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Implementation of a 220v Ac Overload and High Voltage Monitor Alert System with Auto Shut Down

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ABSTRACT
The electricity supply in Nigeria is usually associated with voltage fluctuation that causes damage to connected loads. In this study, implementation of a 220V AC overload and high voltage monitor alert system with auto shutdown was carried out using an ATMega328p microcontroller. The circuit was simulated in Proteus Ver8.12 using Arduino software with C++ programing language. A prototype was constructed on a Vero board and tested for continuity and power ON. Performance analysis with 50 trials (25- high voltage, 25- overload) was used to calculate sensitivity and accuracy. Result shows good circuit continuity with no short circuits or bugs along the paths. Also, no component undergo heating in the circuit. Performance analysis test indicated sensitivity of 96% and 92% for high voltage and overload monitoring respectively. This implies that the device will correctly monitor 96% high voltage and 92% overloading conditions, but it will fail to monitor 4% high voltage and 8% overloading conditions. Accuracy of 94% implies that, the design conforms to the correct value specifications of the simulated circuit and that high voltage and overload monitoring using the constructed device can be compared to that of an ideal device and we are 94% sure. Even though the device shows more sensitivity to high voltage than it is to overloading, the sensitivity level is very good for a practical device, as such, it can be used for protection of our devices on the utility supply in homes and industries for smooth and steady electricity supply.

Keywords: *High voltage; overload; auto shutdown; 555 timer; Proteus; Arduino microcontroller*

1. INTRODUCTION

Electric power is essential to all areas of human life as both industrial and commercial processes are dependent on electric power supply. However, the generated electric power, irrespective of its capacity has very little value or importance if it cannot be effectively and efficiently distributed [1, 2]. If the voltage is too low, the amperage increases, which may result in the components melting down or causing the appliance to malfunction. If the voltage is too high, this will cause appliances to run 'too fast and too high' which will shorten their service life or can cause premature failure of electrical and electronic components (e.g. circuit boards) due to overheating which is cumulative and irreversible [3, 4]. According to UST Power [4] frequent episodes of mild overheating can also result in the same amount of component damage as a few episodes of severe overheating. Motors on the other hand, can often benefit from voltages that tend to be a little bit high. This is because as the voltage level goes up, the current is reduced and lower current usually equates to less heat generation within the motor windings, that is, reduced motor operating temperatures. Low voltage is a major cause of motor overheating and premature failure. A low voltage forces a motor to draw extra current to deliver the power expected of it thus overheating the motor windings. The rule of thumb for motors is “for every 10°C (50°F) a motor is operated above its rated temperature, motor life will be decreased by 50%” [4]. More than motors and circuit boards are at risk for damage when voltage levels are bad, but chronic problems with either is often an indication of a voltage problem [5].

Overload is when a transformer is subjected to voltages and/or currents that exceed its design specifications. According to Osaretinet *et al.* [5], during overloading conditions, excess heat will cause the insulation system to break down, resulting in decreased life expectancy of the transformer. Exceeding the rated load for the circuit wiring causes the circuit breaker to trip, shutting off the power to the entire circuit. If there were no breaker in the circuit, an overload would cause the circuit wiring to overheat, which could melt the wire insulation and lead to a fire. However, according to Lai & Martzloff [6], the recent progress in the availability of surge-protective devices, combined with increased awareness of the need to protect sensitive equipment against surge voltages, has prompted the application of a multistep cascade protection scheme. Hence the development of an overload and high voltage monitoring device will be of great importance to the society.

While the era of fluctuation and failure in supply of electricity is long forgotten in many industrialized nations of the world, many developing countries still suffer setbacks due to power fluctuations and power surge [7]. In the case of Nigeria, due to the absence of an automatic monitoring and control system on the distribution network, which is the major link between electricity utilities and the consumers of electricity, excessive current resulting from overloading occurs resulting in mal-operation and equipment damage. High voltage have also caused a lot of damages to various houses. In short, voltage fluctuation in the electrical supply has affected the stability of power supply. This has caused insulation damage to electrical appliances leading to short circuits, overheating and heavy damage to connected loads. In view of the above, the main objective of this study is to implement a 220V ac overloading and high voltage monitoring alert system with auto shutdown using a microcontroller ATMega328P. The device will be beneficial to both industrial and commercial users on the distribution network of the electric power supply. Since the power supply in Nigeria is unstable, the device will protect the equipment’s from damage due to excessive voltage, voltage surges, voltage sag, and overloading.

2. MATERIALS AND METHODS

2.1 Materials

The materials specification that were used for the design and implementation of the overload and high voltage monitor alert system with auto shut down includes Microcontroller ATMega328P, Vero board, Power switch, 28 pin IC socket, 50k Potentiometer, 5v Boozer, 5.1v Zener diode, 18v Voltage transformer, 240/12v Current transformer, 12v 10A Relay, LED, 7805 Regulator, C945 NPN Transistor, and assorted Resistors and Capacitors.

2.2 Methods

The methods involve for the implementation is in three parts including simulation, construction, and testing methods. The implementation was carried out according to the block diagram as shown in Figure 1.

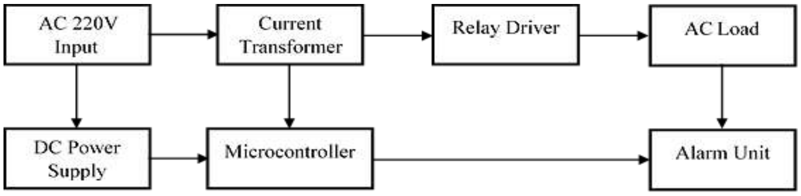


Figure 1. Block diagram of the system

2.2.1 Simulation Method

The system simulation was carried out in stages following the block diagram as shown in Figure 1. The circuit was simulated in Proteus Ver8.12 using Arduino software with C++ programing language. It is chosen because it made Microcontroller easy to debug, test and frees the programmer from the details of multi-byte math and paging and generally improves code readability [8]. The flowchart of the simulation is shown in Figure 2.

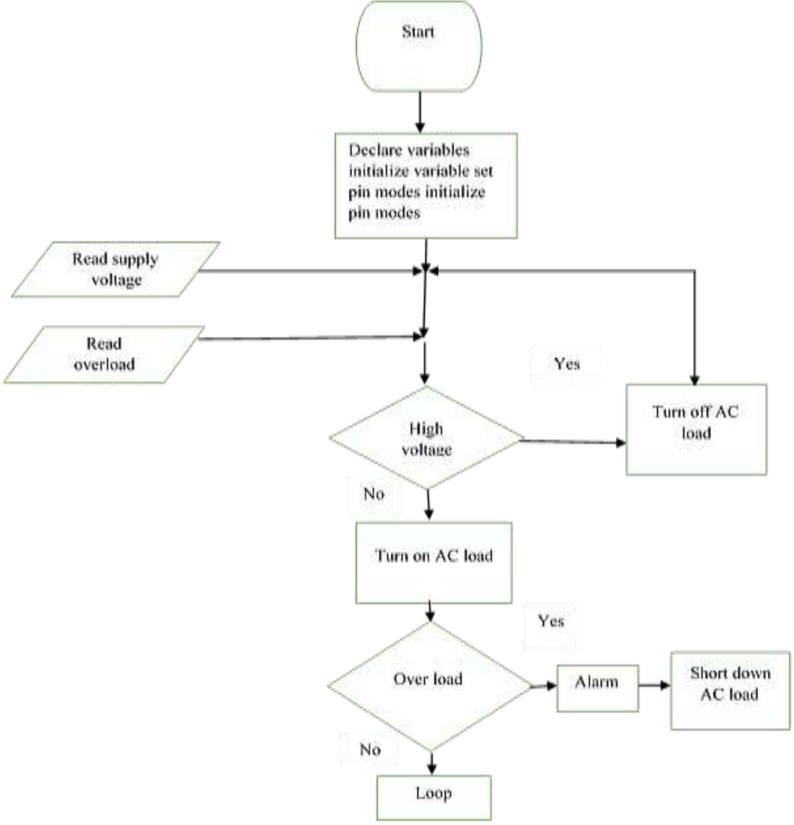


Figure 2. Flowchart of the system

2.2.2 Construction Method

The construction of the circuit was done in two parts which include component temporary assembly and placement on a Bread Board and then soldering of the components on a Vero Board on a permanent basis.

2.2.3 Testing Method

The various tests conducted on the constructed device to ensure proper functioning includes sensitivity and accuracy tests.

Sensitivity Test: This test helps to determine how sensitive pin 17, 18, 19 in ATMega328 detects overload and high voltage within it range, and how pin 13 gives alert in a notification of high voltage then automatically shut the entire system down to protect the device. The sensitivity of the device was calculated as follows:

$$Se = \frac{N_R}{N_R + N_U} x\, 100 \qquad (1)$$

Accuracy Test: This test determines how accurate the system can monitor overload and high voltage and eventually auto shut down the system. The accuracy of the device was calculated as follows:

$$Acc = \frac{N_R + D_{NC}}{N_R + N_W + D_{NC}} x\, 100 \qquad (2)$$

Where;

N_T = Number of trials
N_R = Number of times the system responded
N_W = Number of wrong output
N_U = Number of undetected fault in the component
D_{NC} = Number of detected faulty component used

3. Results

3.1 Simulation Results

This circuit also produces sound when main power resumes. The simulated general circuit for the 220V AC high voltage and overload monitor with alert system and auto shot down is shown in Figure 3.

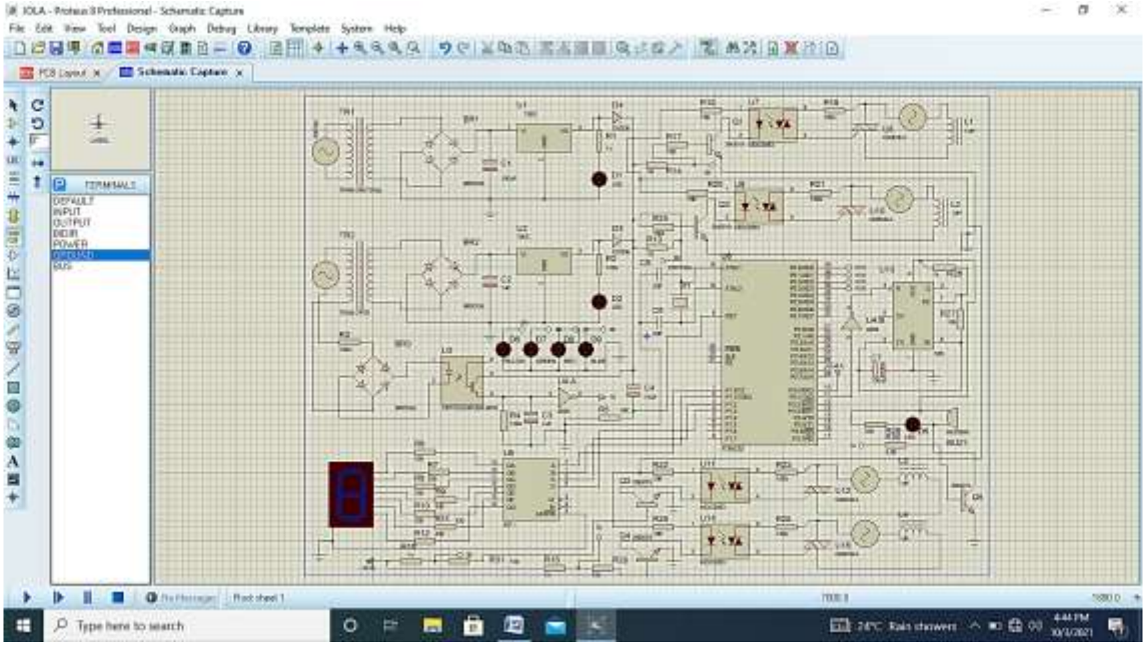


Figure 3. Simulated general circuit diagram at ideal state

From figure 3, when supply voltage is high, the DC voltage at the cathode of Zener diode D4 becomes greater than 5.6V. As a result, transistor Q1 is in ON and transistor Q2 gets switched off. Hence the relay RL1 de-energizes and load would be in OFF condition. Under low supply voltage condition, transistor Q1 switches to ON condition and as a result transistor Q2 switches OFF, making the load OFF. When normal AC supply voltage is applied, the DC voltage at the cathode of Zener diode D4 is less than 5.6V, now transistor Q1 is in OFF condition. As a result, transistor Q2 is in ON condition, hence load switches to ON by indicating the green LED. Table 1 shows AC supply voltage indicating the ON and OFF states.

Table 1: AC supply voltage indicating ON and OFF

Supply Voltage	**Q1 State**	**Q2 State**	**Relay**	**Load**
High	ON	OFF	De-energizes	OFF
Low	ON	OFF	De-energizes	OFF
Normal	OFF	ON	Energizes	ON
Resume	ON	OFF	De-energizes	OFF

However, when supply is resumed after a break, the software timer IC goes low and triggers. The output of software timer IC makes sound to operate through the transistor Q3, at the same time, transistor Q1 switches to ON condition as the output software timer is connected to the base of Q1 and results to transistor Q2 OFF. Thus the relay switches OFF the load. In this circuit, the software timer is configured to operate in Mono-stable mode. Pin4 and pin8 are shorted to avoid sudden resets. The pulse width of the softer timer output signal is about 10 seconds. This output signal drives the speaker. The speaker gives a melodious sound when power is resumed because of the UM66 IC. The volume of the speaker can be controlled by using POT RV3. The green LED indicates normal AC supply voltage. Red LED is used for power indication.

Here Zener diode D4 along with transistor Q1 is used for comparing the input voltage. Transistor Q2 switches the load based on the output of transistor Q1. Diodes D1 and D2 are used for rectification purpose. Capacitor C1 filters the input AC ripples. The results for the simulation representing high voltage, low voltage and overload conditions are presented in Figures 4 to 8.

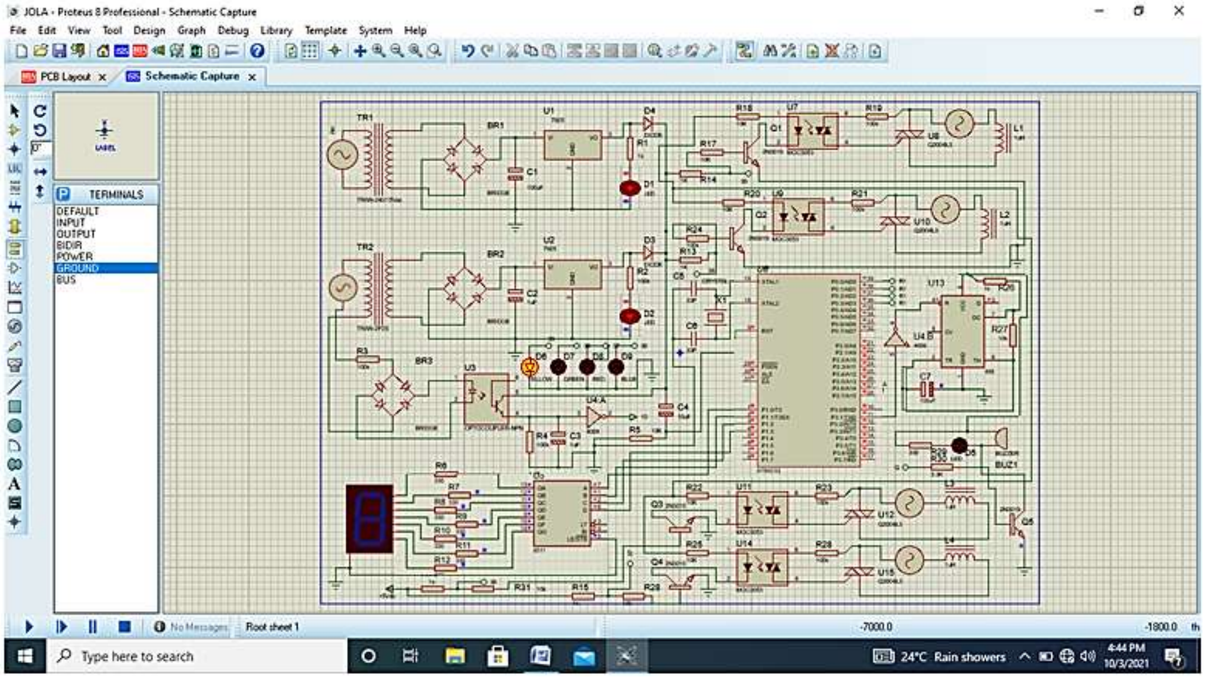


Figure 4. Simulation result indicating low voltage status

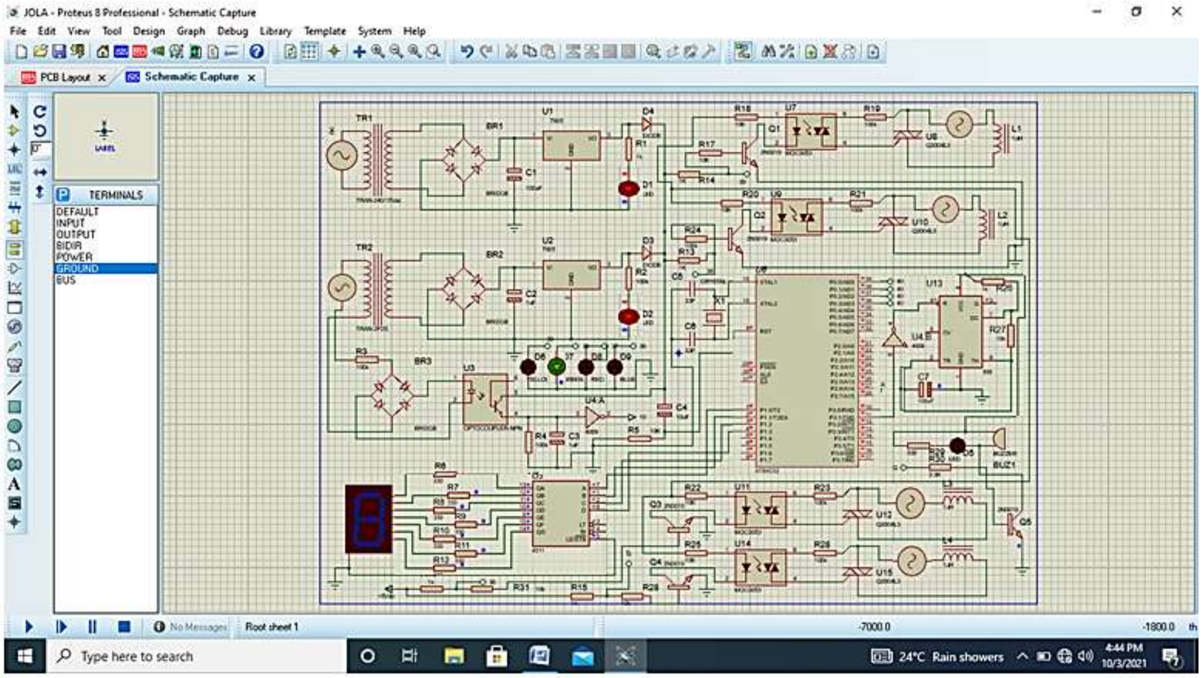


Figure 5. Simulation result indicating Normal Status

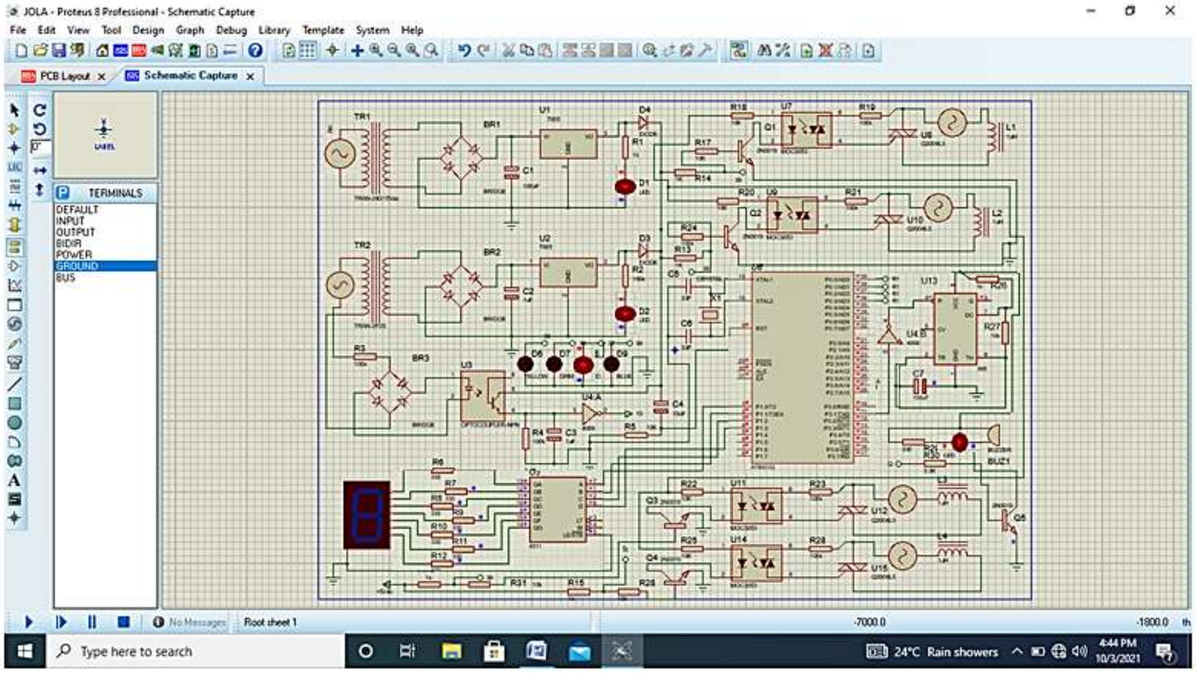


Figure 6. Simulation result indicating High Voltage Status

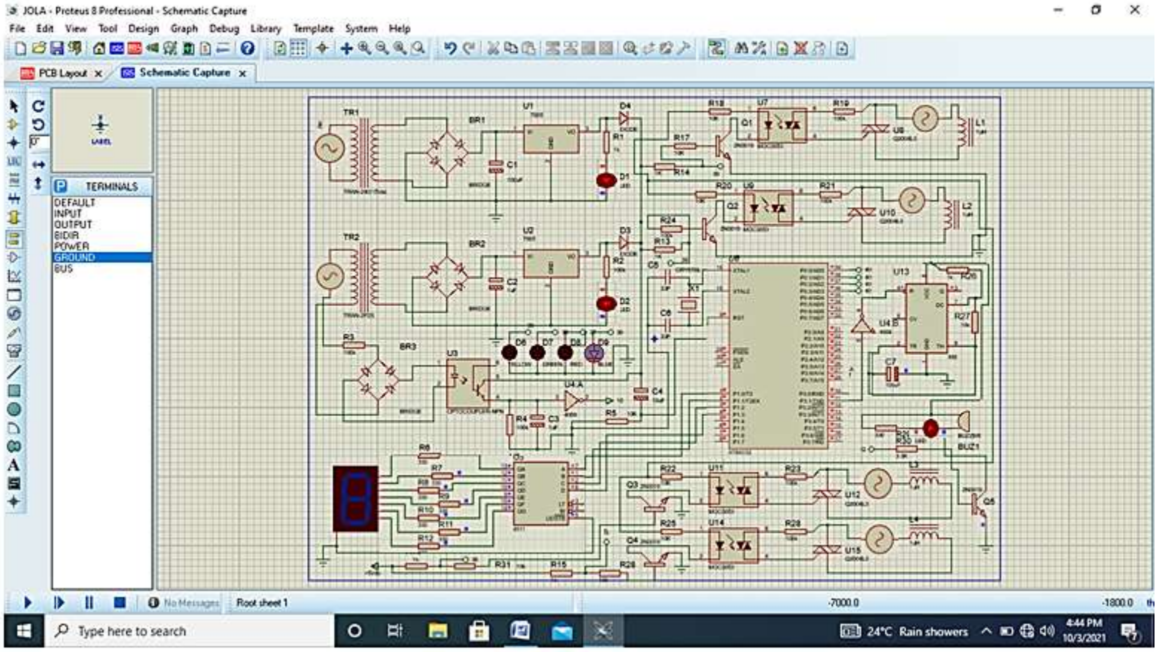


Figure 7. Simulation result indicating Overload at Initial Status

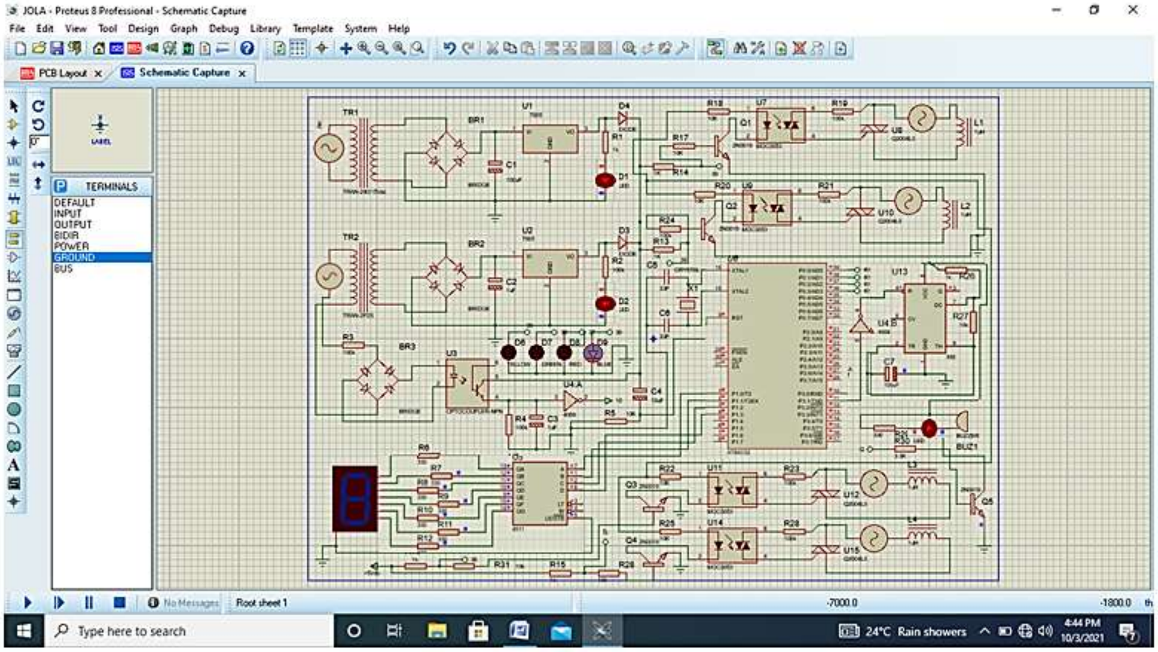
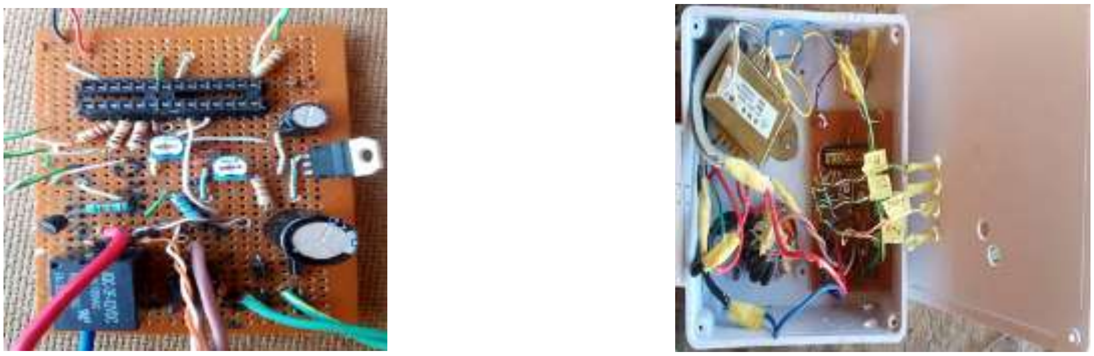


Figure 8. Simulation result indicating Overload Final Status

Figure 4 presents the system powered while initializing indicating low voltage, the power supply LEDs glows, while no other activity as the supply gives no output and the Yellow LED glows, also alarm remains “OFF”. Figure 5 presents the Normal status as the power supply unit LEDs glows, the system gives an output and Green LED glows from the status while alarm LED remains “OFF”. Figure 6 presents the High Voltage status as power supply LEDs glows, system gives NO output, alarm and its LED “ON” while Red LED status “ON”. Figure 7 presents the Overload at initial stage as the power supply unit LEDs glows, system gives output at that moment, alarm and its LED “ON” while Blue LED status “ON” Whereas, Figure 8 presents the Overload after 60secs as power supply unit LEDS glows, automatically output “OFF”, alarm and its LED “ON” with Blue LED status “ON”.

3.2 Circuit Construction

The circuit construction was carried out according to the block diagram in Figure 1 and according to the simulation specifications. It was first carried out on a Bread board and then transferred to a Vero board for permanent soldering. The design layout ensured portability and the component assembly was followed by a continuity test to ensure proper functionality. Too much lead was avoided on the Vero board to avoid short circuit. The constructed device on Vero board and when place in the casing is shown in Figures 9.



a) Top view of component on Vero board b) Constructed circuit inside plastic casing

Figure 9. Constructed device

3.3 Casing and Packaging

A casing measuring 20cm x 20cm x 5cm was finally provided to the system for mechanical protection. The Orthographic projection has shown its three views (Front, Side and Top). It is provided with 4nos. of 0.25cm diameter hole within 0.5cm diameter groove at the edges of its top side for screw lock, 2nos. of 3cm diameter hole spaced by 1cm for the High Voltage set and Overload set and 2nos. of 1cm diameter hole spaced apart 0.5cm for status indicator LEDs (Yellow for Low voltage, Green for Normal supply, Red for High voltage and Blue for Overload). In the front there are 5nos. of 2cm diameter 1no. for input and 4nos. within 8cm x 3cm x 2cm attachment for outputs. Meanwhile, provision of 0.5cm diameter holes has been made for the system ventilation. The isometric diagram of the constructed casing is shown in Figure 10, while the complete packaged device in the casing is shown in Figure 11.

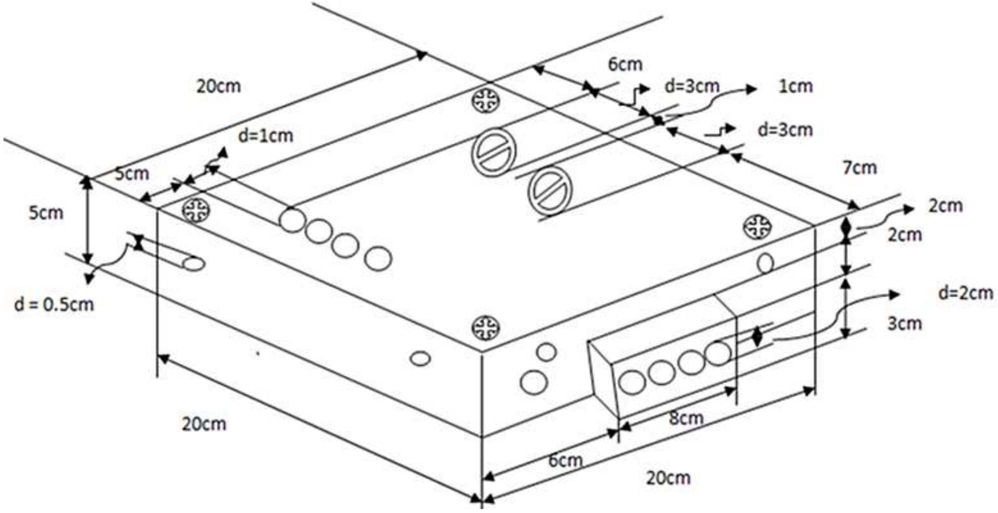


Figure 10. Orthographic projection of the constructed casing

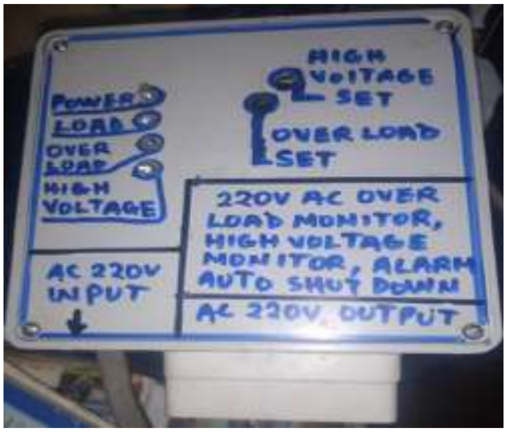


Figure 11. Packaged device in a casing

3.4 Output Test and Analysis

Performance evaluation was carried out with 50 trials (i.e. 25 trials for high voltage monitoring and 25 trials for overload monitoring). The number of times the system responded to high voltage and overloading (N_R), number of times the system gave wrong result of high voltage and overloading (N_W), number of times the system undetected high voltage and overloading (N_U), and number of times the system correctly detected no high voltage and overloading were recorded. The result of the output test is presented in Table 2. From Table 2, the sensitivity and accuracy of the device were calculated using equations 1 and 2.

Table 2: Result of output test

Monitoring Type	**N_T**	**N_R**	**N_W**	**N_U**	**D_{NC}**
High Voltage Monitor	25	23	2	0	0
Overload Monitor	25	0	0	1	24
Total	50	23	2	1	24

Sensitivity Test: The sensitivity to high voltage was calculated from using equation 1 as follows:

$$Se = \frac{24}{24+1}\ x\ 100\% = 96.0\%$$

While sensitivity to overload was also calculated using the same equation 1 as follows:

$$Se = \frac{23}{23+2}\ x\ 100\% = 92.0\%$$

Even though the sensitivity to high voltage was higher than that of overloading, the values obtained were all very good, indicating that the system is highly sensitive to both high voltage and overloading.

Accuracy Test: The accuracy of the device was calculated using equation 2 as follows:

$$ACC = \frac{23+24}{24+1+23+2}\ x\ 100\% = 94.0\%$$

This result indicates a good accuracy level. However, the evaluated parameters represents the device performance based on available test results which is quite reasonable. It shows the effectiveness of the algorithm used and the programming accuracy.

4. Discussion

Figure 3 to 8 represents the simulation result of the implementation of a 220Vac overload and high voltage monitor alert system with auto shut down. According to the result shown in Figure 4 to 8, there was an appreciable respond of the simulated design. On powering the device, it was observed that the reaction of the device from overload to alarm system and shorting down automatically were sensitive and the functionality shows good accuracy. This is in line with the work of Keppens *et al.* [9] who worked on ESD protection solution for high voltage technology, but not in line with the work of Smedes and Guitard [10] worked on harmful voltage overshoots due to turn-on behaviour of ESD protections during fast transients. The result of the simulation obtained from the system clearly shows that the system is quite efficient, therefore is in line with the study of Adabara [11] who used microcontroller and Proteus (8) in designing and implementing an automatic high performance voltage stabilizer. But not in line with the study of Delmas *et al.* [12] because difference TLP was used for high voltage ESD protection base on bipolar transistor on smart power technology.

For the performance analysis on the device, Findings from this study has revealed that the sensitivity is 96% and 92% for high voltage and overload monitoring respectively. This implies that the device will correctly monitor 96% of high voltage conditions but it will fail to monitor 4% of it, while for overloading conditions, it will monitor up to 92% of overloading situations and fail to monitor 8% of such condition. Showing that the device is more sensitive to high voltage than it is to overloading even though the sensitivity levels are both very good and okay for a practical device.

Findings has also revealed that the accuracy of the device is about 94% which implies that the design conforms to the correct value specifications of the simulated circuit and that high voltage and overload monitoring using the constructed device can be achieved very closely to that of an ideal monitoring device and we are 94% sure. However, of all the previous work reviewed in this study, none of the similar works were able to calculate sensitivity and accuracy of their device such as Keppens *et al.* [9], Smedes and Guitard [10], Adabara [11], and Delmas *et al.* [12]. This reveals the additional contribution of this work to the literature.

5. Conclusion

The 220V AC overload and high voltage monitor alert system with auto shut down has been implemented. The prototype of the design worked satisfactorily when tested with low voltage, high voltage and overloading. The prototype is very sensitive, accurate and reliable based on the outcome of the output test. It is very easy to install and relatively cheap. The application of auto shutdown with alert system is of significant important in the protection of electrical appliances in our homes and industries on the electrical distribution network against power fluctuations, power surges, Undervoltage, Overvoltage, and Overloading conditions.

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