ELECTRICAL ENGINEERING
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CHAPTER 1

ORGANIZATION OF ELECTRICAL DEPARTMENT

**RAILWAY BOARD LEVEL**

<table>
<thead>
<tr>
<th>Chairman (CRB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member Electrical (ML)</td>
</tr>
<tr>
<td>Addl. Member Electrical (AML)</td>
</tr>
</tbody>
</table>

**Zonal Head Quarter Level**

<table>
<thead>
<tr>
<th>General Manager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chief Electrical Engineer (CEE)</td>
</tr>
<tr>
<td>CELE (Chief Electrical Loco Engineer)</td>
</tr>
<tr>
<td>CESE (Chief Electrical Service Engineer)</td>
</tr>
<tr>
<td>CEDE (Chief Electrical Distribution Engineer)</td>
</tr>
<tr>
<td>CEE(Plg.) (Chief Electrical Engineer/Planning)</td>
</tr>
<tr>
<td>CEE(RS) (Chief Electrical Engineer/Rolling Stock)</td>
</tr>
<tr>
<td>CEE(C) (Chief Electrical Engineer/Const.)</td>
</tr>
<tr>
<td>CETE (Chief Electrical Traction Engineer)</td>
</tr>
</tbody>
</table>

**DIVISIONAL LEVEL**

<table>
<thead>
<tr>
<th>DRM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADRM</td>
</tr>
</tbody>
</table>
CHAPTER 2

BASICS OF ELECTRICAL ENGINEERING

2.1 Electricity

Electricity refers to presence & flow of electric charge. Flow of electric charge per unit time is known as electric current and it is measured in 'AMPERE' (NAMED AFTER FRENCH SCIENTIST ANDRE-MARIE AMPERE[1775-1836]). Influence produced by electric charge on other charges in its vicinity is known as electric field. Capacity of electric field to do work on an electric charge is known as electric potential measured in 'volt' unit. POTENTIAL DIFFERENCE is WORK DONE TO MOVE A UNIT CHARGE FROM ONE POINT TO ANOTHER POINT. [V=W/Q, 1 VOLT= 1 JOULE/1 COLOUMB] and is measured in VOLT [NAMED AFTER A.VOLTA-ITALIAN PHYSICIST(1745-1827)]

2.2 Electric Energy

It is the rate of work done in specific time. Its unit is Kilowatt hour (KWH). While
power is the rate of doing work, energy is the capacity for doing work.

**DC (Direct Current):** Means direct current or in other terms unidirectional current which flows in an electric circuit without altering the polarity with respect to time.

**AC (Alternating current):** This current in electric circuit changes its polarity as well as magnitude with respect to time. The wave form is in sinusoidal form with respect to time from 0 to 360° and is called one cycle. The time taken to complete one cycle is denoted as 't' and is called time period, and no. of cycles completed by alternating current in one second is known as frequency i.e. 1/t. Normally frequency in India is 50 Hz.
2.3 Single Phase

Generation of alternating current or voltage by a single rotating coil in a magnetic field is known as single phase. Phase value of this quantity generated depends on no. of turns of the coil, strength of the field and the speed at which the coil or magnetic field rotates. Power generated in single phase is \( VI \cos \phi \) where \( \phi \) is the angle difference between voltage and current waveform. Normal voltage level is 230 V, 1 \( \phi \), 50 Hz.

Three Phase:

Generation of alternating current or voltage by three rotating coils in a magnetic field at 120 electrical degrees apart from each other is known as three phase. Power generated in three phase circuit is \( \sqrt{3} VI \cos \phi \). Normal voltage is 440 V, 3 \( \phi \), 50 Hz.

2.4 Power factors

Power factor is the ratio of the true power to apparent power and is denoted as \( \cos \phi \). In a DC circuit, power is the product of voltage and current (\( VI \)). But in AC circuit, this will only hold good if load is purely resistive, such as electric heater or a lighting lamp load. The above formula will not hold good if the load is inductive and/or capacitive. In such cases by multiplying \( V \) and \( I \), we get apparent power which is expressed in volt amp or KVA. To convert this into true power which is expressed in watt or kilowatt, we multiply the apparent power by power factor. \( (P = VI \cos \phi) \).

In an electrical system, a load with low factor draws more current than a load with high power factor for the same amount of power. Effect of low power factor is that the generator capacity in the power house is inefficiently utilized, voltage regulation will be poor and system losses and energy bill will be higher.

Causes of low power factor are the presence of high inductive loads e.g. large number of induction motors working lightly loaded.

\[
\text{Current} \quad \phi \quad \text{Voltage}
\]

\[
\text{Power factor} = \cos \phi
\]

Methods of improving the power factor are:

a) Using induction motors which are designed to operate at or near unity power factor.
b) Installation of synchronous condenser or synchronous induction motors especially designed to operate with over excited field.

c) Taking care while ordering for new induction motors to ensure that they will not work too lightly loaded while in service.

d) Installing a static condenser (Capacitor Bank) which is the very common method for improving the power factor.

2.5 Ohm's Law
It shows the relationship between voltage (V), current (I) and Resistance (R). It states that current (Ampere) through a conductor between two points is directly proportional to the voltage difference (Volt) across the points and inversely proportional to the resistance between them. (I= V/R). It is measured in OHM. (NAMED AFTER G.S.OHM(1787-1854)-GERMAN PHYSICIST IN 1827).
CHAPTER 3

ELECTRICAL GENERAL SERVICES

3.1 Wings of Electrical General Services

Electrical General Services department consists of three wings namely Electrical power maintenance, Train lighting and Air conditioning & refrigeration. The activities of these wings are as under:

1. Electrical Power Maintenance- It deals with:
   - Repair and maintenance to existing power installations for service buildings and staff quarters.
   - Repair and maintenance to existing water pumping installations for service buildings and staff quarters.

2. Train Lighting- It deals with the repair and maintenance to train lighting equipment and accessories

3. Air-conditioning & Refrigeration- It deals with repair and maintenance to stationary refrigeration/AC equipments and Air Conditioned coaches.

Organization: In general services department, the organization setup is as under.

\[ \text{CEE (Principal)} \]
\[ \downarrow \]
\[ \text{CESE/CEGE} \]

At HQ level
Electrical Power is availed from local electricity board at 11kv/33kv volts which is stepped down to 440 volts and 230 volts for feeding three phase and single phase supply (at Sub-stations) to various types of loads.

3.2 Illumination on Railway Stations

Category of Stations: For illumination purpose, the stations have been divided in three categories i.e. A, B & C, based on the location of the station.

A - Stations at Zonal Railway HQ and State Capital
B - Stations at Railway Divl. HQ and State Distt. HQ
C - Other small stations

Recommended Illumination Level:

The recommended illumination level for various station areas is as under:

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Area</th>
<th>Recommended Lux level for category A, B &amp; C stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Station circulating area</td>
<td>50 / 30 / 20</td>
</tr>
<tr>
<td></td>
<td>Out door car parking</td>
<td>20 / 20 / 20</td>
</tr>
<tr>
<td>2.</td>
<td>Station Concourse area</td>
<td>100 / 100 / 100</td>
</tr>
<tr>
<td>3.</td>
<td>Booking office, Reservation office and Enquiry office.</td>
<td>200 above counter and 100 in remaining area.</td>
</tr>
<tr>
<td>4.</td>
<td>Parcel and Luggage office counter</td>
<td>150 / 150 / 150</td>
</tr>
<tr>
<td>5.</td>
<td>Platforms covered open area</td>
<td>50 / 30 / 20</td>
</tr>
<tr>
<td></td>
<td>Open area</td>
<td>-</td>
</tr>
<tr>
<td>6.</td>
<td>Waiting Halls and rooms.</td>
<td>100 / 100 / 100</td>
</tr>
<tr>
<td>7.</td>
<td>Retiring room</td>
<td>100 / 100 / 100</td>
</tr>
<tr>
<td>8.</td>
<td>Restaurant and kitchens</td>
<td>-</td>
</tr>
</tbody>
</table>
Restaurant | 150 / 150 / 150
---|---
Kitchen | 100 / 100 / 100
Store | 100 / 100 / 100
9. Foot over bridge | 50 / 30 / 20
10 Other service building in side railway station area | 200 for SM office.

**Type Of Luminaries:** In general, the recommended types of luminaries are as under:

- At covered platforms under category A and B in general, 70 Watt LPSV lamps luminarie of low bay type are provided, while in case of category C station, lights fitting of 36-Watt thin fluorescent tube are provided.
- For open platforms, foot over bridge for category A and B stations, integral street light luminare with HPSV lamps are provided. For category C stations, fitting recommended is 1 X 36 Watt thin florescent tube.
- For booking, reservation enquiry, telegraph office and office of Station Master, ASM, retiring room at category A and B stations the light system should be provided commercial and decorative fluorescent luminare with a mirror optics reflector of either 2 X 36 Watt thin tube or 1 X 36 Watt. For category C stations, florescent luminare of either 1 X 36 Watt or 2 X 36 Watt thin tube should be provided.
- Lighting system in station approaches, car parks, circulating area, through passage, sectional carriage siding at category A and B stations should be provided with integral street light luminare with 70 Watt or 150 Watt HPSV lamps. For category C station this area should be provided with florescent out door street light type luminare with 1 X 36 Watt or 2 X 36 Watt thin tubes.

As per the latest recommendations, Metal halide lamps are to be used in lieu of Sodium Vapour lamps to enhance the comfort level of public. Selection of these luminaries and lamps for covered area and platforms directives are as under:

<table>
<thead>
<tr>
<th>SN</th>
<th>AREA</th>
<th>TYPE OF LUMINARIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>For indoor area upto 4 mtrs mounting height</td>
<td>Low maintenance FL tube street light and high efficiency electronic ballast</td>
</tr>
<tr>
<td>2</td>
<td>Indoor area with 4 mtrs to 5 mtrs mounting height</td>
<td>Low Bay luminare florescent lamp with ballast with the down rod suspension</td>
</tr>
<tr>
<td>3</td>
<td>For Indoor area with the mounting height 5 to 8 mtrs</td>
<td>Medium Bay luminare with 150 Watt / 250 Watt metal halide lamp</td>
</tr>
<tr>
<td>4</td>
<td>For Indoor area with 8 to 10 mtrs mounting height</td>
<td>High Bay luminare with 250 / 400 Watt metal halide lamp</td>
</tr>
</tbody>
</table>
5. For more than 10 mtrs mounting height High Bay luminare with 400 Watt metal halide lamp.

Fannage: The general guidelines for providing fans are as under-

- One fan should be provided in the centre of two supporting column.
- For platforms having width 6 to 9 mtrs, one row of fans should be provided.
- For platforms with more than 9 mtrs width fans should be provided in two rows.
- Fans should be provided away from drain pipes to avoid rain water dripping on them.
- The installations of light and fans should be so decided that stroboscopic effect is avoided.

3.3 Categories Of Stations For Provision Of Passenger Amenities

<table>
<thead>
<tr>
<th>Category</th>
<th>Criteria.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Non-suburban stations with an annual passenger earnings of more than Rs. 50 Crore</td>
</tr>
<tr>
<td>A</td>
<td>Non suburban stations with annual passenger earning of Rs.6 crores and upto Rs. 50 Crores.</td>
</tr>
</tbody>
</table>
| B        | i)Non suburban stations with annual passenger earning of Rs.3 crores to 6 crores.  
           | ii)Stations of Tourist important and important junction stations. |
| C        | All Suburban stations. |
| D        | Non-suburban stations with a passenger earnings between 1 crore to 3 crores. |
| E        | Non suburban stations with a passenger earning less than 1 crore |
| F        | Halts. |

Recommended Level Of Amenities:

The recommended levels of various passenger electrical amenities to be provided at various categories of stations are as follows:

<table>
<thead>
<tr>
<th>Amenities</th>
<th>Station Category</th>
<th>A1</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes*</td>
<td></td>
</tr>
<tr>
<td>Fans</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Water Cooler</td>
<td></td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AC VIP lounge</td>
<td></td>
<td>Yes</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

*-Where train stops in night.
CHAPTER 4

TRAIN LIGHTING

4.1 Background

Initially, the lighting in trains was done using candles, oil and later on by gas lighting. To prevent the fire accidents, electric lighting was introduced by using stationary batteries. Train Lighting by electricity on Indian Railways was introduced in 1897. 24V DC train lighting system was in practice on Indian Railways till 1998. Subsequently, 110 V DC TL system was introduced on Railways. Now as a policy, Railway have switched over to 110 V DC system from 24 V DC.

4.2 Advantage Of 110 V DC Train Lighting System Over 24 V DC:

The comparative advantages of 110 VDC TL system over earlier 24 V DC are as under:

<table>
<thead>
<tr>
<th>24 V DC System</th>
<th>110 V DC System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Higher weight per KW output</td>
<td>- Lesser weight per KW output</td>
</tr>
<tr>
<td>2. Live working is possible</td>
<td>- Not possible due to 110 V resulting in less chances of Theft</td>
</tr>
<tr>
<td>3. Not possible to cater for additional load</td>
<td>- Additional load is possible</td>
</tr>
<tr>
<td>4. Current is higher, hence cable connections etc. will be of higher size.</td>
<td>- Current will be lesser, hence cable connections will be smaller in size.</td>
</tr>
<tr>
<td>5. Illumination level is less</td>
<td>- Illumination level is better.</td>
</tr>
<tr>
<td>6. Maintenance is more</td>
<td>- Maintenance comparatively is less.</td>
</tr>
</tbody>
</table>

4.3 Types of Train Lighting Systems

The various types of train lighting system are as under-

i) Self Generating System

a) TL system with 24 V DC Dynamo – now phased out.
b) TL system with the 110 V DC brushless Alternator.

ii) Mid-On Generation System

iii) End-On Generation System

4.3.1 Self Generating System of Train Lighting: Due to failures and limitations of 24 V DC system, these days 110 V DC system with brushless alternator system is in practice. Details of this system are described as under.
Under slung alternator of 4.5 Kw, 37.5 Amp is driven by V-belts through axle and alternator pullies. Alternator generates 3 phase AC voltage of 97 V which is rectified and regulated through rectifier and regulator unit (RRU). Out put of this alternator is given to electrical load through junction box. One battery set consisting 56 cells, 120 Amp-hour capacity is in parallel with the alternator and feeds electrical loads when the alternator is not generating. For charging this battery, there is provision for battery charging terminal on the under frame of the coach. Fuses are provided for safety against excessive current for each component. At a junction box, rotary switches and MCBs are provided to switch ON and OFF power supply to light/fan and emergency feeding terminals (EFT). Emergency feeding terminals give electrical power supply to adjoining coach in emergency through temporary connections (TC). The details are shown in Figure 1.

![Self Generating Train Lighting System Diagram](image)

**Fig. 1:** Self Generating Train Lighting System

### 4.3.2 Mid-on Generation:

Self generating train lighting system adopted on Indian Railways assumes a generation to non-generation ratio of 2. This system is therefore not recommended for slow moving branch line services where generation to non-generation is generally less than 2. For such services mid-on generation system has been used.

The maximum Nos. of coaches in a rake on MOG system is limited to 6 coaches on either side of power car for limiting voltage drop in main feeder. Mid-on generation system provides a power car in the middle of the rake. The power car is equipped with Diesel Generator set generating power of 415 V three phase 50 Hz. Each power car is equipped with 2 generating sets of 30 KVA alternator, each capable of taking full load of the rake. Out of two DG sets, one will be 100% standby. A fixed ratio 415 V/110 V three phase step down transformer is provided for feeding 110V three phase power to each coach through inter vehicular coupler for lights and fans.

### 4.3.3 End-on generation:

The under-frame power generating system is not capable of meeting large electrical load of Deluxe trains such as Rajdhani
and Shatabdi Exp. It is also not possible to increase the size of generator due to safety consideration and space constraints. These troubles can be overcome by employing generator in the front and rear end of the rake in power cars. Each power car is equipped with two generating sets of 500 KVA capacity each. Out of four generators provided in two power cars only two generator sets can meet the power requirement of the entire rake. Two types of Diesel engine are being used for high capacity 750V power car, one is Kirloskar Cummins KTA – 427 BHP at 55° C and second one is INTAC 340 6B – 398 BHP at 55° C. Electrical power to the train is supplied at 750 V three phase 50 Hz, via four wire coupler system with neutral solidly earthed in the power car. The electrical load in the coaches of the rake is fed through two sets of feeders. These feeders are run all along the rake and are coupled with the help of inter vehicular electric couplers(IVC) between all adjacent coaches.

Each coach is provided with the control distribution and feeder change over arrangement on the control panel. A step down transformer of 50 KVA capacity, 750 / 415 V three phase 50 Hz is provided on coach for feeding the air conditioning, pantry and lighting load. Another transformer of 5kVA, 415 V / 190 V three phase 50 Hz is provided for lights and fans at 110 voltage single phase.

4.4 Details Of Train Lighting Equipments

The details of equipments used for train lighting systems are as under-

4.4.1 Brushless Alternator:

**Principle of Working:** It works on principle of Faraday’s law of electromagnetic induction. "Whenever the flux linked with the closed circuit is changed, an EMF is induced in that circuit". The magnitude of induced EMF depends on the rate of change of flux and flux intensity.

**Construction:** It has a laminated rotor having teeth and slot arrangement in order to provide variable air gap between stator and rotor. A stator is having two types of windings (a) Three phase AC winding distributed in various slots (b) Field winding concentrated in two coils and each coil covering half the periphery. Rotor is having no winding.

Rotor teeth and slots are not kept parallel to the axial length but given a skew to avoid magnetic locking of rotor when rotor is rotated. Air gap between stator and rotor is varied which causes variation in reluctance to the flux, which is in turn results as a change in flux, and hence due to the change of flux, EMF is induced in three-phase winding.

Alternator is suspended from bogie through suspension rod, which passes through hollow tube welded with the alternator. Safety chain is provided as an extra safety arrangement against falling of alternator in case of failure of
suspension arrangement. A tension rod assembly is provided to maintain proper belt tension.

4.4.2 Rectifier cum Regulator Unit (RRU): The basic function of Rectifier cum Regulator is –

- Converts AC to DC through full wave bridge rectifiers.
- Excites field winding of alternator through excitation transformer, magnetic amplifier (MA) and feed back winding.
- Regulates generated voltage and current through voltage detector (DT) and current detector (Shunt).

4.4.3 Battery: On normal sleeper/general class 110 V coaches, 120Ah capacity battery is provided. On AC coaches, 800/1100 Ah capacity battery is provided. In MG AC coaches, 450AH battery is provided.
CHAPTER 5

AIR-CONDITIONING

5.1 Introduction

Air-conditioning in its primitive stage was started on Railways as far back as 1900 –1920. A crude, but effective system of keeping temperature down in Railway carriages during the peak weather was to provide khas-khas mats which were kept moist by reservoirs specially provided for the purpose. The moisture enveloping the carriages preserved the temperature at a degree of coolness. On some routes, ice containers were provided and these, with fans operating in full swing in the coach, provided the designed comfort of air-conditioning.

Air-conditioning in coaches was first introduced in India in 1936. The first air-conditioned coach employing electromechanical air-conditioning system was constructed in the workshop at Matunga near Mumbai. The first AC coach was manufactured by ICF, chennai in 1965. The present AC coaches are very much modified and light weight coaches in comparison to the older models.

5.2 Types Of Air-Conditioning Coaches:

AC coaching running on Indian Railways are broadly divided into two categories-

1. Self Generating Coaches (SG): In this category power supply demand for AC equipments is met with axle driven brushless alternators which is rated for 110V DC supply. At low speed and halts, the power requirement is met from 110V lead Acid Batteries mounted on the under-frame of the coaches.

2. End-on Generation Coaches (EOG): In this category AC coaches draw power from the diesel generated sets carried in coaches put in the front and rear end of the rake functioning at 750V AC three phase 50 hz. supply. The power is distributed to ensure rake and thus to each coach through 2 sets of three phase 750V feeders. Each coach is provided with control distribution on 750V control panel and AC equipments operate at 415V three phase 50 hz. AC supply.

5.3 Air-Conditioning Comfort Factors

In air-conditioning, the following factors decide comfort or discomfort for human beings–

- Temperature
- Humidity
- Draft (velocity of air)
- Purity of air and
- Noise
**Temperature**  Body fights its comfort due to high temperature by throwing out sweat outside which evaporates the heat of evaporation supplied from the body, resulting in cooling of the body and disappearing of sweat.

**Humidity**  It is a common term in AC, which is a ratio of the moisture content in a given quantity to the quantity of moisture required to saturate that quantity. It is termed as Relative Humidity. (R.H.)

**Dry Bulb Temperature**: This is the temperature indicated by ordinary thermometer.

**Wet Bulb Temperature**: If on the mercury of thermometer a wet wick is put and thermometer is shaken in air, the temperature will show a drop proportionate to the humidity of air.

The difference between a dry & wet bulb temperature is the measurement of humidity in the air. Human comforts depends on

- Body temperature
- Room temperature
- Clothing
- Draft (velocity of air)
- Humidity

Air-conditioning deals with human comfort and refrigeration deals with preservation of perishables.

5.4 **Unit of Refrigeration**

The unit of Refrigeration is expressed in “Ton”. It refers to the latent heat required to melt a ton of ice at 32 degree F in 24 hours i.e. 1 Ton = 2000 lbs and latent heat is 144 BTU / lb.

\[
1 \text{ ton of refrigeration} = 2000 \times 144 = 288000 \text{ in 24 hours}
\]
\[
= 12000 \text{ BTU per hr.}
\]
\[
= 3000 \text{ K Cal. /hr.}
\]

5.5 **Temperature Settings In AC Coach**

<table>
<thead>
<tr>
<th>Type of Coach</th>
<th>In Summer</th>
<th>In Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>III tier / II tier</td>
<td>24°C - 75°F</td>
<td>19°C - 65°F</td>
</tr>
<tr>
<td></td>
<td>25.5°C - 78°F</td>
<td>21.5°C - 60°F</td>
</tr>
<tr>
<td>1st AC</td>
<td>22°C - 72°F</td>
<td>17°C - 62°F</td>
</tr>
<tr>
<td></td>
<td>24°C - 75°F</td>
<td>19°C - 65°F</td>
</tr>
<tr>
<td></td>
<td>25.5°C - 78°F</td>
<td>21.5°C - 68°F</td>
</tr>
</tbody>
</table>
Lately, there are instructions to switch over to single temperature settings with electronic thermostats i.e. 23 – 25°C for summer and 19 – 21°C for winter considering the comfort zone of majority of passengers. The single range of temperature setting should also be displayed in AC coaches. This has been done to keep the passengers informed about temperature setting to reduce complaints of passengers.

5.6 Air-Conditioning System

The System used is vapour compressor system using freon (R-134a – Halogen free now) as refrigerant.
Basically, the following equipments in air-conditioning systems are used:

- **Compressor** - Compresses and delivers gas into condensers at a high pressure & high temperature.
- **Condenser** - It cools the hot gas and liquidifies under pressure.
- **Expansion Valve** - It controls and regulates the rate of flow of liquid freon under high pressure.
- **Evaporator** - This constitutes the cooling unit in which liquid freon under low pressure evaporates & in-doing so takes away the latent heat thereby cooling the medium surrounding the cooling coil.

**Refrigeration Cycle:** The entire system is closed one. The closed system is charged with freon gas depending on the plant capacity. Compressor is worked with motor and increases the pressure and temperature of gas which is then made to pass through the condenser across which air is blown by separate fan and by the time the high pressure, high temperature freon reaches the end of the condenser, it is already condensed. This liquid enters the expansion valve which causes sudden loss of pressure of liquid freon. This sudden loss of pressure cause the freon to evaporate when passes through evaporator. Heat for evaporation is taken from the surrounding air of evaporated tubes and blower fan is blowing across the tube. Thus cold air is blown by blower and low pressure freon gas is again compressed by compressor and the cycle repeats. The refrigeration cycle is shown in figure 1.
Fig. 1- Refrigeration Cycle

BRUSH LESS ALTERNATOR FOR AC COACH
5.8 Roof Mounted Package Unit (RMPU)

To overcome the aforesaid drawbacks of under frame open type AC system with capacity of 5.2 TR each (total 10.4 TR), Roof Mounted Package Unit (RMPU) was introduced in 1992 on Indian Railway with 25 KW alternator for coach air-conditioning. Two high capacity-packaged air-conditioning units of minimum 7.0 TR of cooling in 45°C ambient i.e. total 14 TR plants for each coach are being used. These units are energy efficient, light weight and modular. Two package units are used in one coach for AC II tier & III tier coaches & one unit for first class AC coaches. These units are mounted above the toilets on both ends supplying conditioned air into tapered duct to serve the coach end to end. Each units are fitted with two compressors i.e. four compressors in one coach but operates under normal conditions with only three compressors and fourth one acts as standby, works only during peak days of summer. Three electrical panels are provided in a coach which are power panel for terminating 110V DC generated from under frame equipments, second panel is control panel for operating RMPU units and the third panel is inverter panel for inverting 110V DC to 415 V AC three phase for RMPU unit.
5.10 **SI Units:**  
In past, IR was using 110 volt DC operated system for AC coaches which was inefficient and giving poor battery life. 25 kVA under slung IGBT based static invertors are being used now to supply 3-phase power to motors of RMPUs. It converts 110 volt DC input power from batteries/RRU to 415 volts, 3-phase AC power to operate compressors and fan motors. Use of 3-phase motors, which are compact and maintenance free, has made RMPUs possible.

5.11 **Salient Features Of Linke Hoffman Busch (LHB) Coaches**  
- The customer profile and expectations of
traveling public on Indian Railways have been changing. The focus has shifted to meet the customers’ expectations by providing better passengers amenities &
comfort, addressing the environmental concern arising out of toilet design and providing shorter transit time. Keeping in view, the aspirations of our customers for improved quality of service comparable
to better standard available in the world, a need was felt for improvement in the existing coach design and technology. In view of the imperative need to induct state of the art technology, Indian
Railways entered into a supply-cum-transfer of technology contract with M/s Alstom – LHB of Germany in order to indigenously manufacture modern light weight & longer coaches
with a feature for improved safety, passenger comfort and higher speed potential.

LHB design AC sleeper coaches have been designed & manufactured at RCF, Kapurthala from year 2003 onwards. These coaches are being used in Rajdhani & Shatabdi trains. With improved new generation coach technology, the important benefits in various areas are:

**Greater Passenger Satisfaction:**
- Improved riding comfort
- Aesthetically superior interiors
- Comfortable seats with smooth adjustable back rest
- Noise free ride due to provision of damping arrangement and sound barriers
- Higher speed potential of 160 kmph
- Bigger size panoramic windows for better visibility

**Benefits of the system:**
- Low fare weight and higher seating capacity
- Fuel efficient
- Better maintain ability & higher availability
- Possible to run longer trains
- High speed operations
- Export potential – better export potential with the above improved features
Figure 4 – LHB Coach
CHAPTER 6

TRACTION DISTRIBUTION (TRD)

6.1 Introduction

1. In India, the first electric train was introduced on 3rd February 1925 on ex-G.I.P. Railway from Bombay V.T. to Kurla. Thus, the use of electric traction for rail transport in this country is now more than 80 years old. Prior to this, trams in Kolkata were running on electric traction.

2. There are two systems utilized for collection of current by the moving vehicles.
   i) Overhead system of collection
   ii) Third rail supported on insulators

3. The system consists of overhead conductors suspended above the rolling stock and the vehicle collects the electric power from overhead equipment by pantograph. Such a system is called ‘Overhead system of collection’. The third rail system of electrification is in vogue in Kolkata Metro in which the collection of power is done from a third rail supported on insulators. In this system one additional rail is laid on the side of the track and power is collected by the vehicle from the third rail which is supported on insulators at close intervals. Calcutta Metropolitan Rapid Transport system uses this system.

4. The electric traction either uses DC system or AC system. In the case of DC, the voltage varies from 600 V DC to 3000 V utilizing either the third rail system of current collection or overhead system. In the case of third rail system, the voltage is of the order 600 to 750 while in the case of higher voltage the current collection is through overhead conductors and the voltage may range from 1500 V to 3000 V. On Indian Railway 1500V DC and 25kV, AC systems are in use. The DC traction system is confined to Bombay area of Central Railway. This is also under conversion to 25kV AC traction. As on 31.3.12, total 22199 - route kilometers are electrified in IR.

5. In the AC system on the Indian railways the AC supply delivered to the vehicle is at 25 kV, 50 Hz which is converted to DC by rectifier equipment in rolling stock and DC series motors are employed for traction.

6. On Indian Railways 22199 RKM out of 63332 RKM have already been electrified upto 31st March 2012 which is about 35% of the IR network. Electric traction carries about 66% of freight traffic and 50% of passenger traffic.
We will confine our further discussion to AC Traction which is the standard adopted by Indian Railways. The system is called 25 KV AC single phase 50 Hz system.

6.2 Power Supply Arrangement

1. Supply Arrangement: 25 Kv AC Single phase 50 Hz electric traction system is adopted for the electrified tracks of the Indian Railways. Power is obtained from State Electricity Boards (SEBs) from their network at 220/132/110/66 kV (usually at 132kV) at Traction sub-station (TSS) and is stepped down to 25 kV. The TSSs are spaced at a distance of 60 to 80 km.

Supply to Traction substation is from a double circuit State Electricity Board transmission Line to ensure continuity and reliability of supply. The general supply diagram of a substation is shown in Figure 1.
2. Traction Substation and Feeding Post: The Traction substations receives supply from SEB and steps it down to 25 kV, single phase 50 Hz for feeding to OHE. For ensuring that OHE voltage remains around 25 KV irrespective of incoming supply voltage variation, the traction transformers are provided with OFF load tap changer (Tapping +10% to – 15 %).

The TSS has two nos of 12.5/21.6/ 30 MVA Power Transformers( which step down 132 KV supply to 25 KV) along with associated switchgears and protective relays. One out of two transformers is in service and another is 100 % standby. Lay out of a traction sub-station is shown below in figure 2,
Fig. 2 Typical Traction Power Supply Feeding Arrangement

The high voltage winding of the transformer is connected across two phases and one terminal of the secondary (i.e. 25 kV winding) is solidly connected to the buried rail and then to 25 kV traction rail opposite to traction sub station. The supply to the OHE from TSS is fed through circuit breaker of
TSS and interrupters located at Feeding Post (FP). Adjacent TSSs normally supply power to the OHE on different phases to reduce unbalance in the supply authority’s grid system.

3. **Sectioning of OHE**

   a. **Sectioning and Paralleling Post (SP):** To avoid the pantograph of locomotive or electric multiple unit from bridging the supply from different phases when it passes from one zone to another, a neutral section is provided to separate the OHEs fed from different phases. The switching station provided at neutral section is called **Sectioning and Paralleling Post (SP).**

   In multi track sections and at the SP, the OHEs are paralleled independently on either side of neutral section to reduce voltage drop. The length of standard Neutral Section is 41 meters. Now a days (PTFE type) short neutral section of dead length of 5.16 meter are being used in preference to conventional neutral section as there are no chances of train getting stuck up in neutral section.

   The Driver of the electric loco negotiates the neutral section under momentum which is technically called "**Coasting**". To avoid arcing while changing over from live OHE to neutral OHE, drivers of locomotives have instructions to switch ‘off’ power before entering the neutral section and switch it ‘on’ after negotiating the neutral section.

   To warn the driver that he is approaching a neutral section, suitable warning boards are provided on traction structure in the vicinity of the neutral section. The details of warning boards are given in Figure 3.

   **Extension of feed in emergency:** In an emergency, when a TSS is out of feed from adjacent TSSs on either side is extended up to the failed TSS by closing Bridging interrupter at SP. The pantograph of locomotive or electric multiple unit is lowered at the failed TSS to avoid short circuiting the phases at the insulated over lap.

   b. **Sub-Sectioning and Paralleling Post (SSP):** Between a TSS and adjacent neutral section, the OHE is divided in to sub-sections for isolating the faulty section for the purpose of maintenance and repairs. The switching stations provided at such points are called Sub-Sectioning and Paralleling Posts (SSP).

   i. **Sector** The distance between FP to SP is called Sector. Normally distance is 25 Km to 30 Km.
ii. **Sub Sector** The distance between FP to SSP, SSP to SSP is called sub sector. Normally distance is around 10 Km.

iii. **Elementary Section** The Sub-sections are further divided into elementary sections by use of manually operated isolators.
Warning Boards for negotiation of Neutral Section

Direction of traffic

Neutral Section

500 m
250 m
DJ OPEN
DJ closed

45 cm
75 cm
40 cm
80 cm
c. **Equipments at Power Supply Installations**: At TSS, SP and SSP equipments like power transformers, circuit breakers, interrupters, single and double pole isolators, potential and current transformers, lighting arrestors, LT supply transformers etc. are installed in a fenced enclosure which is locked up. A masonry building is provided for housing the control panels, SCADA equipment, battery and battery chargers, telephones and others.

All TSSs and switching stations are normally unattended and off-circuit tap changer of the transformer, circuit breakers, interrupters are operated by remote control from the RCC, through SCADA equipment.

The off circuit tap changer of transformer, circuit breakers, interrupters and motor operated isolators could also be operated locally at the TSS, SP and SSP as the case may be.

### 6.3 Overhead Equipment (OHE)

1. The subject of electric traction can be broadly divided into two broad areas. These can be further subdivided into smaller sections, which are separate entities by themselves and would need entirely different groups of trained staff to handle their maintenance. This is shown below in the form of a tree chart –

<table>
<thead>
<tr>
<th>Electric Traction</th>
<th>Fixed Installations</th>
<th>Rolling Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead Equipment (OHE)</td>
<td>Power Supply Installation (PSI)</td>
<td>Remote Control Equipment (RC)</td>
</tr>
</tbody>
</table>

2. Traction structures are located at uniform intervals along the track for supporting the traction conductors. The spacing between consecutive structures is called ‘span’. These are standardized the minimum being 27.00 m and maximum being 72m. The span ranges from 27.0 m to 72.0m depending upon the terrain and alignment. The maximum span adopted depends on the wind pressure prevailing in the area. RDSO has standardized three zones of wind pressure viz 75 kg/m², 112.5 kg/m² and 150 kg/m². The standard spans have interval of 4.5 m i.e. 27, 31.5, 36, 40.5, 45, 49.5, 54, 58.5, 63, 67.5 and 72m.

3. The overhead equipment consists of two conductors namely the Catenary (65 Sqmm) and the Contact wire(107 Sqmm). Catenary wire takes the shape of a parabola while the contact wire is kept at the same height.
above the rail level by supporting it from catenary at regular intervals with the help of droppers of dia 5 mm. The whole assembly is a flexible assembly.

4. The normal height of contact wire from rail level is 5.50 m in mid span and 5.60 m at support. For 72.0-meter span pre-sag of 10 cm is provided in the mid span and OHE is fit for 160 Km/h with drop bracket arrangement at cantilever supports.

5. The minimum height of the contact wire is 4.80 m above rail level at overline structures and maximum height is 5.80m at loco inspection pits. On level crossing it is obligatory to maintain the nominal height of 5.50 m so as to permit passing of Road vehicles with power "On".

6. The nominal setting distance of mast is 2.80 m (earlier 2.50 mts). The minimum distance at which the traction structures can be erected is 2.50 mts( earlier2.36m ) from the centre line of the track.

7. In the yards where lines are closely spaced (having insufficient Track Centres) and there is inadequate space to comply with the above requirements, it becomes necessary to use structure called 'Portal' for supporting OHE of various Tracks. The arrangement is shown in Figure 4.

**ARRANGEMENT OF OHE ON PORTAL AT 4 TRACK**

![Figure 4](image)

**FIGURE NO 5**
Fig. 4- Arrangement of OHE on Portal at 4 Track

8. In open route on a double line section, the structures are located opposite each other so that arrangement is independent both electrically as well as mechanically. Shutdown can be taken independently on any one line without affecting the adjacent line. In the case of any derailment only one line affected by the derailment is out of traffic while the other line is still available for service.

9. As against this, arrangement on the portal although may be electrically independent, mechanically it is not so, any damage to the structure would affect movement of the traffic on all the tracks covered by portal.

6.4 General Arrangement Of OHE

1. **Stagger** :

   The contact wire is not at the central axis of the track at the point of the support. The contact wire is displaced either towards the traction structures or away from the structure with respect to the centre line of the track. This displacement is called ‘Stagger’. By shifting contact wire from the central axis of the track it is ensured that contact wire runs in a zig-zag way. This makes the points of the contact between the contact wire and the pantograph of the vehicle to slide over the pantograph by an amount equivalent to stagger at support. This ensures uniform rubbing of the contact wire over certain zone of pantograph. This enables uniform wear of the pantograph strip. The normal value of the stagger on straight Track is $+/-200 \text{ mm.}$ and $+/-300 \text{ mm.}$ on curved track. This arrangement is shown in Figure 5.
2. Regulated and Unregulated OHE:

The traction conductors are subjected to expansion and contraction with variation in the temperature. This will change the tension in the conductors leaving possibility of loose contact / sparking at the Pantograph.

There are two alternative systems adopted for the construction of overhead equipment. In the simplest system the catenary and contact wire are left to adjust themselves for variation in their length due to change in the temperature. Such overhead equipments where traction conductors are not compensated for expansion / contraction is called Unregulated OHE. This is suitable for speeds of less than 100 Kmph.

For higher speeds, it becomes necessary to provide compensation against variation in length due to changes in the temperature. The necessity for the compensation is to keep the contact wire at the same height above the rail level under all conditions of temperature. This is achieved with the provision of Anti
creep arrangement\textsuperscript{1} at the mid Tension Length\textsuperscript{2} and an Auto Tensioning devices (ATD) provided at termination OHE length. This type of OHE is called Regulated OHE.

With the provision of ATD, constant tension of 1000 kg both in Catenary and Contact wire is maintained within the temperature range of 4 degree to 65 degree Centigrade. This arrangement is given in Figure 6.

\begin{center}
\textsuperscript{1} The anti creep arrangement is an arrangement provided for restricting the movement of OHE along the Track due to passage of Pantograph. The arrangement consists of two span catenary wire.

\textsuperscript{2} Tension Length: The length between two anchor points. This is limited to 1.5 kms.
\end{center}
Fig. 6: Termination of Regulating Equipment

TERMINATION OF REGULATING OHE (PULLEY BLOCK TYPE)

- 1250 (NORMAL) REGULATING EQUIPMENT
- MAST ANCHOR FITTING
- GUIDE ROD
- 5 TONNE ADJUSTER
- DOUBLE STRAP
- COUNTER WEIGHT
- TOP OF MUFF 200
- ARRANGEMENT WITH FABRICATED MAST DETAILS OF 'X'

TERMINATION OF REGULATING OHE (PULLEY BLOCK TYPE)

- ANCHOR DOUBLE STRAP
- 9 TONNE ADJUSTER
- COMPENSATING PLATE
- CATENARY(65)
- DISTANCE ROD
- 9-TON INSULATOR
- 5 TONNE ADJUSTER
- ENDING CLAMP
- CONTACT(107)
- MAST ANCHOR FITTING
- MAST GUY ROD FITTING
- REGULATING EQUIPMENT
- MAST ANCHOR FITTING
- GUIDE ROD
- 5 TONNE ADJUSTER
- DOUBLE STRAP
- GUY ROD
- COUNTER WEIGHT
- R.L.

ARRANGEMENT WITH FABRICATED MAST DETAILS OF 'X'
3. **Sectionalizing of OHE**:

3.1 For ease of maintenance and isolation of affected portion of OHE in case of occurrence of fault, the OHE is divided into small sections. This is achieved by providing **overlaps**. The mechanical continuity between two consecutive tension lengths of OHE is maintained by overlap arrangement.

   There are two types of overlaps:
   a. Un-insulated overlap (UIOL)
   b. Insulated overlap (IOL)

   These arrangements are shown in Figure 7.

3.2 In Un-insulated overlaps, two different OHEs are maintained 200 mm apart and are connected by a permanent electrical connection of 105-mm jumper wires.

3.3 In Insulated overlaps, two different OHEs are maintained 500 mm apart and are electrically insulated from each other. This break is bridged by appropriate switch (either an isolator or an interrupter).

3.4 **Section Insulators**:

   Section insulators are provided for electrical isolation on emergency crossovers, Turnouts and Crossover in yards, for loop lines. The section insulator provides electrical isolation with mechanical continuity so that pantograph can glide through smoothly.

3.5 **Neutral Section**: Areas of OHE fed by two adjacent substations are required to be kept electrically separate as the feeds are from different phases and connecting them will result into short circuit fault. This is achieved by provision of a **Neutral Section** approximately midway between two adjacent Substations.

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**Notes**-

3. **Overlap**: Means an arrangement of Overhead equipment over a track, where two sets of Traction conductors overlap each other for a short distance (minimum two metre) providing for smooth passage for the pantograph of Electric Rolling Stock.

4. **Tension Length**: The length between two anchor points. This is limited to 1.5 kms.

5. **Neutral section**: means a short section of insulated dead OHE, which separate areas fed by two adjacent sub stations. The Neutral Section provides electrical isolation with mechanical continuity of OHE.
3.5 **Types of Neutral Sections:** There are two types of neutral sections provided on Indian Railways.
   
   a. Overlap type having dead length of 41 mtrs
   b. PTFE Type (Short Neutral Section.) of 5.16 mtrs.
Fig. 7: Un-insulated and Insulated Overlap
The neutral section arrangement is shown in Figure 8.
6.5.1 Traction Power Controller:

The traction substations and the switching stations in 25 kV AC system is unmanned. The switchgears i.e. the circuit breakers, interrupters and tap
Transformer are controlled remotely from the Remote Control Centre manned round the clock. All switching operations on the system are thus under the control of a single person.
called Traction Power Controller (TPC) who is responsible for maintaining continuity of Power Supply on entire section of OHE. He is also responsible for maintaining close liaison with
supply authority and Section Controller in regard to train operation on electrified section.

6.5.2 Remote Control System: In old days Electro-mechanical relays were used for remote control. With advent in the field of microprocessors, the modern system of Remote Control i.e. SCADA System (Supervisory Control and Data Acquisition System) is used. This system comprises of following major sub systems.

- Remote Terminal Unit (RTU)
- Remote Control Centre (RCC)

a) **RTU** is installed at Controlled post to collect Data such as catenary voltage, Position of CB/ Interrupters, Tap position of Transformer etc and also to execute the commands at TSS, SP and SSP. The RTUs are intelligent devices capable of executing the commands given by TPC, collecting various data from the field and transmitting the same to RCC as required. Various field data such as status of circuit breakers and interrupters catenary indication etc., which are required to decide the appropriate control action by the TPC, are collected through the RTUs.

b) Data collected by RTUs is transmitted to **RCC** for monitoring the various traction parameters and exercising control when needed. RCC achieves the above objectives through the TPC and system administrator. The main equipment configuration at RCC is one Master computer with its standby, two operator work stations (OWS) and two front end computers known as communication processors. Each OWS consists of three Personal Computers (PC) with 19` video display unit. All the above equipments are interconnected through local area Network (LAN). SCADA system acquires various data from
the traction power network through RTUs. The acquired data is stored and then displayed to the TPC for effecting timely control. The system administrator, through suitable software looks after the functions connected with Main / Standby system viz. changing passwords, copying files, providing access rights to user, reloading of software etc. which are essential for management of the SCADA system. RTUs and RCC are connected in Wide area network (WAN) for transfer of data between them.

6.6 Terms commonly use in TRD

(i) **Structure Bond**: An electrical connection, between steel work of traction structures, bridge or station building, to which traction overhead equipment mast is attached.

(ii) **Rail Bond**: An electrical connection across a joint between two adjacent lengths of a rail provided to facilitate the flow of traction return current.

(iii) **Encumbrance**: It is axial distance between catenary and contact wire at support in vertical plane. It is 1.40 m normally and can be reduced to 0.40, 0.75, 0.90 meter in certain cases like Over line Structures, Overlaps to get adequate electrical clearances.

(iv) **Cantilever Assembly**: It is an insulated swiveling type structural member, comprising of different sizes of steel tubes to support & to keep the overhead catenary system in position so as to facilitate current collection by the pantograph at all speed without infringing the structural member. This is shown in **Figure-10**.
Fig. 10 Cantilever Arrangement

(v) **Setting Distance (Implantation)**: It is the distance from the center of the Track to the nearest face of mast measured horizontally. For Tangent Track it is kept as 2.80 mtr. It can be reduced to 2.36 m with specific approval of CEE on difficult locations. On platforms the minimum implantation is kept as 4.75 mtr. Now the minimum implantation has been revised from 2.36 mtr. to 2.5 mtr. for the new track being laid on Indian Railways.

(vi) **The arrangements generally used for supporting OHE are**-
- Independent Structures.
- Portal Structures.
- Two / Three Track Cantilever Structures.

(vii) **Independent structures**: When a structure is used for holding only one OHE on either side or 2/3 OHE of same elementary section on one side by means of Simple Cantilever assembly, it is known as independent structure. This arrangement provides Electrical and mechanical independence. These structures are either Rolled Steel Type (BFB/RSJ) or fabricated. The length of this structure is generally 9.3 m / 9.5 m.

(viii) **Portal Structures**: In Big station yards it is not possible to locate OHE structures in between two tracks due to limited track centers and slewing of Tracks is not possible. In such cases portal structures covering 2 to 8 tracks are
used. Mechanical independence of each track of OHE is not achieved in this type of arrangement. Portal assembly comprises of two up rights, one boom consisting of 2nos end pieces and one centre piece.

(ix) **Two/ Three Track Cantilever Structures**: This is a special type of structure used to wire 2/3 track where use of portal is either not possible due to limited track centre or is uneconomical. The arrangement is generally used for supporting the OHE near turnouts and crossovers. With this arrangement the OHE can be supported up to a distance of 10.50 meters from upright. This arrangement however cannot be used for supporting OHE of two main lines.

(x) **Spans**: This is the distance between two consecutive supports. The max. Span is 72 mtrs & min. 27 mtrs. Difference between two consecutive span shall not exceed 18 mtrs. The max span in unregulated OHE is kept as 67.50 mtrs. The maximum permissible span for heavy, Medium, Light wind pressure zone are 63m, 67.5m and 72m respectively on tangent tracks. The span has to be reduced on the curve track. The standard spans are in multiples of 4.5 mtrs i.e. 27 m, 31.5 m, 36m etc. This arrangement facilitates standardizing the dropper lengths.

(xi) **Stagger**: Stagger of contact wire is the horizontal distance of contact wire from vertical plane passing through the centre of pantograph pan.

(xii) **Section Insulators**: It is a device installed in the contact wire for insulating two elementary electrical sections from each other while providing a continuous path for pantograph without break of current.

(xiii) **Supply control post**: It is a term used to refer an out door assembly of equipments like Interrupters, Isolators, potential transformers, Auxiliary transformers including remote control equipment etc installed in cubicle.

(a) **Feeding post (FP)**: It is a supply post where the incoming 25 kV feeder lines from sub stations are terminated and connected to the OHE through Interrupters.

(b) **Sectioning and paralleling post (SP)**: It is a supply-controlled post situated mid way between two feeding posts at the neutral section and is provided with bridging & paralleling Interrupters.

(c) **Sub-sectioning and Paralleling post (SSP)**: It is a switching station where sectioning and paralleling interrupters are provided.

(xiv) **Switch Gear**: Means isolator switch, circuit breaker, interrupter etc used for operation and control of high voltage electrical circuit at 132/25kV.
(xv) **Circuit Breakers** : Means a device for closing and opening an electrical circuit under all conditions unless otherwise specified, and so designed as to open the circuit automatically under abnormal conditions.

(xvi) **Interrupter** : A switch in all respect similar to circuit breaker but without an automatic tripping device. It is further classified into following depending upon applications.

(i) Bridging . (ii) Sectioning, (iii) Paralleling.

(xvii) **Isolator** : Manually operated 'Off Load' switch i. e. before operating, it is to be ensured that there is no current flowing through it.

(xviii) **Pantograph** : Means a collapsible device mounted & insulated from roof of an electric Engine or motor coach and provided with a means for collecting current from OHE.

(xix) **Dropper** : Means a fitting used in OHE for supporting contact wire from catenary.

The details of Mast and Portal are given in Figure 11.

**Figure 12** shows arrangement of Section Insulator and OHE Terminating arrangement.

**Figure 13** shows Catenary Dropper arrangement
**Fig. 11- Traction Mast and Portals**

- **TRACTION MAST & PORTAL (SECTION)**
  - 1. BFB 6"x6" (25 lbs) (152x152)
  - 2. RSJ 8"x6" (25 lbs) (152x203)
  - 3. CHANNEL VARIABLE SIZE
  - 4. FABRICATED MAST K-100, K-125, K-150, K-250
  - 5. 'G' TYPE PORTAL
  - 6. SPECIAL BFB PORTAL
  - 7. 'P' TYPE PORTAL
  - 8. 'N' TYPE PORTAL
  - 9. 'O' TYPE PORTAL
  - 10. 'R' TYPE PORTAL

- **TYPICAL FOUNDATION FOR ONE MAST & PORTAL**
  - SIDE GRAVITY FOUNDATION
  - ACROSS TRACK PURE GRAVITY FOUNDATION (FOR PORTAL)
  - DWARF MAST
  - ALONG TRACK P.L. ANCHOR FIN.
Fig. 12- Section Insulator and OHE Terminating arrangement
Fig. 13- Catenary Dropper arrangement
6.7 Power Block & Permit To Work

There are generally two types of block required for maintenance of OHE.

(a) **Traffic Block**: Where line is blocked against movement of vehicles, whether steam, diesel or electrical locomotive hauled. This will be required, whenever heavy repairs have to be carried out. A traffic block will be granted by, the section controller in consultation with TPC.

(b) **Power Block**: Where a section of line is blocked against movement of electric locomotive hauled vehicles or Memu only i.e. A section where electric supply 25kv ac to the OHE is switched off and the section made dead. Power block will be required, whenever light repairs to or maintenance of the OHE has to be carried out and the nature of work is such that, traffic block is not necessary. Power block are granted by TPC in consultation with the section controller. In power block movement of vehicles hauled by other than electric power i.e. Steam or diesel may be permitted, provided a caution order is issued as per G & SR drawing the attention of the driver to the fact that the OHE staff are working at the specified kilometer and he should exercise caution when passing over the section and obey signal displayed at the place of work.

**Power blocks are of three different types:**

(i) **Emergency Power Block**: An emergency power block shall be arranged by the TPC and supply to the OHE affected shall be switched off by him immediately on receipt of an advice of any breakdown of the OHE or injury to persons or damage to property particularly in the following case;

(a) The whole or part of the OHE or feeder/cable falling down and or persons/animals or falling trees or vehicles coming in contact with or likely to come in contact with live equipment.
(b) A damaged catenary or contact wire fouling vehicle gauge.
(c) Derailment or any other traffic accident on the electrified lines where cutting off of power supply is considered necessary in the interest of safety.
(d) Electric locomotive getting failed and to rectify, driver requires permit to work.

**Request For Emergency Power Block:**

(a) The persons who gives the first information of breakdown on the OHE shall give all essential information such as his name, designation and kilometer, where the abnormality has been noticed, its nature and place from where he is reporting. He should leave the place only with the permission of TPC.

(b) The reason for asking for an emergency power block should be brief and to the point but explicit and should be clear.
**Action to be taken by TPC:** On receiving the information the TPC shall immediately arrange to switch off power supply to the section affected. He shall at the same time advise the section controller on duty about the section made dead by him. The section controller should arrange with the station master concerned to take protective measures in accordance with “station working rules”

(i) **Pre-arranged power block:** Pre-arranged power block has been agreed to be granted by TPC for daily maintenance of OHE. Section in-charge (JE/SE/SSE) who requires pre-arranged power block should submit ‘requisition of power block’ or Performa containing section, line, date, time, power block duration, type of work and location of work to the TPC one day in advance. TPC in consultation with section controller arranges block and issues ‘safe certificate’ or ‘permit to work (PTW)’, i.e. Performa to the section charge-men containing details of line, section, power block duration. The section controller on receipt of assurance from concerned station master, will advice TPC that the power block may be given. If power block is given over telephone, the section controller or TPC will grant the power block through a message with exchange of private numbers.

After obtaining ptw the authorized person may use a flag signal (yellow flag) to direct the nominated staff to discharge and earth the OHE at two or more points.

The maintenance gang will start the work after taking necessary safety precautions to protect themselves viz. By earthing, display of flags, banner etc., as detailed in GR & SR. On completion of the work, the person who received the PTW shall insure that, all men and materials have been withdrawn from the electrical equipment and its vicinity. All earths provided for the protection of the work have been removed and All staff who, have been deputed to work are warned that the power supply is to be restored. Section in-charge then informs TPC by a message as per Performa i.e. ‘Power block return message’ supported by private number that the work for which PTW was issued has been complete, the men and the materials have been withdrawn from the specified section, the earthings have been removed and power supply may be restored to the section. This shall constitute cancellation of the PTW previously obtained.

(ii) **Local power block:** Power supply for sidings, which do not affect movement of trains on main lines, for loop lines and reception & dispatch yards, is controlled by manually operated isolators. Keys for those isolators are usually in the custody of the Station Master. Concerned power blocks on such sidings can be arranged when required by an authorized official subject to the following, The Station Master, Cabin Assistant Station Master and others responsible for the movement of traffic should take measures to stop electrical loco from entering into power blocked section. TPC shall be informed before and after the shutdown is affected. Isolators may only be opened after the precautions.
Earthing of equipment and issued of ‘Permit to work’ is done as per prescribed rules.

**Procedure for obtaining traffic or power blocks and permit to work:**

Officials in the electrified area who require pre-arrange traffic blocks, power blocks or permit to work for maintenance work shall deliver at the office of Sr.DEE (TRD) not later than 10.00hrs on the first working day of the week statements in the prescribed form, The nature of work and the date on which it is to be performed, By whom the work is to be carried out, Location of the work and the section of the lines to be blocked. The trains between which the block is required and Whether the track will be available for steam or diesel traffic. Works of an urgent nature shall be attended to by obtaining emergency blocks and Permit to work from TPC. The requirements of all departments will be co-coordinated in the office of SrDEE(TRD) and a consolidated statement forwarded to the Senior Divisional Operating Manager concerned by 12 hours on every Wednesday, for inclusion in the weekly programme of traffic and power blocks.

**Telephonic messages :**

(I) Every official who has to exchange such messages shall maintain a private number book. As each message is sent, the private number used should be recorded out in the private number sheet initialed and dated. The message number should also be recorded.

(II) Every message shall start with the private number of the sender and end with the (TPC shall be informed before and after the shutdown is affected) private number of the person who has received it.

(III) Message should be brief and to the point. They shall be written out in full before they are sent. All messages regarding permit to work shall be in standard form.

(IV) The same person who obtains a power block should also cancel it before power supply is restored. The persons exchanging the private number should identify themselves by name over the telephone.

(V) Every private number book and PTW form is an important document and should be carefully preserved for a period of one year unless required for a longer period in connection with any inquiry or investigation.

**6.11 Developments**

**6.11.1 2x25 KV OHE:** OHE system is similar to that for 25 KV OHE system except that an additional conductor called feeder wire is also run parallel to OHE all along the track on super masts. Incoming power supply scheme is similar to conventional 25 KV OHE system.
Scott connected transformers are provided at TSS to keep unbalance on grid within limits. Incoming 220/132/110 KV powers is stepped down to 50 KV (2x25 KV) by main traction transformers. 2x25 KV supply is then fed to an Auto transformer. One terminal of AT is connected to OHE wire and other to a feeder wire. Mid point of AT is connected to rail, thus providing 25 KV supply for traction w.r.t. rail potential.

The spacing of TSS is 100 kms. Heavier Goods Train can be run at full speed on a double line section to full section capacity without low voltage problem. ATs are provided at all SSP/SPs.

6.11.2 ‘Netra Car’- To mechanically monitor various OHE parameters like height, stagger, wear of contact wire, Pantograph force and quality of current without power block and traffic block an OHE recording cum test Car has been developed called "Netra" ([Network of Electrification Testing & Recording Apparatus]). It is suitable for 160 Km/h speed and is provided with on board computer based data acquisition cum processing system. Facility for video recording of sparks/arcs generated due to loss of Pantograph-OHE contact is also available.
CHAPTER 7
ELECTRIC LOCOMOTIVE

7.1 Nomenclature
Electric locomotives are classified by three-letter code followed by version number in numeric.

First letter indicates Gauge of locomotive

<table>
<thead>
<tr>
<th>Letter</th>
<th>Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>Board Gauge</td>
</tr>
<tr>
<td>Y</td>
<td>Meter Gauge</td>
</tr>
<tr>
<td>Z</td>
<td>Narrow Gauge</td>
</tr>
</tbody>
</table>

Second letter indicates type of Traction

<table>
<thead>
<tr>
<th>Letter</th>
<th>Traction</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Continuous Current (DC)</td>
</tr>
<tr>
<td>A</td>
<td>Alternating Current (AC)</td>
</tr>
<tr>
<td>C A</td>
<td>Dual Current (DC/AC)</td>
</tr>
<tr>
<td>D</td>
<td>Diesel</td>
</tr>
</tbody>
</table>

Third letter indicate type of service

<table>
<thead>
<tr>
<th>Letter</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>Mixed Service</td>
</tr>
<tr>
<td>G</td>
<td>Goods Service</td>
</tr>
<tr>
<td>P</td>
<td>Passenger Service</td>
</tr>
<tr>
<td>U</td>
<td>Electrical Multiple Unit</td>
</tr>
<tr>
<td>S</td>
<td>Shunting Service</td>
</tr>
</tbody>
</table>

Version numeric indicates Design / Model e.g.
- WAG.9-Broad gauge, AC electric locomotive suitable for Goods Services version 9
- WCAM.1- BG, Dual current, mixed service, version 1 loco.

7.2 Types of Wheel Arrangement
Further, Electric locos are classified based on wheel arrangement in under frame:

<table>
<thead>
<tr>
<th>Letter</th>
<th>Wheel Arrangement</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Two axle bogie with one traction motor for both the axles</td>
</tr>
<tr>
<td>Bo</td>
<td>Two axle bogie with one Traction motor for each axle</td>
</tr>
</tbody>
</table>
7.2.1 Types of Electric Locos

**AC Locos:**

<table>
<thead>
<tr>
<th>Co-Co</th>
<th>Loco with two <code>Co</code> bogies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bo-Bo</td>
<td>Loco with two <code>Bo</code> bogies.</td>
</tr>
<tr>
<td>Bo-Bo-Bo</td>
<td>Loco with three <code>Bo</code> bogies</td>
</tr>
</tbody>
</table>

**DC Locos:**

| Co-Co | WCM.1, WCM.2, WCM.3, WCM.4, WCM.5 WCG.2 |

Presently Electric Locomotives are manufactured at Chittaranjan Locomotive Works (CLW), Chittaranjan.

7.3 General Description Of Power And Auxiliary Circuit Of A.C. Electric Locomotive

The electric locomotive draws power from the over head equipment (OHE) with the help of Pantograph and converts this electrical energy to mechanical energy, in controlled manner, through Traction Motors which drive the axles. To enable the locomotive to perform this task, it is equipped with suitable equipments, which enable loco pilot to control the speed of the train as per requirement by controlling the applied voltage to traction motors.

In conventional locomotives, 25KV, Single phase, AC supply is collected by a roof-mounted pantograph from the OHE and is stepped down by a transformer inside the locomotive. This supply is then converted to DC supply by a full wave silicon rectifier and associated smoothing filter before being fed to the traction motors. Torque / speed control is achieved by variation of the AC input voltage to the rectifier through an on-load tap changing arrangement on the primary winding of the loco transformer.

The equipments on electric locomotive, depending up on where it is located, can be classified in three different categories viz. **Roof equipments, Inside equipments** and **Under Frame equipments.** Both the roof and the under frame equipments are subjected to lot of dust and atmospheric pollution and are therefore designed to withstand these severe working conditions.
The block diagram of Electric Locomotive is given as above:

### 7.3.1 Roof Equipments:

#### (i) Pantograph:

The High Tension current (25 kV) for feeding locomotive is taken from contact wire by means of current collecting device called pantograph. Each loco is provided with two similar pantographs on the roof. As a practice, the rear pantograph is generally used. In case rear pantograph is damaged, then front pantograph can be used without any restriction.

However in dual voltage locomotives, there are two separate pantographs suitable for AC & DC sections individually.

#### (ii) Circuit breaker:

(a) **Air blast circuit breaker**: 
One compressed air operated high voltage air blast circuit breaker (DJ) is provided on loco roof. When closed manually through remote control, OHE supply collected by pantograph is made available to the main transformer inside the locomotive. DJ can be remote controlled from driving cab to disconnect OHE supply. It opens automatically in case of over current or earth fault in the loco under the action of protective devices.

(b) **Vacuum circuit breaker**

Now, air blast circuit breakers are being replaced by vacuum circuit breaker (VCB) due to its superior qualities and less maintenance.
7.3.2 **Inside Equipments**

(i) **Voltage regulating equipment**

The high OHE voltage is stepped down to low voltage by the main transformer comprising of an Auto transformer with 32 taps and a stepped down transformer with two separate secondary windings. The low voltage can be controlled from Zero to Maximum through on load tap changer which can be compared with a fan regulator used to control the fan speed.

(ii) **Silicon Rectifiers**

Since the traction motors are DC motors, alternating current supplied by secondary windings of main transformer is converted into direct current by means of two silicon rectifiers (RSI), one each feeding to set of three traction motors.

(iii) **ARNO converter**:

ARNO converter converts the single-phase 380 Volt input from transformer auxiliary winding to 3 phase 380 Volt output. The three phase output of ARNO converter is supplied to various auxiliary motors provided for supplying compressed air, creating vacuum in train and cooling of electrical equipments such as Traction motors, smoothing reactor, rectifier block, main transformer etc.

(iv) **Static converter**:

ARNO converter, being a rotating machine, is maintenance intensive equipment. There are large numbers of auxiliary machine failures due to large voltage variations of the order of ± 22.5%. To overcome this, solid state static converter using semi conducting Insulated Gate Bi polar Transistors (IGBTs) are being provided in locomotives for conversion of single phase supply to three phase replacing the ARNO converters. The three phase output of static converters is balanced, which results in improved reliability of auxiliary machines.

7.3.3 **Under frame equipments**:

i) **Traction Motors**: In general, locomotive is provided with six DC series type traction motors(TM). These TMs are mounted in two under frame bogies coupled with wheels through pinion-gear arrangement. 3 Nos. of axles in each bogie are provided as in case of WAG5, WAM4, WAG7 locos which have Co-CO bogie arrangement. In Traction mode, all the six traction motors are fed controlled DC supply by two silicon rectifiers in two groups of three motors each connected in parallel to haul the locomotive.
ii) **Smoothing reactor**: As output of rectifier is of undulating (Pulsating) nature, it is passed through an inductive choke called smoothing reactor (SL) to reduce the undulation of the current and to make current smoother.

### 7.3.4 Protections

Protection for the following abnormalities is provided in the locomotive:

- High current in main transformer winding
- Over current in silicon rectifiers
- Traction power circuit earth fault.
- Over voltage to traction motors.
- No voltage / low voltage protection.
- Auxiliary power circuit earth fault.
- Lighting Arresters for external lightning/line surges

### 7.3.5 Brakes

Loco is provided with following brakes:

(i) **Air brake system**:

In this system, brake shoe pressure on wheels is produced by admitting air under pressure behind brake cylinder piston which moves piston rod against spring force in a direction in which brakes are applied. Releasing of pressure behind the piston enables spring to move the piston rod so as to release the brakes.

(ii) **Independent brake**:

These compressed air brakes are applied or released through independent brake handle SA9 when loco alone is working (Light engine work).

(iii) **Proportionate brake**:

When a train is hauled by loco, compressed air brakes in loco are applied proportionate to the brakes applied in the train with the help of A9, Driver's brake valve. The brakes are applied in proportion to the reduction in brake pipe pressure.

(iv) **Dynamic (Rheostatic) brake**:

To apply these brakes, traction motors are forced to work as generators and the **Kinetic energy (mechanical energy)** of moving train is converted to **electrical energy** which creates braking effect on locomotive. Electrical energy, thus produced, is fed to resistances connected across rotating armatures where electrical energy is converted to heat energy. This is very efficient braking system as it leads to increase in wheel life and reduction in wear of brake blocks, but it is
effective only at speed above 25 Kmph. These brakes are particularly useful for controlling the train going down gradient.

(v) **Regenerating brake:**

If electrical energy, so produced during braking, is fed back to OHE for use by other locomotives in the section instead of dissipating it across the resistance bank, then this type of braking is called **regenerative braking.**
7.3.6 **Control circuit**: Before pantograph is raised and circuit for auxiliary is energized, a battery set acts as source of 110 Volt, DC energy to –
- raise pantograph
- close air blast circuit breaker
- lighting the driver cabin.

When loco is dead, a baby compressor can be worked from battery to build up Pressure of 8 Kg/cm² which facilitates raising of pantograph and closing of circuit Breaker. A battery charger is provided to charge the batteries when locomotive is energized. All the control devices in locomotive are fed 110V DC from Battery set.

7.4 **DC Locomotive**

In DC locomotives, the speed of DC traction motors is controlled by connecting all the traction motors in series during starting period and introducing starting resistances. These starting resistances are gradually cut out from the circuit and the voltage across the traction motors gradually increased. This is further followed by changing motor combinations from series to series parallel and finally all the motors are connected in parallel so that loco can haul the train at its maximum permissible speed.

7.5 **Three phase A.C. Locomotive**

Traditionally, DC series motor has been preferred over any other types of electric motor for traction application due to its inherent high torque at low speed and low torque at high speed characteristics, which makes it most suitable for loco propulsion. The D.C. motor was the mainstay of electric loco drives for many years.

7.5.1 **Shortcomings of D.C. traction motors**:
- Unavoidable stepped jumps in the tractive effort due to notch control impose a limit on the level of adhesion.
- Thyristorised D.C. traction motor drive, though made the DC motor drive more efficient, but suffered because of high harmonic injection in to the power supply.
- DC motor has inherent problem of brush gear & commutators and is maintenance intensive.
- There is voltage limit due to bar to bar voltage and speed restriction due to peripheral speed constraints of commutators.
- It is essentially high current, low voltage machine which requires large diameter cables & heavy associated switch gears which are expensive.
- Reversal of direction and rheostatic braking on DC motor locomotives require other maintenance intensive switchgear.
• DC current at the output of the rectifier / converter causes the input current from the OHE to be more rectangular than sinusoidal which in turn results in introduction of harmonics in the power system in addition to poor power factor.
• Low power to weight ratio-about 800 kW/axle

7.5.2 Advantages of Three phase traction motors over D.C. traction motors:
• These are robust & require little maintenance.
• Due to absence of commutator, its peripheral speed puts no limit on speed of motor. AC traction motors can easily operate at 4000 RPM in contrast to DC motors which normally operate at speeds of 2400 RPM.
• The limit imposed due to bar to bar voltage for DC commutator is eliminated in induction motors. This means that the whole power flow from Transformer to the motor is chosen at higher operating voltages. Against nominal system of 750 volts, 1000 ampere with DC motor, the three phase motor works at around 2800 volts, 300 ampere. With heavy reduction in operating current, power cables & switch gears are much lighter there by losses are reduced.
• Power to weight ratio of three phase traction motor is much higher than the DC motor -1500 kW per axle can be packed with these motors.
• Due to steeper torque-speed characteristic of three phase motor, three phase locos have higher mean adhesion coefficient.
• Three phase motor drives are 20 % more energy efficient compared to DC drives.

7.5.3 Other Advantages of 3-Phase Drive :
• Microprocessor based fault diagnostic system guides crew about fault location and suggests remedial action. It also keeps record of faults, which can be analysed later.
• Low life cycle cost.
• Three phase drive allows Regenerative braking down to standstill and Unity power factor operation.

7.5.4 Three Phase Locomotive: The block diagram of three-phase locomotive is as under:
MODERN 3-PHASE PROPULSION SYSTEM
Working Of Three-Phase Loco: 25 kV overhead A.C. supply is stepped down with the main transformer in the locomotive and fed to a front end (line) twin 4-quadrant line converter where AC is converted to DC through Pulse Width Modulation (PWM) thus achieve unity power factor. This supply is linked with an input side converter through DC link which is a reservoir of energy. Drive converter (VVVF Converter) converts DC supply in to 3 phase which is then fed to 3 phase traction motors. Gate turn off (GTO), thyristors are used in converter / inverter. The out put of Drive converter (inverter) is Variable Voltage Variable Frequency (VVVF) supply which helps in controlling the starting and running torques of three phase traction motors to suite traffic requirements.

7.5.4.1 Variable Voltage Variable Frequency Drive:

In adjustable frequency drive, the supply frequency is reduced for starting. This frequency
reduction improves the rotor power factor and thus increases the torque/ampere at starting. In this manner, rated torque is available at start and the induction motor is accelerated rapidly.
to its operating speed by increasing the supply frequency. This method also avoids danger of low frequency crawling which sometimes occurs when induction motors
are started on fixed frequency supply.

During regenerative braking, the traction motors are made to act as induction generators by controlling output frequency. In the line converter, the resultant 3-phase electrical energy is converted to single phase through D.C. link and is fed back to OHE via main transformer.

In WAP.5 locomotives 750V, 850 kVA Supply can be fed to trailing coaching load of train lighting / air conditioning coupled as Hotel Load thereby eliminating the necessity of additional Generating Car.

7.6 Preventive Maintenance Schedule Of Electric Locos

Based upon the maintenance instructions supplied by Locomotive manufacturer, Equipment manufacturers, specific instructions laid down regarding safety/fire prevention requirement and experience of user railways taking into account environmental and working/operating conditions, following preventive maintenance schedules have been standardized by Railway Board to improve the reliability of locomotives:
<table>
<thead>
<tr>
<th>SN</th>
<th>Name</th>
<th>WAG5 A/B, WAG5 HA, HB WAG7</th>
<th>WAM 4 WAP 4</th>
<th>WCAM 1</th>
<th>WCAM 2</th>
<th>PLACE OF MAINTENANCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IA</td>
<td>45 ± 3 days</td>
<td>40 ± 3 days</td>
<td>40 ± 3 days</td>
<td>40 ± 3 days</td>
<td>Home Shed</td>
</tr>
<tr>
<td>2</td>
<td>IB</td>
<td>90 ± 3 days</td>
<td>80 ± 3 days</td>
<td>80 ± 3 days</td>
<td>80 ± 3 days</td>
<td>Home Shed</td>
</tr>
<tr>
<td>3</td>
<td>IC</td>
<td>135 ± 3 days</td>
<td>120 ± 3 days</td>
<td>120 ± 3 days</td>
<td>120 ± 3 days</td>
<td>Home Shed</td>
</tr>
<tr>
<td>4</td>
<td>AOH</td>
<td>18 months ± 10 days</td>
<td>18 months ± 15 days</td>
<td>NOT TO BE DONE</td>
<td>NOT TO BE DONE</td>
<td>Home Shed</td>
</tr>
<tr>
<td>5</td>
<td>IOH</td>
<td>54 months ± 1 month or 6 lakh km</td>
<td>36 months ± 1 month or 4 lakhs km</td>
<td>18 months ± 1 month</td>
<td>12 months ± 1 month</td>
<td>Home Shed</td>
</tr>
<tr>
<td>6</td>
<td>POH</td>
<td>9 Yrs ± 3 months or 12 lakh km</td>
<td>6 Yrs ± 3 months or 8 lakh km</td>
<td>6 Yrs ± 3 months or 8 lakh km</td>
<td>6 Yrs ± 3 months or 8 lakh km</td>
<td>Work Shop</td>
</tr>
</tbody>
</table>

| 7   | TI   | **Goods locos:**         |             |        |        |                     |
|     |      | i) Locos with Hitachi TMs – 20 days |        |        |        |                     |
|     |      | ii) Locos with TAO TM – 15 days |        |        |        |                     |

| 8   |     | **Passenger locos** – As per loco link. |        |        |        |                     |

There are 30 electric loco sheds and 5 electric loco workshops on IR to carry out above maintenance activities. Holding of electric locos at present is 4310 (as on 31.03.12) which includes 129 AC-DC locos & 10 DC locos.

**Appx. Cost of Electric locomotives:**

<table>
<thead>
<tr>
<th>SN</th>
<th>Loco Type</th>
<th>Cost (in Rs. Crores)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WAP.4</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>WAG.7</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>WAP.5</td>
<td>13.5</td>
</tr>
<tr>
<td>4</td>
<td>WAP.7</td>
<td>13.0</td>
</tr>
<tr>
<td>5</td>
<td>WAG.9</td>
<td>13.0</td>
</tr>
</tbody>
</table>
### 7.7 Important Features Of Electric Locomotives

#### CLASS OF LOCOMOTIVES

<table>
<thead>
<tr>
<th>SN</th>
<th>Features</th>
<th>WAG.5</th>
<th>WAG.7</th>
<th>WAG.9</th>
<th>WAM.4</th>
<th>WCAM.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Supply system</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25 Kv, 50 Hz Single Phase AC.</td>
</tr>
<tr>
<td>2</td>
<td>Type of Service</td>
<td>FREIGHT</td>
<td>FREIGHT</td>
<td>FREIGHT</td>
<td>MIXED</td>
<td>MIXED</td>
</tr>
<tr>
<td>4</td>
<td>Year Put on Line</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Continuous Rating in kW (HP)</td>
<td>2840 (3850)</td>
<td>3675 (5000)</td>
<td>4500 (6122)</td>
<td>2676 (3640)</td>
<td>AC 2676 (3460) DC 2185 (2930)</td>
</tr>
<tr>
<td>6</td>
<td>Axle Arrangement</td>
<td>CO-CO</td>
<td>CO-CO</td>
<td>CO-CO</td>
<td>CO-CO</td>
<td>CO-CO</td>
</tr>
<tr>
<td>7</td>
<td>Axle Load (Tonnes)</td>
<td>19.8</td>
<td>20.5</td>
<td>20.5</td>
<td>18.8</td>
<td>19.6</td>
</tr>
<tr>
<td>8</td>
<td>Total WT of loco (Tonnes)</td>
<td>118.8(TAO)</td>
<td>123</td>
<td>123</td>
<td>112.8</td>
<td>118.0</td>
</tr>
<tr>
<td>9</td>
<td>Max. Speed in km/h DESIGNED</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>120</td>
<td>100</td>
</tr>
<tr>
<td>10</td>
<td>No. of Motors &amp; Suspension</td>
<td>---6 AXLE HUNG &amp; NOSE SUSPENDED---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Gear Ratio (No. of Teeth on Pinion &amp; Gear)</td>
<td>1:4.13, 1:3.55, 1:4.92, 1:2.76, 28:64, 17:77</td>
<td>1:3.55, 18.64</td>
<td>1:5.133, 15.77</td>
<td>1:4.13, 15.62, 1:2.76, 21:58</td>
<td>1:3.81, 16.61</td>
</tr>
</tbody>
</table>

#### CLASS OF LOCOMOTIVES

<table>
<thead>
<tr>
<th>SN</th>
<th>Features</th>
<th>WAG.5</th>
<th>WAG.7</th>
<th>WAG.9</th>
<th>WAM.4</th>
<th>WCAM.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>Braking for loco</td>
<td>AIR RHEOSTATIC &amp; HAND</td>
<td>RHEOSTAT IC AIR &amp; HAND</td>
<td>AIR REGNERATIVE PARKING BRAKE</td>
<td>AIR &amp; HAND BRAKE</td>
<td>AIR &amp; HAND BRAKE.</td>
</tr>
<tr>
<td>13</td>
<td>Braking for Train</td>
<td>AIR TWIN PIPE</td>
<td>VAC &amp; AIR TWIN PIPE</td>
<td>AIR</td>
<td>VACUUM, AIR, DUAL</td>
<td>VACUUM</td>
</tr>
<tr>
<td>No.</td>
<td>Description</td>
<td>HIT.15250 A 6X 630(857) &amp; TAO-659 D 6X 566 (770)</td>
<td>HIT.15250 A 6X 630(857)</td>
<td>6 FRA 6068 6X 850 kW</td>
<td>TAO-659 D 6X 566 (770)</td>
<td>TAO-659 D 6X 566 (770)</td>
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</tr>
<tr>
<td>14.</td>
<td>Drive on Bogie</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
</tr>
<tr>
<td>15.</td>
<td>Tr. Motor Type &amp; Rating in kW(HP)</td>
<td>6X 630(857)</td>
<td>6 FRA 6068 6X 850 kW</td>
<td>TAO-659 D 6X 566 (770)</td>
<td>TAO-659 D 6X 566 (770)</td>
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<tr>
<td>16.</td>
<td>Transformer Type &amp; kVARating</td>
<td>NEI AXLE BOX</td>
<td>AXLE BOX THRUST PAD TYPE</td>
<td>NEI AXLE BOX</td>
<td>NEI AXLE BOX</td>
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<tr>
<td>17.</td>
<td>Rectifier (Type)</td>
<td>SILICON</td>
<td>SILICON</td>
<td>SILICON</td>
<td>SILICON</td>
<td></td>
</tr>
<tr>
<td>18.</td>
<td>Control</td>
<td>MU.OP</td>
<td>MU.OP</td>
<td>MU.OP</td>
<td>MU.OP</td>
<td></td>
</tr>
<tr>
<td>19.</td>
<td>AUX. M/C DRIVE</td>
<td>AC,3PH</td>
<td>AC,3PH</td>
<td>AC,3PH</td>
<td>AC,3PH</td>
<td></td>
</tr>
<tr>
<td>20.</td>
<td>Type of Axle Box</td>
<td>NEI AXLE BOX</td>
<td>AXLE BOX THRUST PAD TYPE</td>
<td>NEI AXLE BOX</td>
<td>NEI AXLE BOX</td>
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</tr>
<tr>
<td>21.</td>
<td>Max. Elec. Braking Power in kW</td>
<td>2430</td>
<td>2430</td>
<td>260 (regenerative braking effort)</td>
<td>-</td>
<td>-</td>
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<tr>
<td>22.</td>
<td>Cont. Rated Current for TM</td>
<td>750 A FOR BOTH TYPE OF MOTORS</td>
<td>900A</td>
<td>270 A PER PHASE AT 2180 V</td>
<td>840 A IN 3S 2P, 667A IN 2S 3P</td>
<td>667 A IN AC 840 A IN DC</td>
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<tr>
<td>23.</td>
<td>Tractive Effort</td>
<td>START (t)</td>
<td>33.5 t</td>
<td>42 t</td>
<td>460 kN (46.9t)</td>
<td>30t</td>
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<tr>
<td></td>
<td></td>
<td>CONT (t)</td>
<td>20.6t</td>
<td>27t</td>
<td>325 kN (33.1t)</td>
<td>17.6t</td>
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</tbody>
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### Important Features Of Electric Locomotives

<table>
<thead>
<tr>
<th><strong>CLASS OF LOCOMOTIVES</strong></th>
<th><strong>6</strong></th>
<th><strong>7</strong></th>
<th><strong>8</strong></th>
<th><strong>9</strong></th>
<th><strong>10</strong></th>
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<tbody>
<tr>
<td><strong>SN</strong></td>
<td>Features</td>
<td>WCAM.2</td>
<td>WAP.1</td>
<td>WAP.3, WAP.4,</td>
<td>WAP.5</td>
</tr>
<tr>
<td>1.</td>
<td>Supply system</td>
<td>25 kV, 50 Hz Single Phase AC/ 1500 V DC</td>
<td></td>
<td>---25 kV, 50 Hz, Single Phase AC---</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Type of Service</td>
<td>Mixed</td>
<td>Passenger</td>
<td>Passenger</td>
<td>Passenger</td>
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<tr>
<td>5.</td>
<td>Continuous Rating in KW (HP)</td>
<td>AC: 3517 (4718) DC: 2175 (2916)</td>
<td>2764 (3760)</td>
<td>2764 (3760)</td>
<td>3675 (5060)</td>
</tr>
<tr>
<td>7.</td>
<td>Axle Load (Tonnes)</td>
<td>18.8</td>
<td>18.8</td>
<td>18.8</td>
<td>18.8</td>
</tr>
<tr>
<td>8.</td>
<td>Total WT of loco (Tonnes)</td>
<td>112.8</td>
<td>112.8</td>
<td>112.8</td>
<td>112.8</td>
</tr>
<tr>
<td>9.</td>
<td>Max. Speed in Km PH DESIGNED</td>
<td>120</td>
<td>130</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>10.</td>
<td>No. of Motors &amp; Suspension</td>
<td>6, AXLE HUNG &amp; NOSE SUSPENDED---</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Braking for loco</td>
<td>AIR &amp; HAND</td>
<td>AIR BRAKE &amp; HAND BRAKE</td>
<td>AIR BRAKE &amp; HAND BRAKE</td>
<td>AIR &amp; HAND</td>
</tr>
<tr>
<td>13.</td>
<td>Braking for Train</td>
<td>VAC &amp; AIR TWIN PIPE</td>
<td>VAC &amp; AIR TWIN PIPE</td>
<td>VAC &amp; AIR TWIN PIPE</td>
<td>AIR BRAKE TWIN PIPE</td>
</tr>
<tr>
<td>14.</td>
<td>Drive on Bogie</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
<td>GEAR PINION</td>
</tr>
<tr>
<td></td>
<td>GEAR COUPLING</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>15.</td>
<td>Tr. Motor Type &amp; Rating in kW(HP)</td>
<td>TAO-659 D 6X 566 (770) 750 V,DC</td>
<td>TAO-659 D 6X 566 (770) 750 V,DC</td>
<td>TAO-659 D 6X 566 (770) 750 V,DC</td>
<td>HIT. 152 50 A 6X 630(857) 750 V,DC</td>
</tr>
</tbody>
</table>

| 16. | Transformer Type & kVA Rating | HETT-5400 5400 | HETT-3900 3900 | HETT-3900 3900 | HETT-3900 3900 | LOT-7500 7475 |

| 17. | Rectifier (Type) | SILICON | SILICON | SILICON | SILICON | - |

| 18. | Control | MU.OP | MU.OP | MU.OP | SINGLE LOC O | MU.OP ONLY TWO LOCOS |

| 19. | AUX. M/C DRIVE | AC,3PH | AC,3PH | AC,3PH | AC, 3PH & 1PH |

| 20. | Type of Axle Box | NEI AXLE BOX | NEI A/B WITH HORN GUIDE | NEI A/B WING TYPE WITH TR BAR | NEI A/B WITH HORN GUIDE | - |

| 21. | Max. Elec Braking Power | - | - | - | - | 160 kN (16.32 t) |

| 22. | Cont. Rated Current for TM | 840 A IN AC 840 A IN DC | 750A | 750A | 900 A | 370A PER PHASE AT 2180V,3ph |

| 23. | Tractive Effort | START (t) | AC:34.0 t DC:27.7 t | 22.2t | 37.5t | 30.8 t | 258 kN (MAX) (26.3 t) |
|   |   | CONT (t) | - | 13.8t | 30.1t | 19.0 t | 220 kN (22.4t) |
7.8 MEMU - An overview

MEMU is an acronym for **Main Line Electrical Multiple Unit** services.

**MEMU Rake Formation** -
A MEMU consists of 2 or more units. Each unit consists of:

- One **Driving Motor Coach (DMC)** which has a driving cab & other control & traction equipments including Traction Motors and Three **Trailer Coaches (TC)** which do not have any driving cab or Traction equipments.
- The formation of one MEMU unit is:
  
  DMC==TC==TC==TC

- On Indian Railways, in general 8 car, 12 car & 16 car multiple units are in service.

  DMC==TC==TC==TC==TC==TC==TC==TC==TC==TC==TC==TC==TC= DMC

  OR

  DMC==TC==TC==TC==TC==TC==TC=TC==TC==TC==TC==TC==TC= DMC
7.8.3 **Advantages**:

- Caters the need of daily passengers in **Minimum time** with **frequent stops**.
- It has **High acceleration** due to use of DC Series Traction Motors (High Starting torque) and distributed power.
- **High retardation** due to quick application & release of Air brakes through EP (Electro-Pneumatic) Brake system (simultaneous Application & Release of Brakes in all coaches through electrical signal).
- Draw-bar pull is less in Multiple unit operation due to push-pull effect
- Operation by **Single operator** (Driver without assistant) due to provision of dead man's safety device.
- **Higher Passenger capacity**—
  a. DMC- 1st class- **seats**- 36, **Standing** – 52;
  b. Ladies – **Seats** – 42, **Standing** – 62;
  c. TC - **seats**- 108, **Standing** – 216
  d. Total in one unit = 402 seats & 762 Standing.
- **Economical** as works on existing traction system & Units can be combined as per traffic requirement.
- Reversal at terminals is not required.

**Working of MEMU**:

- 25 kV OHE supply is drawn through a single Pantograph provided in DMC which is fed to the Transformer via circuit breaker. The Transformer is provided with suitable taps for giving varying voltages.
- Tap changer contactors close in sequence to increase the Voltage applied to four DC Traction motors in each DMC after rectification (i.e. conversion to DC) by a rectifier. The voltage available at the traction motor is function of position of Master controller handle.
- The Master Controller is provided with a **dead man's device** which cuts off power and applies **emergency brakes** in case the driver gets incapacitated.
- Two auxiliary windings are provided to run auxiliary motors such as Transformer oil circulating pump, Radiator cooling fans, Rectifier cooling fans, Main compressor motor & supply to Lights and Fans in the unit.
- The 110V Control supply is fed throughout the length of the rake via 4 electrical jumpers for controlling the rear DMC & EP brakes.
- The **brake Controller** is provided in the driving cab to apply EP, Auto & Emergency brakes in the rake. Main air supply is maintained by the compressor in MR pipe from one end to other which is connected through out the rake. Similarly the brake pipe is also running from one to the other & 5 kg/cm² pressure is maintained by the brake controller in its **Release & Run** position.
- The EP brake is applied when electric signal sent via electrical jumpers by brake controller to all application valves of the EP units.
provided in under frame of each coach. Release of brakes takes place when the handle is brought back to Release position.

- In case EP brakes fails or Auto brakes are to be applied the Brake controller handle is further moved to Auto position. This causes reduction in brake pipe pressure & triple valve provided in EP unit Applies brakes to each Coach.
- Bringing the Brake controller handle to Emergency position exhausts brake pipe pressure rapidly to apply emergency Brakes at a faster rate. Restoration of Brake pipe pressure, releases the brakes.

7.9 Three Phase -EMU

On Indian Railway, 1500 V DC traction system exists over on Mumbai division of Central Railway. All other electrification is on 25000 V AC system. Railways have decided to convert existing 1500 V DC traction system to 25000 V AC Traction system.

Advantages: The main advantages and benefits envisaged after conversion from 1500 V DC system to 25000 V AC are-

- The number of AC substations required will be 18 on Central Railway as against existing 70 DC sub-stations. Similarly there will be 5 sub-stations as against 21 DC sub-stations on Western Railway
- Increased number of train services and increased train loads/speeds.
- Electrical energy saving in the range of 25 - 30 %.
- Improved reliability.
- Less fire hazards.
- Scope for expansion and capacity enhancement.

7.9.1 Three phase technology for dual voltage (1500 V DC/25000 V AC) EMUs:

The system consists fundamentally of four asynchronous three phase traction motors controlled by a variable voltage variable frequency inverter. The inverter takes power either directly from 1500 V DC overhead supply or at a fixed 1700 V DC obtained from 25000 V AC over head Supply via a step down transformer and twin four quadrant controlled power converters.

Major components are:
- 25 kV Transformer
- Single phase forced commutated bridge.
- DC link.
- Inverter.
- Three phase traction motor.
The schematic diagram of three-phase EMU is as under:

Brief Description: Output of two secondary windings of 25 kV Transformer is fed to two single phase forced commutated bridge connected in parallel. Both these forced commutated bridges convert AC into DC supply. Output of two converters in parallel is connected to DC link. 

Output of DC link is connected to variable voltage and variable frequency inverter. The inverter generates variable voltage and variable frequency (VVVF) supply with the help of gate turn off thyristors (GTOs). The VVVF three phase output of the inverter is supplied to traction motors connected in parallel.
Advantages:
- Higher Acceleration and deceleration
- Higher speed
- Jerk free working
- Regeneration of energy
- Less maintenance
- Smooth ride due to air suspension
- Audio visual PIS
- Forced ventilation for passenger comfort

7.10 12000 hp loco

IR is setting up a Green field facility for manufacture of 12000 HP twin Bo-Bo electric locos. 800 IGBT based locos will be manufactured in 10 years and maintained for 15 years by the PPP partner. This loco will have 25 Ton axle load and will be suitable for working double stack container trains on Dedicated Freight Corridors (DFC).

CHAPTER 8

ENERGY CONSERVATION

8.1 Monitoring of Energy Conservation

8.1.1. The Staff connected with electric traction makes every effort to avoid wastage in use of electricity through constant vigil.
8.1.2. One Senior Administrative Grade Officer of Electrical Department is nominated by Chief Electrical Engineer to be in charge of matters pertaining to Energy Conservation. The officer shall:

- Monitor pattern of consumption of electrical energy on electrified divisions based on the reports from Divisions;
- Plan for Energy Conservation measures and monitor their implementation;
- Provide guidance to Divisional Officers;
- Arrange for training of officers and supervisors;
- Discharge other related functions.

8.1.3. Sr. DEE (Tr D) and Sr. DEE (OP) hold, monthly meetings to analyze energy consumption and maximum demand for the preceding month vis-a-vis earlier months. The figures should have a relation to the traffic moved. In the event of maximum demand and energy consumption being found disproportionately high, a detailed investigation should be made and corrective action, if any, should be advised to concerned departments.
8.2 Energy Conservation Measures

While development of better designs and use of energy efficient equipment will bring about reduction in energy consumption, yet on the existing systems the following measures listed below will contribute to conservation of electrical energy in traction. While working to these recommended measures no compromise shall be made with the safe and reliable operation of equipment and train services.

8.2.1 Energy Conservation Measures for Traction Installations:

1. Shunt capacitor banks shall be provided at traction sub-stations, where not done, to reduce maximum demand and line losses. Priority should be given to the sub-stations feeding large marshalling yards.
2. Standby traction transformers shall be kept de-energized to save on no load losses.
3. Demand monitoring equipment, wherever provided, shall be maintained in the working order.
4. Traction Power Controller shall co-ordinate with the Section Controller to avoid simultaneous starts of trains, as far as practicable. Bunching of the train in the event of breakdown has to be avoided to the extent feasible.
5. Wherever standby emergency power supply is also derived from OHE, the associated auxiliary transformer should be kept isolated from 25 kV side to avoid no load loss. This, however, shall not be applicable for power supply to signals where changeover has to be immediate.
6. Ensuring of good electrical contact to attain low resistance at conductor joints (splices) and parallel groove (PG) clamps through periodical inspection and maintenance.
7. Connections to buried rail opposite sub-stations for return current are prone to corrosion leading to increased resistance and loss of energy. These connections should be inspected periodically and maintained to obtain good electrical connection.

8.2.2 Energy Conservation Measures for Rolling Stock:

1. Drivers/Motormen are expected to be well - conversant with the road to make the best use of down gradients to effect maximum possible saving in energy consumption.
2. In level sections and particularly in suburban sections, coasting should be resorted to as much as possible and brake applied only when essential to control the speed or stop the train. To help Drivers and Motormen "Coasting Boards" are fixed at appropriate points on suburban sections. In some Railways, time totalizes have been provided in EMUs.
3. In the undulating terrain, speed may be allowed to drop down when going up a short up-gradient. After passing over the crest, the train will automatically pickup the speed with power off when going downhill, so that it attains maximum permissible speed on the section when it arrives at the foot of the next up-gradient. This feature should receive special emphasis during learning the road period.

4. Re-scheduling of booked speed of EMU to help conservation of energy.

8.2.3 Energy Conservation Measures for Maintenance Installations:
1. Switch off lights, fans and air conditioners when not required.
2. Keep standby transformers de-energized from HV side.
3. Check idle running of machines.
4. Check leakage and misuse of compressed air.
5. Check leakage and wastage of water.
6. Maximise use of natural day light in service building to reduce need for electric light.

8.3 New Developments:
1. The traction staff should keep themselves fully abreast of technological developments like 3 phase drive Electric locos being made elsewhere, within the country and abroad, in respect of efficient utilization of electric power in traction applications and try to derive benefits from such developments.
2. Electric locomotives simulator: Training of Drivers on simulator can help drivers in running of trains with optimum consumption of energy.
CHAPTER 9

THREE PHASE TECHNOLOGY FOR TRACTION APPLICATION

9.1 Introduction: Three phase AC drive technology has become very common and significant for modern rail vehicles. These vehicles are equipped with GTO thyristors and microprocessor control systems. Microprocessor is used for vehicle control, supervision of health and operations of all major components and diagnostics. It permits electric breaking down to standstill and selection of best PWM technique for improved performance of motor as well as unity pf. The advantages associated with this technology are evident in technical as well as economic aspects.

9.2 What’s need for change?: Earlier, all the locomotives were using DC traction motors. The speed/torque regulation is achieved by using either tap changer on transformer or through resistance control on majority of these locomotives. Conventional relay based protection schemes are used. In most of the cases, the driver uses his discretion to diagnose and get past the problem.

1. FRPCPY for Tap changer and its associated equipments is about 10%.
2. DC motor has inherent problems of brush gear, commutator and low power to weight ratio. DC motor is essentially a high current low voltage design which calls for expensive large diameter cables and large electro-pneumatic reverser, contactors, switches etc.
3. Thyristorised DC traction motor drives, though made the DC motor drive more efficient, suffer because of high harmonic injection into. Power supply. Loss associated large filters had to be carried on Locomotives to overcome this.
4. Emphasis on regeneration is increasing day by day to reduce energy bill as well as to save energy for greater national cause.
5. With ever increasing need for hauling higher loads, there is need to make maximum use of available adhesion.
6. There is need for track friendly locomotives to reduce track maintenance efforts.


1. Three phase traction motors are robust and require little maintenance. Apart from bearing, it has no parts subjected to wear.
2. No restriction on speed of motor in absence of commutators, Ac traction motors can easily operate at 4000 rpm in contrast to 2500 rpm in case of DC machines.
3. The limit imposed due to bar-to-bar voltage for DC commutator motor is no more relevant with squirrel cage induction motors. Whole power flow from transformer to converter to DC link and down to inverter / motor may
be chosen at higher operating voltage. Against nominal 750 V, 1000A system with DC machines equivalent three phase propulsion is configured around 2800 V, 300A. Due to heavy reduction in operating current, power cables are much lighter and losses are reduced.

4. Power to weight ratio of induction motor is much higher than the DC motor. As a typical example, 1500 KW per axle can be packed per Axle with induction motors compared to 800 KW maximum with DC motors.

5. Since the torque speed characteristic of the induction motor is markedly steeper than that attainable by conventional DC machines, the induction machine can take better advantage of maximum possible tractive effort. A high mean adhesion coefficient can be expected.

6. As the adhesion coefficient is high, it is possible to transfer a part of the braking forces for the trailing load to electric brakes of locomotive. That is, in the case where regenerative braking is used, the regenerated electric energy can be increased.

7. High power/weight ratio of induction motor, reduction in cable thickness, reduction in number of contactors, switches etc. result in reduction in physical dimension and weight of the entire system.

**Advantages of microprocessor based control**

8. Almost all moving contactors, switches, relays, reversers etc. are eliminated and operation is sequenced by means of solid state logic

9. The microprocessor is used for drive control. The microprocessor allows the redundancy to be built in controls rather than the power equipments.

10. Microprocessor based fault diagnostic system guides driving crew about the fault location and suggests remedial action. It also keeps records of faults, which can be analysed by shed staff later.

11. Microprocessor control software has flexibility to provide software-based solution to local operational needs.

**Other advantage of three phase drive**

12. The induction motor drives are about 20% energy efficient compared to DC drives.

13. Three phase drives allow regeneration and unity power factor operation. The energy saving due to regeneration and improved power factor are sizable.

14. Electric braking down to standstill is possible. It improves operational efficiency besides reduction in maintenance efforts.

**9.4 Then Why So late?** To achieve these advantages of induction motor, it is necessary to supply it with a three phase variable voltage variable frequency (VVVF) source. This could not be achieved under technically and economically feasible conditions, until the advent of GTOs and microprocessor based control system in the last few years.
Variable voltage variable frequency drive: In adjustable frequency drive, the supply frequency is reduced for starting, this frequency reduction improves the rotor power factor and this increases the torque/ampere at starting. In this manner, rated torque is available at start and the induction motor is accelerated rapidly to its operating speed by increasing the supply frequency. This method also avoids danger of low frequency crawling, which sometimes occurs when induction motors are started on fixed frequency supply.

Fig.1.2 shows T.S. characteristic for constant v/f (constant air gap flux) at different supply frequencies. The breakdown torque is maintained constant by maintaining v/f constant. The stator voltage cannot be increased beyond rated voltage. With voltage remaining fixed further, as frequency is increased above base or rated motor speed, the air gap flux and breakdown torque decreases, as shown in fig.1.3. These characteristics are suitable for traction applications, where a large torque is required below base speed and a reduced torque is sufficient for high speed running. The torque-speed characteristic for a practical traction drive system evolved from the above two strategies is shown in fig.1.4. The variation in motor voltage & current, slip freq. and torque as the function of speed for operating regions shown in fig.1.4 is shown in fig.1.5.

9.5 Three phase induction motor drive: The block diagram for such an induction motor drive is shown in fig.2.1 Motor-end inverter can be a current source inverter or a voltage source inverter. In the past, when conventional thyristors were the only choice, designers opted for current source inverter. About 70% of all underground railways and light rail transport in the world today are partly or fully equipped with this technology.

The voltage source inverter, which required very complicated control electronics, when equipped with thyristors did not become a paying proposition until the development of GTOs and microprocessor based control techniques.

The circuitry of the input converter which provides a DC supply for the load side converter depends on the following:

1) Type of input power supply i.e. AC or DC.
2) Electricity utility s limits on reactive power harmonics.
3) Type of electric brakes; that s regenerative, rheostatic or both.

Fig.2.2 shows power schematic of ABB three phases AC locomotive.

The following stages are involved in power conversion:

- AC voltage is stepped down by main transformer.
• AC to DC conversion and boost up by 2.0 to 2.5-boost factor by means of front-end converter.
• Filter stage to reduce ripple in rectified DC.
• Link over voltage protection.
Technical Particulars for WAP5 Locomotive

1.1 Guaranteed performance at 22.5 kV and half worn wheel:

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<thead>
<tr>
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<tbody>
<tr>
<td>(i)</td>
<td>Starting tractive effort</td>
</tr>
<tr>
<td>(ii)</td>
<td>Continuous rated tractive effort in the speed range of 0-50 km/h</td>
</tr>
<tr>
<td>(iii)</td>
<td>Continuous rated speed</td>
</tr>
<tr>
<td>(iv)</td>
<td>Continuous rated power at wheel rim in the speed range of 80-160 km/h</td>
</tr>
<tr>
<td>(v)</td>
<td>Maximum regenerative breaking effort</td>
</tr>
<tr>
<td>(vi)</td>
<td>Maximum service speed</td>
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1.2 Arrangement:

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<tbody>
<tr>
<td>(i)</td>
<td>Axle arrangement</td>
</tr>
<tr>
<td>(ii)</td>
<td>Traction motor mounting</td>
</tr>
<tr>
<td>(iii)</td>
<td>Brake system</td>
</tr>
<tr>
<td>(iv)</td>
<td>Control circuit Voltage</td>
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1.3 Important dimensions:

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<tbody>
<tr>
<td>(i)</td>
<td>Total weight</td>
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<tr>
<td>(ii)</td>
<td>Axle load</td>
</tr>
<tr>
<td>(iii)</td>
<td>Unsprung mass per axle</td>
</tr>
<tr>
<td>(iv)</td>
<td>Wheel Dia - new - half worn - full worn</td>
</tr>
<tr>
<td>(v)</td>
<td>Gear ratio</td>
</tr>
<tr>
<td>(vi)</td>
<td>Length of loco over buffers</td>
</tr>
<tr>
<td>(vii)</td>
<td>Length of loco over headstock</td>
</tr>
<tr>
<td>(viii)</td>
<td>Bogie center distance</td>
</tr>
<tr>
<td>(ix)</td>
<td>Loco wheel base</td>
</tr>
<tr>
<td>(x)</td>
<td>Bogie wheel base</td>
</tr>
<tr>
<td>(xi)</td>
<td>Overall width</td>
</tr>
<tr>
<td>(xii)</td>
<td>Length of cab</td>
</tr>
<tr>
<td>(xiii)</td>
<td>Panto locked down height</td>
</tr>
<tr>
<td>(xiv)</td>
<td>Height of C.G. from rail level</td>
</tr>
</tbody>
</table>

1.4 Other salient features:
3-phase drive with GTO thyristors and MICAS – S2 microprocessor based control system.
- Provision for multiple unit operation of two locomotives.
- Provision for ballasting to increase the loco weight to 135 tones in future.
- The design permits interfacing and provision of "inching control" in future.

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Question Bank for Quiz
(Electrical Engineering)

I) Power/Coaching

Q.1 Illuminance is defined as Quantity of light (lumen) falling on unit area (M²).
Q.2 The unit for measuring illuminance is LUX.
Q.3 Full form of CFL is Compact Fluracent Lamp.
Q.4 The diameter of T8 version of Fluorescent tube light is 1 inch.
Q.5 Wattage of T5 Fluorescent tube light is 28W.
Q.6 Life of T5 lamp is approximately 15000 to 18000 burning hours.
Q.7 Full form of LED lamp is Light Emitting Diode lamp.
Q.8 The platform lighting at railway station is divided in two circuits. Before arrival of train, 70% light is switched on.
Q.9 DCP type of fire extinguisher used for electrical fire.
Q.10 Full form of ACSR conductor is Aluminum Conductor Steel Reinforced.
Q.11 The voltage and frequency of domestic power supply system in India is 2415V and 50Hz.
Q.12 Average life of lead acid battery is 4 yrs.

Q.13 Battery of 1100 ampere hour capacity is used in AC 3 tier coach.

Q.14 Rating of alternator for BG AC coach is 18/25 KW.

Q.15 The cut in speed for 4.5kw alternator used in Sleeper class coach is 19 kmph.

Q.16 In sleeper class coach, 16/40 lux of illumination level is minimum needed.

Q.17 Term "air-conditioning" was coined by Mr. S.W. Cramer in 1906.

Q.18 The EFT in coaches is provided for
   a. Controlling the DC supply  
b. Feeding the battery  
c. Extending power supply to/from the adjoining coaches  
d. None of the above

Q.19 Subject of Air conditioning of coaches on Indian Railways comes under the jurisdiction of
   a. CESE  
b. CEGE  
c. CELE  
d. CEDE

Q.20 Platform lighting at station is divided in two circuits in ratio of 70:30.

Q.21 The yard stick for provision of Electrical points in staff quarters can be changed by the Zonal railways with the approval of
   a. Railway Board  
b. EIG  
c. General Manager  
d. CSO

Q.22 The type of refrigerant used in LHB type of AC coaches is
   a. R 12  
b. F22  
c. R 134a  
d. none of the above

Q.23 Who functions as Electrical Inspector to Government of India in the Indian Railways?

   (a) Chief Electrical Loco Engineer  
   (b) Chief Electrical Services Engineer  
   (c) Chief Electrical Engineer  
   (d) Chief Safety Officer
Q.24 The human comfort level in an AC environment is affected by
   a. Level of lighting   b. Draft
   c. Level of tiredness   d. Speed of the train

Q.25 The illumination is measured in term of
   a. Tesla   b. Candela/m²   c. Lux   d. Gauss

Q.26 The train lighting system used on EMUs is known as
   a. Head on Generation System   b. Self Generation System
   c. End on Generation System   d. Mid on Generation System

Q.27 Railway stations with annual passenger earnings from Rs. 3 to 6 Crs. are
categorized as
   a. A1 class   b. C Class   c. B Class   d. F class

Q.28 The capacity of battery used in LHB Rajdhani coaches is
   a. 120 Ah   b. 1100 Ah   c. 90 Ah   d. 70 Ah

Q.29 In the months of rainy season what role can the air-conditioning system of
   conventional AC coaches perform?
   (a) It can increase the Relative humidity
   (b) It can decrease the Relative humidity
   (c) It can neither increase nor decrease the Relative humidity.
   (d) Relative humidity can both be increased and decreased from the
       setting of the control panel.

Q.30 The system of power supply used in the Coaches of Rajdhani &
   Shatabdi Express on IR is known as
   (a) Self Generation
   (b) End-on-Generation
   (c) Mid-on-Generation
   (d) Head-on- Generation

Q 31 The numbers of AC Plants in an AC 1st Class coach (open type
system) are:
   (a) Three   (b) Two
   (c) One   (d) Four

Q.32 The EIG draws his powers from
   a. The “Indian Electricity Act”   b. The “Indian Electricity Rules”
   c. The “Indian Railways Act”   d. The “Electricity Act, 2003”

Q.33 The frequency of domestic AC power supply adopted in India is
a. 60 Hz.   b. 50 Hz   c. 75 Hz.   d. 90 Hz.

Q.34 Train lighting on Indian Railways comes under the jurisdiction of
a. CESE   b. CEGE   c. CELE   d. CEDE

Q.35 Both of the pump and motor are inside water in case of
a. Turbine pump   b. Submersible pump
  c. Centrifugal pump   d. Jet pumps

Q.36 The Mid on Generation system of train lighting is used for
a. Rajdhani Exp. Trains   b. MEMU trains
  c. Slow passengers trains   d. Garibrath Exp. trains

Q.37 Branch officer in division looking after maintenance of AC coaches in
Division is known as
a) Sr.DEE/M   b) Sr.DEE /P   c) Sr.DEE /G   d) Any of a,b,or c

Q.38 To reduce Electrical energy bill, power factor should be kept
a) as less as possible
b) as high as possible
c) power factor does not effect energy bill
d) as close to unity as possible

Q.39 Railway stations with annual passenger earnings from Rs. 1 to 3 Crs. are
categorized as
a. A1 class   b. C Class   c. B Class   d. F class

Q.40 If you are posted as a branch officer in Vadodara Division for Power related works, you are likely to be known as-
 a) Sr.DEE/TRS   b) Sr.DEE (P)
  c) Sr.DEE /TRO   d) either b or c

Q.41 A section of ADI division has been electrified recently. Before energizing this section, whose sanction is essential
a) GM/WR   b) CEE/WR
  c) DRM/ADI   d) Sr.DEE/TRD/ADI

Q.42 Who is designated as EIG. in railways? --------

Q.43 The standard voltage adopted for 3 phase AC system in India is
a. 750 V AC   b. 440 V AC   c. 230 V AC   d. 110V AC
Q. 44 Modified TL system is 2 wire unearthed system.

Q. 45 In RMPU type AC coach, 4 number of compressors are used.

Q.46 Capacity of inverter in RMPU AC coach is 25 kva.

Q.47 Presently following type of AC coaches are used:
   a. HOG
   b. MOG
   c. LHB
   d. None

II) TRD/RE

Q.1 Electrification in Indian Railways was introduced for the first time in the year 1925

Q.2 Average cost of electrification on double line section is around 1 crore per route km.

Q.3 As per Vision -2020 plan of electrification, 1400 km are to be electrified every year till 2020.

Q.4 Minimum vertical distance between live OHE and fixed structure / moving loads is 250mm for long duration.

Q.5 Minimum lateral distance between live OHE and fixed structure / moving loads is 250mm for long duration.

Q.6 Minimum safe clearance for men to work near OHE is 2 mtr.

Q.7 N Type portals are used to cover OHEs of 4 number of tracks.

Q.8 O Type portal are used to cover OHEs of 6 number of tracks.

Q.9 R Type portals are used to cover OHEs of 8 number of tracks.

Q.10 The standard height of contact wire above the track plane is kept as 5.60 mtr. at cantilever.

Q.11 The height of OHE at level crossing gate is kept as minimum 5.50 mtr.
Q.12 The stagger of OHE on tangent track is normally kept as +200 mm.

Q.13 The full form of UIOL is Uninsulated Overlap.

Q.14 The Section insulator in OHE is provided for the purpose of ..........................................................

Q.15 The PTFE type neutral section is located on tangent track at least 400 mtr. after the stop signal.

Q.16 The setting distance of mass on tangent track shall be normally 2.80 mtr for the broad gauge.

Q.17 The normal setting distance of portal is kept as 4.65 mtr.

Q.18 The maximum span in OHE is restricted to 72 mtr. In IR.

Q.19 10 KVA capacity Auxiliary transformers are provided at stations for supply power to signaling system.

Q.20 The head quarter of CORE in Indian Railway is at Allahabad.

Q.21 The full form of CORE is Central Organization in Railway Electrification.

Q.22 The average yearly Railway Electrification planned under Vision 2020 is
   a. 5000 RKM  b. 1400 RKM  c. 4500 RKM  d. 2500 RKM

Q.23 The horizontal distance between the Center Line of the Track and nearest face of the mast is known as
   (a) Stagger  (b) Implantation  (c) Span  (d) Height

Q.24 The requirement of copper and steel is reduced in 25 KV single phase AC system as compared to DC system because of
   a. Lower voltage  b. Lower current  c. Lower power  d. Lower energy

Q.25 O type portals are used for supporting OHE up to
   a. 4 tracks  b. 6 tracks  c. 8 tracks  d. 3 tracks

Q.26 Overlap provided at an SSP is
   a. UIOL  b. IOL  c. Neutral section  d. Section insulator with isolator

Q.27 What is the distance of warning boards from neutral section location:
   (a) 100 m & 500 m.  (b) 2000 m & 1000 m  (c) 500 m & 250 m  (d) 250 m & 150 m
Q. 28 Contact wire is placed in zig-zag manner in entire span length, in order to-
(a) to avoid formation of groove on panto pan strip
(b) to ensure uniform rubbing of pantopan strip within current collection strip
(c) to avoid breakdown due to formation of groove in pantopan strip
(d) all of the above

Q.29 All RE works on Indian Railways are centrally controlled by
a. Zonal Railways  b. Divisions  c. CORE  d. Production Units

Q.30 Bracket tube is a part of
a. RMPU  b. Cantilever Assembly
  c. Arno Converter  d. Submersible Pump

Q.31 The stagger of contact wire at 'push off' location is directed
a. Towards the OHE structure  b. Away from the OHE structure
  c. Right at the centre line of track  d. None of the above

Q.32 The section insulator is used for
a. Insulating the two phases in a TSS
b. Insulating two elementary sections of OHE
c. Insulating the OHE at insulated overlap
d. None of the above

Q.33 In an AC TSS, which phase of 132 KV/25 KV traction transformer should be earthed?
(a) one phase of 132 KV primary side
(b) both phases of 132 KV primary side
(c) one phase of 25 KV secondary side
(d) both phases of 25 KV secondary side

Q.34 The power supply between two adjacent Traction Substations feeding the OHE in TRD is separated by
(a) SP  (b) SSP
(c) FP  (d) RCC

Q.35 The horizontal distance between the Center Line of the Track and nearest face of the mast is known as
(a) Stagger  (b) Implantation
  (c) Span  (d) Height

Q.36 Freight traffic hauled on electric traction on IR is
a. 75%    b. 67% 
c. 60%    d. None of a,b,c

Q.37 Numbering of OHE structures on up line in a double line section will always be 
a. Even nos.    b. In sequence  
c. Odd nos.    d. None of the above

Q.38 Minimum height of contact wire on level crossings is 
a. 5.8 Mtr.    b. 5.6 Mtr.    c. 4.67 Mtr.    d. 5.5 Mtr.

Q.39 Before charging any new electrified section on 25 kv AC, whose sanction is required.  
a) CRS    b) ML    c) GM    d) CEE

Q.40 Before approaching neutral section, loco pilot is required to open DJ in loco to avoid ____________ in OHE.

Q.41 First Electric train in India started on 3rd February ________.

Q.42 The horizontal distance between the Center Line of the Track and nearest face of the mast is known As  
(a) Stagger     (b) Implantation     (c) Span     (d) Height

Q.43 Which of the following is a permissible span 
a) 62 m    b) 49.5m    c) 45.5m    d) 35m

Q.44 To avoid formation of groove on panto, contact wire is held in a Zig Zag fashion. This arrangement is known as ______________

Q.45 Before approaching neutral section, loco pilot is required to open ___________ in OHE.

Q.46 While length of conventional neutral section is 41 mt, modern PTFE neutral section are only ___________ mt long.

Q.47 Which of the following is a permissible OHE span 
a) 62 m    b) 41 m    c) 48 m    d) 54m

Q.48 What is the distance of warning boards from neutral section location:-  
a. 100 m & 500 m.    b. 2000 m & 1000 m   
c. 500 m & 250 m    d. 250 m & 150 M

Q.49 In general Traction Voltages on India Rly is.  
a. 1500 Volt    b. 3000 Volt    c. 25000 Volt    d. 750 Volt
Q.50 Indicate normal values of following
SPAN-----------------
Setting Distance-------------
Encumbrance--------------

Q.51 What is the material used in Contact wire---------

Q.52 Where is portal used?---------------

Q.53 Regulating winding of auto transformer is provided with taps.
a) 6   b) 8     c) 16   d) 15      (    )

Q.54 Define Elementary section of OHE-----------------

Q.55 In yards where adequate distance between tracks in not available, OHE is supported with the help of-
a) Mast       b) Upright    c) Broom    d) Portal?

Q.56 Electric supply in a sector of OHE is controlled by
a) Isolator   b) Interrupter  c) Circuit Breaker  d) Either b or c

Q.57 HOD looking of the maintenance of traction distribution is known as?

Q.58 In AC traction, span length varies in steps of :-
(a) 4.5 meters          (b) 9 meters  
(c) 6 meter          (d) 18 meters

Q.59 Maximum span length in AC traction is :-
(a) 67.5 meter       (b) 72 meter       (c) 63 meter    (d) 22 meter

Q.60 Difference between two consecutive span length should not be more than:--
(a) 25 m.              (b) 20 m.       (c) 18 m.   (d) 16 m.

Q.61 Maximum wind pressure considered to design OHE structures for Red zone is :-
(a) 180 kgf/sq. m.          (b) 160 kgf/sq. m.
(c) 150 kgf/sq. m.         (d) 110 kgf/sq. m.
Q.62 Maximum tension length in AC traction is:-
(a) 1500 m    (b) 1600 m    (c) 1000 m    (d) 750 m

Q.63 At the end of tension length, an overlap is provided:-
(a) to maintain electrical clearance.
(b) to maintain mechanical clearance
(c) to maintain mechanical & electrical clearance.
(d) to provide smooth passage for pantograph.

Q.64 A small tension length is much useful at the time of OHE breakdown or maintenance work due to:-
(a) mechanical independence of each tension length.
(b) to maintain uniform tension in entire tension length.
(c) easy transportation of OHE conductors.
(d) all of the above

Q.65 Which type of overlap is formed at the end of every tension length:-
(a) insulated overlap
(b) un-insulated overlap
(c) either Insulated overlap or un-insulated overlap.
(d) none of the above.

Q.66 Axial distance between catenary & contact wire at the OHE support, in vertical plane is called:-
(a) implantation  (b) gradient of OHE  (c) encumbrance  (d) stagger

Q.67 In AC traction, normal encumbrance at support is:-
(a) 1.9 m    (b) 1.4 m    (c) 0.9 m    (d) 2.0 m

Q.68 In AC traction, height of contact wire at support from rail level (regulated OHE) with 100mm pre sag in contact wire is:-
(a) 5.5 m    (b) 5.55 m    (c) 5.6 m    (d) 5.75 m
Q.69 In AC traction, height of contact wire from rail level in Carshed is :-
(a) 5.6 m      (b) 5.65 m     (c) 5.75 m     (d) 5.8 m

Q.70 In AC traction, normal height of the catenary wire at support from rail level (regulated OHE) with 100 mm pre sag in contact wire is about :-
(a) 7 m         (b) 7.75 m     (c) 7.25 m     (d) 7.45 m

Q71 At level crossing gate, maximum height of rail height gauge from the road surface is
(a) 4.381 m     (b) 4.67 m      (c) 4.80 m      (d) 4.45 m

Q.72 At level crossing gate, normal height of contact wire from the rail level is
(a) 5.80 m     (b) 4.67 m        (c) 4.80 m     (d) 5.50 m

Q.73 The fitting, which is used to transfer the weight of contact wire to the catenary wire is called:-
(a) Section insulator (b) Jumpers       (c) cantilever assembly     (d) droppers

Q.74 Diameter of in-span dropper in AC traction is:-
(a) 7 mm         (b) 6.75 mm      (c) 6 mm       (d) 5 mm

Q. 75 Material of AC contact wire is :-
(a) hard drawn copper       (b) annealed copper
(c) cadmium copper            (d) brass

Q.76 In AC traction, maximum stagger of contact wire on tangent track is :-
(a) 380 mm         (b) 300 mm      (c) 229 mm     (d) 200 mm

Q.77 On tangent track, contact stagger is 200 mm at support, what will be the catenary stagger?
(a) 300 mm.     (b) 200 mm.      (c) 100 mm.     (d) Zero

Q.78 In regulated OHE, how much tension is kept in OHE:-
(a) as per tension / temperature chart       (b) 3000 kg
(c) 2000 kg                          (d) 1500 kg
Q. 79 In regulated OHE, Where anti-creep point is provided ?
(a) starting of tension length           (b) finishing of tension length
(c) midway of tension length                 (d) all of the above

Q. 80 Tramway type OHE can be used for :-
(a) main line          (b) siding only
(c) wiring of turnouts                   (d) all of the above

Q. 81 A neutral section is provided in OHE between two 25 KV , single phase, 50 Hz. traction sub-stations due to :-
(a) to separate the zones, which fed by the adjacent sub station of different phase
(b) to increases the current carrying capacity of the OHE
(c) to minimise the voltage drop in OHE conductors
(d) all of the above

Q. 82 25 KV traction system needs the supply of :-
(a) single phase       (b) two phase       (c) three phase       (d) three phase & neutral wire

Q. 83 In an AC TSS , which phase of 132 KV/25 KV traction transformer should be earthed ?
(a) one phase of 132 KV primary side
(b) both phases of 132 KV primary side
(c) one phase of 25 KV secondary side
(d) both phases of 25 KV secondary side

Q. 84 Sub- Sectioning & parallel Post (SSP) are employed in OHE due to ?
(a) to minimise voltage drop                   (b) OHE sectioning purpose
(c) restrict tension length                      (d) all of the above

Q. 85 The distance of OHE section between FP & SP is called :-
Q. 86 The shortest section of OHE, which can be isolated through remote control by TPC is called :-
(a) elementary section (b) feeding zone
(c) sector (d) sub sector

Q. 87 The shortest section of OHE, which can be isolated manually is called :-
(a) elementary section (b) feeding zone
(c) sector (d) sub sector

Q. 88 In AC traction, distance between two OHE’s conductor uninsulated overlap is kept:
(a) 500 mm. (b) 380 mm. (c) 300 mm. (d) 200 mm.

Q. 89 In AC traction, distance between two OHE’s conductor in un-insulated overlap is kept:
(a) 375 mm. (b) 300 mm. (c) 150 mm. (d) 200 mm.

Q. 90 Which type of neutral section, you prefer in heavily graded or suburban section?
(a) overlap type (b) PTFE. Type neutral section
(c) short neutral section comprising section insulator assembly (d) none of the above

Q. 91 PTFE stands for :-
(a) Plastic Tetra Floro Ethane (b) Poly Thermo Finials Ethane
(c) Poly Tetra Floro Ethane (d) Poly Tetra Floro Ethylene
Q.92 In P.T.F.E. type neutral section assembly, Anti torsion droppers are used for:

(a) good current collection at higher speed
(b) to prevent oscillation of OHE
(c) push up of contact wire very gradually
(d) all of the above

Q.93 What is the distance of caution boards from neutral section location:-
(a) 100 m. & 500 m.  
(b) 2000 m. & 1000 m.  
(c) 500 m. & 250 m.  
(d) 250 m. & 150 m.

Q.94 A device, which installed in contact wire to separate two elementary section & provide smooth passage for pantograph is called:-
(a) insulated overlap  
(b) section insulator  
(c) bracket Assembly  
(d) cut-in insulator

Q.95 At the location of section insulator, stagger of contact wire should be:-
(a) zero  
(b) 200 mm  
(c) 300 mm  
(d) 380 mm

Q.96 Which insulator is used in ac section insulator assembly:-
(a) sectioning insulator  
(b) cut insulator  
(c) 9-ton insulator  
(d) stay tube insulator

Q.97 The arrangement of the cantilever assembly depends upon the:
(a) height of contact wire  
(b) setting distance  
(c) stagger  
(d) all of the above

Q.98 Which is not a part of the cantilever assembly?
(a) steady arm  
(b) adjuster sleeve  
(c) anti wind clamp  
(d) PG clamp.

Q.99 Why gap should be required between register arm tube & anti wind clamp strap:-
(a) to avoid hard spot  
(b) to hold the register arm
Q.100 Minimum working clearance for 25 KV AC is :-
(a) 500 mm  
(b) 1 m  
(c) 2 m  
(d) 3 m

Q.101 Normally, which type earth electrode is preferred for earthing in 25 KV AC Installations: -
(a) plate type  
(b) pipe type  
(c) strip type  
(d) none of the above

Q.102 Minimum earth resistance when not specified should not be more than :-
(a) 9 ohm  
(b) 10 ohm  
(c) 5 ohm  
(d) 2.5 ohm

Q.103 Minimum earth resistance for 25 KV TSS should not be more than :-
(a) 5 ohm  
(b) 2 ohm  
(c) 1 ohm  
(d) 0.5 ohm

Q.104 Minimum earth resistance for 25 KV switching station (SSP / SP etc) should not be more than :-
(a) 5 ohm  
(b) 2 ohm  
(c) 1 ohm  
(d) 0.5 ohm

Q.105 Lightning arrester prevents OHE from :-
(a) surge & transient voltage  
(b) corrosion of –ve path conductor  
(c) back e.m.f.  
(d) all of the above

Q.106 The distance between centre line of the track to the nearest face of the structure is called:-
(a) clear span  
(b) track separation  
(c) implantation  
(d) track clearance

Q.107 Implantation is also known as :-
(a) skip distance  
(b) setting distance  
(c) clear span  
(d) track separation
Q.108 What will be the “regulating ratio” of 3 pulley block system type ATD?
(a) 1:1          (b) 2:1          (c) 3:1          (d) 5:1

Q.109 If SS wire of ATD broken, OHE does not come on ground due to:-
(a) 9-ton insulator  (b) fixed pulley  (c) movable pulley  (d) hex tie rod

Q.110 Current collection test is carried out during:-
(a) before monsoon  (b) during monsoon  
(c) after monsoon  (d) night only

Q.111 What may be the reason of sparking during current collection test.
(a) OHE is not proper  (b) track is not proper  
(c) rolling stock is not proper  (d) all of the above or either (a) or (b) or (c)

Q.112 In locally arranged power block, supply of the siding or yard is shut down by:-
(a) TPC          (b) section controller  
(c) yard master  (d) OHE incharge, who required power block

Q.113 TPC arranges emergency power block in which of following case/s?
(a) a damaged OHE or feeder falling down and or persons or animals or vehicle or falling trees coming in contact with or likely to come in contact with live equipment  
(b) a damaged electric loco & driver requires the permit to work  
(c) derailment or any other accident on the electrified section  
(d) all of the above

Q.114 In the private no. book, private nos. are printed in the form of:-
Q.115 During power block, which type of vehicles movement is blocked in power block section?
(a) electric hauled (b) diesel hauled (c) steam hauled (d) all of the above

Q.116 Before granting power block in the section, the longitudinal protection and lateral protection in the section is arranged by:
(a) TPC (b) section controller (c) TNL (d) station master

Q.117 If OHE breakdown or defect in OHE, which are likely to affect the train services, noticed by any railway servant, will be reported immediately to:
(a) TPC (b) station master (c) section controller (d) either (a) or (b) or (c)

Q.118 Cross section area of contact wire in AC OHE is 107 mm².

Q119 Diameter of dropper is 5 mm.

Q120 Spacing between droppers in span is 9 mts

Q121 To pass ODC in electrified territory, clearance should be greater than 100 mm.
III) LOCO/EMU-MEMU/Operation

Q.1 The visibility of flasher light in electric locomotive is 2 km.

Q.2 The maximum speed of fastest train hauled on electric section is 140 km in India.

Q.3 WAP5 loco has designed power rating of 6000 horsepower.

Q.4 The latest loco being manufactured in Indian Railway is WAG9.

Q.5 Electric locos in India are manufactured at CLW.

Q.6 Loco pilot is given headquarter rest for 16 hrs for duty performed of more than 8 hours duration.

Q.7 The out station rest to Loco pilot is given for 8 hrs for duty of more than 8 hours duration.

Q.8 The running staff is entitled for number of rest of 30 hrs. duration.

Q.9 Specific Energy Consumption for goods train which around 11KWH per 1000 GTKM

Q.10 Smoothing reactor (SL) is provided to:
   (a) Convert AC to DC  (b) Increase undulation of current
   (c) Reduce undulation of current (d) Reduce OHE supply

Q.11 ARNO converter is provided to convert:
   (a) Three phase to single phase  (b) AC to DC
   (b) DC to AC (d) Single phase to three phase

Q.12 WAG.5 loco are provided with:
   (a) DC series motor  (b) Single phase Induction motor
   (c) DC compound motor (d) None of the above

Q.13 POH of Electric locos is carried out in
   a. Trips sheds
   b. Loco sheds
   c. Depots
   d. Workshops

Q.14 POH of Electric locos is carried out in
   a. Trips sheds  b. Loco sheds  c. Depots  d. Workshops
Q.15 RDSO designed a new locomotive which will be known as YAP1 Bo-Bo. Each motor is capable of delivering power output of 500 kw. Total weight of the loco is 80 tonnes.

What is the total power of the loco (delivered by all the motors put together) _______________ kw?

What is the weight per axle _______________ ?

For which gauge this loco is designed____________?

Q.16 Various types of Brakes provided in a locomotive could be
1.
2.
3.

Q.17 **What is the principle of speed control in an electric locomotive? Please explain the process briefly.**

Q.18 Write function of following equipments of electric loco in one line -
1. Rectifier
2. DJ
3. Pantograph

Q.19 What operations loco pilot requires to perform before entering a neutral section?

Q.20 In a Bo-Bo-Bo type of locomotive, how many traction motors (axels). Will be there?
   a) 2       b) 3       c) 4       d) 6       (   )

Q.21 What does MEMU stand for?
   a) 220V  
   b) 50Hz  
   (   )

Q.22 Electric loco is provided with 2 pantograph? Which one is normally used.
   a) Front     b) Rear     c) Any one of the two    d) c or b

Q.23 First letter of classification for locomotive numbering scheme indicates ------ ---- of loco.

Q.24 Two axle bogie with one traction motor for each axle is classified as ------- -

Q.25 WAG.5 loco is provided with --------bogie arrangement.
Q 26 WAP.5 loco is provided with -------bogie arrangement.

Q 27 WCG.2 loco can work under -------traction supply.

Q 28 There are ------- No. of maintenance sheds over IR for maintenance of electric locos.

Q 29 -------type Traction motor is used in WAP.4 locos.

Q 30 -------type Traction motor is used in WAP.5 locos.

Q 31 Electric loco draws power from OHE with the help of -------

Q 32 Electric Locomotive is provided with ---------nos of pantograph.

Q 33 -------can be remote controlled from driving cab to disconnect OHE supply.

Q 34 High OHE voltage is stepped down with -------

Q 35 The voltage to traction motors can be controlled through ---------.

Q 36 WAG.5 loco are provided with :
(a) DC series motor  (b) Single phase Induction motor
(c) DC compound motor,  (d) None of the above.

Q 37 Smoothing reactor (SL) is provided to :
(a) Convert AC to DC  (b) Increase undulation of current
(c) Reduce undulation of current  (d) reduce OHE supply.

Q 38 Auxiliary machines in locomotive work on:
Q 39  Traction Motors are mounted:
   (a) On loco roof, (b) In under frame, (c) Inside Locomotive
   (d) None of them.
Q 40  Normally loco pilot uses:
   (a) Front pantograph, (b) Rear Pantograph,
   (c) Both Pantograph, (d) None of them.
Q 41  ARNO converter is provided to convert:
   (a) Three phase to single phase, (b) AC to DC
   (c) DC to AC, (d) Single phase to three phase.
Q 42  Independent brakes are provided for:
   (a) Brake application in loco alone, (b) Brake application in train alone,
   (c) Brake application in loco and train both, (d) None of them.
Q 43  During dynamic braking:
   (a) Kinetic energy of loco is converted to Electrical Energy
   (b) Electrical energy is converted to mechanical energy,
   (c) Mechanical brakes are applied in loco
   (d) None of them.
Q 44  In regenerative braking:
   (a) Electrical energy produced is converted to heat energy,
   (b) Electrical energy produced is fed to traction motor,
   (c) Electrical energy produced is fed back to OHE
   (d) None of above.
Q 45  Supply in control circuit of loco is:
(a) 380 Volt single phase, (b) 380 Volt three phase,  
(c) 110 Volt DC, (d) 110 Volt AC.

Q 46  The input supply to three phase traction motor is:
(a) Fixed frequency variable voltage, (b) Fixed voltage variable frequency,
(c) Variable voltage variable frequency, (d) None of them.

**True or False**
Q 47  In DC locos all the traction motors are connected in parallel in starting
Q 48  In AC locos, starting resistances are introduced to control the speed of
Traction Motors.
Q 49  WAP.4 locos are three phase locomotives.
Q 50  WAG.9 locos are three phase locomotives.
Q 51  Three phase traction motors are used in WAP.5 locos.
Q 52  POH of electric loco motive is carried out at nominated electric loco work
shop.
Q 53  WAG.5 locos have Co-Co bogies.
Q 54  Pantograph is mounted within the driving cab of the loco.
Q 55  Mechanical Brakes in Locomotives are air brake only.
Q 56  Silicon rectifiers reduce the undulation of current.
Q 57  Transformer is used to step down OHE supply.
Q 58  IGBTs are used to convert single phase to three phase supply.
Q 59  Bo wheel arrangement indicate two axle bogie with two traction motors.
Q 60  WAP.5 loco can work both in AC and DC sections.
Q 61  ARNO converter converts AC supply to DC.
Q 62  In locomotive, brakes are applied by destroying vacuum.
Q 63  ARNO converters are being replaced by static converters.
Q 64  Proportionate brakes in loco are applied with A9 brake valve.
Q 65  DC series traction motors are provided in WAG.9 locomotives.
Q 66  AOH of WAG.5 loco is carried out after 18 months.

***************************
Q1 (a) How is the uniform wear of the ‘pantograph strip’ due to rubbing with contact wire ensured in OHE?
   (b) Draw sketch of a ‘Cantilever assembly’ of OHE, name different parts and show location of Contact and Catenary Wires.
Q.2 Explain what do you understand by the following?
   a. DC viz a viz AC Traction
   b. Circuit Breaker
   c. Electric Energy Conservation
   d. End-on-Generation
   e. Factor of AC comfort
   f. LHB
   g. Flasher Light
Q.3 Explain the working of ‘Air Conditioning system’ of AC coach with the help of sketch.
Q.4 (a) What is the difference between ‘regulated & unregulated OHE’? How is OHE regulation achieved?
   (b) What are the functions performed by the following equipments in an electric loco?
      a. Tap Changer
      b. Arno Converter
Q.5 (a) Write brief note on the following:
      a. Neutral Section
      b. Rail Bonds
      c. Power Block & Traffic Block
( b) For a WCAM1 Co-Co 123 T locomotive, indicate the following:-
      a. Type of Traction
      b. Type of Service
      c. Number of Traction Motors
      d. Axle Load
Q.6 Write brief notes on -
      a. Breath Analyser Equipment
      b. Tractive Effort and Adhesion
      c. Electrical Clearance
      d. Difference in requirements of Goods & Passenger Locos
Various types of Brakes on electric locomotives
Electric Loco Maintenance Schedules

Q.7 Draw ‘SINGLE LINE diagram of an AC electric loco.

Q.8 Write brief notes on any four
a. EMU
b. Safety item on Loco
c. Traction Sub Station
d. Various Train Lighting Systems
e. Roof Mounted Package Unit
f. 3-Phase Loco

Q.9 Please mark the correct answer.
Axial distance between catenary & contact wire at the OHE support in vertical plane is called?
(a) implantation  (b) gradient of OHE  (c) encumbrance  (d) stagger

2. The fittings, which is used to transfer the weight of contact wire to the catenary wire is called?
(a) section insulator  (b) Jumpers  (c) cantilever assembly  (d) droppers

3. In regulated OHE, how much tension is kept in OHE?
(a) as per tension / temperature chart  (b) 3000 kg
(c) 2000 kg  (d) 1500 kg

4. What is the distance of caution boards from neutral section location?
(a) 100 m. & 500 m.  (b) 2000 m. & 1000 m.
(c) 500 m. & 250 m.  (d) 250 m. & 150 m.

5. The distance between centre line of the track to the nearest face of the structure is called?
(a) clear span  (b) track separation  (c) implantation  (d) track clearance

Q. 10 WAG4 B-B loco is provided with 1540 horse power motors. For this loco, please indicate

(a) Gauge__________________________.
(b) Type of Traction__________________.
(c) Total Horse Power__________________.
(d) No of bogies_____________________
(e) Type of Service__________________.
Q.11 Describe organization of electrical department in an electrified division. Please indicate responsibilities of each officer.

Q.12 Describe Train lighting systems used in non AC coaches on IR.

Q.13 Explain the following terms in context of 25kv AC traction distribution system.
   1. Portal
   2. Neutral Section
   3. Stagger
   4. Isolator
   5. Remote Control Center

Q.14 For a conventional AC loco motive please explain the following-
   I. Tap change
   II. DJ
   III. Regulating winding
   IV. Rectifier
   V. Dynamic Brakes

Q.15 (a) Please indicate various types of train lighting systems.
   (b) Please name the factors governing comfort of a passengers in an air-conditioned coach.

Q.16 (a) Who is designated EIG on Indian Railways? What is his role?
   (b) A tube light rated 50 watts (electric powers) is used for 10 hours per day for 30 days in a month. How much electric energy is being consumed by it per month?

Q.17 For 25 KV AC traction OHE system explain the following
   1. SPAN
   2. Setting Distance
   3. Encumbrance
   4. Portal

Q.18 (a) Please draw various warning board provided to inform loco pilot about approaching neutral section?
   (b) In a 25 KV OHE system specify the following for contact wire used?
      1. Material
2. **Shape**

Q.19 Please draw a diagram indicating flow of electrical energy from OHE to traction motors in a conventional DC traction motor in an electric loco.

Q.20 Indicate various types of breaks which could be provided in an electric locomotive. Which of these breaks in more energy efficient and why?

Q.21 For minimizing the length of OHE to be isolated under fault, various kind of switches are used. Please mention these along with associated features in terms of their capability to sense fault, open on load and possibility of remote operation. Name the section of OHE controlled by these switches.

<table>
<thead>
<tr>
<th>Name of the switches</th>
<th>Capable of</th>
<th>Name of the section of OHE controlled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fault sensing</td>
<td>Opening on load</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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</tbody>
</table>

Q.22 How is speed of an electric loco controlled? Please explain briefly.

Q.23 What is the purpose of OHE regulation? How is it achieved? How much tension is kept in regulated OHE.

Q.24 Please indicate the illumination levels provided at following locations?
   a. **ASM room**
   b. **Booking Window**
   c. **Officers Chamber**
   d. **Operation theatre in Hospital**

Q.25 Write various advantages of using high mast tower lighting viz a viz Sodium lamps in circulating areas.

Q.26 Draw a schematic diagram of Power supply distribution substation for a rly colony.
Q.27 What are the different type of fire extinguishers used for different type of fires. Describe in brief working of fire extinguisher used for ‘electrical fire’.

Q.28 Indicate power of following electrical appliances-
   a. Incandescent Lamp
   b. T5 Tube light
   c. Ceiling fan
   d. Light socket (5mpr)
   e. 1.5 tone window AC
   f. Electric iron

Q.29 Write short note on two flat rate terry and two parts terry system.

Q.30 Write short note on UPS and its usage in railway system.

Q.31 What are the advantages of ‘sealed maintenance battery’ with viz—a-viz conventional battery.

Q.32 describe in brief various ‘fire preventing measures’ taken in a coach on Railway system.

Q.33 What are different types of pumps used in Railway colony. Write short note on any one of them.

Q.34 What are the criteria taken in to consideration while deciding pump capacity.

Q.35 Write ten steps taken for ‘energy conversation’ in railway system in a non electrified territory.

Q.36 Write short note on different type of train lighting system used in Indian Railways.

Q.37 Draw a schematic diagram of ‘110V DC train lighting system’.

Q.38 Write note on capacity of different batteries used in various type of coaches in IR.

Q.39 Write short note on level of illumination followed in different type of coaches in IR.

Q.40 Please indicate various types of maintenance schedules carried out in AC coaches.

Q.41 Write short note on following-
   a. SSP  b. BSP  c. CFP

Q.42 Write short note on Remote Control Centre.

Q.43 What are the different type of OHE bonds used in electrified territory.

Q.44 Write short note on following-
   a. Sub sector, b. Elementary section, c. Sector
d. Tension length
Q.45 Write short note on following-
   a. Stagger  b. Setting distance  c. Insulated overlap  d. Neutral section
Q.46 Write short note on following-
   a. Different type of Traction masts Used in OHE
   b. Different type of Foundations
   c. Different type of portals
Q.47 Write short note on following-
   a. Type of insulators
   b. Type of jumpers

Q.48 Write short note on quota of scheduled monthly inspections to be carried by TRD officers in a Division.

Q.49 Write short note on
   a. Arno convertor
   b. Tap changer
   c. SL
   d. SIU

Q.50 Indicate wheel arrangements for following type of locomotives-
   a. WAG4
   b. WM4
   c. WAP5
   d. WAG6

Q.51 What are the different maintenance schedules carried in an passenger & goods Electric Loco?

Q.52 What are the different classifications of running staff from safety gradation point of view?

Q.53 Write short note on following-
   a. PME
   b. LRD
   c. Periodical rest
   d. Running duty hours

Q.54 What are the different type of running allowances payable to loco running staff.

Q.55 a) Write five safety items provided in an electric loco.
   b) Write short note on 'Brake power certificate' and 'Caution Order'.