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Design and Construction of Microcontroller Based Automatic Three Phase Selector

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ABSTRACT: The power instability in country has brought about the need for automation in the selection of phase with the best available power supply in the public utility supply and switch to an alternative means of power when there is total power outage. Thus, this work is concerned with design and construction of an microcontroller based automatic three phase selector and improving on the existing system using Arduino module with ATMEGA328P microcontroller for the control unit, 5V, 4-channel relay module for switching unit, liquid crystal display (LCD) for the display unit so as to reduced the bulkiness and to make the system cost efficient and reliable.

Keywords: Arduino, ATMEGA328P, design, phase selector

I. INTRODUCTION

In developing countries like Nigeria today, there is the problem of interrupted power supply as insufficient power is being generated to provide consumers with continuous services and satisfactory quality. This leads to constant power failure which in turn affects both the public and private sectors of the economy. Industries, banks, hospitals and so many other public and private establishment all have major critical loads that needs to be powered at all times in order to carry out various processes efficiently (Adedokun, et al, 2010).

This power instability now brought about the need to select from the phases with available power supply and to create an alternative means of power to back up the public utility supply. The introduction of some of these alternative sources of power supply brings forth the challenge of switching smoothly in a timely manner between the mains supply and the alternative sources whenever there is a failure on the mains source (Oduobuk, 2014).

Automatic three phase selector is an integral part of the process of power generation, allowing smooth and instant transfer of electric current between multiple sources and load (Okome, 2015). The function of the automatic three phase selector is to monitor the incoming public supply voltage and detect when the voltage drops below a certain level that electrical/electronic appliances can function depending on the utility supply. The compares the automatic three phase selector voltage of the other two phases using a comparator circuit and if the voltages are not available, the system changes over from public supply to generator (Bhanu , 2017). When the generator is in operation, it prevents any feedback current to the load. It also ensures that the different power sources are synchronized before the load is transferred to them. The transfer switch senses when there is interruption if the mains supply remains absent. The principle of the automatic three phase selector is such that it links the load and mains supply or the alternative supply together. This enables the use of either the mains supply or an alternative source when there is outage on the mains source which can either be a three phase or a single phase (Ahmed, et al, 2015).

The design of this circuit involves the use of automatic three phase selector but the details of design varies from place to place, time to time and also depends on the type of load involved.

This project involves the use of microcontroller driven relays to affect the change of phase whenever the voltage condition becomes intolerable in the previous phase connected (Roy,et al, 2014).

II. SYSTEM DESIGN

2.1 ARCHITECTURAL DESCRIPTION OF AUTOMATIC PHASE SELECTOR

The automatic phase selector (APS) is designed for power supply applications. The system involves automatic changeover between the utility power supply and an auxiliary power supply (generator).In designing this project, various electrical and electronic components were used. The system block diagram of the constructed

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microcontroller based automatic three phase selector is shown in Figure 1.

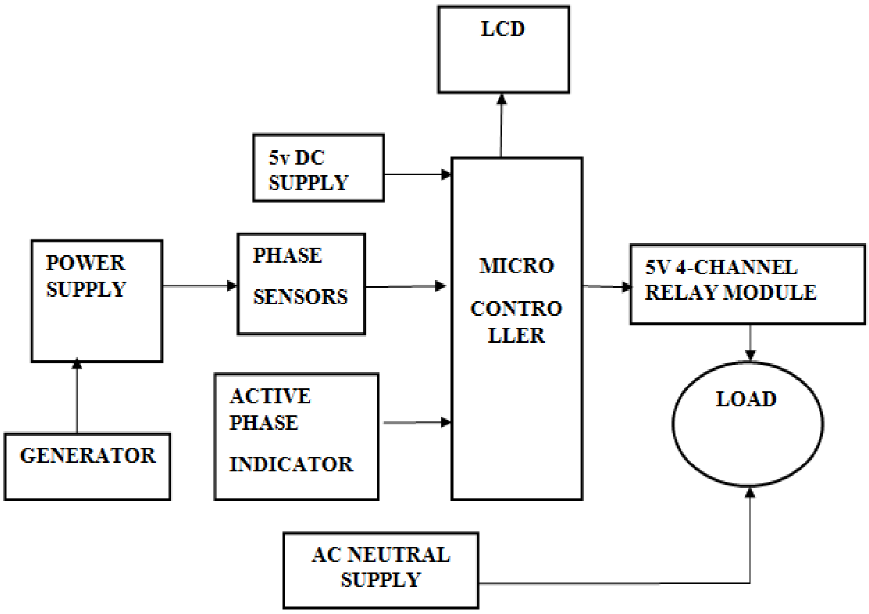

Figure1: Block diagram of Automatic Three Phase Selector

This diagram illustrates how the various modules involved in the system had been implemented. All the modules are inter-connected to each other and are independent of load connected. The system has two major parts, namely: hardware and software .The hardware architecture consists of a phase sensing, control logic, power supply, display unit, relay driver and DC relays.

The phase-sensing circuit has R, Y and B phase sensors to sense the availability of R, Y and B phase respectively. The control logic circuit chooses the phase priority for one out of three phases. The relay-driver section drives the relay according to the signal received from the control logic unit while the power supply provides the power to phase sensors, control logic and relay driver sections. The relay connects the load to the best available phase through the contacts that are fed from all the three phases. The display unit displays the rms voltage of the phase that is connected to the load.

2.2: Components used in the design and construction of the automatic three phase selector

Some important components of the automatic three phase selector are included below;

i. Transformer (step down transformer 220/12V)
ii. Diodes –IN5408
iii. Capacitor-16700uF, 35V
iv. Arduino module with ATMEGA328P
v. Resistors-
vi. variable resistor-10k
vii. Relay Module 5V,

The system operation of automatic three phase selector is of three sub circuit;

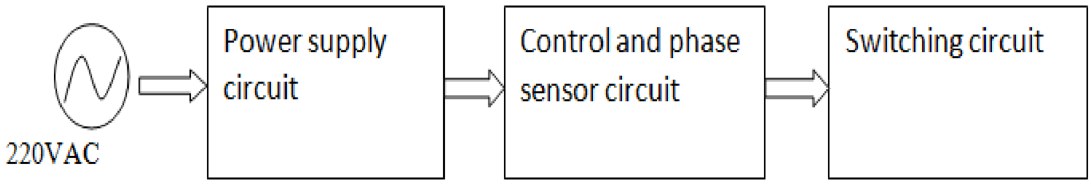

Figure2: Sub-circuit of the automatic three phase selector

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2.2.1 The design calculation

The transform input voltage (voltage in the primary winding) Vp = 220Vac

The transformer output voltage (voltage in the secondary winding) Vs=12Vac

The transformer primary current (current in the primary winding) Ip =?

The transformer secondary current (current in the secondary winding) Is=300mA

From the expression given below,

$$\frac{Vp}{Vs} = \frac{Is}{Ip} \quad (1)$$

Where VP = 220V
Vs = 12V
Is = 0.3sA
Ip = ?

$$\text{Therefore} Ip = Vs \times \frac{Is}{Vp} \quad (2)$$

Ip=12×0.00136=0.0163A

Therefore, the transformer primary current I=16mA

The maximum instantaneous voltage between the terminals of the rectifier circuit is:

V_{max} = Vrms x √**2** (3)

Vmax = 12 x 1.4142= 17V

d.c output voltage,Vdc= Idc× RL (4)

Where Idc= dc output current(average current)
RL=load resistance

In full wave bridge rectifiers, Idc= 2 Vmax /π Rl (5)

Therefore, Vdc= Idc × RL =2 Vmax /π RL × RL = 2 Vmax /π

Finally our

Vdc = 2 Vmax /π (for a 2 – pulse, full wave, bridge ac to dc converter).

Where π=3.142

Vdc = 2 Vmax /π (6)

Vdc = 2 Vmax /3.142
Vdc = o.636Vmax. (7)

It should be noted that the peak inverse voltage (PIV) of the rectifying elements (diode) should be greater than the maximum voltage, Vmax. Since Vmax is already calculated to be 17V. Therefore the peak inverse voltage is twice the maximum voltage across the secondary winding.

Mathematically, PIV=2 Vmax= 2 × 17= 34volts.This value of PIV monitors the selection of the 4 diodes with which to form a bridge rectifier. In this case, the diodes to be selected must be capable of withstanding a potential stress equal to the peak inverse voltage. The IN5408 is suitable for this application.

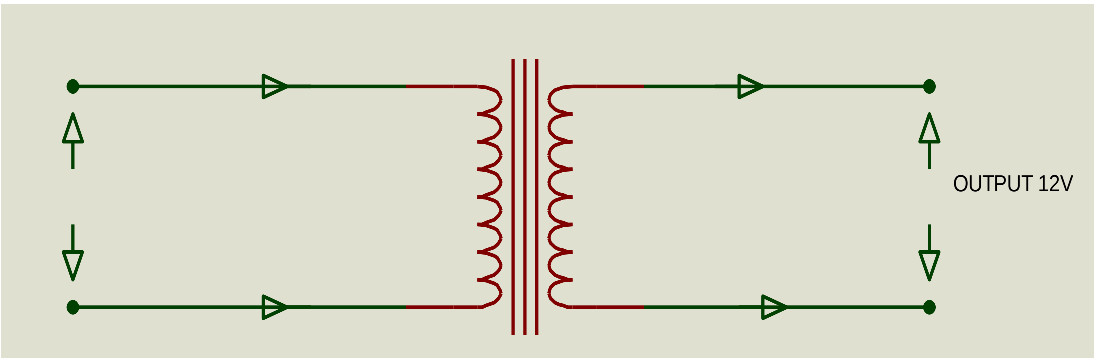

Figure 3: Transformer circuit

2.2.2 SENSING AND CONTROL UNIT

This unit is made of Voltage divider, Display and indicator and Microcontroller

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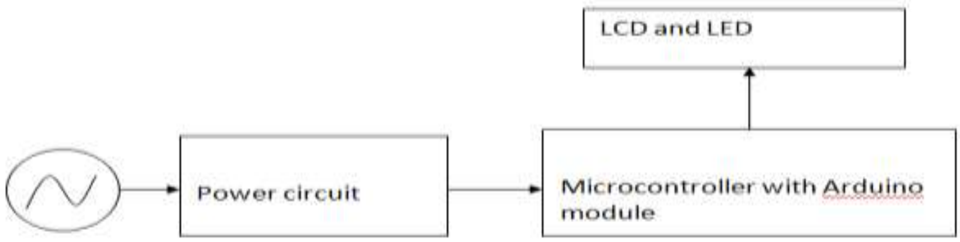

`Figure 4: Sub-circuits of sensing and controlling unit

2.2.3 CONTROL LOGIC CIRCUIT

The control logic circuit comprises mainly microcontroller, which is a compact standalone computer, optimized for control applications. Entire processor with all its support function (clocking and reset), memory (both program storage and RAM), and the I/O interfaces are located on a single piece of silicon so, it takes less time to read and write to external devices.

For this work, ATMEGA328P is used and its selection is due to reliability, effectiveness, low-cost and speed.

2.2.4 DISPLAY AND ACTIVE PHASE INDICATOR UNIT

This unit is made of the liquid crystal display (LCD) and light emitting diode (LED).

The liquid crystal display (LCD) is provided to display all the measured electrical quantities to the connected load. LED Indicator is provided to indicate the phase in which there is an available power supply. It comprises of red, yellow and blue LED.

The LCD in the project will be used to display the phases when they are active or not.

3.9.1 Procedure for interfacing LCD with Arduino in Proteus

In this circuit, the LCD terminals are connected to the Arduino pins. Connect the outer two terminals of the potentiometer to 5V and ground, and the middle terminal to pin 3 of LCD. Rotating the potentiometer controls the brightness of the LCD backlight. The LCD back light pins are connected to 5V and ground.

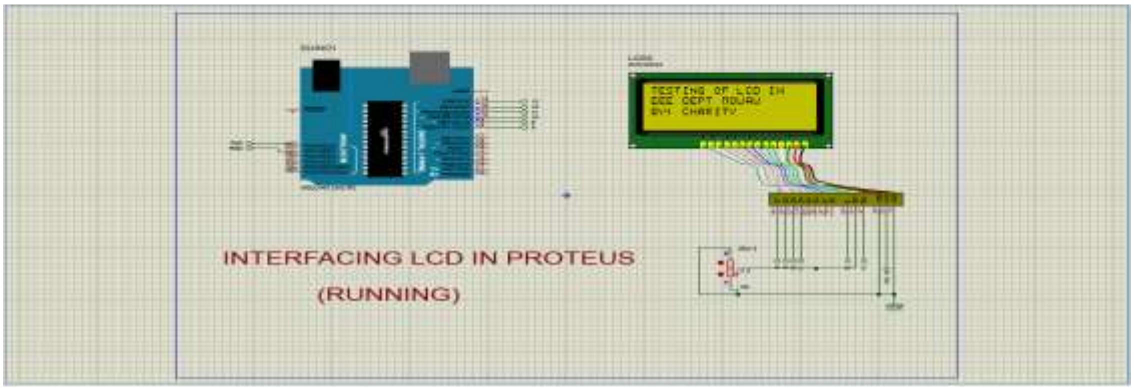

Figure 5: Interface of LCD and Arduino board.

2.2.5 Relay section Proteus circuit

The Arduino is programmed to switch on various sections of the relay. There are 4 relays each for the various phases. If there is voltage supply on the red phase IN4 is switched on same goes for the rest.

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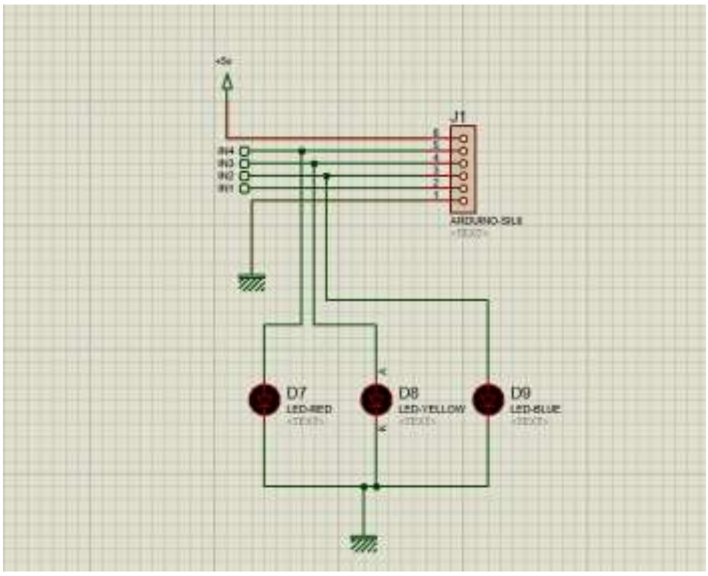

Figure 6: Connection of relay channels and LED

2.2.6 COUPLING OF THE AUTOMATIC THREE PHASE SELECTOR

The circuit is built around with a transformer, microcontroller and relay module. Four identical set of circuit, one each for the three phases and generator are used. Let us now consider the working of the circuit connecting red phase. The main power supply phase R is stepped down by transformer X1 to deliver 12V, 500mA, which is rectified by diode D1 and filtered by capacitor C1 to produce the operating voltage which is fed to the voltage divider circuit of resistor R1 in series with resistor R6 is used to set the reference voltage (5V) according to the requirement. The reference voltage is fed to ADC of Arduino to be converted to digital signal for ATMEGA328P to process.

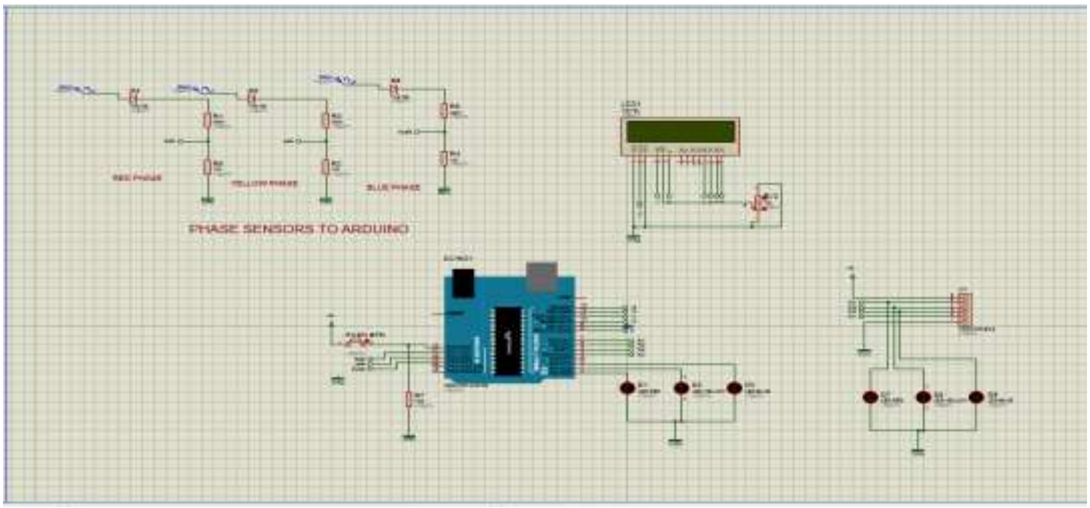

Figure 7: complete circuit diagram in Proteus

2.2.7 FIRMWARE

This Project used the C^{++} language programming using ARDUINO module with ATMEGA328P microcontroller in developing an embedded system for mains phase monitoring, load switching from one phase to another, and display of the voltage at the device's output. Figure 8 shows the flowchart for the firmware that runs in the microcontroller.

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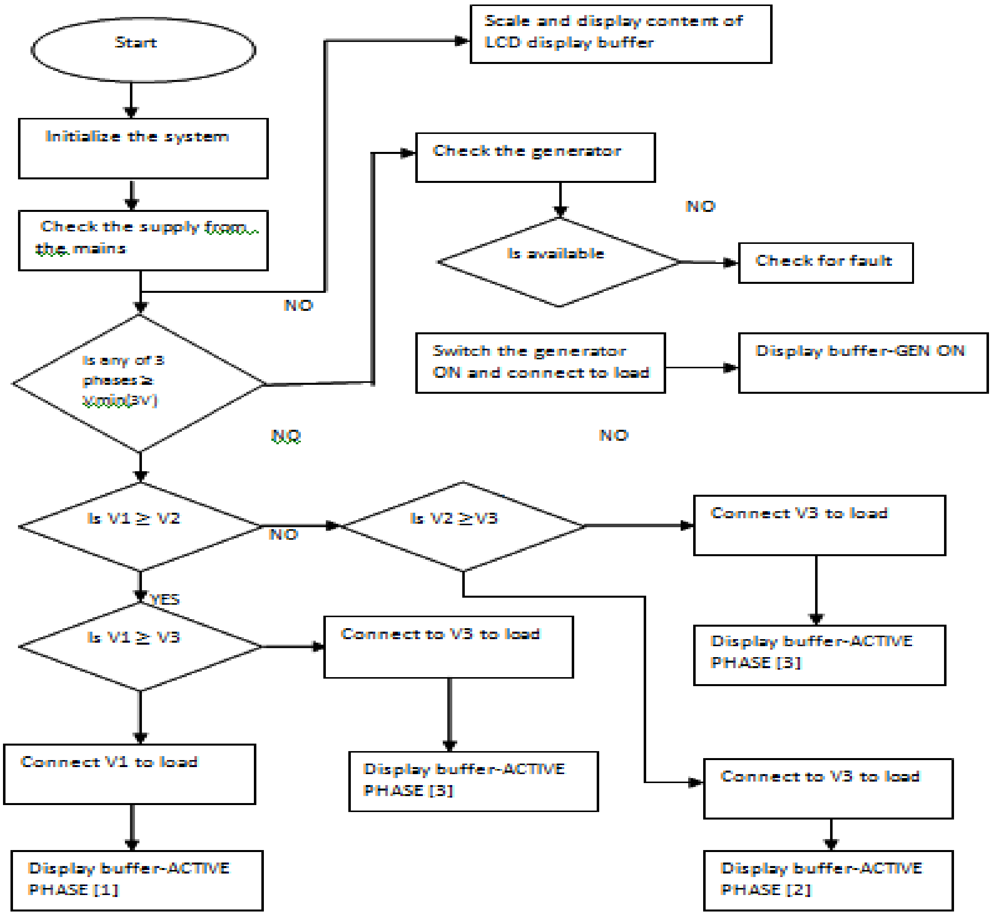

Figure 8: flow chart of automatic three phase selector

3.1 SYSTEM TESTING

System testing is the last step which comes after thorough analysis of the various section explained in chapter four. At this step, the component values specified in the analysis of each were used to realize the section in the breadboard as seen in plate 4.3. A system testing involves testing the entire component on the PCB (printed circuit board). The prototype was then functionally tested using standard electronic testing equipment like multimeters, probes,
oscilloscope etc.

3.2 TESTING PROCEDURES

Here the system is tested with three phase supply system. When the three phase terminal is connected to the pin input terminals of the system, the indicator light emitting diode (LED) comes ON indicating power supply to the system. Just immediately after the powering of the system, one of the LED indicating any of the phases comes ON indicating that one of the lines has being selected and gives an output. It's also applies to the other phases.

3.3 TESTING OF THE POWER CIRCUIT

The power is tested using an oscilloscope. Figure 9 is the Proteus Simulation of the power supply, Channel A of the oscilloscope is connected to the AC mains while channel B of the oscilloscope is connected to the filtered rectified DC and plate 12 shows the AC and DC waveforms of the power circuit from the oscillator.

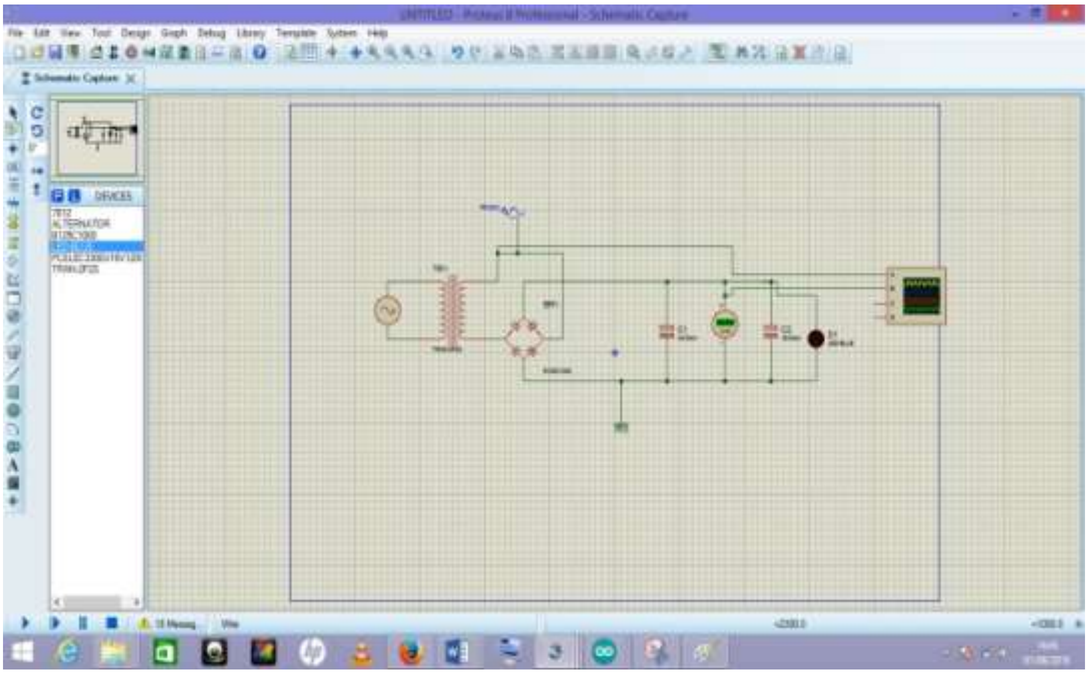

Figure 9: Power supply circuit connected to the oscillator

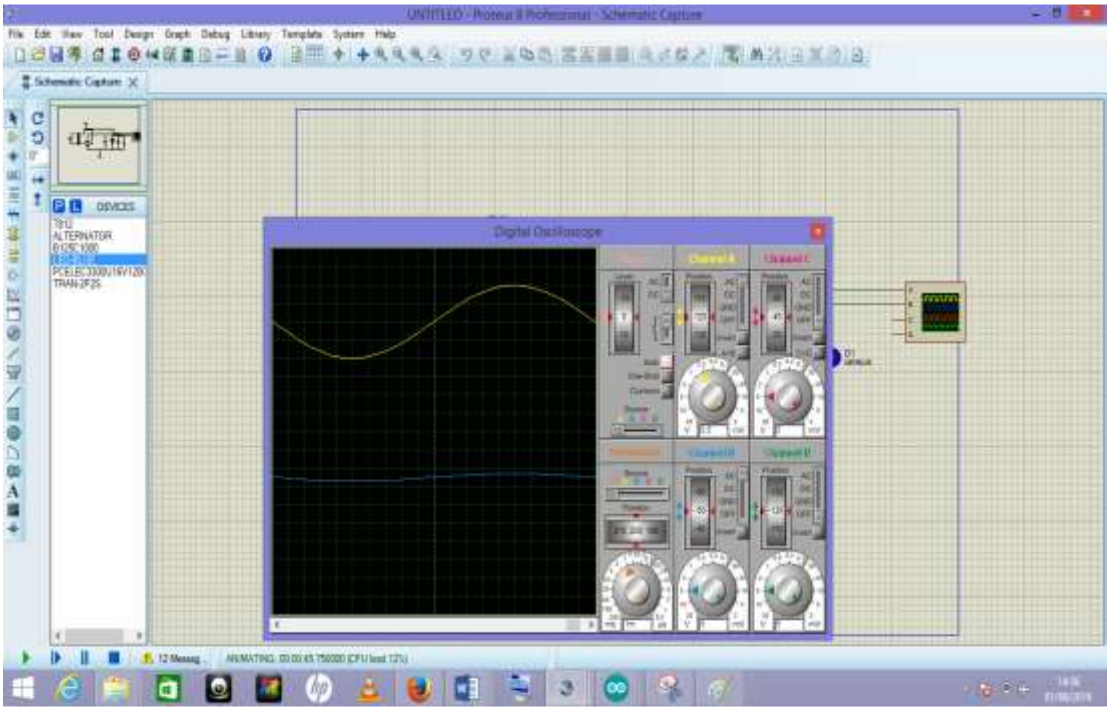

Figure 10: The AC and DC waveforms of the power circuit from the oscillator.

3.4 TESTING AND RESULT OF THE CIRCULT

The automatic three phase selector was tested with the three phases power supply available. The switching process was perfectly executed by the control switching circuit. It put the generator ON and OFF as required and alternated between the two power supplies. The following test results were obtained. Tests and result analysis are show in table 1.

Table 1: Tests and results analysis

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TESTS	RESULTS
Automatic Switching ON and OFF of the generator	The switching control circuit was able to switch ON and OFF the generator when the mains supply in all three phases was not available and when at least one phase was made available.
Switching between the three available phases.	The monitoring unit in the circuit was able to interchange between the phases circuit whenever anyone was of the phases were not available.
Switching between the two available power supply sources	The switching control circuit did the switching between the two power supply sources correctly avoiding any jam in supply when the two supplies are available simultaneously.
Timing of the delay circuits test	All the timed delay circuits worked satisfactorily within ±5secs tolerance.
Reset switch	When the memory of the control unit is full, this done so as to clear/create space on the memory

3.6 PACKAGING

Every quality and good product is often rated by how well it is packaged. Packaging the circuit in a very convenient way so as to avoid damaging its components was done after the testing was carried out successfully. A non-conductive material will be used for the purpose. Due to this fact, plastic casing was preferred for the packaging as seen in Figure 12.

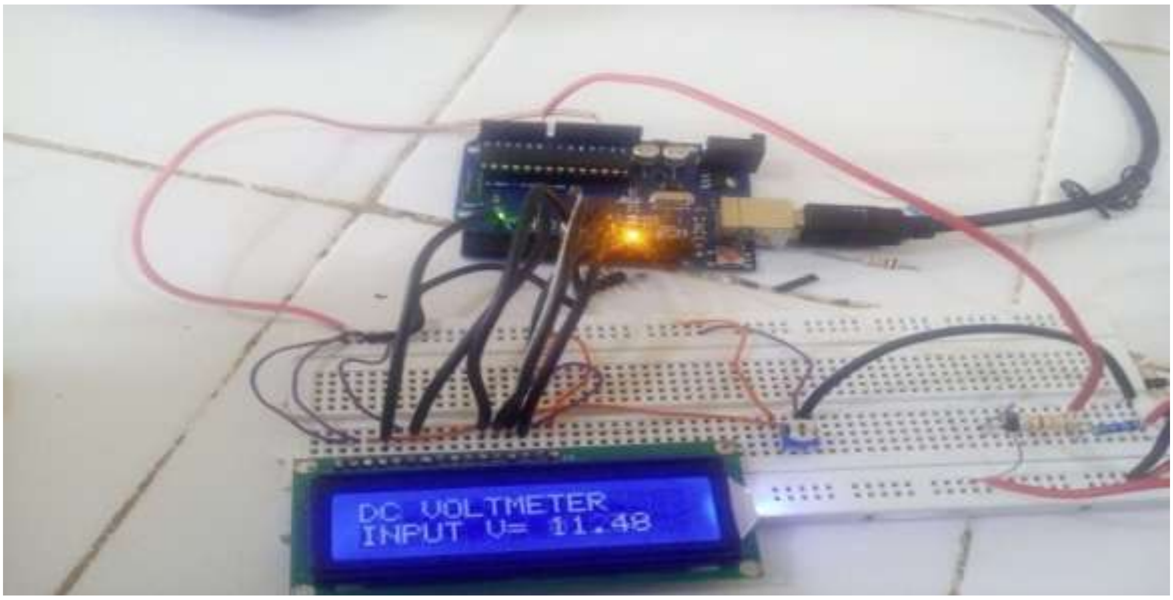

Figure 11: Connection and testing of the project on bread board.

Figure 12: Packaging of the project.

III. CONCLUSION

This research has illustrated how to design and construct a microcontroller based automatic three phase selector. There may be many other ways of achieving a very straight forward way of obtaining the desired result using classical design techniques. The uniqueness of the work lies in the fact that it can be used round the clock and it can neglect a phase with very low voltage.

The construction of this automatic three phase selector was interesting, stimulating and challenging but only in its efficient performance and reliability can any real level of success be measured. The functionality values of this project make it desirable to be developed especially in all residential and small commercial buildings using three phase. The microcontroller based Automatic three phase selector has been designed and constructed which has the ability to monitor, control and switch between power sources in few seconds. It also provides the comfort of starting a standby generator when there is power failure from the mains without the need of human intervention there by eliminating manual phase voltage monitoring, measurement, selection and switching activities. This work saves resources like time, energy and even lives while ensuring automatic and efficient domestic power load sharing from the consumer end. This work will be cost efficient and economically justifiable if this is to be produced in commercial quantity, although there may be slight variation because the design was carried out based on technical and economical consideration. It is believed that the design will operate at minimal cost and at high efficiency. This project ensured to conform to engineering designs, engineering design standards and rules during the design and construction. Its applications range from hospitals domestics homes, small scale industries.

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