In2Rail

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Deliverable D10.4
TMS/MMS Interface Specification

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Executive Summary

The overall aim of the In2Rail (I2R) project is to set the foundation for a resilient, cost-efficient, high capacity, and digitalised European Rail Network.

Intelligent Mobility Management (I2M), a sub-project of I2R, is one of the three technical sub-projects and comprising Work Package 8 (WP8). WP8 addresses and develops a standardised integrated ICT environment capable of supporting diverse TMS (Traffic Management System) dispatching services and operational systems such as power supply systems and Maintenance Management Systems (MMS).

The main objective of Work Package 10 (WP10) is to work on the design of an intelligent traction feeding system for AC rail power supply to allow a controlled energy flow inside the Rail power grid and to optimise the interface with the public power grid.

The current document corresponds to the fourth deliverable of WP10, and is focused on the description of the required data structure and communication pattern structure for the interfaces between TMS/MMS and the ETS (Electric Traction System).

Even if the TMS as well as the ETS and other components are in the hand of an Infrastructure Manager the systems are not fully integrated today and optimized only separately for themselves. Today's TMS do not consider the actual status of the ETS. Hence, train schedules and changes to them typically do not consider restrictions in the ETS and might not be optimized towards energy efficiency. Benefits can be leveraged by interaction of these systems.

Particularly the introduction of an MTS (Multi Train Simulator) is beneficial if considered as a part of the ETS. Evaluation of limitations in the ETS during major outages is enabled and resulting consequences on scheduling of trains can be communicated to the TMS. Model-based now-casting of electric energy is enabled for different points of common coupling between the ETS and the public grid. This potentially leads to new opportunities in energy purchasing by now-casting of peak power and energy demand. Reduced maintenance cost of the ETS is expected by use of the interface to an MMS (Maintenance Management System).

According to WP8 results, these interfaces are to utilise the so called "Canonical Data Model" (CDM) for interfacing with TMS and MMS. Consequentially, the respective enhancements to the CDM being required for communication to and from Power Supply systems are described as part of this document.

The research has been conducted by all partners of WP10, and the input been consolidated to form this comprehensive document.

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Abbreviations and acronyms

Term	Description
AF	Application Framework
AL	Application Layer
API	Application Programming Interface
CDM	Canonical Data Model
CENELEC	European Committee for Electrotechnical Standardization
COTS	Commercial-Off-The-Shelf
EMS	Energy Management System
EN	European Standard
ETS	Electric Traction System: as per definition of FprEN 50562 and described in Chapter 6. In most systems the running rails are forming a major part of the return circuit. The running rails are therefore part of the track work as well as the ETS.
EU	European Union
ICT	Information and Communication Technologies
iEMS	intelligent Energy Management System
IF	Interface
IL	Integration Layer
IM	Infrastructure Manager
IT	Information Technology
I^2M	Intelligent Mobility Management
I2R	In2Rail
JSON	JavaScript Object Notation
MMS	Maintenance Management System integrated with TMS via the IL
MTS	Multi Train Simulator
OBU	On-Board Unit
OCS	Operational Control System
REST	Representational State Transfer
RPC	Remote Procedure Call
RSC	Product name
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCS	Stration Control System
SOAP	Simple Object Access Protocol
TMS	Traffic Management System
TSR	Temporary Speed Restriction
UI	User Interface
UML	Unified Modelling Language
UUID	Universal Unique IDentifier
WP7	Work Package 7
WP8	Work Package 8

Term	Description
WP10	Work Package 10
WP11	Work Package 11: Smart Metering for a Railway Distributed Energy Resource Management System (RDERMS)
RDERMS	Railway Distributed Energy Resource Management System
XML	eXtensible Markup Language
XSD	XML Schema Document

1 Background

The present document constitutes the first issue of Deliverable D10.4 "TMS/MMS Interface Specification" in the framework of the Project titled "Innovative Intelligent Rail" (Project Acronym: In2Rail; Grant Agreement No 635900). It is part of In2Rail's sub-project "Rail Power Supply and Energy Management" under work package number WP10 "Energy Management - Intelligent AC Power Supply System". WP10 defines the design of an intelligent electric traction system using alternative current (AC) power supply. It covers the basic investigations and the design works at technical readiness level TRL 1-3 for implementing the demonstrator for the "Intelligent AC Power Supply System".

Deliverable D10.4 is the outcome of the corresponding Task 10.4 which covers analysis of functional and technical requirements for interfaces to infrastructure management and operation, i.e., Traffic Management System (TMS) and Maintenance Management System (MMS). The results from I²M Work Package 8, task 8.1 (Integration Layer) are incorporated into this analysis.

The objective of this task is to finally specify the interfaces between Energy Management / Power Supply Systems and TMS/MMS as being covered this document.

The Task 8.1 of WP8 (Integration Layer) includes deliverables being related to this document as shown in Figure 1.1.

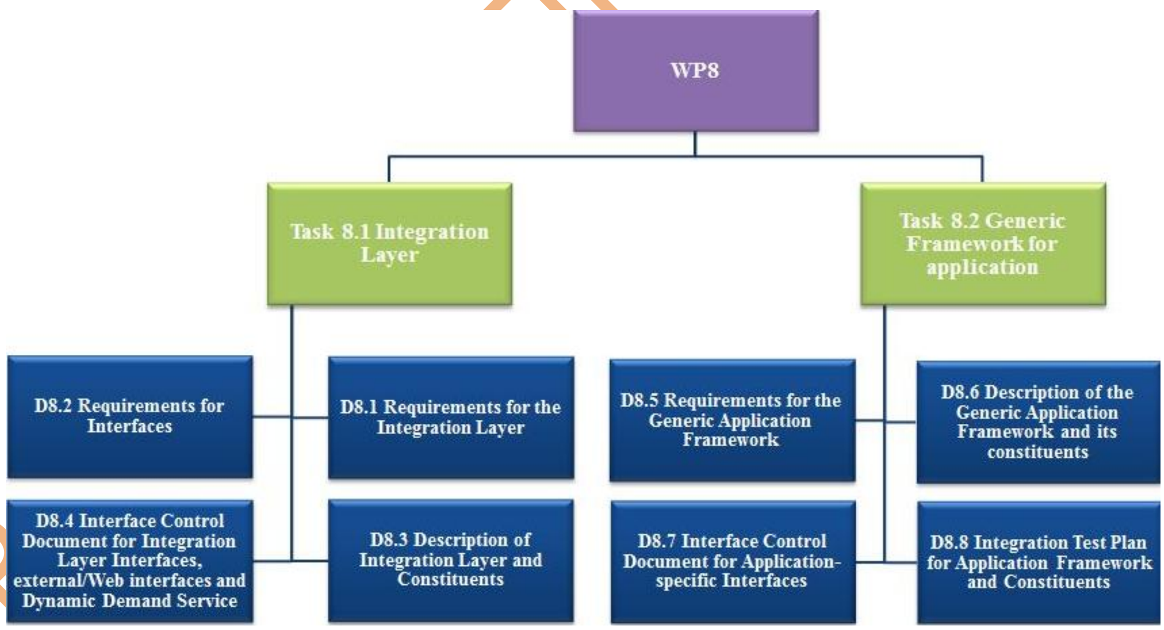

Figure 1.1: Deliverables of WP8

The requirements analysis as part of Task 10.4 was carried out in accordance to the knowledge and skills of the participants. The requirements have been set up in accordance with the deliverables of Task 8.2 which partially were available only as draft version at time of creation of this document. All requirements were discussed within WP10 workshops and meetings.

2 Objective / Aim

The objectives of In2Rail's WP10 are described in ANNEX 1 of the In2Rail Grant Agreement No. 635900 and can be summarized as follows. The main objective is to work on the design of an intelligent electrical traction system for AC rail power supply, in order to allow for a controlled energy flow inside the electric traction system (ETS) itself as well as to optimise its interface with the public power grid. This shall result in reduction of:

- transmission losses up to 50 %;
- investment by reducing installed equipment up to 25 %;
- investment for public grid connection;
- costs resulting from energy consumption and peak power demand.

Deliverable D10.4 as direct outcome of Task 10.4 focuses on specification of the functional and technical requirements resulting from the analysis undertaken in Task 10.4 whilst incorporating the results from the I^2M work package 8 (TMS; here especially Task 2 - Integration Layer). During the analysis phase all relevant asset data have been identified and defined jointly by all participants. Furthermore, a service compliant technical specification for the bidirectional interfaces between Energy Management / Power Supply Systems and TMS/MMS is given.

The interfaces are connected via the Integration Layer (Task 8.2) to integrate with a standard ICT environment which supports diverse TMS and MMS services as well as other operational services and systems of Railway Infrastructure Managers. In this document, a FIS level specification is given only whereas more detailed specifications (i.e., FFFIS) are to be found in deliverable D8.4 (Interface Control Document for Integration Layer Interfaces, external/Web interfaces and Dynamic Demand services).

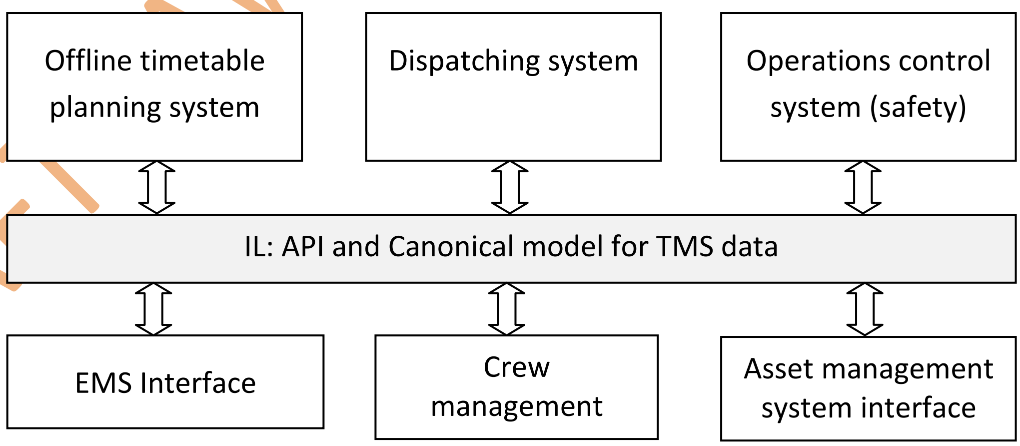

Figure 2.1: Integration of TMS with EMS and other TMS external resource management systems via the Integration Layer (IL)

3 Breakdown

The TMS/MMS Interface Specification is given by the following chapters:

- Chapter 1: “Background”: giving the context of the contents of the document specifically with respect to the scope and relation to WP8;
- Chapter 2: “Objectives / Aim”: defining the purpose of the document and the associated boundaries of applicability;
- Chapter 3: “Breakdown”: this chapter;
- Chapter 4: “Introduction”: a brief introduction into the specific business and technical structure of the energy supply and distribution environment of the European railways;
- Chapter 5: “Access Technology”: provides an overview of different types of access technology as being covered by D8.4 and describes the chosen access technology;
- Chapter 6: “Interface to Railway Traffic Management System (TMS)”: describes the different parts of the TMS interface and how they are connected to the Integration Layer of the TMS;
- Chapter 7: “Interface to Maintenance Management System (MMS)”: describes the different parts of the MMS interface and how they are connected to the Integration Layer of the MMS;
- Chapter 8: “Test scenarios”: includes a description of how scenarios for testing the interfaces are set up and handled within this project;
- Chapter 9: “Conclusions”: a set of conclusions summarising the content of this document and context with respect to further Shift2Rail.

4 Introduction

In the following chapter, we give a brief introduction to better understand the specific business and technical structure of the energy supply and distribution environment of the European railways. A specific focus is set to describing general outlines of an Electric Traction System (ETS), which represents the fundamental part of the electrical power supply architecture for railways.

4.1 Impact of EU Regulation

Different IMs usually have a different structure and organisation with related responsibilities. Similar to the European railways, EU regulations for the European power supply and market and related infrastructure lead to separation of public and private institutions and companies in the different member states. In order to foster correct transposition of the European electricity and gas legislation towards a liberalized market, the EU adopted the Third Internal Energy Market Package in 2009 (*Directive 2009/72/EC*), which sought after acceleration of investments in energy infrastructure for enhancing cross border trade and access to diversified sources of energy. The EU advises three options to weaken the market power of the few biggest electricity firms still existing: ownership unbundling, independent system operator (ISO) and independent transmission operators (ITO).

As a consequence, the EU railway energy market of today is characterised by separation of Energy Supply (DSO=Distribution System Operator, e.g., *DBEnergie*) from the Power Utility (TSO=Transmission System Operator, e.g., *RWE*, *Vattenfall*) whereas the owner of the Infrastructure (Contact Line System) is typically the railway infrastructure manager (IM).

4.2 General description of Electric Traction (Power) System ETS

As there is no general description for the purpose of the interfaces to TMS and MMS to be found in other work package deliverables, a description is given here.

The figure below shows a general description of an Electric Traction System. The source of the graphic is the standardization working group preparing the EN50562 within the CENELEC (see [EN50562]). Please note, that the figure itself is taken from the preliminary standard FprEN 50562 accompanied by a more comprehensive description within Chapter 6.

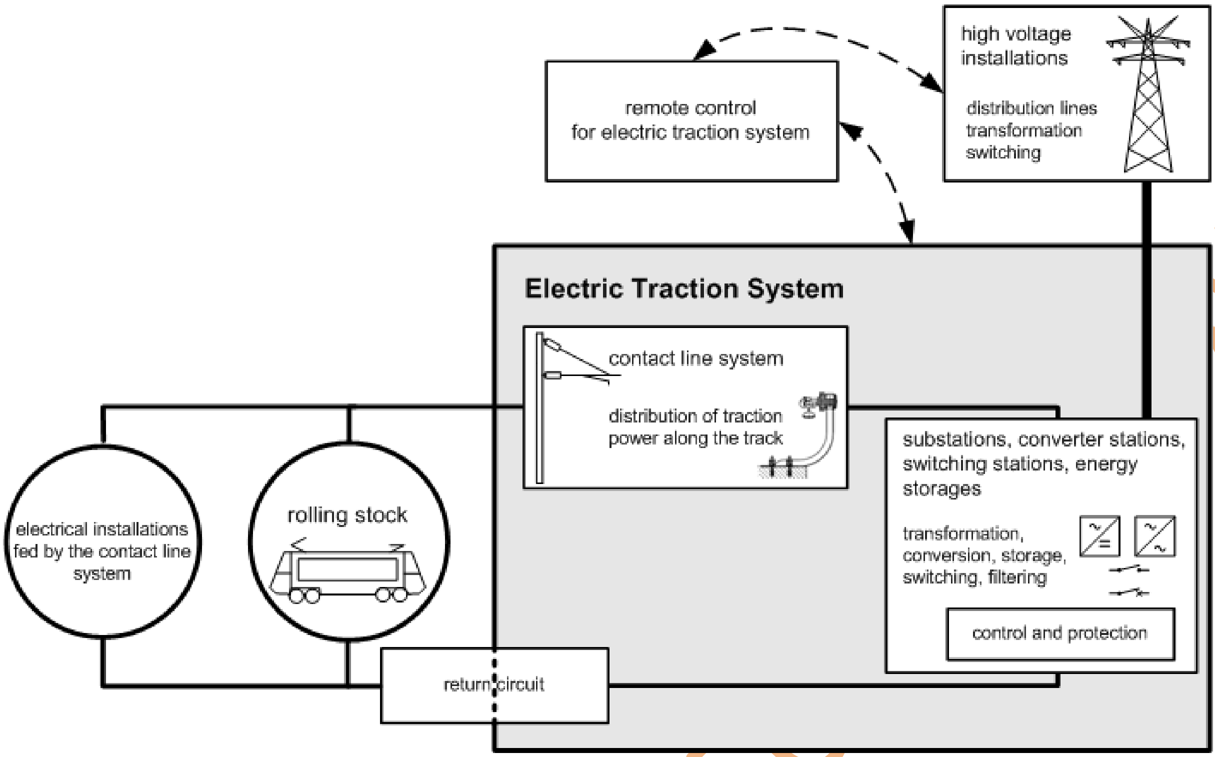

Figure 4.1: Electric Traction System general description according to FprEN50562

It is quite difficult to give a general description for all systems as the organisation is different for every railway. Some infrastructure owners are operating a high voltage network and/or a medium voltage network as well as the electric traction system. Some infrastructure owners are only operating the electric traction system. Some parts of the following description are included or not included for specific railways.

The purpose of the electric traction system is to drive rolling stock. In most systems the trains / vehicles are supplied by a contact system. This contact system is an overhead contact line or a third rail. The running rails are part of the electric traction system as they provide the return path for the current.

The contact line system is divided in sections. These sections can be energized (switched on) or not (switched off). For the purpose of this report it is assumed that it is controlled by the next substation or switching station. In a lot of cases a feeding section is energized from two sides.

A substation is feeding the contact line system, i.e. connection to DSO. A switching station is connecting or disconnecting parts of the overhead contact system. A substation is fed by an upstream network or in some cases by a generator.

4.3 Basic characteristics of ETS

4.3.1 Highly redundant system

The power supply part is highly redundant. In case of any outage other components can take over the function. For example, if a substation is failing the neighbouring substations take over the load. The substation is designed with additional capacity to provide such redundancy during these operational scenarios. This means that they are over-specified for normal operation. A reconfiguration of the electric traction network is needed in order to activate the redundancy. This guarantees that the availability of the electric traction system is far higher than the availability of the components. Exception from this statement is the contact line system, which has a very low failure rate. However, if it fails the affected track cannot be used. Not every fault is a failure of the system as the most common failure is an insulation fault of an overhead contact line. In this case the power supply is switched off. After a short time (i.e. < 1 s), the contact line is energized again and can continue to operate. This is resulting from the kind of transient faults.

4.3.2 No major wear

Electric traction systems do not have major components with a wear. The contact line system has a long term wear over decades. Electric switches can operate normally a lot of cycles. Transformers have no mechanical wear as well as rectifiers. Electronic components like protection relays have a failure rate but no wear. In some cases ventilators and pumps are used for cooling purpose. If so they are mostly redundant.

4.4 Description of ETS control system architecture

The following figures are taken from Siemens products as they are easily available. But the description is deemed to be general. From the requirements of the systems, it is straight forward to build electric traction systems in a similar way.

The figures are showing different levels of automation and their relationship with slightly different vocabulary as it is not completely standardized. The direction top down are commands to the equipment. The direction bottom up is messages and measured values. The connection to other systems is normally done at the highest level.

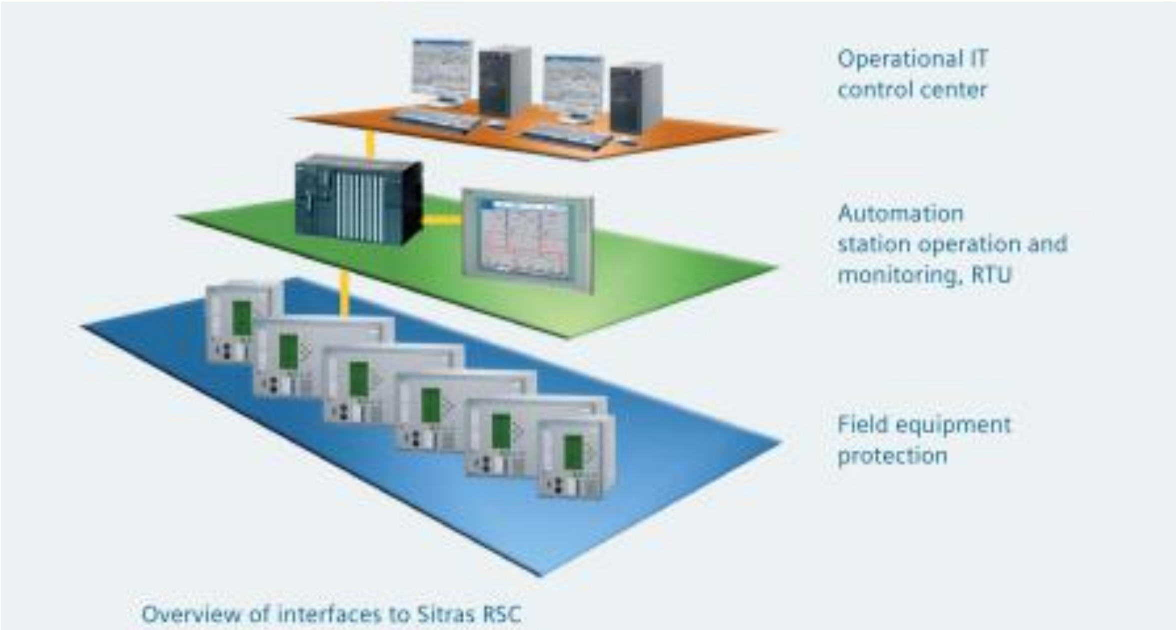

Figure 4.2: Typical components of an ETS on different control levels

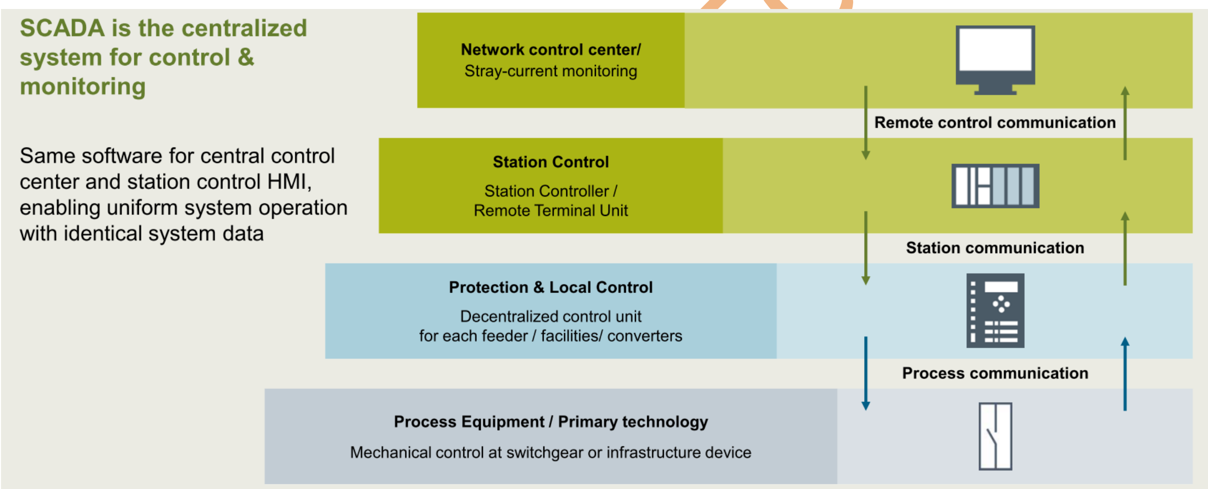

Figure 4.3: Different control levels of an ETS

In the following, the different control levels are described in a bottom-up manner.

The lowest level is the process equipment often called Primary Equipment. This is referring to electrical switching equipment as well as sensors for current and voltage or other physical quantities. Switches can be circuit breakers, disconnectors, interrupters, earth switches. All of these different equipment have different properties and purpose. In order to implement a remote control, motors and other auxiliary equipment like positioning switches, are required. The energy for operation can be stored, for example, in springs.

The second level is the protection and local control often called field equipment. This is mostly consisting out of combined control and protection relays.

Input for these protection relays is a collection of actual values made available through sensors:

- current;
- voltage;
- temperatures;
- other physical quantities;
- electric switch interlocking signals;
- electric switch position signals;
- electric switch commands.

Task of the protection and control equipment is:

- process input values;
- distinguish between operational and fault conditions;
- react accordingly;
- command execution process;
- store operational and fault records;
- provide output signals to connected equipment.

Output of the protection and control equipment is:

- warnings;
- alarms;
- actual values (see above) or post processed information hereof like e.g., power, energy;
- commands for process equipment, e.g. electric switches;
- on demand values like fault recordings e.g., short circuit behaviour.

Most of this protection and control equipment has the additional function to switch over from automatic remote control to local manual control. This is mainly for commissioning and maintenance purpose as well as for fault analysis.

The next level is the station control.

The station control combines all messages from the protection and local control equipment with station overall messages. The messages are facilitating the functions for overall control of a substation:

- interlocking of different equipment;
- complex sequences of operation: e.g. to switch over from one infeed to another, activate station internal redundancy;
- environmental control for the station;
- optional iEMS;
- optional MTS.

The highest level is the network control centre. This level combines messages from all stations. Major reconfiguration involving some stations can be executed.

The figure below describes possible interconnections of all components. In general different options for configuration are possible. These are also incorporating redundancy on different levels.

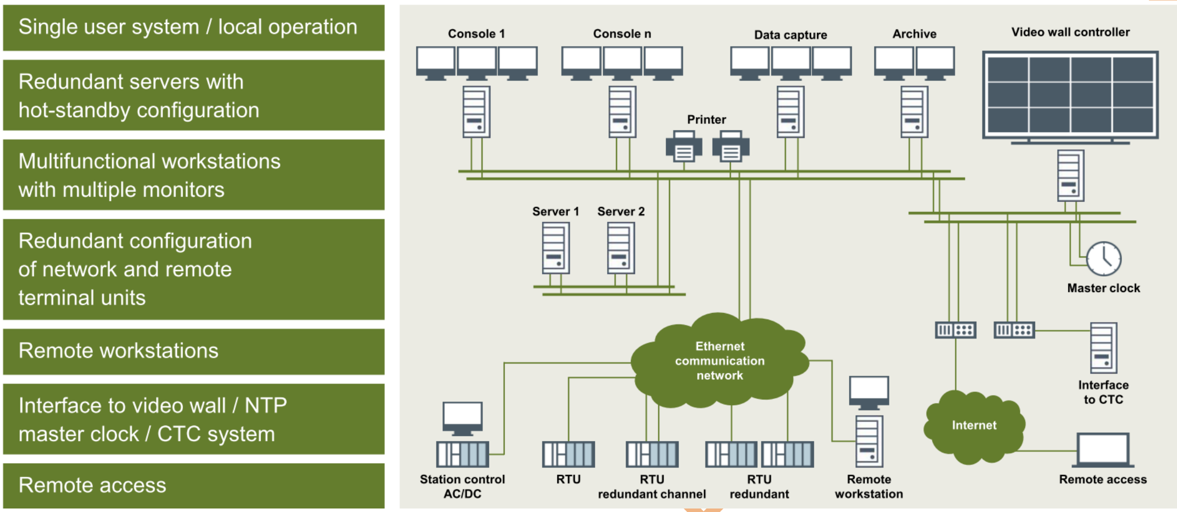

Figure 4.4: Possible interconnection set-ups of station control components

4.5 Overall view of systems

The following sketch shows systems mentioned herein and is included for overall understanding of the following chapters. Please note that a MTS might be part of the ETS or a subroutine to TMS in future.

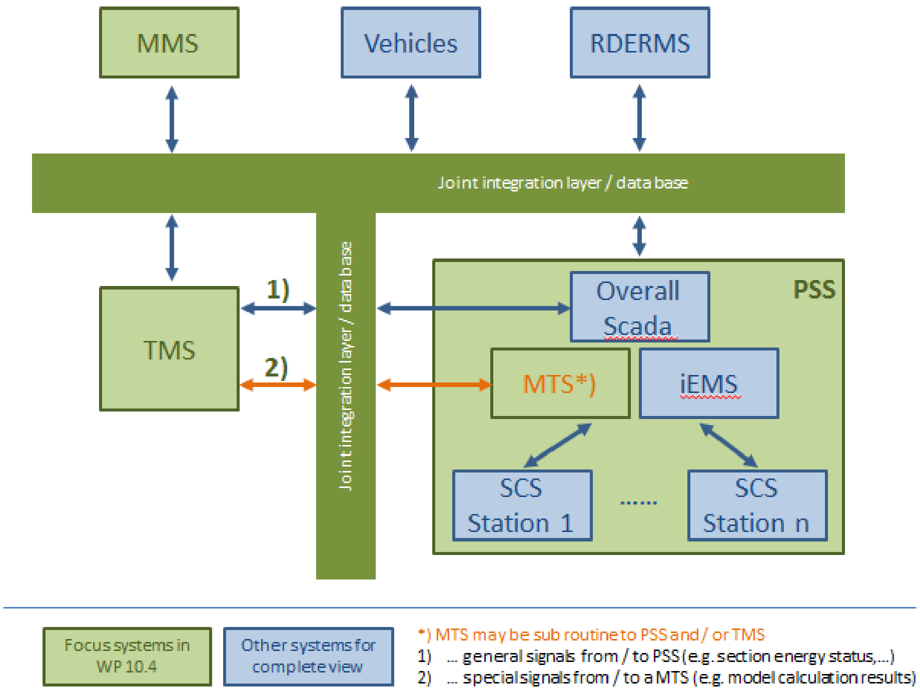

Figure 4.5: Overall systems environment view of a typical IM according to WP8

For completion of the overall view, it should be noted, that data as further described herein also could be exchanged with an overall energy data management system (vehicle & infrastructure) as elaborated within WP11 – "Smart Metering for a Railway Distributed Energy Resource Management System" (RDERMS). As noted under "3. Breakdown", the finally effective architecture is depending on the individual railways existing or targeted IT architecture; nonetheless the described data exchange and functionalities remain applicable.

4.6 General description of multi-train simulators (MTS)

An MTS can verify schedules given from a TMS taking into account the characteristic of the ETS as a whole in the actual configuration. Furthermore it can nowcast/forecast energy consumption in order to optimize energy costs.

The following diagram is taken from the Siemens tool Sitras(R) Sidytrac. It may be used as a representative approach for all multi train simulators as they are working similarly[1].

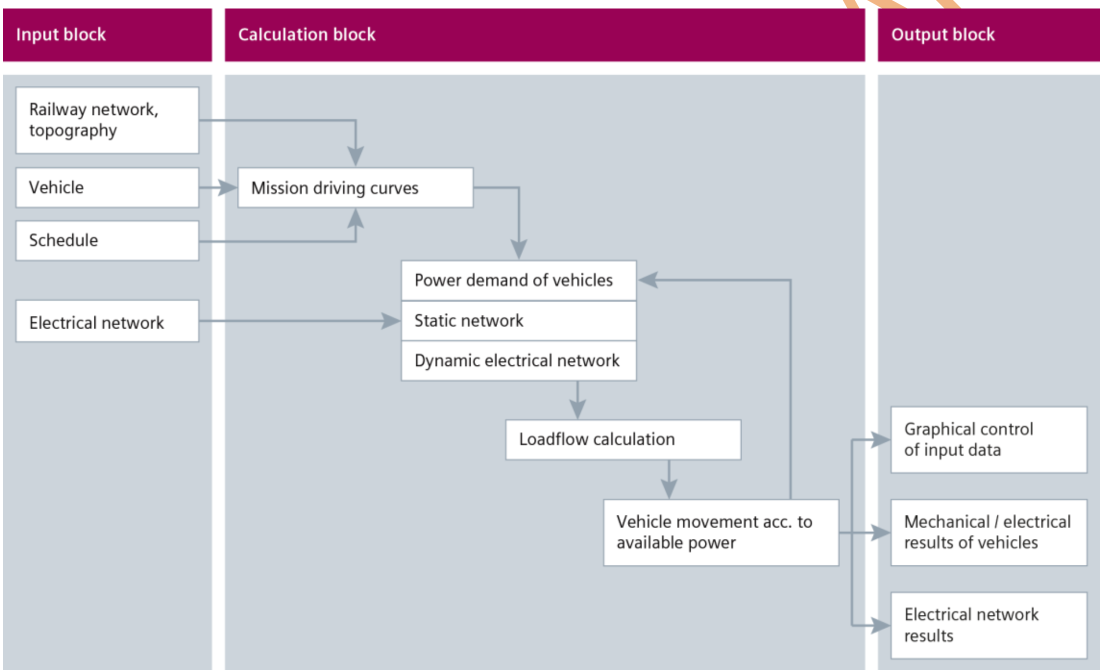

Figure 4.6: Functional MTS diagram

4.6.1 Input block

Railway network topography is normally not changing. It describes:

- slopes (Gradients; up and down);
- curves (need more power);
- tunnel sections (Piston Effect);
- stops;
- speed restrictions.

[1] PREN 50641 in preparation

Vehicles have changing and not changing parameters, such as:

- total mass, depending on payload for example passengers;
- maximum power and/or current fix for a fix train;
- acceleration limits fix for a fix train (payload limitations);
- required auxiliary power, varying dynamically with weather and payload.

General actual conditions are:

- train forecast (to be validated by MTS);
- weather conditions/forecast and related restrictions (e.g., temperature , solar radiation);
- payload (passenger load) forecast.

Train Schedules are either:

- contracted schedule;
- forecast schedule.

Train schedules are given by the TMS with assigned train consist information. Different formats are available today. However, the Integration Layer as described in WP8 includes a *Canonical Model* for train schedules as delivered by the TMS (see Chapter 0 for more details).

The electrical network includes all the components and their properties. Some components may be on or off. There is a limited set of possible feeding situations:

- resistance of conductors may vary with the temperature and wear;
- impedance of conductors is depending on the geometric arrangement;
- impedance of transformers, fixed values;
- characteristics of substations;
- upstream network properties like short circuit power;
- power electronic equipment.

This type of information belongs to the ETS data environment rather than to a TMS system with its Integration Layer. The actual configuration of the ETS can be taken over from the ETS control system.

4.6.2 Calculation block

First step is to calculate, from the schedule, the power demand of every vehicle. This is a mechanical calculation.

In the electrical calculation, the mutual influence of all components is calculated. This may include the power limit of a vehicle in under-voltage condition. Such a power limit is influencing the position of the vehicle in the next calculation step. It may limit for example acceleration. The vehicle cannot follow the foreseen schedule and has a delay.

4.6.3 Output block

Once the calculations are done all relevant values are available. Part of the resulting calculations could be used within an interface from the multi-train simulator to the TMS (MTS to TMS). Signals like this could be:

- expected under-voltage situations in a certain power network section;
- expected power limitation in a certain power network section.

As a result, the TMS is capable of considering the status of the electric traction network in the schedule generation for vehicles, thus avoiding unforeseen disturbances in operation especially in case of abnormal situations (e.g. emergency operations, partial black out etc.)

Beneath this basic result for the TMS, detailed results may be available.

4.6.4 Use of a multi-train simulator

The multi-train simulators are developed for the design of the electric traction system. For the purpose of interaction with TMS they may be used differently:

- pre-calculation for a set of parameters: this mainly comes down to calculation of different standard feeding scenarios like normal feeding configuration or outage of predetermined components. The calculation may include also assumptions of auxiliary power for different weather conditions or passenger loads;
- on demand calculations: giving actual values from all participants’, i.e., trains’ schedules from the TMS can be forecasted. The multi-train simulator is set up with actual values from all participants and therefore schedules from the TMS can be forecasted or validated respectively.

For the power supply multi-train simulators can be used for the energy forecast at different locations, particularly in meshed networks.

If the accuracy need is not too high, simple train simulators may be used. They do not consider the mutual influence of all components but may be sufficient for energy forecasts at all input points.

5 Access Technology

Within this chapter, an overview of different types of access technology as being covered by D8.4 (Interface Control Document for Integration Layer Interfaces, external Web interfaces and Dynamic Demand Service) is given. The technologies are described in the light of potential use for the TMS/MMS interface. Finally, one technology is chosen and the rationale given for this choice.

Interfaces of TMS/MMS systems for exchange of information to and from the outside world will have to provide information access compliant to TMS/MMS systems on the one side and to the respective external systems on the other. The basic idea of interface modules and related specification within this document is to provide a standard way of communication towards the Integration Layer of TMS/MMS while leaving the preferred access technology (Web, SOAP/XML, JSON/rpc etc.), and related specification details of existing or future ETS systems open.

5.1 Options and reasoning for IL access technology

As a result of Work Package 8 architectural assessment activities, reasoning and decision making, it was concluded to make sure that a common way is to be used for accessing the Integration Layer of a TMS/MMS in order to allow standardised communication between application and interface modules of the respective systems. As a consequence, Chapter 4.2 (Integration patterns in Application Framework) of deliverable D8.6 applies for interfaces similar to the descriptions provided for TMS application modules as given herein.

It is assumed that due to the generic and state-of-the-art approach chosen for the integration of software components in WP8, a similar approach will be applicable for future MMS environments with their specific application and interface modules.

Due to ongoing work on deliverable D8.4 at the time of finalising this document, it is expected that more details will follow (in deliverable D8.4) on how different types of ETS software modules (e.g., Web technology based) facilitate the specifications within this document. This approach ensures a maximum of flexibility for possible ETS platforms of today and the future.

5.2 Chosen access technology

According to the current design activities in In2Rail WP8, the communication platform for interfaces to and from external systems is provided by the Integration Layer, as it is shown in Figure 5.1. Please note that the term “external systems” denotes systems other than TMS/MMS which are to be integrated.

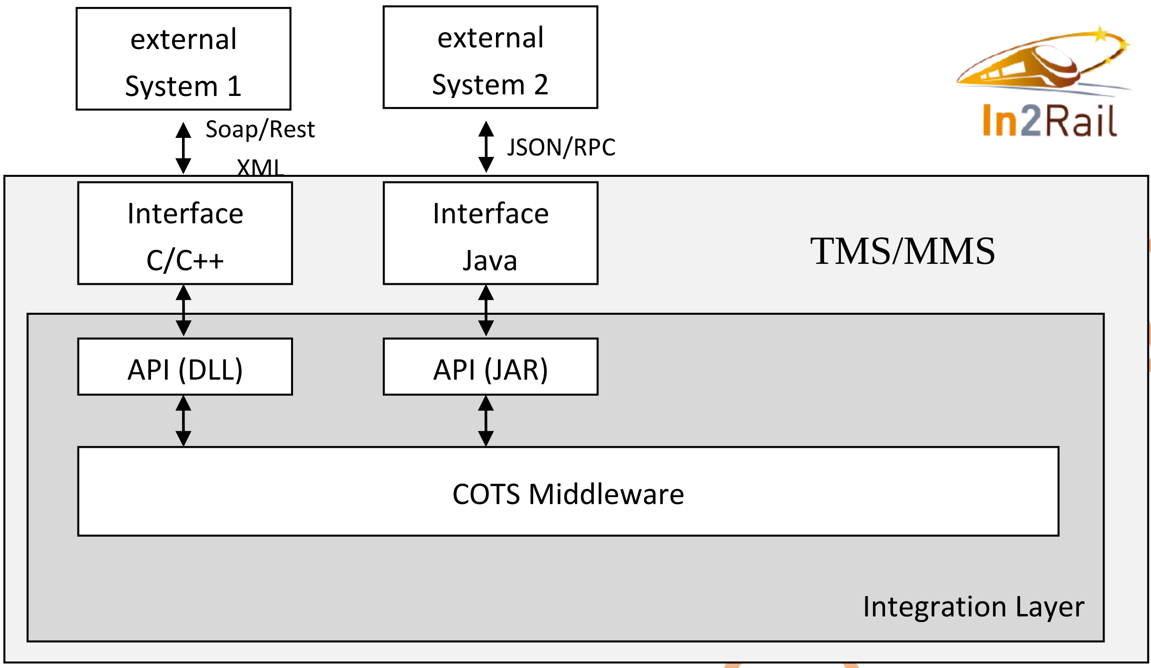

Figure 5.1: Constituents of the TMS/MMS Integration Layer with respect to communication with external systems, e.g. ETS

The Integration Layer provides an API for accessing the communication platform and-Canonical Data Model for communication with the TMS/MMS and its applications. It uses existing COTS middleware and separates it by means of a dynamic library for C/C++ and Java clients. In opposite to the conventional message based middleware products, the IL is responsible not only for the data distribution, but for data management as well. For this purpose, it combines a non-relational database with publish-subscribe mechanism.

The currently best analogy for IL is an In Memory Data Grid. [Hazelcast 2017], [Redis 2017] show the general approach for data access and distribution.

Another important aspect of the IL is the standardized data structures and serialisation, which is managed by the IL. For this purpose, it provides a class diagram in an XML-Format, which can be used for generation of client and serialisation code. At the current stage, the Protobuf-Protocol [Protobuf 2017] has been selected for serialisation, as it combines most of the advantages of a binary protocol with build-in versioning and a "one-command-bi-directional-conversion" into JSON.

Due to the chosen architecture in WP8, interfaces communicating via the IL to the TMS/MMS on the one and to external systems on the other side can be connected to the IL in a plug-and-play manner. A detailed description of TMS interfaces is provided in [In2Rail D8.4].

5.3 General information on connecting to the TMS/MMS Integration Layer

The CDM pattern is described in ref. [EIP]. In short, the idea is to have a consistent format for all data exchange between components. The components may have different data representations internally, but whenever exporting or importing data to/from other components, they must translate this data to the canonical form. The result is that new communication paths may easily be added, as both end points are independent of the other end points internal data model.

Each interface to communicate via the IL has basically three options for how to adapt to the CDM to the external systems' data model (i.e. the external data representation):

1. apply the CDM format also for external data representation. This may be suitable in case of new developments;
2. implement a Messaging Mapper ([EIP]) (i.e. an interface module which maps data between the applications domain objects and the CDM). This may be suitable for migrating existing applications to the IL/AF context;
3. implement a Message Translator ([EIP]) (i.e. an external adaptor, receiving data according to CDM which it relays according to some other interface specification, and vice versa). This is suitable for adapting legacy systems without changing them at all internally.

For further details on the reasoning, overall structure and use of the CDM please see [CDM].

6 Interface to Railway Traffic Management System (TMS)

This chapter describes the different parts of the TMS interface and how they are connected to the Integration Layer of the TMS. For a conceptual view of TMS/MMS interfaces, please also see Figure 5.1 within the previous chapter.

6.1 Information provided to the TMS

In order to understand the required communication via the interface, four use cases are shown below, which are used as a baseline in order to set up requirements and patterns of interface interaction.

6.1.1 Use Cases

The use cases chosen to see which constraints apply to a pattern for information flow from ETS towards TMS are presented in Table 6.1.

Use case #	Use case title	Use case description
Use case 1	Standard procedure	Sending updated vehicle related power limitations for an itinerary and expected power consumption at substations to the forecast calculation module of a TMS
Use Case 2	Change of configuration of ETS (e.g. due to a disruption)	Sending a temporary resource restriction information “Feeding section is not energized” to the TMS module for handling infrastructure restrictions
Use Case 3	Outage of ETS component	Sending disruption information “Outage of a major component <x> of substation <y>” to TMS module for handling infrastructure restrictions
Use Case 4	Dynamic change of component status	Sending changed status information of components “status of component <x> is (secure on, secure off, secure in-between, unknown)” to TMS surveillance module (e.g., SCADA)

Table 6.1: Information provided to the TMS - Use cases

Each use case is described in the next chapters.

6.1.1.1 Use case 1: Standard procedure

Sending updated vehicle related power limitations for an itinerary and expected power consumption at substations to the forecast calculation module of a TMS.

Operational Situation:

> The MTS as being part of the ETS results in several output information, one of it being a power limit for some vehicles. The power limit is resulting from the superposition of many vehicles with their properties and operational situation. The superposition of all currents leads to a voltage drop. The vehicle supply voltage may limit the vehicle current and/or power. A lower power leads to less acceleration and speed. As a consequence, the vehicles are not able to run as fast as planned so that they will be delayed with respect to their current TMS train schedule. Advanced multi-train

simulation programs can evaluate such situations as they consider all components with their operational situation and mutual influences.

Assumed ETS/TMS configuration:

- MTS module being available as part of the ETS;
- forecast calculation module computing acceleration and braking requirements as well as arrival times at operational points of the route;
- optionally, automated conflict resolution module being available as part of TMS;
- available control loops in TMS for continuous train running forecast calculation based on train position reports, restrictions on power availability as derived by MTS, conflict resolution and already performed dispatching decisions;
- the TMS has to decide whether the power availability restrictions are severe enough to initiate actual schedule recalculations closing the control loop by re-issuing the updated forecast schedule to ETS.

Please note that for the TMS forecast calculation module, the availability of both, tight runtime forecast, i.e. resulting times are reflecting maximum acceleration and braking capabilities, as well as eco-driving forecast would be of advantage in order to handle compensation of overall power loss with respect to available runtime reserves along the train's itineraries. This is because the quality of TMS forecast calculation finally depends on realistic information about power availability for all individual trains at the time when it is required. As a consequence, the to-be power usage as well as as-is power usage should be used as input to future forecast calculation modules of TMS systems.

It is expected that the forecast data being persisted in future TMS systems will include updated power limits for the collection of train itineraries ("Online Energy Plan") as resulting from this use case.

6.1.1.2 Use Case 2: Change of configuration of ETS (e.g. due to a disruption)

Sending a temporary resource restriction information "Feeding section is not energized" to the TMS module for handling infrastructure restrictions.

Operational Situation:

Due to an ETS disruption and related component restriction, a feeding section may not be usable for electric trains so that trains being in or entering this section will stop and need to wait for re-energization or rescue. Such restrictions are typically caused by outside reasons as e.g., fallen trees, storm, accident etc. The TMS system should react in order to avoid trains entering the section. Rescue traffic should be organized as well if needed. Every section and all related switches have unique system names according to EN 81346 part 1 to 3 (see [EN81346]). These unique names are consisting of location information as well as functional information. Within the SCADA system they are represented with a different designation and different properties. However, EN 81346 does not specify any required formats of the names so that neither constituents of the names, their format nor the order of the constituents are standardized today. Since the constituents themselves most often refer to other available data keys these are also called “composite keys” in technical terms.

Assumed ETS/TMS configuration:

- shared identification of power sections between ETS and TMS according to EN 81346 part 1 to 3;
- availability of a TMS module being able to handle temporary resource restrictions (reduced or no power availability) for power sections e.g., for updating views, creation of event information.
- communication of composite keys for ETS components (e.g., electrical switches) as single sequences of bytes with a sufficient length; business logic for checking correct format and consistency of the composite key being available within the receiving module;
- optional TMS module for conflict detection and resolution with capability to consider temporary resource restrictions for power sections e.g., by identifying forecasted trains being impacted and resulting re-planning of online production plan;
- available function in ETS for triggering restriction information transfer as soon as ETS configuration change is performed.

6.1.1.3 Use Case 3: Outage of ETS component

Sending disruption information “Outage of a major component <x> of substation <y>” to TMS module for handling infrastructure restrictions.

Operational Situation:

The outage normally leads to a major reconfiguration of the electric traction system. This reconfiguration may not be limited to the affected substation only. Under normal circumstances it is an activation of a redundancy. Failed components lead to higher source impedance. This may result in higher voltage drop and may lead to limitation of the available power for trains. General limits of power, current or energy cannot be given as it depends on the superposition of the power demand of all trains in the affected area. As described in Chapter 4.6 above under the headline of “Use of a multi-train simulator”, a multi-train simulation program could be used for “On Demand Calculation” as a subroutine or in parallel to the TMS. In this case, the train schedules elaborated by the TMS for an abnormal situation based on the incoming infrastructure restriction could be validated by results from the multi-train simulator with respect to network resilience (e.g. avoidance of under-voltage …). It is unimportant which component failed. The ETS should immediately (as soon as possible) hand over actual power restrictions to the TMS.

Assumed ETS/TMS configuration:

- shared identification of power sections between ETS and TMS according to EN 81346 part 1 to 3;
- availability of a TMS module being able to handle temporary resource restrictions (reduced or no power availability) for power sections e.g., for updating views, creation of event information;
- optional TMS module for conflict detection and resolution with capability to consider temporary resource restrictions for power sections e.g., by identifying forecasted trains being impacted and resulting re-calculation and updating of the TMS online production plan;
- available function in ETS for triggering restriction information transfer as soon as ETS configuration change is performed.

6.1.1.4 Use Case 4: Dynamic change of component status

Sending changed status information of components "status of component <x> is (secure on, secure off, secure in-between, unknown)" to TMS surveillance module (e.g., SCADA).

Operational Situation:

In contrast to Use Case 3, this Use Case is dealing with information not directly causing more elaborated TMS actions in terms of re-scheduling etc. These component statuses indicate more or less normal operation of components which occur during regular operation or controlled operations for the components. However, although a planned temporary restriction of the infrastructure including the controlled switch-off of a power section should be available at the time the corresponding switches are operated and set to "secure off", a TMS may decide to create a separate restriction or validate the planned one accordingly. Please note that it is assumed that trains which have been in conflict with the planned restriction have been re-scheduled already before. These types of messages are usually subscribed by SCADA applications or other track view applications of a TMS.

Assumed ETS/TMS configuration:

- shared identification of ETS components (e.g., electrical switches) between ETS and TMS according to EN 81346 part 1 to 3;
- availability of a TMS module being able to handle ETS component status information (switch status values secure on, secure off, secure in-between, unknown and related transitions between them) for power sections e.g., for updating views, creation of event information;
- optional TMS module for validation or creation of temporary resource restrictions for power sections based on related component status changes;
- available function in ETS for triggering component status change information transfer as soon as ETS component status changes are performed.

6.1.2 Specific Communication Requirements

The following requirements for sending information (objects, attributes etc.) from ETS to TMS are derived from the Use Cases above:

1. vehicle related power limits and expected power usage for a train itinerary in kW;
2. temporary resource restriction “Feeding section is not energized”;
3. disruption information “Outage of a major component <x> of substation <y>”;
4. changed status information of components “status of component <x> is (secure on, secure off, secure in-between, unknown)”.

6.1.3 Proposed pattern

To describe the pattern the CDM object references are used, which themselves are described in the Canonical Data Model, see [In2Rail CDM].

The CDM nodes are represented by paths as shown Table 6.2. The location of CDM data as represented by its path gives just a hint for the interface implementation. The column “Reference” includes references to the specific communication requirements within the previous chapter.

Path	Content	Reference
/network/Timetables/Timetable/TrainParts/TrainPart/	Path for all commands concerning parts of train schedules for which no change of train consists (i.e., vehicles) is planned.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>	Path for one instance of the parts of train schedules for which no change of train consists is planned.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>/ocpsTT/ocpTT/<uuid>/sectionTT/Power	Path for power related information for schedule sections.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>/ocpsTT/ocpTT/<uuid>/sectionTT/Power/Limitation	Path for power limitation information in relation to schedule sections.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>/ocpsTT/ocpTT[n]/sectionTT/Power/Consumption	Path for power consumption information in relation to schedule sections.	1
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem	Path for information about constituents of an ETS.	2, 3, 4
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/*component*/<uuid>/*module*	Path for information of the modules of an ETS-component’s. All modules of a component are modelled as functional assets from here.	2, 3, 4
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/*component*/<uuid>/*module*[n]/ AssetStatus	Path for operational status of an ETS-component’s module. Note: values could be depending on the module e.g., {secure on, secure off, secure in-between, unknown} for power section switches. These are modelled as subclasses starting from this path, see also [CDM], chapter “Functional Assets”.	4
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/Substation	Path for information in relation to ETS-component “substation”. All modules of a substation are modelled as functional assets from here.	3

Path	Content	Reference
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/Substation[n]/*module*/<uuid>/Asset/blockedTime	Path for a substation module's asset information in relation to scheduled or observed functional non availability based on time spans .i.e., begin and end time (if available).	3
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/PowerSection	Path for information in relation to ETS-component "power section".	2
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/PowerSection/<uuid>/Asset/blockedTime	Path for power section asset information in relation to scheduled or observed functional non availability based on time spans .i.e., begin and end time (if available).	2

Table 6.2: Information provided to the TMS - Paths representing CDM nodes

6.2 Information obtained from the TMS

In order to understand the required communication via the interface, five use cases are shown below which are used as a baseline in order to set up requirements and patterns of interface interaction.

6.2.1 Use Cases

The use cases chosen to see which constraints apply to a pattern for information flow from TMS towards ETS are presented in Table 6.3.

Use case #	Use case title	Use case description
Use case 1	Standard procedure	Sending TMS online production plan, forecasted times and vehicle characteristics to ETS module for calculation of power consumption and power limits (MTS module)
Use Case 2	Updated information on expected traffic load available in TMS leads to information update in ETS	Sending information about traffic load expected in a certain area in a certain time frame to ETS module MTS
Use Case 3	Adjustment of protection settings in TMS leads to information update in ETS	Sending TMS information about changes of protection settings to ETS module MTS
Use Case 4	Updated information on possession activities available in TMS leads to information update in ETS	Sending TMS information about status and/or forecast changes of possessions with assigned protection settings to ETS module MTS
Use Case 5	Updated disruption information for specific sections available in TMS leads to information update in ETS	Sending TMS information about disruption information for track sections to ETS module MTS

Table 6.3: Information obtained from the TMS - Use cases

Each use case is described in the next chapters.

6.2.1.1 Use Case 1: TMS standard procedure

Sending TMS online production plan, forecasted times and vehicle characteristics to ETS module for calculation of power consumption and power limits (MTS module).

Operational Situation:

As a standard the actual (forecast) schedule is given from the TMS to the ETS. The ETS is designed for a worst case operation. Minor changes should not have significant impact. The MTS in the ETS is using the information from the TMS to predict the power consumption of the trains along the itinerary and at the interface points with the energy suppliers, see also figure below. In addition to the schedule, information about auxiliary power consumption of the vehicles is required as well as details about relevant external factors (e.g., weather conditions, tunnel sections) along the journey of a train. Please note that for the different combinations of external factors, predefined, experienced based mean parameter values for expected auxiliary power consumption are used. These together with the dynamic information about actual traction power needs of the trains form the basis of simulation. It is assumed that the schedule information already reflects the actual positions and operational situations of the vehicles. The necessary information includes:

- schedule;
- auxiliary power of vehicles; actual values from OBU or other source;
- load of the vehicles; actual value from TMS, OBU or other source;
- vehicle resistance force may change significantly for cargo trains.

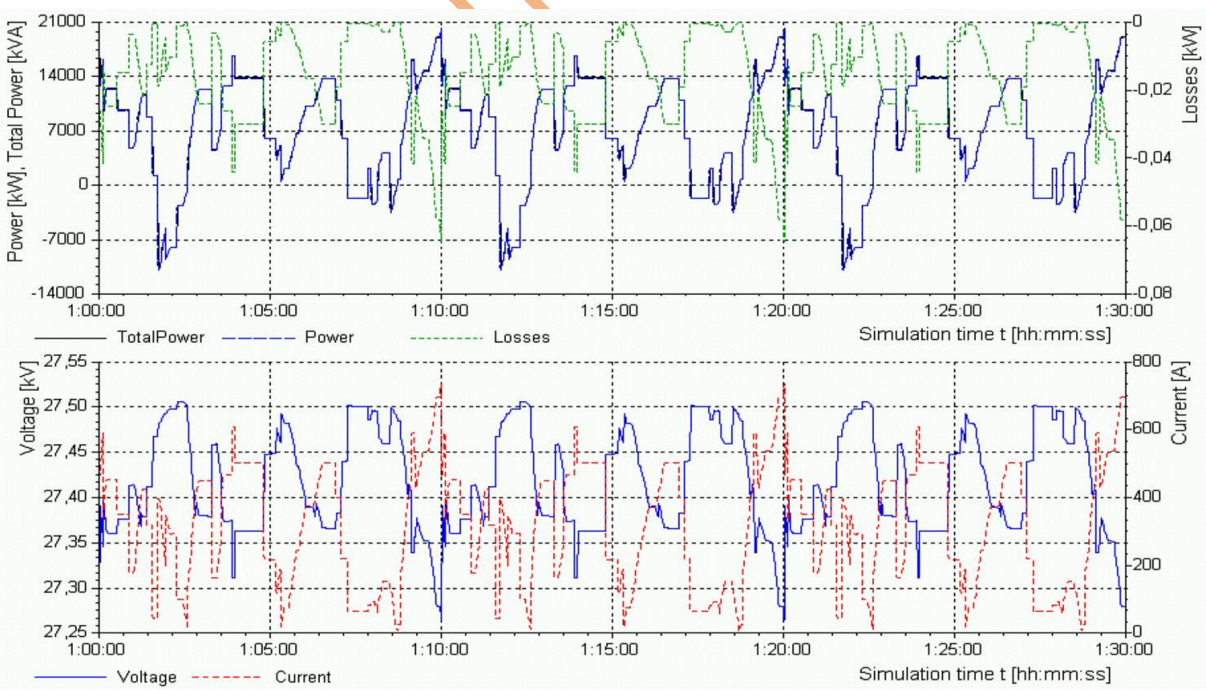

Figure 6.1: Power consumption of a substation determined by trains in the feeding section

Assumed ETS/TMS configuration:

- MTS module being available as part of the ETS;
- forecast times based on acceleration and braking requirements and including arrival times at operational points of the route;
- available control loops in TMS for continuous train running forecast calculation based on train position reports, restrictions on power availability as derived by MTS, conflict resolution and already performed dispatching decisions;
- the TMS has to decide whether the power availability restrictions are severe enough to initiate actual schedule recalculations closing the control loop by re-issuing the updated forecast schedule to ETS.

6.2.1.2 Use Case 2: Updated information on expected traffic load available in TMS leads to information update in ETS

Sending information about traffic load expected in a certain area in a certain time frame to ETS module MTS.

Operational Situation:

- reduction of no load losses according to the forecast: for example switch off one out of 2 parallel transformers;
- tap changer positions, minimize number of operations, no change for a short time;
- less wear if the current is low. Predictive switching during low current if higher is expected;
- if power conversion (chemical to electric) is involved it can be pre-controlled;
- going into direction of energy management.

This may involve planned/forecasted train running in terms of numbers of trains (with power supply specifics) on certain sections in a given time frame to come. The planned traffic may be lower because of lower demand or because of unavailability of other infrastructure components. The planned traffic may be higher for example for special events or rerouted traffic from other routes

Assumed ETS/TMS configuration:

- See 6.1.1.1. above.

6.2.1.3 Use Case 3: Adjustment of protection settings in TMS leads to information update in ETS

Sending TMS information about changes of protection settings to ETS module MTS.

Operational Situation:

Due to planned or currently operated track maintenance or construction, controlled switch-off of power sections may happen. The MTS of an ETS needs to consider the actual plan or operation status of these protection measures in order to provide realistic results of power consumption calculation. Hence any new or changed (e.g., postponed, extended in section length, changed operations mode) settings are to be communicated. Interruptions of the return circuit as well as coasting through not energized sections for example in phase separations are considered in the MTS.

Assumed ETS/TMS configuration:

- MTS module being available as part of the ETS;
- shared identification of power sections between ETS (MTS) and TMS according to EN 81346 part 1 to 3;
- MTS module being able to handle protection settings related to power sections and changes hereof;
- available function in TMS for triggering transfer of protection settings changes as soon as the changes are performed within TMS.

6.2.1.4 Use Case 4: Updated information on possession activities available in TMS leads to information update in ETS

Sending TMS information about status and/or forecast changes of possessions with assigned protection settings to ETS module MTS.

Operational Situation:

If possessions with assigned protection measures are changed, this can have an implication on protection settings as well. This may involve planned or forecasted possessions (with power supply specifics) on certain sections in a given time frame to come. It is deemed that the business logic or required user activity for adapting changes of protection settings as a consequence of changes applied to the related possession is to be covered by TMS rather than ETS so that this use case is covered by solution for Use Case 3.

Assumed ETS/TMS configuration:

- See Use Case 3 above.

6.2.1.5 Use Case 5: Updated disruption information for specific sections available in TMS leads to information update in ETS

Sending TMS information about disruption information for track sections to ETS module MTS.

Operational Situation:

This may involve track sections temporarily not usable or restricted for use, e.g., through temporary speed restriction defined on that section due to temporary failures. It is expected that the adapted traffic plan will be communicated as new (forecast) schedule to ETS. However, due to potential latency effects in re-scheduling, it is seen as useful to communicate non available track sections to the MTS of an ETS for consideration.

Assumed ETS/TMS configuration:

- MTS module being available as part of the ETS;
- shared identification of track sections between ETS (MTS) and TMS;
- MTS module being able to handle changes of availability or maximum speed of track sections;
- available function in TMS for triggering transfer of changes of availability of track sections as soon as the changes are performed within TMS.

6.2.2 Specific Communication Requirements

The following requirements for sending information from TMS to ETS are derived from the Use Cases above:

1. updated (forecast) schedule for one or multiple filtered train itineraries; filters: section and/or time frame;
2. actual auxiliary power consumption of vehicles;
3. external factors along the journey of a train e.g., weather conditions.
4. physical characteristics, especially load and resistance coefficients of the train under consideration of multiple locomotives in one train;
5. planned or operated temporary resource restriction "power section switched-off";
6. availability information (non availability, reduced maximum speed) for specific track sections.

6.2.3 Proposed pattern

To describe the pattern the CDM object references are used, which themselves are described in the Canonical Data Model, see [In2Rail CDM]. The CDM-nodes are represented by paths as shown in Table 6.4. The location of CDM data as represented by its path gives just a hint for the interface implementation. The column "Reference" includes references to the specific communication requirements within the previous chapter.

Path	Content	Reference
/network/Timetables/Timetable/TrainParts/TrainPart/	Path for all commands concerning parts of train schedules for which no change of train consists (i.e., vehicles) is planned.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>	Path for one instance of the parts of train schedules for which no change of train consists is planned.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>/ocpsTT/ocpTT/<uuid>/times	Path for arrival and departure times at locations within the train schedule.	1
/network/Timetables/Timetable/TrainParts/TrainPart/<uuid>/ocpsTT/ocpTT[n]/sectionTT/Power/AuxiliaryConsumption	Path for auxiliary power consumption information in relation to schedule sections.	2
/network/Realtime/AccessRestriction	Path for any types of access restrictions for tracks. All related attributes and information available from here.	3, 6

Path	Content	Reference
/network/Realtime/AccessRestriction/RestrictionType	Path for the type of an access restriction.	3, 6
/network/Realtime/AccessRestriction/RestrictionState	Path for the state of an access restriction.	3, 6
/network/Realtime/AccessRestriction/TempRestriction	Path for the details of an access restriction (timespan, description etc.).	3, 6
/network/RollingStock/Formation/formations/<uuid>	Path for physical characteristics of the train consist involving one or multiple locomotives starting from here.	4
/network/RollingStock/Formation/formations/<uuid>/trainEngine	Path for maximum and mean acceleration values of the train consist.	4
/network/RollingStock/Formation/formations/<uuid>/trainEngine/trainMeanAcceleration	Path for mean acceleration value of the train consist.	4
/network/RollingStock/Formation/formations/<uuid>/trainEngine/trainMaxAcceleration	Path for maximum acceleration value of the train consist.	4
/network/RollingStock/Formation/formations/<uuid>/trainBrakes	Path for the brake information of the train consist.	4
/network/RollingStock/Formation/formations/<uuid>/trainBrakes/brakeType	Path for the brake type information of the train consist (vacuum or compressed air brake, hand brake, parking brake, cable brake)	4
/network/RollingStock/Formation/formations/<uuid>/trainBrakes/airBrakeApplicationPosition	Path for the brake application position information of the train consist (base brake switch, one of G, P or R).	4
/network/RollingStock/Formation/formations/<uuid>/trainBrakes/regularBrakeMass	Path for the regular brake mass information of the train consist (normal brake operations, non-automatic brakes).	4
/network/RollingStock/Formation/formations/<uuid>/trainBrakes/meanDeceleration	Path for the mean deceleration information of the train consist.	4
/network/RollingStock/Formation/formations/<uuid>/trainBrakes/maxDeceleration	Path for the maximum deceleration information of the train consist.	4
/network/RollingStock/Formation/formations/<uuid>/trainResistance/valueTable/valueLine/values/yValue[n]	Path for coefficients a, b, c of the standard resistance formula a+bx+cx*x of the train consist i.e., n = 0, 1, 2.	4
/network/RollingStock/Formation/formations/<uuid>/length	Path for the … information of the train consist in meters.	4
/network/RollingStock/Formation/formations/<uuid>/speed	Path for the … information of the train consist in kilometres per hour.	4
/network/RollingStock/Formation/formations/<uuid>/bruttoWeight	Path for the total load information of the train consist in tons.	4
/network/RollingStock/Formation/formations/<uuid>/nettoWeight	Path for the payload weight information of the train consist in tons.	4
/network/RollingStock/Formation/formations/<uuid>/tareWeight	Path for the empty train load information of the train consist in tons.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine	Path for the technical details of a traction engine.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/pantograph[n]	Path for the technical details of a traction engine's pantograph.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/pantograph[n]/dedicatedSupplySystem/voltage	Path for the voltage of a traction engine's pantograph in Volt.	4

Path	Content	Reference
/network/RollingStock/Vehicles/vehicle[n]/Engine/pantograph[n]/dedicatedSupplySystem/frequency	Path for the frequency of a traction engine's pantograph in Hertz.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/pantograph[n]/orderNumber	Path for the technical details of a traction engine as related to a train consist, here: the number within the sequence of pantographs.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]	Path for the technical details of a traction engine's propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/code	Path for typical, specific abbreviation used in different systems with the same understanding of a traction engine's propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/name	Path for the generic name of a traction engine's propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/voltage	Path for the voltage of a traction engine's propulsion system in Volt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/frequency	Path for the frequency of a traction engine's propulsion system in Hertz.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/power	Path for the installed power of a traction engine's propulsion system per vehicle in Watt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/powerType	Path for the type of power of a traction engine's propulsion system in the vehicle.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/controlType	Path for the type of control of a traction engine's propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/maxTractEffort	Path for the maximum tractive effort per vehicle of a traction engine's propulsion system in Newton (to be used in conjunction with the 'tractiveEffort' element).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/rotationMassFactor	Path of the factor for increased running resistance per vehicle of a traction engine's propulsion system in Newton.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/additionalRotationMass	Path of a load figure for increased running resistance per vehicle of a traction engine's propulsion system in tons of weight.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/maxBrakeEffort	Path for maximum braking effort of propulsion system per vehicle of a traction engine's propulsion system in Newton (to be used in conjunction with the 'brakeEffort' element).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/maxBrakePower	Path for the maximum braking power for regenerative braking of a traction engine's propulsion system in Watt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/totalTracEffciency	Path for the average efficiency of a traction engine's propulsion system in the range 0…1.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/totalBrakeEfficiency	Path for the average efficiency of a traction engine's propulsion system in braking mode in the range 0…1.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/tractionOffUndervoltageThreshold	Path for the undervoltage threshold of a traction engine's propulsion system to switch-off traction power in case of net voltage being out of limit in Volt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/speedCurrentLimitation	Path for the current limitation of a traction engine's propulsion system at zero speed in Ampère.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/maxRegenerativeVoltage	Path for the maximum voltage of a traction engine's propulsion system for regenerative braking in Volts.	4

Path	Content	Reference
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/forwardSpeed	Path for the permissible speed of a traction engine’s propulsion system with front ahead (normal direction) in kilometres per hour.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/reverseSpeed	Path for the permissible speed of a traction engine’s propulsion system with tail ahead (reverse direction) in kilometres per hour.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/Transformer	Path for the transformer information of a traction engine’s propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/Transformer/ferrumResistance	Path for the transformer information of the resistance of iron core of one transformer in Ohms (open-circuit core loss).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/Transformer/additionalResistance	Path for the transformer information of the additional resistance of one transformer in Ohms due to non-sinusoid currents (stray loss).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/Transformer/mainInductance	Path for the transformer information of the main inductance of one transformer in Henry (H).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/Transformer/meanEfficiency	Path for the transformer information of the transformer mean efficiency in the range 0...1.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/link	Path for the information about nominal values of link circuit between input inverter and motor inverter of a traction engine’s propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/link/nominalVoltage	Path for the nominal voltage of link circuit between input inverter and motor inverter of a traction engine’s propulsion system in Volt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion[n]/link/nominalCurrent	Path for the nominal current of link circuit between input inverter and motor inverter of a traction engine’s propulsion system in Ampère.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionInverter[m]	Path for the information about technical data of inverter between link circuit and motors of a traction engine’s propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionInverter[m]/meanEfficiency	Path for the mean efficiency of inverter between link circuit and motors of a traction engine’s propulsion system in the range of 0…1.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionInverter[m]/efficiency	Path for efficiency of inverter between link circuit and motors of a traction engine’s propulsion system in a table against speed.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionInverter[m]/pulsPattern	Path for the pulse pattern of inverter between link circuit and motors of a traction engine’s propulsion system in a table of 3 pairs of columns (Name, Unit).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]	Path for the information about technical data of a traction motor of a traction engine’s propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalPower	Path for the nominal power of a traction motor of a traction engine’s propulsion system in Watt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalVoltage	Path for the nominal voltage of a traction motor of a traction engine’s propulsion system in Volt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalCurrent	Path for the nominal Current of a traction motor of a traction engine’s propulsion system in Ampère.	4

Path	Content	Reference
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalFrequency	Path for the nominal frequency of the traction motor windings of a traction engine's propulsion system in Hertz.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalFlux	Path for the nominal flux of a traction motor of a traction engine's propulsion system in Volt*sec.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalPhi	Path for the nominal phase angle Phi of a traction motor of a traction engine's propulsion system in the range -180…+180.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/numberPolePairs	Path for the number of pole pairs of a traction motor of a traction engine's propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/statorResistance	Path for stator winding resistance of a traction motor of a traction engine's propulsion system in Ohms.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/rotorResistance	Path for rotor winding resistance of a traction motor of a traction engine's propulsion system in Ohms.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/ferrumResistance	Path for iron core resistance of a traction motor of a traction engine's propulsion system in Ohms.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/additionalResistance	Path for additional resistance of a traction motor of a traction engine's propulsion system due to non-sinusoid currents (stray loss) in Ohms.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/mainInductance	Path for main inductance of a traction motor of a traction engine's propulsion system in Henry (H).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/statorLeakageInductance	Path for stator winding leakage inductance of a traction motor of a traction engine's propulsion system in Henry (H).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/rotorLeakageInductance	Path for rotor winding leakage inductance of a traction motor of a traction engine's propulsion system in Henry (H).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/nominalRevolutions	Path for the nominal number of revolutions of a traction motor of a traction engine's propulsion system in revolutions per minute (rpm).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractionMotor[m]/meanEfficiency	Path for the mean efficiency of a traction motor of a traction engine's propulsion system in the range of 0…1.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/auxiliarySupply	Path for the information about auxiliary systems (supply and consumption) of a traction engine's propulsion system.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/auxiliarySupply/power	Path for power consumption of constant load by auxiliary equipment of a traction engine's propulsion system in Watt.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/auxiliarySupply/powerPhi	Path for phase angle Phi of constant power of auxiliary load of a traction engine's propulsion system in a range of -180…+180..	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/auxiliarySupply/resistance	Path for resistance of constant load by auxiliary equipment of a traction engine's propulsion system in Ohms.	4

Path	Content	Reference
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/auxiliarySupply/powerBraking	Path for power consumption of constant load by auxiliary equipment of a traction engine's propulsion system in Watt (only during braking mode).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/auxiliarySupply/powerPhiBraking	Path for phase angle Phi of constant power of auxiliary load of a traction engine's propulsion system in the range -180…+180 (only during braking mode).	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractiveEffort	Path for diagram data related to mechanical tractive effort of a traction engine's propulsion system measured at wheel vs. speed.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/brakeEffort	Path for diagram data related to mechanical brake effort of a traction engine's propulsion system measured at wheel vs. speed in braking mode.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractiveCurrent	Path for diagram data related to net current of a traction engine's propulsion system measured at wheel vs. speed.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/brakeCurrent	Path for diagram data related net current of a traction engine's propulsion system measured at wheel vs. speed in braking mode.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractiveCurrentLimitation	Path for diagram data related to limitation curve of net current of a traction engine's propulsion system vs. net voltage.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/brakeCurrentLimitation	Path for diagram data related to limitation curve of net current of a traction engine's propulsion system vs. net voltage in braking mode.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/tractiveVehicleEfficiency	Path for diagram data related to the efficiency of a traction engine's propulsion system vs. speed.	4
/network/RollingStock/Vehicles/vehicle[n]/Engine/propulsion/brakeVehicleEfficiency	Path for diagram data related to the efficiency of a traction engine's propulsion system vs. speed in braking mode.	4

Table 6.4: Information obtained from the TMS - Paths representing CDM nodes

6.3 Formal definition of the Interface

Please see Deliverable D8.4 [In2rail D8.4] for details.

6.4 Validation of the Interface Specification

As part of Task 7.3 of WP7 in the I2M subproject of In2Rail, a number of prototyping and testing activities for the Proof of Concept (PoC) of the TMS architecture as specified in WP8 are performed. The scope of these activities is focussed on testing of communication between TMS applications as well as between applications and interfaces where each of the modules are to facilitate the IL as the central medium for communication between them. Please note that any prototyping and testing activities in relation to TMS business logic will be performed within the forthcoming Shift2Rail projects X2Rail-2 and X2Rail-4.

In order to allow a validation of interfaces as specified within this chapter, the following precautions as derived from this chapter are to be taken into account for the work of Task 7.3:

- provision of technical environment with
  - runtime version of the IL,
  - TMS prototype modules for publishing TMS and subscribing ETS information via the IL according to the use cases,
  - ETS prototype module for publishing ETS and subscribing TMS information via the IL according to the use cases;
- the prototype modules will need to log any activity in conjunction with the IL, i.e., data/ timestamp for sending/publishing and data/ timestamp for receiving/subscribing activities.
- availability of sample data in accordance with the use cases;
- scripts for injecting sample data and saving information logged by the components related to each of the tests for all use cases;

The prototype modules as prescribed above will allow for a simulation of the typical communication between future ETS and TMS components.

It is expected that the resulting set up will be able to serve as an initial basis for automated testing of future TMS and ETS components in coherence with the goals of TD2.6 (Zero On-site Testing) of the Shift2Rail project, please also see [Shift2Rail].

7 Interface to Maintenance Management System (MMS)

This chapter describes the different parts of the MMS interface and how they are connected to the Integration Layer of the MMS. For a conceptual view of TMS/MMS interfaces, please also see Figure 5.1.

Note: It is assumed that the Integration Layer of TMS is shared with the MMS and thus, is technically the same. However, certain parts of the interface will probably apply only for communication to or from MMS only which is then achieved by appropriate configuration of the service environment of the Infrastructure Manager.

7.1 Information provided to the MMS

In order to understand the required communication via the interface, four use cases are shown below which are used as a baseline in order to set up requirements and patterns of interface interaction.

7.1.1 Use Cases

The use cases chosen to see which constraints apply to a pattern for information flow from ETS towards MMS are presented in Table 7.1.

Use case #	Use case title	Use case description
Use case 1	Change of basic characteristics or configuration of contact line system in ETS leads to updated information for MMS	Sending a temporary resource restriction information "Feeding section is not energized" to the MMS module for handling infrastructure restrictions as noticed by the ETS
Use Case 2	A maintenance request for ETS components is entered within ETS which leads to information update within MMS	Sending a maintenance request for an ETS component to the MMS module for handling maintenance requests as entered within the ETS
Use Case 3	Dynamic change of component status leads to information update within MMS for surveillance screens and revision planning	Sending changed status information of components "status of component <x> is (secure on, secure off, secure in-between, unknown)" to MMS surveillance module (e.g., SCADA)
Use Case 4	Dynamic change of component or equipment status leads to conditional alarm in ETS being transferred to MMS	Sending a conditional ETS alarm to MMS surveillance (e.g., SCADA) and/or revision planning module

Table 7.1: Information provided to the MMS - Use cases

Each use case is described in the next chapters.

For the purpose of TMS it is sufficient to indicate that a major component failed. This can be for example a converter. For the purpose of MMS it is more important which component in the converter is causing the unavailability. This can be for example a pump for the heat exchanger for the cooling of the converter. More details are needed in order to have the right spare parts at hand as well as personnel and tools. The time for corrective maintenance has to be planned.

7.1.1.1 Use Case 1: Change of basic characteristics or configuration of contact line system in ETS leads to updated information for MMS

Sending a temporary resource restriction information “Feeding section is not energized” to the MMS module for handling infrastructure restrictions as noticed by the ETS.

Operational Situation:

> Due to an ETS disruption and related component restriction, a feeding section may not be usable for electric trains so that trains being in or entering this section will stop and need to wait for re-energization or rescue. Such restrictions are typically caused by outside reasons as e.g., fallen trees, storm, accident etc. The MMS system should react in order to trigger appropriate maintenance activities. Every section and all related switches have unique system names according to EN 81346 part 1 to 3 (see [EN81346]). These unique names are consisting of location information as well as functional information. Within the SCADA system they are represented with a different designation and different properties. Please note: If damages of operational control systems like the ETS are encountered, they usually would require immediate (maintenance) action as to be indicated within the MMS. See also Chapter 7.1.1.4 below.

Assumed ETS/MMS configuration:

- shared identification of power sections between ETS and MMS according to EN 81346 part 1 to 3;
- availability of a MMS module being able to handle temporary resource restrictions (reduced or no power availability) for power sections e.g., for updating views, creation of event information in order to trigger maintenance activities;
- available function in ETS for triggering restriction information transfer as soon as ETS configuration change is performed.

7.1.1.2 Use Case 2: A maintenance request for ETS components is entered within ETS which leads to information update within MMS

Sending a maintenance request for an ETS component to the MMS module for handling maintenance requests as entered within the ETS.

Operational Situation:

Due to loss of redundancy for converters and other equipment, appropriate maintenance activities have to be triggered in order to re-establish full operational redundancy of ETS components as soon as possible. A maintenance request is entered or automatically generated within the ETS accordingly. Similar situations where maintenance requests will have to be created and sent to MMS are:

- exceeding threshold of operational hours for pumps and ventilators;
- exceeding thresholds of counter values for operations of switches;
- yearly measurement of contact wire leads to prediction of end of lifetime;

These may involve required revisions of ventilators, pumps, circuit breakers etc.

Assumed ETS/MMS configuration:

- shared identification of ETS components (e.g., electrical switches) between ETS and TMS according to EN 81346 part 1 to 3;
- availability of a MMS module being able to handle maintenance requests for ETS components;
- available function in ETS for entering or automatic creation of a maintenance request for the respective component(s) and triggering the transfer of maintenance request information to MMS.

7.1.1.3 Use Case 3: Dynamic change of component status leads to information update within MMS for surveillance screens and revision planning

Sending changed status information of components "status of component <x> is (secure on, secure off, secure in-between, unknown)" to MMS surveillance module (e.g., SCADA).

Operational Situation:

The changes of component statuses indicate more or less normal operation of components which occur during regular operation or controlled operations for the components. However, although a planned maintenance of the infrastructure including the controlled switch-off of a power section should be available at the time the corresponding switches are operated and set to "secure off", a MMS may decide to create separate restriction information or validate the planned maintenance information accordingly. These type of messages are usually subscribed by SCADA applications or other infrastructure view applications of a MMS.

Assumed ETS/TMS configuration:

- shared identification of ETS components as e.g., switches between ETS and MMS according to EN 81346 part 1 to 3;
- availability of a MMS module being able to handle ETS component status information (switch status values secure on, secure off, secure in-between, unknown and related transitions between them) for power sections e.g., for updating views, creation of event information;

- optional MMS module for validation of existing planned maintenance information or creation of separate restriction information for power sections based on related component status changes;
- available function in ETS for triggering component status change information transfer as soon as ETS component status changes are performed.

7.1.1.4 Use Case 4: Dynamic change of component or equipment status leads to conditional alarm in ETS being transferred to MMS

Sending a conditional ETS alarm to MMS surveillance (e.g., SCADA) and/or revision planning module.

Operational Situation:

The changes of one or more ETS component or equipment statuses are triggering a conditional alarm within ETS. Based on the alarm event received from ETS, a MMS may decide to create separate emergency or maintenance request information or update already existing information about related planned maintenance activities. This type of message is usually subscribed by SCADA applications or other infrastructure view applications of a MMS.

Assumed ETS/TMS configuration:

- shared identification of ETS alarms between ETS and MMS;
- shared identification of ETS components (e.g., electrical switches) between ETS and MMS according to EN 81346 part 1 to 3;
- availability of a MMS module being able to handle ETS alarms e.g., for updating views, creation of event information;
- optional MMS module for validation of existing planned maintenance information or creation of separate maintenance request information related components;
- available function in ETS for triggering conditional alarm transfer to MMS based on ETS component or equipment status changes as soon as ETS conditional alarm is triggered.

7.1.2 Specific Communication Requirements

The following requirements for sending information (objects, attributes etc.) from ETS to MMS are derived from the Use Cases above:

1. temporary resource restrictions (reduced or no power availability) for power sections;
2. maintenance requests for ETS components;
3. changed status information of components "status of component <x> is (secure on, secure off, secure in-between, unknown)";
4. conditional ETS alarm and related component / equipment.

7.1.3 Proposed pattern

To describe the pattern the CDM object references are used, which themselves are described in the Canonical Data Model, see [In2Rail CDM].

The CDM-nodes are represented by paths as shown in Table 7.2. The location of CDM data as represented by its path gives just a hint for the interface implementation. The column "Reference" includes references to the specific communication requirements within the previous chapter.

Path	Content	Reference
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem	Path for information about constituents of an ETS.	1, 3
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/*component*/<uuid>/*module*	Path for information of the modules of an ETS-component's. All modules of a component are modelled as functional assets from here.	1, 3
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/PowerSection	Path for information in relation to ETS-component "power section".	1
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/PowerSection/<uuid>/Asset/blockedTime	Path for power section asset information in relation to scheduled or observed functional non availability based on time spans .i.e., begin and end time (if available).	1
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order	Path for any types of orders of change requests in conjunction with one or more operational objects i.e., trains or asset objects.	2
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderState	Path for the state of a change request order.	2
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderType	Path for the type of a change request order e.g., type 'Maintenance Request'.	2
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderItem[n]	Path for any items of change request orders for an operational object i.e., a train or asset object.	2
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderItem[n]/OrderItemState	Path for the state of an item of a change request order for an operational object i.e., a train or asset object.	2
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderItem[n]/OrderItemObject	Path for the train or asset object ID related to the change request order item.	2
/network/Infrastructure/FunctionalAssets/ElectricTractionSystem/*component*/<uuid>/*module*[n]/ AssetStatus	Path for operational status of an ETS-component's module. Note: values could be depending on the module e.g., {secure on, secure off, secure in-between, unknown} for power section switches. These are modelled as subclasses starting from this path, see also [CDM], chapter "Functional Assets".	3
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/Priority	Path for the priority of a change request order e.g., 'Emergency Alarm'.	4

Table 7.2: Information provided to the MMS - Paths representing CDM nodes

7.2 Information obtained from the MMS

In order to understand the required communication via the interface, a use case is shown below, which is used as a baseline in order to set up requirements and patterns of interface interaction.

7.2.1 Use Cases

The use case chosen to see which constraints apply to a pattern for information flow from MMS towards ETS is presented in Table 7.3.

Use case #	Use case title	Use case description
Use case 1	Updated information on status and/or forecast of maintenance activities available within MMS leads to information update in ETS	Sending information about status and/or forecasted changes of maintenance activities in MMS to ETS

Table 7.3: Information obtained from the MMS - Use case

Each use case is described in the next chapters.

7.2.1.1 Use Case 1: Updated information on status and/or forecast of maintenance activities available within MMS leads to information update in ETS

Sending information about status and/or forecasted changes of maintenance activities in MMS to ETS.

Operational Situation:

Changes of maintenance activities (e.g., status, planned duration, conditions) may lead to the need for reconfiguration of the electric traction system. The sections to be maintained can be temporarily de-energized. These kind of activities are to be performed while fulfilling a high degree of safety requirements which typically leads to significant effort and may introduce functional safety methods, please also see [EN 50110]. Besides delivering the resource restriction information related to the planned or currently operated maintenance to the MTS module of an ETS, it is expected that related safety conditions according to EN 50110 safety rules are to be handled by components of an ETS (or even TMS). In case of maintenance activities near the border of two neighboring Infrastructure Managers, it is expected that the interface will also be used for cross border or near border dissemination of the respective resource restriction information coming from the external IM. This will require availability of a part of the external network configuration data for the MTS component of the local ETS which is to be exchanged via different channels e.g., through publishing of relevant parts of the CDM.

Assumed ETS/TMS configuration:

- MTS module being available as part of the ETS;
- shared identification of power sections between ETS (MTS) and MMS according to EN 81346 part 1 to 3;
- MTS module being able to handle planned and operational maintenance activities;
- available function in MMS for triggering transfer of planned or operational maintenance activities as soon as related changes are performed within MMS.

7.2.2 Specific Communication Requirements

Change of status, expected duration and/or conditions of planned or already operational maintenance activities.

7.2.3 Proposed pattern

To describe the pattern the CDM object references are used, which themselves are described in the Canonical Data Model, see [In2Rail CDM].

The CDM-nodes are represented by paths as shown in the table below. The location of CDM data as represented by its path gives just a hint for the interface implementation. The column "Reference" includes references to the specific communication requirements within the previous chapter.

Path	Content	Reference
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order	Path for any types of orders of change requests in conjunction with one or more objects e.g., trains or asset objects.	1
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderState	Path for the state of a change request order.	1
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderType	Path for the type of a change request order e.g., type 'Maintenance Request'.	1
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderItem[n]	Path for any items of change request orders for an object e.g., a train or asset object.	1
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderItem[n]/OrderItemState	Path for the state of an item of a change request order for an object e.g., a train or asset object.	1
/network/Realtime/ChangeRequest/Applicant/<uuid>/Order/<uuid>/OrderItem[n]/OrderItemObject	Path for the train or asset object ID related to the change request order item.	1
/network/Realtime/AccessRestriction	Path for any types of access restrictions for tracks e.g., due to requested maintenance. All related attributes and information available from here.	1
/network/Realtime/AccessRestriction/RestrictionType	Path for the type of an access restriction e.g., maintenance activity	1
/network/Realtime/AccessRestriction/RestrictionState	Path for the state of an access restriction e.g., maintenance activity	1
/network/Realtime/AccessRestriction/TempRestriction	Path for the details of an access restriction e.g., maintenance activity (timespan, description, conditions etc.).	1

Table 7.4: Information obtained from the MMS - Paths representing CDM nodes

7.3 Formal definition of the Interface

Please see [In2Rail D8.4] for details.

7.4 Validation of the Interface Specification

As part of Task 7.3 of WP7 in the I2M subproject of In2Rail, a number of prototyping and testing activities for the Proof of Concept (PoC) of the TMS architecture as specified in WP8 are performed. It is assumed that future MMS will share the same data structures for infrastructure resource restrictions as defined within the CDM. Hence, it will be sufficient to apply the same methodology for testing and validating the MMS/ETS interface as for the respective TMS/ETS interfaces (see Chapter 6).

In order to allow a validation of the interfaces as specified within this chapter, the following precautions as derived from this chapter are to be taken into account for the work of Task 7.3:

- provision of technical environment with:
  - runtime version of the IL,
  - TMS(MMS) prototype modules for publishing TMS(MMS) and subscribing ETS information via the IL according to the use cases,
  - ETS prototype module for publishing ETS and subscribing TMS(MMS) information via the IL according to the use cases;
- the prototype modules will need to log any activity in conjunction with the IL, i.e., data/ timestamp for sending/publishing and data/ timestamp for receiving/subscribing activities;
- availability of sample data in accordance with the use cases;
- scripts for injecting sample data and saving information logged by the components related to each of the tests for all use cases.

The prototype modules as prescribed above will allow for a simulation of the typical communication between future ETS and TMS(MMS) components.

It is expected that the resulting set up will be able to serve as an initial basis for automated testing of future MMS and ETS components in coherence with the goals of TD2.6 (Zero On-site Testing) of the Shift2Rail project, please also see [SHIFT2RAIL].

8 Test scenarios

In general, it is assumed that test scenarios will have to consider field testing as well as lab testing situations. However, since within the In2Rail project, prototypes are to be developed with TRL-levels not higher than 3, field level testing will not be covered within this project.

The test scenarios for lab level testing depend very much on availability of realistic test data and test cases from real operations' practice. At the time of writing this document, it was not yet clear from which source the test data will be made available so that test cases were not able to specify in detail.

However, it is expected that the test scenarios used for validation of this interface in WP7, Task 7.3 will be set up in line with the use case description as described in the above sections and will be performed as part of the respective Proof of Concept environment and test cases as described in deliverable D7.4 (Definition of the Proof of Concept, [In2Rail D7.4]).

The results of these activities are to be found in deliverable D7.5 (Evaluation of the Proof of Concept, [In2Rail D7.5]).

9 Conclusions

Even if the TMS (Traffic Management System) as well as the ETS (Electrical Traction System) and other components are in the hand of an IM (Infrastructure Manager) the systems are not fully integrated today and optimized only separately for themselves. Today's TMS do not consider the actual status of the ETS. Hence, train schedules and changes to them typically do not consider restrictions in the ETS and might not be optimized towards energy efficiency. Benefits can be leveraged by interaction of these systems.

This document defines interfaces to integrate these different components and describes the expected benefits. Particularly the introduction of an MTS (Multi Train Simulator) is beneficial if considered as a part of the ETS. Evaluation of limitations in the ETS during major outages is enabled and resulting consequences on scheduling of trains can be communicated to the TMS. Model-based now-casting of electric energy is enabled for different points of common coupling between the ETS and the public grid. This might lead to new opportunities in energy purchasing by now-casting of peak power and energy demand. Reduced maintenance cost of the ETS is expected by use of the interface to an MMS (Maintenance Management System).

In this context the mutual need for information is defined.

The chosen method to select use cases, analyse them for possible constraints and formalise them into requirements has been very successful in defining the requirements for the Interfaces which are within the scope of this document.

The overall approach to apply a Canonical Data Model as the "Language of the Integration Layer" allows the formulation of the requirements for the Interfaces of the IL and the access pattern for the different use cases in an effective and unique way.

However, this document is a "living document" and will require periodical updates during the lifetime of In2Rail and the proceeding projects of the Shift2Rail program (see [Shift2Rail]) and will need to incorporate evolving requirements triggered from the subsequent design works on the Integration Layer.

The results of this activity will be integrated into the "Proof of Concept" activities under In2Rail WP7 Task 3, which is in line with the use cases presented in this document.

The "manageable complexity" of the achieved results is supporting a process towards standardisation of the Interfaces of the Integration Layer as soon as the design of the data model and processes of the communication infrastructure are finalised and agreed within the railway sector.

10 References

[EIP] http://www.enterpriseintegrationpatterns.com/index.html.

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[EN 50122-1] Electrical safety, earthing and the return circuit. Protective provisions against electric shock.

[EN 50388] Power supply and rolling stock. Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability.

[EN 50562] Process, protective measures and demonstration of safety for electric traction systems.

[EN 81346] Industrial systems, installations and equipment and industrial product. Structuring principles and reference designations. Parts 1 to 3.

[EU 2009/72/EC] EU Directive 2009/72/EC (3rd Internal Energy Market Package).

[FprEN 50562] Process, protective measures and demonstration of safety for electric traction systems (EN 50562 draft).

[In2Rail CDM] Annex to D8.3 and D8.6. Description of the Canonical Data Model Description of the Canonical Data Model, In2Rail, 2017.

[In2Rail D7.1] State-of-the-Art and High Level Requirements, In2Rail, 2016.

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[In2Rail D7.4] Definition of the Proof of Concept, In2Rail, 2017.

[In2Rail D7.5] Evaluation of the Proof of Concept, In2Rail, expected in April 2018.

[In2Rail D8.3] Description of Integration layer and Constituents, In2Rail, 2017.

[In2Rail D8.4] Interface Control Document for Integration Layer Interfaces, external/Web interfaces and Dynamic Demand services, In2Rail, expected in April 2018.

[In2Rail D8.5] Requirements for the Generic Application Framework, In2Rail, 2017.

[In2Rail D8.6] Description of the Generic Application Framework and its constituents, In2Rail, 2017.

[Hazelcast 2017] http://docs.hazelcast.org/docs/3.8.1/manual/html-single.

[Protobuf 2017] https://developers.google.com/protocol-buffers/.

[Redis 2017] https://redis.io/documentation.

[Shift2Rail] https://shift2rail.org/.

11 Appendix A - Collated Requirements

ID	Text
REQ_TMS_1	ETS to TMS: Vehicle related power limits and expected power usage for a train itinerary in kW
REQ_TMS_2	ETS to TMS: Temporary resource restriction “Feeding section is not energized”
REQ_TMS_3	ETS to TMS: Disruption information “Outage of a major component <x> of substation <y>”
REQ_TMS_4	ETS to TMS: Changed status information of components “status of component <x> is (secure on, secure off, secure in-between, unknown)”
REQ_TMS_5	TMS to ETS: Updated (forecast) schedule for one or multiple filtered train itineraries; filters: section and/or time frame
REQ_TMS_6	TMS to ETS: Actual auxiliary power consumption of vehicles
REQ_TMS_7	TMS to ETS: External factors along the journey of a train e.g., weather conditions
REQ_TMS_8	TMS to ETS: Physical characteristics, especially load and resistance coefficients of the train under consideration of multiple locomotives in one train
REQ_TMS_9	TMS to ETS: Planned or operated temporary resource restriction “power section switched-off”
REQ_TMS_10	TMS to ETS: Availability information (non availability, reduced maximum speed) for specific track sections
REQ_MMS_1	ETS to MMS: Temporary resource restrictions (reduced or no power availability) for power sections
REQ_MMS_2	ETS to MMS: Maintenance requests for ETS components
REQ_MMS_3	ETS to MMS: Changed status information of components “status of component <x> is (secure on, secure off, secure in-between, unknown)”;
REQ_MMS_4	ETS to MMS: Conditional ETS alarm and related component / equipment
REQ_MMS_5	MMS to ETS: Planned or forecasted temporary resource restriction for maintenance activities