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Arduino based Transmission Line Fault Detection System

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Abstract: Transmission line fault detection is a critical aspect of modern power systems to ensure reliability, safety, and uninterrupted power supply. Transmission lines are a critical, yet highly exposed and vulnerable, component of the power system. The reliability of power delivery largely depends on their fault-free operation. Hence, it is essential to develop a reliable fault detection and classification approach using digital relaying systems to accurately differentiate between healthy and faulty phases, isolate affected sections from the grid, and enable rapid restoration. This review presents a comprehensive analysis of various signal processing techniques used for extracting features from fault signals in transmission lines integrated with FACTS devices, including scenarios involving cross-country and evolving faults. It also examines different fault classification methods in terms of their accuracy, memory requirements, computational efficiency, ability to capture long-term dependencies, susceptibility to vanishing gradient issues, and effectiveness of their receptive fields. This paper presents a Transmission Line Fault Detection System based on real-time monitoring of voltage and current parameters using sensors, microcontroller-based logic, protective relays, and communication modules. The proposed system detects, classifies, and isolates faults such as single line-to-ground, line-to-line, double line-to-ground and three-phase faults.
Keywords: Transmission Line, Fault Detection, Smart Grid, Microcontroller, Protective Relay.

I. INTRODUCTION

With the more improvement and technical developments, this concept can be put in the market. The Electrical Fault Detection in Transmission Line system is very convenient system for that consumers.Regarding to the distribution system, transmission lines perform the most important part that is to transfer electric power from the generating station to load centers. Since the development of the distribution and transmission system, power system engineers have been an object for locating and detecting faults. As long as the fault detected in short duration, it provides a good service for protecting the apparatus as well as an open way for disconnecting the part where this incident happened at fault, and with the help of this, it gives safe way to the system from any damages. So itis needed to detect the fault otherwise due to fault it causes any disturbance which further tough time to the interconnected system that based on limitations. The structure of the transmission line constructed to investigate the location of the fault and can give separation only the part where the fault occurs. Stimulating method help in identify and isolate the fault in short period. Suppose when more than two conductors develop contact each other or with the contact take place on the groundto 3 phase systems that are considered at fault which could be a balanced fault or unbalanced fault. Due to these faults stresses are produced in power system equipment that could damage the power system components. So to avoid these harms and to make power quality better, it is essential to know the reasons of fault as well as the location of the transmission lines and solve it properly.

Modern electrical power systems are continuously expanding in scale, leading to increased complexity across generation, transmission, distribution, and load sectors, particularly due to the integration of renewable energy sources into existing grids. Faults within the power system result in both technical disruptions and economic losses, ultimately reducing overall system reliability. These faults can arise in various forms, including short circuits, transient disturbances, lightning strikes, fire incidents, snow, and wind effects, all of which can significantly degrade performance and, in severe cases, cause total system failure.

To ensure system security, rapid detection and accurate classification of faults are essential, especially as power systems are expected to operate continuously at high capacity. Faults in transmission lines are broadly categorized into series and shunt types. Among these, unsymmetrical faults are more frequently encountered, although they are generally less severe than symmetrical faults. Common unsymmetrical faults include Line-to-Ground (LG), Line-to-Line (LL), and Double Line-to-Ground (LLG) faults. Studies indicate that LG faults are the most prevalent, accounting for approximately 65–70% of all transmission line faults, while LLG faults contribute around 15–20%.

Environmental factors such as strong wind forces can cause conductors to sway and come into contact, leading to line-to-line faults. These are also referred to as unbalanced faults because they create unequal currents in the phases due to differences in impedance.

Protective relays must operate with high speed and precision to detect and accurately locate faults, thereby maintaining system reliability and power quality. If faults are not identified and cleared promptly, and the system is not restored to normal operation in time, power quality deteriorates. Interruptions caused by faults can lead to significant financial and operational losses, along with potential damage to sensitive and high-value consumer equipment.

The extent of damage is largely influenced by the duration of the fault and the response time of the protection system. Protective relays, functioning as intelligent devices, respond when current levels exceed predefined limits and act within milliseconds to safeguard the system. Modern digital relays, which utilize advanced signal processing methods, offer superior performance compared to conventional relays. Studies indicate that traditional protection schemes are less efficient and lag behind digital relays in terms of speed, accuracy, and overall effectiveness.

II. PROJECT OBJECTIVE

The primary goal of a transmission system is to ensure the availability of multiple pathways between generators and loads, so that the loss of a single transmission line does not interrupt power supply.A short circuit produces an unsymmetrical current, meaning the current does not remain constant in magnitude and reduces progressively over successive cycles of the power system. This phenomenon is referred to as an asymmetrical fault condition. Identifying and locating faults in transmission lines is essential for effective protection and maintenance of the power system. Various fault detection and location techniques rely on voltage measurements obtained through current and voltage transformers.

III. BLOCKDIAGRAM AND WORKING

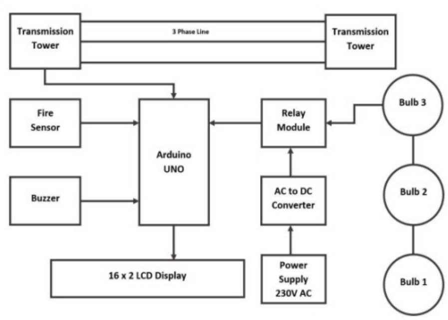

Fig. 1. Block Diagram of Transmission Line Fault Detection System

AnArduino-based system forfaultdetectioninoverheadtransmissionlines typicallyinvolvesthe use of sensors to monitor parameters such as current, voltage,and temperaturealong the line as shown in Fig.1. Themethodology begins with the installation of sensors at strategic points along the transmission line to continuously collect data.The collected data is then processed by the Arduino microcontroller using algorithms designed to detect abnormal patterns indicative of faults, such as short circuits or line breaks. Upon detecting a fault, the system triggers alerts or initiates appropriate actions, such as isolating the faulty section or notifying maintenance personnel.Additionally,machinelearning techniquescan beemployedto improvefaultdetection accuracy by analyzing historical data and identifying patterns associated with different fault types. Overall, the Arduino-based approach offers a cost-effectiveandcustomizablesolutionforenhancingthereliabilityandefficiencyofoverheadtransmissionlineoperations.

The system operates using a 230V AC supply from the mains. This alternating current is fed into an AC to DC converter, which converts it into a regulated DC voltage suitable for electronic components. The regulated DC output is then used to power the Arduino UNO, the relay module, the fire sensor, and the LCD display, ensuring stable and reliable operation of the entire system.

A three-phase transmission line is depicted between two transmission towers in the system. The three bulbs: Bulb 1, Bulb 2, and Bulb 3, symbolize the loads connected to each of the three phases. During normal operating conditions, power is supplied evenly across all phases, allowing all the bulbs to glow properly and indicate balanced operation of the transmission line.

A fire sensor is installed near the transmission line to continuously monitor for unsafe conditions. If fire, excessive heat, or sparking occurs in the vicinity of the line, the sensor detects the presence of heat or flame. Upon detection, it immediately sends a signal to the Arduino UNO, enabling the system to take appropriate protective action.

Table 1. Model Component Details

S. No.	Component Name	Component Description
1	Microcontroller (Arduino / 8051 / PIC)	Processes sensor data and executes fault detection and classification logic
2	Current Sensor	Measures line current to detect abnormal fault conditions
3	Voltage Sensor	Monitors transmission line voltage variations
4	Protective Relay	Isolates the faulty section of the transmission line
5	GSM / IoT Module	Sends fault information to the control center in real time
6	Power Supply Unit	Provides regulated power to all system components

The Arduino UNO functions as the central control unit, or the brain, of the entire system. It continuously monitors input signals from the fire sensor and any other fault-detection components that may be programmed into the system. When it detects an abnormal condition, such as fire or overheating, it immediately processes the signal and initiates protective actions. The Arduino sends a control signal to the relay module to disconnect the affected line or load, activates the buzzer to provide an audible alarm, and displays an appropriate fault message on the 16×2 LCD display to inform users about the detected issue.

The relay module is installed between the power supply and the bulbs that represent the loads. It acts as a switching device controlled by the Arduino UNO. When the Arduino detects a fault condition, such as fire or overheating, it sends a signal to energize or de-energize the relay. As a result, the relay interrupts the power supply to the affected load, effectively isolating it from the system. This action helps prevent further damage to the transmission line and ensures the safety of the overall setup as shown in Fig.2.

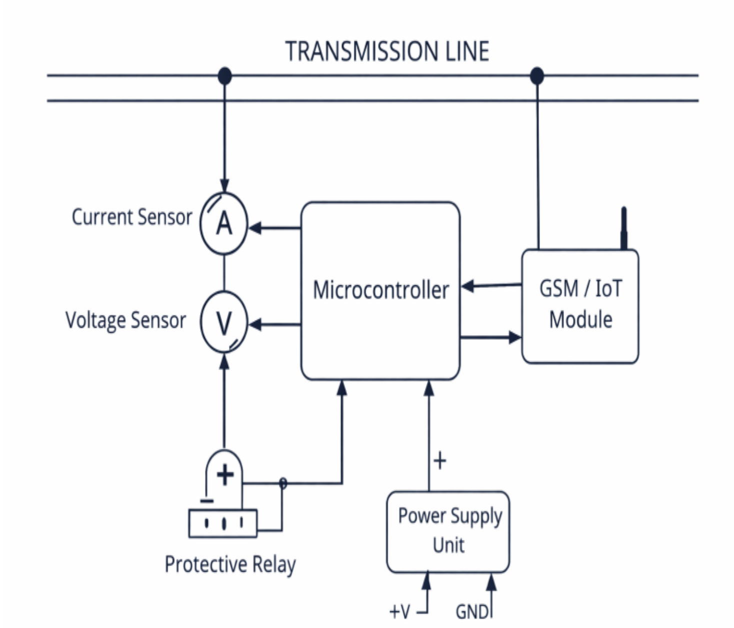

Fig. 2. Schematic Diagram for Transmission fault detection

The buzzer and the 16×2 LCD display together form the alert and information system of the project shown in Fig.3. The buzzer provides an immediate audible warning whenever a fault condition, such as fire or overheating, is detected. This sound alert ensures that people nearby are instantly aware of the abnormal situation, even if they are not directly observing the system. At the same time, the 16×2 LCD display presents clear and specific status messages to inform users about the system's condition. Under normal operating circumstances, the display shows a message such as "System Normal," indicating that the transmission line and connected loads are functioning properly. If a fault occurs, the display changes to messages like "Fire Detected" or "Line Fault," clearly identifying the nature of the problem. By combining both sound and visual indications, the system ensures quick awareness, better monitoring, and effective response to emergency situations.

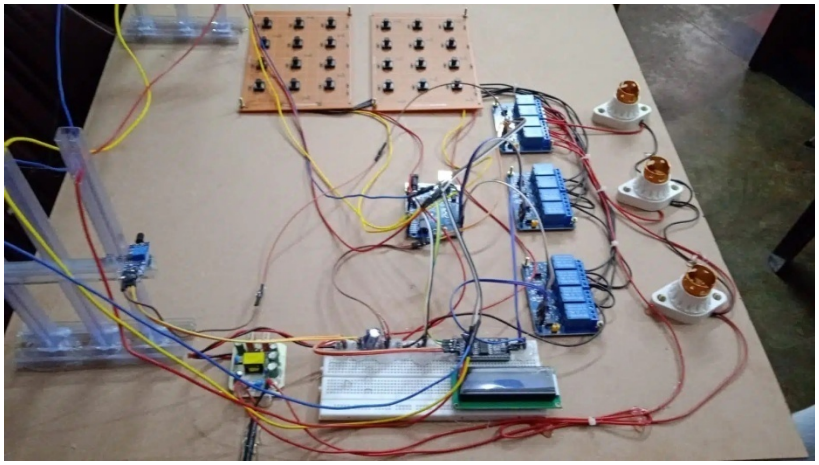

Fig.3. Three Phase Fault Detection model

IV. RESULT

Under normal operating conditions, the fire sensor remains inactive as no heat or flame is detected near the transmission line. The relay stays in the ON state, allowing power to flow to the loads, and all the bulbs glow normally, indicating proper system operation. The 16×2 LCD display shows the message "System Normal," confirming that the system is functioning safely and efficiently. However, during a fault condition such as fire or overheating, the fire sensor detects the abnormality and immediately sends a signal to the Arduino UNO. The Arduino then processes this input and responds by turning OFF the relay to disconnect the transmission line from the power supply. Simultaneously, it activates the buzzer to provide an audible warning and displays an appropriate alert message on the LCD, informing users about the detected fault.

Fig.4. Single Line to Ground Fault Detection

V. CONCLUSION

In conclusion, locating a short circuit fault at a specific distance along the transmission line is essential for addressing the problem quickly and effectively. Accurate identification of the fault location helps maintenance teams focus directly on the affected section, reducing unnecessary inspection along the entire line. With the assistance of the Arduino-based system, the project is capable of automatically indicating the phase involved, estimating the distance to the fault, and identifying the type or cause of the fault event. This automated monitoring and reporting significantly improves the reliability and efficiency of the power system. Precise fault location leads to faster restoration of power supply, enhanced overall system performance, reduced operational and maintenance costs, and minimized downtime in the field. By integrating sensing, processing, and alert mechanisms, the system provides a practical and cost-effective solution for modern transmission line protection and monitoring.

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