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Advanced Commuter Train using Information Technology

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Abstract

East Japan Railway Company (EJR) has progressed the development of next generation commuter vehicles called AC-Train (Advance Commuter Train). Main goals of this development are the improvement of passenger service, the reliability, the improvement of transport and the decrease of lifecycle cost.
The big system change of the vehicle structure is carried out to realize these. And the various functions of the vehicles are improved by making use of IT.
This paper reports the affairs of the latest test vehicle.

1 Introduction

East Japan Railway Company (EJR) possesses railway network consisting of 17 lines in Tokyo metropolitan area. 14 million passengers are transported every day. The number of the train is 8200 and the number of the vehicles being used is 8000.The halves of vehicles have been exchanged by new-models in these 10 years.
EJR has developed next generation commuter vehicles called AC-Train (Advance Commuter Train). As for the future railway transportation of Tokyo metropolitan area, it is important to raise service level and cost performance about commuter transport. Also the new transport services suitable for the new century are needed. The main goals for development of AC-Train are as follows.
(1)Improvement of passenger service
(2)Safety improvement of transport
(3)Decrease of lifecycle cost

Development of technology has been advanced in two territories shown below to attain these goal concepts.
(1)Big system changes of vehicle structure and electric systems
(2)Full use of information technology (IT)

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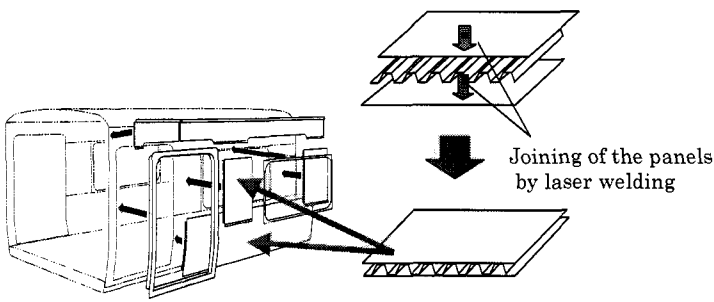
2. Cost reduction by big system change in AC-Train

2.1. System change of vehicle formation structure to reduce main components

As for most Japanese commuter vehicles, the length of car-body is 20 m and each vehicle is equipped with 2 bogies. This connection type has the advantage that division and connection of train set can be done easily in the middle of transport operation. However fixed train sets are increasing recently. So we have attempted the system change of train set structure.
In the concrete, the length of vehicles in the middle of train set is shortened even in 13 m, and a bogie is arranged at the connecting point between two vehicles.
The number of bogies and electric parts in the whole train set can be decreased by adopting articulated vehicles. Moreover the width of car-body becomes wider, then we can provide comfortable transport space rather than before.

2.2. Simplification of vehicle body structure by stainless double- skin panels method

Even if it isn't painted on the surface, clean condition is maintained for a long time with body surface made of stainless steel. Stainless steel is used widely as a material for commuter vehicles for the reason in Japan.
On the other hand, aluminum has been used for Shinkansen or Limited express vehicles recently. That is because Aluminum Double Skin Method has been introduced for manufacturing car body-shell.
We have developed and succeeded in the Stainless Double-Skin Method for manufacturing commuter vehicles.
Honeycomb-shaped member is put into between two sheets of thin stainless steel. These are combined by laser welding and become a sort of module-panel. Module-panels are put together and body-shell is completed. We call such way of manufacturing as Stainless Double-Skin Method. The advantages of this method are the two points written below.
(1)This method needs fewer materials and the structure is simple
(2)Use of the inner side of double-skin panels reduces interior finishing work



- This method needs fewer parts, and the structure is simple.
  → It reduces the processes of design and manufacturing.
- Use of the inner side of the double-skin panels
  → It reduces interior finishing work.

Figure 1. Stainless double-skin method

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2.3. Direct driving synchronous motor (DDM)

At present, as for the Japanese commuter vehicles, cardan driving induction motor is widely used. We have advanced the development of DDM as a main driving system in place of this.

As for the DDM system, a rotor of the motor is connected directly with an axle through the joint. Some problems of cardan driving system can be dissolved by introducing this system. The advantages of DDM are as the following.

(1) More over 5% are reduced in electric power consumption by improvement of motor efficiency

(2) Maintenance is unnecessary for a long time by the shutting up structure

(3)Noise surrounding of the motor is decreased with 15 dB

2.4. Autonomous and decentralized power control system

Integration and functional centralization have been advanced so far about the control system of the vehicles. The whole cost reduction of the system has proceeded by this thing. But, a big influence is given to the whole system of the vehicle when a trouble occurs in the important electric part in the case of integrated system. So we have decided to turn the control system to decentralized one by the idea contrary to before. An example in the power control system is stated below.

Four motors were being controlled so far with one VVVF control devices.

From now, one motor is controlled respectively with four small- sized VVVF control devices. Even if there is a trouble in one VVVF control device, an influence to give to the whole is small by this.

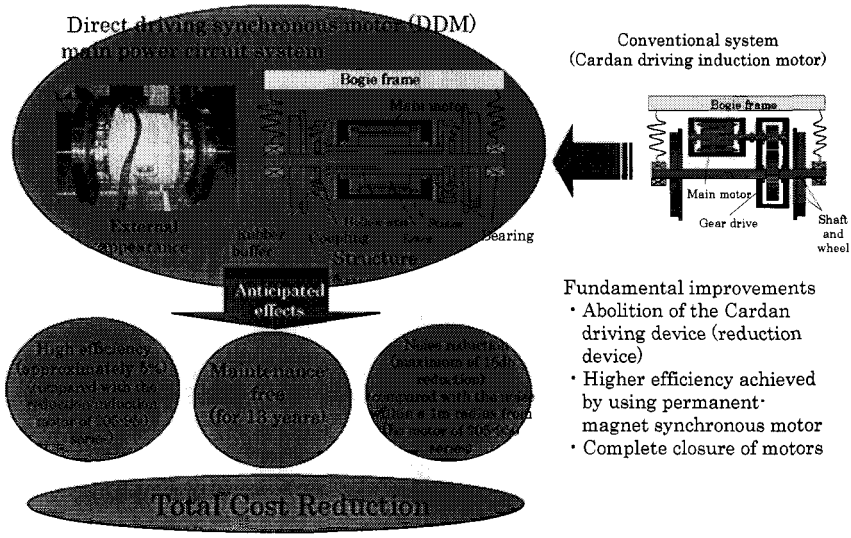

Figure 2. DDM System

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3. IT use in AC-Train

3.1 Concepts about IT use for vehicles

Advanced technology including IT has been made use of to realize the goal of AC-Train. Especially, it is important to innovate the function of railway vehicles by IT. The concept is that IT makes it possible [The information to want is always provided everywhere].
In the concrete, the network inside the train should be combined with various networks on the ground. Networks on the ground are for example the Internet, networks between dispatcher and vehicle depots and so on. Information service to the passengers or transport function will be improved due to the combination of networks.
Concrete contents are shown below.

3.2 Information service to the passengers in the train

It has become one of the advanced services that various kinds of information are provided to the passengers inside the vehicle. As for AC-Train, radio transmission unit, server and information LAN are equipped. Each vehicle is equipped with large displays and Internet displays for the individual passenger. The characteristics of these information platforms are reliability, generality and economies. These characteristics are very important to introduce it into the transport in Tokyo metropolitan area on a large scale. The functions possible in this information platform are the followings.

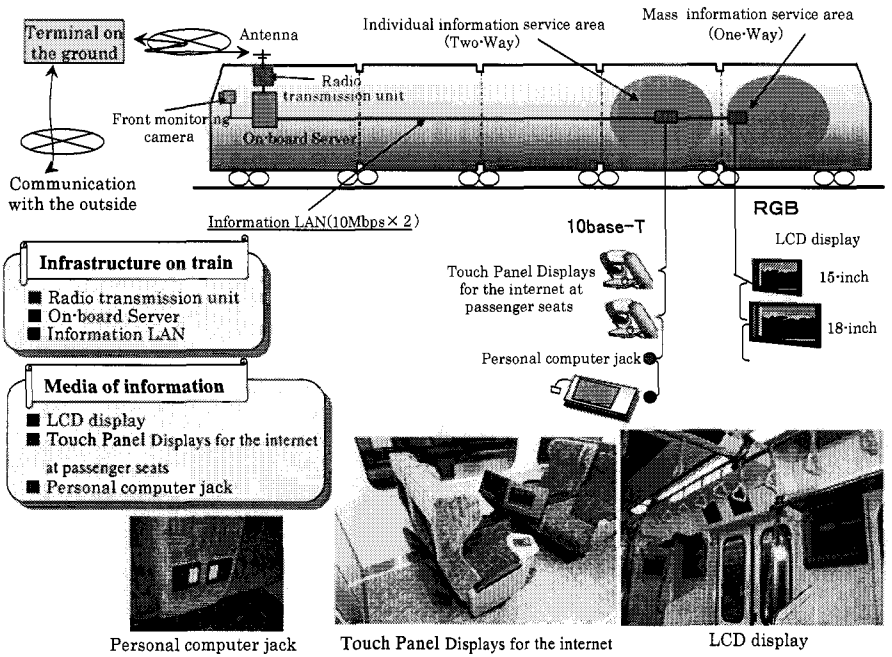

Figure 3. Outline of information service

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3.2.1 Information indication to the display in the vehicle

Large liquid crystal displays (15 inches and 18 inches) are put in the vehicle, and various kinds of information are offered for the passengers in the vehicle.

The contents are (1) image information, (2) guidance information, such as train operation received from the control center on the ground, transit information, and tourist guidance, (3) news and advertisements. These contents are offered for mass people, so the service is one way.

The information of train operation and news needs to be get at real-time. The information is periodically updated by radio transmission unit between the vehicle and the ground.

3.2.2 Information offer by the seat terminal or the personal mobile terminal

We developed in this test train not only about the information service system for commuter trains but about it for limited expresses. The seats imitated limited express have been arranged in a part in the vehicle. The seats are equipped with information terminals, and each passenger is provided with interactive information service. Furthermore, at these terminals, the connection with the Internet from a vehicle and transmission and reception of E-mail are also possible. Moreover, the Ethernet LAN port and the access point of wireless LAN are arranged in the vehicle. Thus, the same information as the seat terminals can be also offered to the PC or PDA carried by each passenger individually

3.3.The reliability improvement, support against the transport difficulty restoration, passenger safety countermeasure

3.3.1The mutual back up system

The down time tends to become bigger once main components (ATS-P, Door operating control unit or Brake control unit) brakes down. Especially, as for highly frequent railway

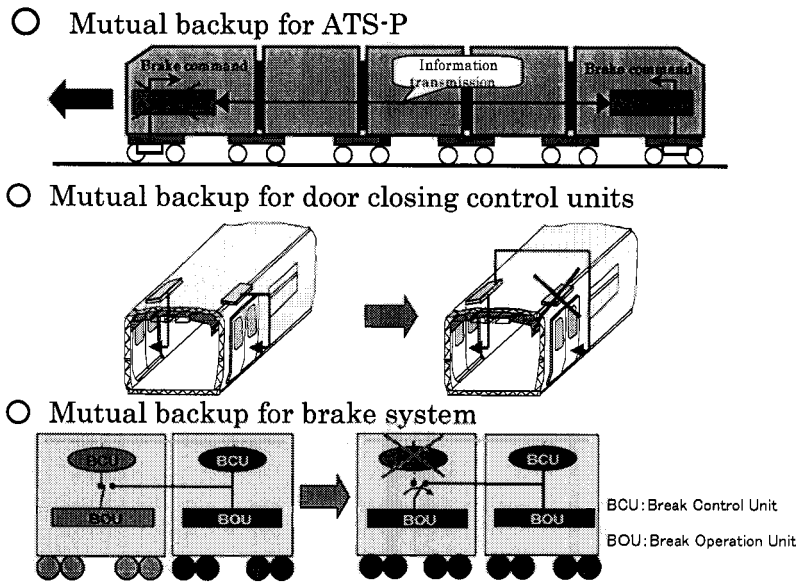

Figure 4. Mutual back up system by the application of IT

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transport of Tokyo area, transport may fall into the disorder greatly. Usually countermeasure is to double these units, but weight and cost may increase. So attention have been paid to that these units are already equipped plurally, and each unit backs up each other in case one is broken down. Information transmission technology is used for this system.

3.3.2 Self-examination function and emergency restoration function

Recently, electronic control system has been introduced widely into the railway vehicle. Once a trouble happens, the condition judgment and temporary repairs take time compared before. So, vehicles themselves are made to have a self-examination function, and a result is notified to a driver by monitoring system. Furthermore, temporary repairs are made automatically if necessary. By these means restoration time will be shortened.

3.3.3 The transmission of monitoring data and visual image to the control center

When a trouble occurs, transmitting the conditions of the spot to the control center on the ground was made by oral conventionally. The judgment and instruction of dispatcher become precise if the conditions of the spot are conveyed by data or image information instead of oral transmitting. For example, the information of the monitor equipped on the vehicle will be transmitted to the dispatcher in the case of the breakdown. Image information in front of the train will be also transmitted in the case of the accident in the crossing.

3.3.4 Electrical transmission of instruction from control center

It has an electrical transmission between ground and the vehicle. Instruction from dispatcher on the ground, such as restoration or train operation, is made transmitted when a trouble occurs.

3.3.5 CCD monitoring for passengers' safety

Some cameras are arranged on AC-Train for passengers' safety.
A camera inside the vehicle can show a situation in the vehicle in the display of a conductor's compartment.
Some cameras attached above the doors display the image of the entrance. Moreover, the function which detects whether something placed between doors by image processing is under development.

3.4 Train information system by the application of widely used transmission technology

EJR has applied information technology for development of monitoring systems of vehicles.
A development history in the monitoring function is shown in the Fig 5.
Monitoring device made its debut as the 1st generation in 1988. At this stage, monitoring of equipment performance, control command over service equipment and recording of onboard tests were carried out. After that, TIMS (Train Information Management System) developed in 1998 exceeded a monitor's level through the generation. As for TIMS, reduction of electric wires through the train, automated inspection before departure from depots and optimization of train control were realized.
As for AC-Train, we have introduced widely-used transmission technology, to attain the

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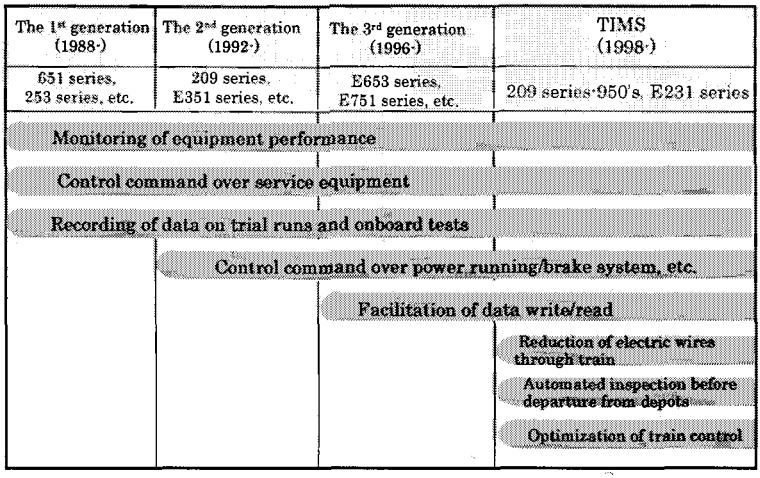

Figure 5. History of monitoring functions

cost reduction of the system. The approach of cost reduction is as follows.
(1) Efficient development will be attained if not only the exclusive technology of railway vehicles but widely-used technology, for example Etharnet and LON(Local Operating Network) is utilized as much as possible. Moreover, it becomes possible to perform selection of cheap parts.
(2) Regardless of the conventional system configuration, the control device has been more flexibly arranged so that it may become an efficient system configuration. The system configuration was improved and the terminal units have been arranged according to the amount of information in the vehicle.
(3) The new transmission system using widely-used communication chip LON make possible to reduce the electric wires for control in each vehicle, thus fitting cost and material cost will be cut down.

3.4.1 Train bus applied Widely-used transmission technology (Ethernet)

As for AC-Train Ethernet has been applied for the train bus.
This New Train Information System has the ability of 10Mbps and this is 4 times as TIMS.
The structure of the transmission system is the ladder type.
With this system, since obstruction evading route for transmission has been increased, the performance of a fault tolerant has been improved.
Since transmission rate became larger, it became possible to also transmit the image data acquired from the indoor camera, the door cameras and the front camera besides the sound data of announcement unit.
The control command pass througt both transmission lines of the two (transmission lines). And the sound data of announcement unit pass through one transmission lines of the two, and the image data of the camera pass through the other line. Thus, the two transmission lines are utilized effectively.
Conventionally the number of the display units of commuter vehicles was one at the drivers' cabin. In AC-Train, two displays are in one cab. It became possible to offer thereby more many information. It is possible to display a picture on one of two sets.

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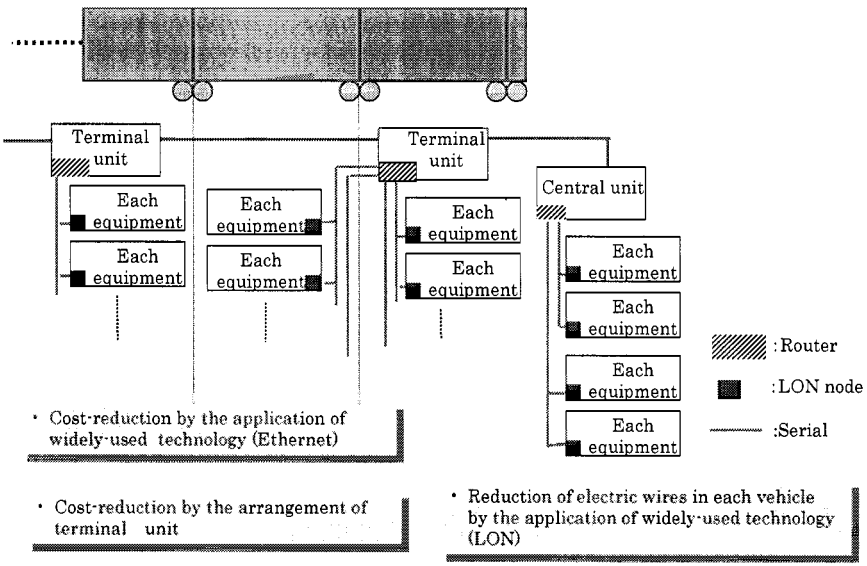

Figure 6. Train information system by the application of widely used transmission technology

3.4.2 Arrangement of the terminal unit according to the amount of information in each vehicle

As for the train information system, it was common to arrange a terminal unit on each vehicle conventionally. Now, the ratio of a trailer car is in the increasing tendency. Most of the trailer cars are only mounting extremely few equipments. So a trailer car does not need so many information. On the other hand, a motor car mounting many equipments and needs various information to control them. Therefore, a difference arises to required information for every vehicles.

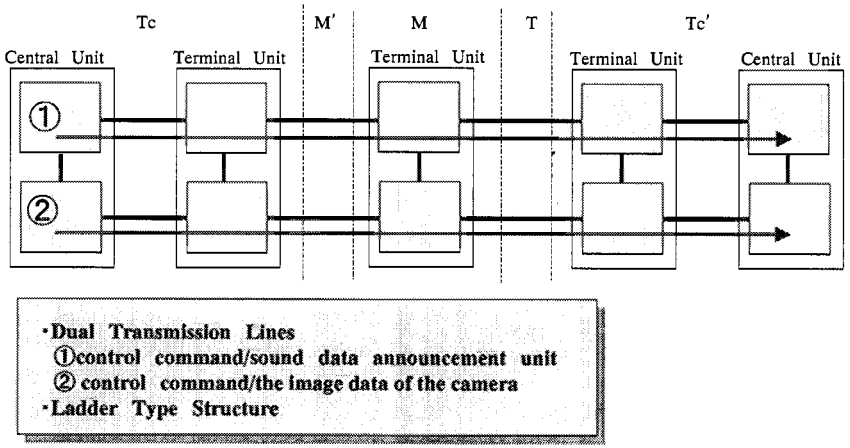

Figure 7. Train bus of the AC-Train

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Then, we improved arrangement of a terminal unit so that it might become the composition of the terminal corresponding to the amount of information required in the vehicle.
The terminal unit has been arranged only on the vehicles which need much amount of information.
The equipment of the vehicles without terminal unit is connected with the terminal unit currently attached to the vehicles of before or back. Thereby, as for AC-Train, terminal unit is arranged every other car. We are cutting down terminal equipment and count upon the total cost of the train information system being held down.

3.4.3 Vehicle bus using the widely-used communication tip (LON)

Furthermore, we used the general-purpose communication tip LON (Local Operation Network), and aimed at the cost reduction of the transmission system in each vehicles.
The advantage of LON is as follows.
(1) A communication tip is small and low cost.
(2) Specification is standardized. This enables manufacture of efficient software. Moreover, it is advantageous to connection. It is advantageous to extension of a function.
(3)It is possible to constitute an efficient topology.
We used LON, and decided to make signals pass through transmission line as much as possible, and the amount of electric wires for control in vehicle was cut down.
The signal was checked [whether to have been data relevant to an interlock / whether it is data of which a high-speed response is especially required for reasons of security]. By putting the node using the LON tip an inside or near the equipment, the signals have been collected and the electric wires were cut down. About 30 % of the control electric wires in vehicle was cut down.
The access speed of the system in vehicles is 1.25Mbps. As for the transmission cycle, 10ms or 100ms are set up for every equipment. A transmission cycle is 10ms or 100ms. Equipments are connected in the shape of a loop. Even when disconnection arises, communication is continued by taking the course of the circumference of the contrary. Thus, redundancy is maintained without forming a circuit into a double system.

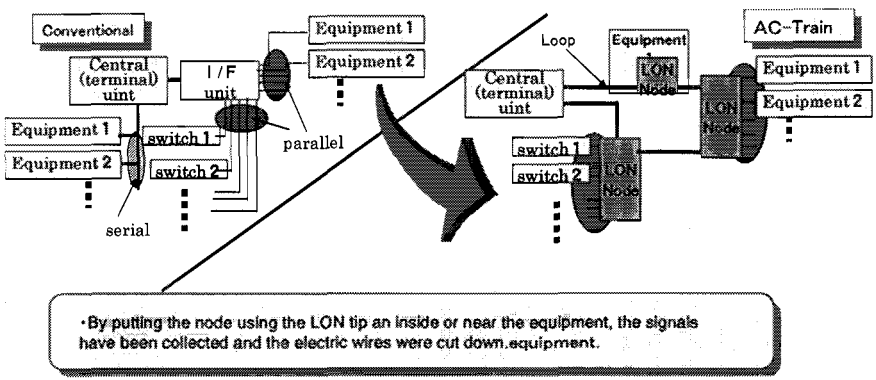

Figure 8. Vehicle bus of the AC-Train

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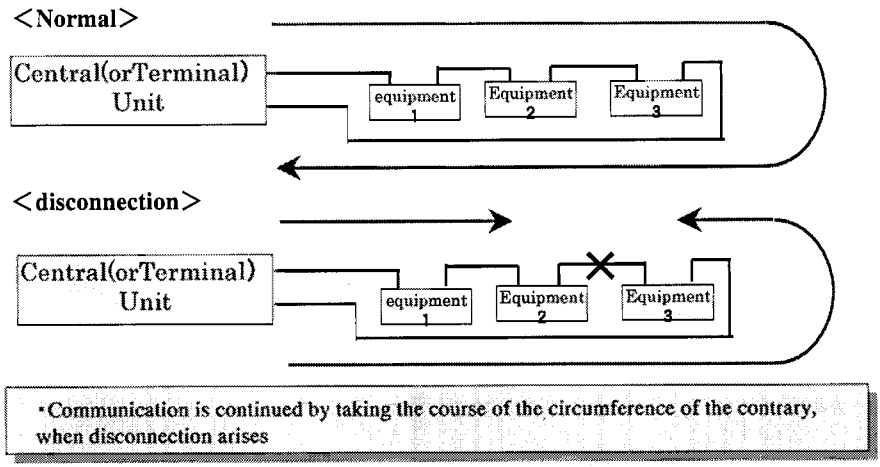

Figure 9. Redundancy of the Vehicle Bus of the AC-Train

4. Conclusion

The test vehicles of AC-Train has been completed recently. AC-Train consists of 5 vehicles. General description of the AC-Train is shown in the Fig 9.
Various functions will be examined and the reliability will be verified through the endurance test. After that, mass production will be planned as a commuter train of the next generation for Tokyo metropolitan area.

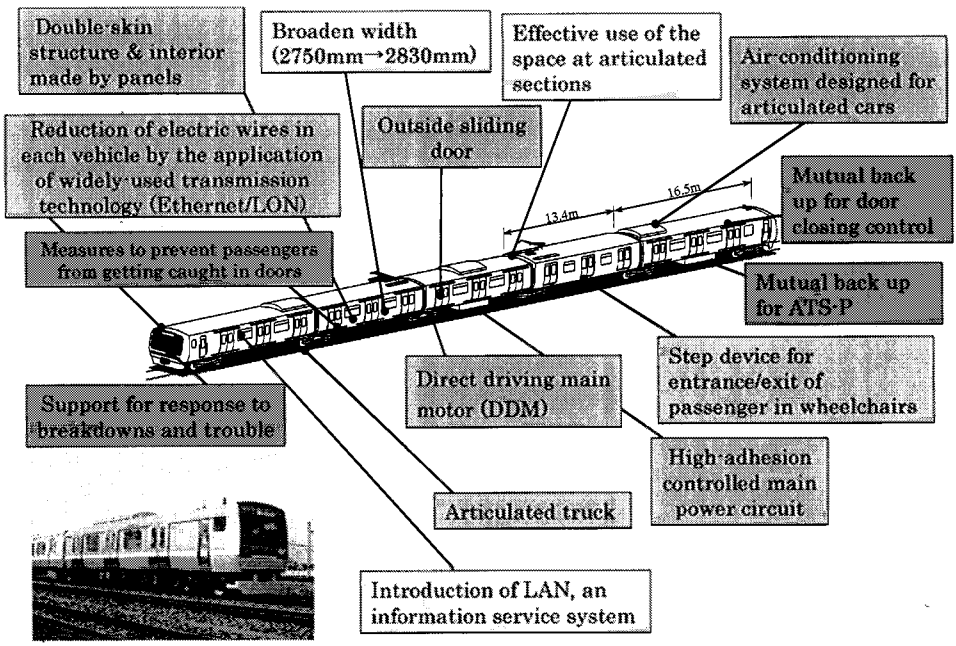

Figure 10. General description of the AC-Train