P-ISSN: 2659-1561
E-ISSN: 2635-3040

Research Article

Simulation and Implementation of Approximate Sine Wave Inverter for Sustainable Energy Supply for Domestic Appliances

EZUGWU Chukwudi, AHMED Sagir and KWEMBE Benjamin, A.

Department of Electrical/Electronic Engineering Technology, Federal Polytechnic, Nasarawa, Nigeria
Corresponding Author Email: Chidusky2010@yahoo.com

Received: Sep 27, 2019 **Accepted:** Oct 4, 2019 **Published:** Oct 11, 2019

Abstract: The concept in this paper simulate and implemented an approximate sine wave inverter for sustainable energy supply for home appliances. Renewable Power Generation (RPG) is a promising alternative source of energy. These sources of energy; solar, wind, bio-energy are available in nature and readily available to harness. Thus, there is incompatibility between the output of these energy sources and the conventional power supply input of most appliances which are in D.C and A.C respectively. The solar cells also comes in modular forms which necessitate the use of the cascaded H-bridge inverter topology. The H-bridge inverter topology entails performing power conversion in multiple voltage steps to obtain required voltage level with a reduced harmonics and losses. An algorithm implements a logic control and Pulse Width Modulation (PWM) technique was used to drive gates of each of the MOSFET in all the levels. A single phase induction motor was used to validate the output of the inverter. The data collected from hardware realization was compared with MATLAB/SIMULINK model results. The analyzed data revealed close correlation between the hardware realization and simulated result. Therefore, approximate sine wave inverter can be used in driving inductive load directly. This is recommended for water pump, washing machine, refrigerator in homes as optimized utilization of renewable energy.
Keywords: H-bridge, RPG, MATLAB, SIMULINK, MOSFET PWM, Five levels.

I. Introduction

It is a well-known fact today that electrical power supply is not reliable. All over the world, there is a significant electrical power supply interruption. These electrical power supply interruption have resulted in many electrical instruments developing problems or even stopped working entirely. Hence this crippled much business thereby affecting many countries economy as Nigeria. Also there is increase in occurrence of power supply disturbance, which can be viewed as a form of power pollution. High voltage spikes and momentary voltage drops are therefore common. These power disturbance may affect the performance of sensitive equipment in private and corporate organization causing loss of data and even damage to equipment (Diyoke and Nnadi, 2014).

The progress made in developing alternate source of energy over the last decades has showed that independent power system are not only possible but also very practical. In fact a wide variety of generating equipment is now available to allow individuals take advantage of just any renewable source of energy, for number of reasons however, most of these systems produce only direct current (DC) and often do so only at low voltage (Nor *et al.,* 2017). Nevertheless, it is generally agreed that the greatest and most useful form of current is the alternating current (AC) since the appliances exist in the vast majority of homes

(Sivagamasundari and Mary, 2014). Therefore, there arises the need to be able to convert direct current (DC) to alternating current (AC) that will be of a constant frequency and also be used to power electrical circuits either in homes or in industries. Such electrical device is called inverter (Sachin and Prabodh, 2014).

The classical two level inverter exhibits many problems when used in high power applications. Many of the connected loads are of nonlinear type, meaning that they draw current with a non-sinusoidal or distorted sine waveform. This also causes distorted sine voltage drop, thus resulting in distorted network voltage waveform. The overall distortion level is described by total harmonic distortion (THD) (Niitsoo, *et al.,* 2013).

Cascaded multilevel inverter is based on series connection of single phase H-bridge inverters with separate DC sources. The Cascaded multi-level inverter circuit provides high quality output when the number of levels in the output increases and also this reduces the filter components size and cost (Amarita, Eldhose, and Ninu, 2014). The circuit has many advantages like simple, modular, improved waveform which result in reduced total harmonic distortion and losses (Melba and Sivagama, 2016).

The presence of significant amount of harmonic makes motor to undergo severe torque pulsation, especially at low speed, which manifest themselves in cogging of the shaft. It will also cause undesired motor heating and electromagnetic interference (Senthilkumar, Balachandran and Subramaniam, 2013).

The purpose of this research work is to substitute the usual method with the use of peripheral interface (PIC) microcontroller.

Microcontroller possess the qualities of storing operating instructions to generate the required pulse width modulation waveform due to the built in PWM module. The PIC16f628 microcontroller supplies the variable frequency pulse width modulation signal that controls the applied voltage on the gate drive of the cascaded H-bridge circuit (Jatin and Hardik, 2015).

II. Multilevel Inverters

A multilevel voltage source inverter splits the main DC supply voltage into more little DC sources which are used to synthesize an AC voltage into a staircase voltage nearly exact of the desired sinusoidal waveform. Among the significant benefits of multilevel inverter topology is the harmonic reduction in the output voltage waveform without increasing switching frequency or decreasing the inverter power output (Pooja, 2015).

Production of the staircase output voltage waveform is the main aim of multilevel inverters. The main component of multilevel inverter configuration is power semiconductor switches, diodes, and DC voltage sources. By increasing the number of DC voltage supply on the input side, the number of output levels can be increased and as a result, the output waveform will be much approximate to a sinusoidal waveform (Manasa *et al*., 2012).

There are three main types of multilevel inverters that of are great importance in industrial applications; capacitor clamped multilevel inverter, diode clamped multilevel inverter and cascaded H-bridge multilevel inverter with separate DC sources. This paper simulate and implemented cascaded H-bridge multilevel inverters due to its importance in renewable energy application (Saro and Tanmoy, 2017).

III. Approximate Sine Wave Inverter

An approximate sine wave resemble a square wave but instead has a “stair case” look to it that corresponds more in shape to a sine wave. An approximate sine wave tries to mimic the sine wave itself. An approximate sine wave inverters is close to a sine wave and have low enough harmonics that do not cause problem with household equipment. It also overcome the problems associated with the two level conventional inverters (Ifeagwu, Alor, and Ugwu . (2016).

IV. Methods

The five level H-bridge inverter and a split-phase induction motor drive as load was modeled with MATLAB/SIMULINK software. It allows the user to simulate the design over a specified period. A logic control circuit was modeled to generate pulses to drive each gate of the MOSFET in the cascaded H-bridge circuit. The generated staircase five level output voltage wave forms is used to drive the single-phase induction motor as the load. The control methods adopted is sinusoidal pulse width modulation technique. The PIC 16F628 micro controller is used to generate PWM signals to switch each gate of the IRF740 MOSFETs of the cascaded H-bridge inverter circuit of the implemented hardware prototype. Figure1 depicts the MATLAB simulations model.

A schematic diagram of cascaded H-bridge inverter topology is shown in Figure 2

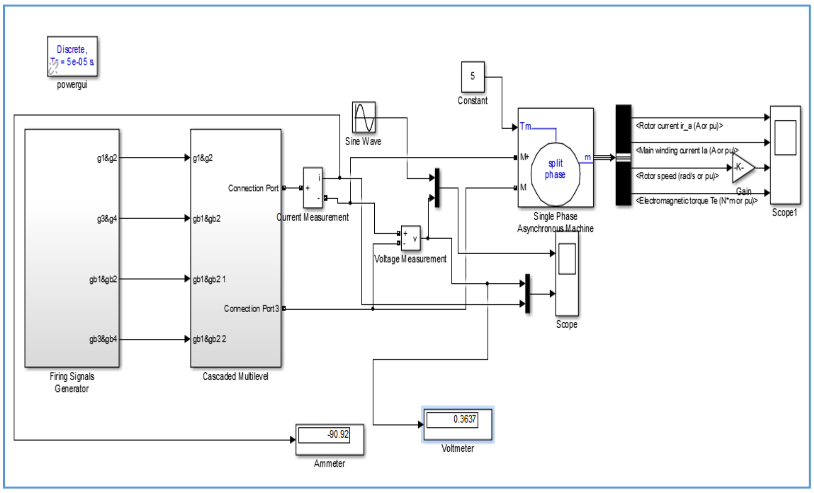

Figure 1. Single-Phase Simulink Model for Five-Level Cascaded H-bridge Inverter

V. Design Analysis of H-Bridge Circuit

The rating of MOSFET switches used were determined by considering the maximum load current of the induction motor first and then the DC-DC converter block output voltage.

$I_{load} = 3$ A , $V_{dc\text{-}dc} = 200$ V

Therefore, selecting power MOSFET IRF740 with rated drain current of 10 A and Drain to Source voltage of 600 V for switching is in order even at the face of surge. With the triggering pulse of 2.5 milli seconds to different combination of the eight switches, gives a total period of 20 milli seconds. Therefore, the final output frequency can be calculated as follows:

$$f = \frac{1}{T} \tag{1}$$

P-ISSN: 2659-1561
E-ISSN: 2635-3040

$$f = \frac{1}{20} = 50 \ Hz$$

Where T= 20 milli seconds

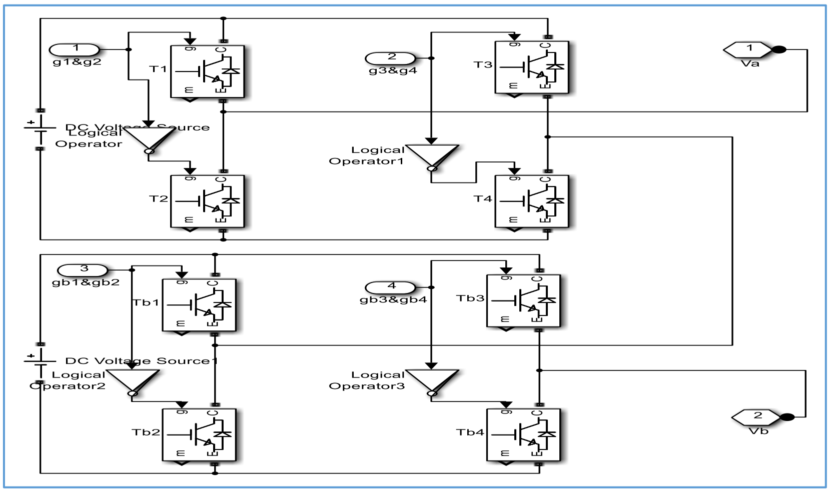

Figure 2. Single-Phase Matlab Model of Cascaded Five-Level H-Bridge Circuit

VI. Implementation of Five Level Cascaded H-Bridge Inverter

The cascaded H-bridge inverter is a five-level inverter. The algorithm used for PWM generation is PIC16F628 micro-controller is shown in Figure 3. Two batteries have been used independently to make two 12 V–120 V DC-DC Converters rated at 170 VA each.

The cascade block is where the two converters are cascaded to give 50 Hz 240 VAC at 340 VA and contains the processing block that handles the DC-AC inversion using the Pulse Width Modulated (PWM) technology. The circuit diagram and implemented hardware are shown in Figure 4 and five respectively.

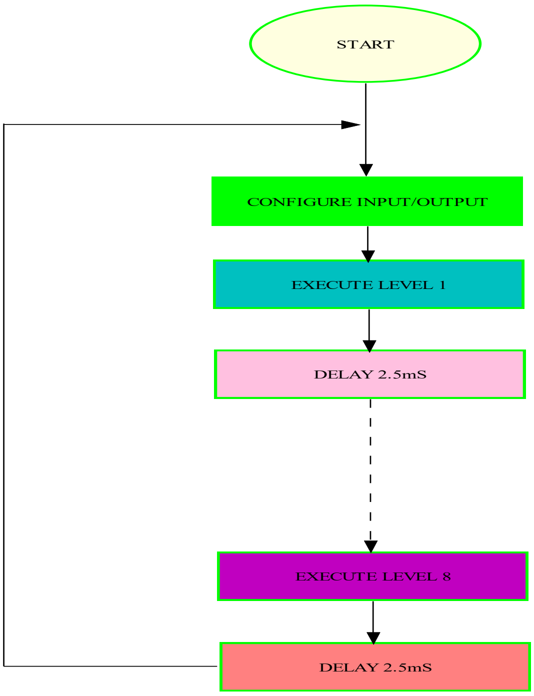

Figure 3. Algorithm for the Two H-Bridge Controller–PIC 16 F628

P-ISSN: 2659-1561
E-ISSN: 2635-3040

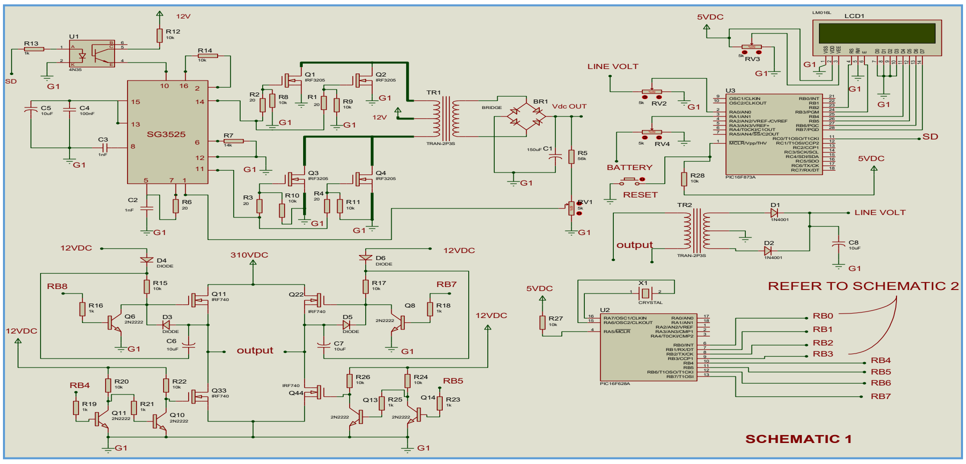

Figure 4. Circuit Diagram of the Part A of the Inverter

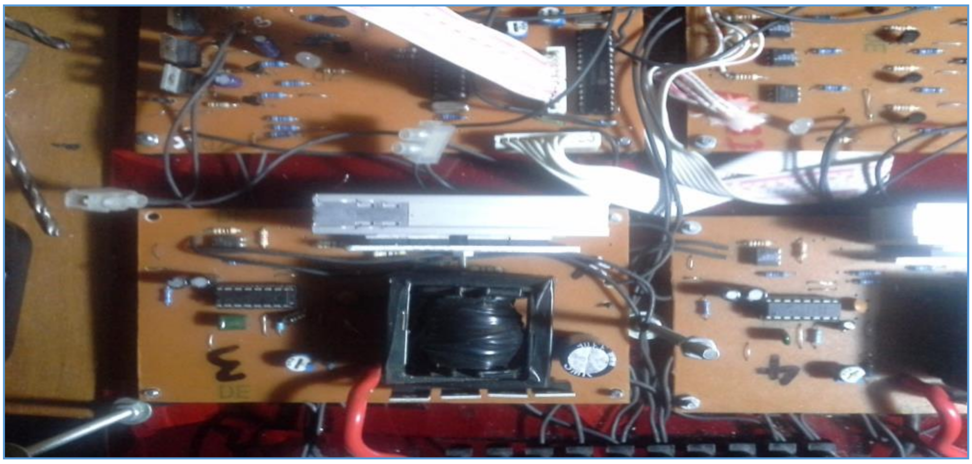

Figure 5. The Implemented Circuit of the Five Level Cascaded H-Bridge Inverter

VII. Simulation Results

The reference and carrier signals are shown in Figure 6. The gating or firing Signals for the Inverter Power Switches are shown in Figure 7. The Five level output current and voltage waveforms of the inverter simulation is shown in Figure 8 and 9. The rotor speed of split phase induction motor is shown in Figure 10. The Fast Fourier Transform (FFT) plot of the five level H-bridge inverter to analyse total harmonic distortion is shown in Figure 11. The THD voltages and percentage THDs at different modulation indexes are shown in Table 1

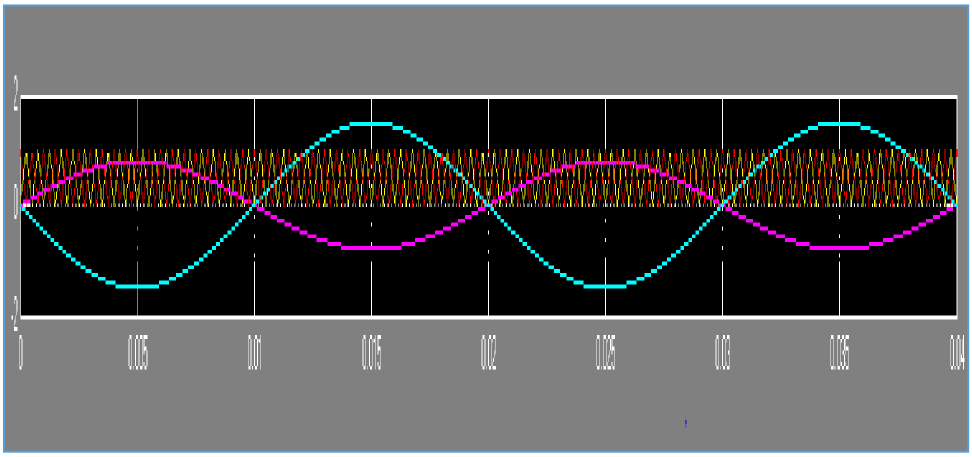

Figure 6. Reference and Carrier Signals

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

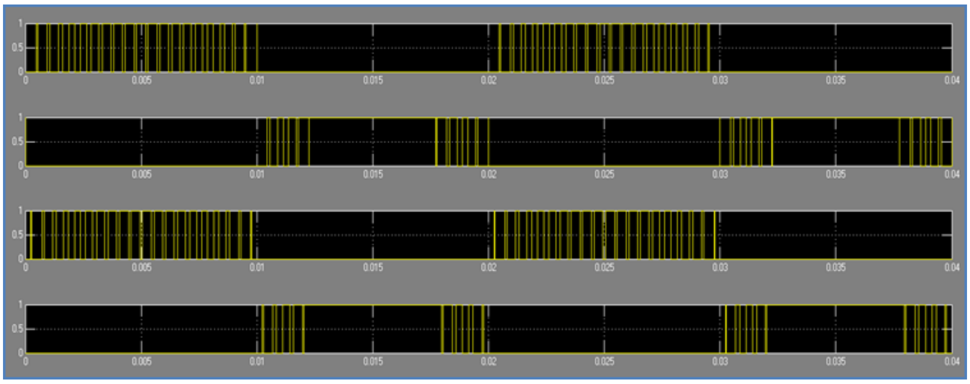

Figure 7. Gating or Firing Signals for the Inverter Power Switches

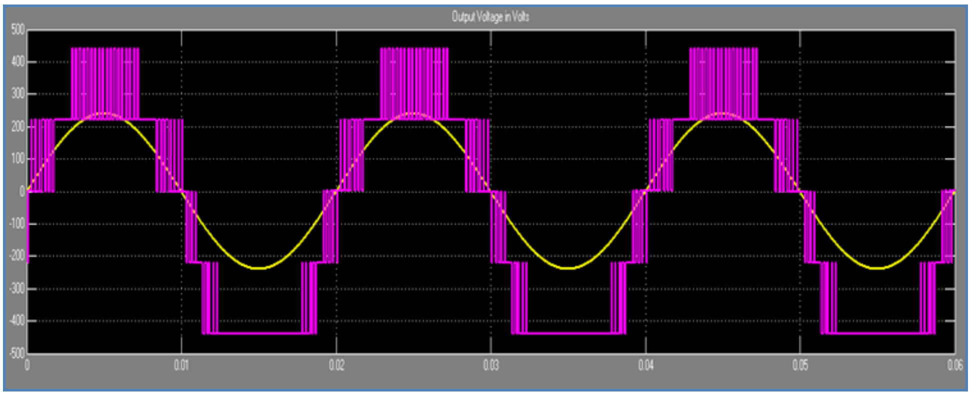

Figure 8. Voltage Waveforms of the Inverter Simulation

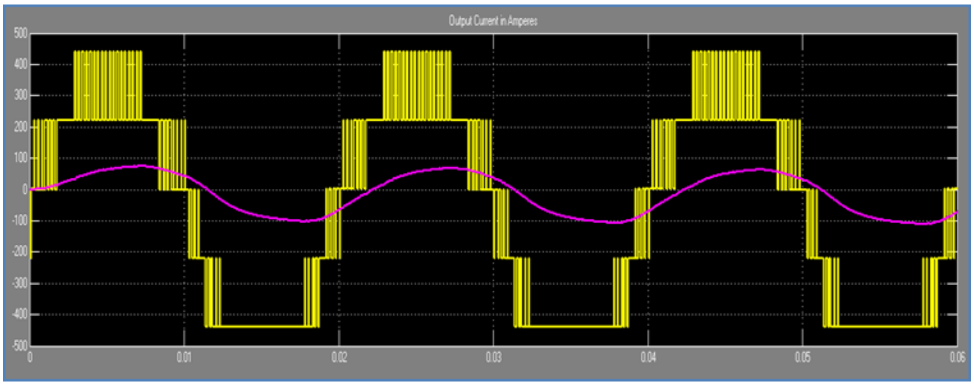

Figure 9. Five Level Output Current Waveforms of the Inverter Simulation

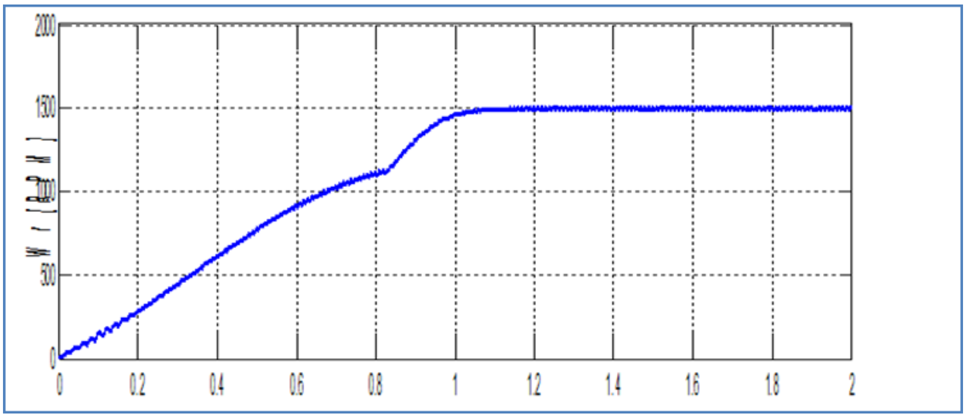

Figure 10. Rotor Speed of Split Phase Induction Motor

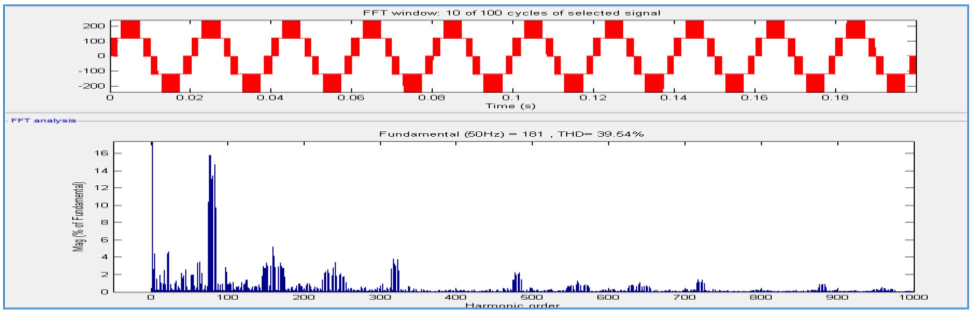

Figure 11. FFT Plot of THD at Modulation Index of 0.8

Table 1. Total Harmonic Distortion Voltage and Percentage Total Harmonic Distortion of Simulation of Cascaded H-bridge Five Level Inverter at different Modulation Index

Modulation Index	THD Voltage (V)	Percentage THD
1.0	238.9	29.56
0.9	219.5	31.69
0.8	181.0	39.54
0.7	170.6	41.64
0.6	133.5	39.36
0.5	122.2	48.92
0.4	83.63	92.59
0.3	75.23	101.42
0.2	27.58	229.99
0.1	26.17	225.86

VIII. Hardware Results

The waveforms of the implemented single-phase H-bridge cascaded five level inverter are presented. Figure 12–19 shows the firing signals to each of the eight switches. The output voltage waveforms of the inverter on load is shown in Figure 20.

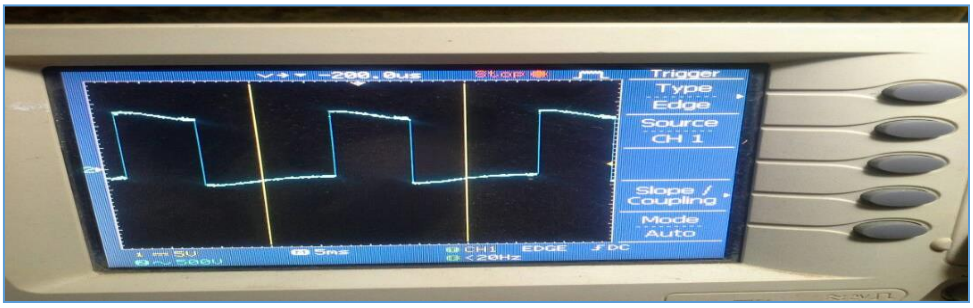

Figure 12. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q1

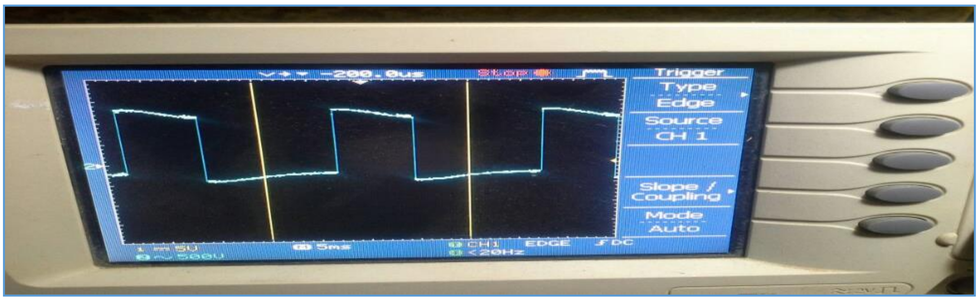

Figure 13. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q2

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

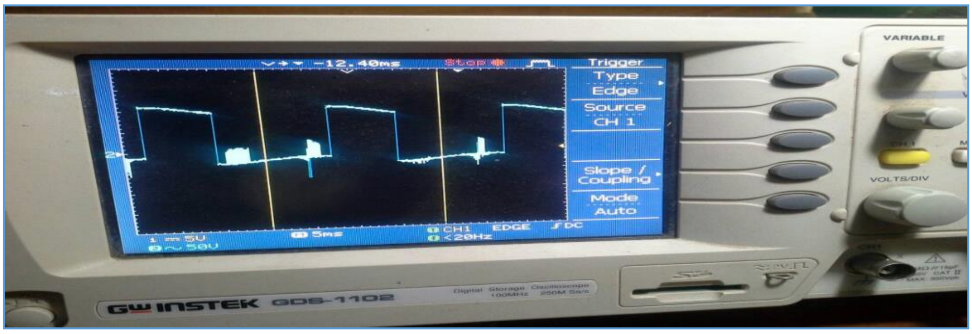

Figure 14. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q3

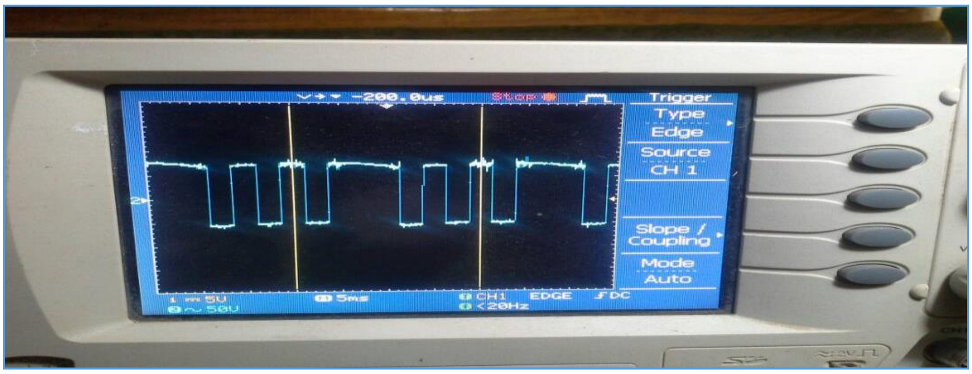

Figure 15. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q4

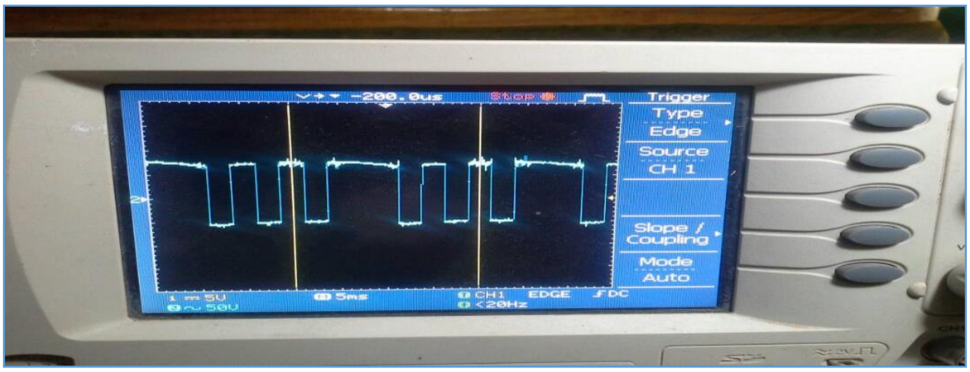

Figure 16. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q5

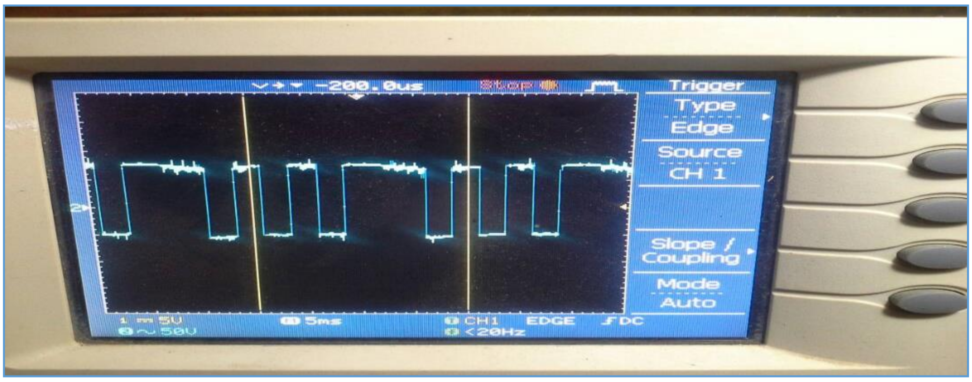

Figure 17. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q6

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

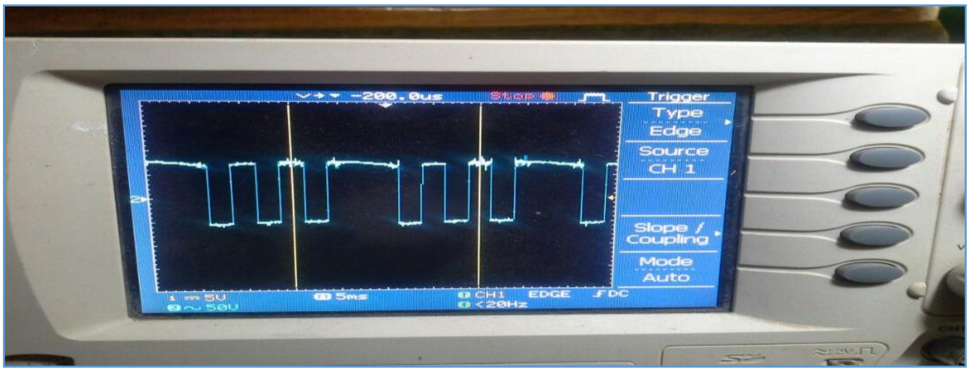

Figure 18. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q7

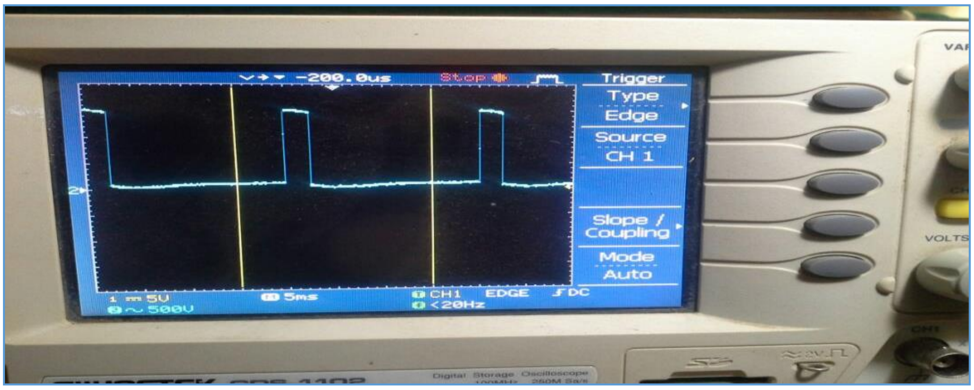

Figure 19. The Triggering Pulse Generated from the Micro Controller to Drive the MOSFET Q8

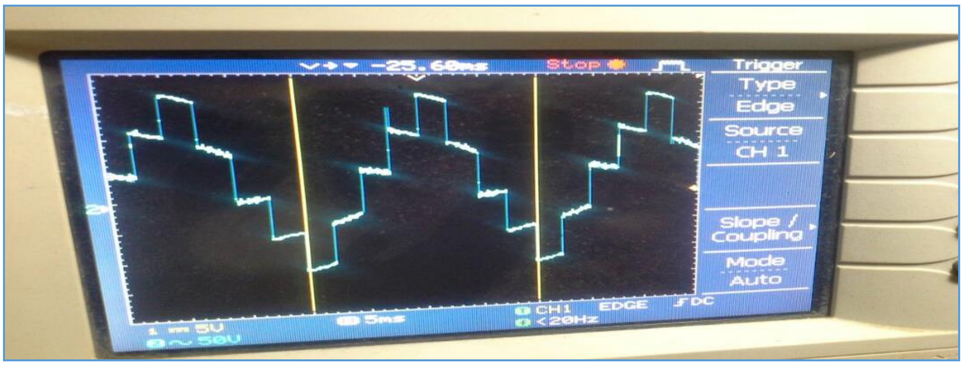

Figure 20. The Output Voltage Waveform of the Implemented Cascaded H-Bridge Inverter

IX. Conclusion

The main goal of this paper is to build a approximate Sine wave, single phase, 300Watts, 50Hz, 12V DC to 220VAC inverter, which can be used to power home appliances, considering this goal and the end result it can be said that it was met. A H-bridge cascaded multi-level inverter is simulated and implemented to give an approximate sinusoidal wave forms to power non-linear load. The simulation results presented showed that with the proposed topology, some percentage of harmonic is reduced thus enhancing better performance of the proposed topology in high power applications. A better performance is achieved as the modulation index of the converter is increased within the acceptable modulation index range that is less than or equal to one. This is to avoid the inherent emergence of lower harmonics associated with over-modulation which can result to excessive

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

humming and overheating of the insulation level of most power devices applied in electric drives. The hardware circuit of single-phase five level H-bridge inverter was implemented. The test results were in close agreement with the simulated results.

X. Recommendations

Although, this discussion covered most of the issues and challenges of the of the conventional inverters for induction motor drives, however approximate sine wave inverter does have some drawbacks as not all devices work properly on a modified sine wave, products such as computers and medical equipment are not resistant to the distortion of the signal and must be run of a pure sine wave power source. Other challenges such as fast discharging of the batteries sources and noise experienced at the load encountered during implementation can be worked on for future research.

The discharging of the batteries can be solved by incorporating a feedback signal to the DC sources to maintain the supply and invariably maintaining the desired output during system operation. The noise at the output can be improved by increasing the number of levels of the inverter to produce a wave forms that are close to a sinusoidal waveforms and incorporating a filter circuit at the output.

Conflicts of interest: The authors declare no conflicts of interest.

References

1. Amarita, M.V., Eldhose, K.A. and Ninu, J. 2014. Single phase inverter for ac motor. International Journal of Engineering Research and Development, 9(11): 50-56.
2. Chakraborty, S., Mohammed, M.H. and Razzak, M.A. 2016. Transformer-less single-phase grid-tie photovoltaic inverter topologies for residential application with various filter circuits. Renewable and Sustainable Energy Reviews, 32(10): 2-10.
3. Diyoke, G., Offiong, A. and Nnadi, C. 2014. Design and Simulation of Single-Phase Three-Level, Four-Level and Five-level Inverter Fed Asynchronous Motor Drive with Diode Clamped Topology. International Journal Engineering Trends and Technology, 12(1): 1-12.
4. Ifeagwu, N.E., Alor, M. and Ugwu, C.I. 2016. Performance Analysis of better Designed Pure Sine Wave Inverter in Mitigating Frequent Power Outages in Nigerian Homes. International Journal of Trend in Research and Development, 3(4): 515-519.
5. Jatin, A.P. and Hardik, H.R. 2015. Design of Sinusoidal Pulse Width Modulation Inverter. International Journal for Technological Research in Engineering, 2(8): 2347–4718.
6. Manasa, S., Balaji Ramakrishna, S., Madhura, S. and Mohan, H. 2012. Design and Simulation of three-phase five level and seven level inverter fed induction motor drive with two cascaded H-bridge configuration. International Journal of Electrical/Electronic Engineering, 1(4): 2231-5284.
7. Melba, M.P.R. and Sivagama, S.M.S. 2016. Cascaded H-Bridge Five-Level Inverter for Grid-Connected Photovoltaic System Using Proportional–Integral Controller. Institute of Measurement and Control, Tisaiyanvilai, India, 49(1): 33–41.
8. Niitsoo, J., Klter, J., Palu, I. and Taklaja, P. 2013. Harmonic Levels of Domestic and Electrical Vehicle Loads in Residential Distribution Networks.

 P-ISSN: 2659-1561
E-ISSN: 2635-3040

9. Nor, S.H., Norzanah, R., Dygku, A.A.O. and Aede, H.M. 2017. Reviews on multilevel converter and modulation techniques. Renewable and Sustainable Energy Reviews, 80: 3–18.

10. Pooja, J. 2015. Cascaded H-BRIDGE Converter for Domestic Applications. International Journal for Trends in Engineering and Technology, 5(2): 2349–9303.

11. Sachin, M. and Prabodh, K. 2014. Simulation of single phase SPWM (unipolar) inverter. International Journal of Innovative Research in Advanced Engineering, 1(9): 12-19.

12. Saroj, K.S. and Tanmoy, B. 2017. Pulse Width Modulation Techniques for Cascaded H-Bridge Multi-Level Inverter. Institute of Electrical/ Electronic Engineering Transaction on Power Electronics, 28(11): 1-15

13. Senthilkumar, P., Balachandran, M. and Subramaniam, N.P. 2013. Cascaded H-bridge Multilevel Inverter Using Sinusoidal Pulse Width Modulation.

14. Sivagamasundari, M.S. and Mary, P.M. 2014. Sinusoidal PWM Based Cascaded H-bridge Five Level Inverter Using Fuzzy Logic Controller. Journal of Applied Sciences, 14(24): 3486-3492.

Citation: EZUGWU Chukwudi, AHMED Sagir and KWEMBE Benjamin, A. 2019. Simulation and Implementation of Approximate Sine Wave Inverter for Sustainable Energy Supply for Domestic Appliances. International Journal of Recent Innovations in Academic Research, 3(10): 20-30.