DESIGN AND CONSTRUCTION OF MICROCONTROLLER BASED AUTOMATIC THREE PHASE CHANGE-OVER AND GENERATOR STARTER/STOPPER

BY

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IN ENGINEERING (B.ENG).

NOVEMBER, 2011

DEDICATION

This project work is primarily dedicated to 'THE ONLY REALITY IN BOTH UNIVERSE AND HEAVENLY (GOD)' and to the sad and early departure of a friend, a mentor and a brother...LATE MODAMORI DANIEL OLAITAN.

DECLARATION

I, MODAMORI SUNDAY, declares that this work was done by me and has never been presented anywhere for the award of any degree. I also hereby relinquish the copyright to the Department of Electrical Electronics Engineering, Federal university of Technology, Minna.

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(Name of student) (Signature and date)

CERTIFICATION

This is to certify that this project was carried out by MODAMORI SUNDAY (2007/2/26406EE) in the Department of Electrical/Electronic Engineering, Federal University of Technology, Minna for the award of Bachelor of Engineering (B.ENG) in Electrical/Electronic

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ABSTRACT

The main aim of any electric power supply in the world is to provide uninterrupted power supply at all times to all its consumers. Although, in developing countries, the electric power generated to meet the demands of the growing consumers of electricity is insufficient, hence power instability. This project is a design of an automatic changeover switch. This means that when there is any mains failure, the automatic changeover switch will change to an alternative power supply (Generator), and back to the main supply when it is restored. The purpose of this project is to maintain constant supply to the main circuit that is being supplied by making-up for the time lapse or delay that usually accompanies the manual switching from one source to another. The design comprises of the power connection circuit and control connection circuit. The main components to be used include; contactors, relays and timer

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CHAPTER ONE

1.0 INTRODUCTION

The growth and development of any nation can be traced to the availability of electricity. Electrical power has been the bedrock and driving force for growth in industrial as well as commercial activities.

The instability in electrical power in Nigeria as well as most developing countries creates the needs for an auxiliary power source (s) hence automation is needed in changing from one source to another source in the event of failure. Most industrial and commercial activities are dependent on power supply and if the process of change-over is manual, time would have been wasted which might leads to damage of equipment. The automatic change-over switch becomes a key element in any emergency power system [1].

A switch is device use to make and break electrical circuit [2]. An auto-operated switch is designed to protect an electric circuit from fluctuation cause by over load or short circuit by interrupting continuity of electric flow.

A switch can be normally closed or normally open. It is normally closed when flow of current is allow in one direction from one point to other and open when no current is allow to flow. A change-over switch is one that has both open and close characteristics.

A change-over switch can be defined as a switch that allows safe switching from utility power (PHCN) to emergency or auxiliary source (generator) while maintaining isolation of each source without back feeding to either. The automatic change-over switch is designed to monitor the voltage and frequency of the incoming alternating current from the mains supply and in the event of failure will kick start the generator. The automatic-change –over supervise the automatic transfer of utility load from the main supply to the standby source and vice versa. In event of mains voltage failure, the relays are energized and the load is automatically transferred from the mains to the generator source. When the main source is restored, the module will return the load back to the utility source and off the generator automatically.

There are majorly two types of automatic change- over switch namely;

- The opened transfer change over switch
- The closed transfer change-over switch.

  An open transfer change-over switch is also known as a break-before make transfer switch. It breaks contact with one source of power before it makes contact with another source. This is to prevent back feeding.

  A closed transfer change-over switch on the other hand is called a make- before break. In a typical emergency systems, there is an inherent momentarily interruption of power to load when it is transferred from one available source to the other.

1.1 AIMS AND OBJECTIVES OF THE PROJECT

The project is aimed at designing and constructing an automatic change over switch and generator starter/ stopper. The project is aimed at achieving the following objectives:

- Quick automatic phase change when any of the of the phase fails
- Supply of electric power in all the three phases
- Automatically kick-start the generator
- Restore actual lines when failed lines are restore

1.2 METHODOLOGY

. The method employed in this design is to carry out the individual unit which is then assembled to a single unit to achieve the overall aims of the design. The operation of the automatic change-over switching unit was well organized and coordinated for efficient performance. The method adopted in this project is based on programmed micro-controller. The operational process is outlined in figure 1.1 .

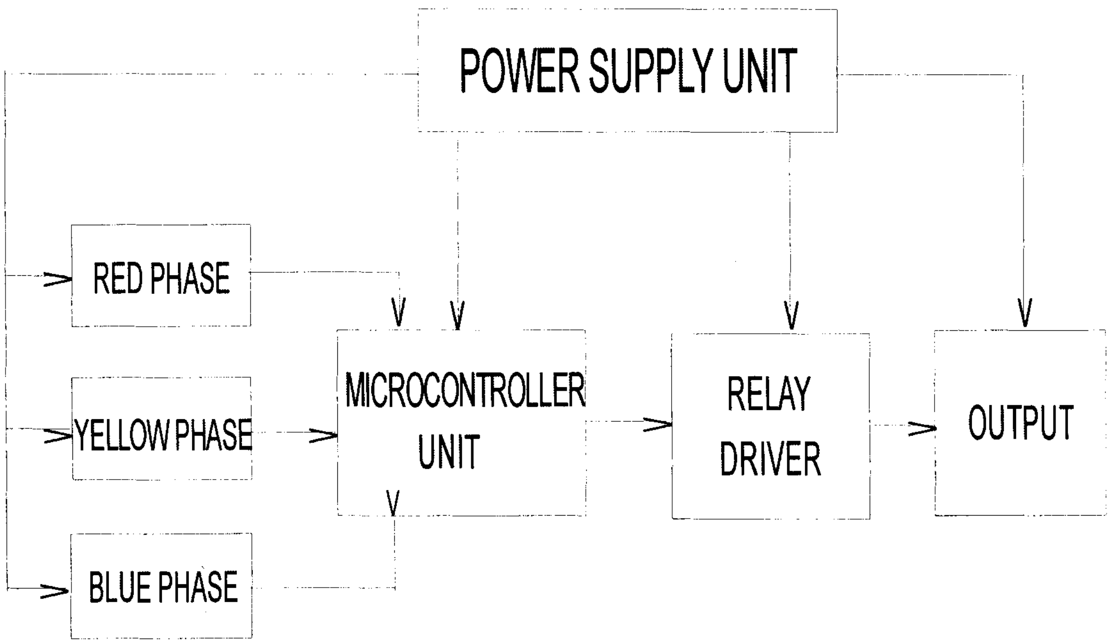


Fig 1.1 Block diagram of automatic three phase change-over and generator starter

1.3 JUSTIFICATION OF THE PROJECT

Though there are many automatic change over both in the market and in our laboratory with much electronics components (Analogue) but this particular design is unique in that it uses a programmable component thereby reducing the size and increasing the efficiency of the circuit.

The design is also essential considering the fact that every establishment in Nigeria has a standby generator and a generator operator and in order to reduce cost and time wasting to change from one source to another during power failure necessitated for this design.

1.4 LIMITATIONS OF THE DESIGN

- The design will only switch on the generator if the generator has a kick starter.
- The design will also set one of the three phases of the PHCN as default phase on which all loads are Connected.
- The design cannot detect surge voltage or the least voltage level which each phase can be reduced to before changing to generator.
- The design will not also monitor other factors like fuel level of the generator or the general state of the generator.

CHAPTER TWO

LITERATURE REVIEW/ THEORETICALBACKGROUND

2.0 LITERATURE REVIEW

The erratic nature of the power system in Nigeria has forced virtually all the consumers of electric power to source for additional sources of power beside the supply from PHCN which is not only unstable but epileptic. Before the advent of automatic change over switches, the process of changing from one power source to another source has been by manual method which comes in any of the following forms. Switch box, cut-out, connector fuse, switch gear and circuit breaker. All these methods of changing over serve to protect the connected load and transition of circuits or appliances to alternatives sources of electrical power [3].The major drawback to the afore-mentioned methods is the tedious work involved.

The first voltage regulator was discovered in the 19th century by Thomas Edison which was used in the motorized system controlled by a circuit to change the tap on the secondary winding of an auto transformer [4]. The major drawback was the cost and size (very expensive and bulky). Ever since then different modifications have been made to reduce the size, cost both in single phase and three-phase.

In our departmental laboratory also, there are different types (based on method of construction) of automatic change over but this project seeks to perform the same task using a programmable microcontroller which is not common and also start the auxiliary source (generator) when there is failure and stop the generator when electric power have been restored.

Another approach was the phase-controlled automatic voltage regulator. The system is connected in series with the voltage controlling device (which is usually a silicon-controlled rectifier). The major drawback to this was it could only handle a single phase and the output waveform is distorted.

A typical change-over switch is made up of an actuator and toggle mechanism (relay) [5]. The actuator (Micro-controller) operates by supplying the needed voltage and instruction to toggle mechanism to maneuver movable contacts that are within the toggle mechanism relatives to stationary power input contacts.

2.1 THEORETICAL BACKGROUND.

Electrical energy has been a subject of interest for centuries among the then scientist (now electrical engineer) with Michael Faraday discovery of what is now known as electricity as the first giant step in this direction.

The Thomson technology T5842 series of automatic transfer switch uses two mechanically interlocked enclosed contact power switching units and micro-processor based controller to automatically transfer load to a generator supply in the event of failure [6]. The load is also automatically re-transferred back to the utility supply when the fault have been rectify.

By-pass isolation transfer switch consists of two major modules: transfer and the by-pass isolation switch. The by-pass isolation is the basic switch provided with quick make, quick break manual load transfer handling. The control (interlock) systems consist of both mechanical and electrical interlocks.

CHAPTER THREE

3.0 DESIGN AND CONSTRUCTION

The design and implementation of this project was influenced by the choice of component (s).These components includes:

- 3 230/12v 300mA transformer
- 1 230/15v 500mA transformer
- IN4001 diodes
- Resistors
- 5v/1A 7805 regulator
- 12v/1A regulator

The design of an automatic (3-phase) change over switch and generator starter/stopper begins with the specification of task to be performed by the circuit, and then the circuit to carry out the function as designed. The design is base around the following sub-systems:

- Power supply unit
- Microcontroller unit
- Relay driver

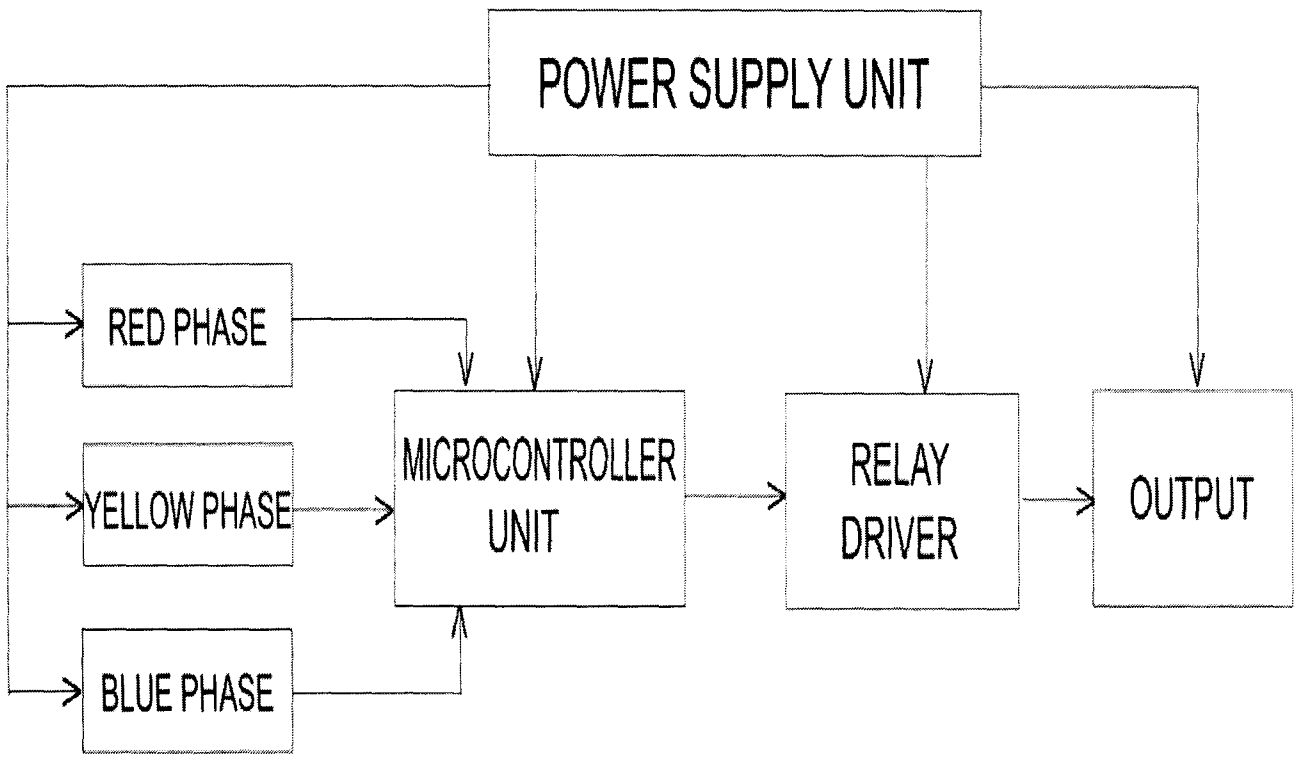


Fig 3.1 Block diagram of automatic 3 phase change over and Generator starter/ stopper.

3.1.0 POWER SUPPLY UNIT

For any electronic circuit, the power supply is designed to convert high voltage AC supply to a suitable low voltage supply (DC). The power supply unit can be broken down into various sub units which include:

- The transformer unit and phase monitor unit
- The rectifier unit
- Smoothing unit
- regulator

This power supply unit is one of the vital part of the design since every electronic components need to be powered. The power supply unit of this design consists of a 230/ 15V step down transformer with 500 mA Current rating, bridge rectifier 2200uf capacitors. These three (3) phases are labeled Red (R), Yellow (Y) and Blue (B) as convention for indication. Each of the voltage between a line and a neutral point (phase voltage) is rectified, filtered, stabilized to 5v which is the voltage the micro-controller can work with. Each of the phases is treated separately. The micro controller is seeing three different DC voltages.

3.1.1 TRANSFORMATION

A transformer transforms AC supply from one voltage level to another voltage level. It has the primary side which is the part connected to the mains and the secondary side from which the output is gotten. Various types of transformers are current and voltage transformer, instrument transformer to mention but few.

THE STEP DOWN TRANSFORMER

This is the type of transformer in which the secondary voltage is less than the primary voltage. The step-down transformers (4 in number) in the power supply unit have the following specification:

- 230/15V, 55omA.
- 230/12V 300mA

The ratio of the turns of the primary coil to that of the secondary coil also determine the ratio of their voltages

$$\frac{Vp}{Vs} = \frac{Np}{Ns}$$

$$Power = Vs \times Is = Vp \times Ip$$

$$Vp = primary\ (input) voltage$$

$$Ip = primary (input) current$$

$$Np = Number\ of\ turns\ on\ primary\ coil$$

$$Vs = secondary\ (output) voltage$$

$$Ns = Number\ of\ turns\ in\ secondary\ coil$$

$$Is = Secondary (output) current$$

3.1.2 RECTIFICATION

This involves the process of changing an alternating source (A.C.) to a pulsating DC source. The process makes use of majorly diode. The diodes can be arranged in half wave rectifier and full wave rectifier.

The half wave rectifier makes use of just a single diode, to convert the A.C supply to the pulsating D.C. The type used in this design is a bridge rectifier because it is the most efficient. It makes use of four diodes connected in such a way that two of the diodes are forward biased and the other two are reversed biased. The full wave rectifier uses both the positive and negative side of the supply (mains).

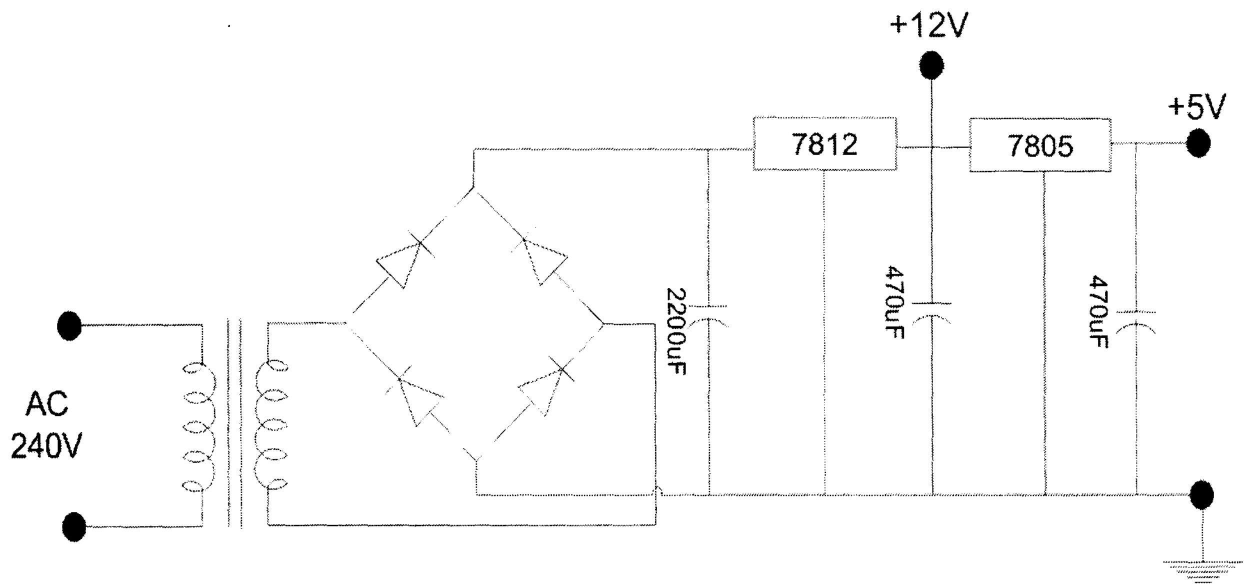


Fig. 3.2 Power supply

3.1.3 FILTERATION

A filter is a network that reduces the ripples presents in rectified signal. The pulsating D.C output of the rectifier is not usable by most electronic circuits since it contains some A.C components called ripple. Filters are circuits that remove these ripples. The output from the filter is a D.C output that can be compared with that of a battery or any other DC source. Filter circuits are majorly achieved by an electrolytic capacitor connected across a DC supply.

This can be arranged in any of the following ways:

- Series capacitor filter

- Series inductor filter
- L-c filter

The type used in this project is the series capacitor type.

Justification of the capacitor

$$Q = CV$$

$$Q = IT$$

$$CV = IT$$

$$T = {}^{1}/_{2}f$$

$$T = {}^{1}/_{100}$$

$$= 0.01$$

$$But\,peak\ voltage = Vrms \times \sqrt{2}$$

$$Vrms = 15V$$

$$= 15 \times \sqrt{2}$$

$$= 21.2V$$

$$Voltage\ drop\ across\ rectifier\ Ic = 0.7 \times 2 = 1.4V$$

$$Assuming\ dv = 15\%\ of\ peak\ voltage$$

$$dv = (21.2 - 1.4) \times {}^{15}/_{100}$$

$$dv = 2.97$$

$$C = {}^{It}/_{dv}$$

$$C = 0.3 \times {}^{0.01}/_{2.79}$$

$$C = 1.03 \times 10-^{3}\ F$$

Since the exact value of this capacitor is not available in market, hence, the closest available is 2200μF capacitor.

3.1.4 REGULATOR (STABILIZER)

The output of the filter varies with the varying supply and load. To obtain a stable D.C output, a regulator is placed to give out a constant voltage irrespective of the variation in the voltage of the input

For this design, the IC (7805) gives out a constant 5v D.C output that the micro controller (APT 89965) can work with. Its features include easy installation, self protection [8]

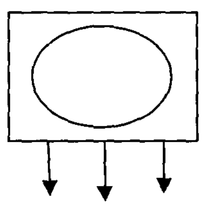


Fig 3.3 voltage regulator LM7805

This is a 3 pin integrated circuit that supplies a regulated 5v dc from an input ranging from 7v to 20v.

3.2.0 THE CONTROL UNIT

The control section is the brain of the design. It is the part that perform the switching from PHCN to generator and vice-versa based on the instruction (programs) written to the micro controller.

The major elements in this section are:

a) The micro controller (processor)

b) The relay driver

The operation of the control circuit provides an automatic transfer switch which monitors the incoming A.C mains (utility) supply and should a mains failure occur the control will triggers the generator on. When the mains supply returns within limits, the control, after configurable stabilization time period, will transfer the load back to the mains. .

3.2.1 MICRO CONTROLLER

A micro-controller is a single-chip microcomputer. This unit serves as the control and co-ordination point for this design. The micro controller unit regulates all other units together to act as a single unit. Its functions are:

- To control the multiplexer

➢ To control the conversion pulse

➢ To select the appropriate phase

The unit consists of two parts viz:

➢ Hardware

➢ Software

HARDWARE: This consists of AP856 micro controller, a 12 MHz crystal with its biasing capacitor and resistors, a reset button. These hardware enable the micro controller operate effectively and are from the manufacturer's data sheet [10].

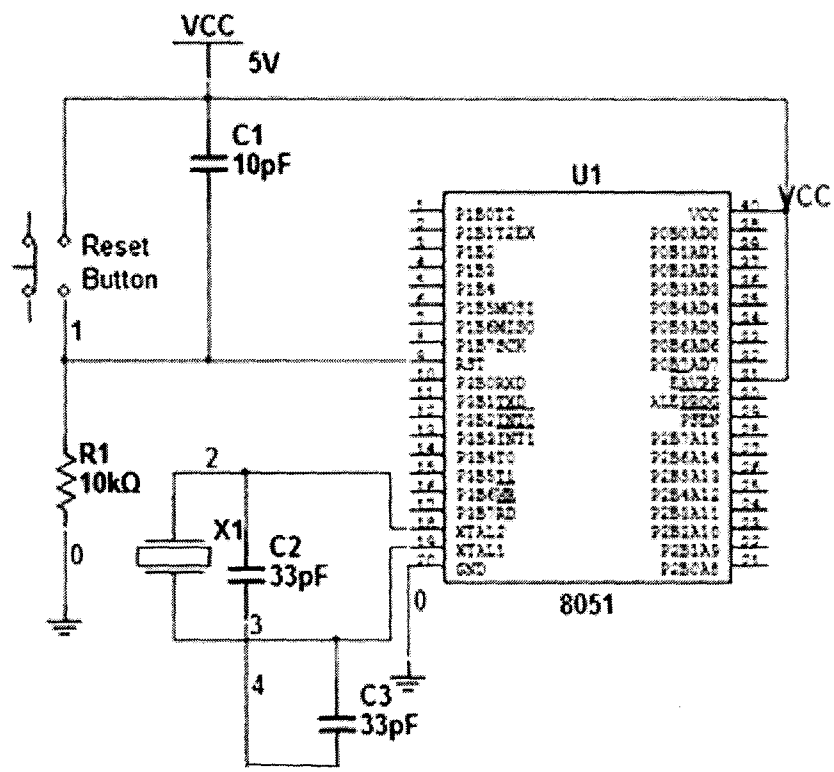


Fig 3.4 micro-controller internal circuitry

The software is a program written in assembly language (appendix i) to instructs the micro-controller. The sequences of operations to be carried out is outlined in Fig 3.5

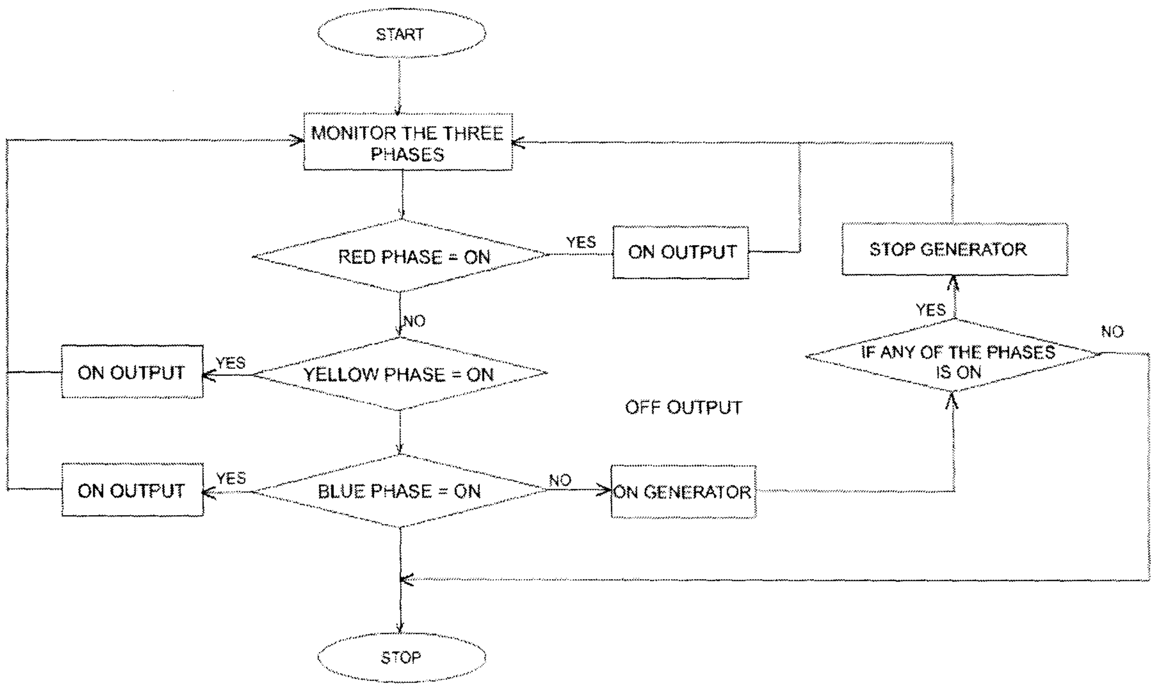


Fig 3.5 Flow chart

3.2.2 TIMING CIRCUIT

The timing circuit determines when switching is to occur either from PHCN or generator. This is because the generator needs to reach synchronous speed before the load can be transferred to it. This gives the required delayed say 5-10secs before the load is being transferred to it. The major component in this section is the crystal oscillator attached to the micro controller pin 18 and 19.

CALCULATION ON TIMING CIRCUIT

On the micro controller is crystal oscillator used in time delay. Since the oscillator is 12MHz hence

$$12\ clock\ cycle\ = One\ instruction$$

$$Clock\ cycle\ \ = One\ instruction$$

$$Time\ (t)\ to\ execute\ one\ instruction$$

$$t\ \ = 12 = 1\mu S\ /12MHz\ \ = 12/12x106\ cycle/sec$$

$$t = 1\mu s$$

3.2.3 CHANGE OVER CONTACTOR

A contactor is an electro-magnetic switching device used for remotely switching a power or control circuit. It is a class of switching device design to make and break electric circuit by remote control that may be either automatic or manual. A contactor is activated by control input which can either be a higher voltage/current or a lower voltage/current. Contactors come in many forms with varying capacities and features. The major difference between a contactor and a circuit breaker in that circuit breaker interrupts during a short circuit only. The major function of a contractor is to break high current device and to provide continuous service and to use a relatively small amount of electrical power to control the switching of a large amount of power [9]

3.2.4 RELAY DRIVER (UNL2803)

This is a special type of integrated circuit used majorly to supply the correct amount of current to a group of relays. It is usually grounded for it to either sink the necessary current. The IC can sinks up to 550mA.UNL2803 works like a Darlington pair .It is an interconnection of multiple NPN transistors connected in such a format as shown in fig 3.6. It has a fast recovery time.

$$Coil\ resistance\ = 480\Omega$$

$$Supplied\ voltage\ =\ 12V$$

$$From\ Ohm's\ law,$$

$$V = IR$$

$$I\ = V/R$$

$$Current\ required\ to\ trigger\ each\ relay\ I\ = 12/480$$

$$I = 0.025A$$

$$For\ eight\ (8) relays,\ Total\ current\ the\ IC\ must\ source\ =\ 8\ x\ 0.025$$

$$I\ = 0.2A$$

This value falls within the current the IC can sink.

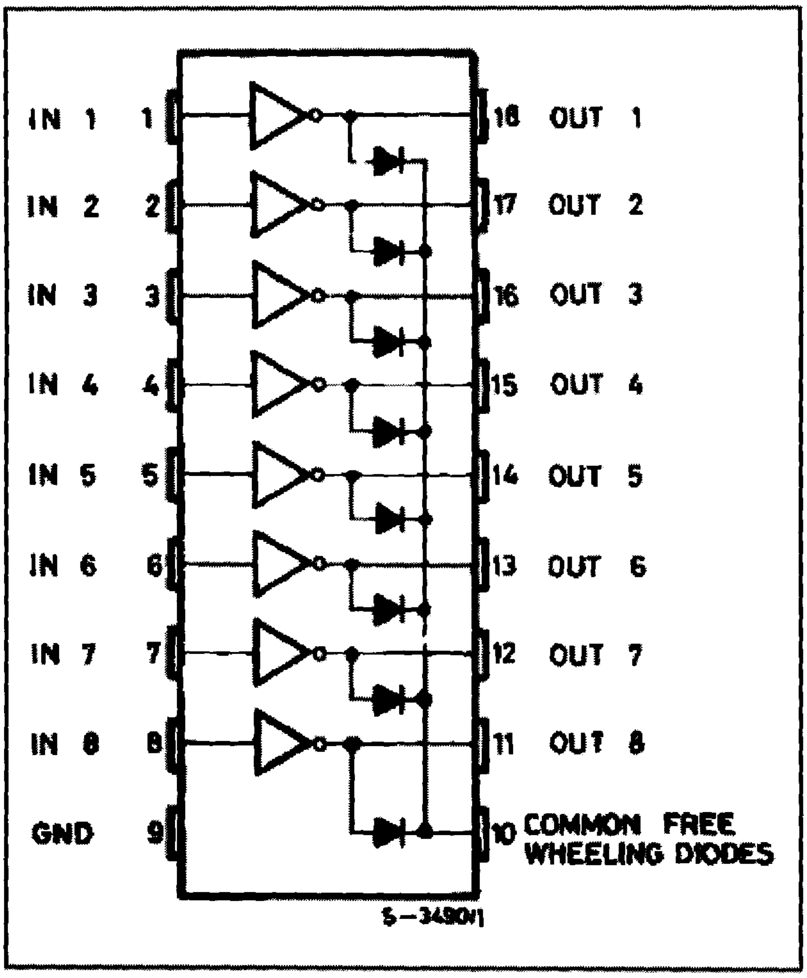


Fig3.6 Pin connection of UNL2803.

3.3.0 SWITCHING UNIT

The switching unit consists of transistor and set of eight relays. Their function is simply to latch the load resistance to an active line following a trigger from the micro controller unit. Two of those relays are meant to switch ON and switch OFF the generator [8].

MODE OF OPERATION

The whole load on the system is connected across the Red phase. The red phase has been looped to the other two phases. The loads connected would be powered as long as any of the phases is powered and a signal is sent to start the whenever none of the three phases has power.

CHAPTER FOUR

TEST, RESULTS AND DISCUSSION

4.0.0 GENERAL CONSTRUCTION

The construction of this project is base on three stages;

a) Bread Board: separate modules of the circuit were constructed on bread boards.

b) Vero boarding : The circuit was finally laid out on a vero board and soldered

c) Casing: The whole project was finally encased.

4.1.0 TESTS AND MEASUREMENT METHODS

Tests on the project were carried out in stages

- Conceptualization Test: During conceptualization, tests were carried out on the design using the principles learned throughout the four (4) years of study in school to ensure the working principles of the project were sound.
- Bread board test: Each module was built on a breadboard and several tests of various units were carried out to ascertain the workability of the components.
- Vero board tests: The project is finally soldered on the vero board

4.1.1 TESTING

Several tests were carried out among which is a continuity tests. This was carried out by measuring the output of each unit.

For the purpose of testing the project, three (3) A C bulbs of different colour (Red, yellow and Blue) were connected to the output to indicate the exact phase that is operational. Also looking at how rare it is to get a 3 phase source(s) within the university, I have also used the single phase available at the socket outlet and split it into three (3) parts with controlled switches to turn ON and OFF any of the part to depict the phase currently in use.

4.2.0 RESULT

The exact PHCN phase(s) which are powered are given a number 1 and the phase without power is allotted a value zero representing a high and low state respectively. The phases are arranged in Red R, Yellow Y and Blue B respectively.

Table 4.1 Test result

RED R	YELLOW Y	BLUE B	LOAD	REMARK
0	0	0	0	Load not powered
0	0	1	1	Load powered
0	1	0	1	Load powered
0	1	1	1	Load powered
1	0	0	1	Load powered
1	0	1	1	Load powered
1	1	0	1	Load powered
1	1	1	1	Load powered

4.3.0 DISCUSSION OF RESULT

During the test carried out before the tabulated results were gotten, the Red phase which have been set as a default phase on which all the loads are connected

The red phase has also been looped with the other two phases hence there is power in the red phase as long as there is power in any of the phases .Only when there is no power in all the phases that the generator will be on.

CHAPTER FIVE

5.0.0 CONCLUSION

The design and construction of automatic three phase change over and generator starter was effected with many complications.

The manual plug-in and unplugging of the cut-out fuses in the domestic power supply and the time taken in searching for a phase with voltage could be dangerous to equipment and human life as well but this can conveniently handle by the incorporation of this device in the power to our load. All components used were locally purchased in Minna and Lagos hence the device can be produced commercially

5.1.0 RECOMMENDATION

The following are my recommendation first on the My design and to the students as well as the department of electrical electronics:

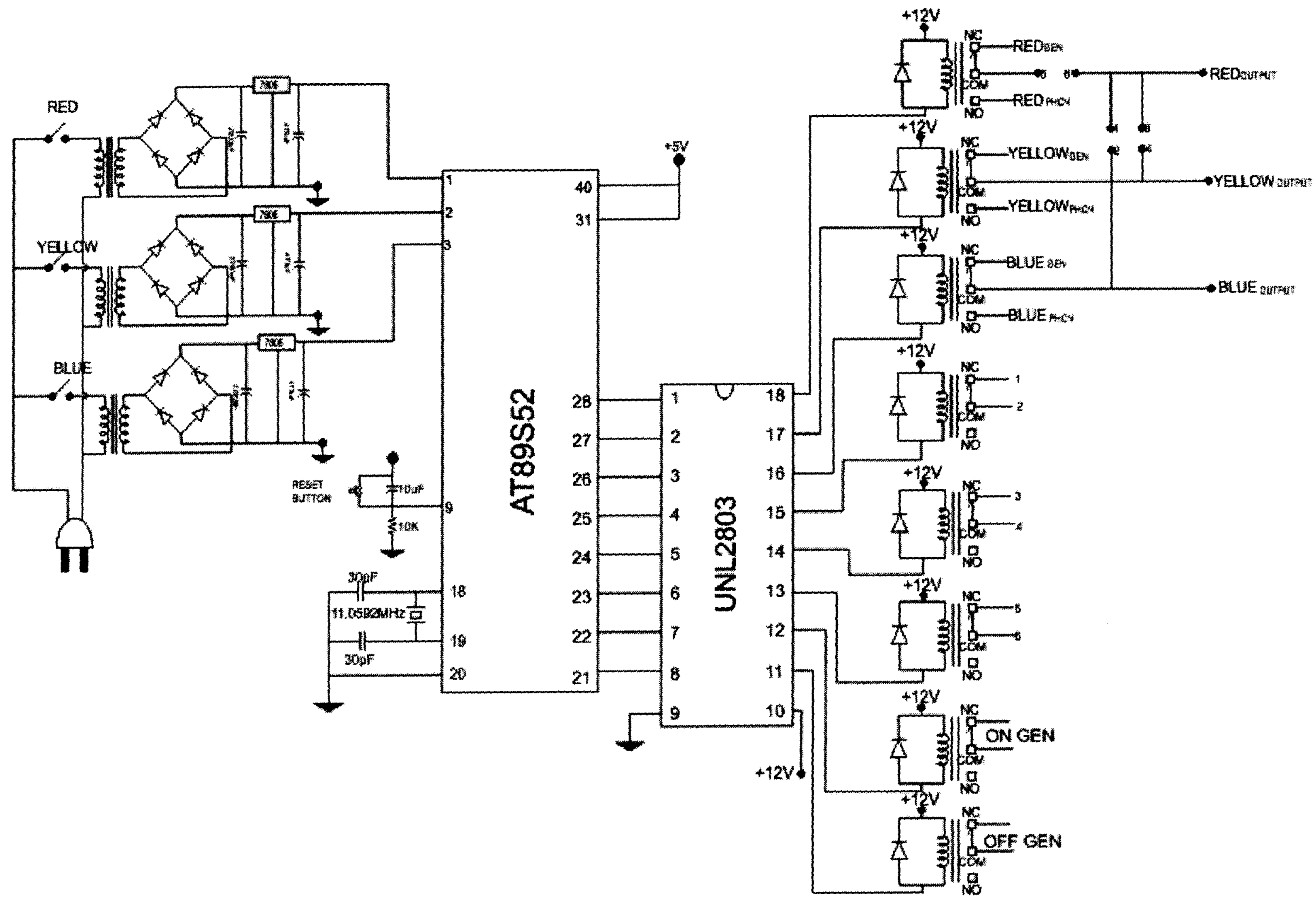
ON THE DESIGN

- The design could be interfaced with an LCD to display the actual phase in use
- The design could also be improved by setting a minimum voltage at which the PHCN supply will cut off and generator come on

TO THE STUDENTS AND DEPARTMENT

- That students should get to know their various supervisor and even project topics before embarking on SIWES
- Students should also be grouped in a reason number for giant project that even touch the present needs of the department

COMPLETE CIRCUIT DIAGRAM OF AUTOMATIC THREE PHASE CHANGE-OVER AND GENERATOR STARTER.



REFERENCES

[1] Usifo F.O "Electrical service design", Federous publication Ltd publishing division, new edition Pg 82-83. 1998

[2] Switches (Online) - www.answers.com/topic/switch

[3] Automatic transfer switches (Online) - www.cumminspower.com

[4] Understanding Relays (Online) - www.autoshop101.com2010'2009

[5] Electronics Device and Circuit Theory, Boyletad L. Robert and Nashelsky Louic, Seventh edition, 1999, Prentice Hallo, New Jersey.

[6] Thomson Ts880 ATSspecs.pdf

[7] Elements of Power Systems Analysis", William D, Stevenson Jr. 4th edition, 1982, McGraw Hill Inc. USA.

[8] www.kspec.uk.com/technology/electronics/7805html

[9] Change over relay: PERKINS (2002) Manual On Load Transfer

[10] Micro-controller: Atmel co-operation, 89c5,data sheet

APPENDIX 1

```
Org 0000h

Red_led equ p1.7

Yello_led equ p1.6

Blue_led equ p1.5

Gen_on equ p1.2

Gen_off equ p1.1

Red equ p3.2

Yello equ p3.3

Blue equ p3.4

Mov p1, #0ffh

Mov p3,        #00h

Start1: jb red, a1

                setb red_led

Start2: jb yello, a2

            setb yello_led

Start3: jb blue, a3
```

```
        setb blue_led
        jb red, a1
        jb yello, a2
        jb blue, a3
        clr gen_on
        setb gen_off
        sjmp start1
A1:     clr red_led
        setb gen_on
        clr gen_off
        ajmp start2
A2:     clr yello_led
        clr red_led
        setb gen_on
        clr gen_off
        ajmp start3
A3:     clr blue_led
        clr red_led
```

```
setb gen_on
        clr gen_off
ajmp start1
end
```