IRSE
Institution of Railway Signal Engineers

Key token signalling with a 21st century twist

Grahame Taylor
Tern Systems Ltd, UK

IRSE News June 2010 featured TERN – Token Exchange using Random Numbers and a demonstration to the IRSE Minor Railways Section on a visit to the Ravenglass and Eskdale Railway. Grahame now provides an update on the principles of key token signalling and the development of the Ternkey project.

It's a favourite (and infuriating) trick of some writers to start any technical article with a statement of the blindingly obvious. Here goes! Key token signalling has been around for a long time. Maybe some members of the IRSE didn't know that, but it's more likely that they did – another obvious statement.

This article examines the Ternkey project which takes the principles of key token signalling and propels them into the digital age. It is a deliberate use of a traditional physical authority – a key with an engraved tag attached – at a time when in-cab signalling and automatic control occupies the energies of the mainstream signalling industry.

The challenge that gave rise to the project was the need to supply train control equipment for a single line steam railway that had five passing loops. However, there was no lineside cabling nor many trained ground staff and all but one of the loops was out of use. Despite these hindrances, the railway did have ambitions to run more trains and a reliable service thus generating more revenue. This it could not do without reinstating the unused passing loops.

Thus the remit was to build a system that would give a Line Controller the operating flexibility of opening loops at the touch of a button to allow trains to pass in order to reduce train and passenger delays. Straight away, after several cab rides, it was obvious that in-cab signalling was a complete non-starter. The steam locomotive environment involves heat, cold, weather, water, dust – lots of dust – vibration and usually at least two people in a cramped space, one of whom wields a hefty shovel loaded with coal. Key tokens appeared to be the only way forward.

A new approach

Installing pairs of conventional key token machines was not an option due to the lack of cabling, key token machines and technical skills.

Even if it had been possible to use conventional machines, however they were linked, there was still the issue of operating flexibility. There are other locations where equipment has been made to work using digital networks, but heritage machines do not lend themselves to being linked in a coordinated structure that allows a whole branch to be controlled by one person.

A new system architecture and new token machines were required. Given that this equipment did not exist, it meant that just about everything had to be constructed out of Components Off The Shelf (COTS) and built using Suppliers And Manufacturers Unknown to the Railway Industry (SAMURaI to coin a new acronym) with the controlling software written from scratch. As a result, the project has been complex with every stage and element presenting possible show-stoppers.

The up-side, of course, is that there has been an opportunity to start from a completely blank piece of paper. It meant designing and building unconventional key token machines based entirely on an operator's needs, allowing a Line Controller the chance to actually manage a train timetable whilst at the same time dealing with passenger enquiries and crises. It meant devolving the issuing of key tokens to drivers under instruction from the Line Controller, using machines that guard against unsafe acts.

The overall architecture:

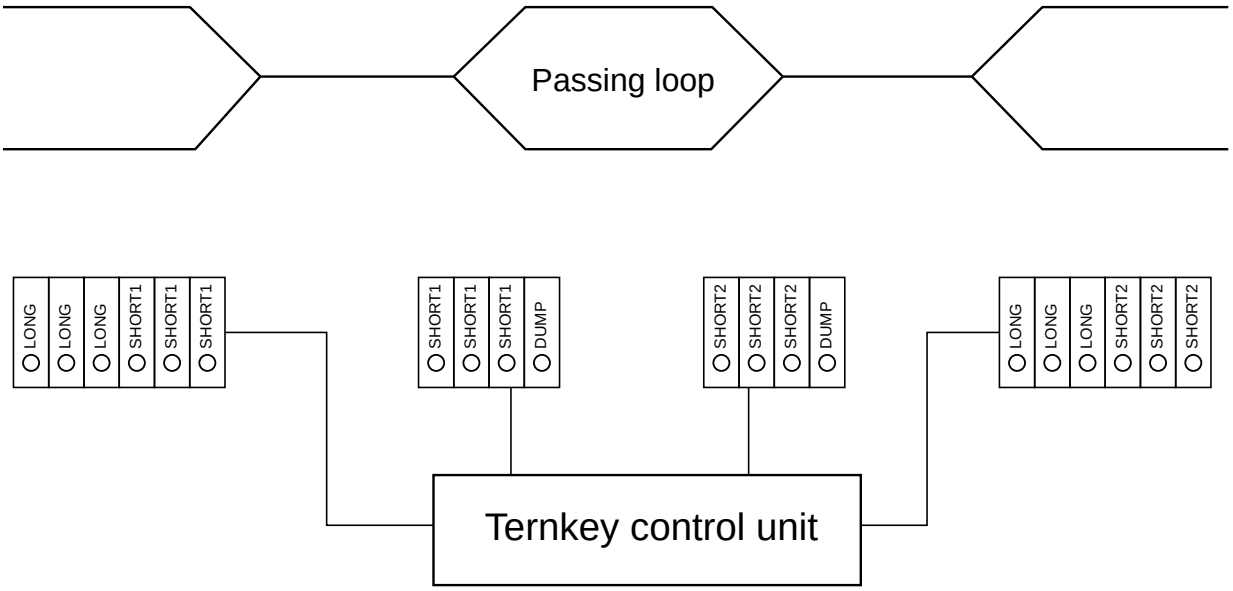
At each end of a single line there is a Ternkey (TK) machine. Each TK communicates via a network to a server program which, in turn communicates with both a controlling program and an audit program.

The controlling program contains all the rules associated with a layout. The audit program monitors the system and its Ternkey transactions, comparing the system inputs and the control program outputs. It is also the second opinion without which no token can be issued.

For a simple single line layout, each TK will hold a number of locks into which keys can be inserted or removed. The number of locks depends on the intensity of the train service and can range from just two to twelve. Each lock is twinned with a corresponding lock in the other TK unit. Each pair of twinned locks has a uniquely cut key.

Herein lies the difference between a conventional key token machine and a TK unit. The former relies on the detection of polarity – an electrical 'one-trick-pony'. Polarity is either + or - . That's it, there's nothing else to detect.

The TK system counts and accounts for keys. That is, the number of captive keys can be counted and the position of the keys in the machines can also



A very simple arrangement of Ternkey machines with three long tokens covering the whole railway, three short tokens covering each of the two single line sections and two long token 'dump' locks in the short token machines. If there is a short token out in either of the single lines, then a long token cannot be issued. If a long token is out, then neither of the short tokens can be issued. If a long token is locked into a dump lock, then short or long tokens can be issued.

be detected. Both the number of keys and the position of the keys has to be consistent – a digital 'two trick pony'.

It is this ability of the system to identify the state of specific locks that allows the management of short, long or very long sections in real time. It is also the basis of the patent granted in 2017.

The components

The locks are simple and robust. The key barrel looks similar to a front door rim lock. This is because it is a front door rim lock. They are the archetypal Component Off the Shelf, made in their millions and all to the same dimensions no matter the manufacturer. They also have the happy property of securely capturing keys once they are rotated past vertical. Those in use in the production models are at the top end of the market in that they are high security locks beautifully manufactured by DormaKaba – but they are door locks nonetheless.

These barrels, completely unaltered, are built in to the front cover of an aluminium extrusion and drive an assembly of components precision manufactured by a firm in Kidderminster more used to working in the aerospace industry. A key is retained in the lock when the rotor behind the rim lock is unable to rotate because of a solenoid plunger forced by two limit switches and gravity into a deep socket in the rotor.

The key can be released when a relay is energised via the audit program that completes a circuit to the solenoid, and when the controlling program energises that solenoid circuit. The solenoid pulls a plunger clear of the rotor so allowing it to be turned. The limit switches detect the new position of the solenoid plunger and thus the possibility of the key being turned. As a point of principle, if the key can be turned, then it is assumed that it has been turned.... and withdrawn.

Other 'key' principles that guide the Ternkey project include

- Whatever happens, the Line Controller is in control – not the drivers.
- The system is a train control system using voice communication with authorities confirmed by the possession of unique key tokens.
- COTS must be treated with caution.
- The construction of the Ternkey units must be modular to allow rapid exchange and off-site repairs.

The sequence

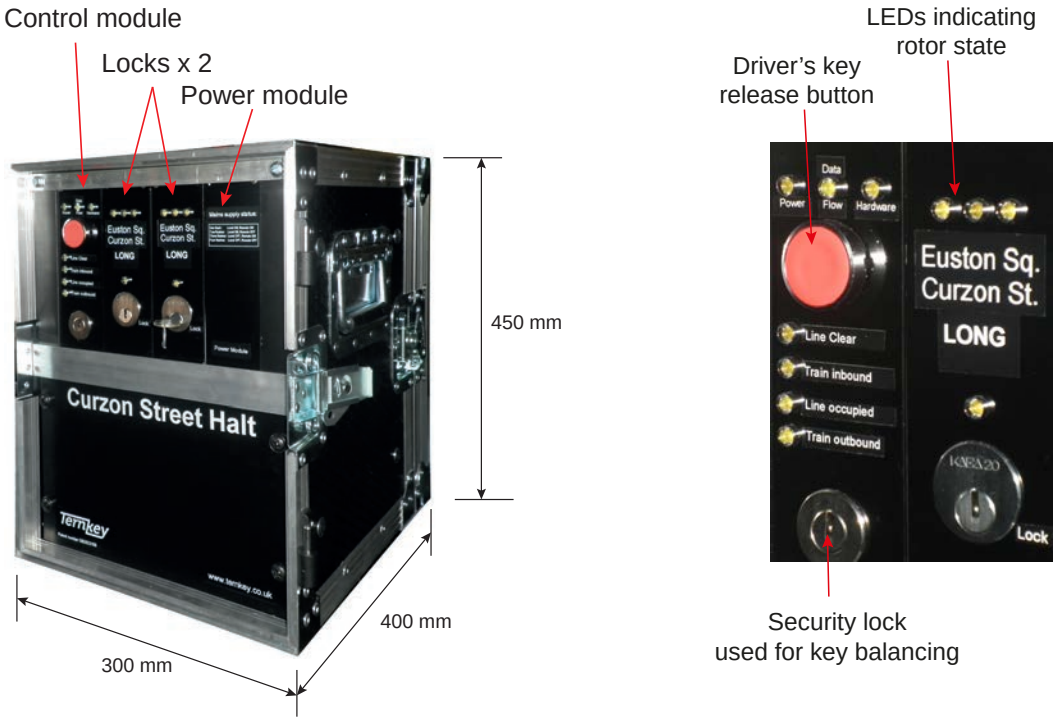
The sequence leading to the solenoid pulling the plunger clear of the rotor is initiated by a driver, standing by a TK machine, contacting the Line Controller to seek permission to obtain a token. If the Line Controller agrees, the driver presses a button on the TK unit. The control program checks that the request is in line with a set of route rules and polls each TK unit asking for a declaration of keys. These are coordinated in the control program which then asks the audit program for its opinion. If the audit program is happy, it causes the relay in the appropriate lock to pick. The control program is then informed that the audit program is content, so prompting the control program to cause the solenoid plunger to lift. The driver can then turn the key and withdraw it from the lock. The transaction is completed by the driver confirming the type of token obtained after which the Line Controller authorises the movement.

Five seconds after the solenoid plunger is lifted, everything is cancelled, the plunger drops and the position of the keys – or rather the state of the rotors – is polled. If the rotor has turned because a key has been withdrawn within the five seconds then the plunger just comes to rest on the rotor body and cannot drop into the socket. If the number of keys between the machines is out of balance then no more keys can be issued. If the key was never taken out, then this too will be detected as the plunger will drop back into the rotor socket and the system will revert back to a balanced state so allowing keys to be requested. When a key is returned to its twinned lock in the other TK machine (or even if it is returned to its original machine) there is an immediate system poll and a balanced state resumes.

This then is the simple option (viewable in a basic video at **www.ternkey.co.uk**).

The long section dump

However, as the software has been written to cater for up to twelve TK units, it is possible to control a line with five passing loops all with a single control program.



The Ternkey unit, left, and a detailed view of the front panel.

The rules become a little more complex, but not outrageously so. They can cater for long and short sections and for complete possessions. They can cater for the hitherto unknown facility – the long section dump. This is a lock located at an intermediate machine that will accept a key from a long section. It would be used if a train with a long token cannot complete its journey and has to stop at a short section machine. Once the long section key is returned to the dump lock, the system again becomes balanced and short tokens can be issued to trains that would otherwise be delayed until the ailing train cleared the long section.

All the above resulted from the original commission. Prototype units covering one single line ran for a year using a closed network. These were replaced and production units ran for another year, again covering one single line and running in shadow mode.

Demonstration units

In the meantime, demonstration units that have a minimum specification have been built. They do not have the touchscreen displays that were fitted to the original units but each just rely on a single large button for the initiation of token requests. Information on the state of traffic is indicated by LEDs along with basic health status reports.

The point of constructing them is to demonstrate a number of possibilities. Firstly, that the system can be portable. They are nominally powered by mains power charging the standby battery, but the battery has the capacity to run for about ten hours before the solenoid will not pull.

The system can be transferable from one railway to another by simply altering the labels on the locks and the tags on the keys.

Exhaustive testing can be completed on or off site as there is no interface with existing systems.

The demonstration units have been assembled from the three basic Ternkey building blocks – a control module, a power module and standard locks. Fitted into a standard 19" rack that's all that's needed to control a single line.

Not only, but also....

It has been observed that what has been built is basically just a mechanism to allocate unique work authorities. Yes, it was designed for a conventional railway, but there are other possibilities where the holding of a physical authority might be preferred over an electronic equivalent:

- Think perhaps about long possessions where the progress of single engineering trains is still painfully slow.
- Perhaps there could be a change from sudden death switch-overs from old to new signalling schemes with an interim planned use of TK units?
- And, as train running is just a process, it could be possible to substitute the word 'electricity' or 'power' for the word 'train'.

The future....

The Ternkey project has come a long way from its origins in 2014 and indeed from much further back. It is a descendant of equipment designed to increase productivity on the Redmire and Eastgate branches in the late 1980s. TERN, at that time, stood for Token Exchange using Random Numbers. As the project has shown, concept is one thing. Design and build is another. Testing, commissioning and real life working is yet another. There are hurdles yet to overcome. For it to be used for signalling a working railway would probably require an independent safety case assessment.

Key token signalling has been around for a long time - but this is not to imply that it is due to be relegated to a dusty chapter of history. The use of physical tokens of authority – key tokens – now has a bright future in the railway industry fired on by the almost limitless possibilities of digital technology that can give an unprecedented level of operating flexibility to our minor railways – and maybe others.....

A video demonstration of the system can be seen at **irse.info/qwvar**

What do you think?

Could Ternkey be used for a conventional minor railway, tramway or other applications where a physical authority key is preferred, such as electrical isolation or hostile working? Would you be able to assist Grahame with taking it forward? Let us know what you think at IRSE News, **irsenews@irse.org** or contact Grahame at **gt@gftaylor.co.uk**.