USING OF dSPACE DS1103 FOR ELECTRIC VEHICLE MODELING

T. Haubert, T. Hlinovsky, P. Mindl

Czech Technical University in Prague, Faculty of El. Engineering, Dept. of El. Drives and Traction

Abstract

This paper presents the using of dSpace DS1103 for the electric vehicle power consumption modeling. The dSpace platform is used as a simulator of electric vehicle in laboratory and it is used for HIL (Hardware In the Loop) tests. The DS1103 board is included in the AutoBox with Ethernet communication interface and Autoboot option is available using Compact Flash card. The complete mathematical model of electric vehicle is loaded in DS1103 board.

1 Introduction

Increasing of living standards increased needs for people transport. Gas emissions and fossil fuel consumption are actual problems for global environment quality on the Earth. Gas emission of car internal combustion engines (ICE) brings many ecological problems in big cities specially. Electric vehicles are tackling this problem, because they do not produce gas emissions. On the board needed electric energy can be stored in batteries, but their disadvantages are limited capacity and inconvenient ratio capacity to mass. Due to driving area of electric vehicles (EV) is lower to compare with vehicles equipped by ICE [1].

2 Hardware structure with DS1103

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

Figure 1: dSpace AutoBox

The dSpace DS1103 board is included in an expansion box called AutoBox. The AutoBox (Fig. 1) is dedicated for using in car. The AutoBox supply voltage is 12 V. The AutoBox has included a Autoboot option. This option enables the boot of application from CF (Compact

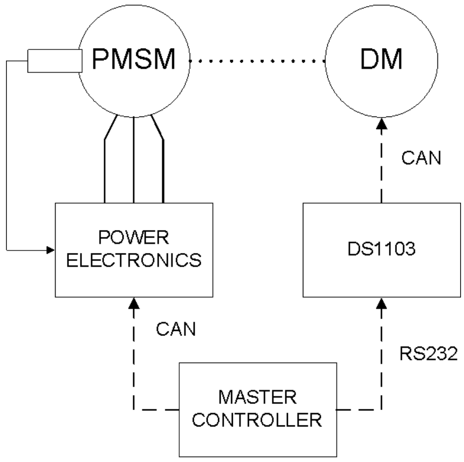


Figure 2: Hardware Structure of Laboratory Stand

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 and it is produced by VUES Brno company. The communication between DS1103 and MC is realized via RS232 using own developed protocole. The schematic of hardware structure is shown in the Fig. 2. Permanent Magnet Synchronous Machine (PMSM) is used for the main electric drive of electric vehicle. The Power Electronics is used for PMSM control and communication with MC is realized via CAN.

3 Mathematical Model of Electric Vehicle

Basic model of vehicle dynamics consists of 4 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.

$$F = F_{acc} + F_{air} + F_{roll} + F_{grade} \tag{1}$$

where

$$F_{acc} = m \cdot a(t) \tag{2}$$

$$F_{air} = \frac{1}{2}\rho_a \cdot A \cdot c_d \cdot v^2(t) \tag{3}$$

$$F_{roll} = c_r \cdot m \cdot g \cdot cos(\alpha(s)) \tag{4}$$

$$F_{grade} = m \cdot g \cdot sin(\alpha(s)) \tag{5}$$

The variables of these equations are

- m is the mass of EV
- $a(t)$ is the acceleration of EV
- $\rho(a)$ is the air density

- A is the frontal surface
- c_d is the aerodynamic constant
- $v(t)$ is the speed if EV
- c_r is the rolling drag force coeficient
- g is the gravity constant
- $\alpha(s)$ is the slope (function of trajectory)

According to general relation for power

$$P(t) = F \cdot v(t) \tag{6}$$

it is possible to create following power balance equation

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

To make the calculation of power consumption more realistic, model also takes in count 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 is either taken from universal driving cycles like NEDC, ECE and Arthemis or measurements in real driving). 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.

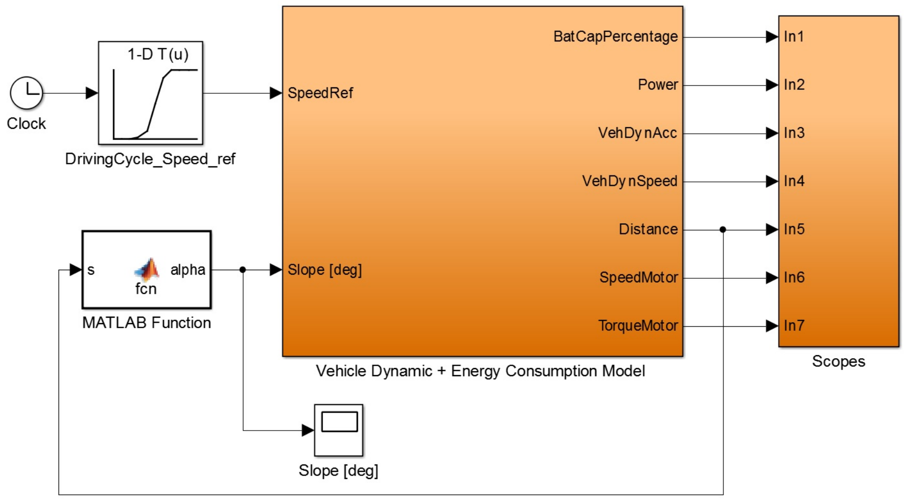


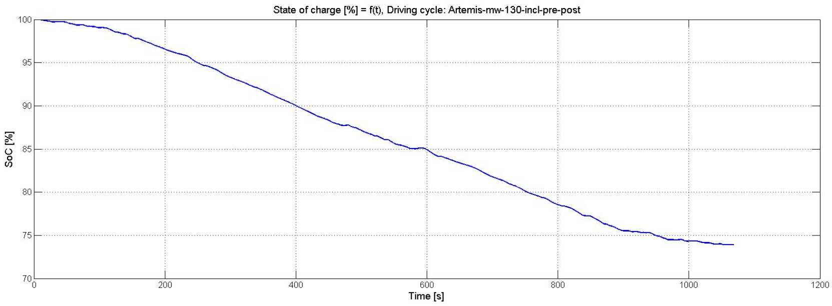
Figure 3: Whole model with inputs and outputs

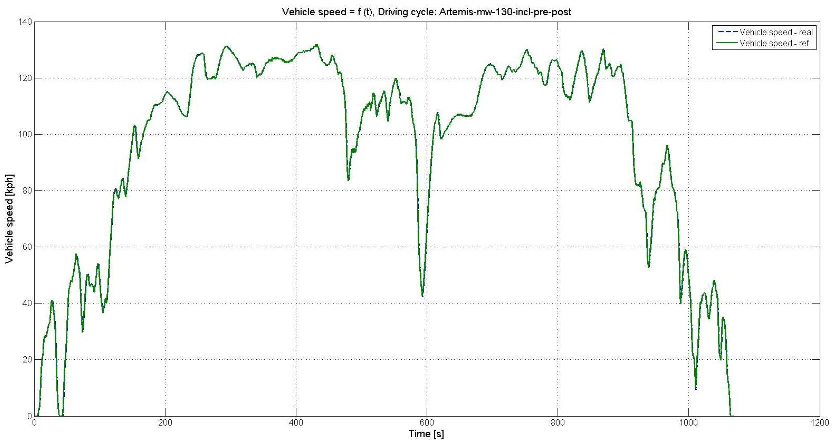
Also speed of the EM is included which depends on the gear ratio (8) which can be set by the user of the model in the initialization m file.

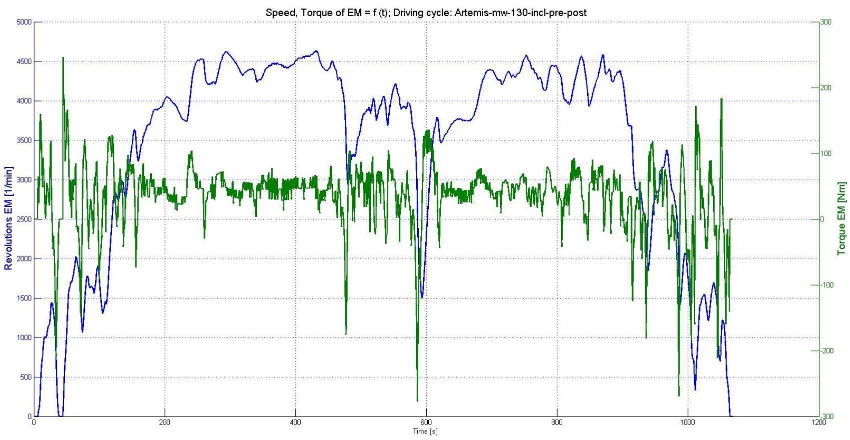
$$n_{mot} = \frac{1}{3.6 \cdot TyrePerimeter} \cdot GearRedRation \cdot 60 \cdot v(t) \tag{8}$$

$$M_{mot} = \frac{P}{n_{mot}} \cdot \frac{60}{2\pi} \tag{9}$$

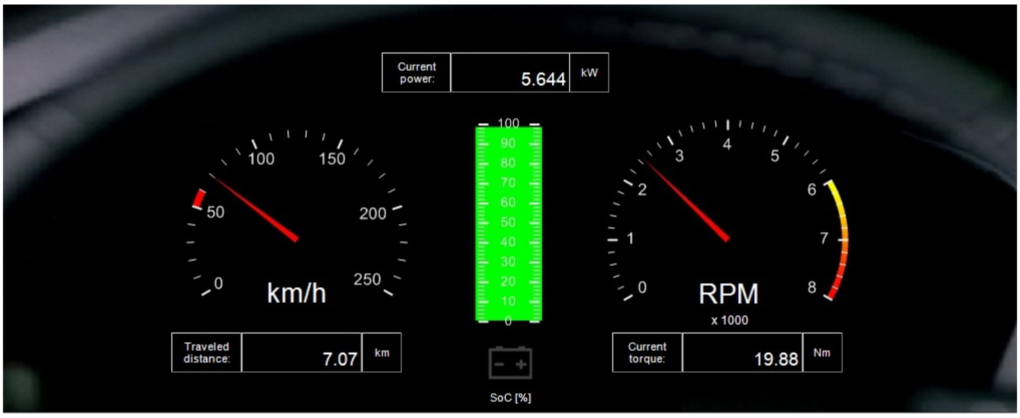
Several driving cycles have been used for testing the model functionality. On the figures displayed below, the virtual vehicle has been driven through a driving cycle called: Artemis-mw-130-incl-pre-post. These driving cycles do not count with any slope of the road and should represent some common traffic situations from everyday driving.







Whole model can be exported into the .sdf file which is then loaded to the AutoBox with dSpace 1103 PPC controller board. This can be done to test the model in the laboratory or in a car by using the autoboot option, when the .sdf file is loaded to a compact flash memory card which is plugged in the periphery of the dSpace controller. Whole application with a loaded model is then launched by powering up the AutoBox. For testing purposes a basic GUI has been created in ControllDesk environment, which only displays the data calculated by the model.



4 Conclusion

This article presents using of DS1103 for modelling of electric vehicle dynamics. This model is used for the control of dynamometer which simulates the real load produced by electric vehicle. This connection (DS1103 and dynamometer) enables the testing of electric motors in real conditions. The goal of the project is to develop an algorithm for optimization of electric energy consumption of electric vehicle with these conditions: known trajectory, traffic situation and weather.

5 Acknowledgement

This research has been realized using the support of Technological Agency, Czech Republic, programme Centres of Competence, project TE01020020 Josef Bozek Competence Centre for Automotive Industry. This support is gratefully acknowledged.

This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS14/068/OHK3/1T/13.

References

[1] T. Haubert, J. Bauer, P. Mindl: Using of dSpace DS1103 for Electric Vehicle Power Consumption Modeling. In *21th Annual Conference Proceedings Technical Computing Prague 2013*. Prague: HUMUSOFT, 2013, p. 24. ISSN 2336-1662.ISBN 978-80-7080-863-4.

Tomas Haubert
Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Electric Drives and Traction: tomas.haubert@fel.cvut.cz

Tomas Hlinovsky
Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Electric Drives and Traction: hlinotom@fel.cvut.cz

Pavel Mindl
Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Electric Drives and Traction: mindl@fel.cvut.cz