SELECTION OF TRACTION SYSTEMS
&
ENERGY CONSERVATION
IN METRO SYSTEMS

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SELECTION OF TRACTION SYSTEMS
TRACTION SYSTEMS

AC Traction

- 25 KV 50 Hz, 15 KV 16.7 Hz, 2x25 KV 50 Hz etc.;
- Most predominant is 25 KV 50 Hz
- Invariably with overhead conductor due to very high voltage

DC Traction

- 600 V, 750 AC, 1.5 KV, 3 KV etc.;
- With overhead conductor or third and fourth rail
- Most common is 750 V with third rail
The first Traction system to be adopted world over was DC traction.

The first train to be driven using electricity was in Germany in 1879.

London underground railway started running Electric trains in 1890 with 630V DC.

This was followed by other Underground Metros which also adopted DC Traction.

*Being the first to be introduced, DC Traction was hence adopted as standard traction globally.*
The first AC traction in railway was introduced in Switzerland in 1899.

France adopted AC traction in railways after WORLD WAR II which resulted in its huge surge.

Due to variable speed requirement, all AC locos of railways used to run on DC motors till 1960s.

AC motors could provide variable speed with change in frequency.
HISTORICAL DEVELOPMENTS

- **Advent of Semiconductors & Power Electronics** —
  - DC motor’s monopoly for Traction motor ended.
  - AC motor could provide variable speed with change in frequency.
  - Need for conversion from AC to DC on locomotive/coach no more required.

- **Regenerative capabilities**
  - AC motors reduce power consumption.
  - Regenerated power can be fed back to the grid.

- **AC Traction** became a clear choice for main lines for long distance, high speed and heavy haul.

*Metros did not go in for a standard Traction adoption pattern and continue to choose both the options.*
HISTORICAL DEVELOPMENTS: SUMMARY OF PROS & CONS 25 KV AC TRACTION

PROS
- No limitation on maximum speed.
- No limitation on PHPDT.
- Indigenization level higher.
- Less transmission losses, lower specific energy consumption.
- Higher regeneration; regenerated power can be fed back to grid.

CONS
- Higher train cost/weight.
- Extra cost for Tunnels in Underground, Depot Infrastructure, Tower Wagons, additional maintenance cost thus higher life cycle cost.
- High voltage requires greater safety precautions.
- Susceptible to damage due to ‘gales & storms’.
- Frequent maintenance, hence less reliable.
- EMI/EMC effect.
- Dangerous to children flying kites.
- Aesthetically less favorable.
- Higher tunneling costs in underground.
HISTORICAL DEVELOPMENTS: SUMMARY OF PROS & CONS 750V DC TRACTION:

PROS
- Aesthetically superior for elevated sections.
- Maintenance/life cycle cost lesser.
- Lower Voltage hence safer in cities
- Not adversely affected by ‘gale & storm’
- More reliable/maintenance free.
- Less tunnel cost in UG lines

CONS
- Capacity to cater to heavy traffic limited
- Imported component higher
- Higher losses due to higher currents
- Closer substation interval
- Phenomena of Stray current
- Low levels of regeneration
Out of 184 transit systems worldwide, more than 50% have 750 V DC third rail system.

More than 12 heavy Metros have overhead 1500 V DC system.

Recently heavy Metros like Seoul, Delhi, Hyderabad and Chennai have adopted 25 KV AC system.

Regeneration of energy feasible in modern rolling stock with VVVF drive.

1500 V DC or 25 KV AC is essentially required for PHPDT above 45000.

Direct cost and energy efficiency of 25 KV AC, electrification is economical compared to 750 V DC above a PHPDT of 30,000.
First electrification in India – 1500V DC Traction in Mumbai Suburban Section of Central Railway in Mumbai-Kurla section in 1925.

Indian Railways Adopted:
- 3000 V DC in Howrah-Burdwan section in 1954.
- 25 KV AC for large scale electrification in 1957.
- Converted Howrah-Burdwan From 3000 V DC to 25 KV AC – 1968.

(Decision strongly guided by uniform Traction to avoid operational constraints of change over).
**Historical Developments – Metros in India**

**25 KV AC Traction System**
- Delhi Metro (DMRC) (Aiming to maintain interchange with IR)
- Mumbai
- Chennai
- Jaipur
- Lucknow Metro
- Hyderabad Metro

**750 V DC Traction System**
- Kolkata Metro (by Indian Railways)
- Kochi **
- Ahmedabad Metro**

**Kochi and Ahmedabad initially planned with 25 KV AC, subsequently switched over to 750 V DC third rail (to suit local conditions).**
INDIAN SCENARIO FOR SELECTION AND ADOPTION OF TRACTION SYSTEMS

**Delhi Metro**
- Adopted 25 KV AC Traction System in Shahdara line for providing connectivity at Shahdara. Continued with it in other sections for uniformity, familiarity, greater indigenous knowledge and also high PHPDT in most of its lines.

**Chennai Metro**
- Adopted 25 KV AC Traction System right from inception due to expected heavy ridership.

**Bangalore Metro**
- Being the garden city of India is very cautious of its aesthetics; adopted 750 V DC Traction System right from inception.

**Kochi Metro**
- Kochi being coastal city preferred 750 V DC Traction System due to frequent gales and storms plus lower PHPDT

**Ahmedabad Metro**
- Ahmedabad is famous for kite flying and wanted to avoid danger to kite flyers; plus lower PHPDT and hence adopted 750 V DC Traction System.
**Jaipur Metro**
- Adopted 25 KV AC Traction System due to association with DMRC.

**Lucknow Metro**
- Adopted 25 KV AC Traction System due to association with DMRC.

**Mumbai Metro**
- This Metro has been constructed on a PPP basis. Concessionaire Reliance Infra decided to adopt 25 KV AC Traction.

**Navi Mumbai Metro**
- This Metro is being constructed by CIDCO and have decided to adopt 25 KV AC Traction.

**Hyderabad Metro**
- This Metro is being constructed on a PPP basis. Concessionaire L & T has decided to adopt 25 KV AC Traction.

**Rapid Metro**
- This metro has been constructed on a private basis by DLF (now taken over by IL&FS). Given the short length and lower PHPDT of the Metro, the operator has adopted 750 V DC.

**Nagpur Metro**
- Adopted 25 KV AC Traction System on the consideration of uniformity with other Metros in the state of Maharashtra – Mumbai Metro -1, Mumbai Metro -3, Navi Mumbai Metro which have already adopted 25 KV AC Traction System.
Different countries and even different cities in the same country continue to follow different Traction systems for Metros.

In the above background, MOUD formed a committee for “Standardization and Indigenization of Metro Rail Systems” in May 2012.

The committee finalized its recommendations in March 2013 and the recommendations on Traction indicate broad guidelines & left the final decision to individual Metro Authorities.

Both systems have their pros & cons and further detailed study is required for adoption in Indian Metros. Thus the quest for standardisation in this regard is still on.
## SUMMARY OF MAIN FINDINGS OF COMMITTEE FORMED BY MOUD

<table>
<thead>
<tr>
<th>Type of MRTS</th>
<th>PHPDT</th>
<th>Traction Voltage Feasible</th>
<th>Cap Cost*</th>
<th>Energy regeneration</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRT</td>
<td>15000 to 30000</td>
<td>750 V dc third rail</td>
<td>(a) 125%</td>
<td>(a) 18-20%</td>
<td>(a) 750 V dc third rail does not have overhead conductor system. It looks good from aesthetic point of view on elevated section.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1500 V dc OCS</td>
<td>(b) 115%</td>
<td>(b) 20-22%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>25 kV ac OCS</td>
<td>(c) 100</td>
<td>(c) &gt;35%</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>30000 to 45000</td>
<td>(a) 750 V dc third rail</td>
<td>(a) 135%</td>
<td>(a) 18-20%</td>
<td>(b) &amp; (c) In U/G OCS does not affect aesthetics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) 1500 V dc OCS</td>
<td>(b) 115%</td>
<td>(b) 20-22%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(c) 25 kV ac OCS</td>
<td>(c) 100</td>
<td>(c) &gt;35%</td>
<td></td>
</tr>
<tr>
<td>Heavy MRTS</td>
<td>&gt; 45000 &lt;75000</td>
<td>(a) 1500 V dc</td>
<td>(a) 120%</td>
<td>(a) 20-22%</td>
<td>May be adopted in busy congested area of city where there are limitations of getting supply at 66kV/22kV and has lesser EMC/EMI problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(b) 25 kV ac</td>
<td>(b) 100</td>
<td>(b) &gt;35%</td>
<td></td>
</tr>
</tbody>
</table>

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*Cap Cost* includes installation costs and electricity costs.
SUMMARY OF MAIN RECOMMENDATIONS OF COMMITTEE FORMED BY MOUD

- Metros in India may consider adoption of 25 KV AC or 750 V DC keeping in view-
  - Level of Ridership – Heavy, Medium, Light
  - Route in the city - Elevated or Underground.
  - Local Conditions – Climatic, Geographic etc.
  - Aesthetics and Environmental Conditions peculiar to the area of the city.
  - Economic Viability based on Capital & Maintenance Costs
ENERGY CONSERVATION IN METRO SYSTEMS
Energy conservation can be achieved by -

- Selection of appropriate design and technology for both Traction & Auxiliary power - including stations & other buildings.
- Rolling Stock – Light weight and Energy efficient capable of regeneration of energy by converting back unutilized kinetic energy to electricity and feeding it back to the grid.
- Generation & use of renewable sources of energy - Solar Energy
STRATEGY FOR ENERGY CONSERVATION

- Metros are heavy Energy Consumers. Roof Tops can be planned and designed for PV solar installation right from the inception to avoid retro fitment costs. There exists an opportunity to install solar roof in Elevated Metros.

- Due to Solar energy costs coming down rapidly & conventional energy costs going up due to input costs, there exists a business case for solar roof tops.

- Central Government policies are incentivizing usage of renewable energy.

- For energy security for a Metro Rail the best strategy is to adopt it from inception stage for maximizing generation and minimizing cost.

  NMRCL is exactly doing the same.
STRATEGY FOR ENERGY CONSERVATION

Traction –

- Selection of most energy efficient system in keeping with other requirements.
- Use of modern Rolling Stocks:
  - Light weight coaches with VVVF drive giving low specific energy consumption
  - Regeneration of energy
- Monitoring of power supply system using SCADA
- Use of optimum combination of train capacity and frequency

NMRCL is adopting all the above strategies
STRATEGY FOR ENERGY CONSERVATION

Stations & Buildings –

- Adoption of green building norms to permit maximum natural lighting and minimize requirement of air-conditioning.
- Using green building materials for indirect saving of energy.
- Lifts and escalators with 3 phase VVVF gearless drives.
- Use of energy efficient fittings like LED lighting, energy efficient transformers, motors etc.
- Use of different circuits (33%, 66%, & 100%) and automatic sensors for switching on & switching off lights as per requirement.

NMRCL is adopting all the above strategies
INITIATIVE OF NAGPUR METRO FOR SOLAR ENERGY

• Nagpur region in Maharashtra with good solar irradiation is comparable to the other “hot spots” of India as indicated in the table below.

<table>
<thead>
<tr>
<th>Location</th>
<th>Air Temp (°C)</th>
<th>Relative Humidity (%)</th>
<th>Daily solar horizontal (kWh/m²/day)*</th>
<th>Wind speed (m/s) at 10mtr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nagpur</td>
<td>26.5</td>
<td>50.1</td>
<td>5.09</td>
<td>2.8</td>
</tr>
</tbody>
</table>

• Metro Rail Operations involve intensive energy consumption. Its estimated that NMRCL when operational will consume over 31 MU per annum (in 2021) and going up to 54.5 MU (by 2041) spread across traction load and auxiliary load.

<table>
<thead>
<tr>
<th>Year</th>
<th>Traction Energy</th>
<th>Auxiliary Load</th>
<th>Total Energy Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>10</td>
<td>5.5</td>
<td>15.5</td>
</tr>
<tr>
<td>2026</td>
<td>12.96</td>
<td>6.2</td>
<td>19.18</td>
</tr>
<tr>
<td>2031</td>
<td>14.26</td>
<td>7</td>
<td>21.26</td>
</tr>
<tr>
<td>2036</td>
<td>15.35</td>
<td>8</td>
<td>23.35</td>
</tr>
<tr>
<td>2041</td>
<td>18.32</td>
<td>9</td>
<td>27.32</td>
</tr>
</tbody>
</table>

North-South corridor

<table>
<thead>
<tr>
<th>Year</th>
<th>Traction Energy</th>
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<tbody>
<tr>
<td>2021</td>
<td>10.27</td>
<td>5</td>
<td>15.27</td>
</tr>
<tr>
<td>2026</td>
<td>13.32</td>
<td>5.8</td>
<td>19.12</td>
</tr>
<tr>
<td>2031</td>
<td>14.66</td>
<td>6.62</td>
<td>21.28</td>
</tr>
<tr>
<td>2036</td>
<td>15.83</td>
<td>7.41</td>
<td>23.24</td>
</tr>
<tr>
<td>2041</td>
<td>18.87</td>
<td>8.22</td>
<td>27.09</td>
</tr>
</tbody>
</table>

• Units in MUs
• Based on the Detailed Project Report, it’s estimated that NMRCL’s energy cost will account for ~23% of the operations cost in 2021, going up to ~30% by 2041. Such a high energy cost creates a case for NMRCL to evaluate other market options including Solar.
INITIATIVE OF NAGPUR METRO FOR SOLAR ENERGY

Solar –

- NMRCL is going to be the first Metro, which is planning introduction & use of solar power right from inception stage.
- NMRCL proposes to set up Roof top solar power project in phases, inline with the growth in annual energy demand.
- A 14 MW Solar Roof top project with an overall investment of ~ INR 100 crs is planned in phase–I for which preparation of DPR is under progress.
- NMRCL is working with consultants to examine the ideal revenue model.
- NMRCL would source 65% of it’s total energy requirement from implementation of 14 MW Solar Roof top while the balance 35% would be sourced from the grid.