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TRAMWAY TRACTION SUBSTATION MINIATURIZATION. SELECTED ISSUES

Introduction

Electric rail transportation (trams), for over a century, has been an efficient mean of passenger transport in both bigger and smaller metropolitan areas in Poland. Currently Poland [1] has 14 tram networks that are being used by 16 entrepreneurs (in Łódź there are three providers present), trams operate in 11 voivodeships. On the streets of Krakow, electric trams appeared on March 16th 1901.

From a technical point of view the main advantage of trams [2] is their low demand for energy as compared to other mechanical means of transport (especially passenger motor cars). Ecological factors present themselves in an especially favorable light. Trams in their place of operation do not pollute the atmosphere with any exhaust fumes (e.g. CO2). Additionally, which isn't without significance, this mean of transport operates based on national energy resources (the operation of power plants is based on lignite and bituminous coal) and for that reason the operational costs are less susceptible to the fluctuations in oil prices on global markets. What's specific about this mean of transport is that trams (as well as other vehicles of electric traction) require a constant supply of energy provided from a specialized power system. This is caused by the fact that they are non-autonomous as vehicles, as they don't posses their own energy source.

Power supply of electric railway transportation

Traction substations constitute the most basic element of the tramway system power supply. These are road structures equipped with conversion devices which adapt the voltage parameters of the national power system to the requirements of the railway rolling stock.

Traction substations are powered from a power system, through overhead and cable transmission lines of voltages ranging from 6 to 110 kV. Tramway system substations are most commonly powered by cables of a voltage between 6 and 15kV [5].

In tramway systems a one-directional power supply system is most commonly used. [3],[4],[5]. This means that the substation power supply is divided into a sequence of sections, where each one is powered by a separate cable (power supply) from the traction substation.

Fig. 1 presents an existing area of power supply of a tramway system „Reja" substation in the center of Krakow [6].

The dimensions of a traction substation building depend, among others, on the power of conversion devices installed in them. For a presented „Reja" substation, it is the power of over 3MW. The decrease of the installed power should translate into the decrease of the substation size.

Fig. 2 shows the proposed method of the power supply of the contact line system by smaller power tram traction substation. It is assumed that every power supply (power supply cable) will be connected with a separate mini-substation.

Results of Calculations

The selection of rectifier units for mini substations was based on traction electricity runs in the power supply cables (power supplies) that were obtained through simulation using a method of so-called theoretical passage [7].

To evaluate the possibility of the power supply of the contact line system from miniaturized tram traction substation in the analyzed area there should be carried out simulations of changes of each power supply (power cable) from analyzed tram traction substation.

To do this, was performed the theoretical rides for all trams moving on the power supplied analyzed area of in directions consistent with their true route taking into account the constraints resulting from:

- route
- hills and arcs which increase the vehicles resistance movement,
- tramway stops, on which the vehicles stop,
- speed limits in the city,
- used vehicles
- maximum accelerations and decelerations.

Results presented in the article (traction load currents were simulated for the real power supply parameters)

Below in Fig. 3 is presented a simplified algorithm for calculation carried out in order to determine the possibilities of applicability of power supply the area under study from miniaturized hypothetical tram traction substations.

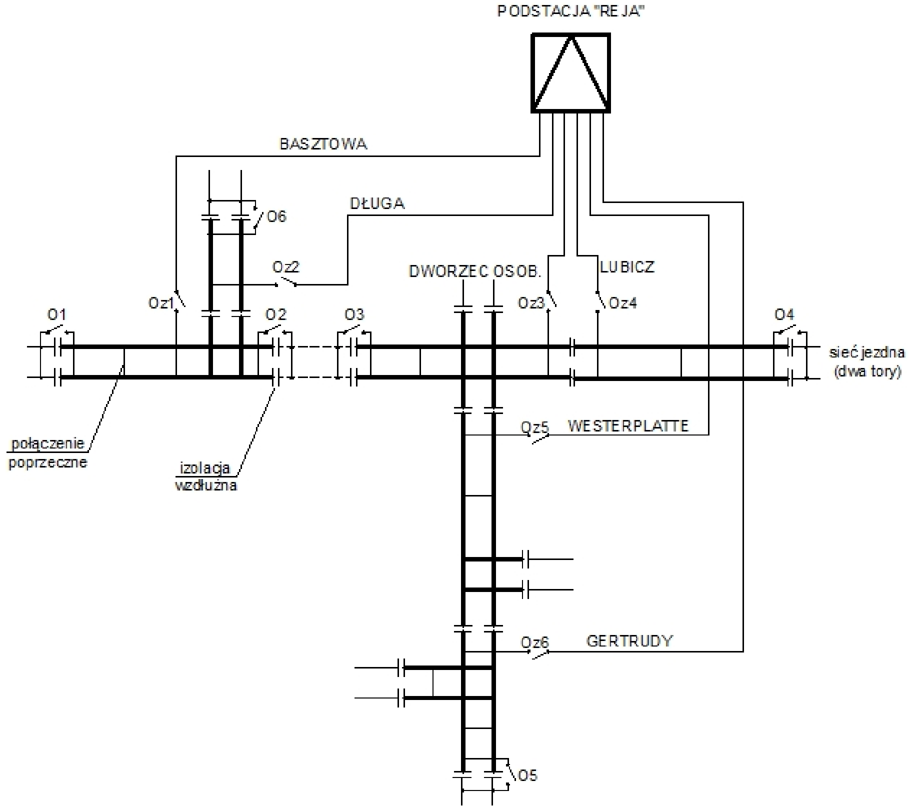

Fig. 1. Schematics of connection between tramway system substations direct current system with the traction network based on an existing „Reja" substation
(Oz1,…,Oz6 – isolating switches for power supply, O1,…,O6 – section isolating switches)

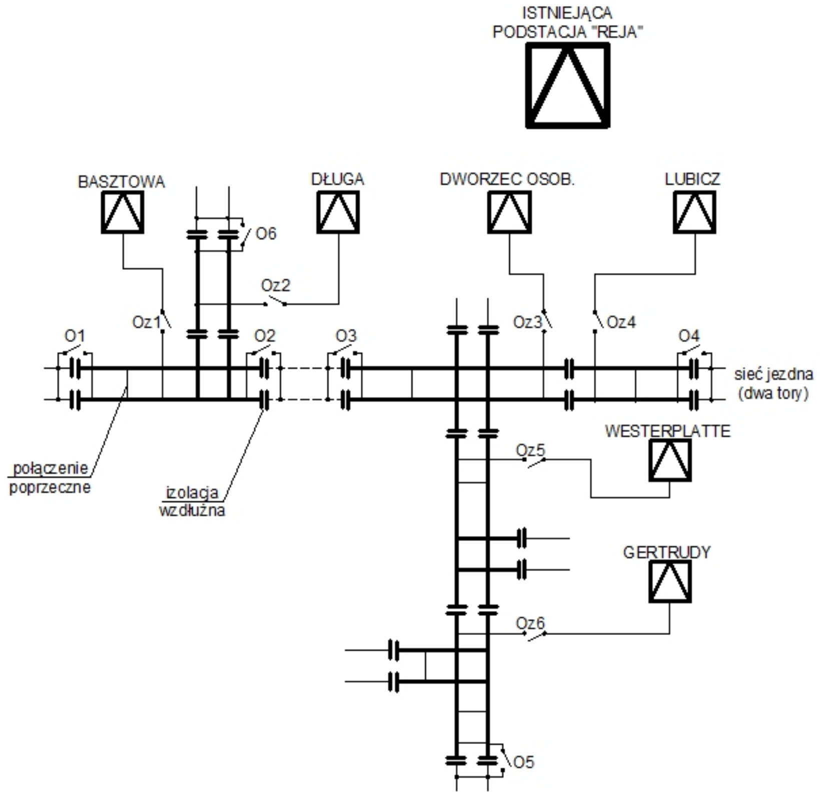

Fig. 2. Connection schematics of hypothetical tramway system direct current mini-substations with the traction network based on an example of the existing „Reja" substation's power supply area
(Oz1,…,Oz6 – isolating switches for power supply, O1,…,O6 – section isolating switches)

Figure 4 presents the current of power supply load – "Basztowa", and figure 5 the current of power supply load – "Długa". Figure 6 shows the traction load at the output of the existing "Reja" tram traction substation.

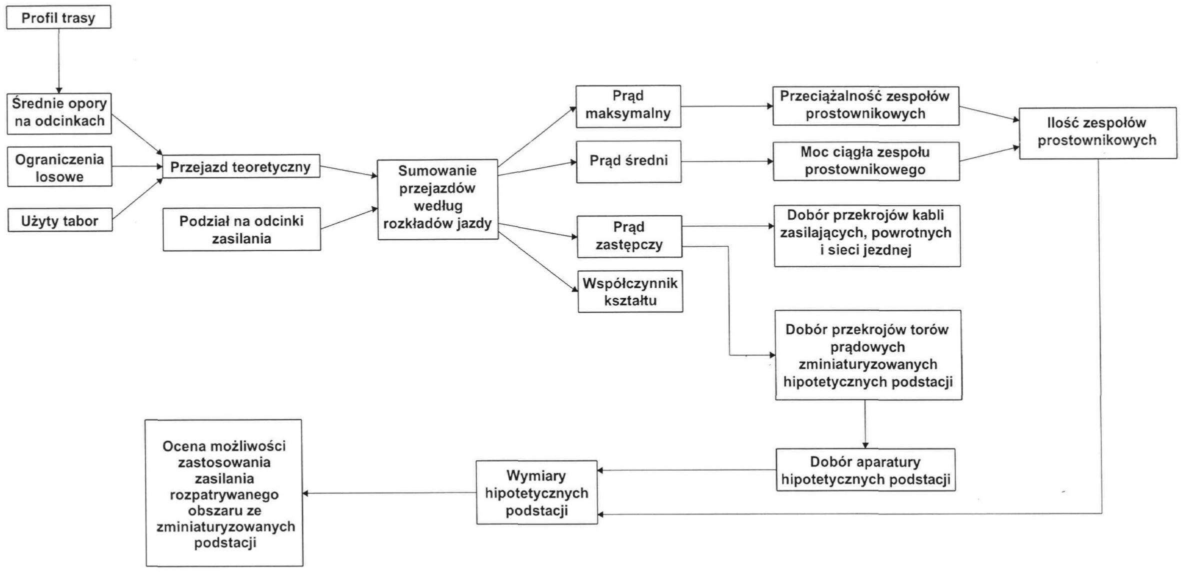

Fig. 3. Simplified algorithm for calculation carried out in order to determine the possibilities of applicability of power supply the area under study from miniaturized hypothetical tram traction substations

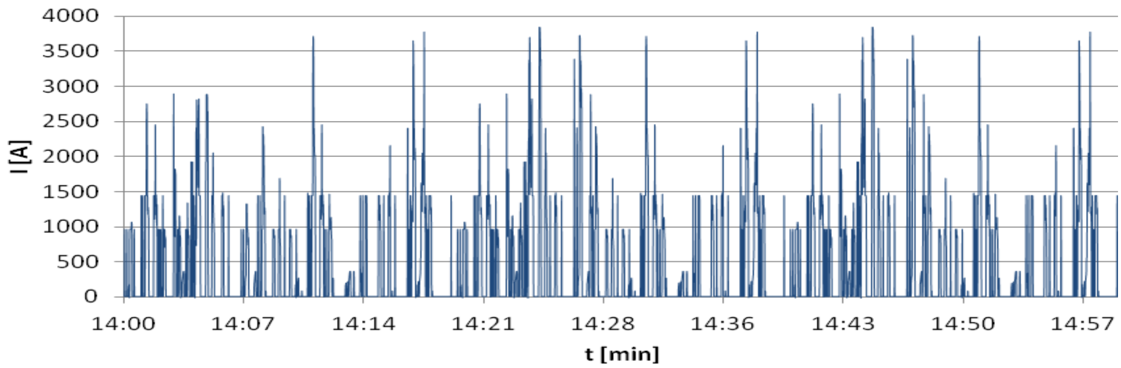

Fig. 4. "Basztowa" power supply: current of load

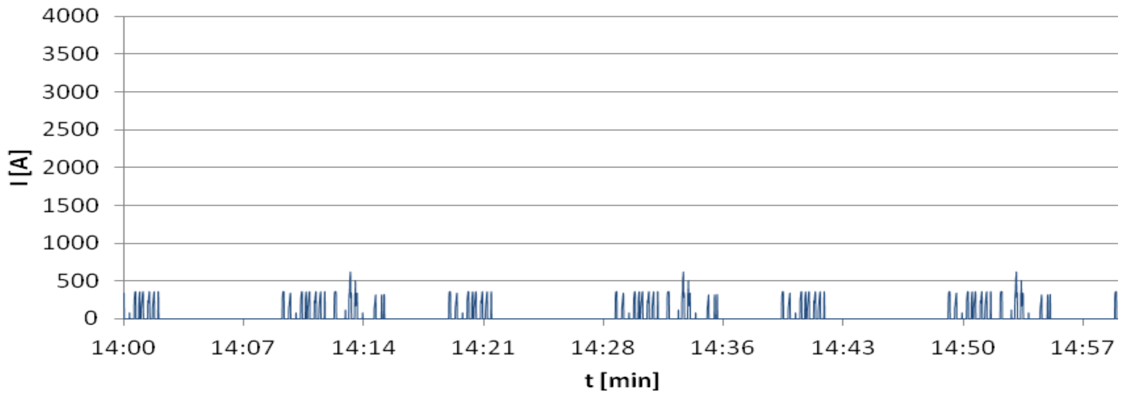

Fig. 5. "Długa" power supply: current of load

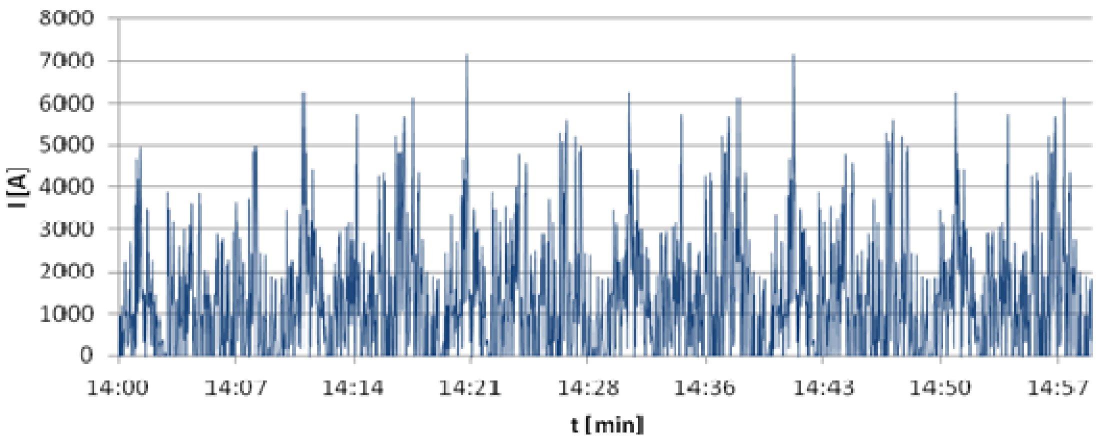

Fig. 6. Traction load at the output of the existing "Reja" tram traction substation

In the above figures (fig. 4 and 5), significant differences between the loads of presented power supplies are conspicuous. This remark pertains to remaining power supplies within reasonable supply area. This variation is a result of a frequency of tram communication, their traction characteristics, line profiles and distances between stops.

On hypothetical mini substations rectifier units (explanation: „transformer with rectifiers) in the fifth class of overload capacity could be used. Such groups are used at modernized tram substations. Rated current of such group on the side of direct current – 660 V equals 1200 A with the V class of overload capacity. [8], [9]. The amounts of overload in this class equal:

100% - permanent load (1200 A),
150% - 2-hour load (1800 A),
200% - 1-minute load (2400 A).

The selection of the amount of rectifier sets is based on the comparison of their permanent current-carrying capacity, with the permanent load of the substation and the temporary current-carrying capacity that stems from the class of the rectifier sets with the maximum instantaneous current of the substation [5].

From the calculated amounts of rectifier sets (under different loads), the highest is being picked and rounded up to an integer. The result is the amount of necessary rectifier sets – n for a given mini substation.

Table 1 presents the results of calculations of rectifier units amount on hypothetical, reduced in size tram substations as well as for the existing "Reja" tram traction substation [7].

Table 1

Determining the amount of rectifier units on hypothetical substations

Miniaturized hypothetical tram traction substation	Imax [A]	I1m-prost [A]	n1m	Ic-podst [A]	Ic-prost [A]	nc	n
"Lubicz"	1922	2400	0,80	107	1200	0,089	1
"Basztowa"	3840	2400	1,6	353	1200	0,29	2
"Dworzec Osob."	2880	2400	1,2	261	1200	0,22	2
"Westerplatte"	2880	2400	1,2	252	1200	0,21	2
"Gertrudy"	1825	2400	0,76	132	1200	0,11	1
"Długa"	617	2400	0,26	27	1200	0,02	1
Existing "Reja" tram tracion substation							
Substation "Reja"	7119	2400	2,97	1308	1200	1,09	3

Where:

$I_{c\text{-}podst}$ – average substation constant current,

$I_{c\text{-}prost}$ – rectifier set constant current,

I_{max} – maximum substation instantaneous current,

$I_{1m\text{-}prost}$ – 1-minute overload current of rectifier set,

n_{1m} –number of installed rectifier units resulting from overload,

nc – number of rectifier units resulting from continuous traction load

Currently on "Reja" traction substation are instaled four rectifier units with power 800kW each, in the fifth overload class and with nominal current 1200A [3].

As may be noted from Table 1, the number of currently used rectifier units in the 'Reja' traction substation is one greater than the amount resulting from the calculation.

A large variability in traffic and different other situations which causes derogation from timetables may result in an increase of the maximum instantaneous current in relation to the value that was calculated (calculations were performed for strictly defined circumstances).

Therefore, it seems reasonable to apply four rectifier units on the existing "Reja" traction substation.

Closing Remarks

Possible advantages of use of power supply from miniaturized traction substations [7]:

- reducing the length of power cables and return cables;
- increase the amount of return points – stray currents reduction;
- smaller substations can be easier integrated into the urban environment;
- smaller amount of space necessary to locate a traction substation.

Disadvantages resulting from the use of miniaturized substation [7]:

- medium voltage network needs to be brought to each substation;
- difficulties in locating of new substations in city centers due to existing underground infrastructure;
- In the concerned power supply area for the conception of miniaturized substations the greater amount of substation devices is needed than for the case of a single substation.

This subject requires further work and analysis

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The article addresses—based on an existing section of a tram line—the evaluation of the capability to substitute an existing tram substation (as a civil structure) with several smaller ones. Replacement of the central tramway substations by smaller ones, situated along the tram line in the shorter distances would allowed to enter the two-sided power supply of the catenary, ensuring alignment substation loads, reducing the voltage drop on the contact line system and thus the power loss [10].

The The article highlights some of the issues that are associated with the selection of the amount of rectifier units for the miniaturized tram traction substations.

Results presented in the article – traction load currents were simulated for the real power supply parameter.

Keywords: tram, traction, substations, rectifier, miniaturization.

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МІНІАТЮРИЗАЦІЯ ПІДСТАНЦІЇ МІСЬКОГО ТРАМВАЙНОГО ТРАНСПОРТУ. ОКРЕМІ ПИТАННЯ

Перевезення міським електричним транспортом (трамваями), протягом понад століття, були ефективним засобом пасажирського транспорту в великих і маленьких міських районах Польщі. В даний час Польща має 14 трамвайних мереж, які експлуатуються 16-ма підприємствами, трамваї працюють в 11 воєводствах. На вулицях Кракова, електричні трамваї з'явились 16 березня 1901.

З технічної точки зору головна перевага трамваїв є їх низький попит на енергію у порівнянні з іншими механічними транспортними засобами (особливо для пасажирських легкових автомобілів). Екологічні фактори проявляють себе в особливо вигідному світлі. Трамваї у місті не забруднюють атмосферу будь-якими вихлопними газами (наприклад CO2). Крім того, цей вид транспорту працює на основі національних енергетичних ресурсів (робота електростанцій на основі бурого вугілля і кам'яного вугілля) і з цієї причини експлуатаційні витрати менш чутливі до коливань цін на нафту на світовому ринку. Особливістю цього виду транспорту є те, що трамваї (а також інші транспортні засоби на електротязі) вимагають постійної подачі енергії, що надається із спеціалізованої системи живлення. Це викликано тим, що вони не є автономними, як звичайні транспортні засоби, оскільки не володіють власним джерелом енергії.

Ключові слова: трамвай, тяга, підстанція, випрямляч, мініатюризація.

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МИНИАТЮРИЗАЦИЯ ПОДСТАНЦИИ ГОРОДСКОГО ТРАМВАЙНОГО ТРАНСПОРТА. ОТДЕЛЬНЫЕ ВОПРОСЫ

Перевозки городским электрическим транспортом (трамваями), на протяжении более века, были эффективным средством пассажирского транспорта в больших и маленьких городских районах Польши. В настоящее время Польша имеет 14 трамвайных сетей, эксплуатируемых 16-ю предприятиями, трамваи работают в 11 воеводствах. На улицах Кракова, электрические трамваи появились 16 марта 1901.

С технической точки зрения главное преимущество трамваев заключается в их низком спросе на энергию по сравнению с другими механическими транспортными средствами (особенно для пассажирских легковых автомобилей). Экологические факторы проявляют себя в особенно выгодном свете. Трамваи в городе не загрязняют атмосферу любыми выхлопными газами (например CO2). Кроме того, этот вид транспорта работает на основе национальных энергетических ресурсов (работа электростанций на основе бурого угля и каменного угля) и по этой причине эксплуатационные расходы менее чувствительны к колебаниям цен на нефть на мировом рынке. Особенностью этого вида транспорта является то, что трамваи (а также другие транспортные средства на электротяге) требуют постоянной подачи энергии, предоставляемой из специализированной системы питания. Это вызвано тем, что они не являются автономными, как обычные транспортные средства, поскольку не обладают собственным источником энергии.

Ключевые слова: трамвай, тяга, подстанция, выпрямитель, миниатюризация.

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