UNIT 6
Electric Traction-I

The propulsion of a vehicle either in streets or in railway systems is called traction. The system of traction involving the use of electricity is called electric traction.

Traction system may be broadly classified into two types. They are electric- traction systems, which use electrical energy, and non-electric traction system, which does not use electrical energy for the propulsion of vehicle.

Requirements of ideal traction system:

Normally, no single traction system fulfills the requirements of ideal traction system, why because each traction system has its merits and suffers from its own demerits, in the fields of applications.

The requirements of ideal traction systems are:

- Ideal traction system should have the capability of developing high tractive effort in order to have rapid acceleration.
- The speed control of the traction motors should be easy.
- Vehicles should be able to run on any route, without interruption.
- Equipment required for traction system should be minimum with high efficiency.
- It must be free from smoke, ash, durt, etc.
- Regenerative braking should be possible and braking should be in such a way to cause minimum wear on the break shoe.
- Locomotive should be self-contained and it must be capable of withstanding overloads.
- Interference to the communication lines should be eliminated while the locomotive running along the track.

Advantages and Disadvantages of Electric Traction

Electric traction system has many advantages compared to non-electric traction systems. The following are the advantages of electric traction:

- Electric traction system is more clean and easy to handle.
- No need of storage of coal and water that in turn reduces the maintenance cost as well as the saving of high-grade coal.
- Electric energy drawn from the supply distribution system is sufficient to maintain the common necessities of locomotives such as fans and lights; therefore, there is no need of providing additional generators.
- The maintenance and running costs are comparatively low.
- The speed control of the electric motor is easy.
- Regenerative braking is possible so that the energy can be fed back to the supply system during the braking period.
- In electric traction system, in addition to the mechanical braking, electrical braking can also be used.
that reduces the wear on the brake shoes, wheels, etc.

- Electrically operated vehicles can withstand for overloads, as the system is capable of drawing more energy from the system.

In addition to the above advantages, the electric traction system suffers from the following drawbacks:

- Electric traction system involves high erection cost of power system.
- Interference causes to the communication lines due to the overhead distribution networks.
- The failure of power supply brings whole traction system to stand still.
- In an electric traction system, the electrically operated vehicles have to move only on the electrified routes.
- Additional equipment should be needed for the provision of regenerative braking, it will increase the overall cost of installation.

**REVIEW OF EXISTING ELECTRIC TRACTION SYSTEM IN INDIA:**

In olden days, first traction system was introduced by Britain in 1890 (600-V DC track). Electrification system was employed for the first traction vehicle. This traction system was introduced in India in the year 1925 and the first traction system employed in India was from Bombay VT to Igatpuri and Pune, with 1,500-V DC supply. This DC supply can be obtained for traction from substations equipped with rotary converters. Development in the rectifiers leads to the replacement of rotary converters by mercury arc rectifiers. But nowadays further development in the technology of semiconductors, these mercury arc valves are replaced by solid-state semiconductors devices due to fast traction system was introduced on 3,000-V DC. Further development in research on traction system by French international railways was suggested that, based on relative merits and demerits, it is advantageous to prefer to AC rather than DC both financially and operationally.

Thus, Indian railways was introduced on 25-kV, 50-Hz single-phase AC system in 1957; this system of track electrification leads to the reduction of the cost of overhead, locomotive equipment, etc. Various systems employed for track electrification are shown in Table.

<table>
<thead>
<tr>
<th>S. no</th>
<th>System</th>
<th>Voltage</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DC system</td>
<td>600 V, 1,500 V, or 3,000 V</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>Single-phase AC system</td>
<td>15–25 kV is stepped down to 300–400 V</td>
<td>(\frac{162}{3}) Hz and 25 Hz</td>
</tr>
<tr>
<td>3</td>
<td>Three-phase AC system</td>
<td>15–25 kV is stepped down to 3,300–3,600 V</td>
<td>(\frac{162}{3}) Hz and 50 Hz</td>
</tr>
</tbody>
</table>

**Table:** Track electrification systems
SYSTEM OF TRACTION

Traction system is normally classified into two types based on the type of energy given as input to drive the system and they are:

1. **Non-electric traction system**
   Traction system develops the necessary propelling torque, which do not involve the use of electrical energy at any stage to drive the traction vehicle known as electric traction system.
   
   *Ex:* Direct steam engine drive and direct internal combustion engine drive.

2. **Electric traction system**
   Traction system develops the necessary propelling torque, which involves the use of electrical energy at any stage to drive the traction vehicle, known as electric traction system.
   
   Based upon the type of sources used to feed electric supply for traction system, electric traction may be classified into two groups:
   1. Self-contained locomotives.
   2. Electric vehicle fed from the distribution networks.

**Self-contained locomotives:**
In this type, the locomotives or vehicles themselves having a capability of generating electrical energy for traction purpose. Examples for such type of locomotives are:

1. **Steam electric drive**
   In steam electric locomotives, the steam turbine is employed for driving a generator used to feed the electric motors. Such types of locomotives are not generally used for traction because of some mechanical difficulties and maintenance problems.

2. **Diesel electric trains**
   Few locomotives employing diesel engine coupled to DC generator used to feed the electric motors producing necessary propelling torque. Diesel engine is a variable high-speed type that feeds the self- or separately excited DC generator. The excitation for generator can be supplied from any auxiliary devices and battery.

   Generally, this type of traction system is suggested in the areas where coal and steam tractions are not available. The advantages and disadvantages of the diesel engine drive are given below:

**Advantages**

- As these are no overhead distribution system, initial cost is low.
- Easy speed control is possible.
- Power loss in speed control is very low
- Time taken to bring the locomotive into service is less.
- In this system, high acceleration and braking retardation can be obtained compared to steam locomotives.
- The overall efficiency is high compared to steam locomotives.
**Disadvantages**

- The overloading capability of the diesel engine is less.
- The running and maintenance costs are high
- The regenerative braking cannot be employed for the diesel engine drives.

**Petrol electric traction**

This system of traction is used in road vehicles such as heavy lorries and buses. These vehicles are capable of handling overloads. At the same time, this system provides fine and smooth control so that they can run along roads without any jerking.

**Battery drives**

In this drive, the locomotive consists of batteries used to supply power to DC motors employed for driving the vehicle. This type of drives can be preferred for frequently operated services such as local delivery goods traction in industrial works and mines, etc. This is due to the unreliability of supply source to feed the electric motors.

**Electric vehicles fed from distribution network**

Vehicles in electrical traction system that receives power from over head distribution network fed or substations with suitable spacing. Based on the available supply, these groups of vehicles are further subdivided into:

1. System operating with DC supply. Ex: tramways, trolley buses, and railways.
2. System operating with AC supply. Ex: railways.

**Systems operating with DC supply**

In case if the available supply is DC, then the necessary propelling power can be obtained for the vehicles from DC system such as tramways, trolley buses, and railways.

**Tramways:** Tramways are similar to the ordinary buses and cars but only the difference is they are able to run only along the track. Operating power supply for the tramways is 500-V DC tramways are fed from single overhead conductor acts as positive polarity that is fed at suitable points from either power station or substations and the track rail acts as return conductor.

The equipment used in tramways is similar to that used in railways but with small output not more than 40–50 kW. Usually, the tramways are provided with two driving axels to control the speed of the vehicles from either ends. The main drawback of tramways is they have to run along the guided routes only. Reheostatic and mechanical braking can be applied to tramways. Mechanical brakes can be applied at low speeds for providing better saturation where electric braking is ineffective, during the normal service. The erection and maintenance costs of tramways are high since the cost of overhead distribution structure is costlier and sometimes, it may cause a source of danger to other road users.
Trolley buses:

The main drawback of tramways is, running along the track is avoided in case of trolley buses. These are electrically operated vehicles, and are fed usually 600-V DC from two overhead conductors, by means of two collectors. Even though overhead distribution structure is costlier, the trolley buses are advantageous because, they eliminate the necessity of track in the roadways.

In case of trolley buses, rehostatic braking is employed, due to high adhesion between roads and rubber types. A DC compound motor is employed in trolley buses.

SYSTEM OF TRACK ELECTRIFICATION

Nowaday, based on the available supply, the track electrification system are categorized into.

1. DC system.
2. Single-phase AC system.
3. Three-phase AC system.
4. Composite system.

1. DC system

In this system of traction, the electric motors employed for getting necessary propelling torque should be selected in such a way that they should be able to operate on DC supply. Examples for such vehicles operating based on DC system are tramways and trolley buses. Usually, DC series motors are preferred for tramways and trolley buses even though DC compound motors are available where regenerative braking is desired. The operating voltages of vehicles for DC track electrification system are 600, 750, 1,500, and 3,000 V. Direct current at 600–750 V is universally employed for tramways in the urban areas and for many suburban and main line railways, 1,500–3,000 V is used. In some cases, DC supply for traction motor can be obtained from substations equipped with rotary converters to convert AC power to DC. These substations receive AC power from 3-φ high-voltage line or single-phase overhead distribution network. The operating voltage for traction purpose can be justified by the spacing between stations and the type of traction motors available. Theses substations are usually automatic and remote controlled and they are so costlier since they involve rotary converting equipment. The DC system is preferred for suburban services and road transport where stops are frequent and distance between the stops is small.

2. Single-phase AC system

In this system of track electrification, usually AC series motors are used for getting the necessary propelling power. The distribution network employed for such traction systems is normally 15–25 kV at reduced frequency of 16 Hz or 25 Hz. The main reason of operating at reduced frequencies is AC series motors that are more efficient and show better performance at low frequency. These high voltages are stepped down to suitable low voltage of 300–400 V by means of step-down transformer. Low frequency can be obtained from normal supply frequency with the help of frequency converter. Low-frequency operation of overhead transmission line reduces the line reactance and hence the voltage drops directly and single-phase AC system is mainly preferred for main line services where the cost of overhead
structure is not much importance moreover rapid acceleration and retardation is not required for suburban services.

3. Three-phase AC system

In this system of track electrification, 3-φ induction motors are employed for getting the necessary propelling power. The operating voltage of induction motors is normally 3,000–3,600-V AC at either normal supply frequency or 16 ⅔-Hz frequency.

Usually 3-φ induction motors are preferable because they have simple and robust construction, high operating efficiency, provision of regenerative braking without placing any additional equipment, and better performance at both normal and sub-seduced frequencies. In addition to the above advantages, the induction motors suffer from some drawbacks; they are low-starting torque, high-starting current, and the absence of speed control. The main disadvantage of such track electrification system is high cost of overhead distribution structure. This distribution system consists of two overhead wires and track rail for the third phase and receives power either directly from the generating station or through transformer substation.

Three-phase AC system is mainly adopted for the services where the output power required is high and regeneration of electrical energy is possible.

4. Composite system

As the above track electrification system have their own merits and demerits, 1-φ AC system is preferable in the view of distribution cost and distribution voltage can be stepped up to high voltage with the use of transformers, which reduces the transmission losses. Whereas in DC system, DC series motors have most desirable features and for 3-φ system, 3-φ induction motor has the advantage of automatic regenerative braking. So, it is necessary to combine the advantages of the DC/AC and 3-φ/1-φ systems. The above cause leads to the evolution of composite system.

Composite systems are of two types.

1. Single-phase to DC system.
2. Single-phase to three-phase system or kando system.

Single-phase to DC system

In this system, the advantages of both 1-φ and DC systems are combined to get high voltage for distribution in order to reduce the losses that can be achieved with 1-φ distribution networks, and DC series motor is employed for producing the necessary propelling torque. Finally, 1-φ AC distribution network results minimum cost with high transmission efficiency and DC series motor is ideally suited for traction purpose. Normal operating voltage employed of distribution is 25 kV at normal frequency of 50 Hz. This track electrification is employed in India.
**Single-phase to 3-φ system or kando system**

In this system, 1-φ AC system is preferred for distribution network. Since single-phase overhead distribution system is cheap and 3-φ induction motors are employed as traction motor because of their simple, robust construction, and the provision of automatic regenerative braking.

The voltage used for the distribution network is about 15–25 kV at 50 Hz. This 1-φ supply is converted to 3-φ supply through the help of the phase converters and high voltage is stepped down transformers to feed the 3-φ induction motors. Frequency converters are also employed to get high-starting torque and to achieve better speed control with the variable supply frequency.

**SPECIAL FEATURES OF TRACTION MOTORS**

The general features of the electric motors used for traction purpose are:

1. Mechanical features.
2. Electrical features.

1. **MECHANICAL FEATURES:**

   - As the motor has to withstand the vibrations continuously due to the severe service conditions therefore motor should be robust.
   - The traction motor is located underneath a motor coach whose space is limited thus the motor must be small in overall dimensions specially in overall diameter.
   - As the motor is provided beneath the coach there is a possibility of ingress of dirt,dust,mud,water etc. thus the motor must be totally enclosed type.
   - The motor should have min possible weight.
   - Use of cast steel is preferred for magnetic circuit of traction motor in comparision of cast iron as it gives good mechanical strength.

2. **ELECTRICAL FEATURES:**

   - A traction motor must have high starting torque especially when the train is to be accelerated at high rate.
   - The traction motor must be amenable to simple speed control methods as the electric train has to be started and stopped very often.
   - The speed of the motor should fall with the increase in the load which in turn prevents the excessive loading as power output =torque*speed.
   - The motor should be capable of withstanding high voltage fluctuations In supply voltage since the traction motor is subjected to rapid voltage fluctuations owing to heavy starting current.
   - It should be possible to employ rheostatic or regenerative braking.
   - Traction motors should be capable to withstanding temporary interruptions at the instant of crossing over the cross overs and section insulators.
   - Traction motor should be capable of taking excessive load as it is subjected to very ardous duty.
Most suitable motors which meet the all most all above requirements are d.c series motors and compound in case of d.c system where single phase a.c series and three phase induction motor in case of a.c system.

**BRAKING**

If at any time, it is required to stop an electric motor, then the electric supply must be disconnected from its terminals to bring the motor to rest. In this method, even though supply is cut off, the motor continue to rotate for long time due to inertia. In some cases, there is delay in bringing the other equipment. So that, it is necessary to bring the motor to rest quickly. The process of bringing the motor to rest within the pre-determined time is known as braking.

A good braking system must have the following features:

- Braking should be fast and reliable.
- The equipment to stop the motor should be in such a way that the kinetic energy of the rotating parts of the motor should be dissipated as soon as the brakes are applied.

Braking applied to bring the motor to rest position is of two types and they are:

1. Electric braking.
2. Mechanical braking.

**Electric braking**

In this process of braking, the kinetic energy of the rotating parts of the motor is converted into electrical energy which in turn is dissipated as heat energy in a resistance or in sometimes, electrical energy is returned to the supply. Here, no energy is dissipated in brake shoes.

**Mechanical braking**

In this process of braking, the kinetic energy of the rotating parts is dissipated in the form of heat by the brake shoes of the brake lining that rubs on a wheel of vehicle or brake drum.

*The advantages of the electric braking over the mechanical braking*

- The electric braking is smooth, fast, and reliable.
- Higher speeds can be maintained; this is because the electric braking is quite fast. This leads to the higher capacity of the system.
- The electric braking is more economical; this is due to excessive wear on brake blocks or brake lining that results frequent and costly replacement in mechanical braking.
- Heat produced in the electric braking is less and not harmful but heat produced in the mechanical braking will cause the failure of brakes.
- In the electric braking, sometimes, it is possible to fed back electric energy during braking period to the supply system. This results in saving in the operating cost. This is not possible in case of mechanical braking.
Disadvantages

In addition to the above advantages, the electric braking suffers from the following disadvantages.

- During the braking period, the traction motor acts generator and electric brakes can almost stop the motor but it cannot hold stationary. Hence, it is necessary to employ mechanical braking in addition to electric braking.
- Traction motor has to work as a generator during braking period. So that, motor has to select in such a way that it should have suitable braking characteristics.
- The initial cost of the electric braking equipment is costlier.

Types of Electric Braking

Electric braking can be applied to the traction vehicle, by any one of the following methods, namely:

1. Plugging.
2. Rheostatic braking.
3. Regenerative braking.

Plugging

In this method of braking, the electric motor is reconnected to the supply in such a way that it has to develop a torque in opposite direction to the movement of the rotor. Now, the motor will decelerates until zero speed is zero and then accelerates in opposite direction. Immediately, it is necessary to disconnect the motor from the supply as soon as system comes to rest.

The main disadvantage of this method is that the kinetic energy of the rotating parts of the motor is wasted and an additional amount of energy from the supply is required to develop the torque in reverse direction, i.e., in this method, the motor should be connected to the supply during braking. This method can be applied to both DC and AC motors.

Rheostatic or dynamic braking

In this method of braking, the electric motor is disconnected from the supply during the braking period and is reconnected across same electrical resistance. But field winding is continuously excited from the supply in the same direction. Thus, during the starts working as generator during the braking period and all the kinetic energy of the rotating parts is converted into electric energy and is dissipated across the external resistance.

One of the main advantages of the rehostatic braking is electrical energy is not drawn by the motor during braking period compared to plugging. The rehostatic braking can be applied to various DC and AC motors.

Regenerative braking:

In this of braking the motor is not disconnected from the supply but remains connected to the supply system. This method is superior as compared to the other two methods of electric braking namely plugging and rheostatic braking because in case of rheostatic braking namely plugging and rheostatic braking because in case of rheostatic braking stored energy of the rotating parts of the motor and its
A driven machine is wasted whilst in plugging extra energy is drawn during the braking period and wasted whereas in regenerative braking no energy is wasted and rather it is supplied back to the system.

The method is used where the duty cycle require the braking or slowing of the machine more frequently. The condition for regeneration is rotational emf is more than applied voltage so that the current is reversed and mode of the operation changes from motoring to generating.

Regeneration is possible with a shunt and separately excited motors and with compound motor where as in case of series motors some modifications has to be made to enable the motor to act as generator.

**COMPARISON BETWEEN D.C TRACTION AND D.C TRACTION:**

<table>
<thead>
<tr>
<th></th>
<th>In D.C traction ,D.C series motor develop more starting and running torque and are capable of giving high acceleration and retardation.</th>
<th>In A.C trains , starting and running torque developed by a.c motor of same size less and hence acceleration and retardation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Number of speeds obtained by d.c motor is limited except by chopper method</td>
<td>Number of speeds obtained are many by tap changing method</td>
</tr>
<tr>
<td>3</td>
<td>D.C series motor are cheap, lighter &amp;more efficient</td>
<td>A.C motors are somewhat expensive and less efficient</td>
</tr>
<tr>
<td>4</td>
<td>In case of d.c ,the overhead distribution is lighter and less costly as the losses.</td>
<td>In case of a.c ,the overhead distribution is heavy and thus expensive</td>
</tr>
<tr>
<td>5</td>
<td>For a given length of track the number of substations required is more as the voltage above prescribe</td>
<td>For a given length of track the number of substations required is less as the voltage above prescribed</td>
</tr>
<tr>
<td>6</td>
<td>D.C .motors requires less maintenance</td>
<td>A.C .motors requires MORE maintenance</td>
</tr>
</tbody>
</table>