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ENHANCING URBAN MOBILITY: THE ROLE OF IN MOTION CHARGING IN MODERN TROLLEYBUS SYSTEMS

In Motion Charging (IMC) is an innovative power system for trolleybuses that combines traditional overhead lines (OHL) with modern traction batteries. This system allows vehicles to charge while in motion, eliminating the need for stopping to recharge. As a result, trolleybuses can cover significant portions of their routes without relying on overhead lines, increasing the overall flexibility and functionality of the system. A key aspect of IMC is optimizing the length of overhead lines, which reduces the required battery capacity and lowers infrastructure costs. This article discusses the principles of the dynamic charging system, the benefits of its implementation, and practical examples of its application in European cities such as Solingen, Freiburg, and Gdynia.

Keywords: inm motion charging, trolleybus, electric buses, electromobility

INTRODUCTION

In the dynamic charging system (In Motion Charging - IMC), part of the route is covered with a trolleybus traction network (OHL - overhead line), which allows for the charging of traction batteries during movement (Fig. 1). The vehicles cover the rest of the route, i.e. the part in which there is no contact line, using traction battery power. This allows for the charging of the vehicle without stop-ping, increasing the flexibility and functionality of the system. In addition, covering a section of the route with a traction network reduces the length of the route to be travelled in battery mode, which in turn allows for a reduction in the capacity of the traction batteries.

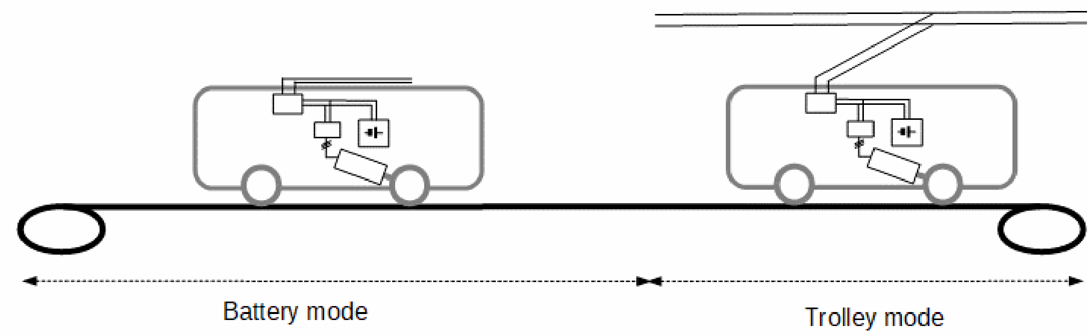

Fig. 1 − Idea of dynamic charging system (In motion charging)

The construction of a traction network is associated with significant financial outlays and is the most expensive element of dynamic charging system. For this reason, it is advisable to limit its length. The length of sections accompanied by contact line must be sufficient to charge the traction batteries with energy at least equal to the energy necessary to cover the catenary-free section. With currently used vehicles, the mini-mum degree of coverage with the traction network is at a level of 40% - 50% [3]. This value can be reduced by increasing charging power to 25%. In the case of a supply system of 750 V DC it is possible to decrease this rate to 20% [1-3]. In the case of a reduction in the heating power of the vehicle or use thermal pumps, it is possible to reduce the degree of coverage below 20%. Fig. 2 shows an estimation of the minimal coverage rate in function of charging power, based on, the energy consumption for a standard vehicle was assumed to be 3 kWh/km (winter) and, correspondingly, for an articulated vehicle 3,9 kWh/km [1, 7].

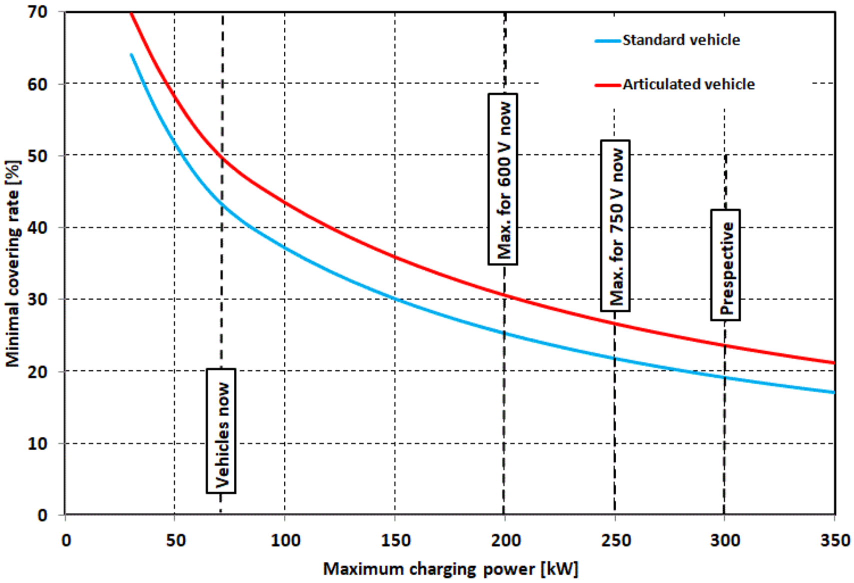

Fig. 2 − Minimum catenary coverage in function of maximal charging power [1, 7]

Modern technical solutions significantly increase the attractiveness of the trolleybus network for IMC charging. One of these is semi-automatic trolleybus pantographs, which enable the vehicle to be quickly connected to the trolleybus overhead line network (Fig. 3). Another solution is rapid charging stations for trolleybuses, which enable batteries to be charged via trolleybus pantographs with an output of 150 - 350 kW. Compared to classic electric buses, this solution has a significant advantage: Similar to the TOSA system, the charging process can begin immediately after connecting the pantograph (no charging station-vehicle synchronization is required) (Figures 4, 5, 6). The impact of the trolleybus overhead line on the appearance of public spaces can also be minimized. Thanks to the use of aesthetic masts and supporting elements, the trolleybus overhead line can be aesthetically integrated into the existing environment (Fig. 7). Importantly, the overhead power supply system for trolleybuses allows for easy integration with renewable energy sources.

Fig 3 − Automatic connection to trolleybus cathenary, fot. Mikołaj Bartłomiejczyk (Bern, Schweiz).

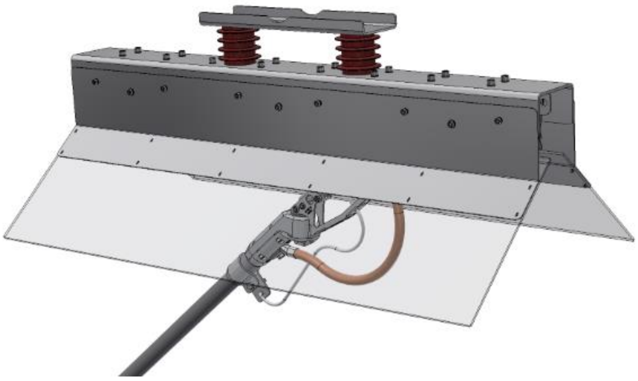

Fig 4 − Kummel+Matter Fast charging station for trolleybuses

Fig. 5 − Fast charging connection point for trolleybuses, designed by the AREX company (Gdynia, Polen)

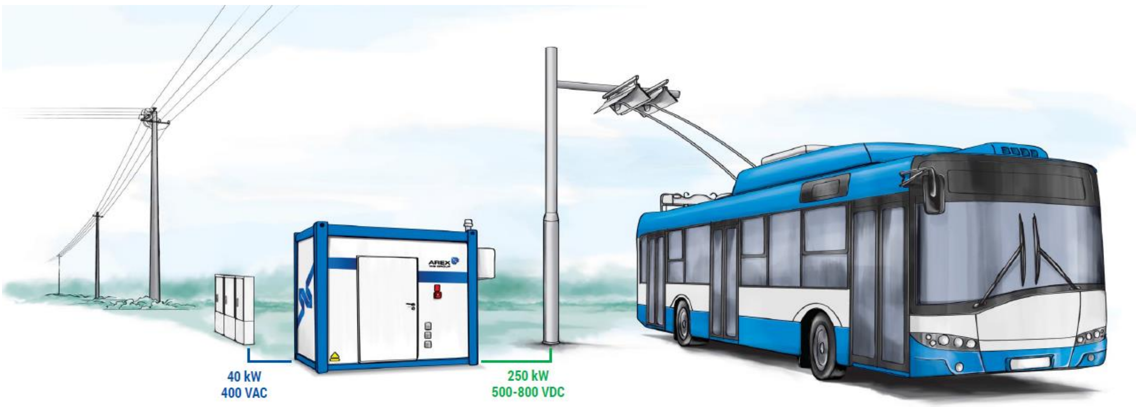

Fig. 6 − Stationary trolleybus charging station with energy storage (Firma AREX, Gdynia, Polen).

Fig. 7 − Trolleybus cathenary, fot. Mikołaj Bartłomiejczyk (Pescara, Italien).

PRACTICAL APPLICATION OF DYNAMIC CHARGING

Solingen

SWS, the public transport company in Solingen (Germany), implemented advanced dynamic charging system: They converted the diesel buses route 695 to IMC electric buses. The existing overhead cathenary wires (Solingen operates trolleybus system) will be used as a approximately 2 km long linear dynamic charging track, used as a charging infrastructure [6]. The new system, which is called BOB (Battery Overhead wire Buses) in Solingen, uses vehicles equipped with LTO traction batteries. Thanks to these batteries with the only 2 x 2.1 km long "IMC charging road" the BOBs can operate nonstop passenger service on the 18 km long (in both way) route (figure 9). Nearly 80 % of the route is operated in battery mode without overhead wires [6]. The vehicles were manufactured in cooperation of Solaris and Kiepe Electric (table 1, fig. 8).

Fig. 8 − The BOB Solaris Trollino Kiepe Electric in Solingen, photo Jürgen Lehmann

Table 1 – Technical data of BOB vehicles in Solingen [6]

Vehicle type	Articulated low-floor trolleybus of the type "Trollino 18.75" (Solaris / Kiepe Electric)
Vehicle size	18.75 length m x 2.55 m width x 3.5 m height
Electric motor	2 x 160 kW asynchronous motors on the 2nd and 3rd axles (4 powered wheels)

Energy of battery	Lithium-titanate-oxide (LTO); 48 kWh usable energy / 60 kWh installed energy; 200 kW continuous power / 300 kW peak power
Charging concept	IMC® (in motion charging) up to 240 kW and opportunity charging (standing)

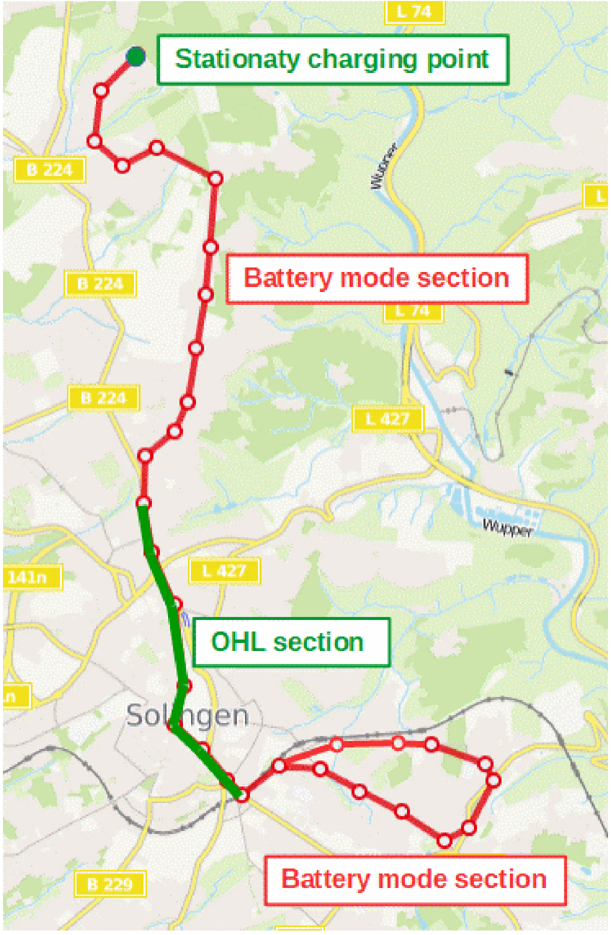

Fig. 9 − The scheme of BOB system (line 695) in Solingen, OHL - overhead trolleybus cathenary line, based on https://moovitapp.com/

Freiburg

An example of a modern IMC system is the city of Freiburg in Switzerland. The 10 km long line 1 is in the middle 3 km long section equipped with overhead lines. The operation is carried out by Hess battery trolleybuses with 66 kWh batteries 350 kW charging in motion (Fig. 10 and 11).

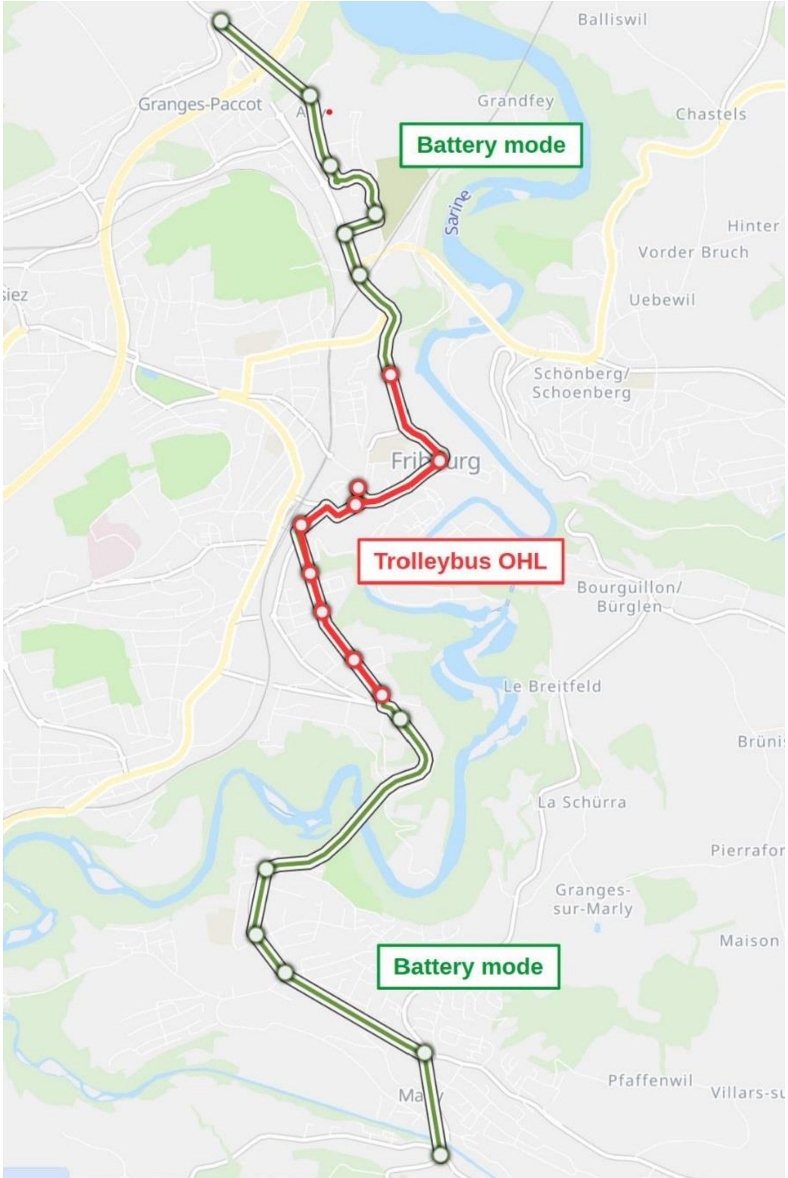

Fig. 10 − Line 1 in Freiburg, Switzerland, operated by IMC trolleybuses, only 30% covered by overhead cathenary, based on https://moovitapp.com/

Fig. 11 − Hess ligh Tram 19 DC trolleybus on line 1 in Freiburg (Switzerland) with the dynamic charging system IMC. The route is only 30% covered by the trolleybus network and a 66 kWh LTO traction battery can be seen on the roof of the first vehicle section. Foto Mikołaj Bartłomiejczyk

Gdynia

In Gdynia (Poland), as part of the Gepard program (supported by National Fund for Environmental Protection and Water Management) bus line 170 was electrified. This electrification was combined with the modification of the route (the route in the central part of the city was extended) and the change of its number to 32. Line 32 has a lengths of cca. 10 km one-way, of which 4 km is under the trolleybus OHL catenary and 6 km are driven in battery mode (Fig. 12).

Due to the specificity of line 32, it was decided to introduce dedicated vehicles with special electrical equipment to serve it – Trolleybus 2.0. In classic trolleybuses, due to the need to provide electric shock protection, all electrical equipment operating at 600 V (traction converter, traction motor, on-board converter, or traction batteries) must be equipped with two-stage insulation from the vehicle body. This requires the implementation of an electrical installation dedicated to trolleybus solutions. In the case of line 32, however, most of the route takes place in battery mode. For this reason, it was decided to use an unusual technical solution that would combine the features of a trolleybus and an electric bus under commercial name Trolleybus 2.0 (Fig. 11). It consisted in the maximum unification of the vehicle with a classic electric bus, i.e. the use of a standard electric bus installation with standard, single-stage insulation and a traction battery as the main power source. The battery is charged from the trolleybus catenary by means of an input DC-DC converter (charger) with a power of 150 kW (during standstill, the current received from the catenary is limited to 160A). So, from the point of view of the electrical installation, the vehicles purchased in the Gepard program are similar to standard battery electric buses, while from the point of view of the passenger or the driver, they are almost identical to the trolleybus. These buses also have double legal approval - as a trolleybus and an electric bus.

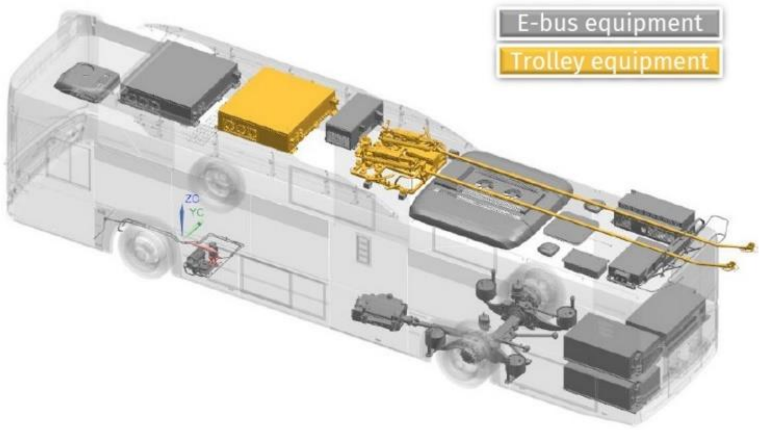

Fig. 12 − Trolleybus 2.0 vehicle © Solaris Bus & Coach

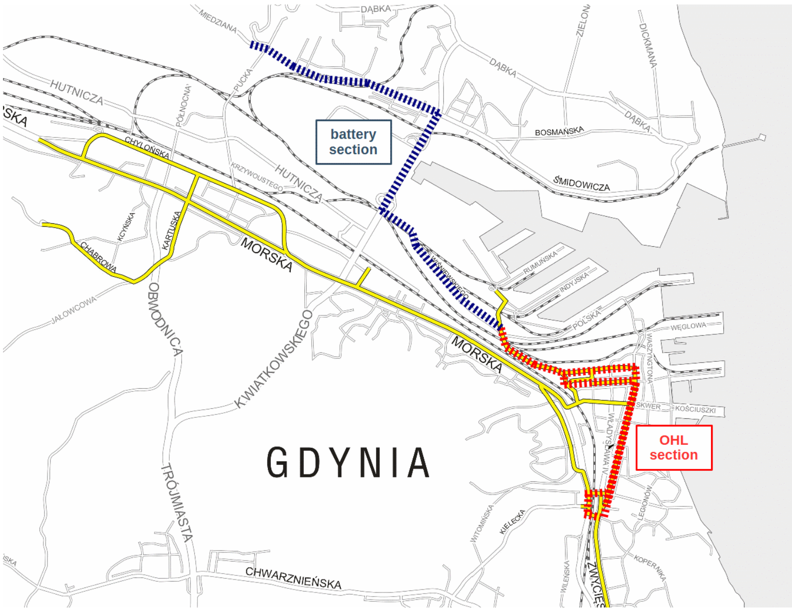

Fig. 13 − The scheme of 32 route, yellow lines: existing trolleybus OHL network

SUMMARY

The In Motion Charging (IMC) system represents a significant advancement in urban public transportation, offering a flexible and efficient solution for powering trolleybuses. By combining traditional overhead lines (OHL) with modern traction batteries, IMC allows vehicles to charge while in motion, reducing the need for extensive battery capacity and lowering infrastructure costs. This system enhances operational efficiency by enabling continuous travel without frequent stops for recharging.

Practical applications of IMC in cities like Solingen, Freiburg, and Gdynia demonstrate its effectiveness. In Solingen, the IMC system enables electric buses to operate on an 18 km route with only 20% of the distance covered by overhead lines. Freiburg's Line 1 shows that with 30% OHL coverage, trolleybuses can efficiently manage a 10 km route. In Gdynia, the integration of IMC with electric buses offers a hybrid solution, improving the flexibility and performance of public transport.

Overall, the IMC system provides a sustainable and aesthetically pleasing alternative to conventional electric buses, with the potential to integrate renewable energy sources. This innovative approach not only reduces emissions and energy consumption but also enhances the attractiveness and functionality of urban transport networks.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

Data will be made available on request.

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