

Calculation of electric power in Matlab Graphic User Interface

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Abstract. The article analyzes the effect of drive power that is required for electric vehicle operation in various driving modes. The following section describes different concepts of spatial arrangement of components of the vehicle. After describing the forces acting on the vehicle was designed Graphic User Interface - GUI windows in Matlab. Mechanical parameters of vehicle serve as input data for calculation. This is the basics for calculations of driving power and parameters of secondary energy source. Traces of performance can be calculated for numerous types of standard driving cycles (EDC, NEDC, JP-08, US-06...). Energy storages used in the EV applications are rated on the basis of three parameters. Namely are specific energy, energy density and specific power. These are the key parameters in selecting appropriate energy source. To design HES consists from battery and ultracapacitor GUI was also created. Finally can be exported executable files bring carry out calculations without programming and using Matlab.

1 Theory

Principle of Matlab GUI

Matlab GUI (Graphical User Interface) presents an environment to create a graphical interface between the users and the source code of the program. Flexible graphical user interface makes it easy to enter input data for calculation required of parameters. Main advantage is export of executable files. This allows you to execute file with calculation without installing Matlab.

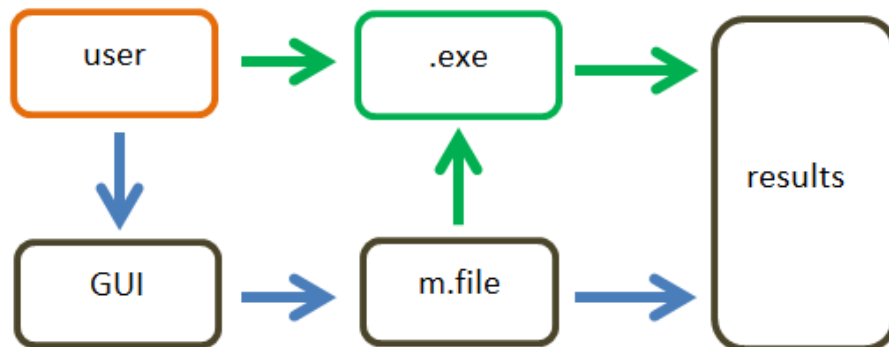


Fig. 1: Principle of use of Matlab GUI

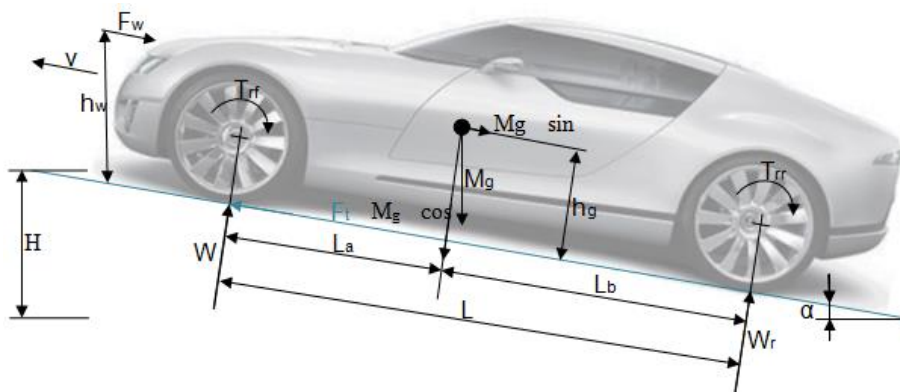


Fig. 2: Description of forces acting on straightforward moving vehicle

Description of Forces

For calculation it is necessary to take into account the mechanical parameters and estimate the weight of the vehicle. According to the 2nd - Newton's law acceleration of the vehicle is given by the equation:

$$\frac{dv}{dt} = \frac{\sum F_t - \sum F_{tr}}{\delta \cdot M_v} \quad (1)$$

where dv / dt is the instantaneous acceleration of the vehicle, $\sum F_t$ - total tractive force of the vehicle, $\sum F_{tr}$ - the total resistance, M_v - gross vehicle weight and δ weighting factor, which includes the inertia of the vehicle itself, but also its rotating parts.

The equation shows that the rate of acceleration of the car is directly proportional dependent on the traction force, and dependence of the weight of the vehicle is inversely proportional.

Estimated weight of the vehicle

Estimated weight is determined by the amount of weight of the components and weight of the driver, considering the upper limit.

Tab.1: Estimation of weight of the components of the vehicle

Weight of component part	Weight [kg]	Pieces [-]	weight [kg]
Construction	38	1	38
Front wheel	3	2	6
Rear wheel	4	2	8
Electric motor	12	1	13
Converter	10	1	10
Traction battery	12	4	48
Driver	75	1	75
Total weight			198

Estimation of mechanical and driving parameters of the vehicle is done on the basis of similarity with existing vehicles. Other important parameters are obtained from the tables and catalogs.

Tab.2: Parameters for calculation

Total weight of vehicle	Frontal area	Rolling resistance coefficient	Drag coefficient	Air density	Climbing α	Wheel diameter	Efficiency drive transfer
M_v	A_f	f_r	C_d	ρ	$100 \cdot \tan \alpha$	rD	η
[kg]	[m ²]	[-]	[-]	[kg.m-3]	[%]	[m]	[-]
200	0,5	0,007	0,6	1,25	2	0,15	0,95

For calculation parameters like as power, torque, RPM, performance and driving range GUI in Matlab was designed. User can enter data into input field in the GUI (such as parameters of batteries, secondary energy source, road profile, driving cycle, efficiency, etc.) The basic mathematical description:

- Approximate estimation of driving time on the accumulated energy in the primary energy source:

$$t_{bat} = \frac{n_{bat} \cdot V_{bat} \cdot C_{bat}}{\Delta P_{ev}} [\text{min}] \quad (2)$$

- drive range:

$$s_{EV} = (v_p \cdot t_{bat} \cdot 3600) / 1.10^3 [km] \quad (3)$$

- speed cruising

$$v_p = \frac{v_{p-in}}{3600} \cdot 10^3 [m \cdot s^{-1}] \quad (4)$$

- Aerodynamic force:

$$F_{aero} = \frac{k_{aero} \cdot \rho_{aero} \cdot v_p^2 \cdot A}{2} [N] \quad (5)$$

- Rolling resistance force:

$$F_{val} = (k_{val} / 100) \cdot m_{cel} \cdot g [N] \quad (6)$$

- Climbing force:

$$F_{\alpha} = (1 - P_r / 100) \cdot \sin(\alpha) \cdot m_{cel} \cdot 10 [N] \quad (7)$$

- Total acting force on the vehicle:

$$F_{cel} = F_{aero} + F_{\alpha} + F_{val} [N] \quad (7)$$

- Required power for overcome aerodynamic force:

$$P_{aero} = (F_{aero} \cdot v_p) / 1.10^3 [kW] \quad (8)$$

- Required power for overcome climbing force:

$$P_{\alpha} = (F_{\alpha} \cdot v_p) / 1.10^3 [kW] \quad (9)$$

- Required power for overcome rolling resistance:

$$P_{val} = (F_{val} \cdot v_p) / 1.10^3 [kW] \quad (10)$$

- Sum of overall power:

$$P_{\Delta P} = (F_{cel} \cdot v_p) / 1.10^3 [kW] \quad (11)$$

- Energy density of battery:

$$E_{bat} = \frac{n_{bat} \cdot C_{bat}}{m_{bat}} [Wh \cdot kg^{-1}] \quad (12)$$

- Max. Weight of the traction accumulators battery:

$$m_{bat} = n_{bat} \cdot m_{bat} [kg] \quad (13)$$

- Total weight of the vehicle:

$$m_{cel} = m_{bat} + m_p + m_n + m_v [kg] \quad (14)$$

Speed range of electric motor

Calculation of the range was determined on the basis of maximal speed value which is equal to wheel circumferential speed of the driving wheel. In calculating we expect wheel diameter of 30 centimeters (to achieve maximal speed transfer. In this case speed for selected wheel diameter is $p = 2.42 [-]$.

$$n = \frac{60 \cdot \omega}{2 \cdot \pi} [\text{ot. min}^{-1}] \quad (15)$$

$$v_o = v \cdot \omega \Rightarrow \omega_{\max} = \frac{v_{o\max}}{r} [\text{rad.s}^{-1}] \quad (16)$$

$$n_{\max} = \frac{60 \cdot (60/3,6)}{2 \cdot \pi \cdot 0,15} [\text{ot. min}^{-1}] \quad (17)$$

Parameters of the ultracapacitors battery

- Energy accumulated in ultracapacitor battery:

$$E = P \cdot t [J] \quad (18)$$

- Capacity required for accumulation of energy:

$$C = \frac{2 \cdot E}{(U_{\max}^2 - U_{\min}^2)} [F] \quad (19)$$

- Number of serially connected cells:

$$n_{\text{serial}} = \frac{U_{\max}}{U_{\text{cell}}} [-] \quad (20)$$

- Total capacity of string:

$$C_{\text{total}} = C + ((0,2 \div 0,40) \cdot C) [F] \quad (21)$$

- Total paralleled strings:

$$n_{\text{parallel}} = \frac{C_{\text{total}}}{C_{\text{one_cell}}} [-] \quad (22)$$

2 Supply link of the electric vehicle

Electric loads in EV

- On board charger
- DC/DC converter for DC BUS
- Drivetrain
- DC/AC chopper for AC traction motor
- DC/DC converter for auxiliary accumulator
- Fun/heating
- Traction battery
- Brake system
- Lighting car
- Steering wheel
- Other electric loads

Block diagram of electric auxiliary circuits is in Figure. 3. Nominal voltage of the traction battery pack can be in range of voltage levels from 100V to 400V. Through a DC / DC converter is a traction battery pack is connected to distribution bus. The distribution bus is used for powering DC / DC converters which its output voltage is at around 12V. These converters provide power for the auxiliary loads of the EV. The advantage of this

configuration is use of the distribution bus with a nominal higher voltage levels which represents a higher efficiency and lower economic demands this system (material savings, lower power loss) compared with 12V power distribution network to the auxiliary loads. Higher voltage level for DC VDC_BUS3 for DC bus is not suitable due to safe voltage.

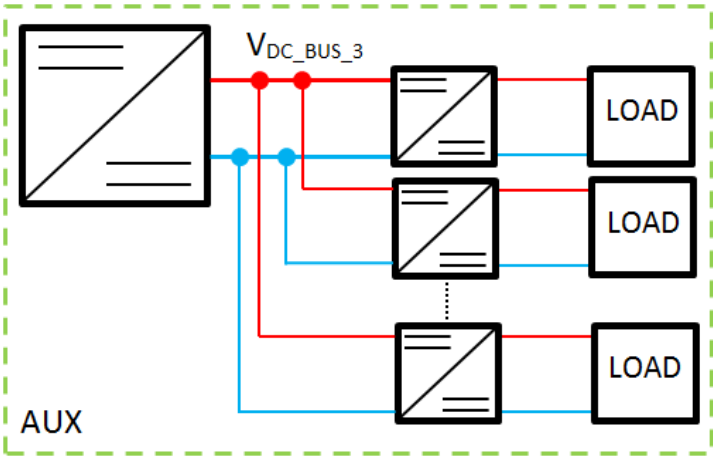


Fig. 3: Block diagram of the auxiliary circuit board network in the EV

Energy consumption of auxiliary devices is one of the factors influencing to range of the vehicle. This includes for example: main lights, exterior lighting, interior lighting, power steering, fans, heating system and other devices connect to distribution link (Table 3). Average value of total energy consumption of auxiliary equipment of a conventional vehicle is approximately 105 A, and power is around 1260W. The main part of the power consumption has exterior lights (around 370W - lamps with bulbs, 120W LED lighting), power steering (300 W) and the main lights (around 180 W) [7]. Sizing of the DC/DC converters supplies these devices is done regarding to the performance parameter of a conventional vehicle. This DC/DC converter has output current between 20 to 30A. Overall Block diagram of electric supply link in the EV shows Fig.4. This system includes several voltage levels. Namely is Voltage of traction battery packs $V_{DC_BUS_1}$, voltage $V_{DC_BUS_2}$, and voltage auxiliary DC bus $V_{DC_BUS_3}$.

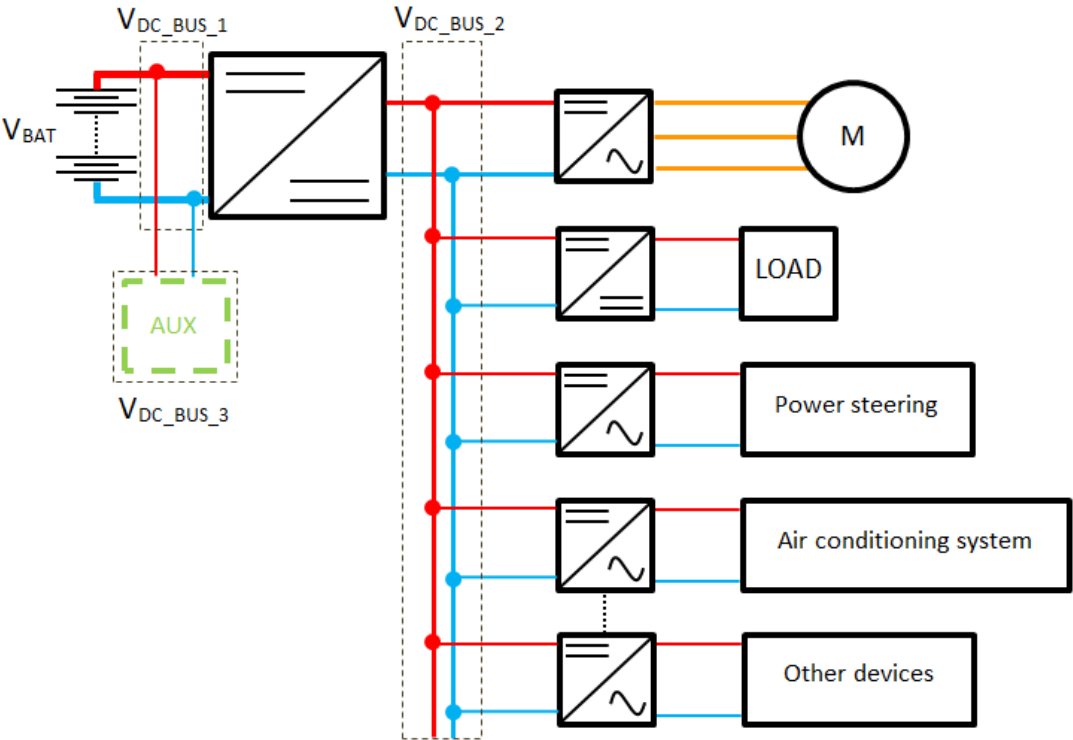


Fig. 4: Block diagram of the board supply network in the EV

Tab.3: Review of energy consumption in vehicle

auxiliary devices	I_max [A]	I_avg [A]
main lights	27,4	15
other lights	64,1	31
power steering	49,2	27,1
fans	25,6	11,8
other devices	42,1	20
	208,4	104,9

3 GUI interface for sizing dedicated parts of the electric vehicle

Using Matlab GUI can be implemented calculation power demands of vehicle with respect before mentioned facts. Input parameters for the calculation are the weight, frontal area, coefficient of rolling resistance, aerodynamic coefficient, air density, the average wheel speed, headwinds, and efficiency of power transmission, speed and acceleration pattern. The results are of the individual forces acting on the vehicle, depending on each parameter. For every force is calculated corresponding power range that are needed to overcome her. Each curve in the graph represent the performance for a constant value of the speed, the required power for acceleration, overall necessary electrical power and total performance consisting of the sum of the partial performance of the drive unit of the vehicle.

The next section shows the dependence of acceleration characteristics, dependence on wheel rotation, speed of the vehicle, torque dependence as a function of speed and torque as a function of overall speed. On the basis of these values are calculated parameters required to electric machine to drive the vehicle.

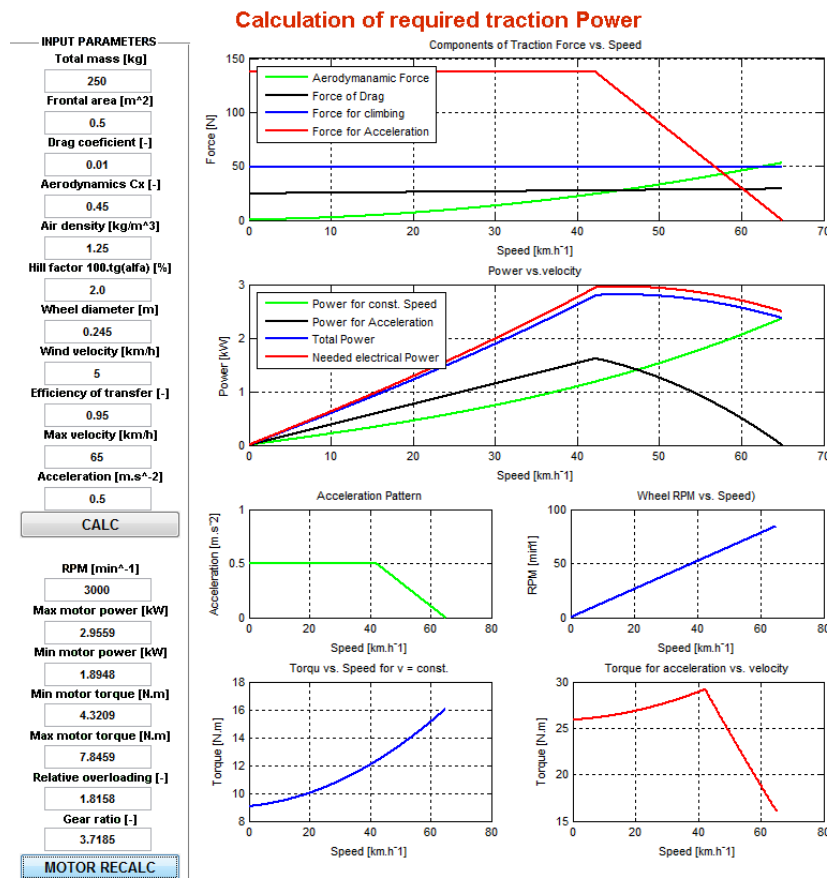


Fig. 5: GUI for calculation of speed characteristics and motor performance

Calculation traction power for driving cycle

To determine the energy consumption of the vehicle is defined several standard driving cycles. These are based on the parameters representing the current traffic situation in different regions of the world. However, estimating of consumption on the base driving cycles isn't equal to real traffic consumption. It is caused by other influences, which aren't represented in parameters of the driving cycles. Waveform on the Fig.7 shows the selected driving cycle and its mean velocity. For this calculation is possible choose total of six different driving cycles. As follows is possible to estimate the energy consumption of our vehicles for different traffic conditions. Next curve show dependence acceleration of the driving time.

Following procedure shows the curve of power for driving at a constant speed and acceleration performance as a function of time.

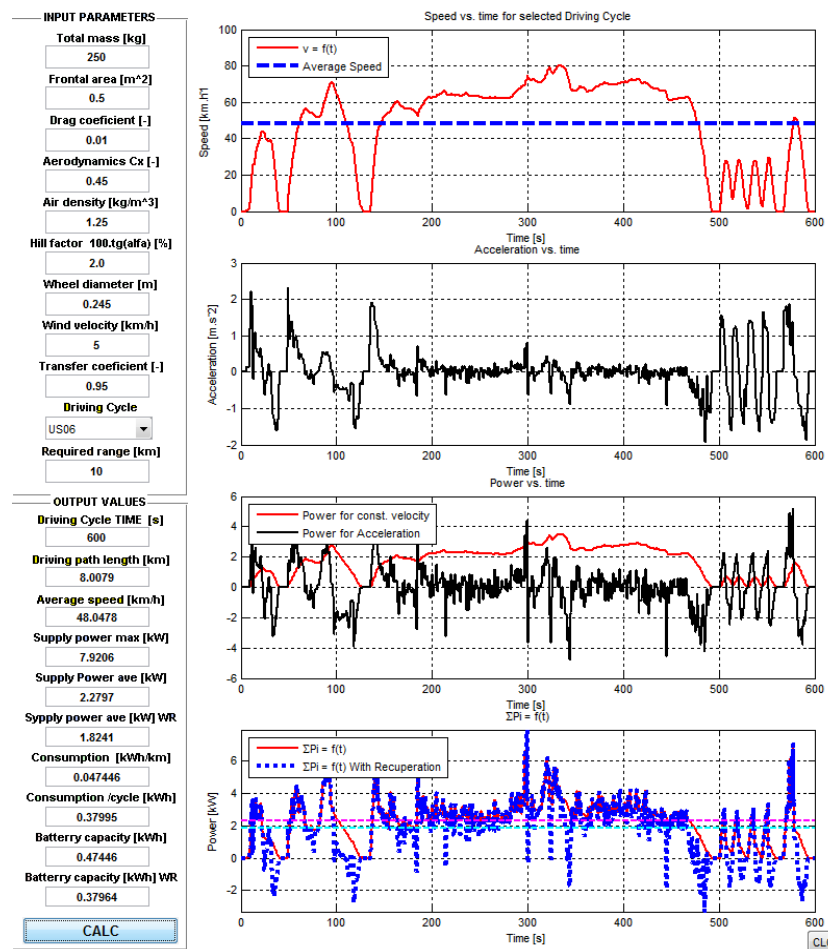


Fig. 6: GUI pre výkonové dimenzovanie pohonu vozidla

Calculation of secondary energy source

After reading data from calculated performance Fig.6 showed values are then used to calculate the parameters of the secondary power energy source.

4 Conclusion

The main benefit of paper is creating complete source code with a graphical user interface. This is a very usefull computing environment for the design of individual parts of the power energy unit. After creating the GUI source code can generate the corresponding executable file. This EXE file is created for each mentioned graphical interface. These allow user to use perform calculation without having to install of Matlab. The result is creation of design procedure for sizing drive train, using exe files without the necessity of programming. This is ultimately approach to elimination time to design.

Acknowledgements

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