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Design and Development of the Electric Vehicle's Monitoring and Control System

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ABSTRACT

An in-house project has been launched at Volvo Group Trucks Technology to develop an electric single-seater demonstration vehicle. In addition to demonstration purposes, the final product will also serve as a test platform. This message is part of this Volvo project. It aims to first structure the control system for a single-seat vehicle, then implement a subset of the required functions, verify the proposed control strategy, and finally document the design using the EAST-ADL architecture description language.

The main function of this work is the control of the propulsion system. For a road vehicle, the three main motions that must be controlled are longitudinal and lateral speed as well as yaw motion. Furthermore, the actuators that can be controlled and contribute to the movement of a particular vehicle are two electric motors for the rear wheels and four brakes, one on each wheel. On the other hand, the steering control is not part of the steering system and the driver can directly affect the angle of the front wheels. Having more actuators that act as control inputs to the system than control motions that are control outputs allows the writer to use a control method that can be used for overscaled systems called control allocation. In addition, a conceptual model developed by Volvo was used to structure the control architecture.

The implementation of the control system was carried out in the Matlab/Simulink environment and several simulation tests are carried out to verify the functionality of the designed system. An already produced vehicle model was modified and used during the simulations.

The results of the simulation tests confirmed that the designed control system can handle the vehicle drive. This delivers the first version of the control system, which could be enriched with additional functions in order to realize the Volvo project.

Key words: *electric vehicle, control system, EAST- ADL language, over-actuated sys- tems, control allocation, CVC architecture*

INTRODUCTION

In general, as the Earth's population grows and living standards improve, the density of vehicles also increases [1]. This increase in the number of vehicles, together with the ability to design ever more powerful vehicles, leads to higher demands on energy consumption. The use of fossil fuels to cover the energy demand causes an increase in environmental pollution as well as a decrease in available natural resources. While the available amount of fossil fuels is decreasing significantly, there is no doubt that resources like oil, given the current rate of energy consumption, will disappear in a few decades. As a result, shipping costs will be very high.

For the reasons mentioned above, the use of sustainable energy sources is becoming a crucial factor for the automotive industry. One proposed solution is the development of electric vehicles (EVs). Unlike conventional vehicles, it uses electric motors for propulsion. EV is not a recent discovery, it was first introduced in the middle of the 19th century. Despite its long existence, it never became as popular as internal combustion engine (ICE) vehicles. Some of the main reasons for this are limitations in range without the need to recharge and in speed. However, in recent decades, as sustainable solutions become more and more important and technological improvements help to overcome the original shortcomings, interest in this type of vehicle is growing rapidly.

There are three main types of EVs [2]. The first uses electrical energy supplied directly by an external power plant, the second uses rechargeable batteries to store and provide electrical energy. The third type uses rechargeable batteries, but also includes ICE. This type is called a hybrid electric vehicle (HEV) and uses the ICE to charge the battery or increase the available energy for the propulsion system. Volvo Technology has launched its own Electric Demonstration Vehicle (EDV) development project. The main goals of this project are twofold:

- Use the constructed EDV as a demonstration vehicle and as a platform for testing new technologies.
- Increase employee competence in designing HEVs from scratch.

The EDV will be approximately the size of a go-kart. The drive system will consist of two electric motors, one for each rear wheel. Although the engines will be powered primarily by the battery, an ICE electric generator will also be included. The output of the ICE will be converted to electrical energy and then fed to the battery motors. The braking system will be electro-hydraulic and will consist of four brakes, one for each wheel. As for the steering system, it will be steering by wire.

This final report is only a small part of Volvo's EDV development project. It will focus on the design of the vehicle control system and more precisely the drive system. As the Volvo project is at an early stage, the work will include the following tasks:

- Identify and characterize vehicle features and divide them into requirements.
- Arrange the control system according to a specific reference architecture to meet Volvo standards.
- Adapt and improve existing control functions or develop new ones to meet requirements.
- Validate and verify the functionality of the control system using simulations.

OBJECTIVE OF THE WORK

In order to overcome some of the anticipated obstacles and difficulties in the course of the work, the following constraints help to define the working framework.

- The design of the control system will focus on the EDV drive system.
- The steering will not be part of the steering system, however the driver's commands will be directly applied to the wheels via a fully mechanical steering system.
- Estimated values of vehicle components that have not yet been decided will be used.
- Sensor models and actuator models will not be included.

Result:-

To verify that the designed control system has the desired behavior, various test cases were simulated. Although the test cases were chosen arbitrarily, their purpose was to cover a variety of different driving commands. Two sets of test cases were performed. The first was to verify the driver's wish interpretation system. The simulation tests were independent of the vehicle model. In addition, the turning speed calculation subsystem was not verified, as a similar system was tested in an earlier Volvo project. The focus of these tests was to establish the desired longitudinal speed based on the GP ratio and driving modes.

The second set of simulation tests was performed with the completion of the current work to validate the control allocator. The ODE23 solver was chosen for the simulations. It is a variable-step implicit method solution that requires fewer time steps than explicit methods and is designed when working with models using the SimMechanics toolset, such as Environment Model. Although in the CVC architecture, different layers have different time spans, a single sampling time was allocated for this work. Its value Ts = 0.2 sec was chosen arbitrarily, but it was taken into account that it must meet the Nyquist criterion. So it was chosen to have at least twice the frequency of what the hardware components can have. In addition, QCAT's weighted least squares function required as input the number of iterations the function could take before it returned a result. The maximum number of iterations allowed by the function constructor was I = 100, which was the value chosen during the simulations.

Conclusion-

After the simulation tests, the general conclusion is that the designed functions of the control system are as expected. This means that the control system is capable of receiving signals such as GP, DM and SWA. Based on these signals, the desired trajectory to be followed by the vehicle is estimated. Then the control allocator calculates the values to be assigned to the motion actors of the system, respecting the specified values of their physical limits based on the desired trajectory. The number of iterations used in the control allocation was said to be 100, but it was observed from the simulations that the optimal solution was computed at a maximum of 15 iterations. Each of the simulation tests verifies different properties of the entire system.

Test case 1 shows different torque demand maps depending on the selected DM. Test cases 2a and 2b show the differences in the estimated required speed due to the selected DM, using all GP positions and constant.

When testing case 3, it can be seen that the control system respects the engine limitations. It doesn't matter how high the required speed is, the controller will try to achieve that speed, but always with respect to the given constraints. A similar observation was made in Test Case 4, not only for the motors but also for the braking constraints. One important issue that should be mentioned at this point concerns the amount of torque required to maintain a constant speed. As can be seen from the graphs, when the desired rpm is reached, very low torque is needed to maintain that rpm, no matter how high it is. Of course, this is not realistic, but it can be explained by the configuration of the vehicle model. The vehicle model only considers the rolling resistance force Froll and not the aerodynamic drag force Fdrag. Froll is always constant and has a much lower value compared to Fdrag, which is why the required motor torque to maintain a constant speed is so low.

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