Railway Smart Meters

Thesis Research Plan

Vítor A. Morais
Supervisor: António P. Martins (UPorto)
Co-supervisor: João L. Afonso (UMinho)

Doctoral Program in Electrical and Computer Engineering
Department of Electrical and Computer Engineering
Engineering Faculty — University of Porto

October 17, 2017

Outline

Outline

Context and motivation

The railway system is responsible for 1.3% of entire European energy consumption, [?]. The debate on energy efficiency in railways is a well-discussed topic due to its impact on the global energy consumption. The energy efficiency analysis and management requires a detailed mapping of the energy consumption/generation in the railway system. This detailed mapping of the energy flows should include, not only the rolling stock level but also the traction substations and the auxiliary services. The knowledge of all the load curves permits load prevision, peak shaving and energy cost optimization for the entirely of the railway system.

Shift2Rail Framework - Main Goal

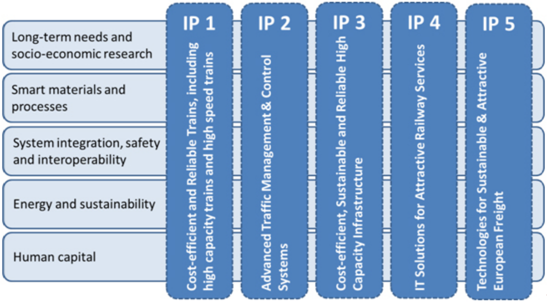
- 1. Cutting the life-cycle cost of railway transport by, at least, 50%;
- 2. Doubling the railway capacity;
- 3. Increasing the reliability and punctuality by 50%, at least.

Shift2Rail Framework - Time Targets

Complementary, the time target goals are the establishment of a framework, by 2020, for a European multimodal transport system for the passenger rail, freight and for the urban mobility. By 2030 is expected to triple the length of the existing high-speed passenger rail network, 30% of the road freight over 300 km should shift to rail or waterborne transport and achieve a CO2-free city logistics in major urban centers. By 2050, the medium-distance passenger transport should go by rail and high-speed rail, with the connection of all core network airports to the high-speed railway network. On the freight is expected to have all seaports connected to the rail freight transport system and on the urban mobility, the "conventionally-fueled" cars will not have place in cities by 2050, [?].

Shift2Rail Framework - Innovation Programmes

The S2R carries five innovation programmes, as presented in figure 1. Framed on the S2R IP3 with the focus on the "Cost efficient and reliable infrastructure", it is proposed the development of a SMD that achieves a detailed monitoring and supervision of various energy flows on the premises of embracing the entire RTS.



Main Goal

The purpose of any energy management strategy is to build the dynamics of every loads and generators of the power system. This should be performed based on an extensive knowledge of every energy flows. This way, the SMD is required to propose and validate a standard metering architecture that involves the coordination of every measurement performed either in on-board and in ground. In advance, energy data analysis should be provided based on relevant stored data.

Outline

Overview of Existing European Railway Power Systems

Table 1: Catenary topology and vehicle characteristics of different railway vehicles. [?].

	Catenary topology		Vehicle characteristics	
	DC supply	**AC supply**	**Power**	**Top speed**
Tram	600V DC, 750V DC, 900V DC	-	150–300kW	50–70km/h
Metro	750V DC, 1500V DC	-	350kW–1MW	80km/h
Train	750V DC, 1500V DC, 3000V DC	15kV AC (16.7Hz) and 25kV AC (50Hz)	200kW–8MW	120–350km/h
Locomotive	750V DC, 1500V DC, 3000V DC	15kV AC (16.7Hz) and 25kV AC (50Hz)	500kW–8MW	100–200km/h

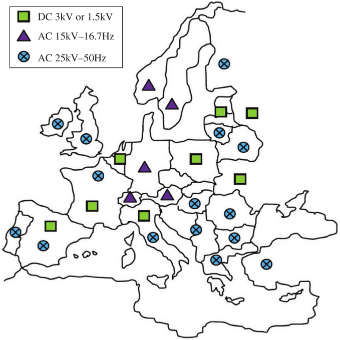


Figure 2: Railway main-line power supply systems in Europe. [?].

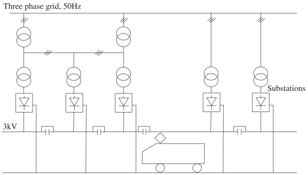


Figure 3: DC supply system architecture. [?].

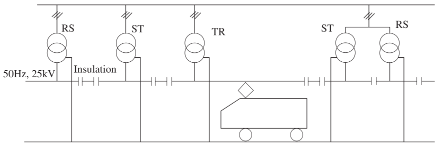


Figure 4: 50 Hz 25 kV supply system. [?].

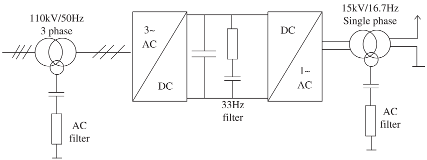


Figure 5: 16.7 Hz 15 kV supply system. [?].

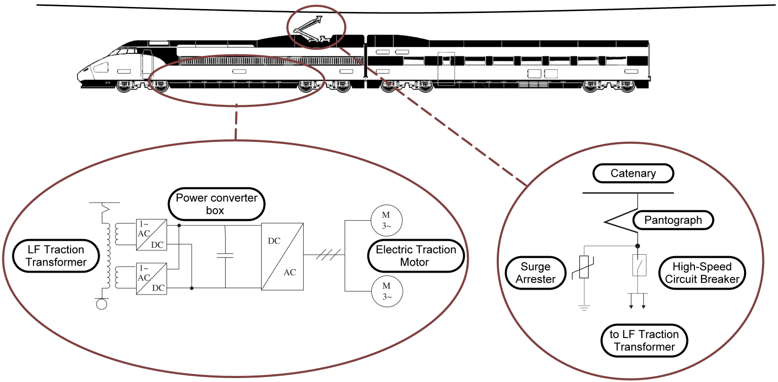


Figure 6: Train Power Components.

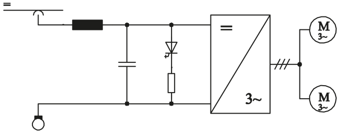


Figure 7: Train internal power circuit of a DC supply system. Adapted from [?].

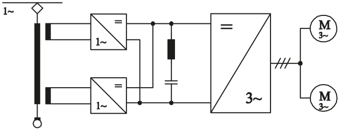


Figure 8: Train internal power circuit of an AC supply system. Adapted from [?].

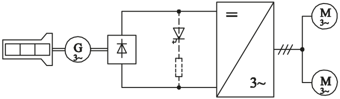


Figure 9: Train internal power circuit of a Diesel electric locomotive with alternator. Adapted from [?].

Case study — Series 3400 train

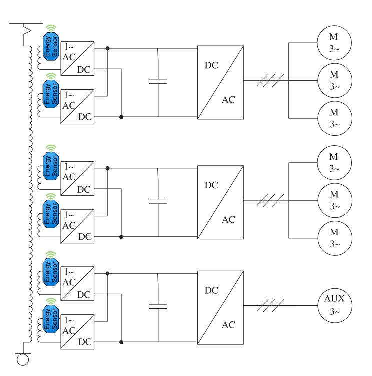


Figure 10: Power architecture of case study train.

Figure 11: Series 3400 case study train. Retrieved from *Comboios de Portugal*

Outline

Transducers

- Magnetic Coupling
- Magneto Resistance
- Faraday Induction
- Hall Effect

Figure 12: 25 kV current transformer. Adapted from *www.railware.it*

Figure 13: 25 kV voltage transformer. Adapted from *www.railware.it*

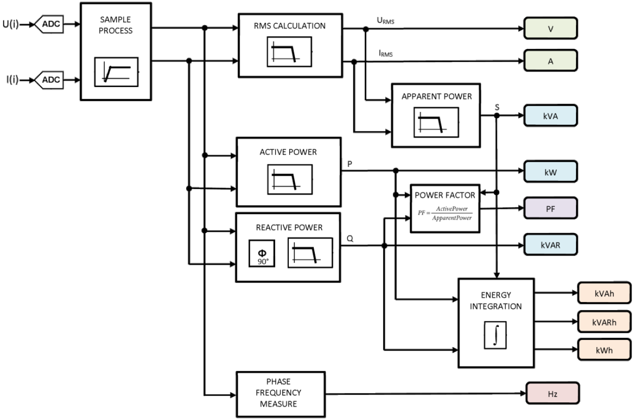


Figure 14: EcoS power calculation function, based on EN50463. Adapted from railware.it

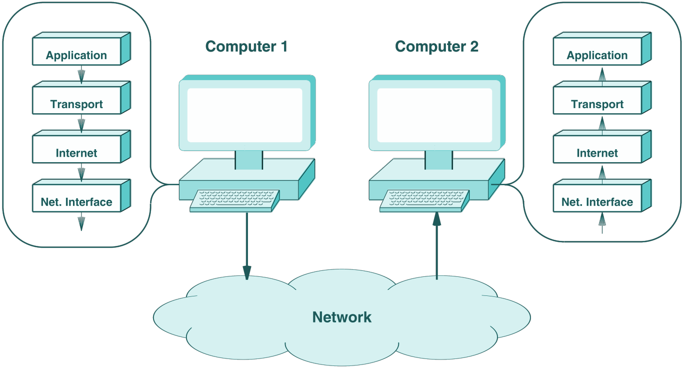


Figure 15: Representation of data flow in a computer network. Adapted from [?].

Wireless Networks — Simulators

- NS-3
- OMNeT++
- QualNet 7.0 + EXata 5
- MatLab + Simulink

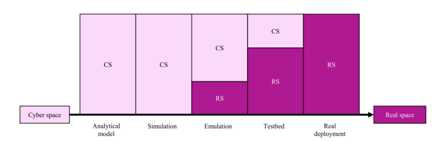


Figure 16: Simulation & emulation framework.

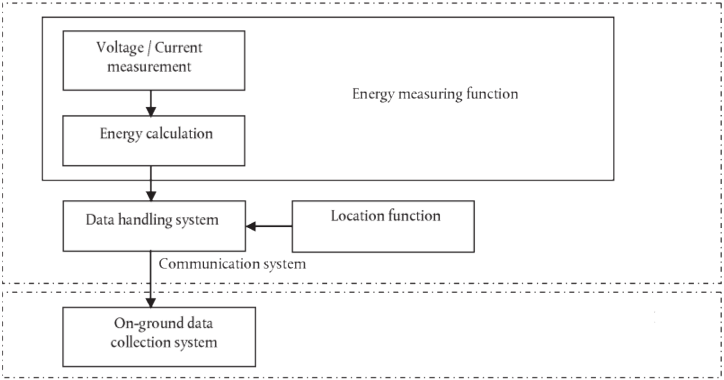


Figure 17: Functions, data flow and regulation scope of on-board energy measurement system.

Decision Support Systems

- Eco-driving — Driving Assistant
- Timetable Scheduling

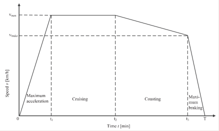


Figure 18: Optimal traction regimes. Adapted from [?].

Outlier Detection Techniques for RTS

- **Classification based techniques.**
  Bayesian Networks
  Rule-based techniques
  Support Vector Machines
- **Statistical based techniques.**
  Parametric — Gaussian based
  Non-parametric — Histogram based
  Non-parametric — Kernel function based
- **Nearest Neighbor-based techniques.**
  Using distance
  Using relative density
- **Clustering based techniques.**
- **Spectral Decomposition based techniques.**

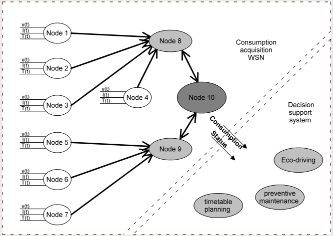


Figure 19: Integration of the WSN with a decision support system.

Outline

Outline

Railway Smart Meters

Thanks for your attention
Questions?

Bibliography I