SJIF Impact Factor (2024): 8.675| ISI I.F. Value: 1.241| Journal DOI: 10.36713/epra2016 ISSN: 2455-7838(Online)
EPRA International Journal of Research and Development (IJRD)
Volume: 9 | Issue: 4 | April 2024 - Peer Reviewed Journal

PERFORMANCE EVALUATION OF A LOCALLY MADE 3KVA SINGLE PHASE INVERTER

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ABSTRACT
This study presents performance evaluation of 3KVA 24/220V 50Hz single Phase inverter. The two 12 Volts 200AH batteries were connected in series to produce 24V, 400AH which is fed into the input terminals of the inverter connecting resistive and inductive loads in the output terminals to determine different measured. It was observed that when the inverter system was working on No-load, the battery voltage kept decreasing, which is an indication that for optimum performance the battery must be charged continuously irrespective of whether load is connected or not. It was observed that as resistive load increases, the terminal voltage of the battery decreases, while the current drawn increases, as the terminal voltage of the battery decrease. It was observed that the higher the load, the more the current drawn, hence the extent of continuity of supply depends on the ampere-hour rating of the battery and the amount of current drawn by the load. Also the resistive load consumes less energy compared with inductive load. Therefore, for highly inductive loads such as electric motors and transformers, there is need for higher capacity inverters for smooth operations. The output waveform analyzed using the Hantek DSO5202B, shows that the inverter that was analyzed has pure sine wave. The prototype design took care of the various lapses in previous designs which included the final output (pure sine wave), cut off voltage to save battery life and very reduced cost of the final product as products were assembled locally.
KEYWORDS: *Battery, environmental sustainability, inverter, power distribution, resistive and inductive load*

1.INTRODUCTION

Electricity generation, transmission, and distribution entities have struggled to provide consistent power to consumers, prompting consumers to seek alternative sources of power for residential, commercial, and industrial needs (Obukoeroro and Uguru 2021; Adoghe *et al*., 2023). Various methods are available for power generation, including generators, wind power, and solar energy. Much of this energy is stored in batteries using inverters, which are power electronic devices that convert direct current (DC) energy, typically found in batteries, into alternating current (AC) energy (Phutane and Suraj, 2013). Man relies on power supply for almost every phase of their daily activities as in houses, offices, computer, security, telecommunication system, farming etc., but with the erratic power supply it is quite evident that there is need for alternative source of supply, as such the need for stand-by power supply is essential which brought into existence the alternative means called the inverter (Govindaraju and Baskaran, 2010).

Between the late nineteenth and mid-twentieth centuries, the conversion of DC to AC power was achieved using rotary converters or motor-generator sets (M-G sets). During the early twentieth century, vacuum tubes and gas-filled tubes emerged as switches in inverter circuits (Sudipta *et al*., 2013; Ezeagwu *et al*., 2019). The origin of electromechanical inverters explains the source of the term inverter, early AC to DC converters used an induction or synchronous AC motor direct-connected to a generator (dynamo) so that the generator's commutator reversed its connections at exactly the right moments to produce DC. A latter development is the synchronous converter in which the motor and generator windings are combined into one armature, with slip rings at one end and a commutator at the other and only one filed frame. The result with either is AC-in, DC-out. Using an M-G set, the DC component can be regarded as being generated independently of the AC component. With a synchronous converter, it can be viewed as a form of "mechanically rectified AC". Moreover, with suitable auxiliary and control apparatus, an M-G set or rotary converter can be operated in reverse, converting DC to AC. Therefore, an inverter can be conceptualized as an inverted converter (Sudipta *et al*. 2013).

When utilizing an M-G set, the DC portion can be seen as generated autonomously from the AC section. Through a synchronous converter, it can be perceived as a type of "mechanically rectified AC". Additionally, with appropriate auxiliary and control equipment, both an M-G set and a rotary converter can be employed in reverse, transforming DC into AC. Thus, an inverter can be understood as a reverse converter (von Jouanne *et al*., 199). SCRs do not turn off or commutate automatically when the gate control signal is shut off. These only turn off when the forward current is reduced to below the minimum holding current, which varies with each kind of SCR, through some external process. For SCRs connected to an AC power source, commutation occurs naturally every time the polarity of the source voltage reverses. In SCR circuits connected to a DC power source, forced commutation

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methods are typically necessary to ensure that the current is forced to zero when commutation is needed. However, simpler SCR circuits often utilize natural commutation rather than forced commutation (Sudipta *et al*., 2013; Tsai *et al*., 2028).

Although inverters provide clean and reliable energy, these are not cost-efficient for high power demands but only on the long run. It is an expensive technology and for years researchers and developer have tried to make the technology more cost-efficient. The idea is that in the future, household electricity could be provided by means of inverters powered by fuel cells and batteries or other alternative energy sources that can help reduce cost of household's energy demands (Phutane and Suraj, 2013). The inverter has become very important in modern technology because of the need to produce continuous electric power supply to critical loads such as computers, surgical equipment, security doors, automated teller machines (ATMS), telecommunication system, broadcast equipment, public address system, lighting system etc. The inverter is a major segment of an uninterrupted supply unit (UPS) (Phutane and Suraj, 2013; Anas and Pratibha, 2014). In applications where inverters transfer power from a DC power source to an AC power source, it is possible to use AC to DC controlled rectifier circuits operating in the inversion mode. In the inversion mode, a controlled circuit operates as a line commutated inverter. This type of operation can be used in HVDC power transmission systems and in regenerative braking operation of motor control systems. Another type of SCR inverter circuit is the Current Source Input (CSI) inverter. A CSI inverter is the dual of a six step voltage source inverter. With a current source inverter, the DC power supply is configured as a current source rather than a voltage source. The inverter SCRs is switched in a six-step sequence to direct the current to a three-phase AC load as a stepped current waveform (Jyoti et al, 2013). SCI inverter commutation methods include load commutation and parallel capacitor commutation. With both methods, the input current regulation assists the commutation. With load commutation, the load is a synchronous motor operated at a leading power factor. As these have become available in higher voltage and current ratings, semiconductors such as transistors or IGBTs that can be turned by means of control signals have become the preferred switching components form used in inverter circuits (Jyoti et al, 2013).

The square wave output with high harmonic content, is not suitable for certain AC loads such as motors or transformers. Square wave units were the pioneers of inverter development (Jyoti et al, 2013). The output of a modified square wave, quasi square or modified sine wave inverter is similar to a square wave output except that the output goes to zero volts from time before switching positive or negative (Osahenvemwen *et al*., 2016). A multilevel inverter synthesizes a desired voltage from several levels of direct current voltage as inputs. The advantages of using multilevel topology include reduction of power ratings of power devices and lower cost. There are three topologies-diode clamp inverters, flying capacitor and cascaded inverter (Jyoti *et al*, 2013). A pure sine wave inverter produces a nearly perfect sine wave output (less than 3% total harmonic distortion) that is essentially the same as utility-supplied grid power. Thus, it is compatible with all AC electronic devices. This is the type used in grid-tie inverters. Its design is more complex, and costs more per unit power (Alaskan, 2006). In achieving a better output voltage waveform (sine wave approximation) lower the harmonic content of the final output which is a problem in most locally assembled inverters. The study will focus on the performance evaluation of a 3KVA locally made inverter carried out with 2x12V/200AH batteries connected in series to give a 24V input supply; it is expected to have an output of 200VAC, 50Hz.

2.MATERIALS AND METHOD

The materials and apparatus used in this study include the following.

i. 3KVA single phase, 50Hz, 24/220volts inverter designed and constructed locally and assembled.
ii. 2-12 volts 200AH mercury deep cycle batteries.
iii. 10-200watts Philip filament lamps
iv. 3-Digital multimeters
v. Wattmeter
vi. Load bank
vii. Hantek DSO 5202B oscilloscope
viii. 125 Watts inductive load

2.1. Experimental Procedures

The two 12 Volts 200AH batteries are connected in series to produce 24V, 400AH which is fed into the input terminals of the inverter as shown in figure 1. The variable resistive and inductive loads were connected to the output terminals of the inverter via the ammeter to measure the load current, while the voltmeter is connected across the load to determine the terminal voltage of the inverter. At the commencement of the experiment, the terminal voltage of the battery bank was measured and battery voltage against time for No load at the output terminals of the inverter was also recorded. First the load was varied in steps of 200Watts by addition of 200Watts filament step up to 400 Watts and more with an inductive load of 125 Watts ratings, readings taken which included V_{dc}, V_{ac}, I_L and V_{ac}.

The experimental data was used to determine the battery voltage, load current and load voltage for both resistive and inductive load test.

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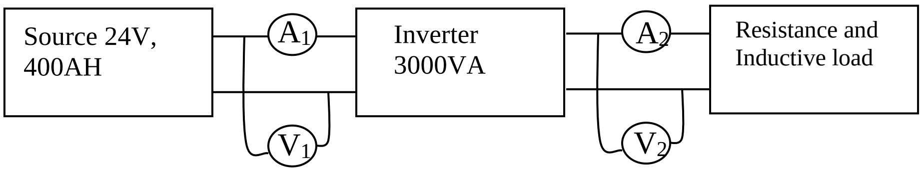

Figure 1: Experimental Diagram

2.2. Digital Multimeter

Digital multimeter was used for measuring and taking reading for both current and voltage. The photograph is shown in plate 1

Plate 1: Photograph of Digital Multimeter Used.

2.3. Digital Oscilloscope

The Hantek DSO5202D 2 channel storage oscilloscope was used to get output waveform to determine if his complete sine wave. The Hantek oscilloscope photograph is shown in plate 2.

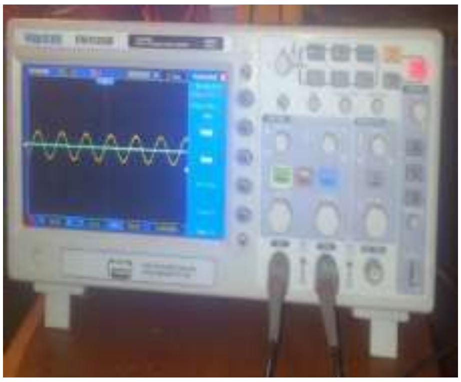

Plate 2 Photograph ofHantek DSOJ202B Oscilloscope used.

3.RESULTS AND DISCUSSION

The test was done to ensure that the inverter circuit is working as expected. The test would help to ascertain its behavior under no load with respect to the output voltage stability. The inverter performance was determined by the measurement of voltages, current and time duration for different loads to the inverter at different periods. The inverter was used to power various resistive and inductive loads under strict supervision in the laboratory. Figure 2 shows battery voltage against time for no load

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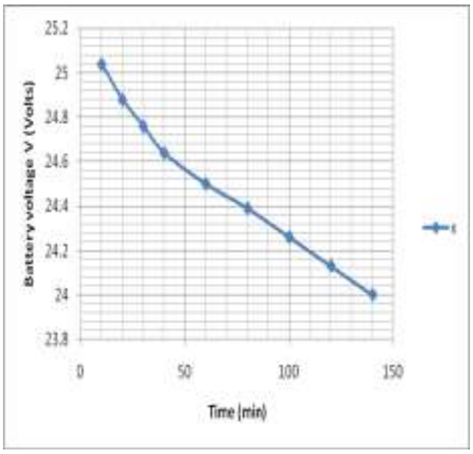

Figure 2: Battery Voltage against Time for Inverter No Load

It is shown in Figure 2 that at no load even when the inverter was working the battery voltage kept dropping which indicates that for optimum performance of a battery it must be charged continuously irrespective of whether load is connected or not. The current drawn recorded for the no load test was very minimal; this current was as a result of the internal impedance of the battery and was constant for the period. The photograph for this experiment and waveform are captured in plate 3 and plate 4 respectively

Plate 3 Experimental Set with No Load and Display

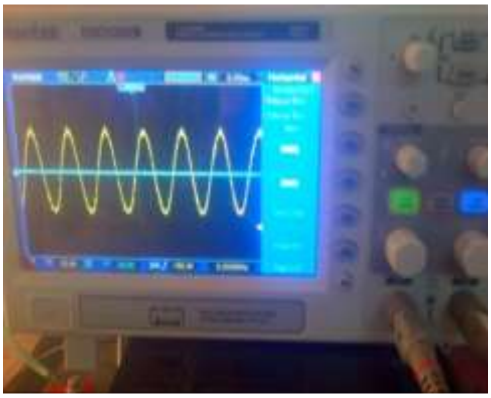

Plate 4: Waveform from Oscilloscope with No Load on Inverter Resistive Load Test

Varied resistive load test was carried out the plot is shown in figure 3, for resistive load (varied) against battery voltage

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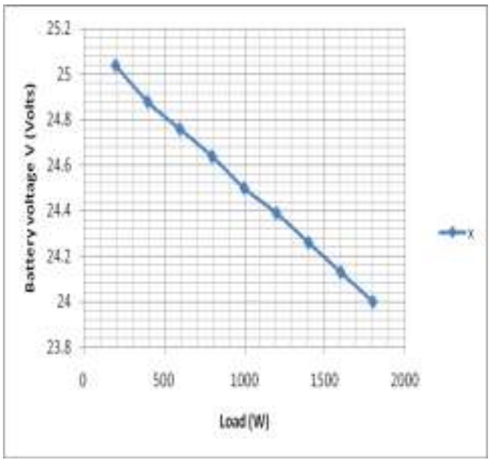

Figure 3: Inverter Resistive Load Test

For battery voltage against resistive load, shows that as the resistive load increases the terminal voltage gradually decrease. The relationship is not linear but decreases exponentially as resistive load increases. The photograph of the experimental waveform (pure sine wave) is recorded in plate 5.

Plate 5: Photograph of Waveform Recorded For Resistive Load

The figure plotted for load versus current show current drawn is proportional to the load as load increases current drawn increases. This is shown in figure 4.

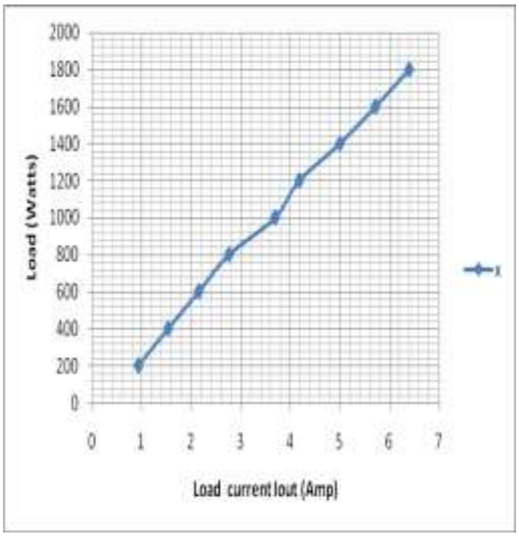

Figure 4: Load Current Characterization

Also the relationship between load current and battery voltage is shown in figure 5 as current drawn increases the terminal voltage of the battery decreases

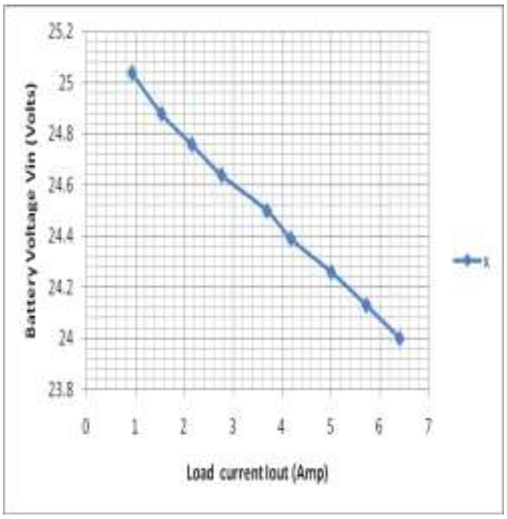

Figure 5: Effect of load current on the terminal voltage of the battery Inductive Load Test

The inverter was used to power inductive load, the results shown in figure 6 (battery voltage against time) and figure 7 (battery current against time).

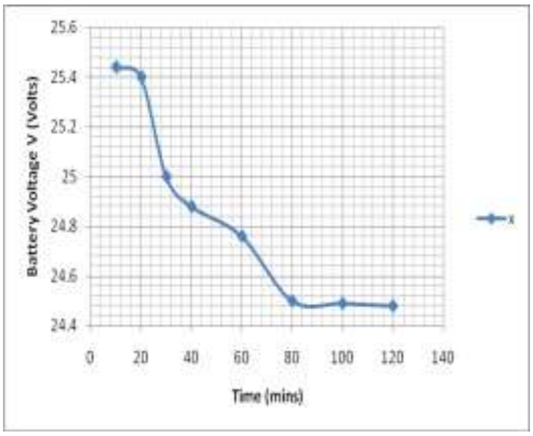

Figure 6: Battery voltage against time with inductive load

Figure 5 and 6 illustrate that the system encounters a sudden voltage drop initially due to the starting current drawn from the battery, particularly attributed to the inductive load. This voltage drop is followed by a gradual increase. It was noted that the inverter depletes its charge more rapidly under an inductive load due to the higher initial inductive load, contrasting with the behavior observed under a resistive load.

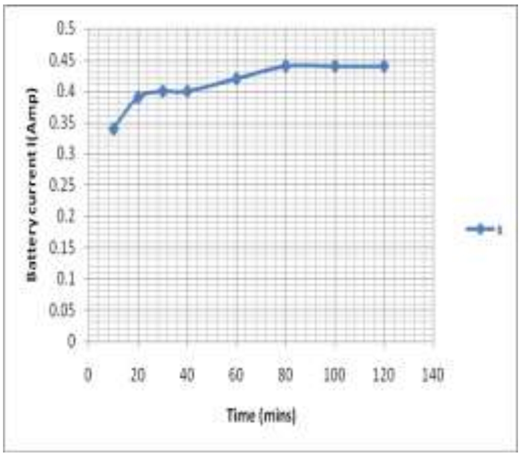

Figure 7: Battery current against time with inductive load

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In Figure 7 it was observed that the battery drops between 0-10 minutes was significant and it then remains almost constant for 10 – 20 minutes this is as a result of high initial starting current of an inductive load, the waveform (pure sine wave) shown in plate 6.

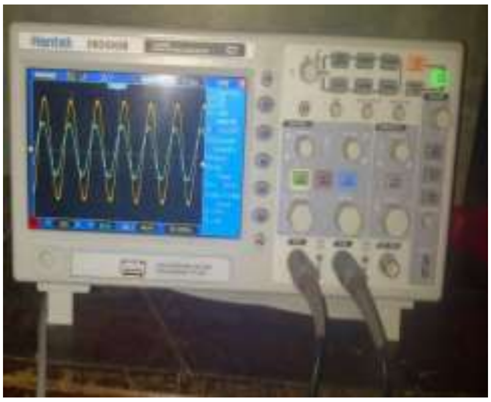

Plate 6: Photograph of waveform recorded for inductive load

Resistive and Inductive Load Test

After readings were taken for resistive and inductive loads separately the load were combined and readings taken, plate 7 shows the waveform (pure sine wave) captured.

Plate 7: photograph of combined load for the experiment (Resistive and Inductive)

4.CONCLUSION

The goal for this study was to analyse the performance of a locally made 3KVA, 220V, 50Hz, single phase inverter in line with the local content policy of the Federal Government of Nigeria to produce appropriate sine wave. The goal, to produce a 220 Volts sine wave with the capability of providing 3000 VA of power was tested with various types of loads (inductive and resistive) and waveform captured which was very close to a pure sine wave, was made possible by the SG3524 oscillator (Featuring inbuilt pulse width modulator) it fires the power MOSFETS ON and OFF in pull push mode i.e. one OFF the other ON for example when the upper FET conducts, The lower one is closed or vice versa at a frequency of 50 HZ. The PWM is a source of oscillation of the power inverter. The circuit converts a DC voltage into a series of pulses, such that the pulses duration is directly proportional to the value of D.C voltage. The greater advantage of such circuits is that there is almost no power loss in the control circuit.

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