Experimental Characterization of Environmental Impacts from Underground Electric Metro in Braking Regime

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Abstract: In the case of underground electric metro operation it is necessary to estimate the environmental impacts of the mechanical brake unrecovered energy. The amount of the material developed in the mechanical brake process (particularly, the clogs wear) it is depending on the mechanical brake unrecovered energy. Because this mechanical braking energy can be considered equal (as value) to the electrical energy (the active component) of the starting process, in the paper had been simulated a transient starting regime, using MATLAB software and SIMULINK-Sim Power Systems Extensions. Consequently, it had evaluated the active braking material wear (the clogs wear) in the underground metro mechanical braking process, which has important environmental impacts.

Key-Words: Electric metro, environmental impacts, mechanical brake, underground transport system

1 Introduction

A rapid transit, underground, subway or metro(politan) system is a railway (usually in an urban area) with a high capacity and frequency of service and separation from other traffic [1]. The oldest rapid transit system in the world is the London Underground, which opened in 1863. There are 162 cities having rapid transit systems, totaling more than 8000 km (4900 miles) of track and 7000 stations.

The modern underground urban electric trains are based on the driving systems with voltage and frequency static converters and traction asynchronous motors [2]. These electrical driving systems allow to realize the vehicle electric brake, even with the energy recovery [3].

But, the vehicle braking regime it is also realized by a mechanical way, on the basis of the mechanical contact between the clog and the motor wheel rim [4]. In this case, the environmental impact is important and it must be taken into account [5],[6], because the underground metro it is operating into a closed (underground) space and the material amount developed into the mechanical braking process (particularly, the clogs wear) it is considerable, depending on the unrecovered energy which it is resulting in the mechanical braking regime.

For the quantitative evaluation of the unrecovered energy in the braking regime it can estimate that this energy is equal to the electrical energy absorbed by the driving system in the transient starting regime of the vehicle. That is true in the most disadvantageous hypotheses of the drive system, meaning:

- only the mechanical braking process it is taken into account (because its pollutant effects); the electrical brake it is not applied in this case;
- the mechanical losses caused by the aerodynamic friction are insignificantly;
- the mechanical losses in the system of the mechanical movement transmission are not important, having been neglected;
- the electric losses in the driving system (electrical cables, power electronics elements etc.) are insignificantly.

Consequently, the mechanical braking energy will be considered equal (as amount) to the electric energy (the active component) received in the starting process. Therefore, in the paper will be simulated the transient starting regime of an electric underground metro, which is equipped with traction asynchronous motors by type MAB T_1.

2 Simulation Model and MATLAB Software

There is considered a traction asynchronous motor MAB T_1, which is an electric motor in a special construction, designed to operate in extremely heavy conditions. These motors are made to ensure the development of the traction torques, respectively, the traction forces at the electrical drive vehicles.

For the simulation model from the Fig.1, there had been used the MATLAB software and the SIMULINK-Sim Power Systems Extensions. This model is based on the blocks specific to the electric drives, such as "Asynchronous Machine". "Machines Measurement Demux", as well as on the blocks with general applications from Simulink library.

In the technical literature [7] there are presented technical data upon these, this paper emphasizing the potential of a such approach in the study of the traction electric motors.

There are graphical drawn the time variation waves of the speed, the stator current and voltage of the electric motor in the transient starting regime of the underground electric train.

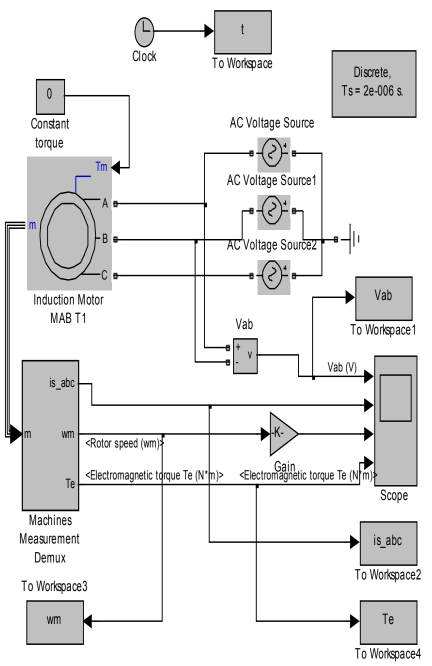

Fig.1. Simulation scheme for the vehicle behavior study in starting

The traction motor MAB T_1, with the technical characteristics presented in Table 1, it is made by S.C. ELECTROPUTERE CRAIOVA S.A., for the electric metro, type underground, from the METROREX Bucuresti network.

Table 1

Nr.	Type	Symbol	MAB T_1 (Y)
1	Rated power (kW)	P_n	70
2	Rated voltage (V)	U_n	560
3	Rated current (A)	I_n	96
4	Starting current (A)	I_p	720
5	Rated frequency (Hz)	f_n	60
6	Variation range of supply voltage frequency (%)	D	2
7	Rated power factor	$\cos\varphi_n$	0,86
8	Poles pairs number	p	3
9	Rated speed (rpm)	n_n	1135
10	Rated efficiency (%)	η_n	0,87
11	Rated torque (Nm)	M_n	589
12	Starting torque (Nm)	M_p	647,9
13	Stator resistance (Ω)	R_1	0,069

Starting from the data presented in Table 1, there have been determined/estimated the quantities values presented in Table 2, where:

- Z_p represents the starting impedance;
- R'_2 represents the rotor resistance related to the stator;
- $X_1 = X'_2$ represent the leakage reactances;
- X_μ represents the magnetizing reactance.

Table 2

1	Z_p	0,4522Ω
2	R_2'	0,0531Ω
3	X_1+X_2'	0,4354Ω
4	X_1	0,2177Ω
5	X_2'	0,2177Ω
6	X_μ	4,5405Ω

On the basis of the values presented in Table 1 and Table 2, there had resulted the characteristics from Fig.2, which are representing, in the MATLAB space, the wave forms for the main quantities which are characterizing the vehicle starting transient regime.

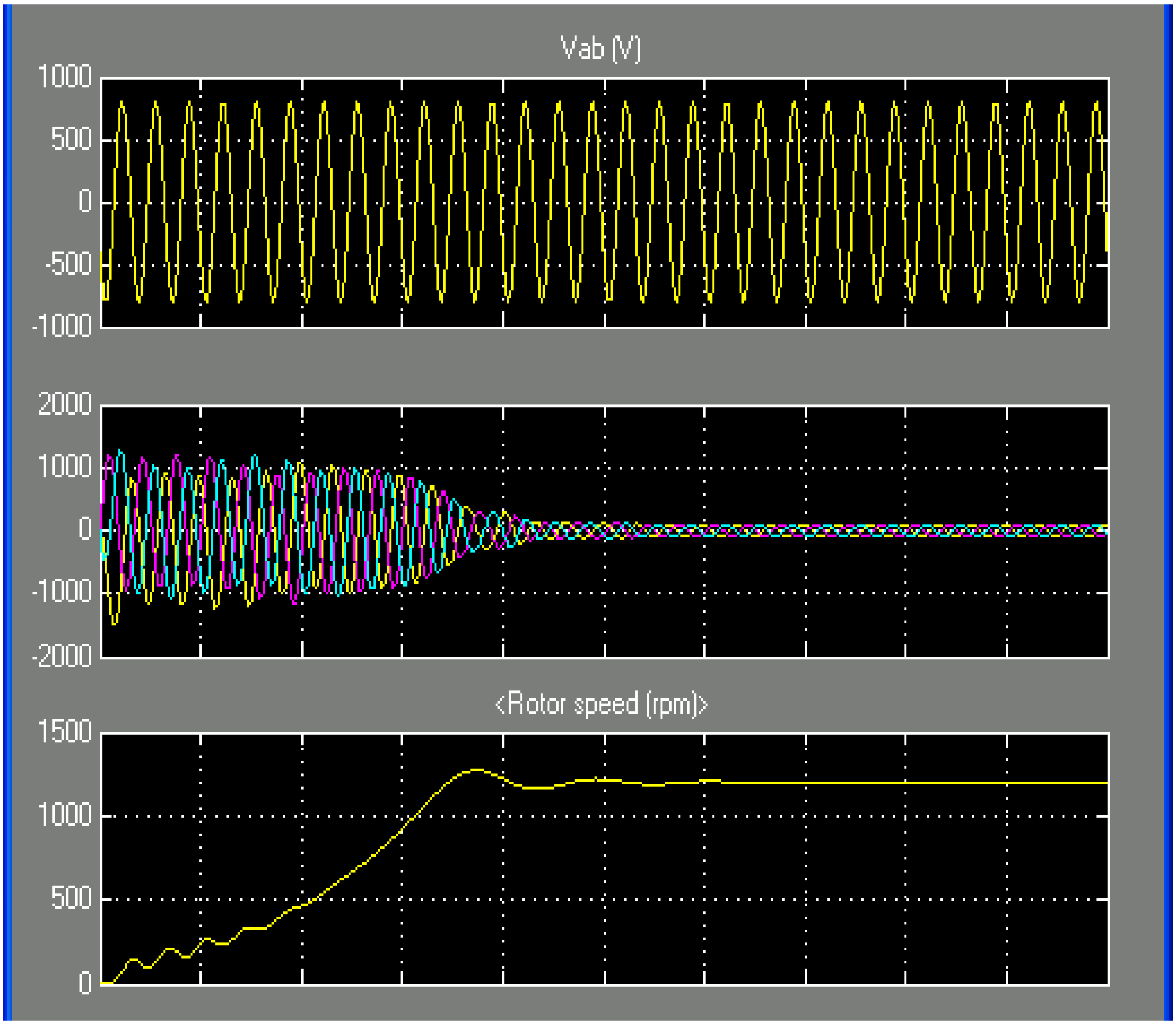

Fig.2. Electromechanical quantities definite for vehicle starting transient regime

Consequently, it can be determined the energy (the active component) absorbed by the system in the transient starting regime:

$$E_{aabs} = \sqrt{3}U_l I_l \cos\varphi \cdot t \cdot 10^{-3}[kWs] \qquad (1)$$

Therefore, it will result:

$$E_{aabs} = \sqrt{3} \cdot 560 \cdot \frac{1000}{\sqrt{2}} \cdot 0{,}86 \cdot 0{,}25 \cdot 10^{-3} = 147{,}9kWs$$

Estimated, it can be considered that the amount of the material developed in the mechanical brake process (particularly, the clogs wear) it is proportional to the mechanical braking unrecovered energy. Taking into account the previous hypothesis, of the equality (as value) between the mechanical braking unrecovered energy and the electrical starting energy (the active component), on the basis of the relation (1) it can be determined the wear rate of the braking active part, as below:

$$r_{Fe} = k_1 k_2 \lg a * E_{aabs} \qquad (2)$$

where the coefficients a, k_1 and k_2 are experimentally determined and they are varying in function of some disturbing factors, like the material type, the contact pressure, the contact surface, the environment temperature and humidity and the local cooling. These coefficients can be selected like value on the basis of the multivariable nomograms.

Further on, considering a traffic with the frequency N_3, on an underground line (thoroughfare) of approximately 20 km, with an average of N_4 stations (equivalent to a tunnel with a complete aerating), it will result (as percentage) the active material wear amount, determined by the following relation:

$$R = 10^{-3} N_1 N_2 N_3 N_4 r_{Fe} [\%] \qquad (3)$$

where:

N_1 = number of days / year
N_2 = number of hours / day
N_3 = number of trains / hour
N_4 = number of stations / thoroughfare

Consequently, it had resulted the data of Table 3.

Table 3.

Q_{Fe}	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$
N_1	240	240	240	288	288	288
N_2	20	20	24	20	20	24
N_3	12	10	12	12	10	12
N_4	20	20	20	20	20	20
R(%)	92	76	110	110	92	132
Q_{Fe}	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$	$80*10^{-3}$
N_1	365	365	365	220	220	220
N_2	20	20	24	20	20	24
N_3	12	10	12	12	10	12
N_4	20	20	20	20	20	20
R(%)	139	116	168	84	70	101

3 Conclusion

The presented method represents a new approach in the study of the underground environmental impacts of the travelling transport on the basis of the rapid transit system realized with urban underground electric trains. On the basis of the data of Table 3 it results that, in the hypothesis of an electrical brake absence, it would appear a wear of the mechanical braking equipment up to 100% during the entire year, leading, therefore, to its replacement. Moreover, it must be taken into account the environmental impact from the mechanical braking process. The material amount released in the air and laid down into an underground (closed) space constitutes an important problem both for the environment and for the travelling transport safety, because the metals oxides can lead to serious perturbations in the centralized control system of the electric metro traffic. Consequently, the future techniques for a sustainable rapid transit will impose that the underground metro operates into the braking regime, next to the train stop, by an electrical energy recovery way.

References:

[1] Nicola D.A. Cismaru D.C., *Tractiune Electrica: Fenomene, Modele, Solutii*, Ed. SITECH Craiova, Romania, 2006.

[2] Buhler H., *Reglage de Systemes d'Electronique de Puissance*, Vol.I, PPUR, Lausanne, 1997.

[3] Kaller R. Allenbach J.M., *Traction Electrique,* Vol.1, 2, PPUR, Lausanne, 1995.

[4] Perticaroli F., *Sistemi Elettrici per i Transporti. Trazione Elettrica,* Ed. MASSON, Milano-Parigi-Barcelona, 1994.

[5] Canter I.W., *Environmental Impact Assessment*, McGraw Hill, 1997.

[6] Brundtland H, *Our Common Future*, Ed. OXFORD Univ. Press, New York, 1987.

[7] Rahn T. Hochbruck H. Moller F.W., *ICE High-tech on Rails*, Hestra Verlag, Darmstadt, 1991.