SUMMARY

By 2013 the Auckland Metropolitan Rail Network (AMRN) will be electrified with a 25kV AC electric traction system. One major hurdle to achieving this goal has been the signalling system in Auckland which was predominately in excess of 30 years old and not immunised against the effects of electric traction. To remedy this, and the other operational deficiencies of the signalling, a major project to completely re-signal the AMRN was initiated.

An important requirement of Auckland’s new signalling system is that it provides some form of Automatic Train Protection (ATP) to mitigate the growing risk of a signal being passed at stop resulting in a dangerous situation. This requirement was born from an extensive risk analysis study that was undertaken by KiwiRail Network (formerly ONTRACK) and included involvement of all Operators on the AMRN.

The ATP system selected for the AMRN is the European Train Control System (ETCS) Level 1. With this decision, and the allocation of Country ID 600 (NID_C:600) by the European Railway Agency (ERA), New Zealand took its first tentative steps towards implementing what is becoming the ATP system of choice around the globe.

This paper gives an overview of how we determined the need for ATP, how we decided that ETCS Level 1 was the right technology for the AMRN, and how we have chosen to implement it. The paper will briefly describe New Zealand’s ETCS application principles and provide some insight into how we developed them. The paper will also discuss some of the problems encountered and lessons learned thus far. Finally, the paper will provide an update on how the AMRN resignalling project and ETCS implementation is progressing.

INTRODUCTION

New Zealand Railways Corporation (NZRC) is a statutory corporation and State Owned Enterprise established under the New Zealand Railways Corporation Act 1981. KiwiRail Network, an operating division of NZRC, owns and is responsible for operating, maintaining and renewing the New Zealand below railhead network. KiwiRail Network also manages and develops the Crown’s land holdings held for rail purposes.

KiwiRail is currently undertaking a number of projects dedicated to Developing Auckland’s Rail Transport (DART). The resignalling project is part of a larger group of projects which includes the implementation of a 25kV AC traction system and major civil construction works. All of these projects support the increased capability for both passenger and freight traffic in Auckland.

The AMRN carries freight, increasing numbers of commuter passenger services, a small number of long distance passenger services, and some steam and diesel excursion trains. Rail is the fastest growing mode of public transport in Auckland, showing a 97% increase during the five years to 2009 when 7.7 million trips were taken on Auckland’s trains [1]. In addition, it is expected that rail freight traffic levels will also increase.

To cater for increasing commuter rail passenger patronage, a programme of rail service improvements and infrastructure upgrading (including electrification) is being undertaken to increase capacity and improve service levels. The procurement of a signalling and train control solution is an important step in the infrastructure upgrade programme to meet the needs of the network in the future.

With electrification of the AMRN, the compatibility of the signalling and train control systems with the proposed 25kV 50Hz AC electrification is a key consideration.

Electrification of the AMRN offers a unique opportunity to build new signalling and control systems concurrent with the provision of new rolling stock.
ELECTRIFICATION SCOPE

Electrification of the rail network is a vital and major step towards building a modern, sustainable passenger transport system for Auckland. It will mean quieter and more reliable train services, allowing rail to take a more prominent role in the region’s transport mix.

The Government gave the green light for KiwiRail (formerly ONTRACK) to build the infrastructure required for electrification of the Auckland metropolitan rail network in the 2007 Budget - with a deadline of 2013 and $500 million to get the job done.

Electrification will extend in from Papakura in the south to Swanson to the west, and include the Onehunga branch line and future Manukau rail link. Trains will be powered from an overhead 25KV AC traction system.

SIGNALLING SCOPE

A review of the signalling infrastructure in Auckland indicated that almost all the track circuits are simple AC/DC circuits that are not AC immune. Most of the point machines are also not immunised. Signalling infrastructure changes associated with AC immunisation to support electrification is the primary driver for complete replacement of ageing and life expired signalling and train control equipment. Additionally the replacement will incorporate capacity and safety improvement works.

The current signalling in Auckland is struggling to meet reliability targets. Approximately 50% of the interlockings utilise technology older than Q style relays (BRB 930 series) and are considered obsolete. For example, the electro-mechanical interlockings using shelf mounted relays at Otahuhu, Wiri, and Papakura are now difficult to modify and maintain, and will not be able to meet the new operational requirements of the network. The telemetry systems used for the remote control of some interlockings are also considered life expired.

It was quickly determined that the most sensible and cost effective solution was to completely replace the existing signalling on most of the AMRN.

The primary requirement of the new signalling system is to enable the required train service frequency. However significant emphasis is also placed on the reliability and maintainability of the resulting signalling and telecommunications systems. Additionally installation and changeover strategies which minimise disruption to rail operations are also important considerations.

PROCUREMENT PROCESS

KiwiRail decided to go to the market seeking a complete solution to its signalling and train control requirements. To do this, a two step procurement process was undertaken with an Expression of Interest (EOI) and a Request for Tender (RFT) phase. The timeline for the procurement process is outlined in Figure 1.

KiwiRail had undertaken significant research to identify the best technology approach before embarking on the procurement process but sought the industry’s input into the decision process. One stated purpose of the EOI was to “assist KiwiRail to define the type or types of signalling technology which could be used for the Auckland Metropolitan Rail Network”. The other purpose was to prequalify a short list of suitably qualified organisations selected by KiwiRail to receive the RFT. Eight EOIs were received by KiwiRail and the four highest ranking respondents were selected to receive the RFT.

The RFT specification was largely performance and outcome based with few architectural requirements. This was done to allow the
tenderers to respond with a solution that was optimised for their products and technology.

In February 2009, Invensys Rail (formerly Westinghouse Rail Systems Australia) were awarded an approximately $90 million design-build contract for the AMRN re-signalling works.

The new signalling will be implemented in five main phases as shown in Figure 2. Phase 1 which includes the inner City area and the primary Rugby World Cup train operations is due for completion in January 2011. The remaining phases will be commissioned over the following year.

Figure 2: AMRN Re-Signalling Phases

TRAIN PROTECTION

1. To ATP or not to ATP

Currently there is no signal overrun protection provided on the Auckland network – in fact many areas are not even equipped with signal overlaps (a section of track beyond a signal that must be unoccupied before the preceding signal will clear providing a safety margin should the signal be overrun). However, recent advances in technology and operator and public expectations regarding train protection aligned with the procurement of new signalling systems and rolling stock necessitated a review of train protection. Interestingly, from an expectation perspective, the question is not “why should train protection be installed” but “why wouldn’t train protection be installed”.

To facilitate this, KiwiRail commissioned a study on the risk of Signals Passed at Danger (SPADs) in the Auckland metropolitan area. This study included involvement of all Operators on the AMRN and covered the following components:

a. An analysis of current SPADA (SPAD Category A - signal was never cleared for the train movement) levels on the network;

b. An analysis of the likely change in SPADA frequency as the volume of traffic increased and the network became more densely signalled;

c. A comparison of SPADA levels against comparable railways (all of who had some form of train protection installed);

d. An analysis of contributors to SPADs and associated mitigating actions.

The risk study concluded that some form of train protection should be installed on the resignalled AMRN. The study recommended that either intermittent or continuous Automatic Train Protection (ATP) would be the most appropriate form of train protection.

2. Choosing the right ATP flavour

In response to our questions regarding train protection, five out of the eight EOIs recommended either ETCS Level 1 or a simplified derivative of ETCS Level 1. Two recommended TPWS and one recommended full Automatic Train Operation (ATO). Both TPWS respondents stated that they could also supply ETCS Level 1 solutions. The budgetary estimates did not appear to indicate a significant difference in cost between TPWS and ETCS Level 1 for infrastructure and new rolling stock fit-out. Based on this, the EOI evaluation committee recommended that the RFT should specify an ETCS based wayside solution with some flexibility in what is provided in regards to onboard equipment.

ETCS provides several advantages to both KiwiRail and rail operators over other train protection systems primarily due to the multi-
vendor support of the standard. Currently six major signalling system suppliers sell ETCS Level 1 systems. This enables the on-board and trackside equipment to be procured from a competitive market without being constrained to sole-source from the same contractor. An ETCS Level 1 system also has the potential to be upgraded in the future to higher levels (such as Level 2) to improve the headway.

It was considered very important that the procurement decision being made for the Auckland electrification project did not negatively impact KiwiRail’s ability to competitively procure signalling extensions or additions to the AMRN in the future. It was also noted that the procurement decision would likely set the New Zealand standard for train protection and that the technology needed to have multi-vendor support, a defined upgrade path, and longevity of support.

3. Choosing what to fit-out

It is proposed that all new Electric Multiple Units (EMUs) will be fitted with onboard ATP equipment but a risk based approach will be used to determine the extent of the existing fleet fit-out including the freight locomotives, Diesel Multiple Units (DMUs), and passenger carriage driving cabs.

The risk model of the AMRP developed earlier for the SPAD risk study was updated and expanded upon to allow KiwiRail to make informed decisions regarding the business case justification for fitting rollingstock with ATP. The risk model allows different operating scenarios and timetables to be assessed against the current baseline. The model will be used in conjunction with fleet planning decisions to determine the best approach.

The implementation of ATP should be seen as a transitional project with full ATP being implemented on the majority of rolling stock over a long period of time. It was acknowledged by the EOI respondents and is widely acknowledged by the industry that fitting out old rolling stock with ETCS equipment is far more expensive than a factory fit out and is often not justified if the rolling stock is approaching end of life. There is also a significant design cost for each class of locomotive to be fitted and minimising the number of different locomotive classes is essential. Ultimately an ATP implementation strategy will be developed by KiwiRail in conjunction with the operators for the AMRN.

IMPLEMENTING ETCS LEVEL 1

ETCS consists of multiple components. Onboard the train there is the Driver Machine Interface (DMI), Euro Vital Computer (EVC), Speed/Distance sensors such as tachometers and doppler radar devices, an Antenna and interface hardware for controlling the train brakes and various other onboard systems. The interface with the vehicle braking systems includes both Service Braking (SB) and Emergency Braking (EB). At the trackside there are the track mounted transponders (Balise or Eurobalise) and the Lineside Electronic Unit (LEU). Figure 3 shows the various components at a high level.

Figure 3: ETCS Level 1 Components

1. Trackside Fitment

The trackside ATP infrastructure for Auckland will be provided by the installation of the Invensys Rail FUTUR 1300 ETCS Level 1 system. The system consists of the two main pieces of hardware mentioned earlier, the Balise and LEU.

The Balise is a non-powered transponder device that is fixed on the sleepers between the rails. A train’s ETCS antenna provides a radio signal which the Balise then returns, modulated with an encoded message. There are two types of Balise: fixed and controlled. Fixed balises are used for static data which does not change based on the signal aspects such as line speed and gradient. The controlled Balise is connected via a cable to the LEU in the nearest location. The controlled balise is re-programmed in real time by the LEU to reflect the state of the signalling system.

Figure 4: Controlled Balise
The LEU is the interface equipment between the Computer Base Interlocking (CBI) and the Balise used by ETCS level 1. The LEUs used for the AMRN re-signalling have the ability to drive 4 separate Balise groups (a Balise group is a Fixed and Controlled Balise pair). The LEUs communicate with the CBI via a vital communications link utilising the railway signalling Ethernet based WNC protocol. This link allows the LEU access to information from a very wide area, which means it can give the train additional information beyond that which is available from the accompanying signal’s aspect alone. This feature is used on the AMRN to provide the driver with longer movement authorities than the standard aspect signalling provides. This in theory will allow the line speeds to be increased in the future for ETCS fitted trains assuming the track geometry was satisfactory without the need to alter the signal spacing to maintain braking distance.

The LEU houses three cards. The three cards are: Power Supply Unit (PSU), Logic Module (LM) which decides which telegram to programme each Balise with, and Balise Output Card (BOC) which can drive up to four controlled Balise.

Figure 5: Two Lineside Electronic Units (LEU) installed in a chassis providing a total of 8 Balise outputs

Unfortunately the delivery of the new electric trains will not occur until well after the wayside portion of the AMRP resignalling is complete. In the interim to facilitate testing, commissioning, validation and training, some existing train cabs will be fitted. Initially two SD units will be fitted. SD units are the existing driving cab carriages used for push-pull operations. The first test runs will take place on the Onehunga branch line later this year.

Figure 6: The onboard ETCS equipment including the EVC and interface equipment

APPLICATION PRINCIPLES

In the earliest stages of the AMRN re-signalling project, extensive effort was focused on developing and documenting both the Signalling and ETCS Principles for the AMRN. Both documents were developed over several months involving multiple stakeholder workshops and review cycles and they are also constantly reviewed and updated as the project progresses. The Signalling Principles document has been revised 10 times in the last year (and is currently being revised again) and the ETCS document 8 times. This has been driven by many inputs including design constraints, rules development, and the learning process that both KiwiRail and Invensys Rail are going through.

The KiwiRail ETCS Principles determine how ETCS is implemented in New Zealand. It documents the array of variables that we have determined are most appropriate for the application here. Some of the variables are

2. Onboard Fitment

The contract with Invensys Rail provides for the ETCS fit-out of the first 35 new Electric Multiple Units and six existing locomotives. The system that will be fitted is the Invensys Rail FUTUR 3000 ETCS Level 1 system. The on-board equipment can be upgraded to ETCS Level 2 in the future with the addition of digital radio equipment in the event that the wayside was upgraded or extensions were fitted with ETCS Level 2.
straightforward such as the definition of the Country ID (NID_C) which is allocated by the ERA and in the case of New Zealand is 600. Others directly impact the way the ETCS system operates and impact the design, deployment or the end users of the system.

1. Dimensioning

One difficult decision was determining the Balise placement positions. From the beginning KiwiRail have been determined to stick with the standards wherever possible. Compliance with the ETCS standard “Dimensioning and Engineering Rules” [2] will be maintained for the positioning of Balise groups. The final positioning that has been chosen can be seen in Figure 7.

![Balise Positioning](image)

2. Precedence of the Cab signalling

A great deal of discussion focused on the precedence of the information presented on the DMI versus the information presented by trackside signage and signals. A significant problem with any intermittent ATP system such as ETCS level 1 is that it only gets updated information when the train passes over a Balise. The signal aspects can change in the period of time between updates leaving the onboard display presenting outdated information. This is most likely to be encountered when a train is approaching a signal at stop which is cleared to proceed after the train has already passed the Caution (yellow) aspect on the preceding signal. In this case the onboard systems believe that the train must commence braking to enable it to stop at the signal when in reality the train has been authorised to proceed. To enable the train to proceed up to the signal at a reasonable speed in order to pick up the updated authority from the Balise a Release Speed is provided. The Release Speed is a speed at which a train can pass a signal (potentially a signal at red) and still safely come to a stop before reaching the Danger Point (the point beyond a signal before the first potential point of conflict). This means that the driver still needs to occasionally read the signal aspects for information on their authority to proceed. This is only required when the ETCS system is targeting a stopping point when the signal has stepped up to proceed. The speed information on the ETCS DMI will always be correct.

In the end it was decided that for a train with operational onboard equipment, the in-cab display shall take precedence over lineside signals and speed signs for permitted train speed information whilst the train is in Full Supervision mode (the normal mode of operation when the ETCS system is fully active) and is permitted to travel faster than the Release Speed. In all other modes of operation, and when approaching signals at less than the Release Speed, the driver must take due cognisance of trackside information other than that presented on the DMI.

3. Release Speeds

The importance of Release Speeds can be seen from the discussion above, however deciding how to implement them opens up an array of options.

Due to the mix of overlap lengths and train types on the Auckland network (suburban passenger trains and slower freight trains with significantly longer braking distance) there is...
not a single Release Speed for each signal that would be acceptable to both train types. Whilst having consistent Release Speeds from signal to signal would be ideal, this is only achievable by dropping Release Speeds lower than the maximum safe value. Therefore it was decided to implement the greatest Release Speeds possible, given the available overlap distances. The highest Release Speed is achieved by calculating the Release Speed onboard the train, as shown below in Figure 8. The calculated Release Speed will be presented to the driver on the DMI and the driver will determine how best to drive the train.

![Figure 8: Release Speeds when calculated onboard](image)

**PROGRESS TO DATE**

Construction of the new signalling for Phase 1 of the AMRN is well underway and will be commissioned in January 2011. The ETCS wayside systems for that phase will also be commissioned at that time. Currently the Onehunga Branch Line is being equipped with the ETCS hardware to enable some tests to be conducted when passenger services are not operating in the weekends. The objective of the tests is to validate the ETCS operating principles and variables that have been developed. In order to conduct the trials two SD units will be fitted with the ETCS equipment. The SD units are locomotive hauled driving cab fitted carriages. As the locomotives will not be fitted for the tests the units will only have ETCS functionality when operated from the SD cab. The design for the installation of the two SD cabs is well advanced and the installation is underway.

**CONCLUSION**

Neither determining the need for ATP, nor adopting the ETCS standard as New Zealand’s ATP system of choice, have been easy decisions to make. However, because the decisions have been driven by comprehensive studies and research which have steered all involved in the decision making so convincingly, it has made gaining acceptance, buy-in, and now support with the implementation phase relatively straightforward.

With the complete replacement of the AMRN signalling and train control systems the decision as to whether we would implement a train protection system really became the question of “why wouldn’t train protection be installed”. It also seems that realistically there are only a few good alternatives to ETCS and the selection of Level 1 was driven by the simple transition and timing requirements where it will be some years between the re-signalling and when the rollingstock will be fitted with the onboard equipment.

From a system perspective, KiwiRail has a preference for systems which utilise open standards. The application of these open standards and associated equipment provides a range of options for the provision of robust, reliable and maintainable signalling and control systems with long term viability.

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**REFERENCES**
