An Innovative Series of Types of Flameproof Lithium-ion Batteries of the SBS-4Lion Type for Powering Battery Locomotives in Underground Mines and Surface Shunting Locomotives with Stored Energy of 105 kWh and 150 kWh

Alojzy KUCZERA, Jarosław KUCZERA, Rafał SMUGA, Łukasz GRZONKA

PHPU Izol-Plast Sp. z o. o.

http://doi.org/10.29227/IM-2022-02-22

Submission date: 24-08-2022 | Review date: 10-11-2022

Battery and diesel locomotives are used in horizontal transport in Polish underground mining plants. At the moment, diesel locomotives have proved to be economically expensive: high diesel fuel consumption, low durability of drive engines and pollution of the workings atmosphere.
Battery locomotives have become more economical and ecological again. Based on the above, the PHPU Izol-Plast Sp. z o. o. company implemented a project co-financed by the EU, developing and implementing a physically innovative solution for a series of battery batteries in lithium-ion technology with a capacity of 105kWh and 150kWh.

Keywords: *flameproof batteries, Li-ion battery*

Introduction

In underground mining plants, battery and diesel locomotives are used for horizontal transport. In recent years, diesel locomotives have been introduced for transport, which at the moment turned out to be a fiasco for several reasons: high diesel fuel consumption, low durability of engines and air pollution in mine workings. At the moment, from the economic and ecological point of view, battery locomotives are more efficient.

Based on the above, the company PHPU Izol-Plast Sp. z o. o. carried out an EU-funded project by developing and physically implementing the design of the SBS-4Lion type battery series mentioned in the title of the article, with an energy capacity of 105 kWh and 150 kWh.

1. Purpose and construction of the SBS-4Lion battery

The SBS-4Lion batteries are made of cells made in the LiFePO4 technology, they are designed to power the Lea-BM12 and ELA-44-1/2/3 battery locomotives. They can also be used to power other machines in underground mines as well as shunting locomotives on the surface.

The battery housing is flameproof in the form of a cuboid divided into chambers. The chambers are divided by 4 rows of through pipes for passive cooling of the battery cells. Cells with a capacity of 1000 Ah were installed in the chambers for the 150 kWh battery, and cells with a capacity of 700 Ah for the 105 kWh battery.

In one of the chambers, a battery controller is built in, supervising the operation of the battery during charging and during its operation.

The CONTROLLER performs the following functions:

- prevents overcharging and deep discharge of cells;
- during charging, it supervises the even charging of the cells;
- controls the cell temperature;
- measures battery voltage and charge/discharge current in real time;
- cuts off the battery charging power supply or its operation in emergency states and in cases intended by the battery operator through external control buttons;
- intrinsically safe circuit supervising battery charging ensures proper connection of battery plugs to battery and charging rectifier sockets, as well as interrupts charging in case of violation of the disconnector of connection sockets or a particular plug.

To connect the battery with the charging rectifier and the locomotive, a special plug socket of the OGB-500 type was designed, equipped with a current disconnector and a set of contacts operating in an intrinsically safe circuit supervising the charging process from the rectifier.

The plug of the connection socket is compatible with the plugs previously used on Lea- BM12 and ELA-44/1/2/3 locomotives.

In order to adapt the locomotive to work with the SBS-4Li-on type battery, equipped with OGB-500 sockets, the protective fuses from the BPS-350 fuse must be replaced with the BPS-350/II in the plugs of the A+ and B- sockets.

2. OPB-500 rectifier

For charging the SBS-4Lion type battery, there is a dedicated charger manufactured by PHPU Izol-Plast Sp. z o. o. OPB-500 flameproof rectifier with passive and forced cooling of the flameproof housing.

The rectifier must be powered from the IT network 3x500 V from a mine circuit breaker, on the surface from a 3x400 V manual switch with 100 A protection .

Rectifier parameters:

- supply voltage – 3x500 V or 3x400 V;
- power – 50 kW;

Tab. 1. Li-ion battery specifications

Tab. 1. Specyfikacja akumulatora Li-ion

	Battery 105 kWh	Battery 150 kWh
Cell type	WB-LYP700AhA	WB-LYP1000AhC(A)
Capacity	700 Ah	1000 Ah
Maximum charging current	300 A	
Minimum temperature of the cell during charging	0ºC	
Nominal cell voltage	3,2 V	
Maximum cell voltage	3,8 V	
Maximum battery voltage	150 V	
The number of cells in a battery connected in series	47	
Level of security	IP 54	
Dimensions of the battery (length x width x height)	2590 x 1070 x 860 mm	
Weight (without cells)	1740 kg	
Weight (with cells, depending on the type of cells)	2900 lub 3860 kg	
Ambient temperature	- 10ºC ≤ Tamb. ≤ + 40ºC	

- charging current max – 350 A;
- mass – 550 kg;
- noise level – 50 db;
- passive cooling + forced coolant (Borygo).

3. Battery charging

The SBS-4Lion type battery will be charged from the OPB-500 type rectifier dedicated by the manufacturer.

The battery can be charged on a locomotive in any excavation with wheeled transport classified as a, b, c methane explosion hazard and A and B coal dust explosion hazard.

The SBS-4Lion battery charging station should be equipped with:

- flameproof mine switch powered from 500 V IT network and 100 A current;
- OPB-500 flameproof rectifier;
- hoist on a rail transverse to the excavation axis with a lifting capacity of 6t, powered by electricity or compressed air;
- position for putting the batteries away during the inspection and service of the locomotive chassis;
- connected SUPO network to the circuit breaker and rectifier;
- while charging the SBS-4Lion type battery, the battery casing must be grounded to the SUPO mine network, on the surface the OPB-500 rectifier should be protected against the influence of weather conditions - mainly precipitation and in a shaded place.

To inspect the locomotive chassis, you can install a gate with a 6-ton load-bearing rail and install an electric hoist with such a lifting capacity that it is possible to remove the battery from the locomotive. The concept of such a station is shown in Fig. 2. The concept of charging stations in underground mining operations is shown in Fig. 1.

4. Battery usage

SBS-4Lion batteries are maintenance-free. The battery cells are completely sealed, they do not have any filler plugs or discharge valves during operation and charging, no gases are emitted from the cells.

Batteries in service should be periodically checked for proper tightening of inter-cell connectors. The inspection should preferably be carried out by a specialist company, e.g. every 6 months. The entire operation of the battery during operation and charging is supervised by a CONTROLLER built in a flameproof housing.

5. Economic and ecological effects

The use in the battery locomotives listed in point 1 will give mining plants the following effects:

- will allow for almost maintenance-free operation of the battery, due to the fact that the cells in li-ion technology are completely maintenance-free. No electrolytes or demineralized water are added to the cells. Cells do not emit any gases;
- will allow only 1 li-ion battery to be used for each locomotive. No reserve is needed.

During operation, the battery can be recharged at any time during short breaks, e.g. between shifts;

- electric motors are simple in construction with a long service life, especially when it comes to the ELA-44 locomotive where the most reliable 3-phase asynchronous motors have been used;
- it will make it possible to resign from servicing the battery charging station, which, due to the harmful atmosphere, works in a shorter time;
- in the construction of new mining levels, it will make it possible to resign from the need to build very expensive battery storage rooms;
- will reduce the cost of battery repairs, because li-ion batteries have at least 5 times higher permissible number of cycles.

6. Second life of li-ion batteries

As mentioned above, li-ion batteries have about 5 times more cycles than classic batteries with electrolyte or gel.

Li-ion batteries after 10 years of operation still retain 70% of their capacity. Therefore, the cells of a worn-out battery can get a so-called second life. They can be used to build energy storage facilities, e.g. in widely understood photovoltaic installations, where they can be used for another 10 years.

7. Disposal of li-ion cells

Used li-ion battery cells can also be recycled.

Manufacturer of li-ion batteries for the mining industry PHPU Izol-Plast Sp. z o. o. can accept used cells for recycling

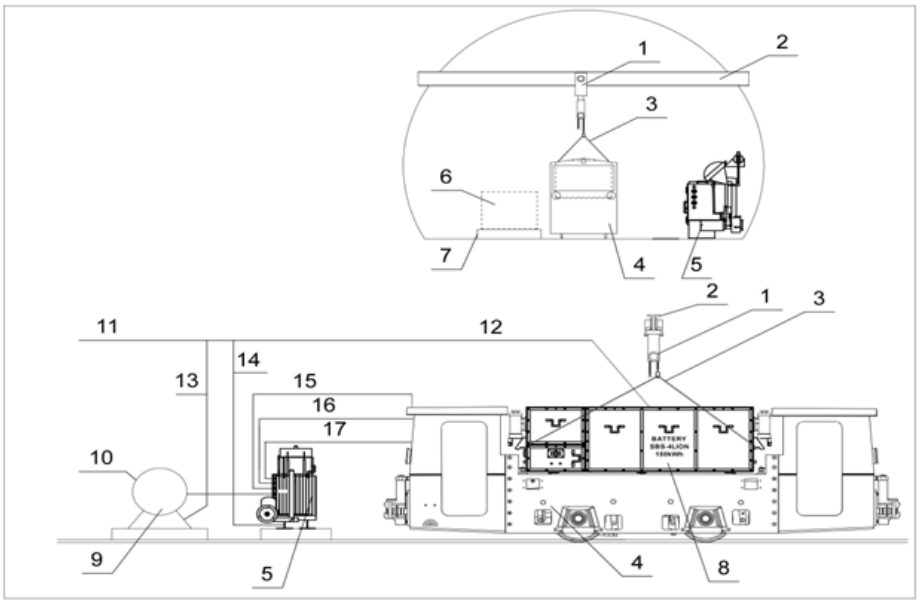

Fig. 1. Stand for fast battery charging on a locomotive in any excavation of an underground mining plant (concept); 1 – self-propelled 6-ton chain hoist type SWŁ-6; 2 – running rail – l-beam 300 mm; 3 – 4-hook rope sling; 4 – electric battery locomotive type ELA-44/3; 5 – OPB-500 rectifier; 6 – SBS-4Lion battery during inspection of the locomotive; 7 – place for batteries -3x1 field – concrete; 8 – battery SBS-4Lion; 9- mine curcuit breaker – 100A; 10 – 500V IT grid; 11 – SUPO grid; 12 – SBS-4Lion battery ground clamp; 13 – mine curcuit breaker ground terminal; 14 – ground clamp of the OPB-500; 15 – instrinsically safe curcuit control cable; 16 – high-current cable B-; 17 – high-current cable A+ [lenght of high-current cables is about 7.5m]

Rys. 1. Stanowisko szybkiego ładowania baterii na lokomotywie na dowolnym przekopie (koncepcja); 1 – samojezdny wciągnik łańcuchowy 6-cio tonowy typu SWŁ-6; 2 – szyna jezdna - dwuteownik 300 mm; 3 – zawiesie linowe 4-rozaczepowe; 4 – elektryczna lokomotywa akumulatorowa typu ELA-44/3; 5 – prostownik OPB-500; 6 – bateria SBS-4Lion podczas przeglądu lokomotywy; 7 – miejsce na baterię – pole 3x1 m –beton; 8 – bateria SBS-4Lion; 9- wyłącznik kopalniany – 100A; 10 – sieć IT 500V; 11 – sieć SUPO; 12 –zacisk uziemienia baterii typu SBS-4Lion; 13 – zacisk uziemienia wyłącznika kopalnianego; 14 – zacisk uziemienia prostownika OPB-500; 15 – kabel sterujący obwodu iskrobezpiecznego; 16 – przewód wysoko-prądowy B-; 17 – przewód wysoko-prądowy A+ [długość przewodów wysoko-prądowych około 7.5]

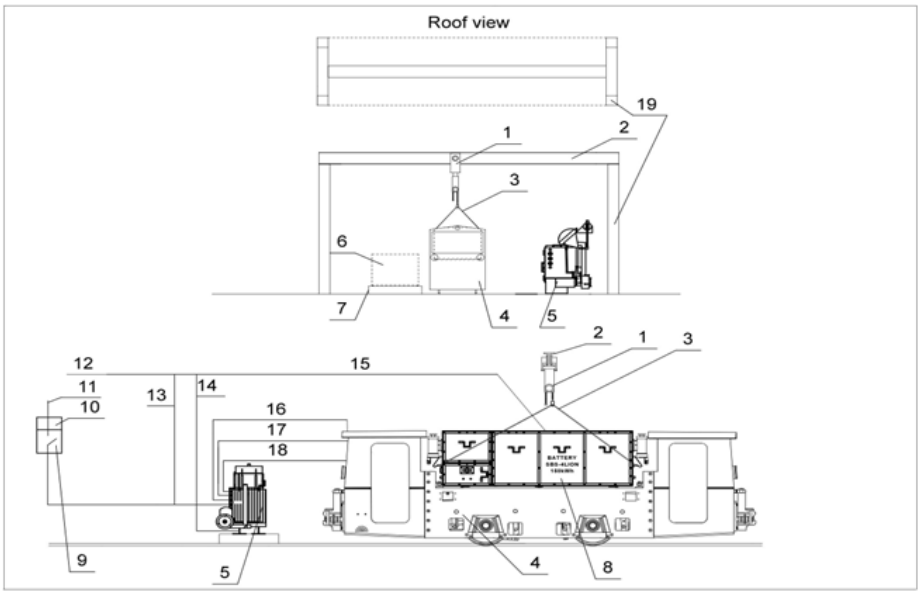

Fig. 2. Quick charging station on the ground (concept); 1 – self-propelled 6-ton chain hoist type SWŁ-6; 2 – running rail – l-beam 300 mm; 3 – 4-hook rope sling; 4 – electric battery locomotive type ELA-44/3; 5 – OPB-500 rectifier; 6 – SBS-4Lion battery during inspection of the locomotive; 7 – place for batteries -3x1 field – concrete; 8 – battery SBS-4Lion; 9 – manual switch; 10 – 3x100A fuse; 11 – 500V IT grid; 12 – SUPO grid; 13 – mine curcuit breaker ground terminal; 14 – ground clamp of the OPB-500; 15 – SBS-4Lion battery ground clamp; 16 – instrinsically safe curcuit control cable; 17 – high-current cable B-; 18 – high- current cable A+ [lenght of high-current cables is about 7.5m]; 19 – pole.w329

Rys. 2 Stanowisko szybkiego ładowania na powierzchni(koncepcja); 1 – samojezdny wciągnik łańcuchowy 6-cio tonowy typu SWŁ-6; 2 – szyna jezdna - dwuteownik 300 mm; 3 – zawiesie linowe 4-ro zaczepowe; 4 – elektryczna lokomotywa akumulatorowa typu ELA-44/3; 5 – prostownik OPB-500; 6 – bateria SBS-4Lion podczas przeglądu lokomotywy; 7 – miejsce na baterię – pole 3x1 m – beton; 8 bateria SBS-4Lion; 9 – wyłącznik ręczny; 10 – bezpiecznik 3x100A; 11 – sieć IT 500V; 12 – sieć SUPO; 13 - zacisk uziemienia wyłącznika kopalnianego; 14 – zacisk uziemienia prostownika OPB-500; 15 – zacisk uziemienia baterii typuSBS-4Lion; 16 – kabel sterujący obwodu iskrobezpiecznego; 17 – przewód wysoko-prądowy B-; 18 – przewód wysoko-prądowy A+ [długość przewodów wysoko-prądowych około 7.5m]; 19 – słup

because it knows companies in the country that deal with this, but at this stage it has not yet selected a specific recipient. During utilization, 80% of the materials used for production are recycled, mainly cobalt, nickel and lithium. These metals currently have high prices on world markets due to the demand for them for the ever-increasing production of li-ion batteries.

8. Summary of the project

PHPU Izol-Plast Sp. z o. o. during the development and implementation of the production of a series of li-ion batteries in flameproof housings, it has acquired the technology of building any type of batteries that can be used in other industries, transport, and in widely understood energy storage installations. Accordingly, interested parties are encouraged to cooperate.

Acknowledgement

The tests of individual elements of the entire project were carried out in the "Laborex" laboratory of the OBAC – Gliwice company, and functional tests in the company PHPU Izol-Plast Sp. z o. o. For the development of the BPS-500 fuses, cooperation with Dr. Eng. Antoni Przygrodzki from the Faculty of Electrical Engineering of the Silesian University of Technology.

The research was carried out as part of the project co-financed from European Funds: "Conducting research and development works to develop an innovative product – a series of types of flameproof Li-Ion batteries for powering locomotives in underground mines with stored energy of 105 kWh and 150 kWh".

Literatura – References

1. POLNIK B.: Development of drive systems for Mining Battery Locomotives. "Electric Machines - Problem Books" , 1/2016
2. PHPU „Izol-Plast" Sp. z o.o. Rogów – Technical Documentation of series flame-proof lithium-ion batteries type SBS-4Lion with an energy capacity of 105 kWh and 150 kWh.
3. Patent description - Flameproof explosion-proof battery box for powering a mining battery locomotive. patent no 237501.
4. Patent description – OGB-500 type flameproof fuse socket assembly with connection plug.patent no. 434800.
5. Patent description - Passive - forced cooling of flameproof enclosures for underground mining plants. patent no. 436282.
6. Patent description - Operation of battery locomotives in horizontal transport without a battery charging station. patent no. 436139
7. Li-ion Battery - Cell test report according to EN-62133-2:2017
8. IGLIŃSKI H.: Second life of electric car batteries. http://www.flota.com.pl/we_flocie/4420/drugie-zycie-baterii-samochodów-elektrycznych.html.
9. Stena Recycling – Research project: Recycling of lithium-ion batteries.

Innowacyjna seria ognioszczelnych akumulatorów litowo-jonowych typu SBS-4Lion do zasilania lokomotyw bateryjnych w kopalniach podziemnych oraz powierzchniowych lokomotyw manewrowych o zmagazynowanej energii 105 kWh i 150 kWh

Lokomotywy akumulatorowe i spalinowe są wykorzystywane w transporcie poziomym w polskich podziemnych zakładach górniczych. W chwili obecnej lokomotywy spalinowe okazały się drogie ekonomicznie: duże zużycie oleju napędowego, mała trwałość silników napędowych oraz zanieczyszczenie środowiska pracy. Lokomotywy akumulatorowe znów stały się bardziej ekonomiczne i ekologiczne. W oparciu o powyższe firma P.H.P.U.Izol-Plast sp. z o o zrealizowała projekt dofinansowany ze środków UE, opracowując i wdrażając nowatorskie fizycznie rozwiązanie dla serii akumulatorów akumulatorowych w technologii litowo-jonowej o pojemności 105kWh i 150kWh

Artykuł powstał w ramach projektu dofinansowanego z Funduszy Europejskich:
Przeprowadzenie prac badawczo-rozwojowych w celu opracowania innowacyjnego produktu – typoszeregu ognioszczelnych baterii Li-Ion do zasilania lokomotyw w podziemnych zakładach górniczych o zmagazynowanej energii 105 kWh i 150 kWh.
Badania poszczególnych elementów całości projektów były prowadzone w laboratorium „Laborex" firmy OBAC – Gliwice a funkcjonalne w firmie PHPU „Izol-Plast" Sp. z o.o.
Dla opracowania bezpieczników BPS-500 współpracowano z dr inż. Antonim Przygrodzkim z Wydziału Elektrycznego Politechniki Śląskiej.

Słowa kluczowe: *ognioszczelne baterie litowo-jonowe ognioodporne, akumulator litowo-jonowy*