DESIGN AND CONSTRUCTION OF PULSE GENERATOR LAB POWER SUPPLY SYSTEM WITH ENERGY RECOVERY: A RELIABLE SUSTAINABLE ENERGY DEVICE

BY

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EEE/13/1109

A PROJECT REPORT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL/ELECTRONICS ENGINEERING
FEDERAL UNIVERSITY OYE-EKITI.

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) IN ELECTRICAL AND ELECTRONICS ENGINEERING.

FEBUARY, 2019

DEDICATION

In our lives three set of people matter most first and greatest is God Almighty, who daily re-creates us second is our family; the people we love the most the third is our friends, the bright side of us, to them I dedicate this project.

DECLARATION OF ORIGINALITY

This project is all my own work and has not been copied in part or in whole from any other source except where duly acknowledged. As such, all use of previously published work (from books, journals, magazines, internet, etc.) has been acknowledged within the main report to an entry in the References list. I agree that an electronic copy or hardcopy of this report may be stored and used for the purposes of plagiarism prevention and detection. I understand that cheating and plagiarism constitute a breach of University Regulations and will be dealt with accordingly.

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CERTIFICATION

This is to certify that the project **"PULSE GENERATOR LAB POWER SUPPLY SYSTEM WITH ENERGY RECOVERY: A RELIABLE SUSTAINABLE ENERGY DEVICE"** submitted to the Department of Electrical and Electronics Engineering, Federal University Oye-Ekiti for the Award of Bachelor of Engineering (BEng. Honors) in Electrical and Electronics Engineering is a record of the original research carried out by **OSINACHI MBAKAMMA EMMANUEL** of the Department of Electrical and Electronics Engineering, Federal University Oye-Ekiti.

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ABSTRACT

The economic, health and environmental costs of kerosene, petrol and other fuel-based energy sources are well documented. One of such is the Pulse Generator Lab Power Supply System with Energy Recovery; as a result of research efforts, the Pulse Generator Lab Power Supply System with Energy Recovery; has been tested to be a reliable energy sustaining device which aims at the lower -income households in the country.

The Pulse Generator Lab Power Supply System with Energy Recovery; is an energy sustaining device that is used in transferring electrical energy from two set of batteries that are connected in series to another two set of batteries that are connected in parallel.

The logic behind the concept was born out of the fact that two batteries connected in series have an effective voltage of 24V; a higher potential than their effective voltage 12V of the same set of two batteries when connected in parallel. The differential in voltage of the device is accountable for charging the batteries while powering a load.

In this work, a prototype model of the Pulse Generator Lab Power Supply System with Energy Recovery; consisting of the switching circuit, a 12V Lead Acid battery, a Pulse Generator Circuit are incorporated altogether serving as an adoption of the mechanical switching approach characterized by the production of sharp current pulses at about 50 cycles per second.

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ACKNOWLEDGEMENT

I would like to express our profound gratitude in appreciation of the contributions of my project supervisor, **Engr. K. Olusuyi** especially for his guidance and assistance during the execution of this project, his input has been valuable and contributed to the timely completion of this project.

Noteworthy thanks are extended to my Head of Department, **Engr. Dr. Oricha**. I also want to appreciate **Engr. Prof. Akinsanmi, Engr. Babarinde, Engr. H.U. Ezea** and the entire staff of Electrical and Electronics Engineering.

I appreciate the efforts of the Departmental Project coordinator **Engr. G.K. Ijemaru** who gave his views when needed, also for his love, patience and guidance, especially for the hinted template provided which was of great help.

I also heartily express my appreciation and gratefulness to **my colleagues, friends and all, who in one way or the other made my period as an undergraduate a successful one.**

Finally, my immense gratitude goes to my parent **Mr. and Mrs. Mbakamma,** my brothers, sisters, and relations for their endless prayers and unquantifiable support.

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CHAPTER ONE

1.0 INTRODUCTION

Since the discovery of fire several millennia ago by the early men, the level of mankind's technological sophistication has taken major leaps forward and never looked back since then. It is interesting to note that most of what man possesses today; the tools of his trade, with which he subdues the forces of nature, the shelter and modern conveniences that protect him from the elements of nature, even the very food he eats to stay alive have all at one point in time or the other in their useful life, evolved out of man's ability' to utilize energy. It is therefore logical to conclude that the quality of life, material welfare, health, employment and income are based on ample energy availability and low-cost (Smith, 1981).

1.1 BACKGROUND OF THE PROJECT

Energy is the capacity of a physical system to perform work Haliday et al (2004). The ability to harness and use different forms of energy has transformed living conditions for billions of people, allowing mankind to enjoy a level of comfort that is unprecedented in human history and enabling them to perform ever more productive task Uttam et al (2012).

Energy exists in various forms for example mechanical, electrical, thermal and so on. One form of energy can be converted into the other by the use of suitable arrangements. Out of all these forms of energy, electrical energy is preferred due to the following advantages (Rajput, 2003).

- It can be easily transported from one place to another
- Losses in transport are minimum
- Can easily be divided
- Economical in use
- Easily converted into other forms of energy
- Easily controlled and regulated to suit requirement.

Any physical unit of energy when divided by a unit of energy automatically becomes power. However, it is in connection with the mechanical and electrical forms of energy that the term power is generally used. The rate of production or consumption of heat energy and, to certain extent radiation energy is not ordinarily thought of as power. Power is primarily associated with mechanical and electrical energy. Therefore, power is defined as the rate of flow of energy (Rajput, 2003).

Energy is central to improved social and economic well-being, and it is indispensable for industrial and commercial wealth generation Rogner et al (2010). However essential it may be for development, energy is only a means to an end. The end is a sustainable economy and a clean environment, high living standards, prosperity and good health. The provision of reliable and sustainable energy services at an affordable cost in a secure and environmentally benign manner is an essential element of sustainable development. Energy is vital for eradicating poverty, improving human welfare and raising living standards. However, most current patterns of energy supply and use are considered unsustainable. Many areas of the world have no reliable and sustainable energy supplies, and hence no energy services thus limiting economic development. In other areas, environmental degradation from energy production and use inhibits sustainable development.

The need for a profound transformation of the world's energy-producing and using infrastructure is, of course, already widely recognized in the context of mounting concern about climatic change. Countless reports have been written on the subject of sustainable energy, but far few have approached these issues specifically from a developing country perspective. In nations where a significant portion of the population still lacks access to basic energy services, concerns about long-term environmental sustainability often are overshadowed by more immediate concerns about energy access and affordability.

1.2 STATEMENT OF THE PROBLEM

In the world at large and with consideration of developing countries such as Nigeria, depends so much on hydro power, solar, use of generators which require burning of fuel and other resource consumption. All these forms of energy are not enough due to the large population and developing nature of the country. Also, technological change is bringing longstanding and broadly held goals within reach in many areas, including energy. Achieving sustainable energy for all is an ambitious but achievable goal, which is becoming increasingly affordable with the rapid advance of technology. If the world is to achieve the Millennium Development Goals (MDGs) and keep global temperatures from rising by more than two degrees Celsius, concrete steps to achieving sustainable energy for all are not only necessary and urgent but very likely represent the lowest-cost energy path forward. Therefore, the goal of this project is to achieve sustainable energy supply in form of electricity via a pulse generator lab power supply system with energy recovery.

1.3 MOTIVATION

My desires to solve the power problems we face currently in Nigeria motivated me to embark on this project "project pulse generator lab power supply with energy recovery" which is a system that generates both AC and DC energy, utilizing the principle of free energy. Considering the economic, environmental and power problem implications which the project addresses such as the cost of fossil fuel used in powering a generator, noise and carbon emission when running a generator, the multiple tripping's which occurs in power stations due to bad weather condition, falling of trees on power lines, creeping weed on transmission lines. All contributing to the problems of power supply in underdeveloped countries such as Nigeria. The project addresses these problems with additional advantage of recoverable energy.

1.4 SIGNIFICANCE OF THE STUDY

Due to environmental pollution, the world is drifting towards reliable and sustainable energy systems in order to satisfy growing energy demand. These systems have their source constantly replenished unlike the fossil fuels that are likely to run out in years to come. Sustainable sources are all about using natural phenomena to create energy and have the following advantages over conventional fossil fuels:

- It is inexhaustible.
- It is environmentally friendly.
- Sustainable energy facilities usually require less maintenance than traditional generators.

1.5 AIM AND OBJECTIVES OF THE STUDY

The aim of this project is to design and construct a system that ensures sustainable energy supply in form of electricity of both AC and DC output via a pulse generator lab power supply system with energy recovery. In order to achieve the stated aim, the objectives are;

- To describe an adaptive prototype model of the pulse generator lab power supply system with energy recovery.
- To evaluate the effectiveness of the system.
- Formulate and implement the design using a hardware prototype.
- To enumerate the cost and benefits of using it as opposed to conventional fossil fuel.
- To identify the limitations of the research effort.

1.6 SCOPE AND LIMITATIONS OF THE STUDY

This project concentrates on the development of an appropriate pulse generator lab power supply system with energy recovery that powers a load and simultaneously recharges one another. The scope of this project is therefore, to build a prototype of a system that can supply electrical energy in the order of 216 Volt-Ampere powers and simultaneously recharge the batteries. This is possible because when a rechargeable battery delivers current to a load, it can recharge a similar battery when connected to the circuit due to the back electromotive force generated. It is upon this idea that the pulse generator lab power supply system was conceived. Some of the limitations are:

- You have to keep the output (load) consumption to minimum (not to exceed the maximum rated capacity) to sustain the back electromotive force.
- It cannot be used for systems that requires pure sign wave output AC source such as some hospital Equipment.

CHAPTER TWO

LITERATURE REVIEW

2.0 PREAMBLE

This chapter concentrates on the informative and technical literatures on the pulse generator lab power supply system with energy recovery. It describes past works and compares them with the intended design, stressing clearly the benefits this design has over them. Also presented in this chapter, are several energy generation technologies and several battery systems that has been researched upon and implemented by other researchers.

2.1 ENERGY AS AN ECONOMIC DEVELOPMENT

Energy development is an integral part of enhanced economic development Michael Toman et al (2003). This energy is a fundamental resource, it gives the ability to transform and manufacture goods, providing services to mankind and it is vital to the development of any economy. Efficient energy management however necessitates the development and utilization of an energy plan to ensure a balance between demand and supply with any economy. The fact that expanded provision and use of energy services is strongly associated with economic development leaves open how important energy is as a causal factor in economic development. However, energy development competes with other opportunities for scarce capital and opportunities for policy and institutional reform Barbora et al (2003).

Energy is necessary for daily survival, and future developments crucially depends on its long- term availability in increasing quantities from sources that are dependable, safe, and environmentally sound. At present, no single or mix of sources is at hand to meet this future need. Concern about a dependable future for energy is only natural since energy provides 'essential services' for human life - heat for warmth, cooking, and manufacturing, or power for transport and mechanical work. At present, the energy to provide these services comes from fossil fuel, gas, coal, nuclear, wood, and other primary sources (solar, wind, or water power).

These forms of energy are not useful until they are converted into the energy services needed, by machines or other kinds of end-use equipment, such as stoves, turbines, or motors. As the United States addresses the challenges of achieving energy sustainability in the 21st century, the recognition of the need to find alternatives to current practices has been stymied by the identification of many complexities: including matching supply and demand, the scale of current and projected needs, and the difficulty of replacing the present unidirectional system with far more complex hybrid systems utilizing disparate sources and supplies of energy Marsden et al (2010). One of the major challenges is designing new systems that leverage existing infrastructure based on centralized generation to take advantage of alternative sources at a local level. The examination of past energy technology practices at historic sites provide ideas for new system designs that integrate centralized generation with local resources, and match distributed demand with local supply.

2.2 REVIEW OF RELATED WORK

PULSE GENERATOR LAB POWER SUPPLY SYSTEM WITH ENERGY RECOVERY

Most developing countries such as Nigeria, depends so much on hydro power, solar, use of generators which require burning of fuel etc. All these forms of energy are not enough due to the large population in the country, and as a result some areas lack this electricity supply. In order to respond to this energy crises, the design and implementation of pulse generator lab power supply system as a source of both AC and DC power output is carried out. The pulse generator lab power supply basically, is a four-battery system that supplies energy to power a load and at the same time recharges itself through the back electromotive force created from the transformer. This is the background to the design of the pulse generator lab power supply system with energy recovery. The following are the contributions and design of various inventions.

2.2.1 THE FOUR BATTERY SYSTEM

The four-battery system exploits electrical linear network theorems governing identical cells in serial and parallel connections. When two or more identical cells are connected serially, the effective open-circuit voltage across the combination is the algebraic sum of their respective terminal voltages. When connected in parallel, the effective open-circuit voltage across the combination is the value of the terminal voltage across any one cell Theraja B.T. (2004). Moreover, when two or more cells with unequal terminal voltages are connected in parallel, current will flow round the circuit from the cell with the highest terminal voltage to the cell with the lowest terminal voltage, thus powering a load connected to the circuit with the potential of equalizing the terminal voltages.

2.2.2 NIKOLA TESLA 4 BATTERY SYSTEM

Nikola Tesla invented a four-battery system, an arrangement that continuously swap battery connections from series to parallel and vice versa. He found that by varying the frequency and duration of voltage pulses in his four-battery system, lots of effect could be produced such as heating, cooling and lighting. The device consisted of four rechargeable batteries, two of which were connected in series and the other two in parallel. This arrangement was always interchanged so that those batteries in series were connected in parallel and vice versa. Swapping was done continuously for about a hundred times per second. At any given instant, two batteries were always connected in series and two in parallel. The effective voltage across the series combination was 24 volts while that across the parallel combination was always 12 volts. Therefore, at any given instant, two batteries connected in series feed current to those in parallel, thus charging them up Patrick et al (2012). Tesla connected a load in between the two sets of battery arrangements so that power was always delivered to it during swapping. Tesla implemented swapping via a rotating drum powered by a direct current electric motor. As the drum rotated, swapping occurred in the circuit. The figures below show both the top elevation and the side elevation of the switching drum.

Figure 2.0: Top elevation of the switching drum

Figure 2.0: Top elevation of the switch 1

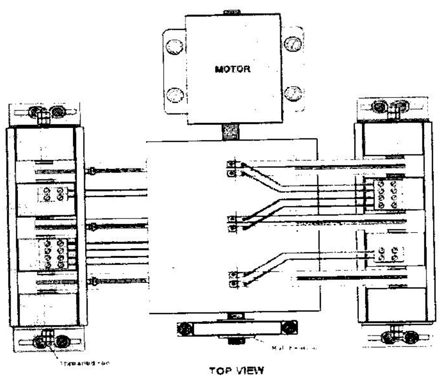
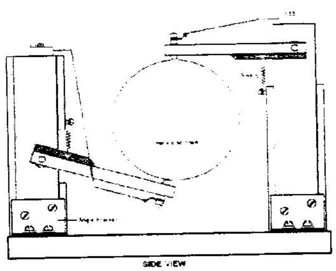


Figure 2.1: Side elevation of the switching drum

Figure 2.1: Side elevation of the switch 1



Tesla designed a wooden drum to have about eight brass strips serving as conducting layers to produce several switching for each revolution of the motor. The switch contacts were rigid arms, pulled against the rotating drum by springs. The contact arms where attached to each other in pairs. The surface of the inserts was gently eased into exact alignment with the surface of the drum, while the pivots for all the switching arms were a length of threaded rod with lock nuts at each end. During rotation of the drum, there was no movement of the switching arms ensuring effective contacts between the conducting layers and the switching arms, and the contacts make and brake connections by sliding on and off the conducting strips in the cylinder at exactly the same time.

2.2.3 JOHN BEDINI THREE BATTERY SYSTEM

The Tesla four battery system can be reduced to a three-battery combination reproducing the similar electrical effects and this was described by John Bedini. Two batteries were always connected in series, thus feeding current to a third battery and powering a load. The figure below shows Bedini's arrangement of his three-battery system.

Fig 2.1: Batteries tagged 1 and 2, charge battery tagged 3, and powers a load.

Fig 2.1: Batteries tagged 1 and 2, charge 1

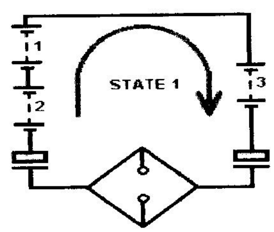


Figure 2.1 above shows two batteries tagged 1 and 2 connected in series giving an effective terminal voltage of 24 volts. The combination is used to charge a third battery tagged 3 with a terminal voltage of 12 volts simultaneously powering a load. The figure 2.2 below shows batteries tagged 1 and 3, connected in series, charging battery tagged 2 and simultaneously powering a load.

Figure 2.2: Batteries tagged 1 and 3, charge battery tagged 2, and powers a load

Figure 2.2: Batteries tagged 1 and 3, charge 1

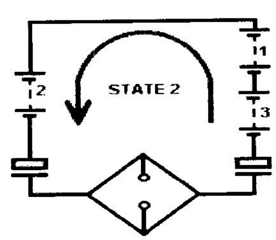
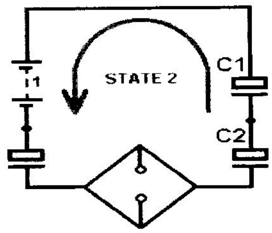


Figure 2.5: Both charged capacitors feed current back to battery tagged 1, and a load

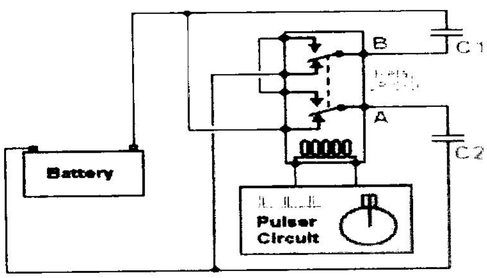
Figure 2.5: Both charged capacitors feed 1



Both states 1 and 2 can be continuously attained via the circuit diagram as shown in the figure below.

Figure 2.6: Ron Cole's one battery system circuit

Figure 2.6: Ron Cole's one battery system 1

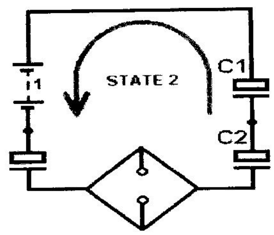


Source: www.universallyaware.ning.com

The pulse circuit is put in place to give short, very sharp pulses to drive the relay. The relay has two changeover contacts "A" and "B". Initially, the capacitors "C1" and "C2" are charged up when the relay is in its unpowered state. However, then the relay coil is energized, "C1" and "C2" are connected in series with an effective voltage of 24 volts, thus, undergoing discharge by charging up the battery. The relay is then de-energized resulting in both capacitors reconnecting in parallel and thus current-fed by the battery. This process is repeated continuously.

Figure 2.5: Both charged capacitors feed current back to battery tagged 1, and a load

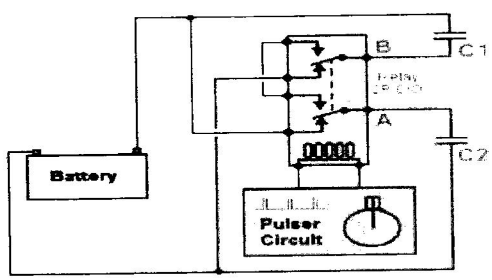
Figure 2.5: Both charged capacitors feed 1



Both states 1 and 2 can be continuously attained via the circuit diagram as shown in the figure below.

Figure 2.6: Ron Cole's one battery system circuit

Figure 2.6: Ron Cole's one battery system 1



Source: www.universallyaware.ning.com

The pulse circuit is put in place to give short, very sharp pulses to drive the relay. The relay has two changeover contacts "A" and "B". Initially, the capacitors "C1" and "C2" are charged up when the relay is in its unpowered state. However, then the relay coil is energized, "C1" and "C2" are connected in series with an effective voltage of 24 volts, thus, undergoing discharge by charging up the battery. The relay is then de-energized resulting in both capacitors reconnecting in parallel and thus current-fed by the battery. This process is repeated continuously.

2.2.5 SELF - CHARGING INVERTER BY ABATAN ET AL

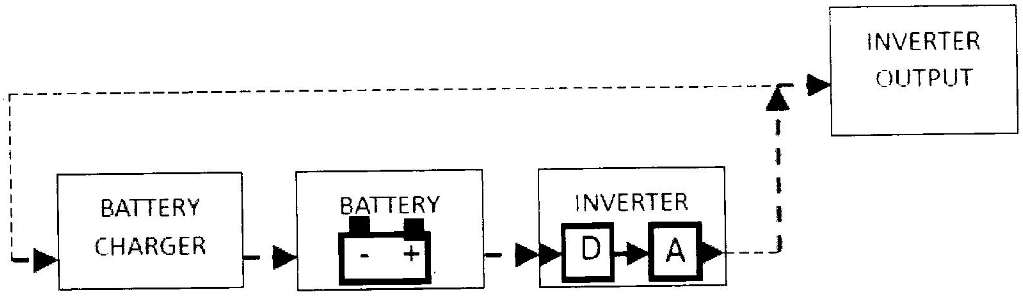
In a research carried out by Abatan et al (2013) on a self-charging inverter for constant electricity generation, they outlined that generators and inverters come with adverse problems such as cost of fueling, noise, emissions and need to recharge the inverter batteries after use.

In the research they showed the advantages of a self-charging inverter which included uninterrupted supply of electricity for 24/7 on daily basis. They showed that it could be applied to television sets, microwaves, printers, radio sets and other house hold appliances.

The main objective was to design and construct a self-charging inverter with relay switch, a noiseless, non-polluting, non-toxic source of energy that requires no cost of running.

Fig 2.7 Block diagram of a practical self-charging inverter

Fig 2.7 Block diagram of a practical self-charging inverter 1



Source: www.ijetae.com

2.2.6 DUAL SOURCE POWER GENERATING SYSTEM

Gregory I Rozman, Mahesh J. Shah and Alan E. King invented the Dual source power generating system, a power generating system which provides high voltage AC power and low voltage DC power using a single generator. The generator includes a rotor and a stator that is wound with a first winding and a second winding. The first winding has a greater number of turns than the second winding and generates high voltage AC power in response to the rotating magnetic field created by the rotor. The second winding generates low voltage AC power in response to the rotating magnetic field created by the rotor. The low voltage AC power is converted to low voltage DC power by a rectifier. The low voltage DC power is further controlled by a DC-DC converter to generate controlled DC power. A controller monitors the DC power generated by the DC-DC converter, and generates pulse width modulation signals that are provided to the DC-DC converter, selectively increasing or decreasing the controlled DC power provided by the DC-DC converter.

2.2.7 FOOT STEP POWER GENERATION USING PIC MICROCONTROLLER

Manisha B. Kanawade, Amruta N. Jadhav, Rohini B. Jadhav, and Prof. Kalpesh K Bamb invented the foot step power generation using PIC microcontroller. This invention is all about generating electricity when people walk on the Floor. Think about the forces you exert which is wasted when a person walks. The idea is to convert the weight energy to electrical energy. The Power generating floor intends to trans- late the kinetic energy to the electrical power. It can produce 100W on just 12 steps, then for 120 steps we can produce 1000 Watt and if we install such type of 100 floors with this system then it can produce 1MegaWatt. This system continuously generates energy so long as we step on the piezoelectric sensor which converts the mechanical energy of the foot to electrical energy. Also, the electrical energy generated can be stored in the battery.

CHAPTER THREE

METHODOLOGY

3.0 PREAMBLE

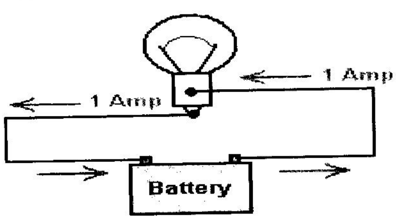
In this chapter, the design is discussed in details in terms of configurations, mode of operation and its useful applications. The device comprises of four lead acid batteries (12V, 18AH, each), an iron core center tap transformer, (220V, 300W, 20:1), 5mm single core copper wires, eight transistors (800V) and a microcontroller (PIC16F84A).

3.1 THE CONCEPT

According to the theory of electrical circuitry, current flows in a close circuit from a battery via a load causing the battery to be discharged over a space of time. The implication of this analogy is that stored energy from the battery has been utilized to do equivalent work exhibited by the load. Figure 3.1 is a schematic description of the analogy of a simple circuitry system described above.

Figure 3.1: Schematic description of a Simple Circuitry System

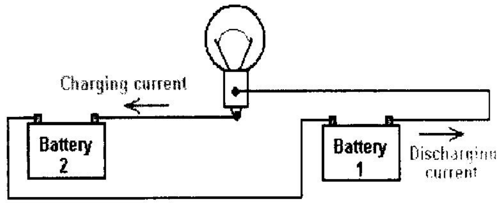
Figure 3.1: Schematic description



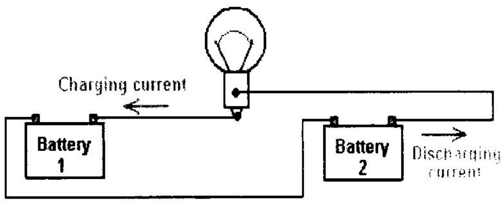
In the works of Tesla, continuous supply of electric current to the load can be achieved if two batteries are connected as shown in Figure 3.2 below if an additional battery of the capacity is incorporated into the circuitry system whereby battery 1 powers the 1-amp load causing battery 1 to be discharging while charging battery 2 in the process. To achieve sustainability of supply to the load, battery 1 is swapped for battery 2 to enable battery 2 assume the role of battery 1 while charging battery 1 and the process continues. That was the logic behind the Tesla's four battery system.

Figure 3.2: The two swapping battery system for sustainable energy supply

Figure 3.2: The two-swapping battery



a: battery 1 powers load and charges battery 2

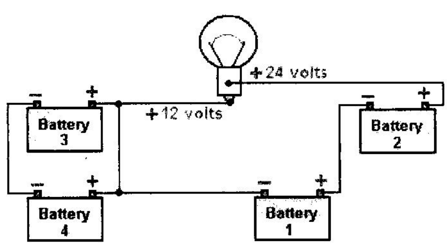


b: battery 2 powers load and charges battery 1

The principle behind the Nikola Tesla four battery switching system is as enumerated above. With his "4-battery switch" system, Nikola Tesla demonstrated that using four identical batteries a sustainable energy system is achievable based on the circuitry system in Figure 3.3 below:

Figure 3.3: Nikolas Tesla's basic 4 battery switch circuitry system

Figure 3.3: Nikolas Tesla's basic 4 battery



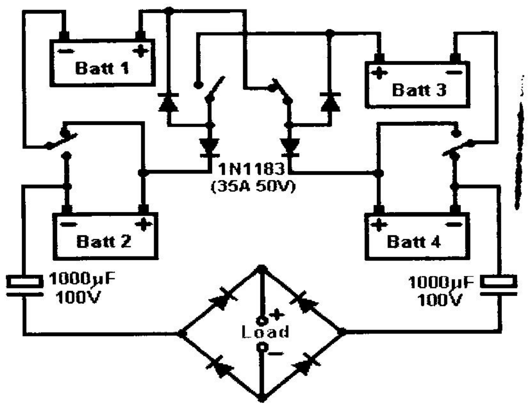
The arrangement revealed that with four 12-volt batteries, a load of the same 12 volts across its circuit as it would have had with the single battery shown in Figure 3.1 may be sustained ad infinitum, if the first two batteries labeled 1 and 2 are connected "in series" to give 24 volts, while last two batteries tagged 3 and 4 are connected in parallel to give 12 volts. Tesla arranged the circuit to swap the two pairs of batteries over with 1 and 2 taking the place of 3 and 4.

3.2 OPERATING FREQUENCY OF SWAPPING

The circuit diagram that aids to implement swapping of batteries from series to parallel and from parallel to series is as shown in the figure below:

Figure 3.4: Circuit diagram that aids implementation of battery swapping

Figure 3.4: Circuit diagram that aids the implementation



The switches are four in number and are synchronized in pairs. With the switches in position as shown in figure 3.4, batteries tagged 1 and 2 are connected in series while batteries tagged 3 and 4 are connected in parallel. With the switches in opposite configuration, batteries tagged 1 and 2 are connected in parallel while batteries tagged 3 and 4 are connected in series. In this way, reversed pulse current flows continuously through the circuit. The load however is protected by a bridge rectifier so that only direct current pulses are allowed through it. These pulses are however, smoothened by the 1000 micro farad capacitors in the circuit. The frequency of the making and breaking of the switches is a function of the amount of direct current pulse cycles per second that flow through the load. A low frequency results in a small number of pulse cycles per second, while a high frequency results in a large number of pulse cycles per second. In this project, we swap battery connections within an interval of frequency from 20 hertz to 100 hertz.

In practice, there are three approaches to swapping battery connections which include:

- Using a direct current motor, as Nikola Tesla did
- Using a 555 Timer Chip
- Using a Micro-controller

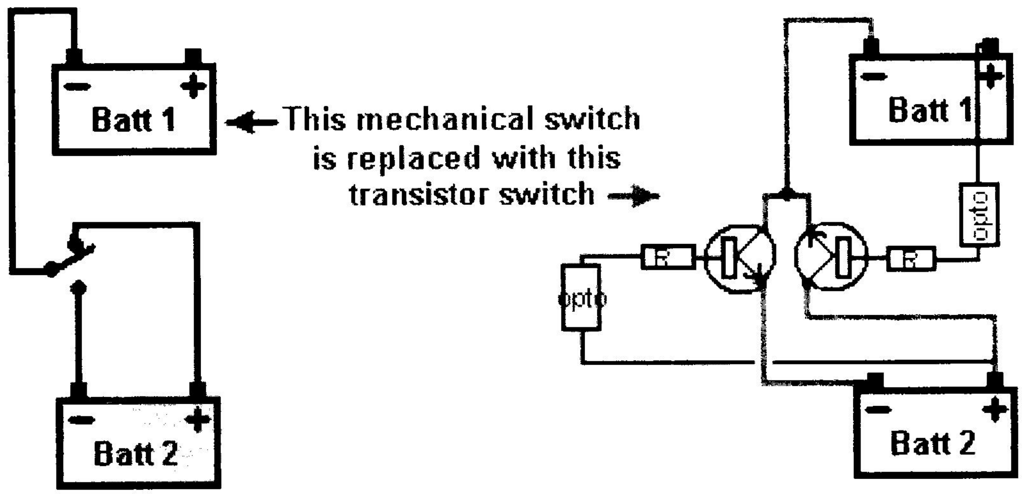
3.3 SOLID STATE SWITCHING

Mechanical switching involves the use of an electrical motor and relay switch to generate the pulse signals as seen from the literature review, while solid state switching is an automatic system of switching and involves no moving parts.

The Mechanical change over switch can be replaced with transistors or implementing the concept below:

Figure 3.5: Shows the opto-coupler and transistors replacing the relay switch

Figure 3.5: Shows the opto-coupler and transistor



From the above diagram the conventional mechanical relay switch is replaced with a transistor, while the opto-isolator transfers the electrical signal from the oscillator (microcontroller) to the transistors. The system will require a crystal oscillator in order to generate an accurate frequency of switching.

3.4 H-BRIDGE CIRCUIT

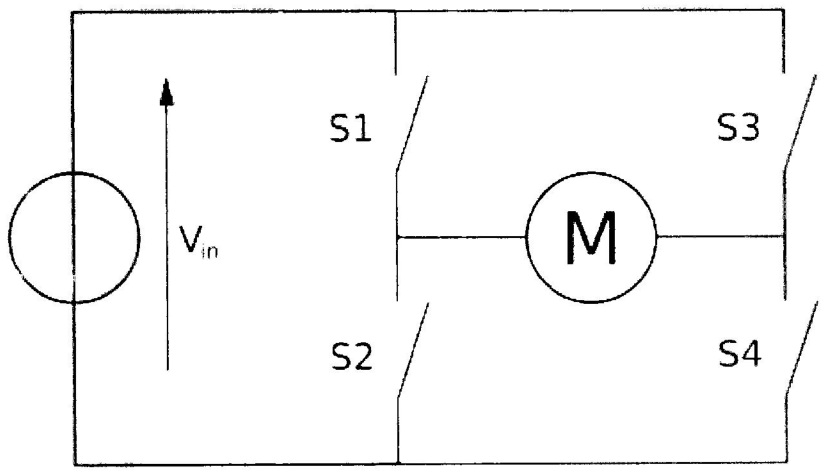
Using the concept of H-bridge to fire the transistors will improve the quality and effectiveness of the reverse pulsed current.

An H-bridge is built with four switches (solid-state or mechanical). When the switches S1 and S4 are closed and S2 and S3 are open, a positive voltage will be applied across the motor. By opening S1 and S4 switches and closing S2 and S3 switches, this voltage is reversed, allowing reverse operation of the motor.

This concept was used to switch on and off the transistors continuously.

Figure 3.6: Shows a H-Bridge circuit.

Figure 3.6: Shows a H-Bridge circuit.



3.5 DESIGN CHOICE

After a walk-through of possible considerations of methods of switching as highlighted above, the PIC16F84A Microcontroller was adopted due to the following reasons:

- Frequency of switching can easily be stabilized when a crystal oscillator is added to the microcontroller.
- The pic16f84A lets you use the pins in a more flexible manner.
- With a micro-controller, frequency can only be adjusted at compile time before code is burnt into the chip.
- The PIC16F84A has a very simple design in terms of circuit components which are affordable and available in any electronic market.

3.6 THE DESIGN PROCESS

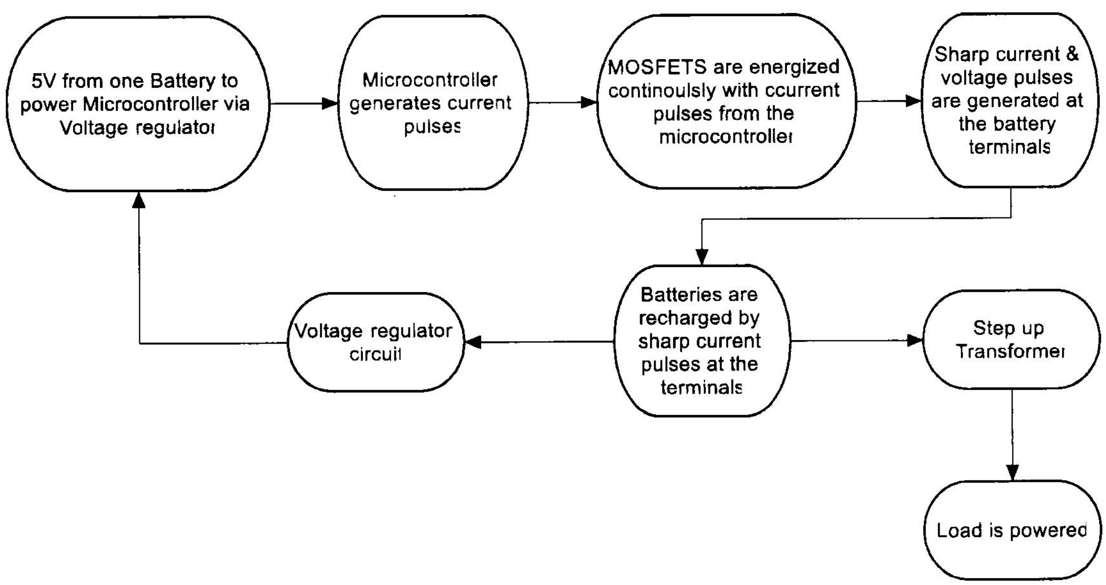
There are four components of the pulse generator lab power supply system with energy recovery which include:

- The "four battery bank"
- The "main circuitry", connecting the batteries in accordance with the circuit diagram in Figure 3.4.
- The "control circuitry" that regulates "makes" and "brakes" in the main circuitry. This circuit consists of the microcontroller.
- The load compartment and to the step up transformer.

When the switches in the main circuitry are activated continuously, swapping of batteries occurs, thus generating sustainable energy transfer to the load. The switches in the main circuitry are transistors driven by pulse signal from a control circuitry. The control circuitry is principally driven by the logic of flip-flops embedded in the PIC16F84A microcontroller. The microcontroller is powered from one of the batteries, via a voltage regulator.

Figure 3.7: Project Schematic diagram

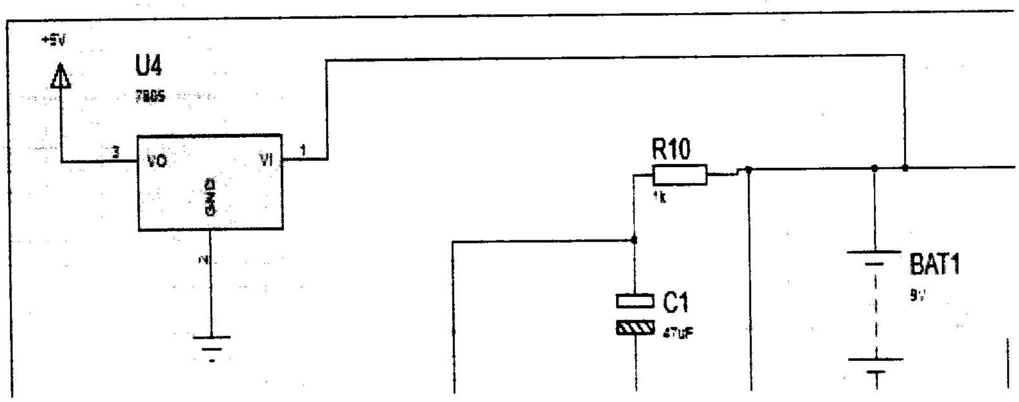
Figure 3.7: Project Schematic diagram



The initial energy needed to drive the system is obtained from a 5-volt subsystem, taken from one of the batteries according to the circuit diagram as shown in the figure below:

Figure 3.8: Circuit design to channel out 5 volts from one battery to the microprocessor via a voltage regulator.

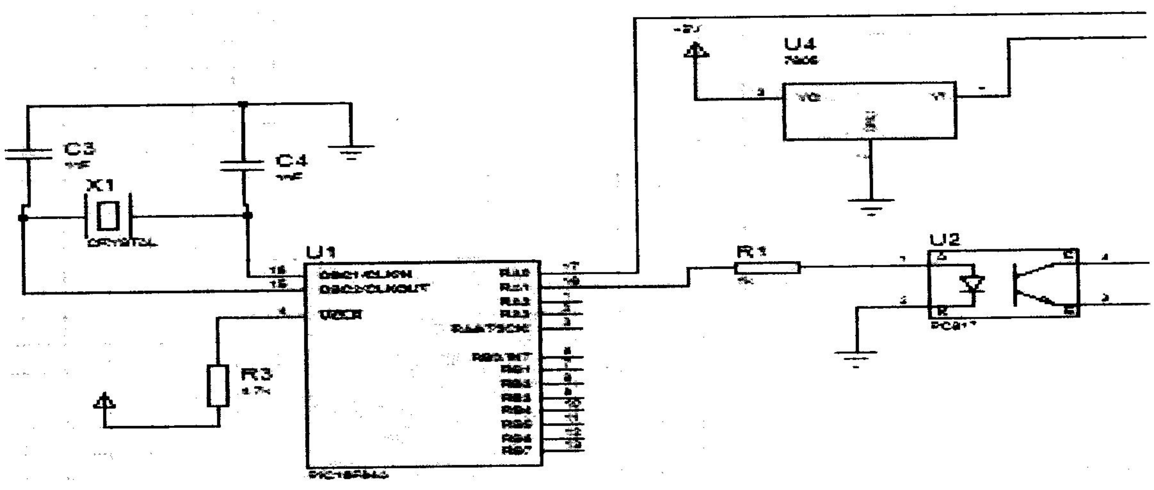
Figure 3.8: Circuit design to channel out 5V



This circuit diagram above shows how the voltage regulator is connected to one of the 12volt batteries to channel out 5volts to power the PIC 16F84A microcontroller.

Figure 3.9: PIC16F84A Circuitry

Figure 3.9: 16F84A Circuitry



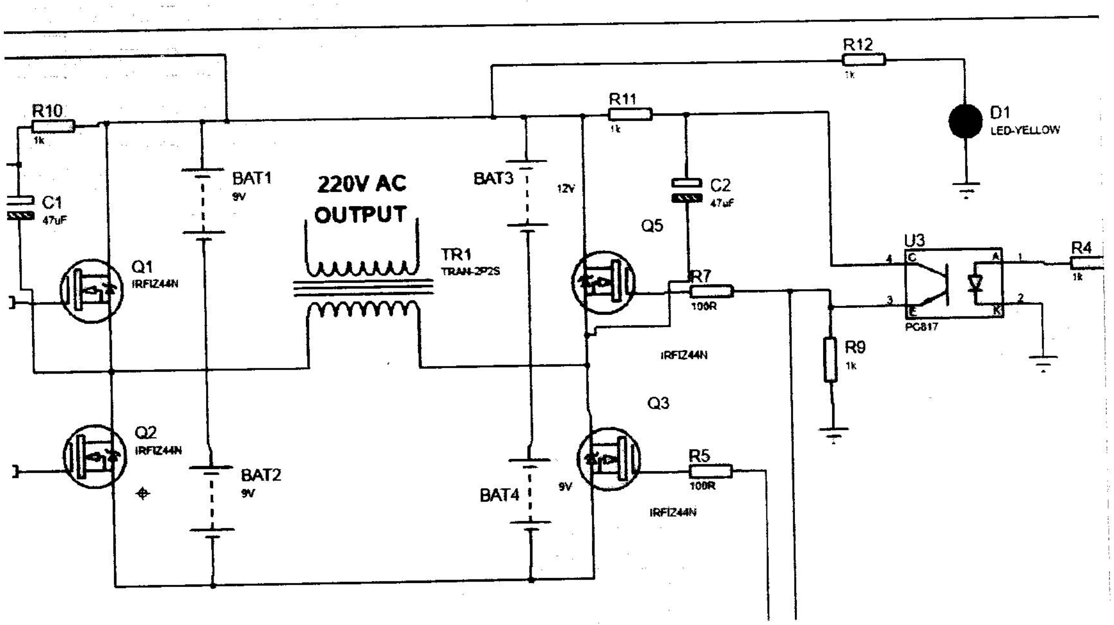
The PIC16F84A microcontroller has a total of eighteen pins; five were used to drive the main circuitry system. They include pins 4, 15, 16 and 18 while the rest were left dormant.

- Pin 4 is the master clear
- Pin 14 is the input for the voltage regulator with a maximum voltage of 5.5volts
- Pins 15 & 16 are connected to the Crystal oscillator to generate a precise frequency of switching.
- Pins 18 was connected the opto-isolator to transfer the electrical signals generated by the microcontroller to the transistors.

The outputs of the microcontroller were pin 15, 16 & 18. They send out current pulse signals channeled to the eight transistors in the entire circuit. These transistors were connected in a way that when two are in low state, the other two are in high state.

Figure 3.10: Main Circuitry Diagram

Figure 3.10: Main Circuitry Diagram



The figure above shows the circuitry system separate from the microprocessor with all the main components which include; the batteries, transistors (MOFSETS), capacitors, resistors, opto-isolator and transformer. The main circuitry is responsible for finalizing the switching process and stepping up the current and voltage via a transformer.

3.72 RAM (Random Access Memory) File Registers

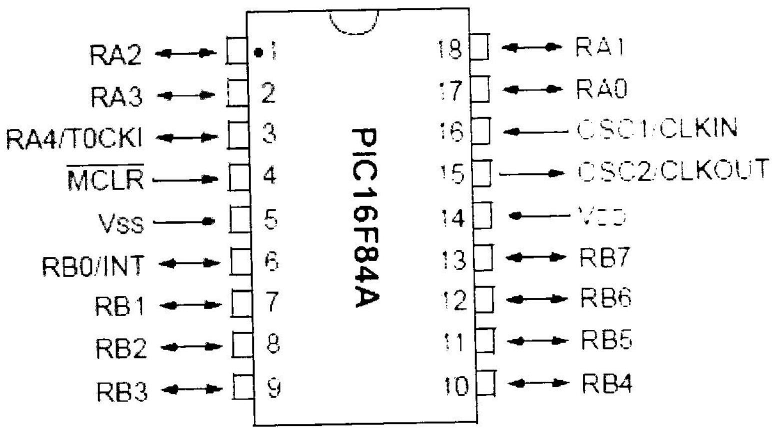
Bank switching is used to access this memory. Each bank has a memory capacity of 80 bytes (00h-4Fh). The PIC16F84A has two banks.

3.73 EEPROM (Electrically Erasable Programmable Read Only Memory)

This is non-volatile memory, the contents are not lost when power is turned off. The memory contents can be rewritten by the program. The total capacity is 64 bytes, and the number of times it can be rewritten to is limited to about one million. For this reason, it is not recommended for temporary data storage. It is used to store data which will not change frequently. Data can be safely stored for 40 years.

Figure 3.12: Schematic diagram and pin configuration of PIC16F84A

Figure 3.12: Schematic diagram and pin labels



OSC1/CLKIN : Oscillator crystal input.
External clock source input.

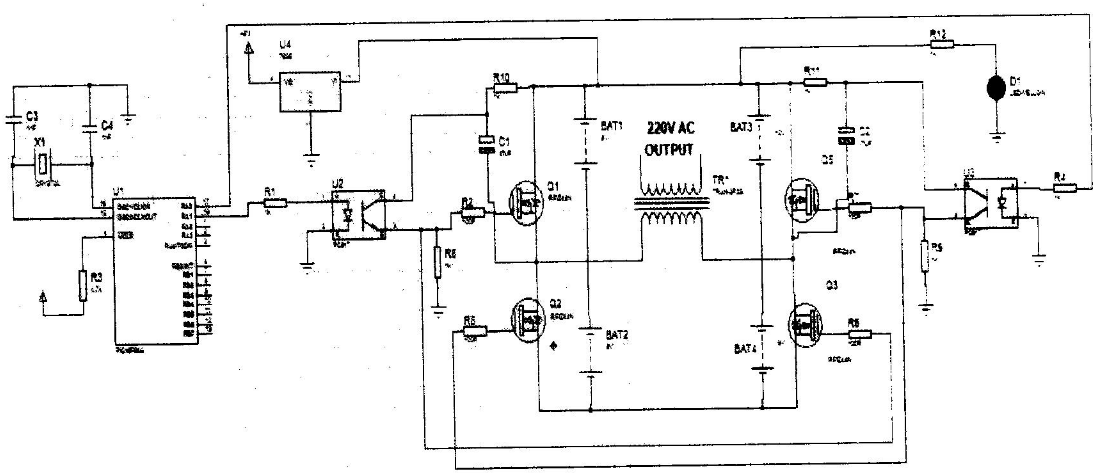
OSC2/CLKOUT : Oscillator crystal output.
Connects to crystal or resonator in crystal oscillator mode

MCLR (inv) : Master clear (reset) input.
Programming voltage input.

RA0 - RA3 : Bi-directional I/O port.

Figure 3.11: Interfacing the main circuitry with the PIC16F84A microcontroller

Figure 3.11: Interfacing the main circuit



3.7 OSCILLATOR

The PIC16F84A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, and toys. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes.

The PIC16F84/PIC16F84A is an improved version of the PIC16C84, and almost completely compatible, with better program security and using flash memory instead of EEPROM memory for program memory. The PIC16F84/PIC16F84A has 68 bytes of RAM whilst the PIC16C84 has 36 bytes.

3.71 Flash program memory

Flash memory is used to store the program. One word is 14 bits long and 1024 words (1k words) can be stored. Even if power is switched off the contents of the flash memory will not be lost.

RA4/T0CKI	: Bi-directional I/O port. Clock input to the TMR0 timer/counter.
RB0/INT	: Bi-directional I/O port. External interrupt pin
RB1 - RB7	: Bi-directional I/O port.
VSS	: Ground
VDD	Positive supply (+2.0V to +5.5V)

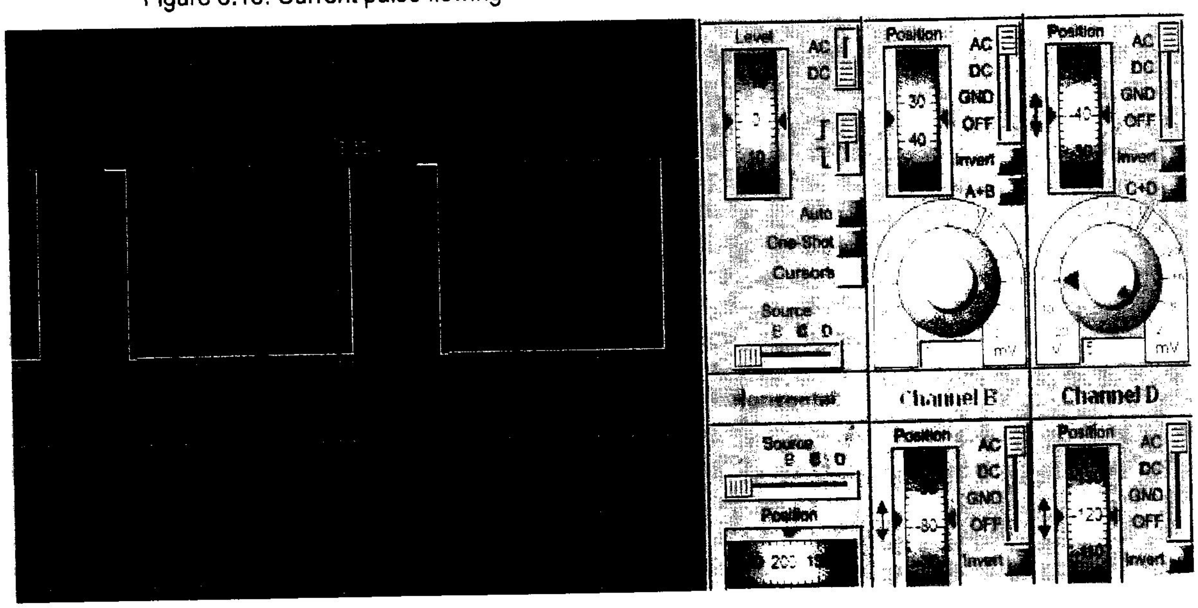
3.8 POWER SURGE AT BATTERY TERMINALS

Lead acid batteries are termed Starting, Lighting and Ignition (SLI) batteries because they deliver high current for a very short time. These batteries are designed to deliver large bursts of power for a short time, as is needed to start an engine. The amount of power surge obtained from such brief connection is a function of how short the connection time is. We exploit this phenomenon in generating sustainable energy by swapping battery connections as suggested in the circuit diagram in Figure 3.4. The effect of swapping for very short durations is that the batteries are recharged, and at the same time, a load is powered.

The current that flows through the circuit is a reversed pulsed current as shown in the figure below:

Figure 3.13: Current pulse flowing in the circuit

Figure 3.13: Current pulse flowing



3.9 DESIGN CONSIDERATIONS

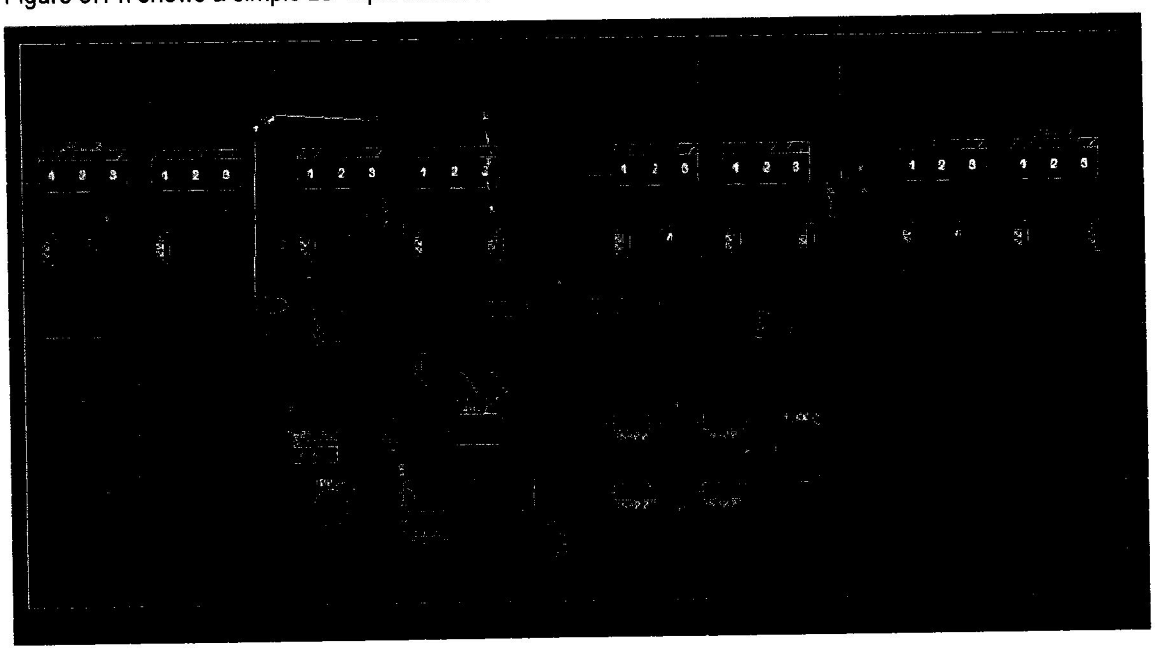
In carrying out the project design and construction, we took into cognizance the following factors:

- The actual design parameters for the construction of the control circuitry, (Microcontroller circuitry) such as resistor value, capacitor value, the required voltage to activate the microcontroller and kind of opto isolator were considered before the design of the full circuit diagram.
- The actual regime of pulse required to always activate the MOSFETS for efficient power surge generations at battery terminals are in the sequence: "on-off-pause…on-off-pause…on-off-pause…" ad infinitum.
- The switching speed was set at 60Hz due to the capacity of the transistors (MOSFETS), and for the protection of the circuit itself with the load that may be connected to it.
- The internal wiring used was 5mm single core for higher resistance, while outer wiring was 6mm single core due to the heat generated at the battery terminals.
- Due to the generation of current burst at battery terminals, an inductive load is most preferably powered by the system.

3.10 2D VIEW OF PRINTED CIRCUIT BOARD

Figure 3.14: shows a simple 2D representation of the electrical components on the PCB

Figure 3.14: shows a simple 2D representation

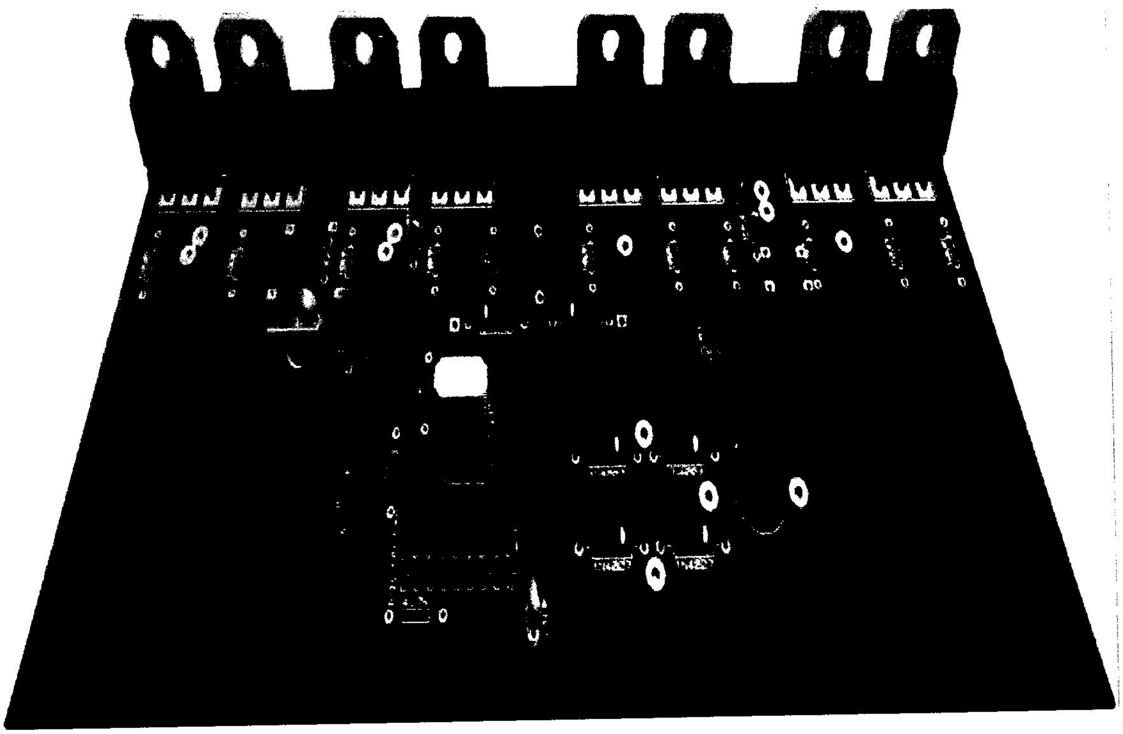


The MOSFETS which are eight in number are arranged in two's, and are fired on and off in a H-Bridge manner. When one is on the other is off in every set as seen in the figure above, if two of the MOSFETS are switched on at the same time it could lead to a bridge in the circuit and may damage some of its electrical components. The micocontroller is programmed to switch on and off each transistor at 60Hz. When one is turned on then it allows sharp current pulses flow throughout the circuit.

3.11 3D VIEW OF PRINTED CIRCUIT BOARD

Figure 3.15: showing the arrangements of the MOSFETS and other components

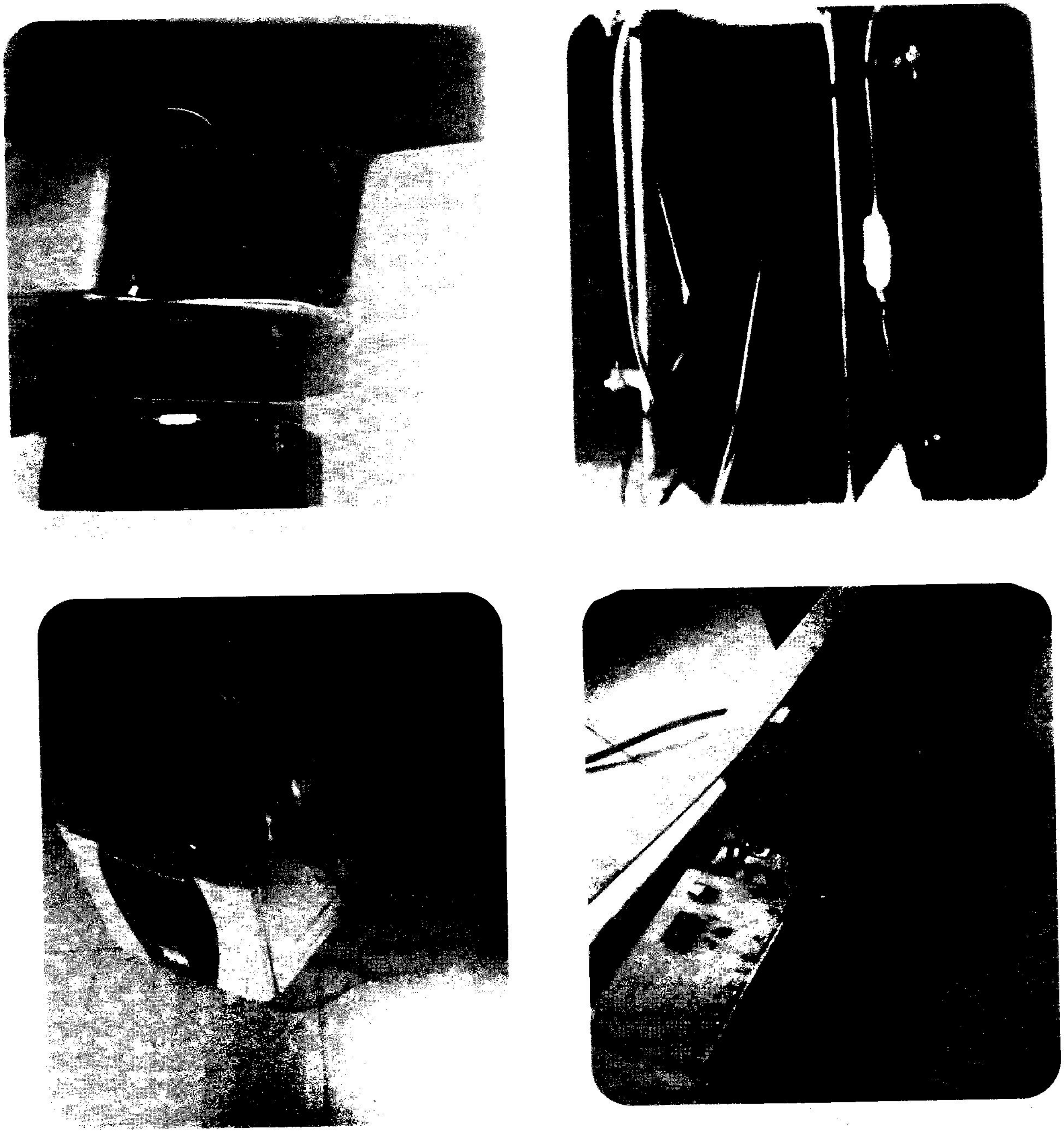
Figure 3.15: showing the arrangements



3.12 PROJECT SETUP OF THE SOLID-STATE APPROACH

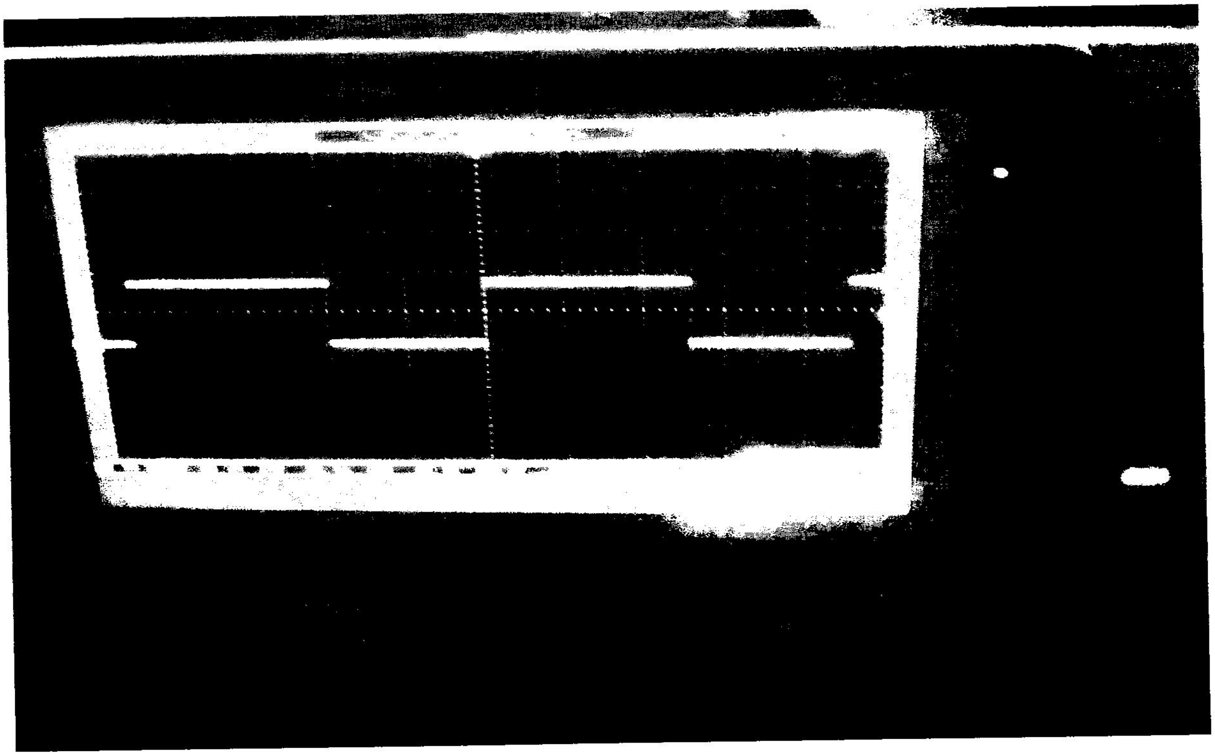
Figure 3.16: Experimental setup showing the switching circuit connected to the four batteries.

Figure 3.16: Experimental setup



The figure below shows a snap-shot of pulses generated from the microcontroller through the Cathode Ray Oscilloscope. The peak of these pulses compared to the regular terminal voltage of the batteries suggests that high voltage surges are generated from the microcontroller and transmitted to each battery terminal via MOSFETS.

Figure 3.17: Current surges generated



CHAPTER FOUR

ANALYSIS OF RESULTS

4.0 PREAMBLE

This chapter presents and discusses results obtained from the experiment carried out to validate the operation of the pulse generator lab power supply system with energy recovery. It explains the physical laws and principles such as the Superposition theorem, Kirchhoff's laws upon which this project is based, analyzing the experimental results obtained after executing the project.

4.1 RELEVANCE OF PHYSICAL LAWS AND PRINCIPLES

The underlying laws of physics, and principles associated with this project are examined with a view to presenting a formal scientific explanation for the overall operation of the pulse generator lab power supply system with energy recovery.

Superposition Theorem

Superposition theorem states that the voltage across (or current through) an element in a linear circuit is the algebraic sum of the voltages across (or current through) that element due to each independent source acting alone Alexander et al (2004).

The principle of superposition analyses a linear circuit with more than one independent source by calculating the contribution of each independent source separately. However, two things must be in mind:

- One independent source is considered at a time while all other independent sources are turned off. This implies that we replace every voltage source by a short circuit, and every current source by an open circuit. In this way, simpler and more manageable circuits are obtained.
- Dependent sources are left intact because they are controlled by circuit variables.

Superposition is based on linearity. For this reason, it is not applicable to the effect on power due to each source, because the power absorbed by a resistor depends on the square of the voltage or current. If the power value is needed, the current through (or voltage across) the element must be calculated first using superposition.

Kirchhoff's Laws

Ohm's law considered on its own is not sufficient to analyze circuits. However, when it is used with Kirchhoff's two laws, we have a sufficient, powerful set of tools for analyzing a large variety of electric circuits. Kirchhoff's laws were first introduced in 1847 by the German physicist Gustav Robert Kirchhoff (1824–1887). These laws are formally known as Kirchhoff's Current law (KCL) and Kirchhoff's Voltage law (KVL). Kirchhoff's first law is based on the law of conservation of charge, which requires that the algebraic sum of charges within a system cannot change.

Kirchhoff's Current law

Kirchhoff's current law (KCL) states that at any node in an electrical circuit, the sum of currents flowing into that node is equal to the sum of currents flowing out of that node.

$$\sum_{k=1}^{n} I_k = 0 \quad \text{.......} (4.1)$$

n is the total number of branches with currents flowing towards or away from the node.

Kirchhoff's Voltage law

This law states that the algebraic sum of the products of the resistances of the conductors and the currents in them in a closed loop is equal to the total voltage available to that loop.

Similarly to KCL, it can be stated as follows:

$$\sum_{k=1}^{n} V_k = 0 \quad \text{.......} (4.2)$$

n is the number of voltages measured

This law is based on the Law of conservation of energy whereby voltage is defined as the energy per unit charge.

$$V = \frac{E}{Q} \quad \text{.......} (4.3)$$

where E is energy required to move the charge Q through a potential difference of V. From the theory of quantisation of charge, the smallest unit of charge is the charge of an electron given as:

$$e = -1.6 \times 10^{-19} C \quad \text{.......} (4.4)$$

The charge Q on any particle is given as:

$$Q = ne \quad \text{.......} (4.5)$$

where n is an integer representing number of electrons that make up the charge.

The total amount of energy gained per unit charge must equal the total amount of energy lost per unit charge which is the consequence of the law of conservation of energy.

Analysis of the pulse generator lab power supply system with energy recovery using superposition principle.

The assumptions made are as follows:

- The load is serially resistive, capacitive and inductive.
- The internal resistance of each battery is r (measured in ohm), and constant over a space of time.
- The terminal open-circuit voltage of each battery is V (measured in volt), and constant over a space of time.
- The capacitance of the capacitors in the system is C, equal and constant over a space of time.
- The system is relaxed, that is, initial values of charge stored in the capacitor are zero.

Across the series combination

Effective internal resistance is:

$$r_{series} = 2r \quad \text{(4.6)}$$

Where r is the internal resistance of each battery.

Effective terminal voltage is:

$$V_{series} = 2V \quad \text{(4.7)}$$

Across parallel combination

Effective internal resistance is:

$$r_{parallel} = \frac{1}{2}r \quad \text{(4.8)}$$

Effective terminal voltage is:

$$V_{parallel} = V \quad \text{(4.7)}$$

Voltage across external load is:

$$V_{open} = V_{series} - V_{parallel} = 2V - V = V \quad \text{(4.8)}$$

With two batteries connected in series and the other two connected in parallel, the effective internal resistance in the circuit is as follows:

$$R_{\text{int}} = r_{series} + r_{parallel} = 2r + \frac{1}{2}r = \frac{5}{2}r \text{ ......} (4.9)$$

According to Ohms law which states that the voltage across a conductor is directly proportional to the current flowing through it, by Kirchhoff's voltage law, the sum of potential drops across all elements round the circuit is constant and equal to the effective open-circuit voltage of the battery.

$$\text{Voltage across Capacitors} + \text{Voltage across internal resistance of the batteries} + \text{Voltage across Load} = \text{Open Circuit Voltage} \text{ ......} (4.10)$$

$$2v_c + v_{\text{int}} + v_{load} = v_{open} \text{ ......} (4.11)$$

The "2" in equation (4.11) accounts for the two capacitors in the circuit, v_c represents the voltage across a capacitor, v_{int} represents the voltage across the internal resistance of the four batteries, v_{Load} represents the voltage across the load and v_{open} represents the open-circuit voltage of the four battery system on no-load.

The following equations below give relationships between voltage and current for terms in equation (4.11).

$$v_c = \frac{1}{C}\int idt \text{ ......} (4.12)$$

$$v_{\text{int}} = iR_{\text{int}} = \frac{5}{2}ir \text{ ......} (4.13)$$

$$v_{load} = iR_{load} + \frac{1}{C_{load}}\int idt + L_{load}\frac{di}{dt} \text{ ......} (4.14)$$

where R_{load} the resistive component of the load is, C_{load} is the capacitive component of the load and L_{load} is the inductive component of the load. Substituting Equations (4.12), (4.13) and (4.14) in equation (4.11), we have:

$$\frac{2}{C}\int idt + \frac{5}{2}ir + iR_{load} + \frac{1}{C_{load}}\int idt + L_{load}\frac{di}{dt} = Vu(t) \text{ ......} (4.15)$$

On differentiating both sides of equation (4.15), we obtain

$$\frac{2}{C}i+\frac{5}{2}r\frac{di}{dt}+R_{load}\frac{di}{dt}+\frac{1}{C_{load}}i+L_{load}\frac{d^2i}{dt^2}=V\delta(t) \quad \text{or}$$

$$L_{load}\frac{d^2i}{dt^2}+\left(R_{load}+\frac{5}{2}r\right)\frac{di}{dt}+\left(\frac{2}{C}+\frac{1}{C_{load}}\right)i=V\delta(t) \quad \text{(4.16)}$$

where $u(t)$ and $\delta(t)$ are the Unit step function and Dirac delta function related as follows:

$$\delta(t)=\frac{d(u(t))}{dt} \quad \text{(4.17)}$$

A unit step function is defined as follows:

$$u(t-t_0)=\begin{cases}0 & \text{for } t<t_0\\ 1 & \text{for } t\geq t_0\end{cases} \quad \text{(4.18)}$$

The unit step function has the ability to switch 'on' or 'off' signal Stroud et al (1999). Therefore, we model the four-battery switching mechanism with the unit step function. The product $Vu(t-t_0)$ switches the voltage signal on for all time, t such that $t\geq t_0$.

A Dirac delta function is defined as follows:

$$\delta(t-t_0)=\begin{cases}0 & \text{otherwise}\\ \infty & \text{for } t=t_0\end{cases} \quad \text{(4.19)}$$

This function is also called an impulse function Stroud et al (1999). When multiplied by a function, say, V, the result is $V\delta(t-t_0)$. The physical interpretation of the result is that a voltage V is suddenly applied and removed from the system within the space of a very short time about t_0.

The parameters that determine the behavior of the system are as follows:

- Internal resistance 'r' of the battery
- Capacitance 'C' of the Capacitors in the system
- The input parameters to the system are as follows:
- Inductance 'L_{load}' of load
- Capacitance C_{load} of load
- Resistance R_{load} of load
- The applied voltage V.

Equation (4.16) relates both kinds of parameters in a second order ordinary differential equation, whose solution is confined to a set of initial conditions stated below and gives the output of the system, that is, the current that flows through the load.

$$Q(0) = 0 \quad \text{.......... (4.20)}$$

$$i(0) = \frac{dQ(0)}{dt} \quad \text{.......... (4.21)}$$

In the pulse generator lab power supply system with energy recovery, battery swapping always take place from serial arrangement to parallel arrangement and vice-versa, continuously. As a consequence, current reverses continuously round the circuit, with a frequency whose value is a function of the number of times swapping take place in a second. More practically, we model this situation with the input voltage given as:

$$V(t) = V\left(u(t) + 2\sum_{k=1}^{n}(-1)^k u(t-k)\right) \quad \text{.......... (4.22)}$$

where n is an integer given as follows:

$$n = 0,1,2,... \quad \text{.......... (4.23)}$$

where $\mathrm{n} = 0$ corresponds to no swap, $\mathrm{n} = 1$ corresponds to one swap, $\mathrm{n} = 2$ corresponds to 2 swaps. k is a dummy variable that runs from 1 to n.

On differentiating Equation (4.22) with respect to t, we obtain:

$$\frac{dV(t)}{dt} = V\left(\delta(t) + 2\sum_{k=1}^{n}(-1)^k \delta(t-k)\right) \quad \text{.......... (4.24)}$$

Equation (4.24) is the input voltage to the system, thus we substitute in equation (4.16) as follows:

$$L_{load}\frac{d^2 i}{dt^2} + \left(R_{load} + \frac{5}{2}r\right)\frac{di}{dt} + \left(\frac{2}{C} + \frac{1}{C_{load}}\right)i = V\left(\delta(t) + 2\sum_{k=1}^{n}(-1)^k \delta(t-k)\right) \quad \text{.......... (4.25)}$$

The solution to equation (4.25) gives the relationship between current flowing through a load with resistance $\mathrm{R_{load}}$, inductance $\mathrm{L_{load}}$, and capacitance $\mathrm{C_{load}}$; which may be obtained analytically using the Laplace Transforms method. Equation (4.25) models the pulse generator lab power supply system with energy recovery in accordance with the assumptions stated above.

4.2 ANALYSIS OF RESULTS

This section represents the analysis of the results from the testing of the prototype. These experimental results and their graphical interpretations are presented in the following Tables and Figures below. However, all graphs were plotted using Microsoft Excel 2010 package.

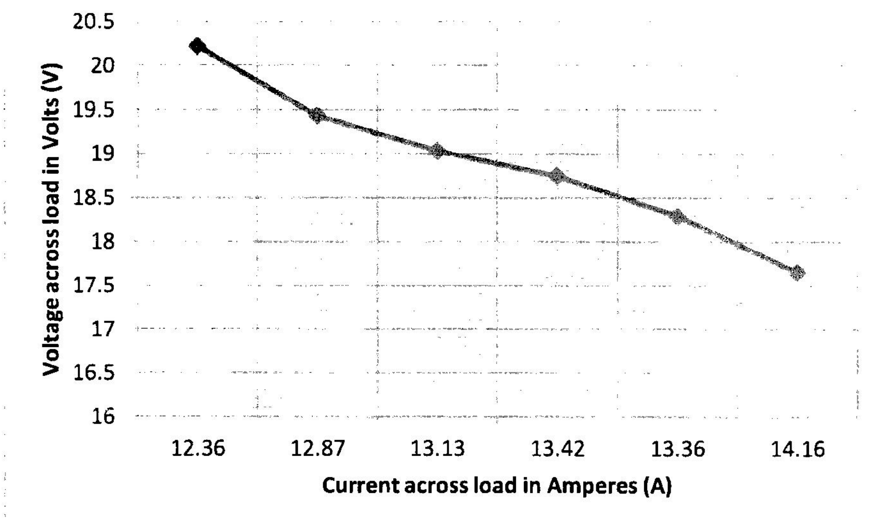
Table 4.1: Experimental Result

Table 4.1: Experimental Result

Serial Number	Battery 1	Battery 2	Battery 3	Battery 4	Voltage (V)	Power (W)	Current (I)
1	11.04	11.60	11.52	12.68	20.22	216	12.36
2	12.11	12.82	11.91	11.74	19.43	216	12.88
3	12.15	11.17	12.40	12.53	19.03	216	13.13
4	12.34	12.58	11.33	11.73	18.74	216	13.42
5	11.26	11.45	12.42	12.40	18.29	216	13.66
6	12.39	12.58	11.50	11.23	17.65	216	14.16

Figure 4.1: Graph of Voltage across load (V) against Current across load (A) for the Battery swapping process

Figure 4.1: Graph of Voltage across load



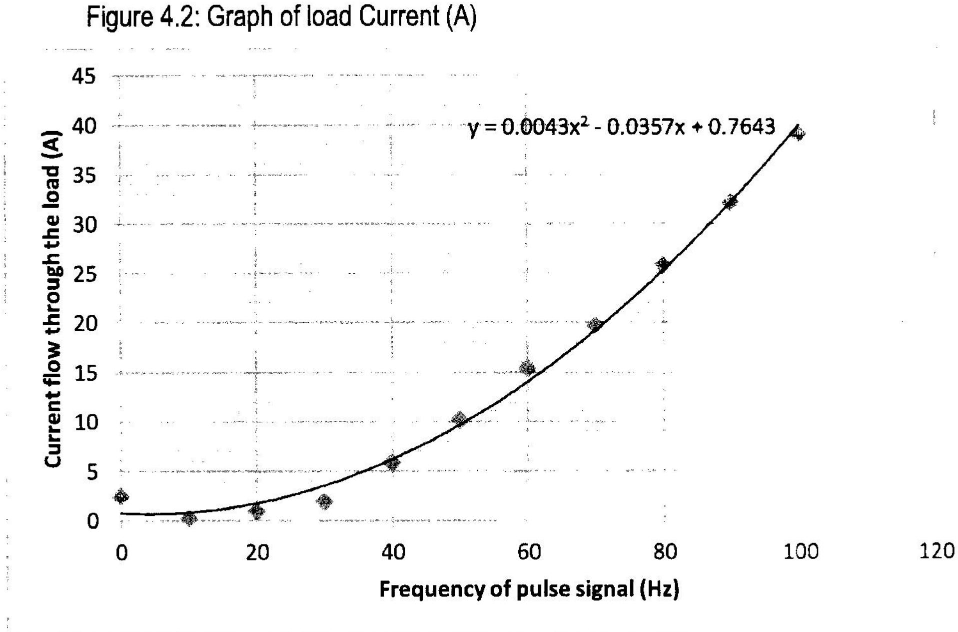
The readings in Table 4.1 were obtained by connecting two batteries in parallel and two in series manually, powering a 216watt load Swapping batteries from series to parallel and from parallel to series took place at 60Hz. The graph of Figure 4.1 shows the variation of the voltage across the load, against current flowing through the load. According to the plot, within a space of time, both current and voltage values change indicating that the four batteries undergo continuous discharge and recharge. As the voltage increases the current drops but the power remains constant. For the device to attain sustainability, it must generate more power than it supplies to the load in order to charge the batteries. With the mechanical version, friction between the wooden drum and the conducting arm was so great that when an attempt was made to alter the speed of the motor, the shaft stopped spinning.

Table 4.2: Measured Current Values, Frequency and Control Resistance Readings

Table 4.2: Measured Current Values, Frequency and control resistance readings

Control Resistance (MΩ)	Frequency (Hz)	Load Current (A)
0	0	2.41
5.82	10	0.15
5.3	20	0.87
4.11	30	1.91
2.84	40	5.83
2.5	50	10.17
1.76	60	15.34
1.38	70	19.72
1.17	80	25.8
0.73	90	32.15
0.54	100	39.04

Figure 4.2: Graph of load Current (A) versus Frequency of pulse signal



The frequency of swapping was changed several times in the main circuit while a dc load of 200 watts was powered for 3 hours thus obtaining the frequency reading. Table 4-2 above shows various values of current flowing through the load as frequency was varied from 0 to 100Hz. Figure 4.2 shows a graph of current flowing through the load as frequency of the output signal of the microcontroller is varied.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0 PREAMBLE

The focus of this project is to design and construct a pulse generator lab power supply system with energy recovery that is sustainable and reliable; a system that may be produced to provide power in rural areas where there is no national grid. The system has the potential of improving the lives of average Nigerians who have lost hope in the efficacy of the Power Holding Company of Nigeria, the sole utility concern of the Nigerian government which has failed in all intent for which it was created. As a way forward in solving the energy crisis, we have chosen to embark upon the project that we may provide a bridge that could fill the gap created by the inadequacies of existing structure by constructing a sustainable and reliable energy device for that purpose.

5.1 THE PULSE GENERATOR LAB POWER SUPPLY SYSTEM WITH ENERGY RECOVERY

The need for a sustainable and reliable supply of energy is of optimum importance for national development. This project has presented the development of a pulse generator lab power supply system with energy recovery that sustainably supply power to a load whose operational mechanism is predicated on the integration of a couple of electrical components via: lead acid batteries [12V, 18AH], diodes [1N4007, 35A, 50V], 1200μF, 100V electrolytic capacitors, Alternating Bridge Rectifier [35A], 4mm single core copper wires, a microcontroller and other components.

The solid-state version of the system when compared with the mechanical version has more advantages, some of which include;

- It occupies less space, since most of its parts are small and compact involving no moving part.
- It delivers less or zero noise level as compared to the mechanical version.
- Most of its parts are less expensive when compared with the mechanical version which includes an electric motor.

However, a number of challenges and some inherent limitations associated with the system components are not to be ruled out during the construction process, they are presented in the section for recommendation and future work below.

5.2 CONCLUSION

In the project, the principles of physics were applied for designing and constructing the pulse generator lab power supply system with energy recovery in order to produce a sustainable and reliable source of energy. Also, a comprehensive analysis of the project was carried out via the continuous charging and discharging of the four batteries. It is my belief that the proposed method will eradicate all economic discomfort and waste currently incurred in the power sector, thus leading to improved technological advancement if properly harnessed.

5.3 RECOMMENDATIONS

The solid-state version of the system partly due to a higher load carrying capacity and partly due to the numerous experiences of the experiment was not without some form of challenges at the design, fabrication and operational stages. Major limitations to be considered amongst others for future work are:

- The use of thyroid transformers in place of the regular ones will greatly reduce losses in the system and increase efficiency.
- The use thyristors in place of transistors will deliver more current pulses as they can accommodate higher switching rate of the microcontroller.

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APPENDIX I

PROGRAMMING IN ASSEMBLY LANGUAGE USING PROTEUS PROFESSIONAL

```
LIST P=16F84
 #INCLUDE "P16F84A.INC"

MBAKAMMA EQU 0CH
Reg_1 EQU 0DH
Reg_2 EQU 0EH
 BSF STATUS,5
 CLRF TRISA
 MOVLW B'01000000'
88 MOVWF TRISB
 BCF STATUS,5
 CLRF PORTA
 CLRF PORTB

BEGIN
 MOVLW B'00000010'
 MOVWF PORTB
 MOVLW B'00010'
 MOVWF PORTA
 CALL DELAY
 CALL DELAY1
 MOVLW B'00001'
 MOVWF PORTA
 CALL DELAY
 CALL DELAY1
 BTFSS PORTB,6
 GOTO BEGIN

DELAY
        movlw    .167
        movwf    Reg_1
        movlw    .7
        movwf    Reg_2
        decfsz   Reg_1,F
        goto     $-1
        decfsz   Reg_2,F
        goto     $-3
        nop
        nop
 RETURN
```

```
DELAY1
 MOVLW B'00000000'
 MOVWF PORTA

        movlw     .22
        movwf     Reg_1
        movlw     .6
        movwf     Reg_2
        decfsz    Reg_1,F
        goto      $-1
        decfsz    Reg_2,F
        goto      $-3
        nop
 RETURN
END
```

APPENDIX II

BUDGET ESTIMATE

Materials	**Quantity**	**Specification**	**Unit price (Naira)**	**Total price**
Lead Acid Batteries	4	12V, 18AH	9500	38000
Diodes	6	1N007,35A, 50V	50	300
Electrolytic Capacitor	4	1200micro-farad, 100V	600	2400
Voltage Regulator	1	LM317, 3V-30V	100	100
Transformer	1	Iron-core, 220V, 2.5KVA	6000	6000
Microcontroller	1	PIC16F84A	1000	1000
Transistors	8	IRF264 (MOSFETS)	300	2400
Crystal Oscillator	1	AN2049, 4MHZ	70	70
Opto-isolator	2	L1319,816C	200	400
Resistors	10	0.5W, 200V	50	500
Printed Circuit Board	1	300mm by 75mm	2000	2000
Copper wires	5yards	6mm single core	1300	1300
Clamps	8		80	640
ETC.				
				Total Price: ₦55,110