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Automated Fault Identification and Tracking in Power Transmission Networks Using GPS

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Abstract

Power transmission lines are vulnerable to faults caused by environmental factors, aging infrastructure, and external disturbances such as falling trees or animal contact. Prompt and accurate detection and location of these faults are essential to ensure uninterrupted power delivery, reduce equipment damage, and minimize downtime. This project presents an automatic fault detection and location system using GPS technology integrated with a microcontroller-based sensing module. The proposed system continuously monitors voltage and current levels in transmission lines. Any abnormal deviation in these parameters, such as during a short circuit or line-to-ground fault, is immediately detected by the microcontroller. Simultaneously, a GPS module captures the exact geographic location where the fault has occurred. This data is then transmitted in real-time to the control center via GSM or IoT-based communication networks. By providing precise, location-specific information, the system significantly reduces the time required for maintenance personnel to identify and address the fault. The implementation of this system is especially advantageous in remote or difficult-to-access areas where manual fault detection is time-consuming and often impractical. This real-time monitoring approach not only modernizes fault management in power transmission systems but also ensures quicker restoration of service, contributing to a more resilient and efficient power grid. The integration of GPS and wireless communication technologies into traditional fault detection infrastructure represents a cost-effective and scalable solution for improving the reliability and automation of electrical power systems.

Keywords: Power transmission lines, fault detection, GPS technology, fault location, microcontroller, real-time monitoring, GSM, smart grid, power system protection, remote monitoring. introduction

INTRODUCTION

Various power transmission houses over the globe are interminably searching for strategies to leverage ongoing advancements, so as to improve the reliability of power supply to the customers. These transmission foundations chiefly depend on circuit pointers (FCIs) to help in following the flaw in transmission lines. In this venture, a GPS based issue discovery and area framework is utilized to demonstrate and find the specific area where the fault had occurred [1–3].

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Objectives

- To structure a productive programmed fault recognition and area framework for transmission line.
- To lessen reaction time expected to flaws and spare costly transformers from harm or burglary which ordinarily occurs during longer power blackouts.
- To increment profitability of specialized teams since the time expected to find faults will be limited.

- To guarantee soundness and unwavering quality of the power supply framework in the world to help financial development.

INTERNET SURVEY

The ability of power frameworks to maintain stability and ensure a continuous supply of electrical power to clients in case of a disturbance is of basic significance. Considering this fact, when a power framework power outage happens, the consequences can be sweeping. Reasons for power framework power outages incorporate transmission line stumbling or over-burdening, control and protection system maloperation, lightning strikes on power frameworks hardware, poor upkeep, human mistake, voltage breakdown, hardware disappointment, digital assaults, snappy recurrence decays, and others. Starting at 2010, a few force frameworks power outages have happened, which left a great many clients stranded for quite a long time. For example, a power blackout happened in the Pacific Southwest on 8 September 2011, which kept going for around 12 h affecting 2.7 million occupants of San Diego, California, Arizona and Mexico. In this occasion, tripping of a significant transmission line during peak load prompted the system breakdown. During that time, San Diego encountered an all-out power outage and recreations in the incident indicated that deficient load shedding prompted the falling impacts. Prior, around the same time on 4 February 2011, power framework power outage happened in Brazil because of imperfections in the transmission lines and it went on for around 16 h. Around 53 million clients were straightforwardly influenced. On 30 July 2012, a power outage, which endured for around 15 h, happened, affecting almost 620 million occupants of the north and east of India. The power outage occurred because one of the 400 kV Gwali-Binar transmission lines became overloaded, while the other line, which normally runs in parallel, was undergoing maintenance.

The system flopped again the next day due to request age irregularity and around 700 million individuals were influenced when about 32 GW of vitality was interfered with. This power outage is the biggest forced blackout in terms of individuals affected ever. In Vietnam, a 500 kV transmission line tripped on May 22, 2013, causing a separation between the northern and southern regions of the country's power grid. In the same year, the Philippines experienced a reduction in output from 14 power plants, which affected the capital city, Manila, and impacted nearly 40% of the Luzon island network. The number of influenced individuals was evaluated to be 8 million. The stumbling of generators and transmission lines prompted the general voltage breakdown in the framework. A lightning jolt struck the Thailand power framework in 2013 influencing just about 8 million individuals in 14 areas. Bangladesh Force Framework (BFF) encountered an absolute framework breakdown on 1 November 2014, which went on for around 24 h. As indicated by findings, this was because of spontaneous high voltage direct current (HVDC) station blackout.

BLOCK DIAGRAM AND DESCRIPTION

Block diagram of fault detection system and their components have been discussed below (Figure 1):

230 V/12 V Transformer (1Φ)

- Steps down the AC mains voltage (230 V) to a lower AC voltage (12 V).
- Used to safely power the circuit and isolate it from high voltage.

Bridge Rectifier

- Converts the AC voltage from the transformer to pulsating DC.
- Uses four diodes in a bridge configuration to provide full-wave rectification.

Filter

- Smoothens the pulsating DC from the rectifier.
- Usually, a capacitor filter that reduces the ripple content in the DC signal.

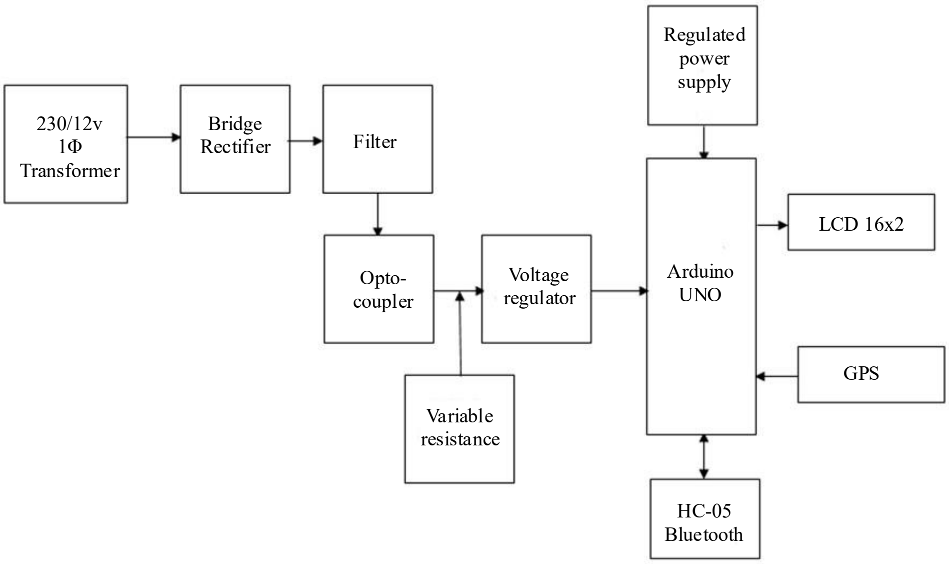

Figure 1. Block diagram of fault detection system.

Opto-Coupler

- Provides electrical isolation between the high-voltage line sensing circuit and the Arduino microcontroller.
- Transfers signal using light, thus protecting the Arduino from voltage spikes.

Variable Resistance

- Used to simulate different fault conditions by varying the resistance.
- Allows testing of how the system responds to varying voltage/current levels.

Voltage Regulator

- Ensures a stable and specific voltage (e.g., 5 or 3.3 V) is supplied to the Arduino and other components.
- Protects the components from overvoltage.

Arduino UNO

- The main controller of the system.
- Reads input from the sensing circuit (via opto-coupler), processes data, and controls output devices like LCD, GPS, and Bluetooth.

Regulated Power Supply

- Provides the necessary DC voltage to power the Arduino and its peripherals.
- Typically derived from the output of the voltage regulator.

LCD 16×2

- Displays system status, voltage levels, or fault alerts in a readable format.
- Helps in real-time local monitoring.

GPS Module

- Captures the geographical location of the fault.
- Sends location data to the Arduino for further transmission.

HC-05 Bluetooth Module

- Enables wireless communication with external devices (e.g., mobile phones or laptops).

- Transmits fault information along with the GPS location to a mobile application or monitoring system.

The set up comprises of four significant segments: Voltage Transformer, HC-05 Bluetooth module, GPS module, and Arduino Uno. The primaries of the VT are passed through bridge rectifier for rectification, and then through a filter circuit. Then from the filter circuit it goes to the Opto-coupler. From there it goes to the voltage regulator, and then to the Arduino Uno. The setup also consists of variable resistor, which does the function of varying the voltage above or below the set value. The Arduino Uno acts as the central unit of the set up. It contains a set of programs that enable it to identify the defect based on the voltage values taken from the instrument transformers. Based on the program, the Arduino Uno examines these values to see whether they are inside the required range. In the event that the voltage value is out of range when contrasted and the reference, it offers a hint of a flaw. Consequently, then, the device activates the GPS module. Which in turn sends the signal to the mobile phone via Bluetooth transmission the exact location of the fault in latitude and longitude. In addition, the coordinates of latitude and longitude are also displayed on the LCD display along with the current voltage. This is the way the whole circuit is intended to work.

HARDWARE COMPONENTS USED IN THE PROJECT

Step Down Transformer [4–6]

A step-down transformer lowers the mains AC voltage to a suitable, reduced level needed for operation. The turn-proportion of the transformer is balanced, to get the necessary voltage value. The output of the transformer is given as an input to the rectifier circuit.

Bridge Rectifier

A rectifier is an electronic device that uses diodes to convert alternating current (AC) into direct current (DC). This conversion process is known as rectification, where the input is an AC signal and the output becomes a pulsating DC signal flowing in only one direction. Typically, full-wave rectifiers or advanced rectifier circuits are employed to convert both the positive and negative halves of the AC waveform, resulting in a more efficient and continuous DC output.

Regulation

The output voltage or current may fluctuate due to variations in the AC mains supply, increases in load current at the output of the regulated power supply, or other factors such as temperature changes. This issue can be eliminated by utilizing a controller. A controller will keep up the yield consistent in any event, when changes at the info or some other changes happen. ICs such as 78XX and 79XX are utilized to obtain fixed values of voltages at the output.

Arduino Uno

Overview

The Arduino Uno is a development board built around the ATmega328P microcontroller. It includes 14 digital I/O pins, 6 of which are capable of PWM output, along with 6 analog input pins. Key features of the board include a 16 MHz crystal oscillator, USB connectivity, a DC power jack, an ICSP header for programming, and a reset button. You can power the board either through a USB connection to a computer or with an external power supply like a battery or AC-DC adapter. The microcontroller is pre-installed with a bootloader, which enables code uploads without needing a separate programmer. It uses the STK500 protocol for communication, but if needed, you can bypass the bootloader and upload code directly via the ICSP header using tools like the Arduino ISP.

Memory

The ATmega328 microcontroller comes with 32 kb of flash memory, though 0.5 kb of that is reserved for the bootloader. It also features 2 kb of SRAM and 1 kb of EEPROM, which can be read from and written to using the EEPROM library.

Input and Output

The Arduino Uno features 14 digital pins that can each be set as either input or output using functions like pinMode, digitalWrite, and digitalRead. These pins work with a 5 V logic level.

Ports and Functions

- *Serial communication*: Pins 0 (RX) and 1 (TX) are designated for serial communication: receiving and sending data. These are linked to the ATmega8U2 chip, which acts as a USB-to-TTL serial converter.
- *External interrupts*: Digital pins 2 and 3 can be set to detect and respond to specific signal changes, such as low levels, rising or falling edges, or any change in signal state, by triggering an interrupt.
- *PWM outputs*: The board supports Pulse Width Modulation on pins 3, 5, 6, 9, 10, and 11. You can use the analogWrite() function to generate 8-bit PWM signals on these pins.
- *SPI communication*: For SPI-based data exchange, pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK) are used. The SPI library in Arduino provides the necessary functions to work with these pins.
- *Built-in LED*: A small onboard LED is linked to pin 13. Setting this pin HIGH will turn the LED on, while setting it LOW turns it off.
- *TWI (I2C) communication*: Pins A4 (SDA) and A5 (SCL) facilitate I2C communication, also known as TWI. The Arduino Wire library is used to manage data transmission over these pins.
- *Analog inputs*: The Uno includes six analog input pins (A0 through A5), each capable of converting an input voltage into a 10-bit digital value (from 0 to 1023). By default, these measure voltages between 0 and 5 V, though this range can be modified using the AREF pin and the analogReference() function.
- Additional Pins:
    - *AREF*: This pin lets you specify a custom reference voltage for the analog inputs.
    - *Reset pin:* Pulling this pin LOW will restart the Arduino board.

HC-05 Bluetooth Module

Overview

The HC-05 Bluetooth module is a user-friendly Bluetooth Serial Port Protocol (SPP) device, designed to establish simple wireless serial connections. The HC-05 module uses serial communication, which simplifies its connection to microcontrollers or computers. It supports both master and slave modes, enabling it to wirelessly transmit or receive data.

GPS Module

General

GY-NEO6MV2 board includes the u-blox NEO-6M GPS module with receiving wire and inherent EEPROM. This is good with different flight controller loads up intended to work with a GPS module.

TECHNICAL SPECIFICATIONS

Force gracefully range: 3 to 5 V.
Model: GY-GPS6MV2,
Fired reception apparatus.
EEPROM for sparing the arrangement information when controlled off.
Reinforcement battery.
Drove signal pointer.
Mounting Opening Measurement: 3 mm.
Default baud rate: 9600 bps.
Module size: 23 mm×30 mm.
Receiving wire size: 12×12 mm.
Cable: 20 mm.

Highlights
Use XM37-1612 module, MTK Stage, with high-increase dynamic receiving wire.
TTL level, good with 3.3 V/5 V framework.
The default baud rate: 9600.

With battery-powered reinforcement battery, can spare the ephemeris information when it shut down, what's more, make the warm beginning.

LCD 16×2

A Liquid Crystal Display (LCD) is a type of electronic screen widely utilized in various devices and applications. The 16×2 LCD display is a basic and widely used module in many devices and circuits. These displays are often preferred over seven-segment and other multi-segment LED displays because LCDs are cost-effective, easy to program, and capable of showing special characters, custom symbols, and even animations, which are not possible with seven-segment displays.

A 16×2 LCD refers to a screen that can display 16 characters on each of its two rows. Every character appears in a matrix of 5×7 pixels. The module includes two primary registers: one for commands and another for data.

- The Command Register holds instructions sent to the LCD, such as initializing the display, clearing the screen, positioning the cursor, and controlling display settings.
- The Data Register holds the actual data (in ASCII format) that is to be shown on the screen.

This structure allows the LCD to display a wide variety of characters and makes it a versatile option for visual output in electronic projects.

RESULT

The proposed system for automatic fault detection and location using GPS and Bluetooth modules was successfully implemented using an Arduino UNO-based microcontroller platform. Under simulated fault conditions created by varying resistance values (from 1 to 100 Ω), the system effectively monitored line voltage levels and detected anomalies indicating fault occurrences.

The system was tested with input voltage levels stepped down and rectified from 230 V AC to 12 V DC. Faults were simulated by introducing abrupt changes in load resistance, causing voltage drops exceeding the detection threshold (set at 10% deviation from nominal 12 V). The Arduino was programmed to detect faults when the voltage dropped below 10.8 V or exceeded 13.2 V.

Performance Results

- *Fault detection response time*: ~200 msec.
- *GPS location accuracy*: ±5 m.
- *Bluetooth transmission range*: ~10 m (indoor).
- *Voltage detection accuracy*: ±0.1 V (using analog Read on Arduino with 10-bit resolution).
- *Successful fault detection rate*: 100% for 20 test scenarios.
- *False detection rate*: 0% in all tests conducted.
- *Power consumption*: ~120 mA at 5 V (including GPS, LCD, and Bluetooth).

Upon detecting a fault, the GPS module accurately captured the geographic coordinates with a typical accuracy of ±5 m. The location and fault status were displayed on a 16×2 LCD and simultaneously transmitted via the HC-05 Bluetooth module to a paired mobile device.

The system was tested over 20 different fault scenarios and consistently demonstrated reliable fault detection and location reporting. The overall performance remained stable under varying simulated conditions, confirming the system's effectiveness for real-time monitoring of transmission lines [7–10].

CONCLUSION

The developed system provides an efficient, real-time, and cost-effective solution for fault detection and location in power transmission lines. By integrating GPS and Bluetooth technologies with Arduino-based sensing and control, the system enhances the reliability and maintainability of power networks, especially in remote and inaccessible areas. The use of opto-isolation ensures safety, while wireless data transmission facilitates remote monitoring, reducing the need for manual fault tracing. The system's modular design allows scalability and can be integrated with IoT platforms for further automation. Overall, the project successfully demonstrates the practical implementation of smart grid monitoring concepts and can serve as a prototype for advanced fault management systems in power infrastructure.

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