

Real Time Transformer Fault Detection and Wireless Electrical Billing System Using Embedded System and IoT

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Abstract

This project focuses on developing a real-time transformer monitoring and wireless electricity billing system using an embedded system combined with Internet of Things (IoT) technology. The system continuously observes important electrical parameters in power distribution networks to improve safety, control, and billing accuracy. Current Transformer (CT) and Potential Transformer (PT) sensors are used to sense current and voltage values, while a temperature sensor checks the heat level of the transformer. An Arduino microcontroller collects and processes this data, and the measured values are shown on an LCD for easy local monitoring. In summary, this system integrates fault detection, protection, and smart energy billing into a single IoT-based embedded solution. It improves transformer safety, simplifies maintenance, and ensures transparent energy usage monitoring, making it suitable for modern power distribution systems.

Keywords: Transformer Fault Detection, Embedded System, Internet of Things (IoT), Arduino, Current Transformer (CT), Potential Transformer (PT), Temperature Monitoring, Energy Meter, Smart Billing, Wireless Monitoring, Relay Protection, Power Distribution System

1. Introduction

Electric power systems are essential for daily activities, as a continuous and dependable electricity supply is required for homes, industries, and commercial sectors [1]-[4]. Transformers are key components in power distribution systems, as they handle voltage regulation and enable efficient transmission of electrical energy. However, transformers can experience issues such as excessive voltage, high current, overheating, and insulation problems, which may cause equipment damage, energy losses, and service interruptions. Hence, continuous monitoring and early fault detection are necessary to maintain reliable operation and prevent failures [5]-[8]. In this system, an electronic energy meter is used to record electricity consumption and automatically compute the electricity charges based on the units used. Important parameters such as voltage, current, temperature, energy usage, and

billing information are sent to a cloud-based IoT platform [9]-[12]. This allows consumers and utility personnel to view real-time data remotely through the internet [13]-[15]. The system reduces manual effort in meter reading and improves accuracy and transparency in the electricity billing process [16]-[18].

2. Literature Survey

2.1. Meena, D., and Rajesh, P. — Embedded-Based Fault Detection in Distribution Transformers (2019)

Summary / Method: This research focuses on monitoring distribution transformer conditions using sensors interfaced with a PIC microcontroller. The system measures temperature, voltage, and current and triggers alarms upon detecting abnormalities.

Key Findings: The embedded fault detection approach reduces manual inspection needs and

provides immediate alerts to prevent transformer burnout.

Relevance: Justifies the use of embedded controllers for transformer fault detection and supports integrating temperature, voltage, and current sensors as used in this project.

2.2. Patel, N., et al. — Transformer Protection using Arduino and GSM Technology (2020)

Summary/Method: This study describes a transformer protection system using Arduino, GSM module, and sensors for current, voltage, and temperature measurement.

Key Findings: Combining Arduino and GSM technology ensures real-time protection and communication, enhancing transformer safety.

Relevance: Confirms that Arduino-based embedded systems are effective for transformer protection, and relay-based isolation provides efficient fault handling.

3. Proposed System

The developed real-time transformer monitoring and wireless billing system using embedded technology and IoT addresses the drawbacks of conventional monitoring and manual billing methods. It combines continuous sensing, automatic safety control, and online energy billing into a single smart solution. In this setup, current and voltage levels are continuously tracked using Current Transformer (CT) and Potential Transformer (PT) sensors, while a temperature sensor observes the thermal condition of the transformer. An Arduino microcontroller receives and analyzes the sensor data and presents the key parameters on a 16×2 LCD screen for immediate on-site observation. The system also includes an electronic energy meter to record power usage. Based on the measured energy units, the billing amount is computed automatically using predefined tariff rules. If unsafe conditions such as excessive voltage, current, or temperature are detected, the controller instantly activates a relay to disconnect the supply and protect the transformer from damage. All operational data and alert information are a cloud-based IoT platform via a Wi-Fi or GSM communication module. This allows utility staff and consumers to access real-time readings, receive notifications, and review stored data through a web

interface or mobile application. Overall, the system provides reliable fault protection, precise energy billing, and remote monitoring in a cost-efficient manner, making it suitable for deployment in both urban and rural power distribution systems to enhance safety and operational performance.

4. Arduino UNO

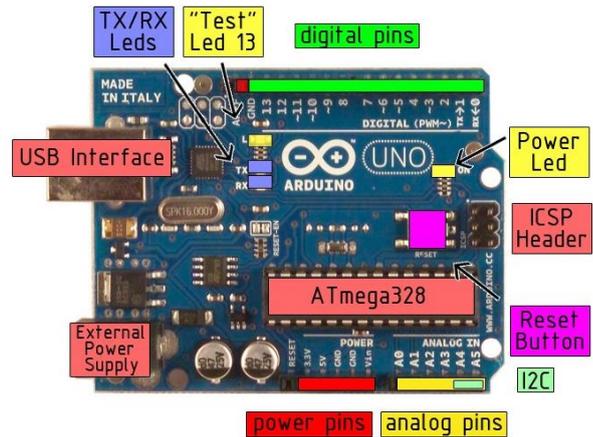


Figure 1 Arduino UNO Board

Power: The Arduino Uno can receive power either through a USB cable or from an external power source, with the board automatically choosing the appropriate supply. An external power input may be provided using an AC-to-DC adapter or a battery source. The adapter is connected using a 2.1 mm center-positive plug through the board's power jack, while a battery can be connected directly to the Vin and GND pins on the power header. The Arduino Uno supports an external voltage range between 6 V and 20 V. Supplying less than 7 V may result in insufficient output on the 5 V pin, causing unstable operation. On the other hand, applying more than 12 V can lead to excessive heating of the onboard voltage regulator, potentially damaging the board (Figure 1).

5. Results and Discussion

The developed setup effectively combines current, voltage, and temperature sensing units with an Arduino controller to enable continuous transformer supervision. Measurements obtained from the CT, PT, and thermal sensors are shown on a 16×2 LCD, presenting real-time values of voltage, current, temperature, and total energy usage in kilowatt-hours. Based on the recorded energy consumption

and preset tariff values, the system computes the electricity charges automatically. If unsafe conditions such as high or low voltage, excessive current, or abnormal temperature are detected, the relay is immediately deactivated to isolate the transformer load and prevent damage. Under safe operating conditions, the relay remains active, allowing uninterrupted power flow. All sensor readings and system status updates are transmitted to an IoT cloud platform, enabling remote observation and data analysis through web or mobile interfaces. The system was tested under different operating scenarios. During standard conditions (230 V, 2 A,

35 °C), stable readings were observed and the relay stayed active. When the temperature exceeded 90 °C or the voltage crossed 250 V, the relay responded instantly by disconnecting the load, validating the protection mechanism. Energy meter pulse counting was precise, and the IoT module reliably uploaded data to the cloud for real-time visualization. In conclusion, the system proved to be accurate, responsive, and dependable in monitoring and protection operations, offering an affordable and intelligent solution for modern electrical monitoring and smart billing applications (Figure 2).

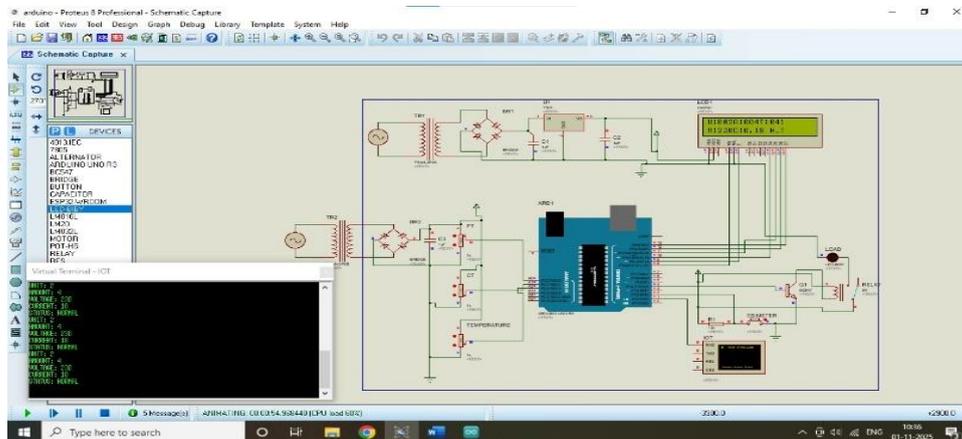


Figure 2 Simulation Result

Conclusion

The proposed “Real-Time Transformer Fault Detection and Wireless Electrical Billing System” offers a reliable solution for monitoring transformer conditions and automating electricity billing. By integrating embedded hardware with IoT technology, the system enables continuous fault monitoring, quick protective action, and seamless wireless communication of data. This method significantly reduces the need for manual meter readings, lowers the chances of transformer damage, and enhances overall power distribution efficiency. Remote monitoring and data storage through IoT support the development of intelligent and sustainable energy systems. Future improvements may include the use of advanced sensing devices, artificial intelligence for predictive fault analysis, and interactive cloud-based dashboards. These upgrades would increase system accuracy, adaptability, and scalability, making it

suitable for large-scale smart grid applications. work being published. Place Acknowledgments, including information on the source of any financial support received for the work being published.

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