ELECTRICAL TRACTION & UTILIZATION

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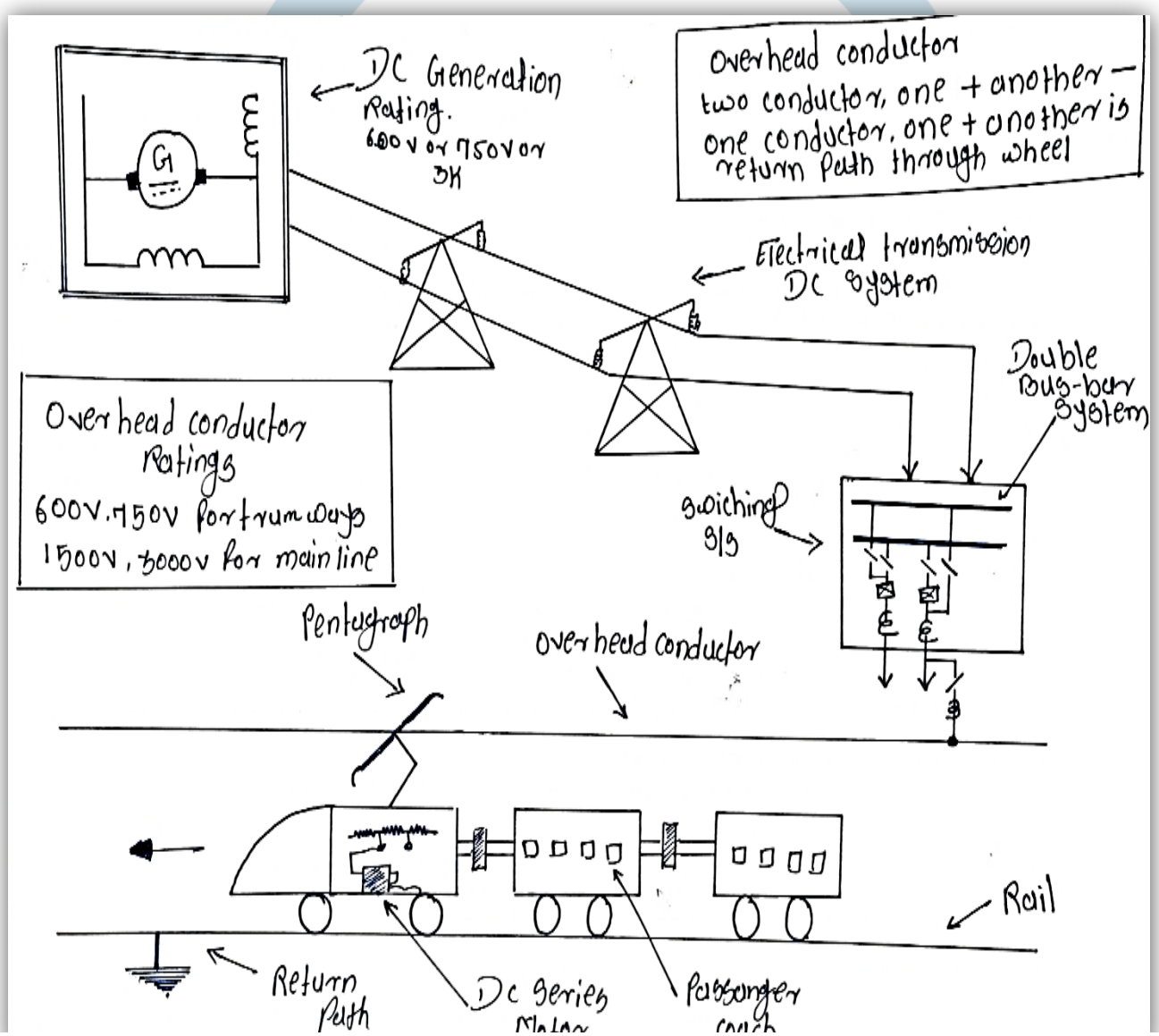
UNIT I: ELECTRICAL TRACTION SYSTEM

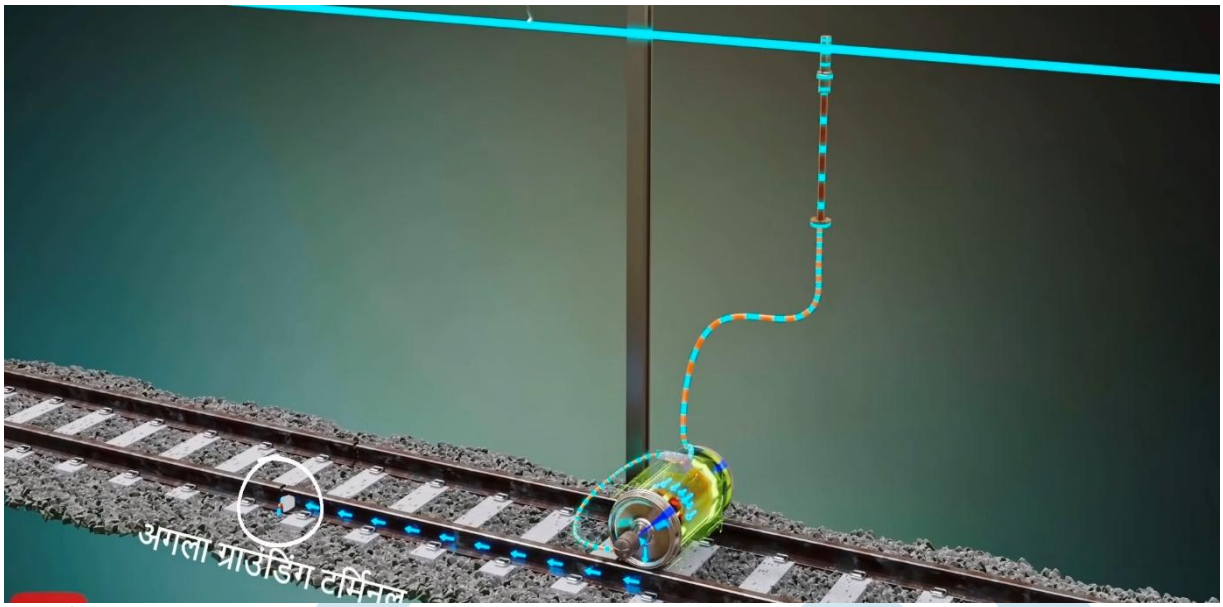
- **ELECTRICAL TRANMISSION SYSTEM EMPLOYING D.C. GENERATOR D.C. SERIES MOTOR.**

In this transmission system, the generation of power is dc and this generation is especially for traction system. Generally, DC shunt generator is used for to generate the DC power. Why use this generator because the voltage kept in constant. The generation of DC is 3.3 kV or 6.6KV or 33KV or according to requirement. That generating power is transmitted through transmission towers shown in above figure or block diagram. Transmitted power is transfer through two conductors one is positive and another is negative. After transmission of power fetch to switching substation. In switching substation, the double bus bar system is used. There are number of conductors are outgoing from switching substation. From that substation single conductor is used for electric traction or electrical trains. In this system single wire overhead conductor is totally DC voltage. Overhead conductor is act as a positive and return path through wheel rail shown in figure or block diagram. Generally, Reostatic breaking is used in this system and control of speed is done from tap changes through resistance sections.



In this system generally DC series motor is used for drive because DC series motor produce or give high torque. In this system current collector is pantograph system is used as shown in block diagram.

- **Advantages**
  - ✓ Return path is through wheel rail so another conductor cost is reduced



- ✓ Installation cost is low compared to AC system
- ✓ For main transmission of power, only two conductors are used
- ✓ Line losses is minimum because voltage rating is low according to AC system

- **Application**
- ✓ This system is used for tram way

In this system, following ratings are here

❖ **Supply fed to overhead conductor**

600-volt dc supply
750-volt dc supply
1500-volt dc supply
3000-volt dc supply

❖ **Types traction motor used**

DC series and compound motor are used

❖ **Weight of motor**

Weight off DC series motor is less than AC series motor

❖ **Maintenance cost**

Maintenance cost of DC motor is less than AC motor

❖ **Acceleration and retardation**

Acceleration and retardation is more than AC series motor

❖ **Overload capacity**

Overload capacity of DC motor is more than AC

❖ **Cross section of conductor**

In DC cross section of conductor is greater than AC

❖ **Regenerative breaking**

Regenerative breaking of DC is difficult

❖ **Design of supporting structure**

Supporting structure of DC is heavier

❖ **Number of traction substation required**

Traction substation are more than AC supply system

❖ **Transmission efficiency**

Transmission efficiency is less than AC supply system

❖ **Cost of track electrification**

In DC supply system it is more than AC supply system for same track distance

❖ **Insulation cost**

Insulation cost is less having voltage level is low than AC

❖ **Starting efficiency**

Starting efficiency is less than AC supply system

❖ **Application**

Used for AC main line service

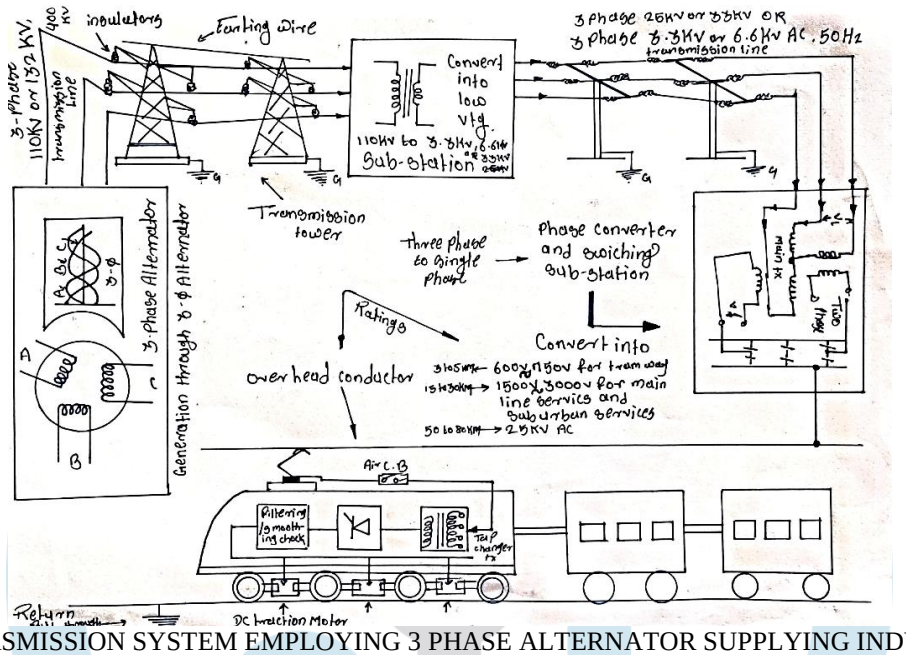
➢ **ELECTRICAL TRANSMISSION SYSTEM EMPLOYING 3 PHASE ALTERNATOR SUPPLYING D.C. TRACTION MOTOR**

In this system, three phase alternator is used for to generate the three phase power and that power is alternating in nature. Generation ratings is 110 KB or 132 KV according to their requirements is transmitted through transmission towers shown in

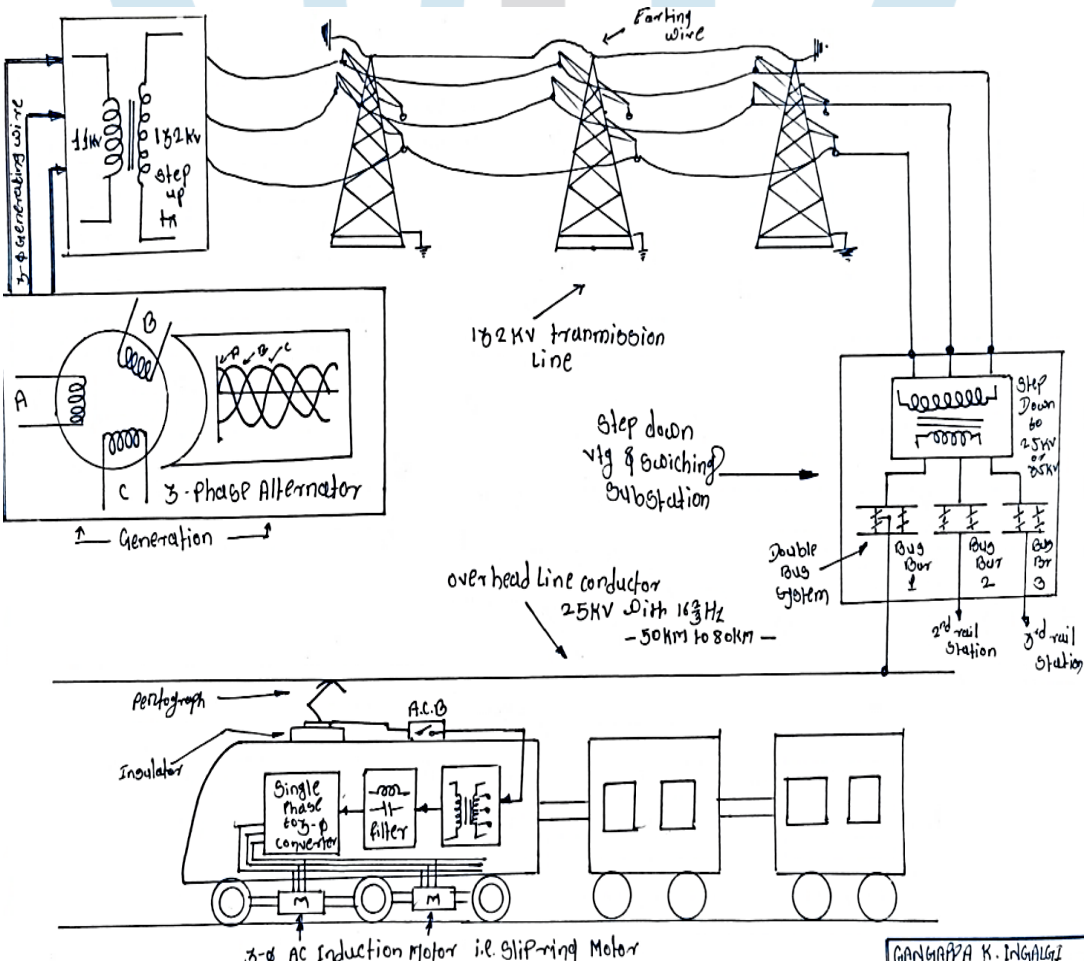
above block diagram. voltage level is very high so to necessary to reduce it through step down transformer. Voltage level converter substation is used in this system. Convert into 3.3 KV or 6.6 KV or 33 KV according to their requirements.

That power is transmitted up to switching substation, phase converter and switching substation is used for to control the voltage level and convert three phase convert into single phase supply through Scott connections. Double bus bar system is used in converter and switching substation and many phases is outgoing from it and supply to traction overhead conductor, figure or block diagram.

Overhead conductor is totally alternating in nature that power is taken from pantograph for main engine.



ELECTRICAL TRASMISSION SYSTEM EMPLOYING 3 PHASE ALTERNATOR SUPPLYING INDUCTION MOTOR.



- **Supply fed to overhead conductors**

Single phase 25 kiva 25 Hertz
Single phase 3.3 KV 2500 3000 Hertz
Three phase 3.3 KV 25 Hertz
Single phase 15 KV 16 KV 50 Hertz three phase Kendo
Single phase 25 KV 50 Hertz system

- **Types traction motor used**

Single phase AC series motor
Three phase AC series motor

- **Weight of motor**

Single phase AC motor is 1.5 times more than weight of DC series motor for same HP

- **Maintenance cost**

Maintenance cost of AC motor is more than DC motor

- **Acceleration and retardation**

Acceleration and retardation is less than DC series motor

- **Overload capacity**

Overload capacity of AC motor is less than DC

- **Cross section of conductor**

In AC cross section of conductor is less than DC due to high voltage

- **Regenerative breaking**

Regenerative breaking of AC is easily

- **Design of supporting structure**

Supporting structure of AC is lighter

- **Number of traction substation required**

In AC system traction substation are less than DC supply system

- **Transmission efficiency**

Transmission efficiency is more than DC supply as losses are less

- **Cost of track electrification**

In AC supply system is less than DC supply system for same track distance

- **Insulation cost**

Insulation cost is high having voltage level is high than DC

- **Starting efficiency**

Starting efficiency is more than DC supply system

- **Application**

Used for urban and suburban services

- **DIFFERENT BETWEEN DC SYSTEM AND COMPOSITE SYSTEM**

Points	DC SYSTEM	COMPOSITE SYSTEM
Types of traction motors used	DC series motor is used	Three phase sleeping induction motor is used
Number of traction substation required	For DC it is more for same distance to be travel	It is less than DC for same distance to be travel
Cross section of head conductor	Cross section of overhead conductor is increases	Cross section of overhead conductor is decreases
Losses	I square losses increases	I square loss is decreases
Regenerative breaking	It is difficult for DC motor	It is easily for AC motor
Starting efficiency	Low	High
Applications	Used for urban and suburban services	Used for hilly area where requirement of output is more

- **CHOICE OF TRACTION SYSTEM**

Battery Drive:

a) In this Derive the locomotive carries the secondary batteries which supply power to DC motor employed for driving the vehicles.
b) It is Suited for frequent operated services like, local delivery of goods in large towns with maximum run of 50 to 60 km.
c) It is easy to control & very convenient to use.
d) It has low maintenance cost & absence of fumes.
e) Disadvantages, small capacity of batteries, regularly charging, speed limitations.
f) Started by Series parallel grouping of batteries.
g) Special province of application of battery drive in mines.
h) Mine regulations provided for the use of trolley wire locomotives specially in gassy mines under following conditions:

i. The roadways are properly ventilated with minimum air velocity of 1 m/sec.
ii. The roadways have methane content not more than 0.3%.
iii. The roadways do not happen to be within the zone of mining influence.
iv. In gassy mines where gathering services are rendered, above conditions cannot be fulfilled and as such flame proof battery is to be use.
v. Because of limited amp hour capacity of batteries, it becomes utmost importance to have economy on the discharge of batteries.

- **Advantages:**

1. Battery driven is easy to control and very convenient to use.
2. Low Maintenance Cost.

- **Dis-advantages:**

1. The major dis-advantage of this type of drive is the small capacity of batteries and the necessity for frequent charging.
2. Limited speed range.

Hybrid Drive:

- In this Derives, Locomotive Derives power for part journey from overhead D.C system for other part form batteries.
- It is economical where long tunnels have to be excavated.
- Extensions of overhead conductor cannot be economical in small length.
- It takes power from overhead wires, trolley wires but switched to batteries.
- For long tunnels it will require large & costly batteries.
- Its application is in mines.
- Inside mines journey used batteries & for rest journey used trolley wires.
- Locomotive takes power from overhead trolley wires for most of the journey but at either ends it is switched on to batteries.
- These are recharged from trolley wire on the return journey.
- For long tunnels pure battery drive will require large and costly batteries.
- Certain sections of main haulage, roads either lie within the zone of mining influence or are inadequately ventilated.
- Mining regulations prohibit the use of trolley wire locomotives.
- For these sections, locomotives are worked from battery while for for the rest of journey, trolley wire feed is use

Flywheel Derive:

- A flywheel is a mechanical device specifically designed to efficiently store rotational energy (kinetic energy).
- Flywheels resist changes in rotational speed by their moment of inertia. The amount of energy stored in a flywheel is proportional to the square of its rotational speed and its mass in this Derives, K.E of driving wheels is used to derive the vehicles.
- Vehicle equipped with 3 phase I.M, coupled to the flywheel & D.C generator.
- At each Halting station, 3 phase I.M is supplied with power for sufficient time to bring the flywheel to full speed.
- K.E of fly wheel, on the way drives D.C generators to run the traction motor.
- K.E of flywheel is sufficient to move vehicle for long distance.
- It can be employed where distance between two station is not much.
- Main Advantage of this Drive is, no electric supply has to made between station.

- **Advantages of Flywheel over General Battery**

- Greater capability to store energy
- More life span
- Storage capability is not affected by charging / discharging cycle
- Less Maintenance involved
- Lesser thermal loss
- More round trip efficiency
- More peak-load capability
- Ease of operation

- **Applications of Flywheels**

- along with motor driven generator to store energy
- in automobile engines
- in electric cars to boost speed (in experimental stage)

- In advanced locomotive propulsion systems
- In advanced technology transit buses
- In satellites to control direction
- In Big electricity grids for protection against interruptions.
- In Wind turbine.

Tramways:

- The power is supplied to the tramcar is usually 600V dc volts, from a single overhead conductor fed at suitable points from a central power station or substation.
- The tramcar is provided with at least two driving axles so that necessary adhesion is secured and control is possible from either end.
- The use of two or more driving axles lends itself to the use of two motors with series-parallel control.
- Field weakening method may be employed to obtain higher running speeds for suburban service.
- Two drum type controllers, one at each end, usually employed to control the vehicle.
- Great dis-advantage is need overhead supply system which is costly & danger to road users.
- For very dense traffic in large cities the tramway is not economical for transportation.
- The equipment required for tramcars is similar to that used in railways but of smaller output (not exceeding 45 to 55 kW).
- Life is more than IC engine.
- The conditions for regenerative braking are not favorable but it may be used in hilly areas and on level track up to a speed of 20 mph.
- Rheostatic & mechanical braking is employed for normal service.
- Magnetic brakes are also employed for providing better retardation.
- Tramcars, if provided with magnetic brakes, can be excited by rheostatic braking current.

Trolley Bus:

- Serious Drawback of Tramways is lack of manoeurability in congested areas.
- These are overcome by Trolley bus is an electrical operated pneumatic tired vehicle of 600 V DC, two overhead wires & two collectors.
- In this Trolley Bus Overhead wire system is more expensive than Tramway.
- Another advantage is able to maneuver in traffic over a width of several meters on each side of trolley wire.
- Adhesion between rubber tired wheel & roadways is sufficiently high therefore need single driving axle is used.
- DC compound motor of output 50 to 100 kW is usually employed.
- Speed Control is obtained by field weakening (providing resistance in shunt field).
- Foot operated master controller are used, therefore hands of driver are free to steer the vehicle & apply handbrake.
- Regenerative braking is not employed.
- Rheostatic braking is used because of high adhesion between rubber-tire and road.
- Secondary batteries also provide in case of emergency.
- Body of vehicle is insulated from earth because of rubber-tire but resistance have to be checked at the end of the day.
- The trolley bus can accommodate slightly more passengers than an oil engine bus.

Oil engine buses are more expensive to maintain and operate than a trolley bus.

- **SYSTEM OF TRACK ELECTRIFICATION**

1. DC System
2. Single Phase AC system
3. 3 phase AC System
4. Composite System

a) Single phase to 3 phase system (Kendo System)
b) Single Phase AC to DC system

DC System:

- In this system the electric motors employed for getting the necessary motive power are usually dc series motors, although the compound motors are coming into favor for tramways and trolley buses.
- Operating Voltage is from 600 V to 750 V for Tramways for many sub-urban railways & from 1500 V to 3000 V for main line railways.
- Driving motor receive power from Distribution system.
- Distribution System Consist of one contact wire for tramways & 2 wire for trolley buses.
- The spacing of substation depends upon the voltage & traffic density of the route.
- For 600 V, space is 3 to 5 km in sub-urban area and for 1500 V to 3000 V, spaced is 15 to 40 km in main line substation are spaced.
- These substations receive AC power from 33 or 132 KV substation & convert to DC by suitable step-down transformer & rectifier.
- Substation uses supervisory control system; this reduces cost of transmission line & copper losses in transmission line.
- DC system has advantage, Better characteristics, low maintenance cost, smaller weight per KW output.
- Disadvantage is cost of substation is more, low operating voltage conductor for large cross section.
- As regards merits and demerits of dc system the dc motors have better characteristics, low maintenance cost and smaller weight per kW output, better speed control.
- The cost of substations is more due to heavy cost of converting machinery required for converting ac into dc and of additional equipment such as negative boosters etc. Required to keep the voltage of return rail within limits.
- The dc system is preferred for suburban services and road transport where stops are frequent and distances of run are small.

Single phase AC system

- In this system, AC series motors are used.
- Voltage employed are 15 KV to 25 KV at 25 Hz, which is step down locomotive to low voltage (300 to 400 V) to single phase AC series motor by means of transformer.
- The Distribution network, fed directly at high voltage from generating station, if electrification is under 30 KM radius from generation station.
- The spacing of substation is 50 to 80 KM because of Low current required at high voltage.
- Substation receives power & step down to voltage required value or change the supply frequency by frequency convertor.
- Low frequency is for better performance.
- Low frequency operation of AC series motor improves its communication properties, pp., Efficiency & reduces Line reactance and hence Voltage drop directly.
- Supply at low frequency get directly from generating station for traction.
- If industry is also getting power, so for low frequency operation, frequency convertors, that convert 50 Hz to 25 Hz is required.
- AC single phase system is adopted for main line service where cost of Overhead structure is more important.

Three phase AC system

3. In this system, Induction Motor operating at 3000 to 3600 V & normal frequency 25 Hz are employed for getting motive power.
4. 3 phase I.M is robust, simple in construction, high efficiency and property of Regenerative Braking.
5. Drawbacks are Low Starting Torque, High starting current & absence of speed control.
6. The Distribution system consist of 2 overhead wire & track rail for third phase & receive power from transformer substation of generating station.
7. Substation receives power from transmission station at power frequency & step down the voltage & change the frequency.
8. This system is employed in some hilly areas where output power required is high & regeneration on large scale is possible.
9. Disadvantages are, consist of characteristics of 3 phase Induction motor, no longer likely to be adopted.

Composite System

a) Single phase to 3 phase system (Kendo system)

b) Single Phase AC to DC system

Single Phase to three phase system (Kendo System): -

- In this system, single phase high voltage ac system is employed for distribution purpose & three phase I.M for getting the necessary motive power.
- Voltage used for distribution network is 15000 V at 50 Hz.
- Locomotive Carries a phase convertor for converting single phase into three phase supply at relatively low frequency.
- SCR used as inverter has made possible to get variable low frequency (1/2 to 10 Hz) at which induction motor develops high starting torque without drawing excessive current from the system and speed can be control by varying frequency.
- This is good possibility of this system of traction system for further adoption.

Single phase to Direct Current System:

- In this system, two systems are combined together by employing high voltage ac single phase system for overhead distribution and dc series motor for the necessary drive.
- In this system, Locomotive carries transformer & converting machinery to step-down the voltage & convert that into DC.
- The voltage for Overhead system is 25KV at 50 Hz, this system adopted in major traffic areas on main lines.
- This system has been decided to adopt in our country.

This system has many advantages:

- Due to high voltage, the Substation can be spaced at longer distances (50 to 80 Km) whereas the substations are spaced at 12 to 3 km in case of 3000 V dc system. and at 5 to 12 km in case of 1500V dc system.
- Greater amount of adhesion between wheel and rail track. In case of ac rectifier locomotive employing dc traction motors, coefficient of adhesion is obtained as much as 45% against the value of 27% in case of dc locomotives.

  AC substations are simpler and cheaper than dc substations as they only have step-down transformer and associated switchgear.

3. Starting efficiency is higher than that of a DC locomotive as in case of AC locomotive supply voltage for starting is reduced by means of 'on load tap changer' (OLTC) installed on either on pry. or sec. side of transformer where as in case of DC locomotive it is obtained by using starting resistors.
4. AC locomotives has less kW demand at starting than that of a DC locomotive owing to elimination of starting resistance in AC locomotives.

   This is of particular importance at peak hours specially when a number locomotives are to be started after an interruption of supply.

. Since DC series motor have ideal traction characteristics are employed in this system for getting the required propelling power, therefore this system has got the advantages of the DC system.

- There are some drawbacks with single phase AC system, such as unbalanced imposed on power supply system & interference with neighboring communication line.
- These drawbacks can be minimized by taking suitable precautions.

Precaution to overcome drawback

- Taking the supply for the traction substation at very high voltage (say 132 or 220 kV) and from a supply system having high capacity.
- Balancing of traction loads equally on all the 3 phases which is possible by connecting different traction substations across different phases in rotation.
- Employing the Scott or T-connected three phase/two phase transformers in the traction substation.
- iv. Replacing the open aerial communication lines by lead or aluminum sheathed U/G cables and earthling the sheathing of cables at regular intervals.
- Provide isolating transformer which reduced the induced voltage and keep them below 60 V under operating conditions.
- Making use of booster transformer and return conductor for suppressing interference at the source in case of populated areas.