Newsletter on the Latest Technologies Developed by RTRI

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Research and Development for Sustainable Evolution of Railways

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Vice President

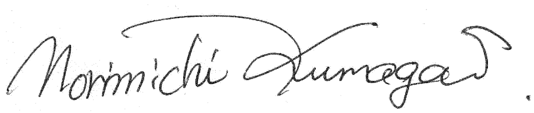
After starting revenue service first in 1872, the railways in Japan are now in their 140th year. They have introduced knowledge and know-how from the United Kingdom, France and the US on railway technologies and management in abundance in terms of human and physical resources. With this knowledge and the wisdom of Japanese engineers, Japan has constructed a nationwide railway network tailored to be in harmony with the specific geographical environment and transport demands of the country. These efforts bore fruit such as construction of the Shinkansen system to accelerate the social and economic development of the country. Unexpectedly, the Shinkansen system triggered the recognition that high-speed railways were of high value to the aforementioned pioneer countries in the railway industry.

A number of other countries are now discussing the construction of high-speed railways that combine high-speed performance and large transport capacities to rival those of airplanes as a basic infrastructure of the nation. These countries recognize the efficiency that high speed railways bring to inter-city transportation, while recognizing the merits of small amounts of CO_2 emission. It is no exaggeration to say that the unprecedented safety of the Shinkansen system has been supported by the research and development continued for 45 years, before and after the start of revenue service. The distressing experience of system trouble in the past gave railway operators the impetus to further improve the safety of Shinkansen. For instance, the Hanshin-Awaji Great Earthquake in 1995 collapsed part of Shinkansen bridge piers, which motivated railway operators to implement reinforcing work for the viaducts of the nationwide Shinkansen network. At an earthquake in 2004, a Shinkansen train was derailed. With this incident as a momentum, railway operators now positively promote measures to prevent the derailment and de-tracking accidents of Shinkansen cars. Due to these measures, Shinkansen structures were not seriously damaged by the Higashinihon Great Earthquake in 2011. The high-speed railways in Japan, which have repeatedly been re-engineered with various problems eliminated, are superior from the viewpoints of energy conservation, safety, reliability and other characteristics. With this experience, Japan will be able to support various projects in other countries.

To respond to the requirements of the nation and the Shinkansen operating companies as a whole, Railway Technical Research Institute (RTRI) has been promoting widely ranged themes to upgrade the performance of the Shinkansen railway system. These include the improvement of safety, suppression of aerodynamic noise in high-speed operation, development of lightweight cars and systems to save regenerative brake energy, in addition to the evaluation of the safety related to man-machine interfaces.

I still remember that RTRI owes much to the cooperative relations with overseas railway sectors during the process of such research and development. Research at RTRI has been accelerated by the detailed discussions with the researchers of SNCF, China Academy of Railway Sciences, Korea Railroad Research Institute, Rail Safety and Standards Board in the UK, Southampton University, Cambridge University, MIT and other research organizations.

I suppose that the research results thus obtained shall be of benefit to railways of the world. The basis of research and development is to raise the knowledge level of human resources. If railway researchers meet together, stimulate each other and strengthen the will to undertake research and development, the potential success of railway technologies will continue to improve. Those who are addressing research and development in railway technologies should promote activities toward the sustainable development of railways in the world. We are sure to play our part in such a role in international circles.



Activities of the Railway International Standards Center

Hiroshi TANAKA
Director, Railway International Standards Center

The Railway International Standards Center (hereinafter referred to as “the Center”) centralizes the promotion of international standardization activities on railways in Japan. This report introduces a summary of the Center’s activities in fiscal 2011.

Review of IEC and ISO standards

In the field of International Electrotechnical Commission (IEC) standards, while acting as an IEC/Technical Committee 9 (TC9) national reviewing organization in Japan, the Center hosted the TC9 national committee meeting three times to discuss the status of the standard reviewing activities and the schedule of the Center in fiscal 2011. It also reviewed the revision of the railway standardization business plans in Japan and the reports of the TC9 management and Chairman's Advisory Group (CAG) meetings.

The Center held more than 70 national working committee meetings to review standards and delegated approximately 100 experts to international Working Groups.

The Center also plays the role of a national reviewing organization of ISO/TC17/Sub Committee 15 (SC15) and participates in the review of railway-related ISO standards dealt with under other standard reviewing organizations.

IEC/TC9 Plenary Meeting held in Japan

The IEC/TC9 Plenary Meeting was held in Japan for the first time in six years, with the venue changed from the original candidate city of Tokyo to Fukuoka, because of the potential effects of the accident at the Fukushima Nuclear Power Plant caused by the earthquakes and tsunamis in March 2011.

A number of essential persons participated in the meeting, including 19 persons from seven European countries, one from Canada, seven from China, three from Korea, two from Singapore and 10 from Japan, or 42 members in total from 12 countries, including the TC9 Chairman (Italy), Secretary (France), Assistant Secretary (France) and Technical Officer. As the delegates from Korea, Singapore and other participating member (P-member) countries, who did not participate in the last session in Changsha, China, were also present this time, it is thought that the activities in Asia by the Center have been fruitful. The meeting at Fukuoka officially adopted 44 resolutions including one proposed by Japan on “the standardization work for the procedures to determine the requirement specifications for train control radio systems.”

The technical visit to the Kumamoto Integrated Rolling Stock Base, conducted with the cooperation of JR Kyushu, provided a chance for the participants to experience the excellence of Japanese railways.

Proposals on domestic standardization work

The Center has discussed the necessity to domestically standardize international standards already issued or to be issued and is now supporting their incorporation into Japanese Industrial Standard (JIS). There are eight standards related to rolling stock currently on the agenda.

Lecture classes on standardization

As a means of helping people to cope with international standardization, the Center conducts lecture classes on a regular basis for people working in the railway field. In fiscal 2011, the class was held five times to provide the attendees with the basic knowledge required for international standardization and disseminate the movement in recent years. Other themes include the basis of international standardization activities, the status of international standards under review and the development of the standards that will become important in the future.

Other activities

The Center is making efforts to promote exchanges with railway personnel in Japan, establish close relationships with overseas organizations for international standardization and promote mutual understanding and information/opinion exchanges, thereby helping to create better international standards.

IEC/TC9 Plenary Meeting

A Tilt Control System Focused on Preventing Motion Sickness

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We developed a tilt control system (Fig. 1) focused on preventing motion sickness, an indisposition that is thought to be caused by lateral vibration at a frequency of approximately 0.3 Hz. To reduce the vibration at such low frequencies, it is essential to tilt the car body to precisely match the track curve profile. For this purpose, we developed a new system that detects train position with high precision and determines target tilt values (by drawing a tilting pattern for all sections of track) to optimize the relation between ride comfort and motion sickness. After that, we developed a highly responsive pneumatic actuator for "active" tilt control that follows the tilting pattern. It should be noted that the tilting patterns match track irregularities in both straight and curve sections of track. For reference, typical tilting cars in Japan adopt "passive tilting systems" that tilt car bodies by centrifugal force (Fig. 2).

The new position detecting system combines GPS measurement, an on-board track curvature database and wheel rotation counts. It first uses GPS to determine an approximate running position and then collates the track curvature for several hundred meters before and after the running position with that measured by the car body (using a value of car body yaw angular speed divided by the running speed). The system then uses wheel rotation counts to refine the current running position (Fig. 3), with errors of ±4 m as verified through running tests.

If the track profile at the running position is known, it is possible to predict car body vibration that fluctuates as the car body proceeds. To achieve this goal, we devised a process to estimate (1) car body lateral acceleration, (2) its changing rate (jerk), (3) car body roll angular speed and (4) its changing rate (angular acceleration) based on the running speed. The process then refers to the curvature/cant of the track stored in a database installed on the car body and we developed a technique to calculate the minimum value of the formula for tilt angle by using the physical quantities (1) to (4) above as parameters.

We adopted a term "JTM pattern" to describe the process that determines the values of the target tilt angle calculated for all locations in each curve (Fig. 4). In particular, the process places a larger weight on the lateral acceleration having a component of 0.3 Hz. This reduces the vibration in this frequency band and mitigates the effect of motion sickness.

The tilt angle control based on the JTM pattern requires a high-response high-output actuator. Such characteristics are easily attained with hydraulic or power-driven actuators.

After comparing the merits/demerits of different actuators, we adopted a low-cost pneumatic actuator featuring high performance characteristics to insulate the vibration in high-frequency bands (Fig. 5). The servo valve of the conventional pneumatic tilting actuators (a pressure control valve) is replaced by a flow control valve to improve air flow characteristics. The hydraulic damper, which is called a tilt damper, is normally used in parallel but was removed to decrease the resistance against tilting motion, while changing the actuator control mechanism to compensate for the control stability that would otherwise be lost. This was done by adding an acceleration feedback to the actuator in addition to the normal displacement feedback. To confirm the effect of the highly responsive actuator that follows the JTM pattern to mitigate motion sickness, we implemented a simulation using multi-body dynamics, while using the motion sickness dose value (MSDVy) as the value to evaluate motion sickness. See Fig. 6 for the results. The MSDVy decreased 45% and 25%, respectively, from that of the passive tilt system and the conventional tilt control system respectively, while ride comfort remained unchanged as the vibration at high frequencies did not increase.

The rolling stock installed with a tilt control system is highly important in Japan, a small country enclosed with sea coasts and studded with mountainous areas that result in areas with highly curved track. We are now making efforts to improve the car body tilting technology further, thereby aiming at implementing rolling stock featuring high-level curve negotiating performance that will be at the forefront of passenger transport services.

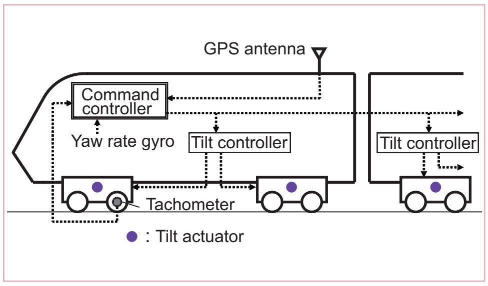

Fig. 1 System configuration of proposed tilting system

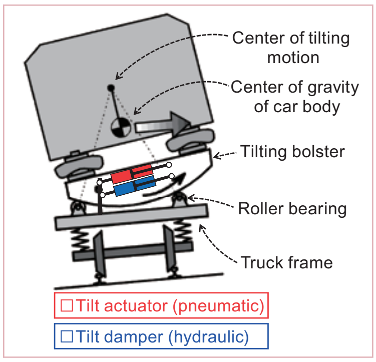

Fig. 2 Structure of tilting vehicle in Japan

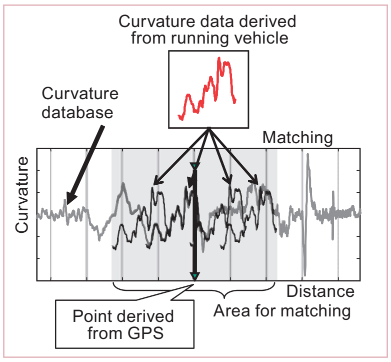

Fig. 3 Curvature matching

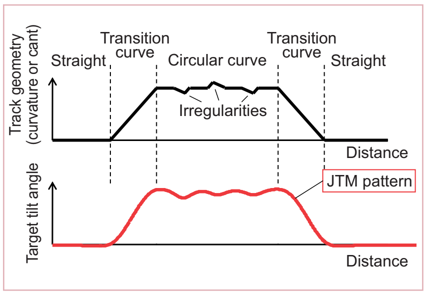

Fig. 4 Example waveform of JTM pattern

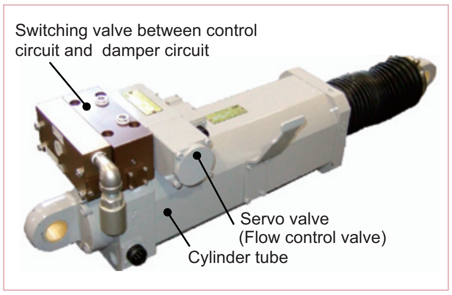

Fig. 5 High performance pneumatic tilt actuator

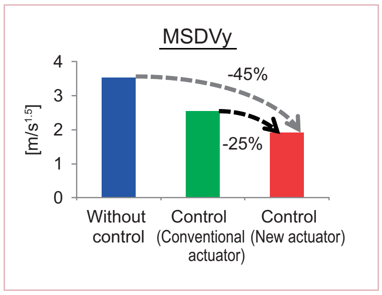

Fig. 6 Improvement of motion sickness (simulation result)

A Simplified Method to Calculate the Energy Consumed by Rolling Stock

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Making an effective energy saving plan requires the ability to calculate the reduction of energy consumption achieved by replacing rolling stock. Although energy consumption can be calculated by running train operation simulations, these programs require considerable input data such as gradients between stations, curves, turnouts and signals. This can amount to a large volume of data when the running distance is long. In the case of railway operators having various rolling stock and tracks in particular, there will be a number of combinations of these facilities. Therefore, simpler and quicker calculating methods are of value and we developed a simple method to calculate the energy consumed by rolling stock without implementing running simulations.

Figure 1 shows an example of the changes in the energy consumed by EMUs after starting from a station until stopping at the next station. In running simulations, the energy consumption is normally obtained by subtracting the volume of regenerated energy from that of the powering energy. However, it is also possible to calculate the energy consumption by summing the separately calculated amounts of machine loss, running resistance loss and non-regenerative braking loss (see Fig. 1). We adopted this latter method, and developed the following calculation method. In the method, information equivalent to the train timetable is used as input data to represent the train operation, with the average distance (AD) and average running time (ART) being calculated for the section between stations. The following calculations are made while assuming a case where a train operates over the distance (AD) in the running time (ART) by following the pattern in Fig. 1.

For the purpose of the calculation, we follow the steps below.

1. Calculate the average speed (AS) from AD and ART.
2. Calculate the running resistance loss from AS using the formula of running resistance and the empirical formula obtained in advance through the analysis of actual running data.
3. Calculate the maximum speed attained (MS) and initial braking speed from AS using the empirical formula obtained in advance through the analysis of actual running data.
4. Calculate the machine loss at powering from the kinetic energy at MS, running resistance loss and the efficiency of rolling stock.
5. Calculate the machine loss and non-regenerative braking loss at braking from the kinetic energy at the initial braking speed, the efficiency of rolling stock and regenerative brake performance.

A summation of these losses gives an approximation to the energy consumption.

To verify the validity of this method, we repeated the above calculation process for multiple sets of EMUs and compared the calculated and measured values. The results indicate that these two sets of values are approximately in agreement with errors of 7% or less, as shown in Fig. 2. This is evidence that this method is an effective means to calculate the approximate energy consumption.

As this method calculates not only the energy consumption but also its breakdown, it is easily understood how energy saving can be attained. Although the above calculations were made for EMUs, this method is equally applicable to DMUs with satisfactory results expected.

We hope this method will be applied to energy saving plans by railway operators and contribute to further energy conservation in the railway industry.

Table 1 EMUs used for this study

	Traction control	Train category	Average distance between stations	Average speed
EMU 1	Inverter control	Local	2.28 km	58.2 km/h
EMU 2		Rapid	6.64 km	83.6 km/h
EMU 3	Armature chopper control	Local	2.12 km	52.6 km/h
EMU 4	Field added excitation control	Local	1.18 km	41.8 km/h
EMU 5	Rheostatic control	Local	1.23 km	41.2 km/h
EMU 6		Limited express	19.3 km	76.7 km/h

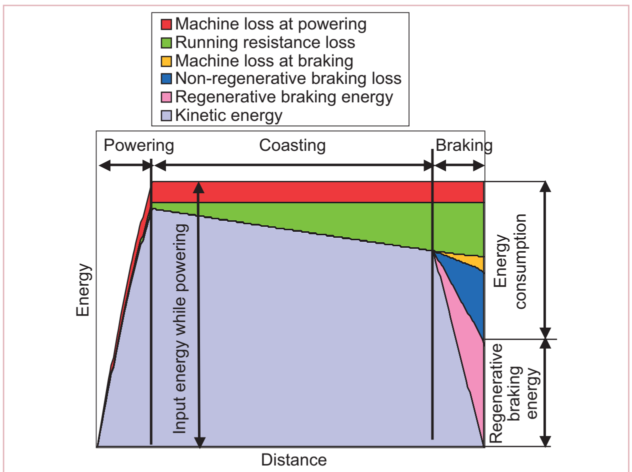

Fig. 1 Changes in energy during the operation of EMUs

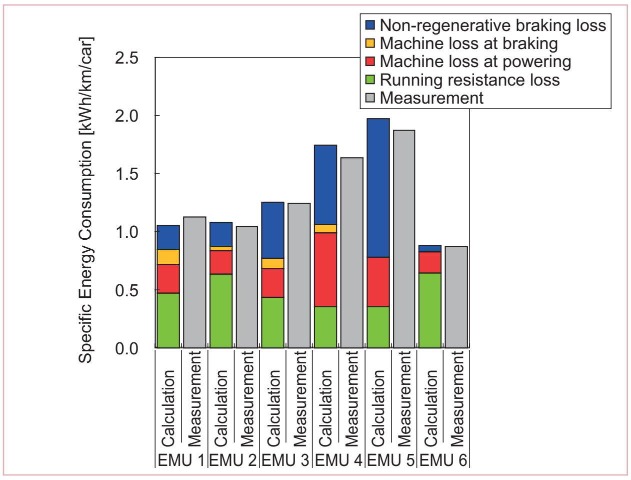

Fig. 2 Comparison between calculated and measured values

Listening Difficulty Tests on Broadcast Announcements for Passengers at Stations

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Information announcements are broadcasted in concourses and other places in railway stations. Good speech transmission quality is necessary to ensure that the announcements are understood by station users. Methods to evaluate the speech transmission quality can broadly be divided into two: one is a physical method to measure quality by using test signals and the other is a subjective method using test subjects. Both methods require monitoring loud test announcements. It is difficult to measure the speech transmission quality by the subjective method during business hours at stations or other public venues as a large number of test subjects are required. Thus, the subjective method has rarely been used to evaluate the speech transmission quality at stations. Fortunately, however, we had a chance recently to perform subjective evaluation tests with subjects at concourses and underground platforms at stations as explained below.

A means to evaluate the speech transmission quality by the subjective method is to measure the listening difficulty. The methodology used required the evaluation of the announcements heard by a number of test subjects using a four-stage scale from "not difficult to listen" to "extremely difficult to listen."

We implemented the listening difficulty tests at the following six locations in four stations in the Tokyo district.

(1) Underground platform, station A
(2) Underground platform, station B
(3) Underground concourse, station B
(4) Ground concourse, station C
(5) Ground concourse, station D
(6) Ground ticket barrier, station D

Among these test locations, (1) and (6) are furnished with sound absorption work on the ceiling and surrounding walls, while others are not. The test points (1), (2), (3) and (5) are in large spaces, while (4) and (6) present medium-sized configurations.

For the sound source, we used actual broadcast announcements (automatic) at (1), (2) and (3) (stations A and B) and read a message for testing at other test locations (stations C and D), as there were few broadcast announcements at these stations.

The stations A and B had 15 test subjects (7 males and 8 females, average age 35.1 years) each. Stations C and D had 14 test subjects (6 males and 8 females, averaged age 31.9 years). At each location, the test subjects were all subjected to the test simultaneously, while standing at a point horizontally 3 m distant from the speaker-projection point on the floor (Fig. 1).

Figure 2 shows the relation between the listening difficulty and the sound level of passenger information broadcasting. (Note that 100% listening difficulty indicates extreme hearing difficulty, with easier hearing occurring at the lower percentage numbers.) The graph indicates that listening difficulty has a minimum value at the sound level of 68 to 74 dB. The listening difficulty tends to increase at sound levels higher than 85 dB, though it must be noted that only the data at the test location (2) (underground platform, station B) are available for these higher sound levels. The data suggests that there may be an optimum volume for the broadcast announcements to minimize the listening difficulty.

See Fig. 3 for the relation between the listening difficulty and the signal to noise (S/N) ratio. The listening difficulty is somewhat lower at test location (1), the underground platform, station A, and higher at the test location (2), the underground platform at station B. On the whole, the higher the S/N ratio is, the lower the listening difficulty becomes. At test locations (1), (3), (4), (5) and (6), the listening difficulty is close to 0% (easy to hear and understand) at an S/N ratio of approximately 5 to 12 dB. This suggests that there may not be any significant differences in the listening difficulty relative to the spatial size of the test location or the existence/non-existence of sound absorption work.

This study has clarified the relation between the sound level of broadcast announcements and the S/N ratio to minimize the listening difficulty. It also provided useful knowledge to improve the transmission quality of the information broadcasting at railway stations.

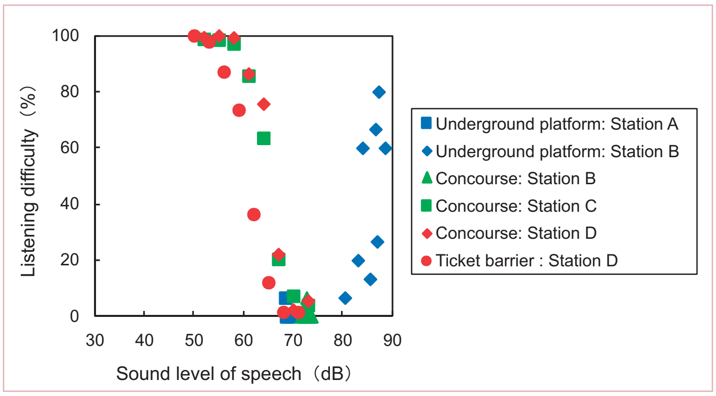

Fig. 2 Relation between sound level of speech and listening difficulty

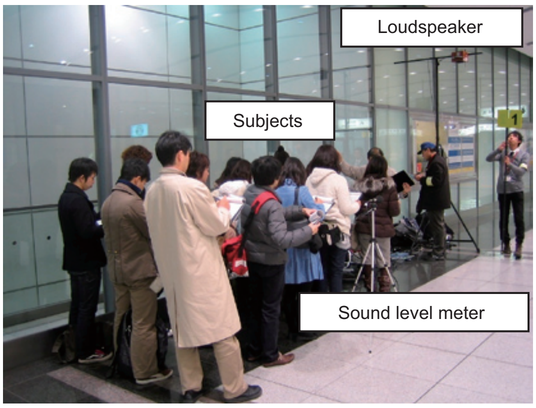

Fig. 1 Listening difficulty test

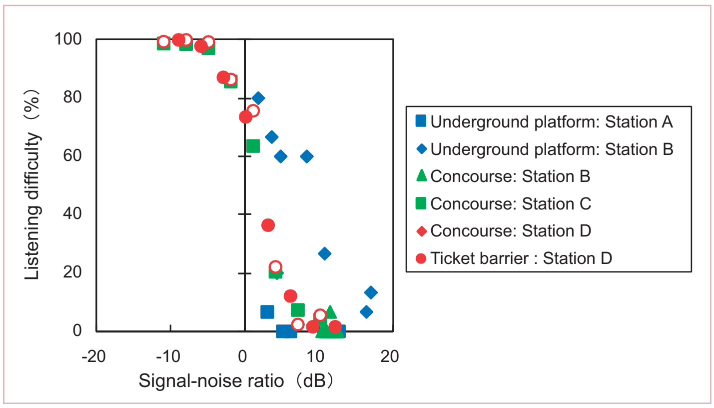

Fig. 3 Relation between signal-noise ratio and listening difficulty

Development of Surge Detection Type Fault Locating System for AC Feeding Circuits

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When a ground fault or a short circuit has occurred in the contact wire system due to bird strikes, fallen trees, flying objects or rolling stock failures, normal service will immediately be recovered to restart train operations if the fault point can quickly be located. Two types of fault locating systems are now used for this purpose in AC electric railways: one is the type to measure the reactance of fault circuits in feeding circuits as an indicator of the distance to the fault point (widely used across the world) and the other uses the ratio of the neutral terminal current of adjacent autotransformers as the indicator (developed in Japan and used for Shinkansen railways in Japan and Taiwan). These systems can normally locate the fault point with errors of 1 km or less, but the measurement involves substantially large errors and sometimes it is impossible to locate the fault point for certain types of accidents. Thus improving the precision of fault locating system to quickly resume train operation is very desirable.

As high voltages such as 20 kV and 25 kV are used for AC electrification, a fault generates a surge voltage that is propagated in the contact wire. Recently, we developed a new surge voltage detecting device used to locate fault points (see Figs. 1 and 2 for its principle of operation). To calculate the distance from a substation to the fault point, this device uses the difference between the surge voltage arrival time at the substation on either end of a section and that at the sectioning post, together with the surge propagating speed in the contact wire. This principle has already been applied to the system of power transmission cables. As the surge propagating characteristics in feeding circuits are different from those in power transmission cables, however, several technologies had to be developed.

There is virtually no prior literature on the measurement of the waveforms or the propagating speed of surge voltage in railway feeding circuits. Therefore, we implemented a test to inject an impulse voltage into a contact wire to confirm that (1) the surge voltage propagating speed is approximately 90% of the velocity of light and (2) the surge voltage can be captured at the secondary winding of the instrument voltage transformer (VT) normally installed at substations, though it is attenuated and deformed to a large extent. We also manufactured a surge voltage measuring/recording device that synchronizes the times at two distant places using the GPS clock (Fig. 3). The methodology requires only a GPS antenna to be connected and use of the voltage output from the instrument voltage transformer (VT) at substations as an input. No expensive high-voltage high-speed voltage sensors are required. We also developed software to automatically (1) determine the surge voltage arrival time from the surge voltage waveform recorded by the prototype device and (2) locate the distance to the fault point. Finally, we implemented an artificial fault test and used the prototype device under working conditions to locate actual faults at a substation on a revenue service line for approximately seven months to verify its precision. As a result, we were able to confirm that the device can locate fault points at high precision with errors of about 100 m or less when applied to approximately 20 km-long feeding sections.

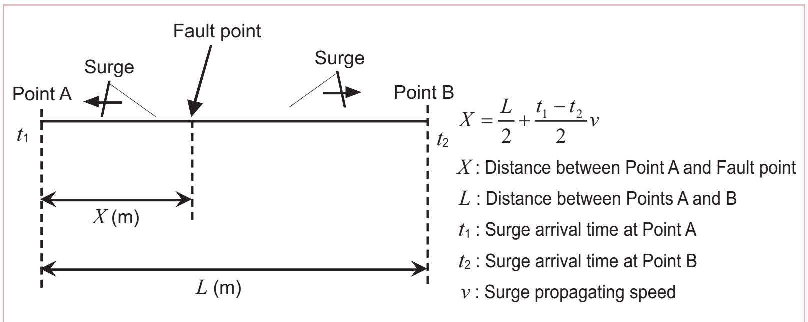

Fig. 1 Principle of the surge detection type fault locating system

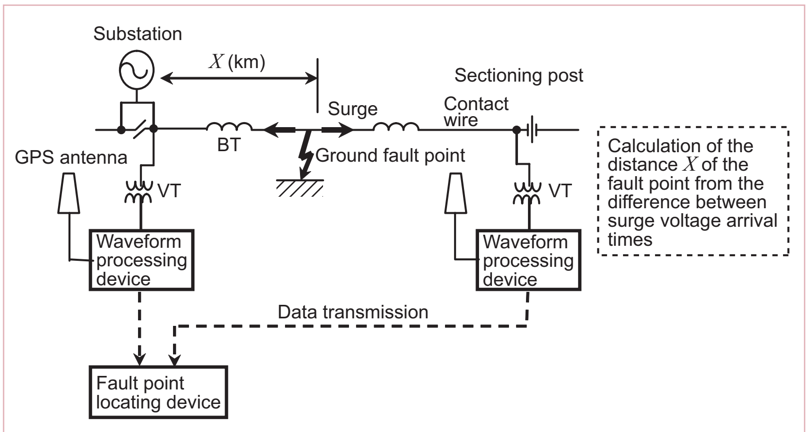

Fig. 2 System composition

Fig. 3 Prototype surge detection type fault locating system (waveform processing device)