ARDUINO BASED LINEMAN PROTECTION SYSTEM USING USER-CHANGEABLE PASSWORD AUTHENTICATION

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Abstract

Electrical accidents involving linemen during maintenance of power distribution lines are increasing due to improper communication between substations and field workers. Accidental energizing of lines during maintenance leads to severe injuries and fatalities. This paper presents a microcontroller-based lineman protection system using password authentication to ensure authorized control of circuit breakers. The system is implemented using the Arduino Uno microcontroller, 4×4 matrix keypad, 16×2 LCD display, relay module, piezo buzzer, and optional SIM900 GSM/GPRS Module for remote notification. The password is stored in EEPROM and can be modified securely using a master code. Experimental results demonstrate reliable operation, enhanced safety, and prevention of unauthorized energizing of distribution lines. The system is cost-effective, easy to install, and suitable for substation-level implementation.

Keywords—Lineman Safety, Arduino, Password Authentication, Circuit Breaker Control, GSM, Embedded Systems.

1. Introduction

Electrical distribution maintenance work exposes linemen to highly hazardous conditions, particularly when working on live or potentially energized lines. In many conventional systems, coordination between substation operators and field maintenance personnel is carried out through verbal communication or manual procedures. Such methods are prone to human error, miscommunication, and delays, which can result in the accidental switching ON of lines that are under repair. These unexpected energizing incidents often lead to severe injuries, electrical shocks, or even fatalities. Traditional circuit breakers are designed primarily for overload and short-circuit protection and do not incorporate authentication or access-control mechanisms. As a result, any authorized control room personnel can reclose the breaker without real-time confirmation from the lineman at the work site.

To address this critical safety concern, a secure password-based switching mechanism is proposed. The system introduces an authentication layer between the operator and the circuit breaker, ensuring that only authorized personnel can energize or de-energize the line. By shifting the control authority directly to the lineman performing the maintenance work, the risk of accidental switching is significantly reduced. The lineman must authenticate access using a secure, user-changeable password before the breaker can be operated. This approach enhances accountability, minimizes dependency on manual coordination, and establishes a safer working environment within power distribution networks.

2. Literature Review

Several safety systems have been developed in recent years to enhance the protection of linemen during maintenance operations. These include OTP-based circuit breaker systems, which use one-time passwords for temporary authorization, GSM-based lineman alert systems that provide remote notifications through mobile networks, and microcontroller-based load control systems designed to automate switching operations. While these approaches contribute to improved safety and automation, many of the existing systems have certain limitations. In particular, they often lack user-changeable authentication mechanisms, restricting flexibility in access control. Additionally, several systems do not provide local password storage flexibility, making it difficult to securely update credentials without reprogramming the controller.

Moreover, many traditional designs fail to offer real-time feedback display to inform users about system status and authentication results. They also lack a multi-layer alert mechanism that can simultaneously provide visual and audible warnings during unauthorized access attempts. The proposed system addresses these shortcomings by incorporating EEPROM-based password storage, which allows secure and persistent credential modification without losing data during power interruptions. Furthermore, it implements a dual alert mechanism using both an LCD display and a buzzer, ensuring clear communication of system status and enhancing overall operational safety and reliability.

3. System Architecture

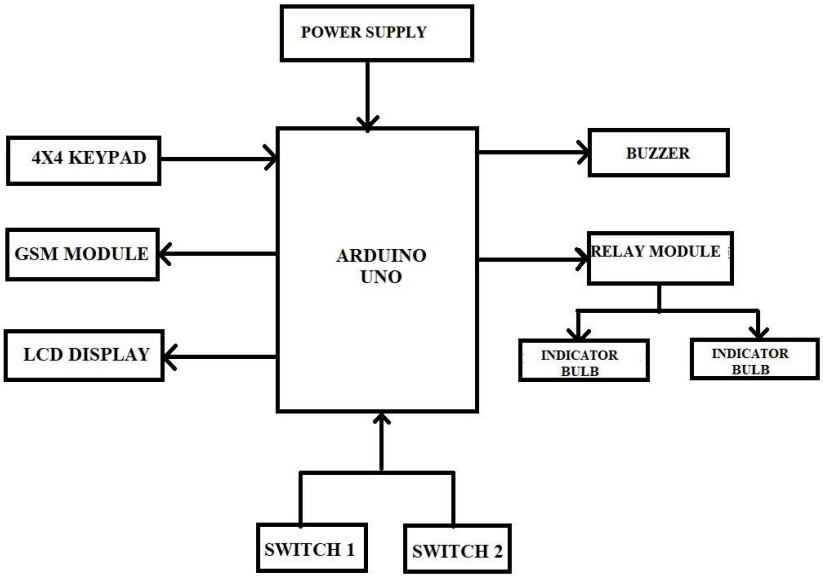


Figure 1. Block Diagram Arduino Based Lineman Protection System

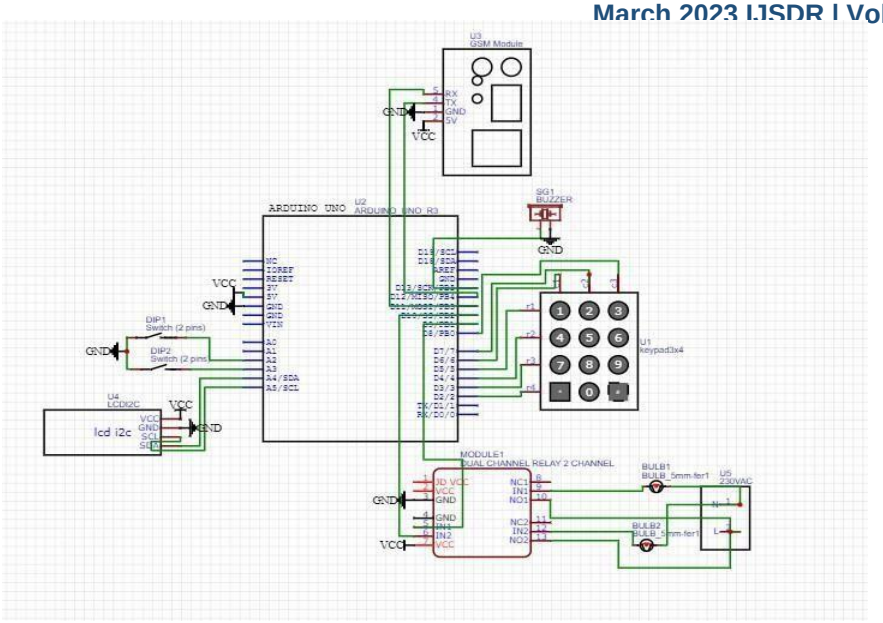


Figure 2.Schematic Diagram Arduino Based Lineman Protection System

4. Hardware Description

4.1 Microcontroller Unit

The **Arduino Uno** is based on the ATmega328P microcontroller and functions as the central control unit of the lineman protection system. It provides 14 digital I/O pins to interface with the keypad, relay, buzzer, and LCD, along with 6 analog inputs for possible future sensor integration. Operating at 16 MHz, it ensures reliable and fast execution of authentication and control tasks. The built-in EEPROM enables secure storage of the user-defined password even during power loss. In this system, the Arduino reads keypad input, verifies the password, controls the relay operation, activates alerts for unauthorized access, and updates system status on the LCD display.4.2 Keypad InterfaceThe 4×4 matrix keypad allows secure password entry. Row-column scanning technique is used to detect key presses.

4.3 Display Unit

The 16×2 LCD display provides real-time feedback to the user by showing system prompts and status messages. It displays “Enter Password” to request authentication input, “Access Granted” when the correct password is entered, and “Access Denied” if the authentication fails. Additionally, it indicates the current breaker status, informing the user whether the power line is in the ON or OFF condition.

4.4 Relay Control Circuit

The relay module plays a critical role in ensuring electrical isolation between the low-voltage control circuitry and the high-voltage AC power line. By using electromagnetic switching, it allows the microcontroller, which operates at 5V DC, to safely control high-voltage loads without direct electrical contact. This isolation protects the Arduino and associated components from voltage spikes, short circuits, and potential damage caused by high-power switching operations.The relay module used in this system typically supports loads of up to 10A at 250V AC (or 10A at 30V DC), making it suitable for controlling distribution lines, industrial loads, and household electrical appliances. Additionally, the module often includes an onboard transistor driver circuit and flyback diode to safely energize the relay coil and suppress back EMF, further enhancing system reliability and operational safety.

4.5 GSM Communication

The optional SIM900 GSM/GPRS Module enables:

- SMS alerts
- Remote status notification
- GPRS connectivity
- The optional **SIM900 GSM/GPRS Module** enhances the system by enabling SMS alerts to notify authorized personnel about circuit breaker status and security events. It also provides remote status notifications, allowing supervisors or maintenance staff to receive real-time updates regarding line conditions and system operations. In addition, the module supports GPRS connectivity, facilitating data transmission over the cellular network for remote monitoring and potential integration with online platforms.

5. Experimental Results

The system was tested under different operating conditions.

When the system is powered ON, the LCD displays **"Enter Password"** in Figure 4. The user enters a password using the keypad. The Arduino compares this input with the stored password in EEPROM.

- If the password is correct, the relay is activated, allowing the circuit breaker to toggle (ON/OFF).
- If the password is incorrect, the buzzer sounds and access is denied.

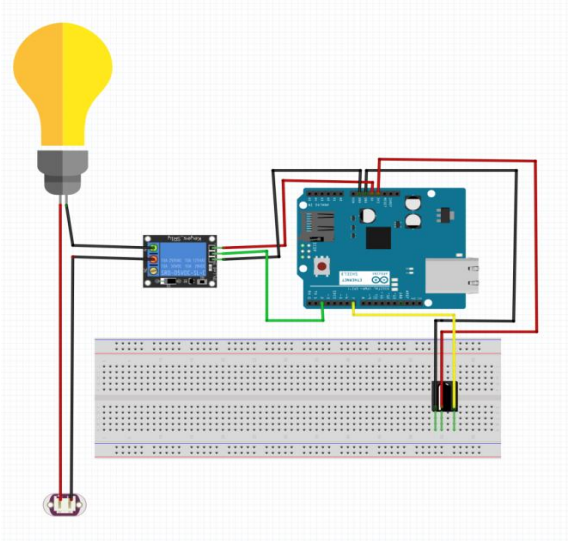
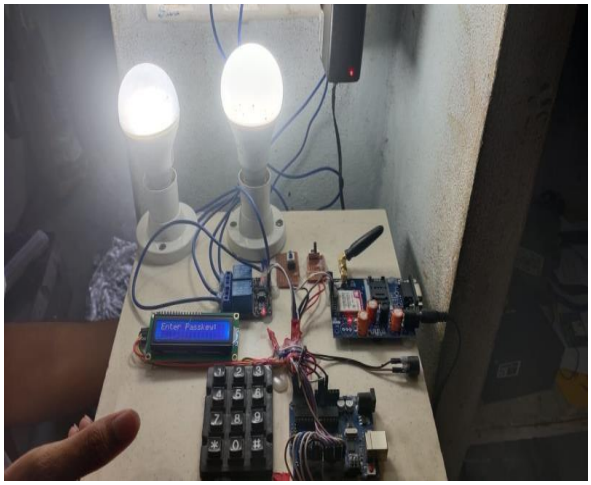


Figure3. Simulation Setup



(a)**Entering Password**



(b)



(c)

Figure 3. Experimental Setup: Light The First Blub When Password Is Correct (a) and Incorrecr(b)

The proposed system effectively prevents accidental energizing of distribution lines during maintenance, thereby significantly enhancing the safety of linemen. It incorporates a user-changeable password mechanism, allowing authorized personnel to update access credentials as needed, improving both security and operational flexibility. The design is cost-effective, utilizing readily available components such as an Arduino microcontroller and relay module, which reduces overall implementation expenses. Furthermore, the system is easy to install and can be integrated into existing electrical setups without requiring complex modifications. Most importantly, it ensures reliable authentication, allowing only authorized individuals to control the circuit breaker and operate the power supply system.

6. Conclusion

The proposed Arduino-based lineman protection system provides an effective and economical solution to prevent electrical accidents during maintenance. The password-based authentication ensures that only authorized personnel can operate the circuit breaker. The addition of GSM notification enhances monitoring capability. The system can be deployed in substations and distribution networks to significantly improve worker safety and operational reliability. Future enhancements of the proposed Arduino-based lineman protection system can improve its functionality and monitoring capabilities. IoT-based remote monitoring can enable authorized personnel to supervise and control the circuit breaker from any location via the internet. Additionally, a dedicated mobile application can provide real-time status updates, remote control access, and alert notifications, making the system more suitable for modern smart grid environments.

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