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# Evaluating the Effect of Optical Coupler in a 1.5KVA PWM Inverter

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

This paper presents the design and implementation of a 1.5KVA inverter system. The aim of the paper is to evaluate the effect of optocoupling technology on inverter system. The developed circuit compares the output load with the input voltage when 4N35 opto coupler is used and in the absence of it. Two different inverter systems were designed and the voltages at the output pins of Sg3524 were measured. It was observed that there seems to be fluctuation in the output voltage of the system without optocoupling and the voltage of the inverter keeps dropping till the system shuts down. The basic principle of the operation of the inverter is a simple conversion of 12V DC at a frequency of 50Hz to 230V AC. The result shows that optocoupling technique is essential part of an inverter system to achieve a good efficiency.

*Keywords: SG3524; IRFZ44N; Optocoupler; Pulse Width Modulation (PWM); MOSFET.*

## 1. INTRODUCTION

In this modern society, electricity has great control over most daily activities for instance in domestic and industrial utilization of electrical power for operations [1]. Electronic power generator can be simply described as an engine which burns fuel to generate electricity at a

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desired frequency in alternating current form (Ganiyu S,Lautech, Ogbomosho, unpublished thesis). Though it is an alternative to erratic power, it has inherent noise pollution problem, air pollution and constant expenditure on maintenance. To solve this problem, an inverter system plays significant role.

An inverter is an electrical device that converts direct current to alternating current. Inverters mostly employ pulse width modulation technique due to its superior factors compared to other types not making use of it. PWM is a way of digitally encoding analog signal levels. It's a technique that is now gradually taking over the inverter market of control [2]. PWM is an internal control method and it gives better result than an external control methods. There are number of PWM methods for variable frequency voltage-sourced inverters. A suitable PWM technique is employed in order to obtain the required output voltage in the line side of the inverter [3]. Inverters that use PWM switching techniques have a DC input voltage that is usually constant in magnitude. The inverters job is to take this input voltage and output ac where the magnitude and frequency can be controlled. There are many different ways that pulse-width modulation can be implemented to shape the output to be AC power [4]. As a result of switching arrangement, a fixed DC voltage can be converted into an ac output voltage and frequency. It is therefore the reverse of rectification [5]. Inverters have been in existence and need for converting direct current (DC) to alternating current (AC) [6,7].

The penetration of renewable energies in the context of distributed generation represents challenges such as maintaining the reliability and stability of the system and considering the random behavior proper of generation and consumption [8]. For effective and efficient management of both power generation and consumption, Baek, Cho, and Yeo (2019) propose a voltage control scheme with an inner repetitive current controller to achieve lower output impedance and better disturbance rejection capability for a UPS system, for which it is important to ensure the output voltage regulation and low total harmonic distortion (THD) under non-linear loads The performance of the inverter is usually measured as the value of the total harmonic distortion (THD) of the output voltage under the standard non-linear repetitive controller (RC) rectifier load. Another measure of performance is the distortion of the output voltage caused by a sudden decrease or increase in the resistive load. Since the performance of simple inverters without feedback control is usually not satisfactory, different control schemes are employed [9]. The control methods of the sine wave inverter mainly include proportional integral (PI) control, proportional resonance (PR) control, repetitive control, deadbeat control, hysteresis control, etc. Aiming at more and more occasions where the sine wave output inverter is used for power supply of a non-linear load, the sine wave output waveform distortion of the inverter caused by the non-linear load is serious. To avoid this, the feedback control strategy of sine wave inverter based on instantaneous reactive power was investigated and the result showed that through the fundamental wave instantaneous tracking feedback control based on the instantaneous reactive power theory and the detection and feedback control of the output harmonic signal, the ability of the inverter to maintain the output waveform with high sine degree and low distortion under various load conditions is possible [10].

The PWM technique is an advanced and useful technique in which the width of the gate pulses are controlled by various gate mechanisms. The PWM inverter is used to keep the output voltage of the inverter at the rated voltage irrespective of the output load. In conventional inverter the output voltage changes according to the changes in the load. Using a fixed frequency continuous-time sliding mode controller, the control signal is generated by applying a signal to a hysteric comparator, which is a function of output current, output voltage and capacitor current [11].

This study looks at the performance of PWM inverters using opto-coupling technique to determine the stability of the output voltage when resistive load is connected and the effect of resistive load on the inverter without optocoupler.

## 2. METHODOLOGY

The system is made up of PWM circuitry, step up transformer, MOSFET drivers circuitry, the opto coupler circuit that functions as a feedback gate from which the variation of the output load is given to input of the PWM IC. This pulse width maintains the width of all pulses as it varies in relation to the amplitude of a sine wave evaluated at the center of the same pulse [12]. The block diagram of the system is s shown in Fig. 1. The system derives its energy from the AC source/solar panel as the case maybe, then, gets converted by the oscillator that IC that passes small amount of voltage to trigger the MOSFET's. The switching ON/OFF of the mosfet's sends alternating signal to the output transformer which steps it up to 220Vac. The feedback system is gotten from the output of the transformer which passes through the optocoupler IC to the sg3524 oscillator for modulation.

## 2.1 Design Analysis

By supplying a constant volt 12V DC through a regulated 12V supply to the SG3524, the frequency of the oscillation is determined using a 50kΩ connected in series to a 100kΩ variable resistor and both are connected in parallel with 0.2µf to give, [1];

$$F = \frac{1}{1.1C_T R_T} \quad (1a)$$

Where f is the frequency of oscillation , $C_T$ is the timing capacitor and $R_T$ is the timing resistor.

To achieve a 50Hz frequency, we determined the value of the timing resistor from equation (1a) thus;

$$R_T = \frac{1}{1.1C_T F} \quad (1b)$$

$$R_T = \frac{1}{1.1 \; x \; 0.2 \; x \; 50 \; x \; 10^{-6}}$$

$$R_T = 91k\Omega$$

This implies that to achieve a frequency of 50Hz, the resistor has to be varied through 91kΩ.

The switching time of the oscillation of the PWM SG3524 is achieved using

$$T = R_T C_T \quad (2)$$

Where T is the period of oscillation.

$$T = 91000 \; x \; 0.2 \; x \; 10^{-6}$$

$$T = 18ms$$

This means that the output of the SG3524 pulses at 18ms supplying signal to the BC547 transistors connected at its terminals.

The values of the components connected to the biasing transistor is achieved by noting its transistor parameters such as minimum current gain hfe=110, collector emitter voltage $V_{CE}$= 5V, collector current $I_C$= 2mA. If the collector resistance is 1kΩ, the load line for the amplify is achieved from the equation given by [13]

$$V_{CE} = V_{CC} - I_C R_C \quad (3)$$

At open circuit, $V_{CE} = 0$,

$$V_{CC} = I_C R_C \quad (4)$$

$$I_C = \frac{V_{CC}}{R_C} \quad (5)$$

$$I_C = \frac{12}{1000} = 12mA$$

At open current, $I_C = 0$,

$$V_{CE} = V_{CC} = 12V$$

The dc current gain is expressed as [14]

$$\beta = \frac{I_C}{I_B} \quad (6)$$

$$I_B = \frac{2mA}{130}$$

$$I_B = 26\mu F$$

$V_E$ can is obtained using [2]

$$V_E = 0.1V_{CC} \quad (7)$$

$$V_E = 0.1 \; x \; 12 = 1.2V$$

The emitter resistor, $R_E$ is found using;

$$R_E = \frac{V_E}{I_E} \quad (8)$$

$$R_E = \frac{1.2}{2mA} = 600\Omega$$

1kΩ is chosen because of unavailability of the calculated value.

The base voltage $V_B$ is obtained from the relation;

$$V_E = V_B - V_{BE} \quad (9)$$

$$V_B = 1.2 + 0.7 = 1.9V$$

Where the base-emitter voltage of silicon is 0.7V.

From the equation of stiff voltage source condition for voltage divider bias given as;

$$R_2 \leq 0.01\beta_{dc}R_E \tag{10}$$
$$R_2 \leq 0.01 \; x \; 130 \; x \; 1000 = 1.3k\Omega$$

To calculate the value of $R_1$, we use;

$$V_E = \frac{V_{CC} \; x \; R_2}{R_1 + R_2} \tag{11}$$

$$R_1 = \frac{V_{CC}R_2}{V_B} - R_2$$

$$R_1 = \frac{12 \; x \; 1300}{1.9} - 1300$$

$$R_1 = 6.9K\Omega$$

The PWM circuitry is shown in Fig. 2 while Fig. 3 is the driver circuitry. In each case while Fig. 2 serves as oscillating control which comprises of SG3524, 4n35IC and a number of resistors and capacitors. It is in charge of generation of oscillating signals that is fed to the inverter transformer through the driver circuitry and to monitor the output load for modulation purposes.

Fig. 3 is the driver circuitry which comprises of amplifier transistors, switching transistors, some resistors and transformer. It is responsible for boosting to high current and voltage levels the oscillating pulses from the oscillating circuit. The channels of the MOSFET get their voltages from pin 1 and 14 of Sg3524 IC. The base of the BC547 transistor is connected with a voltage divider resistor and its emitter connected to a 1KΩ resistor. This 1KΩ resistor is used to ground the current flowing through the emitter.

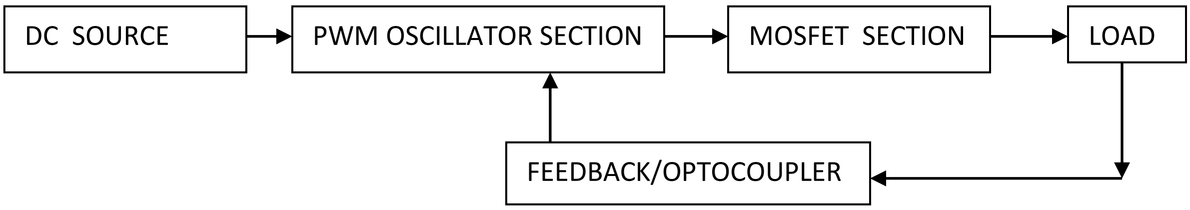


**Fig. 1. Block diagram of inverter system**

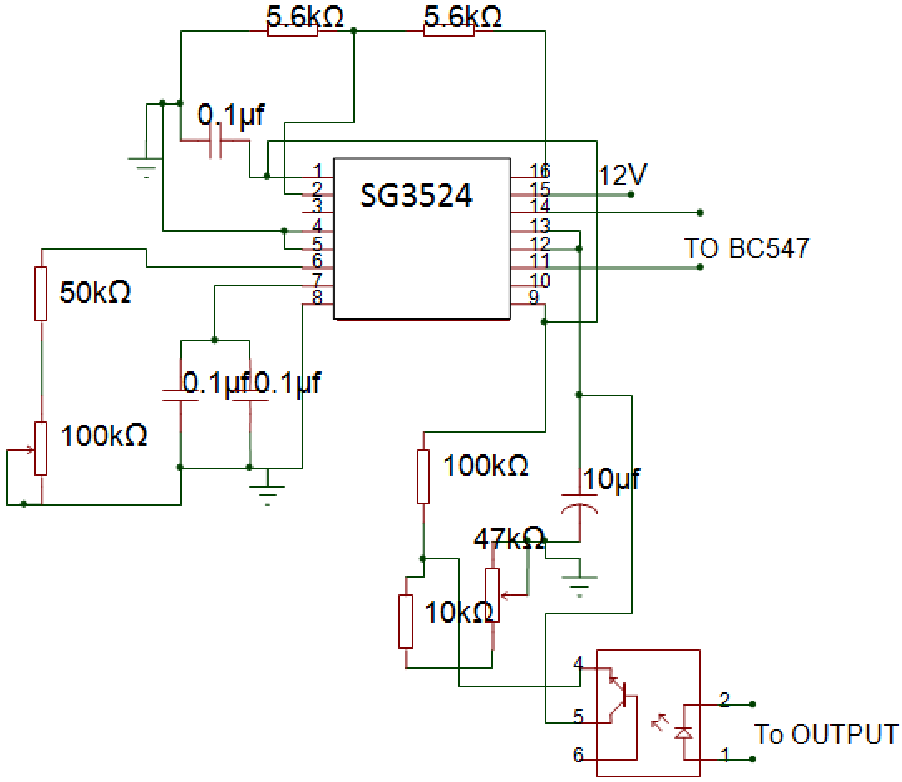


**Fig. 2. PWM circuitry**

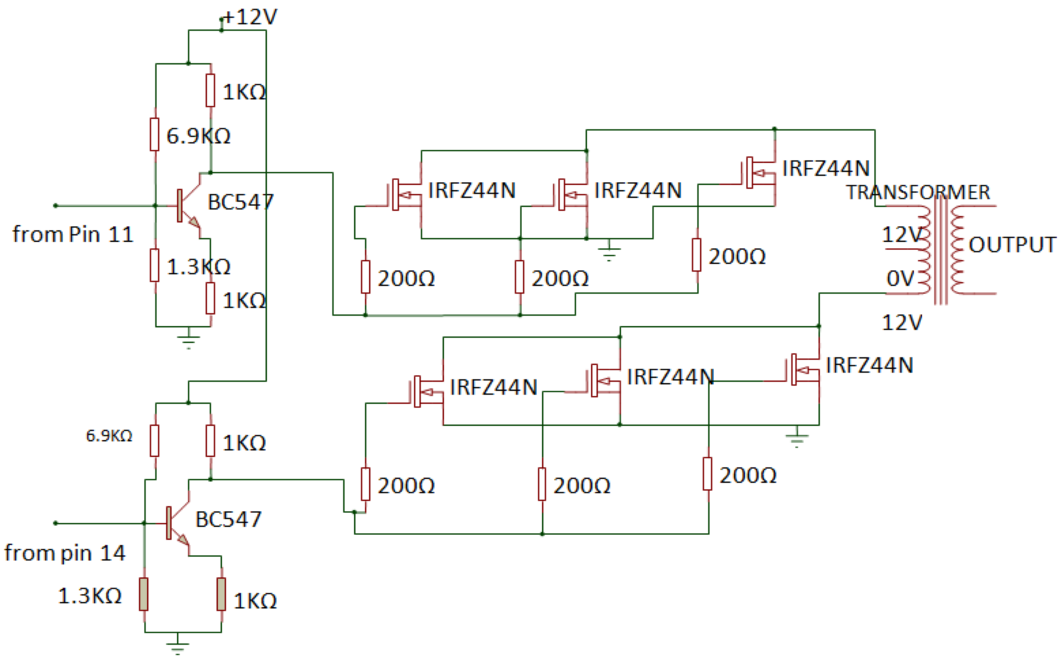


**Fig. 3. Driver circuitry**

From Fig. 2, the systems input voltage to the mosfet's are measured for the two established inverters to differentiate what function the 4n35IC does in inverter systems. The corresponding voltage reading for the inverter systems are as shown in Table 1 and Table 2.

## 3. RESULTS AND DISCUSSION

The developed circuit was powered by a 12V dc supply. Test carried out on the developed system includes, voltage stability in response to varying output load of the system. The output voltage of the inverter was tested with different resistive load and it was found that despite changes in load values, the voltage from the PWM IC did not decrease as shown in Table 1.

Table 1 shows experimental measurements of load voltages taken at the output terminal using different loads.

**Table 1. Voltage at pins 11, 14 of SG3524 operating with 4N35**

| Load (W) | Voltage (V) |
|---|---|
| 100 | 4.10 |
| 200 | 4.35 |
| 260 | 4.39 |
| 460 | 4.84 |
| 620 | 5.10 |
| 780 | 5.99 |
| 860 | 6.15 |

Fig. 4 shows the graphical interpretation of Table 1. It shows the variation of voltage with load when the inverter system is operating under feedback mechanism. The graph of Fig. 4 confirms that increase in load leads to increase in the voltage at the MOSFET driver circuit.

The output voltage of the inverter was also tested with different resistive load when the inverter system operates without optocoupler. It was found that as load values changes, the voltage from the PWM IC decreases as shown in Table 2.

Table 2 shows experimental measurements of load voltages taken at the output terminal using different loads when the inverter was designed to operate without a feedback mechanism.

Fig. 5 shows the graphical interpretation of Table 1. It shows the variation of voltage with load when the inverter system is operating without feedback mechanism. The graph of Fig. 5 confirms that increase in load leads to decrease in the voltage at the MOSFET driver circuit. It can be seen that there is a sharp decrease in the voltage as the load reaches 780W.

As shown in "Table 1", it can be seen that as the load is increased, the PWM IC outputs a corresponding increase at its output pins 11 and 14 whereas in "Table 2", the voltage drops with an increase in load showing the importance of opto coupling mechanism.

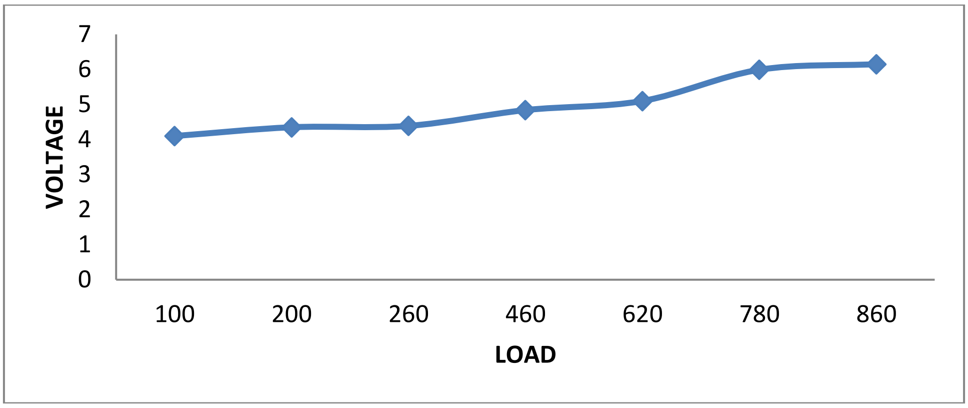


**Fig. 4. Graph of voltage against Load**

**Table 2. Voltage at pin 11, 14 of SG3524 operating without 4N35**

| Load (W) | Voltage(V) |
|---|---|
| 100 | 3.42 |
| 200 | 3.38 |
| 260 | 3.31 |
| 460 | 3.05 |
| 620 | 2.85 |
| 780 | 2.54 |
| 860 | 0.45 |

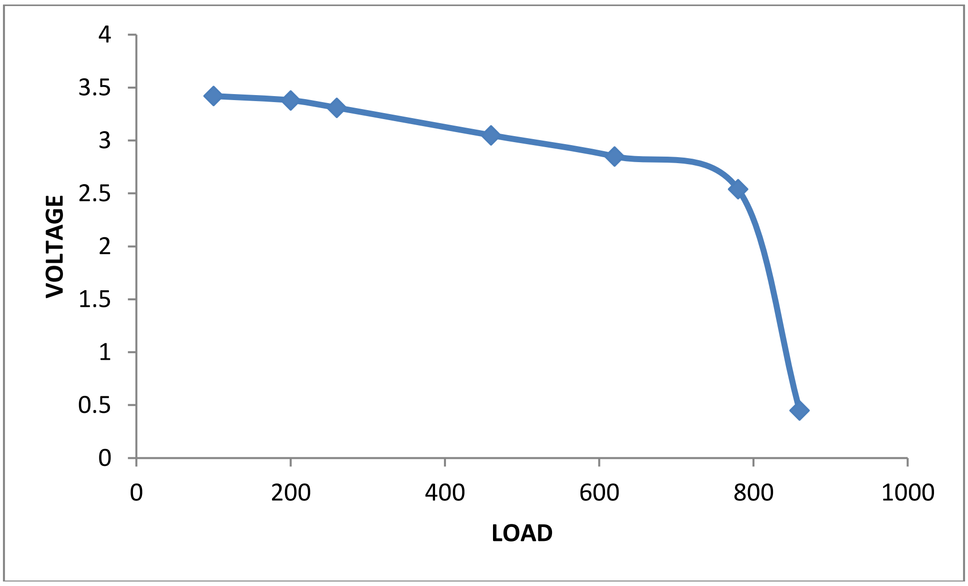


**Fig. 5. Graphical representation of Voltage against load for non-feedback mode It was observed that as the load given to the inverter system is increased, there is a resultant decrease in the output voltage until at certain load value 780W, the voltage dropped drastically that it could not power any appliance**

## 4. CONCLUSION

In this paper, the impact of optocoupler to PWM inverter system was investigated. We successfully ascertained the effect of optical isolator IC as a feedback mechanism for inverter system. It is shown that systems that do not make use of this device can be achieved but its efficiency is very poor since the output voltage is a function of the load it is drawing from the inverter. With each additional load, the AC voltage keeps dropping until the voltage at the SG3524 was 0.45V at a load of 860W.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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