COLLEGE OF ENGINEERING/ CENTER FOR AUTOMOTIVE RESEARCH

Model-Based Design Approach to Predict Performance of BAS/Electric Motor for OSU EcoCAR 3 Vehicle

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Introduction

The OSU EcoCAR 3 vehicle is a Chevrolet Camaro that has been converted to a plug-in hybrid electric vehicle by the EcoCAR team based at The Ohio State University Center for Automotive Research. The team takes place in yearly competitions against other universities with the task of making the Camaro more energy efficient and sustainable while maintaining its signature performance aspects.

OSU EcoCAR 3 vehicle at GM's Desert Proving Grounds in Yuma, AZ for Year 2 in EcoCAR 3 competition

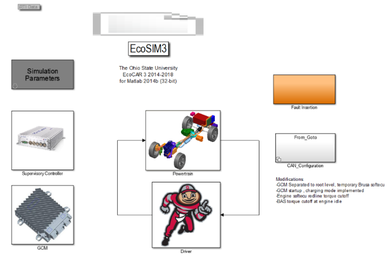
Objectives

The goals of this research were to:

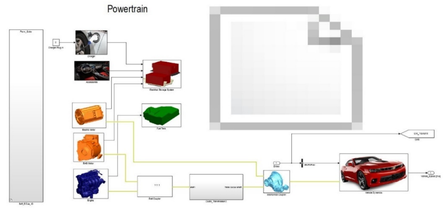
(a) Model, predict, and improve the performance of the belted alternator/starter (BAS) and traction motor in the vehicle.
(b) Test the BAS and/or traction motor and compare model performance with vehicle performance
(c) Tune the model to appropriately to achieve component level functionality

Methodology

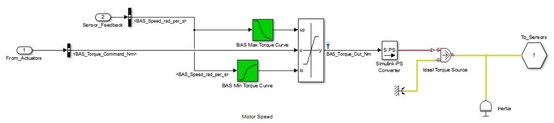
After gaining exposure to full vehicle and component models created by the team using MATLAB and Simulink, a new, higher fidelity model of the BAS was created using dynamic equations of the electric machine.



EcoCAR Vehicle Model, *EcoSIM3*



Powertrain model of EcoCAR 3 vehicle inside *EcoSIM3*



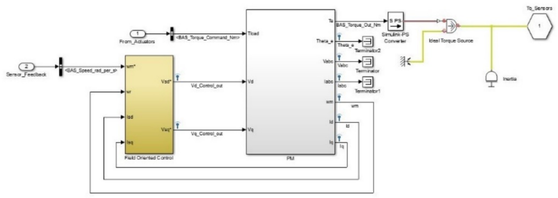
Old BAS model using lookup tables

$$v_d = Ri_d + L_d\frac{d}{dt}i_d - \omega_s L_q i_q$$

$$v_q = Ri_q + L_q\frac{d}{dt}i_q + \omega_s(L_d i_d + \lambda)$$

$$T_e = \frac{3}{2}p(\lambda i_q + (L_d - L_q)i_d i_q)$$

Equations used to model behavior of electric machine

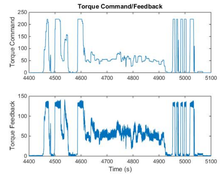


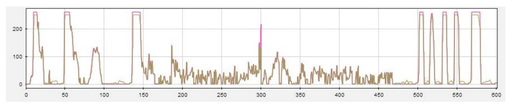
New BAS model in Simulink

Though the BAS could not be physically tested due to inverter calibration constraints, testing was carried out on the traction motor. The vehicle was placed on a chassis dynamometer and run through multiple drive cycles. Data from these tests were logged, analyzed, and compared with corresponding drive cycle results from *EcoSIM3.*

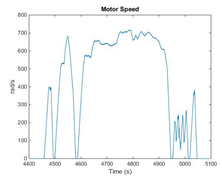
Results

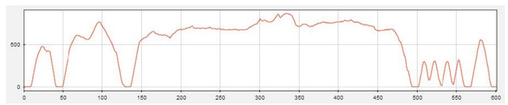
The graphs shown below come from data logged from a US06 drive cycle while the vehicle was on the dynamometer and the results of a US06 simulation with *EcoSIM3*. The criteria examined included torque command and feedback, speed, and temperature of the motor.



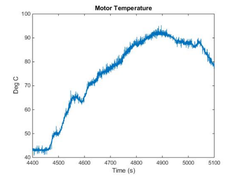


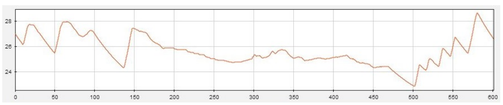
The first figure in blue is logged data from the dynamometer, while the second figure comes from the MATLAB and Simulink Data Inspector. The brown represents the torque feedback and pink represents the commanded torque in Nm. In both the simulation and drive cycle, the lower torque commands were met, but there is a cap at which no more torque is provided. This will have to be worked around in the future.





Continuing from the bottom of the column, the motor speed from the dynamometer testing is again in blue, while the simulation is in dark orange. The magnitude of the speed from the dynamometer test seems to be down across the board from the simulation, making it difficult to tell if there is a control issue or just driver error. Further testing may be required.





It is immediately apparent that the simulation temperature data and the data from the testing vary greatly. This could be due to the limited coolant flow for the electronics cooling loop, but more likely, the thermal model in *EcoSIM3* should be revisited.

Conclusions & Future Work

Based on this study, *EcoSIM3* will be able to run more accurate simulations. This will help the team better develop controls and increase performance of individual components as well as the whole vehicle.

Work to still be done regarding this research includes fine tuning the controls of the electric motor as well as debugging the new model of the BAS motor.

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