Comfortable and Safe Elevator System with Emergency Features and Smooth Braking using PLC

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***Abstract*—Elevators provide convenience for people who need to travel multiple stories, especially when carrying large items. It also includes people with disabilities who may not be able to use stairs.**

Here the system is designed to provide a smooth and comfortable ride for passengers and safety in an emergency. The use of a PLC allows less cost compared to others with precise control of the elevator's movements and the implementation of advanced safety features. Here we have used a ladder logic program to execute various concepts in the elevator system. It consists of different safety, and emergency measures and a smooth braking system to ensure confront of the users. We have included safety measures to execute during emergency conditions like sudden power cut off, earthquakes, fires, etc. We have shown a 3-floor elevator working system under these mentioned conditions. The system is optimized and detailed. The paper demonstrates the ladder logic program can be used to design and control an elevator system with high efficiency and reliability.

Keywords—PLC, Safety, Comfort, Power cut, Emergency, Reliability, Optimize, Enhance, Ladder Logic Programs

I. Introduction

An elevator system consists of a lift car, a motor, a brake, a door, and a control panel. The lift car contains people or cargo which are to be uplifted by the elevator. PLC performs extraordinary work in diminishing the workload. Industrial processes have become more complex, require to be performed at more incredible speeds, and have better accuracy. An elevator system works on the essential four-quadrant operation of the electric drive. This operation introduces motors, brakes, and control panels. Various research works are being held earlier in time. We used PLC to control the whole elevator system at a very base level. This PLC can be optimized for better operation using machine learning concepts. We have discussed that part in our future work. In this paper, there is a brief explanation and definitions of different subjects that we tried to implement. Our implementation improves the cost management system as using PLC is cost-effective in both installation and maintenance. The easy maintenance process will help the system to be more usable.

In section II, we have discussed the objective of this study. Here, we have also discussed how we can overcome some difficulties faced by elevators and how we tried to fix that.

In section III, we have discussed modern PLC architecture in brief and how it works. What we have implemented in this system is also mentioned.

In section IV, we have discussed the logic behind the ladder logic program which is created.

In section V, we have shown the PLC Ladder Logic implementation. The added function in this system is briefly explained in this section.

In section VI, we have summarized the whole study and the future work aspect where we can optimize and enhance the system more to bring the system a new factor.

II. OBJECTIVE

An elevator system faces many challenges and limitations, such as consuming a large amount of energy and generating a high level of noise and vibration. Regular and costly maintenance is also required to ensure a proper and safe operation. Faults or failures cause the malfunction or the breakdown of the system. The system is also affected by external factors, such as the weather, traffic, or user behavior. It influences the performance of the system. We will try to explain how we can overcome these limitations.

III. PROGRAMMABLE LOGIC CONTROLLER (PLC)

Today PLCs are widely used in Industrial Automation and control systems. Modern PLCs can be programmed using a variety of languages. It can communicate with other devices. The hardware system of the elevator PLC control system mainly includes CPL, memory (RAM, ROM), input and output equipment, as well as power supply equipment. CPL is the core processor of the PLC system. The PLC host is the core of the elevator control system. PLC and frequency converter constitute the control system [6].

This single elevator car system is tested and evaluated using different scenarios and performance criteria and in different braking conditions.

1. Under a sudden power cut scenario
2. Under emergency conditions like fire, earthquakes
3. Under overload condition

IV. SOFTWARE IMPLEMENTATION

To implement some modern features to the elevator system we added logic using Siemens Simatic Manager S7 Professional Software. We have introduced some innovative thoughts which we can include in a contemporary elevator system to make it more powerful and effective.

When the elevator is in a static state, the elevator will receive two kinds of signals. If the call signal from other floors is received, PLC will control the lift based on the signal response program. When the elevator is in operation if the elevator is going down, the elevator will only feedback on the received down call signal otherwise, it will only respond to the up call signal [1][6].

The elevator system implements the Four Quadrant operation of the electric drive.

V. WORKING ON THE LADDER LOGIC IMPLEMENTATION

We are implementing a ladder logic diagram where each network is interconnected with the other. The power of the building is isolated from the power supply of the elevator. It is done by a parallel connection from the source power through the auxiliary emergency service providing inverter. That way we can count the elevator car blockage during a sudden power cut in the building. We also tried to include soft braking in the elevator. The lift doors working is shown below (fig 1 a, b, c, d).

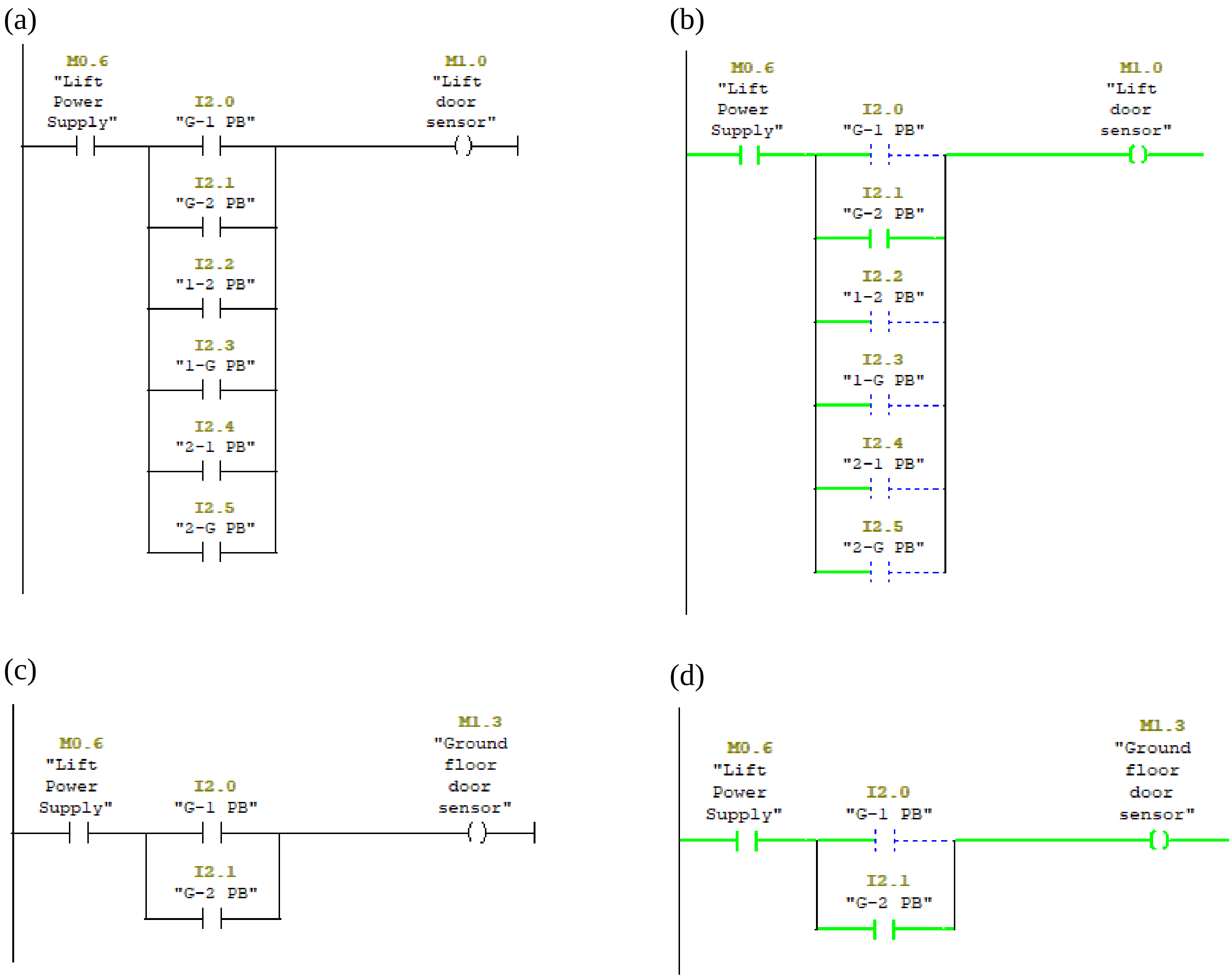

Fig 1: (a) Logic diagram of Lift Door Sensors
(b) Running condition of lift door sensor closes the door when Ground to 2nd Floor push button is pressed: green color signifies power path (color online)
(c)Logic diagrams of Ground Floor Door Sensors
(d) Running condition of Ground Floor Door Sensors closes the floor door when Ground to 2nd Floor push button is pressed: green color signifies power path (color online)

The automated door controls are shown above in Fig 1 (a), (b), (c), and (d).
The logic circuit works with the elevator car position detection system according to the floor. The ladder logic is made for 3 floors. As the system is generated for simulation purposes only, we have used MPI (Multipoint interface), which is the interface of SIMATIC S7 multipoint communication. It is a network suitable for communication between a small number of sites. It is mostly used for short-distance communication between the upper computer and a small number of PLCs.

- ***Features included in Ladder Logic**:*

***Emergency condition**:* Here we are going to show the feature we have added for sudden emergency conditions like fire, earthquakes, etc. Here we have attached the lift emergency with the building emergency. So whenever the Building emergency state will be at the on state, the elevator's emergency state will also be on, and thus the logic will start running, resulting in all elevator cars reaching the ground floor(Fig 2(b)) and opening elevator doors and remaining in the same condition until the emergency state gets off state (Fig 2(d)). This ensures that none is trapped inside the elevator during the emergency condition and that the elevators remain operational. This also prevents any damage to the elevator due to electrical or mechanical failures during an emergency. This feature can be activated both manually and automatically by detecting building emergency systems like smoke, fire, or seismic activity in the building. In Fig 2 (e), the ground call from the 2nd and 1st floor to the ground floor is seen to be dependent on the floor detection system. The running condition is shown in Fig 2(f). If the elevator is on the 2nd floor, the "2nd to ground floor"(M0.4) command will run and similarly if the floor is on the 1st floor, the "1st to ground floor"(M0.3) command will run.

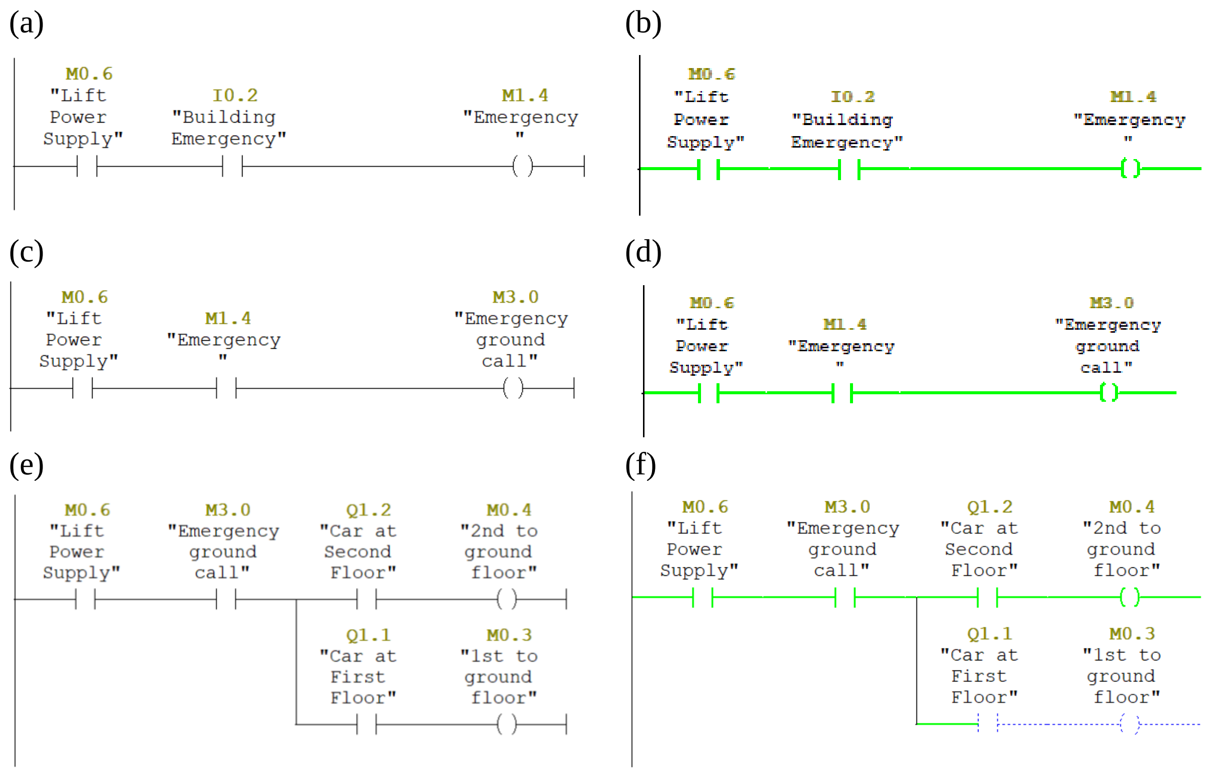

Fig 2:(a) Logic Diagram of building emergency is connected with Elevator emergency system
(b) Running condition of building emergency is connected with Elevator emergency sensor: green color signifies power path (color online)
(c) Logic Diagram of Elevator emergency system
(d) Running condition of Elevator emergency system when the emergency sensor is turned on: green color signifies power path (color online)
(e)Logic Diagram of commands connected with elevator emergency
(f) Running condition of commands with elevator emergency when car is in second floor: green color signifies power path (color online)

Sudden Power cut condition: For such conditions, we have installed an auxiliary power supply just to supply the elevator to the nearest floor can be reached. The lift should not draw any more power from the auxiliary power supply. An inverter as an additional device is added to the system. The automatic auxiliary supply switching with ON logic and power-OFF logic are used. In Fig. 3(a) we can see the power cut condition. The logic detected the power cut condition and enables the Auxiliary Power automatically Fig. 3(b). As well as when the power comes back, the auxiliary power switches off automatically as the logic condition does not fulfill.

Advantages of using an auxiliary power supply:

- Prevents users from being trapped inside the elevator in a power cut.

- Reduces the chance of damaging elevator components due to voltage fluctuations.
- Increases safety and reliability of the elevator system.

Although it can increase overall cost, complexity, and space requirement for the system it is worth it in case of the safety of the passengers.

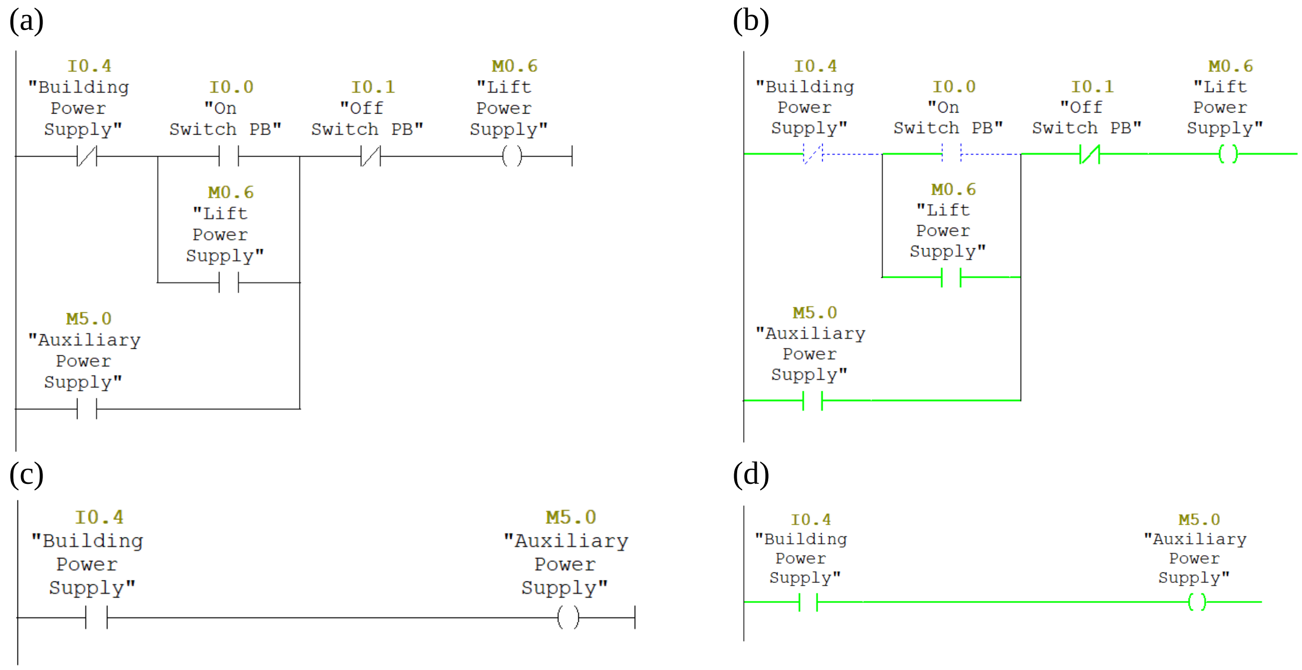

Fig 3: (a) Logic diagram of power supply in the elevator system
(b) Running condition of power supply in elevator system in power cut condition, the auxiliary power supply is automatically turned on: green color signifies power path (color online)
(c) Logic diagram of building power supply logic connection with auxiliary power supply
(d) Running condition of building power supply logic connection with the auxiliary power supply: green color signifies power path (color online)

Smooth Braking System: The smooth braking system is introduced via a timer system. For simulation purposes, we are assuming that 5 secs are needed to reach a single floor. In the case of direct calls like from ground to 2^{nd,} timer will give signal after (5*2)-2 = 8 secs. As we have implemented the simulation, we did not consider any use of safety belts as it comes with the manufacturer side as per the model and usage of the elevator car. But, for smooth braking and comfort of the passenger, we included a time-based braking system. It automatically detects the floor calls and works accordingly.

A time split is used to detect the reaching floor and engaging the braking system right away. In fig 4 (a), we can see that first 3 seconds is allocated for travelling from one floor to another and engaging the braking instance for last 2 seconds (fig 4 (a)). In fig 4 (b), all the cabin up commands and all cabin down commands are connected with ‘Cabin Up’ (M 2.1) and ‘Cabin down’ (M2.2) commands and those both are connected parallelly with the Braking system command (M2.0). This braking system command is split into 4 branches where ‘Empty Elevator’ and ‘Loaded Elevator’ conditions are shown. And the four-quadrant operation is shown in the simulation in fig (c, d, e, f) for forward braking, reverse motoring, forward motoring and reverse braking respectively.

The simulation is shown as follows.

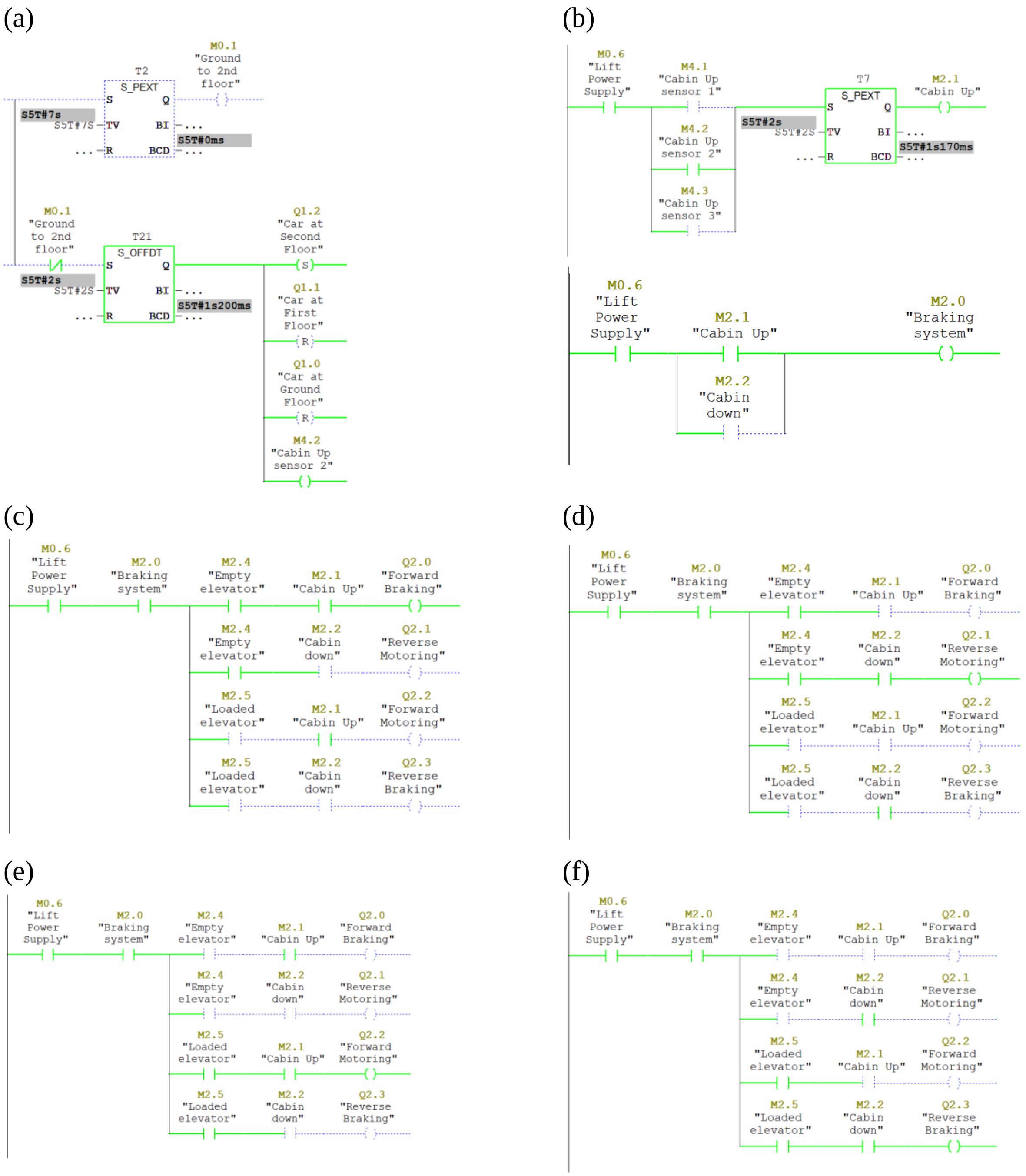

Fig 4 (a) Running condition of Cabin Up sensor to sense the elevator car going upwards: green color signifies power path (color online)
(b) Running condition of Similar Cabin down and Cabin Up command connected parallelly Braking system command: green color signifies power path (color online)
(c)(d)(e)(f) Running condition of various modes of four quadrant operations as forward braking, reverse motoring, forward motoring and reverse braking respectively in the condition of empty elevator cage or loaded elevator cage: green color signifies power path (color online)

Most importantly, the smooth braking is not only depending on PLC program but also depends on the various parts and mechanism of mechanical system and motors. We have only studied the software model of PLC which will help to achieve a smooth braking system by giving proper time of braking signal.

Conclusion

In this paper, we have presented a modern lift system using PLC which is very cost effective compared to other system and can handle emergencies such as sudden power cuts, high-intensity storms, earthquakes, or fires. We have designed and implemented an emergency power supply that can keep the lift running for a limited time until it reaches the nearest floor. We have also added an emergency ground call feature that can alert the ground staff and bring the passengers to the ground floor in case of any danger. Our system is reliable, safe, and efficient for various scenarios. Also, for the comfort of the users, we introduced a smooth braking system upon reaching the destination floor. We included a timer that detects the time to reach and initiates the braking system as required. In future work, we are determined to improve the system using Density Entry, we can make assumptions about the number of people inside the elevator and the number of people waiting outside, and their corresponding input command. Density Entry uses depth data, machine learning, and computer vision to anonymously count people. Moreover, we can use Zoning techniques and Reinforcement Learning Algorithms to optimize the system more effectively.

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