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SAFETY ASPECTS OF E-CARS CHARGING AT RAILWAY STATIONS

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Abstract. The article focuses on introducing e-cars in the Czech Republic and the safety aspects of electric cars, particularly when charging at railway stations. Safety aspects are comprehensively linked to the charging of electric vehicles, where maintaining the balance of the electrical network is crucial to prevent asymmetric loading. The article's primary aim is to inform readers about the introduction of railway station charging stations and highlight the proactive measures taken to address possible technical problems that can arise during recharging. Fire intervention is a key part of the safety plan, ready to be deployed when an electric vehicle catches fire and poses a risk to the surroundings.

Keywords: Electric car, safety aspect, charging, fire prevention, parking.

1. Introduction

Transportation is essential to our economy and society. Mobility is important for the internal market and citizens' standard of living, enabling them to enjoy the freedom of travel. Transport contributes to economic growth and job creation, and it must be sustainable in relation to the new challenges we face [1, 2]. Congestions, poor air quality, and, above all, noise pollution affect cities the most. Urban transport accounts for roughly one-quarter of CO_2 emissions from transport [3, 4].

To reduce the emission footprint not only in transportation, the European Union (EU) adopted the Green Deal for Europe [5]. The Green Deal for Europe is a set of policy initiatives to set the EU on the path to ecological transformation with the ultimate goal of achieving climate neutrality by 2050. It supports the transformation of the EU into a fair and prosperous society with a modern and competitive economy. This goal can be achieved in transportation by switching from fossil fuels to alternative fuels. Alternative sources of propulsion include electric power or hydrogen fuel. In the article, the authors delve into the safety aspects of electric cars. The authors, who work at Správa železnic, the Czech State Rail Infrastructure manager, are actively involved in installing charging stations at railway stations across the country.

Electromobility in road transport originated early in the 19th century. The car, assembled by the Dutch professor Sibrandus Stratinghem in 1835, is considered the first electric car in history. An electric drive powers an electric car. Regarding e-mobility, it is necessary to control the fire risks [6]. As described in the article, fighting e-car fires requires three different methods. The Czech State Rail Infrastructure Manager (SZCZ) Fire Service has already applied all three methods on a training basis in connection to the operation of P+R and parking houses at railway stations.

The authors[1] participate in the introduction of electromobility at Správa železnic. Electromobility corresponds with the *"Policy statement of the Government"* [7] as well as the corporate strategy of the Správa železnic [8]. In cooperation with colleagues, they edited the internal document *"Infrastructure Development Plan for Electric Vehicle Charging"*, which deals with public charging infrastructure at train stations. Project documentation is required before constructing parking places for electric cars at railway stations, and this paper's authors are currently supervisors. As part of the project documentation, it is always necessary that the *"Fire safety solution for the building"* is being prepared within the scope of § 41 of Directive No. 246/2001 Coll., as amended, in all contexts following the *"Methodological Guide for Design and Assessment of a Fire Safety Solution"* (edited by the Ministry of the Interior – General Directorate of Czech Fire Service, August 2018) so that details can be incorporated into individual professions. The proposal to ensure the fire safety of buildings is based on the *" Methodological Recommendation Fire Safety of Buildings – Electromobility"* (edited by the Ministry of the Interior – General Directorate of the Fire Service CZ, April 2021).

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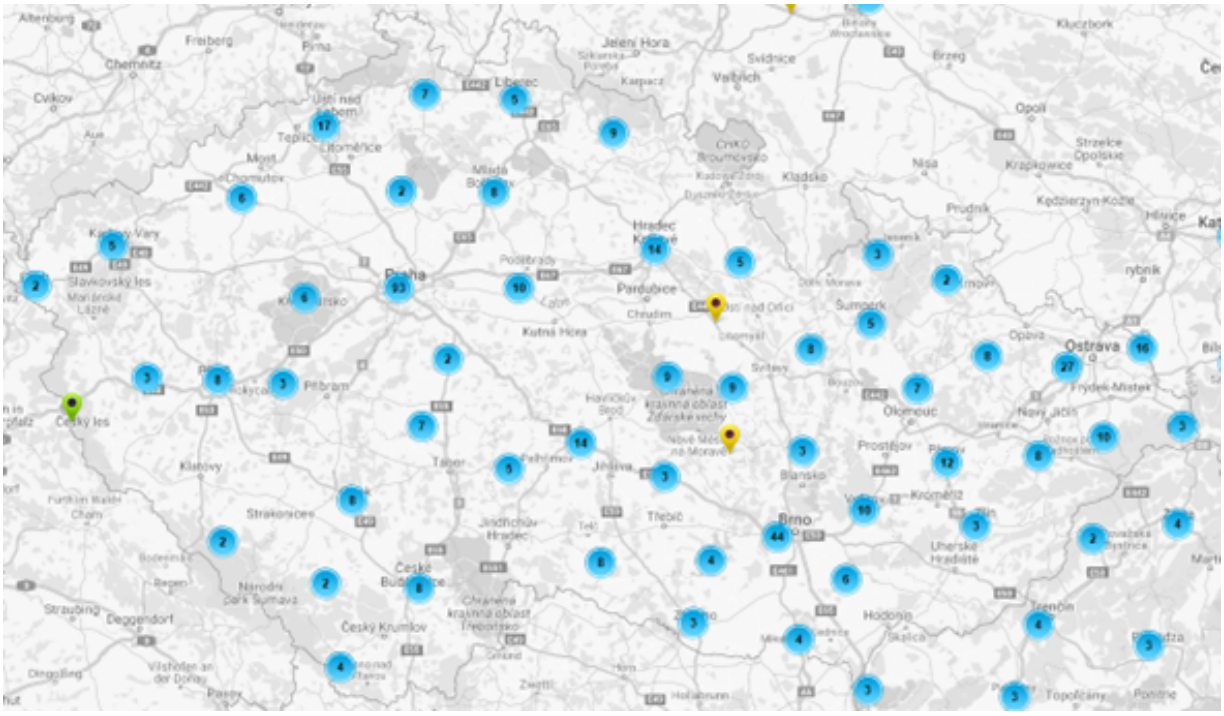

FIGURE 1. Map of charging stations in Czechia [9].

2. PUBLIC PARKING WITH CHARGING STATIONS

The *"National Action Plan for Clean Mobility"* [10] envisages the development of transport using alternative fuels and aims to develop electromobility with the support of subsidy programs [10]. In the same way as the laws, decrees, and standards of ČSN apply to the design and placement of gas stations (e.g., ČSN 73 6060), there are also laws, decrees, and standards that must be followed when placing charging points for electric cars. In particular, from the point of view of fire safety, it is necessary to follow the rules for the placement of charging stations and for parking the electric car while charging.

By the end of 2022, 1 364 charging stations and 2 643 charging points had been installed in the Czech Republic [11]. Other charging stations become operational every day. The strategic plan of the *"National Action Plan for Clean Mobility"* is to ensure 19 000–35 000 public charging points by the end of 2030 [10].

Concerning the number of charging stations in operation, the Czech Republic still lags behind the EU in the funds invested in building charging infrastructure. The current map of charging stations (Figure 1) is on the website [9, 12].

The charging station or charging point in the public parking area must meet the parking requirements ČSN EN 61851-1, ČSN EN 61851-21, ČSN EN 61851-23, ČSN 332000-4-41, ČSN 332000-5-54, ČSN EN 62196- 2, ČSN EN 62196-3 and related standards.

When placing charging stations, it is necessary to respect the safe distances from the equipment and the normative distances specified in the standards of the ČSN EN 7308xx series and related regulations.

2.1. PLANNING PUBLIC CHARGING INFRASTRUCTURE AT TRAIN STATIONS

When planning public charging infrastructure at train stations managed by Správa železnic, it is first necessary to determine whether there is reserved power at that location. If not, a new power line with sufficient power must be built in agreement with the electricity distributor. Správa železnic already cooperates with both the electricity supplier and the distributor in the development of charging points within the rail network, e.g., this is the case of the newly designed station Prague – Dlouhá Míle on the newly constructed Václav Havel airport railway line. The authors are involved in the technical solution of charging points. The following factors need to be taken into account when recharging:

(1.) Duration of charging (charging speed) determines the performance of the charging point (collection point) and the vehicle's capability.
  (a) By the power of the on-board AC charger. If the vehicle can be recharged with 7 kW AC power, it also recharges when connected to a station with a power of 11 or 22 kW.
  (b) Charging management during DC charging. The vehicle battery controls the station's performance depending on several factors, including weather (today, vehicle batteries can be preheated), battery condition, and device operating temperature.

(2.) Duration of charging at a public station calculated as charging the battery from 0 to 100 % is misleading. From the practical experience, it is better to indicate the charging duration from 10 % to 80 %.

(a) The average charging volume per charging station is approximately 17 kWh. Cooperation with the control and controlled stations is necessary to avoid exceeding the contracted quarter-hour maximums.

(b) Except for long-distance transit, where there is an interest in charging as much as possible as quickly as possible, people charge part of the battery capacity. Still, more powerful charging stations logically provide them with greater comfort (the range increases by 100 km during charging instead of 20 km).

(3.) When recharging at railway stations, a combination of stations with different capacities is offered. Railway stations represent natural points of interest with good transport accessibility and facilities, thus an opportunity for high-performance stations.

Every electric car supports AC charging. The onboard device is one of the more expensive components in an electric vehicle, and it limits the number of phases used and the maximum charging. DC charging has not been supported by older electric car models since the beginning of electromobility. While AC charging is constant from the user's point of view throughout the charging period due to lower powers, DC charging reduces the drop in charging current and significantly slows down charging.

Charging stations are connected to the distribution system at low or high voltage levels. The connection from the low voltage level is intended for charging powers up to approximately 150 kW. The protection is at 200–250 A at a voltage of 400 V. The connection from the high voltage level is for charging stations with higher output from 150 kW onwards.

2.2. Distribution of charging stations

Currently, the fire service can meet specialized public charging stations for electric cars. The fundamental division of charging stations can be done, for example, according to the following criteria:

(a) **Power:**

- Figure 2 shows slow charging station (regular charging station) with an output of up to 22 kW,
- Figure 3 shows fast charging station.

(b) **Type of charging:**

- AC charging,
- DC charging.

(c) **Vehicle connection method:**

- station equipped with a socket (the vehicle is connected with a cable that is an accessory of the vehicle),
- station equipped with an integrated cable.

(d) **Functional equipment:**

- common charging stations,
- stations equipped with "smart" functions.

Figure 2. A slow-charging station in Czechia [9].

Figure 3. A fast-charging station in Czechia [13].

Table 1 shows the ranges of electric cars as measured by What car magazine. Ultra-fast charging stations with a power of up to 350 kW are already being installed.

If there is insufficient reserved power for fast charging stations, a new connection with valid conditions must be built. When installing stations in parking slots or parking garages, the technical conditions of buildings regarding fire safety must be observed. Both passive and active fire separation must be observed according to applicable standards. Designing a charging station for electric cars needs to be based primarily on Decree No. 268/2009 Coll., as amended, and the set of standards ČSN EN 62196 and ČSN EN 61851. All parking space markings must follow Act No. 361/2000 Coll., as amended, ČSN EN 12899-1 and ČSN EN 1436. For the possible safe implementation of a fire intervention, it is recommended that parking places for charging electric cars shall be implemented at least as wide as parking spaces for physically disabled persons

Car	Indicated range	Real range	Difference
Tesla Model S 75D	490 km	328,3 km	161,7 km
Hyundai Ioniq Electric	280 km	188,3 km	91,7 km
Renault Zoe R110	316 km	235,0 km	81,0 km
Kia e-Niro	485 km	407,2 km	77,8 km
Hyundai Kona Electric 64 kWh	482 km	416,8 km	65,2 km
Smart ForTwo EQ	160 km	95,0 km	65,0 km
Nissan Leaf	270 km	206,0 km	64,0 km
Smart ForFour EQ	155 km	91,7 km	63,3 km
Jaguar I-Pace	470 km	407,2 km	62,8 km
Hyundai Kona Electric 39 kWh	312 km	254,3 km	57,7 km
Volkswagen e-Golf	231 km	188,3 km	42,7 km
BMW i3 94 Ah	235 km	194,7km	40,3 km

TABLE 1. Ranges of electric cars as measured by the magazine What car? [14, 15] on our test track, combining different types of traffic under the same conditions for all vehicles and without the influence of surrounding traffic.

(people with reduced mobility), i.e., at least 3.5 m wide (or according to ČSN 73 6056, article 6.6.2).

3. Fire prevention

The fire sections of individual parking places and garages are equipped beyond the scope of building fire safety standards:

a) When charging stations are implemented in closed spaces, fire detectors must be installed following the set of ČSN EN 54 standards connected to Alarm security and emergency systems/Electronic fire signalization.

b) To ensure the safe execution of a fire intervention, a parking space for recharging an electric car is recommended to be at least as wide as a parking space for physically disabled persons, i.e., at least 3.5 m wide (or according to ČSN 6056, article 6.6.2).

The investor evaluates the possibilities of a fire intervention as part of the processing of the "Fire safety solution of the building". In addition, the investor applies to the manufacturer of the charging station a request for the processing of "Fire Fighting Documentation", if it is an activity with an increased fire risk for which one there are no normal conditions for intervention[2].

4. Safety rules when charging electric cars

When charging, it is important to remember that it is an electrical device that can be powered by a high-voltage system. When connecting the cable, which is protected by insulation, there is no danger even in the rain, as the charging process starts only after the circuit is closed, when both connectors at both ends are securely connected. The electric current only starts flowing into the vehicle after checking both the car and charging infrastructure sides; the connection must be secure.

Another safety risk is charging an electric car during a storm. The question of what happens if the charging stand or the superior network is struck by lightning arises. During a local thunderstorm, the general rule is to avoid contact with electrical equipment. A lightning strike in or near an electric car can damage the internal electrical installations and equipment of the vehicle and the charging station, even if it is usually protected by surge protection.

If the charging cable is disconnected from the vehicle, charging shall stop, and there is no risk of electric shock when touching the body of the electric car. The high-voltage battery system includes precautions against electric shock.

5. Preparedness to deal with electric vehicle fires

5.1. Detection of increased temperature of electric cars

For monitoring the critical temperature of an electric car or battery, it is recommended to choose a system of fixed thermal cameras with direct connection to the existing camera system with recording and connection of the alarm signal from the thermal camera directly to the electronic fire alarm/centralized protection desk system operated by fire service. For monitoring outdoor charging stations, it is recommended to monitor only the critical state, i.e., exceeding the temperature of approximately 90 °C [16]. This system is designed based on more than ten years of Czech fire service experience in designing and implementing these systems. Also, it considers the newly prepared ČSN dealing with the issue of electromobility.

[2]The conditions of § 4 paragraph 2 letter j) of Act No. 133/1985 Coll., as amended; complex conditions for intervention according to § 18 of Decree No. 246/2001 Coll., as amended

Figure 4. A container that can be used in the event of an electric car fire [17].

5.2. General distribution of electrified vehicles

Currently, the fire service can meet the following types of e-cars:

- **Micro hybrid**: vehicles with Start/Stop and recuperation, 12 V battery,
- **Mild hybrid**: vehicles that are powered by an internal combustion engine supported by an electric motor and Lithium-ion batteries 12 V/48 V,
- **Full hybrid** (HEV): vehicles capable of purely electric driving, NiMH battery 288 V/Lithium-ion battery 266 V,
- **Plug-In Hybrid**: (PHEV) hybrids with the possibility of recharging using a local mains supply or charging station, Lithium-ion batteries 300–400 V,
- **Elektromobil** (BEV): drive only by electric motor, Lithium-ion batteries 300–400 V,
- **RXBEV** (Range-Extender): additional internal combustion engine to drive the generator charging the HV battery (extending the driving range, not used to drive the wheels),
- **Fuel Cell** Battery Electric Vehicle (FCBEV): fuel cell vehicle.

5.3. Extinguishing methodology and options for intervention in the event of an electric car fire

With the boom of e-mobility in the Czech Republic, the question arises of how to put out a possible electric car fire. In the case of an electric car with traction batteries, the way an electric car burns is different from how a conventional vehicle burns. The traction batteries of electric or hybrid cars are the most considerable risk for firefighters when responding to these vehicles. The battery consists of many cells arranged in segments, and everything is sophisticatedly connected so that the resulting capacity best meets the needs of the given vehicle. Everything is then protected against damage by a durable cover, in some cases, formed by, e.g., a titanium shell (Tesla). Although the packaging protects the battery from damage to a large extent, it represents a major obstacle in a fire or an incipient thermal reaction. The battery is also specific in that when it is mechanically damaged, it may not start burning immediately. However, if a fire occurs, it can re-ignite several times in a row. A chemical reaction occurs inside that can result in a fire within hours or even days. Therefore, it is necessary to monitor it, for example, with a thermal camera, and if it is warming up, start to cool it down. Lithium-ion batteries, part of today's electric cars, need a large amount of water to interrupt the chemical processes. Certified high-pressure equipment (CCS Cobra), including special accessories for extinguishing traction batteries, can extinguish traction battery fires. It is thus possible to apply a specially certified fire extinguisher directly into the battery via a high-pressure jet, where the temperature drops and the burning reaction stops. This is achieved by gradually creating holes in the battery's casing with the help of a high-pressure water jet and an abrasive admixture. After the battery has been extinguished and cooled down, the vehicle continues to be monitored, preferably in a quarantine container that enables transport, monitoring, and safe flooding of the traction battery in the event of another unexpected reaction with regard to ecology. Contaminated water must be disposed of ecologically by a specialist company.

(1.) Using a particular container (Figure 4) for extinguishing electric cars appears to be an effective method. It is a container where an electric car is placed and filled with water from a cistern. The electric car is submerged in the container for several days until the traction batteries cool down [17].

(2.) With the development of electromobility, firefighters in the Czech Republic adopted a unique fire engine specially equipped for extinguishing electric cars. Its basis is the Toyota Hilux pick-up truck, which is structurally modified (Figure 5).

The fire truck Toyota Hilux 6x6 is low enough to move even in tight spaces. It fits up to 185 cm in height, allowing it to enter underground garages. In addition to the prescribed equipment for rapid response vehicles, the car is equipped with the CCS

FIGURE 5. Firefighting vehicle in the Czech Republic for extinguishing electric car fires [18].

Cobra high-pressure fire extinguishing and cutting system, which operates with a pressure of up to 300 bar at a flow rate of 28 liters per minute. At the end of the 80-meter hose is a streamer able to regulate the current from a beam to a wide cone, enabling fast and efficient extinguishing of traction accumulators. Due to the high efficiency of the fire-fighting medium and the pump, fire brigades can use the vehicle for a wide range of interventions. The equipment also includes Holmatro battery rescue tools, positive pressure ventilation, detection technology, and the prescribed equipment for a rapid-response vehicle. A portable and stable thermal imaging monitoring system is also available.

(3.) As a third option, special carts (Figure 6) that take the electric car to a safe distance from buildings or other vehicles have been developed. Then, the firefighting operation can be started [19].

If the battery is mechanically damaged, it may not burn immediately. However, if a fire occurs, it can re-ignite several times in a row. A chemical reaction occurs inside, resulting in a fire within hours or even days. Therefore, it is necessary to monitor the battery, for example, with a thermal camera, and if it is warming up, start to cool it down.

FIGURE 6. Special trolleys for handling an electric car [19].

6. Conclusion

With the boom of electric cars, there is a need to create an appropriate charging infrastructure that is safe for users and their surroundings. Mobile technology constantly evolves, and a traction battery is being developed for the greatest possible range.

Správa železnic promotes electromobility and multimodality, employing charging stations at railway stations. It pays attention to the safety risks of charging electric vehicles. Therefore, the crucial recommendation is to monitor the temperature of the electric car or battery with a system of fixed thermal cameras with direct connection to the existing camera system with recording and connection of the alarm signal from the thermal camera directly to the electronic fire alarm/centralized protection desk managed by Fire service. For monitoring outdoor charging stations, it is recommended to monitor only the critical state, i.e., exceeding the temperature of approximately 70 °C. This system is designed based on more than ten years of experience in designing and implementing these systems. Also, it considers the newly prepared ČSN dealing with the issue of electromobility.

Both authors are involved in the charging station project at Správa železnic, focusing on charging station design, construction, operation, and fire prevention for both duty and public use. The article described extinguishing methodology, including options for intervention in the event of an electric car fire.

Acknowledgements

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