1. Introduction

Several pilot projects are currently underway to prepare for the introduction of ERTMS/ETCS, the new European train control system. By introducing ERTMS/ETCS it is designed to achieve interoperability, cut costs for command-control systems, improve infrastructure capacity, and create a larger market by standardising key system interfaces.

Crucial parameters for future operations management and hence also for the command-control technology can be extrapolated from the following:

- Forecasts for traffic volumes in the emergent European single market suggest there will be a substantial rise in the mid to long term. In the light of this, the railway system will need to raise its operating efficiency if it is to defend and extend its share of the transport market.

- The Railways are going to have to stand their ground as providers of transnational transport services. Concrete requirements for interoperable production systems are either already in force in the form of EU Directives or are in the course of preparation.

- Where passenger traffic in particular is concerned, commercial speeds and the frequency of services have a key bearing on how attractive the product is. In the process, demand for additional train paths on the open track and at junctions is increased.

- Building new lines will become increasingly difficult in future. Optimum utilisation of existing infrastructure accordingly has a crucial role to play.

The following illustrates how, by combining ETCS Levels 2 and 3, a contribution can be made to putting these objectives to effect. Attention is given to engineering and operating procedures as well as to further developments in train-protection and interlocking technology required.

2. Opportunities and problems involved in implementing ETCS Levels 2 and 3

ETCS Levels 2 and 3 are of particular interest when it comes to meeting the demand for economic implementation of train-protection systems in the high-speed sector and to operating high-density traffic.
2.1 ETCS Level 2

ETCS Level 2 allows trackside signalling to be dispensed with; instead, drivers receive the necessary movement authorities via their cab signalling systems. Movement authorities are determined by the radio block centre, the RBC, in conjunction with the signalbox and transmitted to the train. The line is fitted with clear-track signalling equipment and optionally with signals.

A Track section, which are defined by clear-track signalling equipment without signals is called partial block (PB).

With GSM-R being used to transmit information from the RBC to the vehicle, there is no longer any need for an inductive loop as with LZB continuous automatic train control. Investment in the line can be cut by approx. 50% and the cost of maintaining it by approx. 60%. This would make an expansion of the network of lines fitted today with continuous automatic train control as a means of raising line speeds and train-path throughput a far more favourable proposition than with LZB.

In the context of migration planning, therefore, studies are to be made of the most advantageous scenarios with regard to LZB replacement strategies, expansion of networks with continuous automatic train control, and the cost of refitting traction units.

2.2 ETCS Level 3

Given that, at ETCS Level 3, the train can clear the track in rear itself, there is then no longer any need for expensive trackside clear-track signalling equipment. Depending on a train’s configuration, it is presumed that the train can be regarded as being indivisible or else it is required to monitor its integrity. The same applies in respect of train length.

Level 3 permits movement of trains by means of either virtual or moving blocks.

The term ‘virtual block’ (VB) is used to designate a headway section in the ETCS radio block centre which is not defined by trackside clear-track signalling sections. The ETCS radio block centre assigns trains to these sections on the basis of location messages supplied by the trains itself and ensures that no section is subject to more than one train movement at any one time. The RBC assumes classical signalbox duties here - train-protection and signalbox functions are merged.

A moving block is one that moves at a defined distance behind the train in advance.

In terms of infrastructure capacity, virtual and moving blocks do not differ significantly since, at the latest when a junction at which groups of trains separate is involved, distances between trains have to be such as to enable safe operation of switches.

With both the virtual and the moving block, clear-track signalling equipment is no longer required, meaning that if, for instance, there were a need for additional paths, it would no longer be necessary to create additional clear-track signalling sections as is customary today.
2.3 Main problems concerning the introduction of ERTMS/ETCS

The following provides an overview of the main migration-planning and design-engineering problems facing the introduction of ETCS.

1. In the migration phase, there will be a need for a certain amount of duplicate fitting-out of traction units (or else of the track) with, on the one hand, conventional train control technology and, on the other, ERTMS/ETCS, since financial and organisational constraints make it impossible to refit all vehicles within a comparatively short time.

2. Retrofitting traction units with ETCS can be highly resource-intensive, especially where vehicles have not been prepared for such a retrofit. Cases in point are the cabling for sensors and antennas.

3. There are problems attached to the introduction of ETCS Level 3 because train integrity monitoring for freight trains has yet to be satisfactorily solved. Solutions are in sight for passenger trains with their own electric lines.

4. To implement Level 3 functionality, additions to the signalbox functionality are required.

5. As it is intended to dispense with trackside signals and clear-track signalling equipment at ETCS Level 3, all trains travelling over the portion of line or network concerned would have to be fitted out with ERTMS/ETCS. By contrast, train operators expect to be able to deploy their traction units as flexible as possible whilst only adopting the new technology for traction units that regularly travel over the lines concerned.

3. Concept for combining ETCS Levels 2 and 3

The combination of Levels 2 and 3 assumes trackside installations in which there is still a certain amount of clear-track signalling equipment and, overlaying these, virtual blocks are managed from the RBC.

Movement of trains in the virtual block is possible if the train in advance is established as being complete and if its length is known. Should a train in advance not have integrity, the train in rear may only follow at intervals defined by clear-track signalling equipment, that means in intervals of block sections or partial block sections. A train with ETCS Level 2 equipment can in the process run in partial or complete-block mode, whereas a train not fitted with ETCS can only operate in complete-block mode (from signal to signal).

From the point of view of cost (once migration has been completed) and of infrastructure capacity, Level 3 is to be preferred. Combining it with Level 2 reduces impediments to migration, however, enabling the advantages of Level 3 to be exploited at as early a stage as possible.

Under this concept, therefore, it would be possible to work the majority of local and long-distance passenger trains on a line in virtual blocks. Some trains for freight or long-distance passenger services - off-peak services for instance - can travel over this line despite only being equipped to ETCS Level 2. This reduces the carrying capacity of the line, however, since it is not possible to follow a Level 2 train at virtual block intervals.
If trains with no ETCS equipment are to work this line, signals will be required at specified intervals.

The concept of combining ETCS Levels 2 and 3 provides an opportunity to strike a golden mean between the practical benefits of the new system and the cost of fitting out traction units.

4. Example of procedure for Level 2/3

4.1 Considered track side infrastructure

Signal-controlled and ETCS-controlled vehicles are to be run at the migration stage.
In this specimen procedure, the increase in infrastructure capacity brought about by ETCS is only considered on the open track.
For an improvement in infrastructure capacity to be achieved at junctions, it would be additionally necessary to consider partial routes in the entry and exit areas of stations.
High carrying capacity is achieved on the open track by running at short block intervals under ETCS without the need to subdivide the line into block sections of the shortest possible length (braking distance spacings or half standard intervals) by means of fixed signalling. The open track is subdivided in virtual blocks.
To improve carrying capacity when the line is worked by non ETCS-equipped vehicles (e.g. as a fallback option in the event of the RBC failing), the line is generally subdivided into two admittedly very long block sections.
Each block section has its own clear-track signalling system and is protected by main signals.

4.2 Virtual partial blocks

In a virtual partial block (VB), ETCS-controlled vehicles may follow other ETCS-controlled vehicles.
This configuration is only feasible given modifications and additions to the route logic in the signalbox and the addition of features to the RBC.
The line may be subdivided into rigid VBs.
   The first virtual block on the open track always begins at the station/line (S/L) interface
   • for either-direction working, the S/L interface is level with the home signals
   • for one-direction running, the S/L interface is on the departure track at the axle-counting site for the line (see Fig. 4.2-1).

*** 447   Fig. 4.2-1 Station/Line interface ****
4.3 Train-sequence restrictions

Restrictions for non ETCS-controlled vehicles
- A complete block on the open track and limited by signals may be travelled over by non ETCS-controlled vehicles only on an overall block route.
- It is not possible for an ETCS-controlled vehicle to follow a non ETCS-controlled vehicle in a VB.
- It is not possible for a non ETCS-controlled vehicle to follow an ETCS-controlled vehicle in a VB.

Restrictions for ETCS-controlled vehicles
- An ETCS-controlled vehicle can only follow another ETCS-controlled vehicle in a VB if train integrity and train length of the ETCS-controlled vehicle in advance have been clearly established.

4.4. Minimum requirements for the existing command-control technology

Route setting, route monitoring and route release by means of electronic signalboxes at the station are prerequisites.
Signalboxes which already command LZB functions automatically meet - in generally - the minimum requirements for ETCS Level 2/3. The signalbox is required to be able to communicate with the RBC for the purpose of agreeing the formation and release of routes.
4.5 Interface between functional responsibilities

The first virtual block on the open track always begins at the S/L interface and this interface also always forms the limit up to which the station is responsible for clear-track signalling. It is worth considering locating a block marker at this position (e.g. for fall back situations). This does not necessitate any fundamental alteration of signalbox functions and provides a topographically defined interface between the functional responsibilities of the electronic signalbox (ESTW) for the station and of the RBC for the open track (ESTW/RBC).

4.6 Areas of functional responsibility

Area of responsibility of the ESTW
The ESTW continues to be responsible for the station area. In route logic terms, it is responsible for:
- Partial routes in the direction of exit up to the S/L interface.
- Overall routes in the direction of exit up to the central block signal and up to the home signal at the neighbouring station.
- Overall routes (and with the CIR-ELKE function possibly also partial routes) in the direction of entry from the S/L interface.

Area of responsibility of the RBC
The RBC is responsible for the open track. In route logic terms, it is responsible for:
- Virtual routes on the open track between the S/L interfaces of neighbouring stations.

4.7 Operational admissibility of an exit movement into a VPB

Operationally speaking, the two approaches cited below are feasible:

Early succeeding movement in the entry/exit area of the station (‘bundling’)
If an ETCS-controlled vehicle is to be allowed to follow another departing ETCS-controlled vehicle at the earliest possible opportunity, it is a condition of proving the admissibility of an exit route that the vehicle in advance is protected in the entry/exit area of the station by means of a virtual block (VB).

Keeping the entry/exit area of the station clear
If a vehicle on an outward run into a VB is to be able to pass speedily through the entry/exit area of the station so as to clear this production area as early as possible for other applications (e.g. an entry run), any disruptions on the open track must not be allowed to feed back into the entry/exit area of the station. Setting an exit route into a VB would accordingly only be admissible if the compete train fit to the free VB.
4.8 Conditions for route-logic functions in the signalbox

Releasing a route (‘train out of section’)
Following an entry run from a complete-block route, the signalbox releases the route (‘train out of section’)
if:
  • the home signal has displayed an illuminated proceed aspect
    and
  • the home signal has returned to stop
    and
  • the ‘line clear’ message has been given.

Exit routes
Permission by the RBC
The signalbox always requires permission from the RBC when setting a partial route (PR) up to the
S/L interface or another virtual block marker in the entry/exit (EE) area.
This is so because only the RBC can control trains at partial-route intervals or in a VB. So as to
avoid operational disruptions, routes of this type may accordingly only be set if the RBC is also
willing to assume control. Where this is not the case, such exit movements are only permissible at a
later time or else must be processed in a complete block.
4.9 Central block signals and their distant signals

Central block signals and their distant signals are controlled from the signalbox. Interdependencies with the RBC are as for starting signals. In the event of ETCS failing, they can be used as a fall-back option.

4.10 Extinguishing stand-alone distant home signals

A stand-alone distant home signal is to be extinguished when the home signal is extinguished. If an ETCS-controlled vehicle enters the station and occupies the clear-track signalling section in rear of the entry section, the home signal would be set at “Hp0 lit” by the signalbox. The stand-alone distant home signal would then also be set at “Vr0 lit”.

Under certain circumstances, the driver of a following ETCS-controlled vehicle travelling within view of the distant home signal might then see the signal being switched from extinguished to “Vr0 lit” and, shortly thereafter, to extinguished again, since the RBC will in the meantime have requested that the distant signal be extinguished for that vehicle (see Fig. 4.9-1).

This change in signal status can be circumvented if extinction of the distant signal is initiated by the RBC.

This presupposes the following exchange between the signalbox and the RBC:
- The RBC requests the extinction of a distant home signal when the first ETCS-controlled vehicle enters the open track.
- The signalbox extinguishes the distant home signal and indicates this on the display medium.

*** 447 Fig. 4.9-1 Potentially visible changes at the distant signal ***

Fig. 4.9-1 Potentially visible changes at the distant signal

Illumination of the distant home signal by the RBC

Once the last ETCS-controlled vehicle has run past the distant home signal, the RBC requests the signalbox to illuminate that signal.
- The signalbox illuminates the distant home signal and indicates this on the display medium. The distant home signal only needs to be lit in this way if the corresponding home signal is reset at “Hp0 lit”. Only once the home signal has been set at “Hp0 lit” is a complete-block route ending at this signal and commencing at the central block signal in rear permissible and functionally feasible.
4.11 Extinguishing the home signal

If train headways are very tight or sighting conditions for the home signal are particularly favourable, the driver of a succeeding ETCS-controlled vehicle might be able to observe similar changes of status as set out for the distant signal when approaching the home signal.

Illumination of the home signal by the RBC

These changes in home-signal status could be avoided if illumination of the home signal were only initiated by the signalbox with permission from the RBC. This presupposes the following exchange between the signalbox and the RBC:

- The signalbox requests illumination of a home signal when an ETCS-controlled vehicle occupies the clear-track signalling section in rear of the entry section.
- The RBC assents to this if the ETCS-controlled vehicle entering is the last vehicle on the open track.

5. Outlook

Combining ETCS Levels 2 and 3 offers a flexible means of shaping the ETCS migration process - notably as regards the refitting of traction units. The long-term approach makes for a significant reduction in the cost of migration. This concerns preparations for fitting out traction units as well as, in future, the adaptation of signalboxes, in particular with regard to Level 3 functions. At some later point, potential for integration in this respect will need to be investigated.

Where the monitoring of train integrity and train length is concerned, concepts for passenger traffic have already been trialled. Operationally and economically suitable solutions for freight traffic have still to be devised. Potential solutions could be the integration of train integrity functions in new brake systems of trains in the future and the track side monitoring of the train length at stations, where freight trains are formed.

ETCS Level 2/3 can make an important contribution towards exploiting infrastructure capacity to the full in both micro-economic and macro-economic terms. Implementation necessitates a long-term approach to scheduled traction-unit and signalbox procurement programmes as well as targeted initiatives to provide and test yet-to-be-finalised system components.