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Vehicle Plant Model and Supervisory Control Development for a Parallel Pre-Trans Plug-In Hybrid Electric Vehicle

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Abstract: The Arizona State University EcoCAR-3 team is a new team in Advanced Vehicle Technology Competitions (AVTCs), competing among 16 North American Universities under a 4 year competition aimed at redesigning a high performance conventional vehicle into a hybrid electric vehicle, reducing the environmental impacts while maintaining the performance of the vehicle. The team imitates General Motors (GM) Vehicle Development Process (VDP) in designing, building and refining the vehicle. The first step in design process is Powertrain Architecture selection, and the team is designing a parallel pre-transmission plug-in hybrid vehicle to meet the competition targets. The proposed powertrain consists of a 2.4L gasoline (E85) engine, a 140 kW electric motor, 6-speed automatic gearbox and 18.9 kWh battery pack. The vehicle is capable of delivering 30 mile all-electric operation, along with an impressive Utility Factor weighted fuel economy of 50 mpgee.

This paper presents the vehicle model development done by the Arizona State University EcoCAR-3 team in year-1 of the competition. The paper explains the detailed vehicle architecture, modeling platform, technical goals of the team and vehicle performance and energy consumption calculations. Control strategies for power flow management, as well as control system development has been addressed, along with approaches used to address any modeling imperfection.

Keywords: Hybrid, Powertrain, Control, Architecture, Modeling, AVTC, EcoCAR 3

1. INTRODUCTION

EcoCAR 3 is the latest iteration in the longstanding tradition of Advanced Vehicle Technology Competitions. Sponsored by the U.S Department of Energy (DOE) and General Motors (GM), these competitions serve to educate the next generation of automotive engineers, while inspiring new vehicle technology innovations. EcoCAR 3 is a four year premier collegiate competition challenging sixteen schools across North America to redesign a Chevrolet Camaro as a Hybrid Electric Vehicle. Teams must work to improve energy efficiency, reduce vehicle emissions, and maintain the muscle and performance expected from this iconic American car.

To ensure vehicles are successfully developed to a showroom quality level within the four year program, teams utilize a Vehicle Development Process (VDP) process plan developed by GM that mimics the VDP used by GM as a whole. This plan has been adjusted to meet the requirements of the EcoCAR competition but it does operate on a similar timeline to GM's timeline for new vehicle development or full vehicle redesign. This gives students a clear idea of the timelines OEMs operate under when they are redesigning a vehicle platform. While full new vehicle platform designs operate on a slightly longer timeline, the EcoCAR VDP is very much representative of real world OEM production engineering.

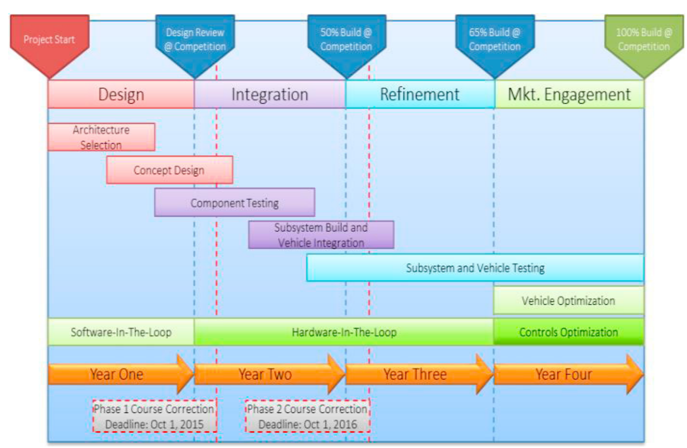

Fig. 1. Vehicle Development Plan – EcoCAR 3

Each competition year is broken down into a major goal: design, integration, refinement, and market engagement (or optimization). These goals can only be achieved by completing all of the tasks and deliverables set out along the way as shown above.

EcoCAR 3 is Arizona State University's (ASU) first opportunity to participate in AVTCs. This opportunity is helping to drastically expand and improve the school's new automotive program. ASU's automotive program was

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initiated only five years ago but has since, and with the help of EcoCAR, grown tremendously. Well-equipped machining facilities are available to students in addition to extensive opportunities for hands on learning through projects, labs, and courses. Though the ASU automotive program is still young, it has always strived to teach true engineering practices through design and manufacturing. This ‘maker mentality’ has proven to be a great benefit to the ASU EcoCAR 3 team in progressing through the VDP.

2. VEHICLE ARCHITECTURE

The ASU EcoCAR 3 team has chosen to build on a parallel pre-transmission hybrid due to high performance capabilities while maintaining efficiency. The vehicle will run on an E85 engine with a 140 kW electric motor placed between the engine and transmission. E85 was chosen as the preferred fuel type because of its low well to wheel (WTW) emission. Because it is generated from corn, E85 actually generates energy during the fuel production process. This lowers overall energy consumption and emissions across the total life of the fuel.

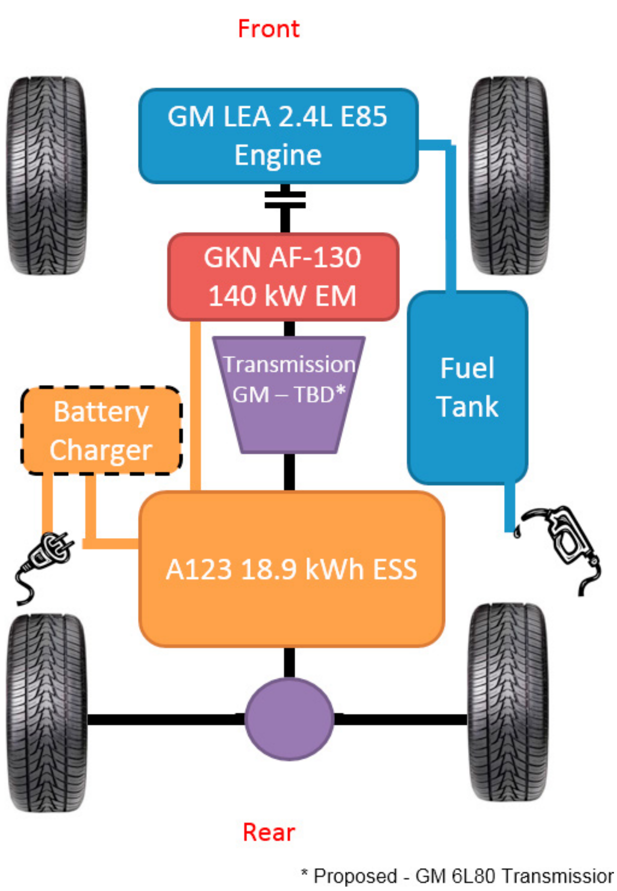

Fig. 2. Powerflow Diagram for proposed vehicle

To meet performance goals, the combined power and torque from the internal combustion engine (ICE) and electric motor (EM) combined must exceed those of the stock Camaro which has 241 kW of power and 377 Nm of torque. The maximum power and torque outputs of the GM donated ICE 134 kW of power and 232 Nm of torque for the E85 LEA ICE respectively. Using these as a baseline, the EM power and torque requirements were estimated to be 140 kW and 78 Nm. Based on these requirements, appropriate components were selected and their performance specifications are listed below.

Table 1. Component Specifications

Component	Model	Performance Specifications
Engine	GM 2.4 L LEA E85	Peak Power: 134 kW Peak Torque: 232 Nm
Electric Motor	GKN AF-130	Max Speed: 8000 rpm Peak Power: 140 kW Peak Torque: 350 Nm
Inverter	Reinhart PM150DX	Peak Power: 150 kW Supply Voltage: 360 V DC
Battery	A123 7M15s3p	Peak Current: 612 A Energy: 18.9 kWh Capacity: 19.4 Ah

These performance specifications allow the ASU EcoCAR 3 team vehicle to meet all of the team performance and energy consumptions goals. While it results in some sacrifices in cost as well as handling, the main goal was high performance, low energy consumption. Handling will be improved upon later with vehicle dynamics studies and redesigned suspension/handling.

The overall goal of the ASU EcoCAR 3 team is to design a performance vehicle that meets the needs of muscle car enthusiasts around the country but still maintains an efficiency level expected for a plug in hybrid electric vehicle.

3. VEHICLE SYSTEM MODELING

3.1 Modeling Platform

The high-level modeling and initial simulations for all possible hybrid powertrain architectures was done in Autonomie because of its ease of use and component interchangeability. A detailed parametric study was done to finalize the powertrain component sizes and fuel used in order to meet the team VTSs. The Autonomie results were used to determine the performance and energy consumption of different vehicle architectures, and assisted in determining the best candidate for fulfilling team goals. The finalized architecture was developed in Simulink using the same component data for the ease of future competition deliverables because of its ability to provide more flexibility for in-depth data analysis, managing simulations, and closed-loop testing. Autonomie models were used as a reference to develop component and subsystem models in Simulink. The Autonomie data and equations were utilized, as a baseline, for the Simulink model to match fidelity between the models.