

**DESIGN AND INSTALLATION OF 1.5 KVA INVERTER
SYSTEM**

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DEDICATION

This endeavour is dedicated to God Almighty for his grace, provision, and good health over the duration of the project.

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We would want to thank God for providing us with the insight, expertise, courage, and strength to successfully complete this project.

Thanks are also extended to our parents and siblings for their encouragement and moral and financial assistance. May the Lord bless them

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CHAPTER ONE

1.1 INTRODUCTION

Nature provides an endless source of renewable energy that will never be depleted (Oseni, 2012). The use of renewable resources such as the sun, the wind, and even nuclear fission are all good examples. The depletion of traditional fossil fuels and the damage they cause to the environment have increased interest in studying renewable energy sources (Abu-Rub, 2010). As a result of technological advancements, electricity is now the most common power source for homes, businesses, schools, and hospitals.

In Nigeria, there isn't enough power going from power plants to consumers because of broken equipment, human error, and broken transmission and distribution lines. Because of this, there was an unexpected break in the power supply, which led to the loss of valuable information while computers were processing data. It also made hospital equipment and refineries less effective, which in some cases caused people to die. Alternative energy sources, like fuel generators, have been made to cut down on the number of power outages and hiccups. Even though the fuel generator makes the expected amount of power, it has a lot of bad side effects. Carbon monoxide gas is released through the exhaust, which is bad for human health and contributes to the depletion of the ozone layer. The generator is also loud, big, and expensive to maintain and fuel. Solar inverters got around these problems by using semiconductor power devices like the Bipolar Transistor, Unipolar Transistor, Thyristor, and especially MOSFET to make electricity with a DC battery in a few kilowatts. These devices are less noisy, don't need fuel, don't pollute the air, are more efficient, and have low or no maintenance costs.

When installing a solar energy system, the inverter is a crucial part of the setup. It takes the varying DC current from a photovoltaic (PV) solar panel and transforms it into AC current at utility frequency, which can then be supplied into the commercial electrical grid or a small, off-grid electrical network. The smallest device capable of directly converting sunlight into electricity via the photovoltaic effect is a solar cell,

also known as a photovoltaic cell. The voltage and current of a photovoltaic (PV) system can be increased by connecting multiple PV cells in series or parallel. Quite simply, a Panel is a modular framework. It's a vital part of the photovoltaic system's BOS because it lets you utilize regular AC appliances. Maximum power point tracking and anti-islanding prevention are only two of the many functions included in solar power converters made specifically for use with photovoltaic arrays.

By allowing electrons to travel from negative to positive, the solar panel utilized in the solar inverter generates direct electricity. The great majority of our household appliances run on alternating current. The continual passage of electrons from negative to positive creates alternating current (AC). Depending on how the appliance is used, the voltage of alternating current power can be modified. Solar inverters are used to convert DC to AC because solar panels only provide direct current [2] [3]. The inverter produces square or sine waves that can be used to power devices like lights, televisions, and motors. However, harmonic distortion is produced by these inverters.

1.2 STUDY BACKGROUND

Use of the sun's energy is not new. Its rich history dates back to the seventh century B.C. Before lighting fires, we would focus the sun's rays using glass and mirrors. Solar panels may now be found on everything from homes to cars. You may learn more about the significant years and centuries in the development of solar technology by reading further. From Archimedes' employment of brass shields to concentrate the sun's beams on Roman ships in the third century BC, it is clear that harnessing the sun's power has been an aim of human invention (causing them to burst into flame).

In 1767, Swiss physicist, Alpine explorer, and aristocrat Horace de Saussure is credited with creating the first practical sun oven. The oven's five panes of glass allowed light to pass through, and the black interior turned that light into heat. It measured roughly 12 inches in diameter. Because the glass reflects the heat, the temperature inside the container quickly rises to 87.5 degrees Celsius.

Edmond Bequerel found in 1839 that light falling on an electrolyte (electricity-conducting fluid) between two electrodes created a voltage. The solar power's underlying principles have been exposed.

An increasing number of people are turning to solar power, attesting to the field's rising significance. Instead of using electricity, a solar inverter converts the energy from the sun into usable form. Direct current from solar panels must be converted to alternating current via an inverter. During power outages, a circuit can benefit from direct power, which flows only in one way inside the system. Battery-powered electronics like cell phones, MP3 players, and iPods need direct currents to operate.

To use appliances that run on alternating current (AC) instead of direct current (DC), a solar inverter must be installed. Solar energy is abundant, clean, and pollution-free, therefore it makes sense to utilize a solar inverter instead of a traditional electric one. Inverters that convert electricity generated from the sun into usable energy are also known as photovoltaic solar inverters. You can cut your expenses significantly with the help of these gadgets. Off-grid systems are more complicated and require batteries to allow customers to use appliances at night when there is no sunshine, whereas small-scale grid systems merely require panels and inverters. Solar cells installed on rooftops and stored in batteries can transform sunshine into usable energy. Additional energy is stored by the batteries and used to run electronics at night.

1.3 PROBLEM STATEMENT

The electrical industry in Nigeria is largely responsible for the country's continued classification as a developing nation. Prior to this, a large number of private residences as well as commercial establishments were unable to depend on the public grid for a reliable supply of power. At this stage in the country's social and economic development, Nigeria is unable to deliver sufficient energy to its population, despite the large financial investments that have been made in the industry.

Instead, Nigerians have continued to rely on electricity generators for power, fuel marketers are extracting a sizeable portion of household and business incomes to supply power, and noise pollution from regularly humming generators has become an unavoidable part of life for many Nigerians, with unimaginable health

consequences as a result. As a consequence of this, there is a requirement for the design and production of solar panel inverters in order to complement the electrical supply provided by the public grid. It is completely silent, and it does not in any way compromise human health (Lookman Oshodi, 2014).

1.4 THE PROJECT'S GOAL

The purpose of this project is to design and construct a 1.5KVA solar inverter device that is capable of collecting a DC voltage input from a 300-Watt solar panel and a 150Amp 12V battery and converting it to a 220V - 230V AC output that can be used to power AC appliances. In doing so, the problem of power outages and the use of polluting nonrenewable alternatives will be alleviated.

1.5 PROJECT SCOPE

A solar inverter converts battery-generated DC into pure sine wave AC. This project will design and build a 1.5KVA solar inverter system that outputs 220V to 230V AC at 50Hz from 12V DC. This inverter powers laptops, TVs, home theaters, energy-saving lamps, fans, and phones.

1.6 THE PROJECT'S SIGNIFICANCE

When it comes to solar power, a Solar Inverter is preferable than a regular inverter. For instance, solar energy will be given higher priority. When the sun's rays are strong enough, as in the afternoon, the inverter will use only the energy produced by the solar panels to run the building, regardless of whether or not the grid is present. You may be able to cut your monthly electricity bill in half by doing this. In contrast, a solar hybrid inverter gives preference to charging via solar panels, so your batteries can be charged via PV panels even when the grid is active.

The usage of a solar inverter has historically resulted in less warmth and fewer emissions of greenhouse gases. Using a solar inverter also reduces costs associated with purchasing gasoline for a conventional generator. Those who just consume a minimal quantity of power will benefit from this.

When compared to conventional electric inverters, solar-powered ones work better and require less upkeep. Providing their batteries have been fully charged by sunshine, solar inverters can continue to operate even when the sun isn't out.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 PREVIOUS WORKS REVIEW

Design Analysis of a 1.5 KVA Hybrid Power Supply for Power Reliability by Ekpenyong et al. Their work entails designing a 1.5 KVA hybrid power supply for power reliability. The system is intended to be used at the administrative office of Cross River University of Technology's electrical and electronics engineering department in Calabar, Nigeria. The system has a low operating cost, is quiet and dependable, and provides the convenience of a twenty-four-hour power source.

Yusuf et al. created a 1 KVA inverter utilizing pulse width modulation (2020). They employed pulse width modulation to design, develop, and install a 1 KVA solar inverter system in this work. The design phases include the oscillator unit, switching unit, inverter transformer unit, battery charging unit, power supply unit, and changeover unit. A 32-inch colour plasma TV, a table fan, a cassette player, and an electric lamp were all powered by the inverter. According to the results, the output power rating with the various modules in cascade was 1 KVA with a modified sinusoidal waveform frequency of 50Hz and voltage 220V. When a 12V battery is tested under load, a discharge rate of 100A/hr results in an 8-hour discharge time for a total load of 150W and a 4-hour discharge time for a total load of 300W.

Akpan and Ewetumo's Low-Cost Automatic 2 KVA Inverter System Design, Development, and Construction (2010). This study details the design and construction of a low-cost automatic inverter system that converts 24 VDC to 220VAC 60Hz with a power handling capacity of 2 KVA, focusing on step-up transformer specification. The driver and switching circuit, automatic battery charger, battery voltage level indicator, and capacitive/inductive filter comprise the inverter system. Both solid-state and electromechanical relays were used to

automatically switch power without affecting load voltage, regardless of whether a public power supply (PPS) was available.

Nwokoye et al. designed and implemented a 1.5 KVA pulse width modulation inverter system based on a microprocessor (2016). A microcontroller-based 1.5 KVA pulse width modulation inverter system is conceived, manufactured, and tested in their work. This device converts the DC output of the battery to AC output. In the constructed circuit, control circuitry for the SG3524 is used. It is designed to automatically switch over when the supply voltage falls below 160V. The microcontroller receives power from an Analog to Digital converter. When the supply voltage falls below 160V, the microcontroller checks it and biases the BC547 transistor connected to one of its pins, thereby turning on the inverter. To prevent overload, the inverter continuously measures the total output power consumed, which is accomplished through the use of operational amplifiers, resistors, and transistors. The system receives a 12VDC supply and generates a modified square wave form with a 50Hz frequency and a 20ms period within a voltage range of 200V to 230V.

Nnabuikwe et al. created a 1.5 KVA Robust, Efficient, and Low-Cost Inverter System (2021). The main focus of their efforts is the design of a 1.5 KVA inverter system with controls and an alarm. The subcircuits that comprise the circuit in its design include the oscillator stage (PWM circuit), driver stage, power amplification stage (MOSFET stage, transformer stage, filter stage, and output stage). At 220V, 50Hz, the system generates modified sine waves.

The case study "The Use of Solar Energy for The Provision of Cost-Effective and Environmentally Friendly Power Supply in Health Facilities In The Developing World- Lessons From A Community Cottage Hospital In Southern Nigeria" by Ekanem et al. presents an analysis of a community cottage hospital in southern Nigeria (2017). At 2010, the Rivers State of Nigeria and Shell Petroleum Development Company collaborated to install solar power as an alternative electrical supply system in a Community Cottage Hospital in southern Nigeria. Since then, an average of sixteen to twenty-four hours of electricity per day has been achieved, with a steady reduction in dependency on fossil fuels. The cost of power has also decreased since the installations, and more people are using the facility.

Ezeagwu and colleagues created a 1 KVA solar inverter system. Their mission was to design, analyse, and build a solar conversion system consisting of a solar panel, an inverter, and a battery. The solar panel collects solar energy and charges the battery with direct current via the charging circuit. The inverter converts direct current electricity to alternating current power, and the battery is charged using either a solar panel or the power grid. A test was performed to determine its effectiveness.

Solar Inverter and Charger, Poonam et al. Their design consists of a solar array, a 12V lead acid battery, and a control section that employs the PIC16F72 microprocessor. The control section gets data from the photovoltaic array via the Analogue and Digital (A/D) ports on microcontrollers and uses that data to perform pulse width modulation (PWM) on the converter via its D/A ports. The microprocessor also controls the charge level of the battery to prevent overcharging. When the battery is charging, the red LED will illuminate until it reaches the fully charged, floating state, at which point the green LED will illuminate. The PIC16F72 will determine whether it is day or night by using a sensor circuit. The light will turn on automatically when the sensor circuit sends an input to the PIC and the PIC sends an output to the relay to turn on the light. The detecting circuit detects the sun's rays as night turns to day. The PIC then sends the output to the lamp to turn it off, while the charging circuit continues to charge the battery throughout the day.

2.2 SOLAR INVERTER SYSTEM TYPES

Solar inverter systems are classified into two types:

- A grid-connected photovoltaic system
- An off-grid or stand-alone solar system

2.2.1 PHOTOVOLTAIC SYSTEM ON GRID

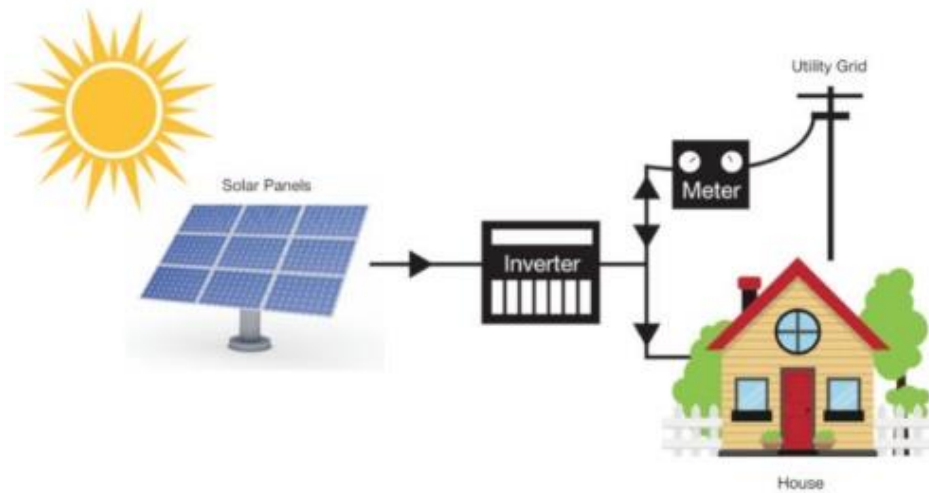


Figure 1: Photovoltaic System Connected to the Grid.

The most basic definition of a grid-tied solar system is an electrical power grid link. This infrastructure is required for the system to create effective solar energy while also channelling any excess energy for later usage, clean energy credits, or net metering (Moxie solar, 2022). A grid-tied solar system is a power system that generates electricity from a solar photovoltaic array. A specialized inverter regulates and converts the generated energy into the required utility power (single or three phase output). This electricity is synchronized with utility power by the inverter, which also gives feedback to the utility grid.

2.2.2 PHOTOVOLTAIC SYSTEM OFF-GRID

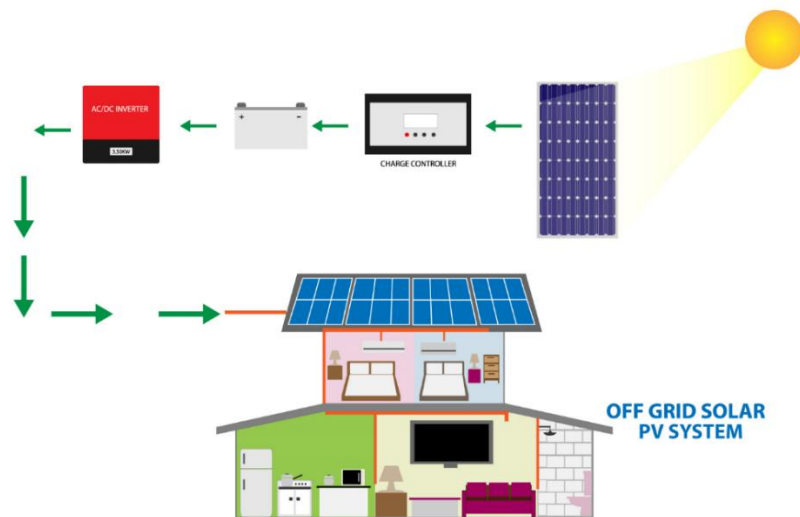


Figure 2: Photovoltaic System Off-Grid.

A stand-alone photovoltaic system generates power during the day to charge batteries for use at night. Rechargeable batteries store solar energy in freestanding small-scale photovoltaic systems.

Stand-alone photovoltaic systems are appropriate for rural areas and applications where alternate power sources are difficult or unavailable for lighting, appliances, and other uses. A freestanding PV system is often cheaper than paying the local power company to construct electricity lines and connections on the site for a grid-connected PV system.

2.3 SOLAR INVERTER SYSTEMS' HISTORY

Solar energy is old. Originating in the seventh century B.C. Glass and mirrors focused sunlight to start fires. Solar energy currently powers buildings and cars.

1767 saw the first "solar collector cell" developed. Swiss scientist Horace-Benedict de Saussure (right) discovered it while studying thermal power, mostly steam. He built a three-glass insulated box with a door. This glass was utilized in various ways to raise the sun's warmth above 230 degrees Fahrenheit.

The 1839 discovery of the photovoltaic effect changed solar energy. In his father's lab, 19-year-old French physicist Edmund Becquerel studied the photovoltaic effect using an electrolytic cell, two metal electrodes submerged in an electrolyte. Light enhanced energy. Nature's February 1873 edition featured Willoughby Smith's "Effect of Light on Selenium during the Passage of Electric Current" article. Charles Fritts invented the solid-state solar cell six years later. Fritts connected selenium semiconductors with a thin gold layer. This device had 1% efficiency. It was the first to convert sunlight into electrical energy using a solid substance without moving parts.

Since Aleksandr Stoletov's 1888 discovery, research has focused on improving photovoltaic cell performance (left). He created the first exterior photoelectric cell. Hertz discovered the effect in 1887. The photoelectric effect releases electrons from solids, liquids, and gases that absorb light. UV rays can jump a spark between electrodes. The solar heater unit was invented in 1891.

Einstein explained this photoelectric phenomena and light-initiated carrier excitation in a 1905 study. He won the 1921 Nobel Prize in Physics. In 1908, William J. Bailey created the Copper Collector. Copper insulation made the collector more efficient. Modern machinery uses this technique's advances. However, Russell Ohl patented the contemporary junction semiconductor solar cell in 1946.

In 1953, global warming studies were published. Time and Popular Mechanics covered it. People noticed fossil resources were dwindling swiftly. Renewable energy was needed. Bell Laboratories' Calvin Souther Fuller, Gerald Pearson, and

Daryl Chaplin produced the first usable solar cell in 1954. The US Signal Corps Laboratories developed Earth-orbiting satellite photovoltaic cells a few years later. The Vanguard 1 solar array resulted. Technology made solar energy the main space energy source.

Hoffman Electronics increased efficiency 14%. Technology enabled several attempts to commercialize solar photovoltaic cells in the 1950s and 1960s. Little worked. In the 1970s, the unit could be used in isolated areas where grid-connected utilities were too expensive.

By 1980, ARCO Solar had built solar panel power plants that produced over 1 megawatt of photovoltaic modules per year. The business helped build the first megawatt-scale power plant in Hisperia, California. That year, the US Department of Energy completed Solar One. Solar One focused solar energy on a single point to generate heat and a 10-megawatt current. Heat generated steam turbines. 1818 mirrors with a total surface area of 72,650 m² (40 m² apiece) accomplish this (430 ft²). Photovoltaic cells sold \$250,000,000 by 1985. Silicone solar cells gained 20% efficiency at the University of South Wales. First Sunday of the month. ARCO commercialized the first thin-film solar power module a year later. The US National Renewable Energy Lab invented the solar cell in 1994. Gallium arsenide and gallium indium phosphide formed the cell. It turns 30% of solar energy into useful power, exceeding 30% efficiency. Some floors of a New York City building used these thinner, more efficient cells (see image, right). Years later, they supplied the building's energy.

Today is 2000. The largest solar panel factory generates 100 megawatts each year. Merchants and producers worldwide profited from solar energy. World leaders and others were becoming increasingly aware of the need to minimize fossil fuel use. We needed greener lifestyle fuels. Renewable energy science has grown significantly. Solar power dominated.

Large-scale household and business solar activities began around the turn of the century. Schwarzenegger proposed one million solar roofs in 2004. Germany and other countries have successful household solar PV markets. 2006 garnered media interest. Due to numerous large high-street electrical stores carrying solar PV

modules. The UK started with their installation service. Photovoltaic arrays are everywhere. They are on nearby roofs. 230,000 UK solar power systems existed by 2011. 4 million UK houses will be solar-powered in eight years. Official forecasts attribute this to technology advances and our sun radiation being comparable to Germany's. Insolation level is incident solar energy. Germany has been the largest domestic photovoltaics market. The nation has over a third of its installed capacity. The UK still underuses solar energy. UK energy comes mostly from expensive, polluting fossil fuels like coal and gas.

Utility-scale solar power projects have received significant investment recently. The world's biggest record keeps falling. China's Golmud Solar Energy Station is the world's largest. It will generate 200 megawatts when finished. India's Gujarat Solar Park has 605 megawatts installed. Solar inverters next. Tesla's inventions made them possible. Inverters were invented in the late 1800s and improved till the mid-1900s.

In 2000, Sandia Laboratories in Albuquerque, New Mexico, produced the modern inverter, making household solar possible.

Sandia Laboratories' "non-islanding inverter" rapidly shuts down grid-connected PV arrays when an electric distribution line fails.

Safety concerns and equipment damage prevented utility providers from connecting solar panels. A utility had to totally de-energize a distribution line to turn off power for repair or other reasons. This protects line workers and spectators. Solar systems could not reliably detect de-energized wires before the Sandia breakthrough. The "non-islanding inverter" allowed solar power systems to detect de-energized lines and either stop producing electricity or send it to the linked building or institution. It was vital to domestic solar energy system growth. Solar panels need inverters to convert DC to AC.

2.4 COMPONENT FUNDAMENTALLY USED IN SOLAR INVERTER SYSTEMS

1. Inverter
2. The photovoltaic panels
3. The Battery
4. The Charge Controller

2.4.1 INVERTER

An inverter is a critical component of a solar energy system. It is a device that converts the direct current (DC) electricity generated by solar panels into the alternating current (AC) electricity required by the electrical grid. DC maintains a steady voltage of electricity in one direction. In an alternating current circuit, electricity flows in both directions as the voltage changes from positive to negative. Inverters are a type of power electronics—a class of devices that control the flow of electrical power.

In essence, an inverter converts a direct current (DC) input into alternating current (AC) by rapidly reversing the direction of the input. As a result, from a DC input, an AC output is produced. Filters and other electronics can also be used to generate a clean, repeating sine wave that fluctuates in voltage and can be injected into the electrical grid. The sine wave is a shape or pattern that the voltage takes over time, and it is the type of power that the grid can use without harming electrical apparatus that is designed to operate at specific frequencies and voltages.

The first inverters were mechanical and were invented in the nineteenth century. A spinning motor, for example, might be used to alternate between connecting the DC source forward and backward. Transistors, which are solid-state electronics with no moving parts, are now used to make electrical switches. Transistors are

made from semiconductor materials such as silicon or gallium arsenide. They regulate the flow of electricity in response to electrical signals from the outside world.

2.4.1.1 SELECTING AN INVERTER

When selecting an inverter, the following factors must be considered:

- Efficiency, which refers to how efficient the inverter is at low, medium, and high-power draws, as well as how much power is used when it is idle.
- Wattage rating, or how much electricity the inverter can deliver in watts.
- Surge power: How much power it can supply and how long it can deliver it to start motors or other loads.
- Functionality. From simple DC to AC conversion to highly sophisticated, multifunctional grid tie inverters that accept and convert energy from multiple sources and route excess into the grid in a compatible and safe manner.
- The electrical wave's quality or shape, whether pure sine wave or modified sine wave.

2.4.1.2 SOLAR INVERTER BENEFITS

We must discuss the many benefits of a solar inverter after thoroughly understanding what it is and how well-suited it is for making appliances work at both the domestic and industrial levels.

- Using solar-powered devices will help you save money and energy. Because many people have begun to use these devices.
- A solar inverter converts direct current (DC) to alternating current (AC). This helps people who only use a small amount of electricity.

- Solar energy has consistently contributed to the reduction of the greenhouse effect and global warming.
- The synchronous solar inverter, which benefits both small homeowners and power companies due to their large size.
- The synchronous solar inverter, which benefits both small homeowners and power companies due to their large size.

2.4.1.3 SOLAR INVERTER DISADVANTAGES

- Solar inverters can operate even when there is no sunlight, but the battery can only be used once it has been fully charged by sunlight.
- First and foremost, we must spend a lot of money to purchase a solar inverter.
 - It will work efficiently and produce DC only when the sunlight is strong.



Figure 3: 1.5 KVA Luminous Inverter

2.4.2 SOLAR PANELS

A photovoltaic (PV) cell is a form of energy-harvesting technology that uses the photovoltaic effect to convert solar energy into usable electricity. Various types of PV cells employ semiconducting materials to interact with light from the Sun. A photovoltaic cell consists of multiple layers of materials, each of which serves a distinct function. The carefully made semiconductor layer is the most essential layer in a solar cell. Through a mechanism known as the photovoltaic effect, it converts the Sun's energy into usable electricity. As seen in Figure 2.4 below, it is made of two separate layers. A layer of conducting material "collects" the generated electricity on either side of the semiconductor. It should be highlighted that the front or illuminated side of the cell's conductors should not obstruct too many of the Sun's rays from reaching the semiconducting material. On the other hand, the opposite or shaded side of the cell can be entirely coated with the conductor. Only the lighted side of the cell is coated with an anti-reflection coating. Reflection loss can be substantial due to the inherent reflectivity of semiconductors. The solution is to put one or more layers of an anti-reflection coating to the surface of the cell to limit the amount of solar energy reflected from its surface (like those used for cameras and spectacles).

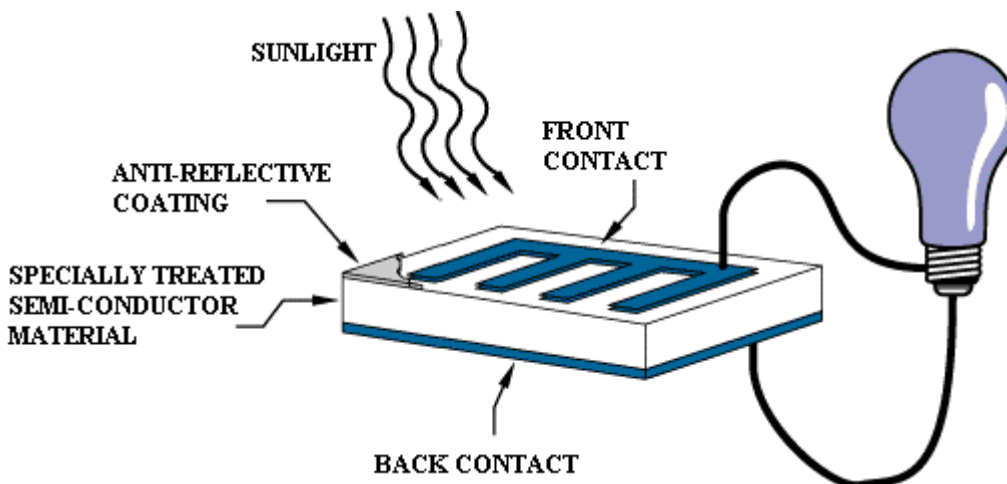


Figure 4: A PV panel's basic operation

2.4.2.1 SOLAR PANELS TYPES

The three main types of solar panels used in homes and commercial buildings are polycrystalline, monocrystalline, and thin film. Solar panels can be made in a variety of ways, which influences how they look in the end.

It is simple to distinguish between the various types of solar panels based on their appearance; each type has advantages and disadvantages. Silicon is the most common component of solar panels, and it is used in both monocrystalline and polycrystalline cells. Although other materials can be used to create thin film solar panels, silicon is widely used in many of them.

2.4.2.1.1 MONOCRYSTALLINE SOLAR PANELS

Monocrystalline solar panels are the market's most established type, having been in use for over 40 years. The fact that some original mono panels from the 1970s are still in use today demonstrates their durability. However, as the value of sustainability has become clearer, prominent producers of these panels have continued to work to increase their efficiency in order to sufficiently power buildings in the modern era. Of the three types of solar panels, monocrystalline solar panels produce the smallest solar cells. Monocrystalline panels may be preferable to thin film/amorphous panels for properties with limited space because they require fewer panels and thus less roof area to install. Monocrystalline panels are typically black or another dark colour with surfaces covered in white diamond forms. These panels typically have an efficiency of 18% or higher. Furthermore, they provide gradual efficiency depreciation, resulting in a minimal annual efficiency loss.

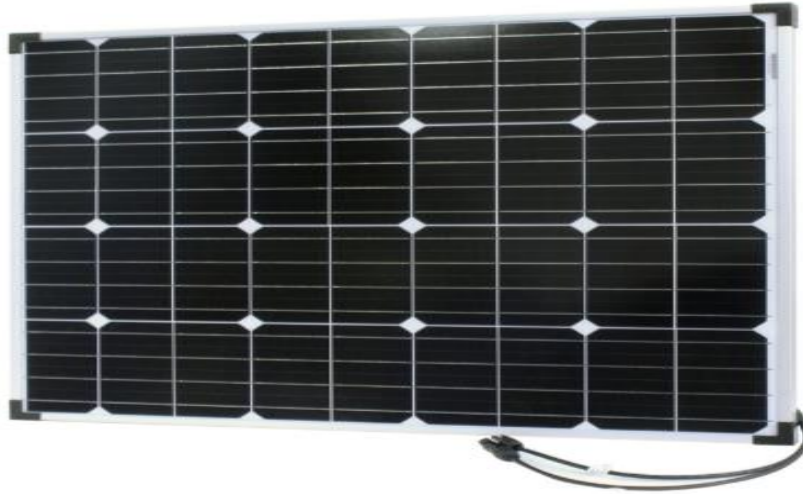


Figure 5: Monocrystalline Solar Panel

2.4.2.1.2 SOLAR PANELS MADE OF POLYCRYSTALLINE (OR MULTICRYSTALLINE)

Although polycrystalline solar panels are a newer technology in the production of renewable energy, their efficiency can vary slightly between manufacturers, even though they are similar to monocrystalline panels in some ways. Despite the fact that the silicon used to construct these panels is less expensive to produce than monocrystalline technology, they frequently have efficiency rates that are on par with or slightly lower than monocrystalline technology, with an average of 15-16% or more. However, the efficiency of these panels may vary depending on the manufacturer, with some companies, such as Trina Solar, recently boasting of panels with up to 21% efficiency. Because of its lower temperature co-efficiency, monocrystalline panels are often at a disadvantage. Polycrystalline solar panels have a blue tinge and may require a greater surface area than monocrystalline panels due to the need for additional panels. This variation may still be favoured

for properties with restricted panel area because it requires less surface/roof space than thin film panels.

Polycrystalline panels are often used for residential solar panel installation, despite the fact that their usefulness in contrast to monocrystalline panels is controversial due to lower production costs.



Figure 6: Polycrystalline Panel

2.4.2.1.3 SOLAR PANELS WITH THIN FILM (AMORPHOUS)

Thin film panels differ from monocrystalline and polycrystalline panels in that they are manufactured entirely differently. Because they are the most recently developed variation, they are the least developed of the three. The efficiency of the technology is expected to rise during the next ten years as a result of subsequent development operations. These solid black panels were commercially manufactured utilizing a number of photovoltaic materials, both separately and in combination, such as cadmium telluride (CdTe), dye-sensitized solar cells (DSC), amorphous silicon, and copper indium gallium selenide (CGIS). These panels have the lowest efficiency compared to the previous two proven technologies due to the greater amount of installation space required, but because their manufacturing costs are lower, they are now cheaper. The projected efficiency rates of these

panels currently range from 7 to 13%, but it is expected that they will eventually reach up to 16%.



Figure 7: Thin Film Solar Panel

2.4.3 BATTERIES FOR INVERTERS

Inverter batteries are designed to produce a little amount of current steadily over a long period of time. All backup power systems, inverters, and UPS work by converting DC current into AC current because all of our electric appliances rely on AC power. Deep cycle batteries are also known as UPS and inverter batteries since they are designed to deliver consistent power with minimum current drain over long periods of time. Marathon runners, sometimes known as deep cycle batteries, are designed to supply consistent power for an extended period of time while consuming little current. Depth of discharge (DOD) is the percentage of a battery's total capacity that represents the amount of energy spent. 50% DOD, for example, indicates that 50% of the battery's energy has been consumed. 80% DOD indicates that 80% of the energy has been consumed, leaving the battery with only 20% of its original capacity.

Many customers choose a deep cycle battery based on price, product dimensions, weight, or capacity without considering where the battery will be used. Should the battery be discovered:

- Use an AGM or SMF flooded battery near sensitive electronics. Avoid using maintainable batteries because the higher gassing rates can corrode and damage the application's electrics.
- Use an AGM or SMF flooded battery in confined spaces.
- Under seats and sleeping areas: use an AGM or SMF flooded battery. When inhaled, hydrogen and oxygen gas produced by maintainable batteries can be harmful to your lungs and respiratory system.
- When installed under the hood, use a maintainable SMF flooded battery.

When the battery is not in use, if the open circuit voltage (OCV) falls below 12.5 volts, recharge it. Deep cycle batteries should not be kept in a low state of charge because sulphating will form on the battery plates, reducing performance and cycle life.

It is critical to ensure that there is adequate electrolyte in the battery to cover the battery plates. When charging the battery, take care not to overfill it because fluid levels will rise when the battery is recharged and may overflow. Never use sulfuric acid to finish; instead, use distilled or demineralized water. After the battery has been fully charged, fill the spout extensions all the way to the bottom. Deep cycle lead acid batteries should never be completely depleted because it reduces their overall cycle life. A battery should be depleted up to 80% DOD, but not less. If you merely discharge the battery to 50% of its maximum capacity rather than 100%, it will produce 40% more amps over the duration of its lifespan. Always double-check the charging parameters of the battery.

2.4.3.1 DEEP CYCLE BATTERY TYPES

There are five basic types of batteries used in solar inverter systems:

- Lead-acid battery that has been flooded (Tubular Batteries).
- Gel and AGM valve-regulated lead-acid (VRLA) batteries
- Lithium-ion rechargeable battery
- Nickel Cadmium Batteries

2.4.3.1.1 LEAD-ACID BATTERY FLOODED (TUBULAR BATTERIES)

It is built of lead plates or grids in a container filled with a liquid electrolyte, usually concentrated sulphuric acid, and is sometimes referred to as a lead-acid, FLA, or wet-cell. In terms of battery weight to energy output ratio, the FLA is somewhat heavy. As a result, this sort of battery is becoming less widespread. Because it is the cheapest and oldest battery technology, it has gained popularity among solar energy users on a small budget who live off-grid.



Figure 8: Tubular Batteries

2.4.3.1.2 LEAD-ACID BATTERY WITH VALVE REGULATED LEAD-ACID (VRLA)- GEL AND AGM

This battery is the next generation of flooded lead-acid batteries, designed to overcome FLA-related issues. The electrolyte in the VRLA is thicker and flows less readily than liquid electrolyte. The name sealed lead-acid battery comes from the fact that it is sealed.

VRLA comes in two varieties: absorbed glass matt and gel (AGM). Gel batteries have a gelled electrolyte. On AGM deep cycle batteries, an electrolyte is encapsulated in a glass mat. Because these liquids do not flow easily, there is no need to add water.



Figure 9: AGM and Gel Batteries

2.4.3.1.3 BATTERY LITHIUM-ION

It is sometimes referred to as a lithium battery since it is built up of cathode and anode plates or cylinders that have been dipped in a solution of lithium salts. It is the most secure for use in RVs and comes in a variety of chemistries. Despite being the most expensive deep cycle batteries, lithium batteries last significantly longer than lead-acid models.



Figure 10: Lithium-Ion Battery

2.4.3.1.4 NICKEL-CADMIUM BATTERIES

The nickel-cadmium battery electrodes were nickel oxide hydroxide and metallic cadmium (also known as a Ni-Cd battery or NiCad battery). Ni-Cd batteries retain voltage and charge well when idle. When partially charged Ni-Cd batteries are recharged, the memory effect reduces their capacity. Ni-Cd batteries have a good capacity and extended lifespan. They perform well at low temperatures (Energy Storage Systems Technologies, 2014).

Their ability to provide their complete rated capacity at high discharge rates will be their most significant advantage. They are available in a range of sizes, including AAA to D, which are alkaline battery sizes. Ni-Cd batteries can be used either individually or in groups of at least two. Toys, electronics, and portable devices employ smaller packs, whereas backup power supplies, electric cars, and aviation starting batteries require larger packs.



Figure 11: Nickel-Cadmium Battery

2.4.3.1.5 NICKEL-METAL HYDRIDE BATTERIES

Nickel metal hydride is another type of chemical arrangement used in rechargeable batteries (NiMH). The positive electrode of a battery undergoes a chemical reaction that is identical to that of a nickel-cadmium cell (NiCad), using the same nickel oxide hydroxide (NiOOH). Unlike NiCad batteries, which use cadmium for the negative electrodes, Nickel-Metal Hydride batteries use a hydrogen-absorbing alloy. NiMH batteries are employed in high drain devices due to their high capacity and energy density. A NiMH battery has the same energy density as a lithium-ion battery and two to three times the capacity of a NiCad battery of the same size. NiMH batteries, as opposed to NiCad batteries, do not experience the memory effect that NiCad batteries do.



Figure 12: Nickel-Metal Hydride Batteries

2.4.4 SOLAR CHARGE CONTROLLER

An electronic device called a solar charge controller controls the current that is sent from the solar system to the storage batteries. At night, power can't flow backwards to the solar panels and drain the deep cycle batteries, and during the day, the batteries don't get overloaded. Managing electricity consumption is the primary function of charge controllers, while some also feature auxiliary functions like lighting and load management.

2.4.4.1 SOLAR CHARGE CONTROLLER TYPES

PWM and MPPT are the two technologies available for solar charge controllers. In a system, they perform very differently from one another. Even though an MPPT charge controller is more expensive than a PWM charge controller, the extra expense is sometimes justified.

2.4.4.1.1 SOLAR CHARGE CONTROLLER WITH PWM

PWM is a type of solar charge controller. PWM stands for "Pulse Width Modulation." These work by directly connecting the array of solar panels to the bank of batteries. When the array is always connected to the battery bank, the output voltage of the array is "driven down" to the voltage of the batteries. This is called bulk charging. Since the battery's voltage goes up as it charges, so does the solar panel's voltage output. This means that more solar energy is used. So, you need to make sure that the nominal voltage of the solar array and the voltage of the battery bank are the same.



Figure 13: PWM charging controller

2.4.4.1.2 SOLAR CHARGE CONTROLLER WITH MPPT

MPPT solar charge controllers track maximum power point. Measure the panel's maximum power voltage and convert PV voltage to battery voltage. Since power into the charge controller equals power out, lowering the voltage to match the battery bank increases current, using more of the panel's electricity. Use 60 cell nominal 20V grid-tie solar panels instead of batteries. A 20V solar panel can charge a 12V, 24V, or 48V battery bank. This lets you use more solar panels for your off-grid solar setup.



Figure 14: MPPT Solar Charge Controller

2.5 SOLAR INVERTER SYSTEM PROS

- **Renewable Energy Source:** The most important thing about solar energy is that it is a source of energy that can be used over and over again. It can be used at any time and in any place in the world. Solar energy, unlike some other energy sources, will never run out. Solar energy will be available as long as there is a sun, which experts say is at least 5 billion years before the sun dies.
- **Cuts down on electric bills:** Since you will be able to use some of the electricity that your solar system makes, your energy costs will go down. Depending on the size of your solar system and how much electricity or heat you use, you can save different amounts on your utility bill. For instance, if your business already uses commercial solar panels, upgrading to a larger system could cut your energy costs by a lot. In addition to saving money on your power bill, the Smart Export Guarantee may pay you back for any extra energy you send back to the grid. If you make more electricity than you use (considering that your solar panel system is connected to the grid).
- **Lots of Uses:** There are lots of ways to use solar energy. With photovoltaics, you can make both heat and electricity (solar thermal). Solar energy can be used to make clean water from dirty water, make electricity in places that don't have access to the power grid, and power spacecraft. Building materials can also be made with solar energy in mind. Sharp's clear solar energy windows just came out.
- **Low operating costs:** Most solar energy systems don't need a lot of upkeep. They only need to be kept moderately clean, so only a few times a year should be spent cleaning. Most reputable companies that make solar panels offer a warranty of 20 to 25 years. There is no wear and tear because there are no moving parts. Most of the time, the only part that needs to be replaced after 5 to 10 years is the inverter. This is because it is constantly turning solar energy into electricity and heat (solar PV vs. solar thermal). To make sure your solar power system works as well as possible, you need to take care of both the inverter and the cables. After you've paid for the solar system itself, you may not have to spend much on repairs or maintenance.
- **Progress in technology:** Technology in the solar energy sector is always getting better, and this will only get better in the coming years. Advances in

nanotechnology and quantum physics could make solar panels work better and double or triple the amount of electricity that solar power systems can produce.

CHAPTER THREE

DESIGN AND METHODOLOGY

This chapter covers the project's design and analysis, as well as the computations required for the component values. We attempt to determine the proper sizes and ratings of the important loads involved in the apartment's PV Power Supply Unit. Every device has a fixed power consumption, which is listed on the name plate. This data is retrieved and written on the table below from all of the devices that will be used. Other information that must be supplied is the number of each appliance that will be used and the number of hours the appliances are expected to be left on. After entering the necessary information into the table, the total Watt-hours of energy that will be utilized, i.e., the total energy consumed or the wattage of the PV system, will be computed.

Another thing to keep in mind is the system voltage. It is necessary to select the system level before proceeding with the design. The system voltage level would be used to design subsequent devices.

3.1 Load Audit of All Electrical Loads in the Apartment

Before designing the photo-voltaic (PV) inverter system to power the critical loads, the energy demand of the critical loads in the apartment has to be determined. The critical loads require continuous operation for 6 hours period and their energy demand were determined by conducting load audit. The table 3.1 shows the load audit of all the electrical loads in the apartment.

Table 3. 1 Load Audit of all Electrical Loads in the Apartment

S/N	Location (Room)	Critical Load	Quantity	Rating (KW)	Total (KW)
1	Sitting Room	Television	1	0.05	0.05
		DSTV Decoder	1	0.01	0.01
		Electric Fan	1	0.07	0.07
		Electric Bulbs	1	0.03	0.03
		Additional loads	-	0.1	0.1
				Total	0.36
2	Bedroom1	Electric Fan	1	0.07	0.07
		Electric Bulb	3	0.01	0.03
		Television	1	0.05	0.05
		Additional Load	-	0.1	0.1
				Total	0.39
3	Bedroom2	Electric Fan	1	0.07	0.07
		Electric Bulbs	3	0.01	0.03
		Additional Loads	-	0.1	0.1

				Total	0.25
6	Kitchen	Electric Bulbs	1	0.01	0.01
				Total	0.01
7	Store Room	Electric Bulb	1	0.01	0.01
8	Front Veranda	Electric Bulb	1	0.01	0.01
9	Back Veranda	Electric Bulb	1	0.01	0.01
10	Lobby	Electric Bulb	1	0.01	0.01
11	Toilet	Electric Bulb	1	0.01	0.01
12	Master Bedroom Toilet	Electric Bulb	1	0.01	0.01
13	Outside	Electric Bulbs	4	0.01	0.04
	Gross Total Load	-	-	-	0.98

3.2 Critical Load Analysis for the Apartment

From the load audit in table 3.1, it can be seen that the general load 0.98KW will require a number of deep cycle batteries of 12V/200Ah, solar panels and an inverter. For correct design of an inverter system, we would require that we convert the Kilowatt power rating to an approximate KVA rating, this is done by assuming a suitable power factor value. For this work we will be using a power factor value of 0.9. Thus, converting to KVA we have;

$$\frac{1.08}{0.9} = 1.08\text{KVA} \text{-----} (3.1)$$

3.3 Selecting Inverter Power Rating

Inverter products come in specific KVA ratings such as 1 KVA, 1.5 KVA, 2.5 KVA etc. Giving room for load expansion a 1.5 KVA inverter will be deployed to handle the already existing load of 1.08 KVA bearing in mind that the 1.5 KVA inverter can conveniently handle this load.

3.4 Selecting Voltage value of the entire PV Inverter System

1.5 KVA inverters are built to work either with 12V supply or a 24V supply from the batteries, since deep cycle batteries give a voltage of 12V, one deep cycle batteries will be connected to the inverter achieve the voltage and current requirement for this inverter system.

3.5 Minimum Usage Time Calculations

The minimum usage time describes an estimated the length of time the inverter batteries are expected to last when the inverter system is used at full load capacity. Although the system is never practically used in this condition. An assumption based on the user's requirement is made such that the inverter system must last a minimum of 2 hours on full load.

3.6 Battery Capacity, Number of Batteries Required

The number of batteries used is dependent on the minimum usage duration (in this case 2 hours). For a 3.052 KVA load operating at 24V, we can derive its full load current as

$$\frac{1080}{12} = 90A \text{ ----- (3.2)}$$

The battery capacity required to meet this current demand for as long as 2hours is calculated thus;

$$90A \times 2h = 180Ah \text{----- (3.3)}$$

Using 12V/200Ah deep Cycle wet cell Batteries, a 200Ah battery will be required to meet this load demand being it is the next available capacity of battery in the market. The battery connection is shown below

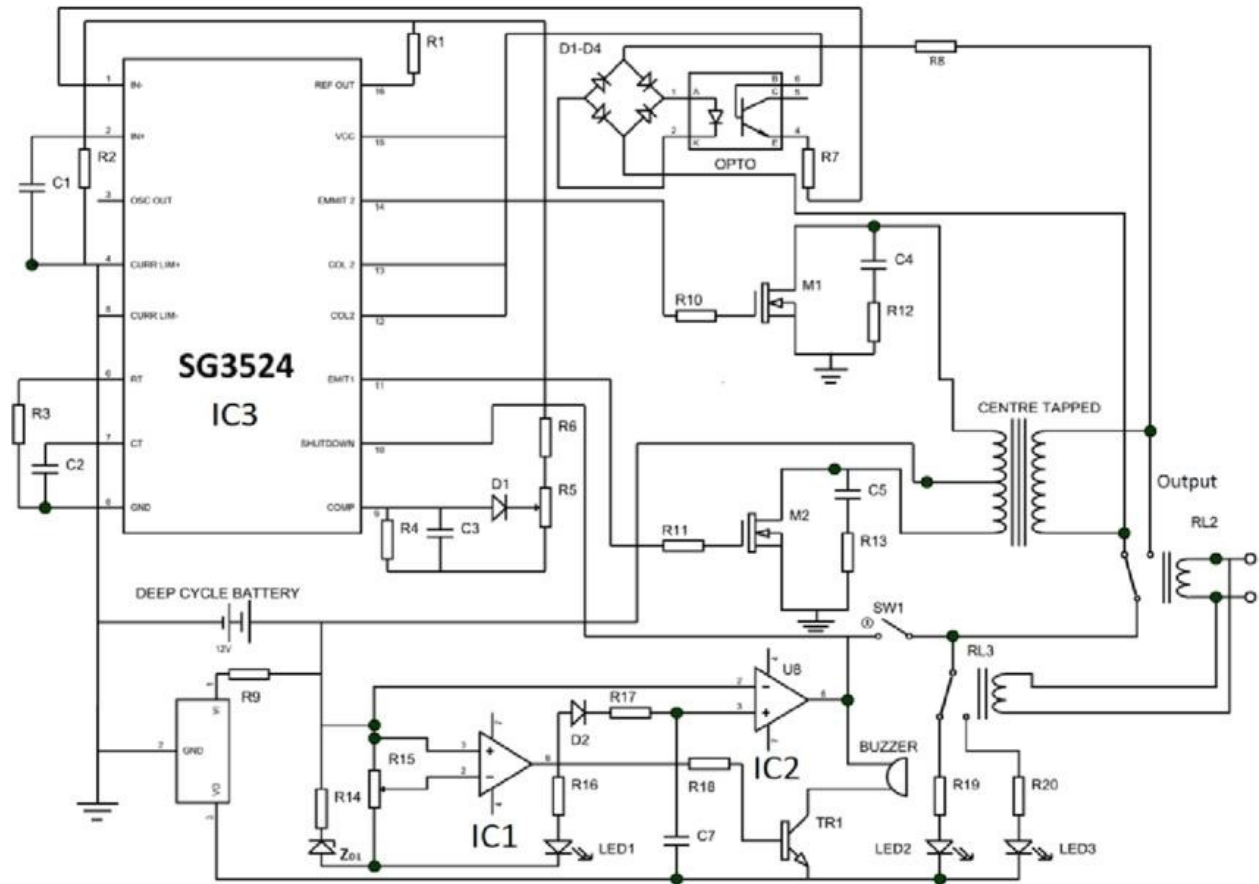


Figure 15: Circuit Diagram

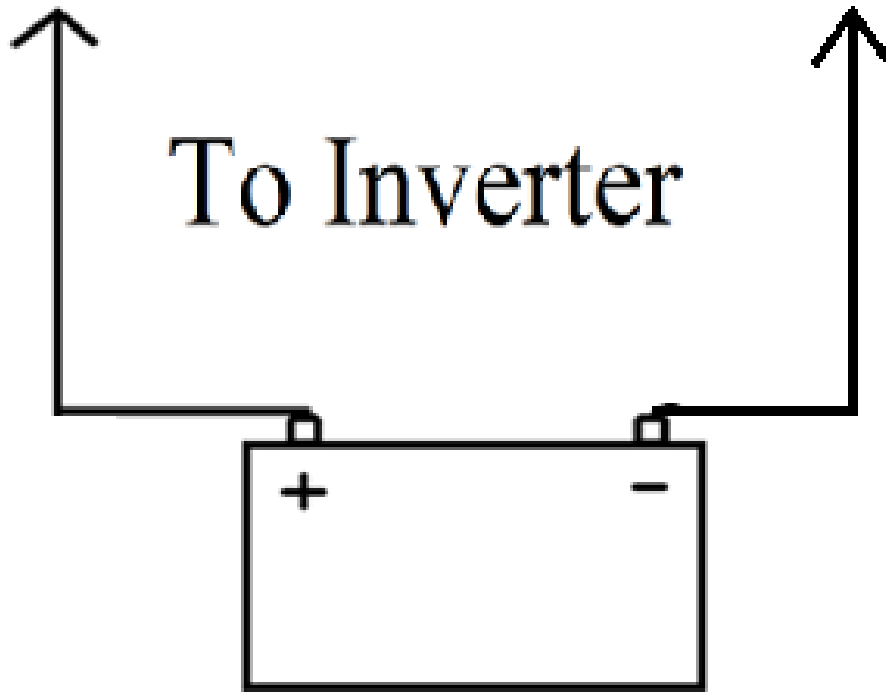


Figure 16: Battery Connection

3.7 Battery Autonomy

Battery Autonomy is the amount of time that the PV system will power the load appliances without recharging the battery system. Duration of use is proportional to the Ampere-hour (Ah) rating of the battery set and the applied load, with longer duration possible for a given Ah rating the lower the load.

A 1.5 KVA solar inverter system with a load rating of 900W and a 200Ah battery will have its battery autonomy calculated as follows.

$$\text{Battery autonomy} = \text{Battery Capacity} \div \frac{\text{load rating}}{\text{Battery Voltage}} \text{----- (3.4)}$$

$$\text{Battery autonomy} = 200\text{Ah} \div \frac{900\text{W}}{12\text{V}} = 2.63\text{hrs} \text{----- (3.5)}$$

But battery autonomy might be extended powering a reduced load, at 50% capacity, the battery autonomy becomes 5.3hours approximately 6hours.

3.8 Solar Charge Controller Calculations

Charge controllers track battery charging and discharge. It prohibits battery charging or discharging. Overcharging destroys batteries and undercharging shortens their lifespan. Use a charge controller to prevent battery-to-system reverse current.

Daily we have an average of 10hours of Sunlight and based on this assumption, we will design the photovoltaic system to supply 1/10th of the total battery capacity of the inverter system. 1/10th of the total battery capacity is;

$$\frac{200Ah}{10h} = 20A \text{-----} (3.6)$$

With a charging current of 20A, a charge controller with a rating of 60A/ 12V is required to effectively charge the battery.

3.9 Photovoltaic (P.V) Panel Calculations

After determining the total load that will be powered by the PV system, we must then determine the total area of solar panels needed to meet that demand. It is a characteristic of every panel to have some sort of internal losses. This is something that has to be considered.

Since we already know the total watt-hours from the energy calculation, we can easily determine the wattage of panels that would be needed by dividing the total watt-hours by the peak sun hours.

Assuming a nominal charging voltage of 12V from the PV panels, we have a required charging power of;

$$18A \times 12V = 216Watt \text{-----} (3.7)$$

Considering that the inverter system will be used during the day and all the energy generated from the PV panels will not be saved up in the battery, it is important to modify our calculations to cater for the day time inverter usage.

To do this we add 40% the full load usage current (90A) to the charging current (18A), 40% of the usage current is calculated as:

$$\frac{40}{100} \times 90A = 36A \text{-----} (3.9)$$

Adding this to the usage current:

$$36A + 18A = 54A \text{-----} (3.10)$$

Assuming a nominal charging Voltage is 12V, the new required Charging power is;

$$12V \times 54A = 648W \text{-----} (3.11)$$

Using 300W panels without considering the losses, the number of panels required is;

$$\frac{648W}{300W} = 2.16 \text{-----} (3.12)$$

3.10 Losses Analysis and Compensation

In every energy conversion system, we have to consider the losses, some of which are;

- Wiring and connection losses (0.5%)
- Battery losses (1%).

Making the total losses 0.15%. Therefore, the total energy required from the solar PV is 1.15 or 1.5% to power the critical loads in the apartment. Multiplying the new energy demand percentage (losses included) with that of the lossless system, the total energy needed from solar PV panels is;

$$101.5\% \times 648W = 657.72W$$

Using 300W panels the number of panels required is;

$$\frac{657.72W}{300W} = 2.1924 \text{-----} (3.13)$$

Approximating to the next whole number, two 300Watt panels will be required and it will be connected in parallel as shown below.

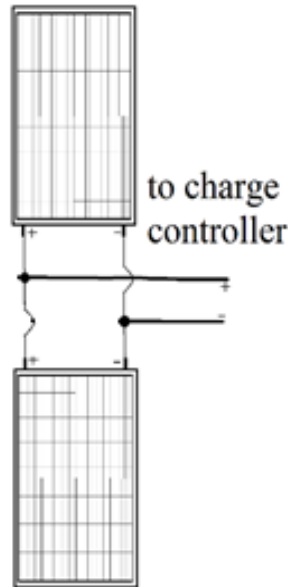


Figure 17: Solar Panel Connection.

3.11 Sizing of the Solar Panel Circuit Breaker

The total current supplied from the PV module is 54A

Panel Circuit Breaker Rating = 145% x Solar Panel in parallel

$$\text{Panel Circuit Breaker Rating} = 145\% \times 54A = 78.3A \text{-----} (3.14)$$

The circuit breaker rating needed for the solar panel would be 100A, being the closest available circuit breaker rating in the market

3.12 Cable Sizing

In order to determine the cable size that would be required for the inverter, solar panel and battery to power the Apartment, we take into account the amount of voltage and current required for each of the component. Then, we try to determine the best cable size for them by using the cable gauge chart as shown in the table below.

Table 3.2 Average wire Gauges

Cable Cross Sectional Area	2 cables, single phase AC or DC		3 or 4 cables, three phase AC	
	Current Carrying Capacity	Volt drop per ampere per meter	Current Carrying Capacity	Volt drop per ampere per meter
mm ²	A	mV	A	mV
1.0	14	42	12	37
1.5	17	28	14	24
2.5	24	17	21	15
4	32	11	29	9.2
6	45	7.1	37	6.2
10	55	4.2	51	3.7
16	74	2.7	66	2.7
20	103	2.3	78	2.3
35	119	1.3	106	1.1
50	145	0.97AC	125	0.84

		0.91DC		
70	185	0.71AC 0.63DC	160	0.62
95	230	0.56AC 0.45DC	195	0.48
120	260	0.48AC 0.36DC	220	0.42

3.13 Solar Panel Cable Sizing

We have to determine the cable size which we shall check from the cable chart in table above, from the cable chart, a 20 mm² multiple stranded DC cable is suitable with a current capacity 103A of and volt drop of 0.48mV.

We assume a distance of 15m from the point of installing our PV to where the circuit breaker is connected.

$$\text{Voltage-drop for a distance 15m} = 1.82\text{V} \text{ ----- (3.15)}$$

3.14 Battery Cable Sizing

The maximum current drawn from of the battery is 90A.

We have to determine the cable size which we shall check from the cable chart in table above, from the cable chart a 20mm² multiple stranded DC cable is suitable with a current capacity of 103A and volt drop of 2.3mV.

$$\text{Voltage-drop for a distance 1m} = 0.05\text{V}$$

Since the voltage drop for the 1m distance is less than the permissible voltage drop, therefore we make use of 20mm² DC cable.

3.15 AC Cable Sizing

The total electrical load to be powered on the PV system is 3.2KW and taking AC voltage as 240V. We get the electrical load in KVA to account for extra losses using a power factor of 0.85

Power in KVA = 1.08KVA

$$I = 4.5A \text{-----} (3.16)$$

We have to determine the cable size which we shall check from the cable chart in table 3.2, from the cable chart a 1.5mm² cable which has a current capacity of 17A and voltage drop ampere per meter of 4.2mV will be use. Voltage drop for a distance 15m = 2.508V.

3.16 Summary of the Design

After putting the design considerations and power requirements in to our analysis, we have come up with the following summary for the required components of this inverter system.

Inverter Size: 1.5KVA

Inverter Voltage: 12V

Inverter Type: Pure Sine wave.

Charge Controller rating: 60A

Charge Controller Type: Pulse Width Modulated (PWM)

Overall Capacity of Battery required: 381.56Ah

Number and type of Battery required: One 200Ah Deep cycle Tubular batteries.

Number of Solar Panels needed: 2 panels.

Type of Solar Panels: 300W, Monocrystalline.

Capacity of Solar Panel Breaker: 100A.

Solar Panel Cable: 20mm²

Battery Cable: 20mm²

AC Output Cable: 1.5mm²

3.17 Block Diagram of the Inverter System

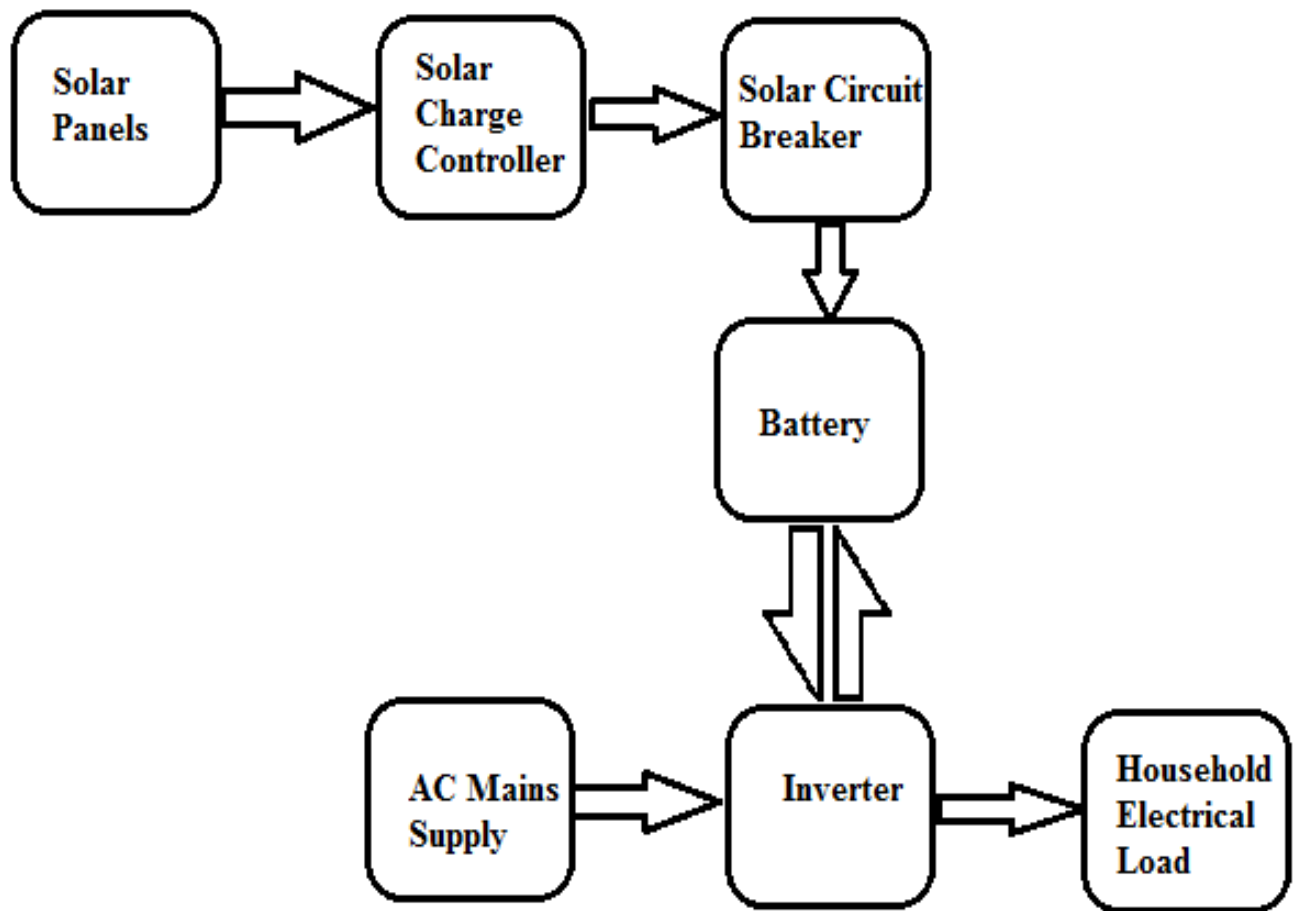


Figure 18: Block Diagram.

3.18 Principle of operation

The purpose of this project is to design and install a 1.5 KVA 220V to 230V solar inverter system operating at 50Hz which incorporates 2 PV solar panels and one deep cycle battery. It involves using monocrystalline solar panels to capture solar energy from the sun to charge the batteries. In this work, a pair 300W monocrystalline solar panels is installed on the rooftop of the apartment. A 12V, 1.5 KVA hybrid inverter is connected to the 12V, 200Ah deep cycle batteries. The Solar panels make use of a pulse width modulated 60A charge controller to charge up the batteries from the ambient sun light.

CHAPTER FOUR

INSTALLATION, TESTING AND RESULT ANALYSIS

The diagram below illustrates the procedures needed to build a 1.5 KVA solar inverter system.

This chapter goes in-depth on each step of the installation process.

4.1 Installation Process

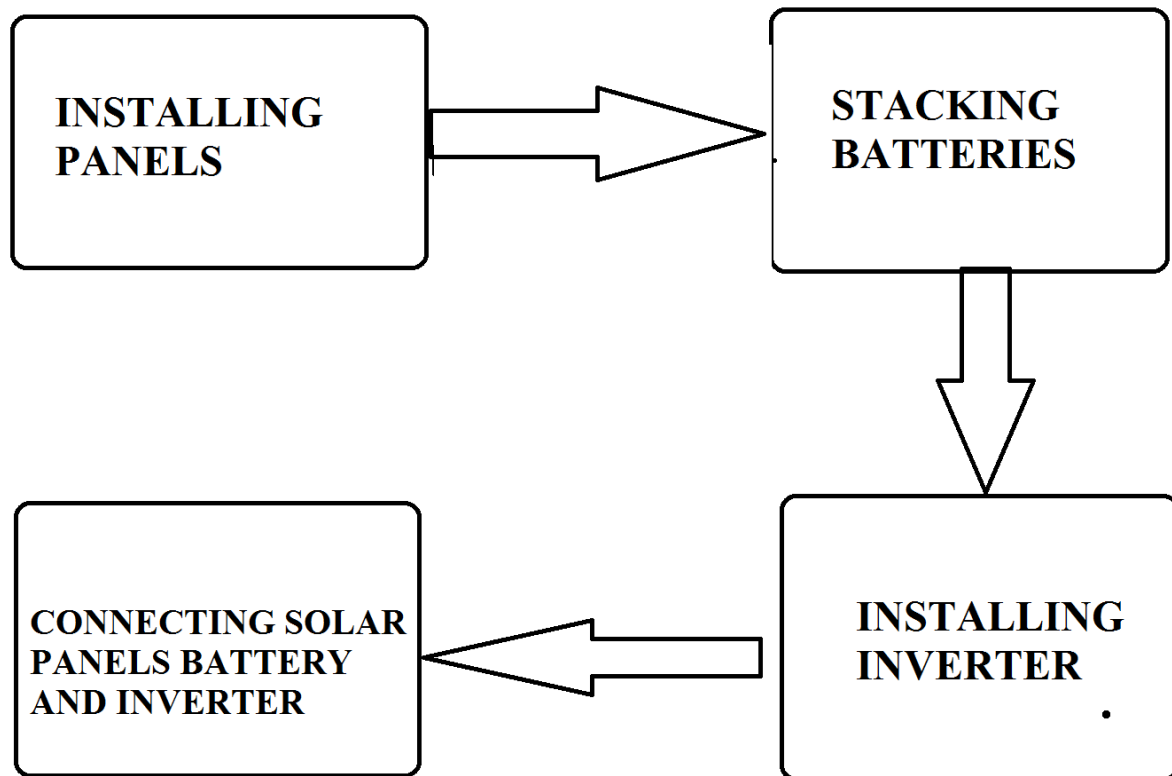


Figure 19: Installation Process

4.1.1 Mounting of Solar Panels

On the home's roof, two monocrystalline photovoltaic cells have been mounted using angle aluminum bars, screws, bolts, and nuts. Before the PV panel installation process begins, the panels are mounted on the portion of the rooftop that faces east.

The steps in the PV panel installation process as follows:

- Confirm all materials required for the installation process are available
- Identify the eastward direction
- Mount the aluminum angle bars on the part of the roof top facing the east, fasten them with bolts and screws
- With the aid of a rope, pull up the PV panels to the roof top
- Bolt and screw the PV panels to the aluminum angle bars, ensure they are properly tightened
- Make the proper connections as shown in fig 3.2 of this work ensuring that the correct polarity of the panels is connected.
- Connect the output solar wire and route it to the point designated for the inverter system setup
- Trunk the solar wires.

The PV panel installation processes are shown in the following images.



Figure 20: PV panel Installation Process



Figure 21: PV panel Installation Process

4.1.2 Stacking and Connection of Deep Cycle Batteries

In a metal frame battery holder, four 12V/200Ah deep cycle batteries are placed on top of one another. Each battery will be linked up in series, and then each pair will be connected in parallel, as shown in Figure 3.1 of chapter three of this work. These are connected in pairs to reach 24V.

25mm² Copper Stranded cables with battery logs attached at each end are used to connect each battery terminal to the appropriate one as shown in figure 3.1.

The following images show the batteries stacked up in a metal frame.



Figure 22: Battery Stacking

4.1.3 Installation of Inverter

- A pure sine wave 24Volts 3.5KVA Hybrid inverter with a 60A inbuilt solar charge controller system has been installed in this work. The installation process is as follows;
- Prepare the inverter to be installed by unpacking it from its carton
- The inverter being a wall mount type will require that a wooden ply board will be fixed to the wall using concrete nails
- Screw the inverter to the wooden board and ensure it is properly fixed
- Also attach the knife switch and circuit breakers beside to the ply board just beside the inverter as shown in the figure below

- Confirm that they are all firmly placed and then carry on with the installation process

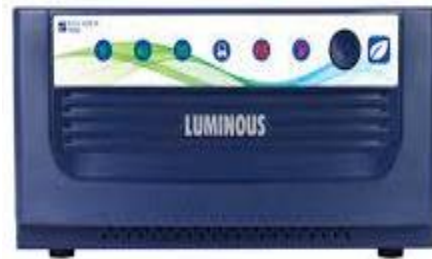


Figure 23: Installation of Inverter

4.1.4 Interconnection between Solar Panels, Battery and Inverter

These connections are done by using the following steps:

- Install the by-pass changeover or knife switch.
- Identify the load input point, the mains supply, and the inverter input.
- Connect the solar wire to the solar input terminal of the inverter, while ensuring that the solar input breaker is turned off.
- Connect the mains supply wires to the mains input terminal of the inverter, also ensuring it is turn off before connecting them.
- Connect the positive and negative battery terminals to the appropriate points on the battery stack as shown in figure 3.1.
- Connect the inverter output wires from the changeover switch to the inverter output terminal on the inverter.
- Cross check connections before carrying on with the installation process.

The image below shows the already installed inverter.



Figure 24: Interconnection between Solar Panels, Battery, and Inverter

4.2 Testing the System

After the installation of the solar inverter system, the system is expected supply the house (with a rated electrical load of 1.08KVA) with a 220V to 230V 50Hz AC power. The system is expected to be power efficient and have a relatively fast solar charging response.

Based on these, the following Tests will be carried out

- Output Voltage and Frequency Test
- Load and Over Load test
- Power Efficiency test
- Rate of Solar Charge Test
- Battery Usage Time

4.2.1 Output Voltage and Frequency Test.

This a simple test done with aid of a digital multi-meter. For the voltage test, set the multi-meter to the AC voltmeter mode, then use the probes of the meter to read the inverter output terminals, the AC voltage value is displayed on the multi-meter screen. After testing this reading was observed to be stable with an AC voltage value between 220V to 230V.

A similar process is done for the frequency test, set the multi-meter to the frequency mode, then use the probes of the meter to read the inverter output terminals, the frequency of the AC voltage value is displayed on the multi-meter screen. After testing this reading was observed to be stable with a frequency value of 50Hz. The Images below show the output voltage and frequency tests



Figure 25: Output Voltage Test



Figure 26: Frequency of output Voltage.

4.2.2 Load and Overload Test.

This test aims to check the ability of the installed inverter system to meet the load requirement of the home without switching into its overload protection mode. This test is done by gradually loading the inverter system from no load to full load while observing for overload indication from the device. The results from these tests are shown in the table below.

Table 4.1 Load and Overload Test

S/N	Description of Load	Overload Indication
1.	No Load	No
2.	Lights Only	No
3.	Lights, TV, Laptop, Fans and Phones	No
4.	Lights, TV, Laptop, Fans, Phones and Refrigerator	No

4.2.3 Power Efficiency Test

The aim of this test is to test the power efficiency of the inverter system, a clamp meter is used to measure the input current drawn from the battery and output current fed into the house while the inverter system while it running on full load. The battery voltage and the output ac voltage are also measured. The inverter percentage efficiency is calculated as follows;

$$\text{Percentage Efficiency} = \frac{\text{output power}}{\text{input power}} \times 100$$

Output Power in VA = Output Voltage x Output Current

Assuming a Power factor of 0.95,

Output Power in Watts = Output Voltage x Output Current x 0.95

Input Power = Input Voltage x input Current

The table below show the voltage and current readings entering and leaving inverter system while it is operating in on full load, a clamp meter is used to extract these readings.

Table 4.2 Power Efficiency Test

	Voltage (V)	Current(A)	Power (Watts)
Input	24.5	81.63	1989.9
Output	220V	8.63	1803.7

$$\text{Percentage Efficiency} = \frac{1803.7}{1989.9} \times 100 = 90.64\%$$

4.2.4 Rate of Solar Charge Test

To test the performance of the solar panels, this test is done to see the rate of increase in voltage of the batteries while they are being charged the solar panels once they have been depleted. The table below shows the charging time in hours against the battery voltage of the depleted deep cycle batteries.

Table 4.3 Rate of Solar Charge

Charging Time (Hours)	Battery Voltage (Volts)
1	12.23
2	12.27
3	12.37

4	12.41
5	12.47
6	12.69
7	12.78
8	12.85
9	12.97
10	12.99

4.2.5 Battery Usage Time Test.

This is a simple experiment carried out to test how long the user can use to inverter system on full load before it runs low. The inverter system was on run on full load was observed to last for 6 Hours.

4.3 Summary and Result Analysis

The above experiments and tests show that installed inverter system meets the required design performance. The summary of these tests is as follows;

- The output voltage and frequency are 220V to 230V and 50Hz respectively.
- The Power efficiency is 90.64%.
- The Inverter meets the load requirement.
- Usage Time on full load is 3.5hours.
- Time to full Charge on solar panels is 10hours.

4.4 Bill of Engineering Measurements Evaluation (BEME)

Table 4.4: Bill of engineering measurements and evaluation.

S/N	Items Required	Description	Unit	Price Per Unit (N)	Amount Required	Price Per Amount (N)
1)	Inverter	1.5KVA, 12V	Piece	134000	1	134000
2)	Deep Cycle Battery	12V, 200Ah	Pieces	130000	1	130000
3)	Solar Panels	300Watt	Panels	60000	2	120000
4)	Solar Wire	10mm ²	Yards	800	20	16000
5)	Circuit Breaker	200Amp	Piece	6000	1	6000
6)	Aluminium Angle Bar	20 Feet	Bar	6500	2	13000
7)	Knife Switch	100Amp	Piece	2000	1	2000
8)	Single Core* Wire	1.5mm ²	Yards	150	20	3000
9)	Nails	2 inches	Packet	500	1	500
10)	Screws	1 inch	Packet	500	1	500
11)	Wall mount Board	6 x 10 inches	Board	500	2	1000
12)	Cost Of Materials	-	-	-	-	419500

13)	Logistics And Transportation of Materials	-	-	-	-	20000
14)						
15)	GROSS TOTAL	-	-	-	-	439500

CHAPTER FIVE

RECOMMENDATION AND CONCLUSION

5.1 CLARIFICATION

The main goal was to design, build, and modify a 1.5 KVA, 230 V AC, 50 Hz inverter with feedback. The design and construction are based on discrete components such as an optocoupler, DTMF module, and pulse width modulator integrated circuit (IC).

The apparatus produced a satisfactory result, achieving the project's objective. As a result, this project has a high level of control flexibility while also maximizing battery life. It is useful, efficient, and simple to use. This product has improved my understanding of design analysis and research.

5.2 RECOMMENDATION

Even if the project work was excellent, there are some details that could have been improved. They are as follows:

- 1) A transform-less inverter can be created using a DC chopper to make the device smaller.
- 2) A solar panel could be added to the design to reduce the inverter's reliance on mains power to charge the battery.
- 3) Filters can be used to improve an inverter's output waveform.

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