G.PULLAIAH COLLEGE OF ENGINEERING AND TECHNOLOGY: KURNOOL

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

CLASS/SEM: IV.B.Tech I-SEM **SUB: UTILISATION OF ELECTRICAL ENERGY**

UNIT-III

BASIC TERMS AND DEFINITIONS:

Traction System	The system that causes the propulsion of a vehicle in which that driving force or tractive force is obtained from various devices such as electric motors, steam engine drives, diesel engine dives, etc. is known as traction system.
Types of 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.
Braking	The process of bringing the motor to rest within the pre-determined time is known as braking.
Electric 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	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 ofvehicle or brake drum.
Drive	Drive is a system used to create the movement of electric train.

CONCEPTS

The system that causes the propulsion of a vehicle in which that driving force or tractive force is obtained from various devices such as electric motors, steam engine drives, diesel engine dives, etc. is known as traction system. 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.
- 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.

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.

SYSTEMS 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**

A 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:

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 tram ways, 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.

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

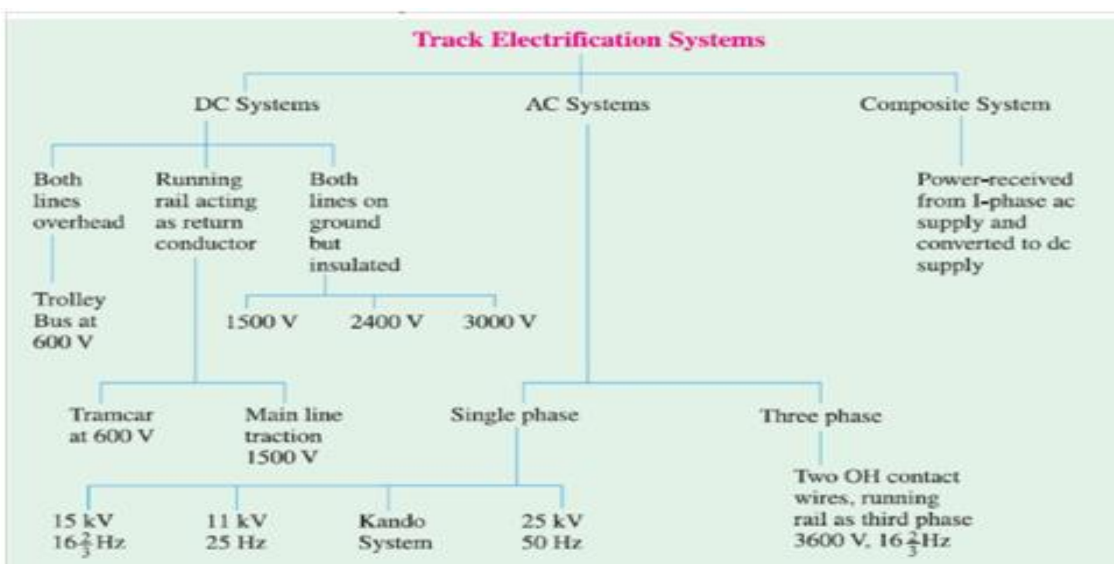


Fig.3.1.Types of Track Electrification Systems

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 600–750V is universally employed for tramways in the urban areas and for many suburban and main line railways, 1,500–3,000 V is used.

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 163⅔ 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 rtance 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 16⅔-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 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.

MECHANICAL FEATURES

1. A traction motor must be mechanically strong and robust and it should be capable of withstanding severe mechanical vibrations.

2. The traction motor should be completely enclosed type when placed beneath the locomotive to protect against dirt, dust, mud, etc.

3. In overall dimensions, the traction motor must have small diameter, to arrange easily beneath the motor coach.

4. A traction motor must have minimum weight so the weight of locomotive will decrease. Hence, the load carrying capability of the motor will increase.

ELECTRICAL FEATURES

High-starting torque*:*A traction motor must have high-starting torque, which is required to start the motor on load during the starting conditions in urban and suburban services.

Speed control*:*The speed control of the traction motor must be simple and easy. This is necessary for the frequent starting and stopping of the motor in traction purpose.

Dynamic and regenerative braking*:*Traction motors should be able to provide easy simple rehostatic and regenerative braking subjected to higher voltages so that system must have the capability of withstanding voltage fluctuations.

Temperature*:*The traction motor should have the capability of withstanding high temperatures during transient conditions.

Overload capacity *:*The traction motor should have the capability of handling excessecive overloads

Parallel running*:*In traction work, more number of motors need to run in parallel to carry more load.Therefore, the traction motor should have such speed–torque and current–torque characteristics and those motors may share the total load almost equally.

Commutation*:*Traction motor should have the feature of better commutation, to avoid the sparking at the brushes and commutator segments.

TRACTION MOTORS

No single motor can have all the electrical operating features required for traction. In earlier days, DC motor is suited for traction because of the high-starting torque and having the capability of handling overloads. In addition to the above characteristics, the speed control of the DC motor is very complicated through semiconductor switches. So that, the motor must be designed for high base speed initially by reducing the number of turns in the field winding. But this will decrease the torque developed per ampere at the time of staring. And regenerative braking is also complicated in DC series motor; so that, the separately excited motors can be preferred over the series motor because their speed control is possible through semi-controlled converters. And also dynamic and regenerative braking in separately excited DC motor is simple and efficient.

DC compound motors are also preferred for traction applications since it is having advantageous features than series and separately excited motors. But nowadays squirrel cage induction and synchronous motors are widely used for traction because of the availability of reliable variable frequency semiconductor inverters.

The squirrel cage induction motor has several advantages over the DC motors. They are:

1. Robust construction.

2. Highly reliable.

3. Low maintenance and low cost.

4. High efficiency.

Synchronous motor features lie in between the squirrel cage induction motor and the DC motor. The main advantages of the synchronous motor over the squirrel cage induction motor are:

1. The synchronous motors can be operated at leading power by varying the field excitation.

2. Load commutated thyristor inverter is used in synchronous motors as compared to forced commutation thyristor inverter in squirrel cage induction motors.Even though such forced commutation reduces the weight and volume of induction motor, the synchronous motor is less expensive.

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:

o Braking should be fast and reliable.

o 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

o The electric braking is smooth, fast, and reliable.

o Higher speeds can be maintained; this is because the electric braking is quite fast. This leads to the higher capacity of the system.

Disadvantages

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

o 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.

TYPES OF ELECTRIC BRAKING

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

1. Plugging.

2. Rehostatic 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 toboth 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 motor.

TRACTION MOTOR CONTROL

Normally, at the time of starting, the excessive current drawn by the electric motor from the main supply causes to the effects. So that, it is necessary to reduce the current drawn by the traction motor for its smooth control such as:

1. To achieve smooth acceleration without any jerking and sudden shocks.

2. To prevent damage to coupling.

3. To achieve various speed depending upon the type of services.

CONTROL OF DC MOTORS

At the time of starting, excessive current is drawn by the traction motor when rated voltage is applied across its terminals. During the starting period, the current drawn by the motor is limited to its rated current. This can be achieved by placing a resistance in series with the armature winding. This is known as starting resistance; it will be cut off during the normal running period thereby applying rated voltage across its armature terminals. By the resistance of stating resistor, there is

considerable loss of energy takes place in it.

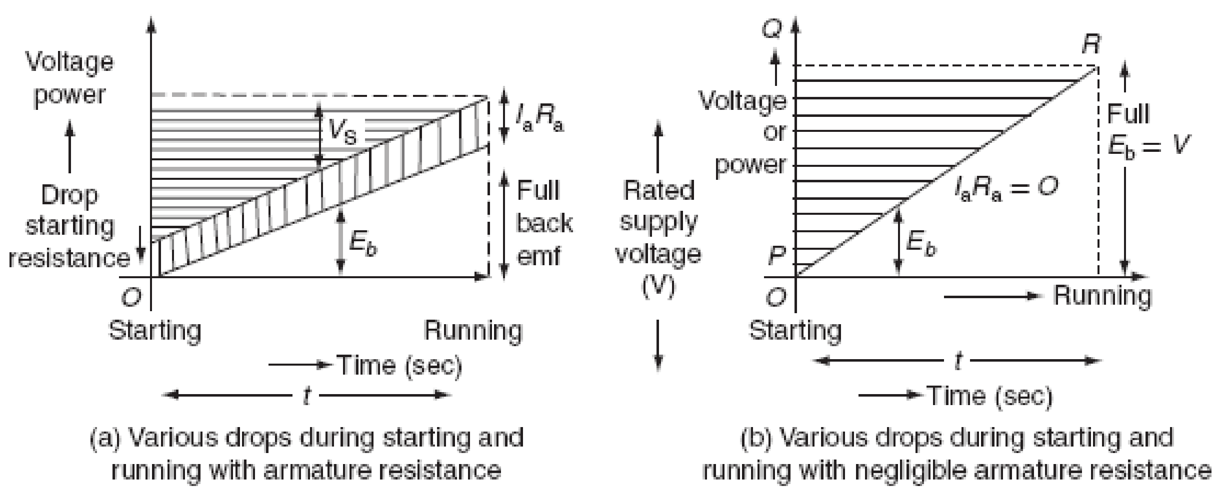


Fig.3.2.Traction control of DC motor

AUXILIARY EQUIPMENT

A traction system comprises of the following auxiliary equipment in addition to the main traction motors required to be arranged in the locomotive are discussed below.

Motor–generator set

Motor–generator set consists of a series motor and shunt generator. It is mainly used for lighting, control system, and the other power circuits of low voltages in the range 10–100 V. The voltage of generator is effectively controlled by automatic voltage regulator.

Battery

It is very important to use the battery as a source of energy for pantograph, to run auxiliary compressor, to operate air blast circuit breaker, etc. The capacity of battery used in the locomotive is depending on the vehicle. Normally, the battery may be charged by a separate rectifier.

Rectifier unit

If the track electrification system is AC motors and available traction motors are DC motors, then rectifiers are to be equipped with the traction motors to convert AC supply to DC to feed the DC traction motors.

Transformer or autotransformer

Depending on the track electrification system employed, the locomotive should be equipped with tap-changing transformers to step-down high voltages from the distribution network to the feed low-voltage traction motors.

Driving axles and gear arrangements

All the driving motors are connected to the driving axle through a gear arrangement, with ratios of 4:1 or 6:1.

TRANSMISSION OF DRIVE

Drive is a system used to create the movement of electric train. The electric locomotives are specially designed to have springs between the driving axles and the main body. This arrangement of springs reduces the damage not only to the track wings but also to the hammer blows. The power developed by the armature of the traction motors must be transferred to the driving axels through pinion and gear drive. There are several methods by which power developed by the armature can be transferred to the driving wheel.

Gearless Drive

Gearless drives are of two types.

DIRECT DRIVE

It is a simple drive. The armatures of the electric motors are mounted directly on the driving axle with the field attached to the frame of locomotive. In this system, the poles of electric motors should be flat so that the armature can be able to move freely without affecting of the operation. Here, the size of the armatures of the traction motor is limited by the diameter of the driving wheels. The arrangement of direct drive is shown in fig,

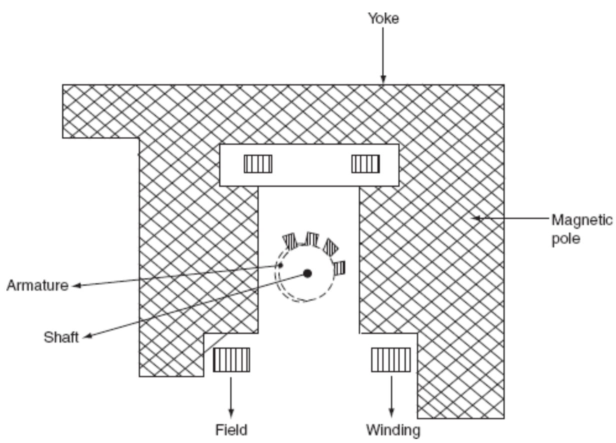


Fig.3.3.Direct drive

DIRECT QUILL DRIVE

Quill is nothing but a hallow shaft. Driving axle is surrounded by the hollow shaft attached by springs. The armature of the motor is mounted on a quill. The speed and the size of the armature are limited by the diameter of the driving wheels.

GEARED DRIVE

In this drive, the armature of the traction motor is attached to the driving wheel through the gear wheel system. Now, the power developed by the armature is transferred to the driving wheel through the gear system. Here, gear drive is necessary to reduce the size of the motor for given output at high speeds. The gear ratio of the system is usually 3–5:1.

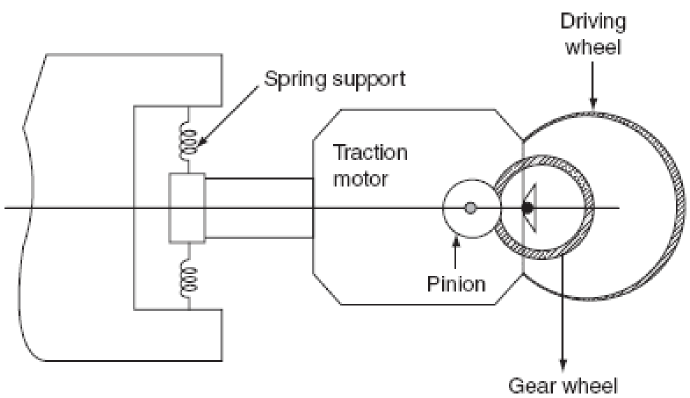


Fig.3.4. Geared drive

BROWN–BOVERI INDIVIDUAL DRIVE

In this drive, a special link is provided between the gear wheel and driving wheel, which provides more flexibility of the system.

AC LOCOMOTIVE

The various components of an ac locomotive running on single-phase 25-kV, 50-Hz ac supply are numbered in Fig.3.5.

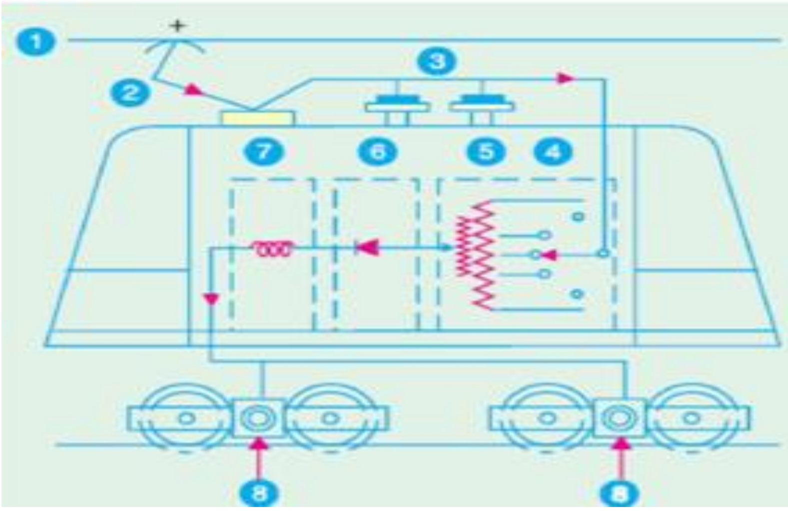


Fig.3.5.AC Locomotive

1. OH Contact Wire

2. Pantograph

3. Circuit Breakers

4. On-Load Tap-Changers

5. Transformer

6. Rectifier

7. Smoothing Choke

8. Dc Traction Motors.

OVERHEAD EQUIPMENT (OHE)

There are two systems of current collection by traction unit :

***i*)** Third Rail System and **(*ii*)** Overhead Wire System.

It has been found that current collection from overhead wire is far superior to that from the third rail. Moreover, insulation of third rail at high voltage becomes an impracticable proposition and endangers the safety of the working personnel.The simplest type of OHE consists of a single contact wire of hard drawn copper or silicon-bronze supported either by bracket or an overhead span. To facilitate connection to the supports, the wire is grooved as shown in Fig. Because there is appreciable sag of the wire between supports, it limits the speed of the traction unit to about 30 km/h. Hence, single contact wire system is suitable for tramways and in complicated yards and terminal stations where speeds are low and simplicity of layout is desirable. For collection of current by high-speed trains, the contact (or trolley) wire has to be kept level without any abrupt changes in its height between the supporting structures. It can be done by using the single catenary system which consists of one catenary or messenger wire of steel with high sag and the trolley (or contact) wire supported from messenger wire by means of droppers clipped to both wires as shown in Fig.3.6.

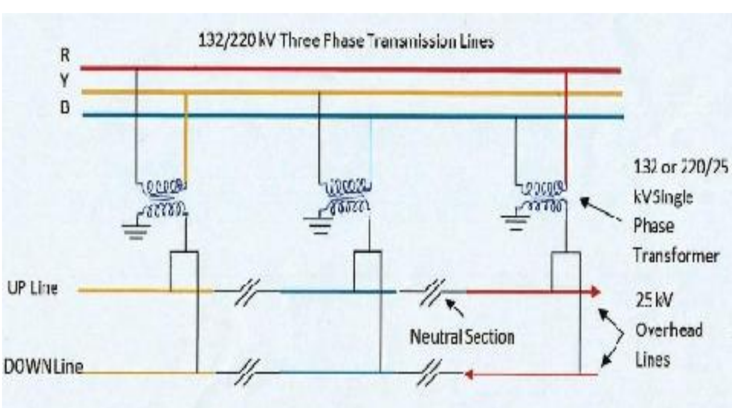


Fig.3.6. Overhead Wire System

COLLECTOR GEAR FOR OHE

The most essential requirement of a collector is that it should keep continuous contact with trolley wire at all speeds. Three types of gear are in common use :

1.Trolley collector **2.** Bow collector and **3.** Pantograph collector.

To ensure even pressure on OHE, the gear equipment must, be flexible in order to follow variations in the sag of the contact wire. Also, reasonable precautions must be taken to prevent the collector from leaving the overhead wire at points and crossings.

TROLLEY COLLECTOR

This collector is employed on tramways and trolley buses and is mounted on the roof of the vehicle. Contact with the OH wire is made by means of either a grooved wheel or a sliding shoe carried at the end of a light trolley pole attached to the top of the vehicle and held in contact with OH wire by means of a spring. The pole is hinged to a swivelling base so that it may be reversed for reverse running thereby making it unnecessary for the trolley wire to be accurately maintained above the centre of the track. Trolley collectors always operate in the trailing position. The trolley collector is suitable for low speeds up to 32 km/h beyond which there is a risk of its jumping off the OH contact wire particularly at points and crossing.

BOW COLLECTOR

It can be used for higher speeds. As shown in Fig., it consists of two roof mounted trolley poles at the ends of which is placed a light metal strip (or bow) about one metre long for current collection. The collection strip is purposely made of soft material (copper, aluminium or carbon) in order that most of the wear may occur on it rather than on the trolley wire. The bow collector also operates in the trailing position. Hence, it requires provision of either duplicate bows or an arrangement for reversing the bow for running in the reverse direction. Bow collector is not suitable for railway work where speeds up to 120 km/h and currents up to 3000 A are encountered. It is so because the inertia of the bow collector is too high to ensure satisfactory current collection.

PANTOGRAPH COLLECTOR

Its function is to maintain link between overhead contact wire and power circuit of the electric locomotive at different speeds under all wind conditions and stiffness of OHE. It means that positive pressure has to be maintained at all times to avoid loss of contact and sparking but the pressure must be as low as possible in order to minimize wear of OH contact wire. A diamond'type single-pan pantograph is shown in Fig. It consists of a pentagonal framework of high-tensile alloy-steel tubing. The contact portion consists of a pressed steel pan fitted with renewable copper wearing strips which are forced against the OH contact wire by the upward action of pantograph springs. The pantograph can be raised or lowered from cabin by air cylinders.

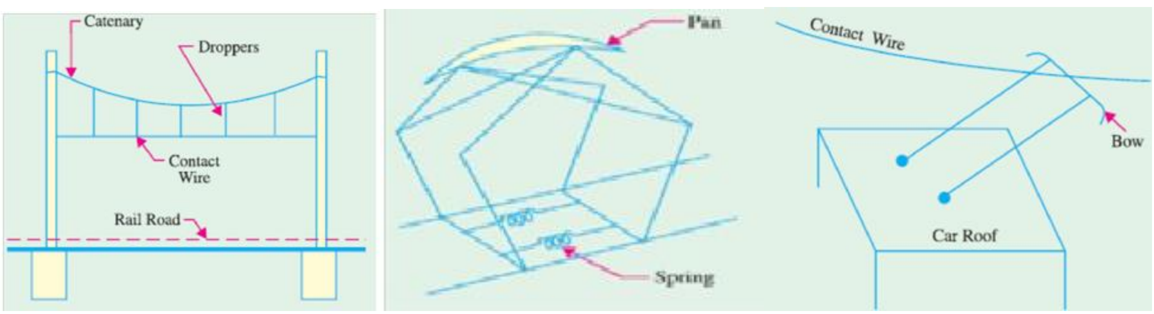
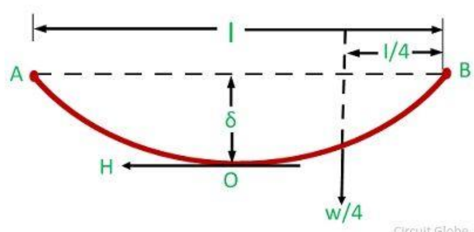


Fig.3.7. Types of Collector Gear for OHE

CALCULATION OF SAG & TENSION

Calculation of sag and tension in transmission line depend on the span of the conductor. Span having equal level supports is called level span, whereas when the level of the supports is not at an equal level is known as unequal level span. The calculation of conductor at an equal level shown below. Consider a conductor AOB suspended freely between level supports A and B at the same level.The lowest point of the conductor is O. Let the shape of the conductor be a parabola.



Let l – span length
w- weight per unit length of the conductor
δ – conductor sag
H – tension in the conductor at the point of maximum deflection O
T_B – tension in the conductor at the point of support B.

Consider OB is the equilibrium tension of the conductor and force acting on it are the horizontal tension H at O. The weight (w.OB) of the conductor OB acting vertically downwards through the center of gravity at a distance l/4 from B, and the tension T_B at the support B.

$$H\delta = (w.OB)l/4$$

$$H.\delta = w.\frac{l}{2} \times \frac{l}{4}$$

$$\delta = \frac{wl^2}{8H}$$

Above equation shows that the sag in a freely suspended conductor is directly proportional to the weight per unit length of the conductor, and the square of the span length and inversely proportional to the horizontal tension H.

Important Questions

1. Explain in detail the systems of track electrification.

2. Give a detail Comparison Between A. C And D. C Traction .

3. What are the special features of traction motors.

4. Explain the electric braking methods. i) Plugging (ii) Rheostatic braking (iii) Regenerative braking.
5. Explain in detail the over head equipment above the track.

6. Explain in detail about the auxiliary equipment apart from the driving motors for track electrification and Collector Gear for Overhead Equipment.

7. Explain in detail the Characteristics and Control of Locomotives and Motor Coaches for Track electrification.

8. Analyse with a neat sketch the Sags and Tensions Calculation for a trolley wire.