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 project, 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.

**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.

**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

**HYBRID DRIVE TRAIN MECHANICAL DESIGN**

### Series Drive Train Configuration

**Parallel HEV Control Strategy**

- **Hybridization Factor (HF)**

  \[ HF = \frac{P_{M} + P_{EM}}{P_{M} + P_{ICE} + P_{EM}} \]

  - \( P_{M} \): Power of the electric machine
  - \( P_{ICE} \): Power of the ICE

**Series Drive Train Configuration**

- **SOC > Lo SOC**
- **SOC < Lo SOC**

**Vehicle Input Parameters:**

- Engine power (kW)
- Engine speed (rpm)
- Time
- Engine efficiency

**Simulation Parameters:**

- Result:
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

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 & Results

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%
   and engine kept constant at 100%

2) Varying Motor Power
   Engine is scaled from 100% to 30% and motor is scaled from 0% to 70% in increments of 5%
   and engine kept constant at 100%

Fuel Economy Charts & Results

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: 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%
   and engine kept constant at 100%

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 & Results

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

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

Optimum Hybridization Factor = 35%