

# ECOLOGY AND ENERGY ASPECTS OF EXPLOITATION FULLY ELECTRICAL BUSES ON THE NEW LINE IN PUBLIC TRANSPORTATION BELGRADE

*Slobodan Mišanović<sup>1</sup>, Slaven Tica<sup>2</sup>, Željko Milković<sup>3</sup>, Pavle Krstić<sup>4</sup>, Branko Milovanović<sup>5</sup>*

**UDC: 629.071**

## 1. INTRODUCTION

JKP GSP "Beograd" is the carrier of function public transport in Belgrade and the largest operator. In their development plans JKP GSP "Beograd" special attention dedicate on the possibilities of application of the concept of E-bus, on the operation on the most endangered traffic corridors in terms of pollution. In the past the emphasis were on monitoring trends in their development, exchange of experience with companies for public transport, bus manufacturers and was carried one pilot test.

Since August 2016, the JKP GSP "Beograd", is began a regular exploitation with 5 solo bus on purely electric drive as a first step in a long-term strategy of using buses with electric drive. These vehicles have a steady trend of development and improvement, which makes them more competitive in comparison with other concepts buses (diesel, CNG). It should be noted a significant improvement in terms of reducing vehicle weight, which is reflected in the increase in the capacity of the vehicle (80-90 passengers), which is approaching the capacity of a standard diesel-powered buses (100-105 passengers). These are significant assumptions allowing their use on the first place on the central lines in the bus subsystem Belgrade.

## 2. FROM IDEA TO REALISATION

Idea of introducing buses on pure electric drive was stemmed from JKP GSP "Belgrade" on the basis of permanent monitoring of development trends the bus subsystem in many cities of Europe and the world, as well as the positive experiences of companies that have buses on electric drive in operation. The idea is that the City of Belgrade to be included in the "green" maps cities that have electric buses in operation, on the way that the E-buses will operate on a completely new line in the city center that will be recognizable in that. Carrier of project is JKP GSP "Belgrade" in cooperation with the Secretariat of Environment and Secretariat of Traffic. The project of introducing buses on electric power

---

<sup>1</sup> *Slobodan Mišanović, Project manager, City Public Transport Company "Belgrade", Kneginje Ljubice 29, 11000 Belgrade Ph. D. student, University of Kragujevac, Faculty of Engineering, slobodan.misanovic@gsp.co.rs*

<sup>2</sup> *Slaven Tica, Ph. D., prof. assist., University of Belgrade, Faculty of Transport and Traffic Engineering, 305 Vojvode Stepe Str., 11000 Belgrade, Serbia, slaven.tica@sf.bg.ac.rs*

<sup>3</sup> *Željko Milkovic, M. Sc., CEO of the company, City Public Transport Company "Belgrade", Kneginje Ljubice 29, 11000 Belgrade, zeljko.milkovic@gsp.co.rs*

<sup>4</sup> *Pavle Krstić, M. Sc., City Public Transport Company "Belgrade", Kneginje Ljubice 29, 11000 Belgrade, pavle.krstic@gsp.co.rs*

<sup>5</sup> *Branko Milovanović, Ph. D., assist. prof., University of Belgrade, Faculty of Transport and Traffic Engineering, 305 Vojvode Stepe Str., 11000 Belgrade, Serbia, b.milovanovic@sf.bg.ac.rs*

in Belgrade included the following phases, (Table 1) which lasted from January 2015 to August 2016.

*Table 1 Phases of the E-bus project in Belgrade*

Activity	Period
The idea of introducing E-bus in public transportation system	January 2015
Formation of the working team'	February 2015
Analysis of the most acceptable concept of E-bus	March-September 2015
Analysis of variants of the new line	March-September 2015
The adoption of the concept of E-bus and the route of the new line	September 2015
The decision to purchase 5 E-bus	September 2015
Financing model	September 2015
Preparation of tender documents	September 2015
An invitation to tender for the purchase of 5 E-bus	October 2015
Opening of offer	December 2015
Signing the contract with 'Chariot motors' for purchase of 5 E-bus' 'HIGHER' A6L	January 2016
Production control of 5 E-buses	April 2016
Delivery and exploitation	July /August 2016

### 3. THE CHOICE OF LINE: LINE 1E

Introduction of the buses on electric drive is a good way "rehabilitation " of electrical transport system on the left bank of the Sava River, considering that until 1970 were in exploitation 3 trolleybus lines that connected the old part of the city with Zemun and New Belgrade.

In this regard the line 1E (Vukov spomenik - TC "Delta City") fully justifies the use of electrically-powered buses, since that line is passes near the attractive location and transport corridors which in some sections have high levels of aero pollution and noise. (Brankova ulica, boulevard of Kralj Aleksandar) [1].



*Figure 1 Brankova street*



*Figure 2 National Assembly*



*Figure 3 Shopping malle "Usce"*

Line 1E is planned as a diametrical line that would connect Vukov monument, over the Nikola Pasic Square, Branko's Bridge to the New Belgrade (Figure 4). This line would provide the missing direct connection with New Belgrade on the Nikola Pasic Square and King Alexander Boulevard. The route located along of many tourist attractions (National Assembly , St. Mark's Church ...), administrative center of Belgrade, Faculty of Law, Faculty of Engineering, Shopping Malls "Usce" and "Delta City", Kombank arena, Railway station "Novi Beograd ".

The route of the line 1E:

- Direction A: Kraljice Marije, Bulevar kralja Aleksandra, Trg Nikole Pašića, Dečanska, tunel, Brankova ulica, Brankov most, Bulevar Mihajla Pupina, Milentija Popovića, Bulevar Zorana Đinđića, Antifašističke borbe, Bulevar Milutina Milankovića, Đorđa Stanojevića.
- Direction B: (Đorđa Stanojevića, Omladinskih brigada, Antifašističke borbe, Bulevar Zorana Đinđića, Milentija Popovića, bulevar mihajla Pupina, Brankov most, Brankova, Trg Nikole Pašića, Bulevar kralja Aleksandra, Ruzveltova, Kraljice Marije.

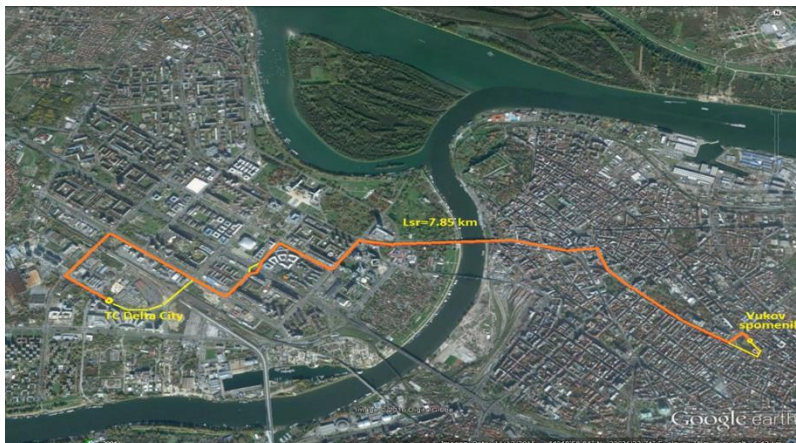


Figure 4 Route of line 1E (Vukov spomenik – TC "Delta City")

Mean length of route is 7.68 km stations and distance on the directions are given in Table 2.

Table 2 Static elements of line 1E

Direction A:		<b>Vukov spomenik - TC "Delta City"</b>
terminal	station	(m)
Vukov spomenik		0
	Tehnički fakulteti	518
	Pravni fakultet	364
	Park "Tašmajdan"	344
	Glavna pošta	204
	Pionirski park	332
	Zeleni venac	762
	Brankov most	415
	Blok 21	1548
	Milentija Popovića	438
	Blok 25	560
TC "Delta City"	Blok 24	418
	Milutina Milankovića TC "Vero"	283
	Depo "Sava"	830
		454

**7.470**

Direction B:		<b>TC "Delta City" - Vukov spomenik</b>
terminal	station	(m)
<b>TC "Delta "</b>		0
	Airport city	706
	Omladinskih brigada 1	416
	Bulevar umetnosti	340
	Španskih boraca	384
	Milutina Milankovića	469
	Blok 24	194
	Blok 25	491
	Milentija Popovića	515
	Blok 21	345
	Brankov most	1560
	Zeleni venac	337
	Pionirski park	850
	Resavska	300
	Pravni fakultet	237
	Tehnički fakulteti	323
	Vukov spomenik	300
<b>VUKOV SPOMENIK</b>		128
		<b>7.895</b>

Dynamic elements on the line 1E, are presented in the following table 3. With five vehicles in operation, interval a vehicle passes amounted to 12-13 minutes. The offered capacity on the line would be 289 places / hour.

Table 3 Dynamic elements on the line 1E

1E		Vukov spomenik-TC Delta City		5 E-buses in the operation	
Total length of rute [km]	driving time [min]	charging time[min]	time of turnround [min]	interval [min]	offered capacity (places/hour)
15,36	34	5-10	88	17-18	273

#### 4. CHOICE OF CONCEPT BUS ON ELECTRIC DRIVE

Analysis of experience in the exploitation of E-buses by different manufacturers with different concepts of charging and storage of electricity, came to the decision that for conditions of exploitation in Belgrade most acceptable is "pantograph" fast-charging system on the terminals and application systems for electrical energy storage using super capacitors. [4].

Advantages of pantograph charging system [2]

- Acceptable charging time 5-8 minutes
- Possibility to connect the charger to the tram network (DC) or public distribution network (AC)
- E.bus can operate throughout the work day (Especially important in summer conditions when using the air conditioner)

Advantages of storage electricity using supercapacitors [2]

- Principle: Electro Static
- Flexibility for rapid charging and emptying
- High efficiency 92-98%
- Acceptable weight: 900 kg
- Temperature range: -40 to +65 Co.
- Fast charge 5-8 min
- The possibility of accepting the entire electricity in the process of recuperation
- Long life: min. 10 years
- Convenience recycling



Figure 5 Charging station "Belvile"



Figure 6 Position of supercapacitors



Figure 7 Charging station "Vukov spomenik"



Figure 8 Charger



Figure 9 E-bus Higer KLQ6125GEV3



Figure 10 Interior of the E-bus Higer

Table 4 Technical characteristics E-bus Higer [3]

Manufacturer	Higher
Type	Electric KLQ6125GFV3
Length/width/height	12000/2550/3630 mm
Curb weight	12540 kg
Passengers	82+1
Max. speed	70 km/h
Charging the terminus: 660 V DC or 380 V AC, 580 V DC output, 250 A	
Charging time at the terminus	5-8 minutes
Storage systems	
Electricity	Super capacitors
Capacity	20 kWh
Manufacture	Aowei
Type	U-CAP (37DT6-03210)
Traction motors	2
Manufacture	Siemens
Type	1PV5135
Power	2x90 kW (peak opt.)
	2x67 kW (nom. Opt.)
Torque	2x430 Nm
Inverter	DC / AC
Manufacture	Zhonglian
Type	IEVD 130-60ZO6GA
Working range	580 V DC / AC 500-650V
Converter	DC / DC
Manufacture	Zhonglian
Type	DY074C

Working range	12-24-48 V DC
Charging systems	
Pantograph	Aowei 37DT6-03212
Plug-in	DU OSIDA 37XL2-3709
Auxiliary systems	
Air conditioning	Thermoking 81 DT6
Pump control	KVD HDZXB 1416
Compressor	IEM ER 230
UC-Cooler	Aowei 37DT6
Traction control	Siemens 10DT6
External display	NFHS-020

## 5. EXPECTATIONS OF THE USE OF E-BUSES (ECOLOGICAL AND ENERGY ASPECTS)

Putting into operation first line with the purely electric buses would start a new chapter in the exploitation of the bus subsystem in Belgrade. Given that this is a completely new drive concept, special attention will be focused on the monitoring of all the techno-exploitation characteristics, in order to give real insight into the advantages and disadvantages of this concept, which was first applied not only in Belgrade but also in the region of South Eastern Europe. During July and August 2016, before the start of the regular exploitation, test-driving was done, which showed satisfactory results, which are expected, when will start regular exploitation (end of August or beginning of September 2016).

Expectations of introducing buses on pure electric drive are:

- Zero emissions by E-bus at the micro location
- Significantly advantageous carbon dioxide emissions at the macro level, from the production electricity from the electrical energy system of the Republic of Serbia in comparison to the CO<sub>2</sub> emissions, derived from the combustion of hydrocarbons fuels.
- Lower level emitted noise of 12-17 dB
- High energy efficiency compared to diesel-powered buses. Expected electricity Consumption
- E-bus on the new line is between 1,06 to 1,30 kWh/km, depending on the mode, passengers load, use of air conditioning .
- Profitability of invested assets after 6 years
- E-bus is technology of future.

## 4. CONCLUSION

The introduction of buses with electric drive in regular operation represents a significant development step in the improvement of the system of public transport in Belgrade. E-buses with pantograph system supplementing on the terminus fully meet the requirements for operation in terms of supply of electricity, the daily route and transportation demands of passengers. The proposed route of the first line in staffed by electric buses allow the full effect of the use of this concept in terms of environmental,



transport requirements (the arrival interval, the offered capacity) and a high level of attractiveness of the locations they serve.

Monitoring the results of using the buses on electric drive on the line 1E, will serve as the best argument for defining future strategies of public transport in Belgrade as well as in other major cities of the Republic of Serbia (Novi Sad, Niš, Kragujevac ...) when this concept of buses issue and its mass application.

## **REFERENCES**

- [1] ЖКП ГСП"Београд": Елаборат о увођењу прве линије са аутобусима на електрични погон у ЖКП ГСП"Београд", октобар 2015.
- [2] M.Milev: The Ultra capacitors electric bus-the future of urban transportation, Elektrobusse-markt der zukunft, Berlin, 23.02.2015.
- [3] Higer Electric bus – EC TYPE APPROVAL CERTIFICATE, Idiada automotive technology .A.C, 2016.
- [4] Mišanović S.: Mogućnosti korišćenja autobusa sa električnim pogonom u sistemu javnog gradskog prevoza putnika, seminarski rad na doktorskim studijama, Fakultet inženjerskih nauka, Univerzitet u Kragujevcu, 2016.

*Intentionally blank*