Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

December 26, 2007 No. 20

Railway Technical Research Institute
2-8-38 Hikari-cho, Kokubunji-shi
Tokyo 185-8540, JAPAN

URL: http://www.rtri.or.jp

GENERAL INFORMATION

ARTICLES

Brightening the Future of Railways Using New Technologies

Eisuke MASADA
Chairman

Reflecting the mounting concern over global warming, the sharp rise in energy costs, and the aging of society, public demand for railway use has been ever-increasing in Japan. Most of the main intercity railways and high-density urban railways are making a good showing today, especially owing to the improved convenience for passengers who use extensive railway networks, such as the development of a new fare collection system using contact-free IC cards. Many local railways, on the contrary, are suffering hard times because of the continued decrease in ridership, which has been absorbed by more convenient forms of road transportation. From a long-range viewpoint, the main intercity railways and urban railways also have a problem with the human resources that are required to maintain the safety and comfort of railways as transportation facilities.

In order to solve the above problems, consolidate the position of railways as transportation facilities and expand the scope of railway services, it is indispensable to introduce new technologies. Backed by the brisk world economy, various seeds of technologies that can have an enormous impact on the future of railways are growing. These include fuel cells, low-cost solar cells, effective power storage devices including SMES[1] systems and Ni-H batteries, high voltage endurance and low-loss SiC and GaN compact power devices, and the Y-based high-temperature superconductor. Extensive studies aimed at applying these new technologies to railway facilities are being conducted.

Moreover, to solve the long-term problems that railways are faced with, new system concepts will need to be presented and those new technologies applied to clarify the feasibility of materializing those concepts for the public. As an example concept to ensure both the safety and profitability of low-demand local railways, a combination of minimized wayside facilities, on-board concentrated operation control functions and self energy supplies using high performance batteries can be proposed. More research must still be conducted to accomplish such systems, but some of the operation control functions have been validated in ARAMIS[2] and ATACS[3].

Turning our eyes to the Maglev railway system, which was once called "a railway of dreams," the Transrapid Shanghai system has been operated practically since 2003. Recently railway operators have announced practical use plans for both a Superconducting Maglev system and a Transrapid system. Including HSST, which already operate in Japan as an urban transport system, I think we can expect the use of Maglev systems to spread throughout the world. However, it should be noted that we still have a large barrier—the problem of cost—to overcome before the system can be widely used. Nonetheless, the innovative concept of Maglev transport should be introduced for broader applicability.

In conclusion, I believe the public strongly expects us to integrate the newly developed seed technologies, propose a "railway of tomorrow" that meets current social demand, and consolidate the technological foundations of innovative systems.

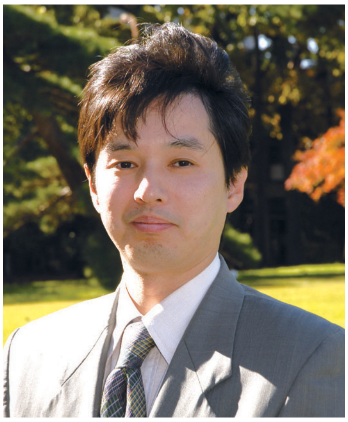
1 Superconducting Magnetic Energy Storage
2 Agencement en Rames Automatisées de Modules Indépendants dans les Stations (Arrangement in automated trains of independent modules in stations)
3 Advanced Train Administration and Communications System

Publishing English Digests of Design and Maintenance Standards for Railway Structures and Commentaries

Kenichi KOJIMA
Manager, Market Planning, Marketing and Business Development Division

The Railway Technical Research Institute (RTRI) provides standard design and maintenance techniques for railway structures (design and maintenance standards for railway structures with commentaries) based on relevant government ordinances. So far, RTRI has published 11 types of design techniques and five types of maintenance techniques for railway structures. These techniques are employed in the design, construction and maintenance of railway structures in Japan. They are among the most advanced techniques in the field of railways in the world. With the aim of introducing them to many countries around the world and making them become widespread in the future, RTRI has prepared English digests of the basic matters contained in its standards. The digests concisely describe the characteristics and essential points of the original texts so that the underlying concepts of the standards can be understood easily.

As a first step, RTRI published four digests of the most needed design standards for concrete structures, earth structures, seismic design and displacement limits, respectively, and one digest of the maintenance standards for railway structures. They represent a performance-based system that is still rare in the world. RTRI considers that they can be applied at many different construction sites overseas. Concerning English digests of the design and maintenance standards for railway tunnels (cut-and-cover, mountain and shield) and composite structures, RTRI are preparing them for publication early next year. In addition, RTRI has plans to publish English digests of the other standards in the near future.



Price: ¥8,000 for one set of five volumes
(¥3,000 for each of the volumes when ordered separately)

Inquiries: Ken-yusha, Inc.
(http//www.kenf.or.jp, FAX: +81-42-572-7190,
E-mail: kijyun@kenf.or.jp)

1. Design Standards for Railway Structures and Commentary (Concrete Structures)
2. Design Standards for Railway Structures and Commentary (Earth Structures)
3. Design Standards for Railway Structures and Commentary (Seismic Design)
4. Design Standards for Railway Structures and Commentary (Displacement Limits)
5. Maintenance Standards for Railway Structures and Commentary

New-Type Transformer for AC Feeding Systems

Hiroaki MORIMOTO
Assistant Senior Researcher, Power Supply Systems, Power Supply Technology Division

The Shinkansen and other high-speed trains require large single phase AC power sources. That AC power is supplied from electric power companies. However, if much of the required single phase AC power is obtained exclusively from a specific phase of three-phase AC power, it affects the power utilities of the electric power companies. In Japan, since the AC electrification of railways was begun in earnest, the Scott-connected transformer that transforms a three-phase AC voltage into two single-phase AC voltages having a phase difference of 90° has been used to reduce the adverse effect of high-speed train operation on the electric power system.

During construction of the Sanyo Shinkansen that was to open in 1972, it was planned to receive the required power from an ultrahigh-voltage electric power system in order to allow for train operation at higher speeds and supply the train with the required high power stably and economically. However, since the ultrahigh-voltage electric power system is a solidly earthed neutral system, the Scott-connected transformer cannot be used for it. Therefore, as a transformer suitable for solidly earthed neutral systems, the modified Woodbridge-connected transformer, as shown in Fig. 1, was developed and put into practical use. For quite a while since then, it has been used as the standard transformer for ultrahigh-voltage electric power systems.

A modified Woodbridge-connected (conventional-connected) transformer can be designed and fabricated easily using the same technology as applied to the ordinary three-phase transformer. However, since it has a separate step-up transformer on the B phase for obtaining the same output voltage as that of A phase, an extra space is required for installation of the step-up transformer, and the wiring is complicated.

The RTRI has developed a new-type transformer whose connection is shown in Fig. 2. This new connection is simpler than the conventional connection and does not require the step-up transformer. Even so, since the transformer windings are three-phase asymmetrical ones, sophisticated transformer design and fabrication techniques are required. In the beginning, we fabricated a mini-sized model of a low-voltage transformer (Fig. 3) and tested the basic functions and performance of the model. As a result, it was found that the new connection was functionally compatible with the conventional connection. In addition, we test-designed a large-capacity transformer that was the same as the one used in the Shinkansen, except that the conventional connection was replaced with the new connection. As a result, it was found that the new connection not only saved installation space but also reduced power loss.

It was decided to carry out demonstration tests at a substation for conventional railways, so we fabricated transformers with the new connection for verification (Fig. 4). After the basic characteristics of the transformers (withstand voltage, neutral-point current, etc.) were confirmed by factory tests, the transformers were temporarily installed in the substation and the condition of power supply to a train was tested (Figs. 5 and 6). As a result, we reached the conclusion that the new-type transformer could be applied to substations for the Shinkansen.

Transformers of the new type are planned to be installed in new Shinkansen substations scheduled for construction in the future and in existing Shinkansen substations for replacement of their obsolescent transformers.

Of the present research and development, the fabrication and testing of transformers for verification were carried out jointly by the RTRI; Japan Railway Construction, Transport and Technology Agency; and JR East.

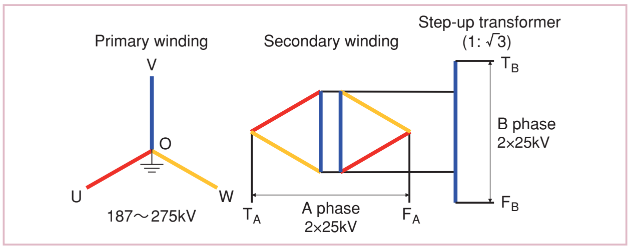


Fig. 1 Modified woodbridge connection (conventional connection)

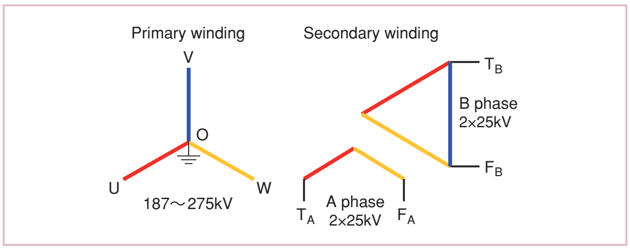


Fig. 2 New connection

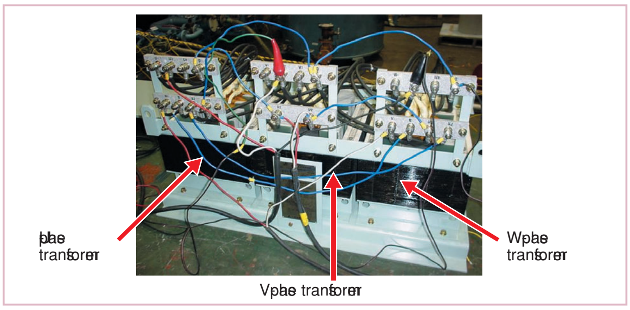


Fig. 3 Test-made mini-sized model of new-type transformer (200 V)

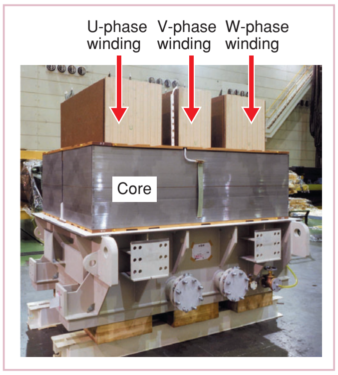


Fig. 4 Contents of transformer for verification (66kV/22kV 10MVA)

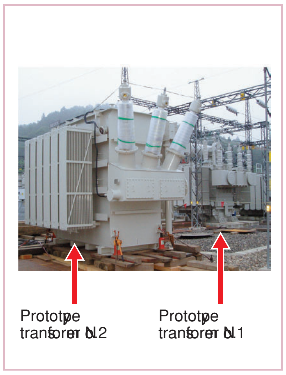


Fig. 5 Demonstration test at substation for operation of conventional railway

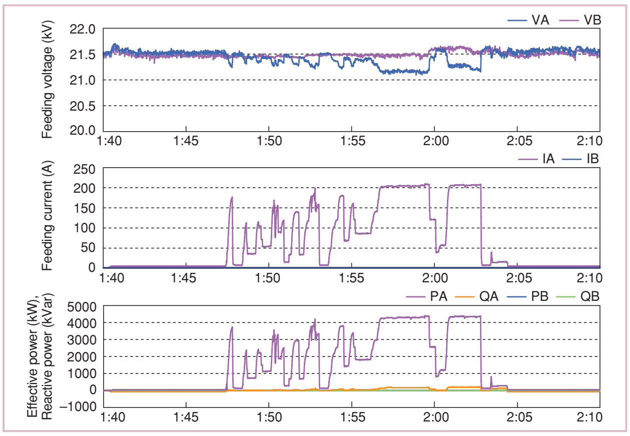


Fig. 6 Results of power supply to train

New Railway Roadbed Design

Yoshitsugu MOMOYA
Assistant Senior Researcher, Track Structures and Geotechnology,
Track Technology Division

When laying track on earth structures, roadbed performance is extremely important for controlling track settlement and dynamic deflection. In order to meet roadbed performance demands in Japan, concrete roadbed is used for slab track (Fig. 1), and asphalt roadbed is used for ballasted track (Fig. 2); this structure is also standard for the Shinkansen bullet train. The roadbed design methods are described in the "Design Standard for Railway Structures (Earth Structures)." In the January 2007 revision to this design standard, a performance based design method was introduced.

As the previous Design Standard for Railway Structures (Earth Structures) was based on specifications, the thickness of each layer of the roadbed design was specifically defined. With the performance based design method, however, it has become possible for the designers to design roadbed thickness to satisfy roadbed performance requirements. Specifically, by considering the fatigue life related to the number of trains, a method of designing thickness according to the importance of a particular section of track is described. Also, while the previous design concept was not consolidated with regard to a concrete roadbed for slab track or an asphalt roadbed for ballasted track, with this revision the roadbed design methods have been grouped together systematically.

With the new design standard, the earth structure performance rank for the relevant track is determined by the relative importance of the section of track and the track type. When designing the roadbed, a type of roadbed is selected to suit each of the various performance ranks. For performance rank I, concrete roadbed or asphalt roadbed for ballastless track is selected; for performance rank II, asphalt roadbed for ballasted track is used; and for performance rank III, crushed stone roadbed for ballasted track is selected. After the type of roadbed has been selected in this way, the roadbed structure design is carried out.

In the case of a concrete roadbed (Fig. 3), the following effects of train loads are checked for: displacement of the roadbed, breakage of the reinforced concrete base, fatigue damage, cracking, contraction, and thermal stresses. For asphalt roadbeds, the following effects of train loading are checked: displacement of the roadbed and fatigue damage of the asphalt mixture layer. In particular, in the case of an asphalt roadbed for ballasted track (Fig. 4), fatigue failure had not been considered in the previous design; however, this time a design method based on fatigue life has been introduced.

In this way, by systemizing roadbed design thinking to suit the design standard revision, and with the introduction of the performance-based design method, flexible design to suit the importance of the track section has now been made possible.

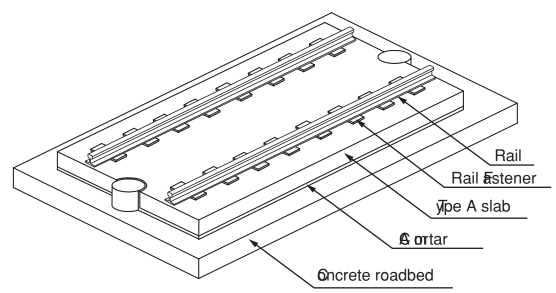


Fig. 1 Slab track

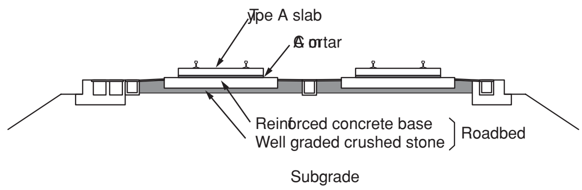


Fig. 3 Cross section of slab track and concrete roadbed (Embankment)

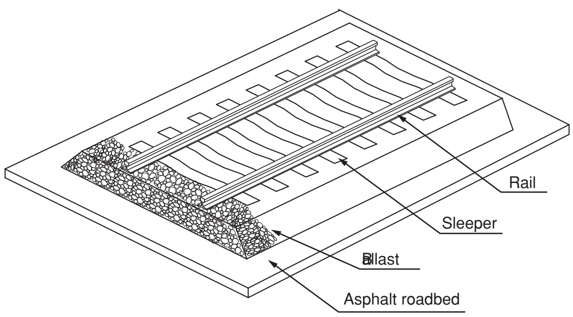


Fig. 2 Ballasted track

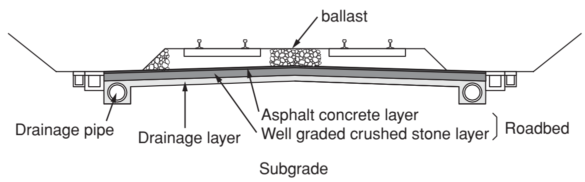
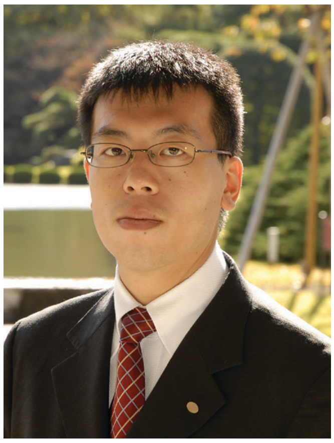


Fig. 4 Cross section of ballasted track and asphalt roadbed (Cutting)

Development of a Method of Pinpointing Trackside Spots That Are Subject to Strong Winds

Takaaki FUKUHARA
Researcher, Meteorological Disaster Prevention, Disaster Prevention Technology Division



1. Introduction

In order to ensure the safety of train operation in a strong wind, it is important to install anemometers for operation control at appropriate points. To that end, it is necessary to carefully scrutinize the wind conditions at trackside areas. Recent years have seen progress in techniques for predicting wind velocities at points about 30 to 100 m above the ground by applying numerical simulations in surveys for selecting optimum locations of windmills for wind power generation, etc. The average wind velocity is predicted in those surveys. To provide railways with measures to cope with strong winds, however, a new technique for predicting the instantaneous wind velocity near the surface of the ground is called for, since in a very strong cross wind, the train can overturn in a short time. In the present study, which was intended to determine appropriate trackside points at which to install anemometers, we used a statistical technique to calculate the expected maximum value (in return period)[1] of the maximum instantaneous wind velocity at trackside areas, in addition to a numerical simulation to obtain the average wind velocity.

2. Calculating expected maximum values of average wind velocities at trackside areas

In order to calculate the expected maximum value of an average wind velocity at a given point at a trackside area, we first studied meteorological disturbances that brought strong winds to the area in the past and calculated average wind velocities in meshes of 20 km square and 3 km square, respectively, using a numerical meteorological simulation model that is applicable to a large area about 500 km square. Then we used a numerical airflow prediction model to obtain average wind velocities in smaller meshes (200 m square), and the ratios of these to the average wind velocities in the 3 km square meshes (wind velocity ratios) were calculated. The calculation results are shown in Fig. 1. The values thus obtained were used to calculate the distribution of expected maximum values of average wind velocities.

3. Calculating expected maximum values of maximum instantaneous wind velocity

Next we calculated the distribution of the expected maximum values of maximum instantaneous wind velocities. Since there are no established methods of numerically calculating the maximum instantaneous wind velocity, it was necessary to use another method. In view of the fact that any place where the ratio of maximum instantaneous wind velocity to average wind velocity (i.e., the gust factor) is relatively large has some definite topographic characteristics, we estimated the gust factor by an analytical method based on topographic characteristics. With the ratio of a day's maximum instantaneous wind velocity to a day's average wind velocity (i.e., the day's gust factor) observed by the meteorological agencies in the large area under consideration as the object variable, we estimated the day's gust factor by a multiple regression analysis with the windward topographic characteristics(undulation, openness, levelness and roughness) that significantly influence the day's gust factor as the explanatory variables. The estimation results are shown in Fig. 2.

On the basis of the results shown in Figs. 1 and 2, we obtained the expected maximum values of maximum instantaneous wind velocities over 50 years that occur at specific points on the track in a specific wind direction θ (8 different directions). By taking into account these results and the incidence of a specific wind direction on a very windy day, it was possible to calculate the expected maximum value of a specific maximum instantaneous wind velocity over 50 years at a point 10 m above the ground in each of the meshes under consideration. Fig. 3 shows an example of the distribution of expected maximum values calculated at intervals of 100 m along the track. The result provides an objective base upon which to discuss the appropriate points of installation of anemometers for operation control in a strong wind.

4. Conclusion

If the method described above is put into practical use, it should be possible to calculate the expected maximum values of maximum instantaneous wind velocities in areas along various linear structures, including railways. The tasks to tackle in the future are to verify the results obtained by the method and improve the accuracy of the expression for estimating gust factor derived from the topographic characteristic analysis. In addition, there is a need to develop a method of objectively determining the trackside points that call for special attention in regard to strong winds, with consideration given to the estimated distribution of the expected maximum values of wind velocities and the critical wind velocity at which a specific ground structure or railway vehicle can overturn.

1 The maximum value that is expected to be exceeded at least once in the given (return) period

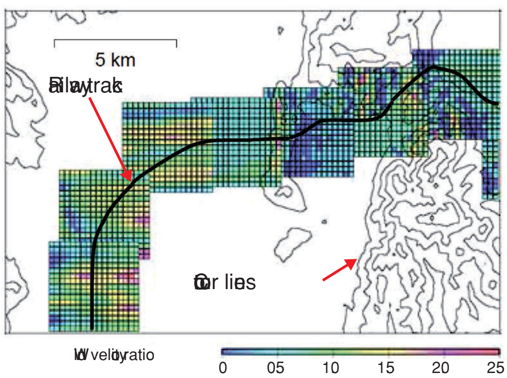


Fig. 1 Ratios of average wind velocities in a 200 m square mesh area to average wind velocities in a 3 km square mesh area, obtained by numerical calculation

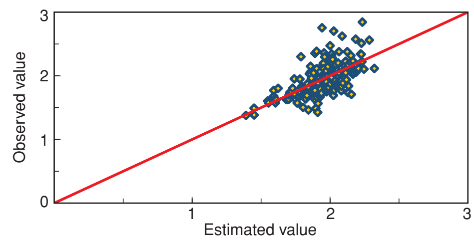


Fig. 2 Day's gust factors estimated by topographical characteristic analysis and observed day's gust factors

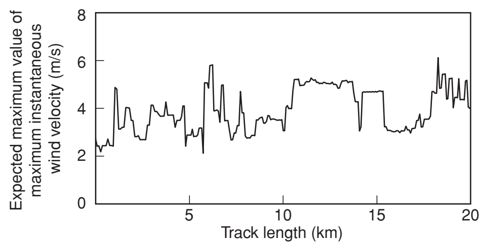


Fig. 3 Example of the calculated distribution of the expected maximum values of maximum instantaneous wind velocities (over 50 years)

Estimation of Occurrence Probability of Lightning Overvoltages on Wayside Signalling Equipment

Hideki ARAI
Senior Researcher, Signalling Systems, Signalling and Telecommunications Technology Division

Effective and economical lightning protection measures are necessary for railway signalling systems because suspended operation or train delays due to lightning damage may cause social disruptions to daily life. However, countermeasures against lightning damage are often implemented by trial and error as and when such damage occurs in railway signalling systems. This is because the overvoltages that occur during lightning strikes have not yet been quantitatively analyzed. The authors therefore measured overvoltages caused by lightning in railway level crossing systems representing typical examples of wayside electronic signalling equipment in the field. These measurements were carried out to analyze quantitatively the frequency of lightning overvoltage occurrences and to collect basic data to aid in developing countermeasures against lightning.

The two level crossing systems selected as field test sites are located in the Takasaki area, a district of Japan well known for its frequent lightning.

Fig. 1 shows a diagram of the measurement set-up at the field test site. Measuring instruments such as oscilloscopes were placed in a measurement hut installed temporarily beside the level crossing system's equipment cabinet. The wires for measuring lightning overvoltages were connected from the measuring points at the level crossing equipment to the measurement hut through an earthen pipe, and lightning overvoltages were measured using high-voltage probes in the hut. The measuring points were as follows:

[No. 1] AC power line (50 Hz, 100 V) for the level crossing system

[No. 2] AC power line (400 Hz, 200 V) for the electronic train detector to close the crossing gates

[No. 3] DC power line (24 V) for the electronic train detector to open the crossing gates

[No. 4] Communication line

The lightning overvoltages were measured between the above measuring points and the grounding of the level crossing system. Data on lightning overvoltages was registered when overvoltages occurring at the measuring points outlined above exceeded 400 V. Waveform data files of lightning overvoltages, named as a triggered time by GPS (Global Positioning System) were stored on a laptop computer. Measurements of lightning overvoltages were carried out during the summer of 2004 and 2005.

Fig. 2 shows the cumulative frequency of the lightning overvoltages in the level crossing system obtained during these measurements. The overvoltages that occurred on the AC power line for the level crossing system were higher than those that occurred at the other measurement points. Fig. 2 therefore shows the lightning overvoltages occurring on the AC power line. The horizontal axis indicates the value of the lightning overvoltages that occurred, and the vertical axis indicates the occurrence frequency of lightning overvoltages exceeding the value of the horizontal axis.

Eq. (1) approximates the cumulative frequency of the lightning overvoltages shown in Fig. 2, where Pv [times/year·quipment] is the cumulative frequency in excess of V [kV], and V is the value of the lightning overvoltages occurring in the level crossing system. The approximate line calculated by Eq. (1) is also indicated in Fig. 2.

$$Pv=168.3\times V^{-2.19} \quad (1)$$

As a result, Eq. (1) estimates the occurrence probability of lightning damage caused when the withstand voltage of the level crossing system is exceeded. Moreover, the rate of reduction in lightning damages against the level of lightning protection can be evaluated using Eq. (1). For example, if the level of lightning protection can be improved from 10 kV to 30 kV, it is calculated that the occurrence probability of lightning damage will be reduced to 1/10 or less, according to Eq. (1).

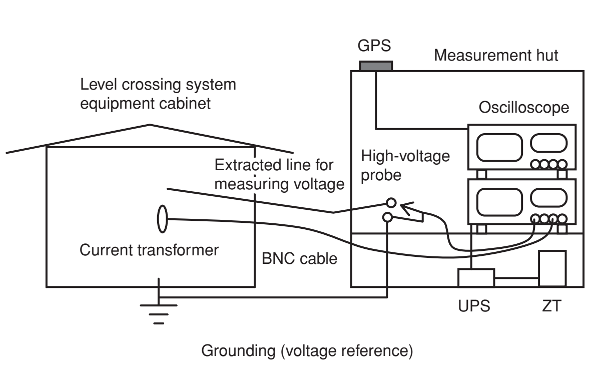


Fig. 1 Measurement diagram

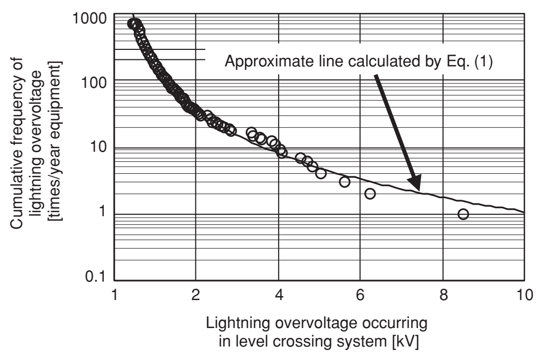


Fig. 2 Cumulative frequency of lightning overvoltages occurring in the level crossing system