Function of Motive Situation in Procedure of Leadership of Train Equipped with System ERTMS

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The Railway Infrastructure Manager in Poland initiated the implementation of the ERTMS system. This paper presents the description of level system, modes of work traction vehicles, basic parameters of system and also the exemplary principles of the system operations. These parameters are the elements used by operating scenarios which describe the behaviour in traffic situations on railway lines included in the development of the ERTMS system.

Keywords: ERTMS/ETCS, system levels, work modes of traction vehicles, operation scenario.

1. INTRODUCTION

The European Union aims to achieve a unified European railway system, where railway interoperable infrastructure managers will permit for operations interoperable rolling stock from different operators, realising passenger and cargo transport.

It is estimated that through such transport policy interoperable European railways will be able to meet the following goals by 2020:

- 10% market share of passenger transport in the EU, which doubles the number of carriages in passenger-kilometres in less than 20 years,
- 15% market share of cargo transport in the EU, which triples the number of carriages in tonne-kilometres in less than 20 years,
- triple increase in effectiveness,
- elimination of disasters in the European interoperable railway traffic,
- increase of 50% energy consumption effectives
- decrease of 50% harmful substance emission
- increase in railway network efficiency for allowing realisation of planned railway carriages.

The goal is to ensure the maximal interoperability of transport, especially rail transport in Europe. This is one of the key ventures which should be realised with the use of ERTMS (European Rail Traffic Management System).

EU countries form the final shape of the ERTMS implementation plan for the whole EU by passing their National ERTMS Implementation Plans, the moment they are submitted to the European Commission. The European ERTMS implementation plan establishes the development of interoperable railway pan-European connections.

According to the National ERTMS Implementation Plan in Poland, the implementation of ERTMS/ETCS is planned on 5,000 km of lines and ERTMS/GSM-R on 15,000 km of lines.

At this time the railway infrastructure managed by the company PKP Polish Railway Lines (PKP PLK S.A.) is equipped with both systems, according to the above mentioned plan. From the ERTMS/ETCS side, the realised projects are developed with level 1 track side infrastructure elements on section of E 65 railway line (about 224 km), CMK line (Central Rail Main line), Grodzisk Mazowiecki – Zawiercie and both track side infrastructure elements and on-board equipment on section of E 30 line (about 84 km) Legnica – Węgliniec – Bielawa Dolna (national border). From the ERTMS/GSM-R side the system's equipment is installed on the above mentioned section of E 30 railway line (as a

separate contract exclusively in regard to the communication system).

All systems operated on the PKP PLK S.A. managed network are described in documents presenting overall information on the topic of operated system functional scope. Such documents should be prepared for the currently installed system. The easiest way to gather and forward information on both ERTMS/ETCS and ERTMS/GSM-R system functional principles to the users is the preparation of a set of scenarios, which show the sequence of events seen from the operation activities' side. Information on the ERTMS/ETCS system functional scope will be presented further in this article.

The prepared scenarios are based on one main source, which is the SRS ERTMS/ETCS – Class 1 document, Subset-026, version 2.3.0. along with Subset-108, version 1.2.0. All terms and abbreviations are in compliance with Subset-023.

2. LEVEL DESCRIPTION ACCORDING TO ERTMS/ETCS

The full description of all levels is enclosed in the SRS ERTMS/ETCS Class 1. All trains not equipped with ERMS/ETCS on-board equipment will receive the Drive Permit (free path signal) through the track side traffic lights. Vehicles equipped with level 2 ERTMS/ETCS on-board system will receive the Drive Permit from the RBC (Radio Block Centre) via GSM-R secure data transition. Vehicles equipped with level 1 ERTMS/ETCS on-board system after passing the balises located by the track side signalling system traffic lights. Traction vehicles may have the ability to work in different regimes (levels and modes) depending on the compatibility between on-board and track-side equipment.

Trains equipped with ERTMS/ETCS on-board equipment will be informed about which ERTMS level is operated on a particular area the moment the train passes the set of balises, which inform about approaching to a specific ERTMS/ETCS area. The on-board equipment will switch to their highest operated ERTMS level, which is defined in the available transition table in compliance with SRS ERTMS/ETCS Class 1.

2.1. LEVEL 0

Level 0 is used by trains equipped with ERTMS on-board equipment without being equipped with STM (Specific Transmission Module) for class B national systems (in Poland SHP [Automatic Train Braking System] and RADIOSTOP), at the same time equipped with independently working class B national systems. Level 0 is used during drives of above mentioned trains on railway lines not equipped with track side ERTMS/ETCS system equipment. Handling of trans not equipped with on-board ERTMS/ETCS system equipment, but at the same time equipped with independently working class B national equipment is based on current traffic operation rules.

One must notice the on-board ERTMS/ETCS system equipment operating at level 0 only oversees/supervises the maximal speed limit exceeding on a non-equipped area.

2.2. LEVEL STM

Level STM is used by trains equipped with ERMS/ETCS system on-board equipment as well as equipped with STM module for class B national systems. Level STM is used during the above mentioned trains drives on railway lines nor equipped with track side ERTMS/ETCS system equipment.

In the level STM the on-board ERTMS/ETCS system equipment is not used to supervise/oversee train drives and the train driver is obliged to supervise/oversee the train speed according to information provided from the track side traffic lights and from class B national systems.

2.3. LEVEL 1

This level is used for drives of trains equipped with level 1 or level 2 on-board ERTMS/ETCS system equipment in areas equipped with level 1 track side ERTMS/ETCS system equipment.

2.4. LEVEL 2

This level is used for drives of trains equipped with level 2 on-board ERTMS/ETCS system equipment in areas equipped with level 2 track side ERTMS/ETCS system equipment.

In order to achieve the use of lines by trains equipped with proper level on-board ERTMS/ETCS system equipment and non-equipped trains, the equipping of railway line sections in the framework of currently run contracts should be equipped in such a manner, that the above mentioned levels are supported. This means they are equipped with: rail circuits or axle meters, SHP electromagnets, traffic lights and will by additionally equipped with sets of balises.

3. ON-BOARD EQUIPMENT WORK MODES

Details regarding particular work modes of on-board equipment, both regarding level 1 or level 2, described in the document SRS ERTMS/ETCS – Class 1, Subset-026, chapter 4, are as follows:

Mode symbol	Mode title
IS	Isolation
NP	No Power
SF	System Failure
SL	Sleeping
SB	Stand By
SH	Shunting
FS	Full Supervision
UN	Unfitted
SR	Staff Responsible
OS	On Sight
TR	Trip
PT	Post trip
NL	Non Leading
SE	STM European
SN	STM National
RV	Reversing

The level of supervision of train drive will be appropriate to a particular work mode. In case of level 2 the train additionally informs RBC of current work mode of the on-board ERTMS/ETCS system equipment. Some work modes may be implemented only on demand sent by the RBC.

The full description of conditions and possibilities of transition between the above mentioned modes is presented in a detailed manner by an appropriate diagram of transition in the SRS ERTMS/ETCS Class 1 document.

4. SYSTEM PARAMETERS

The ability to attribute value variables, while preparing application data, should be possible for the whole area of ERTMS/ETCS system influence, in the following parameters:

- Package 3: National Variables,

and for level 2 also different additional packages, required for proper track-vehicle transmission in the whole area of RBC system influence.

Package 3 (National Variables) – values PKP PLK S.A.		
D_NVOVTRP	200 m	Maximal movement distance able to achieve, when "Override EoA" function is activated
D_NVPOTRP	0 m	Maximal reverse movement distance in PT mode
D_NVROLL	2 m	Acceptable rolling distance
D_NVSTFF	∞ (= infinity)	Maximal movement distance in SR mode
M_NVCONTACT	1 (= service braking)	ETCS system equipment reaction determination on elapsed time specified by T_NVCONTACT variable
M_NVDERUN	1 (= Yes)	Variable determining if the train driver can input a ne driver id value during train drive
Q_NVDRIVER_ADHES	1 (= Allowed)	Modification of trackside adhesion factor by the train driver
Q_NVEMRRLS	1 (=immediate release function is available)	Qualifier of authorization of emergency braking interruption
Q_NVSRBKTRG	1 (= Yes)	Qualifier of authorization of the service brake during the implementation of the controlled braking to the target destination
T_NVCONTACT	20 s	The maximum time of an acceptable lack of communication between ERTMS/ETCS system on-board equipment and the RBC. If the time is longer than described by T_NVCONTACT value, telegrams from the RBC will not be received ERTMS/ETCS system on-board equipment shall undertake the response defined by the M_NVCONTACT variable
T_NVOVTRP	60 s	Maximal time of function "Override EoA" activity
V_NVALLOWOVTRP	0 km/h	Maximal allowed speed for the train driver to activate the "Override EoA" function
V_NVONSIGHT	20 km/h	Maximal allowed train speed for drives in OS mode
V_NVREL	20 km/h	Maximal allowed speed limit for Release Speed
V_NVSHUNT	25 km/h	Maximal allowed train speed for drives in SH mode
V_NVSTFF	40 km/h	Maximal allowed train speed for drives in SR mode
V_NVSUPOVTRP	20 km/h	Maximal allowed train speed "Override EoA" function is active
V_NVUNFIT	160 km/h	Maximal allowed train speed for drives in UN mode

5. OVERALL RULES

Other different definitions and functions, not repeated when describing a particular operation scenario, are also used for specific traffic situations, described as ERTMS/ETCS system functional rules, in the framework of specified contract parameters in currently realised projects (different ERTMS/ETCS system equipment development architecture). The examples of constituents created for system functioning rules are presented below.

5.1. MOVEMENT AUTHORITY

Movement Authority (MA)is a permit presented to the train to use a set and confirmed drive path for that train, particularly through the path length it allows the train to pass. MA sent to the train provides the distance as a total of consecutive confirmed path elements. The end of MA, so called EoA (End of Movement Authority), describes the end of the last element of the whole confirmed path for the train. The place the MA ends is signalised by an actual track side traffic light.

In level 1 the information from MA is sent to the on-board equipment via balises, and in level 2 the information from MA is sent to the on-board equipment via RBC.

5.2. PATH DESCRIPTION

Along with MA an additional information on track description in the train path is necessary. This information concerns at least the path between the estimated front of the train and the EoA. The on-board equipment should reject such MA if the information is incomplete.

The track description always contains the statistical speed profile and reliable slope profile. As an option the description may also contain different circumstances such as for instance the speed profile dependent on axle pressure, track

situation, data on path adaptation or also information of adhesion factor change.

5.3. INFORMATION FROM SET OF BALISES

All sets of balises have their own unique identification number. It is used for train position determination. The cumulating train position calculation error is neutralised when the train passes a set of balises. It is recommended the reaction to balises connection (balises correlation) discrepancy is set to "Service Braking Implementation"

In case of level 2 sets of balises, installed in front of the RBC supervised area, the set of balises contains information demanding the on-board equipment to register in an appropriate GSM-R network and demand establishing connection to RBC of a given id and a phone number.

Sets of balises installed on the RBC area border contain so called priority table for ERTMS/ETCS levels, supervised by track side system equipment.

5.4. KEY MANAGEMENT

In case of level 2 ERTMS/ETCS, cryptographic keys (KMAC) are used during the time a communication session is initiated between the on-board equipment and the RBC. The IM (Infrastructure Manager) is responsible for key service and maintenance.

5.5. TIME STAMPS AND TIME EXCEEDING CONTROL

All telegrams sent between the RBC and the train include so called time stamps (T_TRAIN) in case of level 2 ERTMS/ETCS system, which is used to detect expired telegrams and to begin time measurement for sections with a term MA. All time stamps refer to the on-board time, that means both the train and the RBC use time stamps declared by the on-board equipment time. When the RBC sends a telegram to the train, the RBC measures the time (Dt), which has passed since the last received message from the train.

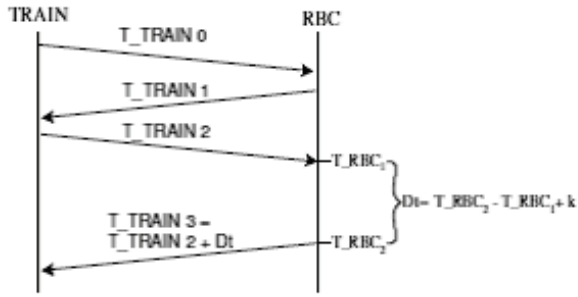

Fig.1. Time stamps and time exceeding control.

Both the RBC and on-board equipment should verify whether the received telegram has a time stamp higher from the time stamp sent in the previously received message. Telegrams with repeated or older time stamps cannot be accepted, that means such a telegram is rejected and the supervision is carried out on the basis of the correctly previously received telegram. To ensure two telegrams sent to the train in the same RBC work cycle do not have the same time stamps a certain constant (τ) is added.

6. OPERATION SCENARIOS

6.1. GENERAL INFORMATION

Within each realised project appropriate operational scenarios are developed, which constitute a set of functional rules of level 1 or level 2 ERTMS/ETCS system for determined possible to exist traffic situations, in compliance with determined contract requirements. A description of each scenario is divides into several parts, which consist of:

The initial stage – describes the assumed/estimated beginning conditions. A proper figure diagram (figure/picture) is prepared for the initial stage description in some cases.

Chain of events – description of event sequence, which may be presented as a list of consecutive events or as block schemes (so called information flow diagrams). In basic scenarios ERTMS/ETCS language telegram and package numbers may be additionally presented in order to characterise a specific transition.

Expected results are presented as a sequence of further events in the case of an event list. An exact sequence of events may slightly differ in reality, because the actions of a traffic operator and a train driver are not exactly synchronised.

A description using conditional operators generates many possible transition sequences in case of a block scheme. Basically only one sequence is described in the scenario. In some

cases it is enough to describe the events in text form (without diagrams).

Intermediate stage – optional form of the final state of an event, which at the same time is the initial stage for a consecutive event. For some more complicated scenarios such additional intermediate stage is initiated in order to ease the understanding of the system state after using the previous event and before the consecutive event occurs.

The final stage – describes the final stage after all events described in a particular scenario are used and sometimes describes also the conditions for an activity continuation after intercepting a specific event sequence. Not in all cases an end state must emerge. Sometimes a situation occurs in which an operational scenario can include several final stages which are precisely distinguished and described as consecutive situations.

Comments – some scenarios may require a comment. The comments may comprise of:

- short description of a different system behaviour in case some events occur in a different sequence to the one described in the main scenario.
- information that the system behaviour can be the same if a different event, not described in the main chain of events, occurs in the meantime.
- additional requirements which are necessary for one of the evens described in main event sequence to occur.
- reference to a different scenario, which presents the problem announced in a singular event in a more complex manner.

Each scenario describes strictly a sequence of events connected with a specific case. In order to achieve a complete scenario sometimes one must compile several scenarios.

6.2. BLOCK SCHEMES

Some operational scenarios are described using block schemes (information flow diagrams), for construction of which the following blocks are used

- unit block responsible for all actions along the transition line,
- event or action block with a definite result,
- event or action block with a definite result, which is dependent on certain conditions,
- block indicating the main chain of events or information flow,
- block of an alternative chain of events or information flow,
- block of an alternative chain of events which may plead back to the main sequence,
- indication block, that means indications on train driver's or traffic operator's monitor,
- ETCS on-board equipment work block.

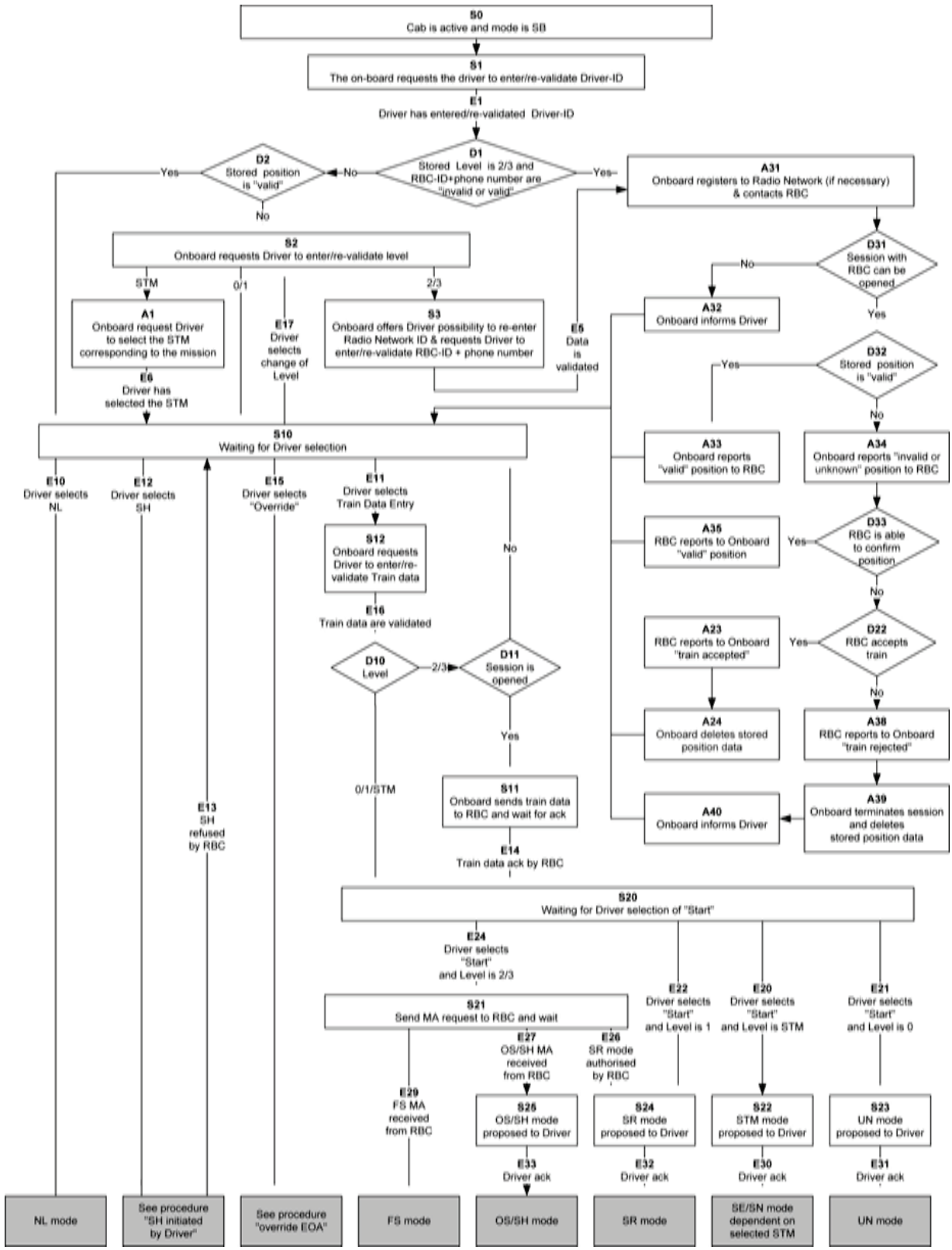

Fig. 2. Block scheme of traction vehicle starting up in a defined on-board equipment work mode.

The following can be found as units in the block schemes:

- Track – presents information arriving from sets of balises,
- Train driver/ DMI – presents the activities of the train driver and information shown to the driver on the on-board ERTMS/ETCS-DMI desk,
- Train/ETCS – presents events connected with the on-board ERTMS/ECS equipment activities,
- RBC – presents events connected with the Radio Block Centre activities,
- CMI – presents events connected with the CMI panel activities, which is used by the traffic operator to operate ERTMS/ETCS system track side equipment, i.e. RBC computer,
- Traffic operator – presents events connected with the activities of the traffic operator.

Some block schemes may also consist of a telegram list, which are sent between particular units.

7. RECAPITULATION

The above presented elements are the basis for the development of level 1 and level 2 ERTMS system operation rules. These rules for both projects are described in the operation scenarios dedicated to the particular sections, which also contain such operational elements as: entry to ERTMS/ETCS area, exit from the ERTMS/ETCS area, issuing MA, train start at traffic post, train division and joining, implemented temporary speed restrictions, sent text messages, shunting, special situations (separately) both for traction buildings and ERTMS/ETCS system, dangerous situations, railway crossings and many other specific conditions defined in the contract as well as in the traffic conditions on the considered railway line.

LITERATURE

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