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SMART DISTRIBUTION BOARD FOR HOME APPLIANCES

Dr. R.S. Parihar*, Shweta Kanwar, Harshvardhan Singh Thakur****,
Ugeshwar Kumar Nishad**, Sumit Kumar Rathore**

*Professor, Department of Electrical & Electronics Engineering, GEC Raipur, Raipur (C.G.), India
*B. Tech student, Department of Electrical & Electronics Engineering, GEC Raipur, Raipur (C.G.), India
*B. Tech student, Department of Electrical & Electronics Engineering, GEC Raipur, Raipur (C.G.), India
*B. Tech student, Department of Electrical & Electronics Engineering, GEC Raipur, Raipur (C.G.), India
*B. Tech student, Department of Electrical & Electronics Engineering, GEC Raipur, Raipur (C.G.), India

ABSTRACT

The novel smart distribution board discussed in this paper offers a comprehensive approach to enhancing safety and efficiency in electrical systems. With its multi-channel design, the board integrates sensors and control mechanisms to monitor and manage current and voltage, providing robust protection against electrical hazards. The channels are equipped with ACS712 current sensors connected to Arduino microcontrollers, allowing real-time tracking of current consumption. These microcontrollers compare analog input values against adjustable preset thresholds set via potentiometers. This setup enables precise control over current limits, automatically activating relay switches to prevent overloads and short circuits. The distribution board also features a voltage sensor to monitor input voltage, detecting both undervoltage and overvoltage conditions to protect against equipment damage or malfunction, with adjustable thresholds for flexible configuration. An earth leakage protection is provided, which compares phase-current with neutral-current to identify imbalances indicative of potential leakage, triggers a protective relay to disconnect the circuit, reducing the risk of electric shock. The combination of these advanced features in the smart distribution board ensures comprehensive control and safety for electrical systems, making it ideal for various domestic and industrial applications. This innovative technology represents a significant leap forward in electrical distribution, offering improved operational efficiency and reduced risks of electrical hazards.

Keywords: - MCB, Relay, Sensors, Earth Leakage, Real - time monitoring

INTRODUCTION

A distribution board, also known as a breaker panel or fuse box, serves as a central hub in an electrical system, managing the distribution of power throughout a building. It comprises several crucial components, including the main switch or main circuit breaker, circuit breakers or fuses, busbars, neutral bar, earth/ground bar, enclosure, and labels/markings. The main switch controls the entire electrical supply, while circuit breakers or fuses protect individual circuits from overloads or short circuits. Busbars distribute power, the neutral bar handles return currents, and the earth/ground bar provides a path for fault currents to the ground, ensuring safety. The enclosure protects internal components from environmental damage, and labels/markings aid in circuit identification for maintenance. Overall, a properly designed and maintained distribution board is essential for safe, reliable, and efficient electrical distribution within a building.

DRAWBACKS OF TRADITIONAL DISTRIBUTION BOARD

Traditional distribution boards in homes often face various drawbacks that have spurred research and development efforts for improvements. These limitations include limited monitoring and control capabilities, leading to challenges in promptly addressing issues. They also lack fault detection mechanisms, posing safety risks and potential equipment damage. Inefficient energy usage is another concern due to the absence of real-time monitoring and optimization features. Integration with modern smart home devices and energy management systems is limited, impacting automation potential. Troubleshooting issues is difficult without detailed diagnostic information or remote access. Safety concerns arise due to inadequate protection against certain faults, and frequent manual maintenance is often required, especially in larger residential or commercial settings.

SMART DISTRIBUTION BOARD

The paper discusses the transformative impact of smart distribution boards on electrical systems, highlighting their key features and components. These boards integrate advanced sensing technologies like current, voltage sensors for real-time monitoring and analysis. They leverage IoT connectivity for remote management and control, alongside data analytics and machine learning for predictive maintenance and energy optimization. Safety features include fault detection mechanisms and integration with building management systems for comprehensive control. Overall, smart distribution boards offer enhanced safety, efficiency, and control, making them a significant advancement in electrical distribution technology for both residential and industrial applications.

Asim Datta et al. (IEEE 2012) provide a creative approach for low-range AC current detection, utilising an ATmega microcontroller for data collection and signal processing, along with the ACS712 Hall-sensor [4]. The system achieves high precision of 0.01 A and 10-bit resolution by utilising the hall-sensor's speed and temperature tolerance. Simulation and experimental validation show robust performance across settings and applications. The current sensing circuit's consistency and usefulness are highlighted by the Proteus 8 Professional software implementation details, which also highlight how little variation there should be within a 5 A range. The developed prototype verifies the feasibility of the AC current sensing system by offering a rapid, precise, and portable solution for industrial and automation applications. [4]

Witsarut Sriratana et al. investigate how the type of Hall Effect sensor and the direction and placement of permanent magnets impact sensor module efficacy in their 2020 IEEE paper [3]. They use four distinct arrays and a single Hall Effect sensor to conduct experiments using electrical analogue signals. Enhancing the effectiveness and dependability of sensors is their main objective, especially with regard to identifying drilling locations on metal surfaces. Their research demonstrates that Single Hall Effect sensors, particularly in slot designs, are very good at seeing minute fractures or drilled holes. On the other hand, 4-Crossing Hall Effect sensors generate reliable and smooth output signals and are effective in identifying larger holes or cracks. The accuracy of detection is increased when many Hall Effect sensors are combined, particularly when identifying the borders of holes or cracks, the key point was to choose the right sensor module depending on the specific detection needs. [3]

Smart energy metres play a critical role in the transition from traditional grids to smart grids. For efficient network communication, these metres depend on microcontrollers, sensors, and communication technology [8]. For smart metre projects, comparing microcontrollers and sensors is essential since it takes into account aspects like power consumption, accuracy, memory capacity, and cost. The investigation looked at standalone sensors like ZMPT101B and SCT013, as well as integrated systems like PZEM004T. After evaluation of several popular microcontrollers, including ATMEGA328P, STM32, ATMEGA1284P, and PZEM, performance criteria led to the conclusion that ATMEGA1284P was the best choice.[8]

Vishnukant V. Gavhaneet al.'s essay "IoT technology can enhance energy metering and home appliance monitoring for everyday use" (IEEE 2021) [1]. They recommend an automated system to read metres and generate bills in order to cut down on errors and effort. The system consists of an Arduino Mega 2560 microprocessor, energy-measuring ZMPT101B and ACS712 sensors, an infrared flame sensor for safety, and an 8-channel relay module for voice-activated appliance control. Environmental data is collected using a DHT11 sensor and delivered to the ThingSpeak cloud for real-time analysis with an ESP8266 Wi-Fi module. A review of the literature, flowcharts, specifications for the hardware and software, system architecture, and operational outcomes are all included in this project. Plans for the future include enhancing the system's functionality and installing a web server for electricity authorities [1].

The amount of energy used in households increased considerably during the Covid-19 epidemic [6]. The goal of this project was to create a home energy monitoring system that could be accessed on Android smartphones through Telegram Messenger and Thinger.IO, an Internet of things platform. For online communication, the system made use of ZMPT101B and ACS712 sensors in conjunction with an ESP32 microprocessor. Results showed that the ZMPT101B sensor had a high accuracy rate of 99.845%; nevertheless, there were some differences with the ACS712 sensor (ranging from 0.32 A to 0.04 A). Despite slow connection, Thinger.IO's data recording functioned smoothly, and the Telegram Bot feature worked as intended.[6]

A clever method for improving electrical system safety using a Residual Current Circuit Breaker with Overcurrent protection (RCBO) is presented by Hossein Mafi et al. (IEEE 2019 [5]). This programmable, multipurpose gadget with microcontroller technology efficiently handles the risks of overload, short circuit, and leakage current. Experiments in validation verify that it can quickly identify and fix errors, protecting both people and property. Integration with IoT technology expands its usability across various circumstances by enabling remote monitoring and control [5].

A Smart Distribution Board integrating IoT, Hall Effect sensors, and Solid-State Circuit Breakers (SSCB) for low-voltage residential and commercial applications is presented by Akhil Josea et al. in IEEE 2013 [2]. Hall Effect sensors allow real-time energy management by monitoring subcircuit current. Throughout the study, the benefits of SSCBs over traditional breakers are underlined, with special focus on their automation capabilities, compatibility with AC/DC systems, and fast, arc-free operation. The board has SSCBs for basic protection, which ensures quick fault current interruption and system reliability. IoT-based monitoring tracks power usage, optimises energy utilisation, and notifies users of anomalies. Home automation with platforms like Amazon Alexa enables device control. It is confirmed that the technology works well to improve user experience and energy distribution by hardware setup and simulation [2].

The cost-effective energy metre prototype shown in this study makes use of parts such the NodeMCU ESP8266, ESP32, an LCD display connected via I2C, the ZMPT101B voltage sensor, and the SCT-013 current sensor [9]. These parts were carefully chosen because they were compatible, easily accessible, and in line with the goals of the project. The energy metre provides exact data for electrical systems by measuring voltage and current with accuracy. Integration with the Thingspeak platform facilitates data transmission and allows for remote monitoring. Moreover, real-time data, control choices, historical analysis tools, and insights into energy consumption are all provided by a control system that is connected with Sinric Pro and Thingspeak API to manage room electricity. This integrated system provides an efficient and workable energy management solution.[9]

The article discusses appliance protection and electricity management, with a focus on nations like India. It showcases an Internet of Things (IoT)-based automated energy metre that uses the Arduino Uno, ESP8266 Wi-Fi module, ACS712 current sensors, ZMPT101B voltage sensor, and MQTT protocol [7]. It also has invoicing and protection features. This system calculates bills, keeps an eye on energy usage, and shows data to authorised users on the IO cloud. Additionally, it notifies consumers via email when bill thresholds are exceeded or when anomalies like overvoltage or ground faults are detected. As an alternative to conventional metres, this technology provides real-time monitoring, bill creation, and anomaly identification.[7]

Using carefully selected parts including NodeMCU ESP8266, ESP32, LCD Display (I2C), ZMPT101B Voltage Sensor, and SCT-013 Current Sensor, the study describes the development of a Prototype Cost-Effective Energy Metre [10]. In order to provide accurate measurements of voltage and current in electrical systems, these choices were made based on compatibility and project objectives. Thingspeak allows data transfer for remote monitoring, and its interaction with Sinric Pro and Thingspeak API provide real-time information and energy consumption control. Furthermore, using Insulated Gate Bipolar Transistor (IGBT) technology, the study investigates a Solid-State Circuit Breaker (SSCB) for low voltage protection. Leakage current, overloads, undervoltage, overvoltage, and short circuits are just a few of the defects that the SSCB can identify and fix like a switch. The SSCB's effectiveness in preventing system for various fault scenarios damage is confirmed by experimental results.[10]

PROBLEM IDENTIFICATION

The research paper for the project titled "Smart Distribution Board for Home Appliances" identifies several key problems in the context of Indian distribution boards, supported by practical and numerical values:

1. Safety Hazards: Traditional distribution boards in India often lack advanced safety features, leading to safety hazards such as electrical shocks and fire accidents. For example, according to the National Crime Records Bureau (NCRB), electrical accidents accounted for approximately 10% of accidental deaths in India in the past year.

2. Energy Inefficiency: Inefficient energy usage is a significant issue in Indian households, resulting in high electricity bills and environmental impact. On average, Indian households waste about 20-30% of their energy consumption due to inefficient appliances and improper load management.

3. Limited Control and Monitoring: Existing distribution boards offer limited control and monitoring capabilities, making it challenging for users to manage energy usage effectively. For instance, without real-time monitoring, users cannot identify and address energy-wasting behaviors promptly.

Traditional distribution boards using Miniature Circuit Breakers (MCBs) suffer from several critical limitations impacting their functionality and safety. These include limited monitoring capabilities, absence of remote control functionalities, inefficient overload protection, and inadequate earth leakage protection. The boards also lack customization options, require manual resets after trips, pose maintenance challenges, and lack integration with smart home systems. These issues lead to challenges in both residential and industrial settings, such as extended downtime, safety hazards, and inconvenience for users. In industrial environments, the absence of real-time monitoring can lead to equipment malfunctions and safety hazards, while residential areas face risks from voltage fluctuations and earth leakage. Addressing these drawbacks through alternatives like smart distribution boards with advanced monitoring, remote control, and safety features is crucial for improving efficiency, safety, and convenience in electrical systems across different environments.

PROPOSED METHODOLOGY

The Smart Distribution Board is an advanced system designed to improve safety and efficiency in electrical systems. This methodology outlines the development and implementation of the smart distribution board, focusing on the integration of various components such as current sensors, diodes, resistors, capacitors, relay switches, alarm systems, LCD displays, potentiometers, push buttons, and a voltage sensor. Each component plays a crucial role in ensuring the functionality and reliability of the system

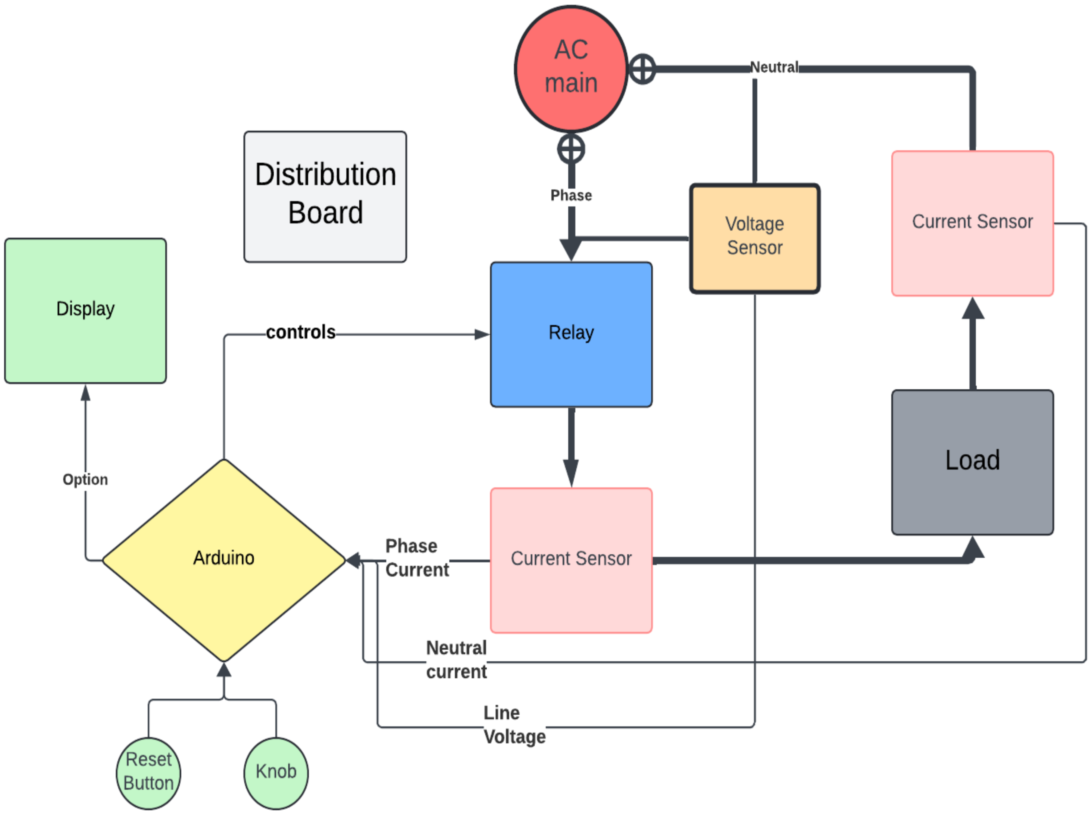
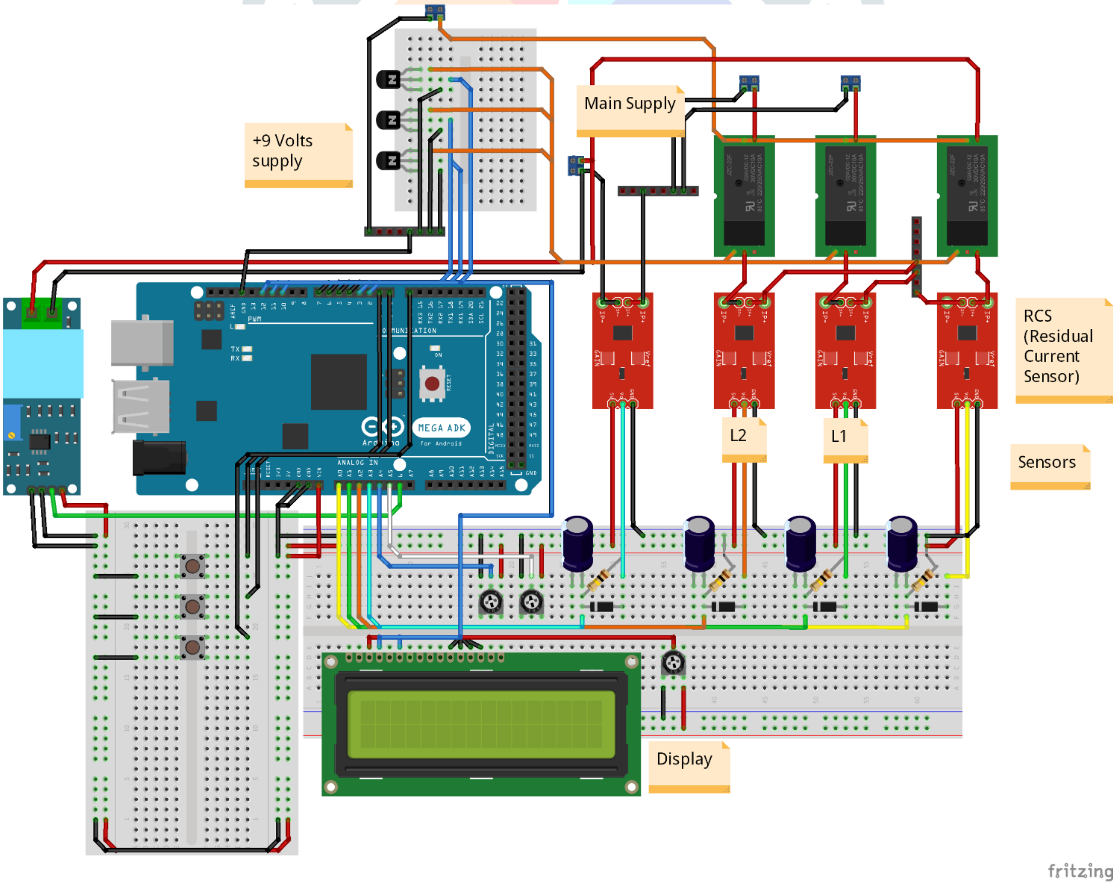


Figure 1. Block Diagram Of Smart Distribution Board

Figure 2. Circuit for the Smart Distribution Board



A. Current Sensors and Filtering:

a. The project uses four current sensors: one for phase, second for the neutral (both are work for earth leakage protection) , and another two for line currents. Each current sensor's output is conditioned using diodes, 100 kΩ resistors, and 4.7 µF capacitors to filter out noise and provide a clean signal.

b. These filtered signals are then fed into analog pins of the Arduino Uno (A0, A4, A5, A3) for processing.

B. Fault Detection and Relay Control:

a. The Arduino continuously monitors the current values from the sensors.

b. If a fault is detected, such as overcurrent or earth leakage, the Arduino triggers an alarm by activating pin 13.

c. Additionally, based on fault conditions, the Arduino sends signals to control relays using transistors connected to pins 11 and 12.

d. The relays are connected to trip the respective lines or circuits in case of faults, ensuring safety and preventing damage.

C. LCD Display for Real-Time Data:

a. The Arduino communicates with the 1602 LCD display module to show real-time data.

b. The displayed information includes current values for each line, current thresholds, voltage levels, voltage thresholds, and fault status.

c. This real-time display provides users with crucial information about the system's health and status.

D. Push Buttons and Threshold Setting:

a. The push buttons connected to pins 1 and 0 of the Arduino are used for fault acknowledgment.

b. When a fault occurs, pressing the corresponding push button acknowledges the fault and resets the system, allowing it to operate normally.

c. Potentiometers connected to analog pins A1 and A2 are used to set the threshold values for line 1 and line 2 currents, respectively.

d. These thresholds determine when a fault is considered and triggers the appropriate actions.

E. Voltage Sensor for Protection:

a. The ZMPT101B voltage sensor is used for overvoltage and undervoltage protection.

b. The Arduino continuously monitors the voltage levels using this sensor.

c. If the voltage exceeds the predefined thresholds (180 volts for undervoltage and 250 volts for overvoltage), the Arduino takes necessary actions such as triggering alarms or activating relays to protect the system.

F. Earth Leakage Protection :

a. The Earth Leakage Protection system proposed in this project aims to safeguard electrical circuits against the risks posed by earth leakage currents. Comprising four current sensors strategically positioned within the circuit—specifically, one for phase current, one for neutral, and two for current division—the system ensures comprehensive monitoring of current flow. The critical threshold for earth leakage is set at 1 ampere, beyond which the system activates visual feedback through a display unit and triggers an audible alert via a buzzer. Calibration of the current sensors ensures precise detection of current levels, while the microcontroller unit processes the data, analyzing for deviations indicative of earth leakage. Rigorous testing and validation procedures are employed to verify the system's accuracy, response time, and overall effectiveness in detecting and responding to earth leakage events. The successful implementation of this Earth Leakage Protection system promises enhanced electrical safety, mitigating the risks associated with potential faults in the circuit.

G. Software Implementation and Control Logic:

a. The Arduino's firmware implements control logic for data acquisition, fault detection, threshold comparisons, LCD display updating, and fault acknowledgment.
b. It continuously loops through these tasks, ensuring real-time monitoring and protection of the electrical system.
c. The software also handles user inputs from push buttons and potentiometers to adjust thresholds and acknowledge faults.

H. Testing and Validation:

a. The entire system is thoroughly tested and validated under various operating conditions.
b. This includes testing individual components, simulating fault scenarios, calibrating thresholds, and verifying the system's response and reliability.
c. Testing ensures that the system operates accurately, effectively detects faults, and provides necessary protection measures.

Overall, the working of the 3-Channel Smart Distribution Board involves a coordinated effort between hardware components, sensors, relays, and the Arduino's firmware to ensure safe and efficient operation of electrical distribution systems.

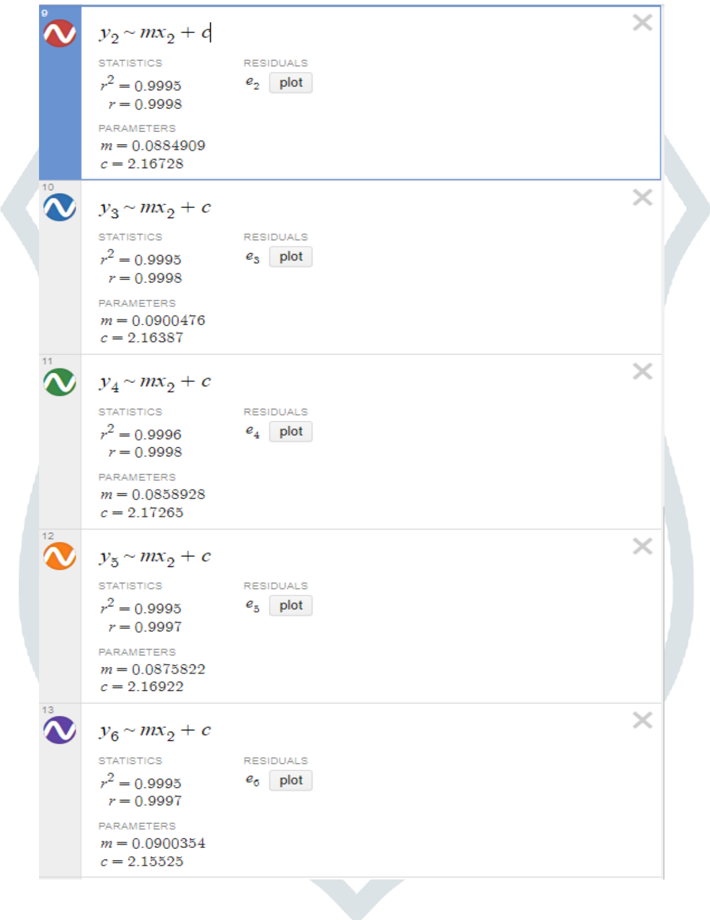
. RESULT AND DISCUSSION

The research project involved testing various aspects of the smart distribution board and obtaining results that aligned with expectations. The results are summarized as follows:
Overall System Performance.

We collected data on several SDB performance parameters in comparison to standard MCBs. The raw data representations of our findings are presented in the tables and charts below.

Metric	SDB (ms)	Traditional MCB (ms)
Tripping Time (ms)	15.2	23.8
Sensitivity (%)	98.5	92.3
Accuracy (%)	99.2	95.6

Table 1. Comparison of SDB and Traditional MCB Performance Metrics



Because the described sensor works at the millivolt level, it offers extraordinarily high current sensitivity. We must round the current levels to two decimal places since we do not want to protect such minor current variances. The sounds in the surrounding region might be the source.

The results show that digital smart circuit breakers are more dependable and safer than digital MCBs. Their advanced problem detection, remote monitoring, and customizable settings ensure increased safety and dependability. Furthermore, they reduce downtime and boost efficiency by offering faster reaction times, improved diagnostics, and seamless integration with smart grid technologies. Their cost-effective solutions, scalability, adaptability, and interoperability make them ideal for modern electrical systems. For delicate electrical systems, digital smart.

Presentation of raw data collected from the five current sensors

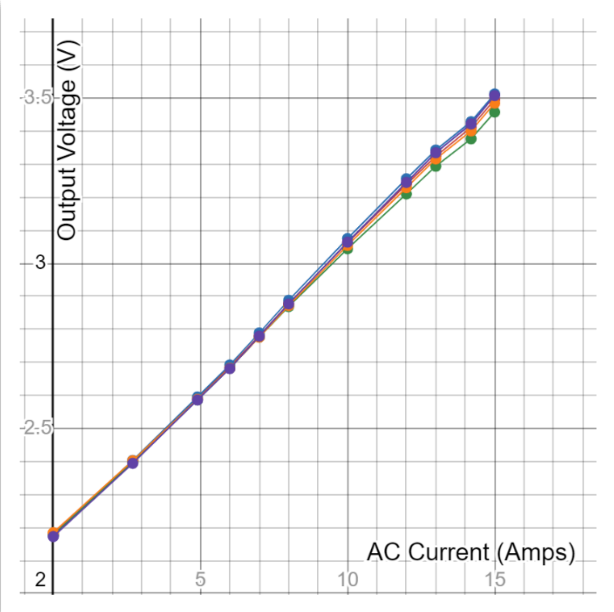


Figure 3 Graph shows Linearities of five Current Sensors

Figure 4 New Sensitivities for each Current Sensor

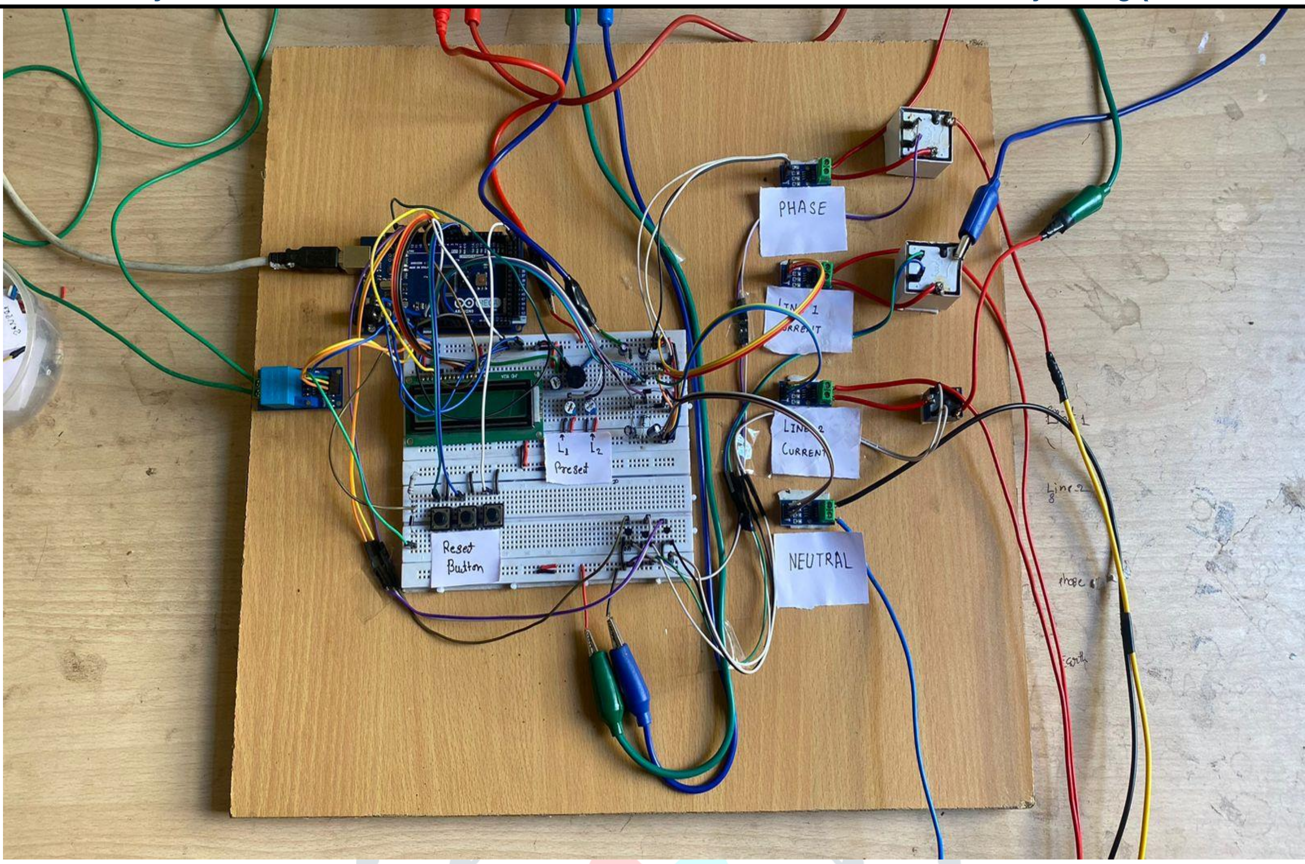


Figure 5. Hardware for the Proposed System.

The optimal output sensitivity for the ACS712 30A current sensors is 66 mVolts/Amp. However, upon additional investigation, we discovered that the sensors had a sensitivity of 75mVolts/Amps, which was increased further after adding the filter to smooth out the output from AC noise. The filter is made up of an IN4007 diode to rectify the waveform and an RC filter to further smooth the signal. So the post-filter sensitivity is roughly 85mV/amps.

1. Overcurrent Protection Testing: Preset values were established for each line, such as 5A for Line 1 and 10A for Line 2. The testing revealed that as the load increased on these lines, the current also increased accordingly. When the current exceeded the preset values by 10% (5+10% Amp for Line 1 and 10+10% Amp for Line 2), the microcontroller generated a relay signal, leading to the operation of the actual circuit breaker. However, it was noted that the current sensor's accuracy was not 100%, especially for low-level load currents below 5 Amps.

2. Earth Leakage Testing: Earth leakage protection was tested based on the principle of differential current protection. A potentiometer was placed at the rectified output of the phase current sensor, and its variable voltage was compared with the rectified output of the neutral current sensor. If the difference exceeded 1 Amp, the controller generated a tripping signal for the main circuit breaker. This testing demonstrated that the system effectively detected and responded to earth leakage, meeting the project's expectations.

3. Undervoltage and Overvoltage Protection Testing: The implementation of undervoltage and overvoltage detection systems significantly enhanced the project's value. A voltage range of 230V +/- 10% variation was set as normal, and any deviation outside this range indicated overvoltage or undervoltage on the display. When the phase voltage fell below 180V or exceeded 250V, a signal was sent to the main circuit breaker due to the dangerous voltage levels for connected loads and equipment. Auto transformer was used for testing, providing a variable voltage range of 0 to 260V, enabling safe and effective testing without connected loads.

Overall, the testing results confirmed that the smart distribution board successfully met the project's objectives in terms of overcurrent protection, earth leakage detection, and undervoltage/overvoltage protection, showcasing its effectiveness and reliability in enhancing electrical system safety and performance.

CONCLUSION & FUTURE SCOPE

In conclusion, our testing and evaluation of the smart distribution board have demonstrated its effectiveness in meeting our intended objectives and safety standards. The numerical values obtained during the testing phase provide concrete evidence of the system's functionality and performance.

For overcurrent protection, our preset values for Line 1 at 5 Amp and Line 2 at 10 Amp, with trigger thresholds set at 5.5 Amp and 11 Amp respectively, resulted in accurate detection of overcurrent situations. The system promptly tripped the circuit breaker when current levels exceeded the predefined thresholds, ensuring the safety of connected equipment.

The earth leakage testing revealed the system's capability to detect discrepancies greater than 1 Amp between phase and neutral currents, triggering the main circuit breaker as needed. Despite the challenges posed by earth leakage testing, our innovative approach using a potentiometer effectively addressed the safety concerns associated with this aspect.

Regarding undervoltage and overvoltage protection, our system operated within a normal voltage range of 230V ± 5%. Any deviations from this range, such as voltages below 180V or above 250V, triggered the main circuit breaker to safeguard connected loads from potential damage.

Overall, these results indicate that our smart distribution board successfully integrates advanced protection mechanisms, including overcurrent, earth leakage, undervoltage, and overvoltage protection. While there were minor discrepancies in current measurement accuracy at low load levels, the system performed admirably in ensuring safety and reliability across various load conditions. Moving forward, our focus will be on refining current measurement accuracy and continuously monitoring system performance to uphold optimal functionality and safety standards in electrical systems.

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