A SUCCESSFUL APPROACH TO SOLID STATE INTERLOCKING (SSI) MODERNISATION

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Solid State Interlocking is a British design successfully exported to the rail networks of a dozen countries. In this paper, we review the benefits of improved design, in particular the use of open-standard communication equipment and centralised architectures against maintenance costs and system availability. Through the case study of the Belgian Railway Infrastructure Objectives, we demonstrate how the SSI installed base can be upgraded intelligently and without impact to revenue operations. In particular, we show how re-using the existing interfacing equipment to track products – and benefiting from a backward compatibility with the SSI data configuration – translates into a cost-effective migration path for asset owners and rail operators.

1. THE BELGIAN RAILWAY INFRASTRUCTURE OBJECTIVES

The Belgian Railway Infrastructure Objectives (BRIO) project, part of the infrastructure owner (Infrabel) strategy's, aim at concentrating the existing 368 signalling centres into 31 main signalling centres. Completion of this migration is targeted before the end of 2015. Overall signalling system availability is to be improved.

2. SOLID STATE INTERLOCKING

Solid State Interlocking (SSI) is the first generation of electronic interlocking deployed on the Belgian and British railways. SSI were developed under a consortium composed by British Rail Research (BRR), GEC (today Alstom) and Westinghouse. The first installation took place in the U.K. in 1985.

A SSI system includes the following components:
- A main SSI cubicle, based on a two-out-of-three platform architecture
- Trackside Functional Modules; TFM are compact modules installed along the track to interface with track products such as signals, point machines, and track circuits
- Data Link Modules; DLMs are small communication modules used to interface the TFM to the main SSI cubicle
- A Technician Terminal, providing troubleshooting and maintenance information, as well as data logging capabilities

The SSI system is configured for each specific application using a dedicated SSI language and applying the Signalling Principles adopted by rail authorities. The SSI language is a high level language specifically developed for the configuration of signalling system. It is based on “if”, “then”, “else” instructions and features signalling variables which are associated to signalling objects such as signals, point machines, track sections and routes. Once the signalling principles are translated into the SSI language, moving to another language requires a heavy investment. Understandably, infrastructure owners currently using the SSI language are reluctant to move to another configuration language.

Figure 1: SSI system architecture
3. **SSI ON THE BELGIAN RAILWAYS**

In the 90’s, Alstom developed dedicated Trackside Functional Modules called Universal Module (UM), Point Module (PM), Signal Module (SM), Axle Counter Module (ACM), Optical Data Link Modules (ODLM), and Electrical Data Link Modules (EDLM) for the particular needs of the Belgian infrastructure owner.

Today more than 200 SSI cubicles, 10,000 TFMs, and 4,000 DLMs are deployed throughout the Belgian railways. Half the rail network is managed by SSI technology, the other half being mostly controlled by relay technology.

4. **SMARTLOCK 400–THE SUCCESSOR TO SSI**

Smartlock 400 is a new generation of electronic interlocking developed by Alstom.

4.1. **Compatibility with SSI**

One of the key drivers during the product development was to maintain a compatibility with the SSI through:
- trackside modules (TFM and DLM),
- SSI application language,
- management of axle counters,
- system dynamic behaviours, i.e. the sequence of interpretation of the instructions and system timings.

As a result, any SSI application can be migrated to Smartlock 400 technology by compiling the original SSI data files with the Smartlock 400 SIL4 compilation system.

4.2. **Higher Capacity**

Although Smartlock 400 is compatible with SSI, it offers a higher capacity, allowing for managing from a single central computer an area previously controlled by six fully-loaded Turbo SSI cubicles.

To achieve this higher capacity, the central computer runs virtual interlocking (VIXL), each of them emulating the process of a SSI cubicle.

In addition, full backward compatibility is ensured by replicating the data exchanges between SSI cubicles in the central computer.

4.3. **Other Technical Enhancements**

Besides improved capacity, other significant enhancements are implemented:
- the original SSI limitation of 16 messages between two SSI cubicles is removed and the data flows between the VIXLs are now defined for each specific application;
- the memory available for each VIXL is extended;
- a VIXL can have read/write access to the memory of another VIXL thus easing the data preparation;
- a single "extended VIXL" can be configured in the main computer to remove boundaries and simplify the data preparation of a very large installation;
- the language is now formally defined and the "SSI Specials" (macros used in the SSI language) are expanded in elementary instructions to improve flexibility.

4.4. **Compliance to Standards**

Another key driver of the Smartlock 400 development is the compliance to standards and norms. Smartlock 400 is compliant to the latest European railway standards such as CENELEC and Euro-Interlocking. In addition, it is ERTMS-ready and open-standard communication networks can be used between the various modules.
4.5. Traffic Control System Interface

Smartlock 400 is compatible with the existing SSI traffic control interfaces such as IECC, NX Panel, Train Descriptor, as well as the Euroradio+ safety protocol with a SIL4 implementation.

4.6. Support System

The Smartlock 400 interlocking comes with a Support System. This peripheral equipment allows for maintenance, Signalling Technician, installer and logging functions through an ergonomic Human Machine Interface (HMI).

Based on a client/server architecture, the Support System can be accessed remotely over open-standard communication systems and is a key element for setting-up a centralized maintenance strategy.

4.7. Offline tools

As part of the offline tools, the Configuration System and Simulation Environment help design, test and validate new applications. Existing SSI applications are also converted into Smartlock 400 technology using these tools.

Section 6.2 describes how the Configuration System and Simulation Environment are used to develop automatic tests. Automated tests reduce drastically the time required to design, test and validate a new application or the time required to validate an existing application imported into Smartlock 400 technology.

5. SMARTLOCK 400 INTRODUCTION

PROCESS ON THE BELGIAN NETWORK

5.1. First Pilot

Smartlock 400 was first deployed on the Waaslandhaven station, a freight station in the Infrabel railway network, located in Antwerp harbour. The Waaslandhaven station controls 22 points, 31 main signals—including 8 block signals—and 9 dwarf signals. One Smartlock 400 computer replaced two Turbo SSI cubicles.

The Waaslandhaven project was managed as a SSI replacement project: the station was first commissioned in SSI technology in March 2006, then switched to Smartlock 400 technology in October 2006. A safe switchover mechanism was designed to facilitate the switch between SSI and Smartlock 400. Site acceptance tests were conducted over the weekends.

Infrabel performed the data preparation required for the SSI technology. As required by the Infrabel data preparation process, all functional and safety tests were run on these data prior to the commissioning in SSI technology.

Then, the SSI data files were converted to Smartlock 400 technology using compilers. Results were fully tested by Infrabel staff. No change in the source code was required, demonstrating full backward compatibility.

Finally, prior to commissioning the Smartlock 400, all safety-related tests and a representative sample of functional tests were carried-out on the physical installation.

5.2. Safety Approval Strategy

An incremental approach to safety certification has been agreed between Infrabel, Alstom and Certifer, the Independent Safety Assessor. All safety activities were concentrated on the differences between the SSI and Smartlock 400 behaviour.

Following this strategy, Waaslandhaven was commissioned based on a Specific Application Safety Case (SASC). The Support System was removed from the scope of this SASC, after a demonstration showing that the Support System had no safety impact on the overall system.

Three other SASC were submitted in July 2007, May 2008, and October 2008 for the stations Floreffe, Jemelle, and Braine-Le-Comte.


6. ADDRESSING THE BELGIAN RAILWAY INFRASTRUCTURE OBJECTIVES

6.1. Concentration

The first objective is to concentrate the 368 existing signalling centres into 31 main signalling centres, thus reducing maintenance costs.

This objective is achieved through the processing capacity improvements of the central computers and the capability to connect to the existing TFMs via open-standard communication systems.
6.2. Rapid Deployment

In order to meet the planning set by the infrastructure owner, the time to migrate an existing SSI application to Smartlock 400 technology, and the time to design a new application, had to be optimised.

To this end, an efficient process for re-validation of SSI data converted to Smartlock 400 and for the test and validation of new applications has been developed.

This process is based on automatic testing and is split in two phases: encoding and testing. First, a database mapping the InfraBel signalling principles is to be filled-in using forms or a graphical tool. This is the encoding phase (figure 3). Then, the control tables of the specific application are generated from the database, and the generic test scripts specifically developed for the InfraBel signalling principles are launched against these control tables (figure 4).

Based on this process and using the Smartlock 400 tools, the conversion of an existing SSI application into Smartlock 400 is efficient: first the SSI data conversion is automatically performed without any change in the original SSI data. Then the validation of the Smartlock 400 data is partially performed through automatic testing. Some safety-related tests still need to be run manually, but we estimate that automated tests decrease the time to migrate an existing SSI application by 50%.

6.3. Improved Availability

Three factors directly contribute to an improved signalling system availability compared to the existing SSI system:

- The Mean Time Between Significant Failure of the Smartlock 400 computer is higher than that of the SSI;
- Standard communication systems allow for redundant communication path featuring higher diversity between the control centre and the central computers;
- Standard communication systems allow for the deployment of backup control centre in case of major incident in one of the in service control centres. This was previously not achievable due to point-to-point communication constraints.

The other contribution to improved availability is due to the centralisation of several SSI into one central computer: reducing the number of cubicles directly increases the overall system availability.

Arguably, because the controlled zone is larger, a failure of a central computer has a larger impact than that of a SSI. However, this is such a rare event that the benefit of higher overall availability more than compensates for this drawback.

7. CONCLUSION

Modern centralised interlocking architectures reduce maintenance costs and offer a higher availability.

Through the Brio case study we demonstrated that the migration can be completed through minimal labour and material expenditures and that the commissioning phase was sufficiently straightforward to not impact revenue operations.

The SSI installed base is large, especially in the U.K, Western Europe, Australia, and Hong Kong. We have no doubt that this attractive upgrade path will be of much interest to asset owners and rail operators.