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Smart Pay and Park System

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Abstract **- The Smart Pay and Park System using a Programmable Logic Controller (PLC) is developed to automate and optimize parking management. It controls vehicle entry, slot detection, duration-based billing, and exit operations to ensure efficient use of parking space, minimize human intervention, and reduce over traffic.**

The system uses an IR sensor at the entry gate to detect the presence of a vehicle. If a parking slot is available, the entry gate opens automatically, when vehicle is parked at slot timer starts to calculate the parking duration. When the vehicle exits, another IR sensor detects its presence, and the PLC stops the timer. The total parking Charge will be calculated based on predefined billing rates and parking duration. This charge is displayed on an HMI display, and after successful payment, the exit gate opens to allow the vehicle to leave.

The PLC is programmed using ladder logic. The system can be further enhanced with IoT integration for remote monitoring, and automated payment systems. This project showcases a cost effective, scalable, and smart parking management solution for urban areas, malls, hospitals, airports, and commercial complexes.

Keywords - Smart Parking System, Programmable Logic Controller (PLC), IR Sensors, Automated Gate Control, Parking Management, HMI (Human Machine Interface), Ladder Logic, Time-Based Billing, Industrial Automation, Smart City.

I. INTRODUCTION

In today's rapidly growing urban environments, the number of vehicles on the road is increasing at an exponential rate. This growth has created significant challenges in managing parking spaces efficiently. Finding a suitable parking spot in crowded areas such as malls, airports, and commercial complexes has become time-consuming and frustrating for peoples. Traditional parking systems, which rely mainly on manual supervision, are often inefficient and prone to errors. These systems may lead to improper space utilization, long waiting times at entry and exit points, and increased traffic congestion within parking areas. Manual parking management also requires continuous human involvement, which increases operational costs and reduces overall system reliability. In many cases, the lack of real-time information about parking availability causes unnecessary vehicle movement, leading to fuel wastage and environmental pollution. Therefore, there is a growing need for an automated and intelligent parking solution that can improve efficiency and reduce these challenges.

To address these issues, this project focuses on the development of a Smart Car Parking System using a Siemens S7 1200 Programmable Logic Controller (PLC). PLCs are widely used in industrial automation due to their high reliability, fast response time, and ability to perform complex control operations. In this system, sensors are installed to detect the presence of vehicles and monitor the availability of parking slots. The input signals from these sensors are sent to the PLC, which processes the data based on predefined ladder logic.

Based on the processed information, the PLC controls various output devices such as gate motors and indicators through relay modules. The system automatically manages vehicle entry and exits by opening or closing the gates depending on slot availability. This ensures smooth traffic flow and prevents overcrowding within the parking area. Additionally, the automated system minimizes human intervention, thereby reducing the chances of errors and improving overall operational efficiency. It can be easily implemented in small to medium-scale parking areas and can be further enhanced by integrating advanced features such as real-time monitoring, digital payment systems.

Overall, this Smart Parking System provides a practical and scalable solution to modern parking problems, contributing to better space management, reduced congestion, and improved user convenience in urban environments.

II. LITERATURE REVIEW

In recent years, parking management has become a major problem in urban areas due to the continuous increase in the number of vehicles. Traditional parking systems are mostly manual and often result in issues such as traffic congestion, longer waiting times, and inefficient use of parking space. These systems also depend heavily on human operators, which increases the chances of errors and reduces overall efficiency.

To overcome these problems, researchers have developed automated parking systems using different technologies. One of the common approaches is the use of sensor-based systems, where sensors like IR and ultrasonic sensors are used to detect the presence of vehicles in parking slots. These systems help in identifying available spaces and reduce manual effort. They are simple and cost-effective, but their accuracy can sometimes be affected by environmental conditions.

Another important development in parking systems is the use of automatic gate control mechanisms. In these systems, sensors are used to detect vehicles at entry and exit points, and gates are controlled automatically using motors and relay

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circuits. This reduces the need for manual operation and improves the overall flow of vehicles within the parking area. Some studies have also focused on time-based billing systems, where the parking charges is calculated based on the duration for which the vehicle is parked. These systems use timers and control units to calculate and display the parking charges. This method ensures fair billing and reduces human errors in charges calculation. Among the various technologies used for automation, Programmable Logic Controllers (PLC) have gained significant importance in industrial applications due to their reliability, fast response, and ease of programming. PLC-based systems are widely used for controlling sequential operations and real-time processes. In parking systems, PLCs can be used to integrate sensor inputs, control gate operations, and manage timing functions effectively. Compared to more complex systems, PLC based solutions are simple, robust, and do not require continuous internet connectivity. This makes them suitable for small to medium scale parking areas where cost and reliability are important factors.

Therefore, this project proposes a Smart Pay and Park System using PLC, which combines sensor-based detection, automatic gate control, and time-based billing into a single integrated system. The proposed system provides an efficient, reliable, and cost-effective solution to modern parking challenges.

III. PROBLEM DESCRIPTION

Traditional parking systems mainly depend on manual operations such as issuing tickets, noting vehicle entry and exit times, and calculating parking charges. These processes are not only time-consuming but also prone to human errors, which can lead to incorrect billing and lack of transparency. Since most of the work is handled manually, there is often inconsistency in managing records and handling vehicle flow. At entry and exit points, vehicles frequently experience long waiting times due to slow processing, which results in queues and creates inconvenience for users. This not only affects the overall user experience but also contributes to traffic congestion within and around the parking area. In addition, the heavy dependence on human operators reduces system efficiency and reliability, as continuous monitoring and quick decision-making become difficult.

Figure1: Traditional and Smart PLC-Based Parking System

Another major issue with traditional systems is the improper utilization of available parking spaces. Without an automated mechanism to track and manage slot availability, parking areas are often either overcrowded. This leads to confusion, wasted time, and increased fuel consumption.

All these challenges increase operational costs and negatively impact the overall performance of the parking system. Therefore, there is a strong need to develop a fully automated, reliable, and accurate parking solution using PLC technology. Such a system can streamline parking operations, ensure precise and transparent billing, reduce human intervention, and significantly improve the efficiency of parking management.

IV. METHODOLOGY

The Smart Pay and Park System is designed to automate the entire parking process using a PLC. The main idea behind this system is to reduce manual work and make parking operations faster, accurate, and more reliable. The system is built using a PLC as the main controller along with IR sensors, relay modules, entry and exit gates, and an HMI display. All these components work together, where sensors send signals to the PLC, and the PLC controls the gates and display based on programmed logic. When a vehicle arrives at the entry gate, the IR sensor detects its presence and sends a signal to the PLC. The PLC then checks whether parking space is available. If there is space, the entry gate opens automatically using the relay module. At the same time, a timer inside the PLC starts to record how long the vehicle stays in the parking area. If the parking is full, the gate does not open, which helps in avoiding overcrowding. After entering, the vehicle occupies a parking slot. The system keeps track of available slots so that it can manage further entries properly. This helps in better use of the parking space and reduces confusion. When the vehicle is ready to leave, it reaches the exit gate where another IR sensor detects it. This signal is sent to the PLC, which immediately stops the timer. Based on the total time recorded, the system calculates the parking charge using predefined rates. This calculation is done automatically, which avoids manual errors.

The calculated amount is then displayed on the HMI screen so that the user can clearly see the parking charges. After the payment is completed, the PLC sends a signal to open the exit gate through the relay module. The vehicle exits smoothly, and once it leaves, the system resets itself and becomes ready for the next vehicle. The entire system is controlled using ladder logic programming in the PLC. This type of programming is simple, reliable, and suitable for real-time control applications. It ensures that all operations happen in the correct sequence without delay. Overall, this methodology provides a smooth and automatic parking system that reduces human effort, improves accuracy in billing, and manages parking space efficiently. The Smart Pay and Park System is developed to automate the complete parking process using a Programmable Logic Controller. The main objective of this system is to reduce manual work, improve accuracy, and ensure smooth vehicle movement inside the parking area.

The system consists of a PLC, IR sensors, relay modules, entry and exit gates, and an HMI display. The PLC acts as the central controller of the system. It continuously receives signals

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from the sensors, processes them based on the programmed logic, and controls the outputs such as gate operation and display. When a vehicle approaches the entry gate, the IR sensor placed at the entry detects its presence. This signal is sent to the PLC. After receiving the signal, the PLC checks whether any parking slot is available. If space is available, the PLC sends a command to the relay module, which activates the motor and opens the entry gate. At the same time, a timer inside the PLC is started to record the parking duration. If no parking slot is available, the PLC does not open the gate, which helps prevent unnecessary entry and avoids congestion inside the parking area. Once the vehicle enters, it occupies a parking slot. The system keeps track of the number of vehicles inside the parking area to determine slot availability. This helps in managing the parking space efficiently and ensures that vehicles are only allowed when space is available. When the vehicle is ready to exit, it reaches the exit gate where another IR sensor is installed. This sensor detects the vehicle and sends a signal to the PLC. As soon as the PLC receives this signal, it stops the timer that was started at the time of entry. The total parking time is then calculated automatically.

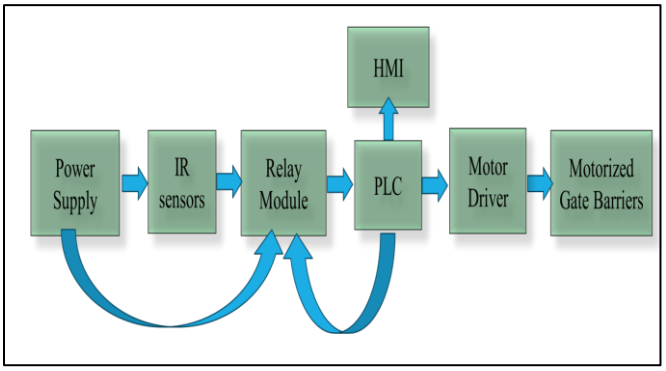

Figure2: Block Diagram

Based on this parking duration, the PLC calculates the parking charges using predefined rates stored in the program. This automatic calculation eliminates manual errors and ensures fair and accurate billing. The calculated amount is then displayed on the HMI screen so that the user can clearly see the parking charges. After the payment is completed, the PLC sends a signal to the relay module to open the exit gate. The vehicle exits the parking area smoothly. Once the vehicle leaves, the system updates the slot availability and resets the timer, making the system ready for the next vehicle.

The entire system is controlled using ladder logic programming in the PLC. Ladder logic is simple and reliable, and it is widely used in industrial automation. It allows the system to perform operations in a proper sequence, such as checking conditions, timers, and operating outputs without delay. This methodology ensures that all parking operations from entry to exit are handled automatically and efficiently. It reduces the need for human involvement, minimizes errors, improves time management, and provides a better experience for users.

V. PROPOSED SOLUTION

To overcome the limitations of traditional parking systems, a Smart Pay and Park System based on a Programmable Logic Controller 898989is proposed. The main aim of this system is to automate the entire parking process, including vehicle entry, slot management, time calculation, billing, and exit operations. In the proposed system, IR sensors are installed at the entry and exit points to detect the presence of vehicles. When a vehicle arrives at the entry gate, the sensor sends a signal to the PLC. The PLC then checks the availability of parking slots. If space is available, the system automatically opens the entry gate using a relay-controlled mechanism. At the same time, a timer is started to record the parking duration. The system continuously monitors the number of vehicles inside the parking area to ensure efficient space utilization. If the parking area is full, the entry gate remains closed, preventing further vehicles from entering and avoiding congestion.

When the vehicle moves towards the exit, another IR sensor detects it and sends a signal to the PLC. The timer is then stopped, and the total parking time is calculated. Based on this duration, the system automatically calculates the parking charge using predefined rates. The calculated amount is displayed on the HMI screen, providing clear and transparent billing to the user. After the payment is completed, the PLC activates the exit gate through the relay module, allowing the vehicle to leave the parking area. The system then updates the parking availability and resets itself for the next vehicle. The entire operation is controlled using ladder logic programming in the PLC, which ensures reliable, fast, and real-time performance. Compared to manual systems, the proposed solution significantly reduces human intervention, minimizes errors, and improves overall efficiency. This system is cost-effective and suitable for small to medium-scale parking areas such as malls, offices, and commercial complexes. It can also be further enhanced in the future by adding features like automated payment systems and remote monitoring.

VI. HARDWARE REQUIRED

1) POWER SUPPLY

The system begins with the power supply unit, which provides stable electrical power to all components including IR sensors, relay module, PLC, motor driver, and gate barriers. Typically, a 24V DC industrial power supply is used for PLCs, while IR sensors and relay modules may operate on 5V DC. The power supply ensures that the system operates reliably and continuously without interruption.

2) IR SENSORS

IR (Infrared) sensors are used for **vehicle detection** at different points of the parking system:
Sensor 1– detects vehicle arrival at the gate.
Sensor 2 – indicates that the vehicle has parked in the slot.
Sensor 3– detects vehicle leaving the parking area.

International Journal of Engineering Research & Technology (IJERT)
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When a vehicle parked, the sensor sends a digital signal to the PLC through the relay. These signals trigger the timer, initiate gate operations, and start the charge calculation process.

3) Relay Module

The relay acts as an interface between the low-voltage IR sensor signals and the PLC input terminals.

Its functions include:

- Amplifying the sensor signal.
- Protecting the PLC from voltage spikes.
- Ensuring safe switching of input signals.

4) PLC (Programmable Logic Controller)

The PLC is the main control unit of the entire system. It processes all inputs from sensors and executes the programmed logic to control outputs. A Programmable Logic Controller (PLC) is a special computer used for industrial automation. It processes inputs from field devices like sensors and produces outputs that control actuators or indicators based on pre-programmed logic. The PLC receives digital input signals from IR sensors placed at the entry point, exit point, and both parking slots. The ladder logic program inside the PLC continuously scans these inputs. The PLC cycles through the input-scan → logic execution → output-update process at high speed, ensuring real-time system control.

Based on the status of parking slots and the presence of a vehicle at the entry, it decides whether to open or keep the entry gate closed. Similarly, it opens the exit gate when a vehicle is detected by the exit IR sensor.

5) HMI (Human Machine Interface)

HMI is used for:

- Displaying parking time
- Showing parking Charge
- Indicating free parking slots.
- Providing operator interface (Start/Stop/Reset)

6) Motor Driver

The motor driver is used to control the **entry and exit gate motors**. The PLC sends control signals to the motor driver, but since the PLC cannot provide enough current to run the motor, the motor driver converts these signals into high-power output. When a vehicle arrives or exits, the PLC gives a command to the motor driver:

To **open the gate** → motor rotates in one direction

To **close the gate** → motor rotates in the opposite direction

The motor driver ensures smooth movement of the gate and proper control of motor operation. It also protects the PLC from high current and voltage, making the system safe and reliable.

7) Motorized Gate Barriers

Motorized gate barriers are electromechanical systems designed to manage and control vehicle movement at entry and exit points. They operate using a motor-driven arm or sliding mechanism that opens and closes based on PLC commands. These barriers ensure smooth traffic flow, prevent unauthorized access, and enhance safety by coordinating with sensors to avoid accidental closure on vehicles. Their reliable operation makes them ideal for automated parking and access control systems.

VII. WORKING

- **Vehicle Detection at Entry:** When a vehicle approaches the entry gate, the IR sensor installed at the entrance detects its presence. This sensor acts as the first point of interaction in the system and sends an electrical signal to the PLC, indicating that a vehicle is waiting to enter the parking area.
- **Slot Availability:** After receiving the signal from the entry sensor, the PLC checks the status of all parking slot sensors. It continuously monitors whether each slot is occupied or free. Based on this information, the PLC decides whether to allow the vehicle to enter or not.
- **Entry Gate Operation:** If at least one parking slot is available, the PLC sends a command to the relay module connected to the gate motor. The relay activates the motor, and the entry gate opens automatically. If no slot is available, the gate remains closed, preventing unnecessary entry and avoiding crowd inside the parking area.
- **Vehicle Enters and Parks:** Once the gate opens, the vehicle enters the parking area and occupies an available slot. Each parking slot is equipped with a sensor that detects the presence of the vehicle. As soon as the vehicle is parked, the corresponding sensor updates the slot status from “available” to “occupied” in the PLC system.
- **Timer Activation:** After the vehicle is successfully parked, the PLC starts timer. This timer keeps track of the total duration for which the vehicle remains in the parking area. This automated timing system ensures accurate measurement without any manual involvement.
- **Vehicle Detection at Exit:** When the vehicle is ready to leave, it moves towards the exit gate. The IR sensor placed at the exit detects the vehicle and sends a signal to the PLC, indicating that the vehicle is about to exit the system.
- **Parking Charges Calculation:** Upon receiving the exit signal, the PLC immediately stops the timer. The recorded time is then processed and converted into hours or minutes as per the system design. Based on predefined billing rates stored in the PLC program, the system calculates the total parking charge.
- **Charges Display:** After calculating the parking charges, the PLC sends this information to the HMI display. The amount is clearly shown on the screen so that the user can easily read and understand the charges, ensuring transparency in the billing process.
- **Payment Confirmation:** Once the user completes the payment, the system verifies whether the payment has been successfully made. This step ensures that the exit process only continues after proper payment, preventing any loss of revenue.
- **Exit Gate Operation:** After successful payment confirmation, the PLC sends a signal to the relay module to activate the exit gate motor. The gate opens automatically, allowing the vehicle to exit smoothly without any manual process.
- **Vehicle Leaves:** After the vehicle exits the parking area, the gate closes automatically. At the same time, the system

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Vol. 15 Issue 04 , April - 2026

updates the parking slot status back to "available." The timer and other parameters are reset, making the system ready to handle the next vehicle efficiently.

VIII. DISCUSSION OF RESULTS

Timer Performance: The timer in the PLC responded immediately when a vehicle occupied a parking slot. There was no noticeable delay in starting or stopping the timer, which shows that the system has good real-time performance. This accurate timing ensures correct measurement of parking duration, which is essential for accurate billing.

Accuracy of Charges Calculation: The mathematical operations performed in the PLC, such as division (DIV) and multiplication (MUL), worked accurately throughout the testing. The system consistently calculated the parking charges based on the recorded time without any errors. This confirms that the billing logic is reliable and suitable for practical use.

Gate Operation Efficiency: The entry and exit gate barriers operated smoothly during all test conditions. The motor driver successfully controlled the gate movement without any delay. This indicates that the motor driver and relay system are properly integrated with the PLC, ensuring efficient and controlled gate operation.

Slot Availability Management: The system correctly updated the status of parking slots after each vehicle exit. Once a vehicle left the parking area, the corresponding slot was marked as available without delay. This feature is important for managing multiple vehicles and maintaining accurate information about parking availability.

Sensor and Logic Reliability: During test, no false triggering or unwanted gate opening was observed. The IR sensors accurately detected vehicle presence, and the PLC logic responded correctly to each condition. This demonstrates that the system is stable, reliable, and free from major logical or sensor-related errors.

IX. BENEFITS OF THIS SYSTEM

- Time Saving: The automated entry and exit process reduces waiting time for vehicles. Since gates operate automatically based on sensor input, vehicles do not need to wait for manual verification, improving overall efficiency.
- Reduced Human Effort: The system minimizes the need for human operators by automating tasks such as gate control, time tracking, and billing. This reduces workload and lowers the chances of human errors.
- Accurate Time-Based Billing: The PLC timer records the exact parking duration, ensuring precise calculation of charges. This eliminates manual mistakes and provides fair and consistent billing for all users.
- Efficient Space Management: The system continuously monitors slot availability using sensors. It allows entry only when space is available, ensuring proper utilization of parking areas and avoiding overcrowding.
- Improved Traffic Flow: Automatic gate operation and controlled entry help in maintaining a smooth flow of vehicles. This reduces congestion both inside and outside the parking area.
- High Reliability and Stability: PLC-based systems are known for their reliability and ability to operate continuously without failure. This makes the system suitable for real-time and long-term applications.
- User-Friendly Operation: The HMI display provides clear information such as parking charges and system status. This makes the system easy to understand and use for both operators and customers.
- Cost Effective in the Long Run: Although the initial setup cost is higher, the system reduces the need for manpower and minimizes operational costs over time, making it economical in the long term.
- Enhanced User Experience: The fast, automated, and transparent process improves customer satisfaction by reducing delays and providing a hassle-free parking experience.
- Improved Safety: Automatic control of gates reduces the chances of accidents caused by manual operation. The system ensures smooth and controlled movement of vehicles.
- Transparent and Fair System: Since all operations like timing and billing are automated, the system ensures transparency and avoids disputes between users and operators.

X. LIMITATIONS

- Higher Initial Investment: PLC, sensors, and motor drivers increase overall system cost compared to simpler systems.
- Dependence on Stable Power Supply: The system requires continuous power; failure can stop operation without backup.
- Sensor Sensitivity: IR sensors may give inaccurate results in dust, rain, or strong sunlight.
- Maintenance Requirements: Regular maintenance is needed for mechanical parts.
- Manual Payment Dependency: Manual payment can cause delays during peak hours.
- Limited User Interaction: Basic HMI provides limited features and no advanced options.
- Mechanical Wear and Tear: Continuous use of gates may lead to wear and require servicing.

XI. FUTURE SCOPE

Digital Payment Integration: The system can be upgraded by adding digital payment methods such as UPI, smart cards, or QR code scanning to make the payment process fully automatic and faster.

Remote Monitoring: The parking system can be connected to a central monitoring system to track parking status, vehicle count, and system performance from a remote location.

Mobile Application Support: A mobile app can be developed to allow users to check parking availability and view charges before entering the parking area.

Advanced User Interface: The HMI can be improved with a more interactive and graphical interface to provide better user experience and additional information.

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Multi-Level Parking Support: The system can be extended to handle multi-floor or large-scale parking areas by adding more sensors and PLC expansion modules.
Improved Sensor Technology: More advanced sensors (like ultrasonic or camera-based systems) can be used to increase detection accuracy under all environmental conditions.
Automatic Number Plate Recognition (ANPR): Camera-based vehicle identification can be added for automatic entry, exit tracking, and enhanced security.
Energy Efficient System: The system can be optimized to reduce power consumption by using energy-efficient components and smart control techniques.
Data Logging and Analysis: The system can store parking data for analysis, helping in better management and future planning.
Integration with Smart City Systems: The system can be connected with larger smart city infrastructure for better traffic and parking management.

XII. CONCLUSION

The Smart Pay and Park System successfully demonstrate a fully automated parking management solution using PLC technology. The system integrates IR sensors, PLC, motor driver, relay modules, and HMI to perform key operations such as vehicle detection, gate control, parking time measurement, and accurate charge calculation. All processes are carried out automatically, ensuring smooth and coordinated functioning. The PLC processes sensor inputs in real time and makes logical decisions for entry and exit operations, while the timer ensures precise duration tracking for fair billing. The motor driver enables smooth gate movement, and the HMI provides clear display of parking charges, improving user interaction and transparency. During testing, the system showed reliable performance with accurate timing, correct billing, and proper slot management. Compared to traditional manual systems, it reduces human effort, minimizes errors, and improves efficiency.

Overall, the system is a practical and cost-effective solution for small to medium-scale parking areas. It also provides a strong foundation for future improvements such as digital payment and enhanced user interfaces.

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