The evolution of computer-based railway signalling interlocking systems

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INTRODUCTION

Over the last 200 years, worldwide railway expansion has resulted in a significant transformation in public transportation. The railway signaling system has progressed from directing trains by humans on horses to complex technologies based on network technology, computer technology, and electrical technology as the railway has evolved. Additionally, the railway interlocking system (RIS) went through multiple stages of mechanical interlocking, relay interlocking, and computer-based interlocking or communications-based signalling systems.

The paper examines the history of essential railway signaling equipment and concentrates on the evolution of interlocking systems. An interlocking, on the other hand, is described as the system in in charge of safe train routing and equipment monitoring inside the station's boundaries. The risk management of the computer-based interlocking system's life cycle has greatly improved, and it will undoubtedly be the primary railway signal system (Li, 2014).

The emphasis is only on the growth of interlocking equipment at railway stations. Section 2 methodology illustrates the research methodologies and techniques. Section outcomes deconstructs the important outcomes and maps the industrial revolutions against traditional trackside signaling systems. Finally, the results give a comprehensive perspective of the evolution of signaling systems and asset management across time.

MATERIALS & METHODS (METHODOLOGY)

This paper adopts the qualitative approach and the research strategy employed was a case study. The study uses the exploratory case study. The data collection methods includes use of computers as the search tools. The literature sources comes from three types of sources primary, secondary and tertiary sources (Saunders, Lewis, & Thornhill, 2011).

The data collection stage involves following the case study protocol, using multiple sources of evidence, creating a case study database, and maintaining a chain of proof. Case study research designs entail examining a small group or initiatives. Furthermore, case studies depend on numerous sources of information and typically describe a tale in chronological sequence.

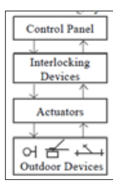
The aim of this study is to provide an overview of the evolution of the communications-based signaling system in Africa, as well as worldwide references. The study examines the systems engineering principles of verification and validation the V-Model and application of the vertical layer of cyber-security. Examination of the deployment of the European Railway Traffic Management System (ERTMS) in South African Railways.

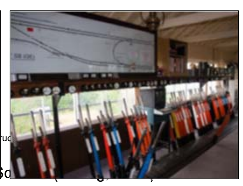
RESULTS

The first industrial revolution solution was mechanical interlocking, which coordinated train movements by employing steel bars and wires to form a grid and levers to activate switches, derailers, and signals to determine routes. Then, during the second industrial revolution (2IR), mechanical interlockings gave way to electro-mechanical interlocking, which employed a combination of power and mechanical locking to assure appropriate lever sequencing for operations. Similarly, relay interlocking emerged, which exclusively relied on electric complicated circuitry made up of relays in an arrangement of relay logic to determine the state or location of each signal element. The third industrial revolution (3IR) saw the introduction of the first modern solid-state electronic interlocking, in which wired networks of relays were replaced with software logic operating on special-purpose control hardware.

According to (Li, 2014), computer-based interlocking systems are the result of advances in information technology, computer technology, and communication technology. Furthermore, (Li, 2014) emphasizes that the computer-based interlocking system is powerful, informative, and safe, which is critical to the quality of transportation and the efficiency of work in a railway station.

Figure 1 displays the railway interlocking signalling system in three stages, according to (Huang, 2020): mechanical interlocking system, relay interlocking system, and computer-based interlocking system.





As explained by (Bădău, 2022), to maintain a consistent approach in electronic interlocking design, several nations have developed standards that must be followed by all manufacturers. For example, current British SSI (Solid State Interlocking), Japanese SMILE (Safe Multi-processor for Interlocking Equipment), and other Original Equipment Manufactures (OEM) are included.

The evolutionary road to cloud-based signaling systems, according to (Mobility, 2018), offers safety and capacity. Additionally, it eliminates trackside infrastructure, cable costs, and combines interlocking devices with a strong communications layer. South African Railways both Freight and Commuters are modernizing the mechanical, electro-mechanical, relay to computer-based interlockings which includes train control systems.

CONCLUSION

Finally, the global signaling system is progressing toward cloud-based or computer-based Communications Signalling Systems. Interlocking systems fulfill safety integrity levels 0 - 4, and cybersecurity is incorporated into the solution from the start (Thales, 2022). The drivers includes:

- Safety.
- High availability.
- Adopting digitalisation (IoT and database decision-making approach).
- Reduction in 'traditional' trackside infrastructure to minimise vandalism, theft & decrease operating costs (OPEX) of maintenance.
- Standardisation and Interoperability
- OEM independence

Cloud-based Train Control Systems can offer high availability systems that can be swiftly installed at reduced costs by consolidating CTCs and utilizing economies of scale due to universal, reliable, and high bandwidth connections.

(George, 2020) concludes that ETCS and PTC are used alongside with CBI systems to evolve in preparation for future trackside infrastructure rationalization. Future research will focus on the growth of cloud-based communications systems that integrate satellite and terrestrial communications networks.

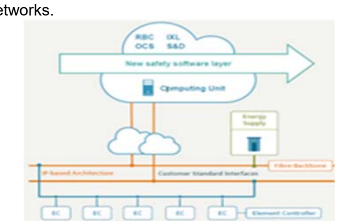


Figure 2 – Cloud-Based Interlocking Architecture

Source: (Mobility, 2018)

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