

DESIGN AND CONSTRUCTION OF A 2KVA HYBRID SOLAR POWER**Engr. Kema-Okolo Agberia Patience***okolopatienc33@gmail.com***Electrical Electronic Engineering Department
Delta State Polytechnic, Ogwashi-uku, Nigeria****ABSTRACT**

Most commercial industrial and domestic process and activities depends on quality and quantity of electrical power available. This work provides basically an alternative source of electrical energy especially in an environment where power supply is not stable. It is achieved solely by the conversion of direct current (A.C). The inverter operates in two modes, normal charging mode where there is power supply and the backup mode, where there is no power from supply the design and construction of this work are in module. The modules are power supply unit, charging unit, switch circuit unit, and inverter unit. the modules are assembled together after construction to form a complete circuit.

Keywords: Power Supply, Design Analysis, Construction, KVA

Introduction

The growing global demand for renewable energy solutions has led to increased interest in solar power as sustainable and environmentally friendly energy source. This project focuses on designing, constructing and installation a 2Kva solar power inverter, which can be charged both by solar panels and the mains electricity supply. This dual charging capability ensures continuous power availability, making it a visible and reliable power solution.

The global energy landscape is undergoing a significant transformation, driven by the need to address climate change, reduce dependence on fossil fuels, and ensure energy security. Renewable energy sources, particularly solar power, have emerged as viable alternatives to conventional energy systems. Solar power harnesses energy from the sun, offering an inexhaustible and environmental friendly energy source. Despite its advantages, the intermittent nature of solar energy necessitates the development of efficient storage and conversion systems to ensure a stable and reliable power supply.

The primary challenge with solar power systems lies in their dependency of weather conditions and daylight availability. During cloudy days or at night, solar panels cannot generate electricity, leading to potential power shortages to address the issue, hybrid power systems that combine solar energy and the main supply, ensuring that electricity is always available, regardless of weather conditions.

This work aims to design and construct a 2KVA solar power inverter that can be charged by both solar energy and main electricity. The inverter is a crucial component of the system, converting the direct current (DC) generated by solar panels into alternating current (AC) suitable for house hold appliances, by integrating a dual charging capability, the system can optimize the use of solar energy while relying on main electricity as a backup during periods of low solar generation.

The development of such a hybrid inverter system is particularly relevant in regions with unreliable electricity supply, frequent power outages, or limited access to power grid. It offers sustainable solution that not only reduce electricity bills but also contributes to environmental conservation by decreasing reliance on fossil fuels. Furthermore, the work aligns with global efforts to promote renewable energy adoption and reduce greenhouse gas emissions

The advent of solar cells has made it possible for an average Nigerian to tap the energy from the sun to generate electrical power. The electronic power generator being an alternative source of power generation that is readily available has some major limitations which includes:

- 1) During their operations, most of the power generators are noisy which causes disturbance to the neighbourhood in form of noise pollution.
- 2) The waste product of the power generator in form of smoke and black oil poses a major threat to the environment contributing to the global warming and soil/water pollution.
- 3) Cost of maintenance of electronic power generator is high compared to its alternative, inverter (Ganiyu,2004). All these limitation (gaps) are bridged with the aid of introduction of solar energy.

According to power electronics,(2019),it started with the development of mercury arc rectifier, which was used to convert alternating current into direct current. Continuous application of thyratrons and grid-controlled mercury over the years, leads to the development of mercury valve with grading electrodes making it suitable for high voltage direct current power transmission.

Ehikhamenle and okeke 2017 reported that in the quest of conversion of direct current to alternating current power, limitations such as very low load current (in the order of milliamps) and poor power efficiency where identified with the regards to the circuit design by lane fox in 1970. These gaps was bridged by Jacob design and construction of direct current to alternating current converter that yielded an output power of 6KVA, 220v ac and 50HZ with efficiency of 93.5% in 1986 to have a noiseless cheap, pollution free and portable mechanism of converting direct current to alternating current power, uninterrupted power supply (UPS) designed an inverter circuit that produces 4KVA output 27AC, 50HZ and efficiency of 95% a huge achievement of inverter of uninterrupted power. Supplies Everonmaru facturing company

Ac is the standard electrical current in which flow of electrons is reversed 120 times/second (i.e 60 cycles per second .) while DC is direct current, which is the type supplied by batteries (scientific communities 2019).

The design helps to reduce the challenges of power supplies at all times, as energy is stored up during the day via charging of the battery and the stored up energy is used up when needed as an alternative source of energy supply when supply from national grid fails without affecting the integrity of the battery (Ekwurigbe and uchegebu, 2016).

This is made possible via the solar panels that generates solar energy from the sun and convert it to electricity with the aid of collection of individual silicon cells that the solar panel is made up of. According to Olajuyin and Olubakinde (2017) multiple solar panels can be wired both in parallel and series to increase current capacity and to increase voltage respectively, in which smaller wire sizes are used to transfer electronic power from solar panels array to the charge controller and the attached batteries to favour the use of higher voltage output.

In their discussion, Olajuyin and Olubakinde (2017) report that there are three basic types of solar panels which includes monocrystalline solar panels, polycrystalline solar panels and amorphous solar panels ; state in their order of effectiveness with the most effective being the most costly while the least effective type is the cheapest in using amophous solar panel, more square footage is required to produce the same amount of power as monocrystalline and polycrystalline type of solar panel will produce.

According to solar alawys (2018) there are three types of solar panel array mounts which includes:

- 1) Fixed solar panel mounts; fixed panels are stationary and are mounted correctly to absorb as much light from the sun as possible. Is the simplest and cheapest system available but offers the least flexibility, hence the amount of sunlight it can absorb is

limited. Also as the earth orbit changes throughout the year, the inability to modify the position of the mount (and thus the panels) to the varying angle of the sun limits the amount of energy absorption.

- 2) Adjustable solar panel mounts; adjustable panel and array mountings provide more flexibility, as their seasons change, their positions can be altered to compensate for the sun angle in order to maximize the panels exposure and level of energy absorbed by modifying the inclination of the panels mounts, the solar output of the panels can be increased by 25%.

Tracking solar panel mounts; is the most efficient mountings, they follow from the sun throughout the day to absorb the most energy possible. They are available as a single axis or double axis system while the transformer tracks the trajectory of the sun as it rises and sets during the day. The latter will do the same but also automatically compensate for the sun's changing angle throughout the year through their expensive they will provide up to 30% where more solar output than adjustable and fixed mountings. Some people prefer to buy additional solar panels and place them on adjustable mounts rather than invest in trackers.

According to kraemer et al. (2018) a solar inverter is a device that converts direct current (DC) electricity generated by solar panels into alternating current electricity (AC) electricity, which can be used by house hold appliances and fed into the grid.

kraemer et al. (2018) provide an in-depth analysis of the fundamental principles of solar inverters, emphasizing their critical role in converting DC electricity generated by solar panels into the AC electricity suitable for house hold and commercial use. They highlight the importance on inverter efficiency, noticing that even small improvement can significantly impact the overall performance and economic viability of solar power systems. The study also discuss the roles of advanced features like maximum power point tracking (MPPT) which optimizes the energy harvest from solar panels by continuously adjusting their operating point to maximize output.

kraemer et al. (2018) discussed technological advancement in inverter design, including the use of high efficiency semiconductor materials and improved cooling techniques. These advancements have led to inverters that are not only more efficient but also reliable and longer lasting. kraemer et al. also emphasized the importance of reducing power losses and improving thermal management to enhance inverter performance.

According to wotye et al. 2019: solar inverter is an essential component of a photovoltaic system, the solar inverter contains DC electricity produced by solar panels into AC electricity, suitable for home and commercial use.

Wotye et al. 2019 categorize solar inverters into three main types: string inverters, micro-inverters, and central inverters. Each type has central inverters. Each types has distinct applications, advantages, and limitations. String inverters are noted for their cost-effectiveness and suitability for residential systems, whereas micro-inverters offer improved performance monitoring and flexibility, particularly in systems with shading issues or complex roof layouts. Central inverters are highlighted for their application in large scale commercial and utility projects due to their ability to handle higher power levels. Wotye et al 2019. Emphasize the importance of selecting the appropriate inverter type based on the specific needs and constraints of the solar power system, ensuring optimal performance and cost effectiveness.

According to Zhang et al. 2020 a solar inverter power electronics devices that converts DC output of solar panels into AC power, facilitating the integration of solar energy into electrical grid.

Zhang et al. 2020 focus on recent advancements in semi-conductor materials used in solar inverters, particularly silicon carbide SiC and gallium nitride GaN. These materials offer significant benefits over traditional silicon-based devices, including higher efficiency, better thermal management, and the ability to operate at higher switching frequencies. The authors highlight that SiC and GaN devices can reduce power losses and improve the overall performance of solar inverters, making them more suitable for modern, high efficiency solar power systems.

According to utarsun et al 2018: a device that enables the conversion of solar energy converted by PV panels into usable AC electricity, forming a crucial part of hybrid energy solar systems.

Urtasun et al. 2018 explore the concept of hybrid energy systems, which combine solar power with other energy sources, such as mains electricity or diesel generators, to provide a reliable and continuous power supply. The authors emphasize that hybrid system can mitigate the intermittency of solar power and enhance energy security, particularly in regions with unreliable grid infrastructure or frequent power outages. By optimizing the use of solar energy and reducing reliance on fossil fuels, hybrid systems and lower electricity cost and decrease greenhouse gas emissions.

According to Adaramola et al. 2017 solar inverters convert the variable DC output from solar panels into a stable AC output, suitable for use by common electrical appliances and for grid injection. Adaramola et al. 2017 propose a comprehensive frame work for designing and optimizing hybrid solar power systems. The frame work considers factors such as load demand, nsystem reliability, and cost-effectiveness, emphasizing the importance of accurate load forecasting and proper sizing of system components. The authors suggest the well-designed hybrid systems can significantly improve energy access and reliability, particularly in off grid and remote areas.

According to Nandi and Ghosh 2019: a solar inverter is a power conversion device that transforms the DC electricity generated by solar PV systems into AC electricity for home use and businesses. Nandi and Ghosh 2019 present a detailed case study of a hybrid solar-wind system implemented in a remote village. The study illustrates how combining solar and wind energy can provide a reliable and continuous power supply, improving the quality of life for residents and supporting local economic development.

The author discuss the technical and economic aspects of the system, including the integration of energy storage and control mechanisms to balance supply and demand.

According to Patel and Argawal 2018: solar inverters are devices that change the DC output from solar panels into AC, making solar energy usable for home appliances and capable of feeding into the electric grid.

Patel and Argawal 2018 explore various dual charging mechanism for solar inverters, which enables the system to be charged by both solar panels and mains electricity. The authors discuss different approaches, such as automatic switching and parallel charging, highlighting the benefits of each method. Dual charging systems can enhance reliability and ensure a continuous power supply, even during periods of low solar generation.

According to Yadav and the Sharma 2020: the power electronic device that converts the DC electricity produced by solar panels into AC electricity, which can be used by household appliances or injected into the power grid. Yadav and Sharma 2020 address the technical challenges associated with integrating dual charging capabilities into solar inverters. These challenges includes synchronization of energy sources, protection against overcharging, and maintaining system stability. The authors propose several solutions, such as the use of advanced charge controllers, protection circuits, and robust design principles to ensure reliable operations.

MATERIALS AND METHOD

Principle of operation of inverter

In figure 1, is the battery source, a switch and a transformer

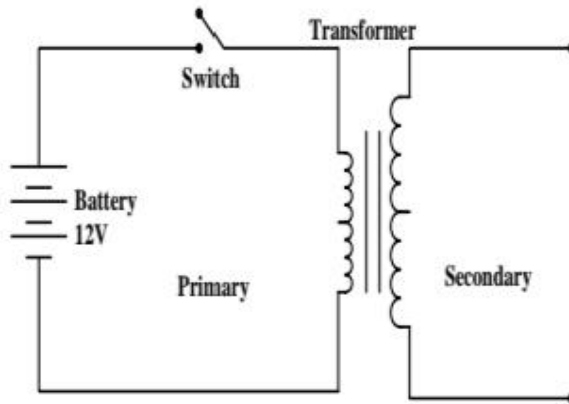


Fig 1: Basic Inverter Diagram

When the switches is closed current starts to flow in the circuits, this will make the transformer EWF, opposing the EWF of the battery. This rise will depend on the inductance of the transformer, the greater the inductance, the more time will be required to produce the current required to balance the EMF of the battery. Now, if the switch is opened before the current of the transformer grows fully, the current in the circuit will start to fall. This will make the transformer to generate reverse EMF. Once the circuit current reaches zero, the switch is once again closed by producing open, close cycle of switch in this circuit, we can produce an alternating current (AC) output from DC current source, i.e the battery. If the switch is kept in close or open state for a long duration then there will not be any current in the secondary but if the switch is opened and closed at a constant rate, then the changes at the primary of the transformer will reduce output at the secondary of the transformer. The output from the secondary winding of the transformer is a square wave of frequency at which the switch is opened and closed. A transistor was used as a switch in place of manual switch; transistor is used for switching the primary circuit on/off. This generates an automatic AC current output without need of someone opening and closing a switch.

Construction

The construction of this module is of two sections; the external structure and the internal structure. The construction is of great importance because after designing the whole circuit, it ensured that all circuit works to what it is specially designed for. All materials components used in the construction of this work were mostly locally sourced.

Module description

External structure. The body (or casing) is made of galvanized steel. Measuring 14.0cm x 14 .0cm x 26 cm. the compact size was chosen for easy carriage whenever it is needed.

Internal structure: the components including integrated circuit (SG3524IC). Capacitors, resistors, variable resistors, diodes, poi-polar junction transistors comparators and so on are soldered t the vero board. This components made up the control board.(I . e oscillator and buffer stages).

The power MOsFETs. The transformer is mounted on the inner part of the module, which is provided with cooling fans to allow ventilation. The transformer core is built with 76 lamination sheets. The ticker wire used for primary winding because it carries much current (42A) and lower voltage (12V) while the thinner were used for secondary winding because it carried less current (4.35A) and higher voltage (230V)

Design analysis

Design calculation of the oscillator system

The oscillator uses an external resistor R_T to establish a constant charging current into an external capacitor C_T . this uses more current than series connected RC

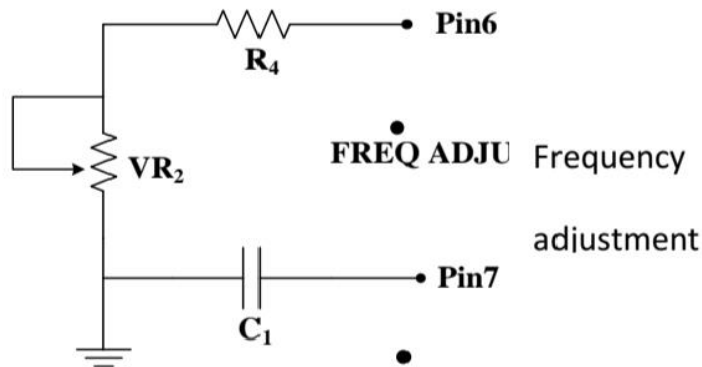


Fig 2 Schematic Diagram of the Frequency Unit

It provides a linear dependent reference for the PWM comparator. The oscillator IC SGG3524 has the following specifications.

- i. Supply current less than 10Ma
- ii. Supply voltage up to 40v max
- iii. Current at pm 16 vcc =50Ma
- iv. Current at oscillator output transistor (dual)50Ma
- v. Regulated output (linear) 5v at pin 16
- vi. Voltage at inverting input at pin 2=2.4v
- vii. Voltage at pin 1=2v
- viii. Voltage at pin 3= 47mv

Calculation of resistor at the input of the error amplifier

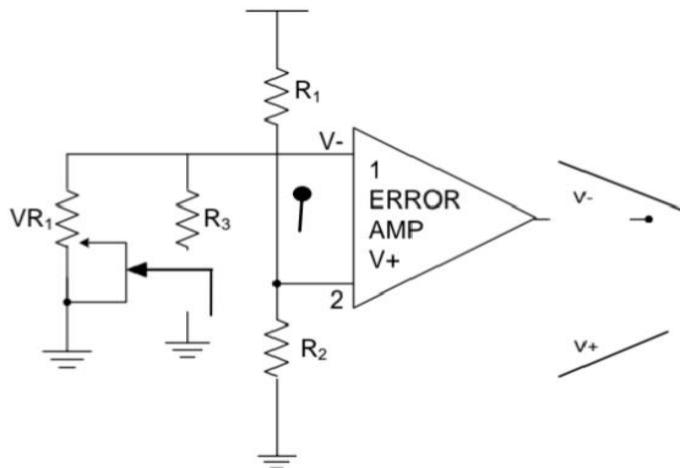


Fig 3: Circuit Diagram of an Error Amplifier

Making use of voltage divider Rule.

$$V_{in} \text{ at Pin } 2 = 2.4V$$

$$V_{cc} \text{ at Pin } 16 = 4.93V$$

$$V_{in} = \frac{R_2}{R_2 + R_1} \times V_{CC}$$

$$\text{Let } R_2 = 10 \text{ k}\Omega$$

$$2.4 = \frac{10000}{10000 + R_1} \times 4.93V$$

$$24000 + 2.4 R_1 = 49300$$

$$2.4 R_1 = 49300 - 24000$$

$$2.4 R_1 = 25300$$

$$R_1 = \frac{25300}{2.4}$$

$$R_1 = 10.541 \Omega$$

Preferred value of $R_1 = 10K\Omega$

At pin 1 of SG3524 the voltage can be varied from 0v to 2.8v initially the voltage at pin 1 must be greater than that of pin 2 in order to 0v at pin 10(shutdown). $v_+ > v_-$ the output is approximately equals to vcc but when $V_+ < V_-$ the output voltage is equals to zero

Therefore when $V_+ = V_-$ the output voltage shutdown the whole system through pin 10 because pin 10 needs more 0.6V to shut down the oscillator section

To calculate V_{R1} let $R_3 = 10k\Omega$; V -at pin 1=2.1V

$$V_{R1} =$$

$$\left\{ \left(\frac{V_-}{V_+} \right) - 1 \right\}$$

$$= 10000 \left[\left(\frac{2.8}{2.1} \right) - 1 \right]$$

$$V_{R1} = 10000 [(1.33) - 1]$$

$$1000 \times 0.33$$

$$V_{R1} = 333.3K\Omega$$

The frequency used for lighting the electronic devices in Nigeria and some other countries is 50Hz. In order to produce 220VAC secondary voltage output in the inverter design, therefore the frequency must be well designed by using RC network (resistance and capacitor network to determine the frequency of operation) if one does not get a 50Hz frequency from the inverter then one may get flickering in tube light run on inverter, also fan running on such inverter shows irregular variations in speed.

Calculation of frequency adjustment circuit

Let $C_1 = 0.1\mu f = 10 \text{ picofarad}$

$$F = 50\text{Hz}$$

$$F = \frac{1}{T} = 1.1 R_4 C I \quad \text{where } 1.1 \text{ is constant}$$

$$50 = 1.1 \times R_4 \times 0.1 \times 10^{-6}$$

$$1 = 1.1 \times R_4 \times 0.1 \times 10^{-6}$$

$$R_4 = \frac{1}{55.5 \times 10^{-6}}$$

$$181,818\Omega$$

$$R_4 =$$

Since 181, 818 Ω resistor is not available in the market 300k Ω variable resistor was used to adjust to frequency of 50Hz within the resistance value. To obtain 50Hz output frequency from the inverter the VR_1 (variable resistor) 300k Ω was adjusted with the aid of an oscilloscope. To calculate current limiting resistor for the voltage regulator

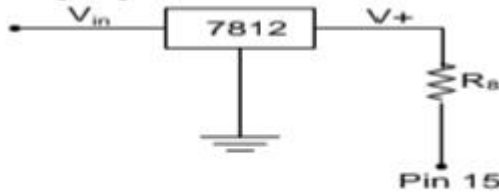


Fig 4: Voltage Regulator

At the output of the regulator, there will be voltage drop across the IC regulator of about 0.7V therefore, output voltage from 7812=11.3V
The specified current of the regulator is 50Ma .

$$11.3 = 50 \times 10^{-3} R_8$$

$$\frac{11.3}{50 \times 10^{-3}} R_8 = 226 \Omega$$

Preferred value of $R_8 = 320 \Omega$

$$V_{+} = IR_8$$

$$R_8 =$$

Driver section

In a two signal that is changing polarity, when the first signal is positive, the second signal will be negative and vice versa. This process will be repeated 50 times per second, that is, alternating signal with 50 Hz frequency is generated inside the flip-flop section of the IC .

This 50Hz alternating signal is output at pin 11 and 14 of the IC. This alternating signal is known as "MOS drive signal". The MOS drive signal at pin-11 and 14 is between 3 to 4V. voltage at these pins should be of the same value; any difference in the voltage at these pins could damage the MOSFET at the output

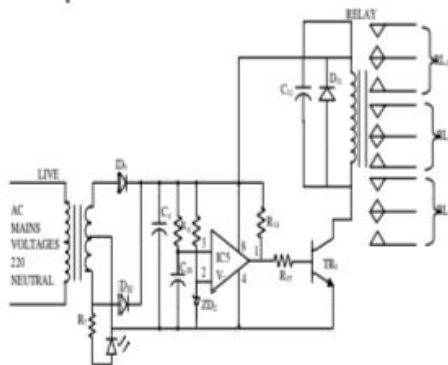


Fig 5: Circuit Diagram of Inverter Change over

MOS drive signal from pin-11 and 14 of the IC_2 is given to the base of MOS driver T_1 AND T_2 . This result in the MOS drive signal getting separated into two different channels.

Transistor T_1 AND T_2 amplify the 50Hz MOS drive signal at their bases to a sufficient level and output

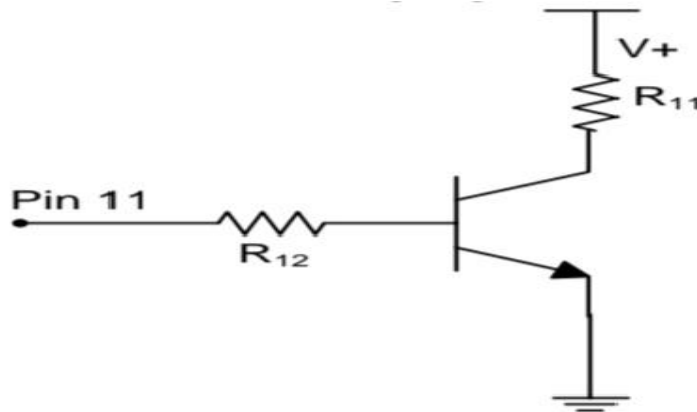


Fig 6: Schematic Diagram of Driver Stage

them from emitter. 50Hz signal from the emitter if T_1 is given to the gate (G) of each MOSFET channel. Through resistance R_{10} (2.2k Ω) each MOSFET gate (G) receives the 50Hz signal through a resistor (100 Ω). The process also goes for the second channel of the signal generated.

Fig 6: Schematic Diagram of Driver Stage

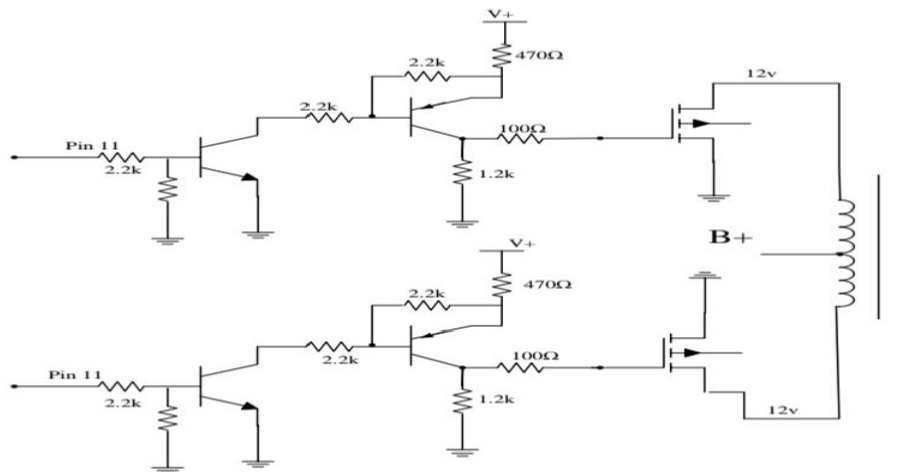


Figure 7: Circuit Diagram of Driver unit

Switching section (MOSFET)

MOSFET is a metal oxide semi-conductor field effect transistor with three terminal legs that can be used either as an amplifier or as a switching device.

The three terminals are drain, sources and the gate.

The resistor values at the base of TR_1 and TR_2 was obtained from the transistor parameter (i.e the specification according to the data given by the manufacturer, through data book or catalog). The type of transistor used in c945 is of the following specifications. $I_C \text{ max} = 500\text{mA}$

$H_{fe} = b = \text{from } 100 - 600$

Using the formula given below

$$V_{cc} - \frac{V_{be}}{I_B}$$

$$b = \frac{I_C}{I_b} \text{ or } I_C \div I_b$$

$$R_b =$$

$$H_{fe} =$$

$$\frac{100-500 \times 10^{-3}}{I_B}$$

$$I_B = 5\text{mA}$$

$$R_B = \frac{12-0.7}{0.005} = \frac{11.3}{0.005}$$
$$R_B = 2.260\Omega = 2.2K\Omega$$

Preferred value of $R_B = 2.2k\Omega$

In the oscillator unit, a 50 Hz is generated alternatively, reaching each channel of the MOSFET separately. This results in alternative switching of the mosfet drive on and off and when the second channel is on, the first one will be off. This on and off switching process is repeated 50 times per second therefore, with this system of operation, MOSFET is used as a switching system for inverter.

CONCLUSIONS

The construction of a solar powered inverter at a frequency of 50Hz was designed to complement the power supply from the national grid and put to use under load conditions. The inverter functioned in compliance with the model specification. The installation was done correctly while all design procedures were duly observed.

FUNDING

Tertiary Education Trust Fund(TETFund), Nigeria through The Institution Based Research (IBR) Interventions, supported this work.

ACKNOWLEDGEMENT

The author acknowledges the Tertiary Education Trust Fund (TETFund), Nigeria for supporting this research through the Institution Based Research (IBR) Interventions

REFERENCES

- Andrew, A.L 1998. Applied physics for electronic technology, Arnold holder headline .org/publishers, London
- Ehikhamenle M. and okeke R.O. 2017 design and development of 2.5KVA Inverter Adopting a Microcontroller Based Frequency Meter, International Journal of Engineering and Modern Technology, Vol 3(!),p.2.
- Ekwuribe J. Michael uchegebu E. chineye 2016.
- Design and construction of a 2.5KVA photovoltaic inverter, American journal of science, engineering and technology. Vol.1, no,1 pp. 7-12.
- Ganiyu, 5. 2004. Design and construction of a 1kva power inverter. Unpublished B .tech thesis LAUTHEC, ogbomoso, oyo state Nigeria
- Olajuyin Elijah Adebayo and Olubakinde Eniola 2017. Design of a 2KVA solar inverter journal of emerging trends in engineering and applied science (JETEAS) 8(6):257-262.
- Power electronics, 2019(Accessed 5th June, 2019,available from https://en.wikipedia.org/power_electronics.)
- Scientific communities,2019. Alternating current & direct. (accessed 18 may,2019 available From http://ec.europa.eu/health/scientific_committees/opinions_lay/en/electromagnetic_fields/glossary/abc/alternating_current.Htm)
- Solar always,2019. (Accessed 18 may,2019, available from <http://www.solaralways.com/types/array-mounts>)

- Adeyanju, A. Y (2003). Design and construction of 750 watts inverter. Unpublished B. tech thesis lautech Ogbomoso, Nigeria.
- Allan, c.(1997) the principle of computer hardware. oxford science publication, New york.
- C.A Awosope (2017). Epileptic power outage and unreliable services from public power supply in Nigeria
- Decree NO. 24 (November 1971) of the Nigerian military government
- ECN Ordinance NO. 15 (1950).
- Electric power sector reform Act of 2005 in Nigeria .
- Emmanuel Umbu, Esq (December 6, 2016). Electronic power implementation committee of Nigeria (EPIC)
- Hughes E. (1998) Electrical Technology, Longman scientific Technology book series, London 8th edition.
- [http://www:maxim](http://www.maxim) icsg3524 pulse with modulation
[http://www:maxim](http://www.maxim) ICTC 4066BP
IEF industry applications Magazine(1st January – Feb 1996) volume 2.
- Innovative system design and engineering ISSN2222.17 27 (paper)
ISSN2222.287.1 (online) vol.5 No.2 2014- www.icle.org
- Nelson J.C (1986).basic operation amplifier butter and Co. limited
- Oladimeji, T.T (2018) and Okereke, C.O (2018) performance analysis of a branded and locally constructed modified 1KVA sinewave solar inverter for domestic electric power supply (Nigeria)
- Peter Prenar (April 8, 2016). Importance of electricity in the economy
- Say (1978). Physical basis of a transformer
- Solar max 25C: RF Interference voltsage (dBp,V)
- Theraja (2002): Effect of power failure
- Thomas C.B.(1991). Computer architecture and logic design.cgraw Hill New York
- Yusmarhita yusop (2016). Study of capacitance power transfer using class-E Resenan Inverter (Nigeria)