〈**Case Study**〉

OCS Inspection System for Tokyu Corporation

Tokyu, Electric railway, OCS inspection system, Image processing, Contact loss

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Abstract

The Overhead Catenary System (OCS) inspection system is one of key items for the safety and stable operation of electric railways. We commercialized a high accuracy OCS inspection system, named CATENARY EYE, which features non-contact cameras and image processing technology. We continue to deliver it to railway companies. Tokyu Corporation (Tokyu) had a dedicated general inspection car that could measure the OCS condition in high-speed trains during the daytime. Tokyu, however, aimed to make their maintenance more efficient because it was decrepit. Tokyu and our company improved CATENARY EYE for high-speed daytime inspection and replaced the existing OCS inspection system.

1. Preface

Tokyu Corporation (Tokyu) has a dedicated general inspection car, which can measure the OCS condition in high-speed trains during daytime. Tokyu, however, aimed to make their maintenance more efficient by updating it because it was decrepit.

CATENARY EYE is a high accuracy, non-contact type OCS inspection system that uses cameras and image processing technology. The main features are the streamlining of maintenance and the compactness of the equipment. The user can check the caution data not only as numerical values but also with image data before going to a site survey. Furthermore, we can replace the existing system with CATENARY EYE first followed by transfer it to the new car because of the compactness of equipment.

We improved CATENARY EYE for high-speed daytime inspection in cooperation with Tokyu and replaced their existing system. This paper introduces this case study.

2. System Configuration

Fig. 1 shows the system configuration. CATENARY EYE is configured with on-board equipment and a computer installed in an office (offline PC). An on-board computer will record image data and the offline PC will perform the data analysis. The offline PC displays the analysis reports, prints the reports, and manages the data.

Fig. 2 shows the rooftop equipment and Fig. 3 shows the interior equipment. There are Line Sensor cameras (LS camera), a CCD camera, illuminations, laser sensors, and arcing sensors on the rooftop. They are connected to the interior equipment, and data from them are stored on a portable hard disk connected to the on-board computer. The portable HDD will be conveyed and connected to the offline PC. Then, the analysis will be done with the data on the disk.

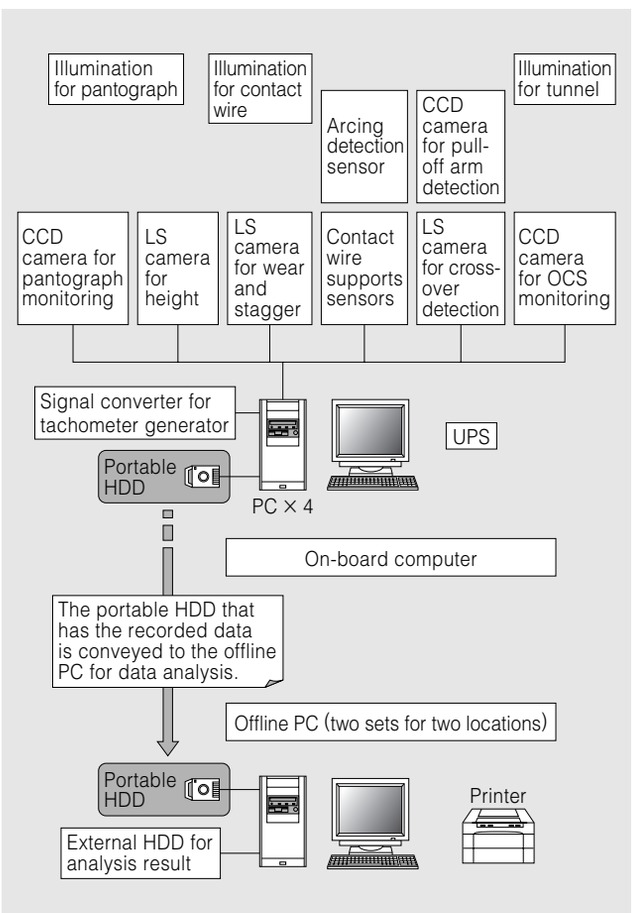

Fig. 1 Outline of CATENARY EYE

CATENARY EYE is configured with on-board equipment for recording images and off-line PC to analyze the recorded images.

The rooftop equipment is under the FRP cover as

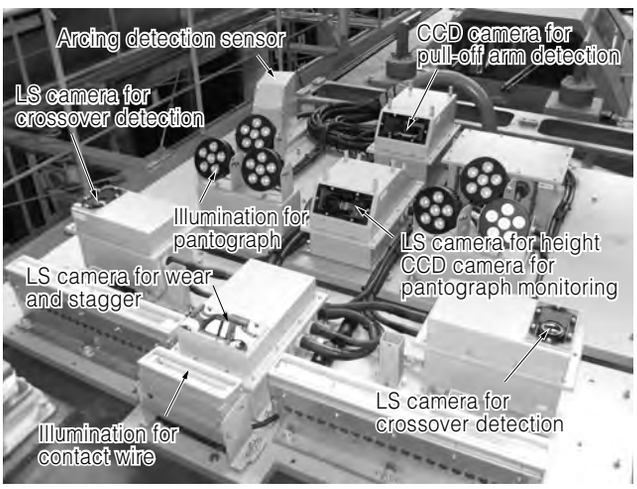

Fig. 2 Rooftop Equipment
Cameras, sensors and illuminations are arranged optimally for the measurement items.

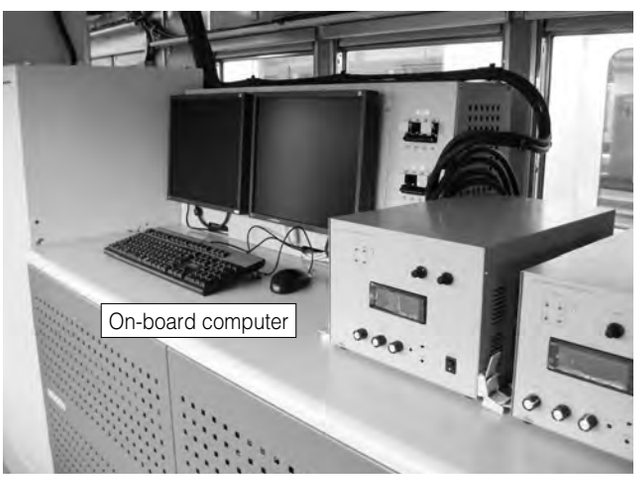

Fig. 3 Interior Equipment
The on-board computer provides the attribute setting, start and stop of measurement, and monitoring of the pantograph and OCS during measurement.

countermeasures against heat during summer. We adopted a sliding cover for the rooftop equipment instead of a removable cover to avoid the case of being left behind. Fig. 4 shows the cover for the rooftop equipment.

3. System Specification

Table 1 shows the capacity and the specifications for the system. This is a non-contact type OCS inspection system using cameras and sensors with an existing pantograph for power collection.

3.1 On-Board Equipment

(1) LS cameras for height measurement

The LS cameras scan a marker for measurement on the pantograph in the vertical direction, and the on-board computer records the image.

(2) LS cameras for wear and stagger measurement

The LS cameras scan the contact wire in the horizontal direction, and the on-board computer records the image.

Fig. 4 FRP Cover for Rooftop Equipment
Opening the sliding cover for the measurement.

(3) Illuminations

We adopted LED illumination because of easy maintenance and low power consumption. The illumination for the pantograph shines on the whole pantograph for the pantograph monitoring function. The illumination for the contact wire shines on the contact wire in the vertical direction for the wear and stagger measurement. The illumination for the tunnel shines on the ceiling of the tunnel for the OCS monitoring function.

(4) Contact wire support sensors

The sensors were installed on both the lower right and lower left of the pantograph for detecting a steady arm and a pull-off arm. The sensors are designed to detect only a certain height from the rooftop. When detecting supports, a signal from the sensor triggers the taking of a picture by an pull-off arm detection camera, and it will be reported to the on-board computer. The information is used for location adjustment in the offline PC.

(5) Signal converter for tachometer generator

The device converts the pulse signal with the axle rolling to the train location data.

(6) Arcing detection sensors

The sensor detects certain UV waves in an arc between the contact wire and the pantograph in the event of contact loss.

(7) LS cameras for crossover detection

The cameras were installed at both ends of the rooftop and at right angles. They scan the crossover in the direction of the sleeper, and the on-board computer records the image. The crossover is detected with the recorded images and the trace of the contact wire height in the offline PC.

(8) CCD cameras for pull-off arm geometry detection

The camera shoots a whole pantograph image from the triggering of the contact wire support sensors, and the on-board computer records the image. The offline PC detects pull-off arm that conflicts with a certain area of the pantograph.

Table 1 System Capacity and Equipment Specification

Determine appropriate capacity and specification for measuring condition, measuring facilities, and items.

(1) System capacity

Item	Capacity
Maximum number of measurement work in a year	Six round trips
Storage life for measurement data	Three years
Maximum number of electric poles in a railway line	10,000
Maximum mileage in a measurement	40km
Maximum title number in a portable HDD	100

(2) Equipment specifications

Item	Specifications
Camera for height measurement	Line sensor camera
Number of camera	1
Resolution	7450 × 1
Frequency	1000Hz
Camera for wear and stagger measurement	Line sensor camera
Number of camera	2
Resolution	7450 × 1
Frequency	1000Hz
Camera for crossover detection	Line sensor camera
Number of camera	2
Resolution	7450 × 1
Frequency	1000Hz
Camera for pull-off arm detection	CCD camera
Number of camera	2
Resolution	640 × 480
Frequency	By triggering of the contact wire support sensor
Camera for pantograph monitoring	CCD camera
Number of camera	1
Resolution	640 × 480
Frequency	30fps
Camera for OCS monitoring	CCD camera
Number of camera	1
Resolution	640 × 480
Frequency	30fps
Arcing detection sensor	Dedicated UV sensor
Number of sensor	2
Interference filter	200～240nm
Frequency	2000Hz

Item	Specifications
On-board PC-A1	For height, wear, stagger measurement Location information
Memory size	2.0GB
Hard drive size for OS	20.0GB
Hard drive size for applications	100.0MB or more
Portable HDD size	1.0TB or more
On-board PC-A2	Crossover detection, Pull-off arm detection
Memory size	2.0GB
Hard drive size for OS	20.0GB
Hard drive size for applications	100.0MB or more
Portable HDD size	1.0TB or more
On-board PC-A3	Arcing detection Pantograph monitoring
Memory size	2.0GB
Hard drive size for OS	20.0GB
Hard drive size for applications	100.0MB or more
Portable HDD size	120.0GB or more
On-board PC-A4	OCS monitoring
Memory size	2.0GB
Hard drive size for OS	20.0GB
Hard drive size for applications	100.0MB or more
Portable HDD size	120.0GB or more
Offline PC-B	Data analysis, Analysis result management
Memory size	3.0GB
Hard drive size for the OS and system	20.0GB
Hard drive size for applications	3.0GB or more
Hard drive size for the database	1.5TB or more

(9) CCD camera for pantograph monitoring

The camera is installed in the direction of the pantograph and shoots the whole pantograph image.

(10) CCD camera for OCS monitoring

The camera is installed in the direction of movement on the cab roof and takes a video of the OCS.

(11) On-board computer

The images and sensor data described above are stored on a portable HDD in chronological order. The portable HDD is removed from the on-board computer after measurement and conveyed to the offline PC for data analysis.

3.2 Offline PC

The offline PC was installed in two maintenance offices. The portable HDD from the on-board computer is mounted on the offline PC, and data analysis is

Table 2 Measurement Item

CATENARY EYE is a non-contact measuring system by cameras and sensors without any dedicated pantograph for measurement.

Item	Sensor	Output	Static measurement accuracy
Contact wire height	LS camera	Contact wire height Channel number: 1	±5mm for 4400mm to 5400mm height
Contact wire stagger	LS camera	Contact wire stagger Channel number: 4	±5mm for ±250mm stagger
Wear of contact wire	LS camera	Wear of contact wire Channel number: 4	0.1mm basis 30mm span @110km/h
Contact wire gradient	LS camera	Gradient between electric poles (‰)	
Hard spot	LS camera	Accelerated velocity in the vertical direction of pantograph	Up to 30G
Location information	Axle pulse counter	Chainage, Travelling speed	Depends on the accuracy of the tachometer generator
	Laser sensor	Chainage of steady arm and pull-off arm	
Arcing contact loss	UV sensor	Arcing chainage, arcing time	Detect more than 1ms of arcing
Crossover	LS camera	Chainage and height of contact point between crossover and pantograph horn	
Pull-off arm	CCD camera	With or without pull-off arm that conflicts with a certain area of the pantograph.	
Pantograph monitoring	CCD camera	Display and record video images of the pantograph while the train is running	30Hz
OCS monitoring	CCD camera	Display and record video images of the OCS while the train is running Extract still pictures of electric poles from recorded images	30Hz

Note: A dedicated pantograph for measurement is not required.

Table 3 Measurement Report Output Window

Any recorded chainage data can be reviewed in the tabular form window, in the chart form window, and in the recorded image window. Each window has a cross-reference function.

Name	Outline
Measurement report window	Attribute data, including measurement condition, measurement results including warning data, and severe data, are shown and can be printed out.
Message list window	Messages recorded during measurement are shown and can be printed out.
Tabular form window (wear)	Remaining diameter of contact wires as wear measurement results is shown and can be printed out. Data are compiled by pole span and by hanger span.
Warning data list window (wear)	
Severe data list window (wear)	
Tabular form window (Except wear)	Measurement results except wear are compiled in tabular form, shown, and can be printed out. Data are compiled by pole span.
Warning data list window (Except wear)	
	Re-measurement results except wear are compiled and can be printed out
Chart form window	All measurement result data, compiled in chart form as a horizontal axis as chainage, are shown and can be printed out.
	Mode switch function provides a superimposed display that can review several wear charts in a window. Re-measurement results for wear are compiled and can be printed out. Span length deviance due to wheel slip and slide during measurement can be corrected.
Pantograph monitoring	Monitored images of pantograph are shown and reviewed. All measurement results (numerical value) are shown in sync with the images. Register and cancel the pull-off arm. Register and cancel the crossover.
Line sensor image window for wear and stagger	Line sensor Image of wear and stagger are shown and reviewed.
	Superimposed display of charts is available with the mode switch function.
Line sensor image window of height and hard spot	Line sensor Image of height and hard spot are shown and reviewed.
	Superimposed display of charts is available with the mode switch function.

Note: Each display has interconnection among display windows.

carried out. The analysis reports are stored on the external hard disk and can be shown on the monitor as well as printed out. Furthermore, it can be output in Microsoft Excel CSV format and copied to a USB memory device.

4. Measurement Item

The target is the Tokyu lines and Minatomirai Line except the Setagaya Line. The target contact wire is GT110, GT150, and GTM170 of the OCS and the overhead rigid conductor system regardless of inside or outside the tunnel.

Table 2 shows the measurement items. In addition, an antireflection treatment to OCS against illumination is not required. The OCS attributes of electric pole number, pole span, pole span information, and type of contact wire are the predefined data of the system.

5. Measurement Result Display Window

Table 3 shows the measurement report display windows and each outline. Each display has specialized information and interconnection among display windows for operability.

The tabular form window (see Fig. 5) and the chart form window (see Fig. 6) are linked to the image data, so that you can directly display the pantograph monitoring window (see Fig. 7) or the LS camera image

Fig. 5 Tabular Form Window

Various reports specialized for each measurement items are available. Fig. 5 shows a sample report for wear measurement in tabular form.

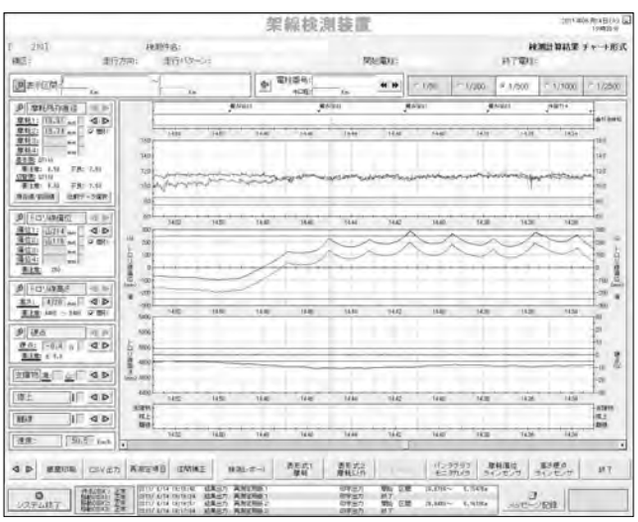

Fig. 6 Chart Form Window

Fig. 6 shows a sample report in chart form and the selected point by the operator is shown as a numerical value.

Fig. 7 Pantograph Monitoring Window

This function provides a video replay of pantograph images by the CCD camera together with other measurement results as numerical values.

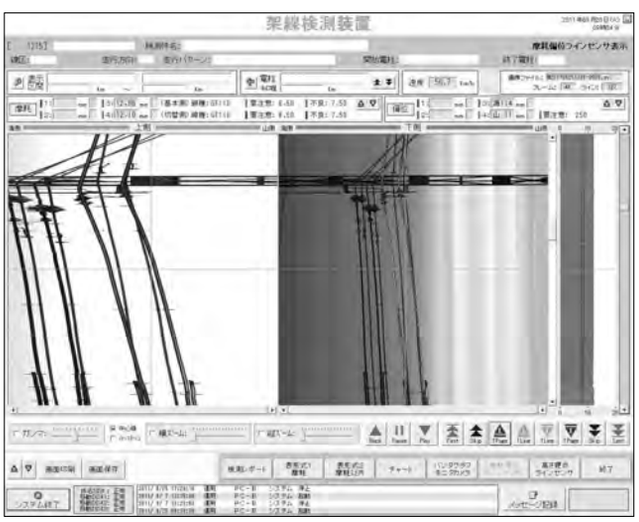

Fig. 8 LS Camera Image Window

This function provides a video replay of the sliding surface images of the contact wire by the LS camera together with other measurement results as numerical values.

window (see Fig. 8) from them with the desired location. You can check both numerical values and images in the same window and replay them just like a video on the pantograph monitoring window and the LS camera image window.

In addition, the zoom function and the brightness control function are available for checking the details of images more efficiently.

By using these functions, not only contact wires but also messenger wires, insulators, and support can be checked in the images. The data in excess of a certain pre-defined value by the user is compiled in a caution list or a warning list.

For checking the site condition reflecting the measurement result, the desired section data from tabular form window or chart form window can be recompiled and printed out.

6. OCS Monitoring System

This is an option for the CATENARY EYE and the purpose is to manage electric poles and their attachments to the OCS.

6.1 OCS Recording Function

This system records OCS video images automatically interlocking with the OCS inspection system and stores the data to the portable HDD.

6.2 OCS Monitoring Window

Fig. 9 shows the OCS monitoring window. The recorded data can be replayed, and the electric pole images can be extracted from the data and stored as each still picture in JPEG format on the offline PC. The stored JPEG file is automatically given a useful name to identify the recorded date, line, and electric pole name, so that changing the file name by the user is not necessary while it is required when using a digital camera.

Fig. 9 OCS Monitoring Window

This function provides a video replay of recorded OCS monitoring images by the CCD camera and then extracts and saves still pictures of the electric poles.

7. Postscript

We transferred both the OCS inspection system and the OCS monitoring system for Tokyu to their new hi-speed inspection car called TOQ-i. The recorded data from daytime will be useful for checking not only wear surfaces but also other support more clearly. Therefore, we expect our CATENARY EYE will contribute to their maintenance work more efficiently. Lastly, we would like to express our deepest gratitude to the people who gave us valuable advice and help in improving our OCS inspection system, CATENARY EYE.