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AUTOMATED RAILWAY SIGNALING SYSTEM WITH LOOPLINE FEEDBACK

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Abstract: This project presents an **Automated Railway Signaling System with Loopline Feedback** designed to enhance railway safety and reduce human error at stations. The system is built around ESP32microcontroller board that coordinates multiple hardware components, including an **LCD display**, **servo motor**, **IR sensors**, **limit switch**, **manual switches**, **buzzer**, and a **Wi-Fi module**. Two manual switches are used by the station master to select the track and set the signal (red or green). Based on the switch status, a servo motor automatically changes the track alignment. A limit switch provides loopline feedback to confirm whether the track has been correctly changed, ensuring reliable operation. Two IR sensors are placed on the main line and loop line respectively to detect the presence of a train on either track. When the station master sets the signal to green, the system first verifies track alignment using the limit switch and checks for any existing train presence using the IR sensors. If the track is not properly set or a train is already present, the system prevents unsafe operation by activating a buzzer and displaying a warning on the LCD. Simultaneously, fault and status information is transmitted to a mobile application via the **ThingSpeak cloud** using internal Wi-Fi module. This integrated feedback and communication mechanism ensures real-time monitoring, improves operational safety, and demonstrates a low-cost, reliable approach to automated railway signaling and track management.

Index Terms: Automated Railway Signaling System, Loop Line Feedback, Railway Safety, Track Switching, Signal Control, Train Detection, Real-Time Monitoring, Embedded System, IoT-based System

I. INTRODUCTION

The Odisha Koraput - Kandhamal - Boudh – Nayagarh (Koraput- Kandhamal – Boudh - Nayagarh) is an accident –prone area due to several reasons including poor roadinfrastructure, overloading and over speeding, lack of trafficmanagement, geographical challenges, driver negligence andvehicle maintenance. An accident occurred in Odisha, India on 2nd June 2023 where three trains collided. The first train entered the passing loop instead of the main line at full speed and collided with the goods train. Due to the high speed of the train, its 21 coaches derailed and three of those collided with the oncoming train on the adjacent track. The cause of this accident is for unknown reasons, the signal was taken off for the main line and the track was switched to a loop line adjacent to the main line. The Railway Loop Line Changer with Auto Feedback and Signalling project emphasizes the crucial need for enhancing railway operations and introduces an automated system designed to streamline loop line changes. In the realm of modern transportation, railways play a pivotal role, making it imperative to ensure their efficiency and safety. The manual handling of loop line changes can lead to a host of issues, including delays, errors, and potential safety risks. In response to these challenges, this project proposes an inventive solution that integrates cutting- edge technologies such as limit switches, servo motors, WS2812 lights, and a buzzer. This amalgamation of technologies aims to automate the loop line change process while providing real-time feedback to operators. The overarching goal is to elevate operational efficiency and safety by introducing automation and immediate alerts, thereby revolutionizing the management of loop line changes in railway opera

II. LITERATURE SURVEY

According to the [1] this invention related to track switching system for the two railway tracks and this device is designed for the ultra-high-speed magnetic floating stock. The magnetic floating system makes the magnetic forces for non contact support and guidance on the side-by-side rails which is unique to this system and the rolling stock features a bulge magnetic device between the rails it will restricting the use of conventional crossing rails in track switching system. The challenges in controlling the multiple route in railway system [2] this invention mainly focus on how to control the movement of a lengthy freight(goods) train. which the movements of the train is accurately monitoring and organize

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according to the dynamic schedule based on the evaluation of, among the things, applicable speed restrictions, delivery schedule requirements and the coordination among all the trains. The project [3] comprises four modules the first one is Dispatcher's control interface for commands and status visualization. The second one is a centralized server system managing relay communication, the third module is a communication network. And the final module is a relay House hardware interface unit. the train dispatcher's uses the LAN connected PC's and the relay houses employ equipment with twenty-four DC voltage--triggered relays

Jaya kumar ,et al [11] in 2021, introduced a railway safety system at Nandha Engineering College in Erode, Tamil Nadu, India. The system employs an ATmega168 microcontroller, LCD display, voltage regulator, capacitor, GPS sensor, ADC for sensor data conversion, GSM module for communication, buzzer for alerts, DC motor for train control, RF module for wireless communication, and relay for switching. This integrated hardware, guided by machine language software, ensures real-time monitoring, early anomaly detection, and automated communication to prevent head-on collisions. The solution enhances situational awareness, improves safety, and provides a reliable approach for efficient railway operations.

Kalam et al [12] College of Engineering and Science, Victoria University, Melbourne, Australia in 2022 they are saying about Industry 4.0 drives innovation in Enterprise Management Systems (EMS) for railways, using IoT frameworks for operational efficiency. Challenges like interoperability and cybersecurity must be addressed. Technologies include advanced data analysis and integrated IoT platforms for connectivity with the Operation Control Centre (OCC).

Moudgil et al [13] from Life Cycle Management Laboratory (LCML) at School of Engineering, The University of British Columbia (Okanagan Campus), 1137 Alumni, Avenue,Kelowna, BC, V1V 1V7, Canada. in 2023 The study Utilizing a thorough review, the study identifies interventions for integrating IoT into Building Infrastructure (BI), encompassing academic, technological, and industrial research. Emphasizing both technological and behavioral aspects, it aims to bridge the research gap and establish a generic framework with cognitive intelligence for enhanced BI functionalities using cutting-edge IoT technologies.

Marek Jablonski et al [15] and Quality Institute, WSB University in Poznan,Poland in the year 2022 Methodology is about This chapter employs a critical literature review toexplore emerging trends and technologies shaping rail transport safety. The focus is on theoretical and practical reflections to identify the profound impact of digitalization on railway safety the Technologies are the research delves into key technical solutions driving the evolution of digital safety in rail transport, highlighting the transformative impact of various technologies within the rapidly progressing digitalization landscape.

III. METHODOLGY

Electric Circuit Design: Create an electrical circuit diagram illustrating how the components will be connected to microcontroller (e.g., ESP 32). Microcontroller programming: Write the code the microcontroller (e.g., ESP 32) to control the various hardware components. The code should include logic for detecting loop line status, activating the servo motor, and providing feedback through lights and a buzzer. ESP32 acts as the central controller, interfacing with various hardware components such as manual switches, a servo motor, IR sensors, a limit switch, LCD display, buzzer, and a Wi-Fi module. Two manual switches are provided to the station master: one for selecting the desired track (main line or loop line) and another for setting the signal status (red or green). Based on the selected track, the ESP32controls a servo motor that physically changes the track alignment.

The block diagram represents an automated railway signaling and track control system using an Arduino. A regulated power supply provides power to all components in the system.

The Arduino acts as the central controller, receiving inputs from devices like the limit switch, signaling switch, and loop change switch, which are used to detect train position and control track operations. Based on these inputs, the Arduino controls output devices such as the servo motor for track switching, signal lights for indication, and a buzzer for alerts. A Wi-Fi module is used to send data to the cloud, enabling communication with a mobile application for real-time monitoring by railway authorities.

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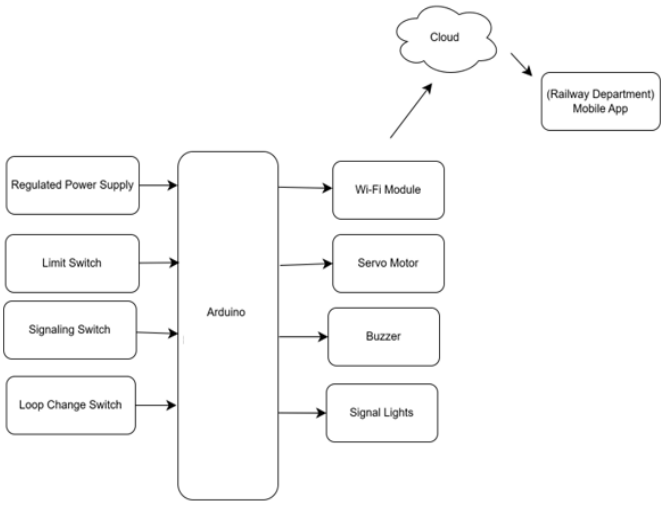

Fig: Operation of the Proposed System

Servo motors work by using a pulse-width modulation (PWM) signal to control the motor's position. The PWM signal is a series of pulses that are sent to the motor at a regular frequency. The width of each pulse determines how far the motors will rotate. This helps to move the loop line tracks.

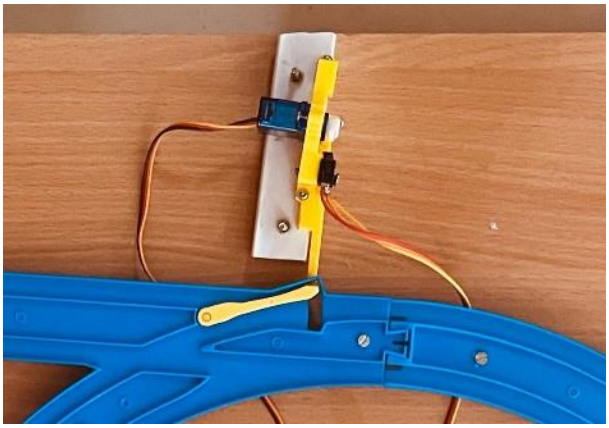

Fig : Servo motor and Track Switching

LCD is used to show the train status and signaling. This shows if there are any faults present in the signaling then it shows the fault on the digital screen.

Fig: LCD Display

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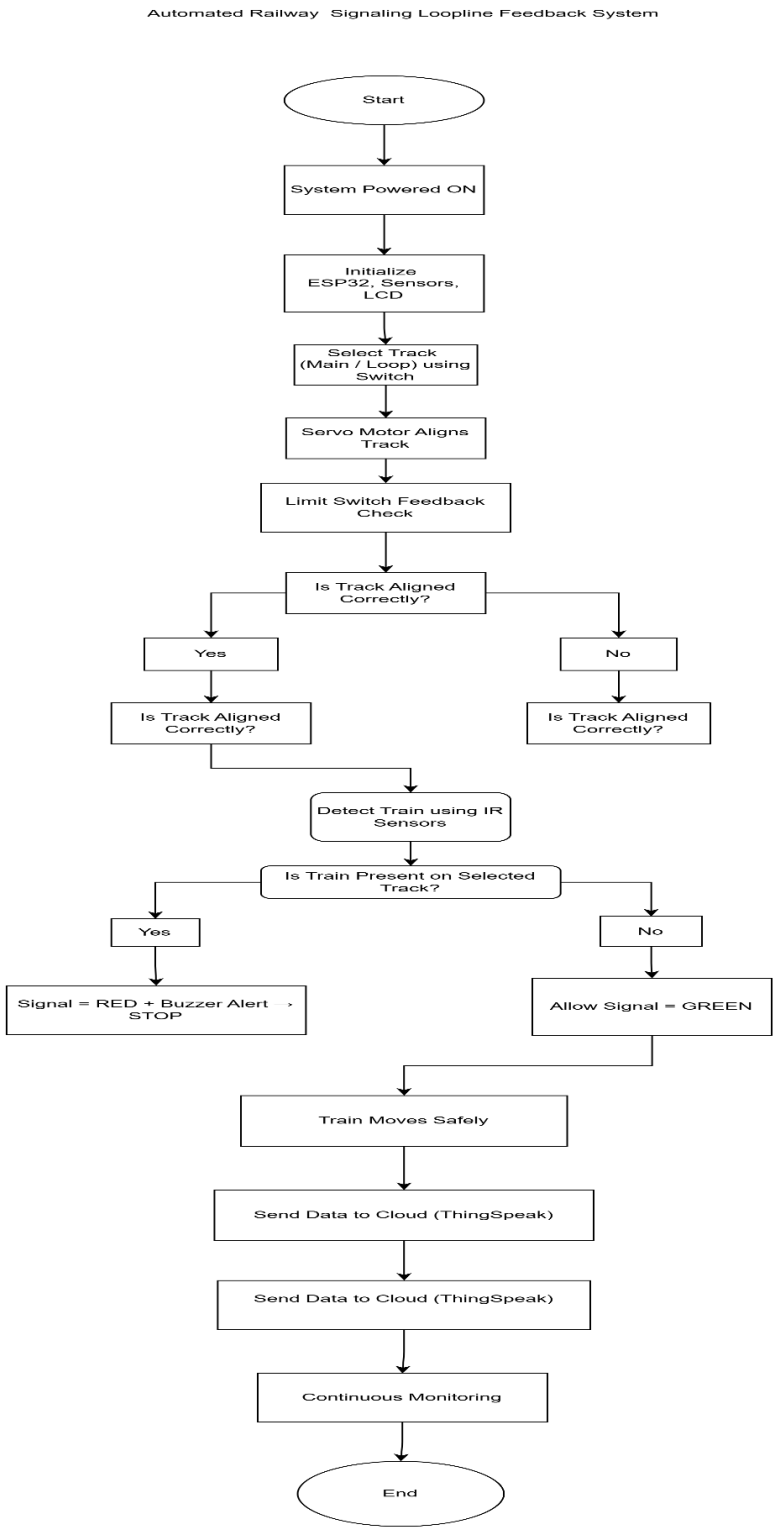
Flowchart:



IV. RESULTS

As a part of the configuration process, the proposed system is linked to the mobile application. The app will showcase the status of the loop line. In the event of a red signal, the train seamlessly halts without any issues. However, when the signal turn green and a train is present in loop line, the proposed system responds by triggering an error message on the

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LCD screen accompanied by a buzzer sound. Simultaneously, the mobile application updates the status from 0 to 1 along with an audible alert.

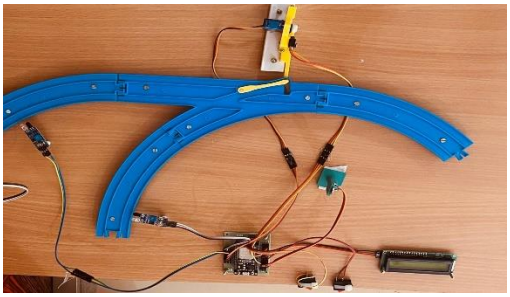

Fig: Overall System

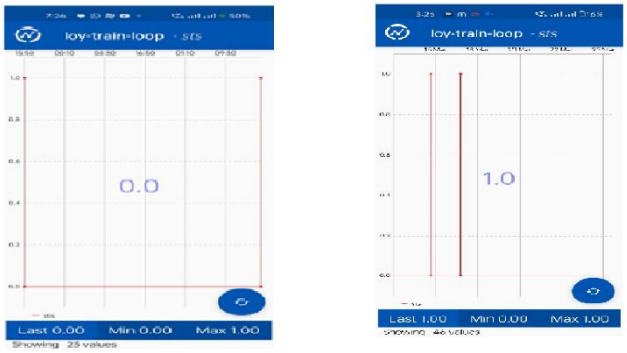

Fig: Graphical Representation of Thingspeak Platform

V. FUTURE SCOPE

In the future, the proposed System will integrate with machine learning algorithm to enhance predictive capabilities, allowing the system to adapt dynamically to varying operational conditions. Ongoing research into advanced sensor technologies could enhance the system accuracy in detecting and responding to train movements, ensuring continuous improvements in safety and operational effectiveness.

VI. CONCLUSION

The proposed system offers a smart and automated solution for railway signaling using embedded systems and sensors. It reduces human intervention, minimizing errors caused by manual operations and miscommunication. The system ensures safety by verifying track alignment and detecting train presence before signal clearance. It prevents accidents by allowing train movement only on safe and properly aligned tracks. Automation improves efficiency through automatic track switching and continuous monitoring. IoT integration enables real-time supervision and quick response to faults or unsafe conditions. The system is cost-effective, scalable, and suitable for both small and large railway networks. Overall, it enhances safety, reliability, and modernization of railway transportation systems.

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