Researcher Links UK-Russia Workshop

Scientific and Technical Grounds of Future Low-Carbon Propulsion

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Hybrid minibus development

Oleg Chudakov

Bauman Moscow State Technical University (BMSTU)

RUSSIA, MOSCOW

Northumbria University NEWCASTLE

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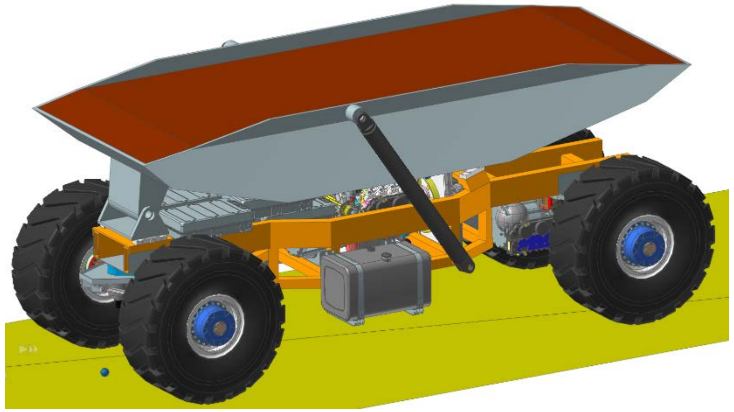
Bauman Moscow State Technical University, Department "Wheeled vehicles"

Electric bus LiAZ-6274

KamAZ Arctic

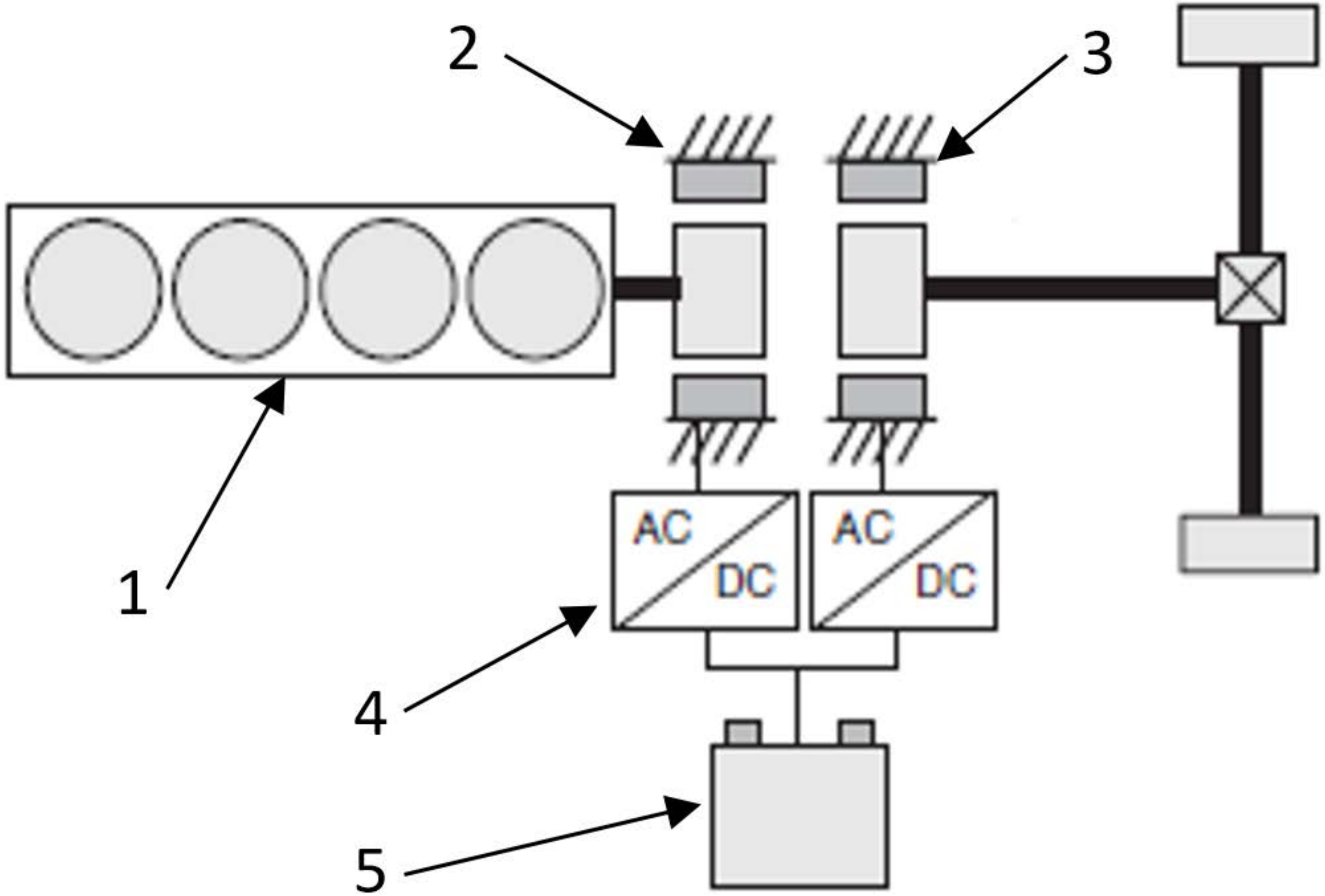


Self-driving KamAZ Dumper

Electric Quad Bike and Snowmobile

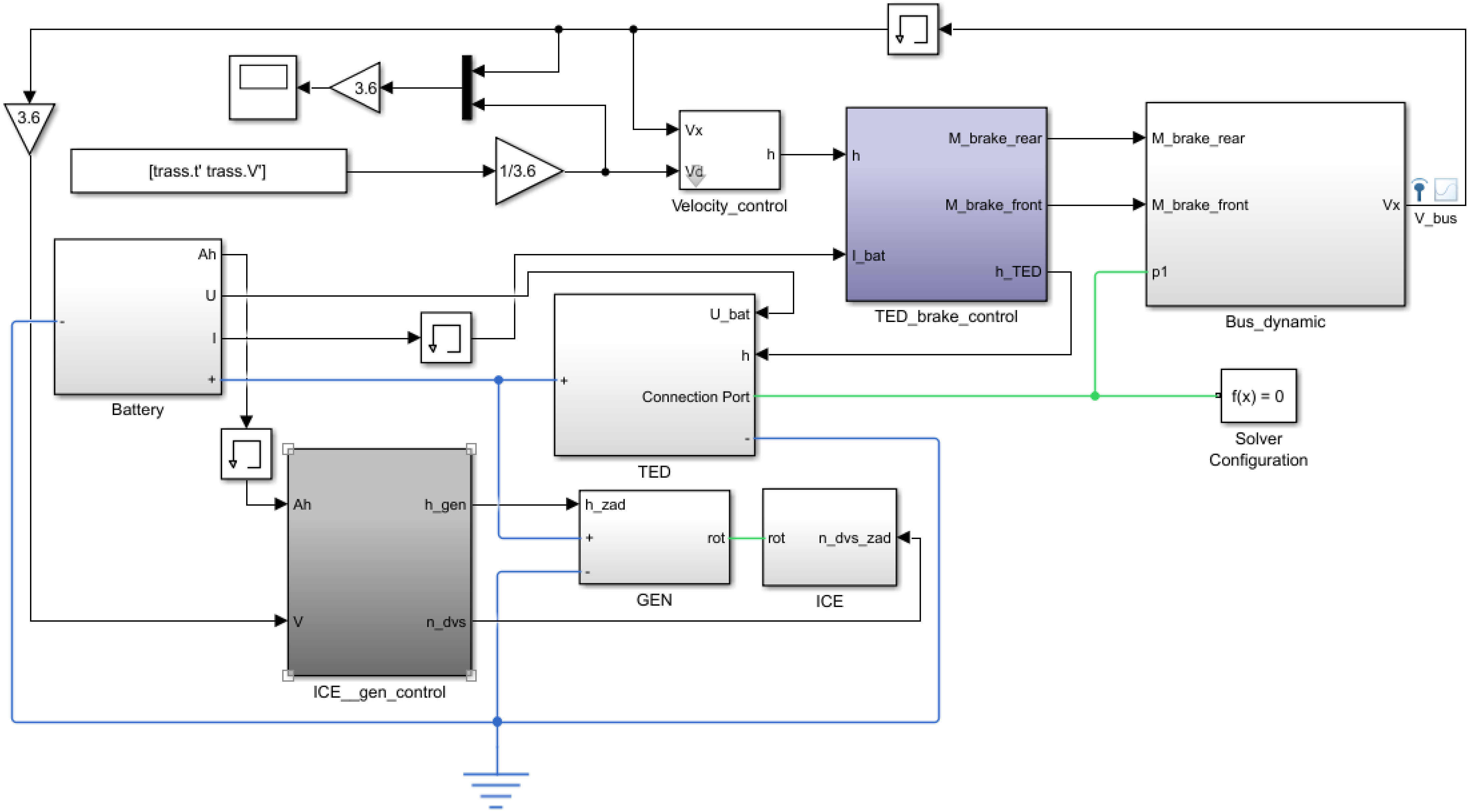
PAZ Hybrid

The scheme of the series hybrid powertrain



1 - ICE; 2 - generator, 3 - traction electric motor (TEM);
4 - power converters; 5 - energy storage device

Structure of the computer model of the hybrid bus



Equations used in the model

$$J_{ICE} \cdot \dot{\omega} = h \cdot M_{ICE} - M_{gen}$$

where J_{ICE} – moment of inertia of the internal combustion engine elements reduced to the crankshaft , $\dot{\omega}$ – angular acceleration of the ICE output shaft, M_{ICE} – torque developed on the ICE output shaft, which is determined by the given engine external speed characteristic (ESC), h – degree of ICE power use, M_{gen} – the generator torque.

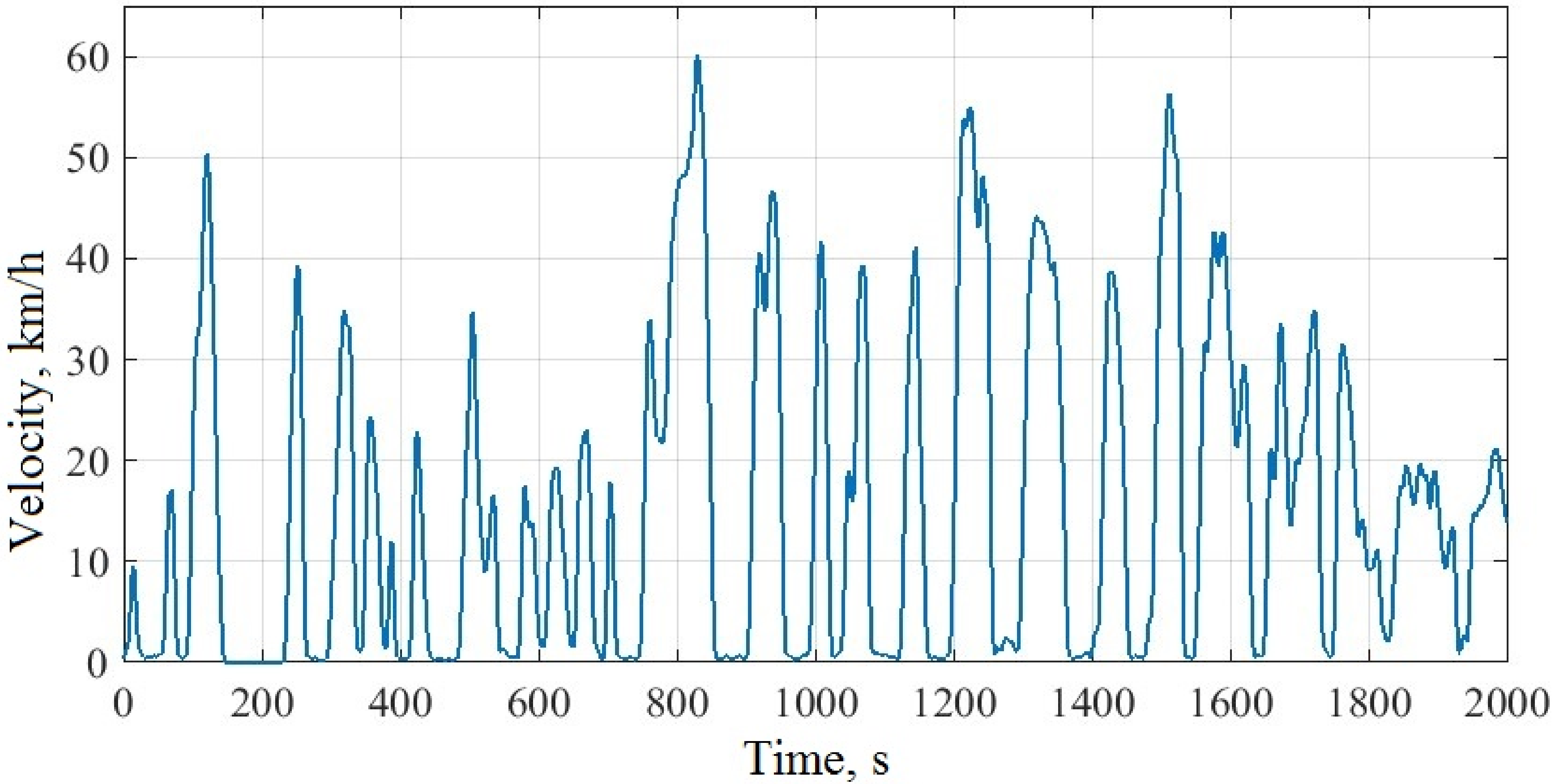
$$\begin{cases} N_{el} = I_{cur} \cdot U_{dc} \\ N_{el} = M_{mech} \cdot \omega + N_{los} \end{cases}$$

where I_{cur} – current consumed by the motor, U_{dc} – DC link voltage, N_{los} – power loss, ω – angular velocity of the electric machine shaft, M_{mech} – TEM shaft torque.

$$N_{los} = I_{cur}^2 \cdot R_{bat}$$

where I_{cur} – current on battery, R_{bat} – internal battery resistance.

Fragment of the electric bus speed recording on the route M2 "Fili - m. Kitay-Gorod"



Hybrid powertrain units parameters identification

$$N_{TEM}^{nom} = \max(N_{TEM}^{maxV}, N_{TEM}^{max\alpha})$$

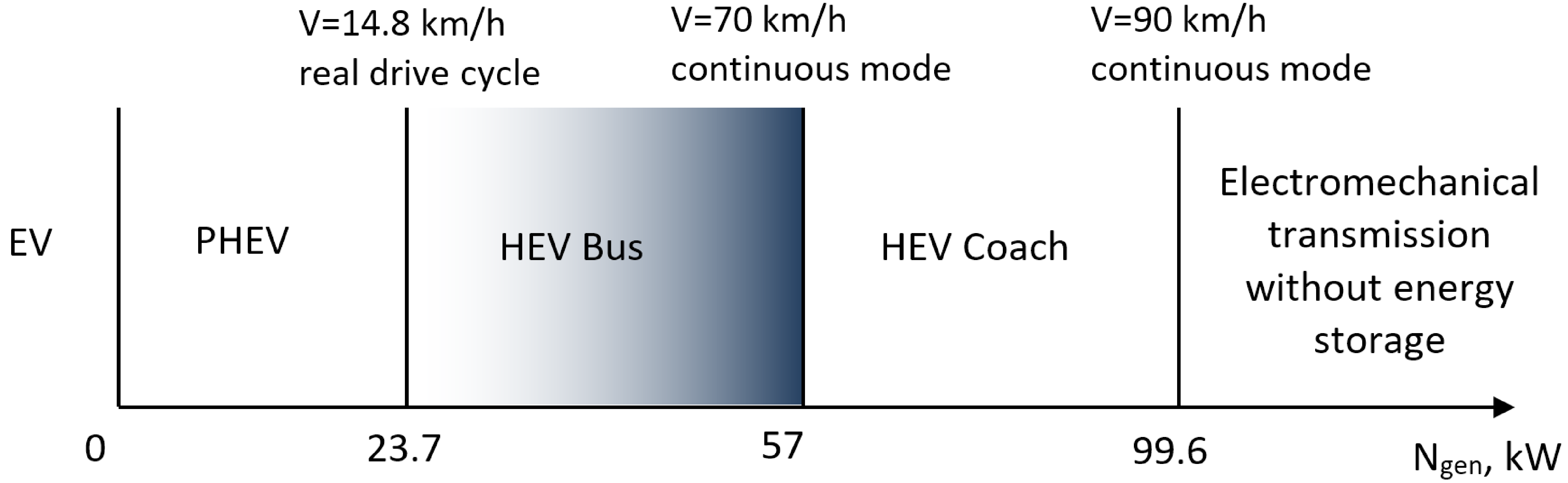
where the powers N_{TEM}^{maxV} и $N_{TEM}^{max\alpha}$ are determined as

$$N_{TEM}^{maxV} = (m \cdot g \cdot f + P_w) \cdot V_{max}/(\eta_{tr} \cdot \eta_{TEM})$$

$$N_{TEM}^{max\alpha} = (m \cdot g \cdot (f \cdot \cos(\alpha) + \sin(\alpha)) + P_w) \cdot V_\alpha/(\eta_{tr} \cdot \eta_{TEM}^{\alpha})$$

where m – the bus gross weight, f – the road resistance coefficient, P_W – the air resistance force, V_{max} – maximum speed, V_α – the steady-state climbing speed given in the technical specification, with the angle of inclination of the supporting surface α, η_{TEM} – the TEM efficiency at maximum speed, η_{TEM}^{α} – the TEM efficiency at V_α speed, η_{tr} – the efficiency of the mechanical part of the transmission.

Results of determining the generator power



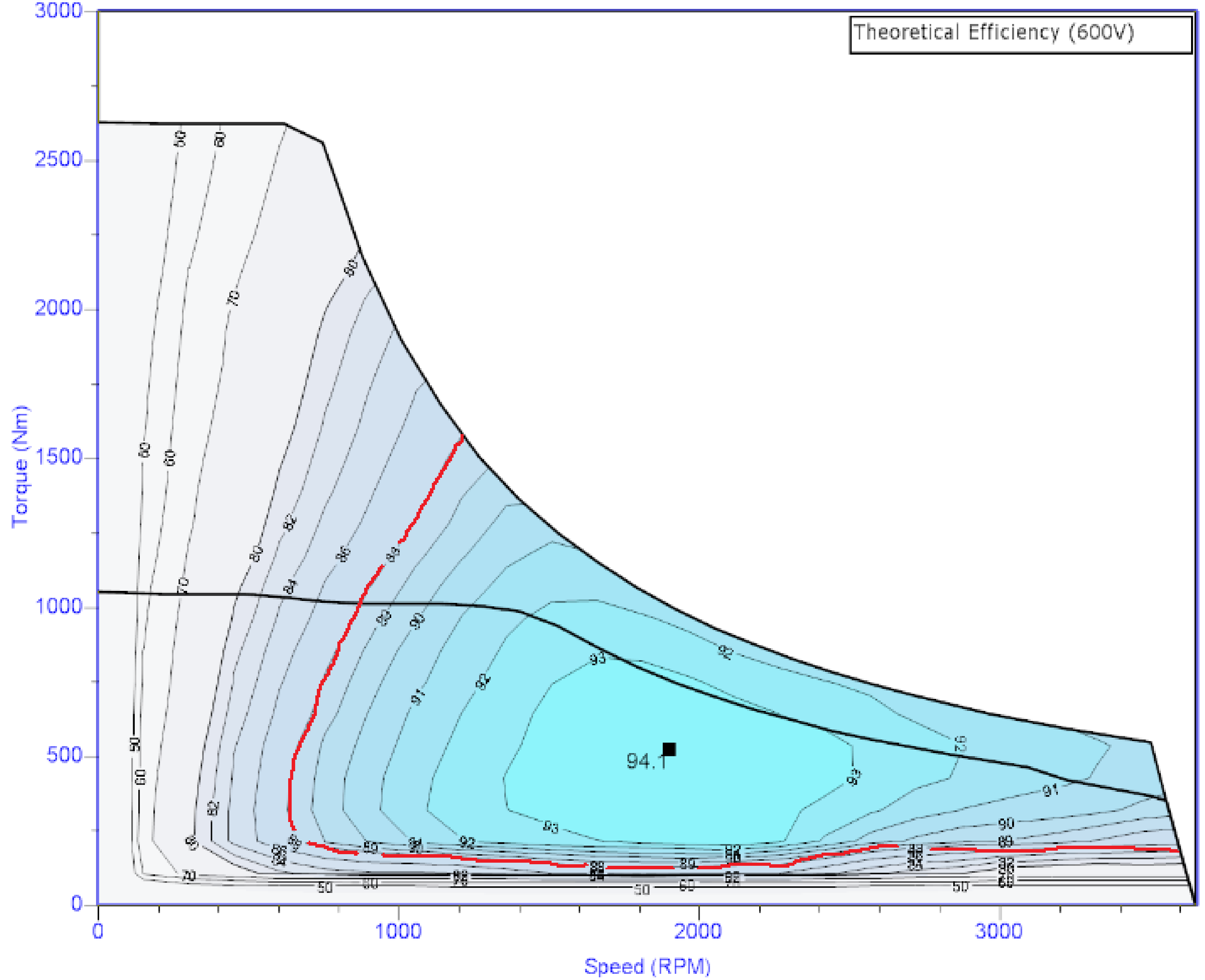
Battery charge at the stop

ICE rotation speed, rpm	2000	2500	3000
Change of charge, Ah	10	10	10
Charging time, sec	572,9	457,6	382,3
Generator efficiency	0,9193	0,926	0,9287
Battery loss, kWh	0,1259	0,1578	0,1889
Fuel consumption, kg	1,755	1,787	2,07

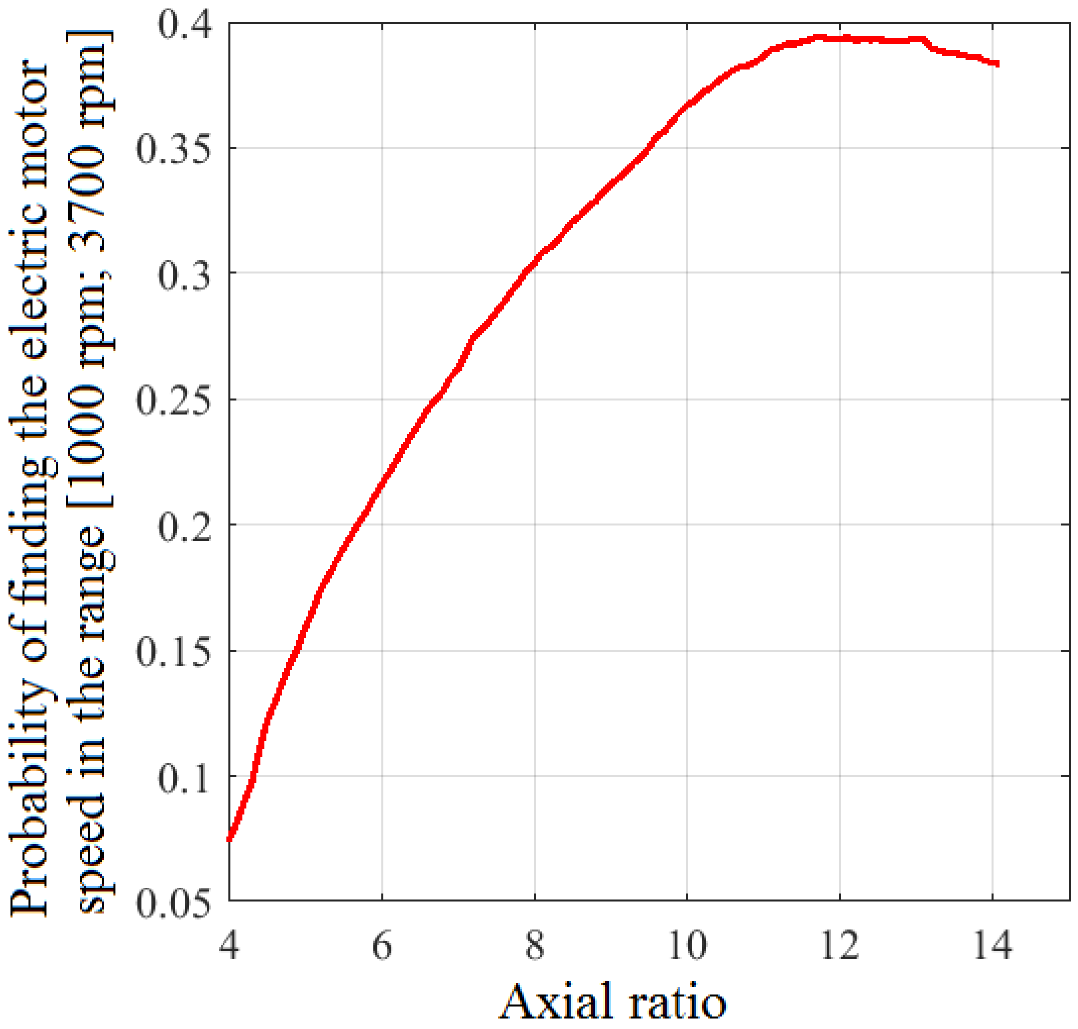
Characteristics of energy storage devices

	NaNiCl2	LFP	LMO	LTO	NMC	UltraCap
Max Charge Rate	+1C	+1C	+1C	+6C	+2C	+20C
Max Discharge Rate	-1C	-2C	-1C	-6C	-2C	-20C
Max operating SOC	100%	90%	100%	85%	80%	100%
Min operating SOC	20%	10%	20%	15%	20%	10%
Cycle Life @100%DoD	4500	2000	3000	20000	1000	50000

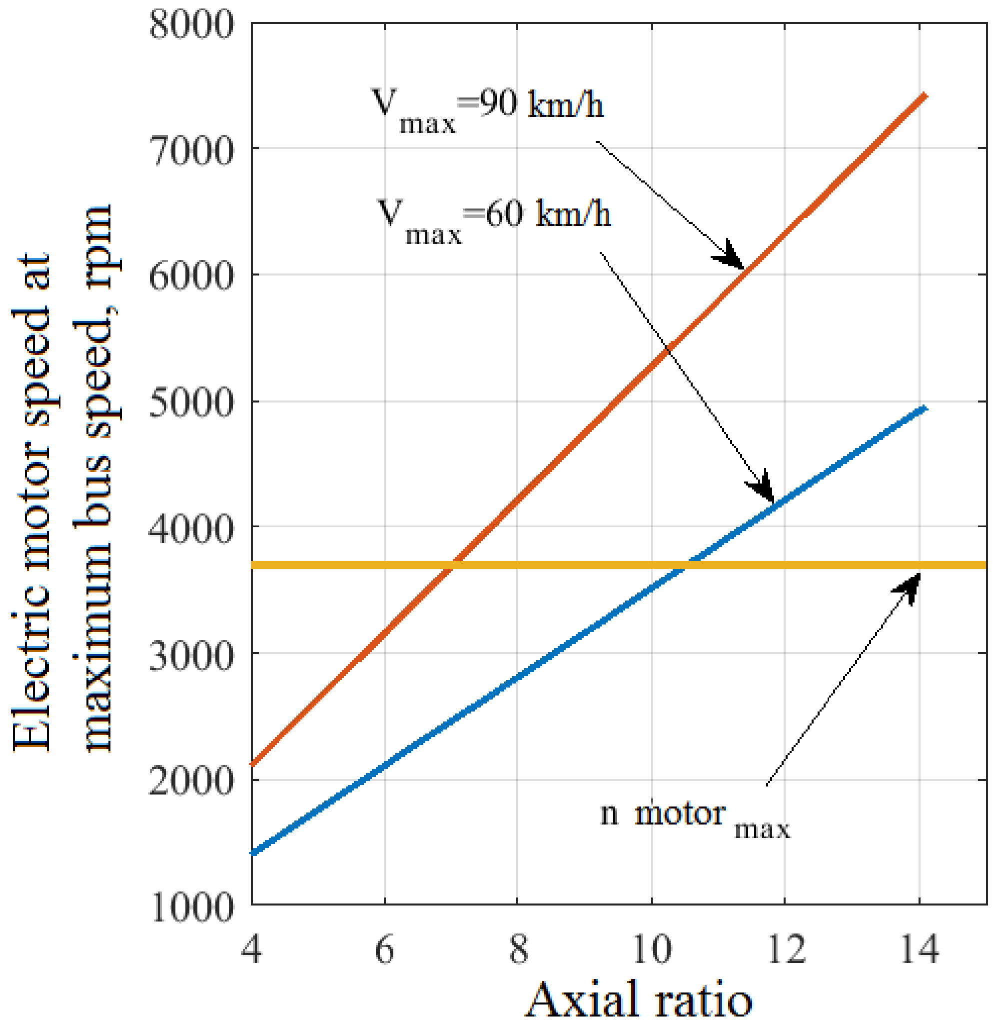
TEM performance map



Calculation of the final drive gear ratio

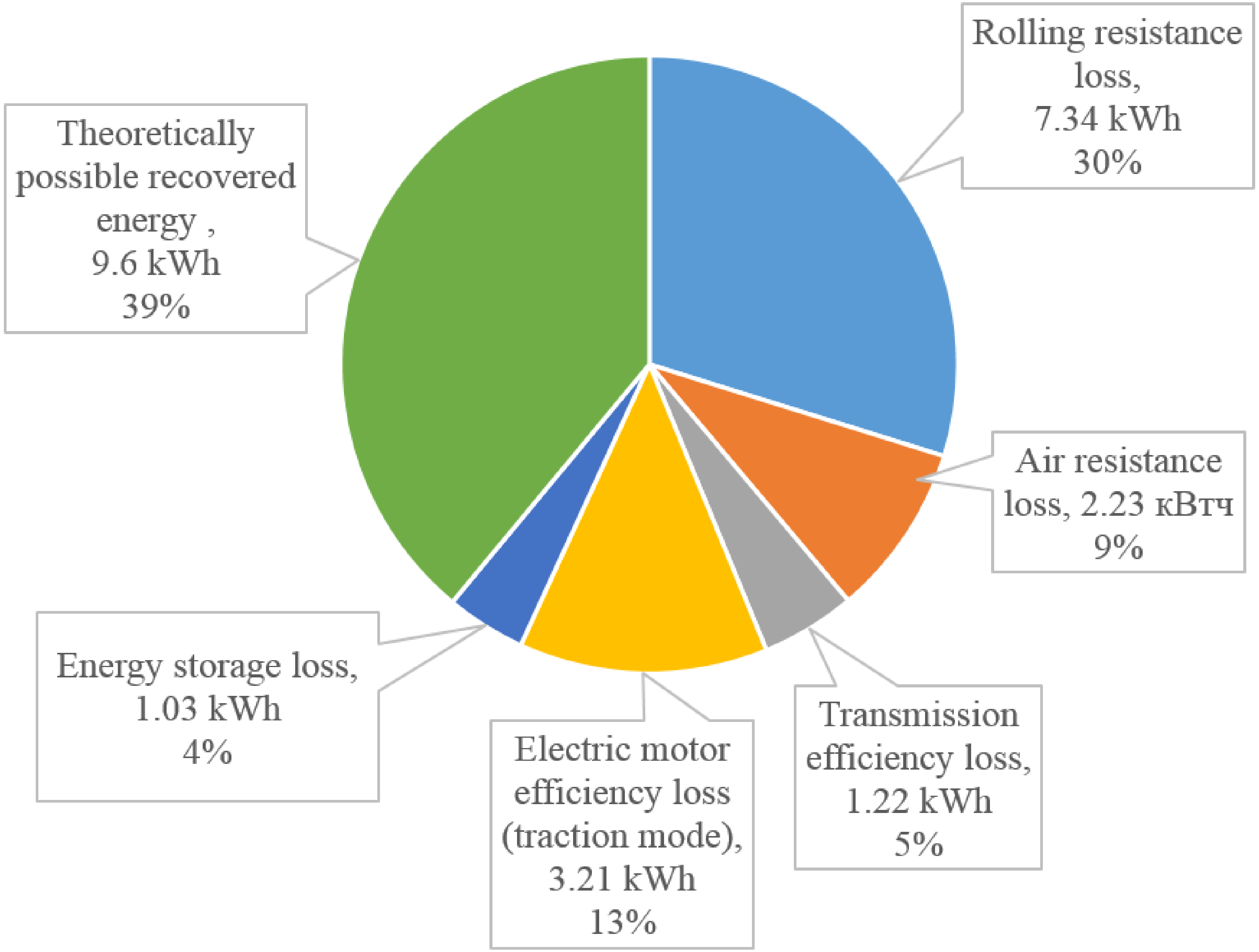


The probability of finding the TEM speed values in the range of [1000 … 3700] rpm, depending on the final drive gear ratio

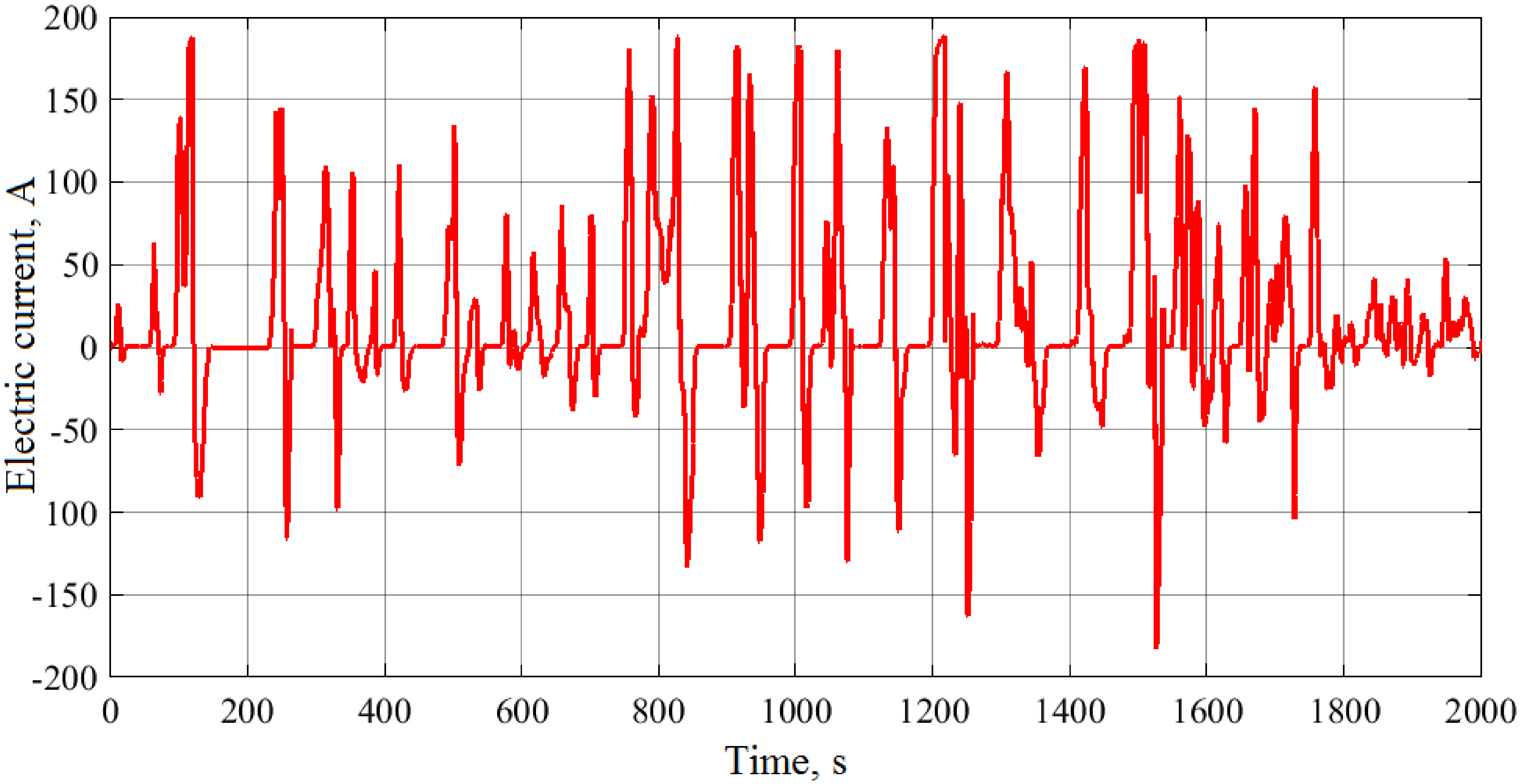


The dependence of the TEM rotational speed on the final drive gear ratio at a given speed

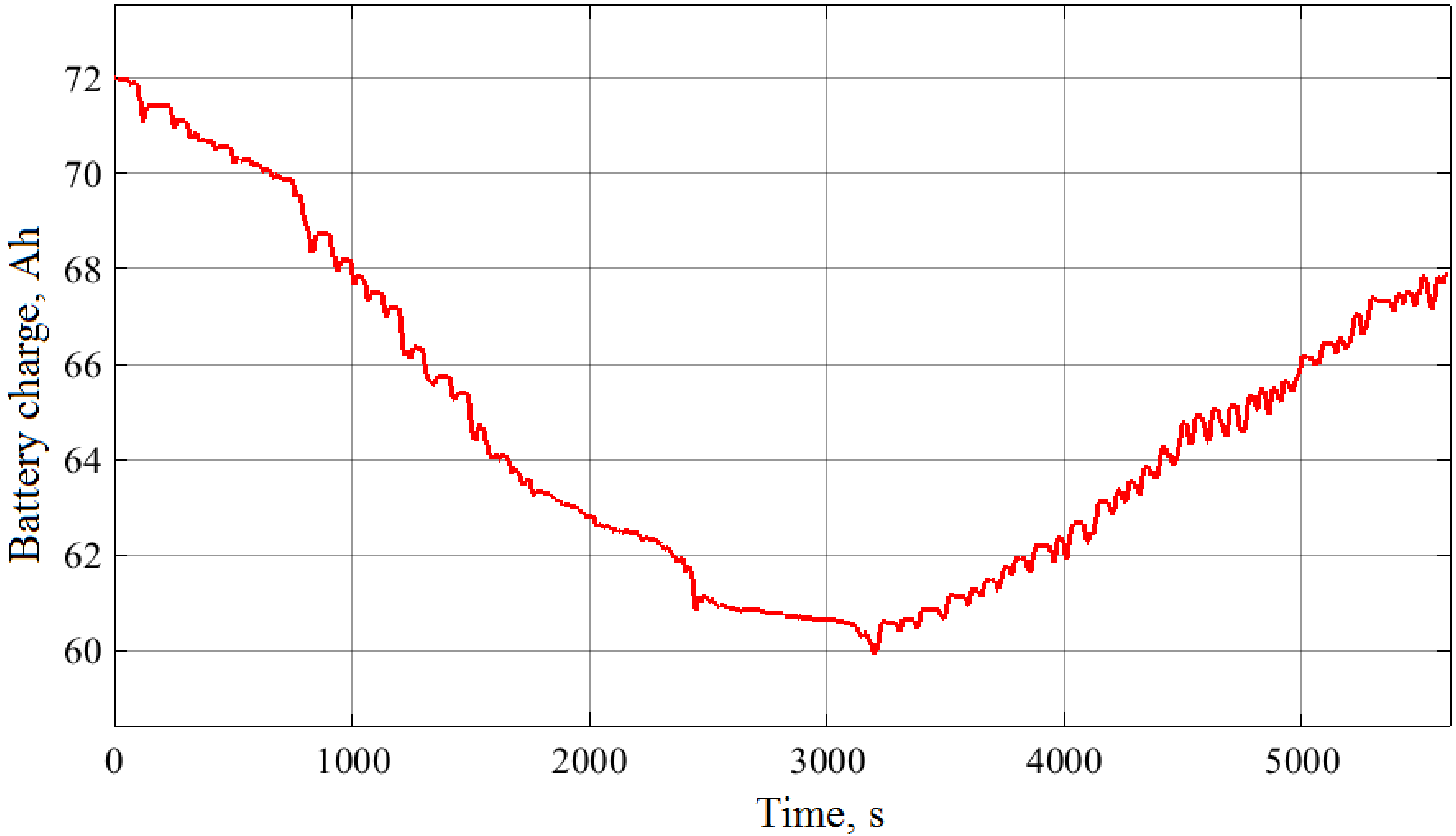
The distribution of energy spent on traffic, by types of losses



The change of current in the battery



The change of the battery charge



Conclusions

1. Methods of mathematical simulation give an opportunity of a complex solution of parameters identification of hybrid powertrain and its control system development at the design stage.

2. For a hybrid bus with a gross weight of 11,500 kg with a power reserve of 30 km, a traction motor with a maximum continuous power of 140 kW, a generator of 50 kW, a rated power of an internal combustion engine of 60 kW (maximum 90 kW) and a storage battery capacity of 22.6 kW h were selected.

3. The parameters of the units of the hybrid powertrain, obtained from the simulation of the bus traffic along the existing city route, will provide acceptable traction and dynamic characteristics of the bus and high fuel economy and environmental performance.

Thank you for your attention
Ready to answer your questions

Oleg Chudakov
Bauman Moscow State Technical University
chudakov@bmstu.ru
Mobile: +7 917 515 09 26
2nd Baumanskaya St., Bldg. 5, Block 1, Moscow, Russia, 105005
http://www.bmstu.ru