RAILWAY TRACTION SYSTEM: CURRENT STATUS OF RAILWAY TRACK SYSTEM IN INDIA

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Abstract: In India most common means of transportation is railway. Most of the railway line is electrified, which increases the demand for electricity. Indian Rail uses only two phases from three-phase electric power supply to fed locomotive. Arrivals of locomotive at substation are dynamic load. Due to this voltage drop occur at OHE and three phase supply line also, result of this is inefficient operation of motor in loco. Due to excessive load the circuit breakers may trip without any fault on line. To avoid this problem many research is going on, some are given in this paper. This paper summarize the latest trends in the railway traction system .AC traction as an achievement in the power electronics after 1980's contributes to the present efficient high speed mass transportation service.

***Index Terms*- traction substation, OHE, loco, AC drive.**

Introduction

The railway as a means of transport is a very old idea. At its beginnings, it was mainly utilised in the central European mines with different means of traction being applied. But it did not come into general use until the invention of the steam engine. Since the 18th century it has developed faster and faster until in the 21st century it has become the most efficient means of transport for medium distances thanks to the development of High Speed. Railway is a largest means of transportation in India and it is ranked in the world as fourth largest railway network. Railway works under the Indian railway which is a state-owned organization of the Ministry of railway. Indian railway traction system uses 1.5 kV DC around Bombay and 25Kv ac is used in rest of the country. The supply for traction system is taken from state utility which is three phase source at 132/220 kV. The traction OHE required 25 kV supply, so only two phases are taken and step down to single phase 25 kV through transformer which is present at traction substation. This 25kV is fed to the OHE from feeder then to loco via pantograph which is at the roof of loco. When there are several loco at substation operating at a time then there is voltage drop at OHE. Because of this, inefficient operation of motor takes place as large amount of current is drawn from line

HISTORY OF RAILWAY TRACTION IN INDIA

In 1853 railways were started in India from Mumbai to Thane. Starting with steam locomotive, railway up gradation is continuously going with advancement of technology. The first commercial train journey on 16 April 1853 in India between Bombay and Thane with 14 carriage long train drawn by 3 locomotives named Sultan, Sindh and Sahib. It was around 21 miles in length and took approximately 45 minutes. The electrification of railway in Indian is started in 1925 as it is free from pollution, fast response than earlier loco, energy efficient regenerative breaking system. Indian railway adopted 25 kv 50 Hz AC traction which was based on French railway technology in 1957 and the first train run was on 1959. In 80's up-gradation of took place towards ac drives that is three phase induction motor drive. In 2000, a new WAP7 was built by CLW engineer which is most powerful and preferable passenger locomotive. DC-AC conversion has various advantages as energy cost due to VVVF drive, regeneration system, less maintenance.
The first railways were powered by steam engines. Although the first electric railway motor came on the scene halfway through the 19th century, the high infrastructure costs meant that its use was very limited. The first Diesel engines for railway usage were not developed until halfway through the 20th century. The evolution of electric motors for railways and the development of electrification from the middle of the 20th century meant that this kind of motor was suitable for railways. Nowadays, practically all commercial locomotives are powered by electric motors.

Fig.1 electric traction system

I. SUPPLY SYSTEMS OF ELECTRIC TRACTION :-The way of giving the power supply to locomotive unit is generally referred as traction electrification system. Presently, there are four types of track electrification systems are available based on the availability of supply. These are

- DC traction system
- Single phase AC traction syste Three phase AC traction system
- Composite traction system

DC Traction System:-*In this traction system, electrical motors are operates on DC supply to produce necessary movement of the vehicle. Mostly DC series motors are used in this system. For trolley buses and tramways, DC compound motors are used where regenerative braking is required. The various operating voltages of DC traction system include 600V, 750 V, 1500V and 3000V.*

- DC supply at 600-750V is universally employed for tramways and light metros in urban areas and for many suburban areas. This supply is obtained from a third rail or conductor rail, which involves very large currents.
- DC supply at 1500- 3000 is used for main line services such as light and heavy metros. This supply is drawn mostly from an overhead line system that involves small currents.

In both cases, only one conductor or rail is required to supply power to locomotive while track rails are used as return conductors in majority of cases. Both these supply voltages are fed from substations which are located 3-5 KM for suburban services and 40 to 50KMs for main line services. These substations receive power (typically, 110/132 KV, 3 phase) from electric power grids. This three phase high voltage is stepped-down and converted into single phase low voltage using Scott-connected three phase transformers. This single phase low voltage is then converted into DC voltage using suitable converters or rectifier such as power electronic converter, rotary converters, mercury arc converters, etc. The DC supply is then applied to the DC motor via suitable contact system and additional circuitry.

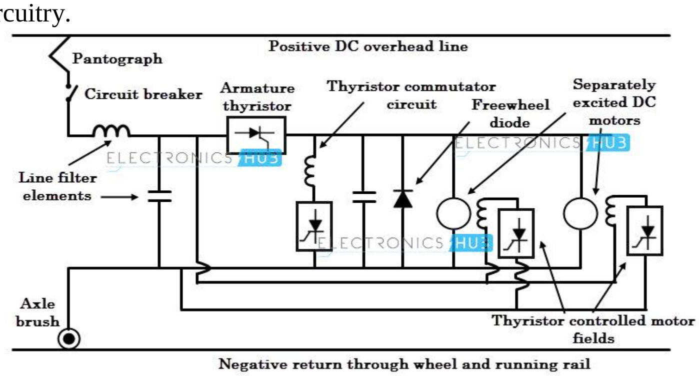


Fig.2 negative return through wheel and running rail

The advantages of this system include

- In case of heavy trains that require frequent and rapid accelerations, DC traction motors are better choice as compared AC motors.
- DC train consumes less energy compared to AC unit for operating same service conditions.
- The equipment in DC traction system is less costly, lighter and more efficient than AC traction system.
- It causes no electrical interference with nearby communication lines.

Despite all these advantages, DC electrical system necessitates AC to DC conversion substations relatively at very short distances. This is the main disadvantage of DC traction system.That's why this system is preferred only for suburban and road transport services wherein stops are frequent and also distance between stops is small.

Single Phase AC Traction System

In this type of traction system, AC series motors are used to produce the propulsion of vehicle. This system uses AC voltages from 15-25KV at a frequency of 16.7 (i.e., 16 2/3) or 25 Hz. This low frequency leads to give better performance and more efficient operation by the series motor. This single phase supply is fed to the locomotive unit via a single overhead line while track provides the return path. The high voltages (15-25KV) obtained from overhead conductor are stepped down to a suitable motor operating range (typically 300-400V range) using step-down transformer carried by the locomotive unit itself. The secondary tapping of this transformer offer variable voltage to AC series motor for speed regulation. The low frequency operation of overhead line reduces the communication interferences. Also, the reactance of the line is low at lower frequency and hence the voltage drop in the line is reduced. Because of this low line voltage drop, it is feasible to locate the substations at 50 to 80kms apart from each other. Therefore, this system is preferred for main line services where cost of overhead system is not a much important factor and for suburban services where rapid acceleration and retardation are not required.

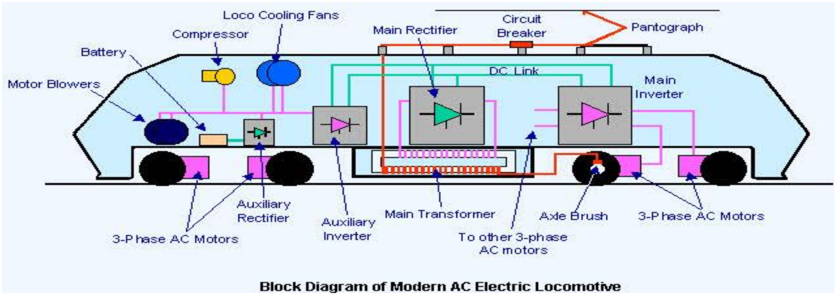


Fig.3 block diagram of modern ac electric locomotive

Three Phase AC Traction System

In this, three phase induction motors are used for the movement of locomotive. This system normally works on 3000-3600V AC at a frequency either 16 2/3 or normal supply frequency. This system employs two overhead lines for two phases, whereas the track forms third phase. These conductors are powered from substations which are rated at higher voltages and they receive power from three-phase transmission lines. The high voltages from transmission lines are stepped down to 3.3 KV (3000-3600 V) by transformers while the frequency is reduced by frequency converters installed at substations.

The three phase induction motor used in this system has the following characteristics; simple and robust construction, provision of regenerative braking without additional equipment and high operating efficiency, better performance, etc.However, these motors are suffer with some drawbacks such as high starting current, low starting torque, complicated overhead structure, especially at crossings and junctions and not suitable constant speed characteristics of induction motor traction work. These systems are adopted where high output power is required and also where automatic regeneration braking is needed. However, these systems do not found much favour compared to other systems.

Composite Traction System

The above discussed methods have their own merits and demerits. Single phase AC system has less distribution cost whereas DC system has excellent driving capability by DC series motors and three phase system has automatic regenerative braking capacity. So by combining the advantages of AC/DC and single/three phase systems, the overall performance of the traction system gives better result than individual system and hence the evolution of composite system.Basically composite systems are of two types, namely

- Single phase to three phase system
- Single phase to DC system

Single phase to three phase system

This traction system is also called Kando system. It consists of single phase16KV, 50 Hz supply which is fed from the substation and is being carried through a single overhead conductor.

The single phase supply is then converted into three phase supply of the same frequency using phase converter equipment in the locomotive itself. The three phase supply is then fed to induction motors to drive the locomotive.

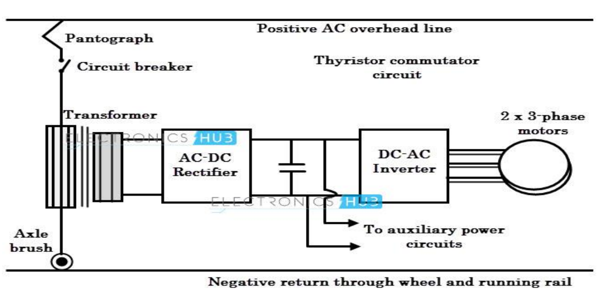


Fig.4 negative return through wheel and running rail

It is also possible to develop high starting torque of induction motors by reducing the supply frequency at ½ to 9 Hz by means of inverter controlled through silicon controlled rectifiers. The main advantage of this system is that the overhead two conductor arrangement of three phase AC system is reduced to a single overhead conductor and hence more economical.

Single phase to DC system

This traction system is most popular and widely used system everywhere. It combines the single phase high voltage AC distribution at industrial frequency with DC series motor traction. In this, the overhead line carries single phase, 25KV, 50 Hz supply which is then stepped down to a desired range using step-down transformer located in the locomotive unit itself.

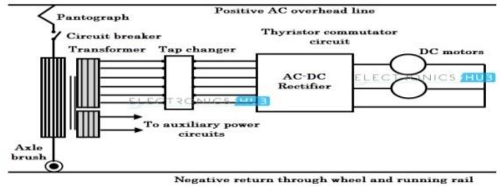


Fig.5 negative return through wheel and running rail

This single phase supply is then converted into DC using rectifier (in the locomotive) and then applied to DC series motor.The advantages of this system include higher starting efficiency, less number of substations, simple substation design and lower cost of fixed installations

PROBLEMS RELATED WITH TRACTION SYSTEM

A. Load Unbalancing

Conventional Power system is single phase or three phase system but traction system is two phase system. This use of two from three phase system causes unbalance in three phase network. The result of this unbalance is generation of negative phase sequence component besides positive phase sequence component which is harmful for power system as well as traction system. The control of the load balancer may be based on the component of the current through them is controlled by simple fact that three line to line voltages having the same thyristor valves, giving apparent variable impedance., means that the different phase sequence components are derived and it will acts to nullify the negative one.

B. Power Quality Issues

Power quality phenomenon related with traction system is voltage fluctuation, voltage and current distortion, voltage sag, harmonics, reactive power and lower power factor. There is uncertainty in arrival and departure of locomotive load at traction substation. If suppose at a time many loco arrives then there is overloading and this causes voltage drop and dip in voltage which in turn degrades voltage profile as power demand depends on loco traffic. Starting, acceleration, deceleration also causes the effect on voltage profile. Due to this relay actuates even though there is not a fault. Loco subsystem consists of converter which creates harmonics which also contributes to the degradation of voltage profile. Because of this problem traction motor draws large amount of current and actuates relay without any fault in traction system.

OPPORTUNITIES

To reduce the tariff it is required to reduce the losses and improve system performance. The compensation scheme can be used to overcome problem in traction system which are listed above but it should have lower cost and higher efficiency. Voltage support is essential to reduce voltage fluctuation at a given terminal of a line. Advantage of reactive power compensation in transmission systems is that it improves the stability of the ac system by increasing the capacity of maximum active power that can be transmitted.

II. CURRENTLY USES TRENDS

Use of FACTS Devices

Flexible AC Transmission Systems (FACTS), uses power electronic devices are widely used for mitigation of harmonics and sag which will in turn improve quality of power and enhancing the traction system reliability. Railway is one of the major load on the grid. There it is necessary to control the harmonics and voltage fluctuation FACTS-devices provide a better control on reactive power, power factor and improve the reliability of existing installations. As the length of line increases line losses also increases and need for FACTS also gets important. The FACTS-devices can be switched or controlled shunt compensation, series compensation. These devices are fast current, voltage or impedance controllers.

Static VAR Compensator (SVC)

Static VAR Compensator (SVC) is shunt connected FACTS devices which gives fast control of reactive power either by absorbing or injecting of reactive power to maintain voltage level. SVC consists of Thyristor Controlled Reactor (TCR), Thyristor Switch Capacitor (TSC) and mechanically switch capacitor or inductor harmonic filter. Advantages SVC in traction system:

- SVC has the capability of not only compensating the NSC but also reactive power.
- To improve voltage profile when one of two f eed er st at ion trips and two sections has to be fed from single station this not only degrades the traction efficiency and performance.
- To maintain power factor close to unity.

STATCOM

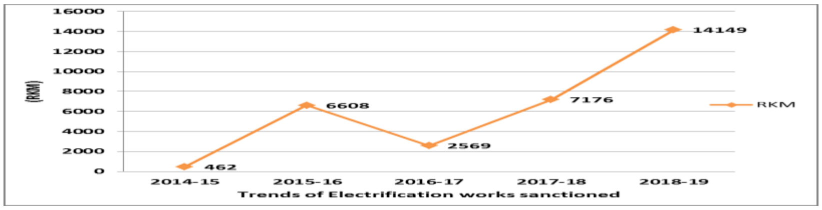
A STATCOM is a shunt device similar to SVC but it consists of a voltage source converter (VSC) and a coupling transformer, connected in shunt with the AC system. STATCOM is used to improve the system stability by reducing losses and reactive power compensation Compared with SVC, STATCOM has advantages such as fast speed, gat loading rate high work efficiency, and small output harmonic content. STATCOM is frequently used for mitigation of voltage flicker. STATCOM reduces the voltage flicker to the factor, negative phase sequence compensation, improves power factor.

Dynamic Voltage Regulator

DVR is most widely used series compensation with voltage source to improve voltage sag. DVR boosted the voltage and injects at required phase angle with respect to line voltage. DVR not only compensate line resistance but also reactance by injecting active and reactive power into system.

C. Railway Power Conditioner

Power quality phenomenon related with traction system is voltage fluctuation, voltage and current distortion, voltage sag, harmonics, reactive power etc. There is uncertainty in Railway power conditioner is intentionally used to compensate the negative power component. It consists of back to back converter with a dc link It is able to compensate the reactive power as well as harmonics. Table1 trends of electrification works



III. ADVANTAGES AND DISADVANTAGES OF ELECTRIFICATION

Advantages of Electrification:

Newly electrified lines often show a "sparks effect", whereby electrification in passenger rail systems leads to significant jumps in patronage / revenue. The reasons may include electric trains being seen as more modern and attractive to ride, faster and smoother service, and the fact that electrification often goes hand in hand with a general infrastructure and rolling stock overhaul / replacement, which leads to better service quality (in a way that theoretically could also be achieved by doing similar upgrades yet without electrification). Whatever the causes of the sparks effect, it is well established for numerous routes that have electrified over decades.

• Lower cost of building, running and maintaining locomotives and multiple units.

• less noise pollution (quieter operation)

• faster acceleration clears lines quicker to run more trains on the track in urban rail uses
• reduced power loss at higher altitudes (for *power loss* see Diesel engine)
• independence of running costs from fluctuating fuel prices
• service to underground stations where diesel trains cannot operate for safety reasons
• reduced environmental pollution, especially in highly populated urban areas, even if electricity is produced by fossil fuels
• easily accommodates kinetic energy brake reclaim using super capacitors

Disadvantages of Electrification:

Electrification cost: electrification requires an entire new infrastructure to be built around the existing tracks at a significant cost. Costs are especially high when tunnels, bridges and other obstructions have to be altered for clearance. Another aspect that can raise the cost of electrification are the alterations or upgrades to railway signalling needed for new traffic characteristics, and to protect signalling circuitry and track circuits from interference by traction current.

• Electrical grid load: adding a major new consumer of electricity can have adverse effects on the electrical grid and may necessitate an increase in the grid's power output. However, a railway can be electrified in such manner, that it has a closed and independent electrical network of its own and backup power available if the national or state electrical grid suffers from downtime.
• Appearance: the overhead line structures and cabling can have a significant landscape impact compared with a non-electrified or third rail electrified line that has only occasional signaling equipment above ground level.
• Fragility and vulnerability: overhead electrification systems can suffer severe disruption due to minor mechanical faults or the effects of high winds causing the pantograph of a moving train to become entangled with the catenary, ripping the wires from their supports. The damage is often not limited to the supply to one track, but extends to those for adjacent tracks as well, causing the entire route to be blocked for a considerable time. Third-rail systems can suffer disruption in cold weather due to ice forming on the conductor rail.

VII.CONCLUSION

As there is large load on traction system FACTS controller enhances the power transfer capability of existing line there by reduces the cost for new transmission line installation. SVC and STATCOM provide dynamic voltage support for high power traction system and prevents it from harmful voltage sag. But STATCOM is more superior then SVC. FACTS devices provide voltage control and harmonic reduction of AC supply systems which is due to a converter fed traction. DVR gives better solution to overcome sags in system voltage. Along with compensation, the DVR and FACTS devices can prevent the false triggering of protection relay due to over loading on line. TPC or railway power conditioner performance better to compensate NSC, harmonics and reactive power, simultaneously.

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