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Under Ground Power Line Fault Detection & Information System Powered by Internet of Things

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Abstract: The deployment of underground electrical cable systems has led to the development of an Arduino-based fault distance locator, addressing the unique challenges of fault detection in concealed networks. This innovative system uses current sensing circuits and digital data processing to accurately determine fault locations in kilometers by measuring variations in current with respect to resistance. Key components include a power supply unit, control unit, tripping unit, and display unit, which together enable real-time fault detection and location display on an LCD screen. This technology enhances the efficiency and reliability of urban power distribution by providing a cost-effective solution for swift fault identification and repair.

Index Terms **– LCD display, Tripping Unit, Digital Data processing**

I. INTRODUCTION

The project aims to detect the exact location of faults in underground cable lines, measured in kilometers from a base station, using an Arduino microcontroller kit. In urban areas, electrical cables are installed underground instead of overhead, presenting challenges in fault detection and repair. The proposed system leverages an Arduino microcontroller and a rectified power supply to pinpoint fault locations accurately. Current sensing circuits, designed with resistors, are interfaced with the Arduino to utilize its internal ADC for converting analog signals into digital data, representing the cable length. Fault creation is simulated using a set of switches, and relays are controlled by a relay driver. A 16x2 LCD display connected to the microcontroller shows the fault information. When a short circuit occurs, the voltage across series resistors changes, and this data is fed to the ADC. The Arduino processes this data to display the fault location in kilometers. An alarm buzzer alerts field workers to take immediate action upon fault detection.The growing need for safety and infrastructure development in densely populated urban and suburban areas has driven the shift towards underground cabling, which offers aesthetic and safety advantages over overhead lines. However, underground installations are prone to faults such as short circuits and open circuits, which are challenging to locate due to the concealed nature of the cables. This project addresses these challenges by using Ohm's Law to measure current variations relative to resistance, thereby determining the fault position. The system consists of several key units: the power supply unit, cable unit, control unit, tripping unit, and display unit. The power supply unit provides necessary power, while the cable unit features a three-phase cabling system with switches to activate faults. The control unit processes signals from the cable unit, directing the tripping and display units. The tripping unit detects the faulty phase, and the display unit shows fault characteristics and distance on the LCD, facilitating efficient fault clearance. In modern urban and suburban settings, the preference for underground cabling over traditional overhead lines is motivated by enhanced safety, improved aesthetics, and reduced environmental damage. While underground cables are less prone to weather-related issues and vandalism, they pose significant challenges in fault detection. Traditional fault location methods are labor-intensive, costly, and often require disruptive excavation work.

II. METHODOLOGY

2.1 BLOCK DIAGRAM

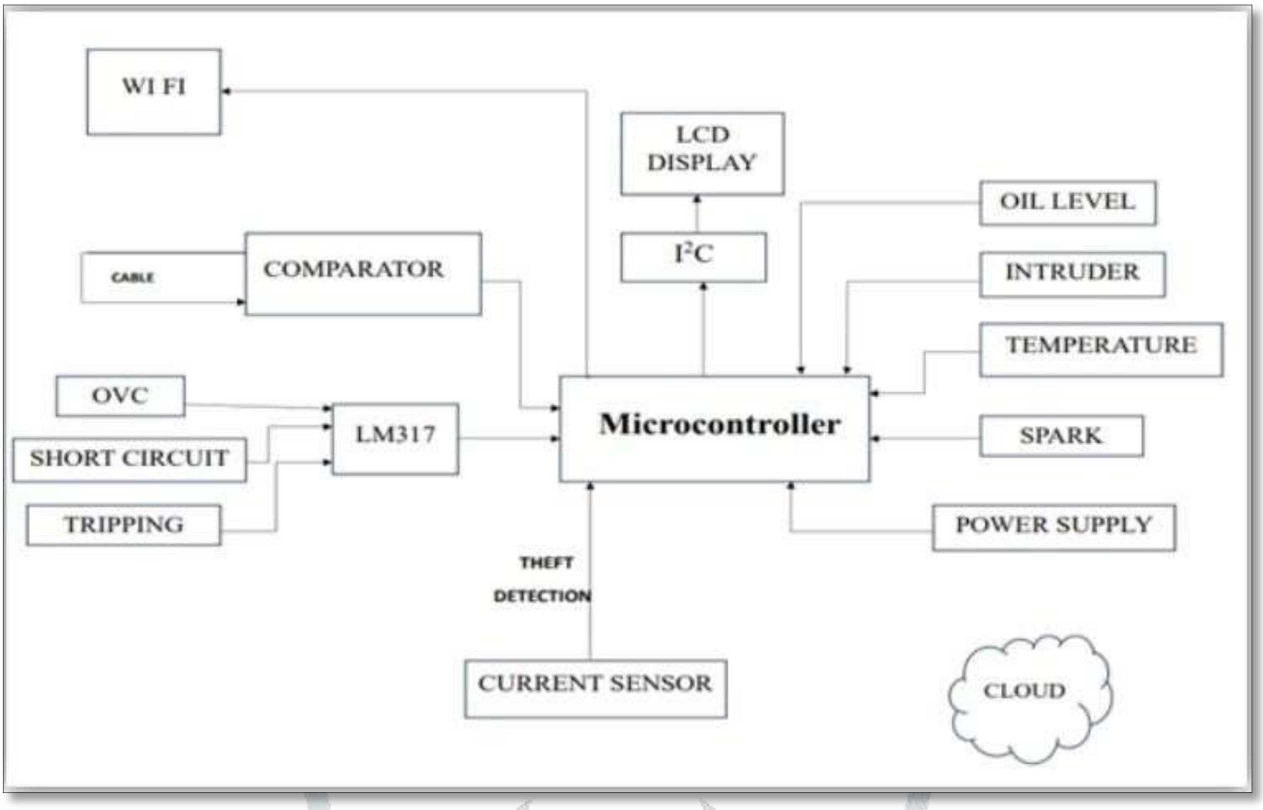

Fig 2.1.1- System Architecture

The proposed system integrates various sensors and components to monitor and control multiple parameters using the ESP8266 WiFi module. This system addresses essential parameters such as oil level, intrusion detection, temperature, spark, power supply, and theft detection. Additionally, it incorporates safety features for handling overvoltage, short circuits, and tripping. The Arduino IDE is employed for programming the ESP8266, and the Blynk IoT app facilitates remote monitoring and control, ensuring comprehensive system management and user interaction.

2.2 IMPLEMENTATION

The developed system, as illustrated in the block diagram, provides a comprehensive solution for detecting and managing various faults in underground power cables, such as open circuits, short circuits, and power theft. This integrated approach enhances the reliability and safety of power distribution networks. By continuously monitoring critical parameters, the system places a strong emphasis on transformer safety. Key parameters monitored include transformer oil level, occurrence of sparks, ambient humidity, and temperature. Monitoring these parameters is essential for preventing transformer failures and ensuring operational efficiency. The fault detection system is a crucial component of the design. It includes mechanisms for identifying open circuit faults by detecting interruptions in the circuit. Short circuit faults are identified using sensors that detect insulation failures between conductors or between conductors and the earth. For power theft detection, the system employs current sensors to monitor abnormal consumption patterns and tampering methods. By establishing a threshold level for normal power losses, such as those inherent in transformer operations, the system can trigger an alert when the current drawn exceeds this threshold, indicating potential power theft.

Components and Sensors

The system comprises several key components and sensors. At its core, the ESP8266 Wi-Fi module functions as the central processing unit, handling data from sensors, communicating with the Blynk IoT app, and executing control actions. The integrated Wi-Fi module within the ESP8266 facilitates wireless communication and data transfer. An LCD display is utilized for displaying real-time data and system status, interfaced via I²C. To monitor various parameters, the system includes a current sensor for detecting current levels, particularly for theft detection, and an LM317 voltage regulator to manage power supply and handle overvoltage conditions. A comparator is used to compare input signals to predetermined thresholds, triggering appropriate actions when necessary. Additionally, various sensors are incorporated for monitoring oil level, intrusion, temperature, and spark.

Data Collection and Processing

The data collection and processing methodology begins with continuous data acquisition by the sensors, which monitor oil level, intrusion, temperature, spark, and power supply. The collected data is then transmitted to the ESP8266 for processing. Specifically, data from the current sensor is used for theft detection. A comparator compares incoming signals with preset thresholds to identify overvoltage, short circuits, and tripping conditions. This systematic approach ensures that all relevant data is accurately collected and processed for effective monitoring and control.

Control and Monitoring

Control and monitoring are central to the system's functionality. The ESP8266 processes the data received from sensors and the comparator, making decisions based on predefined algorithms and thresholds. Real-time data and system status are displayed on the LCD, while alerts are generated for any detected anomalies, such as low oil levels, intrusions, high temperatures, sparks, or power supply issues. To ensure safety, the system includes mechanisms for handling overvoltage (OVC), short circuits, and tripping. The LM317 voltage regulator plays a crucial role in maintaining a stable power supply and activating safety measures when anomalies are detected.

Wireless Communication and Cloud Integration

Wireless communication and cloud integration are pivotal aspects of the system. The ESP8266 enables wireless communication, allowing data transmission to the Blynk IoT app. This integration with the Blynk platform facilitates remote monitoring and data analysis, enabling users to access system data and receive alerts from any location. This connectivity ensures that the system is not only locally effective but also globally accessible and manageable.

Flowchart of Arduino Algorithm

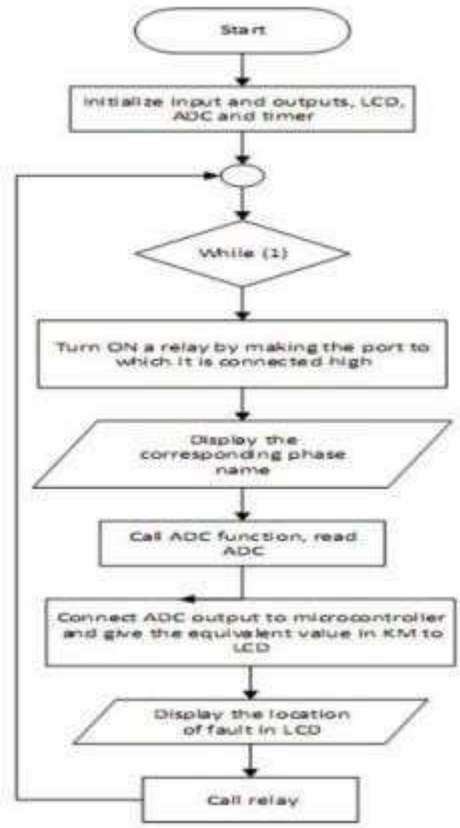

Fig 4.2: Flowchart of Arduino algorithm

The flowchart outlines the sequence of operations for detecting faults in underground power cables using an Arduino-based system:

1. Initialization: The system initializes all necessary inputs and outputs, including the LCD, ADC (Analog-to-Digital Converter), and timer.
2. Relay Activation: The microcontroller activates a relay to initiate the fault detection process.
3. Phase Monitoring: The system displays the name of the phase being monitored and reads analog signals from the sensors.
4. Fault Location: The ADC output is fed into the microcontroller, which processes the data to determine the location of any fault. The equivalent distance to the fault location is calculated and displayed on the LCD.

By integrating these components, the proposed IoT-based device provides a comprehensive monitoring and fault detection system for underground power lines and transformers. This real-time monitoring capability enhances the ability to quickly identify and rectify faults, reducing downtime and operational disruptions. The system ensures continuous and safe power supply, minimizes financial losses, and improves the overall reliability and efficiency of the power distribution network.

III. Results and Discussion

3.1 Results

The developed system was evaluated using various sensors integrated into the fault detection and transformer protection system.

- **Oil Level Detection Sensor:** This sensor monitors the oil levels in transformers using a float mechanism or ultrasonic technology, providing real-time alerts displayed on an LCD screen and through the Blynk app.

Fig 3.1.1: LCD display of oil level detection sensor

Fig 3.1.2: Blynk app display of oil level detection sensor

- **Humidity and Temperature Sensor:** These sensors measure ambient conditions inside the transformer using thermistors or capacitive sensors, displaying results on an LCD and triggering maintenance alerts as needed.

Fig 3.1.3: LCD display of humidity and temperature sensor

- **Intruder Detection Sensor:** Utilizing infrared motion detection, ultrasonic sensors, or cameras, this sensor detects unauthorized access and sends alerts via the LCD screen and Blynk app.

Fig 3.1.4: Intruder detection sensor

Fig 3.1.5: Blynk app display of intruder detection

Fig 3.1.6: Intruder location sent through SMS app

- **Fire Detection Sensor:** Using smoke, heat, or flame detection technologies, this sensor provides immediate alerts for early fire signs, displayed on the LCD and sent through the monitoring system.

Fig 3.1.7: Fire Detection Circuit

- **Short Circuit Detection:** Integrated with the ESP8266, this sensor detects short circuits, displaying "Short Circuit Detected" on the LCD and sending notifications via the Blynk app, enhancing safety through immediate power interruption and alerts.

Fig 3.1.8: LCD display of short circuit detection

Fig 3.1.9: Blynk app display of short circuit detection

- **Open Circuit Detection:** Using an LM397 comparator and ESP8266 module, this sensor detects open circuits, updating the LCD to show "Open Circuit Detected" and sending notifications via the Blynk app.

Fig 3.1.10: LCD display of open circuit detection

Fig 3.1.11: Bynk app display of open circuit detection

- **Theft Detection:** The theft detection system effectively identifies unauthorized power usage by monitoring power draw through two sockets. When a high wattage bulb is connected, the current sensor detects the increased power draw, triggering a blinking indicator. Notifications are sent via the Blynk app and SMS, while the LCD displays a theft detection message and the transformer's location. This ensures prompt tracking and quick action against power theft.

Fig 3.1.12: Blynk app display theft detection

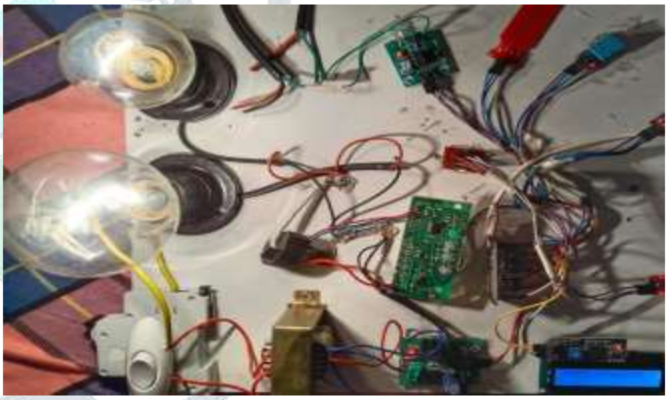

Fig 3.1.13: Theft detection circuit

3.2 DISCUSSION

The results demonstrate the successful integration of various sensors with the Blynk IoT platform, utilizing the ESP8266 module for real-time monitoring and alerts. The oil level detection sensor reliably identifies low oil levels, displaying alerts on an LCD screen and the Blynk app. The humidity and temperature sensor effectively monitors ambient conditions, providing necessary maintenance alerts. Intruder detection sensors, employing infrared motion detection, ensure security by sending unauthorized access notifications. Fire detection sensors promptly identify early fire signs, enhancing safety.

Short circuit and open circuit detection systems efficiently detect and alert respective faults, ensuring immediate response and improved electrical safety management. The short circuit detection sensor displays "Short Circuit Detected" on the LCD and sends notifications via the Blynk app, allowing for swift power interruption and alerting. Similarly, the open circuit detection system uses an LM397 comparator and ESP8266 module to identify open circuits, updating the LCD and Blynk app with alerts for immediate action.

Additionally, theft detection is implemented using a current sensor. This sensor monitors unusual current fluctuations indicative of unauthorized power usage, such as power theft. When such anomalies are detected, the system updates the LCD with "Power Theft Detected" and sends alerts through the Blynk app, allowing for quick investigation and mitigation.

These implementations collectively showcase the efficacy of IoT in enhancing monitoring, safety, and security protocols in various applications. The seamless integration of sensors with the Blynk IoT platform and ESP8266 ensures real-time data collection, alerting, and response, significantly improving operational efficiency and safety management.

Hardware Implementation

The hardware implementation of this project involves integrating various sensors with an ESP8266 module to enable IoT functionalities. Key components include oil level detection sensors, humidity and temperature sensors, intruder detection sensors, fire detection sensors, short circuit detection sensors, open circuit detection sensors, and current sensors for theft detection. Each sensor is connected to the ESP8266, which communicates data to the Blynk IoT platform. An LCD screen is used to display realtime alerts locally. The ESP8266 module, programmed via the Arduino IDE, serves as the central hub, processing sensor inputs and facilitating remote monitoring and alerts through the Blynk app.

Fig 3.2.1: project hardware

Software Implementation

Blynk IoT can be implemented on Arduino IDE by installing the Blynk library and configuring the ESP8266 as a Wi-Fi module. Users create a Blynk account, design a dashboard, and obtain an authentication token. The token is then added to the Arduino code, allowing remote control and monitoring of the ESP8266-connected devices.

Fig 3.2.2: Creating project in BLYNK app

IV Conclusion

In conclusion, this project aimed to design and implement a cost-effective Internet of Things (IoT) powered device to address and mitigate common underground faults in electrical systems. By exploring both the advantages and limitations of underground electrical systems, the project sought to enhance the reliability and safety of power distribution, particularly in areas prone to severe weather conditions. The system successfully detects power theft by monitoring power usage and provides real-time alerts through multiple channels, ensuring quick and efficient responses to power theft incidents.

V Future Work

- **Integration of Advanced AI and Machine Learning:** Advanced AI and machine learning algorithms are expected to enhance fault detection accuracy and speed. These technologies will analyze patterns to predict potential issues before they occur, optimize maintenance schedules, and allocate resources efficiently, thereby reducing downtime and operational costs.
- **Enhanced Communication Networks:** The deployment of 5G and other advanced communication technologies will improve data transmission speed and reliability between IoT devices and central monitoring systems. This enhancement will enable real-time monitoring and faster response to detected faults, significantly boosting system efficiency and responsiveness.

- **Edge Computing:** The implementation of edge computing in IoT systems will allow data processing closer to the data source, reducing latency and improving the speed of fault detection and response. This is particularly crucial for applications like fault detection in electrical systems, where rapid response times are essential.

- **Blockchain for Security and Transparency:** Blockchain technology will be employed to enhance the security and transparency of data collected by IoT devices. By creating a tamper-proof ledger of all activities and data, blockchain can prevent unauthorized access and ensure the integrity of the system. This is particularly important for preventing power theft and ensuring the reliability of monitoring and maintenance data.

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