Creation of a Driverless Electric Cargo Vehicle with a Modern Energy Storage System

K Karpukhin\textsuperscript{1} and A Terenchenko\textsuperscript{1}

\textsuperscript{1} NAMI Russian State Scientific Research Center, 2 Automotornaya st, Moscow, Russia, 125438

E-mail: K.Karpukhin@nami.ru

Abstract. The paper describes development of an experimental cargo electric vehicle equipped with automated driving features. The focus is made on the powertrain design. In particular, a description of the electrical system is given detailing its modular design. The latter allowed for convenient arrangement of the units and devices intended for energy storage and feeding of high voltage and low voltage components of the traction system and auxiliary systems of the vehicle. The bulk of the paper describes the key features of the design process beginning with CAD models, from which the vehicle chassis and the powertrain were designed, proceeding to selection of the powertrain components, and concludes with the description of the vehicle produced in accordance with the elaborated design. The paper also gives a survey of automatic driving functions being implemented within the vehicle at the present stage of development, including path tracking, lane keeping, keeping safe distances to surrounding objects, and some others.

1. Introduction

Personal mobility is a basic need of humans. In 1998, we had a total about 700 million vehicles, but in 2019, we have over 1 billion vehicles in the world. Hybrid and electric vehicles developed differently in the last 30 years, but they had hard way into the market. 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 [1, 2, 3].

Nowadays, the share of electric vehicles in the global fleet constitutes 1-2\%. Great Britain and France have declared the ban for the gasoline and diesel vehicle sales would be introduced by 2040. The similar announcement was made by the Ministry of Industry of China, which is conducting researches of this issue. In the same time, China has intention to become the world leader in production of electric vehicles.

The main obstacle preventing electric vehicles from large scale commissioning is the cost issue. Prices of “low-budget” passenger EVs start from $30 000, not to say about commercial EVs, which are far more expensive. Meanwhile their conventional counterparts are at least twofold cheaper.

Expert estimates suggest that electric vehicles will be able to compete with conventional ones when the kilowatt per hour price of lithium ion batteries drops from current $250 (and above) to $100. In the expert opinion, this should happen by 2026. Note that back in 2010 the kWh price was $1000. Other complications also exist. The charging infrastructure is far from mature; battery price drop may be
slower than expected; the governmental policy may change. For example, the Chinese government
imposed a ban for foreign investments in the production of lithium ion accumulators and the most
valuable components thereof, i.e. cathodes.

The Russian EV market and fleet are still small – statistical data states that by 1 March 2019 only
3600 electric vehicles were in commission. Unlike China, EU and USA, the Russian ecology policy
doesn’t provide sufficient stimulating measures in respect of EV. Buyers and owners of electric
vehicles aren’t granted with decent privileges. As a result, the demand for electric vehicles is small
entailing low production volumes as well as high prices thereof. Another issue complicating the
expansion of EV in Russia is specifics of regional climate. In some regions, air temperature may vary
from -40 to 40°C throughout the year [4, 5, 6].

Despite these complications, Russian vehicle manufacturers conduct R&D projects in order to
advance EV technology into the market. One of such projects is conducted by NAMI Russian State
Scientific Research Center in collaboration with a vehicle manufacturer “KAMAZ”. In this project, a
heavy-duty electric vehicle is being developed having state of the art electric storage system and also
equipped with automated driving features. The sequel of this paper describes the powertrain of this
vehicle and gives a survey of automated driving features being implemented within the vehicle at the
current stage of the project [7, 8].

2. Powertrain design of the experimental electric vehicle

The traction electric drive was integrated into the mechanical transmission and mounted on the chassis
“KamAZ-4308”. Figure 1 shows a model of the chassis including the powertrain, which consists of the
electrical system (1), and the traction electric motor (2) connected to the driving axle (4) by a cardan
shaft. The axle 5 is of driven type. All the components are mounted on the chassis frame 3.

![Figure 1. The chassis of the experimental electric vehicle.](image)

The said electrical system is shown in figure 2. It includes the traction battery (1) organized in
modules, the battery charger (2) with the plug socket (3), high voltage (4) and low voltage (5) power
electronics. It also includes a number of voltage converters for feeding the auxiliary systems. In
particular, DC/AC converter 6 feeds the motor driving the air compressor. DC/AC converter 7
provides energy supply to the system responsible for thermal regulation of the powertrain components.
One of the DC/DC converters 8 feeds the electric motor driving the pump of the power steering
system. Other converters 8 provide power supply for the low voltage components of the thermal
management system, low voltage part of the traction electric equipment, and other auxiliary loads of
the vehicle. All the components of the electric system are installed within the common frame. The
latter and the modular design of the electrical system allow assembling of this system independently
from the vehicle chassis. In turn, this allows for minimal complexity of the assembling process and technological tools employed, thus entailing reduced assembling time.

Figure 2. Design of the modular electric system.

The used traction electric motor TM4 SUMO HD (figure 3) is a permanent magnet electric machine with 195 kW continuous power and 2060 Nm continuous torque. The motor is mounted on the chassis frame by means of additional cross-members. The inverter is placed between the traction motor and the battery on the specially designed cross-members.

Figure 3. Traction electric motor (TM4 SUMO HD).

The traction battery consists of three modules, whose characteristics are listed in Table 1. The traction battery modules are placed in the bottom of the frame. This allows for lowering the vehicle center of gravity, which is relevant for reducing risk of rollovers. In order to prevent harmful impact of the environment and road unevenness, the battery modules are installed on a metal platform providing protection thereof [9].

The charging device (EVO22KL) implements an interface of the traction battery with the standard electric grid 220V/50Hz. The charger location provides an easy access to the device for performing
maintenance operations. The casing of the charging device ensures protection level complying with IP56 rating.

Design of the described vehicle implies no cab since it is supposed to operate either in automated or remote-controlled mode. The vehicle was constructed and equipped with the described electric powertrain. Figure 4 shows a general view of the vehicle.

Table1. Specification of the traction battery and its modules.

| Manufacturer | Microvast |
|--------------|-----------|
| Model, number of modules | MV-B, 2  
                   MV-C, 1 |
| Battery voltage, V | 437-680.5 |
| Energy content, kWh | 75.5 |
| Dimensions of the module, mm (WxHxD) | 1060x240x660  
                   820x240x660 |
| Life span of the battery (20% capacity drop) | 300 000 km, 8 years |

Figure 4. The developed autonomous electric vehicle.

3. Automated driving functions implemented within the experimental vehicle

The following automated driving functions are being implemented within the described vehicle [10]:

- tracking of a predetermined path;
- tracking of specified speed and keeping safe distances between the vehicle and surrounding objects;
- automatic braking preventing collisions with obstacles, automatic emergency braking;
- electronic stability control and rollover prevention;
- recognition of traffic signs and lane markings;

The path-tracking feature provides an automatic control of vehicle directional motion based on data received from the machine vision tools (cameras and radars) and/or from the navigation system. The way of using these data sources depends on the visibility of lane markings. Allowed deviation of the vehicle from the lane center is 0.5 m. The operating velocity range of the feature is 1-25 km/h.

Velocity tracking, distance keeping, and automatic braking functions operate within the same velocity range as the path tracking. The factors taken in account by these functions are speed limits established within the operational domain of the vehicle and obstacles detected in the heading direction of the vehicle. The automatic emergency braking feature activates when the vehicle control
system detects a fault considered critical in respect of driving safety. In that case, vehicle decelerates at a moderate constant rate (not exceeding 2 m/s²) until the full stop, turning on the hazard flashers.

The stability control feature prevents excessive understeering and oversteering of the vehicle while maneuvering (e.g. negotiating a turn). In order to do this the feature employs the regenerative braking system regulating the vehicle speed and yawing moment exerted by the driving wheel tire forces. The feature also prevents the driving wheels from excessive slip, thus providing sufficient reserve of the lateral tire force during directional maneuvering.

4. Conclusions and future work
The described electric vehicle has been constructed in accordance with the elaborated design of the chassis and powertrain. A distinctive feature of the developed powertrain is the electrical system with a modular structure. This system provides an energy storage for both traction needs and feeding of the onboard auxiliary systems. Interfaces between the components with different voltage levels and forms were implemented by means of DC/DC and DC/AC converters included in the said electric system. At the current stage of the project, the automated driving functions are being implemented within the vehicle controller. The next stage implies testing of the vehicle with respect to functioning of the powertrain and the automatic driving features.

5. References
[1] Miller M J 2010 Propulsion systems for hybrid vehicles 2nd Edition. UK: The Institution of Engineering and Technology.
[2] International Energy Agency. Hybrid and Electric Vehicles M. The Electric Drive Chauffeurs, 2017.
[3] 2014 Encyclopedia of Automotive Engineering M. John Wiley & Sons ISBN: 978-0-470-97402-5 Online.
[4] Terenchenko A, Karpukhin K, Kurmaev R 2015 Features of operation of electromobile transport in the conditions of Russia J. Paper of EVS 28 International Electric Vehicle Symposium and Exhibition, KINTEX, Korea.
[5] Gaines L, Cuenca R, Life-Cycle Costs of Lithium-Ion Vehicle Batteries 2000 J. SAE Technical papers 2000-01-1483.
[6] AL-Refai A, Rawashdeh O, Abousleiman R 2016 An Experimental Survey of Li-Ion Battery Charging Methods J. SAE International Journal of Alternative Powertrains, 5 (1).
[7] Kulikov I.A., Shorin A.A., Bakhmutov S.V., Terenchenko A.S., Karpukhin K.E. 2016 A Method of Powertrain's Components Sizing for a Range Extended Electric Vehicle. J. SAE Technical Papers 2016-01-8096.
[8] Singh S, Mathur A, Das S, Sinha P, et al 2017 Development of Smart Public Transport System by Converting the Existing Conventional Vehicles to EV's in Indian Smart Cities. J. SAE Technical Papers 2017-01-2011.
[9] Shorin A A, Karpukhin K E, Terenchenko A S, Kondrashov V N 2018 Traction module of cableless unmanned cargo vehicles with electric drive J. International Journal of Mechanical Engineering and Technology 9 (11) 1903–1909.
[10] Ramesh K., Siddhesh N., Kundan S., Deepak V. 2013 Data Acquisition System And Telemetry System For Unmanned Aerial Vehicles For Sae Aero Design Series. J. International Journal of Electronics and Communication Engineering & Technology 4 (5), pp. 90-100.

Acknowledgments
The paper was prepared under the agreement # 14.624.21.0049 with the Ministry of Education and Science of the Russian Federation (unique project identifier RFMEFI62417X0049).