

Performance Analysis of a Branded and Locally Constructed Modified 1 KVA Sine Wave Solar Power Inverter for Domestic Electric Power Supply

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Abstract

The locally constructed inverter in this paper has the rating of 1kva and 220V AC output. Requirement for the implementation include locally sourced 100AH 12V deep cycle battery, IC SG3524 oscillator, MOSFET'S and BJT types of transistors, transformer, diodes, resistor, contactor, relay, capacitor and other electronic components. The stages comprise of oscillator unit, MOSFET assembly unit, Transformer unit and battery charge unit. Each constructed unit was independently tested for accurate functionality before the composite was coupled. The inverter in an electronic device converts DC supply to AC. The input is 12VDC and the output is 220V modified sine wave. The waveform and the output stability parameters of these two inverters were compared and the result shows that the locally constructed inverter has a better performance and cost effective than the branded one.

Keywords: Load; Inverter; Performance; Voltage; Transistors

Introduction

Power electronic systems are used widely to convert electric energy from one form to the other using electronic devices. Four basic power electronics functions are AC to DC conversion, DC to AC conversion, DC to DC conversion and AC to AC conversion. These basic functions are used to build power supplies, DC transmission systems, electric drives and others. In today's scenario the demand of electricity has increased tremendously. The cause of it is increase in population day by day, economic development of a country and diminution of fossil based fuels. So alternative energy sources i.e., renewable energy sources are the best option without any harm to the nature. With the advancement in technology in the field of power electronics more than past few years and rising crises for energy have led to increase progress in generating power using renewable energy sources like Photovoltaic (PV), Wind, Fuel cell (FC) based renewable energy technologies. Among all renewable energy sources, solar photovoltaic (PV) electricity generation is the fastest growing source now are days throughout the world. In a PV system, a PV array converts solar power to electrical power and a grid connected inverter is required for inverting the electrical power to ac power then it is fed back to the grid. The power electronics device which converts DC power to AC power at required output voltage and frequency level is known as inverter.

At present time almost all instruments whether electrical or electronic require power inverter. The instruments which use ups (uninterruptible power supply) are mostly square or quasi sine wave inverters. They have large harmonics in their output and may damage the devices or electronic instruments. For getting pure sine wave in power electronics sinusoidal pulse width modulation (SPWM) technique is needed. Today this technique is used in inverters to obtain pure sinusoidal wave in the output. The inverters of such technique in the market are very costly and their output is also not true sine wave. So lot of research in this direction is required. A commanding method SPWM is very useful in the area of power electronics such as electrical drives, UPS, renewable energy system and so on. Mobility and versatility have become a must for the fast-paced society today. People can no longer afford to be tied down to a fixed power source location when using their equipment's. Overcoming the obstacle of fixed power has led to the invention of a DC/AC power inverter.

Companies, Industries, Organizations, Homes among the others

are posed with a major problem of power shortage especially here in Nigeria. Although in developing countries, shortage of power is a problem commercially and domestically. New offices have tremendous load on already existing power generation sources. When added to rapidly increasing private and domestic demand, the situation, especially in certain urban areas becomes devastating. Simply stated, our ability to consume power is growing faster than our ability to supply power. Under such conditions, failure will occur unpredictably and without any warning due to stresses on the inadequate sources of power. Hence, there is need for the alternative source of power which could fill in the gap and cover the lapses of shortage in power supply. Overcoming this obstacle led to the invention of DC/AC power inverters. Short term solution of power disruption could be addressed through this project work. The system embraces the use of electronic means to generate electricity. It involves the conversion of direct current (DC) source from the battery to alternating current (AC) that can be used to power our house, offices, hospital, banks etc. This system also incorporates an AC to DC converter which serves as a charging system, responsible for recharging the batteries when they go below a threshold value of 18V. The aim of the study is to evaluate and analyse the performance of a branded and locally constructed Modified 1kva Sine Wave Solar Power Inverter for domestic electric power supply.

Literature Review

Inverters are crucial energy conversion components in any renewable energy scheme which converts DC power to AC energy required by most electrical loads. The ideal inverter has hundred percent efficiency and produces a perfectly sinusoidal output waveform [1]. Production of a perfect sinusoidal output waveform will require the inverter to operate as a linear amplifier which reduces the efficiency

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figure. To achieve reasonably high efficiency, inverters replace the temporal variations of a sine wave with waveforms that have square edges. Examples of such waveforms include square waves, modified square wave, sinusoidal pulse width modulation (SPWM) synthesized sine wave, and multilevel waveforms [2-4]. The process of synthesizing AC power from DC sources is commonly achieved using two basic methods. In the first method, a high voltage DC source whose average value equals the peak value of the AC voltage to be synthesized is generated from the battery using high frequency DC to DC converters. The AC waveform is then generated from the high voltage source using electronic switches. This approach leads to a compact design because heavy 50Hz magnetics are not used. The other approach involves the direct generation of AC power from the available DC power using 50Hz step-up transformer and electronic switches. Either of these methods can be used to make square wave, modified sine wave and sinusoidal pulse width modulated sine wave inverters. A circuit block related to inverters is the DC to DC converter which converts input DC power to an output DC power at a different voltage level [5,6]. A class of DC to DC converters known as multi-input converters and have the ability to operate from more than one voltage sources have been developed and analyzed in the literature. These converters are used in renewable energy conversion systems that have multiple sources of energy such as solar and wind energy sources, as exemplified. They adjust their voltage gain in relation to the input DC voltage, as needed to generate the required output voltage using pulse-width modulation techniques [1].

However, direction of direct current is not reversed. It is direct potential (voltage) at the rectifier terminals that is inverted or reversed. Because potential is reversed with current continuing in the same direction as before, the flow of electric power is also reversed or transferred from the DC system to the AC system [4].

Prince reviews prior art by first examining operation of a single-phase full-wave center-tap rectifier circuit. The DC output of the rectifier circuit includes both passive resistance and reactance [7]. His figures provide ideal waveforms of most circuit variables, including potential and current at AC and DC terminals. On the left side of the Figure 1 is the "rectifier circuit". This figure is identical in topology to Prince's, except that modern symbols for rectifier circuit elements replace his archaic vacuum tube (diode) symbols [3]. With this small change, his figure is identical to any modern single-phase full wave center-tap rectifier circuit [8-10].

However the recent advancement in technology and rising cost in the manufacture of modified sine wave inverters has call for a review and analysis of the performance so as to achieve efficiency and also have a cost effectiveness in the production for domestic power supply [11].

Testing and Performance Analysis

After the construction/assembly of the locally made inverter system, it was tested to ensure that it meets specification. Prior to this time other tests were done on the transformer before now i.e., after its construction. The test results and performance tests are shown in the sub-sections below.

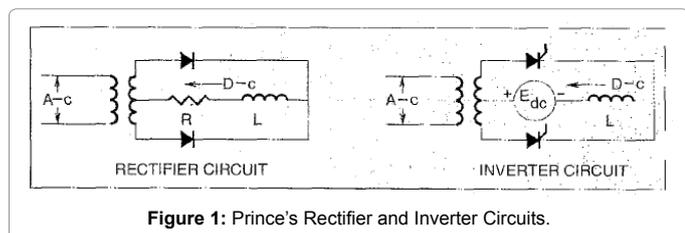


Figure 1: Prince's Rectifier and Inverter Circuits.

Oscillator testing

The voltage regulator input (LM7809) is connected to the positive battery terminal line while the regulator output terminal is connected to pin 15 of SG3524 via a low value resistor (of about 47Ω) in other to limit the current flowing into the IC and central terminal of the regulator and the pin 8 of the IC are both connected to the ground. The output of the oscillator was measured and ensured it fall between the ranges of the output voltage

Performance analysis

A no-loads test was done on the inverter initially after completion; the output of the transformer was measured (Tables 1-8).

The branded inverter and the locally constructed were subject to two kinds of loads to determine the efficiency, how long the inverter systems can power the loads.

- The resistive loads which are electric incandescent bulbs and soldering iron.
- The inductive load which are electric fan and drilling machine.

The tests carried out on both the branded and the locally constructed inverter and the readings taken with the use of multimeter are as follows:

The tables of values were taken with the following conditions in place.

- The branded inverter was supplied with 12v battery source.
- There was no public utility supply to the inverter.

Input voltage	12V
Output voltage	230V
Current drawn from the battery	1.1A
Frequency	50Hz

Table 1: Showing no-load test on the inverter.

Open circuit voltage	19.90V
Short circuit current	5.23A

Table 2: No load test on solar panel, temperature: 30°C, charging current: 0.70A inclined position.

Open circuit voltage	19.3V
Short circuit current	0.44A

Table 3: At cool weather.

Open circuit voltage	19.6V
Short circuit current	0.56A

Table 4: Raining position (wet position).

Open circuit voltage	5.6V
Short circuit current	0.03A

Table 5: Night condition.

Open circuit voltage	20.6V
Short circuit current	4.47A

Table 6: Flat position (sunny condition).

Open circuit voltage	3.3V
Short circuit current	0.01A

Table 7: At Night Condition.

Open circuit voltage	19.3V
Short circuit current	1.12A

Table 8: Raining condition (wet condition).

- The inverter was made to operate idle i.e., no load was placed on it (Table 9).

Observation: Made was that the inverter system does not drain the voltage of the battery when it isn't loaded.

The tables of values were taken with the following conditions as stated in Table 10.

- The branded inverter was supplied with a 12 V battery source.
- There was no public utility supply to the inverter.
- The inverter was made to operate idle i.e., no load was placed on it (Table 10).

Resistive loads test for the branded inverter

The table of values were taken with the following conditions put in place as reflected in Table 11 below

- The banded inverter was supplied with a 12V battery source.
- There was no public utility supply to the inverter.
- The inverter was made to operate under resistive loads.
- The connection of the inverter, the load, the ammeter and the voltmeter was connected in parallel to get the voltage drop

Start Time (10 min Interval)	DC (V) input	AC (V) output	I (A) output
10:00 am	12.0V	220V	-
10:10am	12.0V	220V	-
10:20 am	12.0V	220V	-
10:30am	12.0V	220V	-
10:40am	12.0V	220V	-
10:50am	12.0V	220V	-
11:00am	12.0V	220V	-

Table 9: Values for the branded inverter on no load.

Start Time (10 min Interval)	DC (V) input	AC (V) output	I (A) output
10:00 am	12.0V	220V	-
10:10am	12.0V	220V	-
10:20 am	12.0V	220V	-
10:30am	12.0V	220V	-
10:40am	12.0V	220V	-
10:50am	12.0V	220V	-
11:00am	12.0V	220V	-

Table 10: Table of values for locally made inverter on load.

S/N	Item	P (W)	AC(V) output	Duration 10 Mins interval		
				DC(V) input	AC(V) output	I(A) output
1	4 filament lamps bulb	600	230V	11.9	220	1.53

Table 11: Resistive loads test for the branded inverter.

S/N	Item	P (W)	Duration (10 Mins)		
			DC(V) input	AC(V) output	I(A) output
1	3 lamps	220	12.26	204	1.08

Table 12: Resistive loads test for the locally constructed inverter.

S/N	Item	P (W)	AC(V) output	Duration \10 Mins		
				DC(V) input	AC(V) output	I(A) output
1	Drilling machine	240	220V	12.05	180	1.33

Table 13: Inductive loads test for the branded inverter.

reading of the loads and also an amps meter was connected in series to the load to get the current drawn (Table 11).

Observation: The rate at which the battery is being drained depends upon the magnitude of the load. The lesser the load the longer time it will take to drain the battery. As the load power increases so also the draining increases, thereby causing the battery voltage to drop greatly.

Resistive loads test for the locally constructed inverter

The table of values were taken with the following conditions put in place as reflected in Table 12 below

- The banded inverter was supplied with a 12V battery source.
- The inverter was made to operate under resistive loads.
- The connection of the inverter, the load and the voltmeter was connected in parallel to get the voltage drop reading of the loads and also an amps meter was connected in series to the load to get the current drawn (Table 12).

Observation: The rate at which the load drains the battery is a little higher compared to the branded inverter and this is due to the output voltage drop on the locally made inverter.

Inductive loads test for the branded inverter

The table of values was taken with the following conditions put in place as reflected in Table 13 below

- The banded inverter was supplied with a 12V battery source.
- The inverter was made to operate under inductive loads.
- The connection of the inverter, the load and the voltmeter was connected in parallel to get the voltage drop reading of the loads and also an amps meter was connected in series to the load to get the current drawn.

The tables of values were taken with the following conditions put in place as reflected in Table 13 and the connection remain the same (Table 13).

Observation: The rate at which the load drains the battery when on inductive loads is higher.

Inductive loads test for the locally constructed inverter

The tables of values were taken with the following conditions put in place as reflected in Table and the connections remain the same.

The tables of values were taken with the following conditions put in place as reflected in Table 14 below

- The branded inverter was supplied with a 12V battery source.
- The inverter was made to operate under resistive loads (Table 14).

Observation: The rate at which the inverter drains the battery when on inductive loads is higher on inductive loads than resistive loads.

The wave forms were generated by the oscilloscope connected to the inverters both on no load and when subjected to both resistive and inductive loads and the following wave forms were generated.

Comparison between the Waveform of both Inverters

Locally made inverter and branded inverter (Figures 2-7).

The other test that was carried out on the branded 1KVA inverter and the locally made 1 KVA inverter are as follows (Tables 15-20) (Figures 8-13).

Similarities between the Branded Inverter and the Locally Constructed Inverter.

- They both generate a modified sine wave
- They both makes sound due to the effect of the distortion in their waveform

S/N	Item	P (W)	AC(V) output	Duration \10 Mins		
				DC(V) input	AC(V) output	I(A) output
1	Drilling machine	240	230V	11.99	185	1.75

Table 14: Inductive loads test for the locally constructed inverter.

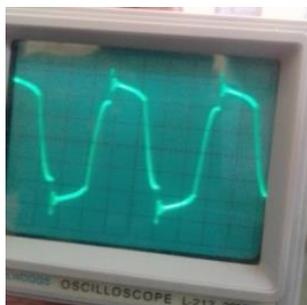


Figure 2: Locally made inverter on no load.



Figure 3: Branded inverter on no load.



Figure 4: Branded inverter on resistive load.



Figure 5: Locally constructed inverter on resistive load.



Figure 6: Branded inverter on inductive load.



Figure 7: Locally constructed inverter on inductive load.

Rated load (W)	Output voltage (V) (AC)	Output current (A)
No load	230	0
145	230	0.84
345	230	1.63
545	207	2.49
645	191	2.83

Table 15: Load performance test for the branded inverter.

Rated Load(W)	Output voltage (V) (AC)	Output current(A)
No load	238	0
100	238	0.42
285	231	0.96
600	200	1.63
645	191	2.83

Table 16: Load performance test for the locally constructed inverter.

Time (10 min interval)	Load (W)	DC voltage (V)
2:50	0	12.31
3:05	60	12.31
3:15	160	12.26
3:35	220	12.26
3:45	285	12.08
3:45	525	11.99
3:55	600	11.92

Table 17: Relationship between load and battery of the constructed.

Time (10 min interval)	Load (W)	DC voltage (V)
Load (W)	DC voltage	12.31
1:20	0	12.50
1:30	45.8	12.40
1:40	145	12.10
1:50	345	11.70
2:00	545	11.40
2:20	645	11.10

Table 18: Relationship between load and battery (branded).

Load	AC (V)	I (A)	DC (V)	Time (pm)
360W	199	1.82	11.91	2:12
360W	190	1.41	11.80	2:25
360W	189	1.40	11.80	2:42
360W	182	1.47	11.60	2:52
360W	175	1.53	11.40	3.:02
360W	169	1.56	11.20	3:12
360W	163	1.59	11.00	3:20
360W	147	1.64	10.4	3:30

The inverter on a steady load with respect to time battery capacity: 12.50V, no load voltage: 220V, no load current: 0.

Table 19: Inverter on a steady load of 360W (Locally built).

Load	AC (V)	I (A)	DC (V)	Time (pm)
360W	199	1.72	11.91	2:12
360W	190	1.35	11.80	2:25
360W	189	1.39	11.80	2:42
360W	182	1.44	11.60	2:52
360W	175	1.50	11.40	3.:02
360W	169	1.52	11.55	3:12
360W	163	1.58	10.45	3:20
360W	147	1.60	10.39	3:30

Observation: The longer time it takes the load will cause a decrease in the DC voltage which causes an increase in the current and it drains the battery at higher rate compared to the students' built.

Table 20: Inverter on a steady load of 360W (branded).

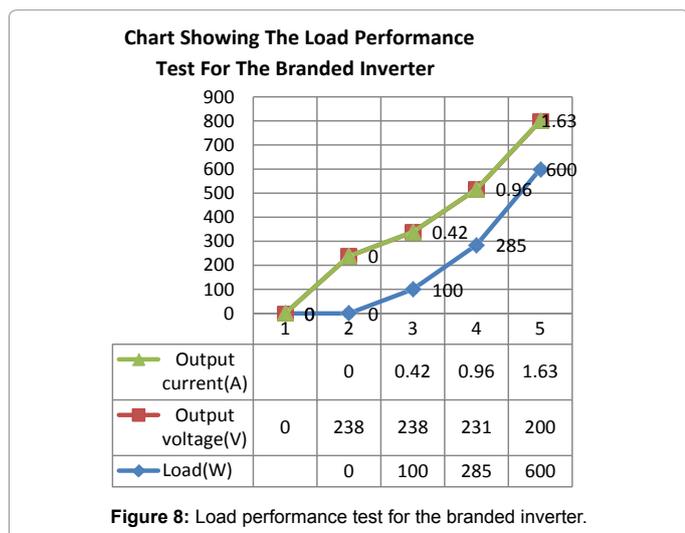


Figure 8: Load performance test for the branded inverter.

- They both have a protection circuit
- They are both DC to AC converters (Table 21).

Summary

The design and analysis was done under strict supervision and the

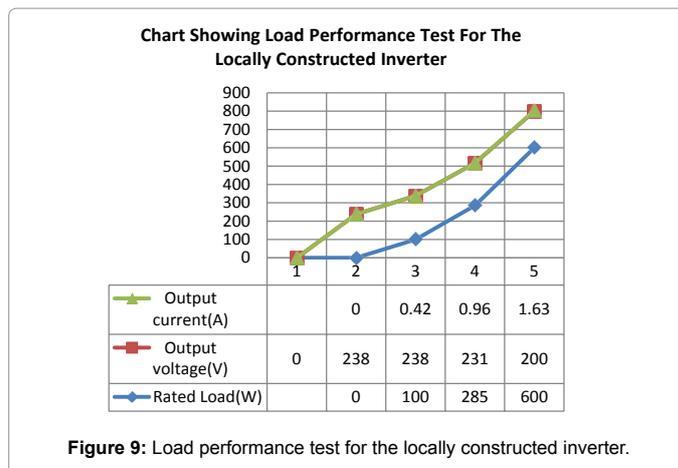


Figure 9: Load performance test for the locally constructed inverter.

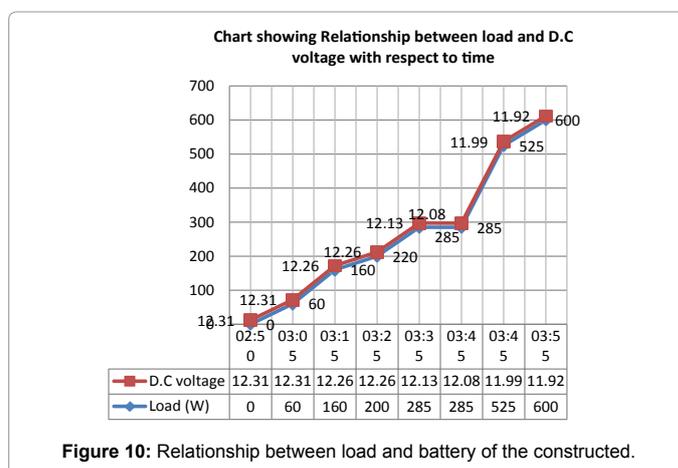


Figure 10: Relationship between load and battery of the constructed.

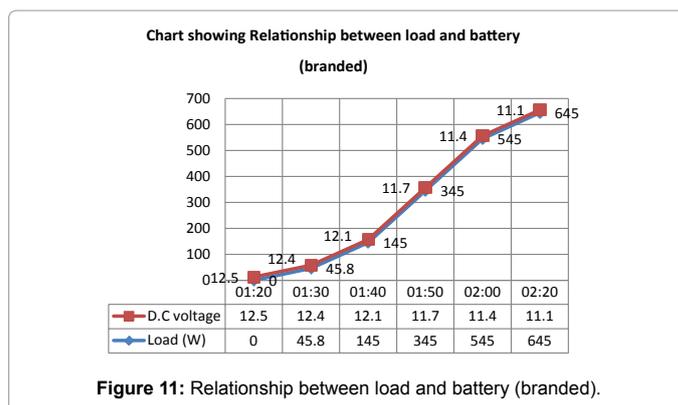
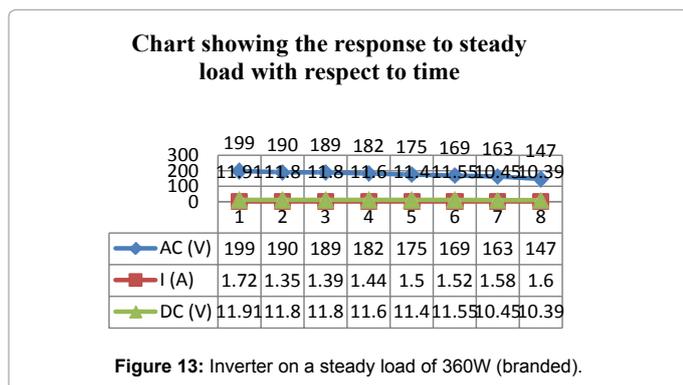
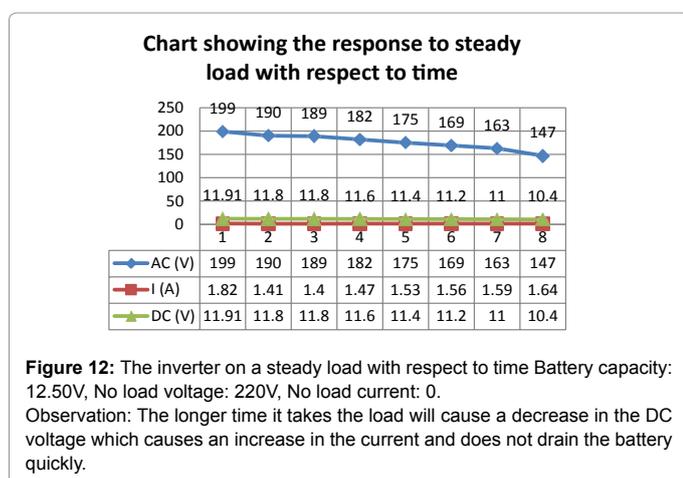


Figure 11: Relationship between load and battery (branded).

testing was also carried out to ascertain the claim that the factory made will be better than the students' built. Looking at the result above and the various curves, it indicates the rigidity of the students' built and the life span which is far better than the factory made. Due to the components used in the project which include a laminated transformer, which can withstand stress more than the ferrite core which is used in the factory made, makes it more reliable than the factory made. The various curves include the curve of battery against load and the output voltage; the implication is that the students' built maintain a low drain of the battery and with the respect to the increase in the load. The system drains the battery more on inductive load than resistive load [12].

Inverter (Branded New)	Inverter Constructed
It is less expensive.	It is more expensive.
It emits lesser heat due to the use of ferrite core.	It emits greater heat due to the use of laminated core.
It is difficult to repair when faulty due to the microchip used.	It can be repaired due to the components used.
Its spare part is not easily found in market places.	Its spare part is easily found in market places.
It uses an h-bridge configuration.	It uses a push pull configuration.
It is smaller, portable and light in size and weight.	It is bigger in size and construction but heavier in weight.
It operates internally both at high and low frequency.	It operates internally only at low frequency only (50Hz).
It has an excellent voltage regulation due to the use of switching mode ferrite core.	It drops with respect to battery voltage and loads connected due to the response of laminated core transformer.
It can't withstand a very high starting current of some lesser power equipment e.g. printer and some TV set.	It can withstand a very high starting current of some lesser power loads e.g. printer and some TV set.
It indicates fault when subjected to loads of nearer power to its specification.	It can be subjected to loads of nearer power to its specification.
It is mechanically fragile.	It is mechanically rugged.
Ferrite cores are used for minimum power converters (below 2KVA).	Laminated core are used for both low and very high power converters (above 10KVA).

Table 21: Differences between the branded new inverter and the locally constructed inverter.



The design and development of the project has been challenging both mentally and physically as we have been faced with choices far beyond what we expected, but in the long run the result paid off [13]. After the complete design of the system, the deviation between expected result and the actual result was very close. The performance and efficiency was beyond expectation and from every ramification, the design of the project was a success.

Recommendation

The results from the analysis of the two inverters shows that the built/locally constructed inverter has a better waveform and the performance far outweighs that of the branded one. It can be inferred from this result that the locally manufactured inverter should be improved better so that it will make a far greater improvement than the one shown in this evaluation report, since the materials for the production are readily available.

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