Sustainable and intelligent management of energy for smarter railway systems in Europe: an integrated optimization approach

D7.2. Position paper for agent integration and interaction

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EXECUTIVE SUMMARY

The WP7 objectives are to ensure the exploitation of the project results by transferring them into standardisation and thus leading to implementation market uptake. In order to fulfil these objectives a position paper is elaborated within the task 7.2: "Position paper for agents integration and interaction".

The aim of this position paper is to describe the technical and economic aspects of the adaptation of electricity distribution in the railway sector when a railway smart grid is implemented. Besides, this position paper specifically will argue for a modification of the structure that allows the integration of the different agents when a railway smart grid is put into service.

Nowadays trains are merely energy consumers, but the tendency is to change towards railways smart grids, where the energy consumption profiles are optimised in real time in coordination with other trains and SSTs. The development of the railway smart grid is pushing forward a change in the paradigm in the electricity management in railway sector, which enriches interactions among the agents.

Within the MERLIN project several architectures and protocols have been developed that allow new ways of interaction between the involved agents (IM, RU, EMO, TSO, DSO, etc.) which were not possible without Smart Grid technologies. Some of the services (which correspond to these interactions) are described in this position paper, namely:

(i) railway system operation services, provided by the REM-S.
(ii) execution of the control actions (provided by the REM-S), performed by the trains (Dynamic Onboard Energy Manager, DOEM), ESSs, DESs, etc.
(iii) energy procurement services, provided by the Electricity Buyer Decision Maker (EBDM), which is a module of the REM-S.

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LIST OF ACRONYMS

CDS	Closed Distribution System
CDSO	Closed Distribution System Operator
DES	Distributed Energy Sources
DOEM	Dynamic Onboard Energy Manager
DSO	Distribution System Operator
EBDM	Energy Buying Decision Maker
EC	European Commission
EMO	Electricity Market Operator
ERA	European Railway Agency
ESO	Electrical System Operator
ESS	Energy Storage System
EU	European Union
GenCom	Generation Companies
IEM	Internal Electricity Market
IM	Infrastructure Manager
PCC	Points of Common Coupling
RDG	Railway-side Distributed Generation
REM-S	Railway Energy Management System
RPS	Railway Power System
RU	Railway Undertaking
T&D	Transmission and Distribution
TSI	Technical Specifications for Interoperability
TSO	Transmission System Operator

1 INTRODUCTION

The aim of this position paper is to describe the technical and economic aspects of the adaptation of electricity distribution in the railway sector when a railway smart grid is implemented. Besides, this position paper specifically argues for a modification of the structure that allows the integration of the different agents when a railway smart grid is put into service.

In order to fulfil these objectives, it is necessary a brief description of the different agents that interact between the electric sector and the railway sector and a description of the interactions between agents when a smart grid is implemented.

1.1 RAILWAYS AND OTHER POWER SYSTEMS

Figure 1 represents the interconnection among electrical and railway systems, whose most relevant agents are:

- An Electricity Market Operator (EMO) is a company that operates an organized electricity market: It manages the bids submitted by energy sellers and buyers, matches them (according to the pre-specified market rules) to determine which are accepted and carries out the payments of the energy transaction.
- Electrical System Operators (ESO) are companies in charge of balancing the generation and the demand. As the electricity cannot be stored in large quantities, the power plants have to adjust in real time their production to be equal to the consumption.
- Transmission System Operators (TSO) are companies operating a transmission grid, by setting the operating point of every element of the grid, in such a way that the reliability of the system is guaranteed. It should be noted that, in most cases, the ESO and the TSO activities are performed by the same company.

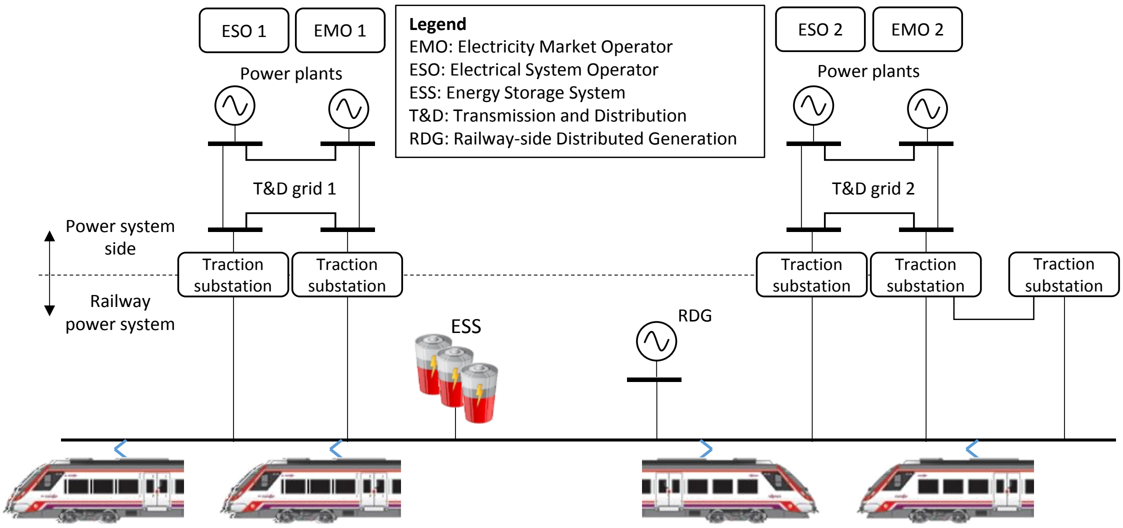

Figure 1: Interconnections of railway power systems (RPS) to the power systems

- Distribution System Operators (DSO) are companies which are in charge of operating the distribution grids so that the electricity is supplied to every customer with the required quality.

- Closed Distribution System (CDS) are systems which distribute electricity within small areas (small industrial, commercial or shared services zones) that do not supply energy to household customers and which fulfil the following conditions: (i) integrated operations and production process, (ii) energy distributed to the owner and the operator of the system and (iii) other industrial, commercial and shared services[1]. As the CDS normally are proprietary networks, their owner normally plays the role of Closed Distribution System Operator (CDSO).
- Trading companies (Retailers) buy electricity (by means of contractual agreements with wholesale retailers or with generation companies; or by means of organized electricity markets, etc.) and re-sell it at a higher price to their customers. In their role of demand aggregators, they are supposed to mitigate the volatility of the prices (for example, by diversifying their suppliers and using long term contracts) and the volatility load profiles (the aggregation of many different load profiles tends to reduce the volatility of the demand).
- Generation companies (GenCom) are responsible for producing the energy that has been committed in each power plant. The energy produced can be sold by means of contractual agreements or in wholesale organized electricity markets, operated by an EMO. However, final corrections to the program may be introduced by the ESO/TSO to solve technical restriction and to respond to the unexpected variations that occur in real time.
- An Infrastructure Manager (IM) is any body or firm responsible for establishing, managing and maintaining railway infrastructure, including traffic management and control-command and signalling. An IM must also provide ancillary services to RUs, such as traction current. Railway infrastructure which is managed by the IM consists of: ground area, track and track bed, engineering structures (bridges, tunnels, etc.), level crossings, superstructure (rails, sleepers, etc.), safety, signalling and telecommunications installations, lighting installations, plant for transforming and carrying electric power for electric haulage and buildings used by the infrastructure department (Directive 2012/34/EU[2]).
- A Railway Undertaking (RU) is any public or private undertaking licensed whose main business is to provide services for the transport of goods and/or passengers by rail with a requirement that the undertaking ensure traction; this also includes undertakings which provide traction only. It has the rolling stock in property. (Directive 2012/34/EU).

The following systems can be owned and/or operated by some of the agents mentioned before or even a third party to achieve very different objectives:

- Railway-side distributed energy sources (DES) are generators (typically using renewable sources) connected only to the railways electrical grid.

[1] *Directive 2009/72/EC. Article 28*

[2][2] *Directive 2012/34/EC. Article1: This Directive lays down:*

(a) the rules applicable to the management of railway infrastructure and to rail transport activities of the railway undertakings established or to be established in a Member State as set out in Chapter II;

(b) the criteria applicable to the issuing, renewal or amendment of licences by a Member State intended for railway undertakings which are or will be established in the Union as set out in Chapter III;

(c) the principles and procedures applicable to the setting and collecting of railway infrastructure charges and the allocation of railway infrastructure capacity as set out in Chapter IV.

- Energy Storage Systems (ESS) are devices that are able to defer the power consumption: to store energy (charging process) and to return it (discharging process) at a different moment.

1.2 INTERACTION AND INTEGRATION WITH ELECTRICAL SMART GRIDS

In the near future, the development of electrical railway smart grid technologies is expected to allow an improved controllability of most of the elements of a railway power system (trains, substations, DESs, ESSs, etc.) and, even more importantly, new types of interaction among them. An example of these interactions is given by the way trains are driven, which will be able to change dynamically in order to keep the operation optimal when some limitation will appear in the infrastructure.

Because of their physical interconnection, both the electrical systems and the railway systems are coupled (i.e. what happens in one side has an impact in the other side, and vice versa), although traditionally only the electrical system has been reactive –whenever the power flows change in the railway grid, the control schemes of the public grid will change the production immediately and adapt the characteristics of the transmission and distribution grids–. It should be noted that the interactions are typically twofold, as an electrical exchange use to imply also an economic exchange.

The development of the railway smart grid is pushing forward a change in the paradigm in the electricity management in railway sector, which richer interactions among the agents (see Figure 2). The aim of this position paper is to describe the technical and economic aspects of the adaptation of electricity distribution in the railway sector to this new paradigm.

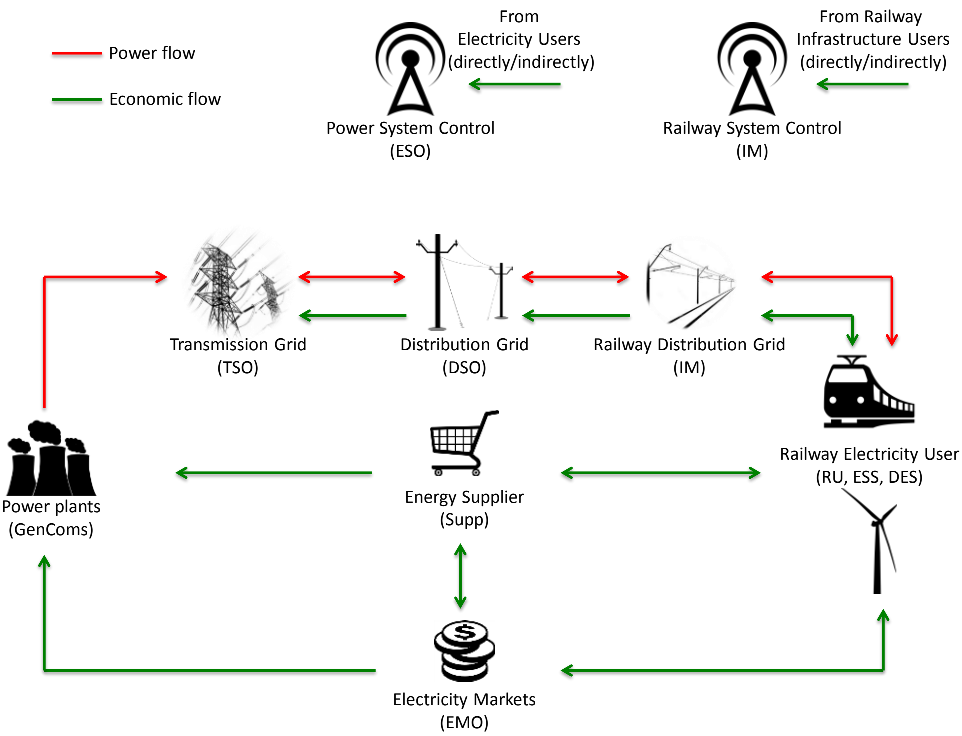

Figure 2: Agent integration and interaction in electrical and railway systems

This adaptation will require the deployment of cutting edge smart grid technologies, but also a revision of the current legal framework, since some of the new kinds of interaction were not even conceivable when it was designed.

In addition to this introduction (Section 1.1) and the definitions (Section 1.2), this document has three sections. Section 2 describes how the “traditional” interactions (those which exist even without any smart grid technology) are modified by the adoption of the smart grid paradigm. Finally, Section 3 analyses new ways of interaction which will be possible thanks to smart grid technologies.

2 TRADITIONAL AGENT INTERACTIONS

As illustrated in Figure 1, railway power systems are typically connected to distribution and/or transmission grids (public T&D grids or railway-specific grids) by points of common coupling (PCC). In traditional electrical (i.e. non-smart grid) railways, trains and other loads consume power as they need it. From the point of view of the electrical sector, the railways are merely consumers of electrical services (transmission/distribution, trading, etc.).

In the smart grids, the different agents are able to interact among them. For instance, power profiles (and therefore driving styles) can be optimized dynamically and in a coordinated way with other trains and/or ESS, DES, etc. The traditional interactions will continue to exist (the smart grid will use the transmission/distribution infrastructure, will purchase the energy in the markets, etc.), although the precise terms will change.

2.1 INTERACTION WITH ENERGY MARKET

Every consumer can freely choose their energy supplier and the energy can be purchased by two different kinds of mechanism:

- Contractual agreements (non-organized market) with a GenCom or with any other supplier (retail or wholesale) or even the IM. In order to mitigate the risks, supply contracts incorporate a risk premium (which is normally lower when agreed prices are indexed to market prices).
- Direct purchase in organized markets. As the production of every power plant at each hour has to be established in advance (power plants may require several hours or even a few days, depending on the generation technology and the previous operating conditions, to start up), a multi-timescale scheme is commonly used in operation and, consequently, in organized markets (where acquisition of the energy is done in different moments, with different time horizons).

Both ways of purchasing/selling energy are possible today, without using any smart grid technology. Only the appropriate measuring equipment is required.

However, the direct purchase in organized markets may be very challenging in practice because of the uncertainty in the estimation of prices (final prices are not known when the bids are submitted) and in the estimation of the energy demand (the real consumption/generation is only known in real time, when it is measured and, in fact, varies every day).

As deviations from the expected consumption/generation profile are normally penalized in the electricity market (because it causes inefficiencies in the operation of the system), these uncertainties involve an important economic risk. For that reason, unless appropriate tools (such as those developed in MERLIN) are used to handle the uncertainties, only contractual agreements are suitable in practice for energy purchase.

In Malaga scenario (see document MRL-WP2-D-FFE-148-03), a 50% reduction of the risk premium charged by an existing energy supplier thanks to the improved predictability achieved by the REM-S has led to overall estimated savings of 1.84%.

2.2 Interaction with Public Grid

Most of the energy used in railways is produced in power plants external to the railway (see Figure 1) and crosses different intermediate grids (transmission and distribution) before reaching the railway infrastructure. As a user of the electrical system, each railway agent has to pay:

- a toll to the intermediate grid operators, which typically include two terms: (i) a term proportional to the supplied energy and (ii) a term proportional to the supplied power (which corresponds to the part of the capacity reserved for this user) and
- a fee to the ESO for the different operation costs (voltage control, balancing services, losses, secondary and tertiary regulation, management of the deviations, solution of technical restrictions, etc.), which is normally proportional to the consumed energy.

It should be noted that the impact of the terms which depend on the maximum power (specified in the supply contract or measured in a maximeter) is normally significant (it can represent about 30-40% of the total electricity bill). From an electrical point of view, these power peaks also have a negative impact in the distribution grids. An appropriate integration with the electrical system would be beneficial for both systems, but it is not feasible without using smart grid technologies.

According to the on-field test carried out in Malaga (scenario 3), the implementation of a system such as the REM-S can lead to an average reduction of 15% of the power peaks (see document MRL-WP6-R-CAF-174-03). As described in document MRL-WP2-D-FFE-148-03, the electricity bill can be reduced a 5.54% thanks to this reduction in the power peaks.

2.3 Interaction with the Railway Electrical Grids

According to the Directive 2009/72, the railway power system can be considered as a CDS and, therefore, the IM would act as a CDSO (Closed Distribution System Operator).The responsibilities of a CDSO are [3]:

- Building, maintaining and operating the electrical grids linking the transmission grid with the consumption centres.
- Expanding facilities to meet new demands of power supply.
- Operate the power grid so that it ensures an adequate level of service quality.
- Replying equally to all requests for access and connection.

[3] *Directive 2009/72/EC. Article 2: 'distribution system operator' means a natural or legal person responsible for operating, ensuring the maintenance of and, if necessary, developing the distribution system in a given area and, where applicable, its interconnections with other systems and for ensuring the long term ability of the system to meet reasonable demands for the distribution of electricity.*

- Measure consumption.
- Applying consumer charges for access.
- Reporting to agents and customers involved.
- Annually submitting their investment plants to the Region Authorities.

According to Directive 2009/72, the IM must allow the Third Party Access, provided that the established technical requirements are met. Although the energy supply choice is free, it should be pointed out that distributor choice is not, especially in closed distribution networks.

As a CDSO, the IM charge the users of the electrical infrastructure for providing these services. These charges are fixed by the IM and must be published in the network statement[4] and fulfil the Directive 2012/34 requirements.

One of the most important goals of railways smart grids is to achieve a more efficient utilization of the available resources, not only of the energy but also of the installed capacity of the infrastructure. For that reason, it is important to pay more attention to the management of the electrical capacity, especially to its assignment to the trains. To allow a proper optimization of the operation, which is one of the objectives of MERLIN, the train power profiles must be predictable for all the trains (those equipped with smart grid technologies and those which are not) and their allocated power at each substation (which is dynamic) should not be exceeded (unless the control system authorize it). An appropriate regulation of the capacity usage is missing and would be necessary to allow the expected improvements in the operation.

3 SMART- GRIDS NEW AGENT INTERACTIONS

Within the MERLIN project several architectures and information exchanges structures have been developed that allow new ways of interaction between the involved agents (IM, RU, EMO, TSO, DSO, etc.) which were not possible without Smart Grid technologies. Some of the services (which correspond to these interactions) are, namely:

(i) railway system operation services, provided by the Railway Energy Management System (REM-S)–,
(ii) execution of the control actions (provided by REM-S), performed by the trains (Dynamic Onboard Energy Manager, DOEM), ESSs, DESs, etc.,
(iii) energy procurement services, provided by the Electricity Buyer Decision Maker (EBDM) –part of the REM-S–.

[4] *Directive 2012/34/EC. Annex IV: The network statement referred to in Article 27 shall contain the following information:[…] 2. A section on charging principles and tariffs. This shall contain appropriate details of the charging scheme as well as sufficient information on charges as well as other relevant information on access applying to the services listed in Annex II which are provided by only one supplier. It shall detail the methodology, rules and, where applicable, scales used for the application of Articles 31 to 36, as regards both costs and charges. It shall contain information on changes in charges already decided upon or foreseen in the next five years, if available.*

3.1 ELECTRICAL RAILWAY SYSTEM OPERATION SERVICES

These services aim to optimise the energy flows (trains consumption/regeneration, infrastructure consumption, ESS charge/discharge, DES production, etc.) and are provided by the Energy Dispatcher, a service offered commonly by the IM to all the agents which adhered to MERLIN system (it is important to highlight that the adhesion to the MERLIN system should be optional).

The entity supplying this operation control services (normally the IM) should be paid for providing these services, either by means of a fixed term (that should be established in the network statement) or using a distribution mechanism of the achieved savings. In the on-field tests carried out in Malaga (scenario 3), these savings have been estimated (see document MRL-WP2-D-FFE-148-03) in 101k€/yr-9.64% (energy minimization under traffic congestion situation), 108k€/yr-10.28% (power peak minimization) and 126k€/yr-11.97% (combined energy and power peak minimization). A "mark-up" mechanism (e.g. a percentage of the total savings) has been proposed for remunerating the control services provided by the IM.

3.2 EXECUTION OF THE CONTROL ACTIONS (DOEM)

These services consist in executing the instructions received from the REM-S to enhance the operation (for example, to reduce power peaks, to reduce losses, etc.) and are provided to all the agents involved in the operation (RUs, IMs, etc.). The agents that follow these instructions should be paid according to a distribution mechanism of the achieved savings.

The total savings estimated in Malaga scenario (see section 3.1) minus the "mark-up" establish to pay the IM, should be distributed among the agents that have followed the control instructions provided by the IM, for instance proportionally to their contribution to the total power flows.

The adhesion to this service should be optional and reserved to trains that effectively can provide them. In other words, those elements which are not able to follow the instructions should not benefit from the savings.

3.3 ENERGY PROCUREMENT SERVICES

In order to minimize the volatility of energy prices, a practical solution is to manage a portfolio of supply alternatives, combining long term contracts and participation in the spot markets. The EBDM helps to determine the best way of combining the available contracts with the participation in the spot markets to optimize the price of the energy.

To minimize the uncertainty in the volume of energy, two approaches must be combined. Firstly, the Energy Dispatcher has to be able to minimize the deviations by operating the system (giving instructions to the trains and to the infrastructure). Secondly, the management of the portfolio of supply alternatives has to minimize the exposure to the deviations. For this second approach, the EBDM can determine the way of combining contracts and the participation in the spot market in order to minimize the impact of the deviations.

This service can be provided by the IM (or, alternatively by a third party retailer) and should be paid for, either by means of a fixed term (that should be established in the network statement) or using a distribution mechanism of the achieved savings.

The adhesion to this service should be optional (as established by the Directives).

In project MERLIN (see document MRL-WP2-D-FFE-148-00), a reduction higher than 50% in the total premium added to the wholesale price (including both the reduction in the commercial margin and in the risk premium) has been considered.

4 RECOMMENDATIONS

After the analysis carried out in MERLIN the following recommendation can be pointed out:

- The adoption of smart grid technologies has achieved savings of 11% of the total energy consumption under traffic congestion situation and 15% of the power peaks (obtained for the Malaga on-field test scenario). Based on these results, the implementation of this kind of technologies is advisable, but detailed cost-benefit analyses should be carried out in order to determine the profitability of the required investments in each case.
- The optimization of the energy procurement is advisable, not only because of the average energy price reduction it can achieved, but also because of the risk management strategies that can be follow to reduce the exposure to the volatilities of spot market prices and the energy demand. Although only a short-term optimization has been addressed in MERLIN, a longer-term management would improve the results of the energy procurement.
- To allow a proper optimization of the operation, the train power profiles must be predictable for all the trains (those equipped with smart grid technologies and those which are not) and their allocated power at each substation (which is dynamic) should not be exceeded (unless the control system authorize it). An appropriate regulation of the capacity usage is missing and would be necessary to allow the expected improvements in the operation.
- In other to provide the appropriate economic signals, a mechanism for distributing the economic savings that can be achieved by the smart grid has to be detailed, including both the “mark-up” to be paid to the IM and the payments to the RUs.

Annex I. **LEGAL FRAMEWORK**

Since the beginning, energy and railway markets have been treated separately, as the ERA underlines[5], but nowadays, they present some similarities that make pertinent a deeper analysis of their links.

I.1 RAILWAY LEGAL FRAMEWORK

The Directive 2012/34/EC –which establishes a single European railway area– defines several rights and obligations for IMs concerning aspects such as the access to supply equipment for traction current or the provision of the traction current. Among the main points laid down in this Directive, Art.13[6] and the Annex II[7], should be highlighted as both of them define services which can be provided by IM for RUs.. Article 2 introduces some exemptions of the application of the Directive for urban and regional isolated rail networks. However this Directive also includes other important aspects related to railway operation. To ensure equality and non-discriminatory access to infrastructure, the Directive establishes that the IM should be completely independent of any RU candidate to provide transport services. RUs require a license that allows them to provide transport services throughout the EU, removing the borders, hampering the free competition of RUs in the EU international services. It also sets up the main functions that the IM must comply with, namely:

- Maintenance of the infrastructure and ensure the provision of services such as traction current, signalling, etc.
- Fixing and collecting charges for infrastructure use, so that the reduction of disturbances that harm the proper operation of transport services is motivated.
- Regulation and allocation of infrastructure capacity, ensuring competition and non-discrimination of candidates.
- When infrastructure is unable to respond capacity requests, the IM will determine that it is congested and should take steps to increase capacity and set preferences among the most important services as determined in the Network statement.
- The energy traction billing has to be segregated from other charges for the usage of the infrastructure (Annex II, 3.a).

This Directive has to be applied in line with the requirements established by the 2014/25/EC Directive on procurement by entities operating in the water, energy, transport and postal services sectors and subsequent norms.

I.2 ENERGY MARKET LEGAL FRAMEWORK

The creation of a European Internal Electricity Market (IEM) is the objective of Directive 96/92/EC, Directive 2003/54/EC and Directive 2009/72/EC. In short, the first step was to identify eligible

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[5] *ERA Interoperability Unit Study: Traction Current Settlement System.*

[4] *Directive 2012/34/EC. Article 13: Infrastructure managers shall supply to all railway undertakings, in a non-discriminatory manner, the minimum access package laid down in point 1 of Annex II.*

[7] *Directive 2012/34/EC, Annex II: The minimum access package shall comprise:[…] (e) use of electrical supply equipment for traction current, where available.*

customers who have the legal capacity to contract energy from any supplier (Directive 96/92/EC). Then, Directive 2003/54/EC introduced the concept of Third Party Access by which suppliers and generators are granted access to the grid to settle negotiated electrical energy transactions for delivering electrical energy.
In 2009, Directive 2009/72/EC (often referred to as Third Electricity Package) repealed Directive 2003/54/EC. The objective of this Directive 2009/72/EC is to establish common rules for the generation, transmission, distribution and supply of electricity (Art.2) and their obligations (Chapters IV, V and VI), together with consumer protection provisions, with a view to improving and integrating competitive electricity markets in the Community. In addition, common rules for the electricity sector organization (how to grant authorizations, definition of the universal service obligations, etc.) are also established.

Furthermore, the directive imposes the obligation to the network owner/operators to offer any supplier to use its distribution network (Third Party Access, Art. 32[8]). This concept appears as a consequence of the electricity market liberalization, in which Third Parties can access to the market with published non-discriminatory tariffs. Also, the end-users have the possibility to choose the energy supplier they prefer.

The Energy Union package published on 25th February 2015 by the European Commission intends to establish a European-wide union for sustainable energy production, transportation and consumption in all its forms (electricity, gas, oil, new energy sources ...). Such a large scale encompasses all modes of transportation, particularly in emissions reduction. The package incorporates: "A framework Strategy for a Resilient Energy Union with a Forward-Looking Climate Change Policy", "The Paris Protocol – A blueprint for tackling global climate change beyond 2020", the staff working document "The Paris Protocol – A blueprint for tackling global climate change beyond 2020" and the Communication "Achieving the 10% electricity interconnection target, Making Europe's electricity grid fit for 2020", within its annexes.

Control actions could be determined under the regulation of the 2012/27/EU Directive of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC. This Directive set a common frame to regulate energy efficiency and, depending on the national transposition, the rail traction electricity consumptions will have to accomplish the energy audits.

The Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sectors and repealing Directive 2004/17/EC regulates the relations of procurement in the electricity sector by public entities, defining the contract procedures, the open market access rights and the technical specifications. This Directive includes norms to foster the quality and the environmental protection criteria inside the contracts. The scope of the directive includes the construction of rail infrastructure and the installation of electrical networks and the transport services electricity networks railways network are directly included. One of the main requirements

[8] Directive 2009/72/EC. Article 32: Member States shall ensure the implementation of a system of third party access to the transmission and distribution systems based on published tariffs, applicable to all eligible customers and applied objectively and without discrimination between system users. Member States shall ensure that those tariffs, or the methodologies underlying their calculation, are approved prior to their entry into force in accordance with Article 37 and that those tariffs, and the methodologies — where only methodologies are approved — are published prior to their entry into force.

of this Directive is the inclusion of the split of the contract in lots to be opened to tenders of the electricity supply companies to ensure the security of supply.

Furthermore, the 2009/28/EC Directive of 23 April, on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC regulates the main exchanges and disclosures of green energy certificates in order to adopt renewable energies in the European electricity sector. For the rail electric sector this Directive allows the implementation of a clear and regulated frame for the procurement of green certificates, increasing the possibilities for rail companies to adopt renewable energies. This Directive is the basic legal frame for the purchasing, exchange and reporting of green certificates in the rail electric sector, a key issue in order to accomplish a relevant reduction targets on greenhouse gases emissions.

I.3 COMPARISON BETWEEN RAILWAY AND ELECTRIC LEGAL FRAMEWORKS

To carry out a comparison between rail sector and electricity sector directives (Directive 2012/34 and 2009/72) must be taken into account, they have the common objective of opening markets for competition but in different terms.

Both Directives state that Member States must appoint an independent authority, which does not provide any service related to the scope of the infrastructure (electrical or railways), for licensing and ensuring compliance with obligations. In the case of Directive 2009/72, this authority can be the same as the regulatory one but, Directive 2012/34 specifies that this authority must be independent of any regulatory authority.

In addition, with reference to the management of the infrastructure in railways and the transmission and distribution network, both Directives name an independent entity which manages the infrastructure and assigns capacity. In the case of railways, it is the Infrastructure Manager (IM) and, in case of electricity sector, for each case a Transmission and/or Distribution System Operator (TSO/DSO) is appointed. In both cases, operators must pay a particular tariff to access the system. These tariffs must be public and guarantee free access to the infrastructure(electric or railways).

In terms of current supply, both Directives express the free supplier choice but, in Directive 2009/72 it is included as a mandatory issue, while Directive 2012/34 includes traction current as additional service offered by IM.

Also, both Directives include some aspects as tariffs, contracts, property and operation independency, in terms of non-discrimination and free access of any candidates…which must be supplemented with the respective TSIs (Technical Specifications for Interoperability).

In summary, it is clear that electricity rules are more general than in the railway sector as they could be applied to other sectors, but both regulations follow the idea of transparency, free access and the establishment of the same conditions in all European Countries. The railway electric system, because of its characteristics could be operated as a Closed Distribution System as set out in Directive 2009/72. For this reason, rules established in the electric directive could also be applied to the railway sector, e.g. any railway undertaking could choose the energy supplier that best suits its needs, causing the entrance of different energy providers to the railway energy network.