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Countermeasures for Pantograph Heads Damage by Detecting Frost on Overhead Contact Line with the Pantograph Monitoring System.

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Abstract

Pantograph heads damage occurs due to the frost on overhead lines in winter. This is because the pantograph heads separate from the overhead line due to the frost and a large electric arc is generated. Large damage to the pantograph not only leads to vehicle breakdown but also to the damage on trolley wire. In this study, we use a pantograph monitoring method to understand the current state of frost areas, and study the frost detection method to prevent damage and reduce delay by automatic current control.
Keywords: high speed train, pantograph, monitoring data, overhead contact line, frost detection, current control, pantograph head damage, train delay

1 Introduction

Since the opening of the Tokaido Shinkansen in 1964, Shinkansen trains have evolved from Series 0 to Series N700A, and the amount of monitoring data that can be acquired has increased. In order to realize safer and more stable operation of Shinkansen trains, a pantograph monitoring system with current sensors and monitoring cameras was installed on the N700A tertiary vehicle, and the pantograph monitoring function during traveling was enhanced [1].

Pantograph heads damage occurs due to the frost on overhead lines in winter. This is because the pantograph heads separate from the overhead line due to the frost and a large electric arc is generated. Large damage to the pantograph not only leads to vehicle breakdown but also to the damage on trolley wire [2], [3]. In the Tokaido Shinkansen, the arc protection is applied on a part of pantograph heads, in which area the damage of pantograph heads are likely to occur. In addition, to prevent the generation of a large electric arc, maintenance workers judge the presence or absence of frost on overhead lines, and the control center commands the driver to restrict notch in certain areas (notch control). However, the arc protection alone is not enough to prevent the damage, and a wide range of notch control can cause delay of trains. From the above, (i)"Pantograph heads damage prevention by appropriate frost detection" and (ii) "Shortening of delay by optimizing notch control" are important issues in pantographs, and we carried out a research into new monitoring methods to solve these issues.

From 2015, based on the testing car data, the collected current analysis and the image analysis have been performed, and the prospect of practical use of pantograph monitoring system has been established. In 2016, a pantograph monitoring device for commercial vehicles developed based on the knowledge obtained during the test run was installed on three N700A type vehicles in advance, and data collection and analysis were performed. From 2017, based on the results of the past two years, the "automatic current control" function which analyzes the on-board data with a pantograph monitoring device and controls the main circuit current was installed on some N700A type vehicles.

In this study, we use a pantograph monitoring method to understand the current state of frost areas, and study the frost detection method to prevent damage and reduce delay by automatic current control.

2 Methods

2.1 Monitoring data

On Shinkansen trains with pantograph monitoring system, "collected current data" measured by current sensors attached to the high voltage pull-through cables of each pantograph (Car 5 and Car 12) and "image data" obtained by monitoring cameras can be obtained (Fig. 1). In ordinary areas, the currents collected by Car 5 and Car 12 have no difference, remain stable, and change according to the notch and speed.

2.2 Characteristics of collected current in the frost areas

When the front pantograph enters a frost area, the current collection ratio of the rear pantograph increases. After that, when the rear pantograph also enters the frost area, it becomes difficult for both pantographs to collect current, and a characteristic disturbance in the collected current occurs (Fig. 2).

2.3 Issues of current notch control

On the first train of one day, damage of contact strip mounting occurred in spite of the notch control. Therefore, analysis of current data up to the third train in addition to the first and second trains (under notch control) that ran in the same areas (Fig. 3). After the notch control area of the day, the first train in which the damage of contact strip mounting occurred, showed the characteristic disturbance of the collected current of Car 5 and Car 12 due to the frost. (Fig. 4). In addition, similar to the first train, the characteristic disturbance of the collected current was shown on the second train and the third train, so it was found that frost on the overhead lines was not scraped off after several trains passed (Figs. 5 and 6). From the above results, it was found that it is difficult to completely grasp the frost areas with the current notch control conditions.

2.4 Analysis method using the derivative of the difference of the collected current

We paid attention to the characteristic waveform of collected current in the frost areas, in which the difference of the collected current between Car 5 and Car 12 fluctuates in a short cycle (Fig. 7). By graphing with this point (the "current difference" on the horizontal axis and the "derivative of the difference" on the vertical axis), the plots of large electric arc area can be distinguished with the plots of ordinary area (Fig. 8).

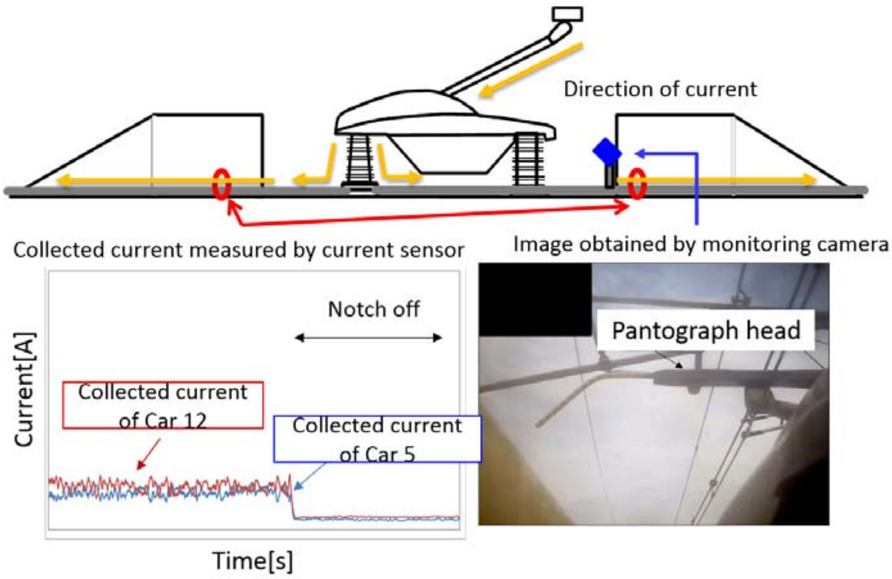

Figure 1: Overview of the pantograph monitoring system

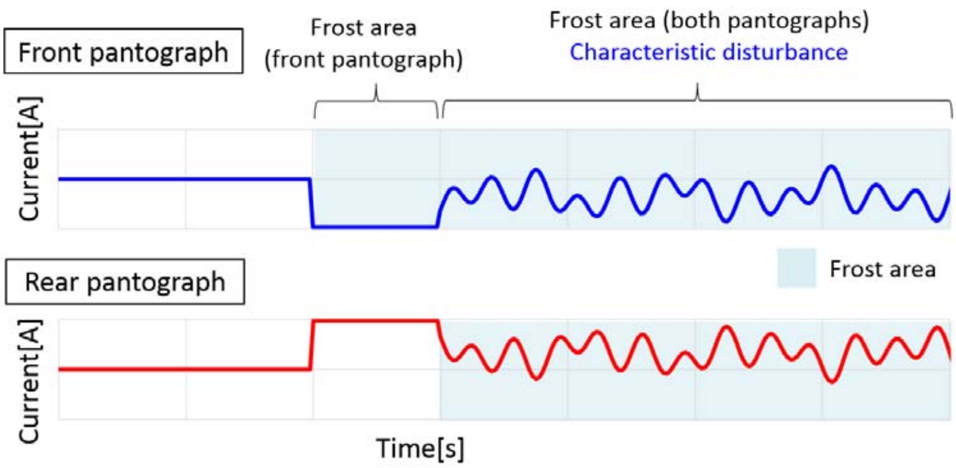

Figure 2: Collected current in a frost area

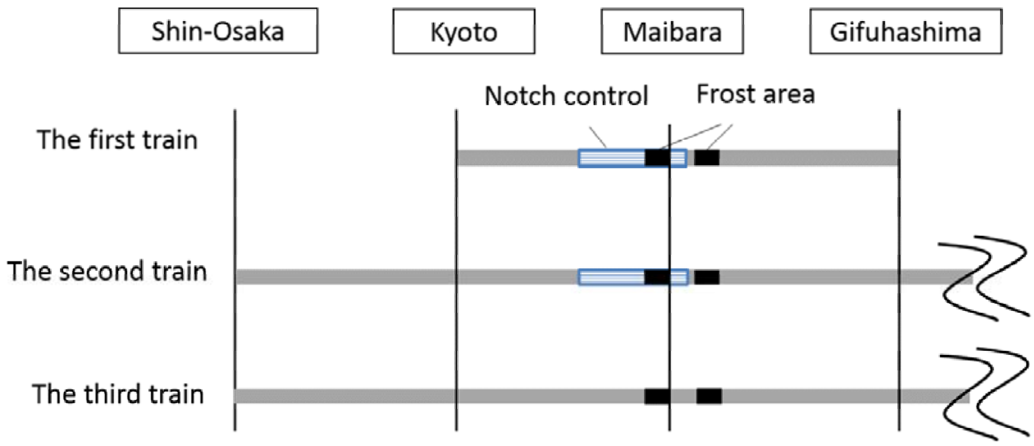

Figure 3: Courses of the trains(the first to the third)

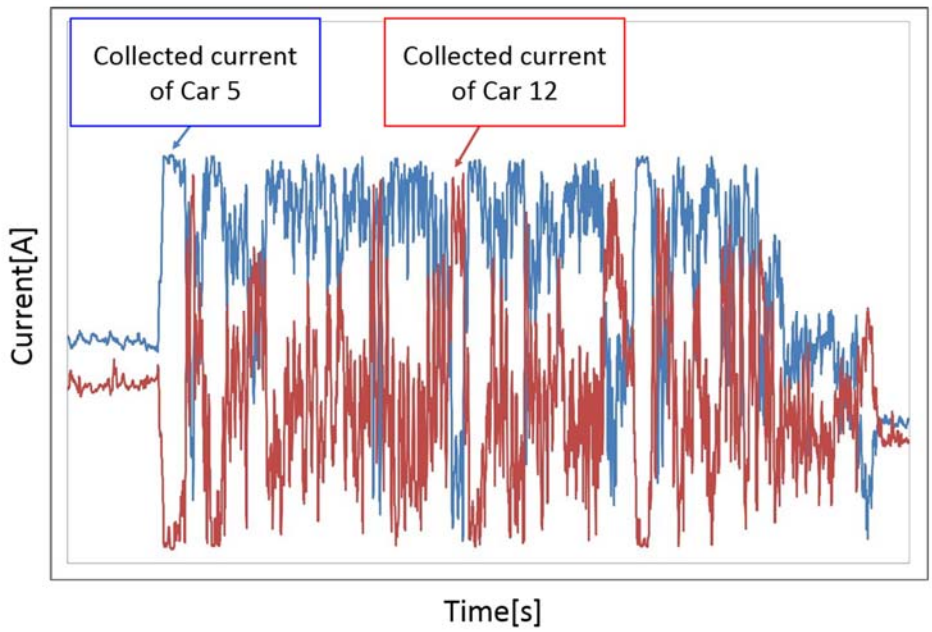

Figure 4: Collected current of the first train: pantograph head damage occurred

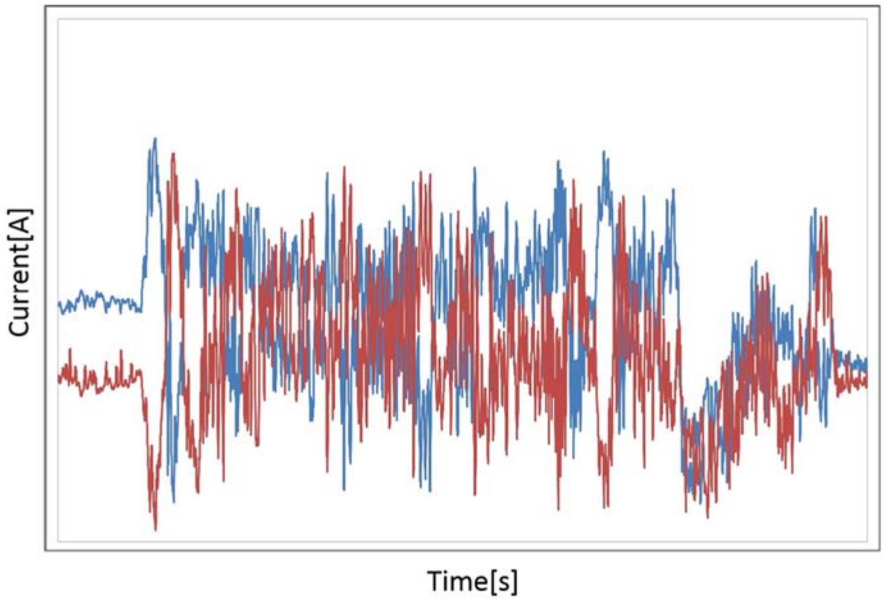

Figure 5: Collected current of the second train: no pantograph head damage

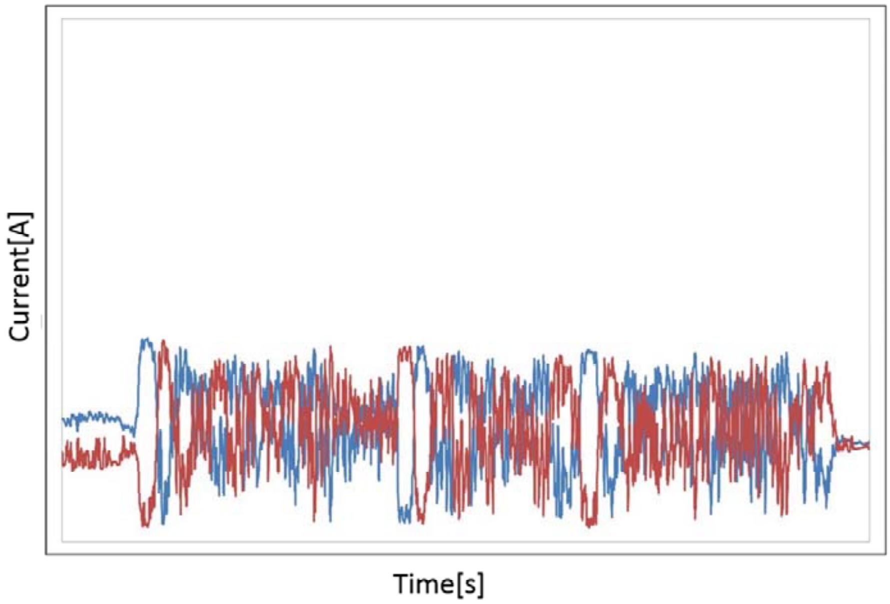

Figure 6: Collected current of the third train: no pantograph head damage

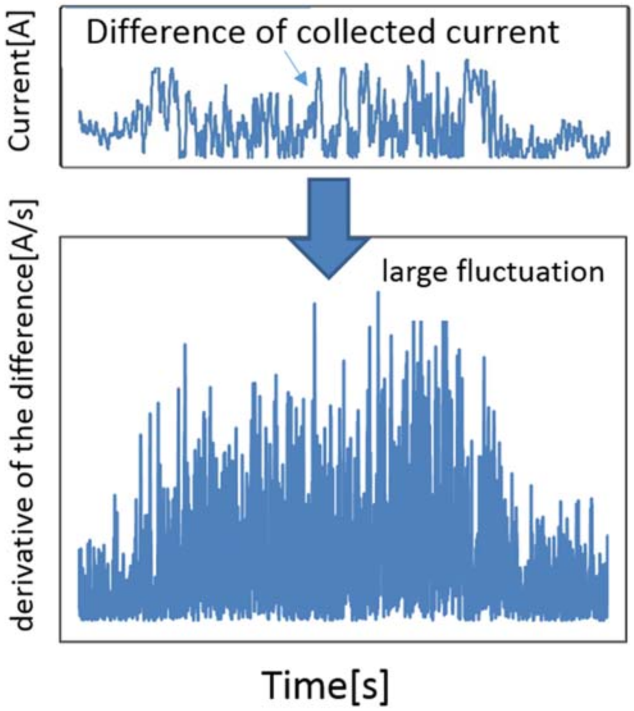

Figure 7: New analysis method

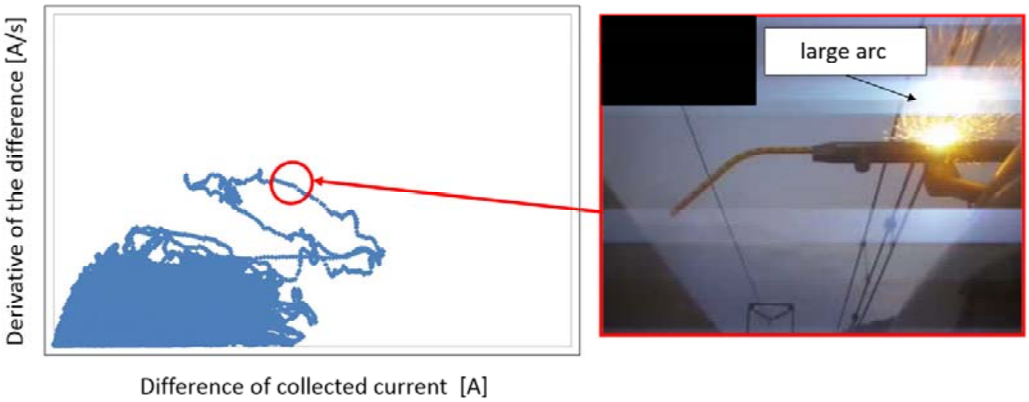

Figure 8: Detection of large electric arc

3 Results

3.1 Automatic current control

From 2017, based on the results of the past two years, we examined the "automatic current control" function that controls the main circuit current by analyzing the on-board data with a pantograph monitoring device. The purpose of this function is to prevent the occurrence of large electric arc. The advantage of the automatic current control is that the frost can be detected on the trains in operation, so that the current control can be restricted only to the frost areas and is also effective for areas that cannot be covered by the current notch control (Fig. 9).

3.2 Results of automatic current control

A collected current analysis was performed on the train that activated the automatic current control. From the current data, the pantograph monitoring device analyzed the on-board data to detect the frost, and then the collected current was controlled and suppressed (Fig. 10).

3.3 Prevention of pantograph heads damage by automatic current control

Comparing this data with the data of train on which a damage of contact strip mounting occurred, the current waveform in the frost areas were almost the same at first, but as a result of the current control, the damage on the pantograph was reduced (Fig. 11).

3.4 Reduction of delay by automatic current control

We compared a run curve of a train with the automatic current control with another run curve of same train number without the notch control on another day (Fig. 12). As a result, the delay due to the speed reduction in the automatic current control area is about 13 seconds at the maximum, and arrives at Kyoto Station on time. This result shows that the effect of the automatic current control is not only preventing the pantograph heads damage but also minimizing the delay by minimizing the notch control areas.

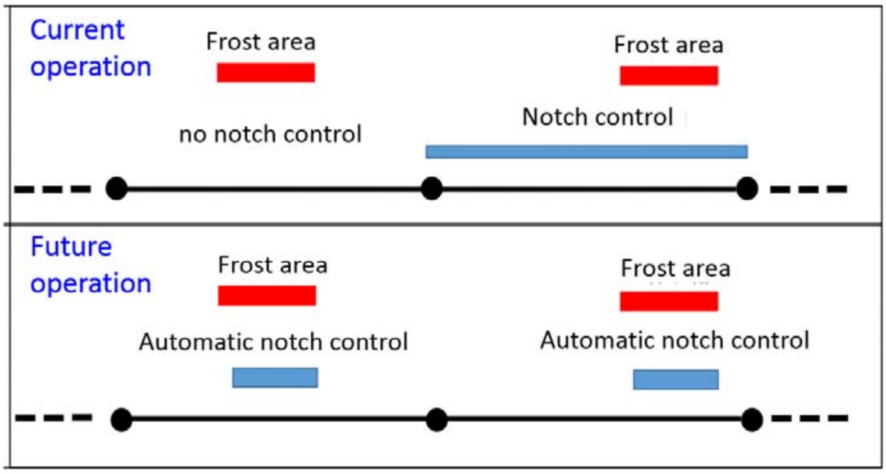

Figure 9: Difference between current notch control and the automatic current control

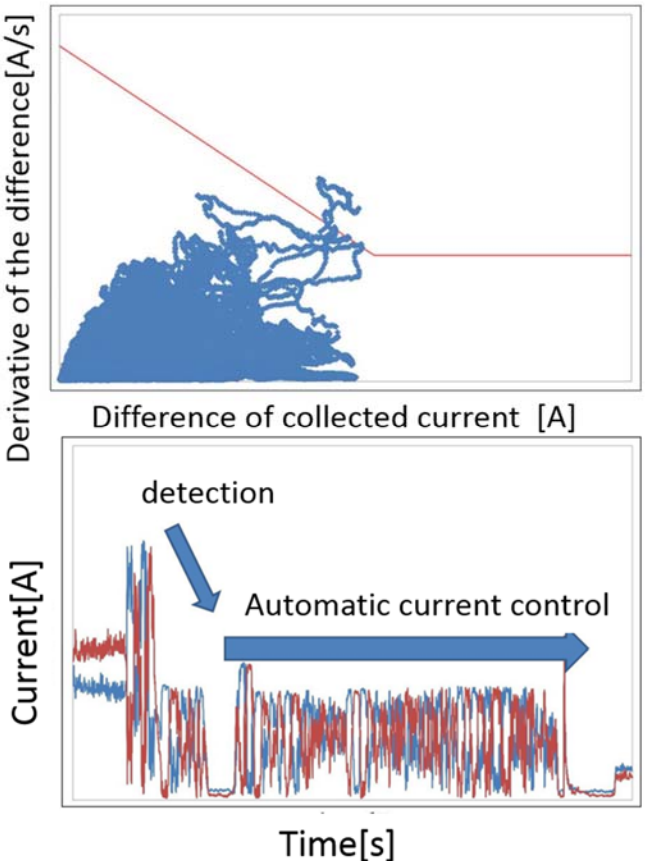

Figure 10: Collected current data with automatic current control

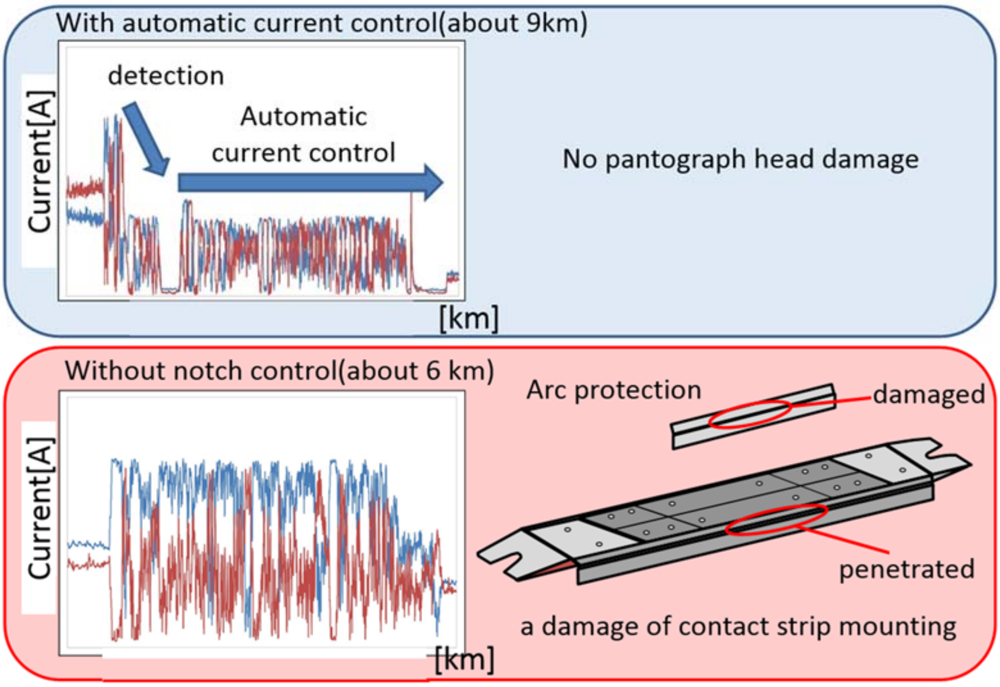

Figure 11: Comparison of current data

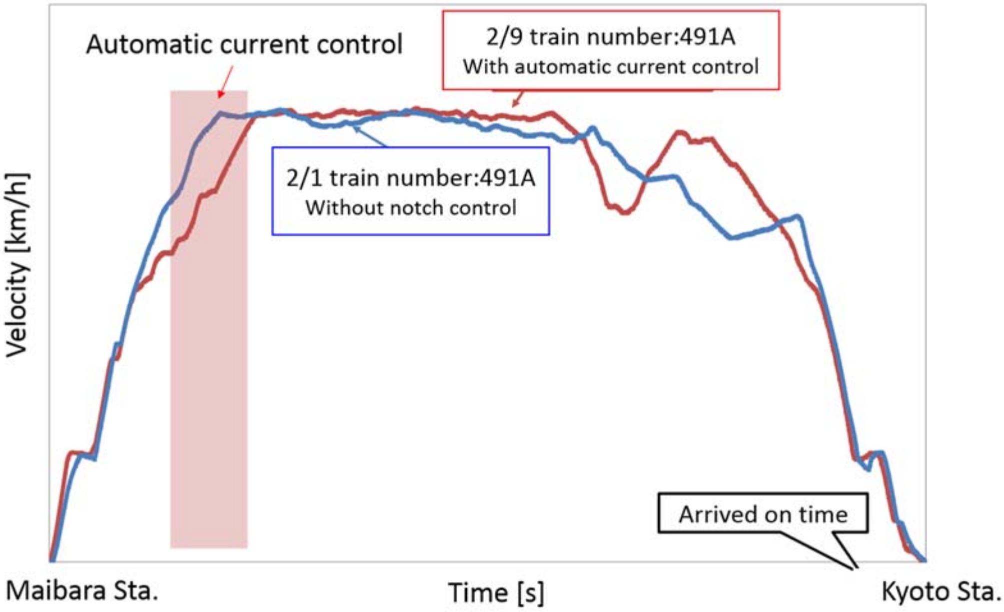

Figure 12: Comparison of run curve

4 Conclusions and Contributions

4.1 Understanding the current state of frost areas

We found the characteristic disturbances of collected current in frost areas and paid attention to the characteristic waveform of collected current in the frost areas, in which the difference of the collected current between Car 5 and Car 12 fluctuates in a short cycle. The characteristic disturbances of the collected current in the frost areas were confirmed outside of the current notch control areas and on the trains without notch control (third train or after). This result shows that, it is difficult to grasp all of the frost areas under the current notch control. Therefore automatic current control is effective to prevent pantograph heads damage.

4.2 Prevention of pantograph heads damage and reduction of delay by automatic current control

The automatic current control reduced the damage on the pantographs by reducing collected current in the frost areas, and it showed the effect of preventing pantograph heads damage. The "proper area" and "minimum control" by automatic current control minimized delay and contributed to safe and stable operation. The system which detects frost on overhead contact lines and prevents a generation of large electric arc by controlling collected current is the first technology in Japan.

References

[1] M. Furuya, “Overview of Shinkansen Series N700A tertiary vehicle”, JREA, Vol.60, No.5, pp24-27,May, 2017(in Japanese)

[2] H. Shiraishi, M. Kobayashi, ”Countermeasures for the frost on trolley wire”, Railway & electrical engineering, Vol.2, No.8, pp40-44, Aug, 1991(in Japanese)
[3] Y. Kamata, M. Shishido, T. Endo, S. Iikura, “Resolution of frost-phenomena adherent to the overhead lines and a study on prediction method of overhead line frosting”, RTRI REPORT, Vol.22, No.1, pp5-10, Jan, 2008(in Japanese)