



## Development of a Microcontroller-Based Power Transformer Overload Protection Scheme

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### ABSTRACT

Over the years the power systems of developing countries specifically Nigeria is becoming more unstable due to several factors among which is the continuous faults developed by power system components and of particular interest is power transformers, providing a solution to this challenge is the motivation behind this research work. This paper presents the development of a microcontroller-based power transformer overload protection system, with a communication capacity to notify the utility staff a case of abnormalities caused by overloading. The protection system consists of a GSM Module, Voltage sensor, Buzzer, Relay and an ATMEGA328 microcontroller programmed in C-Language. The system was designed to intelligently senses a situation where the transformer is overloaded using the voltage sensor. A relay is triggered to disconnect the primary side of the transformer from the load and also send an SMS message to the utility staff, that a certain transformer is overloaded. The results obtained from the test carried out on the system shows that the SMS was sent to the utility company as overload condition occurred likewise the relay disconnected the load to isolate the transformer from service thereby securing it from damage.

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### INTRODUCTION

Transformers are critical and expensive power system components. They are employed for transformation or transfer of electric power from one circuit to another through electromagnetic induction and without a change of frequency. A major goal of protecting transformers is to minimize faults and consequent damage as any unscheduled maintenance or repairs especially replacement of faulty part or a complete transformer is labour intensive, time-consuming, and expensive (Syed et al.,

2015). Transformers are mainly designed to operate between 40-60% of their full loads for continuity of operation and sustained reliability (Jamal et al., 2018). Operating them over an extended period under abnormal conditions of faults and overloads will compromise their life and health. There are two types of faults occurring in a transformer; internal faults and through faults or external faults (Bashi et al., 2007). Internal faults are faults due to phase to earth on the primary or secondary windings or terminals, short circuits between turns of



high voltage and low voltage windings, and inter-turn faults in high voltage and/or low voltage windings (NAPTIN, 2014). External frequency, and over-fluxing (NAPTIN, 2014; Bashi et al., 2007). The type of protection used largely depends on the application and importance of the transformers. For instance, an emphasis is faulted are caused by overloads, external short circuits, terminal faults, over-voltages, the reduced system placed more on providing robust protection schemes such as differential protection, gas-operated relays or sudden pressure relays, over-current and unrestricted earth fault protection, balanced earth fault protection or restricted earth fault protection, frame leakage protection, etc, for transformers used in transmission networks than those used for power distribution that is commonly protected with just high rupturing capacity fuses. In any case, the transformer needs to be provided adequate protection scheme to avoid a forced outage or catastrophic failure resulting from its operation beyond the acceptable limits.

Electricity demand increases with an increase in population, and this results in overloading the existing power infrastructure in the absence of corresponding expansion. In simple terms, overload is currently drawn by loads over the nameplate rating (Chavan et al., 2018). These overloads appear at the terminals of the transformer and if sustained over an extended period can lead to reduced dielectric property and mechanical strength in the insulation of windings and the transformer structure as a whole.

It is a common practice in Nigeria for utility engineers to use meters to clap on the low voltage side of the distribution transformers (33/0.415kV and 11/0.415kV) to establish overloading. Apart from the frequent exposure to the porous and safety threatening conditions of most of the distribution substations, it is laborious and resource-consuming for the utility Engineer to visit every substation to take load readings and manually relieve the overloaded

transformers of some loads or completely isolate them from the system.

In this paper, a protection system is introduced into a power transformer to provide a high level of safety precaution through an advance algorithm embedded in a microcontroller to intelligently detect overload situations; that is, the introduction of voltage sensors was able to monitor the voltage drop at the predefined limit, as soon as the voltage goes above a certain threshold an SMS is sent to the utility staff alerting them that a transformer is overloaded and consequently the relay disconnects the primary side of the transformer in other to protect and safeguard the power transformer due to fault currents. However, the cost of maintaining the transformer would be reduced, leading to a continuous supply of electricity to consumers for a long time.

#### REVIEW OF RELATED WORKS

Naseem and Alam (2015) implemented a system to protect the transformer from the dangers of overloads, voltage spikes and overheating of transformer oil. An Arduino microcontroller (ATMEGA328P) was utilized to monitor these conditions, and if the predetermined values are exceeded, the system disconnects the load from the transformer.

Okhueigbe and Ogbekhiule (2019) developed a digital differential current protection scheme of a transformer using an Arduino Uno microcontroller. The system identifies an imbalance in differential current values using PIC16F690 microcontroller and sends a trip signal to the relay acting as a circuit breaker to open the circuit.

Jawale et al. (2019) developed a protection and monitoring scheme of a transformer using Arduino. The system uses a current transformer to measure the current and display it on LCD. When the fault occurs due to overloading or overvoltages, the microcontroller then sends a signal to energize the relay coil to trip the circuit.



Loko (2015) designed and implemented an automatic method of protecting a transformer against overload, high input voltage, and high temperature to replace the use of fuse technique. This was achieved through the use of ATMEGA328 microcontroller by monitoring these parameters and information about the operation is transmitted to the utility's computer for general monitoring and control.

Phadke and Thorp (1983) implemented a technique that uses a flux-current relationship of the transformer to obtain the restraint function. It was shown that this protection technique required fewer computations as compared to the harmonic current computation, and hence was implemented on a microcomputer of modest capability.

Shin et al. (2003) proposed a relaying algorithm to improve the sensitivities of fault detection using a fuzzy logic approach. The proposed fuzzy-based relaying algorithm consists of the equal flux-differential current derivative curve, harmonic restraint, and percentage differential characteristic curve. The algorithm was tested with a relaying signal accumulated from the Salford EMTP simulation package that showed a fast and accurate trip operation.

Kasztenny and Campbell (2001) proposed a magnetizing inrush restraining or protection algorithm for power transformer protection, which uses the angular relationship between the first and second harmonics of the differential current. Thus, the technique added a new dimension to the traditional approach that measures the magnitude ratio only between the fundamental frequency component and the second harmonic.

Sarsamba et al. (2013) proposed an approach of monitoring load and power lines based on GSM Technology. The approach was designed and implemented using a mobile embedded device for tracking and recording current and voltage change in electrical power lines and it also controls these parameters when line breaks during

high loads. Kalyan, *et al.*, (2013) worked on the Analysis and Design of Power Electronic Transformer based Power Quality Improvement. Their work shows a new type of transformer based on Power Electronics (PET), which realizes voltage transformation, galvanic isolation, and power quality improvements in a single system. It was observed that the PET was designed using power electronics on the primary and secondary sides of the transformer. Several features such as instantaneous voltage regulation, voltage sag compensation and power factor correction were combined into the PET. Also, the AC/DC, DC/AC, AC/AC converters and the high-frequency transformer was used in their system. The designed system had advantages such as power factor correction, voltage sag and swell elimination, voltage flicker reduction and protection capability in fault situations. However, the analyzed power electronic transformer was modelled using MATLAB/SIMULINK and wasn't constructed to validate the result obtained. Dey, *et al.*, (2012) proposed a topic titled Implementation of Power Transformer Differential Protection Based on Clarke's Transform and Fuzzy Systems.

The system was implemented using AT89S52, PIC16F877A and came up with a prototype relay. The coding was developed using microcontroller C and PIC basic languages. Kiel uVision3 and PIC Simulator IDE, this two software been used for loading the programs on-chip. A special terminal program, developed in C language was used to apply the current input signals to the prototype relay in real-time by using MAX232 serial data communication. Their studies depicted that transformer differential protection is generally exposed to faulty operation related to abnormal operating conditions such as the inrush and over excitation. A method for protecting and monitoring power transformers based on fuzzy logic and the application of Clarke's transform was proposed. It was seen that the fuzzy logic allowed the analyses of the operating conditions attached to the power transformers such as energization, inrush,



and overexcitation. Decision making was performed by fuzzy logic after the pre-processing of the input signals through Clarke's transformation. However, the electrical power system was modelled using MATLAB software to obtain the operational conditions and fault situations needed to test the algorithm developed which generated data for distinct situations for the verification and the analysis of their proposed methodology. It was also shown that in the fuzzy logic relay analyses the operating regime for the equipment was also able to eliminate abnormal work situations which generate failures.

Ezema, *et al.*, (2016) worked on Microcomputer Based Multipoint Time Operated Power Switching System (With Overload Protection). The system employed eight relays which were controlled independently through the parallel port of a computer using visual basic software. It is a timely operated electrical appliance controlling system that has a circuit responsible for switching electrical devices attached to it ON/OFF concerning time. With the aid of software devices on/off indicate the set time perimeter (hr. Min: sec) and the corresponding real-time clock were displayed at the front of the panel. The system makes use of a real-time check built around the computer system clock and keeps track of time. In a situation where this time equals the programmed off time of the device, the corresponding relay attached to the device is switched off. However, the switching time can be edited using peripheral devices like the keyboard and mouse.

Sukumar, *et al.*, K (2018) worked on Power transformer protection using microcontroller in an embedded system. Their system was able to check the operating parameters of the transformer i.e. current and reports the quantity that is flowing through the transformer. The system is also designed to detect currents above the normal operating level in order to isolate the power transformer from the distribution line. This isolation process is to ensure that the transformer is safe from any excess

current levels that can make it to overheat thus get damaged. It was observed that a current sensor ACS712x series was used as the interfacing instrument between the power transformer and the PIC16F690 microcontroller in their design. The PIC16F690 controls all operations that the device does. A relay and a contactor were used as the switching gears to isolate the current transformer (CT) from the power system in case a fault occurs. A monochrome LCD has been used to show system current readings and indicate cases of over-current fault. In an occurrence of a fault, LEDs and a piezoelectric buzzer were used. However, MPLAB programming software was used to write the program.

Dhobale, *et al.*, (2018) designed and implemented an RF-based distribution transformer monitoring system. This system monitors and records key parameters of a distribution transformer like load currents, load voltage, and transformer oil temperatures. These parameters provide useful information about the status of a transformer. The acquired parameters were processed and the data was sent to a central monitoring station through the RF interface. Their data was then further processed and analyzed regularly by the system operator. They found out that RF has a very low latency which is best for real-time systems. Besides that, they also realized that it provided a balance among trade-offs between cost, capacity, performance, and density. Their results show that the variations of the recorded values assisted them in identifying the possible failure that could occur, in a situation whereby the values are over the rated values. However, it was able to only detect an error in balancing of load which in turns makes the controller send a signal to the relay in order to break the circuit and hence completely switch the transformer but don't suggest in the condition of an unbalance load.

The research by (Zheng, *et al.*, 2004) shows a new method algorithm of differentiating the inrush and fault current for power transformer protection, based on the behaviour of current waveform context

extracted by mathematical morphology. It was found out that the morphological detector of the defatation was used to sight the peak and bottom of the waveform attached to the current. They further divided the morphological gradient into three parts having the same size, the area of each section was calculated and the standard qualitative discrimination based on the comparable size of each area was made. However, the algorithm proposed requires further calculations. From their simulated results using the HYBRISIM (Hybrid Simulator), it was observed that the algorithm was capable of distinguishing between the inrush, fault current and immune to CT's saturation.

This paper focuses on designing a protection system to a power transformer in other to provide a high level of safety precaution through an advance algorithm embedded in a microcontroller to intelligently detect overload situations. The introduction of voltage sensors was able to monitor the voltage drop as compared with predefined limit, and the communication system was also introduced to inform through SMS to the utility providers alerting them that a transformer is overloaded and consequently the relay disconnects the primary side of the transformer in other to protect the load from excessive damages that might be caused by faults currents serves a major contribution to the improvement in the protection of power transformer. It reduces the cost of maintenance and ensures that the supply of electricity to consumers is not interrupted for long periods.

## METHODOLOGY

This section employs the use of voltage sensors, GSM-module, Arduino Uno microcontroller board, 1000Watts, 220/210V transformer and 200 watts' incandescent bulbs as loads to demonstrate this concept.

This system is categorized into four (4) units which are;

- a. The power unit
- b. The control unit
- c. Protection unit
- d. Alerting unit

Figure 1 shows the block diagram of the system.

### The Power Unit

The power unit consists of Ac source, power input. The AC source supply AC voltage of 220V for both power input the power input consists of a transformer, rectifier circuit, filter and a voltage regulator. The rectifier circuit is implemented as a four bridged diode that converts the AC voltage of the transformer to a full-wave rectified DC voltage. In The filter section a 2200uf, 50V capacitor is used to reduce the ripple waveform and increase the dc voltage level to a voltage of 18V when the capacitor is at its charge state. The voltage regulator used in this project is LM7805. It is a fixed voltage regulator, its step down the input voltage coming from the filter circuit to a constant 5V. This thus powered the microcontroller, relay and GSM, since their maximum input voltage should not exceed 5V. Figure 2 shows the circuit diagram of the power supply section

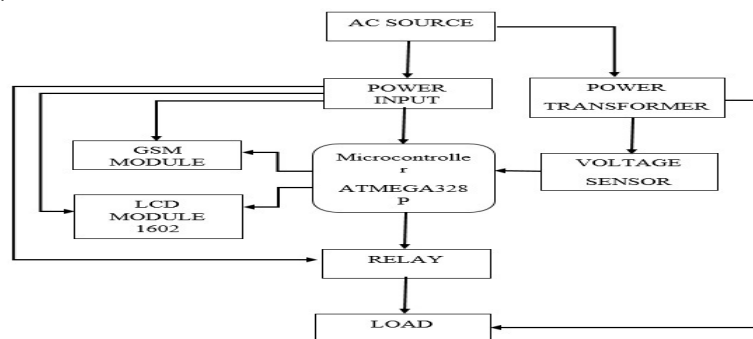


Figure 1: Block Diagram of the System

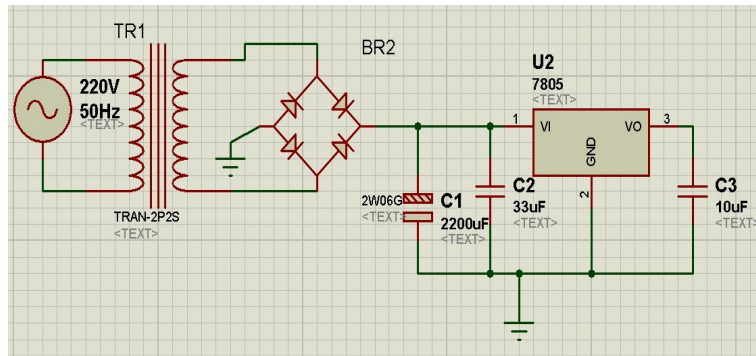


Figure 2: Circuit diagram of the power supply section

### The Control Unit

This unit consists of the microcontroller ATMEGA328P and 1 channel relay module for the power transformer overloading control cut off.

### Microcontroller (ATMEG328P)

The microcontroller has twenty-eight (28) pins. 10 pins were used, out of which they are input pins, reset pin etc. The table below shows the pin used and their function. Table 1 shows the pin used and its function

Table 1: Microcontroller (ATMEG328P) pin used and their various function

S/N	Pin	Description and Function
1	4, 5, 6, 7	LCD 4-bit data communication
2	8, 9	Enable and write pins to the LCD
3	10	Input pin for GSM data transmission data TX
4	11	Data Receiving (RX) pin from GSM
5	12	Input trigger signal for the buzzer
6	3	Connected to the trigger pin of the relay
7	A0	Connected to the voltage sensor
8	RESET	Connected to the reset pin

### Channel Relay Module

The relay module has 3 input terminal VCC, GND and IN1. VCC of the relay is connected to 5V of the power input and GND to the ground (0V) or negative terminal the IN1 is the input terminal of the relay, the IN1 of the relay is connected to pin 3 of Arduino microcontroller, a LOW signal is sent to the relay from the microcontroller to close the relay and a HIGH signal is sent to open the relay. This is thus used to control the overloading of the power transformer by disconnecting the load from the power transformer when the microcontroller senses the overloading.

### Voltage Sensor

The voltage sensor used in this research is not ZMPT101B voltage sensor module because it was expensive. The voltage sensor used in this paper is a circuit that consists of a transformer, rectifier, filter, voltage regulator and voltage divider circuit. The transformer steps down the AC voltage from 220 to 12V, a rectifier circuit is needed to convert the AC voltage to DC rectified voltage after that a 2200uf capacitor is used as a filter. The analogue input of the microcontroller A0 is used as the input of the voltage sensor reading, the input A0 of the microcontroller can read the change of sensor values that has a constant DC voltage without any ripples of AC voltage otherwise



it with generating random and unstable sensor values, introducing a variable voltage regulator LM317 after the filter will give a constant DC voltage. The variable voltage regulator has two resistors the first resistor R1 is a fixed resistor of 120 ohms and the second resistor R2 is a variable resistor used to vary the output voltage of the LM317 voltage regulator. The resistors were removed so that the output voltage of the

voltage regulator can be affected by the input voltage that changes in input voltage will result to change in the output voltage of the microcontroller. The microcontroller analogue input A0 can only accept an input voltage of 5V having a voltage divider after the voltage regulator will divide the 6V voltage into half thus not allowing the voltage to exceed 5V. Figure 3 shows the circuit diagram for the voltage sensor

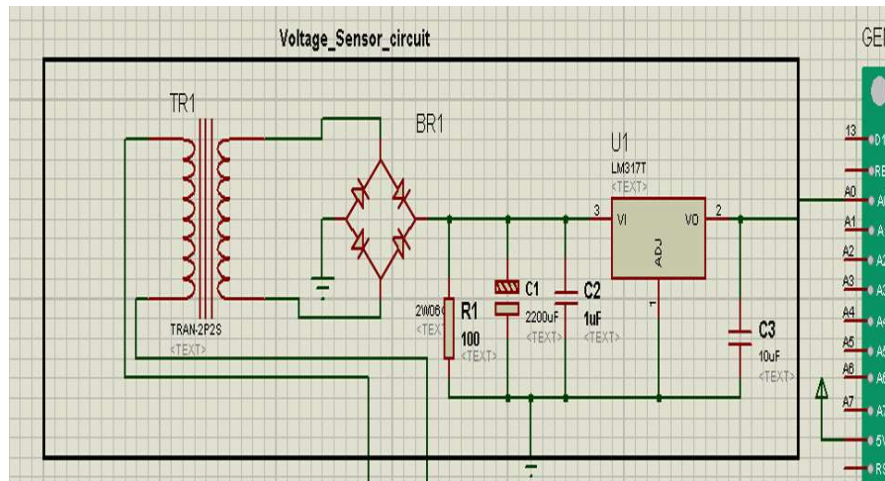


Figure 3: Voltage Sensor Circuit Diagram

### Protection Unit

The protection unit or relay module is shown in Figure 4 comprises an integrated circuit ULN2003 and a relay. The integrated

circuit receives a signal from the microcontroller via pin 1, while pins 18 and 10 serve as the input to the relay that isolates the loads in the event of overloads.

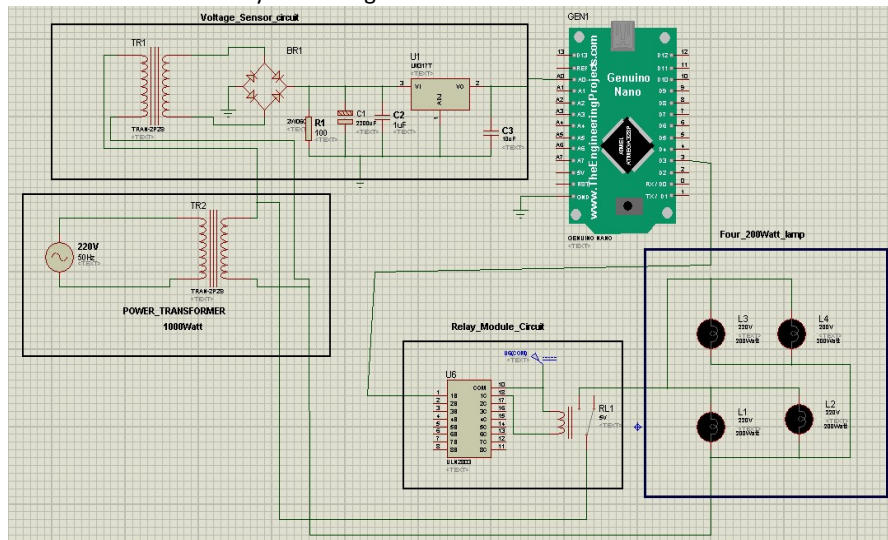


Figure 4: Circuit Diagram of Protection Unit.

### Power Transformer

The power transformer used in this paper is a 1000Watts transformer with an input voltage of 220V and output voltage of 210V. It was observed that the output voltage of the transformer is affected by the input voltage that is increase or decrease of input voltage of the transformer will as well

increase or decrease the output voltage of the power transformer. If the load is applied to the transformer it will affect the output voltage of the transformer thus by decreasing the voltage which can cause overheating of the transformer. Figure 5 shows the circuit diagram of the hardware system

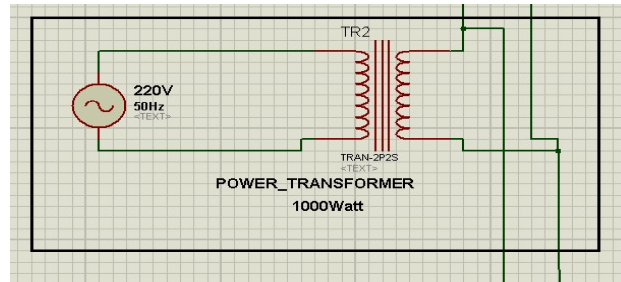


Figure.5: Block Diagram of the Hardware System

### Power Transformer Load

Four 200WATT incandescent bulbs were used in this paper because of its high wattage value, as the load increases there will be a voltage drop, the differences between the voltage drop of the first bulb, second bulb, third bulb and fourth bulb values can be used as the calibrated value to dictated the overloading. The value of either the third or fourth bulb is used in this paper as the calibrated value for the overloading, however, when inserted, the microcontroller sends a LOW signal to the relay in other to disconnect the load from the power transformer. Figure 6 shows the Circuit

Diagram of the Power Transformer Load and a Relay.

### Alerting Unit

In case of overloading of the power transformer, two alerting systems were used Buzzer and GSM module.

### Buzzer

The buzzer is connected to pin 12 of Arduino microcontroller, whenever overloading occurs, the microcontroller will send a HIGH signal to the buzzer for 10 seconds before disconnecting the load from the power transformer.

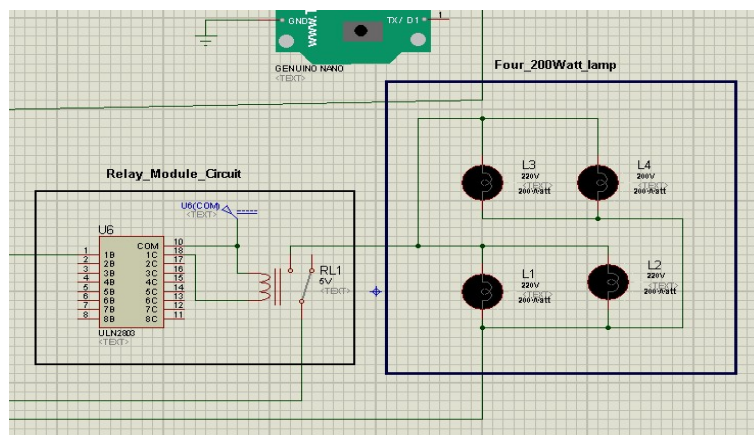


Figure 6: Power Transformer Load and Relay Circuit Diagram.



### GSM Module

The GSM module has four active pins the VCC, GND, RX, TX, the VCC pin is connected to 5V input power and the GND to the Ground (negative terminal), The communication pin between the microcontroller and the GSM is the TX and RX pin which is connected to pin 11 and 12 of Arduino microcontroller. The GSM module used in this paper is SIM900a GSM

module whenever overloading occur the GSM will send an SMS to the operator alerting that there is Overloading of the power transformer.

### 3.9 Software Implementation

The software implementation is a flowchart showing how the system was executed from the start to its end. Figure 7 shows the flowchart of the scheme.

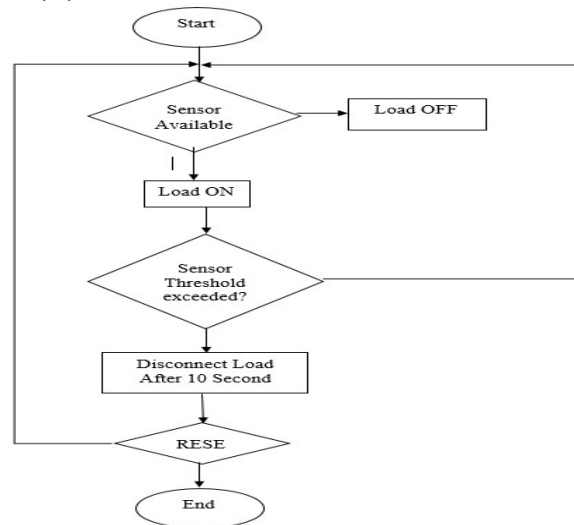


Figure 7: The Flowchart of the System

### Circuit Diagram

The complete circuit diagram of the implemented transformer overload protection system is shown in Figure 8. While Figure 9 shows the implemented Transformer Overload Protection System.

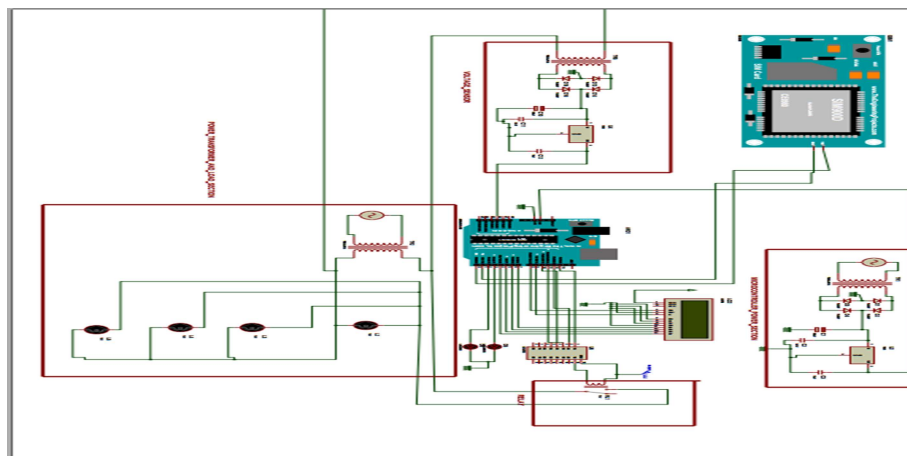


Figure 8: Complete Circuit Diagram of the System



Figure 9: Implemented Transformer Overload Protection System

### RESULTS AND DISCUSSION

The following results have been obtained after simulating the design on Proteus ISIS software which was later transferred to Vero-board for final implementation. Table 2 shows the state of the relay, voltage sensor and status on LCD as the power rating of the transformer increases due to load. A decrease in load makes the current sensors reading to increase. A decrease in the sensor output voltage up to its preset threshold led to a corresponding increase in the power rating displayed on the LCD. Little reading by the current sensor means that the load has increased thus more power is drawn from the transformer. More reading limits power flow, signifying reduced load. So as reading is reduced by varying the current sensor, power increases up to a point where the relay trips the circuit. Thus, the secondary

terminal voltage and the load current are inversely related, and this supports the voltage transformation equation of

$$\text{transformers (i.e. } I_2 = I_1 \frac{V_1}{V_2}, \text{ where } I_1 =$$

primary current,  $I_2$  = secondary current,  $V_1$ = input voltage, and  $V_2$  = secondary terminal voltage). This confirms that the system has been designed well and thus it can read and record the power as it changes. Finally, it is observed that when the current sensor is varied up to the pre-set level of 3.00V, the relay and buzzer are triggered. The buzzer sounds an alarm and the GSM Module sends an SMS notifying the utility staff of the fault, the relay isolates the transformer from the system in other to protect it from damage. The LCDs a notification that there is an OVERLOAD.

Table 2: Results obtained for different loads

LOAD	VOLTAGE SENSOR (V)	RELAY STATE	LCD DISPLAY
NO LOAD	0	OPEN	NO SENSOR INPUT
NO LOAD	3.11	CLOSE	NOT OVERLOADED
200WATT	3.08	CLOSE	NOT OVERLOADED
400WATT	3.06	CLOSE	NOT OVERLOADED
600WATT	3.04	CLOSE	NOT OVERLOADED
800WATT	3.00	OPEN	OVERLOADED

### CONCLUSION

In this paper, a protection system for a power transformer was developed,

considering the additional feature of the GSM Module, SMS manipulation was executed. It senses a situation where the



transformer is overloaded using voltage sensors. The relay was activated in order to disconnect the primary side of the transformer from the load as soon as the transformer is overloaded. It was observed that as the power circulating through the transformer increases, the output of the sensor decreases as well. It can be depicted that an increase in load leads to a decrease in the value of its voltage sensors. This confirms the accuracy of the designed system.

#### RECOMMENDATION

The voltage sensors used in this design was constructed using a transformer, rectifier, filter and voltage regulator, due to sensitivity of this prototype, to further improved the accuracy of the overload sensing, voltage sensors such as ZMPT101B should be used alongside with a current sensor, this will give an improved reading. Also, temperature sensors can be incorporated in order to detect the hotness of the transformer as soon it goes beyond a predefined threshold.

#### REFERENCES

- Bashi, S. M., Mariun, N., & Rafa, A. (2007). Power Transformer Protection Using Microcontroller-Based Relay. *Journal of Applied Sciences*, 7(12), 1602-1607.
- Chavan, S. A., Gaikwad, M. A., Ganyarpawar, T. V., Shinge, A. A., Shirgaonkar, S. D., & Barhate, U. (2018). Remote Monitoring of Distribution Transformer Using GSM Module. *National Conference on Current Trends in Engineering, Science, and Technology (NACCTEST- 2018)* (pp. 1-5). Jalgaon: GF's Godavari College of Engineering, Jalgaon.
- Dey, P. Das, P., & Chakraborty, A. K. (2012). Implementation of Power Transformer Differential Protection Based on Clarke's Transform and Fuzzy Systems. *International Journal of Engineering Research & Technology (IJERT)*. Vol. 1 Issue 7, September – 2012 ISSN: 2278-0181
- Dhobale, R., Mahalle, A., Wankhede, A., Hallmark, K., & Preeti, M. (2018). Design and Implementation of an RF-based distribution transformer monitoring system. *International Research Journal of Engineering and Technology (IRJET)* e-ISSN: 2395-0056 Volume: 05 Issue: 03 Mar-2018. Retrieved from [www.irjet.net](http://www.irjet.net). p-ISSN: 2395-0072
- Ezema, C. N., Onuoha, O., Nwogu, N., Agulanna, A. C., & Nonyelu, H. U. (2016). Microcomputer Based Multipoint Time Operated Power Switching System (With Overload Protection). *British Journal of Applied Science & Technology* 17(2): 1-19.
- Jamal, H., Waseem, M., Sajjad, I. A., Anjum, A., & Khan, M. S. (2018). Low-Cost Feedback Control Thermal Protection System for 3-Phase Distribution Transformer Using Microcontroller. *6th IEEE International Conference on Smart Energy Grid Engineering* (pp. 200-204).
- Jawale, N., Kumbhar, P., Kurle, G., & Shinde, A. (2019). "Transformer Parameter Monitoring and Protection System Based on Arduino," *Journal of Engineering Research*, 3, 2-8.
- Jongen, R., Morshuis, P., Smit, J., Janssen, A., & Gulski, E. (2007). "A statistical approach to processing power transformer failure data," in *Cired 19th International Conference on Electricity Distribution*, 7(1), 2-7.
- Kalyan, B.T. & Ram, P., & Prasad, M. (2013). Analysis and Design of Power Electronic Transformer based Power Quality Improvement. *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)* e-ISSN: 2278-1676 Volume 5, Issue 1 (Mar. - Apr. 2013), PP 61-69 retrieved from [www.iosrjournals.org](http://www.iosrjournals.org).



- Kulidjian, A., Kasztenny, B., & Campbell, B. (2001). "New magnetizing inrush restraining algorithm for power transformer protection." *Asian Journal of Technology*, 2, 4, 12-19.
- Loko, A. Z., Bugaje, A. I., & Bature, A. A. (2015). Automatic Method of Protecting Transformer using PIC Microcontroller as an alternative to the Fuse Protection Technique. *International Journal of Technical Research and Applications*, 3(2), 23-27. Retrieved from [www.ijtra.com](http://www.ijtra.com)
- Ma, J., Wang, Z., & Wang, X. (2006). "Novel principle of power transformer protection based on equivalent instantaneous leakage inductance," *Automation of Electric Power Systems*, vol. 30, no. 23, pp. 64-68.
- NAPTIN. (2014). *Basic Power Relaying Protection Course - P1 (Manual)*. National Power Training Institute of Nigeria (NAPTIN), Protection, Control, and Metering Department. Abuja: National Power Training Institute of Nigeria (NAPTIN).
- Naseem, A., & Alam, N. (2015). Protection of Distribution Transformer using Arduino Platform. *Sci. Int. (Lahore)*, 27(1), 403-406.
- Okhueigbe, E. I., & Ogbekhiule, J. A. (2019). Digital Differential Current Protection Scheme of Transformer Using an Arduino UNO Microcontroller. *International Journal on Data Science and Technology*, 6(1), 35-39. doi:10.11648/j.ijdst.20190501.15.
- Phadke, A., & Thorp, J. (1983). "A new computer-based flux-restrained current-differential relay for power transformer protection," *IEEE Transactions on Power Apparatus and Systems*, no. 11, pp. 3624-3629.
- Sarsamba, M., Sangulagi, P., & Yanamshetty, D. R. (2013). "The load monitoring and protection on electricity power lines using GSM network," *International Journal of Advanced Research in Computer Science and Software Engineering*, vol. 3, no. 9, 14-23
- Shin, M. C., Park, C. W., & Kim, J.H. (2003). "Fuzzy logic-based relaying for large power transformer protection," *IEEE transactions on Power Delivery*, vol. 18, no. 3, pp. 718-724.
- Sukumar, P., Mothiram, K., Narmatha, N., Pavithra, B., Velgnana, V. A., & Venkatesh, S. (2019). Power transformer protection using microcontroller in an embedded system. *Inter. J. Int. Adv. & Res. In Engg. Comp.*, Vol.-06(01) [209-213]
- Syed, S. N., Radhika, S., & Rani, M.N. (2015). Differential Current Protection of Transformer using Arduino with Voice Alert. *International Journal of Innovations in Engineering and Technology (IJJET)*, 6(2), 206-212
- Zheng, T., Liu, W. S., Xiao, S. W., & JIAO, S. H. (2004). "A new algorithm based on the mathematical morphology for power transformer protection," *Proceedings-Chinese Society of Electrical Engineering*, 24, no. 7, pp. 18-24.