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3KW Pure Sine Wave Inverter Design for Grid Tie System

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***Abstract* - Stand-alone renewable energy systems are used to supply electricity to remote areas where access to the utility grid is not available. Mostly common systems store energy in battery banks in order to compensate intermittence and peak power limitation of renewable energy sources. The battery is DC source and so it is needed to convert to AC. It can be done by using the pure sine wave inverters. They operate with specific frequency and present high efficiency. Pulse Width Modulation (PWM) technique is used in inverter to get pure sine wave and reduce harmonic content. The ratings of inverter are 3KW, single phase, 220V, and 50Hz. The design is essentially focused on low power electronic appliances such as personal computers, chargers, television sets. The system is based on pure sine wave rather than square wave. In full bridge inverter circuit, an AC output is synthesized from a DC input by closing and opening the switches in appropriate sequence or switching scheme. For that, the Pulse Width Modulation technique is used in control the closing and opening switches. An H-Bridge driver is designed using power FET for final load driving. System design should be flexibility for using various types of load without changing basic system design.**

***Keywords* – PWM, Grid Tie, Inverter, AC,DC, FET.**

I. INTRODUCTION

In Myanmar, the role of Distributed Generation is increasingly being recognized as a supplement and an alternative to large conventional central power supply. The government and many non-governmental organizations have tried to comprehend and strived to address the problem of energy through promoting Solar Home Systems (SHSs) in off-grid areas. Though centralized economic system that solely depends on cities is hampered due to energy deficiency, the use of solar energy in cities is never been tried widely due to technical inconvenience and high installment cost. To mitigate these problems, this thesis proposes an optimized design of grid-tied PV system without storage which is suitable for Myanmar as it requires less installment cost and supplies residential loads when the grid power is unavailable. This thesis also analyzes the implementation outcome of integrating this grid-tied PV system in grid connected areas, especially in the capital of Myanmar.

Solar based DC to AC power inverters, which aim to efficiently transform a solar pack to a AC output, similar to power that would be available at an electrical wall outlet [1] to [5]. There are many types of inverters, and they are classified according to number of phases, use of power semiconductor devices and output waveforms. Inverters are used for many applications, as in situations where low voltage DC sources such as batteries, solar panels or fuel cells must be converted so that devices can run off of AC power [6] [7].

The method, in which the high voltage DC power is inverted, is completed in two steps. The first being the conversion of the low voltage solar panel to a high voltage DC source using series and parallel combination, and the second step being the conversion of the high DC source to an AC waveform using pulse width modulation. The PWM inverter derives are used with standard induction motors in very large number throughout the world and their advantages are well known in terms of improved energy efficiency and flexibility of control [8].

Of the different DC/AC inverters on the market today there are essentially two different forms of AC output generated: modified sine wave, and pure sine wave. A modified sine wave can be seen as more of a square wave than a sine wave; it passes the high DC voltage for specified amounts of time so that the average power and rms voltage are the same as if it were a sine wave. Pure sine wave inverters, on the other hand, produce a sine wave output identical to the power coming out of an electrical outlet. These devices are able to run more sensitive devices that a modified sine wave may cause damage to such as: laser printers, laptop computers, power tools, digital clocks and medical equipment. [9]

In this paper, the design of grid-tie inverter system in which the DC is converted to AC by using pure sine wave inverter. The grid tie inverter operation can be explained by using the following block diagram in Figure. 1.

II. OVERALL BLOCK DIAGRAM

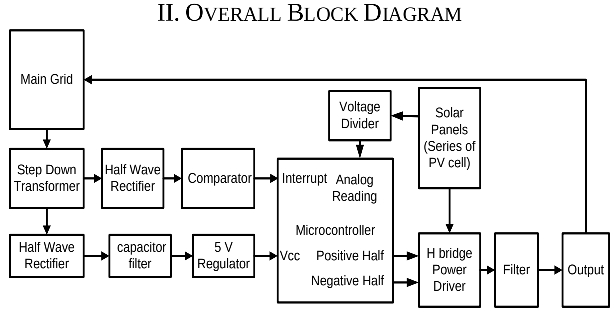

Figure 1. Overall Block Diagram of the system

In Figure 1 the solar panels are used because of the production of enough DC level. The solar panel produces dc by converting the solar energy to electrical energy. The improved GTI is obtained by connecting the solar panel to the H bridge power driver of the main power supply. The size of the panel depends upon the input power required for the operation of the GTI. The ratings of the normal household main grid are 220V, single phase, 50Hz AC. Hence the household supply at the specified range should be obtained from the existing electric grid.

To protect the unnecessary damage, the solar voltage is sensed by using the voltage divider circuit. To be synchronized, the main grid is needed to be measured as zero-cross status in Figure 2. For this section, step-down transformer, half-wave rectifier and comparator are used here. Moreover, another part of transformer is used to convert regulated DC 5V for controller.

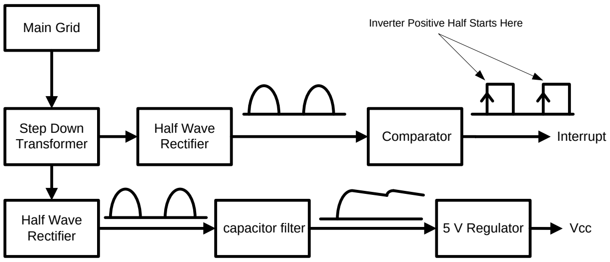

Figure 2. Comparator and regulator for interrupt and supply

In this paper, IR2111 based high side and low side driver is emphasized for high power operation.

III. SYSTEM DESCRIPTION

Arduino microcontroller circuit gate driver and inverter amplifier circuit are the main parts of the DC to AC conversion system. Instead of maintaining the width of all pulses the same as in the case of multiple-pulse modulation, the SPWM is used. The width of each output pulse is varied in proportion to the amplitude of a sine wave evaluated at the center of the same pulse. This helps to reduce distortion factor. The calculation of the pure sine wave can be displayed by using the Microsoft Excel. The results are shown in Figure 3.

		555	555	555	555	555	555	555	555	555	555	555	555	555	555	555	555	555	555
Degree	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180
center point		555	1110	1665	2220	2775	3330	3885	4440	4995	5550	6105	6660	7215	7770	8325	8880	9435	9990
sine value	0.0	0.2	0.3	0.5	0.6	0.8	0.9	0.9	1.0	1.0	1.0	0.9	0.9	0.8	0.6	0.5	0.3	0.2	0.0
on time	0	96	190	277	357	425	480	521	546	555	547	522	481	426	357	278	191	97	1
start of ON		507	1015	1526	2042	2563	3090	3624	4167	4718	5277	5844	6420	7002	7591	8186	8785	9386	9990
end of ON		603	1205	1804	2398	2987	3570	4146	4713	5272	5823	6366	6900	7428	7949	8464	8975	9484	9990
off time	507	412	321	238	164	102	54	21	4	4	21	54	102	164	237	321	411	506	

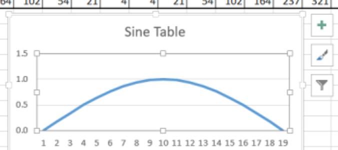

Figure 3. Sine function and proportional graph

For 18 segments of half cycle of 50 Hz is equal to 555 microseconds. Equivalent start and end time of PWM pulse can be calculated by adding equivalent sine ratio to center of 555 microseconds. Interval of off time will be minimum value of 4 at 90 degree point. These time interval are equal for both positive half and negative half cycle.

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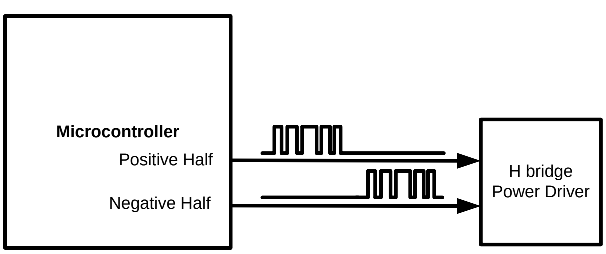

Figure 4. Positive part and negative part of gate pulse for driver

There are different types of techniques developed to achieve synchronization but the system used in this study is simple, reliable, and requires small area for installation. The proposed system is designed for 200W and the H bridge power driver should meet that power rating. The principle of H bridge driver is can be described as shown in Figure 4 in which positive part and negative part should be SPWM form.

A. Operating Principle of IR2110 based Driver

The MOSFETs are used in the system because they are voltage control device and to drive MOSFET the gate capacitance should be charged to operating voltage which is usually between 9-10 volt. One can do it very easily but there is one issue. High voltage on drain of MOSFET cause problem by interaction with gate-drain capacitance. This problem is known as miller effect. MOSFET drivers are used to avoid these issues.

In many applications, floating circuit is required to drive high side MOSFET. In H bridge used in pure sine wave inverter design, two MOSFETs are used as high side MOSFETs and the other two MOSFETs are used as low side MOSFETs. International rectifiers IR2110 MOSFET driver can be used as high side and low side MOSFET driver. It has a floating circuit to handle to bootstrap operation. IR2210 can with stand voltage up to 500v (offset voltage). Its output pins can provide peak current up to 2 ampere. It can also be used to as IGBT driver. IR2210 floating circuit can drive high side MOSFET up to 500 volt.

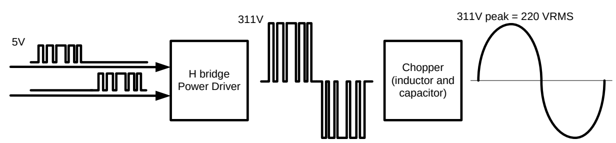

Figure 5. Logic level conversion for Power Driver

Figure 5 shows the logic level conversion from 5V compactable Arduino to high power 311V ac output. H-bridge driver is designed using four n-channel mosfet IRF840.

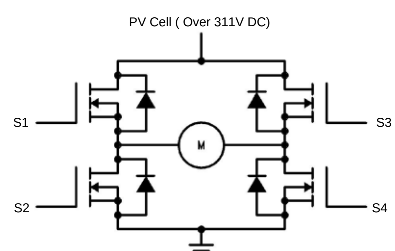

Figure 6. H-bridge design using four n-channel MOSFET

S1 and S4 should be activated for positive half cycle drive and S2 and S3 stand for negative half cycle. For power drive, MOSFET, IGHT and BJT can be used. For this drive IRF840 are used as shown in Figure 6. It is a high power rating as VDS 500V and pulse drain current 52A. Its symbol is shown in Figure 7.

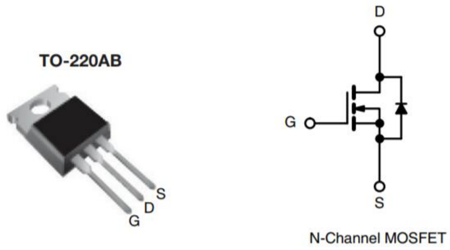

Figure 7. IRF840 pin layout for MOSFET driver

The working of MOSFET depends upon the metal oxide capacitor (MOS) that is the main part of the MOSFET. The oxide layer presents among the source and drain terminal. It can be set from p-type to n-type by applying positive or negative gate voltages respectively. When apply the positive gate voltage the holes present under the oxide layer with a repulsive force and holes are pushed downward through the substrate. The deflection region populated by the bound negative charges which are allied with the acceptor atoms.

When the positive gate voltage is applied, the holes present under the oxide layer pushed downward into the substrate with a repulsive force. The deflection region is populated by the bound negative charges which are allied with the acceptor atoms. The positive voltage also attracts electrons from the n+ source and drain regions into the channel. Now, if a voltage is applied among the drain and source the current flows freely between the source and drain and the gate voltage controls the electrons in the channel. In place of positive voltage if a negative voltage is supplied, (hole) channel will be formed under the oxide layer.

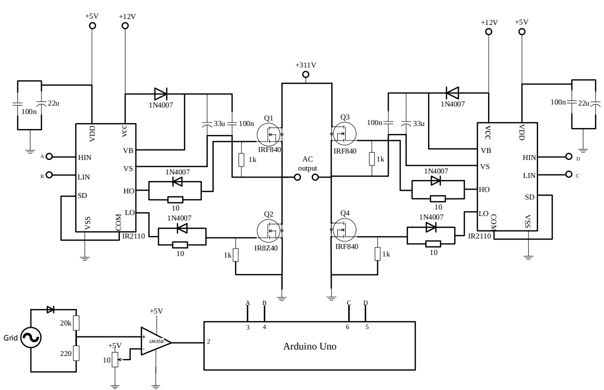

Figure 8. Overall circuit diagram of the power drive

For this inverter final output driver, a solid-state H-bridge is typically constructed using reverse polarity. The IRF840 MOSFETs are used in this circuit as shown in Figure 8. The most efficient MOSFET designs use N-channel MOSFETs on both the high side and low side because they typically have a third of ON resistance of P-channel MOSFETs. This requires a more complex design since charge pump circuits must be used to drive the gates of the high side MOSFETs. The IR2110 driver IC is used to drive high and low side FET's gates. Most high side FET needs high voltage gate voltage to trigger. To avoid circuit complex and to drive high voltage Vdd with Vcc low voltage, IR2110 can do this function without any problem.

For high side, required bootstrap capacitor value can be calculated as follows.

$$Cb \geq \frac{2\left[2Q_g + \frac{I_{qbs}}{f} + Q_{ls} + \frac{I_{cbs}(leak)}{f}\right]}{V_{cc} - V_f - V_{ls} - V_{min}}$$

IV. Simulation Test and Experimental Result

The grid line wave pulse are read from interrupt.In order to see the gate triggering pulses, simulation of gate driver circuit is performed in Proteus simulation soft

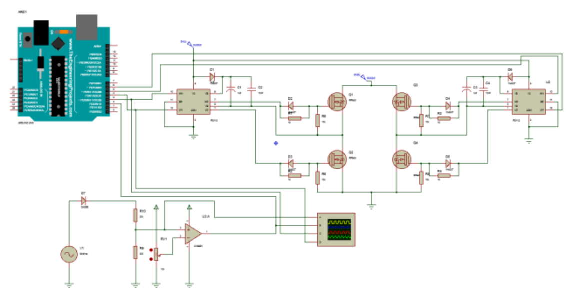

Figure 9. Simulation Test using Proteus GSM

Figure 9 shows the simulation diagram for low voltage to high voltage conversion.

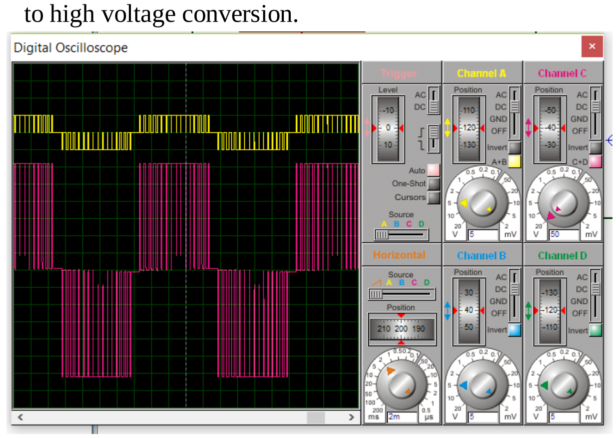

Figure 10. Logic gate from Arduino and amplified signal of Bridge Driver

Fig 10 shows the gate output in yellow color and unfiltered high voltage output in red color. The gate output level is 5V and the high voltage output is about 311 V maximum.

Figure 11. Constructed Prototype Design

The Figure 11 shows the pure sine wave inverter circuit. This system can be used for many applications which required AC power and at the condition where is no AC commercial source is available. The inverter supports 200W rating with 220V pure sine output.

To use this system, the power switch from panel is needed to switch on. The green LED indicates that system is power up and running. In this system, 310V AC supply is used for power backup so that it can power up controller even the main grid and solar power are off. Solar output is filtered using high voltage capacitor. In this system, the power can give AC supply for auxiliaries when the solar power is low. Figure 12 show the power supply for grid connected PV system.

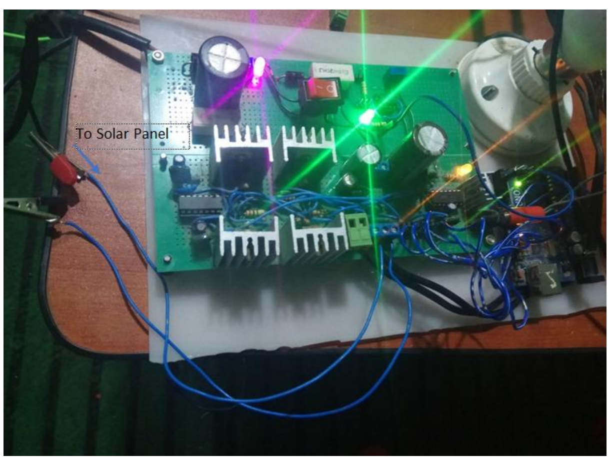

Figure 12 Power Supply of the System

The AC voltage sample is taken from grid which is converted into 312V pulsating DC through half bridge rectifier as shown in Figure. The comparator is used to give the signal to the interrupt pin of the Arduino. The following Figure 13 also shows at LM-324 comparator IC outputs.

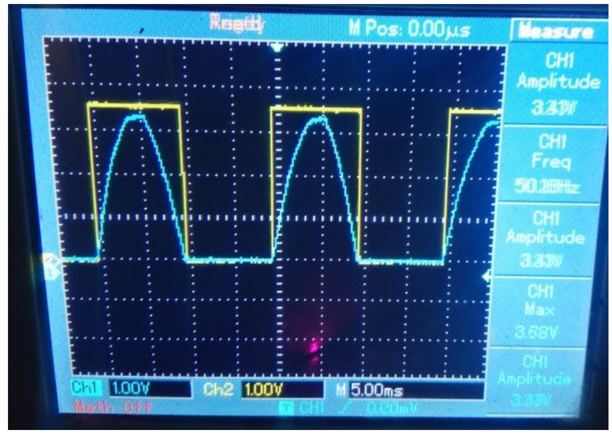

Figure . 13 Square Wave Output Waveform

In order to convert the DC input to AC output, the DC to AC converters are used, which take DC voltage at input and provide AC output voltage and frequency as per desired design specifications to the load. A typical DC to AC converter is known as H-Bridge, which is most commonly used inverter for converting DC to AC.

Figure 14 shows tested output waveform from the output of FET gate driver IR2110 IC. The output waveform is measured at the high and low side driver output pins of IR2110 IC. In the tested waveform represent the switching pulses of the respective switch of the inverter. The switches S1 and S2 pulse represent the positive switching and the switches S3 and S4 pulse represent the negative switching.

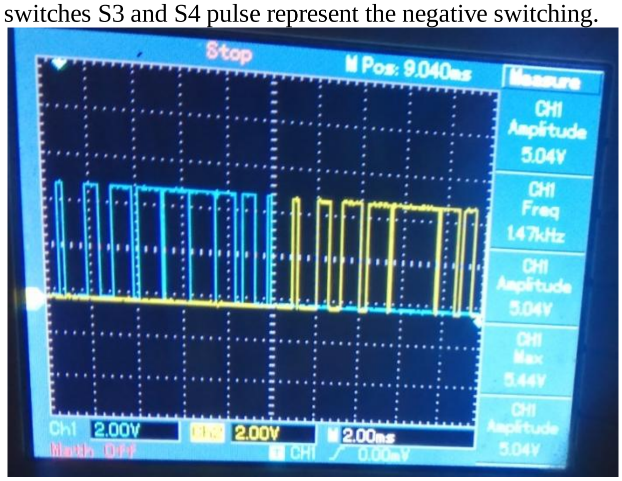

Figure. 14 IR 2110 Gate Driver Output Waveform

Fig 15 shows the output waveform of Arduino for High side and low side driver of Power Amplifier using IR2110. The frequency response is exactly 50 Hz and the timing control follows the calculated delay time using MS Excel.

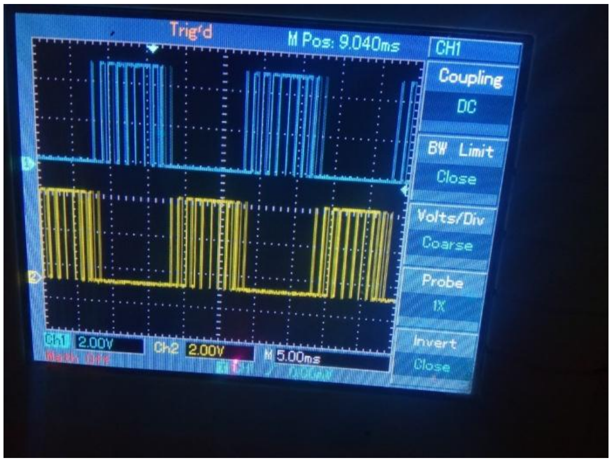

Figure.15 H-bridge Output Waveform

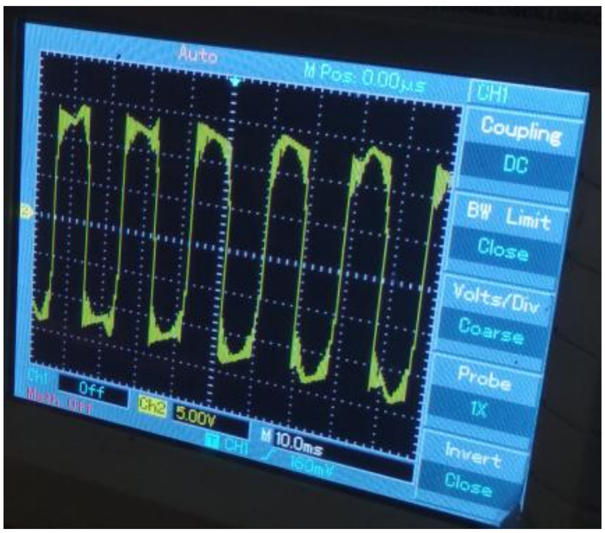

Figure 16. Output waveform of Inverter

Figure 16 represents the output waveform of our proposed GTI in a digital storage oscilloscope. It is voltage vs time output. Output of GTI is pure sine wave synchronized with the grid which can be supplied to the grid.

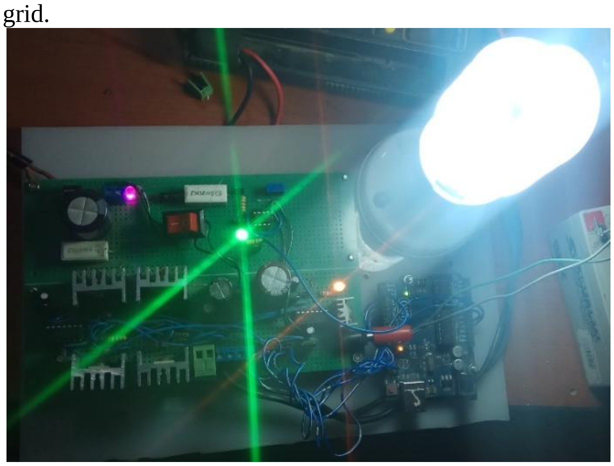

Figure. 17 Resistive load connected with the inverter circuit

Firstly, user clicks the button to switch on the lamp. The Figure 17 show the load is connected with the inverter circuit. And the Figure 18 show the output voltage of the inverter circuit when the load is connected. The synchronized system will be extended in next study.

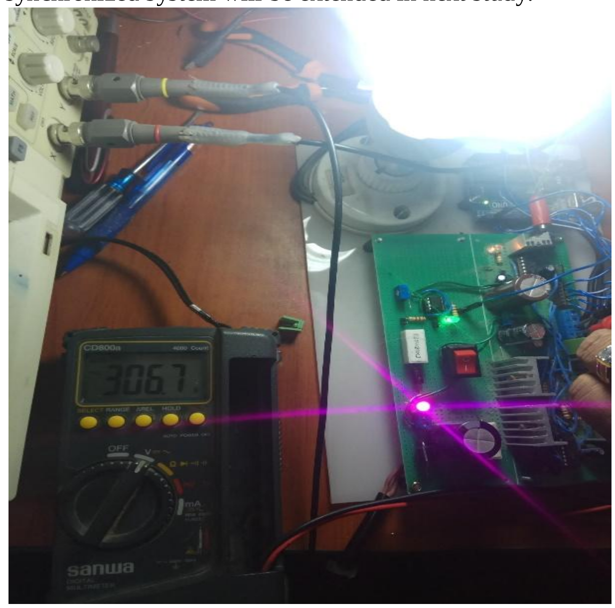

Figure. 18 Output Voltage of the Inverter Circuit when the load is connected

V. Conclusions

The main purpose of this research is to establish a model for the grid connected photovoltaic system which produces a pure sine wave with an output voltage that has the same magnitude and frequency as a grid voltage. A microcontroller, based on an advanced technology to generate a sinewave with fewer harmonics, less cost and a simpler design is constructed. The technique used is the sinusoidal pulse width modulation signal (SPWM) which is generated by microcontroller. The designed inverter is tested on various AC loads and is essentially focused upon low power electronic applications such as a lamp, etc. The total harmonic distortion (THD) of the inverter output is less than 0.1% which is much lower than the IEEE519 standard, and the efficiency of the inverter also increases up to 98%. Therefore, the proposed inverter is highly efficient, cost effective as well as compact in size for being transformer-less, and it is appropriate for supplying constant current.

This pure grid inverter can get more advantages such as low power consumption, low power factor error if use a power factor load such as AC motor, BLDC motor and synchronous motor than typical square wave inverter. The advanced inverter circuit can be constructed based on the system. It is in this capability that the option of a closed loop control circuit could be implemented. One of the major factors in the power savings is the use of a three level PWM signal instead of a two level, this allows a much lower average power output to produce the sine wave needed and assisting in the efficiency of the device.

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