

Efficient Power Outage Solution in Nigeria University Laboratories Using Micro-Controller Based Portable Solar Generator

¹Ifeagwu Emmanuel N., ²Ejimofor Ihekeremma A.U.

¹Department of Electrical and Electronic Engineering, Federal University, Otuoke, Bayelsa State, Nigeria

²Department of Computer Engineering, Madonna University, Akpugo Enugu State, Nigeria

Authors E-mail: ifeagwuen@fuotuoche.edu.ng, ejimofor@madonnauniversity.edu.ng

Abstract - This paper concentrates on the efficient power outage solution in Nigeria University laboratories using Micro- controller based portable Solar Generator. The design specification include the System Capacity 1000Volts Ampere, modified Sine wave alternating current power, Output Voltage: 220-240 Volts, Output Frequency: 50Hz, battery Bank Capacity: 12Volts/40Ampere-hour, Solar Panel Specification: 30Watts, Pulse width modulator charge controller. During the design a voltage level of 5Volts was fed from preamplifier to the switching Metallic Oxide Silicon Field Effect Transistor that produces the gate current of 0.05 Ampere: Result showed that the oscillator rated output of 5v was obtained at pins 11 and 14 to switch the transistor. Result also showed that the frequency of the oscillator was adjusted and measured until standard frequency of 50Hz was achieved, for the MOSFETs operating at 50Hz and the period of the switching was 0.02sec. The transformer secondary voltage was measured and it gave the expected output of 230v.

Keywords: Inverter, MOSFET, Panel, Oscillator, Solar Generator, Efficient power outage.

I. INTRODUCTION

The existing system of depending on the local electricity grid is laced with the grievous experience of insufficient and inefficient power supply. The rate at which power supply is being interrupted or denied in some areas is quite alarming and devastating because electricity is a necessity to human lives and it should be constant (Ifeagwu *et al.*, 2016a). It is a must-have by everyone from the industrial settings down to the homes. The laboratories in the higher institutions of learning especially Nigeria are no different. Most of the equipment or apparatus used in these laboratories need electric power to function. Almost all modern appliances depend on electricity. Also, the interruption of power supply at the laboratories reduces the effective use of equipment and tools by the students. To overcome this problem a stable or constant power supply is needed (Ifeagwu *et al.*, 2016b).

Thus, in recent times there has been an increasing demand for alternative energy sources as global oil reserves dwindle and concerns for the environment continue to grow (Esper (2018)). Today, we increasingly depend on devices that require electricity, but in Nigeria, one of the most populated nations in Africa, only 40% of the people are connected to the energy grid; those connected experience total blackouts around 60% of the time (Ifeagwu *et al.*, 2015a). Meanwhile, it is sunny 43% of daylight hours in Nigeria, which is an average of 1885 hours of sunlight per year, this means solar as an alternative energy solution is very much feasible in this part of the world.

Solar power is the conversion of energy from sunlight into electricity, either directly using photovoltaic (PV), concentrated solar power system use lenses or mirror or tracking system to focus a large area of sunlight into a small beam (Ifeagwu *et al.*, 2016a). A solar cell (also called a photovoltaic cell) is the smallest solid-state device that converts the energy of sunlight directly into electricity through the photovoltaic effect. A Photovoltaic (PV) module is an assembly of cells in series or parallel to increase voltage and/or current. A Panel is an assembly of modules on a structure. An array is an assembly of panels at a site. At the heart of the inverter is a real-time microcontroller. The controller executes the very precise algorithms required to convert the DC voltage generated by the solar module into AC. This controller is programmed to perform the control loops necessary for all the power management functions necessary including DC/DC and DC/AC. The functions also include overload control (Ifeagwu *et al.*, 2015b). The PV maximum output power is dependent on the operating conditions and varies from moment to moment due to temperature, shading, cloud cover, and time of day so adjusting for this maximum power point is a continuous process. For systems with battery energy storage, the two controllers can control the charging as well as switch over to battery power once the sun sets or cloud cover reduces the PV output power (Ifeagwu *et al.*, 2015c).

II. PHOTOVOLTAIC EFFECT

The photovoltaic effect is a process that generates a voltage or electric current in a photovoltaic cell when it is exposed to sunlight (Ltonel, 2002). It is this effect that makes solar panels useful, as it is how the cells within the panel convert sunlight to electrical energy (Cassedy and Grossma 2008). The photovoltaic effect was first discovered in 1839 by Edmond Becquerel. When doing experiments involving wet cells, he noted that the voltage of the cell increased when its silver plates were exposed to the sunlight.

The photovoltaic effect occurs in solar cells. These solar cells are composed of two different types of semiconductors - a p-type and an n-type - that are joined together to create a p-n junction. By joining these two types of semiconductors, an electric field is formed in the region of the junction as electrons move to the positive p-side and holes move to the negative n-side. This field causes negatively charged particles to move in one direction and positively charged particles in the other direction.

Light is composed of photons, which are simply small bundles of electromagnetic radiation or energy. These photons can be absorbed by a photovoltaic cell - the type of cell that composes solar panels. When the light of a suitable wavelength is incident on these cells, energy from the photon is transferred to an atom of the semiconducting material in the p-n junction. Specifically, the energy is transferred to the electrons in the material. This causes the electrons to jump to a higher energy state known as the conduction band. This leaves behind a "hole" in the valence band that the electron jumped up from. This movement of the electron as a result of added energy creates two charge carriers, an electron-hole pair.

When unexcited, electrons hold the semiconducting material together by forming bonds with surrounding atoms, and thus they cannot move (Sangwine, 1994). However, in their excited state in the conduction band, these electrons are free to move through the material. Because of the electric field that exists as a result of the p-n junction, electrons and holes move in the opposite direction as expected. Instead of being attracted to the p-side, the freed electron tends to move to the n-side. This motion of the electron creates an electric current in the cell. Once the electron moves, there's a "hole" that is left (Theraja, B. and Theraja, A. 1999). This hole can also move, but in the opposite direction to the p-side. It is this process that creates a current in the cell. The concept of the photovoltaic effect is illustrated below:

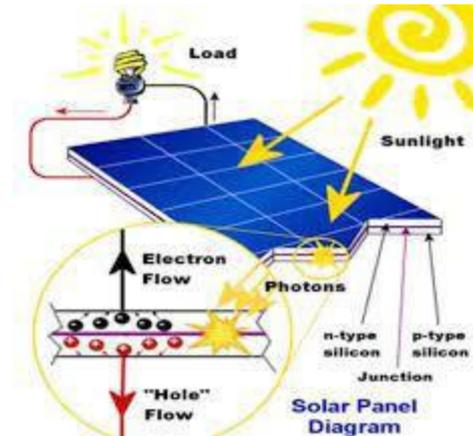


Figure 1: Diagram of The Photovoltaic Effect (@researchgate.net)

III. MATERIALS AND METHOD

The materials used in this work include battery unit, solar panel, charge controller, inverter, Oscillator, Control Unit.

3.1 Design Specifications

The mobile solar generator was designed based on the following specifications:

- i. System Capacity (Output Power): 1000VA (1KVA)
- ii. Type of output Waveform: Modified Sine wave AC power
- iii. Output Voltage: 220-240 Volts
- iv. Output Frequency: 50Hz
- v. Battery Bank Capacity: 12Volts/40Ampere-hour
- vi. Solar Panel Specification: 30Watts
- vii. Charge Controller Specifications: PWM charge controller

3.1.1 Battery Unit

The presentation and life of an inverter relies upon its battery used. The most widely used is the deep cycle battery. The type selected for this paper is the seal lead acid battery, and it is a deep cycle 40AH battery. Lead. The battery used is rated 12V DC, 40Ah.

A 40Ah battery has ability to deliver 40A in one hour, with 1KVA i.e. 1000W, (Assuming a power factor of 0.8)

$$\text{Real Power} = \text{Power} * \text{Power Factor} \quad (1)$$

$$= 1000 * 0.8 = 800W$$

$$\text{The maximum current required at 12V is given by } I = \frac{P}{V} \quad (2)$$

Where I is the maximum current, p is the power, v is the voltage. Therefore, the maximum current required is $1000/12 = 66A$

It shows the inverter can last 2 hours on full load and last more if not fully loaded.

3.1.2 Battery Charging Unit

The battery charging the circuit uses the connected solar panel. For a 1KVA inverter to operate for one hour at maximum load, the required current is given below.

$$I = \frac{\text{rated power}}{\text{battery voltage}} \quad (3)$$

Assuming a power factor of 0.8

$$\text{Thus } \frac{1000 \times 0.8}{12}$$

Therefore, $I = 67A$ (Since the battery is 12V)

Converting the battery power to a Watt hour (Wh). Since the battery is rated 40Ah, multiplying 40Ah by 12volt will give 480Wh.

With the 30W solar panel operating at its full capacity means that it will take

$$\text{Time to fully charge the battery} = \frac{\text{Power(Wh)}}{\text{solar power rating}} \quad (4)$$

$$480Wh/30W = 16 \text{ hours to fully charge the battery.}$$

Taking an average of 7 hours of sunlight per day in Nigeria, it will take 2 days to fully charge the battery.

3.1.3 Charge Controller

The charge controller used was a PWM charge controller.

Determining the total time, the battery will serve in the absence of grid power

$$\text{The total hour} = \frac{(40AH) \times 12V}{1000VA} = 0.48\text{hrs} \quad (5)$$

Determining the rating of the solar charge controller to be used

Total current received by battery = solar charge controller current output

$$\frac{\text{battery rating in Ampere Hour}}{\text{total hour}} = \frac{40AH}{0.48H} = 83A \quad (6)$$

Assuming the efficiency of a wind charge controller is 80%

$$\text{Assume } 80\% = 0.80$$

$$\text{Therefore, rating of solar charge controller} = \frac{40}{0.8} = 50A$$

3.1.4 Oscillator

The oscillator used in this design was Pulse Width Modulation regulator control (SG3524) which was modified to sine wave using BC557 transistors. The major functional unit of the IC (SG3524) is the oscillator circuitry.

The SG3524 IC has 16pin dual-in-line-dip as shown in Figure 2 dual alternating out-put switches, current limiting and shut down circuitry, voltage stability.

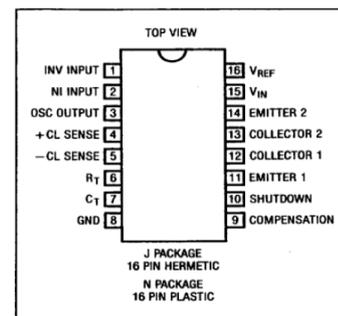


Figure 2: Diagram Showing the SG3524 IC Pin Out

In the design, the IC is supplied with 12V DC at pin 15. However, the internal circuitry of the device required 5V DC. The excess voltage is being fed to both inverting and non-inverting pins 1 and 2 error amplifier respectively via pin 16 voltage reference pin. The voltage output of the comparator sunk to the ground through pin 4 and pin 5 which are clock sense pin. The major functional unit of the IC (SG3524) is oscillator circuitry. The oscillating frequency is varied through the resistor and capacitor connected to pin 6 and pin 7 respectively. The output of oscillator is pin 3 which is a single ended pulse fed directly into a flip flop. The flip flop divides the single ended output into two and fed to NOR gate, then to transistors each attached to a NOR gate at pin 12, 11, 13 and 14, pin 14 and 11 of each transistor is grounded (emitter) while pin 12 and 13 are the output pin used for push pull application. The internal circuitry of SG3524 is as shown in Figure 2.

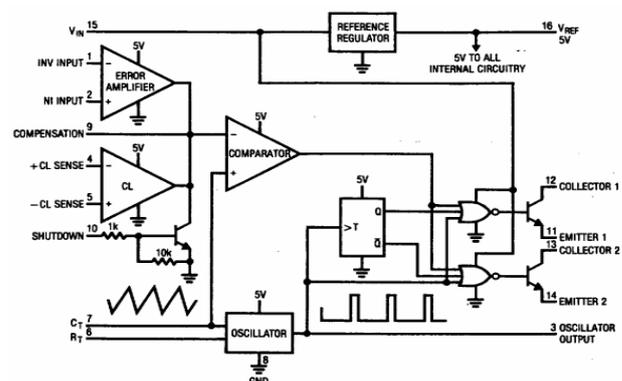


Figure 3: Diagram Showing the Internal Circuitry Of SG3524 IC

▪ Frequency Configuration of the Oscillator

SG3524 requires external synchronization for the designer to vary the pulse duration derived and consequently the frequency. The formula generated from the manufacturer of SG3524 for pulse duration is given as:

$$T = 1.1 RC \text{ (where T is in microsecond.)} \quad (7)$$

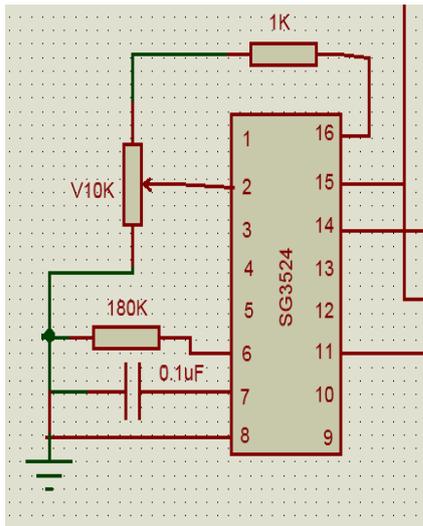


Figure 4: Circuit Diagram of the Oscillator

Thus, assuming R is chosen to be 180kΩ, which is a readily available resistance value, with capacitance value of 0.1uF, also readily available, the goal is to achieve an oscillating frequency of 50Hz which is the standard required for appliances in Nigeria.

Therefore,

$$T = 1.1 \times 180 \times 10^3 \times 0.1 \times 10^{-6}$$

$$T = 0.018\text{secs. which can be approximated to } 0.02\text{sec}$$

However, frequency (f) can be obtained using (8).

$$f = \frac{1}{T} \quad (8)$$

$$f = 1/0.02$$

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

The flip-flop divides the frequency into two i.e. F = 50Hz = 25Hz (half cycle) which will later summed at the output transformer. Resistor 10kΩ was used to drop voltage that feeds the inverting and non-inverting error amplifier at pin 1 and 2 and finally sink into the ground via pin 4 and pin 5. Pin 9 is a compensation pin and function in the case where there is error amplification.

3.1.5 Power Switching MOSFET

MOSFETs are metallic oxide semiconductors in which the gate is completely insulated from the channel by a thin (about 1dm) layer of silicon oxide. This permit operation with gate source or gate channel voltage above and below zero. The insulated gate of the MOSFET further reduces substantially the gate current, in which the gate current is less than one Pico ampere (pA). On the design, the MOSFET received 5V alternating voltage. Therefore, to OFF the MOSFET completely, the MOSFET gate was negatively biased to avoid the damage of the component, because without the negative bias, the MOSFET will not completely OFF before the arrival of the other pulses which might damage the MOSFET. In addition, 22KΩ resistor connected between the gate and the source to completely turn OFF the MOSFET. Diodes were connected across the drain of the MOSFET to avoid surge at reverse direction, which might also damage the MOSFET.

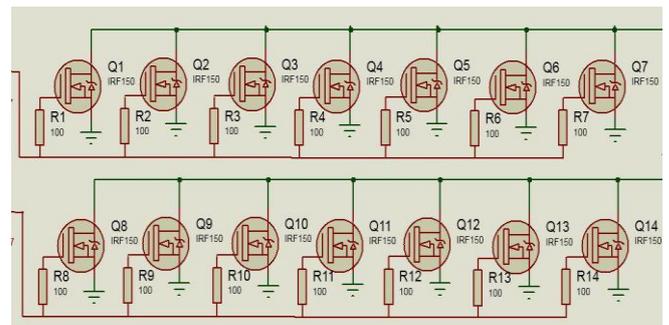


Figure 5: Circuit Configuration of the MOSFET

▪ MOSFET Design Calculation

A voltage level of 5V was fed from preamplifier to the switching MOSFET that makes $V_{GS} = 0$ at self-bias. Thus, the gate current can be obtained as:

$$I_G = \frac{V_H - V_{GS}}{R_b} \quad (9)$$

Where, V_{GS} is the gate to source voltage, V_H is the preamplifier voltage level, and R_b is the gate resistor. Thus,

$$I_G = \frac{5-0}{100} = \frac{5}{100} = 0.05\text{Amp}$$

If $V_G = 5V$ at V_H

Therefore:

$$\text{Drain Current} = D_i$$

$$\text{Since drain current} = \frac{V_{DD}}{R_D} \quad (10)$$

RD = the reactance of the coil of the transformer.

Therefore, the reactance of the coil must be known.

Since L (inductance) is not noted

$$\therefore X_L = \frac{V}{I}, V = 12 \text{ and } I = ?$$

Targeted power rating = 1KW = P = IV

$$1000 = 12 \times I$$

Assuming 0.8 power factor

$$\frac{1000 \times 0.8}{12} \text{ There for } I = 66A$$

The IRF150 has capacity of 40 Amp, therefore the MOSFET should be arranged in parallel to compensate for the current.

$$\text{If } X_L = \frac{V}{I} = \frac{12}{100} = 0.12\Omega$$

At 50Hz the reactance of the coil was noted to be 0.12Ω . Hence, RD = 0.12Ω

$$\text{Drain current} = Di = \frac{V_{DD}}{R_D} = \frac{12}{0.12} = 100Amps$$

The arrangement of three IRF150in parallel will give total of 200A and the full load actually require 100A which is the reason why three MOSFET are connected in parallel to form the push pull configuration.

3.1.6 Transformer Design

A transformer is a static (stationary) piece of apparatus by means of which electric power in one circuit transformed into electric power of the same frequency in another circuit. It can raise or low the voltage in a circuit in response to ratio of the coil at the primary and secondary winding but with a corresponding decrease or increase in current. The transformer used here is a step-up transformer from 12V to 230 V AC.

Transformer Design Calculation

The transformer calculation was carried out on the assumption that there is no power loss. Assuming no power loss, the rated power of the inverter is equal to the output power. Thus recall that input current = 66A,

Let E_s = Emf of secondary side of the transformer = 220V
 E_p = Emf of primary side of the transformer = 12V
 N_s = number of turns in secondary side of the transformer = 580turns
 N_p = number of turns in primary side of the transformer = ?

Also, transformer ratio (K) is given as in (11).

$$K = \frac{E_s}{E_p} = \frac{N_s}{N_p} \quad (11)$$

$$\frac{230}{12} = 19.2 = K$$

Given that the number of turns of the secondary side (NS) =580 turns

To find N_p i.e. number of turns in primary side

Given $E_p = 12V, E_s = 230V$

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

$$N_p = \frac{E_p}{E_s} \times N_s = \frac{12}{230} \times 580 = 30 \text{ turns}$$

To achieve the impedance of the coil the parameters are noted:

Secondary coil turns = 580 turns
 Primary coil turns = 30 turns
 Secondary Voltage = 230V
 Primary Voltage = 12V
 Secondary current = ?
 Primary current = 66A

The secondary current obtained by the current that runs through the source to the drain of the MOSFET. This help in powering the transformer, because the transformer is the RL (Load resistor of the MOSFET).

∴ Is (primary current) is given by transformer ratio:

$$\frac{I_p}{I_s} = \frac{V_s}{V_p} = I_p \quad (12)$$

$$= \frac{12 \times 66}{230} = 3.4A$$

∴ Secondary current = 3.4A

Power efficiency = power input = power output

$$\begin{aligned} \text{Power efficiency} &= 12 \times 100 = 230 \times 3.4A \\ &= 782W \end{aligned}$$

If primary reactance $X_{sr} = \frac{V}{I} = \frac{12}{66}$

$$= 0.18$$

∴ Inductance of the primary coil

$$\begin{aligned} X_L &= 2\pi fL \quad (13) \\ &= 0.12 \end{aligned}$$

$$= 2 \times 3.142 \times 50 \times L$$

$$L = \frac{X_L}{2\pi f} = \frac{0.12}{2 \times 3.142 \times 50}$$

$$L = 0.382 \times 10^{-3} \text{H}$$

Inductance of the primary coil

$$X_L = \frac{230}{5.45} = 42.20\Omega$$

$$X_L = 2\pi fL$$

$$X_L = 2 \times 3.142 \times 50 \times L$$

$$L = \frac{42.20}{2 \times 3.142 \times 50}$$

$$L = 0.134 \text{H}$$

Therefore, the resonant factor (Q) = $\frac{\omega L}{R_{dc}}$ (14)

Where R_{dc} = dc pure resistivity

DC resistivity for secondary coil is 1.6Ω

DC resistivity for primary coil = 2.5Ω

$$\frac{2\pi fL}{R_{dc}} = Q - \text{for primary coil} \quad (15)$$

$$\frac{2 \times 3.142 \times 50 \times 0.382 \times 10^{-3}}{1.6}$$

$$= 0.075$$

$$Q \text{ factor for secondary coil} = \frac{2 \times 3.142 \times 50 \times 0.134 \times 50}{2.5} = 16.84$$

Hence, impedance for secondary coils,

$$R = Q \times X_L \quad (16)$$

$$R = 0.075 \times 0.072$$

$$R = 0.0054\Omega$$

Impedance for primary coil

$$= Q \times X_L$$

$$= 16.84 \times 0.12$$

$$= 2.02 \Omega$$

3.1.7 Control Unit

This unit is made up of AVR microcontroller ATMEGA16 which performs the control function of the mobile solar generator. It also monitors the two temperature

sensors, AC and DC voltage level, switching of the relays, control the cooling fan, oscillator and display all necessary information on the LCD. ATMEGA16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATMEGA16 achieves, through approaching 1 MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed. ATMEGA16 has 131 powerful instructions most single-clock cycle execution, 32×8 general purpose working Registers, fully static operation, up to 16 MIPS throughput at 16 MHz, 16 Kbytes of In-System self-programmable flash program memory, 512 bytes EEPROM, 8-channel 10-bit ADC, 1 Kbyte Internal SRAM, Byte-oriented Two-wire serial interface, programmable serial USART, Master/Slave SPI Serial Interface, programmable watchdog timer.

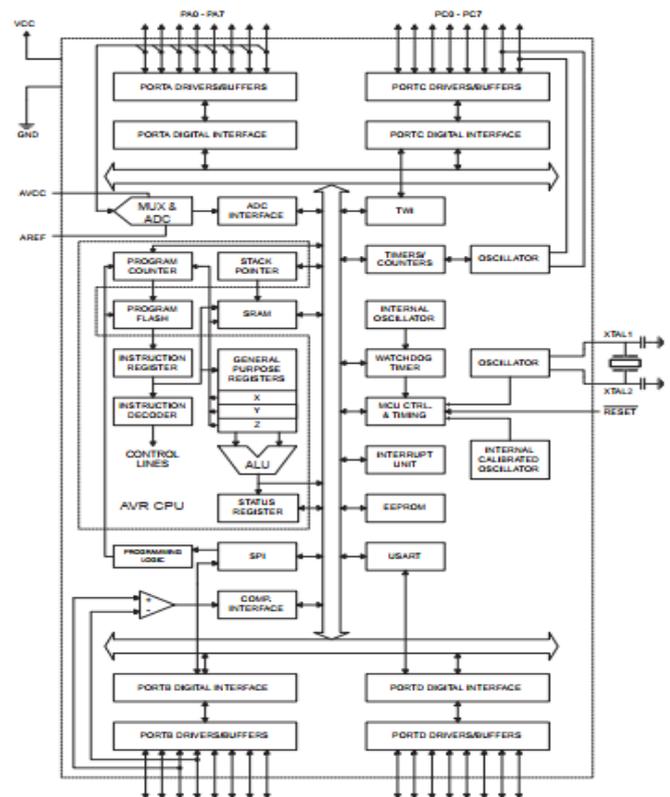


Figure 6: The Internal Block Diagram for ATMEGA16

SOURCE CODE for the automated control operation only

```

/*****
*****

* Program for sine wave generation using ATMEGA16
*
*/
unsigned char sin_table[32]={0, 25, 49, 73, 96, 118, 139, 159,
177, 193, 208, 220, 231, 239, 245, 249, 250, 249, 245, 239,
231, 220, 208, 193, 177, 159, 139, 118, 96, 73, 49, 25}; int

```

```
duty=0; float fb_constant=0.8; bit alt; bit inv_mask; void
Interrupt() iv 0x0004 ics
```

```
ICS_AUTO
{ if (TMR2IF_bit == 1)
{
    duty++;
    if(duty>=32)
    {
        duty=0;
        alt=~alt;
        CCPR1L = 0;//inverter shutdown
        CCPR2L = 0;
        RC0_bit=0;
        RC3_bit=0;
        asmnop;
        asmnop;
    }
    if(inv_mask)
    {
        if(alt)
        {
            CCPR1L = sin_table[duty]*fb_constant;
            CCPR2L=0;
            RC0_bit=1;
            RC3_bit=0;
        }
        else
        {
            CCPR2L = sin_table[duty]*fb_constant;
            CCPR1L=0;
            RC0_bit=0;
            RC3_bit=1;
        }
        }
    else
    {
        CCPR1L = 0;//inverter shutdown
        CCPR2L = 0;
        RC0_bit=0;
        RC3_bit=0;
    }
    TMR2IF_bit = 0;
}
}
int k=0; unsigned int battery=0,output=0; bit lcd_clr; char
msg[]="000";

void main()
{
    TRISA=0xFF;//all input
    TRISC = 0x00;//all output
    PORTC=0x00;
```

```
RC4_bit = 1;//for LCD backlight
ADC_Init();
PR2 = 249;
CCP1CON = 0x4C;
CCP2CON = 0x4C;
TMR2IF_bit = 0;
T2CON = 0x2C;
TMR2IF_bit = 0; TRISC = 0;
TMR2IE_bit = 1;
GIE_bit = 1;
PEIE_bit = 1; UART1_Init(9600); while(1)
{
    RC4_bit = 1;
//switch operation
    if(!RA4_bit)
    {
        inv_mask=1;
        lcd_clr=1;
    }
    else
    {
        inv_mask=0;
        if(lcd_clr)
        {
            lcd_clr=0;
            Delay_ms(1000);
        }
    }
//read output
    output=0;
    for(k=0;k<20;k++)
    {
        output+=ADC_Get_Sample(3);
        Delay_ms(1);
    }
    output/=20;
    if(output<100)
    {
        if(fb_constant<0.7)fb_constant+=0.1;
    }
    if(output>115)
    {
        if(fb_constant>0.5)fb_constant-=0.1;
    }
    }
}
// end
```

3.1.8 Complete Inverter Circuit Diagram

The complete inverter diagram is shown in Figure 7 which shows all the interconnection between all the components involved.

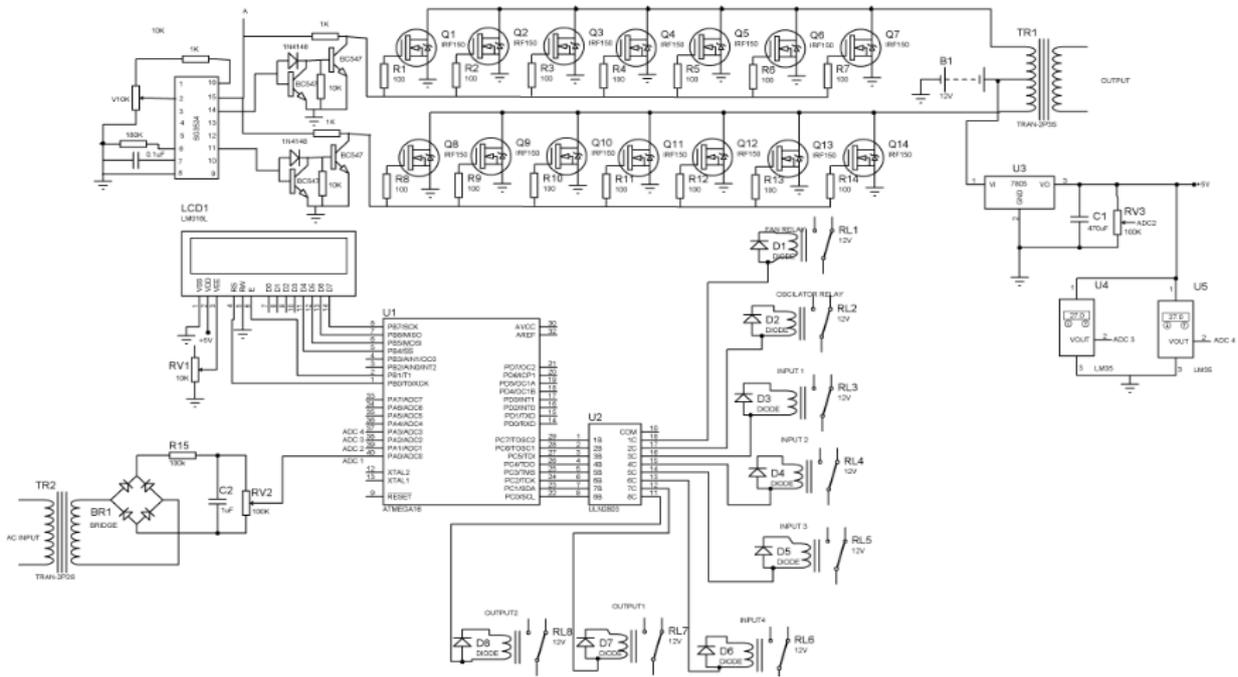


Figure 7: Complete circuit diagram of 1kVA Solar Inverter

IV. RESULTS AND DISCUSSION

With the components acquired, it became imperative to combine this solar power grid into a portable setting. It was achieved in different stages: Figure 6 shows assembled solar power grid. Figure 7 shows fully functional 1KVA Solar generator for Nigeria University laboratories.

4.1 Testing Of the Entire System and Result

The inverter delivered a maximum power of 1000w when the required rated battery was used. A standing fan, laboratory kits, and a personal computer were all connected to test the capability of the generator. The summary of the analysis is given below:



Figure 8: Assembled Solar Power Grid

Table 1: Input Specifications Parameters

Input parameters	Specification	Reality
Voltage	12V DC	Correct
Current	40 Ah	Realized around 30Ah

Table 2: Quality Test of the 1Kva Solar Generator

S/No.	Testing parameter	Required	Observed
At Battery Mode			
1	No Load Output Voltage	220-240V	220V
2	Output Frequency	50Hz	50Hz
3	Full Load Output Voltage at 12V	60-80A	64A
4	Overload Protection	OPTIMUM	SATISFACTORY
5	Fan at full Load	OPTIMUM	SATISFACTORY
6	Short Circuit Protection	OPTIMUM	SATISFACTORY

V. CONCLUSION

The application of our knowledge of engineering in solving our local problem is one thing desperately needed in our country today. That is the opportunity this project offered us; by the implementation of this project, we have successfully made the department less reliant on grid supplied energy which would boost productivity.



Figure 9: Fully functional Efficient Solar Generator

REFERENCES

- [1] Anene, G. and Ekpunobi, A. J. (1997). Modern Physics and Relativity, *For Science and Engineering Students*. 97-98.
- [2] Awake, (2003). A Journal Publication of Watch Tower Bible and Track Society. *Pennsylvania*, 21.
- [3] Cassedy, E. and Grossma, P. Z. (2008). Introduction to Energy Resources Technology and Society. *Cambridge University Press, New York*, 311, 52-53.
- [4] Esper, A. (2018). Solar Energy, Energy for Biological System, *UNESCO/FAO Working Group* .67 – 69.
- [5] Ifeagwu, N.E., Alor, M., Ugwu, C.I. (2016a). Performance Analysis of Better designed pure sine wave Inverter in Mitigating Frequent power outages in Nigerian Homes. *International Journal of Trend in Research and Development*, 3(4), 515-519.
- [6] Ifeagwu, N.E, Alor, M., Ugwu, C.I. (2016b). Designing a secured Private Network Connection across a Public Network. *International Journal of Trend in Research and Development*, 3(4), 509 -514.
- [7] Ifeagwu, E.N., Alor, M., Obi, P.I., Ejiofor, H.C., Okoro, K.C.(2015a). Improving Signal Reception in CDMA20001x Network Using Antenna Diversity Technique. *International Journal of Engineering and Innovative Technology*, 4(11), 56-59.
- [8] Ifeagwu, E.N., Ogu, C.J, Alagbu E. (2015b). Enhancing the performance of Wideband Code Division Multiple Access(WCDMA) network using antenna diversity. *American Journal of Computer Science and Information Technology* 3(1), 14-25.
- [9] Ifeagwu, E.N., Obi, P.I., Ejiofor, H.C., Okoro, K.C. (2015c). Analysis of base Station Adaptive Antenna Array Performance in CDMA 20001x Mobile Radio Network. *International Journal of Computer Science Trend and Technology*, 3(3), 114-121.
- [10] Ltonel, W. (2002). *Electrical/Electronic Engineering*, 1, 312-318. *Palgrave, London*.
- [11] Sangwine. S.J. (1994). *Electronic Components and Technology*, *Stanley Thorne's Publishers Ltd, UK*. 80, .51, 105.
- [12] Theraja, B.L. and Theraja, A.K. (1999). *Textbook of Electrical Technology, (Twenty-Second Edition)*, *Prentice Hall Inc*. 117.

Citation of this Article:

Ifeagwu Emmanuel N., & Ejimofor Ihekeremma A.U. (2024). Efficient Power Outage Solution in Nigeria University Laboratories Using Micro-Controller Based Portable Solar Generator. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 8(10), 85-93. Article DOI <https://doi.org/10.47001/IRJIET/2024.810014>
