IPRO 326 – Fall 2004 – Illinois Institute of Technology

HYBRID ELECTRIC VEHICLES: Simulation, Design, & Implementation

INTRODUCTION

Increasing use of electrical power to drive automobile subsystems, which historically have been driven by a combination of mechanical and hydraulic power transfer systems, is seen as a dominant trend in advanced automotive power systems. This trend manifests itself through the more electric cars (MEC) concept, which is seen as the direction of automotive technology. The most practical and promising solution feasible for the automotive industry to achieve very high fuel economy and very low emissions through the MEC concept is hybrid electric vehicle (HEV) technology. In this IPRO, based on the previous student team works and guidelines set by Dr. Emadi, a team of eleven systematically tested both parallel and series vehicle configurations of the Hummer and HMMWV (High-Mobility Multipurpose Wheeled Vehicle) to find the optimum hybridization factor specific to each configuration. The team also worked in coordination with a Ph.D. student to simulate a hybrid electric bus system that is scheduled to have practical implementations in India by the end of the year. In addition, the team reviewed the FutureTruck 2004 Competition, which involved designing a most energy-efficient truck with a hybrid-electric drive train; the team used data from this competition to work on a more efficient mechanical design of a hybrid drive train. All vehicle simulations and structured testing were performed using ADVISOR, as well as other software packages available in the Power Electronics and Motor Drives Laboratory at IIT.

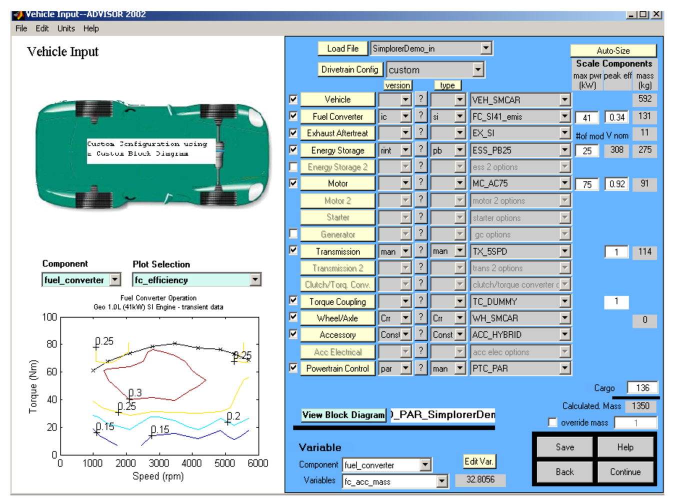
IPRO 326 Team (Fall 2004)

Dr. Ali Emadi
Thomas Hittie
Chad Johnson
Ali Naqvi
Sadia Sadiq
Gregory Waliczek
Marta Bastrzyk
Theresa Hudik
Mahdi Mohammad
Paul Reinhard
Jeffrey Stano
Tiana Washington

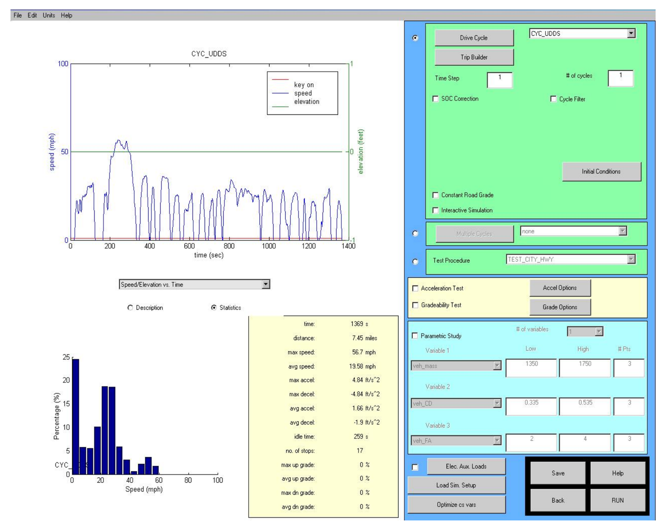
SIMULATION TOOL: ADVISOR

ADVISOR is an Advanced Vehicle Simulator that simulates the performance of hybrid electric, conventional, electric, and fuel cell vehicles. The software was created by the U.S. Department of Energy's (DOE) Office of Transportation Technologies' (OTT) Hybrid Vehicle Program. ADVISOR calculates the fuel economy, emissions released, acceleration times, and much more for a given drive cycle.

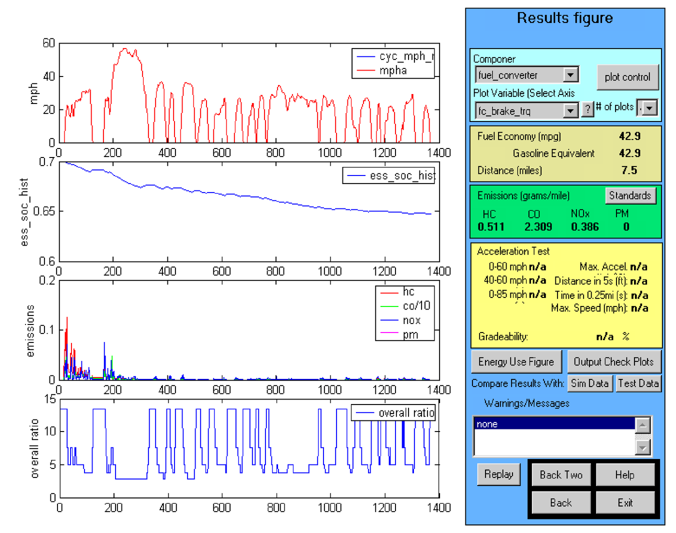
Vehicle Input Parameters:



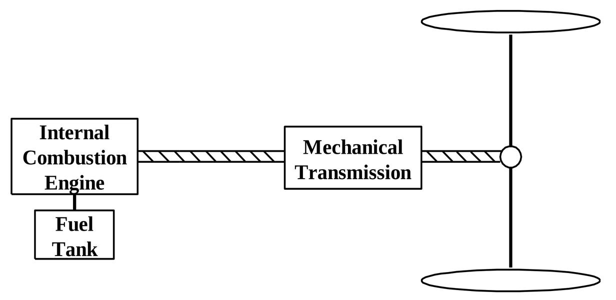
Simulation Parameters:

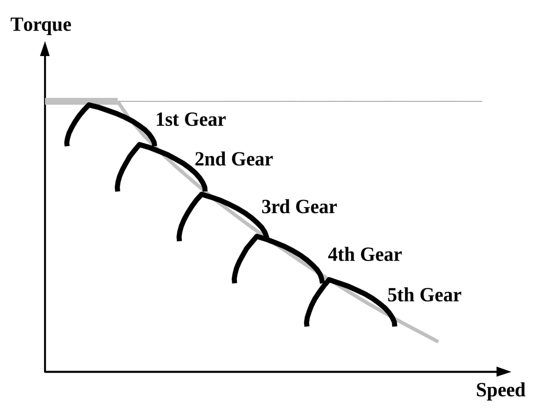


Result:

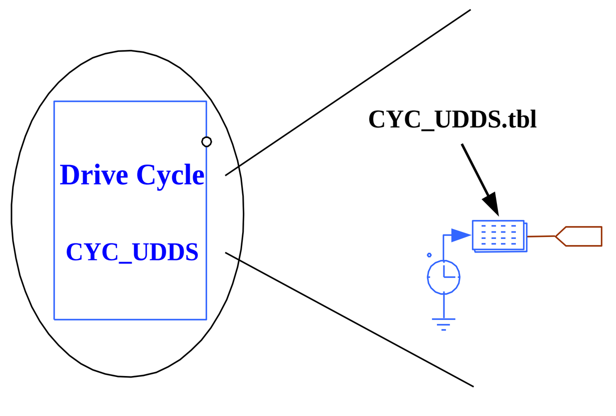


CONVENTIONAL VEHICLES

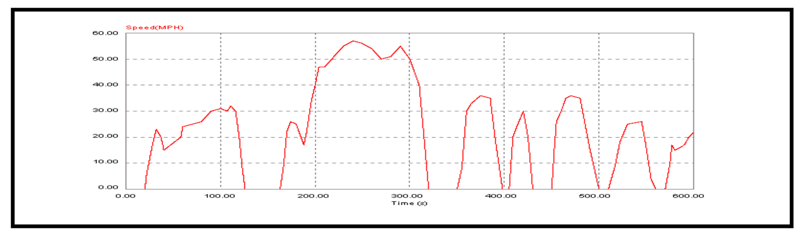




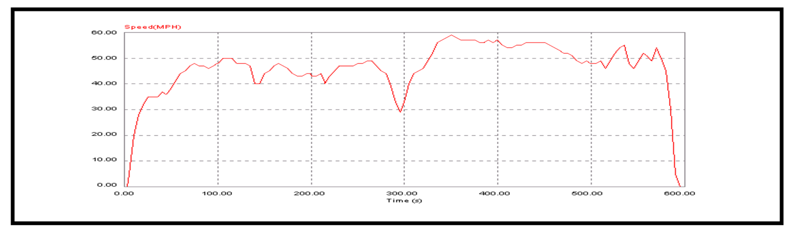
The Drive Cycle defines the speed of the vehicle for a certain driving pattern.



Drive Cycle Module



Urban Dynamic Driving Schedule (UDDS)

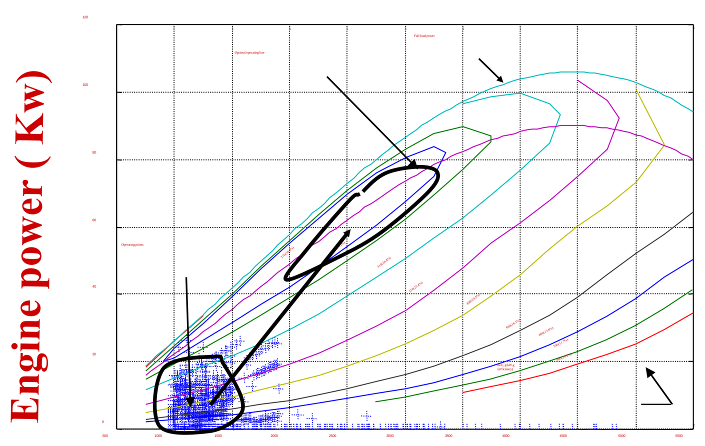


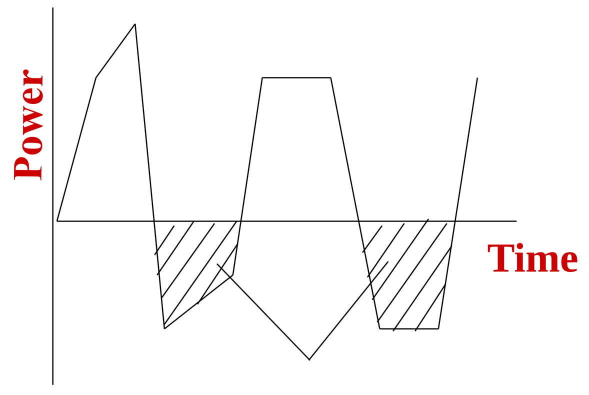
Highway Fuel Economy Certification Test (HWFET)

HYBRID ELECTRIC VEHICLES

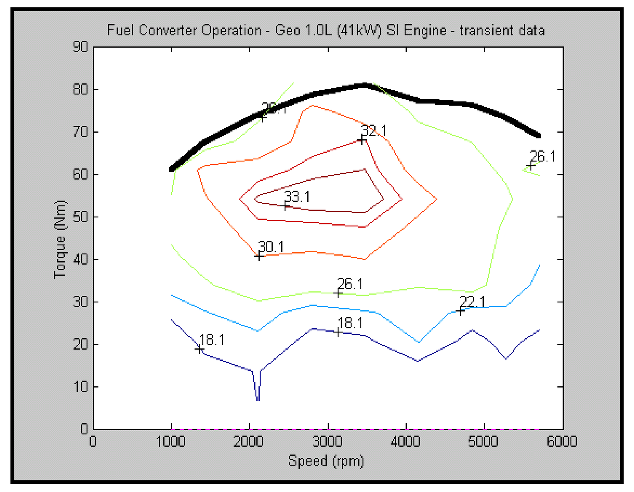
HEVs are promising the most practical more electric solution to reach very high fuel economy and very low emissions. Reasons:

- Use of smaller internal combustion engines (ICE)
- Operate the ICE at its maximum efficiency region
- Effectiveness of regenerative braking to recharge the batteries

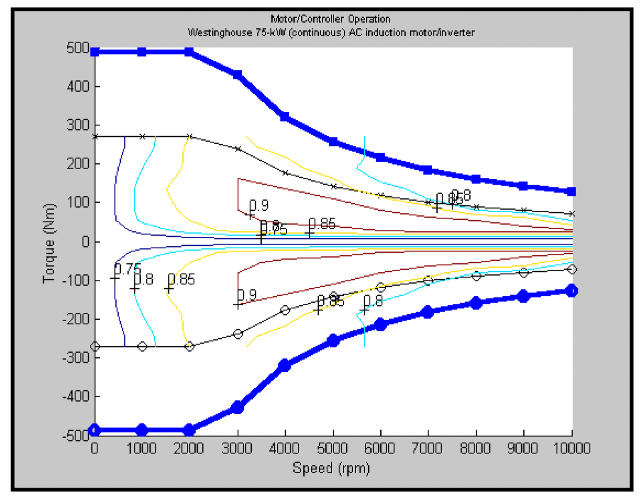




Energy consumed in braking which is lost in conventional vehicles, but recovered in HEVs.

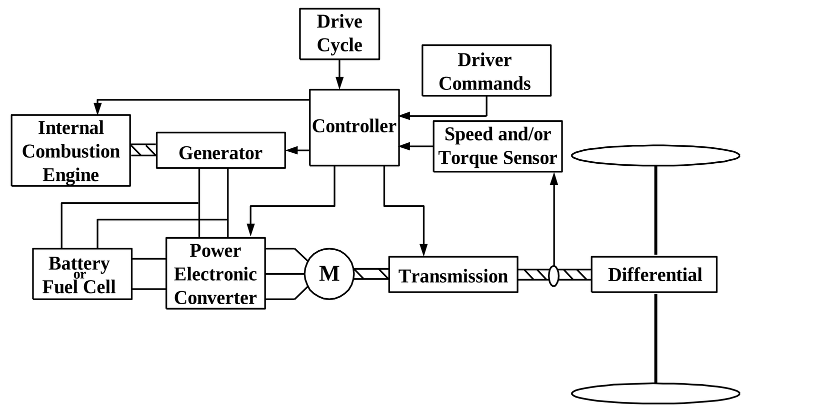


Engine Efficiency Map



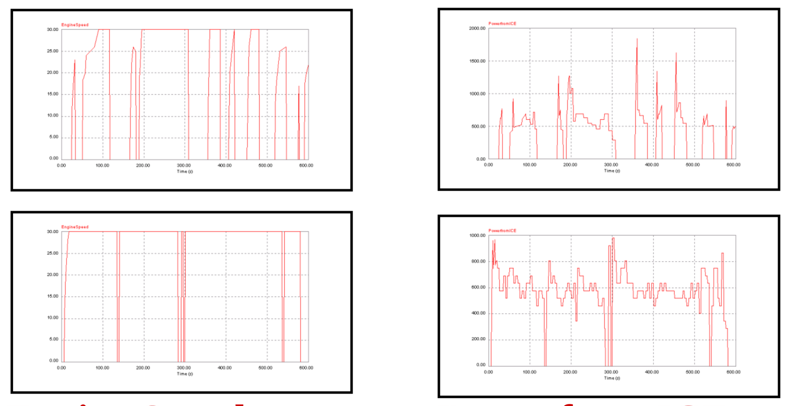
Motor Efficiency Map

SERIES DRIVE TRAIN CONFIGURATION

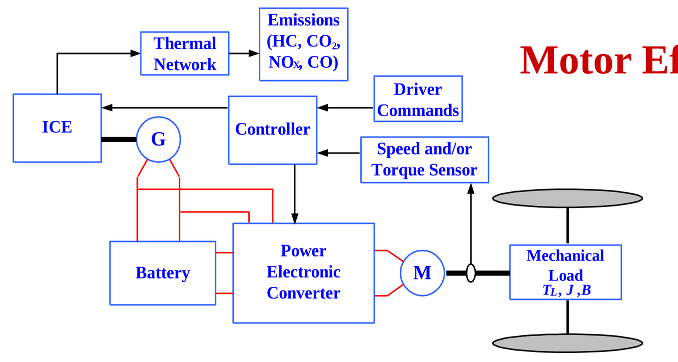


	Fuel Consumption (MPG)	HC	CO_2	NOx
Series HEV	80.0	0.41	1.26	0.34
Conventional Car	40.4	0.61	2.47	0.45
Improvement(%)	98.0	32.8	49.0	24.4

	Fuel Consumption (MPG)	HC	CO_2	NOx
Series HEV	98.7	0.20	0.64	0.17
Conventional Car	40.4	0.61	2.47	0.45
Improvement(%)	98.0	32.8	74.0	62.2

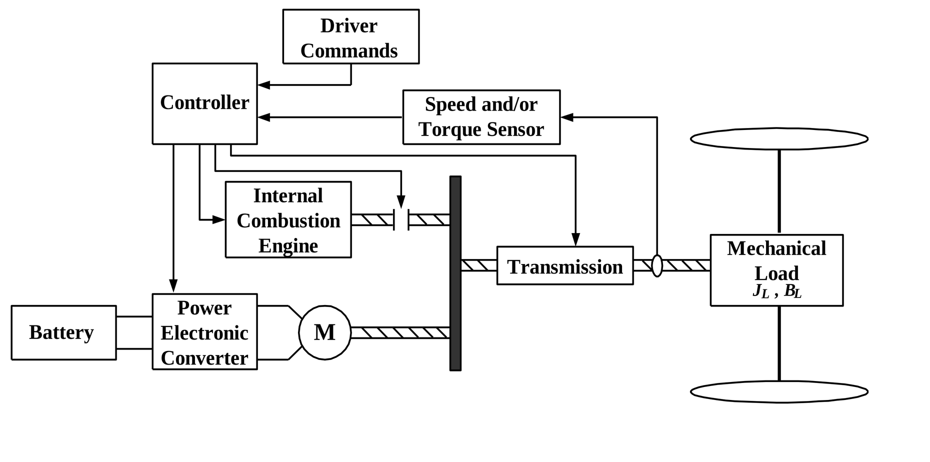


Engine Speed   Power from ICE



Motor Efficiency Map

PARALLEL DRIVE TRAIN CONFIGURATION



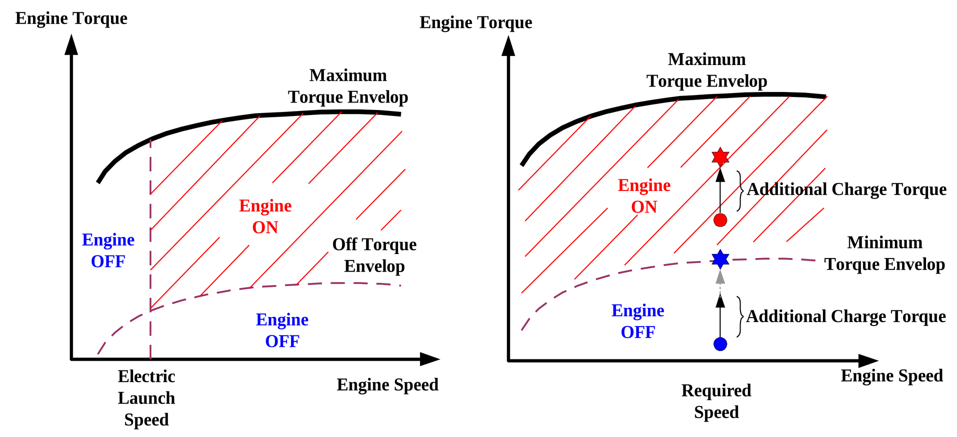
Parallel HEV Control Strategy

Hybridization Factor (HF)

$$HF = \frac{P_{EM}}{P_{EM} + P_{ICE}} = \frac{P_{EM}}{P_{vehicle} = const.}$$

PEM : Power of the electric machine

PICE : Power of the ICE

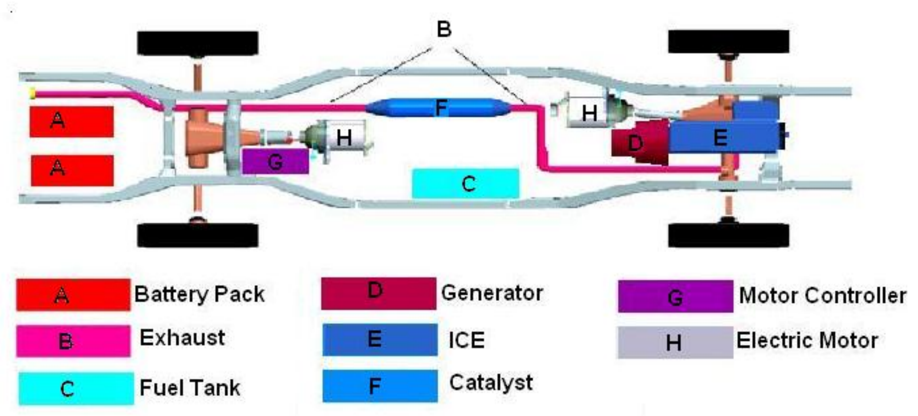


SOC > Lo SOC   SOC < Lo SOC

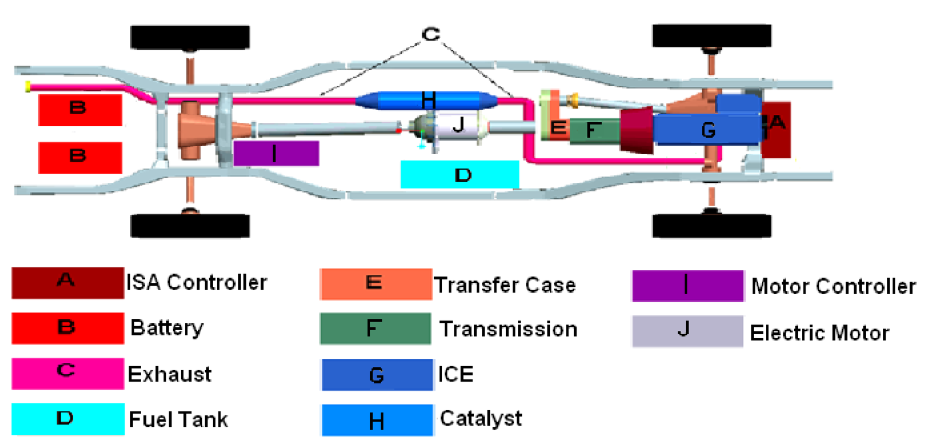
	Fuel Consumption (MPG)	HC	CO_2	NOx
Parallel HEV	61.0	0.32	0.98	0.28
Conventional Car	40.4	2.47	0.42	0.45
Improvement(%)	50.9	47.5	60.3	37.8

HYBRID DRIVE TRAIN MECHANICAL DESIGN

Series Configuration:



Parallel Configuration:

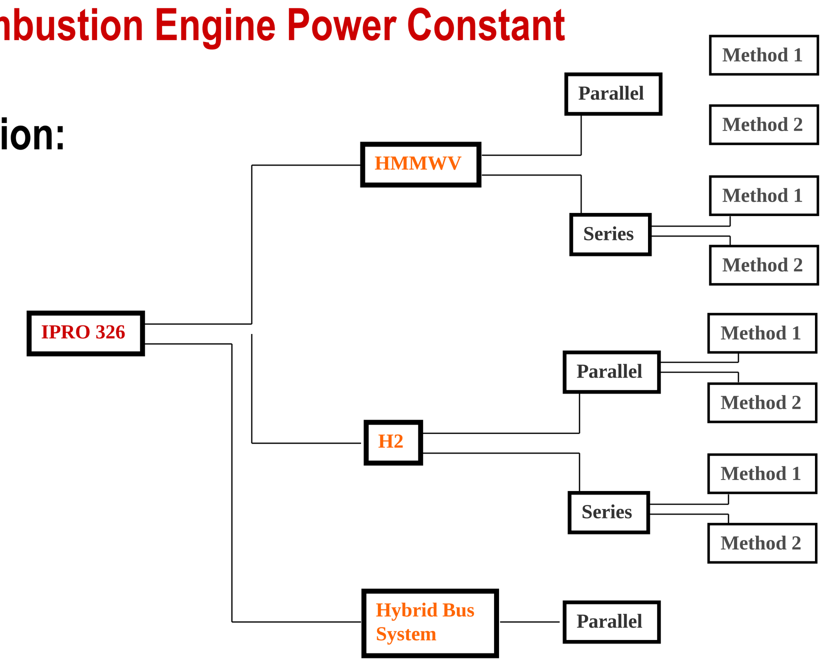


IPRO 326 – Fall 2004 – Illinois Institute of Technology
HYBRID ELECTRIC VEHICLES:
Simulation, Design, & Implementation

OUR TECHNICAL APPROACH

The Hybridization Factor (HF) is the ratio of the electric motor in comparison to the total vehicle power. The optimum HF yields the highest fuel economy for the vehicle. In this IPRO, we utilized two different test methods for each of the series and parallel vehicle configurations to determine the optimum hybridization factor.

- For the H2 and HMMWV Parallel Configuration:
  - Method 1: Total Vehicle Power Constant
  - Method 2: Internal Combustion Engine Power Constant
- For the H2 and HMMWV Series Configuration:
  - Method 1: Total Motor Power Constant
  - Method 2: Internal Combustion Engine Power Constant
- Our technical team organization:



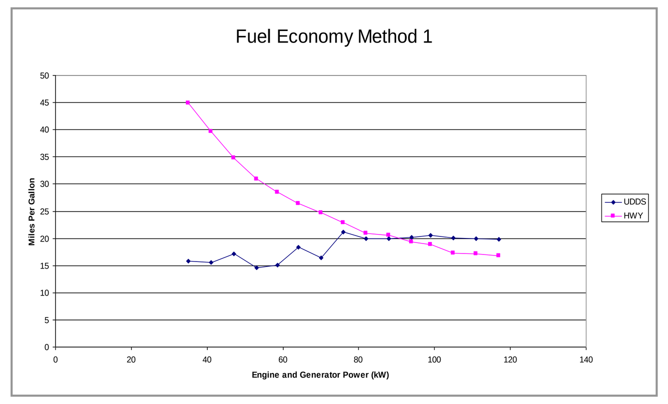
HMMWV: SERIES CONFIGURATION

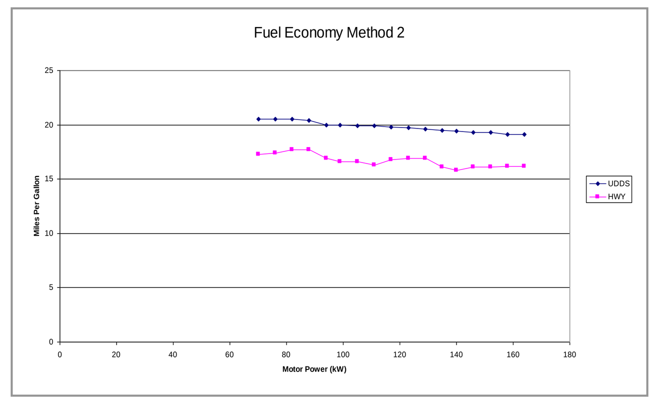
Simulation Methods

1) Constant Motor Power:
Engine and generator are scaled from 100% to 30% in increments of 5%

2) Varying Motor Power::
Motor power is changed between 60% and 140% in increments of 5%

Fuel Economy Charts & Results





		Acceleration			Fuel Economy (mpg)	
	HF	0-30 mph	0-50 mph	Max Speed	City	Highway
Conventional		9.5s	27.8s	87.8mph	10.8	18.8
Hybrid Method 1	0.2	6.4s	17.9s	80.6mph	20.2	19.4
Hybrid Method 2	0.05	7.0s	18.7s	80.7mph	19	20.5
Max Improvement		26.30%	35.60%	-8%	87%	9%

Conclusion

Both the performance and fuel economy of the hybridized HMMWV M1097 A2 result in high increase when compared with conventional values.

Note: The battery power is the least that could meet the UDDS cycle expressed in number of battery modules.

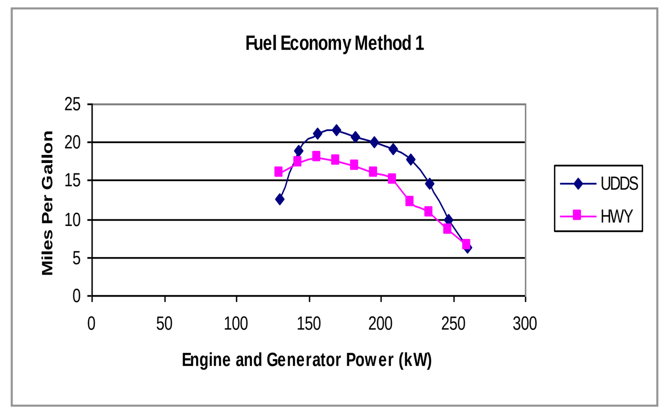
H2: SERIES CONFIGURATION

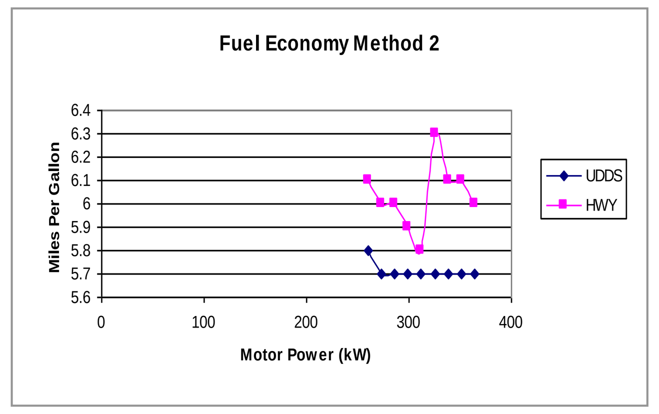
Simulation Methods

1) Constant Motor Power:
Engine and generator are scaled from 100% to 30% in increments of 5%

2) Varying Motor Power::
Motor power is changed between 60% and 140% in increments of 5%

Fuel Economy Charts





		Acceleration			Fuel Economy (mpg)	
	HF	0 - 60 mph	1/4 mile	Max Speed	City	Highway
Conventional		9.8 s	17.9 s	101.2 mph	9.6	13.8
Hybrid Method 1	0.35	14.1s	19.6s	96.5	21.6	17.6
Hybrid Method 2	0.2	31.6s	23.8s	72.2	5.7	6.3
Max Improvement		-44%	-9.50%	-5%	40.60%	54.30%

Conclusion:

Fuel economy of the hybridized Hummer H2 increased for method 1 and decreased for method 2. Performance decreased for both methods when compared with conventional values.

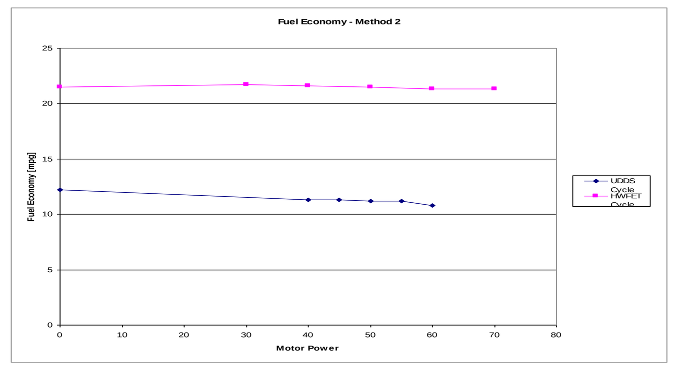
HMMWV: PARALLEL CONFIGURATION

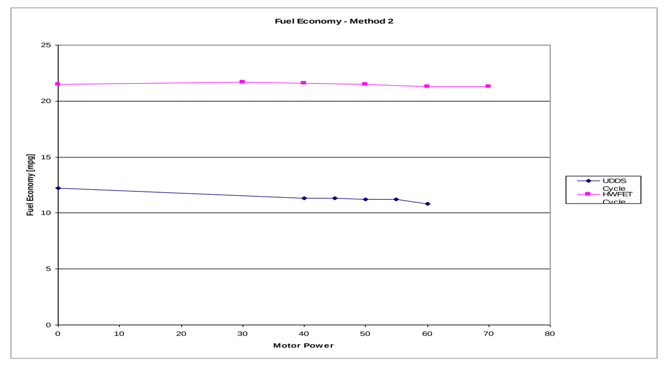
Simulation Methods

1) Constant Total Power
Engine is scaled from 100% to 30% and motor is scaled from 0% to 70% in increments of 5%

2) Varying Motor Power
Motor is scaled from 0% to 70% in increments of 5%, and engine kept Constant at 100%

Fuel Economy Charts & Results





		Acceleration			Fuel Economy (mpg)	
	HF	0-30mph	0-50mph	Max Speed	City	Highway
Conventional		10.70s	33.4s	80.5mph	10.6	18.8
Hybrid Method 1	0.5	9.60s	18.5s	95.6mph	15.2	23.2
Hybrid Method 2	0.4	8.40s	17.0s	105.9mph	9.9	18.9

Conclusion:

Both the performance and fuel economy of Method 1 increased when compared with conventional values. However only the performance, not the fuel economy, of Method 2 hybridized Parallel HMMWV increased.

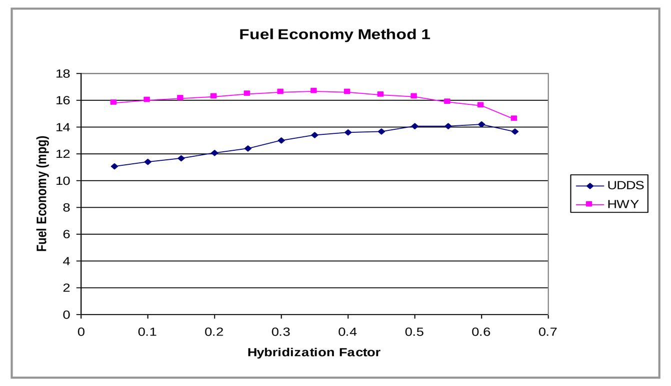
H2: PARALLEL CONFIGURATION

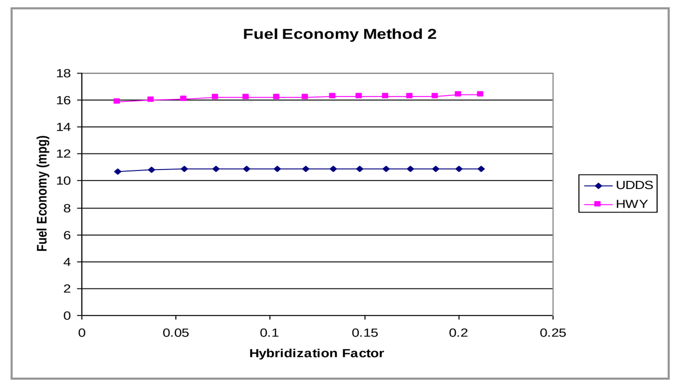
Simulation Methods

1) Constant Total Power
Engine is scaled from 100% to 30% and motor is scaled from 0% to 70% in increments of 5%

2) Constant Total Power
Engine is scaled from 100% to 30% and motor is scaled from 0% to 70% in increments of 5%

Fuel Economy Charts & Resultsc





		Acceleration			Fuel Economy (mpg)	
	HF	0 - 60 mph	1/4 mile	Max Speed	City	Highway
Conventional		9.8 s	17.9 s	101.2 mph	9.6	13.8
Hybrid Method 1	0.05	10.3 s	18.2 s	101.7 mph	11.1	15.8
Hybrid Method 2	0.212	9.5 s	17.5 s	115.3 mph	10.9	16.4
Max Improvement		5%	2.20%	14%	15.60%	18..8%

Conclusion:

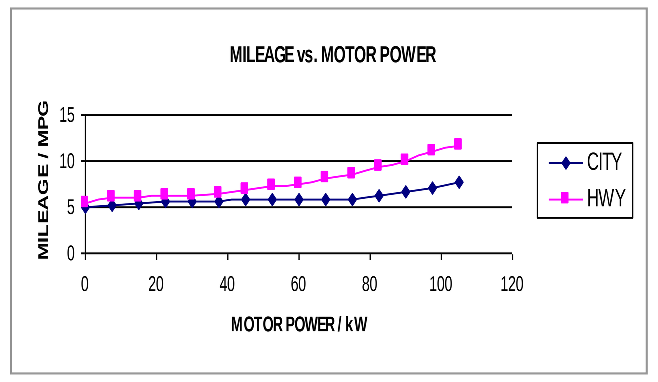
The change in performance of the hybridized H2, except max speed of method 2, is negligible, while both methods dramatically increase fuel economy

HYBRID BUS SYSTEM RESEARCH

Method of Simulation

Varying Motor Power
The motor power was ranged from 0% to 70% of 150 kW in increments of 5%

Fuel Economy Charts & Resultsc



		Fuel Economy (mpg)	
	HF	City	Highway
Conventional		4.9	5.5
Hybrid Method 1	0.35	5.9	7.2
Max Improvement		20.40%	31%

Conclusion:

The performance of the hybridized electric bus is amplified greatly after incorporating an electric motor.

Optimum Hybridization Factor = 35%