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A e-Magazine dedicated to Electrical Engineers on Indian Railways

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From the pen of the Guardian

Dear Readers,

We are pleased to present the second issue of the IRIEEN e-Journal following its revival in 2026 after a hiatus of nearly two years. This issue brings together a diverse collection of technical articles, covering a wide range of subjects and varying levels of depth. We are confident that these contributions will prove both informative and valuable to our readers. IRIEEN remains committed to delivering high-quality training to railway officers and supervisors. The publication of this e-Journal is another important initiative in that direction, serving as a platform to share technical knowledge, practical insights, and advancements in emerging technologies. It also enables the valuable experience and expertise of both our retired Electrical fraternity and serving professionals to be documented and disseminated for the benefit of the wider community. We encourage all readers to circulate this Journal widely within their professional networks. Your feedback is equally important to us—constructive suggestions will help us further improve the quality and relevance of future issues. We also invite contributions in the form of technical articles, case studies, and field experiences for upcoming editions. We look forward to your continued support and active participation in making this initiative a meaningful and enduring success.

(Ishaq Khan)

IRSEE-Batch-87

Director General, IRIEEN

Through the eyes of the Deputy Guardian

We are pleased to announce that the vol 34th and issue no 1 of the "IRIEEN e-Journal"- a quarterly magazine published by the IRIEEN Institute, Nashik Road—for the period of January–March 2026 has been released. This issue features specialized and valuable research papers and articles that will prove to be highly informative for the entire fraternity of Indian Railway. The articles contained in this issue provide insights into various subjects of Electrical branch, which will undoubtedly prove beneficial for staff and officers of Electrical Department.

(Pramod B. Gadre)
Additional Director General,
IRIEEN

Editorial

It gives us great pleasure to announce the publication of the quarterly "IRIEEN e-Journal," for the quarter “January-March" 2026 issue (Volume 34, Issue 1 no). This issue contains 10 articles primarily focused on Railway Electrical Engineering, which will assist electrical engineers of Indian Railways in gaining a better understanding of various subjects related to the field. Your suggestions for further improvement are always welcome. This journal also dedicates ample space to our Hindi-speaking readers. With the objective of promoting the usage and dissemination of the Hindi language, we invite technical articles from the Institute's faculty members and other railway officials who wish to publish their work in Hindi. We hope you find this journal informative and useful, IRIEEN look forward to receive your valuable feedback.

(Hari Ram)
Senior Professor (TRD)
IRIEEN

History of Railway Electrification: Global and Indian Railways Perspective

PRAMOD B. GADRE
Additional. Director General
IRIEEN

Abstract:

The history of railway electrification marks a transformative journey in the development of global transportation systems, replacing traditional steam locomotives with electric-powered trains. Beginning in the late 19th century, early experiments with electric railways were conducted in Europe, notably in Germany and England, paving the way for widespread adoption. Over time, countries such as Japan and France advanced high-speed electric trains, revolutionizing both passenger and freight transport. In India, railway electrification began in the early 20th century, but significant progress only occurred after independence. The Indian Railways electrification effort accelerated in the 1960s and 1970s with the introduction of 25 kV AC systems, and today, India aims for complete electrification by 2025, with a goal to achieve carbon-neutrality by 2030. This article explores the global history of railway electrification, high-lighting key milestones, technological advancements, and India's efforts to modernize its railway network, ensuring sustainability and efficiency in the future.

► Introduction

Railways have been one of the most efficient modes of transportation for both passengers and freight, contributing immensely to the industrial revolution and the global economy. From their humble beginnings in the early 19th century, railways have evolved significantly, incorporating various technological advancements. One of the most important of these advancements is the electrification of railways, which has led to more efficient, cleaner, and faster trains. This article explores the history of railway electrification around the world, with a special focus on India's electrification journey.

► The Early Beginnings of Railway Electrification

The concept of electrification in railways emerged in the late 19th century. The initial experiments with electric locomotives took place in the 1870s and 1880s, predominantly in Europe and North America. Before electrification, steam engines were the primary source of power for trains, which posed several limitations such as high fuel consumption, pollution, and the need for frequent maintenance.

One of the first major breakthroughs came in the 1870s when the German engineer Werner von Siemens developed a practical method for powering trains with electricity. Siemens demonstrated the first electric railway in Berlin in 1879. The system was based on a third rail supplying electric current, which powered an electric locomotive. This was the beginning of the transition from steam-powered trains to electric trains.

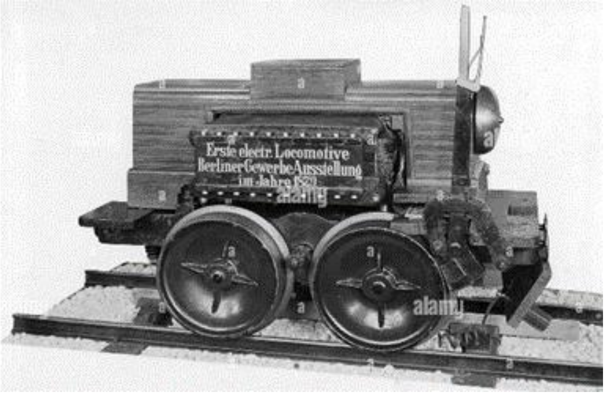

Fig: First electric locomotives, such as the one developed by Werner von Siemens in Berlin.

The world's first electric railway to operate regularly was the Volk's Electric Railway in Brighton, England, which opened in 1883. However, it was the electrification of the South East-ern Railway in London in 1905 that marked a significant milestone in the adoption of electric trains for urban transportation.

► Early 20th Century Developments

The early 20th century saw several countries experimenting with electrification for different types of railway networks. In the United States, the Pennsylvania Railroad started electrifying its tracks in the early 1900s. However, it was in Europe, especially in Switzerland, that electrify-cation took off. The Swiss Federal Railways (SBB) electrified its main routes by 1920, paving the way for more widespread adoption.

By the 1930s, several countries, including Germany, the United Kingdom, France, and Japan, began electrifying their railways to replace steam engines. The introduction of the electric locomotive, which could pull heavier loads at higher speeds, offered a significant advantage over steam engines. Electrification also allowed for better acceleration and a more consistent power supply, leading to improvements in scheduling and operational efficiency.

► The Golden Age of Electrification

The post-World War II period saw a boom in railway electrification across the world, driven by the need for more efficient transportation systems and reduced reliance on fossil fuels. One of the key drivers of electrification during this period was the rapid expansion of high-speed rail services.

In the 1950s and 1960s, countries like Japan and France introduced high-speed electric trains. The Shinkansen, or "Bullet Train," introduced in Japan in 1964, was one of the first mass-produced high-speed electric trains in the world, traveling at speeds exceeding 200 km/h. This milestone revolutionized the way people traveled, providing a model for other nations to follow.

Fig: First Bullet train being inaugurated in Japan in 1960

In Europe, countries like France and Italy also made significant strides in electrifying their railways, using a variety of electrification systems, including overhead lines and third rails. The French TGV (Train à Grande Vitesse) network, which began in the 1980s, is now one of the fastest and most efficient electric railway systems in the world.

► Railway Electrification in India

India's railway system, one of the largest in the world, has undergone substantial changes in its infrastructure and operations since its inception in the mid-19th century. The introduction of electrification to Indian Railways began in the early 20th century but did not see widespread adoption until the 1980s.

1. The Early Years of Electrification in India

The first experiment in railway electrification in India took place in 1925, when a 10 km stretch of track between Bombay (now Mumbai) and Pune was electrified using a 1500-volt DC system. However, due to various technical and financial challenges, this experiment was short-lived, and steam locomotives continued to dominate the Indian railway network for decades.

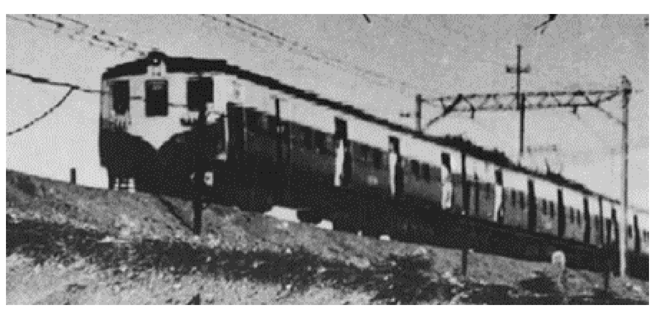

Fig: First DC Electric traction train in Mumbai

2. Post-Independence Electrification

After India gained independence in 1947, the need for modernization and expansion of the railway network became more pressing. The Indian government recognized the importance of electrification to improve efficiency, reduce dependence on coal, and minimize air pollution. In the 1960s, Indian Railways began experiment-ting with 25 kV AC (alternating current) electrification, which had proven successful in Europe.

In 1967, the first major stretch of Indian Railways was electrified with 25 kV AC systems, on the Howrah-Delhi route. This marked the beginning of large-scale electrification in India. Over the next few decades, several important routes across the country, including Delhi-Mumbai and Chennai-Hyderabad, were electrified.

3. Modern Era and Ambitious Electrification Plans

In the 1990s and 2000s, the pace of electrification in India accelerated significantly. The Indian government set ambitious targets to electrify more than 60% of its railway network, a move that would reduce fuel costs and improve environmental sustainability. By 2018, India had electrified approximately 60% of its rail network, and by 2025, the goal is to achieve 100% electrification.

One of the key milestones in India's electrification journey is the shift from DC (direct current) to AC (alternating current) systems, which are more efficient and better suited for long-distance trains. The electrification of high-density corridors, like the Delhi-Mumbai and Delhi-Howrah routes, has significantly improved the speed, efficiency, and environmental footprint of Indian Railways.

4. Future of Electrification in India

As part of its modernization efforts, the Indian government aims to make the entire railway system carbon-neutral by 2030. This includes not only electrifying all routes but also adopting renewable energy sources such as solar power to run trains. Projects like the installation of solar panels on railway stations and trains are already in progress.-

Fig: Proliferation of Electric traction for high speed

► Trends in Railway Electrification in Global and Indian context

Globally, the trend towards railway electrify-cation is intensifying as countries look to reduce their carbon emissions and improve the efficiency of their transport systems. Europe and East Asia have led the way in adopting high-speed electric trains, but many countries in Africa, South America, and South-east Asia are also working to electrify their railway networks to improve connectivity and reduce reliance on diesel engines.

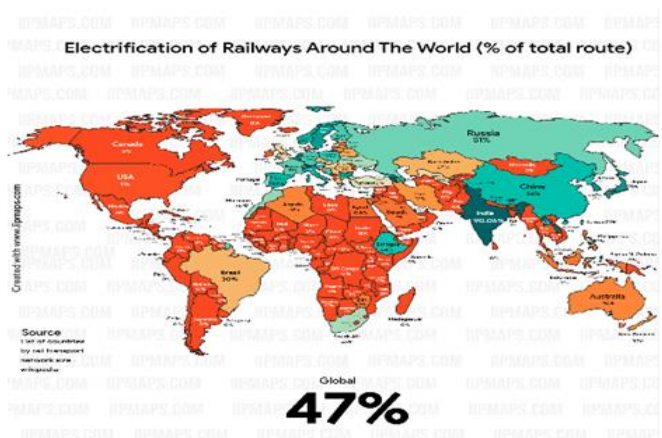

Fig: Progress of Electrification around the Globe

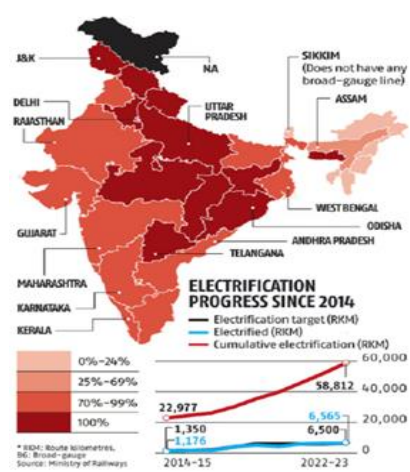

Fig: Progress of Electrification in India

Conclusion

The electrification of railways has been a critical milestone in the development of modern transport systems, significantly improving operational efficiency, speed, and sustainability. From its humble beginnings in the 19th century to the global adoption of electric high-speed trains in the 20th and 21st centuries, railway electrification has played a major role in shaping the future of transportation.

India's railway electrification journey is a testament to the country's ambition to modernize its infrastructure and reduce its carbon footprint. With the goal of achieving 100% electrification by 2025 and becoming carbon-neutral by 2030, Indian Railways is on track to lead the way in railway electrification.

The Invisible Revolution of the Modern Digital Age

In today's world, it is difficult to imagine life without the internet, and Wi-Fi plays a crucial role in bringing internet connectivity to every home.

This technology enables wireless data communication, making our lives simpler, faster, and more connected. This article presents a comprehensive and authentic analysis of various aspects of Wi-Fi.

1. Origin of Wi-Fi

The concept of Wi-Fi is based on data communication through radio waves. Its foundation was laid in the 20th century with the development of wireless communication technologies by scientists.

In the 1990s, the need for wireless networking increased, leading the IEEE (Institute of Electrical and Electronics Engineers) to develop the 802.11 standard, which became the basis of Wi-Fi technology.

The first 802.11 standard was released in 1997, capable of transferring data at a speed of 2 Mbps. Continuous improvements have been made since then.

2. History of Wi-Fi

The development of Wi-Fi has taken place in several stages:

- 1997: IEEE released the first 802.11 standard
- 1999: Formation of the Wi-Fi Alliance, giving global recognition to the technology
- 2003: Introduction of 802.11g (54 Mbps speed)
- 2009: 802.11n offered higher speed and better range
- 2019: Launch of Wi-Fi 6 (802.11ax), faster and more efficient

Today, modern technologies like Wi-Fi 6 and Wi-Fi 7 are in use, which are essential for smart devices and IoT.

3. How Wi-Fi Works

Wi-Fi transmits data through radio waves.

Working Process:

- Data comes from the Internet Service Provider (ISP) to the router
- The router converts this data into radio signals
- These signals are transmitted through the air
- Devices like mobile phones and laptops receive these signals
- Wi-Fi primarily operates on 2.4 GHz and 5 GHz frequency bands.

4. Importance of Wi-Fi

- Easy and quick access to the internet
- Boosts education, business, and communication
- Contributes to Smart Cities and Digital India
- Forms the foundation of IoT (Internet of Things)
- Wi-Fi has played a significant role in transforming the world into a "Global Village."

5. Uses of Wi-Fi in Daily Life

Wi-Fi has become an integral part of everyday life:

- Mobile usage and internet browsing
- Online education (e-learning)
- Work from home
- OTT platforms (video streaming)
- Online banking and digital payments
- Smart home devices (CCTV, Alexa, etc.)

6. Disadvantages of Wi-Fi

- Security Risks: Possibility of hacking, data theft, and cyber-attacks
- Health Concerns: Although no conclusive evidence exists, prolonged exposure raises some concerns
- Network Issues: Weak signals may lead to slow internet speeds
- Addiction: Easy access can lead to excessive internet usage

See Next Page no…20

WAG-12B Locomotive and Train Tracer System

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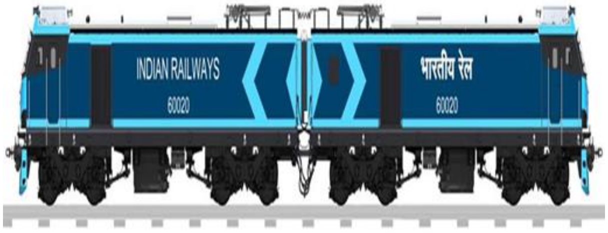
Abstract

This technical Artical describes the architecture, data flow, and operational significance of the WAG-12B locomotive and its Train Tracer system. It explains how onboard data is acquired, transmitted, stored in the cloud, analyzed through digital platforms, and utilized by maintenance depots for predictive maintenance and operational optimization.

1. Overview of WAG-12B Locomotive

The WAG-12B locomotive is a high-power (12,000 HP) three-phase electric freight locomotive developed under a joint venture between Indian Railways and Alstom. It is engineered for heavy-haul freight operations on Dedicated Freight Corridors (DFC) and conventional railway routes, with advanced traction, braking, and digital monitoring systems to ensure high reliability and operational efficiency. The locomotive is equipped with multiple control units, sensors, and communication interfaces that continuously generate operational and diagnostic data.



2. Technical Overview of WAG-12B Loco- motive

2.1 Key Specifications

- Power output: 12,000 HP
- Configuration: Bo-Bo + Bo-Bo (twin-section locomotive)
- Maximum speed: 100 km/h (upgradable to 120 km/h)
- Tractive effort: ~706 kN at 22.5 t axle load (upgradable ~785 kN at 25 t axle load)
- Axle load: 22.5 tonnes (upgradable to 25 tonnes)
- Braking: Regenerative + pneumatic air brakes
- Train haulage capability: ~6,000 tonnes
  Application: Heavy freight on DFC and IR network

The locomotive is based on Alstom's Prima T8 platform and incorporates IGBT-based propulsion technology, which improves efficiency and reduces energy consumption through regenerative braking.

3. Digital Ecosystem of WAG-12B The digital ecosystem includes:

- ICMS (Integrated Condition Monitoring System)
- CFM (Centered Fleet Monitoring)
- Train Tracer
- Onboard Control Units (TCU, TCMS, BCM, VCU, etc.)
- Communication Interfaces (Ethernet, CAN, MVB, Cellular, GPS)

These systems together form a cyber-physical architecture enabling real-time monitoring and analytics.

4. Train Tracer System Architecture

Train Tracer acts as an interface between onboard systems and cloud-based analytics platforms. It collects real-time data related to traction performance, braking, auxiliaries, compressor health, faults, alarms, and GPS location.

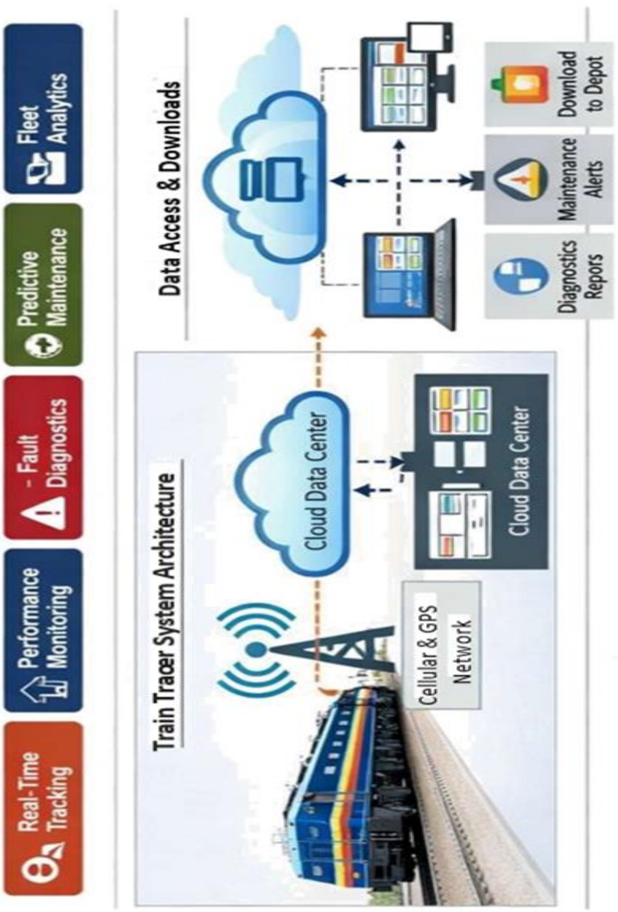
- Data acquisition layer (sensors and controllers)
- Communication layer (cellular/GPS)
- Cloud storage and analytics layer.
- User interface layer (dashboards and reports)

5. Data Flow and Cloud Storage Mechanism

- **Types of data stored in cloud:**
- Fault codes and event logs
- Operational parameters (current, voltage, temperature, speed)
- Energy consumption and regeneration data
- Health indices and trends
- GPS location and route history

6. Train Tracer Architecture Diagram

Below diagram illustrates the end-to-end data flow from locomotive to cloud and depot users.



7. Applications in Maintenance and Operations

- Predictive maintenance through trend analysis
- Root cause analysis of failures
- Reliability and availability monitoring
- Energy optimization
- Fleet performance benchmarking
- Decision support for maintenance planning

8. Advantages for Indian Railways

- Reduction in unscheduled failures
- Faster fault diagnosis
- Improved locomotive availability
- Enhanced safety and reliability
- Data-driven maintenance culture
- Digital transformation of freight operations

9. Importance of CFM Data and Train Tracer in WAG-12 Locomotives

The CFM data(Event data) is a highly vital source of information in WAG-12 locomotives. The events in CFM data are generated and recorded at millisecond intervals, providing a detailed chronological record of locomotive operations. The CFM data can be accessed and downloaded through the Train Tracer system.

CFM data is extremely useful for failure investigation and technical analysis of any abnormal or unusual occurrence in the locomotive. It monitors and records all operational events performed by the operator, such as locomotive power ON, pantograph ON demand, VCB close command, direction selector command, tractive effort (TE) demand, brake application, and other critical operational actions.

In addition, CFM data records multiple locomotive parameters, including OHE voltage, load current, speed, brake pipe (BP) pressure, brake cylinder (BC) pressure, main reservoir (MR) pressure, TE demanded, TE realized, auto brake handle position, direct brake handle position, and several other parameters. These parameters help in assessing the operational condition and health of the locomotive.

For every abnormality, there is a provision for generation of IOS alert messages for the concerned equipment, which alerts the Loco Pilot about associated equipment faults. This enables the Loco Pilot to carry out necessary troubleshooting in real time. which alerts the Loco Pilot about associated equipment faults. This enables the Loco Pilot to carry out necessary troubleshooting in real time.

The locomotive events and status can also be monitored live through the Train Tracer system, provided the locomotive is connected to the mobile communication network. Based on real-time data, engineers and control offices can guide the operator to take necessary corrective actions in case of any abnormality on the main line.

The CFM data plays a crucial role during failure investigation, as it provides a complete sequence of pre-events prior to the occurrence of a major fault. It helps in identifying the root cause of failures by correlating operational commands, system responses, and fault events.

For example, in the case of emergency brake application on the main line, CFM data enables detailed analysis of the actual cause of the emergency braking. It can determine whether the emergency brake was triggered due to traction converter failure, OHE disturbance, brake system malfunction, control system fault, or manual initiation by the Loco Pilot or Assistant Loco Pilot, or any other technical issue.

Thus, CFM data serves as a powerful diagnostic and analytical tool for engineers, supporting accurate root cause analysis, improving reliability, and enhancing maintenance strategies of WAG-12 locomotives.

10. Advantage of Cloud-Based Data

Cloud-based data enables centralized storage and real-time access to information from anywhere, improving coordination and decision-making. It enhances data reliability through automatic backup and disaster recovery, reducing the risk of data loss. Cloud platforms also offer scalability, allowing systems to handle increasing data volumes without additional infrastructure. Overall, cloud-based data improves efficiency, availability, and security while reducing operational and maintenance costs.

11. Procedure for Manual Download of Event Data from 3 Phase Locomotive

For manual downloading of event data from a WAG-9 locomotive, maintenance staff are required to physically attend the locomotive at the shed. The download is carried out by connecting an approved laptop with the requisite diagnostic software to the locomotive's onboard event recorder/diagnostic port provided in the control cab. After establishing communication with the system, the required event logs and operational data are downloaded as per the prescribed procedure. The downloaded data is then saved, verified for completeness, and forwarded to the concerned section for analysis and record purposes.

Here are clear, practical notes on the difficulties faced during data acquisition from WAG-9 locomotives, written in standard technical/railway language and suitable for reports or justifications:

12. Difficulties Faced During Data Acquisition from 3 phase Locomotives

1. Requirement of Physical Presence

Data acquisition from 3 phase locomotives requires physical attendance of maintenance staff at the shed or siding, leading to delays, especially when the locomotive is outstation or under traffic.

2. Limited Access Windows

Data can be downloaded only when the locomotive is available at the shed, resulting in missed or delayed data collection due to tight operational schedules.

3. Dependency on Laptop and Software Compatibility

Successful data download depends on availability of compatible laptops, cables, and approved diagnostic software. Software version mismatch or hardware issues often hinder data acquisition.

4. Power Supply Constraints

Data download requires adequate locomotive power supply. In cases of low battery voltage or shutdown conditions, data extraction becomes difficult or impossible.

5. Risk of Data Overwriting or Loss

Event data has limited storage capacity and may be overwritten if not downloaded promptly, leading to loss of critical failure-related information.

6.Time-Consuming Process

Manual data download and verification is time-intensive, delaying analysis and corrective action, particularly in safety-related failures.

7. Manpower Dependency

The process is highly dependent on trained manpower. Non-availability of skilled staff can result in delays or improper data extraction.

8. Environmental and Site Constraints

Poor lighting, weather conditions or limited space inside the cab can affect safe and effective data downloading.

9. Post-Event Analysis Only

Manual data acquisition supports only post-failure analysis, limiting the ability to monitor trends or detect issues proactively.

Cloud-based data is extremely helpful in technical and safety investigations because it changes the process from **delayed, manual analysis** to **real-time, evidence-based investigation**.

13. How Cloud-Based Data Helps in Investigation

1. Immediate Availability of Event Data- Event logs are available in near real time without waiting for physical data download, enabling prompt initiation of investigation after an incident.

2. Accurate Event Time Correlation- Cloud data provides precise time-stamped records, allowing accurate correlation of brake commands, system responses and operator actions.

3. Complete and Continuous Data- Continuous data logging avoids loss or overwriting of critical events, ensuring availability of complete pre-event, event and post-event data.

4. Faster Root Cause Analysis (RCA)- Investigator can quickly analyse trends, command execution and system behaviour, reducing investigation time and improving RCA accuracy.

5. Multi-Parameter Analysis- Simultaneous analysis of electrical, pneumatic, control and safety parameters is possible, helping identify inter-system failures.

6. Remote Access for Multiple Stakeholders- Data can be accessed by sheds, headquarters, OEMs and safety officers simultaneously, enabling collaborative and transparent investigations.

7. Reduction of Human Dependency- Eliminates dependency on manual downloading and handling, reducing chances of human error or data manipulation.

8. Trend and Pattern Identification- Historical cloud data helps identify recurring faults or degradation patterns that may not be evident from a single event.

9. Evidence-Based Decision Making- Provides factual and traceable digital evidence, strengthening safety reviews, audit compliance and accountability.

10. Support for Preventive Measures Insights from cloud data allow formulation of corrective and preventive actions to avoid recurrence of similar incidents. Some case studies are presented below for further reference.

14. Case studies of Technical Investigation based on Train Tracer

Case Study-1

Technical Investigation Analysis Report of issue experienced with Loco 60395

Detailed Investigation:

1. Sec-B CP has already completed 30 ON/OFF Cycles in previous 1 hour.
2. It was analysed that because of low oil level inside the compressor, temperature inside the compressor increased beyond the threshold value which triggered the thermal safety.

अल्बर्ट आइंस्टीन का कहना है, "ज्ञान से अधिक महत्वपूर्ण कल्पना है, और "आप तब तक असफल नहीं होते जब तक आप कोशिश करना बंद नहीं कर देते" ।

Loco No	UOR reported	Location	Date & Time of UOR	UOR description	Investigation Analysis
60395	Compressor	DLI NR	07.12.2025	JHJ/EBCN BLZ 60395 REPORTED BY TLC / NDLS LOCO FAILED DUE TO CP ISOLATE FRESH LOCO ARRANGE 49313	• Helpline got a call from loco pilot on 06-12-2025 stating that 'FC-153 is active' As, Sec-B CP was showing red as it has already completed 30 ON/OFF Cycles in previous 1 hour. • It was analysed that because of low oil level inside both the compressors, which resulted increase in the temperature inside the compressor beyond the threshold value. • Further, PRT attended this locomotive on 07-12-2025 itself and topped up both section CP oil and locomotive was given fit for service.

Case Study-2

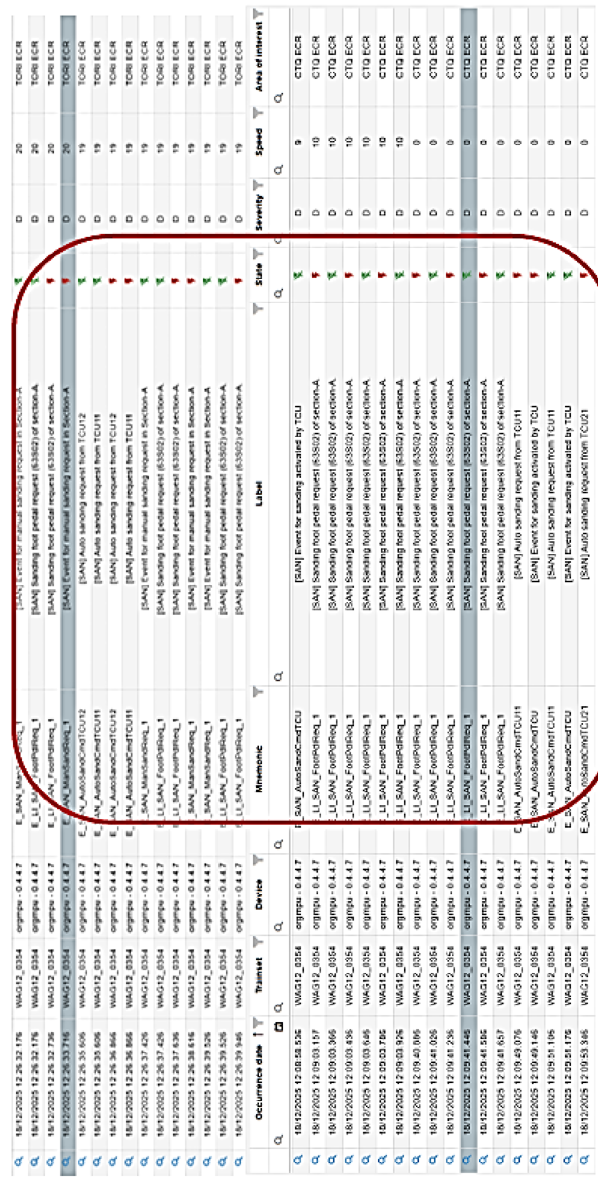
Technical Investigation Analysis Report of issue experienced with Loco 60354

Loco No	UOR reported	Location	Date & Time of UOR	UOR description	Investigation Analysis
60354	Load stalling	CTQ-TORI (DHN) ECR	18/12 /2025; 12:25 Hrs	LOCO NO.-60354 IDBR PASSED CTQ AT 12/10 HRS, PASSED IBH-11 BET. CTQ-TORI AT 12/23 HRS AND STALLED BET. CTQ-TORI AT KM. Gross weight -4931 T, Permissible weight – 6090 T, Gradient – 1:182, Curve - 4° , Sander - Working, Weather – Fair.	• Call was received in helpline at 13:45hrs and LP informed helpline that TCU22 was isolated earlier and same was normalized by him though DDU screen at 12:37hrs. • As per CFM data analysis, between 12:09hrs to 12:37hrs TCU22 remain isolated due to intermittent fault "Main pipe pressure drop information fault local". • As per CFM data chronology, loco started from standstill by 12:13 Hrs with one TCU isolated and observed a caution of 30kph and achieved 45kph speed by 12:20hrs. After that loco speed keep on decrease irrespective of around 90% effort demand in time frame of 12:20hrs to 12:28 Hrs due to continuous wheel slipping. • After loco stop at 12:29 Hrs, LP itself normalized TCU22 through DDU screen at 12:37hrs. **Findings**: • TCU22 was isolated due to intermittent issue of "Main pipe pressure information fault local" at 12:09 Hrs and LP started without normalizing TCU. Meanwhile TCU22 was normalized after load stalling at 12:37hrs and block section was cleared without assisting loco.

CFM data : As per CFM data, sanding was activated through foot pedal by LP and TCU itself, indicates continuous wheel slip was happening.

TCU Health Status: One TCU remain isolated from 12:09hrs to 12:38hrs.

उम्मीद कभी हमें छोड़ कर नहीं जाती,
जल्दबाजी में हम ही उसे छोड़ देते हैं।



Case Study-3

Technical Investigation Analysis Report of issue experienced with Loco 60325

Loco No	UOR reported	Location	Date & Time of UOR	UOR description	Investigation Analysis
60325	Loco Trouble	NGP CR	09-11-2025	WRR:-MLSW-60325(NEDA 12/01) WRR UP/L/LINE ARR-00.57,LOCO FAILLED AT 02.00,LOAD DETN & POWER SEND TO AJNI/NEDA	• TCU11 was Isolated due to 'PMCF22 IGBT dynamic no closing fault' since 22-09-2025 as observed through remote data. • Helpline again received a call from Loco pilot on 04-11-2025, stating that 'TCU 11 is isolated'. As per remote data TCU11 was isolated due to 'PMCF22 IGBT dynamic no closing fault' • When Locomotive visited depot, Troubleshooting was carried out and PMCF22 was replaced and locomotive was given fit for service.

Occurrence date	Trainset	Device	State	Label	Speed
22/09/2025 06:33:18.917	WAG12_0325	tcu11 - 2.0.14.1		ME_INH: Traction inverter 1 inhibition monitoring	
22/09/2025 06:33:18.917	WAG12_0325	tcu11 - 2.0.14.1		ME_INH: Traction inverter 2 inhibition monitoring	
22/09/2025 06:33:18.857	WAG12_0325	tcu11 - 2.0.14.1		ME_INH: Traction inverter 2 inhibition monitoring	
22/09/2025 06:33:18.857	WAG12_0325	tcu11 - 2.0.14.1		ME_INH: Traction inverter 1 inhibition monitoring	
22/09/2025 06:33:18.857	WAG12_0325	tcu11 - 2.0.14.1		-	
22/09/2025 06:33:18.582	WAG12_0325	orgmpu - 0.4.4.7		[TBS] IOS6183: TCU11 is isolated	0
22/09/2025 06:33:16.297	WAG12_0325	tcu11 - 2.0.14.1		DA_PROTPM: PMCF22 IGBT static status counted fault	
22/09/2025 06:33:16.297	WAG12_0325	tcu11 - 2.0.14.1		ME_PROTPM: PMCF22 IGBT static status fault	

CFM Data: As per remote data, TCU11 was Isolated due to "PMCF22 IGBT dynamic no closing fault."

PMCF22 – IGBT Dynamic "No Closing" Fault

Meaning of the fault : PMCF22 indicates that the **dynamic braking IGBT (chopper IGBT)** has failed to **close (turn ON)** when commanded by the traction control system. In other words, the system issues a command to activate dynamic braking, but feedback confirms that the IGBT did not close as expected.

What this implies in operation

- Dynamic braking is not effective or not available.
- Energy from traction motors is not properly dissipated through the braking resistor.
- The locomotive may rely only on pneumatic brakes, reducing braking redundancy.
- In some cases, traction effort may be reduced or isolated for safety.

Possible causes

- IGBT device failure (open circuit / internal damage)
- Gate drive circuit fault (gate signal not reaching IGBT)
- Control or feedback signal failure (IGBT status feedback mismatch)
- DC link voltage abnormality, preventing IGBT firing
- Wiring or connector issues of IGBT module

Action required

- Fault to be investigated immediately.
- Check IGBT health, gate driver card, feedback signals, and DC link parameters.
- Clear fault only after confirmation of proper IGBT operation during test braking.

Case Study-4

Technical Investigation Analysis Report of issue experienced with Loco 60265

Loco No	UOR reported	Location	Date & Time of UOR	UOR description	Investigation Analysis
60265	Load Stalling	ASO-ATG (BB) CR	05-11-2025	REW ALP- KK SAINI, TM- PAWAN KUMAR18:45 Load dep Ex KYN. 19:35-19:43 KDV loop arr/dep. 20:07-22:11 ASO loop arr/dep. 22:36 Load stalled at KM 90/26.22:41 Stalling message received from NE SCOR.22:45 Asst Engine Planned Ex KDV. (Asst Loco- 34039+34043/KZJ) from Load JSWD/VSD.23:00 Asst Engine Detached from Load.23:03 Asst Engine Dep Ex KDV.23:15 Asst Engine VSD passing.23:25-23:28 ASST Engine ASO arr/dep.23:49 Asst engine arrival on spot.23:55 Asst engine on load (asst from rear).00:00 Load ready and dep00:07 ATG passing.00:41 KSRA arrival. NOTE- SECTION-B 2 TM ISOLATE SINCE 19.08.25 (6 TM WKG). MEMO GIVEN TO CHIEF GOODS MR SONKAR AT 16:00 HRS SHIFT AND PERMITTEDTHE LOCO UPTO KYN ONLY BUT TRAFFIC RUN THE LOAD. **Load= 3975T, Gradient= 1/100, Curve= 2.18°, Track Conditions=Dry.**	• TCU21 was isolated rom 08-10-2025 due to **'In consistance between the two DC link voltage sensors'** and was isolated since. • The difference between Effort demand and effort realisation was not that large but still the speed was gradually decreasing which means that the required effort is not enough to cross the gradient. • Auto sanding was continuously getting activated by TCU which indicates wheel slipping which in turn leads to adhesion loss. So, availability of sand in all sand boxes is mandatory for its prevention.

Occurrence date	Trainset	Device	State	Label	Speed	Area of interest
08/10/2025 06:45:17.238	WAG12_0265	orgmpu - 0.4.4.7		[TBS] VCB closing command-2 status (NC contact) in Section-A	0	SBI WR
08/10/2025 06:45:17.238	WAG12_0265	orgmpu - 0.4.4.7		[TBS] VCB closing command-1 status (NO contact) in Section-A	0	SBI WR
08/10/2025 06:45:17.238	WAG12_0265	orgmpu - 0.4.4.7		[TBS] VCB closing command-1 status (NC contact) in Section-A	0	SBI WR
08/10/2025 06:45:17.238	WAG12_0265	orgmpu - 0.4.4.7		[MVS] Event for Auxiliary Transefer contactor operation in Section-B	0	SBI WR
08/10/2025 06:45:16.958	WAG12_0265	orgmpu - 0.4.4.7		[TBS] IOS6185: TCU21 is isolated	0	SBI WR
08/10/2025 06:45:16.888	WAG12_0265	orgmpu - 0.4.4.7		[TCU] Bogie-3 isolated due to fault in TCU-21	0	SBI WR
08/10/2025 06:45:16.328	WAG12_0265	orgmpu - 0.4.4.7		[TBS] VCB holding chain overcurrent feedback status in Section-A	0	SBI WR
08/10/2025 06:45:14.428	WAG12_0265	tcu21 - 2.0.14.1		ME_STATUS: CB opening requested by TCU		SBI WR
08/10/2025 06:45:14.408	WAG12_0265	tcu21 - 2.0.14.1		DA_CA(U)OND: Inconsistency between the two DC link voltage sensors		SBI WR

CFM Data: As per remote data, TCU21 was isolated on 08-10-2025 at 06:45 due to 'Inconsistency between the two DC link voltage sensors'

Inconsistency Between the Two DC Link Voltage Sensors"

Meaning:

This failure indicates that the two independent DC link voltage sensors are giving different voltage readings beyond the permissible tolerance. Since both sensors are used for cross-checking safety and control, the system detects the mismatch as an abnormal condition and generates a fault.

What this means for the locomotive

- The traction control system cannot reliably determine the actual DC link voltage.
- To prevent damage to power electronics (IGBTs, converters), the system blocks or limits traction/dynamic braking.
- The fault is treated as a protective/safety fault, not a performance issue.

Possible Causes

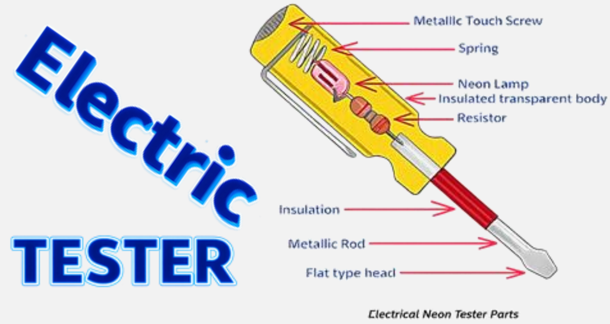
1. Faulty DC link voltage sensor (drift, calibration error, internal failure)
2. Wiring or connector issues (loose contact, high resistance, intermittent signal)
3. Difference in reference supply to the sensors
4. EMI/noise interference affecting one sensor signal
5. Input card or A/D converter fault in the control electronics
6. Actual unstable DC link voltage due to converter or filter issues (less common)

Required action

- Compare both sensor readings in CFM/ diagnostic logs
- Check sensor calibration, connectors, and wiring.
- Inspect DC link measurement circuit and control card

15. Conclusion

The implementation of Train Tracer in WAG-12 locomotives significantly enhances monitoring, diagnostics, and safety of operations. It enables real-time and continuous recording of critical traction, braking, and control system parameters, providing accurate and reliable data for technical investigation and root cause analysis. Train Tracer reduces dependency on manual data download, minimizes data loss, and allows faster identification of system abnormalities. The availability of centralized, cloud-based data supports predictive maintenance, improves fleet reliability, and strengthens safety assurance. Overall, Train Tracer is a valuable tool for improving operational efficiency, availability, and safety of WAG-12 locomotives.



An ‘Electrical Tester’ is an essential tool used to check for the presence of current and voltage within electrical circuits.

Origin: The development of the electrical tester coincided with the expansion of electr-ical science in the 19th century. Early testers were very simple and merely indicated whether or not electricity was flowing through a circuit. Over time, technological advancements led to the development of more precise and digital testers.

Definition: An electrical tester is a device used to verify the presence of electric current, voltage levels, and the status of connections in a wire, socket, or appliance. It is of paramount importance for electrical safety.

Applications: It is utilized in both domestic and industrial settings- for tasks such as identi-fying phase and neutral lines, detecting faulty wiring, testing appliances, and ensuring safety during electrical repair work.

Types: Currently, there are primarily four types of testers available:

1. Screwdriver (Line) Tester
2. Non-Contact Tester
3. Multimeter (Analog/Digital)
4. Digital Voltage Tester

Thus, the electrical tester is a simple yet extre-mely useful and indispensable tool that plays a crucial role in ensuring safe electrical operations.

Analysis and Implementation of Unbalance Compensation Methodologies in Indian Railway Traction System

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ABSTRACT

This article discusses the unbalance created due to single phase loading; the limited utilization rate of the regenerative braking energy (RBE) due to electrical separation in Indian Railway (IR) traction system. This article proposes a co-phase compensator to tackle the above scenario. A corresponding algorithm is also proposed to calculate the distribution of the regenerative braking power in the railway power circuits. The structure and working principle of the compensator are introduced. Finally, the simulation is carried out, the effectiveness of the proposed compensator and the electricity cost analysis are verified.

Keywords – regenerative braking energy (RBE), unbalance regulation, co-phase compensator, steinmetz theory, single phase IR traction system

I. INTRODUCTION

The railway is in urgent demand for expanding the capacity of the railway network which put forwards many challenges as economies like India are facing a looming energy deficit situation; at present, nearly 50% of its primary energy is being imported. Indian Railways as an organization is consuming nearly 30 billion units per annum which is nearly 2.5% of the total country's consumption and is growing at a high rate annually [1].

Indian Railways (IR) is predominately a single-phase traction system which results in deteriorating the power quality of the grid due to heavy unbalance loading as traction energy consumption is the main contributing factor that is to be reduced and regulated.

Besides, four quadrant converters are widely used in AC–DC–AC electric locomotives to recover the braking energy generated when the locomotive goes downhill or decelerates regenerative braking energy (RBE) needs to be consumed in the same section or to be fed back to the utility grid, as a result, there is a negative impact on the balancing of the utility grid due to single-phasing. In addition to that the electric power sector has adopted the billing method of not counting the reverse delivery of active power, the cost of electricity consumption cannot be reduced for railway operators.

This research proposes a methodology for the single-phase transformer-fed Indian railway circuits. In this methodology, a compensator is modeled to overcome the phase separation issue in the single-phase traction system to regulate the unbalance in the utility grid and also to utilize the RBE effectively among the power circuits. The effectiveness of the proposed model is demonstrated by the computer simulations on MATLAB/Simulink.

2. ANALYSIS & IMPLEMENTATION

A. Conventional Traction System & Hypothesis

The Indian Railways traction system adopts single-phase AC circuits, which are supplied by single-phase Traction.
Sub-Stations (TSS). Consecutive circuits are connected to the different phases of the three-phase utility grid and isolated from each other by the Neutral Sections (NS) as shown in Fig. 1. Since the traction loading varies with the time and the locations of locomotives, unbalanced loading at the utility grid is observed and would cause a significant power quality problem. In addition to it, the RBE is either to be used by the accelerating trains in the same power arm or directly fed back to the grid which again deteriorates the quality of the grid.

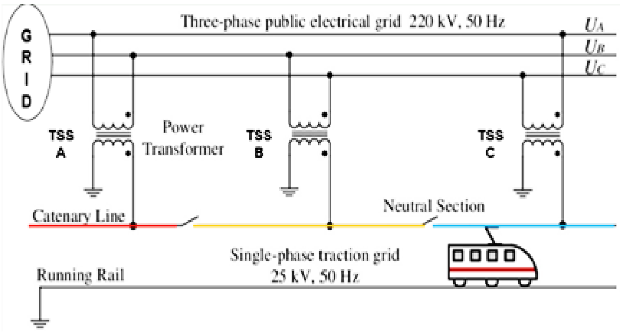

Fig. 1. Single-Phase Railway Traction System.

As the unbalance factor [2] is one of the main reasons for the power quality issue of the utility grid

$$Unbalance\ Factor\ \% = \frac{S_L}{(S_L + S_C)} = \frac{I^-}{I^+} * 100 \qquad (1)$$

S_C = SCC (Short Circuit Capacity) of the grid;
S_L= Apparent power supplied by TSS;
I^- = negative sequence current; I^+ = positive sequence current.

From the above equation it is understood that either by minimizing the power supplied by TSS or I^- of the TSS loading, the unbalance factor can be minimized up to the standard limits of the traction network.

Hence, in this research, an unbalance compensator at the neutral section is proposed as shown in Fig. 2 in which back-to-back converter topology is considered so that there will be a provision of transfer of power among adjacent sections and to minimize the number of compensators in the traction network.

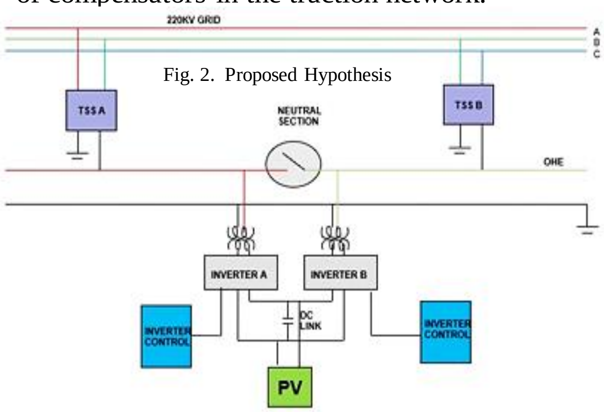

Fig. 2. Proposed Hypothesis

B. Implementation of Co-Phase Compensator (CPC)

CPC comprises bidirectional back-to-back converters with a control module that works through an algorithm to calculate the distribution of the active power in the railway power circuits including RBE for unbalance regulation and cost efficiency.

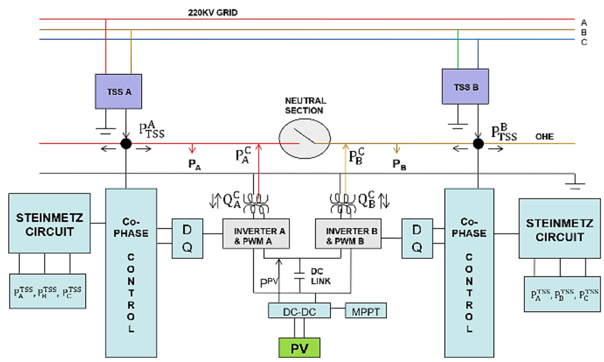

Fig. 3. Schematic Diagram of Compensator

C. Control Module

In this Control Scheme, equalizing the loading among adjacent sections of the traction network through the transfer of active power is considered the governing principle of the Co-phase Transfer Scheme. For practical modeling of the IR sections, the control scheme includes RBE utilization locally, to regulate the unbalance and achieve monetary benefit.

As shown in Fig. 4, the scheme's first leg indicates the co-phase transfer during traction mode, the second leg indicates the co-phase of RBE during braking mode, and the third leg is the Steinmetz control for minimizing the negative sequence currents.

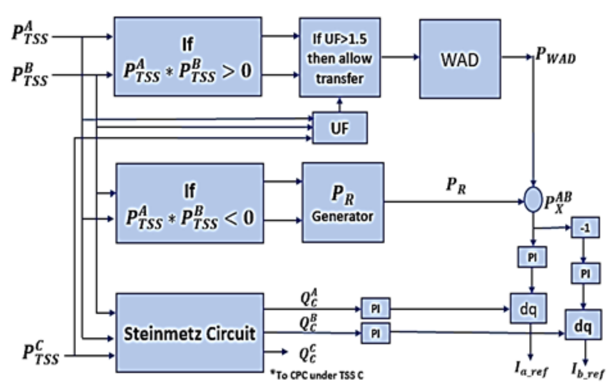

Fig. 4. Detailed Control Scheme of CPC

As per the above control scheme the condition of the feeder power of the TSSs i.e., P^A_{TSS}, P^B_{TSS} and P^C_{TSS} (which in turn depends on the train operating mode) are to be considered to

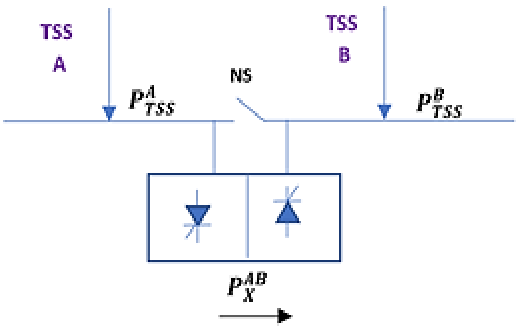

Fig. 5a. Power Flow Nomenclature

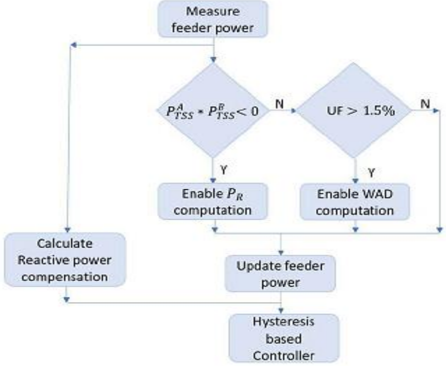

Fig. 5b. Control Scheme Flowchart

implement the scheme.

Based on the above flow chart and power flow nomenclature shown in Fig 5a & 5b, the below algorithm is designed.

Step 1: If the trains on either side of the CPC are in traction or regenerative braking mode, then any of the following conditions prevail i.e.,

If $P^A_{TSS} * P^B_{TSS} > 0$, then implement step 2 where both the sections are in the same operating mode.

If the above conditions don't satisfy then the below condition applies which is one of the sections under CPC's jurisdiction is in braking mode i.e.,

If $P^A_{TSS} * P^B_{TSS} < 0$, then

$$P_R = \begin{cases} -min\left(P^B_{TSS}, \left|P^A_{TSS}\right|\right), when\ P^A_{TSS} < 0, P^B_{TSS} > 0 \\ min\left(P^A_{TSS}, \left|P^B_{TSS}\right|\right), when\ P^A_{TSS} > 0, P^B_{TSS} < 0 \end{cases} \quad (2a)$$

$$P^{AB}_X = P_R \quad (2b)$$

where, P_R is the regenerative braking power to be transferred; P^{AB}_X is the transferred power

Step 2: If $P^A_{TSS} * P^B_{TSS} > 0$, then the co-phase transfer will be carried only if the unbalance factor (UF) is more than 1.5% as per the Fig.4, then the transfer power is given as per the weighted average difference (WAD) as shown below:

$$P_{WAD} = \left|\frac{(\sum P^p_{TSS})}{2} - \left(P^p_{TSS}\right)\right| \quad (3a)$$

$$P^{AB}_X = \begin{cases} P_{WAD}, when\ P^A_{TSS} > 0, P^B_{TSS} > 0 \\ -P_{WAD}, when\ P^A_{TSS} < 0, P^B_{TSS} < 0 \end{cases} \quad (3b)$$

The feeder power of each TSS at this time should be written as:

$$\begin{cases} P^A_{TSS} \leftarrow P^A_{TSS} + P^{AB}_X \\ P^B_{TSS} \leftarrow P^B_{TSS} - P^{AB}_X \end{cases} \quad (4)$$

For implementing the third leg to minimize the negative sequence current due to single-phase loading, a required amount of reactance or reactive power to be injected as per the principle of Steinmetz circuit [5]. When the load is modeled as constant power. The compensation reactive power injections Q^A_C, Q^B_C, Q^C_C can be written as follows:

$$\begin{bmatrix} Q^A_C \\ Q^B_C \\ Q^C_C \end{bmatrix} = \frac{1}{2\sqrt{3}} \begin{bmatrix} 0 & 1 & -1 \\ 1 & 0 & -1 \\ 1 & -1 & 0 \end{bmatrix} \begin{bmatrix} P^A_{TSS} \\ P^B_{TSS} \\ P^C_{TSS} \end{bmatrix} \quad (5)$$

In the scheme, using PQ Controllers [9] the required active and reactive power injections are made to regulate the unbalance factor.

III. SIMULATION RESULTS

The Simulations for different traffic conditions including RBE, in a specific section of Indian Railways are carried out which has 7 traffic slots. In each slot it is assumed that the loading is constant.

In the below graph, the section loading with a negative sign indicates that the locomotive in that section is under regenerative braking mode and a positive sign indicates the traction mode operation of the locomotive.

It is observed that with CPC under operation, during the traffic slots 3&5 and slots 1&6 of Fig.7, the feeder powers of respective sections A & B respectively, became '0', which indicates regenerative braking in one section is been used to supply the required amount of power to its adjacent section.

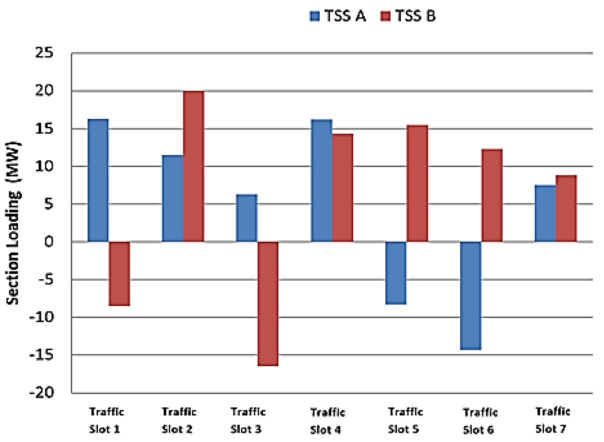

Fig.6. Assumed section loading

Similarly, during the other traffic slots when both the sections are in traction mode and whenever the unbalance factor >1.5% condition prevails, the required amount of feeder power has been transferred to equalize the section loading.

In Fig. 8 it is observed from traffic slot 2 that the feeder power in both the adjacent section is same with CPC implementation.

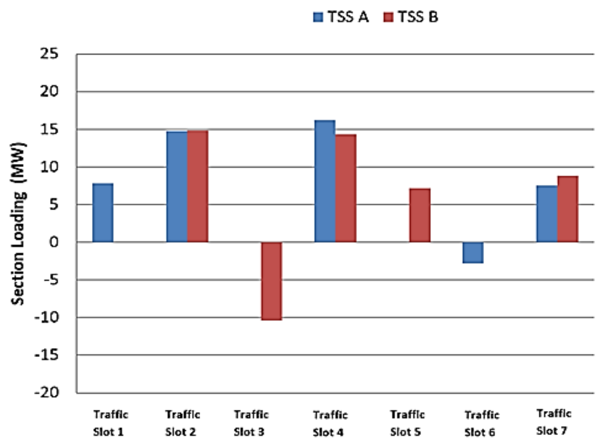

Fig.7. feeder power cpc

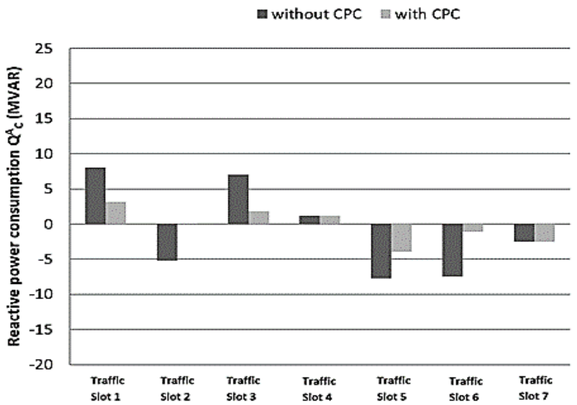

Fig.8. Reactive power injection in the section under TSSA

In other slots the value of injection is less in red bars compare to blue bars, this indicates less variation in the feeder powers of the adjacent sections.

This graph in Fig. 9 indicates the apparent power variation during each traffic slot for a 10MVA rated CPC A, the amount of apparent power utilization is high i.e., in slots 1,3,5&6 compared to other slots.

Fig.10 depicts the unbalance factor during the different case studies, the solid black line indicates 2% standard, it is observed that the unbalance factor with the co-phase controller implementation is able to work effectively.

Table 1 illustrates the electricity cost comparison with the implementation of CPC. As there is no monetary benefit for RBE,

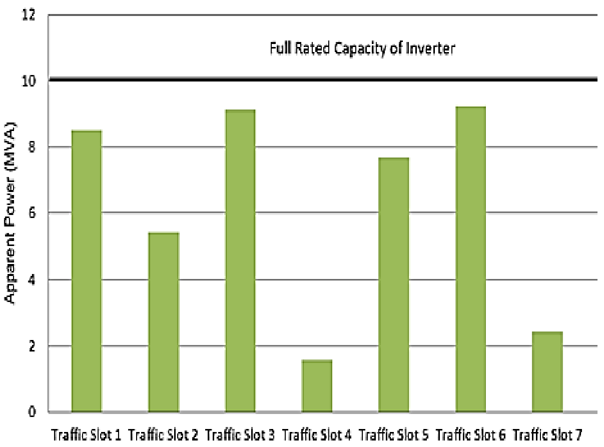

Fig.9 Apparent power

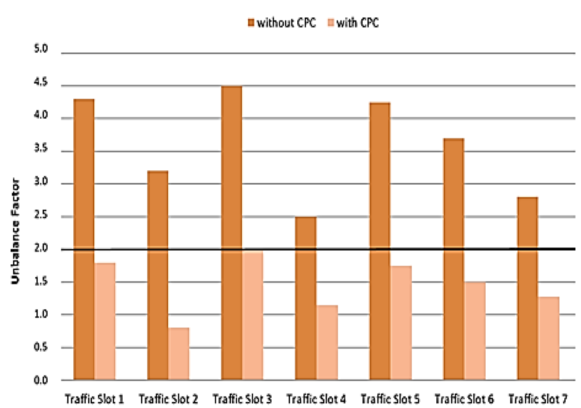

Fig.10. Unbalanced power

TABLE1
ELECTRICITY COST COMPARISON [3]

Traffic Slot	TSS A Electricity cost (in millions)		TSS B Electricity cost (in millions)	
	Without CPC	With CPC	Without CPC	With CPC
1	0.586	0.3354	*0	0
2	0.3135	0.4575	0.603	0.4575
3	0.2667	0	*0	*0
4	0.4731	0.4731	0.4236	0.4236
5	*0	0	0.6063	0.4092
6	*0	*0	0.3522	0
7	0.2214	0.2214	0.2799	0.2799

Electrical Cost per traffic slot is calculated as follows:
$C_h = \alpha * P^p_{TSS} * t_h$ (¥) where, α is the $¥/kwh$ (30 $¥/kwh$ for commercial purpose); P^p_{TSS} is feeder power in p phase; t_h is the duration of each traffic slot (4hrs each)

*no monetary benefit for RBE

here is no advantage of regeneration in conventional traction system but with CPC under operation the RBE is transferred between sections so that the electricity cost of adjacent section got reduced as shown in 1,3,5&6 slots.

IV. CONCLUSION & FUTURE WORK

Therefore, through this research we are able to model the existing railway traction network and design a controller to regulate the unbalance scenario. In addition to this, in this research we tried to design a controller considering the practical scenario i.e., considering Regenerative braking energy, to implement the CPC for equalizing and effective utilization of feeder power in the single-phase traction system and the corresponding cost comparison were presented.

In the future work the continuous traffic scenario will be studied and corresponding continuous analysis of the controller and its effectiveness will be studied and implemented.

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कष्ट और विपत्ति मनुष्य को शिक्षा देने वाले श्रेष्ठ गुण हैं,
जो व्यक्ति साहस के साथ उनका सामना करते हैं,
वे सदैव सफल होते है ।

Lithium-ion battery- a game changer in energy storing techniques.

Dr. Ravikumaran Nair C
Professor (Electronics),IRIEEN

Abstract

Search for alternative fuels or technologies in transportation sectors gaining more and more momentum nowadays in oil importing countries, especially in light of recent unstable geo-political scenarios. Blending of 20 % Ethanol with Petrol is one of its kind, through which country like India had already saved INR 1.36 lakhs crore with the reduction of 244 lakhs Metric Ton of Crude Oil import. In the year 2025 itself, India saved $12 billion in oil import. Increase in Indian farmers' income in tune of Rs 1.18 lakh crore by selling the Ethanol was an additional benefit of it. Besides, it directly helped in reduction of approximately 698 lakh tonnes of CO_2 emission. However, the invention or instruction of alternate fuel is not the 'cup of the tea' in large quantity electric energy saving requirements.

Shifting of Internal Combustion Engines to Electric Motors in road vehicles is another fast growing scenario on the above mentioned context. The utilization of storage cells made up of Lead-Acid was the main constraint in the path of conversion of automotive engines from fossil fuel to electric.

But, with the advent of storage cell technologies, the Lithium-ion batteries are found to be fit in the present fossil fuel saving requirements in automobile industries, as well as in bulk energy storage arenas. The energy density of a Li-ion cell is typically 150-200 Watt-hour/Kilogram, where as that of Lead-Acid cell is around 30-40 only. In short, a ability of Li-ion cell in energy saving is more or less five times higher that of a Lead-Acid cell. However, the Li-ion cell is around 2.5 times costlier than Lead-Acid cell of same capacity. But the life span and Cycles of charging & discharging in Li-ion cell is almost 4 times higher. As such, the cost per kWh of Li-Ion battery is worked to be around Rs 10 , whereas it is around Rs 25 in Lead-Acid battery.

♣ Lithium-ion or Li-ion battery

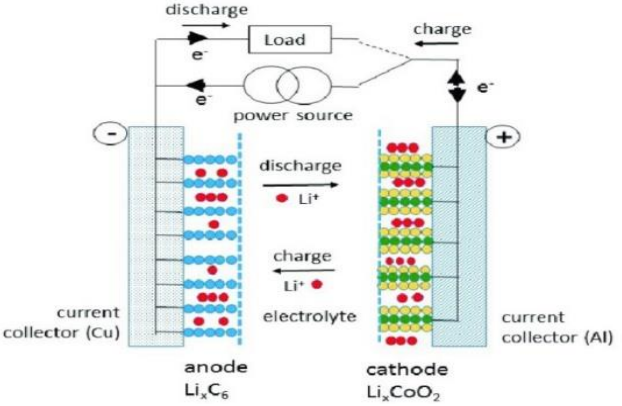


Fig no.1

Lithium-ion batteries is a group type of rechargeable batteries that use reversible intercalation of Li+ ions (ie. the process of inserting ions into a host material like a layered structure) into electronically conducting solids to store energy (Fig.1). Compared to other types of rechargeable batteries, they generally have higher specific energy, energy density, and energy efficiency, and longer cycle life & calendar life. In the three decades after Li-ion batteries were first introduced in market in 1991, their volumetric energy density increased three folds while their cost dropped ten folds.

In late 2024, global demand passed 'One Terawatt -hour' (TWh) per year. China dominates in production of Li-ion batteries, accounting 80 % of the global production. The country's production capacity is expected to reach 1.2 TWh by 2030.

Drives of Demand

- ✓ Electric Vehicles: Expected to account for 70-80% of lithium consumption across scenarios
- ✓ Energy Storage Systems: Growing at 6-7% annually as renewables dominate new power capacity

.

✓ Consumer Electronics: Increasing demand for high-performance batteries

Invention of Li-ion batteries has had a large impact on technology, which was recognized by Nobel Prize Committee in 2029 in Chemistry stream.

Li-ion batteries have enabled; portable Consumer electronics, laptop computers, cellular phones, and electric cars. They are used for grid-scale energy storage, in military and in aerospace applications.

Lithium-ion batteries can be a fire or explosion hazard as they contain flammable electrolytes. Progress has been made in the development and manufacturing of safer lithium-ion batteries And hence, Lithium-ion solid-state batteries were been developed to eliminate the flammable electrolyte.

Recycled batteries can create toxic waste, including from toxic metals, and are a fire risk. Lithium and other minerals can have significant issues in mining, with lithium being water intensive in ‘often arid regions’, and other minerals used in some Li-ion chemistries potentially being conflict minerals such as cobalt. Environmental issues have encouraged the Researchers to improve mineral efficiency and find alternatives such as Lithium - Iron - Phosphate lithium-ion chemistries or non-lithium-based battery chemistries such as Sodium-ion and Iron-air batteries etc..

♣ Chemistries of Li-ion batteries

"Li-ion battery” encompasses battery types of at least 12 chemistries. Lithium-ion cells can be manufactured to optimize energy density or power density. Handheld electronics mostly use Lithium polymer batteries, with a polymer gel as an electrolyte, a Lithium Cobalt Oxide ($LiCoO_2$) cathode material, and a Graphite (C) anode, which together offer high energy density. Lithium Iron Phosphate ($LiFePO_4$), Lithium Manganese Oxide ($LiMn_2O_4$ spinel, or Li_2MnO_3) based Lithium-rich layered materials, (LMR-NMC), and Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$ or NMC) offer longer life and a higher discharge rate. NMC and its derivatives are widely used in the electrification of transport; one of the main technologies (combined with renewable energy) for reducing greenhouse gas emissions from vehicles.

Generally, the negative electrode of a conventional Lithium-ion cell is made from graphite. The positive electrode is typically a metal oxide or phosphate.

The electrolyte is a lithium salt in an organic solvent. The negative electrode (the anode when the cell is discharging) and the positive electrode (the cathode when discharging) are prevented from shorting by a solid separator. The electrodes are connected to the powered circuit through two pieces of metal called current collectors
The negative and positive electrodes swap their electrochemical roles (anode and cathode) when the cell is charged. Despite this, in discussions of battery design, the negative electrode of a rechargeable cell is often just called "the anode" and the positive electrode "the cathode".

In its fully ‘lithiated’ state of LiC_6, graphite correlates to a theoretical capacity of 1339 coulombs per gram (372 mAh/g). The positive electrode is generally one of three materials: (i) a layered oxide (such as lithium cobalt oxide, $LiCoO_2$), (ii) a poly-anion (such as lithium iron phosphate, $LiFePO_4$) or (iii) a spinel (such as $LiMnO_2$, Lithium Manganese Oxide).

Lithium reacts vigorously with water to form Lithium Hydroxide (LiOH) and Hydrogen (H_2) gas. Hence, a non-aqueous electrolyte is typically used, and a sealed container rigidly excludes moisture from the battery pack. The non-aqueous electrolyte is typically a mixture of organic carbonates such as ethylene Carbonate and Propylene Carbonate containing complexes of Lithium ions. Ethylene Carbonate is essential for making solid electrolyte interphase on the Carbon anode, but since it is solid at room temperature, a liquid solvent (such as Propylene Carbonate or Diethyl Carbonate) is added.

The electrolyte salt is always Lithium HexaFluoro Phosphate ($LiPF_6$), which combines good ionic conductivity with chemical and electrochemical stability. The Hexa Fluoro Phosphate anion is essential for passivating (means, making a material less chemically reactive by creating a protective layer on its surface) the aluminium current collector used for the positive electrode. A Titanium (Ti) tab (connection) is ultrasonically welded to the Aluminium current collector.

Other salts like; $LiClO_4$, $LiBF_4$, $LiC_2F_6NO_4S_2$ are frequently used in research in 'tab-less coin cells' (a type of battery design where the electrode connections are eliminated, making the cell more compact and potentially improving performance), but are not usable in larger format cells, often because they are not compatible with the Aluminium current collector. Copper (with a spot-welded Nickel tab) is used as the current collector at the negative electrode.

Current collector design and surface treatments may take various forms: foil, mesh, foam (de-alloyed), etched (wholly or selectively), and coated with various materials to improve electrical characteristics.

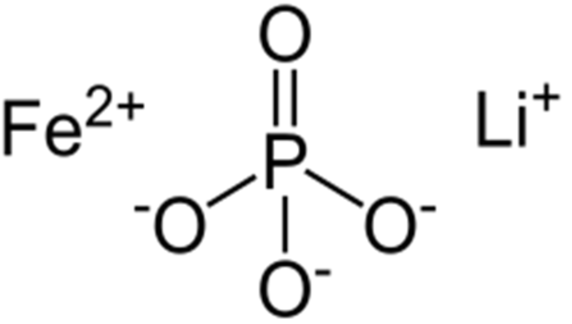
Depending on materials choices, the voltage, energy density, life, and safety of a Lithium-ion cell can change dramatically. Current effort has been exploring the use of novel architectures using nanotechnology to improve performance. Areas of interest include nano-scale electrode materials and alternative electrode structures.

The reactants in the electrochemical reactions in a Li-ion cell are the materials of the electrodes, both of which are compounds containing Lithium atoms. Although many thousands of different materials have been investigated for use in Lithium-ion batteries, only a very small number are commercially usable. All commercial Li-ion cells use intercalation compounds (like graphite or clay) as active materials. The negative electrode is usually graphite, although silicon is often mixed in to increase the capacity. The electrolyte is usually LiPF6, dissolved in a mixture of organic Carbonates. A number of different materials are used for the positive electrode, such as LiCoO2, LiFePO4, and LiNiMnCoO2.

♣ Lithium-Iron-Phosphate Battery

Lithium Iron Phosphate or Lithium FerroPhosphate (LFP) is an inorganic compound . It is a gray, red-grey, brown or black solid that is insoleble in water. The material has attracted attention as a component of LFP batteries.This battery chemistry is targeted for use in power tools, electric vehicles, solar energy installations, and more recently in large grid-scale energy storage.

Lithium iron phosphate exists naturally in the form of the mineral triphylite (the name comes from Greek, meaning 'threefold', referring to its three main components; Li, Fe and PO4), but this material has insufficient purity for use in batteries.



♣ $LiMPO_4$

General chemical formula of LiMPO4, compounds in the LiFePO4 family adopt the olivine structure (the orthorhombic crystal system, as shown in Fig.2). M includes not only the Fe, but also the Co, Mn and Ti. As the first introduced commercial LiMPO4 was LiFePO4, the whole group of LiMPO4 is informally called "Lithium Iron Phosphate" (LFP) or "LiFePO4". However, more than one olivine-type phase may be used as a battery's cathode material. Olivine compounds have the same crystal structures as LiMPO4, and may replace it in a cathode. Although the term 'LiFePO4' (LFP) strictly refers to the iron-based compound, the related olivine-type phosphates with similar structures are included under the LFP designation due to structural and electrochemical similarities.

♣ Physical and chemical properties

In LiFePO4, lithium has a +1 charge, iron has a +2 charge, and phosphate carries a −3 charge, balancing the charges. Upon removal of Li, the material converts to the ferric form, FePO4.

The Iron atom and 6 Oxygen atoms form an octahedral coordination sphere, described as FeO6, with the Fe-ion at the centre. The phosphate groups, PO4, are tetrahedral.

The three-dimensional framework is formed by the FeO6 octahedral sharing 'O' corners (Fig.2). Lithium ions reside within the octahedral channels in a zigzag manner.

In contrast to two traditional cathode materials, LiMnO4 and LiCoO2, Lithium ions of LiFePO4 migrate in the lattice's one-dimensional free volume. During charge/discharge, the lithium ions are extracted concomitant (means, happening at the same time) with the oxidation of Fe(II) ions:

$LiFeIIPO4 \rightleftharpoons FeIIIPO4 + Li+ + e-$

A nearly close-packed hexagonal array of oxide centres provides relatively little free volume for Li+ ions to migrate within. For this reason, the ionic conductivity of Li+ is relatively low at ambient temperature.

Conclusion

The development of the Lithium-ion battery has significantly transformed modern energy storage technology. With its high energy density, lightweight design, long cycle life, and relatively low maintenance requirements, it has become the backbone of many modern devices and systems. From smartphones and laptops to electric vehicles and renewable energy storage systems, lithium-ion batteries have enabled greater efficiency, portability, and reliability in energy use.

Moreover, as the world moves toward cleaner and more sustainable energy solutions, lithium-ion technology plays a crucial role in supporting renewable energy sources such as solar and wind by providing efficient storage and stable power supply. This capability helps bridge the gap between energy generation and consumption, making renewable energy more practical and dependable.

Although challenges such as resource availability, recycling, safety concerns, and environmental impact remain, continuous research and technological advancements are steadily addressing these issues. Innovations in battery chemistry, recycling technologies, and alternative materials are expected to make lithium-ion batteries even more efficient, safer, and environmentally friendly in the future.

Therefore, lithium-ion batteries are not merely an improvement in energy storage—they represent a **revolution in how energy is stored, managed, and utilized**, paving the way for a more sustainable, electrified, and technologically advanced world.

Continued from page no-04

7. Advantages of Wi-Fi

- Wireless convenience
- Fast and easy connectivity
- Multiple device connections simultaneously
- Cost-effective
- Mobility (usable anywhere within range)

8. Factual Statistics on Wi-Fi

- Over 5 billion internet users worldwide
- India is expected to have over 900 million internet users by 2025
- Around 80% of internet usage happens through Wi-Fi
- Wi-Fi 6 can deliver speeds up to 9.6 Gbps

9. Social Impact of Wi-Fi on Media

Wi-Fi has had a profound impact on media and society:

Positive Effects:

- Rapid dissemination of information
- Connectivity through social media
- Growth of digital journalism

Negative Effects:

- Spread of fake news
- Increased screen time
- Growing social isolation

10. Conclusion

Wi-Fi is one of the most important technologies of the modern era. It has not only simplified communication but also revolutionized education, business, and entertainment.

Although it has some drawbacks, when used in a balanced and secure manner, it proves to be extremely beneficial for human life.

Message:

"The right use of technology drives progress, and Wi-Fi is a powerful medium for it."

A Comparative Study of Overhead Equipment Earthing in Indian Railways, Metro Railways and HSR System

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Abstracts

The Earthing system is an essential part of electrical systems which protects infrastructure, equipment, and people from the danger of high voltage and achieve safety from fatal electrical surges. This paper aims to comparatively present the system The Earthing system is an essential part of electrical systems which protects infrastructure, equipment, and people from the danger of high voltage and achieve safety from fatal electrical surges. This paper aims to comparatively present the system of earthing used in AC electrified railways in particular Indian Railways (IR), Metro Railways and the upcoming Mumbai-Ahmedabad High-Speed Rail (MAHSR). The study focuses on the Overhead Equipment (OHE)/Traction earthing system used in various railway systems. With a vision of providing eco-friendly and energy efficient transportation, 94% of route km of lndian railways is electrified and marching towards 100% electrification. Metro railway and MAHSR in electrified system. Hence OHE earthing in all the electrified system becomes important.

Keyword: Electric Traction, OHE. Buried Rail Track Circuit, Impedance Bond. III, Protection wire, Grounding wire

1. Introduction

The railway has gradually evolved from the time of its inception in India from steam engine hauled train to diesel engine hauled train to electric engine hauled train. As a result, there is development of several metro trains and the construction of high speed rail is undergoing at a fast pace. Almost all new trains are based on electric rolling stock traction system. Hence earthing system forms an indispensable part for the safety and protection system. The purpose is to ensure that in general all parts shall be at same potential so that there is no potential difference between two metallic surfaces and hence the touch potential is less than the prescribed potential.

Ii. Ohe Earthing System In Indian Railways

Indian Railway runs its operation on 25kV, 50 Hz AC Traction system. The current is drawn from the OHE by the Electric rolling stock and the return current passes through the tracks and earth after passing through the loco to the wheel. The tracks are electrically grounded. The return current flows mostly through the earth leaving the traction rail except in a zone extending over a few hundred meters on both sides of the electric rolling stock in operation in the section or in the vicinity of a feeding station and return to the traction sub-station (Fig. 1.) Bonding of rail facilitates passage of the traction return current from the earth to the traction rails which are connected to the rail to earth and vice versa and is, therefore, provided in the vicinity of traction sub-station-feeding posts where the traction return current has to flow back from the earth to the traction rails which are connected to the earthed leg of the traction transformer at the sub-station, through a buried rail opposite the feeding post

The traction power return system consists of the running rails, impedance bonds, cross-bonds, overhead static wires, return conductors, and the ground (earth) itself. Assistance has been taken from the following standards/ codes of practices in the preparation of code of practice for earthing for lndian Railway: (1) IS:3043-2018-Code of Practice for Earthing (latest edition) (ii) IEEE Guide for safety in a.c. substation grounding IEEE Standard 80-2013. It may be further noted that full load current would not necessarily take: Running Rail> Buried Rail> Transformer. Some current can as well get to the transformer from Earth Electrode> Earth Grid> Transformer traction power

With advances in track technology, the Rail is no longer at ground potential. Thus, it was decided to create Earthing stations at about 10 km separation (for sale of convenience, this can be sited close to Switching Posts). Ides is to create a positive, strong and deliberate earth connection to improve system resilience.

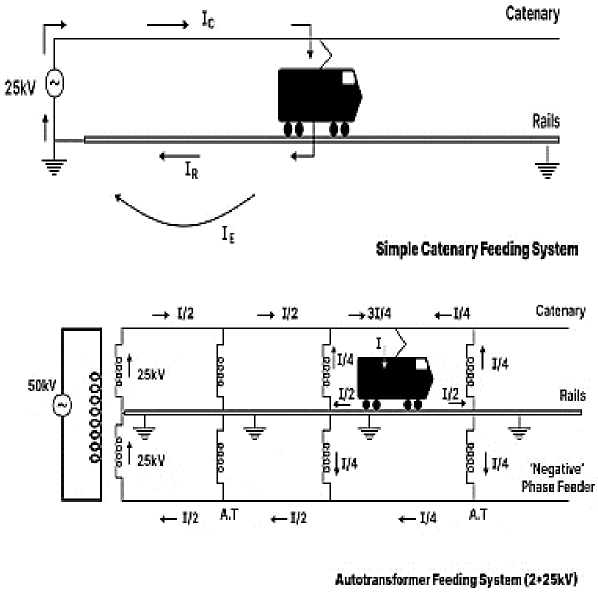
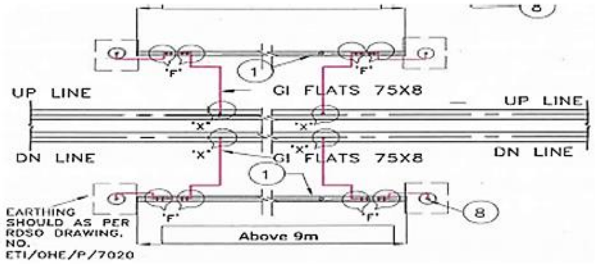


Fig. 1. Traction current and return current. [3]

There are no direct earth connections except at the Feeding posts. The design philosophy assumes that the Rails are naturally at ground potential and the structures get earthed by connection to the rails (Fig. 2)



1-Buried Rail 8 -Earth electrode [1]

Fig. 2. Buried Earth Rail connection to traction rail

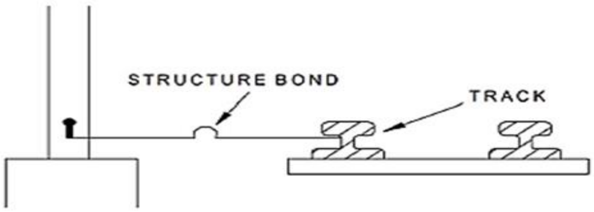


Fig.3. Structure bond to OHE mast

All non-current carrying metallic parts of traction masts (Fig. 3) of structures or supports or metallic parts of concrete /wooden masts, supporting the traction overhead equipment shall be connected by means of the structure- bond to the nearest traction rail or to an earth wire run on the traction mast structures/supports or to an earth [3]

III METRO RAILWAY

The Delhi Metro system is our of its first Metro Rail System in India. The Delhi metro is based on the 25 KV AC metro traction system. The basic design of the earthing system is based on French railway design (SNCF). About 70% of Delhi Metro Rail Corridor alignment is on the elevated via duct. piers and parapet in connected to common grounding conductor known as Buried Earth Conductor (BEC) [4]

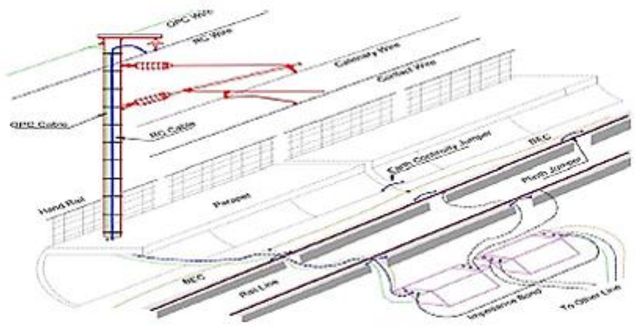


Fig. 4. Buried Rail

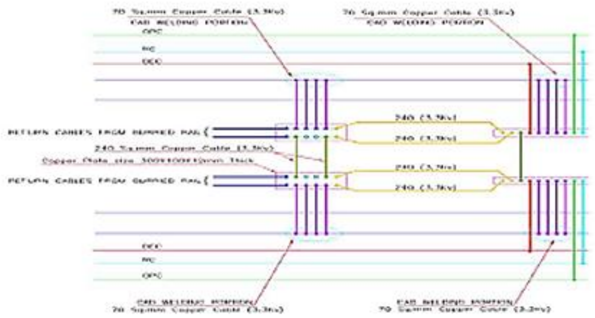


Fig. 5. Integral Transversal Link

The return current flows mostly through the rails return cable conductor and partially through the BEC The return current flows to the traction substation through the impedance bond. Impedance bond provides low impedance path for the traction return current and relatively high impedance path for truck circuit current. There is no deliberate connection to earth in the track rails in double rail track circuit signaling, while impedance bond is not used in single rail track signaling. BEC in connected to Earth to Earth grid of Auxiliary substation through Integral Transversal Link (ITL). The Earth grid is connected to the Buried rail in the substation which serves as common earth for OHE earthing. Now a days buried copper strip is used as buried rail network.

Integral Transversal Link (ITL) is an interconnection (Fig.5) of DN line OPC, BEC and Up line OPC, REC and tracks direct or through impedance bond. It is connected to the return cable from the buried rail [4].

This shall be provided at an interval of 1 km or less than 1 km [4]. Various structural provisions are implemented in order to provide low impedance return path on the via duct [5]. Reinforcement of steel bars of plinth are interconnected and then in turn connected to Buried Earth Cable (BEC). Reinforcement steel bars of one segment of viaduct is connected to the reinforcement steel bar of adjacent segment. Reinforcement steel bar of via-duct is connected to common earthing bar at an interval of 100-200 m. Reinforcement steel bars of the viaduct is connected to the reinforcement steel bars of piers. Earthing plate is provided at both ends of viaduct span (Up and Dn.)

The main line and around 60% of depot network is provided with double rail track circuits. Hence rails cannot be earthed and hence impedance bonds are being used. Phase III metro line network including line 7 and line & 8 uses CBTC system of signaling. Airport Line and Line-3 in on single track circuit in such system ITL is used for bonding in place of impedance bond. In non-track circuit areas, structure bond, rail bond and cross bond shall be provided as is provided in Indian Railways.

Iv. High Speed Railway

High Speed Rail (HSR) in India is based on Shinkansen train system of Japan. About 92% of HSR is based on raised viaduct [5]. The earthing system shall conform to IEFE 80 Guide for Safety in AC Sub station Grounding.

In HSR, the traction feeding system is based on the 2x25 Auto Transformer (AT) feeding system (Fig.6).The neutral of the auto- trans-former is connected to the protection wise (PW) The neutral of the auto transformer is also connected through the Neutral wire (NW) and impedance bond to the rail. Hence in HSR, the return current partially flows through the rails and is channeled through the impedance bond to the PW. Connecting wire for auto transformer protection wire (CPW) shall connect the autotransformer protection wires (PW) with neutral wire inside the feeder lead-out structure. Between two auto-transformers, CPW shall connect protection wire with impedance bond [6]. Unlike conventional railway the potential of the rail is around 500 V. However, if the potential of rail in HSR reaches a threshold value say 500 V or more, protection mechanism such as Grounding Protector (GP) comes in to picture.

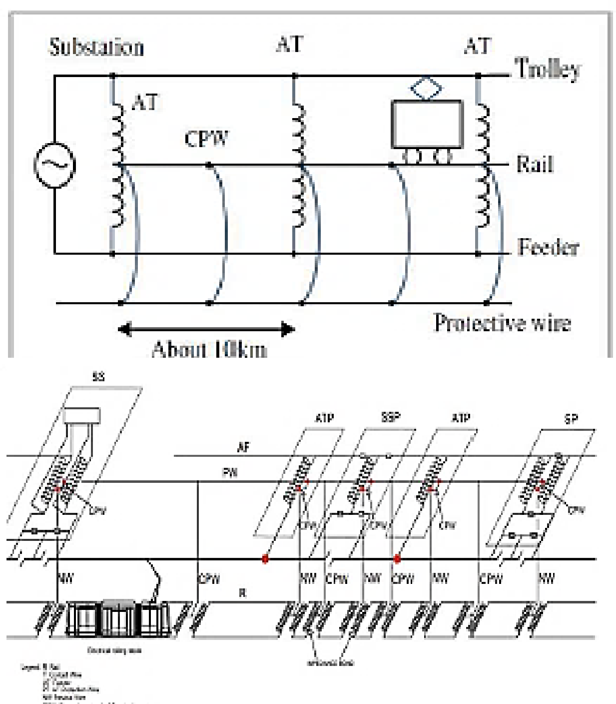


Fig.6. HSR Feeding System and its connection to PW, NW

For earthing on viaduct for OHE mast other metal installations, earthing cable will be installed from reinforcing bars or earth electrodes (depending on type of foundation for civil structures). Over head grounding wire (GW) shall be installed for all lines in

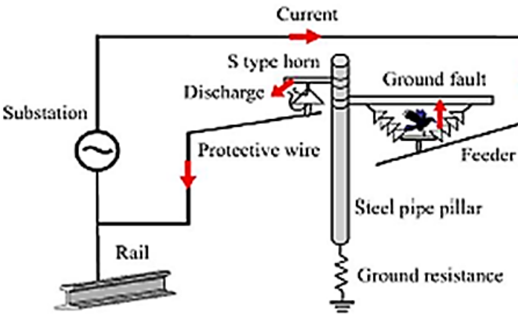


Fig. 7 OHE connection to ground [7]

open area (Fig. 7). The earthing wire is further provided at intervals of 200 m and connected to the overhead grounding wire and grounded. Earthing wire shall be connected with mast. S type horn (Fig. 7) is installed on the suspension insulators of auto-transformer protection wire to detect flashover at the insulators and for its protection. It is also installed at the termination section of overhead grounding wire. Length of the gap of S type horn is adjustable both on the cap side and the clevis side according to the grounding resistance of the support.

GP stands for Gap for Ground fault protection equipment for discharging the rise of potential of the earth mesh in the switching station thereby ensuring its protection.

Overhead ground wire shall be terminated at earth overload anchor metal fittings of stations and at tunnel entrance. OHE Feeder support in station shall be connected to ground and connected to the Station earth via Station structures. Earth Mat provided at ground floor of the station for Structure and OHE earthing is a special feature of HSR, OHE support earthing in by connecting risers from the Earth Mat to OHE support (Fig.9.). To suppress the rail potential in the station and Depots premises and to prevent electric shock accident to personnel, a rail potential suppression facility [7] shall be provided (Fig. 10). It is connected through cable to the rail impedance bond and the grounded steel frame of the building.

Metallic structures on HSR viaduct such an Evacuation Barrier, Metal Fencing. Anemometer, is earthed through earthing strip connected to earthing cable of OHE foundation (Fig. 8)

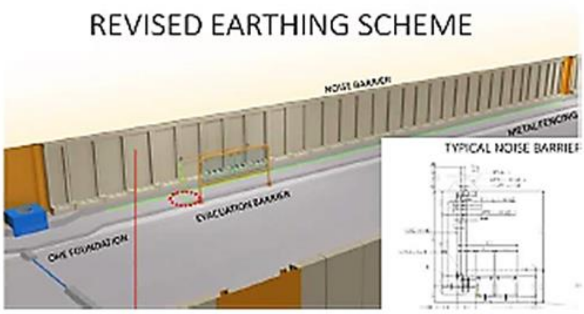


Fig.8. Metal fencing, evacuation barrier earthing connection

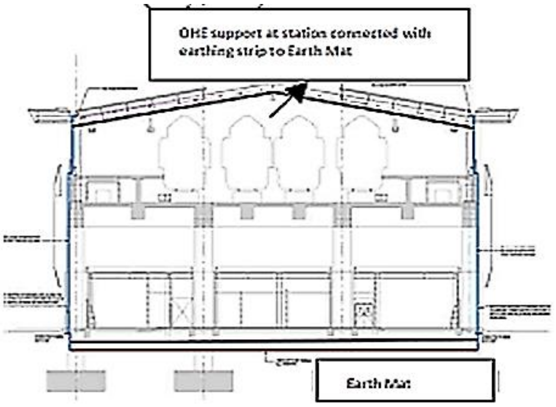


Fig 10. Rail connection to Station grounded steel frame.

For the structure along the HSR alignment such as substation, fault protection grounding wire is installed for lightning protection.

V. Conclusion

The mode of providing OHE earthing changes as the technology changes while the basic intent of the earthing remains same. The metro railway and HSR are primarily based on the viaduct. Hence the rail is not grounded while conventional railway is based on ground hence rails are grounded. Also in HSR the train moves at high speed of 320 kmph. Therefore elaborate protective arrangements are made. In HSR the rail is at floating potential thereby prohibiting personnel to approach track in normal conditions. There is no concept of buried rail in HSR as it is there in Indian Railways or Metro railways.

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वह गलतियाँ जो "अविष्कार" बनी

कई महान आविष्कार जानबूझकर नहीं, बल्कि वैज्ञानिकों की गलतियों, लापरवाही या असफल प्रयोगों (Accidental Inventions) का नतीजा थे, जिन्होंने दुनिया बदल दी। प्रमुख उदाहरणों में अलेक्जेंडर फ्लेमिंग द्वारा पेनिसिलिन (एंटीबायोटिक) की खोज, परसी स्पेंसर द्वारा माइक्रोवेव ओवन, और विलियम पर्किन द्वारा पहले सिंथेटिक डाई (Mauveine) का आविष्कार शामिल है। यहाँ कुछ प्रमुख वैज्ञानिक गलतियाँ हैं जो महान आविष्कार बनीं:

- **पेनिसिलिन (Penicillin) :** 1928 में, अलेक्जेंडर फ्लेमिंग अपनी प्रयोगशाला में फंगस (फफूंद) को खुला छोड़कर छुट्टी पर चले गए थे। वापस आने पर उन्होंने पाया कि फंगस ने बैक्टीरिया को नष्ट कर दिया है, जिससे दुनिया की पहली एंटीबायोटिक का जन्म हुआ।
- **माइक्रोवेव ओवन (Microwave Oven) :** परसी स्पेंसर रडार के लिए मैग्नेट्रॉन पर काम कर रहे थे। उन्होंने महसूस किया कि उनकी जेब में रखी चॉकलेट चॉकलेट बार पिघल गई है, जिससे उन्हें माइक्रोवेव तकनीक का अंदाजा हुआ।
- **एक्स-रे (X-ray):** विल्हेम रोंटजेन कैथोड रे ट्यूब के साथ प्रयोग कर रहे थे, जब उन्होंने गलती से कुछ ऐसी किरणें देखीं जो उनकी त्वचा के आर-पार जाकर हड्डियों की तस्वीर ले सकती थीं।
- **टेफ्लॉन (Teflon):** रॉय प्लंकेट रेफ्रिजरेंट गैस पर काम कर रहे थे, लेकिन प्रयोग के दौरान गैस जम गई। जब उन्होंने उस जमे हुए पदार्थ की जांच की, तो वह 'नॉन-स्टिक' (चिपकने रहित) निकला।
- **पोस्ट-इट नोट्स (Post-it Notes):** 3M कंपनी के वैज्ञानिक स्पेंसर सिल्वर एक बेहद मजबूत गोंद बनाने की कोशिश कर रहे थे, लेकिन गलती से एक ऐसा गोंद बन गया जो कमजोर था और आसानी से उतर जाता था।
- **वेल्क्रो (Velcro) :** जॉर्ज डी मेस्ट्रल ने देखा कि जंगल में घूमने के बाद उनके कपड़ों और कुत्ते के बालों में बर्डोक के बीज चिपक गए थे। सूक्ष्मदर्शी से देखने पर उन्होंने हुक-एंड-लूप सिस्टम की खोज की।
- **फायर एक्सटिंग्विशर (Fire Extinguisher) :** आग बुझाने का पहला पोर्टेबल यंत्र 1818 में ब्रिटिश कैप्टन George William Manby द्वारा बनाया गया। कहा जाता है कि एक भीषण आग की घटना के बाद उन्होंने दबावयुक्त (pressurized) केमिकल्स के प्रयोग किए। इसी प्रयोग के दौरान ऐसा यंत्र विकसित हुआ, जिसे हाथ में पकड़कर आग बुझाई जा सकती थी। यह आविष्कार लाखों जानें बचाने में सहायक साबित हुआ।
- **कोका-कोला (Coca-Cola) :** कहा जाता है कि जॉन पेम्बर्टन सिर दर्द की दवाई बनाने की कोशिश कर रहे थे. इसके लिए उन्होंने कोका पत्तों और कोला नट्स का मिश्रण तैयार किया था. गलती से उसमें कार्बोनेटेड पानी मिल गया और फिर ये बन गया कोका-कोला।
- **आइसक्रीम कोन्स (Ice-cream Cons)**: आज हम जिन रंग-बिरंगी कोन्स में आस्क्रीम भरकर खाते हैं उसकी खोज भी बस यूंही हो गई थी. क्योंकि उस समय आइसक्रीम परोसने के लिए बर्तन खत्म हो गए थे. पास के विक्रेता ने अपनी कुरकुरी वाफल रोल करके दे दी और आज वही का आइसक्रीम कोन बना.

Shell design in electric Locomotives Including camber

Chetna Nand singh
CAD/GPL/ECR

Abstract

In Indian Railway, Locomotives design start with Shell/Truck design. Need was felt to highlight the different features of shell/camber design and compare the green field locomotives with WAG9.

In Electric Locomotives, Car body shell Base or truck provides the basic structure on which other mechanical/Electrical components are fixed. Manufacturing of Locomotive starts from truck/base.

Camber is applied to Car body during manufacturing to avoid deflection/sagging beyond acceptable limits during its service period. Locomotives are condemned mainly based on Camber & age.

RDSO locomotive specification mainly talks about buffing load of 400Ton RDSO Para 4.5.9 Under-frame 'Design of the under frame/body of the Locomotive shall be made to safely with stand the following loading conditions. Also detailed FEA report for these loading conditions shall be provided to IR at Design Stage:

Stationary Locomotive under a squeeze load of 400 tones applied at the center buffer coupler.

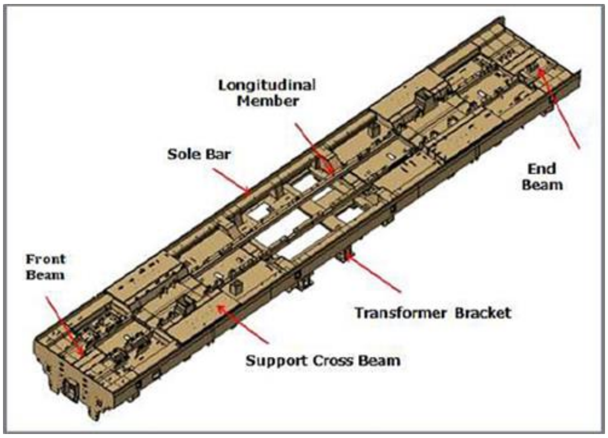
4.5.9.2 The design of the under-frame and body of the Locomotive shall be such that the stresses shall not exceed endurance limit of the material for loading conditions prescribed in Clause 4.5.9. The pivot arrangement transferring forces between body and bogies shall be designed and manufactured not only for the repeated traction and braking cycles, but also for repeated shunting shocks.

सब के लिए अच्छा होना भी, खुद के लिए अच्छा नहीं होता ।

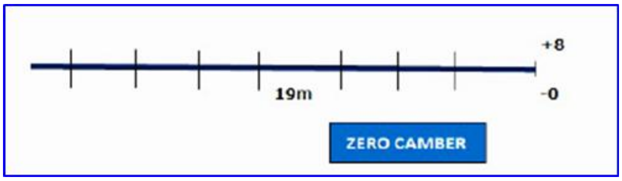
Salient features of green- field locomotive & wag 9

SN	DESCRIPTIONS	WAG12B	WDG4G /WDG6G	WAG9
1	Configuration	Bo'Bo +Bo'Bo	Co-Co	Co-Co
2	Weight of Loco Tone	180	132	132
3	Length of Loco mm	38400	22567	20562
4	Width of Loco mm	3058	3200	3152
5	Height of Loco mm	4150	4227	4255
6	Wheel Base mm	2600	1900	1850
7	Pivot centers mm	10200	14478	12000
8	Axle Load Tone	22.5	22/23	22
9	HP	12000 (6000+6000)	4500/6000	6000
10	Starting (TE) KN	706	544 KN/570 KN	510

WAG12B Underframe/truck design



WAG12B Camber design



WAG12B MAJOR COMP ONENT OF UNDERFRAME/ TRUCK DESIGN

LOCO	PART DESCRIPTION
WAG12B	Assembly Sole Bar Left & Right and Longitudinal Beam Left & Right Assembly
	Front & Rear Beam
	Bolster Assembly
	Pivot Housing
	Folded Plates

WAG12B CAMBER DETAILS

In WAG12 B, the loads in the CBS are uniformly distributed and are well balanced. There is no need of Camber for WAG12 B Locomotives as there is no passenger flow and/or any other environmental impacts which may cause uneven loading on the Locomotive. Further, according to FEA simulations, the deflections under worst case conditions with zero camber, with 1.3g loading (EN12663-1), are well within 4mm (sag). Even at this maximum loading, the Locomotive meets the gauge requirements even with worn out wheels, detailed in Annexure 1. Due to the above-mentioned reasons, provision of camber is not needed in the WAG12B CBS and hence design considerations had been also without camber. However, as per industrial requirements for manufacturing CBS, a tolerance range of 8mm for approx. 19m length of CBS as in WAG12B is required, based on proven design and good industry practice.

- Zero Camber is considered in WAG12B CBS with max deflection at 1.0g Load < 3mm and at 1.3g < 4mm.
- With a maximum deflection of 4mm, No Gauge Infringement is observed, and sufficient clearance is maintained between Equipment and Top of Rail (considering both new wheel Ø1250mm & Worn wheel Ø1164mm conditions).
- In WAG 12B, the loads in the CBS are uniformly distributed and are well balanced and the deflections observed in FEA are well within 4mm because of which, No Camber is provided.
- **Alstom's Return of Experience:** KZ8A Electric Locomotive (Twin Section Bo-Bo) with same Axle load requirement developed for Kazakhstan, Zero Camber is considered in design and these Locos are in services for approximately 10+ years.

WAG12B CAMBER MEASURED DATA

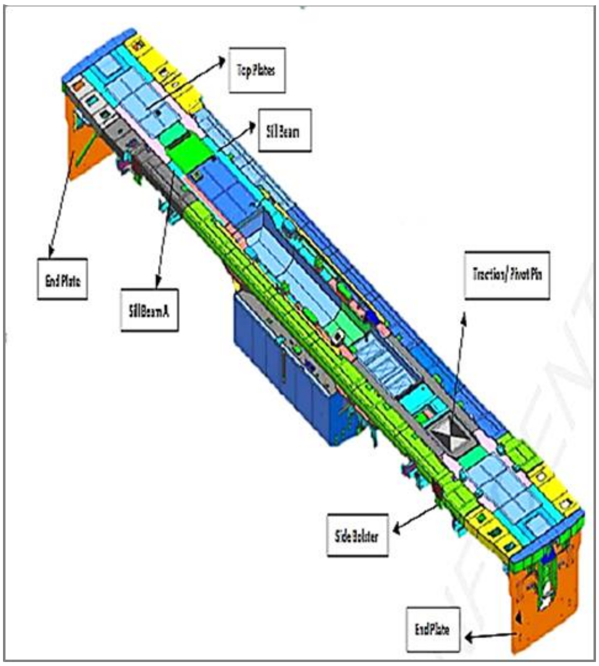
WDG4G Major component of underframe /truck design

LOCO	PART DESCRIPTION
WDG4G	Sill Beam A and Sill Beam B
	End Plate/End Assembly
	Side Bolster
	Traction/Pivot Pin

Camber specification of WDG4G / 6G

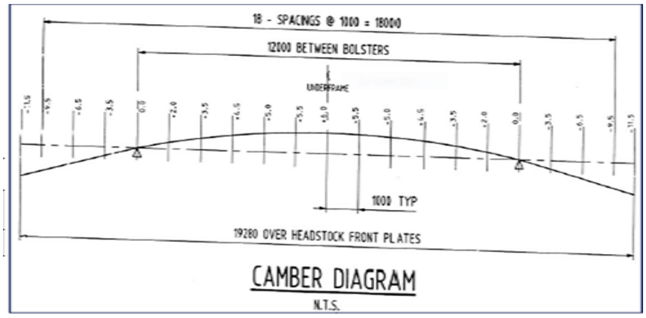
LOCO NO (PLATFORM)	CAMBER VALUE (SPECIFICATION)	ACTUAL END#1	ACTUAL END#2
WDG4G	32mm - 46mm	42.7mm	36.5mm
WDG6G	35mm-53mm	50.2mm	41.2mm

WDG4G UNDERFAME / TRUCK DESIGN



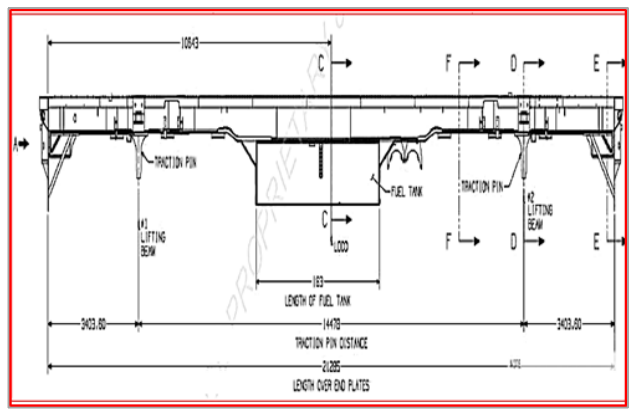
In Diesel Locomotives camber provided is 32 mm to 46mm. Locomotive body steel fabrication consisting of weld fabricated under frame oblique platform assembly with an integrated fuel tank which is the backbone to support all the above deck components and other structures. The cab frontal collision structure has been designed to load cases defined in EN12663 crashworthiness is being provided for anti-climber protection and standard design, guidelines and practices are followed for the major structural members, including the under-frame. FEA analysis has been completed to confirm adequate strength and stresses within limits at various under-frame locations.

WAG9 Camber design



UP	DOWN	TOTAL CAMBER
(+) 6	(-) 11.5	17.5

WDG4G CAMBER DESIGN



Comparative chart for major sub-components of car body shell under frame

LOCO UNDER FRAME		PART DESCRIPTION	IEC/EN/IS	CLASSIFICATION OF STEEL	THICKNESS (MM)
A	WAG12B	ASSEMBLY SOLE BAR LEFT/RIGHT	EN 10149-2	S 500 MC	8
		LONGITUDINAL BEAM RIGHT/LEFT ASSEMBLY	EN 10149-2	S 500 MC	4
	WDG4G	SILL BEAM A/B	IS 2062	E 350 C	Combination of 12,25,32 & 52
		CENTRE SECTION/FUEL TANK	IS 2062	E 550 BR	Combination of 6,8 & 12
	WAG9	SIDE SILL ASM R.H/L.H	IS-2062	E 250 C	7,8
		CENTRAL SILL ASM	IS-2062		50
B	WAG12B	FRONT BEAM/REAR BEAM	EN 10149-2, EN 10025-2	S 500 MC , S 355 J2+N	Combination of 4,6,8 & 25
	WDG4G	END PLATE/END ASSEMBLY	IS 2062	E-350 C	Combination of 10,16 & 25
	WAG9	HEAD STOCK ASSEMBLY	IS-2062	E 410 BR, E 250 C	Combination of 25, 50, 16, 40

C	WAG12B	BOLSTER ASSEMBLY	EN 10149-2, EN 10025-2	S 500 MC , S 355 J2+N	Combination of 6,25 & 100
	WDG4G	SIDE BOLSTER	IS 2062	E 350 C	Combination of 16 & 32
	WAG9	BOLSTER ASM	IS-2062	E 250 C	16
D	WAG12B	PIVOT HOUSING	EN 10025-2	S 355 J2+N	40
	WDG4G	TRACTION/PIVOT PIN	IS 2062	E 350 C	25
	WAG9	CENTRAL UNDERFRAME ASM	IS-2062	E 250 C	Combination of 16,20,40,50
E	WAG12B	FOLDED PLATES	EN 10149-2	S 500 MC	Combination of 6,8,10
	WDG4G/6G	TOP PLATES	IS 2062	E- 250 BR	Combination of 2.5,3.2

Comparison Of Chemical And Mechanical Properties Of Material Used In The Manufacturing Of WAG 12B, WDG 4G & WAG 9 Under Frame Is Given As Under.

LOCO TYPE	CLASSIFICATION OF STEEL	COMPOSITION	MIN. YIELD STRENGTH (MPA)	IMPACT TEST
WAG12B	EN 10149-2 S 500 MC	C-0.12,Mn-1.70,S-0.015,P-0.025,Si-0.50,Al-0.015,Nb-0.09,V-0.20,Ti-0.15	500	40 J at -20°C
	EN 10025-2 S 355 J2+N	C-0.20,Mn-1.60,S-0.025,P-0.025,Si-0.55	355 Range from 355 to 265 on Thickness 16 to 400 mm	27 J at -20°C
WDG4G	IS 2062 E 350 C	C-0.20,Mn-1.55,P-0.040,S-0.040,Si-0.45	350	27 J at -20°C
	IS 2062 E 550 BR	C-0.22,Mn-1.65,P-0.025,S-0.02,Si-0.5,Nb+Ti+V-0.25,N-0.012,Cu-0.2 to 0.35	550	15 J at RT
WAG9	IS 2062 E 250 C	C-0.20,Mn-1.50,P-0.040,S-0.040,Si-0.40	250	27 J at -20°C

विकास क्या है..?
पेड़ काटकर किताब बना देना,
पतन क्या है ..?
फिर उन्हीं किताबों में लिखना
पेड़ मत काटो ..!

We often feel tired—not because we have done too much work, but because we have done too little of the things that spark enthusiasm within us."

- Alexander Den Heijer

A Comparative Engineering Study on the Neutral Section Design in Conventional and High-Speed Railway Systems

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Abstract

Neutral sections (also known as phase breaks) are critical components in single-phase AC railway electrification systems. They electrically isolate adjacent traction power supply sections fed from different grid phases or substations while maintaining mechanical continuity for uninterrupted pantograph passage. This paper presents a comparative technical review of neutral section methodologies used in Indian Railways, China, Japan, South Korea, and European high-speed rail networks (France, Spain, UK, Italy, Germany, etc.), examining their electrical principles, structural configurations, operational handling strategies, and emerging technologies. Implementation differences are analyzed in relation to Feeding System, Neutral Section Type, Neutral Section Length, Phase Separation Method, Switching Operation through Neutral Section, Automation Level, Coasting Duration, and emerging technologies, such as automatically switched neutral sections.

1. Introduction

Modern electrified railways predominantly use 25 kV single-phase AC overhead systems derived from a three-phase public utility grid, where the three phases are ideally loaded equally to ensure system stability and efficiency. Connecting a large, single-phase load directly to one phase of the grid would create a severe imbalance. To minimize unbalancing on the grid, phases are tapped from adjacent substations in sequence. This is achieved by feeding consecutive traction substations (TSS) from different phases of the grid. Each substation powers a section of the track, typically 30-40 km long. Consequently, the interface between these sections powered by different phases cannot be a direct connection, as that would result in a short circuit. The solution is to install a Neutral Section (NS), which electrically isolates two different traction power phases.

A Neutral Section (also called a dead zone or phase break) is a short stretch of overhead catenary that is electrically dead or de-energized and separates two traction supply sections that are fed by different sources or phases of the electrical supply.

Neutral Sections are typically provided near Traction Substations (TSS) and Sectioning Posts (SP). The neutral section allows a locomotive's pantograph to pass smoothly and safely from one phase to another without causing phase-to-phase short circuits while ensuring uninterrupted mechanical continuity of the contact wire.

The fundamental issue with a neutral section is that it creates a temporary "dead zone" in the overhead supply, through which the train must pass without drawing power. During this interval, the locomotive coasts without traction input, resulting in a momentary reduction in speed and tractive effort. This paper analyzes the various technical approaches adopted by railway systems across the globe to overcome neutral section constraints, with emphasis on high-speed railways.

2. The Fundamental Challenges

2.1. Need for Phase Balancing

A single-phase traction load inherently unbalances a three-phase grid. To balance this asymmetry, adjacent feeding sections are supplied from rotating phases of the grid. The similar principle of rotating phases is applied globally, from the European high-speed network to the systems in Japan, South Korea, and China.

2.2. Operational Challenges of the Neutral Section

While essential for grid balance, the neutral section introduces several operational problems for a high-speed train:

- **Loss of Traction Power and Speed Reduction:** The train must pass through the neutral section in a power-off (coasting) mode, as no traction supply is available within the electrically dead zone. During this interval, tractive effort drops to zero, resulting in a temporary reduction in speed.
- **Risk of Train Stranding:** If a train stops within the NS due to operational or emergency conditions, it cannot directly draw traction power. Restoration requires special operational procedures or rescue assistance, leading to delays and safety concerns.
- **Component Stress:** The frequent opening and closing of the main vacuum circuit breaker (VCB) to enter and exit the NS leads to significant wear.
- **Electrical Transients:** The closing of the breaker can cause massive inrush currents in the train's transformer, while opening can generate overvoltage and arcing, accelerating equipment aging.
- **Electromagnetic Interference (EMI):** The arcing during transition can create EMI, potentially affecting signaling systems, track circuits, and communication lines.

3. Neutral Section Design Comparison

Railway Systems / Parameter	India (Indian Railways) (130-160 km/h)	India (HSR)* (320 km/h)	Japan (Shinkansen) (320 km/h)	France (TGV / LGV) (300–320 km/h)	South Korea (KTX), Spain (AVE) & China (320-350 km/h)	Europe (General) UK, Germany, Italy & others (200-300 km/h)
Feeding System	25 kV, AT systems	2×25 kV AT feeding		2×25 kV AT feeding	2×25 kV AT feeding	2×25 kV AT feeding
Neutral Section Type	1.Conventional Overlap, 2. Short Neutral section a. Section Insulator b. Arthur Flury PTFE	Power Supply Controlled changeover switching		1. Long Neutral Section (LNS) & 2. Split Neutral Section (SNS)	1. Long Neutral Section (LNS) &	1. Long Neutral Section (Carrier Wire NS) & 2. Split Neutral Section (SNS)
Neutral Section Length	Short dead zone 49.5 m & (5 m – 41 m)	Very short dead zone with electrical switching		200 – 400 m, <142 m (SNS)	800 – 1000 m	> 402 m (CWNS) & <142 m (SNS)
Phase Separation Method	Dead neutral zone between phases	Controlled switching between phases		Long de-energized overlap	Long de-energized overlap	Long de-energized overlap
Switching Operation through Neutral Section	Pilot switches OFF traction and coasts	Electronic switching manages the transition		Auto power cut-off (Balise-driven)	Auto power cut-off (Balise-driven)	Auto power cut-off (Balise-driven)
Automation Level	Fully driver-operated procedure	Highly automated electronic switching		On-board automatic control	On-board automatic control	On-board automatic control
Electrical System Complexity	Low	High (power electronics & control systems)		Moderate	Moderate	Moderate
Coasting Duration	13 – 16 Sec	0.30 sec (300 milliseconds)		3 – 5 Sec.	13 – 16 Sec.	5 – 8 Sec.

* *High-speed rail (HSR) networks are currently under construction in India, utilizing Japanese Shinkansen technology.*

4. System Architecture / Methodology

Globally, neutral section (NS) passing methodologies are classified based on how the traction power interruption is managed during phase separation. These neutral sections are typically categorized into two types based on the switching method:

1) On-board Circuit Breaker Off switching systems.
- Manual Circuit Breaker off Switching system.
- Long Neutral Section (Automatic Circuit Breaker switching)
- Split Neutral section (Automatic Circuit Breaker switching)

2) Power Supply Installation (PSI) side switching systems (Using Changeover Switch).

Each one of the above-mentioned Neutral section type reflects a different engineering philosophy for handling the dead zone.

4.1.1. Manual Circuit Breaker Off Switching System (On-Board Neutral Section)

The earliest method is the manual neutral section passing system used in conventional Indian Railways. In this arrangement, the loco pilot is alerted by trackside warning boards to open the main Vacuum Circuit Breaker (VCB) before entering the NS and to reclose it after exiting. This approach relies heavily on human intervention and is therefore susceptible to operational error and inconsistency, and can only be used in low-speed operations (up to 160 km/h)

Indian Railways has adopted four principal types of neutral sections, each suited to specific operational requirements and track conditions.

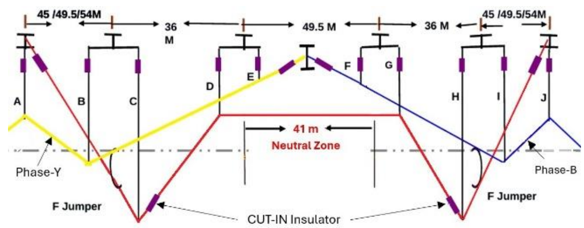
4.1.1.1 <u>Conventional Overlap Type Neutral Section (Manual CB off)</u>

The conventional overlap-type neutral section represents the earliest design on Indian Railways.

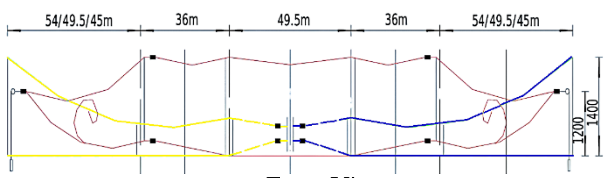
It consists of a five-span arrangement with specific span lengths:

Central span: Strictly 49.5 meters
Adjacent spans: 36 meters on each side
Effective dead length: 41 meters

The Dead zone is created by the physical separation of the live zone of the yellow and blue phases through a carefully planned staggered arrangement. This ensures electrical isolation while maintaining mechanical continuity so that the pantograph remains properly supported under its upward contact force.



<u>Top View</u>



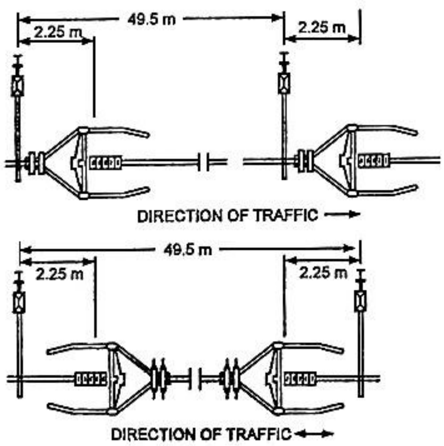
<u>Front View</u>

Description	A	B	C	D	E	F	G	H	I	J
Stagger (mm)	-200	300	1300	-50	-550	-550	-50	1300	300	-200
Encumbrance (mm)	1400	750	1050	1400	750	750	1400	1050	750	1400
Height (m)	5.50	5.50	5.90	5.50	5.575	5.50	5.50	5.90	5.50	5.50

This type of neutral section is generally maintenance-free under normal operating conditions and has proven reliable on mainline routes. The permissible speed through the section is the same as that of the parent overhead equipment, making it suitable for mainline applications. However, this arrangement has inherent limitations. There is a risk of a locomotive stopping within the dead zone due to alarm chain pulling or improper driving. In such cases, the train may become stranded, and recovery may require assistance from another locomotive.

4.1.1.2 Short Neutral Section Comprising a Section Insulator Assembly

In 25 kV AC railway electrification, a short neutral section using two back-to-back section insulators (SI) is provided where the conventional five-span overlap neutral section cannot be accommodated—typically in steep gradients, dense suburban areas, or locations with space and geometry constraints.

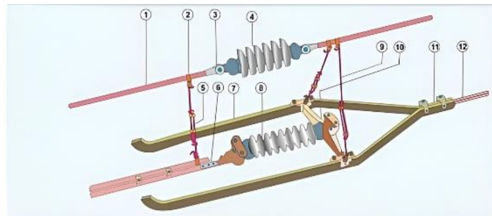


The short neutral section consists of two section insulators installed back-to-back in the contact wire, forming an electrically insulated dead zone of approximately 5 m in length. Unlike the overlap-type neutral section, which relies on staggered contact wires and an extended insulated overlap, this configuration creates a compact neutral zone within a single span.

Due to the presence of rigid section insulator components and their associated dynamic implications, speed restrictions are imposed under this arrangement:

- 100 km/h, when the runners are in the trailing direction.
- 70 km/h, in single-line working when the runners are in the leading direction.

These restrictions are essential to limit impact forces between the pantograph and the section insulator assembly, thereby preventing mech-anical damage and ensuring current collection reliability.

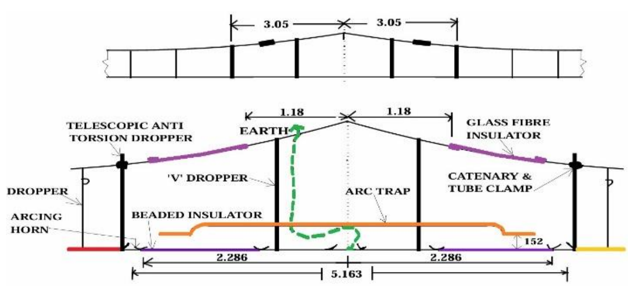


1. Catenary Wire	5. PG Clamp 6170	9. Adjustable Dropper
2. Catenary Clip	6. Trailing Grip	10. Cross Beam
3. Catenary Ending Clamp	7. Runner	11. Facing Grip
4. 9 Tonne Insulator	8. Core Insulator	12. Contact Wire

- Although the short neutral section offers a compact solution in constrained locations, its adoption on main lines is generally discouraged. The principal reasons include:
  - Increased mechanical weight compared to overlap-type designs,
  - Mandatory speed restrictions affecting line capacity, and
  - Higher maintenance requirements due to wear of runners and arcing surfaces.

4.1.1.3 Short Neutral Section with Ceramic Beads

This type of short neutral section consists of a composite contact wire insulator made of resin-bonded glass fibre rod, externally covered with ceramic beads. This type of Neutral Section has an effective length (dead length) of 4.572 meters, while the total length of the complete assembly is 5.163 meters.



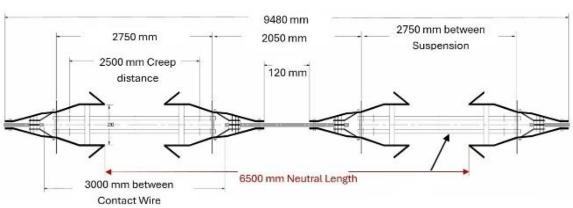
However, due to the presence of secondary beads, the mechanical strength of the rail section is comparatively lower. These beads also tend to accumulate dirt and contaminants, which increases the need for frequent cleaning and maintenance.

Because of these structural and maintenance limitations, the neutral section is restricted to a maximum permissible speed of 130 km/h, making it less suitable for high-speed applications.

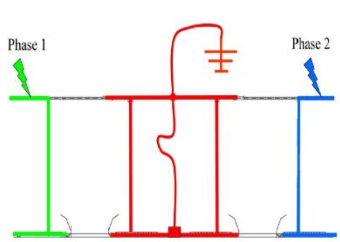
4.1.1.4 Short Neutral Section (PTFE Type)

a) Arthur-Flury Make:

An Arthur-Flury's Make Short Neutral Section Assembly of PTFE type uses PTFE (Polytetrafluoroethylene) as the insulating medium. PTFE-type neutral sections are primarily used in heavy-gradient and suburban railway sections where conventional overlap-type neutral sections are not suitable due to operational constraints.



The neutral section manufactured by Arthur Flury has an effective (dead) section length of 6.5 meters, while the total length of the complete assembly is 9.5 meters. This assembly is mounted symmetrically on the mast and is properly aligned with the track to ensure smooth interaction with the pantograph. Mechanically, it is robust, as it uses high-tensile insulator rods arranged in parallel. These rods are designed for longer service life through periodic rotation. When the rod wear accumulated to 2 mm, they are rotated by 72 degrees.



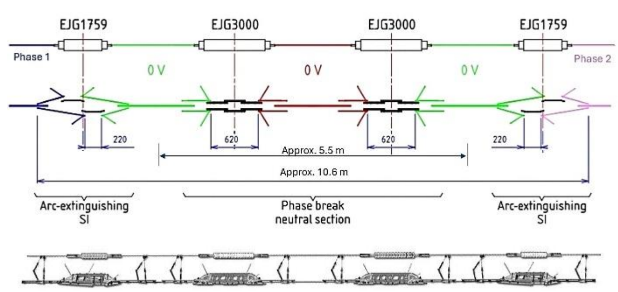
The composite design significantly reduces weight compared to earlier ceramic-beaded insulator assemblies. The midpoint of the arrangement, which forms the dead section, is earthed to prevent any possibility of short-circuiting between different phase supplies.

The PTFE-type Short Neutral Section assembly is suitable for train speeds up to 200 km/h, subject to compliance with overall OHE design parameters and dynamic performance requirements.

b) Galland Make:

A Galland's make PTFE Neutral section also uses arc-extinguishing section insulators. If a train passes through a neutral section with the pantograph raised and current still being drawn (VCB closed), an electric arc will be produced. This arc must be safely extinguished using a four-unit assembly consisting of:

- Two arc-generating and arc-extinguishing section insulators (suitable for bidirectional operation)
- Two neutral section insulators

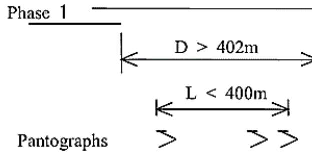


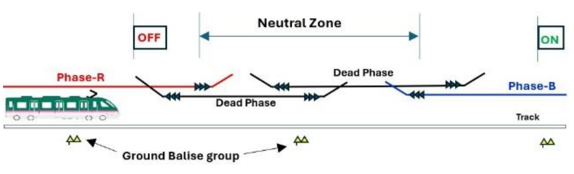
These systems use the on-board CB off method, where the train's circuit breaker is momentarily opened by either manual or automatic command to prevent bridging of different phases during passage.

4.1.2 Automatic On-Board Circuit Breaker Off Switching System

4.1.2.1 Long Neutral Section (Carrier Wire)

To improve reliability, Automatic Neutral Section Systems were introduced. The philosophy of this long Neutral section (carrier wire) is similar to the Conventional Overlap type with automatic VCB switching. A carrier wire neutral section is constructed from a series of overlaps arranged in sequence, where successive overlaps allow the pantograph to transition smoothly from one live phase to a dead phase, then back to the next live phase. In Long Neutral section the dead section length (D) must be greater than the spacing between the pantograph (L) to avoid the direct short circuit (phase bridging) in the contact wire line.



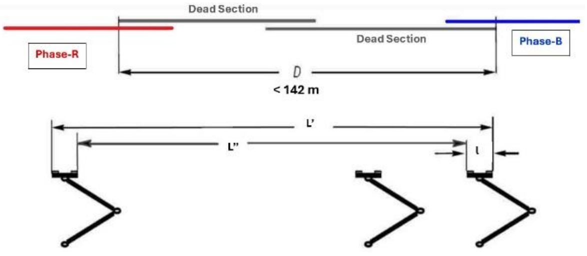


It consists of separate insulated lengths of contact wire in the overlap between two normal sections. In systems equipped with Automatic Train Control (ATC) or on-board control equipment, the train position data is obtained from track-mounted balises or other magnetic inductors installed on the track. Based on this information, the system can automatically regulate VCB by switching it OFF or ON.

Under Automatic mode, when a train is moving in the forward direction, the on-board control equipment issues a command to switch off traction power before the train reaches the forward power-off sign. After the train passes through the neutral section and its front end clears the reverse power-off sign, the on-board system issues another command to restore traction power.

4.1.2.2 Split Neutral Section (SNS)

A Split Neutral Section (SNS) is an advanced form of the conventional neutral section, specifically designed for high-speed railway lines where trains operate with multiple pantographs. Unlike a single continuous dead zone, the SNS generally consists of two dead spans.



From a design perspective, the span covering three consecutive pantographs (L”) shall be greater than D. The intermediate pantograph may be arranged at any position within this range, but the minimum distance between operating pantographs is 8 m (L’). Depending on the minimum spacing between two adjacent operating pantographs the maximum operating train speed shall be stated. In AC system, no electrical connection may exist between pantographs in service.

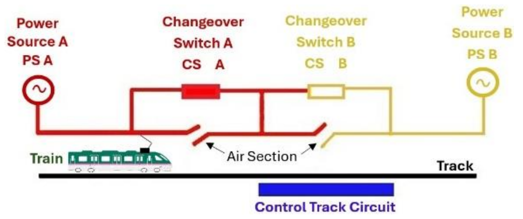
The operation is similar to a standard neutral section pantographs remain raised while the train coasts through, but the vacuum circuit breaker (VCB) remains open until the rear pantograph clears the last span. Once clear, the VCB recloses and traction resumes.

Additionally, the section must be designed with appropriate electrical clearances, insulation coordination, and mechanical smoothness to maintain stable pantograph–catenary interaction at high speeds, often exceeding 200–320 km/h.

“Split neutral section” system, which has been developed in recent years. The split neutral section system has been used on the LGV Est in France since 2007 and other railway systems across Europe, including the United Kingdom, Germany, Italy, etc.

4.2 Power Supply Installation (PSI) side switching (Auto Switched NS Using Changeover Switch).

An Auto Switched Neutral Section using a changeover switch that is controlled from the power supply side. A pioneer example of this method is Japan's High-Speed Changeover Section, implemented on the Shinkansen network and also planned for the under-construction Indian High-Speed Rail network (MAHSR). This concept represents a significant technological advancement and serves as a benchmark for modern high-speed Neutral Section design at 320–350 km/h.



The components of this type of neutral section are:

1. Changeover switch
   (2 pairs each for UP-line and Down-line)
2. Air Section (Insulated Overlap)
3. Control Track Circuit.

a) When there is no train on the track circuit, the changeover switch located in the direction towards the starting point shall be closed, and the changeover switch in the direction towards the end point shall be open.

b) When the train enters the track circuit, the changeover switch located in the direction towards the starting point shall be open, and the changeover switch in the direction towards the end point shall be closed.

The changeover switch interlocking processing for the neutral section is done via the switching PLC, which controls the changeover switch.

The Changeover Operation:

(1) While the train runs towards the neutral section.
CS A: Close, CS B: Opened
The neutral section is powered by "PS A".

(2) While the train runs in the Neutral section and does not reach the Control track circuit.
CS A: Closed; CS B: Opened.
Neutral section is powered by "PS A"

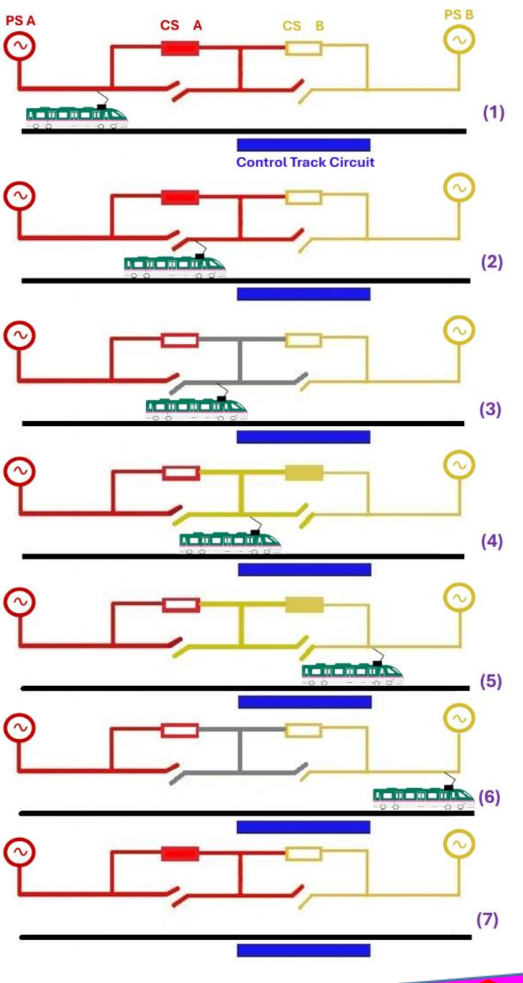
(3) The moment the Control Track Circuit detects the train.
"CS A": Opened; "CS B": Closed after 300ms.

(4) While the train runs within the control Track circuit in the Neutral Section.
"CS A": Opened; "CS B": Closed

(5) While the train is about to leave the Control Track Circuit in the neutral section
"CS A": Opened; "CS B": Closed

(6) The moment the train has passed through the Control Track Circuit completely,
"CS B": Opened; "CS A": Closed after 300ms.

(7) The Changeover Switch is powered by "PS A" in this stage for the next train passage.



5. CONCLUSION

This study examines various neutral section configurations, including conventional overlap types (long and split), short neutral sections using section insulators, PTFE, and automatic switched (changeover-type) neutral sections.

Among these, conventional overlap neutral sections remain the most widely adopted on mainline electrified routes due to their capability to support higher operating speeds, ensure smooth pantograph–OHE interaction, and require comparatively lower maintenance.

In contrast, short neutral sections provide a compact solution for constrained locations such as areas with limited space, steep gradients, or complex track layouts. However, they are associated with operational limitations, including speed restrictions, increased mechanical wear, and the potential risk of trains halting within the electrically dead zone.

Automatic switched (changeover-type) neutral sections represent the most advanced configuration, offering minimal power interruption with a dead time of approximately 300 milliseconds, even at high speeds of up to 320-350 km/h.

A comparative review of global practices shows that neutral section design varies depending on speed requirements, infrastructure constraints, and technological advancements. Indian Railways predominantly employs conventional dead neutral sections, whereas high-speed networks in Europe, China, and South Korea utilize on-board automatic long and split neutral sections. Japan adopts automated switching (power supply side) integrated with advanced control systems.

Furthermore, the Mumbai–Ahmedabad High-Speed Rail (MAHSR) Project is implementing the Shinkansen technology for the neutral section design, i.e. Automatic switched (changeover-type) neutral sections.

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Siemens 9000 HP Locomotive General Technical Description

A.K Pathak
Professor (LOCO),IRIEEN

❖ Purpose

This document gives an technical overview of the functionalities of the complete locomotive developed against the RDSO specification . no. RDSO/2010/EL/SPEC/0108, Rev.'3'.

Electric Locomotive Manufacturing Unit- Dahod

❖ Project brief

Hon'ble Prime Minister of India, Shri Narendra Modi had laid foundation stone on 20.04.2022.

- Manufacturing Cum Maintenance Agreement for 35 years was signed on 16.01.2023
- Each Locomotive Base Price is Rs. 10.981 Crore with IR manpower and Rs. 12.08 Crore without Railway manpower.
- Co-Co Configuration Electric Locomotives of 7000 kW (9000 H.P.) .
- Nominated Indian Railway's Depots are Visakhapatnam, Raipur, Kharagpur and Pune.
- Loco Holding of each depots will be 300.
- Flagging Off of Prototype Locomotive was done by Hon'ble Prime Minister on 26.05.2025.

❖ Key Milestones of Project

❖ Site Overview

❖ Highlights -

- State of the Art Plant
- Provision of State-of-the-Art M&Ps
- Production sheds & Ancillary Buildings designed for IGBC Gold Certification
- Administrative Building designed for IGBC PLATINUM Certification

❖ Sustainability -

- Day light access for workplace
- 500 kW Solar Plant
- Solar tube lighting & Streetlights
- Rainwater harvesting with 36 bore holes
- Zero Liquid Discharge (ZLD) through Effluent Treatment Plant (ETP)
- Efficient Irrigation Syste

❖ Staff Friendly & Safety-

- Provision of High-Volume Low speed fans, Brushless DC fans & Turbine Roof Ventilation
- Centralized RO Water system
- Creche to facilitate Women staff
- Fire Hydrant Pipeline with Smoke & Fire Detection
- Access Control system for Dynamic Test Zone & 25 KV OHE Areas

❖ Locomotive Key Features & Project Overview -

1,200 nos. locomotives of 9000 hp ; max 160 nos. to be supplied per annum to be delivered over 11 years up to 2034-35. Locomotives of 9000 hp will haul 5,800 tonnes with 22.5 tonnes axle load Haulage capacity at a gradient of 1/200 at a speed of at least 60 km/h and 120 km/h max speed in levelled track.

Existing WAG9HH has a haulage capacity of 5400 tonnes at a gradient of 1/200 at a speed of 20 km/h

State of the Art Features-

- Real Time Remote Monitoring system for Predictive Maintenance using Artificial Intelligence based Data Analytics.
- Ex- Ambient Temp Sensor, Fire Detection Sensor etc.
- Crew Voice & Video recording with Track Side and Pantograph view camera.
- Slip Slide Control for optimum adhesion.
- Integration of Traction & Aux Converter.
- Machine Room designed to minimize Dust & Water Ingress.
- Event recorder with Crash protected memory.
- Driver Advisory System (Energy Optimizer.)
- KAVACH ready.

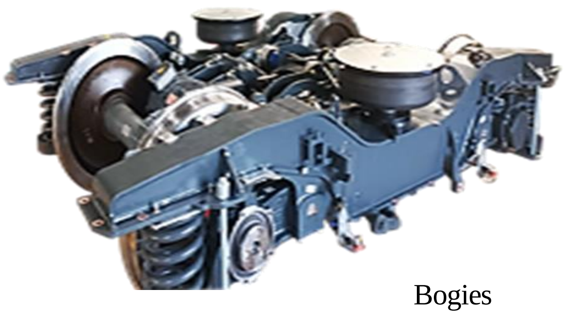
❖ 2. General

2.1 Overview

This is to give a brief overview of the vehicle as well as to provide some basic understanding of the locomotive..

The design and manufacture of the Locomotive and

- Ergonomic Driver Seat.
- Water less Urinal.
- Signal Exchange Lights.
- Global Standard Driver desk.



Bogies

Auxiliary Converter

Auxiliary Converter

Modular constructions shall be adopted and easy access for inspection and maintenance shall be given special consideration in the design and layout of the Locomotive. Siemens ensures that there is no infringement of patent rights arising due to similarity in design, manufacturing process, use of similar components in the design and development of the Locomotive and any other factor not mentioned herein which may cause such a dispute. The entire responsibility to settle any such disputes/matters lies with the Siemens.

For avoidance of any doubt, in case of any conflict between the content in this document and the content of the additional documents, the content in the sub documents apply.

❖ 1.2 Standards-

According to "RDSO/2010/EL/SPEC/0108 Rev '3' issued on14.09.2022"

❖ 3.5 Tractive/ Braking Effort Diagram

The tractive and braking characteristic curves require an adequate adhesion value between wheel and rail. The maximum utilization of the available adhesion value is enabled by a highly effective electronic slip/slide control.

❖ 4 Locomotive complete

The locomotive is a dual cab locomotive. A central walkway is arranged inside machine room for easy access and maintenance of components. For major repair of systems, the equipment can be easily removed from the locomotive through the 3 detachable roofs.

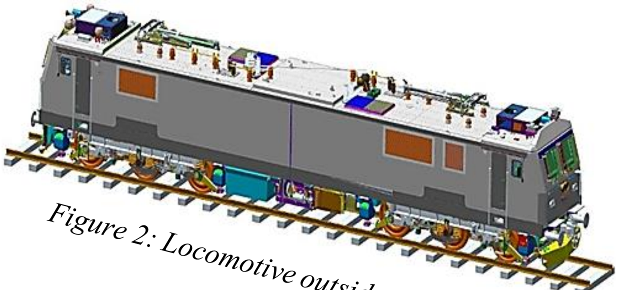
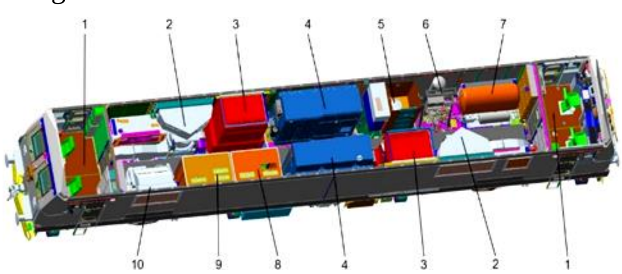


Figure 2: Locomotive outside view

The main modules of the locomotive are carbody shell, driver's cab, detachable roofs, machine room, underframe arrangement, bogies and front arrangement.

The driver cabs and machine room are separated by a rear wall. Access to the driver's cab is via two entrance doors on the left and right of the driver's cab. Access to the machine room is via a door situated in the middle of the real wall. The driver cabs are insulated against noise, heat and low temperatures and have a modern and ergonomic design.



1	Drivers cab	6	Brake rack
2	Traction motor blower (TMB)	7	Air reservoirs
3	Cooling unit	8	Low voltage cubicle
4	Traction converter	9	Auxiliary cubicle
5	Urinal	10	Machine room blower

Figure 3: Locomotive inside view Brake Control and Air

The weight balance and the wight distribution down to each wheel is calculated in an excle table considering all assambly groups of the loco-motive. This wight balance table will be updated frequently during the project phase.

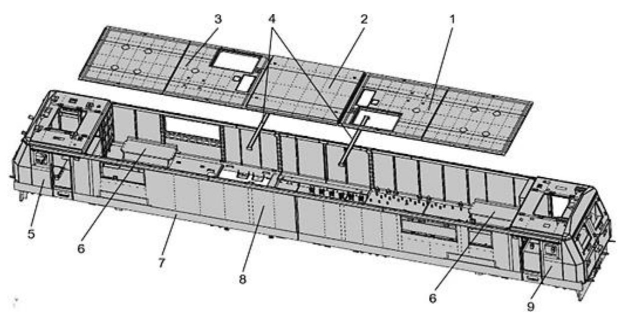
Each locomotive will be weighted after finalizing the assambly of the locomotive. That weighing test will be documented for each locomotive. For this purpose a template sheet called "weight balance test report" will be prepared to be used for each individual weight test.

For detailed information of locomotive com-plete refere to customer documents accord-ing to the document submission plan:

❖ 5 Locomotive Body

▪ 5.1 Carbody shell

The carbody shell, in the following consistently named as "CBS", is designed as a self-supporting structure made entirely of steel and welded. The locomotive carbody shell consists mainly of underframe, two driver's cabs, two cab rear walls, the side walls, and two cross-sectional stiffeners
On top of the carbody shell two detachable roof arches and three detachable roofs.



1	Roof 1	6	Cross beam with secondary spring
2	Roof 2	7	Side sill
3	Roof 3	8	Side wall
4	Cross sectional stiffner	9	Cab 1
5	Cab 2		

Figure 4: Carbody shell

❖ 5.2 Coupling system

Both ends of the locomotive are fitted with a draw and buffing gear. AAR "E" type coupler head with AAR "F" type shank and AAR "F" type yoke as well as a screw coupling at a height of 1090 mm.

❖ 5.3 Side Buffers

Two side buffers used. The buffers will be mounted at a height of 1105 mm from Rail Level with 1955 mm center distance.

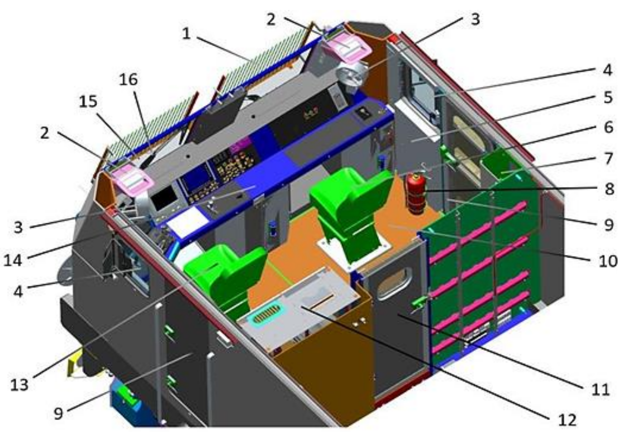
❖ 6 Driver's cab

▪ 6.1 Overview

Two driver's cabs provided at each end of the locomotive . The driver's cab is accessible through two outside doors.

Each driver's cab has two seats, one for the locomotive driver and one for a co-driver, with the driver sitting on the left.

The two swing doors provided, to the right and left for accessing the driver's cab from outside, with handholds.



1	Protection grill	9	Entrance door
2	Air duct	10	Floor
3	Crew fan	11	Machine room door
4	Side window	12	Rear wall cabinet
5	Side wall paneling	13	Driver seat
6	Driver assistant seat	14	Driver desk
7	Tool cabinet	15	Windscreen
8	Fire extinguisher	16	Windscreen wiper system

Figure 6: Machine room

❖ 6.2 Driver's Desk

In the drivers desk colour graphics driver display unit for the driver (DDU) is provided in each cab . The display is menu driven. All menu pages arranged in a tree-like fashion. Switching between menu pages is done by pressing the appropriate application key. The display will show all important information relevant to the driver, including operational aspects, fault status and messages.

Operation and driver assistant system The modular designed driver's desk is ergonomically designed based on the directive UIC 651. An operation manual including drivers desc but also other operating panels on the locomotive will be provided.

Driver assistant system will be provided in locomotive. It assists to driver for achieving better energy saving.

❖ 6.4 Air Conditioning

The driver's cab is air-conditioned. A HVAC system in compliance to UIC 651 is mounted on each cab roof. Supply air outlets are from the sides of the cab sidewall. Return air interface is at the cab ceiling. The ceiling and the walls are protected with heat insulation.

❖ 6.4 Air Conditioning

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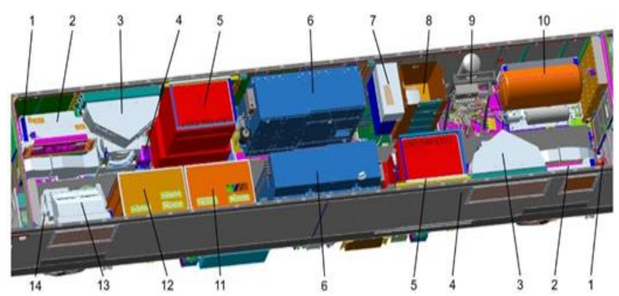


1	Fire extinguisher	8	Urinal
2	Ballast	9	Brake rack
3	Traction motor blower (TMB)	10	Air reservoirs and ballast below
4	Scavenge blower for TMB	11	Low voltage cubicle
5	Cooling unit	12	Auxiliary cubicle with two battery chargers
6	Traction converter	13	Machin room blower (MRB) and ballast below
7	Expansion tank for main transformer	14	Scavenge blower for MRB

Figure 6: Machine room

❖ 7.2 Ventilation and filtering

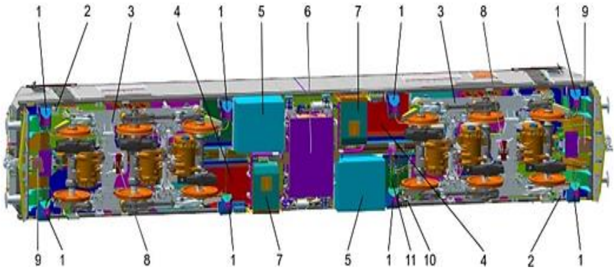
For machine room and traction motor ventilation and filtering a two-stage system will be used. First stage is a vertical centrifugal separator grill at the upper sidewall with 25% choking reserve for water and dust. For second stage a cyclone separator will be used as efficient additional dust filter. During operation the machine

machine room is in slightly pressurized to reduce intrusion of dust from the outside.

For detailed information of the machine room refere to customer documents according to the document submission plan:

❖ 8 Underfloor arrangement

Primary components of the underfloor arrangement are the main transformer, two bogies, two air generation and treatment units (AGTU), two battery boxes and eight sand boxes. Further provided equipment consists of antennas, external power supply as well as a wheel flange lubrication. Because rotating machines are more vulnerable due to their vibrations, they will have safety slings to protect them from falling into the track, these are the traction motor and the compressor.



1		7	Battery box
2	Shore supply	8	Centre pin
3	Bogie	9	KAVACH antenna
4	Air outlet cooling unit	10	Wheel flange lubrication reservoir
5	Air generation and treatment unit (AGTU)	11	Urinal outlet pipe
6	Main transformer		

Figure 7: Locomotive underfloor view

❖ 8.1 Main transformer

The main transformer is equipped with two ester pumps and is suspended on four points below the locomotive body. The transformer cooling circuit is connected to the two cooling systems inside the machine room using cooling pipes and compensators.

❖ 8.2 Battery box

The two battery boxes are attached to the under-frame of the locomotive. They are self-ventilating and extracting. The battery NiCd battery cells are fixed in a tray which can be easily forklifted.

❖ 8.3 Sanding

The sand distributor consists of eight individual sanders. Each sander is assigned to a locomotive wheel. The sand is ejected in front of the wheels of the relevant front axle of both bogies, depending on the direction of travel (axle 1 and 4 or axle 6 and 3). The sand boxes can be filled by hand. Each sandbox will have a volume of 50 litres. Sandboxes are mounted on the car body and the sanding nozzle is mounted on the Bogie.

❖ 8.4 Wheel flange lubrication

Wheel flange lubrication tank mounted. is pneumatically driven. There are two distributor valves and the 4 nozzles mounted on the bogies. Depen-ding on the direction of travel, the wheel flanges of the respective front wheelset of the locomotive are lubricated (axle 1 or 6).

❖ 8.5 Train Collision Avoidance System

Train Collision Avoidance System (TCAS) ante-nnas are mounted underslung between head stock and bogie on each side of the Loco. The height of antennas could be adjusted from top of the rail.

For detailed information of the underfloor equipment refere to customer documents accor-ding to the document submission plan:

❖ 9 Energy supply

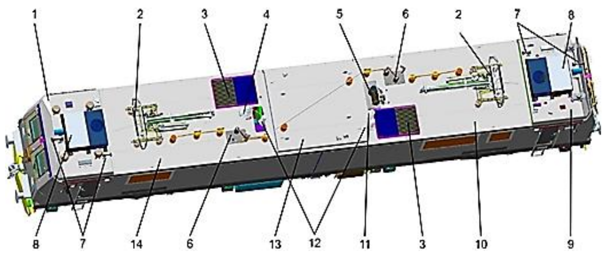
▪ 9.1 Pantograph

Pantographs are mounted on machinery room one and three. Each pantograph will be equipped with a carbon strip. Each pantograph can be electrically disconnected from the roof equipment and earthed by a selector switch on the roof. The pantograph is suitable to work both in normal OHE and high-rise OHE.

9.2 High voltage roof components

Vacuum circuit breaker (VCB) will be mounted on the machine room roof. VCB will be opened b control electronics in case of any disturbance overwriting driver's command.

Lightning arrestors will be provided on the Locomotive for protection against the line voltage transients caused by lightning and system switching. A voltage transformer will also be placed on the machine room roof.



1	Driver cab 2	8	Heating ventilation and air conditioning (HVAC)
2	High rise pantograph	9	Driver cab 1
3	Air inlet cooling unit	10	Roof 1
4	Voltage transformer	11	High voltage bushing
5	Vacuum circuit breaker (VCB)	12	Surge arrestor
6	Roof disconnector	13	Roof 2
7	Horns	14	Roof 3

Figure 8: Roof Layout

❖ 10 Traction system

▪ 10.1 General

The Locomotive will be equipped with state-of-the-art Propulsion system and bogie drive system on open platform to ensure interoperability of different make equipment supplied within the contrac- tual obligations of M/s. Siemens. The following schematic diagram illustrates the main power circuit of one traction converter for one of the locomotive's bogies. The second traction converter is identical and therefore not shown in the diagram. Below the main components and their respective functions are described.

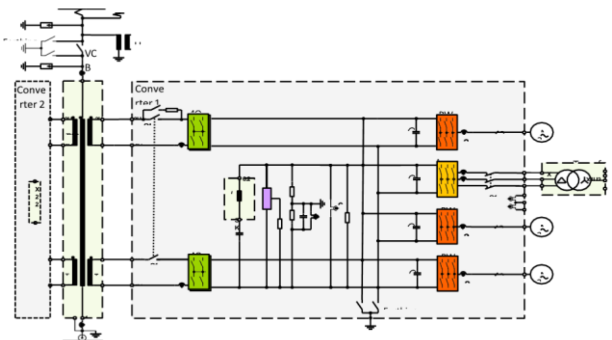


Figure 9: Maine circuit diagram

❖ 10.2 Main transformer

The main transformer is designed as AC 25 kV 50 Hz single phase transformer. The transformer environmentally friendly ester (MIDEL 7131) used. Two pumps mounted to the transformer, each pump will feed a separate cooling unit inside the machinery room. The expansion tank with Buchholz relay will also be placed inside the machinery room.

❖ 10.3 Traction converter

Each of the two traction converters is located in a separate cabinet. Each bogie is assigned to one traction converter. Each traction converter is equipped with its own traction control. The power electronics of the traction converter is based on IGBT technology (insulated gate bipolar transistor) The traction converter cabinets are IP54 encased (dust and splash proof). The entire cabinets can be removed and fitted through the roof opening after the central roof panel is removed.

Each traction converter is equipped with two four quadrant choppers (4QC). These 4QC feed the power to the DC link. DC link circuit includes the resonant circuit for filtering out the 100 Hz frequency components.

There are three traction inverters (PWMI) within each traction converter. The PWMI allow an energy flow in both directions (traction/braking). Each traction motor (M) is connected to a separate PWMI. The PWMI supplies the traction motor with variable voltage and frequency.

❖ 10.4 Cooling of Traction Converter and Main Transformer

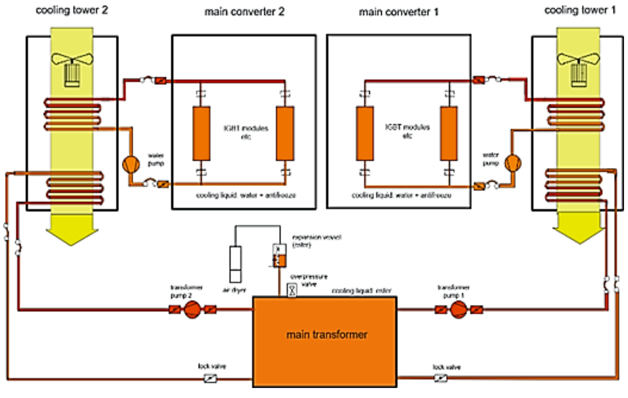


Figure 10: Principle of cooling system

In the middle, there are the two traction converters with their cooling water system. Each traction converter has a combined cooling tower located directly beside the traction converter.

Each cooling tower has two heat exchangers. One for cooling the transformer ester (lower one) and one for cooling the converter water (upper one), a water pump and a blower. The cooling air is drawn from the top of the Locomotive, flows through the heat exchanger for the cooling water of the traction converter first and then cooling the transformer ester before it is blown out of the locomotive at the bottom.

❖ 10.5 Drive

A nose suspended drive will be used consisting of the traction motor, the gear and the motor suspension unit.

The three-phase current asynchronous motor with squirrel-cage rotor fitted in parallel to the wheel-set shaft is designed for use on traction converters without motor input chokes. It is externally ventilated by a traction motor fan fitted in the machine room. The gear unit is located on the wheel set shaft and the traction motor frame.

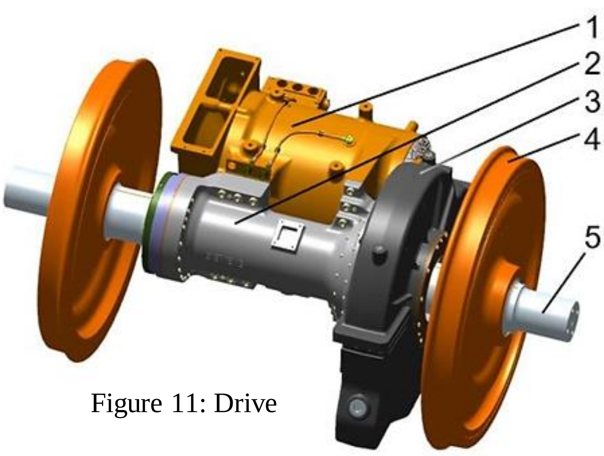


Figure 11: Drive

1	Traction motor	4	Wheel
2	Motor suspension unit	5	Axle
3	Gear		

Each traction motor is equipped with protective chain to protect against the falling on the track in case of torque arm failure condition.

For detailed information of the traction and auxiliary equipment refer to customer documents according to the document submission plan:

❖ 11 Auxiliary system

▪ 11.1 General

The Aux-PWM modules are integrated in the traction converter. The auxiliary transformers are located in the tank of the main transformer under floor. They are cooled with ester. Sine filter capac itors for the auxiliary converter output voltage will be included in the auxiliary cubicle, located in the machine room. Two identical battery chargers will be placed inside the auxiliary cubicle, operated by the auxiliary converter output power for charging the control battery of 110V DC. The rating of these battery chargers are such that there is 100% redundancy available for charging the battery.

❖ 11.2 AC on-board power supply

A fixed frequency and a variable frequency three-phase on-board supply system supplies the electrically driven auxiliary and ancillary facilities.

The fixed frequency system operates at a fixed voltage and frequency of 3AC, 415 V, 50 Hz. The variable frequency system operates at a variable voltage and frequency from 3 AC 80 V, 10 Hz to 415 V, 53 Hz, to be able to vary the cooling power of the connected traction motor blower and cool ing unit fans.

Both on-board power supply systems are fed by an own auxiliary inverter each (Aux PWI). Disruption of an Aux. PWI reconfigures the consumers using coupling. Operation of all consumers will then be with fixed frequency 3AC 415 V 50 Hz. Every consumer can be separated from the circuit with an automatic protective device.

❖ 11.3 DC on-board power supply

The battery and DC on-board power supply are galvanically isolated from the AC on-board power supply by the battery charger. The battery charger charges the battery from the three-phase on- board power supply. Two redundant battery chargers will be used in the auxiliary cubicle. Ni-Cd battery with nominal voltage of 110 V with low maintenance is mounted in two battery boxes underfloor.

For detailed information of the traction and auxiliary equipment refer to customer documents according to the document submission plan:

❖ 12 Locomotive control

The central control units CCU1 and CCU2 (also called VCU Vehicle control unit) together with the traction control units TCU1 and TCU2 are the main components of the control equipment for the complete Locomotive. In each traction converter one common processor card hosting the functions of both CCU and TCU is installed. They are linked to other subsystems via the multifunctional vehicle bus (MVB) for purposes of data exchange.

The control equipment consists of the following components:

- One common processor card for both CCU and TCU functionality assigned to each traction converter
- The brake control unit (BCU)
- The I/O stations in the driver's cab and machine room
- The displays in the driver's cab

The CCU has at least for the following functions:

- It processes all commands from operator (throttle handle, switches, etc.) or train bus.
- It controls and monitors on/off devices on the locomotive.
- Processes inputs and outputs hardwired signals via external I/O modules.
- It communicates with other units via the available interfaces.

❖ The basic control architecture scheme is as follows:

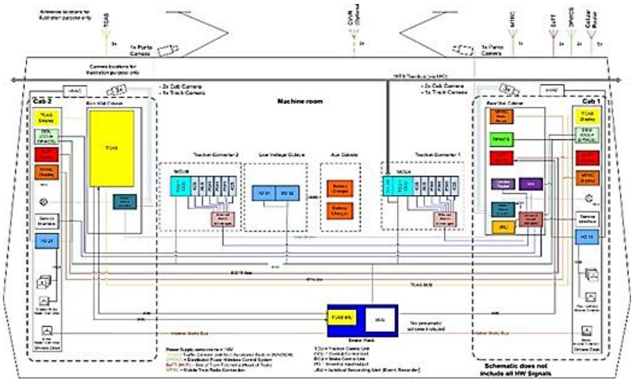


Figure 13: Locomotive control

❖ 13 Diagnosis

The diagnostics system provides both the locomotive driver and the workshop personnel with comprehensive information about the locomotive and the status of the locomotive and allows the maintenance personel to analyse the technical condition of its vehicle fleet.

On the vehicle, the vehicle diagnosis is shown on the Drivers Display Unit (DDU).

The service interfaces in the driver's cabs can also be used to output the diagnostics data for further analysis using laptop and service software. The diagnostic data will also be transmitted to a diagnosis server.

For detailed information of the locomotive control refere to customer documents according to the document submission plan:

❖ 14 Brake

The locomotive has following types of brakes for various types of braking requirements.

1) Pneumatic Braking. 2) Re-Generative Braking. 3) Parking Brakes.

▪ 14.1 Pneumatic Brake System

Operator/ driver can apply the independent and automatic braking (self-lapping type) through the operating elements of brake master controller on driver's desk which is continuously communicating with the brake control module in machine room.

The driver's brake master controller is equipped with the following operating elements:

- Automatic brake handle
- Bail Off Ring
- Independent brake handle
- Selector Switch (TEST, LEAD, TRAIL, HLPR)

Controlling the train-wide brake pipe pressure is done with an electronic controlled air brake system for operation of twin pipe graduated released air braked train.

At emergency brake only pneumatic brake is applied and the electrodynamic-brake is cut off.

The automatic brake handle is equipped with a dedicated and latched emergency position. In this position a pneumatic pilot pressure pipe is vented through a mechanical activated valve. A piston valve that is kept closed by the pilot pressure opens BP with a large cross section.

In each cab a driver assistant cock is provided on right hand side in each cab near assistant driver. Emergency brake can be applied by venting the brake pipe by the driver assistant cock

A driver's backup brake valve is placed in the left side of the drivers desk. In case of failure of electronic controlled brake system, the auto-matic brakes of train and locomotive can be applied and released by controlling the brake pipe pressure using back-up brake lever after putting the PER cock in back up mode. Via Driver's Backup brake valve a time dependent pneumatic control of brake pipe pressure is possible. This allows the train to move at predetermined restri-cted speed. The restricted speed for back up brake after emergency distance will be reported after execution of brake test runs.

The locomotive is equipped with the following end- to end pipes:

- Brake pipe: to control all automatic brakes in the train.
- Direct brake pipe: to control the independent brakes of the locomotives.
- Main reservoir equalizing pipe: pipe for all the locomotives connected thru hoses, in multiple operations or whenever there is more demand of compressed air
- Feed pipe: supplies air exclusively for the Auxiliary Reservoirs for quick/repetitive application of brakes.

For coupled locomotives, the brakes on the Locomotives will be applied automatically, in the event of parting.

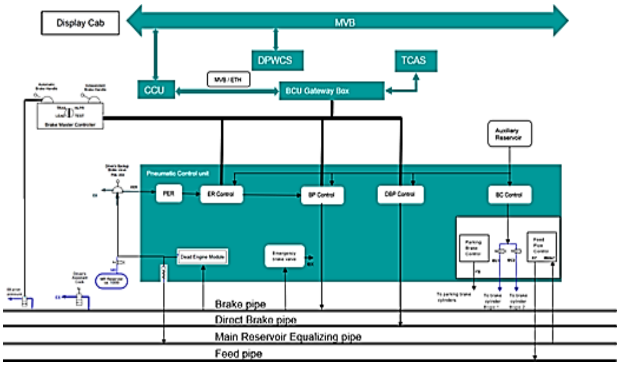


Figure 14: Pneumatic brake control

▪ 14.1.1 Automatic brake

To control the pressure of the brake pipe (BP), there is a position-dependent, electronically con-trolled driver's brake valve. The driver's brake valve is in accordance with UIC 541-03.

The braking system of the locomotive is based on proven design for operation of a twin pipe graduated release air braked train. One graduated release distributor valve per loco according to EN 540 is installed.

The operating mode of the automatic brake can be chosen by a lever on the distributor valve which directly is part of BCU system. The possible operating modes are "G" (Goods) or "P" (Passenger). For selection of the brake position a suitable handle or an electrical switch is installed in the brake system.

The electronic controlled brake sys-tem reads the positions of the G/P selector switch and controls the gradients for building up and reducing brake cylinder pressure according to the chosen operating mode of the automatic brake.

▪ 14.1.2 Bail Off

A bail off functionality is provided to release the automatic brake of the locomotive when the brake pipe pressure of the train still is reduced.

In each cab a foot switch for releasing of locomotive brake (bail off) is installed. Bail off function also is provided from the bail off ring of the independent brake (direct brake) handle.

The automatic brake of the locomotive will be released for the duration of the manual activation of the bail off by the driver. The bail off command also is active on the trailed locomotives.

▪ 14.1.3 Independent Brake (Direct Brake)

The independent brake is a not-self-acting, pneumatic brake subsystem with graduated application and release. The independent brake is designed to work unaffected from automatic service braking and electrodynamic braking.

A lower brake demand of any other brake subsystem must not overwrite a higher brake demand of the independent brake.

Handling and activation of the electrical control signals are independent from automatic and dynamic braking.

Independent brake handle is active and full operational in the activated cab of the leading loco or the banking loco. The loco brakes and direct brake pressure (DBP) control is according to the independent brake handle position.

The locomotive is equipped with a direct brake pipe. The direct brake pipe is only coupled be-tween locomotives in multiple unit operation. The DBP is used to control the brakes in slave locos.

- **14.1.4 Brake Cylinder Pressure Generation**

The brake cylinder pressure is the result of the maximum pre-control pressure of the automatic and independent brake.

For manual isolation of the pneumatic brake per bogie one isolation cock is provided to isolate the pneumatic brake individually on each bogie.

The brake cylinder pressure of each bogie of the locomotive is displayed on the driver's display in the activated cab.

- **14.2 Re-Generative Braking**

Driver can apply electrical braking by moving the throttle of the Traction-/ Electric-Brake Controller (TE/BE-Throttle) to the braking zone. Then the control system will operate the traction motors in such a way, that they behave like the generators and the energy will be fed back to grid from each traction converter. This leads to reduction in locomotive speed which can literally bring down the locomotive to standstill condition.

The Re-Generative brake of the locomotive is used for gradual braking, for service braking according to brake pipe pressure reduction or is used when the driver puts the TE/BE-Throttle in brake position.

Re-Generative Brake is cut off in the following cases:

- At emergency brake application
- At independent brake application

✓ **Gradual braking**

The braking energy of the Re-Generative brake is feed in the power line when the power grid is receptive.

In a single locomotive or in the leading locomot-ive in multi-unit operation, the percentage regen-erative brake set value is read from the TE/BE-Throttle in the active cab and used by the CCU.

Regenerative brake is applied according to the service brake demand of the TE/BE-Throttle.
Retention of the automatic brake is provided when the regenerative braking effort exceeds 10 kN.
The substitution of the regenerative brake with the EP-brake is used in case that the re-generative brake fails

✓ **Service braking according to brake pipe pressure reduction.**

The loco control unit calculates a braking effort set value according to the brake pipe pressure reduction. This braking effort set value is used primarily as Re-Generative brake effort set value.
The resulting Re-Generative brake effort set value is the maximum Re-Generative brake effort set values from gradual braking and service brake according to brake pipe pressure reduction.

In this case using the Re-Generative brake for gradual braking by moving the traction/brake manipulator still is possible.

✓ **Display of Re-Generative brake effort values**

The set and actual value for the ED braking force of the vehicle is shown on driver's display.

- **14.13 Parking Brake**

A pneumatic spring-loaded brake is used as a parking brake.
The parking brake is applied and released by using a single switch in the driver's cab. The parking brake's compressed air supply is provided from ain reservoir. If the supply tank's pressure drops, the parking brake applies automatically.

Each parking brake cylinder is equipped with a mechanical auxiliary release device. The auxiliary release device is actuated directly on the brake cylinder. Before the auxiliary release, the parking brake must be vented through the parking brake cut-out cock. This ensures that the unintentional readiness of an auxiliary released parking brake cylinder cannot be restored.

Also, anti-compounding function is achieved by means of duplex check valves that ensure parking brake and service brake are not applied together hence protecting the bogie brake from damaging.

14.14 Bogie brake

All wheels of the Locomotive are provided with tread brake with high composition brake blocks. The total braking force is 7-12% of the maximum designed weight of the Locomotive in working order. Slack adjustment mechanism is provided to automatically adjust to the wheel and brake blocks wear.

Bogie wise isolation cocks for pneumatic brakes provided to isolate individual bogies in case of any failure of component. Parking brake isolation cock are provided at loco level.

14.15 Indicators

Brake pipe (BP) pressure, flow Indication, main reservoir (MR) pressure, feed pipe pressure as well as the bogie related brake cylinder pressures C1 and C2 are shown on gauges at the driver's desk on the left-hand side.

The following pressure gauges are provided:

- Double Pressure gauge MR/FP
- Double Pressure gauge BC1/BC2 pressure
- BP-Pressure gauge
- Parking brake pressure gauge

15 Air generation

15.1 Main air supply

- On driver’s desk a compressor operation mode selector switch is installed. The following operating modes are foreseen:
- Operating mode “Auto”:
- In automatic operation the compressors are switched on and off depending on main reservoir pressure level.
- Operating mode "OFF":
- When operating mode "Off" is active in this position all compressors are inactive.
- Operating mode "Direct" (ON):
- When operating mode "Direct" is selected, both compressors are requested for the duration of the operation, regardless of the main reservoir pressure.

Two identical air generation and treatment units (AGTU), mounted in the underframe, provides compressed air supply for continuous operation at a pressure of 10 kg/cm².

The compressors are controlled in automatic mode based on main reservoir pressure measurement to ensure that the pressure in the system is regulated between 8 kg/cm² and 10 kg/cm². A safety valve is provided to protect the compressor against excess pressure. Safety slings are provided to ensure the compressor unit doesn't fall on the track in case of mounting bracket failure.

Each AGTU unit has a heatless regenerative twin tower type air dryer to ensure that the dry air is available for controls and pneumatic operation on the locomotive.

15.2 Auxiliary compressor

The auxiliary air supply system produces the compressed air which is used by the components (pantograph, roof disconnector, vacuum circuit breaker) which establish the electrical connection between the transformer and the overhead line.

During operation in progress meaning the main air compressor is available, the air supply of the auxiliary air supply system is provided by the main air supply system.

For the auxiliary air supply an electric driven auxiliary air compressor will be used. The power supply of auxiliary compressor is directly connected to battery voltage.

15.3 Compressed Air Storage and distribution

The locomotive has main air reservoirs for storage and buffering the compressed air generated by the compressor. In total a main air reservoir of around 1000 ltrs is provided.

For the drainage and the purging the main air reservoirs of the air supply system manual operated cocks are foreseen. The main air reservoirs can be manually isolated by isolation cock.

For detailed information of the air generation, main- and auxiliary reservoirs as well as the automatic drain valve please refer to customer document: “9000 hp Air Supply System“ A6Z00056407877

16 Bogie

The bogie is characterized by following features:

- Robust, fully welded bogie frame
- Tractive force transfer by means of low-level traction linkage with a pivot to the first crossbeam of the bogie frame
- Wear free axle guidance
- Primary coil spring
- Secondary coil spring (flexi-coil suspension)
- Lateral and vertical hydraulic damper
- Robust nose suspended drive
- One-sided wheel tread brakes

Good accessibility to be checked during the maintenance periods is provided by the design. Wear and tear components are also easily accessible

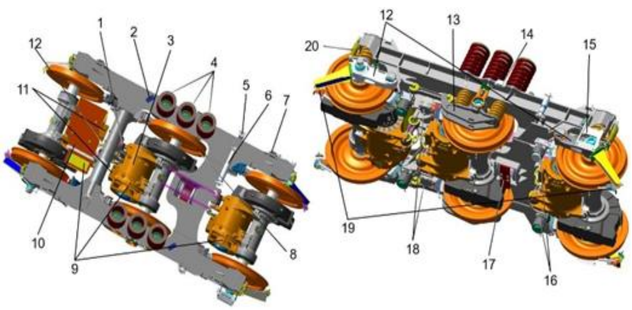


Figure 15: Bogie

For detailed information of the bogie refere to customer documents according to the document submission plan:

❖ 17 Train protection

▪ 17.1 Train Protection and Warning System

Space for Train Protection and Warning System (TPWS)/Train Collision Avoidance System (TCAS) supplied by IR is provided. The control unit will be installed in the rear wall cabinet in driver's cab two. Space for display on each driver's desk is provided.

▪ 17.2 Mobile Train Radio Communication System (MTRC)

Space for Mobile train Radio system supplied by IR is provided.

▪ 17.3 End of Train Telemetry (EoTT) System

Locomotive will be equipped with End of Train Telemetry (EoTT) System. The control unit will be installed in the rear wall cabinet in driver's cab one. Space for display on each driver's desk is provided.

For detailed information of the train protection system refere to customer documents according to the document submission plan:

❖ 18 Maximum moving dimensions

The locomotive with new wheel will have overall moving dimensions according to Diagram No. 1D (EDO/T-2202) 1676 mm Gauge Revised 2022.

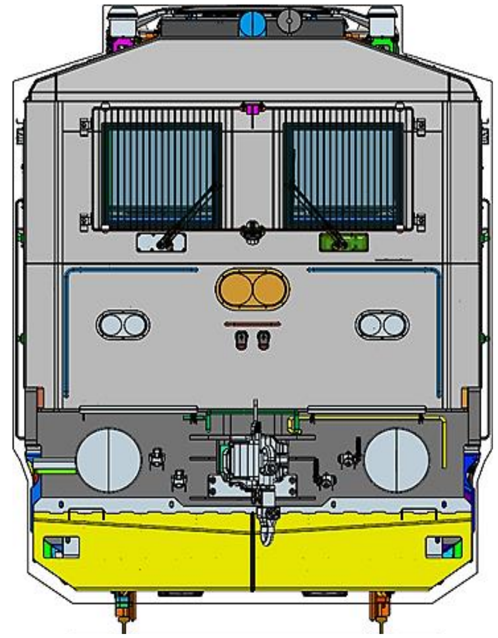


Figure 16: Maximum moving dimensions

1	Traction motor support	11	Terminal box
2	Vertical stop	12	Axle bearing in swingarm
3	Nose suspended traction motor	13	Axle bearing with binary rod
4	Secondary spring	14	Lateral stop
5	Vertical damper	15	Entrance steps
6	Lateral damper	16	Two brake cylinders with spring loaded parking brake for axle 1+3
7	Rotation stop	17	Bogie lifting link to carbody
8	Transfer of longitudinal and lateral forces (center pivot part of carbody)	18	Two brake cylinders without spring loaded parking brake for axle 2
9	Air inlet	19	Sanding of axle 1+3 of each bogie
10	Air duct for axle 3 and 4	20	Primary Damper

Semiconductor Technology: Foundation of Modern Electronics and Its Growing Significance in India

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Abstract:

Semiconductors are the fundamental building blocks of modern electronic systems, enabling the development of devices ranging from basic diodes to advanced microprocessors. Their unique property of controllable electrical conductivity has revolutionized industries such as communication, computing, transportation, and defense. Similar to how technological advancements like railway electrification have improved efficiency and sustainability in large-scale systems , semiconductor technology has driven the digital revolution. This article presents an overview of semiconductor fundamentals, types, devices, applications, and global trends, with a focused discussion on the emerging semiconductor ecosystem in India.

➢ Introduction:

In the present digital era, semiconductors play a role as crucial as electrification did in transforming industrial and transportation systems. Their ability to control the flow of electric current under varying conditions makes them indispensable in modern electronics. A semiconductor is defined as a material whose electrical conductivity lies between that of a conductor and an insulator. This intermediate conductivity allows it to function as a controlled medium for current flow. Silicon is the most widely used semiconductor material, accounting for the majority of electronic devices, while germanium and gallium arsenide are used in specialized applications.

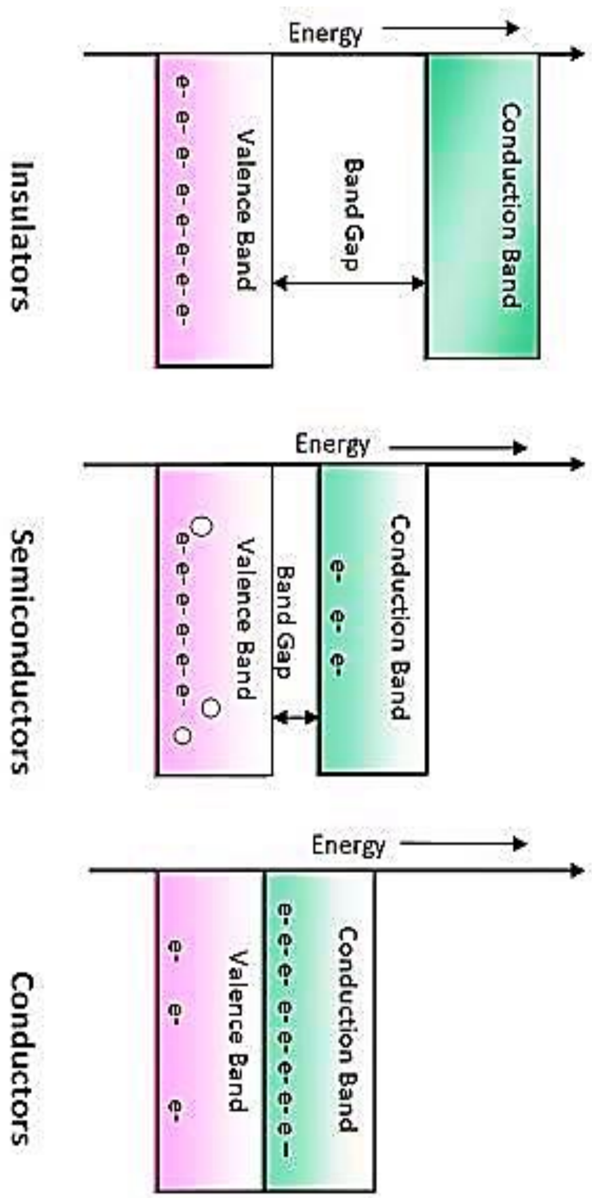


Figure 1. Energy band comparison of conductor, semiconductor, and insulator.

➢ Fundamental character-istic of semiconductors :

The electrical behavior of semiconductors is highly sensitive to external conditions such as temperature, light, and impurity concentration. Unlike conductors, the conductivity of semiconductors increases with temperature due to the generation of additional charge carriers. Semiconductors possess two types of charge carriers: electrons, which carry negative charge, and holes, which represent the absence of electrons and behave as positive charge carriers. The movement of these carriers under an applied electric field results in electric current. Another important characteristic is the ability to control conductivity through a process known as doping, which involves the intentional addition of impurities to the semiconductor material.

➢ Types of semiconductor:

Semiconductors are broadly classified into intrinsic and extrinsic types based on their purity and conductivity characteristics. Intrinsic semiconductors are pure materials such as silicon or germanium, in which the number of electrons and holes is equal. These materials exhibit relatively low conductivity. Extrinsic semiconductors are formed by doping intrinsic materials with specific impurities to enhance conductivity. Based on the type of impurity added, they are classified into two categories. In N-type semiconductors, elements such as phosphorus or arsenic are added, resulting in an excess of electrons as the majority charge carriers. In contrast, P-type semiconductors are formed by doping with elements such as boron or gallium, which create an excess of holes.

➢ Semiconductor devices ;

The controlled electrical properties of semiconductors enable the fabrication of various electronic devices that form the backbone of modern technology. Diodes are semiconductor devices that allow current to flow in only one direction, making them essential for rectification. Transistors act as switches and amplifiers and are the fundamental components of digital circuits. Integrated circuits (ICs) combine millions or even billions of transistors on a single chip, enabling complex functionalities. Microprocessors, which are the core of computing systems, are also built using semiconductor technology. In addition, semiconductor materials are used in light-emitting diodes (LEDs) and solar cells, contributing to energy-efficient lighting and renewable energy generation.

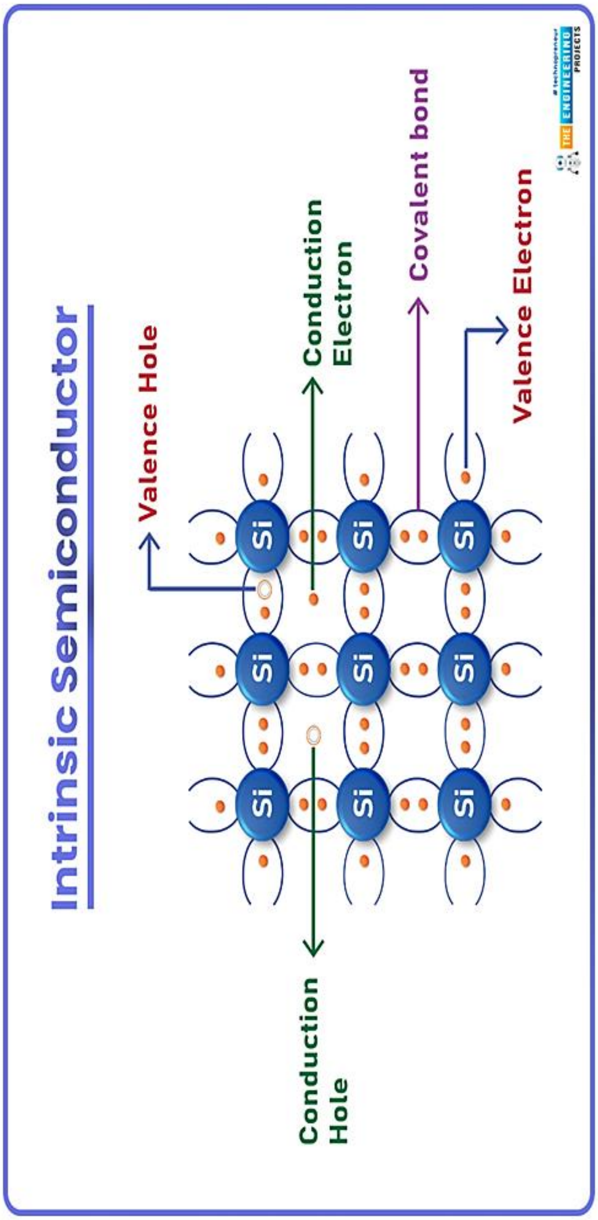


Figure 2. Intrinsic Semiconductors

1.Application of semiconductor technology

Semiconductors are used extensively across a wide range of industries and technologies. In computing and mobile devices, they form the basis of processors, memory chips, and graphics units. In the automobile industry, semiconductor devices are used in engine control units, braking systems, sensors, and , Navigation systems. In telecommunications, semiconductors are essential for the functioning of 4G and 5G networks, satellite communication, and networking equipment. They are also widely used in defense and space technologies, including radar systems, missile guidance, and satellites. Consumer electronics such as televisions, washing machines, air conditioners, and smart devices also rely heavily on semiconductor-based components. A modern smartphone, for example, contains more than 100 semiconductor chips.

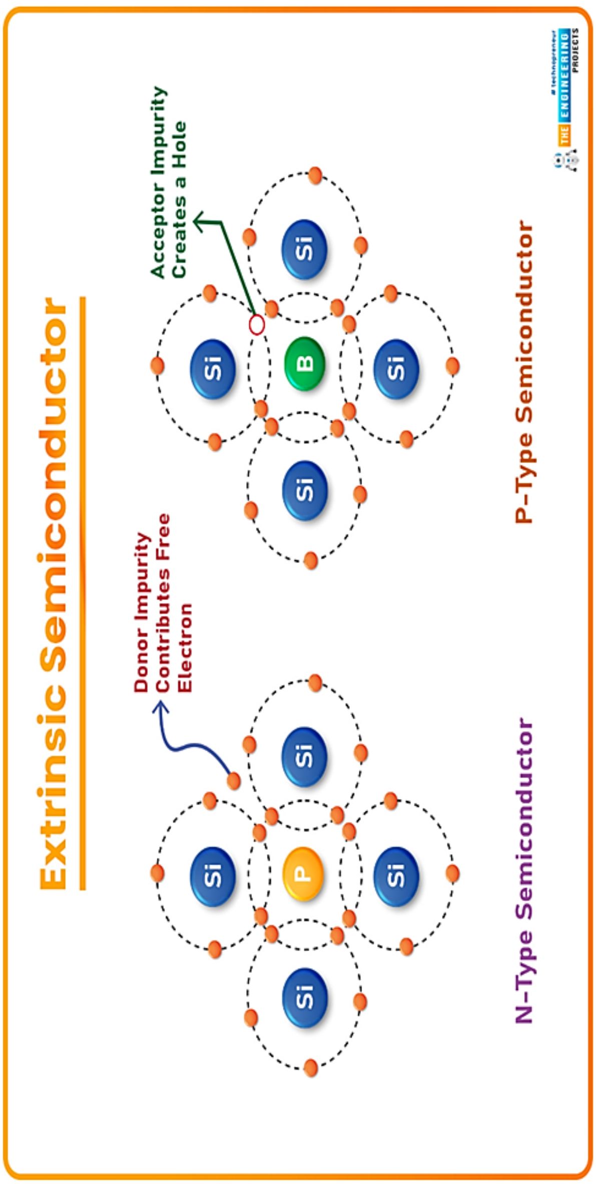


Figure 3. Extrinsic Semiconductors

➢ Global semiconductor industry :

The semiconductor industry is one of the most critical sectors in the global economy. In 2023, the global semiconductor market was valued at approximately 526 billion dollars and is projected to exceed 1 trillion dollars by 2030. More than one trillion semiconductor chips are manufactured annually, highlighting their widespread use. The major production regions include Taiwan, South Korea, the United States, Japan, and China, which dominate the global semiconductor supply chain. This concentration of manufacturing capabilities has made semiconductors strategically important for economic and technological security.

➢ Semiconductor industry in india:

India has historically depended on imports to meet its semiconductor requirements. However, with the rapid growth of the electronics sector, there has been a significant increase in demand for semiconductor devices. To address this, the Government of India launched the India Semiconductor Mission in 2021, with an investment package of approximately 10 billion dollars aimed at promoting domestic manufacturing. Several key initiatives are underway, including semiconductor fabrication projects by Tata Electronics, an assembly and testing facility by Micron Technology in Gujarat, and proposed investments by the Vedanta Group. India’s electronics market, valued at around 155 billion dollars in 2022, is expected to grow to 300–350 billion dollars by 2030, further driving semiconductor demand.

➢ Demand and future prospects of india :

The semiconductor market in India was valued at approximately 15 billion dollars in 2020 and is expected to reach 80–100 billion dollars by 2030. This growth is driven by increasing smartphone penetration, expansion of 5G networks, growth in automotive electronics, and advancements in artificial intelligence and the Internet of Things. With strong policy support, increasing investments, and a large pool of skilled engineers, India has the potential to become asignificant player in the global semiconductor ecosystem..

➢ Significance in modern technology :

Semiconductors form the foundation of modern technological advancements, including artificial intelligence, robotics, communication systems, and space exploration. They enable the integration of billions of transistors into a single microchip, resulting in powerful and efficient computing systems. Without semiconductors, the development of modern digital infrastructure would not be possible.

❖ Conclusion :

Semiconductors have transformed the world by enabling the development of advanced electronic systems and digital technologies. Their role in modern society is comparable to that of electrification in large-scale infrastructure systems, which significantly improved efficiency and sustainability. India's efforts to develop its semiconductor industry represent a crucial step toward technological self-reliance and economic growth. With continued investment, innovation, and policy support, India is well-positioned to emerge as a key hub in the global semiconductor industry in the coming years.

A Mother's Thoughts

One day, a mother-who supported herself and her son by going from house to house to wash dishes-received a sealed envelope from her son. Handing it to her, the boy explained that his teacher had instructed him to give the letter 'only' to his mother. As soon as the mother read the letter, she began to smile inwardly. Seeing her smile, the boy asked the reason for her happiness; gently stroking his head, she replied, "Son, it says here that you are the smartest student in your class. We do not have teachers capable of teaching a child as brilliant as you. Therefore, you should be enrolled in a different school." Hearing this, the boy was overjoyed and began to study with great dedication.

The mother subsequently enrolled her son in another school. The boy studied with immense diligence, and later in life-through the sheer strength of his hard work-he became the renowned scientist, **"Albert Einstein"**.

Time passed, and eventually, Albert Einstein's mother passed away. Some time after her death, when Einstein opened his mother's wardrobe, he discovered that very same letter written by his teacher-the one he had been instructed to deliver to his mother all those years ago when he was just a little boy. Einstein opened the letter and began to read it; it stated: "We regret to inform you that your son is extremely weak academically. His intellectual development is not keeping pace with his physical growth. Therefore, we are expelling him from the school. You must enroll him in another school, or else educate him at home."

Upon reading the letter, Einstein broke down and wept bitterly, reflecting on how his mother had completely transformed her son's future.

'Lesson': In exactly the same way, you too can shape a bright future for children who have lost hope in life, simply by changing their mindset.

भारतीय रेलवे में 'ऊर्जा संरक्षण' की उपयोगिता।

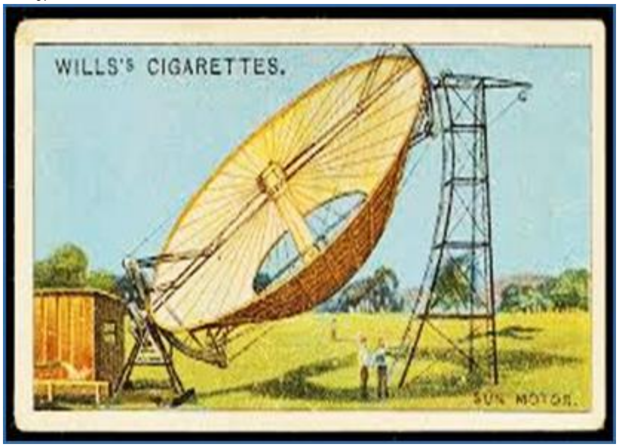
विकास कुमार बघेल
वरिष्ठ अनुवादक, इरीन

ऊर्जा संरक्षण का अर्थ है- "ऊर्जा का विवेकपूर्ण उपयोग करना, अनावश्यक अपव्यय को रोकना तथा कम ऊर्जा में अधिक कार्य प्राप्त करना और पर्यावरण को स्वच्छ रखना "।

भारतीय रेल विश्व की चौथी सबसे बड़ी यातायात रेल सेवा ही नहीं , बल्कि यह आर्थिक गतिविधियों, सामाजिक विकास तथा औद्योगिक प्रगति का भी प्रमुख आधार है। भारत में रेल परिवहन करोड़ों लोगों की रोजमर्रा की जरूरत है और उनके आर्थिक, व्यापारिक एवं रोजगार की रोजी-रोटी का सशक्त माध्यम भी बनी हुई है और यह वर्षों से सफ़र के साथ-साथ माल-ढुलाई एवं कार्गो का भी भरोसेमंद माध्यम रहा है। परंपरागत रूप से रेलवे अपनी ऊर्जा जरूरतों के लिए कोयले, डीज़ल और ग्रिड बिजली पर निर्भर रहा है। इसके कारण भारी मात्रा में कार्बन उत्सर्जन, ऊर्जा लागत में वृद्धि तथा पारिस्थितिक प्रभाव पैदा होते रहे हैं

वर्तमान में प्राकृतिक संसाधनों में कोयला, गैस, डीजल-पेट्रोल की उपलब्धता में निरंतर की कमी के चलते यदि आज हमने कल के बारे में नहीं सोचा तो निश्चित रुप से हम अंधकार की ओर बढ़ जाएंगे। इसलिए भारत सरकार ने रेलवे के लिए नए ईधन के रुप में और नये विकल्पों को तलाशना जारी रखा जो रेलवे के पहिए को निरंतर चलाए रख सके।

रेलवे ने नाभिकीय परमाणु ऊर्जा का विकल्प खुला रखा है लेकिन जोखिम भरा होने के कारण इसको अमल में लाना अभी संभव नहीं है। दूसरा विकल्प हाइड्रोजन से गाडियों को चलाने के लिए प्रयास किया जा रहा है लेकिन वर्तमान में हाइड्रोजन महंगा होने के कारण इस पर रेलवे पूरी तरह से निर्भर नहीं रह सकता है। तीसरे विकल्प के रुप में हमारे पास सोलर ऊर्जा और पवन ऊर्जा का एक अच्छा विकल्प हो साबित सकता है। लेकिन इससे गाड़ी को चलाना मुश्किल है क्यों कि भारत में हजारों गाड़ियों जो रोजना पटरियों पर दौड़ रही है। उनके लिए इसके द्वारा ईधन की आपूर्ति करना संभव नहीं है फिलहाल सोलर ऊर्जा द्वारा रेलवे स्टेशनों और गाड़ी के अंदर की विद्युतीय प्रकाश ऊर्जा तक ही सीमित रखा गया है। वर्तमान में फीडरों के पास सोलर प्लांट और पवन चक्की लगाने के लिए रेलवे में प्रयास जारी है जिससे विद्युत ट्रेनों को चलाने के लिए बिजली तैयार की जा सके। सौर ऊर्जा को कम खर्चीला और लंबे समय तक प्रयोग की जाने वाली और कभी खत्म न होने वाला ईधन कहा जा सकता है। हम कह सकते है कि सौर ऊर्जा (Solar Energy) एक साफ़, सस्ता और टिकाऊ विकल्प बनकर उभर रहा है। भारतीय रेल ने अब सौर ऊर्जा का उपयोग व्यापक स्तर पर करना शुरू कर दिया है ताकि स्वच्छ ऊर्जा अपनाई जा सके, पर्यावरण प्रदूषण घटाया जा सके और लागत में भी बचत हो सके।



वर्तमान में सोलर ऊर्जा प्रयोग ने भारतीय रेलवे के संचालन में एक बड़ा बदलाव लाया है। यह न सिर्फ स्वच्छ और नवीकरणीय ऊर्जा स्रोत प्रदान करती है, बल्कि रेल संचालन के खर्च में भी कमी लाती है, पर्यावरण को बचाती है, तथा भारत को ऊर्जा-आधारित आत्मनिर्भरता की ओर अग्रसर करती है।

आईए सौर ऊर्जा को समझते है: सौर ऊर्जा सूर्य द्वारा उत्पन्न ऊर्जा है जो पृथ्वी पर प्रकाश और ऊष्मा के रूप में पहुँचती है। इसे सौर पैनलों (Solar Panels) के माध्यम से विद्युत ऊर्जा में बदला जा सकता है। यह एक नवीकरणीय, हरित (ग्रीन) तथा प्रदूषण-रहित ऊर्जा स्रोत है, क्योंकि इसका उपयोग करने से कोई हानिकारक गैसें नहीं निकलतीं।

आज के आधुनिक युग में ऊर्जा मानव जीवन की सबसे बड़ी आवश्यकता बन चुकी है। उद्योग, परिवहन, कृषि, शिक्षा, चिकित्सा, संचार तथा घरेलू कार्यों से लेकर राष्ट्रीय विकास तक हर क्षेत्र ऊर्जा पर निर्भर है। लेकिन बढ़ती जनसंख्या, शहरीकरण और तकनीकी विकास के कारण ऊर्जा की मांग तेजी से बढ़ रही है। इसी कारण ऊर्जा संरक्षण आज विश्व की सबसे बड़ी जरूरत बन गया है। ऊर्जा मानव जीवन की सबसे महत्वपूर्ण आवश्यकताओं में से एक है। मनुष्य के दैनिक जीवन से लेकर समाज, उद्योग, कृषि, परिवहन, चिकित्सा, शिक्षा और संचार तक प्रत्येक क्षेत्र ऊर्जा पर निर्भर है। ऊर्जा के बिना आधुनिक जीवन की कल्पना भी संभव नहीं है। आज हम जिस तेज गति से विकास कर रहे हैं, वह ऊर्जा के निरंतर उपयोग का परिणाम है। परंतु यह भी सत्य है कि ऊर्जा के संसाधन सीमित हैं, जबकि ऊर्जा की मांग दिन-प्रतिदिन बढ़ती जा रही है।

ऊर्जा संरक्षण से हम प्राकृतिक संसाधनों की रक्षा कर सकते हैं, प्रदूषण कम कर सकते हैं, और आने वाली पीढ़ियों के लिए ऊर्जा उपलब्ध करा सकते हैं। ऊर्जा संरक्षण आज समय की सबसे बड़ी आवश्यकता है। ऊर्जा के बिना विकास संभव नहीं, लेकिन ऊर्जा संसाधनों का अनियंत्रित उपयोग भविष्य को संकट में डाल सकता है। ऊर्जा संरक्षण का अर्थ केवल बिजली बचाना नहीं है, बल्कि यह प्राकृतिक संसाधनों की रक्षा, पर्यावरण सुरक्षा और राष्ट्रीय विकास का आधार है। ऊर्जा संरक्षण से आर्थिक बचत होती है, प्रदूषण कम होता है, ग्लोबल वार्मिंग पर नियंत्रण संभव होता है और भविष्य की पीढ़ियों के लिए संसाधन सुरक्षित रहते हैं। ऊर्जा संरक्षण केवल एक विकल्प नहीं, बल्कि आज की अनिवार्यता है। यदि हम समय रहते ऊर्जा का सही उपयोग नहीं करेंगे तो भविष्य में ऊर्जा संकट गंभीर रूप ले सकता है। इसलिए हमें ऊर्जा दक्ष उपकरण अपनाने, अनावश्यक बिजली उपयोग रोकने, सार्वजनिक परिवहन को बढ़ावा देने तथा नवीकरणीय ऊर्जा स्त्रोतोंजैसे सौर एवं पवन ऊर्जा को अपनाने की आवश्यकता है। वास्तव में, ऊर्जा बचाना ही ऊर्जा पैदा करने के समान है। ऊर्जा संरक्षण से हम अपने देश को आत्मनिर्भर, पर्यावरण को स्वच्छ और भविष्य को सुरक्षित बना सकते हैं।

रेलवे में पारंपरिक ऊर्जा स्रोतों की सीमाएँ-भारतीय रेल ने दशकों तक कोयला-अधारित बिजली, डीज़ल इंजन तथा ग्रिड बिजली का इस्तेमाल किया है

ये स्रोत-

- पर्यावरण प्रदूषण बढ़ाते हैं,
- गैसीय उत्सर्जन को नियंत्रित नहीं करते,
- भविष्य में ऊर्जा संकट का कारण बन सकते हैं।
- महंगे होने के कारण रेलवे पर आर्थिक बोझ का संकट बना रहता है।
- ऊर्जा तैयार करने की लागत में लगातार वृद्धि।
- स्वच्छ पर्यावरण और जलवायु परिवर्तन का कारण।

इन कारणों को रोकने के लिए रेल को अपनी ऊर्जा जरूरतों के लिए स्वच्छ और स्थायी विकल्प की तलाश थी। गैर-नवीकरणीय स्रोतों से बिजली तथा ईंधन की लागत बढ़ती जा रही है। रेलवे एक विशाल संगठन है—जिसकी बिजली और ऊर्जा मांग बहुत अधिक है। सौर ऊर्जा अपनाकर ऊर्जा खर्च को कम किया जा सकता है।

भारत ने 2030 तक कार्बन उत्सर्जन में कटौती तथा नेट-जीरो (Net Zero) लक्ष्य हासिल करने की प्रतिबद्धता ली है। सोलर ऊर्जा इस दिशा में एक निर्णायक भूमिका निभा सकता है।

भारतीय रेल ने अब तक करीब 898 मेगावाट सौर ऊर्जा क्षमता स्थापित कर दी है, जो पुराने स्तर (2014 में 3.68 मेगावाट) से लगभग 244 गुना अधिक है। इसके तहत 2,626 रेलवे स्टेशन सौर ऊर्जा से संचालित हो रहे हैं।

भारतीय रेलों में सोलर पैनल रेलवे स्टेशनों, कार्यालय भवनों, कार्यशालाओं, आवासीय क्वार्टरों और सेवा भवनों की छतों पर लगाए जाते हैं। इससे- स्टेशन की लाइटिंग, सार्वजनिक प्रकाश व्यवस्था, स्टेशन के संकेतक, एलिवेटर, लिफ्ट और रेल परिसरों में सुरक्षा-जगहें ,पंप सेट, प्रशासकीय ऊर्जा जरूरतें आवासीय रेलवे कॉलोनियों में स्ट्रीट लाइटों के लिए प्रयोग में लाई जाती है।

ट्रैक्शन के लिए कुल स्थापित सौर ऊर्जा में से लगभग 70% हिस्सा ट्रैक्शन के लिए उपयोग हो रहा है, जिससे ग्रिड ऊर्जा की निर्भरता कम हो रही है कुछ स्थानों पर रेलवे ट्रैक के बीच भी सौर पैनल लगाए गए हैं-जैसे बनारस लोकोमोटिव वर्क्स (BLW), वाराणसी में 70 मीटर लंबा रिम्यूवल सोलर सिस्टम लगाया गया है, जो बिना अतिरिक्त भूमि उपयोग के बिजली उत्पादन कर रहा है।

- **सोलर ऊर्जा की विशेषताएँ** -सौर ऊर्जा तब तक उपलब्ध है जब तक सूरज है, इसलिए यह कभी खत्म नहीं होने वाला स्रोत है। यह पृथ्वी के हर कोने में उपलब्ध है, विशेष रूप से भारत जैसे धूप वाले देशों में यह प्रचुर मात्रा में है । यह हमारे लिए प्राकृतिक रूप से उपलब्ध रहती है और इसके इस्तेमाल से कोई हानिकारक गैस उत्सर्जित नहीं होती। इसमें प्रदूषण शून्य के करीब होता है। सोलर प्रारंभिक निवेश अधिक हो सकता है, लेकिन सौर ऊर्जा के रख-रखाव तथा संचालन की लागत कम होती है। सौर ऊर्जा उत्पन्न करने की प्रक्रिया में कोई शोर नहीं होता है। सौर ऊर्जा न केवल आत्मनिर्भरता बढ़ाती है बल्कि भविष्य में ऊर्जा सुरक्षा के लिए एक भरोसेमंद विकल्प है ।
- **सोलर ऊर्जा के फायदे** -रेलवे द्वारा सौर ऊर्जा से बिजली उत्पन्न करने पर रेलवे के वित्तीय लाभ पहुंचा है जैसें-स्टेशन बिजली लागत में कमी आई है, रेलवे को करोड़ों रुपये की बचत हुई है।उदाहरण के तौर पर उत्तर मध्य रेलवे मंडल ने सौर ऊर्जा से 42.19 लाख यूनिट बिजली बनाई और ₹1.6 करोड़ से अधिक बचत की है।
- **पर्यावरण संरक्षण मे लाभ-** सौर ऊर्जा उत्सर्जन-रहित है। रेल की पारंपरिक ऊर्जा से निकलने वाले CO_2 और अन्य गैसों को कम करके वायु प्रदूषण घटता है, वातावरण स्वच्छ रहता है, जलवायु पर साकारात्मक असर पड़ता है। सोलर पैनलों से सीधे ऊर्जा लेने से पर्यावरण में करोड़ों टन CO_2 उत्सर्जन कम किया जा सकता है। सौर ऊर्जा से रेल अपनी ऊर्जा जरूरतों के लिए ग्रिड से कम निर्भर रहती है। इससे ऊर्जा आपूर्ति में क्षमता तथा सुरक्षा बढ़ती है।
- **रोजगार और आर्थिक विकास-** सौर ऊर्जा उद्योग में उत्पादन, निर्माण, रख-रखाव सहित रोजगार के नए अवसर उत्पन्न होते हैं।
- **सोलर ऊर्जा के नुकसान और चुनौतियाँ –** शुरुआत में उच्च प्रारंभिक लागत आती है जैसे- सौर पैनल, बैटरी स्टोरेज, इंवर्टर सिस्टम, माउंटिंग संरचनाएँ आदि की खरीद और स्थापना प्रारंभ में महँगी होती है। बेहतर ऊर्जा भंडारण के लिए बैटरी स्टोरेज की आवश्यक को बढ़ाती है ताकि रात के समय और खराब मौसम में भी बिजली उपलब्ध रहे। यह तकनीकी रूप से महँगा समाधान है।परंतु यह भविष्य के लिए वन टाइम इनवेस्टमेंट के रुप में फायदे का सौदा साबित होती है।

मौसम पर निर्भरता -सौर ऊर्जा केवल दिन में और धूप हो तो उत्पन्न होती है। रात के समय, बारिश या बादलों में उत्पादन कम हो जाता है।यह चुनौती सौर ऊर्जा के लिए बैटरी स्टोरेज सिस्टम को आवश्यक बनाती है, जिससे लागत और जटिलता बढ़ सकती है।

- **रख-रखाव और सफाई की कठिनाइयाँ-** सौर पैनलों को नियमित रूप से साफ़ रखना पड़ता है, विशेषकर रेल परिसरों में धूल, पक्षी मल, पत्तियाँ और वायु-गलन प्रभाव पैदा कर सकती हैं।
- **तकनीकी प्रस्ताव और जटिलताएँ-** रेल नेटवर्क बेहद विस्तृत है। ट्रैक पर पैनल लगाने जैसी नवाचारी योजनाएँ अभी परीक्षण चरण में हैं और तकनीकी रूप से अधिक सुधार की आवश्यकता है।
- **सफल उदाहरण और आँकड़े** -बड़े पैमाने पर सौर ऊर्जा स्थापना (Mass Solar Installation)2,626 रेलवे स्टेशन सौर ऊर्जा से संचालित हो रहे हैं। कुल सौर क्षमता 898 मेगावाट तक पहुँच चुकी है, जिसमें करीब 629 मेगावाट ट्रैक्शन और 269 मेगावाट गैर-ट्रैक्शन उपयोग के लिए है।
- **ऊर्जा उत्पादन और बचत-** दक्षिण-पश्चिम रेलवे ने छह महीनों में 4.13 मिलियन यूनिट सौर ऊर्जा उत्पन्न की तथा करोड़ों रुपये की बचत दर्ज की। पूर्वोत्तर रेलवे ने 166 स्टेशनों पर सौर पैनल से 38.20 लाख यूनिट ऊर्जा उत्पन्न की और लगभग ₹1.41 करोड़ की बचत की।
- **ट्रैक पर नवाचारी प्रयोग (Solar On Track)-** वाराणसी में BLW ने 70 मीटर ट्रैक पर पहली बार removable solar panel system लगाया है, जिससे भविष्य की ऊर्जा उत्पादन स्थितियों का परीक्षण किया जा रहा है।

- **भविष्य की संभावनाएँ (Future Prospects)-** भारतीय रेलवे ने 2030 तक नेट-ज़ीरो कार्बन उत्सर्जन का लक्ष्य रखा है। इस दिशा में सौर ऊर्जा बहुत महत्वपूर्ण भूमिका निभा सकती है—
  - ✔ पैमाने पर सौर ऊर्जा क्षमता बढ़ाना
  - ✔ बैटरी स्टोरेज समाधान और ऊर्जा भंडारण सिस्टम विकसित करना
  - ✔ सौर-ट्रैक सिस्टम का व्यापक परीक्षण और scaling
  - ✔ सौर चालन वाली ट्रेनें भविष्योन्मुख विकल्प

सार- रेलवे में ऊर्जा संरक्षण आज की आवश्यकता ही नहीं, बल्कि भविष्य की अनिवार्यता है। बढ़ती ऊर्जा मांग, ईंधन की सीमित उपलब्धता तथा पर्यावरण संरक्षण की आवश्यकता को देखते हुए रेल क्षेत्र में ऊर्जा दक्षता पर विशेष ध्यान दिया जा रहा है। भारतीय रेल विश्व के सबसे बड़े रेल नेटवर्कों में से एक है, जहाँ प्रतिदिन हजारों ट्रेनों का संचालन होता है। ऐसी स्थिति में ऊर्जा की बचत से न केवल लागत में कमी आती है, बल्कि कार्बन उत्सर्जन भी घटता है और पर्यावरण सुरक्षित भी रहता है।

रेलवे में ऊर्जा संरक्षण के लिए विद्युतीकरण, एलईडी प्रकाश व्यवस्था, ऊर्जा दक्ष लोकोमोटिव, ब्रेकिंग प्रणाली सोलर पैनल स्थापना तथा ऊर्जा प्रबंधन प्रणालियों का उपयोग किया जा रहा है। स्टेशनों की छतों पर सौर ऊर्जा संयंत्र स्थापित किए जा रहे हैं, आधुनिक ट्रेनों में ऊर्जा संरक्षण को ध्यान में रखते हुए विशेष उपकरण लगाए जा रहे है जिससे डीजल ईधन या कोयले पर से निर्भरता कम हो। ऊर्जा संरक्षण से परिचालन लागत में कमी, पर्यावरण संरक्षण, ईंधन आयात पर निर्भरता में कमी तथा सतत विकास को बढ़ावा मिलता है। अतः रेलवे में ऊर्जा संरक्षण न केवल आर्थिक दृष्टि से लाभकारी है, बल्कि यह हरित एवं स्वच्छ परिवहन व्यवस्था की दिशा में एक महत्वपूर्ण कदम है।

खुश रहने का एक सीधा सा मंत्र-

कौन क्या कर रहा है ?, कैसे कर रहा है ?

क्यों कर रहा है ?

इन बातों से आप जितना दूर रहेंगे,

आप उतने ही शांत और प्रसन्न रहेंगे

महान 'वैज्ञानिकों' के रोचक प्रसंग

महान वैज्ञानिक अपने शोधकार्यों से तो महान होते ही हैं, कुशाग्र बुद्धि होने के कारण उनका हास्य भी अधिक पैना और प्रखर होता है। उनके जीवन की घटनाएं अन्य लोगों को भी जीवन में आगे बढ़ने के लिए नई राह दिखाती हैं और उनकी हौसला अफजाई करती हैं। जिनमें से निम्न हैं;

1. रंगून में सहायक लेखा महानिदेशक, चंद्रशेखर वेंकट रामन से उनका घमंडी अंग्रेज लेखा महानिदेशक चेहरे के सामने फाइल झुलाते हुए कहता है, 'रामन, जो लाल स्याही की दवात तुम्हारे सामने मेज पर पड़ी है, अगर मैं कहूं कि यह काली स्याही है तो तुम्हें यहीं कहना होगा कि हां, यह काली स्याही है श्रीमान'

लेकिन, स्वाभिमानी रामन शांति से उत्तर देते हैं, 'यदि आप ऐसा कहेंगे तो मैं सिर्फ यही कहूंगा कि या तो आप अंधे हैं या पागल अथवा दोनों।'

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2. हंगरी के प्रसिद्ध गणितज्ञ पॉल अर्डोस एक बार एक सेमीनार में किसी गणितज्ञ से मिले तो उन्होंने पूछा, 'आप कहां से पधारे हैं?' गणितज्ञ ने कहा कि वह वेनकुवर से आप हैं। अर्डोस ने तपाक से पूछा, 'तब तो आप मेरे घनिष्ठ मित्र इलियट मैंडेलसन को अवश्य जानते होंगे?' 'क्यों नहीं,' गणितज्ञ ने कहा, 'मैं ही इलियट मैंडेलसन हूं।'

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3. अमेरिकी गणितज्ञ और खगोलविद् नारबर्ट वाइनर के भुलक्कड़पने का भी एक रोचक किस्सा दिया गया है। उन्हें घर बदल कर परिवार के साथ कैंब्रिज से न्यूटन शहर जाना था। लेकिन, काम की व्यस्तता के कारण उन्होंने पत्नी से कहा कि वे लोग चले जाएं, वे स्वयं शाम को वहां पहुंच जाएंगे। पत्नी ने न्यूटन शहर में नए घर का पता एक पर्ची में लिख कर उनकी जेब में डाल दिया। वाइनर ने दिन में किसी समय गणित की एक समस्या उस पर्ची पर हल की और संतुष्ट न होने पर पर्ची फाड़ कर फैंक दी। आदतन शाम को वे घर पहुंचे तो याद आया कि उन्हें तो कहीं जाना था। उन्होंने वहां खड़ी एक छोटी लड़की से पूछा, 'बेटी मैं नारबर्ट वाइनर हूं। सामने के घर में रहता हूं। मुझे कहीं जाना था, लेकिन भूल गया हूं। क्या तुम्हें पता है, इस घर के लोग कहां गए हैं?'

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4. प्रोफेसर नील रत्न धर के बारे में है। इलाहाबाद विश्वविद्यालय में जब प्रोफेसर नील रत्न धर ने देखा कि उनका अत्यंत मेधावी शिष्य आत्माराम भोजनालय का खर्च नहीं दे सकता और अपने लिए खाना खुद बनाता है, तो उसे कुछ रुपए देकर वे बोले, 'ये रुपए छात्रावास के भोजनालय के लिए हैं। तुम्हारी फाइनल परीक्षाएं निकट हैं। अब तुम अपने लिए भोजन नहीं बनाना और अपना सारा ध्यान अपनी पढ़ाई पर लगाना।'

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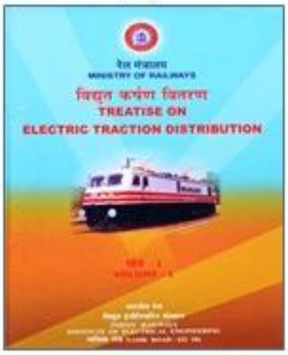

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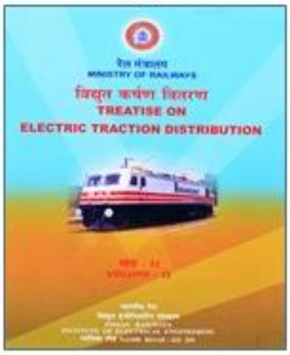

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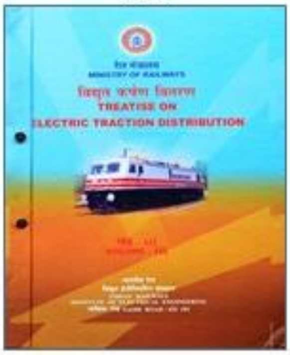

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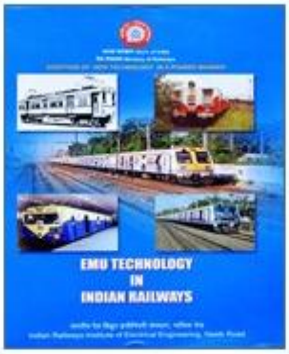

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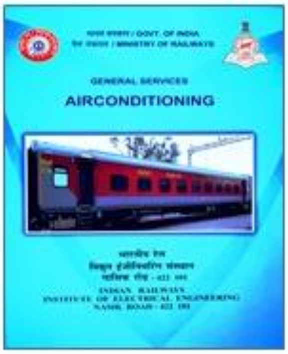

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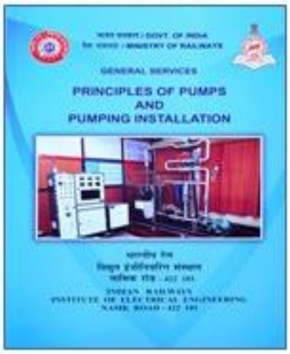

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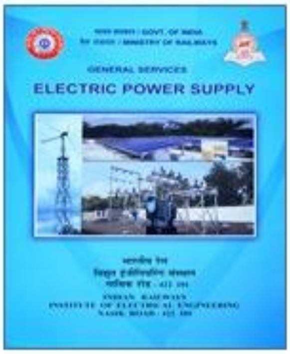

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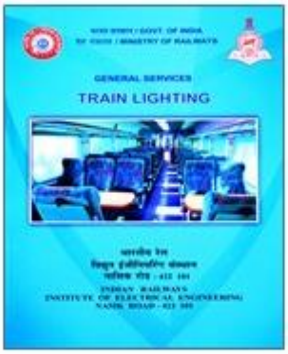

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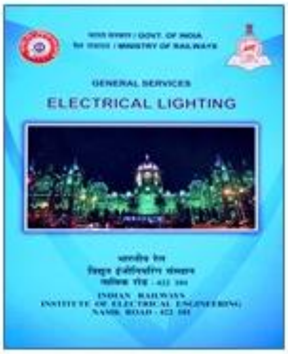

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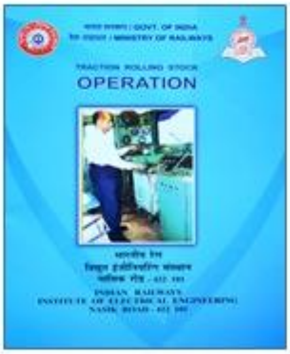

MAINTENANCE

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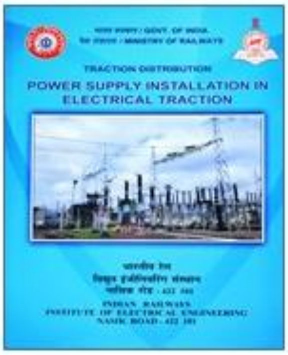

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