Researcher Links UK-Russia Workshop

Scientific and Technical Grounds of Future Low-Carbon Propulsion

19th - 22nd November 2018, Northumbria University at Newcastle, UK

The usage of photovoltaic converters as an additional source of energy for electric vehicles

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BRITISH COUNCIL

2016 moscow polytech

1997 MSTU “Moscow Automechanical Institute”

1932 Moscow Automechanical Institute Lomonosov (MAMI Lomonosov M.U.)

1864 Komisarovskoe Technical School

16
faculties

82
departments

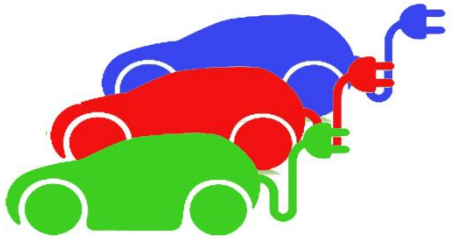
1522
professors

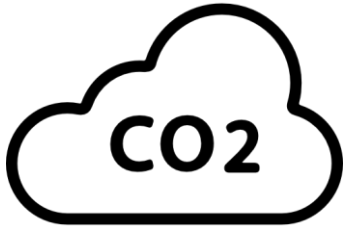
more than
20 000
students

FDR
Formula Student

SMC
POLYTECH TEAM
Smart Moto Team

200
industrial partners





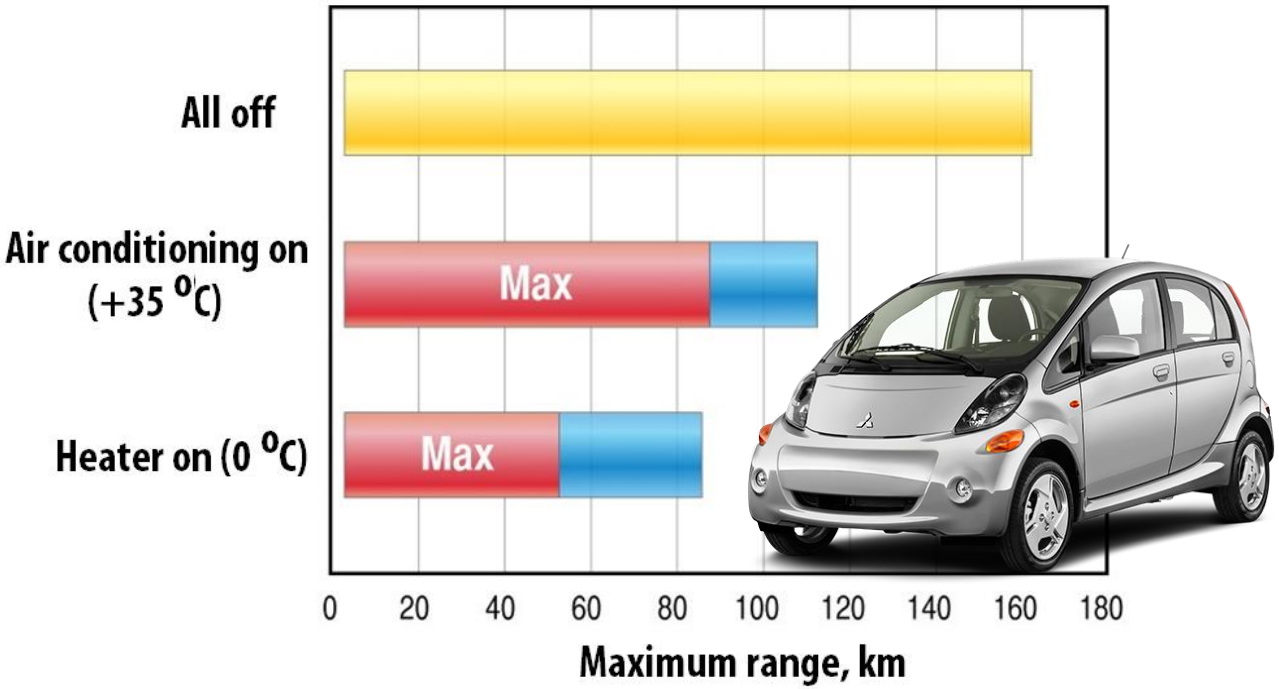
VOLUME OF ELECTRIC VEHICLES:

Russia	2530
China	about 2 000 000
UK	about 190 000

STATISTICS OF CO_2 EMISSIONS PER 1 kWh

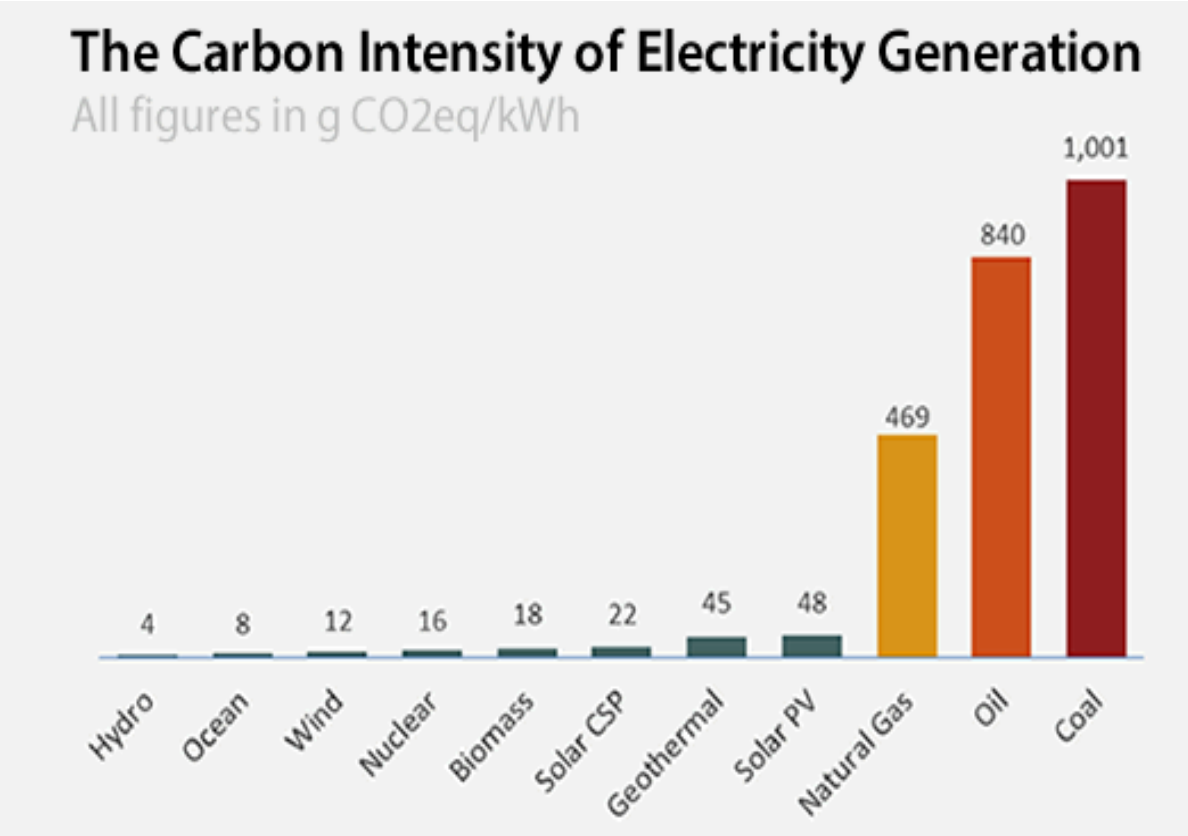
Russia	597
China	745
UK	225

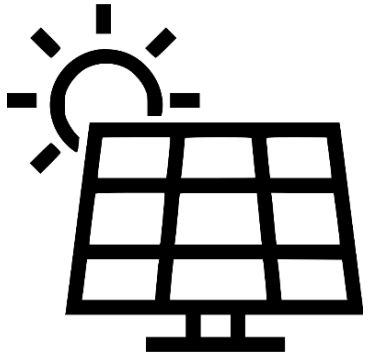
The total volume in the world: 4 million pieces of EV and 500 thousand electric buses.



Range, km	CO_2, g/km		
	Moscow	London	Beijing
160	70	26	86
85(110)	130 (100)	49(39)	162(125)
50(85)	220 (130)	83(49)	275(162)
CO_2 / on full charge*, g	11 044	4 162	13 782
Cost 1 kWh, GBP	6,2 p	16 p	6 p

* taking into account losses in the electricity transfer (15%)

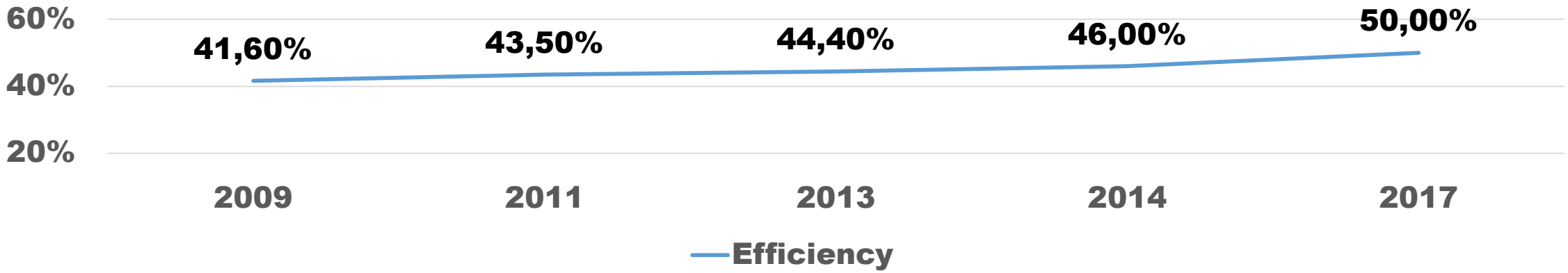




SOLAR POWER RADIATION, KWh/M² PER YEAR

Moscow	**1000**
London	**975**
Beijing	**1400**

Efficiency of photovoltaic converters



Trends in the development of electric transport with photovoltaic converters

Venturi Electric (2006)

Pininfarina B0 (2010)

Dacia Hamster Hybrid E-4WD (2011)

Ford C-MAX Solar Energi (2014)

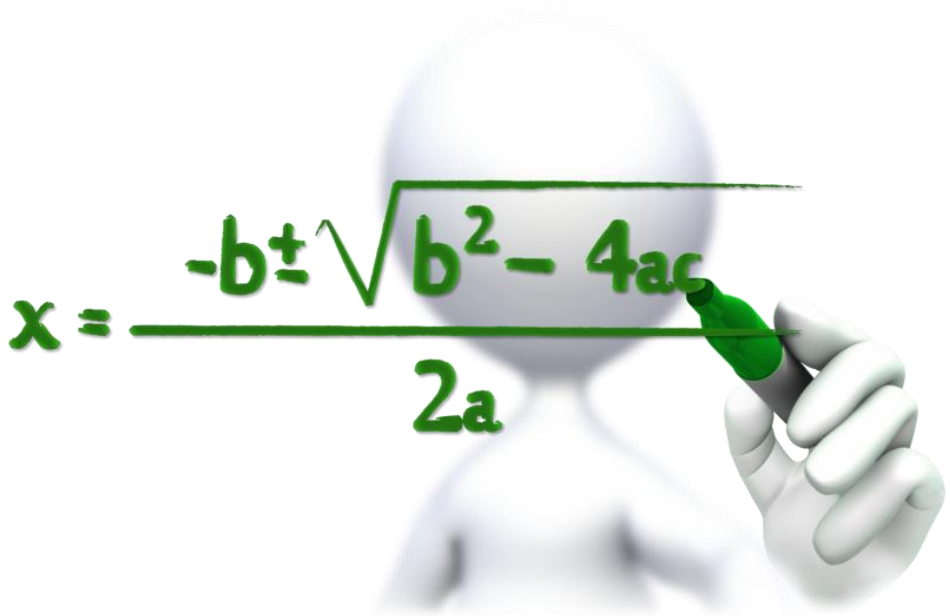
Sport solar EV since 1983

Fisker Karma (2011)

Toyota Prius Phv (2016)

Sono Sion (2018)

Creating a mathematical model



Stages:

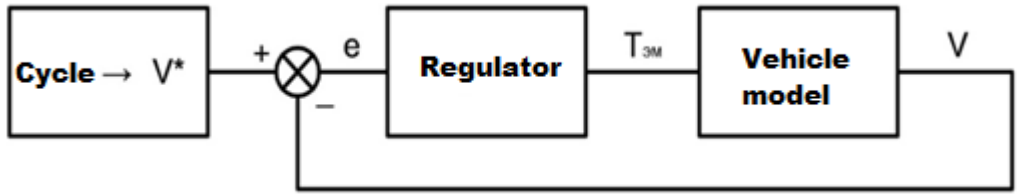
- Car movement model
- Modeling of EV components
- Driver model
- Solar radiation model (Baird model)
- Implementation of EV model on a computer
- Definition of initial data for simulation
- Computational testing
- EV simulation
- Evaluation of traction-speed and energy characteristics of the EV
- Simulation of an EV with a battery of photovoltaic converters
- The method of estimation of power properties of EV batteries photovoltaic converters using computer simulation

Development of mathematical model of motion and calculation method of traction-dynamic characteristics EV

The equation of straight-line motion of a vehicle in normal form

$$\frac{dV}{dt} = \frac{T_к / r_0 - F_ψ}{M + (I_к n_к + I_{mp}) / r^2}$$

Driver model in the form of feedback system and regulator



Energy exchange between electric motor, traction battery and photovoltaic converter battery

$$\frac{dE_б}{dt} = \left[P_{ф.э.} \cdot n_{ф.э.} \cdot \eta_{dc/dc} - P_{ЭМ} \eta_{ЭМ,ср}^{-\mathrm{sgn}(P_{ЭМ})}\right] \eta_{бат,ср}^{-\mathrm{sgn}(P_б)}$$

$E_б$ – traction battery;

$P_{ф.э.}$ – electric power, single solar cell;

$n_{ф.э.}$ – number of solar cells in the battery;

$\eta_{dc/dc}$ – Efficiency DC/DC;

$P_{ЭМ}$ – mechanical power of electric motor

$\eta_{ЭМ,ср}$ – average efficiency of traction electric machine;

$\eta_{бат,ср}$ – average efficiency of traction battery;

$P_б$ – the power of the charge/discharge of the traction battery

Solar radiation model

density of solar radiation incident on the a horizontal platform without considering the atmosphere

$$\Psi^{0}_{гор} = \Psi_{C\perp} \cdot \cos\theta_z$$

$\Psi_{C\perp} = 1367 \text{W / m2}$ - constant;

θ_z – the angle of incidence of sunlight.

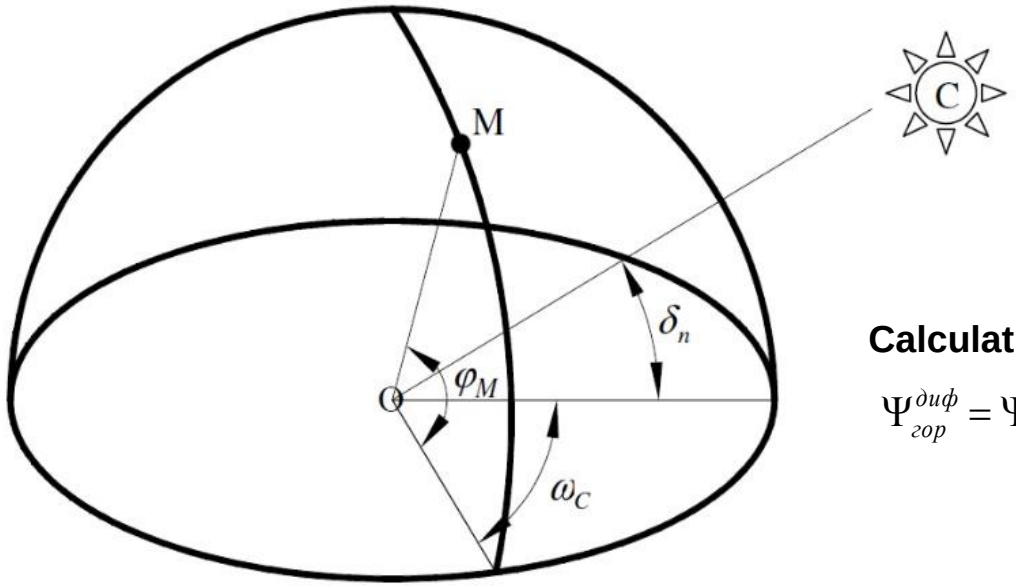
Cosine of the angle of incidence of sunlight

$$\cos\theta_z = \cos\delta_n \cdot \cos\varphi_M \cdot \cos\omega_C + \sin\varphi_M \cdot \sin\delta_n$$

δ_n – the angle of declination of the Sun;

φ_M – the latitude of the place;

ω_C – the hour angle of the Sun.



The angle of declination of the Sun

$$\delta_n = 23.5^o \sin\left(360^o \frac{n-81}{365}\right)$$

n-the serial number of the day of the year, starting from January 1.

Calculation of the hour angle of the Sun

$$\omega_C = \frac{15^o}{час}\left(t_M - \Delta t_{декр} - 12 + t_{вр}\right) + \left(\lambda_M - \lambda_{ср}\right)$$

t_M – local times;

$\Delta t_{декр}$ - adjustment for the time used in Russia (1 hour);

$t_{вр}$ – time correction;

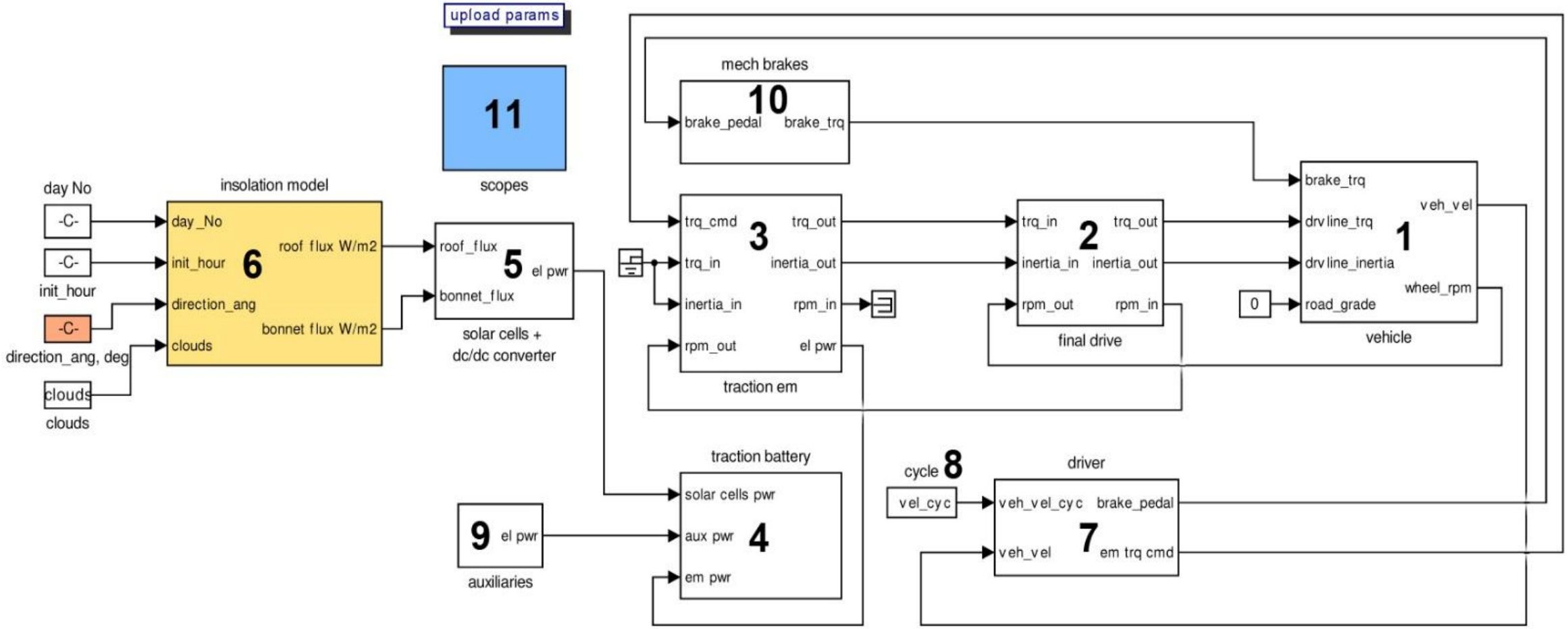
λ_M – the longitude of the place;

$\lambda_{ср}$ – longitude of the middle Meridian of the time zone.

Calculation of the density of diffuse solar radiation incident on a horizontal platform :

$$\Psi^{диф}_{гор} = \Psi_{C\perp} \cdot \cos\theta_z \cdot \tau_{O3} \cdot \tau_{газ} \cdot \tau_{H2O} \cdot \tau_{AA}(0.5 \cdot (1-\tau_R) + B_a \cdot (1-\tau_{AS}))/(1 - M^* + (M^*)^{1.02}) \cdot K^{диф}_{гор}$$

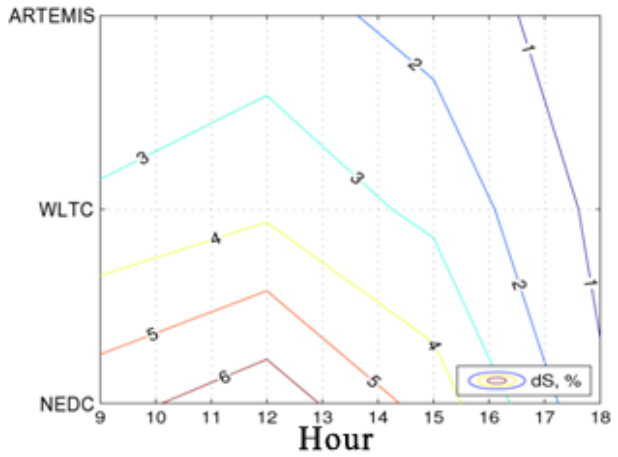
The upper level of the model EV with photoelectric converters in the Simulink software environment



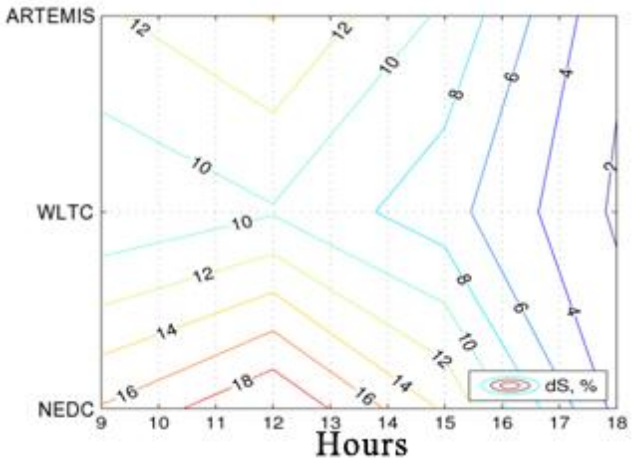
1 - Vehicle
2 - Final drive (gearbox)
3 - Traction EM
4 - High voltage battery
5 - Photovoltaic converters + DC/DC converter
6 - Insolation model (roof and hood)
7 and 8 - Car speed control system
9 - Simulations of power consumption from on-Board devices
10 - Mech brakes system
11 - Scopes virtual oscilloscopes and digital displays

The results of the mathematical tests

Estimation of the influence of the driving mode on the mileage of the EV at the time of day

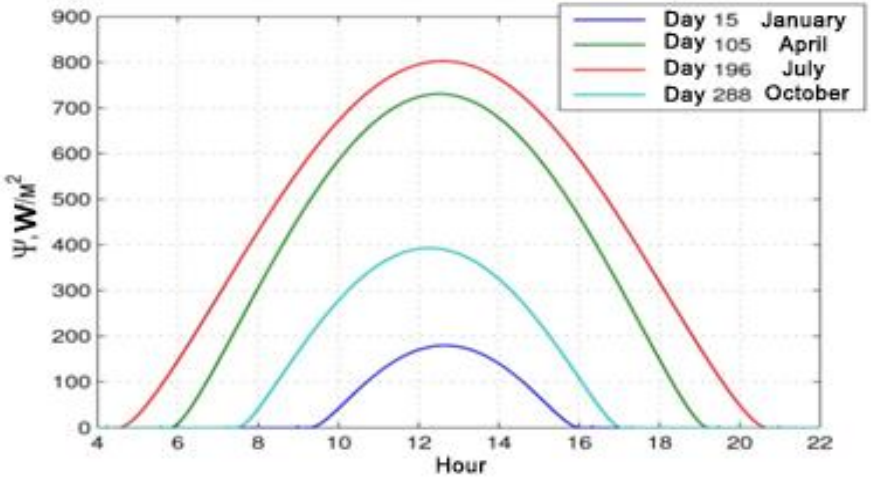


Combined cycle
Day 196 (July), clear sky

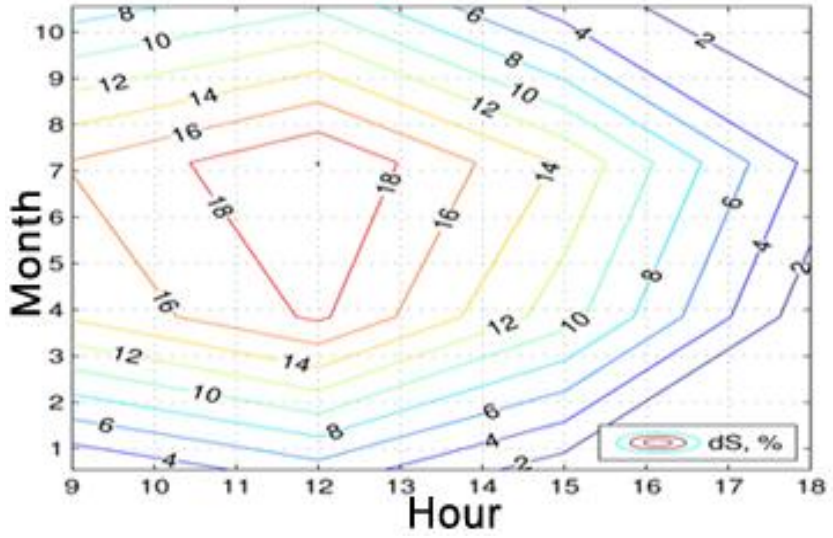


City cycle
Day 196 (July), clear sky

The density of solar radiation on a horizontal surface, depending on the time of year

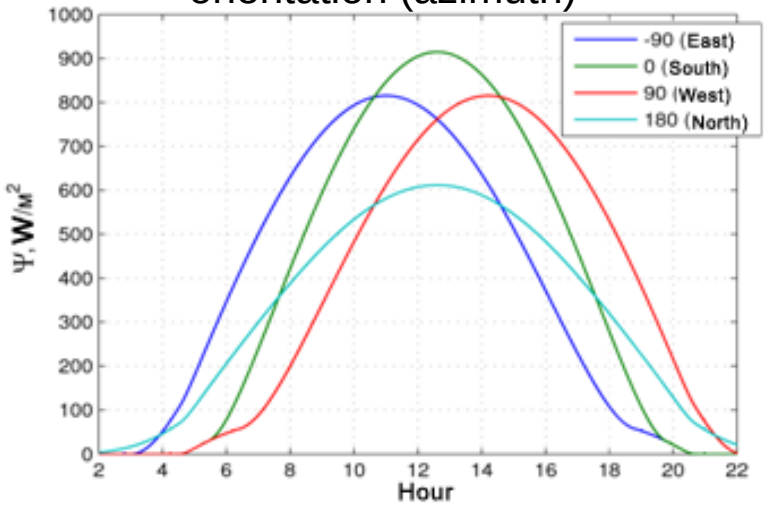


Effect of the season on electric vehicle mileage by time of day

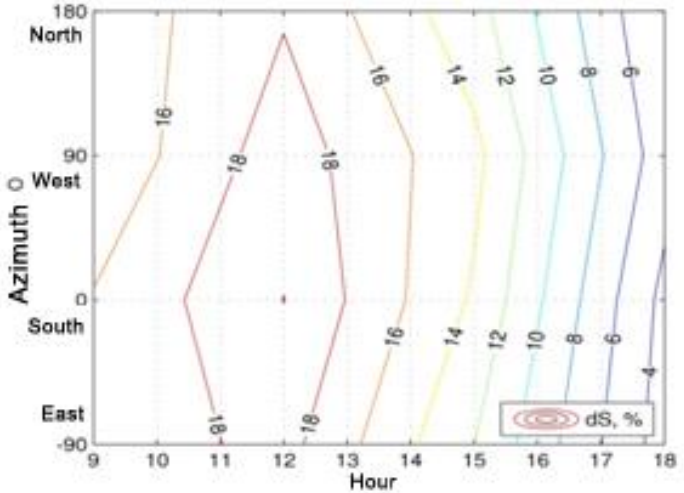


NEDC (city), clear sky

Solar radiation depending on orientation (azimuth)

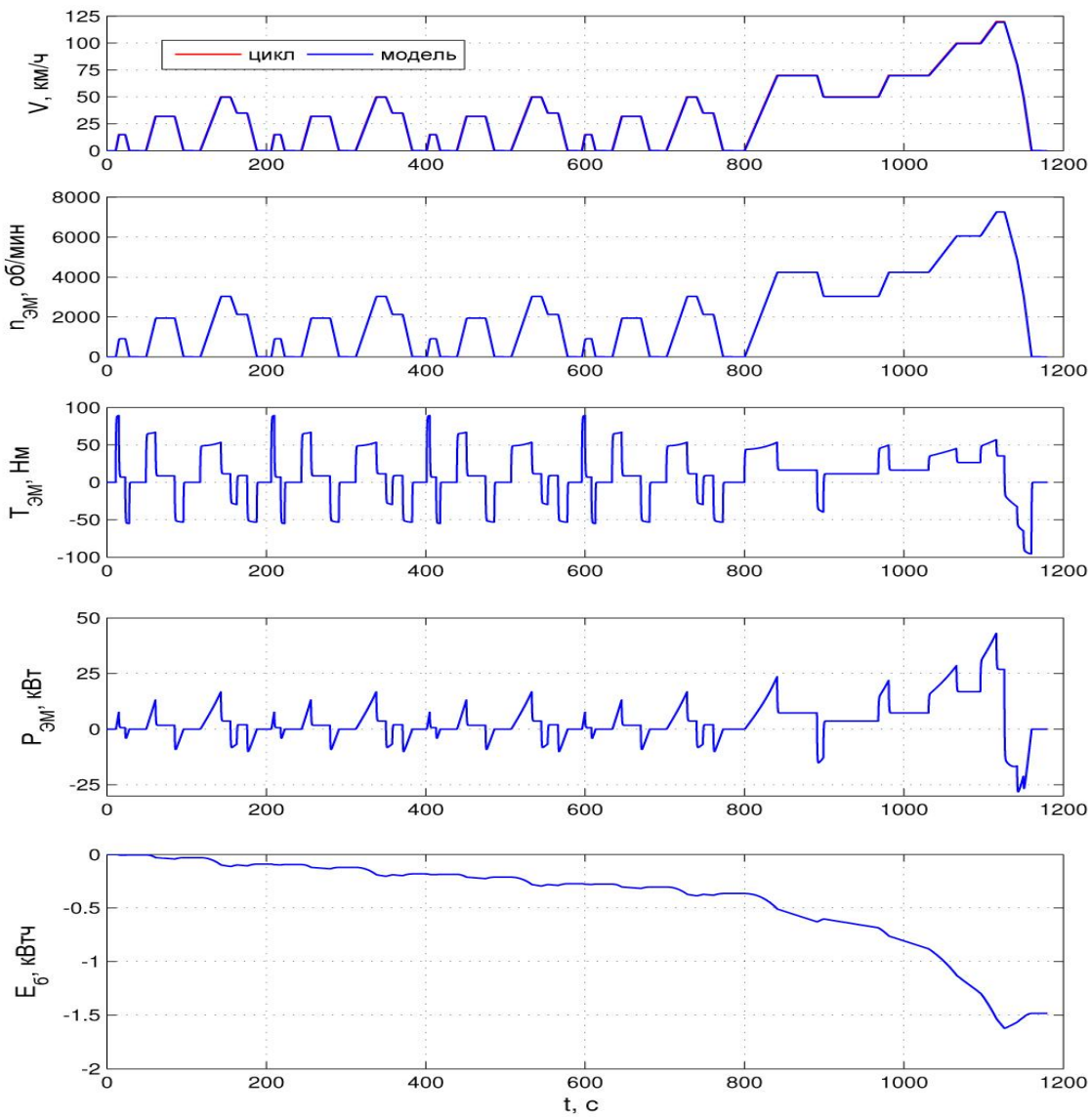


The effect of movement direction (azimuth) at the range of EV (PHV) at the time of day

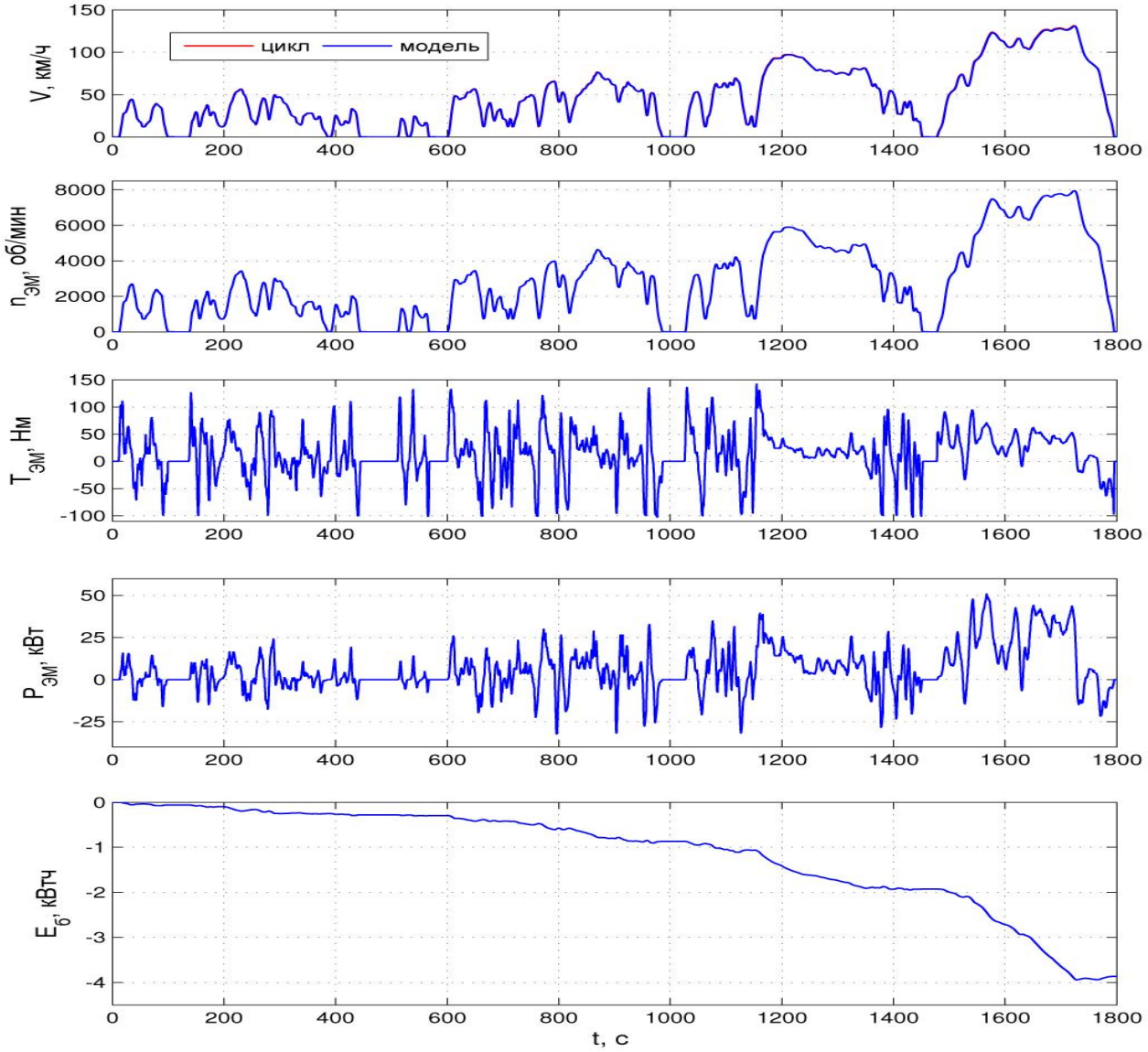


NEDC (city),
Day 196 (July), clear sky

Results of calculation of traction, power and energy parameters of the power plant of the base vehicle in cycles

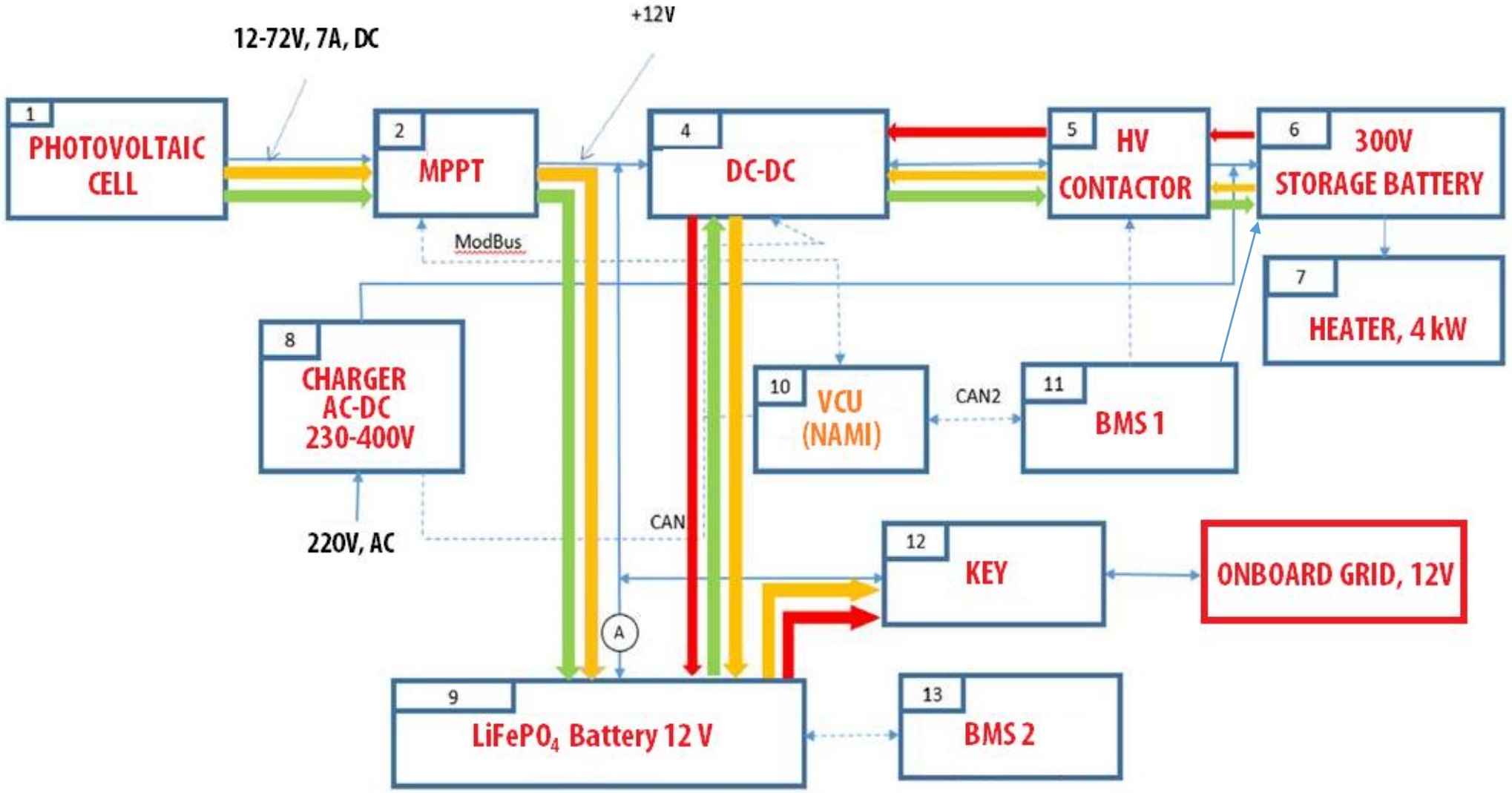


NEDC



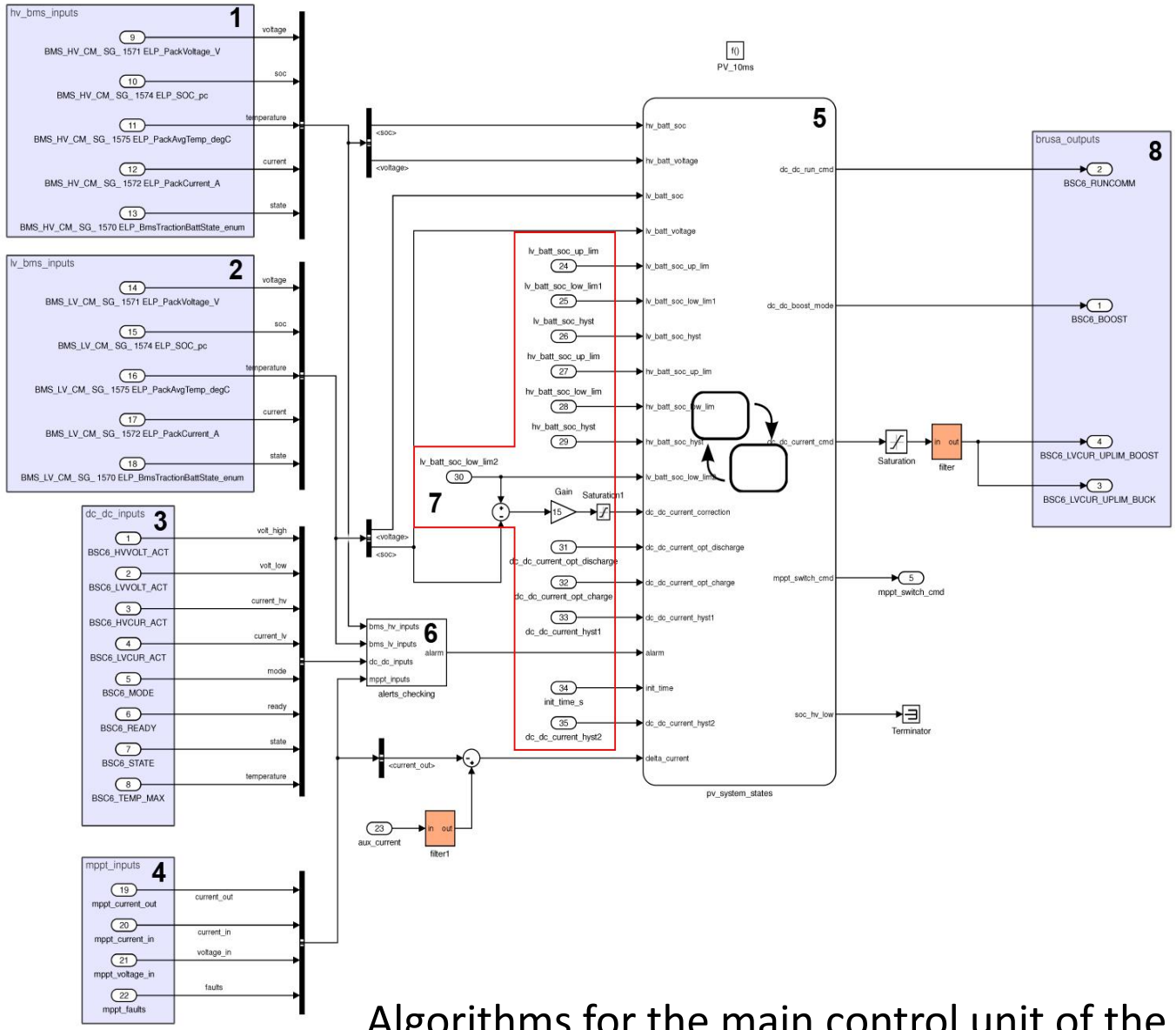
WLTC

Scheme of the system of photovoltaic converters of EV



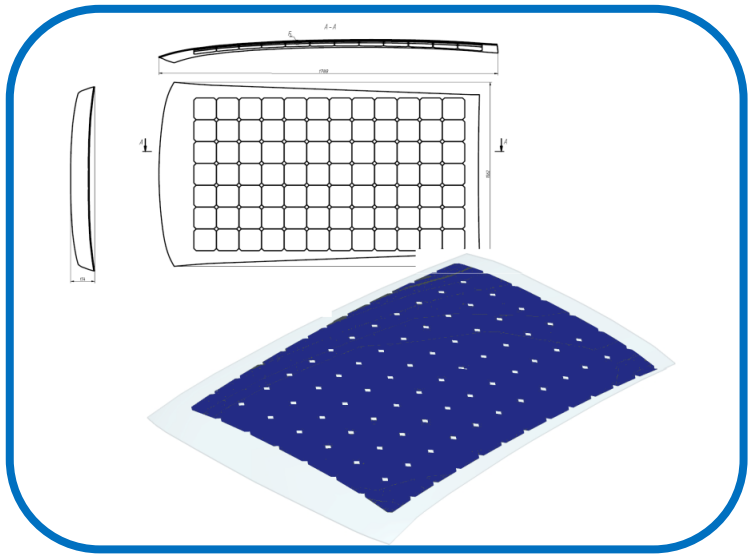
In the figure: the normal mode of operation of the electric power supply and 2 modes of operation with the system of photovoltaic converters: «stationary» and «drive»

Implementation of algorithms for the system of photovoltaic converters for electric vehicles

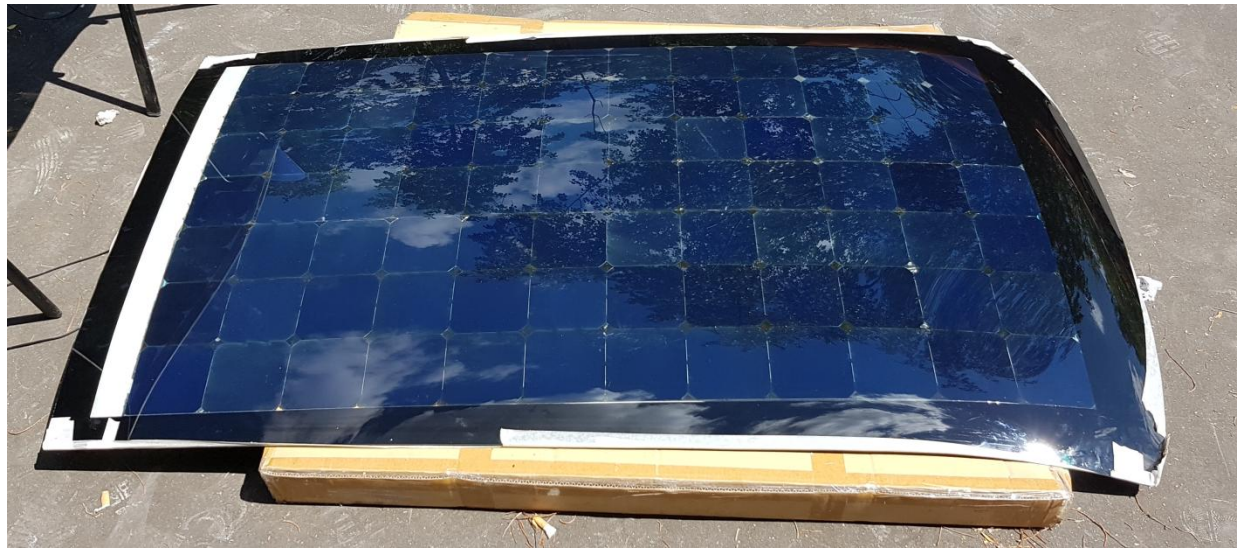


1-high voltage battery BMS inputs;
2 – input signals the BMS low-voltage;
3-DC/DC Converter inputs;
4-MPPT controller inputs;
5-subsystem containing the main part of the control algorithm;
6-subsystem for checking warnings about faults in the components of the PHV system;
7-input signals specifying the boundary values of the parameters used by the control algorithm;
8 - DC / DC Converter control signals;
9-MPPT controller control signal (on / off)

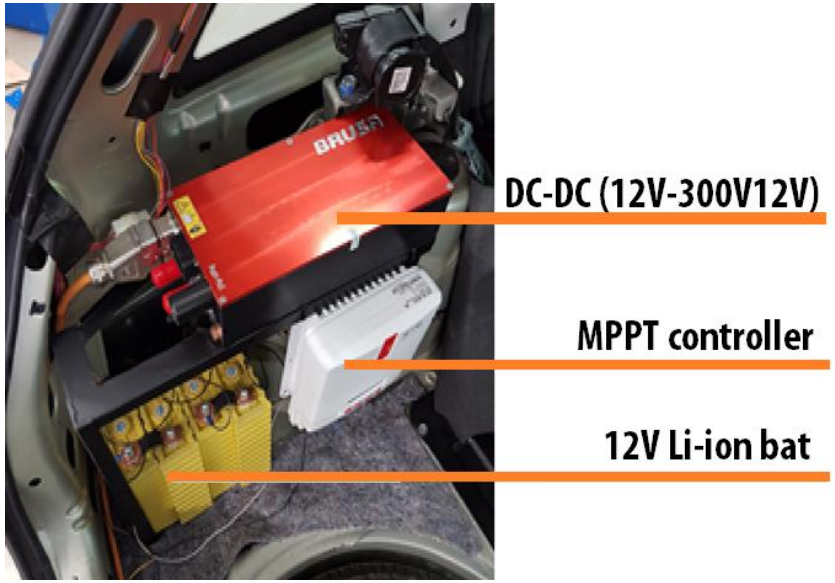
Algorithms for the main control unit of the PHV system are compiled into C++ code



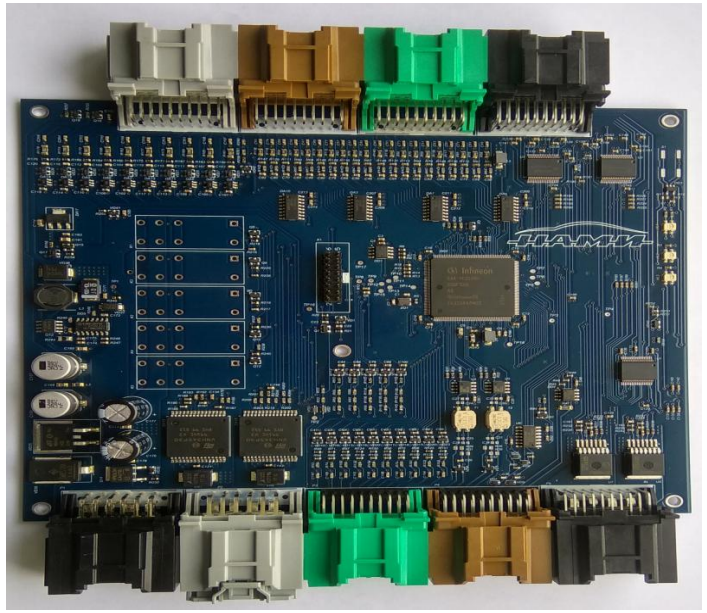
3D-modeling



manufacture of battery for roof



installing components



designing and production of the main controller

monitoring system

An experimental model of an EV with a system of photovoltaic converters

120 elements (roof + hood), Maximum performance: 6A, 62V.

Statistics of electricity generation photovoltaic converters (1.8 m2, angle 0)

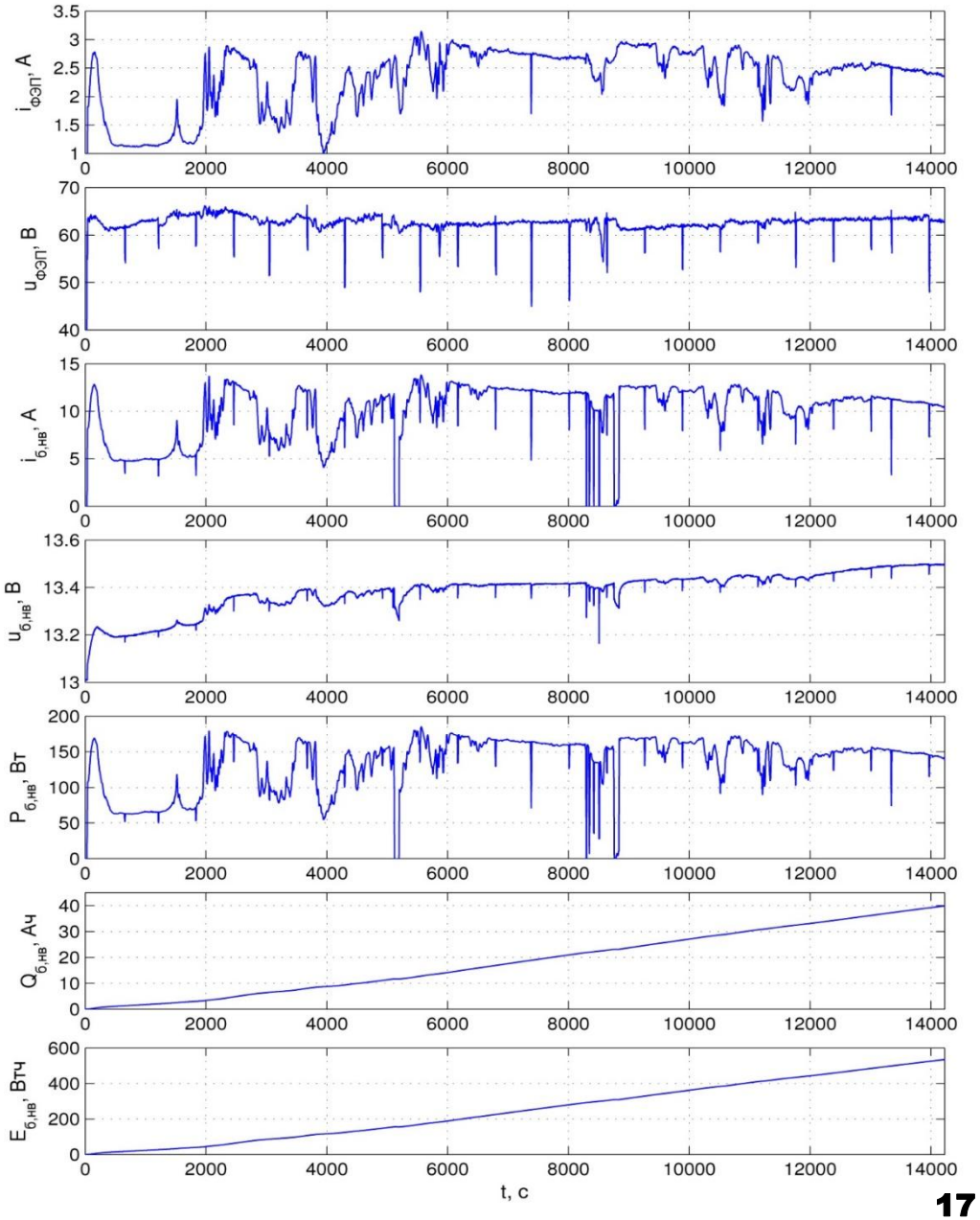
Moscow	292 kWh per year
London	280 kWh per year
Beijing	495 kWh per year

Testing of electric vehicle

Test results

Configuration	NEDC. S, km	DS, %	NEDC-urban.S, km	DS, %
day 227 (August), South, 12 hours				
EV without PHV	142.4	0.00	211	0.00
EV+ PHV	149,6	5.08%	230,3	9,15%

Graphs of performance of the PHV-converters system



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Thank you for your attention
Ready to answer your questions

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