Design and Implementation of Microcontroller Low Voltage Switched 1.5 KVA Pulse Width Modulation Inverter System

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Abstract: **This paper presents the design, construction and implementation of microcontroller low voltage switched 1.5KVA pulse width modulation inverter system. This device is used to convert the DC generated by battery to AC output. The developed circuit utilizes SG3524 control circuitry. It was designed to provide automatic changeover once the supply voltage is below 160V. The supply voltage is fed to the microcontroller through an Analog to Digital converter. The microcontroller monitors the supply voltage and biases the BC547 transistor connected to one of its pins once the supply voltage is below 160V and then switches on the inverter. The inverter monitors the overall output power drawn from the inverter using a combination of operational amplifier, resistors and transistors to avoid overload. The system takes in 12V DC source and delivers a modified square wave form at a frequency of 50Hz at a period of 20ms within a voltage range of 200V to 230V.**

Keywords: **Inverter, Direct Current, Alternating Current, Pulse Width Modulation, Microcontroller, Analog to Digital Converter, SG3524.**

1. INTRODUCTION

The world demand for electrical energy is constantly increasing and conventional energy resources are diminishing and even threatened to be depleted[1].The uncertainty surrounding the use of fossil fuel resources and ever increasing global climate change surrounding its use has led to alternative means of generating energy. Advances in science and technology have provided us with several alternative means of producing energy on a sustainable level such as wind, geothermal, biomass and solar [2]. The power from these energy sources is random in nature and not suitable for direct utilization by domestic loads, hence means are required to store the energy during off peak periods [3].

Inverters are nothing new. They have been in existence as long as there has been need for converting direct current (DC) to alternating current (AC) [4]. In today's world, inverters mostly employ pulse width modulation (PWM) technique due to its superior factors compared to other types not making use of it. Pulse width modulation is a way of digitally encoding analog signal levels. It is a technique that is now gradually taking over the inverter market of control application [5].

The PWM circuit outputs a chain of constant amplitude pulses in which the pulse duration is modulated to obtain necessary specific waveform on constant output periods [6]. Performance of a PWM inverter depends significantly on the control method and type of modulation. PWM are now available in a variety of design and integrated circuit, which greatly simplifies the design and implementation [5].

In some parts of the world with fluctuating voltage, there is need to incorporate some safe mechanism in designing inverter systems. Low voltage has some measure of impact on electronics in the same way high voltage does. Using microcontroller inverter system, the inverter is programmed to switch ON when it detects low voltage from the power source.

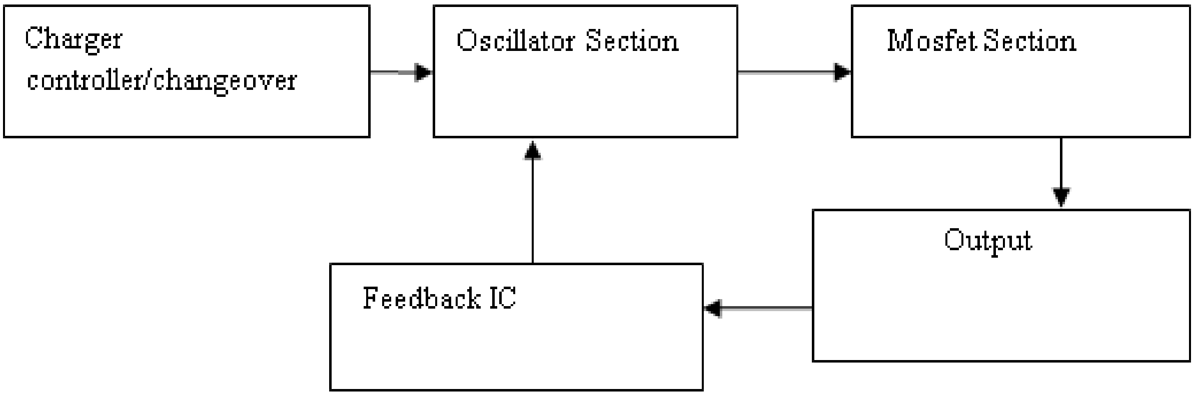

Fig. 1 Block diagram of the inverter

2. SYSTEM DESIGN

The design is much easier to manage when broken down into sections. The designed system has two broad section; namely

1. Control Circuitry Section
2. MOSFET Driver Section

2.1 control circuitry section:

This part comprises the SG3524 IC, a monolithic integrated circuit which incorporates all the functions required in the construction of regulating power supply, inverter or switching regulator on a single chip, resistors, capacitors, analog to digital converter (ADC), microcontroller.

The oscillating frequency of the PWM SG3524 is set using the equation

$$F_T = 1.30/ R_TC_T \quad \text{……………(1)}$$

Where R_T and C_T are the timing resistor and capacitor respectively.

For a frequency of 50Hz, the timing resistor can be calculated assuming the timing capacitor to be 0.2 µf. Thus,

$$R_T = 1.30/ F_TC_T \quad \text{……………………(2)}$$

This results in R_T of 130KΩ.

This implies that R_T must be varied at 130KΩ to obtain the set frequency of 50Hz. This was achieved using a fixed resistor of 100KΩ and a variable resistor of 50KΩ.

The period of oscillation of PWM SG3524 is obtained using

$$T = R_TC_T \quad \text{………………………….. (3)}$$

Hence, the period of oscillation was obtained as 26ms.

The microcontroller used in the design is AT89C52. The output of the AC is feedback to the ADC through a 50KΩ resistor which is used to set the voltage to the required level. The ADC then converts the analog signal to digital format and fed to port 2 of the microcontroller. At voltage less than 160V, the microcontroller output sent to the base of the transistor is high and the relay becomes energized, thereby switching OFF the AC source while at the same time switching ON the inverter.

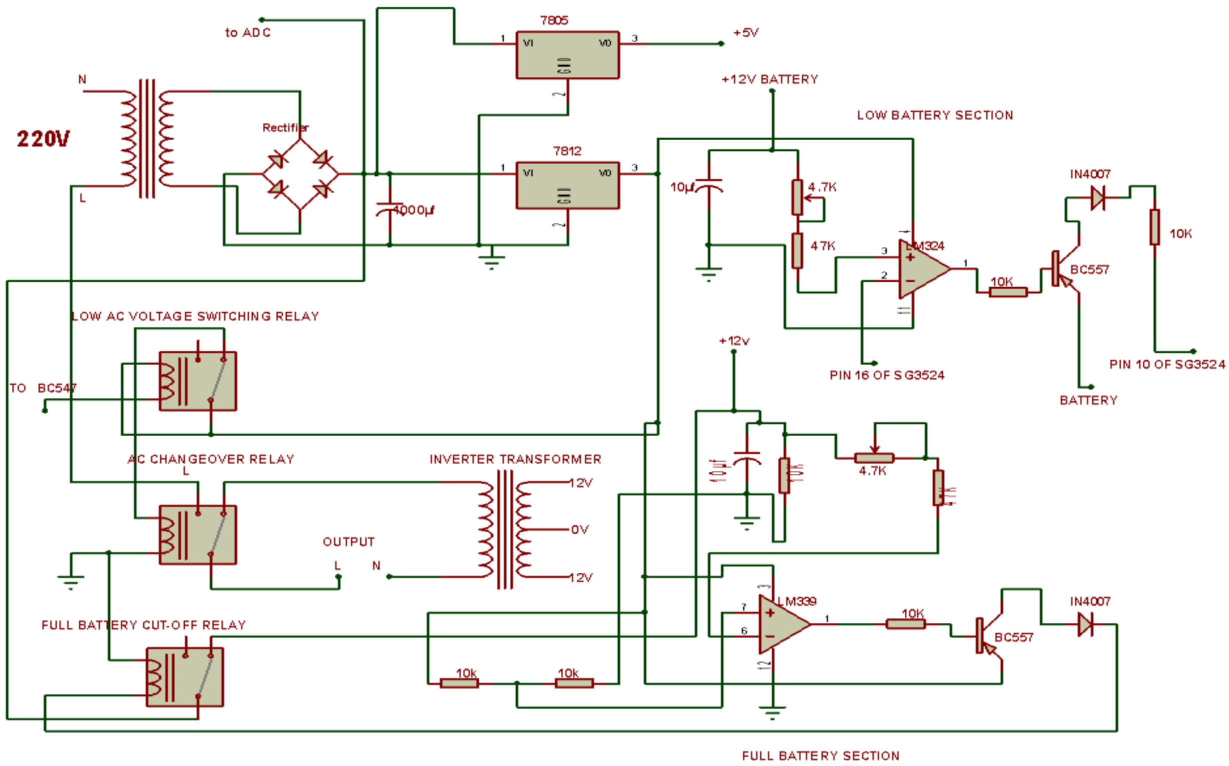

Fig 2. charger control/ changeover section

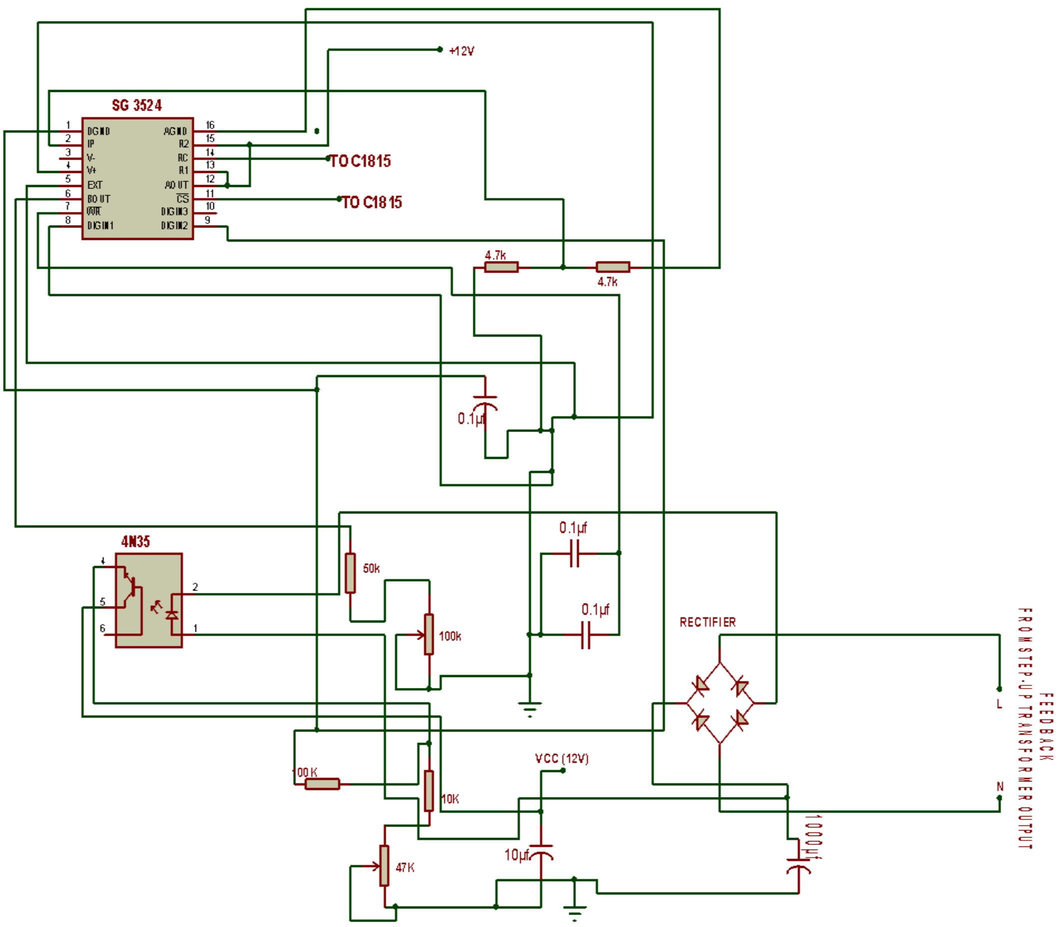

Fig 3. Circuit diagram of Oscillator Section

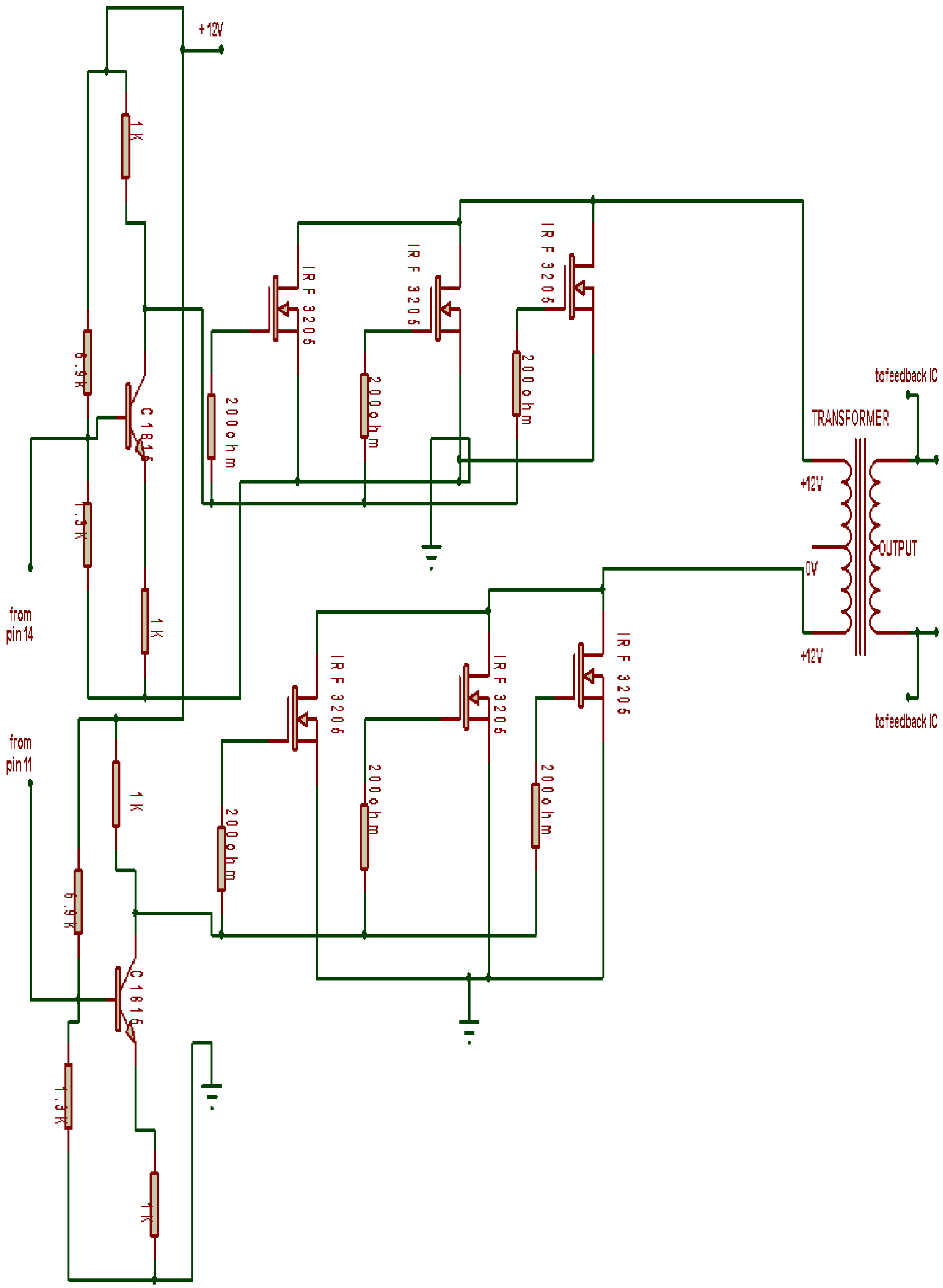

Fig 4. Mosfet driver section

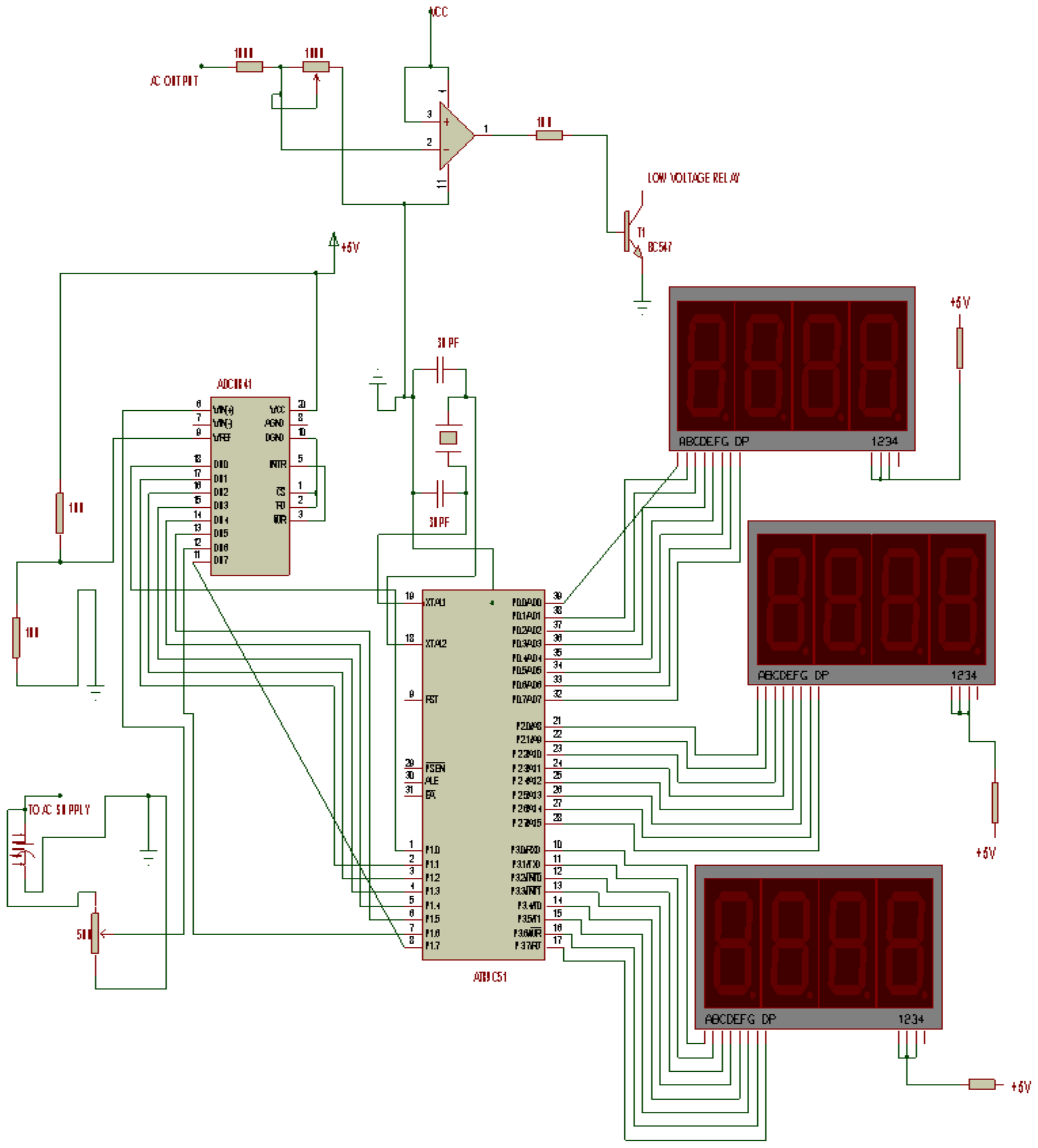

Fig.5. Microcontroller Section

2.2 MOSFET Driver Section:

In other to generate enough biasing current input to the MOSFET terminal, an NPN transistor was used. C1815 transistor has a minimum current hfe = 130, collector-emitter voltage VcE= 6V and collector current Ic = 2mA. If collector resistance is Rc = 1k, the DC load line for the driver amplify is obtained from [7]as;

VcE = Vcc – IcRc……………..(4)

This results in Ic value of 12mA at open current.

VE is obtained to be 1.2V using [8]

Thus,

VE = 0.1Vcc…………………….(5)

From [9], Re value results to 100.

RE = VE/IE……………………….(6)

According to [8], VBB becomes 1.9V from its equation of the form

VE = VBB – VBE……………….(7)

Where the base-emitter voltage VBE of silicon is 0.7V [10]

These results were used in selecting the values of some components used in the driver section. When the first channel of the MOSFET is switched ON, the other channel is OFF and current flows through the MOSFET to the inverter transformer. This happens as calculated from eqn (3).

3. TESTING AND RESULT

The developed circuit was powered by a 12V dc supply. Test carried out on the developed system includes, voltage stability, current changes in response to varying output load and efficiency of the system. The output voltage of the inverter was tested with different input load and it was found that despite changes in load values, the voltage remained the same.

Table 1 shows experimental measurements of output currents as well as load voltages taken at the output terminal using different loads. Also shown in the table is the maximum allowed wattage the inverter can carry which is 1200W. if the inverter output load is greater than 1200W, the inverter will shut down for safety measures.

Table 1:Measurement at SG3524 output using different load

Load (W)	Voltage (V)	Battery Current (A)	AC Output Current (A)
100	4.10	2.34	0.43
200	4.35	2.46	0.93
260	4.39	2.52	1.37
460	4.84	2.84	1.86
620	5.10	3.12	2.32
780	5.99	3.56	2.68
896	6.19	3.62	3.15
1008	6.36	4.05	3.86
1100	6.42	4.31	4.05
1200	6.49	4.47	4.15

Fig 5 is the graphical interpretation of table 1. The graph of fig 5 confirms that increase in load leads to increase in the voltage at the MOSFET driver circuit

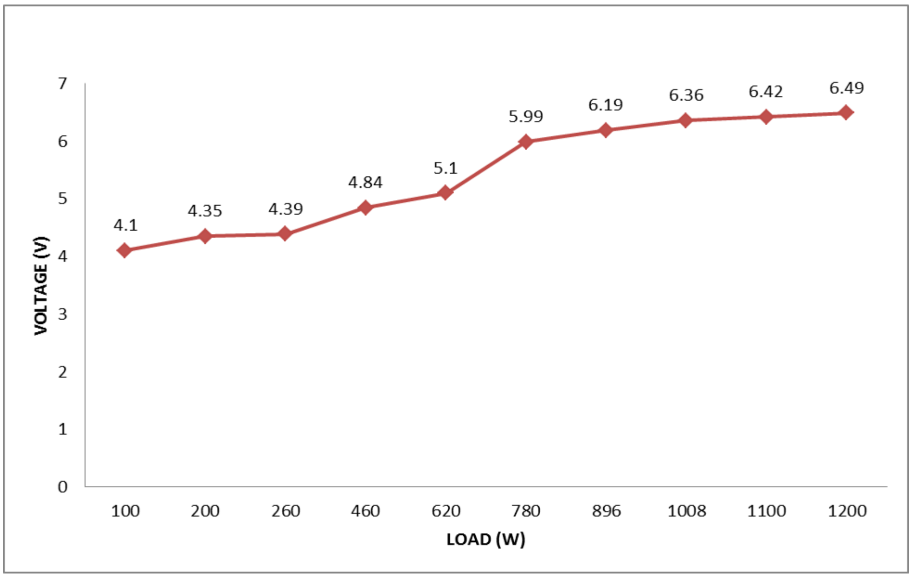

Fig 5. Graph of voltage against load

Table 2 shows the input and output power as well as the efficiency of the developed system.

Table 2: Load, Input and Output Power and Efficiency

LOAD(W)	INPUT POWER(W)	OUTPUT POWER(W)	EFFICIENCY (%)
100	103.2	95.03	92.1
200	223.2	205.53	92.1
260	328.8	302.77	92.1
460	446.4	411.06	92.1
620	556.8	512.72	92.1
780	643.2	592.28	92.2
896	756.0	696.15	92.1
1008	926.4	853.06	92.1
1100	972.0	895.05	92.1
1200	995.82	917.15	92.1

Fig 6 shows that the higher the load at the output terminal of the inverter, the greater the output power at the transformer output which agrees with [4].

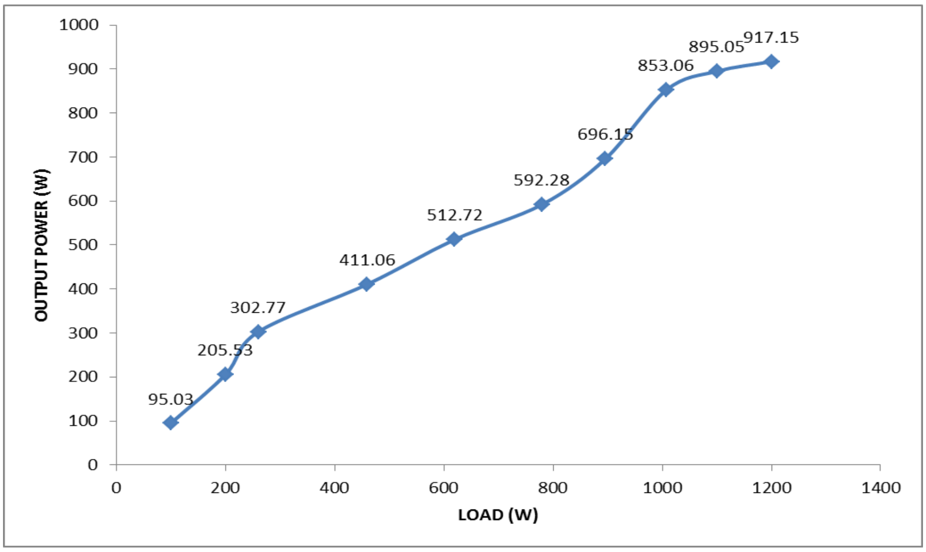

Fig 6 Graph of output power against load

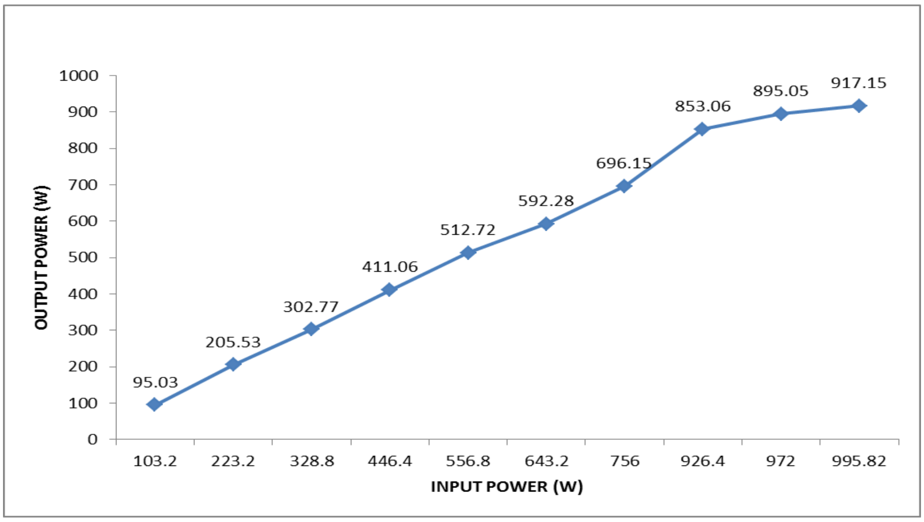

Fig 7 Graph of output power against input power

Fig 7 is a plot of output power against input power. From the graph, it can be shown that as the power at the output is increased, the input power increases and at maximum load of 1200W, the input power is 995.8W while the power at the output terminal is 917.2W. the output and input power readings agrees with [11],[12].

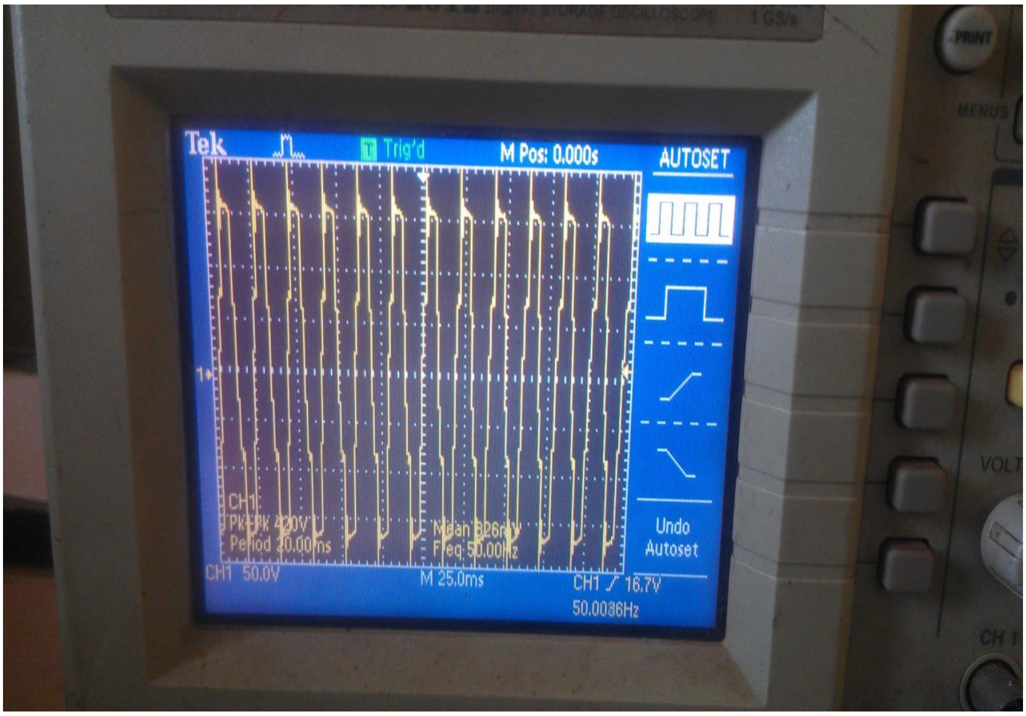

Fig 8 Waveform of the developed Inverter

Fig 8 shows the output waveform of the inverter captured on an oscilloscope. It can be seen that the frequency of 50Hz was achieved with a period of 20ms which deviated from theoretical value by 6ms.

4. CONCLUSION

The design and implementation of a 1.5KVA Dc to AC microcontroller low voltage switched single phase inverter was embarked upon. We found out that the inverter switched ON immediately the AC power source went below 180V. The output of the inverter was fluctuating between 200V and 223V but when the battery voltage dropped to 10.2V at a load of 1100W, the output voltage went down to 185V.

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