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Development of Shinkansen Simple Catenary System for Operation over 300 km/h

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Abstract

Compound catenary systems on Shinkansen lines have just entered a period where they have to be replaced on a large-scale. To facilitate renewal and reduce maintenance costs, it is efficient to replace compound catenary systems with simple catenary systems when renewing compound catenary systems. Pantographs, which used to have a maximum of eight per trainset, is now a maximum of four, typically one or two. New type of simple catenary system was developed and was being installed on Tokaido Shinkansen line where the maximum operating speed was less than 300 km/h. Moreover, the Shinkansen lines over 300 km/h are in the direction of renewing to install simple catenary systems. However, comparing with compound catenary systems, simple catenary systems tend to cause large vertical oscillations of the pantograph in the intervals between support points. When thick wires are used to ensure current capacity, fluctuations in the contact force between the contact wire and the pantograph due to the dropper intervals tend to be large: the resulting increase in contact force fluctuations due to this, is a problem for high-speed operations. This study explores new types of simple catenary systems developed for running speeds of about 320 km/h, which is the current maximum Shinkansen commercial operating speed. In addition, a simple catenary system for operation up to 360 km/h is also being developed.

Keywords: electric railways, overhead catenary system, current collection, contact loss, current capacity.

1 Introduction

Since 1964 when Tokaido Shinkansen line started operation, compound catenary systems have been mainly used in overhead contact line structures on high-speed lines in Japan. Shinkansen employs EMU, and its trainset was equipped with a maximum of eight pantographs. One feature of the compound catenary system is that oscillation of the overhead contact lines due to a plurality of pantographs can be suppressed to low levels. Simple catenary systems for Shinkansen high-speed lines were first installed on the Hokuriku Shinkansen line which entered into operation in 1994. This simple catenary system was designed for lines with low traffic density in contrast with lines where heavy compound catenary systems were installed. The current capacity of the simple catenary system is approximately 70% of that of the heavy compound catenary system [1].

Soon however, it is necessary to replace compound catenary systems on Shinkansen lines on a large-scale. To facilitate renewal and reduce maintenance costs, it is efficient to replace compound catenary systems with simple catenary systems when renewing compound catenary systems. Pantographs, which used to have a maximum of eight per trainset, is now a maximum of four, typically one or two. New type of simple catenary system was developed and is being installed on Tokaido Shinkansen line where the maximum operating speed is less than 300 km/h [2]. Moreover, the Shinkansen lines over 300 km/h are in the direction of renewing to install simple catenary systems. However, comparing with compound catenary systems, simple catenary systems tend to cause large vertical oscillations of the pantograph in the intervals between support points. When thick wires are used to ensure current capacity, fluctuations in the contact force between the contact wire and the pantograph due to the dropper intervals tend to be large: the resulting increase in contact force fluctuations due to this, is a problem for high-speed operations.

This study describes the development of a new type of simple catenary system for operating speeds of 320 km/h, which is the current maximum speed on commercial Shinkansen lines, and of a simple catenary system for operating speeds up to 360 km/h.

2 Methods

(1) An excessive contact force between the contact wire and the pantograph may generate significant stress in the contact wire, which may lead to fatigue failure of the contact wire. On the other hand, when the contact force is too small, contact loss occurs and the electric power supply to a vehicle will be interrupted. In general, contact force fluctuations increase due to a range of factors as train speed increases. Therefore, it is necessary to keep contact force fluctuations within an appropriate range. The factors that cause contact force fluctuation are due to overhead contact line structures such as the interval of support points and droppers, and irregular unevenness of contact wire height. Contact force fluctuations stemming from intervals between support points and droppers were examined by simplified mathematic models [3, 4].

(2) Estimation of the contact force fluctuation by using calculation models [3, 4] is useful for qualitative evaluation, but is not reliable enough for quantitative evaluation. Furthermore, in a trainset with more than one pantograph, the following pantographs are affected by overhead-contact-line oscillation caused by the front pantograph. Therefore, to quantitatively evaluate the effect of the pantograph interval on the current collection performance of the following pantographs, dynamic characteristic evaluation [5] was performed using the dynamic numerical simulation of overhead contact lines and pantographs.

(3) From the result of above mentioned (1) and (2), the new types of simple catenary systems were proposed. To verify the current collection performance, the proposed simple catenary systems were installed on a commercial Shinkansen line (Figure 1), and the current collection performance was measured at train speeds up to 320 km/h.

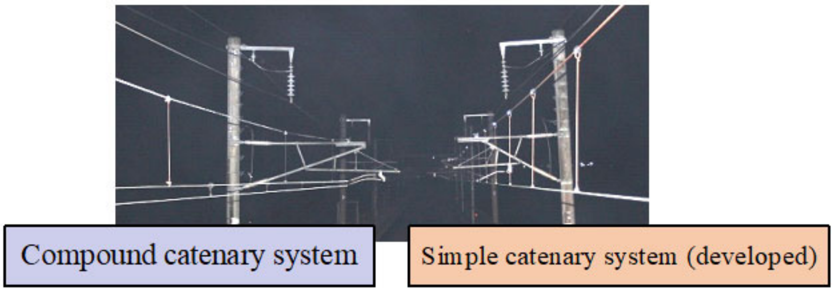


Figure 1: Installation situation of overhead contact lines.

3 Results

3.1 Specification

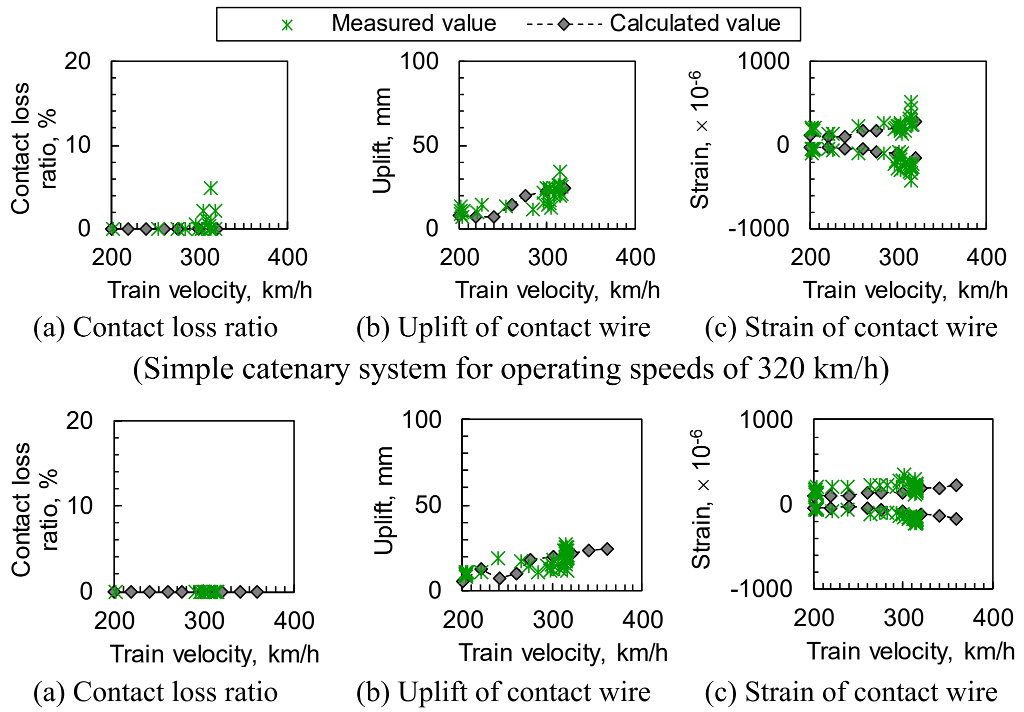
From the results of theoretical calculations and dynamic numerical simulations, the new types of simple catenary systems for operating speeds of 320 km/h and up to 360 km/h were proposed as shown in Table 1. The contact force fluctuation of the simple catenary systems calculated by the theoretical calculations were compared with high-tension heavy compound catenary systems for 320 km/h operations in Japan. For the simple catenary system for operating speeds of 320 km/h, the contact wire cross-sectional area is set to 170 mm^2, and the contact wire tension is set to 22.54 kN. And for the simple catenary system for operating speeds up to 360 km/h, the contact wire cross-sectional area is set to 130 mm^2, and the contact wire tension is set to 24.50 kN. For the simple catenary systems for operating speeds of 320 km/h and up to 360 km/h, the total tension is set to 53.90 kN.

3.2 Verification results

From the results of actual installation test on a commercial line as shown in Figure 2, it can be seen that the measured values and the calculated values of uplift and strain of the contact wire were almost the same in both catenary systems. These results demonstrate that both newly proposed simple catenary systems meet the expected current collection performance.

No.	Overhead contact line	Contact wire (nominal tension)	Messenger wire (nominal tension)
1	Simple catenary system for operating speeds of 320 km/h	GT-SNN170 (22.54 kN)	PH200 (31.36 kN)
2	Simple catenary system for operating speeds up to 360 km/h	GT-PHC130 (24.50 kN)	PH200 (29.40 kN)

Table 1: Specifications of proposed overhead contact lines.



(a) Contact loss ratio (b) Uplift of contact wire (c) Strain of contact wire

(Simple catenary system for operating speeds of 320 km/h)

(a) Contact loss ratio (b) Uplift of contact wire (c) Strain of contact wire

(Simple catenary system for operating speeds up to 360 km/h)

Figure 2: Measurement result of current collection performance on commercial line.

4 Conclusions and Contributions

This study explores new types of simple catenary systems developed for running speeds of 320 km/h, which is the current maximum Shinkansen commercial operating speed. In addition, a simple catenary system for operation up to 360 km/h is also being developed.

The results of theoretical studies and numerical simulations for dynamic behavior of overhead contact lines and pantograph system, the new types of simple catenary systems for operating speeds of 320 km/h and up to 360 km/h were developed.

The results of installation test on a commercial line with operating speeds up to 320 km/h, confirmed that both simple catenary systems achieve the expected current collection performance. In both catenary systems, the measured values and the calculated values of uplift and strain of the contact wire were almost the same. These results demonstrate that both newly developed simple catenary systems meet the expected current collection performance. Furthermore, for each of the simple catenary systems, during the installation period (approximately half a year), there was no progress in local wear of the contact wire.

The simple catenary system is being installed on Tohoku Shinkansen line in sequence since 2020. Plans are in place to install the developed simple catenary system for operating speeds up to 360 km/h to conduct current collection performance tests on a commercial Shikansen line.

References

[1] M. Aboshi, Y. Oura, T. Kobayashi, T. Tsuburaya, K. Ueno, M. Kaneko, "Development of Overhead Catenary System for Projected Shinkansen", IEEJ Trans. IA, Vol. 116, No. 4, 490-496, 1996 (in Japanese).

[2] H. Konishi, T. Tateno, H. Shingai, H. Andou, Y. Terada, H. Komine, "A Development of Heavy Simple Catenary for Tokaido Shinkansens", J-RAIL2014, S1-4-4, 2014 (in Japanese).

[3] M. Aboshi, K. Manabe, "Contact Force Fluctuation between Catenary and Pantograph", RTRI Report, Vol. 13, No. 7, 7-12, 1999 (in Japanese).

[4] G. Gilbert, H. Davies, "Pantograph motion on a nearly uniform railway overhead line", PROC.IEE, Vol. 113, No. 3, 485-492, 1966.

[5] M. Aboshi, "Estimation Method of Contact Line Unevenness using Dynamic Simulation", IEEJ Trans. IA, Vol. 126, No. 7, 983-988, 2006 (in Japanese).