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One Railway -One Signalling: Unlocking Hidden Potential of IR with Standardization & Automation



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Abstract : RDSO is a globally recognized organization that has successfully standardized the fourth-largest rail network in the world. By skillfully integrating various technologies, they have achieved economies of scale, uniformity, lower operating, maintenance, and production costs. Over the years, the IR signalling has made considerable efforts to standardize its practices through the use of signal engineering manuals and instructions, resulting in uniformity, ease of maintenance, and increased installation quality. However, one crucial area of signalling design and drawing has been neglected, leading to the proliferation of unstandardized practices that adhere to the same interlocking principles. As a result, timely and high-quality project execution, skilled manpower development, and in-house modifications have been adversely affected, hindering the use of technologies to achieve automation. In light of India's aspiration to position itself as an "engine of growth" and fulfil the national mission of "Gatishakti," standardization is the key to achieving that dream. This study aims to explore the causes, obstacles, initiatives, and future course of action in addressing this critical issue.

सारांश : आरडीएसओ एक वैश्विक रूप से मान्यता प्राप्त संगठन है जो दुनिया के चौथे सबसे बड़े रेल नेटवर्क को सफलतापूर्वक मानकीकृत किया है। विभिन्न तकनीकों को कुशलतापूर्वक एकीकृत करके उन्होंने स्केल की अर्थव्यवस्था, एकसमता और लोवर ऑपरेटिंग, रखरखाव और उत्पादन लागत हासिल की है। वर्षों से, इण्डियन रेलवे सिग्नलिंग ने सिग्नल इंजीनियरिंग मैनुअल और निर्देशों का उपयोग करके अपनी अभ्यास और आदर्शों को मानकीकृत करने के लिए बड़े प्रयास किए हैं, जिससे एकसमता, रखरखाव की सुविधा और अधिकतम स्थापना गुणवत्ता हासिल हुई है। हालांकि, सिग्नल डिजाइन और ड्राइंग का एक महत्वपूर्ण क्षेत्र अवहेलना किया गया है, जिससे एक ही इंटरलॉकिंग सिद्धांत का पालन करने वाली बिना मानकीकृत प्रथाओं की वृद्धि हुई है। इससे समय पर और उच्च गुणवत्ता वाले प्रोजेक्ट का निष्पादन, कुशल मानव संसाधन का विकास और इन–हाउस संशोधनों में नुकसान हुआ है, जो स्वचालन की तकनीकों का उपयोग करके स्थापित किया जा सकता है। भारत के ''विकास की इंजन'' बनने और ''गति शक्ति'' राष्ट्रीय मिशन को पूरा करने की आशा में, मानकीकरण उस सपने को हासिल करने की कुंजी है। इस अध्ययन का उद्देश्य इस महत्वपूर्ण मुद्दे का समाधान करने के लिए कारणों, बाधाओं, पहलों और भविष्य के कार्य के रूप में जांच करना है।

One Railway- One Signalling:

Railway transport is the most cost-effective, safe, and environmentally friendly mode of transport. Every year, Indian Railways (IR) carries more than 8 billion people across India, which is continually growing. During covid pandemic, IR tireless efforts ensured uninterrupted supply chains across country. Thereby, rightfully claimed itself as the" lifeline of nation" or "engine of growth". Logistics and supply chain costs currently account for approximately 12% of India's gross domestic product (GDP), compared to 8% globally, attributed to the country's excessive reliance on road transport. To address this critical issue, Indian Railways has planned a massive capital expenditure of Rs. 2,15,058 crores in fiscal year 2022-23 to align with the prime minister's mission gatishakti missive. Swift and high-quality project execution becomes critical to achieving this national mission and vision.

The Research Design and Standards Organization (RDSO) played a pioneer role in the world by standardising technologies and ensuring their seamless implementation across Indian railways. Through a deliberate policy, it achieved economies of scale, uniformity, and lower operating, maintenance, and production costs. All across the world, uniform standards such as EN, IEC, and IS have contributed to product uniformity and quality by requiring manufacturers to adhere to certain criteria when deploying their products. Only after the integration of the European Union (EU), EU emphasized standardisation pan EU, as evidenced by the adoption of uniform technologies and protocols such as ETCS and recently introduced the EULYNX protocol. Chinese railways have also successfully leveraged standardisation across their network in pursuit of their mission of "intelligence, integration, standardisation, and openness". It has facilitated them in seamlessly integrating new technologies while keeping implementation costs low.

The process of standardization involves developing and implementing common technical standards to establish a shared understanding of engineering criteria, principles, and practices. These standards provide organizations with a set of processes that, when carried out by qualified individuals using appropriate tools and methods, enable them to perform effective and efficient system engineering. They define expected tasks and outcomes and describe how processes and tasks interact to produce required inputs and outputs. Technical specifications or other precise criteria make up the standards, which provide several advantages, such as consistency of output, production efficiency, reduced complexity of systems, shorter operation time, and faster development of qualified personnel for a particular task. Standardization also serves as a first step toward automation, enabling the creation of an automated SIL2/SIL4 tool. Additionally, it allows for establishing centres of excellence to focus on design improvement and provides an easier, faster way to put new policies or designs into practice.

Since 1955, Indian railways have used the Signalling Engineering Manual (SEM) to standardise signalling principles in an effort to improve safety, efficiency, and cost effectiveness. In addition, it facilitated the Indian Railways to achieve its goal of "safety, security, and punctuality" by modernising its signalling system. Indian Railways is becoming digital by integrating systems and technology to better manage and control trains for passenger safety and comfort. Indian Railways' signalling systems are rapidly moving from analogue to digital, which requires standardisation. Standardisation of drawings is the first step towards automation, improving productivity and project delivery times . IR signalling was largely successful in standardising their products through uniform policies & manuals such as SEM; however, guidelines for standardising S&T drawings remained insufficient. In addition, zonal railways have their own naming conventions for signalling functions based on their own preferences and practises. Because of this, IR now has around 72 different types of interface circuits and 150 different types of application logics, which impedes the timely completion of projects. Since primary objective of entire IR is “SAFETY”, it is essential to standardize design & drawing practices to overcome challenges of speedy & quality project execution. The study delves into current issues surrounding design and drawing preparation, their associated challenges, and finally, the methodology for overcoming those obstacles.

Challenges in Signalling Design and Drawings for Indian Railways

Signalling system is the vital part of a railway system which ensures safe travel and improves overall capacity of the system. One of the primary reasons that signalling systems are critical and difficult to develop is that they must adhere to the recommendations of related functional safety standards such as EN 50128, EN 50126, and EN 50129. Railway interlocking systems are categorized as safety critical systems with SIL-4, based on EN50126 and IEC61508 standards. The railway interlocking systems' functional specifications are defined in signalling interlocking plans (SIP) and interlocking control tables (or table of control) (TOC). They spell out the conditions that must be met before a train can be moved on railway lines or stations. TOC serves as both an interlocking design specification for interlocking designers and a test specification for testers. These tables summarise the interlocking system's critical functional safety requirements. Railways design application logic for signalling circuits using SIP and TOC. The process of developing these SIP & TOC, particularly for medium to large scale stations, is labour intensive, time consuming, and requires specialised skills. Currently, the process is entirely manual. Obviously, this can be a significant source of human error during the interlocking system design process. Fig. 1 illustrates a typical work flow for the design and drawing process associated with yard commissioning. The process is repeated if any of these steps for document preparation are altered.

Fig. 1

Signalling plan is a complicated set of safety related documents that necessitates a high level of technical expertise to prepare, verify and validates. Further, due to manual processing of specialized of work and extensive work load of different project in recent times, The D & D department is severely understaffed, resulting in a massive backlog of work. Projects are frequently delayed due to a severe staff shortage and the nature of the work. The typical working days required to prepare these critical documents, such as SIP, TOC, and application logic with IFAT is given in fig.1, which increases significantly as number increases higher beyond 500 routes.:

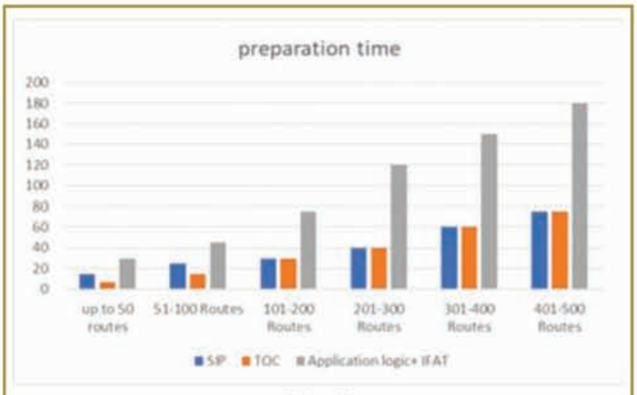

Fig. 2

During the course of a project's execution, changes made to the SIP and TOC can trigger further changes, leading to project delays. Additionally, CRS recommendations during the final commissioning stage may cause delays or result in insufficient testing. In order to accommodate these changes, project deadlines are often compromised, resulting in increased costs, planning failures, and bunching of projects. These constraints can also compromise the quality of the final output, with qualitative issues being discovered at a critical final stage or going unnoticed for extended periods of time.

Preparing D&D documents poses a number of typical challenges that affect changes, necessitating due care during preparation. For example, multiple zonal/divisional/sub-divisional practices can complicate the preparation of input for automation, with input from railways differing from zone to zone and resulting in 72 types of interface circuits patterns and 150 types of application logic patterns. Additionally, time constraints may lead to the initiation of the design process with unapproved SIP/RCC inputs, which are then subject to numerous modifications during the approval process, requiring additional design work. Even approved inputs, such as SIP and TOC, can be modified at the last minute due to observations by CRS or other agencies, leading to design delays and requiring additional effort and time. Finally, unwritten policies and practices of zones/divisions or D&D officials can also affect the design implementation process. Below are some typical challenges in preparing D&D documents that affect changes, which mandates due care while preparation: -

Common Design Elements Affecting Frequent Changes in SIP

1. Signalling gear addition/ deletions / Renaming
2. Shifting the Signal position
3. Crank handle Group changes
4. Level crossing controls (addition/removal)
5. Uncontrolled signalling gears scope changes
6. Aspect controls changes
7. Block Instrument changes (UFSBI, SGE etc)
8. BPAC changes (HASSDAC / MSDAC)
9. Gradient changes

Common Design Elements Affecting Frequent Changes in TOC

1. Finalization of number of routes
2. Converse locking clarification
3. Back Shunt/ short shunt movement finalization
4. Long halt train movements
5. Level cross control limits
6. Cup shape movements practice/ reference changes
7. Conditional locking for Yard flexibility

Common Design Elements Affecting Frequent Changes for Sectional Route Release Table

1. Method of SRR table preparation (Route Wise or Section Wise)
2. Sections to achieve Yard flexibility (Grouping of Multiple track for section) is getting changed based on individual perspective. No solid standard for allocating sections.
3. Design as per SIP/SM position

Other challenges in Design Document

1. VDU Screen resolution changes/ size changes as per Site requirements (2K, 4K & multiple 4K)
2. Axle counter Reset functions (Hard Panel/VDU)
3. Mismatch in site requirement and standard practice might lead changes in later stages.
4. Different type of relay nomenclature.
5. Variety of block working requirement.
6. Different type of signal & Lighting circuit.

Standardization and Automation in Application Data Design and its importance

The standardisation of application data design plays a crucial role in improving the efficiency and effectiveness of railway design processes. It enables quick turnaround and dispensing of manual approval processes, resulting in an expeditious approval process. Standardisation also allows for validation and verification through formal methods, improving the understanding and ease of maintenance. Conformance to RDSO Relay Logic standards and verification of interlocking logic with respect to safety principles are also ensured through standardisation. Additionally, it enables simulation and visualization of yard working, and the generation of test plans for factory and site acceptance tests. Overall, standardisation leads to improved design quality and reliability, reduced cost, enhanced safety and more importantly pave way for automation.

Success of 21st century is credited to automation. Automation of manual repetitive job based on standarization result increased productivity, more efficient use of man & materials, better quality, improved safety, and reduced delivery period. Despite the claims of high quality from good workmanship by humans, automated systems typically perform the manufacturing process with less variability than human workers, resulting in greater control and consistency of product quality. Furthermore, Automation provides advantages such as efficient change request handling, minimized risk of project delays, validation of system requirements, automated safety verification, streamlined development process, and simplified maintenance and upgrades.

Consequently, standardization of typical yard layout and other D&D practices will help CRS to scrutinize plans faster without much change suggestions. Due to complexity of application design, IR is usually dependent on OEM for even simpler yard modification. Standardization along with automation will make railways self-sufficient and expedite yard modifications.

Action Plan for Implementing Standardization in Design & Drawing

Interface circuits (to reduce 30 to 40% of time without even using tools)

- Sheet numbers of circuits standardised to make detailing faster
- Each circuit to be standardised including block circuits across IR
- Upto 4 road stations, bit position and relays position to be standardised to the maximum possible
- CT rack termination of cable and type of cable to be standardized.
- System configuration and switches to be standardized
- Relay contacts to be standardised for each circuit

Application Logic (to reduce 30 to 40% time)

- Each circuit and contact proving standardised across IR. It should be mandatory to be implemented for minimum 100 routes stations.
- Application logic structure to be standardized by OEM
- Each route should prove contact as per RCC line for easy verification
- Each route should have it's own UCR & HR to avoid more parallel circuits and finally one common UCR / HR to be picked for signals having multiple routes
- Except stick path & ASR circuits, parallel paths to be avoided for faster verification

Areas of Automation

Signalling systems are amenable for automated computerized testing as the sequence of activities is precise and repetitive; results are predictable.

1. Automation of design and drawing document of signalling plans like signal Interlocking plan, table of control , application logic etc.
2. Automation in preparation of system integrity test plan and verification and validation of system integrity.
3. Automation in Factory Acceptance testing (FAT) & Site acceptance testing (SAT)

Indian Railways Initiatives for Standardization & Automation

Realisation of above challenges prompted Indian railways to focus on addressing above issues in last decade. In 2018, Railway Board constituted two separate committees for

(i) Standardisation of drawings - Signalling Plans, Control Tables, Scheme Plan and Version Control concepts.

(ii) Finalisation of the typical Electronic Interlocking circuits.

Based on the drawing practices of major railways, The committee for 'Standardisation of Drawings' published booklet 'Standardisation of Drawings V2.0' in 2019. available on Railnet at url http://10.195.2.19/iriweb/wiki/Learning Resources. This report elaborates on the common standards to be adopted by all railways in preparation of signalling plans, associated tables, notes and symbols; standard interlocking table, VDU diagram and introduction of version control and scheme plans. Similarly, second committee on typical electronic circuits has issued second report.

Following standardizations schemes have been submitted by RDSO & IRISET :

1. Signal scheme plan has been standardized with layout, signalling details along with other associated information which includes main signals, train detection, gradients, symbols, numbering. Further more it has detailed to their modification process, updates and approval process.
2. Interlocking control table or TOC has been standardized.
3. It has defined document upkeep and their version control measures. Detailing has been done in such way each document and their subsequent modification are uniquely identified.
4. Type of relays both interface and internal and their nomenclature standardised
5. Signal functions for signalling plans as well as for VDU panel has been standardized.
6. VDU menu commands as well as VDU layout has been standardized.
7. Symbol for signal, different boards, operation place, gradient, indicators, LC gates, track circuits, points lines have been standardized for signalling plan as well as VDU panel.

The RDSO has developed a suite of techniques and tools to assist with the design of railway signaling systems, including Train Operation Control (TOC) and application logic. The railway yard is captured using a layout editor (LEWeb), which automatically identifies routes, conflicts, isolation requirements, and other aspects of the system. This information is then used to generate a route control chart (RCC), which in turn is utilized to produce relay logic expressions for the electronic interlocking equipment. Furthermore, the RDSO is planning to seek SIL-2 certification for regular use of these automation tools after developments.

Conclusion

India's railway industry is on the brink of significant growth, driven by the country's ambitious vision for progress under the auspices of the PM mission gatishakti. However, in order to achieve these aspirations, there is a pressing need to expedite project execution while simultaneously enhancing quality, reducing costs, and minimizing time. While Indian Railways has already made significant strides towards standardization, there remains a crucial imperative to translate these frameworks into meaningful action. Effective implementation represents an unparalleled opportunity to bring all zonal and divisional railways onto a shared platform, facilitating greater coherence, consistency, and productivity across the industry. It is important to note that standardization is not a one-time event but a continual process, requiring the establishment of a center of excellence for design that can address the complex and evolving challenges associated with this rapidly changing sector. Ultimately, standardization is the key to unlocking technical development and realizing the full potential of India's railway industry.

The development of standardized design principles has already begun to yield significant benefits, particularly in the realm of automation, where established techniques and tools have transformed the design process for railway signaling systems. While these automation tools are widely used in developed countries and metros, they have yet to be fully exploited in India to address the complex demands of railway signaling. However, the recent progress made by the RDSO in developing these tools represents a major milestone in the modernization of India's railway signaling systems. By automating the design process, these tools can minimize the risk of errors and inconsistencies, and substantially enhance productivity and efficiency. Moreover, the planned SIL-2 certification will further ensure the reliability and safety of systems designed using these tools. Overall, standardization is a vital enabler of the Indian railway industry's journey towards greater growth and prosperity, and the RDSO's endeavors are a promising indication of the transformative power of modernization in this vital sector.

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Preventive Measures for Landslide/Rockfall in Railway Cuttings



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Abstract : Slope stabilization is a critical aspect of civil engineering, ensuring the safety and longevity of infrastructure in areas prone to landslides, rockfalls, debris flows, shallow landslides, and avalanche hazards. This paper explores contemporary techniques for slope stabilization, with a particular focus on high tensile strength steel mesh systems, drapery systems, flexible rockfall barriers, attenuators, debris flow barriers, Gabion, rock shed and avalanche barriers etc. By analysing their applications, advantages, and case studies, this paper aims to provide engineers and stakeholders with insights into these innovative methods, ultimately enhancing the understanding and implementation of slope stabilization in infrastructure projects. The construction and maintenance of railway lines require a profound understanding of soil conditions, slope stability, and rockfall protection. This paper delves into the latest techniques and innovations in soil investigation, slope stabilization, and rockfall protection in the context of railway line construction.

सारांश : ढलान स्थिरीकरण सिविल इंजीनियरिंग का एक महत्वपूर्ण पहलू है, जो भूस्खलन, चट्टानों के गिरने, मलबे के प्रवाह, उथले भूस्खलन और हिमस्खलन के खतरों वाले क्षेत्रों में बुनियादी ढांचे की सुरक्षा और दीर्घायु सुनिश्चित करता है। यह पेपर ढलान स्थिरीकरण के लिए समकालीन तकनीकों की खोज करता है, जिसमें उच्च तन्यता ताकत वाले स्टील जाल सिस्टम, ड्रेपर सिस्टम, फ्लेक्सिबल रॉकफॉल बैरियर, एटेन्यूएटर्स, मलबे प्रवाह बैरियर, गेबियन, रॉक शेड और हिमस्खलन बैरियर इत्यादि पर विशेष ध्यान दिया जाता है। उनके अनुप्रयोगों, फायदों और केस अध्ययनों का विश्लेषण करके, इस पेपर का उद्देश्य इंजीनियरों और हितधारकों को इन नवीन तरीकों में अंतर्दृष्टि प्रदान करना है, जिससे अंततः बुनियादी ढांचा परियोजनाओं में ढलान स्थिरीकरण की समझ और कार्यान्वयन में वृद्धि होगी। रेलवे लाइनों के निर्माण और रखरखाव के लिए मिट्टी की स्थिति, ढलान स्थिरता और चट्टानों से सुरक्षा की गहन समझ की आवश्यकता होती है। यह पेपर रेलवे लाइन निर्माण के संदर्भ में मिट्टी की जांच, ढलान स्थिरीकरण और रॉकफॉल संरक्षण में नवीनतम तकनीकों और नवाचारों पर प्रकाश डालता है।

1.0 Introduction

Slope stabilization is a fundamental aspect of Railway Engineering, particularly in regions with challenging terrain, geological vulnerabilities and a need for infrastructure resilience. In such areas, the stability of slopes directly impacts the safety and functionality of Railway routes, buildings, and environmental protection measures. To address these challenges, modern engineering has introduced innovative techniques and materials. This paper examines the latest advancements in slope stabilization, with a specific focus on the utilization of high tensile strength steel mesh systems, drapery systems, ring net rockfall barriers, attenuators, canopy barriers, debris flow barriers, shallow landslide barriers, and avalanche barriers. Railways have been the backbone of transportation systems for centuries and their relevance has not waned in the modern era. As the global demand for efficient, eco-friendly, and reliable transportation continues to grow, the expansion, improvement, and maintenance of railway networks are of paramount importance. Constructing and maintaining railway lines demand meticulous attention to geological and environmental factors, particularly soil properties, slope stability and protection against rockfalls. The seamless functioning of railway lines and the safety of passengers depend on these critical factors.

2.0 Soil Investigation Techniques

2.1 Traditional Methods

Soil investigation for railway construction relied on conventional techniques such as drilling and soil sampling. While these traditional methods have been reliable to some extent, they exhibit limitations concerning accuracy, efficiency, and their environmental impact.

2.2 Modern Methods

The advent of modern soil investigation methods has revolutionized the field of railway construction. Advanced technologies, including geophysics, remote sensing, and geospatial tools, now provide more accurate and less intrusive ways to evaluate soil conditions. These contemporary methods not only enhance precision but also minimize the ecological footprint of construction projects.

2.3 Geophysics

Geophysical methods respond to the physical properties of the subsurface materials (rocks, sediments, water, voids, etc.) and can be used successfully when one region differs sufficiently from another in some physical property. These methods are cost-effective and minimize disruption to the surrounding environment.

Remote sensing is the collection of information about the Earth's surface and environment from a distance using sensors and instruments, typically from satellites or aircraft such as LiDAR and satellite imagery enable the rapid acquisition of extensive soil information. These tools are invaluable for detecting potential hazards and evaluating large areas efficiently.

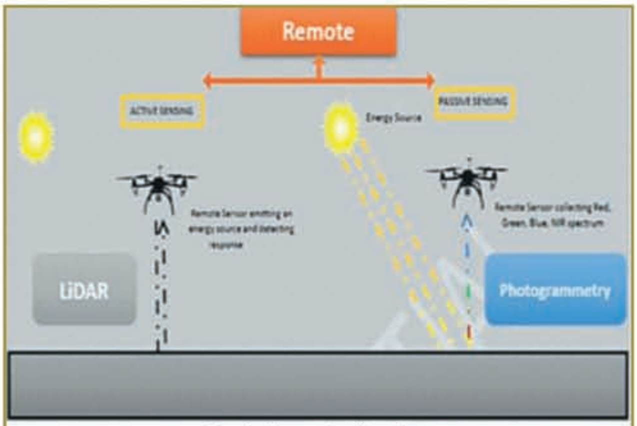

Fig-1: Remote Sensing

2.5 Geospatial Technologies

Geospatial technologies refer to tools and techniques used to collect, analyse and visualize data related to the Earth's surface and its features, often using geographic information systems (GIS), GPS remote sensing and mapping technologies.

GIS allows for data integration and real-time monitoring, making it an integral part of modern soil investigation.

3.0 Advantages of Modern Soil Investigation

Modern soil investigation techniques offer several advantages, including increased accuracy, reduced costs, and minimized environmental impact. By enabling engineers to make informed decisions and plan railway construction with greater confidence these techniques are transforming the industry.

4.0 Slope Stabilization Techniques

Slope stabilization is a critical aspect of railway construction as unstable slopes can lead to landslides, erosion and interruptions in service. Challenges in this domain encompass:

- Erosion control to prevent soil loss and maintain the structural integrity of slopes.
- Landslide prevention to ensure the stability of the railway lines.
- Managing the impact of changing weather conditions on slope stability.

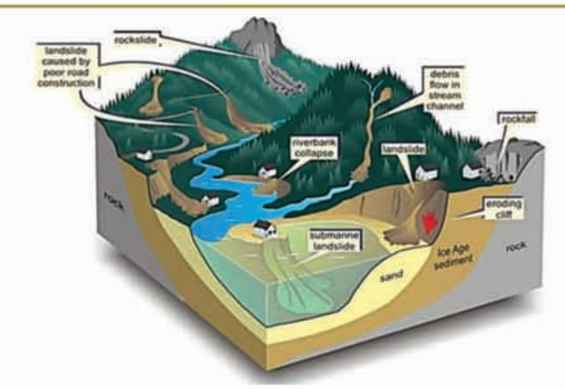

Fig-2: Landslide/rockfall terminology

5.0 Modern Stabilization Techniques

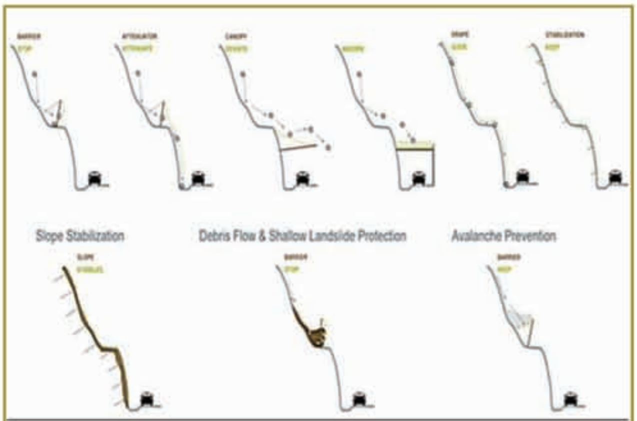

Fig-3: Rockfall Protection

5.1 High Tensile Strength Steel Mesh and Rope net Systems

Flexible slope stabilization systems made from wire meshes in combination with nailing are widely used in practice to stabilize soil and rock slopes. They are economical solutions and a good alternative to measures based on rigid concrete liner walls or massive supporting structures. Apart from designs using conventional steel wire, meshes from high-tensile steel wire are now also available on the market. Stabilizations implemented in soil and rock with and without vegetated face confirm that these measures are suitable for practical application.

High tensile strength steel mesh systems have become a staple in slope stabilization projects due to their durability, versatility and cost-effectiveness. These systems are primarily used for retaining walls, slope protection and erosion control. Their high tensile strength and flexibility make them suitable for a wide range of applications.

5.2 Drapery Systems with High Tensile Strength Steel Meshes and Rope Nets

Drapery systems combine the flexibility of high tensile strength steel mesh with geotechnical engineering principles to provide a reliable solution for slope stabilization. These systems are particularly effective in addressing challenging geological conditions and steep slopes.

Drapery systems are engineered to stabilize steep slopes where soil nailing might be too prohibitive due to engineering or financial challenges. Drapery systems effectively guide the falling rocks or boulders into a containment area thereby also serving as rockfall protection measures, catching and redirecting falling rocks to prevent damage to infrastructure or endangering lives.

These can be used in conjunction with soil nails on the top and bottom if no catchment area can be created due to lack of space. With regular maintenance, these systems can work just as well as soil nails but in a fraction of the total cost. Drape mesh systems are used as a mean to guide rocks behind the mesh when falling from a slope. The design calculations are split in two parts: "Fixing area" and the "Rockfall area".

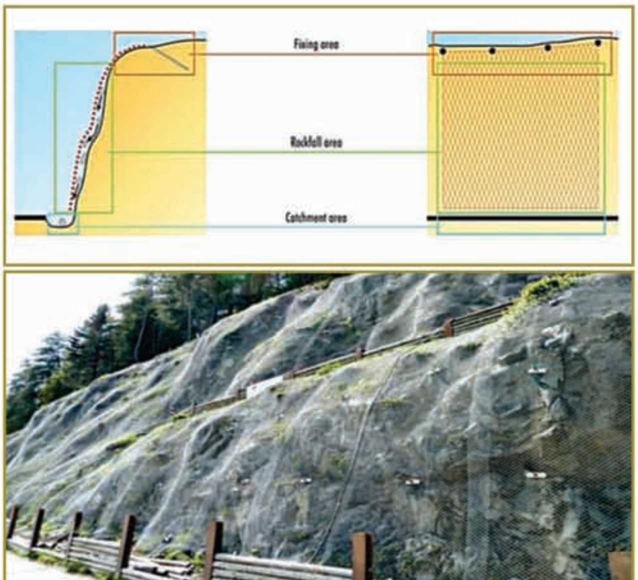

Fig-4: Drapery Systems

5.3 Flexible Rockfall Barriers

In areas where the slope height might be too great rendering soil nailing and mesh systems too expensive or impractical, flexible rockfall barriers are an innovative solution designed to protect infrastructure from the impact of falling rocks and debris in mountainous or rocky terrains. These barriers are comprised of a network of high strength steel meshes and posts that capture and contain falling materials preventing them from reaching critical areas.

These barriers are commonly used to shield transport networks from the danger of rockfall incidents. Rockfall barriers are strategically placed along vulnerable sections of the railway lines to absorb the energy of falling rocks. Railway lines traversing hilly or mountainous terrain are often fitted with rockfall barriers to ensure the safety of train passengers and maintain uninterrupted service. These systems have a hinged connection between the post and base plates

Fig-5: Flexible Rockfall Barrier

5.4 Attenuators

Attenuators, often referred to as energy-absorbing systems, are crucial in mitigating the impact of rockfalls and other debris on infrastructure. These systems are designed to dissipate the kinetic energy of falling materials, reducing the potential for damage and injuries. They work by capturing the falling rock energy and slowly dissipating it by guiding the boulders into a containment area.

Fig-6: Attenuator

5.5 Debris Flow Barriers

Debris flow barriers are specialized protective systems designed to mitigate the impact of fast-moving debris flows in regions prone to these hazardous events. These barriers are composed of sturdy materials that can divert, slow down and contain debris flows] reducing their destructive potential. Their design ensures that the flow's energy is dissipated, preventing damage. Debris flow barriers also play a role in slope stabilization, preventing debris flows from eroding or destabilizing slopes.

Fig-7: Debris Flow Barriers

5.6 Reinforced Gabion Blocks

Reinforced Gabion Blocks are designed to offer the benefits of traditional gabions such as good drainage and flexibility while also providing increased strength and stability making them a versatile choice for various civil engineering and construction projects.

Fig-8: Reinforced Gabion Blocks

increased strength and stability making them a versatile choice for various civil engineering and construction projects.

5.7 Rock sheds

A rock shed is built over a roadway that is in the path of the slide. They are equally used to protect railroads.

These external stabilization and rockfall protection methods are chosen based on site-specific conditions and the severity of rockfall hazards, ensuring the safety of infrastructure and the public.

Fig-9: Rock Shed

5.8 Avalanche Barriers

Avalanche barriers are specialized protective systems designed to mitigate the impact of avalanches in regions prone to these hazardous events. These barriers are engineered to intercept and contain the avalanche debris, reducing its destructive potential safeguarding infrastructure, including buildings and rail/roads from impact. Their design ensures that the avalanche's energy is dissipated, preventing damage. It is commonly installed in numerous lines in the avalanche starting zones.

Fig-10: Avalanche Barrier

6.0 Post Commissioning Monitoring

Even after a railway project is commissioned, continuous monitoring of slopes is essential to detect and address any signs of instability or hazards. This section provides insights into post-commissioning monitoring of slopes.

6.1 Monitoring Mechanisms

a) **Baseline Surveys:** Baseline surveys are conducted to establish the initial condition of the slope and the surrounding area. These surveys serve as reference points for future assessments.

b) **Instrumentation:** Various instruments are used to monitor slope movement, stress and other relevant parameters. These include total stations, inclinometers, piezometers, borehole extensometers, load cells and ground-based radar.

c) **Satellite-Based Monitoring:** Satellite-based monitoring using remote sensing technologies is increasingly being employed to assess slope movement and deformation over larger areas.

d) **Visual Inspection:** Regular visual inspections by trained personnel are essential to identify signs of instability, such as cracks, movement or drainage issues.

e) **Geophysical Surveys:** Geophysical surveys, such as electrical resistivity tomography (ERT) can be conducted to assess subsurface conditions.

6.2 Inspection Frequency

The frequency of slope inspections and monitoring varies based on factors like the type of slope, geological conditions, climate and historical instability. Critical slopes may require daily or real-time monitoring while less critical slopes may be inspected on a quarterly or annual basis.

6.3 Triggering Factors

Pre-defined triggering factors should be established for different types of slope instability. These factors such as changes in groundwater levels rainfall thresholds and deformation rates, trigger further investigations and actions if exceeded.

6.4 Data Management and Analysis

The data collected from monitoring should be effectively managed and analysed. This involves the use of geospatial information systems (GIS) and statistical tools to identify trends and potential instability.

7.0 Some Experience/Photographs in Indian Railways

7.1 Case Study

Landslide on 24.09.2023 at Km 202/23-31 between stations Manabar-Jarati on Kothavalsa-Kirundul Section (KK Lines) of Waltair Division, ECoR.

Section	Kothavalsa-Kirundul Section (KK Lines) of Waltair Division, ECoR.
Km	Km 202/23-31
Types & Nature	• The middle and top sections of the cutting consist of loose soil mixed with subrounded boulders. • The height of the cutting is 26 meters with a slope of 1.5:1. • There is a substantial overburden at the hilltop.
History of Problem	• Land slide & falling rocks had occurred in 1994, 1998, 2006–2014. The section was blocked for 28 days in year 1994 due to such type of failure.
Recent Landslide	A massive landslide occurred on 24.09.2023 at 03:15 AM due to heavy rainfall, resulting in a large mass of debris that directly affected the railway track. The railway track was fully blocked.
Remedial Measures for Immediate restoration work	• The slope was flattened with provision of about 5m wide berms at the interval of 6m height. • Rail piling was carried out near the toe of the cutting with anchorage length of 3 to 3-5m below the existing rail level so as to arrest the lateral movement. • Gabions were also provided to strengthen the toe.
Intermediate remedial measures	• Remove all debris and overburden (including loose soil, boulders, fallen trees) from the cutting slope and smoothen the slope. • Extend the railway piling and Gabion wall by 50 meters on both sides of the affected area. • Install horizontal perforated pipes (4-6 inch diameter) at 2-3 meter intervals along the berm to reduce pore water pressure. Connect these pipes to a lined drain at the berm's junction with the bank to collect seepage water. • Regularly monitor slope movements by placing targets or reflectors at the top, middle and bottom of the cutting.
Landslide Location image	 **Fig-11: Landslide location**
Tentative permanent remedial measures suggested	Gradual easing of the slope after conducting a comprehensive slope stability analysis, Development of a detailed drainage plan, encompassing a network of appropriately sized catch water drains and intermediate side drains at berm level, Implementation of suitable erosion control measures to protect the hill and cutting slope, Removal of loose boulders from the slope to prevent future incidents, Installation of designed anchored wire mesh or high-strength boulder nets on the side slope to retain loose boulders, Construction of designed retaining walls or gabion walls near the toe of the side slope, Conducting detailed geological and geotechnical investigations before embarking on further doubling work & Provisions of cut & cover may be explored and adopted if required based on techno-economic consideration.

8.0 Conclusion

In modern Railway engineering the importance of slope stabilization with high tensile strength steel mesh systems and innovative protective barriers cannot be overstated. These techniques along with debris flow shallow landslide and avalanche barriers offer a comprehensive approach to safeguarding infrastructure in hazardous terrain.

By adopting modern techniques and integrating them into Railway engineering projects we can ensure the safety of lives the longevity of infrastructure and the continued functionality of Railway networks and environmental protection efforts. As Railway engineering continues to evolve it is imperative that engineers and planners remain at the forefront of these modern approaches leveraging the latest technology and strategies to build resilient and safe infrastructure.

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Dedicated Test Track

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Abstract : At present the testing of Rolling Stocks is being done on commercial tracks. A lot of problem is being faced due to over congestion, difficulty in finding track with lower maintenance standards as per testing criteria due to improved level of track maintenance and track structures, and significant change in condition of track stretches nominated for trials due to maintenance input by field units before actual trials. At the same time, presently dynamic assessment of rolling stock is being done as per Third Criteria Committee Report issued by RDSO for introduction of new rolling stock in IR system. However this assessment is not as per universally acceptable criteria as issued by UIC/EN standards. To bring assessment of rolling stock at par with global standards, IR decided to switch over to assessment as per UIC-518/EN-14363. For dynamic assessment of rolling stock as per UIC-518/EN-14363 a peculiar track geometry is required which is not readily available in existing commercial lines. Due to this reason, a need for constructing a Dedicated Test Track arises as provided in other parts of world. At present a Dedicated Test Track is under construction. This will introduce many new technologies in assessment of rolling stock & open new avenue for testing/trial/study of plethora of new technology in all aspects of rail infrastructure including P.Way.

सारांश : वर्तमान में रोलिंग स्टॉक्स का परीक्षण वाणिज्यिक ट्रैकों पर किया जा रहा है। अत्यधिक भीड़भाड़, ट्रैक संरचनाओं के बेहतर रखरखाव स्तर के कारण परीक्षण मानदंडों के अनुसार कम रखरखाव मानकों वाले ट्रैक को खोजने में कठिनाई और वास्तविक परीक्षणों से पहले फील्ड इकाइयों द्वारा रखरखाव इनपुट के कारण परीक्षणों के लिए नामांकित ट्रैक हिस्सों की स्थिति में महत्वपूर्ण बदलाव के कारण बहुत सारी समस्याओं का सामना करना पड़ रहा है। वहीं, वर्तमान में भारतीय रेल प्रणाली में नए रोलिंग स्टॉक की शुरूआत के लिए आरडीएसओ द्वारा जारी तीसरी मानदंड समिति की रिपोर्ट के अनुसार रोलिंग स्टॉक का गतिशील मूल्यांकन किया जा रहा है। यह मूल्यांकन यूआईसी/ईएन मानकों द्वारा जारी सार्वभौमिक रूप से स्वीकार्य मानदंडों के अनुसार नहीं है। रोलिंग स्टॉक के मूल्यांकन को वैश्विक मानकों के बराबर लाने के लिए, भारतीय रेलवे ने यूआईसी–518/ईएन–14363 के अनुसार मूल्यांकन पर स्विच करने का निर्णय लिया। यूआईसी–518/ईएन–14363 के अनुसार रोलिंग स्टॉक के गतिशील मूल्यांकन के लिए एक विशिष्ट ट्रैक ज्यामिति की आवश्यकता होती है जो मौजूदा वाणिज्यिक लाइनों में आसानी से उपलब्ध नहीं है। इस कारण से, एक समर्पित परीक्षण ट्रैक के निर्माण की आवश्यकता उत्पन्न होती है जैसा कि दुनिया के अन्य हिस्सों में प्रदान किया जाता है। वर्तमान में एक समर्पित परीक्षण ट्रैक निर्माणाधीन है। यह रोलिंग स्टॉक के मूल्यांकन में कई नई तकनीकों को पेश करेगा और पी. वे सहित रेल बुनियादी ढांचे के सभी पहलुओं में नई तकनीक के परीक्षण/जाँच/अध्ययन के लिए नये रास्ते खोलेगा।

1. Introduction

Use of new locomotive or rolling stock, introduction of new trains, increase or decrease in speed of existing trains/ rolling stock etc. is done as per directives issued by Policy Circular No. 6 (Revised 2023). For compliance to lay down procedure for introduction lays down the circumstances under which it is mandatory to conduct Oscillation trials. According to Policy Circular No. 6 (Revised 2023) Central Govt. (Railway Board) is the final authority to introduce a new locomotive or rolling stock under Section 27 of "The Railways Act, 1989"

2. Provisions of Policy Circular No.

The provisional maximum permissible speed for new/derived design of a locomotive or rolling stock is determined and certified by Executive Director Standards (Motive Power)/ RDSO in consultation with Executive Director Standards (Track) and Executive Director (Bridges & Structure) and other concerned Directorates, based on design features. Simulation study & data and where appropriate, on comparison of the performance of similar designs of locomotives or rolling stocks already in service.

The provisional speed will normally be lower than the designed or projected service speed of the stock, and, shall not be more than the following:

- 80 km/hr for Broad Gauge passenger stock.
- 65 km/hr for Broad Gauge goods stock.
- 60 Km/hr for Broad Gauge Track Machine and other departmental stock.
- 60 Km/hr Metre Gauge passenger stock.
- 45 km/hr Metre Gauge goods stock.
- 35 km/hr Narrow Gauge stock.

The validity of provisional speed certificate shall be five years for departmental stock and three years for locomotive or rolling stock other than departmental stock, except when it is superseded by final maximum permissible speed certificate. However, issue of provisional speed certificate should be kept to the bare minimum.

The final maximum permissible speed for new/derived design of a locomotive or rolling stock is determined and certified by Executive Director Standards (Motive Power), RDSO in consultation with Executive Director Standards (Track) and Executive Director (Bridges & Structure) and other concerned Directorates. In case of any dispute, the matter is referred to railway board for deliberations among concerned technical members and final orders.

The final maximum permissible speed of new/derived design of a locomotive or rolling stock shall be determined after due consideration of the services to be performed, comparison with the similar stock already in service, and based on detailed Oscillation Trials for assessing the riding quality and/or stability. For oscillation trials, the test stretches for conducting oscillation trials along with Track parameters (kilometer wise) for complete section is advised by Executive Director Standards (Track Machines & Monitoring) as per stipulations of Standing Criteria Committee.

For conducting trial, on the advice of the RDSO to test a new/derived locomotive or rolling stock, General Manager of the concerned railway shall allow conducting the trials on their system, on the test section identified by RDSO, after considering the joint safety certificate duly signed by the Principal Chief Engineer, Principal Chief Mechanical Engineer, Principal Chief Operating Manager and Principal Chief Signal & Telecommunication Engineer (Principal Chief Electrical Engineer also in case of locomotive or involvement of electrified section). GM sanction shall be valid for two years, after which it shall require revalidation by the General Manager on the advise of RDSO.

Executive Director Standards (Motive Power) in consultation with Executive Director Standards (Track), Executive Director (Bridges & Structure) and other concerned directorates will issue a Generic Oscillation Trial Speed Certificate to the Zonal Railway, duly including all the boundary conditions for trial, for processing of the standing sanction.

Based on the standing sanction of GM and generic oscillation trial speed certificate, a supplementary speed certificate for conducting the trial of particular locomotive or rolling stock would be issued by Executive Director Standards (Motive Power) in consultation with the design directorate only, who would keep the other concerned directorates apprised of issuance of such a supplementary speed certificate for a particular rolling stock/locomotives.

The detailed Oscillation Trials shall be conducted by Executive Director (Testing) in consultation with Executive Director Standards (Motive Power), Executive Director Standards (Track), Executive Director (Bridges & Structure) and the head of the concerned Locomotive/Rolling Stock. The evaluation of detail Oscillation trials data shall be done by

Executive Director Standards (Motive Power) in consultation with Executive Director Standard (Track) and Executive Director (Bridge & Structure) and concerned design directorate, who can order re-trials and suggest modifications, if necessary.

Oscillation trials are conducted with the following in view:

(i) To establish that the vehicle is safe to run at a desired speed

(ii) To check the stability of vehicle at that speed

(iii) To check Oscillation behaviour of the vehicle, and

(iv) To check the riding comfort of the vehicle as applicable

3. Provisions of Standing Criteria Committee

Presently, for Assessment of Stability/ Riding of Rolling Stock RDSO has a Standing Criteria Committee, which deliberates over the criteria to be met by Rolling Stock, and other issues related to performance of vehicles on rails with respect to Ride Quality and /or Stability. Oscillation trials shall be conducted over a section containing the following:

(i) A Tangent (straight) track - of about 1 km length. Efforts shall be made to conduct trials over two such stretches.

(ii) A Station Yard having facing/trailing points, and

(iii) A curved track having about 2° (1.9 °-2.1°) curve of length about 700-800m. Normally, above criteria shall be applicable.

However, In case of non-availability of 2° curve fit for requisite speed, following shall be applicable:

(a) For C&M I Vol. I Standard Track: A curved track having 1.75° to 2.2° curve of about 700-800 m and a curved track having 0.5° to 1° curve of length about 700-800 m.

(b) For other than C&M I Vol. I Standard Track: A curved track having 1.75° to 2.2° curve (or a sharper curve up to 3-3.5 degree in case of non-availability) of about 700-800 m and a curve track having 1° to 1.5° curve of length about 700-800 m.

Indian Railways track is classified in two categories:

(a) Main line track - fit for operation less than 110 km/h and

(b) High Speed (C&M I Vol. I) track, permitting operation upto 160 km/h.

Since main line standard track permits speeds less than 110 km/h, in case the test vehicle is designed to run at speeds 110 km/h and beyond, its Oscillation trials become necessary on High-Speed track also. However, if maximum designed operational speed of rolling stock is 110 km/h and it shows satisfactory riding during oscillation trial at 120 km/h on track maintained to "other than C&M 1 Vol. 1 standard track", repeat oscillation trial of stock at 120 km/h on track maintained to C&M 1 Vol. 1 standard is not required for operation of the rolling stock at 110 km/h.

In view of non-availability of adequate number of section of 105 km/h suiting criteria for selection of test stretch for other than C&M 1 Vol. 1route, it has been decided that section of 100 km/h can also be considered for trial up to 115 km/h . This will have to be mentioned clearly in the speed certificate issued for detailed oscillation trials.

Since Oscillation trials cannot be conducted all over the Railway system, the section chosen for detailed Oscillation trials should be a representative 'run down' section. The section should generally be such that 90% of Indian Railways track should be better than this section - the philosophy being that if a vehicle manages to run satisfactorily on this track stretch, it will be able to run satisfactorily anywhere else on Indian Railways.

Subject to full-fillment of stipulations, the parameters of the selected track should be as per the following:

Parameters	Main line Standard (Speeds < 110 km/h)	C&M-1 (Vol-l) (Speed > 110 km/h)
Unevenness	B or C	A or B
Twist	B or C or D	B or C
Gauge	B or C	A or B
Alignment	B or C	B or C

Parameters	Category	Extent of irregularities
Peak Values On Short Chord		
Unevenness (3.6M chord)	A	0-6 mm (inclusive)
	B	6 mm (exclusive) to 10 mm (inclusive)
	C	10 mm (exclusive) to 15 mm (inclusive)
	D	Above 15 mm
Twist (3.6M base)	A	Up to and inclusive of 1.39 mm/M
	B	1.39 mm/M to 2.08 mm/M (inclusive)
	C	2.08 mm/M to 2.78 mm/M (inclusive)
	D	Above 2.78 mm/M
Gauge	A	Up to and +3 mm (inclusive)
	B	+ 3 mm to + 6 mm (inclusive)
	C	Above + 6 mm
Alignment (7.2M Chord)	A	Up to 3 mm versine (inclusive)
	B	More than 3 mm & less than 5 mm versine
	C	5 mm versine and above

N.B: Unevenness parameter to only one rail (either left or right) is accepted for curves.

For certain trials only limited sections can be available due to constraints of axle load, speeds, bridges, signalling, structures etc. For such limited sections, if test stretches are not available as per above criteria, stretches should generally be selected such that 90% of the track of these limited sections should be better than the stretch chosen for conduct of trials for issue of speed certificate. However, the limitation of trial shall be clearly indicated in speed certificate issued subsequent to such trials.

After detailed oscillation, trials are completed and the safe speed thereby determined, a 'Long Confirmatory Run' should be conducted in each of the configurations. The basic idea of the 'long run' is to confirm that the values of parameters are in general conformity with the values found in the detailed trial section. Long Confirmatory run should be undertaken for a distance as much as practically possible in the section. In most of the cases Long run is possible for more than 40 km. However, in some cases length of long confirmatory run at maximum speed is possible in the order of 10 to 25 km. Cover a few 'hard spots' like level crossings, culverts and bridges as far as possible. Riding of the vehicle over such points (resonance or amplitude build up) will be specially mentioned in the trial report.

Test Speed: The vehicle must meet the criteria requirements at a speed which is 10% higher than its proposed operational maximum speed except on curves where it will be governed by the provisions of IRPWM. For instance, if a vehicle is designed to run at 110 km/h maximum speed, it must meet the criteria when tested at 121 Km/h (say, 120 km/h, rounded off to the nearest 5 km/h). The speed shall be increased in steps of 10 km/h or less, as decided by the officer in charge of the trial based on the results obtained in previous run. The increment however in no case shall exceed 20 km/h and beyond 100 km/h for coaching stock and 80 km/h for fright stock, the increase in speed shall be 10 km/h or less. Emergency Braking Distance, Rating and Performance, Coupler Force and Signal Interference trial: Same as the maximum permissible speed for the train. The speeds mentioned above will have a tolerance of +5 km/h and -2 km/h except for RPR/COCR for which tolerance of ±5 km/h will be permitted.

4. Areas of Concern in the Present Method

The present criteria suffer from the following drawbacks:

a) The system is peak based. This implies that the vehicle suspension is declared unsuitable if one (or a very few) acceleration peaks go above the criteria limits. The presence of thousands of satisfactory acceleration readings thus gets ignored, and the decision gets based on the existence of isolated high peaks.

b) The test track quality is not clearly defined, in the sense that a few bad points in the track tend to affect the judgment of vehicle suspension. Present categorization of track has certain constraints. Upper limit of the 'last' categorization of parameters, magnitude and the number of peaks need better definition.

c) At present, instrumentation for measurement of forces at rail-wheel contact point does not exist in Indian Railways.

d) Lots of difficulties are being faced as same is being performed in existing sections of IR due to Over congestion, Difficulty in finding track with lower maintenance standards as per testing criteria due to improved level of track maintenance and track structures, Condition of track stretches nominated for trials gets significantly changed due to maintenance input by field units before actual trials.

e) Difficulty/ delay in obtaining CRS sanction and joint safety certificate (Average of 6 months delay), Non availability of block / through path in busy sections, Track parameters are not precisely known, Track parameters change after every run due to track disturbance by normal traffic, Safety related problems of adjacent track on double line sections, Track / OHE fitness certificate is required after runs beyond sectional speed, Non-contiguous test stretch cause to & fro movement after every run, Need to reverse the locomotive after every run, Problem of berthing facilities of staff coaches.

f) Cost of testing higher in the present system.

g) As a result, a number of rolling stocks etc. are pending for clearing such trials leading to delays in introduction of modern rolling stocks on IR, DFC.

5. Switching Over To Uic-518/en-14363/ Need of DTT

Keeping above in view, after many discussions and deliberations at Railway Board Level and Governing Council Meetings, it has been decided to opt international practices for testing of rolling stocks by Switching over to standard deviation based parameters for test track, Switching over to 'simplified method' of UIC-518 and to construct a Dedicated Test Track.

At present, various oscillation trials of rolling stocks are being conducted on running track due to which not only the trials get delayed but also the movement of traffic on these sections gets adversely affected. Moreover, there is always a problem to find the track meeting out the requirement of trials in running track due to improved level of maintenance. With construction of Dedicated Test Track, these trials will be conducted expeditiously as per International Standards without any hindrance to movement of traffic. Moreover, due to expeditious completion of these trials, new/improved designs of rolling stocks (locomotives, coaches & wagons) may be introduced much earlier as compared to present, leading to improvement in earning etc.

As the Dedicated Test Track is being constructed for carrying out the trials of rolling stocks as per International Standards, testing of rolling stocks supplied by foreign firms to international standards will be possible. Moreover, the rolling stocks being manufactured in India (by Railway and private parties) will be possible to be tested as per International Standards for their export to other countries.

Various other tests and trials which are presently conducted on running track will also be done on Dedicated Test Track without affecting the movement of traffic and in a more expeditious manner. It will lead to improved designs of rolling stocks and various other infrastructure components leading to improved reliability and safety.

After construction of Dedicated Test Track, it will be possible to do testing of rolling stocks for speed upto 200 kmph (trial speed 220 kmph), whereas it is presently possible for speed upto 160 kmph only.

6. Design of Dedicated Test Track

Design of Dedicated Test Track has been done in house by RDSO based on knowledge gained through a consultancy with CETEST, Spain, on methodology of testing of rolling stocks as per UIC-518/EN-14363. By utilising the stipulation of para M.3.1 of UIC "To run through the same section in both directions and using the same leading vehicle end will result in different dynamic responses of the vehicle. This can for instance be achieved by triangulating the vehicle at the end of the test line and go back on the same line. Such a method can be used to increase the statistical basis and double the number of sections". In designing the alignment of Dedicated Test Track, 20-25 km track length (250-300 Cr) has been saved. Section-specific trials (60% of total trial time) like Confirmatory Oscillograph car runs, track monitoring runs, controllability trials would continue on service track.

The list of curves in design of dedicated test track for testing of rolling stocks as per UIC-518/EN-14363 is given below:

List of curves in alignment of Dedicated Test Track

Curve no.	Degree of curve	Radius	Transition in m	Transition in m	Curve Length	Circular Length	Ca	Cd
1	0.945	1852.148	0.000	40.000	1380.000	1340.000	60	40
2	0.676	2589.670	160.000	160.000	2190.080	1870.080	135	110
3	1.000	1750.000	160.000	160.000	1361.933	1041.933	100	100
4	1.321	1325.254	150.000	150.000	1185.718	885.718	165	110
5	1.503	1164.698	140.000	140.000	620.269	340.269	165	110
6	1.725	1014.554	130.000	130.000	590.284	330.284	165	110
7	2.000	874.802	120.000	120.000	580.299	340.299	165	110

8	2.348	745.400	100.000	100.000	560.235	360.235	165	110
9	2.794	626.340	100.000	100.000	560.333	360.333	165	110
10	3.365	520.000	100.000	100.000	602.458	402.458	165	110
11	3.017	580.000	100.000	100.000	449.620	249.620	165	110
12	2.059	850.000	90.000	90.000	677.015	497.015	135	110
13	3.796	461.000	70.000	70.000	698.810	558.810	140	110
14	4.118	425.000	70.000	70.000	301.060	161.060	130	90
15	4.430	395.000	60.000	60.000	570.870	450.870	130	90
16	4.167	420.000	60.000	60.000	608.690	488.690	120	80
17	4.032	434.000	60.000	60.000	714.560	594.560	120	80
18	4.237	413.000	60.000	60.000	420.380	300.380	120	80
19	2.966	590.000	60.000	60.000	778.070	658.070	120	80
20	3.199	547.000	60.000	60.000	885.180	765.180	120	80
21	3.221	543.310	60.000	60.000	909.540	789.540	120	80
22	3.608	485.000	50.000	50.000	811.800	711.800	120	80
23	2.966	590.000	60.000	60.000	986.760	866.760	120	80
24	4.167	420.000	60.000	60.000	720.090	600.090	120	80
25	3.277	534.000	60.000	60.000	1073.930	953.930	100	60
26	2.966	590.000	40.000	40.000	788.390	708.390	85	45
27	4.408	397.000	40.000	40.000	663.660	583.660	30	80
28	3.385	517.000	40.000	40.000	763.980	683.980	30	80
29	2.951	593.000	40.000	40.000	964.810	884.810	20	65
30	3.924	446.000	40.000	40.000	740.620	660.620	20	60
31	5.418	323.000	40.000	40.000	653.410	573.410	30	60
32	5.401	324.000	40.000	40.000	729.100	649.100	30	70
33	2.936	596.000	50.000	50.000	400.880	300.880	30	70
34	3.906	448.000	40.000	40.000	681.610	601.610	30	60
35	5.014	349.000	40.000	40.000	362.960	282.960	40	70
36	4.408	397.000	40.000	40.000	339.800	259.800	40	70
37	4.730	370.000	40.000	40.000	449.210	369.210	40	70
38	4.581	382.000	40.000	40.000	420.180	340.180	40	70
39	5.503	318.000	40.000	40.000	511.650	431.650	50	70
A	6.972	251.000	0.000	0.000	442.970	442.970	40	60
B	6.463	270.761	70.000	70.000	297.520	157.520	25	110
C	1.944	900.000	40.000	40.000	650.630	570.630	0	90
F	2.307	758.500	180.000	180.000	548.960	148.960	165	110
G	0.848	2064.000	200.000	200.000	1898.710	1498.710	165	110
H	1.170	1495.980	200.000	200.000	1150.480	750.480	165	110
I	1.054	1660.000	200.000	200.000	1140.660	740.660	165	110
J	0.919	1904.000	190.000	190.000	1158.210	778.210	165	110
K	0.838	2089.000	180.000	180.000	1138.640	778.640	165	110

Cant Deficiency for Rolling Stocks:

(A) For 'nominated' rolling stocks – 100 mm/150 mm

(a) For rolling stocks permitted with 150 mm Cant deficiency, cant deficiency to be limited to 115 mm on track with turnout with crossing on outer rail and on track with expansion device.

(b) Nominated stock shall be permitted cant deficiency of 100 mm/115 mm/150 mm after found satisfactory during oscillation trial and specified as such in Speed Certificate issued by RDSO.

(B) For other rolling stocks not covered above-75mm

Note: The cant and cant deficiency shown in the table are provisional and as per cant deficiency design for the vehicle, tweaking in cant and cant deficiency may be required as per vehicle design.

7. DTT Sanction Details: Railway Board has sanctioned this prestigious project of Dedicated Test Track in two phases-

- **Phase-I:** Sanctioned at a cost of Rs.353.48 Cr during 2018-19 (Dec'2018) for a length of 25 km under Plan Head -11 (New Lines) with NWR as construction agency. (Capital 353.48 Cr.).
- **Phase-II :** Work Sanctioned at a cost of Rs.466.22 Cr in 2020-21 for a length of 34 km under Plan Head – 11 (New Lines) in CAP in Works programme of NWR.

The work is being executed by Construction wing of NWR under the guidance of RDSO and the Dedicated Test Track is taking shape and is expected to be completed by December-2024.

8. Test and Studies Planned by Different Directorates on DTT: The detail of tests to be carried out on Dedicated Test Track is summarised below:

(A) Test & Studies - Rolling Stocks: Testing for riding characteristics/behavior of the vehicles as per UIC-518/EN- 14363 by dynamic measurements (at semi high speed and low speed) of ride quality, accelerations, stability, jerks, wheel and rail contact forces, Braking performance tests, Coupler force trials, Semi high speed rolling stock components testing, Crashworthiness testing, Rating, performance and adhesion test of locomotive, HV and LV Testing, Acoustic Measurement, Weighing and distortion, Twist and Yaw Rig Testing, Static & Impact Tests i.e. compressive end load, coupler vertical loads, jacking test, Twist load, curve stability, Impact Test – Single Car Impact, Current collection test of electric locomotives, Temperature measurement test of traction electronics, Accelerated testing of vehicle components on a separate close test track loop, Weighing and Distortion, Turn Table-Tilting Test.

(B) Test & Studies–Track: Tests on rails, sleepers, formation, track fittings for stresses on various track components, (it includes Rails, welds, Fastening system, Sleepers, Point and crossing, Switch Expansion Joints, Glued Joints etc.), Tests required for various deterioration models as applicable for various track items for axle load upto 25t and 32.5t, Instrumentation for continuous monitoring of stresses at various locations in rails, sleepers and fastenings etc. and

Track Laid on DTT

Accelerated testing of track components on a separate close test track loop.

(C) **Test & Studies– Bridges:** Study of transfer of Longitudinal forces from superstructure to sub structure, Study of transfer of Impact loads, Effect of speeds on CDA, Resonance on bridges, Pier and abutments, Deflection of substructures, Study of different types of Bearings, Transfer of Vertical and Horizontal Loads, Horizontal Forces Management i.e. STU Study (Shock Transmission Units), Load distribution on box bridges & foundation pressure below box bridges, Vertical Deflection, Deck Accelerations, Rotation etc. in all types of bridges, study on loss of prestressing forces in PSC Bridges, study of stresses in different bridge components to validate calculated stresses/ over stressing and Corrosion in studs/reinforcement in ballasted deck girders. Validation of Dynamic Analysis study has been done by IIT, Mumbai - CDA values, resonance behavior, superstructure deflections, deck acceleration, end- rotation, substructure deflection. Instrumentation of bridges has been planned for Validation of forces arisen due to continuation of LWR on bridge structure and related Rail Structure Interaction (RSI) studies, Forces transferred through bridge bearing (instrumented bearing), Horizontal Force management through STU (Shock Transmission Unit), Stresses in steel girder due to higher speed (200kmph) & higher axle load (25t/DFC loading), Resonance, Deck-acceleration, End-rotation, Vertical Deflection, Bridge Health Monitoring System for bridge condition assessment.

Need of Dynamic Analysis for Bridges of Dedicated Test Track

Bridges on Dedicated Test Track is to be designed for OSCILLATION TRIAL speed upto 220kmph for passenger trains.

Dynamic Behavior of Bridges:

For existing speeds (upto 160kmph), current codes prescribe only limits of vertical deflection. However, for higher speeds Deck acceleration, Coefficient of dynamic augment, Vertical and lateral deflections, Horizontal rotations & Resonance are Parameters for assessment for suitability of existing bridges. Natural Frequencies of bridges need to be worked out and compared with those of the rolling stocks at different speeds. Hence suitability of RDSO designs of DFC loading was checked for TRIAL speed upto 220kmph in association with IIT-Mumbai. Major findings of Project with IIT/Mumbai on bridges of Dedicated Test Track are given below:

1. For higher speeds even with passenger train loading, Plate and Open Web Girder designed for DFC loading are not suitable without ballasted deck due to higher deck accelerations.
2. Composite steel girder with ballasted deck designed for DFC loading found suitable.
3. RCC boxes designed for DFC loading found suitable only with minimum earth fill of 2m.
4. For designing Bridges for High Speed Trains, control on deflection and control on deck accelerations is very important.

Construction of Bridge

For these studies, Open Web Girders with ballasted deck, Composite girders, PSC Girder, RCC Boxes (with stipulation of minimum earth cushion), Plate Girder, PSC slabs, PSC girder and Composite Plate Girder are being constructed. The detail of Number, span & type of bridges is tabulated below:

Bifurcation of Bridges of DTT

S. No.	Type of Bridge	Span length	No. of Span	No. of Bridges	Bridge No.
1	RCC BOX	2.00 x 2.15	1	13	10,11,12,14,16,17,19,21,24,25,26, 38 & 109
2	RCC BOX	2.00 x 2.50	1	1	36
3	RCC BOX	2.00 x 2.65	1	1	41
4	RCC BOX	2.00 x 2.75	1	1	35
5	RCC BOX	2.00 x 3.00	1	10	1,2,4,5,7,8,9,31,32 & 44
6	RCC BOX	2.00 x 3.65	1	1	34
7	RCC BOX	2.00 x 4.00	1	2	12A & 71A
8	RCC BOX	3.00 x 3.00	1	1	49
9	RCC BOX	4.00 x 4.15	1	9	3,52,63,116,117,118,88,92(A) & 114
10	RCC BOX	4.50 x 4.65	1	8	41A,45A,53,87,89,94,110 & 115
11	RCC BOX	4.50 x 5.00	1	1	69
12	RCC BOX	4.50 x 5.15	1	2	120 & 115A
13	RCC BOX	4.50 x 5.55	1	1	112
14	RCC BOX	4.50 x 6.00	1	13	66,73,75,77,78,82,85,86,121,123,12 5,126 & 127
15	RCC BOX	5.00 x 6.00	1	1	43
16	RCC BOX	6.00 x 3.35	1	1	30
17	RCC BOX	6.00 x 3.50	1	1	37
18	RCC BOX	6.00 x 3.65	1	1	20
19	RCC BOX	6.00 x 3.75	1	1	102
20	RCC BOX	6.00 x 4.15	1	12	23,27,28,57,62,79,95,96,98,100,101 & 106
21	RCC BOX	6.00 x 4.15	2	3	15,18 & 80
22	RCC BOX	6.00 x 4.65	1	2	55 & 108
23	RCC BOX	6.00 x 5.00	1	1	113
24	RCC BOX	6.00 x 5.55	1	1	111
25	RCC BOX	6.00 x 6.00	1	5	45,81,84,97 & 104
	TOTAL RCC BOX			**93**	
26	RCC BOX-RUB	4.50 x 4.15	1	5	40,50,70,72 & 119
27	RCC BOX-RUB	4.50 x 4.65	1	5	39,53A,54,56 & 61
28	RCC BOX-RUB	4.50 x 5.00	1	2	58 & 65
29	RCC BOX-RUB	4.50 x 5.65	1	1	64
30	RCC BOX-RUB	4.50 x 6.00	1	5	67,68,74,76 & 122
31	RCC BOX-RUB	6.00 x 3.65	1	1	47
32	RCC BOX-RUB	6.00 x 3.75/4.35	1	1	33

33	RCC BOX-RUB	6.00 x 4.15	1	5	48,51,71,93 & 99
34	RCC BOX-RUB	6.00 x 4.65	1	3	13,103 & 105
35	RCC BOX-RUB	6.00 x 5.00	1	1	83
36	RCC BOX-RUB	6.00 x 5.00	2	1	29
37	RCC BOX-RUB	6.00 x 6.00	1	2	124 & 128
	TOTAL RCC BOX RUB			**32**	
38	St.PL GIRDER	1 X 18.30	1	1	6
	TOTAL STEEL PLATE GIRDER			**1**	
39	PSC GIRDER	12.2	1	2	60 & 107
40	PSC GIRDER	12.2	2	1	59
41	PSC GIRDER	18.3	1	1	46
	TOTAL PSC GIRDER			**4**	
42	PSC SLAB	12.2	1	1	42
	TOTAL PSC SLAB			**1**	
43	NP4	1.2	2	1	5A
44	NP4	2.0	1	3	74A, 82A & 83A
	Total Hume Pipe (NP4)			**4**	
45	COMPOSITE GIRDER	1 X 18.30	7	1	22
	OWG	2 X 30.50			
	OWG	1 X 61.00			
	OWG	1 X 45.70			
	COMPOSITE GIRDER	1 X 30.50			
	COMPOSITE GIRDER	1 X 24.40			
	GRAND TOTAL			**136**	

(D) Geotechnical Tests & Studies

i. **Study of Formation Stresses and Optimization of Blanket Layer Thickness:** Study/Trials for establishing adequacy & optimization of formation layer thickness including blanket layer, required for different axle loads, speed, GMT for local soil/weak soil, trials on effect of increasing/optimizing formation width on formation performance w.r.t. stresses/settlement and ballast penetration for different formation widths. (7.85m, 8.1m & 8.5m) has been planned along with Instrumentation for measurement of stresses and settlements at various depths/different formation layers in Railway Formation.

ii. **Geosynthetics Studies:** Trial on effect of Geosynthetics usage (Geogrid, Geotextile etc.) at various depths/layer interfaces on reduction of formation pressure and blanket thickness, Use of Geocell below ballast for formation strengthening to avoid use of blanket layer in existing formation, Trial on slope erosion control measures using Geocell/geo-mesh with hydro- seeding and other alternatives has been planned.

iii. **Studies of Transition System at Bridge Approaches:** Study/Trials of different types of transition system viz. with different drainage arrangement as per GE:R-50 (rev.1) 2021 report, use of geosynthetics material for transition systems at bridge approach viz. Geocell for strengthening of top formation layers and measurement of vertical pressure at top and bottom of box culvert has been planned.

iv. **Geo-Technical Studies:** These have been planned for different quality soils at nominated locations with different thickness of blanketing material (300 to 700mm), different embankment width (7.85, 8.1 & 8.5m), Provision of different side slopes (1:2,1:2.5), Provision of different geo-synthetics and geo-textiles and Instrumentation for formation stress measurement. Settlement at different levels are also to be observed using settlement gauge / pegs, Piezometers for pore water pressure measurement in weak soil section and bridge approach is planned. Track settlement and drainage functionality are also to be observed at bridge approaches.

Figure 1: Earth Work

Figure 2: Compaction

Figure 3: Geotextile

Figure 4: Geo-Cells

Formation Treatment

(E) **Test & Studies-Traction Installation:** Catenary Pantograph Interaction study as per EN 50367, Study for efficacy of Earthing Bonding system for touch & step potential of the rail under normal and short circuit conditions for compliance with EN 50122-1 and IEC 62128-1 (2013), Suitability of newly developed OHE component, viz. Modular Cantilever, Spring ATD, Current Carrying Droppers, Section Insulators etc., Measurement of OHE parameters and forces in dynamic conditions between OHE & Pantograph & its validation with respect to simulation results, High Voltage Test on PSI equipment to check Insulation Level are to be done.

(F) **Test & Studies – Signal and Telecom**

(a) **Studies on KAVACH :** Trial on head on collision prevention, rear end collision prevention, Monitoring of Signal Passed at Danger (SPAD), loop line speed control, permanent and temporary speed restriction monitoring, unusual stoppage in block section monitoring, roll back protection, trial without line side signals.

(b) **Studies on Electronic Interlocking:** Testing of direct interface of electronic interlocking with KAVACH, track detection systems, signal aspects etc.

(c) **EMI/EMC Tests:** EMI/EMC testing of rolling stock, All makes of track detection systems such as digital axle counters, AFTCs and DC Track circuits are to be provided in the area fit for 200 kmph.

(d) **Interoperability Tests:** Interoperability tests between different sub signaling systems are also planned.

(e) **Signal & Telecom Design:** Provision of KAVACH for full section, Signal interlocking (EI) at New Gudha, Jabdinagar, Nawa City and Thathana Mithri, All the lines of the test track shall be provided with facility for both Up and Down signaling movement and The DAC/ AFTC/ DC track circuit will be used for the track Detection system.

9. Concluson

Efforts for establishing a Dedicated Test Track has been going on since a long period and now this noble concept is taking shape in reality in field. It will enable conducting of almost the entire gamut of field investigations required by the RDSO for performance evaluation and design development of Rolling Stock. Also, the various ingredients of the infrastructure under controlled conditions.Testing of Rolling stocks will be done as per International Standards for speeds upto 200 km/h. Speed Certificate, CRS Sanction, GM Sanction etc. not needed for trials, No disturbance to normal traffic, track parameters will be precisely controlled and Destructive tests are also possible. This will reduce the testing time: 8-12 days (Approx.) v/s. 20-30 days and will lead to Faster introduction of new designs of rolling stocks and other infrastructure items. Line capacity and earning potential of Main line track will not be compromised It would be possible to simulate and engineer environment as would be encountered by the equipment under normal operating conditions. Continuous tests can be performed to determine efficiency, efficacy and endurance limits of equipment and materials. Laboratory and Simulation test results can be verified in field avoiding need for replication in future. Finally, Indian Railway will be globally a leading hand in testing & trials as facility for such a large number of infrastructure/ component tests is not available anywhere in a single test track.

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Minimisation of Transmission Losses for Solar Power Plant Involving Voltage Multiplier Technique to provide supply to the Stations

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Abstract : The emergence of solar power has changed the face of renewable energy generation. Amongst all other renewable sources solar power being cheaper, reliable and widely available leads the race. However the only problem with solar generation is losses, hence leads to lesser efficiency than other renewable energy generation methods. These losses include panel loss, transmission loss, etc. However transmission loss can be minimized significantly by boosting of solar output voltage, which in turn leads to minimization of current. Here, we have used voltage multiplier technique to boost the solar output. Details of this work are illustrated in this paper.

सारांश : सौर ऊर्जा के उद्भव ने नवीकरणीय ऊर्जा उत्पादन का चेहरा बदल दिया है। अन्य सभी नवीकरणीय स्रोतों में सौर ऊर्जा सस्ती, विश्वसनीय और व्यापक रूप से उपलब्ध होने के कारण दौड़ में सबसे आगे है। हालाँकि, सौर ऊर्जा उत्पादन के साथ एकमात्र समस्या हानि है, इसलिए अन्य नवीकरणीय ऊर्जा उत्पादन विधियों की तुलना में कम दक्षता होती है। इन नुकसानों में पैनल हानि, ट्रांसमिशन हानि आदि शामिल हैं। हालाँकि, सौर आउटपुट वोल्टेज को बढ़ाकर ट्रांसमिशन हानि को काफी कम किया जा सकता है, जिसके परिणामस्वरूप करंट कम हो जाता है। यहां, हमने सौर ऊर्जा उत्पादन को बढ़ावा देने के लिए वोल्टेज गुणक तकनीक का उपयोग किया है। इस कार्य का विवरण इस पेपर में दर्शाया गया है।

Key words

- Voltage Multiplier Circuit (VMC)
- High Voltage DC Transmission (HVDC)
- Maximum Power Point Tracking (MPPT)

Introduction

The average solar energy intercepted by earth is about 164W/m^2 over 24 hours. The objective is to harness this solar irradiation for sustainable development. This has been a major challenge for researchers as to how to increase the efficiency of solar cells. Many techniques have been adopted for this purpose. This paper proposes the technique of optimizing the transmission losses incurred while supplying power to charge the batteries and supplying to the load centres [3]. In grid connected systems, the battery banks are situated away from the solar panels which may be more than 100 metres in distance. A majority of the power is lost in form of transmission loss.

Transmission loss is governed by the amount of voltage being supplied. Increasing the voltage while transmission compensates the I2R loss and thus saving power which was earlier being wasted [4]. This is achieved by the help of Voltage Multiplier Circuit (VMC) [1]. The paper provides an extensive work done on the adaptation of VMC which proves efficient in serving the purpose of magnifying voltage level to minimize the loss. It is anticipated that this process would be widely used in decades to come.

Methodology

From the beginning of electronics technology era DC-AC inverter technology has been developed and this system is used in order to support AC bus system for AC load and is also vital component in the solar cell system. The class B push-pull amplifier was use to amplify the sinusoidal oscillator which was being used to developed. The DC to AC inverter and this is 50% efficient due to voltage drop at the push-pull amplifier. There is 50% power loss and the sinusoidal form of the current and voltage running through the final transistor is the reason for 80% power loss.

The full bridge inverter technology was developed to overcome the half bridge inverter which was 50% efficient. The Fig 1 and 2 also shows the work mechanism of the inverter which is based on the switching method. The voltage drop (V_{DR}) is minimum where as the load current (I_L) is minimum across the switch. Hence the power loss is very small which can be represented in equation.

$$P_L = V_{DR} I_L$$

To control bridge inverter switches on-off discrete signal is feed and the power input to the final transistor is kept constant in this way bridge inverter idea is realised. The discrete signal is modified from on-off signal. The efficiency of electrical power conversion from DC-AC is improved by using bridge inverter in which ideal is closed to 100%. Push-pull B class amplifier which is used for DC-AC inverter which is replaced by the bridge converter technique which has high output efficiency. Half and full bridge inverter are the two basic fundamental of bridge inverter configuration.

Half Bridge Inverter

The Circuit configuration of half bridge inverter is shown in Fig-1 s1& s2 are the two switching elements with one anti parallel diode each. It can be transistor, MOSFET or IGBT.

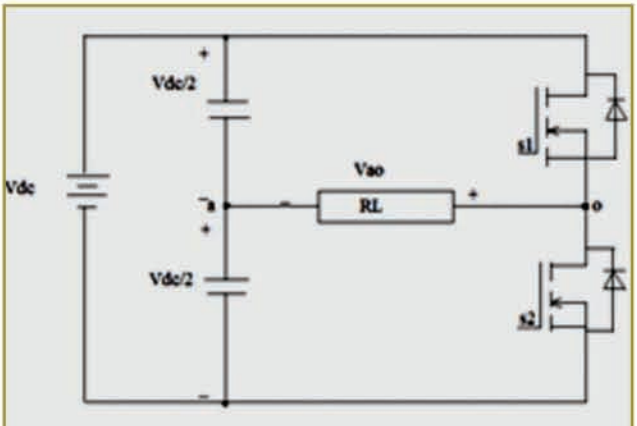


Fig-1(a)
(Circuit Configuration of Half-bridge Inverter)

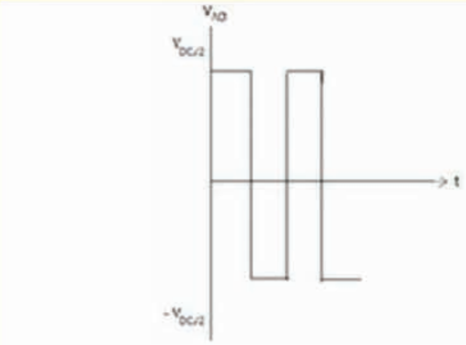


Fig-1(b)
(Output Signal of Half-bridge Inverter)

The Basic operation of half bridge inverter circuit consists of two conditions.

(i) When s1 is on i. e from 0-T/2 period the output voltage drop value is $v_{dc}/2$

(ii) When s2 is on i. e from T/2-T period the output voltage drop value is $-/2\ V_{dc}$.

During this process of switching it is being made sure that both the switches are hot in on condition at the same time. It is done to avoid short connection input V_{DC} which in turn damage the switching elements.

1-phase full bridge inverter circuit configuration is shown in Fig-2.

It consists of s1, s2, s3 & s4 switching elements.

The two operational conditions are

(i) When s1 & s4 are on s2 & s3 are off, the output value is V_{DC}.

(ii) When s2 & s3 are on s1 & s4 are off, the output value is $-V_{DC}$.

It is being make sure that no two pair of switches

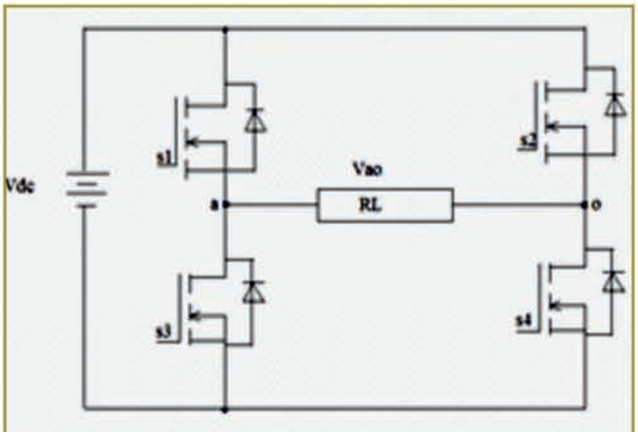


Fig-2(a)
(Circuit Configuration of Full-bridge Inverter)

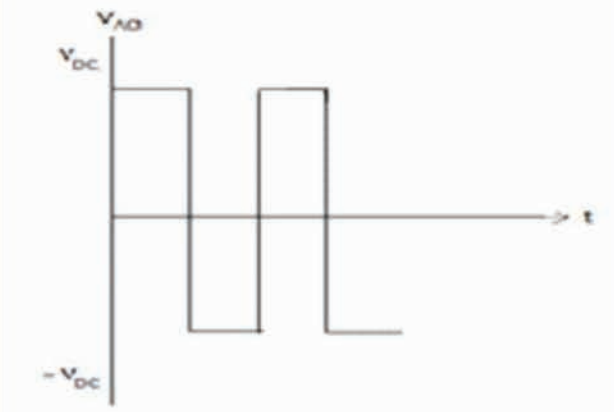


Fig-2(b)
(Output Signal of Full-bridge Inverter)

s1 & s4 or s3 & s2 are on at the same time to avoid short conditions on VDC. Gate drivers are used with dead time mechanism to avoid the above short condition.

From above Figure we can conclude that peak to peak output voltage of half bridge is half of full bridge [6].

Generated HVAC through the transformer when fed to a voltage multiplier circuit (VMC) yields HVDC for optimizing transmission loss over long distance for maximizing transmission efficiency. The VMC [1] generates HVDC which basically is achieved through intermittent charging & discharging of capacitors making that of heavy duty gang capacitors level detectors and clippers and clampers. The level detector is realised through polarized relay [2] reference voltage and comparators. The simulated VMC output yields less ripples of high voltage and more ripple of low voltage rectified ac input which proves beneficial in optimizing ripples at long distance DC transmission. The simulation results suggest that the HVDC [4] does not suffer more from losses due to ripple which proves beneficial to maximize the efficiency of solar power plant.

As an example:

1. Here every solar panels used are of 24V and 7A ratting.
2. Total number of panel used is 6 (germanium).
3. 2 pairs of 3 panels are used in series and finally both are in parallel.

Circuit Diagram of 1.5 KW Solar Power Plant:

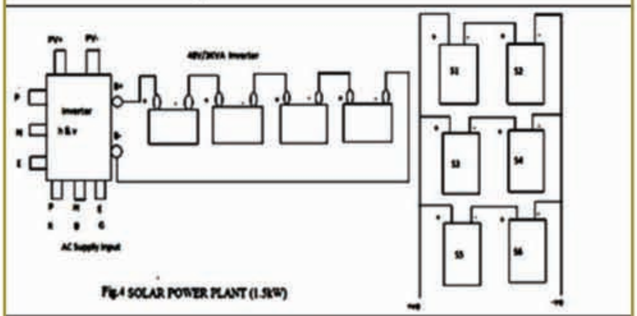


Fig-2

The circuit of 1.5kW solar power plant shown in Fig-2 is arranged in a manner where the output of the 6 solar panels is fed directly to the inverter through which the batteries are charged. A total of 48 Volt is generated which is stored in the battery and stepped up by a transformer inside the hybrid inverter while supplying to the load.

Block Diagram for Proposed Design of VMC:

The block diagram representation for the proposed VMC in this dissertation is shown in Fig-3.

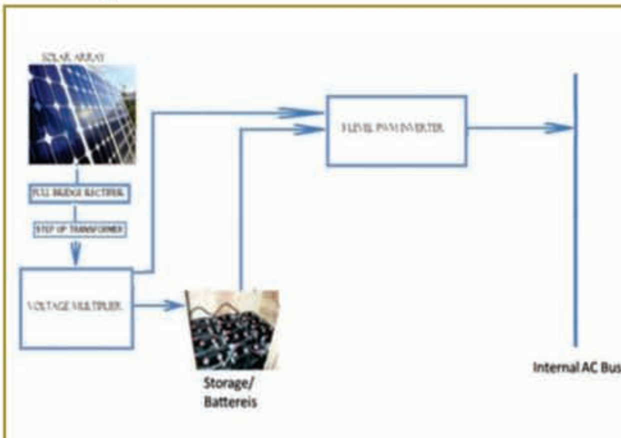


Fig-3

The setups involving large distance battery charging lines often encounter enormous transmission losses in the form of I^2R loss. Hence a great amount of reduction in these transmission losses is prevented by directing the output power first to the VMC circuitry shown in Fig-4 which multiplies the voltage level to a desired value and then sends power for storage in the batteries. Thus, resistance being fixed, the amount of current is reduced thereby reducing the I^2R loss. The DC output of the panels is first fed to an inverter converting it into AC form which is then fed into the transformer circuitry of the VMC. The VMC then plays the role of magnifying the voltage and manifolds it again into DC before finally discharging into the batteries.

Circuit Diagram of the VMC

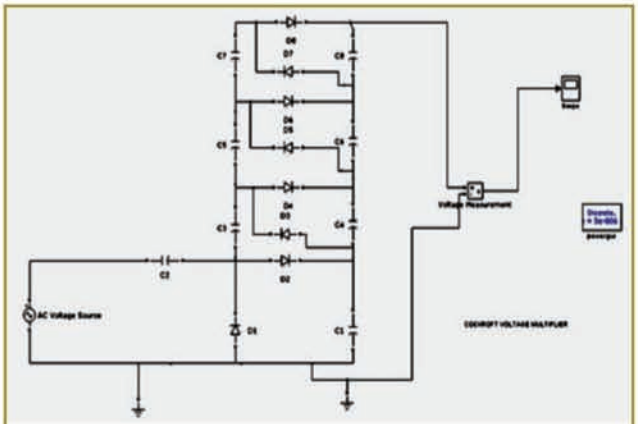


Fig-4

Details of the methodology

During the negative half of the ac supply the diode D1 is forward biased and starts conducting and charges the capacitor C2 to the maximum peak value of the input voltage as it acts as a short circuit path. In the next positive half cycle, the diode D2 is forward biased and charges capacitor C1. During this event, however, the previously charged capacitor C2, acts as a voltage source of magnitude equal to that of the source voltage and aids in the charging of the capacitor C1 to a value nearly equal to twice the source voltage's value. Thus C1 is charged to a value of 2Vp [1] (source voltage).

In this way, voltage is doubled and can be magnified to any desired value with the successive addition of further capacitors and diodes in the similar fashion. Voltage magnification of any magnitude is thus obtained by adding these voltage multiplier circuits in series.

Thus if a VMC consists of "n" no. of stages, then the Open Circuit Voltage Vo(n) across the multiplier is given by:

$$Vo(n) = nVp$$

The use of the transformer and the drawing of a substantial amount of current I_1, causes a drop in the output given by a ripple voltage V_{rip}, which causes a superimposition of ac waves on the dc output. In this dissertation we obtain the ripple voltage output of VMC as;

$$V_{rip} = I_L X \left\{ \frac{2n^3}{3} + \frac{n^2}{2} - \frac{n}{6} \right\} \div (f \text{ x } c)$$

The output of VMC is expressed as;

$$V_o = (n \text{ x } V_P - V_{rip}) x (1 - e^{\frac{-t}{rc}})$$

Where,

n = *number of capacitor used*

I_L = *load current*

V_P = *voltage input to VMC*

r = *load resis tance*

c = *capaci tance of each capacitor*

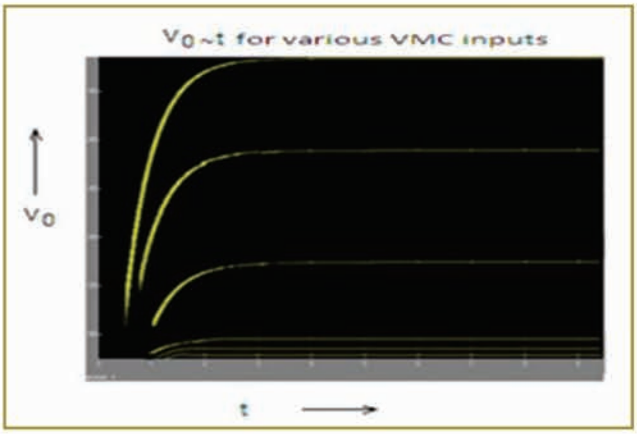
V_O = *VMC output*

Apart from this, the efficiency of the solar cells can be enhanced by switching to techniques like use of reflectors, CdS solar cells, by using MPPT solar tracking system [5], etc.

Result Analysis

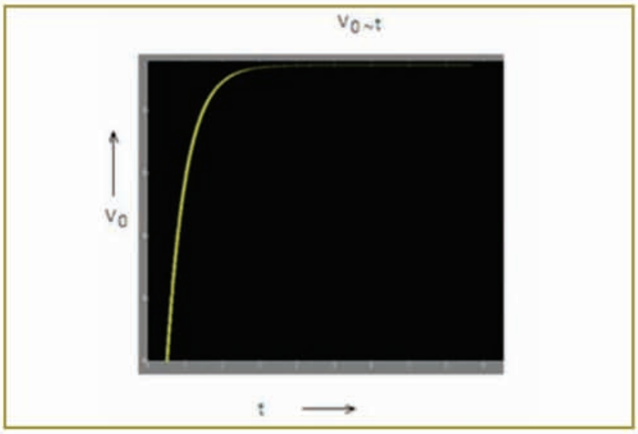
The variation of various simulated VMC outputs for different values of VMC inputs

Versus time are described below through Fig-5 (a-f)

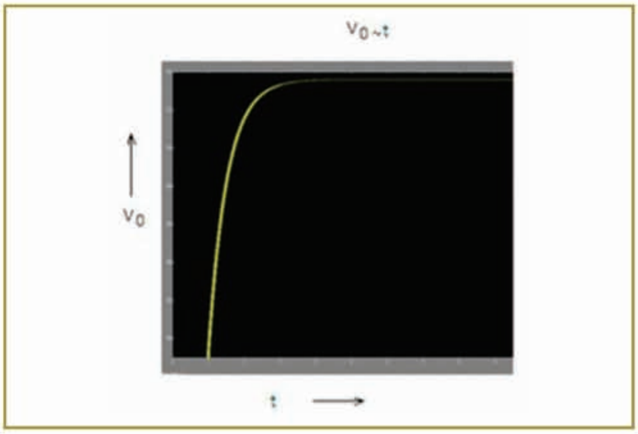


Plots (Vo ~ t):-

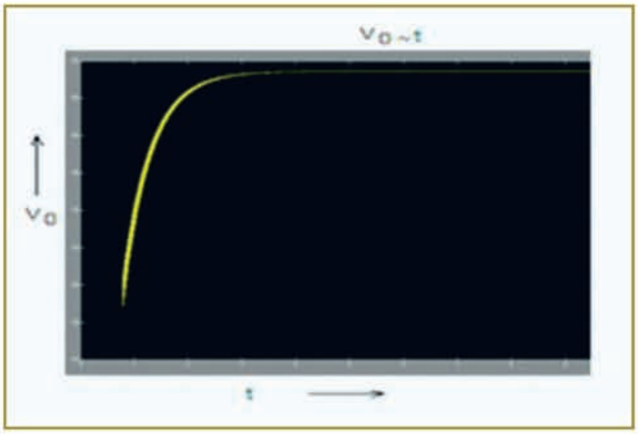
(a) When voltage input to VMC =10V



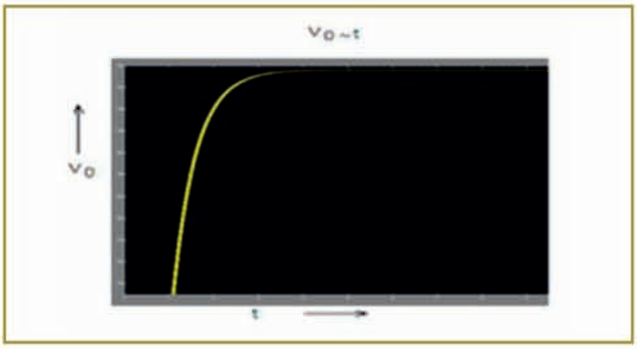
(b) When voltage input to VMC=15V



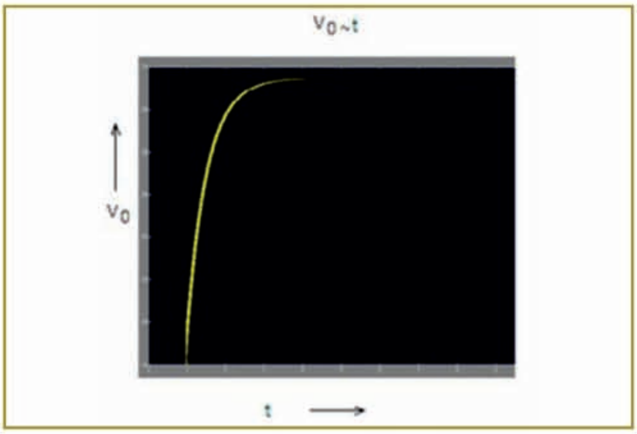
(c) When voltage input to VMC=20V



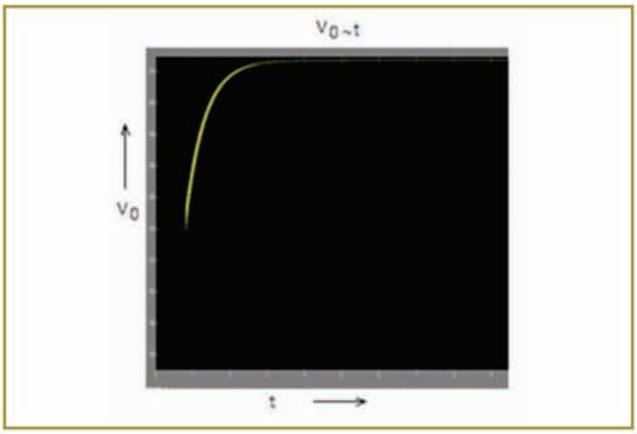
(d) When voltage input to VMC=25V



(e) When voltage input to VMC=30V



(f) When voltage input to VMC=35V



(g) When voltage input to VMC=40V

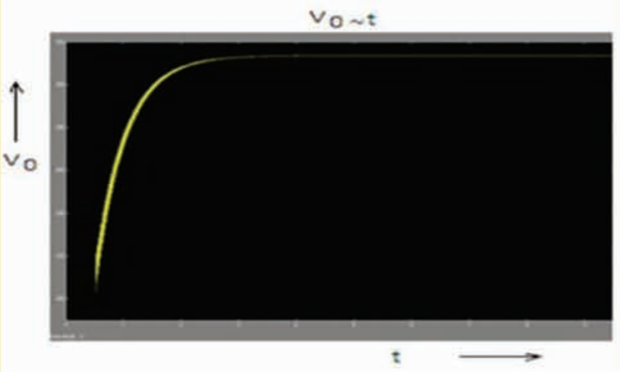


Fig-5 (a-g)

Conclusion

The rigorous study of 1.5kW solar power plant (as a MAT LAB) observation compelled us to go for the optimization of transmission losses in load centre and in the feeder connecting solar PV cell and battery charger unit incorporating a VMC unit for maximizing the AC voltage obtained out of inverter which is fed with solar panel output of 48 volts. As a result of this increased AC voltage the transmission loss being inversely proportional to square of the AC voltage gets minimized. The Ac voltage obtained through process is almost free of ripples which prove most beneficial for distortion free load dispatch for solar power transmission. This method can be utilized for huge MW and GW solar power plants in place of converter and inverter stations.

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Industrial Computed Radiography- First time in Indian Railways

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Abstract : Non-destructive Testing (NDT) is a crucial set of testing techniques used to inspect and evaluate materials and components without causing damage to them. Radiographic Testing is a vital NDT method that uses X-rays or gamma rays to examine the internal structure of objects.

Industrial Computed Radiography is an advanced NDT technique within radiographic testing offers numerous benefits including high resolution of digital image, efficient image storage, image sharing, and reduced radiation exposure time compared to traditional film-based radiography.

Many industries have made NDT as a mandatory testing technique to ensure the reliability, safety and quality of various industrial assets.

सारांश : गैर विनाशकारी परीक्षण (एनडीटी) परीक्षण तकनीकों का एक महत्वपूर्ण सेट है जिसका उपयोग सामग्रियों और घटकों को नुकसान पहुंचाए बिना उनका निरीक्षण और मूल्यांकन करने के लिए किया जाता है। रेडियोग्राफिक परीक्षण एक महत्वपूर्ण एनडीटी विधि है जो वस्तुओं की आंतरिक संरचना की जांच करने के लिए एक्स–किरणों या गामा किरणों का उपयोग करती है।

औद्योगिक गणना रेडियोग्राफी रेडियोग्राफिक परीक्षण के भीतर एक उन्नत एनडीटी तकनीक है जो पारंपरिक फिल्म–आधारित रेडियोग्राफी की तुलना में डिजिटल छवि के उच्च रिजॉल्यूशन, कुशल छवि भंडारण, छवि साझाकरण और कम विकिरण जोखिम समय सहित कई लाभ प्रदान करती है।

कई उद्योगों ने विभिन्न औद्योगिक परिसंपत्तियों की विश्वसनीयता, सुरक्षा और गुणवत्ता सुनिश्चित करने के लिए एनडीटी को एक अनिवार्य परीक्षण तकनीक बना दिया है।

Introduction

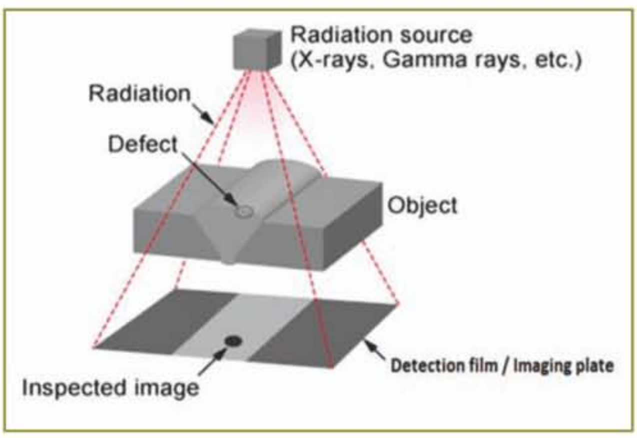
In 1895, Roentgen's ground-breaking discovery paved the way for the application of ionising radiation (X-ray) in various fields including medicine and industry.

Industrial radiography, a vital branch of Non-Destructive Testing (NDT) plays a pivotal role in ensuring the structural integrity, safety and reliability of various components and materials used across several industries. Through the use of ionizing radiation, this technology allows for the inspection of hidden defects, discontinuities and material properties without causing any damage to the test material.

Industries such as aerospace, railways, automotive, oil and gas, manufacturing and construction have made NDT as a mandatory testing technique to ensure the reliability, safety and quality of various industrial assets.

Radiographic Testing is a fundamental NDT method that uses X-rays or gamma rays to examine the internal structure of objects. It is particularly essential for inspecting welds, castings and other critical components, as it can reveal defects and discontinuities which are not visible to the naked eye.

Industrial Radiography

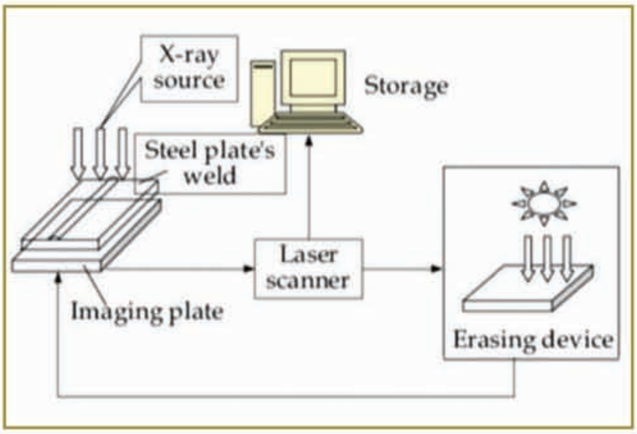


Over the years, industrial radiography has undergone significant advancements, transforming the way inspections are conducted and enhancing the overall quality control processes in numerous sectors.

In conventional radiography, X-ray images are captured on film which requires chemical solutions to develop the images in a dark room and film developing depends on the individual skill. This process is time consuming and proper storage room facility is required to preserve the films.

The Processes Involved in Computed Radiography

The Computed Radiography (CR) is an advanced imaging technique widely used in Non-destructive Testing to detect internal defects and flaws in various materials and components. Computed Radiography testing is very similar to film radiography except the film is replaced by reusable flexible imaging plate. The exposure time depends on the thickness of the test specimen.

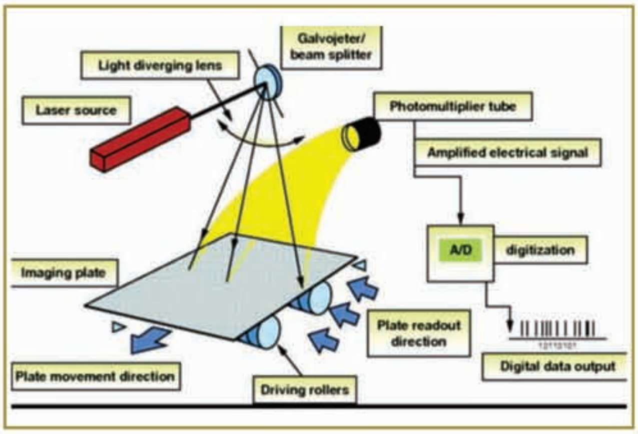


In general the imaging plates are of two types, namely white imaging plate and blue imaging plate. White image plate is of lesser resolution can be used for general purpose radiography. Blue imaging plates are used for very precise imaging and higher resolution radiographs.

The imaging plates are coated with a special phosphor layer and when exposed to X-rays or gamma rays] the energy of the incoming radiation after passing through the test material is stored in the phosphor coating of the imaging plate as a latent image.

Working Mechanism of Computed Radiography Scanner

A specialized machine known as a computed radiography scanner is used to read out the latent image from the imaging plate by stimulating it with a very finely focused laser beam. When stimulated the plate emits blue light with intensity proportional to the amount of radiation received during the exposure.



The light is then detected by a highly sensitive analog device known as a photomultiplier (PMT) and converted to a digital signal using an analog-to-digital converter (ADC). The generated digital image can be stored in the computer which can be further processed, analysed and evaluated on a computer. After an imaging plate is read the latent image can be erased by a high-intensity light source and the imaging plate can be re-used immediately.

After converting the latent image from the imaging plate to digital image the latent image can be erased using the same computed radiography scanner. Either erasing can be carried out automatically in the scanner or the same image can be scanned multiple times from the imaging plate with different scanning speed for better resolution and then it can be erased separately using the scanner. Thus after erasing the image in the imaging plate the imaging plate can be used for next radiography imaging cycle.

Computed Radiography has become an indispensable tool in many industries due to its ability to provide high-quality radiographic images without the need for traditional film-based methods. This transformation offers several advantages. First and foremost, it eliminates the need for chemical processing, significantly reducing inspection time. Additionally, digital images can be enhanced, manipulated and transmitted electronically making them easier to interpret and share among inspectors and experts regardless of their location.

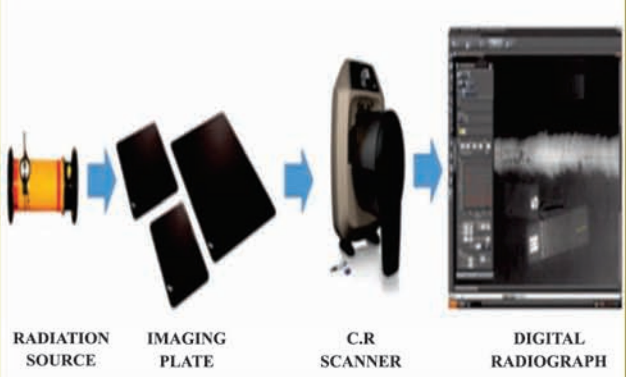
The computed radiography in Integral Coach Factory, Chennai

The Integral Coach Factory, Chennai achieved a remarkable leap forward in its industrial radiographic inspection processes with the introduction of computed radiography technique in 2018 and this technique is the first time in Indian Railways. Prior to this technological upgrade, ICF relied on traditional film radiography, which requires a dark room, trained person for preparing the chemical solutions for film processing, film developing, water requirement for film washing and effluent treatment for used chemical solution. This method demanded a substantial amount of time and effort, with the advent of computed radiography has accelerated the production timelines.

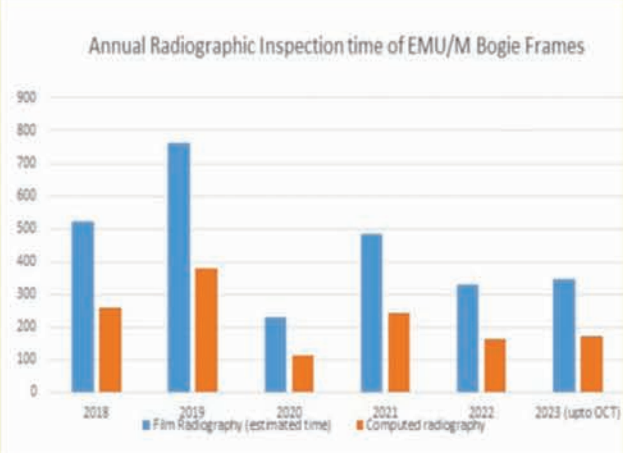
With the induction of computed radiography, ICF has smoothly changed its track to acquire the certification of ISO 3834 and accreditation to ISO 17025 (NABL). Previously in film radiography the defects were compared with the standard defects and the interpretation may vary from one to another. Whereas in computed radiography the defect size can be measured precisely. Enhancement of image by adjusting contrast, brightness and grey value is an added advantage to study and identify the defects in the varying cross sections of the test objects.

Computed Radiography Setup in ICF

With this superior technology of computed radiography in ICF, quality audits on cast and weld components have been conducted to provide radiography image feed backs to the vendors for improving the manufacturing process to supply the quality components for the railway coaches.



The transparency in radiography work is an added advantage on witnessing the computed radiography work and by sharing of the radiography images, vendors have gained confidence on the reliability of radiography results of ICF and the demand for joint inspections by the vendors have been reduced significantly.



The graph is the estimated Inspection time of film radiography for one EMU/M bogie frame at ICF vs real time computed radiography of EMU/M bogie frames inspected in the corresponding years. The reduction of inspection time by more than 50% in computed radiography is mainly due to the reduction in radiation exposure time by the use of imaging plate and reduction in image processing time by the use of CR scanner.

The Vande Bharat bogie frames are having more than forty butt weld joints in different orientation and the suitability is precisely assessed by computed radiography work. The images of the welds are shared to educate the welders for improving their performance. With the support of computed radiography images, ICF has educated] trained and improved the performance of the welders to the international level. Number of reworks have been reduced considerably.

Advantages of Computed Radiography

- Imaging plates are not light sensitive– developing of image can be carried out in normal light
- Image resolution is very high is in the order of 0-04mm
- Practically Imaging plate can be reused for more than 300 times by erasing the captured image
- Image is of digital nature and can be stored in computer
- Original image features cannot be changed
- Contrast and brightness can be modified at any time
- Artificial defects (artifacts) occur during film processing is eliminated
- Can be shared across the globe instantaneously
- Multiple copies can be made to study different sections of a component
- Automated scanning and conversion (A/D) Analog to digital format
- Scanning time is less than one minute to scan an imaging plate size of 300 X 300 mm
- Weld or cast filters can be used to study the defects with better resolution
- Image can be enlarged and defect sizes can be measured precisely
- Reduced exposure time & processing time by more than 50% when compared to film radiography
- Enhancement of image quality by using Intensifying lead screen is not required
- In addition to the reduced cost on consumables, the return on investment of CR systems is strongly determined by savings in exposure time, processing times and archival times.

Conclusion

The journey of industrial radiography from its humble beginnings to its current state of technological expertise is an evidence to human creativity and our relentless pursuit of safety and quality. As we stand on the precipice of a new era in NDT the advancements in this field are poised to transform industries, enhance asset integrity and contribute to a safer and more efficient world.

With the induction computed radiography in Integral coach factory, it has enhanced the detection capability of defects and thereby ensuring the safety and reliability of railway systems. ICF has acquired the sufficient years of experience in the field of computed radiography will pave the way for implementing this new technology throughout the Indian Railways. With the advancements in technology, radiography continues to play a key role in preserving train integrity.

As technology continues to evolve so too will the capabilities of industrial radiography. The ability to see the invisible to uncover defects hidden from plain sight and to do so efficiently and accurately ensures that industrial radiography will remain a cornerstone of quality control and safety across numerous industries for years to come.

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