Trolleybus with traction batteries for autonomous running

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Abstract — **In 2009 the transport company of city Gdynia (Poland) introduced in the operation trolleybuses fitted with traction batteries. This solution was designed for emergency situations, such as: damage of overhead lines or power loss. Transport company also considering the use of batteries in regular use. The article presents the operational experiences gained during the current operation. Furthermore, there are presented new trends in traction batteries technologies**

Keywords: trolleybuses, electrical vehicles, public transport, traction batteries

I. INTRODUCTION

The dependence on power supply via overhead lines is a substantial drawback of trolleybus traffic. This drawback is felt, e.g., during power supply failures (blackout) or when the necessity arises to change the traffic route (traffic closure). The problem is usually solved by equipping the vehicle with an autonomous power source, which can have the form of [1, 2]:

a) an auxiliary internal combustion generator
b) supercapacitors
c) electrochemical batteries

An auxiliary internal combustion generator is a very popular option and currently forms part of the basic equipment of new trolleybuses. This approach is convenient especially owing to its virtually unlimited travel length and a high flexibility of the vehicle. However, the assets of an electric vehicle are lost by using a diesel engine. Frequently, the drivers use this engine unnecessarily even though a functioning overhead supply line exists along the route or they use this engine on route segments where installation of an overhead line would be a more appropriate approach.

The main asset of supercapacitors is their short charging times. Its capacity, however, is limited, being about 0.75 kWh, so the travel cannot be longer than 500 m. It is clear that its use in regular traffic is impractical. Hence, a supercapacitor can be discussed more as an electricity consumption reduction option than as a solution for completing a route without power supply.

On the contrary, electrochemical batteries appear to be a suitable compromise, being sufficient for completing a route without polluting the environment with combustion products. This was the reasoning behind the decision by Gdynia to purchase 25 new trolleybuses equipped with electrochemical batteries [3, 4, 6].

II. EASE OF USE

The first two trolleybuses equipped with auxiliary Solaris Trollino 12 battery-driven motors, with electrical accessories manufactured by the Polish company Medcom, were put in operation in 2009. Another 25 trolleybuses of the same type were purchased one year later, financed by the Regional Operational Fund.

Fig.1 Solaris Trollino 12 Medcom trolleybus

The trolleybuses are equipped with NiCd STH 800 batteries obtained from SAFT. The capacity of the batteries with 168 cells is 80 Ah. The total weight of the battery equipment, DC/DC converter included, is 800 kg. The maximum power when running the vehicle by using the traction batteries is 70 kW. This allows the vehicle to be run at a speed up to 40 km/h and with acceleration 0.4 m/s^2. The battery converter fulfils 3 tasks:

a) Increases the battery voltage from 201.6 V to 600 V during autonomous travel
b) Charges the traction batteries during normal run, when the vehicle is supplied with power from the overhead line
c) Provides galvanic separation between the batteries and the 600 V traction installation

Fig. 2 Traction batteries (right) and DC converter (left)

III. Operationa Experience

Before PKT Gdynia (Przedsiębiorstwo Komunikacji Trolejbusowej w Gdyni) has been operating trolleybuses with auxiliary battery-driven motors for 2 year now. During that time, the option of completing a route by means of this motor was used several times within planned route changes and in emergency situations (such as overhead line damage or HV power supply failures at the converter stations).

The trolleybuses are also equipped with a recording system which records some relevant parameters, such as the depth of discharge of the traction batteries.

The use of traction batteries can be well illustrated on the closure of Chwaszczyńská street in November 2010, where traffic without power supply from the overhead line was required along a path of 0.8 to 2.1 km due to bitumen surface renewal.

Fig. 3 shows the dependence of the traction battery depth of discharge (DOD) on the travel length.

The dependence of the depth of discharge in possible emergency situations during the 2009 – 2010 period is shown in Fig. 4.

Power consumption data for the various traffic regimes are presented in Table 1. This table demonstrates that power consumption is higher in emergency situations than in normal circumstances, due to the more severe traffic conditions (traffic congestions, ...) [5].

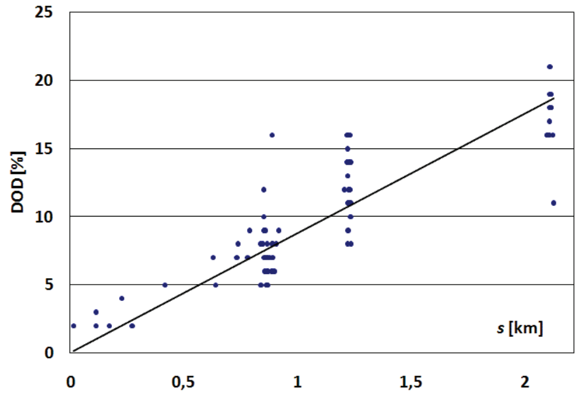

Fig. 3. Dependence of the depth of discharge (DOD) of the traction batteries on the travel length in normal traffic circumstances

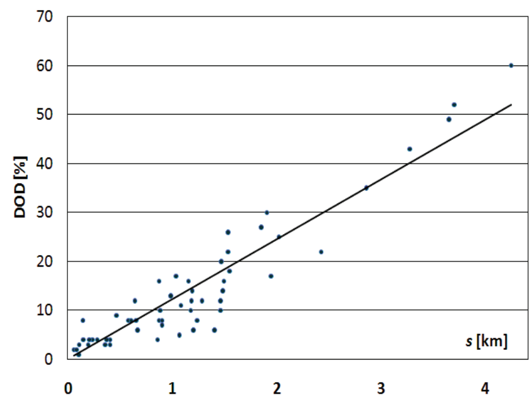

Fig. 4. Dependence of the depth of discharge (DOD) of the traction batteries on the travel length in emergency situations

Table 1. Comparison of the properties of the auxiliary drive

Parameter	Normal traffic	Emergency traffic
Travel distance causing DOD = 20%	2.28 km	1.63 km
Mean power consumption	1.51 kWh/km	1.86 kWh/km
Minimum power consumption *	0.83 kWh/km	0.68 kWh/km
Maximum power consumption: *	2.36 kWh/km	2.72 kWh/km
Largest travel length	2.164 km	7.105 km

IV. Li-Ion Batteries: the future for electrical vehicles

The term "lithium battery" encompasses several types of battery, whose typical properties include a favourable capacity-to-weight ratio and a rather high voltage of the cells (3.3 V to 3.8 V). This makes lithium batteries the core of the most advanced battery systems which are currently available.

For instance, lithium batteries are used in the OAF Graf & Sfift NGE 152 M17 hybrid trolleybus, operated by the public transport company in Eberswalde, Germany. This vehicle is equipped with an auxiliary hybrid drive supplied by RWR Railway Service GmbH, containing:

- supercapacitors possessing a power capacity of 0.4 kWh, in order to increase recuperation efficiency
- lithium batteries 12 kWh capacity for emergency travel completion

The battery compartment accommodates ten HEM 40/36 lithium modules having the following parameters:

- Voltage: 36 V, each module containing 10 cells
- Capacity: 40 Ah,
- Maximum recharging current: 160 A short-time (30 s), 80 A continuous
- Maximum discharging current: 200 A,
- Lifetime with 20% discharge: 2000 cycles
- Weight: 17 kg.

Each battery module is equipped with an autonomous control system The lithium batteries can be used at temperatures down to -20°C. Each module contains electric heating 50 W power to ensure reliable performance of the module at low temperatures.

Fig. 5. OAF Graf & Sfift NGE 152 M17 hybrid trolleybus

An alternative battery system intended for emergency powering of trolleybuses, specifically designed for Vancouver, Canada, is marketed by Hoppecke. This system comprises 220 lithium cells connected in series in 2 parallel sections containing 110 cells each. The parameters are as follows:

- Total voltage: 407 V,
- Capacity: 40 Ah, 16.3 kWh
- Weight: 390 kg.

Li-Ion batteries feature capacity-to-weight ratios three times as high as Ni-Cd batteries. The battery storage system in a Li-Ion technology 800 kg weight possesses a power capacity of 80 kWh, enabling the trolleybus to run a path of approx. 10 km in normal traffic situations and up to 40 km in emergency situations.

V. Conclusions

Experience with the use of traction batteries by PKT Gdynia support the potential of an auxiliary Ni-Cd battery drive system both in normal traffic and in emergency situations. If using the batteries to the maximum depth of discharge of 20%, which is optimum with respect to the battery lifetime, the travel length is 2 km. In such circumstances the battery lifetime is 15,000 cycles, which is equivalent to 7 years of daily use (5 to 10 routes per day). The recharging time is 20 to 40 minutes, which implies that the batteries can be fully recharged from the overhead supply line during the shift.

A larger depth of discharge, up to approx. 40%, is admissible in emergency situations. The travel length then is about 4 km. The longest path travelled on the battery drive system with passengers on board was 7 km.

Undoubtedly, the Li-Ion battery is the technology of the future. The main issue today is the lifetime of such batteries, due to lack of adequate practical experience. The rather high minimum operating temperature, -20°C, is another issue. This is a problem in settings where batteries serve as a standby drive system in trolleybuses. They are seldom used, so they do not heat up through operation and require an external heating system. In electrobuses, the battery temperature is increased due to internal losses. The high price is, of course, another drawback of lithium batteries. This is partly due to their still low popularity.

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