VÉDELEM TUDOMÁNY
KATASZTRÓFAVÉDELMI ONLINE TUDOMÁNYOS FOLYÓIRAT

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METHODS OF ELECTRIC CAR CHARGINGS ACCORDING TO ASPECTS OF THE FIRE PROTECTION

Abstract

In parallel with the spread of electric cars, more and more companies are setting up car chargers at their premises. The design of the charger and charging cable also differs in case of different charging methods, therefore, they present other risks in terms of fire hazard. Generally Mode 1 and Mode 2 charging modes are common. In our paper, the Mode 3 and Mode 4 charging modes are more relevant, when the charging is already carried out through charging devices specially designed for this purpose. This equipment is similar to different switchboards, they contain all the necessary protection and communication devices to ensure a safe charging process. Mode 4 DC charger is larger, more complex and therefore it has more significant fire risk. Overload also appears as a source of danger, so it is important to use appropriate overcurrent protection devices. Based on the causes of electric fires, the authors examine each case and propose a coherent regulation.

Keywords: electric fire, charging mode, charger, firefighting

ELEKTROMOS AUTÓTÖLTÉSEK MÓDJAI TŰZVÉDELMI SZEMPONTOK SZERINT

Absztrakt

Az elektromos autók terjedésével párhuzamosan egyre több vállalat létesít autó töltőt a saját telephelyén. Az egyes töltési módok esetében más és más a töltőberendezés és töltőkábel kialakítása, ezért tűzveszélyességi szempontból különböző kockázatokat jelentenek. A Mode 1 és Mode 2 típusú töltési mód a lakossági használatnál elterjedt. Tanulmányunk szempontjából

nagyobb relevanciája van a Mode 3 és Mode 4 töltési módoknak, amikor a töltés már külön erre a célra tervezett töltőberendezéseken keresztül valósul meg. Ezek a berendezések nagymértékben hasonlítanak a különböző kapcsoló- és vezérlőszekrényekre, tartalmaznak minden szükséges védelmi és kommunikációs eszközt a biztonságos töltési folyamat megvalósulásának érdekében. Mode 4 DC töltőberendezés nagyobb, robosztusabb, kialakítása bonyolultabb, és ezért tűzvédelmi szempontból is nagyobb kockázatokat hordoz magában. A túlterhelés szintén megjelenik, mint veszélyforrás, ezért fontos a megfelelő túláramvédelmi eszközök használata. Az elektromos tüzek keletkezésének okaira alapozva vizsgáljuk az egyes eseteket és teszünk javaslatot egy egységes szabályozásra.

Kulcsszavak: elektromos tűz, töltési mód, töltő, tűzoltás

1. INTRODUCTION

1.1. The history of electric cars

The history of electric vehicles dates back to the middle of the 19th century. During these years Robert Anderson built the first electric vehicle.

The invention was preceded by the innovation activities of many people:

- Alessandro Volta discovered the galvanic cell in 1800
- André-Marie Ampère formulated the law of excitation in 1820
- Michael Faraday introduced the operation of the electric motor in 1821 and then discovered electromagnetic induction
- Ányos Jedlik invented the lightning-fast rotor, which was the world's first DC motor in 1828

After Anderson’s invention, many inventors began to take an interest in electric vehicles. The best known of these are Robert Davidson, Thomas Davenport and Gaston Planté, who invented the scrap lead-acid battery. Also known inventors are Nikola Tesla and Thomas Alva Edison.

Edison developed nickel-iron batteries for his self-designed electric cars, but these eventually did not make series production. [1] [2]

Picture 1 - Thomas Davenport's electric car

Source: carmudi.com

Picture 2 - Thomas Alva Edison with his electric car

Source: businessinsider.com

The years between 1880 and 1920 were about an intense development called the golden age of electric cars. During this period, three types of cars were present in the market: gasoline-powered cars, steam-powered vehicles, and electric cars. The advantage of electric vehicles was the minimal maintenance and the silent operation.

However, these benefits were quickly forgotten due to:

- They could cover a maximum of 100-150 km distance with a single charge.
- They were relatively slow (average speed around 30 km/h),
- With the fall in the price of petrol, cars with internal combustion engines have become more economical
- Mass production of the gasoline-powered cars have begun

[1] [2]

The change was in the 1960s and1970s. At that time, pollution increased greatly and the air in the larger cities became almost unbearable, leading to a gradual decline in oil stocks and the subsequent oil crisis. The production of electric cars has become popular again. [1] [2]

1.2. Charging process and the related legislation

The main element of the charger is the controller. It communicates with the electric car via communication cables built into the cable, it enables the charging process and if it is necessary, it communicates with external devices. The controller operates a latch before charging begins, which prevents the cable from being removed from the car. Then the contactor retracts and the car starts charging. Charging is completed in reverse order, first by the contactor and then by the latch (Figure 1). [3] [4]. However, the regulations for live equipment must be applied, which appears in the Decree No. 72/2003. (X. 29.) GKM of the Minister of Economics and Transport on the Issue of the Safety Code for Working on

Live Equipment [5].

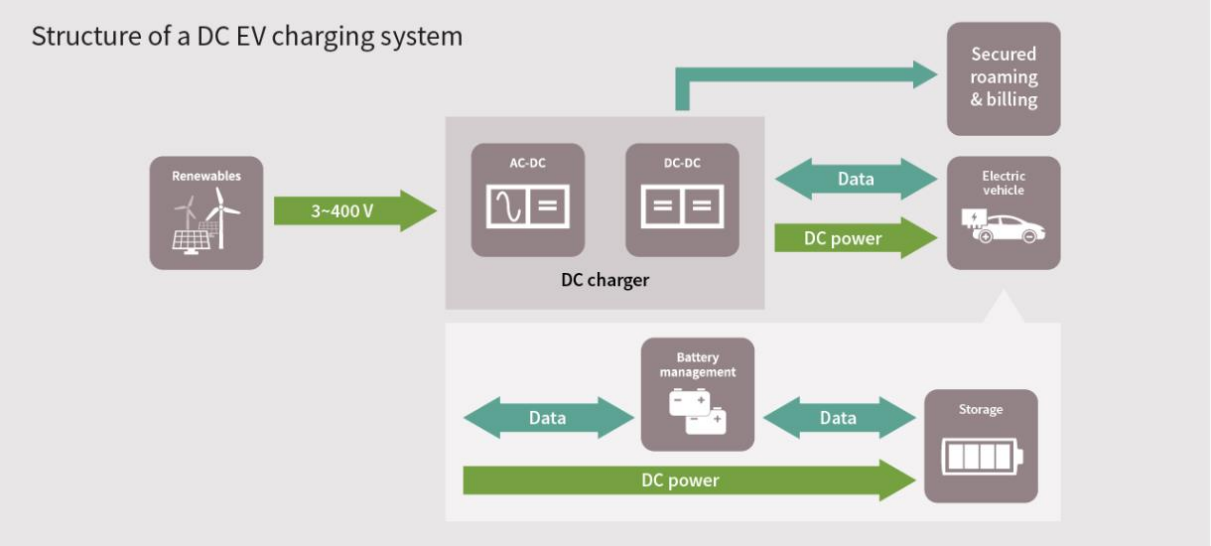

Figure 1 - Process of DC charging in case of electric car. (*Source: infineon.com)*

2. CHARGING METHODS

Based on the standards presented above, 4 charging modes can be distinguished.

1. Mode 1

In case of charging, the car receives power from the electrical grid via a standard connector. This charging mode is not intelligent, so the charger does not communicate with the vehicle, so

for safety reasons it is rarely used. The maximum value of the current can be 16 A, and the value of the voltage can be 250 V for 1 phase, while 480 V for 3 phases. Figure 4 shows a suitable cable for this. [3] [4]

2. Mode 2

During charging, the car receives the power through a standard AC connector. The charging cable includes a special control box (Figure 5) that makes the device an intelligent charger. It means that the box controller and the car's on-board charger communicate with each other. The communication reveals:

- how much energy the car can absorb
- how much power the network can provide
- how much electricity the charging cable can safely conduct
- is there any grounding.

When all conditions are met, the controller only in this case applies voltage to the vehicle charger. The maximum allowable current is 32 A, the voltage is maximum 250 V for 1 phase, while 480 V for 3 phases [3] [4].

Picture 3 - Charging cable for Mode 1

Source: alibaba.com

Picture 4 - Charging cable for Mode 2

Source: besen-group.com

3. Mode 3

Cars are already charged from equipment. In case of charging they can be connected to the car in two ways. The first option is a fixed cable connection, in this case one end of the charging cable is connected to the charging point and the other end can be connected to the car with a connector. The second option is only one socket at the charging point, for which a separate charging cable must be used. One end of the cable is pluggable into the charging station and the other end into the car [3] [4] [6].

4. Mode 4

This is the so-called rapid charging, where a high voltage direct current is used for charging. Because of the high voltage, it is subject to strict regulations, such as it can be only a fixed charging cable. The investment of a rapid charger (Picture 6) is very expensive, so it is commonly used along the highways [3] [4] [6] [24].

Picture 5 – Normal charger for Mode 3

Source: villanyautosok.hu

Picture 6 –Rapid charger for Mode 4

Source: elektromotive.hu

3. TYPES OF CONNECTORS

Initially, only AC charging was widespread, so IEC 62196-1 recommends a type of connector suitable for 3 AC charging:

- Type 1: single phase vehicle connector – SAE J1772-2009 „Yazaki” specification.
- Type 2: single and three phase vehicle connector – VDE-AR-E 2623-2-2 „Mennekes”
- Type 3: single and three phase vehicle connector – „EV Plug Alliance” specification. [4]

To serve higher power DC charging, IEC 62196-3 recommends additional connector types such as:

- CHAdeMO
- CCS (Combined Charging System) Type 1
- CCS (Combined Charging System) Type 2 [4]

The main components of a charger

Different producers make different chargers, however, due to the same operating principle, each of them includes standard devices. I will present these in the next chapters.

1.E-mobility control

The most important element of the car chargers. There are several products available in the market. In addition to charging and related communication tasks, the controllers can have a variety of setting modes. There are products for both private and business use. For the cost-effective operation, manufacturers create their controllers so that they can be easily integrated with their other self-developed solutions. In case of controllers, it is possible to connect to an external application, so providers and operators can easily integrate car chargers into their own systems. [7]

2. Contactor

Electromagnetically operated coupling device, so-called magnetic switches. In car chargers, its function is that when the e-mobility controller gives permission to charge, the contactor retracts and the working contact closes, so that the current is flowing through it and reaches the vehicle. If there is no charge, it prevents the cable from being under voltage. [8]

3. Power supply

The function of the power supply is to convert the supply voltage of 230 V or 400 V to 5 V, 12 V or 24 V for the devices in the charger (for example controller). From the supply voltage, the transformer generates the required amount of alternating voltage. From this, the rectifier generates a DC voltage of the same magnitude. Eventually, this signal even needs to be stabilized [9].

4. Circuit breaker and switchers

The function of the circuit breaker is to protect against overloads and short circuits in electrical networks. It is also suitable for switching the power on and off and for the conduction. The switcher is a touch protection solution that is primarily used in the conductive contact protection modes. The basis of its operation is that the conductors of the protected circuit carrying the operating current are passed through a common current transformer, while the protective conductor is built around it and does not protect against overcurrent and short-circuit current.

. [8]

5. Sockets and cables

The electric car can be connected to the charger via a socket or cable. Most important features of charger cables are:

- Suitable for Mode 3 and Mode 4,
- They can include Type 1, Type 2, CCS coupling head,
- The other side has an open cable end
- They are rated for the transmission of a given charging current
- They can be spiral or straight

Most important features of charger sockets are:

- They are suitable for standard Mode 3
- They have Type 2 design
- They are rated for specific current transmission.[7]

Causes of electric fires

Electric fires are very common and have significant negative economic effects, so it is very important to deal with the topic [10] [11]. From the fire prtection point of view in case of electrical equipment and electric car chargers, it is essential to know the phenomena that can lead to cables becoming a source of ignition.

According to the studies, fires caused by electricity can be divided into 3 main groups according to the cause:

- overload of the cables
- high transient resistance
- short circuit or electric arc [12] [13] [14]

Firefighting under voltage

In many cases, the de-energizing of live equipment cannot be done. Furthermore, due to the protection of human lives, the risk of explosion [15] and the risk of major damage to property, it is necessary to intervene as soon as possible [16]. In case of electric fires the firefighting have to be performed according to the regulation 6/2016 (VI.24) NDGDM instruction is the Rules of Fire-fighting Tactics on the release of the Rules of Technical Backup Operation[17]. This is important primarily for the safety of the interveners [18] [19] [20]. So firefighters can avoid the threats during the firefighting [21] [22].

4. SUMMARY

The development of the charger and its cable is different in case of each charging method and therefore it poses different risks in terms of fire protection [23]. Investigation the causes of electric fires, we examined the charging methods and devices.

In case of Mode 1 charging mode, we only use one cable to charge the car. One end of the cable is connected to the mains socket and the other to the car. There is no communication or protection device in the cable. The grids must be earthed and should have a 16 A rated circuit

breaker in order to prevent the overload. Charging with high current can overheat the cable and connectors. It means that the conductor can be flammable, if a wrong cross-section is used for this purpose. An additional hazard can be the connection of the connectors to the cable, which is often accomplished by soldering, so if the design is wrong, it can also lead to a generation of fire. It is usually used in generally by the citizens, so it does not pose a hazard in case of testing the charging equipment.

The Mode 2 charging mode is a complement of the Mode 1 with communication and protection devices. As a result, the risk is lower in terms of the fire protection, but the hazards remain due to the wrong sizing of the cables or the poor connection of the connector. It is also usually used in generally by the citizens. Mode 3 and Mode 4 charging modes are more relevant. The charging is already done through special equipment. These devices are similar to the different switch cabinets, as they contain all the necessary protection and communication means to ensure a safe charging process. The main difference between the two types is that the Mode 3 is AC chargeable, it transmits the energy, so it is a simpler design.

In contrast, Mode 4 implements DC charging. In this case, the electronics are not in the car but in the charger. So the device is larger, its design is more complicated, and therefore it carries greater risks from the fire protection point of view. In chargers, the cables and wires are connected via terminals, so proper installation is very important to avoid high transient resistance. Overload is also a source of danger, so it is important to use appropriate protection measures and to think of the same cable ducts for high-current conductors. In case of such conductors, we can use fireproof wires or cables. Compliance with fire protection requirements must be guaranteed by the manufacturers, and it is the responsibility of the owner or operator to ensure this with the maximal accuracy.

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