# DESIGN, CONSTRUCTION AND TESTING OF A 600VA UNINTERRUPTIBLE POWER SUPPLY (UPS) SYSTEM WITH PHOTOVOLTAIC GENERATOR (SOLAR POWER) BACK UP

*BY*


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SUBMITTED IN PARTIAL FULFILMENT OF THE BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN THE DEPARTMENT OF ELECTRICAL/ COMPUTER ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

*DECEMBER 2000.*

## DECLARATION

I hereby declare that this project is an original concept wholly carried out by me,under the supervision of Mr. KENNETH K. PINNE of the department of Electricaland Computer Engineering, Federal University of Technology, Minna.

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Adekilekun Jeleil A.  Date

## DEDICATION

This project work is dedicated to my late father, Alhaji AbdulKareem **Adebayo** Adekilekun. May his gentle soul rest in perfect peace.

# ACKNOWLEDGEMENT

God has everything and to him be the glory. My special thanks goes to God Almighty who has sustained me through the thin and thick of my education life. My reserved gratitude goes to my dear mother, Mrs. Rafatu Ibidun Adekilekun who has always given the support in terms of moral, love and finance. May God bless her. Amen.

Also, worthy of note is the immerse contribution of Mr. Abimbola Adekilekun for his fatherly love, regular financial assistance and deep interest in my success. You will not miss your reward.

I equally remain very much grateful to the entire family of Adekilekun. Badmus for their understanding, emotional and financial support; Mr. Ayoade Adekilekun, Mr. Teslim Adekilekun, Alhaji Najeem Adekilekun and mr AbdulLateef Adekilekun.

Also my profound appreciation goes to entire family of Mr. and Mrs. Adekola Adediran, Mr. and Mrs. Dele Adedoja and Mr. and Mrs. Adegoke Adelakun of the global technologies and investment limited.

My sincere gratitude to my following contemporaries who have always made things lively and interesting during our staying together; Mr. Aderemi Adeleke, Mr. Kehinde Abolarin, Miss Olaide Alade, Mr. Ismail Olaosun, Mr. Oluwaseyi Olaoye and Mr. AbdulKadir Arowosaye.

Lastly, my colleagues in accademic Tomori AbdulMujib, Salau Kazeem, Sikiru Isah, Jide Olatunde, Olutola Ogungbemi, Olowoniyi Kehinde and Shiawoya Job. I say thank you all.

# ABSTRACT

This project highlights the design and construction of an Uninterruptible Power Supply with photovoltaic generator back up. This is made possible by the use of high current semi-conductor controllable switches that convert d.c. low voltage power to a.c. line voltage power.

An Uninterruptible Power Supply Unit thus ensures supply of AC voltage to an equipment by changing over to an inverted back up DC voltage in the event of mains failure or other irregularities in the main supply.

During the process of circuit design of the Uninterruptible Power Supply (UPS), various factors such as change over speed, commutation, output waveforms and power quality and efficiency were considered.

A just switching relay and power transistors are amongst the various components employed. The pulses generated from astable multivibrator were used for firing the base of the power transistors. Although a more efficient technique is the sinusoidal pulse width modulation.

The UPS unit was designed to convert a 12V dc supply to feed a 600watts 220V a.c. load at 50Hz frequency,

## CERTIFICATION

This is to certify that this project tilted Design and Construction of 600VA Uninterruptible Power Supply (UPS) system is carried out by Adekilekun Jeleil Ayinde under the supervision of Mr. K. Pinne and submitted to Electrical and Computer Engineering Department, Federal University of Technology, Minna in partial fulfilment of the requirement for the award of Bachelor of Engineering (B.Eng.) degree in Electrical and Computer Engineering.

| | |
|---|---|
| Mr. K. Pinne | Date |
| Eng. (Dr.) Y.A. Adediran<br>Head of Department | Date |
| External Examiner | 17/01/2001<br>Date |

## TABLE OF CONTENT

# CHAPTER ONE

## 1.0 INTRODUCTION

The role of a good a reliable source of electrical power cannot be over-emphasised. Considering some processes, which cannot be stopped due to high cost of the equipment downtime and the irreparable damage that may be done.

In ensuring a reliable power supply, the Uninterruptible Power Supply System (UPS) was developed. This provides power by conversion of dc power to ac power whose magnitude and frequency are controllable, this then supply power to equipment that should not experience power outage i.e. critical loads.

In this work, the sources of dc power (dc battery) for conversion experiences loss during operation and this is being compensated for, by charging unit. This charging unit involved is in two forms, these are: Controllable charger and the solar power panel backup known as photovoltaic generator.

The solar panel can be incorporated in the design so as to made the UPS very efficient in the area wherethey enjoy little or no electricity from public utilities like N.E.P.A.

The photovoltaic generator is then responsible for continuos charging of the battery as long as it is connected to the battery during the day when there is sunlight, hence, bypassing the dependence of the charger which operates only with the public mains.

In such, the whole system is a power supply pack, which ensures continuous supply of electrical power by inversion of dc, which is drawn from dc battery.

The Ups consists of vital sections; the charger (DUAL), battery, inverter unit; change over switch (Relay), filter and transformer. The charger is used to keep the battery charged. The battery supplies power (dc) to the inverter circuit and inverter does the inversion of dc into ac.

The filter filters out the high frequency harmonics to ensure 'clean' ac power. The relay charges the supply to the load from the public utilities mains to UPS when there is outage of supply and take it back when the supply comes. It does this automatically.

## 1.1 THE PROJECT AIMS AND OBJECTIVES

This project work aims at reducing or avoiding if possible the problem of erratic supply of electricity from public mains which could be dangerous to critical loads and also to mankind. It ensures a reliable and constant power supply needed in the developing countries. This is achieved through design, construction and testing of the 600VA Uninterruptible Power supply System (UPS).

## 1.2 THE PROJECT OUTLINE

The project comes up in four chapters. Chapter one gives the general introduction, stating the problem and the way out. Chapter two discusses the system design. Chapter three deals with construction, testing and result and lastly, chapter four gives conclusion and recommendations together with a list of reference.

## 1.3 THE UPS SYSTEM

### *1.3.1 BATTERY:*

This is device which converts the chemical energy contained in its active materials directly into electrical energy by means of an oxidation, reduction and electrochemical reactions. This type of reaction involves the transfer of electrons from one material to another. Battery is generally identified as primary or secondary. The major different is that, the while secondary batteries are capable of being recharged, the primary is not rechargeable in nature.

### *1.3.2 BATTERY CHARGER:*

The charger unit of this project is in dual form. These are controllablecharger and the photovoltaic generator (Solar power).

The controllable charger incorporates the full wave rectifying circuit and overcharging protective device of mainly Zener diode and some active and passive circuit element.

Also, the photovoltaic generator used as other means of charging the battery is realised by interconnection of several solar cells in series or parallel or both to provide the desired output of 12V characteristic.

### *1.3.3 INVERTER:*

This is the heart of the UPS system. It is the electronic connection converting a dc power source into an ac power of predetermined frequency, amplitude and phase. There are many type of inverter based on principle of operation and the nature of the switch used being fully or semi controllable; these are transistors switched, thyristor switched inverter etc.

### *1.3.4 FILTER:*

The output of an inverter is often sine wave superimposed on several harmonics. The filter converts this square wave to its sinusoidal equivalent. It is necessary to filter the inverter output to prevent damage to inductive load. Also, the output of full wave rectifier used in controllable charger is filtered to obtain smooth dc required.

### *1.3.5 CHANGE OVER SWITCH (RELAY):*

Relay are used to change the supply from mains to the UPS are Vise verse. The relays used are electromagnetic in nature.

### *1.3.6 TRANSFORMER:*

Transformer converts ac voltage and current in one winding to an ac voltage and current at different values in another winding by electromagnetic induction at the same frequency.

## 1.4 LITERATURE REVIEW

There are various types of UPS. T depends on the mode of operation and the component installed.

The world first UPS/inverter is produced in 1983 by heart interface who has been a leader in inverter and charger technology.

Today, the common UPS are:

### 1.4.1 SINGLE TRACK UPS

This is also called online UPS. It has a single path from the mains supply to the load. The main supply is first steped down to the battery level, rectified and used to charge the battery continuously. The battery voltage is also fed into the inverter to convert it to ac. There is no changing over from the inverter to the mains or vice verse.

The advantage of this is that there is no need for charging over but it will require a very bulky transformer that can sustain the supply. See Fig. 1.1 below.

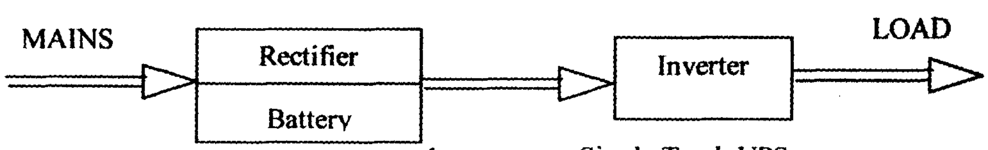



Fig. 1.1 Single Track UPS

### 1.4.2 DUAL TRACK UPS

It is also called offline UPS. There are two alternative power supply paths and a switch (relay) to choose which source is to power the load.

The advantage of this is that, there is always no need of bulky transformer and the components are not over stressed but there is a delay in the charging over from a source to the other. See fig: 1.2 below.

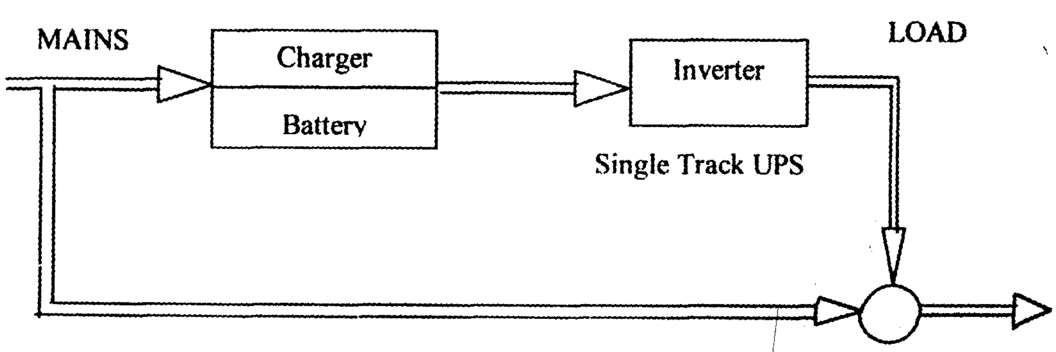


Figure 1.2 ***Dual Track UPS***

### 1.4.3 DOUBLE CONVERSION UPS

Here, the inverter is constantly on. The inverters takes supply from the large charger or from the battery when the mains fails. The inverter is heavily stressed and there is complete failure when the inverter is faulty. See fig.1.3 below.

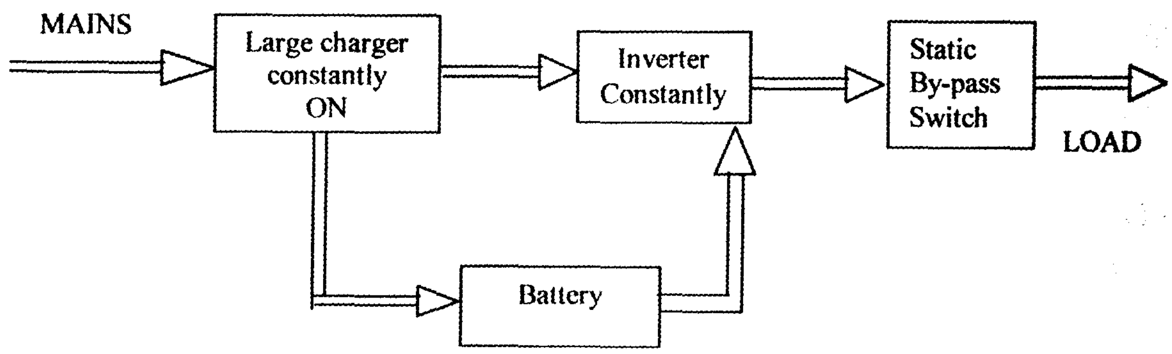



Figure 1.3 ***Double Conversion UPS***

# CHAPTER TWO

## 2.0 SYSTEM DESIGN ANALYSIS

## 2.1 GENERAL MODE OF OPERATION AND SYSTEM DESIGN OVERVIEW

The operation of the ups is divided into a number of units as shown in the general module of fig. 2.9

The D.C. battery serves as D.C. source in which it is being compensated for (recharging), by the controllable charger and the photovoltaic generator otherwise called solar power.

The BJT makes the controllable switches which periodically intercept the d.c. and convert it to A.C of which the frequency is determined by the astable multivibrator (AMV) configurated to operate at the frequency of 50Hz.

The inverting power transformer served dual purposes in that, it steps up the 12V a.c to 220V a.c in the output and that it steps down 220V a.c to 12V a.c which is some little than 12V after rectification through rectifier circuit. This makes it to charge the 12V d.c. battery.

A separate step-down transformer of 12V a.c feeds the rectifier to which the two 12V relays $RL_1$ and $RL_2$ are powered to operate in normal On and OFF states respectively.

The low pass filter to smooth the d.c. used by charger in charging the 12V battery. Also, the output filter converts the square wave a.c to pure sine wave a.c of 220V in the output.

The UPS "Enable Switch" should be put ON if the UPS is to be alerted while the voltage level indicator shows the level of the voltage of d.c. battery with the aid of LED and Zener diode.

## 2.2 CONTROLLABLE CHARGING UNIT

The configuration made in the controllable charger is done in such a way that the charger itself incorporates the protective device, which avoids overcharging of the battery. This is done by the action of Zener diode and the transistor (PNP) to control the MOSFET that serves as the open and close switch in the whole charger unit.

After the rectification of 12v a.c, the output d.c. is boosted to about 15v d.c., and this is put across the 12v d.c. battery via the configuration of the charger.

## 2.3 OPERATION OF THE CHARGER

Based on the diagram of fig.2.1,the charger drives the charging current through the battery. The negative terminal(of –12v) is connected to the 4.7v Zener diode adjusted by the variable resistor through limiter resistor R1 of 1k.

The adjustable variable resistor is adjusted so that if battery voltage is12v ,the voltage across the Zener diode is –4.7v which makes the Zener diode conducts in reverse direction so as to allow collector-base current in transistor Q1 and disallow collector-base current to flow in transistor Q2, hence connecting the source of MOSFET to the ground and no current flows in its GATE ,G .

By this, the MOSFET is off to disallow the driving of the charging current round the closed loop of the charger

At instance the level of the battery voltage falls below 12v,the Zener diode deviate from – 4.7v and passes the current in the forward direction to disallow the collector-base current in $Q_1$thereby allowing the collector-base current in $Q_2$ which fires the GATE G of the MOSFET hence the MOSFET is closed to complete the charger circuit to operate in charging mode.

The diode D functions to separate the –12V terminal of battery from –15V of the output of the rectifier.

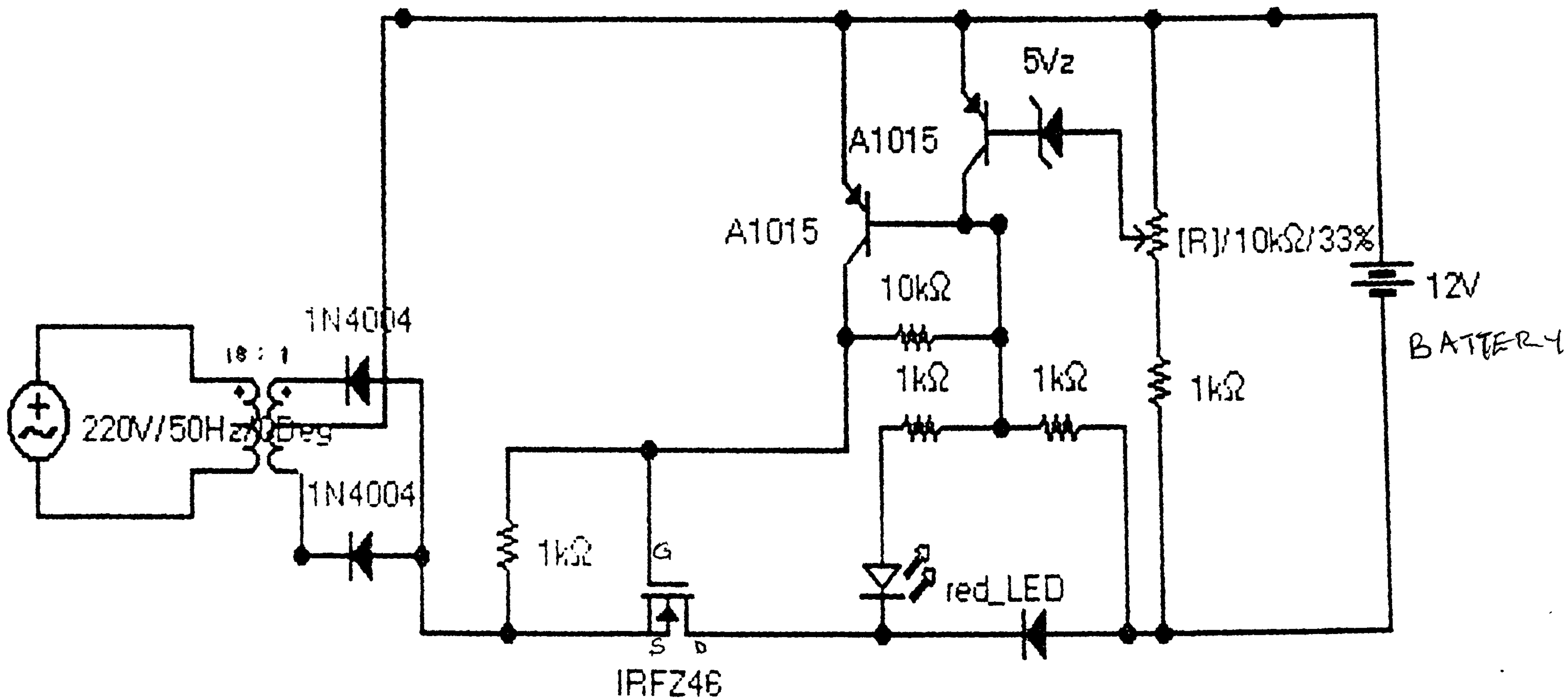
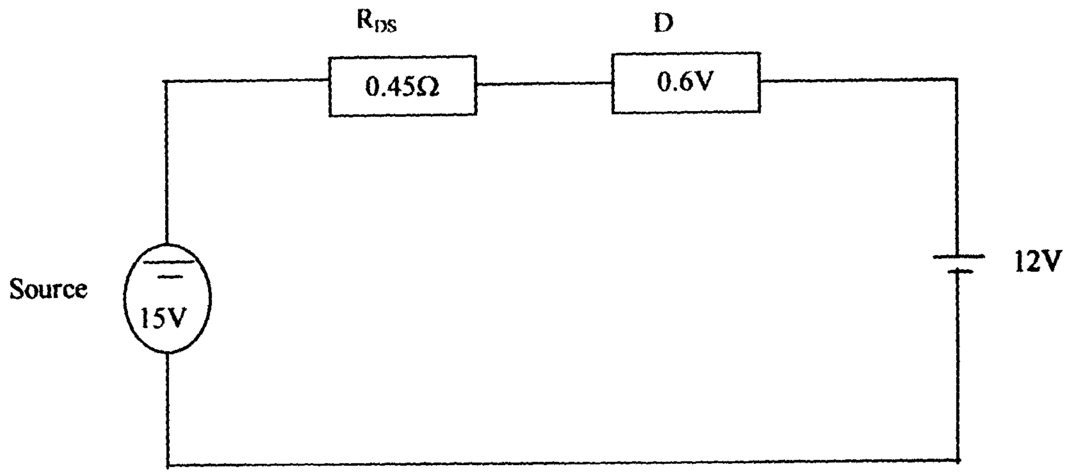



FIGURE 2.1 THE CONTROLLABLE CHARGING UNIT

**DETERMINATION OF THE CHARGING CURRENT**




The minimum charging current is achieved when the battery is at 12V just before the charger goes off.

$$I_{Qmin} = \frac{15V - (12 + 0.6)V}{0.45} = 5.33A$$

If the battery level is about 10V;

$$I_Q = \frac{15V - (10 + 0.6)V}{0.45} = 9.78A$$

## 2.4 THE BATTERY VOLTAGE LEVEL INDICATOR

The battery voltage level indicator consists of three Zener diodes of 10, 11 and 12V. Each of them connected in series with LED (Light Emitting Diode) of Yellow, Green and Red respectively, also, with limiter resistor of 100Ω each. The three of them were then connected in parallel across the positive terminal of the 12V battery.

To operate, each of the Zener diode compares its rated voltage with the level of battery voltage. If the battery voltage level is 12V, all of them are ON, if the level is 11V Yellow and Green are On, if the level is 10V only yellow LED is on – invariably, if the level is below 10V, non of them is on.

The diagram of the voltage level indicator is shown in fig. 2.2 below.

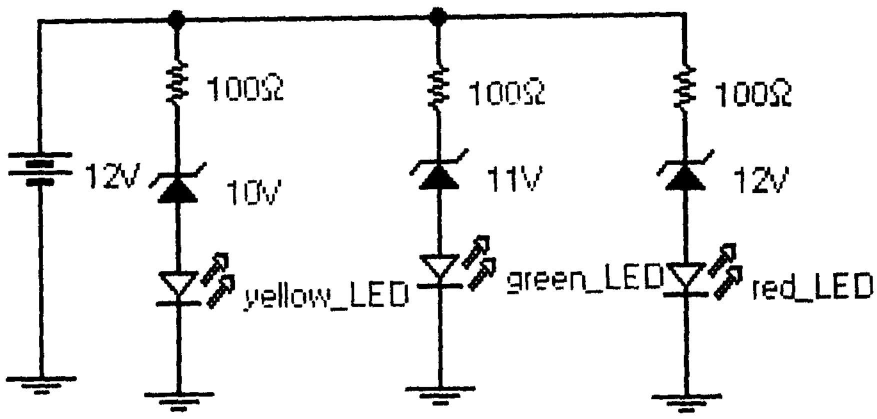



Fig. 2.2 *The Battery Voltage Level Indicator*

## 2.5 THE PHOTOVOLTAIC GENERATOR (SOLAR POWER)

The heart of the photovoltaic generator is the solar cell. Solar cell is a semiconductor electrical junction device, which absorbs and converts the radiant energy of sunlight directly and efficiently into electrical energy.

Solar cells are connected in series, parallel or both to obtain the required value of current and voltage for electric power generation. This is known as photovolatic generation.

## 2.6 CONVERSION OF SUNLIGHT TO ELECTRICAL ENERGY

This involves three stages:

1. Absorption of sunlight in the semi conductor material.
2. Generation and separation of free positive and negative charges which moves to different regions of the solar cell creating a voltage in it.
3. Transfer of these separated charges through electric terminals to the outside application inform of electric current.

In the first stage, the absorption of sunlight by a solar cell depends on the intensity and quality of the sunlight, the amount of light reflected from the front surface of solar cell, the semi conductor, energy which is the minimum light (photon) energy, the material absorbs and the layer thickness. Some materials such as Silicon require tens of micrometer thickness to absorb most of the sunlight while other such as gallium arsenide, Cadmium and Copper Sulphate require only few micrometer.

When light is absorbed in the semiconductor, negatively charged electrons and positively charged holes are created. The heart of solar cell is the electrical junction which separates these electrons and holes from one another after they are created by the light. An electrical junction may be formed by contact of a metal to a semi conductor (called Schottky barrier); a liquid to a semiconductor to form a photo-electrochemical cell, or semi-conductor region called a PN junction.

The silicon PN junction is an example of electrical junction. Pure silicon to which a trace amount of fifth – column element such as phosphorus has been added is an N – type semiconductor, where electric current is carried by free electron(s). Each phosphorous atom bound to the crystal structure with a unit positive charge. Similarly, pure silicon to which a trace amount of column three element such as Boron with a unit negatively charge added is a P-type semi-conductor, where the electric current is carried be free holes leaving behind the boron atom with a unit negative charge.

The interface between P and N types is called the PN junction. The charges at the interface due to the bound boron and phosphorous atom creates a permanent dipole charge larger with a high electric field.

When photon of light energy from the sun electron hole pairs near the junction, the built-in electric field forces the holes to the P side and the electron to the N side.

The displacement of free charges results in a voltage difference between the two regions of the crystal, the P-region being plus and the N-region being minus. When a load is connected at the terminals, an electron currents flows in the direction shown by the arrow (fig. 2.3) and the useful power is available at the load see fig 2.3.

## 2.7 ARRAY DESIGN

Individual silicon solar cells are limited in sizes to about 40cm$^2$ of surface area. At about 15 % conversion efficiency, such a cell can deliver about 0.6W at 0.5V when in full sunlight. To obtain higher power and voltage, a number of cells must be assembled in the array or panels. Cells may be connected in series to multiply their output current.

Cells operated in series must be closely matched in short circuited currents since the overall performance of a solar cell array is limited by the cell having the lower current.

## 2.8 THE DESIGN CONSIDERATION PARAMETERS OF PHOTOVOLTAIC GENERATOR

The solar cell fabricated from single crystal, polycrystalline or amorphous silicon is usually mounted in a solar cell panel sized to produce peak power output level under condition of maximum radiation. This is referred to as photovoltaic generator.

The d.c. output voltage per cell is typically of the order of 0.5Volts and the output current is governed primarily by the cell area and intensity of the sunlight. Panels may be wired together to for solar cells arrays designed to match the required power, voltage and current requirement of the particular load application.

The output of solar panel is well matched to the task of battery charging as if it is the current rather than the voltage, which varies with radiation intensity.

In this project, the construction design is made so as to charge the 12V battery with the protective device, which is basically, Zener diode and other active and passive circuit element to protect the battery from over-charging condition.

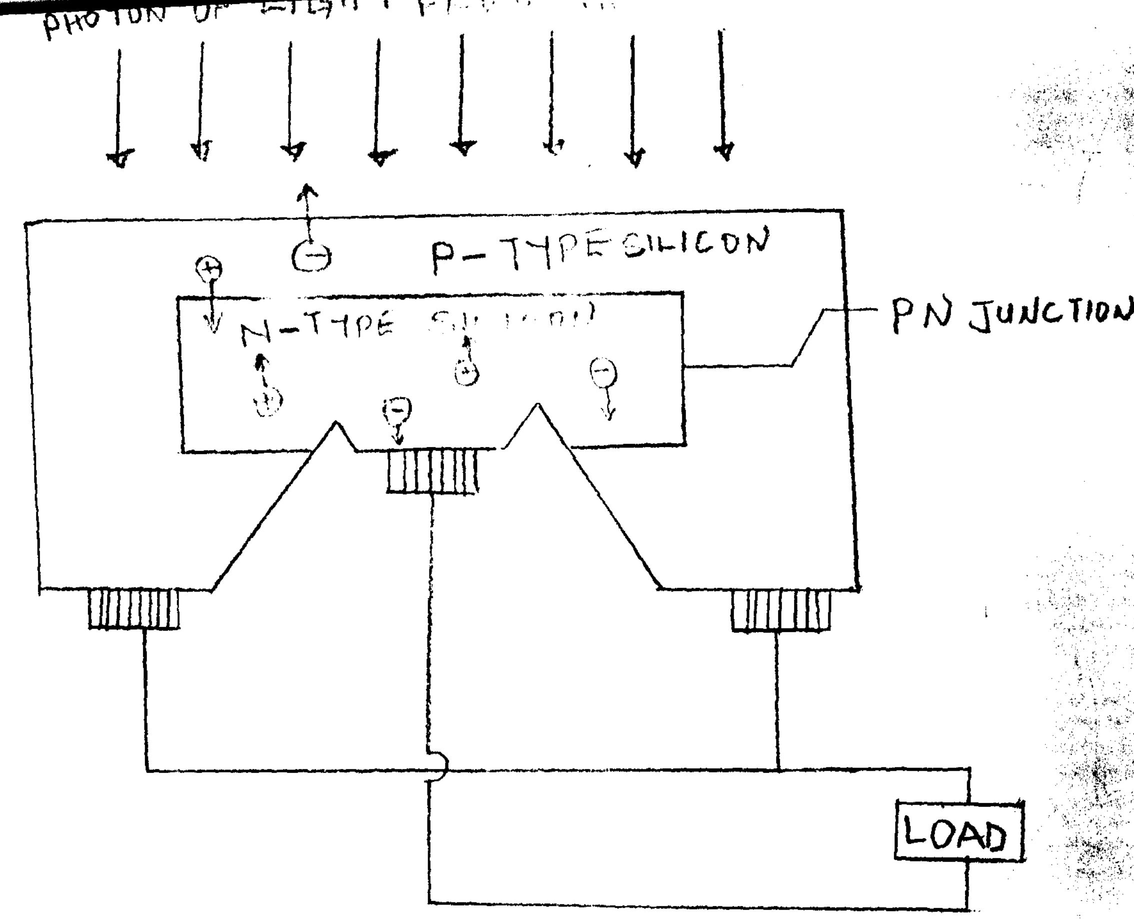



Fig.2.3 CROSS SECTION OF SILICON PN JUNCTION IN SOLAR CELL.

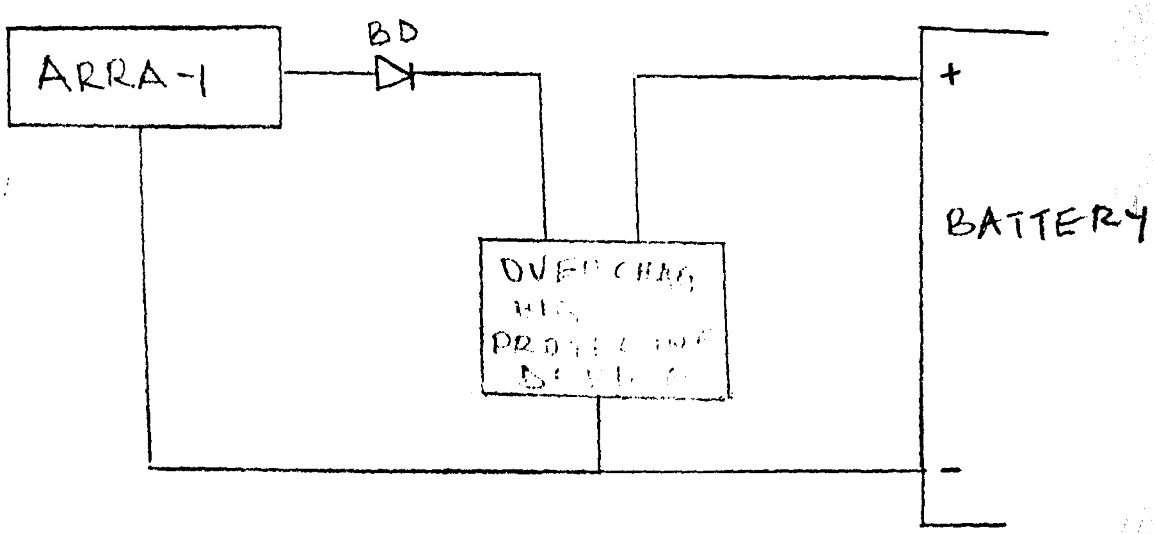



Fig.2.4 PHOTOVOLTAIC GENERATOR AS A CHARGER

Also, a "Blocking diode" between the photovoltaic generator and the battery to prevent the current flow at night from battery to the array. This is pictorially represented in fig. 2.4.

The construction design consideration includes:

***2.8.1 POWER SUPPLY:*** This is specified as current output at certain voltage, it refers to the power (watt) available at the power generator.

***2.8.2 ENERGY OUTPUT:*** This is the time-integrated value of power, the energy (watt-hour) output indicates the amount of energy produced by the array during one day.

***2.8.3 AMPERE-HOUR OUTPUT:*** This is the rating often used for array delivering electricity primarily into energy storage battery.

***2.8.4 SOLAR CELL EFFICIENCY:*** The conversion efficiency of solar cell is given by the expression:

$$\text{Eff.} = \frac{\text{Power output from cell/array}}{\text{Power input from the sun}}$$

$$= \frac{V_m I_m}{S.\ A_c}$$

where $V_m$ and $I_m$ is voltage and current at the maximum operating point respectively. S is the insolation per unit area and $A_c$ is the effective area of the cell. Actually, this varies with the operating temperature of insolation and humidity.

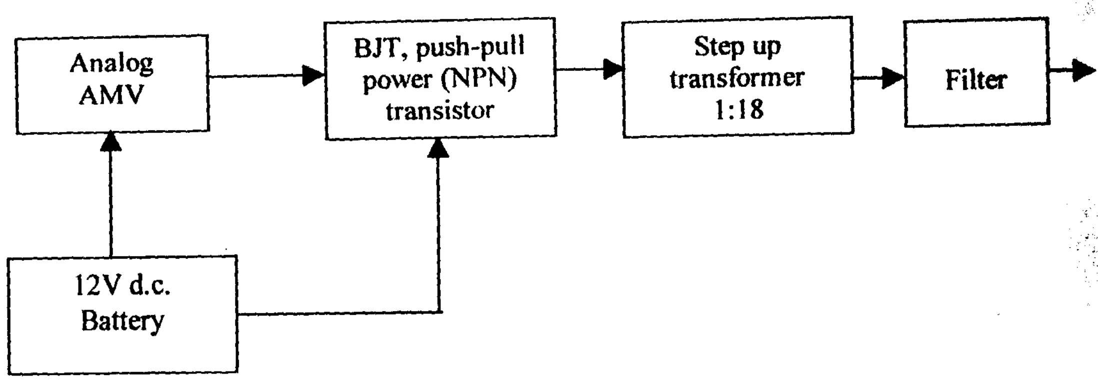
***2.8.5 INSOLATION:*** It is the amount of solar energy radiation which reaches a unit horizontal area of the earth.

## 2.9 INVERTING CIRCUIT UNIT

The inverting unit is the heart of the UPS. It consists of the controllable switches that periodically interrupts the d.c. also, it consists of multivibrator, which generates the frequency upon which the switches convert the d.c. to a.c.

Lastly, it consists of the step up transformer to transform the 12V a.c to the required 220V a.c output, which is filtered by the filter incorporated in the output..

The module is depicted below.




## 2.10 THE ASTABLE MULTIVIBRATOR

The configuration of the Analog Astable Multivibrator (AMV) used is shown in fig. 2.5 below. The AMV is also called free running relaxation oscillator. It involves two-stage amplifier with positive feedback from output of one amplifier to the input of the other.

The two common emitter amplifier stages each provide a unity feedback ratio at $180^0$.

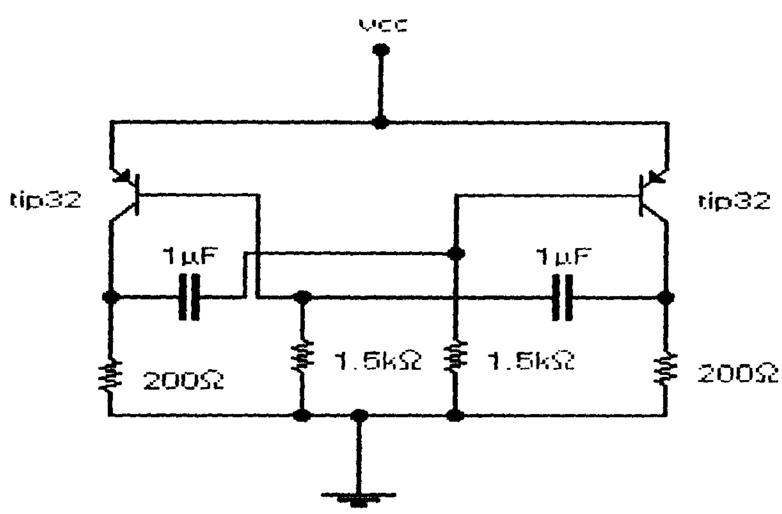



Fig. 2.5 ***Astable Multivibrator***

When the transistor $Q_1$ is in the saturation, the voltage drop across $RL_1$ is $V_{cc}$, so that capacitor $C_1$ will start charging through $R_2$. This charging process will forward bias $Q_2$, so setting it to cut off and the voltage at $RL_2$ will be zero.

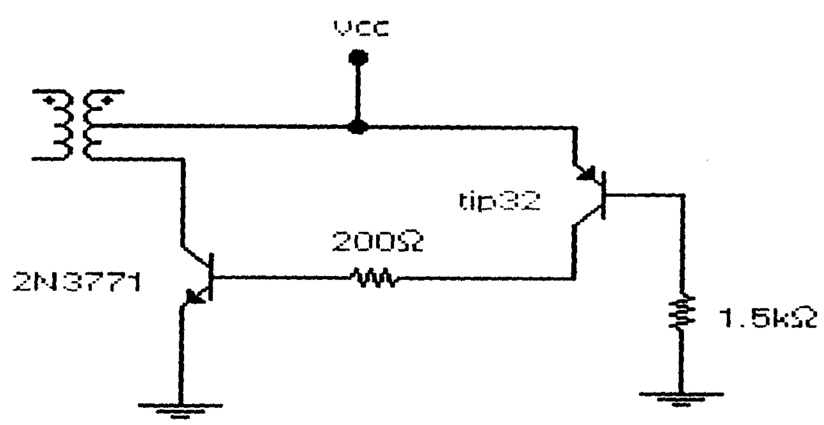
The voltage across $R_2$ at the beginning of the design process is $V_{cc}$ and it will continue to drop until the potential difference is below ($V_{cc}$ – 0.7V) which will eventually reverse bias $Q_2$ and then drive $Q_2$ to saturation.

When $Q_2$ is saturated, the potential at point B is $V_{cc}$ and capacitor $C_2$ will start charging through $R_1$. The potential head of $R_1$ at the beginning of the charging of $C_2$ is $V_{cc}$, which will set Q1 to cut off by forward biasing Q.C1 will start discharging at that point.

The voltage across $R_2$ will continue to drop until it is below ($V_{cc}$ – 0.7V).

## 2.11 THE SYMMETRICAL DYNAMIC EQUIVALENT OF THE INVERTER CIRCUIT OF THE UPS.

This is the design calculation that enables us known the value of the base resistors, capacitor base current, collector current and voltage in the configuration of the inverter circuit. This involves the AMV and controllable switches section of the UPS fig 2.6




*A SECTION OF FIG 2.6*

$I_S$ = secondary winding current

$I_P$ = primary winding current

$N_P$ = primary number of turns

$N_S$ = secondary number of turns

$\beta_1 = h_{fe}$ of $Q_1$

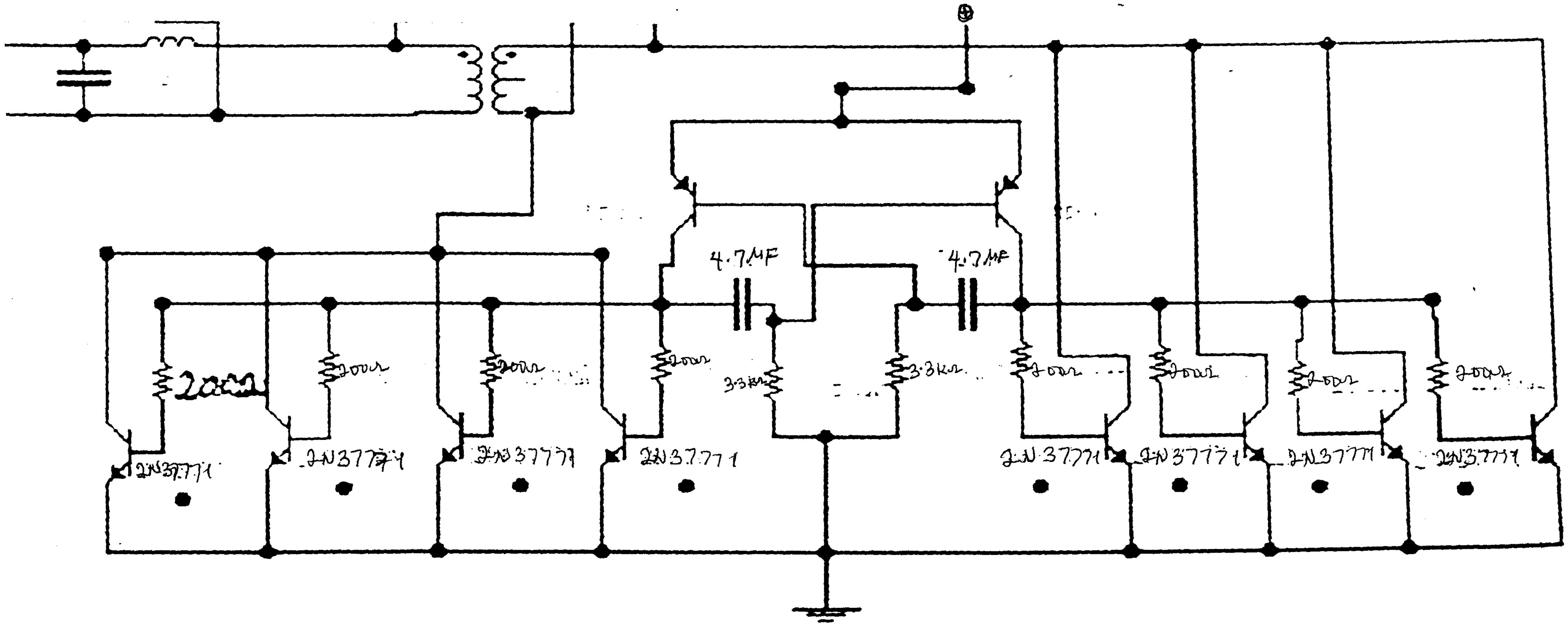



FIGURE 2.6, THE DC - AC INVERTER CIRCUIT

$\beta_2 = h_{fe}$ of $Q_2$

the target power output of the ups =600VA

at 220v. assume the transformer is ideal,

$P = VI_S$

$600 = 220Is$ $\qquad\qquad$ $Is = 2.73A$

The turns ratio $= \frac{NP}{NS}$

$\approx 1:18$

hence, $\frac{E_P}{E_S} = \frac{N_P}{N_S} = \frac{I_S}{I_P}$

$I_P = \frac{N_S X I_S}{N_P} = \frac{220x2.73}{12}$

$I_P = 50.05A$

$I_{C2} = I_P = 50.05A$

Using four transistors connected in parrallel, the current to be switched by each is given by:

$P = \frac{I_P}{4}$

$= 50.05/4 = 12.5125A$

for each transistor

$I_{B2} = \frac{I_{C2}}{B_2}$

$= \frac{12.5125}{100} = 0.125A$

$\therefore$ for each transistor, $I_{B2(MAX)}$ must be greater than 0.125A

for total of 4 x 12.5125A

= 50.05A

Total $I_{B2} = \frac{50.05}{100}$

0.501A

$$I_{B1} = \frac{I_{C1}}{\beta} \text{ where } I_{C1} = IB_2$$

$$\therefore I_{B1} = \frac{50.05}{75}$$

$= 0.007A \approx 7mA$

$$R_1 = \frac{V_{cc} - 0.6}{I_{B1}} = \frac{12 - 0.6}{0.007}$$

$R_1 = 1628.6$

$\approx 1.630K\Omega$

The value of the capacitor required to generate the output signal at 50Hz is found as follows:

Using $F = \frac{1}{T}$

Where $T = 0.69\ (R_1C_1 + R_2C_2)$

$$\therefore \quad F = \frac{1}{0.69\ (R_1C_1 + R_2C_2)}$$

Since $R_1 = R_2 =$ and $C_1 = C_2$ for perfect square wave

$$\therefore \quad F = \frac{1}{0.69\ (2 \times R_1C_1)}$$

Target frequency =50Hz $\qquad R_1 = 1.6K\Omega$

$$F = \frac{1}{0.69 \times 2 \times 1.6 \times C_1}$$

$$C_1 = \frac{1}{0.69 \times 2 \times 1.6K \times 50}$$

$C_1 \approx 10\mu F$

Hence, $C_1$ is chosen to be $10\mu F$

## 2.12 TRANSFORMER

## DESIGN AND MODE OF OPERATION

The design, type and accessories of the transformer depend on its size, application and its location. The principal components are:

1. ***STEEL TANK:*** Used for housing the core and for the mounting various accessories required for the operation on of the transformer.
2. ***CORE:*** This is constructed from insulated iron steel lamination to keep iron loss low. Stalloy sheets of 0.35mm thickness containing 3.5% silicon are normally used.
3. ***WINDING:*** There are one primary and one secondary in a single phase transformer which are suitably connected. The low voltage winding is place next to the core and high voltage winding placed concentrically over it.

The important relations in the transformer design are as follows:

1. The transformer turns ratio =

$$K = \frac{E_2}{E_1} = \frac{I_1}{I_2} = \frac{T_2}{T_1}$$

where $E_1$ = phase voltage in primary side

$E_2$ = phase voltage in secondary side

$I_1$ = primary side current

$I_2$ = secondary side current

$T_1$ = Number of turns in primary

$T_2$ = Number of turns in secondary.

2. The induced E.M.F $E = 4.44fT\phi \times 10^{-8}$

$\phi = B \times A$

F = frequency

T = Number of turn per winding

$\phi$ = flux

B = Flux density

A = Cross sectional area of the core

3. Primary equivalent resistance

$$= R_1 + \left(\frac{T_1}{T_2}\right)^2 R_2$$

4. Primary equivalent reactance

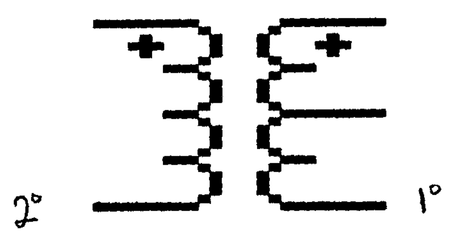
$$= X_1 + (\frac{T_1}{T_2})^2 R_2$$

where $R_1$ and $X_1$ are resistance and reactance of the primary winding.

If the number of turns is know, the flux can be worked out from the formular

$$\phi = E \times \frac{10^8}{4.44ft}$$

the inverting transformer used in this project in this project is of turn 1: 18 and as shown below:




The rated power of the transformer used is 1000VA, which can conveniently withstand the 600VA output of the UPS.

## 2.13 RELAY

This also called the change over switch. It is an electrical switching device comprising one or more contacts, which opens or closes the circuit.

The design is done in a way that, the switching device is mostly actuated by an electromagnetic, which opens or closes the circuit by means of movable armature, which attracts or releases.

The typically designed diagram of the relay of electromagnetic material is as shown in fig.2.7 below.

The relay has a coil of wire with an iron core and yoke that carriers movable armature. The yoke serves as an easy path for magnetic core, imparts the polarity of the end of the armature which is thus powerfully attracted by the opposite polarity of the front end of the core.

On this projects, a 5oomA 12VAC-transformer output passes through a bridge rectifier before it is used to power or operate the Relay $RL_1$ and $RL_2$ for change of state.

$RL_1$ connects the normal astable multivibrator when there is no source from public mains and disconnects it when the mains is on.

$RL_2$ connects the mains to the output of the inverting power transformer only when the mains is on. This is shown in figure 2.7.

The synchronisation takes place in a microsecond, which is not noticeable by the electronic equipment in use.

## 2.14 FILTER

The design of the filter is done in such that it separates specific frequencies. In this work, filters are used in the output of the rectifier circuit that works with charger and also in the output of the inverting power transformer.

In the charger a capacitor of 220μF is connected across the output of the rectifier circuit to generate pure and smooth d.c. current and voltage as required to charge the 12V dc battery.

In the output of the inverting transformer, the output is often sine wave superimposed on the several harmonics. The filter coverts this square waves to its sinusoidal equivalence. This is done to prevent damages to the inductive load.

The filter circuit used in this project has inductor in series with signal voltage and also a capacitor in shunt or across the line. The fig, 2.8 below shows a simplified design of the filter. The particular circuit frequency may be found by the resonance formula.

$$F = \frac{1}{2\pi\sqrt{LC}}$$

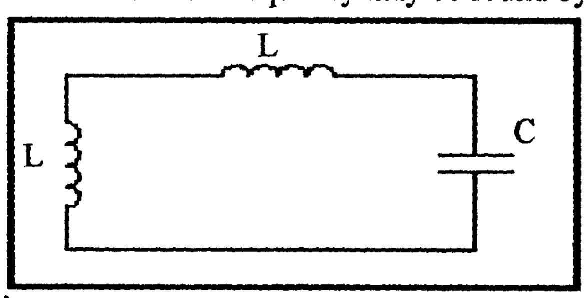



Fig 2.8 *Filter Circuit*

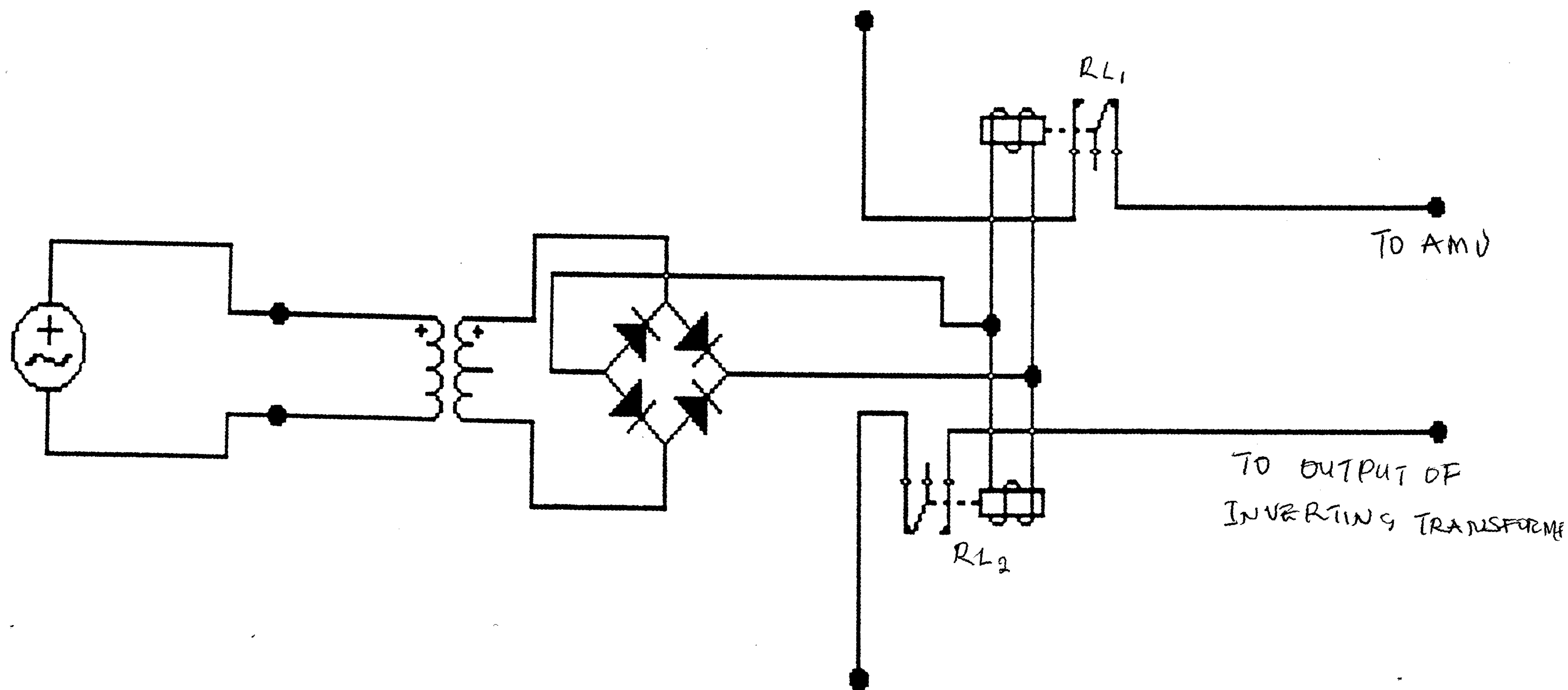
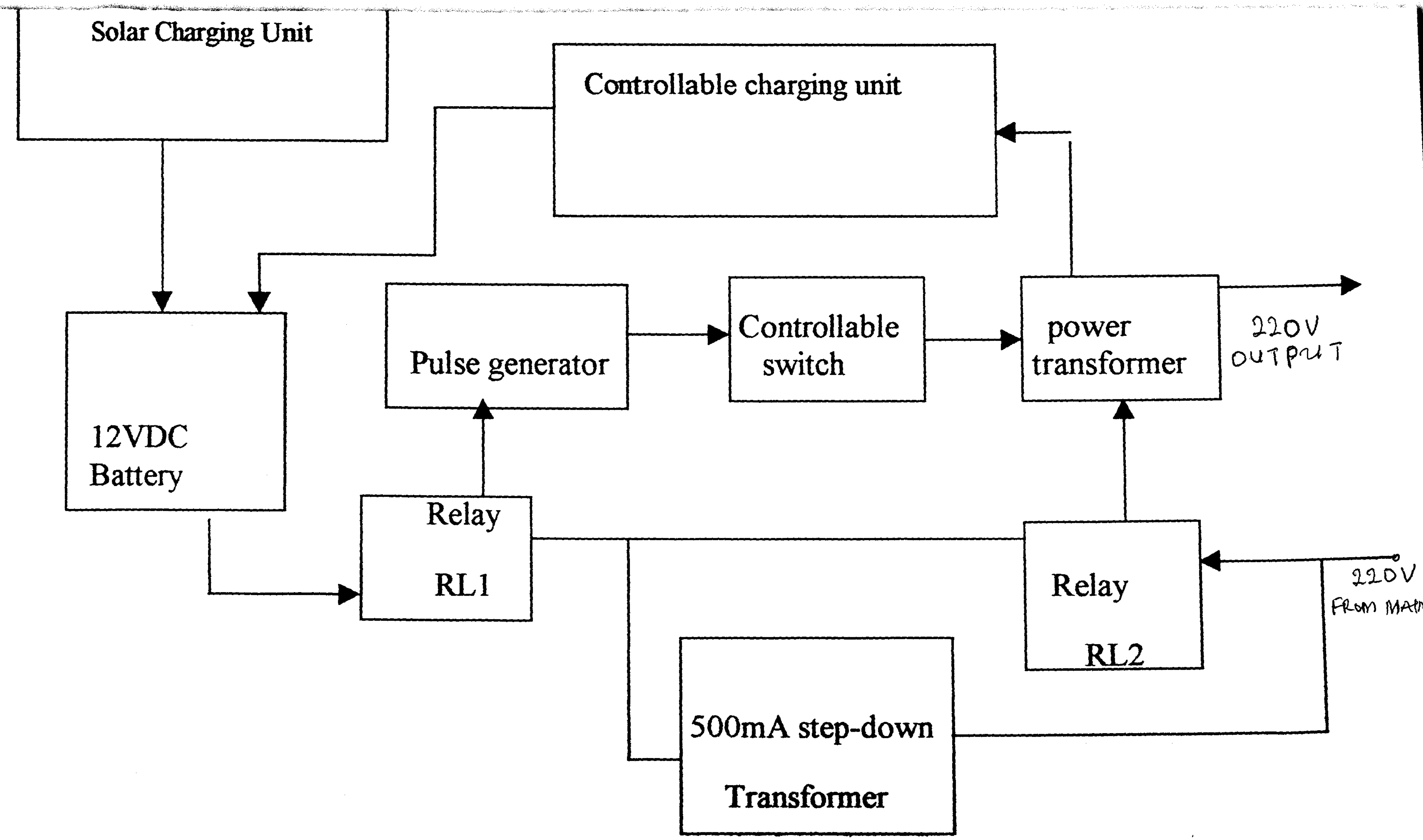
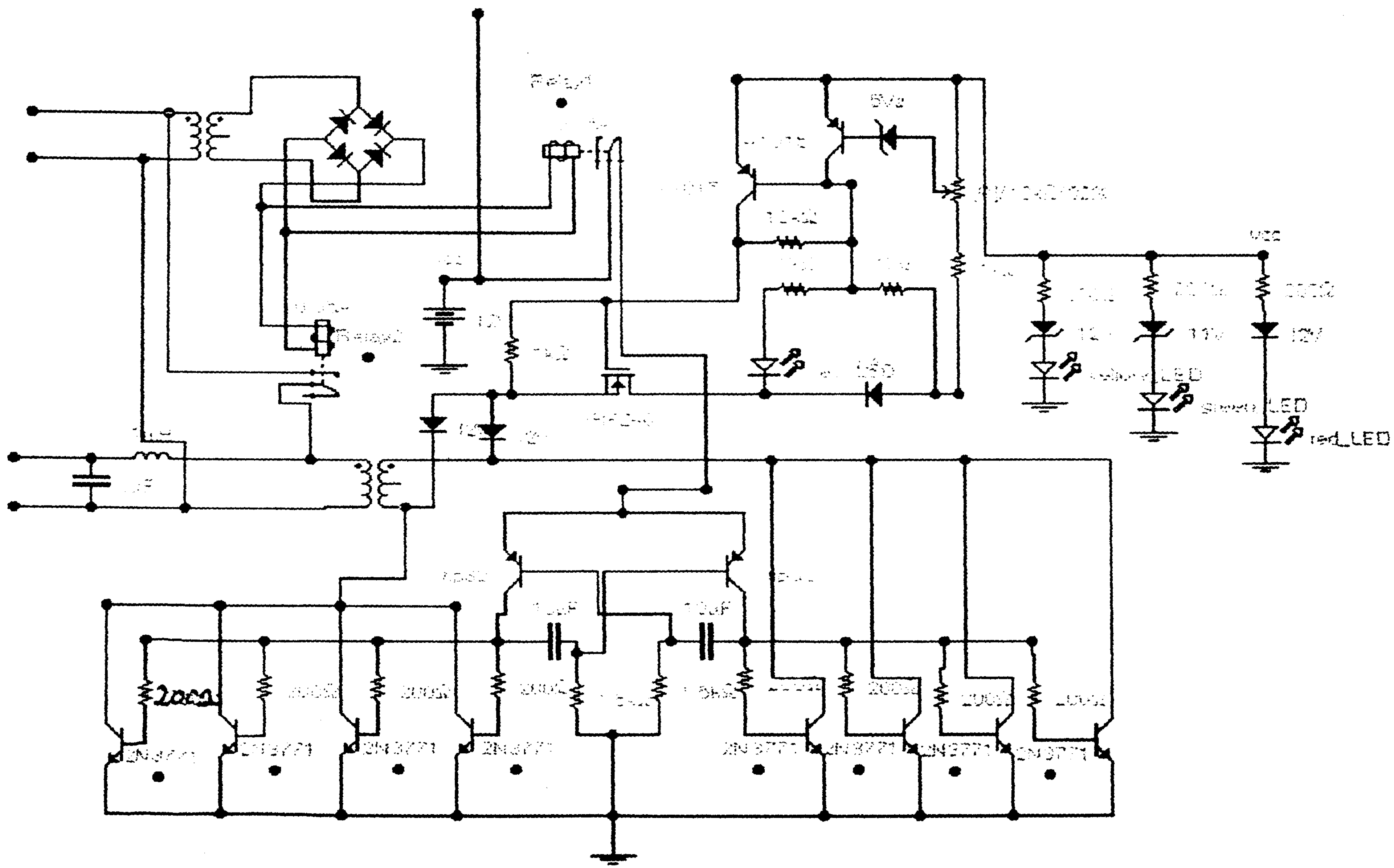



FIGURE 2.7, THE SYNCHRONOUS SWITCHING CIRCUIT
[RELAY]


Solar Charging Unit
Controllable charging unit
12VDC
Battery
Pulse generator
Controllable
switch
power
transformer
220V
OUTPUT
Relay
RL1
Relay
RL2
220V
FROM
500mA step-down
Transformer




Final Circuit D

# CHAPTER THREE

## 3.0 CONSTRUCTION AND TESTING

The process here involves three stages viz: design stage, pre construction on breadboard and construction on vero board

## 3.1 BREAD BOARDING

A breadboard is a technical device that is used for interconnection of the electronic components such as resistors, diode, transistors etc. without having to solder them. This gives room to effect necessary modification in the course of reconstruction without having unsolder them.

Each unit of the project was first developed on the breadboard and its performance observed before transferring them to veroboard for permanent construction. By this, the pain of fault finding will greatly reduce.

In bread boarding this work, the astable multivibrator circuit was first developed on the breadboard and the output is grounded through light emitting diode (LED) to monitor the behaviour of multivibrator.

The output frequency was tested using a digital multimeter. The outputs of the multivibrator were then connected to the base of power transistor which were already set aside. The output signal was also tested with the digital multimeter.

The 12V d.c. relays were also fixed on breadboard with the inverter and the charger combined to confirm the expected operation.

The light emitting diode (LED)for the battery voltage level indicator was also put in place across the battery and tested with a potential divider to see that it is actually regulating with respect to the control of battery voltage level as the potential is varied.

The power transistors were then mounted on the heat sink. This power transistors are two in number connected in parallel on both sides of the push –pull design. This led to large dissipation of heat and insufficient power transferred to the step up transformer.

Also, there are over-charging of the battery. The LED of the battery voltage indicator were over glowing and secondary coil of the transformer got heated up because of absence of required number of transistor in parallel.

### 3.2 MODIFICATION

The power transistors were made four on each side and heat dissipation was very minimised on the components.

The charger was introduced in the charging unit and this prevents the overcharging of the battery and also, limiting resistors stop over glowing of the LED.

### 3.3 VERO BOARDING

This is the final stage of construction as each module of the project work was transferred to the vero board and soldered in order.

The power transistor were moulted on heat sink so that internal power dissipated in form of heat will be conducted away and reduce thermal run away effect.

The actual component connected was sketched on the paper to view the appearance of component on vero board for compatibility and simplicity to avoid mistake during the actual transfer to vero board.

Step by step soldering was done following the stage on the paper and special care was taken to prevent short circuiting and wrong polarity of the various component being soldered on the vero board.

The soldered circuit veroboard was later transfered to the wooden box along with the battery and the transformer.

The wooden box is perforated at the top to aid free ventilation for the heat dissipated by the power transistor on the heat sink.

### 3.4 INSTALLATION OF PHOTOVOLTAIC GENERATOR

Actually, the solar cells are connected both in series and parallel in practice to generate the required power in the module. In this project work it is expected that the module generates 12V dc at 8.0 Amperes.

The panel would incorporate about forty (40) solar cells wired in series and parallel and mounted on the roof of a building or near by on a supporting structure facing south.

The outlet of the photovoltaic generator is then connected through copper wire cable to the12V d.c. battery inside the UPS system pack.

The solar panels output of electricity normally vary between seasons and according to prevailing solar radiation. Under average condition during the year, the solar panel will provide sufficient electricity to the battery to update the required voltage of the battery.

### 3.5 DISCUSSION OF RESULTS

The design goal of this work was a UPS system with an output power of 600VA, that is,to power a load up to 600W at an output voltage of 220V.

The output results obtained confirmed to a great extent with the expected values obtained from the design specification. The discharged time of the battery used in the system was expected to be Twenty (20) minutes and recharging time to be 3.3hours.

The following table gives summary of the result and target of the system.

| PARAMETER | TARGET | RESULTS |
|---|---|---|
| Output voltage (V) | 220 | 220 |
| Output current (A) | 2.73 | 2.65 |
| Output power (W) | 600 | 583 |

From the discussion above, it can be seen that, considering all experimental errors, the aims of this project work has been achieved.

# CHAPTER FOUR

## 4.0 CONCLUSION AND RECOMMENDATION

### 4.1 CONCLUSION

One of the primary objective of an engineer is to endeavour to deliver the best product or the most efficient service at the lowest cost to its consuming public.

The aims of this project is to design and construct a 600VA Uninterruptible power supply (UPS) system with solar power backup (photovoltaic generator). This has been achieved after solving problems encountered during the designing, construction and connecting stages. The system was tested and found to meet the expected results considering all the experimental error.

This project work can be used to provide power supply to critical load for minimum of twenty (20) minutes as long as the power rating of the load not more than the capacity specified on this system.

It is therefore confirmed that a reliable and maintainable unit for supplying uninterruptible power to critical load would be constructed using readily available components.

### 4.2 RECOMMENDATION

There is always room for improvement. It is therefore recommended that an improvement be made on the circuit such that when there is low voltage supply from the mains supply, the backup should take over and supply the load. This will further increase the life span of the critical lod and also makes it efficient and more reliable.

The good project should be exhibitedto the general public to boost intellect of the students and lecturer alike. This will also act as source of an income for the student, department and society as a whole.

## 4.3 REFERENCES


1. A textbook of Electrical Technology

   By B.L Theraja, A.K Theraja. Pp. 1024, 1189

2. Rectifier Circuit: Theory and Design

   By Schaeter J. Published by Oxford Press in 1986

3. Basic Electron System Technology

   By William Dugger, Dale Patrick. Published by Oxford in 1982

4. Power Electronics: Converter, Application and Design

   By Mohan Underland Robbins. Published by Oxford in 1991. Pp. 91-92, 129-131

5. Lecture notes on Analog Electronics I & II

   By Engr. (Dr.) Y.A. Adediran

6. The Art of Electronics

   By Paul Horowitz and Winfield Hill. Pp. 180-182

7. Design of a photovoltaic electric power system for an Indian village. Solar Energy, vol. 27, No 2. By H. Saho. Pp 103-107

8. Solar cells: A Technology Assessment, Solar Energy, vol.31. No 5. By James. R. Bolton. Pp. 483

## LIST OF COMPONENTS AND PRICES

| COMPONENT | QTY | UNIT PRICE ₦ | COST ₦ |
|---|---|---|---|
| Wooding case | 1 | 200 | 200 |
| 2N3771 power transistor (NPN) | 8 | 100 | 800 |
| Tip 32 power transistor (PNP) | 2 | 35 | 70 |
| 1.5 k ohm's resistor | 2 | 5 | 10 |
| 10 microfarad capacitor | 2 | 10 | 20 |
| RFz 46 power MOSFET | 1 | 120 | 120 |
| Heat sink | 2 | 50 | 100 |
| A transistor (PA) | 2 | 15 | 30 |
| 5V zener diode | 1 | 10 | 10 |
| LED | 4 | 10 | 40 |
| 200 ohm's resistor | 8 | 5 | 40 |
| 1k ohm's resistor | 4 | 5 | 20 |
| 10k ohm's resistor | 1 | 5 | 5 |
| 12v relay | 2 | 50 | 100 |
| 1 microfarad 300V capacitor | 1 | 50 | 50 |
| 1KVA power transistor | 1 | 1000 | 1000 |
| 12V\500mA transistor | 1 | 100 | 100 |
| Power diode | 5 | 10 | 50 |
| 1N4004 Power diode | 2 | 20 | 40 |
| 2200microfarad\50V capacitor | 1 | 50 | 50 |
| 5A bridge rectifier | 1 | 40 | 40 |
| 10k ohm's variable resistor | 1 | 20 | 20 |
| 100ohm's resistor | 3 | 5 | 15 |
| Zener 10V\11V\12V | 3 | 10 | 30 |
| 6V battery | 2 | 800 | 1600 |
| Plug and socket | 2 | 50 | 100 |
| Battery clips | 2 | 10 | 20 |
| TOTAL | | TOTAL | 4680 |