DESIGN OF AN AUTOMATIC TRANSFER SWITCHING DEVICE

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TO

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CERTIFICATION

This is to certify that this project work was carried out by, URHIBO OGHENEOCHUKO BETHEL of the Department of Electrical/ Electronic Engineering, University Of Benin, Benin City, Edo State. In fulfillment of the requirements for the award of the Bachelor of Engineering (B. Eng) Degree in ELECTRICAL ELECTRONICS ENGINEERING.

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DATE	DATE

DEDICATION

This project is dedicated to God Almighty for His infinite mercy and giving me the grace to be able to complete this project. I also want to dedicate the work to our supervisor Mrs. L.E OMOZE for her invaluable support, sacrifice and motivation.

ACKNOWLEDGEMENT

I express my deepest gratitude to Almighty God Who in His great mercy sustains me.

I owe a lot to my project supervisor Mrs. L.E Omoze, of Electrical and Electronics Engineering who sought to make my project worthwhile. I am thankful for your guidance and motherly support.

My appreciation also goes to my parents for giving me the enthusiasm, encouragement and assistance, to ensure that I accomplish this work.

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ABSTRACT

The power supply in developing countries is practically low owing to the inability of public power plants to meet the demand of its population and this has brought in the need for an alternative source of electrical power. Where this is the case, a transfer switch is needed to transfer the supply of power from the different sources to the load. A manual transfer switch requires that a user effects the overall process of power changeover from the different supply sources to the load and this could become cumbersome hence, the need for an automatic transfer switch.

The objective of this design centers on sensing the primary/main power supply source, to startup the secondary power source (generator) when the main power supply source fails, shutdown the generator when the main power supply source is restored, to startup the secondary power source when power fluctuations from the main power supply source is detected and to automatically transfer the load to the available power source, thereby making the entire process easy and reliable.

The design was carried out with low cost solid state electronic components such as; Relays, transformer, microcontroller, voltage regulator, resistors, capacitors, diodes.

Keywords - Automatic transfer switch; electrical power; generator; public power plant; transfer switch;

CHAPTER ONE

INTRODUCTION

The poor state of power supply in developing countries, calls for alternatives sources of power generation and automation of electrical power generation to back up the utility supply. Over time, automation of electrical power supply has become so vital as the rate of power outage is predominantly high (Ahmed et al, 2006). As a result of this power outage, developing countries like Nigeria, experience slow development processes in both the public and private sectors of their economy. This according to Agbetuyi et al (2017) made investors from foreign lands to feel insecure in setting up businesses or industries in spite of the large market made available in such populated nations.

Some complicated processes and business activities such as internet servers, surgery, render farms, transfer of money between banks, require constant electricity supply in order to prevent loss of life or loss of business computational hours. The poor state of power supply in developing countries calls for replacement in the sources of power generation and automation of electrical power to back up the utility supply. Over time, automation of electrical power supply has become vital as the rate of power outage is practically high. This is why Harish et al, (2018), posited that as a result of power outage, developing countries, experience slow development processes in both the public and private sectors of their economy.

Initially, these transfer switches were designed for manual operations but with an increase in the technological advancement of electrical power control, Automatic transfer switches (ATS) were created as it eliminates the element of a user starting a generator and changing power supply from one source to another. Some of the approaches which have been engaged to implement change over system include manual change over switch box, automatic change over system with electromechanical relays and change over system with automatic transfer switch. Each of these methods have some drawbacks that make it undesirable especially in terms of cost implication as noted by Godwin, (2012), These contribute to the high cost of these methods.

A transfer switch is an electrical switch that switches a load between two or more sources, some transfer switches are manual, in that an operator is expected to effect the transfer by throwing a switch, while others are automatic and triggered when they sense one of the sources has lost or gained power. (Wikipedia, 2021). The transfer switch is situated between a generator or shore and inverter. If the voltage level or the frequency of the generator or the shore varies (input 1), then the transfer switches to the inverter (input 2) (Victron Energy, 2008). Automatic transfer switch systems act as a brain between your building, utility power and the generator. They detect changes in power and act accordingly to maintain electricity for your building with the help of a generator. If utility cuts out, the automatic transfer switch will turn on your generator and switch to it, when the utility power is back it shuts down the generator and switches back to the utility power automatically (https://ps.buckeyepowersales.com, 2021*)*.

Automatic transfer switch also known as "Generator Transfer Switches", has an additional circuit component which is normally in the form of a computer that monitors the incoming power supply. This circuit according to (Silva, 2009 and Kolo, 2007), also monitors the voltage sags, power surges, power spikes, or brownouts. Hence it is mandatory as noted by National Electrical Code, (2021), to use a transfer switch whenever a generator is used.

All automatic transfer switches for generators According to Brown and Guditis, (2006), consist of three parts namely:

1. Contacts to connect and disconnect the load to source of power;
2. A transfer mechanism to move the contacts from one source to another and
3. An intelligent or logic control unit to constantly monitor the condition of the power sources that provides the brain necessary for switching which relate the circuit to operate correctly.

The ATS monitors the supply of voltage from a single phase line and a generator supply. To do so, it bases its control operation on the availability or unavailability of power supply from either source. The process consists of a series of relays contactors and protective devices that help form the control circuit of the ATS (Agbetuyi et al, 2017). In view of this, there is a need to design an ATS that will have high power capability, efficiency, as well as cost effectiveness.

1.1 PROBLEM STATEMENT

According to Oji (2012), Nigeria's annual average daily solar radiation is about 5535 KWh/m^2/day, with about 3.5 KWh/m^2/day to 70 KWh/m^2/day at the costal areas in the southern and northern boundaries. Adaramola and Oyewola (2011) noted that wind energy is available in Nigeria at an annual speed of about 2.0 m/s to 5.0 m/s at a height of 10m. The Nigerian National Petroleum Corporation (NNPC) indicates that Nigeria's oil production of 2014 stood at 25 million barrels per day making it the 13^{th} largest producer of crude oil in the world and also the 9^{th} largest natural gas reserves in the world.

Babanyara and Saleh (2010) opined that despite the availability of these resources, majority of Nigerians continue to experience epileptic power supply and therefore rely on wood fuel for their entire energy needs resulting in massive deforestation. Ohajianya et al (2014) emphasized the widely acknowledged fact that erratic power supply in Nigeria is the bane of economic and industrial development in the country.

According to Agbetuyi et al (2011), the poor state of power supply in developing countries, calls for alternatives sources of power generation and automation of electrical power to back up the utility supply. Ahmed et al (2006), opined that the automation of electrical power supply has become so vital as the rate of power outage is predominantly high.

1.2 AIM

The aim of this project is to create an automatic device for switching between the use of electricity supply from the national grid and the use of a generator.

1.3 OBJECTIVES

The objectives of this work are:

1. To design a device to sense the main supply voltage
2. To design a device to control the on/off switch of the generator automatically
3. To design a device to start the generator automatically
4. To design a device to automatically transfer the load.

1.4 METHODOLOGY

1. A comprehensive literature review will be carried based on the topic.
2. The automatic transfer switch circuit will be designed.
3. To simulate the automatic transfer switch circuit on Proteus.

1.5 SCOPE

The scope of this work is limited to the design of an automatic changeover switching device to alternate between the use of the national grid and the use of a generator.

1.6 RELEVANCE OF THIS WORK

The relevance of this work is to provide a simple low cost device to automatically changeover between two electricity sources.

1.7 EXPECTED RESULT

It is expected that at the end of this process, a device to automatically switch between two electricity supply sources will be designed and constructed.

CHAPTER TWO

LITERATURE REVIEW

A transfer switch is an electrical switch that switches a load between two sources. Some transfer switches are manual, in that an operator effects the transfer by throwing a switch, while others are automatic and trigger when they sense one of the sources has lost or gained power (Wikipedia, 2021).

The block diagram of the automatic transfer switch circuit is shown below.

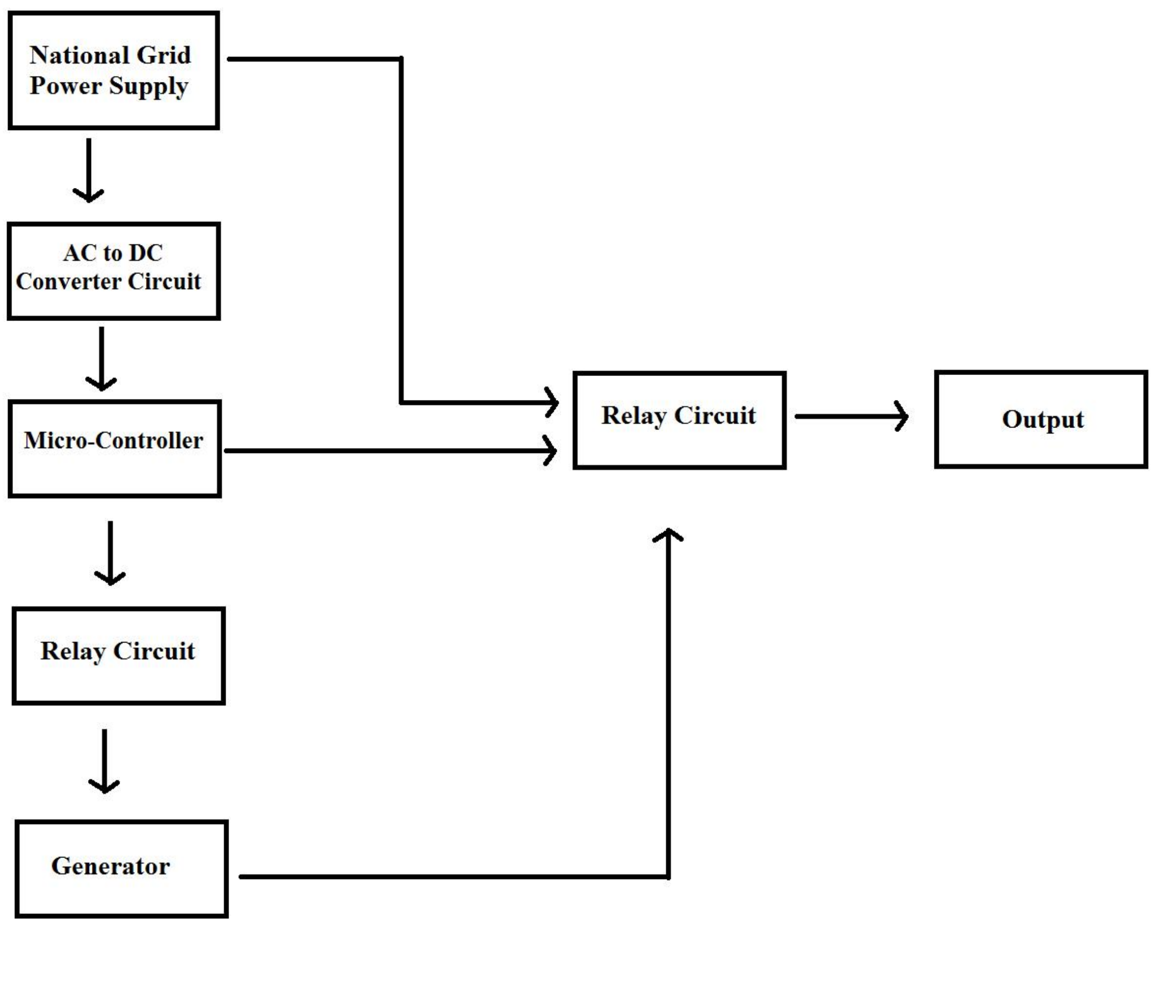

Figure 2.1 Automatic Transfer Switch Circuit Block Diagram.

A changeover switch is designed to transfer electricity supply from the commercial power grid to a local generator when an outage occurs, this is connected directly to the generator, commercial power supply or line, and the house or businesses (nelson-miller.com*, 2016)*.

Automatic transfer switches also known as “Generator Transfer Switches” have an additional circuit component which is normally in the form of a computer that monitors the incoming power supply. Silva (2009) and Kolo, (2007) noted that this circuit also monitors the voltage sags, power surges, power spikes, or brownouts.

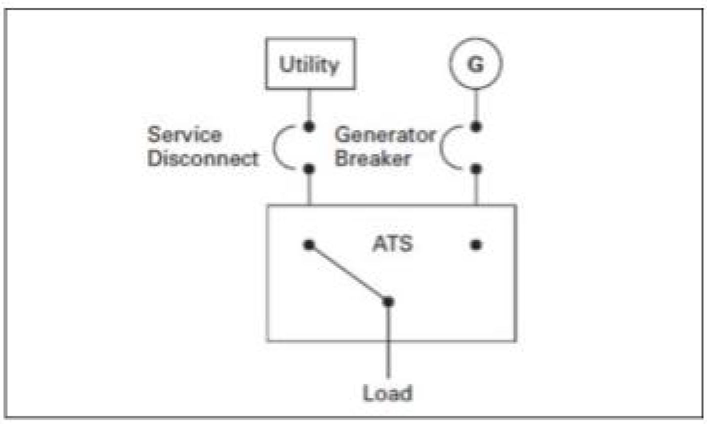

Figure 2.2. One-line drawing of the basic elements of a transfer switch (Eaton, 2018)

In contrast to the manual change over switch system that requires manual stress in starting the generator and switching over from public supply to generator and vice-versa, the automatic transfer switch effectively manages power supply between two sources, utility and standby power generator (Agbetuyi et al, 2017).

2.1 NATIONAL GRID SUPPLY

Adequate power supply is an unavoidable prerequisite to any nation's development, and electricity generation, transmission and distribution are capital-intensive activities requiring huge resources of both funds and capacity. In the prevailing circumstances in Nigeria where funds availability is progressively dwindling, Sambo et al, (2006), suggested that creative and innovative solutions are necessary to address the power supply problem. Nigeria is endowed with large oil, gas, hydro and solar resources, and it has the potential to generate about 12,522 MW of electric power from its existing plants. On most days however, it is only able to dispatch around 4,000 MW which is insufficient for a country of over 195 million people (https://www.usaid.gov/powerafrica/nigeria, 2021).

Electricity supply in Nigeria dates back to 1886 when two (2) small generating sets were installed to serve the then Colony of Lagos. By an Act of the Parliament in 1951, the Electricity Corporation of Nigeria (ECN) was established and in 1962, the Niger Dams Authority (NDA) was also established for the development of Hydro Electric Power. However, a merger of the two was made in 1972 to form the National Electric power Authority (NEPA) which as a result of unbundling and the power reform process was renamed Power holding Company of Nigeria (PHCN) in 2005 (Energy Commission of Nigeria, 2005).

Energy is the bedrock for development as it determines and creates growth and increase in the technological, economical and health sectors of any nation. (Obomate et al, 2009). Nigeria is the seventh most populated country in the world with approximately 196 million, yet over 60% of the population do not have access to electricity. (Sanni Timilehin et al, 2019). This lack of adequate energy supply they noted is largely due to insufficient energy supply generation by the inefficient power plants. According to Ohajianya et al, (2014), the factors responsible for the erratic power supply in Nigeria are;

1. Government policy,
2. Inefficiency in power generation, transmission, distribution and consumption and
3. Incompetent staff of the energy companies.

2.2 ALTERNATING CURRENT (AC) TO DIRECT CURRENT (DC) CONVERTER

Alternating current (AC) power is available commercially at low cost but Direct current (DC) power is more expensive to produce, this is why a method of changing AC to DC is needed as an inexpensive power source. AC power can be converted to DC power using rectifiers. (Pyakuryal and Matin, 2012). When AC power is converted to DC power using rectifiers, the DC output contains undesirable AC components called ripples. Many applications of rectifiers require that these ripples do not exceed a particular value, this is because when the ripple exceeds the specified value, different unwanted effects appear in the system. Some of the unwanted effects according to Mazaheri et al, (2003) are stray heating and audible noises. When a capacitor is used alone or an inductor is used alone as a filter, there is a mathematical expression available for calculating the values of the capacitor or the inductor for controlling the ripple under the specified value. However, when both capacitor and inductor are used together, there is no mathematical formula available to calculate their values (Doval-Gandoy et al, 2003).

The ripple factor according to Miller and Miller, (2002) is a ratio of the Root Mean Square (RMS) value of the ripple voltage V_{rms} to the average value V_0 at the output of a rectifier filter as given.

Percentage of ripple = (RMS value of ripple/Average DC output) x 100 = (V_{rms}/V_0) x 100

Where; V_{rms} =0.707 x V_p

V_p= Peak value of the ripple voltage.

2.3 MICROCONTROLLER

A microcontroller can be considered as a self-contained system with a processor, memory and peripherals that can be used as an embedded system. The majority of microcontrollers in use today are embedded in other machinery, such as automobiles, telephones, appliances, and peripherals for computer systems (Wikipedia).

Figure 2.3 ATMega328P Micro-controller (Robu 2021)

In simple words, a Microcontroller Unit (MCU) is a small computer integrated in to a single chip. We can also explain it as programmable silicon chip which is clock driven, register based, accepts input and provides output after processing it as per the instructions stored in the memory (https://electrosome.com/microcontroller, 2021).

2.4 RELAY

Relays are electrically operated switches that open and close the circuits by receiving electrical signals from outside sources (https://components.omron.com, 2021). Relays can be used for switching as well as protection application. A relay is used to switch a circuit such that current through it can be diverted from the present circuit to another. This switching operation can be performed either manually or automatically. Manual operation for switching a relay is performed through push buttons and other conventional switches. (https://www.electronicshub.org/electromechanical-relay-basics, 2016).

According to Vladimir **(**2005)**,** a Danish physicist by name "Hans Christian Oersted" demonstrated for the first time in 1820 that the interaction between a magnetic field and an electric current shows a slight impact of a single conductor on a compass needle. It was with this principle that the first prototype of the electromechanical relay was created.

2.5 GENERATOR

Starting with Faraday's law of electromagnetic induction in 1831, electric (electromagnetic) machines have been developed ever since as "assembles" of electric and magnetic coupled circuits that convert mechanical to electrical energy (in generators) and vice versa (in motors), via magnetic energy storage (Boldea, 2017).

In electricity generation, a generator is a device that converts motive power (mechanical energy) into electrical power for use in an external circuit. Sources of mechanical energy according to Augustus (1896) are, steam turbines, gas turbines, water turbines, internal combustion engines, wind turbines and even hand cranks.

The operating principle of electromagnetic generators was discovered in the years of 1831–1832 by Michael Faraday. The principle, later called Faraday's law, is a process where an electromotive force is generated in an electrical conductor which encircles a varying magnetic flux. Faraday was noted to have also built the first electromagnetic generator, called the Faraday disk; a type of homopolar generator, using a copper disc rotating between the poles of a horseshoe magnet. It produced a small DC voltage as indicated. (Figure 2.4) *(*Thomas and John, 1991*)*.

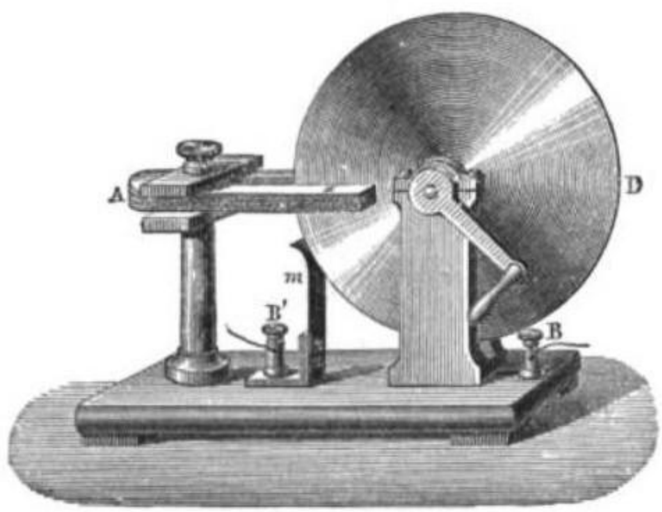

Figure 2.4. Faraday disk generator (Wikipedia).

CHAPTER THREE

DESIGN, MODELLING AND SIMULATION

3.0 INTRODUCTION

This chapter presents the design and simulation of a changeover switching circuit in some possible operation situations. The circuit block diagram is illustrated figure 2.1 and is implemented using Proteus software version 8.7.

The algorithm for the designed automatic transfer switch is shown in the diagram below.

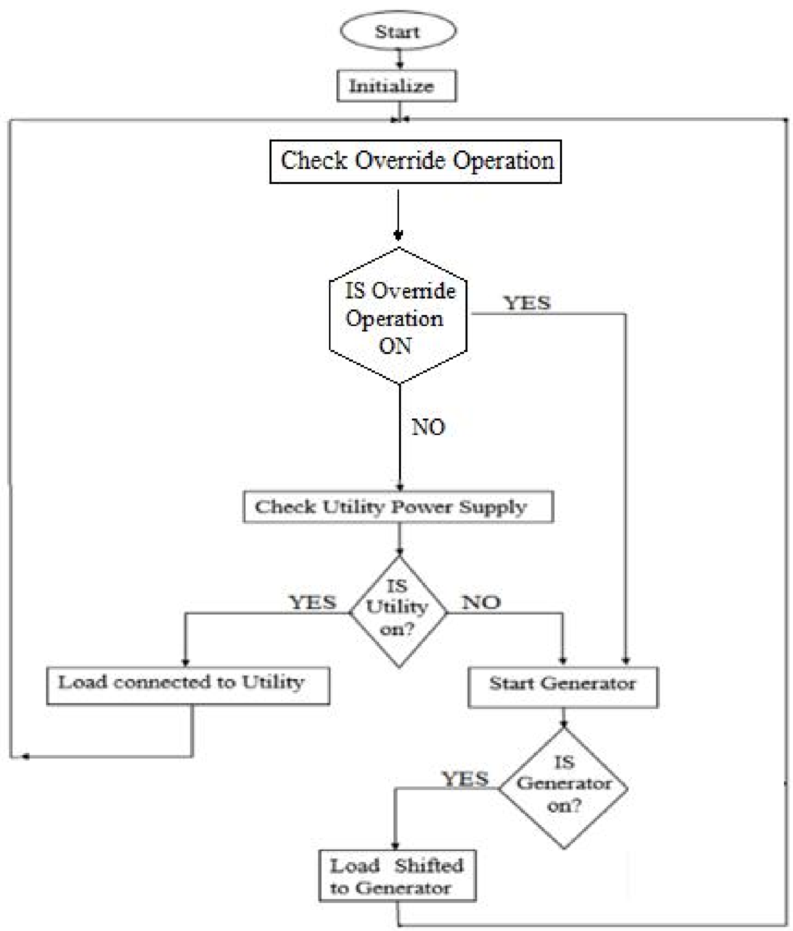

Figure 3.1 Automatic transfer switch algorithm

3.1 CIRCUIT DESCRIPTION

For the simulation of the changeover switching device, several active and passive components are needed in the circuitry, it involves the use of a micro controller to detect the supply of power from the utility grid, hence take decisions using the detected parameters.

The decisions taken by the micro-controller are as follows;

1. To turn on the backup utility generator in the absence of power from the utility grid.
2. To automatically turn off the generator in the presence of power from the utility grid.
3. In the situation of fluctuating supply from the utility grid, continue the circuit supply with the backup utility generator.
4. To override the programmed operation.

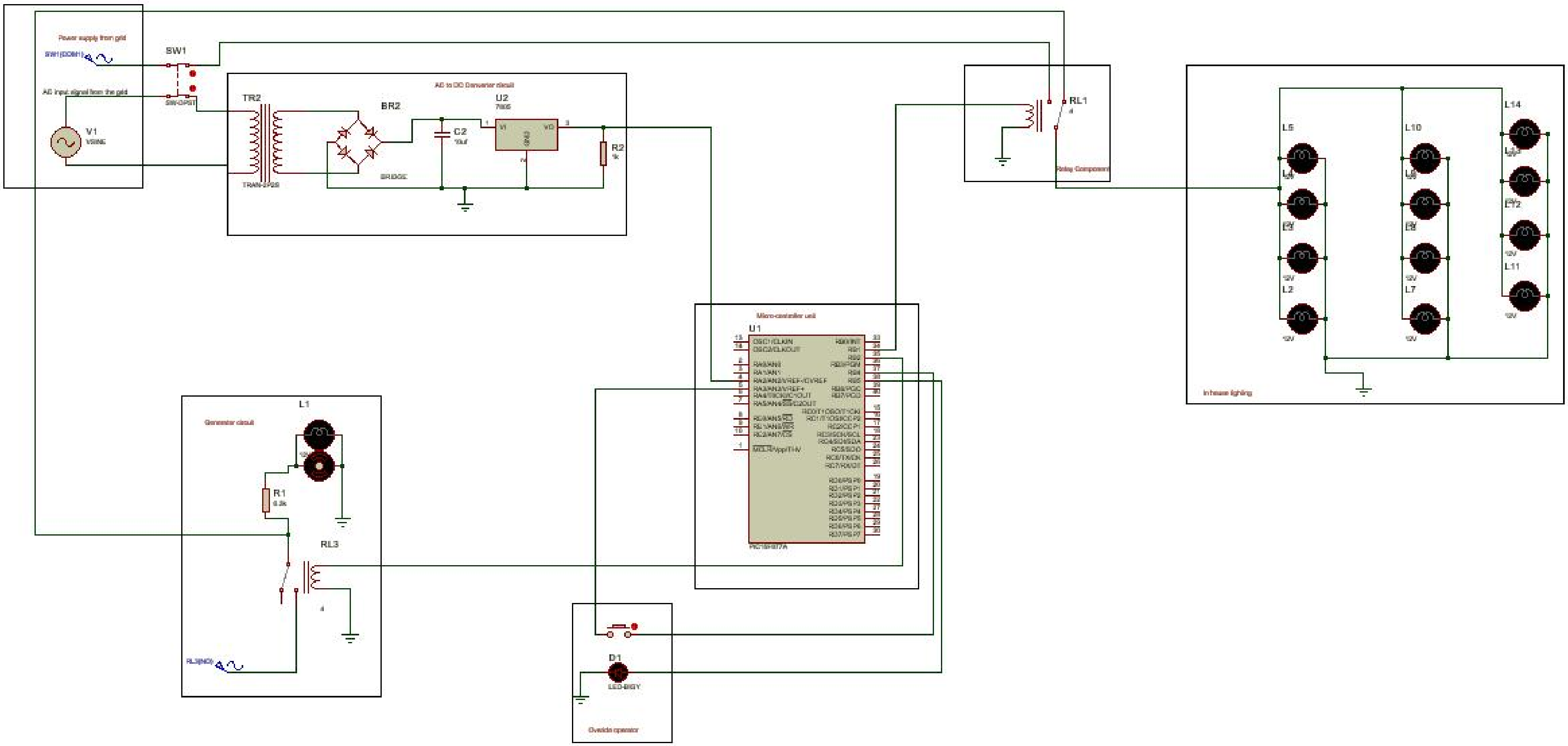

Figure. 3.2 The designed automatic changeover circuit

Taking a critical look at the different design stages in the above circuit, the following components can be identified;

1. The Power supply circuit from the grid
2. The AC to DC converter circuit
3. The Backup Generator circuit
4. The Micro-controller circuit
5. The override operator button and indicator led
6. The relay circuit
7. The internal lighting circuit.

3.2 DESIGN COMPONENTS

Table 3.1 shows a list of the components used for the simulation of the circuit in Proteus.

Table 3.1: Design components and specifications

Component	**Specification**
Transformer	TRAN-2P2S, Rating: 240V/15.7V, Coupling Factor: 0.06542, Primary Inductance: 1H, Secondary Inductance: 1H
Silicon Rectifier Diode	1N4004, Maximum Recurrent Peak Reverse Voltage: 400V, Maximum Average Forward Rectified Current: 1.0A

Smoothing Capacitor	CAP-ELEC, 10µF
Voltage Regulator	LM317EMP 5V Output Voltage
Resistor	Resistance: 1000Ω
Relay	5V Relay
LED's	LED-BIGY, Forward Voltage: 2.2V, Full Drive Current: 10mA, Breakdown Voltage: 4V
Alternator	Amplitude: 240, Frequency: 50Hz
Button	Push Button switching time: 1ms
Lamp	Nominal Voltage: 12V
Motor	No of rev: 6, Nominal Voltage: 12V
Micro-controller	Frequency: 1MHz, ID: PIC16F877A

3.3 CIRCUIT DESIGN AND SIMULATION

Each part of the circuit was carefully designed in Proteus design suite (PDS) and simulated separately. After successful simulation, the parts were put together to form the complete circuit.

3.4 THE UTILITY SUPPLY FROM THE GRID

In Nigeria the power plugs and sockets are of type D and G. The standard voltage is 230 V and the standard frequency is 50 Hz. (https://www.power-plugs-sockets.com/nigeria, 2021).

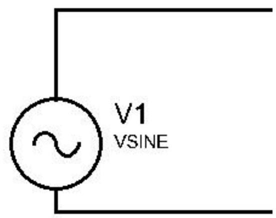

Figure 3.3 Power supply circuit

For the simulation of the utility supply, an AC sine pulsating wave is used to generate the voltage input, this is done using a component tagged "VSINE" in Proteus. For this simulation, the voltage is set to a value of 240 volts single phase in this simulation.

3.5 THE AC TO DC CONVERTER CIRCUIT

An AC to DC converter is an electrical circuit that transforms alternating current (AC) input into direct current (DC) output. They are used in power electronic applications where the power input a 50Hz or 60Hz sine wave AC voltage that requires power conversion for a DC output. (http://globalspec.com)

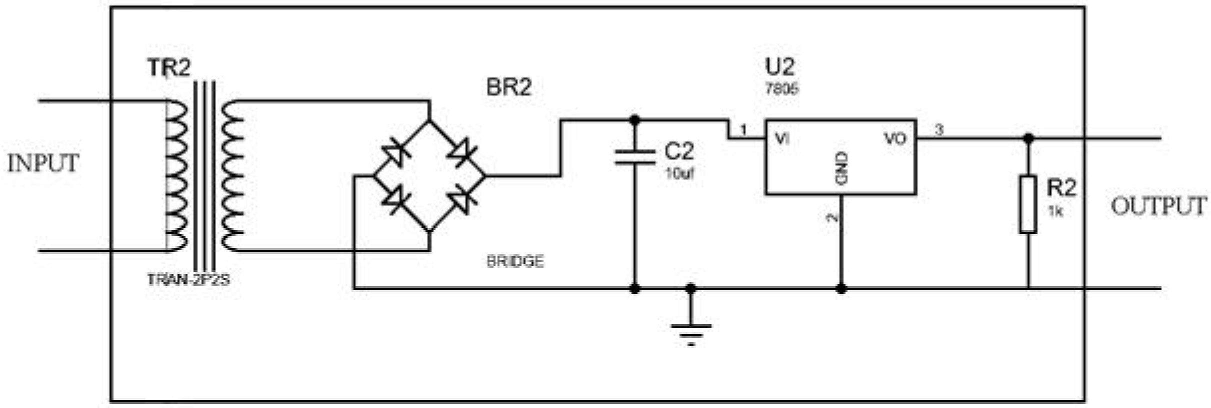

Figure 3.4 AC to DC converter circuit

The AC to DC converter circuit is made up of a step down transformer, diode rectifier circuit, filter circuit, resistor, and IC voltage regulator as shown in figure 3.4. The following specifications are considered in the selection of the transformer used in the design; output voltage: 12V (min), ripple voltage: 2V, load current: 1A (max), diode forward voltage drop: 0.7V according to the following equations;

$V_{max} = V_{out} + 2$ (diode forward voltage drop).

Peak voltage, $V_p = V_{rms} \times \sqrt{2}$

Also, the amplitude of the output voltage or the peak output voltage of the rectifier VP2, for a full wave bridge rectification is given as;

$V_{p2} = V_p - 2V_d$

Where V_d is forward voltage drop across the diode.

The overall conversion process is given in the diagram below

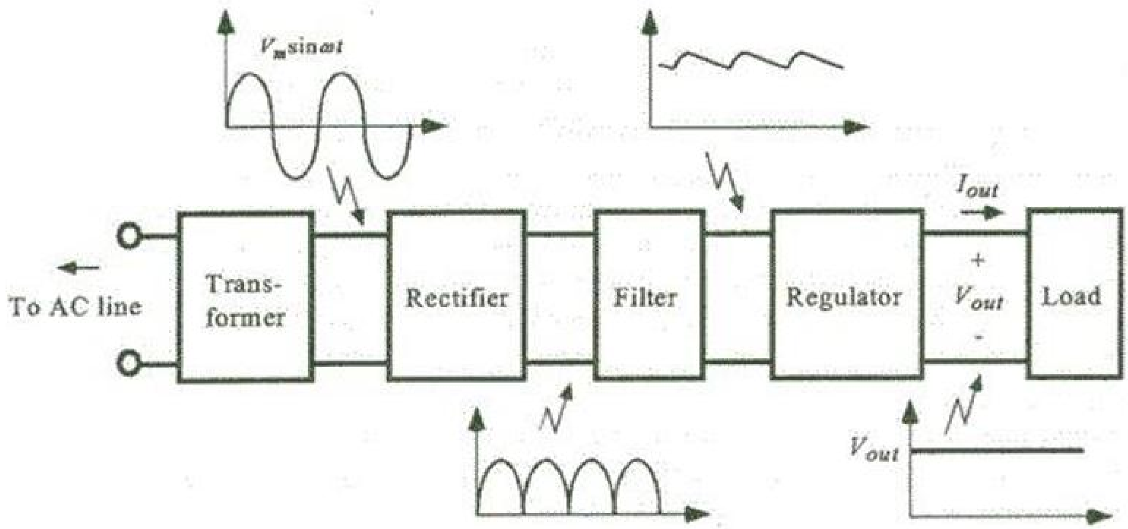

Figure 3.5 AC to DC Conversion process. (Sakib, et al, 2015).

The input AC signal is expressed by the equation

$V_s = V_m \sin(\omega t)$

Where V_m is the peak voltage, V_s is the supply voltage, ω is the angular frequency, and t and is the time.

In this circuit, the transformer TR_1 steps down the A.C mains voltage from 240V at 50Hz to an approximate value of 15.7V as expressed by the equations below.

$$\frac{N_p}{N_s} = \frac{I_s}{I_p} = \frac{V_p}{V_s} = \frac{240}{15.7} = 15.28 \cong 15$$

This means that the current will rise by approximately 15 times and the primary coil is about 15 times more than the secondary coil, hence the coupling factor of the transformer is calculated to be 15.7V/240V = 0.06542.

Diodes D_1, D_2, D_3 and D_4 form a bridge rectifier that rectifies the AC output voltage from the transformer TR_1 to a pulsating DC voltage of the same value. Since the output of the diode network is a pulsating DC voltage, it will experience a null voltage at every half cycle. The figure below shows the graph of a pulsating DC voltage output.

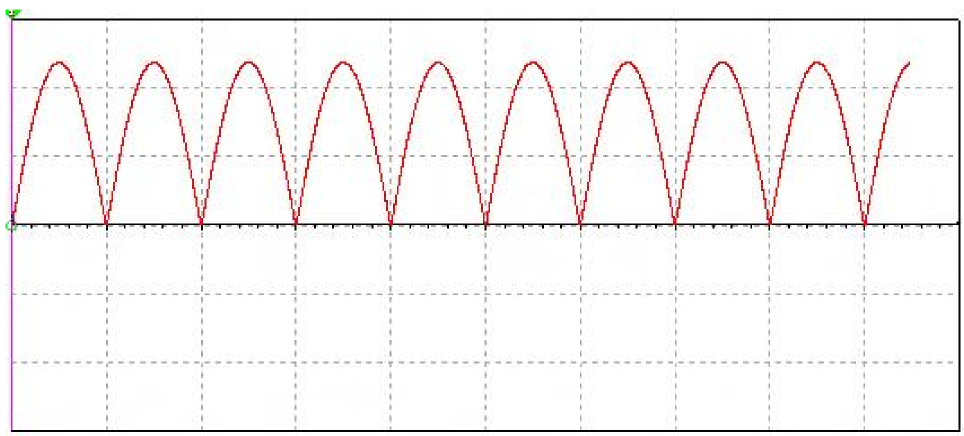

Figure 3.6. Pulsating DC Voltage Output.

In order to compensate for this null voltage, a capacitor is connected in parallel with the bridge circuit. The capacitor C_1 which compensates for the null half cycle is known as a smoothing or filtering capacitor.

The primary factor which contributes in selecting the capacitor with the right value is the time-constant. In order to achieve a sensitivity of 10 milliseconds using a 1000Ω resistor;

$$\tau = RC,\ C = \frac{\tau}{R} = \frac{0.01}{1000} = 1\text{x } 10^{-5}\mu F = 10\mu F$$

Where R is the resistance in Ohm (Ω), τ is the time constant and C is the capacitance in farad (F).

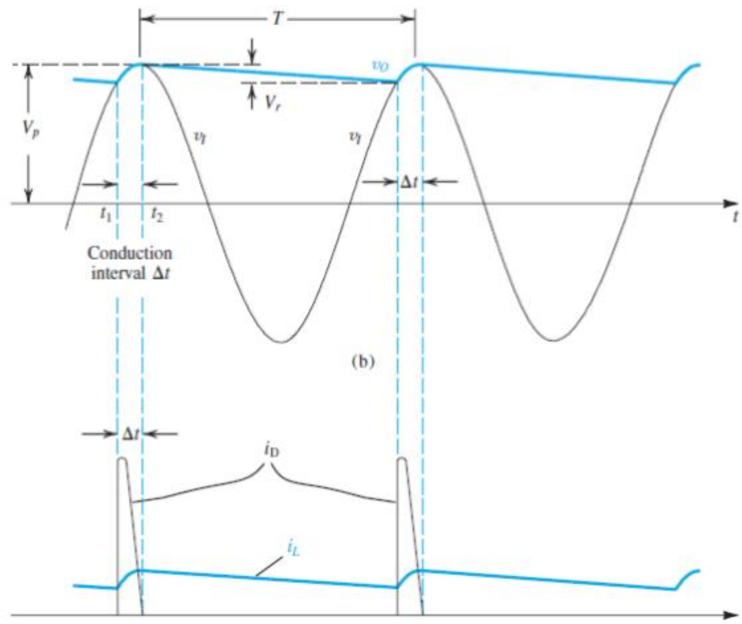

Figure 3.7. Smoothening of ripples by a capacitor. (Sedra and Smith, 2015).

Capacitors with less time-constant would not be so effective since it's charge would drop or dissipate quickly, hence a capacitor with a high capacity of charge storage or farad is used for this purpose. A capacitor reduces the ripple up to 10 times in its output than the input voltage (Alexander and Sadiku, 2013).

A voltage regulator (LM317) is then connected to the circuit to regulate the output voltage from the AC to DC converter to a stable output value of 5V. The output of the voltage regulator is varied by connecting a resistor in parallel.

The purpose of converting the input voltage from the utility grid to a DC voltage is because the micro-controller used for the logic decisions does not work with high voltages as this high voltage can damage the circuit.

3.6 THE BACKUP GENERATOR CIRCUIT

A standby generator is a back-up electrical system that operates automatically. Within seconds of a utility outage an automatic transfer switch senses the power loss, commands the generator to start and then transfers the electrical load to the generator (Robert, 2002).

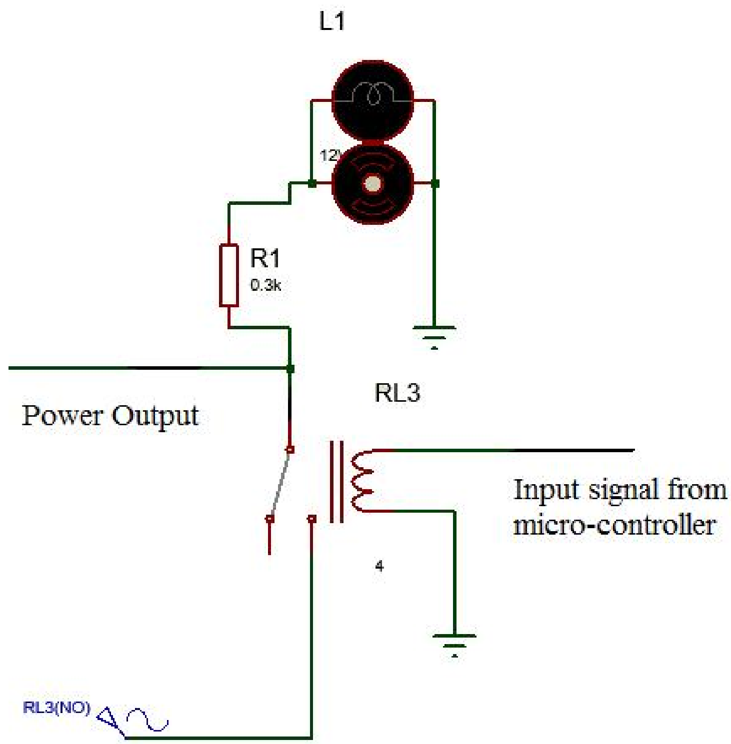

Fig 3.5 Backup generator circuit

The backup generator circuit is simulated with a 240 volts power supply. The generator used in this circuit has a key starter for its operation with the micro-controller circuit, this key starter is simulated using a relay circuit.

In the absence of power from the utility grid the micro-controller sends a voltage signal to the generator key starter. This voltage signal triggers the generator to turn on and the micro-controller transfers the load to the generator circuit.

The generator is indicated with the use of a motor to represent the alternator circuit in the generator and the use of a lamp to indicate the supply of power from the generator.

3.7 THE MICRO-CONTROLLER

A micro-controller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical micro-controller includes a processor, memory and input/output (I/O) peripherals on a single chip *(*Lutkevich*,* 2019*)*.

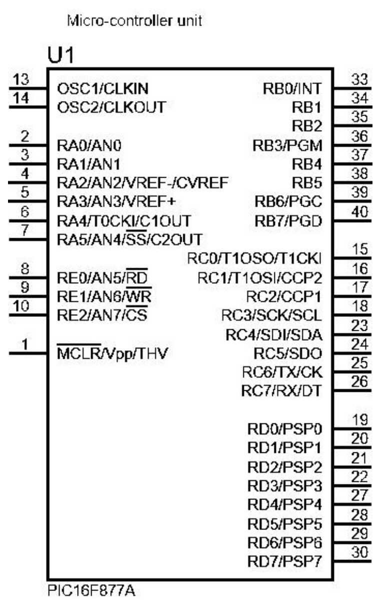

Fig 3.6 The PIC16F877A Micro-controller

The micro-controller circuit above has 40 pins which are well labeled, it is the component responsible for taking decisive actions on the operation of the overall circuit. The micro-controller makes logic operations in order to;

1. Turn on the backup generator in the absence of power from the utility grid.
2. To automatically turn off the generator in the presence of power from the utility grid.
3. To keep the generator supply in use in the situation of fluctuating supply from the utility grid.
4. To keep the generator supply in use when the override operation mode is set.

In this circuit design, a 16 bit PIC16F877A programmable micro-controller is used. The micro-controller is programmed with C programming language using Mikro C software, this software generates a hexadecimal file with can be interpreted by the micro-controller.

The syntax code for the micro-controller is given below.

```
int fluctuate=0;   //define a variable to process the power fluctuation
int pgrid=0;       //define a variable to detect power supply form the grid
int pcount=0;    //define a variable to count the time of supply from the grid
int overide=0;   //define a variable for the override operation

void main() {
 PORTB = 0;      //clear all power supply in port b
 TRISB = 0;       // set port b as output
 ADCON1 = 6;      //set port a as input
 PORTA=255;
 TRISA= 255  ;
  OPTION_REG.TOCS=0;      // SELCT INTERNAL SOURCE
  OPTION_REG.PSA=1;       // Pre scaler Assigned to WDT
  OPTION_REG&=0xF8 ;      // SELECT 1:1 Pre scaler
  TMR0=0;                       // CLEAR TIMER0
```

```
 while(1) {   //loop for the operation of the micro-controller
 //check fluctuations
   if(INTCON.T0IF){
    INTCON.T0IF=0;

    if(pgrid==1){                                    //check power grid supply
    if(PORTA.F2==0){  fluctuate++; pcount=0; }
    else{     pcount++; }
    pgrid=0; }

    if(pgrid==2){
        pcount++;                          //count time of power supply from grid
    }

     if(PORTA.F3==1){
      if(overide==1){ overide=0; }else{ overide=1; }
}
     }

    if(pcount>=10000){ fluctuate=0; pcount=0; }
PORTB.F4=1;  //Set port rb4 to high
if(overide==0){
PORTB.F5=0;

 //actual operations
if(fluctuate<5){
```

```
if(PORTA.F2==1){  pgrid=1;
PORTB.F1=1;
PORTB.F2=0;
}
else{
 PORTB.F1=0;
PORTB.F2=1;
}
}
else{
  if(PORTA.F2==1){ pgrid=2; }
 PORTB.F1=0;
PORTB.F2=1;
}
   }
//if the overide button is activated
else{
if(PORTA.F2==1){ pgrid=2; }
 PORTB.F1=0;
PORTB.F2=1;
PORTB.F5=1;
}
  }
}
```

The explanations for the above syntax are commented in the code above.

If no power is detected from the utility supply, a voltage signal is sent to turn on the backup generator. On the other hand if there is power supply from the utility grid, a voltage signal is sent to turn off the backup generator and the load is transferred to the utility grid. If there is a situation of power fluctuation in the utility grid supply, the backup generator is left on.

If the utility grid supply is at a low voltage, the user can push an override key to transfer the load to the backup generator.

3.8 THE OVERRIDE OPERATION BUTTON AND INDICATOR

Sometimes the supply of power from the utility grid may be at a low power supply, extremely high power supply or a fluctuation from a low power to an extremely high power supply and this is not satisfactory. When situations like this arise, the override button can be used to transfer the load to the backup generator.

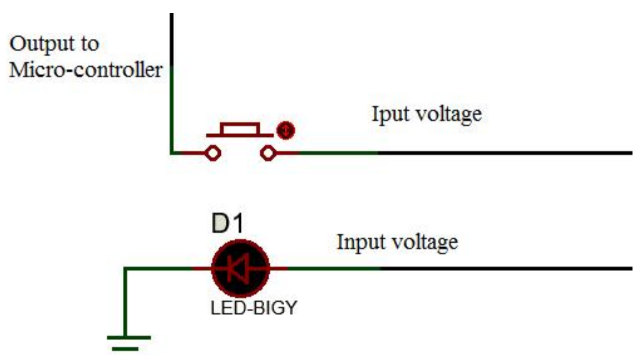

Fig 3.6. The Override button and Indicator

As a check a led light bulb is used to indicate when the system is operating in the override mode.

3.9 THE RELAY

A relay is an electrically operated switch, it consists of a set of input terminals of a single or multiple control signals and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms such as make contacts, break contacts or combinations (Dalakov, 2012).

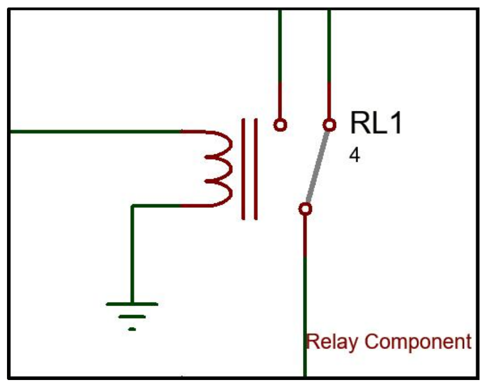

Fig 3.6 The Relay Circuit

As shown in the fig 3.6, the relay is used to switch between power supply from the utility grid and the backup generator. The relay has an electro-magnetic coil that triggers when a voltage is supplied to its input terminal.

In this circuit, when power is supplied from the utility grid, no voltage is supplied to the relay, hence the relay stays in its default switching position. However, in the absence of power from the utility grid a voltage is sent by the micro-controller to the relay and this causes the relay to switch from the utility supply to the backup generator supply.

3.10 THE INTERNAL LIGHTING CIRCUIT

The internal lighting circuit represents the electrical load that requires a constant power supply. This could be a stack of several electrical components forming a system or a simple electrical load.

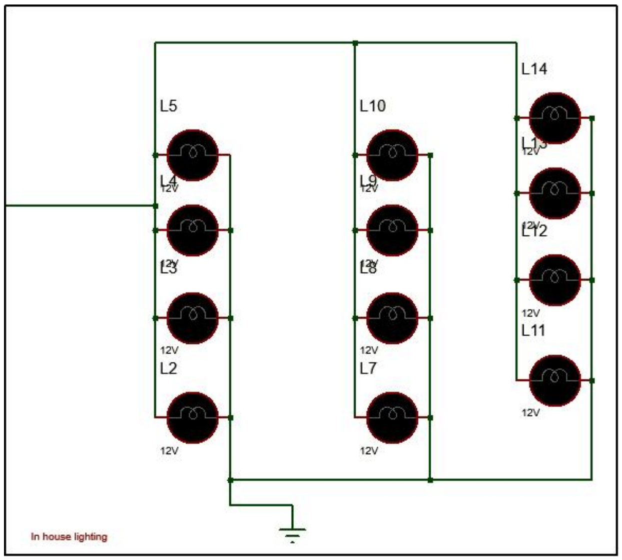

Figure 3.7. Led Matrix

For the purpose of this simulation, a 4 by 4 light array matrix is used to express the supply of power to the system for which the automatic transfer switch is designed.

CHAPTER FOUR

RESULT AND ANALYSIS

This chapter discusses the tests carried out while simulating the circuit in Proteus design suite (PDS) 8.7. Each part of the circuit as described in chapter three of this paper will be tested individually while simulating the circuit. The components used in the design and simulation of the circuit were outlined in table 3.1.

4.1 TESTS

The following tests were performed to ensure proper functioning of the circuit in order to eliminate any irregularities.

4.1.1 POWER SUPPLY TEST

The power supply unit consists of an AC source, a transformer, a bride rectifier circuit and a smoothing capacitor for obtaining a pure DC voltage. A voltmeter was connected across the ends to measure the voltage output from the unit. Figure 4.1 shows the design of the circuit and Simulation in Proteus.

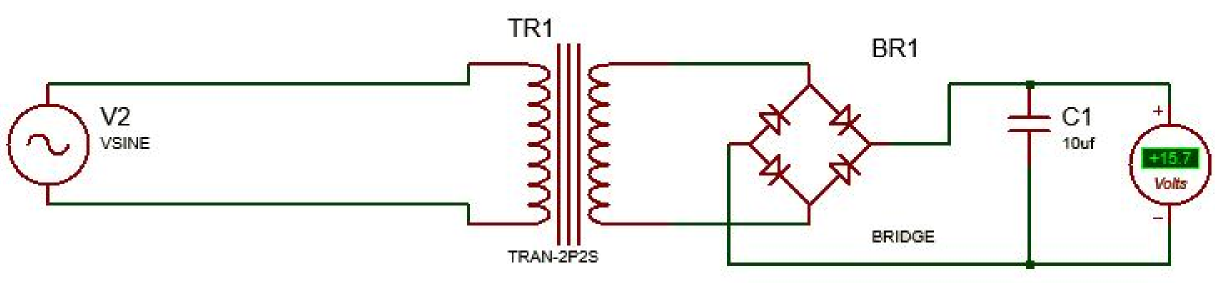

Figure 4.1 Design of the power supply unit with a voltmeter for measuring the voltage supplied.

The result of the measurement using the voltmeter along with the values of the individual components used is presented in table 4.1 below.

Table 4.1: Output voltage of power supply unit

Alternator ratings	Transformer	Capacitor	Voltmeter reading
Amplitude: 240V, Frequency: 50Hz	Primary voltage: 240V Secondary voltage: 40V Transformer ratio: 0.17	10 micro farads	Output voltage: 15.7V

From the above result, it can be seen that the supply of power from the simulated utility grid is at the expected supply of 240v and the AC to DC converter converts the AC voltage signal into a DC voltage signal of approximately 15.7 volts.

4.1.2 OVERRIDE OPERATION TEST

The override circuit consists of an override button and a led lamp to indicate when the circuit is operating in the override mode.

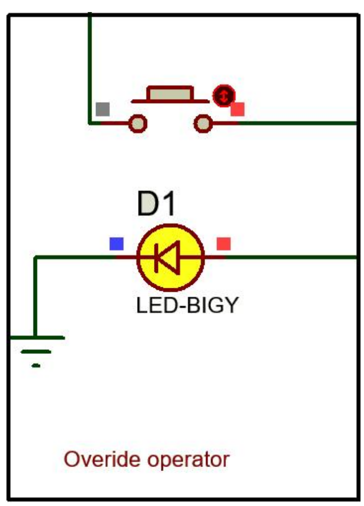

Figure 4.2: Design of the override operator circuit.

Figure 4.2 above shows the design of the circuit and simulation in Proteus

The result of the override test is given below.

Table 4.2: Override operator result

Operation Mode	Led Status	Load Operation
Override Mode: OFF	Led: OFF	Utility supply
Override Mode: ON	Led: ON	Backup Generator supply

From the test, when the override operation mode is turned off, the led lamp remains off and the circuit operates using the utility supply. However when the override operation mode is turned on, the circuit transfers the load to the backup generator without taking the utility grid supply into consideration.

4.1.3 BACKUP GENERATOR SUPPLY TEST

The backup generator consist of an AC sine wave generator, a relay circuit to act as the key starter of the generator, a motor to indicate the rotation of the generators alternator and a lamp to indicate when the motor is in a working state. A voltmeter was connected across the ends to measure the voltage produced by the unit. Figure 4.3 shows the design of the circuit and Simulation in ISIS Proteus.

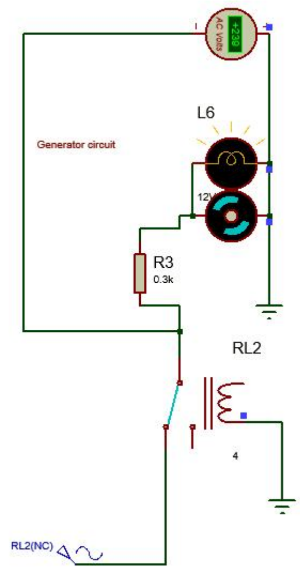

Figure 4.3: Design of the backup generator supply unit with voltmeter for measuring voltage supplied.

The result of the measurement using the voltmeter along with the values of the individual components used is presented in table 4.3 below.

Table 4.3: Output voltage of generator unit

AC Sine ratings	**Relay**	**Resistor**	**Motor**	**Lamp**
Amplitude: 240V, Frequency: 50Hz	Primary voltage: 12V	Resistance: 300 Ω	Primary voltage: 12V	Primary Voltage: 12V

The backup generator is designed to supply in the absence of power from the utility grid.

It should however be noted that the motor and the lamp components in this simulated circuit are not necessary for the design but are provided as an indication of the working operation of the backup generator.

4.1.4 OVERALL CIRCUIT OPERATION

The entire circuit with all the different components combined was tested with all possible programmed modes that could trigger an operation in the circuit.

The result of the test is given below

Table 4.4 Overall circuit operation

Test	**Result**
Power from Utility grid ON	Generator is off and power is supplied to load by the utility grid
Power from utility grid OFF	Generator is on and power is supplied to load by the backup generator
Override operation ON	Generator is on and power is supplied to load by the backup generator
Power from utility grid fluctuating	Generator supply is kept on and power is supplied to load by the backup generator
Power from utility grid remains constant after fluctuations	Generator is off and power is supplied to load by the utility grid

From the entire test as presented in the table above, it can be observed that the circuit uses the power supply from the backup generator only when;

1. The power from the utility grid is cut off
2. The override operation is on
3. Power from the utility grid is fluctuating

For the purpose of this test, a time scale of 10 seconds was used for the fluctuation test but this time scale should be changed to a higher value in real life situation.

4.2 LIMITATIONS

The limitations experienced during the design and simulation of the automatic transfer switch circuit are outlined below:

1. The circuit design is only suitable for backup generators with a key starter.
2. A timeline history of the circuit operation is not provided to the user.
3. This circuit is theoretical and may require some changes to work in practical.
4. The circuit does not protect the system from voltages surges.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

This chapter discusses the recommendations for future work on this topic and conclusions made.

5.0 CONCLUSION

The aim of this project was to design and simulate an automatic transfer switch capable of transferring power supply from the power grid to the backup generator in the case of power failure. The circuit was simulated on Proteus successfully. The results from the simulation indicate that the transfer switch worked according to design. It kept a continuous power supply to the load by transferring between the utility grid and the backup generator. Testing revisions and analysis of the completed circuit was performed. With this design the automatic transfer switch kept a constant power supply to the load which met the purpose of this study.

5.1 RECOMMENDATIONS

Considering the importance of a reliable power supply, it will be proper that this type of design is provided to every individual in order to enhance regular power supply to eliminate blackouts.

1. This circuitry should be implemented in the design of distribution fuse boxes.
2. The implementation of this project should be further modified to create the possibility of using multiple backup power supplies in order to create redundancy.
3. Further programming should be carried out to create more logic decisions.

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