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Microgrid Design to Improve Power Supply in University of Port Harcourt Using Solar PV System

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Abstract
The persistent inadequacy and unreliability of electricity supply in Nigerian universities have significantly affected academic activities, research productivity, and operational efficiency. The University of Port Harcourt (UNIPORT) currently relies heavily on the national grid and diesel generators, which are characterized by frequent outages, voltage instability, high operational costs, and environmental pollution. This study addresses this challenge by designing and technically evaluating a solar photovoltaic (PV)based microgrid system aimed at improving power supply reliability and sustainability within the UNIPORT campus. The purpose of this research is to develop an optimal solar PV microgrid configuration capable of meeting the university's electrical demand while minimizing dependence on fossil-fuel-based backup generation. A comprehensive load assessment of campus facilities was conducted to determine the total connected load and the effective peak demand of the university. The analysis revealed an estimated peak load of 3.2MW after applying appropriate demand factors. Solar resource potential for the study location (Aluu, Rivers State) was evaluated using satellite-based meteorological datasets integrated within RETScreen Expert, which indicated an average global horizontal irradiance of approximately 3.96 kWh/m²/day, confirming the technical feasibility of solar PV deployment in the region. The methodological framework integrates solar resource assessment, load demand analysis, PV system sizing, electrical network modelling, and performance simulation. RETScreen Expert software was employed and the annual energy yield energy was about 9,636.2MWh. In addition, the Electrical Transient Analyzer Program (ETAP) was utilized to model the campus electrical network and perform load flow analysis using the Newton–Raphson iterative algorithm, enabling accurate determination of bus voltages, real and reactive power flows, and voltage stability within the proposed microgrid architecture, the real power loss in the distribution network is approximately 54.83kW, while the reactive power loss is about 76.69kvar, demonstrating acceptable network performance. Results from the design analysis demonstrate that a properly sized 8MW solar PV-based microgrid integrated with battery energy storage of 42.67kWh and 834 units of 48volts, 200 amps MPPT charge controller can significantly enhance energy reliability, reduce operational costs associated with diesel generation, and improve power quality across the campus distribution network. Furthermore, the proposed system offers substantial environmental benefits through the reduction of greenhouse gas emissions and supports the transition toward sustainable energy infrastructure within higher education institutions. The study therefore provides a comprehensive technical framework for implementing solar PV microgrids in large institutional environments and contributes to the advancement of decentralized renewable energy systems for improving electricity supply reliability in developing countries.

Keywords: *Electrical Transient Analyzer Program, University of Port Harcourt, Renewable Energy Technology Software, Solar PV System, Microgrid*

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I. INTRODUCTION

The global electric power sector is gradually transitioning from centralized fossilfuelbased generation to decentralized renewable energy systems. This transformation is driven by the need to improve energy security, reduce greenhouse gas emissions, enhance grid resilience, and support sustainable development. According to the International Energy Agency, distributed generation and microgrid technologies are increasingly recognized as reliable solutions for improving electricity accessibility and system stability, particularly in regions with weak grid infrastructure.In many developing countries such as Nigeria, the national electricity network is characterized by inadequate generation capacity, frequent system collapse, voltage instability, and high transmission losses. These challenges significantly affect critical institutions, including universities. The University of Port Harcourt located in Port Harcourt relies largely on the national grid and diesel generators for electricity supply. However, frequent outages, voltage fluctuations, and rising diesel costs result in unreliable power availability across the campus, thereby disrupting laboratory activities, research operations, administrative services, and student facilities. In addition, continuous reliance on diesel generators leads to increased operational costs, noise pollution, and greenhouse gas emissions.A microgrid is a localized electrical network that integrates distributed energy resources, energy storage units, and intelligent control systems capable of operating in either grid-connected or islanded modes. Integrating solar photovoltaic (PV) systems within campus microgrids can significantly enhance power reliability while reducing dependence on fossil-fuel-based generators. The solar energy potential in Port Harcourt is suitable for PV deployment, with an average global horizontal irradiation of approximately 3.8–4.2 kWh/m²/day.Solar photovoltaic technology converts incident solar radiation directly into electrical energy through the photovoltaic effect. The generated direct current is converted to alternating current using power electronic inverters for compatibility with conventional electrical loads. Effective microgrid design requires detailed analysis of load demand, peak power requirements, PV array capacity, and battery energy storage systems to ensure reliable energy supply during periods of low solar irradiation or grid failure.Several researchers have investigated different configurations and control strategies for renewable energy-based microgrid systems. For instance, Sedaghati&Shakarami (2019) proposed an energy management strategy for a hybrid microgrid incorporating photovoltaic generation, battery storage, supercapacitors, and a solid oxide fuel cell. In their configuration, the PV system served as the main energy source, while the battery and supercapacitor addressed steady-state and transient load variations respectively. An adaptive fractional fuzzy sliding mode control technique was implemented to maintain system stability and ensure efficient power sharing.Similarly, Yuqi Wang et al. (2018) developed an optimization model for an intelligent microgrid used in an industrial park that integrated PV generation, combined cooling heating and power systems, and energy storage units. Using a genetic algorithm optimization approach, the system was able to minimize operational costs while maximizing renewable energy utilization. Their simulation results from a microgrid project in China demonstrated improved system efficiency and reduced operating expenses.Research conducted by Ting-Chia Ou and Chih-Ming Hong (2014) analyzed the dynamic performance of a hybrid wind-PV-fuel cell microgrid. The system included wind turbines, photovoltaic modules, a fuel cell, and a static VAR compensator for reactive power support and voltage regulation. Artificial intelligence techniques such as general regression neural networks and particle swarm optimization were applied to enhance PV performance and optimize wind turbine operation.In another study, Boussetta et al. (2019) developed a real-time energy management system for a hybrid renewable microgrid installed in an isolated mosque in Morocco. The system consisted of solar PV modules, wind turbines, batteries, and a diesel generator. The energy management algorithm was implemented using LabVIEW on an embedded platform to enable efficient real-time control of the power system.A comprehensive review conducted by Vera G. et al. (2019) examined different optimization methods, operational constraints, and simulation tools used in renewable energy-based microgrid systems. The study highlighted that the intermittent nature of renewable energy sources necessitates advanced energy management strategies and efficient storage technologies to ensure reliable system operation.Other studies have focused on microgrid applications for addressing electricity shortages in developing regions. For example, Waqar A. et al. (2017) investigated energy shortages in Pakistan and proposed a hybrid microgrid system integrating PV arrays, diesel generators, and battery storage modeled using HOMER Pro. Their analysis considered multiple optimization objectives such as minimizing net present cost, cost of energy, and greenhouse gas emissions. Similarly, Shoeb M. and Shafiullah G. (2018) evaluated solar PV-based microgrids as a solution for rural electrification in Bangladesh, concluding that daytime solar-powered irrigation systems could significantly reduce energy costs and emissions.Further research by Yoshida Y. and Farzaneh H. (2020) focused on the optimal design of standalone hybrid microgrids integrating PV, wind turbines, batteries, and diesel generators. Using the particle swarm optimization technique, the study minimized system cost while ensuring reliable powersupply for residential communities. Likewise, Shirzadi, Navid et al. (2020) investigated optimal sizing methods for renewable energy microgrids and demonstrated that integrating renewable sources with grid support could significantly reduce the levelized cost of energy.Additional studies have examined microgrid applications in isolated island communities. For instance, Agua O. F. B. et al. (2020) compared decentralized and clustered hybrid microgrids for the Polillo Islands in the Philippines using HOMER Pro simulations. The results indicated that hybrid renewable energy systems could reduce electricity generation costs by over 40% while significantly increasing renewable energy penetration.Field performance analysis of hybrid microgrid systems has also been reported. Canziani F. et al. (2021) analyzed operational data from a 9kW hybrid microgrid installed in Peru and used real-world measurements to optimize system design and evaluate reliability and cost performance. Earlier work by Ravichandrudu K. et al. (2013) investigated the operational characteristics of renewable energy microgrids using simulation models developed in MATLAB and Simulink, emphasizing the importance of coordinated control systems and energy storage for stable microgrid operation.Overall, these studies demonstrate that renewable energy-based microgrids provide a promising solution for improving electricity reliability, reducing operational costs, and enhancing environmental sustainability. However, site-specific system design and detailed technical evaluation remain necessary to ensure optimal performance. Therefore, this study focuses on the design and technical assessment of a solar PV-based microgrid for the

University of Port Harcourt using simulation tools such as ETAP and RETScreen Expert to evaluate system performance, reliability, and economic feasibility.

II. MATERIALS AND METHOD

2.1 Materials Used

The materials utilized in this research include computational software, field measurement devices, and data sources essential for modeling, simulation, and techno-economic assessment of a solar photovoltaic (PV) microgrid system for UNIPORT. The main materials are described as follows:

i. **RETScreen Expert Software**: This software served as the primary tool for evaluating solar resources, modeling energy generation, estimating greenhouse gas emissions, and performing financial feasibility analyses for the proposed PV system. RETScreen leverages global climate datasets, including those from NASA, to accurately calculate parameters such as annual solar energy yield, performance ratio, and system capacity factor for the study location.

ii. **Electrical Transient Analyzer Program (ETAP):** ETAP was employed to conduct detailed electrical network modeling of the proposed mini-grid. The software facilitated load flow analysis, voltage profile studies, and other network evaluations, ensuring that the designed system satisfied power quality standards and maintained operational stability suitable for electrification within UNIPORT.

iii. **Meteorological and Solar Resource Data**: Data on solar irradiance, ambient temperature, and climate conditions for UNIPORT (Aluu) were retrieved from the RETScreen climate database, powered by NASA and NREL. These datasets enabled the calculation of Global Horizontal Irradiance (GHI), monthly solar availability, and predicted PV system performance.

2.2 Method

For this study, the Newton–Raphson method integrated within ETAP was utilized to perform power flow analysis and assess voltage stability of the proposed smart microgrid system. This algorithm is a widely recognized iterative numerical approach for solving the nonlinear algebraic equations that govern power system operations.

The method was applied to solve the microgrid's load flow equations, providing detailed information on bus voltage magnitudes, phase angles, real power, and reactive power flows under various operating scenarios. By iteratively updating the system Jacobian matrix, the Newton–Raphson method ensures rapid convergence and high accuracy, making it particularly effective for analyzing systems with significant renewable energy integration and power electronic interfaces.

2.3 Load Estimation for UNIPORT (Aluu)

The load requirements for UNIPORT were determined through a survey of the various offices, lecture halls, workshops, cafeterias, and other campus facilities, prioritized according to their energy demand. The individual load demands for each building, along with the existing distribution grid configuration on campus, are summarized in Table 1

Table 1: Table of Load Estimation

S/N	Name Of Building	Location	Components	Power Demand (kW)
1.	Faculty of science	Abuja Campus	Offices, conference rooms, class room, library, eatery, etc	100.8
2	Faculty of education building	Abuja campus	Offices, conference rooms, class room, library, eatery, etc	100.8
3	Faculty of arts and humanities	Abuja campus	Offices, conference rooms, class room, library, eatery, etc	100.8
4	Indoor sports recreational center	Choba campus	Offices, class room, sport gym center	27.6
5	Institute of foundation studies	Abuja campus	Office, class room	30.8
6	University main library	Abuja campus	Office, conference room, halls	80.8
7	ICT library	Abuja campus	Offices, hall, ICT	37.7

			reseach library	
8	Faculty of engineering	Abuja campus	Offices, hall, laboratories, class rooms	370.6
9	Engineering workshop	Abuja campus	Offices, workshop	55.6
10	Faculty of science laboratory	Abuja campus	Offices, practical laboratories	79.38
11	Faculty of science laboratory 2	Abuja campus	Offices, practical laboratories	79.38
12	Faculty of science lecture theatre	Abuja campus	Office, class room, conference room	21.4
13	Faculty of humanitarian and social science lecture theatre	Choba campus	Offices, class room, conference room	21.16
14	SERVICOM building	Abuja campus	Offices, conference room	37.6
15	SIWES building	Choba campus	Offices, conference room	37.6
16	ASUU building	Delta campus	Offices	30.8
17	NASU building	Delta campus	Offices	30.8
18	SSANU	Delta campus	Offices	30.8
19	NATE building	Delta campus	Offices	30.8
20	SUG building	Abuja campus	Offices	30.8
21	Works and services unit	Delta campus	Offices, store room	32.4
22	Public relation unit	Delta campus	Offices, conference room	32.4
23	Sport complex	Abuja campus	Offices, indoor game center	36.6
24	Uniport bottling water plant	Abuja campus	Offices, water treatment plant	51.56
25	Ebitemi Cafeteria	Abuja campus	Offices, canteen	15.34
26	Chapel	Abuja campus	Offices, hall, convenience	17.4
27	NDDC girls hostel	Abuja campus	Residential	357
28	Goodluck Jonathan girls hostel	Abuja campus	Residential	357

29	Dan Etete girls hostel	Abuja campus	Residential	60.08
30	Mandela boys hostel	Abuja campus	Residential	33
31	TETFUND built convenience	Abuja campus	Offices, convenience	7.6
32	Commercial bank UBA	Abuja campus	Offices, banking hall, ATM machines	32.5
33	ECO Bank	Choba campus	Offices, banking hall, ATM machines	32.5
34	U&C bank	Abuja campus	Offices, banking hall, ATM machines	20.46
35	Zenith Bank	Abuja campus	Offices, banking hall, ATM machines	33
36	Access bank	Abuja campus	Offices, banking hall, ATM machines	24.68
37	Shopping complex 1	Abuja campus	Bookshops, business center	69.08
38	Fire station	Choba campus	Offices	19.3
39	Street lighting system	Delta campus	Municipal	20.46
40	Academic planning building	Abuja campus	Offices, conference room	15
41	DVC office	Abuja campus	Offices, conference room	15
42	PG school building	Abuja campus	Offices, conference room	15
43	TETFUND office	Delta campus	Offices, conference room	15
44	Exams and Records	Abuja campus	Offices, conference room	15
45	Lulu briggs medical center	Abuja campus	Offices, wards, pharmacy, laboratory	29.2

46	Lecture hall for management student	Abuja campus	Offices classroom	17.12
47	Uniport staff club	Delta campus	Offices, bar and canteen	17.24
48	Convocation Arena	Abuja campus	Pavilions	20.46
49	Faculty of management building	Abuja campus	Offices, conference room	30.48
50	750 capacity building	Abuja campus	Offices, class room	50
51	VC’s lodge	Abuja campus	Residential	84.2
52	Staff quarters	Delta campus	Residential	207.08
53	Boys hostel A	Abuja campus	Residential	222.66
54	Boys hostel B	Abuja	Residential	222.66
55	Water treatment plant 2	Choba campus	Offices, water treatment plant	51.26
56	TETFUND built convenient 2	Delta campus	Offices, convenience	7.60
57	Street lighting system	Choba campus	Municipal	26.5
58	VC office building	Senate(administrative) building	Offices, conference room	16.24
59	Registry office building	Senate(administrative) building	Offices, conference room	16.24
60	Bursary office building	Senate(administrative) building	Offices, conference room	16.24
61	Security office	Senate(administrative) building	Offices, conference room	16.24
62	Auditor office building	Senate(administrative) building	Offices, conference room	16.24
63	Institutional advancement and linkage	Senate(administrative) building	Offices, conference room	16.24
64	Establishment	Senate(administrative)	Offices,	11.48

	office building	building	conference room	
65	Uniport research and quality assurance centre	Senate(administrative) building	Offices, conference room	17
66	Counsil and building senate	Senate(administrative) building	Offices, conference room	16.24
67	Procurement and store building	Senate(administrative) building	Offices, conference room	16.24
68	LANSON cafeteria	Senate(administrative) building	Offices, conference room	12.62
69	Uniport water treatment 3	Senate(administrative) building	Offices, conference room	51.56
70	TETFUND built convenience 3	Senate(administrative) building	Offices, conference room	7.60
71	Street lighting system	Senate(administrative) building	Offices, conference room	24.86

2.4Photovoltaic System Modeling

The PV module (Figure 1) consist of a semiconductor which convert light into electricity. The Conversion process is based on photovoltaic effect.

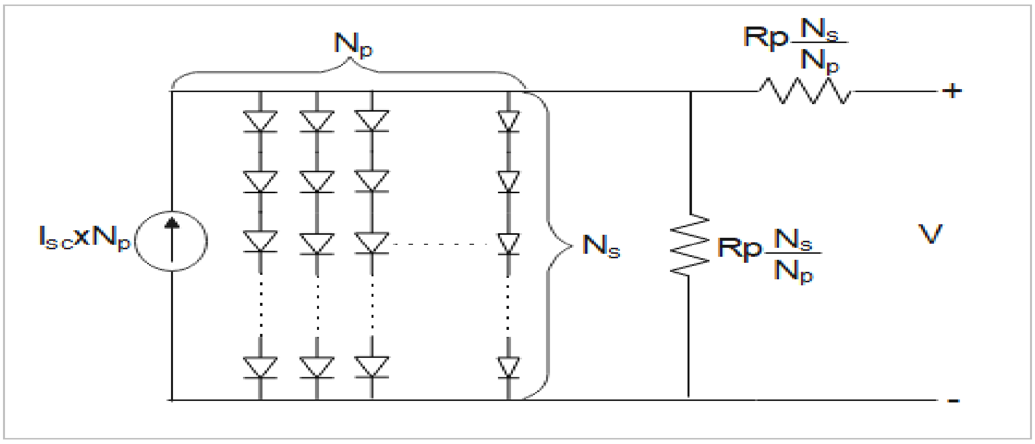

Figure 1: Model of a Photovoltaic Array

2.7.1 The photo-current (I_L) given by

$$I_L = [I_{SC} + K_i(T - T_r)]G \qquad (1)$$

Where;

I_{SC}: short circuit current (A)

K_i: short circuit current at a 25°C and 1kW/m2,

T: operating temperature(K)

$\boldsymbol{Tr}$: reference temperature =298.15K

$\boldsymbol{G}$: solar irradiation in kW/m^2

3.5.3 Module Reverse Saturation Current ($\boldsymbol{I_{rs}}$) is given by

$$I_{rs} = \frac{I_{SC}}{exp\left(\frac{qV_{OC}}{N_S knT}\right)} - 1 \qquad (2)$$

Where;
I_{SC}: short circuit current (A)
q: electron charge, = 1.6 × 10^{-19} C
Voc: open circuit voltage (V)
Ns: number of cells connected in series;
n: the ideality factor of the diode
k: Boltzmann's constant, = 1.3805 × 10^{-23} J/K.
2.7.2 Module Saturation Current (**I_O**) given by

$$I_O = I_{rs}\left(\frac{T}{T_r}\right)^3 exp\left[\frac{qV_G}{Kn}\left(\frac{1}{T}-\frac{1}{T_r}\right)\right] \qquad (3)$$

Where;
I_{rs}: reverse saturation current
T: operating temperature(K)
$\boldsymbol{Tr}$**:** reference temperature =298.15K
Q: electron charge (1.60217646 * 10^{-19} C)
K: Boltzmann constant (1.3806503 * 10^{-23} J/K)
n: the ideality factor of the diode
VG: band gap energy of the semiconductor
2.7.3 Diode Current (**I_d**) given by

$$I_d = I_O\left[exp\left(\frac{qV_d}{KnT}\right)-1\right] \qquad (4)$$

Where;
Io: dark saturation current dependent on the cell temperature
q: electron charge (1.60217646 * 10^{-19} C)
K: Boltzmann constant (1.3806503 * 10^{-23} J/K)
n: cell idealizing factor
Vd: diode voltage
T: operating temperature (K)
2.7.4 Shunt current (Ish) is given by

$$I_{sh} = \frac{\frac{V*N_p}{N_S}+I*R_S}{R_{sh}} \qquad (5)$$

Where;
Ns: No of modules in series
Np: No of modules in parallel
I: generated current

2.8 Battery Energy Storage System

Battery energy storage is essential for stabilizing intermittent renewable generation from solar and wind. The battery's state of charge (SOC) changes based on the charging and discharging processes. The change in battery energy

$$SoC(t) = SoC(t-1) + \frac{\eta_{charge}\ x\ P_{charge}(t)-\frac{P_{discharge}(t)}{\eta_{discharge}}}{E_{bat}} \qquad (6)$$

Where;
$SoC(t)$:state of charge at time (t)
$P_{charge}(t)$: power used to charge the battery (W)
$P_{discharge}(t)$: power discharged from the battery (W)
$\eta_{charge}\ and\ \eta_{discharge}$: efficiencies for charging and discharging the battery
E_{bat}: battery capacity

$$Battery\ kWh = \frac{E_{daily}\ x\ Autonomy\ days}{DoD\ x\ \eta} (7)$$

III. RESULTS AND DISCUSSION

3.1 Electrical Load Demand.

Figure 2 clearly shows the daily load profile of the university and the variation in electrical power demand over a 24hour period, highlighting both peak and off-peak usage patterns. From the graph, it is evident that the peak load reaches approximately 3.2 MW and persists for around twelve hours, from 6 AM to 6 PM. This sustained high demand corresponds to the simultaneous operation of academic, administrative, and essential service buildings. During this period, classrooms, lecture halls, laboratories, and offices are fully operational, contributing significantly through lighting, computers, HVAC systems, and laboratory equipment.

The peak load of 3.2 MW, which is roughly 70% of the total connected load of 4.566 MW, reflects the diversity factor applied to the connected load and provides a realistic measure of the university's maximum operational demand.

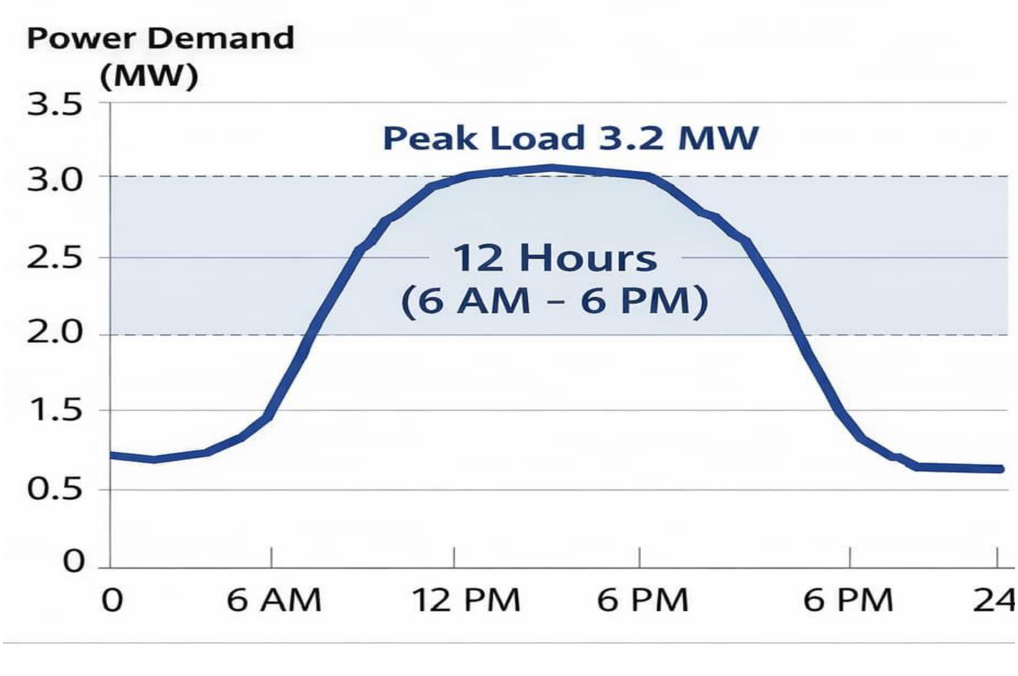

Figure 2. Daily Load Profile of UNIPORT (source: RETScreen)

In contrast, the early morning hours before 6 AM exhibit low power consumption, ranging between 0.5 MW and 1 MW, as most academic and administrative activities have not commenced. The electricity consumed during this period is primarily from residential hostels, street lighting, and utility services, representing a minimal fraction of total campus demand. Similarly, the evening hours after 6 PM show a gradual decline in load, with residential and essential utility buildings maintaining a small but continuous energy demand. This pattern indicates a clear distinction between peak operational hours and off-peak periods, which is typical for large educational institutions.The daily load profile has important implications for energy planning and management within the university. The extended 12-hour peak highlights the need for careful sizing of power supply systems, including potential solar photovoltaic installations and energy storage solutions, to meet demand reliably. It also indicates opportunities for demand-side management, such as scheduling energy-intensive operations outside peak periods or employing energy-efficient technologies to reduce peak load stress. Furthermore, the off-peak hours could be strategically utilized for charging batteries or storing energy generated from renewable sources, thereby enhancing overall energy efficiency and sustainability.

Overall, the daily load profile provides critical insight into the university's energy requirements. It demonstrates that while academic and administrative buildings drive peak consumption during the day, residential and utility loads dominate during off-peak hours. Understanding these patterns is essential for optimizing power generation, minimizing operational costs, and planning renewable energy integration. Consequently, any proposed energy system, particularly a hybrid or solar PV-based microgrid, should be designed to reliably supply the 3.2 MW peak load while accommodating the 38.4 MWh of daily energy demand efficiently. By aligning supply with the observed load profile, the university can achieve both operational reliability and sustainable energy management.

3.2Proposed Microgrid Design for the University of Port Harcourt

The design of the proposed solar photovoltaic (PV) system was carried out based on the estimated peak electrical load of the University of Port Harcourt (UNIPORT), the objective of this design is to develop a reliable solar-based microgrid capable of supplying the university's electricity demand while also incorporating energy storage to ensure continuous power supply during periods of low solar radiation or at night.

Table 2. Components of the Proposed Microgrid

Component	Rating	Quantity
Solar PV array	550W	14546
Inverter	4MW	1
Battery bank	48V, 230Ah	3865
MPPT charge controller	200A	834

From the load analysis, the total daily energy consumption of the university was estimated using the peak load and the assumed operational period of 12 hours per day. The resulting daily energy demand is 38.4 MWh, which represents the total electrical energy required to meet the operational activities of the university buildings such as lecture halls, laboratories, offices, cafeterias, and workshops. This value serves as the fundamental parameter for determining the size of the battery storage system and photovoltaic array required for the mini-grid design. The battery bank sizing was performed to ensure adequate energy storage for the system. Considering a system voltage of 48 V, the required battery capacity was calculated by converting the daily energy demand into ampere-hours. The resulting value of approximately 800kAh represents the theoretical storage requirement. However, in practical battery systems, the depth of discharge (DoD) must be considered to prevent excessive battery degradation and prolong battery lifespan. Assuming a maximum depth of discharge of 90%, the adjusted battery capacity increased to approximately 888,888.88 Ah.To realize this storage capacity, lithium batteries rated at 48 V and 230 Ah were selected due to their high energy density, longer lifespan, and better efficiency compared to conventional lead-acid batteries. Based on the required total capacity, the system requires approximately 3865 batteries connected in parallel, since the system voltage matches the battery voltage (48V), meaning only one battery is required in series. The large number of batteries ensures that sufficient energy is stored to supply the university load even during periods when solar generation is unavailable.The PV array sizing was carried out using the solar resource data for Rivers State obtained from the NASA database. The minimum solar radiation occurs in August, with an average value of 3.29 kWh/m²/day, which represents the worst-case solar condition for the region. Designing the system based on the worst solar month ensures that the system will operate reliably throughout the year. In order to fully recharge the battery bank within an estimated 6 hours of effective sunshine, the required generation power was calculated as 6.4MW. Considering system losses and an assumed efficiency of 80%, the required PV capacity increases to approximately 8 MW.For this design, 550 W monocrystalline solar panels were selected because of their high efficiency and suitability for large-scale solar installations. The total number of panels required to achieve the 8MW PV capacities was calculated to be approximately 14,546 panels. Since the nominal module voltage is the same as the system voltage (48 V), only one module is required in series, while 14,546 modules are connected in parallel to achieve the desired output power. This large solar array ensures that adequate solar energy is captured to meet both the load demand and battery charging requirements.The solar charge controller plays an essential role in regulating the power flow from the PV array to the battery bank. It ensures that the batteries are charged efficiently while protecting them from overcharging or excessive discharge. Based on the PV array power of 8 MW and the system voltage of 48 V, the required charging current was calculated to be approximately 166,667 A. In this design, 200 A, 48 V Maximum Power Point Tracking (MPPT) charge controllers were selected because MPPT technology improves the efficiency of solar energy harvesting by continuously tracking the optimal operating point of the PV modules. Consequently, approximately 834 MPPT charge controllers are required to handle the total charging current from the PV array.Finally, the inverter system was selected to convert the stored DC power from the PV array and battery bank into AC power suitable for supplying the university electrical loads. According to inverter design recommendations, the inverter capacity should typically be 25–30% higher than the peak load in order to accommodate transient loads and prevent system overload. Since the peak load of the university is 3.2 MW, a 4 MW inverter was selected for the system. The inverter efficiency was assumed to be 80%, which is within the acceptable performance range for large-scale power conversion systems.Overall, the proposed solar PV system design demonstrates that a properly sized 8 MW solar PV array combined with a large-capacity lithium battery storage system can effectively supply the 3.2 MW peak load of the University of Port Harcourt. The integration of MPPT charge controllers, a high-capacity inverter, and a large battery bank ensures stable power delivery, improved energy management, and enhanced reliability of the proposed mini-grid system.

IV. CONCLUSION

This study presented the design and analysis of a solar photovoltaic mini-grid system for improving power supply reliability at the University of Port Harcourt (UNIPORT), Aluu. The research was motivated by the persistent electricity supply challenges experienced within the university due to unreliable grid power and heavy dependence on diesel generators.Through a detailed load assessment of various academic, residential, administrative, and commercial buildings within the university, the total connected load was estimated to be approximately 4.566 MW. By applying a realistic demand factor of 0.7, the actual peak load of the university was determined to be approximately 3.2 MW, with an estimated daily energy demand of about 38.4 MWh.The results showed that the study area receives an average solar radiation of approximately 3.96–4.21 kWh/m²/day, indicating a moderate but suitable solar energy resource for photovoltaic electricity generation. This level of solar irradiation confirms that the geographical location of UNIPORT is favorable for the deployment of solar PV technology.The electrical network modelling and load flow analysis provided insight into the operational characteristics of the campus distribution system and helped ensure that the proposed renewable energy integration would operate within acceptable voltage and system stability limits.Finally, the design results showed that approximately 14,546 solar panels rated at 550 W each, along with appropriately sized battery storage and power conversion systems, would be required to support the proposed system.

This research contributes to knowledge in the field of renewable energy systems and microgrid design in several important ways.

i. First, the study provides a comprehensive framework for designing a solar PV-based micro-grid system for large institutional environments, particularly university campuses. Unlike many previous studies that focused on small residential systems or rural electrification, this research addresses the unique load characteristics and energy demands of a large educational institution.

ii. Secondly, the study integrates solar resource assessment, detailed load analysis, PV system sizing, electrical network modelling using ETAP, and energy performance simulation using RETScreen within a single analytical framework. This integrated approach enhances the accuracy and reliability of renewable energy system design for institutional power systems**.**

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