Electric buses with ultracapacitors in Sofia

We tend to equate electric mobility with fully battery-powered electric vehicles (BEVs). Why, then, are the 13 electric bus lines of the city transport mostly driven by Higer ultracapacitor buses?

What are the reasons for choosing ultracapacitor buses and what are their characteristic features, are just some of the questions, answers to which we sought from the people from Chariot Motors AD, who manage the supply and servicing of these electric buses - Milen Milev, manager, and Ilko Ivanov, technical director of the company.

The transition from internal combustion engines to electric propulsion has created numerous problems in the transportation of people and goods. One of the most serious is the replacement of light fuels (diesel and gasoline), ensuring the operation of internal combustion engines, with electricity, which has given rise to some more serious challenges:

- electricity transmission requires additional large-scale and costly infrastructure;
- energy storage facilities are bulky and heavy due to their low energy density;
- electrical energy cannot be stored for a long time.

As a result, specific, highly specialized solutions have to be developed and implemented for the various transport applications. Electric buses for urban passenger transport are a typical example of this. With them, depending on the load of the lines and the work shifts, the required average mileage is up to 250-300 km.

The pilot project with ultracapacitor electric bus in the capital was launched in 2014. The green model e-bus, photographed during its charging

Slow and fast charging

Battery and ultracapacitor buses are the product of two different concepts for urban vehicles – slow and fast charging.

Battery Electric Buses (BEVs) are slow-charging. Charging them, as with electric cars, takes at least a few (3-5) hours. The power of slow-charging stations for electric buses is of the order of 50-100 kW.

Fast charging is applicable to electric buses with ultracapacitors (UC). A UC (or supercapacitor) is an electrical energy storage system consisting of individual cells. Depending on the set requirements, UCs with different capacity and power are produced. The specified voltage, amperage and capacity are achieved by arranging the cells in the appropriate order.

The duration of charging the UC is several minutes. It is carried out by stations with a power of the order of 400-500 kW, which, depending on the available network, are supplied with direct or alternating current.

One of the great advantages of electric buses with UC is that, using fast charging stations located at final stops, they can run for 24 hours, since charging each one takes 5-8 minutes, as well as the mandatory rest of the driver.

The situation for battery electric buses (BEVs) is far less favourable.

The background

UK electric buses in Sofia are designed and manufactured for Chariot Motors AD - a Bulgarian-Israeli company founded in 2013 by Zwika Zimmerman, a person with many years of experience in the automotive industry. 10 years ago, in a purely visionary way, he decided that the future of urban transport was in electric buses. At that time, there are almost no electric buses in Europe, and batteries with a capacity of 200-250 kWh in no way meet the operators' requirements for mileage even in a medium-sized European city. Logically, Zimmerman is targeting fast-charging technology, in which China is ahead.

As early as 2005, UC electric buses were running in Shanghai. Initially, these were transformed trolleybuses and very good operating characteristics were achieved, first of all – safety.

After talks with European and Chinese companies, Zimmerman settled on the idea of creating a product designed for the European market but manufactured in China. The result is an electric bus with Higer branding and bodywork and the Chariot e-bus logo. Created in the middle of the second decade, it was developed for Europe and meets European requirements. The range is expanding, and the company has homologated 8-, 8.5-, 12- and 18-meter electric buses with UC in its list.

Ilko Ivanov, the technical director of Chariot Motors AD

They are manufactured in China by one of the largest manufacturers of buses and electric buses in the world, Higer, under the control of Chariot Motors technical specialists. The capacitors are from AOWEI, and the rest of the main components are European - Siemens, Sachs, WABCO, ZF, etc. – a combination that ensures both quality and reliable system support.

Chariot Motors has an exclusive representative office for Higer UC electric buses in Europe.

In Sofia, the first pilot project of the company started in 2014. Then the Sofia Municipality in the person of the mayor Yordanka Fandakova and the Metropolitan Electric Transport in the person of Mr. Evgeniy Ganchev give the opportunity for the green UC electric bus to run for about a year in order to evaluate its technical and operational characteristics. Sofia Municipality buys 15 electric buses, which entered into operation in 2019 under a procedure financed by the EBRD. The purchase of more electric buses follows.

Currently, there are nearly 50 UC electric buses in Sofia, with charging stations in various locations. In Belgrade, 15 UC electric buses of this brand have been in operation since 2016, a large number have been sold in Israel as well. Through pilot projects, carriers in Rome and Turin, in Austria and Denmark have become familiar with the qualities of this electric bus.

In order to meet the market demands, Chariot Motors also offers battery electric buses. At the end of 2022, twenty-two such vehicles were delivered to the Sofia Municipality. They have lithium ferrophosphate batteries produced by the leader CATL, which tolerate significantly faster charging than Li-Ion analogues and withstand a greater number of charge cycles.

UC or BEV electric buses

In big cities, electric buses are starting to replace conventional ones. There is a greater supply of BEVs because the experience gained with them is greater. Both types of vehicles have their advantages and disadvantages. The choice of one or the other type of electric bus depends on how their features correspond to the operational formula/scheme adopted.

Safety + control

In ultracapacitors, there is much less electrochemistry than in batteries. They do not undergo electrochemical reactions, which are also exothermic (accompanied by heat release), overheating does not cause reactions either. The insulation of the individual cells and elements is mineral-based in the form of a gel, non-flammable and non-toxic. The absence of an exothermic reaction in UC makes the risks of a possible total failure of a cell far smaller than in Li-Ion batteries. In the event of a short circuit, the UC cell turns into an ingot and the process ends there without initiating a combustion process with an exponential increase in temperature and pressure.

UC never stops all of a sudden, it starts showing signs. In a UC where there are "bad" cells, only the problematic ones are replaced. And there were "bad" ones only in case of systemic overloading of the very first generations of UC. Technology has developed rapidly, and in 10 years the seventh generation is already available with significant improvements, in which Chariot Motors also participates with its experience.

Years of operation confirm that UC is the best technology in terms of safety. Cases of fires with particularly severe consequences have been registered with BEV buses, when similar machines are parked nearby - due to the exothermic reaction, the batteries burn violently, until they are completely burned out, without being particularly affected by the fire extinguishing means and methods.

The "innate" advantages of UC are supported by real-time control. Each operating electric bus of the company is monitored online by several sensors, so the information is duplicated. In power lines, especially in connections, the temperature rises over time. The multiple temperature sensors allow, depending on the different information and values they report, to draw conclusions whether the problem is in the cooling circulation, whether it is due to bad contact (repeatability of high values only at a certain point), etc. By taking into account the values and mileage of the particular machine, it is possible to determine the necessary actions and their urgency with sufficient accuracy. Limits are set in the program that monitors the operating parameters, and if they are exceeded, an alarm is activated on the site.

In BEV or UC electric vehicles, the cooling principle of the systems is the same. The energy source is cooled separately and independently of the power unit (traction engine and its inverter), under the control of an electronic BMS (Battery Management System), which constantly monitors the balance of the cells.

The current colouring of UC electric buses in the capital is like that of trolleybuses

Another, different electronics monitor the electric motors, which are inverters, with permanent magnets.

Cooling systems are liquid. The BMS uses a thermal engine that maintains a temperature suitable for cell operation by cooling or heating the liquid circulating in the hermetically sealed power source/UC. And it is in a solid metal container filled with nitrogen under minimal overpressure (1.01 to 1.05 bar) to protect the connections from oxidation.

On the cost scale

The batteries or UC are the most expensive part of the electric bus, and 1 kWh of UC is several times more expensive than a battery. And while the initial investment in fast charging technology is about 20 percent higher than battery technology, the difference can be compensated in operation, primarily through operating costs, because consumption is slightly lower compared to batteries. This is due to better recuperation - manufacturers protect against overheating of batteries by diverting some of the recuperated electricity to load resistors and "destroy" it, turning it into heat. UC that drains energy quickly is able to immediately absorb energy from a standstill, while a battery that is not at least 80 percent discharged cannot handle recuperation.

The limit on the number of charging cycles with UC is negligible compared to that of batteries. The AOWEI supercapacitor comes with a 10-year warranty, a level unattainable for batteries that have half the factory warranty.

Due to the higher energy density of the batteries, electric buses with them provide greater autonomy and usability on different lines.

Why is the fast-charging scheme being implemented in Sofia?

In small cities with a relatively light transport task, preferences tend towards the slow-charging BEV technology. In Sofia, with its busy transport scheme, the fast-charging technology with UC is preferred due to the available prerequisites for easy integration of charging stations. The charging of UC electric buses is calculated in their operating cycle, at stations located where drivers rest. Built at the time far-sightedly, with a large reserve, the structure of the metropolitan electric network for trams and trolleybuses copes with the heavy load during the rapid charging of UC electric buses. The fast-charging stations in Sofia have sufficient power, using directly from the RS (rectifier stations) direct current with a voltage of 650 V DC, which is used to power the contact network for the trolleybus and tram lines.

For comparison, during the night slow charging of 100 BEV electric buses for the next day's journey, with each of them drawing 40 kW, one power plant must be operating. Building and fitting such new infrastructure into city centres is expensive and difficult.

Reasons to be proud

At Chariot Motors AD, they are confident that they know fast charging technology best in Europe, as they are pioneers and have the longest experience in it. They are also proud of the fact that the charging structure used by UC electric buses in our country has been completely developed and manufactured in Bulgaria, no matter how much effort this cost them.

Eng. Radoslav GESHOV