The wait for ERTMS – Keeping the conventional systems safe

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SUMMARY

In the Netherlands, a network-wide rollout of ERTMS is planned. Policy in the Netherlands is that conventional train detection (track circuits) will be replaced by axle counters when ERTMS is installed. The rollout will take time. It is expected that the full roll-out will take over 30 years. ProRail now faces the challenge of keeping the conventional lines safe during the time that ERTMS is not yet installed. A double investment in new systems or additional systems is costly.

Therefore ProRail has started development of the so-called Electronic Track Relay (ETR). The aim is to replace the conventional track relay by a smart receiver with improved train detection functionality, and thus allowing the use of track circuits for another 30+ years. This paper describes the challenges and solutions found when developing the ETR prototype.

1 INTRODUCTION

In the Netherlands, railway safety is largely based on low frequency track circuits that combine train detection and automatic train protection functions. The Automatic Train Protection (ATP) system (called ATBEG) uses the 75Hz signal of the track circuits. This binds both systems. Replacing the track circuits by other train detection system is only economically feasible when the ATP system (including the onboard ATP equipment) is replaced or when other expensive measures can be prevented.

The policy in the Netherlands is to introduce axle counters when ERTMS is installed. With ERTMS, 75Hz ATP is no longer required. In this unbound situation, track circuits can be replaced. The nationwide roll-out of ERTMS will take over 30 years. On not yet renewed lines, the reliability of the train detection may not be guaranteed due to a possible increased occurrence of loss of shunt due to improved running characteristics of modern trains. This leads to the question: can we increase the safe life span of the existing track circuit and to what cost?

2 ATP – THE PRESENT SITUATION

2.1 The Network

The rail network in the Netherlands can be characterised as follows:

- The network is approximately 3500km long, most lines are double track.
- Most lines are electrified with a 1500VDC system. Some lines in the North and East are not electrified.
- Almost 100% coverage by ATP systems. The main network (1500V DC) is equipped with 75Hz track circuits for both the ATBEG ATP-system and train detection. The rest of the network is mostly equipped with ATBNG ATP system and axle counters for train detection. To date, around 370 kilometres of lines are equipped with ERTMS, including the HSL-Zuid (Schiphol-Antwerp) and the Betuweroute freight line Rotterdam-Germany.

2.2 Short History of ATP in the Netherlands

2.2.1 ATB First Generation (ATBEG)

The signalling system in the Netherlands is mostly based on relay interlocking, introduced since 1945. Train detection is done by track circuits. Initially, the track circuits used 50Hz power. ATP functions were developed since the 1950's. The principle of pulse code cab signalling was adopted. Pulse code cab signalling uses the track circuits, offering a continuous transmission of the allowed maximum speed to the train. The current through the rails is switched on and off in a specific frequency, see Figure 1. The pulses are received by coils, placed before the first axles of the train and decoded by the onboard system.

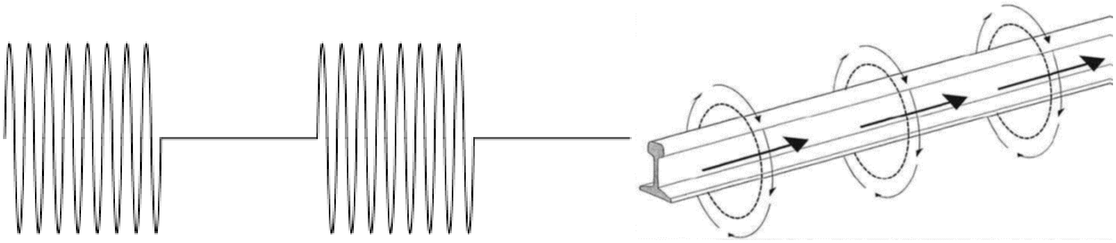

Figure 1. Pulse code

Codes are expressed as pulses per minute. For speeds, 6 codes are used, ranging from 0 (no code) to 220 pulses per minute allowing speeds from 40 to 140 km/h.

Track circuits for ATP were found to be susceptible for 50Hz interference from overhead power lines. Therefore, the track circuit frequency was changed to 75Hz. This frequency allowed the use of the same track circuit components and could be easily produced by rotating inverters, placed at substations and delivering a 3kV, 75Hz power supply, transported along the lines and locally transformed to 110V. Today, static inverters are used.

The 75Hz ATP system is called ATB, later renamed to ATBEG (EG for first generation).

In 1962, a severe train accident took place at Harmelen. Two trains collided at high speed, leading to 93 dead and 52 injured. The line was not equipped with ATBEG. Under bad weather conditions, the driver of one of the trains had missed the yellow aspect signal and consequently passed the following stop signal. This accident led to an increased introduction rate of the ATBEG system.

In 1970, around 100 km of lines were equipped with ATBEG; in 1992, on most main lines ATBEG was available. The last conventional lines (with line speeds > 40 km/h) were equipped with ATP in 2002. Since 2009, all trains that run on the main network must be equipped with the ATBEG system, even museum trains.

Initially, the ATBEG train equipment was relay based and delivered by GRS Railway Signal. In later years (around 1985), a computer-based version was developed by GEC Alsthom (now Alstom Transport). Also, a version was developed for museum trains by Nedtrain Consulting (now Ricardo), called ATB-E (ATB Retrenched). Based on the functional decoding design of ATB-E, Bombardier Transportation developed a failsafe version. For all these versions, the track equipment is the same.

Since 2005, ATBEG is extended with a function to further reduce the risks of passing signals at danger , called ATB-Vv (ATB improved version). ATB-Vv requires additional track side equipment (beacons and loops).

2.2.2 ATB New Generation (ATBNG)

The ATBNG system was developed around 1995 and is based on the TBL system, used in Belgium. It was intended to eventually replace the ATBEG system, offering increased speeds, cab signalling, distance-to-go and protection for speeds under 40 km/h. The system was first introduced on regional lines (mostly diesel lines) that lacked ATP. A nationwide implementation to replace ATBEG was not done, because of costs and the development of ETCS/ERTMS that would offer the same or more advanced safety features and would be more standardised.

ATBNG train borne equipment is backward compatible with ATBEG.

2.2.3 ERTMS / ETCS

ERTMS is implemented since 2005. It is installed on the Betuweroute (freight line Rotterdam Harbors to Germany) and the HSL-Zuid (High Speed line Amsterdam-Antwerp). A dual signalling implementation is installed on the Hanzelijn (Lelystad-Zwolle) and Amsterdam-Utrecht. The dual signalling implementation means that both ATBEG (and line signals) are installed plus a level 2 ERTMS system for trains that have an ERTMS onboard system.

2.3 Migration to ERTMS

In May 2019, the government [] decided to implement ERTMS on the complete rail network. Migration is expected to be completed in 2050.

It is foreseen that in 2030 the following will be achieved, costing 2.4 Billion Euros:

- 7 additional lines (345km line) will be equipped with ERTMS (level 2)
- Amsterdam-Utrecht and Hanzelijn will be operationally harmonized with the new baseline 3 lines and will allow train speeds up to 160 km/h
- 1300 train sets and locomotives will be equipped or upgraded with ERTMS baseline 3
- Lelystad Station and Yard will be equipped with ERTMS and Hanzelijn will be further upgraded to facilitate testing and gaining experience

Figure 2 shows the status in 2019. All blue (light and dark) and orange lines present lines that will be operating under ERTMS in 2030.

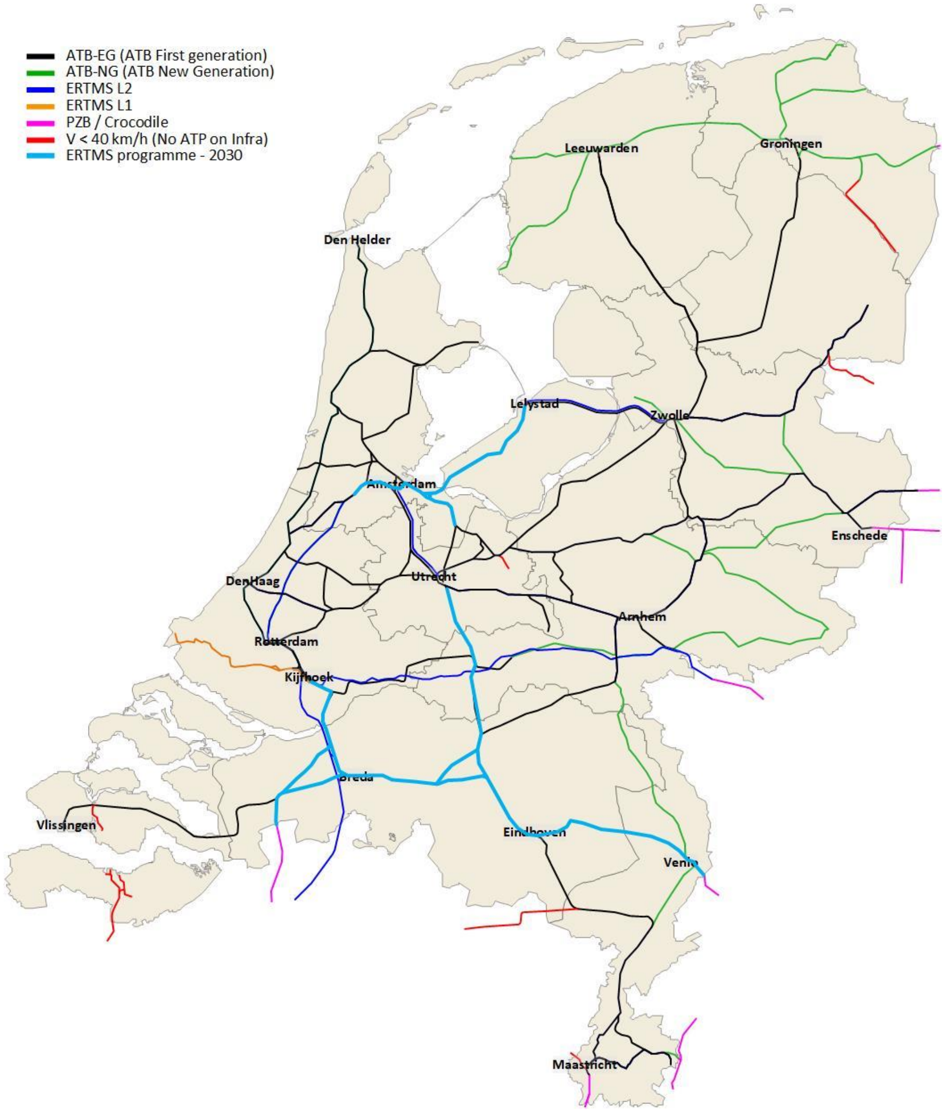

Figure 2. Railway lines in the Netherlands with ATP systems. Light blue: ERTMS in the 2030 scope

This leaves many lines to be equipped with ERTMS after 2030.

All black coloured lines are equipped with ATBEG and track circuits. Green lines are lines with ATBNG, mostly in combination with axle counters for train detection.

For new implementations, ERTMS L2 will not be installed as dual signalling. The rolling stock that will run on ERTMS L2 lines will need to have ERTMS onboard equipment as ATBEG will no longer be available on the ERTMS lines. When ATBEG is no longer needed on a line, there is also no longer the need for track circuits for ATBEG. The policy is to replace the track circuits by axle counters for the train detection functionality.

Using L2, with new interlocking systems and axle counters, installation and testing of new equipment can be largely performed without modifications of the existing systems, allowing a quick changeover when the installation is complete.

3 KEEPING THE CONVENTIONAL SYSTEMS SAFE

As discussed in section 2.3, the implementation of ERTMS will take many years. In 2030, approximately 20% of the network will be equipped with ERTMS. So, what about the 80% rest of the network?

- Many lines that will not yet get ERTMS have older interlocking systems that need to be replaced in 15 years or less, as they are entering their end of life and reliability and availability will be an issue.
- The ATBNG system was installed since the mid-nineties and is now also over 25 years old, nearing the expected life time of signalling electronics.
- From a functionality point of view, conventional signalling is not fit for the future. Train detection by 75Hz track circuits already poses problems related to loss of shunt (mainly because of improved running characteristics of trains) and problems related to traction power incompatibilities.

This calls for a strategy where investments are done optimally: a minimal investment in conventional technology while maintaining availability and reliability of the infrastructure in anticipation for the installation of ERTMS.

3.1 Replacing or renewal

ProRail has already commissioned several projects in which the signalling is renewed [2]. The functional changes are minimal in order to reduce the design and building efforts and costs. Central (B-relay) interlockings are replaced by electronic types and for the rest, systems are renewed by systems of the same type (cables, line signals, track circuits, etcetera). Per case it is decided what the extent of the replacement is, depending on the state of the equipment (especially outside cables and wiring in cabinets).

As long ATBEG is needed, so will track circuits, since the track circuit is used as a carrier for the ATBEG codes.

For the lines with ATBNG, replacement by ERTMS is foreseen, but the planning is not yet decided. On most lines with ATBNG, no track circuits are used.

3.2 Track circuits

Track circuits form a specifically interesting and important part of the strategy. In itself, the 75Hz track circuit is a very reliable system. Hardware failures are very rare. The basic components are relatively simple and can be easily reproduced if needed. ProRail owns the designs. Track circuits need insulated joints in the rails. These joints, necessary for separating the tracks, are the weak point of track circuits.

To date, there are some 16.000 track circuits on the ProRail Network.

Since the ATP system also uses the track circuits, replacement of track circuits is not simple. As long as the ATP system ATBEG is needed, track circuits and insulated joints will be needed because the current in the track circuit is used as ATP code.

However, from a functional point of view, maintaining safe operation of track circuits will be become an ever bigger problem. Two main issues are of concern:

- Track circuits require a continuous shortcircuit between the rails via the train wheels and axles. Developments in the characteristics of trains show that this shortcircuit is becoming less reliable. Trains are becoming lighter, run very smooth over the rails, use disk brakes with advanced braking performance. The running area on the rails is becoming more narrow and pollution of the contact area is less well removed by the train wheels. The impact of environmental conditions like wind, rain, falling leaves is therefore becoming bigger. The risk of loss of shunt needs to be controlled.

- Electric trains use more and more advanced and complex traction systems with high power. Traction systems of different trains may interfere, leading to unexpected interference currents. New rolling stock is required to have interference current detectors, but to prevent too many "trips", the interference current detector should be able to allow relatively high interference currents. A better immunity to transients is needed.

The present 75Hz track circuits are not sensitive enough to face these challenges. The conventional signalling systems rely on a reliable train detection and in most cases, no backup or secondary system is used, not even on level crossing systems.

Currently, the following solutions to increase safety are used:

- Additional detection systems like treadles for level crossings, combined with a functional change in the relay circuits (stick system).
- Sequence checking in interlockings
- High Voltage Impulse Track Circuits (no longer accepted)
- Axle counters combined with track circuits for ATP (not all combinations are accepted)

Evidently, the implementation costs for these measures are very high. If the reliability of the track circuits could be improved, this would save significant costs.

Enter the Electronic Track Relay, ETR.

4 ETR

4.1 Introduction

Track circuits are wonderful systems, providing a safe way of notifying if a track is clear in an elegant way by using the principle of continuous powering a relay. Any failure will lead to the drop of the relay.

Reliable detection of a train however relies on the fulfilment of two external conditions:

- A sufficient short circuit of the rails
- Interference currents from the traction and other power system that comply to limits.

Track circuits in the Netherlands use a 75Hz power and a double element vane relay, see Figure 3. The figure shows the complete relay and the principle of vane operation.

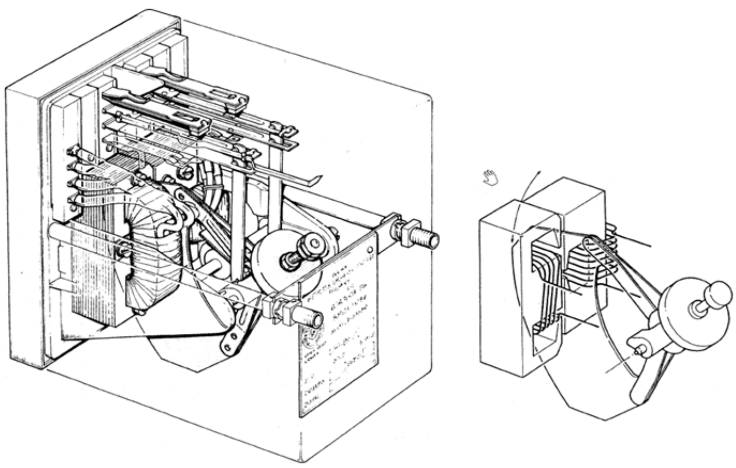

Figure 3. Double Element Vane Relay

The relay operates on the combination of two currents: a fixed local current (from the power supply) and the track current, this is the resulting current coming from the track. Both currents are fed from the same power supply so they have a constant phase relation and the exact same frequency. The relay will pick up if the local and track currents have a sufficient amplitude and correct phase relation. With a train present, the train axles short circuit the track and the track current to the relay falls, resulting in a drop of the relay.

The vane rotates in the relay over an angle of approximately 42 degrees. The rotation of the vane operates a set of contacts, giving the status of the relay (pick up or drop).

Contacts of the relays are used for:

- Track clear indication to the interlocking or block signal system.
- Switching on of the ATBEG current by switching a code repeater relay

The relay is used in both single and double rail track circuits. The relay is adapted to the track circuit by using different arrangements of the track coils.

Track circuits are highly standardised (although some 20 different variants can be found), all using the exact same type of track relay. The relay is placed in track side cabinets and is a plugin type. They can be easily replaced.

The adjustment of track circuits is done by setting transformer taps, resistor taps and or capacitor taps that set the currents for the track current and local current in the track relay.

4.2 Concept of the ETR

The concept of the ETR was proposed by Movares and (initially) Mors Smitt (a Wabtec company) to ProRail in 2012 and resulted in a contract for development in 2014.

The main idea behind the ETR is to only replace the track relay in the track circuit and nothing else. The ETR could then replace the conventional relay without modifications in the track circuits, which is economically very interesting (fast reconstruction, reduces expensive engineering and changes of the system). The ETR should then be compatible with the conventional relay:

- Downwards pin compatible (fit on the standard plug board)
- Electrical compatible (same impedance)
- Functional compatible (timing)
- Fit for the environment in cabinets along the track

On top of that, the ETR would give improvements for the track circuits as a system:

- Improved behaviour under loss of shunt conditions
- Less sensitive to transients
- Improved behaviour under varying ballast impedance
- Facilitate easy adjustment of the track circuit
- Integrated monitoring and diagnostic with standard ethernet interface

4.3 Development strategy

ProRail decided to develop the ETR as a specification rather than a product. The idea was that the ETR would be described as a complete product, including a reference design that has a CENELEC compliant Generic Product and Application Safety Case. One or more suppliers could then produce the ETR with a minimal in safety effort. Components must be off the shelf components, available as an open specification or have more than one supplier.

This strategy requires a complete specification. ProRail is the owner and thus responsible for the safety of the design. Part of the project is to produce a prototype to demonstrate and test the ETR in a pilot project. Movares was contracted to develop the specification and the software for the core function (the detection algorithms) of the ETR .

Other parties that were involved in the development were mostly Topic Products for the electronics design and some smaller contributions by Tegema for the design of the enclosure and Wijdeven for the development of the input transformer.

The algorithms of the core function are developed using Matlab®. This enables to demonstrate the correct functioning of the algorithms by software tests. A model of the conventional relay was already developed several years ago. Using this model, the behaviour of the ETR can be compared with the behaviour of the conventional relay. This has big advantages as most tests can be completely done in software. It enables the use of an extensive test set.

The implementation in Matlab code is used as the specification of the algorithm. As part of the integration in hardware, this code is translated to lower level code (C).

4.4 Basic design

The design of the ETR is based on the following concepts:

- The enclosure has the same size and connector layout as the conventional relay, allowing the ETR to be installed without changing any wiring in the relay cabinet.
- The principle functionality of the relay behaviour was kept, albeit in software. This means that a relay "torque" is calculated in software in the same way that the conventional vane relay operates. This also benefits the safety case, as the principle operation can be easily demonstrated to be equal to the conventional relay. Additional functionalities to improve the performance can then be done in software: more reliable detection in case of bad train shunt, improved detection in case of rail breaks, higher immunity to traction interference currents.
- The input circuit for the track current is based on a transformer with two primary and three secondary windings. The primary circuit of the transformer is designed to have the same impedance as the coils of the conventional relay, thus fulfilling the electrical requirements. The three secondary windings allow for an isolated three channel electronics design.
- The safety core of the ETR is designed as a two out of three concept, with diverse design of the processors, allowing a SIL4 compliant integrity level for the hardware.

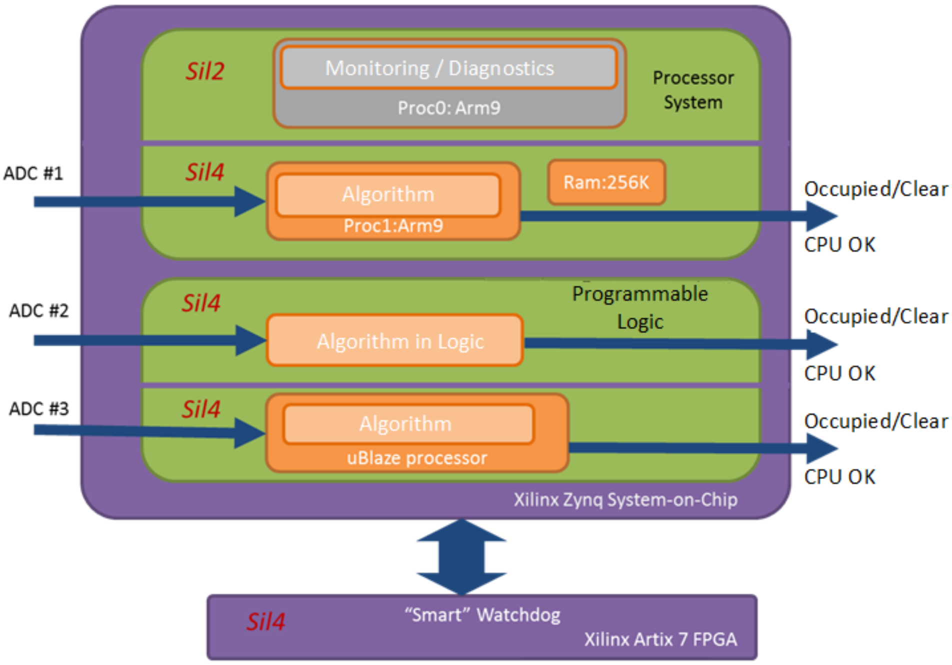

Figure 4. Processor core

- The monitoring device is placed on a SIL2 part of the hardware, with software that helps to improve the availability of the track circuit. This software can be remotely updated over a data connection, thus enabling to further improve these functions in the future.
- To improve the performance of the track circuit, and to simplify the setup of the track circuit, the ETR must be configured per track circuit. After configuration, the data is written to a safe removable key. In case an ETR malfunctions, the data key can be transferred to a new ETR so that this new ETR is already setup and replacing the ETR is simple.
- The ETR includes an internal web server, through which the ETR can be set-up and the track circuit can be commissioned. The web server and a standard ethernet connection allow for a standard laptop or other device to be used. An impression of the tool is given in Figure 5.

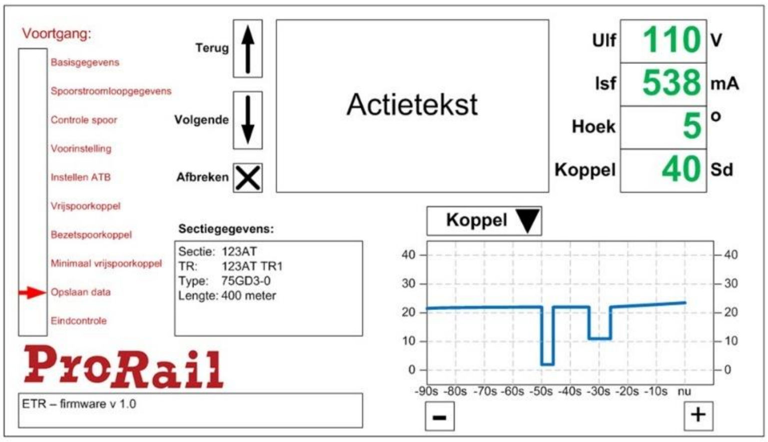

Figure 5. Impression of the commissioning tool

- For monitoring & diagnostics, the ETR is equipped with a dedicated ethernet connection. By this connection, diagnostic data of the ETR and the track circuit is made available. This allows to further improve the performance of the railway: monitor detection quality, early fault finding, …

- Cables for diagnostic are connected at the front, since the standard plug board needs to be used and this does not allow for other connectors.

4.5 Understanding the track circuit

Even though the specialists who made the specification have a lot of experience and a thorough knowledge of the track circuit, it was appreciated that not everything can be foreseen using desk studies. Therefore, measurement data was obtained from contractors. In addition to that, on 6 locations on the network, additional measurements were done, where for more than a year the track and local currents were measured and stored for analysis. Valuable lessons were learned on:

- Loss of shunt (not-detecting a train because of insufficient short-circuiting of the rails by the train axles/wheels).
- Impact of the saturation of transformers (by DC traction current) on the track current in the relay
- Influence of special arrangements in the track circuit like faulty relay contacts or the switchover of relay contacts in the track circuits leading to short interruptions of the currents through the relay.
- Timing. For ATBEG, a quick drop of the relay is needed because the ATBEG is switched on by track occupation (train enters the track). If the ATBEG code is missing too long, the train will apply the brakes. On the other hand, to enable a robust detection it is important to have time to reliably determine the track status.

4.6 Improved behaviour with Loss of Shunt

4.6.1 Introduction

Train detection by track circuits relay on the sufficient short circuit of both rails of a track by the axles and wheels of the train. On clean rails and clean wheels, this short circuit is achieved without problems. In practice, rails and wheels are not clean. Older trains, with (cast steel) wheel brakes, have a cleaning effect for wheels and rails, keeping the top of the rail free of rust and other pollutions.

Reliable train detection is more difficult due to improved running characteristic of modern trains (driven by required improved ride comfort, minimisation of wheel wear and reduction of environmental noise). The development of rolling stock with such characteristics, while still enabling reliable detection on track circuits is a real challenge.

4.6.2 Loss of shunt case

The next two figures illustrate the behaviour of the track relay during the passing of a train with bad shunting properties. The data is obtained on a non-electrified line. The three colours represent three subsequent track circuits: 830CDET, 826AT and 826BT. 826AT is a short track circuit of approximately 30 meters; the other two are several hundred meters long.

The figures show two graphs: the upper part shows the relay torque; the lower part shows the position of the relay vane. The vane rotates over 42 degrees. An angle of 0 means the vane is down (track occupied); an angle of 42 means the vane is up (track free). The figures show the passage of a train over the three track circuits.

Figure 6 shows the calculated relay torque and vane position (conventional relay) for a normal passage of a train. Figure 7 shows the same track circuits, passed by the next train (a train of the same type!), 15 minutes later. In this passage, the residual torque is very high and the vane can be seen tot attract several times, leading to a false track free indication of several seconds. This is a severe case of loss of shunt. Especially the last parts of the train passage are hard to discriminate, as the torque has almost reached its default track free status.

It is in fact a bit shocking to see that in 15 minutes time, detection can be so completely different. In this case, strong winds contributed to the loss of shunt.

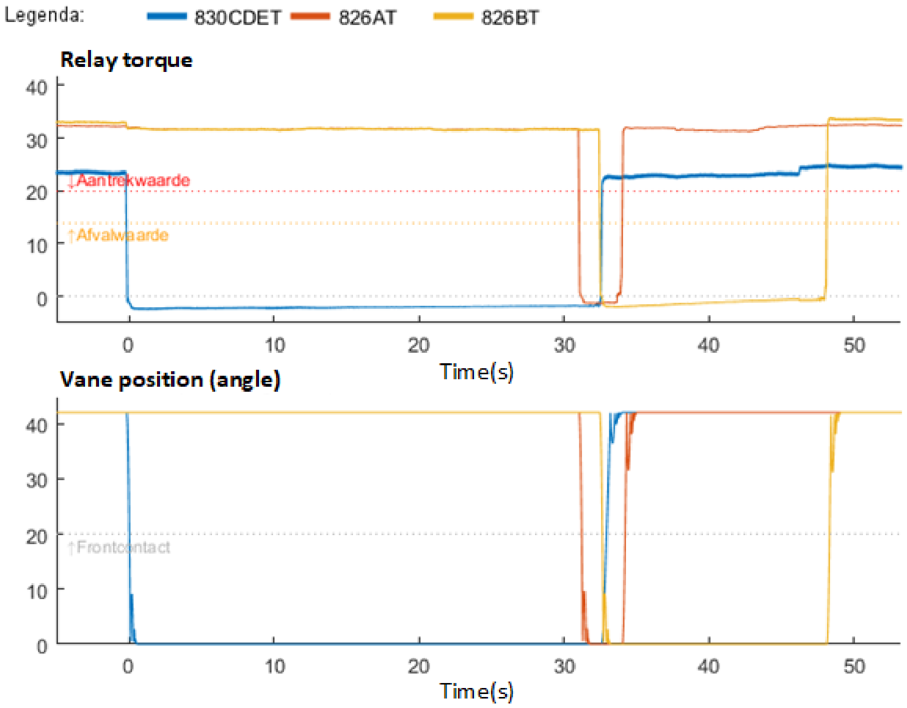

Figure 6. Behaviour of the track circuit, normal condition

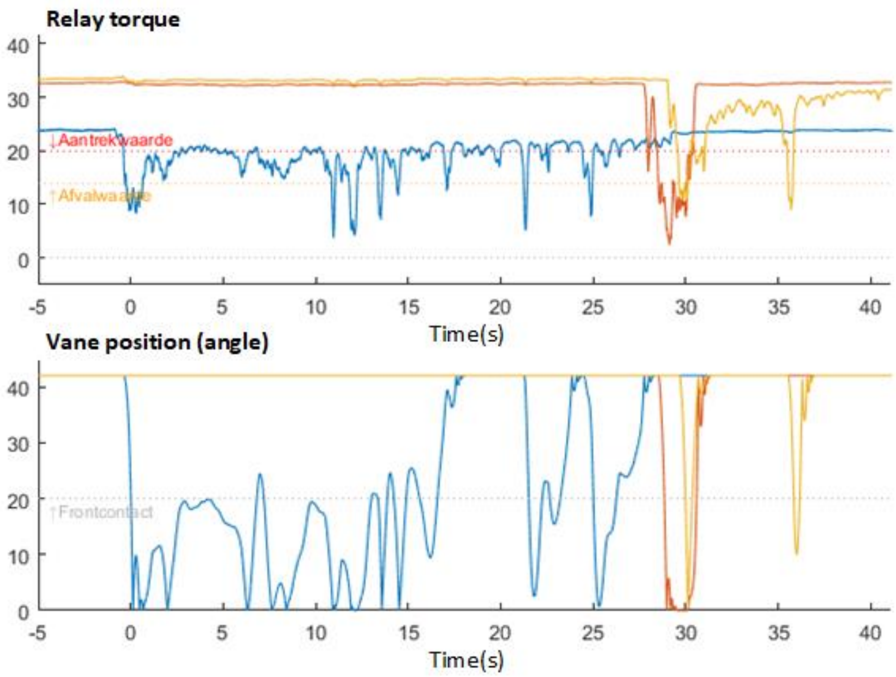

Figure 7. Behaviour of the track circuit, extreme condition

4.6.3 Solution in ETR

A standard track relay has a fixed threshold to drop and pickup. In Figure 6 and Figure 7 these are depicted as "afvalwaarde" and "aantrekwaarde" respectively. These thresholds are insufficient in case of bad shunt. Choosing other fixed thresholds is not an option. The relay torque varies depending on track conditions and higher thresholds would lead to false occupations when track conditions change.

The basic solution in ETR is depicted in Figure 8. The picture shows in a blue line the variation of the relay "torque" over time. The red line is the resulting torque when a test shunt (0.2 Ohm) is placed in the track. The dip in the blue line depicts the torque with a train passing with a bad shunt. The torque decreases, but for a standard track relay, the decrease in not enough for the relay top drop. But in a relative way, the sudden change in torque is noticeable.

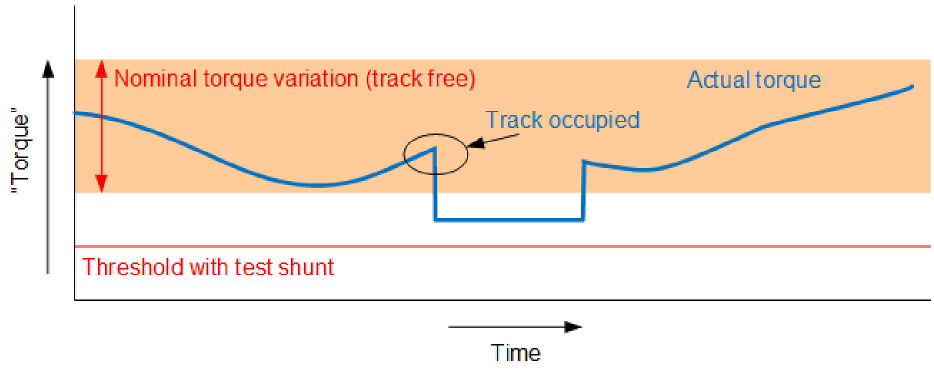

Figure 8. Principe of detection related to loss of shunt

In ETR, at the commissioning, the track free "torque" is determined. Also, the torque is measured with two test shunts in the track. These values, and theoretical determined parameters, define the expected normal range of torque (the orange band in Figure 8). Over time, the torque varies, because of environmental conditions like rain. This variation is slow, and the relay takes this into account as acceptable. But if the torque drops instantaneously; this will be evaluated as a train axle. This is determined by the relative change, not by a fixed threshold. Phase angles and a time window are taken into account to discriminate between this behaviour and the influence of saturation of track circuit components or traction transients.

A variable timing window is used to optimise this behaviour. If the relative torque decrease is small (bad shunt), more time is used than when the decrease is larger (good shunt). This may result in a bit slower drop and pickup of the relay, but as this only happens under severe loss of shunt conditions, this is acceptable with certain margins and can be kept within constraints over minimum overlap between track circuits. The consequence of a slower drop can be a trip of the ABTEG system (to a more restrictive speed). The margins that are applied prevent that other timing constraints (e.g. level crossing) are effected.

To determine the correct moment of the track free status, a variable time is used. When the torque is relatively high during the train passage, a longer time is used to ensure the track relay does not pick up too soon. This is also acceptable with certain limits.

4.6.4 Evidence

An interesting question is: how can you prove that the ETR delivers a sufficient improvement with loss of shunt? A full loss of shunt (a train with perfect isolation) can never be detected because the currents in the track relay are not changed. A safety case that proves that a loss of shunt can never occur can never be delivered. However the occurrence frequency of the loss of shunt is not extremely high so improvement with for example a factor 10 reduction will already be a great achievement.

It was agreed with ProRail that a set of test signals would be defined. Test signals are recorded or generated currents that flow in the track relay and on which the algorithm decides whether the track is occupied or free. These signals will be fed to the algorithm and (later) to the complete ETR.

The test signals includes several types of behaviour including loss of shunt conditions. Most test signals are data obtained from measurements and recordings. Very "bad case" conditions were artificially generated by software. After the test case set (2563 cases) was agreed, and the expected behaviour per test was determined, the test set was (and successfully!) used to demonstrate that the ETR functionality is correct.

4.7 Other design challenges and solutions

4.7.1 Behaviour on transients

For transients (traction interference) the same approach is used as for loss of shunts. Digital filters ensure that the ETR is less susceptible for out of band interference and optimisation of timing improves the behaviour with transients. The set of test cases as mentioned before was used to demonstrate the correct functioning also in cases of traction interference.

4.7.2 Interface to the interlocking

The ProRail relay interlockings use relays with an extremely high inductance. The output circuits of the ETR must use potential free contacts to be compatible. For reliability, the relay contacts must be able to withstand the high voltage arcs that occur when the interface relays switch off (more than 5kV). Two solutions were considered:

- Implementing a Q-style (intrinsic fail safe) relay in the ETR enclosure
- Implementing smaller relays in a safe array and use snubbers to protect the relay contacts.

The second option was chosen in the reference design, as there is not enough room in the enclosure for a Q-style relay (as a result of other design considerations). The ETR core uses a two out of three structure. By using an array of three smaller safety relays with sufficient contacts (force guided), the "voter" for the two-out-of-three concept was made as shown in Figure 9. Relays K2, K3 and K4 are relays per channel. One additional relay K1 is used to allow for a test circuit to check the snubber that is used for the normally open contacts (safety function). This check can be done when the track is reported occupied.

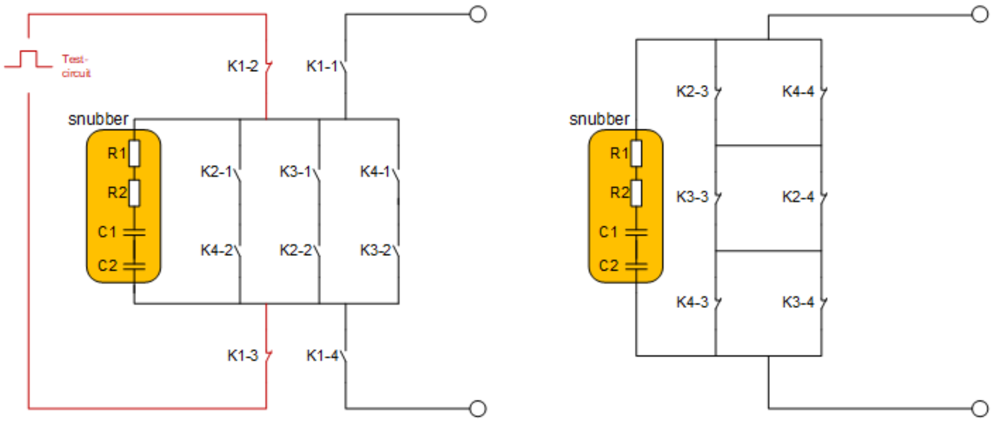

Figure 9. Interface output relays

The internal snubber circuit and check would not be needed if it is accepted to put snubbers on the external relay. However, as this would mean a change in the system outside the ETR, this was not accepted.

4.7.3 Power supply

The ETR needs electric power for the electronics to operate and to drive the internal relays. The local voltage on track relays is 110V. This is a constant AC voltage and very suitable. However, in case of double rail track circuits, the voltage to the local coil is adapted as part of the setup of the track circuit. This would mean that a power supply needs to be designed that would allow a range between 20V and 140V. On level crossing island track circuits, a capacitor and resistor is used in series with the local voltage to obtain a correct phase angle.

This issue was resolved by allowing the local voltage to be set to a fixed 110V and bridging the capacitor and resistor. The benefit is a more efficient power supply although this means that a modification of the track circuit is inevitable. The change of local voltage and phase is resolved in the software as part of the setup.

Another challenge is a possible temporary drop of the power supply. A conventional relay will pick up as soon as the voltage is restored. An electronic device with software needs a bit more time if it needs to reboot. In the specification phase, we found that a voltage dip of 200ms should not lead to a reboot, so that an energy buffer is needed for the electronics and relay drivers. The use of batteries cannot be united with the demands for the reliability and life span, so electrolytic capacitors may be needed to provide sufficient energy.

4.7.4 Input circuit for track current

The input circuit puts several challenges:

- Impedance. For transparent behaviour, the impedance of the input circuit should be comparable. The track current per relay coil can be up to 1A AC. In single rail track circuits, DC or AC interference current may flow through the track relay as well. The impedance has a relatively high resistive part and that means that heat is formed in the relay. It was calculated that the dissipation of the transformer could be as high as 15Watts in worst case conditions.
- Isolation. In some configurations, the track relay coils are placed within a resonant electrical circuit. This means that an AC voltage of 1kV can be present. Also, the impact of lightning needs to be withstood. Conventional track circuits (in DC powered areas) have no lightning protection. As external protection was not accepted, the input transformer was designed to be able to withstand 10kV (line to ground).
- Size. The track transformer is relatively big because of the other constraints (power, isolation). The arrangement of all the components in the housing is challenging but could be overcome because of the high isolation, reducing the need of other protection circuits.

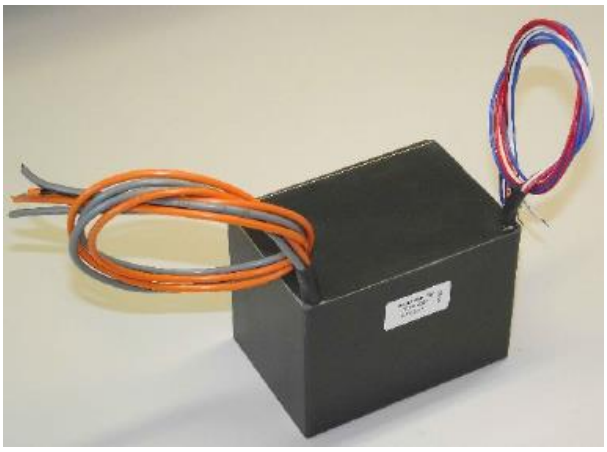

Figure 10. Prototype of the input transformer

4.7.5 Environmental conditions

Relay cabinets at ProRail are steel cabinets placed along the track, containing components for block signalling, ATBEG, track circuits and signals and little or no electronics. Especially in the summertime, the internal temperature of cabinets can reach temperatures over 50 degrees, sometimes even up to 70 degrees. For electronic components, heat is the enemy of lifespan and reliability. As a rule of thumb, the MTBF of a system is halved with every 10 degrees in rise of temperature.

The input transformer, power supply and the output relays all create heat as well. Especially the input transformer is a challenge as it dissipates power, up to 15W. The vital PCB, relays and power supply dissipate another 10 to 15W. Without any measures, the internal temperature of the ETR will rise above 85 degrees Celsius in summer days, which is the limit for reliable operation of the electronic and processors.

Two solutions are foreseen:

- A redesign of the ETR where the input circuit does not use a transformer and where a single safety relay is used as interface. This reduces the internally dissipated power from 30 to approximately 5 Watt. The drawback is however that the ETR will not be plug and play compatible. External adaptions in the cabinet will be needed (some wiring changes and the replacement of a resistor in 20% of the track circuits).

- Install ventilation openings in the cabinets and in cases where the temperature is still too high install forced air ventilation.

ProRail opted for the second solution, because external changes to the wiring are not accepted in the scope of ETR. And of course, other systems in the cabinet benefit from the lower temperatures as well.

4.8 Development status

In 2016, a first prototype was developed as a proof of concept. This prototype shows that it is possible to develop the ETR and the necessary functions.

The next step should be a second prototype, in which the experience with the first prototype would be used and that would be fit for testing in the actual railway environment.

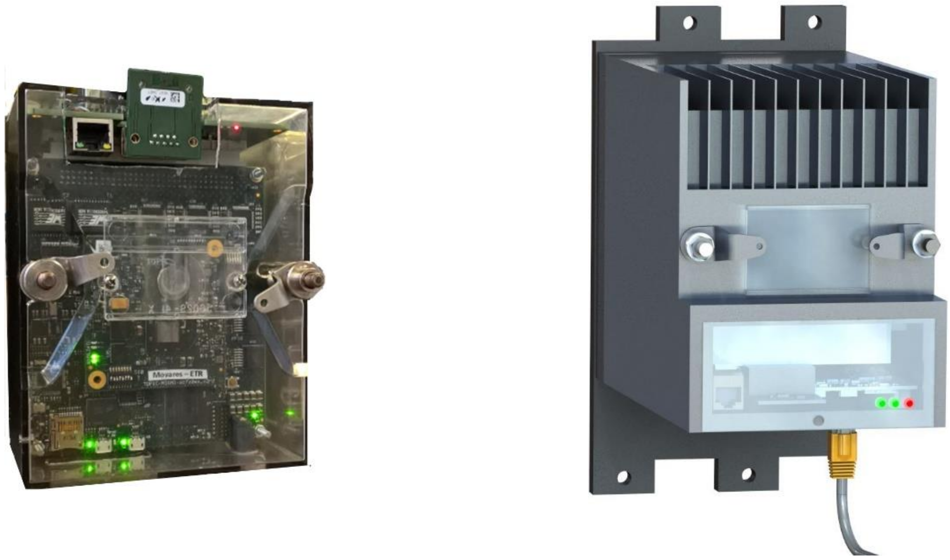

Figure 11. Prototype (left) and impression of expected final ETR version (right)

In 2017, it was decided that the concept of developing a full specification for an ETR that could be reproduced by several parties was not considered feasible. A new tender for the next development steps including production and service was considered.

In 2019, ProRail decided that the ETR project will not be continued by ProRail. This decision is based on the following considerations:

- The development costs of the ETR. Although the business case for ETR is positive, ProRail considers that the risk that this will become negative is too high.
- The development and testing of the ETR is expected to take several more years, and ETR will come too late to be really beneficial.
- For the mitigation of loss of shunt, other technical measures are available (axle counters or treadles in combination with additional interlocking functionalities).
- ProRail policy is to not use track circuits for reliable train detection and to phase out the track circuits more quickly.

5 CONCLUSION

As a concept the ETR is an improved track relay with a lot of potential. From a functional point of view, the ETR can provide improved performance with a lower susceptibility to loss of shunt and improved traction interference immunity. The added functions for monitoring and diagnosis can improve the reliability and availability of track circuits. Potentially, the improvements of the ETR may extend the safe lifetime of track circuit and prevent other costs.

On the other hand, the condition that the ETR should be fully compatible with the conventional relay and that external modifications are not accepted, poses challenges. The imposed condition has the benefit of installation with low costs, but the disadvantage that the ETR product is more complex, more expensive and not optimal. Optimisations could be possible when small external modifications are allowed.

Even though the ETR has a lot of potential, for ProRail, the ETR has come too late to fit in the policy for ERTMS and train detection.

6 REFERENCES

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