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Modern propulsion equipment for new Bombay suburban trains

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The city of Bombay has the largest suburban network in India with 275 route kilometres and 90 stations. The Indian Railways decided to modernize its fleet in Bombay by introducing of new EMUs with a state-of-art three-phase propulsion equipment. In the last years, they awarded two orders comprising the complete electrical equipment for new dual voltage electrical multiple units.

Moderne Antriebsausrüstung für neue Vorortzüge in Bombay
Die Stadt Bombay hat das größte Vorortbahn-Netz Indiens mit 275 km Streckenlänge und 90 Stationen. Die Indian Railways haben beschlossen, ihre dortige Fahrzeugflotte durch neue Züge mit einer Drehstrom-Antriebsausrüstung des letzten technischen Standes zu modernisieren. In den vergangenen Jahren haben sie zwei Aufträge erteilt, welche die komplette elektrische Ausrüstung für neue Zweisystemzüge umfassen.

Chaîne de traction moderne pour les nouveaux trains de banlieue de Bombay
La ville de Bombay dispose du réseau de banlieue le plus étendu de l'Inde avec 275 km de lignes et 90 gares. Les chemins de fer indiens ont décidé de moderniser leur parc de la banlieue de Bombay en introduisant des éléments automoteurs équipés de chaine de traction triphasée intégrant les derniers développements du domaine. Ces dernières années, une adjudication a eu lieu concernant deux contrats comprenant l'équipement électrique pour des nouvelles rames électriques bi tension

1 Introduction

In 2003 and 2005, Indian Railways (IR) awarded two orders to Siemens Transportation Systems comprising the manufacture, supply and, to a certain extent, assembly supervision and commissioning of the electrical equipment for new electrical multiple units (EMUs). The scope of supplies includes, among other components, the traction motors, traction converters, transformers, auxiliary converters, train control system, high voltage equipment, passenger information system and fire detection and extinguishing system for 473 three-car trains. The trains will be utilized on regional routes in and around the West Indian city of Bombay. The components are designed for two power supplies, the existing DC 1,5 kV voltage supply in Bombay as well as the countrywide used AC 25 kV 50 Hz voltage supply. The AC supply will replace the DC supply in Bombay in future. While the main traction equipment will be built in the Siemens plants for traction motors in Kalwa and for converters in Nashik near Bombay, the new EMU coaches will be manufactured by the Integral Coach Factory (ICF), one of IR's car body manufacturers based in Madras (Chennai).

Fig. 1: EMU suburban train of IR today at Bombay.

2 Demand for local trains

The local trains in the city of Bombay, officially called Mumbai since 1996, are known as the city's lifeline, carrying 6 million commuters per day, nearly half of Bombay's population. Each train has a capacity of about 1800 people only, but accommodates over 4500 commuters each way, severely straining both the commuters and the assets. The passenger density in Bombay's local trains is the highest in the world: the so-called Super Dense Crush Load is equivalent to 16 standing passengers per square meter. In view of the intense pressure with the city's ever-expanding population, the local train fleet is in desperate need of upgrading and renewal. Realizing this need, the Indian Ministry of Railways launched the Mumbai Urban Transport Project as early as 1990. One of the aims of this project is the acquisition of dual-voltage EMUs by 2008 in order to be prepared for the subsequent phase of DC/AC conversion. Dual-voltage EMUs are capable of running under AC as well as DC power supply. Former schemes to retrofit existing trains from single-voltage to dual-voltage EMUs have been discarded. The existing train is illustrated in Fig. 1.

Under the Mumbai Urban Transport Project the demand for new trains in the Bombay region had been estimated to be 875 three-car trains. Out of these, the first 100 traction sets, based on GTO converter technology, were awarded to a consortium of Alstom and BHEL in 1998. In 2003, Siemens received the so-called GP194 order of 170 traction sets from IR. The subsequent order award by Mumbai Railway Vikas Corporation (MRVC) in May 2005 comprises an additional 303 traction sets. The first prototype trains will run in Bombay area in 2007 and be followed by the series from 2007 to 2010.

Approximately 300 traction sets for Bombay are still expected to be tendered by IR until 2008.

Fig. 2: Map of the Bombay rail lines.

3 Network of Bombay

There are three suburban rail lines in Bombay that link the central business districts of Bombay Island with the suburban areas in the north of the city:

- Western line from Churchgate over Dahisar to Dohanu Road
- Central line from Mumbai CS Terminal over Thane to Kasara
- Harbour line from Mumbai CS Terminal over Mankhurd to Panvel/Karjat

Fig. 2 shows a map of the Bombay rail lines. Western and Central Railways, the two operators of IR in Bombay, provide suburban railway services on 300 km of electrified broad gauge. They transport millions of passengers on 2000 daily EMU services with nine- and twelve-car trains, so-called rakes.

The older section of the Bombay suburban network has been operating on a DC 1,5 kV power supply since

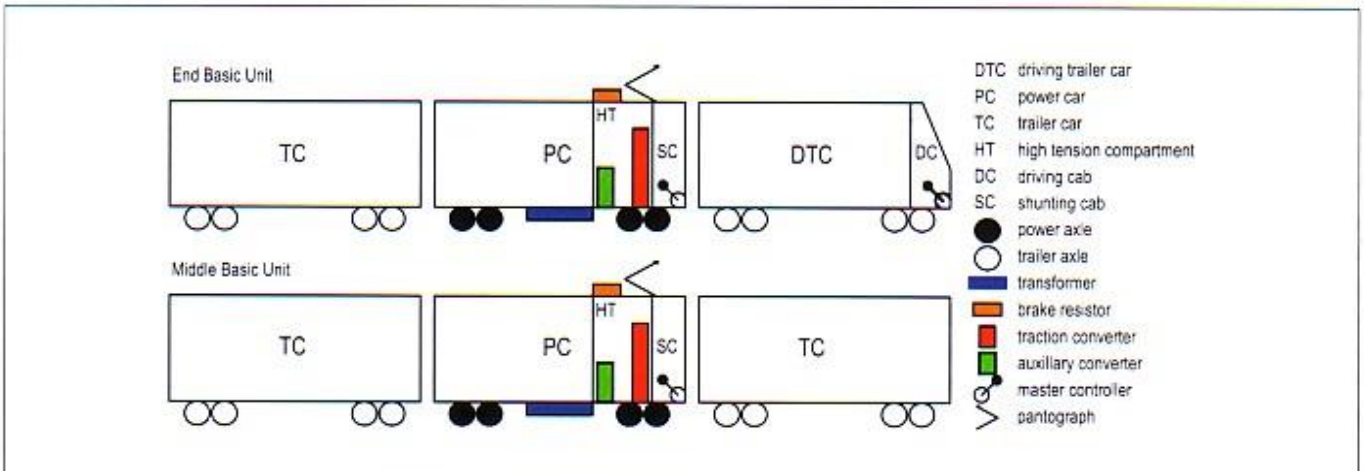

Fig. 3: Train configuration for end basic unit and middle basic unit.

1925, while the railway tracks surrounding the Bombay suburbs, which were electrified later in the 1960s, operate on the nationwide installed AC 25 kV 50 Hz power supply. Bombay's railway electrification, the last bastion of DC-powered lines in the whole of India, is supposed to be converted to AC power supply in 2010 according to the ambitious Mumbai Urban Transport Project.

4 New electrical train-equipment

4.1 System and technology

The EMU Bombay trains are built for a track gauge of 1,676 mm and operate on a voltage of DC 1,4 kV, which varies under normal working conditions between 1,2 kV and 1,8 kV. A basic three-car train unit consists of a driving trailer car, a power car and a non-driving trailer car as illustrated in Fig. 3.

The power car has a small emergency driving cab for shunting in yards. The so-called high tension compartment is also located in the power car and accommodates the traction converter, the auxiliary converter and the electrical cabinets. Four self-ventilated nose-suspended traction motors are mounted on the two bogies of the power car, while the transformer is located under frame. Three-car units may be coupled together to form trains of six, nine, twelve or, later on, even fifteen and eighteen cars. Technical and ambient particulars of the EMU Bombay projects are given in Tab. 1.

Tab. 1: EMU Bombay particulars.

Years of delivery		2007 ... 2010		
Numbers built		473 3-car basic units		
Power system		AC 25 kV 50 Hz and DC 1,5 kV		
Maximum speed	km/h	100		
Track gauge	mm	1676		
Acceleration	m/s^2	0,54		
Deceleration	m/s^2	0,76 ... 0,84		
Maximum ambient temperature	°C	50		
Maximum humidity	%	100		
Number of cars per train/rake		9	12	15
Maximum power at wheel	kW	3300	4400	5500
Weight		630	840	1050

The design of the entire electrical equipment has been developed based on sound engineering practices and proven technology with consideration to Bombay's specific requirements regarding ambient conditions such as passenger loading, variations of electric load, route conditions and shock and vibration levels. The electrical equipment features state-of-the-art components such as AC three-phase asynchronous induction traction motors with associated IGBT-based microprocessor-controlled converters providing recuperating braking, passenger information system, multifunctional vehicle bus, fault diagnostic system, and fire alarm and extinguishing system. The supplied equipment will be installed and commissioned in new coaches at ICF.

4.2 Transformer

The forced-air- and forced-oil-cooled transformer has a power rating of 1,250 kVA at a nominal line voltage of 22.5 kV and a fixed winding ratio. Tab. 2 provides detailed transformer particulars.

Tab. 2: Transformer details.

Power rating	kVA	1250
Rated primary voltage	kV	22,5
Rated secondary voltage	V	855
Winding ratio		26,3
Frequency	Hz	50
Weight	kg	3300
Protection level		IP 67

The active part of the transformer is mounted in a steel tank. The transformer is fixed under the car body of the power coach by a rubber damper mounting arrangement. Rubber dampers are known for their ability to reduce vibrations.

4.3 Traction converter and main circuit

The forced-air-cooled power converter is IGBT-based and PWM-controlled to ensure regeneration of braking energy and a power factor of almost unity. The converter consists of two 4-quadrant choppers, one DC link, two PWM inverters which each feed two traction motors. The traction converter is controlled and monitored by the Sibas® traction control unit (TCU) in order to guarantee performance under wide fluctuations of the catenary voltage and frequency. Tab. 3 informs about electrical details of the traction converter.

Tab. 3: Traction converter details.

Input power rating	kW	2 X 620
Rated input voltage	kV	2 x 0,95 AC or 1,5 DC
Output 3 AC voltage	V	0 ... 1400
Power factor		1,0
Weight	kg	2600

The traction converter operates on a dual voltage system, which means either AC 25 kV 50 Hz or DC 1.5 kV. In AC mode, the traction converter is connected to a single-phase alternating input voltage. The transformer secondary windings can be disconnected from the traction converter with the help of the AC line main contactor. In

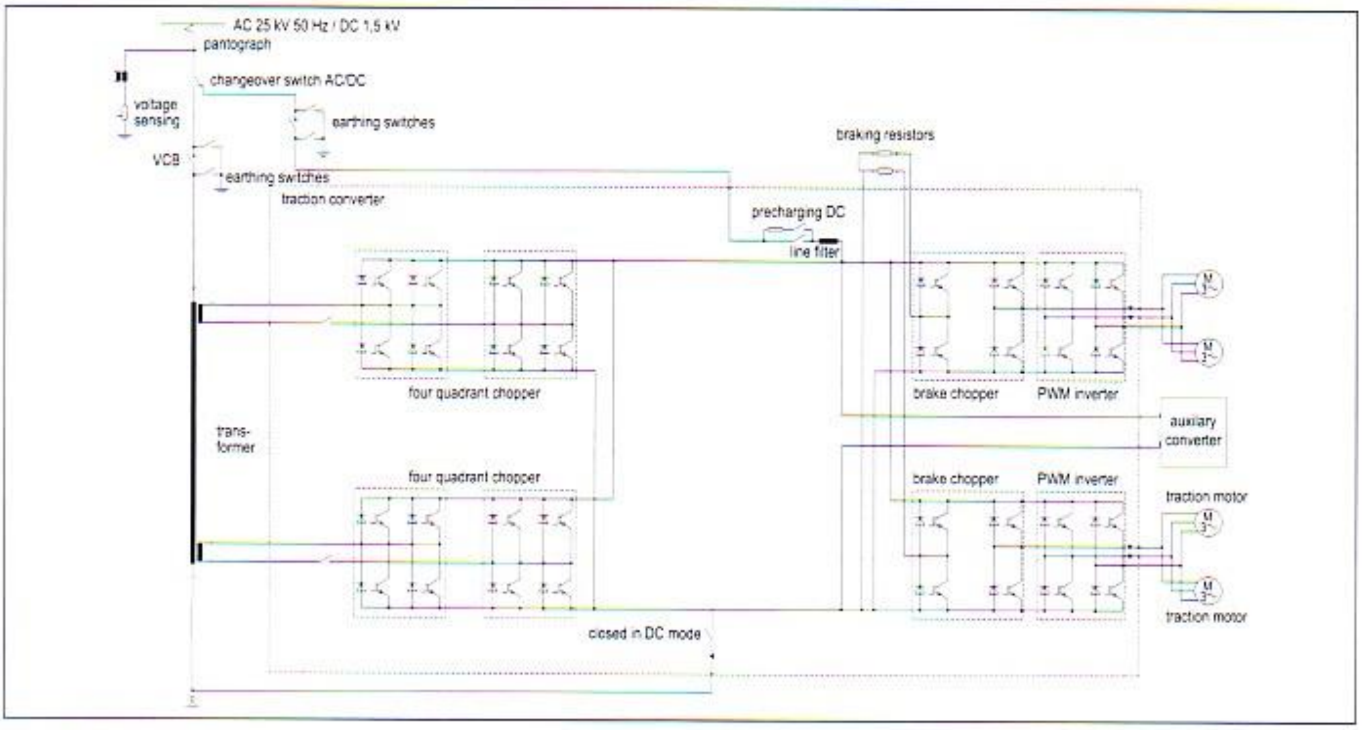

Fig. 4: Main circuit diagram.

DC mode, the traction converter DC link is connected to the DC line via the line choke and DC line main contactor. Details of the main circuit are given in at Fig. 4.

4.4 Traction motor and gear

The three-phase asynchronous traction motors suitable for IGBT converters are designed to be capable of withstanding the shock and vibration level from the track, high temperature and humidity. They are self-ventilated.

In braking mode, the motor operates as a generator and supplies energy back into the catenary power system.

The traction motor has a power rating of 240 kW at 2000 rpm and a voltage rating of 1,4 kV. The maximum motor speed permits a maximum train speed of 100 km/h with half worn wheels. Gear and bearing are of state-of-the-art nose-suspended construction with common oil lubrication at drive end. At not drive end the bearings are ball bearings.

Detailed motor and gear particulars are specified in Tab. 4, while Fig. 5 shows a picture of the drive.

Tab. 4: Traction motor details.

Power rating at 2000 rpm	kW	240
Rated 3 AC voltage	V	1400
Maximum speed	rpm	3452
Gear ratio		5,71
Weight including gear	kg	1660
Class of insulation		200

Fig. 5: New traction motor design.

4.5 Auxiliary converter

The power supply for the auxiliaries is realized by IGBT-based auxiliary converters suitable for both AC and DC traction supplies. One auxiliary converter caters for the complete auxiliary load of a three-car unit, such as the full need of auxiliary machines, battery charging, fans and the complete lighting.

The auxiliary converter unit is connected to the DC link of the traction converter. On its output side, the auxiliary converter supplies the following outputs of a three-car basic unit:

- 3 AC 50 Hz output for supplying fans and compressors
- 1 AC 50 Hz output for supplying the primary lighting, ventilation and the passenger area
- DC output for supplying battery charger, controls and low-power lighting

Electrical and other details of the auxiliary converter are listed in Tab. 5.

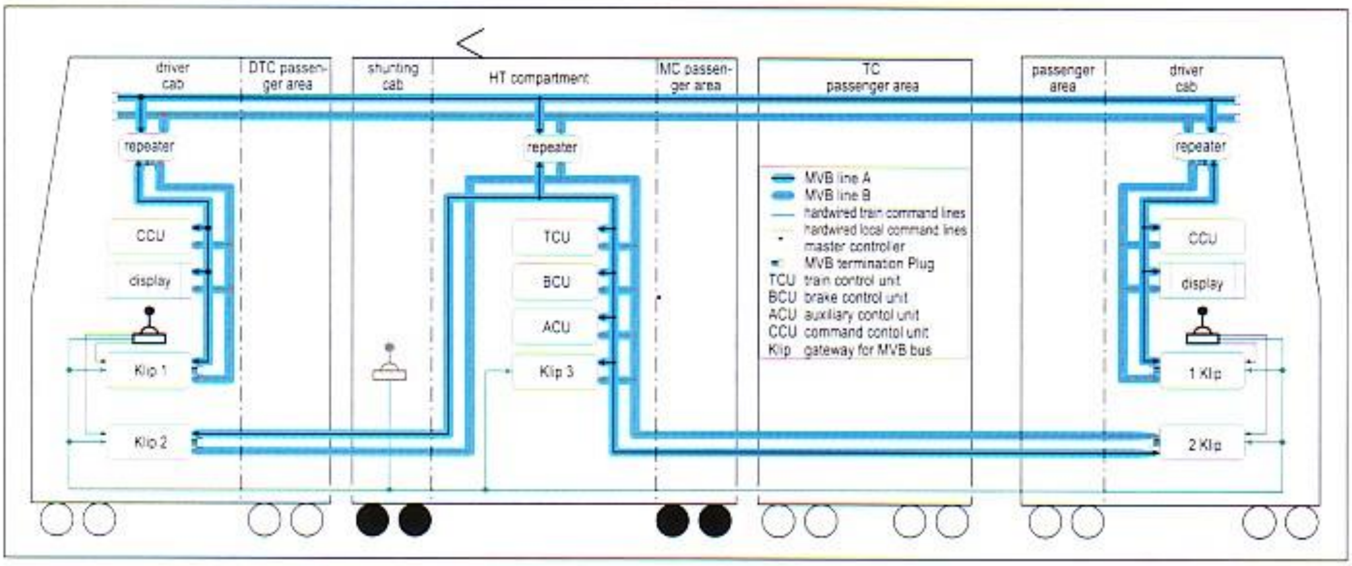

Fig. 6: Train management system design.

Tab. 5: Auxiliary converter details.

Total power rating	kVA	115
Rated input voltage	kV	1,6 AC 1,5 DC
Output 1 voltage	V	415 3 AC
Output 2 voltage	V	110 AC
Output 3 voltage	V	110 DC
Weight	kg	1 200
Type of cooling		forced air

4.6 Train management system

The train management system (TMS) is based on the Sibas® 32 control system and combines drive and brake control including the slide and slip protection, monitoring of commands to the control unit as well as the fault diagnosis. The system communication backbone for all connected components is a redundant multifunctional vehicle bus system (MVB). It connects the drivers cabs with the control command unit (CCU) and the driver's display on both sides of the train with the traction control, the brake control unit and the auxiliary unit. By specific gateways, the Sibas® 32 klip-units, the functions for lighting, ventilation etc. are controlled. For coupling of the trains, the MVB is directly connected to the next car and in this manner over the whole train consist by specific MVB couplers.

Fig. 6 shows the structure of the TMS. The Sibas® 32-TMS is proven state of the art train control technology and it is the basis for more than 60 train projects worldwide.

4.7 New features

The passenger information system (PIS) features public announcements addressed by the driver and displays information like name of the approaching station, platform direction, final destination and so on. Four display panels in each car ensure this kind of passenger amenities for the first time in EMU Bombay trains.

Fire detection and extinguishing system (FDES) protects valuable equipment in the high tension compartment of each power car. Smoke detectors in each compartment transmit an alarm signal to the control board in case of smoke or aerosols inside. This signal is forwarded to the driver, who decides to activate the extinguishing system in the high tension compartment. The extinguishing system medium is stored in high pressure tanks in the high tension compartment. This system will cause no damage to the electrical equipment in case of activation.

5 Conclusion

The new equipment for the EMU Bombay local trains combines state of the art technology and proven design. The dual voltage concept for AC 25 kV 50 Hz and DC 1,5 kV operation enables seamless operation of the commuters throughout the whole system. Modern IGBT traction technology with three phase motors provide high performance and optimized energy efficiency. In both modes of operation, maximum recuperation of braking energy back to the power network is achieved by the converter technology. The supply of the auxiliary converter from DC-link of the traction converter is one contribution for the optimized use of braking energy.

The modern structure of the train management system is the prerequisite for most effective drive and brake control as well as for flexible coupling of many train sets. Safety systems, such as a fire extinguishing system in the traction units respond to the latest user requirements. A high passenger comfort is supported by a passenger information system with graphic colour displays in the coaches. The equipment is the basis for a modern transportation system with outstanding performance in the Bombay region.

The new EMU Bombay trains will offer the 6 million daily commuters excellent services and an appreciable as well as distinct increase in comfort and availability.

References + Links

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