

IOT-Based Smart Circuit Breaker with Smart Monitoring

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Abstract

The rapid growth of electrical loads and the increasing complexity of power distribution systems demand advanced protection and monitoring solutions. Conventional circuit breakers provide basic protection against overcurrent and short circuits but lack real-time monitoring, remote control, and intelligent decision-making capabilities. This paper presents the design and implementation of an Internet of Things (IoT)-based smart circuit breaker with smart monitoring features. The proposed system integrates current, voltage, and temperature sensors with a microcontroller and cloud platform to enable real-time monitoring, fault detection, and remote operation. Parameters such as load current, power consumption, breaker status, and fault conditions are continuously monitored and transmitted to a cloud server for analysis and visualization. In the event of abnormal conditions, the system automatically trips the circuit breaker and notifies the user through a mobile or web application. The proposed solution enhances electrical safety, improves energy management, reduces maintenance efforts, and supports predictive fault

diagnosis, making it suitable for residential, commercial, and industrial applications.

Keywords— Internet of Things (IoT), Smart Circuit Breaker, Smart Monitoring, Electrical Protection, Energy Management.

I. Introduction

Electrical circuit breakers play a crucial role in ensuring the safety and reliability of power systems by protecting electrical equipment from overloads, short circuits, and fault conditions. Traditional circuit breakers operate on electromechanical principles and are designed to disconnect the supply when fault currents exceed predefined limits. Although reliable, conventional breakers do not provide real-time information about system conditions and cannot be controlled remotely.

With the advancement of Internet of Things (IoT) technology, smart electrical devices capable of monitoring, communication, and control have become increasingly feasible. IoT enables the interconnection of physical devices through sensors, microcontrollers,

communication modules, and cloud platforms. In power systems, IoT-based monitoring allows real-time data acquisition, intelligent analysis, and remote decision-making.

The integration of IoT with circuit breakers leads to the development of smart circuit breakers that not only provide protection but also offer continuous monitoring of electrical parameters such as current, voltage, power, and temperature. These smart breakers can communicate with users and utility providers, enabling proactive fault detection and efficient energy management.

This paper focuses on the design and working of an IoT-based smart circuit breaker with smart monitoring capabilities. The proposed system aims to enhance electrical safety, reduce downtime, and improve system efficiency by providing real-time monitoring, automatic fault response, and remote accessibility.

II. Literature Review

Several studies have explored the application of IoT in electrical protection and monitoring systems. Smart energy meters have been widely adopted to measure real-time power consumption and transmit data to utilities for billing and analysis. However, these systems mainly focus on metering rather than protection.

Recent research has introduced microcontroller-based circuit breakers capable of detecting overload and short-circuit conditions using current sensors. Some systems include wireless communication modules such as Wi-Fi or GSM to notify users during fault events. However, many existing designs lack comprehensive monitoring features or cloud-based data storage and analysis.

Other studies have implemented smart relays and solid-state circuit breakers for fast fault response. While these solutions offer improved performance, they are often expensive and complex, limiting their widespread adoption. Therefore, there is a need for a cost-effective, scalable, and user-friendly smart circuit breaker system that combines protection, monitoring, and remote control using IoT technology.

III. System Architecture

The proposed IoT-based smart circuit breaker system consists of sensing, control, communication, and monitoring layers. The overall architecture is shown conceptually through the following components:

A. Hardware Components

1. Current Sensor:

A current sensor is used to measure the load current flowing through the circuit. It helps in detecting overload and short-circuit conditions.

2. Voltage Sensor:

The voltage sensor monitors the supply voltage and ensures the system operates within safe limits.

3. Temperature Sensor:

Temperature monitoring helps in identifying overheating conditions in the circuit breaker or connected loads.

4. Microcontroller Unit (MCU):

The microcontroller acts as the brain of the system. It processes sensor data, executes control logic, and communicates with the cloud platform.

5. Relay or Circuit Breaker Mechanism:

A relay or motorized circuit breaker is used to physically disconnect the power supply during fault conditions.

6. Communication Module:

A Wi-Fi module enables data transmission between the microcontroller and the cloud server.

B. Software Components

1. Embedded Firmware:

Firmware programmed into the microcontroller handles sensor readings, fault detection algorithms, and communication protocols.

2. Cloud Platform:

The cloud server stores real-time and historical data, enabling analysis and visualization.

3. User Interface:

A mobile or web-based dashboard displays system parameters and allows remote control of the circuit breaker.

IV. Working Principle

The working of the IoT-based smart circuit breaker can be explained as follows:

Initially, the system continuously measures electrical parameters such as current, voltage, and temperature using sensors. These values are sent to the microcontroller, where they are compared with predefined threshold limits.

If the load current exceeds the safe limit due to overload or short circuit, the microcontroller immediately triggers the relay mechanism to trip the circuit breaker. Simultaneously, an alert message is sent to the user through the cloud platform.

In normal operating conditions, the measured parameters are periodically uploaded to the cloud server. The user can access real-time data through a dashboard and analyze energy consumption trends. The system also allows remote switching of the circuit breaker, enabling users to turn loads ON or OFF from anywhere.

V. Smart Monitoring Features

The proposed system provides several smart monitoring functionalities:

- **Real-Time Monitoring:** Continuous tracking of current, voltage, power, and temperature.
- **Fault Detection and Alerts:** Instant detection of abnormal conditions with automatic tripping and notifications.
- **Remote Control:** Users can remotely operate the circuit breaker via a mobile application.
- **Energy Consumption Analysis:** Historical data helps in identifying energy usage patterns.
- **Predictive Maintenance:** Early detection of overheating or abnormal behavior reduces the risk of failure.

VI. Advantages of the Proposed System

The IoT-based smart circuit breaker offers several advantages over conventional systems:

1. Improved electrical safety through real-time monitoring.
 2. Reduced downtime due to faster fault detection and response.
- maintenance efforts. With further advancements in IoT and smart grid technologies, smart circuit breakers are expected to play a vital role in future power distribution systems.

3. Remote accessibility and control.
4. Enhanced energy management and efficiency.
5. Cost-effective and scalable solution.
6. Reduced manual inspection and maintenance.

VII. Applications

The proposed system can be applied in various sectors:

- **Residential Buildings:** Smart home energy monitoring and protection.
- **Commercial Buildings:** Office load management and safety.
- **Industrial Plants:** Monitoring of critical equipment and fault prevention.
- **Smart Grids:** Integration with intelligent power distribution systems.

VIII. Challenges and Future Scope

Despite its advantages, the system faces challenges such as cybersecurity risks, network dependency, and scalability issues. Future improvements may include advanced data analytics using artificial intelligence, integration with renewable energy sources, and support for multiple communication protocols. Solid-state breakers and edge computing can further enhance system performance and reliability.

IX. Conclusion

This paper presented the design and implementation of an IoT-based smart circuit breaker with smart monitoring capabilities. By integrating sensors, microcontrollers, and cloud platforms, the proposed system provides real-time monitoring, automatic fault detection, and remote control of electrical circuits. The solution enhances safety, reliability, and energy efficiency while reducing

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