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Design and Implementation of an Inbuilt Phase Selector in Single Phase Automatic Change Over Switch

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Abstract: *In developing countries, power supply is relatively unstable, the use of alternative power sources such as generators, inverter, solar systems, etc. has become necessary in order to compensate the required supply of power in homes, industries, institutions, commercial firms and so on. This paper aimed at designing and implementation of an automatic changeover switch with an inbuilt phase selector. This work was achieved by putting together a circuit combination of a microcontroller, phase voltage sensing circuit, display unit, switching unit and other discrete electronic components. The microcontroller was used to interpret the data received from the phase sensing unit, process the data and send signal to the switching unit; it also switches the voltage from range of 220V to 240V while voltages below 220V and above 240V are identified as unhealthy, and are therefore ignored. The system could smartly measure the voltage profile of each phase and with the information obtained can decide to changeover to the healthiest phase or to generator if there's no healthy phase according to the design. The results show that the system worked according to design where the reference voltage was always in used and switches to generator where any of the phases are unhealthy.*

Key words: *change over switch, phase selectors, electromechanical switching, healthy and unhealthy voltages.*

1. INTRODUCTION:

The supply of power to the public plays a major role in the economic development of every nation. In most unindustrialized countries where the power supplied is erratic, the use of alternative power supply like generator, inverter, solar system, etc. are employed to give the necessary power required for companies or industries, institutions and other commercial places that required stable power supply to run daily activities. Operating the source of power manually has adverse effects like damage to the machine, loss of lives, electrocution and even unexpected injuries to individuals and companies. The public power supply is associated with some problems such as, unhealthy voltage supplied on the phases or even failure of voltage on the phases which required an alternative source to keep the daily activities functioning. This paper is aimed at designing a system that can supply uninterrupted healthy voltage in an organization. The system will help in saving time of operation, and to avoid unnecessary risk that is accompanied with doing it manually. This design is reliable, effective and perfect in its performance because the switching is done by automation and without time wastage. The automatic changeover system disconnects the load and transfer it from one power source to another when there is power failure. It also has the capacity to shut down generator terminals that switches off the generator after the main supply has been restored depending on the design using a microcontroller [1]. The sources of power supply are interconnected for the purpose of switching whenever there is a power failure. These sources may be public supply, a generator, an inverter etc. The design and construction of the inbuilt phase selector in change-over switch is necessary because the system could access the healthiest voltage before switching to that for effective performance of the company or usage at home. This system ensures the supply of constant power supply to the load. The system consists of three main parts, which are; electromechanical switching devices (relay/contactors), display unit and microcontroller. The relay is used for switching operation between the phases [2]. The display unit displays the phase with the healthiest voltage. When there is available power in the three phases, the microcontroller compares the voltage in the phases and chooses a healthy phase for power supply based on the already programmed system which could display the reference voltage.

2. LITERATURE REVIEW:

It is paramount to X-ray, efforts made by researchers on how to get a stable and healthy power supply. [3] on their part, designed an automatic three phase selector that can be used for load control in home appliances using microcontroller and other discrete electronics components. The system detects voltage fluctuation in phases which could be due to overloading, loose connections and electric shock, the phase selector detects this phase and switches to the next phase with an appropriate voltage within milliseconds and connect to the load. The switching unit consists of relays, and the power supply unit while [4] designed a microcontroller-based circuit that controls power supply from four sources: solar, inverter, generator, and mains. The objective of the paper was to have constant supply of power using four different sources. But [5] designed an inbuilt generator control mechanism in automatic changeover switch. The system switching mechanism could switch from a generator to another source at milliseconds without any stress or loss of supply to the user. Apart from that, [6] designed an automatic three phase change over switch employing logic gate and Relay driver. The paper aimed at designing a system that can minimize or erase faults in power system like open circuit faults, short circuit faults, ground/earth faults, symmetrical and unequal faults in 3-phase systems. The system is designed in such a way that it detects and interrupts power system faults. Similarly, [7] designed and constructed automatic changeover using controlled logic unit. The control logic unit consists of the microcontroller and the control program running in its memory. The microcontroller does the power failure detecting and switching between lines. According to the authors, the three modes that determines the operation of the changeover includes auto mode, timed mode and the manual mode which were selected by the push buttons. If the mode is auto, the changeover switch turns on. If the time mode is selected, it measures the selected time before switching over. If the manual mode is selected, it waits until the user turns on the changeover switch.

Meanwhile, [8] designed a human relief standby change over switch which was aimed at simply monitoring, operating and maintaining power in homes or institutions by automatically switching to either of the available source with preference to the source from the national grid. Also, [9], presented a paper on the design of a system that can detect low voltage in a single phase system and switches to alternative source to ensure constant power supply. The system is designed in such a way that the selector links the load, the relays and the other phases, these interface enabled constant supply of power to the load. It maintains constant power supply to the load by automatically activating the phases when the need arises while [10], Simulated an Automatic Phase Changer (APC) circuit using Proteus 8. The APC automatically changes the phase as the name suggests. In three phase power system 3 inputs of APC circuit were connected to three phases of the system and its three outputs are connected to three different loads. The voltages supplied to the loads required constant voltages across the phases to ensure proper operation. Results observed that contrary to the nominal voltage rating may cause the three phase system to malfunction. Therefore, the APC help in compensating for the lost in voltage on the phases and, [11], designed and constructed a switchgear called Automatic Transfer Switch (ATS) for a single-phase power generator. According to the authors, the system helps in transferring power between a public utility and a power generator. The ATS, provides a functional system that provides an automatic switching of power supply between a primary source (public utility) and a secondary power source (generator). Furthermore, [12] designed an automatic power phase selector. This project was designed to select an active phase from other available phases within very few seconds. The purpose of this project was to design a system to monitor, operate and maintain power. A single-phase contactor with three poles operating at a frequency of 50Hz was used to control and transfer the load. A relay was also introduced to isolate other phases incase more than one phase comes up and it was set up in a way that the phases are selected based on preference i.e. red phase-yellow phase-blue phase unless a phase preceding another phase or two other phases has a voltage lower than the standard voltage that was set to operate on.

It is clear from the findings that all the work done by researcher focused on switching from one power source to the other or monitors only the phases. But the combination of the two systems in other to have a stable and healthy voltage has not been considered. For this reason, this paper shall combine the phase selector and change over switch for effective supply of power.

3. MATERIALS AND METHOD:

3.1 Conceptual Framework

Figure 1 shows the block diagram of an inbuilt phase selector in automatic change-over switch with ATMEGA 328 acting as the brain behind the other components. The microcontroller ATMEGA 328 was programmed using the C++ language in order for it to transmit information to each of the units interfacing with it on the action to activate per the state of the voltage from the National grid. For instance, the LCD was used to display the voltage value in each phase before enabling switching of power supply to the phase with the healthiest voltage value.

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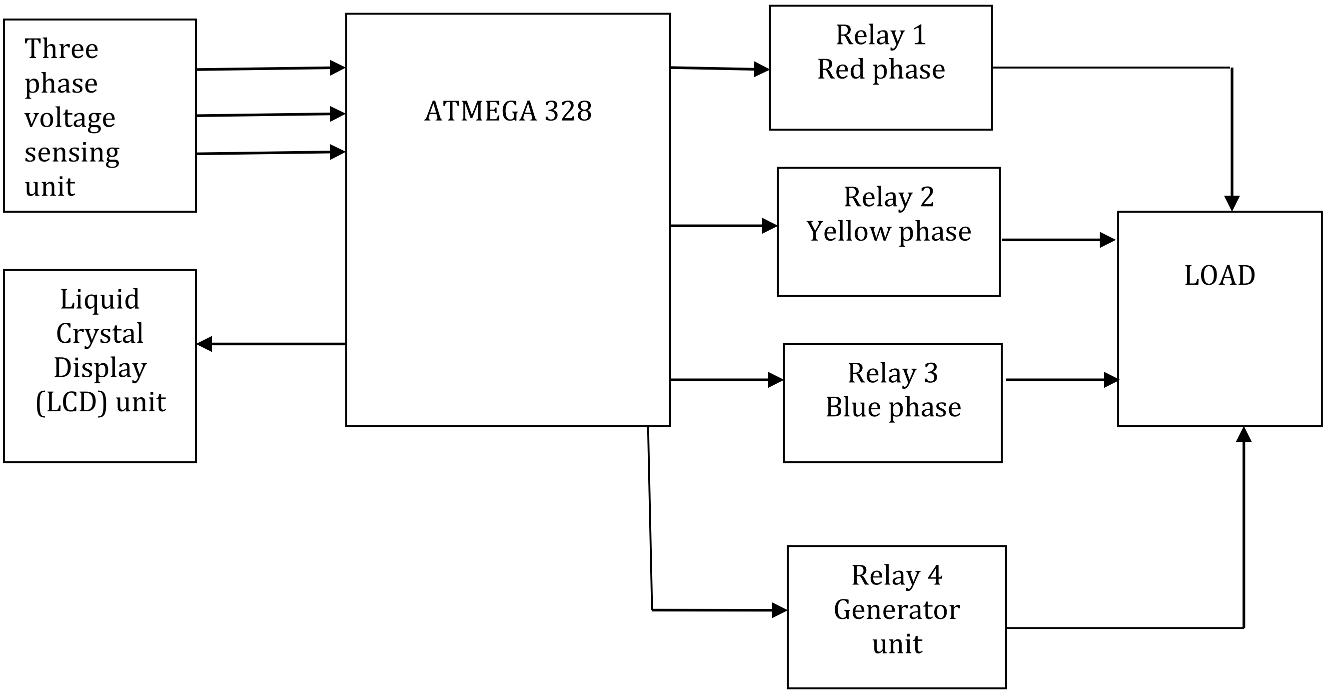

Figure 1. Block diagram of an Automatic change over switch with an inbuilt phase selector

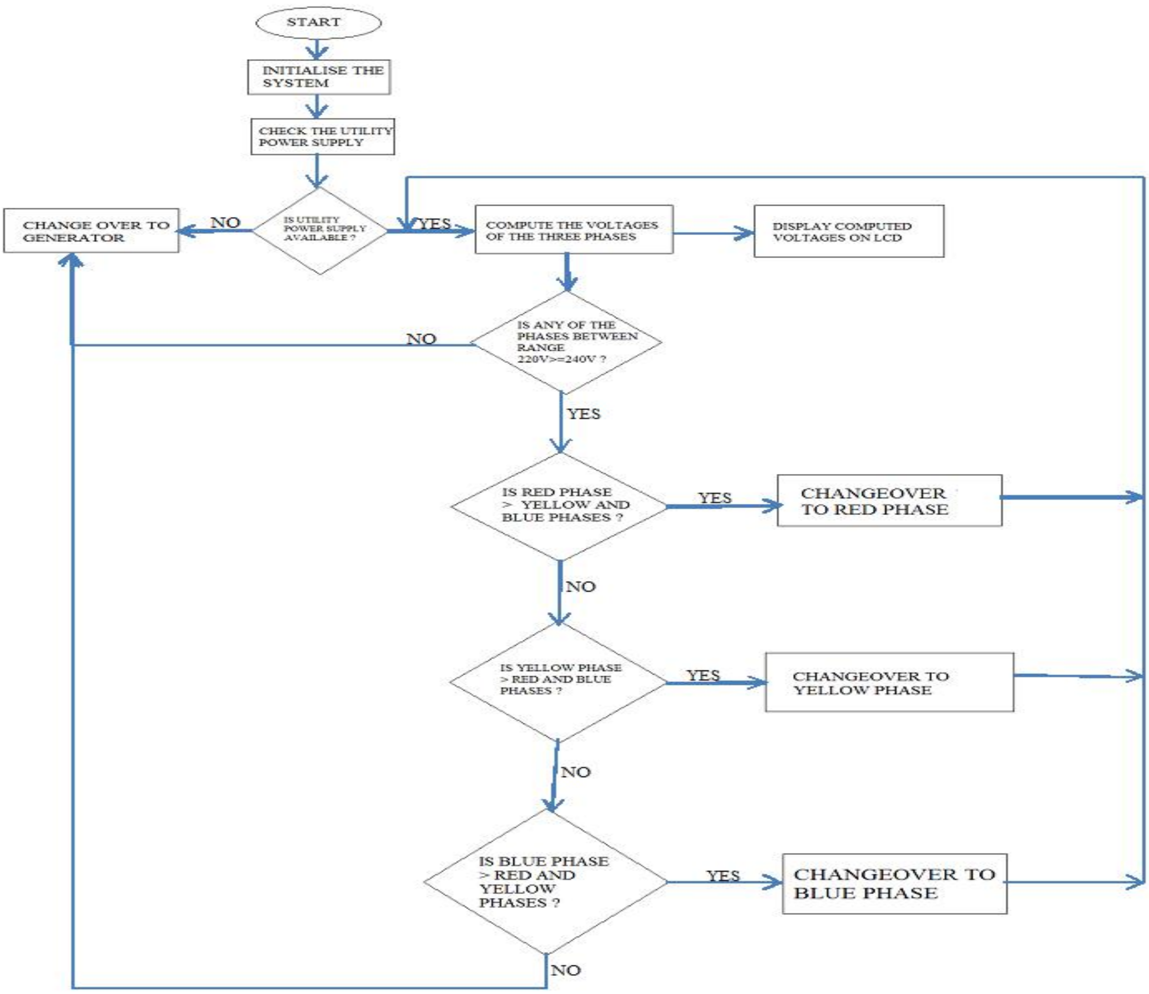

Figure 2. Flow chart of automatic egg incubator control system.

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The flowchart is shown in figure 2, it shows that several processes were required in order for it to serve as an automatic changeover switch with an inbuilt phase selector. When there is an input supply into the three phases. The microcontroller reads the voltage from the phases and then compares the voltage levels for the three phases such that it switches to and maintains the healthiest phase or switch to generator once the voltage from the three phases are not reliable or available. The relays which are driven by ULN2003A is connected to the microcontroller which determines when to energize and de-energize the relay which is powered by a 12V and 5V is supplied to ULN2003A. The 12V relay triggers the generator phase while the 5V triggers the three phase supply. The relay that is triggered and selected now determines the phase that powers the entire system.

4. ANALYSIS:

4.1 CIRCUIT DESIGN AND ANALYSIS

In the design of an inbuilt phase selector in automatic changeover switch with, the components specification has been considered. Such specifications have been used to ensure that each component is within the manufacturer's design specification

4.2 Circuit analysis

4.2.1 The power supply analysis:

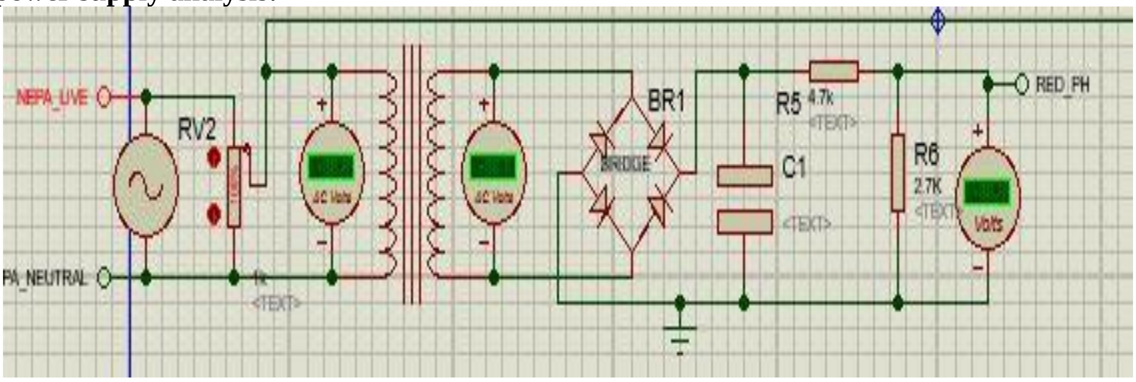


Figure 3. Diagram showing the power supply unit

The transformer at the power supply steps down 230V AC from the input side of the primary winding to give an output of 15V AC at the secondary winding. Below is the necessary specification of the transformer.
Primary Voltage – 230 AC, Secondary Voltage – 15V AC, Current – 0.5A, Output Power rating – 7.5VA
Frequency – 50Hz
Using the transformer ratio equation,

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = K \qquad 4.0$$

Where;

$E_1 = 15V$, $E_2 = 230V$, K = ?

$$K = \frac{15}{230} = 0.065$$

$$V_{rms} = V_{max}/\sqrt{2} \qquad 4.1$$

Where;
V_{rms} = is the root mean square voltage of the secondary side, V_{max} = maximum voltage of the secondary side

$$V_{max} = 15\sqrt{2} = 21.21V$$

The dc voltage is gotten with the formula below:

$$V_{dc} = \frac{2V_{max}}{\pi} \qquad 4.2$$

$$V_{dc} = \frac{2 \times 21.21}{\pi} = 13.50V$$

The value of R_l can be determined from the formular;

$$R_l = \frac{V_{max}}{I_{rating}} \qquad 4.3$$

Where $V_{max} = \sqrt{2}\, V_{r.m.s}$ ($V_{r.m.s}$ = r m s value of the stepped down voltage)
I_{rated} = Current rating of the transformer=500mA

$R_l = \frac{15\sqrt{2}}{500mA} = \frac{15\sqrt{2}}{0.5} = 42.43\Omega$

The dc current is gotten with the formula below:

$$I_{dc} = \frac{2V_{max}}{\pi R_l} \quad 4.4$$

$$= \frac{2\times 21.23}{\pi \times 42.43} = 0.32\text{A}$$

- **Rectifier**

The rectifier circuit used from the above circuit diagram is a full wave bridge rectifier which comprises of four (4) diodes (1N4007) each with a current of 1.0A and it can handle up to 1000V. It has the following specification which makes it very suitable for the design. Low forward voltage drops, high current capability, high reliability, high surge current capability.

- **Filter Capacitor**

We can improve the average DC output of the rectifier while at the same time reducing the AC variation of the rectified output by using smoothing capacitors to filter the output waveform. The capacitor $\boldsymbol{C_1}$ is connected in parallel with the rectified output of the rectifier circuit.

To operate at a minimal ripple voltage of 5%, then the minimum value of the $\boldsymbol{C_1}$ can be calculated as follow.

Peak primary voltage = $230V * \sqrt{3} = 325$V

Recall that from transformer equation, $\frac{V_2}{V_1} = \frac{N_2}{N_1}$ 4.5

Turns ratio = $\frac{V_2}{V_1} = \frac{15}{230} = 1:15$

Peak secondary voltage = **325V** $* \frac{1}{15}$ **= 21.7V**

Peak full wave rectified voltage at the filter input is

V_{ip} **= 21.7 – (2** $* 0.7$**) = 20.3V**

NB; During each half cycle the current flows through two diodes instead of just one so the amplitude of the output voltage is two voltage drops **(2*0.7 = 1.4V)**

Let the percentage ripple (%$_V$) = 5% = 0.05

$$C_1 = \frac{1}{4*f*\gamma*\sqrt{3}*R_l} = \frac{I\,dc}{4*f*\gamma*\sqrt{3}*V_{ip}} \quad 4.6$$

$$C_1 = \frac{0.5}{4*50*0.05*\sqrt{3}*20.3} = 1422\mu F$$

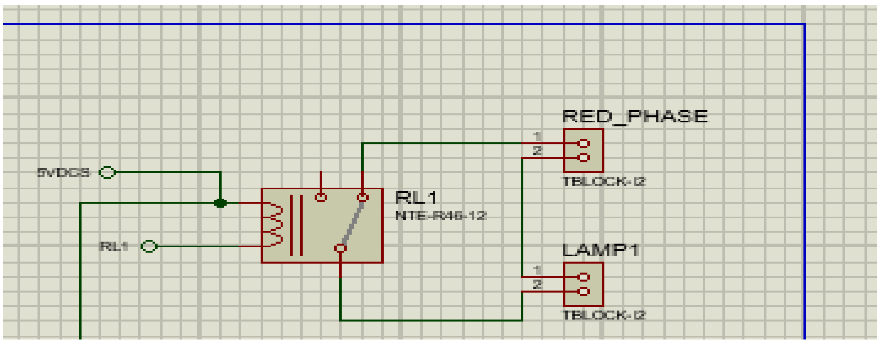
The minimum value of C_1 is $1422\mu F$, a higher value of C_1 will be chosen since the higher the value of C_1 the more the stability and the lesser the existence of ripple in the power supply. So, therefore C_1 is then approximated to $4700\mu F$.

- **Voltage Regulator**

The voltage regulators selected in this project are LM7812 and LM7805. A 12V voltage regulator supplies a steady 12V and 5V output to the input of the relays. The 12V relay was used for the generator phase while the 5V relay was used for the three-phase supply.

4.2.2 Switching unit analysis

The switching unit consist of relays and ULN2003A.



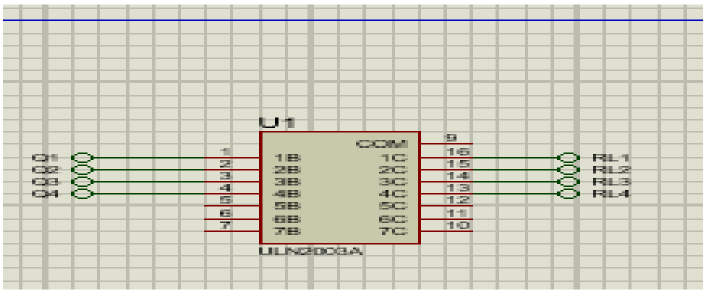


Figure 4. Diagram of a relay and ULN2003A

- **ULN2003A**

The ULN2003A is an array of seven NPN Darlington transistors capable of 500mA, 50V output, it is required for very high current amplification by connecting two bipolar transistors in direct dc coupling. It also has the capability to interface with a stepper motor for other device interface.

CIRCUIT AND SIMULATION MODEL

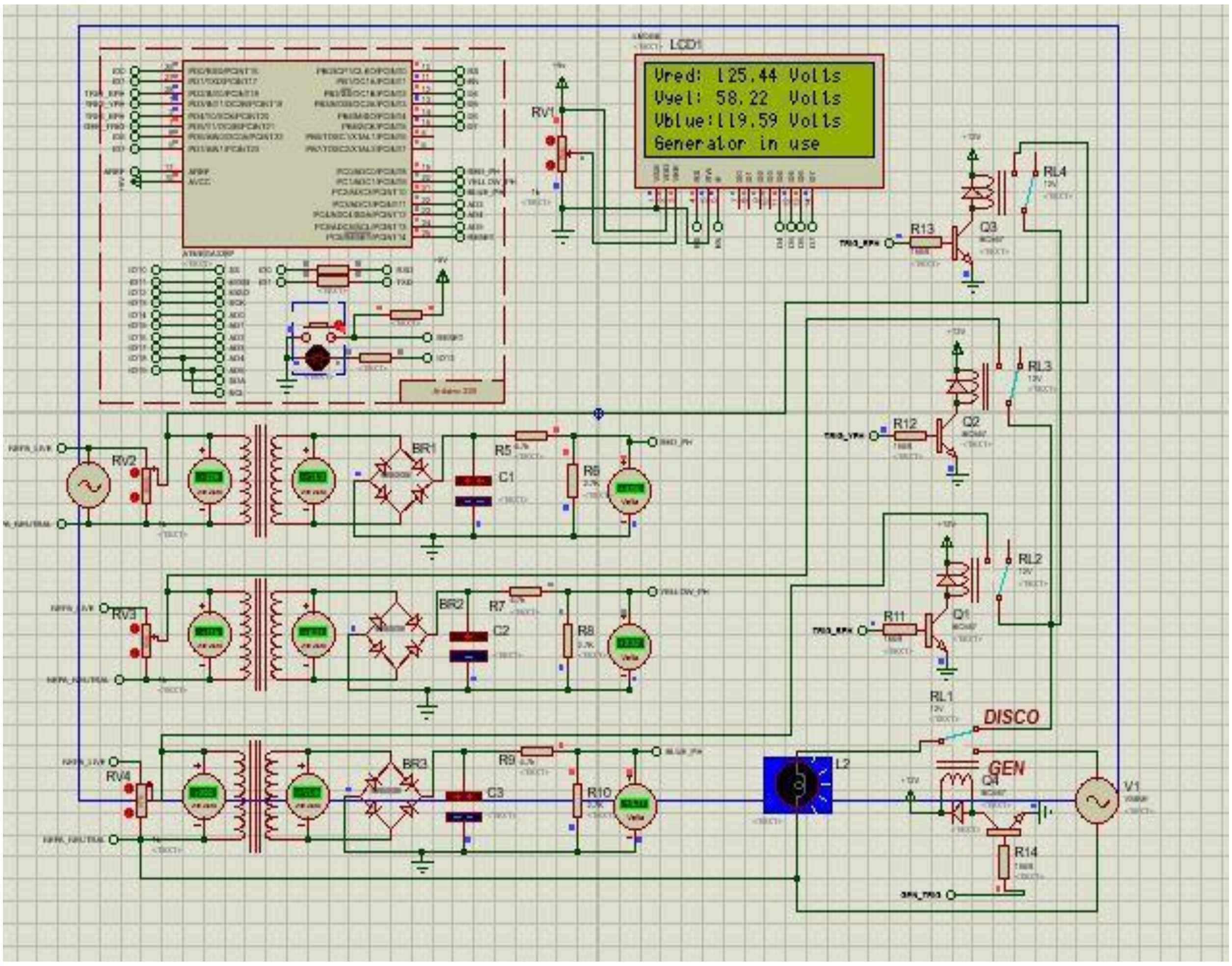


Figure 5. Circuit and Simulation of an Automatic Changeover switch with an inbuilt phase selector

5. CONSTRUCTION AND TESTING :

5.1 Construction:

Figures 4.3 and 4.4 represent the circuits on breadboard and printed circuit board (PCB) respectively. The circuit was first of all connected on a breadboard in order to achieve the designed analysis before it was transferred to the PCB. On the bread board, the power supply unit was first of all successfully connected before connecting other parts in stages to the output stage. The circuit components are logically arranged and soldered permanently to the board. Further test is carried out before encasement. Components soldered to the board include; Relays, ULN2003A, Arduino chip, Voltage regulator, etc.

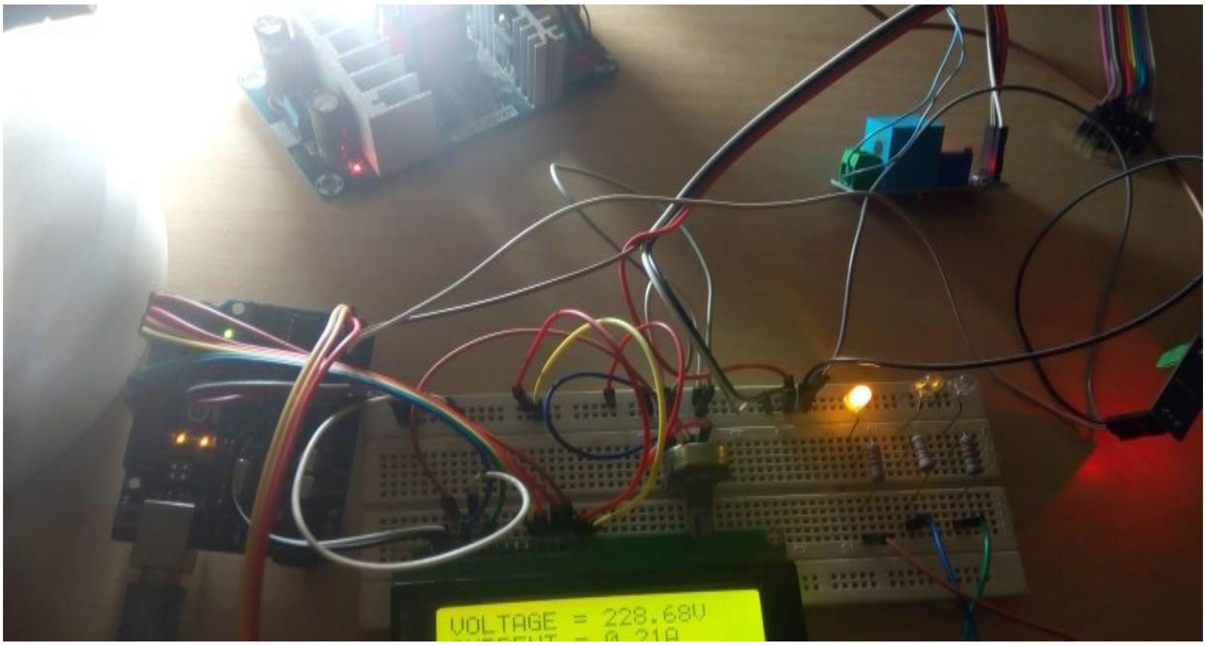


Figure 6: Circuit Connection on Breadboard.

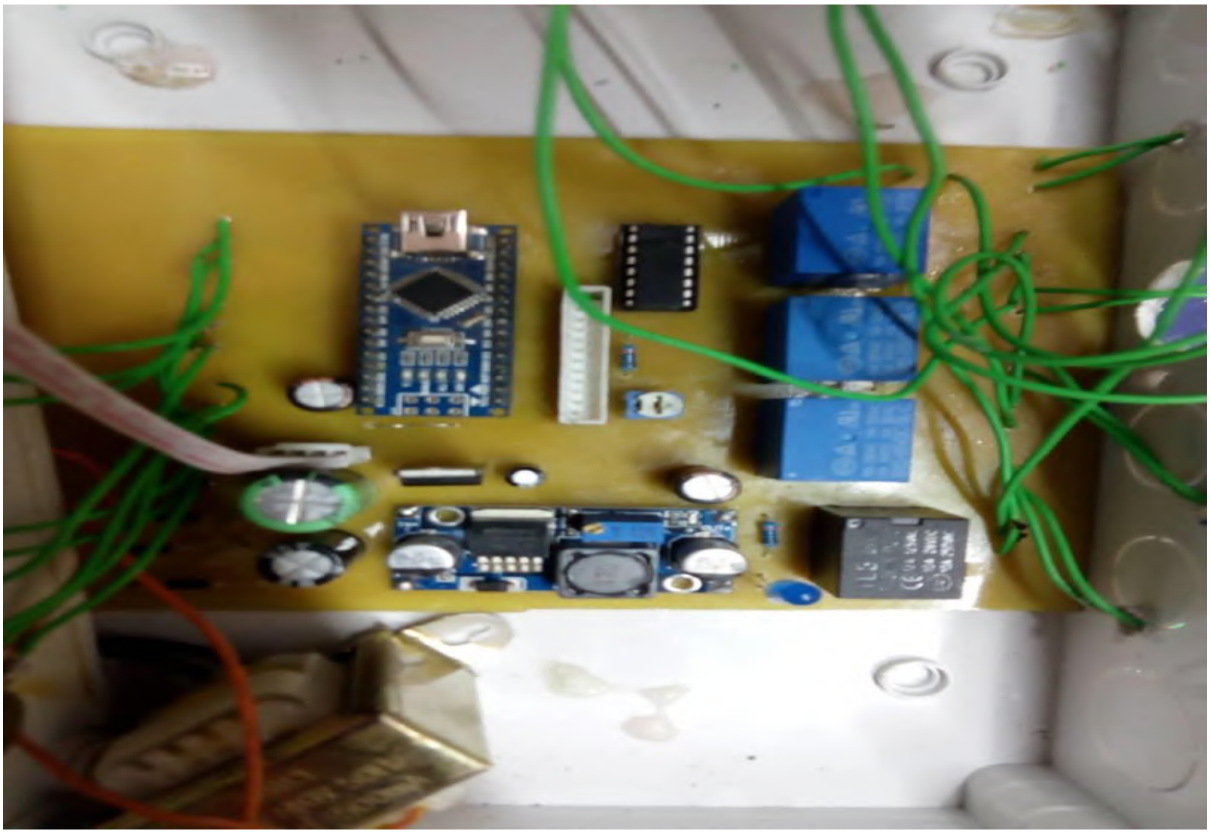


Figure 7. Construction on PCB.

5.2 Testing

The system was tested at every stage to ensure the stated objectives of the work were achieved. At the end of all the tests, the showed that the objectives of the paper such as healthy voltage selection, avoiding over and under voltages and switching to alternative source if the public supply phases are not healthy were accomplished.

6. RESULTS AND DISCUSSIONS ;

The results show that, at every voltage below or above the range of the reference voltage between 220 V to 240 V, the system will declare it unhealthy and the change-over switch unit switches from the public power supply to the generator, it also shows that, the system has the capacity to select healthy phase and stay on it pending when there is a disruption.

7. CONCLUSION ;

It is interesting to note here that the aim and objectives of this paper has been achieved. The designed system can smartly measure the voltage profiles of each phase and with that information decide which phase is healthier for use as source of supply. The system also has the ability to switch automatically to generator once the three phases are not reliable or available. Having concluded this work perfectly, it is recommended that, the change-over switch can also be build using contactors and the results of the working performance compared with this present work.

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