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A Review on Technology in Locomotives of Indian Railways

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*Abstract**:** The most energy efficient motorized land transportation system known to man is the operation of trains on a railroad. In order to reduce the dependence on petroleum based energy in railway transport, Indian Railways have been progressively switching over to Electric Traction. Railway electric traction describes the various types of locomotives and multiple units that are used on electrification systems around the world. This paper considers the evolution of technology inlocomotive**,** how dc traction was replaced by single phase ac traction and further by three phase ac. It focuses on advent of electric traction in India, working principle of electric multiple unit (EMU). In India we have mainline electric multiple unit (MEMU) train, a high speed electric train. And thereby this paper deals with the difference between EMU and MEMU trains .It also throws light on the progress of power electronics in the field of electric locos*

I. Introduction

A train consists of a series of railroad cars with steel wheels running along the steel rails of a railroad track. The power to move a train usually comes from one or more locomotives at the head of the train pulling the cars behind it. There are two types of locomotives today:
1: Diesel Electric
2: Electric
Locomotives in the US are usually powered by diesel but elsewhere(especially in Europe) many locomotives are electric and obtain electric power from an overhead wire strung above the track. In this paper the most relevant locomotive i.e Electric Traction is analyzed. There is a wide variety of electric traction systems around the world, which have been built according to the type of railway, its location and the technology available at the time of the installation. Many installations seen today were first built up to 100 years ago.A major advantage of electric trains is that diesel trains may use a wide variety of fuels such as coal. It results in lower maintenance cost and lower energy costs. Electric traction reduce the haulage of heavier loads at higher speeds, thus increasing the output. It is a pollution free system and with use of modern high horse power locos having regenerative braking, it becomes vastly energy efficient. The chief disadvantage of electrification is the cost of infrastructure.

History

In the last 20 years there has been a gigantic acceleration in railway traction development. This has run in parallel with the development of power electronics and microprocessors.

- Electric traction was introduced on Indian Railways in the year 1925 on 1.5KV DC and the first electric train ran between Bombay's Victoria Terminus and Kurla along the Harbour line of CR, on February 3,1925, a distance of 9.5 metres, flagged off by then Governor of Bombay Sir Leslie Orme Wilson.

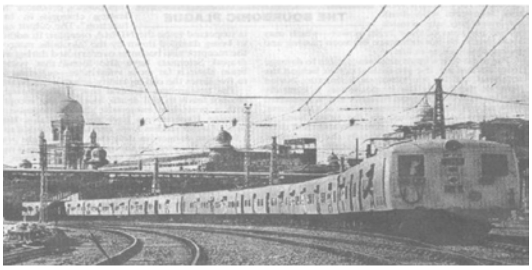

Figure 1: One of the earliest DC EMUs in Mumbai suburban area

- In the year 1957, Indian Railways decided to adopt 25KV 50Hz AC traction based on French Railway technology. The first 25KV AC electrified section was Burdwan-Mughalsarai, completed in 1957. The first actual train run (apart from trial runs) using 25KV AC was on December 15,1959 on the Dongaposi-Rajkharswan section.

Figure 2: Start of AC Electric Traction on 15th December, 1959

Considering the advantages of 25KV AC system, it was commissioned between Bina and Katni on January 16,1995. This was later extended to Bishrampur.

Electric locomotive

An electric train or an electric locomotive is a locomotive powered by electricity from an external source. External sources may include overhead lines, third rail, or an on-board electricity storage device such as a battery or flywheel system.

There are two basic types of Railway Electrification:
1: DC (Direct Current)
2: AC (Alternating Current)

- Direct Current (DC) traction units use direct current drawn from either a conductor rail or an overhead line. AC voltage is converted into DC voltage by using rectifier.

- Alternating Current (AC) traction units draw alternating current from an overhead line.

Most urban rail transit uses DC to run without locomotives, each car having its own motors. In order to have an efficient power distribution system, a much higher voltage is desirable in the overhead lines than the voltage required to operate the motors. Thus modern locomotives contain devices to reduce the voltage to that suitable for the motors. DC voltages are usually 600 to 3000 volts, while AC is usually 12000 to 25000 volts. With 3000 volts DC it is possible to put 4 traction motors in series and get only 750 volts on each motor.

In India,1500V DC and 25kV AC, 50Hz is used for main line trains. The 1500V DC overhead system is used around Mumbai. The Mumbai region is the last bastion of 1500V DC electrified lines on Indian Railways.

Electric currents create magnetic fields to which people are exposed. Advantage of DC over AC is that DC currents create a steady magnetic field and are thought to pose no hazard to health whereas AC fields may increase the risk of leukemia in children.

II. Three Phase Technology

After reaching a power level of 5000HP, there was no further scope for up-gradation with minimal inputs in the dc drive locomotives, as the capacity of equipment in the traction chain was fully utilized. Any further upgradation needed a total new design. During the late 80's development took place in developed railways towards three phase induction motor based drives for traction due to the distinct advantages of less maintainence intensiveness in comparision to dc drives. Induction motor drives are also known for extremely effective regeneration, thereby reducing the energy cost. A new variant WAP7 was intended for passenger operation for service speeds upto 130KM/hr, which is the maximum speed of Rajdhani and Shatabdi trains today.

Advantages of three phase locos:

- Better reliability and availability of three phase locos.
- It regenerates energy about 15-18%, a moving power house. Regeneration of power is available in three phase locomotives. Regenerative braking effort is available from the full speed till dead stop. Consequently, the overall efficiency of operation is higher.
- Maintenance cost of a three phase locomotive is less due to the absence of brush-gear/commutator in the traction motors and switch gears in the power circuit.
- Three phase locomotives operates at near unity power factor throughout the speed range except at very low speeds.

III. Mainline Electric Multiple Unit (Memu) Trains

The recent development of the Mainline EMU (MEMU), manufactured by ICF was intended to address precisely this, to allow EMU operations in more areas. They have a width of 10'8''. MEMUs run on 25kV AC power. MEMU driving motor coaches seat 76 and the trailer coaches seat 108. They have a rated speed of about 105km/h and are equipped with electro-pneumatic brakes, the trailer coaches weigh about 33.6 tonnes and the motor coaches weigh about 60 tonnes. Earlier versions of MEMUs have a top speed of 60km/h. RDSO improved on these by increasing the horsepower of the traction motors and providing a weak field arrangement in them for higher speeds.

MEMU trains are designed for semi-urban and rural areas, unlike **EMU** (**electric multiple unit**) trains that are designed for urban and semi-urban areas. **MEMU** trains also have end vestibules (gangway connections) that are not found on **EMU** trains. In EMUs one power car is required for 3 coaches. So for an EMU 12 coaches in length will have 4 power cars. So MEMU trains generate more power (or they are more powerful) than EMU trains. That's why MEMUs are normally 16-20 coaches long whereas EMUs are generally of 12 coaches only. MEMU trains run on main line where normal passengers don't. EMU are slower than MEMU.

IV. Electric Multiple Unit (Emu):

Electric trains in big cities are called EMU, electric multiple unit trains. The term multiple unit is used to describe a self-propelling train unit capable of

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coupling with other units of the same or similar type and still being controlled from one cab. In the year 1893, the first EMUs were used on the elevated Liverpool Overhead Railway. It had two carriages and later got extended to three carriages, with the front and rear carriages powered.Majority of EMUs have nine or twelve coaches and sometimes even fifteen to handle rush hour traffic. In EMU's 1 power car is required for 3 coaches so for an EMU 12 coaches in length will have 4 power cars. Most EMUs are used as passenger trains, but some are also specialized for non-passenger roles, such as carrying mail or luggage. EMUs are popular in railways because of their fast acceleration and pollution-free operation.

V. Power Supply

The electric railway needs a power supply that the trains can access at all times. It must be safe, economical and user friendly. It can use either DC (direct current) or AC (alternating current), the former being, for many years, simpler for railway traction purposes, the latter being better over long distances and cheaper to install but, until recently, more complicated to control at train level. Transmission of power is always along the track by means of an overhead wire or at ground level, using an extra, third rail laid close to the running rails.

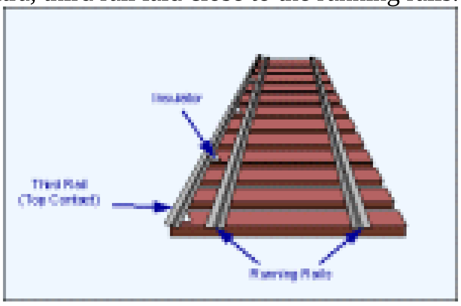

Figure: DC 3-Rail Traction System

The above diagram shows a DC 3-Rail Traction System with the location of the current rail in relation to the running rails. The third rail system uses a "shoe" to collect the current on the train. In AC systems, the supply of electricity is through an overhead system of suspended cables or wires known as the **catenary.** A contact wireor contact cable actually carries the electricity. It is suspended from or attached to other cables above which it ensures that the contact cable is at a uniform height and in the right position. DC can use either an overhead wire or a third rail; both are common. Both overhead systems require at least one collector attached to the train so it can always be in contact with the power. Overhead current collectors use a "**pantograph**", so called because that was the shape of most of them until about 30 years ago. The return circuit is via the running rails back to the substation. The running rails are at earth potential and are connected to the substation. Pantograph is a metal structure which can be raised or lowered to make contact with the overhead contact cable and draw electricity from it to power its motors. (Usually it goes first through a transformer and not directly to the motors.) It is held up by compressed air pressure. It is designed to collapse if it detects an obstruction. It can also be lowered manually to isolate the locomotive or train. The pantograph has one or two blades, shoes or collector pans that actually slide against the contact wire. It has the following characteristics:

- It must remain in continuous contact with the overhead wire while the EMU is running.
- It must not abrade the overhead wire and neither must it be subject to excessive wear.
- It must have low aerodynamic resistance.

VI. Working Of EMU

Catenary and pantograph together transmit the electricity required to power the motor of an electric train. Electricity is fed to the catenary via substations. When the pantograph enters into the contact with the catenary, it’s as if the train was plugging itself into the circuit. The pantograph is a system of articulated arms fixed to the roof of locomotive. It holds and extends along a vertical axis, its horizontal end piece is called as the head. This head is fitted with carbon strips. Their number and type depends on nature and intensity of current to be transmitted; DC or AC for example. These carbon strips slide along the catenary contact wire, thus capturing the electricity required to power the train’s traction motor. The catenary is more complex than a simple power cable minimum it is made up of messenger cables, contact wires, droppers, steady arms and tensioning devices. All these are supported at regular intervals. The catenary’s architecture is designed so that even at high speed, contact between the catenary contact wire and the pantograph is permanent and uninterrupted. The cables of the overhead lines are so heavy that suspended between two points they do not form a straight line but sga due to their weight. For speeds about 60km/h and in order to guarantee a continuous contact between the catenary and the head of the pantograph thus avoiding excessive power loss, the catenary contact wire must be maintained in a horizontal position. It must also be rigid enough to interact in a dynamic way with the pantograph. The solution is that the contact wire is supported at regular intervals with the droppers. Due to these droppers and tensioning loads the contact wire is maintained in the horizontal axis with a controlled level of rigidity. These droppers have variable lengths calculated in accordance with several parameters such as the tensioning loads of the contact and messenger wires or their mechanical characteristics. Almost 10,000 kms of catenary wires have been installed worldwide.

VII. Conclusion

Electric trains reduce the dependency on fossil fuels, run on higher speed and thus are more efficient. In comparison to the principal alternative, the diesel engine, electric railways offer substantially better energy efficiency, lower emissions and lower operating costs. The recent development of the Main-line EMU (MEMU), manufactured by ICF is more powerful than EMU. **EMU** (**electric multiple unit**) trains are designed for urban and semi-urban areas. Electric locomotives are usually quieter, more powerful, and more responsive and reliable than diesels. Electricity is typically generated in large and relatively efficient generating stations, transmitted to the railway network and distributed to the trains. Electrification has many advantages but requires significant capital expenditure. Selection of an electrification system is based on economics of energy supply, maintenance, and capital cost.

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