PROJECT REPORT

ON

DESIGN AND INSTALLATION OF A 3.5KVA SOLAR POWER SYSTEM

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CERTIFICATION

This is to certify that this project report titled "Design and Installation of a 3.5KVA Solar Power System" by Enabulele Osawaru Wilson an undergraduate student in the Department of Industrial Engineering, Faculty of Engineering, University of Benin, Edo State, satisfactorily completed this work on his own as partial fulfillment of the requirement for the award of Bachelor's Degree in Production Engineering in the department of Production Engineering.

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ABSTRACT

This project focuses on the design and building of a solar inverter with a 3.5KVA capacity. Solar inverters convert the variable direct current (DV) output of a photovoltaic (PV) solar panel into utility-frequency alternating current (AC), ready for connection to a home's electrical system. It is essential to solar systems since it permits the use of common AC-powered devices.

Solar panels in solar inverters produce direct electricity by moving electrons from a negative to a positive direction. Most home appliances run on alternating current. This AC continuously fluctuates between negative and positive elections.

You can adjust the voltage in the AC power according to the equipment's intended use. Solar inverters convert DC to AC because solar panels can only provide direct current.

We created a 3.5KVA electrical inverter for this project. Two 22Ah wet cell batteries, a 220V/24-0-24V center-tapped inverter, an MPPT charge controller, and six 300W solar panels make up the architecture of the inverting circuitry assembly. The design provided power for a television, refrigerator (200 watts), air conditioner (1120 watts), and other devices totaling 2465 watts. The system operated at peak efficiency for almost 12 hours while under full load.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

The use of solar power systems has increased dramatically in recent years due to the growing need for ecologically friendly and sustainable energy alternatives. It is now critical to find cleaner and more efficient energy sources as the globe struggles with the effects of climate change and an expanding population. Additionally, the world's population and the amount of energy consumed are directly correlated *(Salihu Usman Ibrahim, 2022).*

The purpose of our project is to meet this need by designing, building, and installing a solar power system with a 3.5KVA inverter. The project is significant because it demonstrates our dedication to offering a dependable and sustainable energy solution for residential and commercial applications.

This project's centerpiece is a 3.5KVA solar panel inverter, representing a significant advancement in using solar energy to generate electricity. This capability is critical to meet the growing energy needs of modern homes and businesses while reducing reliance on traditional grid-based power sources. It converts photovoltaic (PV) modules' erratic DC output into a pure sinusoidal 50 or 60 Hz AC. The commercial electrical grid or a neighboring off-grid electrical network connects this AC. A solar cell, or a photovoltaic cell, is a simple solid-state device that directly converts solar energy into electrical power using the photovoltaic effect.

A photovoltaic (PV) module is an arrangement of cells placed in series or parallel to increase voltage and current. As we ascend the hierarchy, we find that a panel consists of multiple modules installed on a framework. At the same time, an array is a collection of panels situated at a specific location.

As the most abundant energy source currently available to humans, solar energy is estimated to generate 10000 TW on Earth's surface daily *(Bosshard, 2006).* To put this into perspective, the world's energy consumption in 2015 was 17.4 TW *(Seger, 2016),* growing at a steady rate of 1 to 1.5% per year. Projections indicate that global energy consumption will rise by 56% by 2040 (U.S. Energy Information Administration, 2013). The vast potential of solar energy is apparent when we consider the current consumption, the projected increase over the next 20 years, and the amount of solar radiation received in an hour.

The real-time microcontroller is the central component of the solar inverter. This controller executes the precise algorithms required to convert the DC power from solar panels into AC. The controller uses advanced algorithms, such as maximum power point tracking (MPPT), to optimize the power output from the photovoltaic (PV) system. It is programmed to manage power functions, including DC/DC and DC/AC. Variations in temperature, shade, cloud cover, and time of day can affect the photovoltaic cell's maximum output power, necessitating constant adjustment of the maximum power point.

When a system uses battery energy storage, the controller assumes additional responsibilities. It manages charging and the smooth switch to battery power when sunshine decreases or cloud cover lowers PV output power (*Aditee P. Bapat et al., 2013*).

Despite our vast energy potential, global solar energy utilization remains below 5%. However, certain initiative-taking countries are making strides in transitioning from fossil fuels to solar applications. These nations collectively form the G-20 group, demonstrating global leadership in adopting renewable energy sources. Germany, a prominent G-20 member, has successfully shifted approximately 38% of its energy needs to solar power. It has set an ambitious goal to completely phase out its reliance on nuclear energy, replacing it entirely with solar energy by the year 2050 (*Richardson, 2017*). Other nations with abundant solar potential can draw inspiration from Germany's successful example and consider similar transitions.

One cannot overstate the transformative role of solar inverters. They serve as the conduit, converting the variable output of solar panels into a consistent and usable form of electricity.

This project's focus on a 3.5KVA inverter reflects a strategic choice, balancing the need for versatility and efficiency in catering to the diverse energy requirements of modern society.

The 3.5KVA Inverter and Solar System Design and Installation Project is a responsible step toward a sustainable energy future rather than merely a technological undertaking. This project aims to catalyze the global transition to more environmentally friendly and cleaner energy alternatives by integrating state-of-the-art technology and solar power potential.

1.2 STATEMENT OF THE PROBLEM

Nigeria faces urgent challenges requiring innovative solutions due to its infrastructure, energy consumption, and environmental sustainability issues. The main cause of this problem is our reliance on antiquated power networks, which frequently result in disruptions and power outages. The unstable power infrastructure significantly impacts businesses and educational institutions in Nigeria, making this issue particularly severe. As a result, there is an urgent need for alternative energy solutions, such as the design and installation project of a 3.5KVA inverter and solar system.

The persistent problem of power outages severely impacts Nigerian universities, which serve as centers for research and instruction. The unreliability of the country's electrical system directly affects academic endeavors, research initiatives, and the institution's overall operation. Labs, research centers, and educational facilities typically suffer from a lack of a consistent power supply, which hinders research initiatives, lowers educational standards, and slows the progress of academic institutions overall. Affected universities struggle to compete internationally with Nigerian institutions and produce high-quality teaching and research.

In Nigeria, power outages have a variety of effects on businesses and households, in addition to the educational sector. Businesses face various operational challenges, such as reduced global competitiveness, rising operating costs due to alternative power sources, and production disruptions. In addition, the unreliable power supply lowers people's overall standard of living and increases the cost of alternate energy sources like generators, thereby increasing household expenses.

In summary, the primary goal of the design and installation project of a 3.5KVA inverter and solar system is to address the pervasive and detrimental consequences of power outages in Nigeria. This problem encompasses the ineffectiveness of converting solar energy into usable power, the damaging effects on colleges and other educational establishments, and the wider ramifications for customers and companies. We must design and implement effective and sustainable energy solutions to mitigate the various problems caused by Nigeria's current power crisis.

1.3 AIMS AND OBJECTIVES

The following aim and objectives are presented below:

1.3.1 Aim

The main goal of this project is to design, build, and install a 3.5KVA inverter in conjunction with a solar power system to address Nigeria's widespread power outage problem. The initiative aims to offer an affordable, dependable, and sustainable alternative energy source to meet the various energy requirements of homes, businesses, and educational institutions.

1.3.2 Objectives

The objectives of the study are:

1. I am reviewing valuable literature in close relation to this work to see what has been done in the field of photovoltaic systems.
2. We will design the solar PV system, which includes the selection of appropriate solar modules and mounting structures.
3. Conduct performance evaluation and load-bearing tests to determine the overall efficiency of the system.

1.4 SCOPE OF THE PROJECT

Clearly defining the project's specifications is necessary before beginning to design, construct, and install a 3.5KVA inverter integrated with a solar power infrastructure. We will meticulously create the electrical architecture, circuitry, and configuration during the design process to meet the specific energy needs of educational laboratories.

Superior components and cutting-edge technology will be the primary fabrication priorities, ensuring durability and seamless integration. Solar panel integration will maximize energy harvesting with an intelligent solar charge controller, as well as careful design and positioning.

An easy-to-use monitoring and control interface, a focus on efficiency and steady power distribution, and load management are all essential components. Quality assurance, intensive testing, and safety features will all attest to the system's reliability.

Installation planning that includes detailed criteria will support differentiated learning environments. Training programs and knowledge-sharing gatherings will empower users, while archives and manuals will ensure accessibility. An Environmental Impact Assessment will incorporate a sustainability analysis.

The primary objective of the project is to supply a cutting-edge, sustainable, and 3.5KVA solar panel inverter system that is specially made to satisfy the needs of educational laboratories. To provide a comprehensive and efficient energy solution, the scope carefully addresses user empowerment, installation problems and design complications.

1.5 SIGNIFICANCE OF THE PROJECT

The 3.5KVA Inverter and Solar System Design and Installation Project is vital for addressing Nigeria's energy problems. The project addresses the common issue of power outages, particularly in higher education institutions like colleges. By establishing the current 3.5KVA solar-powered power supply, Nigerian institutions would be able to maintain their competitiveness in the global market and create an atmosphere that is favorable to innovative research.

The initiative not only benefits directly but also advances energy efficiency. The 3.5KVA solar panel converter promotes an ecology where creativity can thrive by ensuring a steady and continuous power supply to labs, research centers, and academic buildings. The project supports global sustainability goals by using solar energy, decreasing dependence on traditional power sources, and reducing carbon emissions.

The project represents technological innovation by integrating cutting-edge technologies into the 3.5KVA inverter system. It establishes a standard for initiatives of a similar nature. It promotes a more widespread move towards sustainable energy practices by demonstrating how to combine innovative technology with renewable energy sources.

The project is important because it would help Nigeria have a robust, sustainable, and technologically sophisticated energy future, in addition to solving urgent problems.

CHAPTER TWO

LITERATURE REVIEW

2.1 OVERVIEW

In the pursuit of sustainable energy solutions, the integration of inverters and solar systems has emerged as a pivotal avenue, embodying the essence of eco-friendly and efficient power generation. This literature review delves into the existing body of knowledge surrounding the design and installation of a 3.5KVA inverter and solar system—an ambitious venture that seeks to redefine energy consumption paradigms.

The project at hand, titled "Design and Installation Project of a 3.5KVA Inverter and Solar System," envisions a convergence of advanced technology, engineering ingenuity, and environmental consciousness. In this chapter, we look at relevant scholarly works and industry practices to build a strong base for the next section, which talks about the proposed energy system's design principles and installation challenges.

As we embark on this journey through the scholarly landscape, the goal is not only to garner insights into the theoretical underpinnings but also to glean practical wisdom from real-world applications. By synthesizing the collective knowledge amassed in this domain, we endeavor to lay the groundwork for a project that not only meets technical specifications but stands as a testament to the transformative power of sustainable energy solutions.

2.2 REVIEW OF RELATED WORKS

Depending on the needs of the customer, solar cells are often arranged in parallel or series modules. Parallel designs generate more current, but they also have drawbacks, such as the influence of shadow effects on weaker parallel strings. Over time, the design of solar modules has changed; more modern versions have single power boxes for every module.

Inverter circuits switch between vacuum tubes and gas-filled tubes. Components used in modern inverters include transistors, diodes, MOSFETs, resistors, capacitors, and integrated circuits (B.L. Theraja, 1997). A variety of inverter types, such as power, solar, resonant, synchronous, grid-tie, stand-alone, air conditioner, and three-phase inverters, function in different modes. Square waves, quasi-square waves, and true/pure sine waves are the three types of output waveforms; each has a distinct function. Considerations such as cost, ease of use, and load compatibility determine the type of inverter to select.

Nigeria's energy policy from 2003 recognized that expanding the grid was not a sufficient solution for meeting the country's rural electrification demands and stressed the need to utilize renewable and non-conventional energy sources, such as solar power (Jesuleye et al., 2008). Adejumobi et al. (2011) assert that inverter systems, particularly in isolated regions with restricted generator usage hours and rising fuel prices, are essential for mitigating the drawbacks of traditional power supply techniques.

Solar power, which can store solar energy in lead acid cells after absorption, serves as an affordable alternative to traditional power sources in areas with inadequate power supply infrastructures (Ezugwu, 2012). To overcome issues related to transformer size, researchers such as Swagatam Majumdar (2012) have investigated DIY power inverter circuits.

According to S. I. Suleiman et al. (2012), research has also concentrated on developing independent solar systems based on Watt-hour demand, with real-world implementations shown in homes with moderate energy usage. We desire higher voltage outputs from solar panels to minimize the number of wires when transmitting electricity to charge controllers and batteries (Embark Electronics, 2013).

The SG3524 and SG2524 integrated circuits are crucial components for building switching regulators, inverters, and regulating power supplies. These circuits support a wide range of applications using fixed-frequency PWM approaches (Texas Instruments, 2014).

Researchers such as Audu, N.P., ThankGod, A.O. (2013), Abolarinwa, J. et al. (2010), and Omotosho et al. (2017) have investigated switch mode square wave (SMSW) and low-cost, high-efficiency inverters with DC-DC converters and H-bridge configurations.

Smart inverters with automated voltage management have integrated oscillating circuits and microcontrollers to enhance the versatility and efficiency of household appliances (Olawale, O.E., et al., 2019). These developments in inverter technology highlight continued attempts to solve issues with power supply and enhance environmentally friendly energy alternatives.

2.3 PRESENT RESEARCH WORK

This present research work consists of the latest technology, which involves building a 3.5KVA inverter and solar system from scratch. We accomplished the work using a 24V inverter, six 250-watt solar panels, a PMW 100A solar charge controller, and two newly developed 220Ah wet cell batteries.

Furthermore, this design incorporates an ABB circuit breaker to manage and control surplus power from the AC mains, ensuring precise output voltage with optimal current requirements. We use a Solar Pulse-Width Modulation (PWM) charge controller as a control unit, and the green LED on the PWM indicates system activation. We interconnected all units and thoroughly assessed them to ensure satisfactory performance.

2.4 SOLAR COMPONENTS REVIEW

A standard solar power supply system consists of fundamental components, including solar panels (photovoltaic or PV panels), a charge controller, and a power inverter equipped with a meter or monitoring system. This monitoring system is capable of overseeing voltages, system conditions, and the electrical distribution network. The block diagram below illustrates the project's implementation method.

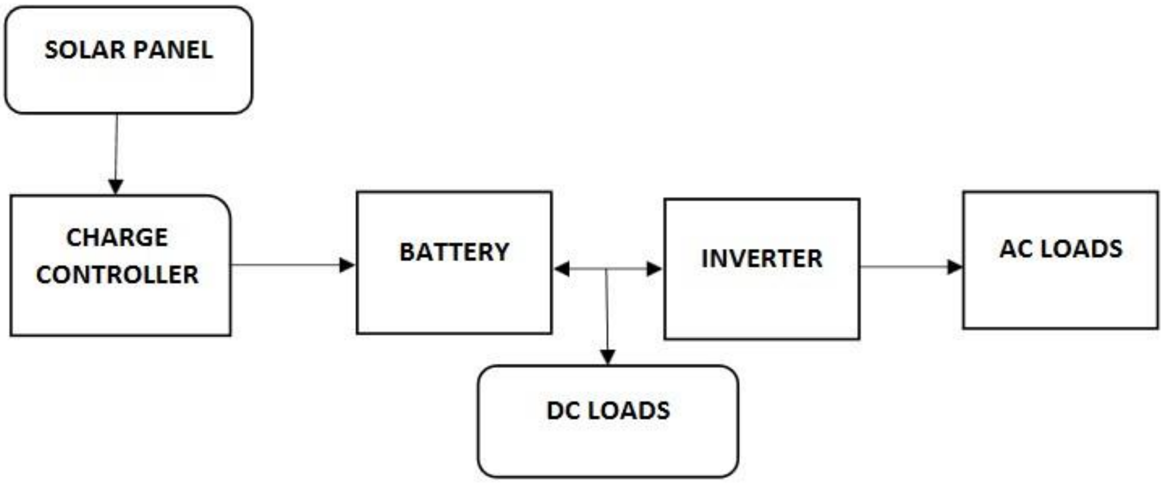

Figure 2.4: Block Diagram of Solar Power System

2.4.1 Solar Panel

A solar panel effectively captures solar radiation and converts it into electrical energy, primarily direct current (DC). The silicon crystals in the photovoltaic panel react with sunlight to initiate the conversion of solar energy into electrical power. We can use the produced electricity to charge batteries and power appliances directly or through an inverter. We use several modules to optimize energy output, storing any excess energy in batteries for use in cloudy or wet weather. These panels come in a range of sizes, voltages, and amperages. You can customize their arrangement by wiring them in series or parallel, depending on the system design.

2.4.2 Solar Charge Controllers

By controlling the pace at which electric current enters or exits the batteries, the charge controller functions as an electronic voltage regulator. This critical component does its job by turning off the charging process when the battery reaches the ideal charge level and turning it back on when the charge drops below a certain point. It ensures full battery charging without the risk of overcharging and prevents reverse current flow, which could compromise the battery's safety, longevity, and performance. The charge controller also shows the battery's condition, important system operating parameters, and over-discharge protections. The charge controller, acting as the primary control unit for the system, continuously monitors the solar panel's energy output and modifies the charging process to prevent overcharging of the batteries. For optimal operational efficiency, this design makes use of a 100-amp pulse width modulation (PMW) charge controller.

The system's design places a high priority on correctly charging the batteries in order to protect them and eventually increase their lifespan and performance. We selected technologies such as pulse width modulation (PWM) and other charge controllers.

Solar charge controllers use two different charging techniques, namely PWM and MPPT, to charge batteries from solar panels or arrays. The off-grid solar market commonly uses both technologies, which offer effective charging options. The decision between PWM and MPPT regulation is not only about which is better for your solar system; it also includes carefully evaluating which controller type best fits your system's unique design.

2.4.2.1 PWM Charge Controllers

Pulse-width modulation (PWM) begins to function when the battery bank reaches full charge. During the charging process, the controller allows the PV panel or array's maximum current to meet the preset voltage needed for the charge stage that is underway. The charge controller quickly switches between connecting the battery bank to the panel array and disconnecting it when the battery gets closer to this desired voltage. This dynamic switching process efficiently regulates and maintains the battery voltage.

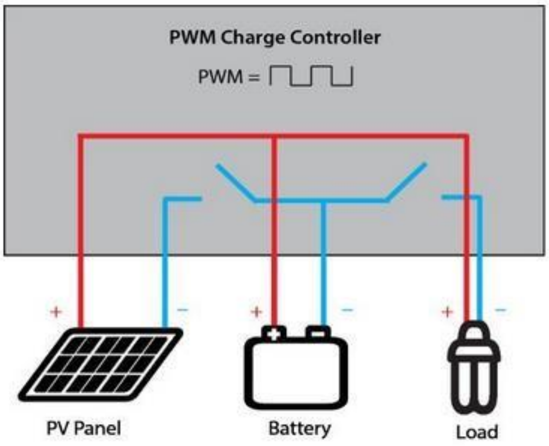

Figure 2.4.1.2: PWM charge controller Connection

This quick switching is called PWM, and it ensures your battery bank is efficiently charged while protecting it from being overcharged by the PV panel/array. PWM controllers will operate close to the maximum power point but often slightly “above” it.

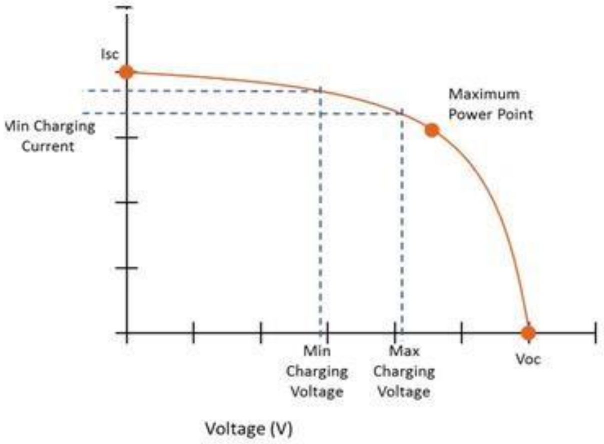

Figure 2.4.1.3: Power Curve for a PMW Panel

2.4.2.2 MPPT Charge Controllers

The Maximum Power Point Tracking (MPPT) charge controller incorporates an indirect link between the PV array and the battery bank. This indirect connection involves a DC/DC voltage converter capable of harnessing surplus PV voltage and transforming it into additional current at a lower voltage, all while preserving power efficiency.

MPPT controllers achieve this by using an adaptive algorithm that tracks the PV array's maximum power point. The controller then adjusts the incoming voltage to sustain the most efficient power output for the system.

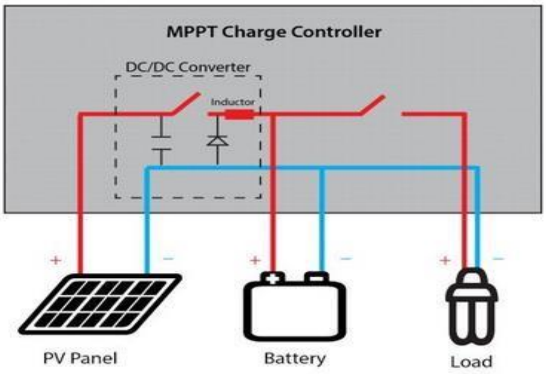

Figure 2.4.2.1: MPPT Charge Controller

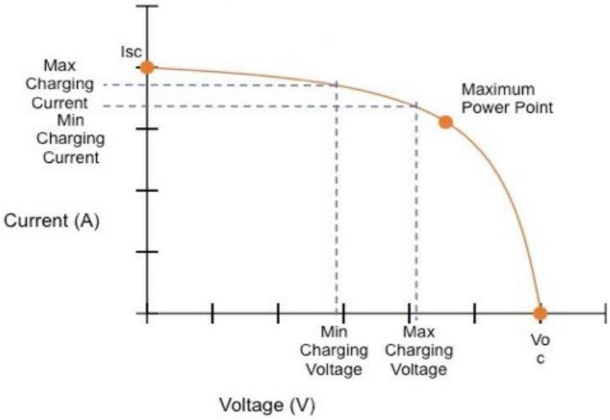

Figure 2.4.2.2: Power Curve for a PV Panel with Charging Ranges for MPPT Controllers

2.5 Battery

Without a battery, the solar power system could only generate electricity when the sun is shining, which could lead to interruptions whenever clouds pass by. This scenario could lead to significant frustration for users. The inclusion of a solar battery addresses this issue by providing a consistent source of electricity, allowing the system to operate even when sunlight is temporarily unavailable. The batteries play a pivotal role, discharging up to 80% of their stored charge to sustain a continuous power supply. Batteries, tailored to meet the specific requirements of each system, are available in diverse voltages and amp-hour ratings.

Batteries serve as the core of the system, storing direct-current electrical energy for later use. However, this energy storage capability comes with a trade-off, as batteries tend to reduce the efficiency and output of the PV system, typically by around 10% for lead-acid batteries. Additionally, batteries contribute to increased system complexity and cost. PV systems typically employ the following types of batteries:

2.5.1 Lead-Acid Batteries

In photovoltaic systems, lead-acid batteries are commonly utilized, with sealed lead-acid batteries being the recommended option for grid-connected configurations. The spill-proof nature of AGM (Absorbent Glass Mat) and other sealed batteries eliminates the need for regular maintenance. Because they require no maintenance, they have established themselves as the industry standard. Grid-tied systems, which typically maintain batteries at full charge, find them especially suitable. On the other hand, we do not recommend gel-cell batteries due to the potential for permanent damage from overcharging. Manufacturers design gel-cell batteries to endure freezing temperatures.

Although flooded lead-acid batteries are less expensive, they require monthly additions of distilled water to make up for water lost during regular charging.

There are two types of sealed lead-acid batteries: gel cells and sealed absorbent glass mats (AGM). Because AGM batteries require less maintenance and work well in grid-tied systems, they have become increasingly common. Gel-cell batteries, on the other hand, are meant to be freeze-resistant; nevertheless, because overcharging can cause irreversible damage, they are usually not recommended.

Lead-acid batteries typically specify their rated capacity at different hour rates, such as C/8, C/10, and /20. UPS batteries, for example, have an 8-hour capacity rating, while telecommunication batteries have a 10-hour capacity rating and come in either 12VDC or

There are 24VDC configurations available, with capacities of 150Ah or 200Ah.

2.5.2 Lithium Batteries

Lithium batteries offer numerous advantages compared to traditional battery types, boasting an exceptionally long cycle life and impressive discharge and recharge rates.

Lithium batteries, like lead-acid batteries and other types, consist of multiple cells. Each lithium battery cell carries a nominal voltage of 3.2 volts. To attain a 12V battery, a typical configuration involves connecting four cells in series, resulting in a nominal voltage of 12.8V.

Similarly, a 24V battery comprises eight cells in series, resulting in a nominal voltage of 25.6V. For a 48V battery, sixteen cells connected in series yield a nominal voltage of 51.2V. These voltage configurations seamlessly align with standard 12V, 24V, and 48V inverters, with the choice of ampere rating contingent on decisions made during the solar system installation process.

2.5.3 Tubular Batteries

This is an example of cutting-edge battery technology with increased energy storage capability. The Valve Regulated Lead Acid (VRLA) batteries contain a modern gel battery, sometimes referred to as a "gel cell," which is an electrolyte-like gel. Combining sulfuric acid and fumed silica produces a gel-like, immobile mass. Unlike flooded wet-cell lead-acid batteries, these batteries do not require an upright orientation. The frame structure of the battery's tubular plates consists of vertical spines connected to a single bus bar. This tubular construction guarantees the mechanical cohesiveness of the active material inside the porous gauntlet and around the spines.

With their elegant form, these solar inverter batteries are appropriate for high-end uses. They have a high cycle life and reliably function even at high temperatures. They are available in different ampere standards, including one hundred Ah, 120 Ah, 150 Ah, 180 Ah, 200 Ah, and 220 Ah, and have a lifespan of 4 to 5 years.

2.6 Inverter

The inverter is an essential component of every solar power system. It converts the DC voltage produced by the solar panels and extracted from the energy stored in the batteries into AC voltage. Furthermore, the inverter can utilize other sources, like the mains or a connected generator, to charge the batteries when available. Consider the system's power and load needs when choosing the right inverter for optimum performance.

The inverter, also referred to as a DC-AC converter, converts DC electricity into AC power at the appropriate output voltage and frequency. We divide inverters into two main types: voltage-source inverters and current-source inverters. A voltage-fed inverter (VFI), also known as a voltage-source inverter (VSI), has a DC source with very little resistance that keeps the input terminal voltage constant. Conversely, a high-impedance DC source, usually a continuous DC source, provides adjustable current to a current-source inverter (CSI).

There are three primary types of inverters based on their output characteristics: square wave inverters, sine wave inverters, and modified sine wave inverters. Several types have distinct functions depending on the intended application and output waveform.

2.6.1 Square Wave Inverter

This inverter's output waveform is a square wave. Square wave inverters are the least commonly used type of inverter overall, as most appliances operate on a sine wave power source. If supplied with a square wave, appliances designed for a sine wave may sustain damage or suffer significant losses. Although this inverter is inexpensive, it has extremely rare uses. It is useful for basic tools that have a universal motor.

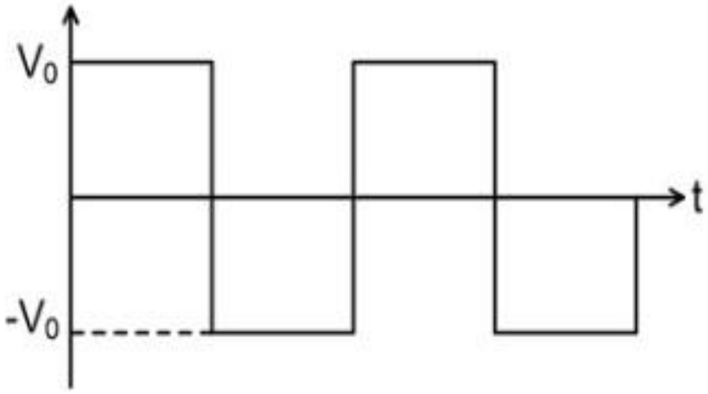

Figure 2.6.1 : Square wave inverter graph

2.6.2 Sine Wave Inverter

As its output waveform, this inverter produces a sine wave, providing a remarkably similar output to the utility supply. This inverter's significant advantage is its compatibility with common appliances designed for a sine wave power supply. This ensures the perfect output, guaranteeing the proper functionality of the equipment. Despite its higher cost, both residential and commercial applications widely employ this type of inverter.

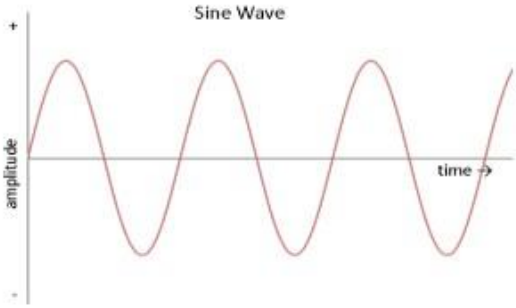

Figure 2.6.2: Sine wave inverter graph

2.6.3 Modified Sine Wave Inverter

This type of inverter is less difficult to build than a pure sine wave inverter, but its construction is more complex than that of a square wave inverter. This inverter outputs a hybrid waveform, which is neither a square wave nor a pure sine wave. It blends the qualities of two square waves. The output waveform has a sine wave-like shape, even though it does not exactly match one.

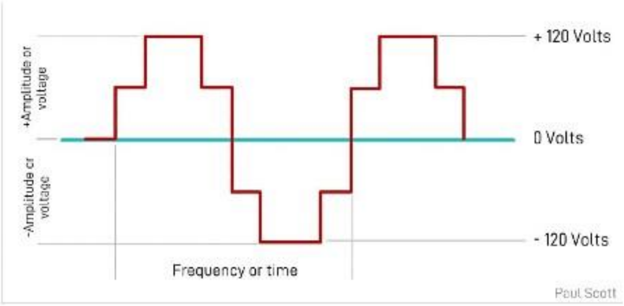

Figure 2.6.3: Modified sine wave inverter graph

CHAPTER THREE

METHODOLOGY

3.1 Material Selection

The materials chosen significantly impact the design, performance, and longevity of a photovoltaic (PV) system. To improve the system's resilience to environmental changes, optimize energy production, and ensure dependability throughout its operational lifetime, a thorough and deliberate material selection process is necessary.

The selection of necessary components for the design of the 3.5KVA solar photovoltaic system involves key considerations.

Solar Cell Technology: When choosing solar cell technology,

The choice of monocrystalline, polycrystalline, or thin film modules significantly influences the efficiency, cost, and spatial requirements of a photovoltaic (PV) system. This investigation selected monocrystalline modules due to their high efficiency and minimal space requirements in comparison to polycrystalline alternatives.

1. **Encapsulation Materials:** Encapsulation materials, such as glass or synthetic polymers, play a vital role in shielding sensitive solar cells from environmental elements like humidity and ultraviolet radiation while facilitating sunlight penetration. The ideal encapsulation material should possess durability, high transparency, and resistance to degradation over time; glass emerged as a fitting choice.

2. **Battery Selection:** involves considering factors such as type, voltage, capacity, depth of discharge, charging and discharging characteristics, environmental impact, cost, and maintenance requirements.
3. **Charge Controller:** The charge controller selection process involves assessing factors like type, voltage compatibility with both solar arrays and batteries, maximum charging current, efficiency ratings, temperature compensation capabilities, load control, and built-in protection features.
4. We chose materials such as aluminum or stainless steel for frames and mounting structures due to their resistance to rust and their ability to withstand environmental stressors like wind, snow loads, and moisture. These materials provide mechanical strength, ensuring durability and structural integrity in challenging conditions.
5. **Wiring and Connectors:** The selection of proper wire materials (e.g., copper, aluminum) and connectors is crucial for ensuring efficient electrical connectivity, minimizing power losses, and protecting against moisture and corrosion.
6. **Inverters and Power Electronics:** Inverter housings and components require materials with optimal thermal conductivity, electrical insulation properties, and long-term reliability to facilitate efficient power conversion and sustained system performance.

The table below outlines the materials considered for this design, along with their brands, specifications, grades, and price as per the design of the project.

Table 3.1: List of materials, Quantity, Specifications, Grades, and Price

S/N	Materials	Quantity	Specifications	Price (₦)
1	Solar Panels	6	300Watts	550,000 each
2	Railings for mounting the panels	6		25,000

3	Connecting cables	20yards	25mm^2, 35mm^2, 6mm^2	30,000
4	Change over	1	100Amps	10,000
5	Battery Rack	1		30,000
6	Super Speed Tubular Wet Cell Batteries	2	12V, 220AH	540,000
7	SMS Sunmate Solar Charge Controler	1	80A, 24V, 3500KW	218,000
8	15A Socket and Plug	1		5,000
9	FelicitySolar Inverter	1	3.5KVA	880,000
Total				2,296,000

3.1.1 Details on Selected Materials and their Functions

i. **Solar Panels / PV Module:** Solar panels are specialized devices that use silicon crystals to capture sunlight and transform it into electrical energy, specifically direct current (DC).

Figure 3.1.1 image of solar panel Okaybiz Enterprise

ii. **Charge Controller:** To protect batteries from overcharging or depletion and prolong their lifespan, the charge controller is essential. It ensures full charging without running the risk of overcharging by controlling the charging process by turning off when the battery gets an ideal charge and restarting when it drops below a predetermined threshold.

Figure 3.1.2 Image of MPPT Charge Controller

Okeybiz Enterprise

iii. **Solar Rails (Figure 3.1.3):** Solar rails serve as structural supports designed to securely fasten solar panels onto various surfaces like rooftops, building facades, or the ground. Their primary function is to provide a stable and reliable framework for the installation of solar panels.

Figure3.1.3 image of Solar Panel Rails

www.solaracks.com/solar-panel-roof-mounting-kits

iv. **Battery Rack:** The battery rack is designed to house individual battery modules, offering a dedicated space for storage while facilitating efficient cable management. By consolidating batteries into a rack, it minimizes tripping hazards and enhances safety.

Figure 3.1.4 image of Battery Rack

yaoota.com/en-ng/product/luminous-inverter-

v. **Wiring and Connectors**: In order to facilitate the passage of generated power to the load, wiring and connectors are used to build electrical connections between components. The cable size is defined at $16mm^2$ and is calculated using current flow calculations and IEEE tables.

vi. **Changeover Switch (Figure 3.1.5):** A changeover switch uses a lever, usually made of copper rods, to make it easier to convert the electrical flow from one power source to another. The seamless transition between active and inactive power sources is made possible by this switch.

Figure 3.1.5 Image of a Change Over Switch

https://yaoota.com/en-ng/product/manual-knife-changeover-switch

vii. **Inverter (Figure 3.1.6):** The purpose of the inverter is to change the direct current (DC) power generated by solar panels into alternating current (AC) at the proper network frequency. It is essential for making solar power integration with traditional electrical systems possible.

Figure 3.1.6 Image of 3.5KVA Inverter

Okeybiz Enterprise

viii. **Battery (Figure 3.1.7):** Batteries in solar systems serve to store excess energy generated by solar modules, ensuring energy generated by solar modules, ensuring energy availability during periods of low sunlight or at night. The depict wet cell tubular battery is specifically suited for solar system applications.

Figure 3.17 Image of 3.5KVA Inverter

Okeybiz Enterprise

ix. **On/Off Switches and Reset Switches (figure 3.1.8):** On/Off switches and reset switches are commonly employed in inverters to control power supply. The reset switch allows for the interruption and restart of the power supply as needed, ensuring operational flexibility and safety.

Figure 3.1.8 Image of an on/Off Switch

https://tme.eu/en/details/rms201a2c3bk/rocker-switches

x. Socket and Plug 15A (Figure 3.1.9): Designed for heavy-duty systems and appliances requiring up to 3KW load, the 15A plug and socket facilitate robust electrical connections. These components are essential for powering high demand electrical equipment in solar systems.

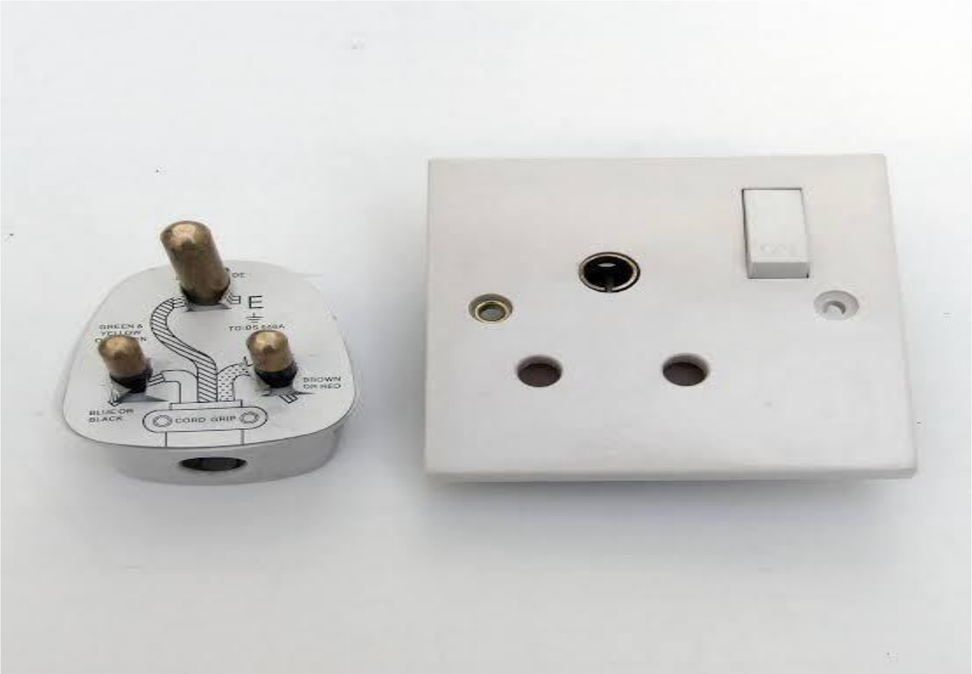

Figure 3.1.9 Image of a 15A Plug and Socket

https://www.ebay.ie/itm/112608836178

Within each photovoltaic system, pivotal components orchestrate the transformation of solar energy into electrical power, facilitating its conversion from direct current (DC) to alternating current (AC) for transmission to various loads. These core elements include:

1. Solar Panels: Acting as the foundation, they capture sunlight and transform it into

The photovoltaic effect generates DC electricity.

1. Charge Controller: The charge controller regulates the charging process of batteries, ensuring optimal performance and preventing overcharging or deep discharge, thus extending battery lifespan.

2. Battery: Acting as energy reservoirs, batteries store excess electricity generated by solar panels for later use during periods of low sunlight or at night.
3. Inverter: Vital for compatibility with standard electrical systems, the inverter converts DC electricity from the solar panels into AC power, enabling seamless integration with existing infrastructure.
4. Changeover Switch: Offering flexibility and control, the changeover switch facilitates the seamless transition between different power sources, ensuring uninterrupted power supply to connected loads.

These fundamental components work in harmony to harness solar energy efficiently, enabling sustainable and reliable power generation for a variety of applications.

Figures 3.1.10 and 3.1.11 illustrate a computer-aided design depicting these elements along with their corresponding system linkages, respectively.

3.2 Methodology

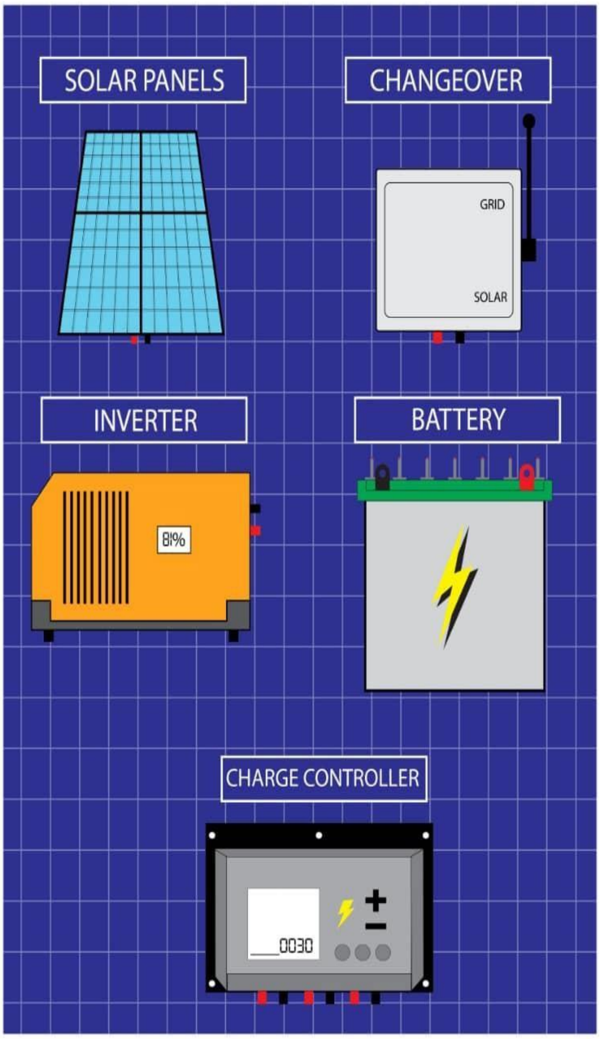

Figure 3.1.10 Computer Aided Design Showing the Components of the PV System

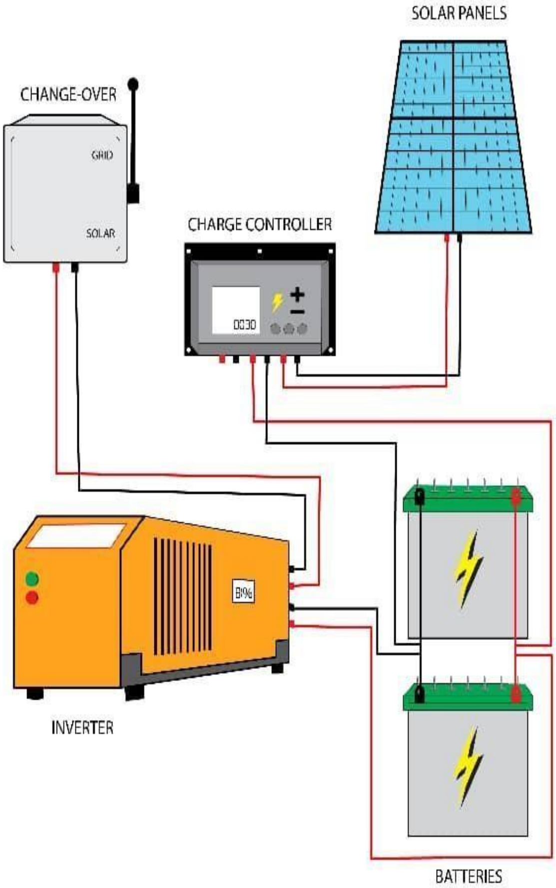

Figure 3.1.11 Computer Aided Design Showing how the System is Connected

Prior to the installation of the chosen materials, it is imperative to assess the anticipated load requirements that the photovoltaic system will be tasked with supplying power to.

3.2.1 Load Evaluation and Examination:

A comprehensive analysis of the AC load capacity that the photovoltaic system is expected to support is presented in Table 3.2 below.

Table 3.2 Load Evaluation Chart displaying the appliances, their quantities, power ratings, cumulative loads, total operating hours, and their daily energy consumption in watt-hours (WH).

S/N	Load/Appliances (AC)	Quantity	Power Rating (Watts)	Connected Loads (Watts)	Operating Hours (HR)	Daily Energy (Watthour)
1	Ceiling fan	3	70	210	4	840
2	Light Bulbs	10	15	150	10	1500
3	TV(LCD)	1	120	120	5	600
4	Refrigerator	1	200	200	5	1000
5	Laptop	1	65	65	4	260
6	Air-conditioner (1.5hp)	1	1120	1120	4	4480
7	Miscellaneous		600	600	3	1800
Total				2465W		10480WH

DC (Generation Phase)

$DC_{Load} = SL + DD$ ………equation (3.1) (*Ibrahim Saliu Usman 2022, Marwa S. Salem 2017)*

SL = Allowance for System Internal Losses

DD = Total Daily Energy Demand » DD = 10480WH

Where, Max internal system loss (ç) is 0.35 » ç = 0.35

$$SL = ç \times DD$$

$$SL = 0.35 \times 10480 = 3668\text{WH}$$

From equation (3.1); $DC_{Load} = SL + DD$

$$\text{DCLoad} = 3668 + 10480 = 14148\text{WH/Day}$$

This is value of 14148WH is the minimum power required to flow into the battery and inverter.

AC (Power Consumption Phase)

Max Inverter Efficiency (µ) 90% ~ 0.9

ACLoad = $\frac{DD}{\quad}$...............equation (3.2) (*Ibrahim Saliu Usman 2022, Marwa S. Salem 2017)* µ

$$\text{ACLoad} = \frac{141480}{0.9} = 11644.4WH$$

Load Requirement in Ampere-Hour:

$AC_{Load} = 11644\text{WH}$

System Voltage rating (V_r) = 24V

AHLoad = $\frac{ACLoad}{\text{Vr}}$.......... equation (3.3) (*Ibrahim Saliu Usman 2022, Marwa S. Salem 2017)*

$$\text{AHLoad} = \frac{11644}{24} = 485.2AH$$

Following the load assessment and determination of Daily Demand, the installation of the photovoltaic system prioritizes components capable of generating electrical power, namely the solar panels and charge controller.

3.2.2 Solar Panels

The 300W-rated monocrystalline solar panels in the photovoltaic system maximize electricity generation while using the least amount of space. Equations 3.4 and 3.5 are used to determine the precise number of these panels needed, as suggested by Jim Bruce and James Diwa Enyi (2023) (2023).

Analysis to determine the number of Solar panels:

This analysis is done using equation (4) and (5) as proven in *James Diwa Enyi, 2023 Mustafa Abdulateef 2022.*

$$NSP = \frac{Prating}{ꞇ}$$

……………………………………………………………………………………………..

.equation (3.4)

$$Prating = \frac{DCLoad}{PSH}$$

…………………………………………………...………………………………

equation (3.5) Were.

NSP = Number of Solar Panels Required P_{rating} =

Power Rating at Peak Sun Hours in Watts ꞇ =

Grade of Solar panel

PSH = Peak Sun Hours

Peak Sun Hours (PSH) = 8hrs

DC_{Load} = 14148WH

Using equation (3.5)

$$P_{rating} = \frac{14148}{8} = 1769W \sim 1800W$$

$\therefore$ Prating = 1800W

Grade of Solar Panels Available (ɕ) = 300W

Recalling equation (3.4),

NSP = 1800W/300W

= **6 Solar Panels**

Based on the findings of this analysis, a configuration of six solar panels rated at 300 watts each is affixed to solar rails, strategically positioned in an area abundant with sunlight and devoid of shading. In adherence to optimal positioning guidelines, the panels are oriented to face true south, a standard practice for installations located in the northern hemisphere.

Considering the geographical coordinates of Benin City, where this photovoltaic system is designed and installed, situated at a latitude of 6.34°, the solar panels are angled towards the south. Mounted on a stationary surface, they are tilted at an angle of 6° to maximize sun exposure throughout the day.

Given that the system voltage rating is determined to be 24 volts, as indicated in equation (3.3), and each of the 6 panels carries a 12-volt rating, a series connection of two panels is employed to create 3 sets, each producing 24 volts. These sets are then connected in parallel to establish a 6-panel arrangement operating at 24 volts.

3.2.3 Solar Charge Controller Overview:

The solar charge controller features a total of six terminals, each serving a distinct purpose within the system:

i. Two terminals designated for input, facilitating the connection of the panel output cables through which power generated by the solar panels is directed into the charge controller.

ii. Two connecting terminals responsible for establishing a link between the charge controller and the battery, ensuring efficient charging and management of the battery's energy storage.

iii. Two additional terminals designated for DC loads or appliances, offering the option to directly connect devices to the charge controller for power supply.

To integrate the 24V 300W DC electrical output generated by the solar panels into the system, the output cables are securely attached to the solar panel terminal on the charge controller, ensuring seamless energy flow and effective control of the charging process.

To determine the specific grade of Charge controller capable of withstanding this much energy, we analyzed using equation (3.6) (3.7) and (3.8) *James Diwa Enyi, 2023*

Analysis to determine suitable specifications of the charge controller to be used:

NSP = 6 panels

$I_{max} = {}^{1}\!/\!_{I_1} + {}^{1}\!/\!_{I_2} + {}^{1}\!/\!_{I_3}$……………………..………………………………equation (3.6)

Maximum current for each Solar Panel (I) = 8.24A

Were.

I_{max} = Total Maximum Current

$\therefore I_{max} = {}^{1}\!/\!_{8.24} + {}^{1}\!/\!_{8.24} + {}^{1}\!/\!_{8.24}$ ……………………………………. (from equation 3.6)

= 24.724A

SArating = 3 × Imax × Vr

………………………………………………………………………….……………….. equation

(3.7) Were.

SA_{rating} =Total Power rating of Solar Array

Applying equation (3.7)

$SA_{rating} = 3 \times 24.724 \times 24$

$\therefore SA_{rating} = 1779.8$Watts

Recall, that system voltage (V_r) = 24V

And Power equation is.

$$P = IV$$

$$\therefore P = IV_r$$

$$I = {}^{P}\!/\!{}_{Vr}$$

$$I = 1779.8/24$$

$$I = 74.16A$$

According to the computations conducted previously, it is advised to utilize an 80A, 24V MPPT solar charge controller, which allows for ample flexibility to accommodate days with high sun exposure.

Upon connecting the photovoltaic modules to the charge controller, two cables extend from the charge controller's battery terminal to the batteries, completing the circuit.

3.2.4 Battery

Two wet cell tubular batteries, each rated at 220AH and 12V, are linked in series to produce a 24V battery output.

This selection of batteries, along with their specifications, aligns with the load assessment outlined in Table 3.2 above.

Analysis to determine appropriate number of the batteries to be used:

To determine the appropriate number of batteries we use equation (3.8) and (3.9) *Ayaz Khamisani, 2022 and Simon Mugo 2022.*

$\mathrm{BS} = \mathrm{AH}_{\mathrm{Load}} \times {}^{ß}/_{ƿ}$ …………………………………………….. equation (3.8)

BS = Battery Size

$\mathrm{AH}_{\mathrm{Load}}$ = Effective load Requirement in AH

ß = Days of Autonomy

ƿ = Depth of Discharge for Tubular Batteries

In implementing this design for a 3.5KVA solar system within the African continent, which experiences abundant sunshine almost year-round, the days of autonomy are calculated to be a value greater than 0 but less than 1.$ß = 0.5$

$p = 50\% = 0.5$ (*Abigail Jibril, 2018)*
Recall $AH_{Load} = 485.2AH$

Battery size = $485.2 \times {}^{0.5}\!/0.5 = 485.2AH$

Grade of Batteries ($ꞇ_b$)= 220AH

$NBs = {}^{BS}\!/ꞇb$ …………………………….……………………………… equation (3.9)

NBs = Number of Batteries

$\therefore NBs = {}^{485.2}\!/220 = 2.21 \sim$ **2 Batteries Rated at 220AH**

After linking the charge controller output cables to the batteries and connecting the batteries in series to achieve a 24V rating, the inverter is subsequently connected to the output cables of the batteries.

3.2.5 Inverter:

By drawing power from its connection with the batteries' output cables, the inverter receives an approximate total power of 3.5KW and is tasked with converting this DC energy into AC.

To ascertain the precise type of inverter best suited for this system, equation (3.10) is employed, as referenced by Usman (2022) and Heltsley (2023).

$In_{size} = {}^{Total}/\mu$ ……………………………..…………………………..……. equation (3.10)

$P_{total = Cload} + C_{load} \times (MoS)$ …………………………………...………… equation (3.11)

Were.

In_{size} = Inverter Size

P_{total} = Total Power of the System

μ = Max Inverter Efficiency

C_{load} = Total Cumulative Load

From Table 3.2,

$C_{load} = 2465W$

Margin of Safety (MoS) = 25% = 0.25 (Sourced from *Ibrahim Saliu Usman 2022 and Kathrn Heltsley 2023).*

Max Inverter Efficiency(μ) = 90% = 0.9

Applying equation (3.11),

$P_{total} = 2465 + 2465(0.25)$

$= 2465 + 616.25$

$= 3081W$

Recalling equation (3.10),

Insize = 3081⁄0.9

= 3423KVA

Hence, a 3.5KVA inverter proves to be the appropriate choice.

The 3.5KW DC power furnished by the battery undergoes conversion into an equivalent 3.5KW AC power, subsequently directed to the Changeover switch. Tasked with distributing this power, the Changeover switch supplies it to the designated load units/appliances for operation.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESULTS OBTAINED FROM EQUIPMENT SIZING FOR THE SYSTEM

It is crucial that we review the sizing calculations from the previous chapter to go on. This will allow us to provide the foundation for the ideal outcomes from testing that we should hope to achieve.

Table 4.1 Sizing calculations for 3.5KVA Solar Power System

Component	**Description of Component**	**Result**
Load Estimate	Total Load Estimated	14148WH/Day
PV Array	PV module Capacity	1800W
	Number of modules in series	2
	Number of modules in parallel	3
	Total Number of Modules	6
Battery Bank	Battery Bank Capacity	220AH
	Number of batteries in series	2
Charge Controller	Capacity of Charge Controller	74.16A
	Number of charge controllers	1
Inverter	Capacity of Inverter	3.5KVA
Wire	From module through charge controller to Battery	25mm^2

	Between battery and inverter unit	35mm^2
	From inverter to load circuit	6mm^2

With these calculations (made in chapter three), we can proceed to testing, and confirming if our system is capable of powering the 10.48KWH home. To get the list of materials, quantity, and specifications, see Table3.1

4.2 Testing and Results

After installation, the inverter was assessed in the absence of a load. At this stage, the inverter's output voltage was measured. Afterwards, one load at a time was turned on until each load was fully powered on, evaluating the inverter system. It was found that the inverter system could handle the loads fairly effectively. Several experiments were conducted to determine the solar panel, battery, and inverter system's efficiency at a particular load. The following is a list of the testing types that were performed.:

i. Solar Irradiation Test

ii. Voltage Comparison Test (on no-load)

iii. Open circuit voltage (Voc) and short circuit voltage (Isc)

4.2.1 Solar Irradiation Test

The test was conducted in conditions of intense solar radiation, which is the greatest amount of electrical energy that photo-voltaic panels can produce. After 100 minutes, the radiation reached its maximum at a rate of 964 W/m2, and after 360 minutes, it reached its minimum at a rate of 335 W/m2. The test's radiation is good since solar irradiation may stay steady over 800W/m2 for ±3 hours.

Table 4.2.1 Below shows the solar irradiance results of power generated by 1m^2 of PV modules at peak sun hours.

S/N	Time Elapsed (Seconds)	Energy Generated in Watts by 1m^2 module (W/m^2)
1	0	800
2	20	832
3	40	887
4	60	902
5	80	955
6	100	981
7	120	950
8	140	980.5
9	160	981
10	180	830
11	200	800
12	220	790
13	240	745
14	260	600

15	280	592
16	300	588
17	320	420
18	340	395
19	360	372

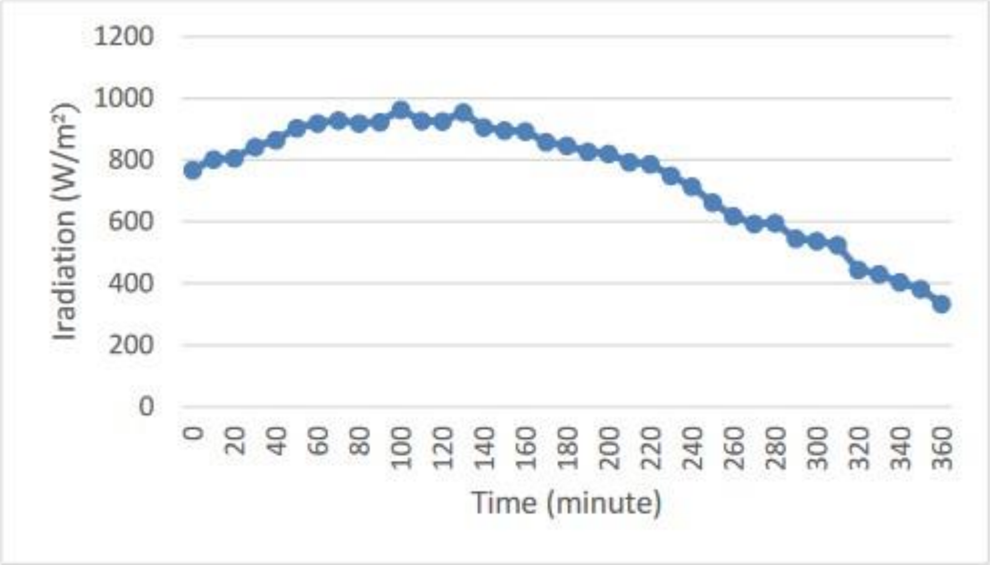

Figure 4.2.1 Test Graph of Solar Irradiation 300Wp

4.2.2 Voltage Comparison Test

The picture below compares the panel output, inverter output, and BCR voltage of an off-grid 3.5KVA solar power system. Since the relay does not need electricity, the graph shows that the output voltages of the inverter and relay match. The output voltage of the inverter and relay typically stabilizes in the 225–234 V range in six hours. We then tested the voltage on an electric stove that had dimmers installed. We discovered that the voltage of the electric stove is linearly proportional to the heat it generates. A dimmer is required to lower the power to 120 to 140 volts since an electric stove emits heat at temperatures between 70 and 80 degrees Celsius.

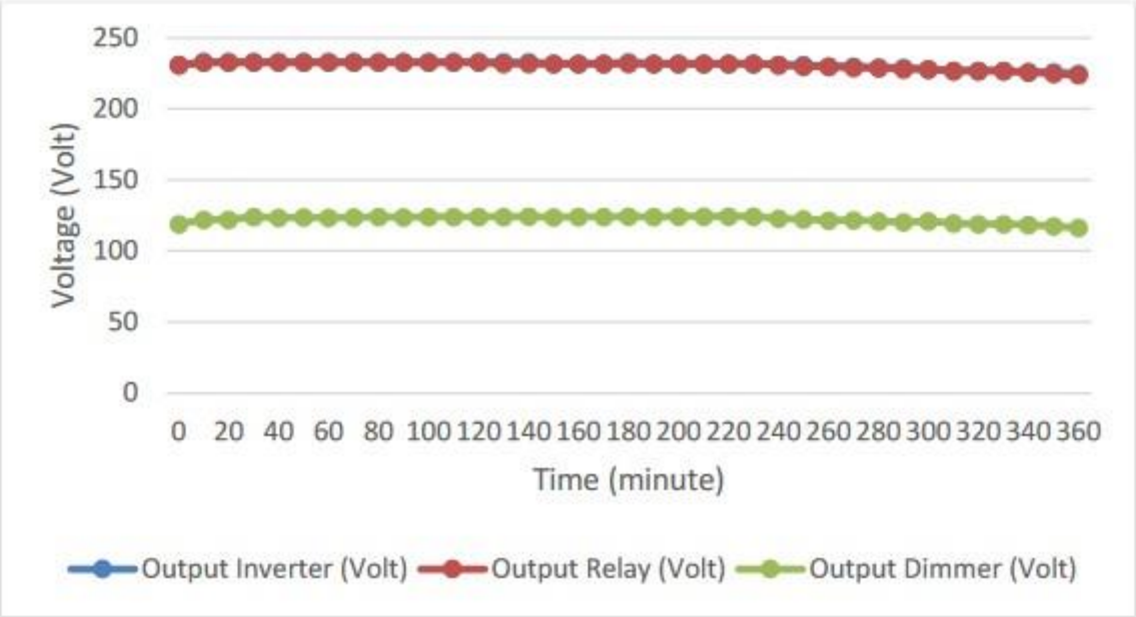

Figure 4.2.2 Graph of voltage comparison in 300 Wp PLTS Off-Grid System

4.2.3 Open Circuit Voltage (Voc) and Short Circuit Voltage Tests (Isc)

After completing the solar panel installation, the open circuit voltage (Voc) and short circuit (Isc) of the installed solar panels were measured for an optimal analysis. The measurement was carried out at various interval, and a graph of efficiency against load was plotted. The table below contain the data for system efficiency.

Table 4.2 Results from Daily Demand Tests

S/N	Input Current (A)	Input Voltage (V)	Input Power (W)	Connected Load (W)	Output Current (A)	Output Voltage (V)	Actual Load (W)	Efficiency (%)
1	2.75	25	68	No Load	0	0	No Load	0
2	8	24.9	206.6	100	0.4	220.0	88	42
3	11.7	24.7	288.9	200	0.7	220.0	154	53

4	19.7	24	474.7	400	1.5	218.7	328.05	69
5	27.5	23.8	654.5	600	2.4	219.0	525.8	80
6	36.7	23.5	862.45	800	3.5	214.6	751.1	87
7	51.0	23.1	1178.1	1000	5	207.7	1038.5	88
8	74..3	22.54	1674.4	1500	7.36	200.5	1476	0.88
9	102	21.27	2170	2000	10.12	189	1912.8	0.88
10	127.4	20.9	2666.3	2500	13.28	177	2350.3	0.88
11	157.5	20.01	3162.6	3000	16.5	169	2787.8	0.88
12	187.4	19.53	3658.9	3500	20.944	154	3225.3	0.88

Figure 4.2.3 Efficiency Curve

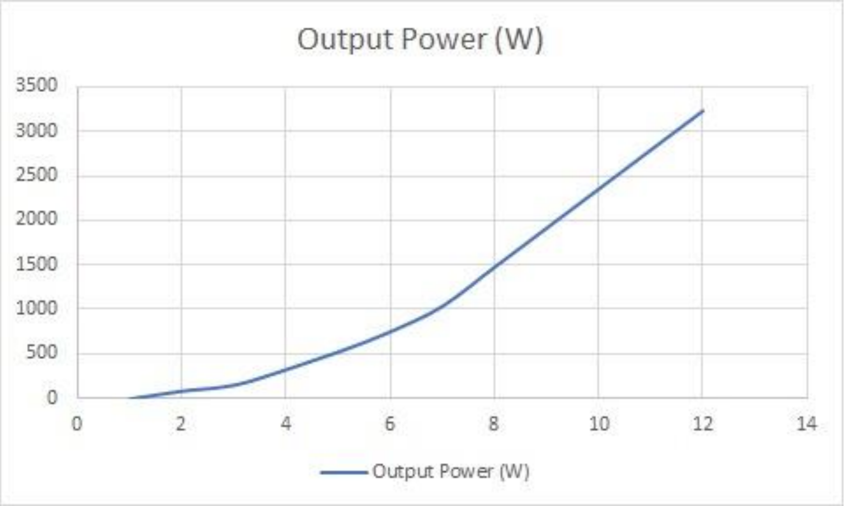

Figure 4.2.4 Output Power Curve

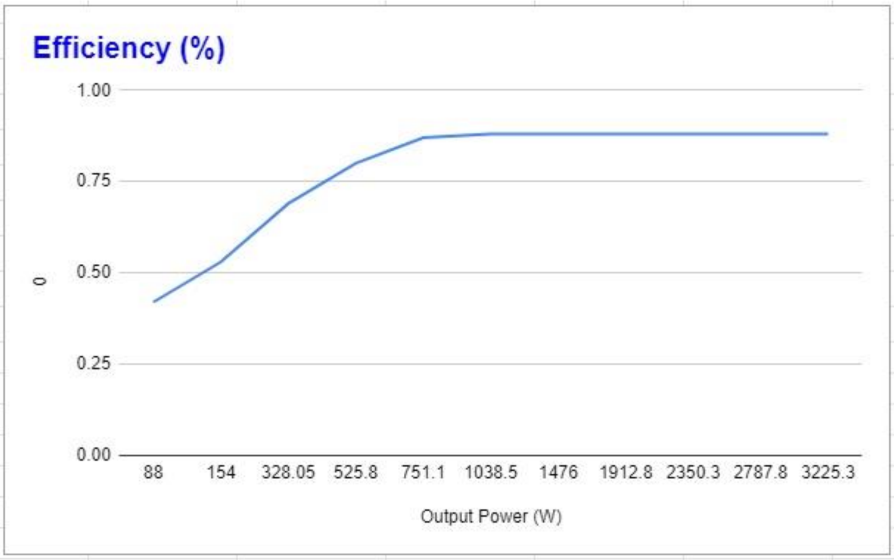

Figure 4.2.5 Graph of Efficiency Against Output Load

According to the results, the increase in (Isc) is proportional to an increase in the panel's Voc. Additionally, we observed a notable increase in voltage and current at a constant temperature.

Using the observed data, we were able to plot a graph of efficiency against load. As we add more loads, the inverter system's efficiency gradually increases, peaking at loads over 3000W.

4.3 Discussion

We designed the proposed standalone PV system based on the projected load demand from appliances, measured in watthours. Table 4.2 displays the outcome of the expected daily demand, which added up to 14.148 kWh every day. Table 1 shows the specific design outcome and component sizes. It consists of six ENP Sonne 300W, 24V PV modules, each of which can produce 1.8 kW of array power. To achieve the required current and voltages for the load system, the PV array design consists of three parallel and two series components.

The load requirement was considered when designing the storage system. The storage system utilizes a total of two 12V 220AH Super Speed Tall Tubular batteries, which consist of three series and four parallel battery configurations with a bank capacity of 1930AH. For this design, we chose an 80-amp SMS Summate Charge Controller, taking into account the aggregate current from the photovoltaic arrays. We selected the FelicitySolar 3 series inverter due to its 3.5kW rating and its ability to convert DC to AC power.

The wire size took into account each component's capacity to conduct current. 3 copper wire (AWG), or 25mm2 copper wire, was chosen to run a current of 74.16 amps between the PV panel via the charge controller and the battery.

The design calculation dictates that the optimal length of 1 copper wire (AWG), or 35 mm2, should terminate the battery and inverter. The ideal wire size for feeding the load distribution would be 10 copper wires (AWG), or 6 mm2, which is sufficient to carry the 15.91 amps the inverter can deliver at full load.

After successfully completing the tests, we were able to conclude that we satisfied the project's objectives, which were

1. Review important literature that closely relates to this work to understand the advancements made in the field of solar systems.
2. Design the solar PV system, including the selection of appropriate solar modules and mounting structures. iii. Install these components according to our design and calculations. iv. Conduct performance evaluations and load-bearing tests to ascertain the overall efficiency of the system.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATON

5.1 Conclusion

Rising solar energy is going to change the energy landscape by providing a solution to reduce dependence on fossil fuels while also taking environmental issues into account. In contrast to conventional energy paradigms, this study emphasizes the integration of solar photovoltaic (PV) systems as a means of promoting sustainable power generation. Key benefits of PV systems are their appropriateness for off-grid applications, minimal maintenance requirements, cost-effectiveness, sustainability, and renewability.

This PV system's key component, the solar cell array, effectively transforms DC energy into AC to feed it into the utility grid. We carefully built, tested, and found the 3.5KVA solar panel system, which consists of solar cells, a battery bank for energy storage, a charge controller for voltage management, and an inverter for DC to AC conversion, to function within predetermined parameters. System sizing was carefully considered to ensure efficiency and appropriateness.

We can modify and customize these techniques for applications with a larger demand and a variety of geographic situations if we take local design parameters into consideration. Cost, component availability, efficacy, compatibility, and durability were some of the factors that influenced project design and execution.

5.2 Recommendations:

I. Precision in system design, including accurate site and demand data, is critical for maximizing solar PV system performance. Detailed assessments of energy demand, operational patterns, and availability are essential, necessitating adequate storage capacity for surplus energy during peak generation.

II. A sustained investigation focused on optimizing solar photovoltaic system constituents will increase solar radiation absorption and power output capacities. Improvements may include solar tracking systems, more panels, or the use of solar concentrator panels.

III. Increasing the production of solar energy helps with global sustainability initiatives and climate change targets by reducing greenhouse gas emissions and pollutants from traditional energy sources.

IV. To reduce hazards, pay attention to how shading affects solar panel performance and ensure proper electrical component installation and grounding.

V. The selection of high-quality components from reputable brands is imperative for a reliable 3.5kVA system, encompassing solar panels, inverters, charge controllers, and batteries.

VI. Using a charge controller with a matched panel amperage ensures effective charging and battery protection.

VII. Careful panel arrangement, whether in series or parallel, maximizes system performance by optimizing voltage and current capacity.

VIII. To prevent overloading and guarantee continuous functioning, future innovations should concentrate on increasing system capacity for higher loads while giving appropriate maintenance top priority.

REFERENCES

The study was conducted by Abanihi, V. K., Ezomo, P. I., Aliu, D., Chinedu, P. U., Obari, J. A., & Momoh, M. O. in 2020.

“Complementarity Problem Approach to Economic Power Dispatch in the Nigerian Power System".

ATBU Journal of Science, Technology, and Education, 8(2), 240–249, June 2020.

Abdulateef, M. (2022). Estimation of loads for off-grid solar photovoltaic systems.

Abu, N., & Rahman, A. (2014). *Design and Construction of a Square Sine Wave Inverter*. (An Unpublished Project Report) The report was submitted to the Department of Electrical and Electronics Engineering at Kaduna Polytechnic, Kaduna. September.

Aitken, D. W. (2010). You can access "History of PV solar" online at www.

Solarstarttechnologies.com.

Ali, N. A., Mohd, Y. H., Sohif, M., Ruslan, M. H., Azher, M. A., & Sopian, K. (2014). “Design and Sizing of a Stand-alone Power System; A House in Iraq.” *Recent advances in renewable energy sources.*

Andrew, A. L. (2008). *Applied Physics for Electronic Technology.* Arnold Holder Headline Publishers, London.

The research was conducted by Amara, S., Toumi, S., Ben Salah, C., and Saidi, A. S. in 2022. Optimization and sizing of an autonomous photovoltaic battery microgrid system.

Arun, K. V., Bhim, S., & Kaushik, S. C. (2010). “An Isolated Solar Power Generation Using

Boost Inverter.” *The article was published in the International Journal of Engineering and Information Technology.*

Badrul, H. (2002). *Design, Construction, and Installation of a 2KVA Inverter.* (An Unpublished Project Report) The report was submitted to the Department of Electrical and Electronics Engineering at Kaduna Polytechnic, Kaduna. August.

Bazilian, M., Onyeji, I., & Liebreich, M. (2013). “Photovoltaic System”, Available online at www.wikipedia.com/wiki/photovolatic_system.

Bruce, J. (2023). Sizing solar panels, batteries, and inverters for solar systems.

Chaitrashree, C. N., Kashyap, Y., & Sidharthan, V. (2023). The study focuses on the Li-ion Battery Energy Storage Management System for Solar PV.

The study was conducted by Dare, A. T., David, T. W., & Emmanuel, S. T. in 2023. Design Methodology and

Implementation of Stand-Alone Solar Photovoltaic Power System for a daily energy consumption of 9.16kWh.

Eliabban, O., Abu-Rab, H., & Blaabjerg, F. (2014). “Renewable Energy Resources: Current Status, Future Prospects and Their Enabling Technology.” *Renewable and Sustainable Energy Reviews*.

Eminov, S. O., Hashimov, A., & Rajabli, A. (2024). Integration of Electrical Energy Storage Devices with Photovoltaic Solar Cells in One Hybrid System.

Enyi, J. D. (2023). Design and Installation of a 3.5KVA Solar photovoltaic power system.

Gajbhiye, T. S., Nikam, K., & Seeniappan, K. (2023). Sustainable renewable energy sources and solar mounting systems for PV panels: A critical review.

Gette, J. (2014). Socket for an electrical plug-and-socket connection.

Heltsley, K. (2023). How do I calculate what inverter size I need?

James, P. Dunlop. (1997). *Batteries and Charge Control in Stand-Alone Photovoltaic Systems: Fundamentals and Application*.

Khamisani, A. (2022). Design Methodology for an off-grid PV solar-powered system.

King, D. (proceeding Year not provided). "Photovoltaic Module and Array Performance Characterization Methods for All System Operating Conditions", *Proceeding of the NREL/SNL Photovoltaic Program Review*.

Mugo, S. (2022). Battery Sizing Explained.

Mundada, A., Nilsiam, Y., & Pearce, J. M. (2016). A review of technical requirements for plug-and-play solar photovoltaic microinverter systems in the United States.

Ohanu, C. P., & Godson, N. (2024). They conducted a sizing and analysis of a standalone photovoltaics system for a three-bedroom residence in Nigeria.

Praveen, G. B., Kumar, M. S., & Shenoy, L. (2023). Review and Study of Solar String Inverters for a PV System.

Pushparaj, N. K., & Balasubramanian, P. N. (Year not provided). Enhancing grid-connected solar PV systems with a novel three-phase hybrid multilevel inverter.

Reddy, M. L., & Kumar, P. J. R. P. (2017). A comparative study on charge controller techniques for solar PV system.

Salem, M. S. (2017). Design, Sizing, and Implementation of a PV system for Powering a living room.

Sözen, M., & Griffin, J. (2024). Optimal Angle of Inclination for Fixed Solar Panels and Collectors.

Usman, I. S. (2022). Redesign, Rehabilitation, and Implementation of 2.5KVA Solar System at Power Laboratory. A HND Research Project.

Vanitha, A. S., & Rajendran. (2022). A Novel Asymmetric Multilevel Inverter with Reduced Number of Switches for Grid-Tied Solar PV System.

Wang, Z., Luther, M. B., & Horan, P. (2023). Battery Storage Analysis for Residential Solar Photovoltaic Systems.