Marcin Koniak
mgr inż.
Wydział Transportu Politechniki Warszawskiej
koniakm@wt.pw.edu.pl

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The impact of working conditions package traction on the exploitation of buses with electric drive

Abstract This paper described the impact of the traction batteries operating conditions on their parameters and the operation of the electric bus. The author in introduction pointed out the advantages of transport based on vehicles with electric drive. He also said that most of the electric buses disadvantages is related to the batteries. The most popular types of energy storage devices used in electric buses have been presented. The rest of this paper is mentioned a number of factors and their impact on the battery exploitation. Are described, among others, temperature, number of cycles, depth of discharge, the operating current. Problems arising from the use of lithium-ion batteries can be reduced by proper selection of its type preceded by an analysis of its future operating conditions.

Keywords: Package traction; Electric drive

Introduction

The development of public transport based on the use of electric buses has become a fact, the growth of this market is estimated at about 19% per year [5]. There are several factors behind such a scenario. The first of these are the advantages of withdrawing from buses gas, and thus the transfer of the production of pollutants from the densely populated cities beyond. It should be noted that coal-fired power plants are equipped with very efficient chimney cleaning systems, which results in a slight negative impact on the environment. Another great advantage of urban electric vehicles is their quiet operation, which in the case of tightly packed high street traffic is an important parameterIt is also important even three times lower cost, 1 km by electric buses compared to diesel. This parameter improves the braking energy recovery systems currently used in these vehicles. Unfortunately, the transport using electric vehicles is not devoid of defects. Actually, all of them are related to the use of chemical batteries that store energy. Due to the high cost of batteries and their considerable weight and volume, they represent a significant limitation of the electric buses range compared to diesel. Dodatkowo wymagają infrastruktury do ładowania w wyznaczonych miejscach trasy. This infrastructure may adversely affect urban distribution networks, which also requires analysis at the investment stage. Traction batteries as part of the bus constituting more than 30% of its value are subject to a number of analyzes in their proper use. This article will review the operating conditions of traction batteries in relation to their operation in electric buses.

Types of batteries used in electric vehicles.

The most commonly used type of energy storage vehicle is a lithium-ion battery pack. Use of lithium is justified by its:

- highest electrodativity at level 4 V,
- high density of energy at level 200 Wh/kg, 400 Wh/L.
- wide range of operating temperatures are usually given in the range -40 +60 °C
- high density of power and energy,
- long time of calendar work

- large number of work cycles.

The common feature of the lithium-ion battery group is their structure based on a positive electrode of lithium metal oxide, a negative porous carbon electrode, and an electrolyte containing lithium salts dissolved in a mixture of organic solvents. It is precisely these differences in the composition of these elements that determine the useful and operational properties of a particular technology. Most commonly used are batteries based on the following compounds LiNiCoAIO2 (NCA), LiNiMnCoO2 (NMC), LiFePO4 (LFP) and Li4Ti5O12 (LTO).

An example of a cell using LiNiCoAIO2 compounds is the very popular Panasonic NCR18650B. The link has been appreciated by Tesla and is used in their vehicles. It is characterized by a very high specific energy of 243 Wh / kg and an energy density of 676 Wh / L. These parameters allow to build traction packages of relatively small size and high capacity. Another very important argument for such a solution is the price of $ 200 / kWh. Unfortunately, there are a limited number of cycles, according to the manufacturer, to about 500 at 100 discharges. Luckily, by adjusting the capacity and operating regime, this parameter can be significantly extended to reach 5 years of service intervals.

The second most common type of rechargeable batteries are those based on LiFePO4 cells. They are offered, among others, Company A123. Batteries consisting of such cells are assembled in Polish and foreign electric buses. In this case, the specific energy is 131 Wh / kg, and the energy density is 247 Wh / L. As can be seen, packets made of cells in this technology are more than twice as large and heavier at the same capacity than the previously presented Panasonic. However, their use is justified by the manufacturer's high charging current of 4C and many times more durability on completed cycles. The price of LFP batteries is currently around $ 450 / kWh.

Another type of batteries used in transport are those based on a cell using a compound LiNiMnCoO2. The use of nickel resulted in a high specific energy of 250 Wh / kg, but the cobalt stabilized the cell mechanically and provided a low internal resistance. The energy density of this cell is 550 Wh / l. As you can see it is a technology that is very suitable for use in transport. In addition, its lifetime is from 4000 to 10,000 cycles depending on the depth of discharge for the most up-to-date representatives of this type of battery. Unfortunately the price is quite high and it is about $ 800 / kWh.

The last type of battery that is increasingly used in electric buses is the LTO, which contains Li4Ti5O12. Buses are the most suitable application of this technology because of a large amount of available space. In case of LTO batteries, it is necessary because their energy is at 80 Wh / kg and the energy density is 150 Wh / L. As you can see with these parameters, to provide the required traction capacity of the battery, it is necessary to prepare a large space for its assembly. In this case, the greatest advantage in a significant degree of compensation for the disadvantages of this technology is the number of cycles in combination with high operating currents both for charging and discharging. The manufacturer states that it is possible to charge up to 8C. The price of LTO batteries is currently around $ 900 / kWh upwards, depending on the manufacturer.

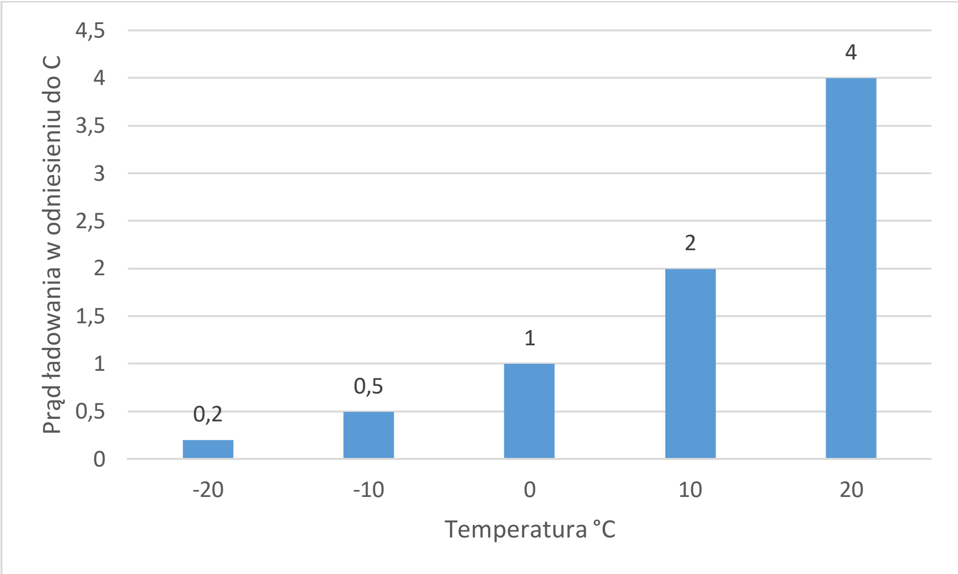
The influence of climatic conditions on the operation of buses with electric drive.

All manufacturers of lithium-ion batteries depend on their operating temperature. These limitations are related to both charging and discharging currents. The table below shows examples of such ranges.

Tab. 1. Sample battery temperature ranges for discharge and charge.

Type of cell	Operating temperature range (discharge)	Temperature range for charging
NCA	-20 ÷ +60 °C [3]	-0 ÷ +45 °C [3]
NMC	-20 ÷ +60 °C [3]	-0 ÷ +45 °C [3]
LFP	-30 ÷ +55 °C [2]	-20 ÷ +55 °C [2]
LTO	-30 ÷ +60 °C [2]	-20 ÷ +45 °C [3]

Usually there is also a relationship between the battery temperature and a maximum permissible charging current. For example, for the LFP batteries, it has been presented in Figure 1.

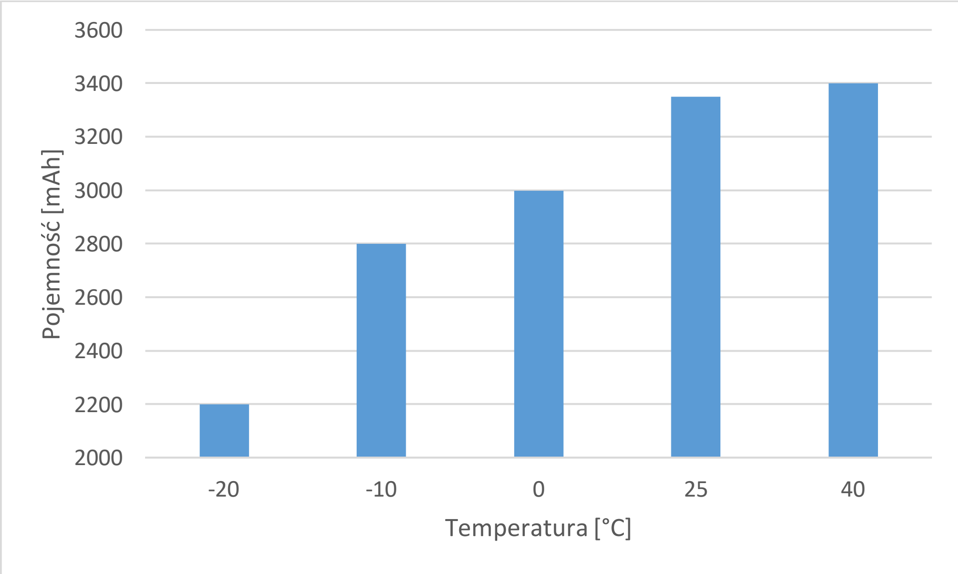


1. An exemplary dependence of the charging current of the cell temperature [2].

As can be seen in Table 1, the temperature ranges for charging and discharging currents do not overlap. This means that the charging process is more electrochemical and thus higher temperature parameters necessary for its implementation. In addition, Figure 1 illustrates the dependence of the charging current in the range of acceptable temperatures for this process. You can see that for the lowest temperatures, these currents are also the lowest. This results in longer charging times. The consequence of this may be for example that, in spite of this, the bus has a fast charge battery packs, the temperature will not use this parameter. This, however, may affect delays in the implementation of the transport cycle.

This situation can also occur if the package temperature is too high, then the charging current is reduced accordingly. This is to limit the further heating of the battery.

Another consideration that must be taken into account is the effect of temperature on the available battery capacity. Unfortunately, even in the temperature range allowed by the manufacturer, this phenomenon exists and is related to an increase in the internal resistance of the cell along with its cooling. Figure 2 shows an example of this relationship, as shown by the loss of available capacitance as a function of the cell temperature of over 35%. There are technologies where this loss may exceed up to 50% in the manufacturer's approved temperature range.



2. Dependency of available capacity on cell temperature [4]

Battery operation at too low and too high temperatures contributes to its faster wear. It is recommended to use them at a temperature close to 20-25 ° C.

In order to prevent the situations described above, it is possible to integrate packages with passive or active thermal conditioning systems. Depending on your needs it can be a heating, cooling or both. Depending on the characteristics of such a system, it is used in heating / cooling, external air ventilation or heating and cooling by means of a liquid.

In addition to the obvious functionality of protecting the package from overheating and excessive cooling, thermal conditioning systems are designed to level the inside temperature as much as possible. This is important in that the cells operating at different temperatures differ in their operating characteristics, as already mentioned in this publication. Such differences in a single package can affect its use faster and reduce operational functionality.

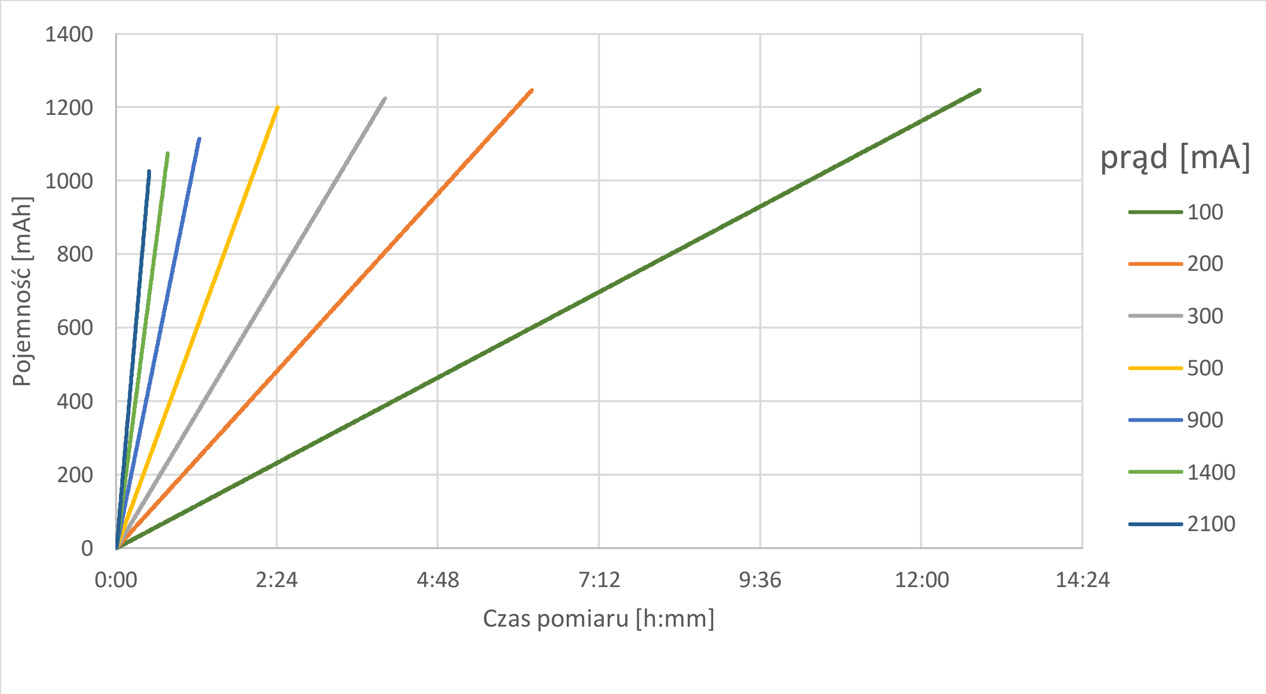
The impact of work cycles on buses with electric drive exploitation.

Another important issue is the impact of the battery charge characteristics caused by its operation cycle. This applies both to the time it takes to complete the transport task and to recharge the battery at the end or depot. Both operating modes affect the battery life and its capacity.

For traction batteries, more emphasis is placed on their quick-acting. This is associated with short stopover times, maximizing the use of the fleet of buses and limiting the battery capacity, as well as the cost of recharging it. However, the negative effects that may occur with the use of fast loading, these are:

- limiting the charge level,
- faster wear,
- increase in package temperature.

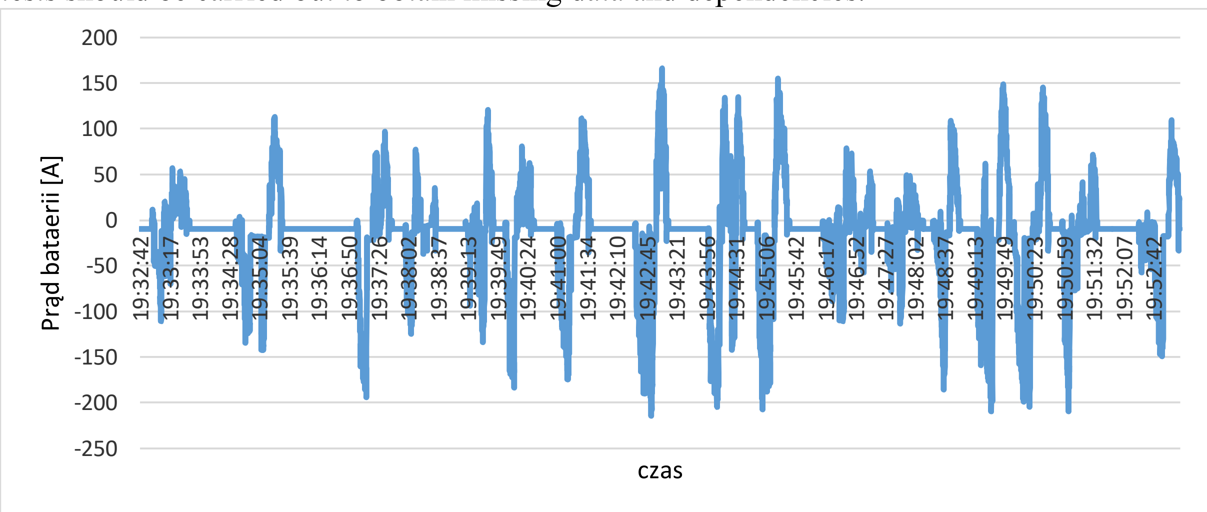
An exemplary connection between the charging current and the charge level of a 1200 mAh battery is shown in Figure 3. Of course, these levels will vary depending on the type of lithium ion battery, but this is always the case. The only way to get the full workload is to switch from DC (Continuous Current) charging to Continuous Voltage (CV) [1].



3. The connection between the charge current and the charge level of a 1200 mAh nominal cell.

Battery manufacturers typically present in the product data sheets what are the available charge levels for the individual charging currents. This parameter should be considered when planning the operation of electric buses on individual routes. Consider both the energy consumption due to the transport task and the end-of-life allowance for the charger, acceptable battery currents and downtime..

Also an important aspect of battery operation is the flow of current during operation. This example of the characteristics of the energy recovery from the braking of the vehicle is presented in Figure 4. We deal with the discharge and loading of the vehicle while driving. These small changes in the direction of energy flow in the battery are called micro-cycles and can affect its life span. Unfortunately, information about this type of work is not provided by manufacturers. In case of need to analyze their impact on battery life, additional laboratory tests should be carried out to obtain missing data and dependencies.



4. An example of the traction current of the traction battery, positive values indicate the braking with energy recovery.

The type and capacity of the battery should also be selected due to the depth of discharge. This is important because there is a connection between the depth of discharge and the loss of capacity measured by the number of cycles. For example, for the LiFePo4 battery [6], this is respectively

- 80% DoD 2500 cycles,
- 70% DoD 3000 cycles,
- 50% DoD 5000 cycles.

Therefore, you should pay attention to the type of battery for which the Deep of Discharge (DoD) indicates the battery life with respect to the number of battery cycles.

Summary

The article presents selected basic conditions of operation of lithium-ion traction packages for their operation. As you can see the problem is complex. In the case of selection of the battery for the electric bus, a detailed analysis of many factors such as the type of chemical cells used, loading currents, route characteristics (length, line load, location of loading points and stopping time), discharge depth, operating temperature seasons in the area and possible addition of air conditioning and heating. Proper battery operation and proper operation can increase the operating time between the necessary replacements, thus reducing the cost of operating the electric bus.

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Source materials

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