

IoT-Based Smart Socket Power Monitoring and Protection System for Indian Railway Coaches

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Abstract - The misuse of passenger charging sockets for using unauthorized high-power electrical appliances in Indian Railway coaches presents significant challenges related to electrical safety, power efficiency, and system reliability. Conventional protection schemes in Sleeper (SL) and AC 3-Tier (3AC) coaches are limited to sectional overload protection and do not provide socket-level monitoring or control. This paper presents an IoT-based smart socket monitoring and protection system for railway coaches that detects illegal appliance usage and responds automatically in real-time. This system utilizes a PZEM-004T Energy monitoring sensor module to measure electrical parameters like voltage, current, and power consuming at individual sockets. The Arduino Uno continuously analyzes the measured parameters against predefined threshold values. Upon detection of excessive power consumption indicates the unauthorized appliance usage, the system activates a relay-based isolation mechanism to disconnect the affected socket. Simultaneously, a GSM communication module transmits an alert message to the concerned railway authority, while an audible buzzer provides local indication. The socket is automatically restored after a configurable delay to allowing normal usage. The proposed solution is cost-effective, scalable, and compatible with existing railway power distribution infrastructure. Experimental evaluation demonstrates its effectiveness in detecting illegal loads, preventing overload conditions, and improving operational safety in passenger coaches.

Keywords—PZEM-004T, Arduino Uno, Relay, GSM Communication (Global System for Mobile Communication), Buzzer.

I. INTRODUCTION

Railway passenger coaches are increasingly equipped with charging sockets to enhance passenger convenience. However, these sockets are frequently misused for powering high-voltage appliances such as heaters, kettles, and other appliances. leading to electrical overloads and safety hazards. Traditional monitoring systems lack real-time detection and control capabilities. The integration of Internet of Things technology enables continuous monitoring and intelligent decision-making for energy systems [1],[2]. GSM communication further

improves system reliability by providing remote alerts and monitoring [5],[7],[11]. However, existing systems do not provide socket-level protection. This paper proposes a smart IoT-based system that monitors real-time energy usage, detects abnormal consumption, automatically disconnects unauthorized loads, and sends alerts to authorities.

II. SYSTEM ARCHITECTURE

A. Functional Block Diagram of the System

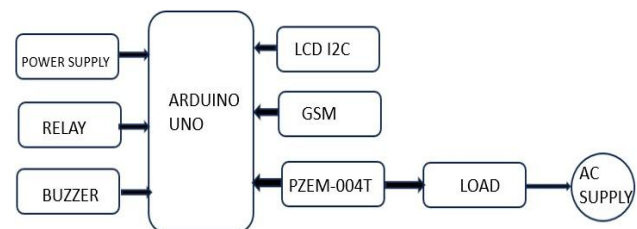


Fig.1 The Operational Block Diagram of the Smart Socket.

The block diagram in Fig.1 of a smart socket system used in railway coaches to monitor power usage and prevent misuse and hazards. Here, the Microcontroller used is the Arduino Uno, which controls the entire system. Power from the AC supply goes to the socket, and the PZEM-004T energy meter Sensor measures values like voltage, current, and power in real-time. The parameters are sent to Arduino Uno, which checks if the current drawn is below the threshold. If it is below the threshold, the socket receives the power. If a high-power appliance is connected and the threshold is exceeded, the Arduino switches off the relay to cut the AC supply to avoid overload.

The buzzer sounds to alert, the LCD display shows the current readings, and the GSM module sends a message to the concerned authorities. This way, the system helps to maintain the safe and proper use of charging sockets in railway coaches.

B. Circuit Diagram of the System

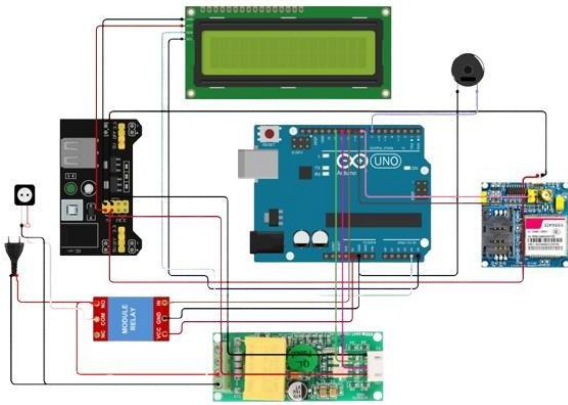


Fig.2 The Circuit Diagram of the Smart Socket System

In the Fig.2 it shows the circuit diagram of the IOT Based Smart Socket Power Monitoring and Protection System, The Arduino Uno is the central microcontroller for this circuit and it is powered using a USB cable connecting with a Adapter to the power supply, The other circuit components are powered by a regulated power supply module, which provides 5V and GND to the PZEM-004T, GSM, Relay. The buzzer is connected to the digital pin and ground of the Arduino board, enabling it to produce an alert sound when abnormal usage is detected. The LCD Module is connected using I2C communication, where the SDA and SCL pins are connected to Arduino Analog pins.

III. METHODOLOGY

A. Working of the model

The Arduino Uno is powered using a USB cable and an adapter connecting it to a power supply. The Microcontroller is programmed using the software called Arduino IDE version 2.0. When the power is supplied to the circuit, the relay turns on, and the circuit start working, the sockets start working, by which we can charge our mobile phones and laptops. But whenever a high-load appliance is connected to the socket, it draws high currents. The microcontroller is programmed in such a way that whenever the current consumption exceeds the threshold, in this case, is 2.5Amperes.

So, whenever the socket exceeds the current threshold, the current readings are sensed through the PZEM-004T sensor, then the Arduino cuts off the relay and turns off the power supply to the sockets, the Buzzer turns on, the LCD shows the alert display, and sends an SMS to the concerned authority. After 10 seconds again, the relay turns on, and the socket starts working as usual.

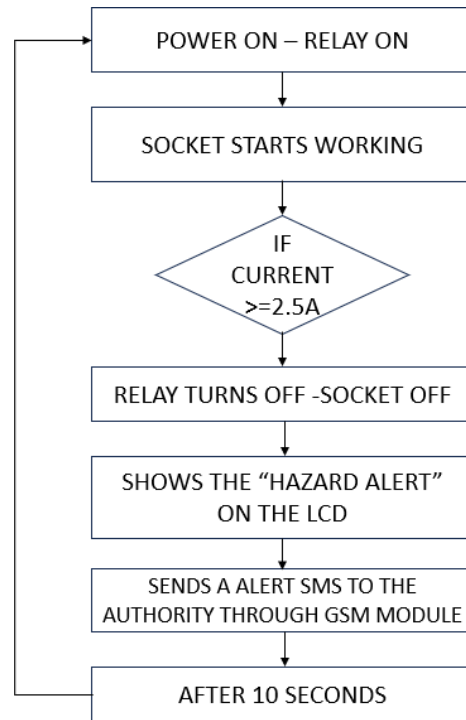


Fig.3 The operational flowchart of the proposed system.

B. Conditions

Condition no.	Voltage(V)	Current(I)	Condition status	Relay action	Lcd response	Gsm alert
1	220-240V	<2 Amperes	SAFE	ON	NORMAL	NO ALERT
2	>240V	>2 Amperes	NOT SAFE	OFF	HAZARD ALERT !	SENDS ALERT

Fig.4 Operational threshold conditions for IOT-based smart socket power monitoring and protection system for indian railway coaches.

The proposed system functions by continuously monitoring the electrical parameters and comparing them to established safety limits. The PZEM-004T sensor module continuously measures voltage, current, and power. The power consumption is calculated using the basic electrical relation.

$$P = V \times I \tag{1}$$

Under normal operating conditions, when the voltage lies within the safe limits, that is, voltage < 240V and the current < 2A, the calculated power remains within the acceptable limits, and the system and the system maintain a safe status with the relay ON condition. However, when the voltage exceeds the voltage >240V and the current >2A, the power consumption increases significantly, indicating a potential overload or misuse. In such cases, the system considers the condition as not safe, triggers the relay to switch OFF the load, activates a hazard alert on the LCD, and sends a notification through the GSM module. This threshold-based decision mechanism provides effective protection by stopping excessive power use and by keeping the railway coach sockets operate safely.

C. Prototype development

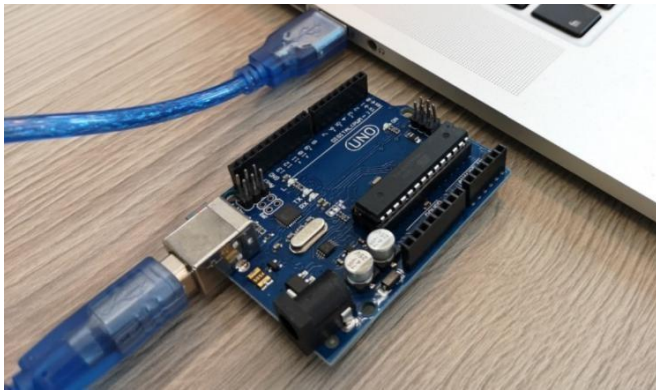


Fig.5 Prototype development setup where the Arduino UNO is interfaced with a laptop for program uploading.

The prototype of the suggested system was developed to confirm the real-time monitoring and protection mechanism under different operating conditions. The implementation primarily focuses on the integration of sensing, processing, and control logic to ensure safe power usage.

The software development was carried out using the Arduino IDE version 2.0, which was used to write, compile, and upload the program to the controller. The code was developed in embedded C and structured to continuously read electrical parameters such as voltage, current and power from the sensing module through serial communication. A threshold-based control algorithm was implemented to analyze the incoming data in real time. The system compares the measured values with predefined safety limits, and based on this comparison, appropriate actions are executed.

IV. RESULTS AND DISCUSSION

A. Hardware prototype

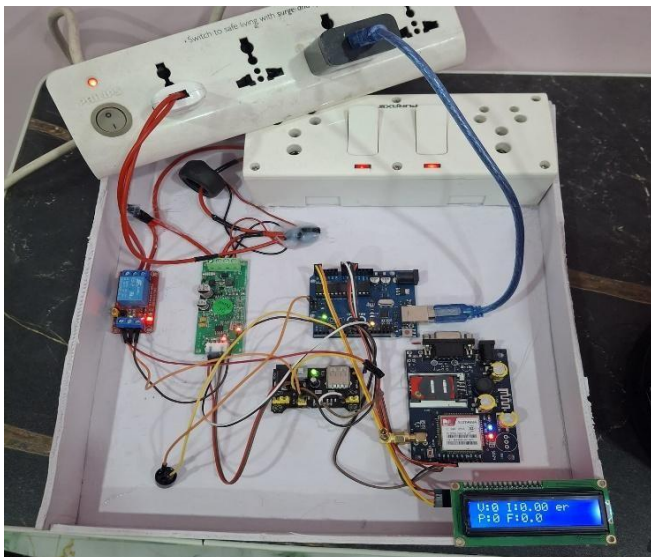


Fig.6 The Hardware prototype of the IoT- based socket power monitoring and protection system for Indian railway coaches.

The prototype of the proposed system successfully integrated all functional modules into a single working model, as illustrated in Fig.6 The system used an Arduino Uno as the main

controller, connected to a PZEM-004T energy meter, a relay module, a GSM module, and an LCD display. The system's stable operation is ensured by correctly wiring the components and providing a controlled power supply. The LCD display shows electrical parameters as they change, and the GSM module allows for remote alerts through communication capabilities. The prototype's less complex design makes it well-suited for real-world applications.

B. LCD display outputs



Fig.7 The LCD display showing real-time readings of the electrical parameters when the load is connected, and its range is below the threshold limits.

As displayed in the Fig.7, the LCD display presents real-time values of the voltage, current, and power when a mobile charger is connected to the system. The displayed readings fall within the predefined threshold limits, that is, voltage=258V <280V and current=0.16A <2A, indicating safe operating conditions. This typically corresponds to low-power loads such as mobile chargers or laptop chargers that do not draw excessive current. As the parameters are under the threshold limits, voltage < 280V and current < 2A, the system allows continuous normal operation without any interruption in usage.



Fig.8 The LCD display showing real-time reading of the electrical parameters when a load is connected, and its range is above the threshold limits.

In the Fig. 8, the LCD displays a voltage of 250V and a current of 4.02. These readings were obtained when a heater was connected to the socket. These values are higher than the safe limits set in the system, which indicates an unsafe condition. The system recognizes and immediately turns OFF the relay, shuts the power supply to the socket for 10 seconds, and sends

an alert message through the GSM module. This helps prevent misuse and protects the passenger and railway coaches from electrical hazards.

C. GSM alert notification output

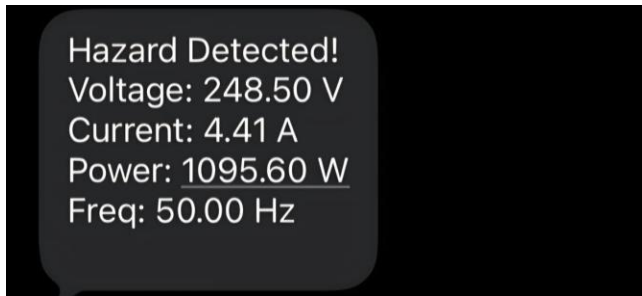


Fig.9 The alert message received through the GSM module when unsafe limits are triggered, indicating abnormal power usage

In the Fig.9, an SMS alert is sent through the GSM module as “HAZARD DETECTED” indicating the abnormal power usage. The message includes important details like voltage, current, and power. So, for the authorities, it is easy to understand that someone is misusing the socket. In real-time, the alert can also include the coach number and berth details, which will help the authorities to quickly find the location of the issue. This makes the system reliable, allowing faster response and better safety by informing the authority at the right time.

V. CONCLUSION AND FUTURE SCOPE

This project is about making the system for monitoring and protecting the sockets where people plug in their devices in Indian railway coaches. This project ensures safe use of socket and reduces the risk of hazards.

In the future we can make the system better by creating an App to monitor and manage the system through it.

VI. ACKNOWLEDGEMENT

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