



TRAMWAY AND ELECTRICAL POWER SUPPLY WITHOUT OVERHEAD WIRES

Stjepan Lakušić¹, Tatjana Satazić², Damir Škrinjar³

¹ University of Zagreb, Faculty of Civil Engineering, Croatia

² University of Split, Faculty of Civil Engineering and Architecture, Croatia

³ Zagreb Holding, Croatia

Abstract

The tramway (electrical) system is a cost-efficient, safe and fast way of passenger transport with the smallest environment pollution (in relation to other types of passenger land transport). As an integral part of the public transport, it is often used in city centres, and it is adjusted to transport needs by prolongation and extension of tracks. However, some city areas need tramway line without overhead wires and their accompanying infrastructure. Motivated by those requirements, producers of tramway vehicles have design new or introduce existing ways of power transmission to vehicle, but without overhead lines and posts to support them. The paper will present systems of wireless electricity transmission which have been applied or are currently in the phase of testing for application in tramway vehicles. With a short description of the working principles and technology, a comparison of particular “wireless” systems will be given, and their advantages and shortcomings will be pointed out. Also, a short review will be given on the possibility of introduction of that type of passenger transport in cities which do not have, and plan to introduce tramways in the public transport system.

Keywords: tram, electrification, power supply system

1 Introduction

Systems of electric traction for rail vehicles are introduced in tramway at the end of 18th century. Electric powered tram rapidly replaced horse power tram, especially in Europe after 2nd World War. Rapid development of internal combustion engines, as well as flexibility of road vehicles caused decrease of tramway use in public transport systems. Increased number of road vehicles that crowded cities, as well as air pollution and traffic noise, forced city authorities worldwide to include existing rail transport systems in public urban and suburban transport system even more. In the meantime, tram manufacturers have developed modern electric vehicles that were, and still are, well accepted by passengers for their daily activities. The demand for preservation of historical heritage and urban landscape brings up need for tram systems without catenary. These systems are in use or planned to be used in urban environment.

2 Power supply systems for electric rail vehicle

Systems of power supply could be divided into two types: systems outside the vehicle and the systems inside the vehicle. The systems of power supply outside the vehicle (contact systems) consist of a conductor (on or over the street level) and of an on-board plug. Representatives of these systems are: a) overhead wires and vehicles with pantograph (the paper do not deal with overhead wires and pantograph); b) power supply systems on the street level. The systems of

power supply in the vehicles are batteries (transform chemical energy into the electric one) and energy savers that recharge during operating and braking. At first, this system substituted the electric power in the contact systems. Today, on-board systems become independent power supply systems and an alternative to the contact systems.

2.1 Ground level supply systems

Electric power transmission on the street level is the oldest way of power supply to the tram vehicles.

2.1.1 Running rails

The first electrical tram developed by Werner von Siemens (Berlin, 1881. [1]) was supplied with electric current through the two running rails. The contact between the rails and wheels closed the electric circuit. Uninsulated rails under voltage pose constant shock hazard for pedestrians. Rain, ice and snow caused disruption of tram traffic.

2.1.2 Third rail and stud

Werner von Siemens made at 1887. [2] Tramway system in Budapest with a kind of third rail inside the track. Siemens's third rail was a steel conductor placed in ditch on the inner side of one rail, with a narrow slit opening upwards. Trolley pole hanged under the tram, slides over the powered rail to collect the current. This track system was water-protected and safe for pedestrians. There was no defence against ice and snow, dirt filled up the ditch, and trolley pole was wearing out. Overhead wires and tram with pantograph replaced Siemens's power supply system by the 1920s. At the beginning of the 20th century (1908.), Kingsway Tramway Subway was opened in London. Underground tunnel [3] with two track linked North London with South London. The current collector, laid in the middle of the track, consisted of two "T" steel sections of opposite polarity, facing each other (Fig.1). Two metal shoes beneath the tram rolled in the collector and closed electrical circuit. The running rails were not part of the electrical circuit. Unsuitable drainage systems kept water between two "T" sections of conductor and caused operating troubles. The last tram operated in 1931.



Figure 1 Kingsway Tramway Subway, London – north entrance, 2003, [4]

Stud contact systems were used in Europe (France, England) and USA at the end of 19th and at the beginning of 20th century. These power supply systems on the ground level (named after their inventors) were: Diatto system, Dolter system and Lorian/Brown system, [5]. Ideas for electric transmission to the vehicle were the same – skate beneath the vehicle switched the studs set in the pavement at intervals. There was no control over the stud turning on/off. The

rain cut electric circuit. The problems were solved by replacing this system with overhead wires or by replacing the trams with other road vehicles (busses, trams with diesel-electric traction).

2.2 On-board systems

The early development of on-board power supply system was stimulated by demand for power on track section with no electric energy input. The tram with Lorian/Brown stud system (1902.) had a battery that ensured power for vehicle to reach “live” stud if it pass by “dead” one, [5]. Since then, all manufactures of rail vehicles have developed an on-board supply system. One in use and one in testing will be described in following text.

2.2.1 Battery systems

Alstom’s battery is autonomous on-board power supply system that allows the tram to operate over distance less than 1km without overhead wires, at speed up to 30km/h [6]. It was integrated in Citadis in Nice (France) at 2007, [7], in order to preserve restricted urban area, such as the Massane squares (Fig.2).

The battery, located beneath the roof in the middle of the tram, recharges during operation with overhead wires. The driver changes operation in “pantograph mode” to operation in “battery mode” by pressing the button. To avoid possible driver error and to facilitate mode change, audible and visual alarms are triggered on the driver console. The system is safe for pedestrians and all road users.



Figure 2 Citadis and Massane square, Nica, France, [7]

Gigacell is battery integrated in prototype vehicle Swimo, both are product of Kawasaki. On-board batteries, installed under passenger seats, recharge during braking and during operating on electric section of route. On no electrified route section, the control system (installed beneath vehicle roof) provides a steady power supply when the tram is accelerating, and returns regenerative power to battery. Testing of system started in 2007. Results of few tests shows that Gigacell could charge in only 5 minutes and the power can ensure Swimo to operate 10km, [8] at speed of 40km/h, [9].

2.2.2 Capacitor systems

Capacitor systems integrated in vehicle ensure energy savings and power supply optimisation. An example of capacitor system is Mitrac energy saver produced by Bombardier [10]. The system is based on high-performance double layer capacitor technology which optimizes power supply and energy saving. Mitrac stores energy released during braking or operating with overhead wires. Stored energy can be used for tram starting and accelerating as well as for tram operating on route segments without overhead wires. Mitrac is tested in Mannheim (Germany) since 2003, [11].

3 New modes of ground level power supply for tram

Previously described systems of ground level power supply (Section 2) are the solutions for “no power input” problems. The operation troubles of the earliest systems were solved by replacing them with much safer system with overhead wires. Today, tram and track manufactures developed or tested new power supply technologies without overhead wires which need innovation in vehicle as well as in track.

3.1 Power supply system from the ground level

At December 2003 in Bordeaux (France) a new power supply system, named APS (Alimentation par Sol – the street level power supply), was introduced on 14km long tram track, [12]. Necessary equipment was integrated in Alstom’s 100% low floor tram Citadis. The switch from APS system to overhead wires is made manually by driver at tram station, [12]. Third contact rail is in the middle of the track (Fig.3) and embedded in pavement. Contact rail is made up of powered segments (8m long) and insulated segments (3m long) fitted alternatively to complete the route length.



Figure 3 Third rail of APS, Bordeaux

The powered section is connected to power boxes buried under the track and located in intervals of 22 m, [12]. Collector shoes, situated beneath middle module of tram (Fig.4), pick up power from energized rail segment by friction. The both ends of the middle module are supply with contact shoes to ensure that at least one shoe is in contact with powered segment.

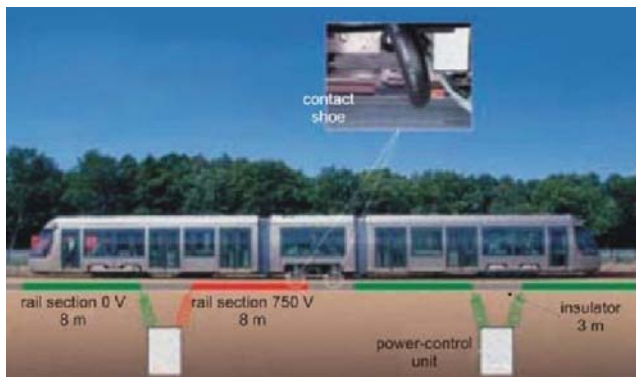


Figure 4 APS – working principle, [13]

The delivery of power to the conducting rail segment is triggered by coded radio signals between the tramway and buried powered boxes. The individual segments of contact rails are energized only when the vehicle is detected over the rail section. The battery, placed beneath roof, is emergency power supply system. It turns on automatically if power supply is missing. The battery ensures 1 minute operation at speed of 3 km/h, [12]. The advantages of APS are: preservation of urban landscapes and historical heritage (Fig.5); total safety for pedestrians and road users; compatibility with all types of road surface. The length of tramway with APS is theoretically endless, but the length of route in restricted urban areas determines the length of APS in practice.



Figure 5 Citadis and APS in Bordeaux (square, bridge) [13]

The disadvantage of APS is possibility of water penetration in energized parts of the system. There is no information about functionality of APS at longitudinal gradients. The costs of APS solutions are approximately 5% [12] to 20% [7] higher than for overhead system, plus 5% [12] to 20% [7] of traditional tram acquisition cost for purchase of an appropriate vehicle.

3.2 Inductive power transfer

The World first catenary free operation (CFO) tram is developed by Bombardier Transportation and offered to the media on 22nd January 2009, [14], at the company test track within the Bau-zen factory (Germany). CFO system unites two products, Mitrac and Primove (Fig.6) installed in 100% low floor Flexity tram.

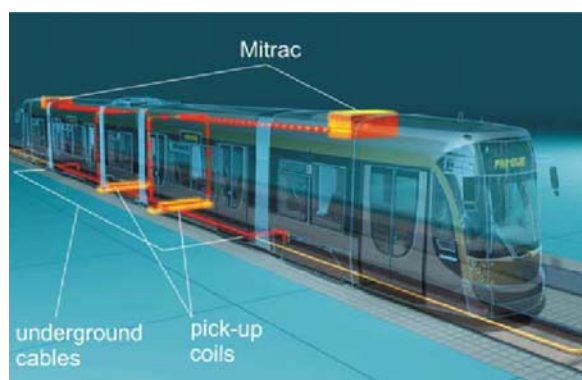


Figure 6 Scheme of energy flow, CFO Primove [14]

The underground cable is laid in the middle of the track. It is divided into sections and connected to the public electric network. The cable section is energized only when is fully covered by the vehicle. Current flow in cable section creates magnetic field in pick-up coils beneath

the vehicle. Induced power is stored in Mitrac and used for traction or acceleration of vehicle. Induced power of 250kW into the 30m long tram ensures average speed up to 40km/h on longitudinal gradient up to 6% [11]. The efficiency of inductive power transmission is between 92% and 95%. The advantages of Primove system are: traction without overhead wires on no-limited distance in different urban environment (squares, parks, tunnels); cables can be integrated into all pavements; resistant to all weather conditions (rain, ice, snow, storms); there is no wear of components. There are no known disadvantages of system because it is still tested in Bautzen – potential commercial use is planned through 2010.

4 Conclusions

Cities around the world, regardless of their size, need sustainable public transport system. That means safe, comfortable and efficient transport system with lowest air pollution which has to be able to integrate in all urban areas. New technology of electric power supply for tramway satisfies the demand for catenary free operation. Increasing of track construction costs and rolling stock costs should be observed through the mitigation of catenary costs, and especially through benefits that are erased from no-catenary operation in restricted urban areas. Besides that, the process for selecting of wireless power supply system should include all relevant facts, such as: applicability of new transport mode in existing public transport system; specifics of transport route in urban area; life time costs of all parts of system.

References

- [1] The Siemens tram from past to present www.siemens.com.
- [2] <http://hampage.hu/trams>, 1.12.2009.
- [3] Watkins, A.E.: The Campaign to save the London Trams 1946-1952. Based on the Collected Papers of The late Alan John Watkins. <http://www.kentarchaeology.ac> 18.02.2010.
- [4] www.yellins.com/transporthistory/bus4/subway.html.
- [5] Surface Contact Collection (by John Prentice) <http://www.tramwayinfo.com>.
- [6] The battery – Autonomous on-board system. www.transport.alstom.com
- [7] MacDonald, M.: Power Distribution for Trams and Electric Trains. Technical Note. July 2008. <http://www.dot.abudhabi.ae/>
- [8] Inside SWIMO, the Next generation Light Rail Vehicle. <http://www.kawasakirailcar.com>
- [9] Hitoya, F: The Modal Shift to Environmentally Sustainable Transport: Prospect of Urban Transport Systems: LRT, BRT and Buses. <http://www.nistep.go.jp>
- [10] BT-ECO4-MITRAC_Energy_Saver. www.bombardier.com
- [11] Primove, TransUrban Volume 4 No. 2/09
- [12] Swanson, J. D.: Light Rail Without Wires - A Dream Come True? <http://onlinepubs.trb.org>
- [13] APS-The street level power supply, www.transport.alstom.com
- [14] BT-ECO4-PRIMOVE. www.bombardier.com