

## Production of the Electric Vehicle Experimental Prototype with the Range Extender

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**This paper proves the expediency of the vehicle developmental prototype use with a Range Extender unit and touches upon its production. It contains layout solutions for mounting of the engine-generator unit, thermostating systems and electric energy storage of the vehicle, as well as describes in details the developed principal scheme of the liquid cooling system.**

**Key words:** Experimental prototype, Electric vehicle, Hybrid vehicle, Combined power unit, Range Extender, Electric energy Accumulation and storage system, Thermostating system.

Ecological cleanliness and fuel efficiency of vehicles become a key problem of development of modern automotive industry. Large amount of developed countries introduce government programs on development of non-polluting and efficient transport. There is an increasing demand for effective and non-polluting vehicles. As a rule, such vehicles have an electric drive. Such vehicles include electromobiles and hybrid vehicles (Bakhmutov and Karpukhin, 2012, Zvonov *et al.*, 2001, Luksho *et al.*, 2015).

Today a competitive and comparatively non-polluting vehicle may be designed following the scheme of a hybrid power unit, which includes

an internal combustion engine, an electric engine, a voltage converter and an energy storage unit (accumulator batteries of various electrochemical systems, supercondensers, hydrogen fuel cells, etc.)<sup>3</sup>.

Research proves technical and economic expediency of creation of the vehicle with the combined power unit, which is more ecologically friendly and 5-10 % more efficient than the vehicle with an ICE.

### **The main part**

The State Research Center of Russian Federation FSUE “NAMI” conducts applied scientific researches on the topic “Development of the combined power unit in vehicles with algorithms of interaction of the basic elements, providing enhancement of their total power efficiency”.

A serial production electric vehicle VAZ 1817 ELLADA of the “AutoVAZ” (Picture 1) was

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taken as a basic model for designing a vehicle with the combined power unit.

This is a small class vehicle developed on the basis of a serial model of VAZ 1117 KALINA, with the station wagon body type. As the traction engine, this vehicle has an asynchronous electric machine with the liquid cooling, located in an engine compartment in the front part of a body, transversely to the longitudinal axle of the vehicle. The front traction wheels drive is performed by electric machine via the two-stage cylindrical constant mesh reducer which is the final drive with rigid kinematic connection via a differential with traction wheels' hubs by means of two drive shafts



**Fig.1.** Electromobile VAZ 1817 ELLADA

of different length with constant velocity joints on both sides for maintenance of combined work of a drive, a suspension and steering control. (Terenchenko *et al.*, 2015, Kurmaev *et al.*, 2015, Shorin *et al.*, 2013).

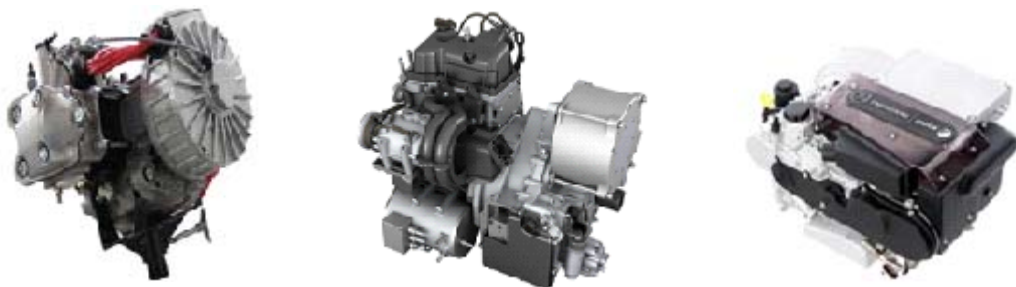
Units of suspension, steering control, brake control are identical to that of the basic VAZ 1117 KALINA vehicle. As a traction accumulator battery, the blocks of accumulator cells located in front and rear parts of a body were used. The first block of accumulator cells (Picture 2a) is located in the engine compartment, directly above the traction electric machine in the special case made of sheet metal.

The second block is in the special niche in a body floor, located under a rear passenger seat. The third block is also located in the special niche behind a rear passenger seat, in front of a spare wheel compartment. The position of the second and third blocks of accumulator cells is shown in the Picture 2b.

An engine-generator unit increasing the electric vehicles driving range without rigid kinematic connection with the vehicles driving axle and globally known as the "Range Extender" was



**Fig.2.** a) the first block of accumulator cells; b) position of the second and the third blocks of accumulator cells



**Fig. 3.** Examples of Range Extender units

used as a combined power unit on this vehicle. Due to the fact that development of Range Extender units is one of the promising directions of the automotive industry development, works on creation and further improvement of these units are actively conducted in many economically developed countries, such as USA, Germany, UK, France etc. (Andert *et al.*, 2012, Noga, 2013, Gage and Bogdanoff, 1997). This unit consists of an internal combustion engine having a small operating volume and an electric machine operating in a generator mode. Examples of such units are shown in the Picture 3.

One of the advantages of this unit is its' small overall dimensions, allowing to use different variants of its configuration on the chassis of small class electric vehicles.

The DSM200300-S 6L04Y model was chosen on the basis of the data obtained when performing a calculation and as a result of the conducted analysis of market offers on the engine - generator units. The supplier of the engine - generator unit is DSM Green Powar Co. This unit comprises an engine QR372 and a generator 20 kW/270V. Overall dimensions of this unit are shown in the Picture 4.

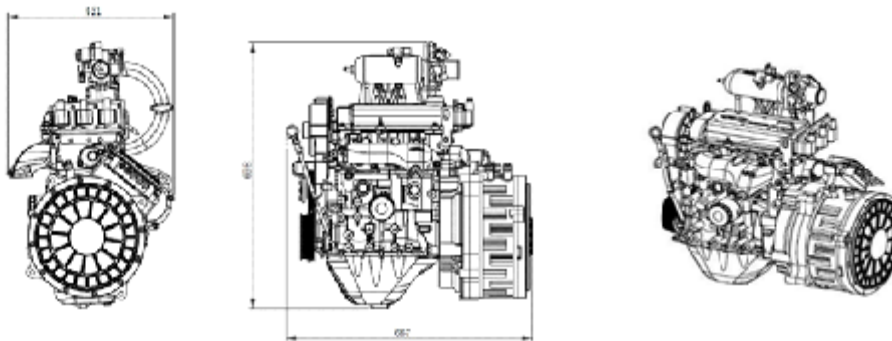
The engine-generator unit has a transverse position in a trunk of the vehicle's body on a place of the removed compartment for spare wheel storage (Picture 5).

It is mounted on a special sub-frame that is fixed with four elasto-kinematic supports to the load-bearing elements of the rear part of the vehicle's body (Picture 6).

The unit is separated from the vehicle's interior by the special partitions equipped with thermal insulation materials.

The electric energy storage system with thermostating system (Picture 7) was developed for the experimental prototype of the vehicle with the Range Extender unit. Picture 7 – the electric energy accumulation and storage system with thermostating system (1 – case of accumulator batteries; 2 – lithium-ion cell Winston LYP90AHA; 3 – copper junction plate; 4 – radial fan SPAL VA32 - Å100-62S; 5 – Peltier element). (Slabosritsky *et al.*, 2011; Slabosritsky *et al.*, 2012, Slabosritsky *et al.*, 2013, Kim and Pesaran, 2006, Pesaran, 2001).

The following preparation works were conducted before installation of the electric energy storage system with a system of thermostating of electrical energy storage units for the vehicle's



**Fig. 4.** Engine-generator unit DSM200300-S 6L04Y and its overall dimensions.

**Table 1.** Technical specifications of the engine-generator unit DSM200300-S 6L04Y

|                                   |                                  |
|-----------------------------------|----------------------------------|
| Type of fuel                      | Gasoline e" 90                   |
| Type of lubricant oil             | 10W/30 of the SAE classification |
| Nominal voltage (DC)              | 270Å DC                          |
| Maximum capacity (kW)             | 20kW                             |
| Fuel efficiency (min)             | 0,5l/kW/h                        |
| Dimensions of generator unit (mm) | 667x451x698                      |
| Weight of generator unit          | <135kg                           |

combined power units under development:

- The system of the vehicle cooling is adapted, liquid lines are laid on a new trajectory;
- The vehicle's electric wiring is adapted, high-voltage wires are laid in new directions, their length and system of fixation are modified as well. The overall view of the underhood space with the developed electric energy storage system is shown in the Picture 8.

The principal diagramme of liquid cooling system was developed for the Range Extender system within the vehicle<sup>6,7</sup>. The overall view of the principal diagramme of the liquid cooling system is shown on the Picture 9.

The distinctive feature of this system is the presence of two independent cooling circuits. The first circuit consists of a cooling subcircuit of the Range Extender unit and a cooling subcircuit of the electric machine.

**Structure of the first circuit includes:**

- A liquid-air radiator with a fan, providing drop of thermal emissions from an ICE and an electric machine;
- An electric liquid pump providing the constant coolant flow through components;
- Three taps with remote adjustment of the coolant flow productivity;

- An expansion tank.

The second circuit consists of a cooling subcircuit of the inverter and a cooling subcircuit of the onboard charger. Such system provides maintenance of the temperature mode set in technical specifications regardless of the work of power components and systems of the vehicle.

**Structure of the second circuit includes:**

- A liquid-air radiator with a fan, providing drop of thermal emissions from an ICE and an electric machine;
- An electric liquid pump providing the constant coolant flow through components;
- Three taps with remote adjustment of the coolant flow productivity;
- An expansion tank.

Both liquid circuits have bypass circuits (in remote adjustment taps) that provide minimum coolant flow when revealing failures in the mode of constant thermal condition of components. Adjustment of the temperature mode of the vehicle's components on electric traction is performed by means of modification of a liquid flow and an airflow in the main radiator in the automatic mode.

In order to analyze the composition of electronic and electric components of the basic



**Fig. 5.** Position of the Range Extender in the vehicle



**Fig. 6.** Mounting of the subframe to the load-bearing elements of the body



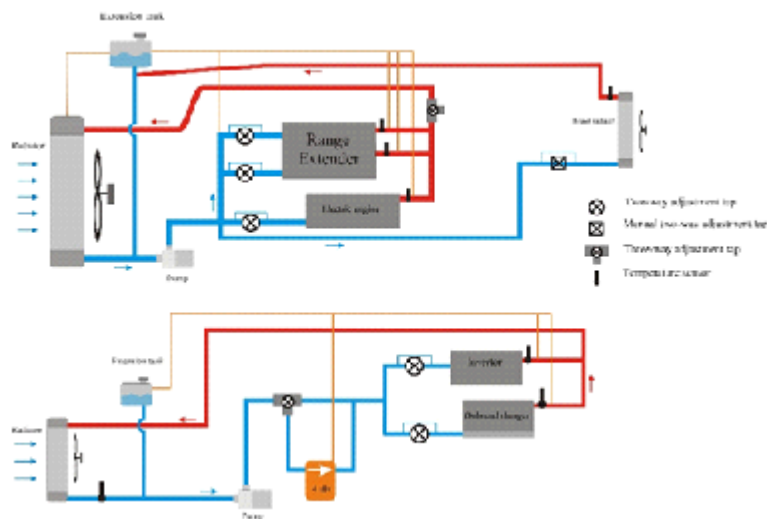
**Fig. 8.** Electric energy storage system in the underhood space of the vehicle's experimental prototype

vehicle, its partial dismantling was performed. The traction electric three-stage asynchronous engine transfers the torque to the traction wheels by means of the two-step cylindrical constant mesh reducer, which is the final drive. The engine's nominal capacity amounts to 30kW, maximum torque – 240 N·m

### Summary

In the course of the performed work on production of the vehicle's experimental prototype with the combined power unit that includes Range Extender the following results were achieved:

- Reduction of fuel flow within 5 - 10 % in comparison to the already existing analogues of



**Fig. 9.** Principal diagramme of the Range Extender cooling system

means of transport with a combined power unit;

- Compliance with ecological regulations no lower than EURO 5;
- Nominal operation mode of the electric engine – continuous S1;
- Maximum speed of the vehicle no less than 130 km/h;
- Recuperative braking on speed no less than 40 km/h with energy recuperation

Special attention was given to the development of the principal scheme of the liquid cooling of the Range Extender unit system within the vehicle. The experimental prototype is fully prepared for analyzing the algorithms of interaction between the basic elements of the combined power unit as well as conducting further complex tests.

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