HIGH SPEED OHE OF INDIAN RAILWAYS ISSUES, CHALLENGES & OPTIONS

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Introduction

Electric traction is mainstay of mass transport. Electricity offers freedom from primary source of energy and hence is in essence free from obsolescence. This feature makes electricity based railways, not just an investment in an economic mode of transport, but also makes it future proof as we move from one source of energy to another. Use of petroleum derived energy is being discouraged actively world over in favour of practical alternatives offered by electric railways. Barring railroads owned by mine owners or for legacy issues, petroleum based locomotion is clearly being looked up as interim measure.

Indian Railways came about its present shape post independence from colonial rule in 1947, when various railways were amalgamated. The electric traction was introduced in erstwhile Bombay (now Mumbai) in 1925 for suburban railway and permitted emergence of Mumbai as the financial capital of India. This 1.5 kV DC system of unregulated electrification served Mumbai well for well over 85 years before being phased out in favour of 25 kVAC, 50 Hz, running rail return system of electrification-which is currently in progress.

Erstwhile Calcutta (now Kolkata) also saw electrification, albeit at 3 kV DC, a well adopted European system with unregulated overhead conductors. However, with 25 kV AC as electrification showing promise, it was decided that Indian Railways would adopt this SNCF pioneered system. This system proposed a simple polygonal overhead electrification system with regulated conductors for all weather maintenance free consistent performance. It was a landmark decision that just electrified 3 kV system was changed over to 25 kV, 50 Hz, electrification, retaining unregulated over head conductor system. 25 kV, 50 Hz, single phase supply was obtained from the utilities which owned the traction sub-stations and the protection of feeders. However, with passage of time, traction sub-stations are being constructed by railways themselves. Where the sub-station is not with Indian Railways, the protection is provided at the feeding post as it was felt that utilities were more concerned for HV side trippings and transformer protection rather than feeder protection, which is of interest to railways.

Overhead conductor system using simple polygonal type of conductor arrangement has stood test of time and vagaries of extreme climate seen in the country. Kolkata's overhead conductor system also is being converted to regulated. Proposal to regulate Mumbai sub-urban overhead conductor system is on cards. It is seen that well thermally compensated conductor system has given maintenance free consistent performance. The predominant construction uses 1000 kgf force in each catenary and contact wire, with common tensioning device. The tensioning device used on Indian Railways is principally pulley type.

Though the contact conductor used has nominal cross-section of 107 mm2, it is proposed to upgrade it to 150 mm2 for superior current carrying characteristics whenever existing conductors get due for replacement. This work entails design of tensioning arrangement and redetermination of speeds, it is felt that such an upgrade is critically needed to support growing traction power needs. Similarly, efforts are underway to convert conventional running rail return system to 2x25 kV AT system. Challenge is to get conversion done with minimal traffic disruptions.

Further, it was explored to procure power directly from the power producers and bring to Indian Railway's own 132 kV transmission lines. The two points of tap on country's 220 kV network exist presently and the major arterial flow between Delhi-Allahabad section is supported by one such 132 kV transmission line. With another grid sub-station coming up at Allahabad, the 132 kV backbone is being extended further. With provision of open access enabled by the Electricity Act, 2003 being operationalised, Indian Railways is in process of setting up 3,020 MW of captive generation capacity which will be wheeled to various traction substations.

State of Overhead Conductor System in India

To give a cryptic overview of the state-of-the deployment on Indian Railways and the way ahead being contemplated table #1 can be referred:

Sr. No.	Features	World Technology	Where Indian Railways Stand	Steps to be taken to fill the gap
1	Type of OHE	a) Simple Polygonal for 225 KMPH speed b) Stitched for 400 kmph c) Compound for more than 400 KMPH	Simple Polygonal for 140 KMPH speed	Upgradation for higher speed potential.
2	Traction Power Control	Computer based supervisory Control and Data Acquisition System with out door type Remote Terminal Units (RTUs)	Computer based Supervisory control and Data Acquisition System with in door type (RTUs)	Development of out door type miniaturised Pole mounted RTUs is in hand
3	O.H.E Monitoring	Facility to measure % Contact loss, Contact force, Pantograph and Contact Wire displacement Stagger under dynamic condition.	Manual under Power Bloc k Conditions.	Procurement of OHE Recording Car.
4	Lighting Arrestors	Gapless type Zinc oxide with porcelain/polymer housings.	Gapless type Zinc oxide	Development of Polymer housing Lightning Aresters.
5	Current Transformers (CT) & Potential Transformers (PT)	Sealed oil filled with Nitrogen cushion at top. In some countries, Dry- Expoxy cast CTs.	Sealed oil filled with Nitrogen cushion at top.	Development of Dry Epoxy cast CTs.

6	Booster Transformer	Conventional oil filled with conservator and Silicagel breather. In some countries, Dry Epoxy cast BTs are in use.	Conventional oil filled	Dry BTs, though maintenance free, cost much more than the conventional BTs. With substantial reduction in the requirement of BTs, it is not worthwhile to develop these for IR.
7	Hard Drawn Grooved Copper (HDGC) Contact Wire	i) Continuous Cast Copper Rod. ii) HDGC rods with a) Cold pressure butt weld b) Electrical resistance butt weld.	Groove Copper Contact (GCC) Wire Rods with silver brazing and Grooved Copper Contact Wire with continuous cast process.	C.P. B. W & ERBW has since been developed. Imported continous cast copper rods are also being used for drawing contact wire.
8	Solid Core Insulators	Hybrid Insulators	Alumina based Solid Core Porcelain insulators developed in 1992, since introduced.	Hybrid Insulators are under development.
9	OHE fittings	Maintenance free lighter fittings e.g. Compression type with PG Clamps, Wedge type Connectors, Droppers Clips.	Bolted type.	7 Nos. Maintenance free fittings have been developed.
10	Dropper Clip	Single piece.	Casting of Aluminium Bronze (in two pieces)	.
11	Maintenance Practices.	Condition based preventive maintenance.	Time Based preventive maintenance.	Development of condition based maintenance.
12	Traction Supply	2 × 25 kV Single – Auto Transformer system.	25 kV Single phase Booster Transformer system.	For evaluation, 2 × 25 kV System has been set up in Bina- Katni-Anuppur – Bishrampur-Chirimiri section of West Central Railway and South Eastern Railway.
13	Traction Transformer	Scott connected Transformer for balanced loading on 3-phase supply network.	Scott connected Transformer in Feeding System.	
14	Traction Transformer Accessories	a) Elliptical Tube radiators. b) Rubber bellow/ air cell in conservator with nitrogen cushioned decrease frequency of filtration of oil. c) Inhibited transformer oil for longer service life.	Pressed Steel radiators. Conventional silica gel breathers are in use. Uninhibited Transformers are in use.	Provisions have been included in RDSO specifications. Studies are on to facilitate use of K3 Class oil.

15	Protection System	Static & Micro Processor based protection systems.	Numerical Relays	Advanced protection schemes as implemented in Mumbai sub-urban network being worked out.
16	Shunt Capacitor Bank.	Thyristor controlled Reactor type & Thyristor switched capacitor.	Fixed switched Capacitor Bank	Specification for Dynamic Reactive Compensation system available
17	Switch gear for AC Traction system	SF-6 Type Vacuum type	Minimum oil type SF-6 type, Vacuum type.	Only SF_6/Vacuum Type indigenous products are used.

Initial Developments

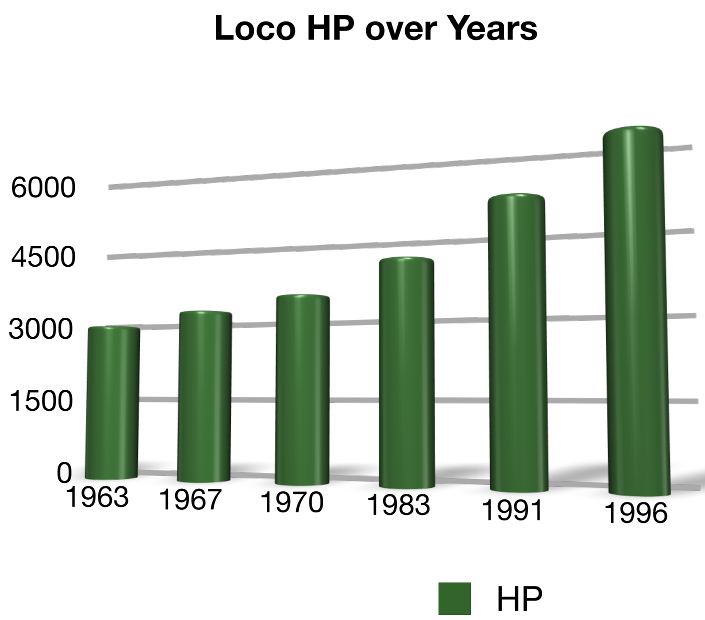
The first Section (Rajkharsan – Kendposi on South Eastern Railway) was commissioned on 25 kV AC on 15.12.1959. Since then due to continuous increase of Passenger as well as Freight traffic the Traction Power density of all the route of Golden Quadrilateral (and Diagonals) i.e. MVA/RKM has increased manifold which is evident from the following Table. It has been prepared by collecting the data of each Traction Sub-station situated over the Golden Quadrilateral (and Diagonals).

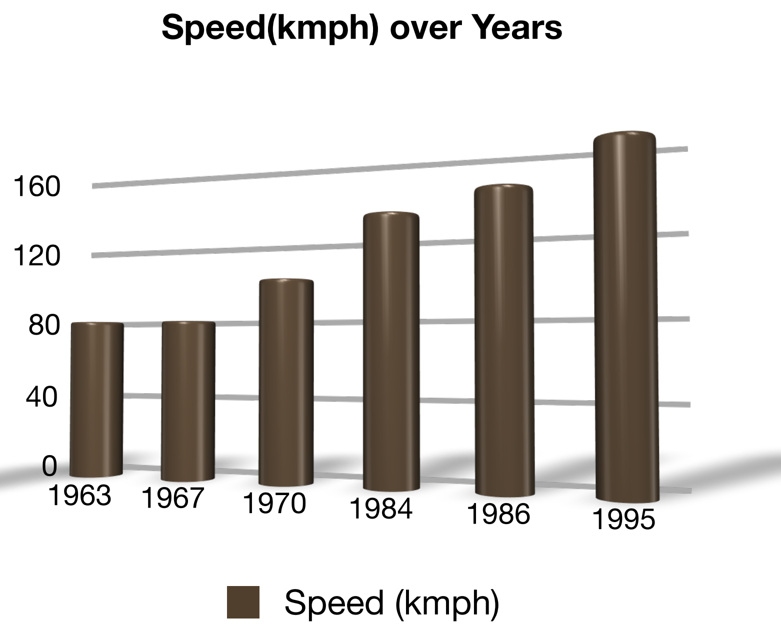
Sl. No.	Section	Power Density During initial Commissioning (MVA/RKM)	Present Power Density (MVA/RKM)
1.	Howrah-New Delhi	0.18	0.53/0.57*
2.	New Delhi- Igatpuri- Mumbai CST	0.24	0.48/0.56*
3.	New Delhi- Kota-Mumbai Central	0.19	0.47/0.49*
4.	Howrah-Vishakhapatnam-Chennai	0.32	0.46/0.63*
5.	Mumbai CST- Pune-Chennai	Section under Electrification.	
6.	Howrah-Nagpur-Mumbai CST	0.28	0.51/0.66*
7.	New Delhi-Nagpur-Chennai	0.29	0.46/0.56*

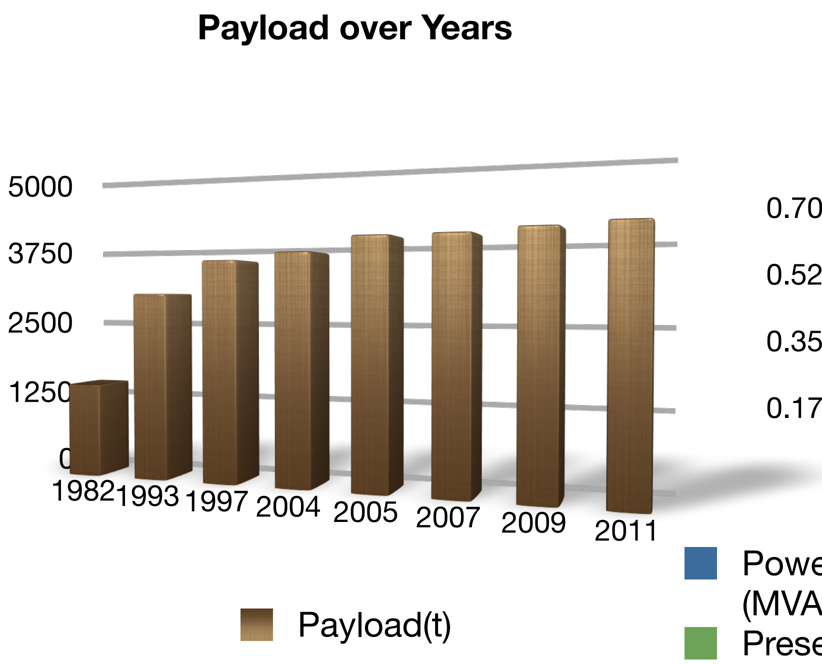
* While traction transformers are operating in ONAF mode.

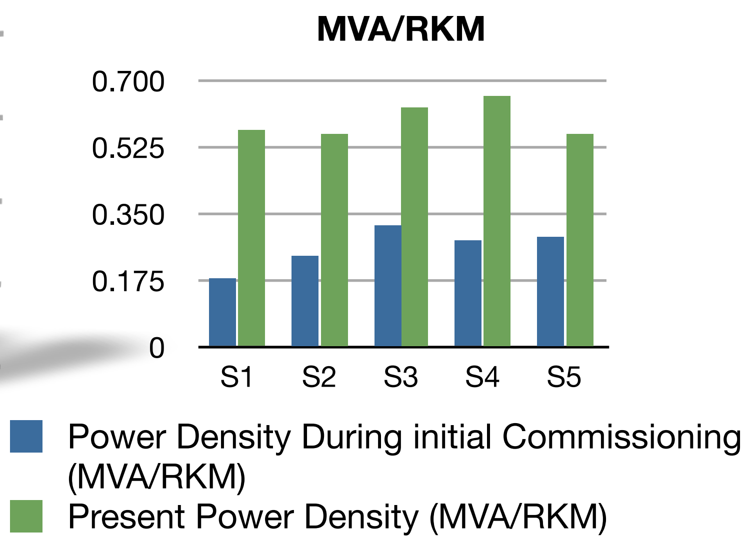
Keeping in view of the overall requirement of capacity enhancement, it is necessary to have the comprehensive review of the required input in the 25 kV AC OHE and Power Supply Installation on high density routes.

Development of Indian Railway Network









S1: Howrah-New Delhi
S2: New Delhi-Igatpuri-Mumbai CST
S3: Howrah-Vishakhapatnam-Chennai
S4: Howrah-Nagpur-Mumbai CST
S5: New Delhi-Nagpur-Chennai

Further increase in Traction Power requirement has other contributors too viz:

(i) Increased number of Mail/Express trains at higher speed are expected to draw higher Electrical energy,

(ii) Increase in number of Mail/Express trains leading to precedences,

(iii) Increase in number and length of EMU/MEMU trains and

(iv) Increased number of Freight trains to transport more goods,

(v) Line capacity Utilisation has gone up to a very high level, resulting in congestion and frequent stops & starts.

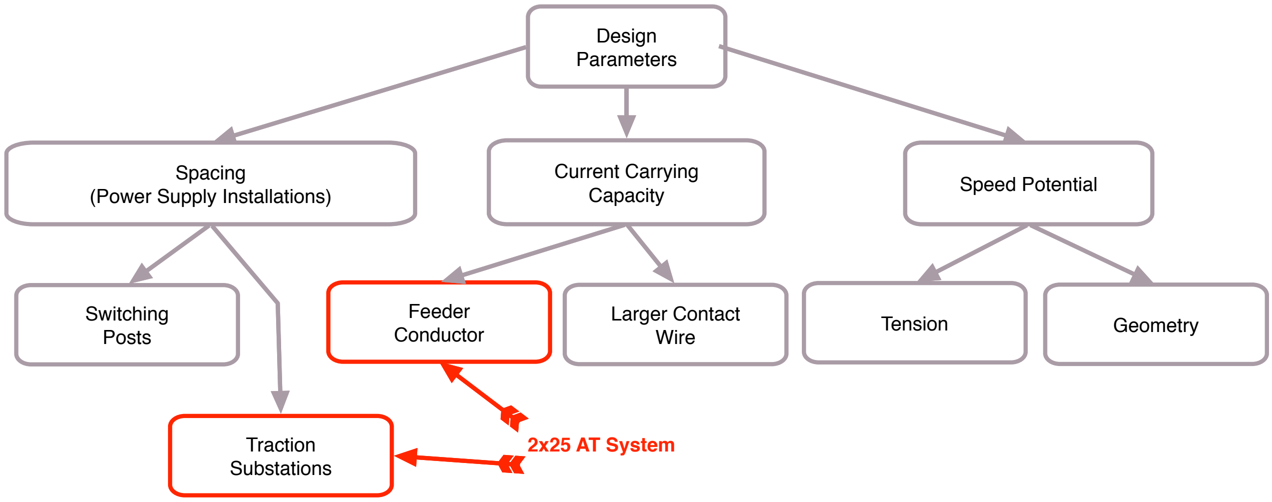
Meeting Increased Demand

The increase in power demand has been met by increasing the no. of traction sub-stations in the section. The summary of increase in Traction Sub-stations & increase in Power requirement over the period has been shown in table below:

Sl.No.	Section	Route (Km)	Traction Sub-Station (Nos.)			
			Initially Constructed	Existing Augmented	Additional Constructed	Total
1.	Howrah-New Delhi	1447	21	26	18	39
2.	New Delhi- Igatpuri-Mumbai CST	1544	27	22	9	36
3.	Churchgate - Mumbai Central-New Delhi	1393				
4.	Howrah-Vishakhapatnam-Chennai	1662	31	15	4	35
5.	Mumbai CST- Pune-Chennai	1283	Electrification of complete section is in progress			
6.	Howrah-Nagpur-Mumbai CST	1968	40	20	13	53
7.	New Delhi-Nagpur-Chennai	2184	44	32	4	48

With this it is evident that at present the average Traction Power requirement has increased to 2.94 to 3.17 times compared to early electrification days.

Depending upon the Traction Power requirement, either existing Traction Sub-Stations has been augmented (from 7.5 MVA to 21.6/30.24 MVA and further to 30/40 MVA) or additional Traction Sub-Station has been added thereby the spacing between two Traction Sub-station has been reduced from 70 Kms to 19 Kms (approx.)



Further reduction of Traction Sub-station spacing will have adverse effect on the performance of Electric locomotive and thereby on train operation. Thus, there is a need for augmentation and refurbishment in the existing infrastructure to meet the increased demand/traffic, which the high speed routes have to carry.

The upgradation of OHE and PSI Assets are essential and warranted immediately.

The following urgent inputs are identified as immediate requirements:

1. <u>Input for OHE</u>
   The inputs in the OHE may be made to ensure smooth train operation:
   1.1. Planning of higher cross section Contact Wire (150 Sq. mm) – during age cum replacement stage/OHE rehabilitation Works.
   1.2. Adopting higher tension 1200 kgf for 65 Sq. mm Catenary Wire and 1200 kgf. for 150 Sq. mm Contact Wire and increase the Balance Weight to 800 kg (from 665 kg) wherever existing 107 Sq. mm Contact Wire to be replaced by 150 Sq. mm Contact Wire.

2. <u>Input for Power Supply</u>
   2.1. Adoption of 2x 25 kV AT System with the spacing of Traction Sub-station as 55 - 65 kms.
   2.2. Conversion of existing Switching Stations to Auto Transformer Stations,
   2.3. Use of latest Traction Sub-station Automation System (IEC- 61850),
   2.4. Upgradation of SCADA system with provision of IP based SCADA & latest Remote Control Protocol (RC-103) along with linking the Traction Sub-station SCADA with the Cable HUT by OFC Cable (instead of Copper Quad Cable).
   2.5. Provision of 3 Zone Protection Scheme (in heavy loaded Section, other than high speed route).
   2.6. Use of higher conductor i.e. 'PANTHER' for 132 kV Transmission Line to transmit more Electrical Power through existing Transmission Lines.

3. <u>Improved maintenance and diagnostic Tools</u>

In order to improve the productivity and optimum utilisation of Power/Traffic Blocks, the modern Intelligent 8 Wheeler Tower Car (for on-line monitoring of OHE), Mobile Instrumentation Car (to diagnose the Power Supply Equipment), modern Diagnostic and measuring Tools/Gadgets/Instruments, including Pneumatic/Power Tools, are to be provided in the Tower Car and at OHE Maintenance Depots.

2x25 kV AT System of Electrification:

Incidentally 2 x 25 kV AT system are in use world over for high speed and/or high haul routes. A Pilot Project over Indian Railways has already been commissioned in Bina-Katni Section of West Central Railway on 16.01.1995 as well as Katni – Annupur - Bishrampur/Chirimiri Section of South East Central Railway.

In 2 x 25 kV AT system, Power is fed from the Traction Sub-station at 50 kV and utilisation is achieved at 25 kV by providing Auto Transformers of adequate capacity and by running a Feeder Wire. Centre point of Auto-Transformer is connected to the Earth/Rail. This arrangement facilitates (+) 25 kV Voltage between OHE and Rail and (-) 25 kV Voltage between Rail/Earth and the Feeder Wire. The current distribution is independent of AT spacing.

The advantages being:

(a) Less Electric Current on the Feeder Circuit resulting in lesser Voltage drop and reduced energy losses.
(b) Better Voltage regulation even at heavier load currents.
(c) Traction Sub-station spacing can be much more (almost doubled) as compared to the conventional system due to lesser system impedance.
(d) Minimised Rail Currents resulting in reduction in induced voltage on the nearby telecommunication circuits.

The technical requirement for Howrah – New Delhi and New Delhi – Mumbai Central Route has been worked and will be as under:

Description	Howrah – New Delhi Route	New Delhi – Mumbai Central Route
Power Supply System	2 x 25 kV System	2 x 25 kV System
No. of Traction Sub-stations each with 2 nos. 50 MVA SCOTT connected transformers	30 (with spacing of 50 Kms.)	24 (with spacing from 55 to 60 Kms.)
No. of Switching control posts with Auto Transformer stations	130 to 150	100 to 120

Need for conversion /up gradation to 2x25 kV AT System over Indian Railways were expressed and deliberated in 'Electrical Standards Committee' meeting held at Jaipur on 28th & 29th September, 2012. The committee has unanimous view that it is imperative to switch over to 2x25 kV AT System in high density route which can support higher traction power delivery with longer spacing of Traction Sub-Station.

OVERHEAD EQUIPMENT REQUIREMENT

The overhead contact line must be capable of reliably transmitting the electric current to the traction vehicles. The current carrying capacity depends upon the conductor cross section. The OHE of 65 sq. mm catenary wire & 150 sq.mm contact wire shall be capable for taking the speed potential of 200 kmph. The wave propagation speed should be chosen in such a way that the Doppler Factor never drops below 0.2 and the wave propagation speed should be between 1.4 to 1.5 times the planned train speed. EN 50119 limits the operational speed to 70% of the wave propagation speed. The overhead Equipment should be designed to keep the Amplification coefficient below 2.0. Reflection coefficient around 0.4 meet this requirement. The interaction of a pantograph with an overhead contact line can be assessed by observing the % of arcing and the contact wire uplift. The interaction requirement should met the interaction performance according to EN 50367.

The permissible range of contact wire uplift in a span is maximum 100 mm upto 200 km/hour speed for single pantograph and leading pantograph of a multi-pantograph train and 120 mm for trailing pantographs of dual pantograph trains. This should be verified by measurement according to EN 50317 or simulation validated according to EN 50318.

In case of several pantographs the minimum spacing between two pantographs should be 200 m. For lower spacing the running speed has to be reduced accordingly. Cantilevers should have space for maximum uplift of the steady arm equal to twice the uplift value.

In order to upgrade OHE for 200 kmph, the differential Elasticity between support and mid span should be less. To achieve this , the Elasticity at support should be increased alongwith the reduction in elasticity at mid span. Elasticity at mid span is being reduced by increasing the tension from 1000 kgf to 1200 kgf in Contact wire and Catenary wire. To reduce rigidity at support, the existing cantilever assembly shall replaced by light weight modular cantilever assembly and the existing rigid droppers shall also be replaced by stranded wire crimped dropper (similar to the droppers used in Delhi Metro Rail Corporation).

CHALLENGES

1. Replacement of 65/107 conventional OHE with 65/150 conventional OHE will have following challenges:-
   - 1.1. Replacement of existing 107 sq. mm HDGC contact wire by 150 sq. mm HDGC contact wire and
   - 1.2. Change of Dropper Schedule, with 50 mm presage in OHE.
2. Wiring train of latest type, having the simultaneous facilities for unrolling (the existing conductor) and rolling (the new conductor) as well as with simultaneous dropering & adjustment facilities (to the maximum extent) is essential for Zonal Railways.
3. Contact wire gradient (Variation in Contact Wire height).
   - 3.1. Gradient of Contact wire (absolute Gradient) and change of gradient (Relative Gradient) are function of speed.
   - 3.2. During maintenance, efforts shall be made to upgrade the contact wire absolute gradient as 2 mm/ metre and relative gradient (maximum change of gradient) as 1 mm/ metre to

achieve the sectional speed of 200 kmph at the later date following EN- 50119: 2009. For sectional speed of 160 kmph, the contact wire absolute gradient as 3 mm / metre and Relative gradient (maximum change of gradient) of 1.5 mm/ metre is sufficient. The contact wire absolute gradient & relative gradient shall be adjusted to 2mm/ metre & 1 mm/ metre respectively, while replacing the 107 sq. mm contact wire with 150 sq. mm contact wire, if not changed earlier.

4. Minimum Dropper Length

4.1. It is noted that at a maximum permissible span length, the minimum dropper length shall not be less than 300 mm for the speed less than 120 kmph. But according to Para 9.3 of ACTM (Volume-II, Part-II), IR maintains minimum distance of 150 mm between Catenary wire & Contact wire. It is recommended to adhere it for 160 kmph.

4.2. Minimum dropper length of 500 mm shall be maintained for 200 kmph.

5. Steps to be taken for introducing trains at 160 & 200 kmph.

5.1. Now Indian Railways are planning towards high speed. Facilities are being planned & developed at the Traction Installation Directorate to validate the Dynamic behavior of Overhead Equipment to co-relate with the theoretical approach. This should be verified by measurement according to EN- 50317 and simulation validated according to EN 50318.

5.2. System level reviews of interaction between pantograph & overhead equipment is essential at high speed, following EN- 50367, for optimal & efficient functioning of Electric traction.

6. Overhead Equipment Requirement for 200 kmph

6.1. The contact wire near the support, is much harder than either the German or British design.

6.2. The bracket Assembly of Indian design is heavier thus elasticity is les at support.

6.3. Modular Cantilever Assembly (i.e. lighter Assembly) has to be adopted having light weight, minimum number of components (including stainless steel steady arm) and better pushup allowance characteristic.