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Design Of A Distribution Station Monitoring System Using Nigeria Secondary Distribution Substation As A Case Study

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Abstract: **This paper is aimed at designing a microcontroller based distribution substation monitoring system that monitors the voltages, current, oil temperature and the moisture content of the silical gel. The generation and the transmission sections are properly monitored by the utility companies involved in its operations. The distribution, seems not to be given the same level of monitoring as the other two sections. Most of the times, when their is a fault in a distribution substation, it always take some time before the utility will be able to restore the supply majorly due to poor monitoring to easily detect the cause of the fault. The design is to cordinate the sensing and tripping of the transformer based on the defiation of the parameters from referenced value set in the programm that controls the operation of the microcontroller. The sensing elements measures the transformer parameters and feeds the information into the ADC port of the microcontroller and a GSM module interfaced with the microcontroller sends the transformer's voltage, current,temperature and the moisture content of the silical gel to the utility station via SMS messages for quick response.**

Keywords: **GSM Module, AVR Microcontroller, Distribution Transformer.**

I. INTRODUCTION

The power system is divided into three main sections; the Generation, Transmission and Distribution. The first two deal with high voltage as it handle bulk power. The generation is where power is being generated at a voltage of 11 kV or 16 kV as in Nigeria case. This voltage is fed into a step up transformer to increase the voltage level for transmission.The main process of a transmission system is to transfer electric power from electric generators to customer area, whereas a distribution system provides an ultimate link between high voltage transmission systems and consumer services. In other words, the power is distributed to different customers from the distribution system through feeders, distributors and service mains [1]. The distribution, which is the third part of the system seems not to be given the same level of monitoring as the other two sections. Most of the times, when their is a fault in a distribution substation, it always take some time before the utility will be able to restore the supply majorly due to poor monitoring to easily detect the cause of the fault and to bring out the quickest solution to the problem. Outage of supply to consumers always directly or indirectly have impact on the economy of the consumers and at the end on the economy of the country [2]. With this situation, this work critically look at the variation in the parameters of the distribution substaion and put some mechanisms in place to check any deviation from the normal operating condition of the substation.

For high reliability, the substation transformer must be kept in a good state for as long as possible. However, the life span is reduced if they are subjected to overloading, resulting in unexpected failures and loss of supply to a large number of consumers thus affecting system reliability. Overloading and ineffective cooling of transformers are the major causes of failure in distribution transformers.

Moreover with the increasing population and their unavoidable need for electric power leads to an increase in demand of electrical power. With this increase in the demand for power, the system may become overloaded which can affect the transformer efficiency and consequently leads to breakdown. The reliability of a substation transformer can be improved by implementing a real-time monitoring system to detect all operating parameters, and send to the monitoring station in time to examine the state of the transformer. This action reduces the down time of such transformer.

During strange events for some reasons the transformer is burned out due to the over load and short circuit in their winding. Also the oil temperature is increased due to the increase in the level of current flowing through their internal windings. This results in an unexpected raise in voltage, current or temperature in the distribution transformer [3]. Therefore, we are proposing the automatic monitoring of the distribution transformer. Hence, the work is to design a microcontroller based monitoring system for a substation transformer. The system provides both monitoring and protection capabilities. The sensing elements measures the transformer parameters and feeds the information into the ADC port of the microcontroller and a GSM module interfaced with the microcontroller sends the transformer's voltage, current and temperature to the utility station via SMS messages for quick response. Although, the secondary distribution substation in Nigeria is 11/0.415kV, the design is using a prototype to investigate the monitoring of the substation and the component should be properly sized for implementation.

Various works has been carried out on microcontroller based monitoring system for a transformer. Some of these researches which have been carried out, their setbacks, ambiguities and advantages are discussed in subsequent paragraphs.

Reference [4] desgned and implemented a transientmeter. This is a monitoring system for the detection, classification and measurement of disturbances on electrical power systems. CORBA architecture was utilized as communication interface by the Transientmeter, wavelet-based techniques for automatic signal classification and characterization, and a smart trigger circuit for the detection of disturbances. A measurement algorithm, developed by using the wavelet transform and wavelet networks, had been adopted for the automatic classification and measurement of disturbances.

A design which consists of two units, one in the substation unit, called as transmitter unit, and another in the Main station called the controlling and receiver unit was developed [5]. The transmitter in the substation is where the power is monitored continuously by the microcontroller. In this work, ZIGBEE method was used for communicating between the substation and the utility office.A ZIGBEE is used for transmitting the signals that are obtained. The controlling unit in the main station receives the transmitted signals by means of ZIGBEE receiver and displays in LCD and LED and reacts in accordance to the received signal.

A mobile embedded system was used to monitor and record key parameters of a distribution transformer [6]. If any abnormality or an emergency situation occurs the system sends SMS (short message service) messages to the mobile phones containing information about the abnormality according to some predefined instructions programmed in the microcontroller. This mobile system will help the transformers to operate smoothly and identify problems before any catastrophic failure.

II. DESIGN PROCEDURE

A variable AC source which varies between 0-240VAC was connected to a load. The load current was monitored by connecting a current transformer in series between the load and the variable AC source, while the voltage was monitored by connecting a potential transformer (230V/12VAC) across the variable AC source. The output of the potential transformer was rectified to a pure 5VDC and then fed into the ADC pin of the microcontroller. A temperature sensor, LM35, was used to measure the temperature of the oil. The output pin of the sensor was connected to an ADC pin of the microcontroller. Whenever the input voltage is varied the microcontroller displays the value of the voltage, current, temperature and humidity on the liquid crystal display (LCD).

A. Flow chart of the system:

The flow chart describing the code used in the microcontroller is shown in figure 1

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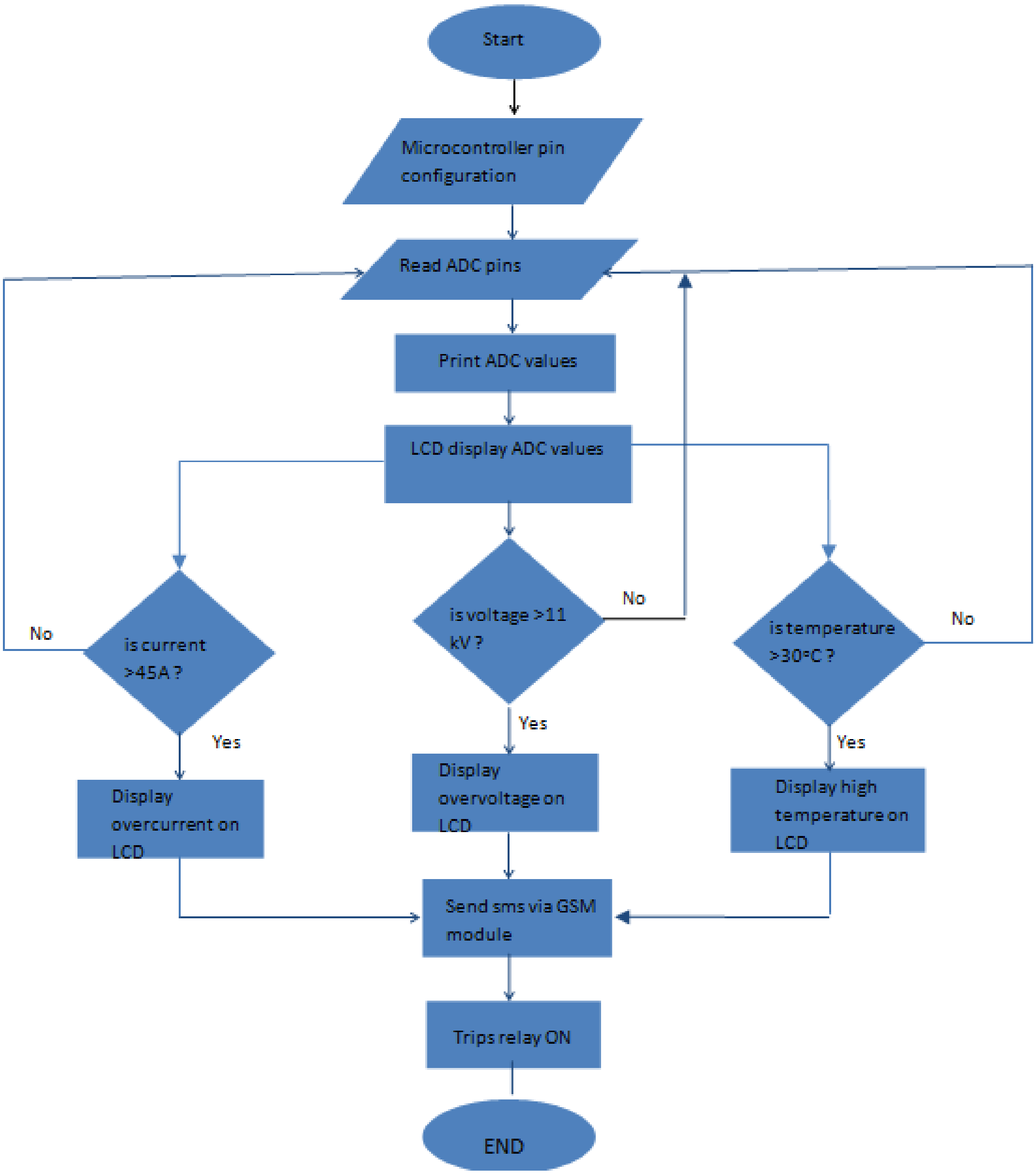

Fig. 1: Flow chart for Coding the Microcontroller

B. Power Supply:

The power supply circuit is the circuit which provides the desired dc voltage of 5V to run the circuits. The voltage obtained from the main line is 220V AC but the other components require 5V DC. Hence a step-down transformer (220V/12V) is used to get 12V AC which is later converted to 12V DC using a bridge rectifier circuit which is basically four diodes where two are connected in reversed and the other two are in forward biased. The output of rectifier still contains some ripples. To remove the ripples and obtain smoothed DC power, a filter circuit is use. Here a capacitor is used. The 12V DC is rated down to 5V using a positive voltage regulator chip (7805), therefore, a fixed DC voltage of 5V is obtained.

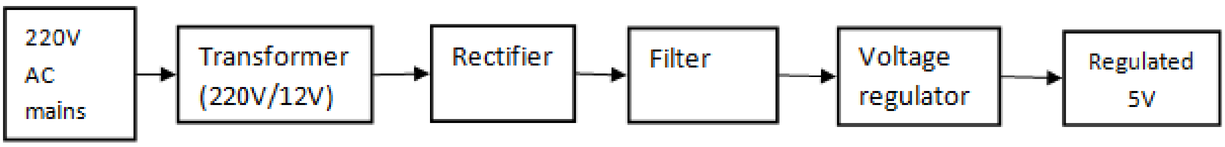

Fig. 2: Power Supply Circuit Design

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Figure three shows the block diagram of the substation monitoring device.

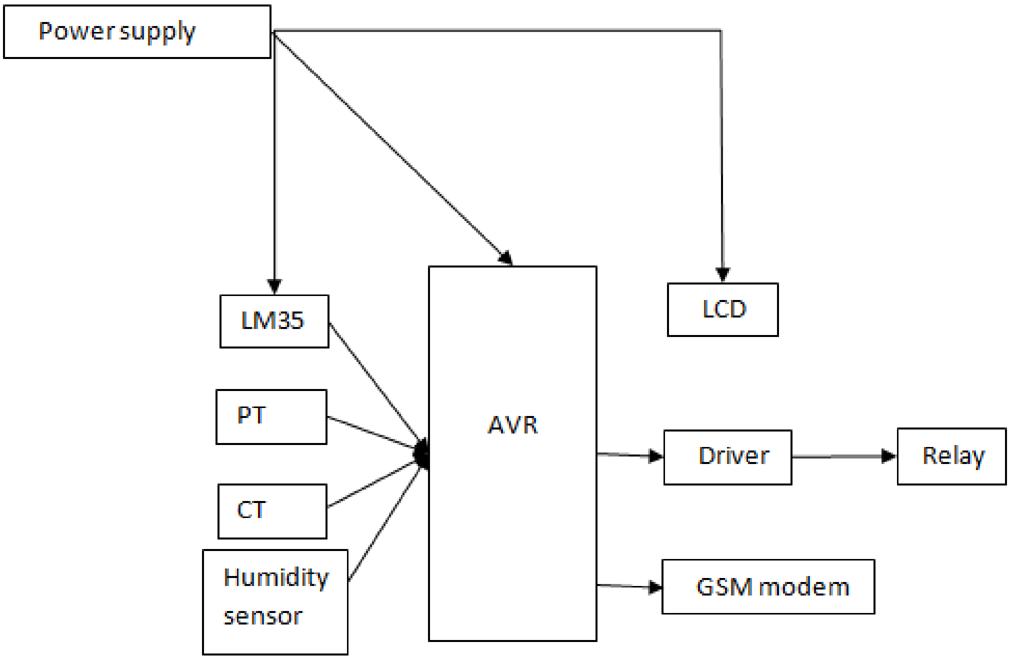

Fig. 3: Block Diagram of the Substation Monitoring Circuit.

C. AVR Microcontroller:

The microcontroller is the heart of the system. It monitors the transformer parameters, displays the values on the LCD, and sends the data to the monitoring station and triggering the relay when there is any fault.

There are number of popular families of microcontrollers which are used in different applications as per their capability and feasibility to perform various task, mostly used of these are 8051, AVR and PIC microcontrollers. For this project, AVR microcontroller will be used. The microcontroller transmits and receives 8-bit data. The input and output registers available are also of 8-bits. An Atmega16 microcontroller is used, consists of a 40-pin IC and it belong to ATmega AVR category of AVR family.

D. LCD (Liquid Crystal Display):

The LCD is use to display the measured values obtained from the sensors. The LCD used is 16x2. LCD (Liquid Crystal Display); which means 16 characters per line by 2 lines. The microcontroller receives data and communicates directly with the LCD. Here 8-bit mode of LCD is used, using 8-bit data bus (DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7.). And also three control lines; EN, RS, and RW. Three additional pins for supply VSS (ground), VDD (+5V power supply), and VEE (to adjust contrast).

Fig. 4: Photo view of the LCD display unit

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E. Potential Transformer (PT):

The Step down transformer is of rating 220/12V. The output of the potential transformer is fed into the bridge rectifier for rectification purpose and the rectified output from the bridge rectifier is again fed into the filter circuit in order to remove any ripples. The DC voltage is stabilized using Zener diode before it is fed into the AVR Microcontroller. Now the stabilized DC Voltage is fed to theADC pin of the AVR microcontroller.

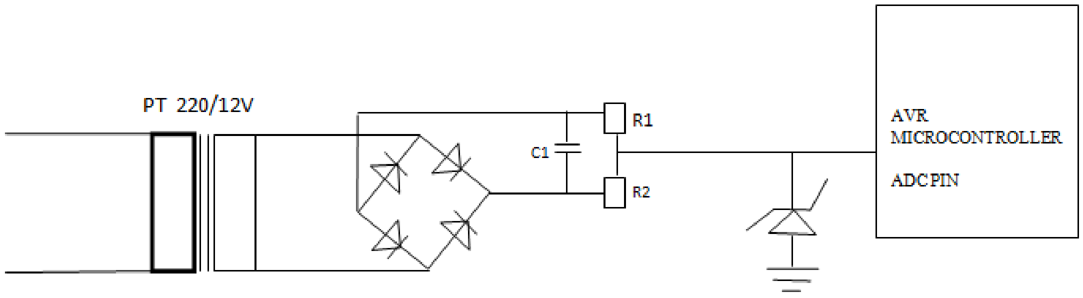

Figure 5: Interfacing the Potential Transformer with the Microcontroller.

The transformer used is a step down transformer. It has a secondary voltage of 12VAC.

$$V_{DC} = V_{AC} \times (2)^{1/2} - (2\times0.7)$$

$$V_{DC} = 12 \times (2)^{1/2} - (2\times0.7) = 15.57V$$

V_{AC} is the RMS value of the transformer and 0.7V is the voltage drop across the rectifier. There are two diodes conducting each half cycle, so therefore voltage drop per cycle is 1.4V.

The microcontroller has a Ref voltage of 5V. Let's divide the Ref voltage by two to increase the safety factor for the microcontroller.

ARef voltage = 5/2 = 2.5V

The voltage divider circuit is use to scale than the voltage to obtain 2.5V across R2. A zener diode permits the flow of current in one direction but in reverse direction if the voltage is greater than the zener breakdown voltage.

Let R1 = 50KΩ, R2 = 10KΩ

Voltage drop across R2 = 15.57 × (10 / (10 + 50)) = 2.6V

2.6V is the maximum voltage that will enter into the microcontroller.

F. Current Transformer (CT):

Current transformer will be used to sense the current. The Current transformer is interfaced with the AVR microcontroller with the same procedure that will be used in interfacing the potential transformer with the AVR Microcontroller except that in Current transformer a resistance (R_3) is connected in parallel in order to convert the current to voltage because the microcontroller accepts only voltage as its input.

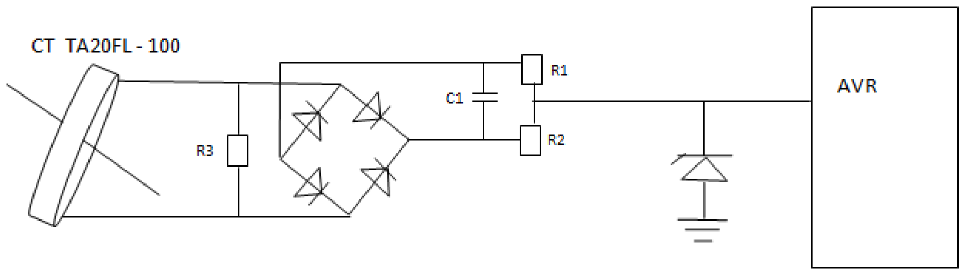

Fig. 6: Interfacing the Current Transformer with Microcontroller.

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Current transformer TA20FL-100 was used. Input current is 20A, output current is 20mA. Therefore, the current ratio is given as 20A/20mA = 1000

Primary peak-current = 20A × 1.414 = 28.28A

Secondary peak-current = primary pea-current / no. of turns

= 28.28/1000 = 0.02828A

To maximise resolution, the voltage across the secondary winding should be half the microcontroller REF voltage. Ref voltage = 5V

$V_S = (5/2) = 2.5V$

Therefore,

R3 = 2.5/0.02828 = 88.4Ω

100Ω is connected across the secondary terminal of the current transformer since 88.4Ω is not readily available.

G. Temperature Sensor LM35:

The temperature sensor (LM35) was to sense the temperature change in the insulating oil. It is calibrated directly in degree Celsius 0.5^0C accuracy. It is rated for full-55^0 to $+150^0$C range.

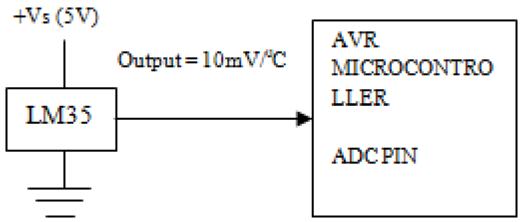

Fig. 7: Interfacing LM35 with the Microcontroller.

H. Relay:

The relay is use to isolate the transformer if there is any abnormality in the transformer.

For this work, Darlington transistor driver IC (ULN2803) was connected between the microcontroller and the relay for amplification purposes. The microcontroller cannot supply a sufficient amount of current needed to energize the relay. The relay needs around 12mA to be energized while the microcontroller can only provide a between 1 and 2mA.

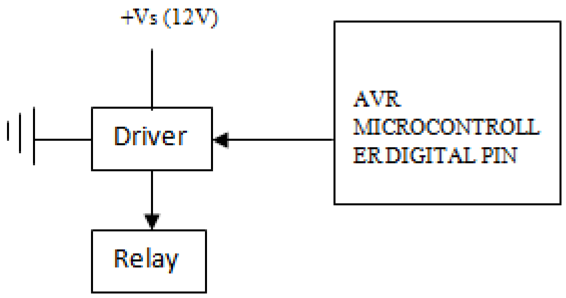

Figure 8: Interfacing the Relay with the Microcontroller.

I. GSM Module:

A GSM module is a wireless modem that works with a GSM wireless network. The wireless modem sends and receives data through waves Like a GSM mobile phone. The GSM also requires a SIM card from a wireless carrier to operate. AT commands are the instructions used for controlling the module.

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The GSM module is connected to the microcontroller by connecting Txd and Rxd pins to the modem's Rxd and Txd pins respectively. And the third pin of modem is grounded. And the third pin of modem is grounded. The circuit diagram for the design is as given in figure eight.

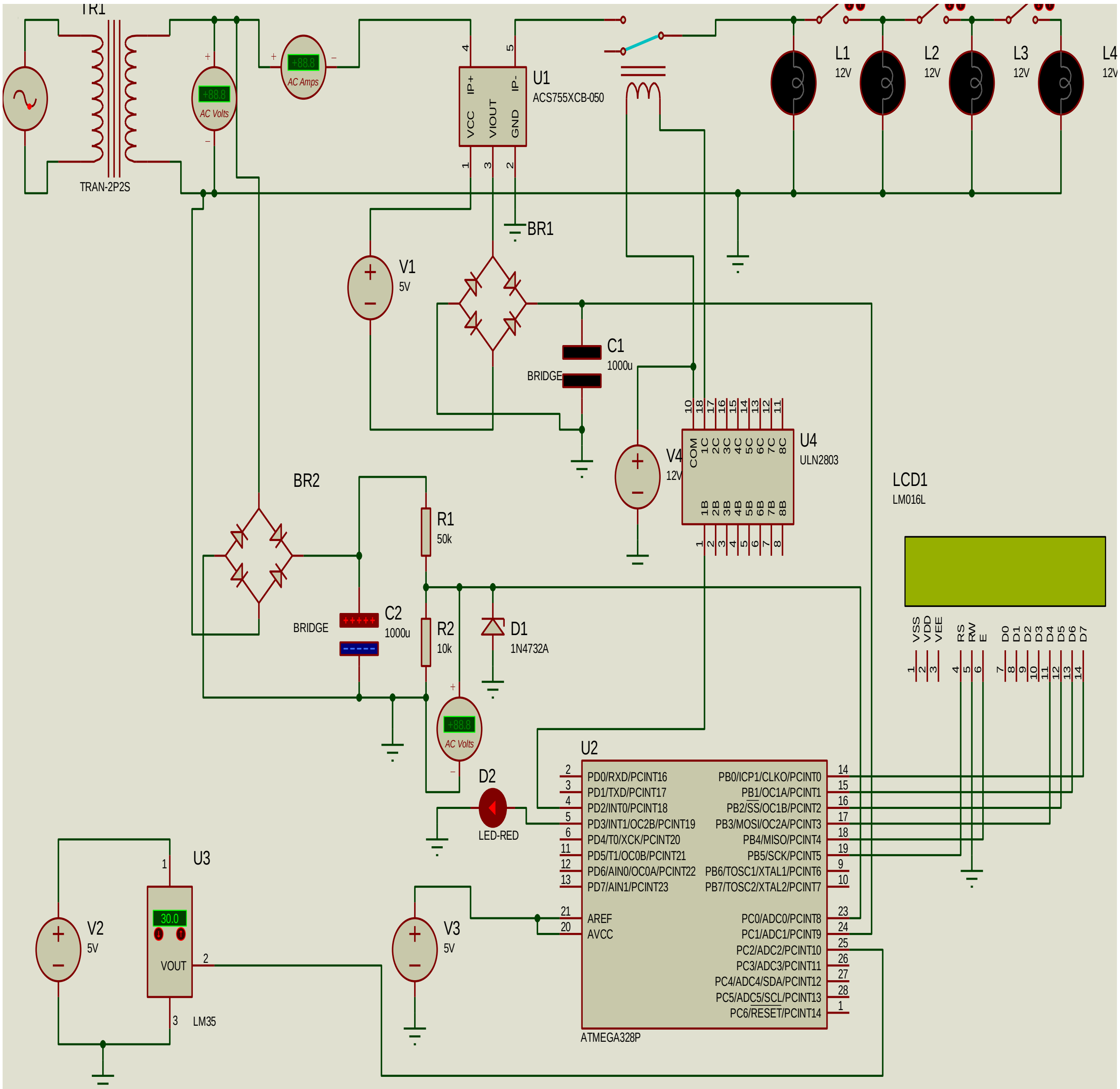

Fig. 9: Circuit Diagram

III. RESULT

As the AC source is varied, the microcontroller detects the change in voltage and sends a signal to trip the relay in order to isolate the transformer from the load if the voltage exceeds the reference voltage. A variable resistor is connected in parallel to the load. As the variable resistor is increased or decreased, the current also increases or decreases. If the load current exceeds the rated output current of the transformer, the microcontroller sends a signal to the relay to isolate the transformer. Similarly, the microcontroller does the same when the temperature of the insulating oil rises above the rating of the transformer. For the moisture content of the silica gel, the GSM modem sends SMS to the monitoring station to inform that the silica gel is saturated. The following results were obtained.

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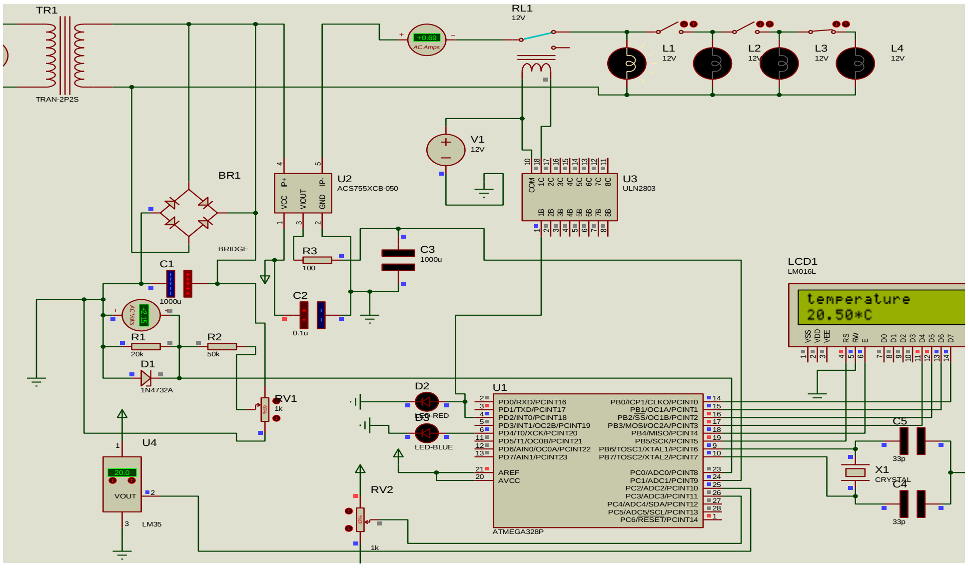

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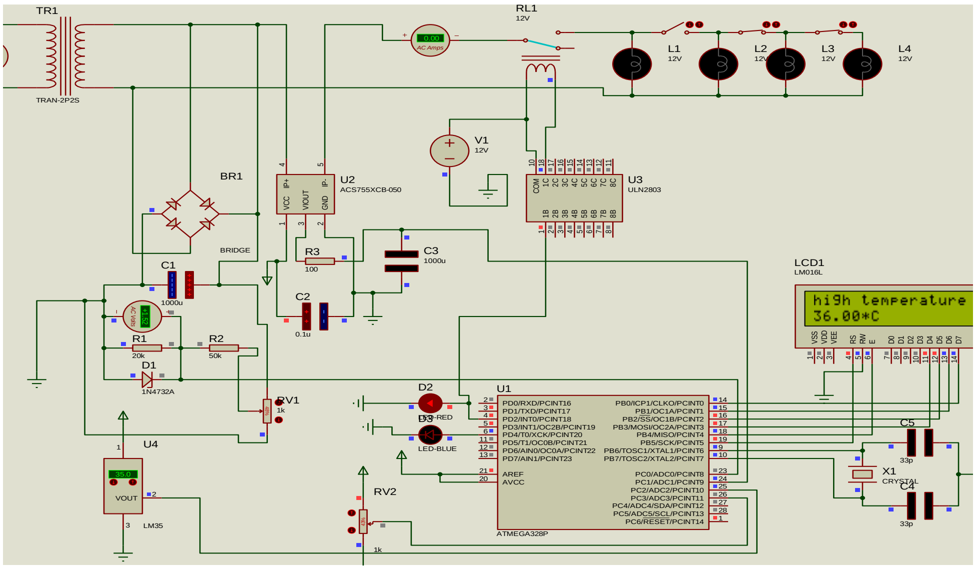

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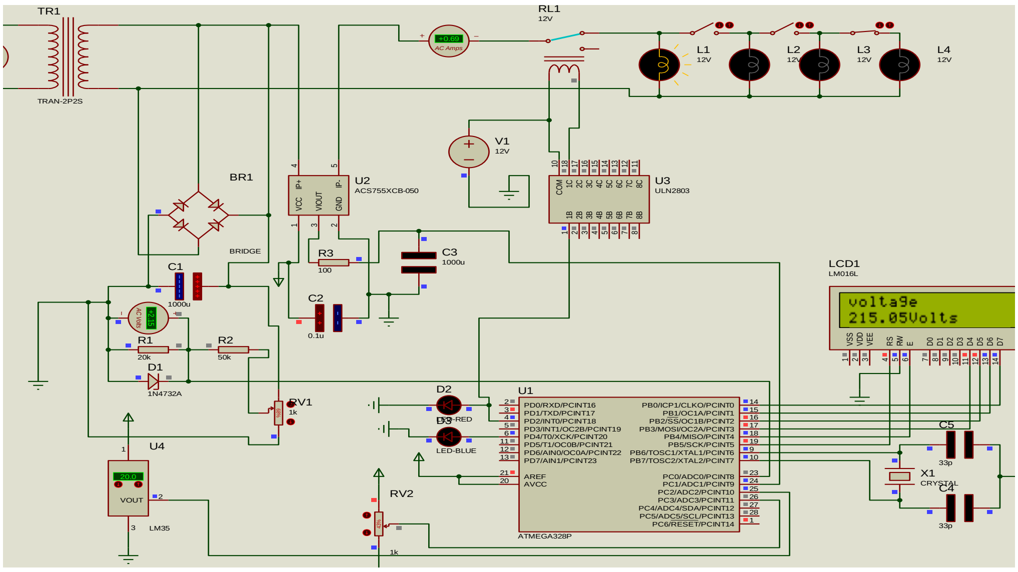

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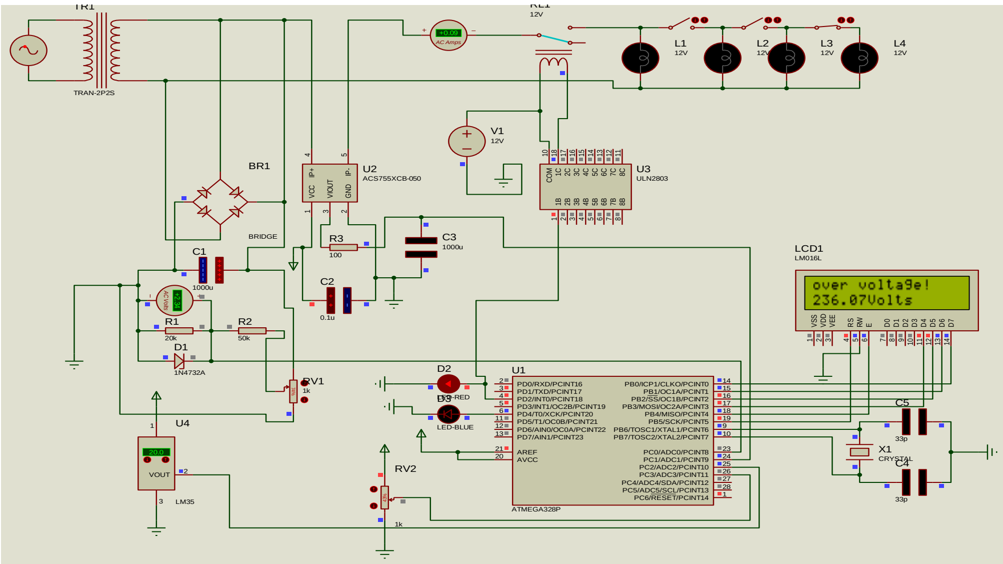

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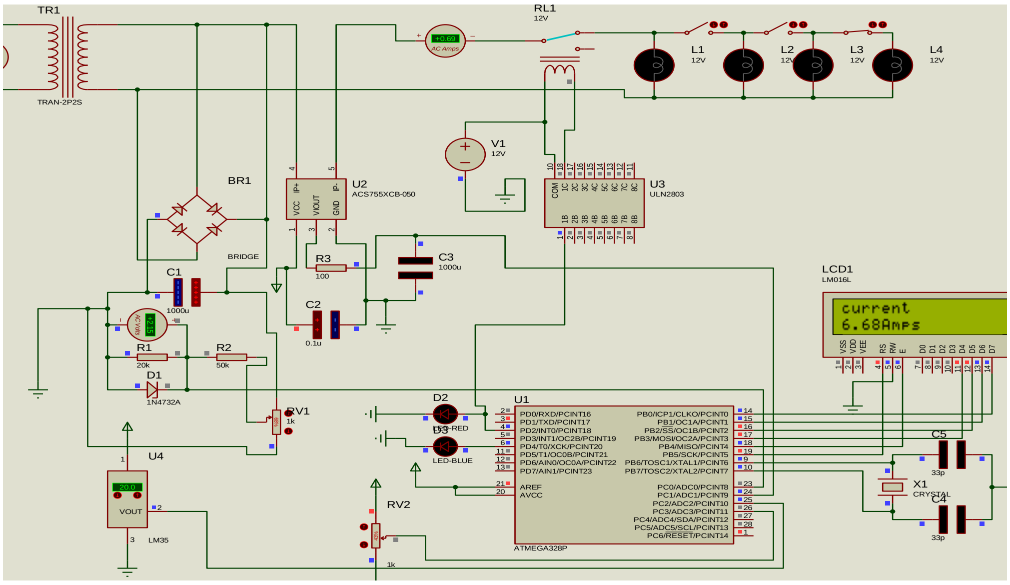

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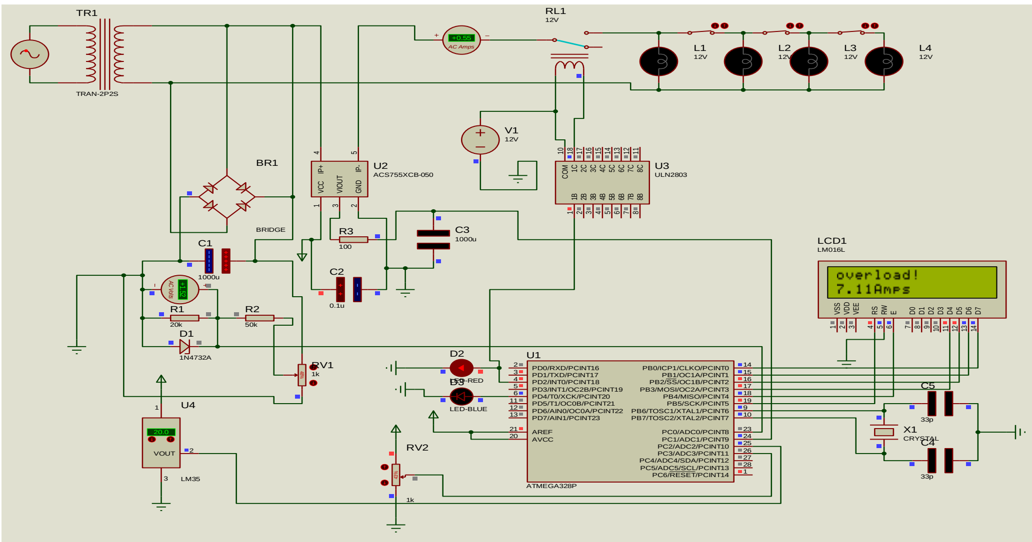

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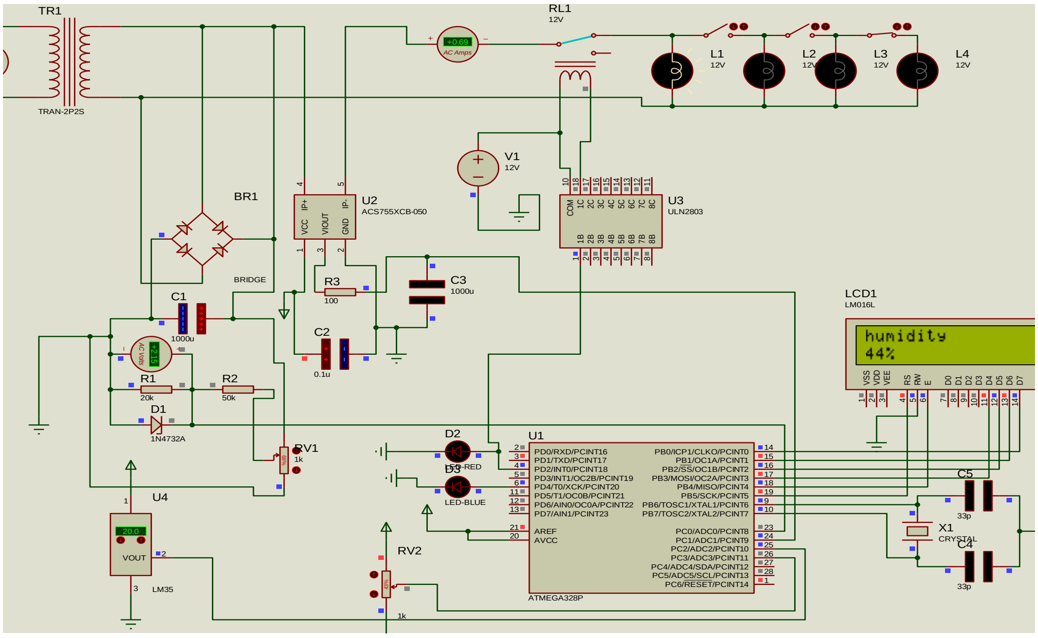

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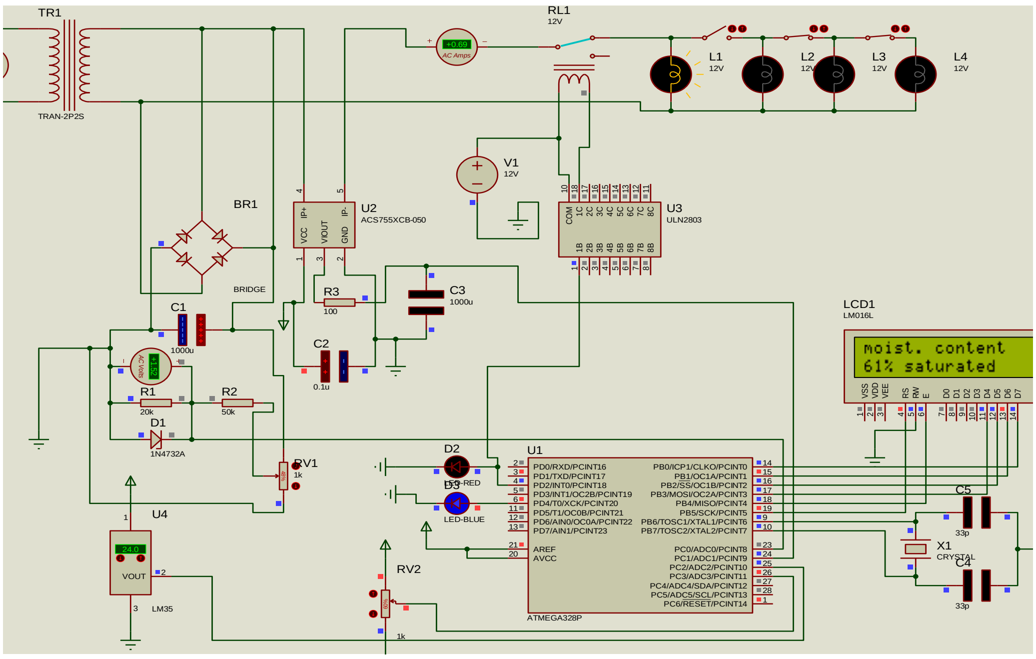

H

Figure 10: Measurements of the substation parameters; (a) normal temperature measurement; (b) high temperature; (c) normal voltage; (d) Over Voltage (e) Normal Current; (f) over load (g) humidity (h) saturated Humidity

From the results above, it was discovered that the relay tripped off when there was an overvoltage, overloads and when the normal working temperature of 30^{o}C set for the temperature sensor was exceeded. The circuit was designed in such a way that when the silica gel is saturated, the relay does not need to trip so as to minimize the number of time the transformer will be isolated. All the readings of the parameters are sent to the monitoring station.

IV. CONCLUSION

Conclusively, monitoring the distribution substation in Nigeria saves the distribution transformers from damage. Another advantage of monitoring the distribution transformer is to prolong the lifespan of the transformer The real time implementation of this design will make the reliability of the power supply to the consumers improved due to the fact that

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the down time of the the transformer will be reduced. In this case, the income for the utility station also increases. The system is carefully designed to send the conditions of the substation transformer to the utility staff anytime the parameters deviate from the acceptable values.

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