Advanced Train Control Mechanism Using Railway Communication Modes

B. Deepalakshmi[1] , A. Primrose[2]

M.E Student (Communication System), Chendhuran College of Engineering and Technology, Pudukkottai,

Tamil Nadu, India

Associate Professor, Head of the Department, Chendhuran College of Engineering and Technology, Pudukkottai, Tamil

Nadu, India

ABSTRACT: Railway accidents, such as collisions, conflicts, and derailments, are still happening, despite the implementation of advanced railway control systems. One of the reasons for this is the architecture employed in current systems and existing operating processes, which allow human errors to occur. This paper processes a design concept and architecture for the next generation of train control systems (NGTCS). Some key technologies, such as parallel monitoring, system-level "fail-safe", data sharing and fusion, common-mode cause error avoidance, and the illegal or incorrect operation of alarms by railway workers, are considered. This paper also details the principle and method of parallel monitoring for some key operations such as train tracking interval, interlocking, and train speed limit protection.

KEYWORDS: Collisions, Derailments, Control Systems, Parallel Monitoring,

I. INTRODUCTION

In order to reduce life cycle costs of a building from construction to maintenance, it is very effective to monitor the structural health of a building. To generalize structural health monitoring of a building, establishment of a low-cost sensor system is desired. In current high-speed train signaling systems, CTC, ATP and CBI are autonomous systems. These types of systems are not able to solve problems caused by control system failure. Equally, they are unable to prevent train accidents caused by wrong-side failures. The shortcomings of autonomous systems can be complemented by implementing heteronymous control systems. Each control element should utilize different methods for collecting signaling data, transmission channels, transmission media, and processing functionality. By realizing such full independence, common-mode cause errors can be mitigated.

The introduced parallel monitoring system is not used as control equipment and only provides monitoring and alarm for both the process of principal control equipment and the human activities. The behavior of parallel monitoring system does not endanger traffic safety but increase system capability of danger identification. The other factors such as reliability, the completeness of data acquisition, and the effectiveness and real time of monitoring will be considered. Train collision accidents still happen worldwide in train operations. Based on some reports, signaling system failure is one of the most significant causes of such accidents. Illegal or incorrect operations by railway workers are one of the most significant causes of railway accidents. It is necessary to improve the skills of workers to avoid these types of accident.

Obstacle Sensor 1 and obstacle Sensor 2 are used for finding any vehicles are located into the railway track. If any vehicles or animals are in the track at the time of train arrival buzzer sound is produced for intimation. Velocity sensor in our project is used for finding the speed ratio of the train. If the speed limit exceeds normal range, then buzzer sound is produced. Ultrasonic Sensor is used for finding any human intervention is there or not. Eddy current Sensor is used to find out whether the train is correctly placed in the track or slipped from the track.GNSS Module is used to find the train location.

The aim of railway signaling systems is to ensure safe and efficient train operations. To ensure safety, relay- or computer based interlocking systems provide an adequate operational train route (i.e., to avoid collisions). Additionally, systems such as automatic train protection (ATP) are used to prevent speeding and to keep headway between trains. To ensure efficient operation with no conflicts, route setting and conflict avoidance are used. The

operation of the train and signaling systems is monitored by centralized traffic management systems, which guarantee safe train operation with speeding prevention, adequate headway, and the ability to manage train routing. A failure in any of the signaling subsystems can potentially lead to a serious accident.

Railway accident reports from recent incidents suggest that current signaling systems may have design defects due to the commonly employed architecture. For example, during the accident on the Yongwen Line, the signaling system did not reach a "fail-safe" state when a failure occurred, which led to the train collision. Previous accidents caused by signaling system failure had occurred on China's network. A train accident occurred on the Jiaoji Line in China when the signaling system did not enforce a speed restriction correctly. Such incidents, although rare, suggest that it is necessary to reconsider the design of railway signaling systems.

A.   Deficiencies in the Existing Train Control System

High-speed train signaling systems have the following disadvantages in their architecture, integration process, and operation.

The high-speed train signaling systems require the integration of a number of subsystems, such as the a forementioned signaling subsystems and support systems. Correct system integration is a key technology to ensure system safety. Train control functional requirement specification, a system requirement specification, functional interface specification (FIS) and form-fit FIS are used as key standards for system integration. The development of current high-speed train control systems focuses on the interface between different subsystems and devices. However, these subsystems and devices are usually developed at different times; hence, it is difficult to ensure that they operate in the most efficient way. Consequently, subsystem monitoring and alerts, critical safety control parallel monitoring, and system-level "failsafe" design are generally not considered.

In current train control systems, the train tracking interval and speed protection are achieved using ATP systems. The train operation will be affected if ATP cannot calculate the correct train tracking intervals and safe braking distances due to signaling system failures, data acquisition faults, communication transmission errors, and other issues.

The interlocking system is the only system to set train routes. However, interlocking operations, operation logic, and track occupation are not monitored at a system level; furthermore, incorrect operations made by signalers, incorrect train route setting, consistency with the timetable, and the interlocking device state are also not monitored.

The process of setting and transmitting TSR data is not adequately monitored. Although the methods for the transmission and management of TSRs have been changed in CTCS-2 and CTCS-3, safety issues still exist. The accident that occurred on the Jiaoji Railway on April 28, 2008, happened due to this safety defect.

Nowadays, train dispatchers monitor train positions, speeds, signaling states, block occupation, and system devices through CTC screens and monitors. Due to heavy workloads, it is almost impossible to monitor train operations manually without any oversights.

Various rules and regulations exist to guide operational and maintenance staff. Variability in the level and adequacy of training may result in staff having insufficient experience to deal with atypical events, which may increase the risk of errors being made. Any illegal or incorrect events may lead to accidents.

B.   Principles of NGTCS

The principles of NGTCS are as follows:

1) Implementation of systems theory and parallel monitoring, optimization of system architecture, full data sharing and fusion, and maximization of system performance;

2) Parallel monitoring of train tracking interval, train route setting, train speed protection, and TSR protection;

3) Decentralized autonomous train control technology integrated with system-level heteronomous monitoring (when any subsystem fails, the parallel monitoring should raise an alarm to alert staff of an abnormal condition);

4) Application of "fail-safe" principles at all levels of the system;

5) Implementation of an independent parallel monitoring regime, using different data acquisition technologies, transmission methods, and software applications to avoid common-mode errors;

6) Monitoring of incorrect behavior by workers during driving, operation, maintenance, and management.

It is necessary to parallel monitor not only safety-critical functions but also human behaviors. It is also important to implement heteronomous monitoring for system states, train operations, and system applications.

II. RELATED WORK

The NGTCS has an architecture similar to most modern train control systems, but with the addition of parallel monitoring hardware. However, the majority of the new key functionality is achieved through modifications to existing software. Based on the framework of current control systems, the new system is designed to meet requirements such as data acquisition, data transmission, data processing, and alarm control. The system will achieve system-wide failure monitoring, data sharing and integration, dual-channel structure, and common-mode cause error avoidance. It is able to implement ATP-and-CTC-based tracking-interval parallel monitoring, CBI-CTC-based train route setting, onboard-ATP-and-trackside-ATP-based train speed limit protection, ATP-and-CTC-based temporary speed limit protection, and MMS-and-DMS-based control operation.

In current high-speed train signaling systems, CTC, ATP, and CBI are autonomous systems. These types of systems are not able to solve problems caused by control system failure. Equally, they are unable to prevent train accidents caused by wrong-side failures. The shortcomings of autonomous systems can be complemented by implementing heteronomous control systems. In the new combined system, the subsystem outputs are linked to each other; therefore, if a failure occurs in any of the subsystems, the parallel monitoring system will alert the user and/or override an individual control system.

In current signaling systems, the "fail-safe" functionality is widely implemented at the device and component levels. However, the "fail-safe" functionality has not been previously applied at the system level. ATP, CBI, and CTC use autonomous control methods, in which each system works independently without supervision from any of the other subsystems. This means that, currently, if one of the subsystems has a functional failure, none of the other subsystems are aware of the problem. In the train collision that occurred on July 23, 2011, the "failsafe" function did not implement following the ATP subsystem failure. If the "fail-safe" functionality had been implemented at the system level, rather than at the device level, the accident may not have occurred.

It is necessary to consider reliable application channels or monitoring patterns at the system layer in order to achieve the system-level "fail-safe". The channels or patterns should consider consistency checking standards in order to ensure the correctness of the outputs. System-level diagnosis is the premise of achieving the system-level "fail-safe". The parallel monitoring pattern between subsystems provides a hardware base for the system-level diagnosis. The methods of system-level diagnosis include monitoring between subsystems, data completeness detection and analysis, train-operation-case-based (DMS and MMS) real-time data analysis, and failure-database-based intelligent diagnosis systems.

In current signaling systems, most ATP and CBI control hosts use 2 out of 2 or 3 out of 2 hardware redundancy structures. Furthermore, different hosts use different software visions to avoid calculation mistakes and common-mode cause errors. Such a redundancy structure uses one input source. If any failure occurs to the input, there is nothing the redundancy can do. The only way to avoid common-mode cause error is by achieving a full dual channel for data collection, data transmission, and channeling. The use of parallel monitoring is able to meet this requirement.

In fact, according to current railway regulations, a number of specific arrangements have already been put into practice. In the parallel monitoring system, not only the devices but also the workers' operations will be supervised. Based on the railway regulations, all illegal and incorrect operations will be alerted.

By crack detection sensor which consists of an RFID tag and electrically conductive material, continuity of the electrically circuit can be known from the propriety of radio communication. Crack detection is possible from continuity condition. Passing Ultra Sonic Frequency to the track manually. Ultrasonic beam is directed towards the flaw in any angle. Monitoring of incorrect behavior by workers during driving, operation, maintenance, and management.

III. PROPOSED APPROACH

In this proposed approach, controlling the speed of the train using Velocity Sensor. By passing Eddy current to the track for identify Derailment of trains. Passing obstacle sensor between the tracks to find the obstacles near to the crossing. Real time location finder.

A.   Localization Algorithm
It is used for estimating the distance between the train and control station.
pinMode(echoPin, INPUT);

```
cm = microsecondsToCentimeters(duration);
  Serial.println("Distances in cm :");
  Serial.println(cm);
if(cm<=100){
  trainStop();
  lcd.setCursor(0,1);
  lcd.print("TRAIN STOPPED ");
 }
 else{
 lcd.setCursor(0,1);
 lcd.print(" TRAIN MOVING ");
 trainStart();
 }
void trainStart(){
  digitalWrite(mot1,HIGH);
  digitalWrite(mot2,LOW);
}
void trainStop(){
  digitalWrite(mot1,LOW);
  digitalWrite(mot2,LOW);
}
long microsecondsToInches(long microseconds)
{
 return microseconds / 74 / 2;
}
long microsecondsToCentimeters(long microseconds)
{
  return microseconds / 29 / 2;
}
```

B.   Hip-Hop Algorithm

It is estimating the track boundaries and provides prediction and innovation steps to make the train remain safe.

```
pinMode(echoPin, INPUT);
duration = pulseIn(echoPin, HIGH);
inches = microsecondsToInches(duration);
if((l>0)&&(l<20)){
   trainStop();
   lcd.setCursor(0,0);
  lcd.print(" TRACK 1 STATUS ");
  lcd.setCursor(0,1);
  lcd.print("  DERAILMENT   ");
  gpslocation(8.615833,76.923518); lcd.clear();
 }
if((r>0)&&(r<20)){
   trainStop();
   lcd.setCursor(0,0);
  lcd.print(" TRACK 2 STATUS ");
  lcd.setCursor(0,1);
  lcd.print("  DERAILMENT    ");
}
```

IV. ARCHITECTURAL DESIGN

This System consists of Microcontroller unit, LCD Display, Sensors like obstacle Sensor,Velocity Sensor and Ultrasonic. Sensor that is feed back to Microcontroller unit. Arduino Uno having 6 ADC Pin with 10 bit resolution. Obstacle Sensor 1 and Obstacle Sensor 2 are used for finding any vehicles are located into the railway track. If any vehicles or animals are in the track at the time of train arrival buzzer sound is produced for intimation. This sensor is connected to analog channel of Arduino Board. If it generates very low resolution say e.g. 8 bit resolution then obstacles is find in the track. If it generates 0 to 5 bit resolution then there is no obstacle is find. Display is connected with Digital IO's for displaying sensor values and others. Derailment is connected to Analog 1st Channel which generates 0-1023 resolution i.e. 10 bit values. How it generates up to 1023 values when the track communicates with the train it generate 1023 values. If not means wheel get slipped from track that time sensor generate values less than 511. If this condition achieved the buzzer makes the beep thrice. This Sensor is used to find out whether the train is correctly placed in the track or slipped from the track.
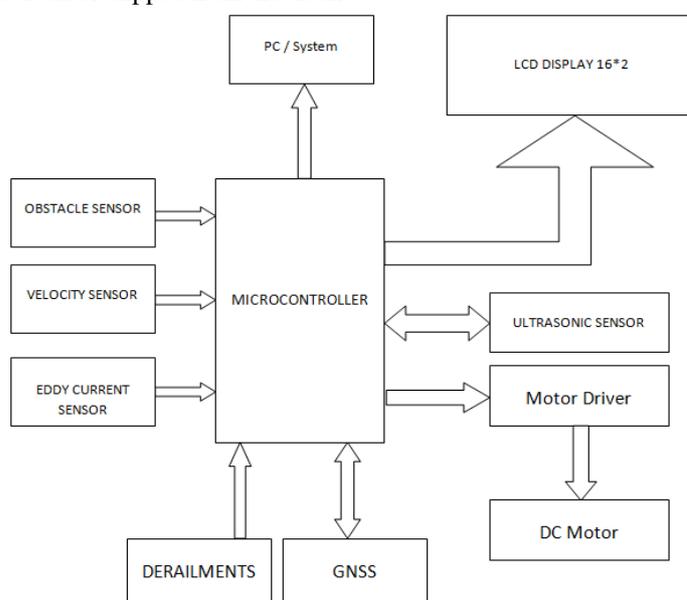
Fig.1 Block Diagram

Velocity Sensor in our project is used for finding the speed ratio of the train. Single- and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration, as a vector quantity, and can be used to sense orientation, coordinate acceleration, vibration, shock, and falling in a resistive medium. Most accelerometers are Micro-Electro-Mechanical Sensors (MEMS). The basic principle of operation behind the MEMS accelerometer is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams. Consistent with Newton's second law of motion ($F = ma$), as an acceleration is applied to the device, a force develops which displaces the mass. The support beams act as a spring, and the fluid (usually air) trapped inside the IC acts as a damper, resulting in a second order lumped physical system. This is the source of the limited operational bandwidth and non-uniform frequency response of accelerometers. If the speed limit exceeds normal range, then buzzer sound is produced. Ultrasonic Sensor is used for finding the obstacles or any human intervention is there or not. GNSS Module is used to find the train location.

V. MODULES

The overall modules are:
1.   Microcontroller
2.   Android Based GNSS Module

3.   LCD Display
4.   Ultrasonic Sensor
5.   Velocity Sensor
6.   Obstacle sensor
7.   Eddy current Sensor

1.   Microcontroller

The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The resulting architecture is more code efficient while achieving throughputs up to ten times faster than conventional CISC microcontrollers. The ATmega328 provides the following features: 32Kbytes of In-System Programmable Flash with Read-While-Write capabilities,1Kbytes EEPROM, 2Kbytes SRAM, 23 general purpose I/O lines, 32 general purpose working registers, three flexible Timer/Counters with compare modes, internal and external interrupts, a serial programmable USART, a byte-oriented 2-wire Serial Interface, an SPI serial port, a 6-channel 10-bit ADC (8 channels in TQFP and QFN/MLF packages), a programmable Watchdog Timer with internal Oscillator, and five software selectable power saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, USART, 2-wire Serial Interface, SPI port, and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the Oscillator, disabling all other chip functions until the next interrupt or hardware reset. In Power-save mode, the asynchronous timer continues to run, allowing the user to maintain a timer base while the rest of the device is sleeping. The ADC Noise Reduction mode stops the CPU and all I/O modules except asynchronous timer and ADC, to minimize switching noise during ADC conversions. In Standby mode, the crystal/resonator Oscillator is running while the rest of the device is sleeping. This allows very fast start-up combined with low power consumption.

2.   Android Based GNSS Module

The SPI interface allows for the connection of external devices with a serial interface. The interface can be operated in master or slave mode. In master mode, one chip select signal is available to select external slaves. In slave mode a single chip select signal enables communication with the host. The I2C compatible DDC interface can be used either to access external devices with a serial interface EEPROM or to interface with a host CPU. It is capable of master and slave operation. NEO-6 modules allow an optional external serial EEPROM to be connected to the DDC interface. This can be used to store Configurations permanently.

3.   LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on. A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD.

4.   Ultrasonic Sensor

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit. The basic principle of work. Using IO trigger for at least 10us high level signal. The Module automatically sends eight 40 kHz and detect whether there is pulse signal back. IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning. Test distance = (high level time× velocity of sound (340M/S) / 2.

5. Velocity Sensor

ADXL335 is a complete 3 axis Velocity measurement system.it contains Polysilicon Surface-micro Machined sensor and signal conditioning circuitry to implement an open loop velocity measurement architecture.so the ouput signals are analog voltages that are propotional to Velocity .it applications as well as dynamic velocity resulting from motion, shock,or vibration.hence the deflection of the structure I measured using diferential capacitor that consists of independent fixed plates and plates attached to the movig mass are driven by 180 degree out of phase square waves.it deflects and unbalanced the differential capacitor resulting in a sensor output whose amplitude is propotional to velocity.

6. Obstacle Sensor

The operating principles of reflex sensors are similar to those of transmissive sensors. Basically, the light emitted by the transmitter is influenced by an object or a medium on its way to the detector. about 45°. This is an advantage in short distance operation. The main difference between reflex couplers and transmissive sensors is in the relative position of the transmitter and detector with respect to each other. In the case of the transmissive sensor, the receiver is opposite the transmitter in the same optical axis, giving a direct light coupling between the two. In the case of the reflex sensor, the detector is positioned next to the transmitter, avoiding a direct light coupling. The transmissive sensor is used in most applications for small distances and narrow objects. The reflex sensor, however, is used for a wide range of distances as well as for materials and objects of different shapes.

7. Eddy Current Sensor

Eddy current sensor has passed as a reference current to the track manually finding the distance using GNSS measuring using the localization and hiphop algorithm finding the distance between the track 1 and track 2 status analysing the Derailment .

VI. CONCLUSION

Based on systems theory and system integration style, the NGTCS improves each train system potency and system safety and intelligence levels exploitation parallel watching, system-level "fail-safe", knowledge sharing and fusion, common mode cause error shunning, and alarms for hot or incorrect operations by railway employees. It parallel monitors the signal system's crucial subjects, like chase interval, train route setting, train speed protection, and TSR. The NGTCS is additionally able to create knowledge comparisons and do knowledge confirmation between systems. If incorrect outputs or system failures occur, the system can do system-level "fail-safe" so as to confirm the protection of train operations. CTC-and-ATP-based chase-interval parallel watching improves the responsibleness of train tracking intervals by 4.52×10^4. Parallel watching of all crucial subjects is in a position to boost the responsibleness and therefore the safety of the complete train system. NGTCS can have an additional fusion with transportation organization, dispatching command, operation management, and employee's operation superintendence.

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