Technological Advancements of EMUs and Introduction of High Speed Trains on Indian Railways

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ABSTRACT
Efficient rail based mass rapid transit system provides a sustainable transport model for large urban areas. Managing urban transport needs becomes more challenging in a city like Mumbai where the land mass is restricted and the city is growing vertically. Over a period of time, Electric Multiple Units (EMU) system has been extensively utilized and to cope with the increasing passenger demand, the system requires massive inputs for technological upgradation and better level of passenger comfort.

In the last two decades, there has been a significant development in power electronics leading to use of 3 phase AC propulsion equipments on EMUs. With the advent of Gate Turn-Off (GTO) power switching semiconductors, EMUs with 3 phase asynchronous motors were introduced in 2001, which had the feature of regenerative braking. This led to significant energy saving. The technology has since developed further and has switched over from GTO to the Insulated Gate Bi-polar Transistor (IGBT) devices. IGBT allows more compact converter designs with integrated drive control, lower weight and higher overall power efficiency.

As part of Mumbai Urban Transport Project (MUTP), involving major expansion of Mumbai Suburban Railway System, new state-of-the-art EMU rakes are being introduced with 3 phase IGBT based propulsion system resulting in the reduced maintenance. The paper outlines the brief history of EMU services since inception, growth of passenger traffic, various technological upgradation and passenger friendly features of the new EMUs leading to the improved energy efficiency, reduced power consumption, benefits of new technology and elucidates future challenges.

Introduction of the distributed traction system has several inherent advantages over loco hauled traction system. IR aims at raising the speed of passenger trains to 160-200 kmph, which will bring about a major paradigm shift in travelling by train. High speed passenger train operation would be necessary to meet the requirement of fast intercity travel between major cities. In the long run, however, genuine high speed trains with travel speeds up to 300 kmph would also be needed to keep pace with developments in other parts of the world.

1.0 INTRODUCTION:
Mumbai is a linear city, spread over a distance of 120 kms. During the early part of the 20th century, planners realized that in order to exploit the full commercial potential of Mumbai, it would be necessary to provide an electric based transport system. Electric suburban trains were introduced in Mumbai on 3rd February 1925 with 1500V Direct Current (DC) traction system. It may be mentioned here that at that time, DC traction was the only modern system available in the London Underground. An incredible 88% of the overall travel in Mumbai is by bus and rail. This statistics in itself illustrates the popularity and the necessity for the public transport system, particularly the suburban railways. Periodic induction of various EMU stock is detailed below:

- In 1925: WCU1-First 1500V DC EMU suburban train service of India procured from the English Electric Co. Ltd, ran from Victoria Terminus (now CSTM) to Kurla on harbour line of Central Railway (CR), Mumbai.
- In 1928: WCU2-Second stock 1500V DC EMU put into services on Western Railway (WR). Electrical equipments were supplied by British Thompson Hoston Co. Ltd. and mechanical parts by M/s Cammel Laird.
- In 1951: WCU3 & WCU4: Two other types of 1500V DC EMU stock put into services on WR & CR, supplied by British Thompson Hoston Co. Ltd and M/s Cammel Laird.
2.0 ADOPTION OF NEW TECHNOLOGY IN A PHASED MANNER

Mumbai suburban railway network in the Central and Western Railways covers a route of 319 kms. There are six corridors, two each on the Western Railway, Central Railway and Harbour Line. Central Railway network connects CSTM in South Mumbai to distant suburbs of Kasara, Karjat & Khopoli. Western Railway covers the area from Churchgate to Virar. The Harbour line runs on CSTM - Panvel and CSTM - Andheri section. Trans-harbour line connects Thane - Vashi and Thane - Panvel. Map showing the Mumbai suburban network is given in Fig. 1. Every day 6.6 million people travel in the suburban sections using the services of 2736 trains. Records suggest that the suburban sections of Mumbai have the highest passenger density in the world.
The salient statistics of suburban sections of the Western and Central Railways are given in Table 1 above.

### Population Growth in Mumbai (in millions)

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>7.78</td>
</tr>
<tr>
<td>1981</td>
<td>11.08</td>
</tr>
<tr>
<td>1991</td>
<td>14.53</td>
</tr>
<tr>
<td>2001</td>
<td>19.2</td>
</tr>
<tr>
<td>2011*</td>
<td>22.45</td>
</tr>
<tr>
<td>2021*</td>
<td>27.26</td>
</tr>
</tbody>
</table>

*Estimated

### Percentage growth (From 1951-52 to 2011-12)

<table>
<thead>
<tr>
<th>Year</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-52</td>
<td>179%</td>
</tr>
<tr>
<td>1961-62</td>
<td>248%</td>
</tr>
<tr>
<td>1971-72</td>
<td>72.3%</td>
</tr>
<tr>
<td>1981-82</td>
<td>52.2%</td>
</tr>
<tr>
<td>1991-92</td>
<td>20.7%</td>
</tr>
<tr>
<td>2001-02</td>
<td>12.7%</td>
</tr>
<tr>
<td>2011-12</td>
<td>10.4%</td>
</tr>
</tbody>
</table>

### 3.0 KEY ISSUES OF MUMBAI SUBURBAN SYSTEM:

Following are the key issues with 1500 V DC EMUs running in the suburban sections of Mumbai:

#### 3.1 Poor Travel Comfort

A phenomenal increase in population (Figure 2) and growth of suburban traffic (Figure 3) leads to overcrowding in the trains. The increase in suburban trains in Mumbai did not keep pace with the passenger demand and because of overcrowding, the conditions in these trains deteriorated over a period of time. This observation is substantiated by Figure 2. Due to unprecedented growth in housing colonies, passenger loading in the already overcrowded suburban trains has exceeded the limits making the travelling conditions poor and uncomfortable. A passenger-friendly environment has been missing inside the old EMU coaches. The windows of the coaches are small. The quality of grab handles and seats is also not up to the mark. The partition panels inside the
coaches are made of sun mica sheets. In the existing coaches, an illumination level of 100 lux is provided, which is not adequate for the passengers. Thus, the overall ambience inside the coach is poor.

3.2 Obsolete Design of the existing EMUs

The design of the DC EMU is obsolete and the following problems are being faced by the commuters:

- At present 5,000 passengers (900 sitting plus more than 4,000 people in standing condition) are travelling during the peak hours in a nine car train against the original design offering a capacity of 1800 passengers (900 sitting plus 900 standing). This has resulted into Super Dense Crush Loading (SDCL) conditions in EMUs.
- Trains do not run smoothly and passengers experience jerks particularly while starting and braking.
- Inadequate illumination levels inside the coaches.
- Use of DC series motors and cumbersome design of bogies & traction equipments lead to excessive maintenance.
- Lack of ventilation is a major problem. Large numbers of standing passengers block the doors and windows of the suburban trains, thus creating difficult conditions inside the coaches. Apart from the above, in the existing trains, physical barriers in the form of semi-bulk head partitions have been provided which also obstruct free circulation of air from one end of the coach to another. Actual measurement during peak hours revealed that CO₂ level inside the coaches goes as high as 2500 ppm against the ambient level of 600 -700 ppm of CO₂ available in the open air.

3.3 High energy consumption and inability of system to cater additional traffic

Mumbai suburban railway system operates on 1500V DC traction system, which was introduced in 1925 on the lines of London Underground. With the increase in loading, each 12-car train draws 4,000 amps from the system. When two trains are leaving and two trains are approaching the terminal stations, approximately 10,000 to 15,000 amps of current is drawn from the system. Due to this large requirement of current, traction substations have been set up at a very short intervals e.g., there are 20 DC traction substations between CSTM and Kalyan for a distance of 54 kms. For increasing the suburban services and number of coaches per train, additional substations need to be set up, which is not considered to be economical. Due to large amount of current drawn by the trains, it has become impractical to increase the number of trains and add additional number of coaches in each train. Therefore, the need for adoption of 25kV traction system was felt and conversion of traction has been undertaken accordingly.

3.4 Lack of Investment

Traditionally, the suburban/metro network operation all over the world falls under the purview of the Central Government which also absorbs the operating losses. In suburban areas of Mumbai city, a large number of housing colonies has been set up and development charges collected by the State Government from the construction sector were not used for the expansion of suburban systems. As an outcome, expansion and modernisation of suburban system could not take place. Over the last fifty years (figure 3), it has been observed that even though, the number of passengers carried has grown by 893%, the number of trains has increased by 266% and average passenger loading per train per has increased by 171%.

4.0 SUBURBAN TRAFFIC GROWTH IN MUMBAI

Year wise growth in number of train services and passengers carried is shown in Figure 4 & 5 respectively.

![Figure 4](image1)

![Figure 5](image2)
5.0 ACTION PLAN TO ADDRESS THE ISSUES

Following steps have been taken to deal with the matter:

- Formation of the Mumbai Railway Vikas Corporation (MRVC) to implement the railway projects with the assistance of World Bank.
- MoU between MRVC and RDSO for technical consultancy involving preparation of specification, technical evaluation of design, approval of design, prototype test, system test, vehicle test and performance monitoring.
- Introduction of new traction technology at 25 KV AC converting from old 1500V DC system.
- Increasing the length of trains from 9 to 12 & 15 cars, thus generating 33% & 66% per cent extra carrying capacity, which will bring down the over-crowding in the trains during peak hours.
- Introduction of rakes with new technology having IGBT-based three phase propulsion system with the advantages of lower specific energy consumption due to regeneration of energy during braking, low maintenance, higher acceleration/deceleration and improved reliability.
- IR has gradually switched over from old DC traction technology to GTO and subsequently to IGBT based three phase propulsion technology along with usage of Train Control & Management System (TCMS) in view of the intrinsic advantages.

Following are the main advantages of IGBT based Converter compared to GTO based Converter Technology:

- Simplified heat sink design due to elimination of snubber circuits.
- Simplified gate drive units.
- Lower switching losses in IGBT enabling higher pulse frequencies, thus, leading to lower harmonic distortion.
- Due to higher switching frequencies of IGBT, the signaling circuits operating at frequencies 1.7 kHz - 2.6 kHz and 5.0 kHz onwards are not affected.
- Higher power efficiency.

EMU stock fitted with Alstom, BHEL and Siemens three phase electrics are running on both, Western & Central Railways. Western Railway has now completely switched over to 25kV AC traction, whereas in Central Railway, except CSTM-KYN & CSTM-Panvel all other sections have been converted to 25kV traction and therefore, EMU stocks with DC propulsion (BHEL), AC-DC BHEL and AC-DC Siemens having three phase electrics are working at present. Some of the DC EMU coaches having residual life are also being retrofitted with AC equipments by retaining the existing bogies for making them suitable to work on AC also. Seventy two new AC EMU trains fitted with IGBT based three phase propulsion equipments to be supplied by M/s Bombardier, will be inducted in Mumbai suburban in next two years. Comparative statement of major propulsion equipments is given in Table-3 below:

<table>
<thead>
<tr>
<th>Equipment/Parameter</th>
<th>Alstom</th>
<th>BHEL</th>
<th>Siemens</th>
<th>Bombardier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make &amp; Type</td>
<td>Nieke</td>
<td>BHEL</td>
<td>ABB, LOT 1250, Oil Immersed Transformer</td>
<td>ABB, LOT 1216, Oil Immersed Transformer</td>
</tr>
<tr>
<td>Traction Transformer</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Power Rating</td>
<td>1200 KVA</td>
<td>1578 KVA</td>
<td>1250 KVA</td>
<td>1216 KVA</td>
</tr>
<tr>
<td>Primary/Secondary traction winding voltage</td>
<td>22500/810 V</td>
<td>22500/2x938 V</td>
<td>22500/2x855 V</td>
<td>22500/2x833 V</td>
</tr>
<tr>
<td>Traction Converter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuous Input Power Rating of Line side converter</td>
<td>1200 kW</td>
<td>--</td>
<td>1240 kW</td>
<td>1178 kW</td>
</tr>
<tr>
<td>Nominal DC link voltage</td>
<td>1500 V</td>
<td>1800 V</td>
<td>1800 V (AC Mode) 1500V (DC Mode)</td>
<td>1650 V DC</td>
</tr>
<tr>
<td>Continuous Output Power rating of Motor side converter</td>
<td>1300 KVA</td>
<td>2x687 kVA</td>
<td>1070 KW</td>
<td>1172 kVA</td>
</tr>
<tr>
<td>Auxiliary Converter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input DC Voltage</td>
<td>1400 V</td>
<td>625 V</td>
<td>1500 V</td>
<td>1650 V</td>
</tr>
<tr>
<td>Max. output power (distributed)</td>
<td>70 kVA (distributed)</td>
<td>100 kVA (distributed)</td>
<td>115 KVA (distributed)</td>
<td>164.3 KVA (distributed)</td>
</tr>
<tr>
<td>Traction Motor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Make &amp; Type</td>
<td>GEC Alstom 4ERA1858A</td>
<td>IM 3601 AZ BHEL</td>
<td>Siemens, 1TB2022-0TA03</td>
<td>Bombardier, Mitrac TM 1800 S</td>
</tr>
<tr>
<td>Continuous Power</td>
<td>240 KW</td>
<td>285 kW</td>
<td>240 kW</td>
<td>247 kW</td>
</tr>
</tbody>
</table>

Table 3

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New EMU stock has been provided with **Train Control & Management System (TCMS)**, which has the following advantages:

- IP and MVB network for train communication
- Microprocessor based fault diagnostics and event recorder
- Control of major functions from Human Machine Interface (HMI)
- Reduction in cabling due to use of digital and analog I/O devices.
- Down loading of events and fault data at remote control centre
- Automatic train configuration
- Redundant drive & brake control unit
- Recording of energy regeneration and consumption data
- Diagnostics software tools for parametric changes & recording of environmental data for a specific event
- Emergency Brake Loop & Emergency Off Loop for safe operation of train
- Ventilation, tractive & braking effort control based on weight sensor feedback.

### 6.0 IMPROVED FEATURES OF NEW EMUs

Mumbai suburban system has received 173 nine-car rakes with passenger amenities in the past 5 years. In order to bring substantial improvements in EMU trains, the following additional features have been incorporated:

#### 6.1 Improved Ventilation

ASHRAE standard has been adopted by restricting the CO₂ levels inside the coaches to 700 ppm above the ambient levels outside the coaches. Approximately, 15,000 m³/hour of fresh air is pumped into each coach, which results in reduction of CO₂ level from 2500 PPM to 1500 PPM (Please Refer Figure 3). In addition, larger windows have also been provided to facilitate better air circulation.

![Figure 3](image-url)
6.2 Improved Illumination

The lighting inside the coaches has been improved to 300 lux from the present 100 lux.

6.3 Improved Seats

In place of wooden seats, polycarbonate seats have been provided in the general coaches and seats with PU cushion have been provided in the First Class coaches.

6.4 Passenger Information System (PIS)

GPS based passenger information system has been provided in all coaches with the following facilities:
- Automatic announcement of approaching stations and destination in three languages, i.e. English, Hindi, and Marathi
- Platform indicator
- Emergency announcement
- LED based head code
- Head Code, internal displays and speakers
- Display of safety messages and advertisements.

6.5 Pneumatic Suspension

Air springs has been provided in the secondary Suspension of bogies to improve the riding comfort.

6.6 Interiors

To give an aesthetic look and improve strength, stainless steel partitions, grab handles, and FRP interior panels have been used inside the coaches.

6.7 Improved Colour Scheme

The National Institute of Design (NID), Ahmedabad has designed the new exterior colour scheme using a combination of violet and white colour with red band. The commuters have highly appreciated this new colour scheme.
6.8 **Ergonomically designed driving cab**

The driving cab in the new AC-DC EMU rakes has been ergonomically designed having the crew friendly features including state-of-art Human Machine Interface (HMI) to provide current status of working equipments, messages and fault diagnostics etc.

![Driver’s Desk](image)

**User Friendly Human Machine Interface (HMI)**

6.9 **Noise Control**

In DC EMU, lot of noise gets generated from DC traction motor while accelerating, from bogie during braking and also from DC driven compressors. The present level of noise inside the coach is more than 85 db. With the introduction of AC motor driven compressors and IGBT based step-less control system with regenerative braking, the noise level inside the coach has been reduced to 65-70 db.

6.10 **Increase in the Number of Coaches per Trains**

When the traction system is changed from DC to AC, the operating current per train gets reduced from 4,000 ampere to approximately 200 ampere for 12 car train. With this, additional carrying capacity can be generated by increasing the number of coaches per train from nine to twelve/fifteen or eighteen. Number of traction substations in the Western and Central Railways will be reduced from the existing 66 to 22 after complete conversion.

6.11 **Energy Efficiency**

In the existing 1,500V DC traction system, the speed control of traction motors is through resistance control. During braking, the rotational energy of trains is wasted due to the friction generated between the brake blocks and wheels. Since, the suburban trains are expected to stop frequently, not only a lot of noise is produced during braking but at the same time the unwanted dust is also generated. The brake blocks and wheels also have a limited life and require high maintenance inputs. In order to cater the need of ongoing traction conversion from DC to AC in Mumbai, dual voltage EMUs have been inducted in to service which can operate on both 1500 V DC and 25KV AC. With the electronic equipments, 25kV is converted into Variable Voltage Variable Frequency AC supply, which is then fed to the 3-phase induction motors fitted in the motor coaches. During braking, traction motors work as generators and up to 35 per cent of the electric energy is fed back into the traction system due to the use of re-generative braking. With the introduction of new three phase EMUs in Mumbai area, a saving to the tune of Rs 1 billion per year due to regeneration feature has been achieved. The World Bank has already identified this project as Clean Development Mechanism (CDM) project to obtain carbon credit. To take advantage of the CDM framework, Indian Railways (IR) has processed, in association with the World Bank, a Project Design Document (PDD) for registration with UNFCCC. The project has already received Host Country Approval and is expected to result in annual reduction of approximately one million tonnes of CO₂ Emissions.

6.12 **Cost Management: Reduction in Cost**

The cost of MRVC-I rake (nine-car) is approximately Rs 200 million. The cost of a fully imported nine-car rake of similar features would be around Rs 600 million. The cost reduction has been achieved by adopting the following strategies:

- Out of the total quantity ordered, only 30 per cent of the equipments were manufactured abroad and the rest were manufactured in the facilities that were set up by the firms in India.

- Improved features of passenger amenity items were developed indigenously at the Integrated Coach Factory (ICF) with the features matching the international standards. This also led to cost reduction, by manufacturing the coach body and shell at ICF, which is a premier coach builder of IR.
Apart from the above, in order to provide a reasonable and efficient transport system in Mumbai area, MUTP Phase II project has been sanctioned in the Railway Budget: 2008-09. In this project, 72, twelve car rakes will be inducted in Mumbai suburban system by 2014-15.

7.0 OPPORTUNITIES, CHALLENGES & TECHNOLOGICAL UP GRADATION

The main challenges on suburban segment are the creation of adequate capacity, segregation of commuter lines from long-distance lines and expansion of services to ensure passengers comfort. Partnership with state authorities is necessary for development of suburban rail infrastructure.

IR has been adopting the latest international best practices in various facets of railway system construction, maintenance and operation, albeit with a time lag. Air-conditioned EMU rake fitted with 3 phase propulsion equipments has also been planned for Mumbai suburban which will provide enhanced comfort to the passengers. A conscious policy needs to be evolved to close the gap existing now, when compared to the advanced railway systems by adopting the latest technology on priority. Adaptation cycle on a continuous basis is to be developed with a view to achieve stable improvement in quality of services and cost of operations.

8.0 ADOPTION OF HIGH SPEED TRAIN TECHNOLOGY:

IR aims to raise the speed of passenger trains to 160–200 km/h on existing conventional tracks. A combination of prudent investment decisions in the areas of track, bridges, signalling and train-sets is to be made to enable train running at speed of 160 kmph and above. This would significantly reduce the travel time for passenger trains by 20-25%. Such infrastructure would also enable Railways to run train-sets on long distance trunk routes and between metros. IR’s approach to high-speed is incremental improvement on the existing conventional lines up to speed of 200 km/h, with a forward vision of speed above 200 km/h on new tracks with state-of-the-art technology. Following measures need to be considered for high speed trains:

- Separate corridors for freight trains and suburban traffic need to be built so that train-sets can run at the maximum speed limit of the rolling stock on the existing tracks.
- Upgrade the existing passenger tracks with heavier rails and build the new elevated tracks fit for 250–300 km/h.
- High-speed tracks to be maintained & inspected using automation to ensure required track geometry and safety.
- Improve coaches, which can support 160 km/h, with stainless steel bodies and crash-worthy designs, incorporating passenger and crew protection and fire-retardant materials.
- Equip coaches with electro-pneumatic brake systems to enhance safe operations at 160–200 km/h.

IR has signed MoU with IIT Kharagpur to conduct research to obtain the technological knowhow for increasing the maximum attainable speed up to 200 km/h. The project to be executed in the Railway Research Centre of IIT Kharagpur, has four main goals; improving speed, improving carrying capacity, use of advanced materials, advanced signalling and maintenance for better safety.

The IR’s Vision 2020 document submitted to Indian Parliament in December 2009, envisages the implementation of regional high-speed rail projects to provide services at 250–350 km/h and planning for corridors connecting commercial, tourist and pilgrimage hubs. Six corridors have already been identified and pre-feasibility study on setting up of high-speed rail corridors has been completed: Delhi-Chandigarh-Amritsar, Pune-Mumbai-Ahmedabad, Hyderabad-Dornakal-Vijayawada-Chennai, Howrah-Haldia, Chennai-Bangalore-Coimbatore-Trivandrum, Delhi-Agra-Lucknow-Varanasi-Patna. These high-speed rail lines will be built as elevated corridors in keeping with the pattern of habitation and the constraint of land.
IR also plans to set up National High Speed Rail Authority (NHSRA) that will exclusively deal with the proposed ambitious high speed rail corridor projects. It will handle tendering, pre-feasibility studies, awarding contracts and execution of the projects. All high-speed rail lines will be implemented through PPP mode on a Design, Build, Finance, Operate and Transfer (DBFOT) basis.

**8.1 Cost benefit analysis**

Train set costs around Rs 80 million per car. This is likely to reduce to Rs 60 million, with indigenous manufacture as almost all leading manufacturers like Alstom, Bombardier and Siemens have set up manufacturing units in India. Additional cost incurred on train sets vis-à-vis loco hauled 21 coach Rajdhani train is Rs 1 billion. Due to energy efficiency and increase in passenger carrying capacity, the additional investment gets recovered in three years as rate of return is as high as 35%. Train sets are most economical for a train-run of more than 800 kilometres. Other benefits such as increase in line capacity and reduction in track maintenance are long term and are not quantified.

**8.2 Technical requirements for high speed rail corridors:**

Following measures are required for the high speed rail corridor:

- Superior and well compacted formation including a provision of sub ballast
- Well designed ballasted track or ballast less bed
- Alignment parameters: vertical and horizontal curves
- Yards - high speed turnouts
- Strong and resilient track components
- Special design for bridges and tunnels including approaches
- Grade separation and fencing
- Environmental protection
- Dedicated coaching stock
- Appropriate signalling technology
- High speed overhead equipments (OHE)
- High power traction sub stations

**8.3 Global High Speed Scenario:**

The global high speed rail (HSR) network is rapidly expanding across continents world wide - delivering fast and efficient mobility. HSR is currently in operation in more than 20 countries including the UK, France, Germany, Belgium, Spain, Italy, Japan, China, Korea and Taiwan. HSR lines are under construction in more than 10 countries including China, Spain, Saudi Arabia, France and Italy and the process of development in another 14 countries including Turkey, Qatar, Morocco, Russia, Poland, Portugal, South Africa, India, Argentina, and Brazil. HSR has been in operation in Japan for 45 years which has carried more than 9 billion passengers safely till now.

The first high speed rail system started with the opening of Tōkaidō Shinkansen line in Japan in 1964, with operating speeds of 210 km/h. On 25 December 2012, world's longest high speed line opened in China; Beijing–Guangzhou–Shenzhen–Hong Kong High-Speed Railway for 2,298 kilometres, operating at a maximum speed of 350 kmph.

At present, maximum commercial speed is about 300 km/h for majority of the installed systems in the world. Spain has regular services running at 310 km/h, and in France, services reach 320 km/h. The only commercial high-speed maglev train, the Shanghai Maglev Train, reaches 431 km/h in regular service. High-speed trains travel at their maximum speed on specific tracks, using continuously welded rail at standard gauge, on grade separated right of way with a large curve radius.

Most of the Railways in the advance countries have switched over from the locomotive hauled intercity train services to Train Sets, progressively due to the advantages of distributed power of EMU Train Sets. Such trains are energy efficient because of regenerative braking, provides better riding comfort, noise and pollution free journeys.

**8.4 Plan for Introduction of Train-sets on IR**

IR is planning to acquire Electrical Multiple Units (EMU) train sets for intercity journeys. The EMU train sets will have operating speeds up to 160 km/hour. IR proposes to introduce modern EMU train sets for running at 20% higher average speed than the fastest train on IR without any additional expenditure on the existing track and signalling infrastructure.
EMU train sets are highly energy efficient and aerodynamically light weight. Some of the advantages of EMU train sets over conventional loco hauled trains operating at similar speeds are:

- Higher reliability on account of distributed power units
- Lower and distributed axle load, thus reducing the track/bridge maintenance and increasing the assets life.
- Higher acceleration/deceleration performance due to distributed traction/power units
- Higher floor area utilisation due to elimination of loco and power cars
- Elimination of reversal at terminal stations leading to better operational efficiency
- Noiseless and environment friendly due to absence of power generating cars
- Reduced maintenance and long life of wheels and brake equipments on account of regenerative braking in multiple units
- Reduced coupler forces

EMU Train sets have higher acceleration and deceleration due to which it takes them much lesser time in negotiating speed restrictions and achieving maximum permissible speed. Thus, it is possible to reduce the run time between Howrah and New Delhi up to 3 hours by operating train sets at an existing speed of 130 kmph without any additional expenditure on track and other infrastructure.

9.0 CONCLUSION

It may be observed that IR has already adopted 3-phase propulsion technology in EMUs, which has resulted in the reduced maintenance, higher reliability, energy saving and shorter run time.

From the Global High Speed Scenario, it may be seen that most of the Railways have progressively switched over their intercity prestigious passenger services from locomotive hauled trains to the distributed power EMU Train Sets. IR has also planned to induct modern train sets replacing the existing Rajdhani & Shatabdi trains. IR’s Vision 2020 document also envisages the adoption of high speed train sets i.e. distributed power EMU train sets.

There are global suppliers, who have established manufacturing facilities in India and can supply new generation train sets from Indian facilities at the reduced cost. Introduction of modern distributed power EMU Train sets on IR will provide faster, safer, cleaner, comfortable and reliable passenger friendly inter city services.

Attainment of the goals discussed in the paper would call for the concerted actions outlined above and exploring the feasibility for adoption of next generation technology viz. SiC semiconductor devices and permanent magnet traction motor, which will greatly help in reducing the space & weight of propulsion equipments, thus, improving the power weight ratio.

10.0 REFERENCES

- AC-DC EMU Practical Guide issued by Central Railway: Feb’2009
- Book titled ‘Practical Project Management’ by Dr. P. C. Sehgal
- Working Time Tables of Central and Western Railway.