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Railway Traction System: Current Status and Apportunities

Shweta E. Kale
PG Student
G.H. Raisoni College Of Engineering
Department of electrical Engineering,
India.

K. D. Joshi
Associate professor
G.H. Raisoni College Of Engineering
Department of electrical Engineering,
India.

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.

The paper shows the present scenario and advancement of Indian railway

Index Terms: traction substation, OHE , loco

I. INTRODUCTION

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.

II. 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.

Fig.2. Early Locomotive model

III. CURRENT STATUS OF TRACTION IN INDIA

Electrification is most important up gradation of Indian railway. But this increases the consumption electricity. There is most important to study traction system and its effect on power system .A total 27,999 (route) km was electrified by 31 march 2016 which is 42.42% of the total railway network. In present scenario approximately 51.2% of passenger traffic and 65.02% of freight traffic is operated by electric traction. The detailed traction system can be described by dividing it into three sections such as three phase supply system, traction substation and locomotive system which is described as follows:

A. Three phase supply system

The generated power from generating station is transmitted to the grid substation via three phase distribution system. The three phase distribution system is at voltage level of 220 KV or 132 KV from normal. But Indian railway accepted the 25 kv system therefore the available three phase voltage has to be step down to 25 kv. The step down transformer is connected to any of two phases of normal three phase lines to step down the 220/132 Kv to 25kv. This causes imbalance and dip in voltage in three phase system. For balancing of the load on the power system, the OHE contact wires are supplied from A-B, B-C, C-A at regular intervals (about 40-60Km) at traction substation .If one phase is fed from A-B then the next substation is fed from b-c phase. This type of combination of phases does not change the phase sequence of the system. To avoid the short circuit between the phase’s neutral section or dead zone is provided between two consecutive sections which is powered from two different set of phases.

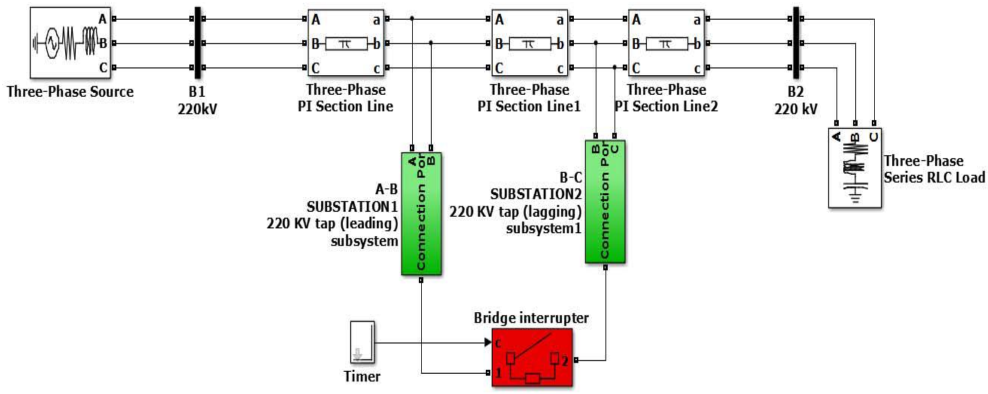

Fig. 2 Typical Feeding Arrangement of 25 KV Traction System of Indian Railway.

Fig.2 shows, two substations are fed from different phases and in between this bridge interrupter is shown. The bridge interrupter is for loco to switch over safely from A-B phase to B-C phase.

B. Traction substation

At traction substation 220/132 kV is step down to 25 kV through single phase transformer. The 25 kV AC voltage is drawn as single phase system from a three phase systems. One connection of transformer is permanently solidly earthed which work as return. The traction substation not only consists of transformer but also various protective devices. It includes lightning arrestor, circuit breaker, transformer protection etc. This 25 kv is then supplied to the feeder then to the OHE line.

Fig.3 Arrangement of Traction Substation

C. Locomotive Subsystem

The power required for propulsion of loco is taken from OHE via pantograph. The AC or DC drives are used for loco. The traction motors used are DC series motor, three phase induction motor. But new locos are come up with three phase induction motor. The induction traction motor has many advantages over dc series motor like high power at low speed, absence of commutator, VVVF control and regenerative breaking system. In today's scenario WAP7 and WAG9 are the passenger and goods loco which are mostly used. It consists of transformer, DC link in between line converter and motor converter. The specification given below is from WAP7 manual.

	specification
Traction transformer	25kV – 1269V
DC link	2800V
Traction motor	3 phase squirrel cage induction motor 1283/2484 rpm
Power output	Max 5100 kW (6000 hP) (1 motor 850kW)

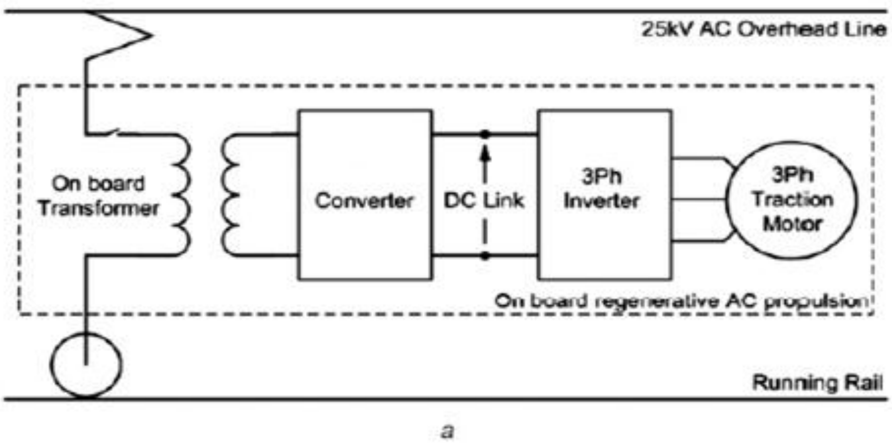

Fig.4. Block diagram of AC locomotive

IV. 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.

V. 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.

A. 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.

1) 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.

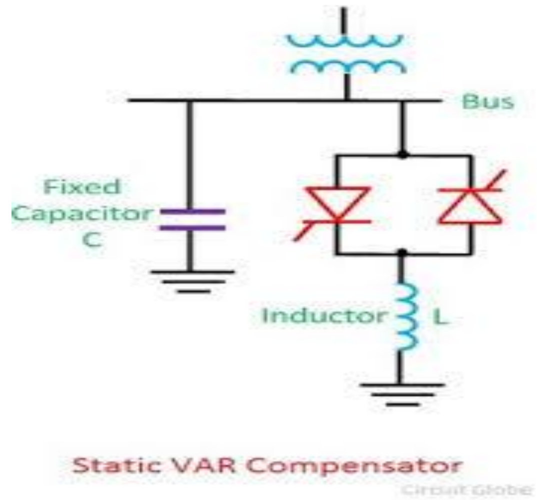

Fig.5 Structure of SVC

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 feeder station 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.

2) 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 [7].

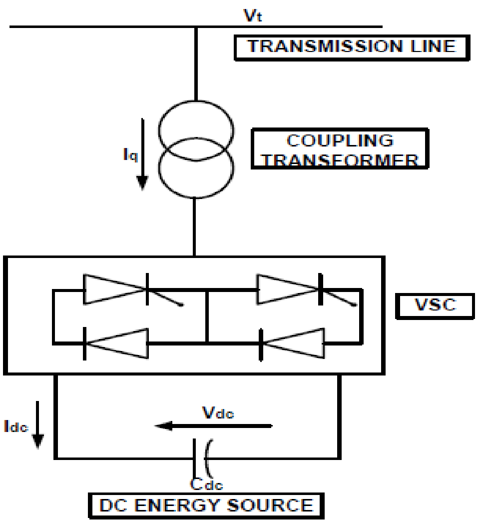

Fig.6 Structure of STATCOM

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.

A. 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.

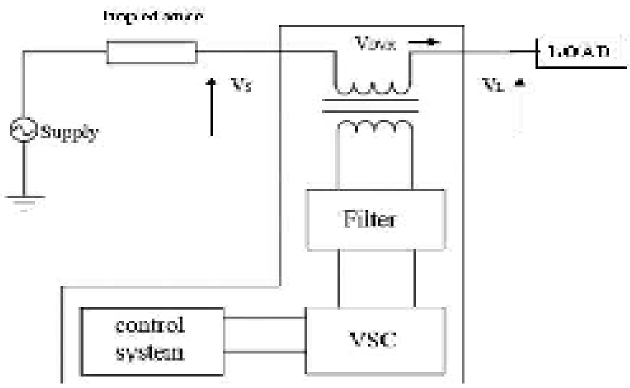

Fig.7 Structure of DVR

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.

VI. 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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