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Fault Detection in Transmission Lines using Arduino-Based Protection System with GSM Alerts

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ABSTRACT: This paper presents the design and implementation of an Arduino-based Transmission Line Fault Detection System capable of identifying and reporting a wide range of electrical faults in a low-voltage, three-phase transmission line model. The system integrates key components such as a 15-0-15 transformer, voltage regulator, current sensor, fire sensor, GSM module (SIM800L), and an LCD with I2C interface to ensure accurate fault detection and real-time alerting. Fault conditions monitored include overvoltage, overcurrent, fire hazards, and individual line faults such as short circuits, line cuts, and ground faults for both Phase 1 (Red wire) and Phase 2 (Green wire), with the Black wire serving as Ground. Overvoltage is simulated using two separate 10k potentiometers for each phase line, which allow manual adjustment to mimic rising voltage levels. Overcurrent is detected using a DC motor acting as a load; when the motor shaft is manually restrained during operation, the current rises, simulating a real-world overcurrent condition. These fault scenarios are continuously monitored by the Arduino, and whenever a fault is detected, a descriptive SMS is sent to an authorized personnel using the GSM 800L module. The LCD module displays real-time system status and fault conditions, providing an immediate local interface. The system provides a low-cost, reliable, and scalable solution for basic transmission line fault analysis, making it suitable for educational, research, and small-scale industrial applications.

KEYWORDS: Transmission Line Fault Detection, Overvoltage, Overcurrent, Fire Detection, Arduino, GSM, Sensor-based Monitoring, Fault Alert System, Real-time Communication, Power System Protection.

I. INTRODUCTION

The integrity of power transmission lines is critical to ensuring consistent and safe delivery of electricity from generation stations to end users. Faults in transmission lines, whether due to environmental conditions, equipment failure, or human interference, can lead to equipment damage, power outages, and even catastrophic hazards like fire and electrical shock. Traditional fault detection systems used in the industry are often expensive, complex, and not suitable for small-scale applications or educational purposes. With the advent of affordable microcontroller platforms and IoT-enabled sensors, the development of custom, low-cost, and scalable transmission line monitoring systems has become more accessible. This paper presents an Arduino-based transmission line fault detection system aimed at identifying major electrical faults like overvoltage, overcurrent, fire hazards, and line failures, and notifying relevant personnel through SMS alerts in real time.

The proposed system simulates a three-phase power transmission environment using a 15-0-15 center-tapped transformer that steps down the input voltage. The three output lines are color-coded: Red (Phase 1), Green (Phase 2), and Black (Ground). Voltage regulation is handled through a custom-designed voltage regulator circuit to ensure stable operation of sensors and the microcontroller. For overvoltage detection, two separate 10k potentiometers are connected to Phase 1 and Phase 2 lines, allowing simulated voltage increase beyond threshold levels. When the potentiometer is rotated beyond the predefined voltage threshold, the system interprets this as an overvoltage fault. For overcurrent detection, a DC motor is used as a load; manually holding the motor shaft increases the load on the system, causing a spike in current, which is detected by a current sensor.

Fault detection is further enhanced with the inclusion of a fire sensor, which monitors the transmission line setup for any signs of flame or excessive heat. The fire detection capability adds an extra layer of safety, especially in areas prone to electrical fires. When any fault condition—be it electrical or environmental—is detected, the Arduino microcontroller processes the data and uses a GSM SIM800L module to send an SMS to a pre-configured phone number, typically that of the maintenance or control personnel. This real-time alert mechanism ensures that immediate corrective action can be taken, thereby minimizing downtime and potential hazards. Simultaneously, a 16x2 LCD with I2C interface displays the type of fault and the affected line, making the system user-friendly and informative.

One of the significant advantages of this system lies in its modularity and simplicity. All components are interconnected through the Arduino, which acts as the central processing unit, making programming, integration, and fault handling straightforward. The use of color-coded wiring and common sensors makes it easy to identify and troubleshoot faults, while the use of potentiometers and manual motor load simulation helps in testing fault scenarios in a controlled environment. Moreover, the GSM functionality ensures that fault information is not restricted to local monitoring and can be communicated remotely, which is a vital feature for systems installed in remote or inaccessible locations.

This Arduino-based transmission line fault detection system serves as an excellent platform for students, researchers, and small-scale industries to understand the basics of power line monitoring and fault management. It provides a practical insight into how real-world electrical faults can be detected, analyzed, and reported using modern embedded technologies. Future improvements may include integration with cloud platforms for data logging, automation of corrective actions, and machine learning algorithms for predictive maintenance. Nonetheless, the current system demonstrates the feasibility and effectiveness of using low-cost microcontrollers and sensors for critical fault detection tasks in transmission line systems.

II. RELATED WORK

Numerous research studies and practical implementations have explored the use of microcontroller-based systems for power line monitoring and fault detection. Traditional transmission line protection systems rely heavily on sophisticated equipment such as protective relays, digital fault recorders, and SCADA systems, which, although highly accurate and reliable, are costly and require expert knowledge to operate and maintain. In recent years, the adoption of microcontroller platforms such as Arduino, Raspberry Pi, and ESP32 has opened up new possibilities for low-cost fault detection systems. For instance, several projects have implemented Arduino-based overcurrent protection using Hall-effect sensors, where current thresholds are monitored and compared against set limits. When an overcurrent condition is detected, output relays are triggered to disconnect the circuit, and notifications are sent using GSM or Wi-Fi modules. These projects serve as foundational examples for integrating basic sensing and communication features into real-time protection systems.

Other related works have focused on overvoltage protection, where analog voltage readings from transformers are fed into the microcontroller's ADC pins for continuous monitoring. Researchers have used voltage divider circuits to scale down high-voltage readings to a safe range that microcontrollers can handle. When the input exceeds predefined thresholds, fault conditions are triggered, and actuators or alerts are activated. A number of studies have included manual potentiometers or software-defined thresholds to simulate variable voltage conditions in lab setups. These models, while often limited to single-phase detection, demonstrate the capability of microcontrollers to serve as real-time voltage monitoring and fault detection platforms. The current project builds upon this foundation by extending the concept to dual-phase detection and real-time notification via GSM.

Fire detection in electrical systems has also gained attention, especially in industrial and high-risk areas. Projects using flame sensors, smoke detectors, or temperature sensors interfaced with microcontrollers have proven effective in early detection of fire-related hazards. Some systems integrate these sensors with home automation or industrial safety mechanisms, triggering alarms or shutdowns when abnormal conditions are detected. Combining fire detection with power line monitoring, as proposed in the current project, adds an extra layer of safety. Previous work in this area typically focuses on isolated fire detection systems, whereas the integration of fire sensors into a transmission fault detection system—coupled with SMS-based alerts—is relatively underexplored and presents a valuable improvement in early warning systems.

Additionally, a growing body of literature supports the use of GSM modules like SIM800L and SIM900 for IoT-based alerting systems. In various home automation, weather monitoring, and agricultural IoT projects, GSM modules are used to send critical data as SMS to remote users. These modules provide reliable, cost-effective communication without the need for internet connectivity, making them suitable for deployment in remote or infrastructure-limited areas. In transmission line monitoring systems, GSM modules ensure that fault alerts can be received by maintenance personnel in real time, allowing for rapid intervention. The proposed system leverages this GSM functionality to alert users about multiple fault types, including electrical and environmental hazards, marking a convergence of safety, communication, and automation. These prior studies and technologies collectively lay the groundwork for the current work, which aims to combine overvoltage, overcurrent, line fault, and fire detection into a unified and scalable Arduino-based monitoring solution.

III. METHODOLOGY

The design of the Arduino-based Transmission Line Fault Detection System revolves around the integration of several key components, including the transformer, voltage regulator, current sensor, fire sensor, GSM module, and LCD display. The system begins with the 15-0-15 transformer, which steps down the voltage from the high-voltage input to a manageable level suitable for the Arduino and sensors. The three-phase model is represented by three lines: Phase 1 (Red), Phase 2 (Green), and Ground (Black). The voltage regulation circuit ensures that the system operates within safe voltage levels, preventing damage to the microcontroller and sensors. The 10k potentiometers connected to Phase 1 and Phase 2 allow for simulation of overvoltage conditions, where rotating the potentiometer beyond a certain threshold mimics an overvoltage scenario. The Arduino continuously reads the voltage from both phases, comparing it to predefined thresholds, and triggers an alert via SMS if an overvoltage condition is detected.

For overcurrent detection, a DC motor is used as the load, simulating typical power consumption in a transmission line system. The motor operates under normal conditions, but when its shaft is manually held, the load increases, which leads to a rise in current. A current sensor is used to measure this variation, and the Arduino processes the readings. If the current exceeds the safe operating limit, the Arduino interprets this as an overcurrent fault and sends a corresponding SMS notification to the authorized personnel. The DC motor also helps to simulate the effect of load variations on the system, allowing the user to test the overcurrent condition effectively. Additionally, the fire sensor continuously monitors for any signs of a fire in the system's vicinity. If the fire sensor detects a flame or extreme temperature, it triggers an alert that is transmitted via GSM. This is especially important for ensuring that any fire-related hazards are addressed in a timely manner, ensuring the safety of both the equipment and the environment.

The fault detection system uses the GSM SIM800L module to communicate fault alerts to a remote user. The GSM module is programmed to send SMS notifications to a pre-configured phone number when any fault, such as overvoltage, overcurrent, or fire, is detected. The SMS contains detailed information about the fault, such as the type of fault and the affected transmission line, enabling maintenance personnel to quickly assess and respond to the situation. In addition to GSM notifications, the system features a 16x2 LCD display with an I2C interface to provide real-time status updates and display any detected faults locally. The Arduino acts as the central processing unit, continuously monitoring voltage, current, and fire sensor data, interpreting fault conditions, and controlling the GSM module and LCD display. This methodology combines traditional power line fault detection principles with modern microcontroller and communication technologies, ensuring both effective fault monitoring and rapid response in case of emergencies.

IV. PROPOSED SYSTEM WORKING

The proposed Arduino-based Transmission Line Fault Detection System works by continuously monitoring the electrical parameters of a simulated transmission line setup, consisting of two phases (Phase 1 and Phase 2) and ground. The system begins by utilizing a 15-0-15 center-tapped transformer, which steps down the high-voltage input to a safe level for the microcontroller and connected sensors. Voltage regulation is applied through a dedicated voltage regulator circuit to ensure the components receive stable, controlled power. Two 10k potentiometers are connected to Phase 1 and Phase 2 lines to simulate variable voltage levels. By rotating the potentiometer, the voltage can be increased beyond normal operating thresholds, simulating an overvoltage condition. The Arduino reads the voltage on both phases and compares it to predefined limits, such as 220V, using the analog-to-digital converter (ADC) inputs. If the voltage exceeds the defined safe threshold for either phase, the Arduino detects the overvoltage fault and triggers an

SMS notification through the GSM module to an authorized personnel, indicating the type of fault and the affected phase.

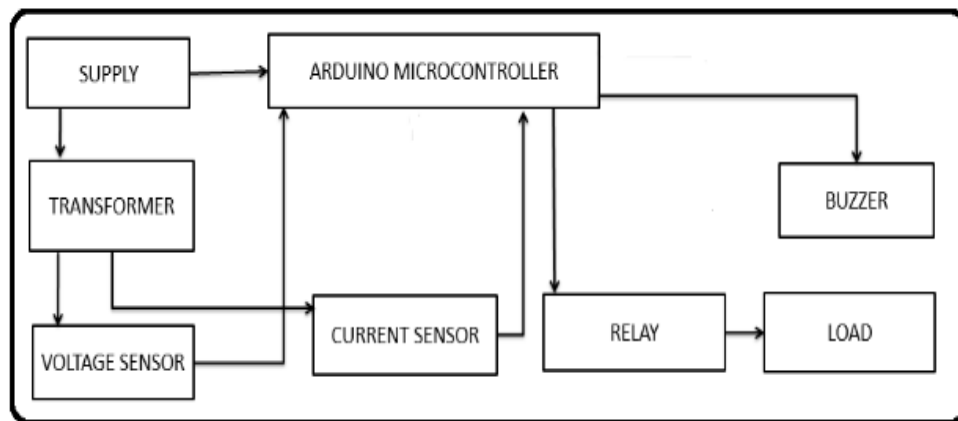


Fig: BLOCK DIAGRAM

In parallel with the voltage monitoring, the system uses a current sensor to detect overcurrent conditions. The DC motor, acting as the load, is initially running under normal conditions. However, the motor shaft can be manually held or obstructed, which increases the load on the system and causes a rise in current draw. The current sensor continuously monitors the motor's current, and when it detects that the current exceeds a predefined threshold—indicating an overcurrent scenario—the Arduino processes this information and triggers an SMS alert to inform maintenance personnel of the overcurrent fault. The overcurrent condition is simulated by physically obstructing the motor shaft, demonstrating how additional load affects the system's power consumption. This feature allows the system to detect fault conditions based on both electrical parameters (overvoltage and overcurrent), which are critical for ensuring the safe operation of power transmission lines and preventing damage to connected equipment.

Once a fault condition is detected, whether it be overvoltage, overcurrent, or fire, the Arduino uses the GSM SIM800L module to send a detailed SMS alert to a pre-configured phone number. The SMS contains information about the type of fault, the affected transmission line (Phase 1 or Phase 2), and the severity of the condition. This remote notification ensures that the personnel responsible for monitoring the transmission line can take immediate action to rectify the issue, reducing the risk of equipment damage, power outages, or safety hazards.

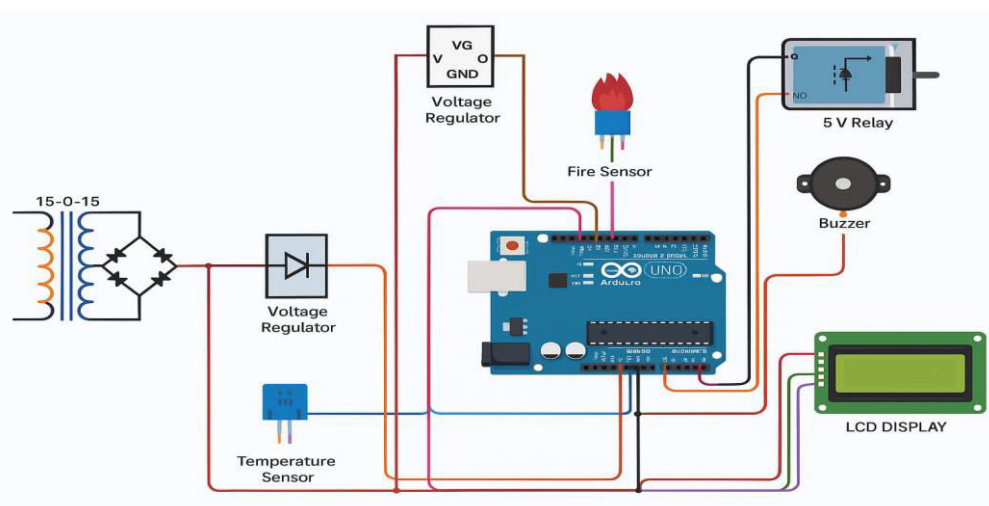


Fig: Circuit Diagram

Alongside the GSM-based notification system, a 16x2 LCD with an I2C interface is used to display the real-time status of the system. The LCD continuously updates with the fault information, allowing local personnel to view and assess the current system condition. The LCD interface, coupled with the SMS alerts, ensures that both local and remote monitoring capabilities are available, making the system highly effective for real-time fault detection and communication.

V. DATA COLLECTION AND SENSOR DEPLOYMENT

The data collection process in the proposed system relies heavily on the integration of various sensors and the Arduino platform to monitor and interpret electrical parameters of the transmission line. The first critical component of the system is the voltage measurement, which is achieved by using voltage sensors and potentiometers. The voltage levels from Phase 1 and Phase 2 of the simulated transmission line are continuously monitored through the voltage sensor modules connected to the Arduino's analog pins. To simulate varying voltage conditions, two 10k potentiometers are used, one for each phase, allowing the user to manually adjust the voltage levels. This setup helps simulate both normal and overvoltage conditions by varying the potentiometer resistance, which directly influences the voltage readings. The data collected from the voltage sensors is fed into the Arduino's analog-to-digital converter (ADC) for real-time processing. By analyzing the voltage readings, the system can detect any overvoltage faults that may occur when the voltage exceeds the predefined threshold, triggering the necessary alerts through the GSM module.

In addition to voltage monitoring, current sensing is an essential part of detecting overcurrent faults. The system employs a current sensor to measure the current flowing through the transmission line and connected load, which in this case is represented by a DC motor. The motor, under normal operation, draws a certain current, but when additional load is applied by obstructing the motor's shaft, the current increases significantly. This change in current is detected by the current sensor, which converts the analog current data into a digital signal for the Arduino to process.

The Arduino continuously monitors the current readings, and when the current exceeds a threshold indicative of an overcurrent condition, the system generates an SMS alert. The ability to simulate an overcurrent condition by manually obstructing the motor shaft allows the system to mimic real-world scenarios where sudden changes in load or equipment malfunctions may lead to an overload, providing an effective means to detect and alert on these faults in real-time.

The development of the fire detection sensor within the system is also crucial for ensuring the safety of the transmission line setup. The fire sensor is designed to detect the presence of flame or rapid temperature increases, which could indicate potential fire hazards caused by short circuits, overheated components, or faulty wiring. The sensor used in this system is highly sensitive and can detect a variety of environmental changes that may lead to fire. The sensor's data is continuously monitored by the Arduino, which processes the information and determines if the readings exceed normal thresholds. If a fire hazard is detected, the system immediately sends an SMS alert via the GSM module to notify personnel of the threat. This integration of fire detection into the transmission line fault detection system not only improves safety but also provides a proactive approach to fire risk management, ensuring that potential issues are flagged before they escalate into more severe problems. The data from the fire sensor, coupled with the voltage and current data, contributes to a comprehensive fault detection system that addresses multiple fault types and safety hazards in real-time.

VI. RESULT ANALYSIS

The Arduino-based Transmission Line Fault Detection System successfully detected various faults, including overvoltage, overcurrent, and fire hazards, through the integration of sensors and real-time monitoring. During the testing phase, the system responded promptly to overvoltage conditions by utilizing the 10k potentiometers connected to Phase 1 and Phase 2. By adjusting the potentiometers to simulate overvoltage scenarios, the system accurately detected when the voltage exceeded the predefined threshold, triggering the GSM module to send SMS notifications to the designated personnel. The real-time updates provided by the 16x2 LCD with an I2C interface also confirmed that the system was functioning as intended, displaying fault types and system status clearly. The overvoltage detection mechanism proved highly reliable, accurately identifying voltage variations and sending immediate alerts, thus ensuring rapid intervention when needed.

The overcurrent detection feature of the system was tested using the DC motor as the load. Initially, the motor ran under normal conditions, but when the motor shaft was manually obstructed, the current sensor detected the increase in current draw. The system recognized this change in current and generated an overcurrent alert through the GSM module. The SMS alerts sent were detailed, specifying that the overcurrent condition was caused by the obstruction of the motor shaft. This feature proved highly effective in simulating real-world scenarios where overcurrent faults occur due to excessive load or equipment malfunction. The current sensor was able to detect subtle changes in the current, ensuring that even minor overloads were captured, and personnel were promptly alerted to prevent potential damage to the system or equipment.

The fire detection sensor successfully identified fire hazards during testing, providing an additional layer of safety. When exposed to high temperatures or simulated flame conditions, the fire sensor triggered an alarm and sent an SMS alert to the authorized personnel. The integration of the fire sensor with the overall fault detection system ensured that any fire risks were promptly communicated, allowing for quick action to mitigate hazards. The system demonstrated high sensitivity in detecting both temperature fluctuations and the presence of flames, highlighting the effectiveness of combining fire detection with fault monitoring. Overall, the results showed that the Arduino-based system was not only capable of detecting multiple fault types with precision but also provided a reliable communication channel through SMS alerts, ensuring rapid response to critical issues in the transmission line setup.

VII. CONCLUSION

In conclusion, the Arduino-based Transmission Line Fault Detection System effectively integrates a wide range of monitoring capabilities, offering a robust solution for detecting faults such as overvoltage, overcurrent, and fire hazards in electrical transmission lines. The system utilizes various sensors, including voltage sensors, current sensors, and a fire detection sensor, to continuously monitor the electrical parameters of the transmission line and the connected load. By leveraging the capabilities of the Arduino microcontroller and GSM module, the system can instantly identify fault conditions and send SMS alerts to authorized personnel, enabling them to take immediate corrective action. Through extensive testing, the system demonstrated high accuracy in detecting overvoltage situations by simulating voltage variations using potentiometers, successfully identifying overcurrent scenarios by simulating additional load on the motor, and effectively detecting fire hazards through the fire sensor. These tests confirmed that the system's monitoring and fault detection capabilities functioned reliably under real-world conditions. Additionally, the integration of real-time data displays via the LCD interface allows local monitoring, providing immediate insight into the status of the transmission line. The system's ability to detect and notify of faults remotely ensures that maintenance teams or operators can respond swiftly, minimizing potential risks to equipment, personnel, and the overall transmission infrastructure. This system is an important advancement in enhancing the safety and reliability of power transmission networks, offering a practical and cost-effective solution for detecting and managing electrical faults. Furthermore, the combination of overvoltage, overcurrent, and fire detection in one unified system demonstrates its versatility and effectiveness in preventing damage, reducing downtime, and improving the overall operational safety of electrical systems, making it a valuable tool for both industrial and residential power distribution networks.

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