

trolley:2.0

for smart cities

Technology and future of trolleybuses at Szeged Transport Company



Ikarus-Škoda trolleybus (from 2013-14)
the first (?) Li-ion battery trolleybus in Europe

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Trolleybus roadmap to hybrid e-bus @ SZKT



Convince public that trolleybus is a viable electric bus

New trolleybuses with (7 km) auxiliary battery mode

50 % PT electrification in Szeged

Replacing an existing diesel bus route where there is long catenary section

Hybrid electric bus prototype development

Driverlessness possible?

3-4 years operation, feasibility measurements

Commercial operation

100 % PT electrification in Szeged

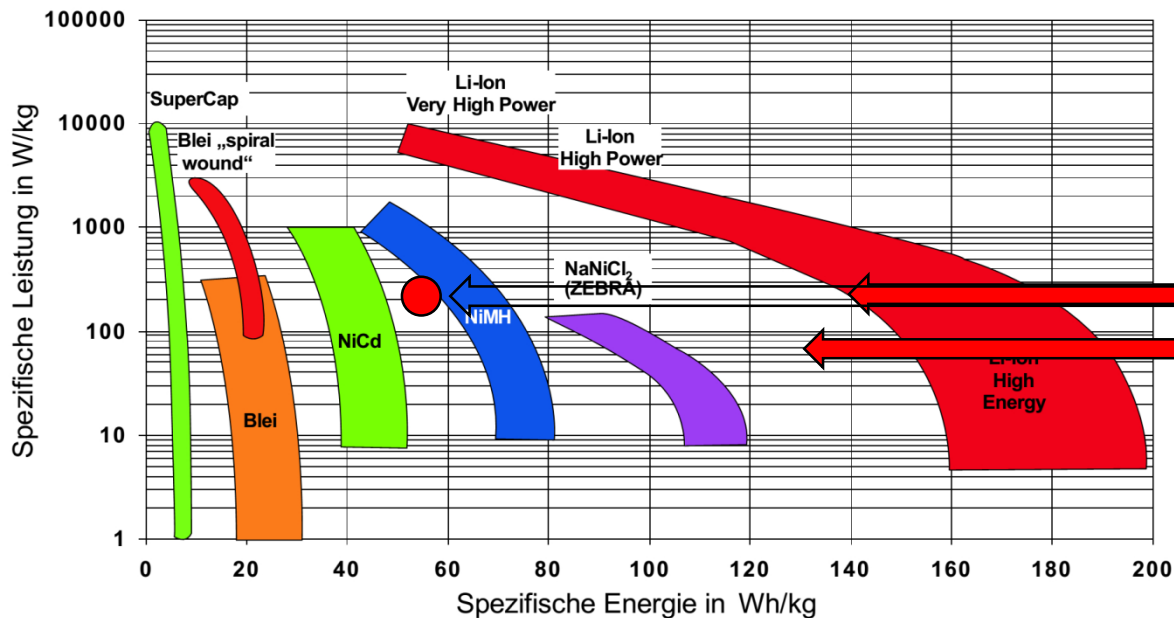


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Development of the electric buses

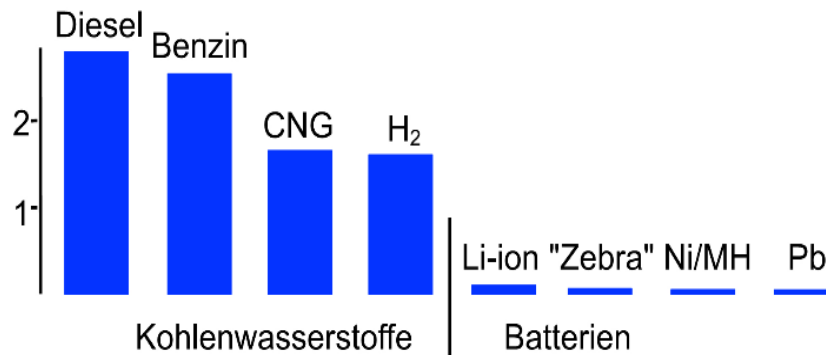
Today's battery energy density and specific power output



Ikarus-Skoda trolley (SZKT)	140Wh/kg (only 40 % is used)
	350 W/kg

BYD e-busz (Fe-P battery)	133 Wh/kg
	72 W/kg

Development of the electric buses



carbohydrogens | battery (kWh/kg)

1 kg petrol -> 14 kg air

Energy density of different sources (kWh/kg)

Can one expect a radical increase in battery specific energy (with chemical energy storage)? **NO**

How about power output? **YES**

Overnight charging

bus category (200 km/day range)	midi (6-8 m length)	solo (12-13 m length)	articulated (18-19 m length)
typical empty/full weight	8/11 tons	13/18 tons	19/28 tons
Consumption (w/o heating)	0,6-0,9 kWh/km	1,2-1,5 kWh/km	2,0-2,5 kWh/km
nominal Li-battery weight for 250 km range (w/o BMS & frame)	approx. 1600 kg	approx. 3000 kg	approx. 4700 kg
remark	The Evopro midibuses consume 0,6 kWh/km in all geographical circumstances in Budapest	Consumption of solo trolleybuses in Budapest and Szeged	Consumption of articulated trolleybuses in Budapest and Szeged

Around 30 % of the load is used to carry batteries instead of passengers.

Heating is with individual diesel stove
(for electric heating
+ ~ 0,3-1 kWh/km)

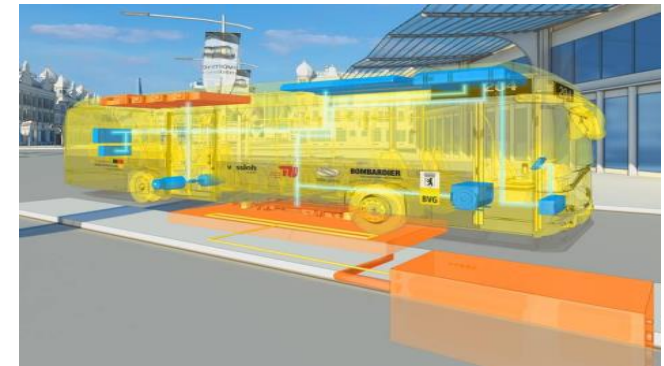


Opportunity/in-motion charging

- Mass of the battery can be decreased, if charging is done on the termini or in motion.
- With high-capacity autobuses this seems to be the only option, if we don't want to carry 4-5 tons of battery on the vehicles.
- By the West-European charging systems the battery balancing function is partly done by the charger (different from the car-chargers).
- Charging infrastructure is „intelligent” (= complicated).
- Charging can be done with current collector or inductive coupling.
- Charging time is dead time for traffic, and can cause problems in case of delays.



VDL articulated bus (Köln)



Bombardier Primove system
(Berlin, Mannheim)



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Opportunity/in-motion charging

Important problem is the construction of the charging infrastructure. That is why it is worth to use the existing trolleybus and tram catenary infrastructure.(„unintelligent charging”).

Charger type	Output	Parameters
AC charger (for cars)	~ 10 kW	Car charging for 6-8 hours
DC lightning charger	~ 50 kW	Car charging for 1 hour
DC terminal bus charger	~ 150 kW (for articulated buses)	Articulated e-buses with 20 km range, 20 minutes charging
Waterloo garage (London)	3200 kW	46 charging slots in the garage
SZKT small converter	1600 kW	In Szeged there are 10 converters, with approx. 60 % power usage

Siemens-Rampini charging
Pardubice – from trolley infrastructure

Göteborg charger infrastructure



Infrastructure, infrastructure, infrastructure ...



Hamburg, Depot Alsterdorf

Elaptic activity by SZKT

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Test operation for **2x2 weeks** on route 77A

- 13,2 km/round
- 7,4 km battery traction/round (56%)
- 2 „rooftop type connection” + at the terminus re-wire by hand



Battery capacity: 81 kWh



We purchased a modified DC charger for cars, which was converted to multipurpose charger.

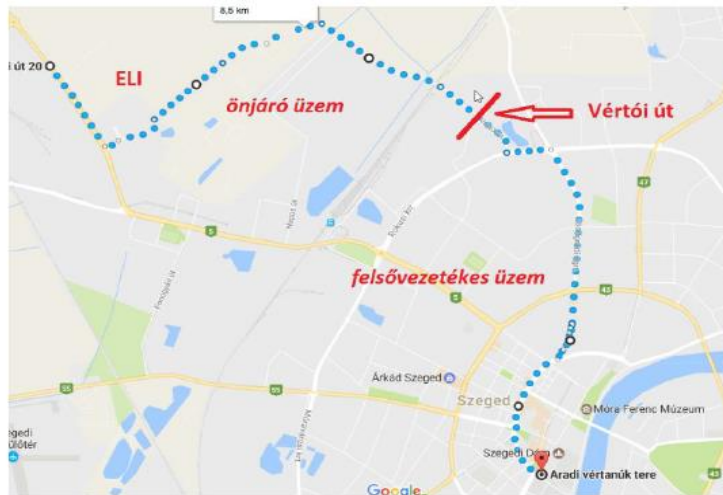
- DC charger (50 kW)
- Trolley charger (30 kW – **needs to be improved to higher output**)
- 230 V AC
- USB

Can be used at the termini far from the 600 V network.



Planned experimental operation

6-os trolibusz: Klinikák VÁ - Aradi vértanúk tere – Dugonics tér – Tisza Lajos krt. – Anna kút – Vidra utca – Szent István tér – Csongrádi sgt. – Rókusi krt. – **Vértói út (szedőlehúzás/felrakás)** – Zsámbokréti sor – Vinkler László utca – Zápor út – ELI út – **Budapesti út (Öthalmi diáklakások) VÁ.**



Útvonal hossz: 8,4 km (ebből önjárással 4,3 km)
 Becsült menetidő: 25 perc
 Részmenetidők: Klinikák – Vértói út: 15 perc (csúcsban),
 Vértói út – Budapesti út: 10 perc, 3 perc vasúti átjárás várakozással
 Becsült fordulódő: 60 perc

Javasolt maximális menetrend (az utasforgalomhoz képest a követési ütem csökkenthető):

időszak	munkanap		iskolaszüneti munkanap		szombat/vasárnap	
	követés	menetszám	követés	menetszám	követés	menetszám
5:00-6:00	30 p.	2	30p.	2	60 p.	17
6:00-8:00	15 p.	8	20 p.	6		
8:00-14:00	30 p.	12	30 p.	12		
14:00-17:00	20 p.	9	20 p.	9		
17:00-20:00	30 p.	6	30 p.	6		
20:00-22:00	60 p.	2	60 p.	2		
Össz:		2 x 37		2 x 35		2 x 17
Össz km:		621,6 km		588 km		285,6 km

Éves össz teljesítmény: (2017-es naptárral): 187.068 jkm (197 MN, 55 IS, 52 SZ, 61 MSZ)



„ ... to use trolleybus catenary as charger”

It is „common knowledge”, that trolleybus and ebus technology will converge.
This has not happened yet.

Main difference: double insulation for trolleybuses.

Within trolley 2.0 we want to finish the evopro
composite bodied „*hybrid battery trolleybus*” prototype.

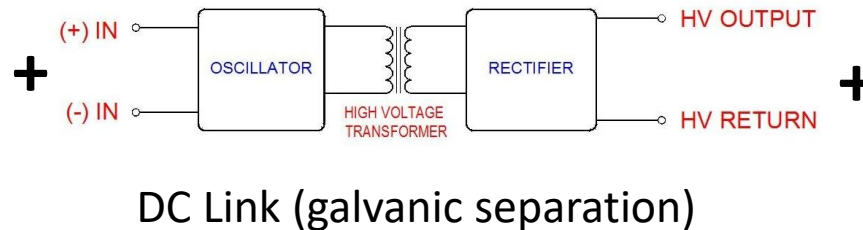
- It has the exact same equipment as the overnight charging ebus type. It runs from battery, not directly from the catenary.
- It has 2/5 battery capacity (150 km -> 60 km).
- *It has a current collector and the DC-Link (60 kW) **only** under double insulation. The rest of the electronics is galvanically separated.*
- It has remarkably low consumption (0,6-0,8 kWh/km).
- We expect with 60 kW DC-Link to spend 1:1 under/without catenary (tests in Trolley 2.0).
- With increasing the DC-Link power to 200 kW we expect to reach 1:3, 1:4. (Range will be less an issue.)
- It will be a bus under Hungarian law.

Battery capacity: 140 kWh



„ ... to use trolleybus catenary as charger”

Double insulation



current collector

e-bus

(with overnight charging)

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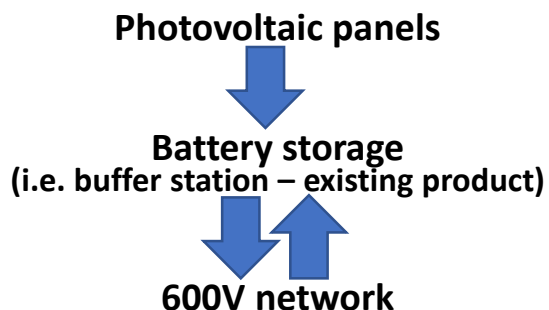
Question: how do we regulate current consumption? This concept separates traction from charging.

Trolleybus catenary has also limits. (also subject in Trolley 2.0)

- Max. 50 A (?) standing and at insulations.
- Max. 400 A (?) in motion (also by braking!)
- We don't want GPS regulation.

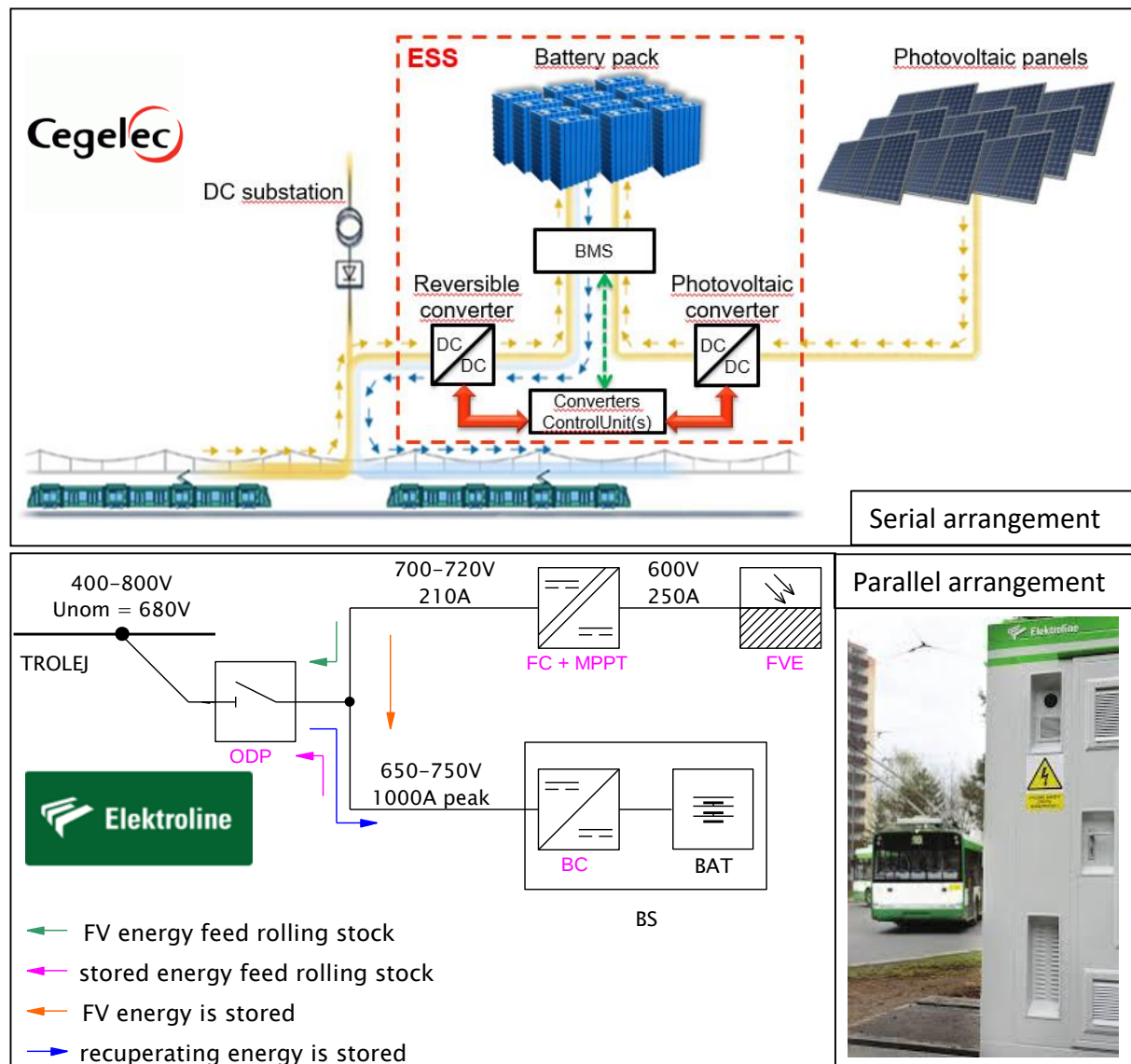
Using renewable energy

SZKT plans to use solar panels for feeding to the DC traction system



Can we use 2nd hand batteries (e.g. used traction batteries?) If we have a fleet of hybrid trolleys, we will have a lot of old batteries!

- **150 kWh capacity needed for**
- 400 kW peak charging power (1 tram recuperating)
- 200 kW continuous charging from photovoltaic panels ($\approx 800 \text{ m}^2$)
- 1-2 % SOC oscillation in operation (very good for used batteries!)
- **250,00 kWh/year expected**
(2,800,000 kWh/year is currently used in Csáky substation $\approx 10 \%$)



Summary

Long term goal: 100 % electric public transport.

It is impossible today to exchange diesel buses to electric buses one-to-one in typical operations.

Maybe battery trolleys can – where the route is aligning the existing infrastructure. (Planned experimental operation in Szeged, 2021-2024)

As trolleybuses leave more the catenary, it is worth to use hybrid battery trolleybuses (Gdynia has already put out the first tender for such vehicles).

The trolleybus catenary has other advantages: **solar panel farms directly can feed to 600 V DC network.**

We need from the Industry *automatic trolleybus reconnection*, without „rooftops”.
(also subject of Trolley 2.0)



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Thank you for the attention!

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