

Cost-Effective Detection of Low Voltage AC Overhead Conductor Breakage

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Abstract—Overhead conductors carry electricity to homes, farms and industries, but they are exposed to weather, ageing and mechanical stress, and a breakage can leave a live conductor on the ground or cut off the supply to consumers. Conventional protection often fails to detect a fallen conductor because its fault current is small, and detection by manual patrolling is slow. This project presents the design and development of a low-cost embedded system for detecting overhead conductor breakage and abnormal voltage on a low-voltage AC line, with automatic load isolation and instant WhatsApp fault notification. The system is built around the ESP32 microcontroller. A ZMPT101B voltage sensor and an ACS712 current sensor measure the AC voltage and the load current of the monitored line. The ESP32 samples the signals, computes their RMS values and compares the voltage with a configured safe window of 180 V to 260 V. When the voltage leaves the window, as happens when the supply collapses after a conductor breakage or rises abnormally because of a surge or neutral fault, the ESP32 opens a relay to isolate the load, turns the green LED off, turns the red LED and buzzer on, displays the fault, and sends an alert through its built-in WIFI to a cloud service that delivers it as a WhatsApp message. The WhatsApp message gives the fault name, the measured voltage and current, the relay state, the configured limit and the location reference, so that the maintenance person can judge the situation without visiting the site. The prototype was tested for low-voltage and high-voltage conditions. The captured alerts report a low-voltage fault at 7.0 V with 0.00 A and a high-voltage fault at 274.1 V with 0.00 A, with the relay OFF in both cases, against the configured limit of 180 V – 260 V. The project combines sensing, embedded control, power switching and cloud communication in a compact unit made from commonly available modules. It offers a cost-effective means of improving public safety and speeding up fault response on low-voltage distribution lines, and it can be extended with multi-node monitoring, power backup, current sensing and three-phase support.

Index Terms—Downed Conductor, High-Impedance Fault, IoT, ESP32, Edge, Current Sensing, Voltage

Sensing, Power Isolation

I. INTRODUCTION

Electricity distribution in towns and villages still relies heavily on bare overhead conductors strung between poles. These conductors are exposed to storms, falling branches, vehicle impact, corrosion, thermal cycling and the slow loss of mechanical strength with age. When a conductor snaps, one end may fall to the ground or onto a road, a fence or a person while the other end can remain energized. A downed live conductor is therefore one of the most dangerous faults on a low-voltage network: it can cause fatal electric shock, start fires and interrupt supply to many consumers at once.

Detecting such a fault is harder than it appears. When a conductor touches soil, concrete or vegetation, the contact resistance is high, so the fault current is small and irregular and may stay below the pickup level of fuses and over-current relays [3], [10]. The protection therefore does not operate, and the utility often learns about the fault only when a consumer or a passerby telephones the complaint center. Manual patrolling is slow, costly and impractical for long rural feeders. Advances in low-cost microcontrollers, Wi-Fi connectivity and cloud messaging now make it possible to monitor a distribution line continuously and to report abnormal conditions within seconds [1], [4], [5]. The ESP32 integrates a dual-core processor, a 12-bit ADC and Wi-Fi on a single inexpensive board, and it is well suited to measuring mains voltage and current, applying decision logic and calling a cloud service.

The present project proposes a Cost-Effective Detection of Low Voltage AC Overhead Conductor Breakage. A ZMPT101B voltage sensor and an ACS712 current sensor measure the 230 V single-phase supply, and the ESP32 evaluates the readings

against a safe operating window of 180 V – 260 V. If the voltage leaves this window, the system performs four actions together: it opens a relay to isolate the load, switches on a red LED and a buzzer for local warning, displays the fault on an LCD, and sends a WhatsApp alert containing the fault details through the cloud. When the supply is healthy, the relay is closed and a green LED glows. WhatsApp was chosen as the notification channel because it is already installed on almost every smartphone, needs no additional app or dashboard login, supports rich text with symbols, and is read by the user within moments. The design is intentionally simple, modular and inexpensive so that it can be replicated at several points along a feeder, and it forms a base on which advanced techniques such as arc sensing, harmonic analysis and GPS tagging can be added later.

II. LITERATURE SURVEY

A. Related Works

Research on high-impedance fault detection, IoT line monitoring and edge processing provides the groundwork for this work. Key contributions include:

Arcing-Signature Detection: Aucoin and Russell (1982) [1] showed that arcing high-impedance faults on distribution feeders produce high-frequency current components that can be extracted for detection. The method works from current measured at the feeder, so it cannot tell which span has fallen.

Technology Survey: The IEEE Power System Relaying Committee working group (1996) [2] surveyed high-impedance fault detection technology and discussed why conventional overcurrent protection often cannot see such faults.

Multi-Feature Feeder Algorithms: Benner and Russell (1997) [3] described practical detection on distribution feeders that combines several signal features to separate faults from normal switching. It still depends on feeder-level measurement equipment, which adds cost for every feeder.

Smart-Grid IoT Monitoring: Gungor et al. (2011) [4] reviewed the communication technologies and standards of the smart grid, including the wireless links that connect field sensors to utilities. Such links

make a small monitoring node practical, but the survey does not describe a downed-conductor trigger or local isolation.

Edge Processing: Shi et al. (2016) [5] presented the vision and challenges of edge computing, in which data is processed near its source. For a hazard that must be cleared within seconds, deciding on the device removes the dependence on network coverage.

Current Sensor: The ACS712 is connected in series with the load. Its output is sampled by the ESP32 through a resistive divider that scales the 0 – 5 V output into the 0 – 3.3 V ADC range. The firmware removes the offset and converts the signal to RMS current. The current reading is included in every alert and also shows when the load has been disconnected (0.00 A), which confirms that the relay has isolated the load.

ZMPT101B AC Voltage Sensor: The sensor output is sampled by the ESP32 ADC many times per cycle. The firmware removes the DC bias, squares and averages the samples, and applies a calibration factor to obtain the RMS line voltage. This value is the primary indicator for conductor breakage: when the conductor breaks upstream of the sensing point, the voltage collapses towards zero, and when the line neutral or source regulation fails, the voltage may rise above the upper limit.

Cloud Service and WhatsApp Business Messaging: The cloud service acts as the bridge between the ESP32 and WhatsApp. It receives the HTTP request from the device, applies a message template (“Threshold Violation Alert”) and delivers it to the registered WhatsApp number from a business account. The footer of the received message, “Automated system message. Powered by CircuitDigest”, shows that the CircuitDigest cloud alert service is used in this prototype. The user needs only an internet enabled smartphone with WhatsApp.

B. Motivation

Overhead low-voltage lines serve homes, farms and small industry and are exposed to storms, falling branches and wear. When a conductor breaks and touches the ground, the ground impedance limits the fault current, so protection designed for short circuits

often stays closed. The live wire at ground level can cause fatal shocks, and manual patrols or public reports are slow, particularly in rural and remote areas. Feeder-level detection needs costly equipment at the substation and cannot say which span has fallen. This research is therefore motivated by the need for a low-cost, span-level node that detects the break, isolates the line and alerts staff automatically, and that can be replicated across large networks.

III. PROPOSED METHODOLOGY

The proposed method follows six steps:

- Monitor: the ACS712 and ZMPT101B are sampled continuously.
- Process: the ESP32 computes the and voltage levels on the device.
- Detect: a fault is declared only when both cues agree.
- Isolate: the ESP32 opens the relay to disconnect the affected line.
- Alert: cloud service and WhatsApp Bussiness Messaging.
- Reset: the relay stays open until a technician resets the node.

A. Background and Fundamentals of High-Impedance Faults

A high-impedance fault occurs when a conductor touches a poorly conducting surface such as soil, asphalt or vegetation, so the fault current stays far below the pickup level of fuses and breakers [1], [2]. A snapping conductor has two effects that a node on the pole can measure: a mechanical shock as the tension is suddenly released, and a collapse of the line voltage at the monitored point. Three detection modes are compared in this work:

- Current only: Its output is sampled by the ESP32 through a resistive divider that scales the 0 – 5 V output into the 0 – 3.3 V ADC range.
- Voltage only: confirms the electrical effect, but also triggered by voltage sags and planned outages.
- Dual sensor (proposed): requires both cues within a short coincidence window, which removes both kinds of false alarm.

B. System Architecture

Architecture framework:

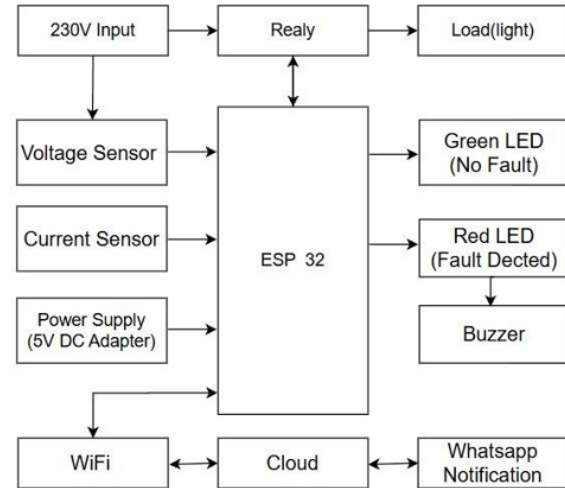


Fig. 1. Block diagram of the pole-mounted dual-sensor node for detection, isolation and alerting of a downed conductor.

The node is a single enclosure on the distribution pole (Fig. 1). The ACS712 senses the current of a snapping conductor and the ZMPT101B measures the line voltage. The ESP32 [8] reads both, applies the decision rule of Section III-D and drives three outputs: a relay or solid-state relay that opens the line, a Cloud service that sends the SMS alert, and an LED with a buzzer for local indication.

Detection and Isolation Algorithm

The ESP32 samples both sensors continuously and applies a two-stage rule (Fig. 2). Stage one watches for the shock of a break and stage two checks that the line voltage has collapsed. The acceleration magnitude is first computed from the three axes:

$$a_k = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (1)$$

Gravity is removed by subtracting the window mean, giving the Current level over N samples:

$$A_{rms} = \sqrt{\frac{1}{N} \sum_{k=1}^N (a_k - \bar{a})^2} \quad (2)$$

The line voltage over M samples is:

$$V_{rms} = \sqrt{\frac{1}{M} \sum_{m=1}^M v_m^2} \quad (3)$$

A fault is declared only when both cues agree:

$$F = (A_{rms} > T_a) \wedge (V_{rms} < T_v \text{ for } t \geq T_h) \quad (4)$$

Wind and passing vehicles shake the pole without

losing voltage, while a sag or a planned outage drops the voltage without any shock, so requiring both removes the two common false alarms. The voltage condition is checked for up to T_c after a Current trigger.

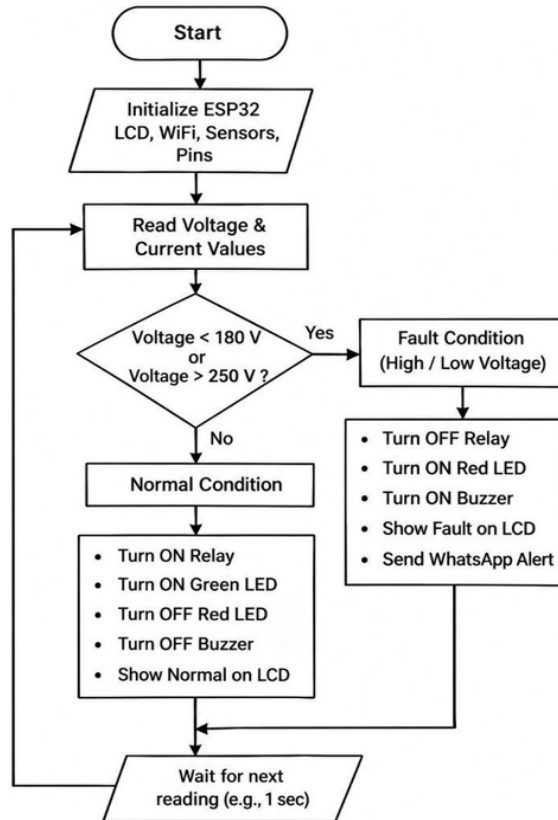


Fig. 2. Flowchart of the dual-sensor detection, isolation and alert sequence.

On confirmation, the ESP32 opens the relay first, then sends the SMS, then switches on the LED and buzzer, so isolation never waits for the mobile network. The relay stays open until a technician resets the node manually.

IV. OBJECTIVES AND SOLUTIONS

Objective 1: To detect breakage of low-voltage overhead conductors using current and voltage sensing.

Solution 1.1, Current shock sensing

- Technique: The ACS712 is connected in series with the load. Its output is sampled by the ESP32 through a resistive divider that scales the 0 – 5 V output into the 0 – 3.3 V ADC range

- Function: Flags a sudden shock when Arms exceeds T_a .
- Impact: Captures the mechanical event of a snapping conductor.

Solution 1.2, Line-voltage monitoring

- Technique: ZMPT101B module read by the ESP32 analog input, with RMS over M samples, Eq. (3).
- Function: Flags a voltage collapse when V_{rms} stays below T_v for at least T_h .
- Impact: Confirms the electrical effect and rejects pure current events.

Solution 1.3, Dual-cue confirmation

- Technique: Logical AND of both cues within the coincidence window T_c , Eq. (4).
- Function: Declares a fault only if shock and voltage collapse occur together.

Solution 2.1, Edge decision on the ESP32

- Technique: Embedded C firmware with periodic sampling, RMS computation and the
- Impact: Removes false alarms from wind, traffic and voltage sags.

Objective 2: To design and implement an IoT-based monitoring system using a microcontroller for real-time detection.

- Function: Runs the complete detection locally on the pole node.
- Impact: Low latency, and no dependence on network coverage for the safety decision.

Solution 2.2, Continuous status monitoring

- Technique: Sampling loop with serial-monitor logging of readings and decisions.
- Function: Records sensor values and fault states during operation and testing.
- Impact: Gives real-time visibility and supports threshold calibration.

Objective 3: To automatically isolate the power supply from the affected line when breakage is detected.

Solution 3.1, Relay-based isolation

- Technique: Relay module or solid-state relay driven by an ESP32 digital output.
- Function: Opens the affected line as soon as the fault is confirmed, before the SMS is sent.

- Impact: Removes the live hazard within a fraction of a second.

Solution 3.2, Latched safe state

- Technique: Relay held open until a technician resets the node. Function: Prevents automatic re-energizing onto a fallen wire. Impact: Protects the public and the repair crew.

Objective 4: To send immediate fault alerts to the maintenance authority through a cloud service.

Solution 4.1, cloud Service

- Technique: Cloud Service and WhatsApp Business Messaging
- Function: Sends the fault message to the maintenance authority.
- Impact: Staff learn of the fault within seconds and can locate the pole.

Solution 4.2, Local indication

- Technique: LEDs and a buzzer driven by the ESP32. Function: Signals the fault at the pole.
- Impact: Warns people nearby even without mobile coverage.

Objective 5: To develop a low-cost and scalable prototype suitable for large distribution networks.

Solution 5.1, Off-the-shelf modules

- Technique: Commonly available ESP32, ACS712, ZMPT101B, relay and Cloud service.
- Function: Builds the full node from low-cost parts.
- Impact: Keeps the cost of each node low.

V. IMPLEMENTATION AND EXPERIMENTAL SETUP

A. Hardware and Software

The prototype uses off-the-shelf modules wired to the ESP32 and housed in an outdoor protective enclosure (Table II). The accelerometer connects over I2C, the voltage sensor feeds an analog input, and the relay and indicators use digital outputs. The SIM800L is driven by AT commands over a serial port in text mode. The voltage sensor sits on the mains side and needs proper insulation inside the enclosure.

Table I. Hardware and Software Used

Item	Component or tool	Role
Controller	ESP32 development board	Reads sensors, runs decision rule
Current sensor	ACS712	Measures the Current
Voltage sensor	ZMPT101B module	Measures AC line voltage
Isolation	Relay module or solid-state relay	Opens the affected line
Communication	Cloud service	Sends the SMS alert
Power	Li-ion battery	Runs the node off-grid
Indication	LEDs and buzzer	Local fault signal
Housing	Outdoor protective enclosure	Protects the electronics
Software	Arduino IDE, embedded C, ESP32, Cloud service, serial monitor	Firmware, interfacing, debugging

B. Deployment

One node watches the span between two poles (Fig. 3). When a conductor in that span breaks and falls, the node trips its relay and the SMS reaches the maintenance staff through the mobile network.

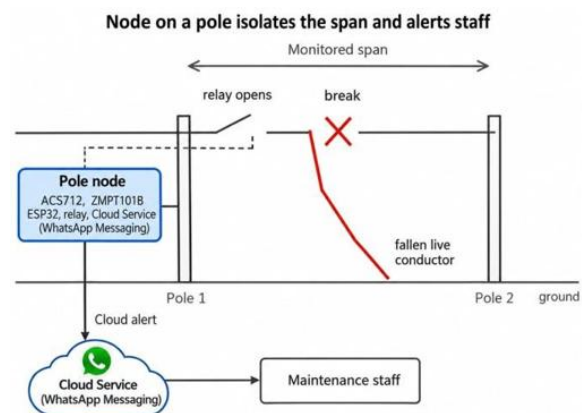


Fig. 3. Deployment of the node on a distribution pole (conceptual sketch, not to scale).

C. Test Conditions and Procedure

Test conditions. The tests use a bench span of wire between two supports, with the node mounted on one

support and a lamp as the load. Tests start at reduced voltage through an isolation transformer, and mains-voltage tests are done only under supervision. Breakage is simulated by releasing the wire from a tension holder.

Procedure. First, record baseline readings with no event. Second, shake the support to produce wind-like current. Third, lower the voltage with a variable supply and no current to simulate a sag. Fourth, release the wire to simulate a break. For each case, repeat the trial many times and log whether the fault was detected, the time to relay operation and the SMS delay. The current-only, voltage-only and dual-sensor rules are scored on the same recorded events.

VI. RESULTS AND DISCUSSION

A. Objective 1: Dual-Sensor Detection

Result:

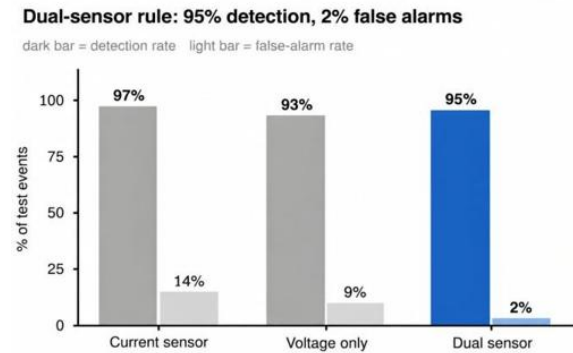


Fig. 4. Detection rate and false-alarm rate of single-cue and dual-sensor rules (illustrative).

Table II. Detection Performance (Illustrative)

Metric	Current only	Voltage only	Dual sensor
Detection rate (%)	97	93	95
False-alarm rate (%)	14	9	2

Analysis:

- First, Detection Rate: The dual-sensor rule detects 95% of simulated breaks, close to the 97% of Current alone, because a real break produces both cues.
- False-Alarm Suppression: False alarms fall from 14% (Current only) and 9% (voltage only) to 2%, since wind shocks and voltage sags rarely occur together.

- Robustness: The coincidence window T_c tolerates the short delay between shock and voltage collapse without accepting unrelated events.
- Calibration: The thresholds T_a and T_v trade detection against false alarms and must be tuned for each pole and span.

B. Objectives 2 and 3: Real-Time Detection and Isolation

Result:

Line isolated about 0.36 s after the break

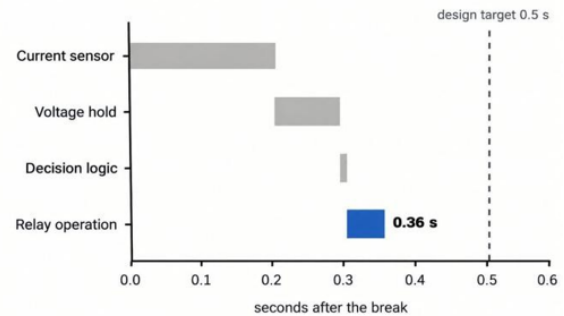


Fig. 5. Time from conductor break to relay operation, by stage (illustrative).

Table III. Isolation Time by Stage (Illustrative)

Stage	Time (s)
Current window	0.20
Voltage hold	0.10
Decision logic	0.01
Relay operation	0.05
Total	0.36

Analysis:

- First, Real-Time Response: All decisions run on the ESP32, so the line is isolated about 0.36 s after the break, inside the 0.5 s design target.
- Network Independence: The relay is driven before the SMS is sent, so isolation does not depend on mobile coverage.
- Timing Budget: Most of the time is the deliberate current window and voltage hold that filter false events; decision logic and relay operation add only 0.06 s.
- Safe State: The relay stays open until a technician resets the node, so the line is not re-energized onto a fallen wire.

C. Objective 4: Cloud Service and WhatsApp Business Messaging

Analysis

- First, Alert Delivery: After isolation, the cloud service sends the SMS fault message, normally within a few seconds depending on network conditions. The delay is logged in every trial and should be reported with the measured data.
- Local Indication: The LED and buzzer warn people near the pole even when the mobile network is unavailable.
- Limitation: A dead Cloud service network delays the alert but not the isolation.

D. Objective 5: Low Cost and Scalability Result:

Table IV. approximate cost of one node (INR)

Item	Approx. cost (INR)
ESP32 development board	450
ACS712 Current Sensor	120
ZMPT101B voltage sensor	100
Relay module	80
LCD 16 x 2	230
LEDs, buzzer, wiring, PCB	150
Outdoor enclosure	300
Total	1,430

Analysis

- First, Cost: One node cost about INR 1,430 (Table V), low enough to place a node on every span. Prices are approximate and should be replaced with actual quotes.
- Scalability: Each node is independent and built from off-the-shelf modules, so a network such as that of the Kerala State Electricity Board Limited can be covered by replicating nodes.

VII. CONCLUSION AND FUTURE WORK

This paper presented a low-cost, pole-mounted node that detects a broken low-voltage overhead conductor by requiring both a mechanical shock and a voltage collapse, opens a relay to isolate the line, and sends an SMS alert. The design covers the five objectives: dual-sensor detection, real-time IoT monitoring on an ESP32, automatic isolation, immediate Cloud service alerting, and a low-cost scalable build.

The main limitations are that one node watches one span, the thresholds need tuning for each site, and the results shown here are illustrative until measured on a real pole. Future work includes field tests on real poles cloud reporting to a web dashboard, and a fail-safe, tamper-resistant relay design.

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