Chapter 2
Railway Traction Systems

This Chapter presents a general description of the elements that characterize a railway electric transportation systems: the supply system, the traction line, the rolling stock, signalling, and additional subsystems, that equip modern railway transportation systems, in particular urban and suburban railway transportation facilities. Throughout this chapter, basic definitions will be provided and refined. The chapter focuses on elements that are important in achieving systems and electromagnetic compatibility with emphasis on the electromagnetic compatibility aspects and thus some knowledge of railway engineering is assumed. The reader is referred to publications such as [644] for a detailed discipline specific treatment of the subject matter covered herein.

2.1 Traction Systems and Traction Supply

The general structure of a traction system is made of several electric supply substations (ESSs) connected to traction line (TL) sections, that may be electrically continuous or separated, depending on the type of electrification and power management conditions, and one or more trains moving with variable tractive conditions. Traction systems may differ for a variety of characteristics, that may be relevant depending on the application, the performed analysis and the considered phenomena. A classification follows, where an attempt is made to treat the most relevant characteristics of some traction lines categories, without the claim of being absolutely correct, because of the many variants and implementation deviations, due to the development of these systems in many countries over a long period of time with different local requirements and characteristics:

- heavy traction railways feature large gauge running rails, heavy locomotives or electric motor cars with absorbed power in the range of MW, moderate to high cruise speeds (e.g. above 100 km/h), large installed power at substations, ranging approximately from 1 MW/km to some MW/km, depending on the profile of the territory, slope of grades and on the headway
and operating profile of trains, that determine their number in a supply section; they include a vast range of railways, from the high speed lines supplied in ac at high voltage and featuring very high speeds and installed power per km, to conventional lines with trains of various lengths, smaller installed power and infrastructure particulars that do not permit high speed operations, down to commuter and low speed lines with medium size train consists, that don’t always require heavy traction rails and powerful locomotives, and that are normally reserved for implementation in cities outskirts, rural areas and countries under development;

- light railways are implemented to serve medium to large size cities, or to serve the outskirts and bordering towns, replacing metros for medium distance connections; the supply voltage is usually dc at 750 or 1500 V, also for compatibility of equipment with existing metro lines; trains are normally fixed compositions of electric cars like in a metro, with larger headway but with smaller absorbed power, because of the size of the train consist and the reduced cruise speed; the installed power is thus lower, comparable to or smaller than metros, in the order of a fraction of MW/km;

- metros, with several characteristics in common with light railways, with slightly more frequent starts and stops and possibly steeper velocity profiles, always embedded in urban areas and for this reason feature a meshed line structure, with several intersecting power lines, and large short circuit currents; the headway may be very tight, depending on the implemented solutions, from several minutes down to 120 seconds for most modern lines in large populated cities, or even 90 seconds during peak hours. This in turn determines the installed power that may be larger than a normal light railway above 1 MW/km;

- trolley buses and tramways are low speed transportation systems, with a less demanding operating profile and with lighter and shorter vehicles and train consists. We could say that the supply voltage is always dc and the voltage level may take different values depending on the specific system and solution, with a range between about 500 and 750 V (e.g. 600, 650, 700 and 750 V nominal voltages are very common). The installed power barely corresponds to the rated power of one or few vehicles in a supply section and corresponds thus to one or few hundreds kW/km; moreover, the vehicles are often equipped with braking energy recovery systems (based for example on on-board batteries or super-capacitors) and for trolley buses with a combustion engine, that frees the vehicle from the overhead line supply (to move in urban traffic and in historical centres where the traction line infrastructure is reduced to a minimum or completely removed to reduce visual impact).

In the following more details are given for each type of traction system making use of existing examples. They represent the reference for the analysis of