Overhead Catenary System (OCS) Facilities Condition Monitoring System

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Abstract

Important infrastructures for mass-transit and transportation, electric railways have greatly improved convenience with its progress. Since facilities with contact wires provide a stable supply of electrical energy, they must assure a long operational life and high quality current collection. Resulting from the enhancement of train velocity and increase in service frequency, it is anticipated to deteriorate the geometry of the contact wires. To enable the monitoring of the dynamic conditions of the contact wires, we developed and delivered high-accuracy geometric inspection equipment to railway companies. In railway operation, the collisions of pantographs with obstacles occur, and often, the cause cannot be identified. The pantograph dynamic gauge condition monitoring equipment detects in real time an abnormal obstacle approaching the pantograph collector head so that a collision can be averted in advance.

1 Preface

Contact wires for the supply of electric energy are essential part of facilities of electric railways. For the stable operation of railway systems, contact wires are required to secure longer operational life and reliable quality current collection.

The quality of current collection is evaluated based on electrical contact loss (percentage of arcing) and contact force between pantograph and contact wire. One of causes of a pantograph's contact loss is due to an abnormality of the geometric condition of contact wires. This puts high-speed vehicles at a greater risk for contact loss. For this reason, it is necessary to use equipment that makes periodical diagnosis of contact wire geometric conditions in railway systems.

Meanwhile, train operations can be hindered by a pantograph's peripheral devices falling off or any flying object attaching itself to it. The pantograph dynamic gauge monitoring equipment detects such an object in real time to avert an accident.

This paper introduces the contact-wire geometry inspection equipment and pantograph dynamic gauge condition monitoring equipment used as an Overhead Catenary System (OCS) facilities diagnostic system.

2 Contact-Wire Geometry Inspection Equipment

2.1 Background

The evaluation standard for the quality of current collection is stipulated by international standard IEC62486 where either electrical contact loss rate (percentage of arcing) or pantograph contact force shall be measured. Since the scale of equipment of contact loss is small, a method of measuring the contact loss is generally adopted. Fig. 1 shows graphs of contact loss rates. These graphs suggest

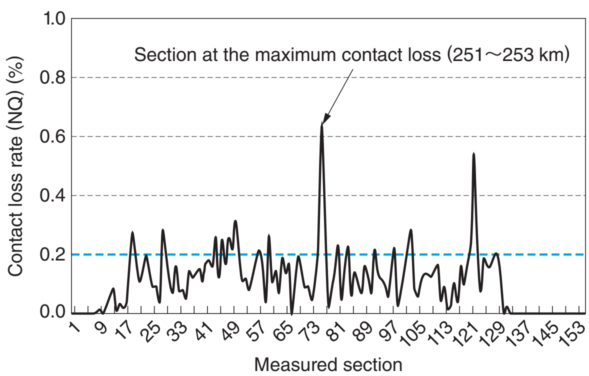

Fig. 1 Graphs of Contact Loss Rates

Graphs of rate of contact loss obtained at a train velocity of 270 km/h are shown. The domain (above blue dotted line) where the contact loss rate is 0.2% or more suggests that the contact loss rate is not favorable.

that the quality of current collection is not favorable if the percentage of arcing is more than 0.2% (ratio of arcing time to running time). In such a case, it is necessary to check the geometry of the OCS in this location.

2.2 Specifications of Geometry Inspection Equipment

2.2.1 Outlined Descriptions of Equipment

(1) Mounting on a maintenance car

Measuring equipment is mounted on a workbench situated in a maintenance car. Since the workbench is also used for other jobs, the measuring equipment is made adjustable so that it can be removed after measurement is completed. Fig. 2 shows an external appearance of the geometry inspection equipment.

(2) Static measurement

Using an area range scanner, the height and stagger of contact wires are statically measured at a high precision.

(3) Detection of a cantilever (Detection of cantilever and hanger locations)

To measure the standard for geometry of the OCS, a photoelectric sensor is used to detect the location where the contact wire is supported (pull-off arm). The hanger is mounted in a location so that height and stagger of the contact wire can be grasped accurately.

(4) Measurement of vertical difference in height at the overlap section

A difference in height between the main and overlap lines is measured to confirm that the measured value is kept within the standard range.

(5) Capture of measuring location

For the capture of the measuring location, a high-accuracy laser Doppler, or speed signals from axle sensors are adopted.

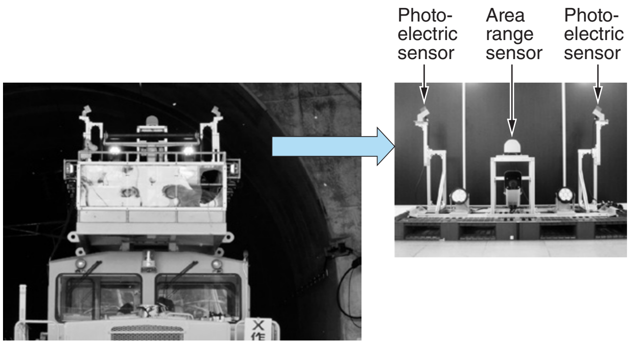

Fig. 2 Geometry Inspection Equipment

Geometry inspection equipment is loaded on a maintenance car of the Shinkansen. (Car for Japan Railway Construction, Transport and Technology Agency)

2.2.2 Detailed Specifications of Equipment

Table 1 shows the specifications of the geometric inspection equipment.

2.2.3 Standard for Geometry of OCS

The basic means to diagnose the conditions of OCS facilities are introduced here. Table 2 shows a standard for the geometry of the OCS (IEC Standard) and Table 3 shows a standard for the geometry of the OCS (Shinkansen Guideline). Both standards are related to OCS installations. They involve standard items about catenary structure diagnosis in the location where an abnormality is monitored.

Table 1 Specifications of Geometry Inspection Equipment

Equipment sensors and their measurement items are shown.

Device name	Quantity	Measurement items
Area range sensor	1 unit	Measurement frequency: 25 Hz, Angular resolution: 0.166° Contact wire height・Displacement measurement
Photo-electric sensor	2 units	Swing-off arm, detection of hanger position Detecting speed: 500 μs
Lighting	1 unit	Round light For contact wire monitoring
PC on the car	1 unit	PC・image board・SSD for saving (Solid State Drive)・MS-Windows-related software・S/W for image pickup・analysis S/W
Velocity sensor	1 unit	Axle sensor or laser Doppler type Accuracy: within 0.2% Measuring position definition
UPS	1 unit	1 kVA (AC100 V)
Jigs for adjustment	1 set	Calibration and others

Table 2 Standard for Geometry of OCS (IEC Standard)

Standard for geometry of the OCS stipulated by the IEC Standard is shown.

Item	Max. car velocity 250 km/h or above
Difference in height between the first hanger position and the last hanger position in a span	±30 mm
Difference in contact wire height in the position of neighboring hanger at the support point.	±10 mm
Difference in contact wire height at the support point in one span	20 mm
Difference in contact wire height between hangers	10 mm
Contact wire height at the overlap section	±10 mm
Displacement of pull-off point	±30 mm
Span gradient	0.6‰

2.2.4 Measuring Accuracy and Example of Standard for Geometry of OCS

The measuring accuracy attained by this equipment is required to conform to the aforementioned standard for the geometry of the OCS. For the improvement of distance-based performance inherent to the measuring laser sensor, a special calibration is adopted to attain a required high accuracy. Based on the result of accuracy verification performed at the factory, an evaluation of accuracy was carried out at the site. Table 4 shows the result of the measuring accuracy verification.

Table 3 Standard for Geometry of OCS (Shinkansen Guideline)

For Shinkansen systems in Japan, standard for geometry of the OCS at 320 km/h is shown.

Item	Max. train velocity 320 km/h	Notes (for 50 m span)
Gradient between the first and last hangers	±1.0‰	Difference in hanger height of neighboring support point: 5 mm
Curvature at the support point (Difference in base line height at the support point)	±4 mm	Difference from the base line height
Amount of sag	20 mm	
Difference in span-to-span gradient	±1.0‰	Difference in gradient between neighboring spans
Span gradient	±0.5‰	Difference in height between neighboring support points: ±25 mm

Table 4 Result of Measuring Accuracy Verification

The result of measuring accuracy verification performed for the testing apparatus is shown.

Pole No.	Result of measurement done by the customer		Result of measurement done with this equipment	Differential (A–B) (mm)
	Distance (m)	Height (A) (mm)	Height (B) (mm)	
170-21	10.25	5058.21	5060	−1.79
170-23	59	5055.89	5057	−1.11
170-25	107.65	5055.73	5055	0.73
170-27	155.55	5056.38	5057	−0.62
170-29	205.85	5057.12	5059	−1.88
170-31	254.6	5056.91	5057	−0.09
170-35	353.25	5056.94	5057	−0.06
170-37	402.95	5055.83	5055	0.83
171-1	451.9	5055.05	5058	−2.95
171-3	496.5	5055.75	5054	1.75
171-5	541.65	5058.03	5058	0.03
171-7	591.7	5055.37	5057	−1.63
171-9	641.7	5058.31	5059	−0.69
171-11	695.75	5055.38	5053	2.38
			Mean differential	−0.36

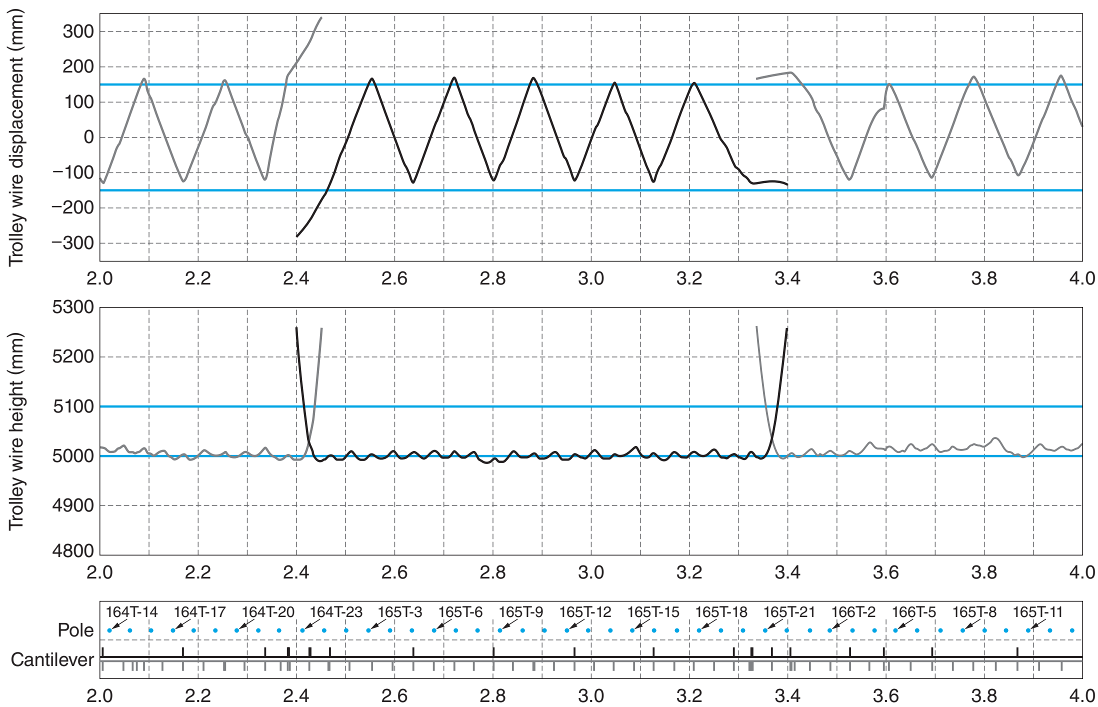

Fig. 3 Result of Measurement (Example)

Charts of measurement with the use of geometric inspection equipment are shown. Differences in height in overlapping sections and height at the support point can be recognized.

This verification test was carried out on an actual railway line. The measured values obtained directly from measurement at the site was compared with the values obtained from this equipment and the result was 0.36 mm of the average error.

Fig. 3 shows the result of measurement (example). This is a chart of measurement performed after the installation of contact wires for the Shinkansen. This diagram shows the differences in height and stagger between the main and overlap lines at the overlap section, and variations in contact wire height in the cantilever position. Evaluation of the standard for the geometry of the OCS is based on the height, stagger, and height data at the hanger recorded in this chart.

3 Pantograph Dynamic Gauge Condition Monitoring Equipment

3.1 Background

Contact wires and pantographs are the source of driving energy for electric railways. They are always required to maintain stabilized contact between the contact wire and the pantograph. There is, however, the danger of encountering any abnormality in the facility adjacent to the pantograph during train operation and a collision with foreign objects, like flying matter or ice block clinging to the contact wire. This equipment continually monitors the presence of any foreign substance in the gauge of the pantograph. It detects and reports any abnormality in real-time. To enable the detection of obstacles as soon as possible, it is recommended to install this equipment in a commercial car that makes frequent operations.

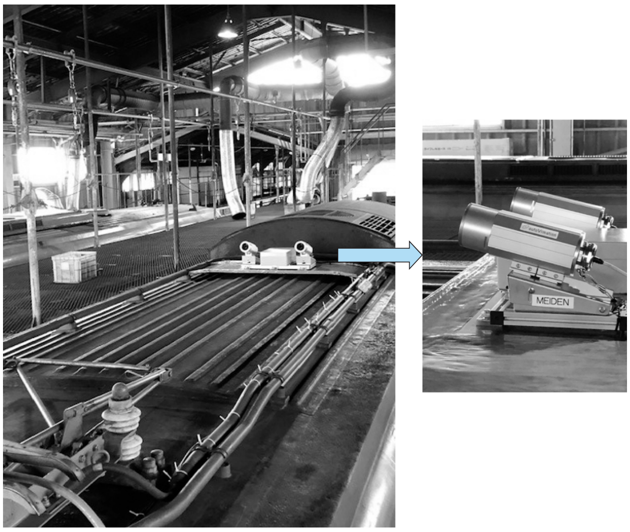

Fig. 4 **Example of Installation of Pantograph Obstacle Condition Monitoring Equipment**

An example of roof-top equipment installed on a commercial car is shown. (A commercial car of Shikoku Railway Company)

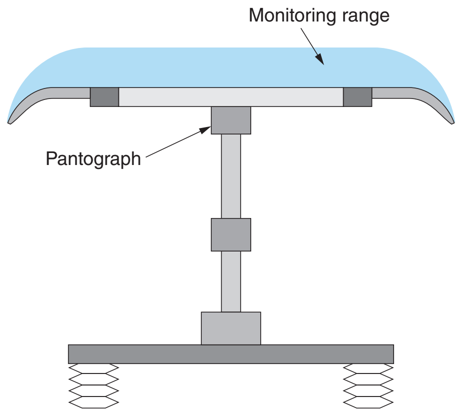

Fig. 5 **Pantograph Dynamic Gauge**

The dynamic gauge located on the pantograph top follows the vertical movement of the pantograph.

3.2 Specifications

3.2.1 Outline of Equipment

(1) Installation on a commercial car

This is a facility consisting of two cameras and two lights installed near the pantograph on a commercial car. During train operation, monitoring is continued as a drive recorder does. If this facility is cooperated with an overhead catenary inspection system called “Catenary Eye”, location data sharing becomes possible. Fig. 4 shows example of installation of the pantograph obstacle condition monitoring equipment.

(2) Error detection method

When a virtual gauge is provided to the upper part of the pantograph, it becomes possible to detect foreign obstacles intermingling in this gauge. For this detection approach, the triangulation method is adopted with the use of two cameras. Fig. 5 shows the pantograph dynamic gauge.

(3) Detection range

Real-time detection is possible up to a train velocity of 120 km/h. Measurement is possible within the range of space from the pantograph’s position to the camera.

(4) Reporting in the case of an error detection

Car information (commercial car with equipment) and detection time are superimposed as images of error detection (images near the pantograph). The obtained data are transmitted to the maintenance office via a 4G line.

Table 5 Specifications of Pantograph Dynamic Gauge Monitoring Equipment

Specifications of the pantograph dynamic gauge condition monitoring equipment are shown.

Unit name	Quantity	Measuring items
Area camera	2 units	Measuring frequency: 10 Hz No. of pixels: 1936 × 1216
Camera cover	2 sets	IP67
Lighting	1 set	Round light
PC on the car	1 unit	PC, image board, SSD for saving, MS-Windows-related software, S/W for image pickup, analysis S/W
Velocity sensor GPS sensor	1 unit	Speed generator I/F or laser Doppler type sensor, GPS sensor (This item shall be selected in accordance with customer specifications.)
UPS	1 unit	1 kVA (AC100 V)
4G router	1 unit	For reporting

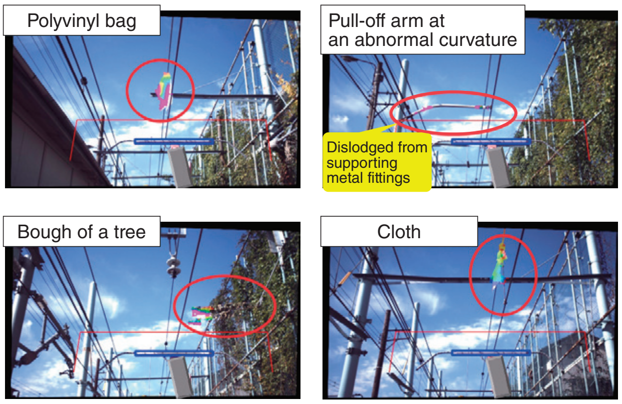

Fig. 6 Examples of Pantograph Obstacle Detection

Actual pantograph obstacles were put on contact wires to verify obstacle detection. (Joint research with Railway Technical Research Institute is currently carried out. This verification is performed on an experimental line.)

3.2.2 Specifications of Equipment Configuration

Table 5 shows specifications of pantograph dynamic gauge monitoring equipment. The main items are two cameras, lightings on the car roof, one unit of Personal Computer (PC), and an Uninterruptible Power System (UPS) installed inside the car.

3.2.3 Examples of Test Result

Fig. 6 shows examples of pantograph obstacle detection. These pictures show detected foreign obstacles provided for the testing during operation of the testing car. An example of the pull-off arm shows a simulation of an abnormal case when the cantilever is dislodged.

4 Postscript

Drawing on our resources of OCS facilities diagnostic technologies, this paper introduced the geometry inspection equipment and pantograph dynamic gauge condition monitoring equipment. The geometry inspection equipment was delivered to Japan Railway Construction, Transport and Technology Agency. It was used for inspections after the completion of the OCS construction for the Hokuriku Shinkansen. Regarding the technical development of the pantograph dynamic gauge condition monitoring, test running for abnormality detection was carried out at Railway Technical Research Institute. In addition, running tests along an actual railway line was carried out with the aid of a commercial car of the Shikoku Railway Company (a JR Group company).

Lastly, we would like to express our sincere gratitude to related people for their heartfelt cooperation and guidance.