

# Features of Creation and Operation of Electric and Hybrid Vehicles in Countries with Difficult Climatic Conditions, for Example, in the Russian Federation

**K Karpukhin, A Terenchenko**

NAMI Russian State Research Center, 2 Automotornaya st, Moscow, Russia, 125438

**Abstract.** The trend of increasing fleet of electric or hybrid vehicles and determines the extension of the geographical areas of operation, including the Northern areas with cold winter weather. Practically in all territory of Russia the average winter temperature is negative. With the winter temperatures can be below in Moscow -30 °C, in Krasnoyarsk -50 °C. Battery system can operate in a wide temperature range, but there are extremes that should be remembered all the time, especially in cold climates like Russia. In the operating instructions of the electric car Tesla Model S indicate that to save the battery don't use at temperatures below -15 °C. The paper presents the dependence of the cooling time and heating of the battery cell at different ambient temperatures and provides guidance on allowable cooling time while using and not thermally insulated thermally containers Suggests using the temperature control on the basis of thermoelectric converters Peltier connection from the onboard electrical network of the electric vehicle.

## 1. Introduction

Personal mobility is a basic need of humans. In 1998, we had a total about 700 million vehicle, but in 2016, we have over 1 billion vehicle in the world. Currently most of the world's automotive countries link the solution of a complex ecological safety and problems of energy saving by regulating CO<sub>2</sub> emissions, as well as increasing adoption in the production of electric vehicles, which can significantly reduce the pollution on the planet. According to forecasts of the European Commission for transport by 2020 in Europe 7 % of all new passenger and light commercial vehicles will be electric, increasing to a massive 31% by 2030. This measure is a forced connection with the sharp deterioration of the situation on the planet associated with air pollution and global warming. The solution of these problems is the creation of electric vehicles, production of which is established in the leading countries of the world.

## 2. Main part

Modern electric vehicle inferior to the vehicle with the internal combustion engine in the range, the absence of a widely developed infrastructure of charging stations and the initial cost. These disadvantages are compensated, by the advantages of this type of transport. The electric vehicle doesn't emit exhaust gases, noise, doesn't require constant and costly maintenance, charging from a household outlet, can make the path of 150 km or more without recharging and doesn't require refueling with petrol. The production of electric vehicles becomes more widespread and almost all automobile corporations have an electric vehicle in their lineup, as a concept or production model.



Today, is very actively developed, green technology. The use of the vehicle environmental product - electricity, instead of non-renewable natural resource of petroleum do electric vehicles really the future of transportation. Thus, it is likely that the electric vehicle will win in the next decade, the auto market and will take on their leading position. Today, when you create energy-efficient vehicles focusing on reducing energy consumption to overcome the resistance movement, the main of which is the force of rolling resistance, the inertial force of the vehicle when the acceleration and the force of aerodynamic resistance. Given the operating conditions of the electric vehicle in the modern metropolis with high density of traffic with frequent cycles of "acceleration- braking", the availability of high capacity battery is inefficient from the point of view of these losses. Regenerative braking, which is used in modern vehicles, the electric traction, when driving in the conditions described does not provide a balance between energy spent on the acceleration and recharged during braking. Of particular importance in the design of electric vehicle, has a choice of type of storage of electrical energy. Modern batteries have several times the best specific characteristics compared to lead-acid batteries (table 1.), however, electric vehicles are inferior to traditional vehicles with internal combustion engine by the ratio of the total mass and transported payloads (1, 2, 3).

**Table 1.** Performance characteristics of various battery chemistries.

Battery type	Theoretical				Practical	
	$V_{\max}$	Charge Capacity Ah/g	Energy Density Wh/kg	$V_{\text{nom}}$	Energy Density Wh/kg	Energy Density Wh/L
Lead-acid	2,1	0,12	252	2,0	35	100
NiCd	1,35	0,181	244	1,2	40	90
Ni-MH	1,35	0,178	240	1,2	80	220
Li-NiCo	4,1	0,109	448	3,8	200	420
IMR	3,5	0,122	426	3,0	150	400
LiFePo4	3,65	0,111	405	3,4	115	255
LiTiO	2,8	0,09	252	2,5	75	150
Li-S	2,5	0,341	950	2,15	400	365

As already mentioned, one of the key drawbacks that prevent the widespread use of electric vehicles is the limited mileage (4). The existing problem is difficult to solve the increase in battery capacity, as it leads to increase the cost of the vehicle and the weight gain that, in turn, increases the consumption of energy to overcome forces of resistance. In addition, the bigger battery has a long charge time (up to 7-8 hours). This circumstance is compounded, if the electric car is operated in difficult climatic conditions in countries where winter air temperature is negative from 0 °C to -30 °C.

The climatic conditions of the Russian Federation are among the harshest in the world. For example, in Moscow, winter temperatures can be -30 °C, and in Irkutsk -50 °C. The Russian Federation has a vast territory and long distances between cities. Lithium-ion battery systems can work in a fairly wide range of temperatures, but there are extremes that should be remembered all the time, especially in countries with challenging climates like Russia. The inherent disadvantages of electric vehicles, superimposed on the climatic features of the countries with a difficult climate, and exacerbate the problems hampering the popularization of electric vehicles.

Negative consumer characteristic of all lithium batteries is that they are very poorly adapted to sub-zero temperatures. As a rule, they allow for discharge at temperatures below -10...-20 °C (with reduction of capacity and a given current), and the charge is only at a positive temperature. Batteries suffer from the cold due to the fact that the electrolyte, which is a conducting substance, the electric battery and provides power transmission between positive and negative pole, in the cold weather thickens, and electrochemical processes in the battery slower. Poor conductivity of the electrolyte increases the internal resistance of the battery system, which produces much less energy (5).

Li-ion batteries are quite well charged with a small positive temperature, and also can be put on a fast charge at a range of temperatures from +5 to +45 °C. Process charge and discharge is well to

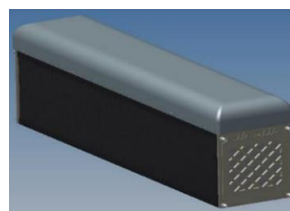
proceed at the highest allowable temperatures (up to +45 °C), but this reduces the lifetime of the battery (6, 7). At temperatures below +5 °C, the charge current must be lowered. The charge is not valid at temperatures below 0 °C, in this case the external changes are observed, but the chemical processes necessary for the correct operation of the battery will be compromised, which could lead to permanent damage to the battery. During charging, at this temperature, the particles of lithium metal can be transferred to the anode, and this coating is not lost during the cycles of charge/discharge (8, 9). The batteries with such a coating become less resilient and can fail under vibrations.

In the NAMI Russian State Research Center for many years works on creation of electric vehicles, adapted to the difficult climate, and explores its nearest competitor. On the roads of avtopolygon NAMI has conducted tests electric vehicle Nissan Leaf (Japan) (10, 11). The aim of experimental researches was to determine the influence of climatic and road conditions on the power reserve of the electric vehicle Nissan Leaf (according to the manufacturer the length of mileage on a single charge of the electric vehicle Nissan Leaf is 160 km). A significant factor influencing the reduction in mileage is higher energy consumption during the winter period of operation, due to the necessity of heating the passenger space and increase the duration of lighting due to short daylight hours. Studies have shown that decreasing ambient temperature from +25 °C to -7 °C causes a decrease in the power reserve at 9% and 44% respectively when turned off and on the consumers of energy. With further decrease of the ambient temperature and when the consumers power reserve of electric vehicles was reduced to 50 km. When driving on loose snow with a power reserve of 14% less than when driving on dry asphalt.

Currently, in the NAMI Russian State Research Center created the experimental model of a driverless electric ecovehicle with system energy storage (figure 1 and figure 2).



**Figure 1.** Driverless electric ecovehicle.



**Figure 2.** 3D model of system energy storage.

On this vehicle was implemented the experimental system of electric energy storage, intended for validation and investigation of engineering solutions in the field of ensuring of electric energy of the traction module, implementation of algorithms for monitoring and active balancing of single batteries battery adapted to climatic conditions of Russia. The unit for monitoring and balancing is built on a modular principle. Each module allows you to balance up to 12 cells and consists of 2 circuit boards, designed to work with battery from 100 to 400V. BCB LT, which serves all elements relating to the low-voltage parts, and PCB transformers, which connects to the entire capacity of the battery. The system of accumulation of electricity consists of 96 battery cells. Nominal voltage — 317V.

When designing the system of energy storage based on lithium cells was taken into account the negative impact of raising or lowering the temperature of batteries in operation with intensive current impact on the operating period of the battery. In the summer, when the weather is hot, even a simple trip through the city leads to the fact that lithium batteries are heated, and their temperature may exceed the critical value lying in the range +60 ÷ +70 °C. In winter the situation is similar, because the temperature below - 5 °C affect the mileage of the electric vehicle and the durability of its battery.

Experimental system of accumulation of energy was developed taking into account the use in difficult climatic conditions of the Russian Federation and was equipped with a system thermostatics. Calculations were made with the battery in stationary mode with constant current.

Thermal power generated in the battery is calculated by the formula 1:

$$P = I^2 r_{ac} = 12.5^2 \times 0.0576 = 9 \text{ W} \quad (1)$$

where: I – charging current;  $r_{ac}$  – accumulator cells total impedance.

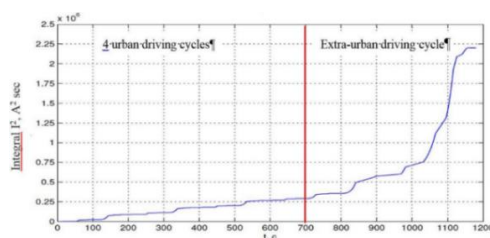
Thus the heat dissipation of the battery during the charge mode will be 9 watts. When charging from an external charging device allowed charging current of 63 A. In this case, the power dissipation of the battery, will be 228.6 W.

Also was calculated the value of the temperature of the battery at the end of the cycle the full charge current of 63 A, on the Duration of this cycle is 1143 seconds. Specific heat capacity of lithium – ion batteries is evaluated with a = 1.1 kJ/kg\*<sup>0</sup>C. The temperature increment for our case is calculated using the following relationship:

$$\Delta T = \frac{P \cdot t}{c \cdot m} \quad (2)$$

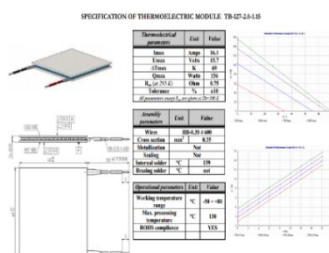
where: P - the heating power, is equal to 228.6 W; t – the duration of the charge, t = 1143 sec.; c - specific heat capacity of lithium – ion batteries; m - the mass of the batteries.

In the result, we find that  $\Delta T = 5^{\circ}\text{C}$ . Thus, during fast charge temperature battery storage system electricity will increase by  $5^{\circ}\text{C}$ . In both operating modes, i.e. in modes of vehicle movement, the calculation of energy dissipation it is advisable to conduct involving mathematical modeling. For conducting computational research of mathematical simulation of the vehicle model VAZ - 1117, taken as the basis for design of the battery, used the software package AVL CRUISE. The required information can be obtained at a design research integrated current values or the square of the current over the cycle. Figure 3 shows the curve of the integral value of the square of the current of the battery, built on a full cycle, according to the UNECE Regulation No. 83.



**Figure 3.** The curve of the squared accumulator battery current integral value on the full cycle, according to the UNECE Regulation # 83.

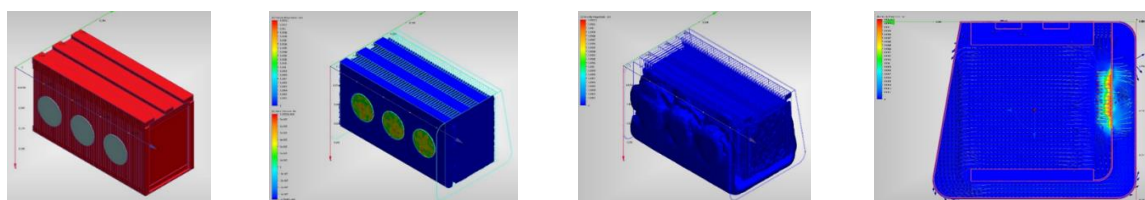
According to the results of calculations and research, it was decided on the placement of the experimental storage system in insulated container with temperature control system. Temperature control system based on the use of Peltier elements. To ensure compensation of heat transfer was selected for the Peltier module, type TB-127-2.0-1.15 ensuring required temperature in storage tanks at a temperature of exposed surface at  $+30^{\circ}\text{C}$ , the main characteristics Peltier module presents on a figure 4.



**Figure 4.** Specification of thermoelectric module TB-127-2.0-1.15.

Using this module allows you to provide temperature control of the battery in this mode of operation level  $+20 - +25^{\circ}\text{C}$ . Temperature control system, is powered by the onboard battery voltage of 12 V. In case of temperature increase in the battery above the desired, i.e. above  $+20^{\circ}\text{C}$ , the block enable control signal U on. The signal U± is absent. Turn on the fan and the Peltier element in the cooling mode. The inclusion continues until the temperature falling below  $+20^{\circ}\text{C}$ . If in conditions of low external temperatures the temperature of the battery decreases below  $+10^{\circ}\text{C}$ , the control unit battery are formed from U on; U± and the Peltier element is switched on in heating mode. The fan also

turns on. Next, the process continues as before, heating the battery module to achieve the desired temperature. The advantage of Peltier element is small, the absence of any moving parts, gases and liquids. When the direction of the current, possibly as cooling and heating, enabling temperature control at ambient temperatures both above and below the temperature of the temperature control. Were also conducted thermal and gas-dynamic calculations of the application. It is possible to find the optimum layout of the battery module. The problem of gas-dynamic calculation was resolved with the use of a complex of programs allowing to perform solid modeling, and the integration of the air flow by the finite element method. Figure 5 shows how the currents of air near the fans, are distributed without significant turbulence, which suggests that the chosen arrangement minimized the effect of the surge.



**Figure 5.** Visualization of airflow near the fans.

As a result, of carried out experimental research into the behavior of two battery modules. In this case, the module number one had an inner insulating coating and an integrated device for temperature control is built on a ventilated thermoelectric Peltier converters, and the module number two hadn't insulation coating. Tests of the two battery modules is presented in figure 6.



**Figure 6.** Climatic testing the experimental system of accumulation of energy.

An experimental study showed that the accumulator unit, which had an inner insulating coating and built-in temperature control device was subjected to cooling in a heat chamber at a temperature of  $-30\text{ }^{\circ}\text{C}$ . During the cooling process, temperature control system is included for heating the internal volume of the container. After the temperature is established to a predetermined level, and the cooling process inside the battery module from ambient temperature to a predetermined temperature lasted about seven hours, the power supply system of temperature control was 69 watt, including the energy consumed by the fan. This coincides with the calculated value for the required heating and shows that in the heating mode thermoelectric Peltier work together effectively. The temperature inside an insulated module maintained at  $+17\text{ }^{\circ}\text{C}$  -  $+20\text{ }^{\circ}\text{C}$ , all battery cells are charged evenly at a temperature in the heat chamber  $-30\text{ }^{\circ}\text{C}$  and applying a charging current of 120 A. In the module that had no insulation coating of any abnormal phenomena in the process of heating or cooling the battery cells not shown, however, when the temperature of the battery module below  $-10\text{ }^{\circ}\text{C}$  the charge of the cells was absent. Reviewed the processes of charge at  $0\text{ }^{\circ}\text{C}$  and  $+5\text{ }^{\circ}\text{C}$ . After a long exposure, about 7 hours, at these temperatures revealed that at  $0\text{ }^{\circ}\text{C}$  the charge current 5A cells was perceived in different ways, and some of the cells, about 8% of the total, the charge was not accepted. At temperatures above  $+5\text{ }^{\circ}\text{C}$ , all cells charged evenly.

### 3. Results and Discussion

The results of the study allow to formulate the main aspects of ensuring the effective functioning of the battery systems of electric vehicles and vehicles with a hybrid powertrain in difficult climatic conditions. Operation not protected against ambient temperatures below  $+5\text{ }^{\circ}\text{C}$  accumulator systems

are not desirable, as leading to accelerated degradation of the batteries. Vehicles containing an insulated battery system, allowed to leave at negative external temperatures for a limited time, decreasing with decreasing temperature. Prolonged Parking is permitted in the conditions of heated rooms or when using independent heating. When implementing independent heating battery systems, for example, by using thermoelectric converters Peltier, daily power consumption is at  $-30^{\circ}\text{C}$  of not less than 1.6 kWh. Therefore, if the long Parking time is not known, and electric cars with a hybrid powertrain must be connected to a stationary power grid, or in vehicles with a hybrid powertrain to provide periodic startup to warm the engine and recharge the battery system.

#### 4. Conclusion

- (1) Claimed by the manufacturers of electric vehicle operational performance, in particular range and required charging time of the batteries, often aren't focused on the country's complex climate, and to the middle European climate zone, excellent road and charging infrastructure.
- (2) Operation not protected against ambient temperatures below  $+5^{\circ}\text{C}$  and above  $+50^{\circ}\text{C}$  battery systems is not desirable, as leading to accelerated degradation of the batteries.
- (3) Vehicles containing an insulated battery system, allowed to leave at negative external temperatures for a limited time, decreasing with decreasing temperature. Prolonged Parking is permitted in the conditions of heated rooms or when using independent heating.
- (4) When implementing independent heating battery systems, for example, by using thermoelectric converters Peltier, daily power consumption is at  $-30^{\circ}\text{C}$  of not less than 1.6 kWh. Therefore, if the long Parking time is not known, hybrid and electric vehicles must be connected to a stationary power grid or hybrid vehicles to provide periodic startup to warm the engine and recharge the battery system.
- (5) Developed temperature control system of energy storage devices designed for hybrid and electric vehicles operating in difficult climatic conditions. Practical application of the developed principle of temperature control enables operation of the rechargeable battery in the most favorable temperature range  $20\pm 30^{\circ}\text{C}$ .

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