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A REVIEW OF SOLAR POWER INVERTERS FOR HOUSEHOLD APPLIANCES

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***Abstract*— Botswana citizens experience energy shortage especially at the rural areas where grid transmission is not accessible. Therefore, rural dwellers find it difficult to use their gadgets and sometimes they are compelled to travel to nearby places or towns in order to get electricity. Sun energy is available and is a cheaper alternative that could be used to address the problem of power accessibility especially in remote areas. Photovoltaic panels are normally used to harvest the solar energy however they generate a DC electrical signal but majority of modern appliances use AC voltage signal. A power inverter is used to convert DC voltage signal to AC signal, suitable for most house hold appliances. The conversion principle output rely on how efficient the converter is, in terms of losses. The aim of this paper is to compare three (3) different circuits modeled via PSIM software in terms of their efficiency, cost and complexity of circuit construction. The PSIM software uses inbuilt gate drivers that generate Pulse width Modulation to drive Mosfet. Simulation results indicate that the four (4) mosfet bridge inverter principle produces nearly pure sine wave waveform that has fewer harmonics and can be easily modified to sinewave form.**

Keywords*— Solar Energy, Solar Inverter, Appliances, Conversion, Pulse width Modulation (PWM).

I. INTRODUCTION

An inverter is a power electronic device used to convert direct current (DC) voltage to alternating current (AC) voltage. The DC input signal may be directly from solar panel, battery, DC motor generator or a solar cell. [1]. Solar inverters are mainly categorized into either stand alone or utility interactive (grid connected) inverters. Stand-alone inverter output is connected to the battery bank of AC device for example solar motor pump whereas utility-interactive inverter output is connected to the grid. However, within these categories each inverter may output certain form of power depending on varying level of efficiency and distortion impacts to appliances [2]. The output forms of inverters may be square wave form, modified sine wave form or pure sine wave form [3].Henceforth, there is a need for inversion of solar power because most of electric appliances require AC power.

Solar is renewable, green and utilizing it will mitigate continuous demand in energy. The development of a country and its economy is mainly dependent on industry basements it possesses, for these industries to suffice or emerge the country has to be self-sufficient in energy production despite of rapid population growth. Therefore, energy stands to be a limiting factor for development in most countries especially third world countries. Solar electrification is led by developed countries like Japan and United States of America which means all these photovoltaic power system that are available on market are mainly meant for their climatic conditions, which differs a lot from African countries hence the need to design solar inverter suitable for local conditions.

This paper presents a comparison of three (3) different circuit models in terms of their efficiency, cost, and number of components or complexity of construction. Simulation results indicate that the four (4) mosfet bridge inverter principle produces nearly pure sine wave waveform that has fewer harmonics and can be easily modified to sinewave form. Results obtained from the comparison will be used to inform the development of a low cost solar power inverter suitable for Botswana's climatic conditions.

II. LITERATURE REVIEW

Solar power inversion was considered when coming to the realization that some electric equipment's like motors, electric shaving clippers and radios use AC power whereas solar panel itself produce DC voltage. The designing of inverters had begun since then, with the mentality of trying to improve the efficiency of solar conversion at a lower cost. For the design to be accomplished, some parameters are considered; These parameters are based on inverter type of application, that is, either common type, charger integration type, telecommunications dedicated inverter or military dedicated inverter and also based on the output wave form types like square wave form inverter, step wave (modified sine wave) inverter and sine wave inverter.

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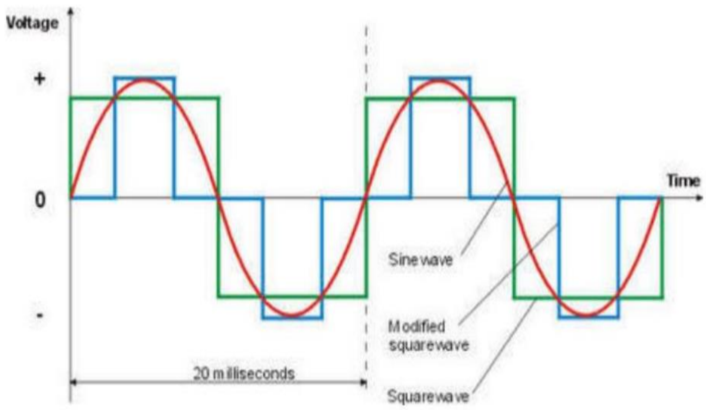

Figure 1; Classification of inverters basing on output waveform (source; Bernard, M. J. (2014). Microcontroller based power inverter)

The capacity of the inverter also plays an important role regardless of the conditions it is exposed to. The findings of Larsen, Gjini & Gray claims that a solar inverter comprises of a heat sink, DC module, an inverter module and AC module arranged in the chassis or printed circuit board in a way that the result is AC power when fed with DC power [8]. The inverter module composes capacitors connected with two switches either bipolar junction (BJT) or Metal oxide field Effect Transistor (MOSFET). These switches are mostly preferred among diodes and thyristors because they are controlled on both turn on and turn off. In some cases a solar inverter is connected dually such that it draws power from either solar panel or battery bank, this helps in case where sunlight is no longer available at night times.

Generally, the inverter comprises of three circuits which are the pulsating circuit, driving circuit and the transformer switching circuit. The pulsating circuit being the heart of the inverter where the DC voltage is subjected to process of switching on and off rapidly producing a square wave. The variation and control of switching times (delays) on and off produce the pulsating current of an inverter when controlled and semi-controlled switches are used. The other component that is used is the oscillator that convert unidirectional current flow from a DC source into an alternating waveform at a particular frequency. The oscillators used for pulsating circuit of inverters are regarded as constant-amplitude whereas other types exist which produce either increasing oscillations or decaying oscillations [9]. The other principle is through pulse-width modulation whereby a modulating and a carrier signal is used to produce the desired constant-amplitude waveform at a frequency.

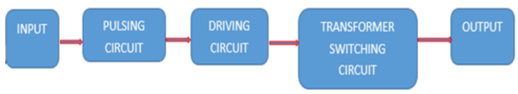

Figure 2: Showing process flow diagram of the inverter.

The diagram (figure 2) illustrate how the inversion system transcends when the input DC voltage is injected at the input pins. The driving circuit is normally the controller gate of the transistors used in processes of switching on and off. The driving circuit controls the frequency of switching, together with the duty cycle the inversion will require. Duty cycle describes the relationship between the operating time and the resting time of these switches. For efficiency purposes in inversion the duty cycle is set to half especially in H-bridge inverters. The transforming circuit collect the inverted power and vary its voltage and current at a constant frequency that suites the appliance connected to the inverter.

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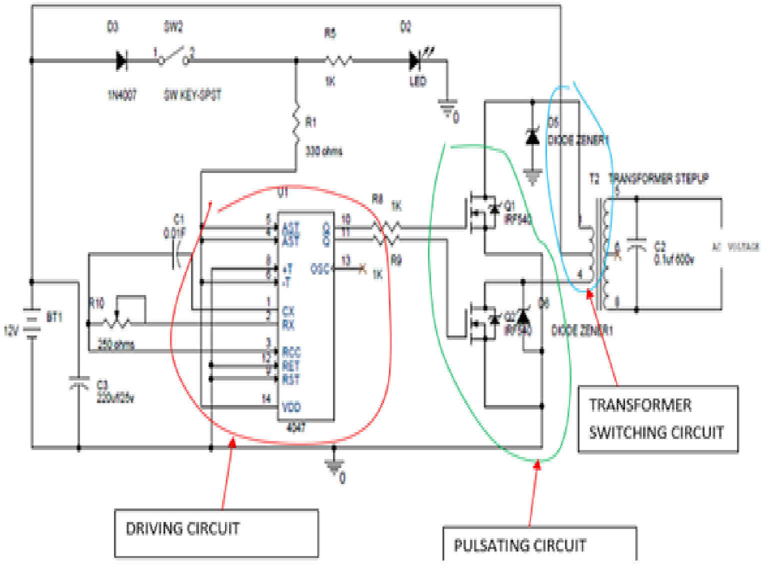

Figure 3: Inverter circuit diagram using PIC 16 micro controller.
(Source; ElectronicsHub.org)

The quantities that often give problems during solar inverter design is the filtration process, because to produce a square wave is simple but it is damaging to some electrical devices. At times a low pass filter or DC is used to modify square wave output that may suite other devices, but still some electrical components are more sensitive in that they would prefer pure sine wave. Henceforth, a multilevel principle of inverting is used to bring the output waveform asymptotic to the pure sine wave. This symbolizes that all energy cannot be converted from one form to another because of losses. According to Good and Johnson conclusions, the inverter loading ratio ought to be considered, 'to decrease the unit cost of electricity and increase the effective capacity factor relative to the inverter rating' [9].

Shafeeque & Subadhra conducted a conference paper titled "A novel single-phase single-stage inverter for solar applications" which emphasized that a single stage inverter working on buck-boost principle is more advantageous than conventional inverters [10]. Since it reduce the size of an inverter which normally depend on series of convention (converters) used. The output signal is closer to the sine wave whereas Ghalib, Abdalla, & Mostafa concluded that the conversant way to produce a pure sine wave output inversion is by implementation of Peripheral Interface Controller (PIC) microcontroller into the Sinusoidal Pulse Width Modulation method of controlling solar inverter [11]. The method is reputed to be superior to others and its results are verifiable by PSIM and Proteus software simulations. The PIC was embedded with a C language which was built in a suitable compiler to produce a HEX file to be burnt in it. The inverter was Full bridge single phase inverter and also tested with varying AC loads. The generation of signal for mosfet driver using the pulse width modulation proved to bear result more especially when using TL 084 (OP AMPS) and LM 339 (OP AMPS). The principle also produce less harmonic distortion, and the output was also tested using various ac appliances that proved compatibility with the voltage waveform produced.

The first step to program is to generate a C code and then translate it into an assembly language with the aid of particular instruction set of that peculiar chip desired to be used to perform embedded instructions of the device. The project targets Atmel / At mega microchip which means an Atmel instruction set is bound to be downloaded and then used for producing assembly language that would be easily understood by the chip to perform instructions. The chip act as the brain of the solar inverter that is by monitoring the following parameters;

1. Battery and input power conditions

The input power has to be of required value or within certain threshold for solar inverter efficiency supply. If the power is too low the chip coordinates the shutting down or disqualifies the input by allocating it with a zero value. The chip also monitors the delay times to prevent the surges from the source. In cases whereby both the battery and the panel inject voltage simultaneously, the chip has to act as a stress reduction snubber circuit.

2. Transistor heat sink

A heat-sink is designed to remove heat from a transistor and dissipate it into the surrounding air as efficiently as possible. Heat-sinks take many different forms, such as finned

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aluminum or copper sheets or blocks, often painted or anodized matt black to help dissipate heat more quickly. Good physical contact between the transistor and heat-sink is essential, and a heat transmitting grease (heat-sink compound) is smeared on the contact area before clamping the transistor to the heat-sink. The heat sink that is more than the required also lead to overcooling which also affect the efficiency of power transmission. Therefore, if the heat dissipated in the heat sink is more than it can handle the chip has to switch off the system to avoid the blowing of transistors or transistor thermal runway. The cooling media might be the air or spongy material (insulator).

1. Phase angle and Frequency

i) Basic Circuit model A

The phase angle and the frequency of the driver circuit that powers transistors need to be optimized by the controller in order to attain the required waveform of the inverter and the important aspect of the inverter is the duty cycle that need to be specified in the program entity.

III. RESULTS AND ANALYSIS

The different circuit models were modelled and simulated using the PSIM software producing different waveforms depending on the components used. The below diagram shows the test result produced by the software, also the analysis of physical components in terms of prices and number.

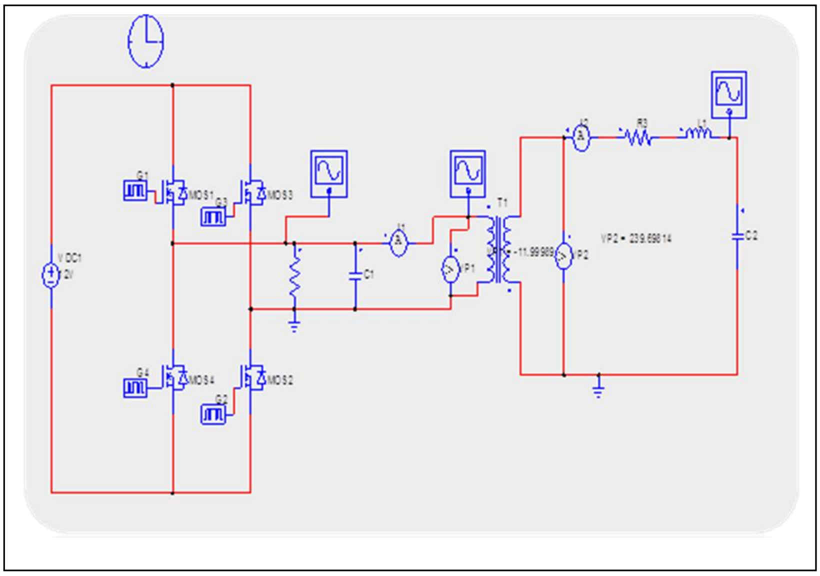

Figure 4: Circuit model A

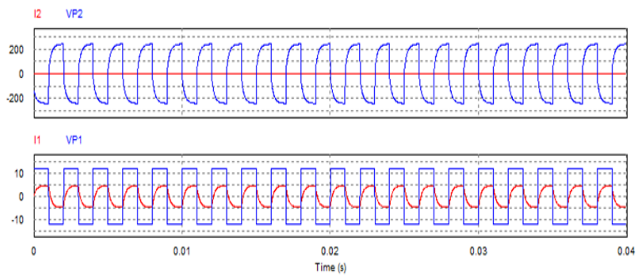

Figure 5: Waveforms

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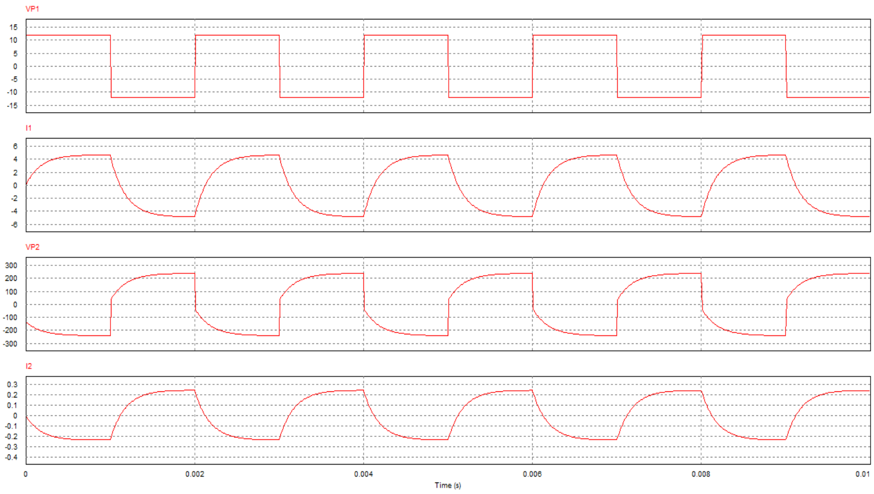

Figure 5: Waveforms

The waveform produced in model A is not a sine wave but it poses some curvature which means modifying it into sine wave would be cheaper provided that controller is cheap also. The components are also fewer but cost of switches and (1:20) transformer might be a little bit high, therefore, the need to reduce cost of this components may also bear the desirable results. It has less harmonic due to the RLC filter at the load but this harmonics could be eliminated by using pulse width modulation principle. The principle could be enhanced by the use of Atmel micro controller.

ii) Circuit model B

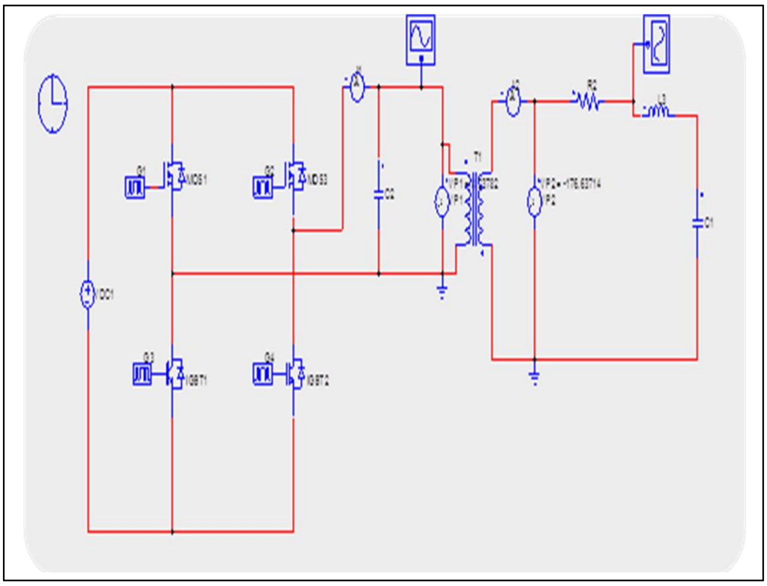

Figure 6: Circuit model B

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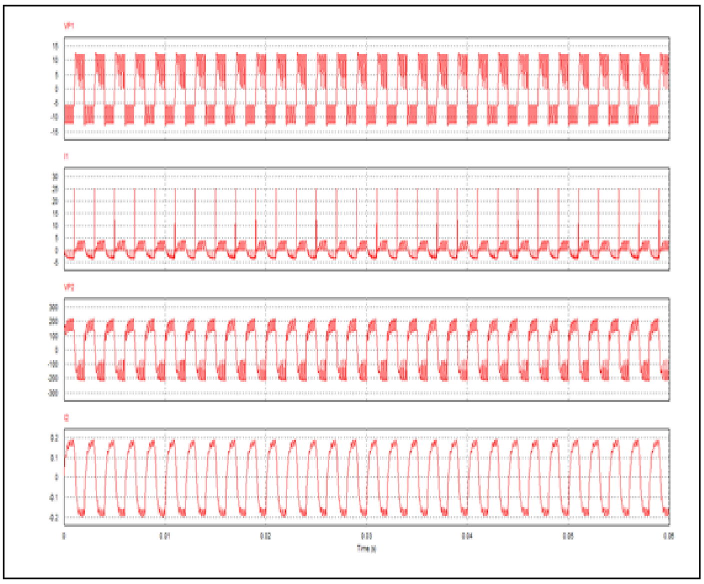

Figure 7: waveforms

The output wave form is not sine wave and also modifying it into sine wave could be intensive. It has more voltage and current ripples that is not filtered enough by rlc filter. The circuit also uses both mosfet and IGBT switches which means the cost will be higher than Circuit A and it will also require a series of filtering that would add to number of components in the inverter and also earn a loss of energy due to series of conversion.

iii) Circuit model C (Boosting & inverter)

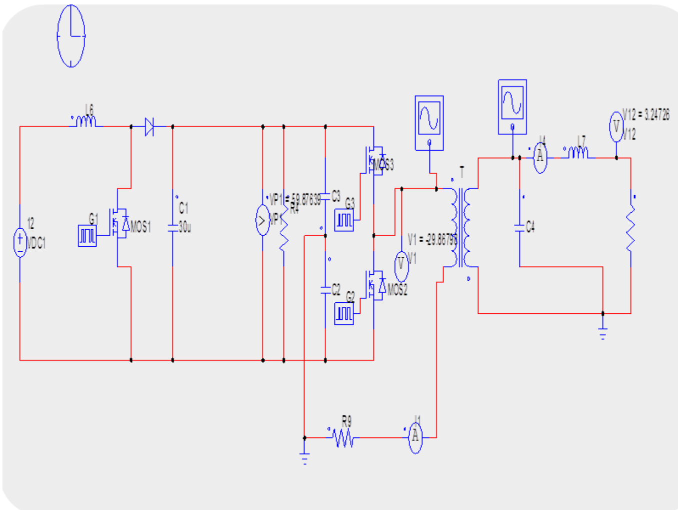

Figure 8: Circuit model C

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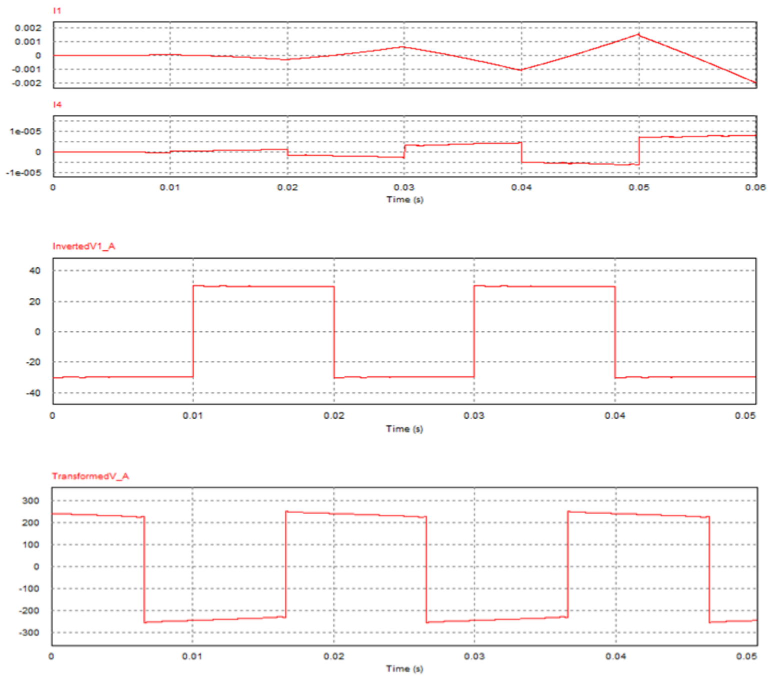

Figure 9: Waveforms

The circuit model produced a square waveform which also have high transient response time. Then, for it to qualify the research it needs transient response time reduction and also the filtration process to reduce harmonics in order to attain sine waveform. The ripples of voltage and current are both lower compared to circuit B. Circuit C also use 3 mosfet, 1 diode and a transformer with less turns ratio compared to other circuits. Henceforth, cost of switches and transformer is minimized. The pulse width modulation principle could be handy in for sine wave generation.

TABLE 1; Summary of Circuit Comparisons

CIRUIT TYPE	SWITCHES	INDUCTORs/Capacitors 100mH; 30 uF	Resistor(s) 1kOhm)	Transformer	Total Components	Cost (Estimated)
A	4 Mosfets	1 inductor,2 capacitors	1	1(1:20 winding)	9	P300.00
B	2 Mosfets 2 IGBT's	1 ,2	1	1(1:20)	9	P500
C	3 Mosfets 1 Diode	1 ,4	2	1(1:8)	12	P330

The circuit A is chosen and with the aid of Atmel micro controller is tested via the proteas software in order to achieve the sine wave waveform. The prototype would be designed and tested via the model also. The delays in order to compensate for transient response will also be viewed and assessed to see whether it bears results or not.

IV. CONCLUSION

The output produced by the proposed circuit was a square wave not the sine wave but through gate drivers, but it would further be introduced into the micro controller for pulse width modulation principle. The controller proposed is the Atmel and would be responsible for PWM signal waveform generation, output voltage regulation, low supply detection and overload protection for prototype testing.

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