Reducing Life Cycle Costs of main line interlockings

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To lower Life Cycle Costs (LCC) of main line interlockings, the Dutch Railway Infrastructure Manager ProRail follows the strategy of an open technology and market approach. A newly developed interlocking based on standard "Commercial Off The Shelf" (COTS) hardware is a full-fledged alternative for existing main line interlockings. The engineering, commissioning, modification and maintenance can be executed by at least two market participants. The PLC interlocking is the first Programmable Logic Controller (PLC) based main line interlocking meeting the requirements of the highest safety level (Safety Integrity Level 4). ProRail has commissioned its first PLC interlocking at the Santpoort Noord station and has reached type approval in December 2012.

1 Introduction

ProRail provides a safe, punctual and sustainable railway network and comfortable stations in cooperation with train operators, contractors and engineering offices in The Netherlands. ProRail stimulates innovations to optimize services for its customers. To achieve these objectives ProRail is using an 'Un-Solicited Proposal (USP)' procedure giving external companies the opportunity to submit commercially feasible, innovative proposals and develop these in cooperation.

Movares consultants and engineers submitted a USP to develop and execute an interlocking based on standard industrial PLCs which resulted in a development cooperation between Movares and ProRail for a PLC interlocking for main line applications. The first PLC interlocking has been commissioned at Santpoort Noord station leading to the type approval in December 2012. Being part of the replacement program for relay-based interlockings, a second PLC interlocking at Beverwijk station will be commissioned in 2014.

2 The OPEN concept

ProRail uses the OPEN concept as a strategy to reduce life cycle costs of interlockings. In this concept ProRail aims to have competition in every phase of the life cycle to avoid a vendor lock-in. The PLC interlocking is developed on the basis of the idea that at least two market participants should be able to deliver engineering, installation, commissioning and maintenance. This includes the possibility to change installations engineered and built by one party, in case of track layout modifications, by another one. ProRail's ownership of all documentation ensures that future development of the generic system functionality can be tendered in an open market.

This OPEN concept differs from the previous approach used for proprietary electronic interlockings in the Netherlands. These systems cause 'vendor lock-in' situations, leading to high costs when changing, modifying or even maintaining these applications.

ProRail does not intend to apply the OPEN concept to PLC interlockings only but aims at stimulating its use for proprietary and other new systems, especially for the upcoming replacement program of outdated relay-based interlockings and the future implementation of ERTMS. Most promising in the case of proprietary systems is that apart from the supplier another certified party will be able to engineer and modify an application.

The PLC Interlocking solution has brought about a unique competitive product, which in a recent tender already lowered the market price of proprietary systems.

Figure 1: Santpoort Noord equipment building

3 The context in the Netherlands

In contrast to most European infrastructure managers, ProRail has been employing standard interfaces for decades. In general the wayside equipment and train control systems can be combined with any type of interlocking. These standard interfaces are implemented in the PLC interlocking.

A PLC uses logic equations to calculate the output (i.e. the signal aspect). The Dutch signalling functionality is already available in design rules in a format of Boolean equations. These equations are transferred into the PLC language where great care has been taken to verify the signalling functionality. In this way modern technology goes together with existing and proven functionality minimizing both development time and risk.

The current design process, including quality management systems, which is used for the existing interlockings, can be used for the PLC interlocking. The signalling engineers are familiar with this process so as to greatly reduce design risks while ensuring that the system is truly open for any certified engineering office.

4 Project management

The basis of the project was an unsolicited proposal of Movares. This proposal contained the concept to implement the existing signalling rules and practices using COTS hardware to reduce LCC. Once the proposal was accepted, a contract was negotiated with the goal to agree on a way of cooperation in which both parties were equally responsible for the risks associated with the development. Furthermore, the strategic goals of both ProRail and Movares were incorporated. The contract contained all elements for a successful cooperation, i.e. the objectives to be reached, the products to develop, the role of ProRail and Movares in reaching these goals, and the documents to be produced. Finally the dates and goals of Go/No Go decisions (i.e. partial milestones) were defined.

One of the key success factors of the project was to appoint one project manager responsible for choosing the route leading to the project goal, taking into account the incentives and goals of both ProRail and Movares. In this way decisions to suit the project goal without too many politics could be made. The threat of scope creep was avoided and the development time was minimized. The dedicated Quality Management Systems of the project was a combination of both QMS's of ProRail and Movares to keep it as simple as possible for the project staff. Final responsibility was in the hands of the project manager to reach a high pace.

Given the strategies and incentives of both partners, a common goal was defined. This goal was to deliver a PLC interlocking compatible with the already existing interlockings, to decrease LCC and to commission it on a real main line station. The match of the strategies with the results in terms of time, cost and quality were evaluated after each project stage by the steering committee with representatives of both ProRail and Movares. Had there been any sign indicating a negative business case or any other unmet target, the project would have been stopped. This Go/No Go decision to continue or to terminate the project was to be approved by the board of directors of ProRail. In this way putting money in a non-feasible project was prevented.

The project used a staged approach. The business case was the first stage with ProRail and Movares calculating the benefit of the development. As it proved to be positive the second stage, proof of concept, commenced.

The objective of the proof of concept stage was to prove the technical feasibility in a mere ten months. Only uncertain parts of the technology and the its application were investigated. The business case was adjusted with this new information and proved to remain positive. The board of directors gave a Go for piloting the technology on Santpoort Noord station (Figure 1).

The pilot stage was split up into two sub-stages. The preparation stage, during which the development of the PLC interlocking was completed, and the realisation stage during which it was installed for verification and validation on a real life railway. The split into two substages was chosen because most of the cost would be incurred during the realisation stage. This would have allowed to end the project in time and to avoid unnecessary expenses in case the development was not completed or problems were encountered. Both stages where completed successfully resulting in the commissioning of the system.

5 Development

The PLC interlocking has been developed according to the CENELEC standards EN50126, EN50128 and EN50129. In the generic development all products were developed to create a specific application. The generic products consist of engineering and maintenance documents, standard building blocks (functional block diagrams), RAMS analysis etc., all incorporated in the Generic Application Safety Case (GASC).

Based on the engineering manuals, a specific application and a Specific Application Safety Case (SASC) has been set up for Santpoort Noord, a station on the main line as depicted in figure 2. This rather small station nevertheless represents all the typical Dutch national functionality. With this specific application the generic products and GASC was verified. The SASC has been minimized by maximizing the contents of the GASC. Fur future applications only the specific setup has to be verified. The SASC can cover custom-built specials for a specific location.

6 System architecture

The architecture of the interlocking hardware is depicted in figure 3. The core of the system consists of standard industrial SIL 4 PLC microprocessors and a

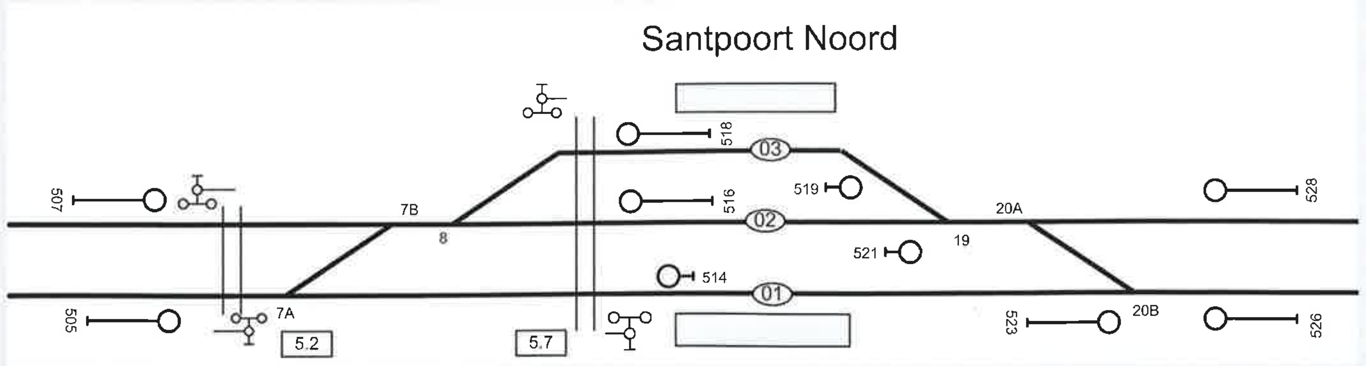

Figure 2: Track layout of Santpoort Noord

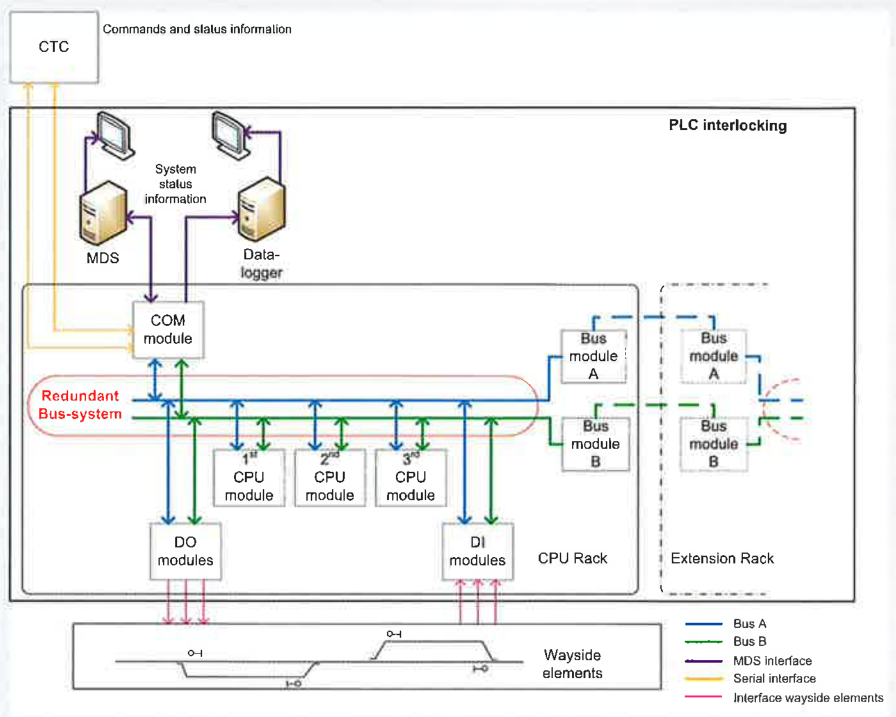

Figure 3: System architecture

(railway specific) SIL 4 application (logic). The application has a generic part consisting of the signalling rules and a specific part containing the local layout; this defines the system as an interlocking. Connected to the PLC are the maintenance and diagnostics system and the data logger via standard Ethernet and open protocols (OPC). The latter will be used in case of incidents to 'rewind' the status of the PLC interlocking. The wayside equipment (such as signals, points, etc. interfaces via COTS digital I/O modules with the CPU. The standard ProRail communication interface of the Centralized Traffic Control (CTC) is programmed in a dedicated software module. This module has the same function as the hardware converter box used in relay-based interlockings to communicate (via the Internet Protocol (standard IP)) with the CTC, but this module is implemented in the software.

6.1 Hardware

In developing an open interlocking only commercial off-the-shelf (COTS) components are applied. None of the standard hardware components are specially designed or modified for their application in the PLC interlocking. As the core of the (safe) PLC interlocking, a safety PLC has been used. The selected CPU modules are internally a two channel SIL 4 system. Additional modules have been inserted to improve availability. Current system availability requirements state 99.9998 % which can be translated as a system downtime of less than two hours every 100 years. The COTS products support various communication standards such as Ethernet and Profibus/Profisafe.

As the hardware modules are independent of the application (the logic), redundant modules can be added (or left out for branch lines) without modification to the (railway) logic in the PLC.

In figure 4 an image of the installation at Santpoort Noord station is shown. In the rightmost rack, the central PLC is placed with CPU's, communication and some I/O. Via a redundant fibre optic connection a remote installation is linked to distant wayside equipment.

On the left the screens of the data logger and MDS systems can be seen. These systems run on industrial computers to cope with the environmental conditions in the equipment building like extended temperature ranges and vibrations. This supersedes the need for air conditioning.

6.2 Logic

Standard logic like AND and OR gates is available in the standard development tools incorporated in the Generic Product Safety Case (GPSC) of the PLC. For the generic signalling functions, for example the points function, standardized building blocks were designed by the project. These building blocks are completely tested once and included in the GASC identified by a unique code (CRC). To create a specific application, the verified building blocks are combined using the defined logic in the engineering manual. This improves the verification and validation process of a specific application as a matter of principle.

6.3 Interfaces

In the design of the interface to the trackside elements, a modular approach has been used. The standardized ProRail Interface Requirement Specifications (IRS) have been implemented in modules (hardware and logic) and can be reused for all wayside equipment.

7 Verification and validation

The verification of the PLC interlocking consisted of several steps. Starting with text and code reviews, to laboratory module and integration tests. A second stage was to test these modules and engineering manuals to design a specific installation which was implemented and tested on the pilot location.

Procedures were tested in addition to the technical tests with a main focus on tests to assure that maintenance staff could deal with all system failures. Limited tests only were executed with train dispatchers as for them the interlocking concept implied no changes. The test setup of the pilot installation is briefly described below.

A new technical building was specifically erected for the PLC interlocking project. A switchover construction has been built to switch from the current relay-based interlocking to the PLC interlocking for testing purposes and as a fall back during the qualification period. The wayside elements and outdoor cabling were unchanged during the pilot.

Testing of this installation has been completed in July 2012 including the assessments by the Independent Safety Assessor (ISA), ProRail (validation and process certification) and the National Safety Authority. Thereafter, the existing relay-based interlocking has been switched over to the new PLC interlocking to start a real life three month qualification period. During this period the system and the maintenance have been monitored closely to validate the assumption that the maintenance efforts (and therefore the costs) are lower than in a relay-based interlocking (and much lower than in proprietary electronic interlockings).

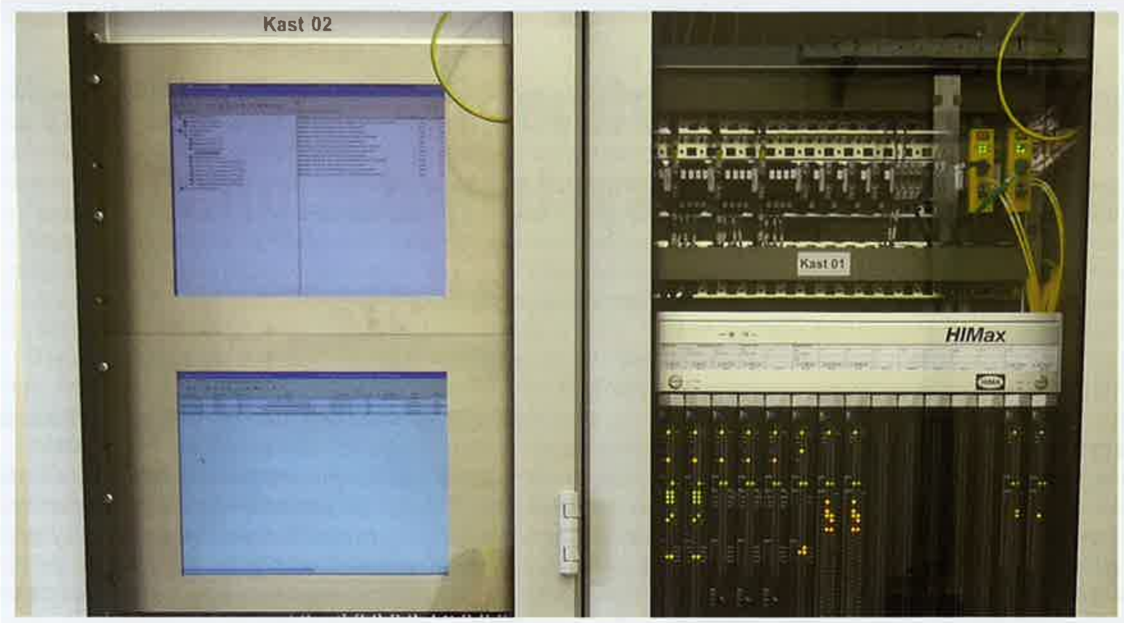

Figure 4: PLC interlocking installed on site

No issues have occurred during the qualification period in the system or in the maintenance organization. These results have been used to finalize the documentation and to apply for type approval allowing the system to be engineered, built and used on all main lines in the Netherlands, which was granted in December 2012.

8 Future prospects

The approved PLC interlocking is open for engineering, building, changing and maintenance. This prepares ProRail for a rapidly changing signalling market. European legislation, regulations and standards, separation between infrastructure and train operation have had their effect in the signalling domain. The ever increasing demands for interoperability, safety, punctuality, cost reduction, accessibility and transport capacity can be added to the more common European or worldwide changes.

To deal with these changes and demands ProRail needed a strategy, in which new opportunities were created without wasting resources. The signalling department of ProRail implemented lessons learned from earlier development projects in this one. They were adopted in the organisation, working processes and methods as well as staffing. Together with the OPEN concept it forms a solid basis for the future approach for signalling developments.

From a technological point of view the newly applied PLC interlocking combines long-standing signalling rules with modern systems, tooling and standards. This has a positive effect on a new generation of signalling engineers who are enabled to develop the concept further. The new interlocking is a solid base for further optimization of the supply chain from design to decommissioning. By simplifying processes, further standardization, automation and the use of formal methods, the labour- intensive and error-prone activities must be further reduced.

The open PLC interlocking fits in an environment providing robust and safe systems, in a time frame with scarce resources and with the possibility for a productivity growth based on 'more for less'.

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LITERATURE

[1] van der Werff, M.; Scholten, H.; Godziejewski, B.: Migration Strategy for Signalling Systems in The Netherlands, SIGNAL+DRAHT, 10/2002
[2] van der Werff, M.; Mistral : A wind of change blowing through Dutch railway signalling, IRSE Technical Meeting, 14 December 2005

ZUSAMMENFASSUNG

Reduzierung der Lebenszykluskosten von Stellwerken für Hauptstrecken

Die Strategie des niederländischen Eisenbahninfrastrukturunternehmens ProRail für die Reduktion der Lebenszykluskosten der Stellwerke auf den Hauptstrecken folgt dem Grundsatz eines offenen Technologie- und Marktansatzes. Ein neu entwickeltes Stellwerk, dessen Hardware auf dem Standard „Commercial Off The Shelf" (COTS) basiert, ist eine vollwertige Alternative für bestehende Stellwerke auf den Hauptstrecken. Engineering, Inbetriebnahme, Anpassung und Wartung können durch mindestens zwei Marktteilnehmer ausgeführt werden. Das SPS-Stellwerk ist das erste auf Speicherprogrammierbaren Steuerungen (SPS) basierende Stellwerk für Hauptstrecken, welches den Anforderungen der höchsten Sicherheitsstufe (Safety Integrity Level 4) entspricht. ProRail hat sein erstes SPS-Stellwerk im Bahnhof Santpoort Noord in Betrieb genommen, und die Typenzulassung im Dezember 2012 erhalten.