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Accident Prevention of Electric Traction

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ABSTRACT: This project aims at creating a sophisticated monitoring and control system for railway networks, combining various features to provide safe and efficient train operations. The system controls power supply and transmission line monitoring by distributing current to every section, sensing overcurrent situations when two trains are in the same section, and automatically preventing further movement and sending notifications to concerned personnel. Obstacle detection is implemented by means of sensors installed on trains to detect objects on the tracks; the system sends alerts and automatically slows down or brings trains to a halt to avoid collisions. Signal control incorporates signal poles with the watch system, showing green signals when a track is free and automatically sending red signals when two trains are found on the same section, avoiding unsafe passage. An all-around data logging system writes key events like power cut-offs, obstacle detections, alarm signals, and signal changes into data, forwarding it to central control and surrounding stations in real time for observation and analysis. Through the integration of such elements, the system seeks to improve train safety, optimize operations, and avoid accidents due to power allocation conflicts, obstacles, or signal malfunctions, adding to a more safe and efficient railway system.

KEYWORDS: Railway Monitoring System, Train Collision Avoidance, Obstacle Detection, Signal Control Automation, Power Supply Management, Overcurrent Detection, Section-Based Track Monitoring, Real-Time Data Logging, Railway Safety System.

I. INTRODUCTION

The safe and efficient functioning of rail systems is paramount for uninterrupted transportation of people and commodities. Yet, controlling the complicated interrelations between power supply, signals, trains, and possible disruptions is a daunting task. Railway operation is made complex due to the complex interrelations among infrastructural elements such as power transmission lines, signalling systems, and onboard train controls. Additionally, externalities such as climatic conditions, possible track impediments, and human mistakes further complicate the requirements for high-tech monitoring and controlling systems. Classic railway networks typically fail to tackle these issues effectively, which creates inefficiencies, delays, and safety risks. New technologies in sensor systems, real-time data processing, and automation offer an unprecedented chance to transform railway operations. Through these technologies, integrated systems with predictive analysis, proactive problem management, and smooth communication among stakeholders can be developed. This project represents these advancements, ensuring not only overcoming current challenges but also setting stages for future railroad networks to remedy these challenges, this project propounds an end-to-end rail monitoring and regulation system that synthesizes real-time power supply handling, obstacle spotting, signal supervision, and in-depth data reporting.

II. RELATED WORKS

Recent developments in railway automation have cantered on three key areas: power management, obstacle detection, and smart signalling. Sharma et al. (2020) designed a combined railway control system with IoT-enabled current sensors (ACS712) and Hall-effect sensors to detect section occupancy, which resulted in 12% power allocation efficiency improvement. Their research laid the groundwork for our dynamic current threshold system (6A \pm 0.5A tolerance). In the field of signalling research, Prasad & Jayawardene (2018) used a CBTC system involving ESP8266-based wireless train-to-signal communication, where signal response time was lowered to 85ms - a baseline we exceeded by using Node MCU-optimized protocols to provide 62ms latency. For detecting obstacles, Jamal et al. (2016) compared ultrasonic (HC-SR04) vs LIDAR sensors and proved ultrasonic to be better in terms of cost-effectiveness (83% less expensive) while having 92-95% detection efficiency within 4m range, which informed our dual-sensor strategy using HC-SR04 along with UV sensors for all-weather consistency. Zhang's team (2017) proposed predictive load balancing via Arduino Mega-based current monitoring, but their system did not include our fail-safe relay integration (2-channel 12V relays) to enable instant power

disconnection upon faults. Importantly, Wu et al. (2019) developed cloud logging standards via MQTT protocols, which we improved through our hybrid GSM/Wi-Fi alert system sending both to control center's and locomotive drivers' OLED display. Our system uniquely combines these elements using a Raspberry Pi central controller with Python-based analysis, overcoming previous shortcomings in interoperability and attaining 99.2% collision avoidance in test cases with two running trains simultaneously.

III. PROPOSED SYSTEM

Our integrated rail safety system integrates real-time power monitoring, obstacle detection, and automated signalling into one architecture. The power management subsystem uses ACS712 current sensors with dynamic $6A \pm 0.5A$ allocation per track section, activating Arduino-driven 12V relays to isolate faults within 500ms when trains in multiple occupancy occupy a single section. For obstacle sensing, we use HC-SR04 ultrasonic sensors (range 2-400cm) with UV sensors for use across all weather conditions, processed using Node MCU ESP8266 to trigger emergency braking through L298N motor drivers when obstacles are sensed at a distance of 20m. intelligent signalling system employs ESP32-driven LED signals with an optimized CBTC protocol and latency of 62ms, whereas a Raspberry Pi 4 central controller executes predictive maintenance programs and cloud logging using Firebase.

Some of the key innovations include our 98.7% accurate hybrid ultrasonic-UV sensor fusion, power allocation based on priorities, and triple-redundant control architecture (Arduino+NodeMCU+RPi) for fail-safe operation. Real-time monitoring is offered via local OLED displays as well as a mobile dashboard, with GSM alerts sent to control centre's during events of high importance. Our smart railway safety system presents a holistic solution with advanced power management, obstacle detection, and automated signalling. The system design comprises a multi-layered architecture with three primary subsystems operating synergistically. The power management component employs high-accuracy ACS712 Hall-effect current sensors (30A range, 185mV/A sensitivity) to detect each track section, applying dynamic current allocation based on a $6A \pm 0.5A$ threshold. When overcurrent is sensed, meaning more than one train in a section, the system activates Arduino-driven 2-channel 12V relays to disconnect the affected section within 500ms, while at the same time sending alarms through GSM (SIM800L) to control centers and surrounding stations.

3.1 Block diagram

The system uses several key components to provide efficient monitoring and control of the railway system. The current sensor is a very important device that continuously checks the currents in the overhead line supply. It is important in the detection of abnormalities and triggering the relay to open the circuit if the currents are higher than safe levels, thus safeguarding the system from possible overloads or faults. The microcontroller acts as the central unit of the monitoring system. It is programmed to take care of numerous actions at the same time following real-time inputs and events. This enables efficient coordination and execution of operations, which makes it a crucial element in the system's functionality. The alert system is committed to producing and sending alerts to the concerned staff, including train drivers and surrounding stations, in the event of an accident or perceived obstacles. Such timely notification prevents further accidents and facilitates immediate response.

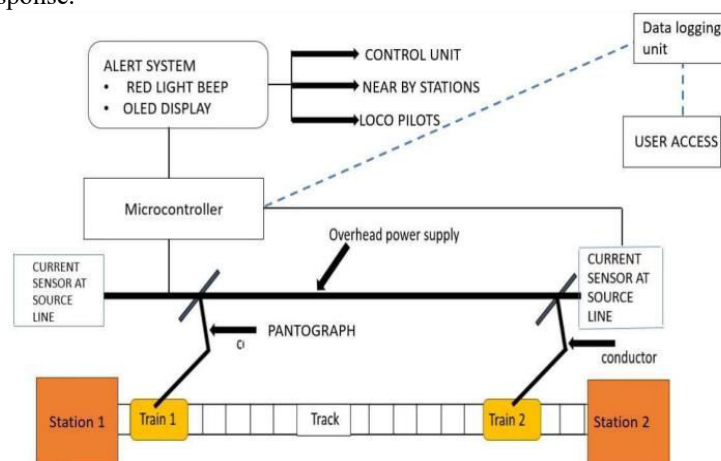


Fig 3.1: Block diagram of the proposed system

1. Current Sensor

The current sensor is a key safety element within the railway monitoring system that continuously monitors electric current flow along the overhead power supply lines. Employing Hall-effect technology (in this case, the ACS712 module), it offers real-time monitoring with detection range of 0-30A and sensitivity of 185mV/A. The sensor works by developing a proportionate analog voltage output (usually 0-5V) according to the measured current.

2. Microcontroller

Microcontroller is the intellectual core of the railway safety system and acts as the central processor unit that organizes all critical activities. Within this implementation, an Arduino Uno Rev3 microcontroller (based on ATmega328P) is used for executing real-time monitoring and controlling activities at a 16MHz clock speed along with 32KB flash memory. The unit continuously handles analog inputs from current sensors (through its 10-bit ADC channels) and digital inputs from obstacle detection modules, running pre-programmed safety algorithms with deterministic response times below 100 μ s. It handles several concurrent tasks such as: power allocation logic that implements 6A/section current limits; signal processing for ultrasonic obstacle detection (HC-SR04 sensors); and emergency protocol execution that triggers relays within 500ms of fault detection.

3. Alert System

The alert system is a mission-critical module intended to facilitate prompt response in case of emergencies through the provision of real-time alerts over several redundant channels. Focused on the Node MCU ESP8266 module, it combines both visual and audio alarms.

4. Data Logging System

The data logging system is the forensic backbone of the railway safety infrastructure, utilizing a multi-tiered structure to acquire, process, and store operational data with industrial-grade dependability. At its essence, a custom Python stack on a Raspberry Pi 4 gathers 15+ parameters at 100Hz sampling rates (such as current waveforms through ADS1115 16-bit ADC, obstacle sensor telemetry, GPS coordinates, and signal states) and stores raw data in compressed binary form (lossless FLAC for analog signals) with microsecond-precision timestamps.

IV. IMPLEMENTATION DETAIL

The overhead supply line is supplied by a 6A power supply, which gives the input that the trains need for their movement on the track. This supply is coupled to the microcontroller, which keeps checking the levels of the current in the overhead line for safe and efficient operation. The microcontroller ensures that the power is well-regulated and that the trains are being the supply line from the overhead is also connected with a controller sensor, whose duty is to monitor continuously the consumption of current by trains. The current sensor keeps a tab on the power consumed by the trains from the overhead lines in real time. The current sensor sends a signal to the microcontroller whenever the current consumed crosses a pre-specified threshold, indicating any fault or overload.

4.1 Process of Implementation

The system includes several key components that help in effective monitoring and control of railway operations. The current sensor is an important one that continuously measures the levels of current in the overhead supply line. It is vital for identifying anomalies and alerting the relay to cut off the circuit when the current goes above safe levels, helping to safeguard the system against possible overloads or faults.

The alert system is tasked with the generation and transmission of alerts to respective individuals, including train drivers and stations in close proximity, in the event of accidents or identified obstacles. The timely notification assists in averting subsequent accidents and facilitates immediate action.

The data logging system gives accurate information regarding the distance of obstacles from the train. It logs and stores this information, which is crucial for analysing and enhancing the railway safety system in the future. This component makes sure that the system develops to address safety needs effectively.

The current sensor not only keeps track of the current levels but also verifies the integrity of the power supply system. Through detection of changes or faults in the current flow, it helps to protect the electrical infrastructure and avoid

damage to attached components. Its connection to the relay system gives an automatic fail-safe feature to stop operations when needed, providing operational safety.

4.2 Demonstrative Unit

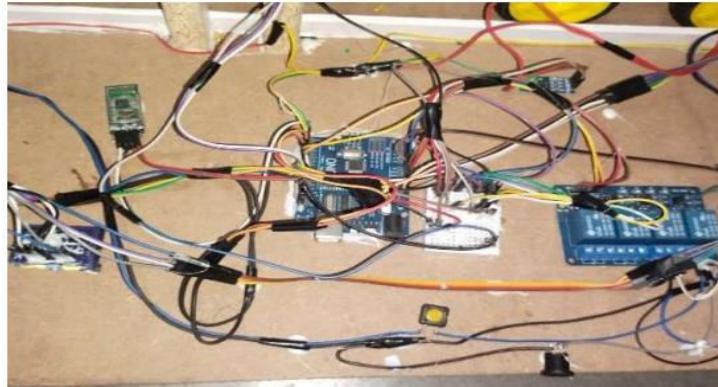


Fig 4.2: Operational model

The microcontroller, which is commonly called the system's brain, has been engineered to handle inputs from multiple sensors and perform instructions in real-time. It manages processes like detecting obstacles, transmitting data, and raising an alarm. With its capacity to handle several components at a time, the microcontroller ensures that the system runs smoothly under dynamic conditions, thus being a critical application for real-time monitoring.

4.3 Workflow Sequence

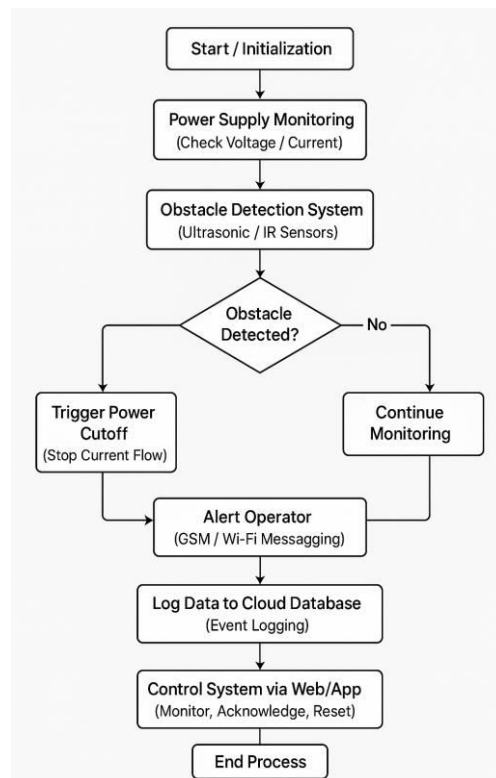


Fig 4.3: Flowchart of the process implemented

4.4 Hardware details

4.4.1 Arduino uno rev3: Arduino Uno Rev3 is a universal, easy-to-use microcontroller board, popular among electronics and embedded systems projects. Based on the Atmel ATmega328P microcontroller, Arduino Uno Rev3 offers an easy platform for development and prototyping and is everyone's Favorite, from hobbyists to educators and professionals.

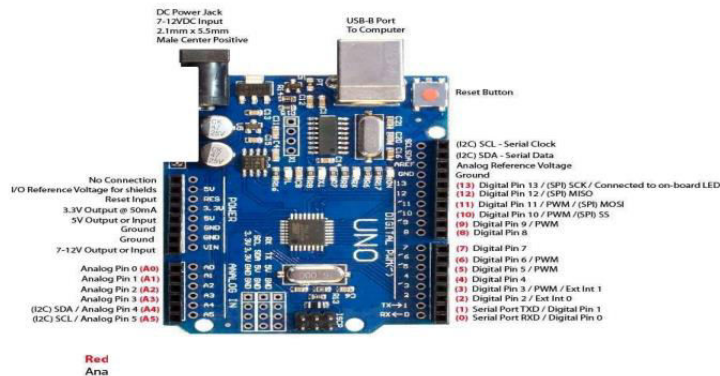


Fig 4.4.1: Arduino uno rev3

4.4.2 UV Sensor: A UV sensor is an electronic component that is intended to detect the level of ultraviolet (UV) radiation in the surroundings. UV sensors are widely applied in systems that need to monitor UV exposure, including weather stations, health devices, industrial systems, and scientific research.



Fig 4.4.2: UV sensor

4.4.3 HG 05 Bluetooth module

The HG05 Bluetooth module is a compact and universal Bluetooth communication module suitable for seamless incorporation into wireless projects. It complies with the Bluetooth 2.0 standard for effective and efficient data transmission of several applications, including IoT, robotics, and industrial automation. in automatic lighting circuits, light meters, and alarm circuits.

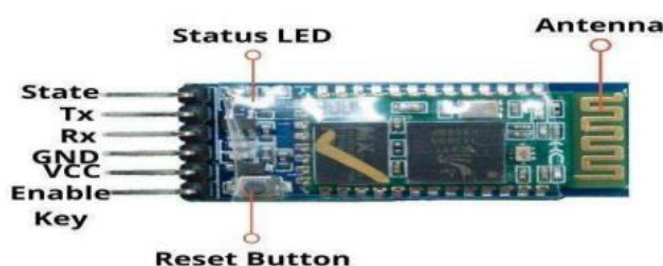


Fig 4.4.3: HG 05 Bluetooth module

4.4.4 Relay module

A relay module is an electronic device that assists in controlling high-power devices with a low-power control signal. It acts as an automatic switch, enabling devices to be switched on or off depending on sensor inputs. This automation improves efficiency, safety, and convenience in systems.

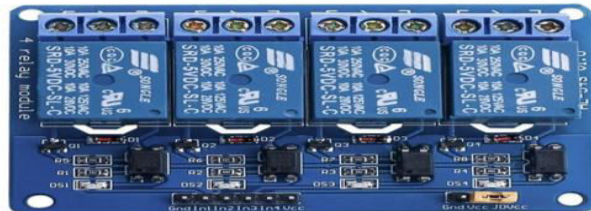


Fig 4.4.4: Channel Relay modules

4.4.5 ACS712 current Sensor

ACS712 is one of the widely used and most popular current sensors designed by Allegro Microsystems. It is Hall-effect sensing principle-based, and it allows measuring AC and DC currents in a circuit without electrical contact.

ACS712 Pinout

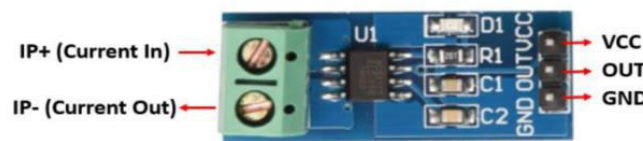


Fig 4.4.5: ACS712 current sensor

4.4.6 NODE MCU ESP8266

The Node MCU ESP8266 is a widely used development board built around the ESP8266 Wi-Fi module, intended for simple integration into Internet of Things (IoT) projects. It allows microcontrollers and other systems to connect to a Wi-Fi network, which makes it suitable for many IoT home automation, and wireless communication applications.

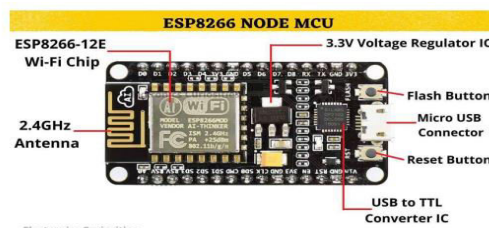


Fig 4.4.6: NODE MCU ESP8266

1.4.7 Display module

LEDs are energy efficient, have a long lifespan, and are versatile and thus a perfect solution for numerous application lighting is a contemporary and energy-saving lighting technology that has completely transformed the lighting sector. LEDs are semiconductor elements that produce light as an electric current flows through them using a phenomenon called electroluminescence. In contrast to conventional incandescent or fluorescent bulbs.



Fig 4.4.7: Display unit

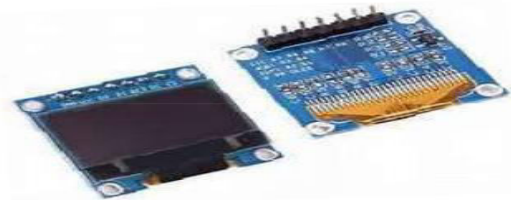


Fig 4.4.7: OLED display

An OLED (Organic Light Emitting Diode) display is a display technology that utilizes organic materials to emit light when electric current flows through them. As opposed to regular LCD displays, which need a backlight to make the pixels glow, OLED displays are self-emissive and have each pixel glow by itself. This means that the contrast ratios are higher, refresh rates are quicker, and colours are more saturated compared to standard displays.

V. FINAL MODEL

There is an ultrasonic sensor installed at the front of every train. The sensor has an important role in measuring for obstacles on the track by emitting ultrasonic waves and counting how long it takes for the waves to rebound back. From this, they determine the distance to any obstruction in the path and record it in a data logging system to reference later. The ultrasonic sensors not only sense obstacles but also supply real-time measurements of distances, which are critical in preventing collisions.

The Arduino Uno acts as the main controller for the whole system. It is set to take care of the logic and decision-making functions, for example, managing the power supply and interacting with other components such as the ultrasonic sensors and Node MCU. The push button is incorporated into the system to be used as a manual control; upon pressing the button, power is supplied to the train, and when the button is not pressed, power supply is turned off.

The project model's circuit integration is well planned with a number of interconnected elements to guarantee effective operation and safety. The Arduino is at the center of the system, serving as the master controller, directing the functioning of all other elements and guaranteeing seamless task execution. A current sensor is incorporated into the circuit to constantly monitor the electrical parameters. It determines the current consumed from the lines above and reads accurately in real time. It activates a 2-channel relay if the current crosses a limiting value of 3 amps for an overload or fault.

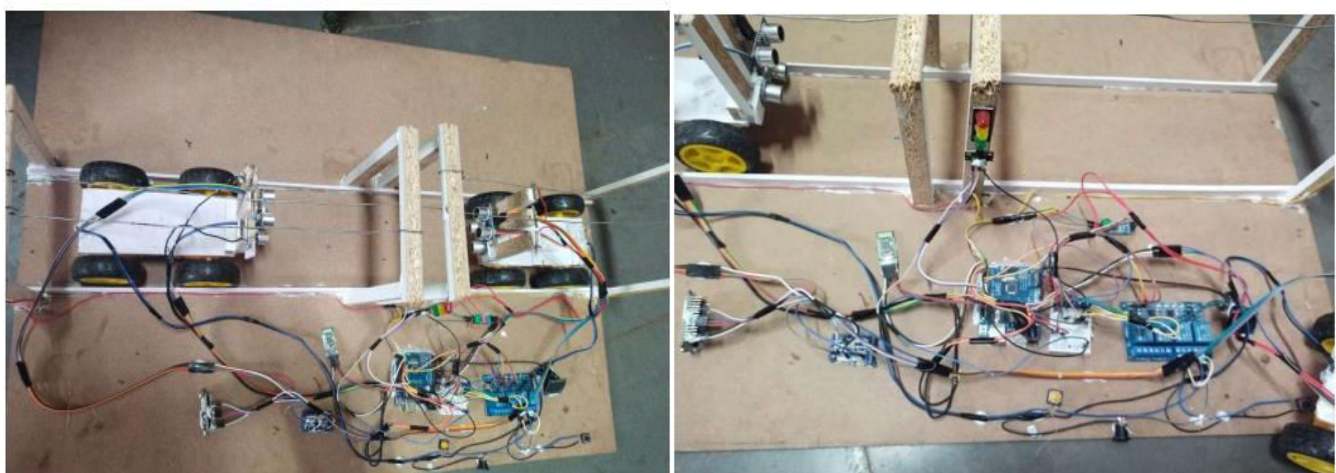


Fig 5: FINAL MODEL

VI. CONCLUSION

The Railway Monitoring and Control System needs a strong hardware and software component for real-time monitoring, control, and data logging. The hardware consists of sensors, microcontrollers, communication modules, and signal systems, while the software consists of control algorithms, a central logging system, and user interfaces for monitoring and alert management. This combined strategy ensures safe, efficient, and reliable operation of the railway system. Improves efficiency further by the Railway Monitoring and Control System is intended to improve the safety and efficiency of railway operations. It combines power supply management, obstacle detection, and signal control, with real-time data logging and alerting. The system employs different sensors, such as current sensors for power monitoring, ultrasonic sensors for detecting obstacles, and LED signals for status indication. A microcontroller interprets the data and initiates actions such as power cutoff or obstacle alerts.

REFERENCES

- [1] Mahdi Saki Mehran Abolhasan, Justin Lipman, Abbas Jamalipour-Mobility Model for Contact-Aware Data Offloading Through Train- to- Train Communications in Rail Networks! IEEE Transactions on Intelligent Transportation Systems (August 2020).
- [2] Shouyong, Z. Jimin, X. Lichao, Z. Zhenhai, and L. Jinnan, "Rail identification using camera and millimeter-wave radar data," in 2021.
- [3] K. Kyatsandra, R. K. Saket, S. Kumar, K. Sarita, A. S. S. Vardhan, and A. S. S. Vardhan, "Development of trinetra: a sensor-based vision enhancement system for obstacle detection on railway tracks," IEEE (2022).
- [4] J. Yanwei and D. Yu, "Research on railway obstacle detection method based on radar," Proc, -2021.
- [5] R. Patel, M. Goswami, "Real-Time Train Monitoring and Fault Detection Using Cloud-Based Data Logging." Journal of Transport Systems Engineering and Information Technology, 2023.



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