FUDMA Journal of Engineering and Technology
ISSN: 3092-9385
https://fjet.fudutsinma.edu.ng/index.php/fjet/
Volume 2, Issue 2, 2026, 80-88

Performance Evaluation of 3.5 kVA Hybrid Inverter Following Standard Engineering Practices and Safety Procedures

Johnson O. ADEOGO[1*], Olawale J. OLALUYI[2], Olumuyiwa A. OJO[3], Abayomi T. AYODELE[4], Elijah A. OLAJUYIN[5], Fasasi BELLO[6], Paul C. OFODU[7]

[1*,2,3,4,5,7]Department of Electrical and Electronic Engineering, Bamidele Olumilua University of Education, Science and Technology, Ikere-Ekiti, Ekiti State, Nigeria
[6]Department of Electrical and Electronic Engineering Technology, Rufus Giwa Polytechnic Owo, Ondo State, Nigeria

[1*]adeogo.johnson@bouesti.edu.ng, [2]olaluyi.olawale@bouesti.edu.ng, [3]ojo.olumuyiwa@bouesti.edu.ng, [4]ayoddele.abayo@bouesti.edu.ng, [5]olajuyin.elijah@bouesti.edu.ng, [6]fasasibell@yahoo.com, [7]ofodu.paul@bouesti.edu.ng

Abstract
The global energy landscape has undergone a significant transformation in recent decades, with renewable energy technologies gaining prominence as alternatives to fossil fuel-based power generation. This shift is driven by the dual challenges of meeting rising electricity demand and mitigating the environmental consequences of greenhouse gas emissions. This study deals with assessment of different types of solar inverters. The purpose of this study is to carry out the performance evaluation of 3.5 kVA Hybrid Inverter following standard engineering practices and safety procedures. To reduce distortion content, filters are designed which in turn improves the power factor and efficiency of the system. Several pulse width modulation performances were used to reduce the percentage of harmonic distortion within IEEE standards. The simulation of the system was evaluated using Excell Software. The output waveforms of percentage harmonic distortion were obtained using Qualister Analyzer (CA 8338). The inverter performs the differing function of a rectifier, which converts DC to AC in different forms. The results show that the projected hybrid inverter can reduce the total power distortion under linear loading environments. A design experiment is presented for a 3.5 kVA, 50Hz power inverter under different load settings to authenticate the study.

Keywords: *Engineering Practice, Evaluation, Hybrid Inverter, Performance, Safety.*

1.0 Introduction

There has been a significant development in power electronics within the last decade, where power has considerably moved sideways with this development. In developing countries such as Nigeria, the urgency of this development is even greater, as unreliable grid supply and infrastructural deficiencies have left households, businesses, and institutions in search of more sustainable and dependable solutions [1]. Consequently, hybrid renewable energy systems, which combine solar photovoltaic (PV), battery storage, and in some cases grid support, have emerged as practical and adaptable approaches to addressing energy reliability challenges [2]. Hybrid inverter technology represents one of the most innovative solutions within this context. Unlike conventional inverters that only convert Direct Current (DC) from solar panels or batteries into Alternating Current (AC), hybrid inverters are designed to intelligently integrate multiple sources of power [3]. They can simultaneously manage energy from PV modules, battery banks, and the national grid, ensuring continuous supply even in the event of grid failure. This capability makes them particularly relevant in Nigeria, where frequent blackouts and voltage fluctuations hinder socio-economic productivity [4]. Several studies have emphasized the potential of small to medium-scale hybrid inverter systems, especially within the 3.5 kVA range, as cost-effective alternatives for powering residential homes, offices, and institutional facilities [5]. Harmonics produced within the system during operation is the major problem associated with an inverter which can be reduced with this hybrid type of inverter as the power quality is very important to commercial and industrial systems [6].

1.1 Performance Evaluation of Hybrid Inverters

The performance evaluation of hybrid inverters is a critical aspect of ensuring their efficiency, reliability, and suitability for different applications. Unlike conventional inverters, hybrid inverters integrate functionalities such as solar power conversion, battery management, and grid synchronization. This makes their performance assessment more complex, as it must consider multiple parameters, including efficiency, load management, power quality, and system durability [7]. One of the most important performance metrics is conversion efficiency, which measures the proportion of input DC power from solar panels or batteries that is successfully converted into usable AC power. In high-quality hybrid inverters, conversion efficiency typically ranges between 93% and 98%, depending on load conditions and component design. Efficiency losses can occur due to poor heat dissipation, undersized wiring, or the use of substandard components. Regular testing under different load scenarios provides insight into how the inverter responds to variations in power demand [8].

Another critical aspect of evaluation is battery charging and discharging management. Hybrid inverters must regulate charging currents to prevent battery overcharging, while also ensuring protection against deep discharge, which can shorten battery lifespan. Modern hybrid inverters incorporate maximum power point tracking (MPPT) technology, which enhances solar utilization efficiency by adjusting voltage and current levels to match solar irradiance conditions. Evaluating the performance of MPPT algorithms is particularly important in tropical regions like Nigeria, where fluctuating weather conditions affect solar output [9]. Power quality is also an essential consideration in hybrid inverter performance. Parameters such as voltage stability, harmonic distortion, and frequency regulation must remain within acceptable limits to ensure compatibility with sensitive electrical appliances. Poorly performing inverters may generate harmonics that degrade equipment performance or cause heating in electrical wiring. Therefore, harmonic analysis and monitoring of total harmonic distortion (THD) are vital in performance assessment. High-performance hybrid inverters usually maintain THD below 5%, in line with IEEE 519 standards [1]. Furthermore, performance evaluation extends to system reliability and durability. Hybrid inverters installed in Nigeria often operate under harsh environmental conditions, including high ambient temperatures, dust accumulation, and unstable grid supply. These factors accelerate wear and tear, thereby affecting long-term system reliability. Field-based evaluations and stress tests, including thermal stability analysis, are essential in determining the inverter's ability to withstand prolonged operation without failure [8].

2.0 Materials and Methods

The hybrid inverter has a lot of electronic components which are connected appropriately in other to work effectively and its installation was done in stages.

2.1 Stages of Hybrid Inverter

The hybrid inverter system for the installation was done based on different stages coupled to perform a specific function of converting DC/AC. There are many stages involved in the construction of the hybrid inverter which include: the sourcing stage; regulatory stage; oscillating stage; driving stage; transformation stage and; the output stage [10]. Generally, an inverter is a combination of a battery, a charger circuit, and an inverting circuit as shown in Fig. 2.

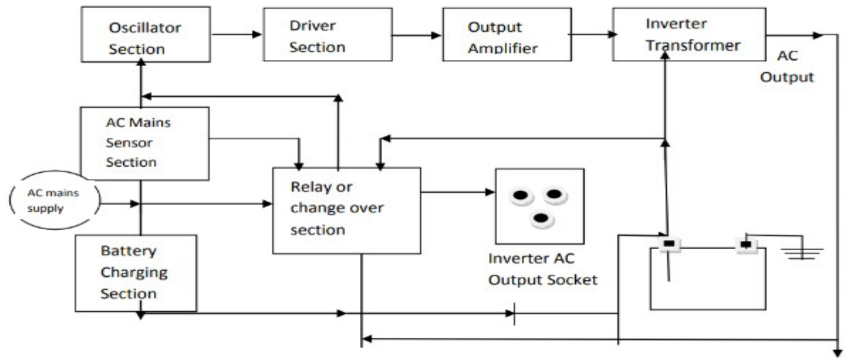

Figure 2 Block Diagram of a Hybrid Inverter [10]

2.2 Circuit Diagram of 3.5 kVA Hybrid Inverter

Fig. 2 presents the basic circuit diagram of a hybrid inverter system which includes an oscillator, control circuit, switching device, and a transformer. The conversion of DC to AC is attained by converting energy stored in DC source such as rectifier output or battery, into AC [4].

Received: 11/06/2026; Revised: 24/07/2026; Accepted: 27/07/2026; Published: 14/08/2026

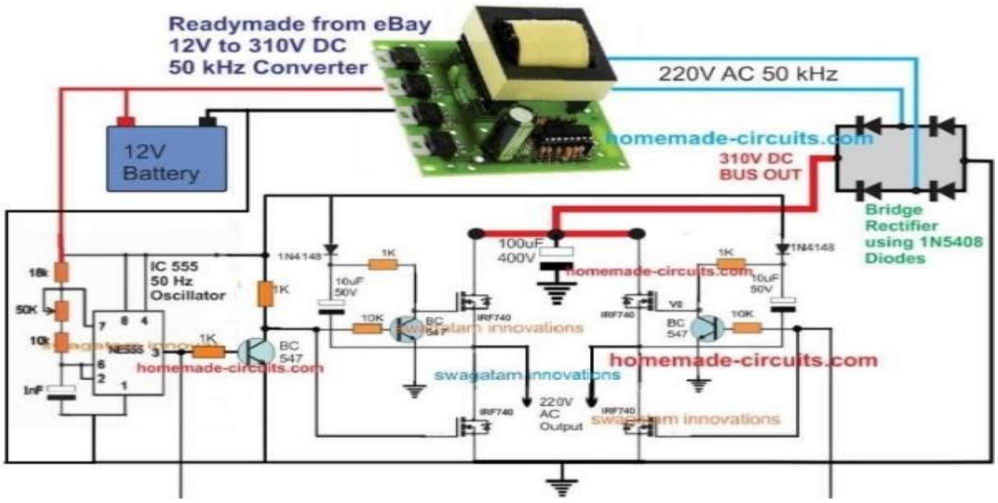

Figure 2: Circuit Diagram of a Hybrid Inverter System [10]

2.3 Off-Grid System of a Hybrid Inverter

In Off-Grid System, the design of the Inverter does not necessitate any connection to electrical grid as it shown in Fig. 3. However, energy generation comes directly from solar panels which convert sunlight into electricity in 3.5 kVA Hybrid Inverter system [6].

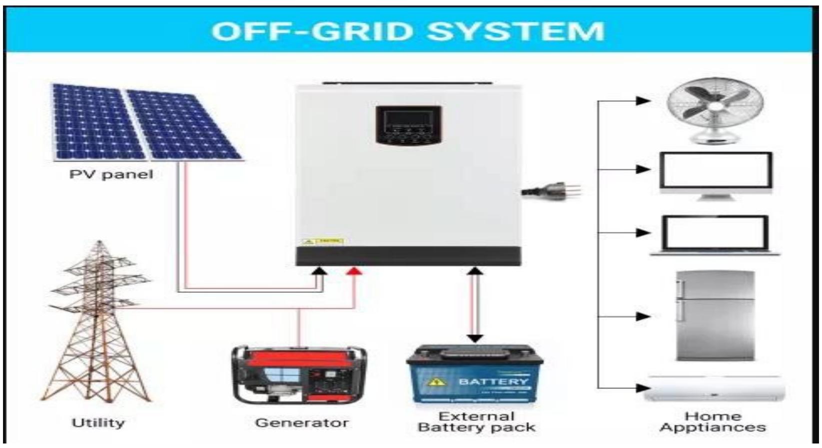

Figure 3: Off-Grid System of a Hybrid Inverter [6]

2.4 Tools and Instrument for the Installation of a Hybrid Inverter System

Copper stripping Knife, Cutter, Razorblade, Plier, Digital Multi-meter, Battery tester are the tools and Instrument used for the installation. The type of analyzer used is Qualister Analyzer (CA 8338) and Third Harmonic Distortion as shown in Fig. 4 and 5. to militate against the recurrent harmonics problem, poor power factor, shortening of the equipment life span and poor efficiency [7].

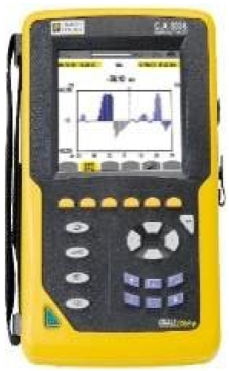

Figure 4: Qualister analyzer [7] Figure 5: Third harmonic distortion [7]

2.5 Design Parameters, Performance Evaluation and Power Consumption

Table 1 demonstrates the weekly watthours, the highest load in watts; the total weekly load connected in watt and the total watthour for each week.

Table 1: Load evaluation and power consumption results

S/N	Appliances	Load (Watts)	Quantity	Load (Watt) Total	Weekly hour of Actual Utilization	Weekly Watt-Hours
1	Bulb	20W	40	800W	45	36,000
2	Celling Fan	45W	4	180W	30	5,400
3	Standing Fan	75W	4	300W	10	3,000
4	Refrigerator	100W	1	100W	4	4,000
5	Laptop Computer	65W	4	260W	15	3,900
6	Printer.	320W	1	320W	5	1,600
7	LED TV 32 Inches	75W	2	150W	5	750
8	Cable Network (DSTV)	25W	1	25W	5	125
	Total	725W		2,135	105	*54,775Wh*

The Table 1 gave us a clear understanding of which appliances that consume the highest power and how to reduce the loads successfully when mandatory.

2.5.1 Battery and its Configuration

Assembling of the battery rack or enclosure to hold the batteries, ensuring it supports their weight and allows easy access for maintenance; arrangement of the battery inside the battery rack in ensuring proper spacing for ventilation and alignment for easy connection, following safety guidelines; connection of the battery in series to increase voltage, forming a series circuit, and secure connections tightly.

The battery configuration is attained using Eq. 1 and Eq. 2.

$$BC = \frac{2fW}{V(Battery)} \qquad 1$$

where:
BC = Battery Capacity
F = Factor of reserve
W = Daily Energy
V(Battery) = System DC voltage

$$TR = \frac{Daily\ Energy\ Consumption\ (kW)}{Battery\ Rating\ (Amp - Hour)} \qquad 2$$

where:
TR = Total Rating of the battery.

Received: 11/06/2026; Revised: 24/07/2026; Accepted: 27/07/2026; Published: 14/08/2026

2.5.2 Sizing of Charge Controller

$$Total\ Module = 1sc * 1.25 * 4\ strings$$

where:
1sc = 8.7

$$Total\ Module = 8.7 * 1.25 * 4\ strings = 43.5A$$

$$Number\ of\ Controllers = \frac{Total\ Current\ in\ the\ Module}{Charge\ Controller\ (Ampere\ Rating)}$$

$$Number\ of\ Controllers = \frac{43.5}{45}$$

= 0.97

Therefore, 1 Charge Controller of 45A, 12V is suggested.

2.5.3 Selection of Circuit Breaker

$$Current\ in\ the\ System = \frac{Total\ Power}{Voltage\ in\ the\ System}$$

$$Current\ in\ the\ System = \frac{725}{12}$$

= 60 x 1.25
= 75 Ampere

Therefore, 80A Circuit Breaker is selected.

2.5.4 Sizing of Inverter

$$Total\ Power\ (Pt) = 725w$$

= 0.725kW

Summation of the total load in wattage (W) is 1,205w and because of this, 3.5KVA inverter is recommended.
P(w) = VICosϕ, where 1Hp = 746w and Cosϕ = 0.8. for future expansion,
ΣP(w) x 1.25, where 1.25 is future expansion coefficient
= 2,135 x 1.25 = 2,668.75w

To get inverter rating of 2,856.25w and since inverter is rated in KVA rating.

$$P(VA) = \frac{P(w)}{Cos\theta} = \frac{2{,}668.7}{0.8} = 3{,}335.94VA$$

So, 3.5KVA inverter rating is recommended.

2.5.5 Required Land Area

$$Efficiency\ of\ the\ Module = \pm 10\%\ (solar\ to\ electricity)$$

Hence, 600W/m² to 60W/m² for 0.550kW = 550W would be transformed by a Module.

2.5.6 Mounting System

Mounting of solar panels on the roof using mounting racks or brackets to ensure proper alignment, stability, and weatherproofing to maximize sunlight exposure; connection of the panels in parallel in increasing current while keeping voltage constant, using junction boxes or combiners; connection of solar rated cables (e.g., PV wire) to the positive and negative terminals of the panels, ensuring secure connections to transmit generated

Received: 11/06/2026; Revised: 24/07/2026; Accepted: 27/07/2026; Published: 14/08/2026

power; routing the solar wire to the solar controller location using conduits or cable trays to protect wires and ensure safety.

The inverter's AC output successfully connected to the office load distribution board using appropriately sized heavy-duty cables, ensuring compliance with electrical standards. A manual changeover switch was installed, enabling seamless toggling between inverter and grid power, which ensured uninterrupted power supply during low solar output. Neutral/earth bonding was verified, and insulation resistance tests confirmed the integrity of the wiring, resulting in a safe and reliable setup that protected the system from electrical faults and supported the office's electrical loads.

3.0 Results and Discussion

Variation in weather varies the voltage and current outputs as charge controller was connected to the output of PV solar panel. The connection of the solar controller to the battery terminals was done to regulate charging and protect the batteries. The Table 2 presents the relationship between the rated load and the output current.

Table 2: Load performance test for 3.5 kVA hybrid inverter with safety procedure

S/N	Rated Load (W)	Output Voltage (V)	Output Current (A)
1	No Load (0)	230	0
2	150	230	0.44
3	250	230	0.58
4	350	230	1.80
5	450	230	2.85

At no load with constant output voltage of 230V, the output current was 0A but at the highest load of 450W, the output current was at the maximum of 2.85A. Fig. 6 shows the performance of the output current from 3.5 kVA Hybrid Inverter under different load conditions.

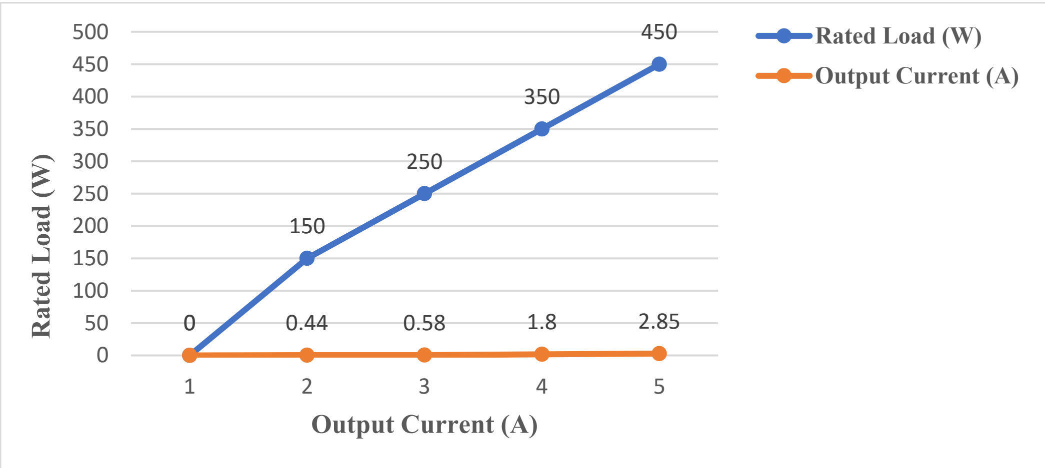

Figure 6: Graphical representation of load performance test for 3.5 kVA hybrid inverter with safety procedure

Table 3: Load performance test for 3.5 kVA hybrid inverter without safety procedure

S/N	Rated Load (W)	Output Voltage (V)	Output Current (A)
1	No Load (0)	230	0
2	150	225	0.86
3	250	215	1.60
4	350	208	2.88
5	450	200	3.95

The output current was at the maximum of 3.95A when output voltage was 230 at no load. With fluctuation in output voltage, at 200V, the output current was 03.95A but at the highest load of 450W.

Received: 11/06/2026; Revised: 24/07/2026; Accepted: 27/07/2026; Published: 14/08/2026

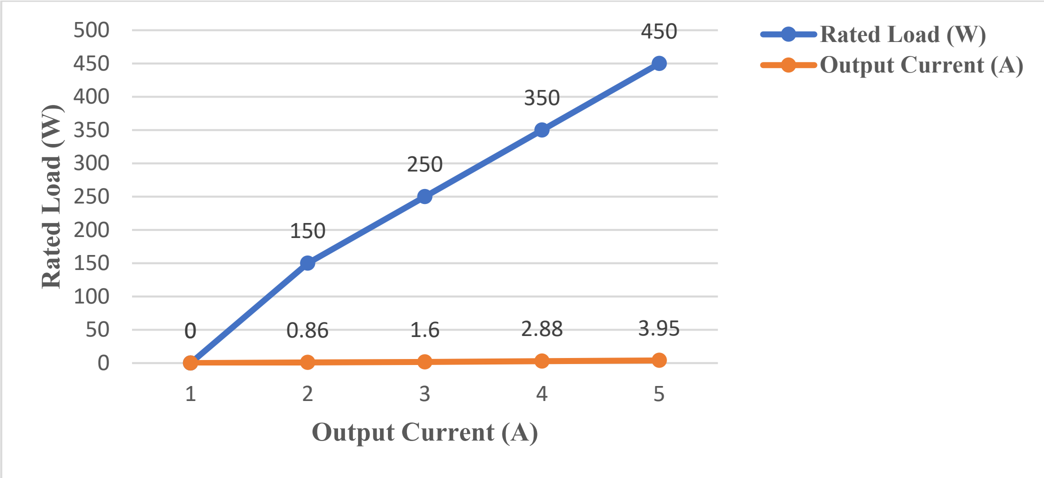

Figure 7: Graphical representation of load performance test for 3.5 kVA hybrid inverter without safety procedure

Generally, from Fig. 6 unlike Fig. 7, as the load increases with constant output voltage, there is small amount of increase in output current.

Table 4 and 5 present the relationship between the load and the rate at which the battery of 3.5 kVA Hybrid Inverter with and without safety procedure discharge.

Table 4: Battery discharge rate of 3.5 kVA hybrid inverter with safety procedure and the load

S/N	Time Interval (I Hour)	Load (W)	DC Voltage (V)
1	9:00am	0	13.00
2	10:00am	100	12.90
3	11:00am	260	12.86
4	12:00pm	385	12.70
5	1:00pm	415	12.55
6	2:00pm	450	12.40
7	3:00pm	480	12.24
8	4:00pm	520	12.15

The maximum voltage discharge rate was 0.16V which occurred between 11:00am and 12:00pm.

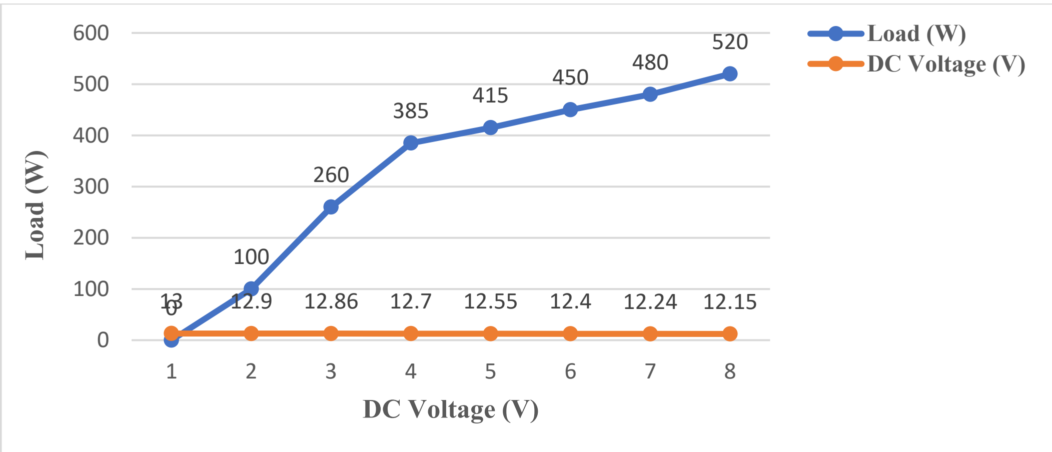

Figure 7: Battery discharge rate of 3.5 kVA hybrid inverter with safety procedure and the load

The rate at which the battery of the inverter discharge is very small compare with the rate of change of the load as it presented in Fig. 7.

Received: 11/06/2026; Revised: 24/07/2026; Accepted: 27/07/2026; Published: 14/08/2026

Table 5: Battery discharge rate of 3.5 kVA hybrid inverter without safety procedure and the load

S/N	Time Interval (I Hour)	Load (W)	DC Voltage (V)
1	9:00am	0	13.00
2	10:00am	100	12.40
3	11:00am	260	12.12
4	12:00pm	385	11.80
5	1:00pm	415	11.50
6	2:00pm	450	11.20
7	3:00pm	480	11.14
8	4:00pm	520	11.05

The maximum voltage discharge rate was 1.6V which occurred between 9:00am and 10:00am.

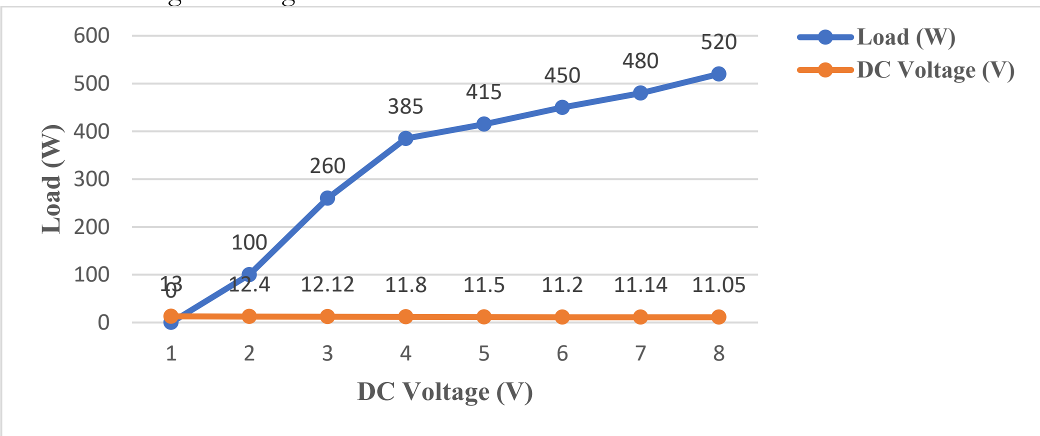

Figure 8: Battery discharge rate of 3.5 kVA hybrid inverter without safety procedure and the load

The battery of the inverter without following engineering practice and safety procedure during installation, discharge rapidly with the rate of change of the load as it accessible in Fig. 8.

4.0 Conclusion and Recommendation

4.1 Conclusion

From the results, within the interval of 1hour, the output current decreased rapidly for a 3.5kVA Inverter without following engineering practice and safety procedure for installation than the inverter following safety procedure for installation. It was also observed that on the same load condition for a 3.5kVA inverter installed with and without following engineering practice and safety procedure, battery output voltage decreases more rapidly in an inverter without following safety procedure than an inverter with safety procedure for installation. We can see that the rate at which battery gets drained in 3.5kVA inverter without following best engineering practice and safety procedure for installation is faster than the installed 3.5kVA inverter with best engineering practice.

4.2 Recommendations

To enhance the performance of the 3.5 kVA hybrid inverter system, installation of inverter must follow best engineering practice and safety procedure. This research is suggested for future expansion if the need arises. There would be a need to complement the solar panels and batteries with additional ones to meet up with the running time and the load capacity. Since the system voltage is adjustable, addition batteries and solar panels could be added to increase the capacity of the system.

References

[1] Abdullahi, M., Usman, A., & Dikko, Y. (2022). "System sizing and component compatibility issues in hybrid renewable energy systems". *International Journal of Energy Systems Engineering, 12*(4), 144–153. https://doi.org/10.1016/j.ijese.2022.04.006.

[2] Adekunle, T. O., &Oladipo, K. S. (2020). "Renewable energy adoption and sustainable development in Sub-Saharan Africa: A review of hybrid systems". *Energy Reports, 6*, 2993–3004. https://doi.org/10.1016/j.egyr.2020.10.042.

[3] Akinyele, D. O., Olabode, E., & Amole, A. (2021). "Design and techno-economic analysis of hybrid renewable energy systems for rural electrification in Nigeria". *Renewable Energy, 164*, 402–417. https://doi.org/10.1016/j.renene.2020.09.078.

[4] Akinyele, D., & Oladimeji, O. (2020). "Technical challenges of hybrid solar PV and inverter installations in sub-Saharan Africa". *Energy for Sustainable Development, 59*, 120–129. https://doi.org/10.1016/j.esd.2020.10.010.

[5] Ezeanya, P., & Suleiman, A. (2024). "Standards and compliance for inverter installation in developing countries: The Nigerian context". *International Journal of Electrical Installation Practices, 9*(1), 34–47.

[6] Hossain, M. I., & Rahman, M. M. (2021). "Recent advances in power electronics for inverter design and control". *Journal of Power Electronics, 21*(4), 765–778. https://doi.org/10.1007/s43236-021-00215-7

[7] Kim, J., & Park, H. (2023). "Battery degradation modeling and management strategies for hybrid renewable energy systems". *Journal of Energy Storage, 63*, 107123. https://doi.org/10.1016/j.est.2023.107123.

[8] Okafor, J., & Eze, C. (2021). "Hybrid inverter design considerations for rural electrification in Nigeria". *Journal of Energy Systems Research, 7*(3), 201–210.

[9] Olatunji, K., & Eze, R. (2021). "Economic barriers to the adoption of hybrid solar inverter systems in Nigeria". *Renewable Energy Focus, 36*, 44–52. https://doi.org/10.1016/j.ref.2021.06.005chnologies/opticool.html.

[10] Oluwole A. S., Omojoyegbe M. O., Adeoye O. S., Amoran A. E., Akinsanmi O., Femi-Jemilohun O. J., Sobowale A. A., Olaluyi O. J. & Adeogo J. O. (2023). "Comparative Analysis of Designed 1kVA 12V Smart Solar Inverter with Locally Made Solar Power Inverter". Journal of Engineering, Technology and Innovation, 2:4; Pp 08-17.

Received: 11/06/2026; Revised: 24/07/2026; Accepted: 27/07/2026; Published: 14/08/2026