ECOMOMIC BENEFITS OF DYNAMIC CHARGING O ELECTRIC BUSES

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ABSTRACT

Diesel engines buses are still the most used buses. Electric buses provide promising green alternatives and a lot of advantages, but the main disadvantage is their limited travel range. This article is a presentation of new as well as innovative solutions for charging of electric busses while financially reaping the benefits of cost efficiency of the use of the above mentioned. This Dynamic Charging while accompanied in the transport routes in a sense where the overhead contact line is used to charge the power of the batteries. Consequently this is a method for the vehicle charge without the need for the vehicle to be forced to be removed from traffic which increases the flexibility and the functionality of the system.

Key words: electric buses, trolley busses, electro mobility, dynamic charging.

INTRODUCTION

In order for the traction batteries to be charged while in movement (Fig.1) the dynamic charging system (In Motion Charging – IMC) allows part of the route to be secured by trolleybus traction network (OHL – overhead line). While using traction battery power we allow with no contact line the vehicle to cover the rest of the course. However while the flexibility and the functionality of the system are increased allowing the charge of the vehicle without stop-ping. Consequently for reduction in the volume of the traction batteries to occur we cover a part of the route where traction network reduces the distance of the route which is travelled in battery mode.

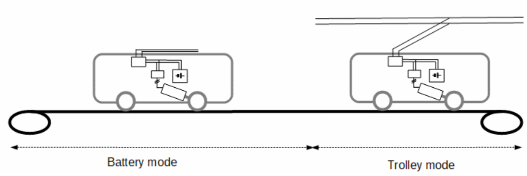

Fig.1. Idea of dynamic charging system (In motion charging)

Moreover the most expensive element of the dynamic charging system is the building of a tracking network. Because of this it is reasonable to take in consideration to cut the length. A contact line with the length of this part has to be enough to charge the traction batteries with energy that is equal at least to the energy needed to uphold the catenary – free section. The lowest degree of uphold of the traction network is at a minimum 40% to 50% at the currently used vehicles. By increasing the charging power to 25% the value of the traction network can be decreased. Consequently in the case of the supply system of 750 V DC the possibility is to be reduced to 20% rate, while in the case of reduction in the heating power of the vehicle or use of thermal pumps, in this case that the coverage should go even below 20%. In Fig. 2 we can see approximately minimal coverage rate in charging power function which means that if we accept that the energy intake for normal vehicle is 3 kWh/km (in the winter) then of an articulated vehicle it is 3,9 kWh/km [1,7].

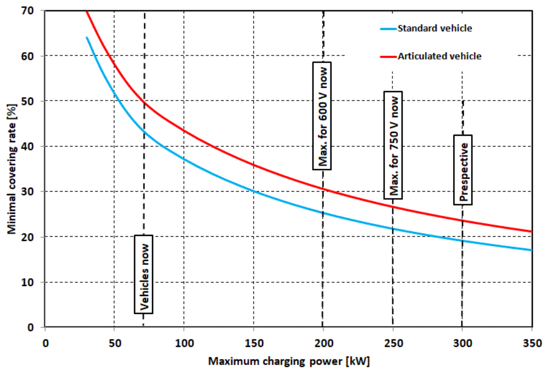

Fig. 2. Minimum catenary coverage in function of maximal charging power [1, 7]

ADVANTAGE OF DYNAMIC CHARGING

Taking in consideration that electric buses are fairly new ways of transport we have to estimate that there is not enough experience in operating them. Consequently it is very hard to determine tendencies toward changes of the purchase prices of the electric vehicles in the future due to the dynamic nature of development of this market. However what is even more obscure is that there is fairly much experience in the field of operating traction batteries with big capacities. Battery life is a key determinant which makes a problem and difficulty assessing it. Inasmuch the risk of entering this kind of transport is very high. There is a difference between them in the main element of the risk:

- Purchasing price and purchasing power of the vehicles
- Cost of replacing the battery
- Risk of traffic crowding and its effect on charging process.

A) Purchasing price and cost of replacing the battery

At this time 50% of the price of the vehicle is the price of the battery. However in a lifetime of a vehicle a battery needs to be replaced at least once. Consequently the drop of the price of the battery is very difficult to evaluate but it is to be anticipated. Inasmuch as what we can predict is that while the electro mobility industry increases in progress as well as increases in demand for energy storage a negative effect in battery cost can be expected.

B) Risk of traffic crowding and its effect on charging process

In order to deliver a right time backup for vehicle charging a stationary charging is required to increase number of servicing transportation line of the vehicle. However this makes a growth in the number of services and the drivers. Inasmuch because of organizational difference of driver services an additional cost can't be assessed however 50% of maintenance costs of the transport system are the cost of driver's accounts. A significant increase in cost can be noticed even at the smallest increase in the number of rolling stocks. Due to this factor we notice that this is also a part of the charging element. Thus it is a primary importance to also notice that when the vehicle stops for charging there is traffic disturbance and traffic congestion. Moreover this means that there is a lateness of scheduled arrival time to the final stop which is another cause for less time for recharge of the vehicle. In Fig. 3 we show a situation where a stationary charging cause's situation where there is not enough stop time to charge the vehicle which is needed to be used as a backup.

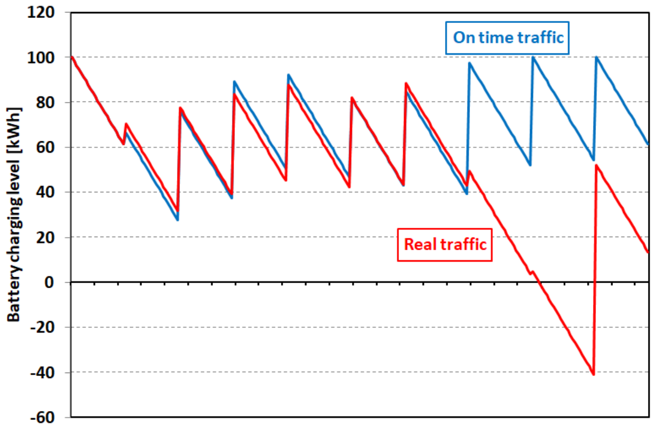

Fig.3. Influence of traffic delays on battery bus operation - during peak hours delays can cause reduction of stopping time, which can be too short for fully charging [7]

C) Comparison of risk related with electrification of the bus routes

From economic point of view there is a difference in stationary charged and dynamic charged electrical buses and that difference is in the cost structure meaning that there are bigger fixed costs and lower level of variable costs. A financial analysis was made in terms of comparing the costs of stationary versus dynamic charged buses meaning analyses of costs like maintenance as well as cost of assets. These analyses of cost or financial analyses will include discounted life cycle cost analyses or LCC. Sole purpose of these analyses is to find extreme life cost values for different inputs: the price of purchasing the vehicle, battery replacement price as well as the influence of traffic circumstances on the charging process. We took in consideration 2 different types of scenarios meaning the optimistic as well as the pessimistic approach made by LCC calculator to see the price of an individual cost element.

Life cost value analyses as well as risk value of life cost for the exposure of 20% by catenary and movement interval of 8 minutes is shown in Fig. 4 [7], while in Fig. 5 we have the structure of the cost. The variance of maximum and minimum value of LCC cost is called risk value. Inasmuch it all defines that the investment in the traction network is available to lower the risk that is related to operating costs.

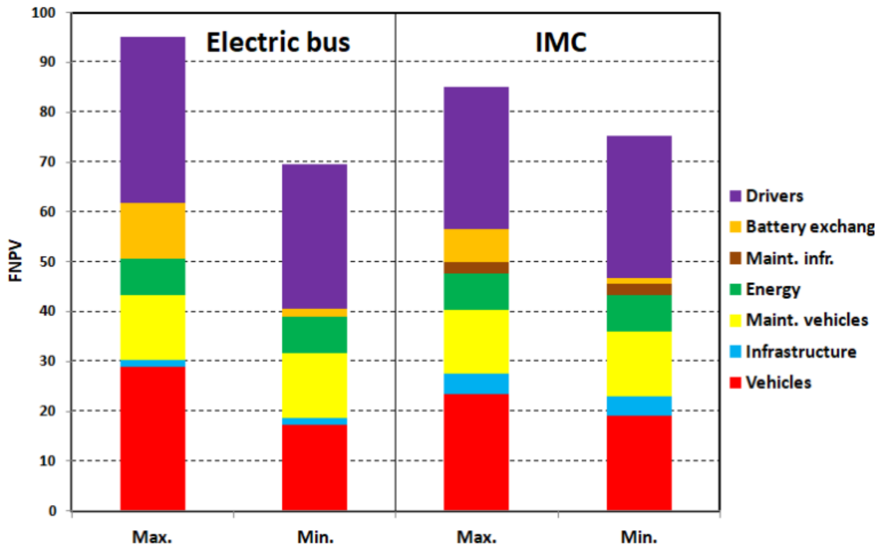

Fig. 4. Life cost analysis with assumption of 20% coverage of transportation route by overhead wires (in case of IMC) [7]

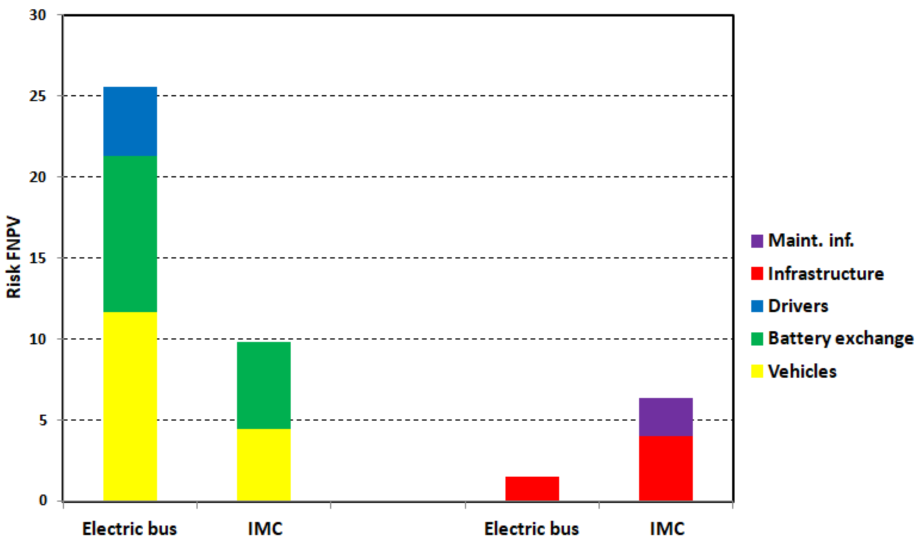

Fig. 5. Analysis of life cost risk with assumption of 20% coverage of transportation route by overhead wires [7]

PRACTICAL IMPLEMENTATION OF DYNAMIC CHARGING

A) BOB system in Solingen

In Germany, Solingen, the public transportation company SWS has a progressive dynamic charged system, their diesel buses route 695 are transformed to IMC electrical buses. As a charging infrastructure the Solingen trolleybus system will use around 2 km linear dynamic charging track which are the current overhead cathenary wires. BOB system (Battery Overhead wire Buses) which will be the innovative system in Solingen practice vehicles with LTO traction batteries. However these batteries that are 2x2.1 km long “IMC charging road” help BOBs to function in a route that 18km long in both ways (Fig.7). Without the overhead wires the vehicles can function 80% of the route on battery mode [6]. These vehicles were a collaboration work between Solaris and Kiepe Electric (Table 2, Fig. 6).

Fig. 6. The BOB Solaris Trollino Kiepe Electric in Solingen (photo Jürgen Lehmann)

TABLE I
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)

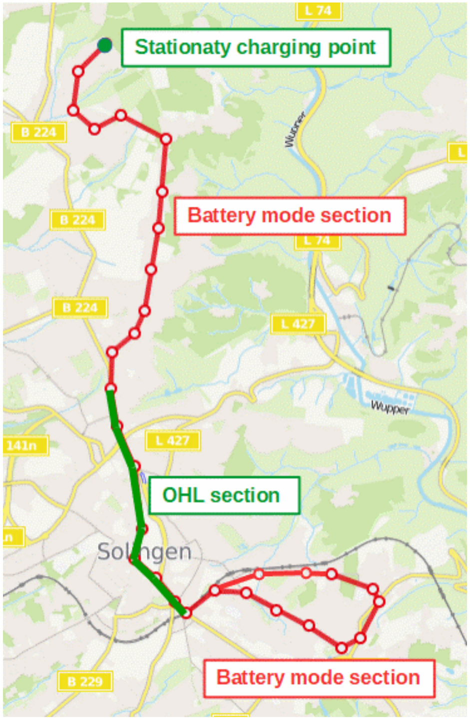

Fig. 7. The scheme of BOB system (line 695) in Solingen, OHL - overhead trolleybus cathenary line, (based on https://moovitapp.com/)

B) Conception of dynamic charging system in Skopje

Republic of Northern Macedonia has a Public Transport Company Skopje (Јавно сообраќајно претпријатие Скопје) that maneuvers over 50 urban and 50 suburban bus lines which makes it the largest passenger carrier in the country. The company has a park that is mostly double decker Yutong Chinese buses as well as LAZ models from Ukraine which are in number way lower than Yutong. Consequently many time the City of Skopje tried to plan a tram transport but without a successes. With global warming and the problem with emission that the whole world is dealing with the most reasonable solution as well as a cheaper solution to the emission problem is the form of dynamic charged electric busses. Moreover there are few boulevards the city has that are crowded during the rush hour but the most crowded with high intensity of traffic during the whole day is Boulevard Partizanski Odredi. This boulevard has 14 bus lines at all hours that connect the heart of the city with all parts urban and suburban. Electric charged buses in the IMC system is a possibility for this boulevard since there are multiple lines to operate with if we take into consideration a construction of an overhead contact line along the boulevard. This infrastructure that would be build can be used by many vehicles while reducing the unit cost (per vehicle or per transport work) for construction as well as maintenance. Moreover the suggested route for the trolleybus network for charging vehicles in the IMC system is shown in Fig. 9. Also in table 9 we list existing bus lines that use dynamic charging. Needless to say the mention trolleybus overhead traction line is 3.5 km long.

TABLE II
JSP BUS ROUTE PREDESTINATED BY IMC OPERATION

Bus route	*Route length [km]*	*Length of route under OHL [km]*	*Covering of route by OHL*
2	13,5	3,5	0,26
2A	14,6	3,5	0,24
4	9,1	3,5	0,38
12	14	3,5	0,25
15	10	2,5	0,25
21	12,5	3,5	0,28
22	12	3,5	0,29
22A	11	3,5	0,32
26	8	2,5	0,31

CONCLUSION

Using linear structure of the bus routes in the Karposh district is due to the use of the IMC system which makes it potential by using a separate bus lane that has and overhead contact line (fig. 8). Unlike building a tram system this way is much cheaper resolution. Rather than building a standard electric bus charger stationary this is more flexible solution while traction network will be used by many buses making it justifiable building the needed infrastructure.

Fig.8. Marrakech's IMC BRT system

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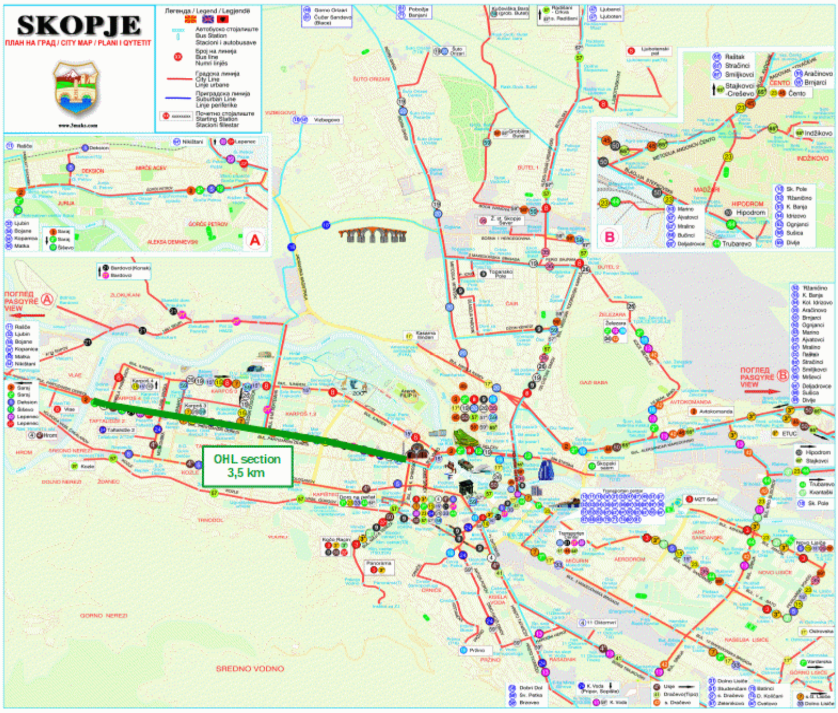

Fig. 9. The idea of IMC system in Skopje, based on www.jsp.com.mk

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