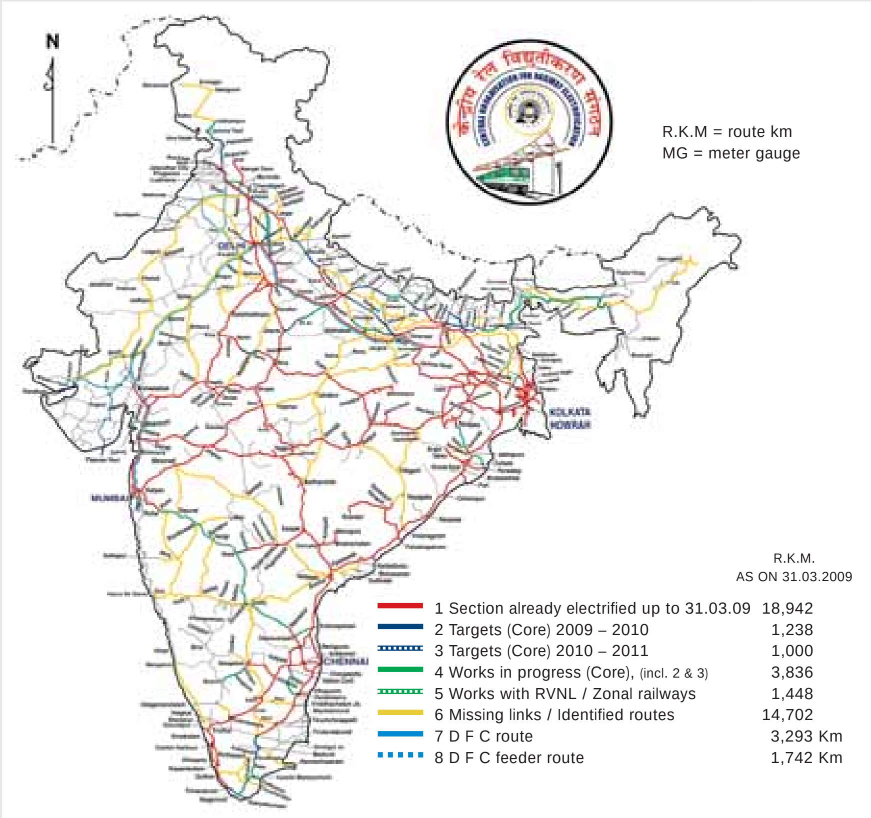
Greener rail for India

ABB is helping upgrade India's railways

LALIT TEJWANI – Since India's (and indeed Asia's) first train steamed from Mumbai in 1853, India's railway network has grown to more than 64,000 route km. It now transports approximately 2.5 million tonnes of freight and 19 million passengers every day. This article looks at some of the developments that are preparing India's railways for the future, and shows how ABB's technologies can make railways greener and more efficient.

1 Indian Railways electrified routes as of 31, March 2009

Status of electrification on Indian Railways



Planwise progress of electrification ob IR (First electric train started on 3.2.1925)

Plan Period	Pre. Indep. 1925-47	1st 1951-56	2nd 1956-61	2rd 1961-66	Annual plan 1966-74	4th 1969-74	5th 1974-78	Inter plan 1978-80	6th 1980-85	7th 1985-90	Inter plan 1990-97	8th 1992-97	9th 1997-2002	10th 2002-2007	11th up to 31.3.09
R.K.M. Electrified	388	141	216	1,678	814	953	533	195	1,522	2,812	1,557	2,708	2,484	1,810	1,299
R.K.M. Cumulative	388	529	745	2,423	3,237	4,190	4,723	4,918	6,440	9,252	10,809	13,517	16,001	17,811	18,942*

* 168 R.K.M. MG electrified line dismantled

Source: http://www.core.railnet.gov.in/_MapElectrificationofIR_eng.htm

Indian Railways (IR) is one of the world's largest railway systems under single management and the largest employer in the world with approximately 1.4 million staff. Organizationally IR is owned and controlled by the Government of India. Day-to-day operations are managed by the Railway Board. In addition to being a rail operator, IR is unique compared with other major rail operators in having its own rolling stock manufacturing facilities. IR manufactures approximately 3,000 coaches annually as well as 500 diesel and electric locomotives, and major aggregates such as wheels, axles and traction motors.

As of March 31, 2008 IR's fleet consisted of 47,375 passenger coaches, including EMUs (electric multiple units). There are almost 8,400 locomotives in operation, 3,400 of which are electric. Electric trains currently account for more than 65 percent of freight traffic and over 50 percent of passenger traffic.

Sustainable growth

Development of the railway network has gained higher priority in recent years due to urbanization, mobility issues and severe road congestion. Rail transportation is far more energy efficient, economical in land use and cost-efficient than road transportation. Among the various modes of rail transportation, electric traction has established itself as the most energy efficient. Since 1925, when India's first electric train ran in Mumbai, there has been a major push for electrification: As of March 31, 2009, IR had electrified 18,942 route km, which is 28 percent of the country's total railway network. The target is to electrify 1,500 km of existing lines every year ➔ 1.

On main lines, electrification has permitted the operation of heavier freight and faster passenger trains. By virtue of their high acceleration and braking capability, EMUs are ideal for suburban services [1]. Another important catalyst for electrification has been India's will to reduce its dependence on costly imported fossil fuels. By centralizing the generation and distribution of energy, electric traction furthermore offers the advantage of reduced air and noise pollution for travelers and the environment.

India's early electrification projects used DC, but since the 1950s, all new projects have used single-phase 25 kV / 50 Hz. IR draws its power from the 220 / 132 / 110 / 66 kV / 50Hz three-phase regional grids, converts it for traction power requirement and supplies it to trains using overhead line (OHL) electrification. Currently, IR consumes more than 2,000 MW of power, mainly through a national network of 400 traction substations.

Since 1980, IR has been automating its substations with microprocessor-based Supervisory Control and Data Acquisition (SCADA) systems to permit their remote

Footnote

1 Electric multiple unit (EMU) refers to coaches used for (mostly suburban) train services that have multiple prime movers for each car. The same car that carries passengers also has integrated motive power, as opposed to the normal situation where the passengers are in coaches that are not self-propelling and a locomotive hauls the train.

control and operation. A divisional SCADA facility can control a region extending some 200 to 300 km. SCADA allows remote monitoring of electrical parameters (voltage, current, power factor, etc.) in real time and the remote operation of switchgear, as well as automatic fault detection and isolation. This facilitates better control of demand peaks, troubleshooting, etc. SCADA is replacing an older system that was based on electromechanical remote-control apparatus.

ABB's contribution

Challenges that IR is currently faces on many of its electrified lines include the following:

- Wide voltage variation between 17 and 31 kV, mainly due to the line impedance varying with the position of trains
- Poor power factor (in the range of 0.7 to 0.8) caused by the inductive nature of the traction load, and the ineffectiveness of existing fixed capacitor banks to adequately compensate dynamic loading
- Low-order harmonics injected into the traction network by conventional locomotives using DC traction

These characteristics cause high system losses, reactive power absorption, and interference with sensitive electronics in signaling and telecommunication equipment. ABB is deploying state-of-the-art technology to address these issues and improve overall efficiency and availability.

Traction transformers

AC electric locomotives and EMUs draw power from the single-phase 25 kV OHL, and then convert it to a lower voltage for the traction motors using the traction transformer. Besides high demands on reliability and performance, traction transformers must also be compact and lightweight and display high efficiency. ABB is the world's leading manufacturer of traction transformers, and can supply them for different sizes, shapes and power ratings, permitting installation in different parts of the train ranging from the roof to the under-floor area [2]. In India, ABB traction transformers are successfully running in high-power electric locomotives, EMUs, and metros.

Vehicle Propulsion & On-Board Auxiliary Power Supply

In IR's locomotives with three-phase drive, the propulsion converters were originally

2 BORDLINE M 180 kVA auxiliary converter (H Module)

3 STATCON panel used to control reactive power power flows

GTO-based. IR has launched a program to upgrade these locomotives with IGBT-based propulsion converters [3]. IR selected ABB's 's BORDLINE CC series of water-cooled converter, which is based on 4.5 kV low-loss HiPak™ IGBTs. The most important accrued benefits are:

- Enhanced tractive effort, performance and availability due to use of axle control and a new generation of adhesion-control system.

In order to meet rising passenger traffic, and offer more competitive intercity travel, IR is improving passenger facilities, increasing platform lengths and introducing more train services.

- Improvement in overall power-converter efficiency due to lower semiconductor losses for an equitable operating point when compared to GTO-based traction converters.
- Improvement in the quality of motor-current waveform leading to reduced motor losses, torque ripple and better ride quality.

In conventional IR locomotives with DC traction system, rotary converters were used to generate three-phase supply (3 × 415 V / 50 Hz) required by machine-room auxiliaries. In addition to the high maintenance requirements of such rotary converters, their drawbacks include poor voltage regulation, low input power factor, low conversion efficiency, presence of lower order harmonics at output and lack of diagnostic facilities. To overcome these limitations, rotary converters are gradually being replaced by static power converters.

ABB caters to this market with its energy-efficient air-cooled BORDLINE M180 auxiliary converters that utilize solid-state IGBTs to generate a sinusoidal and balanced three-phase voltage supply [2]. This solution, featuring an active PWM (pulse-width modulation) rectifier at the input,

Footnotes

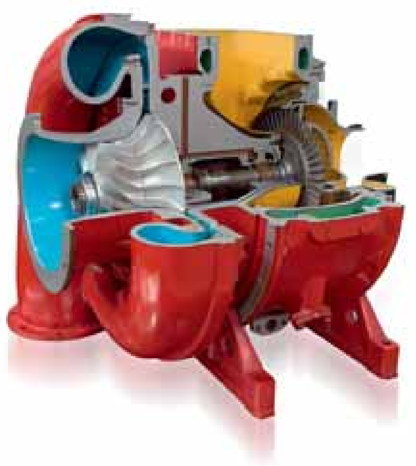
2 See also "Annual Year Book, Indian Railways, 2007-08" and "Emerging Technologies & Strategies for Energy Management in Railways," October 2008.

3 See also www.abb.com/railways

4 FSKII 25kV outdoor breaker to IR specifications

5 ABB turbochargers for Indian diesel locomotives

TPR 61 type turbocharger



VTC 304 type turbocharger

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enables unity power factor (cos ϕ) operation and lowers line-side harmonic distortion. Furthermore, the converter's controlled startup and sinusoidal waveform reduce stress on motor insulation, eliminating the need for special motors. These converters are customized to mechanically and electrically fit into existing locomotives, permitting them to be retrofitted → 2.

Reactive power compensation

The power requirement of trains across the network is characterized by its high variability in demand. In addition, traction converters inject low-order harmonics into the traction network. The line voltage is thus prone to high fluctuations. IR conventionally employs fixed-shunt capacitor banks at most substations to compensate the lagging power factor. The drawbacks of switched capacitor banks are the coarse size of the switching steps and their response time. Power suppliers not only penalize IR when the power factor is lagging, but in some cases also when the power factor is leading as a result of over-compensation. Sub-stations thus need reactive power compensation that can be adjusted dynamically and in real time.

ABB's STATCON is a voltage source converter / inverter that can both absorb and deliver reactive power → 3. It uses IGBT switching devices and is modular, permitting future expansion should demand rise.

STATCON is shunt-connected and therefore easy to install. It totally relieves the source from reactive power, resulting in better utilization of the supply equipment and network. Also by providing very fast dynamic compensation, it improves voltage profile and reduces system losses and hence the loading on incoming power transformers, switchgear, cables, etc.

FSKII outdoor breaker

IR uses 25 kV outdoor circuit breakers and interrupters in all of its traction substations and switching posts. In consultation with IR, ABB has developed its FSKII magnetic actuated range of breakers and interrupters that offer increased reliability due to radically fewer moving parts[2]. The magnetic actuator is a bi-stable device, meaning that it does not require energy to keep it in the open or closed position → 4.

Turbocharger

Every year, IR rolls out approximately 300 new diesel locomotives from its two plants in India. ABB turbochargers have been boosting the performance of these locomotives since 1975. High-efficiency turbochargers such as ABB's TPR 61 and VTC 304 improve reliability and reduce fuel consumption by 5 percent → 5. ABB is also involved in IR's emission-reduction program, and is performing overhauls on turbochargers. IR's workshops have also built rolling stock for export to more than 10 Asian and African countries. ABB's turbochargers are also frequently used on such export locomotives, not least because of the global presence of ABB's service network.

Urban transportation

According to the 2001 census, India has 300 cities with a population of more than 100,000, and 35 cities with a million or more – compared to only five cities in the

6 Delhi Metro Rail Corporation

Delhi Metro Rail Corporation (DMRC) was incorporated to implement and operate a mass transit system in the Delhi area. ABB has been a partner of DMRC since 2002 and provided products and systems for both the traction power supply and rolling stock. These include traction, receiving and auxiliary substations, overhead electrification, SCADA systems, integrated building and asset management solutions, and traction transformers and motors. The system is electrified at 25 kV / 50 Hz. It features ABB's compact gas- and air-insulated switchgear, 25 kV pole-mounted vacuum interrupters and circuit breakers with magnetic actuator mechanisms.

DMRC is the first independent metro operator in India, and has proven to be a role model for on-time project execution and efficiency. DMRC is now providing consultancy services to most of the new metro projects in India, and is also taking on international consulting assignments.

Phase I of the metro, comprising a route length of 65.1 km, was completed in 2006. Phase II, set to be completed in 2010, will add a further 128 km. Upon completion of this second phase, daily passenger trips are expected to reach 2 million per day. DMRC plans to have 381 km of metro operational by 2021.

Of the total 193 km of phases I and II, ABB has executed or is implementing the electrification of approximately 163 km.

7 DMRC SCADA control room

latter category in 1951. Approximately 30 percent of India's population lives in urban areas, which contribute 55 percent of the GDP. India is being urbanized at a faster rate than the rest of the world: Migration is adding millions to urban populations every year. This urban growth is exerting increasing pressure on infrastructure. The deterioration of urban transport systems can rapidly lead to lower economic productivity. Urgent measures are thus needed to improve urban transportation.

An important catalyst for electrification has been India's will to reduce its dependence on costly imported fossil fuels.

Public transport occupies less road space and causes less pollution per passenger-km than personal vehicles. Of the wide variety of public transport options available, high-capacity rail-based metro systems are deemed to be the most suitable for India's densely populated cities. Under the aegis of the Ministry of Urban Development, the central and local state governments are setting up independent organizations to advance urban transport development. Solutions selected include build-own-operate models with private partnerships.

Today, Kolkata and Delhi → 6 are the only two cities to have operating metro systems. Besides ongoing expansion of these systems, new metro projects are at various stages of implementation in Bangalore, Mumbai, Chennai and Hyderabad. In Delhi, Mumbai, and Bangalore, independent metro operators are procuring their own coaches according to international specifications and global tendering processes. With an increasing number of projects, annual demand for metro coaches is expected to grow beyond 1,000 coaches within the next few years. Bombardier Transportation has already set up a coach factory in western India and is supplying coaches for Delhi Metro. Other international transportation companies and Indian rolling-stock manufacturers are also seeking to enter this business through collaborations and technology tie-ups.

SCADA

Delhi's DMRC → 6 needed one unified SCADA control center (with backup), and hence sought to upgrade and integrate the old SCADA system and RTUs[5] with the new system without losing operating time. ABB's latest MicroSCADA Pro system provided one common system for the complete network and delivered high availability as well as savings on maintenance and spare parts → 7.

Because of its experience with DMRC, as well as metros in Mumbai and Bangalore, ABB has emerged as the leader in terms of market share for turnkey electrification, SCADA and power products for metro rail networks in India.

Future outlook

India's growing industrialization and population present an ever increasing need for transportation. Riding on the waves of economic success, IR has witnessed a dramatic turnaround leading to an unprecedented financial turnover in the last few years. This has been made possible by:

- Higher freight volumes without requiring substantial investment in infrastructure
- Increased axle loadings
- The reduction of turnaround times for rolling stock
- The reduced unit cost of transportation
- The rationalization of tariffs resulting in an increased market share for freight.

In the Eleventh Five Year Plan (2007-12), investment in the railway sector is estimated at $65 billion[4]. Almost 17 percent

Footnotes

4 See also "Projections of Investment in Infrastructure during Eleventh Plan, GoI report"(October 2007)

5 RTU: remote terminal unit.

of this investment will be via public-private-partnership (PPP) projects in the freight and high-speed corridors, urban transport systems, rolling stock manufacturing and captive-industrial and port connectivity.

In order to meet rising passenger traffic, and offer more competitive intercity travel, IR is improving passenger facilities, increasing platform lengths and introducing more train services. IR needs to acquire more than 4,500 coaches annually for main-line services (660 of which should be air conditioned). Current captive manufacturing facilities are not able to meet this requirement, and this is limiting the launch of new train services and the rate of replacement of old coaches. To increase the supply, IR is by itself and in partnership with private manufacturers setting up new production units. New diesel and electric locomotive production facilities using the PPP model are also being discussed as a way to augment IR's locomotive fleet with higher power and technologically advanced locomotives.

DMRC is the first independent metro operator in India, and has proven to be a role model for on-time project execution and efficiency.

Freight

Although the freight business is a significant revenue earner, and also helps subsidize IR's passenger business, passenger trains are given a higher priority in scheduling. To nevertheless improve freight throughput and offer industry better transit times, the Dedicated Freight Corridor (DFC) project is being advanced featuring 3,300 km of double-track lines and is budgeted at $12 billion. DFC will permit freight trains with higher axle loadings to run at 100 km/h (compared to the current average of 25 km/h). The western DFC between Mumbai and Delhi is expected to carry mostly container traffic from the ports on the western coast, whereas the Delhi-Howrah eastern DFC will carry mostly bulk cargo such as coal, iron ore, steel, etc. As part of the DFC project, a Special Purpose Vehicle (SPV) is to be developed with foreign funding and expected to be completed by 2015.

High speed

High speed rail takes pressure off roads and short-haul flights and so reduces air pollution, congestion, noise and accidents, and also frees travelers from the frustrations of traffic congestion and airport security lines. In Europe, carbon dioxide emissions per passenger-km on Europe's high-speed trains are equivalent to one third of its cars and only one-fourth of its planes [6]. In India, feasibility studies have already been initiated for a high-speed corridor to link Mumbai and Delhi at 350 km/h. Further links are likely to be added in the future.

IR is continuously adopting new energy-saving and renewable-energy options in rolling stock and non-traction loads [7]. These initiatives range from redesigning the air-conditioning and lighting systems in passenger coaches to harnessing solar power for station facilities, or using wind farms to supply power to manufacturing units. Due to their lack of guaranteed availability, such renewable sources are not suitable for traction loads. They are, however, deemed suitable for stationary non-traction loads. Drawing on both available technologies and experience and the force of innovation, India is on its way to establishing a more efficient rail network for its future.

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Footnotes

6 See also The Hindu (7 Jan. 2010) "Encouraging high-speed trains," and "Vision 2020, Indian Railways"(December 2009).

7 Non-traction loads are defined as the energy consumed by the production units, various workshops, and other infrastructure.