Efficient testing of complex interlocking interfaces HSL-Zuid/ProRail

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The HSL-Zuid is a 100 km high-speed line, running from Amsterdam via Rotterdam to the Belgian border. From there it links through to Antwerp, Brussels and Paris.

The Dutch part of the line connects to existing tracks at five locations. At these points, the interlocking systems of the existing network are linked to those of the HSL-Zuid system.

The existing Dutch rail infrastructure is managed by ProRail. ProRail determines the conditions that must be met by systems that are to be connected to their existing systems, including interlocking systems.

The HSL-Zuid organization has to ensure that these connections are demonstrably safe and reliable.

This article describes the testing of the connection between the HSL-Zuid interlocking and that of the existing infrastructure. It explains the structure of the tests, their content, the division of responsibilities between the parties and how a demonstrably safe overall system is created.

1 Introduction

1.1 HSL Zuid – general

The HSL-Zuid track and associated systems have been built by Infraspeed, a consortium of banks and major contractors, under a "Design, Build, Finance and Maintenance Contract".

Figure 1: HSL-Zuid route

The HSL-Zuid consists of two parts, each approximately 50 km long (Fig. 1). The northern part runs from Hoofddorp to Rotterdam. High-speed trains travel from Amsterdam via the existing network to Hoofddorp (South of Schiphol Airport), where the existing network joins the northern section of the HSL-Zuid. The HSL-Zuid then runs south towards Rotterdam. At Rotterdam-West, high-speed trains leave the HSL-Zuid and continue to Rotterdam via the existing network. There are no other connections between the HSL-Zuid and the existing network in between.

The southern part of the HSL-Zuid starts south of Rotterdam, at Rotterdam-Lombardijen, and continues to the Belgian border. From the border, the HSL-Zuid continues to Antwerp.

Non-international high-speed trains can leave the HSL-Zuid at the Zevenbergschen Hoek junction and continue to Breda via the existing network. High-speed trains from Breda to Antwerp and Brussels can join the HSL-Zuid via a junction south of Breda.

1.2 The HSL-Zuid interlocking system

The HSL-Zuid is equipped with ERTMS level 2. Maximum speed under level 2 is 300 km/h. In fallback mode, trains on the HSL-Zuid can also run under ERTMS level 1, at a maximum speed of 160 km/h.

The northern and southern sections of the HSL-Zuid each have their own Siemens SIMIS-W electronic interlocking and Thales Radio Block Centre (RBC) [1].

Because the northern and southern sections of the HSL-Zuid are not directly connected to each other, there are no connections between the two SIMIS-W interlockings and between the two RBCs.

1.3 The ProRail interlocking systems

ProRail uses a wide variety of interlocking systems. These range from relay interlockings using GRS relays, to electronic interlockings supplied by Alstom, Bombardier and Siemens.

Track circuits are used for train detection at all major stations, yards and junctions. The track circuits are also used to transmit information from the Dutch ATB train protection system to the train.

2 Interfaces in a complex environment

2.1 Connections between two different interlocking systems

Where the HSL-Zuid connects with the existing ProRail network, modifications were made to the infrastructure before the HSL-Zuid was built. At certain locations, extra switches and crossings were installed and new connections were made between tracks to allow simultaneous train movements (Fig. 2). The tracks at Breda were completely modernized and the relay interlocking replaced by an electronic interlocking. At Hoofddorp also, the modifications needed to the existing Alstom electronic interlocking would have been so major that it was more economical to install a complete new interlocking.

The system chosen was the Siemens SIMIS-C interlocking. That choice was made before it was known what system would be used on the HSL-Zuid. The end result was that uniform connections were possible at all points where the HSL-Zuid linked up with the existing Dutch network. This proved to be a great advantage, saving time during both development and approval.

Figure 2: Zevenbergschen Hoek junction (Photo: Rijkswaterstaat HSL-Zuid / Ton Poortvliet)

Infraspeed

The Dutch State has concluded a DBFM contract with Infraspeed.
Under this contract, Infraspeed is responsible for building the superstructure of the HSL-Zuid: rails, electrical system (overhead line and substations), the communications, interlocking and signalling system, noise barriers, walls, fences and for tunnels the facilities, emergency systems and ventilation systems.
The contract includes the management and maintenance of the entire infrastructure (including the track structure) for infrastructure manager ProRail.
The Infraspeed consortium was created in February 1999. It consists of:
- Fluor Infrastructure B.V.
- Siemens Nederland N.V.
- Koninklijke BAM Groep N.V.
- Innisfree Ltd.
- HSBC Infrastructure Ltd.

2.2 Contract parties

The HSL-Zuid project organization acts on behalf of the Dutch State as the customer for the construction of the HSL-Zuid. HSL-Zuid contracted Infraspeed to design and build the track and associated systems, including the interlockings and their outside equipment, and to design the interfaces with existing ProRail interlockings.

The HSL-Zuid project organization contracted ProRail to carry out the modifications to existing ProRail interlocking systems. In turn, ProRail drew up a contract with Siemens Nederland. This only involved the modifications to the electronic interlocking. The HSL-Zuid project organization contracted Movares Nederland to carry out the modifications to existing outside equipment. Figure 3 illustrates these relationships.

HSL-Zuid project organization

The HSL-Zuid project organization falls within the sphere of responsibility of the Directorate-General of Public Works and Water Management, which is part of the Ministry of Transport, Public Works and Water Management. The HSL-Zuid project organization acts as the client for all contracts related to the track structure, track systems and connections to the existing rail network.
It also manages the contracts with all contractors working on those connections and the contracts with the track systems contractor for the HSL-Zuid, Infraspeed. Finally, the HSL-Zuid project organization is responsible for safety, approvals and system integration.

2.3 Transition from ERTMS to ATB and vice-versa

Joining together two interlocking systems is no trivial matter. A complicating factor in this instance is that at the point where the two systems meet, there is also a transition between ERTMS and the Dutch ATB system.

Designing this functionality became a joint effort between Infraspeed and HSL-Zuid. Infraspeed supplied the required knowledge of ERTMS, while HSL-Zuid did likewise for the existing interlocking system, including ATB.

Several design meetings were held, resulting in a relatively simple, yet robust transition.

ProRail

Since 1 January 2003, ProRail has been the independent infrastructure manager of the railways in the Netherlands, resulting from a merger between Railinfrabeheer, Railned and Railverkeersleiding. ProRail's most important task is to ensure capacity, reliability and safety on and around the rail network. As a result, ProRail is responsible for all aspects of Dutch railway infrastructure. This covers new build, infrastructure management and maintenance, traffic management, approval of trainoperators and allocation of capacity.

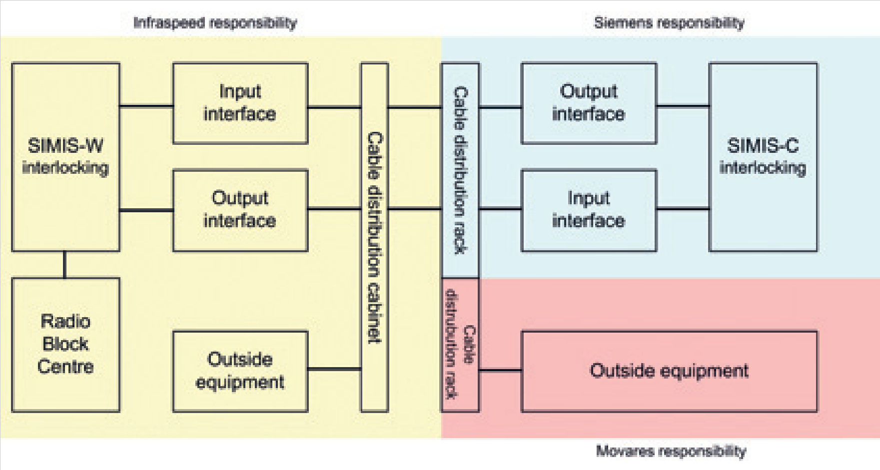

Figure 3: Division of responsibilities

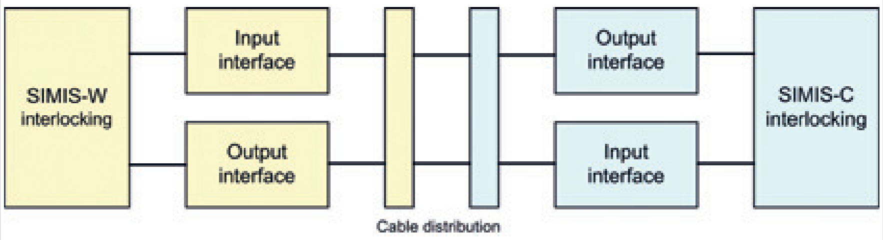

Figure 4: Connections between the HSL-Zuid and existing infrastructure

3 Designing the tests

3.1 Specifying the interface

Infraspeed drew up a Technical Description of Design (TDD). This contains the complete generic technical description of the interface between SIMIS-C and SIMIS-W.

Within Infraspeed, this document was used to produce the location-specific design for the SIMIS-W installation and the interface on the SIMIS-W side.

Within the HSL-Zuid organization, the document formed the basis for writing the Ontwerpvoorschriften (instructions for design, OVS) and the Installatievoorschriften (installation instructions, ISV) required by ProRail. The latter instructions are the basis for designing the modifications to the SIMIS-C installation, and the interface on the SIMIS-C side.

Figure 5: Transition from ERTMS to ATB at Rotterdam–Lombardijen

3.2 Test philosophy

The test philosophy was specified in detail at an early stage in the design process, during a number of discussions between HSL-Zuid and Infraspeed. The test procedure had to be clear and open. Furthermore, the content and results of the tests had to be acceptable to all parties, for assessment by their respective Independent Safety Assessors or quality processes. This led to the following general test procedure:

1. Each party tests its own part in a factory or office environment (Factory Acceptance Test, FAT).
2. A complete test is conducted in a factory environment, with the two systems connected (Factory Integration Test, FIT).
3. The systems are transported to site and assembled.
4. Each party tests their own part on site (Site Acceptance Test, SAT).
5. The two systems are connected on site and integration between the two is tested (Site Integration Test, SIT).

3.2.1 Each party tests their own part

During this test, the site-specific software is installed on a test system. In general, the interface is simulated. In the case of critical interfaces, the usual procedure is to connect one of each interface component.

The (modified) system configuration, site-specific modifications and associated system functions are tested. This includes both functional and failure tests.

The system has to operate completely in accordance with specifications before the next test phase can start.

3.2.2 Complete test in a factory environment

During this phase, the two interlocking systems are connected to each other in a factory environment.

In the case of the link between the HSL-Zuid and the existing network, it was decided to connect each system via its own standard interface to the interface of the other system (Fig. 4).

Connecting the actual systems in this fashion creates a test that gives a reliable impression of how the link between them will work.

The tests are always conducted by one of the parties responsible. The other party works to the test programme of that party.

This test is repeated for each site. This includes both functional and failure tests.

Both systems must operate completely in accordance with specifications before the next test phase can start.

3.2.3 Each party tests their own part on site

Once the factory tests are complete, the systems can be transported to site, or the software can be installed on the existing systems on site.

Site-specific cabling and any system components are added, and the system is tested once again. The emphasis is on testing those components that could not be tested previously.

Because the HSL-Zuid is a complete new infrastructure system, Infraspeed was able to test the interlocking system in the absence of traffic.

In the case of modifications to operational interlocking systems on the existing network, tests were carried out when no trains were running, i.e. during a possession. Because the tests had already been carried out in the factory, there was significantly less risk of faults and hence of overrunning the possession.

3.2.4 Integration tests on site

The tests that involved connecting the two systems and testing integration between the two were broken down into a number of phases. Because existing infrastructure was used for the tests, they were always carried out during possessions.

The tests for the HSL-Zuid are divided into:

The RAS1 test
RAS stands for Railsystemen (rail systems), the department of the HSL-Zuid project organization responsible for connecting the HSL-Zuid to existing rail infrastructure. In this, the first of a series of tests, a static test was carried out of the connection between the two systems. In this context, "static" means that no real trains were involved, but track occupation was simulated. Once these tests were complete, the two systems were separated at the cable distribution rack, to prevent them interfering with each other.

The RAS2 test
This second test was a "dynamic" test of the connection between the two systems. An Infraspeed test train was used to test the connection between the two systems. This included verifying that the transition between ERTMS and ATB was functioning correctly. At the time of this test, only one ERTMS-equipped train was available, and no train was available with an ERTMS Specific Transmission Module for ATB, so only the ERTMS part of the transition could be tested. Once these tests were complete, the two systems were separated at the cable distribution rack, to prevent them interfering with each other.

The RAS COA test
Once the RAS2 tests had been carried out successfully at all sites, the RAS COA tests were conducted. COA stands for Certificate of Availability – contractual approval by the HSL-Zuid project organization confirming correct operation of the HSL-Zuid infrastructure. The connection between the two systems was restored for the RAS COA. Operational tests demonstrated that all connections had indeed been made correctly. Following this test, the systems were left in the fully interconnected state.

The Transition test
This dynamic test could only take place once a train was available with ERTMS and a Specific Transmission Module for the ATB system.

A number of measuring runs took place at each site, under the responsibility of the HSL-Zuid organization, at different speeds and with different signal aspects, to demonstrate correct transition from ERTMS to ATB and vice versa (Fig. 5).

3.3 ProRail approvals procedure

ProRail operates a strict procedure for the use and approval of new rail products.

Before new interlocking systems, or parts of systems, can be brought into service, ProRail issues a Toestemming voor gebruik (permit for use, TvG) for the prototype. ProRail issues a TvG once the supplier or the customer of the new system has provided sufficient evidence to ProRail that the new systems functions safely and reliably.

When the new product or system is used, interaction with other, connected systems must not lead to unacceptable risks – safety-related or other-wise.

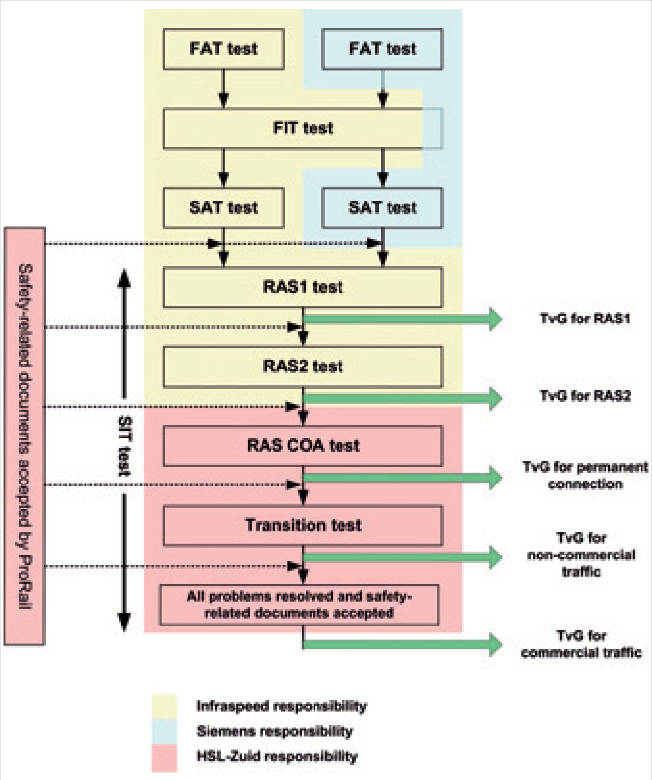

Figure 6: Test structure and TvGs

Routine use of a railway product is only permitted once ProRail has officially approved it. In deciding whether to grant approval, ProRail looks not only at safe operation but also at such aspects as documentation and the training of maintenance personnel. This ensures that the railway product meets functional, technical and RAMS requirements, and the requirements concerning life-cycle costs.

The following elements are of importance for the approval process:

- System documentation,
- Instructions,
- Safety cases,
- Hazard analyses,
- Test results.

3.4 Setting criteria for approval

A number of TvGs were drawn up, in close consultation between ProRail and the HSL-Zuid organization. The following was agreed (Fig. 6):

- Once the RAS1 tests have been carried out successfully and the safety-related documentation has been accepted, a TvG for RAS1 will be issued.
- Once the RAS2 tests have been carried out successfully and the safety-related documentation has been accepted, a TvG for RAS2 will be issued.
- Once the RAS-COA tests have been carried out successfully, a TvG for permanent connection will be issued.
- Once the transition tests have been carried out successfully, a TvG for non-commercial traffic will be issued.
- Once all problems from the previous tests have been resolved, and all safety-related documents are fully accepted, a TvG for commercial traffic will be issued.

4 Conclusions

The chosen test philosophy and approach allowed the HSL-Zuid organization to give a clear structure to the testing of complex interfaces between the HSL-Zuid interlocking system and that of the existing infrastructure. Recognizability for all parties and both understanding and acceptance at management level are key elements.

The test procedure chosen meant that the tests could be carried out in a controlled and efficient manner.

At a technical level, the major advantages of this approach are:

- traceable test results,
- Approval on the basis of demonstrable results.

Standardization reduced the number of interfaces to be tested, significantly accelerating development, implementation and approval.

LITERATURE

[1] Bimmermann, M.: Simis-W-Stellwerk für die niederländische Hochgeschwindigkeitsstrecke HSL-Zuid. SIGNAL+DRAHT, 2007, Heft 1+2

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ZUSAMMENFASSUNG

Effizientes Testen der komplexen Stellwerksschnittstellen HSL-Zuid/ProRail

Die HGV-Strecke HSL-Zuid ist 100 km lang und verläuft von Amsterdam über Rotterdam bis an die Grenze zu Belgien. Von dort führt sie weiter nach Antwerpen, Brüssel und Paris.
Der niederländische Teil dieser Strecke ist an fünf Stellen an das vorhandene Netz angeschlossen. An diesen Stellen sind die Stellwerke des bestehenden Netzes mit den Systemen auf der HSL-Zuid verbunden.
Die bestehende niederländische Infrastruktur wird durch ProRail betrieben. ProRail legt die Bedingungen fest, die von den Systemen erfüllt werden müssen, die mit den bereits vorhandenen verbunden werden sollen (einschließlich der Stellwerke).
Von der Projektorganisation der HSL-Zuid muss sichergestellt werden, dass diese Verbindungen nachweislich sicher und zuverlässig sind.
Dieser Artikel beschreibt das Testen der Verbindungen zwischen den Stellwerken auf der HSL-Zuid und dem bestehenden Netz. Er beschreibt die Struktur der Tests, deren Inhalte, die Verteilung der Verantwortung unter den Beteiligten und wie die nachzuweisende Sicherheit des Gesamtsystems gestaltet ist.