Traction system combined test of the KHST (Korean High Speed Train)


Abstract

This paper introduces the combined test results of the traction system for KHST (Korean High Speed Train: hereafter refer to KHST). The main purpose of this combined test is to verify the performance of the traction system that is designed to operate up to maximum 350km/h speed. Combined test system consists of a traction transformer, two AC-DC PWM converters, a PWM Inverter, two traction motors and flywheel system. Flywheel system represents equivalent model of the train inertia. Also traction control system and MASCON Interfaces are included.

Various kinds of experiments are performed to prove total traction system performance and detailed waveforms are described.

1 Introduction

Recently, the interest of the high-speed railway train increases. Due to its energy conserving and fossil-fuel free, it is environmentally friendly. Because the verification of the traction control algorithm in real track needs a lot of test time and much cost, the development of the traction system control algorithm is often verified by using combined test system that is consisted of related traction systems with large flywheel.

The main goals of the combined test are as follows.
- Verification of the total traction system performance
- Improvement of the system reliability
- Troubleshooting of the traction system interface with safety
The KHST baseline model is summarized as follows:

- Train mass: about 780 tons
- Maximum axle load: 17 tons
- Traction power: 17600kW (1100kW × 16 motors)
- Maximum operating speed: 350 km/h
- Train resistance: 131.4kN (at 350km/h)
- Adhesion coefficient: 0.25 (at 0km/h) to 0.07 (at 350km/h)
- Braking system: regenerative, rheostat, eddy current and disk brakes
- Control network: TCN

In this paper we introduce the traction control algorithm and the combined test results of the traction system which will be used in KHST. Various traction algorithms are tested and verified by combined test. Through the combined test, it is proved that developed traction algorithm can be successfully used.

2 Combined test system configuration

Each traction unit of KHST consists of two AC-DC PWM converters, a PWM inverter with braking chopper and two induction motors. Figure 1 shows the traction system configuration of the combined system and table 1 describes brief specification of the traction system. The torque-speed characteristic of one traction motor is shown in figure 2. The block diagram of the combined system is shown in figure 3. It is combined from the control sides such as a mascon controller, traction control unit, flywheel control unit and interface circuit to the high power traction unit which includes traction motors, inverter, converters and transformer.

Figure 1: Traction system configuration of one traction unit.
Table 1: Specification of the traction system

<table>
<thead>
<tr>
<th></th>
<th>Transformer</th>
<th>Converter</th>
<th>Inverter</th>
<th>Traction Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>AC 25kV,</td>
<td>AC 1400V,</td>
<td>DC 2800V,</td>
<td>AC 0-2183V, 747A,</td>
</tr>
<tr>
<td></td>
<td>356A</td>
<td>890A*2</td>
<td>884A</td>
<td>0-143Hz</td>
</tr>
<tr>
<td>Output</td>
<td>Traction:1400VAC*6,</td>
<td>DC 2800V,</td>
<td>AC 0-2183V,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>893A*6</td>
<td>884A</td>
<td>747A,</td>
<td>0-143Hz</td>
</tr>
<tr>
<td></td>
<td>Auxiliary: 350VAC*4,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>100A*4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated Power</td>
<td>8900kVA</td>
<td>1250kW*2</td>
<td>3000kVA</td>
<td>1100kW*2</td>
</tr>
</tbody>
</table>

Figure 2: Characteristic curve of one traction motor

Figure 3: Block diagram of the combined system.
In the combined test in order to simulate the train inertia, large flywheel is designed. The total inertia moment of the flywheel has the same characteristics of the equivalent load of one traction unit.

3 Traction Control Algorithm of the KHST

Traction control unit of the KHST consists of main traction controller with converter/inverter controllers. Each controller is interfaced with RS-485 communication network and traction controller is communicated with other control units through train control network (TCN).

The main function of each controller is summarized as follows.

- **Traction controller**
  - Direction & drive mode (traction, braking & emergency braking) setting
  - Torque reference generation
  - Jerk & anti-slip/slide control
  - Power limitation control
  - Faulty condition handling & fault record
  - TCN interface with other control systems

- **Converter controller**
  - DC link voltage control
  - Unit power factor control
  - Regeneration braking control
  - Traction system isolation & release

- **Inverter controller**
  - Vector & slip frequency control of traction motors
  - Torque control of induction motor
  - Overmodulation & synchronous PWM control

4 Experimental Results

Depending on the control algorithm of the traction control unit, many kinds of performance test is accomplished using combined test system.

Figure 4 and 5 show the maximum acceleration and deceleration performance. First, traction motor is accelerated from the zero speed to the 350km/h using maximum traction force, after that speed is decreased from maximum speed to 8km/h that is the point of electrical braking fade out using maximum regeneration braking force.

It is confirmed that depending on the maximum torque characteristic curve of the traction motor, torque reference is generated with jerk control and torque control performance shows good characteristic.
Figure 4: Maximum acceleration characteristic (5s/div.)
Figure 5: Maximum electrical braking characteristic (5s/div.)
Figure 6: Power limitation characteristic (5s/div.)
Figure 7: Variable speed characteristic in powering mode (5s/div.)
Figure 8: Variable speed characteristic in braking mode (5s/div.)
Power limitation characteristic is shown in Figure 6. Some faulty condition, such as over-temperature of transformer & motor and fault condition of one oilpump, the maximum output power of motor is restricted as a 70% of full power. In this experiment, faulty condition is intentionally generated at the speed of 100km/h, 200km/h and released faulty at the speed of 150km/h, 250km/h on powering mode. After that, faulty condition is reoccurred at the speed of 250km/h, 150km/h and released at the speed of 200km/h and 100km/h in braking mode. Figure 7 and 8 shows the variable speed characteristic of the system in powering and braking mode respectively.

5 Conclusion

In this paper useful combined test results are introduced. Before the real track operation, in order to verify traction control algorithm, combined test of the KHST is performed. The following issues are verified experimentally on the combined test.

1) Sequence test
2) Traction performance test
3) Power limitation test
4) Line voltage variation test
5) Power factor control and four-quadrant operation of the AC-DC converters.
6) DC link voltage regulation.
7) Traction motor drive and torque control performance.
8) Electrical braking (regenerative, rheostatic) control.
9) Train running simulation controlled by TCN network.
10) System interface troubleshooting among traction components.

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References