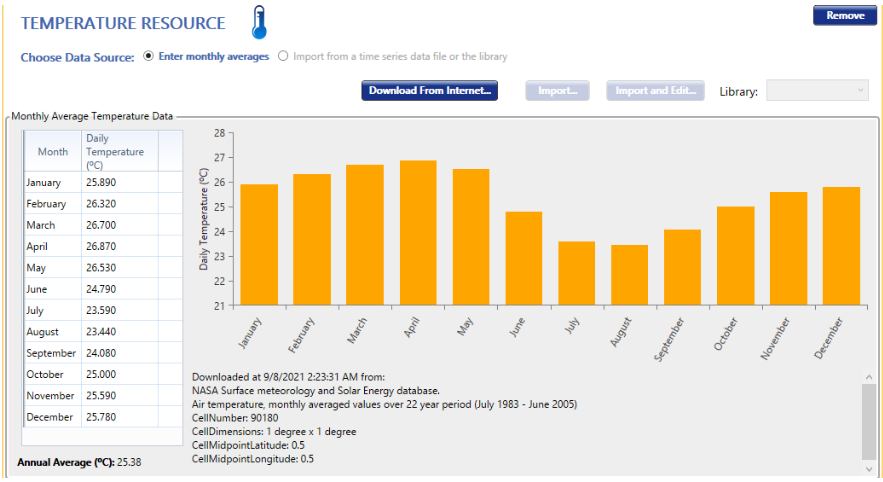

Figure 3. 5: Monthly average temperature data

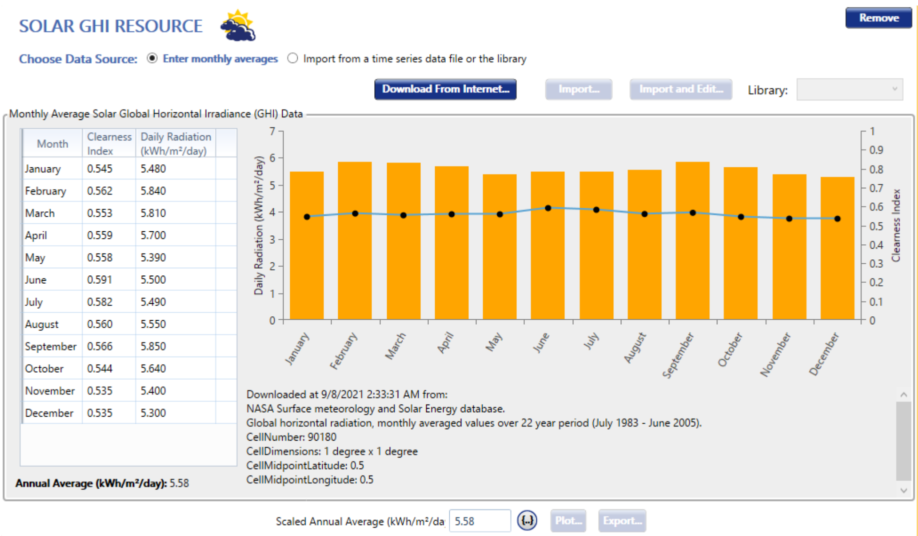

Figure 3. 6: Monthly average solar global horizontal irradiance data

Based on the evaluation on the impact of synchronization, control, and strategy for the solar mobile charging system, the details of the data needed for modelling and simulating the solar design is discussed in Table 3.1 below.

Table 3. 6: Details of solar panel, battery, and charge controller data assessed

S/N	Description	Specification
1.	Solar Mobile Charging Station KVA/Kw Rating	1.5Kw
2.	Number of Solar Panels used for micro grid	300wp/ 24v, 15Ah
3.	Maximum power rating (Pmax) of panel	300w
4.	Output Tolerance of Panel	320w
5.	Current at Pmax (Imp)	0.88
6.	Voltage at Pmax (Vmp)	37.2v
7.	Short-Circuit Current (Isc)	0.54A
8.	Open-Circuit Voltage (Voc)	45.5v
9.	Maximum System Voltage	36.4v
10.	Maximum Series Fuse Rating of panel	15A
11.	E (w/m^2) of Panels	NA
12.	Temperature Compensation of Panel	NA
13.	Charge controller type	MPPT
14.	Rated current of the charge controller	30A
15.	Type of battery used	Lead-acid battery
16.	Battery energy capacity (A.H.)	200AH
17.	Battery Voltage Capacity	12V

3.7.1 Information requirement

The required data necessary for this project is the schematic diagram showing how the solar mobile charging station is interconnected and synchronized to the power network to evaluate the impact of the synchronization on the electrical devices connected.

3.7.2 Functional requirement

From the schematic diagram data showing the solar mobile charging station interconnection, each element in the diagram has various parameters which are necessary to define the function of the entire power system network. When describing the behavior between outputs and inputs as specified in the functional requirements to describe the system results, the parameters of each component of the solar system network are helpful.

3.7.3 Design analysis

The project design analysis of evaluating the impact of synchronizing, controlling and strategy for the solar mobile charging station system involves the electrical load profile, monthly electrical production, and cost analysis

3.7.4 Electrical load profile

Load profile analysis in various areas of the microgrid system is critical for power utilities to manage load needs economically and accurately. The differences in demand must be understood for grid operation and demand management. Typical load profiles based on similar usage are obtained for various zones. The load factor primarily reflects feeder demand differences, while the loss factor aids in estimating average energy loss in distributing power within the system network without load flow studies. The load profile study in any electrical system displays a graph of the differences in electrical load and time, as the load profile varies depending on consumption and temperature. This analysis is used to determine how much energy is required.

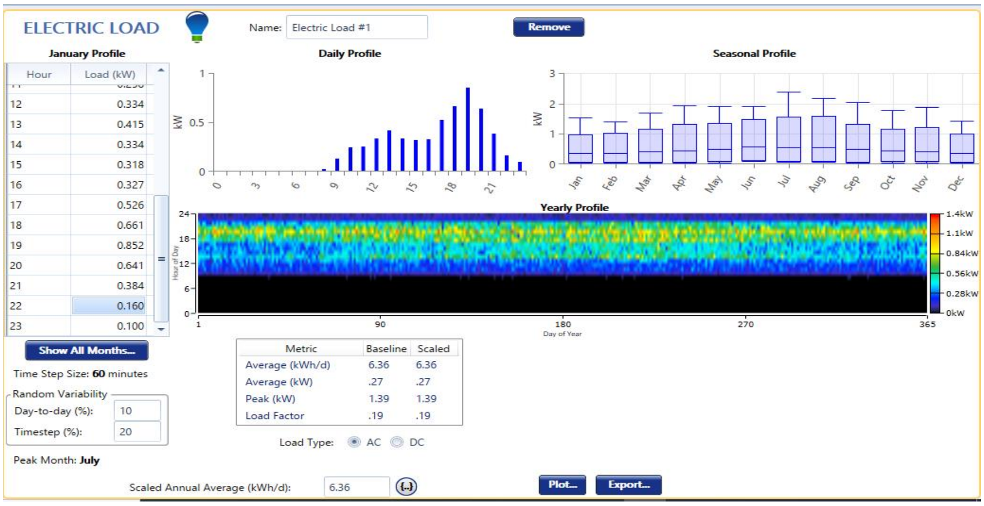

Figure 3. 7: Electrical load profile

3.8 Optimization analysis

The optimization analysis on the synchronized solar mobile charging station is performed after the electrical demand profile on the solar network has been analyzed to minimize the cost of generating electricity. This analysis yields fuel cost savings when comparing the entire generation cost for the initial operating condition of the primary grid when load flow is estimated to the whole generation cost with the optimum generation dispatch after synchronization.

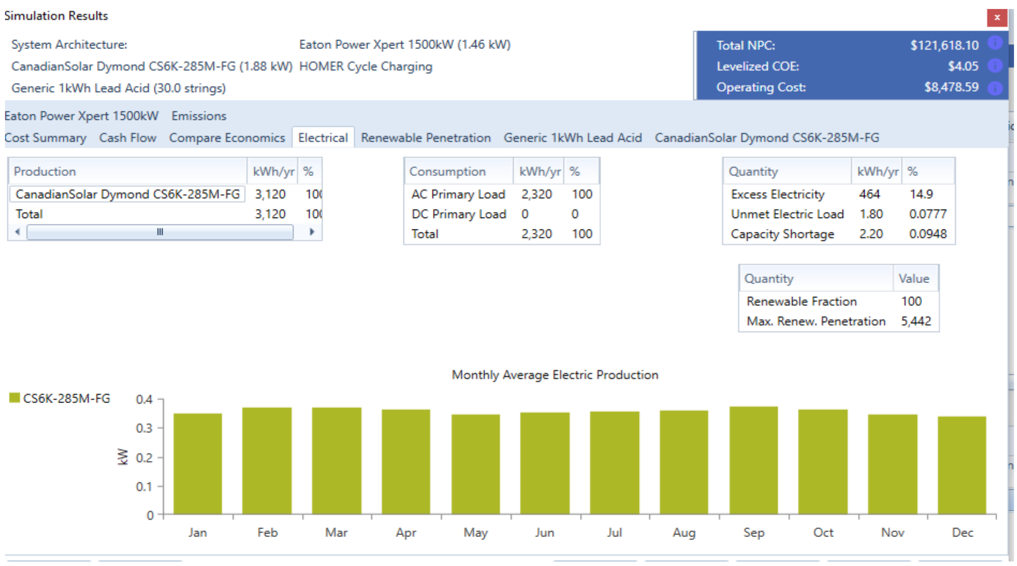

Figure 3. 8: Optimization results

3.9 System architecture

The architecture of the solar mobile charging network system with synchronization to other sources of power generation will be developed based on the analytical method, and it adopts an alternating current coupled as shown in Figure 3.5 below. This system has several sections which are to be configured with the software resources and the most important part of the system is the part of evaluating the impact of synchronizing A.C. power generated via D.C. power generated from the solar P.V. system with the aid of a DC/AC converter. The solar system feeds the direct current portion of the network, and an inverter is installed to change the solar PV system's output from direct current to the alternating current needed by the load. Similarly, vice versa

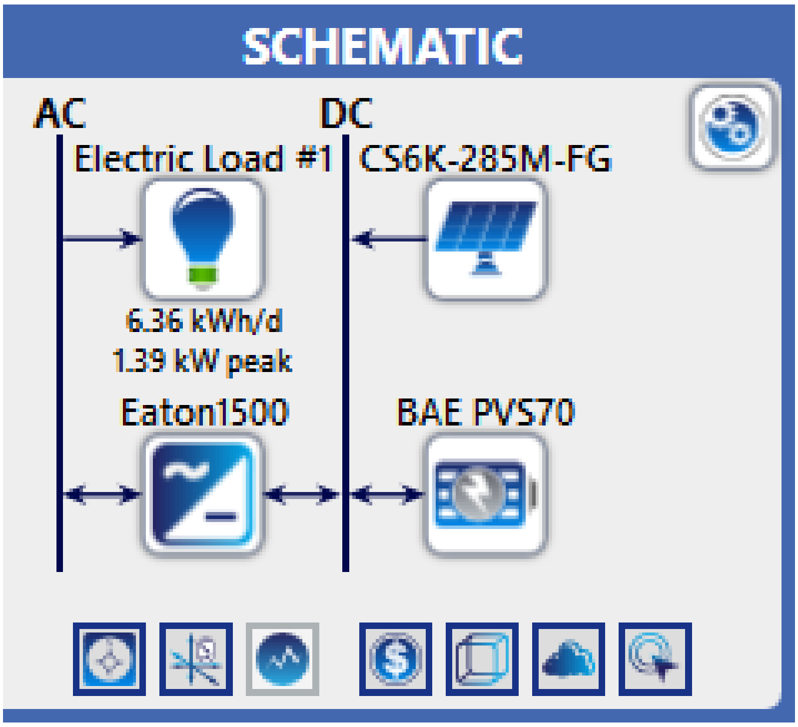

Figure 3. 9: Synchronized solar mobile charging system

3.10 Design Workflow

The process flow for synchronizing the solar mobile charging station system with A.C. generators and the primary electrical grid using HOMER analyzer software is as follows:

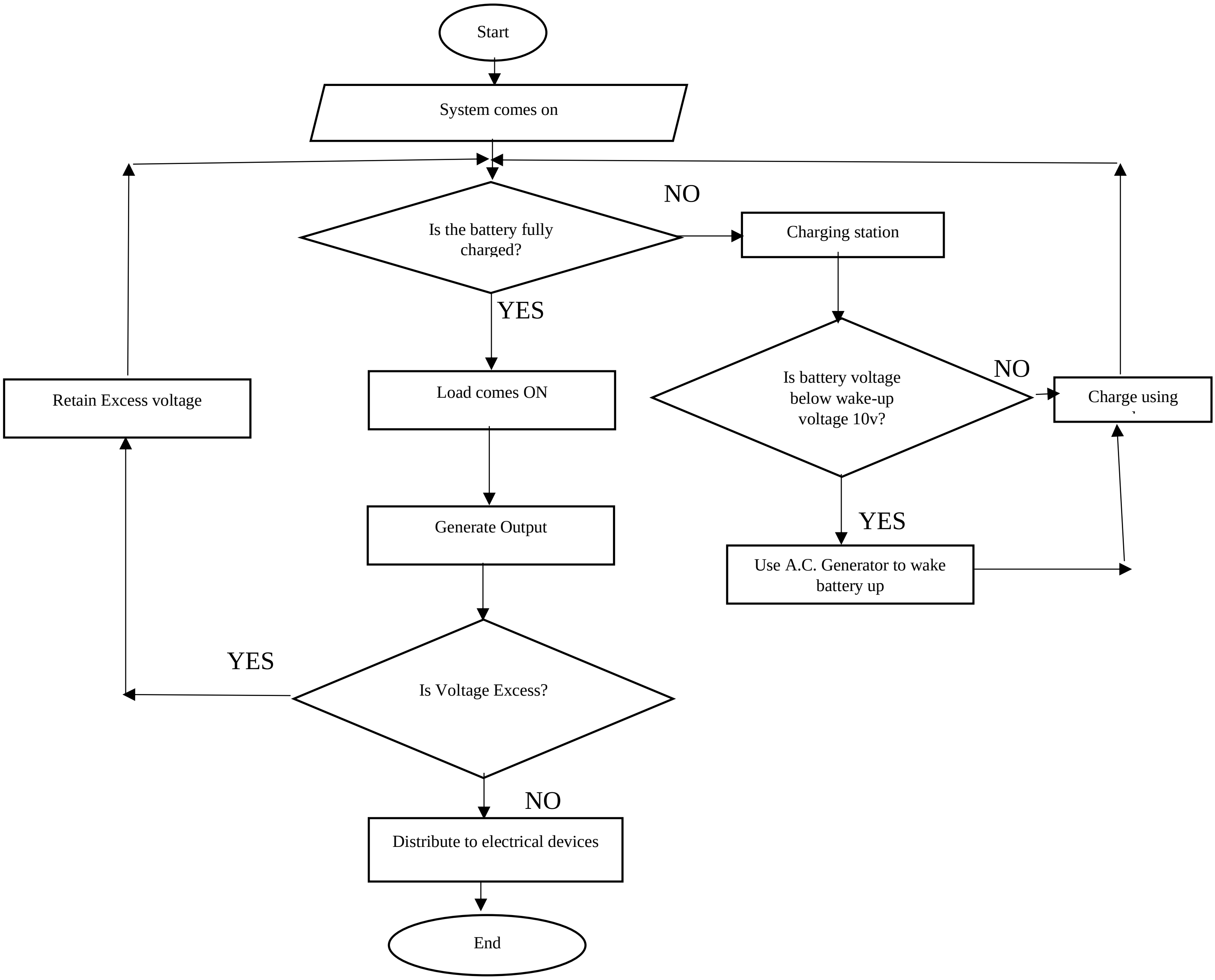

Figure 3. 10: Process flow of the synchronized solar mobile charging station.

The Figure above shows the flow chart of the synchronized solar mobile charging station.

CHAPTER 4

RESULTS AND DISCUSSION

The suggested implementation of the system is covered in this chapter.. It provides a conceptual framework based on design parameters, the expected cost of implementing the design, and the various tests that should be performed. It also includes technical specs and details about the designed system.

4.1 Construction

The step-by-step method used in the project's implementation begins with constructing the frame that will house the other systems. It is divided into three sections:

i. The solar frame

ii. The solar panel

iii. The electrical fittings.

4.2.1 The Solar frame

The material and dimensions needed for the construction of the solar frame include:

i. 3 Mild steel angle bars of five lengths (300mm x 533mm x 588mm of 3mm thickness).

ii. Mild steel sheet 300mm x 533mm x 5mm of 2mm thickness.

iii. The solid wood of thickness 25mm x 200mm x 200mm for shielding of solar system inner layer.

iv. Tyres, 220mm diameter for the tyres.

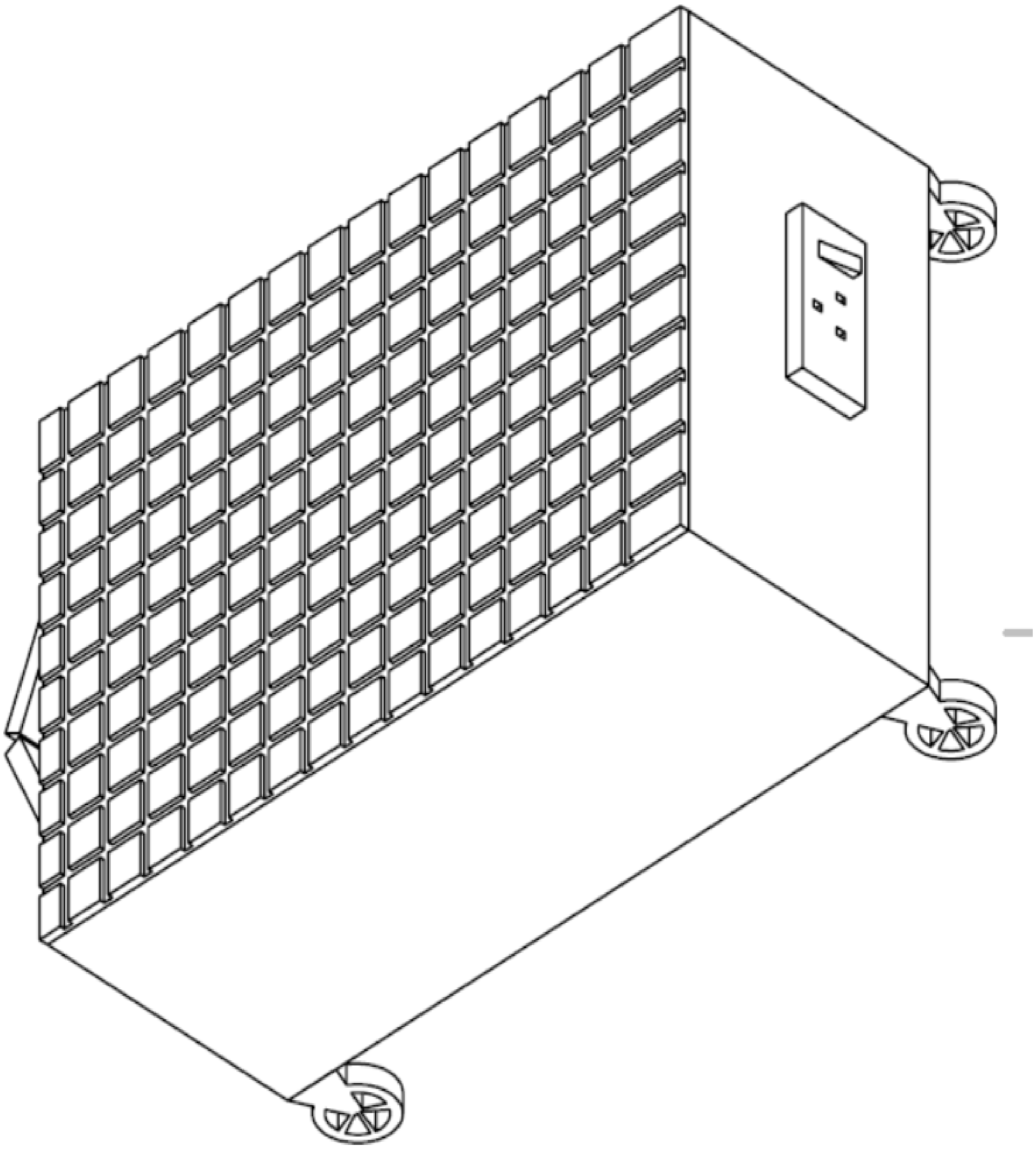

Figure 4. 1: Isometric view A

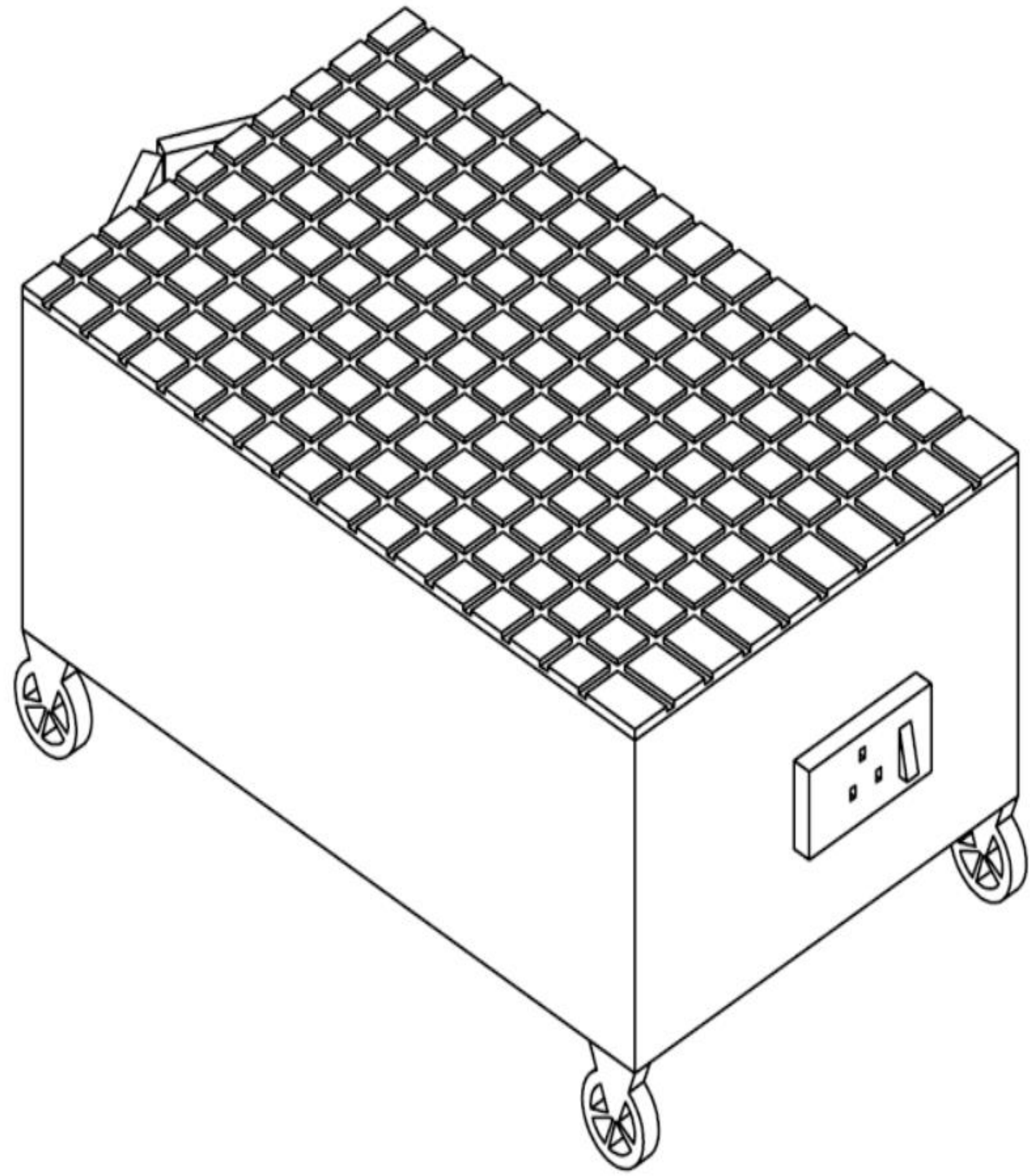

Figure 4. 2: Isometric view B

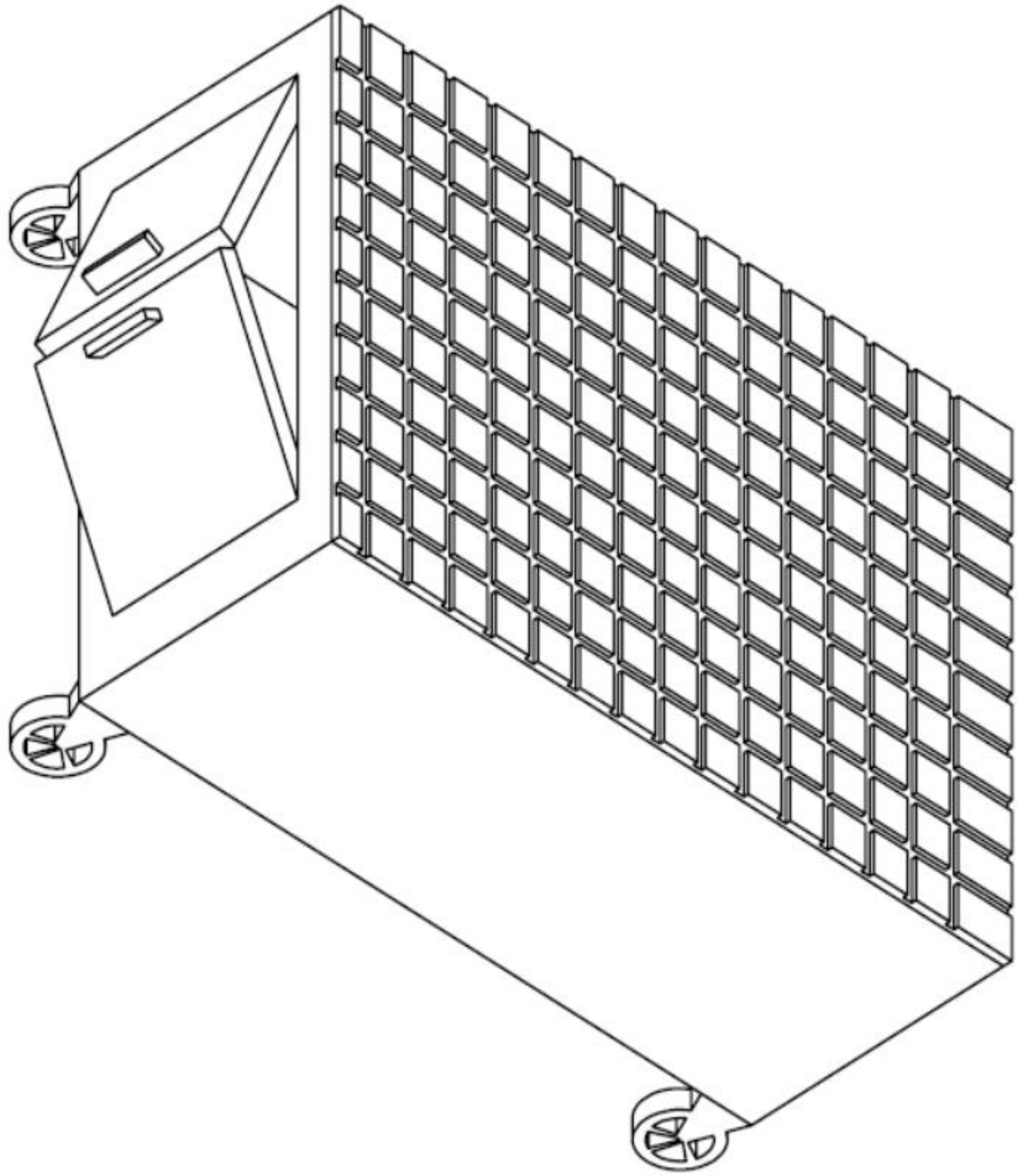

Figure 4. 3: Isometric view C

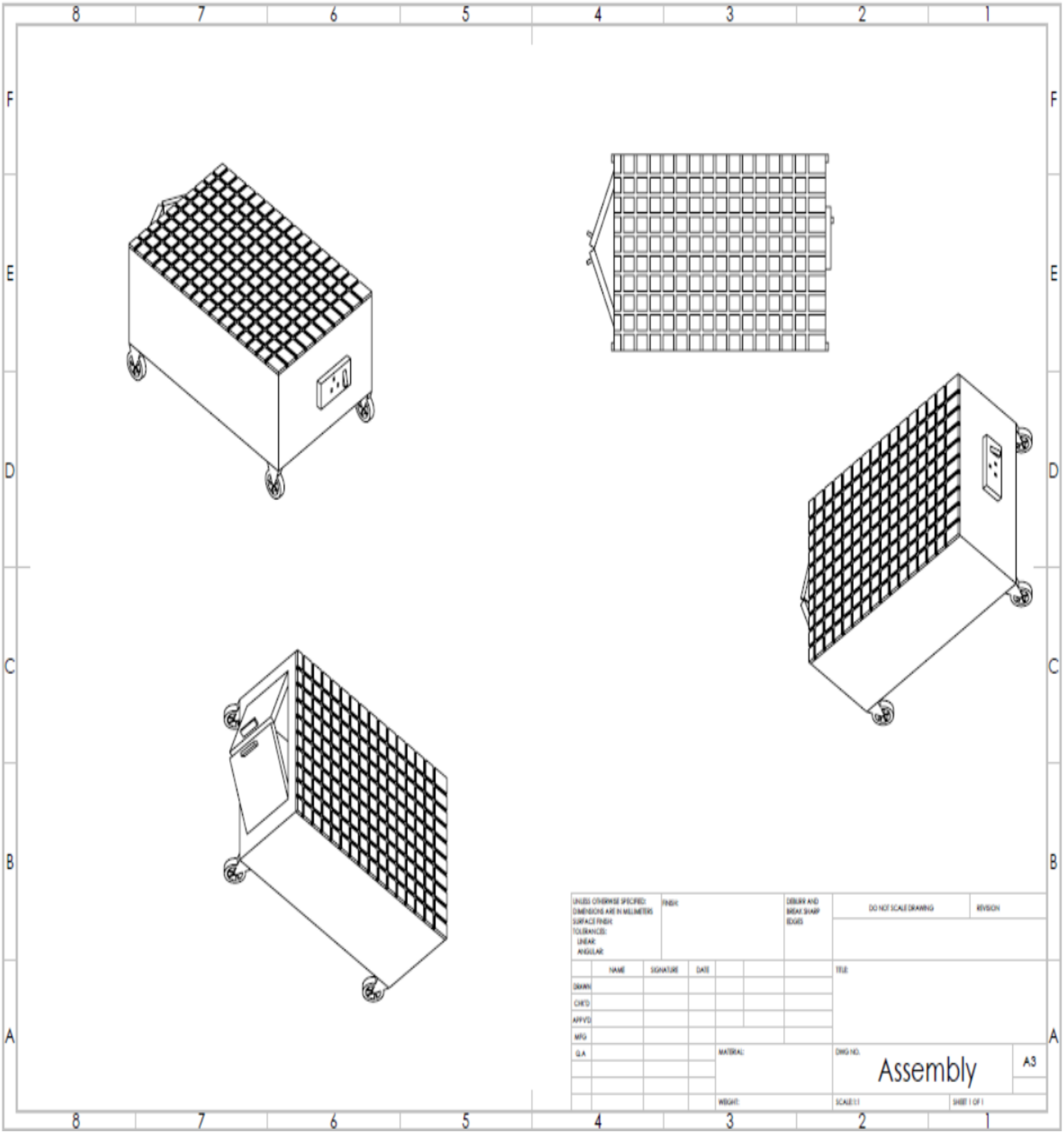

Figure 4. 4: Isometric drawings of the designed mobile solar charging station.

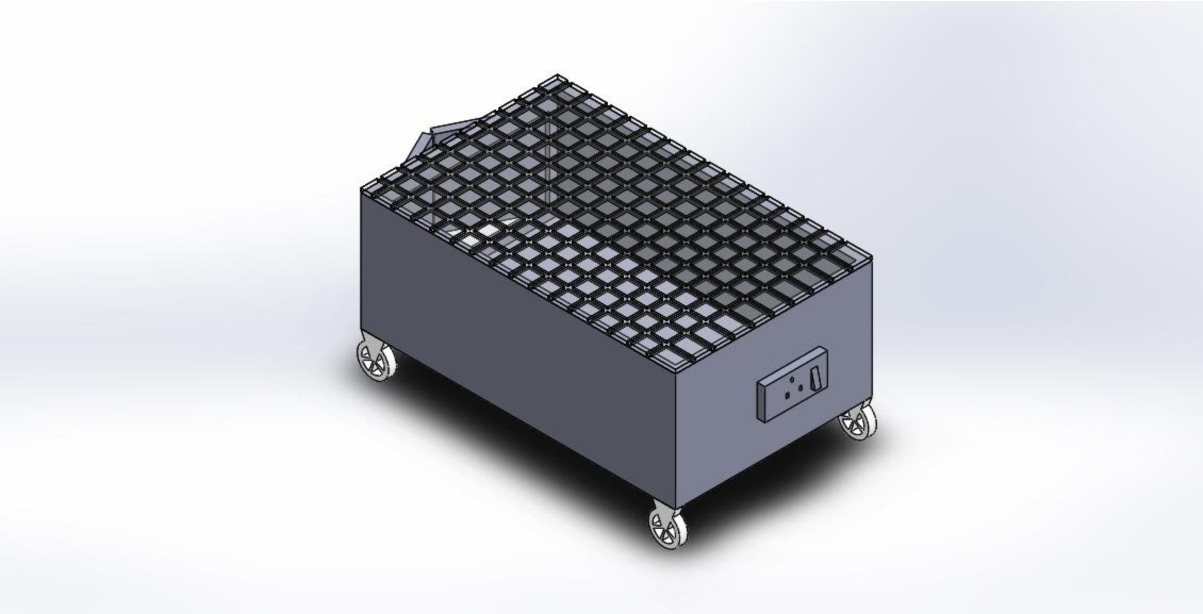

Figure 4. 5: A solid-works diagram of the designed mobile solar power station

Some of the used components needed to make the required adjustments to achieve design accuracy.

4.3 Testing

Several electrical tests are to be carried out to verify the correctness of the design and work done. Also, checks for faults like short-circuiting and open circuits will be conducted. Stimulation software and a properly functioning Multimeter will be used to carry out the tests. The tests are;

4.3.1 Voltage Test

Voltage tests are to be carried out severally to ascertain the voltages at different points in the design. A multimeter will be used in carrying out this test. To carry out this test, the voltage type to be measured (A.C. or D.C.) is selected and the range of the multimeter is set to match the expected voltage to be measured. The positive terminal should have the red probe and the negative end should have the black probe.

4.3.2 Current Test

Current tests are also done to ascertain the current demand of the circuit. It is performed using the multimeter. The multimeter is connected in series with a circuit whose current demand is to be measured.

4.3.3 Continuity test

Continuity test needs to be carried out with the use of a digital multi-meter to ensure that there is continuity in the connections. This is done by setting the multimeter to continuity mode and connecting the probes to the two output leads of each connecting point.

Result

The multi-meter gives a buzzing sound indicating that the connections made are continuous.

4.3.4 Insulation Resistance/short circuit Test

The insulation resistance tests are carried out using a multimeter, to ensure there is no leakage. This is carried out for the following parts:

(i) Live and Neutral

(ii) Live and Earth

(iii) Neutral and Earth.

(iv) Positive and Negative

(v) Positive and Ground

(vi) Negative and Ground

Result

A Reading of 1mΩ on the multimeter indicates the insulation resistance is satisfactory.

4.3.5 Mechanical Test

The test is carried out through various inspections after the completion of the work to ensure that all the components' parts were properly coupled. Here all the screws, wire joints and connections are observed properly.

4.3.6 Running Performance Test

This test is carried out by operating the solar mobile charging station to see if its performance is as expected. This is done by using the Inverter to supply voltage to some electrical equipment with a power rating not exceeding 1.5KV.

4.4 BILL OF ENGINEERING MEASUREMENT AND EVALUATION (BEME)

Table 4. 1: Engineering Measurement and Evaluation Bill

S/N	COMPONENTS	QUANTITY	AMOUNT PER UNIT (₦)	TOTAL AMOUNT (₦)
1.	300W Solar panel	3	60,000	180,000
2.	Charge controller	1	120,000	120,000
3.	Solar frame (Angle Bar)	5 lengths	3000	15,000
4.	Mobile rolling tires	4	2000	8,000
5.	13A sockets	3	300	900
6.	15A sockets	2	500	1,000
7.	Lamp holders	2	150	300
8.	Connecting wires	5 meters	400	2,000
9.	1.5KVA Inverter	1	90,000	90,000
10.	200AH battery	3	150,000	450,000
11.	Wooden Board	1 length	7,000	7,000
12.	Metal Sheet	2	15,000	30,000
	TOTAL			904,200

4.5 Summary of Findings

A coordinated methodology was used to build a mobile 1.5KVA solar power station with a charge controller. The system's structure comprises a photovoltaic solar screen, a charge controller, an inverter, and batteries. The solar panel absorbs solar energy, transforms it into electrical power, and stores it in batteries. The battery's energy is then made accessible through various outlets, powering various domestic and residential electrical appliances and devices. Based on numerous technological and feasibility studies that were conducted, this design strategy was selected. The outcome was compared to computer models and verified to assess the design's accuracy.

The various benefits which can be gotten from the mobile station include:

I. Source of power for domestic and household use in the absence of conventional and on-grid power supply.

II. The presence of a charge controller helps to regulate the amperage and voltage that is being delivered.

III. It will aid in maintaining a constant state of charge without overcharging the system.

IV. Since it is mobile, it can be made available at any location where there is a need for it.

4.6 Limitations

The following limitations that were experienced during this work are listed below to guide future scholars and researchers:

i. Irrefutable information about the solar energy potential in Nigeria for each place is lacking.

ii. The charge controller that was used for the design is the Maximum Power Point Tracking (MPPT) controller. Using any other form of charge controller in the implementation will lead to a difference in the desired output.

iii. The angle of tilt of the solar panel was fixed at a particular reference point. This might decrease the efficiency of the solar panel to harness the solar radiation as the sun rises and sets.

4.7 Contribution to Knowledge

Though the development of solar technology is still comparatively new in Nigeria, the field of solar energy is not recent. Many initiatives have been carried out regarding using solar energy as a power source and electricity instead of conventional sources, mainly due to such traditional sources' unavailability. By offering a source of energy for various domestic uses regardless of location, this research advances the field of solar energy as a genuine replacement for conventional energy sources.

This system has been designed to be able to provide power to charge any form of mobile form in the absence of grid power. From the design and analysis, it can be concluded the design, if properly executed and installed can serve as a suitable alternative power source for powering most electronic and portable devices in the absence of grid power. This system is environmentally friendly, as it releases no emissions, and is easy to maintain since it has no moving parts.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

A mobile 1.5KVA solar power station has been designed. The design was founded on numerous analyses and calculations regarding the sizes of the various system components. The accuracy of the invention to accomplish the intended goal was tested using simulation findings. The results show that proper implementation of the designed unit will go a long way in providing an adequate source of power for both household and domestic use, especially those without access to grid power. The mobile solar power station is suitable for devices and appliances with ratings less than or equal to 1.5KVA.

5.2 Recommendations

After the design of the mobile 1.5KVA solar power station with a charge controller, the following proposals should be considered for further examination:

i. Implementation of the already designed solar station as designed in this work.

ii. Designing a similar system with a higher voltage-ampere rating to be able to carry higher loads.

iii. The cost analysis of implementing such projects in the future should be carried out to evaluate the cost-benefit ratio.

iv. Data on the solar potential at various places in Nigeria should be made available to students and scholars to aid in the development of similar projects.

v. The solar panel's tilt angle should be adaptable to change with the direction of sun radiation.

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