CREATION OF ACCUMULATION AND STORAGE OF ELECTRICAL ENERGY FOR DRIVERLESS ELECTRIC VEHICLES OF RUSSIAN PRODUCTION

СОЗДАНИЕ СИСТЕМЫ НАКОПЛЕНИЯ И ХРАНЕНИЯ ЭЛЕКТРИЧЕСКОЙ ЭНЕРГИИ ДЛЯ БЕСПИЛОТНЫХ ЭЛЕКТРИЧЕСКИХ ТРАНСПОРТНЫХ СРЕДСТВ РОССИЙСКОГО ПРОИЗВОДСТВА

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Abstract: *In recent years, many researches in the field of electromobile transport using as driverless vehicle are carried out in Russia as in the world. Operation electromobile transport in Russia has specific features, among which are the cold climate and heavy traffic conditions. One of the key elements of the functioning of electromobile transport is an energy storage system, the characteristics of which are highly dependent on how and under what conditions the vehicle is operated. The life of the energy storage system is also adversely affected by high temperature and short overvoltage on its elements. To increase the mileage of vehicles on the electric energy storage provides an improved system design, and in this article the experience of creating such an energy storage system for the driverless vehicle, taking into account including the Russian operating conditions. In the process of creating energy storage system were carried out calculations, mathematical and natural layout the basic elements of the system.*

***KEYWORDS**: VEHICLE, DRIVERLESS VEHICLE, ELECTRIC VEHICLE, THE DRIVE OF THE ELECTRIC ENERGY, ENERGY EFFICIENCY*

1. Introduction

International experience, based on the trends of increasing safety, reducing toxicity and fuel consumption, and, consequently, improve energy efficiency of vehicles, shows the priority of development for the creation of driverless vehicles [1]. In recent years, Russia, as well as studies conducted worldwide, associated with the use electromobile transport as driverless vehicles.

2. Preconditions and means for resolving the problem

Operation electromobile transport in Russia has specific features. The main factor that distinguishes the Russian operating conditions - a cold climate. Russia is located in the vast territory of the Eurasian continent and has a variety of climatic conditions. For the Russian Federation as a whole number of days per year with an average daily temperature of 0 °C or less - an average of 171 days, ie, 47% of calendar time of the year [2]. It should be noted that manufacturers claimed electric performance indicators, in particular the power reserve and the required charging time is often not focused on the realities of Russia, and the Central European climate zone, excellent road and charging infrastructure. At the same time these figures are a measure of the applicability of electric transport in the conditions of everyday life. The above-mentioned Russian conditions will undoubtedly affect the initial stated performance values.

One of the key elements of the functioning of electric vehicle is an energy storage system (high voltage battery), the characteristics of which are highly dependent on how and under what conditions is operated by the vehicle on which it is installed [3]. The Center test "NAMI" were conducted bench tests of the effect of ambient temperature on the operational performance electric car. The electric vehicle Nissan Leaf was taken as the test vehicle. Its electric power is 80 kW, and the capacity of the rechargeable Lithium-battery 24 kWh. At the same time declared maximum cruising range of 160 km. As a result of the test [2] found that the lowering of the outdoor temperature to + 25 °C to minus 7 °C causes a reduction in power reserve of 9% and 44% when consumers.

The challenge of operating energy storage system in terms of working for them is extremely important. Research results depending on the battery temperature gradient [4] shown in Figure 1. As shown, the battery power reaches a maximum when charging in the temperature range from + 20 °C to plus 40 °C. To avoid heat problems and achieve better battery performance, it is necessary to maintain the temperature range that affects the battery and its life cycle.

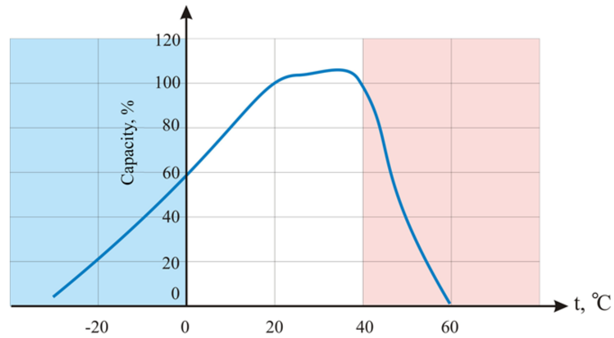

***Fig. 1** Dependence of battery charge on the temperature changes*

To increase the mileage of vehicles on the electric energy storage provides an improved system design, and in this article the experience of creating such an energy storage system for driverless vehicles, taking into account the Russian operating conditions. In the process of creating energy storage system were carried out calculations, mathematical and natural layout the basic elements of the system.

Currently there are many different types of batteries (chemical sources of electrical energy).

Using rechargeable batteries in electric transport places demands on them: a large energy consumption; high rate of resource; relatively low cost [5]. Further, the way these requirements are the main products manufactured and preparing for mass production of the types of batteries (rechargeable battery):

- Traction lead-acid batteries;
- Nickel-metal hydride batteries;
- Lithium - ion battery (Li-Ion);
- Lithium-polymer battery;
- Lithium-iron-phosphate and lithium-iron-phosphate sodium batteries;
- Lithium-cobalt batteries;
- Batteries with lithium titanate anode;
- Battery modified lithium titanate;
- Supercapacitors.

Modern battery systems and electric vehicles with the combined power plants are based on lithium-ion batteries of different types of electrochemical systems.

Comparative characteristics of the main types of battery are shown in Table 1, and the characteristics of the most widely represented in the battery world market are shown in Table 2.

Table 1. *Characteristics of the main types of batteries*

Parameter	Lithium-ion battery ALTAIR–NANO (50 Ah)	lead acid battery	Prism AMP20M 1HD-AA-123 systems	Lithium-ion (modified titanate) SSK
Operating temp. range, °C	–40…+55	+5…+50	–30…+55	–40…+55
Recommended storage temp., °C	–40…+55	–5…+50	–40…+55	–40…+55
Rated voltage, V	2.3	2.0	3.3	3.7
Rated capacity (1C charge / discharge 1C), Ah	50	72	20	25
Weight cell, kg	1,6r	17r	0,496	0,6
Dimensions (LxWxH, mm)	256x259x 13	134x219x 274	245x160x 7,25	227x226x 4,2
Nominal energy, 1C at 25 °C, Wh/kg	72	30	130	254
Life (25°C), year	20	10	15	15
The number of cycles at a charge 2C, a discharge 2C, at 100% depth of discharge at 25 °C	>12000	1500	3000	8000

Table 2. *Characteristics of produced batteries*

Manufacturer	Capacity, Ah	Rated voltage, B	The number of cycles	Specific energy capacity, Wh / kg	Temperature range, C
A123 Systems	20	3,3	≤3000	130	–30/+55
Altair Nano	50	2,3	≤16000	72	–40/+55
Ener1 Battery	16,7/40	3,3-3,7	–	150	0/+45
Dow Kokam	5/200	3,6	>800	125/185	0/+40
Saft Batteries	41	3,2	>1500	136	–25/+60
BYD	40/1000	3,2	>3000	100/120	–45/+85
International Bat	40/160	3,2	>3000	88/97	0/+50
Valence Tech.	40/138	12,8	>2500	19/91	–10/+50
AK Riegel	15/260	3,6	<1000	100/120	–30/+50

When using the battery must take into account the following factors. Modern batteries at nominal operating lithium - reactive element in its pure form is not available, however, when emergency situations (excessive charge or discharge current, short-circuit currents, overcharge or above overcharging below certain voltage levels on batteries) can be allocated to the internal battery electrodes that in certain cases can lead to fire and explosion.

Battery allow the formation of parallel chains of n batteries to provide the necessary capacity. Required battery voltage is provided by a serial connection of individual cells or strings of n parallel-connected batteries. Thus, when connecting the battery by parallel-series connection can construct a given battery capacity and voltage. At the same time, however, each battery or each chain of parallel connected batteries requires strict control. When charging the battery of the series-connected battery charge individual elements is uneven, owing to technological scatter internal resistance of batteries, or an uneven decrease in battery capacity due to aging in service. Batteries with reduced capacity or high internal resistance tend to be large fluctuations of voltage during charge and discharge. When strictly fixed final charge voltage and discharge for a separate battery, increasing from cycle (charge-discharge) to cycle the charge difference will lead to gradually increasing imbalance of battery cells, that is, in fact, a decrease of given capacity [6.7].

Also, during charging and discharging is necessary to protect the battery from overheating. High temperatures and at short overvoltage element can cause a significant reduction in lifetime [8]. Figure 2 shows that the charge element even at 50 mV above the maximum service life decreases to 50% of this for him. Figure 3 shows that the elements discharged more than 80% show a fivefold increase of the internal resistance (milliohms from 0,3 ohm to greater than 1.5 ohm) when the temperature changes from room temperature to 0 ° C.

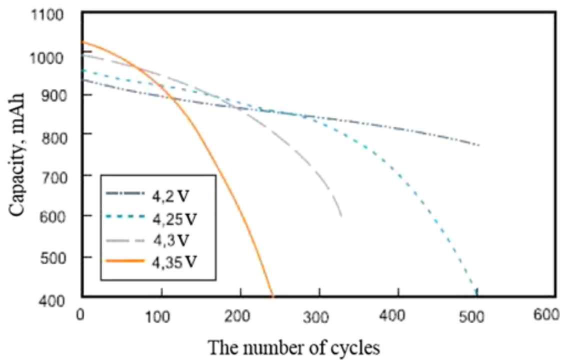

Fig. 2 *The effect of the charging voltage at the battery service life*

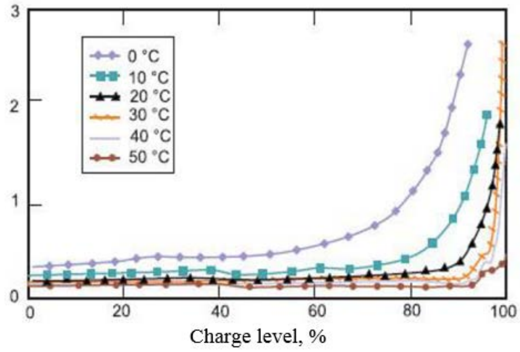

Fig. 3 *The dependence of the internal resistance of the lithium - ion battery temperature and depth of discharge*

Thus, for safety reasons, and improve performance of the batteries should include monitoring and control system, which provides control of the parameters of batteries during the operation of the battery.

Monitoring and control system is compulsorily provide control voltages and battery charge-discharge currents; introduction of other functions is not mandatory, but it can improve the performance of the battery. Alignment voltages of series-connected batteries, the battery allows to operate with the greatest possible impact capacity, capacity calculation system allows the dedicated charging device to control the battery and allows the user to estimate the time remaining until the end of charge or discharge.

NAMI Russian research centre is currently underway to establish an experimental sample of driverless electric vehicle. For the vehicle (Figure 4), and developed the electric power storage system designed for inspection and research developed technical solutions in the field of electric power traction unit, the monitoring algorithms and active balancing of individual batteries and battery, taking into account Russian conditions.

In the process of creating energy storage system were carried out calculations, mathematical and natural layout the basic elements of the system. The use of modern software systems in the development of the battery allows you to automate the design process and perform optimization effectively. Numerical modeling has allowed to determine the required capacity of the energy storage system developed for the driverless vehicle's electric range, which should be at the level of 12 kWh.

Fig. 4 *Appearance a driverless vehicle on electric*

Structural and functional diagram of the developed electric power storage system is shown in Figure 5.

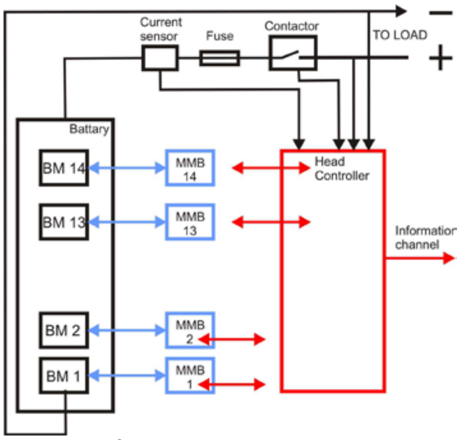

Fig. 5 *Structural and functional power storage system scheme. BM - battery module; MMB - module monitoring and balancing*

The circuit operates as follows. Head controller and MMB are powered by an external power supply of 12 V. When this power head controller polls all blocks MMB and in the absence of extraordinary events include the contactor. Battery ready for use. According to information channel information on the state of individual battery cells, BM temperature and charge level of the battery supplied to external observation device. In that case, if the voltage at the individual battery cells are different by more than 5 mV, the circuit includes an active cell balancing voltage is above average across the battery.

Monitoring and balancing module is built in a modular fashion. Each MMB module allows you to balance up to 12 cells.

To implement the power storage system prismatic batteries AMP20M1HD-A were selected having the following characteristics:

- nominal capacity of 20 Ah (at + 25 °C);
- the specific energy consumption of 130 Wh / kg;
- rated voltage: 3.3 V;
- maximum voltage: 3.65 V;
- the internal resistance of 0.6 milliohms;
- nominal direct current discharge: 3-5S (up to 100 A);
- maximum pulse discharge current: 20C (400A);
- the maximum allowable charge current: 3c;
- service temperature range: - 30 ... + 55 °C;
- the number of working cycles of at least 2000, at 80% depth of discharge.

Developed electric power storage system is comprised of eight modules 12 containing batteries AMP20M1HD-A - only 96 storage locations.

Voltage rating - 316.8 V. The total internal resistance – 0.576 ohm or 0.0576 ohm. The charging current from the on-board charger - 12.5 A. Power battery heat is 9 W.

Lithium batteries, as previously mentioned above have the disadvantage, as the negative effect of increasing the battery temperature during operation with an intense impact on the current period of battery operation. It affects all hybrid and electric cars. At constant overheating, the duration of use of the battery is reduced from 5-6 years to 2-4.

In the design of the power storage system is necessary to determine the need for cooling [9,10].

Calculation of heat energy is advantageously carried out with the assistance of mathematical modeling. For the computational simulation studies the mathematical model of the car VAZ - 1117, taken as a basis for development, developed with battery, used AVL CRUISE package.

According to calculations conducted by Regulation №83 of the UNECE to fast charge mode for cycle developed system power savings without forced cooling, heat up by only 5,0 °C and 2,46 °C respectively. Experience has shown that the resulting heat will be compensated through the housing wall of the battery.

Developed by the original electric power storage system due to new technical solutions for system charge redistribution between the battery cells can significantly extend the life of the batteries, which greatly improves the reliability and cost-effectiveness.

Based on the calculations and analysis of the design features of the construction of electricity storage systems based on lithium batteries, it was carried out development of conceptual design documentation for the experimental model of the power storage system. Figure 6 shows general 3D model developed type power storage systems (without cover).

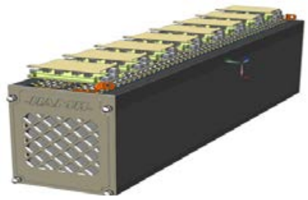

Fig. 6 *3D model of the general form of the developed electric power storage system*

3. Results

On the basis of preliminary modeling of the main functional units and developed design documentation were made experimental rechargeable traction battery module samples in the amount of two copies of the total power consumption of 13 kWh.

The experimental sample of the traction battery module is shown in Figure 7.

Fig. 7 *The experimental sample storage module of the traction battery*

The experimental sample rechargeable traction battery module has a plastic housing. The sides of the body have vent holes. Within each housing 48 placed on the battery cells, each battery cell is mounted in a cradle.

Battery cells are arranged in such a way that a number of positive findings of odd cells are arranged even negative findings. Quality contact had polar conclusions of storage cells provide a copper plate that secure the output terminals and tighten the three screws. One of the screws used to attach information - balancing conductor. The form framework provides a natural convection ventilation. According to calculations, confirmed by the practice of this heatsink is sufficient for normal operation of the battery in the operating conditions of the developed vehicle.

Monitoring and control system battery is placed in the upper part, above the copper contacts. It represents four payment. Each board operates 12 cells. Monitoring and control system battery is shown in Figure 8.

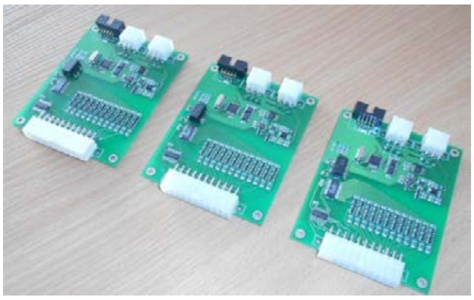

Fig. 8 *Balancing boards*

Designed monitoring and control system battery allows monitoring and balancing of the battery cells, to determine the integrity of the battery state circuits, voltage and cell temperature. The transmission of information takes place in the unit Battery Management System (BMS), which provides communication, configuration and diagnosis of the battery control unit or with a PC via COM port or through the CAN. Designed traction battery module design experimental prototype driverless vehicle provides reliable internal block contacts and the necessary noise immunity control system.

Figure 9 shows an experimental model of a driverless vehicle with the established in the luggage compartment of the traction unit batteries.

Fig. 9 *Experimental model of a driverless vehicle with the energy storage system*

4. Conclusion

Currently, experimental studies of a driverless vehicle with a developed energy storage system, which should confirm or refute the effectiveness of the design of the battery. This scientific study was conducted with the financial support of the state in the face of Russian Ministry of Education, the project unique identifier RFMEF162514X0006.

5. References

[1] John Wiley & Sons Ltd. Encyclopedia of Automotive Engineering, Online © 2014, p.2696.

[2] Terenchenko A., Karpukhin K., Kurmaev R. Features of operation of electromobile transport in the conditions of Russia. Paper of EVS 28 International Electric Vehicle Symposium and Exibition, KINTEX, Korea, 2015.

[3] Slabosritsky R.P., Khazhmuradov M.A., Lukyanova V.P. Studying of battery cooling system. Radioelectronics and informatics, 2012, No.2, pp. 5-8.

[4] Kurmaev R.H., Terenchenko A.S., Karpukhin K.E., Struchkov V.S., Zinov'ev E.V. Maintaining the required temperature of high-voltage batteries in electric cars and hybrid vehicles. Russian engineering research, 2015, vol. 35, No. 9, pp. 666-669.1. S.A.

[5] Karpukhin K.E., Kozlov A.V., Terenchenko A.S., Bakhmutov S.V. Comprehensive life cycle analysis of different types of energy storage for electric or hybrid vehicle. ICAT 2015. Proceeding the international conference on automobile technology for VIETNAM, 2015. pp. 7-14.

[6] Abdullah AL-Refai, Osamah Rawashdeh, Rami Abousleiman. An Experimental Survey of Li-Ion Battery Charging Methods. SAE International Journal of Alternative Powertrains, 2016, No. 5 (1)

[7] Karpukhin K.E., Terenchenko A.S., Shorin A.A. Balancing parameters for a storage battery. Russian engineering research, 2016, vol. 36, No. 2, pp. 86-88.

[8] Karpukhin K.E., Terenchenko A.S., Shorin A.A., Bakhmutov S.V., Kurmaev R.H. Temperature control of the battery for hybrid or electric vehicle. Biosciences biotechnology research Asia, Vol. 12 (2), 2015. P. 1297-1301.

[9] Pesaran A. Battery Thermal Management in EVs and HEVs: Is-sues and Solutions. National Renewable Energy Laboratory. 1617 Cole Blvd. Golden, Colorado 80401. Advanced Automotive Battery Conference. Las Vegas, Nevada, 2001.

[10] Slabosritsky R.P., Khazhmuradov M.A., Lukyanova V.P. Analysis and calculation of battery cooling system. Radioelectronics and informatics, 2011), No.3, pp. 3-8.