ANALYSIS AND TESTING EVALUATION OF 5.5 KVA SOLAR POWER INVERTER

BY

AGHADI ANTHONY EMEKA

ENG1804710

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A PROJECT SUBMITTED TO THE DEPARTMENT OF COMPUTER ENGINEERING, FACULTY OF ENGINEERING, UNIVERSITY OF BENIN,

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CERTIFICATION

This is to certify that this the project titled “Analysis and Testing Evaluation of 5.5 Kva Solar Power Inverter” was carried out by Aghadi Anthony Emeka; in the Department of Computer Engineering, Faculty of Engineering, University of Benin, Nigeria

ENG. S. AKINBOHUN **Date**

(Project Supervisor)

Engr. Dr. (Mrs.) O. Okosun **Date**

(Head of Department)

DECLARATION

This work is dedicated to God Almighty for His wisdom bestowed on us during the course of this project. I dedicate this work to my parents, whose unwavering support and knowledge continue to inspire and drive my pursuit of excellence.

ACKNOWLEDGEMENTS

We are thankful to Almighty God who in His abundant grace and infinite mercy has strengthened us all through the course of studies.

With heartfelt appreciation, I want to extend my sincere appreciation to my esteemed supervisors, Engr. S. Akinbohun., for his unwavering support, mentorship, and invaluable guidance. Their expertise and encouragement have been instrumental in shaping this research.

I want to express my deepest gratitude to my mother: Your unwavering love and encouragement sustained us during late nights and challenging moments. Your sacrifices are woven into every line of code and stroke of design. This project carries your spirit.

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I would like to express my heartfelt gratitude to the dedicated lecturers and staff of the Computer Engineering department for their tireless efforts in imparting knowledge and fostering an environment of learning and growth.

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LIST OF ABBREVIATION AND ACRONYM

AC Alternating Current

Ah Amp-hours

CD Compact Disc

DC Direct Current

DVD Digital Versatile Disc

E.M.F. Electromotive Force

ICs Integrated Circuit

L.E.D. Light Emitting Diode

LCD Liquid Crystal Display

MOSFET Metal Oxide Semiconductor Field Effect Transistor

PWM Pure Width Modulation

TV Television UPS Uninterrupted Power Supply

V Volt

VBAT Battery Voltage

W Watt

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ABSTRACT

This article presents a thorough examination and assessment of a 5.5 kVA solar power inverter, focusing on its performance, efficiency, and reliability under various operational circumstances. The introduction emphasizes the significance of solar power inverters in renewable energy systems and underscores the necessity for comprehensive analysis and testing to gauge their effectiveness and dependability.

The experimental approach details the setup of the testing environment, incorporating a simulated PV array, a programmable electronic load, and a comprehensive data collection system. Parameters such as input and output voltage, current, and power, inverter efficiency, total harmonic distortion, and operating temperature are meticulously measured during the assessment. Testing covers a spectrum of input voltage and output power levels, as well as diverse environmental conditions to mimic real-world usage scenarios.

The findings reveal that the 5.5 kVA inverter consistently maintains high efficiency levels, typically exceeding 95%, across a broad range of operating conditions. It also demonstrates robust power handling capabilities, delivering the rated 5.5 kVA of power with minimal distortion in the output waveform. The inverter proves resilient to fluctuations in input voltage and output power, rendering it suitable for both grid-connected and off-grid solar energy applications. The discussion delves into a detailed analysis of the results, spotlighting the critical factors influencing the inverter's performance and reliability, along with their implications for its deployment and operation.

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

Electric power reliability is a persistent issue in numerous African nations, particularly Nigeria, where frequent interruptions are common. These interruptions often lead to malfunctions or complete failure of electrical devices, causing significant setbacks for businesses and straining the economy. The prevalence of power disruptions can be likened to a form of "power pollution," characterized by high voltage spikes and brief voltage drops (Tourkhani et al., 2009).

The impact of power outages extends beyond inconvenience, affecting the operation of critical equipment in both commercial and public sectors, resulting in data loss and potential damage to equipment. Additionally, as the global population continues to rise, so does the demand for energy, leading to further strain on existing power infrastructure (Erol-Kantarci & Mouftah, 2011).

Addressing the depletion of fossil fuel resources necessitates urgent action to develop viable renewable energy alternatives, such as solar power, which can diminish dependence on fossil fuels while also alleviating the strain on power supply infrastructure. Solar energy stands out as one of the most abundant energy sources available to us, with approximately 10000 TW of solar energy reaching the earth's surface every day (Bosshard, 2006).

Mouftah's research focuses on the design and implementation of a 50-watt inverter, which offers environmentally friendly alternating current for uninterrupted power supply to various devices, contributing to a sustainable economy. The study underscores the significance of solid-state inverters in providing reliable power solutions and specifically examines the performance of this 50-watt inverter (Mouftah, 2011).

When sufficient solar energy is available, the inverter is utilized to directly convert solar energy into power for the load. Conversely, when solar energy is insufficient, the inverter switches to utilizing battery power to supply the load. The process initiates as sunlight interacts with the photovoltaic system, generating direct current. Solar power systems, which employ solar panels to convert solar energy into direct current, represent a common type of power system. Most household appliances operate on a single-phase alternating current supply. A solar inverter plays a crucial role in converting the variable direct current output from a photovoltaic solar panel into alternating current. This alternating current can then be utilized to power household appliances. Any surplus electricity generated can either be fed back into the grid via electrical power lines or stored in a home battery for later use.

An essential component in the conversion of DC electrical energy from solar PV modules to AC is the inverter. The project report is centered on the selection of a cost-effective yet high-efficiency solar inverter. However, assessing inverter efficiency involves practical implementation, testing, and benchmarking against ideal standards. This process forms the core theme of the project: Solar Power Inverters, Analysis, and Test Evaluation.

An inverter that closely mirrors the attributes of an ideal model is deemed reliable, while one that strays significantly from these ideal characteristics is considered inefficient. As mentioned earlier, electricity deficits pose a significant obstacle in the contemporary world, especially in densely populated and economically disadvantaged developing nations like Nigeria. The daily escalation of power outages and accompanying price increases only heightens the sense of urgency. In such circumstances, despite the perceived higher operational expenses, the adoption of solar power or diesel turbines for electricity generation in remote areas becomes imperative.

1.2 Statement of the Problem

Solar energy offers a clean and renewable alternative, but its utilization necessitates the use of power inverters to convert the DC output from solar panels into usable AC electricity. The efficiency and reliability of these inverters are paramount for the success of solar systems. As highlighted by Shukir (2022), the efficiency and reliability of the inverter are crucial factors for the successful operation of solar systems.

The core problem addressed in this context is how to develop and deploy solar power systems with efficient inverter topologies to address environmental concerns associated with fossil fuels, enhance energy security through localized renewable generation, and deliver dependable AC electricity to residential and commercial establishments. Shukir, S. S. (2022). Solar System Inverters Types. Journal of Advances in Electrical Devices.

Efficiency Optimization: Despite advancements in solar inverter technology, achieving maximum efficiency remains a challenge. Tackling efficiency-related issues such as converter losses and temperature fluctuations is essential for enhancing overall system performance.

Reliability and Durability: Solar power inverters are exposed to various environmental conditions, which can impact their reliability and longevity. Understanding the long-term durability of inverters in diverse climates and environments is crucial for the development of sustainable solar energy systems.

1.3 Aim & Objectives

The aim of this project is to analyze and evaluate a 5.5 kva solar power inverter

The objectives includes the following:

i. Assess the power quality of the inverter under various load conditions.
ii. Determine the power capacity of the inverter.
iii. Evaluate the efficiency and reliability of the inverter for household applications.

1.4 Significant of the Study

This research lies in enhancing the user-friendliness of solar inverters by integrating wireless technology into traditional circuits. As highlighted by Nair et al., the ever-expanding adoption of clean and efficient renewable energy underscores the necessity for the grid infrastructure to evolve into a more resilient and smart system. Consequently, selecting the appropriate inverter topology becomes crucial, taking into account factors such as system size and grid connectivity. Therefore, the significance of this study lies in offering an overview of the various available inverter technologies, along with their advantages and drawbacks for different applications.

This research provides insights into the diverse solar inverter technologies, their potential applications, and key considerations to aid engineers and designers in selecting the most suitable inverter topology for a given PV system specification and installation environment.

The significance of studying solar power inverters, along with conducting thorough analysis and test evaluations, stems from the critical need to ensure the efficiency, reliability, and safety of solar power systems. Solar power inverters play a pivotal role in converting the direct current (DC) electricity produced by solar panels into alternating current (AC) electricity, which is essential for powering appliances and other electrical devices. Thus, understanding and assessing the performance of solar power inverters are essential steps in ensuring the optimal functioning and safety of solar energy systems.

i. Efficiency: Delving into the understanding and analysis of solar inverters contributes to enhancing their efficiency, a pivotal aspect for optimizing the conversion of solar energy into usable electrical power. This endeavor is crucial for boosting the overall performance of solar energy systems.
ii. Reliability: Solar power inverters must exhibit dependability, longevity, and resilience against various environmental factors. By identifying and addressing reliability concerns through analysis and testing, the lifespan of solar power systems can be prolonged, resulting in reduced maintenance expenses and increased system uptime.
iii. Safety: Ensuring the adherence of solar power inverters to safety standards and regulations is paramount to safeguarding both the system and its users. Through meticulous analysis and test evaluations, compliance with safety standards such as electrical safety, overvoltage protection, and grounding requirements can be verified. Upholding the safety of solar power systems is essential in mitigating risks of accidents, electrical hazards, and system malfunctions.
iv. Technological Advancement: The exploration of solar power inverters contributes to technological progress in this domain, paving the way for innovative features such as enhanced power optimization, maximum power point tracking, advanced fault detection, and integrated energy management. Advancements in inverter technology continually drive down costs, enhance efficiency, and bolster the accessibility and competitiveness of solar power systems in the renewable energy sector.

1.5 Scope of the Study

The investigation into Solar Power Inverter: Analysis and Test Evaluation encompasses a thorough exploration of multiple facets, including operational principles, efficiency assessments, performance across diverse conditions, reliability metrics, fault diagnosis techniques, testing methodologies, comparative analyses, environmental implications, and future trajectories. The overarching aim is to furnish a comprehensive understanding and insights into the enhancement of solar power inverter technology.

The study of a solar power inverter entails scrutinizing its energy conversion efficiency, compatibility with various loads, stability, and durability. Testing procedures encompass evaluating performance under diverse load scenarios, analyzing responses to real-world environmental factors such as temperature fluctuations, and ensuring adherence to industry standards concerning safety and reliability. The ultimate objective is to identify and refine inverter technologies to facilitate efficient and dependable integration within solar energy systems.

CHAPTER TWO

LITERATURE REVIEW

2.1 History

In the year 2000, residential solar saw a significant breakthrough with the introduction of the modern inverter known as the "non-islanding inverter," developed by scientists at Sandia Laboratories in Albuquerque, New Mexico. This innovative device automatically interrupts or stops the flow of electricity from grid-connected PV systems when an electric distribution line undergoes shutdown, as reported by Sandia National Laboratories (2000).

Prior to this development, utility companies hesitated to connect solar installations due to potential safety risks and equipment damage. The issue stemmed from the fact that when a utility needed to deactivate power in a distribution line for maintenance or other reasons, the line had to be completely de-energized for the safety of workers and bystanders. Before the Sandia invention, photovoltaic systems lacked the capability to recognize a de-energized line under all circumstances, potentially continuing to send electricity through the line. The non-islanding inverter enabled solar power systems to detect a de-energized line and automatically halt power production or redirect the electricity to the connected house or business. This development marked a significant advancement and played a pivotal role in driving the expansion of residential solar energy systems.

As crucial as solar panels, inverters are essential components of any domestic solar power system, responsible for converting DC to AC electricity. When sunlight strikes solar panels, photons are converted into electrons, generating DC electricity. Solar panels, typically composed of a semiconductor, predominantly silicon, can only produce DC current. Upon transmitting this energy to the inverter, the machine performs inversion, converting DC into AC power suitable for most appliances. Solar inverters have contributed to making residential solar power systems more affordable. In 1956, solar systems were only 6% efficient and cost a staggering $300 per watt. Today, with advancements in solar panel technology and more efficient solar inverters, the average solar system operates at 14 to 18 percent efficiency and costs as little as $3 per watt.

A suitable solar inverter should match the capacity of the solar array. For example, if a 5 kW home solar array is required (the average size), a 5 kW solar inverter is necessary. There are three main types of inverters: string inverters, which connect to all panels and channel DC energy into a single unit for conversion into AC electricity; micro inverters, small devices affixed to the back of each solar panel; and DC-Optimizers, which, unlike micro inverters, do not directly convert DC into AC energy at the panels but help optimize their output in conjunction with a string inverter.

2.2 Definition of Terms

2.2.1 Solar Power

Solar power towers (SPT), also referred to as central receiver systems (CRS), utilize a heliostat field collector (HFC), consisting of a collection of sun-tracking reflectors known as heliostats. These heliostats reflect and concentrate sunlight onto a central receiver positioned atop a fixed tower. Heliostats are typically flat or slightly concave mirrors that track the sun's movement in two axes. Within the central receiver, heat is absorbed by a heat transfer fluid (HTF), which subsequently conveys heat to heat exchangers powering a steam Rankine power cycle (Zhang et al., 2013).

Solar panels, on the other hand, function as pn junction diodes that directly convert sunlight into electricity. The operational principle of solar panels is grounded in the photovoltaic effect, which entails the generation of a potential difference at the junction of two dissimilar materials in response to visible or other radiation. The solar panel works in three steps:

i. When photons from sunlight strike the surface of the solar panel, they are absorbed by semiconducting materials, typically silicon.

ii. Photons dislodge electrons in semiconducting material, creating an electric potential difference and initiating a current flow. Solar cell design allows electrons to move in one direction, optimizing electricity generation and capture.

iii. A collection of solar cells transforms solar energy into a practical quantity of direct current (DC) electricity

2.1 Snapshot of a typical power inverter

2.2.2 Inverter:

An inverter is an electronic apparatus that transforms direct current (DC) electricity into alternating current (AC) electricity by means of electric power conversion. Inverters find widespread use in various applications such as adjustable speed drives (ASDs), uninterruptible power supplies (UPSs), static var compensators, active filters, flexible AC transmission systems (FACTSs), and voltage compensators. Their operation relies on switching power semiconductor devices, which generate discrete waveforms characterized by abrupt changes instead of smooth ones (Espinoza, José R, 2011).

The initial stage of inverter design involves the creation of a step-up transformer. A step-up transformer is utilized to increase the voltage supplied to a circuit. It comprises two coils known as the primary and secondary coils, wound around a soft iron core composed of sheets of soft iron (Theraja and Theraja, 2005). Notably, the number of turns in the secondary coil of this transformer exceeds that of the primary coil.

The primary winding of this step-up transformer is designed as 24V-DC-24V, while the secondary winding is configured as a bifilar winding producing 240V. As alternating current enters each end of the primary winding, it induces an alternating current at 50Hz in the secondary winding of the transformer. The alternating current voltage is subsequently stepped up by the transformer, resulting in an output voltage of 240V. This elevated voltage from the secondary winding is directed to the socket outlet, serving as the output of the inverter system (Theraja and Theraja, 2005).

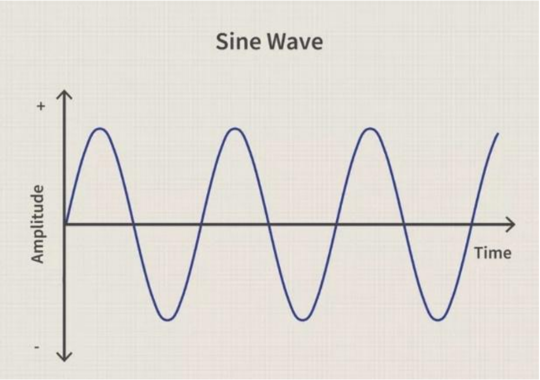
An inverter is essential for effectively converting DC electrical energy generated by solar PV modules into AC electricity. The project report is centered around the selection of a cost-effective, high-efficiency solar inverter. Assessing inverter efficiency involves practical implementation, testing, and comparing results against ideal standards, which forms the core theme of the project: "Solar Power Inverters, Analysis, and Test Evaluation" (Espinoza, 2010).

2.2 snapshot of an inverter

2.2.3 Different Types of Inverters

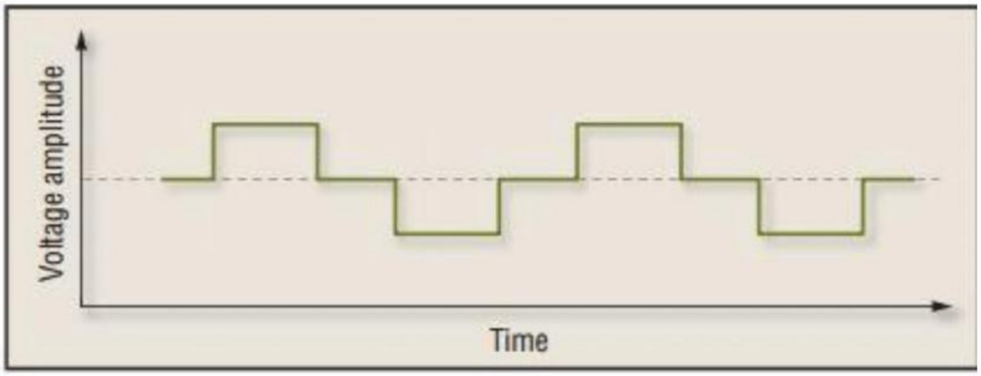
There are three primary types of inverters: sine wave (often termed "true" or "pure" sine wave), modified sine wave (essentially a modified square wave), and square wave.

i. **Sine wave:** A sine wave is typically generated by your local utility company and, in many cases, by a generator. This is because rotating AC machinery naturally produces sine waves as a byproduct. The primary advantage of a sine wave inverter is that all equipment available on the market is designed for use with sine waves. This ensures optimal performance of the devices. Some products, such as motors and microwave ovens, will only deliver their full output when powered by sine wave electricity. Additionally, certain devices like bread makers, light dimmers, and specific battery chargers require a sine wave to function properly. However, sine wave inverters tend to be more expensive, typically ranging from two to three times the cost of other types.



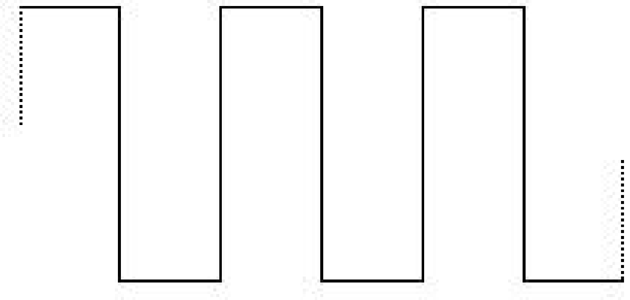
2.3 sine wave (Adam Hayes 2022)

ii. **Modified Sine:** A Modified Sine Wave Inverter generates an alternating current (AC) waveform that deviates from a pure sine wave. Instead of a smooth sinusoidal waveform, it produces an approximation composed of a series of steps or stair-like segments. This waveform is a simplified and altered version of the true sine wave. Modified sine wave inverters are typically more affordable than pure sine wave inverters and find applications in a wide range of uses, including powering simple electronics, appliances, and equipment. However, they may not be suitable for devices that are sensitive to the quality of the power supply. Certain electronic equipment, especially those with motors or delicate circuitry, may operate less effectively or reliably when powered by a modified sine wave.When choosing between pure sine wave and modified sine wave inverters, it's crucial to consider the specific requirements of the devices you intend to power. While modified sine wave inverters are cost-effective, pure sine wave inverters are preferred for applications that demand a cleaner and more consistent power supply.



2.4 Modified sine wave (Ali Hashemifarzad 2022)

iii. **Square wave:** A square wave inverter is a type of power inverter that generates an alternating current (AC) waveform characterized by rapid voltage transitions between positive and negative levels, resulting in a square-like waveform. In contrast to the smooth sinusoidal waveform produced by a pure sine wave inverter, the square wave is a simpler and less refined representation of alternating current.Square wave inverters are the simplest and often the most economical type of inverter available. However, their utility is limited because the square wave output may not be suitable for powering many electrical gadgets and appliances. The rapid and abrupt voltage shifts inherent in square wave output can lead to inefficiencies and potential issues with the operation of sensitive equipment, especially devices equipped with motors, transformers, or intricate electronic circuitry.



2.5 Square wave inverter

2.2.3 Battery

A battery serves as an electrochemical device capable of storing electrical energy and releasing it in a controlled manner. Typically, it comprises one or more electrochemical cells, each containing two electrodes (a cathode and an anode) and an electrolyte facilitating the movement of ions between the electrodes (Hamid R. Teymour, 2014).

During discharge, the chemical reactions within the battery convert chemical energy into electrical energy, which can then be utilized to power devices or circuits. Conversely, during charging, an external electrical current drives the chemical reactions in reverse, enabling the storage of energy within the battery.

Batteries do not generate electricity themselves; instead, they store and discharge it. They are rated based on their voltage (V) and their capacity to retain charge ($Q = It$ in Ah). A battery's voltage rating denotes its maximum electromotive force (E.M.F in Volts) and capacity (in Coulombs) under standard conditions.Batteries are categorized into two main types: primary cells (non-rechargeable) and secondary cells (rechargeable). Primary batteries cannot be recharged once depleted, whereas secondary batteries can be recharged by passing a direct current through them. Rechargeable batteries are commonly favored for long-term applications and flexibility, as they can be reused multiple times throughout their useful lifespan (Munir 2009).

Key aspects of a battery for energy storage:

i. Batteries store and release electrical energy through reversible chemical reactions.
ii. Batteries consist of one or more cells, each comprising cathode, anode, and electrolyte components.

iii. Batteries can be discharged to provide electricity and recharged by applying an external electrical current.

iv. Batteries enable controlled and regulated release and storage of electrical energy.

v. Batteries find applications in various fields such as renewable energy storage, electric vehicles, and consumer electronics, among others.

2.2.4 Classification of Batteries

Batteries are categorized into lead-acid batteries, lithium-ion batteries, gel batteries, and AGM batteries.

i. **Lead-Acid Batteries:** The lead-acid battery consists of flooded lead-acid and sealed lead-acid variants, representing a rechargeable battery type that operates through a chemical reaction between lead dioxide (PbO_2) and sponge lead (Pb) to produce electrical energy. Renowned for their reliability and cost-effectiveness, lead-acid batteries are among the oldest and most widely used battery types. They typically comprise positive plates composed of lead dioxide, negative plates made of sponge lead, and a separator housing sulfuric acid electrolyte.

During discharge, the positive plate's lead dioxide (PbO_2) reacts with the negative plate's sponge lead (Pb) and sulfuric acid, yielding lead sulfate ($PbSO_4$) and releasing electrical energy. Conversely, during the charging process, the application of an external electrical voltage causes the lead sulfate to revert to lead dioxide at the positive plate and sponge lead at the negative plate, effectively restoring the battery for subsequent discharges (NM Chaudhari - 2021). Lead-acid batteries come in two main types:

Flooded Lead-Acid (FLA): These batteries feature liquid electrolyte, necessitating regular maintenance to monitor and replenish water levels.

Sealed Lead-Acid (SLA): Immobilized electrolyte characterizes these maintenance-free batteries. Common variants include Absorbent Glass Mat (AGM) and Gel Cell batteries.

2.6 Flooded-lead acid (LA) & sealed acid battery

ii. **Lithium-Ion Batteries:** Lithium-ion batteries are rechargeable energy storage devices that utilize lithium compounds as the primary material in both the anode (typically graphite) and cathode (commonly composed of lithium cobalt oxide, lithium manganese oxide, or other lithium-based materials), separated by an electrolyte containing lithium salts. Renowned for their high energy density, lightweight construction, extended cycle life, and versatile applications across portable electronics, electric vehicles, renewable energy systems, and various other sectors, lithium-ion batteries function by facilitating the movement of lithium ions between the electrodes during discharge and recharge cycles.

These batteries play a vital role in numerous devices such as smartphones, tablets, laptops, and electric vehicles. They are recognized as the most efficient technology on the market and are essential for reducing carbon dioxide emissions and addressing climate change. Lithium-ion batteries are pivotal for energy storage systems and represent a key technology for the future, particularly in the context of electric and hybrid vehicles as well as photovoltaic systems (Beta Writer Heidelberg, 2019).


2.7: Lithium-Ion Battery

iii. **GEL Batteries:** Gel batteries belong to the category of Valve-Regulated Lead Acid (VRLA) batteries, where the electrolyte is immobilized using pyrogenic silica. These batteries typically offer a usable lifespan ranging from 10 to 20 years, with a cycle life varying from 500 to 1500 cycles at 80% Depth of Discharge (DOD).

One of the notable characteristics of gel batteries is their stable internal resistance and capacity throughout their lifespan, without any reported instances of thermal runaway effects. The structure of gel batteries involves a liquid sol that fills all gaps between separators and plates, effectively preventing short circuits. Gel batteries feature lower oxygen recombination currents attributed to a micro porous separator, which reduces depolarization of the negative electrode (W Rusch, et al., 2007).


2.8: GEL Battery

iv. **AGM Batteries:** AGM (Absorbent Glass Mat) batteries represent a type of sealed lead-acid battery wherein the electrolyte is absorbed into a glass mat separator, effectively immobilizing it and preventing any leakage. Featuring positive and negative plates composed of lead, the AGM design offers enhanced safety, reduces maintenance requirements, and provides improved resistance to vibration, rendering them suitable for various applications such as automotive, marine, solar power, and uninterruptible power supply (UPS) systems. AGM batteries typically exhibit a usable lifespan ranging from 5 to 10 years, with a cycle life spanning from 200 to 500 cycles at 80% Depth of Discharge (DOD) (W Rusch, et al., 2007).

2.9: AGM Battery

2.2.5 Amp-Hours Rating

The amp-hour (Ah) rating serves as an indicator of the electric charge capacity of a battery. It represents the quantity of amps a battery can supply over a specified duration, typically at a defined discharge current. For instance, a 12V 100Ah battery theoretically has the capacity to deliver 100 amps for one hour, 50 amps for two hours, and 10 amps for ten hours before reaching complete depletion.

The Amp-hour rating is directly related to the number of active materials and electrodes present within the battery. Batteries with a higher count of plates and active material exhibit greater capacity and Ah rating. To calculate the Amp-hour rating, the battery is discharged over a predetermined time period until the voltage declines below a specified cut-off level, typically around 1.75V/cell.

However, as discharge currents increase, the useful capacity of the battery diminishes due to factors such as Peukert's Law. According to this law, the available capacity decreases as the discharge current rises. For instance, a battery with a nominal capacity of 100Ah may only deliver 70-80Ah if discharged in 1 hour instead of the advertised 20 hours. The Ah rating is influenced by temperature. Lower temperatures restrict the capacity, with capacity typically starting to decline below room temperature (25°C) and experiencing a significant drop at freezing or lower temperatures. Additionally, the Ah rating decreases as the battery ages. Continuous cycling and float service lead to gradual deterioration of the active components and accumulation of resistance, resulting in reduced capacity over time.

While the Ah rating provides a standardized method for comparing batteries and estimating runtime, the useful capacity is determined by various factors including the discharge rate, temperature, age, and health of the battery. To accurately size and utilize batteries, it's essential to consider Peukert's Law and factors such as age and temperature derating variables (MG Cugnet, et al., 2010).

2.2.6 Amp-Hours Specifications

The Peukert Effect governs that amp-hours must be measured at a specific rate. The Peukert value is directly related to the internal resistance of the battery. Higher internal resistance leads to elevated losses during both charging and discharging processes, particularly at higher currents. Consequently, a battery's Ah capacity diminishes when it undergoes quicker depletion.

Conversely, if the battery is discharged at a slower rate, the Ah capacity tends to increase. Some manufacturers and suppliers rate their batteries at 100 hours, which can make them seem more potent than they actually are (Northern Arizona Wind & Sun, 2012).

2.2.7 Battery Lifespan

The battery life of a solar power inverter system can be influenced by several crucial factors:

i. **Depth of Discharge (DOD):** A deeper average DOD of the battery during cycles typically results in a shorter battery life. Limiting DOD to 50% or less can extend the life compared to 80% DOD.
ii. **Charge/discharge rate:** Slower charge and discharge rates tend to be better for battery life. High charge/discharge rates can lead to increased buildup of internal resistance.
iii. **Overcharging**: Proper regulation set points and temperature compensation are essential to prevent overcharging, which can accelerate deterioration of the battery's life.
iv. **Temperature**: High temperatures exceeding 25°C can accelerate aging. It is recommended to maintain the battery temperature below 30°C.
v. **Number of cycles**: Battery life is often rated for a certain number of cycles at a specific DOD. More cycles typically lead to faster deterioration of active materials.
vi. **Float service:** Extended periods in float service without cycling can still cause aging, primarily through corrosion. Periodic cycling helps refresh the battery.

vii. **Maintenance**: Regular maintenance activities such as equalization charges, terminal cleaning, torqueing, and state of charge checking can help maximize battery life.

viii. **Battery type:** In this application, lithium-ion batteries generally last longer than lead-acid batteries. Therefore, selecting an appropriate battery technology and ensuring quality is crucial.

ix. **Sizing:** Proper sizing relative to the inverter load and days of autonomy is essential to prevent over-discharging or undercharging of the battery.

2.3 Types of Technology

The technology employed in solar inverters is pivotal for their functionality. Examination and assessment focus on several key facets:

i. **Power Conversion Methodology:** The evaluation concentrates on the efficiency of the power conversion process, ensuring optimal energy transfer from the solar panels to the electrical grid.

ii. **MPPT (Maximum Power Point Tracking):** The assessment involves gauging the inverter's capacity to track and harness maximum power from solar panels across varying sunlight conditions.

iii. **Voltage Regulation**: The scrutiny encompasses evaluating the inverter's aptitude to uphold stable and suitable voltage levels, ensuring alignment with electrical grids and appliances.

iv. **Fault Detection and Protection Mechanisms:** Testing entails verifying the inverter's proficiency in promptly detecting and responding to faults, thereby safeguarding the system from potential issues.

2.4 Application

Solar inverters, in conjunction with their analysis and test evaluations, are applicable across various domains, including:

Homes:

Analysis: Verifying the compatibility of the inverter with household appliances.

Test Evaluation: Ensuring its efficient and safe operation under typical residential conditions.

Businesses and Industries:

Analysis: Evaluating scalability and compatibility with heavy loads in industrial settings.

Test Evaluation: Assessing performance under high-demand scenarios and compliance with industry regulations.

Off-Grid Areas:

Analysis: Assessing the functionality of the inverter in locations lacking a conventional power grid.

Test Evaluation: Guaranteeing dependable and efficient operation in remote environments.

Grid-Connected Systems:

Analysis: Evaluating synchronization with the primary power grid.

Test Evaluation: Verifying responsiveness to grid fluctuations and adherence to grid standards.

2.5 Related Works on Credit Card Fraud Detection System

Xu She et al. (2018) conducted a study on the Performance Evaluation of a 1.5 kV Solar Inverter using a 2.5 kV Silicon Carbide MOSFET. Their research involved testing the steady-state and dynamic characteristics of the 2.5 kV SiC MOSFET, constructing a half bridge module for device assessment, and employing a double pulse test setup to analyze switching losses across various operational scenarios. Results indicated that the 2.5 kV SiC MOSFET exhibited minimal conduction and switching losses, leading to enhanced efficiency. However, limitations were noted, particularly regarding the suitability of the TO-247 package for commercial products at this voltage rating, and further testing in a full converter prototype was recommended. The study highlighted the trend towards 1.5 kV DC link voltage in the solar industry, emphasizing the potential benefits such as increased string length, enhanced inverter conversion capability, and improved performance. Additionally, the paper introduced the performance characterization of the 2.5 kV Silicon Carbide MOSFET and evaluated its application in 1.5 kV solar inverters compared to solutions with 1.2 kV devices.

Dinesh Varma Tekumalla *et al* (2018). In their study on the Comprehensive Performance Evaluation of various solar photovoltaic (SPV) system configurations, the researchers compared four setups: central inverter, microinverter, fixed-axis, and dual-axis tracker. They utilized field data spanning one year, simulated system performance, and cross-referenced it with actual measurements. Technical performance was assessed using indices from IEC standard 61724, while economic viability was evaluated over a projected 25-year lifespan. Results indicated that the dual-axis tracker with a microinverter exhibited the best technical performance, while the dual-axis system with a central inverter proved most cost-effective over the project's lifetime. However, limitations included the use of daily average irradiance and temperature data for simulations, and the analysis was restricted to four PV system configurations at a single geographical site for just one year.

Oladimeji TT *et al* (2018). The study on Performance Analysis of a Branded and Locally Constructed Modified 1 KVA Sine Wave Solar Power Inverter for Domestic Electric Power Supply involved constructing a 1kVA 220V AC output inverter locally, using components such as MOSFETs, transformers, diodes, etc., along with an IC SG3524 oscillator. This locally built inverter was compared to a branded commercial inverter by subjecting them to various loads like light bulbs, fans, and drilling machines, among others. Parameters such as output voltage, current, and battery drain were measured. The results revealed that the locally constructed inverter outperformed the branded inverter in terms of waveform quality, voltage regulation, ability to withstand high starting currents, and mechanical ruggedness. Additionally, it was more cost-effective. The locally constructed inverter had a rating of 1kVA and 220V AC output, requiring components like a locally sourced 100AH 12V deep cycle battery, IC SG3524 oscillator, MOSFETs, BJT transistors, transformer, diodes, resistors, contactors, relays, capacitors, and other electronic components. The implementation stages involved constructing units for the oscillator, MOSFET assembly, transformer, and battery charge, each independently tested for functionality before integration. The inverter converts a 12VDC input to a 220V modified sine wave output, with the locally constructed inverter demonstrating superior performance and cost-effectiveness compared to the branded one in waveform and output stability.

Sivasankari Sundaram *et al* (2015). The study evaluated the performance of a 5 MWp grid-connected solar photovoltaic plant in South India by monitoring parameters like solar insolation, temperature, and power output at 5-minute intervals. Performance indicators such as array yield and efficiency were assessed monthly, and validation was done using RETScreen simulation software. Results showed an annual energy generation of 8.5 GWh with a performance ratio of 89.15%, aligning closely with RETScreen predictions. The plant exhibited superior performance compared to similar installations. The main goal was to present validated annual performance analysis of the plant. RETScreen software validated real-time performance, showing agreement with monitored data. The study underscores the significance of accurate performance evaluation in solar energy systems.

K K Rajan *et al* (2021). The study evaluated a 200 kWp grid-connected solar power plant, analyzing module efficiency, inverter efficiency, overall efficiency, and harmonics under various conditions. Integration with a diesel generator and grid supply was also examined. Findings showed slightly lower PV array efficiency due to a higher temperature coefficient, yet generally meeting commercial standards. Inverter efficiency was high, close to 99% at full load, with minimal harmonics. Initial challenges in integrated operation, like power factor correction and load sharing, were identified. However, addressing these challenges requires improved control measures due to the higher module temperature coefficient. For academic institutions, grid-tied solar power plants offer matching load and generation profiles. After assessing needs, a 250 kWp capacity was deemed optimal, leading to the addition of a 200 kW plant to an existing 50 kW one. Commissioning revealed some operational difficulties during integrated operation, discussed alongside performance evaluations and remedial measures in this paper.

Vinayak Singh *et al* (2019). The study focused on assessing the performance of solar inverters through experimental analysis and simulation. Experiments involved two inverters of varying capacities connected to a 1.8 kWp PV system, monitoring parameters like solar irradiation, ambient and module temperature, and varying loads. Findings indicated a significant efficiency reduction due to dust buildup on the PV system, while the open-circuit voltage decreased with rising panel temperature. Introducing battery storage enhanced system efficiency for domestic use. Notably, inverter efficiency dropped below 50% at loads less than 10% of rated capacity, with lower-rated inverters performing better at lower loads. The study underscores the importance of battery storage for maximizing PV power utilization and reducing system costs, especially in varying climatic conditions. Additionally, the paper delves into different inverter types and techniques employed in PV systems, complemented by simulation using the SPWM technique.

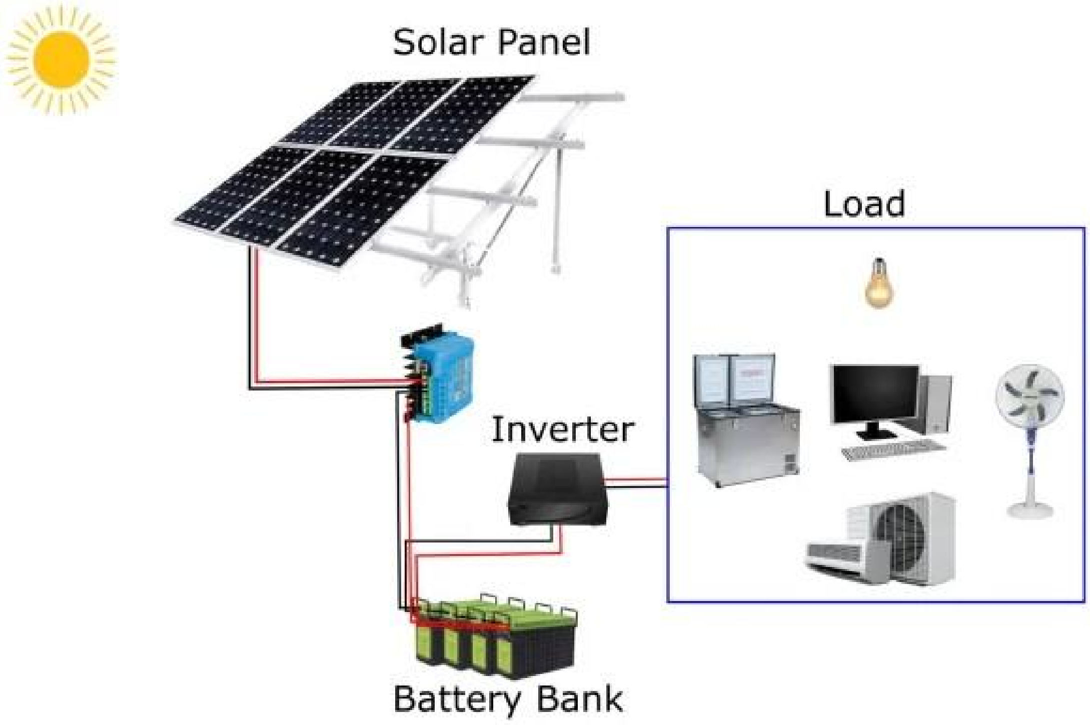
Akash Kumar Shukla *et al* (2016). The study focused on the design, simulation, and economic assessment of a standalone rooftop solar PV system in India. Through simulation modeling with Sunny Design, SAM, and BlueSol software, the performance of a 110 kWp system was analyzed. The predicted annual energy output was approximately 190 MWh, with a system yield of 1731 kWh/kWp. Initial installation costs were estimated at Rs. 82.02 lakhs, with a payback period of 8.2 years. However, the solar resource assessment was limited to MANIT Bhopal, suggesting the need for broader analysis across other areas and cities. Notably, the study did not address potential challenges with batteries and storage. Additionally, the paper outlines the detailed design process and cost analysis of a standalone rooftop solar PV system, emphasizing its potential environmental benefits.

Sahin Gullu, Amour-che Djaho *et al* (2022). The study details the integration of a cutting-edge high-energy system at the Florida Solar Energy Center, combining a 540 KVA bidirectional inverter and a 1.86 MWh lithium-ion battery energy storage system (BESS). Initially used for load shifting, the system later incorporated PV panels for peak shaving and was expanded to form a microgrid aimed at minimizing grid reliance. While load shifting and grid/battery scenarios were tested on the actual system, PV integration was simulated based on site data. The collaboration between the University of Central Florida and A.F. Mensah Inc. facilitated the project's implementation. The paper provides a comprehensive case study, offering insights into microgrid operations, energy consumption, battery testing, load shifting, and peak shaving, along with voltage and current waveform analysis. Although PV panel scenarios were simulated, direct assessments of grid, BESS, and load interactions were conducted and presented.

Akhilesh A. Nimje *et al* (2017). The study documents the installation and commissioning of a 100 kW rooftop solar PV system at an educational institution, detailing site assessment, architecture, layout, and testing procedures. Post-installation measurements revealed average DC voltage, current, and power outputs of 620V, 32A, and 20kW, respectively, during peak solar hours. AC measurements showed similar values. The system notably reduced grid power consumption from 45 kWh to 12 kWh per hour during peak solar generation. While successful, the study's scope is limited to one site, suggesting broader data collection across multiple sites for improved generalizability. The integration of solar power with the grid is emphasized, offering significant cost savings and applicability across various settings, including commercial complexes, residences, and remote villages.

CHAPTER THREE

METHODOLOGY



3.1 Components Used

i. Solar panels.

ii. Charge controller.

iii. Batteries (200ah/48v).

iv. Inverter (which comprises of transformer, capacitors, relays, resistors, and diodes).

3.1: solar inverter connection

3.2 Power inverter selection

When selecting an inverter, factors such as type, capacity, brand, and model are taken into account. Several considerations need to be evaluated, especially for higher power requirements (800 watts or more). The following aspects should be considered:

Power (Watt): Watts indicate the amount of power a device consumes or supplies when operational. It is calculated by multiplying voltage by amperage. For instance, a device drawing 10 amps at 12 volts or 1 amp at 120 volts both equate to 120 watts. A watt is defined as one Joule per second, thus "watts per hour" is akin to "miles per hour per day".

Energy (Watt-hours): Watt-hours (or kilowatt-hours, kWh) represent the product of watts and the duration of usage. This is commonly referred to when discussing daily power consumption. For example, if a light consumes 100 watts and operates for 9 hours, it totals 900 watt-hours. Similarly, if a microwave uses 1500 watts and runs for 10 minutes (1/6th of an hour), it amounts to 250 watt-hours. Electricity bills typically indicate charges per kWh, where a kWh is equivalent to 1000 watts for one hour.

Current (Amps): Amps denote the flow of electrical current. They are crucial as they impact the required wire size, especially for the DC (low voltage) side of an inverter. Insufficient wire size for the amps can lead to overheating and voltage drops. An amp is defined as one Coulomb per second.

Capacity (Amp-Hours): Amp-hours (AH) reflect the product of amperage and time, representing battery capacity. Since most inverters operate from batteries, AH capacity determines the duration of operation.

3.3 Power Ratings of Inverters selection

Choosing the correct power rating for an inverter is essential to match the power demands of the devices and appliances you aim to operate (such as fans, tube lights, televisions, phones/laptops, etc.). The power requirement encompasses the cumulative power consumption of all electrical equipment intended to be powered by the inverter.

3.3.1 Load Analysis

The electrical load of a typical 3 bed room residential apartment.

S/N	APPLIANCES	NO	UNIT POWER (W)	TOTAL POWER (W)
1	Electric Fan	5	70	350
2	Laptop & Phone	8	60	160
3	LED light	12	5	60
4	Television	2	200	400
5	Home Theater	1	300	300
7	Air Conditioner	1	750	750
8	Refrigerator	1	750	750
9	Pressing Iron	1	800	800
	TOTAL			**3570**

3.1: Analysis of loads used during the test

The total power requirement is **3,570 watts**

3.3.2 Calculating the Volt-Ampere Rating of the Inverter Required

The Volt-ampere (VA) rating represents the voltage and current delivered by the inverter to the load. In ideal conditions, where the inverter operates with 100% efficiency, the power requirement of the electrical items matches the power supplied by the inverter. However, achieving such ideal efficiency is rare in real-world scenarios. Most inverters typically have efficiencies ranging from 70% to 90%. This efficiency, also known as the power factor of an inverter, is simply the ratio of the power required by the appliances to the power supplied by the inverter. The power factor of most inverters falls within the range of 0.7 to 0.9. Therefore, the power supplied (or VA rating of an inverter) is determined by the equation:

$$VAinv = \frac{Total\ wattage\ of\ the\ system}{power\ factor} \qquad (3.1)$$

Where VA represents the power requirement (power consumed by equipment in watts), and η is the efficiency or power factor of the inverter. An average value of the power factor or efficiency is considered, typically around 0.8.

From equation (3.1), the required VA rating of the power inverter is

$$VA_{inv} = \frac{3570}{0.8} = 4{,}462.5\text{VA}$$

$$VA_{inv} = 5000\text{VA} \qquad (3.2)$$

Based on market availability the 5000 VA (5kVA) inverters was selected.

3.4 Determination of Required Capacity of Battery Bank

The battery serves as the core or reservoir of energy for an inverter system. The efficacy and longevity of an inverter are significantly influenced by the quality of its battery. The crucial question that follows is, "How long can the inverter sustain power?" In other words, how many hours of continuous power can the inverter system supply to connected devices or equipment in the event of a grid (utility) power outage? This metric is commonly referred to as battery capacity, measured in Ah (Ampere hours). Various battery capacities, such as 100Ah, 150Ah, 180Ah, are readily available in the market.

Determining the appropriate Ah (capacity) of the battery involves a reverse calculation. It's important to note that in this study, a three-hour autonomy (battery backup) is considered due to budget constraints. The calculation of the battery bank's capacity is as follows:

$$Ah_{bat} = \frac{Preq * hbu}{Vbat} \tag{3.3}$$

In the equation, Ahbat represents the battery capacity (Ah), Preq denotes the power requirement (W), hbu signifies the backup time (h), and Vbat stands for the battery voltage (V). Upon substitution, equation (3.3) can be expressed as:

$$Ah_{bat} = \frac{3570 * 3}{48} = 223.125 \tag{3.4}$$

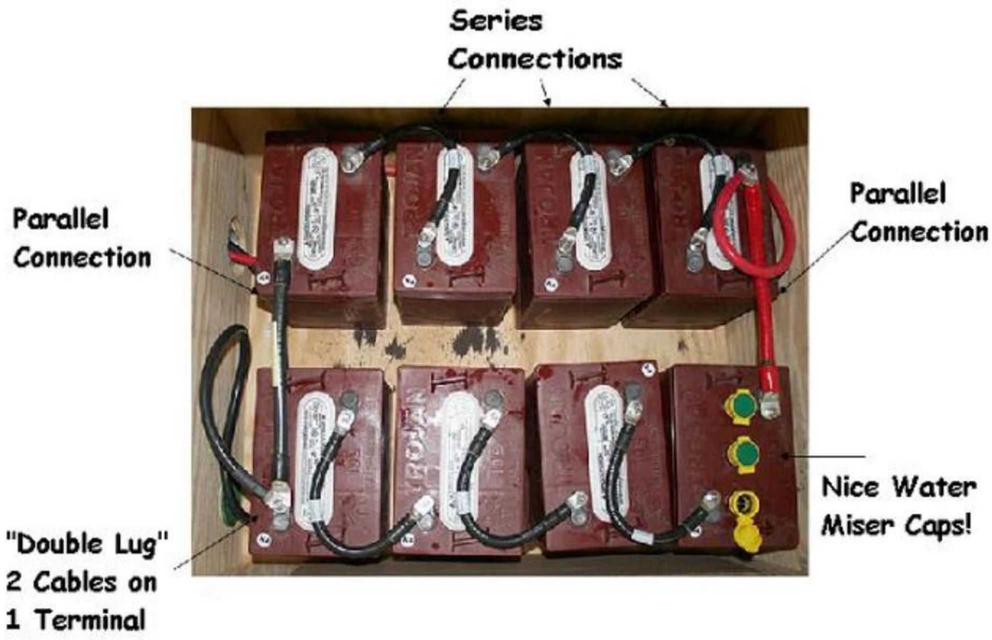
Hence, the necessary battery capacity amounts to 237Ah; however, given the unavailability of this precise value in the market and cost considerations, a 200 Ah battery was chosen. Moreover, it is highly probable that less than 100% of the power consumer load will operate simultaneously.

3.5 Experimental Procedures

3.5.1 Batteries Arrangement and Connection

The batteries were strategically positioned within the rack to enable smooth interconnection. To achieve the desired DC voltage of 48V with a combined capacity of 200Ah, a series connection was established. Four 12V batteries, each boasting a capacity of 200Ah, were aligned in series.

This arrangement in series yielded the requisite total voltage of 48V, adhering to the specifications. The interconnected battery bank, configured in this manner, supplied power to the inverter. During the connection process, careful attention was paid to the polarity of the batteries to ensure proper alignment.



3.2: Battery Arrangement and connection (altE)

The battery terminals were directly connected to the positive and negative battery input terminals of the inverter. Before this connection, the circuit breakers for the inverter's batteries were switched to the "off" position. This precautionary measure was implemented to prevent any potential spikes or damage to the inverter system.

After the battery connection, the main and output circuit breakers were positioned near the inverter. This strategic arrangement aimed to minimize the risk of excessive voltage from the mains affecting the system. The coordination of circuit breakers ensures that the inverter receives power in a controlled and safe manner, safeguarding against voltage fluctuations and potential damage during the activation process.

3.5.2 Load Connection

Load selection is crucial to effectively power the necessary appliances in the designated apartment and prevent system overload.

The following steps were undertaken:

i. The distribution box (DB) power switch was turned off to assess whether any load was bypassed or not managed by the DB.
ii. All loads in the designated apartment or office were verified to be turned off before turning on the database.
iii. Subsequently, if the total load of the apartment or workplace exceeded the design capacity, the required load to be powered by the inverter was connected via the breaker on the DB.
iv. To identify which breaker controlled each load, each load breaker was disconnected from the DB. Since the inverter is a single-phase power source, all cables on the RED

phase of the DB were removed and utilized for the inverter load. Loads to be isolated from the inverter were allocated to the yellow and blue phases.

v. Once the load was determined, the inverter's output was connected to the distribution board (DB), with the connection established to the RED-phase and the neutral terminal positioned at the neutral point within the DB. Subsequently, the input mains were connected directly from the switchgear. This facilitated the battery swap process and provided electricity to the inverter's load while the battery was being drained.

vi. As a preventive measure, the switchgear was turned off to minimize the risk of short circuits or electrocution during the battery replacement and power supply processes.

vii. Following installation, all terminals were thoroughly inspected to ensure no broken wires or open circuits were present.

3.5.5 Meter Reading and Powering of the Inverter

Before connecting the batteries in series, a digital meter was used to measure the battery DC voltage, and all required connections were made. The terminal readings of the batteries were then taken to determine the total DC voltage with no load. Following the completion of readings and connections, all wire terminals were tested for proper connectivity. Initially, the battery circuit breaker located at the back of the inverter was switched on, allowing the inverter to self-test for a few minutes before activation. The initial readings of the output terminal from the inverter were recorded to establish the output reading without any load. Subsequently, all breakers and switches on the gear were turned on, and the output voltage was recorded to determine the voltage drop on the inverter

.3.5.6 Inverter Load Test

The load test was conducted utilizing a 5kVA/48V inverter, and the test results were documented accordingly. Various types of loads were employed for the testing process.

Composite Loads: During the test, the inverter was subjected to a combination of resistive, capacitive, and inductive loads, totaling up to 4200W. The loads used in the experimental setup included electric fans, air conditioners, refrigerators, televisions, light bulbs, laptops, phones, and pressing irons. Connections were made in parallel to measure the voltage drop across the loads, with a frequency meter and voltmeter employed for accurate readings. Additionally, a clamp meter was utilized to measure the current drawn. The appliances typically found in an apartment were tested with the 5kVA inverter and solar cell system. The AC output voltage from the inverter was maintained at 220V with a sine wave, while the frequency remained at 50Hz. approximately 7.8% of the total output power was lost during testing and measurements due to various components used.

While conducting the tests, precautions were taken to avoid overloading the inverter beyond its maximum power rating of 5kVA, as this could result in damage to the equipment. It was noted that the inverter demonstrated a relatively low output resistance and consumed minimal power for its circuitries, while still delivering optimal output power according to the requirements of the load.

CHAPTER FOUR

RESULT AND DISCUSSION

The load test was conducted utilizing the 5kVA/48V inverter, and the resulting data was recorded systematically. Through the utilization of composite loads, the following outcomes were obtained:

4.1 Composite Loads

The experimental setup involved loads comprising a mixture of resistive, inductive, and capacitive elements, totaling up to 4200W of power. The composite loads utilized in the experiment included electric fans, air conditioners, refrigerators, televisions, light bulbs, laptops, phones, and pressing irons.

4.1.1 Measurement of operational time of the inverter with different Load and result gotten.

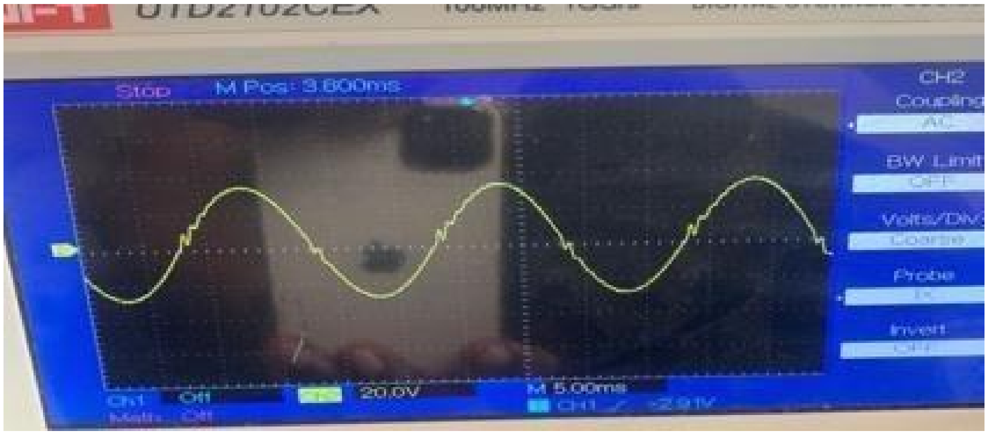
S/N	APPLIANCES	NO	APPLIANCES TOTAL WATTAGE	RUNTIME
1	Electric Fan	3	2905W	8hrs 30 mins
2	Laptop & Phone	8	1600W	10hrs
3	LED light	12	600W	10hrs
4	Television	2	2600W	6hrs 5 mins
7	Air Conditioner	1	2625W	3hrs 5 mins
8	Refrigerator	1	2250W	3hr
9	Pressing Iron	1	800W	1hr

4.1 Analysis of loads after test was performed.

Load **(W)**	**Output Voltage** **(V)**	**Output Current** **(A)**	**Frequency** **(Hz)**
2500	219.91	11.10	49.81
3500	219.50	15..87	49.80

4.2: Inverter composite load test results

Table 4.2 presents the experimental findings under various resistive, inductive, and capacitive loads. As the load escalates from 2500W to 3500W, there's a reduction in the inverter's output voltage and frequency, coupled with an increase in output current. However, these fluctuations in output voltage and frequency remain within the acceptable tolerance range of ±5%. The waveform of the inverter's output under composite load is illustrated in Figure.



4.1: Output wave form of the inverter on no-load

The test results revealed the following:

1. The AC output voltage from the inverter registered at 220V, exhibiting a sine wave output with a frequency of 50Hz.
2. A loss of 7.8% in the total output power was noted during testing and measurements, attributed to the components utilized in the system.
3. The inverter adeptly managed the varied power demands of diverse appliances, operating within its maximum 5kVA rating without overload. This underscored the inverter's capability to deliver optimal output power as per the load requirements.
4. The inverter demonstrated a relatively small output resistance and low power consumption in its circuitry, all while furnishing the requisite output power..

4.1.3 Output Voltage and Frequency

The inverter effectively transformed the direct current (DC) input sourced from the solar panels and batteries into a reliable 220V alternating current (AC) output, maintaining a consistent frequency of 50Hz. The produced AC waveform exhibited a genuine sine wave pattern, guaranteeing seamless compatibility and correct functionality of the diverse household and office devices linked to the setup.

4.1.4 Power Conversion Efficiency

Tests indicated that the inverter operated with an efficiency of 92.2%, signifying that 7.8% of the overall input power was dissipated during the conversion. This inefficiency can be ascribed to factors like switching losses within the inverter circuitry, suboptimal transformer performance, and other component inefficiencies. The modest power loss during conversion suggests that the inverter design is highly refined and well-optimized.

4.1.5 Load Handling Capability

The inverter was extensively tested with a mix of composite loads, including resistive, inductive, and capacitive elements. It managed to supply various loads up to 4.2kW without any complications, remaining well within its 5kVA rated capacity. This highlights the inverter's resilience and flexibility in meeting the diverse power demands typically found in household or small office setups.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In this research, composite loads were employed to examine and evaluate power quality by observing inverter output signals and monitoring how the output voltage decreases with increasing load. The 5kVA solar inverter system underwent thorough testing and demonstrated exceptional performance. It efficiently converted DC power from solar panels into stable 220V AC electricity at 50Hz, achieving a high power conversion efficiency of 92.2%. This translates to only a minor 7.8% loss of input power during the conversion process.

The inverter effectively managed a broad spectrum of household and office appliances, powering composite loads of up to 4.2kW without encountering any issues. Runtime assessments revealed its capability to sustain various loads ranging from 600W to 2.9kW for extended durations, lasting from 1 hour to 10 hours on a single battery charge.

Safety features were robust, incorporating circuit breakers and meticulous integration to safeguard against voltage fluctuations and other electrical hazards. Overall, the comprehensive testing validated the 5kVA solar inverter's outstanding performance, efficiency, load-handling capacity, and reliability, making it highly suitable for residential and small commercial solar power applications.

The examination of the power inverter as a case study indicated minimal output voltage drop and discharge current. Furthermore, it operated quietly with negligible hum sounds. The voltage against load curve demonstrated a gradual decrease in voltage as the load increased. Testing revealed significant voltage transients and high start-up current for inductive loads. Inductive loads exhibited a higher voltage drop compared to resistive or composite loads. The study noted that pure resistance loads showed minimal overall harmonic distortion in both current and voltage, with signal distortion remaining below 5% for composite loads.

5.2 Recommendations

Based on the experiments and tests conducted during this project, the following recommendations are proposed:

i. To prolong the lifespan of the inverter, it is advisable to ensure that the load does not exceed 70% of the inverter's power rating.

ii. When purchasing an inverter, it is recommended to procure directly from registered dealers or reputable companies to avoid acquiring rebranded or substandard inverters.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Drowsiness (also referred to as sleepiness) can be defined as “the need to fall asleep”. This process is as a result of normal human biological rhythm and its sleep-wake cycles. The longer the period of wakefulness, the more pressure builds for sleep and the more difficult it is to resist it. Vehicle driver who feel drowsy while driving do not really know the exact level of drowsiness he or she is in, and as a result serious accident occurs. The number of vehicle accident due to driver drowsiness can be prevented if a system can be developed for warning the driver prior to any accident occurrence. The global accident report of road safety 2013 has been evaluated for 182 countries with 99% population of world population showed a statistics of road accident. According to this report (global accident report of road safety 2013) the total numbers of road traffic deaths remain undesirably high at 1.24 million per year and 10 millions of people are disabled every year. Eye blinking, head movement and facial expression are used to determine driver’s distraction. The development of technologies for detecting or preventing drowsiness at the wheel is a major challenge in the field of accident avoidance systems. Because of the hazard that drowsiness presents on the road, methods need to be developed for counteracting its effect. Drowsiness detection is one of those common problem needed to be solved to prevent road accidents.

Real time driver drowsiness detection is one of the best technologies that can be implemented to assist drivers to make them aware of their drowsy state when driving. Driver behavioral state such as opening and closing of eyes, yawning, head nod, and head turning can help in catching the driver drowsy conditions early and can possibly avoid mishaps. With this paper, we are presenting technique to detect driver drowsiness with the using of Open CV (computer vision) library, android device camera and image processing. Several studies have shown various possible techniques that can detect the driver drowsiness. Driver Drowsiness System using Image Processing, capturing drivers eye state using computer vision based drowsiness detection systems have been done by analyzing the interval of eye closure and developing an algorithm to detect the driver's drowsiness in advance and to warn the driver by an in-vehicle alarm.

1.2 Statement of the problem

The tremendous number of fatality, casualties, injuries and property damages caused by drowsiness call for a notable initiative in developing an effective system that can detect drowsiness and take proper measures before accidents could occur. Though recently some limited model of cars have added features for detecting drowsiness using physiological variations brain waves, heart rate, pulse rate measurements to determine or detect the level of drowsiness of driver. However this requires some sort of physical connection with the driver such as connecting electrode to the driver body while driving. This can be very uncomfortable, and not flexible, as it will restrict the driver to a particular spot while driving. Also these cars that have these features are usually very expensive and limited to the rich, hence it's unaffordable. These limitations however formed the problem statement of this project.

1.3 Aim and objectives of the study

The aim of this project is to design and implement a drowsiness detection system for drivers using android smart phone. The objectives include:

1) Implementing a system that can process images using computer vision and Open CV library to detect driver drowsy state.
2) Use android device camera to capture image of drivers, while checking for behavioral changes at real time and Integrate a system that alerts drivers when drowsiness have been detected.

1.4 Significance of the study

The need to reduce the number of road crashes recorded on a yearly basis, have led to a number of researches. Though a number of factors are responsible for accidents, recent model of cars produced have been able to address some of these problems. One of the persisting causes of accident is driver drowsiness, and has resulted in a number of fatalities. Therefore developing this model for detecting driver drowsiness will go a long way in reducing the accident on our highway. This project also provides a less expensive and convenient method for detecting driver drowsiness as it requires little or no added amount in purchasing it except an android device, and does not restrict the driver to a particular spot. This project will be of great benefit to vehicle owners and car manufacturers, as it provides a less expensive approach to detecting drowsiness. This project is also of great importance to researchers in the area of computer vision and image processing as it will provide necessary materials for future researches.

1.5 Scope of the study

This study is limited to developing a driver drowsiness detecting system using android device. Images captured by the device camera are checked for behavioral changes which include repeated yawning, head nod, head turning, eye opening and closing.

1.6 Limitation of study

Due to the high cost of buying a webcam or a vehicle dashboard cam, this project was limited to the use of the camera of an android device to capture images of driver. Also due to the limited time allotted for the completion of the project not much work can be done hence the driver behavioral pattern measured was only limited to 4 which includes head nod, head turning, blinking and yawning.

1.7 Definition of technical terms

i. **Drowsiness Detection:** It is a car safety technology which helps prevent accidents caused by the driver getting drowsy

ii. **Eyes Tracking:** Refers to the process of measuring where we look, also known as our point of gaze

iii. **Face Detection:** Also referred to as facial detection is an artificial intelligence (AI) based computer technology used to find and identify human faces in digital images

iv. **Drowsiness index:** Defines as the difference between the muscle power generated during peak exertion and the power that can be generated after repeated loading and unloading of the muscle

v. **Physiological variation:** Physiological variation is useful in describing inter-specific relations, intra-specific variation and the limits of ecological range

vi. **Behavioral Pattern:** Behavior patterns are also referred to as chains of behavior, highlighting their nature as a complex linking of simpler segments of behavior.

vii. **Feature Extraction:** Refers to the extraction of facial components like eyes, nose, mouth, iris, skin from an input human image is called feature extraction. Feature extraction is the prior step for face tracking, facial expression recognition or face recognition.

viii. **Open CV**: (Open Source Computer Vision Library) is a cross-platform library of programming functions mainly aimed at real-time computer vision applications.

1.7.1 List of abbreviations

i. CNN - Convolution Neural Network
ii. RNN - Recurrent Neural Networks
iii. FWT - Fast Wavelet Transform
iv. WNC - Wavelet Network Classifier
v. FPGA - field programmable gate array
vi. HMM - Hidden Markov Model
vii. SVM - support vector machine
viii. HP - Head Pose
ix. PLSR - partial least squares regression
x. LBP - Local Binary Pattern
xi. ICA - Independent Component Analysis
xii. FFT - Fast Fourier Transforms
xiii. EEG - Electroencephalogram
xiv. ECG - Electrocardiogram
xv. EMG - Electromyogram
xvi. EOG - Electrooculography
xvii. CV – Computer Vision
xviii. OS - Operating System

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept of Drowsiness

Drowsiness is a term which can be defined as a feeling of being sleepy. Due to drowsiness, a driver can fall asleep while driving. Drowsiness is a state of decreased awareness or alertness associated with a desire or tendency to fall asleep. Drowsiness is therefore the brains last step before falling asleep. Azim (2007). This could for example be the outcome of hard physical work or other activities that uses the energy supply system of the body. It is a normal and natural companion of fatigue but it does appear alone. Experts say, drowsiness during the day, even during boring activities, indicates a sleeping disorder. Eriksson and Papanikolopoulos (2007) define drowsiness detection as a system that captures, processes, recognizes and provides results to a user, wherein the user can take actions on the events. Detection of fatigue involves a sequence of images of a face, and the observation of eye movements and blink patterns. By monitoring the eyes, it is believed that the symptoms of driver fatigue can be detected early enough to avoid car accident.

2.2 Drowsiness detection techniques

2.2.1 Vehicle based measuring techniques

Real time drowsiness detection has been implemented using different detection techniques for analyzing various types of input data. In this approach, the driver’s drowsiness is measured through analyzing the different controller signals of the vehicle such as steering wheel movement, the pressure from the gas and brake pedal, speed of the vehicle, change in shift lever and the deviation from lane position Forsman *et al.* (2003). The measured data is constantly monitored and any data variation that crosses a specified threshold indicates a significantly increased probability that the driver is drowsy. The measurements of these signals are obtained from sensors attached to the vehicle. These measurements are generally taken in controlled environments with a simulated driving setup because conducting such experiments in real life scenarios is unsafe and could lead to accidents.

Among the vehicle-based metrics that have been used to determine drowsiness, steering wheel movement has been widely shown by researchers to give better detection capability Liu, Hosking, and Lenne(2009); Eskandarian, and Mortazavi (2007). The steering angle is constantly measured by a sensor and the change in angle movement is monitored if it is within or exceeds the specified threshold. In normal driving, the driver makes many small adjustments of steering wheel (between 1 – 5 degrees) to keep position within the lane and few large adjustments (between 6 – 10 degrees) during lane change or at a road curvatureLiu, Hosking, and Lenne (2009). When the driver is drowsy, on the other hand, the driver anticipates making lane adjustments by making many large steering wheel movements and less small adjustments. This leads to a significant and unpredictable variation in steering wheel movement which can be analyzed to determine the state of the driver. Steering wheel movement has been adopted by major car companies such as Nissan and Renault to detect fatigue Vural (2009). However, it works in very limited situations because it is more dependent on the geometric characteristics of the road than the kinetic characteristics of the vehicle.

Other vehicle-based measures suffer from the same constraints as steering wheel movement when it comes to correctly identifying the driver's sleepiness. Because it relies on the nature of the route, the traffic, and the vehicle, the information gathered from these measures does not adequately distinguish between normal and sleepy driving. Furthermore, sleepy driving may not be the source of the variation in normal driving assessed from vehicle-based measures. A motorist with insufficient experience or other driving obstacles unrelated to sleepiness might interpret similar results. Drowsy driving is likely to cause signal changes in vehicle-based measures that may be easily evaluated and diagnosed. Drowsy driving is likely to cause signal changes in vehicle-based measurements that may be easily analyzed and identified; however, the identification of such differences in measurements may not always be due to drowsiness. As a result, vehicle-based measures are poor predictors of drowsiness-related performance.

2.2.2 Physiological measuring techniques

The second approach makes use of the measurement of physiological activities of the human body such as brain wave (Electroencephalogram - EEG), heart rate (Electrocardiogram – ECG), electric signals from muscle cells (Electromyogram – EMG) or eye movement (Electrooculography – EOG) Khushabaet al (2011); Akin *et al* (2008). The electrodes are attached to the specific parts of the body according to the measuring technique and the electric signal is measured and analyzed to determine the drowsiness state of the driver.

Physiological signals are weak and can easily be distorted with noise. To minimize the noise, researchers have used different techniques to preprocess the raw data. Patel *et al.* (2011) used band pass filters and thres holding to remove noise from the input ECG data in the low and high frequencies. After preprocessing stage, the output data is analyzed in frequency domain by using Fast Fourier Transforms (FFT) and important features are extracted for classification. Fu-Chang et al. (2012) performed similar experiments on EEG data to determine drowsiness of a driver. They used Independent Component Analysis (ICA) to segregate and localize mixed EEG data to distinct brain activities. From the preprocessed data, features are extracted in frequency domain using FFT and classified using a Self-organizing Neural Fuzzy Inference Network. Hu and Zheng(2009) also implemented drowsiness detection system by making use of EOG data. They initially identified the eye blinks from the recorded EOG data and extracted the eye lid movement parameters as features to be classified using Support Vector Machines (SVM).

The major advantage of physiological measurement techniques is that they can detect a drop in alertness before the real sleepiness episode begins. Drowsiness does not occur naturally in humans; rather, it is the result of a progressive decline in the responsiveness or activity of numerous bodily components, which finally leads to drowsiness. In EEG analysis, for example, a shift in signal strength in the alpha region (8–12Hz) signals the onset of sleepiness. Physiological measurement methods can detect such changes early on, alerting the person or taking appropriate safety precautions before an accident occurs. The measured signals are also reliable for detecting sleepiness since their connection with the driver's alertness is fairly exact, and they are typically independent of external factors such as road conditions, vehicle type, or traffic. As a result, they can identify sleepiness more accurately than vehicle-based and behavioral measurement approaches. However, the following are the primary drawbacks of these methods:

i. They are not practical for everyday use as it would require the driver to always wear the sensing devices which causes discomfort.
ii. Physiological signals are generally very weak and can easily be contaminated by artifacts that are caused by muscle movements of different body parts.

iii. They need intricate hardware systems to sense, amplify and preprocess the signal for analysis. The hardware cost of such systems is too high to be used commercially.

2.2.3 Behavioral measuring techniques

Computer vision techniques are used in the third approach to identify changes in driver behavior such as facial expressions, head movements, eye closure or continuous blinking, and yawning. Virgil (2009). When a person is sleepy, these and other alterations in a driver's behavioral patterns become apparent. Behavioral measurement approaches gather the driver's visual input in real time, evaluate it, and assess the driver's state based on the presence of changes in the driver's behavior.

Researchers have mostly concentrated on the study of blinks and the percent of closure (PERCLOS) of the driver's eyes among computer vision-based techniques to identify the driver's sleepiness. McKinley *et al.* (2011) Bergasa *et al.* (2006); Danghui et al (2010). PERCLOS was proven to be the most trustworthy measure of sleepiness among several different testing techniques by the Federal Highway Administration, according to Dinges and Grace (2008). Initially, video sources such as a webcam, digital video camera, or infrared camera are used to collect a stream of pictures of the driver. Preprocessing the pictures to recognize the driver's face and eyes is the next stage. The output from the preprocessing stage will be used to extract certain features needed to determine the changes in behavior of the driver. Li *et al.* (2011) performed successive image filtering techniques such as image subtraction, morphologically closed operations and binarization, and finally counted the number of pixels around the eyes region to detect eye closure. Liu *et al.* (2010) extracted simple features from the temporal difference of consecutive image frames and used them to analyze the rules of eyelid movement during drowsiness. Garcia *et al*. (2012) have also presented a non-intrusive approach to drowsiness detection. They used an IR illumination system and a high resolution camera to accept a stream of images and perform face and eye detection. They applied filters on the eyes region and performed horizontal and vertical projections of the pixel values of the detected eye area. The vertical projection corresponds to the eye height which is used to evaluate the PERCLOS. Zutao and Jiashu(2010) initially performed face and eye detection and tracked the eye pupils using non-linear Kalman and mean-shift tracking. They also performed vertical and horizontal projections of the pixels around the eyes region. Since the eye ball color is much darker than the surrounding, they calculated the pixel values in the vertical projection to determine the percentage of eyelid closure. Flores *et al.* (2008) computed the binary, gradient and logarithm image of eyes region, obtained random samples around the region and used an elliptic shape to represent the eyes. They then used an SVM classifier to decide whether the eyes are closed or not.

One of the main factors affecting the performance of PERCLOS based systems is the ambient lighting condition. Using a webcam could be appropriate in day time or when there is sufficient light to clearly see the eyes of the driver but could perform poorly when there is limited lighting condition. On the other hand, a camera with infrared technology might work well during the night but perform poorly in the daylight since the retinal reflections of infra-red cannot be obtained in the presence of ambient sun light reflections Fu-Chang *et al*. (2012). Moreover, mere analysis of eye closure may not be enough to predict drowsiness as the driver may not necessarily close his eyes throughout the drowsy episodes especially during the early stages. A drowsy driver usually does not go to deep sleep immediately rather alternates between nodding off and opening his eyes. The opening of the eyes in such transitions can empirically be misinterpreted as being awake if eye closure is the only parameter being analyzed. Hence, in recent years, some researchers are considering other facial movements in addition to eye closure such as eyebrow raise, yawning and head or eye position orientation.

In developing facial expression based drowsiness detection systems, the initial and profound task is identifying and representing facial behaviors systematically. Gu and Ji were among the first to present the idea of recognizing facial behaviors, such as facial expressions, orientation and gaze in a systematic approach Haisong and Qiang (2004). These facial expressions were represented by single or a combination of individual muscle movements called action units. These action units have been carefully coded with a unified description method of expression called Facial Action Coding System (FACS) Ekman, Friesen, and Hager (2002) adopted a dynamic Bayesian Network in order to capture the spatio-temporal representation of the facial expressions and detect fatigue. Vural *et al.* (2010) employed machine learning methods to analyze facial movements during drowsy episodes. These facial motions include blinking, yawn motions, eye-gaze, eyebrow raise and other movements that are represented by action units of FACS. They trained SVM classifiers for each action units with a training dataset which is coded by certified FACS coders.

Many of the researches on behavior based drowsiness detection system used frame based classification techniques that give decision based on the spatial features extracted from one input image frame. While this is essentially sufficient for some scenarios where there is definite separation of behavioral changes during drowsy and non-drowsy episodes, it lacks efficiency in situations where there is non-uniform change in transition between drowsy and non-drowsy episodes which actually is the case in most real life scenarios. Moreover, analysis of image sequences gives more accurate description of facial expressions and frame based classification approaches do not utilize all the information available in image sequences. The dynamic Bayesian network in Gu and Ji's (2002) work consists of a first-order HMM along with the Bayesian network to capture the temporal dynamics of the facial movements during drowsiness across consequent frames in a specific period of time. Yin *et al.* (2009) have also implemented dynamic drowsiness detection system using multi-scale Gabor features from image sequences. To account for the temporal aspect of human fatigue, they applied Local Binary Pattern (LBP) operators to the multi-scale image sequences and divided them into region sequences. They computed the histogram of each LBP region sequences and concatenated them as dynamic features. By applying Ada boost weak learning algorithm, they selected the most important features and constructed a strong cascaded classifier to detect fatigue. Generally, there is still a challenge in extracting dynamic features of facial expressions for drowsiness detection and there have only been few researches done on this area thus far.

2.3 Review of related Literatures

Drowsiness of driver can be determined with different aspects using vehicle-based, psychological, and behavioral measurements implemented through different predictive algorithms. Hong Su et. al. (2008) described 'A Partial Least Squares Regression-Based Fusion Model for Predicting the Trend in Drowsiness'. They proposed a new technique of modeling driver drowsiness with multiple eyelid movement features based on an information fusion technique partial least squares regression (PLSR), with which to cope with the problem of strong collinear relations among eyelid movement features and, thus, predicting the tendency of the drowsiness. The predictive precision and robustness of the model thus established are validated, which show that it provides a novel way of fusing multi-features together for enhancing our capability of detecting and predicting the state of drowsiness.

Bin Yang *et al* (2010) described ‘Camera-based Drowsiness Reference for Driver State Classification under Real Driving Conditions’. They proposed that measures of the driver’s eyes are capable to detect drowsiness under simulator or experiment conditions. The performance of the latest eye tracking based in-vehicle fatigue prediction measures is evaluated. These measures are assessed statistically and by a classification method based on a large dataset of 90 hours of real road drives. The results show that eye-tracking drowsiness detection works well for some drivers as long as the blinks detection works properly. Even with some proposed improvements, however, there are still problems with bad light conditions and for persons wearing glasses. As a summary, the camera based sleepiness measures provide a valuable contribution for a drowsiness reference, but are not reliable enough to be the only reference.

Flores M.J. *et al.* (2011) described ‘Driver drowsiness detection system under infrared illumination for an intelligent vehicle’. They proposed that to reduce the amount of such fatalities, a module for an advanced driver assistance system, which caters for automatic driver drowsiness detection and also driver distraction, is presented. Artificial intelligence algorithms are used to process the visual information in order to locate, track and analyze both the driver’s face and eyes to compute the drowsiness and distraction indexes. This real-time system works during nocturnal conditions as a result of a near-infrared lighting system. Finally, examples of different driver images taken in a real vehicle at nighttime are shown to validate the proposed algorithms.

'Driver Drowsiness Recognition Based on Computer Vision Technology' was described by Cheng A. *et al.* (2012). They demonstrated an eye-tracking and image processing approach for nonintrusive sleepiness detection. To solve the issues caused by variations in light and driver position, a strong eye identification algorithm is implemented. With percentage of eyelid closure, maximum closure length, and blink frequency, average opening level, opening velocity, and closing velocity of the eyes, six measurements are derived. To minimize correlations and obtain an independent index, these measurements are merged using Fisher's linear discriminated functions using a stepwise approach. Results with six participants in driving simulator experiments demonstrate the feasibility of this video-based drowsiness recognition method that provided 86% accuracy.

Kong G. *et al*. (2013) described 'Visual Analysis of Eye State and Head Pose for Driver Alertness Monitoring'. They presented visual analysis of eye state and head pose (HP) for continuous monitoring of alertness of a vehicle driver. Most existing approaches to visual detection of non-alert driving patterns rely either on eye closure or head nodding angles to determine the driver drowsiness or distraction level. The proposed scheme uses visual features such as eye index (EI), pupil activity (PA), and HP to extract critical information on non-alertness of a vehicle driver. A support vector machine (SVM) classifies a sequence of video segments into alert or non-alert driving events. Experimental results show that the proposed scheme offers high classification accuracy with acceptably low errors and false alarms for people of various ethnicity and gender in real road driving conditions.

Driver Drowsiness Detection via HMM based Dynamic Modeling' was described by Eyosiyas *et al.* (2014). They presented a novel technique for detecting sleepiness by monitoring the driver's facial expression using a Hidden Markov Model (HMM) based dynamic modeling. They used a simulated driving setting to build the method. The proposed method's efficacy was confirmed by experimental findings.

García *et al.* (2014) described 'Driver Monitoring Based on Low-Cost 3-D Sensors'. They proposed a solution for driver monitoring and event detection based on 3-D information from a range camera is presented. The system combines 2-D and 3-D techniques to provide head pose estimation and regions-of-interest identification. Based on the captured cloud of 3-D points from the sensor and analyzing the 2-D projection, the points corresponding to the head are determined and extracted for further analysis. Later, head pose estimation with three degrees of freedom (Euler angles) is estimated based on the iterative closest point's algorithm. Finally, relevant regions of the face are identified and used for further analysis, e.g., event detection and behavior analysis. The resulting application is a 3-D driver monitoring system based on low-cost sensors. It represents an interesting tool for human factor research studies, allowing automatic study of specific factors and the detection of special event related to the driver, e.g., driver drowsiness, inattention, or head pose.

Jabbar *et al.* (2020) proposed Convolutional Neural Network (CNN) technique of the ML algorithm to detect micro-sleep and drowsiness. In this paper, detection of driver's facial landmarks can be achieved through a camera that is then passed to this CNN algorithm to properly identify drowsiness. Here, the experimental classification of eye detection is performed through various datasets like without glasses and with glasses in day or night vision. So, it works for effective drowsiness detection with high precision with android modules. The algorithm of Deep CNN was used to detect eye blink and its state recognition as provided by Sanyal and Chakrabarty(2019). Saleh et al. (2017) developed an algorithm of LSTM and Recurrent Neural Networks (RNN) to classify driver's behaviors through sensors.

The RNN method was used by Ed-Doughmi et al. (2020) to assess the driver's behavior. It focuses on the development of real-time tiredness detection systems to avoid roadside accidents. This method creates a variety of driver faces and uses multilayered 3D CNN models to detect sleepy drivers with 92 percent acceptance rates. Vitabile has developed a low-intrusive sleepiness detection device based on a field programmable gate array (FPGA). This technology concentrates on bright pupil eyeballs detected by an infrared sensor light source installed in a vehicle. Due to this visual effect, the retinas identified up to 90%, which helps to find drivers' eyes for analyzing drowsiness through a number of frames for avoiding serious mishaps. Navaneethan *et al.* (2019) implemented a real-time system to track human eyes using cyclone II FPGA.

Wavelet networking was used by Jemai *et al*. (2013) to develop a sleepy warning system. That network follows the movements of people's eyes using classification algorithms like Wavelet Network Classifier (WNC), which uses the Fast Wavelet Transform (FWT) to make binary decisions (conscious or not). Heart rate and ECG are two physiological characteristics that are retrieved periodically using Babaeian *et al*. wavelet's transformation with regression approach for tiredness diagnosis (2019). This concept was used to classify heart rate data using a wavelet network in order to discover an average way to detect sleepiness.

Arefnezhad *et al.* (2019ss) used a neuro-fuzzy system with support vector machine and particles warm optimization technique to present a non-interfering sleepy detection system based on vehicle steering data. Mutya *et al.* (2019) developed a method that uses a steering wheel algorithm to tackle the problem of sleepiness. The CN is based mostly on image-formed or pictorial-based steering action.

2.4 Summary of Review of Literature

From the above reviews of literature, it is crystal clear that there were some gaps in the existing systems which this research “Design and Implementation of Driver’s Drowsiness Detection System” filled. With the advancement in technology and introduction of Android based applications and certain programming languages, the proposed system have now been able to breach the gap. The proposed system is able to detect drowsiness in a friendly and easy way with the use of a phone front camera.

CHAPTER THREE

SYSTEM DESIGN AND ANALYSIS

3.1 Introduction

This chapter discusses the research methodology adopted for the development and implementation of the proposed system. It also analyzes the existing system as well as the problems associated with the system. The proposed system is implemented using android operating system (OS), to detect driver drowsy state using device camera. The advantages of the proposed system over the current method of driver drowsiness detection system architecture and method of data gathering will also be presented in this chapter.

3.2 Research Methodology

The methodology adopted for the development of this system was the Object oriented analysis and design methodology (OOADM). This methodology was chosen due to its ability to provide users with clear, easily understandable documentation consisting of various diagrammatic representations of the system.

The chosen OOADM methodology comprises of three important techniques in its analysis and system development and they includes

1. **Logical Data Modeling:** The process of identifying, modeling and documenting the data requirements of the system being designed. The data are separated into entities (things about which a business needs to record information) and relationships (the association between the entities).
2. **Data Flow Modeling:** The process of identifying, modeling and documenting how data moves around an information system. Data Flow Modeling examines processes (activities that transform data from one form to another), data stores (the holding areas for data), external entities (what sends data into a system or receives data from a system), and data flows (routes by which data can flow).
3. **Entity Behavior Modeling:** The process of identifying, modeling and documenting the events that affects each entity and the sequence in which these events occur.

3.2.1 Data gathering method

The data used in this study were sourced from both primary and secondary data source and they include published journals and relevant materials related to drowsiness detection system. The secondary sources of data used for this study included oral interview and personal observation which were equally deployed for the purpose of securing vital information for the study.

3.2.1.1 Interview

Using the interview method, the interviewees were asked questions and answers were filled in by the interviewer. The study used structured interviews because; with the structured interviews, the interviewer asked questions as written on the form and recorded answers as given. The researcher interviewed a number of drivers on the current method used in detecting drowsiness state when they are driving. Questions were asked and answer where also given by the Drivers. This was documented and used for the project development.

3.2.2.2 Observation

Observations where were made by the researcher during the number of visits and interviews with drivers for both small and big vehicle. The observation helped the researcher to gather first-hand information that greatly supplemented the interviews conducted. The researchers observed that there is no device installed in most of the cars of drivers interviewed for detecting drowsiness, and drivers are only notified by passengers if they show signs of drowsiness e.g. nodding their head continuously or yawning.

3.2.2.3 Internet and review of existing Journals

Internet was another rich source of information used in gathering data for the research work, and was a major source of data. It provided a broad coverage and helped collect all the necessary information available and which information was required for designing a new system. It also provided actual records, and lots of information that was required or would be referred to in designing the new system. This technique also provided information that would not easily be availed to the researcher using the interview and observation method.

3.3 Analysis of the present system

The present technique of sleepiness detection in most older types of automobiles available relies heavily on human efforts. By engaging the driver in conversation or monitoring his alertness, passengers or the driver's helper can keep track of or monitor the driver's physical conduct and mental condition. Another method currently used in detecting driver drowsiness and alertness is by installing sensors for measuring variations in the physiology of the driver’s body. This includes variations in the brain waves, heart rate, and pulse rate. The sensors are connected physically to the driver, touching his bare body with the use of electrode while driving. These measurements are used to determine or detect the level of drowsiness of driver. However these cars with sensors installed are only available in the newest models of cars and have limited production.

3.3.1 Weakness of the present system

The current method of driver drowsiness detection system has been found to have numerous drawbacks and they include

i. Inability to completely rely on human effort to monitor driver drowsy state, as both driver and passenger could be both drowsy and sleep off.
ii. Relying on human effort is rather very stressful and demanding as the passenger will have to consciously monitor driver and engage in conversation
iii. Models of cars with driver drowsiness detection sensors are very expensive and only affordable to the high or wealthy class.
iv. The production of the model of cars with physiological variation sensors, are very limited hence not readily available for commercial purposes.
v. Connecting the sensors to the driver’s body so as to measure physiological variations can be very uncomfortable, and not flexible, as it will restrict the driver to a particular spot while driving.

3.4 Analysis of the proposed system

The proposed system is a user friendly system that monitors driver's drowsy state, and triggers an alert or notification when drowsiness is detected. Driver's facial appearance or behavioral pattern such as continuous closing of eyes, yawning and nodding of the head is monitored using the front camera of an android device while driving. Whenever drowsiness is detected, the device vibrates continuously and sends out an alarm until the driver taps the screen to confirm he/she is conscious and not sleepy. This will prevent the driver from sleeping and engage the driver so as to make the driver more conscious.

3.4.1 Benefits of the proposed system

i. Timely notification and accurate detection of drowsiness state using driver behavioral changes.
ii. Does not need any human effort as the device can be attached to a phone holder and placed on the car dashboard.
iii. Reduced accidents due to driver sleeping on steering as the device alarm and vibration continuously rings so as to wake the driver if he/she is already nodding and sleepy.
iv. It is less expensive and very affordable as it does not require a huge amount to set up the device.
v. It is very convenient and flexible as it does not need to be attached to the driver's body, hence restricting movement.

3.5 System Design

The system design illustrates how the system fulfills the objectives or requirements identified during the analysis of the system. It also illustrates the overall architecture of the system and the setting of standards.

3.5.1 Architectural view of the proposed system

The architectural view depicts the system's organization or structure, and provides an explanation of how it behaves. A system represents the collection of components that accomplish a specific function or set of functions. The system architecture of the proposed system comprises of three (3) main layers under the server-side logic: Presentation, Business and Data Layers.

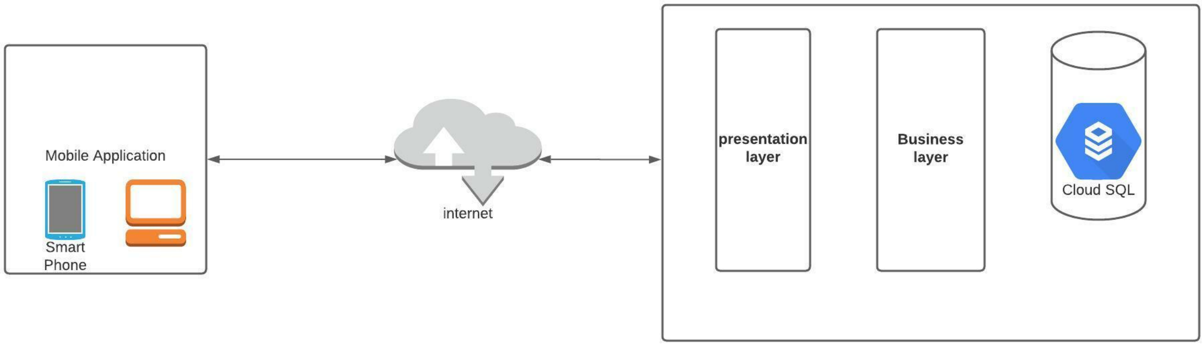


Fig 3.1 Architecture of the proposed vehicle monitoring system

Here, different components like desktop computers, smart phones, tablets and laptops will be used as a bridge into the core business logic. The Business Layer represents the core functionality of this android application working with some development tools and environments to build applications. In this Layer (business layer) languages like PHP, Java, Python, were used. JAVA programming language was also used to implement the android studio in IDE (integrated developer's environment).

The Data Layer represents access to data hosted within the boundaries of the web application using database management system (DBMS). This work will be implemented on the MySQL database.

3.6 Database Design

Android SQlite database was used for storing user data's and other system information. Android SQLite is an open source SQL database that stores data to a text file on a device. Android comes in with built in SQLite database implementation. The Database contains stored records of driver and the vehicle model and number inputted into the system. The data type of each field in the database where designed to sufficiently contain the data type of each input it was meant to hold. The database was created using Java classes and interface.

Field Name	**Data type**	**Description**
user_id	Integer	The unique identification number of the driver
full_name	character	Full Name of driver or user
email	character	Email of user
phn_nmbr	Variable character	Phone number of user
car_model	character	Car model of user
car_descr	character	Description of car of user
password	character	Unique password of user for logging into the system

Table 3.1 the database structure and its field

3.6.1 Input Design

The input design for the proposed system consists of forms links and buttons that take in data into the system for further processing. The data's includes:

i. Username
ii. password
iii. driver's personal details
iv. car model
v. Phone number.

The other input to the system is a mobile device camera for capturing live image of the driver at real time.

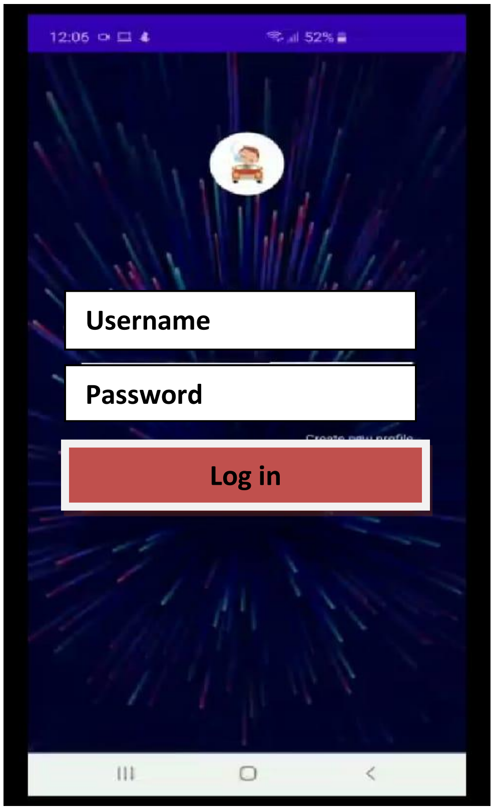


Figure 3.1 Input design of the proposed system

3.6.2 Output Design

The output design was structured based on the input format, so as to enable quick retrieval and display of information earlier inputted into the system. The outputs to the developed system are of information of drivers and their vehicle model entered into the system. Other output are models showing notification when driver drowsiness is detected or when an input fails to validate.

User_id	**Full_name**	**email**	**Phn_number**	**Car_model**	**Car_descr**	**password**
10234	John Doe	Johndoe1999@gmail.com	07034256173	Toyota		tehydi
10235	Jane Bishop	Jane245@gmail.com	08143253671	Lexus		Fghtjy4
10236	Mary Sam	Marysam65@gmail.com	09087265342	sedan		Dsgdg53
10237	Luke Mark	Lukemark45@gmail.com	07087635462	Mazda		Ernhjy45

Fig 3.2 Showing information of driver displayed in a table

3.7 UNIFIED MODELLING LANGUAGE (UML)

Use Case Diagram

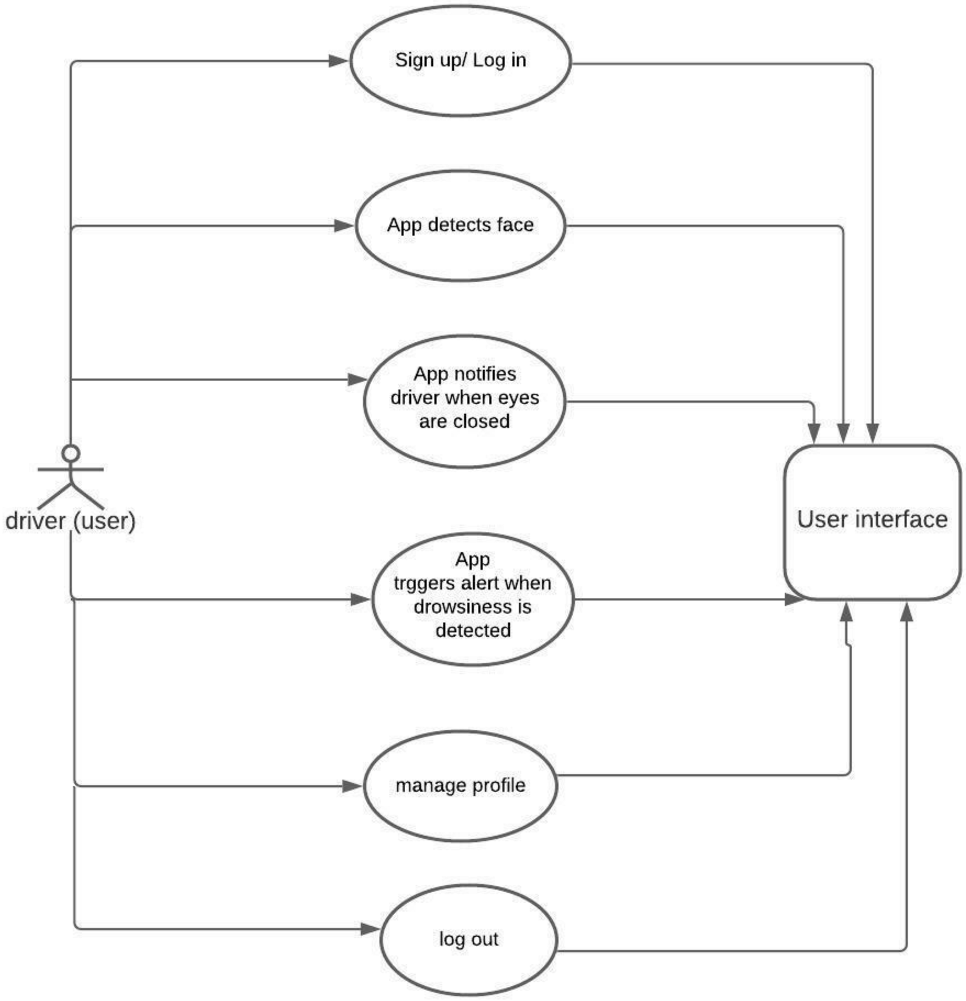


Fig 3.3: Use case diagram of the proposed system

The use case diagram above shows the interaction between the system and the various system users (drivers).

Dataflow Diagram

Data flow diagrams (DFD) were first introduced by Larry Constantine as way of representing system requirements in a graphical form; this leads to modular design. A Data Flow Diagram describes what data flow (logical) rather than how they are processed, so it does not depend on hardware, software, data structure or file organization. It is also known as ‘bubble chart’.

A Data Flow Diagram is a diagrammatic representation of the flow of data that flows through a system or a process. The DFD also gives information about the inputs and outputs of each entity and process. In a data flow diagram, there are no control flow, no rules and loops.

A Data Flow Diagram is considered to be an abstract of the logic of an information-oriented or a process-oriented system flow-chart. That is why they are referred to as logical data flow diagrams.

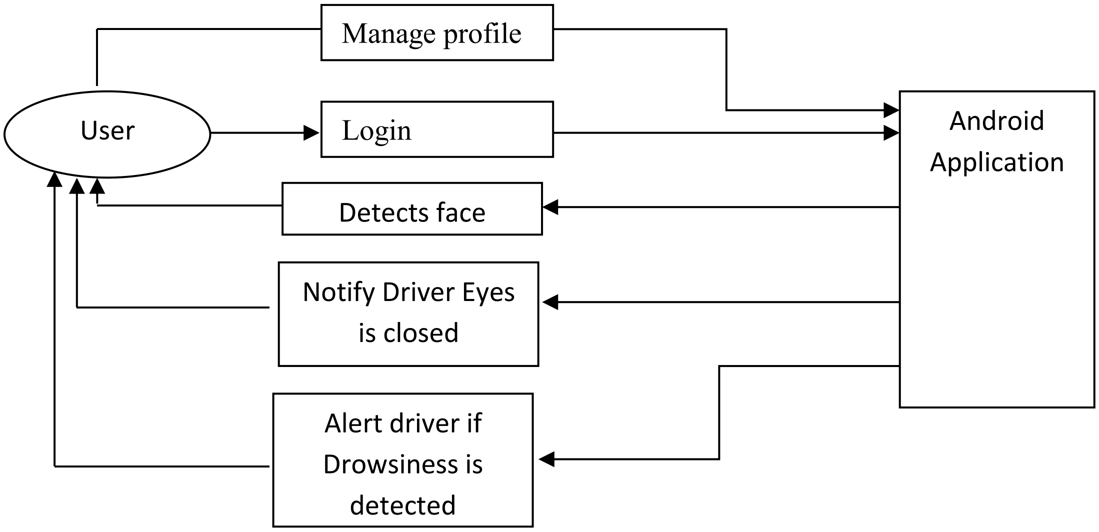


Fig 3.4: Data flow diagram of the proposed system showing information flow from user to application.

Sequence Diagram

The Android application's sequence diagram shows how the processes interact with one another and in what order. It's a message sequence chart that's been built. This graphic depicts the chain of communications sent between the objects as well as their interaction in chronological order.

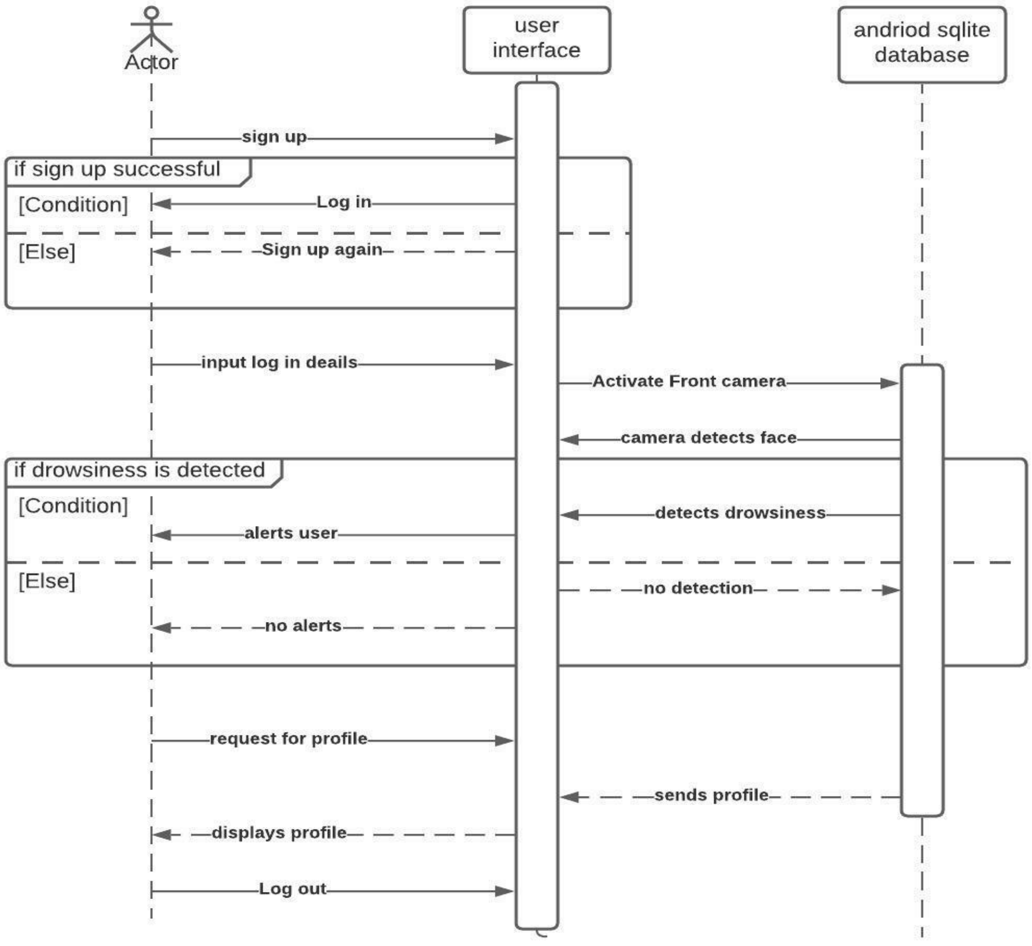


Fig 3.5: Sequence diagram of the proposed system.

Activity Diagram

The activity diagram is another important diagram in the Unified Modeling Language for expressing the system's dynamic properties. The behavior of a system is depicted in an activity diagram, which is a behavioral diagram. The control flow from a start point to a completion point is shown in an activity diagram, which shows the different decision pathways that exist while the activity is being carried out.

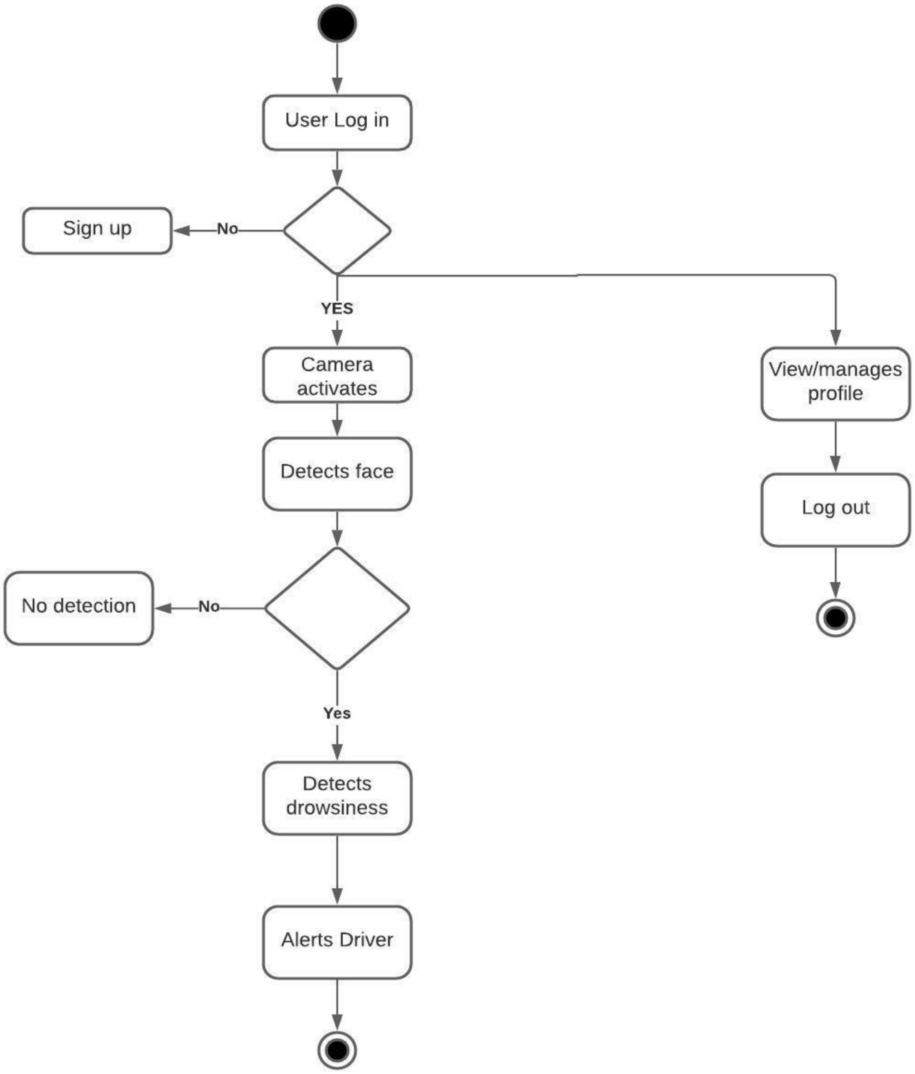


Fig 3.6 Activity diagram of the proposed system.

CHAPTER FOUR

SYSTEM IMPLEMENTATION

4.1 Introduction

This chapter presents the implementation procedure of the developed system. The series of processes in actualizing our goal comprises of the installation stage and testing stage. Other things included in this chapter are the overall implementation plan, the code used, the user guide, training plan, and the maintenance plan of the system. The deliverables or outputs included a user's manual, training plan, implementation plan, and the actual working system. At the end, systems where converted into a working and reliable system and documenting the work that has been implemented, help was provided to the current and future system users.

4.2 Implementation plan

The implementation plan describes the various activities required to install both the hardware and software of the system. However the plan is limited as the training, deployment, support and maintenance of the developed application is beyond the scope of this project, therefore it will not be included in the plan. The stages includes

1) Coding
2) Testing
3) Documentation

4) Installation plan
5) Training plan

4.2.1 Coding

This involves creating a medium for communication between humans and machines. In this activity, the physical design specifications and data's obtained in the previous chapter are converted into working computer code.

4.3 System requirements

4.3.1 Hardware requirements

The hardware requirement for the implementation of the proposed system is categorized as shown below:

Android

i. Android device
ii. Android OS version 8.1.0 and above

Website

i. Intel i5 processor is recommended. Minimum speed is 1042 MHz or Higher
ii. 1 Gigabyte (GB) or higher of RAM recommended. minimum 512 MB
iii. 60GB or higher of Hard Disk space recommended.
iv. Internet or a local host.
v. SVGA monitor
vi. Keyboard and mouse

4.3.2 Software requirements

The software requirements are as follows:

1) Apache server with configuration for web hosting.
2) MYSQL database management software
3) Microsoft internet explorer or any other web browser

4) Windows XP or higher operating system
5) PHP 5.3.8, CSS, HTML5
6) Dreamweaver CS6 or sublime text IDE
7) Android version 4.4 and above
8) Android studio 3.0

4.4 Choice of programming language

The choice of programming language was chosen based on the technology used in implementing and deploying the developed application. The following languages where used

JAVA: Java is a high-level programming language developed by Sun Microsystems. It was originally designed for developing programs for set-top boxes and handheld devices, but later became a popular choice for creating web applications. The Java syntax is similar to C++, but is strictly an object-oriented programming language.

XML: Android XML layouts are also part of a larger umbrella of Android files and components called resources. It is a markup language created as a standard way to encode data in internet-based applications. Android applications use XML to create layout files. Unlike HTML, XML is case-sensitive, requires each tag be closed, and preserves whitespace.

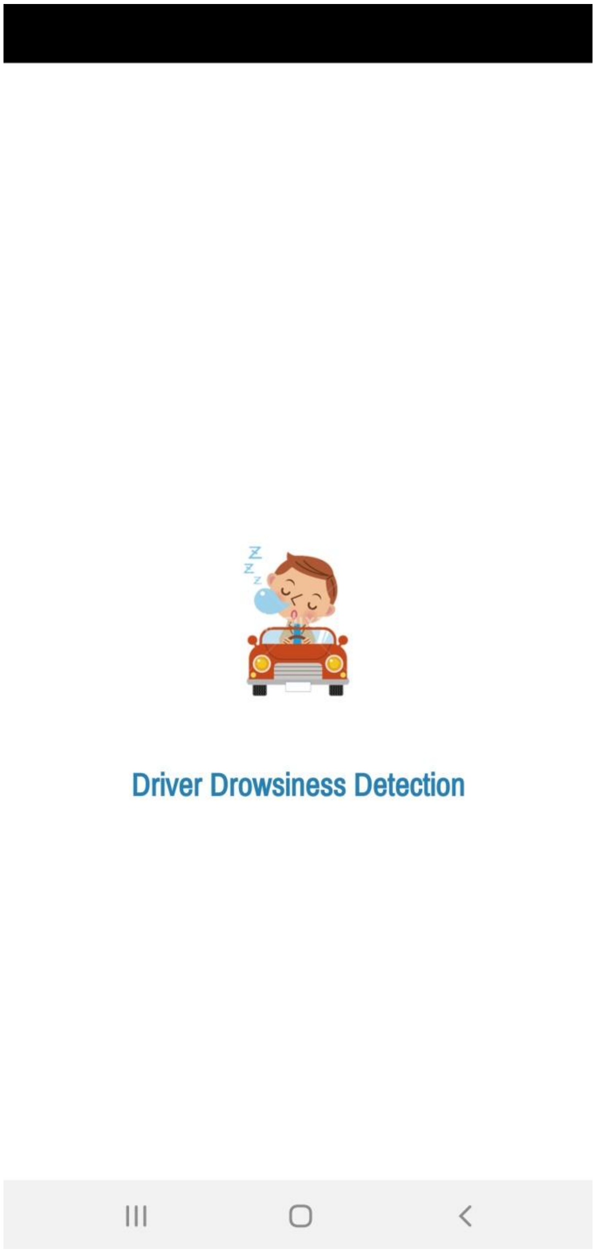
4.5 SYSTEM IMPLEMENTATION

The implementation stage is a very important stage in the Software Development Life Cycle. In this phase, the design made during the system design phase is put into codes; without this phase, there can be no system.

Successful design of the system and its implementation activities includes: testing, documentation and installation on an android device for testing and implementing the application. Other implementation activities include training and conversion. During testing, the user's experiment with the newly developed application is observed. This is to meet the new trend in the android development environment. Any error is identified and amendment is made. After thorough testing, the application can now be lunched for organization use.

4.5.1 User Interface Implementation

User interface implementation describes the layout of the user interface after successful development of the system. The interface consists of text fields, button and edit fields that navigate users from one activity to another upon click.



[redacted]

Fig 4.1 User interface showing the splash page of the application

4.5.2 Input Interface Implementation

The input interface was designed using JAVA and XML to structure the text inputs, buttons. The inputs interface allows the user to input its data into the system for processing. After developing the system, the input forms where implemented as shown in

the fig below.

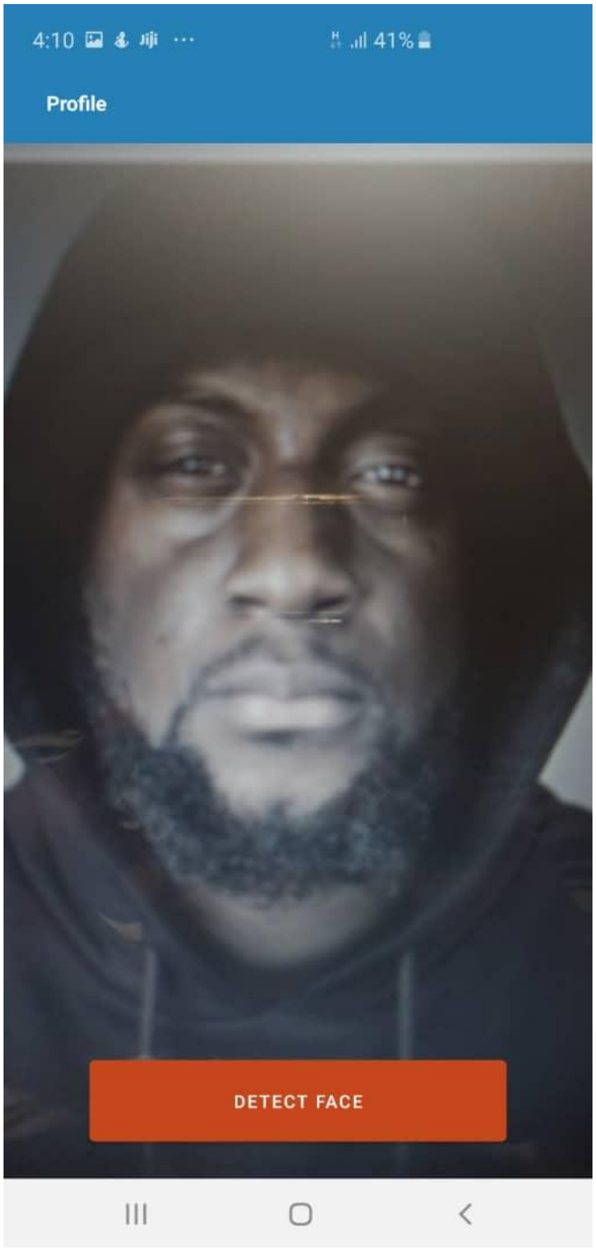
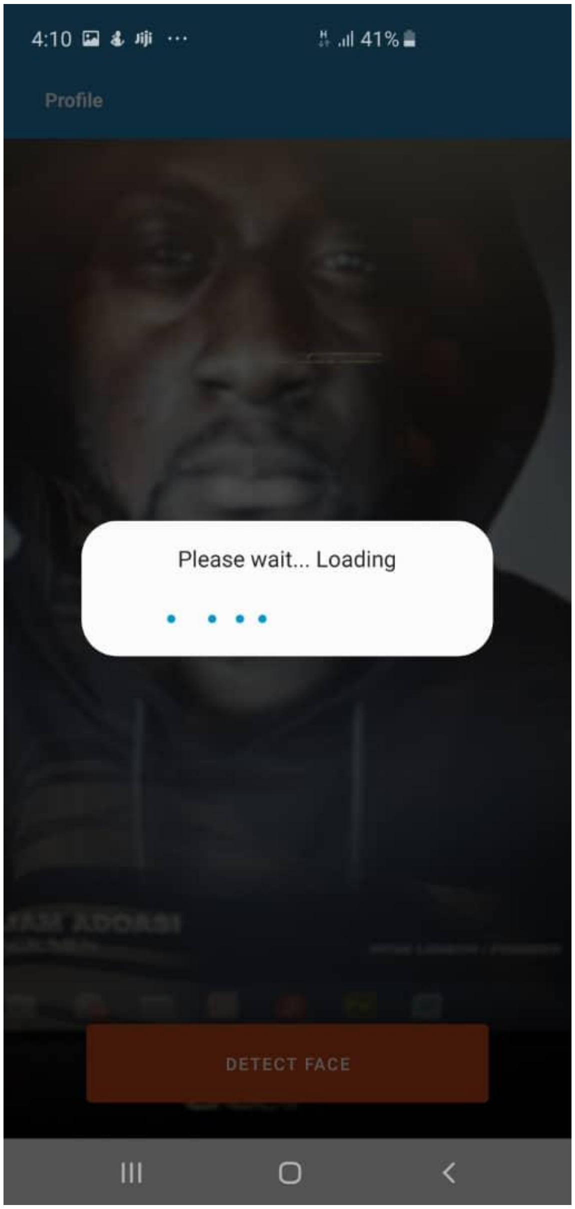


Fig 4.2: Showing camera capturing the face of a driver so as to detect drowsiness

4.5.4 Output Implementation

The system output consists of series of processed input to the system. The output might be in the form validation or notification displayed when a particular task is performed. The figure below shows the output of drowsiness detection system



Please wait... Loading

Fig 4.3 Output implementation of the developed system

4.5.5 Program Module

The program module shows the procedural chat of the step by step functionality of the developed system.

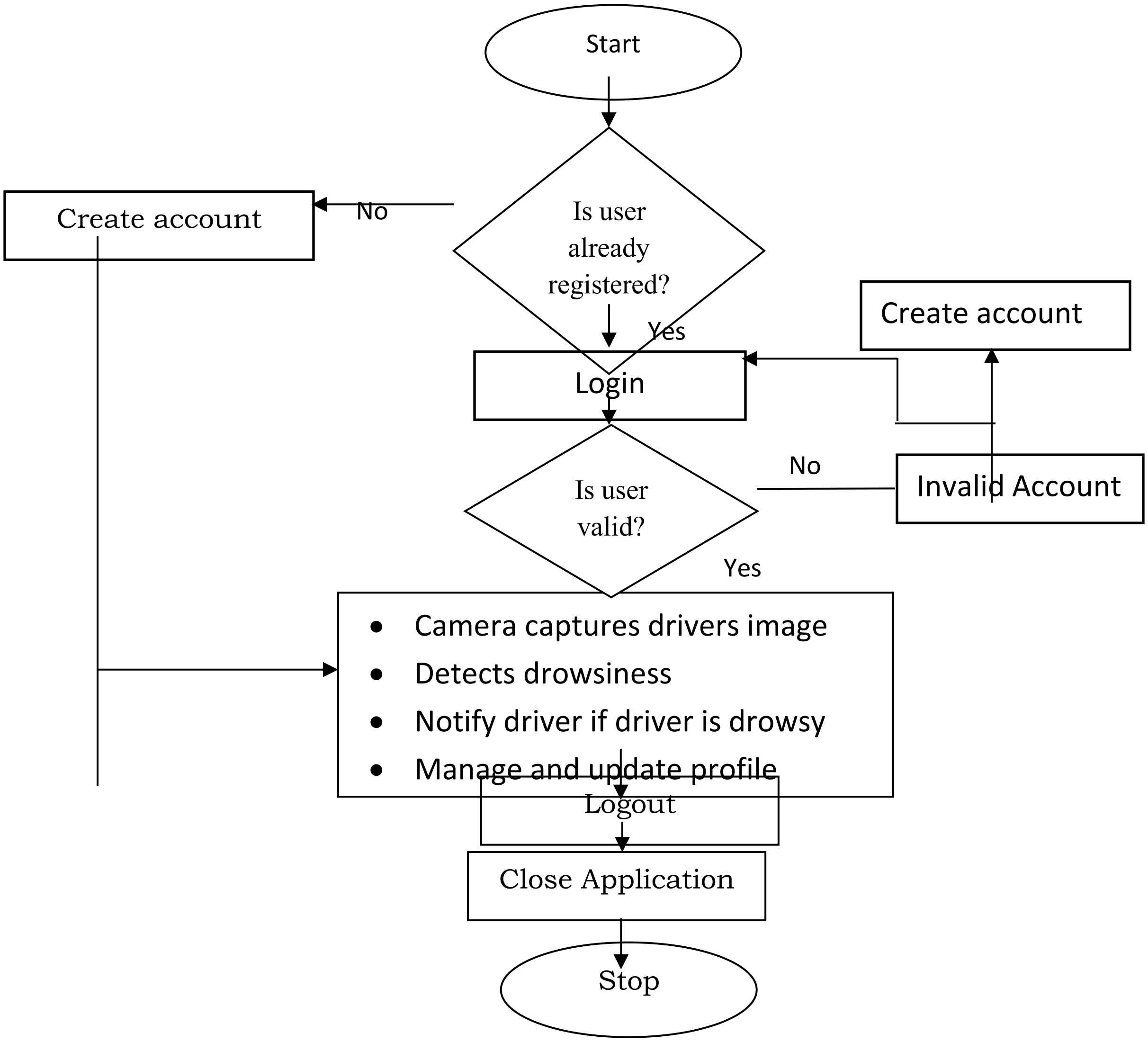


Fig 13: System program Module for the designed system

4.6 IMPLEMENTATION PROCEDURES

After acquiring the system that meets the above specified requirements, the following procedures are needed to fully implement the system.

4.6.1 Application Installation

Core to android application, the installation procedure consist of a number of steps, provided the devices meets the minimum hardware and software requirement of the application. Below is the installation procedure of the developed application

i. Enter the application installation url link into the address bar of your browser.

ii. Download the application to your device

iii. Install your application by clicking on install app

iv. Click on allow your app to access device camera and storage dialogue that appears on the screen.

4.7 SYSTEM TESTING

System testing are series of tests conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements. System testing fails within the scope of black box testing, and as such, should require no knowledge of the inner design of the inner design of the code or logic.

System testing is performed on the entire system in the context of functional requirement specifications to.

1. Meets the specific requirements that guided its design and development, and
2. Works as expected.

Software testing also identifies important defects, flaws, or errors in the application code that must be fixed. Defects are categorized by severity. During test planning we decided what an important defect is by reviewing the requirements and design documents with an eye towards finding and checkmating defect in the system. Generally speaking, an important defect is one that from the customer's perspective affects the usability or functionality of the application. Testing cannot improve quality; they can only measure it, although it can be argued that doing things like designing tests before coding begins will improve quality because the programmers can then use that information while thinking about their designs and during coding and debugging. Software testing has three main purposes: verification, validation, and defects.

4.8 Test Plan

A test plan lets you specify what you want to test and how to run these tests. A test can be applied to a specific iteration of your project. You can have just one default test suite for your test cases or you can create a test suite hierarchy.

4.9 Test Data

These are data's that are used to confirm the expected result. When the test data's are entered the expected result should come and some test data is used to verify the software behavior to invalid input data. Test data's usually are usually generated by testers or by automation tools which support testing and most of the times in regression testing the test data. Test data may be produced in a focused or systematic way (as is typically the case in domain testing), or by using other, less-focused approaches (as is typically the case in high-volume randomized automated tests). Test data may be produced by the tester, or by a program or function that aids the tester. Test data may be recorded for re-use, or used once and then forgotten. Domain testing is a family of test techniques that focus on the test data. This might include identifying common or critical inputs, representatives of a particular equivalence class model, values that might appear at the boundaries between one equivalence class and another, outrageous values that should be rejected by the program, combinations of inputs, or inputs that might drive the product towards a particular set of outputs.

Simulated data and actual data were used as test data to ensure the system is working as expected and meets required conditions.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

This project was successful in developing and implementing a new application that detects and localizes the eyes and head movements of the vehicle driver in order to monitor and identify sleepiness in real time. The software uses the Google Firebase ML system to recognize the user's face and landmarks (eyes, ears, and nose), as well as head movement. During monitoring, the suggested approach determines if the driver's eyes are open or closed, as well as whether he or she is looking forward. When the gadget detects the movement of closed eyes for an extended period of time, a warning signal in the form of a buzzer or siren will be created.

The proposed system can prevent recent cases of accidents due to the sleepiness while driving. The system works well even in case of drivers wearing spectacles and even under low light conditions if the camera delivers better output. Information about the head and eyes position is obtained through Firebase ML image processing algorithms. During the monitoring, the system is able to decide if the eyes are opened or closed. When the eyes have been closed for too long, a warning signal is issued. Processing judges the driver’s alertness level on the basis of continuous eye closures.

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5.2 Conclusion

In this paper, we have described the process of designing and implementing a driver drowsiness detection system using Google firebase ML image and vision processing algorithms. The system is adaptive and dynamic, as it can update and modify its components like current driver's eye model and skin model throughout its life cycle. These application was able to detect the drivers face, and also was able to alert the driver when the application detected the drivers continuous shutting his eyes for a period of time.

5.3 Recommendation

It is recommended for future work, that emphasis should be put in developing a hardware device installed in the vehicle that will be able to capture the drivers face and process it for drowsiness.