# THE ELECTRICITY SUPPLY TO THE ELECTRIC TRACTION SYSTEM

**Anghelescu Lucica,** *"Constantin Brâncuşi" University of Târgu Jiu, ROMANIA*
**Alina Daniela Handra,** *University of Petrosani, Petrosani, ROMANIA*
**Andrei Cristian Rada,** *University of Petrosani, Petrosani, ROMANIA*

**ABSTRACT:** The electric traction power supply system and the electric current return system in the motor vehicle circuit shall be so designed as to ensure continuity of power supply to the motor vehicle with high reliability under both normal and contingency operating conditions. To this end, the traction system is sectioned into sectors which can be coupled if necessary.
The analysis of the electric traction system must include:
− determining the impact on the public supply system;
− knowledge of the impact of the electromagnetic field on the local population;
− determination of electromagnetic interference on equipment in the area.

**KEY WORDS:** electric traction, substation, power system, electric transformers

## 1. INTRODUCTION

Freight and passenger transport now play a particularly important role in the economy, and safe, fast, convenient and cheap transport is the system of the future. To achieve these goals, roads, vehicles, energy, information and regulations are needed.
The main performances that must characterise transport are: safety, reliability, all-weather operation, economy, no environmental pollution.
Electric transport includes rail and road vehicles powered by electric motors, including power supply and distribution systems.
The transport sector uses about a quarter of the world's total energy and accounts for about 20% of global emissions of pollutants into the atmosphere [11].

## 2. SUPPLYING ELECTRICITY TO THE INTERURBAN TRACTION SYSTEM

The power supply system for interurban traction has basically 3 components:
- the power supply system from the public electricity network comprising the traction substations located along the railway;
- the electrical traction distribution system comprising the contact line, the power supply circuit along the railway line, autotransformers and switching stations;
- the return circuit, comprising the rail system, coils, longitudinal and transverse strap, earth return circuit.

The distance between electric traction stations is determined by the power absorbed by the traction system, train characteristics and design concept. Typically, the distance between traction substations is 40-60 km, with power installed in transformers of 15-60 MVA,

with a supply voltage from the public electricity grid of 110-220 kV.
From the point of view of the electrical power system, the interurban electric traction is a receiver with high power consumption connected to the high-voltage grid as a two-phase receiver.
The general design of a power supply system for intercity electric traction with 25 kV contact line supply is shown in Figure 1.
Electric traction substations (ETSS) provide connection to the public power system and provide voltage control at the contact line (CL). Typically, traction substations are included in the electrical substations of the power system, which are located close to the route of the railway line. Most often electric traction substations have two two-phase transformers, with one of the output terminals of the transformer secondary connected to the rail.

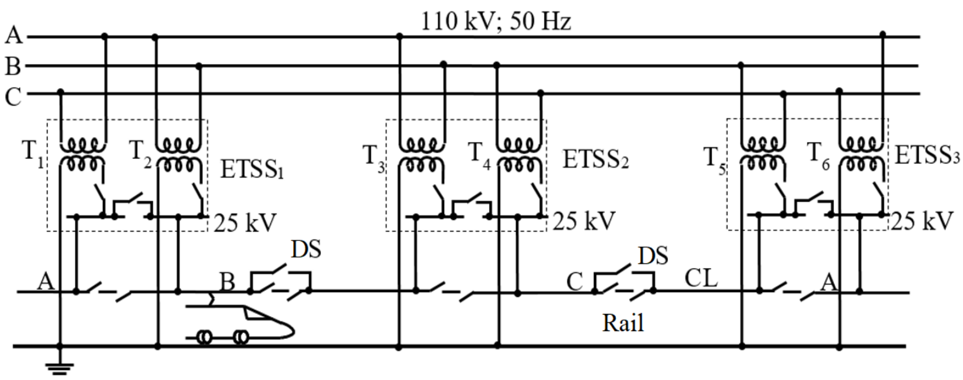


Figure 1. Electricity supply scheme for a railway section
circuit breaker with neutral zone; single-phase circuit breaker.

The contact line at 25 kV to earth is divided into electrically isolated sections and fed successively from the three phases of the power system by means of transformers in the electric traction substations. Typically, the contact line has a cross-sectional area of 50-600 mm$^2$, is made of electrolytic copper and has a special shape to allow clamping.
Disconnecting stations (DS) allow longitudinal connections or disconnections of the contact line between two electric traction substations. They are located approximately midway between two adjacent electrical traction substations. Substation posts, with functions to change the configuration of the contact line feed-scheme, located approximately midway between an electric traction substation and a substation sectioning post, may also be used on the contact line route.
Disconnecting stations with switchgear in the normally open position are provided with neutral zones if the two separate sections cannot operate in parallel, being fed from different phases of the public electricity network.
In order to limit non-symmetry in the public power system, the connection of the traction substations to the system phases is done by rotating two phases at a time. For this purpose, the LC contact line is made in the form of sectors, 40-60 km long, insulated from each other, fed at both ends to limit voltage drops [7].
Electric traction systems are non-linear receivers that can cause significant harmonic disturbances in the public power grid [2].
Interurban traction systems being two-phase receivers (from the point of view of the public power grid) can cause disturbances in the form of non-symmetry. Figure 2 shows the variation over one day of the negative voltage non-symmetry factor at 110 kV busbars of an electric traction system substation, caused by non-symmetrical loading of the grid [1,5].

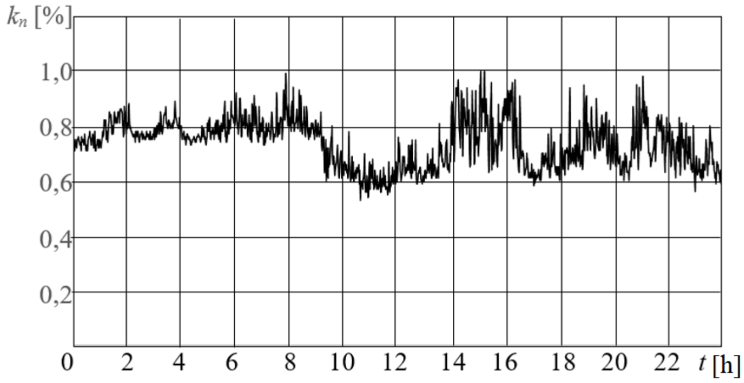


Figure 2. Variation of the negative non-symmetry factor $k_n$ during one day at 110 kV busbars feeding an electric traction substation ($k_{n50\%}$ =0,75; $k_{n95\%}$ = 0,88; $k_{n5\%}$ = 0,63; σ = 12% ).

The structure of the contact line allows the configuration to be changed in the event of faults, repairs in the sector, etc. [3,10].
Modern power supply systems for the electric traction system for high-speed trains use the 2× 25 kV scheme (Figure. 3) in which the power transformer has the secondary winding half connected to the rail, a voltage of 50 kV is applied between the CL contact line and the SC supply circuit, and 25 kV is applied between the CL contact line and the S-rail.

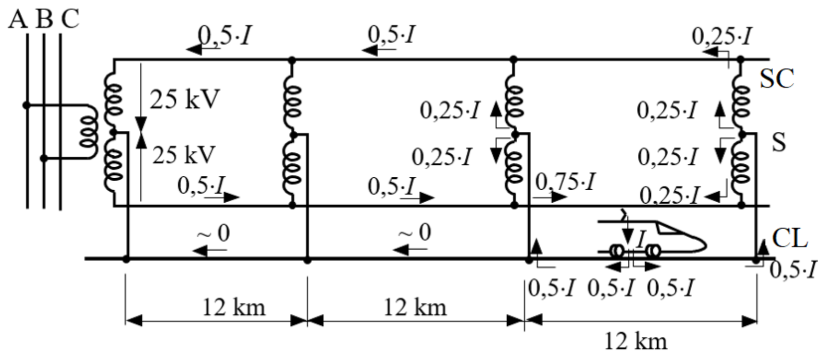


Figure 3. Typical electric current flow for 2× 25 kV system.

The scheme is now widely used for powering high-speed trains (over 80 m/s), with high installed power (over 10 MW), to limit losses in the return circuit, to ensure a virtually constant voltage along the track during train movements, and to make it possible to locate traction stations at greater distances, with less impact on the environment [4, 6, 9].
Autotransformers are connected every 8-12 km to ensure that a virtually constant voltage is maintained at the contact line and to limit losses in the return circuit.
Autotransformers connected between the SC power circuit and the CL contact line have the middle connected to the S-rail, ensuring that voltage drops on the track wire and the flow of electric currents from the rail are limited practically only within the cell between two autotransformers.
In the Figure 4. shows the configuration of the conductors for supplying the 2× 25 kV electrical traction system.

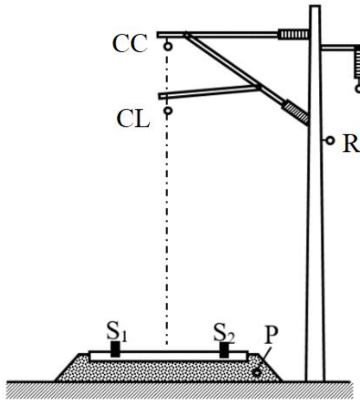


Figure 4. Circuit configuration in a 2× 25 kV electrical traction system.

The CL contact line is supported parallel to the rail with the CC carrying cable. The SC power circuit conductor is laid along the track route on the contact line catenary support poles using 25 kV insulators. The overhead circuit of the RC return circuit is also placed on the same poles. The earthing conductor P ensures the limitation of the electrical currents through the ground and the reduction of the total electrical resistance of the return circuit.

## 3. ELECTRICITY SUPPLY TO THE URBAN TRACTION SYSTEM

Urban traction systems are supplied from the distribution operator's medium voltage network. In principle, the station layout has the structure shown in Figure .5 [5].

In general, the urban traction station scheme comprises two transformers, with two secondaries, one of which is connected in a star and the second in a delta to form a double-phase voltage system. In this way a rectified voltage with a relatively low level of ripple is obtained. The measurement of the electric current at the output of each rectifier is made by means of a Sh shunt at the terminals of which a voltage proportional to the electric current in the circuit is obtained.

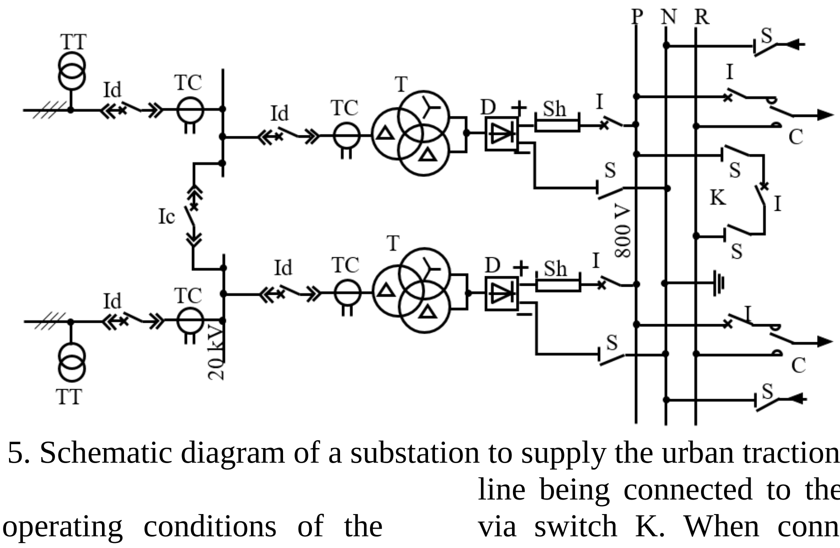


Figure 5. Schematic diagram of a substation to supply the urban traction system.

Given the operating conditions of the urban traction system (overloads and high frequency short circuits), the traction station is designed on the DC side, typically with a working (positive P) and a back-up (R) busbar system, the contact line being connected to the two busbars via switch K. When connecting to the back-up busbar, the coupling switch acts as a line circuit breaker.

The negative pole of the power supply is connected to the N (negative) busbar, the earth and the running rail of the traction system. Absorption lines connected at various points on the running rail are fed to the negative busbar (Figure 6).

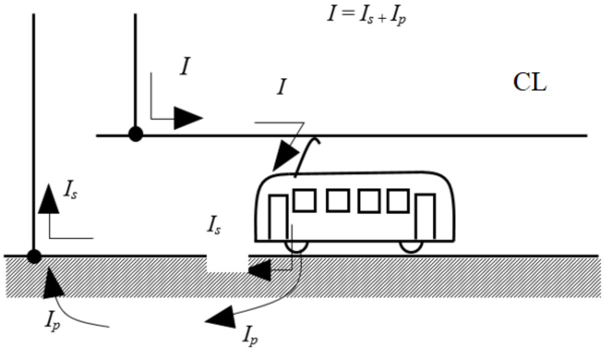


Figure 6. Circulation of electric current absorbed by urban rail vehicle.

In order to increase the efficiency of absorption lines, it is necessary to insulate the running track as well as possible from the ground. Longitudinal and transverse splicing of the running rail results in an equivalent electrical resistance of the absorption lines that is much lower than the electrical resistance of the earth return circuits. In this way, the through-ground component $I_p$ remains small in relation to the electrical current $I_s$ of the rail return.
Reducing the $I_p$ component of the return current is of particular importance for limiting electrochemical corrosion processes in grounded electrical equipment.
Urban traction systems typically fed from the 20 kV urban power grid are characterised by large variations in power consumption, leading to large variations in busbar voltage.
Figure 7 [5] shows the voltage variation on the 20 kV busbar of an urban transmission system power station over a week. The variation of 6.5% is within the permissible limits for the power grid [3,5].

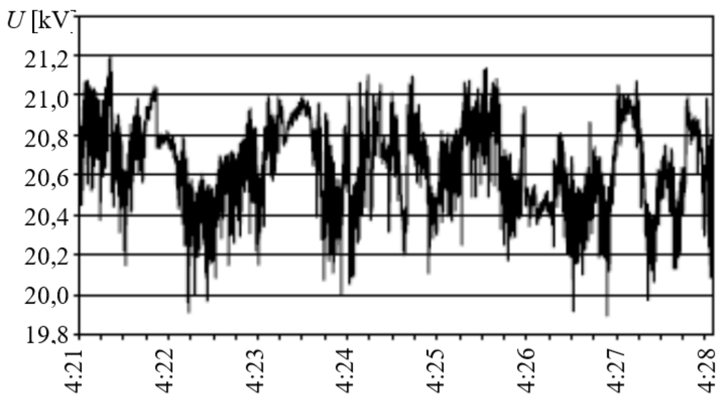


Figure 7. Variation of tension during one week.

The urban traction system does not cause disturbances in the form of non-symmetry as it is fed by a double-phase voltage system obtained from three-phase transformers with two secondaries (one connected in a star and one in a delta).

## 4. CONCLUSIONS

Current speed control and braking energy recovery systems based on power semiconductor circuits, the mode of supply between two phases in the public power system in the case of intercity traction, the displacement of the motor vehicle in relation to the power supply and the different operating modes of the drive motors result in significant electromagnetic disturbances at the common coupling point (electric traction substation) which, in the absence of effective limiting measures, can be transmitted into the public power system. The specific way in which electricity is used can cause: voltage dips, harmonics of electric current and voltage, interharmonics, non-symmetry, voltage fluctuations.

It was possible to supply the traction system from the public power system via a 110/20 kV transformer connected between the phases (to limit non-symmetry, the electric traction being a single-phase receiver).

Interurban electric traction systems, by their characteristic mode of operation (acceleration, deceleration, driving on uneven ground) lead to relatively large fluctuations in power input, which can cause large voltage variations in the supply substation.

The wide variation in apparent power measured in the electric traction substation causes voltage variations at the busbars in the 110 kV public system.

The contact line voltage shows large variations with negative effects on the efficiency of the motor vehicle. Taking measures to limit voltage variations on the contact line is one of the most important measures to ensure the energy performance of electric drive motors of the motor vehicle.

In order to ensure the limitation of electromagnetic disturbances caused by the electric traction system, equipment for limiting harmonic distortion, for power factor control, for non-symmetry and for controlling the level of voltage fluctuations shall be provided in traction substations. Technical solutions for limiting electromagnetic disturbances caused by electric traction are currently available.

## REFERENCES

[1] Brenna, M. etc. Harmonic Analysis of a High Speed Train with Interlaced Four Quadrant Converters. rap. 000221, PESGM, Pittsburgh, 2008.

[2] Claessens, M. etc. A power-electronic traction transformer (PETT). ABB Review, nr.1/2012, pg.11-17.

[3] Delarue, Ph. etc. Study of harmonic current introduced by three-phase PWM-converter connected to the grid. rap. 2-36, CIRED, Barcelona, 2003.

[4] Dolara, A. Gualdoni, M. Leva, S. EMC Disturbances on Track Circuits in the 2×25kV High Speed AC Railways Systems. rap. 206, PowerTech, Trondheim, 2011.

[5] Lamedica, R. Maranzano, G. Marzinotto, M. A. Prudenzi Power Quality Disturbances in Power Supply System of the Subway of Rome. PESGM 2004 – 000775

[6] Nardinocchi, A. Electrification and Power Supply. International Practicum and Implementing High-Speed Rail in the United States, 2011.

[7] Pilo, E. Rouco, L. Fernandez, A. A multi-criteria approach to the analysis of modified 2×25 kV bi-voltage systems using higher negative voltages. Instituto de Investigacion Tecnologica (IIT), Univ. Pont. Comillas de Madrd, Spain.

[8] Popescu, M. Bitoleanu, A. Dobriceanu, M. FBD – based Control in Active DC-Traction Substations, rap. RS6.5, ICATE, Craiova, 2016.

[9] Popovici, O. Tracţiune electrică. Universitatea din Oradea, 2008.

[10] Rezkalla, A.M. etc. Active filters application for metro ac substation. rap.0325, CIRED, Lyon, 2015.

[11] *** Electricity for more efficiency. Electric technologies and their energy savings potential. EURELECTRIC, 2004.