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Research Paper

Modelling and Simulation of Microgrid Energy Systems in Edo State: Unveiling Opportunities and Addressing Challenges

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Abstract
This paper presents the design and simulation of a microgrid energy system tailored for a Polytechnic community in Edo State, Nigeria. The system was initially sized and designed using Homer Pro software, resulting in a configuration that includes the grid system, 3,726 solar panels each rated at 0.5 kW, a 1.5 MVA diesel generator, and a 500 kW inverter, covering an area of 17,696 m² with a total cost of ₦295. The design achieves a simple payback period of 3 years and 5 months, reducing electricity bills by 88% and lowering CO_2 emissions. Given the high PV capacity of 1,863 kW required, additional software tools such as OpenSolar, PVWatt, and REopt were utilized to optimize the PV size. The optimized design features a PV capacity of 675.2 kW, comprising 96-cell modules each rated at 500 W, with 25 modules connected in series and 54 in parallel. The system also includes a utility grid connection and a diesel generator for emergencies. The microgrid was then simulated in a MATLAB/Simulink environment to analyze its dynamic performance. The initial simulation showed acceptable dynamics with load variations but was slow. To address this, a reduced order model was developed in MATLAB/Simulink, enhancing simulation speed by over four times compared to the original model. Additionally, a monitoring system for the microgrid was designed, requiring 54 DC current sensors, one DC voltage sensor, nine AC current sensors, and six AC voltage sensors, all connected to a data logger interfaced with a computer system for remote monitoring and control. This paper provides comprehensive details on system design, sizing, dynamic simulation, reduced order modeling, and monitoring.
Keywords*: Microgrid, Edo State, Nigeria, Homer Pro, MATLAB/Simulink, Renewable Energy, solar PV, system optimization, dynamic simulation, reduced order model, remote monitoring.*

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I. Introduction

Decentralised power sources and loads are connected to and synchronous with the wide-area synchronous grid in microgrids. They can operate in "island mode" without the grid under technological or economic constraints. A microgrid powers a discrete geographic area like a commercial centre, neighbourhood, college campus, or hospital. A microgrid is a group of interconnected loads and distributed energy resources (DERs) inside clearly defined electrical boundaries that behave as a single controllable entity with respect to the grid, according to the US Department of Energy Microgrid Exchange Group. A microgrid can operate in connected and island modes by connecting and disconnecting. A microgrid consists of low-voltage (LV) distribution systems with DERs (microturbines, fuel cells, PV, etc.), storage devices (batteries, flywheels), and flexible loads, according to an EU research project. Efficient micro source management and coordination improve system performance in these systems, which can operate connected or separated from the grid. An integrated group of loads and DERs with defined electrical boundaries forms a local electric power system at distribution voltage levels up to 35 kV, according to Electropedia.

This controlled cluster of consumer and producer nodes can operate in grid-connected or island mode. Recent research and implementations show that microgrids improve energy resilience and sustainability.

Iwuamadi and Dike (2012) examine Nigerian power industry productivity measures, emphasising the need for more efficient and localised energy solutions [1]. Omorogiuwa and Ike (2014) explore power flow regulation in big networks and highlight microgrid technologies' potential for grid stability [2]. Photovoltaic electricity generation is important for sustainable development, according to Evbogbai & Ogbikaya (2019) [3]. A feasibility study on ideal renewable energy systems for towns by Ryan and Longe (2020) provides microgrid design insights for different scales [4]. Stand-alone polygeneration microgrids are examined by Murthy et al. (2020) for their efficiency and versatility [5]. A rural hybrid microgrid design technique by Prakash et al. (2017) may be applicable [6]. Cyprien et al. (2020) found cost-effective photovoltaic solutions for microgrid viability assessments [7].

Shoeb and Shafiullah (2018) explore integrated microgrid solutions for sustainable irrigation, which might inform use case microgrid design [8]. Yoshida and Farzaneh (2020) provide excellent design solutions for residential hybrid microgrid optimisation [9]. Agua et al. (2020) compare decentralised and clustered microgrids to assess off-grid electricity system reliability [10]. Finally, Dash et al. (2018) use HOMER-Pro for cost and sensitivity analysis to assess microgrid economic feasibility [11].

1.1. Microgrid Characteristics

Microgrids can be defined based on their characteristics, such as locality, independence, and intelligence. Locality refers to microgrids generating and supplying energy locally, which sets them apart from large, centralized grids that transmit electricity over long distances and suffer from inefficiencies due to transmission losses. These grids generate power close to those they serve, such as within or near buildings or, in the case of solar panels, on rooftops [1][2]. Independence is another defining feature, as microgrids can disconnect from the central grid and operate independently, a capability known as islanding. This allows them to provide power during outages caused by storms or other disruptions to the central grid [3][4]. While microgrids can operate independently, they typically remain connected to the central grid, functioning symbiotically under normal conditions [5][6]. Additionally, advanced microgrids are equipped with intelligent systems, primarily managed by a microgrid controller. This controller orchestrates generators, batteries, and building energy systems to meet specific energy goals such as cost efficiency, clean energy use, or reliability, dynamically optimizing the use of various resources based on real-time conditions and market prices [7][8].

1.2. Types of Microgrids

There are three main types of microgrids: remote, grid-connected, and networked microgrids. Remote microgrids are isolated from the utility grid, operating in island mode due to the lack of available and affordable transmission or distribution infrastructure. These microgrids often rely on renewable energy sources like wind and solar, complemented by battery energy storage systems for backup power [1][2]. Grid-connected microgrids have a physical connection to the utility grid but can disconnect and operate independently when needed. These microgrids support grid services such as frequency and voltage regulation, demand response, and provide backup power. This makes them economically viable for campuses, medical complexes, public safety facilities, military bases, agricultural farms, commercial buildings, and industrial facilities [3][4]. Networked microgrids consist of multiple Distributed Energy Resources (DERs) and/or microgrids connected to the same utility grid segment, serving a wide geographic area. They are managed by a supervisory control system that optimizes operation across different tiers of the utility grid. Examples of networked microgrids include community microgrids, smart cities, and new utility adaptive protection schemes [5][6].

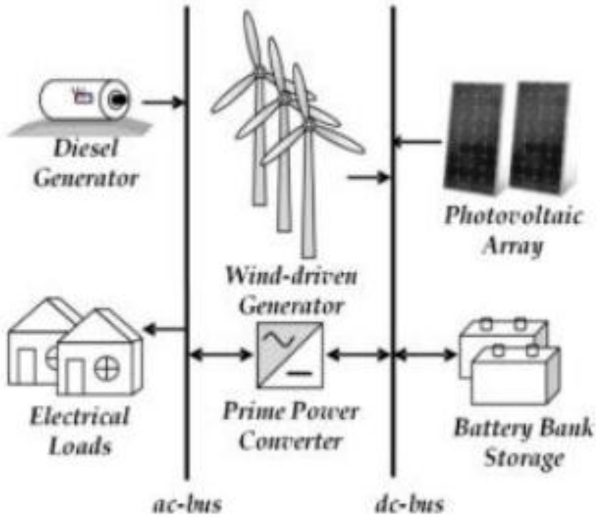


Figure 1: Microgrid hybrid power system with renewable sources and a diesel generator

1.3. Microgrid Topologies

Microgrids can be defined based on their characteristics, such as locality, independence, and intelligence. Locality refers to microgrids generating and supplying energy locally, which sets them apart from large, centralized grids that transmit electricity over long distances and suffer from inefficiencies due to transmission losses. These grids generate power close to those they serve, such as within or near buildings or, in the case of solar panels, on rooftops. Independence is another defining feature, as microgrids can disconnect from the central grid and operate independently, a capability known as islanding. This allows them to provide power during outages caused by storms or other disruptions to the central grid. While microgrids can operate independently, they typically remain connected to the central grid, functioning symbiotically under normal conditions. Additionally, advanced microgrids are equipped with intelligent systems, primarily managed by a microgrid controller. This controller orchestrates generators, batteries, and building energy systems to meet specific energy goals such as cost efficiency, clean energy use, or reliability, dynamically optimizing the use of various resources based on real-time conditions and market prices. There are three main types of microgrids: remote, grid-connected, and networked microgrids. Remote microgrids are isolated from the utility grid, operating in island mode due to the lack of available and affordable transmission or distribution infrastructure, often relying on renewable energy sources like wind and solar, complemented by battery energy storage systems for backup power. Grid-connected microgrids have a physical connection to the utility grid but can disconnect and operate independently when needed. These microgrids support grid services such as frequency and voltage regulation, demand response, and provide backup power, making them economically viable for campuses, medical complexes, public safety, military bases, agricultural farms, commercial buildings, and industrial facilities. Networked microgrids consist of multiple DERs and/or microgrids connected to the same utility grid segment, serving a wide geographic area. They are managed by a supervisory control system that optimizes operation across different tiers of the utility grid, with examples including community microgrids, smart cities, and new utility adaptive protection schemes. Microgrids can also be classified into three topologies: AC, DC, and hybrid. In an AC microgrid, power sources with AC output are interfaced with an AC bus through AC/AC converters, while power sources with DC output use DC/AC converters to connect to the AC bus. In a DC microgrid, power sources with DC output are connected to a DC bus either directly or through DC/DC converters, and power sources with AC output connect to the DC bus via AC/DC converters. A hybrid microgrid includes both AC and DC power sources and buses connected through a bidirectional converter, allowing power flow in both directions between the buses.

1.4. Basic Components in Microgrids

Microgrids comprise several basic components, including local generation, consumption/load, energy storage, and essential equipment. Local generation in microgrids includes various types of sources, divided into thermal energy sources (e.g., natural gas or biogas generators) and renewable generation sources (e.g., wind turbines and solar panels). The loads in microgrids, which consume electricity, heat, and cooling, can range from single devices to entire building systems, with controllable loads that can be adjusted based on network demands. Energy storage systems play a crucial role in ensuring power quality, smoothing renewable energy output, providing backup power, and optimizing costs. These systems include a variety of technologies such as chemical, electrical, pressure, gravitational, flywheel, and heat storage, with coordinated control preferred to balance charging and discharging rates. Additionally, microgrids include critical components like electrical cables, circuit breakers, transformers, and inverters, which connect generation resources to consumers and enable the control system to manage the microgrid effectively.

1.5. Point of Common Coupling (PCC)

The PCC is the point where a microgrid connects to the main grid. Microgrids without a PCC are isolated, typically found in remote areas where grid interconnection is not feasible due to technical or economic constraints. Kotb, K. M. et al. (2020), currently stated that the global gives a unique awareness of sustainable development by exploiting renewables to provide the people with affordable and clean energy and preserve the climate. Their paper proposes a methodical and explicit framework of four phases, to design an autonomous hybrid renewable energy system in a community area in Egypt: preliminarily assessment, design optimization analysis, findings evaluation, and power-quality assessment. In the first three phases which was performed by **HOMER Pro** software, five hybridization scenarios were evaluated and compared regarding their life-cycle cost, carbon outflows, and reliability to distinguish the extraordinary scenario to supply the addressed community area. Contrary to most studies that suffice only the first three phases, the fourth phase is proposed to perform a power-quality valuation based on a power management strategy (PMS). The results reveal that the optimal configuration consists of a photovoltaic generator, winddriven generator, diesel-genset, battery-bank, and a power converter as shown in Figure 1 with the minimum net present cost of 351,223 $ and energy cost of 0.2262 $/kWh among all configurations.

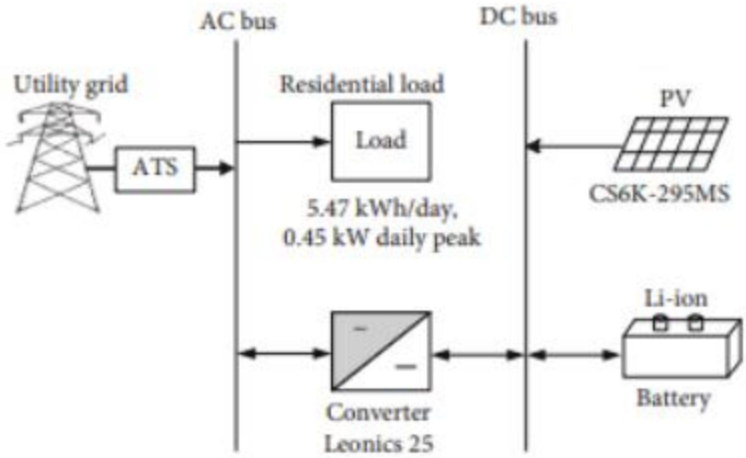


Figure 2 : On-grid power system with PV ,battery and converter

Nsengimana, C. et al. (2020), studies focused on the economic power generation model mainly based on solar resources to minimize the electricity cost and provide income for the excess energy produced. This study covers on-grid power system with PV, battery and converter shown in Figure 2, off-grid power system with generator, PV, battery and converter shown in Figure 3 and off-grid power system with PV, battery and converter shown in Figure 4

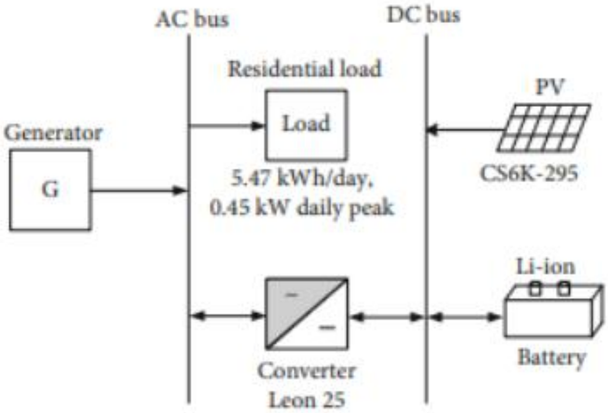


Figure 3: Off-grid power system with generator, PV, battery and converter

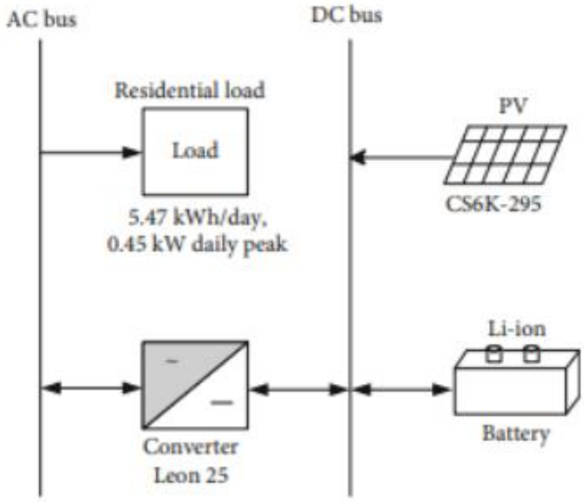


Figure 4 : Off-grid power system with PV ,battery and converter

Moreover, the study resulted in a low-cost (four times cheaper), reliable, and affordable grid-connected PV and battery microgrid model for a residential home with a minimum daily load of 5.467 kWh as shown in Figure 2. The simulation results based on economic comparison analysis found the levelized cost of energy (LCOE) and net present cost (NPC) for each power-generated model by using HOMER Pro software.

1.5.1 Research Objectives

The following are the research objectives of this work:

i. To do a literature review on microgrid system.

ii. To determine the load profile (kWh) of the Polytechnic community.

iii. System design and sizing of the campus microgrid would be done with the aid of Homer Pro and other software such as OpenSolar, PVWatts and REopt to obtain the optimal PV size of the selected site.

II. Literature Review

In this paper, focus is on some reported works done in the field, assumptions, presumptions, and their resolutions.

2.1. Renewable Energy System

Kotb et al. (2020), present a framework for designing an autonomous hybrid renewable energy system in a community area in Egypt. Their method involves four phases: preliminary assessment, design optimization analysis, findings evaluation, and power-quality assessment. Using HOMER Pro software, they evaluated five hybridization scenarios for their life-cycle cost, carbon emissions, and reliability. Their findings indicate that a configuration consisting of a photovoltaic generator, wind-driven generator, diesel generator, battery bank, and a power converter was optimal, with a net present cost of $351,223 and energy cost of $0.2262/kWh. The system, with a renewable fraction of 57%, had a negligible capacity shortage of 0.0955% and produced 50.43 tonnes/year of emitted gases, recovering the investment in 3.4 years .

Ryan and Longe (2020) investigate renewable energy systems in South Africa, focusing on the Rand West Municipality. They used HOMER software for simulations, which suggested an optimal microgrid system consisting of Solar PV panels, a Concentrated Photovoltaic system, Battery Energy Storage System, and a Diesel Generator, with a Cost of Energy (COE) of $0.068/kWh, compared to the grid COE of $0.12/kWh . Ahmad et al. (2018) detail governmental initiatives and investments in the Indian power sector to promote Renewable Energy Sources (RESs), highlighting a framework for deploying microgrids. Using HOMER, they evaluated nine microgrids across different locations, incorporating environmental constraints and grid availability, demonstrating the feasibility of solar and wind-based energy in India. Ishraque et al. (2021) designed and evaluated a solar battery-based hybrid renewable energy system (HRES) with a diesel backup for a remote school in northern Bangladesh. They found the system's Net Present Cost (NPC) to be USD 6191 and COE to be $0.125/kWh, reducing COE and GHG emissions by 29.85% and 69%, respectively, compared to conventional power plants . Evbogbai and Ogbikaya (2019) argue that solar energy is viable for sustainable development in Nigeria. Despite high initial costs, solar power is economical in the long run due to its renewable nature, low maintenance costs, and environmental benefits .

2.2. Hybrid Power System

Majdi Nasab et al. (2021) evaluated the feasibility of a hybrid system with wind and tidal turbines for Stewart Island, New Zealand. They found that combining tidal energy with wind and diesel backup increased reliability and reduced costs. The best configuration included two wind turbines, four tidal turbines, and one diesel generator. Dash et al. (2018) assessed the economic feasibility of a grid-connected hybrid (PV/Wind) power system for a remote village in Khurdha District, Odisha, India. Using HOMER Pro software, they designed and optimized off-grid and on-grid models, finding the grid-connected hybrid system to be the most suitable and cost-competitive for the region. Arribas et al. (2021) addressed technical barriers to incorporating wind generation in hybrid microgrids. Their methodology facilitated wind generation inclusion in an affordable manner, with a case study showing successful integration into an existing PV-Diesel Power System (PVDPS). Ahmad et al. (2018) explored the techno-economic feasibility of a grid-tied hybrid microgrid system in Kallar Kahar, Pakistan, using wind, photovoltaic, and biomass resources. Their research indicated that the hybrid system could generate over 50MW with a levelized cost of energy of $0.05744/kWh. Brunaccini et al. (2019) investigated a combined approach with Fuel Cell (FC) and Fuzzy Logic (FL) for a hybrid system in Italy, optimizing equipment installation, control logic, and service availability. Their simulation showed economic balance affected by natural gas costs, suggesting a hybrid scheme with a single FC generator for multiple ICT stations.

2.3. Micro-Grid Technology

Decentralised power sources and loads are connected to and synchronous with the wide-area synchronous grid in microgrids. They can operate in "island mode" without the grid under technological or economic constraints. A microgrid powers a discrete geographic area like a commercial centre, neighbourhood, college campus, or hospital. A microgrid is a group of interconnected loads and distributed energy resources (DERs) inside clearly defined electrical boundaries that behave as a single controllable entity with respect to the grid, according to the US Department of Energy Microgrid Exchange Group. A microgrid can operate in connected and island modes by connecting and disconnecting. A microgrid consists of low-voltage (LV) distribution systems with DERs (microturbines, fuel cells, PV, etc.), storage devices (batteries, flywheels), and flexible loads, according to an EU research project. Efficient micro source management and coordination improve system performance in these systems, which can operate connected or separated from the grid. An integrated group of loads and DERs with defined electrical boundaries forms a local electric power system at distribution voltage levels up to 35 kV, according to Electropedia.

This controlled cluster of consumer and producer nodes can operate in grid-connected or island mode. Recent research and implementations show that microgrids improve energy resilience and sustainability. Iwuamadi and Dike (2012) examine Nigerian power industry productivity measures, emphasising the need for more efficient and localised energy solutions [1]. Omorogiuwa and Ike (2014) explore power flow regulation in big networks and highlight microgrid technologies' potential for grid stability [2]. Photovoltaic electricity generation is important for sustainable development, according to Evbogbai & Ogbikaya (2019) [3]. A feasibility study on ideal renewable energy systems for towns by Ryan and Longe (2020) provides microgrid design insights for different scales [4]. Stand-alone polygeneration microgrids are examined by Murthy et al. (2020) for their efficiency and versatility [5]. A rural hybrid microgrid design technique by Prakash et al. (2017) may be applicable [6]. Cyprien et al. (2020) found cost-effective photovoltaic solutions for microgrid viability assessments [7]. Shoeb and Shafiullah (2018) explore integrated microgrid solutions for sustainable irrigation, which might inform use case microgrid design [8]. Yoshida and Farzaneh (2020) provide excellent design solutions for residential hybrid microgrid optimisation [9]. Agua et al. (2020) compare decentralised and clustered microgrids to assess off-grid electricity system reliability [10].

III. Methodology

3.1 Literature Review

The initial step involved an extensive review of the literature on microgrid systems to understand the current technologies, methodologies, and applications. This review covered various aspects of microgrid design and operation, including energy generation sources, storage solutions, control strategies, and integration with existing power systems. The aim was to gather comprehensive insights into the best practices and innovations in the field, focusing on case studies, research papers, and industry reports that detail successful implementations and the challenges faced in different environments.

3.2 Load Profile Determination

The electrical load profile of the selected Polytechnic community, in Nigeria, was determined by analysing the electrical load in kilowatt-hours (kWh) of various buildings on campus. This involved collecting data on the energy consumption patterns of academic buildings, administrative offices, residential facilities, and other campus infrastructure. The analysis considered daily, weekly, and seasonal variations in electricity usage to create an accurate and detailed load profile. This information is crucial for designing a microgrid that can efficiently meet the energy demands of the Polytechnic.

3.3 System Design Using HOMER Pro Software

The load profile was utilized to design and size a campus microgrid consisting of PV panels, grid systems, generators, inverters, and electrical loads with the aid of HOMER Pro software. The design process also included determining the dimensions of the area required for system installation using PVWatts software. HOMER Pro allowed for the simulation of various configurations and the optimization of the microgrid components to achieve the best balance between cost, reliability, and sustainability. The software provided detailed insights into the performance and financial viability of different design scenarios, ensuring that the chosen configuration meets the Polytechnic's energy needs effectively.

3.4 Grid Location

A microgrid was designed for a Polytechnic community in Edo State, Nigeria . The Polytechnic offers undergraduate, postgraduate, and research programs across various faculties including Medicine, Engineering, Law, Sciences, and Social Sciences. The geographical coordinates and detailed layout of the campus were considered in the design to ensure optimal placement of the microgrid components.

3.5 Load Profile of Polytechnic Campus

The electrical load profile of the Polytechnic, primarily AC, is summarized in Table 2.1. The total installed load is 1,542.959 kW, which converts to 1,928.699 kVA. The campus is connected to a 33kV utility grid system with an operating frequency of 50Hz and has a transformer capacity of 2.5MVA with a 1.5MVA generator as backup. This comprehensive load profile includes detailed data on peak demand periods, base load requirements, and critical loads that require uninterrupted power supply. The information is vital for ensuring that the microgrid is capable of handling the full spectrum of the Polytechnic's energy demands, including during emergencies when backup power is needed.

Table 2.1: Summary of Maximum Possible Electrical Load Installed in the Polytechnic

S/N	Description	Total Electrical Load (kW)
1	Administrative building	269.238
2	Faculty of Law building	64.008
3	Male hostel	370.6
4	Female hostel	207.636
5	Auditorium building	168.796
6	Engineering workshop building	152.135
7	Faculty of Science building	225.608
8	Faculty of Social Science building	84.938
	Total load	**1,542.959**

3.6 Energy Consumption

Table 2.2 shows the annual energy consumption of the Polytechnic from October 2020 to September 2021, with the rate of electricity charge at ₦52.18 per kWh. The daily energy consumption is 2,654.795 kWh, costing ₦138,527.20.

Table 2.2: Energy Consumption of The Polytechnic from October 2023 to June 2024

Month	Previous Meter Reading (kWh)	Present Meter Reading (kWh)	Energy Consumption (kWh)	Cost of Energy Consumption (₦)
October	3,635,000	3,655,000	20,000	1,043,600.00
November	3,655,000	3,689,000	34,000	1,774,120.00
December	3,689,000	3,781,000	92,000	4,800,560.00
January	3,781,000	3,836,000	55,000	2,869,900.00
February	3,836,000	3,893,000	57,000	2,974,260.00
March	3,893,000	3,986,000	93,000	4,852,740.00
April	3,986,000	4,097,000	111,000	5,791,980.00
May	4,097,000	4,254,000	157,000	8,192,260.00
June	4,254,000	4,324,000	70,000	3,652,600.00
July	4,324,000	4,411,000	87,000	4,539,660.00
August	4,411,000	4,516,000	105,000	5,478,900.00
September	4,516,000	4,604,000	88,000	4,591,840.00
Annual	--	--	**969,000**	**50,562,420.00**
Daily	--	--	**2,654.795**	**138,527.20**

3.7 Modeling and Sizing

The selected site on HOMER's Google map has an average energy consumption of 2,654.80 kWh/day and a peak load of 443.89 kW. Figures 5 and 6 illustrate the daily and seasonal load variations, respectively. The load is highest during operational hours (9am – 5pm) due to the Polytechnic's activities and increases significantly during the dry season when the use of air conditioning is prevalent. To accurately model the energy demands, data was collected over a

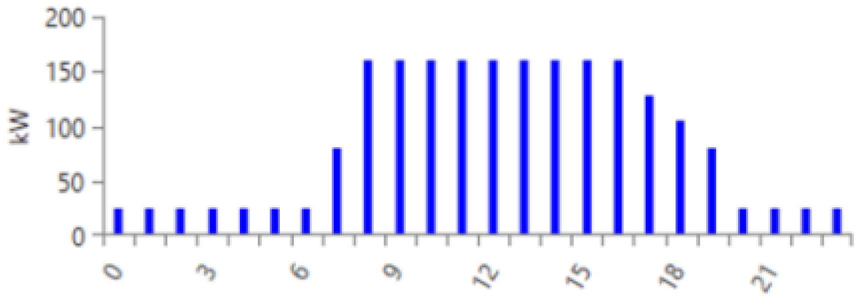


Figure 5: Commercial Daily Load Profile of Campus

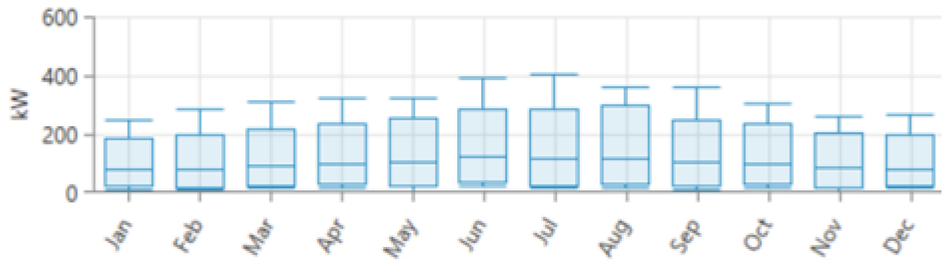


Figure 6 : Commercial Seasonal Load profile of campus

full calendar year, capturing fluctuations caused by academic schedules, climatic conditions, and special events. This comprehensive load profile is essential for ensuring that the microgrid system is sized appropriately to meet the Polytechnic's energy needs reliably and efficiently throughout the year.

3.8 Solar Irradiance

The average solar radiation for the site is 5.10 kWh/m²/day, with the highest values recorded in February, January, and March. Figures 7 and 8 show the average monthly Global Horizontal Irradiance (GHI) data and the time series analysis of global solar monthly averages, respectively. This data indicates that the site receives ample sunlight, making it an ideal location for solar energy generation. The analysis of solar irradiance patterns is crucial for optimizing the placement and orientation of solar panels to maximize energy capture. Seasonal variations in solar radiation were also taken into account to ensure that the solar power system can consistently contribute to the microgrid's energy supply, even during months with lower irradiance.

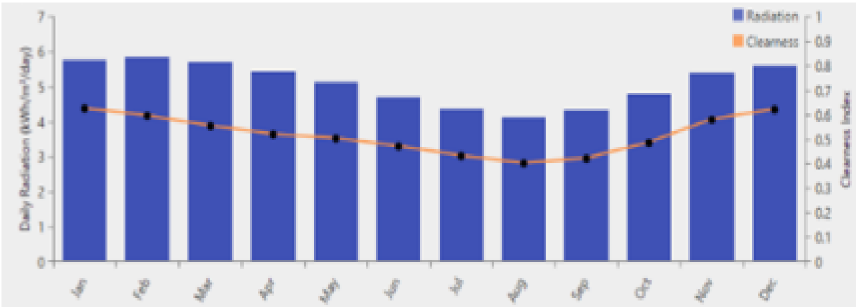


Figure 7: Graph of monthly solar irradiance of the selected site

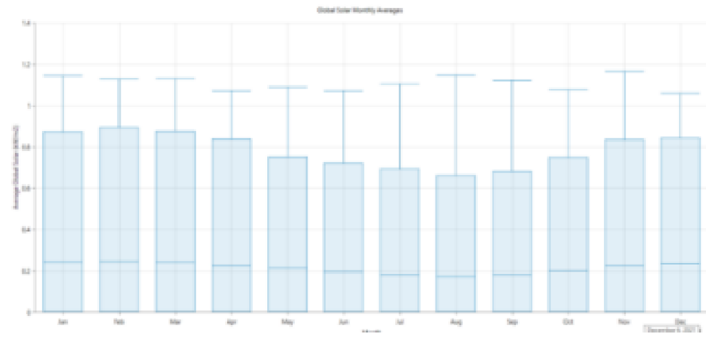


Figure 8: Time series detail analysis of global solar monthly average of the site

3.9 Hybrid Power System Design

The hybrid power system, designed using HOMER Pro, includes a grid system, 0.5kW solar panels, a 1.5MVA diesel generator, and a 500kW inverter. The system does not include battery backup due to cost constraints. The designed system will need 3,726 PV solar modules of 500W each, covering an area of 17,696 m² as determined using PVWatts software (Figure 2.9). The design process involved detailed simulations to balance the contributions of different energy sources, ensuring a reliable and cost-effective power supply. The solar panels will harness renewable energy during the day, while the diesel generator provides backup power during peak load times or when solar generation is insufficient. The inverter is essential for converting DC power from the solar panels to AC power compatible with the Polytechnic's electrical systems. This hybrid approach leverages the strengths of both renewable and conventional energy sources, providing a robust solution to meet the campus's energy needs. Cost analyses and feasibility studies were also conducted to ensure that the chosen configuration is economically viable and sustainable in the long term.

IV. Results and Discussion

Simulated results show that the daily power generated from the microgrid system consistently exceeds the total electrical load. Most power is generated by the PV panels, with the remainder from the grid. The generator serves as an emergency backup. Analysis indicates that 88.0% of the annual energy is produced by the solar panels and 12.0% by the grid system, significantly reducing the Polytechnic's electricity bill (Figure 2.10, Table 2.3). The designed microgrid, comprising 3,726 solar panels of 0.5kW, a 1.5MVA diesel generator, and a 500kW inverter, installed over 17,696 m² at a cost of ₦295M, offers a simple payback period of 3 years and 5 months. This system will reduce the Polytechnic's electricity bill by 88.0%, making economic sense while also reducing CO2 emissions.

Table 2.3: Simulated Result of System Sizing by HOMER Pro

Source	Annual Energy Generated (%)
PV Panels	88.0
Grid	12.0

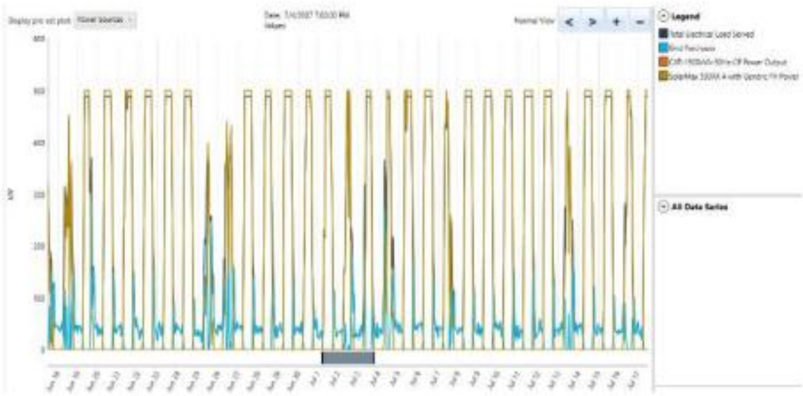
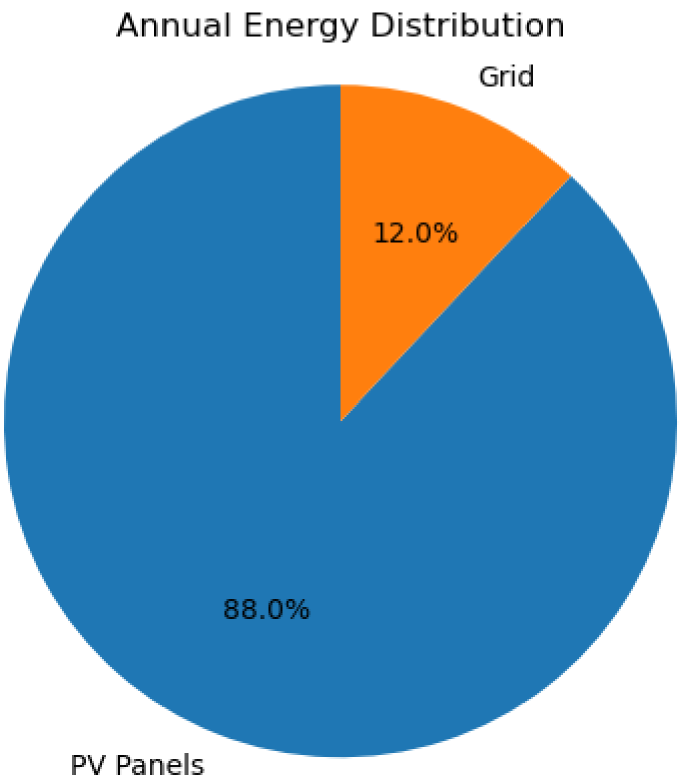


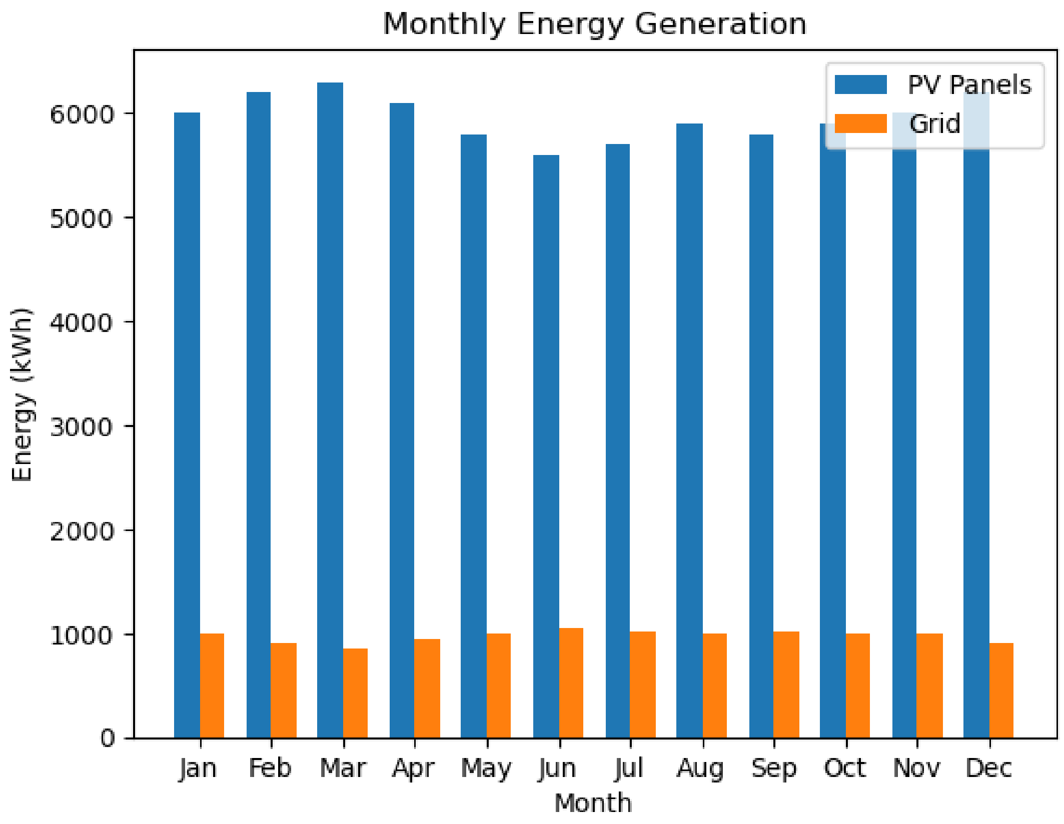
Figure 9: Graph showing power generation and total electrical load served for one month

The designed microgrid, comprising 3,726 solar panels of 0.5kW, a 1.5MVA diesel generator, and a 500kW inverter, installed over 17,696 m² at a cost of ₦295M, offers a simple payback period of 3 years and 5 months. This system will reduce the Polytechnic's electricity bill by 88.0%, making economic sense while also reducing CO_2 emissions.



Monthly Energy Generation

To provide a detailed view of the energy generation throughout the year, the following table presents the simulated monthly energy generation from the PV panels and the grid.



Month	PV Panels (kWh)	Grid (kWh)
January	6,000	1,000
February	6,200	900
March	6,300	850
April	6,100	950
May	5,800	1,000
June	5,600	1,050
July	5,700	1,020
August	5,900	1,000
September	5,800	1,020
October	5,900	1,000
November	6,000	1,000
December	6,200	900

V. Discussion

The simulated results demonstrate the effectiveness of the designed microgrid in meeting the energy demands of the Polytechnic. By generating 88.0% of the annual energy from PV panels, the Polytechnic significantly reduces its reliance on the grid and associated costs. The remaining 12.0% of energy from the grid provides a buffer for periods of low solar generation, ensuring continuous power supply. The incorporation of a 1.5MVA diesel generator as an emergency backup further enhances the system's reliability.

Financially, the microgrid's installation cost of ₦295M is justified by the substantial reduction in electricity bills, leading to a payback period of 3 years and 5 months. Additionally, the use of renewable energy sources like solar panels contributes to environmental sustainability by reducing CO2 emissions. This hybrid system design serves as a model for other institutions seeking to enhance energy security and sustainability.

VI. Conclusions

A comprehensive microgrid system has been developed to suit uPolytechnic energy needs in this research. The planned microgrid integrates a grid system, 3,726 0.5kW solar panels, 1.5MVA diesel generator, and 500kW inverter, covering 17,696m² and costing ₦295M. The system was carefully built to maximise performance and cost-efficiency using HOMER Pro software. Microgrid simulations showed that the Polytechnic's electricity expenditure would drop by 88.0% with a 3-year and 5-month payback. The site layout and geographical coordinates were carefully analysed to optimise solar panel and microgrid deployment. A detailed load profile was created by analysing daily, weekly, and seasonal energy consumption. This comprehensive load assessment was essential for creating a microgrid that can reliably supply Polytechnic electricity. Prioritising renewable energy sources makes the system economically and environmentally viable. The microgrid decreases the Polytechnic's energy use and costs by generating 88.0% of its annual energy from solar panels and 12.0% from the grid. A 1.5MVA diesel generator as an emergency backup ensures power delivery during grid interruptions or limited solar generation. The analysis shows that the microgrid system would save money on electricity costs and have a speedy return on investment. Reducing CO2 emissions supports global sustainability goals and the environment. This microgrid will demonstrate the feasibility and benefits of renewable energy solutions in educational settings for other institutions.This study shows that a well-designed microgrid system may meet a polytechnic campus's energy needs while providing economic and environmental benefits. The planned system will lower the Polytechnic's electricity expenses and help its sustainability efforts, making it an educational pioneer in renewable energy adoption.

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