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IOT-DRIVEN FAULT DETECTION SYSTEM FOR EFFICIENT TRANSMISSION LINE MONITORING

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Abstract : In modern society, electricity is indispensable, driving the development of extensive power transmission networks spanning vast distances. However, these networks are susceptible to faults that can damage critical electrical equipment and disrupt power supply. To mitigate these risks, rapid fault detection is essential. This paper proposes an IoT-based solution for detecting faults in transmission lines. The system utilizes a center-tapped transformer and switches to simulate fault conditions. Voltage signals from the transmission line are compared with reference signals using opt-couplers and a microcontroller. Detected faults trigger real-time notifications displayed on an LCD and transmitted via a WiFi-enabled IoT system. Data is stored on a central server for analysis and monitoring. This research aims to enhance the reliability of transmission line operations through efficient fault detection, contributing to the resilience and efficiency of electricity supply networks.

***IndexTerms* - IoT,Micro-controller,WiFi-enabled IoT system,Real-Time monitoring,Opt-Couplers.**

1.INTRODUCTION:

The modern power grid is a critical infrastructure that delivers electricity across vast distances, supporting essential services and industries worldwide. However, the reliability and efficiency of this network are challenged by the occurrence of faults in overhead transmission lines. When faults occur, instantaneous changes in voltage and current generate high-frequency signals known as travelling waves, which propagate along the transmission line. These faults including line-to-line (L-L) fault, divert power flow and disrupt supply to neighboring zones, leading to unbalanced voltages and potential damage to equipment.

Faults in transmission lines pose significant operational and safety risks, necessitating rapid fault detection and localization to ensure uninterrupted power supply and prevent extensive damage. Traditional methods relying on circuit indicators have limitations in pinpointing fault locations accurately, especially for underground faults. To address these challenges, innovative approaches leveraging Internet of Things (IoT) technology have emerged.

Iot-based fault detection systems offer real-time monitoring and detection capabilities, utilizing wireless sensors deployed along transmission lines to collect and transmit data on electrical parameters. These systems enable faster fault localization, accurate fault diagnosis, and condition-based maintenance, reducing operational costs and enhancing grid reliability. By integrating IoT with transmission line monitoring, utilities gain actionable insights into line health, enabling proactive maintenance and timely response to faults.

This paper explores the implementation of an IoT-based transmission line fault detection system using a micro-controller and WiFi module. The proposed system detects abnormal fluctuations in electrical quantities, such as voltage, and initiates protective measures to safeguard connected loads. Additionally, IoT technology enables seamless data transmission and remote monitoring, facilitating proactive maintenance and ensuring system resilience.

The convergence of IoT and power system monitoring represents a paradigm shift towards intelligent grid management, enabling utilities to enhance reliability, minimize downtime, and optimize resource allocation. This paper aims to contribute to the development of cost-effective and scalable solutions for improving the reliability and security of power transmission networks through advanced fault detection using IoT technology.

Line-to-Line Fault (LL):It is a common type of shunt fault in power transmission systems, occurring when two transmission lines are short-circuited. This can happen if a large bird perches on one line and touches another, or if a tree branch falls across two adjacent power lines. LL faults result in high fault currents and can cause significant disruptions to the electrical system. Protective devices like circuit breakers and fuses are used to quickly detect and isolate LL faults to prevent damage to equipment and ensure system safety. Detection of LL faults is crucial for maintaining the reliability and integrity of power transmission networks.

2.RESEARCH METHODOLOGY:

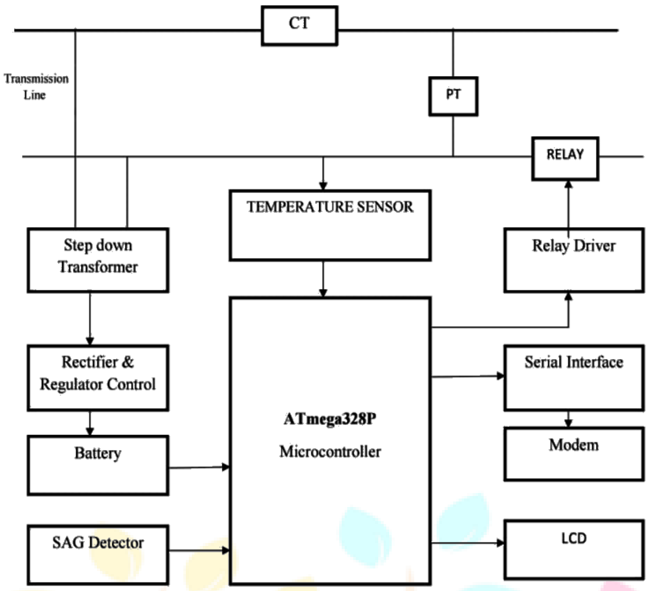

Figure:1 Block Diagram

2.1 Power Transformer Operation:

When alternating current (AC) is applied to the primary winding of a power transformer, it can either step down or step up the voltage depending on the desired output. In our setup, a 230V/15V transformer performs step-down operation, where 230V AC on the primary side results in 15V AC across the secondary winding.

2.2 Rectification Using Diodes:

Rectification in the power supply unit is achieved using solid-state diodes, which allow electron flow in one direction only when properly biased. In an AC input, electrons flow through the diode only when the anode is negative with respect to the cathode, enabling conversion of AC to pulsating DC.

2.3 Bridge Rectifier for Full Wave Rectification:

A bridge rectifier consisting of four diodes (4*IN4007) is employed for full wave rectification, converting AC to constant pulsating DC. This rectified output is then used to power the subsequent circuits in the system.

2.4 Micro-controller Overview:

The Arduino board is based on the ATmega328 micro-controller, featuring 14 digital I/O pins (6 PWM-capable), 6 analog inputs, a 16 MHz crystal oscillator, USB connection, power jack, ICSP header, and a reset button. It serves as the central processing unit for control and data processing in the system.

2.5 LCD Display (HD1234) Interface:

The alphanumeric LCD used in the project (HD1234) features 16 pins, with pins 7 to 14 serving as data pins connected to the micro-controller's port D. Control pins include RS (Pin-4), RW (Pin-5), and EN (Pin-6), enabling communication with the micro-controller for display operations.

2.6 ESP8266 Wi-Fi Module Functionality:

The ESP8266 Wi-Fi module is a self-contained with integrated TCP/IP protocol stack, enabling connectivity to Wi-Fi networks. It can host applications or offload Wi-Fi networking functions from another processor, facilitating wireless data transmission and internet connectivity.

2.7 Transformer Configuration:

The hardware setup includes two transformers: a center-tapped transformer used for fault simulation and a general-purpose step-down transformer connected to the main power supply. The 230V AC input to the step-down transformer yields a 12V AC output used to power the circuit.

2.8 Bridge Rectifier and Capacitor:

The 12V AC output from the transformer is fed into a bridge rectifier (four diodes) to convert AC to pulsating DC. The rectified output is then smoothed using a 1000µF capacitor, converting it into a stable DC supply for subsequent circuitry.

2.9 Voltage Regulation:

Following rectification and smoothing, a voltage regulator is employed to convert the rectified DC (typically 12V) to a fixed 5V DC supply, suitable for powering the micro-controller and display unit. Additional regulation provides a consistent power source for reliable operation.

2.10 Micro-controller Circuit Details:

The Atmega328p micro-controller features a reset circuit comprising a 10kΩ resistor connected to Pin 1, along with a 16 MHz crystal and 22pF capacitors to form a clock circuit. The micro-controller interfaces with current transformers (CTs) for fault detection and conversion of analog signals to digital data.

2.11 Current Transformer (CT) Interface:

Two CTs are connected to the center-tapped transformer phases, interfacing with the micro-controller via burden resistors. These CTs detect current variations due to faults and send signals to the micro-controller for fault analysis and display.

2.12 Fault Simulation and Detection:

Manual switches are used to create faults, such as line-to-line (L-L) shorts, simulating over-current conditions. When faults occur, CTs detect current changes, and the micro-controller processes the analog signals into digital data for display and transmission.

2.13 Communication with Wi-Fi Module:

The micro-controller communicates with the ESP8266 Wi-Fi module via serial communication (T_x/R_x), enabling data transmission to a server for remote monitoring and analysis. The module facilitates wireless connectivity and real-time fault reporting.

2.14 Data Storage and Remote Monitoring:

Data captured from fault detection is stored on a server accessible via a URL. The ESP8266 Wi-Fi module sends signals to the server upon fault detection, allowing remote monitoring of fault conditions and system status.

2.15 System Integration and Implementation:

The integrated system leverages transformer operation, rectification, micro-controller processing, fault detection, and wireless communication to achieve fault detection and reporting in real-time. The combination of hardware components and software algorithms ensures efficient operation and reliable fault monitoring.

3. KIT IMPLEMENTATION:

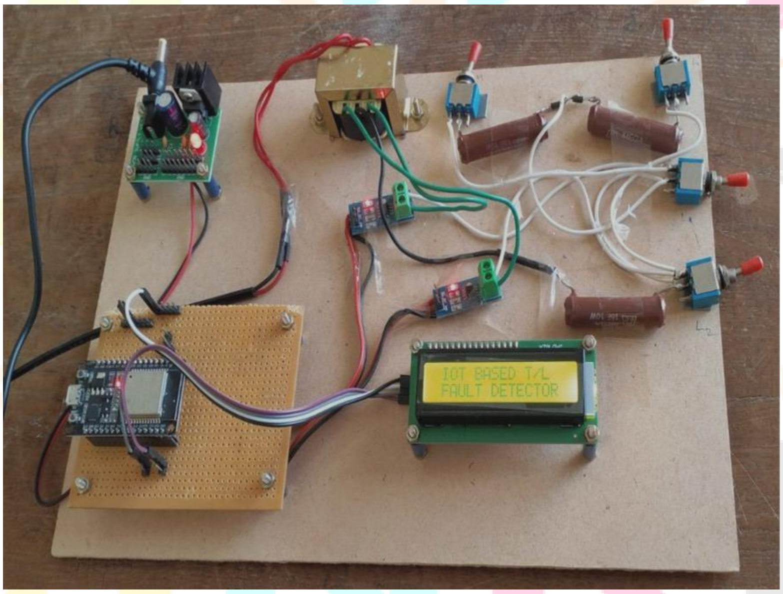

Figure:2 Experimental Setup

When AC voltage is applied to the primary winding of a power transformer, it can be stepped down or stepped up depending on the desired output voltage. In our circuit, a 230V/15V transformer is utilized for step-down operation, where the 230V AC input is transformed into 15V AC across the secondary winding. This step-down voltage is suitable for powering the subsequent components of the circuit.

Rectification of AC voltage in the power supply unit is achieved using solid-state diodes, which allow current to flow in one direction only. When AC is applied to the diode, electrons conduct through the diode during the negative half-cycle when the anode is negative with respect to the cathode. Reversing the voltage polarity will block electron flow through the diode, maintaining a unidirectional current flow necessary for rectification.

To convert AC to DC and supply large amounts of DC power, a bridge rectifier configuration is commonly employed. A bridge rectifier circuit, consisting of four diodes (such as 4*IN4007 diodes), enables full wave rectification. This configuration efficiently converts AC voltage to pulsating DC, which can then be further filtered to provide a steady and constant DC voltage to the connected device.

The micro-controller board, based on the ATmega328, serves as the central processing unit in our project. It features 14 digital I/O pins (including 6 PWM-capable outputs), 6 analog inputs, a 16 MHz crystal oscillator for precise timing, USB connectivity for programming, a power jack, ICSP header for in-circuit programming, and a reset button. This versatile board facilitates control and interfacing with various components within the circuit.

In this setup, we utilize an HD1234 alphanumeric LCD for displaying information. The LCD features 16 pins, with pins 7 to 14 serving as data pins connected to the micro-controller's port D. Additionally, pins 11 to 14 are specifically linked to the micro-controller for data communication. Control pins RS (Pin-4), RW (Pin-5), and EN (Pin-6) enable the micro-controller to send commands and data to the LCD, facilitating visual feedback and interaction with the system.

The ESP8266 Wi-Fi module, integrated as a system-on-chip (SoC), provides wireless connectivity to the micro-controller. With an integrated TCP/IP protocol stack, the ESP8266 enables any MCU to access Wi-Fi networks. This module can host applications independently or offload Wi-Fi networking functions from other processors, enhancing the connectivity and IoT capabilities of this paper.

The faults can be created by using the switches present in the kit. Switches L_1&L_2 of two sets are used in the kit.Bottom two L_1&L_2 switch set is connected to load i.e., under normal condition when the switches are in OFF condition and the circuit shorts under switches are in ON condition thus produces L-L fault.

3.1 Advantages:

- Increased Efficiency
- Real-time monitoring
- Cost-Effective
- Accurate and reliable
- Scalability
- Easy to Maintain
- Enhanced safety
- Data analytics
- Early fault detection
-

3.2 Applications:

- Power Distribution Systems
- Renewable Energy Systems
- Transportation Systems
- Industrial Automation
- Smart Cities
- Building Automation
- Power Grids

4. RESULTS & DISCUSSION:

When circuit is powered ON, the display shows the title name.

Figure:3 LCD Displaying name

When no switches are pressed, no fault is present in system, display shows no fault.

Figure:4 LCD Displaying normal (Without faults)

When both L_1&L_2 switch is pressed, transmission line under goes line to line fault which in turns shows in LCD display as below:

Figure:5 LCD Displaying L-L fault

Got the notifications to mobile phone for selected personnel when fault occurs in the transmission line.

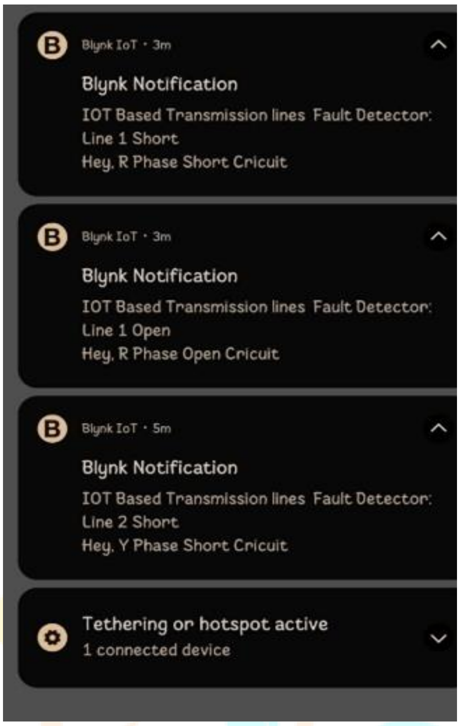

Figure:6 Notifications in mobile phone when fault occurs

Table 1: Comparison between currents with and without faults

S.NO	CURRENT(I_1)	CURRENT(I_2)	TYPE OF FAULT
1.	0.15	0.04	Without Fault
2.	0.23	0.31	Line to Line Fault(L-L)

5.CONCLUSION:

The IoT-based Wi-Fi module system for transmission line fault detection represents a significant advancement in utility monitoring and maintenance. By integrating sensors and cloud-based analytics, the project enables proactive fault detection and preventive measures, reducing downtime and maintenance costs. The wireless nature of Wi-Fi modules facilitates easy deployment and scalability across transmission networks, enhancing accessibility and efficiency. Real-time data analysis and machine learning algorithms empower utilities to predict faults and optimize operational performance. The system's benefits extend to improved reliability, energy efficiency insights, and overall service quality enhancement. Moving forward, further refinement and development of this technology hold promise for widespread adoption and integration into larger-scale transmission networks. Ultimately, this innovation contributes to a more resilient and sustainable energy infrastructure, ensuring reliable power supply and operational excellence in the utility sector.

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