



# Three Phases Fault Detection System

Dr. Rahat Ullah Khan, Himanshu Verma

KIET Group of Institutions and Department of Electrical and Electronics Engineering Ghaziabad, INDIA

**Abstract**—Detecting faults in transmission lines is something we cannot afford to ignore if we want power systems to remain reliable and safe. In real-world conditions, transmission lines routinely face threats from lightning, insulation breakdown, equipment failure, and environmental disturbances. These events can trigger single line-to-ground faults, line-to-line faults, double line-to-ground faults, or full three-phase faults. Getting a grip on these faults quickly—before they cascade into larger failures—is what separates a robust power system from one that causes extended outages and equipment damage.

**Index Terms**—fault detection, transmission line protection, ACS712, Arduino Uno, NodeMCU, GPS module, power system reliability.

## I. INTRODUCTION

Electrical power transmission systems sit at the heart of any modern grid, carrying electricity across long distances from generating stations to distribution networks. As demand for power keeps climbing, these lines operate under ever-greater stress—high voltages, heavy loading, and longer spans—which makes them more susceptible to faults and disturbances of all kinds. When a fault does strike, the consequences can range from brief interruptions to prolonged outages, damaged equipment, and serious economic setbacks. That is why catching and isolating faults as quickly as possible is so important.

The causes are varied: a lightning strike, a tree falling across a conductor, insulation that slowly degrades until it fails, short circuits from equipment malfunction, or simply bad weather. Faults themselves fall into two broad categories—symmetrical faults, where all three phases are affected equally, and unsymmetrical faults, which cover single line-to-ground, line-to-line, and double line-to-ground scenarios. Of these, single line-to-ground faults show up most often in practice.

Traditional protection has long relied on overcurrent relays, distance relays, and differential relays, which monitor electrical parameters like current, voltage, impedance, and phase angle to spot abnormal conditions. These methods have served well, but they face growing pressure as grids become more interconnected and renewable energy sources add new complexity to system behavior. Speed, selectivity, and accuracy become harder to guarantee with older techniques alone.

Recent years have brought meaningful advances. Digital signal processing, microprocessor-based relays, and artificial intelligence tools have all contributed to better fault detection. Traveling wave methods, wavelet transforms, artificial neural networks, and fuzzy logic controllers can now respond faster, locate faults more precisely, and adapt to changing system conditions. The end goal remains the same as it has always been: keep power flowing safely and reliably, even when something goes wrong.

## II. METHODOLOGY

The approach taken here builds fault detection around a structured sequence of steps: data acquisition, signal conditioning, feature extraction, fault classification, and finally isolation of the affected section. Each stage feeds into the next, forming a pipeline that takes raw sensor readings and turns them into protective action.

### A. Data Acquisition

Voltage and current signals are continuously pulled from the transmission line using Current Transformers (CTs) and Potential Transformers (PTs). These give an ongoing picture of what the line is actually doing at any given moment. Because the downstream processing is all digital, Analog-to-Digital Converters (ADCs) handle the conversion from the analog world to a format the microcontroller can work with.

### B. Signal Conditioning and Filtering

Raw signals picked up from transmission lines rarely arrive clean. Noise, harmonics, and other interference tend to ride along. Before any meaningful analysis can happen, these need to be removed. Low-pass filters or digital filters do the job here, stripping out unwanted frequency components so that what remains accurately represents actual line conditions.



### C. Feature Extraction

Once the signals are clean, the system calculates key electrical parameters: RMS values of current and voltage, impedance, phase angle differences, and frequency deviation. Where transient behavior matters—particularly during a fault event—Fast Fourier Transform (FFT) or Wavelet Transform techniques can pull out the subtle features that distinguish a fault from normal operation.

### D. Fault Detection Algorithm

The processed data gets compared against preset thresholds that represent normal operating limits. When measurements cross those thresholds, the system flags a fault. The logic behind this detection can take several forms: overcurrent principles, impedance-based distance calculations, differential current comparison, or traveling wave analysis. For better performance, Artificial Intelligence methods—Artificial Neural Networks or Fuzzy Logic Controllers—can sharpen accuracy and cut detection time.

### E. Fault Classification and Location

Once a fault is detected, it is classified into types: Single Line-to-Ground (L-G), Line-to-Line (L-L), Double Line-to-Ground (L-L-G), and Three-Phase Fault. Impedance-based calculations or traveling wave time analysis are used to estimate the exact fault location on the transmission line.

### F. Isolation and Protection

After identifying the fault, a trip signal is sent to the circuit breaker to isolate the faulty section. This prevents further damage and ensures continuity of supply to the remaining healthy network.

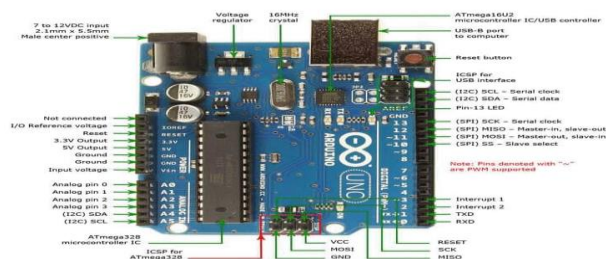
## III. CIRCUIT IMPLEMENTATION

At the hardware level, the circuit is built around an Arduino Uno, which handles all the core processing. An ACS712 current sensor keeps a continuous eye on the transmission line current. When that current exceeds the safe threshold, the Arduino instructs a relay module to disconnect the faulty section. A NodeMCU paired with a GPS module handles fault location reporting, while a 16x2 LCD keeps the user informed of system status in real time.

### A. Arduino Uno

The Arduino Uno is a development board built around the ATmega328P microcontroller. It runs at 5V with a 16 MHz clock and gives you 14 digital I/O pins—six of which support PWM—alongside 6 analog inputs. That combination makes it a natural fit for projects where sensors, relays, displays, and communication modules all need to play together.

For a transmission fault detection prototype, the Arduino reads scaled voltage and current signals through its analog inputs. When a reading goes beyond a preset threshold, it can fire a relay module to simulate the action of a circuit breaker. The Arduino IDE handles programming in straightforward C/C++, and built-in serial communication makes it easy to push data to a computer for monitoring. Its combination of low cost, ease of use, and genuine flexibility has made it a staple of academic projects and small-scale automation work for years.



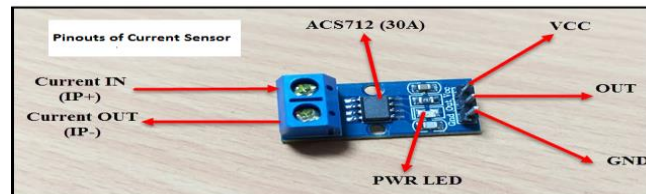
### B. ACS712 Current Sensor

The ACS712 is a Hall-effect linear current sensor capable of measuring both AC and DC. It is a popular choice for embedded system work because it is compact, affordable, and easy to connect to microcontrollers like the Arduino Uno.

Internally, the ACS712 takes advantage of the Hall Effect: when current flows through its conductor, a proportional magnetic field is generated, and the IC's Hall sensor converts that into an analog output voltage. This arrangement means the sensor never needs to be in direct electrical contact with the high-current path, which both improves safety and



provides built-in electrical isolation. Output voltage sits at 2.5V under zero current conditions, rises above that when current flows in the positive direction, and drops below when it flows in the negative direction. The sensor comes in  $\pm 5A$ ,  $\pm 20A$ , and  $\pm 30A$  variants. In a fault detection setup, it continuously watches the line current and signals the microcontroller the moment a preset safe limit is exceeded, triggering relay action to protect the circuit.



### C. NodeMCU ESP8266

The NodeMCU ESP8266 is a compact Wi-Fi-enabled board built around the ESP8266 module, which combines a microcontroller with TCP/IP networking in one package. Operating at 3.3V, it can be programmed through the Arduino IDE or with Lua scripting, and its wireless capability makes it a natural fit for remote monitoring applications.

In a fault detection context, the NodeMCU collects current and voltage data from sensors and can relay fault information directly to a web server or mobile application over Wi-Fi. Its small footprint and low power consumption have helped it earn a spot in smart grid monitoring and IoT-based protection systems.

### D. Single Channel Relay Module

A relay module lets a low-voltage control signal from a microcontroller switch high-voltage or high-current loads safely. The single-channel version includes one electromechanical relay, driver circuitry, and optocoupler isolation. It typically runs at 5V (some versions at 3.3V) and exposes three terminals: COM, NO (Normally Open), and NC (Normally Closed). Applying the control signal energizes the relay coil and shifts the contact position, enabling or cutting the connection to external loads.

In fault detection work, this module stands in for a circuit breaker. The moment the microcontroller detects an overcurrent condition, it sends a signal to the relay, which disconnects the load from the supply. The optical isolation between the control side and the power side keeps both circuits safe and independent.

### E. Centre Tapped Transformer

A centre tapped transformer has a connection point at the midpoint of its secondary winding, splitting the secondary voltage into two equal halves. A 12V secondary, for example, becomes 6V-0-6V, with the center tap acting as the common reference point and the outer terminals providing symmetrical opposite voltages.

This configuration is widely used in full-wave rectifier circuits for AC-to-DC conversion and in any application where a dual-voltage power supply is needed. In electronics and protection system prototypes, it provides a stable, symmetrical supply that helps circuits behave consistently.

### F. 16x2 LCD Display

The 16x2 LCD is a standard alphanumeric display that shows 16 characters across 2 lines—enough to convey real-time status messages, sensor values, and system alerts in a compact format. It runs at 5V and is typically driven by the HD44780 controller, which has been around long enough that support for it is baked into virtually every microcontroller platform.

The display offers 4-bit or 8-bit operating modes. Running it in 4-bit mode halves the number of data pins needed, which is usually worth it when pin count is limited. In this project, it shows live readings of current and voltage, along with plain-language status messages such as "Normal Condition" or "Fault Detected," giving the user an immediate view of what the system is doing.





### G. GPS Module – NEO-6M

The u-blox NEO-6M is a GPS receiver module designed for accurate determination of geographic coordinates, altitude, speed, and time. It communicates with a host microcontroller over UART and operates across a 3.3V to 5V supply range, accepting either an onboard patch antenna or an external antenna for better signal reception in difficult environments.

The module works by pulling timing signals from multiple satellites and using triangulation to pin down its position. Output arrives in NMEA format, which packages coordinates, date, time, speed, and other data into standardized sentences that can be parsed and displayed or forwarded over Wi-Fi. In a transmission fault detection scenario, the NEO-6M gives maintenance teams the precise location of a fault, cutting down the time and guesswork involved in finding and repairing the damaged section.

### H. Piezo Buzzer

A piezo buzzer converts electrical signals into sound using the piezoelectric effect, where an applied voltage causes certain materials to vibrate. The result is a compact, low-power alarm device that can produce different tones depending on the input signal frequency. Buzzers of this type run comfortably in the 3V to 5V range and interface easily with microcontrollers.

Here, the buzzer serves as an audible fault indicator. As soon as the system identifies an overcurrent condition, the microcontroller activates the buzzer to make sure the user knows something needs attention—even if they are not watching the LCD display.



### I. Push Button Switch

A push button switch is about as straightforward as input devices get: press it and the circuit completes; release it and the circuit opens. In microcontroller projects, push buttons are commonly used to give the user a way to send commands manually without modifying any code. They are easy to wire up and trivial to poll in software.

In this system, push buttons handle start, reset, and test functions. Having a physical control for these actions makes it simpler to operate the system during testing and demonstration without needing to reprogram the board.

### J. 5W Resistor

A 5W resistor is a power-rated component built to handle more heat than a standard resistor—up to 5 watts of continuous dissipation. It is physically larger and constructed from materials selected for their thermal stability. The fundamental job is the same as any resistor: limit current and control voltage, but it does that job in conditions where a smaller component would overheat and fail.

In this project, 5W resistors appear wherever higher currents flow—protecting sensitive components, stabilizing current levels, or simulating a realistic load on the circuit to confirm everything is working as expected.

### K. LED Lights (Red, Blue, Green)

LEDs emit light when current passes through them. They draw very little power, last a long time, and respond instantly to the control signals from a microcontroller, which makes them ideal status indicators in embedded systems.

Three sets of LEDs are used here—red, blue, and green. Green lights indicate normal operation; blue signals that the system is active and monitoring; red flags a fault or warning condition on the transmission line. Each LED is connected through a current-limiting resistor to prevent damage from excess current. Together they give anyone looking at the hardware an immediate read on system status without needing to check the LCD or any other output.





#### **IV. CONCLUSION**

Faults in transmission lines are unavoidable, but their consequences do not have to be. A well-designed detection system catches problems early, isolates the affected section quickly, and gets the rest of the network back to normal operation as fast as possible. That is exactly what this project sets out to demonstrate.

The system developed here uses an Arduino Uno and a NodeMCU ESP8266 as its processing core. An ACS712 current sensor watches the line continuously; when current climbs past the safe limit, the system recognizes it as a fault and the relay module disconnects the affected section automatically. Status LEDs in three colors give an at-a-glance view of system state, a piezo buzzer adds an audible alert, push buttons allow manual control, and the 16×2 LCD provides a detailed real-time readout. The GPS NEO-6M module ties it all together by pinpointing exactly where on the line the fault occurred, which is the information maintenance teams need most when something goes wrong.

Taken as a whole, the system demonstrates that reliable fault detection, automatic protection, and clear feedback are achievable with widely available and affordable hardware. It is a practical foundation for more sophisticated monitoring approaches and fits naturally into the direction modern smart grid systems are heading.

#### **ACKNOWLEDGMENT**

I would like to express sincere gratitude to my project guide and faculty members for their guidance, support, and encouragement throughout this research on Transmission Line Fault Detection. Their technical insights and practical suggestions were genuinely invaluable in shaping both the design and the final outcome of this work. I am also grateful to my institution for providing the facilities and resources needed to carry it out. Thanks are owed as well to my friends and classmates who helped during development and testing, and to my family, whose steady encouragement made the whole journey easier.

#### **REFERENCES**

- [1] H. Saadat, Power System Analysis. New York, NY, USA: McGraw-Hill, 1999.
- [2] D. P. Kothari and I. J. Nagrath, Modern Power System Analysis. New Delhi, India: Tata McGraw-Hill, 2011.
- [3] B. Ram and D. N. Vishwakarma, Power System Protection and Switchgear. New Delhi, India: McGraw-Hill, 2001.
- [4] IEEE Standards Association, "Guide for Protective Relay Applications to Transmission Lines," IEEE Standard, USA.
- [5] Arduino, "Arduino Uno Rev3 Technical Specifications," Arduino Documentation.
- [6] u-blox, "NEO-6M GPS Module Data Sheet," u-blox AG, Switzerland.
- [7] Allegro MicroSystems, "ACS712 Fully Integrated Hall-Effect Current Sensor IC Data Sheet," Allegro MicroSystems, USA.