DESIGN AND CONSTRUCTION OF AN ON-SITE MULTI- PURPOSE POWER SUPPLY DEVICE.

BY

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AUGUST 2003

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A THESIS REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY FEDERAL UNIVERSITY OF TECHNOLOGY MINNA NIGER STATE.

AUGUST 2003.

CERTIFICATION

I hereby certify that this project titled "THE DESIGN AND CONSTRUCTION OF AN ON-SITE MULTI-PURPOSE POWER SUPPLY DEVICE" was carried out by AJAYI J. ADEWALE under the supervision of Engr. M.D Abdullahi. And submitted to the department of Electrical and Computer Engineering, Federal University of Technology Minna. In partial fulfillment of the requirement for the award of Bachelor of Engineering (B.Eng), degree in Electrical and Computer Engineering.

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PROJECT SUPERVISOR

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AG. HEAD OF DEPARTMENT

DATE & SIGN

EXTERNAL EXAMINER

DATE & SIGN

DEDICATION

This project is dedicated to Almighty God for his divine favour to me and to all the people He used as instrument to affect my life positively throughout my academic carrier so far.

ACKNOWLEDGEMENT

Glory be to almighty God. It is by His special grace that I am where I am today. It is therefore imperative that I first acknowledge God's divine favor to me in all my life endeavours particularly the period of my university education and all the people he used as instrument in various ways to affect my life positively.

I am grateful to my parents Mr. Samuel Ajayi and Mrs. Juliana Ajayi for their love, concern, prayer and in flinching support. For all sacrifices they made for me.

I am highly indebted to the good nature of my able project supervisor Engr. M. D Abdullahi for his guidance in the course of research, writing and construction of my project. For taking his time and effort to oversee every detail of my project and offering constructive criticism with his characteristic simplicity, I was seriously encouraged. I say thank you sir.

My hearty gratitude goes to all my well wishers and helpers in one way or the other especially Pastor Segun Adegboye, Engr. Dickson, Engr. Joseph Durowaiye, Engr. Joshua Ogunbunmi, Mr. Emmanuel Nkatah, Engr. Obabi Abdulganiyu and to my siblings; Sayo, Tunde and Biodun. You are all wonderful for believing in me and showing so much love.

To all the Lecturers and the entire members of staff of the Department of Electrical and Computer Engineering, I want to wish you God's blessings.

I must not fail to openly appreciate my wonderful friends like Abiodun Omotoriogun, Moshood Isiaka, Adisa O. Jelil, Soyinka Sunday, Ibrahim Abdulmalik. You have been so

aring and you sympathized with me in immeasurable ways. Goodness and mercy is your portion, in Jesus Name

Finally, I wish to thank all friends for making me smile even when things were very tough. Moroof, Jejelola, Ishola, Shuaibu and others, for the reason of space I cannot include here, I hold all of you at heart.

ABSTRACT

This project report is the design and construction of an on-site multi-purpose power supply device. This aim is achieved through an analogue circuit in which 12V direct current (DC) from a car battery or photovoltaic cell (solar cell) is fed into an inverter via a voltage doubler. Alternatively, the supply could be tapped from the car alternator which constitutes the third power supply but for the purpose of doubling. The AC power form this alternator must be rectified and doubled so that it can be fed into an inverter. The three power supplies must operate at the same magnitude in order to perform the required function. The inverter is operated with 24V DC.

The resulting alternating current (AC) from the inverter is applied to the voltage transformer (step up transformer), which increases the magnitude of the input voltage from 24V to 220V and this voltage is then feed to another transformer (Distribution Transformer) which converts or transforms single phase input to three phase output. Analogue meters display the output voltage levels.

TABLE OF CONTENT

CHAPTER ONE

1.0 INTRODUCTION

The design and construction of an on-site multi-purpose power supply is one of the several efforts of the electrical engineering profession at improving comfortability, reliability and maintainability of an on-site electromechanical fabrication, construction, lighting etc in remote areas especially where electrical power supply is not available.

Electrical power (electricity) has formed a large part of human endeavours, as it is the major key factor in industrial and domestic technical operation. The production process is absolutely dependent on the electrical energy due to its cost effectiveness and its easy transformation and control. The invention of electricity came up in the 17^{th} century when Michael Faraday first performed his experiment using permanent magnet and copper wire. He discovered that whenever some a conductor passes through magnetic field, current is induced into the wire and this could be detected by connecting a voltmeter or appropriate measuring equipment to the terminal of this conductor.

After Faraday's experiment, a lot of innovations has taken place in the field of electrical especially power engineering. The increasing demand of electricity has led to commercial generation, transmission at a particular normative quality value, and distribution over a wide range with required transformation from one level to another. A lot of technicalities were adopted in achieving this and today electricity happened to be the cheapest source energy for the production processes and livelihood. No aspect of human life can be exempted from the benefits derived from electricity. Automobile, electronics, Robotic, Computer, Storage process, Cooling and heating systems to mention few take their first source of power electricity. Different means of electricity generation are available today ranging from electromechanical process and non-electromechanical process. Electromechanical power generation could be by Wind turbine, hydroelectric system, Fuel and Gas generator, Steam and Nuclear power station.

Here, mechanical machine produces rotational speed (torque), which in turn set an alternator into motion at relatively high speed and this produces electricity at the output terminal which ideally corresponds to rated power output. Non-electromechanical power generation include battery, solar cell, biomass etc. the battery is an electrochemical component which when charged, stores electricity and can be used then i.e. it can be used to power an equipment. Solar cell converts solar energy from sunlight (solar energy) into electrical energy. Both the battery and solar cell produce direct current (DC) but this can be inverted in order to drive alternating current (AC) equipments. One of the flexibility of electrical energy is that it can be transformed from one range and mode to another.

On-site work that required electrical power supply include, welding, drilling, grinding, shaping, lighting, etc. All these operations need constant and reliable power supply for their proper function. Without the transporting cumbersome power generator, on-site work could easily be organize by taking primary power source from the available means. Meanwhile, the effective service and maintenance of the power generator is obtained at maximum level provided the maximum operating capability of the system is not exceeded.

In view of the unavailability of electrical power system on most of the new sites and remote locations, this device could help in solving the problem of welding, drilling, cutting, shaping, and even supply power to test equipment like hipolotronic tester used for testing fault along underground cable as well as earthing testing equipment.

1.1 LITERATURE REVIEW

Advance in technology in general are basically centered on innovations. In the early days, electrical consumption or demand was not as high as it nowadays. Low power generation was directly proportional to lower power demand. As technological innovation is increasing the electrical demand is also increasing. For example, the cars available before the world war II run all their electrical requirement on 6Volt power supply, but with introduction of facilities like air-conditioner, electrically operated window etc, improvement has to be made which gave better performance and reliable operation of the growing number of electrical accessories.

It was discovered that the continuity of production processes in an industrial plant is constant in as much as its electrical power supply is constant. No standard electrical distribution system is adaptable to all industrial plants because two plants rarely have the same requirements. The specific requirements must be analyzed quantitatively for each plant and the system designed to meet its electrical requirements. Several basic consideration which will enhance the overall operation must be included in any approach to the problem of power generation.

Today, various means of electrical utilization has been designed both domestically and industrially, while first costs are very important, safety, reliability, voltage regulation, maintenance, and the potential for expansion must also be considered in selecting the best from alternate plans. The focus of all these considerations is to enhance confortability, and devising way to increase on-site and remote locations' electrical energy consumption as pertaining to this project. This project will seek to offer a remedial outlet for the on-site operations that requires electrical energy at its cheapest rate, which hopefully the economy of the country will be improved.

1.2 MOTIVATION

Over the years, stand-by generators are the alternative means of power generation on the site to run electrical and electromechanical operations. But under-utilization and over utilization has become the major problem of fuel generator due to the variation in diversity factor of the on-site equipments This eventually led to the development of epileptic effects in a portable electrical power generating systems.

In ideal system, different generators with different power rating are to be assigned to different operation whereby, less power will be wasted and these generators can run effectively for very long term. The consumption of not less than 75% of the total generated power is to be kept constant which enhance optimum operation of the generator. But this condition is not always fulfilled especially in a grossly illustrated society like ours where less conscious handling and improper utilization of machineries and equipment is so common, a more enhanced device that will provide a better services with less obscurity will be more appropriate, this is what motivated me on for this project.

1.3 OBJECTIVE

The objectives of this project work will therefore include.

1 To design and construct a simple low-cost device that will enhance easy machine operation and fabrication work on the site and remote areas where electrical power is not readily available.

2 To form the basic foundation of multi-output electrical power transformation in a simplified form.

3 To create awareness in electrical design in power transformation and stimulate students interest in research in the fast growing field of electrical power transformation and distribution.

4 To demonstrate a less cumbersome inductive training for students and concerned persons toward self-reliance through self-employment after school, by engaging in mass production of this device that suit different purposes.

5 To explain briefly the simplicity and flexibility of various power transformation.

1.4 PROJECT LAYOUT

CHAPTER ONE

This chapter introduces the project and reviews related development to the design and construction of a on-site multi-purpose power supply device, the motivation for the work and its objectives.

CHAPTER TWO

This chapter begins with theories related to the design of the system, the design, its analysis and calculations.

CHAPTER THREE

The construction and testing of the entire work is reported in this chapter.

CHAPTER FOUR

Discuses results obtained, provides recommendations as regard the work. The final conclusions based on findings in the course of the work are included here.

CHAPTER TWO

THEORY AND DESIGN ANALYSIS

2.0 INTRODUCTION

In order to design and analyze the entire circuit, it was broken down into seven groups namely: source A, source B, source C, grid power monitor, 24V inverter circuitry, step-up transformer and distribution transformer. Figure 2.11 below shows a block diagram of the on-site multi-purpose electrical supply.

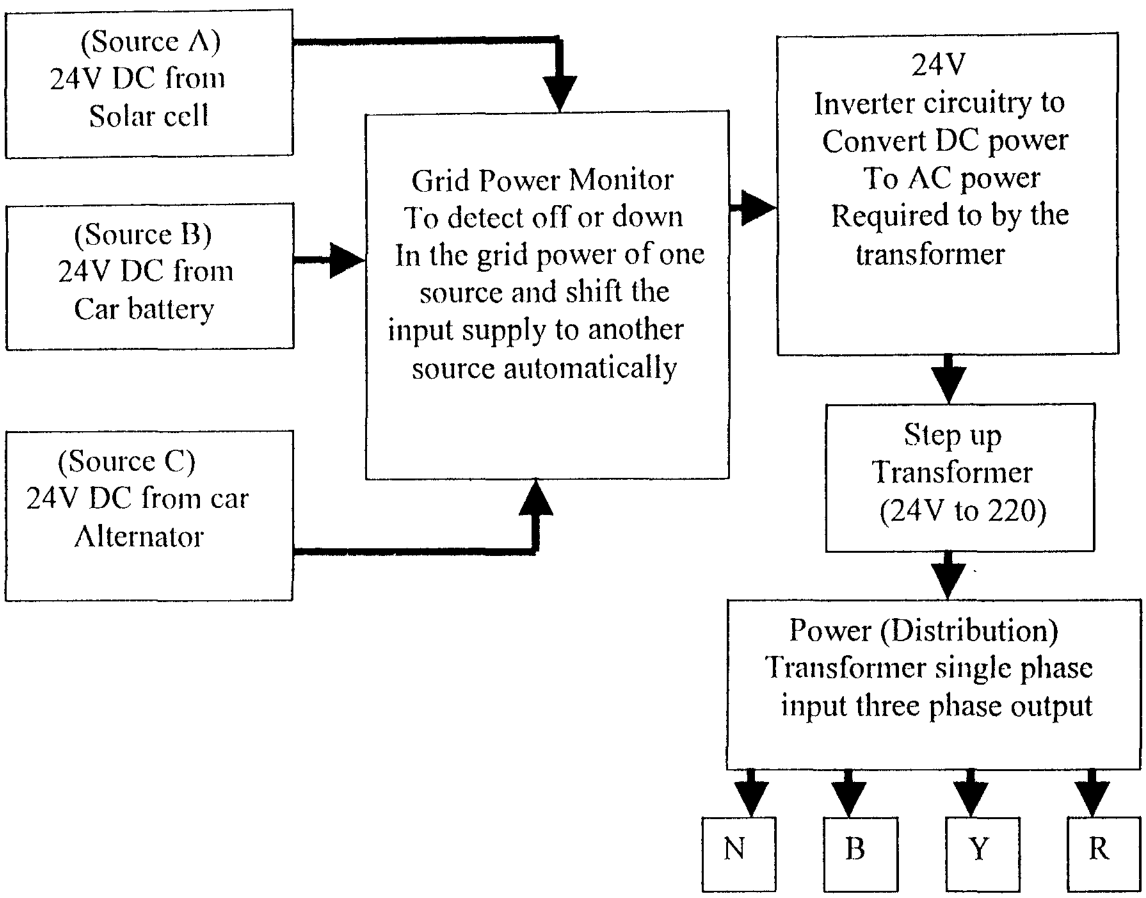


Fig 2.11 A Block Diagram of On-site Multi-purpose Power Supply Device.

2.10 SOURCE A, PHOTOVOLTAIC CELL.

This is a 24V direct current source from a solar panel (photovoltaic cell). This is a material produced from crystalline silicon, either in mono-crystalline or, more recently, semi-crystalline form. The essential features of this type are shown in figure 2.1. It is made from a thin wafer of high purity silicon, doped with a minute quantity of boron. Phosphorus is diffused at a high temperature into the active surface of the wafer. A metallic grid makes the front electrical contact and the back contact usually covers the whole surface. An anti-reflective coating (ARC) is applied to the front surface.

The phosphorus introduced into the silicon gives rise to an excess of what is known as conduction band electrons and the boron an excess of valence-electron vacancies or 'holes', which act like positive charges. At the junction, conduction electrons from the n (negative) region diffuse into the p (positive) region and combine with holes, thus canceling their charges. The area around the junction is thus depleted in charge by the disappearance of electrons and holes close by. Layers of charged impurity atoms (phosphorus and boron), positive in the n region and negative in the p region, are formed either side of the junction, thereby setting up a "reverse' electric field.

When light fall on the active surface, photons with energy exceeding a certain critical level known as the bandgap (1.1 electron-volts in the case silicon) interact with the valence electrons and elevate them to the conduction band. This process leaves 'holes', so the photons are said to generate 'electron hole' pairs depending on the intensity and spectral distribution of light. The electrons move throughout the crystal lattice and the less mobile holes also move by valence-electron substitution from atom to atom. Some recombine, neutralizing their charges, and the energy is converted to heat. Others reach the junction and are separated by the reverse field, the electrons being accelerated to the negative contact and the holes towards the positive. A potential difference, or open-circuit voltage (Voc), is thus established across the cell, which is capable of driving a current through an external load.

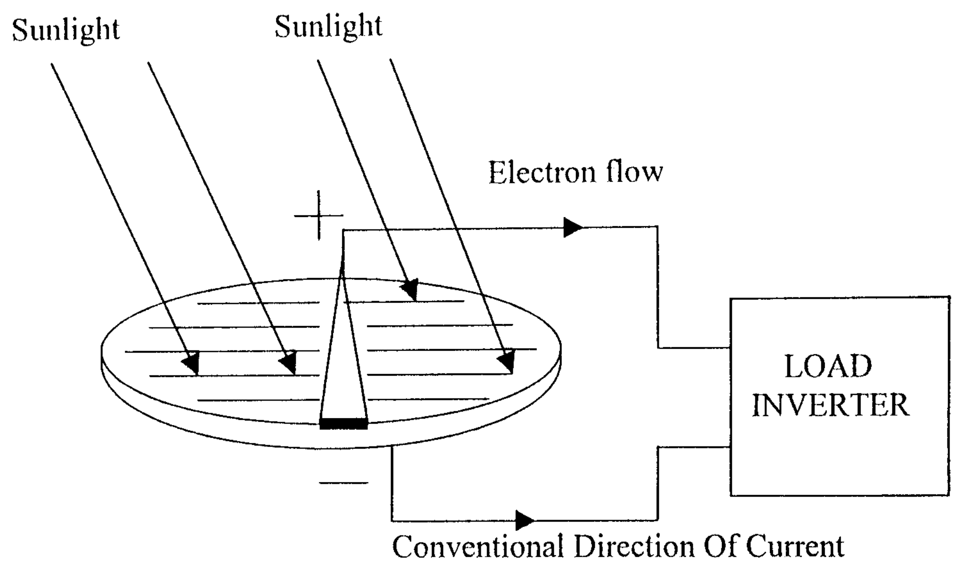


Figure 2.10 Crystalline Silicon Photovoltaic cell.

The cell efficiency is the ratio of the maximum power to the product of gross cell area and irradiance, usually express as a percentage. The photovoltaic process, like other energy conversion process, is subject to a maximum efficiency depending on the physical characteristic of the materials. The achievement of improved working efficiencies, closer to the practicable maximum, is therefore a major objective of research and development work.

Solar cells can be interconnected in series and in parallel to achieve the desired operating voltage and current. The basic building block of a flat-plate solar array is the module in which the interconnected cells are encapsulated behind a transparent window to the cells from the weather and mechanical damage.

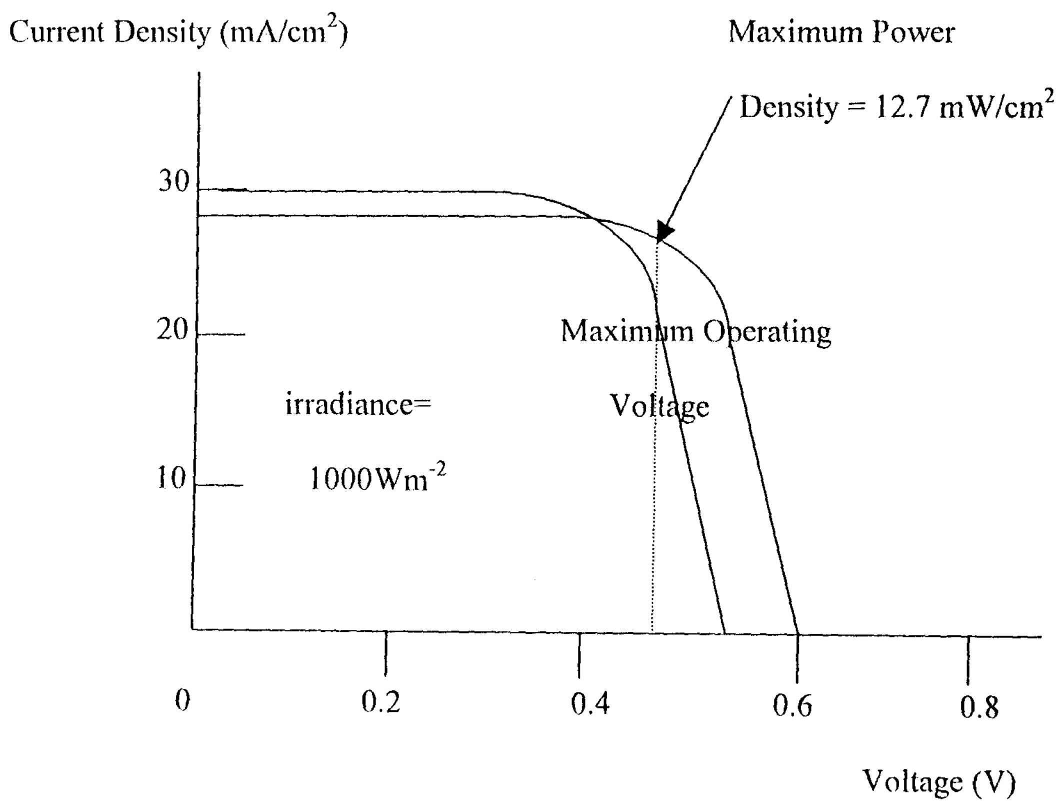


Figure 2.11 a. EFFECT OF CELL TEMPERATURE ON V-I CHARACTERISTIC

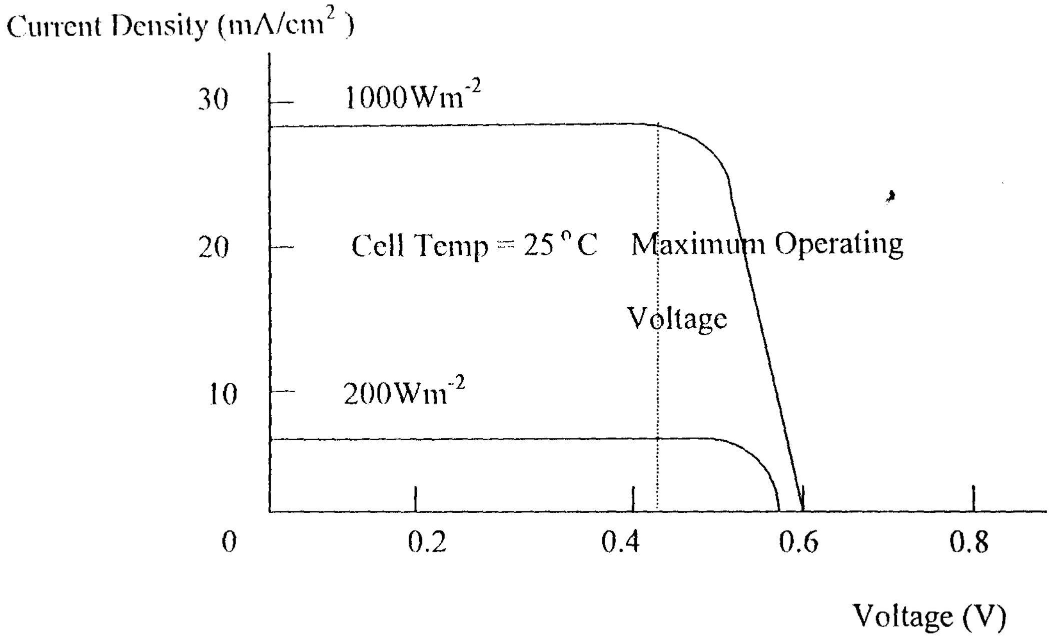


Figure 2.11b. EFFECT OF CHANGE IN IRRADINCE ON V-I CHARACTERISTIC

Figure 2.11a and 2.11b. Typical V-I Characteristics curves

The current-voltage relationship (I-V) characteristic for a typical cell is dependent on irradiance and temperature, as illustrated in figures 2.2a and 2.2b above. For crystalline silicon cells, when illuminated by light with intensity 1000 W/m^2 AM i.5 direct spectrum, at 25^{0}C, the open-circuit voltage (Voc) is about 0. .6V and the short-circuit current (Isc) about 30 mA/cm^2 the series connection of several numbers of photovoltaic cell gives the required voltage capable of exciting a particular load.

2.20: SOURCE B, CAR BATTERY

This is an electro-chemical equipment in which electrical power is being generated by the chemical reaction-taking place in the container. There are two major groups of this equipment namely: Dry Cell Batteries and Wet Cell Batteries. Each of them has specific areas of application. For the purpose of this project, a particular type of wet cell batteries otherwise known as the lead-acid storage batteries will be considered because of its relative degree of flexibility and maintenance.

A lead-acid cell consists essentially of positive plates containing lead peroxide and negative plates containing pure lead immersed in an electrolyte of dilute sulfuric acid. The action of a lead-acid cell when discharging is similar to that of a primary cell, except that the materials of the electrodes, which undergo the chemical reactions, are not dissolved but remain in much the same mechanical condition as before discharge. When this requirement is fulfilled, the materials of the electrodes can be restored to their original condition by "recharging" or passing a current through the cell in the reverse direction to that of the discharge current. In this way the electrical energy of the charging current is transformed into chemical energy and stored as such in the electrodes.

As there is no loss of materials during the discharge of such a battery to expose fresh materials to chemical action, it is necessary that the active materials of the electrodes either be disposed in a very thin layer over a large surface or be porous to permit the use of the interior part of thick materials. In accordance with common engineering practice the terms positive and negative plates are employed in this article to denote the plates, which are connected to the positive and the negative terminals, respectively, of the external circuit on both charge and discharge. The term battery is employed to denote a group of two or more cells, which constitutes an operating unit.

Chemical Reactions. The active elements of the lead-acid type of battery consist of lead peroxide (PbO_2) on the positive plate, spongy lead (Pb) on the negative plate, and dilute sulfuric acid (H_2SO_4) for the electrolyte. Whatever the secondary reactions may be, it is agreed that the final result on discharge is the formation of lead sulfate ($PbSO_4$) on both the positive and the negative plates, the SO_4 radical of the sulfuric acid combining with the lead of both plates to form this compound. As a result some water (H^2O) is formed, with a consequent decrease in the lead sulfate ($PbSO_4$), returning the SO_4 radical to the electrolyte, oxidizes the positive plate to its original condition of lead peroxide (PbO_2), and reduces the negative plate to its original condition of sponge lead (Pb). This action may be represented as follows:

$$\underset{+\text{plate}}{PbO_2} + 2H_2SO_4 + \underset{-\text{plate}}{Pb} \rightleftharpoons \underset{+\text{plate}}{PbSO_4} + 2H_2O + \underset{-\text{plate}}{PbSO_4}$$

This equation, read from left to right, is the equation of discharge; read from right to left, it is the equation of charge. In practice, toward the end of charge, some of the water (H2O) is split up by the current into its component parts, hydrogen (H) and oxygen (O), the hydrogen being librated at the negative plate and the oxygen at the positive plate. This occurs whenever the density of charging current is greater than can be utilized in decomposing the lead sulfate remaining in the plates.

A typical example of lead-acid battery is shown in the figure below.

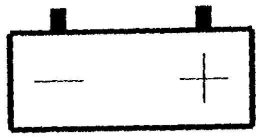
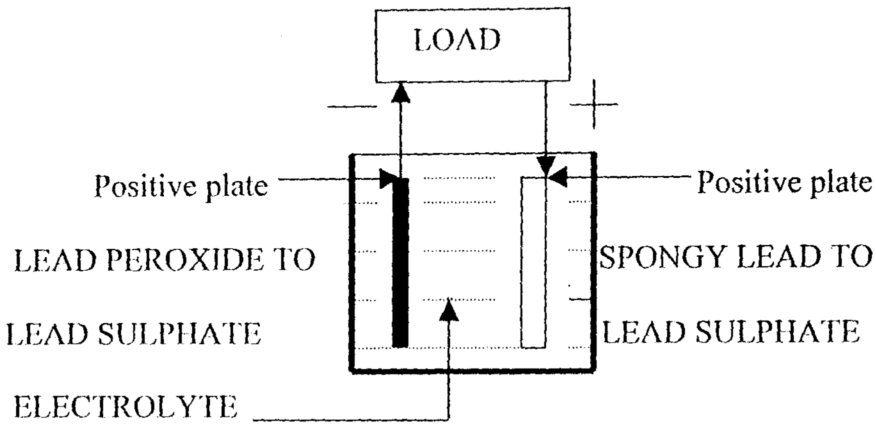
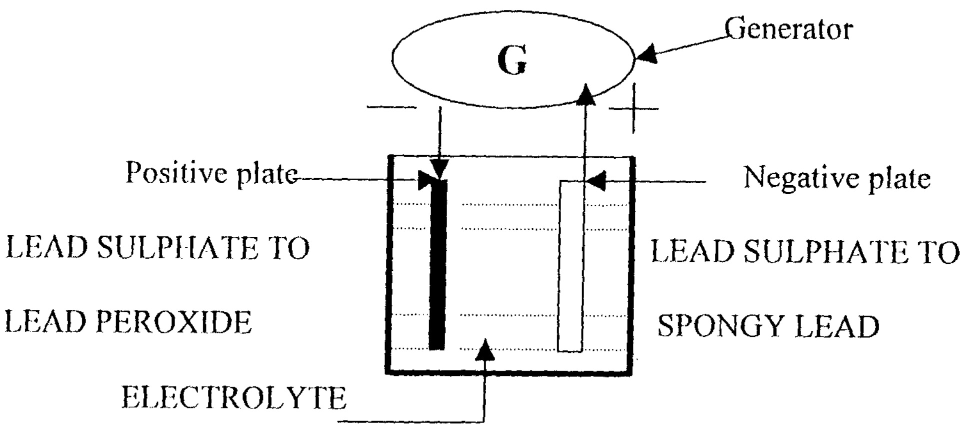


Fig 2.21 BATTERY



(a) Discharging



(b) Charging

Figure 2.22 (a) and (b)

2.30: SOURCE C, CAR ALTERNATOR

This is an electro-mechanical device, which rotates both clockwise and anticlockwise to deliver rated electrical power to an output device (load). The excitation for this device is by torque (mechanical power) produced by an engine basically petrol or diesel in an automobile. Alternator generate an alternating current and give a useful output even at idling speed, a typical figure being 45 Amps at the voltage of 14.5 V, this output being possible because of the higher- than – normal pulley ratios and hence rotational speed of the generators. The high output make the alternator ideal for vehicles, which operate under abnormal conditions such as door-to-door delivery and public service vehicles. The increasing amount of electrically driven auxiliary equipment is also causing heavy demand on the charging circuit.

To convert AC to DC, alternators need rectifier but modern alternators have in-built silicon rectifier. Rectifiers remove the need to have an automatic cutout as they stop current flowing from battery to alternator. a separate current regulator is not required as the maximum output of the alternator is self-regulated, and since there is no commutator or heavy current carrying brush gear and no lubrication is required, maintenance is kept to a maximum. The diagrams below are typical alternators in a running mode.

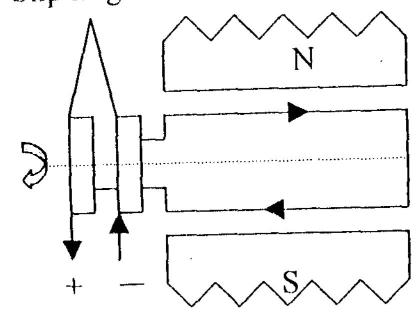


Figure 2.31 (a)

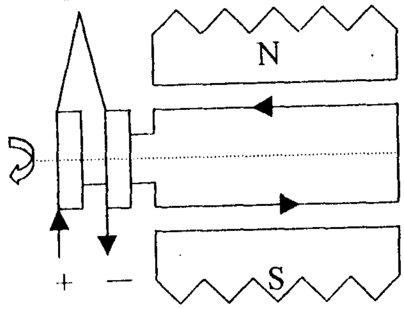


Figure 2.31 (b)

2.40 GRID POWER MONITOR

This is the combination of electric brain (Relays), connected in series. They have the ability to sense low or absolute cut-off in the grid power from one supply and automatically change the source of supply from the one with higher priority to the one of lower priority. In this project, sun is considered to have the highest priority because of its availability and cost nothing to tap except the tapping equipment.

The most appropriate type relay used in this project is induction relay. This operates on the same principles as the induction motor. Torque is produced by subjecting a moving conductor to two alternating fields, which are displaced in both space and time. The moving conductor is typically a metal disc which is pivoted so as t be free to rotate between the poles of two electromagnetic flux and eddy currents induced in the disc by the lower electromagnetic flux, and vice versa.

The torque produced is proportional to the product of upper and lower electromagnetic fluxes and the sine of the angle between them. $T \infty\ Q_aQ_b \sin A$. where

∞ Stands for proportional. This means that maximum torque is produced when the angle between the fluxes is 90^0 and as Q_a and Q_b are proportional to I_a and I_b $T \infty I_a I_b \sin A$. The diagram below shows a typical induction relay.

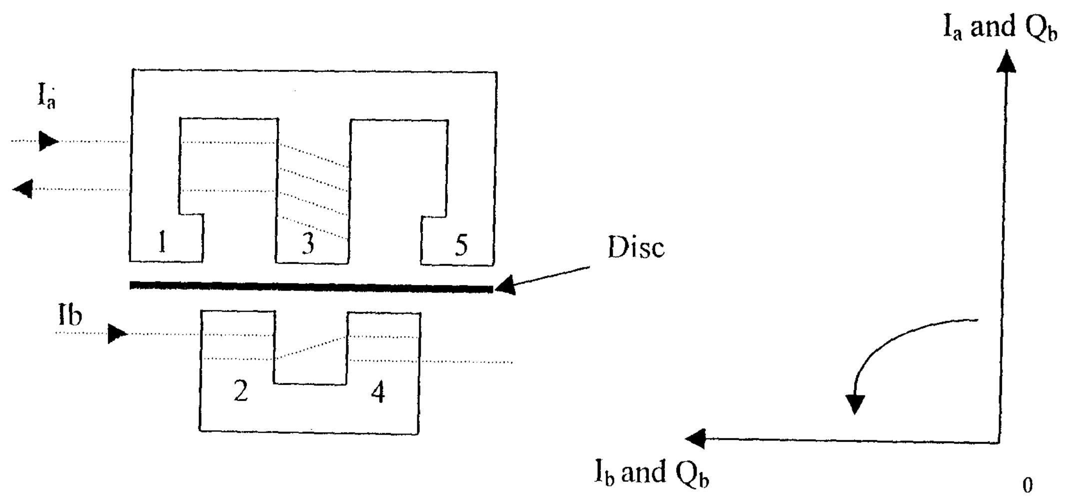


Figure 2.41 (a)Induction Relay Electromagnet System (b)Vector relationship for maximum Torque

2.50: 24-VOLT DC INVERTER

The purpose of an inverter is to convert a source a power into different voltage or frequency. In this case it will convert twenty-four volts DC into twenty-four volts AC. Basically this is just a high power sloppy oscillator. In order to analyze the entire circuit very, it is subdivided into three subsystems namely: Inverter 12 Volt logic supply subsystem, Inverter phase generator subsystem and inverter power circuit subsystem. Figure 3.11 below shows a block diagram for the 24 Volt DC inverter.

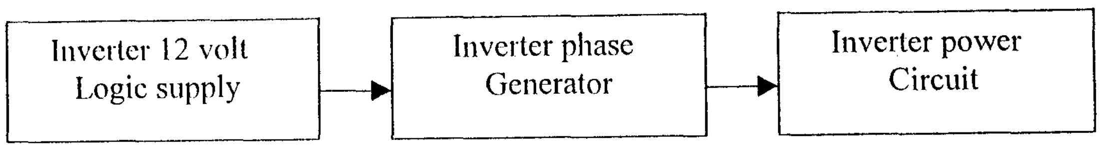


Figure 2.51. A Block Diagram 24Volt DC inverter

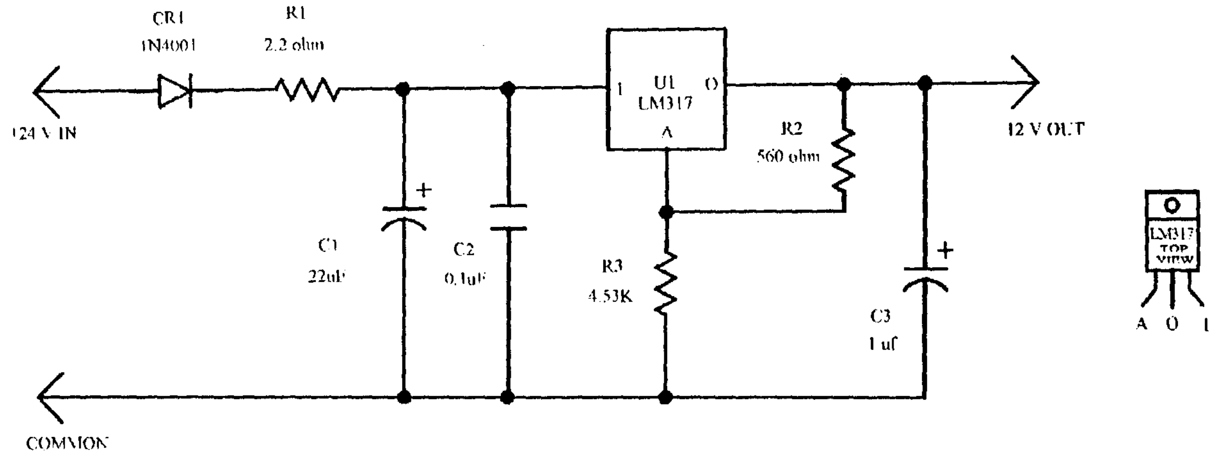
Inverter 12 Volt logic circuit

The purpose of the power supply circuit is to reduce the twenty-four volt source voltage something usable by four thousand series integrated circuits and to isolate the logic circuits from any noise the inverter will introduce to the twenty-four volt source. The circuit for 12V logic circuit otherwise known as 12 Volt regulator is shown in the diagram below. First R1 will limit the surge current into the filter capacitor C1. C1 will hold the voltage supplied to U1 when the source contains noise spikes pulling it below the minimum for U1. CR! Will prevent the inverter from pulling current from C1. C2 has been added to shunt very high frequency noise present on the supply line.

The regulator IC U1 is an adjustable 3-terminal positive voltage regulators capable of supplying in excess of 1.5 A over a 1.2 V to 37 V output range. They are exceptionally easy to use and require only two resistors to set the output voltage.

Further, both line and load regulation are better than standard fixed regulators. In addition to higher performance than fixed regulators, the LM317 offers full overload protection. In operation, the LM317 develops a nominal 1.25V reference voltage, VREF, between the output and adjustment terminal. the IC's reference voltage is impressed across program resistor R2 and, since the voltage is constant, a current the flows through the output set resistor R3, giving an output voltage of Vout=(1.25)(1+(R3/R2)+(0.1mA*R3). Since the 0.1 mA current from the adjustment terminal represents an error, the LM317 was designed to minimize the "A" terminal current and make it very constant with line and load changes. To do this, all quiescent operation current is returned to the output terminal establishing a minimum load current requirement. If there is sufficient load on the output terminal, the output voltage will rise. C3 has been added to improve the transient response of the regulator.

Figure 4.12 below shows the circuit diagram of a 12 volt regulator.



F48 p1 12 volt regulator

Figure.2.52 Inverter 12 Volt logic circuit

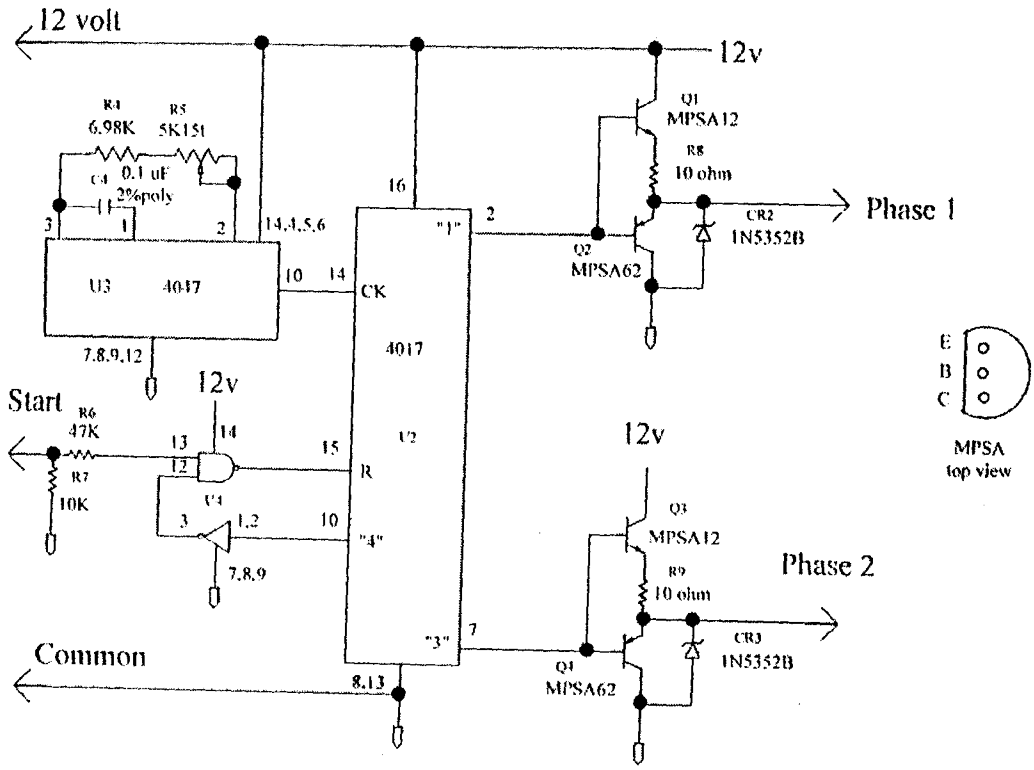
Inverter phase generator

This inverter circuit will produce what is referred to as Psudo-sine wave. That means that it is a partial duty square wave with the same peak-to-peak amplitude as a sine wave and the shape of a square wave. As it turns out, to have the same peak-to-peak voltage with the same area under the curve as a sine wave the duty cycle is fifty percent. That means for each cycle the driver circuit is active for fifty percent of the time.

The phases being a stable time base. This is provided with U3, R4, R5, and C4. U3 is configured as an astable multivibrator with the timing components R4, R5, and C4. The resistors are 100ppm one percent and the capacitor is polyester to enhance stability. R5 is adjusted to give an output of 240 hertz or four times line frequency.

The output of the multivibrator drives a four state decoded output counter configured from a divide by ten counter. The invalid output value of four is gated back to the reset terminal through an inverter and a nand gate that provides an "or" function with the start signal. When the counter reaches the invalid value or when the start signal s low the counter is held in the reset condition. The phase outputs are taken from the "1" and "3" counts. This produces the two fifty percent signals that both will be low, or off when the counter is reset

The two outputs of the counters are then buffered using two identical circuits. Each circuit uses two push-pull Darlington transistors. There is a significant indeterminate state in this type of a driver between the high voltage and low voltage output states. However, the digital outputs of the counter go through this area very quickly. The output of this circuit will drive the power transistors of the inverter. The power transistors are MOSFET's that present very little DC load. But, the gates of MOSFET's present a very significant capacitive load. These Darlington transistors will source and sink over an ampere of current allowing this circuit to drive several MOSFET's transistor for each phase. The resistors, R8 and R9, have been inserted in the driver circuit to operate in conjunction with the gate capacitance of the power transistors to limit the turn-on time to remain within safe dv/dt requirements for the MOSFET transistors in the power section. There are no dv/dt requirements for turning off MOSFET transistors. Finally, CR2 and CR3 are fifteen Volt zener diodes that will ensure that excessive voltage will not exist on the gates of the power transistors. It is a bit of overkill since Q2 and Q3 will pull the gate signal down to the CMOS logic output voltage plus 1.2 volts. But, better safe than sorry since MOSFET transistors are very-very sensitive to excessive gate or drain voltage.



F48 p2 Phase generator

Fig 2.53 Inverter phase generator

Inverter power circuit

This is the section that actually does the work. This circuitry is mounted directly on the chassis or the heat sinks. There is a thirty Amp fuse. This will limit the input power to 720 volt-amps. This should be sufficient to prevent the fuse from blowing under most normal operating conditions. At the same time, the driver transistors can quite easily supply this much current without damage. Of course, the actual instantaneous maximum current that can pass through this fuse is in the neighborhood of ten thousand amperes. So, a sudden short across the transformer primary windings could damage the driver transistors. The MOV CR4 is to prevent excessive voltage spikes from passing through the transformer or damage the 12 Volt regulator. A V130LA20B Metal Oxide Varistor (MOV) protects each of the IRF252 driver transistors from excessive drain voltage. Since the driver transistors have a quite high voltage rating the clamping voltage of this device should provide sufficient protection.

The driver transistors are two pairs of International Rectifier IRF252. These are 200 volt 0.1 ohm 25 ampere N channel Metal Oxide Semiconductor (MOS) Field Effect Transistors (FET) in standard T03 cases. The design of the power circuit revolves around these transistors. Because of the high Drain to Source voltage rating there is no need for complicated clamping or snubbing circuits. The MOV is more than sufficient to knock down the spike on the transformer primary when the transistor turns off. Since the transistors have a very robust power dissipation rating in the T03 case, excessive heating of the chip is of little concern. Also, compared to bipolar transistors, the drive current is an infinitesimal fraction of what would be necessary without FET's. In addition, the very low on resistance of the FET's also mean that there is practically no heat generated so a very small heat sink is more than enough. There is only one small consideration not already covered in the phase generator circuitry. That is to place a small ferrite bead on the gate terminals of each transistor to prevent parasitic oscillation may occur when they are connected in parallel. The diagram below shows a typical inverter power circuit used in the course of design and construction of this project.

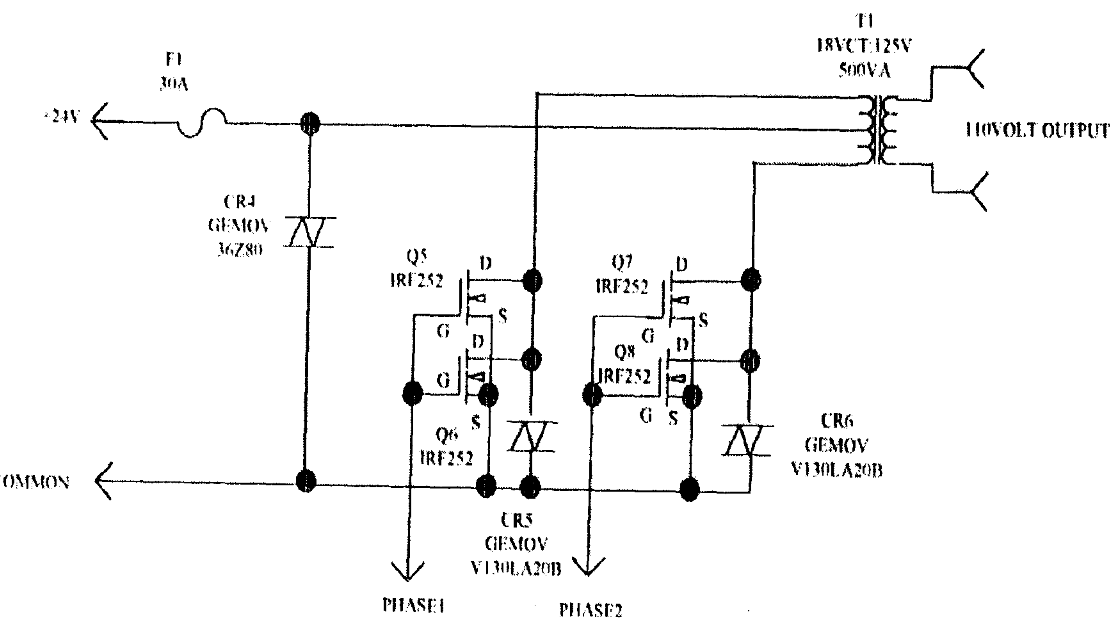


Figure 2.54 Inverter power circuit

2.60. TRANSFORMER

A transformer is a static electrical device, which electromagnetically transforms AC energy from one circuit to another. It usually changes the original voltage to a higher or lower voltage, at the same frequency. For this project, 24 Volt center tapped input and 110 Volt output which could deliver at least 0.5KVA is required. This output is then fed into another transformer to raise the voltage to 220 Volt at the same power rating rating of 0.5 KVA. A distribution transformer is then coupled to this network to raise the voltage to 415V three phase at the required power rating. This could be chosen depend on the choice of the designer but for this project, 2KVA was chosen as the sample or prototype. The figures shown below represent the internal architecture of the transformers used in this project.

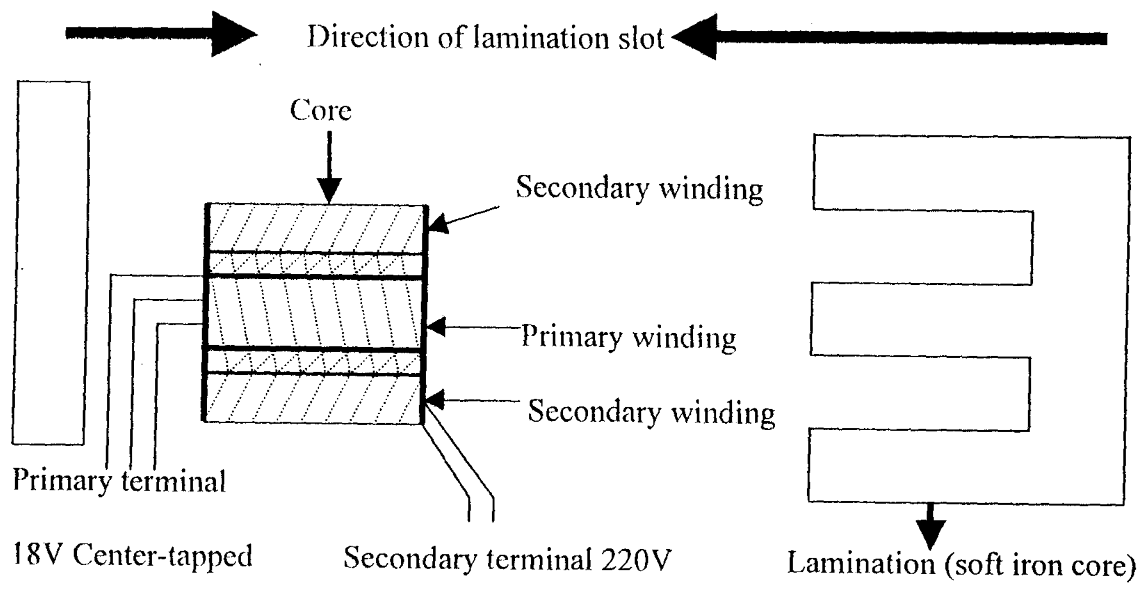


Fig 2.61 Internal Architecture of the step-up transformer (18V to 110V)

Other transformers to be used in this project have the same architecture except that there are little changes in orientation of their coil arrangement. The second transformer is single-phase input and single-phase output, and 110V input, 220V output. But the arrangement of the third transformer is quite different it is single-phase input and three-phase output. The diagram below shows the internal architecture of this transformer.

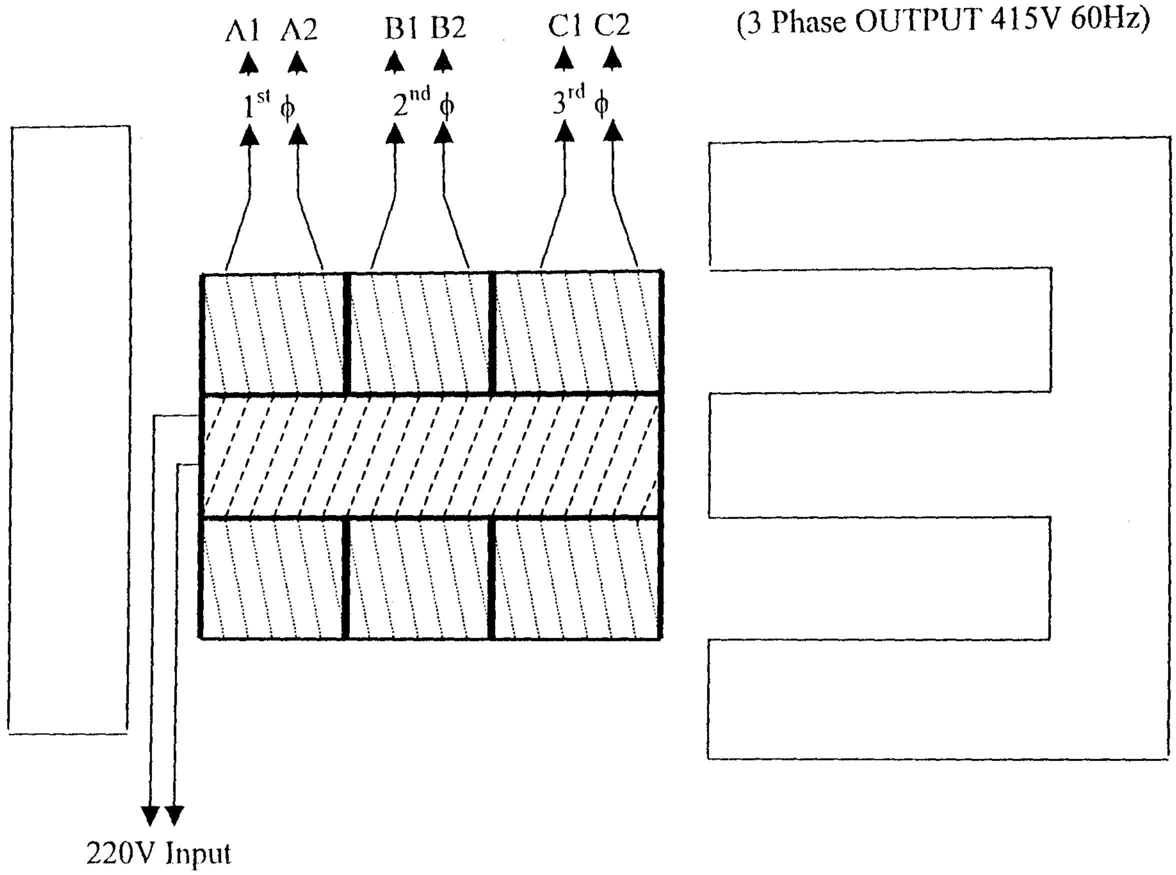


Figure 2.62 Internal architecture of a single-phase 220V input, three-phase 415V output Transformer

The diagrams below showed the connection of the output of the transformer on the busbar, it can be connected in either star or delta mode.

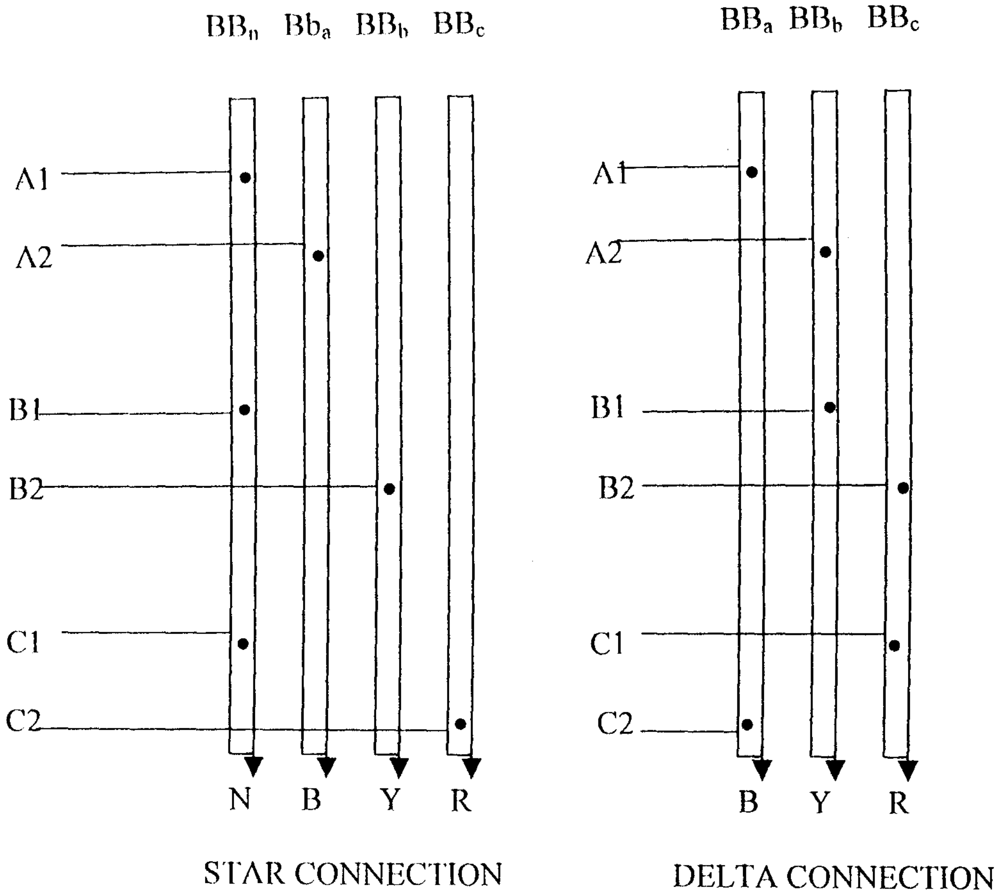


Figure 2.63 Different connections of the three phase on the busbars.

BB= Busbar , N= Neutral, B= Bleu, Y= Yellow, R= Red. The arrangement of the lamination as shown in the diagrams above is known as "imbricated" it is a staggered joints maintain in the alternate layers of the lamination in order to avoid the presence of narrow right through the cross-section of the core to reduce eddy current loss.

The Parameters to be considered in the Transformer design are as follow:

B= the maximum flux density in the iron core or in the air.

V= the voltage per turn of the transformer.

f= the frequency in cycles per second

A= the cross-section area of the iron core.

S= a constant. $3490*10^3$, if A is in square inches, and B is in gausses (lines/cm^2)

S= $22.5*10^6$, if A is in square centimeters, and B is in gausses.

S= $22.5*10^6$, if A is in square inches, and B is in lines per square inch.

NI= the number of rms ampere-turns with a sine-wave of alternating current.

g= effective length of the leakage path.

K= a constant. 0.7 if g is in inches, and B is in gausses.

K= 1.78 if g is in centimeters, and B is in gausses.

K= 4.5 if g is in inches, and B is in lines per square inch.

N= the number turns (in the base winding portion) of the winding group considered.

I= the rated rms current of the base winding.

M= the average of the mean turns of the windings.

w= the effective width of the leakage path.

Other parameters in the design are defined in the circuit. A particular transformer was used as a case study and the analysis obtained is as follows: 220 Volt input, 15 Volt output and 1.5 A with AWG 24 wire gauge. The output winding was removed and the total number of turns when carefully counted was 90 and with the total length of 10 Meters fixed is a core of a specific dimension. From here, it was deduced that;

90 turns = 15 Volt

x turns = 220 Volt therefore x turns = (220 * 90/15) = 1320 turns.

Volt per turn here= 15 Volt/90turns ≈ 0.17 V/turn

Considering the length of the wire, 90 turns =10 meters, 1320 turns =147 meters.

The operating frequency is 60Hz.

CALCULATIONS

From the data obtained above, primary coil gauge is AWG 33 and the secondary coil gauge is AWG 24. The data for the transformer I used is as follows:

(a) Number of turns and length of the wire.

15 Volt = 90 turns = 10 meters

24 Volt = x turns = x meters. Applying comparison formula,

For the primary winding, therefore, x turns = (24*90/15) = 144 turns.

x meters =(144*10/90) = 16 meters.

For the secondary winding, 24 Volt = 144 turns = 16 meters

220 Volt = x turns = x meters

x turns = (220*144/24) = 1320 turns

x meters = (1320*16/144) = 147 meters

With this, the number of turns and voltage values for both primary and secondary coil were obtained.

(b) Maximum flux density in the iron core.

$B = SV/fA$ Since I'm using cm^2 and B in gausses. A=L*B ∴(2.2*2.9)= 6.38cm^2

B = ((22.5*10^6) * 0.17)/(60*6.38)=9992.2 gausses i.e. lines/cm^2

(c) Maximum flux density in the air. Taking the primary winding as the base winding,

$B = KNI/g$ ∴B =((1.78*(1.5*144sin60)/4 = 83 gausses.

(d) Reactance volts of a transformer winding group is equal = (2.01fN^2IMw10-^{7})/g.

. Taking the primary winding into consideration as the base winding since I am powering the system through this winding w=(b+a_1+a_2)/3 where a_1 & a_2 are the core volumes and b is the gap between the two windings and g=H+(a_1+a_2+b)/2 H is space occupied by the entire coil. w=(0.2+(0.7+0.7/3)) = 0.66 and g=0.4+(0.2+0.7+0.7)/2 = 1.2

(2.01fN^2IMw10-7)/g = (2.01*60*144^2*1.5*20*0.66*10^{-7})/1.2 = 4.13

(e) % Reactance=100*(Reactance volts/Winding voltage of the base winding).

=100*(4.13/24)= 17.2% this shows that the bigger the transformer, the higher its efficiency.

(e) The resistance of copper winding

$$R = (9.9 * 10\text{-}6) * \frac{\text{Length of conductor in feet}}{\text{Cross-section are of copper in square inches}}$$

But 1000mm=3.33feet

Here, the area will be presented as the circumference of the wire in order to display the true thickness. A= πr^2. But the wire is AWG 24 which about 1.0mm thick, therefore in inches=(1.0*3.33/1000) = 0.00333Now, radius = 0.00333/2=0.001665. Area = 3.143*0.001665^2=0.000000871

$R = ((9.9*10^{-6})*(16*3.33)/0.00000871) = \underline{60.5\Omega}$

(f) I^2R loss in the winding.

This is equal to the product of the current and the resistance. $(1.5)^2 *60.5=\underline{136.1}$ VA

The rated voltage V=IR =1.5*60.5 = 90.75 V.

(g) % Impedance $= \left(100 * \frac{\text{impedance voltage}}{\text{Rated voltage of the winding to which voltage was applied}} \right)$

% Impedance 100*(24/90.75) = $\underline{26.4\%}$

(h) % Resistance can be derived from impedance formula. $Z=\sqrt{r^2+\chi^2}$.

$Z=26.4\%$, $\chi=17.2\%$

$26.4\%= \sqrt{r^2+17.2^2}$ $r^2=26.4^2-17.2^2$ $r =\sqrt{696.96-295.84}$ $r = \underline{20\%}$

(i)% Regulation= %resistance*cosθ + % reactance*sinθ +0.005 (%reactance*cosθ - %resistance*sinθ)^2

$\theta=60^0$ %Regulation=20*cos60+17.2*sin60+0.005(17.2*cos60-20*sin60)2

% Regulation = $\underline{25.2\%}$

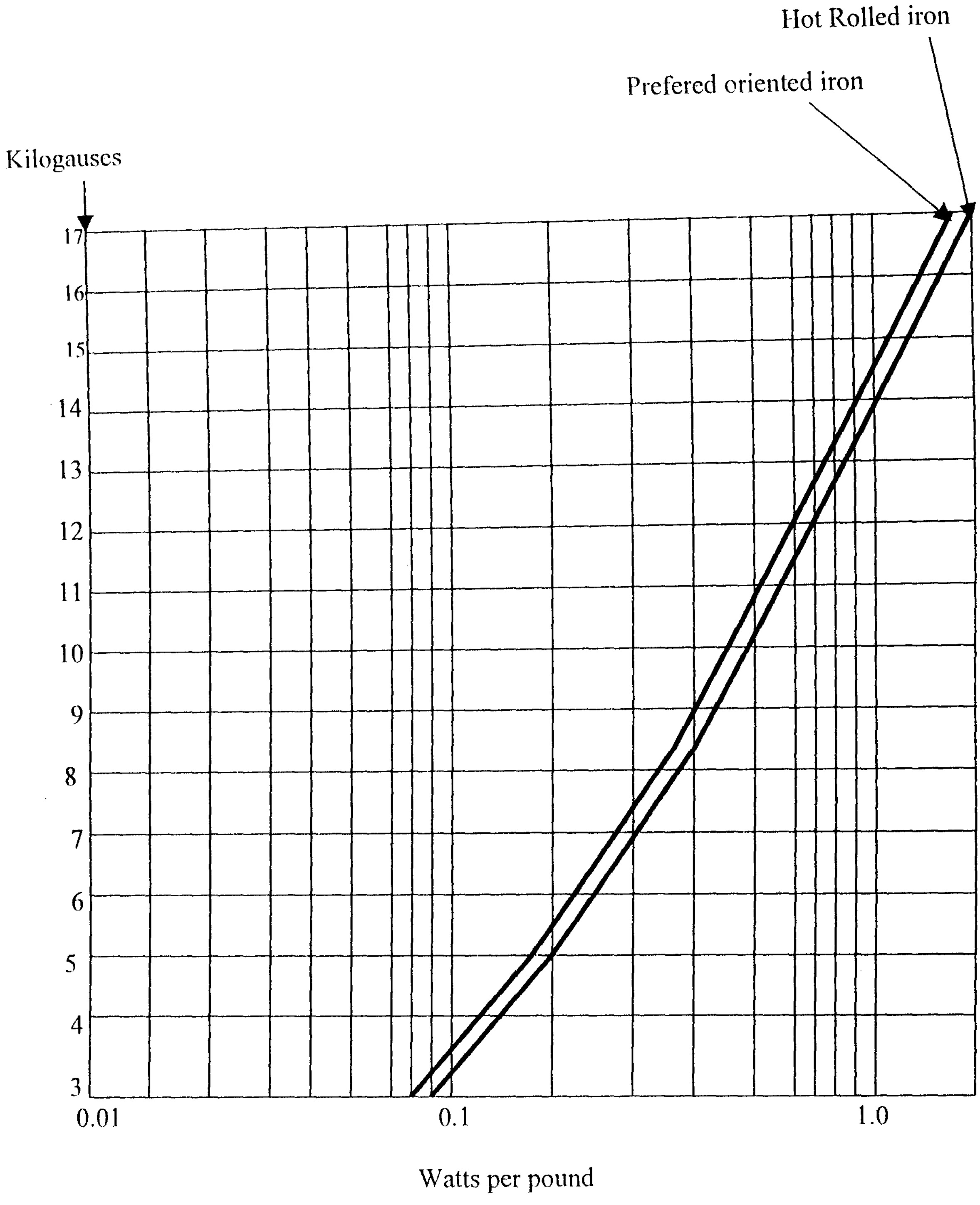


Figure 2.64. Typical Core-loss Curve

The no-load loss of a transformer is usually calculated by multiplying the weight of the core in pounds by the watts per pound of steel taken from a core-loss curve (figure 2.64 is typical) for the particular kind of steel used, corresponding to the calculated flux density in the core.

The exciting volt-amperes for a transformer core may be calculated by multiplying the weight of the core in pounds by the volt-amperes per pound of steel, taken from a curve for the particular kind of steel used

(j) %Efficiency $= 100 \left(1 - \frac{\text{Losses}}{\text{Output + Losses}}\right) = 100((1-(136.1/\ 110+136.1))$

$100(1-136.1/246.1) = \underline{45\%}$

These long procedures were adopted for the calculating other values for the remaining transformers used in the project.

CHAPTER THREE

This chapter reports the construction procedures of the hard ware, the testing and results obtained.

3.1 CONSTRUCTION

In order to effect a smooth construction, the entire work was divided into groups. Then a components layout plan was designed to ease construction problems.

3.1.1 COMPONENT LAYOUT

A plan layout of Vero board made on paper to show where each IC is to be connected and other component was drafted on paper by:

1. Counting how many ICs are involved.
2. Accessing how many ICs a board can accommodate.
3. Considering the connections between each ICs and other components.
4. Using the paper as Vero-board, spaces were allocated to each component and module.

The groups that the device was reduced to ease of construction include:

1. Source A.
2. Source B.
3. Source C.
4. Grid power monitor.
5. 24V inverter circuitry.
6. Step-up transformer.
7. Distribution transformer.

3.1.2 CONSTRUCTION OF GROUPS

GROUP 1

The Source A in this device is a solar panel (photovoltaic cell) which is capable of supplying 24V at the current rating of 1.5 A, in other words, 40W solar cell incorporated. The current was obtained from parallel connection of several cells.

GROUP 2

The Source B is a car battery which when fully charged will deliver 24V and little current of 1.5 A is required by the voltage regulator. This will enhance or prolong the life span of the battery because the rate of discharge is very low.

GROUP 3

The Source C is a car alternator, which is capable of delivering 14 V at the current rating of 45 Amps but the voltage regulator will require 1.5 Amps, therefore enough current will be supplied.

GROUP 4

Grid power monitor is series connection of relays (electric brains) which operate sequentially. They are three in number each connected to different power supply and they are interconnected serially to give discriminating effect. The close of the first one results in open of the second and the third ones, the close of the second one results in open of the first and the third ones and the close of the third one results in the open of the first and the second one.

GROUP 5

24 V Inverter circuitry, this circuit will receive 24 V DC excitation from the output of the grid power monitor and convert it to 24 V AC. This output is used to excite the step-up transformer.

GROUP 6

This group consist of two step-up transformers that step the input voltage from 24 V to 110 V and 110V to 220 V respectively at the same frequency of 60 Hz.

GROUP 7

This is a transformer that converts the 220 V single phase input to 415 V three phase output.

3.13. TESTING

After completing the construction without powering the circuit, a carefully test of all connections and points with digital multi meter was carried out as:

STEP 1. The polarities of the components were checked.

STEP 2. Short circuit test on the power supply and other components was carried out to ensure normal flow of current within the circuit.

STEP 3. The continuity of all the connecting wire were tested.

STEP 4. The voltage, the current, and the resistance value were tested to compare with the design values.

After a satisfactory tests as listed above, the device was placed on full operation and tested.

The input supply from the three sources was turned off one after the other and it was discovered that as one goes off the other following one goes on. The output was tested with digital multi meter which read 220 V per phase and the 50Hz frequency was obtained.

TOOLS USED IN CONSTRUCTION AND TESTING

The tools used in the cause of construction and testing are given below:

1. Computer was used to design and simulate the circuits used. The softwares used were electronic workbench EDA version and circuit maker.
2. Bread board and insulated telephone wires; they were used to build a prototype and to observe variations from the computer model before it was permanently mounted on the Vero board.
3. Soldering iron (220 V, 60 W) and soldering lead were used to solder the entire component to the vero board.
4. Digital multi meter was used to test the continuity of the lines, measure the voltages, the current and the resistance at various points in the circuit.
5. Sanction pump was used to suck unused lead from the circuit to avoid short circuit and to ensure clean job as much as I could.

PACKAGE

The construction device was enclosed in a rectangular box made of light plywood. Provision was made for the inlet of cables from where the supply will enter into the device and the outlet from where the feeder cables will go out. The box was perforated to enhance effective cooling.

CHAPTER FOUR

4.1 CONCLUSION

The aim and objective of this project work has largely been achieved that is to design and construct a low cost, simple and reliable power on-site power supply device. This has been successfully carried out as described in preceding chapters. This venture in the field of power system engineering can also serve as a stimulant for others who would consider undertaking topics related to it.

The final objective and its focus are to meaningfully contribute to the economy of the country and provide comfort and control to power supply on the site especially at remote locations and at a place that has not been electrified. A particular supply unit in the device, which operates on the natural source, made the system to be cost effective in terms of maintenance.

The circuit as desired has very few components namely: 4 numbers of integrated circuit (ICs) capacitors, resistors and diodes three numbers of transformers. The need but for few components allows for a very low cost system to implement.

4.2 RECOMMENDATION

In view of the strategic importance of power supply to our activities, this device gives the alternative to general or national grid power supply especially in remote locations. Based on this and the successes and limitations recorded by the project work, I wish to recommend the following:

1. Presently, almost all the workshops both fixed and mobile lack reliable power supply for their electromechanical operation, to this end a deliberate approach to the design of on-site multi-purpose power supply by our research institutes and universities has to be adopted so that effective work would be ensured at any location.
2. Students should be encouraged to undertake research in other areas of electrical power generation especially from organic sources and renewable and recyclable power source.
3. Everybody can purpose this device as an alternative power supply to the epileptics power supply from the national grid network like NEPA especially when there is abundant sunshine.

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