IPRO 342

HYBRID ELECTRIC VEHICLES:

SIMULATION, DESIGN, AND IMPLEMENTATION

SPRING 2006

MIDTERM PROGRESS REPORT

Spring 2006 MIDTERM PROGRESS REPORT
IPRO-342 Hybrid Electric Vehicles
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Instructor: Sheldon S. Williamson

REVISED OBJECTIVES:

After several weeks of research and modeling, the IPRO 342 team has reached and modified some of its objectives. The team is continuing to aim towards modeling the conversion of a Chicago Transit Authority (CTA) bus and a school bus chassis to hybrid electric vehicle (HEV) drive trains. The CTA bus group will continue to pursue the design of a retrofit parallel HEV design approach. However, the school bus group has added a few new simulations. Initially, the goal was to determine efficient drive trains for a parallel retrofit model and a new parallel drive train with a downsized engine. Currently, the team has set additional goals of modeling a new hybrid drive train, based on an integrated starter/alternator (ISA) parallel HEV design. This new design is expected to result in much better performance compared to other HEV arrangements.

In addition, the teams are also modeling the final layouts and appearances of the designed drive trains in 3-dimension (3-D), using the UNIGRAPHICS NX2 software. Furthermore, individual teams will model the conventional drive trains of an average CTA Bus and the Bluebird Vision Model School Bus, respectively, in the Advanced Vehicle Simulator (ADVISOR) software, available from the National Renewable Energy Laboratory (NREL). The conventional drive train modeling helps in determining critical base-case performance parameters, such as fuel economy and overall drive train efficiency, in order to perform a comprehensive comparative study with the final HEV designs. Finally, the team has also decided to create and maintain a website regarding the project.

RESULTS TO DATE:

Battery Energy Storage Research

Two types of batteries are currently considered the prime options for hybrid vehicles. These batteries are the Lead-Acid and Nickel-Metal Hydride type. These batteries were researched and summaries have been compiled with information about them. There has also been research done on the comparison of the 2 battery options. For now, both groups have chosen to use the lead-acid batteries on their hybrid models, since they have been found successful when used in conjunction with heavy-duty hybrid electric buses. Moreover, they are readily available at an affordable cost level, which strengthens the overall feasibility of the project proposal.

Propulsion Motor Research

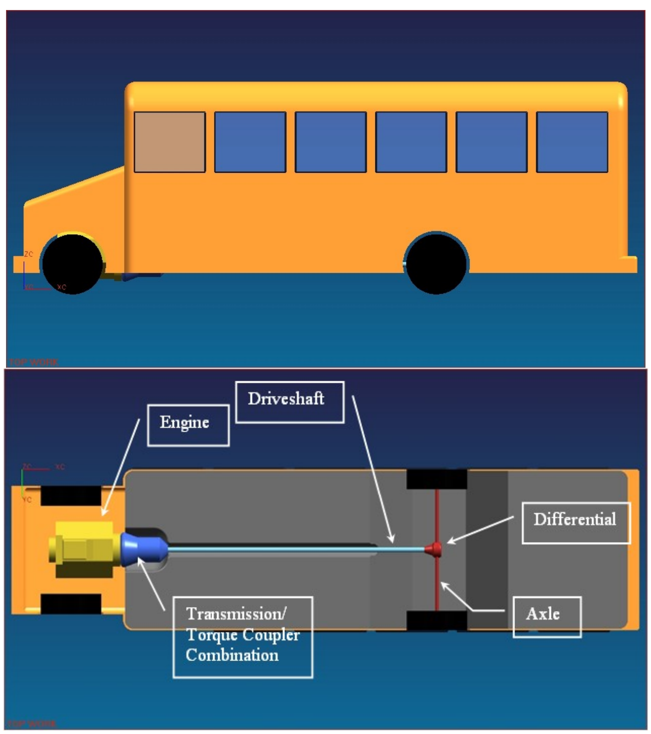
Finding an appropriate electric propulsion motor is an integral part of the hybrid design. Both teams have decided to use an induction motor, which will probably range between 100 and 150 HP, due to its rugged design and tremendous speed-torque capabilities. A precise power rating will be found once the final ADVISOR modeling and simulation studies are completed.

Bus Research

Detailed research was done on various bus models. Finally, the bus models chosen were the Nova Bus LFS 6400 for the CTA and the Bluebird Vision Type C for the school bus. In addition, the technical design specifications of these models were also researched and documented. These specifications are extremely crucial for ADVISOR simulations as well as the 3-D models.

3-D Modeling

The goal of 3-D modeling is to provide a true physical sense of the multiple components of the hybrid system. The 3-D model shows various components of the system, such as the batteries, torque coupler, transmission, and engine, and their probable physical location on the chassis. Several specifications were needed for this part of the project. Preliminary results of the modeling team are shown below. Currently, the basic shape and plan of both buses have been modeled to highlight the positioning of all components. More specifically, a model of the exterior of the school bus and a view of the underside of the bus are shown below.



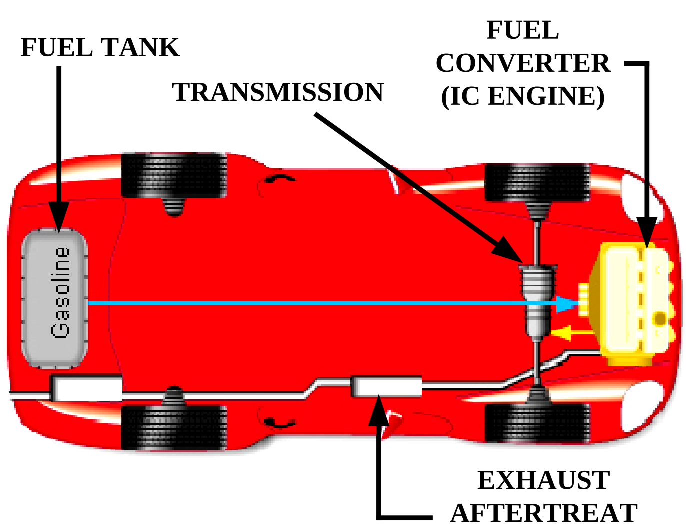
M-File Modification

At the core of IPRO 342 is the ADVISOR software, an acronym for **Ad**vanced **V**eh**i**cle **S**imulat**or,** for systems analysis. ADVISOR is complete with files containing tons of information about different vehicles, their layouts, their components, weight, etc. This software allows the simulation of various bus designs and gives the user options to optimize the results they produce by tweaking the components of the vehicle.

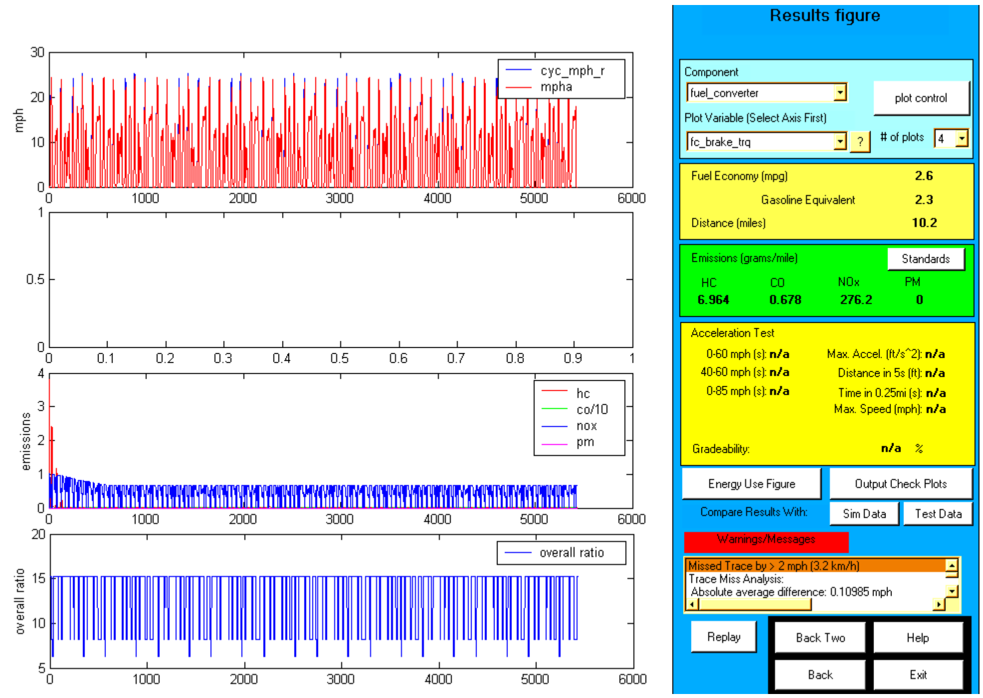
However, for this project, specific files were created, containing the specifics of the Bluebird Vision and the Nova Bus LFS 6400 models. This made it necessary to edit the M-files (ADVISOR runs on Matlab®), to make them compatible with the bus models of interest. Several M-files were edited including the physical specifications, transmission, fuel converter, and power train files. After completion of the updating of files, the team was successful in conducting accurate simulations.

Conventional Bus Simulations

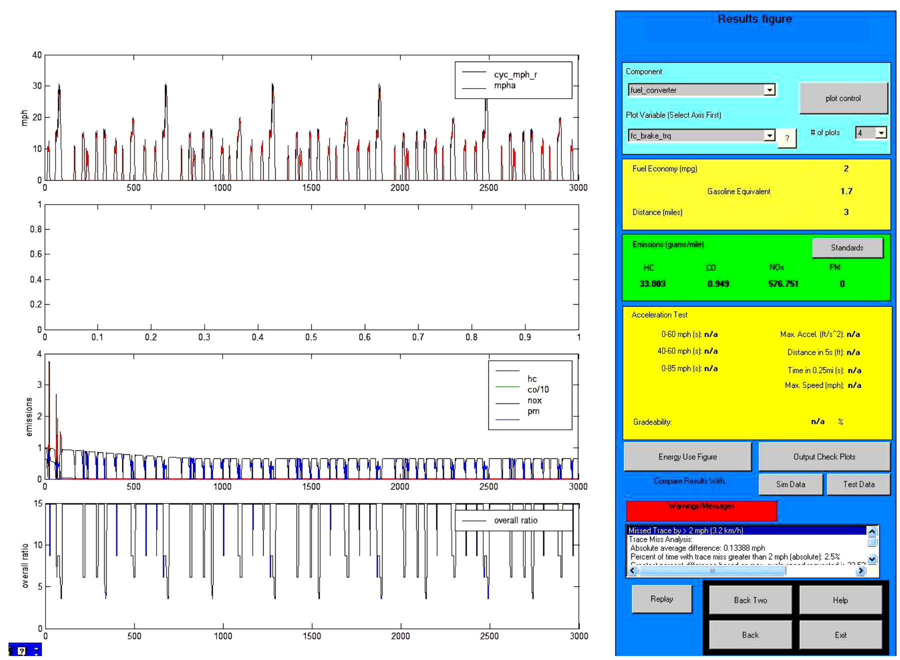
As mentioned earlier, base-case conventional drive train simulations were conducted in order to set up a comparative study. The specific model of this vehicle includes, the conventional drive train configuration, the Caterpillar C7 engine fuel converter, EX_CI_CC exhaust after treat, Blue Bird's PTS2500 transmission, WH_HEAVY wheel/axle, ACC_HEAVY accessory, and PTC_CONVAT5spd power train control. Some of these specifics are only for Bluebird Vision or the Nova bus; some are for general heavy vehicle designs. The figure below shows the conventional drive train that was modeled in ADVISOR for both the CTA as well as school bus.



The following graphic shows the output screen in ADVISOR. This screen shows the results of the modeled vehicle and includes important statistics such as fuel economy, emissions, and in hybrid simulations, the state of charge (SOC) of the battery.



For the simulation of the conventional Bluebird Vision school bus, the fuel economy was 2.6 mpg and emission values were extremely high. The next screen shot shows the results of the conventional CTA bus model.

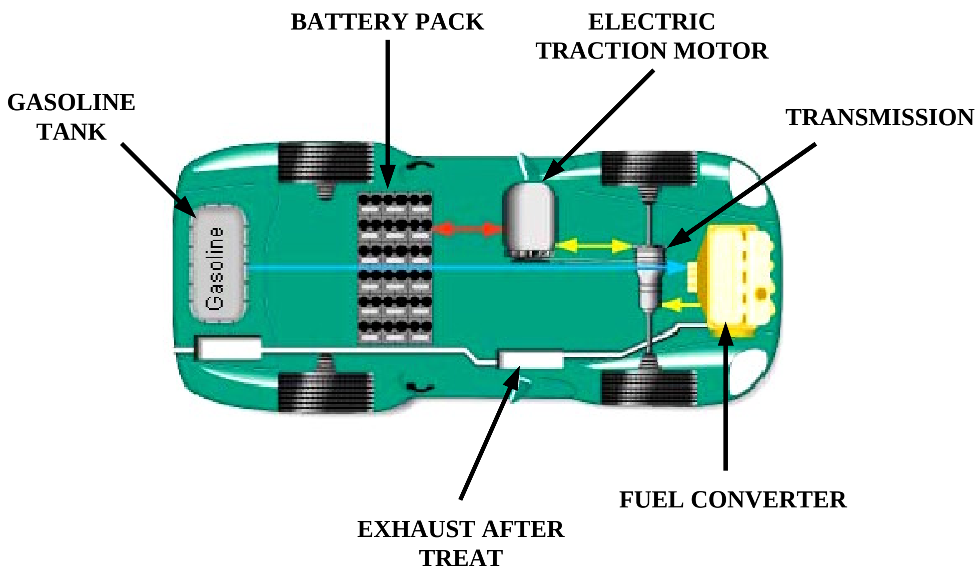


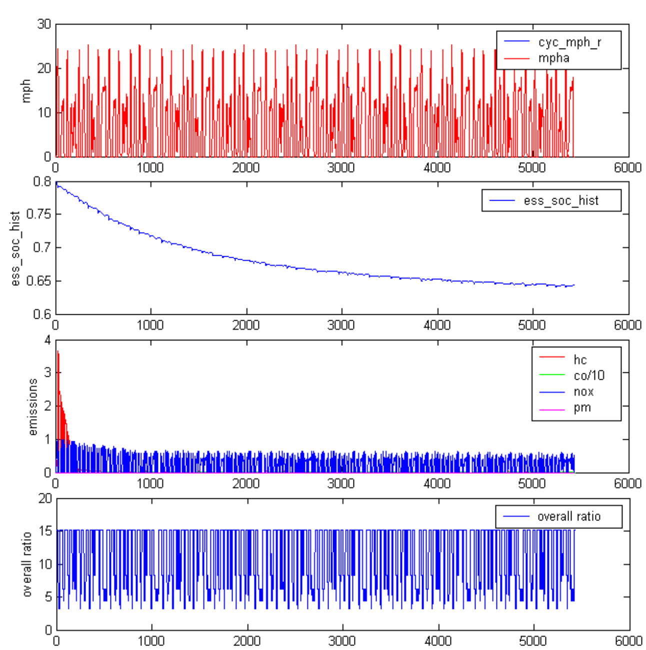
For the simulation of the conventional NOVA bus, the fuel economy was found to be 2 mpg and emission values were again extremely high, as expected.

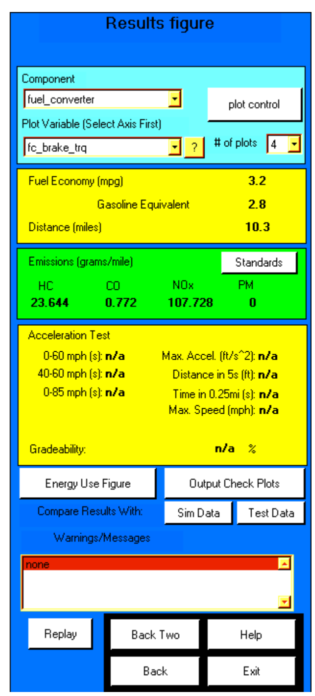
Hybrid Model Simulations

Upon modeling and simulating the conventional drive trains, the hybrid model simulations were initiated. The retrofit design approach in ADVISOR for the parallel HEV design is as shown below.

Bluebird Vision Retrofit Model

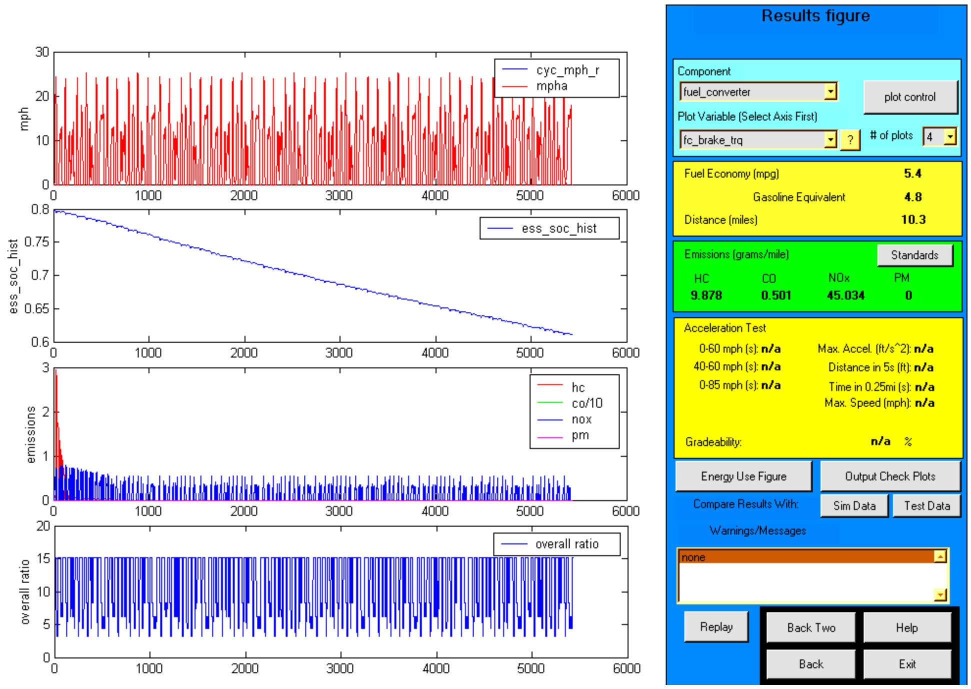






The retrofit model of the Bluebird Vision yielded a fuel economy of 3.2 mpg with a significant decrease in toxic emissions. Approximately 23% increase in fuel efficiency was experienced.

As for the new parallel HEV design, the downsizing of the fuel converter is the major design challenge. As was the case in the retrofit design, a few inputs needed to be changed to account for this design: the main parallel drive train configuration, just as in case of the retrofit, the energy storage unit (batteries), torque coupler, and a smaller engine. The modeling and simulation results for the new engine downsize based parallel HEV design are as summarized in the figure below.



This model resulted in a fuel economy of 5.4 mpg, which is almost 2 times greater than the conventional school bus model. Furthermore, the toxic emissions were lowered by well over 400%.

The only design that has not been simulated for the Bluebird Vision is the new ISA based HEV design. This is due to our unfamiliarity with the ISA device. More research must be conducted to determine what different inputs are needed for this design.

Website

A website was constructed for IPRO 342, to illustrate the progress of the team's work. It includes information pertaining to the specifications of the bus models, performed simulations, external links to research used, and team photos, with an additional section with contact information. The link to the website is: http://www.iit.edu/~jvadgaam/index.htm

UPDATED ASSIGNMENTS:

ADVISOR Team:

Jae Suk, Alex, Priscilla, and Taekmin will keep working on the hybrid models. They need to find the best hybrid coefficient (hybridization factor/ratio) that will give the highest fuel efficiency and the lowest emissions. Both teams will also attempt to work on the future ISA design, if time permits.

Batteries and Motor Team:

Deep, Dipti, and Ana will work on finding the size of the motor and batteries needed for both hybrid buses. Their results will depend on the hybrid coefficients calculated by the ADVISOR team.

Design Team:

Kevin, Jose, Dan, and Rob will continue to work on the 3-D model of the school bus and the CTA bus. After they finish the conventional design, they will add all the components of the final hybrid design. The 3-D design will demonstrate the concrete physical positioning and connections of all the electric as well as mechanical drive train components.

Overall Cost Analysis

After the modeling of both buses is completed, the entire team will do a comprehensive comparative cost analysis and determine the actual cost of the hybrid conversions from the point of view of both the retrofit as well as new design approaches.

BARRIERS/OBSTACLES:

The ADVISOR and 3-D modeling teams encountered the main obstacles. The ADVISOR teams were responsible for finding all the specifications needed for the conventional modeling of the CTA bus and the school bus. After all the required information was compiled, they found out that some of the M-files within ADVISOR needed to be modified further, in order to get accurate results, which were close to the actual bus data as possible. This required a lot of work, time, and effort on part of the individual teams. Also, in the beginning, the 3-D modeling teams were trying to come across exact 3-D models of the buses from specific buses manufacturers. But since this was not possible, they decided to construct exact 3-D models on their own, based on the specification sheets available for both bus chassis. In order to perform this task, the team members learned how to use the Unigraphics NX2 3-D modeling software.