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Electrical Installation Safety Assessment of Buildings in Kumasi, Ghana

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Abstract

This study aims to evaluate the safety status of electrical installations in residential and commercial buildings within the Suame ECG strategic business unit, Ghana, focusing on compliance with international and Ghanaian wiring standards. The research assesses key factors influencing safety, including the certification of electricians, the quality of cable brands used, proper cable sizing, adherence to wiring color codes, the awareness and use of Residual Current Circuit Breakers (RCCBs), and the protection of earth electrodes. A descriptive research design was utilized, involving extensive field surveys and electrical installation audits. Data were collected using standardized tools and analyzed with SPSS software to evaluate the professional competencies of artisans and their adherence to safety standards. The findings indicate significant safety risks, with 69.7% of electricians lacking proper certification, leading to the widespread use of non-approved cable brands, improper cable sizing, and deviations from wiring color codes. Additionally, deficiencies were found in the awareness and use of RCCBs and the protection of earth electrodes. The study concludes with recommendations to enhance electrical safety, including mandatory certification for electricians, public awareness campaigns, regular inspections, and ongoing training and development programs. These measures are crucial for improving the overall safety and quality of electrical installations in the Suame area, Ghana.

Keywords

Earthing System, Energy Commission, Ghana Wiring Code, Residual Current Circuit Breaker, Safety

1. Introduction

Electricity plays a key role in keeping homes, businesses, and the economy running [1]. Despite the benefits of electricity, it poses significant hazards, such as electrocution, fire outbreaks, loss of property, and even death. The increasing number of electrical accidents and fires caused by faulty electrical installations has made safety assessment of electrical installations in residential and commercial buildings a crucial issue [2].

The growing demand for electricity underscores the need to enhance safety measures in its usage [3]. Electrical safety involves methods, measures, and protocols designed to mitigate electrical hazards and protect people, property, and the environment from electrical [4] [5]. This encompasses conforming to electrical codes and standards, professional installation and maintenance of electrical systems, and the use of personal protective equipment (PPE) and safety procedures to reduce risks such as electrical shocks, fires, and other dangerous events [6]. Electrical safety also aims to raise awareness, educate individuals, and ensure the adoption of best practices to prevent injuries, fatalities, and property damage caused by electrical hazards.

According to the Ghana National Fire Service (2023), 90% of recorded domestic fire outbreaks stem from electrical origins [7]. These incidents are often attributed to unprofessional electrical installation practices in homes and shops [7]. To address this issue, it is essential to focus on the standards and ethics established by electrical engineering regulation bodies and associations [8]. Various codes and standards, such as the National Electrical Code (NEC), IEC 60446, BS 7671, the Ghana Wiring Code (GS 1009) [9]-[11], and Electrical Wiring Regulations have been developed globally and locally to regulate the design, installation, and maintenance of electrical installations in buildings. These codes and standards set the minimum requirements to ensure the safety of occupants and the protection of lives and properties.

Despite the extensive research on electrical wiring and installations [3] [5] [12]-[18], there is a significant gap in the literature regarding the method. Therefore, this study aims to evaluate the safety status of electrical wiring across various structures, including residential and commercial buildings, to confirm their adherence to international or Ghanaian wiring standards. The findings are expected to provide valuable insights for relevant agencies and contribute to educating communities, policymakers, and investors about the critical importance of adhering to electrical standards.

The structure of this article is organized as follows: It begins by discussing the theoretical foundations of electrical safety and wiring standards. Next, it examines the practical application of these standards in residential and commercial buildings within the Suame ECG strategic business unit in Ghana. The article then identifies the challenges and gaps in adherence to these standards, providing empirical evidence on safety practices and issues related to electrical installations in the region. Finally, it concludes with recommendations for enhancing electrical safety, including mandatory certification, public awareness campaigns, regular inspections, and ongoing training programs. The study in relation to other work have these distinct contributions:

a. A pioneering scientific methodology for evaluating the safety of electrical installations in residential and commercial buildings across Ghana.

b. A valuable insight into the safety practices and challenges inherent in Ghana's electrical installation works is established using novel approach.

c. The paper presents empirical evidence on the relationship between the artisan, materials used for installation and the technical requirement for installation works in Ghana.

2. Study Area

Suame, an urban area with a mix of residential, commercial, and industrial zones, is a critical hub for Ghana's automotive and engineering industries, significantly contributing to the region's economy [19] [20]. Suame is a vibrant and bustling industrial area located in Kumasi, Ghana, which is located at latitude 6.6881˚N and longitude 1.6248˚W. Suame is known for its significant contribution to Ghana's automotive and engineering industries, making it a hub for manufacturing, repair, and maintenance activities [19] [20]. Suame's industrial activities, including car repairs, metal fabrication, and welding, are carried out by numerous artisans, mechanics, and technicians who operate in a densely packed network of workshops and factories. However, this bustling environment faces significant challenges such as inadequate infrastructure, limited access to basic services, and informal employment practices, which heighten the risk of electrical safety issues [21] [22].

Given its economic importance and the potential hazards associated with its infrastructure, Suame presents a vital case for studying electrical installation safety. Addressing these safety concerns is not only crucial for protecting the lives and properties of its residents but also for ensuring the sustainability of its industrial activities, which are essential to the broader economy of Kumasi and the Ashanti Region [23]. A map of Kumasi Metropolis showing the research area (Suame) is presented in **Figure 1**.

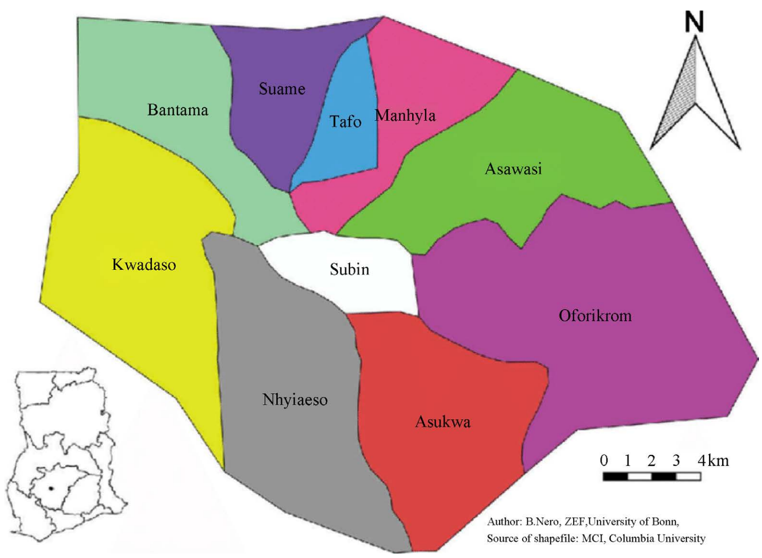

Figure 1. Map of kumasi metropolis [24].

3. Data Collection

To collect data from artisans involved in electrical wiring within the Suame-Kumasi, Ghana, the study employed a mixed-methods approach, utilizing both qualitative and quantitative techniques. Well-structured, closed-ended questionnaires (test sheets) were designed and distributed to gather detailed information. A total of 300 test sheets were administered directly by the study, ensuring prompt collection and providing an opportunity to clarify any ambiguities that arose during the process. A flow chart representing the framework of this paper can be found in Figure 2.

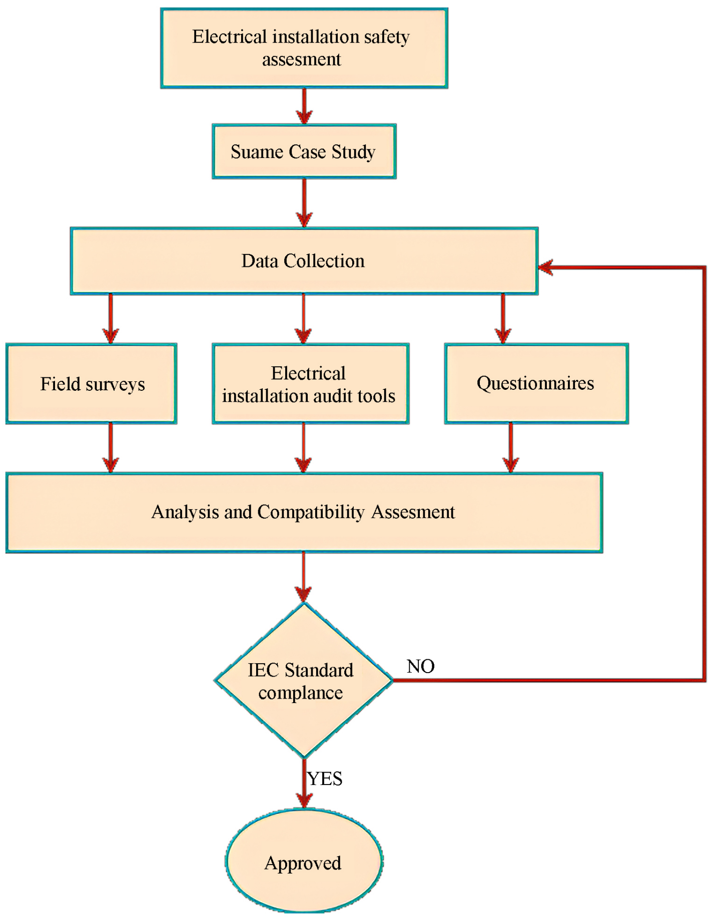

Figure 2. Study framework.

The study focused on electrical installations in commercial and residential buildings in Suame-Kumasi, Ghana. The target population included both certified and uncertified electricians who had worked on these buildings. The study specifically targeted facilities within Suame-Kumasi where the owners had applied for energy meters through the Electricity Company of Ghana (ECG). Out of approximately 1,300 applicants during the study period, a sample size of 300 was selected to achieve a 95% confidence level.

An electrical installation audit was conducted to assess compliance with the standardized wiring requirements set by the Energy Commission's electrical wiring program and the IET wiring regulations (18th edition) [10] [25]. The audit included various testing and inspection procedures to evaluate the materials used, the design of the installations, and the competency levels of the artisans performing the work.

Specific tests, such as continuity and insulation resistance tests, were conducted using the UNIT-UT 501A instrument, while the UNIT-UT 5021 instrument was used for earth electrode resistance testing. These tests, performed before the electrical supply was connected to the facilities, were part of the pre-connection audit process. Additional live tests were also conducted on facilities that already had electrical connections but required new energy meters due to alterations or additions to their electrical circuits.

To achieve the study's objectives, the study utilized three software tools: FlashWorks, Electrical Transient Program (ETAP), and Statistical Package for the Social Sciences (SPSS). SPSS was the primary tool for data analysis, with frequencies and percentages used to illustrate the artisans' perspectives, the resources they utilized, and their typical installation methods. ETAP was employed to simulate common electrical installation circuits and materials, followed by a short circuit study to analyze fault response. FlashWorks was used to determine the appropriate rating for overcurrent protection devices by calculating the model's minimum breaking capacity.

4. Result and Discussion

4.1. Status of the Electricians Working within the Study Area

To align with international electrical safety standards, such as those set by the International Electrotechnical Commission (IEC) and the National Fire Protection Association (NFPA), it is essential that only certified electricians conduct electrical wiring installations to ensure compliance and safety. The Ghana Energy Commission's regulations (L.I. 2008) mandate certification for electricians performing such installations [8] [9]. However, a significant portion of electricians in the study area lack certification, raising concerns about the safety and quality of electrical work. Data presented in **Figure 3** reveals that only 91 electricians (30.3%) were certified, while 209 electricians (69.7%) were uncertified, yet still involved in electrical work on both residential and commercial buildings. This disparity highlights a critical gap in regulatory compliance, which could lead to substandard installations and pose significant safety risks.

To further explore this issue, a targeted quantitative analysis was conducted, comparing the quality of installations between certified and non-certified electricians. The results showed a markedly higher incidence of safety violations and non-compliance with established wiring standards among non-certified electricians, underscoring the urgent need for stricter enforcement of certification requirements. These findings are consistent with global research, including a study by [26], which found similar trends in urban settings, where the lack of electrician certification led to increased safety hazards. To address these risks, it is imperative for the Ghana Energy Commission and other relevant authorities to implement comprehensive public education campaigns, emphasizing the importance of hiring certified electricians. Such measures are crucial for safeguarding the safety and well-being of properties and occupants in Ghana, contributing to a broader commitment to upholding international safety standards.

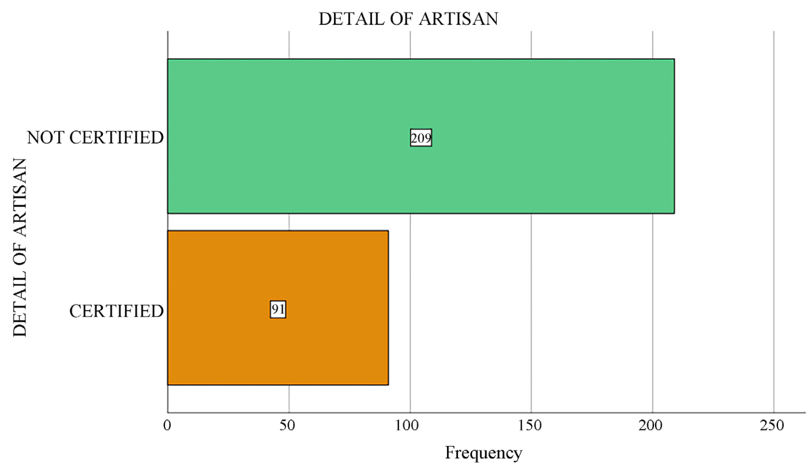

Figure 3. Status of the electricians.

The reasons behind the lack of certification among many electricians are multifaceted. Economic barriers often prevent electricians from pursuing certification due to the costs associated with training programs and exams. Additionally, limited access to accredited training programs, particularly in rural or economically disadvantaged areas, restricts opportunities for obtaining certification. Many electricians acquire their skills through informal apprenticeships rather than formal education, leaving them without the necessary documentation for certification despite their practical experience. Furthermore, there is a general lack of awareness about the importance and benefits of certification, which reduces its priority among electricians. Regulatory gaps also contribute, as weak enforcement of certification requirements allows unlicensed electricians to operate without facing significant penalties. Cultural factors may also play a role, as some communities have a tradition of passing down trade skills through generations without formal certification.

Addressing these issues requires a comprehensive approach, including making certification more accessible and affordable, increasing awareness of its importance, and strengthening regulatory enforcement to encourage electricians to obtain and maintain certification.

4.2. Cable Brands Mostly Used for Electrical Wiring within the Study Area

When selecting an electric cable for a specific task, various factors must be considered, including design temperature, flexibility requirements, abrasion resistance, strength, insulation, electrical resistance, weight, and the applied voltage and current flow, all of which significantly influence the choice of cables to be used [27] [28]. Among the wiring installers, TCCL Ghana cable (8.7%), COSTA cable (16.3%), and BASEC cables (40.0%) emerged as the preferred options, with BASEC cables being widely favored by electricians in the study area, as shown in **Figure 4**.

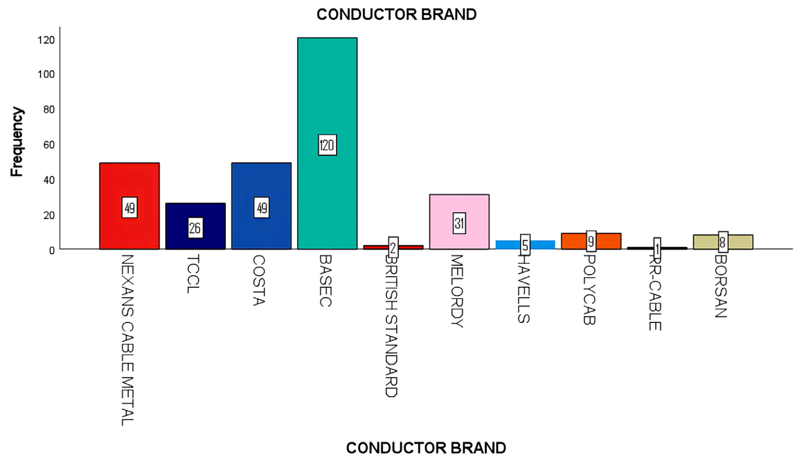

Figure 4. Cable brand mostly used for electrical wiring.

The Ghana Standard Authority (GSA) has approved numerous cable brands for use by electricians, as detailed in GS IEC 60502. However, despite Melody cables lacking approval from the Ghana Standard Authority [11] [29], 10.3% of electrical wiring installers continued to use Melody cables for their work. This raises significant concerns regarding safety and compliance with established standards.

To further analyze this issue, a targeted quantitative analysis was conducted to assess the correlation between the use of non-approved cables and the incidence of electrical failures and safety violations. The results revealed that installations using Melody cables had a markedly higher rate of non-compliance with safety standards and a greater incidence of electrical faults compared to those using GSA-approved cables. This finding aligns with research by [30] [31], who highlighted that non-compliance with approved cable brands is a prevalent issue in many developing regions, contributing to frequent electrical failures and fire hazards. These results underscore the critical need for stricter enforcement of cable standards and increased awareness among electricians about the importance of using approved cables to ensure safety and reliability in electrical installations.

4.3. Insulation Resistance Test for Various Cable Brands

Insulation resistance is a critical parameter for evaluating the quality and performance of an electric cable, as it measures the resistance offered by the insulation material of the cable to the flow of electric current. A high resistance value indicates effective insulation and safe operation [28]. According to Table 61 of BS 7671 [25], Regulation 612.3.2 [32] specifies that the minimum permissible insulation resistance for a distribution circuit with a distribution board or consumer unit, along with all its final circuits, is 1 MΩ. As shown in **Table 1**, out of 300 installations assessed, 293 (97.7%) were classified as satisfactory. Brands such as Nexans cable metal, TCCL, BASEC, British Standard, Melody, Harvells , Polycab, RR-cable, and Borsan achieved 100% satisfaction rates, with BASEC emerging as the most trusted brand, boasting 120 satisfactory installations.

Table 1. Insulation resistance test for various cable brands.

Conductor brands	Satisfactory	Not Satisfactory	Total
Nexans cable metal	49	0	49
TCCL	26	0	26
Costa	42	7	49
BASEC	120	0	120
British standard	2	0	2
Melordy	31	0	31
Harvells	5	0	5
Polycab	9	0	9
RR-cable	1	0	1
Borsan	8	0	8
Total	**293**	**7**	**300**

However, despite being an approved cable by the Ghana Standard Authority, Costa cables exhibited lower performance, with 7 installations classified as not satisfactory, primarily due to issues related to old wiring. Melody cables, although not approved by the Ghana Standard Authority, achieved 100% satisfaction across 31 installations. This overall trend of high reliability across most brands, except for Costa, suggests a need for quality improvement in specific cases. A more detailed quantitative analysis revealed that the insulation resistance of Costa cables in older installations consistently fell below the 1 MΩ threshold, raising concerns about their long-term reliability. These results are consistent with the findings of [28] [33], who also reported problems with certain cable brands not meeting the required insulation resistance standards, which can lead to potential safety risks. This underscores the need for ongoing monitoring and stringent enforcement of quality standards to ensure electrical safety.

4.4. Size of Electrical Cables Used for Electrical Wiring

Table 2 presents feedback from the questionnaires on the sizing of electric cables used in electrical wiring within the study area. The data indicate a significant issue: many uncertified electricians often neglect the current-carrying capacity of cables when performing installations in residential and commercial buildings.

Specifically, **Table 2** reveals that 3.3% of uncertified electricians used 2.5 mm^2 cables for air conditioners and cooking units, and 10.3% used 1.5 mm^2 cables for socket outlets, both of which fall short of the recommended sizes of 4 mm^2 - 6 mm^2 and 2.5 mm^2, respectively, as specified by [8]. This practice, leading to "Not Satisfactory" performance, increases the risk of cable overheating and potential electrical fires [7]. The ability to select the correct cable size for specific appliances is crucial, as outlined in [27] [33] [34]. This issue, previously highlighted by [7], underscores the importance of adhering to recommended cable sizes to ensure the safe and efficient operation of electrical systems.

Table 2. Responses of electrical cables sizes used for electrical wiring in Suame vicinity.

Cable status	Cable size for lighting		Cable size for socket		Cable size for AC		Cable size for heater or heavy machine	
	N	%	N	%	N	%	N	%
Satisfactory	299	99.7%	268	89.3%	83	27.7%	25	8.3%
Not satisfactory	0	0%	31	10.3%	10	3.3%	8	2.7%
Not available	1	0.3%	1	0.3%	207	69.0%	267	89.0%
TOTAL	**300**		**300**		**300**		**300**	

4.5. Termination of Cables in the Distribution Board and Sockets

Cable termination involves securely connecting the ends of electrical wires to various components or devices within a system [35] [36]. This process is essential for ensuring the integrity, reliability, and safety of electrical installations, as proper termination prevents leakage, reduces the risk of electrical fires, and maintains electrical continuity [37] [38]. According to the results, 80.7% of electrical wiring installations had satisfactory cable terminations in distribution boards and socket outlets. Among these, 24.3% of the terminations were performed by certified electricians, while 56.3% were done by uncertified electricians. This raises concerns about safety and quality, as a substantial portion of satisfactory terminations were completed by uncertified individuals, as illustrated in Figure 5.

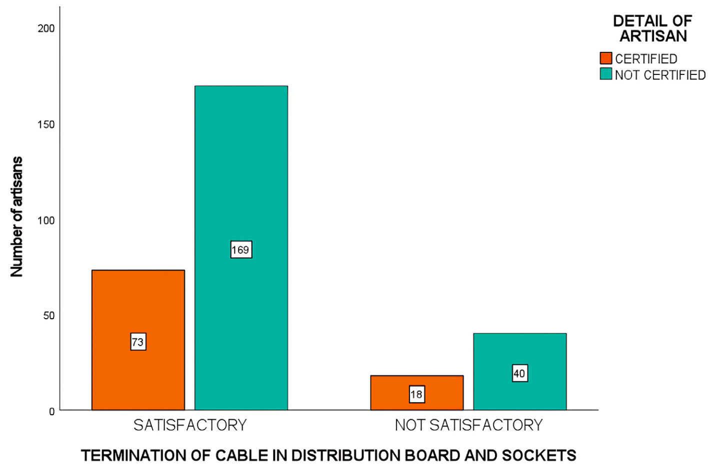

Figure 5. Termination of cables in the distribution board and sockets.

Conversely, 19.3% of terminations were categorized as "Not Satisfactory," with 13.3% performed by uncertified artisans, indicating a higher risk of safety and quality issues. Notably, 6% of "Not Satisfactory" terminations were carried out by certified electricians, suggesting potential gaps in their compliance to safety standards specified in IEC 60364-5-52 [9]. This underscores the critical importance of proper cable termination, as highlighted by [39] [40], who identified improper terminations as a major cause of electrical faults and fire hazards in building installations.

4.6. Cable Color Code Compliance with Wiring Regulation and Specification

Analysis of electrical wiring installations within the Suame-Kumasi, Ghana revealed that 26.3% of certified installers adhered to the IEC 60446 wiring color code standard [8] [9], with only 4% showing non-compliance, as depicted in **Figure 6**. In contrast, 54.7% of uncertified installers followed the standard, while 15% did not comply.

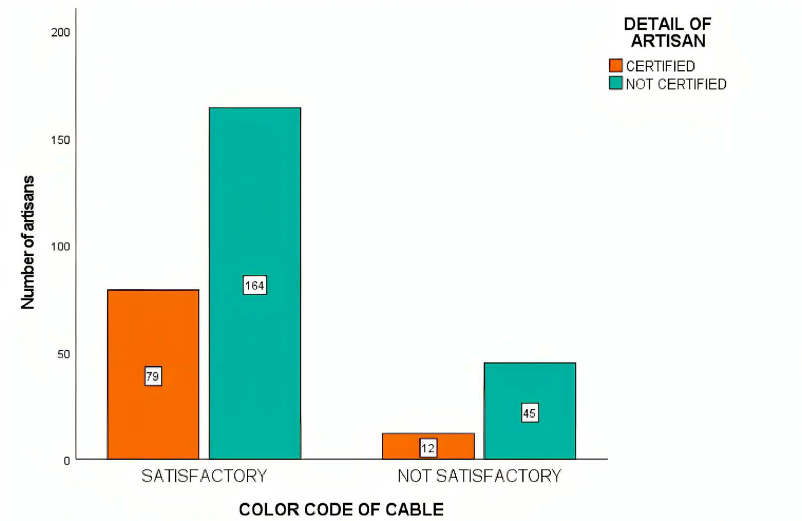

Figure 6. Cables color code compliance with wiring regulation and specification.

This variation in adherence to standard practices among both certified and uncertified electricians poses significant safety risks, such as potential electrical fires or electrocution. To enhance the safety of electrical installations, it is crucial to provide comprehensive training and education to installers on the importance of adhering to established standards, particularly the IEC 60446 wiring color codes standard [8] [9].

4.7. Brand of Residual Current Circuit Breaker (RCCB) Mostly Used and Rating Purpose

The survey conducted among electrical wiring installers in the study area revealed that Harvells RCCB was the preferred brand among both certified and non-certified artisans, with 56.7% of the 300 respondents choosing Harvells , followed by Schneider, as illustrated in **Figure 7**. However, the survey also highlighted a concerning gap in knowledge, as 2.7% of uncertified electricians either lacked awareness of RCCBs or performed electrical wiring without them. According to established standards [8] [9], RCCBs rated at 63 A/30mA are suitable for residential and commercial settings with lower power consumption, designed to trip or disconnect when a leakage fault is detected. Conversely, RCCBs rated at 100 A/300mA are intended for commercial and industrial applications or locations with higher power consumption.

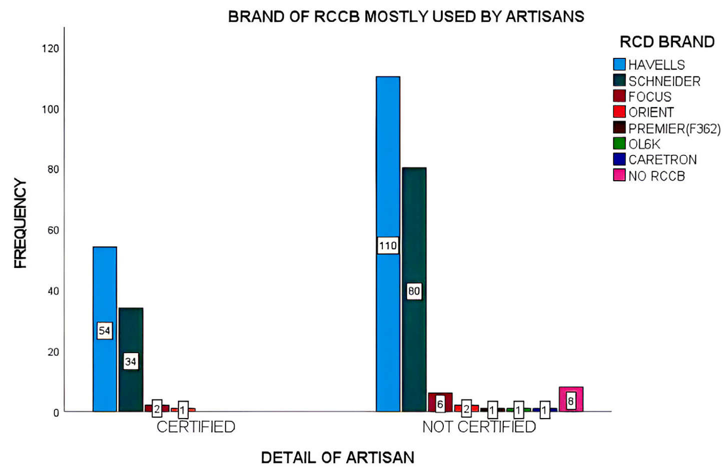

Figure 7. Description of premises and RCCB rating.

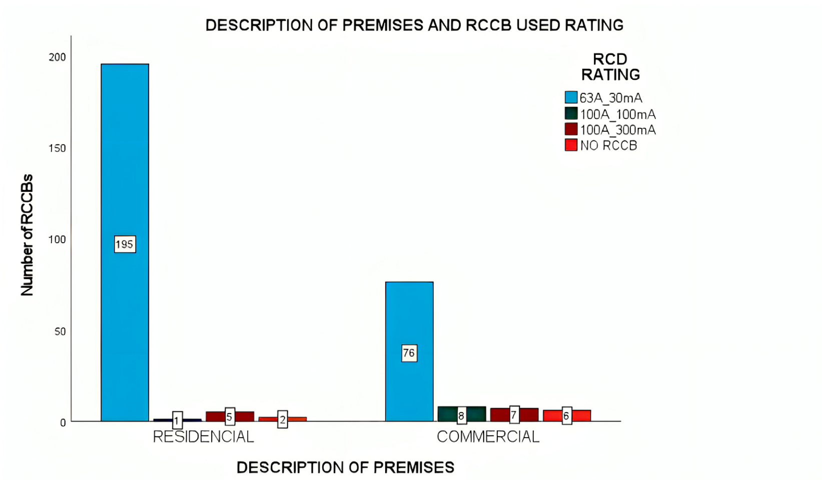

Figure 8. Brand of RCCB mostly used.

Figure 8 further reveals that 4.0% of uncertified electricians misused 100 A/300mA RCCBs in residential and commercial settings, where lower-rated RCCBs would have been more appropriate. This misuse suggests non-compliance with IEC standard 61,008 [9], raising potential safety risks and underscoring the need for stricter adherence to industry standards [9]. The survey indicated that among certified artisans, Harvells was the most preferred brand, chosen by 59.3% of them, followed by Schneider at 37.4%. In contrast, non-certified artisans also favored Harvells , with 54.1% selecting it, followed by Schneider, Focus, Orient, Premier (F362), and OL6K brands. Overall, Harvells was the most popular brand, chosen by 55.7% of the total sample. These findings suggest that the preference for Harvells and Schneider RCCBs among both certified and uncertified electricians may be due to their accessibility, reliability, and safety. However, the lower frequency of RCCB purchases among uncertified electricians may indicate a lack of awareness of their importance in electrical installations. Additionally, the content emphasizes the importance of ensuring that RCCBs are selected based on their suitability for the specific application and in compliance with relevant standards and regulations.

According to IEC standard 61008, RCCBs must have a maximum rated residual operating current of 30 mA and a maximum trip duration of 300 ms. Both Harvells and Schneider RCCBs meet these requirements, making them popular among licensed electricians. The Ghana Standard Authority has approved Harvells , Schneider, and Focus RCCBs for use in Ghana, as shown [11], according to the Ghana Energy Commission. However, the widespread use of unauthorized brands such as Orient, Premier, OL6K, and Caretron by many electricians indicates a need for stricter regulatory enforcement and better education to ensure electrical safety.

4.8. Protection of Earth Electrode and Its Resistance Value

Ensuring the proper protection of earth electrodes is crucial for the effectiveness of grounding systems, especially in power distribution networks. Earth electrodes, which are buried underground, provide a low-resistance path for safely dissipating fault currents into the ground [41]-[44]. According to international guidelines, such as those outlined by IEC 60364 and IEC 62305 [9], the resistance of earth electrodes in both residential and commercial buildings should meet specific safety thresholds to ensure effective grounding [8] [9] [32]. **Figure 9** illustrates the status of earth electrode protection and their resistance values. Among the 300 premises surveyed, 51% of earth electrodes were classified as satisfactory, 22.3% were deemed not satisfactory, and 26.7% were inaccessible for testing.

Additionally, 5.4% of earth electrodes were found to be buried without proper protection or an earth chamber. Within this 5.4%, 3.4% of installations were carried out by uncertified electricians, while 2.0% were performed by certified electricians despite their training. These findings reveal significant deviations from the standards outlined in IEC 62305 for earth electrode protection and IEC 60364-4-41 for earth resistance [9] [32] [40], highlighting the need for improved attachment to these critical safety standards.

4.9. Evaluation of Protective Devices

Short circuit calculations are crucial in the design and analysis of electrical systems, providing essential information on the magnitude and duration of potential short circuit currents. These calculations help ensure that protective devices are appropriately rated to handle such currents, thereby safeguarding the system. In this study, FlashWorks software was utilized to perform a short circuit analysis on a system featuring a single-phase copper wire with a line-to-line voltage of 400 volts and a conductor length of 50 feet. The objective was to determine the short circuit current and assess whether the protective device's equipment rating was adequate.

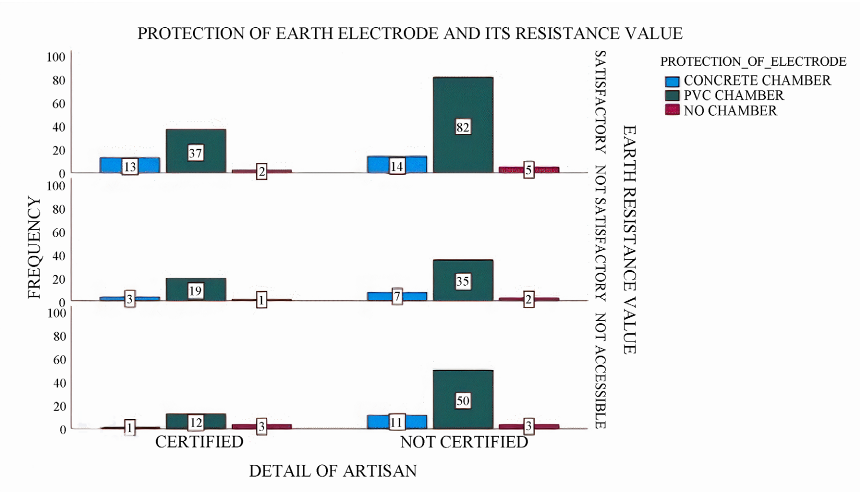

Figure 9. Protection of earth electrode and its resistance value.

The analysis revealed a simulated short circuit current of 8.65 kA, while the protective device had a rating of 10 kA, which exceeds the calculated short circuit current. This indicates that the protective device is adequately rated to manage the expected short circuit current, with a breaking capacity that meets or exceeds the necessary threshold of 10 kA.

Furthermore, the common electrical circuits in the Suame Electricity Strategic Business Unit were modeled using ETAP and simulated under short circuit fault conditions. This allowed for a detailed evaluation of the breaking capacity and sensitivity of the most commonly used brands of circuit breakers. The technical parameters of various circuit breakers, including Harvells, were modeled in ETAP using field data for Short Circuit Fault Analysis.

The results demonstrated that the 6 A breaker in the lighting circuit has a lower rated short-time current of 0.2 kA and minimal thermal energy dissipation capability, indicating potential limitations in handling high short circuit currents. In contrast, breakers with higher ratings, such as 16 A, 25 A, and 32 A, exhibited stronger capabilities in managing short circuit events, with higher short-time current ratings and greater thermal energy dissipation.

The analysis underscores the importance of selecting appropriate circuit breakers based on the specific requirements of each circuit. According to the IEC 60898 standard [9], a minimum breaking capacity of 10 kA is required for protective devices. The Harvells breaker met this requirement, validating its use in installation work within the power circuit. The findings of this study provide valuable insights for selecting and evaluating protective devices, ensuring they are capable of withstanding the demands of short circuit conditions while maintaining the safety and integrity of the electrical system.

5. Conclusions

The study identified significant gaps in compliance with electrical safety standards in the study area, revealing that uncertified electricians frequently neglect best practices. This negligence leads to potential safety hazards, including the use of non-approved cable brands, improper cable sizing, and inadequate protection of earth electrodes, all of which pose substantial risks such as electrical fires and system failures.

To address these issues, it is recommended that the Ghana Energy Commission intensifies efforts to enforce certification requirements and provide ongoing training for both certified and uncertified electricians. Public awareness campaigns should be launched to educate property owners on the importance of hiring certified professionals for electrical installations. Additionally, regular inspections and stricter enforcement of standards, such as IEC 60446, IEC 60364-4-41, and IEC 62305, are crucial for improving the overall safety of electrical installations.

Policymakers should consider revising and updating existing regulations to reflect these findings, ensuring that safety standards are maintained and adapted to evolving technologies and practices. Implementing these recommendations will help reduce electrical hazards and improve the reliability and safety of electrical installations in the region.

Future research should focus on several key areas to further address electrical safety issues. One direction could involve investigating the effectiveness of current public awareness campaigns and training programs for electricians, particularly in underserved areas, to identify gaps and areas for improvement. Additionally, research could explore the development and testing of new certification programs that are more accessible and tailored to the needs of electricians in rural and economically disadvantaged regions.

Another important area for future study could involve evaluating the enforcement mechanisms for electrical safety regulations, assessing their impact on compliance rates and overall safety. This research could help identify weaknesses in the current regulatory framework and suggest more robust enforcement strategies.

Finally, exploring the integration of emerging technologies, such as smart monitoring systems for electrical installations, could provide new insights into preventing safety hazards. This research could lead to innovative solutions that enhance the reliability and safety of electrical systems, aligning with international best practices and standards.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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