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RESEARCH ARTICLE

Quantitative Study of Magnetic, Physical Properties and Microstructural Composition of Tungsten Carbide

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Abstract
Tungsten Carbide is a hard and dense material with very high rigidity. The density is about 15.0g/cm^3 with thermal conductivity of 110w/m^{o}c and coefficient of thermal expansion of 6.2µm^{-1}K^{-1}. The melting and decomposition point is about 2,560^{o}c and boiling point of 6,200^{o}c. The poisson's ratio is 0.31 and the compressive strength at 20^{o}c is about 6200N/mm^2 with young's modulus ranging from 400 to 630 GPa. Tungsten Carbide is slightly magnetic and as an alloy, the magnetic property depends upon either mixed with cobalt or nicked. It is combination with other metals as an alloy make it hard and durable. The mixture of powdered carbon and tungsten heated at the temperature of 1600^{0}c(2,900^{0}F) formed tungsten-carbide. Tungsten Carbide is an important material for metal works, rock, metal manufacturing industries and geological drillings as a result of its hardness and wear resistance.

Keywords: Tungsten Carbide; physical; magnetic properties; microstructural composition

Introduction

Tungsten Carbide is a metal like substance, dense and light gray with a bluish tinge which decomposes at about 2,600^{o}c. Tungsten Carbide is a chemical compound that contains equal parts of Tungsten and carbon atoms. It is prepared by heating powdered Tungsten with carbon black in the presence of hydrogen at 1,600^{o}c. It can be pressed and formed into shapes through sintering for use in industrial machinery, cutting tools, chisels, abrasives, armor-piercing shells and jewelry for possible fabrication, the powdered Tungsten Carbide is mixed with another powdered metal like cobalt and pressed into the desired shape and heated to temperature of 1,600^{o}c, and melts, dissolves the grains of tungsten Carbide, this acts as a binder or cement. Thus, the cemented composites of tungsten Carbide cobalt are usually called Widia and carboloy (WC). It is highly resistance to deformation and keeps its stability at cold and hot temperatures. The combination of hardness, strength, toughness and chemical stability makes the cemented carbide excellent in performance (10). Tungsten Carbide is twice as stiff as steal with a young's modulus 650 GPa and double the density of steel. Tungsten Carbide has high strength for a material so hard and rigid (4). The tungsten carbide-cobalt as base materials, in its most applications, this alloy will contain small addition of carbides such as Tic, Tac and N_bC to improve machinability of steels (1). Tungsten Carbide are cemented together by a tough and ductile binder (Co, Ni, Fe) (11) and the combination of hardness and toughness makes cemented carbides ideal materials for rock drilling inserts, and metal cutting tools (5), (6). Tungsten carbide compounds are also known as hard metals. The properties of hard metals are affected by cobalt concentration and the impurities present in the material and other metals such as tantalum, titanium, variadium and chromium, are added to tungsten carbide for various reasons but mainly to inhibit grain growth (2) in (7). With the continuous use, wearing of the cemented carbide happens which makes its service life drastically reduced (8). Tungsten carbide has resistance to galling and welding at the surface and also has sufficient resistance to corrosion – wear conditions for many applications. Tungsten carbide is used to make the rotating ball in the tips of ball point pens that disperse ink during writing, in the manufacture of ganged blocks, used as a system for producing precision lengths in dimensional metrology and tungsten carbide coating is good for brake discs in high performance automotive applications to improve performance, increase service intervals and reduce brake dust. In this paper, a review on tungsten carbide, its physical, magnetic properties and microstructural composition has been presented.

Physical characterizations of Tungsten Carbide

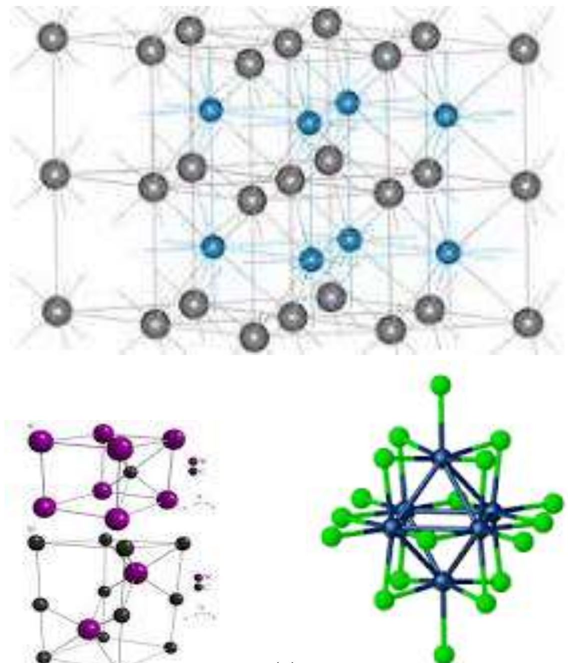
Tungsten Carbide is a hard material with very high rigidity and the impact resistance is high because it is in the range of hardened tool steels of lower hardness and compressive strength of about 2.6 GPa. The density is about 15.0g/cm^3 with thermal conductivity of 110W/m^{o}C and coefficient of thermal expansion of 6.2µ m^{-1}K^{-1}. It undergoes no phase changes during heating and cooling, Tungsten Carbide retains its stability indefinitely and retains toughness and impact strength in the cryogenic temperature ranges. The melting point is about 2560^{o}c and boiling point of 6,200^{o}c. Its hardness varies with WC grain size and co content. The poison's ratio is 0.31 while the compressive strength at 20^{o}c is about 6200N/mm^2 with young's modulus ranging from 400 to 630 GPa which is two to three times higher than that of steel (3). According to (10), it is highly dependent on grain size of 3-20µm and its value approaches 523 GPa when WC grain size becomes 30µm. It is inversely proportional to the Co content (9). Tungsten Carbide has coefficient of friction of 0.25, it is slightly magnetic. In a molten phase with cobalt, an abnormal grain growth occur in the sintering of Tungsten Carbide and this have enormous effects on the performance of the product material. It has ability to resist fracture or energy needed for mechanical failure.

Magnetic Properties of Tungsten Carbide

Tungsten Carbide is slightly magnetic. Tungsten Carbide is an alloy and its magnetic property depends upon either mixed with cobalt or nicked binder (3). Cobalt strongly attracts a magnet but nickel does not. As tungsten carbide has nickel-binder, it will not attract a magnet, but only if the binder is cobalt. Tungsten has a very low susceptibility to magnetism but tungsten Carbide which is an alloy of tungsten and carbon is slightly magnetic because the elements in it are susceptible to magnetism. Tungsten is paramagnetic, so it is weakly attracted to magnets. The Carbide parts of tungsten are magnetized both during production and in use. It is not always possible to identify a single source of the residual magnetism and the common cause is magnetic clamping during grinding that can results in strong magnetization. Tungsten is more valuable as an alloying element to create improved metal alloys when added to base metals while tungsten is an invaluable element in the alloying process, where dements are blended to form new and improved metals known as alloys. Tungsten Carbide is corrosion resistance. Pure cobalt in cemented carbides has normal magnetic properties. The combination of metals in the alloy is what makes tungsten carbide so strong and durable as well as shiny and expensive looking. A regular wire cutter or hacksaw will not even be able to put a dent on the ring but a rotary saw with a diamond coated blade can cut through a tungsten carbide ring in seconds.

Microstructure of Tungsten Carbide

(a)



(b) (c)

Figure 1: (a) Chemical composition (b) Micro Structure and (c) molecular structure of tungsten carbide

Tungsten- Carbide formation consist of a gray powder which is heated at temperature of 1600^{0}c after which can be pressed and mold into different shapes through sintering. Chemically, tungsten carbide has structure similar to diamond structure which are surrounded tetrahedral by atoms of both carbon and silicon. This compound is extremely hard and inert and the formula of Tungsten Carbide (Widia $ Carboloy) is **WC.** The compound of tungsten with different non- metallic elements has covalent bonds chemically in which the electrons are shared between the atoms of the elements. In the preparation process, binder materials are usually added to hold the powder form together for easy pressing into shapes.

Atomic Mass	183.84U
Electron Configuration	[X_e] $6S^2 4f^{14} 5d^4$
Oxidation State	+6
Year discovered	1783

The general properties of carbides includes brittle, hard, and relatively resistance to corrosion. They are gray or black in color and have a metallic luster. The most common carbides are those of carbon and silicon.

The Compositions of Tungsten- Carbide

Tungsten- Carbide with the formula of WC contains both tungsten and carbon atoms shared. Thermal conductivity : 110w/mk, crystal structure: hexagonal, hp2. It is an organic compound of tungsten W and carbon C that is stable at low temperature. WC has tetrahedral structure of diamond and make up of tungsten and carbon at different percentages of combination as observed in the phase diagram.

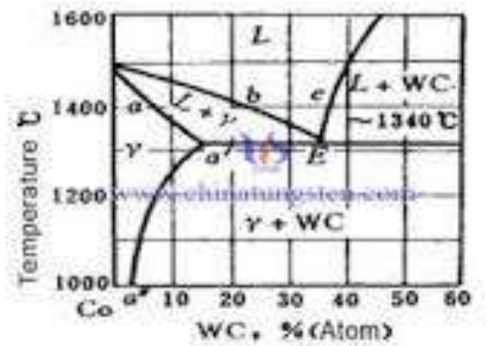


Figure 2: Phase diagram of tungsten carbide.

Tungsten carbide would be very difficult to melt. For commercial purposes, the high tungsten melting point makes liquid tungsten very impossible. High quality tungsten carbide mixed with nicked binder is chemically inert and will not oxide, that is, react with oxygen or tarnish or rust except at temperature reaching 600C.

Conclusion/Summary

Tungsten Carbide is a very important tool material for metal work, drillings, cutting, and mining works.

i. Tungsten carbide is very hard, durable, shining with good looking.
ii. It melts or decomposes at the temperature of 2,600ºc (4,700ºF).
iii. It is processed by heating the mixture of powdered tungsten with carbon at temperature of 1,600ºc (2,900ºF).
iv. Powdered tungsten carbide can be easily mixed with cobalt as binder to form WC .
v. Tungsten Carbide is hard, rigid substance and high strength.
vi. It has wear resistance and very tough
vii. Tungsten Carbide behaves well in oxidizing atmosphere at 1200ºF and non-oxidizing atmospheres at 1600ºF.
viii. It retains its stability of hardness, toughness, strong strength and rigidity as temperature changes..

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RESEARCH ARTICLE

Fire Properties of Hybrid Composites

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ABSTRACT
Thermal conductivity of a components subjected to high temperature is an important property to be considered in a materials to be used in automobile and aerospace fire designated zones; likewise, it is availability, cost, stiffness, resistant to corrosion, and its strength. The main aim of the study is to investigate the fire behavioral properties of fiber metal laminates (FML) composite of a metal, synthetic, natural and polymer matrix. The composites were fabricated in a mould using hand lay-up method and allow curing before test. The fire property test was carried out using the standard properties test equipment as ISO 2685 propane burner, thermocouples, and heat flux meter. The result of the properties test shows a remarkable increase in the properties of only natural fibre metal laminate composites, with a slight decrease in the properties of pure synthetic fiber metal laminates. Flax composite has a high percentage of 21.43% of thermal conductivity and withstands the flame temperature for 15 minutes using an ISO 2685 standard, while kenaf composite fail at 10 minutes 30 seconds. Conclusively, the composites can be used as the component in fire designated zones of automotive, aerospace and other machines.

Keywords: Automotive; burner; calibration; heat flux; thermal conductivity.

Introduction

The fibre-metal laminate (FML) composite consists reinforced fibre (synthetic or natural such as carbon fiber, glass fiber, Kevlar, flax, kenaf, coir, date palm, cotton, hemp, bamboo, jute, abaca, kapok, etc.), with different types of polymer matrix. The combination of metal alloy with reinforced fibres find application in different structural components both in civil and mechanical engineering; due to it is high properties such as its strength, stiffness thermal conductivity, water absorption among other properties such as physical structures as reported in Joseph (2022). FML composites uses as a composite for constructing different structural components (Abu Talib & Mohammed, 2019; Mohammed & Abu Talib, 2021; Mohammed & Abu Talib, 2020; Mohammed et al., 2018. Vogelesang & Vlot, 2000). The type of this composites was constructed to replace the existing steel, monolithic aluminium alloys and other metals due to its properties such as starting fatigue crack and growth of crack with measure, weight, corrosion among other properties (Mohammed & Abu Talib, 2021; Mohammed & Abu Talib, 2019; Mohammed & Abu Talib, 2018). Among the types of FML composites fabricated and used today in different part of machine were Kevlar composite (ARALL) that have the drawback of brittleness that limits its application on the primary structures, carbon fiber and glass fibre reinforced composite (CARALL and GLARE) with excellent properties were developed and been used widely now a day in various industries (Jumahat et al., 2015; Li & WU, 2017; (Mohammed & Abu Talib, 2021; (Mohammed & Abu Talib, 2019).

The glass and carbon fibers reinforced plastic (CFRP and GFRP) composites has been used for many past decade due to its high mechanical, thermal and impact properties in terms of stiffness and strength (Matthews & Rawlings, 1999; Mohammed et al., 2017). These reinforced fibers were in different structures (pre-perg and woven), with carbon fiber been more stronger and lighter than glass-fibre, while in terms of health issues glass fibre is more harmful than carbon fibre. These two composites when used in a structural member reduce the weight of the component, withstand damage tolerance for a high specific time and in turn reduce fuel consumption by increasing the fuel efficiency. Also, the composites withstand a high temperature with low thermal conductivity (Mohammed & Rachid (2022); Mohammed et al., 2018).

Natural fibres such as kenaf and flax were now a day been used in automotive and aerospace industries since its abundant in nature and greener; also, its mechanical and physical properties were very close to that of synthetic fibers. Its limitations were mostly low strength and moisture absorption; therefore, its combination with reinforced synthetic fiber produce a composite with higher mechanical, thermal, and impact properties, which boost the fabrication process of the composites and eliminate/reduces the health risk problem during fabrication (Mohammed et al., 2018; Prabhakaran et al., 2013; Sivakumar et al., 2017; Souza et al., 2011). Bast fiber is the most recognize natural fiber used in hybridization with synthetic fiber as reported by Salman et al. (2015), uses as in form matting or cord; the fiber has flexible and finest form that can be used various form and can be machined easily. Bandaru et al. (2015) study the effect of hybridization of natural/synthetic reinforced fiber on the ballistic impact of armors composite.

This study considers the FML composite of flax and kenaf fiber, carbon fiber and aluminum alloy 2024-T3 bonded with TA/B epoxy resin and hardener. The combination yield a high strength and stiffness composite that has no or little moisture absorption, (Chang et al., 2008). The main aim of this study is to investigate the fire behavioral and thermal conductivity properties of the fabricated composites using an ISO2685 propane-air burner. ISO 2685 propane burner was used in fire behavioral test on the plate were the propane and air were the fluid used in test. The natural/synthetic composites will have excellent properties that almost compete with some types of synthetic composites more in terms of fire behaviors properties.

Materials and Methods

The composite was fabricated using 2024-T3 aluminum alloy, natural fibre (kenaf and flax) carbon fibre and polymer matrix. Two types of composites were fabricated: carbon fibre kenaf reinforced composite and carbon fibre flax reinforced composite.

Aluminium alloy 0.4mm with two layers at the front and rear face of the kenaf and flax composites, four layers of 0.25mm carbon fibre on each composite and two layers each of kenaf and flax of 0.7mm each intersecting the carbon fibre in each composite.

The ratio of resin to hardener is 65:35 mix together before bonding the composites and the weight ratio to polymer to fibre is 70:30 is the weight ratio of polymer to fibre.

In producing the composites, sheets of aluminum alloy, carbon fiber, kenaf and flax fiber were all cut 400mm x 400mm x 4mm and fabricated in a mould of 400mm x 400mm x 4mm, using a hand lay-up method. The epoxy resin/hardener was mixed accordingly and spread on each laid layers by use of the brush.

The fire test was conducted using a propane burner according to ISO 2685 standard. The test was started by calibrating the burner using and R-type thermocouples to measure the flame temperature and a heat flux meter (SBG01) to measure the heat flux according to the standard. The standard stated a flame temperature of 1100±80ºC and a heat flux of 116±10 kW/m^2. The burner was calibrated using seven thermocouples for temperature calibration that were 1-inch apart from each other and SBG01 for heat flux at a distance of 3 inches from the burner face. The calibration was started by turning on the propane gas and igniting the burner, then turning on the primary air and secondary air according to the stated gauge of the standard (propane 440Pa, primary air 4265Pa and secondary air 2940Pa)..

After the burner calibration, the fire test commences using a composite of 200mm x 200mm x 4mm each, three samples from each composite were tested and the average results were recorded using a data logger for each sample. The distance between the burner face and the plate sample was maintained at 3-inch, the samples undergo the fire test for 15 minutes. The composite that withstands the 15-minute flame fire was termed as fireproof composite while the one that fails before 15 and after 5 minutes was termed as fire resistant composite. Three K-type thermocouples were used to measure the rear face temperature of the plates; the thermocouples were placed at the centre of each plate, 1½-inches below the centre and 1½-inches left to the centre. Figure1 shows the burner assembly.

Figure 1: Burner Assembly

Result and Discussion

The properties result of all the composites considered in this investigation was presented in this section, which shows the result of fire behavioural properties of the two composites.
The fire test result of the two composites was recorded as presented in this section. The test was carried out using an ISO 2685 standard, which states the property of the material that withstands a flame fire of 1100±80ºC and a heat flux of 116±10 kW/m^2 for 15 minutes as fireproof materials and less than 15 minutes but greater or equal to 5 minutes as fire-resistant materials. The test uses a propane-air burner and the burner was calibrated before conducting the test; the calibration result shows that the burner was within the standard ranges for the flame temperature and heat flux. Table I shows the average result properties of the two composites under study.

Table I: Fire Properties of the Composite

Composites	Burn-through Time (s)	Observation
Flax	>900	Fireproof
Kenaf	630	Fire Resistant

The result obtained from the table shows that one of the composites was fireproof properties while the other one shows the fire resistant properties. From this result, it is clearly shown that the flax composite could be used in a high-temperature application for at least 15 minutes, whereas the kenaf composite can also be used in high-temperature application composite but with less burn-through time. The two composites could be used in aerospace and automobile industries, to prevent the flame fire from penetrating the component, for example in fire designated zone of an aircraft engine, where there is a required of high flame temperature blanket (firewall). Three K-type thermocoupleswere used to read the temperature of the rear face of the plate as stated in Mohammed et al. (2016) and it records the temperatures using a data logger, the result of the two composites was shown in Figure 2.

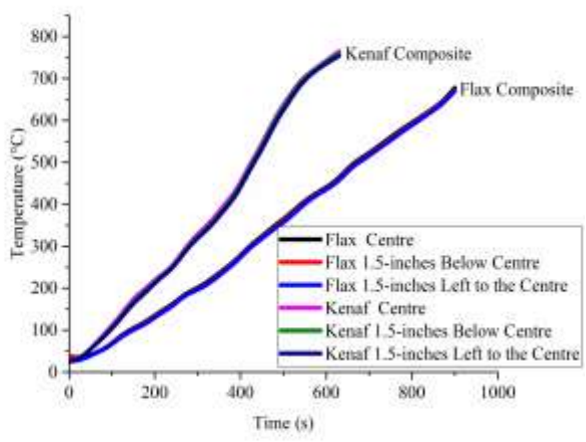

Figure 2: Rear face Temperature for the two composites

The relationships that exist between the time and flame heat temperature conduction is linear as seen from the graph. It is observed that the during the test aluminium alloy melts first before the flame reaches the fibres composite, which is in an agreement with the result reported by Bartlett & Stratford (2001). After the melting of metal alloy the flame was decelerated by the fibre bonded with epoxy resin and hardener, as the flame continues to impinge of the fibre composite a foam and charring formed and prevent the flame from much destruction for a time being, this nature was also reported by Sánchez-Carballido et al. (2017); Mohammed & Abu Talib (2019); Mohammed et al., (2018). After some minutes the flame penetrates the kenaf composite, but the flax composite withstands the standard flame up to 15 minutes.
The thermal conductivity of the two composites was determined using Equation 1 as:

$$K = \frac{W_x D}{A_x \Delta T} \qquad (1)$$

Where K is the thermal conductivity,W is the heat flow D is the thickness of the plate, A the area of the plate, and ΔT is the change in temperature. The thermal conductivity of the flax composite was found to be 1.1 W/mK which is 20.6% better than kenaf composite which is 1.4 W/mK.

Conclusion

The objective of the study was achieved by investigating the behavioural properties of the fabricated fibre metal laminates composites based on reinforced natural/synthetic fibres with thin sheets of aluminium alloy 2024-T3 at the top and bottom of the composite and a polymer matrix. The properties test results obtained shows that the fibre metal laminate composites under study will be capable to be used as a structural component due to its resistant to corrosion, lightweight material, high strength and stiffness and a flame resistant properties. The properties tests result indicates that flax composite, presents good properties result than the kenaf composite. Almost, the two composites considered show the same properties with the same behaviour during the test, but with a little or no differences. The fireproof behaviour of flax composite indicates that the properties of the flax natural fibre were a little bit similar to the properties of synthetic fibres more especially glass fibre. It is clearly seen that a greener fibre would be used in near future to replace the synthetic fibres due to its low cost, properties after treated and it is abundant in nature, required less fabrication process.

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RESEARCH ARTICLE

Offline-Online Submission and Assessment System (OSAS) chatbot as an E-tool on retrieval of learners' outputs in Earth and Life Science during the Distance Learning

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Abstract
The COVID-19 had markedly impacted education that moved to distance learning. The Basic Education Learning Continuity Plan (BE-LCP) emphasized the fairness of learners' access to technology, gadgets, and household assistance. Besides, low-tech and no-tech approaches should consider. In response to the challenge, the researcher created Offline-Online Submission and Assessment System (OSAS) chatbot employed in the Messenger app with features on submission and assessment strategy used in Earth and Life Science core subject where both offline and online can access. The 170 participants were among the selected grade 11 senior high school learners exposed to OSAS chatbot for 6-Week. The 15-item OSAS Usability Scale was assessed, while the 3-item Open-ended Questions to analyze the learners' personal experiences made the study a mixed-method. The result of OSAS's 15-item Usability Scale in terms of (1) Convenience, (2) Applicability, (3) Accessibility, (4) Organization, and (5) Satisfaction were with all high-level interpretations. Besides, the 3-item Open-ended Questions focused on learners' experience revealed the OSAS advantages, such as Accessibility even with a low internet connection, Ease of assessment, Convenience of submission, Ability to track and monitor progress, User-friendly, No stress to use, and Lower cost. On-the-other-hand two drawbacks reported poor network signals and the pressing buttons. Overall, all learners recommended OSAS due to its convenience, ability to access even offline, less hassle on internet cost, effective aid in the teaching-learning process, and ability to track their progress personally.

Keywords: submission; assessment; chatbot education; earth and life science

Introduction

The Coronavirus Disease 2019 (COVID-19) had greatly impacted the lives of many people and caused a major health crisis that brought up a domino effect all over the world including the education process that moved to distance learning. With this, the Department of Education (2020) crafted the Basic Education Learning Continuity Plan (BE-LCP) in response to the challenges brought by the pandemic and one of the primary concerns that need to be addressed in the execution of this is fairness in terms of learners' access to technology, gadgets, and household assistance as per the United Nations (2020) and UNICEF Philippines (2020) was both emphasized, and the equity should be at the center of educational interventions stating that the Low-Tech and No-Tech Approaches should not be overlooked, particularly for those with limited access to technology.

Based on the shared practices during the School-Based Inservice Training 2020, that the main problem needs to be resolved is the assessment of learning, specifically the because of a long time uploading and submitting considering the deadlines. Additionally, in terms of submitting outputs in google drive and performing an retrieval of learners' outputs. In connection to this, the following strategies were shared during the said Inset and its disadvantages that resulted in the conduct of this study, (1) using a Facebook group where learners upload their work in the comment section but can be visible to all learners and could lead to cheating because of lack of data privacy; (2) learners send their work directly to the teacher's messenger account, but this does not provide an organized set of class submission and could lead to a flood of messages, and (3) utilizing of Google Forms to take quizzes and Google Drive to submit activities, however, this is inconvenient for those learners who have no/limited access to the internet, and as for submitting through Google Drive, other learners would be able to read and delete files of other's submission. Moreover, based on the learners' answers during the conducted pre-interview by the researchers about learners' experiences in terms of taking quizzes and submitting outputs in the previous school year 2020-2021, most of them stated that they've experienced the problem of having no/limited internet connection that affects them negatively and triggers their anxiety and stress online quiz that both require strong internet, their slow internet connection causes their delays and most of them stated that these ways of assessment are inconvenient and costly, especially for those who underwent financial problems brought by the pandemic.

In the Philippines, Earth and Life Science is one of the core science subjects in Senior High School (DepEd, 2016). This learning area focuses on the study of general background of Earth Science and Biology. For Earth Science lessons, it includes the history of Earth's geological time scale, the Earth's structure and process, and the earth's natural hazards while for Biology lessons, it includes the basic principles in life science that covers life processes, cellular, organisms, population, and the ecosystem levels (DepEd, 2016). Hence, in spite of the pandemic crisis, the necessity to promote earth and life science education. Funa et al. (2021) cited that the lack of access that supports learning and the slow internet connection led students having difficulty in biology topics. Recent studies reported the practices and challenges in assessment and submission during this distance learning, Calixto et. al. (2021) said that poor internet connection causes a decrease in learners' motivation in learning as Rotas and Cahapay (2020) revealed that the major difficulty of Filipino learners in remote learning is their unstable internet connectivity that results in demotivation on accomplishing activities. Usually, teachers retrieved modules once or twice a month, the parents submit their son's and daughter's module at the designated drop-off points every Saturday, similar to many schools all over the country. Unfortunately, it was reported that most parents and guardians were not following the schedule of retrieval of outputs, making the teachers keep back and forth to the school and/or to the drop-off points just to face the parents and take the outputs (Melorin, n.d.). Also, teachers often receive incomplete output ("Feedback about challenges in distribution and retrieval of module" (n.d.).

Finally, the researchers are motivated enough that we've created an Offline-Online Submission and Assessment System (OSAS) chatbot as an e-tool for retrieving learners' output during this distance learning similar to the Tulong Eskwela Messenger Classroom created by AHA Learning Center (2020), which can be accessed by learners even in a Free Data featured by Facebook Messenger.

Offline-Online Submission and Assessment System (OSAS) chatbot

OSAS chatbot is a digital assistant or artificial conversation entity with specific features for retrieval of learners' output. This chatbot is employed in the Facebook messenger app. It is a free mobile messaging app used for instant messaging, sharing videos, audios, recordings, and group chats without incurring data charges and its ability to interact with users on the use of bot platforms launched in 2016 ("Messenger software," 2022). The term 'Offline' or offline internet means providing access without connection (International Federation of Library Associations and Institutions (IFLA, 2018); or in a free data mode . The system architecture of the OSAS chatbot was shown in *Figure 1 OSAS chatbot Architecture*. The learner will access the OSAS chatbot using the messenger link given by the teacher. The Facebook messenger will then connect the learner to the chatbot powered by Chatrace. Through conversational flow shown in *Figure 2 Conversational flow of OSAS workflow*, the chatbot will communicate with the learner, and vice versa to perform an assessment and/or to submit output. Finally, the teacher will have access to the learner's assessment scores and submitted outputs via a Google sheet database (E-class record).

Figure 1. OSAS chatbot Architecture

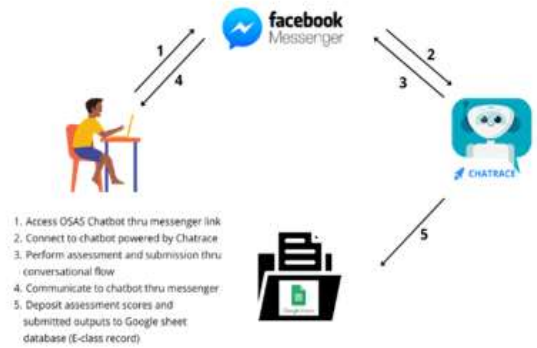
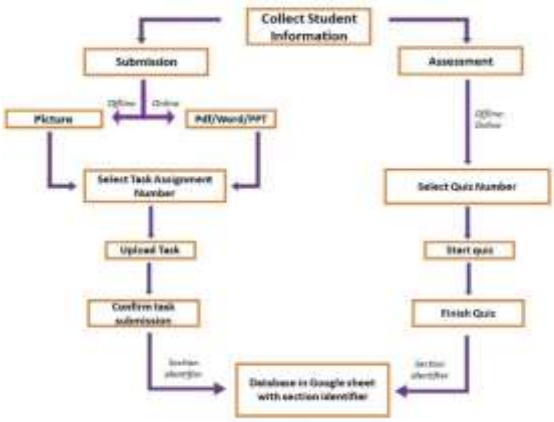


Figure 2. Conversational flow of OSAS workflow



Objectives

The main innovation, intervention, and strategies to contribute to the teaching-learning process are as follows:

• Created Offline-Online Submission and Assessment System (OSAS) chatbot on retrieval of learners' outputs during distance learning;

• The usability of the OSAS chatbot serving as an e-tool was assessed in the context of subjective and objective perspectives;

• Perform an automated database using google sheet in storing submitted task outputs and scores of quizzes; and

• Crafted low-tech approach but an interactive way for learners where they do not need strong internet connectivity to submit task activities and answer assessments.

Research questions
Specifically, the researchers investigated the following research questions:

1. What is the usability level of the Offline-Online Submission and Assessment System (OSAS) chatbot as an E-Tool on Retrieval of Learners' Outputs during Distance Learning in terms of:
1.1. Convenience,
1.2. Chatbot Applicability,
1.3. Accessibility,
1.4. Organization, and
1.5. Satisfaction?

2. What was the feedback from the learners who underwent the Offline-Online Submission and Assessment System (OSAS) chatbot in terms of retrieval of outputs during distance learning in terms of:
2.1 advantages, and
2.2. disadvantages

Method

Participants and/or other Sources of Data and Information

The study conducted at San Lorenzo Ruiz Senior High School was conveniently and purposively conducted on four sections of Grade 11 students, namely 11-HUMSS C, 11-HUMSS D, 11-ICT A, and 11-COOKERY C. The participants were heterogeneous learning modalities consisting of Blended, Text-based, and Modular students that were deemed more appropriate for the study.

Instrument Used

The instrument of this study was a Post-test Usability Evaluation questionnaire. The first part was the five-point Likert scale was used to measure the Usability level of the OSAS chatbot platform consisting of the five variables, namely (1) convenience, (2) chatbot applicability, (3) data/internet accessibility, (4) organization, and (5) satisfaction and the second part was the structured Open-ended interview questions were used to explore feedbacks of the students. This instrument underwent content validation, such as literature reviews adapted from Liu et. al. (2019), Osorio (2021), and Chao et. al. (2020), and by expert fields, and an expert panel in chatbot education.

Data Gathering Methods

The researchers obtained the letter of approval for the permit to conduct the study from the Office of Schools Division of Pasig and the school's principal. Pre-activity interview questions were made for the development of OSAS design and evaluation tool instrumentation. The instruments underwent expert validation. The researcher gathered the participants via the Zoom app for Orientation on the use of the Offline-Online Submission and Assessment System (OSAS) chatbot. The Offline-Online Submission and Assessment System (OSAS) Design chat was conducted for eight weeks covering the 1st Quarter of the first semester. During the 6-weeks intervention, the researchers recorded observations and reflections. After the intervention, the post-evaluation and interview questions were administered.

Research design process

Plan-Do-Study-Act (PDSA) process was used as the Action Research design of this study. The ***'Plan***' phase includes a pre-activity assessment survey on Students experienced in terms of Assessment and Submission during Distance Learning as the basis used for the development of the study. The ***'Do'*** phase was the implementation of the OSAS. The researchers have documented observations for secondary sources of data. After which was the ***'Study'*** phase using the Post-test Usability Evaluation Instrument and an Open-ended question interview. The Post-test Usability evaluations were analyzed using descriptive statistical tools. Then, findings and recommendations were cross-referenced with the relevant literature. On the other hand, the open-ended interview questions were analyzed using qualitative content analysis in which the researcher reads the transcript and scrutinizes them closely in identifying significant concepts and patterns from a careful reading of data (White & Marsh, 2006). The ***'Act'*** phase was the evaluation of the OSAS chatbot with careful analysis based on the findings discussed in the next section. The researchers also aimed to enhance and improve the OSAS especially based on the students' feedback specified in the *3.2.2 disadvantage.* Also, the researchers plan to add 'lesson delivery' in the OSAS features as the best factor to increase academic achievement.

Results And Discussion

Usability of OSAS

The presentation of the findings followed the sequence of the research questions namely 1) usability level of OSAS chatbot respectively to convenience, applicability, accessibility, organization, and satisfaction.

Table 1. Usability of OSAS in terms of Convenience

STATEMENT	MEAN	SD	REMARKS
1. I find the OSAS chatbot is easy to use.	4.24	1.06	Agree

2. I do not need to download an external application to use OSAS.	4.37	1.10	Agree
3. I can answer quizzes and submit task assignments using OSAS whenever needed.	4.43	1.00	Agree
Grand Mean	4.35	1.05	Agree
Interpretation		High	

It can be seen that the student-respondents agree that the OSAS chatbot is easy to use (M=4.24, SD=1.06), does not require them to download external applications (M=4.37, SD=1.10), and can be used whenever needed (M=4.43, 1.00). This implied that the OSAS chatbot is convenient to use for its design purpose.

Table 2. Usability of OSAS in terms of Chatbot Applicability

STATEMENT	MEAN	SD	REMARKS
4. I can use the OSAS chatbot via any device using FB Messenger.	4.56	0.86	Strongly Agree
5. I found out that the various functions in the OSAS chatbot are well-integrated.	4.37	0.86	Agree
6. I do not need technical skills or proficiency in using the OSAS chatbot.	4.27	1.06	Agree
Grand Mean	4.40	0.93	Agree
Interpretation		High	

The student-respondents strongly agree that the OSAS chatbot can be used via any device using FB Messenger (M=4.56, SD=0.86). It can also be seen that the student-respondents agree that the various function in the OSAS chatbot is well-integrated (M=4.37, SD=0.86) and does not need technical skills and proficiency (M=4.47, 1.06).

Table 3. Usability of OSAS in terms of Internet Accessibility

STATEMENT	MEAN	SD	REMARKS
7. I can take quizzes with or without a data/internet subscription with FB Messenger using the OSAS chatbot.	4.14	1.16	Agree
8. I can submit task activities with or without a data/internet subscription.	4.06	1.17	Agree
9. I can use the OSAS chatbot with or without a data/internet subscription.	3.99	1.16	Agree
Grand Mean	4.06	1.16	Agree
Interpretation		High	

This means that this submission and assessment system can still be properly used regardless of the strength of the data/internet connection. The student-respondents agree that they can take quizzes, submit tasks, and use the OSAS chatbot with or without a data/internet subscription with FB Messenger (M=4.14, SD=1.16), (M=4.06, SD=1.17), (M=3.99, SD=1.16). This implied that the OSAS chatbot is accessible online (with data/internet subscription) and even offline (without load data/internet subscription).

Table 4. Usability of OSAS in terms of Organization

STATEMENT	MEAN	SD	REMARKS
10. Communicating with the OSAS chatbot is clear and easy to understand.	4.19	1.04	Agree
11. As a learner, the organization of the content of the OSAS chatbot including its features is interesting.	4.3	0.99	Agree
12. The prompt and instruction found in the OSAS are interactive.	4.21	0.99	Agree
Grand Mean	4.23	1.01	Agree
Interpretation		High	

This implied that the instructions and features of the OSAS chatbot are organized. This result is similar to what was stated in the study of Shukla V., & Verma, A., (2019), the usage of Chatbot in the learning management system can just be done through the natural language generation and intelligent process automation on question answer, assessment, search assistant and teaching. Its features had also helped to resolve the problems/answers queries more quickly, act in a synchronized manner among all devices, and keep a record of communications.

Table 5. Usability of OSAS in terms of Satisfaction

STATEMENT	MEAN	SD	REMARKS
13. The OSAS chatbot provides a fun, interesting, and innovative way of assessing learning.	4.18	0.99	Agree
14. The OSAS chatbot is effective when used as a submission and quiz system e-tool during distance learning.	4.46	0.87	Agree
15. Overall, I would rate the user-friendliness of the OSAS chatbot.	4.38	0.90	Agree
Grand Mean	4.34	0.92	Agree
Interpretation		High	

The student-respondents agree that the OSAS chatbot provides a fun, interesting, and innovative way of assessing learning (M=4.18, SD=0.99), which is effective when used as a submission and quiz system e-tool during distance learning (M=4.46, SD=0.87) and user-friendly (M=4.38, SD=0.90). This implied that the student-respondents were satisfied with using the OSAS chatbot as a submission and assessment e-tool during distance learning.

Personal experiences

Advantages

Category 1: Accessible even with no internet connection. The most recurring advantage experienced by the students using the OSAS chatbot was the accessibility even with no internet connection. A student stated, "I can use it even though I don't have internet or data. Because sometimes our internet is not working properly." A student also wrote, "The advantage of OSAS is we, students, can submit our assignments without load or Wi-Fi, we can use our free data to pass the said outputs."Category 2: Ease of performing the assessment. Another was that the students can perform a quiz even with no internet connection. A student said, "If we have a quiz, I don't have a problem because I can still use it." A student also wrote, "I'm amazed at how OSAS can collect data and answers and tell your scores immediately". On the other hand, the student revealed that the quiz placed in the OSAS was good. A student said, "The quizzes are perfectly shown to the chatbox". Furthermore, the given questions in OSAS during the assessment were good and responded well. A student stated, "OSAS is kind of okay because all the questions are typed right, and the options don't have any flaws".

Category 3: Ease of submission. Using OSAS, it was easy to access and submit outputs. A student stated, "Based on my experience, using the OSAS is easy, to pass the outputs that we need to submit." Students did not experience complicated procedures using the OSAS. A student stated, "When submitting my tasks or taking the quizzes there's no any complicated procedure." Another advantage in terms of submission was that students could send outputs even with no internet. A student stated, "Madali itong gamitin, naipapass ko ang aking aktibidad ng hindi na kailangan pa ng data load o wifi. (It's easy to use. I can still submit my activities without the need for data load o wifi.)"

Category 4: Track and monitor progress. While online learning can be a demotivating factor to accomplish activities because of unstable internet and limited internet data (Sari, 2020), however, OSAS chatbot can track and monitor progress. This will help students be able to keep on track even they do not have an internet connection. A student wrote, "Napadali at natulungan ako neto kung ano bang kulang ko at kahit anong oras pwede mong balikan para malaman kung ano ang kulang. (It helps me to trace easily my progress of work, especially my incomplete activities that can access anytime.)"

Category 5: User-friendly. Furthermore, the students expressed the user-friendliness of the OSAS chatbot. A student stated, "Napapadali lahat ng gawain dahil detalyado niya itong sinasabe at automatic. (It makes the students' work easier because of its detailed instruction, also it is automatic.)" A student also mentioned that it is a better app compared to other apps used in submission.

Category 6: Less stress. The students likewise expressed advantages in OSAS chatbot for distance learning because it is less stressful and no hassle while it is more efficient when it comes to assessment and submission. A student stated, "Mas napapadali nito ang mga gawain or ang pag pasa walang hustle. (It makes the student's work easier and in terms of submission, there's no hustle.)".

Disadvantages

Category 1: Network signal. The majority of the students said that there is no disadvantage to using OSAS in terms of submission and assessment but rather expressed the positive side of it. However, few students reported on network signal issues that one must have a network signal so that Free Data will work. A student stated, "Based on my experience, there's a possibility of it not functioning if you don't have a signal in your sim card using Globe, TNT, or another network."

Category 2: Pressing chat buttons. Another reported disadvantage of the use of OSAS was the pressing of chat buttons. For instance, the student stated, "Sometimes when I made a mistake accidentally while taking a quiz or a test, I can't go back to the quiz and correct my answer." It should be noted that the OSAS chatbot has a pre-identified button that will respond automatically using the pre-identified text. When students mistakenly press the wrong button, it will go to the wrong pre-identified response as well.

Conclusion

Based on the findings of the study and the conclusion drawn, the following reflections were noted:

The use of the Offline-Online and Submission and Assessment System (OSAS) was highly suggested as one a strategic e-tool in collecting and tracking learners' outputs and taking quizzes, especially the OSAS usability level revealed high remarks of its convenient used, applicability, accessibility, organization, and satisfaction level. Furthermore, feedback from students who underwent OSAS expressed its advantages that OSAS was accessible even with no internet connection, easy in taking quizzes and submitting task activities, they can track and monitor their progress, user-friendly, less stress, lower cost on internet subscription, however, noted also its disadvantages in terms of network signals that even OSAS is accessible without internet but having slow network signal can affect its applicability, and few students cited their issues in pressing chat buttons.

Even the study concluded that the OSAS chatbot has significant results, the researchers still recommend that the OSAS chatbot specifically its features for evaluation and submission should be continuously improved to the maximum and enhanced for further significant studies. Additional features and technical improvements can also be added to the OSAS chatbot specifically to address the above-mentioned disadvantage which is the problem with pressing buttons. Parallel studies must be conducted for further comparison to evaluate and assess the result of this study.

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RESEARCH ARTICLE

Solar Photovoltaic System Design and Cost Estimations for Electrification of selected Primary Health Centres in Maiyama Local Government, Kebbi State

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Abstract
The populace continues to turn to primary healthcare centers as their first port of call for medical attention. The majority of people who visit primary healthcare facilities (PHCs) are women and children, whose health has a direct impact on the future of the nation. As a result, PHCs are under pressure to deliver high-quality treatment. One of the healthcare institutions in Maiyama Local Government that needs dependable energy is the Primary Healthcare Center (PHC) that has been chosen. They use a diesel-powered system as their main source of power supply because the electricity supply is unstable. This puts a strain on their operations resources and has a severe impact on people and the environment. The answer to Maiyama's inconsistent, expensive, and unsafe power source is a change in the energy system. LG, and its goal is to raise the standard of healthcare delivery services. It is assumed that greater healthcare services would be available once improved energy sources are in place. The solution was suggested to be a solar-powered system with battery storage, a charge controller, and an inverter. Electricity for the vaccine refrigerator, ceiling fans, light bulbs, and mobile charge station will be provided by the proposed powered system. For each primary health center, the cost of the solar PV system's components [such as PV panels, inverters, batteries, and charge controllers] was calculated. Electrical appliances were projected to use 29,129.41 watt hours per day, 13647.05 watt hours per day, 54174.118 watt hours per day, and 14738.82 watt hours per day for Kawara, Maiyama, Andarai, and Mayalo, respectively. Based on the foregoing Observed outcomes each health center under study's needs was taken into account while designing the solar PV system. According to estimates, PV panels will cost correspondingly ₦1,264,000, ₦632,000, ₦2,370,000, and ₦395,000 for Kawara, Maiyama, Andarai, and Mayalo. The total amount all centers had to pay on PV panels was ₦4,661,000. Similar to this, it was determined that the cost of the inverter utilized in the design was ₦280,000 for the four PHCs, while the cost of the battery was projected to be ₦646,800, ₦1,176,000, ₦4,555,726, and ₦953,442 for Kawara, Maiyama, and Andarai, respectively. For this project, the cost of the inverter and charge controller needed to create the PV system was estimated for each primary health center that was chosen. 4 inverters' combined costs were calculated and determined to be. Each charge controller is expected to cost ₦30,000 and cost ₦210,000. For Kawara, Maiyama, Andarai, and Mayalo Primary Health Center, respectively, the cross-sectional area of each cable needed for the connection between PV& battery, Battery & Inverter, and Inverter & Load was projected to be 3.569 10^{-6} m^2, 2.436 $10^{-6} m^2$, and 2.727 $10^{-6} m^2$. This study's findings support the usage of solar PV systems in primary health centers since they are less expensive to operate, extremely dependable, and have a life expectancy of 20 to 30 years.

Keywords: Primary health Centre; Panels; Battery; Inverter; Photovoltaic system and electrification

Introduction

Since the beginning of time, the sun has produced free energy, with the quantity of solar radiation that the Earth has been able to block reaching up to 1.8 1011 MW in power (Ezema et al., 2019). Nigeria benefits greatly from solar energy due to its year-round sunlight. The whole national energy requirement may be satisfied by solar energy, with solar radiation predicted to be between 3.5 and 7.0 kWh/m2/day (Ezema et al., 2019). The scientific community has made a significant effort to find alternate and clean energy sources to meet the demands of the present and the future. Additionally, given the limited availability of conventional energy sources, it is imperative to investigate renewable energy sources in order to promote global economic growth that is healthy, competitive, and maintaining a clean and healthy environment for future generations. The generation of green energy, especially solar-based energy, has become a practical way to supplement battery supplies (Jordan and Kurtz, 2011). Through a variety of new and developing applications in general and in certain sectors with technical hurdles in particular, recent advancements in PV technologies have reduced some gaps between power demand and supply (Pandey et al., 2016). The annual global energy consumption is currently 10 terawatts (TW), and by 2050, it is anticipated to reach 30 TW. By the middle of the century, the world will require around 20 TW of non-CO2 energy to stabilize CO2 levels (Razykov et al., 2011). According to analysts, Nigeria could produce 600,000MW by installing solar PV panels on just 1% of its geographical mass (Power Nigeria, 2019). Although installing solar devices is inexpensive, there is a technological issue that might prevent this vision from becoming a reality (Jordan and Kurtz, 2011). The difficulties include: shadows, which may be created naturally or artificially; dust, filth, frost, and snow on panels; location; rainfall; module tilt; reflectance of module surface; PV conversion efficiency; and sunlight spectrum. Grid-connected PV systems and off-grid PV systems are the two most common varieties of PV systems. A proposed off-grid PV system is for the research region. In this study, it was suggested that both types of PV panels be used in various situations to help the government finance solar energy investments in Maiyama L.G.'s primary healthcare system. For the last forty years, both the Nigerian government and its populace have had serious concerns about the country's energy situation (NERC, 2019). Businesses have lost money due to this energy issue, while families are totally reliant on off-grid power sources (i.e., electric generators fueled by diesel, gas, or petroleum), resulting in exorbitant expenditures and aggravating other hazardous environmental issues (Emetere et al., 2019).

One of the most important demands of people everywhere is a reliable, efficient, and sustainable source of electricity. Lack of this energy infrastructure, particularly in Local Governments like Maiyama, has an impact on the socioeconomic status of people living in rural communities. These services, such as local health care, water pumping, street lighting, etc., are needed to develop in order to improve the lives of the people living in local communities. Additionally, the absence of a dependable electrical power system can have a harmful effect on people's health, particularly when those individuals are continuously exposed to fossil-fuel energy systems, which raise greenhouse gas (GHG) emissions. Antiretroviral medicines (APV) and other temperature-sensitive medications and chemicals have recently been distributed in healthcare facilities. In order to combat infectious illnesses like HIV/AIDS, the Ebola virus, which is mostly found in West Africa, and the Zika virus, which is primarily found in South American nations, it is necessary to provide an effective and stable electricity power supply (NERC, 2019). This is because the majority of the temperature-sensitive vaccinations used to treat the illnesses listed above must be kept in freezers. One of the most crucial amenities required in health centers is a decent lighting system. Energy supply is also crucial for responding to medical crises, including labor and delivery, patients needing urgent care, etc. The risk of human deaths rises because of the absence of electricity in medical institutions (NERC, 2019).Consequently, the importance of a dependable energy source in assuring how well health clinics and centers operate. Only 183 million people, or around 40% of Nigeria's total population, have access to the national grid (Power Nigeria, 2019). This suggests that the majority of its residents lack access to a reliable source of modern power. A requirement like food and water is energy. Energy is needed by everything around us. The population of the planet has grown throughout time, and this rise is closely correlated with the amount of energy utilized. Every piece of technology and apparatus need energy to operate. Finding sustainable renewable energy sources that may reduce reliance on fossil fuels and the national grid system is important due to the depletion of the national power grid system (Ayaz, 2018). The most plentiful source of energy we have is solar energy. An estimated 10,000 Terawatts of solar energy are incident on the surface of the globe each day. A research claims that the total global energy usage in 2015 was 17.4 TW (Ayaz, 2018). Every year, the energy usage has only slightly increased, growing by about 1 to 1.5%. By the year 2040, the total amount of energy consumed worldwide is anticipated to increase by 56%. We can only begin to grasp the potential that solar energy contains when we compare present consumption, anticipated increase in the next two decades, and the quantity of solar radiation received in an hour. The entire amount of energy used is a significant portion of what we get in an hour (Ayaz, 2018).

A miracle of both nature and technology, a photovoltaic cell is an electrical device that transforms incoming photon energy into electrical energy. The PV system is one that uses the sun's energetic photon radiation to produce electrical current in a particular material. Modern semi-conductor materials are used to directly convert solar energy into electricity. The most readily accessible commercial material for PV system design is often silicon. PV systems can be complicated or simple. Some are referred to as "stand-alone" or "off-grid" systems, meaning they provide all of the households' and hospitals' electricity (Ayaz, 2018). Health institutions of all kinds, especially those with little or no access to grid electricity, can benefit greatly from solar power. No pollutants are produced, no fuel is used, and no maintenance is required for photovoltaic. They are a good alternative for any healthcare facility's energy system when they are commercially feasible. For isolated sites without access to the grid, PV systems are very critical. Therefore, by protecting health clinics from variations in the power supply and cost, PV systems contribute to their long-term financial viability (USAID, 2019). Given that only a small percentage of PHC in Maiyama LG have access to electricity supply due to physical deterioration of the transmission and distribution facilities, high cost of installing solar PV systems, and other factors, this study aims to design PV system and analyze the cost of designing a solar PV system in primary health centers of Maiyama Local Government (Izuchukwu and Peace, 2021).

Material and Method

The operational healthcare systems of Maiyama, Andarai, Mayalo, and Kawara are the focus of the study. They are the most notable wards in Kebbi State's Maiyama Local Government. Geographically, Maiyama LG is located between 110 48'37.08" latitude and 40 21' 23.4468" longitudes. Table 1 below is a summary of each primary health center's descriptions.

Table 1: List of selected primary health centres in Maiyama LG

S/N	Wards	Code	Centre name	No of Bed	Personnel	Longitude	Latitude
1	Kawara	21/15/1/1/1/0036	Kawara Primary Health Centre	10	8	4.23698	12.99883
2	Andarai	21/15/1/1/1/0003	Andarai Primary Health Centre	10	13	4.393051	11.89528
3	Maiyama	21/15/1/1/1/0021	Maiyama Primary Health Centre	0+5	14	4.37196	12.08405
4	S/Mayalo	21/15/1/1/1/0027	Mayalo Primary Health Center	1	11	4.27947	12.24875

To evaluate the site's benefits, solar photovoltaic (PV) clusters for primary health centers are an essential concept (Franklin, 2017). A critical component of developing a PV system is locating and positioning the panels (Ayaz, 2018).

Data Gathering

Each primary health center's data was prospectively gathered using a form made just for that purpose. The information gathered included the amount of lights, fans, mobile charging stations, and refrigerators that were available in the center. The PHC staff directed the collection of every appliance's data.

PV System Design for Primary Health Care Center

PV solar panels are simply one component of photovoltaic systems. To operate the PV panels effectively, a variety of additional system parts known as the balance-of-system (BOS) are necessary. PV panels, inverters, batteries, charge controllers, and cables are a few of the standard parts of PV systems. Any PV system's composition is determined by the sort of load it powers and, more crucially, whether it is an off-grid or grid-connected system (USAID, 2019). This component included building a PV system to supply the Primary Health Center in Maiyama Local Government Area

of Kebbi State with the necessary electricity. The size of the PV panels, inverter, battery bank, solar charger controller, and cost estimation must be determined based on the appliances that are now accessible in the PHC. First, the

PHC was used to determine the total number of appliances and their individual power ratings.

Electrical equipment power usage in primary health centers

A mathematical calculation was used to calculate the amount of power used by each of the equipment (1)

$$\text{Power}_{\text{Consumed}} = \text{No. of Units} \times \frac{\text{Rated wattage per Hour}}{\text{Adjustment factor}} \times \text{Average Hour Use per Day} \quad (1)$$

Where adjustment factor here considered being 0.85

Daily power demand

The total power used by the PHC's available appliances was used to calculate the daily energy consumption.

$$\text{Total power demand per day} = \sum \text{power consumed by the appliances in watt} - \text{hour} \quad (2)$$

Energy required from Panels to run electrical appliances

The total Energy required from the Panels to run the electrical appliance was calculated using equation (2) below:

$$\text{Energy required from the Panels to operate electrical appliance} = \text{P}_{\text{consumed}} \left(\frac{\text{Wh}}{\text{Day}}\right) \times 1.3 \quad (3)$$

PV Panels Sizing

The size of the Panels for a PV system that powers daily-use loads is decided by the daily energy requirement (SECO FACT SHEET, 2020). The total peak wattage necessary to run the appliances was estimated using an equation to determine the number of PV panels needed for this investigation (4)

$$\text{Total peak rating watt require to run the appliances} = \frac{\text{total energy required}}{\text{module generation factor}} \quad (4)$$

The total amount of PV energy needed from the panel divided by the panel generation factor is the total amount of watt-peak power needed to run the appliances. When determining the size of solar photovoltaic cells, the panel generation factor is applied. Depending on the climate where the place is located, it can differ. This analysis took into account 4.8 module generation factors and 500Wp PV modules. Equation (5) below was used to calculate the number of PV panels needed for this investigation.

$$\text{Number of PV Panels for the system} = \frac{\text{Total watt-peak rating require to operate the appliance}}{\text{rated output peak of the PV module available}} \quad (5)$$

The installations of more solar Panels lead to better performance of the system and battery life-span will increased.

Solar PV Panels Arrangement

PV Panels can be arranged in two different ways such as Series and Parallel arrangement

$$\text{Number of Series arrangement of panels [NPS]} = \frac{\text{Voltage of the system}}{\text{Voltage of the Module}} \quad (6)$$

$$\text{Number of Parallel arrangement of Panels [NPP]} = \frac{\text{Total number of Panels}}{\text{Number of module in series}} \quad (7)$$

$$\text{Total Number of solar Panels [NMT]} = \frac{\text{Number of Panels in series}}{\text{Number of module in Parallel}} \quad (8)$$

Estimation of output power of solar panels array

The entire daily power consumption was divided by the typical battery round-trip efficiency of 90% in order to properly build a PV system for the Primary Health Center. As a result, the power output for the PV array in this study was determined using equation (6) as follows.

$$\text{Power}_{\text{Array}}\left(\frac{\text{w}}{\text{day}}\right) = \frac{\text{Total power demand per day}}{\text{Batter round-trip efficiency}} \quad (9)$$

Ampere-Hour per Day

This is the proportion of daily energy use to battery bus voltage. The calculations are displayed below.

$$\text{Ampere} - \text{Hour per Day}\left(\frac{\text{Ah}}{\text{Day}}\right) = \frac{\text{Total Energy Per Day Use}}{\text{Batter Bus Voltage}} \quad (10)$$

Where Batter Bus Voltage = 50V and Round Trip Efficiency = 90% = 0.9

Inverter sizing

The sort of device known as an inverter is able to transform the direct current (DC) electricity generated by solar panels into the alternating current (AC) electricity required to power appliances like lights and other machinery. Since inverters are necessary for every PV system to serve AC loads, they are a fundamental part of almost all PV systems. Keep in mind that many inverters may also serve as disconnect switches or battery charge controllers, among other system components. The most cutting-edge inverters are built to link with a utility grid, either taking power from it or feeding it back into it. These inverters may switch to an islanding mode, where they continue to power the vital loads connected to the PV system, in the event that the utility power fails. The IEEE 1547 requirements for safe grid connection and disengagement must be followed by these inverters. (USAID, 2019). The inverter's input rating should never be less than the combined wattage of the appliances. The inverter's nominal voltage must match that of your battery. The inverter's input rating needs to be 25–30% greater than the wattage of your appliances. The input rating of the inverter for grid-tied or grid-connected systems should match the rating of the PV array to enable for efficient and safe operation. Therefore, the size of inverter needed for electrifying every primary healthcare system chosen for the study was determined using the following equation:

$$\text{Inverter Size [IS]} = \frac{\text{total watt} \times 130}{100} \quad (11)$$

Battery Size

One of the most crucial factors to take into account when selecting the fundamental parts of a standalone solar electric system is the size of the solar battery. When sizing a battery bank, the key goals are to get one energy source that can handle the load from the PV panel array and supply enough stored power for needs when there is no sunshine. Depending on how much voltage the solar system generates, the battery bank system voltage may be 12 volts, 24 volts, 48 volts, or 96 volts. The battery's storage capacity should be sufficient to power the appliances both during the day and during the night.

$$\text{Sizing of Battery (Wh)} = \frac{\text{Energy required per day in watt-hours (battery bank capacity) [C]} \times \text{autonomy days [n]}}{\text{Battery loss} \times \text{Depth of Disccarging} \times \text{system voltage}} \quad 12)$$

Where; loss of battery = 0.85, depth of discharge =0.6, system voltage = 45.7V, Battery voltage rating = 24, C= energy required per day in watt-hours (battery bank capacity), n= 4 (autonomy days). Autonomy is the number of days required for the system to run when there is no power produced by solar panel.

Number of Batteries Require for the System

The total number of battery was determined by multiplied the ratio of battery bank capacity to capacity of selected battery with number of battery. It was calculated based on the given equation below:

$$\text{Total Number of battery [Nbt]} = 1 \text{ battery} \times \frac{\text{batter bank capacity}}{\text{capacity of selected battery}} \quad (13)$$

Arrangement of Batteries

The batteries calculated have two ways of arrangement based on the desire output of the system. These are series and parallel arrangement.

$$\text{Number of battery In series [NBS]} = \frac{\text{Voltage of the system}}{\text{Voltage of battery}}$$
(14)

$$\text{Number of battery in parallel [NBP]} = 1 \times \frac{\textbf{Total Number of battery require by the system}}{\text{Total Number of batteryie in series}}$$ (15)

Solar Charge Controller Sizing

A charge controller's job is to control the charge from the solar panel array that goes into the battery bank, prevent overcharging, and reverse current flow at night. The most popular charge controllers are maximum power point tracing or pulse width modulation (PWM) (MPPT). A MPPT solar charge controller will immediately and effectively convert the lower voltage when it detects a difference in voltage so that the panels, battery bank, and PV charge can all have the same voltage. The size of a series charge controller is determined by the total PV input current given to the controller as well as by the PV panel layout (series or parallel configuration). In our example, the short circuit specification for the PV module, Current = 11.62 A

$$I_{rated} = (NPB \times I_{sc}) \times 1.3$$
(16)

Where: the solar charge controller Current rating is denoted by $\mathbf{I_{rated}}$, short circuit current given by Isc, number of parallel battery is denoted by NPB and Safety factor is considered to be 1.3. The 60A is the charger controller current rating considered in this work.

The total power of module Array was estimated using equation (17) below: $\text{Total power of module array} = \text{NPS} \times \text{NPP} \times \text{Power rating of module ref. system}$ (17)

Wiring and Cable sizing

Wiring is necessary for all electrical systems, and in a PV system, wiring is utilized to link the PV panels and all other electrical parts to the battery bank of the building. The cross-sectional area of the copper determines the range of sizes for wiring, which are often measured in square millimeters (mm2) or in the American Wire Gauge (AWG) standard in the United States. Because undersized cable might provide a safety risk, wiring must be properly chosen. A variety of criteria are taken into consideration when determining the size of wiring utilized in a PV system: rated current, wire length, efficiency, and system voltage. Larger wiring is necessary for systems with higher system voltage, higher rated currents, and greater distances between the PV panels and system loads. Larger wiring also reduces transmission losses caused by the wire's resistance; a typical cabling-related power loss is 5%. (USAID, 2019). Cable sizing is a crucial stage because it affects the reliability and performance of a PV system when the size and type of wire are properly chosen.

Sizing of Cables between Solar Panels and Batteries

In this research work the copper wire was considered. The cables cross sectional are determined by the following equation: Let length of the cable be 1m, the voltage drop (Vd) calculated using equation (18)

$$\text{Max Voltage Drop } [V_d] = \frac{4 \times V_{module}}{100}$$
(18)

The cross-sectional area of the cable was estimated based on the given equation below:

$$\text{Area} = \frac{\rho \times L \times I}{V_d} \times 2$$
(19)

Where resistivity of wire is denoted by rho(ρ), for copper wire the resistivity is given by $\rho=1.724 \times 10^{-8}\Omega \cdot m$, length of the wire denoted by L, while A= cross sectional area of cable, I= the rated current of regulator, Vd =Voltage drop. In both AC and dc wiring for standalone photovoltaic system the voltage drop is taken not to exceed 4% value.

Cable size between the battery bank and the inverter

Let length of the cable is 8m. The maximum voltage drop considered in this work was estimated using equation (18) above.

At full load, batteries maximum current I_{max} is given by

$$I_{max} = \frac{\text{inverter kva}}{\text{efficiency of inverter} \times \text{Vsystem}}$$
(20)

Where inverter kva = 11 kva, efficiency of inverter = 0.97 and V system = 45.7V

The area of the cable required, battery bank, and the inverter was estimated using equation (19). Based on the values calculated means that any copper cable of cross sectional area of $2.5mm^2$, 517.18A, and resistivity $1.724 \times 10^{-8}\Omega \cdot m$ can be used for the wiring between the battery bank and inverters

Cable sizes between the inverter and load

Let the maximum length of cable be 24m and maximum voltage Drop was estimated as follows

$$\text{The maximum voltage Drop} = 4 \times \frac{\text{out put Voltage}}{100}$$
(21)

Where output voltage considered was 220V and 4 were autonomy days. The phase current calculation was done using equation (22) below:

$$I_{phase} = \frac{\text{inverter kva}}{\text{out put Voltage} \times \sqrt{3}}$$
(22)

Then, the cross-sectional area of the cable was computed using equation (19). This means that any copper of cross sectional area $2.727 \times 10^{-6}m^2$ [~$3mm^2$], 29A, and resistivity 1.724×10^{-8} Ω-m can be used for the wiring between the inverter and load.

Cost Estimation and Analysis for PV system design

Cost of Solar PV panel

The SPR-P3-500-UPP (monocrystalline Solar PER) was used, it is the most powerful PV module manufactured by Sun power Solar. The market price of Solar panel is ₦79, 000. The cost per watt was estimated using equation (23)

$$\text{Cost of Panel per watt} = \frac{\text{Market price}}{\text{power rating of the panel}} \quad (23)$$

Cost of n Panel per watt = Number of panel × Cost of 1 panel in the market

Cost of 11KVA Inverter

Only one piece of 11 KVA of an inverter Power was used for each PHC. The cost of one inverter from the market was ₦ 70,000. Therefore, the cost of inverter per watt was calculated using equation (23) below

$$\text{Cost of inverter per watt} = \frac{\text{Market price}}{\text{Watt rating}} \quad (24)$$

Cost estimate of 1Inverter = (Cost of 1 watt × Watt rating on inverter). The total cost of the require inverter calculated as follows

Total Cost of 4 inverter for the PHCs under study = Cost estimate of 1Inverter × 4

Cost of 60A Charge Controller

The solar charge controller was considered in the design of PV system are 48V, 60A and 2.88kw for Mayalo and Maiyama PHCs. Therefore, cost of charge controller from market was ₦ 30,000

$$\text{Cost of Charge controller per watt} = \frac{\text{Market price}}{\text{Power rating}} \quad (25)$$

$$\text{Cost of 1 charge controller} = \text{Cost per watt} \times \text{wattage rating}$$

$$\text{Total Cost of n charge controller} = n \times \text{Cost of 1 charge controller} \text{(where n= 1,2,3.......)}$$

Cost of Battery

The sun power energy solar battery was used in the design of the PV system. The cost of one battery from market is ₦ 98,000.

$$\text{Cost of battery per watt} = \frac{\text{market price}}{\text{Power rating in watt}} \quad (26)$$

$$\text{Cost of 1 battery} = \text{Price per watt} \times \text{Power rating in ampere} - \text{hour}$$

$$\text{Total Cost of n battery} = n \times \text{cost of 1 battery where n is the number of battery}$$

In this work, the Reference System Specification Rating was utilized to develop the PV system. The solar panel, solar charge controller, solar battery, and solar inverter were selected as the market's reference systems. The reference system specs were compiled as stated in table 1 below. Table 2-9 contains estimates of the load profiles and design parameters for each primary healthcare system.

Table 2: Reference system specification for Solar Panel [Monocrystalline solar Perc] and Battery

Parameters for Solar PV	Values	Parameters For Battery	Values
Voltage	45.7 Volts	AC Nominal Voltage	230 V
Short circuit current	11.62 A	Feed-In Type Single	Phase
Wattage (WP)	500 watts	Grid Frequency	50 Hz
Efficiency of PV panel	20.9%	Total Energy	14 kWh
Performance warranty	25years	Usable Energy	13.5 kWh
		Real power	5 kW
		Apparent Power	5 kVA
		Maximum Supply Fault Current	10 kA
		Maximum Output Fault Current	32A
		Power Factor Output Range	+/– 1.0
		Internal Battery DC Voltage	50V
		Round Trip Efficiency	90%
		Warranty	10 years
		Recommended Temperature	0°C to 30°C

Table 3: Kawara Primary Health Centre Load profile

S/N	Appliances	Quantity	Power rating (watts)	Operating Hours	Power consumption per Day [Wh]
1	Vaccine Refrigerator	1	80	8	658.82
2	Fans	11	70	8	7,247.06
3	Bulbs (60 watts)	19	60	8	10,729.41
4	Bulbs (100 watts)	11	100	8	10,352.94
5	Mobile Charging	3	10	4	141.18
	Total	**45**	**320**	**36**	**29,129.41**

Results and Discussions

Table 4: Design parameters and calculated values for KPHC

Design Parameters	Calculated value
Total energy needed from PV	37868.233 wh/day
Total watt- Peak Rating	7889.22 W_P
Total number of PV Panels for the System	16 Panels
Total number of PV Panels in Series	2 Panels
Total Number of module in parallel	8 Panels
Total Power of PV array demanded	32366.01 W/Day
Total ampere-Hour demanded per Day	583 AH/Day
Inverter Size	416 watts

Battery size	4998.61 watt-hours.
Total Number of battery [Nbt]	25 batteries
Number of battery In series	3.8 batteries
Number of battery In parallel	6.6 batteries
Solar Charge Controller Sizing (Irated)	99.38A
Cables size between PV Panels and Batteries	3.569×10^{-6} m^2
Cable size between the battery bank and the inverter	$2.436 \times 10^{-6} m^2$
Cable sizes between the inverter and load	$2.727 \times 10^{-6} m^2$

Table 5: Maiyama Primary Health Centre Load profile

S/N	Appliances	Quantity	Power rating(watts)	Operating Hours	Power consumption [Wh/D]
1	Vaccine Refrigerator	1	70	8	658.82
2	Fans	9	70	8	5929.41
3	Bulbs	12	60	8	6776.47
5	Mobile Charging	3	10	8	282.35
	Total	**25**	**210**	**32**	**13647.05**

Table 6: Design parameters and calculated values for MPHC

Design parameters	Calculated Values
Total energy needed from PV {TEN}	17741.17 WH/D
Total watt- Peak Rating {TWPR}	3431.373
Total number of PV Panels for the System	7 Panels
Total number of PV Panels in Series	1.9 Panels
Total Number of module in parallel	3.69 Panels
Total Power of PV array demanded	15,163.39 Watt
Total ampere-Hour demanded per Day	272.94 AH/Day
Inverter Size	273 watts
Battery size	2342.14 watts-hours
Total Number of battery [Nbt]	12 batteries
Number of battery In series	3.80 batteries
Number of battery In parallel	3.16 batteries
Solar Charge Controller Sizing (Irated)	47.73A
Cables size between PV Panels and Batteries	3.569×10^{-6} m^2
Cable size between the battery bank and the inverter	$2.436 \times 10^{-6} m^2$
Cable sizes between the inverter and load	$2.727 \times 10^{-6} m^2$

Table 7: Andarai Primary Health Centre Load profile

S/N	Appliances	Quantity	Power Rating(w)	Operating Hours	Power consumption (wh/D)
1	Bulbs	58	60	8	32752.941
2	Fans	31	70	8	20423.529
3	Refrigerator	1	70	8	658.82353
4	Mobile charging	3	12	8	338.82353
	Total	93	212	32	54174.118

Table 8: Design parameters and calculated values for APHC

Design parameters	Calculated Values

Total energy needed from PV {TEN}	70426.35
Total watt- Peak Rating {TWPR}	14672.16
Total number of PV Panels for the System	29.34 Panels
Total number of PV Panels in Series	1.90 Panels
Total Number of module in parallel	15.42 Panels
Total Power of PV array demanded	60193.46 watts
Total ampere-Hour demanded per Day	1083.482 ampere-hour per day
Inverter Size	275.6 watts
Battery size	9297.484 watt-hours
Total Number of battery [Nbt]	46.487 batteries
Number of battery In series	3.808 batteries
Number of battery In parallel	12.207 batteries
Solar Charge Controller Sizing (Irated)	184.395A
Cables size between PV Panels and Batteries	3.569×10^{-6} m^2
Cable size between the battery bank and the inverter	2.436×10^{-6}m^2
Cable sizes between the inverter and load	2.727×10^{-6}m^2

Table 9: Mayalo Primary Health Care System Load profile

S/N	Appliances	Quantity	Power Rating (watts)	Operating Hours	Power Consumption (Wh/D)
1	Bulbs	15	60	8	8470.588
2	Fans	8	70	8	5270.588
3	Refrigerator	1	70	8	658.8235
4	Mobile	3	12	8	338.8235
	TOTAL	27	212	32	14738.82

Table 10: Design parameters and calculated values for MAYALO PHC

Design parameters	**Calculated Values**
Total energy needed from PV	11337.5566
Total watt- Peak Rating	2361.991
Total number of PV Panels for the System	4.7 Panels
Total number of PV Panels in Series	1.90 Panels
Total Number of module in parallel	2.49 Panels
Total Power of PV array demanded	16376.47
Total ampere-Hour demanded per Day	294.7765 AH/Day
Inverter Size	275.6 watt-hours
Battery size	1945.78 watts
Total Number of battery [Nbt]	9.729 batteries
Number of battery In series	3.81
Number of battery In parallel	2.55
Solar Charge Controller Sizing (Irated)	38.57A
Cables size between PV Panels and Batteries	3.569×10^{-6} m^2
Cable size between the battery bank and the inverter	2.436×10^{-6}m^2
Cable sizes between the inverter and load	2.727×10^{-6}m^2

Table 11: PV Panel cost estimated

PHCS	No of PV	Wattage	Market Price	Price per watts	Total Cost of PVM
Kawara	16	500	N79000	N158	N1,264,000
Maiyama	8	500	N79000	N158	N632,000
Andarai	30	500	N79000	N158	N2,370,000
Mayalo	5	500	N79000	N158	N395,000

Total	59	2000	N316000	N632	N4,661,000

Table 12: Cost of battery estimated for each PHCs

Primary Health Centres	Quantity	Market Price	Total Cost	
Kawara PHC	6.600 (≅ 7)	₦ 98, 000	₦ 646,800	646800
Maiyama PHC	12.000	₦ 98, 000	₦ 1,176,000	1176000
Andarai PHC	46.487 (≅ 47)	₦ 98, 000	₦ 4,555,726	4555726
Mayalo PHC	9.729(≅ 10)	₦ 98, 000	₦ 953,442	953442
Total	**64**	**₦392, 000**	**₦7,331,968**	**₦7,331,968**

Table 13: Cost of Inverter estimated for each PHC

Primary Health Centres	Quantity	Market Price	Total Cost
Kawara PHC	**1**	N70,000	N70,000
Maiyama PHC	**1**	N70,000	N70,000
Andarai PHC	**1**	N70,000	N70,000
Mayalo PHC	**1**	N70,000	N70,000
Total	**4**	**N280,000**	**N280,000**

Table 14: Cost of Charge controller estimated for each PHC

Primary Health Centres	Quantity	Market Price	Total Cost
Kawara PHC	2	N60,000	N60,000
Maiyama PHC	1	N30,000	N30,000
Andarai PHC	3	N90,000	N90,000
Mayalo PHC	1	N30,000	N30,000
Total	**7**	**N210,000**	**N210,000**

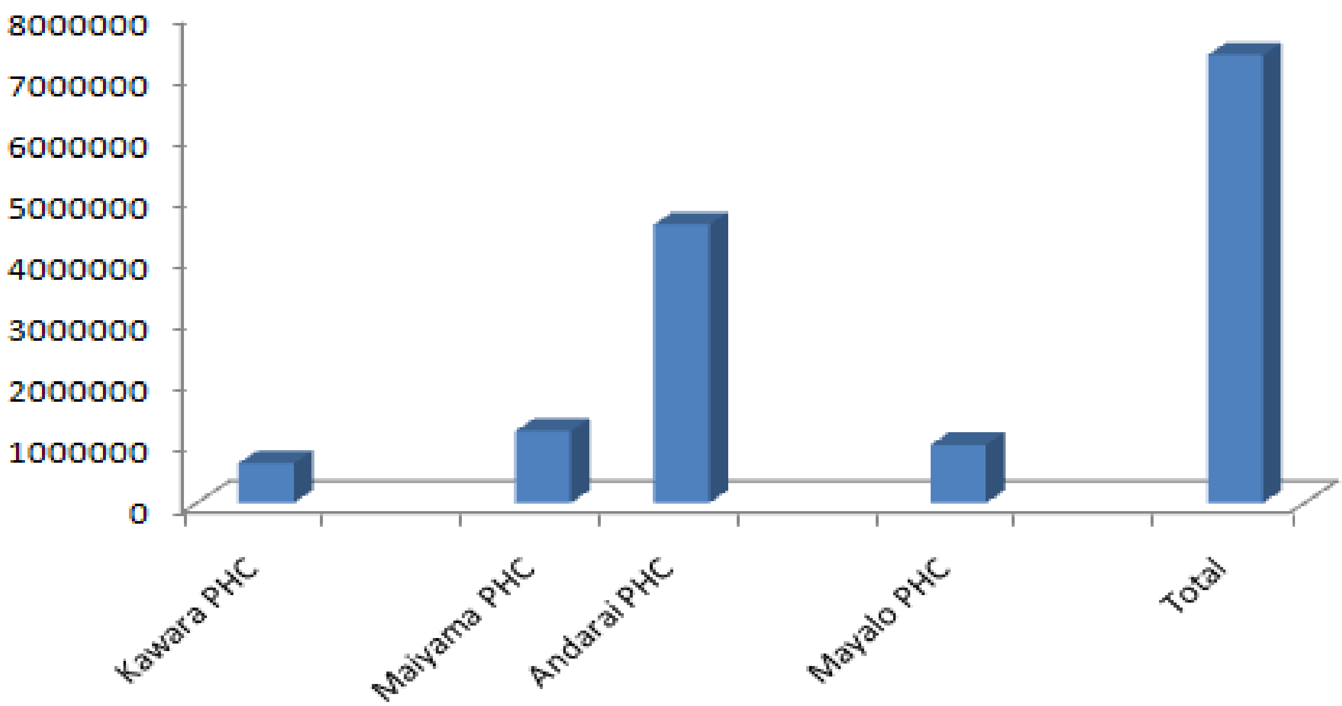

Figure 1: Comparison of battery cost estimated for the four Primary Health Centres

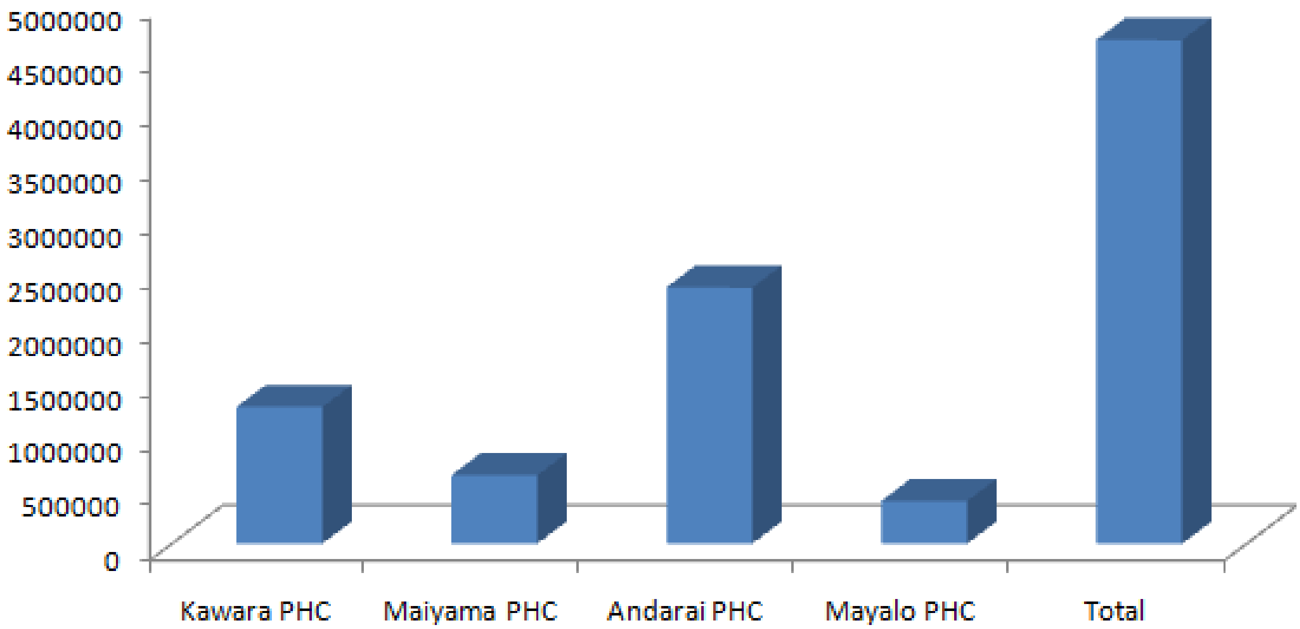

Figure 2: Comparison of total cost analyzed among the four selected PHC

Discussion

Solar energy is viewed as the most promising source of clean, renewable energy and a remedy for the consequences of greenhouse gas emissions in order to address the issue of the use of fossil fuels (Samaila et al., 2021). The main conclusion of this study is that the efficient operation of Primary Health Care Centers depends on the design and cost estimation for access to reliable energy. Through off-grid solar PV, this may be quickly delivered to PHCs. As a result, it is important to give PHC energy demands first priority in order to promote the delivery of 24-hour services in Nigeria, where the electricity system is still underdeveloped and overburdened. The report advises that all PHCs be designed, built, and renovated using typical off-grid renewable energy sources such solar power for lighting, heating, and cooling.

The registration code, personnel, Number of beds, Longitude and latitude of each Primary health centre selected in this study were tabulated in table 1, similarly table 2 indicated reference system used in the designing of Solar Photovoltaic system for Primary health care electrification. Table 3&4 shown the load profile and calculated design parameters of Kawara primary health centre with total of 45 appliances rating 320 watts operating in 36 hours and power consumption of 29,129.41 Watt-hours, for this power consumption per day a total of 16 PV Panels of 32366.01 Watt-hour per day with 583 Ampere-hour per day are required to power KPHC with 25 batteries of 4998.61 watt-hours together with 99.38A charge controller and cable size for the connection between PV& battery, Battery & Inverter, and Inverter & Load were estimated to be 3.569×10^{-6} m^2, 2.436 $\times 10^{-6}$m^2 and 2.727$\times 10^{-6}$m^2 for Kawara, Maiyama, Andarai and Mayalo Primary Health Centre respectively. Table 5&6 indicated the load profile and estimated design parameter of Maiyama PHC with total number of 25 appliances that operating in 32 hours per day with power rating of 210 watts that consumed power of 13647.05 Watt-hour per day. With this power consumption by appliances, a total of 2 PV module of 15,163.39 Watt & 272.94 Ampere-hours per day and 12 batteries of 2342.14 watts-hours are required to Power MPHC with available inverter size of 273 watts and Charge controller of rating of 47.73A. The cable size estimated to connect PV & Batteries, Batteries & inverter and inverter & Load were found to have a cross-sectional area of 3.569×10^{-6} m^2, 2.436 $\times 10^{-6}$m^2 and 2.727$\times 10^{-6}$m^2 respectively. Table 7&8 reported the load profile and calculated parameters required for the designing of solar PV system for Andarai PHC electrification. The table indicated that a total number of 93 appliances were running for 32 hours with power rating 212 watts and power consumption per day of 54174.118 Watt-hours per day. The appliances in this PHC need a total number of 30 solar panels of 60193.46 watts with 1083.482 Ampere-hour per day. The inverter and controller size estimated for this System to power all the appliances are 275.6 watts and 184.395A with total of 47 batteries of 9297.484 watt-hours. The needed cable sizes were the same as that of Kawara and Maiyama PHC. Table 9 & 10, in this table load profile and estimated parameters for the design of Mayalo PCH PV system for electrification were captured. A total of 27 appliances operating for the total of 32 hours per day with total rating of 212 watts consumed a total power of 14738.82 Watt-hour per day. For this power consumptions, a total of 5 Panels of 16376.47 watt-hour and 294.7765 Ampere –hours per day were needed to power the given number of appliances with 10 number of batteries size of 1945.78 watts. The required size of inverter and charge controller for the this PCH were estimated to be 275.6 watt-hours and 38.57A, the sizes of the connection cable were remain the same as in Andarai PHC.

Table 11 summarized the total number of panels needed for each PHC. The total number of PV panels of 500 watts rating required for four primary health centres were estimated to be 59 with total cost of ₦4,661,000. In table 12, the batteries cost estimated were indicated for each PHC. The total batteries needed for the four Primary health centres under study were estimated to be 64 with total cost of ₦7,331,968 with one single battery cost ₦98,000 in the market. Table 13 & 14 indicated the cost of inverter and charge controller calculated for each primary health centre. The cost of inverter and charge controller required for the designing of PV system in this work were estimated for each selected primary health centre. The total cost of 4 inverter analyzed were found to be N280, 000 with each one cost N70, 000, while total cost of 7solar charge controller estimated to be N210,000 with each cost N30,000. In figure 1, the cost of battery compared was remarkably high in Andarai Primary Health Centre due to the large number of appliances available in the PHC. The magnitude of the cost were Andarai PHC > Maiyama PHC > Mayalo PHC > Kawara PHC. Kawara primary health centre has lowest cost analyzed in this work due the limited number of appliances. Similarly in figure 2 indicated that the cost of panels among the four selected primary health centres remarkably high in Andarai PHC. The magnitude of the cost were Andarai PHC > Kawara PHC > Maiyama PHC > Mayalo PHC. The least estimated cost was found in Mayalo PHC. The total amounts of money that will cost four PHC were estimated to be ₦12,482,968 for 20-30 years of PV Panels and 10 years of battery before replacement. The amount was remarkably lower compared to the cost of electricity supply and fossil fuels in the country.

Conclusion

Given that a sizeable number of Maiyama Local Government PHCs lack access to energy supply, the study was conducted to design solar PV systems for electrifying primary health centers and estimates the cost of developing in Maiyama L.G. Despite the fact that Maiyama L.G. typically benefits from abundant solar irradiation, there is a much greater demand for electricity than what can be supplied by the grid. This study promotes the design of PV systems for electrification to close the energy supply-demand gap and enhance the quality of life for the general public in Local Government by drastically lowering fossil fuel usage. According to the research presented above, the overall cost of designing a solar PV system for PHC electricity was ₦12,482,968. The data produced as a result of this study will be extremely helpful not only for the health care system but also for the system design for rural electrification where grid electricity transmissions were not feasible. The fact that carbon dioxide is the main greenhouse gas causing climate change must be understood. Fossil fuel combustion produces a significant amount of carbon dioxide into the atmosphere, increasing CO2 concentrations that are bad for the human race. Therefore, it is crucial to research the viability of photovoltaic system design and cost assessment for the electrification of primary health centers in Maiyama Local Government.

Ethical approval

Verbal approval was obtained prior to the conduct of this research work from the head of each primary health centres and other stakeholders in the communities where PHC located.

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RESEARCH ARTICLE

Evaluation of the optimum Tilt angle of a Monocrystalline Module and performance in Anyigba Kogi State-Nigeria

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Abstract
This research Evaluation the Optimum Tilt Angle of a Monocrystalline solar Module and its Performance using a 100watt solar module, erected on an adjustable wooden rack, the output power was recorded against the tilt angl , the ambient temperature, current and voltage for every tilt angle were also recorded. The result from the experiments showed that the optimum performance angle is at angle between 0° and 10^0 with the highest output been at 81.65 watt at 0^0c,the power output was seen to decline as the temperature increases. It was conclude that the best optimum tilt for Anyigba is 10^0c so the panes can self-clean rather than being on an horizontal surface.

Keywords: Photovoltaic cells; Performance Evaluation; Solar Energy; Mono-crystalline modules

Introduction

Solar energy is gaining traction as the day goes by despite all odds, this is because solar energy is renewable, sustainable, clean and available almost in any location on earth. Solar energy through photovoltaic (pv) cell can convert energy from the sun directly into electricity (Bagnall *et al.*, 2008). Photovoltaic effect generates potential when radiation ionizes the regions in or near the potential barrier . the self-generated electromotive force (e.m.f) delivers power to the load. The photovoltaic phenomenon works based on the principle of quantum theory (Musa 2010). Effort to popular solar cell as a means of generating electricity was not successful ontill the energy crises in 1970s which encourages the use of an alternative sources of energy around the world. The solar pv technology has witness tremendous reduction in price in recent years (kumar and Rosen, 2011)
The energy can be used and applied in many facet of life, such as lighting, transportation, heating, use in homes, offices and health facilities, quit a number of research have been published stemming different aspect of solar energy from boosting efficiency, performance evaluation, and performance based on location. Solar system are assembled in a series and parallel to optimize voltage and current and power . The system can include aside the solar module, a battery for storage, inverter, charge controller and *balance* of systems. Some systems include sensors to record sunlight intensity and other meteorological factors (keogh *et al*, 2004).
Pv cell are classified in the first, second and third generation cell. The first generation are main the crystalline pv cell consisting of monocrystalline and polycrystalline, multi-junction pv cells, and ribbon silicon cell they are the most dominant in the market with an efficiency of between 14-27% (Kumar and Rosen, 2011).
The second generation pv cells are also referred to a thin film solar cell. These are thin layers semiconductor applied on substrate. The main highlight of a thin film solar pv is that it requires less materials in terms of semiconductor materials needed for production and this

results in low cost of production, example of such are the Amorphous silicon(A-Si), Cadmium Tellurid, copper-indium-serinade(CIS) (Parida *et al., 2011*). The second generation cels are promising to reduce cost of production with no adverse effect on our environment, they have efficiency of about 5-10% (chaar et al,2011). The maximum recorded efficiency of a solar cell is 23% under standard test condition (STC) (chaar et al,2011).

The third generation solar cell are mostly in the laboratory, these types of cell are fabricated using various materials apart from silicon, this materials includes conductive plastics, nanotubes, silicon wire, organic dye aided at improving on the commercially available solar cell through efficiency interim of the band of radiation utilized by the cell to generate energy and less cost.

Because of the high cost of the first-generation solar cell, toxic and difficulty in the availability of materials needed for the Second and the third generation pv cells, the third generations emerge to bridge the gap. The third-generation solar cell are different from the first- and second-generation cell, as they do not work on the principle of P-N junction as compared to others. Example are the dye sensitized cell(DSSC),Perovskite Sensitized Solar Cells, and organic cells.

Photon voltaic system have a large initial cost but pay for itself in the long run, it also have small maintenance cost compared to other sources of generation of electricity. Silicon cell are the largest of the various types of solar panel in the market, with a life time period pof 20-30 years (chaar et al,2014)

Solar PV Cell Model

The workings of a photovoltaic cell can be modelled through the equivalent circuit equation which can be used to examine the correct output and parameters of an ideal solar cell. The equivalent circuit represented by equation (1) shows the output current passing into the resistance (Ramakrishna and Mathar, 2009).

$$I = I_L - I_0\left[exp^{\frac{V+IR_{se}}{v_t}} - 1\right] - \frac{V+IR_{se}}{R_{Sh}}$$
(1)

The (V) is the output voltage of the model while (I) is the currrent , (I_0) is the diode reverse saturated current , ($V_{t)}$ is the thermal voltage ($\frac{nKT}{q}$). ($I_{L)}$ is the current generated by absorption at short circuit, (R_{se}) is the series resistant and (R_{sh}) is the shunt resistance in the equivalent circuit (Wansah *et al, 2014*).

Researchers have developed methoxides of evaluating the performance of photovoltaic systems. (Li *et al* , 2005) worked on the performance of a small pv system in city university of Hong Kong and the amount of solar irradiance falling on the panel was estimated using an approach called luminous efficacy approach. (Huang *et al*, 2006) proposed a system design called ‘ near-maximum-power operation’ that maintains the performance of a pv system very close to the MPPT(Maximum power point tracking) and the long term performance was determined to be higher than 90%.

Material and Method

This research evaluates the performance of a 100watt monocrystalline panel empirically to determine the performance, effect of temperature, optimum tilt and the output. The research work was carried out using instruments, such as a digital multimeter, ammeter, angle meter and table/rack to collect and analyze data in kogi state university, Anyigba on coordinate (7.493N, 7.1736E) in North-Central Nigeria. The solar panel was placed on a wooden adjustable rack which was erected several angle upward facing the southern hemisphere and oriented east-west which was supported by adjustable rack at different interval starting from 0^0, 10^0, 20^0, 30^0, 40^0, 50^0, 60^0, 70^0, 80^0 and 90^0 and the readings of the out voltage(V), current(I) and temperature of the PV module in degree centigrade (^{0}c) was recorded at different angle and and different interval of time, 8:00am, 10:00am, 12:00pm and 4:00pm,

Figure 1: Solar panel on an erected wooden rack.

Results

Table 1: Table of value 0°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.3	1.08	24.08	27
10:00	23.2	350	81.20	28
12:00	23.2	3.55	81.65	30
2:00	22.29	3.09	70.76	35
4:00	22.70	2.53	57.42	42

Table 2: Table of value from 10°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	23.00	0.08	18.40	26
10:00	23.30	2.95	68.74	27
12:00	23.10	3.25	75.08	29
2:00	23.20	3.30	76.56	28
4:00	22.70	1.80	40.86	34

Table 3: Table of value from 20°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.90	0.67	15.34	26.
10:00	23.30	2.77	64.54	30.
12:00	28.80	3.15	71.82	33
2:00	22.50	3.01	67.73	35
4:00	22.60	2.65	51.08	36

Table 4: Table of value from 30°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	23.00	0.92	21.16	26
10:00	23.2	2.48	57.54	30
12:00	22.8	2.82	64.29	35
2:00	22.3	3.22	71.80	36
4:00	22.3	1.59	35.46	37

Table 5: Table of value from 40°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.70	0.68	15.44	28
10:00	22.90	2.23	51.07	34
12:00	23.00	3.00	67.00	35
2:00	22.6	2.70	61.02	35
4:00	22.2	2.18	48.40	37

Table 6: Table of value from 50°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.5	0.50	11.25	22
10:00	22.8	2.21	50.39	30
12:00	22.5	2.47	55.56	34
2:00	22.6	2.6	58.76	35
4:00	22.4	2.34	52.42	36

Table 7: Table of value from 60°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.0	0.60	13.20	24
10:00	22.5	2.20	49.50	30
12:00	22.7	2.60	59.02	34
2:00	22.3	2.24	49.95	35
4:00	22.2	2.00	44.40	37

Table 8: Table of value from 70°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	23.3	0.57	12.71	22
10:00	22.7	1.71	38.82	30
12:00	22.3	2.48	55.30	35
2:00	22.4	2.56	57.34	38
4:00	21.8	1.09	24.76	36

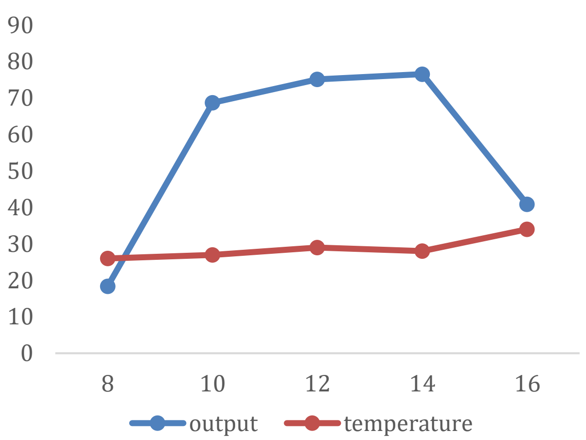
Table 9: Table of value from 80°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.0	0.70	15.40	22
10:00	22.5	2.30	51.75	31
12:00	22.8	2.60	59..28	35
2:00	22.4	2.26	50.40	35
4:00	22.2	20.01	44.62	37

Table 10: Table of value from 90^0

S/N	Tilt of Angle	Average Daily Output (Watt)
1	0°	63.02W
2	10°	55.93W
3	20°	54.10W
4	30°	50.05W
5	40°	48.99W
6	50°	45.68W
7	60°	43.21W
8	70°	37.59W
9	80°	44.29W
10	90°	34.64W

Figure 2: The Graph of Output Against Temperature at angle of 0°



Discussion

The result from the table shows that by 8:00am in the morning, when the solar panel is inclined at 0^0 tilt angle the voltage was 22.3V and the current (I) was given was 1.08A. The temperature of the PV modules was at 27^0C and the output was 24.08watt. At 10:00am the voltage was observed to be 23.2V, the current was 3.50A while the temperature of the PV module increased to 28^0C, the device and the power output was 81.20watt. At 12:00noon, the PV voltage is 23.0V, direct current is reduced to 3.55A and the temperature of the PV module increase to 30^0c and power output was 81.65watt and began to decrease with time , at 4.00pm the current decreased to 22.7V due to the cloud cover over the sunlight, the current also reduces to 2.53A as temperature of the PV module increased to 42^oc and output decreased to 57.43watt. table (2) also follows the same pattern asa table (1) but with a reduction in values of the parameters under investigation. This is as a result of a change in the tilt angle of the module, the output continued to decrease as the tilt angle varies from 0^oc to 90^0c. Table (10) shows the daily average output power of the module and was found to be 63.03Watt at 0^0c and 55.93 Watt and continued to decrease as the tilt angle increases. These results show how the temperature and tilt angle affects the output and determine the best angle tilt compared to the normal capacity of the mono-crystalline solar panel.

Table 11: Table of value for average power output at various panel tilt

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	21.8	0.40	8.72	27
10:00	22.4	1.06	23.74	30
12:00	22.3	2.18	48.61	36
2:00	22.0	2.10	46.20	36
4:00	22.2	2.07	45.95	34

Conclusion

The result shows the performance of the 100watt mono crystalline module, at angle 0° the highest output 81.65 Watt at 30^0c was recorded, follow by a record of 75.08 Watt at 29^oc peak and 10^0c. The peak output is not up to the expected output labeled on the pv module; maximum power (100 watt), and for the current labeled (6.40A). From the result above the maximum performance of Solar PV Module (SPVM) in Anyigba in February is within acceptable value with about 81.65% out at optimum tilt angle and ambient temperature of 30^0c. The average daily output was found to be 63.02 W at 0^0c and 55.93W at 10^0 , which is about 60% output of the nominal output value of the pv module, Therefore the use of mono-crystalline SPVM is encouraged at Anyigba at 10^0c so the system can self clean rather than mounting modules on a horizontal surface (0^0c) .

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RESEARCH ARTICLE

A Comparative Study of Performance About the Integrated Power Quality and Optimized Framework for Smart Grid

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Abstract
As global warming becomes more serious in the 21st century, efforts are being made around the world to reduce greenhouse gas emissions. The greenhouse gas reduction objective is set in 2009 to be a 30% emission forecast and set to low carbon emissions. There are several grids which are using coal for generating electricity. As a result, the environment has got more pollutants and the world needs reducing such type of pollution for a green world. Then the concept of integration of renewable energy sources is coming to force. Their integration of such sources is providing the opportunity of availability of power with less pollution of the environment. A smart grid was developed and applied to the field as a system that can manage the energy in a smart environment. In this paper, a comparative study is performed about the performance of Integrated Technology in a smart environment.

Keywords: Smart Grid; IoT; Power Quality; Performance Analysis; Optimization

Introduction

With the progress and usage of smart devices along with the development and habit of technologies such as electric vehicles, which are being marketed recently, the overall load of the power grid amplified quickly, and at the identical time slot, the peak load derived nearby to the transmission capacity. Due to this problematic area cost of electricity increases strongly and is incipient due to the appearance of the electric power system, in which the generation cost increases as the user's demand increases as well as the risk of blackout. The smart grid, which is an emerging solution for the above issues, is a smart power grid that amalgamation of IT technology and the existing grid system, in which suppliers and consumers exchange information such as electricity price in real-time and electricity demand. By using this technology, consumers can optimize the electricity uses cost by using their smart devices [44] within the available times when electricity prices are cheaper and slots. The Utility can monitor and control of wastage of electricity and unscheduled shutdowns. This study emphasizes the prerequisite information during the integration of energy sources and to power using an optimized schedule [17] to satisfy the power demand of each n every appliance installed by users. It will also monitor the power outage and usage of consumers. The smart grid enables two-way communication or full-duplex mode which can deal with is complete. A typical example is the charging system of an electric vehicle. real-time scheduling methods and techniques. Apart from this point this study also focuses on the power usage schedule in real-time to minimize the cost and prevent the transmission capacity from being exceeded when an unscheduled additional power demand suddenly occurs. We would like to propose a smart grid [3,4,16,21,22] system process that can minimize the inconvenience of consumers.

Integrated Framework

In order to reduce the limitations of the power quality and schedule for the smart grid mentioned in [10], The smart grid serves as a communication system between N no. of consumers and a single grid responsible for power supply and generation. It consists of a multitude of information aggregation units, and a consistent supervision system that manages the usage schedule by integrating the demand-supply information of each consumer. painting.

The smart grid optimization framework proposed in [10] study is categorized into interruptible devices and non-interruptible devices, and it is set to perform optimal scheduling [36] considering the operation characteristics of each load. First, an interruptible device, the start time can be set, and the process can be stopped during the process and restarted at a different time. For other a non-interruptible load can set the start-up time period, but once the device is started, it cannot be stopped until the process

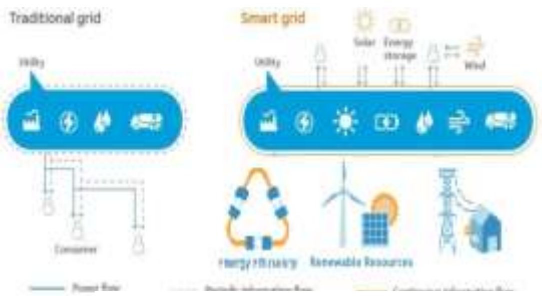


Figure 1: Smart Grid Vs Existing Grid

Table 1: Load Specification Matrix

$E_{1,1}^{NL} = \begin{matrix} 2H \\ 14:00 \\ 0:00 \\ 3\ kwh \end{matrix}$	$E_{1,2}^{NL} = \begin{matrix} 4H \\ 14:00 \\ 0:00 \\ 4kwh \end{matrix}$	$E_{1,t}^{t} = \begin{matrix} 6H \\ 14:00 \\ 0:00 \\ 9kwh \end{matrix}$
$E_{2,1}^{NL} = \begin{matrix} 2H \\ 17:00 \\ 5:00 \\ 4\ kwh \end{matrix}$	$E_{2,2}^{NL} = \begin{matrix} 6H \\ 17:00 \\ 5:00 \\ 6\ kwh \end{matrix}$	$E_{2,t}^{t} = \begin{matrix} 6H \\ 17:00 \\ 5:00 \\ 9kwh \end{matrix}$
$E_{3,1}^{NL} = \begin{matrix} 4H \\ 24:00 \\ 10:00 \\ 5\ kwh \end{matrix}$	$E_{3,1}^{NL} = \begin{matrix} 6H \\ 24:00 \\ 10:00 \\ 7\ kwh \end{matrix}$	$E_{3,t}^{NL} = \begin{matrix} 9H \\ 24:00 \\ 10:00 \\ 9\ kwh \end{matrix}$

CSS calculates the power usage scheduling vector that can minimize the negotiator's power usage cost by bearing in mind the power demand [30] information $E_{1,1}^{NL}$ and $E_{n,1}^{t}$. The grid transmission capacity is derived using a genetic algorithm, and the method is:

$$[Y_{JK}^{NL}(Y_{JK}^{L})] \equiv [Y_{JK1}^{L}(Y_{JK1}^{L}) \dots \dots \dots \dots . Y_{JKh}^{L}(Y_{jkh}^{L})] \text{--------} 1$$

Here, symbolizes the $L_i h$ power consumption essential for agent i at h time. Concluded this, the total power consumption l_h that the grid must supply in h hour, the sum L of the power consumption that needs to be supplied at all times of the day,

$$l_h = \sum_{i=0}^{N} L_i h \text{--} 2$$

$$L = \sum_{h}^{H} l_h \text{---} 3$$

The PAR value can be calculated as

$$PAR = \frac{max_h\, l_h}{\frac{L}{H}} \text{--} 4$$

Case 1: When the transmission capacity exceeds the allowable capacity when a sudden demand request is accepted. Since the power demand in h-hour becomes higher than the transmission capacity, the power supply and demand may become unstable or blackout may occur.

Case 2: When the transmission capacity does not exceed the allowable capacity even when the sudden demand request is accepted. Even if the sudden demand is supplied as it is, the possibility of a power outage is low, but the power consumption in the corresponding time period is high, and the SMP for the sudden demand is very high.

Implementation and Comparative Analysis

The analysis is done by using the MATLAB/SIMULINK 2017b. The Comparative performance analysis is as follows:

Power Usage Scheduling Scenarios

As an experimental condition for analysing the performance of the framework for smart grid presented in this study, it is assumed that a day is divided into 24 time slots at one-hour intervals, and 10 consumers who have Three-types of non-interruptible devices and two-types of interruptible are assumed. The power demand information e_i and importance $im_{i,j}$ of each user were randomly derived within the range of power consumption per hour and operating time of realistic home appliances and used in the relevant experiment. The capacitor, Reactor Bank and decision function used in this experiment, and after assuming several sudden demands that occur as the day progresses, the operation delay discomfort function $dis_{i,j}$. [In order to find obtainable weight, how the weight of the factor dissatisfaction i.e., h] changes the experimental result, the effect of the proposed framework on the performance of the framework was inspected by changing the dissatisfaction weight at 0.25 intervals.

As a result of the scheduling, the PAR value decreased from 1.88 to 1.4567, which reduced the risk of power outage and improved the performance of the power system.

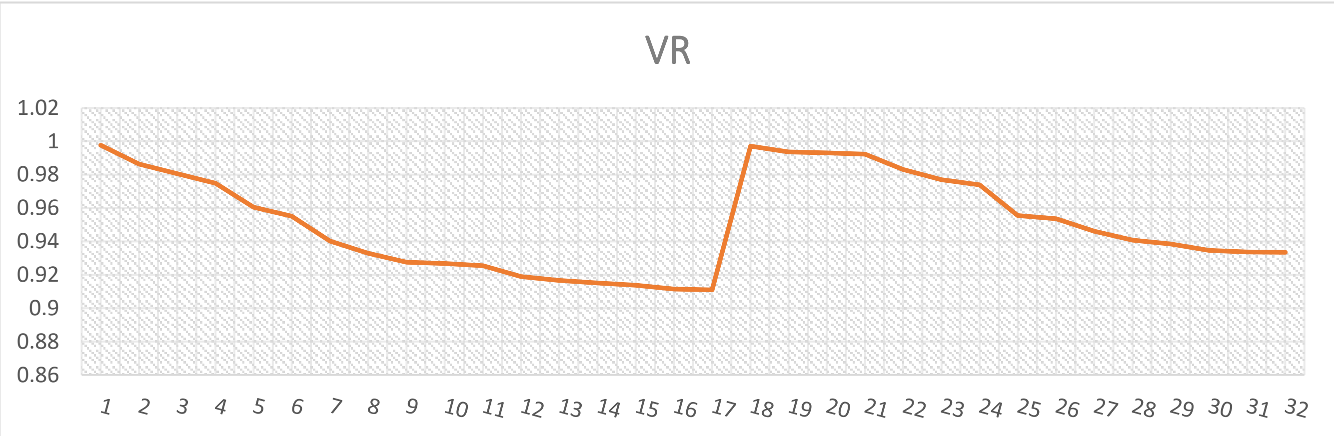
Results and Discussion

Figure shows the variation in consumption outlines beforehand and afterward applying the proposed scheduling framework which is published [10]. The initial random scheduling under the corresponding experimental conditions shows the cost optimization transformation of proposed framework integrated with scheduling through Genetic Algorithm.

As can be seen from the figures, it can be long-established that the scheduling, daily power consumption is distributed much more evenly compared to the initial random schedule, and power usage during peak hours is also reduced.

Table 2 Load Categories and Parameters

Time Slot	Load 1			Load 2			Load 3			Total
	L_1	LD_2	D_1	L_2	LD_2	D_1	L_3	LD_3	D_1	IN
0-1	0	0	7	-	-	-	-	-	-	7
1-2	4	6	0	-	-	-	-	-	-	10
2-3	4	6	7	-	-	-	-	-	-	17
3-4	4	6	0	-	-	-	-	-	-	10
4-5	4	6	0	-	-	-	-	-	-	10
5-6	5	6	7	0	0	0	-	-	-	18
6-7	5	0	0	0	6	0	-	-	-	11
7-8	0	0	7	0	6	0	-	-	-	13
8-9	0	0	0	0	6	8	-	-	-	14
9-10	0	0	8	0	6	8	0	0	8	30
10-11	0	0	0	0	6	8	0	0	0	14
11-12	0	0	0	4	0	0	0	0	8	12
12-13	0	0	0	4	0	0	0	0	8	12
13-14	0	0	8	0	0	8	4	0	0	20
14-15	-	-	-	0	0	8	4	0	0	12
15-16	-	-	-	4	0	0	4	0	8	16
16-17	-	-	-	4	0	8	0	0	0	12
17-18	-	-	-	4	0	0	0	0	8	12
18-19	-	-	-	4	0	0	0	0	8	12
19-20	-	-	-	-	-	-	4	6	8	18
20-21	-	-	-	-	-	-	4	6	0	10
21-22	-	-	-	-	-	-	4	6	0	10
22-23	-	-	-	-	-	-	0	6	8	14
23-24	-	-	-	-	-	-	0	0	0	0
Total	26	30	44	24	30	48	24	24	64	314



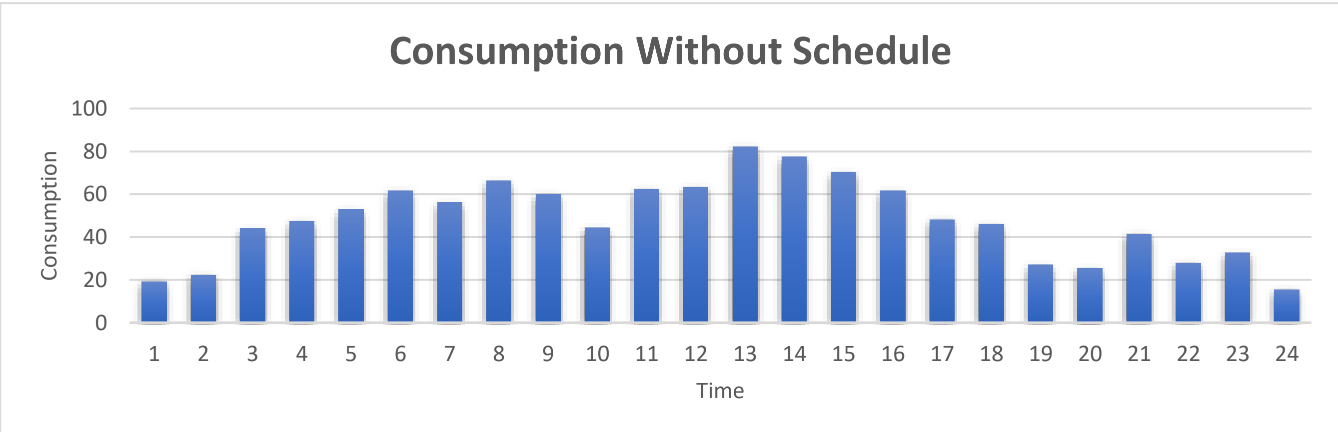


Figure 2:Consumption without Scheduling

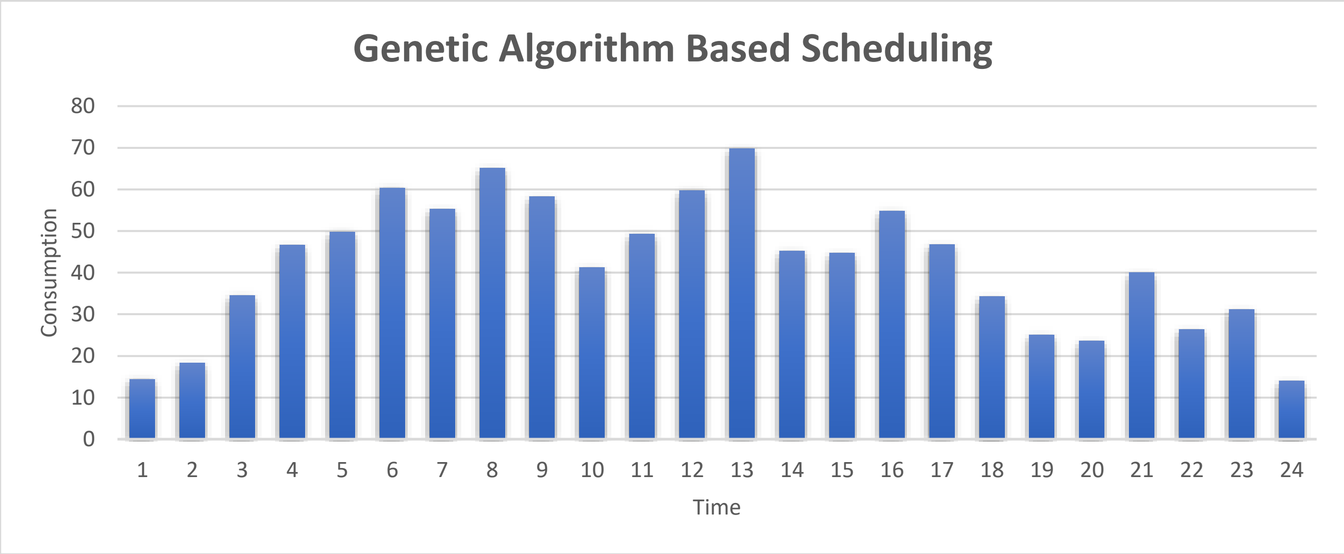


Figure 4: Consumption with Scheduling

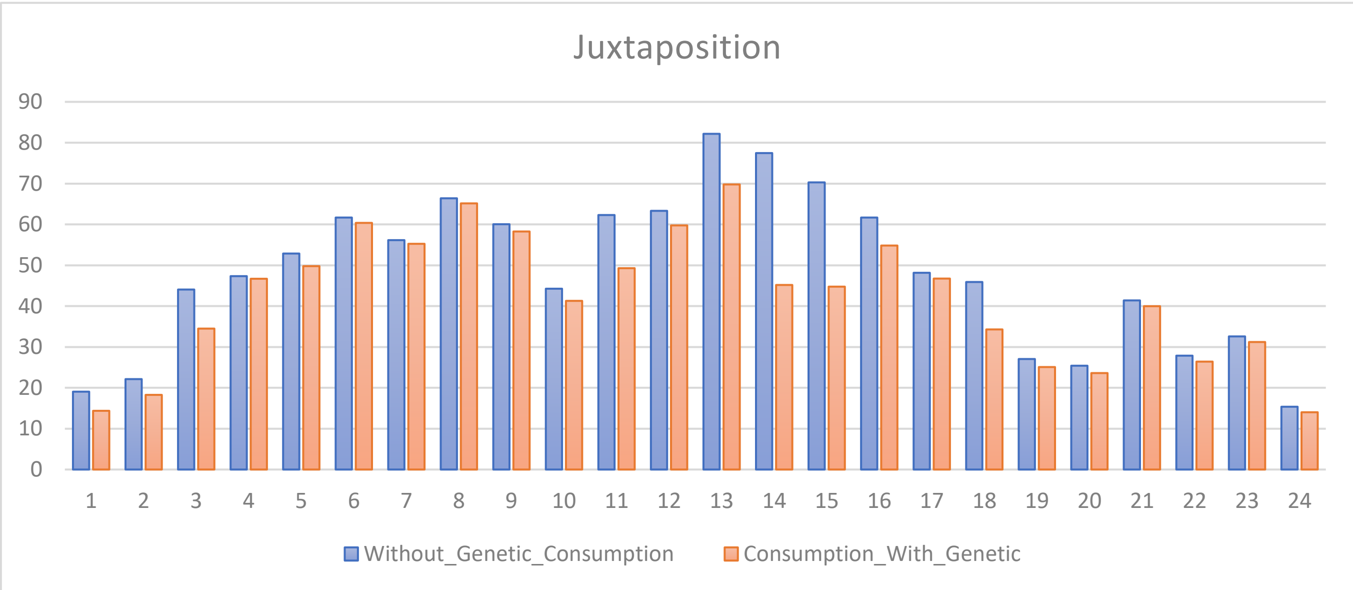


Figure 5: Comparative Analysis

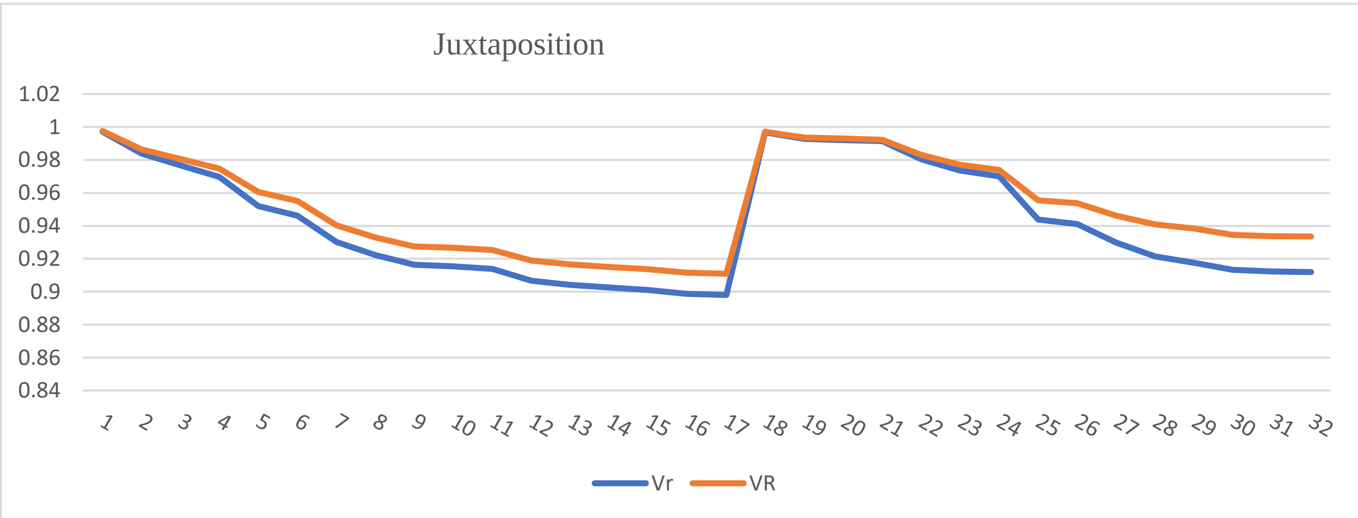


Figure 6: Comparative Analysis of Voltage Profile

Table 3: Cost and PAR of Consumed Power

Sr. No	Cost	Before Unexpected Demand	Accept All Demand
1.	Load_1	16.86	16.86
2.	Load_2	22.69	22.69
3.	Load_3	19.87	24.74
4.	PAR	1.8832	2.4646
5.	Total Cost	59.42	64.29

Table 4: Experiment Condition and Status

Sr. No	Particular	Status
1.	Number of Users	10
2.	Time Interval(h)	1
3.	Number of Interruptible appliances	3
4.	Number of Non-Interruptible appliance	2
5.	Power unit consumption cost function $Ch(l_h)$	$\frac{i_h^2}{1000}$
6.	Discomfort function $dis_{i,j}(h)$	$d_w \cdot i_{mi,j} \cdot 10h^2$ $dw\in[0,1]$ $im_{i,j}\in[0,1]$
7.	Value of Discomfort factor weight dw	0.25: 0.25 : 1
8.	Number of Sudden Demand occurrence	8

The Smart Direct Load Control method proposed by [9], which is to be compared in this paper, occurs in the consistent period analogous pattern with this paper when the power demand surpasses the transmission capacity. It is a method to reduce the risk of a power outage beyond the power supply boundary by suspending the operation schedule of the device with the lowest importance among the power demand array. However, as long as the power supply limit is not exceeded, there is no organic schedule change for the sudden power demand, and recompense for the delay in the process schedule is not taken into account, so the user's discomfort is not resolved. Algorithms to be compared with the method of this study are methods that process power demand in real-time without prior scheduling, which is presented in this paper. Therefore, when comparing the performance of the entire smart grid system, the Comparative analysis is difficult. To this end, it is assumed that the same power demand as the schedule derived from the optimization framework integrated with scheduling and implemented in the [10] and at the same time, the situation in which the sudden demand in each time zone assumed in the experiment occurs together so that the performance under the same situation can be compared. did.

Conclusion

In this study, by applying a real-time data and load using the characteristics of Genetic Algorithm in a smart grid that enables two-way communication in real-time, it is possible to derive an optimized power usage and schedule the load for satisfying the power demand of each consumer and reduce the risk of the wide-area power outage and power usage cost. We have proposed an integrated framework with power quality, optimization as well as scheduling, and a real-time sudden demand processing method that additionally considers the user's inconvenience due to the change in the electricity usage schedule, which was not considered in previous studies in the situation of additional sudden power demand. As a future research plan, research that can further improve the users' satisfaction, and how to find the best operation suspension compensation amount that can minimize the supplementary power consumption cost for the unexpected power demand.

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