Improvements of Existing Overhead Lines for 180km/h operation of the Tilting Train

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Abstract

The purpose of this study is to establish the required improvements to existing overhead lines for 180km/h operation of the tilting train, the TTX, in Korea. Considering the technical requirements of less than 1% loss of contact and 100mm of maximum uplift, we propose the measures to improve the existing overhead lines. The tensions of the contact wire and the messenger wire, as well as the pre-sag were determined based on numerical simulations. To verify the proposed measures, on-line tests were performed under the tension and pre-sag conditions determined in the simulations. During the tests, we measured the uplift of the contact wire at the supports, the variations of the pan-head acceleration, and the force acting on the dropper. At speed up to 170km/h, the uplift fell below the permissible value and the current collection performance was shown to be appropriate. In 2008, the tests at the maximum speed will be performed under the suggested overhead line conditions.

Introduction

The overhead contact lines and pantographs of electric railways in numerous countries have been studied for better current collection quality. The overhead contact line system supplies electrical energy for a train through contact with a pantograph. Therefore, the interaction between these components determines the quality and reliability of the energy supply. In parallel with the theoretical study of interaction between pantographs and overhead contact lines, measurement techniques have been developed to assess the quality of current collection in operational systems. In these techniques, the overhead lines, the pantograph alone and the interaction between these two components are assessed [1]. According to EN50119 [2], the criterion of current collection quality is defined as the statistical minimum contact force, the mean contact force minus three times the standard deviations, which shall be positive. In addition, the criterion restricts the uplift of the contact wire at the support to half of the calculated maximum uplift.

In the past several years, electric railways have progressed greatly in terms of running speeds both in commercial operations and in high-speed test trials in Korea. On the Kyungbu high speed line in Korea, operating up to a maximum speed of 300km/h, in Korea, French TGV trains were imported and the overhead line system was built with our own hands using their given design. Many other electrification projects have also been accomplished, such as the Kyungbu conventional line and the Honam line, since the Kyungbu high speed line was introduces. In addition to research on the infrastructure, the development of trains has been progressed. In order to save operating costs, to minimize the investment of infrastructure, and to improve the speed on existing lines, a tilting train, called the TTX, has been developed, The purpose of this study is to establish the improvements of existing overhead lines required for 180km/h operation of the TTX.

Catenary and pantograph

The TTX is designed to operate at the maximum speed of 180km/h using existing overhead electrical lines. Using the specifications and vibration test results [3, 6] of the TTX pantograph in Figure 1, we obtained the mathematical 3-mass model of the pantograph, shown in Figure 2, for the dynamic simulation.
The catenary specifications of the existing Chungbuk line and Honam line are shown in Table 1. Based on the theoretical study and numerical simulation program [4 - 6], we propose the specifications of the new system described in Table 1.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Chungbuk line</th>
<th>Honam line</th>
<th>Proposed system</th>
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<tbody>
<tr>
<td>Type</td>
<td>Simple catenary</td>
<td>Simple catenary</td>
<td>Simple catenary</td>
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<tr>
<td>Contact wire (tension)</td>
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<td>Cu110 (1.2 ton)</td>
<td>No modification (1.2 ton)</td>
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<tr>
<td>Messenger wire (tension)</td>
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<td>Pre-sag</td>
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<td>1/1,000</td>
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<td>Standard span length</td>
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<td>No modification</td>
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<tr>
<td>Permissible Uplift at the support</td>
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<td>100 mm</td>
<td>No modification</td>
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<tr>
<td>System height</td>
<td>960 mm</td>
<td>960 mm</td>
<td>No modification</td>
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</table>

Table 1 Catenary specifications of the Chungbuk line, Honam line, and proposed system (* Partially pre-sag adopted with the ratio of sag to span = 1:2000)

For the program validation, we compared the simulation results with test results. Figure 3 shows the contact wire uplift (vertical displacement) at the support in the existing Honam line. We measured the uplift with the displacement transducer when the KTX pantograph moves at a speed of 160 km/h. The simulation results agree closely with the tests.
We performed dynamic behavior simulations between the pantograph and the overhead lines, based on the criterion of current collection quality described above, which are the statistical minimum contact force and the uplift at the support. The best current collection results when the contact wire and the messenger wire were tensioned at 1.2 ton, and a pre-sag with a sag to span ratio of 1:1000 was adopted. Table 2 shows the simulation results of current collection performance according to the pre-sag variation of the contact wire in the Honam line, and Figure 4 shows the contact force variation and vertical pan-head movement obtained from the simulation. Using a pre-sag of span/1000, the criteria for the design speed of 200km/h was satisfied. Using a pre-sag of span/2000 and comparing this to span/1000 case, it is not only appropriate for the current collection performance but also for the uplift at the support for this catenary conditions and the train speed. Thus, we have determined the pre-sag quantity and the tension of wires for the design speed of 200km/h and modified one tensioning length of the overhead lines based on the proposed conditions in the Honam line.

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<td>18</td>
<td>49</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 2 Simulation results of current collection performance according to pre-sag variation of the contact wire on the Honam line

On-line test results

The performance of the proposed system has been evaluated by the on-line tests of the TTX at speeds of up to 170km/h. The on-line tests were performed by both on the train and on the overhead lines. Factors such as the variation of pan-head acceleration, the contact wire uplift at the support, and the dynamic force acting on a dropper were measured. Figure 5 shows the telemetry system with the ability to measure these factors. The uplift at the support was measured by both a wire sensor and a high speed camera. The force on the dropper was measured by strain gauges.

Figure 6 shows the test results for the acceleration of the pan-head of TTX pantograph under the modified catenary condition at 160 km/h. The presence of the pre-sag reduced the fluctuation of the acceleration. The acceleration represents a variation of the contact force between a pantograph and a contact wire. The standard deviation of the acceleration at the pre-sag section and the second no-sag section are 2.6 m/s² and 5.1 m/s², respectively. Thus, it is
apparent that the pre-sag improves the current collection performance in the Honam overhead contact lines at 160 km/h, which is near the resonance speed. Based on these results, we estimate that the current collection performance will be good at the maximum speed.

![Fig. 5 System to measure the dynamic behavior of overhead lines](image)

![Fig. 6 Variation in acceleration of the pan-head of TTX pantograph under the modified catenary conditions](image)

![Fig. 7 Contact wire uplift at the support under the modified catenary at 170km/h](image)  
![Fig. 8 Force on the dropper in the existing line at train speed of 160 km/h (with the ratio of sag to span = 1:2000)](image)

The uplift in the modified catenary system, as measured by high speed camera, is shown in Figure 7. The uplift measured about 2 cm when the TTX pantograph moves at a speed of 170 km/h.
km/h. Compared to the uplift with the ratio of sag to span = 1:2000 at 160km/h (Figure 3), the uplift with the ratio of sag to span = 1:2000 at 170km/h is low even though the train speed is higher. This demonstrates that the pre-sag reduces the uplift at the support. At speed up to 170km/h, the uplift fell below the permissible value. Thus, we also estimate that the uplift will be within limits at the maximum speed.

In order to increase the speed of a train, it is necessary to study not only the dynamic behaviors between the overhead lines and the pantograph but also the fatigue behaviors of components to assure safety with the increased vibration level and the different line conditions. The dropper is one of the critical components in the system. Because the force on the dropper and the dynamic behavior change depending on the quantity of pre-sag and the speed of trains, it is necessary to study the dynamic behavior of a dropper. We measured the internal force on the dropper with the passage of a pantograph. The dropper nearest to the supporting bracket, as shown in Figure 5, was chosen for the measurement, because this dropper generally undergoes the highest force variation. We installed a load cell on the dropper clamp on the contact wire. The force variation at a train speed of 160km/h is shown in Figure 8. At 160km/h, the maximum dynamic force on the dropper was estimated to be below 2 times of the static force. Furthermore, we expect that it will be possible to create criteria of fatigue tests for the dropper and dropper clamp using these results.

In addition, we developed essential components for the improvements, such as a support bracket for the narrow tunnel, shown in Figure 9, and a pulley type tensioning device. Considering the system height in the narrow tunnel is 275mm in the Chungbuk line, the brackets system supporting the contact wire and messenger wire were designed separately, and we increased the stiffness of the bracket for the messenger wire in order to achieve better current collection performance. The bracket was tested according to the Korean Railway Standard [7] for the safety assurance. Figure 10 shows the vibration fatigue test of the bracket. Our developed components will be also tested on the Chungbuk line for the performance validation.

Discussion and conclusions

In order to establish the improvements of existing overhead line system for 180km/h operation of the TTX in Korea, we proposed a specification based on a theoretical study and numerical simulation program of the system. We determined the tensions of the contact wire and the messenger wire and pre-sag considering the technical requirements of less than 1% of loss of contact and a maximum uplift of 100mm. To verify the proposed measures, on-line tests at the speeds up to 170km/h were performed under the modified catenary conditions. During the test, we measured the uplift of the contact wire at the support, the acceleration variations of the pan-head and the force acting on the dropper. The uplift fell below the
permissible value at speeds up to 170km/h, and the current collection performance was shown to be appropriate. We conclude that the pre-sag reduces the uplift at the support and improves the current collection performance in the overhead contact lines. Tests at 160km/h show the maximum dynamic force on the dropper was below 2 times of the static force. Furthermore, we expect that it will be possible to create criteria of fatigue tests for a dropper and dropper clamp using these results. Finally, we suggested a support bracket in a narrow tunnel and will validate the bracket on the Chungbuk line.

In 2008, the maximum speed test will be performed under the modified overhead line conditions. We estimate that current collection performance and the uplift will be within specifications at the maximum speed.

Acknowledgements

The authors would like to acknowledge the Ministry of Construction & Transportation of Korea for its financial support in this study.

References