Hybrid Electric Vehicles: Simulation, Design, and Implementation

Illinois Institute Of Technology

IPRO *326* - Fall *2003*

Introduction

Presenter: William Guess

IPRO 326 ORGANIZATION

- **ADVISOR Simulations**
- **Jeep Liberty Technical Report**
- **Future Truck Competition**
- **Garage/Mechanical Works**
- **Hybrid Drivetrain Design**
- **Ultra-Capacitor Research & Design**

MAIN GOALS

- Determine the optimal power distribution between the internal combustion and electric motors
- Develop a hybrid drive train based on the Jeep Liberty
- Lay simulation and design groundwork for the Challenge X competition sponsored by General Motors

Organizing Garage/Mechanical Works Team

Betsy Raju

Bill Guess

Dave Bartik

Grace Nijm

Matt Ayersman

Raul Gonzalez

Ryan Long

Goals

- Organize the IIT automotive garage
- Become familiar with the mechanical aspects of a hybrid vehicle
- Act as a resource for other team members
- Acquire an IPRO 326 project vehicle

Accomplishments

- Successfully reserved and organized a portion of the garage for IPRO 326
- Gained access to a Honda Insight and investigated certain aspects of its mechanical design
- Shared our knowledge and resources with other team members
- Acquired a 1990 GMC Safari van to serve as the official IPRO 326 project vehicle

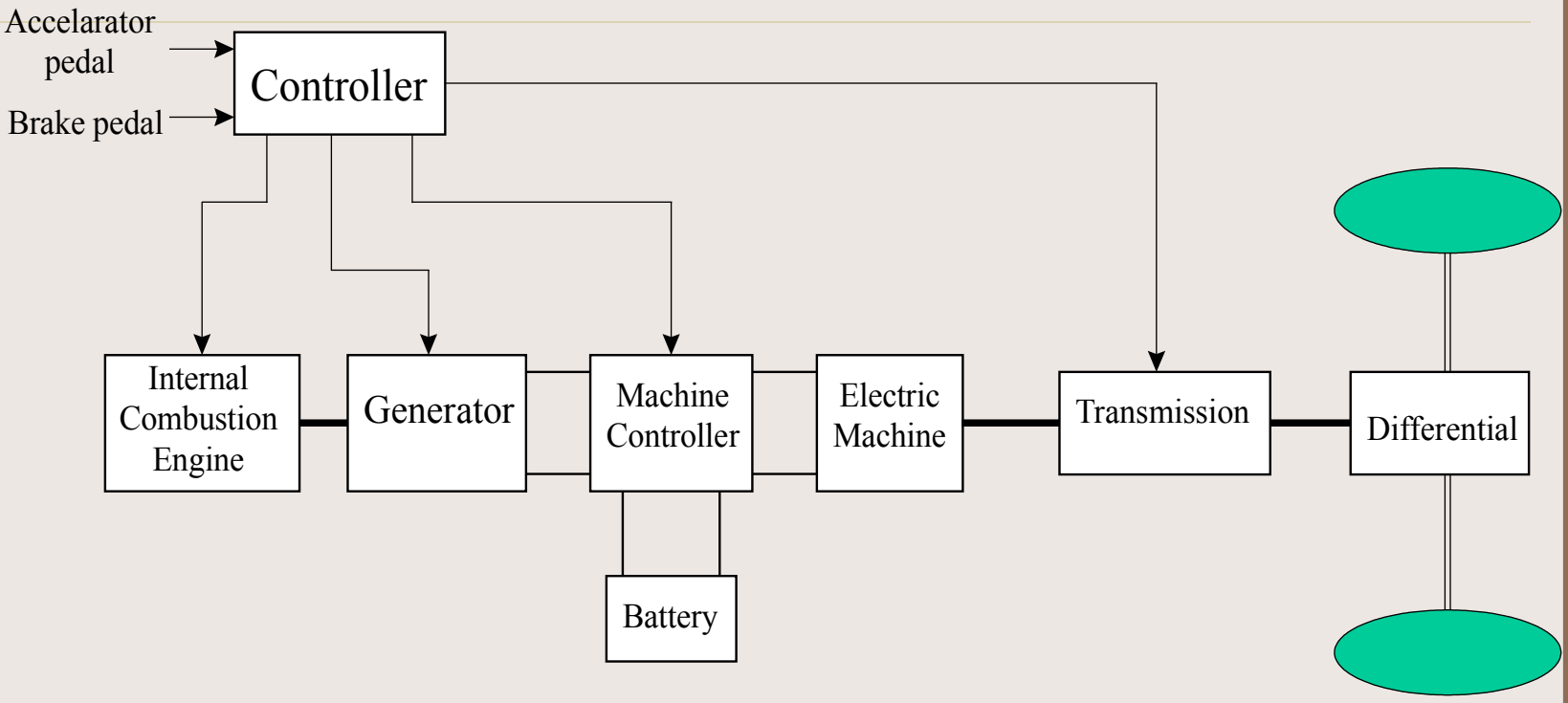
Introduction to Hybrid Electric Vehicles

Presenter: Pavel Reytikh

What is a HEV?

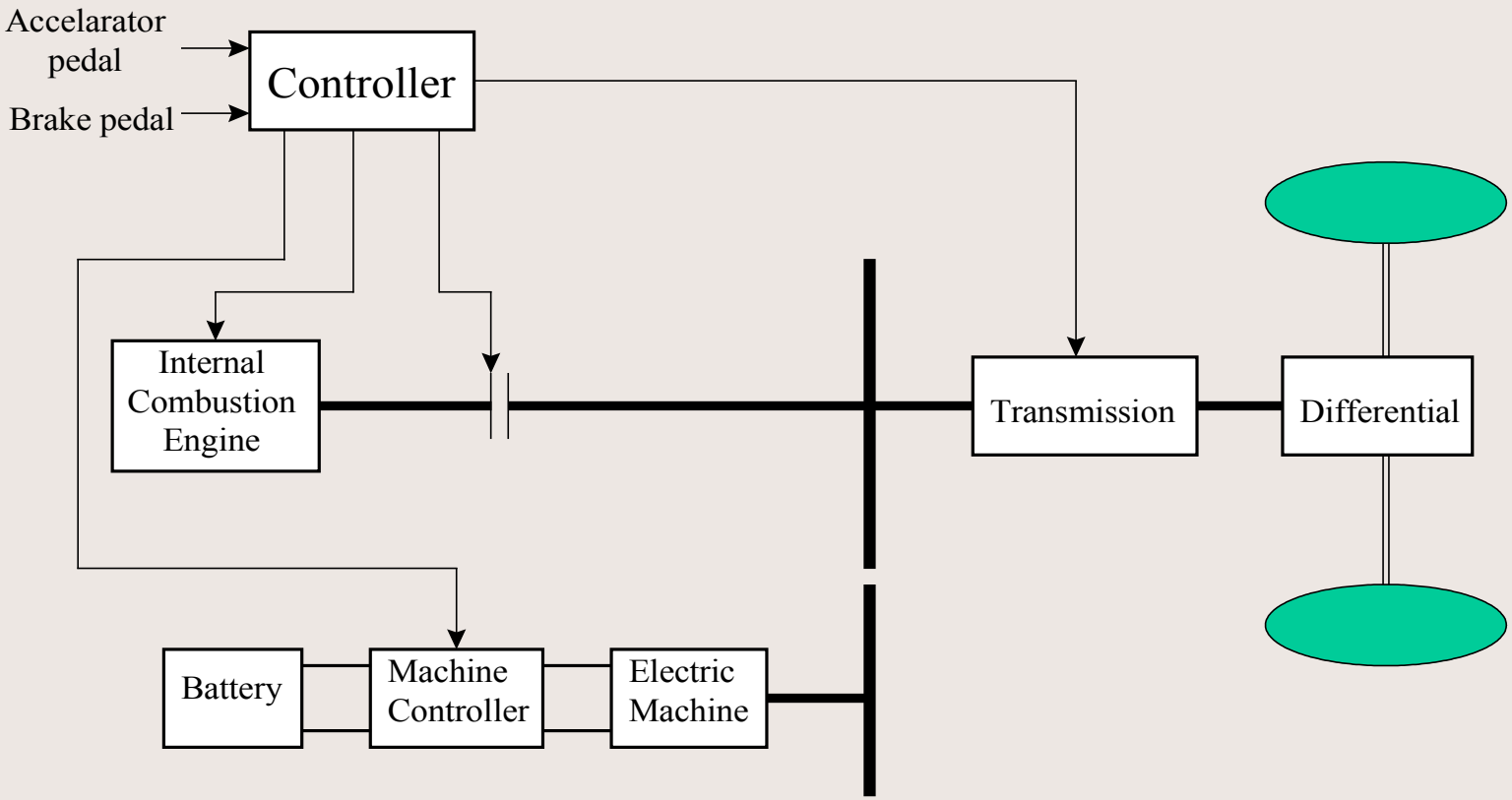
- Hybrid electric vehicles (HEVs) combine the internal combustion engine with the electric motor.
- This results in an increased fuel economy when compared to conventional vehicles.
- Also offers the extended range and rapid refuelling that consumers expect from a normal vehicle, with most of the energy and environmental benefits of an electric vehicle.
- Can be used in a wide range of applications, from personal transportation to commercial hauling.
- 2 types of hybrids: series and parallel

Series HEV Configuration



ICE charges batteries or powers electric motor which drives the transmission

Parallel HEV Configuration



ICE and electric motor can both drive the transmission

Electrical Power System

- HEVs contain a small electric motor
  - Acts as a generator as well
  - Uses battery energy to accelerate car
  - Uses generator properties to recharge batteries
- HEVs contain batteries
  - Used to power the electric motor
  - Recharged each time the brakes are pressed
- The electric component of the car takes over when driving in slow traffic or when you stop frequently
  - The electric motor can be used with the gas engine when accelerating the car

Gasoline Power System

- HEVs have the same internal combustion engine as a regular car
  - Slightly smaller – it isn't doing as much work as in a regular car because the electric motor is able to take over or help in certain circumstances (i.e. accelerating or climbing a hill)
  - More efficient because of the size

Hybrids have a transmission that performs the same job as in non-Hybrid cars

Jeep Liberty Sport

- 2.4 L, 150hp engine
- Rear-wheel drive
- 19/24 mpg (city/highway, 5-spd)

Drive Train Design Team

Presenter: John Brandt

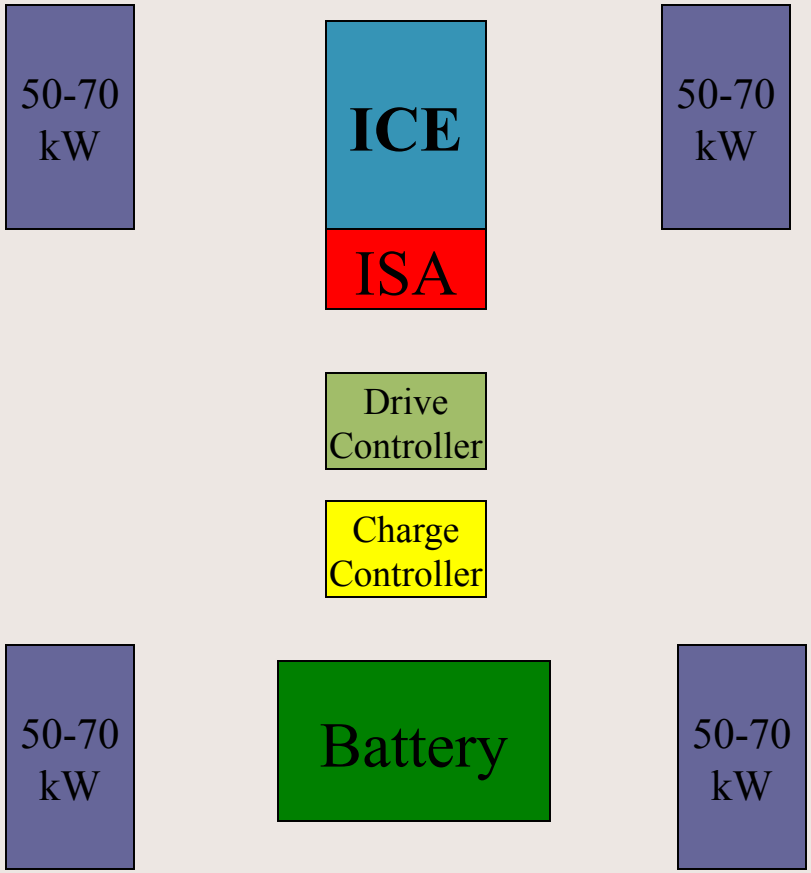
Team Members:

Allan Howard

Pavel Reytikh

Sanjaka Wirasingah

Series Hybrid



Series Hybrid Pros/Cons

Pro

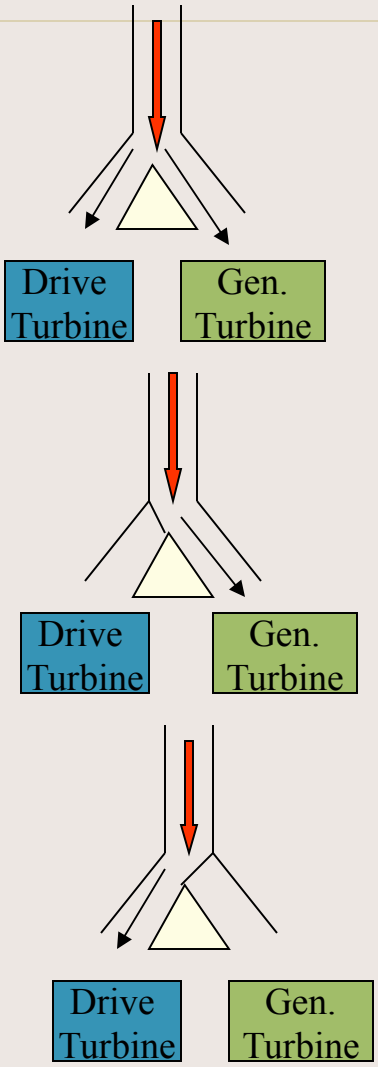
- Most Efficient Option
- Offers Braking Regeneration
- Fairly Compact Design
- Constant RPMs on ICE

Con

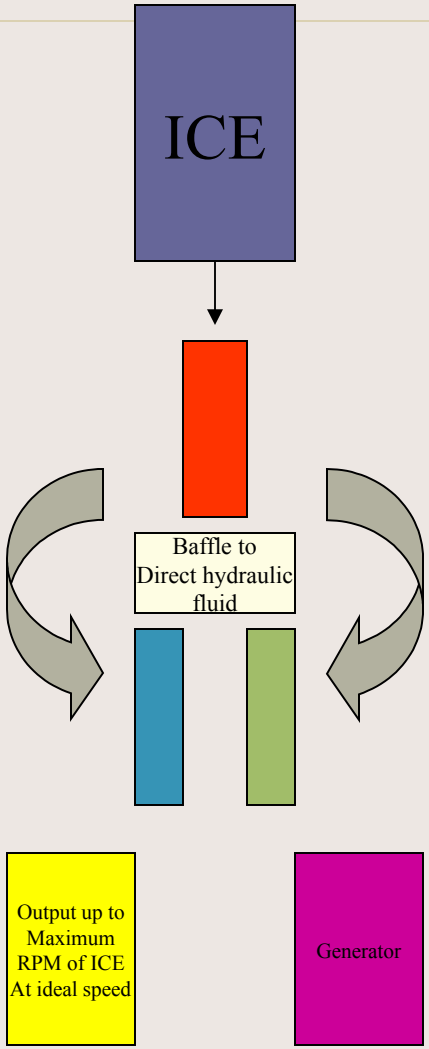
- Complicated System
- Requires near complete overhaul
- Energy changes drop efficiency

Hydraulic Baffle Turbine System

Baffle



Turbine Layout

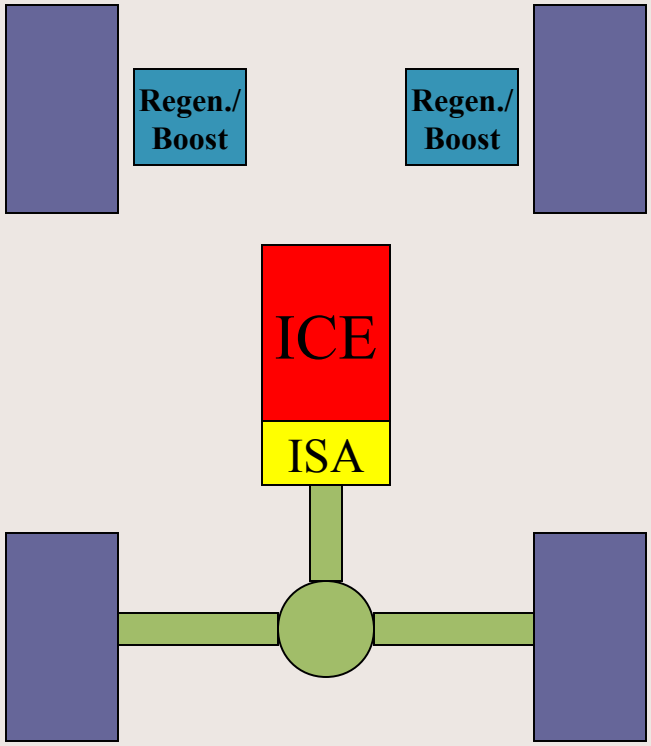


Baffle Turbine Pros/Cons

- Allows constant RPM
- Parts Readily Available
- Fairly Simple System
- Pretty Sweet

- Heavy
- Inefficient
- Never been done before
- No regenerative braking

Incomplete Parallel Hybrid



Incomplete Hybrid Pros/Cons

- Can offer partial regenerative braking (front only)
- Simplest plan
- Fewer modifications required
- Relatively lightweight

- INEFFICIENT
- No constant RPMs
- Power for battery recharge transferred through the road could cause excessive tire wear
- Possibly not powerful enough for a 4x4

Best Hybridization Factor

Presenter: Paul Reinhard

Team Member: Pavel Reytikh

Constant Vehicle Conditions

- Engine: Saturn 1.9L SOHC scaled to 112kW (FC_SI63_emis); peak efficiency 0.34
- Batteries: NiMH (ESS_NIMH93); 21 modules for V_{nom}=299V
- Parallel configuration

Constant Variable Justification

- 299V nominal voltage chosen due to compliance with most rigorous test available (HL07)
- NiMH 93 batteries most powerful available to simulation program
- Saturn engine comparable; emissions data available in simulations

Variable Vehicle Conditions

- **Motor: MC_AC75 varied incrementally from 0 (no motor) to 100kW**

Drive Cycles

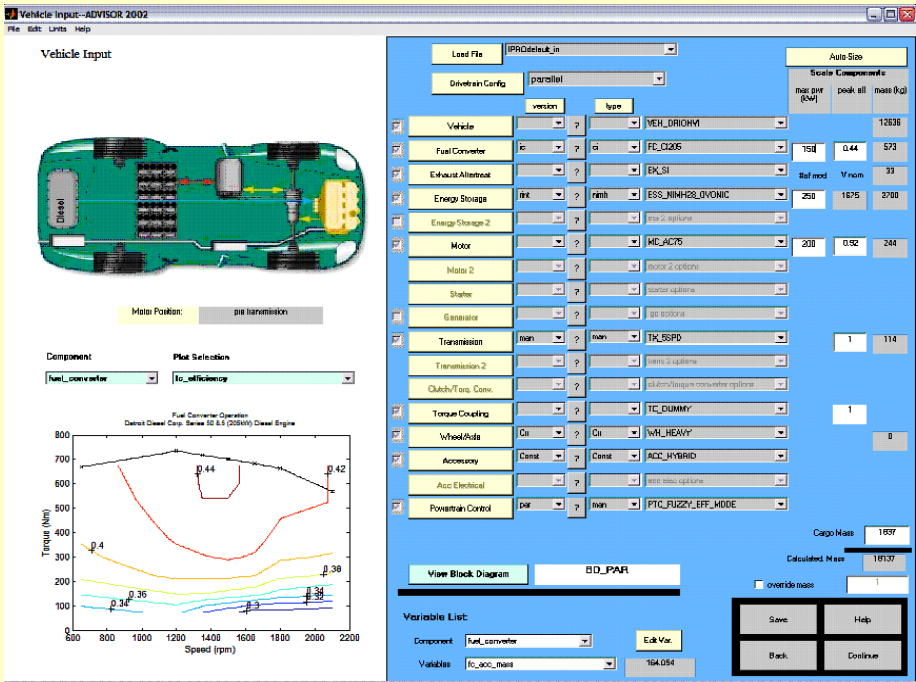
- All tests to be completed using the UDDS drive cycle in ADVISOR (city driving)

What is ADVISOR?

- **ADVISOR** is an **AD**vanced **V**eh**I**cle Simulat**OR** that simulates the performance of hybrid electric, conventional, electric, and fuel cell vehicles.

- Calculates the fuel economy, emissions released, acceleration times, and much more for a given drive cycle.

- Created the U.S. Department of Energy's (DOE) Office of Transportation Technologies' (OTT) Hybrid Vehicle Program



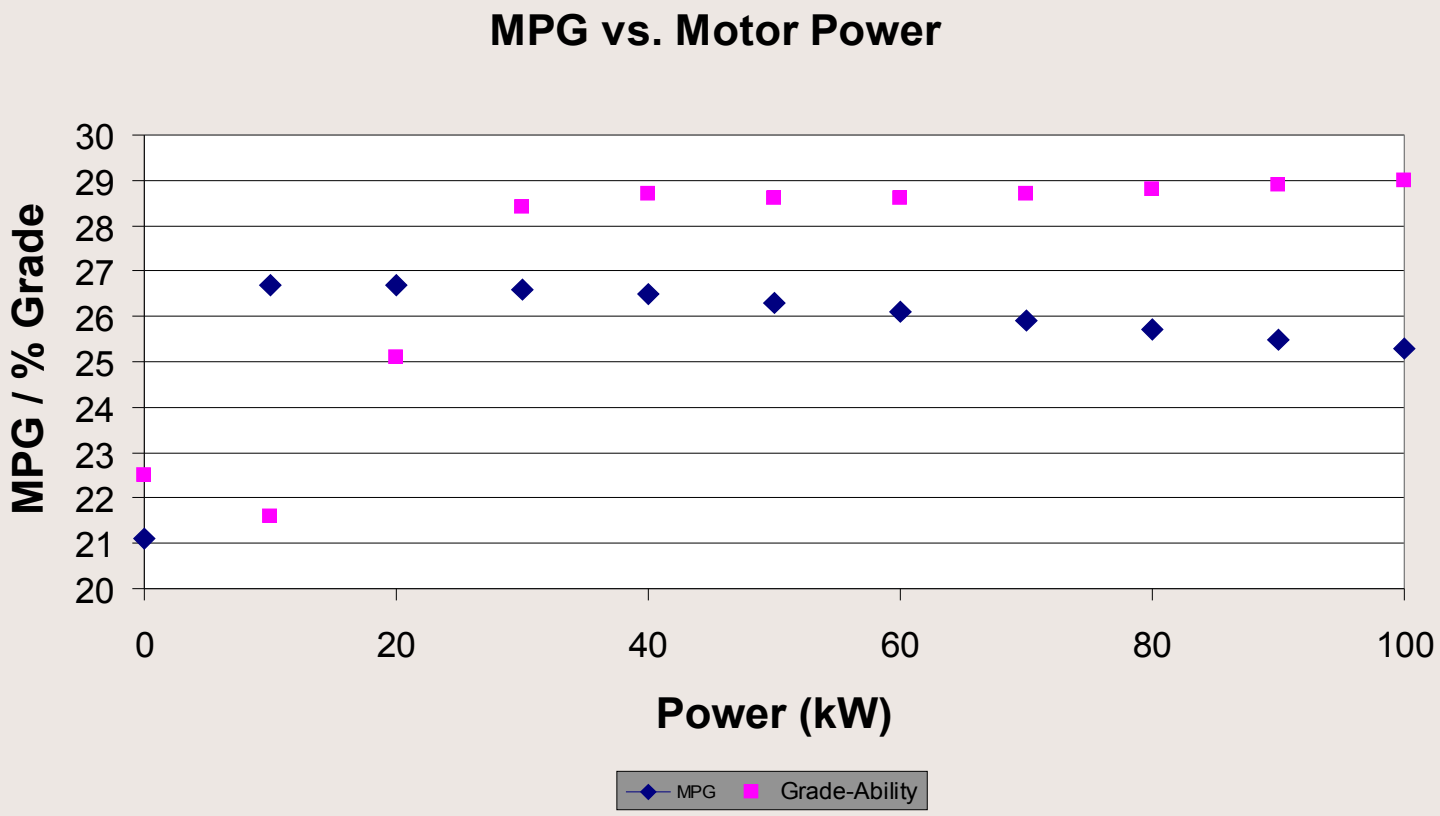
HF-Results

- Tests run in 10 kW increments
- SoC varied from approximately 0.7 (initial) to 0.66 (final) for all tests

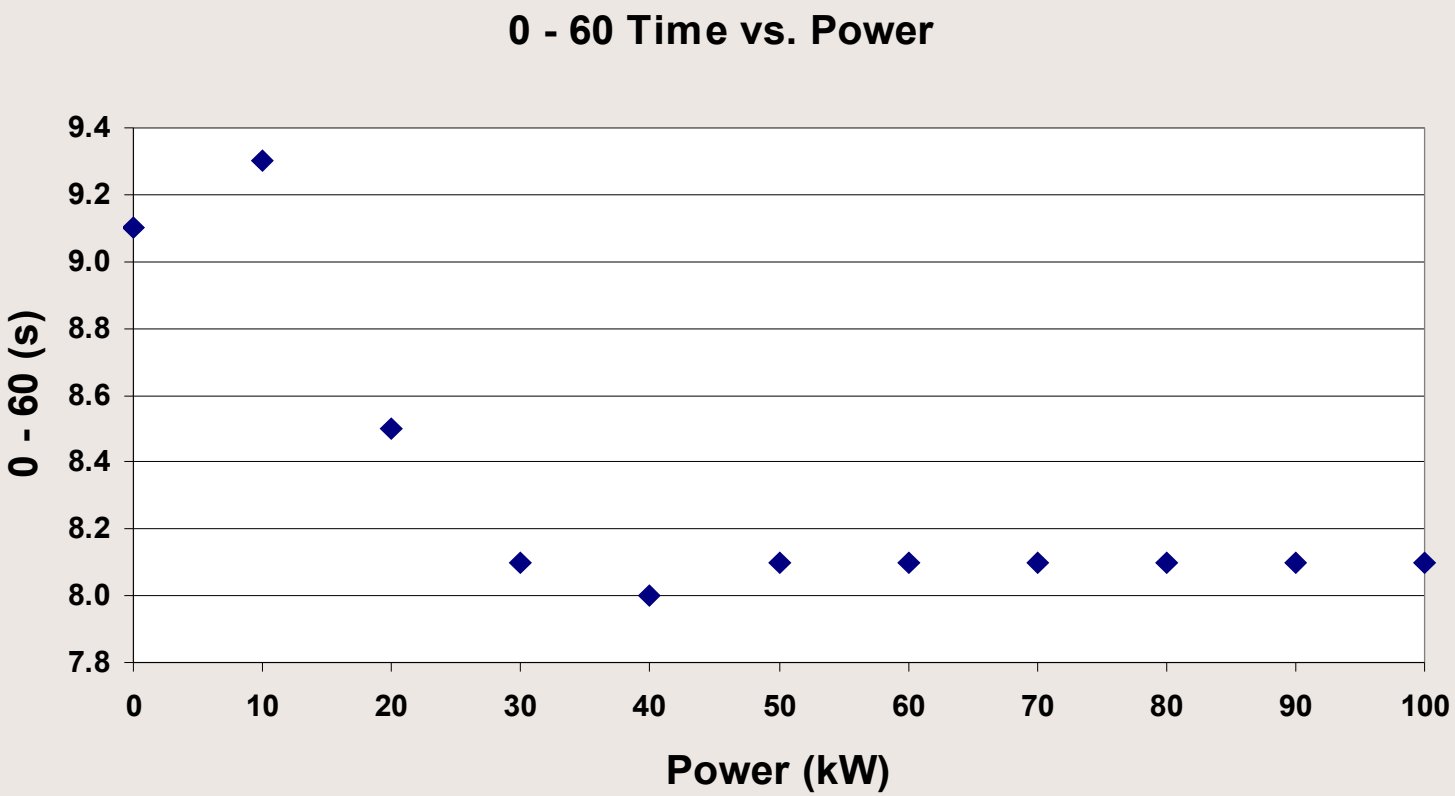
Emissions (grams/mi)

Motor (kW)	mpg	0-60	1/4 mi	Grade	HC	CO	NOx
0	21.1	9.1	17.2	22.5	0.826	3.614	0.331
10	26.7	9.3	17.2	21.6	0.826	4.007	0.357
20	26.7	8.5	16.7	25.1	0.826	4.009	0.358
30	26.6	8.1	16.3	28.4	0.827	4.012	0.360
40	26.5	8.0	16.3	28.7	0.829	4.016	0.362
50	26.3	8.1	16.3	28.6	0.830	4.020	0.365
60	26.1	8.1	16.3	28.6	0.831	4.024	0.368
70	25.9	8.1	16.4	28.7	0.833	4.029	0.371
80	25.7	8.1	16.4	28.8	0.835	4.035	0.374
90	25.5	8.1	16.4	28.9	0.836	4.040	0.377
100	25.3	8.1	16.4	29.0	0.838	4.045	0.380

HF-Results


MPG vs. Motor Power
MPG / % Grade
30
29
28
27
26
25
24
23
22
21
20
0
20
40
60
80
100
Power (kW)
MPG
Grade-Ability

HF-Results


0 - 60 Time vs. Power
0 - 60 (s)
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
0
10
20
30
40
50
60
70
80
90
100
Power (kW)

HF-Conclusions

- Two cases:
  - Highest Fuel Economy:
    - Use 20kW motor; Hybridization Factor is 0.152
    - Gives 26.5% increase in fuel economy (21.1mpg to 26.7)
    - 6.6% decrease in 0-60 time (9.1s to 8.5s)
    - 11.6% increase in grade-ability (22.5% to 25.1%)
  - Performance:
    - Use 40kW motor; Hybridization Factor is 0.263
    - Gives 25.6% increase in fuel economy (21.1mpg to 26.5mpg)
    - 12.1% decrease in 0-60 time (9.1s to 8.0s)
    - 27.6% increase in grade-ability (22.5% to 28.7%)

HF-Conclusions

- Increasing from 20kW to 40kW yields modest increase in performance
- Minor losses to fuel economy with increase in motor size
- Determining variable for hybridization factor would be cost of 20kW setup compared to 40kW setup

The Future Truck Competition

Presented by: Bhuan Agrawal

Team Member: Kavin Ammigan

- **5-year engineering competition to address growing energy-related and environmental concerns**

http://www.futuretruck.org

Future Truck Team Objectives

- Examine past team designs
- Offer advice and input to Drivetrain Design Team

Our Recommendation

- Split-parallel hybrid design
- Maximum flexibility
- Minimum modification to the vehicle

Current Work

- Reference paper
- Will serve as a valuable learning resource for future hybrid work (Challenge X)
- To be presented at SAE World Congress 2005

Ultra-Capacitors

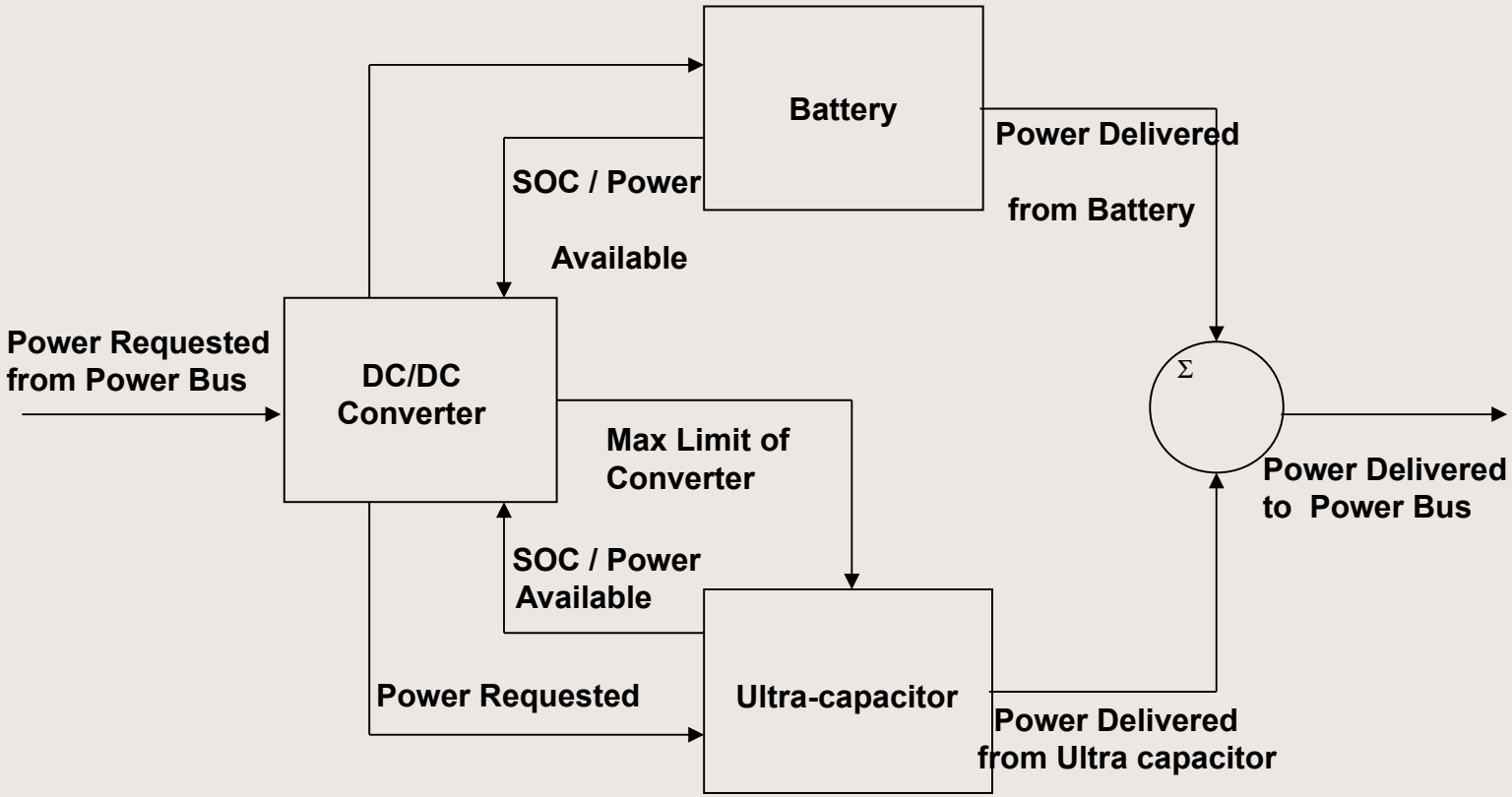
Presenter: Jesse Park

Team Member: Betsy Raju

Advantages of Ultra-Capacitors as a Component of the HEV Energy Storage Model

- Increased Power Delivery
- Increases the Life of the Battery
- Cheap and Efficient
- Overall Cost Reduction of the Energy Storage System

Energy Storage Model



Simulation with 10 year cost: Effect of Ultra-Capacitors on the Energy Storage System

NiMH Battery Units	Ultra-Capacitor Units	Motor (kW)	UDDS (mpg)	Acceleration (s)			Max Speed (mph)	Grade (%)	Cost $	% saved
				0-60	40-60	0-85				
21	0	10	23.9	9.9	4.4	18.9	113.1	18.5	21000	N/A
9	5	10	23.0	9.3	4.2	18.4	113.0	21.0	9150	56.4
21	0	20	23.9	8.8	3.8	16.6	121.4	18.4	21000	N/A
9	30	20	23.0	8.8	3.9	17.5	113.0	20.8	9900	52.9
21	0	30	23.8	8.2	3.4	15.0	126.9	18.3	21000	N/A
10	45	30	23.0	8.2	3.4	16.0	116.6	20.4	11350	46.0

Conclusion

Presenter: Ryan Long

Accomplishments

- Acquisition of test vehicle for hybrid drivetrain designs
- Advisor simulations determining best hybridization factors and engine size
- Research of Future Truck Competition designs in order to determine feasibility of various design options
- Research of Jeep Liberty in order to asses options in hybridizing small SUVs
- Research on Honda Insight
- Preliminary design of hybrid drivetrain

Future Plans

- Use research from this semester in conjunction with research from previous semesters in order to compete in Challenge-X sponsored by General Motors

- ***Questions?***

- ***Refer to Final Progress Report or check us out at:***

http://www.iit.edu/~ipro326