SSL RE-SIGNALLING

by Nick Green

The Metropolitan, District, Circle and Hammersmith & City lines are being re-signalled with an updated version of the Jubilee & Northern lines' Transmission Based Train Control (TBTC) system called Communication Based Train Control (CBTC). The new system will reduce headways and give improvements to capacity and journey times.

The modernisation plan includes replacing rolling stock with S Stock trains, modifying depots, sidings and stations for these longer and faster trains, new Signalling and upgrading existing power infrastructure. We will concentrate on the basics of the new CBTC Signalling system being installed.

SIGNALLING CONTROL CENTRE

As per the Jubilee and Northern lines, the brains of the system will be at the centralised Signalling Control Centre known as the System Management Centre (SMC). This is where the scheduling and regulation is carried out via the timetables which are loaded to this sub-system. The System Management Centre communicates with the Vehicle Control Centre (VCC) which are also located at the centralised Control Room for a specific geographical area. For SSL there are 14 VCCs for 14 different geographical areas, for example, one VCC will manage vehicles (trains) between Finchley Road and Preston Road, another VCC for Preston Road to Moor Park/West Harrow. The VCCs ensure safe train separation and safe train movement throughout the system. They also oversee the train speed, direction, correct side door operation and also provides functions to support Automatic Train Operation (ATO).

The CBTC system is said to be a moving block system rather than a fixed block such as the current LU conventional signalling system. This therefore allows more trains to occupy the same section of track, but they are still kept a safe distance apart. This safety distance between trains is nominally a minimum of 50m.

LOOPS/VIRTUAL LOOPS

With the Jubilee and Northern Line system, the VCCs communicate with the trains via antennae cables (loops) running along the track within the running rails. These loops are up to 1km long on LU with the train reporting back to the VCC via the loop how far along the loop it has travelled. The train can do this accurately as the loop crosses over itself every 25m at what is known as a cross-over separation. The train can accurately position itself within the cross-over separations by counting tachometer pulses and can re-calibrate any wheel diameter changes due to wheel wear. An accelerometer checks acceleration, deceleration and gradient against the positioning system to give accurate positioning. Both the Tachometer & Accelerometer detect wheel slide and slip and correct any distance errors. As the train can accurately identify its position within the loop, the loop is split into virtual positions which allow several trains to be within the same loop. These positions are a loop crossover divided into four, so are therefore 6.25m in length. In turn, to aid accurate stopping, especially at stations these positions are spilt down into fine positions which are just less than 200mm in length. With the CBTC system on SSL the loops are being replaced with virtual loops which can be up to 3.2 km in length. The virtual loops are actually radio signals sent via Wayside Radio Units which the train receives via an antenna at the end of the train. In fact, there are two antennae on the train, one at each end to aid with reliability should one fail. The wayside antennae receive information back from the train which in turn is sent back to the VCC. The cross-over separations are replicated by transponders which are generally located at 25m intervals. They may be installed 25m, 50m or a maximum of 75m from one another but there will always be a minimum of three transponders per 100m. However, in station areas, to improve stopping accuracy, they may be installed at 12.5m intervals.

To aid reliability the Wayside Radio Unit signals overlap each other so that if for whatever reason the train doesn't receive a signal from one Wayside Radio Unit, it can communicate with the other unit.

For a train on the Jubilee & Northern lines to accurately identify itself, it must pass from one loop to another loop so to identify which end of the loop it had entered. A train can then be controlled under the TBTC system when this occurred at what is known as an Entry Point. Trackside marker boards identify these Entry Points. For the SSL CBTC system this can be achieved by traversing two consecutive transponders which are entry point enabled. These areas are also identified to the train operator via Entry Point Trackside marker boards.

TRAIN CARRIED EQUIPMENT AND TRAIN MODES OF OPERATION

In both TBTC & CBTC systems passenger rolling stock have two Vehicle On Board Controllers (VOBCs), whilst other fitted engineer's vehicles such as Battery Locos have one. The Sandite and Asset Inspection Train, however, will also be fitted with 2 VOBCs. With vehicles fitted with two VOBCs, only one will be in command of the train. Each VOBC has a unique Vehicle Identity number so that the Control Centre can identify each train.

The function of the VOBCs is for implementing Automatic Train Protection and, for passenger rolling stock, the Automatic Train Operation functions as well. It implements the commands issued by the VCC and monitors vehicle system status. The VOBC supervises train operation and automatically commands the Emergency Brakes to apply when safe operation cannot continue. It also reports back to the VCC its position along the railway.

There are four states of the VOBC:

Halted: The VOBC has stopped usually due to a fault. If the fault that caused the halt allows it, an auto restart will occur. The Train Operator can also instigate a restart.

Dormant: The VOBC is listening to the commands sent from the VCC.

Passive: The VOBC is in communication with the VCC and is not in control of the train but can take control straight away.

Active: The VOBC is in communication with the VCC and is in control of the train.

Passenger trains can operate in 3 modes:

Auto Mode (AM): Automatic Train Operation Mode – controlled by the VCC and driven by the VOBC. The maximum permitted train speed is enforced by the ATP system.

Protected Manual (PM): Controlled by the VCC and driven by the Train Operator. The maximum permitted train speed is enforced by the ATP system.

Restricted Manual (RM): Supervised and driven by the Train Operator with train speed restricted to 16kph by the train systems.

Both Auto and Protected Manual modes are known by the VCC as Controlled Trains, whereas the Restricted Manual mode is a Non-Controlled Train.

Therefore, Controlled Trains are Communicating Trains as they are a CBTC Equipped Train that is communicating with the VCC.

Non-Controlled Trains are manually driven trains which can't be controlled by the VCC – these include communicating Restricted Manual (RM) trains, Non-Communicating Tracked trains in RM mode and Network Rail trains or LU trains running in Tripcock mode in 'Interoperable' areas.

When the project is finished there will be limited lineside signals though in Interoperable area lineside Signals will remain for use by non-CBTC Trains. So, in CBTC areas, the information needs to be communicated to the Train Operator. This is done by the Signalling Information Display (SID) which displays the status of both VOBCs, the actual speed, target speed, distance to go and train mode.

It may also be noted that without station starting signals and associated platform repeater signals, a means of alerting station staff of that the train is ready to depart is needed. This is done by a flashing white light above the yellow car doors open light on the outside of the S Stock trains, as this denotes that the CBTC is about to issue authority to move.

STATION CONTROLLER SUB-SYSTEM (SCS)

Located at some stations is the Station Controller Sub-system (SCS). The function of this sub-system is to act as an interface with the VCC and trackside equipment and to control and/or monitor this trackside equipment which may include points, staff protection key switches, axle counters, point indicators, signals etc. In short, they are the computer based interlocking for the area.

The main component of the SCS is the Element Controller (known as the INTERSIG on the Jubilee and Northern lines). Each Element Controller has two processors for safety (two out of two voting) and there are two Element Controllers per interlocking for reliability. Therefore, if the two processors disagree, the system will hot-standby to the other system seamlessly (providing the processors on this Element Controller are in agreement!).

A station may have from 0 to 5 Station Controllers dependant on the area that they control. The station controllers as well as communicating with the VCC also communicate with other adjacent station controllers, which may be in the same or adjacent equipment room.

As per the VOBCs each Element Controller has its own unique identity number so the VCC can identify each individual Element Controller.

AXLE COUNTERS

In normal operation, train separation is controlled by the CBTC having detailed knowledge of the precise knowledge of the train’s locations, not the axle counters, so a number of trains can occupy the same axle counter block.

Axle counters are used as the secondary train detection system to track non-equipped trains and as a backup if train communication fails. It is based on the occupancy of Axle Counter Blocks (ACBs). This train position detection system provides an ACB length resolution so is a fixed block system. The ACB based train detection system provides less position accuracy than the CBTC, but enables the VCC to track the location of those trains that do not have functional On-Board CBTC equipment. These trains will therefore be separated by a safe distance of at least an ACB.

In Points and Crossings areas, the axle counter also acts as a diverse way of locking the Points in position when the ACB is occupied.

Axle counters can also be found at the boundaries of VCC areas to confirm that a train has travelled from one VCC area of control to the next one and not that the train has lost communication with a VCC.

AUTOMATIC TRAIN PROTECTION (ATP) AND AUTOMATIC TRAIN OPERATION (ATO) CONTROL

With the VCC knowing the location of the trains within its area of control via the radio virtual loop system and the status of points from the Station Control System, the VCC can issue a Target Point for the train to proceed. The Target Point for the train is calculated dynamically, that’s to say that as the train moves along the line the Target Point is recalculated until it reaches an obstruction such as a train ahead or Points not detected. A Target Point is not set from one end of the line to the other as it will lock out all other conflicting moves along the line. It therefore is set at a short distance ahead of the train. When, for example, the train ahead is approached by a following train, the VCC will issue the Target Point to be the safety distance behind this train ahead. As the train travels closer to the Target Point the speed at which this train can travel is reduced. The train’s speed is monitored by the ATP system so that if the train is travelling too fast for either the line speed or the permitted speed calculated by the VCC, the brakes are applied to reduce the train speed to a permitted level. When the train ahead moves on, the Target Point for the train behind is recalculated by the VCC and allows this train to proceed. This is one of the advantages over a fixed block system as straight away the second train can obtain permission to proceed. Also, with the VCC knowing the speed and location of the train ahead it can calculate the emergency brake application braking distance to allow the train in rear to travel as close is safely possible.