New line 59 – in motion charging trolleybus

Nádraží Veleslavín (Veleslavín Railway Station) –
Letiště Václava Havla Praha (Václav Havel Airport Prague)

Dopravní podnik hlavního města Prahy

eBRT 2030

Václav Havel Airport Prague has seen a very dynamic increase in the number of passengers in recent years. While in 2016 the number was 13.07 million passengers, in the pre-covid year of 2019 it had reached almost 18 million passengers. While the pandemic had caused a temporary decline in air traffic, the situation is turning around again and a quick return to pre-covid numbers is expected. Last year, nearly 14 million passengers passed through Václav Havel Airport Prague, representing a 29% year-on-year increase. However, the airport serviced by public transport had long depended exclusively on bus lines, especially on line 119 (Nádraží Veleslavín – Airport) due to the extensive and complicated preparation of the railway connection. The total number of connections on the line per working day had reached up to 250 in one direction with an operating interval of 3 to 5 minutes. The Prague Transit Company (hereinafter referred to as DPP) deployed only articulated buses on the line. In spite of the short intervals offered, the **buses were overcrowded** at peak times, and it was already very inefficient from an operational and economic standpoint to shorten the interval any further.

Given the time-consuming nature of the airport railway connection preparation, the aim was to find a suitable solution to increase capacity and comfort of travel in the short term, also taking into account the amount of investment costs incurred.

With regard to capacity problems and the possibility to reduce the emission and noise levels along with other negative impacts of diesel vehicles, bus line 119 has been extended in-line with the Climate Commitment of the Capital City of Prague. In this case, the solution consists of **replacing diesel buses with locally emission-free, large-capacity three-cell battery trolleybuses**, which also allows to partially increase the offered capacity of the connection and thus the travel comfort. Battery trolleybuses allow for the operation of up-to-25-metre-long, large-capacity three-cell vehicles, offering a significantly higher capacity as opposed to an 18-metre-long articulated bus.

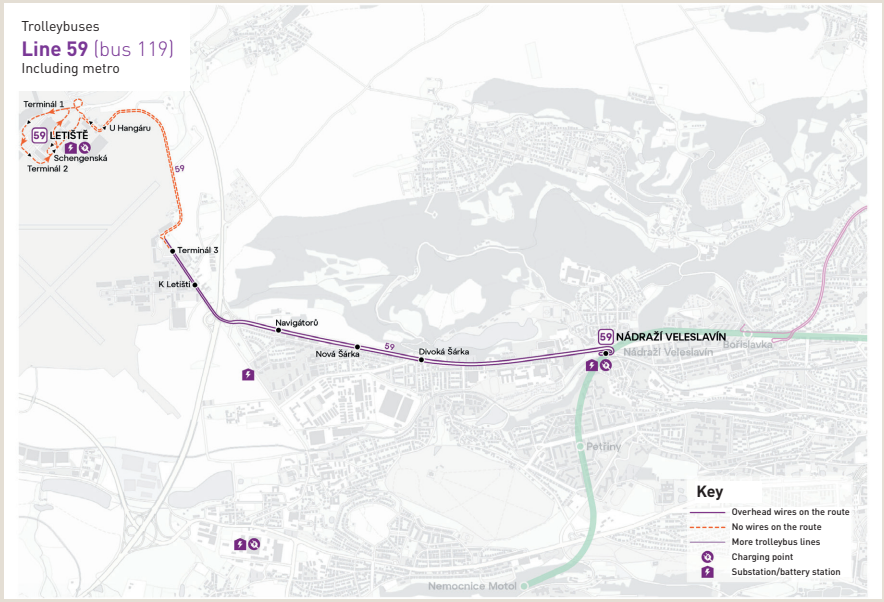
The intention to electrify bus line 119 with large-capacity three-cell battery trolleybuses was approved by the Prague City Council in 2019 (Resolution No. 1953 of 16 September 2019), and DPP has been tasked with the preparation works.

The project accounts for the construction of the necessary charging and power supply infrastructure, as well as the acquisition of 20 large-capacity, three-cell battery trolleybuses to replace the existing articulated diesel buses.

A **total of 11.5 km of the overhead line** in the section Nádraží Veleslavín – Terminal 3 has been **erected** as part of this project, which represents approximately half of the route. Trolleybuses run in battery mode between Terminal 3 and Airport stops. Charging stations have been set up at the Václav Havel Airport Prague and Nádraží Veleslavín turnarounds, where the trolleybuses can also charge during their operating breaks. **Three substations are used to power the** trolleybus line – two container substations (at the Nádraží Veleslavín terminal and the airport turnaround) and one brick substation at the Dědina tram loop; a common substation used to power both the tram and trolleybus infrastructure, as this substation was built as part of the recently opened new tram line Divoká Šárka – Dědina.

The project also included the **construction of charging infrastructure in the Řepy garage**, from where bus line 119 or the existing trolleybus line 59 has always been dispatched. New charging stands were created here along with a new capacity substation, which is already sized for the expected charging needs with regard to the further planned expansion of battery trolleybuses in this part of Prague.

The project was granted a final joint permit in January 2022 and the actual construction took place between 29 November 2022 and 27 February 2024, when it was closely coordinated with the ongoing construction of the new tram line Divoká Šárka – Dědina.



In parallel with the design preparation, a **public tender for the supplier of 20 large-capacity, three-cell battery trolleybuses** was carried out, which was concluded in February 2022. **The winner of the tender was a consortium of Škoda Electric from the Škoda Group, Solaris Bus & Coach and Solaris Czech with the vehicle designated Škoda-Solaris 24m.** With a length of almost 25 metres, the vehicles will offer up to 30% more capacity compared to existing articulated buses, making it possible to suitably adapt the interior for passengers with bulky luggage, prams and disabled passengers.

DPP started regular trolleybus operation on the Nádraží Veleslavín – Václav Havel Airport Prague line on 6 March 2024, when diesel articulated buses were replaced by large-capacity, three-cell battery trolleybuses and **bus line 119 had been converted into trolleybus line 59**. The route of the line, timetable and fares have remained unchanged. The line has several firsts, though: it is the first trolleybus line in the Czech Republic to be served by large-capacity, three-cell trolleybuses; the Škoda-Solaris 24m is currently the longest trolleybus in operation in the Czech Republic and DPP is its first operator.

DPP will be able to use the built infrastructure even after the railway connection to the Airport is operational, for the electrification of other bus lines, especially line 191, whose electrification has been approved by the Prague City Council. Similarly, DPP will also use the acquired large-capacity, three-cell trolleybuses, which are planned to be used, for example, on lines 112 or 136, where the passability of this type of vehicles has already been confirmed by DPP and ROPID in previous years.

The Line 119 electrification project was selected as a demonstration project for the 2030 eBRT European Innovation Project. Prague has thus become one of the seven cities selected to showcase a new generation of modern, fully electric rapid bus / trolleybus transport system for urban and suburban traffic using the latest technologies (automation, connectivity) to foster the role of climate-friendly public transport. The following improvements have been chosen as the objectives of the Prague project as opposed to the standard trolleybus system using battery trolleybuses:

Vehicle energy management

- Optimize vehicle battery charging (in-motion, opportunity at terminus)
- Optimize HVAC (incl. preheating at trolley section / terminuses)
- Operational management (delays, irregularities)
- Decrease energy consumption, decrease peak charging power

Depot energy management

- Optimize fleet battery charging and balancing (incl. vehicle preheating)
- Decrease energy consumption, decrease peak charging power

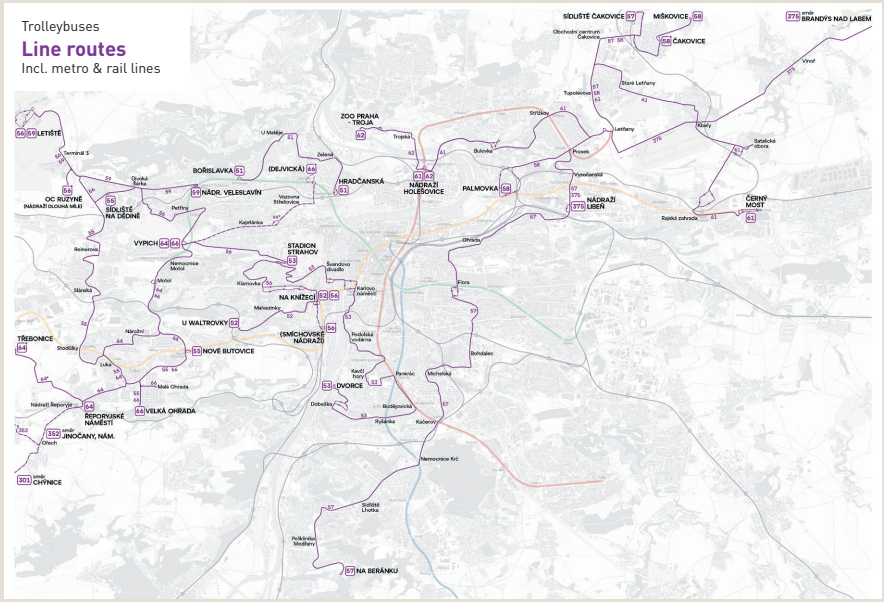
Current collector connection and disconnection

- Automatic disconnection at the end of the catenary section
- Connection remind to driver at the beginning of the catenary section
- Radio communication between infrastructure and vehicle

Why and how do we electrify bus transport?

The general aspiration of society, especially in developed countries, is to implement sustainable solutions not only in transport, but also in energy and other areas of the economy, which will be environmentally friendly, reduce the emission burden and make the use of energy resources more efficient.

In this context, the European Union and, by extension, the Czech Republic have made a number of commitments to which related strategies have gradually been developed to implement them effectively (e.g., the National Action Plan for Clean Mobility, the 2030 National Energy and Climate Plan, and others). As transport in general represents one of the most significant sources of air pollution in the city (up to 40% of CO2 production and 70% of other pollutants), the City of Prague has joined this effort by announcing the so-called **2019 Climate Commitment**, which sets a target of reducing CO2 emissions by up to 45% by 2030 compared to 2010. This commitment was updated in 2021 with the adoption of **the Climate Plan of the Capital City of Prague**, by being even stricter specifying these targets even further. European legislation also responds to these efforts by amending **Directive 2003/33/EC on the promotion of clean and energy-efficient road vehicles** (the Clean Vehicle Directive), the national transposition of which into Czech legislation is directly binding to the City of Prague and the Prague Transit Company. On the basis of this legislation, there is an obligation to comply with the specified proportions of clean and semi-clean vehicles in the bus fleet.



Since 2011, the Prague Transit Company has been intensively engaged in testing various alternative drives and vehicle types, with the aim of **finding a suitable solution which will be operationally functional, technically reliable and economically acceptable in Prague conditions**. Based on this experience, but also on the experience of colleagues from other cities, not only in the Czech Republic, it can be confirmed that **the most effective tool for saving final energy consumption in transport in general is the replacement of the internal combustion engine** (guideline efficiency value of 30%) **by an electric traction engine** (guideline efficiency value of 75%). As a result of 2.5 times higher efficiency, the final energy consumption drops to 40% when replacing the internal combustion engine with an electric one, thus saving 60% of final energy consumption. This substantial saving is further increased by the saving in brake energy recovery. In addition to the above reduction in the energy consumption of transport, the main reasons for the electrification of buses include:

- Possibility of **locally completely emission-free transport** (the general ecological benefit depends on the energy mix of the Czech Republic, but it is gradually improving and will continue to improve in favour of clean energy sources)
- **Reduction of CO2 emissions**
- Reduction of noise pollution as in normal operation (quiet start, reduced vibration and dust)
- Exploiting internal synergies with the tram power system and **thus improving the efficiency of investment and operating costs** (joint energy management, use of tram substations, etc.)
- **Ensuring energy security of** the Capital City of Prague and the Czech Republic by reducing dependence on fossil fuels supplied from countries ranking low on democracy and human rights protection.

The most technically and operationally functional technology seems to be the so-called dynamic charging (charging while driving under the overhead line) **by means of battery trolleybuses** and, in addition, static charging technology (charging at the terminus or in garages) by means of electric buses with two-pole charging technology.

Frequent questions, especially from the general public, about the use of battery-powered trolleybuses are primarily related to the misconception that the trolleybus is an obsolete technology and that electric buses, whose propulsion is provided exclusively by batteries, can be deployed freely on any line. Unfortunately, these simple premises are generally untrue and it is always necessary to take into account the specifics of operation in the conditions of Prague:

a) **The terrain of Prague is very rugged** – buses climb a series of ascents and descents along their route, the difference between the level of the Vltava River and the highest points is over 230 m.

b) **Long lines with high daily mileage** – the length of the lines often exceeds 20 km; the daily mileage is often over 300 km/day.

c) **High transport demand and intensive traffic** – unlike many other cities, including in Western Europe, bus routes in Prague often run in very short intervals, articulated vehicles are deployed and do not have enough time at the final stops to allow, for example in case of electric buses, for sufficient charging time.

d) **Long daily service hours** – daily service runs from 4:30 am to 12:30 am, with the last buses not pulling into the garage until around 1:30 am. Compared to smaller cities with shorter service hours, there is not enough room to charge even during the night period.

e) **A fleet of 1,200 buses** – any change cannot be implemented quickly enough; thus, it is a gradual process.

f) **Air conditioning and electric heating** – in many cities where electric buses are deployed, the heating or air conditioning is provided by a diesel unit, as these components are consumption-intensive (e.g., heating in winter increases consumption by up to 100%). However, if the electric bus is heated by a diesel unit, it is not a clean vehicle, ergo, such a move would go directly against the objective of DPP to operate fully emission-free vehicles.

With that being said, DPP proceeded to prepare measures in the field of **electrification of bus transport** primarily **through battery trolleybuses** (dynamic charging) and additionally also two-pole electric buses (static charging). However, the goal is not to fully electrify the entire bus fleet, but to electrify at least 40% of the said fleet, as we also believe in the potential of hydrogen technology or further development of electric vehicle technologies that are yet to emerge.

In motion charging technology

Thanks to modern dynamic charging technology, long or terrain-intensive lines can be electrified efficiently. **The dynamic charging system combines the advantages of trolleybus technology and battery operation** to eliminate or significantly minimise some of the operational disadvantages of conventional trolleybuses and pure battery electric buses:

- By installing a trolley in a selected part of the route (usually at least 50%), it **is possible to reduce the time required to charge the vehicle** at the final stops or to eliminate charging altogether. Although at the same time, **it is not necessary to build overhead lines along the entire length of the line route**, thus avoiding, for instance, complicated

underpasses, complex overhead structures, etc.; instead, **overhead lines are typically constructed in terrain demanding sections** (climbs), or in sections where congestion occurs (allowing the vehicle to charge while potentially delayed), or in sections where the charging infrastructure can be used synergistically by a larger number of vehicles from several lines (typically, Tupolevova street, Vysočanská flyover, etc.)

- **The required energy consumption is spread over time and location**, meaning **better operating economics** with respect to the ratio of the price component of the reserved power to the total electricity price are achieved.
- A battery trolleybus **does not need to be equipped with a large number of batteries compared to, for example, an electric bus**. The interior of the vehicle is thus fully utilised for passengers.
- **A battery trolleybus is significantly more operative** during short-term closures or emergencies (thanks to traction batteries, it can travel through the affected section or be diverted without additional infrastructure measures).
- A key attribute, however, is the **significant extension of the vehicle's range**, which translates into being able to virtually electrify any long line.

The dynamic charging system is thus **particularly suitable for backbone lines with short service intervals and lines with a demanding, rugged terrain profile**. The undisputed benefit for passengers is a **more comfortable ride in rough terrain** (smooth and fast uphill starts), and for the public in particular a **lower noise level**, whereby the noise and vibration of internal combustion engines are completely eliminated.

The abovementioned advantages have both economic and **environmental** benefits, as they make the investment and operating costs more efficient whilst minimising **the need to use batteries as frequently**. At the same time, the lower charging currents that can be exploited by staggering the charging over time and location mean less burden on the battery life cycle compared to pure battery electric buses. This allows batteries to achieve a longer lifetime.

Implemented and upcoming projects

DPP is currently preparing a number of bus line electrification projects in various parts of Prague. In addition to lines 58 and 59, which are already in operation, the most advanced projects are the electrification of bus lines 137 (future trolleybus line 52), 131 (51) and 176 (53) in the left-bank part of Prague. The project preparation for electrification on these lines has been approved by the Prague City Council. All of these projects include the coordinated modernisation of public lighting so that the maximum number of combined lighting masts and overhead lines is implemented, thus effectively eliminating any mast mazes. Barring any unexpected complications, all three of these electrifications should be ready by mid-2026 at the latest.

Historically speaking, many plans in the pipeline correspond to the original transport relationships deploying trolleybuses between 1936 and 1972. **From today's perspective, undoing trolleybus transport in Prague was as a mistake**, which at that time was primarily driven by political and not professional or technical reasons. After all, cities where trolleybus

transport is still in operation today have a very favourable entry base for converting residual bus capacity to electric traction. And examples from abroad also show that decisions previously taken to phase out trolleybus services have been significantly reassessed in recent years, and **trolleybus services are instead experiencing a resurgence** (e.g., cities in Switzerland, Italy, Germany and Estonia). While battery trolleybuses do benefit from the advantages of battery technology, they use this technology much more efficiently and to a lesser extent than pure battery vehicles.

Construction basic specifications:

Trolleybus line length: 5,308 metres

Number of installed overhead line masts: 235

Total length of the overhead line: 11,457 metres (including stops at turnarounds, Řepy garage and the booster line)

Length of overhead line for en-route power supply: 10,616 metres

Investor and client: Dopravní podnik hl. m. Prahy

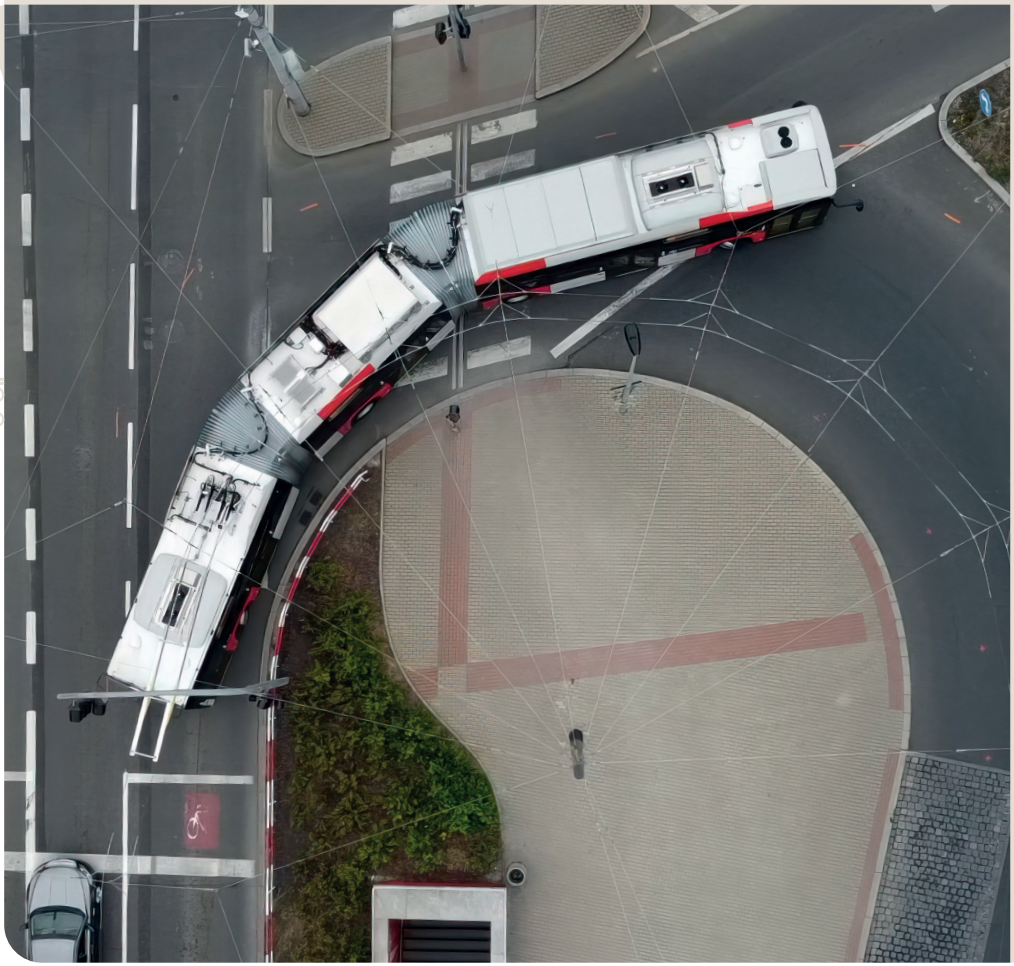
Designer: Pragoprojekt

Contractor: Elektrizace železnic Praha

Estimated value of public tender: CZK 350,000,000 excl. VAT

Construction price as per concluded contract: CZK 354,455,207.12 excl. VAT

The implementation of the above-mentioned projects creates prerequisites for further development of the electrification of bus lines in Prague. In view of the adoption of the Climate Plan of the Capital City of Prague, the Prague City Council approved further electrification plans for 2021 – 2023, e.g., line 112 to ZOO or line 201 between Nádraží Holešovice and Černý Most, which will synergistically use the infrastructure already implemented in Letňany. Additionally, the electrification of bus lines in the area of the South-West City (Jižní město), Motol and Ruzyně (lines 142, 174, 184 and 225), which in turn are functionally linked to the electrification already under preparation in this part of the city. A major challenge will be the electrification of the important and busy transport relationship of the backbone bus lines 136 and 150 (Letňany – Vysočany – Žižkov – Vršovice – Michle – Krč – Modřany), which will lay the foundations for the electrification of other lines departing from the Kačerov garage. Due to the procedural and temporal complexity of the preparation of transport infrastructure in the Czech Republic, DPP aims to start the design preparation of the charging infrastructure in a timely manner, allowing for the continuous renewal of the bus fleet with emission-free vehicles between 2025 and 2030; a task impossible without the necessary charging infrastructure being already in place.



Large capacity, three-cell battery trolleybus basic specifications:

Vehicle name: Škoda – Solaris 24m

Length: 24,700 mm

Width: 2,550 mm

Height: 3,500 mm (with retracted collectors)

Wheelbase: front 5,900 mm / centre 6,000 mm / rear 7,350 mm

Total maximum weight: 38,000 kg

Maximum speed: 70 km/h

Number of axles: 4

Number of driven axles: 2 (second and third)

Number of steered axles: 2 (front and rear)

Number of doors for entry and exit: 5

Starting height: 320 mm

Seat capacity: 52

Passenger capacity: 179

Number of electric motors: 2

Traction electric motor power: 2× 160 kW

Traction battery capacity: 60 kWh

Number of purchased vehicles in the DPP fleet: 20

Public tender's estimated value: CZK 628,000,000 CZK excl. VAT

Price of all vehicles as per concluded contract: CZK 623,216,900 excl. VAT

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