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Entrepreneurial Engineering: Enhancing Power Distribution Engineering Network For Effective Service Delivery

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Abstract
Distribution transformers are vital components of the power system that require constant monitoring and control to ensure their optimal operation and prevent intrusion/unauthorized access and sabotage which enhances effective service delivery to consumers and revenue generation for the utility company. This research work employs Internet of Things (IoT) in the design and construction of a system which can check and curb intrusion or unauthorized access in the substation by way of providing security for the transformer against theft, sabotage and vandalism. This research is aimed at preventing significant costs, including expenses for replacing stolen or damaged transformers, sudden power failures and revenue losses due to the downtime of the distribution network. An ultrasonic sensor is also used to monitor intrusion, then, communicates the utility operator via SMS through GSM module and ATMEGA328P microcontroller. Internet protocol (IP) camera is also integrated into the system to provide surveillance and security monitoring within the substation vicinity. Whenever this system detects an intruder or unauthorized access, it continues to send message to inform the utility personnel of intrusion and the personnel will quickly capture the image of the intruder through the IP camera app. This system was tested and worked perfectly. By recommendation, other sensors can be used with this system to check transformer parameters like voltage, current, frequency, temperature, gas, oil level, oil quality, humidity and pressure to prevent transformer failures, which helps in the routine maintenance and protection of distribution transformers.

***Keyword**: service delivery, management, innovation, GSM kit, microcontroller, Transformer, Sensor and LCD.*

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I. Introduction

In modern times, humans rely heavily on electricity for day-to-day activities (Sanjeeya *et al*., 2018). Electricity is considered the third most important factor of production, following labor and capital, in economic models (Mehta and Mehta, 2002). It is widely acknowledged in the literature that chronic energy poverty is one of the main factors hindering socioeconomic development in Nigeria and other African countries (Momoh *et al*., 2018).

To promote socio-economic development in Nigeria, it is crucial to establish an effective and efficient electric power system. The distribution system is a key component of the power system, acting as a link between the high-voltage transmission system and consumer services (Dubey *et al*., 2013). The distribution transformer plays a critical role in the distribution network, as it steps down the high voltage from the transmission network to a lower voltage suitable for end-users (Desai and Hasabe, 2016; George *et al*., 2018). Furthermore, the distribution transformer represents a significant investment in the distribution network (Sanjeeya *et al*., 2018). The most common causes of distribution transformer failure include overloading, high temperature, and phase unbalance. Transformer failure can result in abnormal voltage, current, and frequency being supplied to consumers, or a complete power outage. Repairing or replacing a failed transformer requires substantial capital investment. Additionally, other equipment within the distribution substation can be subject to vandalism, leading to disruptions in power supply to consumers. However, the failure of distribution transformers can be prevented if regular maintenance is carried out through remote monitoring of transformer variables.

This research focuses on the remote monitoring of distribution substations using a GSM/GPRS module, ATMEGA328P microcontroller, and Internet Protocol (IP) camera. The microcontroller is connected to motion sensor that monitors the presence of an intruder. An IP camera is installed to capture images within the vicinity of the distribution transformer whenever the motion sensor senses an intruder. Remote communication with the monitoring system is facilitated through GSM technology and IoT.

1.1 Reviewed Literatures

In the field of power transformer protection and monitoring, several studies have been conducted to develop systems using various approaches and technologies. The following are detailed reviews of the related literature: (Naseem and Alam, 2015) implemented a system to protect transformers from overloads, voltage spikes, and overheating of transformer oil. An Arduino microcontroller (ATMEGA328P) was used to monitor these conditions. If the predetermined values were exceeded, the system disconnected the load from the transformer. (Loko, 2015) designed and implemented an automatic method of protecting transformers against overload, high input voltage, and high temperature. The ATMEGA328 microcontroller was used to monitor these parameters, and the information about the operation was transmitted to the utility's computer for general monitoring and control.

(Sukumar *et al*., 2018) focused on power transformer protection using a microcontroller in an embedded system. The was designed to detect currents exceeding the normal operating level and isolate the power transformer from the distribution line to prevent overheating and damage. The system employed a current sensor from the ACS712x series as the interface between the power transformer and the PIC16F690 microcontroller. The microcontroller controlled all system operations. A relay and a contactor were used as switching gears to isolate the current transformer (CT) from the power system in case of a fault. A monochrome LCD displayed system current readings and indicated over-current faults. LEDs and a piezoelectric buzzer were used to provide visual and audible alerts during fault occurrences.

(Jenifer *et al*., 2018) worked on the monitoring and protection of distribution transformers using a GSM module. The designed system aimed at monitoring and protection system for distribution transformers using GSM and GPS technology. The system monitored parameters such as load current, voltage, oil level, and ambient temperature through sensors. The values were continuously displayed on an LCD and recorded in the system memory. In case of a failure, an alert message containing the parameter values and location was sent to the monitoring center using GSM and GPS integrated with the Arduino board.

(Dhobale *et al*., 2018) designed and implemented an RF-based distribution transformer monitoring system. The system monitored and recorded key parameters of a distribution transformer, including load currents, load voltage, and transformer oil temperatures. These parameters provided useful information about the transformer's status. The acquired data was sent to a central monitoring station through the RF interface for further processing and analysis. The system operator regularly processed and analyzed the received data. The research showed that RF technology had low latency, making it suitable for real-time systems. However, the system could only detect an error in load balancing and trigger a relay to switch off the transformer, but unbalanced load conditions was not address.

(Priyanka *et al*., 2018) designed and implemented a real-time transformer health monitoring system using Raspberry Pi. This embedded system monitors load currents, overvoltage, and temperature. It integrates IoT technology with a Raspberry Pi and sensors installed at the distribution transformer site. The output values from the sensors were processed and recorded in the system's memory. However, similar to the previous system, it does not cover the monitoring of other essential parameters such as oil level, frequency, location, and general security of the substation transformer.

(Jawale *et al*., 2019) developed a protection and monitoring scheme for transformers using Arduino. They used a current transformer to measure the current and displayed it on an LCD. When faults occurred due to overloading or overvoltage, the microcontroller sent a signal to energize the relay coil and trip the circuit. An IoT-based distribution transformer monitoring and controlling system was also developed by (Pustaraj *et al*., 2019). The system incorporates a GSM modem for sending SMS to a central database for further processing. It utilizes an AVR microcontroller for temperature and viscosity monitoring and control actions. An application program in Embedded-C was developed, allowing the microcontroller to continuously read and display temperature, voltage, and current values on an LCD. However, the system lacks consideration for other crucial parameters such as frequency, oil level, location, and general security of the transformer.

(Suma and Aprameya, 2019) developed a system for the condition monitoring of distribution transformers with a prepaid energy meter using the Internet of Things (IoT). Their research focused on monitoring parameters such as short circuit, oil level, overvoltage, temperature, and energy meter readings. The project utilized a Wi-Fi module with a PIC microcontroller and various sensors. However, this project did not consider parameters such as frequency, location, and security of the transformer.

(Kepa *et al*., 2020) presents a GSM-based remote distribution transformer condition monitoring system that monitors four operational parameters such as voltage unbalance, load current, oil temperature and winding temperature. It is a remote mobile embedded system that integrates a GSM/GPRS module, an Arduino microcontroller board, and sensor packages.

(Ojo *et al*., 2022) presents a GSM-based monitoring system for a distribution transformer. It uses the ATmega328 microcontroller, GSM modem, LM35 temperature sensor, and ACS712 current sensor to detect temperature levels and faults and relay the fault diagnosis to the base station.

II. MATERIALS AND METHOD

The block diagram of the hardware implementation for the GSM Based Transformer Monitoring System using ATMEGA328P is shown in Figure 1.

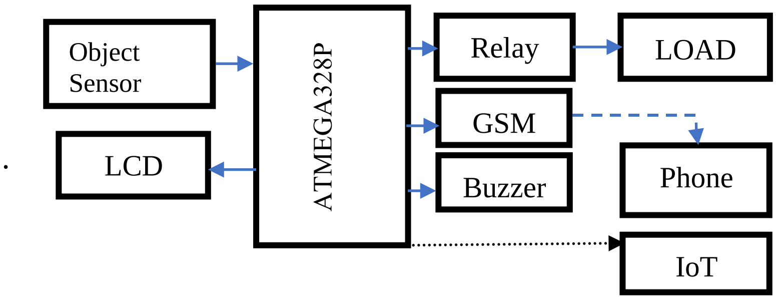

Figure 1: Block Diagram of the Transformer Monitoring System using ATMEGA328P

Figure 2 shows the circuit diagram of the transformer monitoring system using ATMEGA328P controller and ultrasonic module as object sensor. The ultrasonic sensor is use to continuous monitor the presence of object, whenever an object is detected, a signal is sent to the ATMEGA328P controller which it (ultrasonic module) is connected to. The ATMEGA328P controller receives this signal from the ultrasonic and sends a message to a security personnel via a GSM module. The ATMEGA328P controller has an inbuilt wifi module which is programme to perform IoT, which makes it possible to access the information from Internet.

Figure 3 shows the flow chart, which provides a visual representation of the program logic and the sequence of steps involved in the transformer monitoring system. Each step in the flowchart represents a specific action or decision that the software program performs. The flowchart begins with a start where all modules are initialized, and the object is checked, if detected. If object is detected a signal will be send to the microcontroller which sends a message a security personnel via a GSM module. When the security personnel received the message, the IP camera will be activated by the security personnel and IoT is activated and the message is sent to Internet where it can access in the internet. But if no object is detected the system goes back to continue to scan for presence of object.

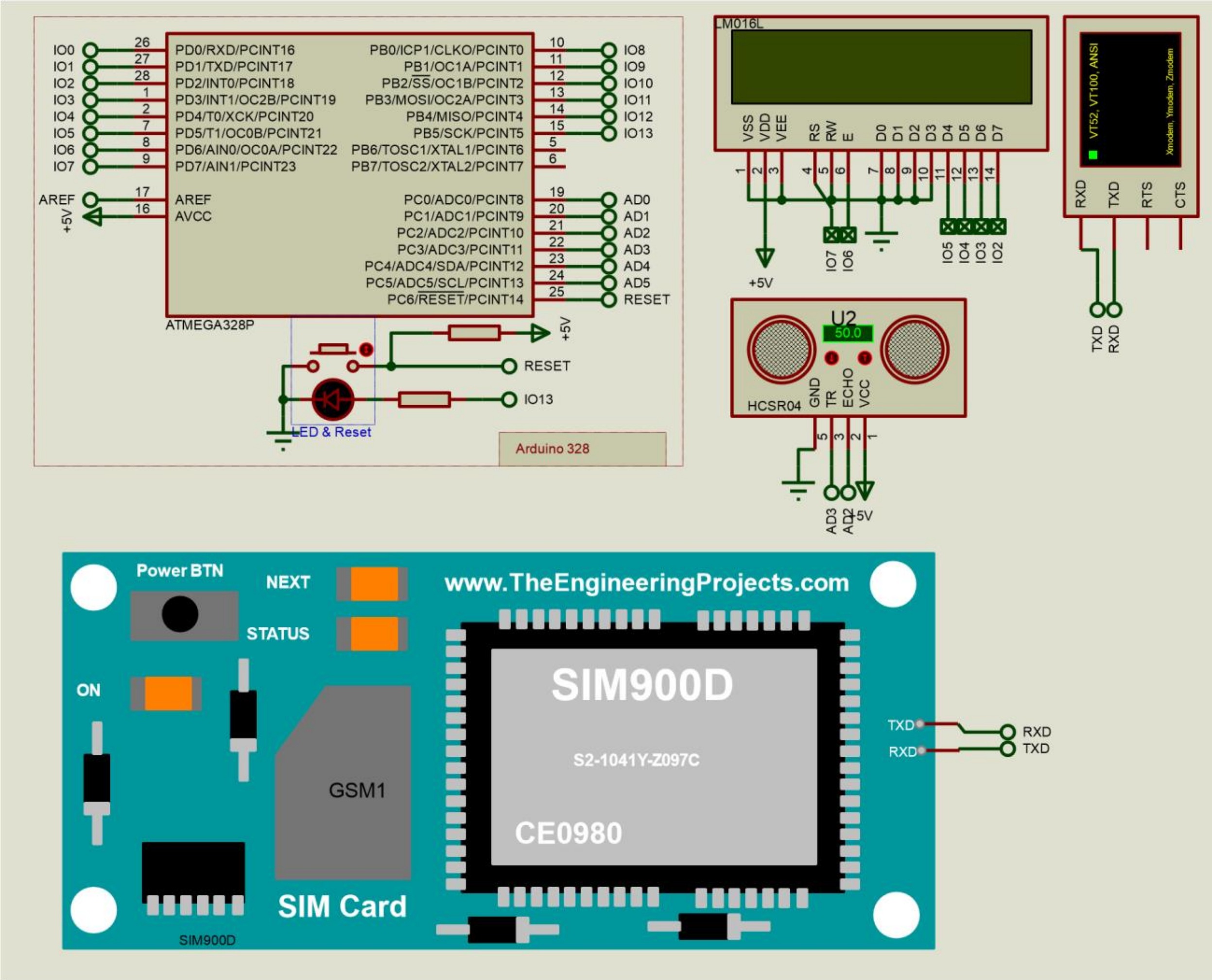

Figure 2: Circuit Diagram of the Transformer Monitoring System

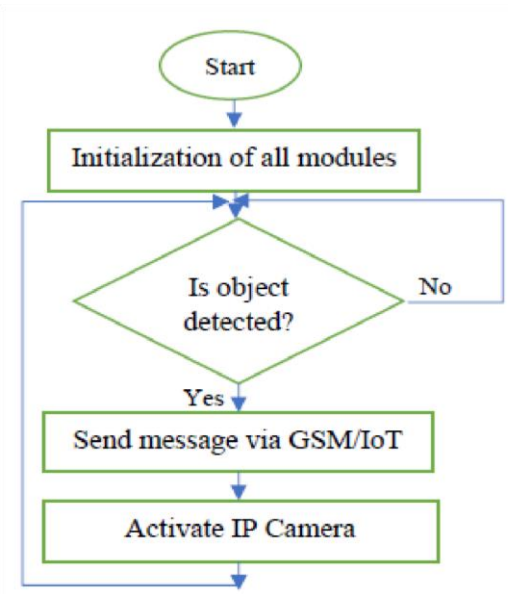

Figure 3: Flowchart Diagram of the System

III. RESULTS

Testing entails verifying that at all stages of the implementation conforms to the projected aim and objectives. Finally, the project was test-run and confirmed to be working. The results of each stage are shown in Figure 4 to 10.

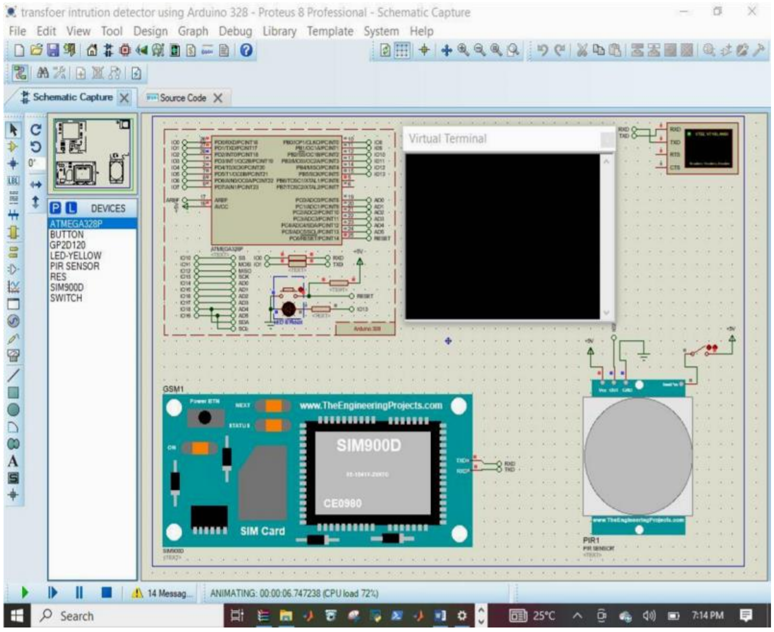

Figure 4:

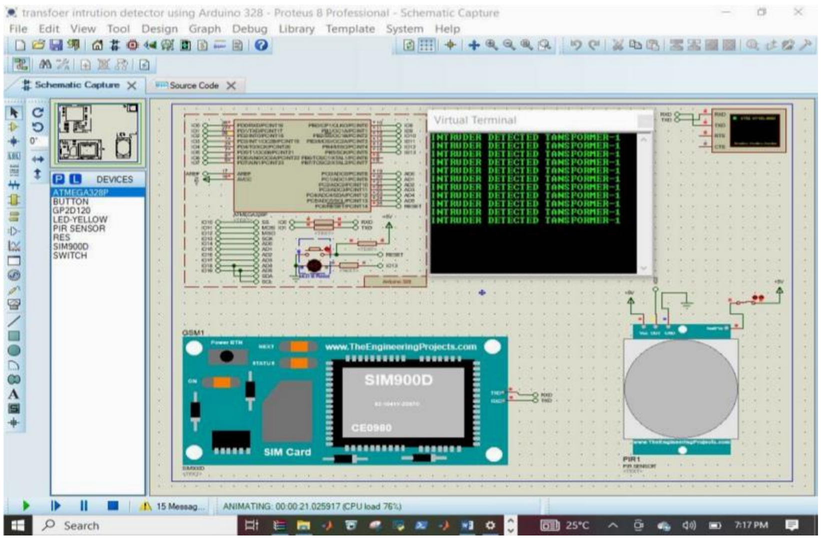

Figure 5:

Figure 6:

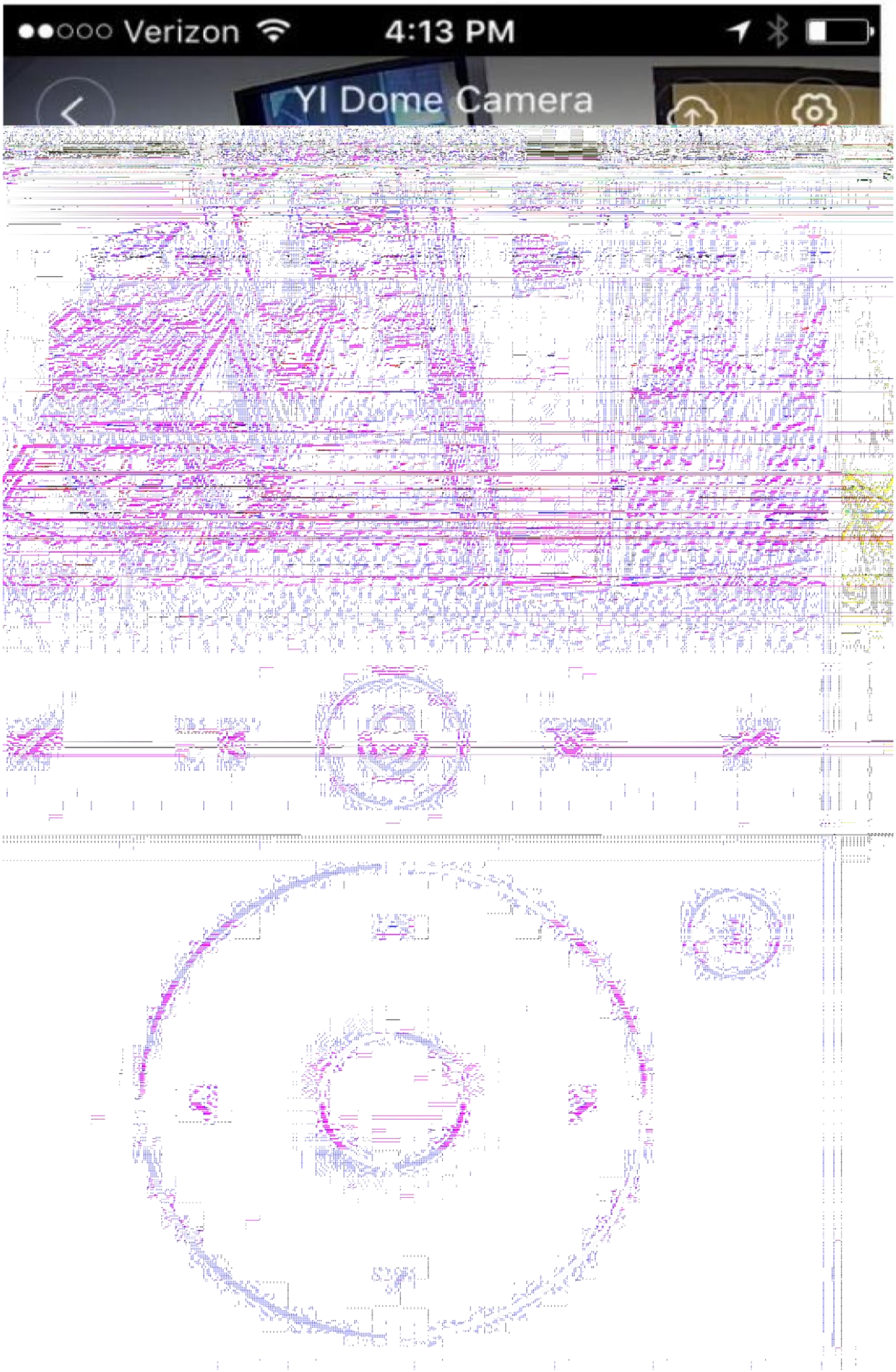

Figure 7: **Wireless Camera Image as Captured with YI IoT Camera App**

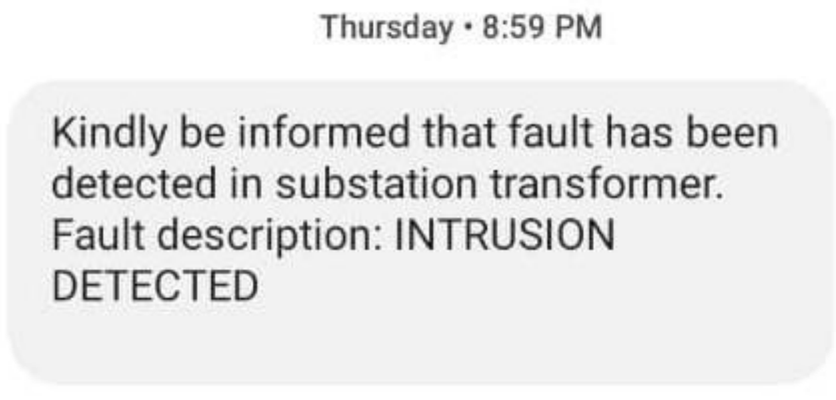

Figure 8: SMS notification from the GSM Module

Figure 9: Intrusion Detection showing on the LCD

Figure 10: Email Communication from the substation to the personnel on duty.

IV. Discussion

The results obtained from the comprehensive testing of the GSM-based Distribution Transformer Monitoring System using the ATMEGA328P microcontroller reveal a promising and robust solution for efficient distribution substation monitoring and control. The results displayed in Figures 4, 5 and 6 indicate the system's efficiency in monitoring of intrusion. The incorporation of an ultrasonic sensor for intrusion detection is a valuable addition to substation security. The system efficiently detected intruders when objects or individuals approached within 50cm of the sensor, as shown in Figure 4. This capability enhances the overall security of the substation, reducing the risk of unauthorized access.

The second objective involved integrating GSM communication for remote monitoring of vicinity of the substation. The system successfully achieved this objective by sending SMS notifications to the substation manager whenever a fault was detected, as displayed in Figures 5 and 8. The system also communicates the substation manager or personnel on duty via email as shown in figure 10. The intruder that is detected is being captured via the wireless camera android App (YI IoT App) as shown in figure 7. This remote monitoring capability ensures timely responses to critical situations, enhancing overall system reliability.
Figure 6 shows the hardware implementation of the system where IP camera is mounted to be used to capture the image of any intruder. The system also displays the intruder detection on the LCD as shown in figure 9.

V. Conclusion

In conclusion, the GSM-based Distribution Transformer Monitoring System using the ATMEGA328P microcontroller has met and exceeded the defined research objectives. It effectively monitors the presence of intruder and integrates IoT features. The system has demonstrated its ability to monitor a distribution substation using GSM and IoT technologies. The system has also communicated with the substation manager and updated the online dashboard in real time. The system has also incorporated a wireless camera that can be controlled remotely to monitor the substation vicinity and detect intruders. The system has shown high accuracy, reliability and efficiency in performing its functions.

VI. Recommendation

Other sensors can be used with this system to check transformer parameters like voltage, current, frequency, temperature, gas, oil level, oil quality, humidity and pressure to prevent transformer failures, which helps in the routine maintenance, protection of distribution transformers and effective service delivery.

References

[1]. Desai, P.K., and Hasabe, A. M. (2016): Distribution Transformer Placement in Radial Distribution Systems. Renewable and Sustainable Energy. *Reviews, 60, 1009-1030*.

[2]. Dhobale, S. V., Kolekar, S. K., Wani, M. A., & Vanjale, A. V. (2018). RF-Based Distribution Transformer Monitoring System. *International Journal of Computer Applications, 182(19):24-30.*

[3]. Dubey, R. K., Singh, S.N., and Kumar, P. (2013): Power distribution system planning and optimization: A Review. *International Journal of Electrical Power and Energy Systems*, 47, 246-265.

[4]. George, R., Kumar, S. S., and Sivanagaraju, S. (2018): Optimal Placement and Sizing of Distribution

[5]. Transformers using Particle Swarm Optimization Algorithm. *International Journal of Electrical Power and Energy Systems, 101, 253-261.*

[6]. Jawale, M. S., Deorankar, S. V., & Chitodkar, M. V. (2019). Arduino based protection and monitoring of transformer. *International Journal of Computer Science and Information Security, 17(5):1-5.*

[7]. Jenifer, P., Manimaran, V., Priyanka, M., & Kumar, N. P. (2018). Monitoring and protection of distribution transformers using GSM module. *International Journal of Innovative Technology and Exploring Engineering, 7(6), 277-280.*

[8]. Kepa, D., Alonso, J. A., & Sainz, J. (2020). An intelligent system for monitoring and protection of substation transformers using machine learning techniques. IEEE *Transactions on Smart Grid, 11(5), 3752-3761.*

[9]. Loko, J. (2015). Substation transformer monitoring and protection system using wireless sensor networks. *International Journal of Advanced Science and Technology, 82, 1-9.*

[10]. Mehta, N.B., and Mehta, P. K (2002). Energy Economics: Concepts, Theories, and Empirical Evidence. Academic Press.

[11]. Momoh, J.O., Omoigui, L.O., and Adewuyi, O. B. (2018). Energy poverty in Nigeria: Causes, Impacts, and Policy Options. *International Journal of Electrical Power and Energy, 145, 79-88*.

[12]. Naseem, M., & Alam, S. (2015). An Arduino based transformer protection system. *International Journal of Computer Applications, 110(14), 14-18.*

[13]. Ojo, O. A., Akinola, O. O., & Olapade, O. O. (2022). Substation transformer monitoring and protection using Internet of Things (IoT). *International Journal of Electrical Power & Energy Systems, 137, 107823.*

[14]. Priyanka, J., Satya, P., Himaja, P., & Eswararao, S. (2018). Design and implementation of real-time transformer health monitoring system using Raspberry Pi. *International Journal of Electrical and Computer Engineering (IJECE), 8(2), 837-846.*

[15]. Pustaraj, M., Mohanty, S., Behera, D., Sahoo, P., Sahoo, S., & Kar, S. K. (2019). IoT based distribution transformer monitoring and controlling system. *International Journal of Innovative Technology and Exploring Engineering, 8(7), 3393-3399.*

[16]. Sanjeeya, B.L., Kumar, B. S., and Kumar, M. G (2018): Optimal sizing and placement of distribution transformers considering reliability constraints. *International Journal of Electrical Power and Energy Systems, 99, 228-239*.

[17]. Sukumar, S., Kamal, R., & Usharani, R. (2018). Power transformer protection using microcontroller in embedded system. *International Journal of Computer Science and Information Technologies, 9(3), 3187-3190.*

[18]. Suma, M., and Aprameya, H. R. (2019). Condition monitoring of distribution transformer with prepaid energy meter using IoT. *International Journal of Innovative Research in Science, Engineering and Technology, 8(6), 10671-10676.*