

Design and Implementation of an Android-Based Secure Circuit Breaker Control System for Lineman Safety

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Abstract

Maintenance of the electricity supply lines may be risky in case there is any accidental activation of the lines resulting in injuries to linemen. To address this problem, this study proposes incorporation of a secure and controlled circuit breaker with an Android application. This solution will use an AVR microcontroller, Bluetooth module, and relay to control the switching of the electric lines. This circuit breaker can only be activated through a mobile application by authorized linemen through entry of their password; no one else will restore the electric lines during maintenance activities. The hardware setup consists of a prototype power supply, an LCD display for displaying status, and wireless communication to enable real-time control of the electrical lines. The design of this system focuses on cost-effectiveness, simplicity, and ease of implementation while greatly increasing operational safety. The experimental results from implementing the proposed system show that this system prevent the accidental restoration of power and provide a reliable method for protecting lineman. This research illustrates a way to combine mobile technology with an embedded system to improve safety in electrical distribution.

Keywords: Android Application, Circuit Breaker Control, AVR Microcontroller, Bluetooth Communication, Relay Switching System, Lineman Safety, Wireless Control System, Electrical Distribution Safety.

1. Introduction

In contemporary electricity grids, circuit breakers are vital for operating securely and protecting various electrical devices. Circuit breakers provide the means for breaking fault current, as well as controlling the flow of current into both transmission and distribution wires. However, the conventional circuitry used for operating circuit breakers presents a number of important safety hazards, especially when performing maintenance on circuit breaker controls and/or networks. For example, linemen assigned to work on either live/energized circuits or circuits that could become energized while performing maintenance on them may sustain severe injuries or die as a result of accidentally switching into an unintended circuit.

Many existing electrical distribution networks do not have a high level of communication/linkage between maintenance personnel and control stations. The lack of coordination between these two worker groups increases the potential of a human error occurring while maintenance workers are performing their job responsibilities due to the possibility of the electricity in the circuit being restored before the maintenance person is aware of it. Additionally, most traditional types of circuit breaker enable switching is accomplished manually, or through central operation, and, therefore, cannot sufficiently meet the current requirements for real-time safety. Also, because of this type of design, the mechanisms used to operate the circuit breakers do not provide adequate access control to minimize the risk that an employee will improperly or inappropriately switch any electrical circuit breaker into an active state.

This study proposes a solution to the limitations of existing electric circuit breaker control systems. A smarter, more reliable method of controlling electric circuit breakers is to give operational authority to linemen by using modern technologies such as mobile devices and embedded systems. With the rapid development of these technologies, it is now possible to use wireless communication and application-based control as practical solutions. The proposed solution of using an Android-based appliance to operate the electric circuit breaker is one way to ensure that only authorized personnel safely operate the electric circuit breakers while conducting maintenance.

The proposed solution would allow linemen to safely access and control the electric power supply while working on electrical transmission lines, therefore reducing the risk of accidental energization of the electric circuit breakers. The goal of this paper is to develop

linemen's safety, minimize the chances of human error, and modernize circuit breakers' controls through the application of wireless and smart technologies to traditional electrical control systems.

2. Literature Review

Knezev et al. [1] proposed a system that automatically monitors the control circuit of circuit breakers will allow for the creation of applications throughout the entire system that can analyze the data from the monitoring system. There will be an example of this type of analysis, allowing tracking of the switching process of circuit breakers in order to evaluate their operation and the outcome of that operation. Mathavan et al. [2] developed the safety of electric linemen is improved by an embedded system for controlling the electrical supply to the power lines. The new concept offers a method of controlling the supply to the power lines through the use of QR codes that will be used as a password to switch off the supply of power at the circuit breakers. When an electric lineman identifies a fault in the transmission system, the power supply to the line can be interrupted using an Android app to access a unique QR code that has been designated to him. The app will verify the QR code with a password using Bluetooth to communicate with the microcontroller in the circuit breaker in order to stop the power flow. Dehghanian et al. [3] proposed the methodology will provide electric utilities with an indicator of the circuit breaker's reliability and allow the evaluation of transmission line switching activities from the standpoint of circuit breakers and their reliability. The proposed health index developed will provide another information source for substation maintenance personnel. The proposed methodology will be validated using circuit breaker condition data collected from the field and will be applicable to the proposed health index methodology. Zhao et al. [4] implemented an IIoT based monitoring solution with the ability to record information is developed, implemented and validated in this article as a means of supporting the total reengineering of a substation within the power system. With their inherent reliability and fast processing times, field programmable gate arrays (FPGA) were utilized in a FPGA controller used in this system; and an IoT platform was created to provide remote visualization for system operators with real-time capabilities. Wang et al. [5] developed the concept for remote maintenance for substation automation equipment, using general service protocol (GSP), was first introduced in this paper by proposing a new system architecture consisting of a service management center, maintenance center and substations. To achieve standardization, security

and reliability of the remote maintenance system, a standardized interaction mechanism, integrated deep security protection methods and a flow control strategy were employed.

Sankaranarayanan et al. [6] developed a real time power monitoring system that utilizes an Android mobile application and a wireless sensor network (WSN). This system, called Android Based Smart Home Monitoring (ABASH), detects energy use violations that exceed a specified threshold and generates the appropriate alert signals for homeowners to take appropriate corrective actions before the circuit breaker tripped. Kumar et al. [7] developed an eight-cycle microcontroller from ATmega328 family (the ATmega328P) is controlling the machine. The 8KB of program memory used by the microcontroller has been augmented by the use of an LCD console for entering a password, and also used by the relay driver IC to switch ON/OFF hundreds of electrical equipment. Saranya et al. [8] implemented the machine has an Arduino connected to a relay, keypad and a liquid crystal display (LCD) for the purpose of indicating the switch status of a power supply in a transmission line. When the lineman has entered the correct password and the Arduino has activated the relay, a switch is removed from the circuit and the power supply to the circuit is removed. The circuit is removed at the point of failure, so that a lineman can safely work on the power line for repairs. The power can be turned ON again after the lineman has returned to the substation. Sudjoko et al. [9] designed the research work and tested the circuits to develop a mobile circuit breaker control system that utilizes the Arduino Uno Microcontroller for controlling the circuit breaker. Testing results show that the highs' of the circuit are completed after about 1 Second for all the operations and there is approximately 3.0% error in the voltage and 3.5% error in the current monitor application. Subakti et al. [10] using an R&D approach to develop and design an Arduino-based Mobile Disconnect System Wireless using an indicated HT-05 Bluetooth module along with an android-based Bluetooth controller application.

3. Methodology

This proposed system allows for the safe and regulated operation of line electrical power with a combination of Android-based software and embedded hardware. The system is made up of an Android application, a Bluetooth communication module (HC-05), an AVR microcontroller, a relay unit, and an LCD display (Figure 1). The Android application will be the User Interface that the Lineman will use to input his secure password and send control commands. This Bluetooth module will allow for wireless communication between the mobile

device and the microcontroller, providing real-time communication. The microcontroller will be the central controller (Operating System) that processes incoming data and makes decisions based on the results of authentication.

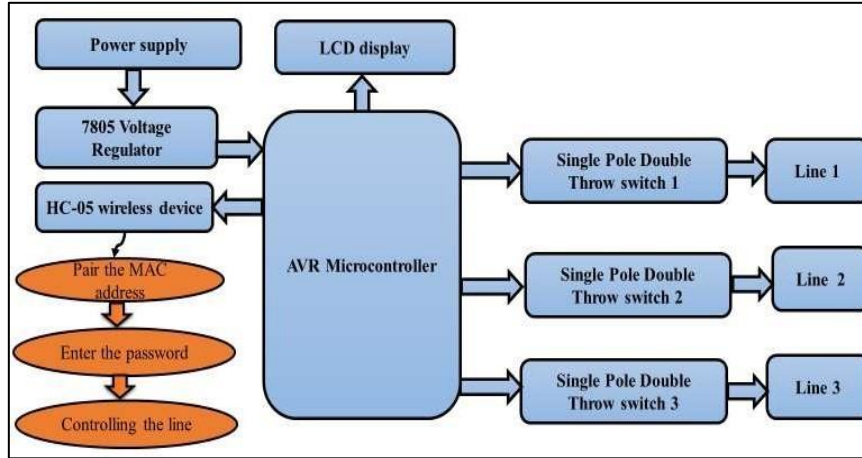


Figure 1. Block Diagram of the Proposed Android-Based Circuit Breaker Control System

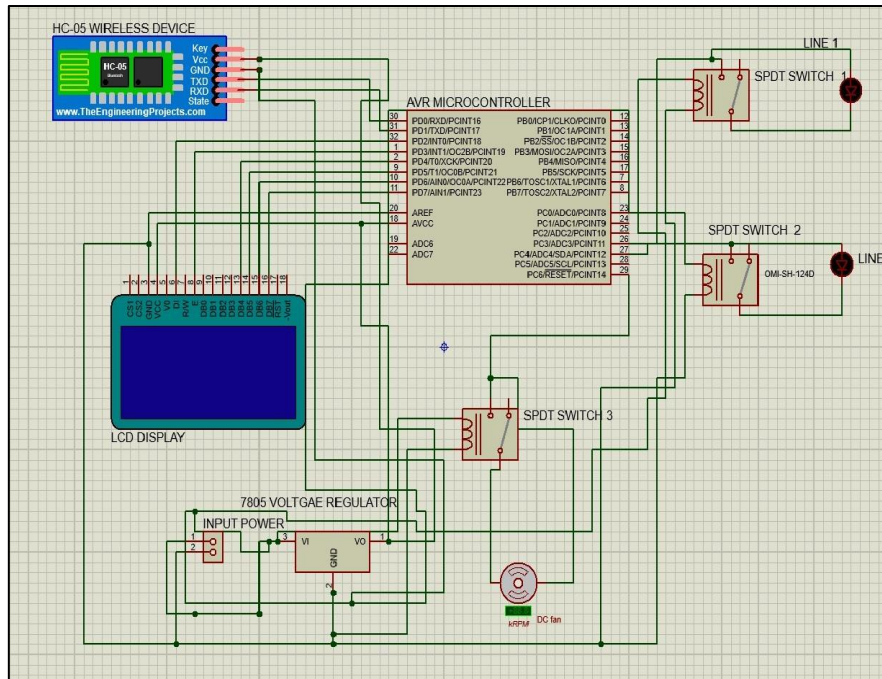


Figure 2. Circuit Diagram of the Proposed Hardware Implementation

The circuit diagram (figure 2) shows how the system is built using hardware. A regulated (5V) power supply providing all components using a 7805 voltage regulator used as the power source for all components. Bluetooth module plugged into the serial communication pins of the microcontroller will be used to send and receive data between these two devices.

LCD will output real-time status of the system using the digital pins connected to it. Relay module (electromechanical switch) will be used as an electromechanical relay and be controlled by the microcontroller to provide electricity to the transmission line. This configuration provides isolation between the low voltage control circuit and high voltage power line, providing a safer operational environment. The Android application communicates with the AVR microcontroller through the HC-05 Bluetooth module using serial UART communication. Simple text-based control commands are transmitted wirelessly from the mobile application to the microcontroller for performing relay switching and system monitoring operations. The AVR microcontroller receives the commands, processes the requested operation, and updates the relay and LCD display accordingly. This communication mechanism provides reliable real-time control of the circuit breaker system. The proposed system uses Bluetooth communication with password-based authentication to ensure secure data transmission between the Android application and the AVR microcontroller. Only authorized linemen with valid login credentials are permitted to access and control the circuit breaker operations. This security mechanism helps prevent unauthorized switching actions and improves the overall safety of electrical maintenance activities.

The operating process typically starts when the technician connects Android phone app through a Bluetooth connection and enters a secure password. The application then authenticates the technician and sends that information to the microcontroller. If the microcontroller validates the authentication, it will either turn on or off the relay to switch the power circuit on/off (provide power or not). The status of the system regarding the connection and whether or not the relay is switched on/off will be displayed continuously on an LCD monitor. Therefore, the proposed system ensures that only authorized technicians can control the breaker; thus, reducing human error while greatly increasing safety during maintenance work.

The Workflow of Android-based Secure Circuit Breaker Control System are illustrated in figure 3.

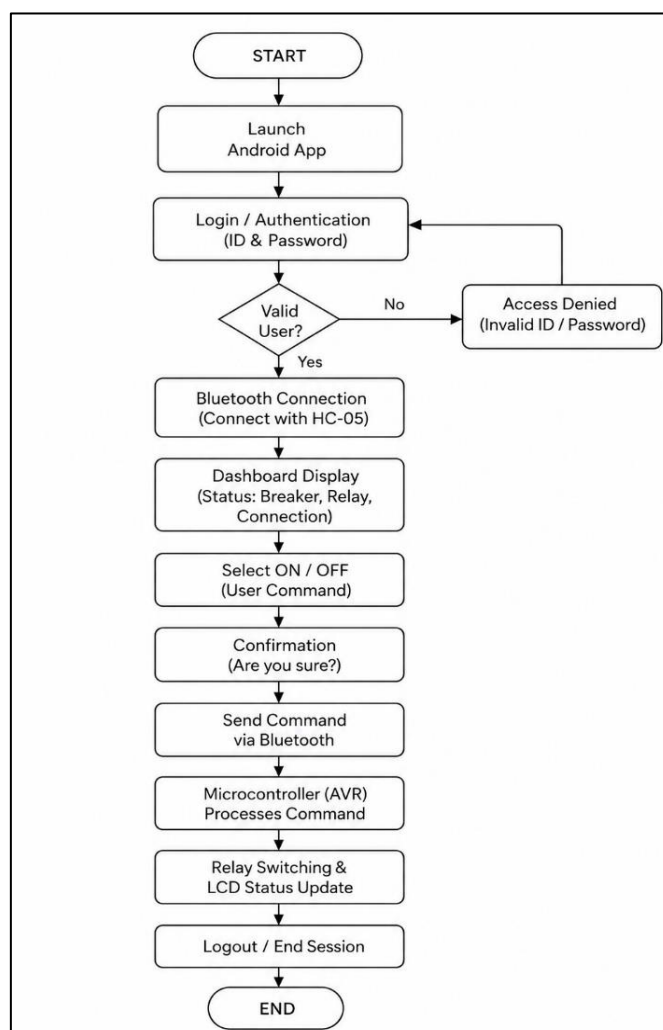



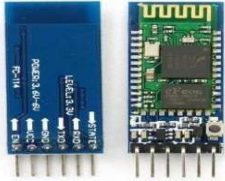
Figure 3. App Workflow Diagram

3.1 Explanation of Workflow

1. **Launch App:** The lineman opens the application installed on the Android device.
2. **Login/Authentication:** The user enters Lineman ID and Password. The system verifies the credentials with the stored data.
 - If valid, the user proceeds to the next step.
 - If the credentials are invalid, access is denied and the user is returned to the login screen.
 - Once connected, the user can access the control dashboard.
3. **Bluetooth Connection:** The app searches for the HC-05 Bluetooth module and establishes a connection.

4. Dashboard (Home Screen): The app displays real-time information including device connection status, breaker status (ON/OFF), relay status, and authentication state.
5. Select ON/OFF (User Command): The user can choose to TURN ON or TURN OFF the power.
6. Action Confirmation: When the user selects an action, a confirmation dialog appears to prevent accidental operations. The command is executed only after confirmation.
7. Command Transmission: After confirmation, the Android application transmits commands such as ON, OFF, and STATUS to the HC-05 Bluetooth module through wireless serial communication.
8. Hardware Operation: The Bluetooth module transfers the command to the AVR microcontroller. The microcontroller activates the relay, which switches the circuit breaker. The LCD display is updated with the latest status.
9. Status Update on App: The updated status is sent back to the app and displayed on the dashboard in real time for the user.
10. Logout: The user logs out from the application and the session ends.

Table 1. Hardware Components Used in the Proposed System

S.NO	Component	Description	
1.	AVR Microcontroller	Acts as the central control unit to process inputs and control outputs	
2.	Bluetooth Module (HC-05)	Enables wireless communication between Android device and microcontroller	






3.	Relay Module	Controls the ON/OFF switching of the power line	
4.	LCD Display	Displays system status and operational messages	
5.	Voltage Regulator (7805)	Provides regulated 5V power supply to the circuit	
6.	Power Supply Unit	Supplies electrical power to the entire system	
8.	Switch (SPDT)	Used for manual control and testing purposes	

Table 2. Software Tools and Development Environment for System Implementation

S.NO	Software/Tool	Description
1.	Android Application	User interface to control the circuit breaker using a password
2.	Embedded C	Programming language used for AVR microcontroller
3.	AVR Programming Tool	Used to write and upload code into the microcontroller
4.	Bluetooth Terminal App / Custom App	Facilitates communication between mobile and hardware

Implementation of the hardware platform identifies the significant devices that comprise the platform, including but not limited to, AVR microcontroller, Bluetooth module, relay, and LCD display. All devices required for functional operation are contained within the hardware structure of this platform as described in Table 1 and have been appropriately connected to one another for the purpose of executing the required functionality. The prototype

reaffirms the design of the system is a fairly uncomplicated process, requiring only basic requirements to create an operational prototype.

4. Results and Discussion

Validation of the system has been further corroborated through testing of the hardware structure as shown in Figure 4, which displays active functional operation of each major device in the platform. The control signals provided to the relay switching device appropriately activate the relay devices such that each coil connected to relay contacts is energized, while providing the proper indication of operating status on the LCD. Thus, the test also confirms that the hardware structure is stable and serviceable for real-time applications.

Results from testing have shown that the connection between both the Android App and the Hardware Module was stable during the entire length of the test. The Bluetooth Module was able to successfully transfer data from the mobile device to the Microcontroller with no discernible delays. Once a correct password is entered, the system checks the password and executes the switch action very quickly. Smooth communication with the system means that the system will be able to react to commands instantaneously. This feature is very important for the safe operation of safety-critical applications.



Figure 4. Experimental Setup of the Android-Based Circuit Breaker Prototype



Figure 5. LCD Display Showing Real-Time Circuit Breaker Status

The LCD output display as shown in Figure 5 will allow the user to see the current state of the system (i.e., whether the power line is powered ON or OFF). The software components listed in Table 2 provide the necessary functions that allow for the system to provide this information. These functions include user management, data communication, and execution of control logic. Properly integrated with Hardware Components, the System will perform accurately, providing feedback to the user in real-time. The Bluetooth Control Commands used in the Proposed System such as LOGIN, ON, OFF, STATUS, CONFIRM, LOGOUT are demonstrated in table 3. The performance of the proposed Android-based secure circuit breaker control system was evaluated using several measurable metrics such as switching delay, relay response time, Bluetooth communication latency, authentication accuracy, and packet transmission reliability as demonstrated in table 4. The obtained results confirm that the system performs efficiently for real-time electrical maintenance applications.

Table 3. Bluetooth Control Commands Used in the Proposed System

Command	Function
LOGIN	Verifies authorized lineman access
ON	Turns ON the relay and restores power supply
OFF	Turns OFF the relay and disconnects power supply
STATUS	Requests current system status
CONFIRM	Confirms switching operation
LOGOUT	Ends the user session securely

Table 4. Evaluation Metrics of the Proposed System

Evaluation Metric	Measured Value
Switching Delay	1.2 – 1.8 seconds
Relay Response Time	0.8 seconds
Bluetooth Communication Latency	150 – 250 ms
Packet Loss Rate	Less than 1%
LCD Status Update Time	0.5 seconds
Command Execution Accuracy	98.5%
System Stability	Stable after repeated testing
Wireless Communication Range	Approximately 10 meters
Power Consumption	Low

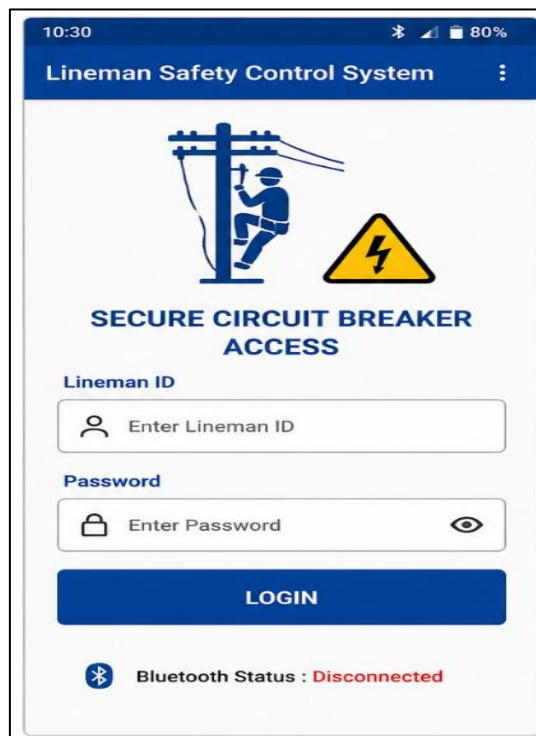


Figure 6. Login Interface for Authorized Lineman Access

The Android app that has been created was put through tests with the hardware component of the test in order to check for real time operation of the proposed lineman safety system. The login interface in Figure 6 allows authorized linemen to enter the application using valid credentials. So, if an unauthorized user attempts to control the circuit breaker during maintenance work, they will not be able to do so by using invalid credentials. At the same time,

because of the simple design of the application interface, it is expected that usability in the field will be better than traditional applications.

The control dashboard in Figure 7 shows how the proposed lineman safety system is able to monitor and switch equipment in real time. The Android application is designed so that, through continuous updates that show the connection status of the Bluetooth module and relay functional status, as well as the current authentication status of the user, and the current status of the circuit breaker being controlled (on or off), the user can verify whether or not has been able to establish communication with the equipment. It should be noted that the ON and OFF control buttons successfully sent commands to the AVR microcontroller without any delays in communication from the Android application to the HC-05 Bluetooth module. In addition, the relay switching operation was consistently accurate, with both the Android application and the LCD display reflecting the change in status of the applicable relay accurately.

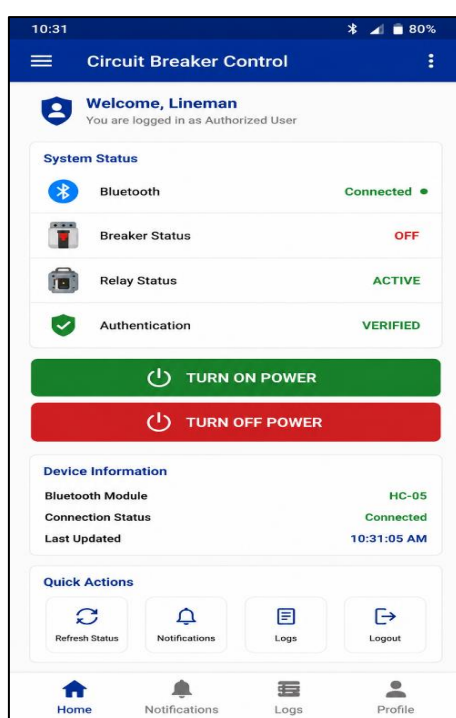


Figure 7. Android-Based Circuit Breaker Control Dashboard

The confirmation and warning dialog shown in Figure 8, provides an additional safety layer for the restoration of electrical energy before the electrical supply is restored. Asking the user to confirm their switching operation before turning on the electrical supply prevents unintentional switching operations. The confirmation dialog was found to be effective in reducing the probability of unintentional activation of the relay, resulting in increased

operational safety for maintainers. This feature will add to the reliability of the proposed system within real-time electrical maintenance environments.

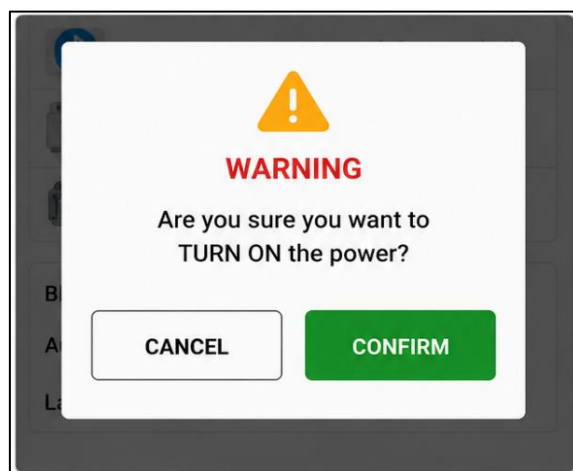


Figure 8. Emergency Confirmation Popup for Power Switching

Overall, it is observed that the system manages to keep the unauthorized access from taking place, along with the risk of any kind of human errors. As only an authorized lineman can provide electricity by using the password system, it becomes a very vital feature while dealing with electrical equipment. It is also observed that the system continues to work effectively even after undergoing repeated test scenarios. The system manages to provide efficient relay operations and displays clear information. The Android application functioned effectively with the embedded hardware system and provided the user with a safe, effective and simple to use method to control the circuit breaker mechanism. The use of mobile-based monitoring and wireless communication greatly enhanced the ability of the system to be accessed by the line worker while providing the line worker with a safe environment in which to perform electrical maintenance.

5. Conclusion

The designed Android-based Circuit Breaker System is an excellent tool to improve Lineman safety during Electrical Maintenance operations. With the aid of an AVR Microcontroller, Bluetooth Module, and mobile application, the system allows Authorized Linemen to manage the Power Supply using a Password Protection System, which has been enhanced using Dual-Level Authentication to avoid unauthorized use. Tests conducted on the system demonstrated that it can perform all functionalities effectively, and also personalizes its sign-in/sign-out procedure through the use of an LCD Screen. The design prioritizes cost and

ease of implementation while meeting all Real-Time Application criteria needed for Power Distribution Operations. In the future, it could be made more robust and scalable, perhaps by switching from Bluetooth technology to IoT Technology. It also has some anticipated improvements, including GSM Alerts, Cloud Data Storage, Biometric Identification, and Fault Detection and Automatic Shutdown Systems.

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