Implementation of a User-Friendly Radio Frequency Identification and Password-Enabled Security Access System

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***Abstract*— Due to the prevailing security concerns in recent times, and the costliness of sophisticated security access systems that require cutting-edge technologies, this paper presents a low-cost design security access system. The design implements a user-friendly Radio Frequency Identification (RFID) and password-enabled security access system to tackle the escalating security threats in homes and industrial outlets. The system components include an RFID reader and card, a matrix keypad, a microcontroller, a buzzer, an LCD, a motor driver, and a low-cost power supply unit. These components are interfaced with the microcontroller, which serves as the central processing unit (CPU) of the security access system. The security system circuit was designed using Proteus – a virtual laboratory and programmed using CloudX C programming language. The system was configured such that it provides higher security measures with the two-level security authentication systems incorporated. The complete design is a low-cost and independent security access system powered by 12V mains. The system was tested against standard metrics, and the results show that it allows access to authorized individuals wholly, but only denied access to unauthorized parties.**

***Index Terms*— Radio Frequency Identification; Security Access System; Password technology; Authentication; CloudX IDE; Internet of Things**

I. INTRODUCTION

The rapid growth of security threats on the global scene has orchestrated the need to deploy highly sophisticated technologies to tackle security-related issues proactively [1], [2]. Individuals and corporate organizations highly treasure the security of personnel and properties. Most existing security technologies are currently quite expensive to deploy, which poses a huge financial burden on low-income earners. To this end, there has been a huge demand for low-cost, reliable security systems, which can efficiently deny access to unauthorized users, attempting to access secured areas at home, industrial premises or other places that require strict security measures [3], [4]. Previously, the normal lock and key arrangement were adopted as the preferred candidate for taming the rapidly growing security challenges [5]. However, this system works well for small-scale applications, but does not apply to places with many users or where a common lock is being used for large numbers of users [6].

Lockers are often being used to keep essential documents in some offices and banks [7], [8], which are no longer safe because they are now easily breakable, especially with the advancement in high-tech intrusion systems [9], [10]. Only password or Radio Frequency Identification (RFID) [11] authentication is used in most existing security access systems. However, when the password and RFID are used separately, weak passwords can easily be brute-forced, while RFID is susceptible to spoofing and cloning. In our implementation, the RFID and password technology were used as the security means to guarantee the security of the access system. This system denies access to unauthorized users, and access can only be granted when the authorized user provides a valid RFID card and the correct password. RFID technology is a wireless technology that can be used in the development of security access systems [11], [12], [13]. It is a preferred candidate to the bar code because no line of sight is needed. Additionally, it has a larger storage capacity, wider reading distance, and rapid signal processing capabilities [14].

The RFID technology comprises a reader and a card (which are of different classes). However, RFID technology has its weaknesses ranging from card scraping, killing of tag, card phishing, and duplication of the tag [15]. Nonetheless, it is worth mentioning that the password technology could make up for these shortcomings, thereby making the proposed system a double-security proof, which is the focus of this paper. Using password technology in the system requires the user to key in the password characters via the keypad provided in the system. This implies that the potential user must meet both requirements or else will be ultimately denied access. The proposed method is tailored to give maximum security due to the double-security authentication. Therefore, we provide a comparatively better security system, which offers adequate protection of personnel, properties, and valuables at homes, corporate offices, and commercial institutions.

The main contribution of this paper is the design and implementation of an automated security access system using RFID and password technologies suitable for application at homes and industrial outlets. The primary objective is to develop a low-cost and effective security access system with readily available components, such as a PIC microcontroller, RFID reader, matrix keypad, and LCD, to grant access to authorized users only using valid RFID card and correct password as valid means of authentication. Our goal is to provide a reliable security access system to tackle the alarming security threats to properties and valuables at homes and offices, which has been a significant concern for

individuals and corporate bodies. The security system is designed to restrict access to authorized persons only and disallow unauthorized users. The use of RFID and password technology provides two-factor authentication, which enhances the security of the access system. It is interesting to mention that failure to provide the required valid authentication would result in complete denial of access.

The remainder of this paper is organized as follows. Section II presents the related works on security and authentication systems. Section III focuses on the design methodology, including the components used for the system design and implementation. Section IV presents an overview of the results achieved, and finally, Section V provides the conclusion and future perspectives.

II. Related Work

The proliferating insecurity issues on the global scene calls for immediate and rapid deployment of highly sophisticated security techniques to secure valuables and personnel in private and public facilities. The security systems need to be ultra-reliable, extremely fast, and highly responsive. Toward this end, several security access systems have been proposed in several works of literature [7], [4], [11], [12], [14]. Most of these schemes present the RFID technology and how it has been used to replace the barcode method [16], [17]. Htwe et al [18] reported a security system using RFID and fingerprint.

Similarly, the RFID-based security access system has been proposed for use in an organization [19]. Additionally, an automated attendance registering device was designed and implemented using RFID technology and a GSM modem [20]. However, this system has some inherent shortcomings, which Mustapha et al [21] improved. The authors designed an automated attendance system to register students and record their attendance. This is done when each student uses their RFID tag at the classroom entrance before gaining access. The ability of the system to send SMS messages to the students' parents or guardians, informing them of the attendance of the student(s) through the GSM module interfaced with the system is quite remarkable. However, the cost of implementing such security access systems, especially on a large scale, is quite prohibitive.

Shafin et al. [22] presented a low-cost security system incorporating a digital door lock to grant authorized users access. In [23], a security system using RFID and biometric to protect an intelligent building from unauthorized users is reported. A related cost-friendly and effective security access system is proposed by Gomathi et al. [24]. Furthermore, an RFID-based system incorporating an Arduino is presented by Adak et al. [25]. Additionally, Sangole et al [26] developed an RFID-based security access system for University campus management. The system is controlled by a central server, guaranteeing seamless communication between the server and the associated access terminals. However, the security measure is limited. Some students can give their RFID tags to unauthorized users to access the campus environment. In the existing literature, several related works on security access systems have been presented by Rohini et al. [27], Adebayo et al. [28], Prajwal et al. [29], Wibowo and Muhammad [30], Komol et al. [31], Rahman et al. [32], Sriharsha et al. [33], Joshi et al. [34], Hymavathi et al. [35], Jain et al. [36], and Diggewadi et al. [37]. These are briefly presented in Table 1, outlining the key contributions and limitations of the existing security access systems.

Similar to the scheme presented in this paper, Suroshi et al. [38] proposed a locker security system to tackle security threats in banks and corporate offices. The system uses GSM, RFID, and OTP technologies for enhanced security. The system is controlled by a microcontroller, giving controls to other interfacing components. Additionally, the system can generate passwords and send them to the registered number through a GSM module, making it relatively difficult to guess the password for easy access. The two-way security authentication provided by the scheme is highly commendable. However, the cost of implementation is highly prohibitive. To tackle the cost problem of the design in [38], and without compromising the security of the system, we provide a design, which implements a user-friendly Radio Frequency Identification (RFID) and password-enabled security access system. The design methodology of our security access system is presented in Section III of this paper.

Table 1
Contributions and limitations of related works

Ref.	Contributions	Limitations
[7]	A password-based security access system was designed using an automatic electronic locker system.	Limited security due to a single authentication.
[4]	A GSM module, keypad module, and Bluetooth module were integrated to develop an electronic door security system.	Requires stable power supply.
[11]	RFID-enabled and biometric-based security access system was designed for use in University hostels.	RFID is susceptible to cloning.
[12]	An RFID-based security system with a GSM module for home and the workplace.	Moderate security
[14]	A security system based on RFID technology was designed using RFID technology, AT89S52 microcontroller, and SIM900 GSM module.	Only one level of security can be used at a time.
[16]	RFID technology was proposed to replace the barcode method, leveraging wireless reading with no sightline.	Limited security, RFID is easily duplicated.
[17]	The benefits of using the RFID technology in security systems over the barcode were reported.	RFID is susceptible to cloning.
[18]	A security system using RFID and fingerprint was designed. The system uses an RFID reader, fingerprint reader, microcontroller, and a PC.	RFID is susceptible to phishing and cloning.
[20]	An automated attendance registering device was designed using RFID technology and a GSM modem.	RFID is susceptible to phishing
[21]	An automated attendance system was designed to register students and record their attendance through the GSM module interfaced with the system.	Relatively expensive to commercialize
[22]	A low-cost digital door lock is proposed using an RFID card.	Limited security measure.
[23]	A security system using RFID and biometric to protect an intelligent building from unauthorized people was designed.	RFID is easily duplicated.
[24]	The RFID technology is used to control the accessibility of the system in which a magnetic door lock is being used.	RFID is susceptible to phishing and cloning.
[25]	An RFID-based security system using Arduino was designed for security in companies.	RFID cards can be easily duplicated.
[26]	An RFID-based security access system for campus management was designed. The system is controlled by a central server, ensuring seamless communication between the central server and other access terminals.	Limited security measure.

[27]	A home security system with biometric and RFID was designed. The system comprises an MCU, RFID reader, tag, biometric unit, communication unit, LCD, motor unit, and control unit.	Quite expensive to implement, limited security is provided.
[28]	A cost-friendly RFID and password-enabled security system were proposed. This system is being built on a microcontroller, which controls all components interfaced with it.	RFID is susceptible to phishing and cloning.
[30]	An RFID-based security system using a microcontroller was designed. Access is granted only to a valid RFID tag	RFID is easily duplicated.
[31]	A dual security system that comprises RFID and biometric security systems was proposed. The system employs a servo-mechanism attached to the door.	Risk of compromised RFID Tag
[32]	A password-enabled lock system to replace the common lock for enhanced security was designed.	Limited security.
[33]	A security door system that requires an input password code for the door to unlock.was designed. If an invalid password is entered, access is denied.	Limited security, the password can be compromised.
[34]	A locker security system that uses a GSM network and random password code to prevent unauthorized access.	Relatively expensive
[35]	A user-friendly password-enabled security lock system for use at home or office.	Limited security
[36]	A low-cost home security system that controls the home appliances by entering the correct password.	Password can be compromised.
[37]	A customized door locking system was developed using Arduino to replace the common mechanical locks used in homes.	Relatively expensive to implement.
[38]	A locker security system was designed to tackle insecurity in offices. The system uses GSM, RFID, and OTP technologies for enhanced security. This system is very similar to that reported in [29].	Reasonable security measure is provided with high cost.
[39]	A low-cost, low-power, and standalone system uses a GSM module, RFID, password, and fingerprint technology.	Applies multiple stages that could be time-consuming.

III. DESIGN METHODOLOGY

The construction of the system comprises electrical and mechanical parts. The mechanical part deals with the rotation of motor control and the door control for opening and closing. A trapdoor is used for the door mechanism in this design, a motor-driven by the motor driver connected to it. The electrical part deals with the security system circuit design that is strong enough to tackle any unauthorized entry. It contains the interconnection of the hardware components and provides the necessary programming for the operation of the components. It is worth mentioning that the coding used on the microcontroller is CloudX IDE. Upon completing the circuit design in the Proteus environment and testing the functionalities of the circuit components on the breadboard, the electrical hardware components were mounted on the Vero board via soldering. The circuit was assembled on a constructed prototype framework. A reasonable size wooden framework is used to mount the electrical and mechanical components to implement the design.

A. Hardware and Software Components

This design deals with the access control of entrances to secured areas using a combination of RFID and password technologies as entrance-gaining keys for improved security. In this system, there are two parts, which are the hardware module and the software module. The hardware module comprises of different units, which are the control unit (microcontroller), input unit (RFID reader and card, and matrix keypad), output unit (LCD, buzzer, motor driver, and DC motor), and the power supply unit as illustrated in figure 1. The other components are voltage regulator, rectifier diode, resistors, and capacitors, as shown in Figure 2. The description of the electronic circuit components and numerical values is presented in Table 2.

The software performs a vital role in the integration and working of the proposed hardware design. The software module deals with the coding for interfacing and configuration. A comprehensive description of the circuit design and configuration components of the security access system is presented in Table 3.

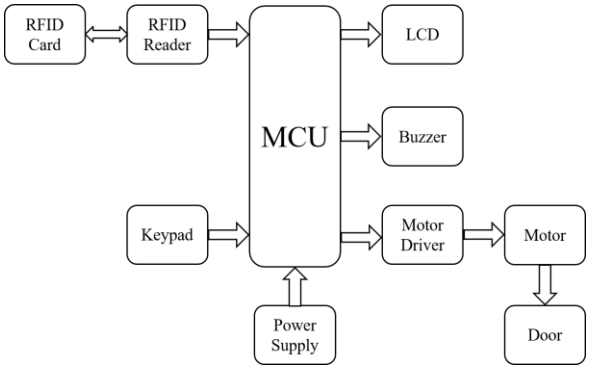

Figure 1: A block diagram showing the hardware components of the system

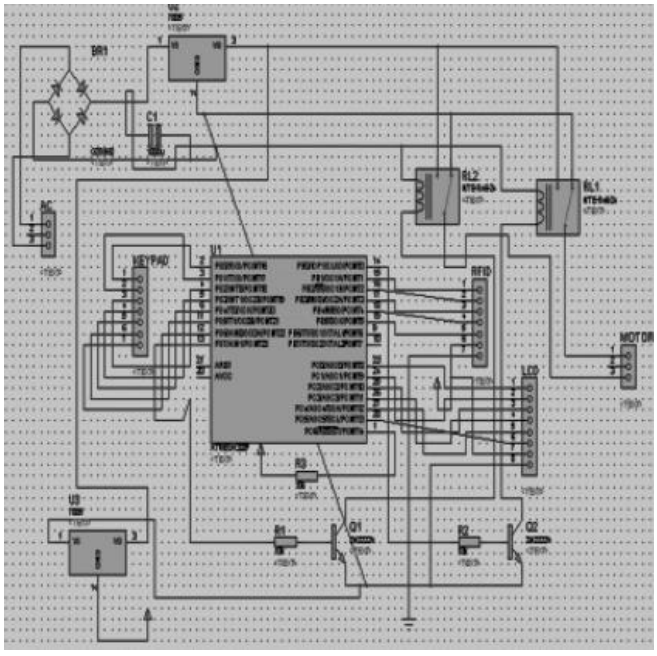

Figure 2: Electronic circuit diagram of the security access system

Table 2
Description of the electronic circuit components and properties

Qty.	Part type	Properties
1	RFID reader	5V input, 125KHz
1	RFID card	Passive tag
1	PIC16F877A microcontroller	40 pins connections
1	Membrane Matrix Keypad	4x4
1	LCD screen	Type character; I6 pins connection
1	Power adapter	AC:100-240V, 50-60Hz, 0.6A DC: 12V, 2A

1	Voltage Regulator - L7806	package TO220 [THT]; fixed voltage V
1	Motor driver L298N	5V DC
2	Capacitor	100μF, 50V 10μF, 50 V
1	1k Ω Resistor	tolerance ±5%; bands 4; resistance 1kΩ; pin spacing 400 mil
4	10k Ω Resistor	tolerance ±5%; bands 4; resistance 10kΩ; pin spacing 400 mil
4	Rectifier diode	600V, 1amp
1	Crystal Oscillator	
1	DC motor	12V

Table 3
Description Circuit Design and Configuration Components

S/N.	Hardware Components	Description
1.	Micro-controller	The microcontroller is the central processing unit of the security system. PIC 16F876A is used for this design because it is cost-friendly and has a wide range of usage. It creates the ground on which this system runs as it receives the signals from the RFID reader and the password keypad, processes it, and sends the proper signals to the LCD and door control motor mechanism.
2.	RFID reader	RFID reader reads an RFID tag and communicates employing radio frequency (RF) path for identification information. There is an antenna in the reader, which sends out radio waves, which the tag receives and responds to it. RFID reads nearby RFID cards or tags and gets their identification number using radio frequency communication. EM-18 RFID reader is used for this design with an operating frequency of 125 kHz and 5V DC supply.
3.	RFID card or tag	RFID tag or card also has a radio frequency transmitter and receiver. It contains two components, the silicon chip and the antenna. The tag receives radio signal messages from the reader and then replies by sending its identification number.
4.	Matrix keypad	The 4x4 matrix keypad is used for this design because of its simplicity. It has 16 characters, including numbers from 0 to 9, letters from A to D, and * and # to make up the 16 characters. It also consists of 8 connecting pins in which four pins are connected to each row and column of the keypad. This keypad is used to set and enter the password manually on the system. Entering the right password shows the authentication of the user.
5.	Graphic LCD	The regular 16x2 LCD is utilized in our design. It shows the output results when the RFID card and password are used, whether right or wrong, and also indicates if access is being granted or not. It also has a backlight of low-power white LEDs to help the user view the screen.
6.	Power supply	The power supply needed for this device is 12V DC; this is done by using a power adapter with an input rating of AC 100-240, 50-60Hz 0.6A, and output rating of DC 12V 2A. The AC ripples are removed by applying the capacitor and the voltage regulator to control the output voltages. 5V DC powers the microcontroller, RFID reader, motor driver, buzzer, LCD, and 12V DC power the DC motor to control the door mechanism.
7.	Buzzer	This is the audio signaling part of the system, which has a 5V buzzer. It is connected to the analog part of the microcontroller. The buzzer is added to this design for sound anytime the RFID card is swiped, and the password is entered to know if it is valid or not and to tell if the password is right or wrong.
8.	LM7805 voltage regulator	This is a voltage regulator with three terminals; it has a fixed 5V output voltage. It gives an internal limitation of current, thermal closing control, local regulation, and safety for this system. Features include output voltage of 5V, an output current of 1.5A, protection of thermal overloading, protection of short circuit, and output transition protection.
9.	The crystal oscillator	This is used in controlling the microcontroller's speed of operation, and for better performance of the microcontroller, a crystal oscillator is interfaced with it.
10.	L298N Motor driver	This is a driver used to drive inductive loads like DC motor, solenoids, and relays. It helps to control the speed and direction of the motor for opening and closing of the door. In this design, the popular L298N motor driver is being used. This driver can control two motors solely with ease, and it is easily interfaced with the microcontroller.
11.	DC motor	DC Motor is generally known to convert electrical energy to mechanical energy. The usual types depend on the magnetic field forces, and they have either electromechanical or electronic internal mechanisms. They can change the pathway of the flow of current in some parts of the motor. It can rotate in a clockwise or anticlockwise direction with the help of a motor driver. It determines the direction of the door, either opening or closing.
12.	Proteus software	The software used to design the circuit is called Proteus professional simulating software. Simulation is also done by testing the code and circuit on the computer before implementation.
13.	CloudX IDE	CloudX IDE is solely IDE used to write codes, compile them, upload them into the microcontroller, and create machine language. In this design, the CloudX IDE is used to program the microcontroller. The code is in CloudX C on the CloudX library, and CloudX IDE is more flexible and more comfortable to use.

B. Design Implementation

After necessary connections of the components (power supply, microcontroller, RFID reader, matrix keypad, LCD, motor driver, voltage regulator, resistors, and capacitors) have been done on a breadboard and checked for correct operation, mounting, and soldering of the hardware components on the Veroboard is carried out. Then, the circuit is fixed to a prototype framework. The RFID and keypad are mounted on the framework to enter the password and scan the RFID card. When required, power is supplied to the electronic circuit through the power supply module [40]. The system initializes immediately and prompts a request for the login of password or change of password. In this design, the password must be valid. A valid password should meet the stipulated requirements. The requirements are briefly described as follows: At least eight (8) characters—the more characters, the better but not more than fourteen (14). A mixture of both uppercase and lowercase letters. A mixture of letters and numbers. Inclusion of at least one special character, e.g.,! @ # ?].

Choosing 'login password' would require the user to provide the right password. After entering the password using the keypad, and the password entered is confirmed to be correct, the card is swiped next. A valid card guarantees that the user would be granted access, all of which will be displayed on the LCD. Simultaneously, the door opens and closes after 5 seconds after the users informed about this duration. However, should any entry means be found invalid, i.e., the password or RFID card, access is denied and it will be displayed on the LCD. The buzzer gives a long beep for up to 5 seconds to notify the user of the access denial, and the door remains closed until valid means of entry is provided. Buzzer also releases short beep sounds when inputting a password or swiping a card. Two RFID cards are being used

for this operation; one with its ID number stored in the microcontroller (making it valid) and the other without ID number stored (making it invalid). These cards are prepared to test the reliability of the design to authenticate and distinguish valid cards from invalid cards. The implementation flowchart of the proposed security access system is shown in Figure 3, and the complete hardware design is shown in Figure 4.

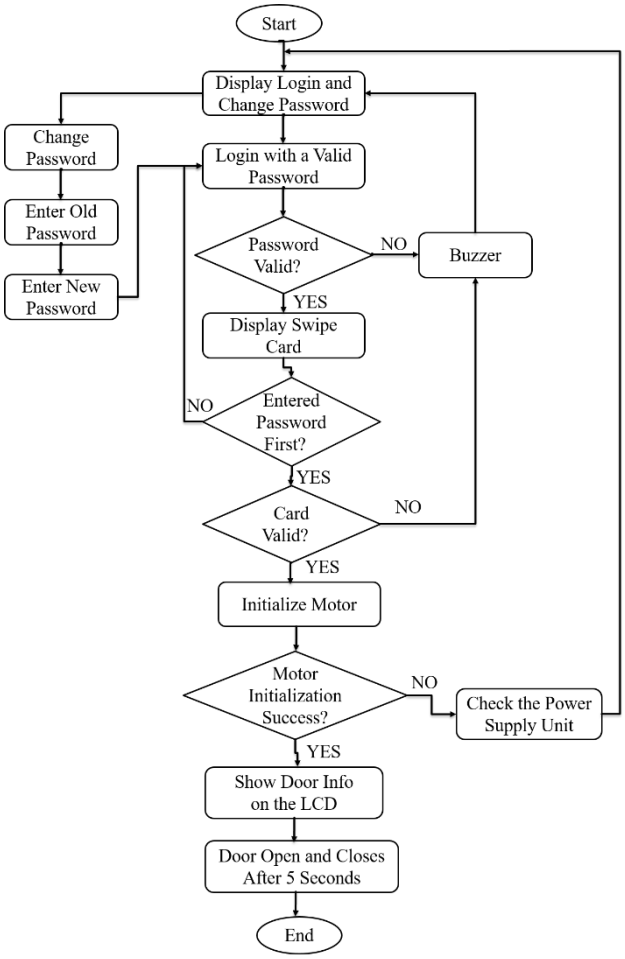

Figure 3: Flowchart of the system implementation

Figure 4: Complete hardware system design

IV. Results and Discussions

The results of the proposed security access system are presented in this section. When the system is powered, it initializes, displays the RFID access control system on the LCD screen for about 2 seconds, as shown in Figure 5, and then changes to the main menu.

The next information displayed is to login password or change password by pressing A for password login or C for change of password, as shown in Figure 6.

Choosing a login password takes the user to "Enter the password," as shown in Figure 7. If correct, it goes to "swipe your card," as shown in Figure 8. However, if it is incorrect, "password error" will be displayed on the LCD, as shown in Figure 9.

If the password entered is correct, it shows "swipe your card," as shown in Figure 8. If the card is valid, access is granted, and the door opens, as shown in Figure 10, but if not, access is denied, and the door remains closed, as shown in Figure 11. The display then goes back to the main menu.

If the password change is chosen, it shows they enter the old password, as shown in Figure 7, and then the new password, as shown in Figure 12. After that, it goes back to the main menu.

The authenticity of the system was tested in line with the stated objectives; allowing access to only authorized users and denying access to unauthorized users. The test results are as shown in Table 4. Here, to gain access through the security access system, the user must enter a correct password and have a valid and correct RFID card. On the contrary, an incorrect password with a valid or invalid RFID card would result in denial of access by the security system. However, it should be noted that the door opens and closes after 5 seconds. Therefore, users are encouraged to read the LCD information and be alert when the door opens to enter before it closes after the specified time.

This design is an integrated and cost-effective solution to tackle security threats in homes and offices. The prototype has been designed and implemented, and the results compare favorably with related schemes reported in the literature. Setting up this system at the entrance door of an organization or home would allow only authorized people to have access, and unauthorized users would be denied access. The development of the security access system using wireless technology has been demonstrated, and its commercialization is strongly recommended.

Figure 5: LCD powered ON

Figure 6: LCDs main menu

Figure 7: "Enter Password" shown on LCD

Figure 8: If the Password is correct

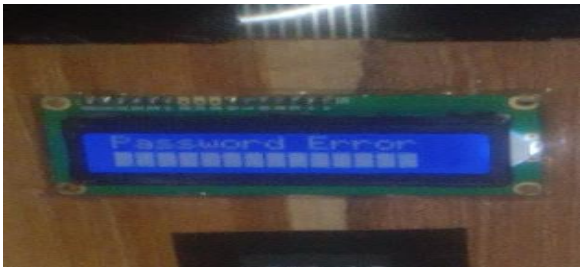

Figure 9: If Password is incorrect

Figure 10: If Authentication is valid

Figure 11: If Authentication is invalid

Figure 12: Enter "New Password" shown on LCD

Table 4
Design execution test results

Serial number	Password Unit	RFID unit	Door open	Door close
1	Correct	Valid	Success	Success
2	Incorrect	Valid	Failure	Success
3	Correct	Invalid	Failure	Success
4	Incorrect	Invalid	Failure	Success
5	Correct	Correct	Success	Success

V. CONCLUSION

In this paper, an RFID and password-enabled security access system, i.e., two security levels, has been presented as a feasible and reliable candidate to tackle the prevailing security challenges in domestic and industrial buildings. This system requires an authorized user to log in with a correct password and swipe a registered and valid RFID card to gain access. It is immensely gratifying that the design has been completed adequately at a minimal cost. Considering the huge financial burdens most security systems present, the components used in our design are relatively cheap and readily available, making the system cost-friendly and highly effective without a substantial compromise on its reliability. However, it should be noted that the RFID card could be used without the owner's consent. This is quite risky, and for this reason, the system has been supported with password technology. The password created must meet the minimum password requirements for use in the security access system.

Additionally, the password can only be known by the authorized users, and it can be changed at any time if and when a compromise is suspected. The security level of the system would be increased by adding biometric security measures such as fingerprint scanner, voice recognition, iris, or retinal scan. Finally, a GSM module could easily interfere with the system to send short alert messages to the system administrators, notifying any unauthorized attempt to gain access. Future work would improve the circuit design to accommodate an actual door instead of the current CD drive used as a trapdoor.

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