AUTOMATIC CAR PARKING AND FIRE DETECTION SYSTEM USING PLC

A Project report is submitted in partial fulfillment of the requirements for the award of Degree of Bachelor of Science in Electrical and Electronic Engineering.

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DECLARATION

We hereby declare that this project “**AUTOMATIC CAR PARKING AND FIRE DETECTION SYSTEM USING PLC**” represents our work, which has been done in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. We have attempted to identify all the risks related to this research that may arise in conducting this research, obtained the relevant ethical and/or safety approval (where applicable), and acknowledged our obligations and the rights of the participants.

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APPROVAL

The project and thesis entitled **“Automatic Car Parking and Fire Detection System Using PLC”** submitted by **Salim Reja Sagor (221-33-1527), Md. Akbar Ali (221-33-1572) & Sharmin Sultana (221-33-1716)** has been done under my supervision and accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** in **August, 2025.**

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Dedicated

To

Parents

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PLC	Programmable Logic Controller
VFD	Variable Frequency Drive
HMI	Human Machine Interface
SMPS	Switch Mode Power Supply
MBUS	Modbus Communication
RS232	Serial Communication
TP	Tripple Pole
LD	Ladder Diagram
DOP Soft	Delta HMI Software
ES	Emergency Stop Switch
SS	Selector Switch
PBS	Push Button Switch
LS	Limit Switch
PDS	Pedal Switch
I/O	Input Output
I/P	Input
O/P	Output
EMR	Environmental Management Review
EPA	Electronic prior authorization
IEA	International Energy Agency
UNEP	United Nations Environment Program

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ABSTRACT

In the modern-day city scene, the situation is such that there is a greater demand toward intelligent and effective parking systems because of increasing the density of vehicles and limited parking spaces. This thesis gives details on the design and actualization of automated car parking and fire tracking system which is operated by Programmable Logic Controller (PLC) and is monitored using a laptop-based system using Delta HMI software. This system has facilitated automated gate control, detection of parking slots and real-time status indication via relays, actuators and infrared (IR) sensors. LED indicators are used at the entry gate and can inform the driver of free parking slots to alleviate the problematic parking process. Alongside with the parking system, the project will have a fire detection application. Sensing of rich fire or smoke is done using sensors installed in different zones of the parking area to sense hazards. When the detection is made a buzzer will sound and immediate signals will be sent to the operator via the HMI. The status of all activities, such as the gate position, the slot status, and fire alerts, are viewed in real-time through an RS232 communications interface between the PLC and the laptop. The system guarantees advanced security, efficiency of operation and convenience to its users. It minimizes the necessity to control it manually, as well as enhances the trustworthiness of parking activities in the case of public or business scenes. This project shows how intelligent parking and safety can be done efficiently, and cost-effectively with an industrial automation approach; this is scalable.

Keywords: Car Parking System, Automation, Fire Detection, PLC, HMI

CHAPTER 1

INTRODUCTION

1.1 Background

In our fast-urbanizing world population, the multiplication of vehicles on the room is a crucial factor that keeps on increasing with the high population in the urban cities. The result is that this increased number of vehicles have come with a number of issues like traffic jams, short supply of parking lots, poor physical management of parking areas and also increased safety concerns like fire outbreaks in subcover parking garages or underground parking garages[1]. The traditional parking systems tend to be manually operated in nature that not only leads to delays, and inconvenience to the drivers, but it also leads to traffic congestion around the parking place. Also, lack of real-time surveillance and emergency alert mechanism may as well present a big safety challenge in case of any accident in the parking facility or the outbreak of fires in the facility. As a way of dealing with such problems, there is the factor of automation technologies that have gained relevance in the current infrastructure. Combining the advantage of Programmable Logic Controllers (PLCs) and Human-Machine Interfaces (HMIs) towards intelligent parking and safety control system integrations is a prospective idea[2]. LCs provide a safe, dependable control on electromechanical processes, and monitoring and display of system conditions is possible using HMI platforms in real time. The technologies are a mainstream in the field of industrial automation, and are increasingly being applied to civil and urban processes, such as car park management, and safety[3]. The proposed study is related to the design and development of an Automatic Car Parking system and a Fire detection system design that would have a control mechanism based on PLC and a monitoring system based on HMI (on a laptop)[4]. The new system will not only automate the car entry and parking space assigning process, but its installation will improve the safety of the new system, as a fire detection alarm system is to be provided. The sensors are installed in a such way so that to notice the caravans and fire circumstances and the overall situation of the parking area is observed by managing convenient HMI interface[5]. This system, with the help of automation, will minimize human participation, minimize errors, and will help manage parking resources, and safety-related issues more easily.

Incorporation of automation into parking systems is one way that indicates a major degree of smarter infrastructure[6]. The study is in the context of the wider objective of strategizing smart cities where systems are interconnected, tracked, and enhanced in regard to efficiency, safety and user-friendliness. Introduction of this system is also in line with the current trends of the industry 4.0 where traditional processes across sectors are undergoing a revolution due to digital technologies.

1.2 Motivation Behind Choosing the Topic

The choice of the topic, Automatic (car) Parking and Fire Detection System that involves the use of PLC and HMI monitoring is an automated system that may solve the need to enhance intelligent systems that should help us, in our daily urban life. With increasing populations in the urban areas, the number of vehicles on the road increases, as well. Such expansion brings immense strain on the already available infrastructure particularly parking facilities where manual systems mostly breakdown due to the sheer volume of parking management it is required to handle[7]. The common problems of finding available parking areas result in time wastage, frustration to the drivers, the consumption of fuel, and traffic jams.

The other critical issue in both the public and the privately owned parking lots is a safety more so the danger of fire breaks out due to overheated engines, electrical conflagration, or fuel leakage. The traditional fire detection systems are commonly single units that have no connection with the overall control and monitoring unit which makes it slow in responding during emergencies[8].

As a matter of academic and engineering approach, the topic provided a superb amendment to study and implement automation, control systems, and safety integration with all the contemporary industrial equipment such as PLCs (Programmable Logic Controllers) and HMI (Human-Machine Interface). These are at the center of automation of modern industries and they are important to learn by the students, in theory and practice.

This choice of the topic led to a system that makes the parking processes very efficient, but also provides increased safety surveillance[9]. Based on the project being an interdisciplinary project because it heavily involves a combination of electrical control systems, automation, sensing technology, user interface design, and safety engineering, the project is indeed both challenging and rewarding.

Also, the subject matter is up-to-date with the general tendencies in the development of smart cities all over the world where units of automation, data, and safety merge together creating more effective, sustainable cities[10]. The personal interest of being automatized and having the possibility of checking the system in real time was one of the reasons that caused the selection of the topic. The practical relevance of the project, social necessity and chance to create a valuable and sensible application into reality greatly inspired the implementation of the project as thesis.

1.3 Objectives

This study is about the conception, design, development and implementation of a smart and automated system that can aid in two aspects of modern infrastructure which are need of efficient vehicle parking system and early fire hazard detection. They are both increasing issues in urban settings where room is scarce and the dangers are high. The system is constructed on the basis of Programmable Logic Controllers (PLC) providing the reliable automation control and Human-Machine Interface (HMI) that shows real-time monitoring and allows the user to interact with it[11].

This thesis as a whole is to come up with a smart, compact, and responsive automation solution that can be installed in any commercial or residential parking structure to:

It automatically controls the traffic of vehicles in and out of the parking area.

Exact monitoring and display of real time parking slot availability, identify dangerous fire risk areas at an early stage and effect instant safety measures,

Create an easy-to-use interface to monitor and control.

In order to achieve this purpose, the following specific objectives have been formulated:

Design a PLC Control Logic of Smart Parking Automation

- To develop a control system with the use of PLC that automates the work of the entry and exit barriers.
- To make sure that the system is able to count vehicles entering and leaving the place and allocate parking slots to them.
- To install sensors (such as proximity and limit switches) to locate vehicles on parking slots or the absence of the same.
- To eliminate the involvement of a lot manpower by computerizing the presenting slots and gate controls.

Part of the parking infrastructure to be installed with a Fire Detection System. Embedment of temperature sensors and smoke detectors in vital sections of the parking place. So that the system has the capacity to keep updating the situation in the environment and can identify whenever there is an abnormal increase in the temperature level or smoke.

To make the PLC react to fire signals by activating an alarm and warning the users through the HMI and possibly other emergency measures involving turning on the ventilation fans or sprinklers (in superior models)[12].

Design the HMI interface which can be used to control and visualize the system

To come up with a user friendly and informative HMI screen where its visual presentation will display the statuses of each parking slot (occupied or not). To show a real-time sensor reading, the system alerts, and fire warnings. To enable administrators (or security personnel) to force certain functions to have the capability to be overridden manually in the event of an emergency or a system failure. To present facility to diagnose and configure with effort.

Make sure it is Real-Time and Have Quick System Response To cut down latency in the system and be quick in operation in the movement of the vehicle, as well as the measurement of the emergency. To ensure that input read by the sensors is processed and reflected on the HMI practically in real-time. To avoid overloading or slowdowns that might cause insecurity or inconveniences to users. Energy Efficiency and Optimize the Resources Utilization to apply automation to switch on and off the electrical gadgets within the building like lights, fans, and alarms whenever necessary to implement the system so that it becomes energy-saving, e.g. by switching off the display or components that are not in use to utilize maximum slots in the available space by using it efficiently[13]. Test, trained and proven the system in a Lab setting, to develop a scaled model of the parking and fire detection system. To carry out experiments to test the accurateness, pace, and dependability of the automatic procedures. To test the emergency procedures (e.g. causing activation of smoke detection by false alarm). It is necessary to create modular and scalable system-design. To design the project in form of modules in such a way that additional parking spots or fire areas can be implemented without much hardware or software modifications to make the system ready to receive future add-ons like mobile application-based data collection, on the internet-of-things communication, or cloud-based data storage, etc.

Solve Real-world Problems with Cost-efficient Engineering to come up with a cost-effective solution which utilizes the available and affordable hardware components. to illustrate how the same model may be applied in real life situations in commerce with a few modifications.

In order to offer an automation model with high performance, reliability, and a reasonable cost. This complete range of goals enables the system to not only work as planned under a controlled environment, but also possess the capabilities of growing, changing, and evolve to accommodate changing future technologies and demands on the real world[14].

1.4 Problem Statement and Proposed Solution

As the world is turning rapidly into an urban place, the world also experiences quite an extensive lack of parking space and inefficient parking management due to increased numbers of vehicles in cities. Parking systems presently in use are more of manualized actions and consequently inefficient resulting in long search of available spaces, using extra fuel, heavy traffic jams and wasted time on the user. In addition to the above, absence of a system that leads to a comprehensive safety feature such as fire detection in parking areas subjects' cars and infrastructure to the risk of fire which may cause colossal losses.

The core problems identified are:

Unstructured car parking: manual based systems or systems that are not fully automated will not be able to offer us real time reports about available car parking spaces. Wastes time and energy: Motoring drivers waste a lot of time and energy in search of an available parking area. There is no monitoring: The old systems lack centralized monitoring or notifications on cars that are parked. Safety issues: In most parking lots, there is a lack of real-time fire detection and alarm systems, which raises the possibility of fires that one cannot detect in time. Failed integration: Systems do not perform to a central point with real-time feedback systems.

Proposed Solution

To overcome the mentioned difficulties, the current thesis suggests installation of Automatic Car Parking and Fire detection System that is controlled by a Programmable Logic Controller (PLC) and is monitored through a Human-Machine Interface (HMI) which is linked to a laptop. The vision of the proposed system is to optimize the process of parking, minimalize the presence of humans, make it safer and be remotely monitored

Key features of the proposed solution include:

- Automated Entry Gate Control: The system also does entry control via sensors and PLCs logics to detect entry vehicles before opening the entry gate.
- Smart Safe Parking Indicator System: A set of Sensors will be placed in all parking places with LED indicators illustrating occupancy in real time. Before they enter, drivers are able to see the availability.

- Real time Monitoring: It monitors the whole status of the system (occupied/vacant spaces, the gate status, the alarm condition using HMI software which is installed in a laptop.
- Sensors with integrated fire detection: each parking zone is equipped with sensors that monitor it all the time in order to identify fire or overheating. When detected an instant alarm is sounded both to the onsite people and the main system.
- Centralized Control With PLC: A PLC is the core of the system that decides what to do with the inputs of the sensors and provides the controlling commands to control the gates, indicators, and alarms efficiently.

This combined automation solution will increase the efficiency of the user-friendliness in parking along with safety and capability to scale larger parking infrastructures[15]. The system is robust, economical and very flexible to use in the commercial buildings, shopping malls, residential complexes and in the parking areas of the public places.

1.5 Brief Methodology

It is a rather formal and methodical initiative that deals with the hardware interface, programming of the PLC, and integration of the HMI software. The methodology represents how the system has been developed- beginning to the final implementation- to make the process of parking the car automatic and a means of detecting fire incidence in real-time.

System Design Planning

The first phase was the analysis of the requirements of the system and the development of a working layout. This covered definition of the equipment as follows:

- The number of parking slots will be done completely
- Entry and exit logics
- Areas of fire detection
- TM Observation of needs through HMI
- The connections between the PLC, sensors, relays, and actuators, the LED and the laptop interface were also drawn schematically using a block diagram and a wiring layout.

Hardware Component Selection and Integration

The following are the key hardware that was used to develop the system

- Programmable Logic Controller (PLC): The heart of the logic of control of all automation.
- Infrared (IR) Sensors: It detects whether there is a vehicle in each parking slot or not.
- Flame Sensors: Deploy where there is need to pose presence of fire in the parking areas.
- Relay Modules: A type of module to switch actuators, alarms, and indicator lights according to outputs of PLC.
- Linear Actuator with Contactors: It is used to control the automatic movement of the parking gate.
- LEDs: Has LED indicators that provide real-time information on a parking slot status.
- Buzzer/Alarm System: Notifies the user on the case of fire detection.
- SMPS: 5V, 12V, and 24 Volt power supply units.

All the components were interfaced with relevant input / Output terminals of the PLC and supplied using regulated special power supplies unit. The communication between the PLC and laptop was through RS232 cable under HMI communication.

PLC Programming

The ladder diagram programming is used to implement the logical operations as this is a standard PLC language. Programming features Feature Key Problem analysis with ease-of-use Problem analysis deals with the realm of problem solving and its ease of implementation. Easy accessibility to changes Problem changes are not only easy but they are also accessible.
Identification of vehicles through IR sensors and updating of slot status. Activating opening and closing of the entry gate by actuators. Making use of LEDs to indicate the visual parking status. Setting off the fire alarm when the flame sensors are aroused. Provision of interlocks to stop, overlapping of operations or false triggering. The input from each sensor and the output of each actuator were accurately bounced to make the system responsive, efficient and, safe.

HMI Design and Laptop Monitoring

A graphical interface to the real-time monitoring and control of the system had been designed with the Delta HMI software. The users can:

- See the availability in each of the parking spaces (free/not available)
- view status gate(open/close)

System Testing and Calibration

Once the integration of hardware and software was done, the system was subjected to series of testing:

- Good detection by calibration of sensors
- Gate actuator and relay testing
- LED and buzzer reaction tests
- HMI data validation against real time inputs

Bugs were eliminated and possible changes were introduced so that both the PLC and HMI system could forgive one another with regard to synchronization issues.

Final Implementation

The entire system was then tested out in a simulative parking situation after it had been verified. The end result was the working prototype.

- Automatic opening of the gate when a car is approaching
- Parking slot availability indicator (mind set (LEDs)
- Monitoring of laptops IN REAL TIME through HMI
- Live fire detection and alarm system
- Steady and synchronized control in PLC

The choice of methodology allowed the creation of such solution, which could be characterized as being very robust and efficient and combining automatization with convenient monitoring related to the main issues of traditional parking systems[16].

1.6 Organization of the Report

The thesis is designed in seven chapters where each of these chapters presents a separate part of the study work. The reporting structure is as follows

Chapter 1: Introduction

The chapter presents the topic of the research and gives a background of the topic, the motivation of the research, the most important objectives, the problem under study and the mode of study. It lays down the framework of the rest of the report.

Chapter 2: Literature Review

This chapter carries out a whole review of research done and technology advancement available concerning the subject. It reviews prior art in the above fields of automated system, PLC-based system, fire detection mechanism and associated environmental and health issues. The existing research that was not fully addressed due to gaps, which are addressed in this project, is also identified.

Chapter 3: Materials and Methods

This chapter provides an overview of the fundamental principles behind antenna design, and it describes the fundamental parameters which influence the performance of antennas, start with the return loss, next is the gain, then the bandwidth and lastly the efficiency. You may include this in your monitoring system even though it appears to be a separate issue as it fits in the wireless communication of monitoring systems.

Chapter 4: Result and Discussions

This chapter discusses the results of experimental investigation and the performance of systems. Data gathered in the process of testing and implementation are interpreted and performance is measured against the expected performance. There are graphs, tables, and screenshots that present the findings in a clear way.

Chapter 5: Project Management

The chapter talks about planning, scheduling and resource allocation in the implementation of the project. It summarizes the schedule of the project, the budgeting, allocation of tasks, risk analysis and the management of the project complications during the developmental process.

Chapter 6: Impact Assessment of the Project on Human Health and Environment

In the mentioned chapter, the risks the project poses to human safety and the environment are considered. The advantages of automation in terms of decreasing the accidents and enhancing the level of fire safety and the diminishing of the energy intake are explained as well as any potential adverse outcomes or dangers.

Chapter 7: Conclusion

In this final chapter, a summary of the research findings will be provided and the key accomplishments will be mentioned, and reflecting on the attainment of the objectives. It gives also recommendations about the future improvements and extension of the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Due to the exponential growth in the number of vehicles in urban settings, modern cities face many issues connected to the problems of traffic congestion, ineffective parking system, and traffic safety. The automation in parking systems has not only become a completely new luxury but a crucial technology as smart cities develop. This chapter will focus on the review and analysis of the relevant past research attempts in the development of crucial automated car parking and fire detection systems[17]. It is concentrated on the systems that are intended to be built with the help of PLCs, HMI interfaces, sensors, and other types of control technologies. Specifically, in this review, the development of automation in parking solutions, the need to implement safety systems, including fire detection will be pointed out as well as the superiority of this or that hardware or software implementation.

2.2 Related Works

Many studies have been focused on automating parking systems with the utilization of Programmable Logic Controller (PLC), Field Programmable Gate Arrays (FPGAs), and microcontrollers. Such systems seek to maximize the use of parking space, improve convenience to the user, and achieve high safety in the operations of the system.

The University of Tripoli conducted one of the remarkable research projects, which implemented the system of rotary car parking relying on FPGA which makes the procedures of entry, exit, and parking automatic[18]. A number of precautionary features are integrated into the system and these features include weight compliance monitoring, password-protected vehicle retrieval and temperature sensors to monitor fire safety. Such a system proves to be highly automated with the view of the fact that users can use it in densely populated urban settings as it is both scalable and has real-time characteristics.

One more study applied Siemens S7-300 PLCs and WinCC Flexible HMI software to develop a car parking lot devoted to automation entirely. The system monitors the number of the vehicles; the times they appear and leave the parking and shows whether the parking spaces are occupied in an HMI interface. It can also be used remotely and is able to calculate the parking fee and can have application in commercial parking setting[19].

In learning process, one of the papers documented a smart parking system that is implemented with Ladder Logic program to enable the student grasp the concepts of automating any processes. It integrated the use of virtual simulation tools and PLCs to simulate real situations in parking, and, therefore, it was appropriate to use it in distance learning conditions and digital improvement of skills during the quarantine caused by the COVID-19 pandemic.

Researchers in China designed a three-dimensional (3D) automated parking garage that has been operated with the use of PLC to maximize space utilization and facilitated better parking. The garage is equipped with automated elevators and turntables that can be used to put the cars into vacant places, as well as the features related to the air quality control, fire precautions, and vehicle security. It stresses cyclic programming and simulation in order to get feasibility and reliability of system.

A significant addition to the designing user-friendly approach is the adoption of a prototype of a smart multi-level parking system that is integrated with DC motors, proximity sensors, microcontrollers, and intelligently automates vehicle parking. The machine eliminates much manual interference and it is effective in addressing parking space bottlenecks in the city. Nonetheless, its use of microcontrollers can be viewed as a shortcoming in terms of scalability and ruggedness in industry[20].

Fire safety with respect to fire safety, component systems are also deployed that include temperature sensors or flame detectors, linked to control logic that switches emergency alarms or fire suppression systems. as an example, the FPGA controller based rotary parking system incorporates thermal monitoring as an in-built facility without which the conventional parking automation systems may not all times possess.

A comparison analysis was also conducted to analyses the differences on the performance over the parking systems that are based on PLC and the microcontroller. It found that PLCs are more reliable, have better modularity and are more secure in operation, suited therefore to high-demand, large scale industrial operations. Microcontroller systems, on the other hand, are not very durable and easy to troubleshoot and they are cost effective.

Further, a number of works consider smart parking systems that are powered by IoT where sensors report data to a cloud, and a mobile app can be used to find empty places. These systems, however, can be complicated to set up with networking and cybersecurity issues that are not practical in small or less interconnected systems[21].

2.3 Compare and Contrast

Based on the gathered literature, it can be ascertained that the automated car parking systems have acquired a number of options, hence the strand of car parking systems can vary based on control platforms, sensor integration, scalability, and user interface design.

The debate between PLCs and Microcontrollers:

The systems based on PLC are characterized by determining their serials as robust, compatible with the industry, and simplified programming with lad logic. They are friendly to service, and fit in situations that will need real-time control and lifetime of the systems. Microcontroller based systems on the other hand are quite economical and versatile, but usually have a limited input/output capability, need precarious maintenance often, and are a bit tricky when it comes to programming environments. PLC systems can therefore use them in large oriented or commercial applications.

HMI-based Monitoring compared to the IoT Cloud Platforms:

HMI software such as Delta HMI or WinCC enable local monitoring in real-time over the whole thing, and it does not need internet connectivity, thus, providing more control and being much more protected. Cloud based IoT systems, in turn, promise to provide remote access and real time data aggregation on an event-based level but also create problems regarding data privacy, low-connectivity performance and intricacy in design and maintenance[22].

Fire Detection:

Lack of application of integrated fire detection can be located within automation of parking. Such safety measure of the flame/ temperature and thermocouples supplementation according to real time alarming e.g. as in the FPGA based or the PLC based design is a necessity in terms of safety. The specification of this current project is that, it will be equipped with fire detection module that is a part of PLC logic and this is unique since this will automatically respond on an emergency situation[23].

Research: Ladder diagram simulators, as well as virtual lab, will compose a great system as a part of the thematic community, particularly when it comes to the explication of the principles of automation. The systems in use are never conducive of allowing them to be applicable in the actual world but are significant to the skills training and prototypes development.

Mechanical Efficiency as opposed to Digital Efficiency: Space efficiency, in the case of economy in space use, automatic parking robotic systems (e.g. rotary parking garage or robotic lift) are beneficial and can be used in high density urban living. However, they must be mechanically regulated in an advanced manner, and also require a regular maintenance. The simpler methods of digital control like the one of the offered projects are targeted to the most basic processes of automating the entry gates, signaling about the available slots, the presence of fire thus being a more comfortable and cheaper option[24].

2.4 Summary

The literature unveils a wide array of automated parking options, which include a basic IR-based solution, complex FPGA-powered rotary parking garages with safety system incorporation. However, few do both automation and safety, especially fire detection, within a single low cost, scalable framework, although most of such systems relate to maximizing parking space or bringing about user convenience using IoT and mobile interfaces.

The uniqueness of the proposed system in this thesis is its ability to deliver the PLC based automated car parking system at nominal costs and together with its built-in fire detections and also to have laptop-based HMI monitoring of the system. It combines the useful functionalities of the best existing designs, including the ladder logic control, real-time visualization and sensor connection, its simplicity and expandability. In addition, it tackles shortfalls present in microcontroller systems as well as does not involve expensive complexity and large-scale mechanical or IoT frameworks. The project is thus a practical, effective and a safe solution to urban parking on the ground problems.

CHAPTER 3

DESIGN PROCEDURE

3.1 Introduction

In this chapter, a detailed explanation of the materials, parts, tools, and techniques adopted in designing and the fabrication of the Automatic Car Parking and Fire Detection System Using PLC is going to be given. The goal of the project is to develop a safe and effective system, which is to automatically park vehicles and is also going to make the system safe, i.e., capable of detecting and warning against fire in real time. This objective was thus attainable by a keen attention in selecting the electronic and electromechanical parts, the inclusion of programmable logic control and creating a monitoring system based on Human Machine Interface (HMI) software.

The materials section describes all of the hardware used, which are sensors, relays, motors, indicators, alarms, power supplies, and the PLC itself. All of the components were chosen with regards to functionality, compatibility, and dependability. Moreover, the software to make real-time contacts and monitoring between PLC and the control-interface presented on a laptop were also used, including Delta HMI software.

The methods section outlines the design and building process that starts with the development of the schematic, wiring and connection between modules and the programming of the PLC logic. It also describes how different parts were set up and connected in order to operate as one system. The sensors were installed to sense the presence of vehicles and fire, relays to drive the output devices like gate motor and alarms, LED indicators were used to provide visual status of parking slots.

Moreover, the commutation system was set with an RS232 connection to have PLC communicate with a laptop that used the Delta HMI software. This allowed real time data representation and monitoring of the system such as number of available parking slots, gates, and fire alarms among others.

In short, the chapter acts as the basis of comprehending the technical and procedural side of the project and describes the entire workflow of the project starting with the choice of materials and ending with the implementation of it. Such systematic methodology guarantees operational safety and error-free performance of the system and automation as well as the main objective of surveillance and monitoring within a contemporary parking scenario.

3.2 System Design and Components

Table No. 3.1 Component List

SL No	Component	Quantity
01	PLC (Programmable Logic Controller)	1
02	HMI Monitoring from Laptop	1
03	SMPS (Power Supply)	3
04	IR Sensor	4
05	Flame Sensor	2
06	Buzzer Alarm	1
07	Indicator Lamp LED	3
08	Miniature Circuit Breaker	1
09	5V Relay Module	2
10	Electromagnetic Relay	2
11	Linear Actuator	1

3.2.1 Programmable Logic Controller (PLC)

A Programmable logic controller (PLC) is a small, robust computer used in control applications of electro-mechanical processes. It accepts input signals of sensors and devices, operates them according to a pre-designed logic algorithm, and, in turn, sends out commands to actuators or indicators. LCs work in real-time and are noted to be quite reliable, fast responding, and their programming is flexible usually written in ladder logic. The PLC will be the master unit that will execute detection of parking slots and fire safety responses in this project.

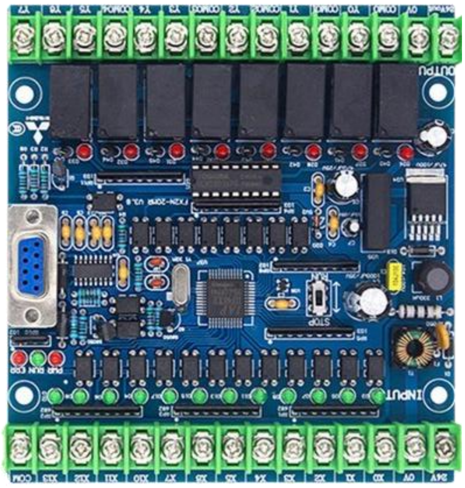

Fig. 3.2.1 Programmable Logic Controller.

3.2.2 Linear Actuator

A linear motor is an electromechanical type of actuator that changes rotary movement into straightforward movement. In the case of car parking system, it is used to automated the gate system so that the gate can open or close in accordance to the presence of a vehicle. The actuator makes vehicle entry and exit without human intervention possible and secure through controlling inputs of the PLC. This is particularly suitable for smart infrastructure systems because of its accuracy of motion within only a small range as well as its load-handling performance of high accuracy of position and velocity control and highest level of load capacity and yield limits in its class of load-handling supplementary motion devices under lifting conditions anywhere in the world.

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Fig. 3.2.2 Linear Actuator.

3.2.3 Delta HMI Software

To connect the operator and the PLCs system, a user-friendly graphical interface such as the Delta Human-Machine Interface (HMI) software is used. It enables real-time monitoring and manual control and the diagnostics of the systems on a touchscreen display or PC. Delta HMI software enables an operator to have a graphical representation of parking slots availability, keep track of fire detection, instant alert or log of system occurrences. It makes the operation of the system and trouble-shooting simple and thus better to use.

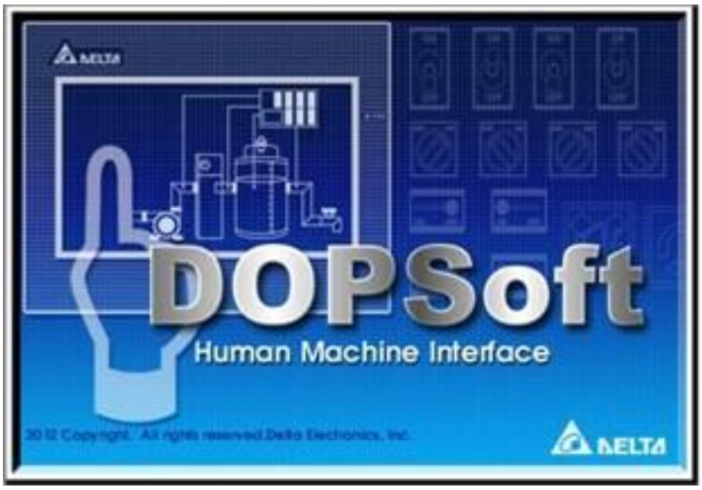

Fig. 3.2.3 Delta HMI Software.

3.2.4 Switched-Mode Power Supply (SMPS)

An SMPS takes the AC power that is mains power and converts it into a steady DC current needed by the PLCs, sensors, and other low-voltage devices. It is also energy efficient, light and small and arrives at regulated power with little energy loss. In this project the SMPS maintains a steady stable power supply of all the electronic parts of the entire system of control and monitoring.

Fig. 3.2.4 Switched-Mode Power Supply.

3.2.5 IR (Infrared) Sensor

An Infrared (IR) sensor is used to sense things and to measure distance through infrared. The IR sensors are applied in the car parking system to determine whether vehicles are at parking slots or not. These sensors transmit data in real time to the PLC, and the latter reports on the system condition to the HMI. IR sensors are affordable, quick to install, and efficient when to be used in automation tasks that may need close-range non-contact particularly in detection.

Fig. 3.2.5 IR Sensor.

3.2.6 Flame Sensor

A flame sensor is an instrument that is used to monitor if there is a flame or a fire in its sensing range. Its mechanism is based on detecting particular infrared light or ultraviolet light that is emitted by fire. The flame sensor in the fire deterrence system of the system always checks out statements of ignition. When a fire is detected through the smoke sensor, it instantaneously sends a message to the PLC into putting the alarm and safety measures into effect including alarms and unlocking the gates.

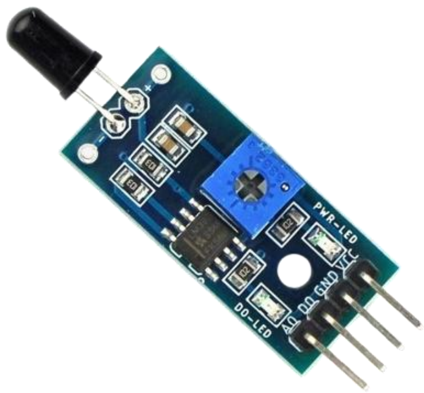

Fig. 3.2.6 Flame Sensor.

3.2.7 Electromagnetic Relay

Electromagnetic relay an electromagnetic relay is a switch that is actuated by an electromagnet. The magnetic field causes a contact to make or break an electrical connection when a current flows through its coil. They are also relays that are utilized to turn off high-current or high-voltage loads by using a low-power PLC signal. Electromagnetic relays are used in the car parking and fire detection system to operate some other device like a motor, siren, or gate mechanism when they are given some control logic by the PLC.

Fig. 3.2.7 Electromagnetic Relay.

3.2.8 Buzzer Alarm

Buzzer alarm is an audible alarming gadget that emits a high alarm when in use. It is applied to alert surrounding personnel in cases of emergency activities like fire detection or illegal parking. The PLC is in control of the buzzer, which provides awareness in case of emergency, to create fast action. The compact design of these systems and the unique sound enable them to be a necessary part of safety and notification systems.

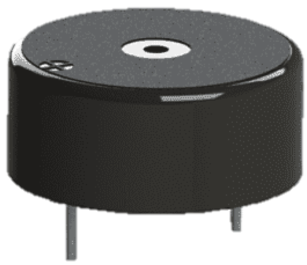

Fig. 3.2.8 Buzzer Alarm.

3.2.9 Relay Module (5V)

A 5V relay module is an electronic switch gadget, and it enables the PLC (operating at low voltage logic) to incorporate and control high voltage controls such as linear actuators or lights. One or more electromechanical relays and opto-isolators are usually used in the module, to switch the signals safely. The relay module is used in this system as a part of contact between the PLC and output high powered devices and allows the automation with the aspects of electrical isolation and safety.

Fig. 3.2.9 Relay Module (5V).

3.2.10 Circuit Breaker

A circuit breaker is a kind of protection gadget that is engineered to obligingly break an electrical current in instances of overloads or short-circuits. With the help of the automation system, it also protects sensitive devices such as the PLCs, sensors, and actuators against electrical damage. The breaker assists in avoiding fire and equipment malfunction by drying the supply of power in case of faults. It is a very essential element when it comes to electrical safety and reliability of the systems in place.

Fig. 3.2.10 Circuit Breaker.

3.2.11 LED Indicator

LED indicators denote the visual indicator that is used to signify the status of some operations within a system. As an example, the possible usage of different colors to denote available parking slots (green when vacant, red, when occupied) or states like standby/error/fire alert of the system. Feedback using LEDs is also fast, power saving and very visible. Coupled to the

PLC, they display real-time output triggered by logic decisions, which makes them conducive to monitoring the system intuitively.

Fig. 3.2.11 LED Indicator.

3.3 Design Specifications, Standards, and Constraints

The Automatic Car Parking and Fire Detection System are designed with special attention given to the technical performance, functional efficiency and safety regulations. A Programmable Logic Controller (PLC) is at the heart of all the logic operation, input signal processing and output control functions. The system is offered with RS232 serial communication using a laptop with Delta HMI to constantly supervise the system. It is fitted with different sets of sensors including infrared (IR) sensors to detect the presence of a vehicle on the entry gate and each parking lot, and the flame sensor to detect fire/smoke in the parking area. The entry gate will be automated by means of an electromagnetic-controlled linear actuator based on vehicle detection. Indicators that help to warn drivers about the availability of parking places are strategically positioned at the gate in the form of red, yellow, and green LEDs. It has a buzzer that gives voice output during emergency cases related to fire. The system is fed with 220V AC supply which is segmented into a controlled 12V DC and 5V DC using SMPS modules to power everything with low voltage. The design conforms to a number of international standards such as IEC 61131-3 of programming PLCs, IEC 60204-1 of the electrical safety of machinery, ISO 13849-1 of safety-related control systems and RS 232 standards of serial communication. Also, it adheres to the established color-coding rules on visual indicators to make it usable and more understood by drivers. In spite of its strong construction, the system has some limitations, namely, the IR and flame sensors produce limited range and sensitivity and can only work in small to medium-sized indoor settings. The scalability is limited by the low cost of the components used and could also adversely impact the long-term reliability. The speed of communication using RS232 is slower when compared to the contemporary protocols it may thus lead to small delays on real-time updates. Moreover, the prototype is constructed, having a limited amount of parking slots, and it is also impossible to implement it outside without any extra weather protection. There are also budget constraints that led to non-industrial parts used and therefore this makes this system to be suited in demonstration and controlled environments other than major commercial use of this system.

3.4 Design Analysis

The methodology of Automatic Car Parking and FIRE Detection System is intended to enable a miniature real-life environment in a practical controlled setting to test the project. This has three main subsystems namely the control unit, the sensing and actuation unit, and the monitoring interface. Every part is integrated into each other and mounted on hardware mounting board to facilitate testing, wiring and system visualization.

A Delta DVP series Programmable Logic Controller (PLC) that is programmed with WPLSoft is at the center of the system. Infrared (IR) sensors that are located at the entry point of the parking lot and on every single parking slot provide the input signal to the PLC. When these sensors identify a vehicle or not they provide a digital signal at the input terminals of the PLC. Flame detectors are suitably located in the prototype parking space to emulate fire sensing ability. When a fire breaks out, the flame sensor gives a high signal to PLC input and the controller switches on a buzzer alarm connected to one of the output relays.

A 12V dc linear actuator will be used in order to automate the gate mechanism. It is operated through a relay module that gets ON/OFF signals of the PLC on the basis of the state of the vehicle detection. The entry gate will open when one car drives up and closes after a delay time after letting the car who came, in. LEDs (red, yellow, green) installed near the gate of entry indicate the real situation about slot availability in different parking slots as detected by the IR sensors.

Entire hardware is energized through an SMPS (Switched Mode Power Supply) system that facilitates conversion of the main 220V AC into 12V and 5V DC to feed the sensors, relays, actuator, and indicator lights. A miniature circuit breaker (MCB) gets added that will ensure protection of the circuit in the event of overcurrent or short circuit.

To interact and monitor, a laptop PC with Delta HMI manifold is linked to the PLC using an RS232 serial connection cable. Via HMI interface, the current conditions of the parking slots (occupied or not) and the gate (open or close) and emergency conditions (fire alarm or normal) are presented. It is also possible to reset alarms or test the system on the interface provided to the operator.

This bodywork layout can allow the checking of various conditions presented like multicar entrance, complete car parking, simulation of fire and operation of the reset of the system. A variety of tests was proceeded in order to verify consistency, responsiveness, and the ability to detect faults in the setup so that one could feel confident in the results analysis and in the evaluation of performance in the following chapters.

3.4.1. Block Diagram

Block diagram of the Automatic Car Parking and Fire Detection System shows how there is interconnection of major hardware components which make the automation central structure. The figure indicates that the system has Programmable Logic Controller (PLC) and different input and output modules, sensors, actuators and power supply units, which will result in the full automation and safety monitoring.

The PLC is the brain of a system and as such, it receives the input signals provided by the obstacle (IR) sensors, the flame sensors, and runs the outputs. The sensors are all linked using 5V relay modules which serves as an intermediate switching gadget, thus the safe transmission of signals to the PLC. The obstacle sensors will sense the vehicles in the parking entry as well as inside a single parking slot, whereas the flame sensor will sense fire hazard in the parking continuously.

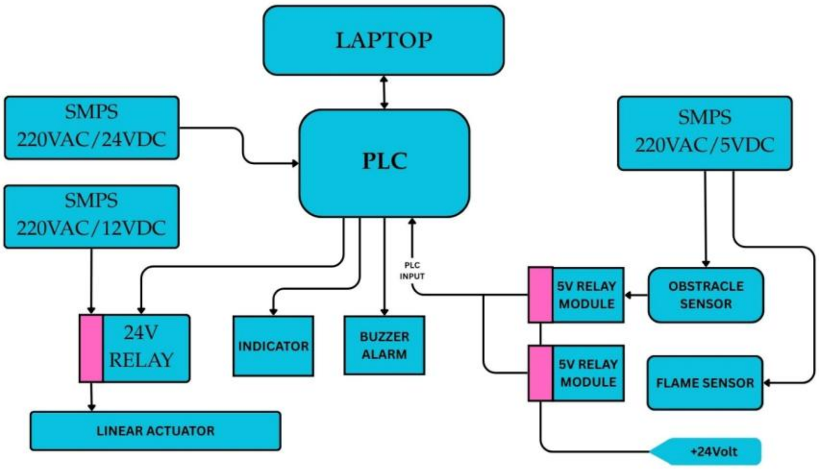

Fig. 3.4.1 Block diagram of the project.

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To recap it all, the block diagram illustrates how the system works logically and functionally, with the sensor detection leading to acts controlling and the user feedback. It is very good in the sense that it has managed to show how the different hardware components converge to give a smooth automated parking management and fire protection system which is orchestrated by the PLC.

3.4.2. Circuit Diagram

The circuit diagram of the Automatic Car Parking and Fire Detection System allows one to have a closer inspection of how each of the hardware components is electrically interconnected and interfaced with one another so as to be in a position to run as an automated control apparatus. Most of the primary devices involved in the circuit were the Programmable Logic Controller (PLC), IR sensors, flame sensors, relay modules, a line actuator, indicator LEDs, buzzer alarm, a PC with HMI software and a few SMPS power supplies.

The PLC is placed in the middle of the circuit and this is considered as the brain of the system. It accepts sensory information on six IR obstacle sensors, and one flame sensor. These sensors are followed by 5V relay modules in order to provide electrical isolation and secure switching. The IR sensors one is located at the entrance gate, and the rest are placed at the parking slots where the presence of a car is detected. The flame sensor is there to detect the occurrence of fire anywhere in the parking lot.

The outputs of the PLC are attached to a number of external devices: A linear actuator (controlled using two electromagnetic relays) is used to either open or close the parking gate automatically following detection of a vehicle. The gate has indicator LEDs- red, yellow and green positioned and it is wired to the PLC to indicate the status of parking to the driver. The

PLC also turns on the buzzer alarm, which will be used like an emergency alarm in case the fire sensor detects the flame as opposed to fire.

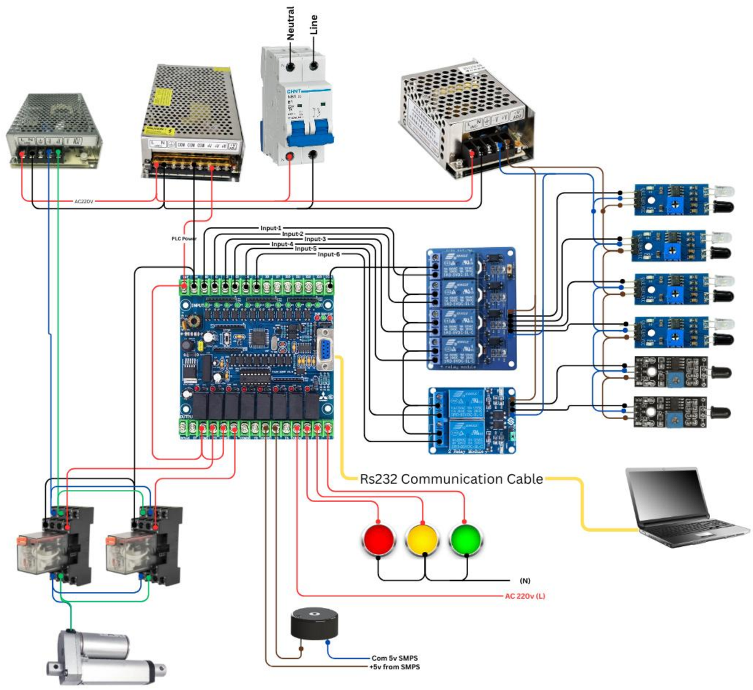

Fig. 3.4.2 Project Circuit Diagram.

Switched Mode Power Supplies (SMPS) is used to power to the circuit. It uses three individual SMPS units: The coils and actuators of the relays are energized utilizing a 220VAC to 12VDC SMPS. IR sensors and flame sensors modules are powered using an available SMPS of 220VAC to 5VDC.The PLC and higher voltage actuators can be driven by a 220VAC to 24VDC SMPS.

Its PLC programming is made via RS232 serial and connected to a laptop using the Delta HMI software to ensure that the system can be monitored in real time and status identified. The operators will be able to see the state of gate by position with the software, car slot occupancy with the software and fire alert giving them the ability to see through the control interface.

Protection of the circuit is done by the circuit breaker of miniature type (MCB) that is inserted between the SMPS inputs. All wiring is standard color-coded AC and DC lines, control and power lines and signal lines.

3.4.3 Electrical Wiring

Electrical wiring of the Automatic Car Parking and Fire Detection System is an essential component of the experiment design, which guarantees the stable connection of all the various components to provide smooth control, communications and powering capabilities. Numerous parts make the system and include SMPS units, a PLC, and sensors, relays, actuators, and protective devices, connected with the adherence to the established practices of wiring and with corresponding cautious attention to safety.

The hardware-based version has a 220V AC input at the core which is converted into outputs of controlled currents of 24V DC, 12V DC and 5V DC using three Switched Mode Power Supplies (SMPS). The power supplies are distinctly installed and their output connections connected to supply relevant voltage levels to various types of the system. The PLC and actuator circuit is powered by 24V DC; the relay coils and indicators use 12V DC; and the sensors and control signals have 5V DC available to them.

The main PLC unit uses an input and output connection. IR obstacle sensors and flame sensors are issued to the input terminals at strategic locations in order to sense the presence of cars and fire respectively. The connection of these sensors is done with yellow signal wires in order to distinguish clarity whereas they are interfaced via relay modules ensuring electrical isolation and signal amplification. Outputs of the PLC go to control signals such as 24V electromagnetic relay, indicator LEDs and a buzzer alarm. Such outputs perform gate control and emergency alerting, according to logic programmed on the PLC.

There are two electromagnetic relays used to operate the linear actuator that makes the gate work. Through the PLC output, the relays are energized to switch the higher voltage /current needed to move the actuator. The phases, neutral, and control signals that are bound by red, yellow, and black wires are mounted on these relays on the top-left of the panel.

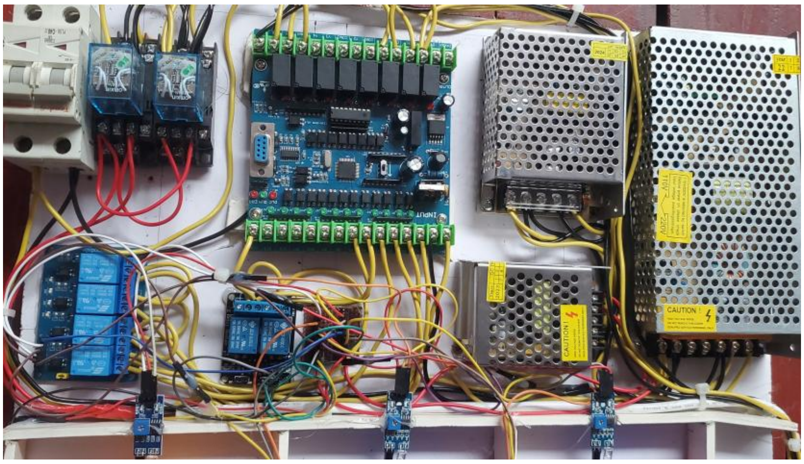

Fig. 3.4.3 Electrical Wiring.

All the wiring is well controlled with cable ties and color-coded conductors as well as organized routing on a white mounting board so that there is no interference of signal and it would be easy to maintain. There is also a short circuit protection fitting at the end in the form of the Miniature Circuit Breaker (MCB) to isolate the whole panel in the event of power fault.

Each sensor and component have been assigned a designated label and tied together using well defined terminals so as to bring about the modularity of and the ease of debugging. This is the physical side of it, that verifies this logical diagram and matches the circuit schematic previously shown. Layout is clean, proper insulation and grounding practices are followed and there is a minimal chance of loose and cross connecting.

Overall, the beginning of electrical wiring shows clearly how this was composed in a properly ordered manner and the system is safe, operational, and reliable to be used in demonstration purposes as well as in real time monitoring processes.

3.4.4. PLC Program (Ladder Diagram)

The Automatic Car Parking and Fire Detection System is implemented under the PLC program written according to the ladder logic that depicts the visualization of the control process. Sensors (X000,X005) detect vehicle presence and fire and will connect to output corresponding outputs (Y005-Y007 slot indication, Y003 fire alarm). Latching of the gate is done by a combination of logic memory bits (M0-M2, M10) and a timer (T0). Once detected in the entry (X004), the gate motor (Y000) opens a fixed time interval upon the assistance of timer T0 (K120). Front-facing LED indicators are used to notify drivers about the availability of slots and fire detection systems provide an alarm within an instance. The whole system is operated through PLC and the system is monitored on laptop in real-time on Delta HMI software.

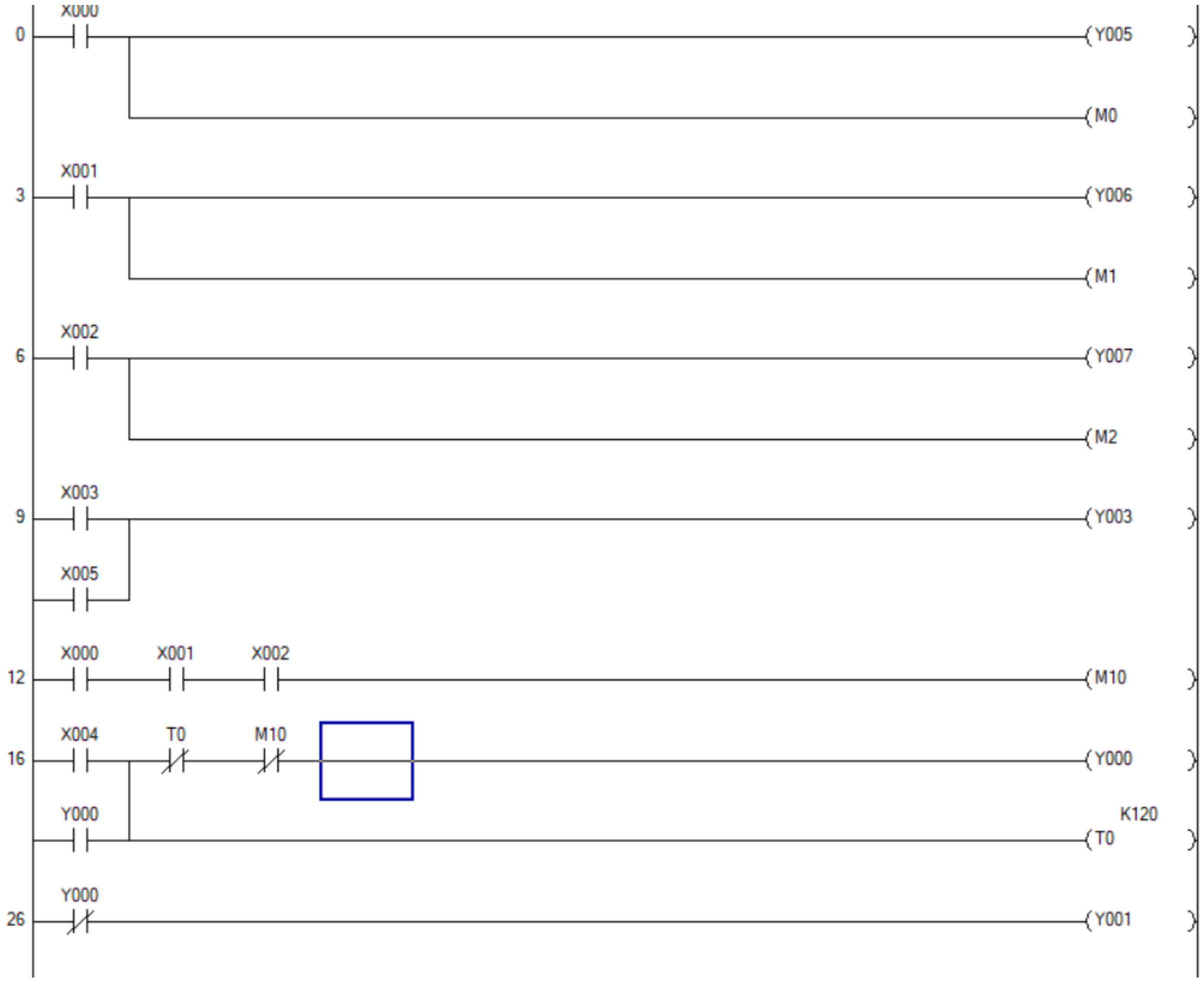

Fig. 3.4.4 PLC Ladder Diagram for the Complete Control Program.

3.4.5. HMI Design

The development of the Human-Machine Interface (HMI) with regard to the Automatic Car Parking and Fire Detection System is achieved with a Delta HMI software to offer real-time graphical monitoring interface. Graphically, the HMI screen shows layout of the parking area, which comprises three parking stations, an entry gate and an exit. Each parking station is labelled (Station-1, Station-2, Station-3) and the occupancy status is indicated as "No Car". The current absence of the parking slot is being presented through the red indicator lights that dynamically change upon the detection of a car by means of sensors. A gate entrance is also presented with an indicator with an open/close display. Moreover, usability navigation buttons including "Go to Home Screen" is also given to facilitate easy controls. Such a convenient interface enables the operator to observe the positions of vehicles, optimization of gate operations, and state of the system with the possibility of control in real-time using a laptop to improve operations and safety levels in general.

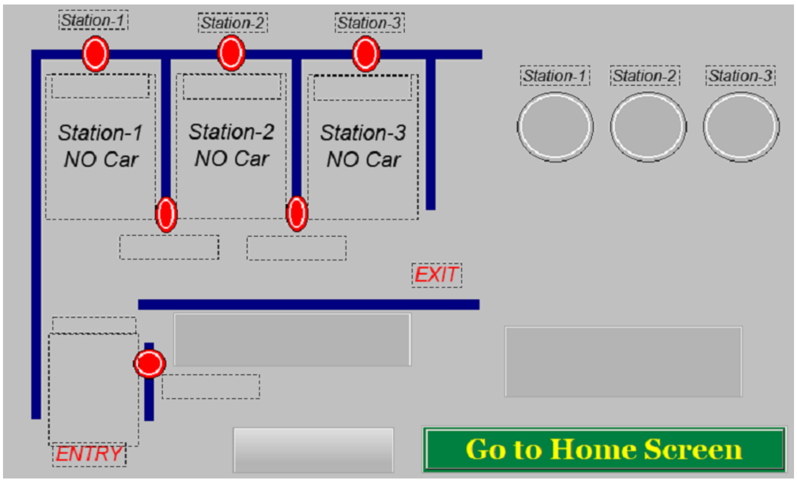

Fig. 3.4.5 HMI Design.

3.4.6. Full Hardware Overview

The figure below indicates the last hardware arrangement of Automatic Car Parking and Fire Detection System. The entire system has been built up on a demonstration board by combining all electrical, electronic and mechanical parts in a well-organized configuration. On the mounting top, the PLC controller is in the center with relay module, SMPS power and circuit breaker to avoid safety incident. Various relay boards are applied to connect low voltage control signals of the PLC to higher voltages appliances such as gate motors and indicators.

Under the control section, 3 IR sensors are fitted above each parking slot to determine when there is the presence of a vehicle. Model cars that crawl in each of the parking stations are used to represent real-time vehicle occupancy. There is another IR sensor as well near the entry so as to sense whether there is a vehicle at the entry point.

At the entry gate part, there is a linear actuator that is fitted to simulate the automatic gate. Sensor detection activates this actuator, while the actuator is adjusted with the help of the PLC. Immediately below and to right there is a control panel consisting of three push buttons (Red, Green and Yellow), which are used to override manually and carry out control actions on the system including start, stop, and reset.

All the arrangement is interlinked with some neat wiring of the input/output and power distribution. This functional system is a good showing of how an automated parking and fire alert system works in real time. It can be fully operated and be monitored using Delta HMI software through a laptop which gives real-time system updates, slot status and also fire alerts.

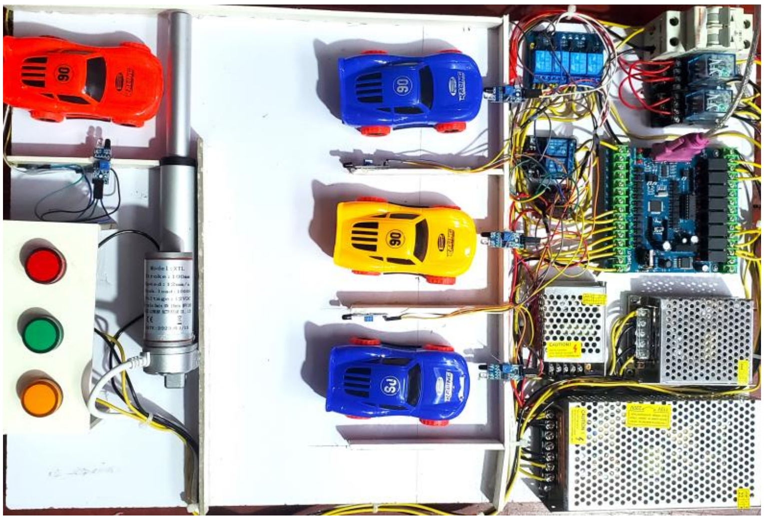

Fig. 3.4.6 Full Hardware Overview.

CHAPTER 4

RESULTS & DISCUSSIONS

4.1 Results

The results section shows the findings in tests done to determine the effectiveness of the Transformer coil winding machine and how effective it is in varied conditions. The experiments were aimed at reviewing the system efficiency, effects on batteries, and cooling.

4.2 Car Entry Hardware and Monitor

The car entry equipment and surveillance system, as the name indicates, is a fully automated machine that controls car entry and the parking slots to offer great efficiency and precision. The hardware part of the system also centers on a control unit, which consists of a microcontroller and serves as a hub device to all sensor feedbacks, actuator command and relay tasks. Various infrared (IR) proximity sensors are placed in a manner that captures whether there is any vehicle present at each parking station and entrance. Such sensors are installed to constantly detect the number of parking spaces available and convey real time information to the microcontroller. Upon the car coming in close vicinity of the entry gate, the entry sensor senses existence of the vehicle and triggers a signal on a linear actuator, which in turn opens the gate physically and allows the vehicle to gain access. After the car has moved the sensor, then the actuator will close the gate and only the members of the parking lot have a controlled access to the parking lot.

The system will consist of several relay modules that will be used as the switching devices in controlling different hardware systems such as the actuator, indicator LEDs and other auxiliary circuits. The supply units contain AC mains and convert them into relatively constant DC voltages (12V and 5V), giving constant power to the sensors, relays and control board. The indicator LEDs, which are provided at each parking station are utilized to visually show the status of the slot: the red LED indicates an empty parking slot and the green or yellow LEDs indicate occupied parking slot. This real-time visual feeding is one that assist drivers in free parking places where the search time is also less and traffic in the facility is also better. Also built into the system is a manual control panel that contains red, green and yellow push buttons to override automatic regime in case of maintenance, emergency or testing the system.

The observational feature of the system is realized in the form of special Human-Machine Interface (HMI) or Supervisory Control and Data Acquisition (SCADA) display. In this interface, there is a version show indicating the detailed graphical layout of the parking area with an individual station, entrance and exits as well as the status of the main entry gate. The HMI itself is a dynamic interface with each station changing depending on the status of the sensors and indicating occupancy status by color coding and "Car Detected" messages. The real time status of the gates, which could have been in the form of open or closed gates, is also indicated. The monitoring screen is kept updated with vehicles constantly entering and leaving the parking facility so that the operators can also receive correct and current information.
The combination of the hardware and the monitoring translates to smooth and effective parking management system. The automated process of detecting, and gate control lessens the factor of manual control, whereas the real-time monitoring interface enhances their decision-making and slots assigning. The system improves the overall safety as it is not possible to arbitrarily access the slot and prevent the conflicts with it. Moreover, it preconditions future scalability, which permits the inclusion of even more advanced technologies like the implementation of remote monitoring on an IoT basis, automatized ticketing and mobile applications support of smart parking systems.

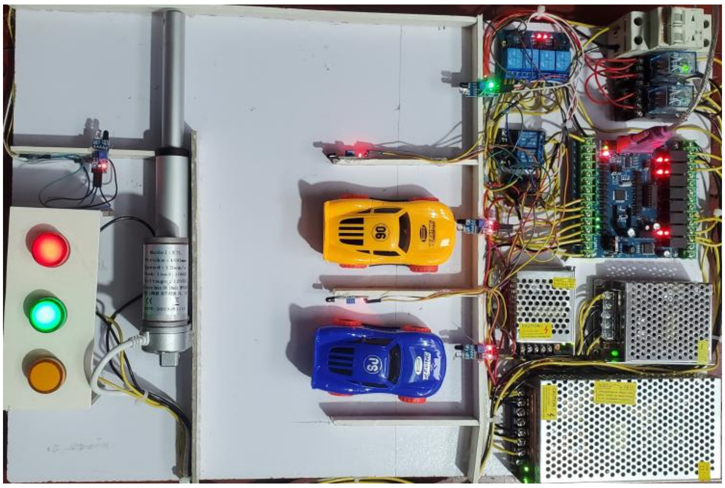

Fig. 4.2.1 Car Monitoring Part- I.

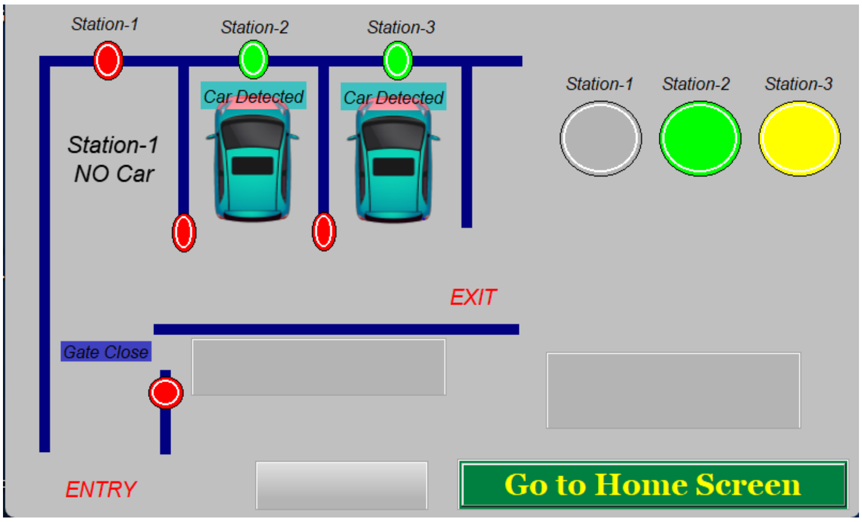

Fig. 4.2.2 Car Monitoring Part- II.

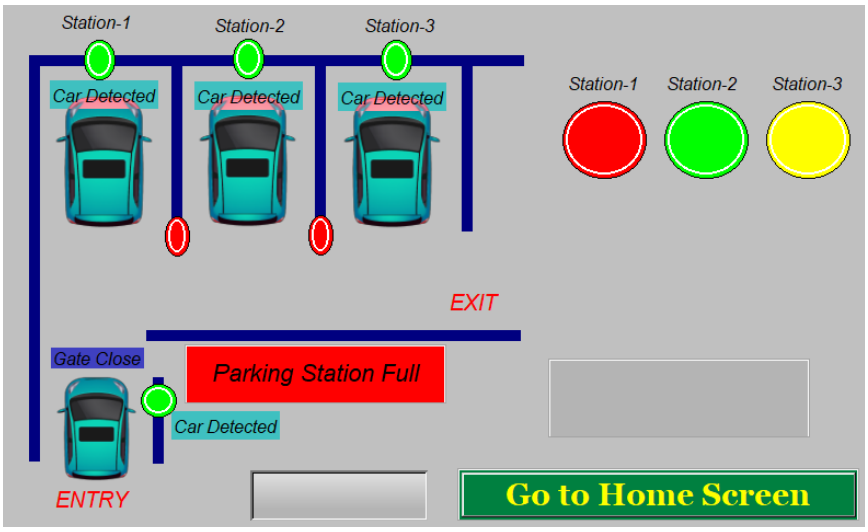

Fig. 4.2.3 Car Monitoring Part- III.

4.2.1 Fire Detection system

Another constituent of this parking facility is the fire detection system which is added to the automated car entry and monitoring system to provide protection of vehicles, property, and personnel which access the parking facility. This subsystem is made up of a number of fire detection sensors that are well placed in every parking station and entrance level. Such sensors can sense abnormal heating or presence of smoke and flames causing a direct intervention in the system. Upon sensing a fire, the sensor initiates a warning signal to the central microcontroller that consequently issues a set of alerts and control measures aimed at alleviating the possible dangers.

When a fire is detected, a warning message of fire detection can be automatically shown via the Human-Machine Interface (HMI) and station-specific indicators that appear on the screen indicate where exactly the fire is. Warning signals are flashing over each affected parking station and even more visual signals (e.g. flashing LEDs) are turned on to attract attention at once. The visualization in real-time assists the operators and emergency responders to rapidly detect and act towards the scenario. At the same time, the entry gate is manned to limit the number of new vehicles entering the facility thus ensuring safety and limiting the risk in case of an emergency.

Moreover, the system also can be programmed to interact with an outside fire suppression system (e.g. water sprinklers or alarm) via relay outputs. It can also decrease the need to use manual intervention and decrease the speed of response to fire related incidents. The fire detection system ensures safety of the operation and together with the parking management features it is fully integrated with early hazard detection and alerting facilities in one system with one user interface.

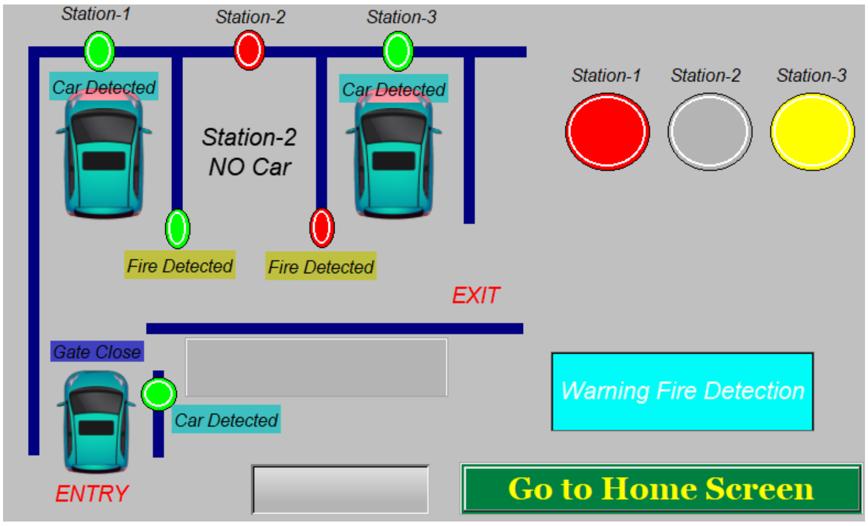

Fig. 4.2.4 Real time coil winding.

4.3 Overall System Performance

The performance of the overall system of the automated car entry, monitoring, and safety solution has been tested on the basis of functionality, responsiveness, accuracy, and reliability under differing operating conditions. The system incorporates a real-time monitoring interface and such hardware as sensors, relays, actuators, and power supplies to offer a user-friendly, efficient management system of the parking problem. During the testing phase, the system followed a pattern of working in terms of vehicle recognition, turnstile control, parking slots availabilities, as well as issues that prompt safety warnings in case of fire risks or in case of an emergency.

Infrared sensors provided the car detection mechanism which was very accurate in determining the presence of vehicles at each of the parking stations. The system was capable of updating the Human-Machine Interface (HMI) in real time reflecting the actual occupancy status with both visual cues and textual alerts. The gate entry control which used a linear actuator and a switching mechanism with relays was reliable with very little latency and entry and exit of vehicles were made without any delay and also remained safe as no one can enter without any permission. During maintenance and emergency situations, manual override buttons gave some extra controls and could maintain continuity of the system even in partial system failure cases. A major safety layer was provided to the whole complex by the use of the fire detection subsystem. In simulated fire scenarios, the sensors properly identified the risks and issued real-time alerts on the surveillance graphical user interface. As a reaction the system showed station-specific fire alerts, prevented further access of vehicles and prepared the installation to the possible use of external fire suppression systems. This preventive safety measure has a considerable effect on strength of the parking.

Based on performance, the combination of the hard and soft computer hardware led to stability and a sound system that could effectively deal with real-time operations with dissimilar levels of reliability. Fire detection is used to keep business efficient and secure, as well as the continuous tracking of gate status and parking slot availability. The system proved to have scalability capabilities and in future expansion may achieve more parking stations, ability to be integrated with internet of things (IoT) platform to enable monitoring remotely and automated payment or ticketing system. On the whole, the system achieves its design aims by offering a full-automated, safe and intelligent parking management system that maximizes the space utilization, decreases manned intervention in the facility and makes it safer.

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CHAPTER 5

PROJECT MANAGEMENT AND FINANCE

Project management is a central part in execution and delivery of every engineering project and the most important aspect of a multidisciplinary task such as hardware integration, software development, system testing as well as documentation. Planning, coordination, and time management were key factors in development of the Automatic Car Parking and Fire Detection System Using PLC and HMI so as to ensure completion of the system within the academic time without compromising on the technical effort.

In this chapter, activities of the project will be set out, i.e. task allocations, schedules and main milestones. It talks as well, of the practicable and managerial lessons that the project taught as part of the project, and of how planning and implementation tactics played a part in overcoming the hurdles and meeting the intended results. The lessons learned during this process can be used in the context of ongoing enhancement on any upcoming automation and control system project.

5.1 Task, Schedule and Milestones

Time and resource management remain vital ingredients in the successful implementation of any given technical project. In the Automatic Car Parking and Fire Detection System Using PLC and HMI, the whole process was subdivided into small and manageable activities that had clear objectives and timelines to be achieved by deadlines. WBS also helped align the tasks of the overall project even though some of the hardware and software work could run in parallel despite the fact that they could be done later without affecting the overall project objectives:

Table No. 5.1 Milestone Completion Table.

Activity	Start Date	End Date	Duration (in Days)	% Complete
Topic selection and initial project planning	11-Jan	18-Jan	7	100
Literature review and problem identification	18-Jan	07-Feb	14	100
Component selection and system design	07-Feb	18-Feb	11	100

PLC programming using ladder logic	18-Feb	06-Mar	18	100
HMI design and laptop interface setup	07-Mar	17-Mar	26	100
Mechanical and electrical integration	17-Apr	20-Apr	32	100
Panel wiring and safety setup	20-Apr	1-May	11	100
Final implementation and functionality check	1-May	15-May	14	100
Documentation and thesis writing	15-May	16-Jun	32	100
Final review and presentation preparation	16-Jun	29-Jun	5	100

We established a milestone before we began the project, and after it was over, we noticed a slight difference. However, the project was finished later than we had anticipated. The Gantt chart with milestones is attached below.

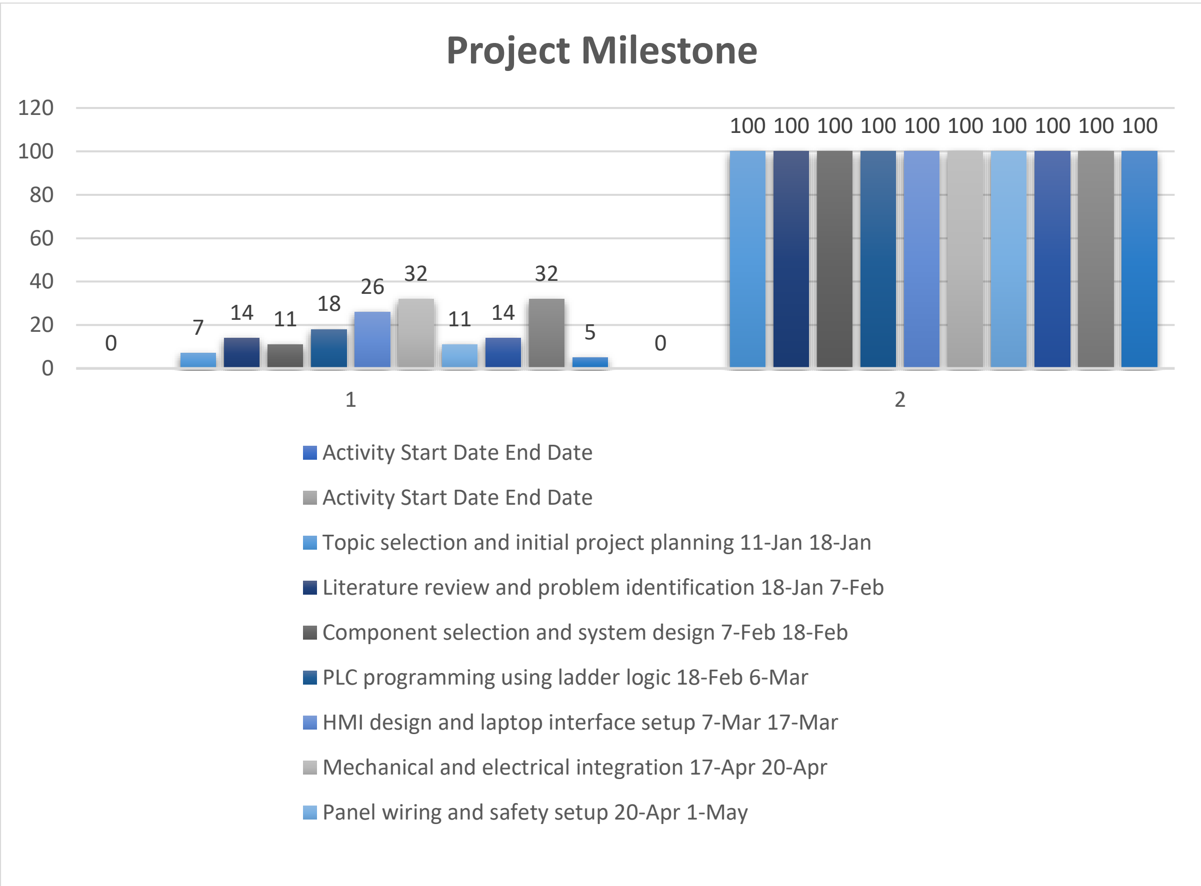

Fig. 5.1 Project Milestone Gantt chart.

5.1.1 Primary Task Completion

Human Resources

- Project Team: Consisted of 3 core members – responsible for programming, electrical setup, and mechanical integration.

Material Resources

- PLC (with Modbus), HMI, Sensors, Relay Module, Actuators, Sun board, PVC Board, wires, and insulation material.

Budget Management

An initial budget of 15,000 BDT was allocated. The project was completed within approximately 13,000 BDT, staying under budget due to:

- Strategic local sourcing of electrical components.
- Use of in-house tools and testing instruments.
- Avoidance of over-engineering in the initial prototype phase.

Table No. 5.2 Budget Management

Category	Estimated Cost (BDT)	Actual Cost (BDT)
Components	9,000	9,000
Hardware Setup	3,000	3,000
Programming tools	500	500
Miscellaneous	500	500
Total	13,000	13,000

5.2 Resource and Cost Management

The management of resources and costs was very essential to the successful implementation of Automatic Car Parking and Fire Detection System. It had to do with the proper planning of the materials, manpower, equipment and finances throughout the lifecycle of the project. The resources were divided by categories, including, the hardware components, and the software tools: and, the labor requirements. Some of the hardware involved programmable logic controllers (PLCs), relay, power supply, sensor, wiring, communication cables and structural material to assemble the system. Programming platform, simulation and interface development related software resources were included which were necessary in configuring and testing the system. Labor resources included the following skilled resources: circuit designers, wires, programmers and mechanical integrators. To ensure that the project is being implemented within the budget, a careful budgeting plan was compiled at the first stage of the project indicating expenditures that will be used in purchase, fabrication, and fixing of the project. It obtained components that were of quality, competitive prices, and were obtained off suppliers who are identified as reliable. Spending was well accounted and followed to ensure that it is within the budget by freezing certain costs when there was a need to do so to meet the unexpected demands. Ways such as reducing wastage, using what was at hand to give it another use and using alternatives that had been put in place in order to avoid certain costs were some of the financial management steps put in place. The application of systematic resource planning and wise financial management in this project makes it clear that disciplined financial control is crucial in the execution of engineering projects since it enabled the project to be accomplished within the project budget and still attain the desired level of performance.

5.3 Lesson Learned

Throughout the course of this project, a wide range of valuable lessons were learned that contributed not only to the successful completion of the Automatic Car Parking and Fire Detection System Using PLC and HMI, but also to the personal and professional growth of the project members. These insights were gained through practical challenges, collaborative work, and iterative development, and are categorized below:

1. **System Integration is Complex**
   Successfully combining multiple components PLC, sensors, actuators, and HMI requires careful coordination and in-depth understanding of both hardware and software compatibility.
2. **PLC Programming Requires Precision**
   Writing ladder logic demands clear logic structuring, accurate sequencing, and thorough testing. Even small mistakes can lead to system failure or unsafe operations.
3. **Importance of Sensor Calibration**
   Sensors, such as proximity and fire detectors, require proper positioning and calibration for accurate results. Inaccuracies can trigger false alarms or system misbehavior.
4. **Planning and Scheduling Save Time**
   Having a structured timeline with task distribution helped keep the team focused and minimized delays.
5. **Improved Problem-Solving Skills**

Facing unexpected technical problems helped build resilience and taught creative thinking in real-world scenarios.

6. **Hands-On Experience with Industry Tools**

   Working with PLCs, sensors, and HMI software provided practical exposure that complements academic learnin.

CHAPTER 6

IMPACT ASSESSMENT OF THE PROJECT

6.1 Introduction

The development in technology has led to a change in the design, operation, and maintenance of infrastructure in terms of how it is done. One of the most significant places, where automation, especially smart infrastructure systems, can be used, is to increase the level of human safety, to decrease the consequences of the human factor, to improve the resource consumption level and to decrease the impact on the environment. An example of such application is the incorporation of automation in the parking and fire safety management of a vehicle by use of Programmable Logic Controllers (PLCs) and human machine interface (HMI) software.

The proposed project Auto-Car Parking and Fire Detection System, based on PLC and Laptop based HMI monitoring aims not just to make parking more convenient in the urban city, this is because safety of the people is also given importance by detecting any possible fire(s) in real-time. Such a system affordability goes beyond its utility in terms of efficiency in operations. It pertains to crucial subjects in economic growth, health and security of the citizens, environmental conservation, societal actions and the amalgamation of technology in the entire world.

The system eradicates human error and labor as well as decreases the cost of labor, improves accuracy, speed, and reliability by eliminating the need to manually manage the parking situation and monitor fire procedures. In addition, the system allows to make centralized and data-based decisions using HMI software that provides real-time updates and alerts about the status.

The present chapter assesses the multidimensional output of the project. It evaluates the impact of the system on the economy, society, the trends in the global technologies, and the natural environment. It also discusses ethical concerns, adoption of relevant codes and standards and other challenges or dangers that lie in the implementation and the long-term utilization of this technology. This type of an assessment is critical not only to know the viability and usefulness of the system but to be sure that the implementation of the system is done under sustainability vision and objectives as well as in a manner of ethical engineering.

By so doing, the relevance and mandate of ensuring greater consideration of the implications of automation when used on real-life systems particularly those that directly relate to human security, open human space and ecological stability are outlined in this impact assessment.

6.2 Economic Impact

Theoretical yields of the development and subsequent carrying out of an automated car parking and fire detection system based on PLC and the use of an HMI system, have significant economic perspectives, both in the short term, and in the long-term. The system does not only focus on enhancing safety and efficiency of the operations but it is an added bonus to the financial saving and economic sustainability in a number of ways.

- Operational Costs Reduction: This advantage is one of the closest economic rewards that will be realized in the form of a reduced cost of manpower. The conventional parking lots usually necessitate employees in: Observing and controlling the vehicles, operation of gates, Responding to emergency calls like fire mishaps.
- Time and Resource Economy: The system reduces the idle time of vehicles by visually highlighting the parking spots available to the users through an LED Panel as well as through the HMI Display. This saves the drivers the time they take when searching to park, which consequently: Enhances fuel consumption, reduces emissions, Enhances customer turnover along commercial parking areas.
- Damage and Loss Prevention: The integrated fire detection system will be a precautionary element against loss of property. Damages to infrastructure or cars in parking garages may result in cars and other objects due to fires which can result in: Expensive repairs, Insurance claims, and Business interruption.
- Future Cost Optimization, Scalability: The nature of having the core system (PLC, sensors, relays, and HMI software) set up is that it can be easily scaled up to larger parking premises without having to undergo any major structural changes. Integration of new sensors or slots does not require great increment of investment. In addition, PLCs and HMIs have a long life and minimal maintenance thus maintenance and replacement work out cheaper over a long period of time.

6.3 Societal Impact

The equating of automation into the public infrastructure and particularly when dealing with critical functions like parking and fire safety introduces drastic changes in societal behaviour, safety, convenience, and the general upheaval on the society on whether to trust or not in technology. Its societal positives and implications on Automatic Car Parking and Fire Detection System Using PLC and HMI Monitoring is discussed in this section:

- Enhanced Public Safety: The system has also increased its standards of safety because an automatized fire detection and heating alarm system will be put in place. With prompt alerts on buzzers and HMI messages, evacuation of people can be done: Quickly during emergencies, Early action by security or fire teams, Lesser possibility of injuries or deaths in parking places.
- Better Convenience and Less Stress: Finding a parking space and the frustrations that are associated with it are common in most cities. This is a direct solution to that problem because: it has a clear indication of available parking spaces, directs the drivers to available parking spaces by LED display in real time, it saves time and confusion by drivers at entry gates.
- Behavioural Change and Technology Acceptance: When enjoying the use of such a system, users will get an exposure to the new generation of technology, and this will be in an accommodating manner. In the long-run, it promotes: more acceptance of automation and intelligent systems, beneficial changes in behaviour to accept machine-assisted services, better understanding of safety protocols and preparedness against emergency situations.
- Improved Community Infrastructure: When this system is installed in communal or residential parking lots, it can: Enhance community security, Increase the worth of property, energize communal safety programs.

6.4 Global Impact

The developed technologies of automation of called the Automatic Car Parking and Fire Detection System with the help of PLC and HMI Monitoring help to make global development of smart infrastructure, urban safety, and sustainable living. In spite of being targeted locally, the application of this system goes far past the borders and corresponds with global ambitions in technology, safety, and environmental responsibility.

- Support to Smart City Projects: Urban centers all over the world are becoming smart cities as they adopt and incorporate digital technologies in the development of urban centers. This project is suitable under this framework because: It will automate the parking process, incorporating the system with peripheral facility (safety system, e.g. fire detection), It will facilitate control with real time monitoring through HMI software.
- Promoting Technological Globalization: Technologies which integrate industrial automation with services which focus on the user fill in the gap of digital divide. This project: Facilitates usage of programmable control systems outside industrial applications, furthering technical learning and on the job experience working with real world systems, adds to the world body of engineering knowledge in real world solutions to automation.
- Potential of Emergency Response Integration: At a larger scale, the sense of fire in this system can be combined with municipal emergency response or building network intelligence in any part of the world. Doing so, the response time can be reduced to the minimum and the loss of property can be avoided in any case, especially in high-population mega-cities around the globe where fire hazard can be critical.

6.5 Environmental Impact

Along with enhancing safety and efficiency, the Automatic Car Parking and Fire Detection System Using PLC and Laptop-Based HMI Monitoring proposed also has a number of beneficial effects on the environment. With the increasing concerns across the world on pollution, energy-intensive activities, and climate change, we need to assess the role played by emerging technologies either to add on the problems or reduce the effects to the environment. In this part, the impact of the system on environmental sustainability (related to energy consumption, emission, materials consumption, and the attention to the long-term ecology concerns) will be examined:

- Decrease in Vehicle Emission: This is one of the most significant advantages of the system as it optimizes the management process by providing the drivers with efficient navigation to availed parking lots using LED displays and real time tracking. This helps reduce unnecessary idle times of the vehicles, extra driving inside the parking facilities and an unjustified use of fuel. Thereby this helps to cut back on green house gas emission which helps in containing the air pollution problem that is most significant in the urban setting, where parking space and traffic jams are major issues.

- Energy-Efficient System Design: The system uses low-power parts of the system such as sensors, relays, LED, and PLC. Use of energy-efficient SMPS units to bring controlled electricity delivery, solid-state relays and sensors, which generate little heat, means that optimum use of power is there. The ladder logic programming is also optimized to reduce any cases of excessive switching or actuation of the loads, hence using relatively low energy compared to manually operated traditional systems.
- Ethical Materials Usage and Modular Build: The solution is built with long life, recyclable, and modular electronic parts. This kind of design will limit the need to replace the product fully and will limit e-waste. Any one part can be repaired easily and thereby leading to wastage of the system and the prospects of product sustainability can also be ensured.
- Sustainable Maintenance Practices: Since it takes minimal work on an actual human level, the system only will need occasional cleaning of the sensors, wiring inspection, and Electrical Verification. This limited maintenance minimizes the requirement of unnecessary spare parts, minimizes the energy loss when there is a downtime and it does not use chemicals or single use tools. Its practices uphold a maintenance model that augers well to both aware and sustainable operations that are environmentally responsible.

6.6 Ethical Issues

The systematic and problem-based approach of the presented Automatic Car Parking and Fire Detection System to addressing privacy, safety, fairness, accountability, environmental sustainability and responsible use focuses on ethical engineering:

- Privacy and data security in use: the system does not utilize personal data and executes with real-time sensor inputs. It has no external communication or cameras, so it maintains the privacy of users and keeps the risks of data breaches minimal.
- Safety and Reliability: Based on ethical aspects that ensure the safety of its users, the system has integrated the quick-fire report properties, reliability in terms of working, and includes design features that ensure that there is fail-safe character such as alarm systems and emergency overriders to ensure that it is safe.
- Fair Accessibility and Usability: The system is non-technical and easy to comprehend, and understand by users, regardless of various parameters, including age and ability. It

promotes the accessibility of parking in a fair manner and eliminates the discrimination risks with an easy-to-use interface.

6.7 Utilization of Existing Standards or Codes

The Automatic Car Parking and Fire Detection System has been designed and implemented as per the standards of a country and an international one to achieve the safety, reliability and compliance:

- Electrical Safety Standards: The system is compliant with the IEC 61131-2, IEC 60204-1, and ISO 12100 standards to maintain the elective safety of the low voltage system, construction wiring, grounding, and mitigating risks during use and maintenance.
- Fire Detection and Alarm: The fire sensing related fire detection aspects complies with NFPA 72, ISO 7240, and the Bangladesh National Building Code (BNBC) to provide a dependable means of sensing and signaling the alarm against local safety.
- Automation instruction set and standardization: The use of IEC 61131-3 allows modular PLC programming, providing more clarity and consistency in the system, IEC 61511 or ISA-5.1 has also been used to standardize symbols used in the instrumentation.
- Environmental and Energy Efficiency Standards: The system adheres to environmental standards of IEC 60034, ISO 50001 and RoHS and has environmentally friendly and energy saving components deployed throughout the system and has minimal e-Waste.
- HMI Standards: The HMI is designed based on the ISO 9241 ergonomic standards and industry-best practices to be intuitive, have clear graphics, and alarms with effective notifications to be operated safely.

6.8 Other Concerns and Considerations

You can use the system effectively in small to medium installations but it has potential limitations in larger plants in that the small number of PLC I/O channels can be insufficient, the network requirements can be an issue and that too many sensors or too many displays can be problematic. More sophisticated algorithms in PLCs or even IoT may be required in the future.

- Reliability and Maintenance of the System: It will be vital that sensors are maintained and kept clean, that there is regular updating of software and that there is protection against power failures (e.g. UPS support). The trained personnel and well-developed maintenance plan ensure the long-term reliability.

- Technical Limits and Scalability: The solution depending on the size of installation may work well with small and medium sized installations, but on a large-scale facility may be limited in PLC I/O, network load and the configurability of sensor or display redundancy. The additional improvements may need the IoT support or complex PLCs.
- Cybersecurity: The outage of alarms or tampering of data would be a possibility since they use Laptops as HMIs. Password access, firewall, and secured PLC and HMI communication are some of the protection measures that will have to be set up.

CHAPTER 7

CONCLUSIONS & RECOMMENDATIONS

7.1 Conclusions

The good design and installation of the Automatic Car Parking and Fire Detection System Using PLC and HMI Monitoring serve as a good example of how industrial automation can be used to mitigate some of the major urban infrastructure concerns, namely, the parking management and fire safety concerns. The system provides a viable, interactive and scalable solution via the involvement of programmable logic controllers (PLC), Delta HMI software, among others, and various sensors.

This type of system works to identify the cars by their proximity sensors, opening the gates automatically and changing the parking slot status with the help of LED indicators. At the same time, there are flame sensors with real-time fire detection. In case of detecting hazard the system instantly switches on audio-visual alarms. The whole operation is visualized and monitored through a laptop-based HMI interface, that serves as an intuitive ground to its users and operators.

The intrinsic success of this project will be mitigation of human control, increase in emergency responsivity, greater safety of operations and a time-saving driving experience. Moreover, the system can also help achieve other objectives, the sustainable design, energy efficiency and creation of intelligent urban technologies.

The efficiency of using software in tandem with hardware in order to come up with functional and smart solutions has also been an item identified by this project. One of the features of this system is the modular architecture permitting it to help formulate and create future specs of larger parking structures, IoT integration, or cloud-based monitoring. Experience acquired by this project forms the firm ground of further research and development in automation, control system, and smart infrastructure.

7.2 New Skills and Experiences Learned

The project helped to gain a thorough learning experience in various spheres of engineering and technology. Both professional and technical expertise has been cultivated during research, design, implementation and testing:

Technical Skills

- PLC Programming (Ladder Logic): Practical experience in the field of ladder logic programming provided with the usage of industrial grade PLCs has helped in the successful development of reliable control programs in the hardware appliances.
- HMI Development: I learned to design real time graphical interface using Delta HMI software in a way such that a control is easy to operate and the system can be visualized easily.
- Sensor Integration: This experience would provide practical knowledge in interface and programming of the proximity and flame sensors to give precise detection of the vehicle and fire.
- Hardware Prototyping Built a working model the relays, power circuits, wiring and LEDs of. Established right layout and grounding of safety.

Practical Engineering Skills

- Technical Documentation: The improved which was the technical documentation capability to produce and organize research results, system architecture, diagrams, and design processes in a thesis format.
- Communication Skills: Enhanced ability to simplify a difficult system both with figures and words using flow chats, wiring diagrams, and other descriptions.

7.3 Future Recommendations

As treated in this research study, the Automatic Car Parking and Fire Detection System developed has proved therein that it can be a cost efficient and reliable means of accommodating integrated parking and monitoring of the safety of a car park facility, provided the system is properly maintained. Nevertheless, it has a number of flaws which can be addressed to make it better, more scalable, and adaptable in practical sense. The next possible development is the upgrade of the RS232 communication interface with faster and more reliable examples, like RS485, Ethernet, or wireless, like Wi-Fi, Zigbee, or LoRa so that the broader range and more data transmission can be achieved. To make it suitable to endure harsh environments, the system can be augmented with enclosures complying to weather and UV resistance and sealed connectors to be used in an outdoor environment. It can also be improved with using ultrasonic or LiDAR modules to better detect vehicles and advanced flame and smoke sensors that triggers fewer false alarms, Solar power and battery backup can enhance efficiency on energy consumed and the reliability of energy when there is power failure. Also, modular expansion may be added to extend the size of the system to accommodate more parking facilities, multiple gates, and more slots. A cloud-based platform, mobile app or web dashboard would provide IoT connectivity to enable remote monitoring and control, and a more advanced Human-Machine Interface (HMI) with touchscreens and multilingual would help improve the user experience. Finally, automatically integrating payment and online reservation system would result in creating a solution that could better suit release into a wider variety of commercial uses and further distinguish the solution as a product rather than a prototype, creating the intelligent parking and safety management system in its entirety.

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APPENDIX B

COMPLEX ENGINEERING PROBLEM SOLVING AND ENGINEERING ACTIVITIES

Provide your statement on which and how the complex engineering problems are being solved in the designed project. P1 is mandatory and some or all from P2 to P7.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
P1	Range of resources	The project integrates multiple resources: PLC, IR & Flame sensors, Linear actuator, Relays, LEDs, Buzzer, SMPS, HMI software, and RS-232 communication.
P2	Level of interaction	Real-time interaction occurs between PLC, sensors, actuators, and HMI; operators communicate with the system through the HMI interface.
P3	Innovation	The innovation lies in integrating both Parking Automation and Fire Detection into a single PLC-based platform, providing a cost-effective and reliable solution.
P4	Consequences of society and environment	The project addresses urban parking challenges, reduces time and fuel consumption, enhances fire safety, and thus contributes to a safer and more sustainable environment.
P5	Familiarity	Parking automation is familiar, but combining Parking and Fire Detection using PLC adds complexity and novelty for students.
P6	Extent of stakeholder involvement and conflicting requirements	Stakeholders include drivers, building managers, and fire safety authorities. Conflicting requirements involve balancing parking efficiency with fire safety compliance.
P7	Interdependence	The fire detection system is interdependent with the parking automation system—when fire is detected, parking control is overridden, and emergency alarms are activated.

Provide your statement on which of the complex engineering activities are being solved in the designed project. Mention some or all of the following characteristics.

Complex Engineering Problems (P) Solving		
	Attributes	Statement from students
A1	Depth of knowledge required	Requires knowledge of PLC ladder logic, sensor interfacing, relay actuation, HMI design, and fire detection circuitry.

A2	Range of conflicting requirements	Trade-offs include cost vs. reliability, fast system response vs. accuracy, and parking efficiency vs. safety priority.
A3	Depth of analysis required	Involves detailed analysis of vehicle detection accuracy, ladder logic debugging, fire alarm response, and real-time troubleshooting.
A4	Familiarity of issues	Issues such as sensor calibration, PLC programming, and actuator delays are known, but integrating them into one system makes the project more complex.
A5	Extent of applicable codes	The project aligns with IEC 61131-3 (PLC programming), IEC 60204-1 (Machine Safety), ISO 13849 (Safety control), NFPA 72 (Fire alarm standards), and BNBC (local building code).

APPENDIX A

TURNITIN REPORT

ORIGINALITY REPORT

12%	11%	6%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	dspace.daffodilvarsity.edu.bd:8080 Internet Source	5%
2	Submitted to Daffodil International University Student Paper	1%
3	avesis.gazi.edu.tr Internet Source	1%
4	journals.zu.edu.ly Internet Source	<1%
5	Lingxiang Wei, Mingming Liu, Nikolai Bobylev, Junyuan Ji, Yanhui Li, Tian Li, Lei Yu. "Design and development of tunnel logistic-type underground car parking system", Computers & Industrial Engineering, 2025 Publication	<1%
6	ijsret.com Internet Source	<1%
7	Weiwei Zhang. "Chapter 7 Architecture Design of Employment Education Network Platform Based on Blockchain Technology", Springer Science and Business Media LLC, 2024 Publication	<1%
8	Xun-You Ni, Daniel Jian Sun, Qing-Chang Lu, Qian Chen. "A Proportional Allocation Model for Parking Reservation Systems Considering Entrance Capacity Constraints", IEEE Intelligent Transportation Systems Magazine, 2023	<1%