Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)

Train information management system for Tokyo commuter trains

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Abstract

The East Japan Railway Company owns a fleet of 8, 000 commuter and suburban train cars to carry commuter traffic in Tokyo's metropolitan zone. For the purpose of maintaining current level of service quality and further upgrading it, we have succeeded in developing a new type of electric car: The Series E231. After elemental development, the prototype of one-unit cars were completed in 1998 and the specifications for serial production were finalized. The primary functions of the new cars are as follows:

1. Train Information Management System (TIMS) is installed to enhance monitoring functions, concentrate and integrate switchboard, air conditioning control and other functions, further upgrade the powering/braking control function, automatic depot departure inspection function, self-diagnosis function, etc. TIMS is a system which greatly expands the functions of past monitoring systems. This system collectively controls and manages the train.
2. All the control signals are basically digitally transmitted. Eighty percent of passing through wires between cars were eliminated and the wiring within a car has been reduced by 35%.
3. In-house production system was achieved.
4. New system and equipment was developed for maintenance.

Currently, we have completed various performance tests and put them into a serial production line. The cars began commercial operation from the middle of February 2000.

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1 Introduction

About 14 million people use JR East Japan trains in the Tokyo area every day. The majority of these passengers are commuters to offices or schools, and only in one hour during the morning rush-hour-time about 1.25 million people use these trains.

Passengers are transported by using about 8000 units of commuter trains (cars). Due to constant traffic, transportation has been a major problem within the Tokyo area. Thus the need for a mass transit system is required. We see trains as the solution in meeting these requirements. Such as easing the congestion, comfortable air-conditioning control, riding comfort, etc. in addition to the safety and steadiness. Further, from the viewpoint of environmental ecology, energy saving has become a major problem. Besides, from the standpoint of the management of railways business, cost reduction (reduction of initial cost, maintenance cost and operation cost) has always been a universal proposition.

In order to solve these problems, JR East Japan Railways has been making incessant efforts in developing new-type trains ever since the inauguration of the company, and completed the 209-series commuter trains and launching them for the Keihin Tohoku Line in February 1993.

The company started further development of the commuter train for the coming generation in 1997, and commenced the mass launching of E231-series in March 2000 through the debug of trial formation. These new-type trains featured highly intelligent functions which dramatically improved the riding comfort and reduce cost performance.

In this way, the trains in Tokyo are showing drastic change. On the other hand, efforts are under way towards the innovation in manufacturing system and maintenance. This paper describes the development condition of train technology in Tokyo area and particularly reports on the development and application of the Train Information Management System (TIMS) which has made a remarkable progress.

2 Development condition of commuter trains

2.1 Development of 209-series commuter trains

The 209-series trains, developed as the trial-manufactured trains of 901-series in 1991, were put to mass-production in the fiscal year 1992. In order to make drastic reduction in life cycle costs related to the trains (the total maintenance cost, operating energy cost, production cost, etc.), developments were promoted under the target concept of "half-weight, half-cost and half-life" by adopting maintenance-free systems, and reducing the weight and production (manufacturing) cost.

As for the maintenance-free system, the VVVF inverter, SIV (static inverter), etc. were introduced as they required less electric contacts, and the number of expendable parts were reduced by introducing the three-phase induction motors, screw-type air compressors, electrical door controller, etc. As a result, compared with the 103-series and other conventional trains, the maintenance cost had reduced to half.

As for the energy consumed in operation, the change in MT ratio (6M4T4M6T) due to improved adhesion and drastic reduction in weight, etc., made possible through the pursuit of threshold design of train structure, contributed to the reduction of energy consumption for operation by 30%.

In order to cut down on the production cost, both the train body and bogie were made of simple structures to allow easy mechanization in production. For example, automatic spot welding could be applied to the outer periphery when coupling the structures, contributing largely to the reduction in the number of man-hour. Further, body parts and machines were set to units to pursue easy manufacture.

About 1000 units of such train are now in service mainly in the Keihin Tohoku Line and the Chuo Sobu Line.

2.2 Development of E231-series, the new-generation commuter trains

Continuous research and development to the concept of an ideal commuter train for the next generation (to follow the 209-series trains) and summing up the achievements in various elementary technologies so far developed, the trial-train of 209-series No. 950 trains were completed in October 1998.

These trains are equipped with the performances of both the commuter-type and suburban-type trains, and have the width enlarged to 2950 mm by standard to accommodate larger number of commuting passengers.

The most up-to-date point in the control system of these trains is the development and application of the Train Information Management System (TIMS) that takes in a large number of information transmission technologies in order to integrate the functions and to carry out collective formation (organization). This has contributed to the drastic improvement in the intelligence of the train. As a result, the new transmission system reduced the number of train lines by 80%, reduced the consumption of control wires (30 km per 1 formation), and automatic inspection before departure from depot, improvement in onboard test functions, appropriate powering, brake control, etc., as a whole formation could be realized.

Further, the main control unit inverter uses IGBT element to ensure low-noise and accurate vector control. The cooling and heating units carry out optimum temperature setting in various modes including “drying” on the basis of the calendar function and the detected temperatures inside and outside, seat occupancy rate, etc. The linear motor driven doors are introduced for the first time to upgrade the door control function and to ensure enhanced maintenance-free system.

The trial-formation was tried in the service line for debugging and improvements followed by the mass-production, before the new-type commuter trains E231-series were completed in March 2000. In future about 1000 units of these trains are planned to be produced and launched in various lines in Tokyo area. The schematic diagram of the new train is given in Fig. 1.

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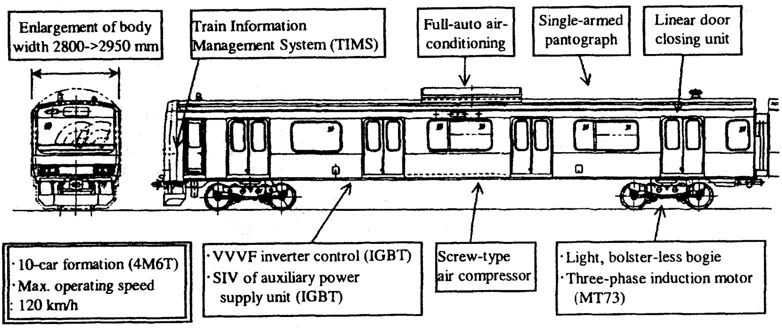

Figure 1: Outline of E231-series train.

3 Development and application of Train Information Management System (TIMS)

3.1 Development process of TIMS

JR East Japan introduced the TIMS in full scale in the 651-series trains (Super Hitachi) launched in the Joban Line in 1988. The system is equipped with an operation support function, control function for passenger service machines and maintenance support system (for trains) in addition to the normal monitoring function, and is ranked as the first-generation system.

Later in 1992 the second-generation system with an additional train control command function was applied in the 209-series trains, and, further, the third-generation system with drastically increased volume of information was introduced in the E653-series trains in 1996.

3.2.1 Functions of TIMS

The newly developed TIMS is a system that controls the whole train and is concerned with all controls in the train. Table 1 summaries the contents of control by TIMS and the contents of control carried out by conventional information system.

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Table 1: Contents of control using train information system.

Machine for control	Control content	1st-generation (1988-	2nd-generation (1992-	3rd-generation (1996-	TIMS (1999-
		651-series 251-series 253-series 215-series	209-series 255-series E351-series E217-series E501-series	E653-series E751-series E2-series E3-series E4-series	209-series No.950 E231-series
[Device on driver's cab]					
Cab select switch	Selection of front, middle or rear car				x
Master controller	Forward-backward/powering command, brake command		x	x	x
	High-acceleration/constant-speed/ hold-command		x	x	x
	Reset/command for releasing the disabled car		x	x	x
	Snow-resisting brake command		x	x	x
	Deadman safety function				x
Indication lamp	Various indication lamps lit up				x
Meters	High/low voltage voltmeters, torque mete control		x	x	x
[Main circuit equipment]					
Pantograph	Up-down control of pantograph				x
Isolator	Onboard test safety interlock	x	x	x	x
VVVF inverter	Regenerative balance control		x	x	x
	Organized management of powering and brake control				x
[Auxiliary circuit equipment]					
SIV	SIV reset command, power induction command		x	x	x
Air compressor	Operation control of air compressor				x
Battery	Battery OFF command				x
[Braking equipment]					
Brake control unit	Organized management of brake control				x
	Insufficient brake force detection				x
Parking brake	Parking brake control				x
[Service equipment]					
Door controller	Transmission of door open/close command				x
Air-conditioning/heating systems	Collective control of air-conditioner and heater	x	x	x	x
	Setting of target temperature for air-conditioner		x	x	x
Interior lamps	Lamp ON/OFF command	x	x	x	x
Announcement/ information/emergency information device	Transmission of sound signals for announcement/information emergency information				x
Passenger information display	Passenger information display command depending on the train running position	x	x	x	x
Seats of 6-door car	Control of storing or drawing the seat		x	x	x

Described below are the special functions of TIMS.

3.2.1.1 Full transmission of train line The train lines have been reduced from 80 (in conventional 209-series trains) to 14 (approximately 80% reduction) by integrating the train control function in TIMS.

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3.2.1.1.1 Types of transmission train line (66 lines)
Control power line
Compressor synchronized control command line
Pantograph UP/DOWN command line
Battery OFF command line
Door OPEN/CLOSE command line
Voltmeter and ammeter command lines
Transmission line for passenger information display
Sound line for announcement and information
Emergency alarm command line
Insufficient brake force detection
Brake delaying command

3.2.1.1.2 Present draw-in lines (14 lines)

DC 100 V power line	:	1 pc
Emergency brake command line	:	4 pcs
Security brake command line	:	1 pc
Pilot lamp command line	:	1 pc
Door close safety command line	:	3 pcs
TIMS transmission line	:	4 pcs

3.2.1.2 Management of powering and braking force The management of powering and braking force is carried out per train formation, ensuring appropriate powering and brake control according to the load condition of the whole train formation.

Powering control	:	Load management has been expanded from unit (group) to formation
Brake control	:	Regenerative and pneumatic control has been expanded from MTT/MT unit to formation

3.2.1.3 Integration of sound (voice) signal The announcement and interphone sound signals were changed to digital signals to integrate with the information transmission of TIMS.

3.2.1.4 Automatic recognition of equipment The following equipment mounted on E231-series trains are produced by several manufactures with different specifications.
VVVF (2 makers), SIV (3 makers), ATS-P (2 makers), Door controller (2 makers)

The TIMS discriminates the manufacturer automatically and carries out automatic switching of the interface program to match with the equipments mounted on the train.

3.2.1.5 Parameter loading to equipments The TIMS carries out loading of the control parameters to the door controller, air-condition control units, brake control units and passenger information display

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3.2.1.6 Automatic inspection before departure from depot Inspections before departure from depot were conventionally carried out at both driver's cab in each car and under the floor. In order to complete the inspections by using only one driver's cab, the following items were automated in TIMS.

Confirmation of ATS operation
Confirmation of equipment maintenance condition
Confirmation of the lighting of headlights and sign lamps
Confirmation of announcement device
Pantograph lifting test
Door opening/closing test
Brake test
Powering test

As a result, the inspection time was reduced from conventional 30 min to 5 min, which substantially reduce the inspection task of the train crew.

3.2.2 Technologies applied in TIMS

The trends in major technologies including the ones changed from the conventional system are summed up in Table 2.

Table 2: Technologies applied in TIMS.

Generation	CPU	Transmission system		I/F unit	Display unit
		Train bus	Local bus		
1st generation	8 bit, 4 MHz (8085) 16 bit, 8 MHz (8088)	Multi-drop bus 9.6 kbps	20-mA current loop 9.6 kbps	Digital I/F	Color CRT EL
2nd generation	32 bit CISC, 12 MHz (MC68020)	Multiplexing multi-drop bus 38.4 kbps/ 9.6 kbps			Color LCD
3rd generation	32 bit CISC, 25 MHz (MC68360)	Bi-directional ring 2.5 Mbps	20-mA current loop 19.2 kbps		
TIMS	32 bit RISC, 50 MHz (MPC860)	Dual daisychain (ladder) 2.5 Mbps	RS485 1 Mbps	Transmission I/F	

3.2.2.1 CPU The selection of CPU was carried out on the basis of the ease for software development in addition to the memory capacity, responsiveness to real-time processing and reliability, with the CPU having been changed from 8-bit (8085) to 16-bit (8088) and 32-bit (MC68020, MC68360). It was necessary to grade up the processing capability of the CPU since the TIMS handled an substantial large quantity of information in addition to the high-speed processing for power running and braking force which was not carried out in the conventional system. Therefore, the RISC-type CPU (MPC860) with improved processing capacity through simplification of command was adopted instead of the conventional CISC-type CPU.

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3.2.2.2 Train bus The train bus used for the 651-series was the multi-drop type, 9. 6 kbps using twist-pair line, but because of the increase in the quantity of information, its transmission speed has been graded up to 38.4 kbps. In the third generation system with the drastic increase in the quantity of information, the bi-directional ring type daisychain system train bus of capacity 2.5 Mbps is adopted. The transmission system used for TIMS is the bi-directional ring type transmission system improved to the ladder type, and has the features given below.

Two transmission circuits are simultaneously used to improve the transmission performance by double

The duplexed node system for each car and the increased obstruction evading route for transmission has improved the fault tolerant performance.

3.2.2.3 Local bus For the local bus, the 20-mA current loop system has conventionally been used by standard, because this system is excellent in the noise resistance and cost performance. But this system must adopt point to point connection. In TIMS, however, the RS 485 bus is adopted to allow the multi-drop connection. The RS485 bus is capable of high-speed transmission, with 1 Mbps used for the transmission of sound data announcement unit.

3.2.2.4 Remote I/F unit In TIMS, the remote I/F unit, made up by adding transmission function to the conventional switchboard, is used and all contact signals are made to pass through the remote I/F unit. TIMS can receive all contact signals through the remote I/F unit, using RS485 BUS between TIMS and switchboard.

3.2.2.5 Display unit Color CRTs were adopted and installed in the driver's cab of the 651-series and 251-series train. However, the thin-type EL display were adopted in the 253-series trains because of the limited installation space of the driver's cab. The color LCD used in present trains is thin and light, has low power consumption and needs no magnetic shielding.

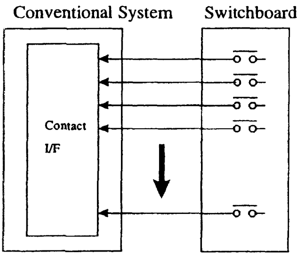

Figure 2: 20 mA current loop
(point to point connection)

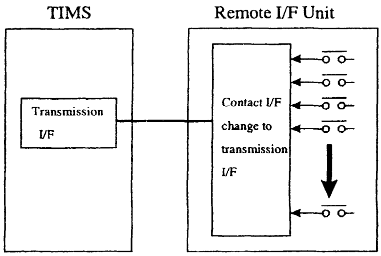

Figure 3: RS485
(Multi-drop connection)

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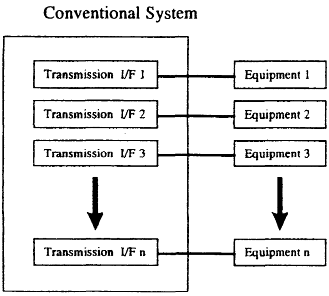

Figure 4: Switchboard I/F.

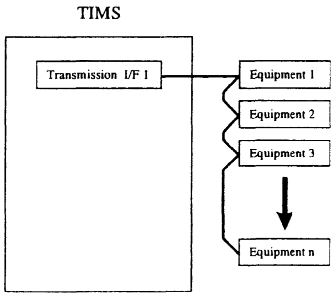

Figure 5: I/F unit.

4 Innovation in production and maintenance

4.1 In-house production of trains (cars)

The Railways Companies normally place order for trains with the train manufactures instead of producing by themselves. In the case of JR East Japan, however, half of the newly launched commuter trains (approximately 200 units) are produced in its Niitsu Train Manufacturing Plant.

Niitsu Manufacturing Plant is a train manufacturing plant, established in Niitsu-city, Niigata-prefecture by using the facility of the Train Maintenance Plant owned by JR East Japan, with an additional equipment investment (extension of building and near installation of production line such as machines and other facilities) amounting to 18 billion yen. The plant has the concepts given below.

Integrated production from car body to bogie.

Capability of producing 1 unit per day through smooth and flow process by making effective layout of production lines.

Introduction of automated and labor-saving machines mainly for material processing, assembly and bogie production.

Promotion of tact system in outfitting line and labor-saving policy.

Material requirement planning type production control system.

The plan for in-house manufacture of trains advanced hand in hand with the development of new-type commuter trains. The Railways Companies stipulate the basic standards for trains on the basis of the business policy and transportation plan, operate the completed trains and carry out the required maintenance. However, in case the design and manufacture of the trains are carried out by the Railways Companies themselves, the solutions to the problems of transportation needs and maintenance can be directly reflected, making it easy to develop the new trains required.

4.2 New maintenance system and equipment

Reduction in maintenance cost is one of the major requirements in the development of new-type commuter trains from managerial standpoint of the Railways Company.

The sophisticated maintenance support function in an E231-series commuter train, a function of TIMS reduces maintenance load.

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The automatic inspection before departure from depot and onboard test of major equipments significantly reduce the maintenance cost involving the daily functional inspections.

Further, the cost for the periodical overhaul maintenance specified by laws and ordinances has also been reduced to half due to the maintenance-free structure of the train and development of the facilities for maintenance.

Conventionally, the cars set in a formation were brought to the plant (workshop) one by one, and the major equipment were removed from the bogie to carry out overhaul maintenance before assembling again.

In the case of the newly developed facility, the cars set in a formation are brought intact to the plant, and the degraded equipments are replaced with the already-repaired equipments at the exclusive working spots. As a result, the time taken for the overhaul of one formation has been reduced from conventional 10 days to 5 days.

5 Conclusion

The newly developed 209-series and E231-series commuter trains in Tokyo area have substantially contributed to the improvements of the comfort and cost performance. Particularly the "Train Information Management System (TIMS)" adopted in E231-series trains has improved the intelligent control of trains.

Further, the progress in train technology has been accelerated also by the innovation in production line and maintenance system.

In the future, we are determined to keep up our quest for the development of commuter trains that takes due account of the environmental ecology, great comfort and reduction of total cost as a Railways Company possessing all cycles of commuter trains from development to design, manufacture, operation and maintenance.

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