Electrical accident risks in electric vehicle service and repair – accidents in Finland and a review on research

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Abstract

The rising number of hybrid and hybrid electric vehicles with high voltage lithium ion batteries poses a variety of new safety risks. Although the risk for an electric shock for passengers is negligible even in severe accidents and the fire safety is generally better than in cars with internal combustion engine only, the high voltage battery poses new risks for car mechanics, breakdown recovery staff, and rescue personnel.

Electrical work in electrical installations in buildings and electricity distribution networks is globally strictly regulated, while the electrical work in electric vehicles is not. There exists little or no scholarly systematic research on the risks, accidents and close calls available and there is a growing need for systematically collecting evidence and best practices. The arc flash accident risk in electric vehicle repair is probably belittled and the risk of an electric shock is overstated, but further research is needed on the topic.

Keywords: electric vehicles; electrical work safety; fire safety; battery safety

1. Introduction

The rising number of hybrid electric (HEV), plug in hybrid electric (PHEV), and battery electric vehicles (BEV) raises new concerns on the safety of operation and service of these vehicles. In this paper, all vehicles with high voltage battery (HEV, PHEV, BEV) are referenced as electric vehicles.

This paper aims to review the main hazards of electrification in traffic and previous literature on them.

All modern mass-produced electric passenger cars contain a high-voltage battery. In PHEVs and BEVs, a lithium ion battery is used for its high energy density, while especially older non-chargeable HEVs utilize a nickel-metal-hydride battery. The nominal voltages of the batteries typically vary from over 100 volts to 800 volts.

The presence of such high voltage poses similar dangers for car mechanics, breakdown recovery staff, and rescue personnel as it does in the electric work done in electrical installations in buildings. In addition, the lithium ion traction battery and its modules have a high short-circuit current, which raises the risk of arc-flash accidents. Although the full battery pack is short-circuit protected with fuses or other similar solution, internal service and repair work, such as changing battery modules and individual cells, are hazardous if the use of proper insulated tools and personal protection gear is omitted.

The presence of lithium ion battery also poses a fire risk. Compared to lead acid batteries and nickel metal hydride batteries which are practically nearly incombustible, lithium ion battery pack can in certain circumstances, such as an internal short circuit or mechanical shock or penetration, catch fire and burn fiercely.

2. Previous research and literature

The electric hazards can be divided into two main categories: electric shock hazards and arc flash hazards. In some rare cases, the intensive electromagnetic fields have to be considered in work safety, but these concerns are limited to rare special fields, like radar equipment and high-power communication links and base stations.

In the field of electrical work in electric installations in buildings, the practices and conventions have been formed during decades and research on work safety and accidents is done. In her doctoral dissertation, Tulonen (2010) reviewed the research done on safety of electrical work and interviewed Finnish electricians and their superiors. Tulonen identified working in a hurry as the main risk for electric accidents. Almost anyone working in the field has experienced or witnessed an electric shock during their working life. According to Tulonen, the underreporting of the accidents is a problem, but the overall electric safety level in Finland is good in global comparison. Working in a hurry leads to omitting basic safety procedures (de-energizing, voltage testing and earthing).

As Batra and Ioannides (2001) note, comparing electrical work safety between different countries is difficult because of differences in how accident data is defined and recorded. In their review article, the authors note that although there is a downward trend in fatal electric accidents, electricity is still a common killer among workers, especially those performing electrical tasks.

To review the previous research made on electric vehicle electric work safety, search with phrases “electric vehicle electric safety”, “electric vehicle electric work safety”, “electric vehicle electric shock” and “electric vehicle electric hazard” were made in Elsevier ScienceDirect, Scopus, Google Scholar, Web of Science and IEEE Explore. From the results, the articles dealing with actual electric work safety for repair, maintenance, crash recovery, roadside assistance and recycling are picked for examination, resulting only in 7 papers, which are discussed below.

As electric vehicles are a quite new product in the market, only few publications on electric safety of electric vehicles exist. In their conference paper, Kjosevski et al. (2017) point out that there is only little experience with electric vehicles and the area will have to be upgraded once there is more information available. The authors emphasize the fire safety of the electric vehicles and review some accidents leading to a battery fire.

López-Arquillos et al. (2015) map the risks of hybrid, battery electric, and hydrogen fuel cell cars based on expert panel interviews and conclude that electric shock caused by, for instance, unexpectedly damaged components or the high voltage wiring are the greatest electric risks in service and repair of electric vehicles.

In their review article, Wang et al. (2019) assess the fire safety and failure mechanisms of lithium ion batteries and conclude that with the currently available data, it is difficult to conduct a realistic risk assessment for lithium battery systems and more thermal runaway tests and combustion tests for large scale lithium batteries are necessary to provide the missing data. Toxic gas generation and difficulties in extinguishing the fire are discussed also, in comparison to a traditional vehicle fire.

Freschi et al. (2017) substantiate that because electric vehicles are systems isolated from the ground, there is no direct contact electrical hazard unless a bipolar contact is made or two separate different faults occur in the system. When charging an electric vehicle, the electric safety is dependent on the safety of the charger. In Freschi et al. (2018), the authors conclude that a high level of safety is achieved with a 30 mA residual current device and ground loop monitoring.

As Visvikis (2012 and 2013) points out, the risk of an electric shock for passengers even in a crash situation is minimal and there are strict UN regulations for electric, post-crash, and functional safety of electric vehicles. The papers focus on the operational safety, not electric safety for service or rescue personnel.

For actual workshop safety, no systematic risk assessment for the actual repair procedures has been made so far. López-Arquillos et al. (2015) assess the general assumptions of risks by analyzing the risks pointed out by an expert panel, but closer analysis for electric vehicles, similar to what Tulonen (2010) has made for electric installations is needed.

3. Situation and practices in Finland

In Finland, electric work has been strictly regulated for decades, and only minor changes have been made to the legislation. In short, all electric work (with some accurately defined exceptions) requires that the company names a specific person as the head of electric work. The head of electric work has to have a qualification certificate, which is issued only when the person fulfills certain requirements: adequate degree from trade school or an engineering degree, adequate work experience, and passed electrical safety examination of the electric safety authority.

The same strict regulations were applied to electric vehicle service and repair until the beginning of 2017, when a new Electric Safety Act was issued. In the new act, the only mandatory requirement for electric work for road vehicles is that the persons performing the work have adequately familiarized themselves or have been introduced to

- the electrical system of the specific vehicle model and
- the dangers of electricity.

Introducing to the dangers of electricity is usually carried out with a one-day classroom course or an online course. The contents of the course are defined in the national standard on electric safety (SFS 6002). The standard is based on the European standard on the operation of electrical installations (EN 50110-1) which has been supplemented by an attachment on electric vehicle repair.

The safety situation is monitored by the national electric safety authority (Tukes), National Electrotechnical Standardization Organization SESKO and the advisory board for hybrid and electric vehicles under The Finnish Central Organization for Motor Trades and Repairs (AKL). Currently, there has been no fatal neither severe accidents with electric vehicle repair. Two close calls have been reported: in one of them, a member of technical training staff was assembling a high voltage battery pack for a go-kart vehicle built for education purposes, when he accidentally short circuited the battery with a tool. The immediate reason for the incident was using an improper full-metal tool, not an insulated tool which is required by the electrical safety standard. In another incident in a different institute, a student was trying to measure the voltage of a high voltage battery with an oscilloscope probe designed for extra low voltage measurements in electronic circuits. The probe was short-circuited and ignited. The immediate reason was inadequate supervision from the instructor which lead to using an improper probe. In both cases, no personal injury was recorded.

In vehicle repair workshops, no incidents with an electric shock or an arch flash have been reported. Some touch-and-go incidents with hybrid vehicles have been reported, in which a hybrid electric vehicle engine has been suddenly started without a warning while the oil pan has been open. The immediate reason has been neglecting the vehicle manufacturer's safety instructions on powering off the vehicle reliably: the gasoline engine of a hybrid vehicle can start without warning, if the vehicle is in on-mode and the battery state of charge drops under a certain level.

4. Review of the national electric accident database

Because of the lack of electric accident data in electric vehicle repair, all the battery related accidents in the Finnish national electric safety authority accident database (Varo-rekisteri) were reviewed. Large battery arrays are common in uninterruptible power systems and similar stationary applications. From 1171 electric accident records with electric equipment and electric installations during years 2005–2019, there exist nine records related to accidents with large batteries. Only one of them is an electric shock accident, seven of them are pure arc flash accidents and one involved both an electric shock and an arc flash.

Based on this history, I argue that the arc flash risk in electric vehicle repair is belittled and the risk of an electric shock is overstated. This is supported also by the fact that getting an electric shock requires touching two parts in different electric potential with bare hands, and there exists almost no normal repair or service stages where this kind of accident is likely or even possible. Dangers with touching live metal parts with bare hands is also a matter that mechanics are aware of. Instead, short circuiting a battery or high voltage bus can happen accidentally if using an improper tool which slips and short circuits the elements with different potential. This can be avoided by using well insulated tools and emphasizing the dangers of high short circuit currents in the electric safety training.

5. Conclusions and further research

There does exist only a little systematic research on actual risks of electric vehicle safety in workshops, rescue situations and road assistance.

The recording of electric accidents varies country by country and traditionally electric accident risks have been present only in electric installations in buildings and electricity production and distribution. The electricity distribution systems and working practices differ country by country, but as popular electric vehicle models are almost same in every country and the manufacturer's repair instructions are the same everywhere, global co-operation and information sharing should be improved to enhance the safe working practices in vehicle repair, rescue and roadside assistance to diminish the risks for the same accident happening again.

In this paper it has been demonstrated that the arc flash risk in electric vehicle repair is probably belittled and the risk of an electric shock is overstated, but further research is needed on the topic. When considering the rising number of electric vehicles, the importance of systematic research for the safety issues is crucial, especially when the vehicle stock is getting aged. Further research should include systematic interviews for the car mechanics, breakdown recovery staff and rescue personnel to map out the actual risks in the work.

About the author

Mr. Vesa Linja-aho received his M.Sc. degree in electrical and electronics engineering from Helsinki University of Technology in 2006. Since 2010 he has worked as Senior Lecturer in Automotive Electronics in Metropolia University of Applied Sciences. He has published two national handbooks on electrical work safety and charging of electric vehicles. Mr. Linja-aho is an expert member of two national committees (Electric work safety and Electric vehicles) in the National Electrotechnical Standardization Organization SESKO, representing Finland in the electrotechnical engineering field as the National Committee of the International Electrotechnical Commission (IEC). He is also a member of the advisory board for hybrid and electric vehicles under The Finnish Central Organization for Motor Trades and Repairs (AKL) and was the electric vehicle safety expert in the technical expert board in preparation of the Electric Safety Act.

References

Batra, E. & Ioannides, M., 2001. Electric Accidents in the Production, Transmission, and Distribution of Electric Energy: A Review of the Literature. International journal of occupational safety and ergonomics, 285–307.

Freschi, F. Mitolo, M., Tommasini, R., 2017. Electrical safety of electric vehicles. IEEE/IAS 53rd Industrial and Commercial Power Systems Technical Conference (I&CPS), 1–5.

Freschi, F. Mitolo, M., Tommasini, R., 2018. Electrical Safety of Plug-In Electric Vehicles: Shielding the Public from Shock. IEEE Industry Applications Magazine 24, no. 3, 58–63.

Kjosevski, S., Kostikj, A., Kochov, A., 2017. Risks and safety issues related to use of electric and hybrid vehicles. Proceedings of XIV international scientific congress “Machines. Technologies. Materials”, winter session.

López-Arquillos A., Rubio-Romero J., Manuel Súarez-Cebador M., del Carmen Pardo-Ferreira, M., 2015. Comparative risk assessment of vehicle maintenance activities: Hybrid, battery electric, and hydrogen fuel cell cars. International Journal of Industrial Ergonomics 47, 53–60.

Tulonen, T., 2010. Electrical accident risks in electrical work. Doctoral dissertation, Tampere university of technology.

Visvikis, C., 2012. Safety considerations for electric vehicles and regulatory activities. 26th Electric Vehicle Symposium (EVS26).

Visvikis, C., 2013. Evolution in electric vehicle safety legislation and global harmonisation activities, 27th World Electric Vehicle Symposium and Exhibition (EVS27), 1–9.

Wang, Q., Mao, B., Stoliarov, S. I., Sun, J., 2019. A review of lithium ion battery failure mechanisms and fire prevention strategies. Progress in Energy and Combustion Science 73, 95–131.