Application of Remote Condition Monitoring in Different Rolling Stock Life Cycle Phases

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Abstract

NedTrain is the Netherlands Railway’s subsidiary responsible for rolling stock maintenance. The life cycle is 30-40 years where the asset condition is maintained to meet its performance requirements and is enhanced to meet the customer expectations through its life. The life cycle costs are roughly 1/3 for the new build investment and 2/3 for subsequent maintenance and further investments. Currently the rolling stock is maintained in fixed maintenance intervals of 3 months with in between service-checks and repairs. A more dynamic and pro-active maintenance approach is required due to the increased complexity of electronics and software, planning of maintenance in short intervals when less rolling stock is required for service and increased customer expectations. NedTrain started an innovation programme that includes remote condition monitoring of the asset condition of individual trains and use of the information to prepare maintenance activities before the train comes in for maintenance. This paper describes the work in progress in three case studies for existing rolling stock, mid-life refurbishment and new build rolling stock.

Keywords: remote condition monitoring, life cycle, intelligent maintenance;

1. Introduction

NedTrain is the Netherlands Railway’s subsidiary responsible for rolling stock maintenance. 3,000 coaches for domestic services are maintained in three depots, 35 service locations and two overhaul shops. The life cycle is 30-40 years where the asset condition is maintained to meet its performance requirements and is enhanced to meet the customer expectations through its life. The life cycle costs are roughly 1/3 for the new build investment and 2/3 for subsequent maintenance and further investments. The use of remote condition monitoring has increased in recent years to reduce life cycle cost (investment and maintenance) and enhance operational performance.

This paper focuses on the use of remote condition monitoring in different life cycle phases by addressing three case studies.

2. Remote Condition Monitoring Roadmap

Currently NedTrain maintains rolling stock in fixed maintenance intervals of three months with in between service-checks and repairs. A more dynamic and pro-active maintenance approach is required due to:

- Increasing functional requirements lead to increased complexity and a strong increase in the use of electronics and software, resulting in a less predictable wear and failure pattern;
- Rolling stock investment and maintenance constitutes roughly a third of the cost to operate the railway, a relatively short morning and evening peak period drives the number of coaches required, short maintenance
intervals in between peaks can reduce the number of spare coaches required for maintenance;

- Increased customer expectations require a constant quality of service also for secondary systems like toilets, travel information, air conditioning etc. As a result the Mean Time To Repair needs to be shorter.

NedTrain started a maintenance innovation programme focussing on four interlinked projects:

- Scheduling maintenance in shorter and more frequent intervals between peaks.

- Up-grading four service locations for urgent repairs at strategic railway junctions in the network, where 80/96% of trains passes by one of the sites each 24/48 hours without the need to reschedule the train services.

- Introducing Risk Based Maintenance in the development of the maintenance schedules to have more transparent trade offs between performance, risk and costs and to be able to change the trade offs over time when required.

- Remote condition monitoring of the asset condition of individual trains and use of the information to prepare maintenance activities before the train comes in for maintenance.

This paper describes the work in progress for the latter project. The approach taken differentiates between the life cycle phases and this is explained in the three case studies below. For all ages a common system architecture is used.

3. Common system architecture

The system architecture consists of four main elements (figure 1). For each element life expectancy and the choice for standardization is a key consideration.

![Fig.1 Block diagram of the architecture with key considerations for life expectancy and standardization](image)

The first element is the on train part, this consists of the sensors and local intelligence for validation, interpretation and diagnostics. This is often a design provided by the Original Equipment Manufacturers (OEMs) and may be integrated to train level by a system integrator in a Train Management System (TMS). Standardization for the on train part is driven by the system integrator and the underlying system suppliers as NS prefers to procure off the shelf rolling stock and technology where possible. The life cycle tends to be long with many sensors and systems that can last 30–40 years although modification and refurbishments do occur. The on train architecture therefore needs to allow for straightforward upgrades or extensions during the life of the system.

The second element is the mobile communications. This technology has rapidly developed in recent years to 3G and 4G is expected. The economic life of the mobile communications is much shorter than the life of the rolling stock. The architecture therefore works with a module that can be replaced when better mobile communications become available with minimum impact to the other elements. Standardization uses IP technology with XML messages and mobile communication technology is standardized by the mobile communications industry.

The third element is the database. This in turn needs to have a long life expectancy as data need to be stored ideally through the life of the rolling stock or even longer for trend analyses. Standard SQL technology is used with a generic database model. Data from different rolling stock manufacturers can therefore be stored in one database and becomes independent of the OEMs in this stage. The database is also fed with configuration data. This can be either configuration of the trainset it self (e.g. compressor serial number or software version of a certain system module) or configuration data linked to the condition monitoring intelligence (e.g. diagnostics algorithms, technician advice for certain failure modes etc.).

The modular architecture allows for the fourth element, the applications, to access the generic database. The user therefore can work with one user interface also for different types of rolling stock. Where required, different applications for different user groups can be bought or developed to access the generic database. For the applications a much shorter economic life is expected, typically 5–7 years.

In this architecture the on train element can easily be extended in the future with an on track element for cross monitoring of infrastructure and rolling stock on the wheel-rail, pantograph – overhead line interfaces as well as other data to enrich the database.

4. Case Study: Existing Rolling Stock

Existing VIRM type double deck intercity trains (figure 2) are equipped from build with an on-board Train Management System for 15 systems with 3,000 – 4,000 sensors depending on train length and build series. To minimise the investments for remote condition monitoring the existing TMS is used as well as existing mobile communications. The technical challenge is therefore in interfacing with systems from different suppliers and technology generations.
For 54 trains a train to shore connection is added to download existing on-board failure reports, operational events (doors opening/closing, coupling), counters (compressor operating hours etc.) and a number of sensor measurements from the TMS. The data are enriched with GPS location data and time. The information is stored in the generic SQL database for use by different applications. The database stores more information than the TMS as sensor measurements are only instantly available in the TMS and also failure reports can be overwritten due to memory limitations.

The train to shore connection makes use of an existing On-Board Information System (OBIS). OBIS consists of an ethernet network throughout the trainset, a GPS receiver which will be used to add location information to the failure reports a 3G mobile connection to the shore where the messages are received in the Network Operating Centre (NOC) which relays the messages to the database. In order to use the platform for remote condition monitoring a processor board is added and a Train Communication Handler (TCH). The TCH is the software to interrogate the TMS for the required information, enrich data with for example GPS and address the XML messages to the generic database with the required security level.

The data are used for different user groups and applications. The first application is an operational dashboard for the NedTrain control room. This presents the current status of the trains. Business rules are used to filter important events. Setting the right business rules was essential to prevent an information overload of alerts where no immediate action is required. Priority 1 events are highlighted and require immediate attention by control room staff. For all priority 1 events the dashboard provides advice on handling of the failure. The handling combines urgency (immediate and of route etc.) and locations where the failure can be treated (with respect to facilities, tooling, staff competence and spare parts) and repair advice (short repair advice or reference to documentation like fault trees, most likely required spare parts and tools).

The maintenance depot uses the data to prepare for both the preventive and corrective maintenance. Each month the trainset comes in for maintenance between the peaks. Prior to the train coming to the depot the failure history is analysed and compared to the fleet average. Based on the analysis work orders are prepared so that the most likely required spare parts can be ordered and the staffing can be planned. In case the repair time is not compatible for the maintenance slot the repair is re-planned to guarantee the timely delivery of the rolling stock for the peak service.

The data are also presented in an analytical dashboard for maintenance and reliability engineers. This allows for trend analysis over the fleet and allows for data driven performance improvements and reviewing maintenance schedules based on performance data. Currently the maintenance schedule is still largely a preventive maintenance schedule based on the fleets performance. The future ambition is to make the maintenance tasks dependant on actual performance and condition of individual trainsets.

Finally data are also provided to the Transport Operating Company NS Reizigers for various analysis like energy usage, passenger loading and wheel slide.

5. Case Study: Mid-Life Refurbishment

50 DDZ type double deck intercity trains (figure 3) are currently undergoing a mid-life refurbishment.

During the refurbishment 4 new systems are added: a static converter to convert 1500 V to 110 V and 230 V, a Heating Ventilation and Air-conditioning system, a vacuum toilet system and a bioreactor system. The mid-life investment in the rolling stock is an opportunity to implement remote condition monitoring for a limited investment. The OEM diagnostic modules for each system are used to extract the required data. Due to the lack of a Train Management System, data from the four separated systems needs to be extracted by the on-board TCH software. In essence this is the same software as for VIRM. The key difference is that the module needs to communicate with four separate systems and integrate the data to trainset level. This includes adding trainset number, the location of the various systems within the trainset (for example the two toilet modules) and synchronised time. The same OBIS mobile communication unit is used. In this case an extra processor board was added in the Main Equipment Room (MER) and extra switches in the Secondary Equipment Rooms (SER) to connect to the different modules in the train rather then one interface with a TMS. A standard protocol had to be specified for the TCH software to communicate with the different modules of the different suppliers.

The technical challenge in the mid-life case is the integration of a large number of suppliers. Both on-board as well as the connectivity path from train to applications. Figure 4 presents the different suppliers involved.

The data are used for the reliability growth period after the midlife refurbishment and to verify the reliability and availability performance of the new systems.
6. Case Study: Procurement of New Build Rolling Stock

For the procurement of new stopping services trains a different approach is taken with design process, functional and performance requirements of the remote condition monitoring system. At each stage of the design process future maintenance and remote condition monitoring to support the maintenance need to be considered. FMECA drives the maintenance schedules, diagnostics and remote condition monitoring design.

Vachtsevanos [1] provides a structured design process for diagnostics and remote condition monitoring. It starts with determining the possible failure modes and the subsequent criticality. FMECAs are already required for the new train design and can also be used to determine which features need to be determined and the sensors to measure these. The data collection includes conversion to standard units and calibration. The data can be analysed and algorithms developed, implemented and verified.

The new trains specifications allow NedTrain as maintainer to evaluate the design process in different stages in the procurement and development of the new trains. From high level design (focus on functions) to detailed design (focus on engineering), testing (validating diagnostic truth) and reliability growth period for the diagnostics. In each stage the FMECAs will be leading. Specific sensors are not specified, however the life cycle costs and required performance levels are specified where remote condition monitoring can be used to optimise these.

Functional requirements specify the different types of data include duty cycle counters, diagnostic reports (with repair advise), events, analogue/digital measurements and metadata information: time, GPS location, relevant measurements of a fault report. Fault diagnoses needs to be possible on three levels: system level, trainset level and for coupled trainsets. The system integrator therefore needs to integrate the diagnostics as well. For example is the on-board voltage is low, many systems may report errors. These need to be suppressed except for the fault report of the low voltage system, as this is the root cause. Further requirements include the use of open interface, configurability from shore (e.g. which measurement that need to be logged) and where possible self identified configuration. This means that a status or fault report from a component comes with a unique mac number of the component. If the fault repeats it can then be determined if it is the same unique component or if it has been changed since the previous fault report.

Performance requirements include bandwidth, quality of service to prioritise urgent messages, and a near real time requirement of 5s from fault detection to control room screen.

In summary the application of remote condition monitoring requires a different approach in the different life cycle phases. This can be supported by a generic modular architecture. The on train module can be different for different rolling stock series and the level of integration will depend on the life cycle phase. The database and applications can be standardised for the user groups independent of rolling stock series. The mobile communications module can in this architecture be replaced when a new generation of mobile communication technology becomes available with limited impact to the other modules.

References