TECHNICAL TRANSACTIONS | **CZASOPISMO TECHNICZNE**
CIVIL ENGINEERING | BUDOWNICTWO

5-B/2014

IRENEUSZ CHRABĄSZCZ, MAREK DUDZIK, JANUSZ PRUSAK*,
WALDEMAR STEC**

INITIAL ANALYSIS OF THE POSSIBILITY TO SUBSTITUTE A GIVEN TRAM SUBSTATION WITH SEVERAL ONES SMALLER IN SIZE

WSTĘPNA ANALIZA MOŻLIWOŚCI ZASTĄPIENIA OBIEKTU WYBRANEJ PODSTACJI TRAMWAJOWEJ KILKOMA O MNIEJSZYCH GABARYTACH

A b s t r a c t

The article addresses – based on an existing section of a tram line – the evaluation of the capability to substitute an existing train substation (as a civil structure) with several smaller ones. Taking into consideration the real estate prices and the shortage of available plots in the centers of larger cities, the localization of a substation building poses a significant location and budget challenge, when it comes to new tram lines. Additionally, such objects (substations) often spark concern and protests among the tenants of the nearby houses, as they are considered to be the source of a dangerous electromagnetic radiation and, sometimes, noise. The possibility to significantly reduce the size of those objects would mitigate the aforementioned challenges – both environmental and budget-related.

Keywords: tramway system substations, rectifier sets

S t r e s z c z e n i e

W artykule dokonano, na przykładzie rzeczywistego odcinka linii tramwajowej, oceny możliwości zastąpienia istniejącej podstacji trakcyjnej (jako obiektu budowlanego) kilkoma mniejszymi podstacjami. Biorąc pod uwagę ceny gruntów i brak wolnych działek w centrach dużych miast, umiejscowienie budynku podstacji stanowi istotną trudność lokalizacyjną i kosztową w przypadku nowych linii tramwajowych. Dodatkowo obiekty te (podstacje) często budzą niepokój i protesty wśród mieszkańców okolicznych kamienic, gdyż traktowane są jako źródło niebezpiecznego promieniowania elektromagnetycznego, a niekiedy hałasu. Możliwość znacznego zmniejszenia tych obiektów ograniczyłaby wspomniane wyżej trudności zarówno kosztowe, jak i środowiskowe.

Słowa kluczowe: tramwajowe podstacje trakcyjne, zespoły prostownikowe

* Ph.D. Ireneusz Chrabąszcz, Eng. Ph.D. Eng. Janusz Prusak, M.Sc. Eng. Marek Dudzik, Institute of Industrial Electrical Engineering and Technical Information Technologies, Faculty of Electrical and Computer Engineering, Cracow University of Technology.

** MA, Eng. Waldemar Stec, a graduate of Faculty of Electrical and Computer Engineering, Cracow University of Technology, specializing in Electrical Engineering in Transport.

1. 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 Kraków, 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. CO_2). Additionally, which isn't without significance, this mean of transport utilizes 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 of 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.

2. 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.

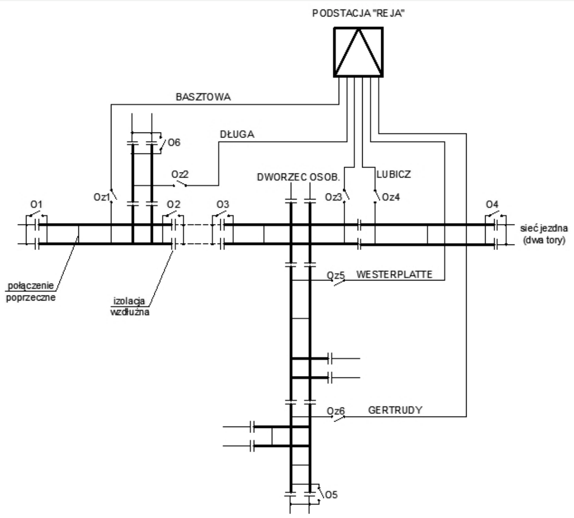

Fig. 1. Schematics of connection between tramway system substations direct current system and the traction network based on an existing „Reja" substation (Oz1, …, Oz6 – isolating switches for power supply, O1, …, O6 – section isolating switches)

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 15 kV [5]

In tramway systems a one-directional power supply system is most commonly used [3–5]. 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.

Figure 1 presents an existing area of power supply of a tramway system „Reja" substation in the center of Kraków [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 3 MW. The decrease of the installed power should translate into the decrease of the substation size.

Figure 2 presents the proposed way of providing power to the traction network from substations, that are substantially lower in capacity. It is assumed that every power supply (power supply cable) will be connected with a separate mini-substation.

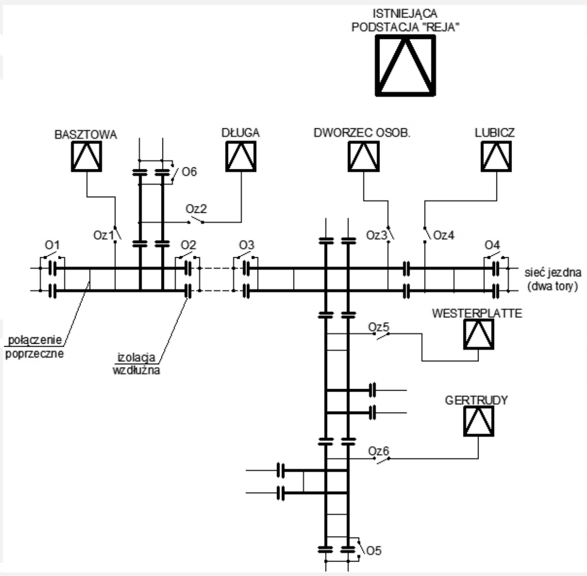

Fig. 2. Connection schematics of a hypothetical tramway system direct current mini-substations with the traction network based on an example of the existing „Reja" substation's power supply area (Oz1, …, Oz6 – isolating switches for power supply, O1, …, O6 – section isolating switches)

3. Results of Calculations

The selection of rectifier sets 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].

Figure 3 presents the current of power supply load – Basztowa, and Fig. 4 the current of power supply load – Długa.

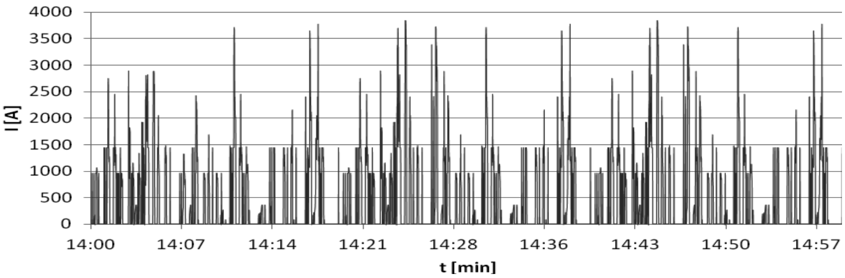

Fig. 3. Basztowa power supply: current of load

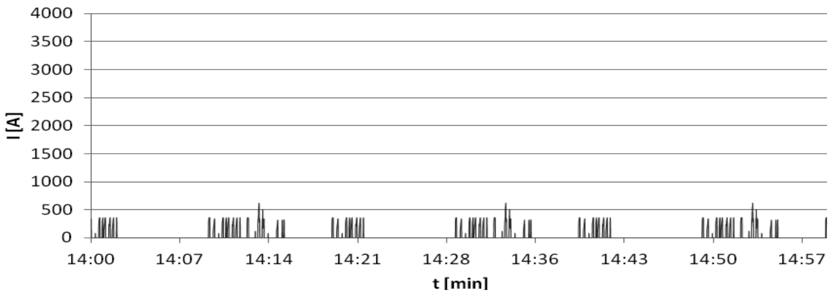

Fig. 4. Długa power supply: current of load

In the above figures (Figs. 3 and 4), 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 sets (explanation: „transformer with diode 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 picked and rounded up to an integer. The result is the amount of necessary rectifier sets – required by a given mini substation.

Table 1 presents the results of calculations of rectifier sets amount on hypothetical, reduced in size tram substations [7].

Table 1

Determining the amount of rectifier sets on hypothetical substations [5]

Substation	I_{max} [A]	$I_{1m\text{-prost}}$ [A]	$I_{c\text{-podst}}$ [A]	$I_{c\text{-prost}}$ [A]	n
Lubicz	1922	2400	107	1200	1
Basztowa	3840	2400	353	1200	2
Dworzec Osob.	2880	2400	261	1200	2
Westerplatte	2880	2400	252	1200	2
Gertrudy	1825	2400	132	1200	1
Długa	617	2400	27	1200	1

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.

4. Closing Remarks

As it can be seen (Table 1), for the traffic situation being analyzed, when supplying power from the hypothetical mini substations, a total of nine rectifier sets should be used in all those substations, which means over twice as many as they are currently used in a real substation (4 units).

Providing power from mini substations to an area of such load diversity as the "Reja" substation is currently not viable using devices available on the market. Because of the capacity, which should be installed, the degree of size reduction of the substation objects will be inadequate to the expectations.

Reducing the (building) size of tramway system substations is a necessity, due to environmental and economic factors (lack of space and real estate prices in cities). Thanks to that, as building structures, they will be less conspicuous and will not spark concern among the nearby tenants, as it is currently the case.

In order to achieve that, the analysis for loads of tramway system power supplies should be carried out and conclusions regarding changes in project methodology should be drawn on the basis of their results. Additionally, substations of the new type will require new technical and design solutions.

References

[1] Wojcieszak J., *Komunikacja tramwajowa w Polsce*, TTS Technika Transportu Szynowego, nr 9/2003, 31-50.
[2] Verkehr auf Schienen: *Herausforgerungen an die Elektrotechnik*, Siemens – Aktiengesellschaft–Berlin, Muenchen 1979.
[3] Mierzejewski L., Szeląg A., Gałuszewsk M., *System zasilania trakcji elektrycznej prądu stałego*, Wydawnictwa Politechniki Warszawskiej, Warszawa 1989.
[4] Chrabąszcz I., Prusak J., Drapik S., *Trakcja elektryczna prądu stałego. Układy zasilania*, podręcznik INPE dla elektryków, zeszyt nr 27, Bełchatów 2009.
[5] Kałuża E., Bartodziej G., Ginalski Z., *Układy zasilania i podstacje trakcyjne*, Politechnika Śląska, Skrypty uczelniane nr 1220, Gliwice 1985.
[6] *Dokumentacja obszaru zasilania prostownikowej podstacji trakcyjnej, „Reja"*, ZIKiT, Kraków 2007.
[7] Stec W., *Ocena wartości prądów obciążenia kabli zasilaczy i kabli powrotnych tramwajowych podstacji trakcyjnych w aspekcie miniaturyzacji tych podstacji*, praca magisterska, Politechnika Krakowska, 2011.
[8] Rysunek ofertowy prostownika PD-12/08k firmy Woltan.
[9] Zespół prostownikowy 12-pulsowy. Prospekt firmy Enika.