AKENTEN APPIAH-MENKA UNIVERSITY OF SKILL TRAINING AND ENTREPRENEURIAL DEVELOPMENT

SAFETY ASSESSMENT OF ELECTRICAL INSTALLATION FOR RESIDENTIAL AND COMMERCIAL BUILDINGS: A CASE STUDY IN SOME SELECTED BUILDINGS WITHIN SUAME ECG STRATEGIC BUSINESS UNIT.

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this dissertation is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: ………………………………………………………………………………

Signature: …………………………………….   Date: ……………………………………..

Supervisor's Declaration

I hereby declare that the preparation and presentation of this dissertation were supervised in accordance with guidelines on supervision of dissertation laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

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ABSTRACT

The research seeks to evaluate the effectiveness of electrical installation safety systems installed in residential and commercial buildings within the Suame Strategic Business Unit of the Electricity Company of Ghana. Electrical installation practices of artisans in Suame ECG Strategic Business Unit (SBU) are assessed to evaluate the adherence of electrical installation works and safety standards including the practices of artisans. A test sheet was design to identify the potential issues in electrical installations and safety precautions. SPSS was utilised to determine the common electrical installation network within the SBU while FlashWorks and ETAP were employed to model the common electrical installations to assess the short circuit currents performance. The result highlighted electrical wiring practices and installation details encompassing protective devices, conductor details, contuinity, polarity, insulation resistance test and ground protection within the Suame ECG unit. concerns such as unlicensed installers, outdated wiring structures, preferred brands of circuit breakers (MCCBs), residual circuit current breakers (RCCBs), conductors, cable termination in distribution boards, earth electrode protection, and adherence to wiring color code standards. The findings showed variations in the ability of circuit breakers to manage short-circuit occurrences, emphasizing the need to select appropriate ratings of breakers based on their short-time current and thermal energy capacities. These further revealed that most residential and commercial buildings lack basic safety standards.

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DEDICATION

I dedicate this work to the highest GOD, my parent MR & MRS MANTE and Engr. Isaac Prempeh for their immense contribution both financially and spiritually, and all friends for their kindness, guidance, and prayers, which were the source of inspiration throughout the course.

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ACRONYMS

ECG	Electricity of Ghana
ETAP	Electrical Transient Analyser Program
MCB	Miniature Circuit Breaker
RCCB	Residual Circuit Current
SBU	Strategic Business Unit
GNFS	Ghana National Fire Service
NEC	National Electrical Code
NFPA	National Fire Protection Association
LI	Legislative Instrument
GS	Ghana Standard
IEC	International Electrotechnical Commission
SPSS	Statistical Package for the Social Sciences

CHAPTER ONE

1.1Background of the study

Electricity plays an important role in keeping homes, businesses, and the economy running smoothly. Electricity is a good servant but it can equally be a bad master if not managed properly. Ghana Fire Service showed that 90% of recorded domestic fire outbreaks are from electrical origin. The reasons presented for these fire outbreaks include the unprofessional electrical installation practices in homes and shops. Safety assessment of electrical installations in residential and commercial buildings has become a crucial issue due to the increasing number of electrical accidents and fires caused by faulty electrical installations (Masterson, 2012). Electrical safety is an important aspect of building design, construction, and maintenance, and it is essential to ensure that electrical installations meet safety standards (Grondzik & Kwok, 2019).

Electrical installations in buildings are responsible for supplying power to various electrical devices and equipment used in residential and commercial buildings. These installations include wiring, switches, outlets, lighting, and other electrical equipment. However, electrical installations can pose safety risks if they are not installed or maintained correctly (Memarian et al., 2022). In recent years, there have been numerous cases of electrical accidents and fires caused by faulty electrical installations. These incidents have resulted in property damage, injuries, and even loss of life. The safety of electrical installations in buildings is a critical issue, and it has been a concern for many years. According to Ghana National Fire Service (GNFS), Ghana recorded 2,177 fire outbreaks from January to March 2023, electrical malfunctions caused 208 fires in Ghana, resulting in loss of life and properties being damaged (GNFS 2022). These figures highlight the need for continuous safety assessments of electrical installations in buildings to prevent electrical accidents and ensure the safety of occupants. Various codes and standards have been developed around the world to regulate the design, installation, and maintenance of electrical installation in buildings. The National Electrical Code (NEC), developed by the National Fire Protection Association (NFPA), International Electrotechnical Commission (IEC) develops international standards for electrical installations and Ghana Wiring Regulations, set by Ghana Energy Commission etc. are standard that outlines the minimum requirements for electrical installations in buildings to ensure safety.

As electricity has become fundamental in our everyday lives a genuine need for safety has followed suit. The utilization of electrical energy implies a risk of overload, short circuits, earth leakages, and arc faults, and their potential to damage infrastructure and indirectly (and directly) impact people's safety. Protection devices like fuses, MCBs, and RCCBs have been available for decades to improve the security of electrical installations. Fuses and MCBs protect well against overload and short-circuit thus mitigating some of the risks of damage and fire. RCCBs can detect current leaks to the ground caused by insulation weaknesses or unintentional contact with live parts thus also increasing personnel and fire protection. In most cases, these devices detect faults by comparing the load current or the difference between the currents in the phase and neutral conductors with a tripping threshold. Since February 2011 the Energy Commission of Ghana responsible for the regulation of Registered Electrical Contractors concerning safety. Only a "Qualified Certifier" is entitled to issue completion certificates and sub-system certificates for Controlled Works. According to the regulations a Qualified Certifier must have completed and pass the exams and interview on Verification and Certification of Electrical Installations. The requirements, concerning verification and testing of electrical installations, are set out in the Safety, Health, and Welfare at Work General Application), Regulations (2011) L.I. 299 part 3. Verification and Certification of Electrical Installations must be in accordance with the National Rules for Electrical Installations ET 101: 2008 – 4th Edition and any amendments to the rules. The Energy

Commission of Ghana regulate enforcement through the safety supervisory bodies to ensure safety in residential and commercial buildings.

1.2 Statement of Problem

Electrical installation safety remains a critical point for protecting the investment of buildings and property. Over the years' various standards have been adopted to improve the safety of building in the context of electrical safety. Despite the existence of regulations and standards governing electrical installations in buildings, the incidence of electrical accidents and fires in Ghana remains high. The Ghana National Fire Service reported that a significant percentage of domestic and commercial fire outbreaks are attributed to electrical issues, emphasizing the urgent need to address the root causes of these incidents. The unprofessional electrical installation practices in residential and commercial buildings, as well as the lack of adherence to safety standards, contribute to the alarming statistics. Furthermore, the potential risks associated with electrical installations, such as overload, short circuits, earth leakages, and arc faults, pose threats to both infrastructure and human safety. Although protection devices like fuses, MCBs, and RCCBs are available to mitigate these risks, their effectiveness relies on proper installation and maintenance. The need for continuous safety assessments of electrical installations is evident, considering the recent surge in fire outbreaks and accidents related to faulty electrical systems.

This situation imposed a need to study the effectiveness of the electrical installation safety issues in Ghana.

1.3 Objectives of the study

The research seeks to evaluate the effectiveness of electrical installation safety systems installed in residential and commercial buildings within the Suame Strategic Business Unit of the Electricity Company of Ghana.

The specific objectives of the study include;

1. Assess the electrical installation practices of artisans in Suame ECG Strategic Business Unit (SBU).
2. Evaluate the adherence of electrical installation works to safety standards and best practices of the artisans

1.4 Significance of the study

The study will enhance safety in buildings by identifying potential hazards associated with electrical installations and developing strategies to mitigate risks. This will help to reduce the number of accidents caused by faulty electrical systems or poor electrical wiring and protect the lives and property of building occupants, and also determine if the electrical installations in buildings comply with safety wiring regulations and guidelines. Non-compliance with these regulations can result in penalties, lawsuits, and damage to the reputation of building owners or managers. Therefore, the study will help to ensure that building owners or managers are aware of the regulations and comply with them.

This study will again contribute to standardization in the installation and maintenance of electrical systems in buildings. This will help to ensure that electrical installations meet the required safety standards and reduce the risk of accidents. Therefore, policymakers and development practitioners can use the insights from this study to highlight opportunities, risks, and trade-offs in this development agenda.

1.5 Limitations of the Study

It is important to recognize some limitations that may affect the generalizability and thoroughness of the findings, even though the survey on electrical installations in the Suame ECG Strategic Business Unit offers insightful information about the state of electrical installations in commercial and residential buildings. These limitations consist of Sampling bias: The survey's sampled population is based on individuals applying for energy meters, which may not fully represent the entire population of commercial and residential buildings in the Suame district. Due to this sampling bias, specific building or electrical installation types may be underrepresented, which could contribute to mistakes in the overall assessment.

1.6 Organization of the Study

To provide the research findings in a structured and systematic manner, this study is separated into chapters. Each chapter focuses on a different aspect of the research and contributes to a broader understanding of the subject. Chapter One introduces the research topic by discussing the background and context of the study. It defines the study's research challenge, objectives, and importance. Chapter two presents a detailed analysis of existing literature on the effectiveness of electrical installation verification and testing in residential and commercial structures. The review includes studies, theories, and best practices concerning electrical safety, certification, standard conformance, and the usage of appropriate electrical devices.

Chapter three outlines the research design, approach, and methods used in the study. It describes the study area, population, and sampling strategies used to collect data. Chapter four analyzes and interprets the findings concerning the research objectives, providing insights into the efficiency of electrical installation verification and testing in the Suame Electricity Strategic Business Unit. Chapter Five presents a complete summary of the study's findings and highlights the important insights gathered from the investigation.

CHAPTER TWO

REVIEW OF RELATED LITERATURE AND STUDIES

2.0 Introduction

In order to guarantee that the occupants of residential and commercial buildings are safe, electrical installations must undergo a safety assessment. Electrical installations that are improperly designed, installed, or maintained can seriously jeopardize the occupants' safety.

This review of related literature provides an overview of electrical wiring in Ghana, the importance of electrical safety assessments, the concept of electricians' awareness of electrical wiring installation, residential, and commercial fires due to electrical faults, the effectiveness of Ghana electrical wiring regulations in promoting electrical safety and strategies for improving electrical safety in buildings.

2.1 Electrical Wiring in Ghana

Modern life style is not complete without electrical wiring, which supplies energy for appliances, heating, and lighting. However, if installed or maintained incorrectly, electrical wiring systems can present serious safety hazards. Electrical accidents, fires, and even fatalities are frequently caused by substandard and non-compliant electrical installations in Ghana, which raises serious concerns about the country's electrical wiring.

The electrical wiring system in residential facilities was determined to be deficient and to constitute a serious risk to the residents in research done by (Vordzorgbe, 2006), the study found that there was a lack of regulatory control to assure compliance and that the wiring systems in the majority of residential buildings did not meet international safety requirements. To increase safety, the report suggested that every government should impose rules on electrical wiring in residential facilities.

Safe Work Australia (2012), assessed the safety of electrical wiring in commercial facilities. The survey discovered that most commercial buildings had substandard electrical wiring systems that constituted a major risk to the inhabitants. The report advised that the government enforce electrical wiring regulations in commercial buildings to increase safety.

Leung, (2007), numerous studies have examined the state of electrical wiring; the majority of them have concluded that there are widespread problems with substandard installations and negligent maintenance procedures. Numerous buildings have electrical wiring systems that do not adhere to national wiring regulations, putting people at risk for electrical accidents. According to Thesis & Masterson, (2012), Electrical fires are a serious issue, with defective wiring serving as their primary source of fire.

One major factor contributing to the prevalence of substandard wiring installations in Ghana is the lack of enforcement of wiring regulations. According to Thesis & Masterson (2012), there is a lack of enforcement of the electrical wiring regulations, leading to non-compliant and unsafe installations. The study found that many electricians are not adequately trained and lack the necessary skills and knowledge to install electrical wiring systems that comply with the regulations.

Along with a lack of regulation enforcement, there is also a lack of public knowledge of the dangers posed by substandard wiring installations. According to a study by Onoh (2015), many homeowners are unaware of the risks associated with electrical fires and fail to take the necessary precautions to avoid them. The study suggests launching public education programs to spread knowledge of the dangers of improper wiring installations and to promote safe electrical practices.

The high expense of supplies and equipment also contributes to the predominance of substandard wiring installations. A study by Kitcher (2015) found that one major obstacle to the adoption of safe wiring methods is the high cost of electrical wiring materials and equipment. According to the study, incentives should be offered by the government to promote the adoption of secure wire supplies and machinery.

2.1.1 Regulations and Codes

Electrical wiring installations are an essential aspect of the construction process in Ghana. A building's electrical wiring must be designed, installed, and maintained to ensure the safety of the residents and the property. To accomplish this purpose, the Ghana Standards Authority (GSA) and the Energy Commission have set regulations and codes that must be followed by all personnel participating in the electrical wiring process.

The Ghana Electrical Wiring Regulations (LI, 2008), is the primary code that outlines the minimum requirements for electrical wiring installations in Ghana. This regulation was developed by the Energy Commission in collaboration with the Ghana Standards Authority to ensure that all electrical installations in Ghana are safe, reliable, and meet internationally recognized standards.

Electrical installations must be designed and built by licensed and registered electricians, which is one of the main requirements of the Ghana Electrical Wiring Regulations (Electrical Wiring Regulations, L.I, 2008). This makes sure that those responsible for designing and installing electrical wiring systems have received the necessary training and competence (LI 2008).

Additionally, according to the Ghana Electrical Wiring Regulations, wiring supplies used in electrical installations must adhere to GSA standards. This guarantees that only premium materials are used in electrical installations, lowering the possibility of electrical failures.

In accordance with the Ghana Electrical Wiring Regulations, electrical installations must also be examined and tested by a qualified individual before being powered on. This lowers the danger of electrical mishaps by allowing any possible problems with the electrical installation to be identified before they occur. To prevent overcurrent, which might start electrical fires, circuit breakers or fuses must also be placed.

Additionally, crucial parts of electrical wiring installations are bonding and grounding (Taylor, 1940). To defend against electrical shock and fire risks, grounding and bonding are necessary, according to the Ghana Electrical Wiring Regulations. To protect against illegal entry and to ensure the safety of the residents, electrical panels and switches must also be installed in appropriate locations.

The National Electrical Code (NEC) and the International Electrotechnical Commission (IEC) standards, among others, may apply to particular types of electrical installations in addition to the Ghana Electrical Wiring Regulations. With the aid of these laws and regulations, Ghanaian electrical systems can be made to comply with international standards and to be both occupant and property safe.

2.1.2 Challenges

To provide dependable and secure power to homes, businesses, and institutions in Ghana, electrical wiring must be installed and maintained in domestic and commercial facilities. However, the industry faces several difficulties that could result in serious safety risks and reliability problems. However, the industry faces several difficulties that could result in serious safety risks and reliability problems.

Poor installation quality is a problem with electrical wiring in residential and commercial facilities (Belcher, 1961). Numerous installations are performed by unqualified, unlicensed electricians who lack the skills and knowledge needed to complete the work safely and efficiently (Mackintosh & Christian, 2020). As a result, inferior materials are frequently used to install cable, creating safety risks like electrocution, fires, and other electrical accidents.

Another major issue in Ghana is the implementation of laws governing electrical wiring. Although there are laws ensuring the secure installation and operation of electrical systems, these laws are frequently not properly enforced. This is brought on by a shortage of manpower and resources, in addition to corruption and other issues (Leung, 2007). For electrical systems to operate safely and effectively, proper maintenance is also necessary. But a lot of people neglect to maintain their electrical systems, which can result in corrosion and insulation problems in the wiring (Kitcher, 2015).

2.1.3 Safety Concerns

The use of unauthorized connections, which is a substantial source of electrical accidents and fires, is one of the safety problems related to electrical wiring (Swann, 1951). To address this issue, the Electricity Company of Ghana (ECG) has developed a variety of initiatives, including frequent inspections of electrical installations to identify and disconnect unlawful connections.

The risk of electrical shock is one of the safety concerns related to electrical wiring in buildings. Coming into contact with exposed electrical wires, damaged or malfunctioning electrical equipment, or appliances that are not properly grounded can cause electrical shock (Taylor, 1940). Electrical shock is more likely in buildings where the wiring system is old or badly maintained.

The possibility of fire is another safety hazard related to electrical wiring. Electrical fires can occur as a result of poor wiring, overloaded circuits, or the usage of incompatible electrical equipment. If the wiring system is not installed appropriately or is not maintained regularly, it can overheat and cause a fire (Mi et al., 2020).

2.2 Importance of Electrical Wiring Safety Assessments

Electrical wiring safety inspections are crucial for assuring the safety of buildings and their occupants. (Mi et al., 2020) studied the electrical safety of buildings. The investigation discovered that the majority of the buildings assessed had serious electrical safety issues. The study suggested that wiring safety inspections be performed regularly to ensure the safety of building occupants.

2.2.1 Impact of Inadequate Electrical Wiring on Safety and Health

In Ghana, inadequate electrical wiring has been related to a variety of safety and health issues. Foli et al. (2018) discovered that electrical fires were the leading cause of building fires in Ghana, with many of them being caused by poor wiring. Another study by Donkor et al. (2020), discovered that electrical shocks posed a considerable risk to Ghanaian construction workers, with 42% of workers getting at least one electrical shock while on the job. The study also discovered that the most common causes of electrical shocks were poor grounding systems and overloaded circuits.

2.2.2 Effectiveness of Safety Assessment Interventions

Several studies have been conducted to investigate the efficacy of safety assessment interventions in improving electrical safety in Ghana. For example, Kemausuor et al. (2018) investigated the influence of an electrical safety awareness campaign on the knowledge and behaviors of Ghanaian electricians. The study discovered that the program was effective in raising electricians' awareness and knowledge of electrical safety concerns and best practices. Another study, conducted by Asamoah et al. (2019), assessed the influence of a safety assessment and training program on the electrical safety of Accra buildings. The program resulted in a considerable reduction in the number of safety hazards in the buildings analyzed, suggesting the usefulness of safety assessment interventions in enhancing electrical safety, according to the study.

2.3 Concept of Artisans Awareness of Electrical Wiring Installation

Electrical wiring installation is a critical component of building and infrastructure development, and its importance cannot be overstated. Electrical wiring is responsible for the transmission and distribution of electrical energy to different areas of a building or structure. As such, the proper installation of electrical wiring is essential in ensuring that it is safe and reliable. Electricity is inherently hazardous and can result in mishaps in our homes. Electrical safety is crucial given our growing reliance on energy in many aspects of life. We use electricity for a variety of daily tasks like heating, cooling, and illuminating our homes and places of education Zohuri, and McDaniel, (2019).

Electricity is a clean, quiet, and invisible source of energy (Showers and Kate, 2018). Because it is invisible, we frequently take it for granted and its inherent hazards are sometimes difficult to see.

Numerous people are killed or gravely injured by electricity each year. The majority of these accidents happen because people don't understand the dangers of electricity. (Knight, 2002). The Utility Company is still concerned about the danger of electrocution from tampering with power lines and other electrical equipment, as well as the ignorance of older people and young adolescents regarding electrical safety. The majority of young people are unaware of the risk that their participation in these activities poses to both themselves and others. Any system installation includes a significant amount of work aimed at preventing accidents or minimizing their impact in the situation in which they do occur. (Reason, J. Ed. 2016). The use of bad or wrong tools can also be a source of hazards. The concept of electricians' awareness of electrical wiring installation is thus a crucial aspect of the electrical installation process.

2.3.1 Awareness of Electrical Wiring Installation

The idea of electrical wiring installation awareness encompasses a variety of aspects that electricians must consider during the installation process. These factors include safety, quality, and compliance with regulatory regulations. In a study conducted by Zohuri, and McDaniel, (2019), the authors studied electricians' knowledge of the installation of electrical wiring in residential buildings. According to the survey, electricians are typically aware of the importance of safety and quality in electrical wiring installation, but they are unaware of regulatory requirements.

Similarly, a study by Kahramaa, (2010) investigated the awareness of electricians regarding the installation of electrical wiring in commercial buildings. The study found that while electricians were generally aware of safety requirements, there was a lack of awareness of regulatory requirements and the importance of quality in electrical wiring installation.

2.3.2 Training and Education

Training and education are critical in ensuring that electricians understand the standards for installing electrical wiring. Eltawil et al. (2019) examined the impact of training on electricians' awareness of the installation of electrical wiring in residential buildings in their study. The study discovered that training greatly increased electricians' understanding of safety, quality, and regulatory requirements. In another study, Oti et al. (2020) in Nigeria evaluated the impact of education on electricians' awareness of the installation of electrical wiring in residential buildings. The study discovered that education considerably enhanced electricians' understanding of safety and compliance with regulations.

2.3.3 Regulatory Requirements

Regulatory requirements are critical in ensuring the safety and reliability of wiring installations. In an investigation conducted by Shadaram and Sadeghi (2020) in Iran, the authors studied the compliance of electricians with regulatory requirements for electrical wiring installation in residential buildings. According to the survey, electricians usually had a low degree of compliance with regulatory standards, and there was a lack of enforcement of regulatory requirements.

Similarly, Breen et al. (2020) evaluated the compliance of electricians with regulatory requirements for electrical wiring installation in commercial buildings in Ireland. The study discovered that, while electricians were typically aware of regulatory obligations, there was a lack of enforcement of regulatory standards.

2.4 Residential and Commercial Fires Due to Electrical Faults

Electrical faults are one of the leading causes of residential and commercial fires. In a study conducted by the National Fire Protection Association (NFPA) in 2019, electrical failures or malfunctions were the second leading cause of U.S. home fires, accounting for 13% of all reported home fires (NFPA 2021). Electrical malfunctions were also responsible for 14% of all civilian deaths and 9% of all civilian injuries from home fires (NFPA, 2021).

Similarly, commercial buildings are also at risk of electrical fires. A study by the NFPA found that electrical malfunction was the third leading cause of non-residential fires in 2018, accounting for 9% of all such fires (NFPA, 2021). Electrical failures or malfunctions were also responsible for 10% of non-residential fire deaths and 14% of non-residential fire injuries (NFPA, 2021). Several factors contribute to electrical fires in both residential and commercial buildings. These include inadequate wiring, overloaded circuits, improper use of extension cords, and malfunctioning electrical appliances and equipment (NFPA 2021). In addition, human error, such as failing to turn off appliances or equipment before leaving a room, can also lead to electrical fires (NFPA 2021). The National Fire Protection Association (NFPA) recommends many procedures for both residential and commercial buildings to prevent electrical fires. These include having a licensed electrician inspect electrical systems regularly, installing smoke detectors in every room and on every floor, using appliances and equipment according to manufacturer instructions, and ensuring that electrical systems are not overloaded (NFPA, 2021).

The National Electrical Code (NEC) provides recommendations for the safe installation and usage of electrical systems in residential and commercial buildings in terms of regulations and standards. The National Electric Code (NEC) is updated every three years and is widely used by state and municipal governments in the United States (NFPA, 2021).

The Occupational Safety and Health Administration (OSHA) also has regulations in place for workplace electrical safety, including requirements for training, the usage of electrical equipment, and safe work practices (OSHA, 2021).

2.5 Effectiveness of the Ghana electrical wiring regulations in promoting electrical safety

Ghana Electrical Wiring Regulations were passed in 2011 to promote electrical safety throughout the country. The regulations establish guidelines for the safe installation, operation, and repair of electrical wiring in Ghana.

Overall, the effectiveness of the Ghana Electrical Wiring Regulations in promoting electrical safety is determined by a variety of factors, including compliance with the regulations, enforcement of the regulations, and general public awareness of the regulations

One of the benefits of the Ghana Electrical Wiring Regulations is that they require licensed electricians to do electrical installations. This helps to ensure that only licensed professionals are in charge of electrical installations, lowering the possibility of accidents caused by defective wiring or other problems. However, the effectiveness of the legislation may be hampered by the general public lack of understanding and education concerning electrical safety Ammerman & Stewart, (2006). Many people may be unaware of the dangers of electricity or how to properly maintain their electrical equipment, which can lead to accidents and injuries.

2.5.1 Enforcement of the Electrical Wiring Regulations

Promoting compliance and ensuring electrical safety depend on the GEWR's strict application. In a study Vordzorgbe, (2006) it was discovered that the Ghana Standards Authority (GSA) has a constrained ability to enforce adherence to the rules. To properly enforce compliance with the GEWR, the authors advised that the GSA be reinforced. Furthermore, a lack of funding and weak legal frameworks hindered the Ghana Standards Authority's (GSA) efforts to execute the law. To ensure effective enforcement of the laws, the authors advised the government to enhance the legislative frameworks and provide the Ghana Standards Authority (GSA) with enough funding.

2.5.2 Public Awareness of the Electrical Wiring Regulations

Public awareness campaigns are essential in promoting compliance with Electrical Wiring Regulations and ensuring electrical safety. In a study by Leung, (2007), the authors found that public awareness of the Electrical Wiring Regulations was low among property owners and electricians. The authors recommended that the government should launch public education campaigns to increase awareness of the regulations and their importance in promoting electrical safety.

While previous studies have examined the compliance, enforcement, and public awareness of the Electrical Wiring Regulations, there is a research gap in exploring the impact of non-compliance with the regulations on electrical safety. Specifically, there is a need to perform a comparative analysis of electrical installation work and propose technical installation requirements for installation work. Understanding the impact of non-compliance on electrical safety will provide policymakers and practitioners with insights into the effectiveness of the Electrical Wiring Regulations and inform strategies to improve electrical.

2.6 Hazards and risks associated with electrical installations in Buildings

Electrical installations are an integral part of buildings and are essential to support modern lifestyles. However, electrical installations are also associated with hazards and risks that can result in injuries or even fatalities (Thesis & Masterson, 2012). Understanding these hazards and risks is crucial to ensure the safety of individuals and property in buildings. This literature provides an overview of the hazards and risks associated with electrical installations in buildings.

2.6.1 Hazards Associated with electrical installations

Hazards associated with electrical installations are a serious concern for individuals and organizations alike. The improper design, installation, or maintenance of electrical systems can lead to severe injuries, property damage, and even loss of life (Thesis & Masterson, 2012). Understanding the risks associated with electrical installations is critical to promoting safety and mitigating potential hazards.

Electric shock is the most common hazard associated with electrical installations (Reason, 2016). Contact with live electrical conductors can result in a range of injuries, from mild tingling sensations to severe burns, cardiac arrest, and death. Electrical shock can occur in a variety of settings, from domestic to industrial, and can be caused by a range of factors such as faulty wiring, damaged electrical equipment, or improper grounding (Gordon & Martinez, 2020).

Electrical installations that are not properly installed, wired, or maintained can cause electrical fires and explosions (Gordon & Martinez, 2020). Faulty wiring, overloaded circuits, and faulty electrical equipment can generate heat and ignite flammable materials, leading to catastrophic fires and explosions. Electrical fires can spread rapidly and are challenging to extinguish, putting people, property, and the environment at significant risk (Hassanain et al., 2022).

Another hazard associated with electrical installations is arc flash. An arc flash is a sudden, bright, and intense electrical discharge that can occur when an electrical fault causes an arc of electrical energy to flow through the air. Arc flashes can cause severe burns, injuries, and even death, as well as damage to equipment and facilities. Arc flash hazards can be mitigated by using appropriate protective equipment, such as arc-rated clothing, helmets, and face shields (Hassanain et al., 2022).

2.6.2 Risks Associated with Electrical Installations

The risks associated with electrical installations are related to the likelihood and severity of the hazards. The risks can vary depending on the type and quality of the installation, as well as the environment in which the installation is located. For example, installations in hazardous locations, such as those with flammable gases or liquids, may pose a higher risk of fire or explosion. Other factors that can increase the risks associated with electrical installations include poor maintenance, improper installation, and inadequate training of personnel. According to OSHA, (2015) the risks associated with electrical installations can also vary depending on the type of building. For example, residential buildings may have a lower risk of electrical hazards than commercial or industrial buildings.

2.6.3 Mitigation of Hazards and Risks

Several measures can be implemented to mitigate the hazards and risks associated with electrical installations in buildings. These measures include proper installation, regular maintenance, and inspection of electrical installations (Ammerman & Stewart, 2006). Additionally, training personnel and the use of appropriate personal protective equipment can also help to reduce risks associated with electrical installations. Electrical safety regulations and standards also play an important role in ensuring the safety of electrical installations in buildings. According to Thesis & Masterson (2012), adherence to electrical safety regulations and standards can significantly reduce the risks associated with electrical installations in buildings. Additionally, proper installation, maintenance, and inspection of electrical installations can help to identify and address potential hazards before they result in injuries or fatalities (Hassanain et al., 2022)

2.7 Strategies for improving electrical safety in Buildings

Electrical safety in buildings is a crucial concern in today's world. Accidents resulting from electrical hazards can cause significant damage to buildings and properties and, more importantly, can result in serious injuries or even death. The implementation of strategies for improving electrical safety in buildings is, therefore, essential. This review explores some of the strategies that can be adopted to improve electrical safety in buildings.

2.7.1 Risk Assessment

A thorough risk assessment is a crucial tactic for enhancing electrical safety in buildings, according to Gordon & Martinez (2018). The procedure entails locating potential dangers, analyzing the risk of an accident occurring, and determining the significance of the results. With this method, building owners and managers can determine the importance of having safety measures in place according to the risk involved.

2.7.2 Regular Maintenance

An essential part of guaranteeing the dependability and safety of electrical equipment in buildings is regular maintenance. Building electrical installations should be maintained regularly in accordance with the safety requirements established by regulatory bodies like the Institution of Electrical Engineers (IEE). Electrical installations in buildings should undergo routine inspections and testing, according to Watkins, (2009), Practice for the Maintenance of Electrical Systems in Buildings.

According to Onoh, (2015), Electrical Installation and Maintenance (EIM) involves performing practical exercises, maintaining electrical systems and circuits, installing electrical components, as well as carrying out inspections and testing procedures. The IEE Wiring Regulations recommend that electrical installations in buildings should be inspected and tested at least every five years or when there is a change of occupancy. This inspection should include a visual inspection of the installation, a test of the earthing system, and an inspection of the main switchgear. Inspection and testing of electrical installations, including visual inspections of the installation, testing of earthing systems, an inspection of main switchgear, and testing of protective devices such as circuit breakers and fuses Watkins, (2009).

2.7.3 Electrical Safety Training

Electrical installation safety training is a crucial aspect of ensuring workplace safety and compliance with regulations. In today's modern world, electrical installations are commonplace in nearly every workplace and environment, from industrial and manufacturing facilities to offices and retail spaces. With the potential for electrocution and other hazards, all employees must be properly trained to identify and mitigate risks associated with electrical installations (Thesis & Masterson, 2012).

According to Ammerman & Stewart (2006), Proper electrical installation safety training provides employees with the knowledge and skills necessary to work safely around electrical equipment, identify potential hazards, and take appropriate action to prevent accidents. The training should cover a wide range of topics, including the principles of electricity, electrical safety codes and regulations, electrical hazards and risks, and safe work practices (Ammerman & Stewart (2006). Providing electrical safety training to building occupants and staff is another critical strategy. According to Mackintosh & Christian (2020), education and training are essential for improving electrical safety in buildings. This training should cover the basics of electrical safety, including the dangers of electrical shock, fire prevention, and safe working practices. Regular training sessions should also be conducted to ensure that everyone is aware of the latest safety procedures and regulations.

2.7.4 Equipment Upgrades

Electrical installation equipment upgrades are an essential aspect of ensuring the safety and efficiency of electrical systems in buildings. Outdated or malfunctioning electrical equipment can pose a significant risk to building occupants and property, making it crucial to identify and upgrade such equipment as needed (Hassanain et al., 2022). Upgrading electrical equipment is another effective strategy for improving electrical safety in buildings. According to Safe Work Australia (2012), outdated or obsolete electrical equipment should be replaced with newer, safer models. Modern equipment is designed to be more efficient and safer to operate, reducing the risk of accidents.

2.8 Summary of the literature review

This chapter delves into the complexities of electrical wiring in Ghana, emphasizing the critical need for safety assessments. The literature review covers the prevalence of substandard installations, regulatory frameworks, challenges faced in enforcement, safety concerns such as electrical fires and shocks, and strategies for improvement. It highlights the importance of public awareness, proper training for electricians, and the effectiveness of safety assessment interventions.

Additionally, the chapter explores the hazards and risks associated with electrical installations, emphasizing mitigation measures. The review concludes by underlining the significance of strategies like risk assessment, regular maintenance, electrical safety training, and equipment upgrades in enhancing electrical safety in buildings.

CHAPTER THREE

METHODOLOGY

3.1 Overview

The study focused on assessing the electrical safety and professional skills of artisans working on residential and commercial buildings in the Suame ECG Strategic Business Unit through a comprehensive electrical installation audit survey. Modeling the common installation by the artisans using FlashWorks and ETAP software to know the short circuit current that passes through a circuit breaker in case a fault occurs along a particular circuit, and also Evaluates the adherence of electrical installation works to safety standards and best practices of the artisans' works through the simulations of the common electrical installation practices from the electrical installation audit survey.

The assessment method of research design was used in achieving the research objective for this case study. As such the study made use of a field survey using electrical installation audit instruments and documentation to collect field data for further analysis. Since the study involved the assessment of the skills of Artisans, questionnaires were also employed in the collection of field data. This research design was appropriate for this study since the study seek to investigate the safety standards of electrical installation works within the Suame Strategic Business Unit by artisans. So, the installation works which include the system components and materials, the artisan’s skill set, and the technical implication of the work done by the artisans are collected and compared against the electrical installation requirements for Ghana and international standards.

The researchers used a descriptive survey study strategy. According to Ali, (2006), a descriptive survey study design. Is methodical unbiased research that focuses on data collecting to define and understand current circumstances, common behaviors, beliefs, attitudes, and processes. Since data were gathered utilizing survey documentation, electrical installation audit instruments, and questionnaires for the artisans, the design was appropriate for this study.

3.1 Study area

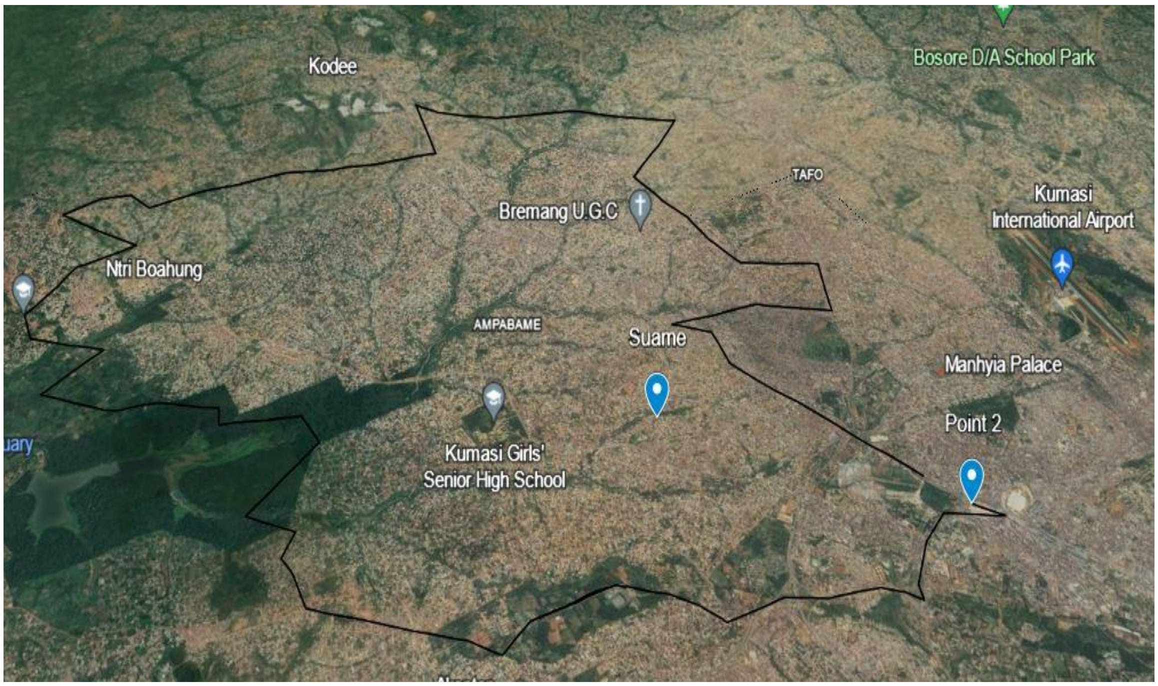

Figure 3. 1 Study Area Map

Suame Municipal, situated in Kumasi, Ghana, encompasses a population of 136,290 within an area of 12.83 square kilometers (Ghana Statistical Services, 2021). It is a thriving industrial hub with a primary focus on manufacturing and automotive services, epitomized by the bustling Suame Magazine, also known as the "Automotive Village." This industrial center significantly contributes to the local economy, shaping Kumasi's economic identity. Notably, due to the prevalence of automotive work, a significant portion of the population relies on electricity for their daily activities. Beyond economic significance, Suame Municipal is likely rich in cultural heritage, blending traditional values with modern industrial practices. Despite facing challenges, the community's skilled population and active engagement contribute to its resilience.

3.2 Research Framework

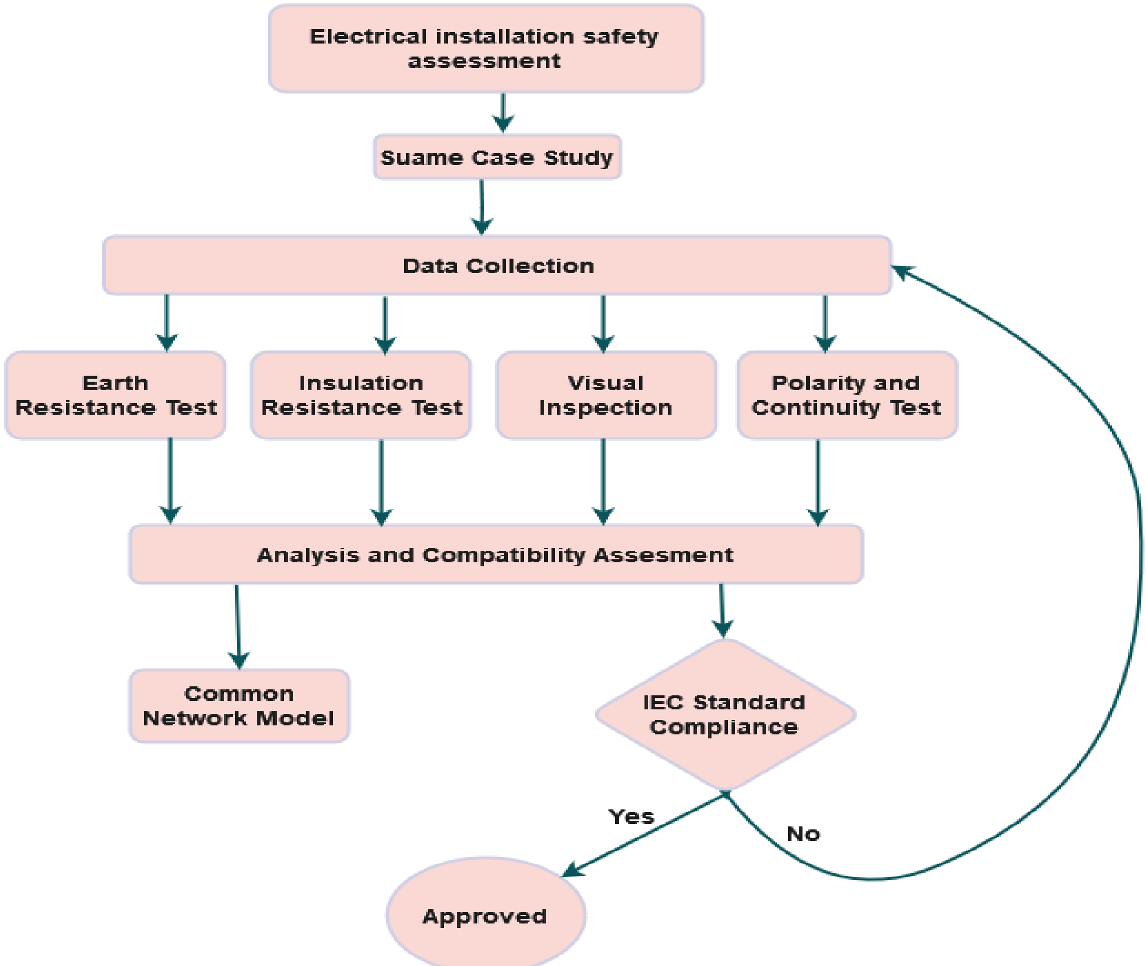

Figure 3.2 Research Framework (Author Construct, 2023)

3.3 Research Design

The research design is the overall structure that provides a comprehensive overview of the techniques adopted by the researcher. According to Rodgers & Yee, (2016), an effective research approach examines contemporary global concerns, is innovative and revolutionary, and influences our lives through ethical, sustainable, and meaningful techniques. An effective research design guarantees confidence and effectiveness while minimising research-process errors.

Access et al. (2023) highlight research designs, including experimental, quasi-experimental, survey, case study, correlational, narrative analysis, ethnography, historical research, phenomenology, convergent parallel, grounded theory, exploratory sequential, explanatory sequential, embedded, transformative, and multiphase. This research both a survey and ethnographic approach, to enhance respondents' engagement Duan & Tan, (2020).

3.4 Instrument for data collection

The instrument shown in Appendix B contained 65 items and was divided into five sections lettered 'A', 'B', 'C', 'D', and 'E'. Section 'A' was on details of the artisan. Section 'B' solicited responses from the artisans based on the stature of the wiring service, whether for commercial or domestic purposes. Section 'C' consisted of 4 items which also solicited responses from the artisans based on the consumer unit. Section 'D' consisted of 45 items which also solicited responses from the artisans based on the visual inspection and testing of the wiring system. While the responses in Section 'E' having 7 items were obtained from the artisan's base on the grounding and its protection. Some of the responses were made by tick [ ], and the scoring of the instrument was done by grouping the responses, Satisfactory and not satisfactory

3.5 Data collection procedure

To gather information from the artisans who perform the electrical wiring on a specific building within the Suame Electricity Strategic Business Unit, the researcher used both qualitative and quantitative methods with well-structured close-ended questionnaires (test sheets).

Three hundred test sheets were administered by the researcher, which helped to cut down on the usual postal wait and gave the researcher the chance to clarify any points that the electricians found unclear.

3.6 Population of the study

The research population of interest for the study was the electrical installation of commercial and residential buildings, and electrical installation work by artisans within Suame ECG Strategic Business Unit. The targeted population for this research comprises both certified and uncertified Electricians who worked on buildings (residential and commercial) in the Suame ECG SBU. The target population focused on a section of the facilities (i.e., residential and commercial buildings) within Suame ECG Strategic Business Unit whose owners specifically go through the application of the energy meter process from the ECG SBU. The total number of individuals applying for energy meters within the duration of the study was 1300. Out of these, the sample size selected was 300. This sample size was selected since it would give a validated confidence level of 95%.

3.7 Electrical installation audit survey

Electrical installation audit survey was performed on facilities to assess their compliance with the Standardized electrical wiring requirements of the energy commission's electrical wiring program, and the IET wiring regulations (18^{th} edition). As such various audit testing and inspection procedures were adopted for the study. The materials for installation work, the design of the installation work, and the competency levels of the artisan performing the wiring were assessed through the audit. The audit survey was done using specialized instruments shown in Appendix A.

The continuity and insulation resistance test were conducted with the UNIT –UT 501A instrument. The UNIT- UT 5021 instrument was used to perform an earth electrode resistance test as part of the electrical installation audit process. Table 3.1 shows a summary of the survey test and the instrument used in conducting the test. Appendix A also shows the brand and specific instruments used for the electrical installation audit.

Table 3. 1 Summary of the survey test and the instrument used in conducting the test.

Type of Test	**Instrument**	**Serial No**	**Value required**
Continuity			
Earth Electrode Resistance	UNI-T, UT 521		Below 50Ω
Insulation Resistance	UNI-T, UT 50A1		Above 2M Ω
Socket/RCCB tester	BSIDE UNI-T	AST01UK	Less than 40ms

According to IEC 60364-6, the acceptable result for the Insulation resistance test should be any value greater than 2MΩ**.** For continuity tests conducted the accepted value in this study was 0.05Ω**.** In terms of earth electrode resistance for residential and commercial facilities, the standard used in this study was valued at less than 50Ω instructed by Ghana energy commission.

For the electrical installation audit survey part of this study, the following tests were conducted by the researcher.

3.7.1 Pre-Connection of the Supply

The testing that was conducted before the supply is connected to the facility is known as the pre-connection test. These were dead tests that used the measuring instruments of auditing. Various test that was used in the survey were Continuity of protective conductors and Bonding Conductors, Resistance of the Earth Electrode, Resistance of the main protective conductor, Insulation Resistance of Cables for all circuits and Polarity Tests.

3.7.2 Post-Connection of the Supply

In some cases, during the survey, additional tests were conducted aside from the pre-connection test. These tests were live tests conducted on facilities that have electricity connections already but needed energy meters for the addition or alteration of electrical installation circuits.

Functional test for Residual Circuit Current Breakers (i.e., RCBO, and GFLD).

Ramp test for Residual Circuit Current Breakers (i.e., RCBO, and GFLD).

Functional test for switches circuit breakers and isolators.

3.1 Validation of the Research Instrument

The study adopted the empirical, comparison, and simulation validation methods. In terms of empirical validation, the adopted methodologies used in this research have been used for other studies in assessing the installation work in different countries (Akashah et al., 2017). The instrument was validated and was then deployed for data collection. The results of the primary data collected were also simulated in the ETAP software. Again, the ETAP analysis was also validated with another industry standard software (i.e., Electrical FlashWorks v1.6). The results of both simulations are detailed in Appendix C and D.

3.2 Ethical considerations

In terms of informed permission and the privacy of personal information, the ethical requirements for research involving human subjects were followed. The requirements of the Data Protection Act 1988, No. 35 of 1988, and the Freedom of Information Act 1997, No. 13 of 1997, and any amendments to these acts were complied with. The design, distribution, and analysis of the questionnaire (auditing test sheet) were conducted in such a way that anonymity was assured. To ensure anonymity some of the question is the certification ID regarded as spurious as it might be possible to trace the identity of some of the Artisans.

3.3 Software packages for analysis, modeling, and validation

To accomplish the goal of this study, the research utilized three different types of software. These software programs included FlashWorks Electrical, Electrical Transient Program (ETAP), and statistical packages for the social sciences (SPSS). The primary tool used to analyze the research data was statistical packages for the social sciences (SPSS). Frequencies and responses to percentages were also utilized to illustrate the artisans' perspectives of their jobs, the resources they used for installation work, and typical methods for installing electrical systems. Based on the data gathered, ETAP was utilized to simulate some of the common electrical installation circuits and materials. Following the modeling, a short circuit study of the circuit was run to see how it would respond under fault situations. By figuring out the model's minimal breaking capacity, the FlashWorks program was also utilized to establish the proper rating for the overcurrent protection device.

3.3.1 ETAP Analysis

ETAP was used to perform short circuit analysis on the common installation carried out within Suame ECG Strategic Business Unit. This technical analysis considered the short circuit, breaker arrangement for each circuit, and faults in the system to analyze the integrity of the materials and constructed electrical installation circuits. Figure 3.2 below shows the single-line diagram of the model from the ETAP software.

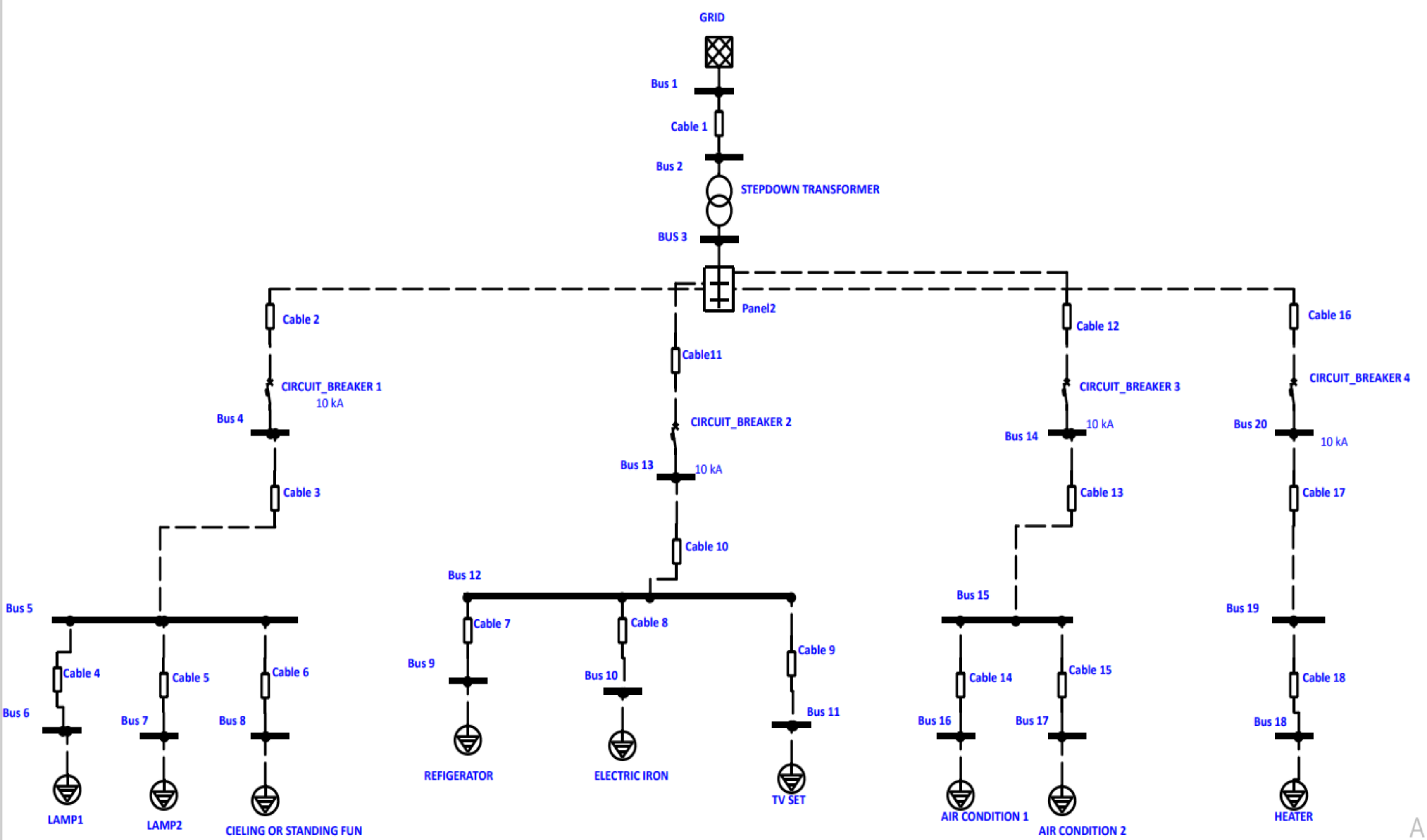

Figure 3. 3 Single line diagram of the common model

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter focuses on the survey responses and the analysis of the data received from the survey in comparison with the applicable standards in electrical installation work in Ghana and throughout the world. The purpose of these analyses is to conduct an assessment of the electrical safety systems that have been implemented by electricians in the course of installation work carried out in residential and commercial facilities within the Suame ECG SBU.

4.1 Detail of the artisans

The analysis of the questionnaire responses revealed that 91 of the 300 electrical wiring installers from various jurisdictions who worked within Suame ECG Strategic Business Unit buildings were certified Electrical Wiring installers. This represents 30.3% of the total number of installers. The other group that worked on the wiring within the Suame ECG Strategic Business Unit consisted of non-certified electricians. This group represented a larger proportion of the workforce, with a total of two hundred and nine (209) electricians accounting for 69.7% of the total workforce. Figure 4.1 illustrates the distribution of artisans who performed electrical work in the Suame SBU.

According to the results, a substantial number of the electrical wiring installers worked within the Suame Electricity Strategic Business Unit are not certified. This may have an impact on both the safety and efficacy of the electrical installations performed within the Suame Electricity Strategic Business Unit. Installers of certified electrical wiring installers are needed to possess the knowledge and abilities necessary to carry out electrical installations in a manner that is both safe and of high quality. To ensure the safety and quality of electrical installations in the area, the Ghana Energy

Commission and the Electricity Company of Ghana must ensure that all wiring installers operating in their strategic business units have been certified.

According to the Ghana Energy Commission, Regulation 7, the only individuals who are qualified to carry out electrical wiring on buildings are electricians who have received their certification. According to the regulations (L.I. 2008), the commission mandates that any work about the installation of electrical wiring must be carried out by an electrician who is certified and has undergone the necessary training to get that certification.

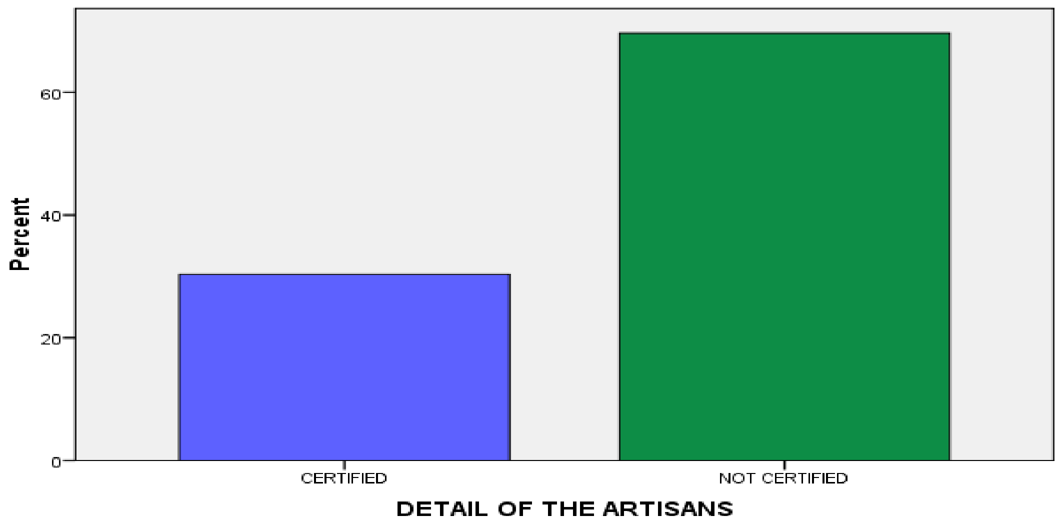

Figure 4. 1 Detail of the artisans

4.2 Normality test

According to (Bayoud, 2021; Hair et al., 2010) normality is a form of data distribution or an individual metric variable and its correspondence to the normal distribution, which is the benchmark for statistical methods. Both skewness and kurtosis are constituents of normality. The skewness represents the distribution's symmetry, whereas the kurtosis is a measure of the heaviness of the tails in a distribution when compared to the normal distribution (Chandio et al., 2013). (Collier, 2020) indicated that data that has its skew values between -2 and +2 and Kurtosis between -10 and +10 is considered normally distributed.

A summary of the dynamics of descriptive statistics and the electrical wiring practices of installation details of encompassing protective devices, conductor details, contuinity, polarity, insulation resistance test and ground protection of electrical artisans within the Suame ECG unit is presented in Table 4.1. the standard deviation (SD) and mean of each indicator is presented to provide a nuanced view of the electrical installation practices.

The results from Table 4.1 indicate a mean score ranging between 21.03 to 1.003. Whereas the standard deviation ranges between 98.35899 to 0.05793. The findings indicates that most artisans within the Suame ECG zone used materials of approved standard. In addition, the electrical installation practices regarding cable terminations, color code compliance and installation protection including both earth and insulation resistance of premises where artisans work within the zone is acceptable and conforms with the IEEE standard.

Table 4. 1 Normality test

Indicators	Mean	S D	Skewness	Kurtosis
Detail of the artisans	1.6967	0.46047	-0.860	-1.269
Description of premises	1.3233	0.46853	0.759	-1.433
Description of installation	1.5800	0.49438	-0.326	-1.907
Brand of RCD	1.5500	0.80602	2.730	12.031
RCD rating	1.1767	0.79218	4.429	18.176
RCD trip test	1.7867	0.96137	0.439	-1.781
Age of wiring	2.2333	1.04684	0.437	-0.708
Correct operation of switches and isolators	1.7633	0.97149	0.490	-1.768
Earth electrode resistance value	20.71	22.995	0.476	-1.234
Earth electrode resistance	2.1233	0.95104	-0.249	-1.856
Protection or accessibility of earth electrode	1.8533	0.39877	-1.175	1.658
Importance of retesting a residential and commercial installation	1.1000	0.35178	3.759	14.420
Termination of cables in the distribution board	1.1933	0.39557	1.561	0.439
Is the color code used comply with IEEE specification?	1.1900	0.39296	1.588	0.526
Breaker brand for lighting	3.6040	4.09371	1.693	1.712

Breaker rating for lighting	1.0369	0.18886	4.937	22.525
Conductor brand for lighting	3.9027	2.19133	1.230	2.137
Continuity for live cable for lighting	1.0034	0.05793	17.263	298.000
Continuity for neutral cable for lighting	1.0034	0.05793	17.263	298.000
Continuity for earth cable for lighting	1.9966	0.05793	-17.263	298.000
Insulation resistance test for live-earth for lighting	1.0336	0.57928	17.263	298.000
Breaker brand for socket	3.5201	3.97144	1.722	1.889
Breaker rating for socket	1.0235	0.15171	6.324	38.254
Conductor brand for socket	3.8523	2.18774	1.200	2.117
Conductor size for live cable for socket	1.0034	0.05793	17.263	298.000
Insulation resistance test for live-earth for socket	1.0034	0.05793	17.263	298.000
Breaker brand for AC	12.5000	7.01432	-0.973	-1.008
Breaker rating for ac	2.4400	0.86151	-0.982	-0.929
Conductor brand for AC	9.5267	3.99028	-1.138	-0.495
Conductor size for live cable for AC	2.4381	0.90042	-0.980	-1.047
Conductor size for neutral cable for AC	2.4400	0.89950	-0.985	-1.037
Conductor size for earth cable for AC	2.4400	0.89950	-0.985	-1.037
Continuity for live cable for AC	2.4400	0.89950	-0.985	-1.037
Continuity for neutral cable for AC	2.4400	0.89950	-0.985	-1.037
Continuity for earth cable for AC	2.4400	0.89950	-0.985	-1.037
Insulation resistance test for live-neutral for AC	2.4400	0.89950	-0.985	-1.037
Insulation resistance test for live-earth for AC	2.4467	0.89620	-1.003	-1.000
Breaker rating for heater/heavy machine	2.7828	0.61502	-2.528	4.493
Conductor brand for heater/heavy machine	10.9267	2.93883	-2.497	4.534
Conductor size for live heater/heavy machine cable	2.8000	0.58407	-2.677	5.365
Conductor size for neutral heater/heavy machine	2.8000	0.58407	-2.677	5.365
Conductor size for earth heater/heavy machine	2.8000	0.58407	-2.677	5.365
Continuity for live heater/heavy machine	2.7800	0.62683	-2.505	4.306
Continuity for neutral heater/heavy machine	2.7800	0.62683	-2.505	4.306
Continuity for earth heater/heavy machine	2.7800	0.62683	-2.505	4.306
Insulation resistance test for live-neutral for heater/heavy machine	2.7800	0.62683	-2.505	4.306
Insulation resistance test for live-earth for heater/heavy machine	2.7800	0.62683	-2.505	4.306

Note SD means Standard Deviation

4.3 FlashWorks electrical

Calculations of short circuits are very important when it comes to the design and analysis of electrical systems. This is because short circuit calculations offer information on the amount and duration of potential short circuit currents that might occur inside the system. Using the FlashWorks software, the short circuit calculation was done on a system consisting of a single-phase copper wire with a line-to-line voltage of 400 volts and a conductor length of 50 feet. This section aimed to determine the short circuit current and assess whether or not the equipment rating of the protective device was sufficient. With the assistance of the questionnaires that were gathered and analyzed with the help of SPSS.

4.3.1 FlashWorks Simulation Result

The short circuit calculation using FlashWorks software on the 1-phase copper wire system produced a simulated short circuit current of 8,644.5 amps. The protection device's equipment rating was determined to be 10,000.0 amps, which is larger than the simulated short circuit current. As a result, the protective device is rated appropriately to manage the predicted short circuit current. The result indicates that the breaking capability of a specified breaker should be at least 10,000.0 amps or 10kA. Results are shown in Appendix D.

4.4 ETAP simulation

The common electrical circuit identified in the Suame ECG unit was modeled using Etap and simulated on short circuit fault condition to analyse the breaking capacity and sensitivity of the most common brands of breakers used.

4.4.1 Short Circuit Fault Analysis

In this section, an electrical system is analyzed or evaluated to identify the magnitude of currents that are capable of flowing during an electrical fault. Those values are then compared to the ratings of the equipment that has been installed as well as the short circuit protection devices.

The technical parameters for the various circuit breakers were used to model the most used brands of protective devices that were investigated. The data from the field was used to model the installation works in the electrical transient analysis program (ETAP) for Short Circuit Fault Analysis using a havells breaker with a breaking capacity of 10kA. Figure 4.10 Show the simulation of the design.

The simulation approach to determine fault currents required validation of essential model data.

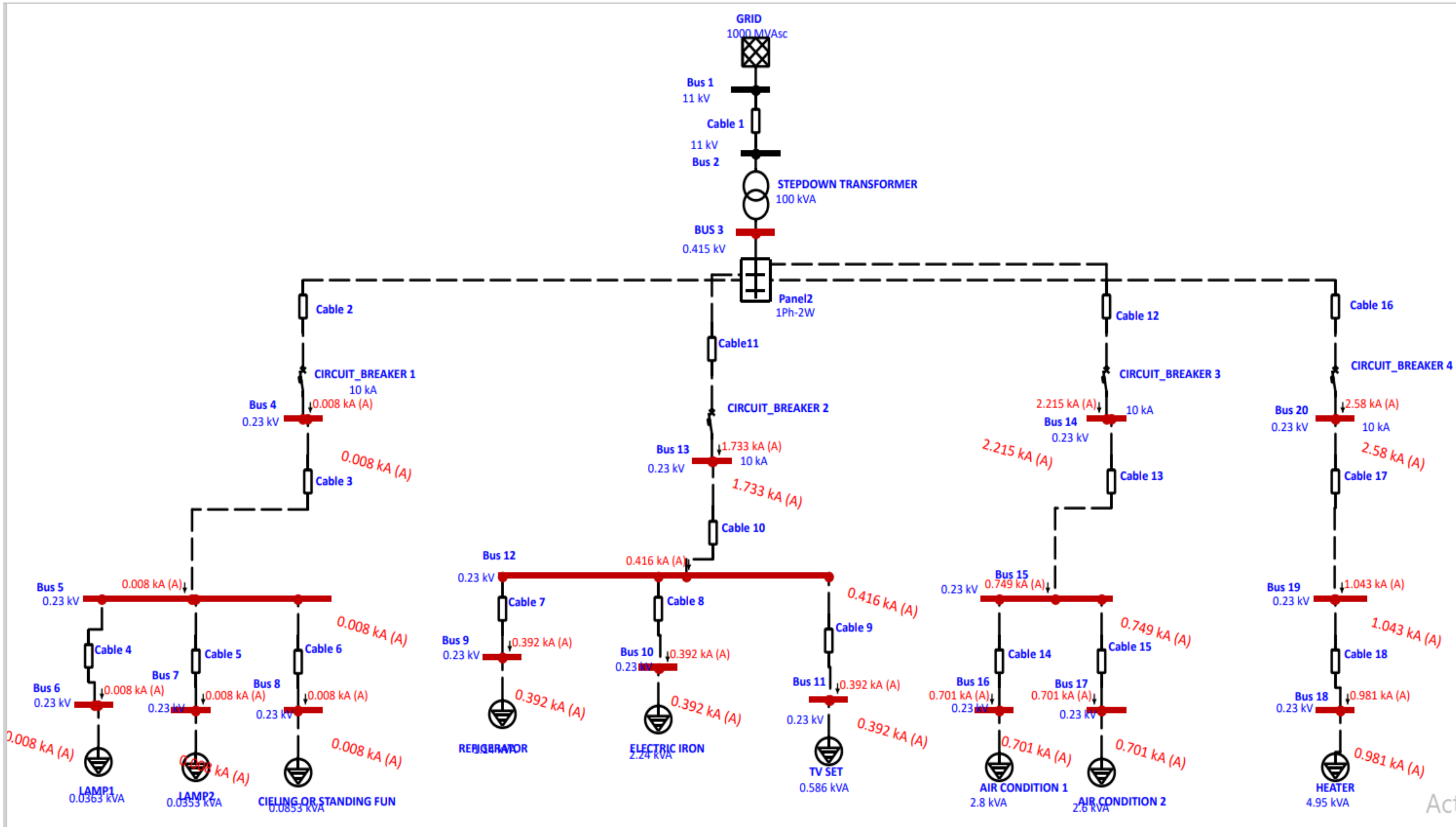

Figure 4. 2 Short Circuit Fault Analysis using havells breaker with breaking capacity of 10k

4.4.2 Simulated Etap Result

Table 4.2 indicates the results obtained from simulation of the common installation circuit. In the event of a short circuit defect, the results of the short circuit analysis revealed the amount of the short circuit current that can flow through each circuit of the electrical installation. To safeguard the circuits and the equipment that is linked to them from damage caused by short circuit faults, the results are critical in making the proper choice of circuit breakers.

After a short circuit analysis was conducted on the model for Havells circuit breaker selection, the results show that the Lighting circuit of 6A breaker, or CIRCUIT_BREAKER 1, has a lower rated short-time withstand current (Ithr) of 0.200 Ka. This suggests that, the breaker may have limitations in handling high currents during short-circuit events. Additionally, a rated thermal energy of 0.00 MJ, indicating a lower capacity to dissipate thermal energy in the breaker. The breaker exhibits an actual thermal equivalent short-time current (Ith) of 0.008 kA and a thermal energy of 0.00 MJ suggesting that a circuit breaker with a lower current rating can be used to protect this circuit.

CIRCUIT_BREAKER 2, on the other hand, has a short time current (Ith) of 1.735 kA and a thermal energy of 3.01 MJ. CIRCUIT_BREAKER 3 for the Air-condition circuit has a short time current (Ith) of 2.218 kA and a thermal energy of 4.92 MJ. The heater circuit, CIRCUIT_BREAKER 4, has the maximum short-time current (Ith) of 2.584 kA and the highest thermal energy of 6.68 MJ. These data represent the magnitudes of current and thermal energy wasted or absorbed by the devices when subjected to short-circuit circumstances.

The results of this analysis are useful for selecting and evaluating relevant devices for certain power system applications. CIRCUIT_BREAKER 1 has lesser capacity in terms of current withstand and thermal energy dissipation, but CIRCUIT_BREAKER 2, CIRCUIT_BREAKER 3, and CIRCUIT_BREAKER 4 has stronger capabilities in managing short-circuit occurrences.

The minimum requirement for a short circuit reaction would have to be 10kA according to the IEC 60898 requirement for a protective device. Since havells met the minimum breaking capacity with the minimum short circuit fault rating and use of the brand for installation is valid. In terms of the power circuit for the installation work.

Table 4. 2 Short-Circuit Summary Report.

		DEVICE CAPACITY			**1-PHASE SHORT-CIRCUIT DUTY RESULTS**		
Bus ID	**Device ID**	**Ithr (Ka)**	**Tkr (sec)**	**Rated Thermal Energy (MJ)**	**Ith (kA)**	**Tkr (sec)**	**Thermal Energy (MJ)**
Bus 13	CIRCUIT_BREAKER 2	5.000	1.00	25.00	1.735	1.00	3.01
Bus 14	CIRCUIT_BREAKER 3	5.000	1.00	25.00	2.218	1.00	4.92
Bus 4	CIRCUIT_BREAKER 1	0.200	0.10	0.00	0.008	0.10	0.00
Bus 20	CIRCUIT_BREAKER 4	5.000	1.00	25.00	2.584	1.00	6.68

4.5 Description of premises

There were 203 residential facilities included in this study's data collection for facilities. Comparing the percentage of commercial facilities to the total number of facilities visited during the study period, there were 97 commercial facilities. However, 67.67% of the facilities were residential, compared to 32.33 % for commercial facilities.

According to the data analysis, only 55 residential buildings out of 300 that were inspected had their wiring or electrical systems installed by certified wiring installers, while 148 residential buildings had their wiring installed by uncertified wiring installers. In addition to the 36 certified wiring installers responsible for the electrical installations in commercial buildings, 61 uncertified wiring installers worked on commercial buildings within the Suame Electricity Strategic Business

Unit. Figure 4.2 presents the proportional representation of facilities relative to electrical installation artisans.

The results indicate that a significant proportion of residential buildings within the Suame ECG Strategic Business Unit were wired by uncertified wiring installers. This has implications for the safety and effectiveness of the electrical installations in the area. Installers of certified electrical wiring must possess the knowledge and abilities necessary to carry out electrical installations that are both safe and of a high standard of quality. In addition, the results reveal that unlicensed electrical installers operate on commercial properties, which can have serious safety and legal implications for property owners. Certified electricians are the only personnel who are permitted to carry out electrical wiring on facilities, as stated by the Ghana Energy Commission. These particular people are the only ones who are permitted to engage in such labor and responsibilities. Any job that requires the installation of electrical wiring must be carried out by a qualified electrician who has been educated and given a license in line with the regulations that have been established by the Energy Commission. The commission has stipulated that this is a criterion that must be met at all times, and it must be adhered to. The result indicates how crucial it is for the Energy Commission of Ghana to take preventative measures to ensure that all electrical wiring installers who are presently working are certified and permitted to work. This may be done by ensuring that all electrical wiring installers currently working hold authentic licenses and permits. This would be beneficial in ensuring that any electrical installations are carried out in a secure way and to the required quality standards to meet the requirements set out.

4.6 Age of electrical installation works

In response to the analysis of the question shown in Appendix B, out of the 300 facilities that had electrical installation works, 89 of them (representing 29.7% of the total) had wiring installations that were less than one year old. In addition, there were 96 buildings, which accounted for 32.0% of the total, which had electrical wiring installation that ranged from 1 to 4 years old. In addition, 75 facilities, or 25.0% of the total, had electrical wiring installations that were between 5 and 9 years old. This represents the age range from 5 to 9 years old. In addition, 36 facilities, representing 12.0% of the total, had electrical wiring installations that were between 10 and 14 years old. This reflected the age range when the facilities were built. Last, but certainly, not least, there were four buildings, representing 1.3% of the total, which included electrical wiring installations that were older than 15 years. Figure 4.3, presents a representation of the distribution of the ages of the installation works that were carried out in the study area.

The results of Figure. 4.3 reveal that a large number of the electrical wiring installations in the Suame Electricity Strategic Business Unit are relatively new or rewired, with installations less than a year old accounting for about 30% of the sample. However, a significant number of installations are also rather old, with over 10% of buildings having electrical wiring installations that were more than 14 years old. This has ramifications for the safety and quality of the electrical installations within the Suame Electricity Strategic Business Unit since older systems are more prone to degrade and represent a risk of electrical dangers (Masterson, 2012).

The results indicate that the existing installations of the investigated facilities did not satisfy the technical requirements for a safe electrical connection. Even though the facilities did not satisfy the minimum safety requirements, the electricity supply was connected to them. This poses a serious risk to the protection of the building's occupants. It is essential to consider the non-enforced installation requirements for electrical installations in all buildings, regardless of age.

Older installations are more likely to have installation materials deteriorate, making them dangerous. Regular inspection and maintenance can help to extend the life of an installation, but it is essential to evaluate the wiring's condition before any work is performed. Installations of electrical wiring should be routinely inspected and maintained to ensure their continued safety and dependability. This includes inspecting for signs of deterioration, corrosion, and insulation damage. Any issues should be resolved expeditiously to prevent dangers.

Electrical installations in Ghana must adhere to all applicable standards and regulations, including the Ghana Energy Commission's standards. It is crucial to ensure that installations are designed, installed, and maintained in accordance with these standards to ensure safety and dependability. Participants in the energy commission's electrical wiring program can enforce this through periodic electrical wiring inspection assessments.

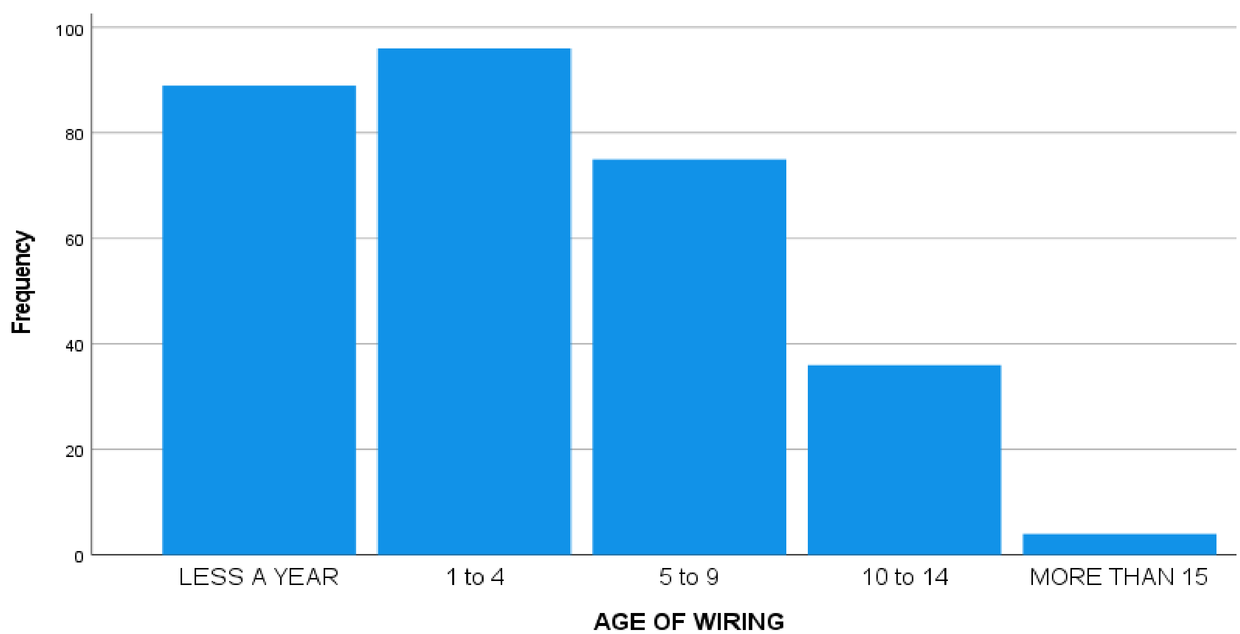

Figure 4. 3 Age of Wiring Structure

4.7 Brand of residual current circuit breaker *(*RCCB) mostly used.

The response from the questionnaire items revealed that among the certified artisans, HAVELLS was the most preferred brand, chosen by 54 artisans (59.3% of certified artisans), followed by SCHNEIDER with 34 artisans (37.4%). FOCUS brand had a minimal representation with only 2 certified artisans. On the other hand, among the non-certified artisans, HAVELLS was also the most commonly used brand, selected by 113 artisans (54.1% of non-certified artisans), followed by SCHNEIDER, FOCUS, ORIENT, PREMIER (F362), and OL6K brands. The analysis of the overall sample of 300 artisans showed that H AVELLS was the most popular brand, selected by 167 artisans (55.7% of the total sample). These findings provide insights into the brand preferences of certified and non-certified artisans and can contribute to understanding market trends and brand popularity within the industry.

The results indicate that both certified and uncertified electrical wiring installers choose Havells and Schneider RCCBs over other brands. The brands' accessibility, dependability, and safety may be the cause of this choice. The result also shows that uncertified electrical installers tend to purchase RCCBs less frequently than certified electrical installers, which may indicate a lack of awareness of the importance of RCCBs in electrical installations.

Based on the results provided in Figure 4.4. It appears that Havells and Schneider's RCCBs are the preferred choices among electrical installers in the Suame ECG Strategic Business Unit of Electricity. However, it is important to assess how these choices compare with the standards set by various electrical organizations such as the International Electrotechnical Commission (IEC) and Ghana Electrical Wiring Regulation.

IEC standard 61008 specifies that RCCBs must have a maximum rated residual operating current of 30 mA and a maximum trip duration of 300ms. Both Havells and Schneider RCCBs satisfy these requirements (Masterson, 2012), and many licensed electrical installers utilize them. The authorized Residual Circuit Current Breaker (RCCB) brand names that the Ghana Standard Authority examined and found suitable for use in Ghana are shown in Appendix F, according to the energy commission of Ghana. The only RCCB brands that were permitted to be used in Ghana were Havells, Schneider, and Focus. Although Orient, Premier, OL6K, and Caretron RCCBs are not authorized for usage in Ghana, the majority of electrical wiring installers reported using them for their wiring works. Havells and Schneider RCCBs are the preferred choices among electrical installers in the Suame Strategic Business Unit of Electricity. It is important to ensure that RCCBs are selected based on their suitability for the application and that they comply with relevant standards and regulations.

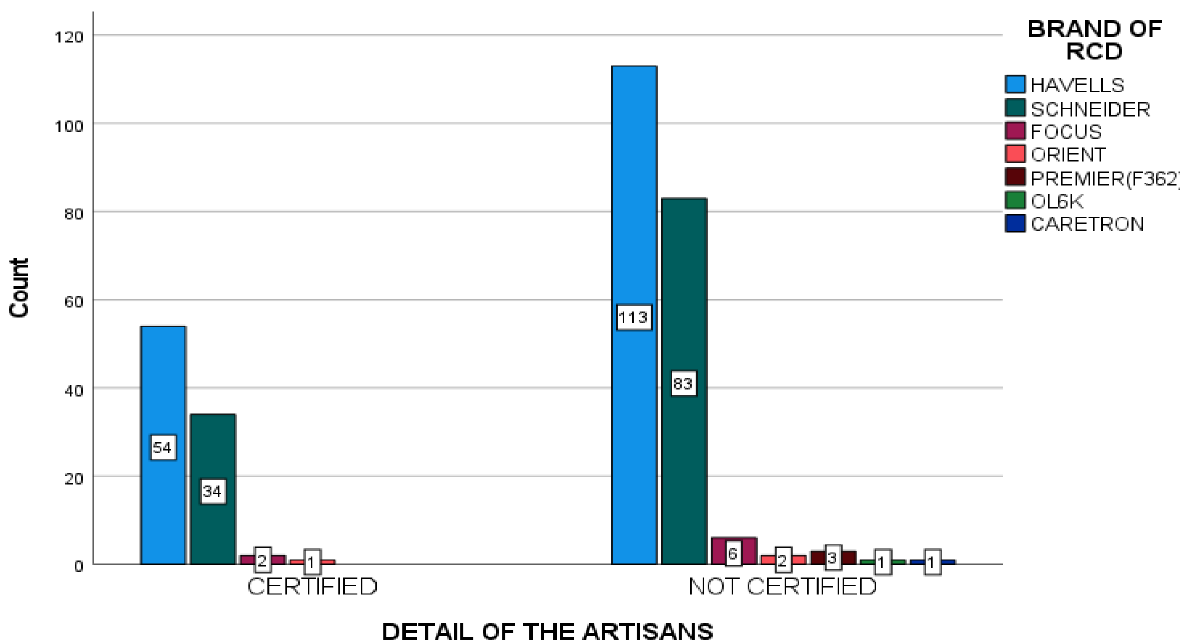

Figure 4. 4 Brand of Residual-Current Device (RCCB) Mostly Used

4.8 Miniature circuit breakers brand mostly used

Figure 4.6 indicates the responses to the survey questions regarding the brands of MCB available in the Ghanaian market. Out of the 300 facilities, the results demonstrate that 88 uncertified electrical wiring installers and 51 certified installers of electrical wiring both utilized havells circuit breakers for their work. Additionally, unlicensed electrical wiring installers used 40 SPE breakers to guarantee the safety of people and property, while certified electrical wiring installers used 18 SPE breakers to guarantee the safety of people and property. 20 COSTA miniature circuit breakers were used by uncertified electrical wiring installers to ensure the safety of properties, while 2 COSTA miniature circuit breakers were also used by certified electrical wiring installers. According to the Etap results After a short circuit analysis conducted on the model for Havells circuit breaker selection, the results show that the havells breaker with the breaking capacity of 10kA in Table 4.2. which shows how the breaker has a lower rated short-time withstand current (Ithr) which suggests the limitations in handling high currents during short-circuit events. Additionally, a rated thermal energy, indicating a lower capacity to dissipate thermal energy in the breaker. SEHGA, (2015)suggests that a Havells circuit breaker with breaking capacity of 10kA is reliable to be used to protect residential and commercial circuit, which all comply with the IEC 60898-1 standard.

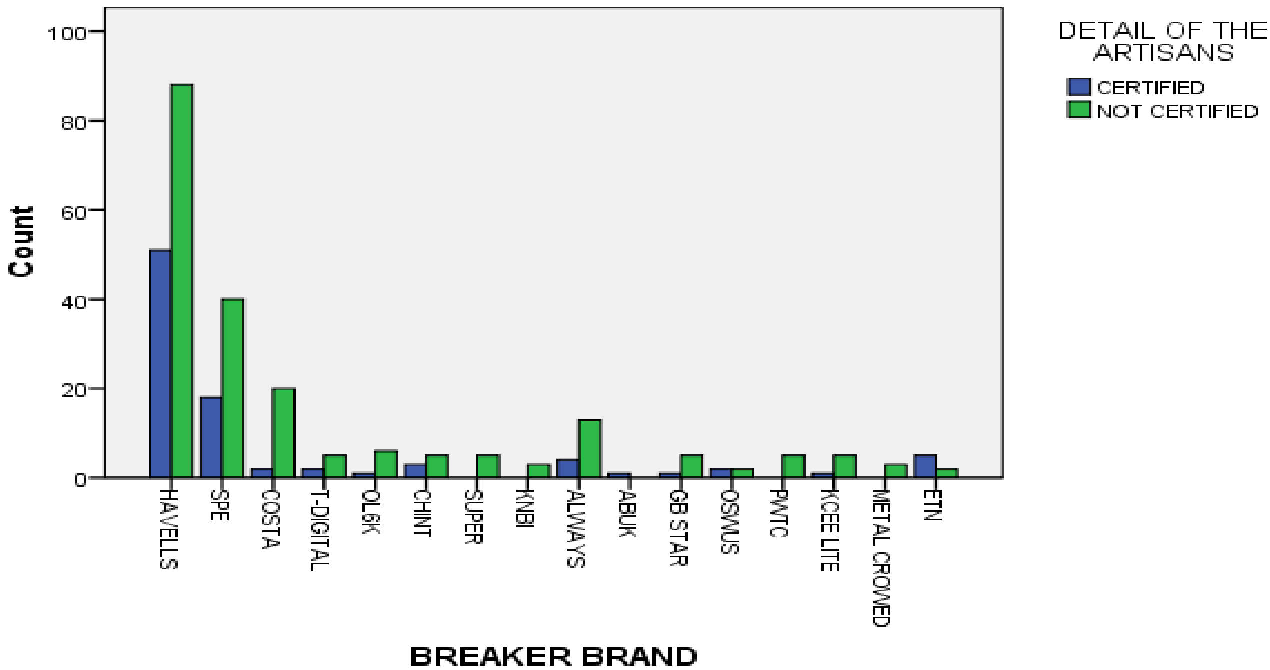

Figure 4. 5 Miniature circuit breakers brand is mostly used by artisans

4.9 Conductor brand mostly used

There are several conditions to be considered when choosing an electric cable for a particular job. The temperature of the design, the requirements for flexibility, the abrasion resistance, the strength, the insulation, the electrical resistance, the weight, and the applied voltage and current flow all affect the wire selection gmilazzo, 2016). Because of these considerations, the wiring installer will know exactly what kind of conductor and insulation to order for a certain project.

17.3% while 8.7% of wiring installers choose to work with TCCL Ghana cable. COSTA cable is the preferred option for working with 52 electrical installers also, representing 17.3% and 39.0% of wiring installers respectively prefer working with COSTA and BASEC cable for both water heater, air condition, socket, and lighting wiring.

This indicates that BASEC cable is widely used in the Suame Strategic Business Unit of Electricity. Therefore, it is important to evaluate if BASEC cable meets the safety, quality, and environmental standards set by the Ghana Standard Authority (GSA).

According to the Ghana Standard Authority (GSA), electrical cables should comply with safety, quality, and environmental standards. The preferred cable brands mentioned by the electrical wiring installers must conform to these standards. GS IEC 60502 recommends that cable brands must be certified by the relevant authorities if they met the necessary safety requirements. Ghana Standard Authority (GSA) has set standards for electrical installations, including the type of cables to be used. Electrical wiring installers in the Suame Strategic Business Unit of Electricity must ensure that their installations meet the Ghana Standard Authority's standards. The type and size of the cable used must be appropriate for the intended application, taking into consideration factors such as voltage rating, current capacity, and environmental conditions.

Appendix E shows the approved cables by Ghana standard authority to be used in the Ghanaian market. A cable is approved based on its electrical characteristics, fire performance, mechanical properties, and environmental considerations, Figure 4.7 indicate that, BASEC cable is the most preferred cable used within Suame ECG unit. Melody cable is not approved by Ghana standard authority as indicate in Appendix E but 10.33% of electrical wiring installers still purchase melody cable for their work.

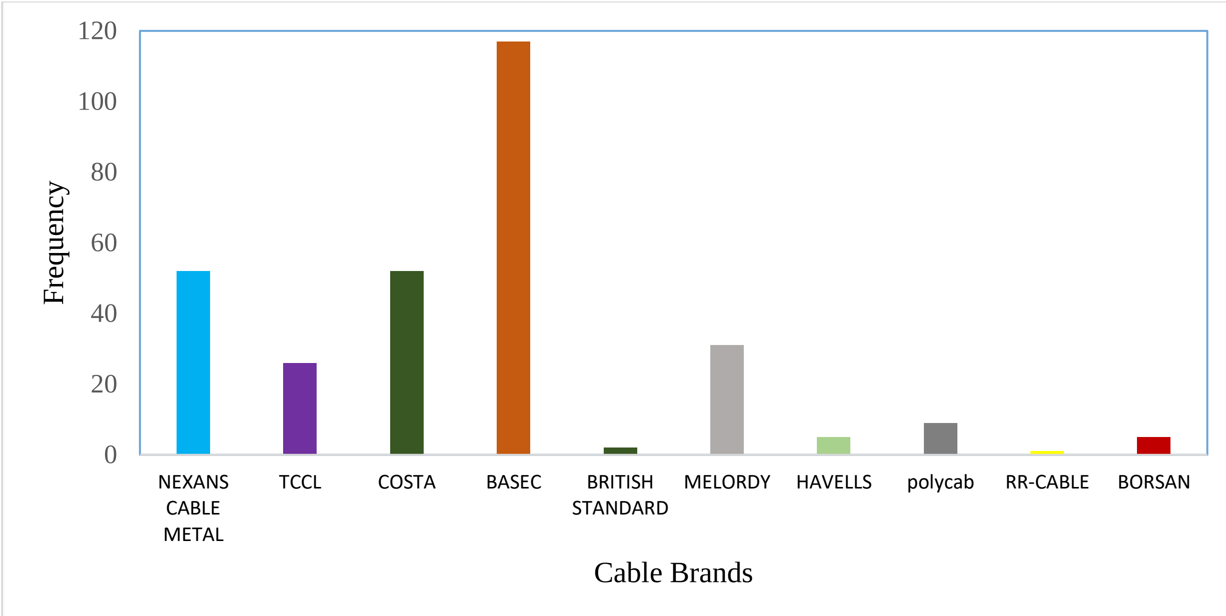

Figure 4. 6 Conductor Brand Mostly Used

4.10 Protection or accessibility of earth electrode

Figure 4.8 reveals that, among the certified electrical wiring installers 17 representing 19.1% used the concrete chamber to protect their earth rod, while 72 electrical installer represents 80.9% used the PVC chamber. 2 certified electrical wiring installers represents 2.2% buried their earth rod without any protective chamber. Among the uncertified electrical wiring installers, 32 electrical installers represented 15.2% used concrete chamber, while 174 represented 82.5% used PVC chamber, and also 3 uncertified electrical wiring installers represented 1.4 % buried their earth rod without any protective chamber.

The results indicate that the majority of both certified and uncertified electrical wiring installers in the Suame Electricity Strategic Business Unit secure their earth rods with PVC chambers. A small percentage of installers, however, use concrete chambers or bury the earth rod without a protective chamber, which can compromise the safety of an electrical installation (Abdul Ali et al., 2020).

The results suggest that electrical wiring installers require regular training and instruction on the significance of using earth rods with the appropriate protective chambers.

Overall, the results indicate that there are some areas where the electrical installation work in the Suame Strategic Business Unit of Electricity does not entirely adhere to the IEC 60364 standard.

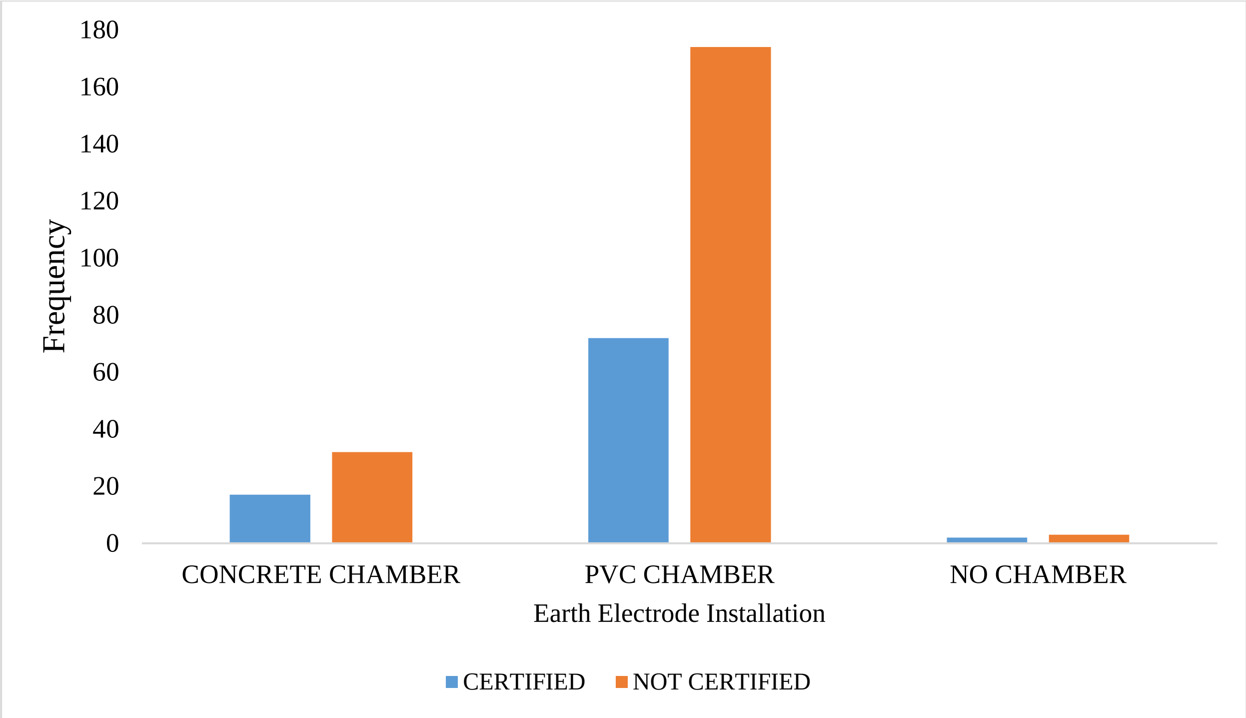

Figure 4. 7 Protection or Accessibility of Earth Electrode

4.11 Color Code Compliance with Wiring Regulation and Specification.

Figure 4.9 indicate that, 79 of the qualified electrical wiring installers representing 26.3% of the total adhered to the standard regulation of IEC 60446 wiring color code, while only 12 of the certified electrical wiring installers representing 4% did not comply with the standard regulation of the IEC wiring color code. On the other hand, 54.7% of uncertified electrical wiring installers conducted their work according to the standard of the IEC wiring color code, while 15% of uncertified electrical wiring installers did not comply with the wiring color code for their work. There were 164 uncertified electrical wiring installers.

According to the results, a sizeable number of the electrical wiring installers working within the Suame Electricity Strategic Business Unit are not adhering to the normal standards of the IEC 60446 wiring color code. This includes both certified and uncertified professionals. This may result in safety risks and raise the possibility of electrical fires or electrocution. Therefore, to maintain the safety of electrical installations, it is vital to inform and train electrical wiring installers on the necessity of complying with standard regulations, including the wiring color code IEC 60446.

The appropriate observance of the wiring color code is essential for the safe and effective functioning of electrical systems, according to the Ghana Electrical Wiring standard and the International Electrotechnical Commission (IEC) 60446 standard. Based on the data given, only 26.3% of certified electrical wiring installers adhered to the wiring color code standard, and 4% did not comply. 54.7% of uncertified electrical wiring installers complied with the wiring color code standard, while 15% did not comply. These figures show that more awareness of and adherence to IEC 60446 guidelines are required. In accordance with the regulations set forth by the Ghana Standard Authority, specifically section 5.10.4, a color identification system has been established for wiring cables. This system aims to provide clear guidelines on the colors to be used for different types of cables to ensure proper identification and safe installation.

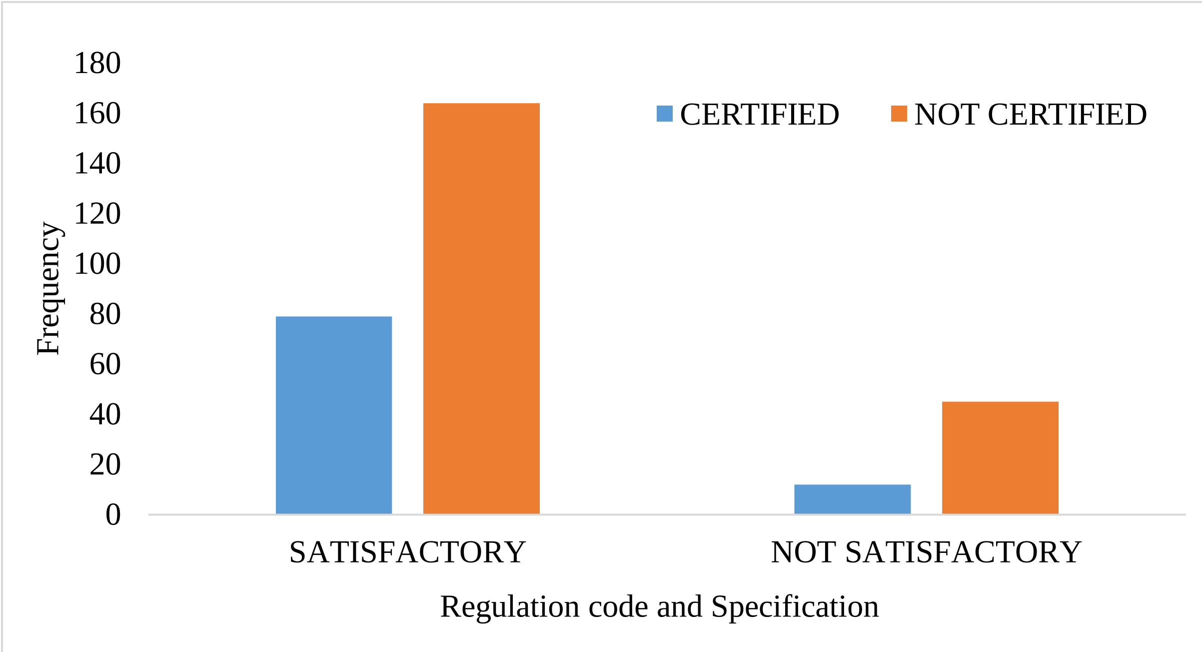

Figure 4. 8 Regulation code and specification of cables color used

4.12 Earth electrode resistance

Figure 4.10 indicate that, 119 instances were classified as "SATISFACTORY" in terms of Earth Electrode Resistance. This indicates that these installations met the specified limits set by the Ghana energy commission and IEC standard, signifying compliance with electrical installation safety requirements. On the other hand, there were 25 instances categorized as "NOT SATISFACTORY," suggesting potential issues with the grounding system that require attention and rectification.

Furthermore, the data reveals that in terms of accessibility for assessment, 156 instances were classified as "NOT ACCESSIBLE." This highlights the challenges faced during the evaluation process, possibly due to limited accessibility or other constraints. It is important to address these accessibility issues to ensure a comprehensive assessment of electrical installation safety.

Analyzing the data based on the certification status of the artisans involved, it was observed that among the "CERTIFIED" artisans, 49 instances were classified as "SATISFACTORY," while 11 instances were categorized as "NOT SATISFACTORY." In comparison, among the "NOT CERTIFIED" artisans, 70 instances were classified as "SATISFACTORY," while 14 instances were categorized as "NOT SATISFACTORY." These findings indicate that certified artisans demonstrated a higher proportion of satisfactory outcomes in terms of Earth Electrode Resistance, emphasizing the importance of certification and training in ensuring electrical installation safety.

The data presented pertains to the assessment of Earth Electrode Resistance in the context of electrical installation safety. Figure 4.10 provides a breakdown of the results based on the certification status of the artisans involved. The IEC 60364-4: Electrical installations of buildings - Part 4-41: Protection for safety - Protection against electric shock. This standard provides guidelines for the selection and installation of earthing systems, including the limits for Earth Electrode Resistance. IEC 60364-6 recommends an earth electrode resistance of 1 ohm or less for general installations. Ghana energy commission also recommends an earth electrode resistance of 50 ohm or less for general installations.

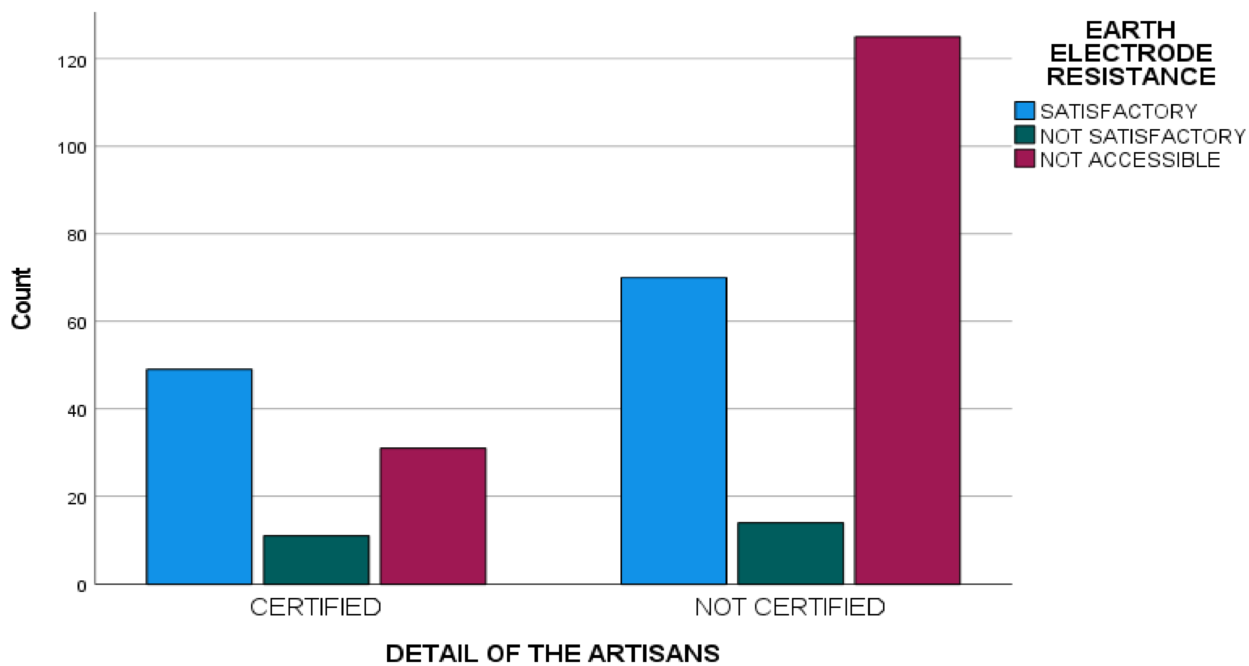

Figure 4. 9 Earth Electrode Resistance

4.13 Termination of cables in the distribution board

Figure 4.11, provided the results of the termination of cables in the distribution board. The results are categorized as "SATISFACTORY" and "NOT SATISFACTORY" based on the certification status of the artisans involved in the termination process.

The results show a total of 242 terminations that were classified as "SATISFACTORY" and 58 terminations that were classified as "NOT SATISFACTORY." Out of the "SATISFACTORY" terminations, 73 were carried out by artisans who are certified by the Ghana energy commission, whereas 169 were carried out by uncertified artisans who work within the ECG strategic business unit. Comparably, 40 of the "NOT SATISFACTORY" terminations were completed by uncertified artisans, compared to 18 completed by certified artisans.

Based on the data, 242 out of 300 cable terminations in the distribution board were classified as "SATISFACTORY." However, it is vital to highlight that a large part of the "SATISFACTORY" terminations (169) was performed by uncertified artisans. This means that, while the terminations were regarded as satisfactory, there is a potential risk in terms of safety standards and quality assurance.

The data, on the other hand, reveals that 58 terminations were classified as "NOT SATISFACTORY." 40 of these terminations were performed by uncertified artisans, indicating a higher chance of safety and quality issues. Furthermore, the fact that 18 terminations were designated as "NOT SATISFACTORY" and were completed by certified artisans raises concerns about their level of knowledge and adherence to IEC 60364-5-52 standard, where installers are to ensure that cable terminations are performed correctly, minimizing the risks of electrical faults, short circuits, and other safety hazards.

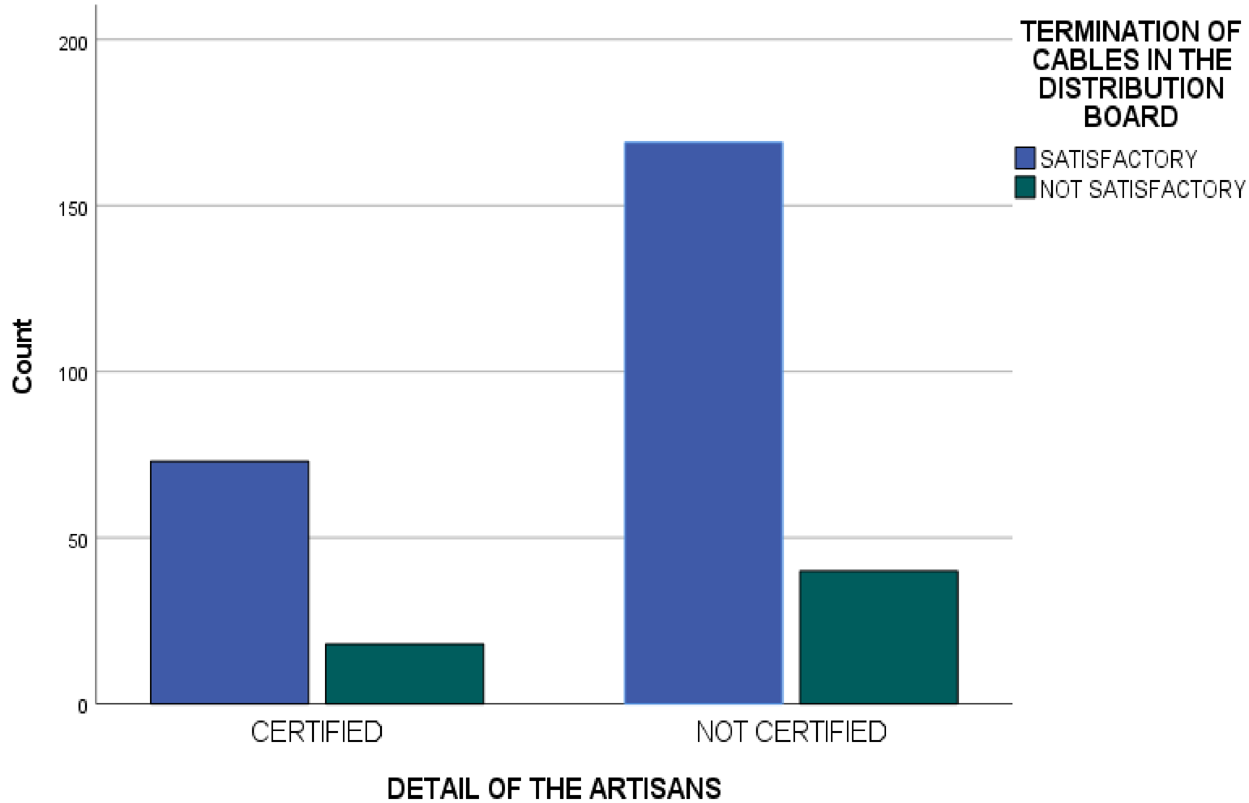

Figure 4. 10 Termination of cables in the distribution board

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary of findings

The study focuses on assessing the efficiency of verification and testing of electrical installations in residential and commercial buildings within the Suame Electricity Strategic Business Unit. The objective was to assess the safeness of electrical installation work, model and simulate common electrical installation networks practiced by artisans and evaluate the adherence of electrical installation works to safety standards and best practices of the artisans.

The study contributes to standardization in the installation and maintenance of electrical systems in buildings, lowering the risk of accidents. A descriptive survey research design was utilized for the study, which entails field surveys employing a test sheet to produce data for analysis. The sample size of interest comprises both certified and uncertified electricians who worked on buildings within Suame Electricity Strategic Business Unit.

The analysis of data collected from the survey conducted within Suame Electricity Strategic Business Unit reveals significant insights into the practices of electrical wiring installers. Key findings include a high percentage of uncertified installers, raising concerns about safety and quality. Many residential and commercial buildings have installations performed by uncertified installers, compromising safety and legal implications. The age of wiring structures varies, with older installations posing higher risks. Preferred brands for Residual Circuit Current Breakers (RCCB) and MCBs are Havells and Schneider, but compliance with international standards is essential. BASEC cable is commonly used, which necessitates the verification of safety and quality criteria. Proper earth electrode shielding with PVC chambers is prevalent, however, education is required for increased safety. Education and enforcement are needed to increase installer compliance with wiring color code standards. The findings of the RCCB trip test reveal a thorough awareness of electrical safety standards, but some testing was impeded by power constraints. Certification does not always imply improved safety knowledge. Some RCCBs failed the test, highlighting the importance of using high-quality devices and performing regular maintenance.

The study of the data centered on figuring out how safe the Earth Electrode Resistance was in terms of electrical installation safety. Out of the 300 observations, 119 were rated as "Satisfactory," which means they met the limits set by the GS IEC standard. But 25 instances were marked as "Not Satisfactory," which might indicate that there are problems with the grounding system. Also, 156 cases were marked as "Not Accessible," highlighting challenges in conducting a comprehensive evaluation. The data also showed that certified artisans had a higher percentage of acceptable results than uncertified artisans.

The results of the analysis of the data on the termination of cables in the distribution board show how well-trained and uncertified artisans perform their tasks to create appropriate terminations. There were 300 terminations in all that were examined, 242 of which were completed by artisans who were certified and 58 of which were uncertified. In the terminations performed by certified artisans, 73 were successful and 18 were unsuccessful. On the other hand, 40 of the terminations completed by uncertified artisans were unsatisfactory, while 169 of them were unsatisfactory.

The short circuit analysis conducted on the electrical installation model provided valuable information regarding the magnitude of short circuit currents in each circuit under fault conditions. This analysis is crucial for selecting appropriate circuit breakers to protect the circuits and connected equipment from damage due to short circuit faults. The results showed variations in the short time withstand current (Ith) and thermal energy dissipation among the circuit breakers.

The analysis highlighted that Circuit Breaker 1, designed for the Lighting circuit, has limitations in handling high currents during short-circuit events. It exhibited lower capacities in terms of current withstand and thermal energy dissipation. On the other hand, Circuit Breaker 2, Circuit Breaker 3, and Circuit Breaker 4 demonstrated higher capabilities in handling short-circuit events, as indicated by their higher short-time currents (Ith) and thermal energy values.

Havells circuit breakers satisfied the requirements for both the minimum breaking capacity and the short circuit fault rating, allowing them to satisfy the minimum requirement of 10 kA for a short circuit reaction as specified by the IEC 60898 standards. These findings give useful insights that may be used in the selection and assessment process of appropriate circuit breakers for certain power system applications.

5.2 Conclusion

The results of the analysis of the data acquired from the survey that was done on electrical safety systems within the Suame Electricity Strategic Business Unit have provided significant insights into the existing practices of wiring installers in residential and commercial buildings. The findings shed light on significant aspects relating to the certification status of artisans, the description of the premises, the age of wiring structures, the brands of residual-circuit current Breaker (RCCBs) and miniature circuit breakers (MCBs) used, the preferred conductor brands, and the protection or accessibility of earth electrodes. These findings have important repercussions for the overall safety and quality of electrical installations carried out within the Suame Electricity Strategic Business Unit.

A significant number of workers in the Suame Electricity Strategic Business Unit are not certified to install electrical wiring. This gives rise to worries over the security and quality of the electrical wiring within the Suame Electricity Strategic Business Unit. The Ghana Energy Commission is responsible for enforcing the certification requirement and ensuring that all electrical wiring installers operating in any ECG strategic business units are qualified. To be able to do electrical installations that are both safe and of high quality, certified electricians are required to have the knowledge and abilities that are essential. The analysis additionally reveals that a significant number of the residential building within the Suame Electricity Strategic Business Unit had electrical wiring systems that were installed by uncertified wiring installers. This not only puts the occupants' well-being in jeopardy but also creates potential legal problems for the owners of the property in concern. It is vital to have stringent enforcement of the standards that regulate the installation of electrical wiring in Ghana, particularly in residential buildings, to guarantee both the safety and the quality of the electrical installations installed.

A key element impacting electrical safety is the age of the wiring structures. Many buildings with electrical wiring installations are more than 15 years old, even if a sizeable portion of the installations are relatively new or have been rewired. Older installations have a higher risk of electrical dangers and are more prone to deterioration. To guarantee the safety and dependability of electrical installations, regardless of their age, regular inspection, maintenance, and adherence to technical installation requirements, as per GS IEC standards and regulations, are essential.

Havells and Schneider are the most popular brands of RCCBs and MCBs among electrical installers in the Suame Electricity Strategic Business Unit. These brands are extensively used and, in most cases, satisfy the necessary safety criteria. However, it is of the utmost importance to check that the RCCBs and MCBs utilized are up to par with the international standards that have been set by organizations such as the International Electrotechnical Commission (IEC) and the Ghana Electrical Wiring. Stricter adherence to these standards and regulations will help to make the area's electrical wiring safer. When it comes to conductor brands, Suame Electricity Strategic Business Unit electrical wiring installers primarily utilize BASEC cable. However, it is critical to ensure that BASEC cable fulfills the IEC and GSA safety, quality, and environmental criteria. Compliance with international and national standards, such as those established by the IEC, BS, and Ghana Standards Authority (GSA), is critical in the selection and use of acceptable cables for electrical wiring.

The protection or accessibility of earth electrodes is another important aspect of electrical safety. The majority of certified and uncertified electrical wiring installers in the Suame Electricity Strategic Business Unit use PVC chambers to protect their earth rods. However, a small percentage of installers use concrete chambers or bury their earth rods without any protective chamber, which compromises the safety of the electrical installation. Continual education and training of electrical wiring installers on the importance of using proper protective chambers for earth rods are necessary to improve safety standards.

The data analysis and the results suggest that there is a need for enhanced education and enforcement of wiring color code standards in Ghana to ensure the safety of electrical installations. This is necessary to ensure that electrical installations are installed correctly. According to the findings of the study, a significant number of the electrical wiring installers working within the Suame Electricity Strategic Business Unit are not adhering to the standard regulations of the wiring color code. This could result in potential safety hazards and increase the risk of electrical fires or electrocution. To promote compliance with wiring color code standards, it is recommended that electrical wiring installers, both qualified and uncertified, get training and instruction on the importance of wiring color code standards as well as the penalties for not adhering to them. This is done to increase the likelihood that wiring color code standards will be met. This will enhance the rate at which wiring color code standards are adhered to. The Suame Strategic Business Unit of Electricity should also increase enforcement efforts to ensure that all electrical installation works comply with the wiring color code standards.

Results of the RCCB trip test reveal that most of the artisans (59%) passed the test, demonstrating that they have a solid awareness of electrical safety procedures. But given that a significant number of artisans (37.67%) were unable to be tested because of a lack of power, the findings also imply that there could be problems with the electrical supply or equipment. To avoid accidents and guarantee worker safety, it is crucial to make sure that all artisans have enough training in electrical safety procedures and that the electrical supply and equipment are routinely examined and maintained. To guarantee that all installations are completed to a high grade, quality control procedures should also be used. One such step is to regularly examine the installations to verify that they conform to applicable electrical codes and regulations.

The RCCB trip test findings also revealed that the pass percentage for uncertified artists (68.42%) was greater than the pass rate for certified artisans (37.36%). This implies that having a certification does not always translate into having a superior grasp of electrical safety procedures. However, the sample size for artisans who were certified was smaller than the sample size for artisans who were not certified, which could have an impact on the pass rate.

Several RCCBs failed the RCCB trip test, which was conducted on multiple brands of RCCBs. To ensure the safety of the system, only high-quality RCCBs must be used in electrical installations. The RCCBs must be routinely tested and maintained to ensure proper operation and adequate electrical shock protection.

The analysis emphasized the importance of adhering to the IEC standard for electrical installation safety. The satisfactory Earth Electrode Resistance results indicated compliance with safety limits and a lower risk of electrical hazards. Conversely, the not satisfactory results underscored the need to address potential issues in the grounding system. The data further highlighted the significance of certification, as certified artisans demonstrated better outcomes. However, limited accessibility hindered the assessment process and impacted the overall evaluation of electrical installation safety.

The analysis shows a clear difference in the performance of certified and uncertified artisans in attaining satisfactory terminations. Certified artisans had a greater proportion of satisfactory terminations, demonstrating that their training and certification had a favorable influence on their ability to execute terminations in accordance with industry standards. In contrast, the significant percentage of unsatisfactory terminations by uncertified craftsmen raises worries about their competency and the possible hazards linked with their work.

The results of the short circuit analysis conducted on the electrical installation model provide valuable insights into the short circuit currents that can flow through each circuit under fault conditions. Upon analyzing the results, it is evident that Circuit Breaker 1, designed for the Lighting circuit, exhibits lower capacities in terms of current withstand and thermal energy dissipation. This indicates limitations in handling high currents during short-circuit events. Therefore, it is recommended to use a circuit breaker with a lower current rating to protect this circuit adequately. On the other hand, Circuit Breaker 2 for the socket circuit demonstrates a higher short-time current (Ith) of 1.735 kA and thermal energy of 3.01 MJ. Similarly, Circuit Breaker 3 for the Air-condition circuit exhibits a short time current (Ith) of 2.218 kA and a thermal energy of 4.92 MJ. The heater circuit protected by Circuit Breaker 4 displays the highest short-time current (Ith) of 2.584 kA and thermal energy of 6.68 MJ. These values reflect the magnitudes of current and thermal energy dissipated or absorbed by the respective devices under short-circuit conditions. The results of this analysis provide valuable information for the selection and evaluation of appropriate devices for specific power system applications. While Circuit Breaker 1 shows lower capacities, Circuit Breaker 2, Circuit Breaker 3, and Circuit Breaker 4 demonstrate higher capabilities in handling short-circuit events.

5.3 Recommendation

Based on the analysis of the data regarding data analysis, results, and discussion of the electrical safety systems adopted by electricians during installation works in residential and commercial facilities within the Suame Electricity Strategic Business Unit, the following recommendations can be made:

Certification and Regulation: The result reveals that a significant percentage of electrical wiring installers within the Suame Electricity Strategic Business Unit are uncertified. It is recommended that the Ghana Energy Commission and Electricity Company of Ghana take proactive measures to ensure that all electrical wiring installers working in their strategic business units are certified. This will help ensure the safety and quality of electrical installations in the area and align with the regulations set out by the Energy Commission.

Age of Wiring Structures: The analysis shows that a considerable percentage of electrical wiring installations in the Suame Electricity Strategic Business Unit are relatively old, with over 10% of the structures having installations that are over 15 years old. To address this, it is recommended to follow the technical installation requirements outlined by IET Wiring Regulations, which include regular inspection and maintenance of older wiring structures to identify potential problems and hazards.

Brand of RCCB and MCB: The preferred brands among electrical installers for RCCBs are Havells and Schneider, while Havells is also commonly used for MCBs. It is important to ensure that the selected RCCBs and MCBs comply with relevant standards such as IEC and Ghana Energy Commission or Ghana Standard Authority. This includes checking if the chosen brands meet the required specifications for rated residual operating current, trip time, and breaking capacity.

Conductor Brand: The result shows that electrical wiring installers in the Suame Strategic Business Unit frequently purchased BASEC cables. It is advised to determine if BASEC cable satisfies the environmental, quality, and safety requirements established by the Ghana Standard Authority and IEC. Installers need to make sure that the cables they choose are suitable for the intended purpose, adhere to all applicable international and national standards, and satisfy Ghana Standards Board regulations.

Protection of Earth Electrode: The majority of electrical wiring installers use PVC chambers to protect their earth rods, while a small percentage use concrete chambers or bury the earth rod without any protective chamber. It is recommended to continue educating and training electrical wiring installers on the importance of using proper protective chambers for earth rods to ensure the safety of electrical installations.

In conclusion, implementing these recommendations will help improve the electrical safety systems during installation works in residential and commercial facilities within the Suame ECG strategic business unit. It will ensure that electrical wiring installers are certified, installations comply with relevant standards and regulations, and proper measures are taken to address the age of wiring structures and protect earth electrodes.

Earth Electrode Resistance: Ensure compliance with the GS IEC standard all electrical installations should adhere to the safety requirements outlined by the GS IEC 60364-4-41 standard. This includes proper grounding and adherence to the specified limits for Earth Electrode Resistance, which is below 50 Ω for residential and commercial buildings. Regularly review and update installation practices to align with the latest revisions of the standard.

Termination of cables in the distribution board: It is recommended that thorough training and certification programs be established to improve the termination of cables in the distribution board and assure compliance with IEC standards. These programs should concentrate on teaching artisans the required skills, knowledge, and awareness of industry standards and regulations. Furthermore, quality assurance procedures must be implemented. This may be accomplished by frequent cable termination inspections, audits, and testing to ensure conformity with standards such as IEC 60364-5-52. Any mistakes may be recognized and corrected in a timely way by creating a comprehensive inspection approach.

Short Circuit Fault Analysis: Based on the results of the short circuit analysis and the limitations observed in Circuit Breaker 1, which is used for the Lighting circuit, it is recommended not to overload Circuit Breaker 1 (6A Breaker). This recommendation is made due to its lower-rated short-time withstand current (Ithr) of 0.200 kA and rated thermal energy of 0.00 MJ. By replacing Circuit Breaker 1 (6A Breaker) with a higher-rated circuit breaker (10A Breaker), the Lighting circuit can better handle high currents during short-circuit events and dissipate thermal energy more effectively, thus ensuring proper protection.

Furthermore, based on the capabilities demonstrated by Circuit Breakers 2 (16A Breaker), 3 (20A Breaker), and 4 (32A Breaker), the following recommendations can be made: for the socket circuit, it is recommended to utilize Circuit Breaker 2, which exhibits a short time current (Ith) of 1.735 kA and thermal energy of 3.01 MJ. This circuit breaker provides sufficient capacity to handle short-circuit events in the socket circuit effectively. For the Air-condition circuit, it is advisable to employ Circuit Breaker 3, which exhibits a short time current (Ith) of 2.218 kA and a thermal energy of 4.92 MJ. This circuit breaker offers higher capabilities, making it suitable for protecting the Air-condition circuit.

The heater circuit should be protected by Circuit Breaker 4, which displays the highest short-time current (Ith) of 2.584 kA and thermal energy of 6.68 MJ. This circuit breaker is designed to handle the substantial current and thermal energy associated with the heater circuit. By selecting circuit breakers with appropriate current ratings and thermal energy capacities, the electrical installation can be safeguarded effectively against short circuit faults. It is important to ensure compliance with safety standards, such as the IEC 60898 requirement for a protective device, which mandates a minimum breaking capacity of 10 kA for a short circuit reaction. Since Havells circuit breakers meet this minimum requirement, their use for the installation is valid.

Regular short circuit studies and adherence to maintenance guidelines are advised to preserve the electrical installation's efficiency and safety. By doing these steps, the power system's overall reliability and performance will be improved as the circuit breakers continue to offer the best possible protection against short circuit problems.

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APPENDICES

Appendix I - Pictures of the actual instruments used for the Electrical Audit Survey

Instrument	Picture
Socket / RCCB tester	
Insulation resistance Tester	
Earth resistance tester	

Appendix II -The questionnaire or basic test sheet used for data collection

BASIC TEST SHEET

DETAILS OF THE ARTISAN

Certified?

1. YES ☐ 2. NO ☐ Certification ID ……………………………

DETAILS OF THE INSTALLATION

Description of premises: Location……………………………

1. Domestic ☐ 2. Commercial ☐

Description of installation: 2. New installation ☐ 3. Additional installation ☐

DETAILS OF CONSUMER UNIT

No. of Phases: ……………… No. of Ways……….

Residual Current Device: Brand………………………………… Rating……A………mA

Trip test of RCD

1. Pass ☐ 2. Fail ☐

Age of wiring

1. Less than a year ☐ 2. 1 to 5 ☐ 3. 5 to 10 ☐ 4. 10 to 15 ☐ 5. more than 15 ☐

VISUAL INSPECTION AND TESTING

TYPE OF WIRING

1. Conduit wiring ☐
2. Surface wiring ☐
3. Trunking wiring ☐

IS EACH TERMINATION OF CABLE IN THE DISTRIBUTION BOARD, OK?

1. YES
2. NO

IS THE TERMINATION OF THE CABLE IN EACH SOCKET OK?

1. YES
2. NO

IS THE COLOR CODE USED COMPLY WITH IEEE SPECIFICATIONS?

1. YES
2. NO

		PROTECTIVE DEVICE			**CONDUCTOR DETAILS (mm ^{2})**				**CONTINUITY (Ω)**			**POLARITY (Ω)**			**INSULATION RESISTANCE TEST (Ω)**		
	Circuit description	Brand	Rating (A)	Breaking Capacity (KA)	Brand	Live	Neutral	CPC	Live	Neutral	CPC	Live	Neutral	CPC	Test Voltage(V)	Live Neutral (MΩ)	Live Earth (MΩ)

GROUNDING PROTECTION

Type of Earthing System

1. TT ☐
2. TNS ☐
3. TNCS ☐

Earth Electrode Resistance ……. Ω

Material for Earth Electrode

1. Solid Copper ☐
2. Stainless Steel ☐

Type of Earth Electrode

1. Driven Rod ☐
2. Ufer Grounds or building foundation ☐
3. Concrete Encased Electrode ☐
4. Grounding Plates ☐

Location of the Earth Electrode …………………………………………

Protection or accessibility of Earth Electrode

1. Concrete Chamber ☐
2. PVC Chamber ☐
3. No Chamber ☐

Importance of retesting a Residential and Commercial installation

1. Important ☐ 2. Not required ☐ 3. No opinion ☐

What is the current required Frequency of retesting Residential and Commercial dwellings

1. 2 years ☐ 2. 5 years ☐ 3. 10 years ☐ 4. Not required ☐

Appendix III - Short circuit analysis using Electrical Transient and Analysis Program (ETAP)

Short-Circuit Summary Report

3-Phase & 1-Phase Fault Currents

Bus		Device			Device Capacity (kA)				Short-Circuit Current (kA)					
ID	kV	ID	Ckt	Type	Makin Peak	Ib sym	Ib	Idc	I"k	ip	Ib sym	Ib asym	Idc	Ik
BUS 3	0.415	BUS 3		Bus					3.725	6.075				3.725
Bus 13	0.230	Bus 13		Bus					1.733	2.503				1.733
	0.230	CIRCUIT BREAK		CB	10.000	10.000	10.000		1.733	2.503	1.733	1.733		
Bus 12	0.230	Bus 12		Bus					0.416	0.600				0.416
Bus 11	0.230	Bus 11		Bus					0.392	0.565				0.392
Bus 10	0.230	Bus 10		Bus					0.392	0.565				0.392
Bus 9	0.230	Bus 9		Bus					0.392	0.565				0.392
Bus 14	0.230	Bus 14		Bus					2.215	3.216				2.215
	0.230	CIRCUIT BREAK		CB	10.000	10.000	10.000		2.215	3.216	2.215	2.215		
Bus 15	0.230	Bus 15		Bus					0.749	1.080				0.749
Bus 17	0.230	Bus 17		Bus					0.701	1.011				0.701
Bus 16	0.230	Bus 16		Bus					0.701	1.011				0.701
Bus 4	0.230	Bus 4		Bus					0.008	0.012				0.008
	0.230	CIRCUIT BREAK		CB	10.000	10.000	10.000		0.008	0.012	0.008	0.008		
Bus 5	0.230	Bus 5		Bus					0.008	0.012				0.008
Bus 8	0.230	Bus 8		Bus					0.008	0.012				0.008
Bus 7	0.230	Bus 7		Bus					0.008	0.012				0.008
Bus 6	0.230	Bus 6		Bus					0.008	0.012				0.008
Bus 20	0.230	Bus 20		Bus					2.580	3.788				2.580
	0.230	CIRCUIT BREAK		CB	10.000	10.000	10.000		2.580	3.788	2.580	2.580		
Bus 19	0.230	Bus 19		Bus					1.043	1.504				1.043
Bus 18	0.230	Bus 18		Bus					0.981	1.415				0.981

ip is calculated using method C
Ib does not include decay of non-terminal faulted induction motors
Ik is the maximum steady-state fault current

Appendix IV -Short circuit calculation using Electrical FlashWorks v1.6

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Short Circuit Calculations
 Service is: 240 Volts, 1-Phase
  Short Circuit Calculation #1
   Transformer kVA            : 200 kVA
   Line to Line Voltage       : 400 Volts
   Phase                      : 1-Phase
   Impendance                 : 0.05
   Length                     : 50 feet
   Wire Material              : Copper (Cu)
   Conductor Type             : 3 Single Conductors (3SC)
   Conduit Type               : Aluminum or PVC
   Conduit is                 : NonShielded
   Wire Size                  : #4
   Times Paralleled           : 1
   Calculated Short Circuit : 12,170.1 amps
   Selected Equipment Rating: 22,000.0 amps

  Short Circuit Calculation #2
   Line to Line Voltage       : 400 Volts
   Phase                      : 1-Phase
   Length                     : 50 feet
   Wire Material              : Copper (Cu)
   Conductor Type             : 3 Single Conductors (3SC)
   Conduit Type               : Aluminum or PVC
   Conduit is                 : NonShielded
   Wire Size                  : #1/0
   Times Paralleled           : 1
   Calculated Short Circuit : 8,644.5 amps
   Selected Equipment Rating: 10,000.0 amps
```

APPENDIX V - Below are the Approved Electrical Cables in Ghana-by-Ghana Standard Authority (2022)

BRAND NAME	SIZE (mm^2)	COLOUR
	MADE IN GHANA	
NEXANS CABLES	All Sizes	All Types
REROY CABLES	All Sizes	All Types
TROPICAL CABLES	All Sizes	All Types
SIGNAL CABLE	1.5, 2.5	RED
SIGNAL CABLE	4.0	YELLOW/GREEN
SIGNAL CABLE	6.0, 10.0, 16.0	BLACK
	IMPORTED CABLES	
POWERTEC	2.5	BLACK
CMC SUPERIOR	4.0, 10.0, 16.0	RED, BLACK
HAVELLS CABLE	1.5, 6.0, 10.0, 16.0, 2×1.5	BLACK, BROWN, BLUE, WINE & BLACK
GOLDAGI	1.5	RED, BLACK, YELLOW & GREEN
HELLUKABEL	1.5, 2.5, 4.0, 6.0	BLUE, YELLOW & GREEN
CABELTE	1.5, 2.5, 4.0, 6.0, 10.0, 16.0	BLACK, YELLOW & GREEN
BEMAS KABLO	1.5, 2.5, 4.0, 6.0, 10.0, 16.0	RED, BLACK
PRYSMIAN	1.5, 2.5	YELLOW & GREEN, RED, BROWN, BLUE, YELLOW, BLACK
COSMOS	1.5, 2.5	RED, YELLOW & GREEN, BLUE, BROWN, BLACK
FOCUS	1.5, 2.5, 4.0, 6.0, 10.0	RED, BLACK
OZGUVEN	2.5	RED

LLOYD	1.5	BLACK
STANDARD	1.5, 2.5	BLACK, RED, YELLOW & GREEN
UNAL KABLO	1.5	BLACK, YELLOW & GREEN
SEVAL KABLO	1.5, 2.5	YELLOW & GREEN, BLUE, RED, BROWN
BORSAN CABLE	1.5, 2.5, 4.0, 6.0, 10.0, 16.0	BLACK, RED, BROWN
AGENDA	2.5	YELLOW & GREEN
U-MAX (STRANDED)	1.5, 2.5, 4.0, 10.0, 16.0	RED, BLACK
PGIL (STRANDED)	1.5, 2.5, 4.0, 6.0, 10.0, 16.0	BLACK, RED, BLUE, YELLOW/GREEN
STATEX	1.5, 2.5, 6.0	BLACK
BELTA	1.5, 2.5	BLACK, RED
BRITCOM KABLO	2.5, 4.0	RED, BLACK
EXZCHELLENT	1.5, 2.5	RED, BLACK
TBEA	1.5, 2.5, 4.0, 6.0	RED, BLACK, BLUE, YELLOW & GREEN
ELSEWEDY	1.5	RED
KABEL PLUS	2.5	RED
BASEC	1.5, 2.5	BROWN, BLACK, YELLOW & GREEN
POLYCAB	1.5, 2.5, 4.0, 10.0	RED, BLACK
METELMO	1.5, 2.5, 4.0	BLACK, RED
HES	6.0	YELLOW, GREEN
RR KABEL	1.5, 2.5, 4.0	RED, BLACK, YELLOW & GREEN
XP	1.5, 2.5	RED, BLACK
ROYAL STANDARD	4 X 16, 4 X 25, 4 X 95, 4 X 185	BLACK
UNITED CABLES	1.5, 2.5, 4.0	BLACK, RED, BLUE
APEC	3 X 1.5, 3 X 2.5	WHITE, ORANGE
ROLLER	1.5, 2.5	BLACK, RED

KOC KABLO	3 X 2.5	WHITE
STAR BOSH	1.5, 2.5, 4.0, 10.0	RED, BLACK
CPR	1.5, 2 x 2.5	GREY
ASTRO METAL	1.5, 2.5	RED, BLACK
NLE	1.5, 2.5	BLUE, RED
OSUWA KABLO	2.5	RED
RAKCAB	1.5, 2.5, 4.0	RED, BLUE, BLACK
KOC KABLO	3 x 2.5	ASH
BASEC OMAN	10.0	RED
VK CABLE	1.5	BLUE, YELLOW & GREEN
BOK	1.5, 2.5, 4.0, 6.0, 10.0	BLACK, RED
DETA	1.5, 2.5, 4.0, 6.0, 10.0	BLACK, RED
PEAK CABLE	1.5	BROWN
CCC	1.5, 2.5	RED
DM	1.5, 2.5, 4.0, 16.0	BLACK, RED, YELLOW & GREEN
AMPA	2.5	BLACK
COSTA	2.5	BLACK
MONDINICAVI	1.5	BLUE
HASCELIK	1.5, 2.5	BLUE
HELUKABEL GMBH	2.5	BLACK
UNIQUE	1.5	YELLOW, BLUE
TCCL	1 x 240RS	–
MFZ KABLO	6.0	BLACK
ECHONIS KABLO	6.0	RED

APPENDIX VI

APPROVED RESIDUAL CURRENT DEVICE (RCD) FOR USE IN GHANA

BRAND PRODUCT	NAME OF DEALER	CONTACT DETAILS
BRISTOL	Goswami Ghana Limited	Tel: 055 314 0315, 026 744 4979 Email: goswamighana@gmail.com
CHINT	Process and Plant Automation	Tel: 030 281 2680 Email: contact@automationghana.com Website: www.automationghana.com
EBASEE	Captain Elect-Link	Tel: 0243502586, 0244674285
FOCUS	Rhinohippo Ghana Limited	Tel: 020 850 3493, 024 423 8408 Email: andy@gsfocus.com Website: www.focuselectricals.com.gh
HAVELLS	Service Merchantile Limited (SMI)	Tel 020 070 7575 Email: sales@smighana.com
	MS Plus Engineering Ltd	Tel: 024 386 4726. Email: info@msplush@gmail.com
INDOASIAN	JMGL. Lad	Tel: 024 498 1593, 050 155 3473
KCEE LIT	Astra World Company Ltd	Tel: 0543460876, 0560664240 Email: fidelisdavid11@gmail.com
OEZ	Mikam International	Tel: 024 465 7130. Email info@mikamtrade.com Website: www.mikamtrade.com
SCHNEIDER	Agenda Commercial	Tel: 020 211 2705, 030 278 1233 Email: info@agenda.com Website: www.agenda.com
SIGMA		
XP ELECTRIC	Rexkamp Company Ltd	Tel: 0302 660 177, 027 756 2423 Email: teakamp20yahoo.com

Note 1: Use the approved RCDs for all Installations.

63A- 30mA Residual Current RCD/RCCB for Domestic/Single Phase Facilities.

300mA Residual Current RCD/RCCB for Commercial/"Three Phase Facilities + 30mA Residual Current RCD/RCCB for equipment such as Water Heaters, Air Conditioners and other sensitive equipment.

Note 2: Please forward other RCD/RCCB Brands to the Ghana Standards Authority (GSA)for testing, Present all approved reports to the Commission for verification and approval for Practitioners use.