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Comparison of Two Solutions of Regeneration Circuits for Tramcars

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Introduction

In this paper an evaluation of the two possible solutions for realization of the braking process of tramcar drive is provided. The first solution is accepted on tramcars T3 for Riga railway traffic and is connected with inserting of extra resistor RB in circuit of motors of tramcar for extinguishing of excessive energy. Other solution is connected with adjusting of magnetic excitation field of motors. Comparison of the both solutions is provided with application of computer simulation.

Description of two solutions

In the first case (Fig. 1) process of braking comprises the two stages: first one at high speed of tramcar when resistor RB is activated in circuit of motors; in the second part of process at low speeds resistor is bypassed. When there are not possibilities of recuperation of energy on network a resistor RR with extra pulse regulator is activated. In the second solution (Fig. 2) excitation current of motor is adjusted with gradually changing of resistor RL.

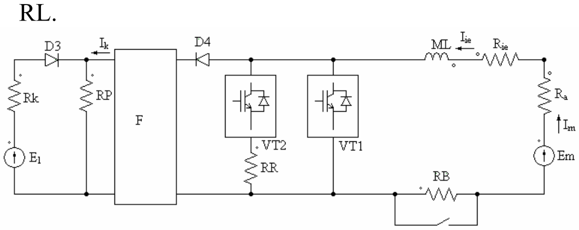

Fig. 1. Scheme of first solution of braking regime

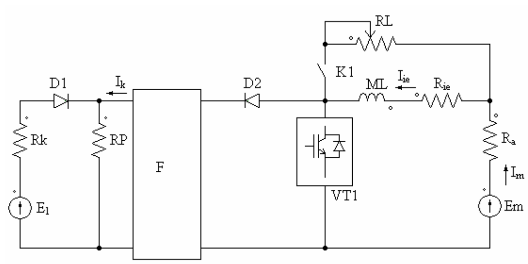

Fig. 2. Scheme of second solution in braking regime

Simulation results

For providing a comparison of the two solutions a computer simulation in accordance with differential equations for both schemes was realized. In the first scheme braking process is provided with constant currents of armature and excitation winding of motor, i.e., with constant torque.

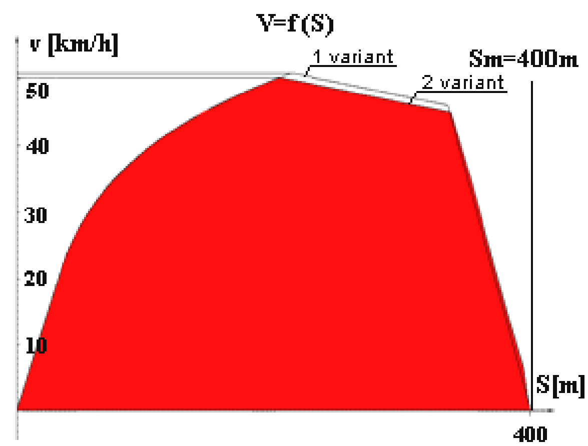

Fig. 3. Diagrams V=f(S) for both realization cases when carriage is empty

In the second case in range of higher speeds a torque is decreased because excitation current is weakened. It means that braking way in the second case is longer than in first case. For obtaining an equal technical speed needs to raise end speed of acceleration stage. On Fig. 3 are presented obtained by simulation curves V=f(S) where V is technical speed, S is realized way, Sm – distance between stops.

As it can be seen the acceleration stage for the second case is longer. It means that energy consumption in the acceleration stage for the second scheme will be higher. Because of distraction of extra resistor from circuit of motor energy recuperation in the second case can be much higher than in the case of the first scheme.

Table 1. Results of data simulation of mathematical model for empty carriage

Indicators	Sm=400[m]			units
	1st scheme		2^{nd} scheme	
Sb	90	=	90	%
Ev	0,63	>	0,59	kWh
Vmax	50,95	>	50,12	km/h
Vv	38,06	>	37,44	km/h
Ea	0,73	>	0,70	kWh
t	37,83	<	38,45	s
Erek	0,02	<	0,04	kWh

Here in the Table 1 Sb is a relative realized way before braking starts, Ev is the consumed energy by tramcar, Ea is the energy supplied from substation, Erek is the recuperation energy. As it can be seen when conditions of simulation are present (with constant Sb for both) energy consumption in the second case is little smaller but technical speed also is lower. Energy of recuperation in the second case is twice as big as for the first scheme but in average both variants are very similar in respect of indicators.

Similar indicators can be also obtained for full carriage (Table 2). As it can bee seen there the indicator Ev for empty carriage is smaller to the indicator Ev for full carriage. Also comparing two solution variants – for full carriage, we can see that the indicators are very similarly for both variants.

Table 2. Results of data simulation of mathematical model for full carriage

Indicators	Sm=400[m]			Indicators
	1st scheme		2^{nd} scheme	
Sb	90	=	90	%
Ev	0,67	>	0,63	kWh
Vmax	50,95	>	50,01	km/h
Vv	37,91	>	37,32	km/h
Ea	0,78	>	0,74	kWh
t	37,98	<	38,56	s
Erek	0,02	<	0,04	kWh

For better evaluation of both variants it is needed to obtain equations for obtaining a qualitative relations between parameters and outputs.

Evaluation of results

Characteristics presented in Fig. 4–9 have been constructed for both variants from acquired data array.

From obtained array of data an equations for influence of parameters in normalized scale can be derived.

$$E_{rek} = 0.0827 + 0.0347 \cdot S_m^* - 0.0507 \cdot S_b^* + 0.0827 \cdot a^* - 0.0132 \cdot S_m^* \cdot S_b^* + 0.0348 \cdot S_m^* \cdot a^* - 0.0507 \cdot S_b^* \cdot a^* - 0.0132 \cdot S_m^* \cdot S_b^* \cdot a^*, \quad (1)$$

$$\delta_{rek} = 1.7881E\text{-}18, \quad (2)$$

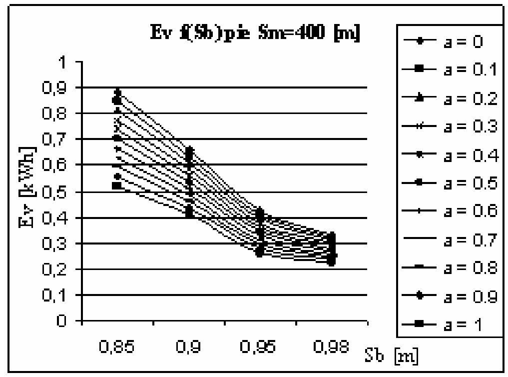

Fig. 4. Ev=f(Sb) for the first scheme, Sm=400 m and empty carriage

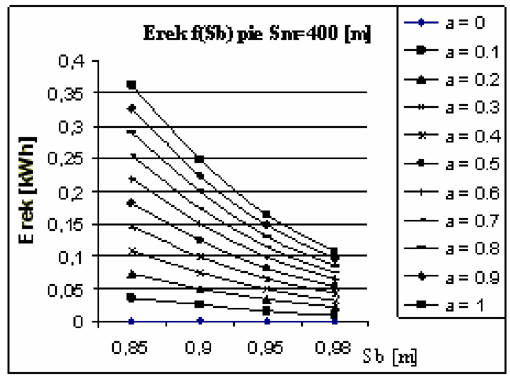

Fig. 5. Erek=f(Sb) for the first scheme, Sm=400 m and empty carriage

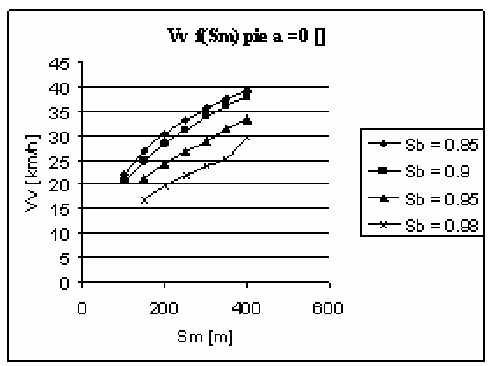

Fig. 6. Vv=f(Sm) for the first scheme and empty carriage

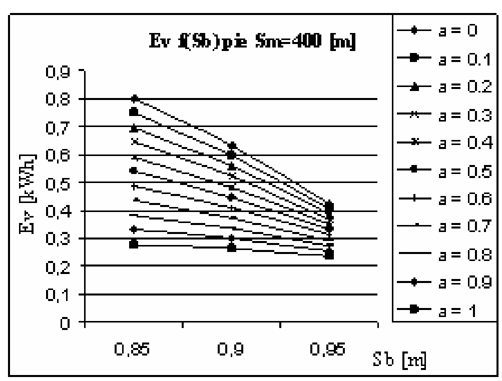

Fig. 7. Ev=f(Sb) for the second scheme, Sm=400 m and empty carriage

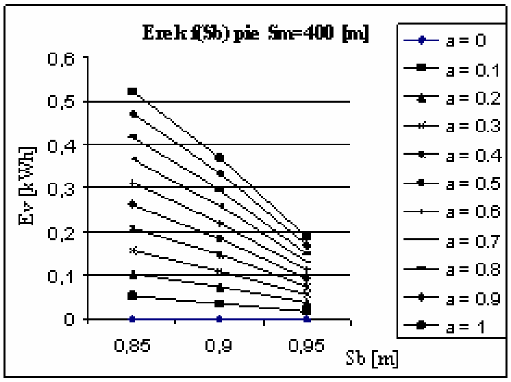

Fig. 8. Erek=f(Sb) for the second scheme, Sm=400 m and empty carriage

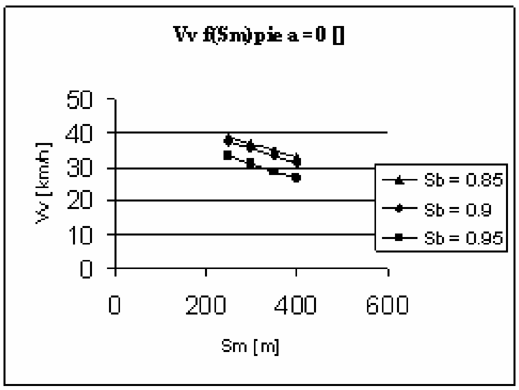

Fig. 9. Vv=f(Sm) for the second scheme and empty carriage

$$V_V = 28{,}1559 - 4{,}8829 \cdot S_b^* + 6{,}3569 \cdot S_m^* , \quad (3)$$

$$E_{rek} = 0.0642 + 0.0285 \cdot S_m^* - 0.0473 \cdot S_b^* + \\ + 0.0642 \cdot a^* - 0.0175 \cdot S_m^* \cdot S_b^* + 0.0285 \cdot S_m^* \cdot \\ \cdot a^* - 0.0473 \cdot S_b^* \cdot a^* - 0.0175 \cdot S_m^* \cdot S_b^* \cdot a^* , \quad (4)$$

$$\delta_{rek} = 3.5E - 18 , \quad (5)$$

$$V_V = 25{,}8146 - 4{,}0286 \cdot S_b^* + 6{,}7335 \cdot S_m^* , \quad (6)$$

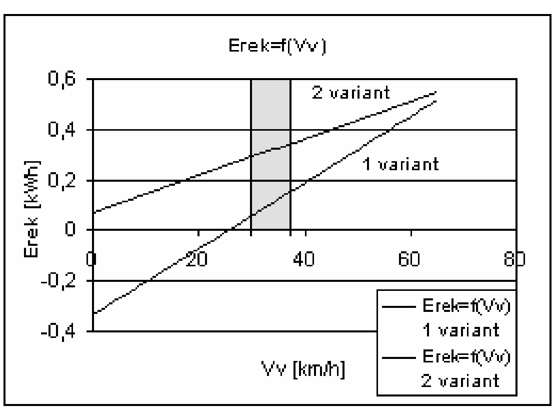

Fig. 10. Characteristics obtained from normalized equations for empty carriage

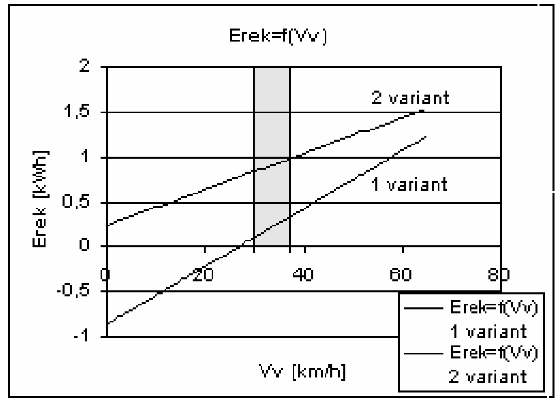

Fig. 11. Characteristics obtained from normalized equations for full carriage

Characteristics showed in Fig. 11 are obtained by using equations with normalized parameters for full carriage, where we can see, that the value of Erek is higher using the first solution variant, than using the second variant by approximately two times or 100% – very similar characteristics are obtained for empty carriage also, shown in Fig. 10.

Conclusions

1. If calculations are made in relative values, then Erek what is returned to network in second variant is 100% higher than in first variant.
2. If calculations are made in absolute values.– then difference among those two solutions variants is 0.02 kWh – not much.
3. These both variants of solutions are very similar to each other notwithstanding according the calculations in relative values not using equitations with normalized parameters – there can be seen very big difference among them.

Note:

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I. Rankis, L. Ribickis, A. Vitols. Comparison of Two Solutions of Regeneration Circuits for Tramcars // Electronics and Electrical Engineering. - Kaunas: Technologija, 2006. – No. 5(69). – P. 53–56.

In the following paper are presented comparison of two solution variants for tramcars T3. There are presented results obtained form computer simulations and two principal schemes of both solutions. Also there are presented results obtained from data array and analysis of them, too. 6 characteristics of simulation of these two schemes are showed, too. Then equations with normalized parameters are presented, what is very important for clear understanding and working principles of both schemes from absolute point of view. Then there are presented characteristics that are obtained from equations with normalized parameters. Il. 11, bibl. 3 (in English; summaries in English, Russian and Lithuanian).

И. Ранкис, Л. Рибицкис, А. Витолс. Сравнение решения двух схем регенерации энергии для трамваев // Электроника и электротехника. – Каунас: Технология, 2006. – № 5(69). – С. 53–56.

Представлены два решения для трамвая Т3. Также показаны результаты, полученные от компьютерной симуляции и две принципиальные схемы двух вариантов решения. Представлены результаты, полученные из массива данных и их анализ. Показано 6 характеристик компьютерной симуляции этих двух схем. Даны уравнения с нормализованными параметрами, что очень важно для понятия сущности работы этих схем в абсолютном масштабе. И наконец показаны характеристики полученные используя уравнении с нормализованными параметрами. Ил. 11, библ. 3 (на английском языке; рефераты на английском, русском и литовском яз.).

I. Rankis, L. Ribickis, A. Vitols. Dviejų energijos regeneracijos tramvajuose schemų variantų palyginimas // Elektronika ir elektrotechnika.- Kaunas: Technologija, 2006. – Nr. 5(69). – P. 53–56.

Pateikiamos dviejų tramvajų T3 energijos regeneracijos variantų principinės schemos ir kompiuterinės imitacijos rezultatai, gauti iš duomenų masyvo, bei jų analizė. Parodytos 6 charakteristikos, gautos jau minėtų dviejų schemų kompiuterinės imitacijos metu. Pateikiamos lygtys su normuotais parametrais, nes tai svarbu norint suvokti šių schemų veikimą absoliučiu požiūriu. Taip pat pateikiamos charakteristikos, gautos panaudojus lygybes su normuotais parametrais. Il. 11, bibl. 3 (anglų kalba, santraukos anglų, rusų ir lietuvių k.).