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Battery with Integrated Power Supply (BALIN)

Matteo Nobili, Lorenzo Flaccomio, David Russo, Giuseppe Grande, and Alfredo Biancucci
Trenitalia, Florence, Italy

Abstract: The BALIN is a modern device, consisting of a battery with integrated battery charger, dedicated to powering the 24 V services of the carriages. In various Trenitalia rolling stock, used for the regional transport of travelers, there are old and obsolete battery charger devices and there are lead acid batteries that need frequent maintenance operations to be kept efficient. These components, due to their low reliability, are the source of serious disruptions to passenger transport, and the management of their maintenance involves high costs for Trenitalia. In order to solve these problems, Trenitalia has therefore decided to invest resources to develop a new system of integrated power supplies and batteries, therefore the BALIN has been developed. The main advantages of BALIN compared to the original components are the presence of a high energy efficiency battery charger designed to operate in a wide range of temperatures and the presence of sealed lead-acid batteries without maintenance with a life exceeding 6 years. The BALIN is able to disconnect its own batteries from the carriage electrical circuits. The BALIN battery charger also implements an intelligent battery management logic and thanks to the interface with the command and control signals present on the rolling stock, the batteries are isolated from the carriage electric load automatically when the train is off and the service it's over. Another important automatic feature of the BALIN is to protect its batteries from deep discharge, in fact the power supply from the batteries to the electric carriage loads is interrupted when the voltage reaches 21 V. The characteristics mentioned go towards the reduction of the charge/discharge cycles of batteries and contribute to increasing the reliability and durability of batteries throughout the entire life of the rolling stock.

Key words: Battery, regional transport, power supply.

1. Introduction

The entire process of developing and implementing BALIN took place through multiple phases. The idea of development of the BALIN started from the need to reduce the costs related to the management of the batteries and battery chargers generating 24 V, installed on the traditional carriages of the Trenitalia park [1]. From the feedback received from operation by the people involved in maintenance of Trenitalia rolling stock, various technical aspects emerged that had to be improved. As a consequence, Trenitalia technical department has developed a technical specification showing the description and requirements of BALIN. The design and construction of the BALIN series in accordance with Trenitalia technical specification has been done to an external company that produces rail power supplies. During the design phase, in order to guarantee the compliance of the project with the desired requirements, various technical meetings were held between the designers of the BALIN and the technical offices of Trenitalia. The bench type tests were made on the first prototype, those tests were necessary for BALIN certification according to the railway regulations and to additional requirements desired by Trenitalia technical specification. During the type tests, the prototype was tested in all possible operating conditions, depending on the electrical parameters relating to the BALIN input power supply and to the electrical output load. The prototype was stressed by varying the environmental conditions (temperature, humidity), the degree of BALIN environmental insulation was also tested. The bench tests were followed by operational tests, installing 6 BALIN prototypes on 3 Trenitalia carriages (2 BALIN for each carriage). These tests, lasting 3 months, were fundamental to verify the operation of the BALIN in real operating conditions

Corresponding Author: Matteo NOBILI, research field: power supply.

and to correct some functionalities of the project in order to guarantee the suitable functional, electrical and mechanical integration between the new device and the rolling stock. Once the operational tests were completed, the conformity of the BALIN project to Trenitalia's requests was confirmed and therefore the series production of the device was started. The final phase of the process concerns the installation of BALIN on rolling stock. This activity is still ongoing and is managed and carried out by the Trenitalia workshops with the coordination of the technical department. Trenitalia managed internally the installation of BALIN, because it has the necessary technical expertise to carry out the modifications and adjustments in the rolling stock in order to guarantee BALIN integration.

2. Technical Description

This paragraph gives a BALIN technical description from an electrical and mechanical point of view. The general electrical architecture of the BALIN is characterized by a switching semiconductor battery charger with "Silicone Carbide" technology connected to two 12 V batteries each, connected in series. Battery technology is lead-acid and the batteries are sealed, so they do not require maintenance or filling. Inside the BALIN there is also a contactor and a diode, ealized in a single module which has the function of disconnecting the batteries from the rest of the electric circuit of the carriage when necessary and decoupling the battery voltage from that of other BALIN or power supplies placed in electric parallel. In Fig. 1, two BALINs are shown schematically in electric parallel with each other, and it is possible to see the internal simplified architecture of the BALIN.

The traditional system that was present on the carriages before the installation of the BALIN consisted in a single battery charger connected to two packs of batteries placed in parallel with each other. This system had multiple disadvantages related to its architecture and technology. A disadvantage was the absence of decoupling between the two battery packs; in this case, the occurrence of a single package failure compromised the operation of both battery packs. The new system, featuring two BALIN in electric parallel to replace the two original battery packs, has no such disadvantage. The BALIN in fact, in addition to guaranteeing the decoupling between its own batteries and those of another BALIN in parallel, optimizes the charge by reading and regulating only the current of its own internal batteries. Another advantage compared to the traditional system is that the

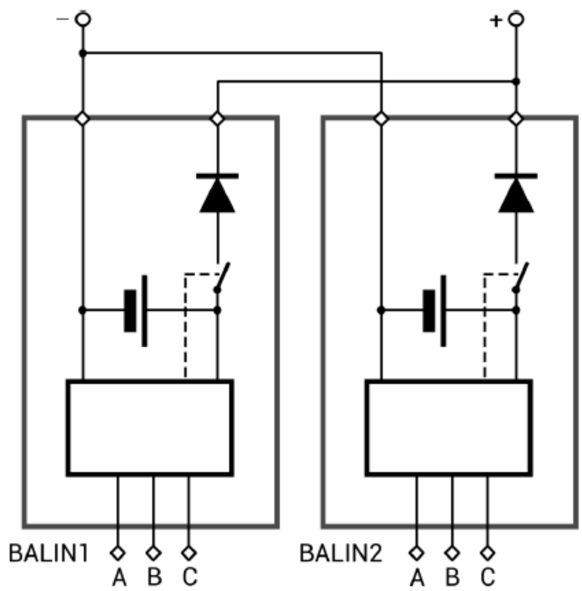

Fig. 1 BALIN internal architecture.

introduction of two BALINs in the carriage architecture guarantees the redundancy in the charge of the batteries and in the 24 V supply of the rolling stock electrical circuits. Finally, using BALIN, filling operations on batteries or their frequent replacement are no more necessary.

2.2 Electrical Characteristics

BALIN battery charger can receive both an alternating three-phase voltage (340 ÷ 500Vac, 40 ÷ 60Hz) and a direct voltage (300 ÷ 750Vdc) and provides a 24 Vdc output voltage. The wide range of acceptable input supply makes the BALIN suitable to be installed on various types of rolling stock according to their power supply system. In the specific case of Trenitalia carriages, the BALIN is powered by an electronic converter that generates the medium voltage (380Vac, 50 Hz) for supplying the auxiliary carriage services too (air-conditioning, heating, etc.). The BALIN is equipped with an "auto starter", so it is able to start and operate regularly with only the input medium voltage supply and does not require any external 24 V auxiliary power supply. In addition, the BALIN can operate in electrical parallel to other BALIN or other power supplies, in this way it is possible to equip a rolling stock with a BALIN number suitable for the required electric power. The BALIN is able to supply a continuous output of 3 kW and its energy efficiency can reach 93% with 90 A output current. The high efficiency allows the battery charger unit to occupy a limited size case and this one uses a cooling system with natural ventilation through an appropriate finned heat sink. The 2 batteries connected in series internal to the BALIN have a nominal voltage of 12 V each other and a stored energy of 4 kWh, they can operate in a wide range of temperatures ranging from -40 C to + 50 C.

2.3 Mechanical Characteristics

The BALIN is characterized by a corrosion-resistant stainless steel case inside which the following elements are present: battery charger unit, 2 batteries, connection wiring. The BALIN case is designed to be inserted inside the original battery boxes present on various types of Trenitalia carriages. In addition, the back side of the BALIN has electrical spring contacts compatible with those in the carriage. With this design philosophy, mechanical and electrical interventions needs in the rolling stock to achieve complete compatibility with BALIN are limited and therefore installation costs significantly reduces too. Another important constructive peculiarity consists in having made the battery charger in a light mechanical unit weighing 25 kg and fixed to the BALIN frame by means of a screwed flange. This feature makes possible, in case of necessity, to easily extract the battery charger only from the carriage, leaving the BALIN case with batteries on the vehicle body. The solution just mentioned introduces a considerable advantage in terms of maintainability on the BALIN if it is necessary to replace only the battery charger after a fault. Fig. 2 represents the complete BALIN in its mechanical appearance. The battery charger case has an IP 67 degree of insulation and this feature makes it resistant to the most adverse environmental conditions, water, humidity and dust. Therefore the BALIN can be installed in critical environment such as the rolling stock underbody. The battery charger is able to operate in an extended temperature range ranging from -25 C to + 45 C.

3. BALIN Functionality and Integration on the Rolling Stock

The logical functions implemented in the BALIN go towards optimal management of the batteries in all operating conditions of the rolling stock and go towards the availability of energy for the supply and operation of the 24 V utilities. On the BALIN front panel there is a signal connector on which it is possible to connect some 24 V HW signals of the carriage control and command system in order to harmonize the BALIN behavior with the train operating status.

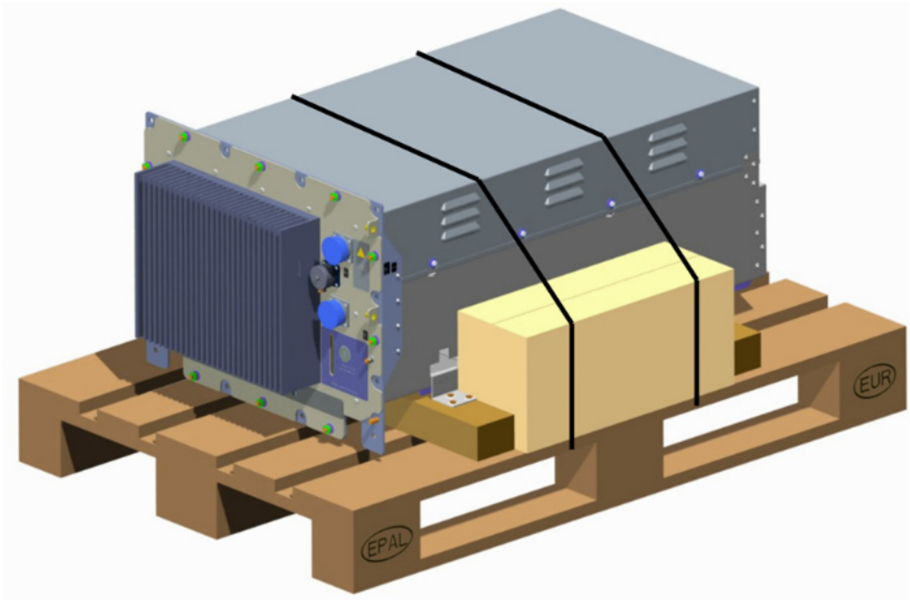

Fig. 2 BALIN.

Acting on the signals of this connector it is possible to carry out various functions, such as, for example, controlling the BALIN switching on and off using the light control already present in the carriage or using the train enable signal coming from the locomotive. With these features, energy is taken from the batteries only when necessary, when the train is running, obtaining the advantage of limiting the charge/discharge cycles of the batteries themselves. In the BALIN, via the signal connector, it is also possible to enable the function called "residual energy". With this functionality, the BALIN, in conditions of absence of the input supply voltage, interrupts the supply of current to the 24 V utilities when the residual energy on the batteries reaches 20% of their nominal capacity. This function, implemented in the BALIN logic, is very important in train operation: it prevents the complete discharge of the batteries when the rolling stock is de-energized at high voltage for long periods and always guarantees the availability of 24 V energy particularly necessary during the power on of the carriage. In BALIN there is also an additional protection that protects the batteries from deep discharge and prevents their degradation, this protection stops the supply of current to the electrical loads of the carriage when the battery voltage reaches 21 V.

The complete discharge of the BALIN internal batteries must be avoided in all operating conditions, both when the BALIN is installed on the rolling stock and when the BALIN is stored in the warehouse for long periods. With reference to storage for a long time of the BALIN, it is necessary to avoid energy consumption from the batteries by the electronic boards of the internal battery charger. Even if there was negligible current, in the order of a few mA, these current could still be critical in the long time, as it would cause the complete discharge of the BALIN batteries irreversibly, damaging them. To avoid this phenomenon, a contactor has been introduced, which has the function of completely isolating the 2 batteries from the battery charger electronics. This contactor opens automatically 4 days after the last controlled BALIN switch-off (both from the signal connector and from 20% threshold of the residual energy) and closes automatically in the case of presence of input medium voltage to the BALIN (380 Vac) or in case of active “switch on” command.

An important requirement taken into consideration in the development process of the BALIN is the selectivity of the protections in case of overcurrents on 24 V electrical system of the rolling stock. This means that, if there are short-circuits at some point in the carriage's electrical system, the BALIN must supply the energy to allow the automatic switch of the carriage to break the circuit. In this way the selectivity of the protections is guaranteed, the fault is isolated and the entire 24 V system is not compromised and continues to operate. One element that had to be worked to guarantee selectivity was the management of the internal static contactor opening, located downstream of the battery charger and the batteries and visible in Fig. 1. Various bench tests have been carried out, in which short circuits have been reproduced in order to achieve the selectivity between the BALIN and a 25A C curve automatic switch (the slowest switch to break the circuit equipped on the carriage). The tests also had the purpose of verifying the thermal capacity of the static contactor in supporting the overcurrents necessary for selectivity. Therefore, a time-current tripping feature on the BALIN SW has been implemented. This feature manages the opening of the static contactor and has tripping times higher than the automatic switch, 25 A, C curve. In Fig. 3, the BALIN tripping feature is highlighted in green and the selectivity with automatic switch, C curve is evident.

In the development of a device it is important for various reasons to pay attention to the issue related to internal diagnostics. One reason among all is the possibility of receiving an accurate and selective troubleshooting search in order to make maintenance operations and repairs more effective; another reason consists in having available parameters that help to monitor the state of life or health of the device in terms of Condition Based Maintenance (CBM). Here

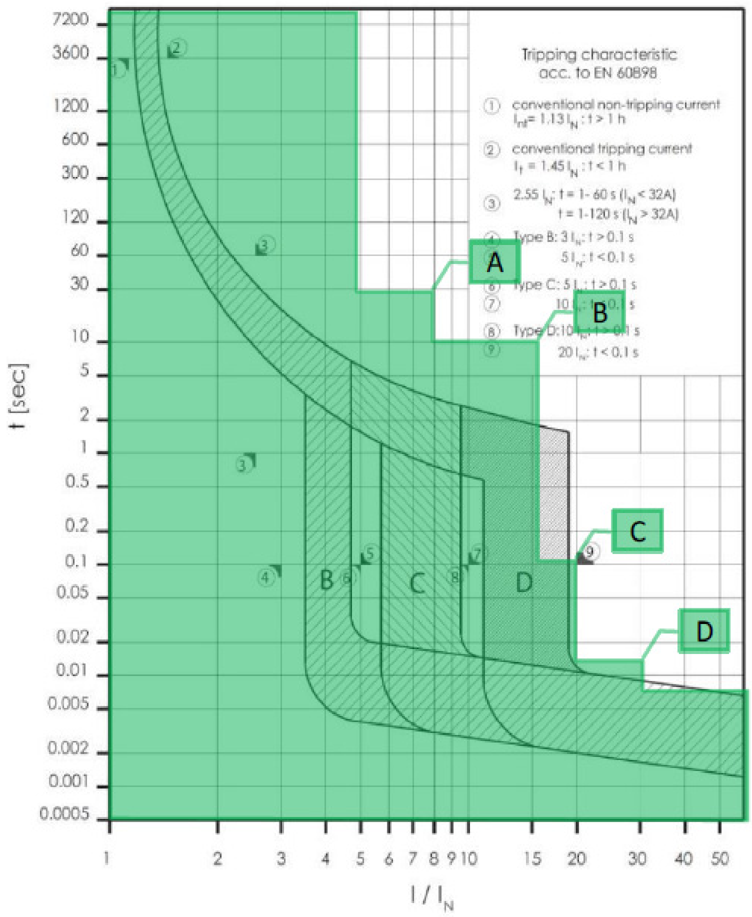

Fig. 3 BALIN tripping feature.

in BALIN a sophisticated internal diagnostic system has been developed; it can provide various information. First of all, there is a non-volatile internal memory, organized in a circular buffer, able to store all the diagnostic variables sampled over time for the last 3 months of device operation. The variables stored are various: battery current, total output current, battery voltage, temperature on each battery, input supply voltage, battery charge status, internal BALIN alarms and protections, digital input and output status (on / off command signals), energy input and output from the battery, etc. The sampling period of these variables is equal, by default, to 10 s but the user can be modify it. It is possible to access to these variables in various ways, according to the needs of the maintenance operator. Variables are available in real time, in order to monitor the operation of the device and check if there are active alarms or anomalies. It is also possible to download the data history for the last 3 months of operation of the BALIN in order to verify the statistics of faults or malfunctions and make analyzes on the health of the batteries.

Another feature that distinguishes the BALIN from a traditional 24 V power supply system is the possibility for the user to configure certain parameters on the SW in order to make the device function flexible according to the needs and the field of application. For example, it is possible to configure the delay time in the start-up of the battery charger from the moment in which the input voltage is present. This parameter can be fundamental in the start-up phase of the carriage auxiliary converter that generates the power supply for all auxiliary utilities and for the BALIN; thus introducing this delay avoids the simultaneous start-up of the BALIN and the other electric loads, as a consequence, the overload on the converter is limited. Other significant parameters that can be configured by the user are the variables relating to battery management such as: maximum charging current, end-of-charge voltage, minimum discharge voltage, residual energy threshold, etc. The configuration of these parameters acts on the charging characteristic of the BALIN battery charger, adapting it to the type of batteries inserted inside the BALIN itself. This configuration is a very powerful tool as it allows the BALIN user to use different types of batteries as spare parts in case of replacing of original internal batteries (i.e., due to a fault). This is a need that could come from the variability of prices on the market and from the continuous improvements of technologies in the field of energy accumulators.

Access to the BALIN internal diagnostics and the SW configuration of the parameters mentioned above is possible via RS 485 serial connection present in the signal connector on the BALIN front panel. The communication protocol on RS 485 is standard so it is possible to carry out the actions described above by any PC or external control unit without using any specific tool or interface. The type of communication chosen is simple to use and it allows a standard communication protocol in more BALIN, which can be purchased by different manufacturers.

4. Conclusions

BALIN represents a technical innovation for Trenitalia in the field of 24 V power supply systems on rolling stock. Compared to traditional systems, BALIN is innovative due to its original architecture, which includes a battery charger dedicated solely to the management of its own battery pack: this aspect, as explained in this article, brings significant advantages in the management of battery charge/discharge cycles and in the redundancy against failures in the case of batteries in parallel. The BALIN responds to important needs of a railway operator such as reducing the maintenance cost of the batteries and such as improving the reliability and availability of the 24 V energy, fundamental for the working of the entire carriage. One of the basic concepts on the development of BALIN was also to create a component with defined technical requirements in order to guarantee product standardization, although achievable by different manufacturers. This guarantees the interchangeability between more BALIN produced by different companies introducing many advantages in the maintenance area where the availability of spare parts is always critical. The BALIN installation program consists for now to equip 220 Trenitalia regional transport carriages, part of the planned fleet has already been equipped and the operating give satisfactory results in terms of improving the general reliability of the rolling stock. Given the considerable technical and economic advantages that this device introduces in the rolling stock life cycle and considering its mechanical and electrical characteristics, easily adaptable to different installation area, the BALIN is suitable for use on various types of vehicles, characterized by obsolete 24 V power systems, expensive to maintain and of poor reliability.

References

[1] Grande, G., and Nobili, M. 2018. “Battery with Built-in Power Supply for Trenitalia Vehicles (BALIN).” “TRENITALIA Technical Department,” 04/05/2018.