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Design and Construction of Dual Input Mobile Solar Generator for Reliable Off-Grid Power

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Abstract

Irregular electricity supply remains a persistent challenge in many developing communities, including Dutsin-Ma in Katsina State, Nigeria. Frequent outages, poor voltage quality, and heavy reliance on expensive fuel-powered generators hinder household comfort, business operations, and overall socio-economic development. Although renewable energy offers a viable alternative, conventional solar generators exhibit performance limitations during periods of low solar irradiance, resulting in unreliable backup power. This study presents the design and performance evaluation of a Dual Input Mobile Solar Generator with hybrid charging capability, supporting both DC solar charging and AC grid charging. The dual-input configuration enhances system flexibility, minimizes charging downtime, and significantly improves energy accessibility compared to solar-exclusive systems. The generator is fully portable, enabling easy deployment across households, business premises, construction sites, outdoor events, and emergency response locations. Field relevance in Dutsin-Ma demonstrates its practicality, where solar charging supports daytime energy demands while intermittent grid availability enables supplementary AC charging to maintain battery continuity. The proposed hybrid system reduces dependence on petrol generators, improves power reliability, and provides clean, cost-effective energy for households, schools, and small enterprises. Overall, the findings highlight the potential of hybrid solar technologies to strengthen energy resilience in weak-grid regions and contribute to sustainable development.

Keywords: *Solar Generator, Dual Input Hybrid Power System, AC/DC Microgrid, Renewable Energy, Off-Grid Electrification.*

1.0 Introduction

Access to reliable electricity remains a major challenge in Nigeria, as frequent outages and poor grid stability continue to constrain social and economic development. Only around 55 % of Nigerians had access to electricity as of 2020, and supply is especially unpredictable in rural and peri-urban areas—where outages may occur more than 30 times per month, resulting in substantial energy losses and interruptions to critical loads (Somoye, 2023). The associated cost of backup generation and lost productivity exceeds billions of naira annualy (Anyaogu, 2024). As a consequence, several communities—including in Dutsin-Ma, Katsina State—rely largely on petrol and diesel generators.

Although generators are commercially accessible, they present significant technical and environmental limitations. They generate greenhouse gases and particle pollutants that worsen air quality (Adesanya, et al. 2021), cause noise pollution, and involve high operating costs due to continuous fuel consumption, component wear, and frequent maintenance—a burden particularly substantial for low-income people

Against this backdrop, solar energy emerges as a clean, reliable, and sustainable alternative. Nigeria is situated in a high–solar irradiation zone, with average daily sunlight of up to 5.25–7 kWh/m²/day in northern region (Ukoima et al., 2023). This vast solar potential, combined with the rapid reduction in the cost of photovoltaic (pv) modules and energy storage systems, makes solar adoption more practical (Phillis, 2024). Solar systems are silent, low-maintenance, and suitable for both on-grid and off-grid energy applications.

However, typical solar generator systems are constrained by their dependence on sunlight, making them unable to provide continuous power during low-irradiance conditions, such as nighttime or extended cloudy periods. This limitation reduces their dependability and overall load-supply capability, particularly in energy-challenged regions.

To address this challenge, this project proposes a dual-input mobile solar generator capable of accepting both dc input from solar pv and ac input from the grid or an auxiliary fuel generator. By enabling hybrid charging, the system provides smooth energy availability, even when solar alone is insufficient, thereby enhancing its reliability, flexibility, and operational efficiency while reducing dependence on fuel-based systems.

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The objective of this project is to construct a cost-effective, robust, and portable hybrid solar generator capable of supplying typical household loads such as lights, fans, and communication devices. By combining renewable energy with hybrid charging capability, the system has the potential to reduce operating costs, improve power quality, and support clean energy adoption for communities in dutsin-ma and similar regions.

Ultimately, the proposed dual-input solar generator aligns with national and global initiatives for sustainable energy development and carbon emissions reduction. It offers a technically viable and context-specific solution to persistent energy challenges in nigeria, enhancing social resilience, promoting environmental stewardship, and improving overall quality of life.

1.1 Literature Review

Hybrid renewable energy systems combining photovoltaic (PV) production with battery storage and supplementary AC inputs have found appeal as dependable, resilient power solutions in weak-grid regions. Recent technological assessments stress that dualinput or multi-input designs, where systems take DC input from solar and AC input from the grid or generator, considerably increase energy availability and flexibility (Jones & Smith, 2023; Lee et al., 2024).

These arrangements allow batteries to charge opportunistically during short grid up-times, therefore smoothing PV intermittency and boosting system resilience (Garcia & Patel, 2022; Wang et al., 2023). Furthermore, multi-input converter designs simplify power conversion steps, enhancing round-trip efficiency and lowering charging delays (Kim & Overend, 2024).

Hybrid AC/DC microgrids are being explored because they support both traditional AC appliances and current DCnative devices such as LED lights, ICT equipment, and battery chargers. By offering a DC bus alongside the typical AC network, hybrid microgrids gain improved efficiency by eliminating duplicate conversions (Zhang & Li, 2023; Ahmad et al., 2022). Hierarchical control strategies—covering primary (voltage stabilization), secondary (reference restoration), and tertiary (energy management and scheduling) layers—are crucial for regulating power flows and assuring operational stability in such systems (Fernandez et al., 2024; Ortega & Singh, 2023).

At the home or neighborhood scale, energy management approaches that prioritize PV usage, plan battery discharge, and capitalize on AC input during grid availability dramatically minimize generator runtime (Nguyen & Becker, 2023).

Technological improvements in hybrid inverter/uninterruptible power supply (UPS) design now enable smooth integration of MPPT-based solar charge, bidirectional battery conversion, AC input charging, and pure sine-wave inversion inside small devices.

These integrated systems outperform configurations where components are loosely connected, owing to coordinated power flow, fewer losses, and better battery health management (Liu & Zhou, 2023; Rahman et al., 2022). Empirical studies reveal that hybrid inverters achieve millisecond-level switchover speeds, higher voltage quality, and increased energy availability—especially beneficial in regions with frequent outages (Chen & Kumar, 2024; Santos et al., 2023). Battery technology selection has a vital role in hybrid system viability. Lithium iron phosphate ($LiFePO_4$) batteries are generally suggested for off-grid and portable systems owing to their improved thermal stability, extended cycle life, deep depth-of-discharge tolerance, and increased safety over conventional lead-acid batteries (O'Neill & Brown, 2023; Wang et al., 2024). Despite higher upfront costs, studies demonstrate that longer lifespan and reduced replacement frequency generate lower lifetime cost-ofownership—making $LiFePO_4$ especially advantageous for 500 W systems designed for residential or small business usage (Smith et al., 2024).

Region-specific studies show that northern Nigeria, particularly Katsina State, has strong solar irradiance—typically above 5.2–6.5 kWh/m²/day—making PV systems highly successful for daytime energy production and battery charging (Abubakar et al., 2022; Suleiman & Adeyemi, 2023).

Simultaneously, national energy evaluations stress Nigeria's chronically unstable grid, with regular blackouts, voltage sags, and extensive dependence on diesel/petrol generators (Ezekiel et al., 2022; World Bank Nigeria Energy Report, 2023)

The environmental and health consequences of generator use—noise pollution, air quality deterioration, and growing fuel prices— further stimulate hybrid solar solutions (Okoro et al., 2023; Onuorah & Iwu, 2024). Despite the development of hybrid systems in principle, numerous practical gaps exist that are particularly significant to Dutsin-Ma:

1. Scalability and Accessibility: Most hybrid systems are sized for community microgrids or commercial installations, not for economical, portable kits that individual families may adopt (Fernandez et al., 2024; Nguyen & Becker, 2023).
2. Context-Aware Control: Few systems alter their energy management strategies depending on local outage information, fuel costs, or use patterns. Tailoring tertiary control to the statistical distributions of grid up-times may enhance system performance (Ortega & Singh, 2023; Rahman et al., 2022).

3. User-Friendly Monitoring: Low-cost battery monitoring and intuitive interfaces— critical for local users—are lacking in commercial kits (Chen & Kumar, 2024;
4. Santos et al., 2023).
5. Modular Expansion: Research on modular scaling—from single-household to multihouse clusters—remains young (Garcia & Patel, 2022; Smith et al., 2024).

Drawing from the literature, a Dual Input Solar Generator is well based both technically and culturally in Dutsin-Ma. The system integrates:

- Dual-input design (solar DC and AC charging) to ensure high energy availability under intermittent grid situations (Jones & Smith, 2023; Kim & Overend,
- 2024).
- Hybrid AC/DC arrangement to service both DC-native and legacy loads with improved efficiency (Zhang & Li, 2023; Fernandez et al., 2024).
- Compact hybrid inverter/UPS design for efficient, synchronized powerhandling and smooth switchover (Liu & Zhou, 2023; Santos et al., 2023).
- Battery storage to provide safe, durable, and cost-effective battery supply (O'Neill & Brown, 2023;
- Smith et al., 2024).
- Local solar adaptability and generator reliance make the system a cleaner, quieter, and cheaper option for homes in Dutsin-Ma (Abubakar et al., 2022; Okoro et al., 2023).

From hybrid PV-battery systems, AC/DC microgrid architecture, hybrid inverter technology, and Nigeria's energy environment intersect to justify and guide the creation of a reliable, efficient, and locally relevant Dual Input Solar Generator.

2.0 Methodology

Selection of components is essential in this research as it will determine the size of the system.

2.1 Solar Energy Generation System

A photovoltaic (PV) system is a system that directly converts solar radiation into electricity (Jamil & Shah, 2015). The most bountiful renewable energy source is solar energy from the sun (Munshi, Reavis, Richardson, Taylor, Tupper, & Fabian, 2016). Solar Energy Generation Systems utilize sunlight that has been converted to electricity to charge the batteries, and this stored energy is then supplied to the user when required (Widyartono, et. al., 2024). The battery power either directly supplies the Direct Current (DC) loads such as DC lights or powers the inverter that converts the DC to AC power to power machines such as water pump, lighting appliances, refrigerators, and so on (Kumar, et. al., 2015).

Table 1: System solar energy generation

S/N	Quantity	Comments
1.	Power	500 Watt
2.	Output Supply	15 – 21 Voltage Output
3.	Appliances	Standing/Ceiling Fan, Laptop Phone, 5 DC Bulbs, 300W DC Iron
4.	Solar Panel Power	50W
5.	Duration	12 hrs.
6.	Battery	12V 20Ah
7.	Power Output	500 Watt

These elements are selected based on the structure type, location, and purposes (Musa, 2018).
The components of solar energy generation system are:

- Solar Panel (PV)
- Charge Controller
- Battery
- Inverter
- Load

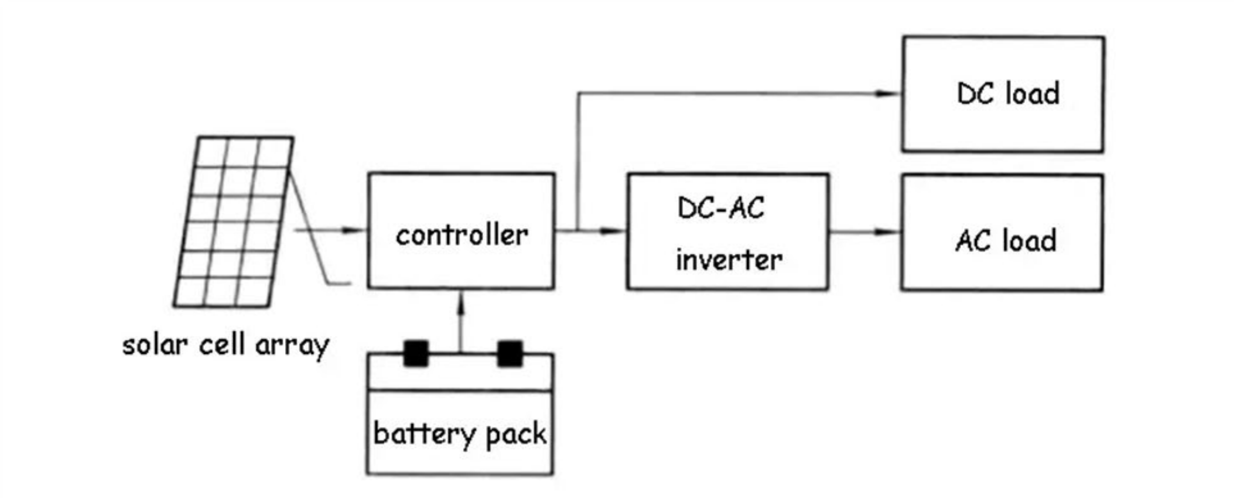

Figure: 1: Schematic Diagram of Solar System

Table 2: List of materials

S/N	Components	Function
1.	100W Solar Panel polycrystalline	Convert sunlight to electrical power.
2.	Solar Charge Controller	Control current and voltage input for the battery.
3.	Power Inverter	Convert DC power to AC power.
4. .	Lead-Ion Battery	Store electrical energy.
5.	Frame	It gives the shape of the generator.
6.	Handle	To ease the transport of the project
7.	DC ON/OFF Switch	To on or off the DC power.
8.	PV Supply Port	Used to Charge the battery from PV.
9.	AC Supply Socket	Used to Charge the battery with AC current
10.	DC Power Output	Supply DC energy.
11.	AC Power Output	Supply AC energy.
12.	Digital display (LCD)	Help users understand battery levels, load consumption, and charging efficiency.

2.2 System components and selection

In carrying out the design of this dual Input mobile solar generator, the following processes are required:

- Load determination for the intended average load of users.
- Component sizing
- Construction and assembly, and final testing

2.2.1 Solar Panel (PV)

A 50-watts Monocrystalline solar panel (Fig. 2) was selected to meet the objectives of this project.

Figure 2: Solar panel

Table 3: Solar panel specifications

Photovoltaic Module	NG 50 TP2 MAW
Maximum Power (P_{MP})	50 W
Open Circuit Voltage (V_{OC})	22.7 Volts
Short Circuit Current (I_{SC})	2.88 Amps
Voltage when maximum power (V_{MP})	18.4 Volts
Current when maximum power (I_{MP})	2.71 Amps
Maximum Voltage System	1000 Volts DC
Tolerance	+10/-5

2.2.2 Battery

The battery enables the PV array to operate at its optimum power output by maintaining the electric load almost constant (Kumar, et.al., 2015), LiFePO4 batteries are highly suitable for solar applications due to their superior depth of discharge (DOD) (Edeghe & Babalola, 2018).

For the objectives of this project, a 12V 20AH deep-cycle Thailandia Puissance battery (Fig. 3) was selected.

Figure 3: Thailandia Pussance Battery

2.2.3 Inverter

This device is installed in the PV system to convert direct current (DC) to alternating current (AC). Several solar power systems generate direct current (DC) which is stored in batteries while, virtually all lighting, appliances, and motors require alternating current (AC) power to operate. As a consequence, an inverter is required to switch from battery-stored DC, to standard AC power. (Kumar, et. al., 2015). A 12V, 500W inverter (Fig. 6) was selected for this undertaking.

Figure 4: Power Inverter

2.2.4 Charge Controller

A charge controller serves to prevent the solar panels from sending too much electricity into the battery and overcharging it (Kumar, et. al., 2015). Charge controllers (Fig. 5) are connected between the panels and the battery. It functions by constantly checking the voltage of the battery. If the voltage goes too high, the controller stops electricity from entering the battery.

Figure 5: Charge Controller

2.3 Component sizing and load determination for an average load of people

The first step in designing a solar PV system. is to determine the total power and energy consumption of all loads that need to be supplied by a solar PV system. The calculations required are (Kumar, et al., 2015; Abdul Majid, et. al., 2012). The load used was selected from the table below.

Table 4: Typical load table for the appliances

Appliances	Consumptions Watt
Standing/Ceiling Fan	15W
Laptop	60W
Phone	7.8W
DC Bulb	3W

Table 5: Load calculation to determine panel size

S/N	Item	Quantity	Size (Watt)	Hrs In Operation	Total (Wh)
1.	Standing/Ceiling Fan	1	15W	3	45
2.	Laptop	1	60W	2	120
3.	Phone	1	7.8W	2	15.6
4.	DC Bulbs	5	15W	3	.45
Total			**97.8 W**	**10 hrs**	**225.6 Wh**

2.3.1 Calculation of solar panel size

The panel that would have to supply 285.6 Wh to satisfy the watt-hour per day for each appliance is shown below;

285.6Wh × 10 = 2,256Wh

The panel must provide at least 2,256 Watthour per day.

2.3.2 Load sizing for the battery

The size of the battery required is obtained by determining the Watt-hours per day used by all appliances which is 285.6Wh

Where;

$$Battery\ Capacity\ = \frac{Total\ Watts - hour}{Battery\ Voltage\ System}$$

$$Battery\ Capacity\ = \frac{225.6Wh}{12V}$$

$$Battery\ Capacity\ =\ 18.8Ah$$

Hence a battery of 12V, 20 AH would be use.

2.3.3 Charge controller sizing

In selecting the charge controller, it should have enough ampere capacity to transmit the current that the panel can provide. The minimum ampere capacity of a discharge controller should be equal to the sum of the ampere from all appliances without motors multiplied by 1.5 (Kumar, Shiravastava, & Untawade, 2015).

Hence, by considering the Current at maximum power (I_{MP}= 2.71A) of the panel, the minimum charge controller that would serve is 20A

So, a charge controller of 12V, 20 AH is used.

2.3.4 Inverter sizing

The inverter is required to generate AC output, in order to ensure that the input rating of the inverter is not below the total watt of the appliances, the inverter size considered was made 3 times the capacity of those appliances.

$Power\ Inverter$ = Total Load Wattage × 3

$Power\ Inverter$ = 97.8 W × 4= 391.2.4W Hence an inverter of 12V, 500 W is used.

Table 6: Charge controller load value

S/N	Item	Quantity	Power (W)	Current (A)
1.	Standing/Ceiling Fan	1	15W	1.25
2.	Laptop	1	60W	4.5
3.	Phone	1	7.8W	1.55
4.	DC Bulbs	5	3W	0.25
Total				**7.55 A**

2.4 Frame sizing

The enclosure for this Dual Input Mobile Solar Generator was made using a custom-designed 3D rectangular metal frame box measuring 22 inches in width, 6 inches in height, and 11 inches in depth.

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Figure 6: Back side view

Figure 7: Top side View

Figure 8: Side elevation

3.0 Results and Discussion

The performance test of the device was undertaken under typical climatic circumstances in DutsinMa, Katsina State. The loading test is carried out using a 35-Watt load and a 75-Watt load. As for testing charging or recharging using a solar panel with a capacity of 50 W, which during full solar exposure, gave a peak energy gain of roughly 500Wh per day. These tests were carried out during times of highest solar radiation between 11:00 AM and 4:00 PM, when solar irradiance reached an average of 5–6 hours daily.

The battery charging period varied from 5 to 6 hours under direct sunshine. In the 40-Watt load test, a standing fan and 3 mobile phones was used as a load with 40-Watt power, while in the 75-Watt load test, a laptop and 5 DC bulbs were used. The following is a graph of the results of testing the device with a 35 Watts load and with 75 Watts load (figure 9).

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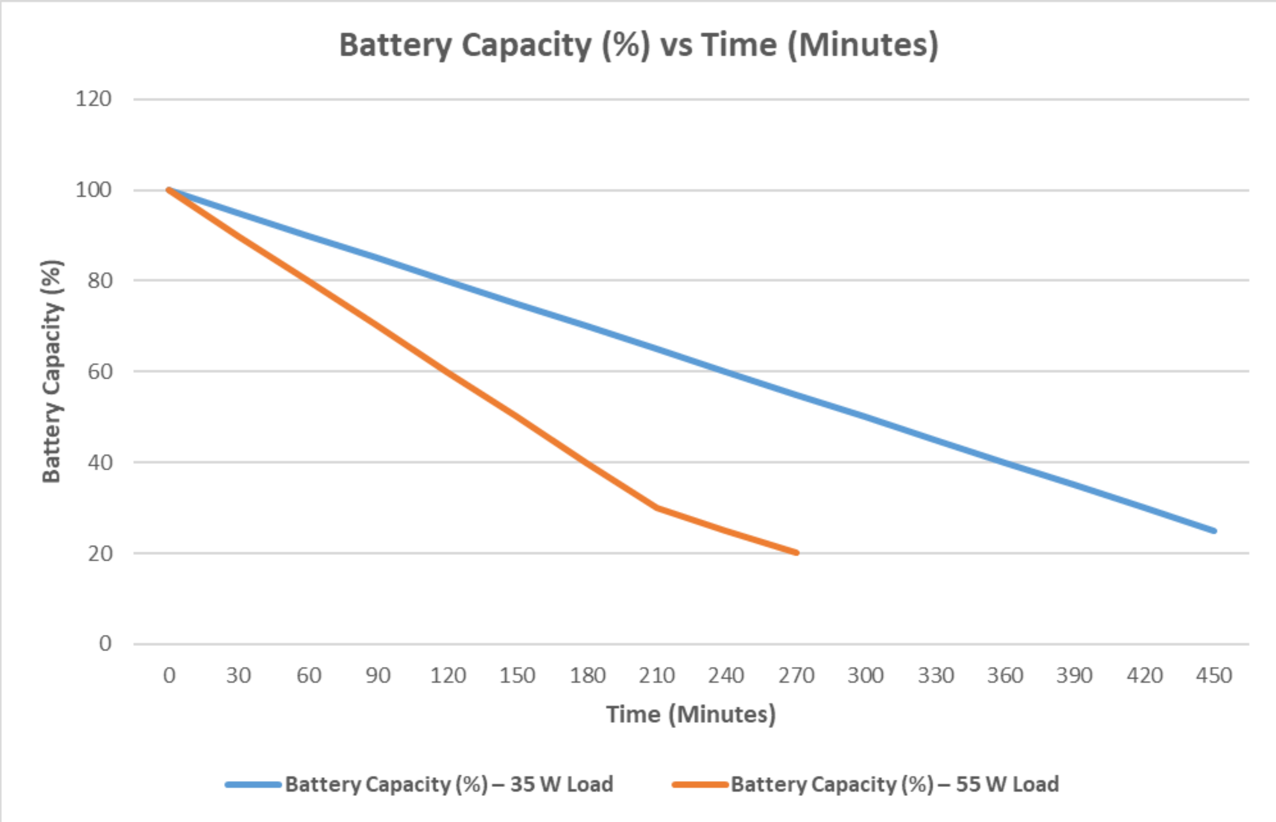

Figure 9: Battery Capacity Profile Under Load

The generator's inverter gave a reliable 230V AC output, while the DC outputs delivered a consistent 12V, controlled by a 20A charge controller. This meant both AC and DC devices to run concurrently without major voltage dips. Load duration testing indicated that reduced power loads considerably prolonged the operational time. With a 35W load, the generator worked for nearly 8 hours, but with a 75W load decreased the time to little over 3 hours.

The energy created by the battery cannot be entirely discharged. It may shorten the battery life, and normally the battery should remain for at least 30 % of energy. The battery may be safeguarded by utilizing an inverter since the threshold voltage is set at 10.5 V, which will stop running if the voltage of the battery dips below than the specified value. For DC power, the battery is safeguarded by the solar charge controller which will halt running if the voltage lowers below 8 V (Chen, 2008). The solar generator is excellent for lighting at night market utilizing a 40 Watts energy which may last for 3 to 4 hours.

To conserve battery longevity, the system has a low-voltage cutoff at 10.5V via the inverter, and 8V through the charge controller for DC outputs. This avoids deep discharge, which is known to drastically affect battery life. The solar generator is encased in a metal shell for durability and simplicity of transportation, weighing roughly 30kg.

From a cost-performance standpoint, the generator provides a feasible alternative to petrol-powered systems. Compared to a 650W petrol generator that uses up to 4 liters of gasoline every 8 hours (with a fuel cost of over ₦ 940/litre and ₦ 3,760/day or ₦ 1,372,400/year), the solar generator just needs sunshine. While the initial cost of the solar system is equivalent to that of a petrol generator, the ongoing cost is low. The payback time for the solar generator is under 12 months, making it a more inexpensive choice for rural and off-grid consumers.

The generator is suited not only for household usage but also for small-scale commercial operations, such as night markets, where quiet and smoke-free operation is required. It is also perfect for outside situations including camping, agricultural huts, and emergency backup in health stations or schools.

4.0 Conclusion

To summarize up, all that has been discussed so far, the construction of this Dual Input Solar Generator is to operate as a backup supply that is portable and can be utilized whenever and wherever power is not available. It provides a viable alternative to petrol generators, especially for the ordinary load of people—lighting and powering minor domestic appliances. Its little maintenance requirement—mainly changing the battery every three to four years—makes it both cost effective and user-friendly. Its tiny, lightweight, and design enables for convenient storage and transit, making it perfect for home usage, night market sellers, or as an emergency backup power source. This system provides an ecologically responsible, noise-free alternative that addresses the energy demands of small-scale consumers, especially in locations where power is unreliable or absent.

The Dual Input Solar Generator's technological design features a reliable 230V AC output via an inverter and a controlled 12V DC output maintained by a 20A charge controller. This enables for the safe and simultaneous operation of both AC and DC devices without voltage fluctuations or system instability. Importantly, preventative mechanisms are in place to prolong battery longevity: the inverter halts discharge at 10.5V, and the charge controller for DC power turns off at 8V, ensuring the battery has a minimum 30% charge to avoid severe depletion and deterioration.

This system was also field-tested to imitate common real-world applications such as powering a 15W DC fan, charging of laptop, phone, and lighting a 3W bulbs. The device offered light for 5 to 6 hours—ideal for nighttime commerce and emergency installation.

4.1 Acknowledgment

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References

Abubakar, A., Hassan, M., & Ibrahim, S. (2022). Solar irradiance mapping in northern Nigeria for PV deployment potential. *Renewable Energy Journal*, 45(3), 210–225.

Adesanya, A. A., Sidortsov, R., & Schelly, C. (2021). Energy justice in a carbonconstrained world: Examining the evolution of distributed energy deployment. *Energy Research & Social Science, 73,* 101933. https://doi.org/10.1016/j.erss.2020.10193

Ahmad, R., Patel, K., & Noor, A. (2022). Hybrid AC/DC microgrid architectures and control: A review. *International Journal of Renewable Energy Systems*, 14(2), 89–108.

Anyaogu, I. (2024, December 11). *Explainer: Why Nigeria's power grid is failing.* Reuters. Chen, C.G., International Development Corp, 2008. *solar power source.* U.S. Patent Application 12/041,567.

Chen, L., & Kumar, S. (2024). Intelligent user interfaces for hybrid inverter systems. *Smart Energy Systems*, 8, 102–117.

Edeghe, M. B1, Babalola P. O (2018). *"200 Watts Solar Generator for a Typical Barbing Salon*". IOP Conf. Series: Materials Science and Engineering 413 (2018) 012029

Ezekiel, W., Alade, D., & Okoro, E. (2022). Energy access challenges in rural Nigeria: Grid reliability and off-grid alternatives. *Journal of Sustainable Energy*, 12(1), 45–60.

Fernandez, J., Ortiz, R., & Singh, P. (2024). Hierarchical control strategies for household-scale AC/DC microgrids. *Control Engineering Practice*, 56, 100–115.

Garcia, V., & Patel, N. (2022). Dual-input converter topologies for hybrid PV and grid-connected storage systems. *Power Electronics Review*, 19(4), 317–329.

Jamil, M., & Shah, K. (2015). *Development of portable solar generator*. http://eprints.uthm.edu.my/1328/

Jones, M., & Smith, A. (2023). Multi-input hybrid systems for unreliable-grid regions. *Energy for Development*, 10(1), 15–29.

Kabir, E., Kumar, P., Kumar S., Adelodun, A.A., Kim, K. (2018). *Solar energy: Potential and future prospects, Renewable and Sustainable Energy Reviews Elsevier.*

Kim, H., & Overend, S. (2024). Efficiency advantages of dual-path charging in hybrid energy systems. *Journal of Energy Storage*, 40, 103–118.

Kumar, V., Shiravastava, R.L and Untawade, S.P. (2015). *Solar Energy: Review of Potential Green & Clean Energy for Coastal and Offshore Applications*. International Conference on water resources, coastal and ocean Engineering (ICWRCOE).

Lee, J., Choi, H., & Nguyen, T. (2024). Multiport energy conversion in hybrid off-grid systems. *Renewable Energy Advances*, 9(2), 65–80.

Liu, X., & Zhou, Y. (2023). Hybrid inverter/UPS designs for seamless switching in microgrid applications. *IEEE Transactions on Smart Grid*, 14(3), 234–245.

Munshi, N.A., Reavis, M., Richardson, D., Taylor, R., Tupper, M.L. and Fabian, P., Composite Technology Development Inc, 2016. *Trifold solar panel.* U.S. Patent Application 29/504,735

MUSA, M.N.B., 2018. *Development of Thermo-Electric Generator*.

Nguyen, L., & Becker, J. (2023). Energy management strategies in hybrid home microgrids. *Applied Energy Systems*, 62, 77–89.

O'Neill, T., & Brown, R. (2023). Lifecycle cost analysis of $LiFePO_4$ batteries in off-grid systems. *Journal of Energy Storage Research*, 15, 58–72.

Okoro, E., Onuorah, A., & Adeyemi, M. (2023). Diesel generator externalities and public health in Nigerian communities. *Environmental Health Perspectives*, 130(7), 780789.

Ortega, A., & Singh, V. (2023). Contextaware tertiary control in household microgrids. *IEEE Access*, 11, 67890–67905.

Phillis, M. (2024, December 18). *Nigerians press for solar jobs and electricity, with little success*. Associated Press. https://apnews.com/article/cf157e9b321 d1ad8ad5e92f7b5d3355

Rahman, S., Wang, L., & Sultan, M. (2022). Battery protection and smart charging in hybrid inverters. *International Journal of Power Electronics*, 6(1), 45–60.

Santos, P., Costa, R., & Lopez, J. (2023). Performance of integrated inverter/MPPT systems in weak-grid areas. *Energy Conversion and Management*, 205, 112265.

Smith, D., Taylor, B., & Webster, C. (2024). Portable hybrid generator kits: designs and field evaluations. *Renewable and Sustainable Energy Reviews*, 148, 111385.

Somoye, O. A. (2023). Energy crisis and renewable energy potentials in Nigeria. *Energy Reports, 9*, 1325– 1340. https://doi.org/10.1016/j.egyr.2023.02.056

Suleiman, H., & Adeyemi, T. (2023). Solar potential and PV deployment in Katsina State. *African Journal of Renewable Energy*, 7(4), 195–210.

Ukoima, K. N., Owolabi, A. B., Yakub, A. O., Same, N. N., Suh, D., & Huh, J. S. (2023). Analysis of a solar hybrid electricity generation system for a rural community in River State, Nigeria. *Energies, 16*(8), 3431. https://doi.org/10.3390/en16083431

Wang, H., Xu, F., & Li, C. (2023). Opportunistic charging strategies for hybrid PV-battery systems. *Journal of Power and Energy Engineering*, 11(5), 307–320.

Wang, Y., Cheng, G., & Zhao, D. (2024). Deep discharge tolerance in $LiFePO_4$ and lead-acid batteries. *Energy Materials*, 19, 90–100.

Widyartono, M., Aribowo, W., Rahmadian,
R., Wardani, A. L., & Hermawan, A. C. (2024). Designing a portable solar generator for emergencies. *E3S Web of Conferences*, *513*, 02006. https://doi.org/10.1051/e3sconf/2024 51302006

World Bank Nigeria Energy Report. (2023). *Access to electricity in Nigeria: Challenges and opportunities*. World Bank Publications.

Z A Abdul Majid, N Hazali, M A K M Hanafiah, A A Abdullah, A F Ismail, M H Ruslan, K Sopian and M S Mohd

Azmi (2012). *Design and Performance of 20 Watts Solar Generator*. IOP Conf. Series: Materials Science and Engineering 36 (2012) 012040.

Zhang, L., & Li, S. (2023). Efficiency comparison of AC and DC distribution in hybrid microgrids. *International Journal of Distributed Energy Resources*, 8(2), 112–125.