Lift Door Sensor Malfunction

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***Abstract*— Elevator safety is a critical concern in modern buildings, where lift systems are required to operate reliably under continuous usage and varying environmental conditions. Among the various safety components used in elevators, lift door sensors play a vital role in preventing accidents by detecting the presence of passengers or obstacles during door operation. However, failures such as sensor misalignment, dust accumulation, wiring faults, electrical interference, and component aging can lead to improper sensor functioning, thereby compromising passenger safety and system reliability. Conventional lift systems primarily focus on obstacle detection and lack dedicated mechanisms to continuously monitor sensor health and detect malfunction conditions in real time. This project presents a Lift Door Sensor Malfunction Detection and Safety System designed to enhance elevator safety by identifying abnormal sensor behavior and enforcing fail-safe operation. The proposed system continuously monitors door sensor signals and validates them against door position feedback and time-based constraints using a PLC or microcontroller-based control unit. Sensor malfunctions such as continuous ON or OFF signals, delayed response, and signal mismatch are accurately detected, and appropriate safety actions including lift immobilization, door control restriction.**

***Index Terms*— Lift Safety System, Elevator Door Sensor, Sensor Malfunction Detection, Elevator Safety Mechanism, Fault Detection System**

I. INTRODUCTION

In the modern era of urban infrastructure, elevators, commonly known as lifts, have become an essential vertical transportation system in residential, commercial, and industrial buildings. With the rapid growth of high-rise structures and increasing population density, the dependence on lifts for safe, efficient, and time-saving movement of people and goods has increased significantly. As a result, safety and reliability have become the most critical aspects of lift system design and operation. Among the various safety subsystems used in elevators, the lift door system plays a vital role, as it directly interacts with passengers during entry and exit. The lift door mechanism is designed to open and close smoothly while ensuring that no passenger or object is trapped between the doors. To achieve this, modern lift systems employ door sensors, such as infrared (IR) sensors, light curtain sensors, or proximity-based detection systems.

II. LITERATURE REVIEW

The literature survey for the Lift Door Sensor Malfunction Detection and Safety System reveals that elevator safety has been an active area of research due to the increasing dependence on lifts in high-rise buildings and the critical nature of passenger safety. Several researchers and industry studies emphasize that lift door-related accidents constitute a significant percentage of total elevator incidents, primarily due to improper obstacle detection, sensor failure, or delayed response of door control systems. Traditional elevator systems rely heavily on infrared-based door sensors or light curtain arrangements that are designed mainly for obstacle detection, but many studies highlight that these systems lack built-in intelligence to evaluate the health and reliability of the sensors themselves during continuous operation. Previous research on elevator door safety systems indicates that infrared and photoelectric sensors are widely used because of their fast response time, non-contact operation, and ease of integration with lift controllers. Studies have shown that light curtain sensors, which use multiple infrared beams arranged vertically across the door opening, significantly reduce the chances of door-closing accidents.

However, various authors report that these sensors are highly sensitive to environmental conditions such as dust, humidity, vibration, and misalignment, which can lead to false triggering or complete signal loss. Literature also points out that most conventional systems do not differentiate between an actual obstacle and a faulty sensor condition, thereby limiting the overall safety effectiveness. Papers related to fault detection in safety-critical systems propose the use of redundancy and signal validation techniques to improve reliability. Researchers have suggested using dual-sensor configurations, time-based consistency checks, and logical correlation between door position feedback and sensor output to identify abnormal behavior. In industrial automation literature, PLC-based safety systems are widely recommended due to their deterministic behavior, high reliability, and compliance with safety standards such as IEC 61508 and ISO 13849. These studies support the idea that incorporating fault detection logic within the controller can significantly enhance system safety without major hardware modifications.

Recent advancements discussed in the literature include the integration of microcontroller-based monitoring units and embedded diagnostics to detect sensor degradation over time. Some researchers have explored the use of self-diagnostic algorithms that monitor signal patterns, response time, and failure frequency to predict sensor faults before complete failure occurs. Although such systems improve preventive maintenance, many studies conclude that their implementation in conventional lifts is limited due to cost constraints and lack of standardization in existing installations. The literature also highlights the growing trend of incorporating communication technologies such as IoT and GSM modules for remote elevator monitoring.

Studies indicate that real-time fault alerts sent to maintenance personnel can significantly reduce response time and improve system uptime. However, most of these solutions focus on overall lift performance and breakdown monitoring rather than specifically targeting lift door sensor malfunction detection. This observation identifies clear research and application gap in existing elevator safety systems. Based on the literature review, it is evident that while substantial work has been done on lift door obstacle detection and general elevator safety, limited emphasis has been placed on continuous monitoring and intelligent detection of door sensor malfunctions. The existing systems lack a dedicated mechanism to distinguish between genuine obstacle conditions and sensor faults, which can compromise safety and reliability. This project addresses the identified gap by proposing a dedicated Lift Door Sensor Malfunction Detection and Safety System that integrates real-time fault detection logic with fail-safe control action, thereby contributing a practical and safety-focused improvement over conventional elevator door systems.

In modern elevator systems, lift door safety is primarily dependent on the correct functioning of door sensors such as infrared sensors or light curtain systems, which are responsible for detecting the presence of passengers or obstacles during door operation. Although these sensors are designed to enhance safety, their performance can degrade over time due to factors such as dust accumulation, mechanical misalignment, electrical noise, wiring faults, component aging, and harsh environmental conditions. When such degradation or failure occurs, the sensor may either fail to detect an obstruction or generate false signals, leading to unsafe door operation, unexpected lift stoppages, or passenger discomfort.

III. METHODOLOGY

This The methodology adopted for the Lift Door Sensor Malfunction Detection and Safety System involves a systematic approach encompassing sensor selection, system design, fault detection logic development, hardware integration, and testing to ensure reliable and fail-safe operation. The first step in the methodology is the selection of appropriate door sensors based on operational requirements, accuracy, response time, and environmental conditions. Infrared (IR) sensors, light curtain sensors, and proximity sensors are commonly considered due to their non-contact operation, fast response, and ease of integration with lift control systems. Redundancy is also considered by implementing backup sensors or multiple beams to enhance detection reliability and minimize false readings caused by dust, misalignment, or electrical noise. Following sensor selection, the next stage involves the development of a control system using either a PLC or a microcontroller platform such as Arduino or ESP32. The controller serves as the central processing unit responsible for acquiring sensor signals, processing input data, and executing fault detection algorithms. The fault detection logic is designed to continuously monitor sensor signals in relation to door position feedback and timing parameters. Abnormal behaviors such as signal continuity beyond expected intervals, delayed response during door opening or closing, and discrepancies between sensor input and mechanical door movement are identified as potential malfunctions. The controller is programmed to respond immediately to any detected fault by triggering a fail-safe action. Hardware integration is a critical step in the methodology, where sensors, relays, indicators, and alarms are connected to the control unit following electrical and safety standards. The system is designed to interrupt lift motion and halt door operation in the event of sensor malfunction. Simultaneously, visual indicators such as LEDs or an LCD display and audible alarms notify passengers and maintenance personnel about the fault condition. Wiring, power supply, and isolation considerations are carefully planned to ensure system reliability and compliance with safety standards like IEC 61508 or relevant national elevator safety codes. The testing phase of the methodology involves simulating various sensor failure scenarios to evaluate the system's fault detection capability and response accuracy. Test cases include 11 sensor disconnection, obstruction detection failure, false triggering, continuous signal states, and delayed sensor response. The system's reaction, including lift immobilization, door halt, and alarm activation, is observed and recorded to verify correct implementation of fault detection logic. Any deviations or inconsistencies are corrected through iterative programming and hardware adjustments. Finally, the methodology emphasizes documentation of system performance, sensor behavior, and fault handling outcomes to provide a comprehensive evaluation of the proposed solution's effectiveness, reliability, and readiness for real-world implementation in lift safety applications. Lift systems are classified based on their driving mechanism, speed, application, and building requirements, and each type is designed to suit specific operational conditions and load demands. One of the most commonly used lift systems is the traction lift system, which operates using steel ropes or belts passing over a motor-driven sheave, with a counterweight balancing the load of the lift.

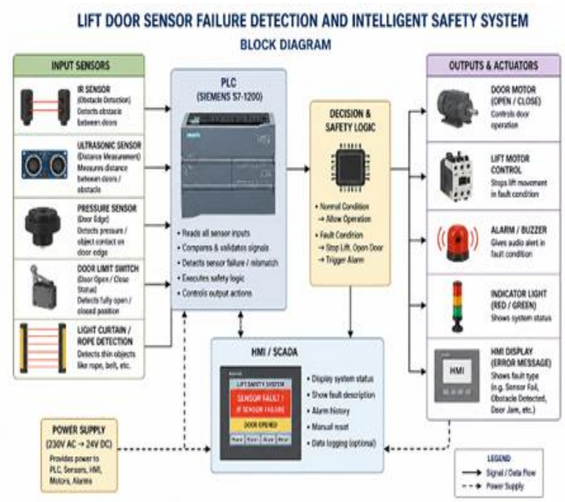

Figure 1: Block Diagram

Traction lifts are widely used in mid-rise and high-rise buildings due to their high efficiency, smooth operation, and ability to travel at high speeds. They are further classified into geared traction lifts, where a gearbox is used between the motor and sheave, and gearless traction lifts, which directly couple the motor to the sheave, offering higher efficiency, lower noise, and better performance for very tall buildings. Another important type is the hydraulic lift system, which operates based on the principle of fluid pressure acting on a piston to move the lift car. Hydraulic lifts are typically used in low-rise buildings with fewer floors because of their limited travel height and lower operating speed. These systems are known for their simple construction, high load-carrying capacity, and cost effectiveness for short travel distances. However, hydraulic lifts consume more power during upward movement and require proper handling of hydraulic oil, which can pose environmental and maintenance concerns. Machine Room-Less (MRL) lift systems represent a modern advancement in elevator technology, designed to eliminate the need for a dedicated machine room. In MRL systems, compact gearless motors and control equipment are installed within the hoistway, reducing building space requirements and construction costs. These lifts are energy-efficient, environmentally friendly, and widely used in residential and commercial buildings where space optimization is a priority. Despite their advantages, MRL systems require precise installation and specialized maintenance due to limited access to equipment. Another category includes pneumatic or vacuum lift systems, which operate using air pressure differences to move the lift car. These lifts are typically used in residential or specialized applications and are suitable for low-rise buildings. Pneumatic lifts offer smooth and quiet operation, require minimal civil construction, and are relatively easy to install. However, their load capacity and travel height are limited, making them unsuitable for large commercial applications. In addition to these, goods lifts and service lifts are designed specifically for transporting materials, equipment, or heavy loads rather than passengers. These lifts are commonly used in industrial facilities, warehouses, hospitals, and hotels, and they prioritize load capacity and durability over speed and passenger comfort. Dumbwaiters, which are small freight lifts, are also used in restaurants and hospitals for transporting food, medicines, or documents between floors.

IV. RESULTS

The implementation of the Malfunction Detection and Safety System successfully demonstrates reliable detection of abnormal sensor behavior and effective enforcement of fail-safe lift operation. During normal operating conditions, the system accurately monitored door sensor signals and allowed smooth opening and closing of lift doors without interruption, indicating stable and correct system performance. The controller consistently validated sensor outputs with door position feedback and timing parameters, ensuring that only valid obstacle detection signals were accepted during normal lift operation. When various sensor malfunction conditions were intentionally simulated, such as sensor disconnection, continuous ON or OFF signal states, delayed sensor response, and signal mismatch between door position and sensor output, the system detected these faults promptly and accurately. Upon fault detection, the controller immediately disabled lift movement and restricted door operation, confirming the effectiveness of the implemented fail-safe control logic. Audible alarms and visual indicators were activated without delay, clearly notifying passengers and maintenance personnel of the fault condition. The system also proved effective in distinguishing between genuine obstacle detection and sensor malfunction, thereby eliminating false door reopening and unnecessary lift stoppages commonly observed in conventional systems. This capability improved overall operational reliability and reduced mechanical stress on door mechanisms caused by repeated or incorrect door movements. Additionally, clear fault indication significantly reduced troubleshooting time, supporting faster maintenance response and minimizing lift downtime.

V. ADVANTAGES

The Lift Door Sensor Malfunction Detection and Safety System offer several significant advantages that contribute to enhanced passenger safety and improved operational reliability of elevator systems. The primary advantage of the proposed system is its ability to continuously monitor the health and performance of lift door sensors in real time, rather than relying solely on basic obstacle detection. This ensures early identification of sensor malfunctions and prevents unsafe lift operation caused by faulty or unreliable sensor inputs. Another important advantage is the implementation of a fail-safe control strategy, which immediately restricts lift movement and door operation upon detection of abnormal sensor behavior. This significantly reduces the risk of door-related accidents and ensures that the lift operates only under safe and verified conditions.

VI. CONCLUSION

The Lift Door Sensor Malfunction Detection and Safety System presented in this project successfully addresses a critical safety concern associated with modern elevator operation by introducing an intelligent and reliable mechanism for detecting door sensor failures in real time. Conventional lift systems primarily focus on obstacle detection and often lack the capability to monitor sensor health, which can lead to unsafe operating conditions when sensor malfunction occurs. The proposed system overcomes this limitation by continuously validating sensor signals against door position feedback and time-based constraints, ensuring accurate identification of abnormal sensor behavior. The implementation of fail-safe control logic ensures that lift movement and door operation are immediately restricted upon detection of sensor malfunction, thereby preventing potential accidents and enhancing passenger safety. The inclusion of audible and visual fault indications further improves system transparency and supports quick maintenance response, reducing downtime and improving overall operational reliability.

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