DESIGN, CONSTRUCTION AND INSTALLATION OF 2KVA POWERED INVERTER

ABSTRACT

This project focuses on the design, construction, and installation of a 2KVA solar-powered inverter, emphasizing the importance and benefits of locally manufactured solar inverters. The study includes precise design calculations to ensure the reliability and efficiency of the inverter, tailored to meet the power demands of various applications. The inverter design process is meticulously detailed, covering all critical aspects such as component selection, circuit design, and thermal management. A significant portion of the project is dedicated to discussing the advantages of locally made solar inverters. These benefits include cost-effectiveness, accessibility, and the potential to stimulate local economies by fostering technological innovation and manufacturing capabilities. By leveraging locally sourced materials and expertise, the project aims to demonstrate that high-quality, efficient solar inverters can be produced domestically, reducing reliance on imported technology and enhancing energy independence.

Additionally, the project explores the technical challenges and solutions encountered during the construction and installation phases, providing valuable insights into the practical aspects of solar inverter design and assembly. The final product is evaluated through rigorous testing to ensure it meets the required standards for performance and durability. This project not only contributes to the field of power electronics but also advocates for the growth of local industries and the adoption of sustainable energy solutions.

CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Access to reliable electricity is a fundamental pillar of modern society, enabling everything from basic household functions to sophisticated industrial operations. It powers lights, appliances, communication systems, and critical infrastructure such as hospitals and schools. Yet, for millions of people around the world, particularly in developing nations like Nigeria, this essential resource remains inconsistent or entirely unavailable. The national power grid in Nigeria, for example, struggles with a host of systemic issues: insufficient generation capacity, outdated infrastructure, inadequate maintenance, and disruptions caused by natural events or human interference. These challenges result in frequent power outages, unpredictable voltage fluctuations, and prolonged periods without electricity, severely impacting quality of life and economic productivity.

In Nigeria, the electricity supply primarily relies on hydroelectric and gas-fired power plants. Hydroelectric systems, while renewable, are heavily influenced by seasonal rainfall patterns, leading to reduced output during dry periods. Gas-fired plants, on the other hand, face challenges such as inconsistent fuel supply, pipeline vandalism, and logistical bottlenecks. Compounding these generation issues is an overburdened transmission and distribution network, which suffers from significant energy losses—sometimes as high as 30%—before electricity even reaches consumers. The World Bank reports that Nigeria experiences an average of 32.8 power outages per month, with each outage lasting several hours. This chronic unreliability costs the nation approximately $29 billion annually in lost economic output, as businesses and households are forced to turn to costly and environmentally harmful alternatives like diesel generators.

The consequences of this energy crisis are particularly pronounced for sensitive electronic equipment, which requires a stable and high-quality power supply to operate effectively. Devices such as computers, medical imaging systems, and telecommunications infrastructure are highly susceptible to damage from voltage spikes or drops. Even brief interruptions can lead to data loss, equipment failure, or disrupted services. In critical settings like hospitals, where power is needed for ventilators, surgical tools, and refrigeration of vaccines, outages can have life-or-death implications. For instance, a sudden power cut during a surgical procedure could jeopardize patient safety if backup systems are unavailable or insufficient [1,2].

To address these pervasive issues, alternative power solutions have gained traction, with inverters emerging as a practical and versatile option. Inverters convert direct current (DC) from batteries into alternating current (AC), the form of electricity used by most household and industrial appliances. This capability allows them to provide uninterrupted power during outages by drawing on stored energy, making them invaluable in regions with unstable grids. However, traditional inverters depend on batteries charged by the grid or external generators, which poses a limitation in areas where power outages are frequent or prolonged, or where grid access is nonexistent.

This is where solar-powered inverters offer a groundbreaking advancement. By integrating solar photovoltaic (PV) panels, these systems use sunlight—a free, abundant, and renewable resource—to charge their batteries, creating a self-sustaining power solution. Nigeria, located near the equator, enjoys an average of 6.25 hours of sunlight daily, translating to a solar energy potential of over 427,000 megawatts (MW), according to the International Renewable Energy Agency (IRENA). Despite this vast potential, only a small fraction is currently harnessed, presenting a significant opportunity for solar-based technologies to bridge the energy gap. Solar-powered inverters reduce reliance on fossil fuels, lower long-term electricity costs, and contribute to environmental sustainability by cutting carbon emissions—a critical consideration as the world grapples with climate change.

The focus of this project is the design, construction, and installation of a 2KVA solar-powered inverter system, a solution tailored to meet the energy needs of small households or businesses. A 2KVA (kilovolt-ampere) inverter can deliver up to 2,000 volt-amperes of power, sufficient to support essential appliances such as lights, fans, televisions, laptops, and small refrigeration units. When paired with appropriately sized solar panels and batteries, this system can provide a reliable power supply even in off-grid locations or during extended grid failures. Beyond its immediate utility, the project emphasizes the use of locally sourced materials and expertise, fostering economic growth, job creation, and technological independence.

Designing such a system, however, involves navigating several technical challenges. The inverter must produce a pure sine wave output, which is essential for powering sensitive electronics without causing noise, inefficiency, or damage. Unlike modified sine wave inverters, which are cheaper but less compatible with modern devices, pure sine wave inverters replicate the smooth, consistent waveform of grid electricity. Additionally, the system requires careful selection and integration of components—solar panels, batteries, charge controllers, and the inverter itself—to optimize performance and durability. For example, the solar panels must be sized to generate enough energy to charge the batteries fully, even on cloudy days, while the batteries must store sufficient power to meet demand during nighttime or prolonged outages.

1.2 Electrical Signal Waves

Electrical sine waves depict electrical signals represented by a sinusoidal graph. The wave shows all the properties of a wave like amplitude, frequency, wavelength, and can exhibit wave-like properties of reflection, refraction, diffraction, and polarization [3]. Moreover, when an electrical signal wave is said to be pure, it means the wave depiction is devoid of harmonics, as shown in Figure 1.1. Furthermore, when the wave output of the oscillation unit of an inverter is free of harmonics, the power inverter is termed a 'pure sine wave power inverter'.

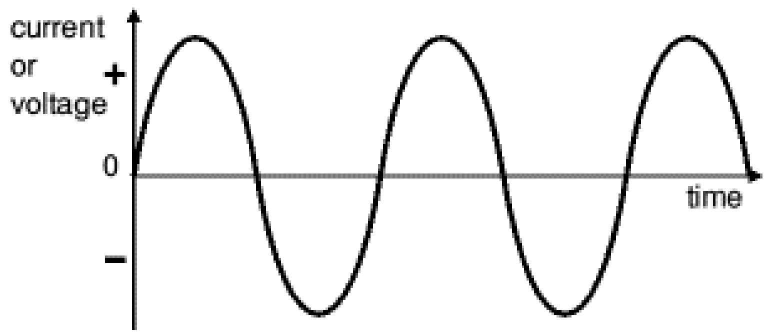

Figure 1.1: AC, DC and Electrical Signal.

Advantages of pure sine wave inverters over modified sine wave inverters:

a) Output voltage waveform is pure sine wave with very low harmonic distortion and clean power like utility-supplied electricity.

b) Inductive loads like microwave ovens and motors run faster, quieter, and cooler.

1.3. Problem Statement

This project work aims to address the challenges of poor power supply delivery to electrical loads by designing, constructing, and installing a 2KVA solar-powered inverter, harnessing the abundant solar energy available.

1.4 Aim of the Project

The aim of the study is to locally design, construct, and install a 2KVA solar-powered inverter for domestic electric power supply.

1.5 Objectives of the Project

1. To design and construct a reliable pure sine wave power inverter.
2. To construct an inverter system using high-quality components and efficient circuitry.
3. To test the performance and reliability of the inverter system.
4. To analyze the efficiency, voltage regulation, and waveform quality of the inverter output.

1.6 SCOPE OF THE PROJECT

The scope of the project encompasses the design, construction, installation, and testing phases of the 2KVA solar-powered inverter system. This includes selecting appropriate components such as solar panels, charge controllers, batteries, inverters, and control circuits, as well as designing the system layout and installation procedures.

1.7 SIGNIFICANCE OF THE PROJECT

The significance of the project lies in its contribution to promoting renewable energy solutions and reducing dependence on fossil fuels. By designing and installing a 2KVA solar-powered inverter, this project aims to provide a sustainable and eco-friendly power source for domestic applications.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

Electricity generation is the process of generating electric power from primary energy sources. Energy conversion processes include thermoelectric (heat-to-electric energy), steam engines (heat-to-mechanical energy), and more. Over the past years, advancements in engineering technology have become highly attractive to power industries, particularly in power electronics applications. The primary motivation behind the development of inverters has been the generation of output signals with low harmonic distortion and reduced switching frequency. This has enabled the conversion from DC power to conventional AC power, suitable for devices such as electric lights, kitchen appliances, power tools, and television sets [1,3].

From the late nineteenth century through the mid-twentieth century, DC-to-AC power conversion was achieved using rotary converters or motor-generator (MG) sets. In the early twentieth century, vacuum tubes and gas-filled tubes began to be used as switches in inverter circuits.

The term "inverter" originates from early electromechanical inverters. Early AC-to-DC converters used an induction or synchronous AC motor directly connected to a generator (dynamo), reversing its connections at precise moments to produce DC. A later development, the synchronous converter, combined motor and generator windings into one armature with slip rings at one end and a commutator at the other, within a single field frame. The result was AC-in, DC-out. With an MG set, the DC could be considered separately generated from the AC; with a synchronous converter, it was "mechanically rectified AC." With appropriate auxiliary and control equipment, an MG set or rotary converter could be "run backwards," converting DC to AC—hence the term "inverter."

Over the years, electricity has been generated using methods such as solar, thermal, wind, and electric generators. These methods have proven reliable and sufficient. However, due to inadequate energy sources, the need for standby supply has led to the development of inverters as an alternative means [4].

Solar energy, a renewable and sustainable power source, has gained significant attention in recent years. Solar-powered inverters integrate solar panels, charge controllers, batteries, and inverters to provide a reliable and eco-friendly power supply. Solar panels convert sunlight into

DC electricity, which is then used to charge batteries through a charge controller. The inverter converts the DC power from the batteries into AC power for household use.

2.2 THE INVERTER

An inverter is a device that converts DC power from sources such as batteries into AC power. In a solar-powered inverter system, the DC power is sourced from solar panels. Figure 2.1 shows the inner circuitry of an inverter power system.

Fig. 2.1: Inverter inner circuitry.

An uninterruptible power supply (UPS) uses batteries and an inverter to supply AC electrical power when main power is not available. When main power is restored, a rectifier supplies DC power to recharge the batteries. An inverter can also be defined as an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage, frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the D.C. source. The basic circuit of the inverter comprises the following parts:

a. Charger Section
b. Rectifier Section
c. DC-AC Converter
d. Drivers Section/FET Gang
e. Inverter Module
f. Transformation Section

a. **Charger Section:** The charger card basically senses the AC input and then generates the silicon-controlled rectifier triggering pulse. The feature for the soft start is incorporated in this card using the concept of sawtooth generation and then its conversion into the triggering pulses, which eventually get transported through the pulse transformer to the output connector of the charger card with its other end connected to the SCR module.

b. **Rectifier Section:** The rectifier module used is a full-wave semi-controlled rectifier with two SCRs and two diodes in single phase. In the case of a three-phase system, the rectification is full-controlled, and six SCRs are used for this purpose.

c. **DC-AC Converter:** This card is responsible for generating the DC voltages (+15V and +5V) to supply it to the other cards. It accepts its input from the tapping over the DC capacitors. The input DC through a fuse is converted into AC and amplified using a TOP switch. This is then fed to a transformer with multiple tappings at its secondary. The AC from the tappings is then rectified through diodes and given to voltage regulators, eventually producing the voltage sources of +15V and +5V. These voltages are then used as a power supply for all other cards.

d. **Driver Section:** The driver card primarily has two features:

1. To provide isolation of the control circuit from the power circuit.
2. To block the PWM pulses, forcing the UPS to go into protection in case of a short circuit at the output end.

e. **Inverter Section:** In this section, conversion of DC to AC is done. The technology of PWM triggering is implicated over the IGBT-based inverters. PWM generated by the DSP card through the driver card, providing electrical isolation, reaches the IGBTs' gate and emitter terminals. Using this high-frequency triggering, the IGBTs produce the AC output from the DC link.

f. **Transformation Section:** This card is basically used to sense the input and output voltages and their conversion into a low-voltage AC for further processing.

g. **Solar Panels:** Convert sunlight into DC electricity to charge the batteries via the charge controller.

h. **Charge Controller:** Regulates battery charging from solar panels, ensuring optimal charging and preventing overcharging.

2.3 Common Components of Inverter

2.3.1 MOSFET:

It is a switching device used to convert AC into DC. It comes in different ratings for different capacities of inverters, e.g., Z44, IRF3205, IRF2807, P55.

2.3.2 Transistor:

It has the same appearance as MOSFETs and is used for signal (voltage and current) amplification in the circuit. It was also used as a switching device earlier. Now, MOSFETs and IGBTs are used in place of it, e.g., BC547, BC557, BD139, etc.

2.3.3 Regulator:

It is a device used to regulate the voltage coming at its input and supply that voltage to the device. For example, a device operates on a 12V supply, and the supply is coming more than this, so we use a 12V regulator to give a 12V supply to it, e.g., 7812, 7805, etc.

2.3.4 Zener Diode:

A Zener diode is a type of diode that permits current to flow in the forward direction like a normal diode but also in the reverse direction if the voltage is larger than the breakdown voltage known as the Zener knee voltage or Zener voltage. Zener diodes are widely used to regulate the voltage across a circuit.

2.3.5 Relay:

A relay is an electrical switch that opens and closes under the control of another electrical circuit. In its original form, the switch is operated by an electromagnet to open or close one or many sets of contacts. It is used as a changeover device in inverters to switch from mains to inverter and inverter to mains, e.g., 40A/12V, 63A/12V.

2.4 Classification of Inverter

Inverters can be classified into three broad types:

1. **Stand-Alone Inverters:** This type of inverter is used in isolated systems where the inverter draws its DC energy from batteries charged by photovoltaic arrays. Many stand-alone inverters also incorporate integral battery chargers to replenish the battery from an AC source when available. Normally, these do not interfere in any way with the utility grid and, as such, are not required to have anti-islanding protection.
2. **Grid-Tied Inverters:** These inverters match phase with a utility-supplied sine wave. Grid-tie inverters are designed to shut down automatically upon loss of utility supply for safety reasons. They do not provide backup power during utility outages.
3. **Battery Backup Inverters:** These are special inverters designed to draw energy from a battery, manage the battery charge via an onboard charger, and export excess energy to

the utility grid. These inverters are capable of supplying AC energy to selected loads during a utility outage and are required to have anti-islanding protection.

2.5 Advantages and Disadvantages of Inverter

A number of advantages include:

1. It is virtually always on.
2. It has no running cost.
3. It brings about the protection of appliances.
4. It changes automatically when the mains goes off.
5. It is easy to maintain.
6. Reduced electricity bills.
7. Environmental friendliness.
8. Energy independence.

One of the disadvantages of an inverter is the High initial cost, including solar panels, charge controllers, and batteries for solar-powered systems.

2.6 Things to Consider Before Buying an Inverter

Since it would cost quite some money for procurement, it is important to ensure that you get good quality that matches your expenditure, i.e., plan for value for money principle. So, be sure of your source and that the quality you get is what you paid for. These things include:

a. Output Waveform

There are two major types of inverter output waveforms available in the market: square waveform inverters and pure sine waveform inverters.

i. Square Wave Inverters:

As the name suggests, the waveform of the output current from this type of inverter is square. The current we get from the grid is neither square wave nor pure sine wave; it’s nearly sine wave. So, electronic devices like fans and tube lights will emit some buzz noise while operating on square wave current. Of course, square wave current won’t spoil your fan or tube light. In some rare cases, these square wave inverters have spoiled the speed control dimmers of ceiling fans. The main reason for this fault is high voltage output [6].

Normally, the voltage output from square wave inverters is between 230 volts to 290 volts; hence, it’s not recommended for sensitive electronic devices like computers. I am just saying “it’s not recommended” based on some experiments carried out and proper observation.

But desktop computers and laptops will operate flawlessly on square wave inverters. As desktop PCs are equipped with SMPS, the current from the square wave inverter won't make any big disturbances in the computer.

2.6.1 Other Names of Square Wave Inverter:

Some inverter UPS manufacturers name their products as digital inverters, modified-sine wave, trapezoidal waveform, stepped time wave, quasi time wave, etc.; all these are nothing but square wave inverters. So, it's pertinent and advisable that one reads carefully the specification of the inverter before purchasing.

b. Pure Sine Wave Inverter:

Pure sine wave inverters provide the purest form of current to your sensitive devices. Most probably, the current from this type of inverter is very safe for desktop computers, laptops, camera batteries, cell phone chargers, mixers, small household water pumping motors, as shown in Figure 2.3, etc.

This type of inverter will save your current bill compared to square wave inverters.

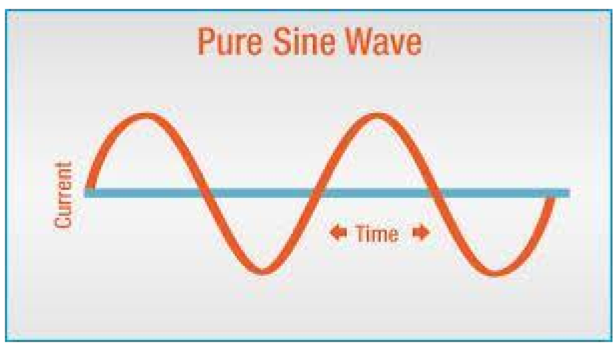

Fig. 2.3: Pure sine wave

No Fan Speed Difference and Noise in square wave inverters:

When power goes off, the speed of the ceiling fan will increase slightly and make some buzz sound, whereas in pure sine wave inverters, the speed of the fan remains the same and makes no noise. You cannot feel the difference when power goes out.

c. Output Frequency:

The AC output frequency of a power inverter device is usually the standard power line frequency, 50 or 60 hertz. If the output of the device or circuit is to be further conditioned (for example, stepped up), the frequency may be much higher for good transformer efficiency [8].

d. Output Voltage:

The AC output voltage of a power inverter device is often the same as the standard power line voltage, such as household 120V or 240V. This allows the inverter to power numerous types of equipment designed to operate off the standard line power.

The designed-for output voltage is often provided as a regulated output. That is, changes in the load the inverter is driving will not result in an output voltage change from the inverter. In a sophisticated inverter, the output voltage may be selectable or even continuously variable.

e. Output Power:

A power inverter will often have an overall power rating expressed in watts (W) or kilowatts (kW). This describes the power that will be available to the device and the power that will be needed from the DC source. Smaller popular consumer and commercial devices designed to mimic line power typically range from 150 to 3000 watts[9].

Not all inverter applications are primarily concerned with brute power delivery; in some cases, the frequency and/or waveform properties are used by the follow-on circuit or device.
Other things to consider when buying an inverter may include inverter size, warranty, durability, and portability, etc.

2.7 Batteries:

A battery is a combination of one or more electrochemical galvanic cells that store chemical energy that can be converted into electric potential energy, creating electricity. Since the invention of the first voltaic pile in 1800 by Alessandro Volta, the battery has become a common power source for many household and industrial applications. The name ‘battery’ was coined by Benjamin Franklin for an arrangement of multiple “Leyden jars” by analogy to a battery of cannon.

If energy is induced in the chemical substance by applying an external source, it is called a secondary battery or rechargeable battery. Examples of secondary cells are the lead-acid cell, nickel-cadmium cell, nickel-iron cell, nickel-zinc cell, etc.

When the energy is inherently present in the chemical substance, it is called a primary cell, e.g., zinc-chlorine cell, alkaline manganese cells. Batteries convert chemical energy directly to electrical energy. A battery consists of some number of voltaic cells. Each cell consists of two half-cells connected in series by a conductive electrolyte containing anions.

A battery is a vital part of an inverter. The performance and life of an inverter largely depend on its battery. There are several classifications of inverter batteries. Here are a few of them[11].

2.8 Types of Batteries

a. Lead ACID Batteries

Lead acid batteries are the most common inverter batteries. They are rechargeable and produce a large amount of current. They are light in weight and most economical. They usually last for a period of 3-4 years but require regular maintenance. The electrolyte level check and topping up have to be done regularly. They also release harmful gases during charging and discharging, so they must be installed in a well-ventilated place in homes or offices. When one cannot afford the deep cycle sealed maintenance-free battery, ideally recommended for your inverter, you can still consider the option of wet cell batteries. They cost far less and can serve you reasonably, though you must realize that they are more challenging to manage. Besides, if they are not deep cycle, they are not designed for deep discharge, which may affect their durability. Good quality wet cell batteries have, however, given satisfactory performance in use.

b. Tubular Batteries

Tubular batteries are the most popular and efficient inverter batteries. They have a complex design, great efficiency, longer operational life (8+ years), and low maintenance. Because of so many advantages, they are costly.

NOTE: Lead-acid batteries, otherwise known as wet cells, use liquid electrolytes, which are prone to leakage and spillage if not handled correctly. Many use glass jars to hold their components, making them fragile. These characteristics make lead-acid batteries unsuitable for portable appliances. Near the end of the nineteenth century, the invention of dry cell batteries, which replaced the liquid electrolyte with a paste, made portable electrical devices practical. These flaws encountered with lead-acid batteries give sealed maintenance-free batteries (SMF) an edge over others.

2.8.1 Inverter Battery Connection

The runtime of an inverter is dependent on the battery power and the amount of power being drawn from the inverter at a given time. As the amount of equipment using the inverter increases, the runtime will decrease. To prolong the runtime of an inverter, additional batteries can be added to the inverter. When attempting to add more batteries to an inverter, there are two basic options for installation: series configuration and parallel configuration.

a. Series Configuration:

If the goal is to increase the overall voltage of the inverter, one can connect batteries in a series configuration, as shown in Figure 2.4. In this type of connection, if a single battery dies, the other batteries would not be able to power the load.

Fig. 2.4: Batteries Connection

b. Parallel Configuration:

If the goal of the connection is to increase capacity and prolong the runtime of the inverter, batteries can be connected in parallel, as shown in Figure 2.5. This increases the overall Ampere-hour (Ah) rating of the battery set.

Fig. 2.5: Diagram of Batteries Connections