Electric Vehicle Control Based on GPS and GSM Path Parameters

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Abstract— Minimizing of energy consumption is important task which is solved at all vehicles. In the case of electric vehicles (EV), energy stored on board in chemical accumulators must be used very effectively. For this purposes mathematical model of EV and real journey data used for energy consumption calculation must be used. On the basis of journey regime optimization lower energy consumption can be achieved. Optimal journey regime is calculated from the demanded travelling time by means of known road data, obtained by means of GPS and GSM navigation system with the aim to travel with minimum fuel consumption. From the road horizontal and vertical data basic route elements are calculated. Basic route elements are compared with needed torque, generated by driver pedal. All this information is processed, optimized and needed mechanical torque is transmitted to the control unit of electric drive.

1. INTRODUCTION

Accumulation of electric energy is serious problem, in case of electric vehicles (EV) especially. Energy stored in chemical accumulators on EV board must be used very effectively and carefully consumed. For this purpose optimization instruments, based on mathematical modelling of EV and real journey data used for energy consumption calculation must be used. By means of optimized journey regime minimized energy consumption will be achieved and longer action radius of EV will be achieved.

Optimal journey regime is calculated using known road data. Road data are gained from GPS and GSM navigation systems. From the road horizontal and vertical data basic route elements are calculated. Basic route elements are compared with needed torque, generated by driver pedal. All this information is used in the process of optimization and needed mechanical torque is transmitted to the control unit of electric drive.

For model implementation the dSpace DS1103 has been used. The dSpace DS1103 platform is used as a simulator of the electric vehicle in laboratory and it is used for HIL (Hardware In the Loop) tests. The DS1103 device is covered in the AutoBox with Ethernet communication interface and Autoboot option enabling usage of Compact Flash card. The complete EV mathematical model is loaded into the DS1103 device.

2. DS1103 HARDWARE STRUCTURE

dSpace DS1103 is single board system with real-time processor and comprehensive I/O. It is used for the modern rapid control prototyping and it should be used for:

- Induction motor control.
- Automotive applications.
- Robotics.

The dSpace DS1103 board is included in an expansion box AutoBox. The AutoBox (see Fig. 1) is dedicated to be used in the automotive applications. Therefore the AutoBox supply voltage is of 12 V. The AutoBox has option which enables to boot application from CF (Compact Flash) card without computer. An interface board was designed for connection between dSpace and master controller (MC) and dynamometer (DM). DS1103 enables the real-time simulation of EV and produces the torque which simulates the load torque in real EV. The communication between DS1103 and dynamometer is realized via CAN.

The dynamometer has own control and measurement unit. The communication between DS1103 and MC is realized via RS232 using own developed protocol. The schematic diagram of hardware structure is depicted in Fig. 2. Permanent Magnet Synchronous Machine (PMSM) is used as the main electric drive of electric vehicle. The Power Electronics block controls PMSM and communicates with MC via CAN bus.

Figure 1: dSpace AutoBox.

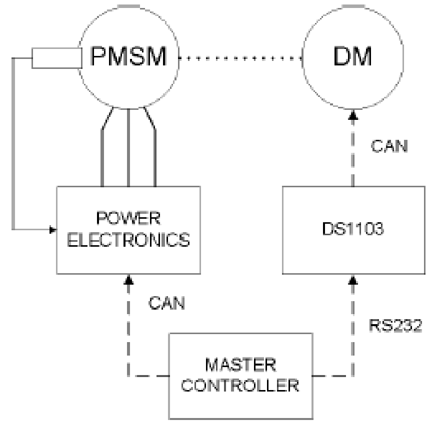

Figure 2: Hardware structure of the laboratory stand.

3. MATHEMATICAL MODEL OF ELECTRIC VEHICLE

Basic model of vehicle dynamics consists of 4 basic equations. The angle of the track (slope) is function of trajectory because it matters, in which part of the track the vehicle is at the moment.

$$
\begin{aligned}
F_{acc} &= m * a(t) && (1)\\
F_{air} &= \frac{1}{2}\rho_a * A * C_d * v^2(t) && (2)\\
F_{roll} &= c_r * m * g * \cos(a(s)) && (3)\\
F_{grade} &= m * g * \sin(a(s)) && (4)\\
& && (5)
\end{aligned}
$$

m — mass of EV;
$a(t)$ — acceleration of EV;
ρ_a — air density;
A — frontal surface;
C_d — aerodynamic constant;
$v(t)$ — speed of EV;
c_r — rolling resistance coefficient;
g — gravity constant;
$a(s)$ — slope (function of trajectory).

According to the general equation for power

$$P(t) = F * v(t) \quad (6)$$

It is possible to create the following power balance equation:

$$P(t) = (F_{acc} + F_{air} + F_{roll} + F_{grade}) * v(t) \quad (7)$$

To make the calculation of power consumption more realistic, model also takes into account consumed energy for heating, lights and other features or efficiency map of a specified electric motor (EM) used for a drive. Several different inputs can be used for the model. Basically we need a reference speed or a position of the throttle pedal. Then road slope (angle) is needed and also a travelled distance (this data are either taken from universal driving cycles like NEDC, ECE and Arthemis or measurements in the real driving conditions).

The working point (needed for efficiency map) of the electric motor is calculated from a tyre dimensions and speed of the vehicle, so we can get a current torque and revolutions of the EM. There are various outputs of the model such as current amount of energy stored in a battery, current power and torque produced by EM, vehicle speed and acceleration and travelled distance.

4. APPLICATION OF GPS AND GSM NAVIGATION SYSTEMS

Needed actual power and torque of electric drive must be calculated with respect to route resistances and other meteorological conditions. In the first step meteorological conditions are neglected and needed power and torque are calculated with respect to the route horizontal and vertical parameters. To obtain actual route parameters, electronic maps and actual vehicle position must be known. Therefore cruising data are scanned using GPS and GSM systems. With respect to big amount of route data and board computer calculation capacity, cruising data are compressed into optimised broken lines. These lines with sufficient accuracy and minimized calculating effort approximate real route. Real illustration of this approximation process for horizontal and vertical route profile is presented in Fig. 3 and Fig. 4. Obtained data can be used on EV board for real time drive control or for laboratory experiments, when optimisation working regime of EV drive will be tested. For this purposes real or simulated driving profiles can be used. Following results present both methods.

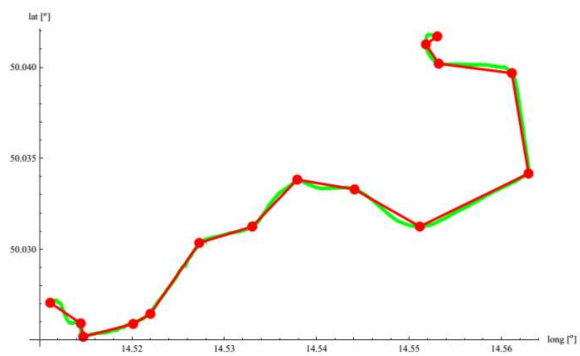

Figure 3: Illustration of horizontal road profile approximation using minimized broken lines. Horizontal axis: longitude. Vertical axis: latitude.

Figure 4: Illustration of vertical road profile approximation using minimized broken lines. Horizontal axis: time. Vertical axis: altitude.

5. RESULTS OF THE MODEL USING SPECIFIC ARTEMIS DRIVING CYCLE

The Artemis-mw-130-incl-pre-post driving cycle has been used to demonstrate hardware and software ability to operate under high vehicle velocity and for longer cruising time. Velocity profile, motor torque and battery state of charge for Artemis driving cycle are depicted in the graphs in Fig. 5, Fig. 6 and Fig. 7.

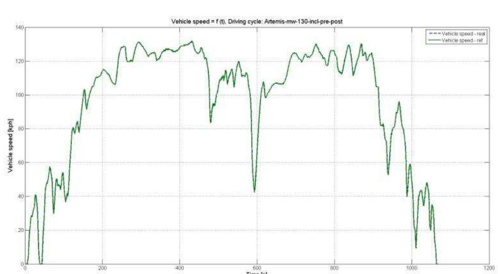

Figure 5: Artemis: vehicle speed = f (time).

Figure 6: Artemis: torque = f (time) and electric motor revolutions = f (time).

6. RESULTS OF THE MODEL USING REAL MEASURED DRIVING CYCLE

In this paragraph are presented results of a real measured driving cycle, scanned in Prague during the route from the city to the highway (Real driving cycle — city). Road data were generated by an apparatus called myTracks. This apparatus is based on the iPhone 5S with built-in GPS module. Generated road data file consist of current longitude, latitude, altitude and travelled distance between the current and before sampled point, absolute travelled distance and speed. Real

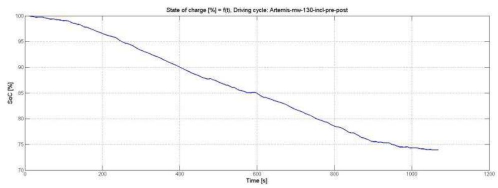

Figure 7: Artemis: battery state-of-charge = f (time).

Figure 8: Real driving cycle — city: altitude = F (distance).

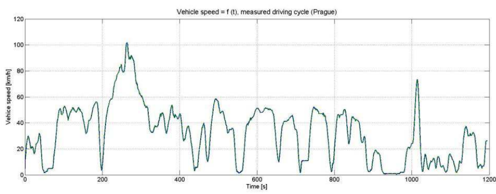

Figure 9: Real driving cycle — city: vehicle speed = f (time).

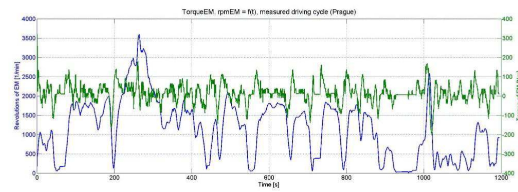

Figure 10: Real driving cycle — city: torque = f (time) and electric motor revolutions = f (time).

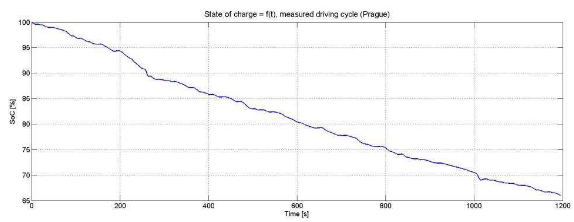

Figure 11: Real driving cycle — city: battery state-of-charge = f (time).

vehicle speed is taken from the car system as a physically measured value. Obtained measured and simulated results are presented in Fig. 8–Fig. 11.

7. CONCLUSIONS

This paper presents the possibility of GPS and GSM systems for EV drive control using cruise data calculation. For EV dynamic modelling and cruise condition optimization the dSpace DS1103 system is used. This system is designated for experimental laboratory verification of electric vehicle dynamics, when real road data will be implemented into dynamometric measuring laboratory system, which will simulate real route resistances.

The goal of the project is to develop a control algorithm for optimization of vehicle electric energy consumption not only with respect to the road trajectory, but also with respect to the traffic situation and meteorological conditions.

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