Modeling Grid-Connected Hybrid Electric Vehicles Using ADVISOR

Annual Battery Conference
Long Beach, California
January 9, 2001

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Presentation Outline

- Grid-connected hybrid vehicle concept
- Vehicle design problem and process
- Energy management strategy parametric study
- Summary and conclusions
Grid-Connected Hybrid Vehicle Concept

- EV-like vehicle
  - large battery/motor
  - small engine
  - all electric range
- Grid electricity used to offset petroleum fuel usage
Typical Grid-Connected Vehicle Operation

- Charge-Depleting Behavior
- Charge-Sustaining Behavior
- Torque Moving Average

Vehicle Speed (mph)

Motor Torque (Nm)

SOC (—)

Engine Torque (Nm)

Motor Torque (Nm) Engine Torque (Nm)
Engine State Based on Battery State of Charge and Vehicle Speed

![Graph showing engine state based on battery state of charge and vehicle speed. The graph is a plot with the x-axis representing state of charge (--) and the y-axis representing electric launch speed (m/s). The graph includes two regions: Engine On and Engine May Be Off.](image-url)
Personal Travel Characteristics Based on 1995 NPTS Data
Grid-Connected Hybrid Vehicle Benefits

- No range penalty of EVs
  - on-board “back-up” engine
- Smaller incremental cost than pure EV
  - smaller battery pack
- Displacement of petroleum fuel
- Utility load leveling
- Possible PZEV qualification under CARB ZEV mandate
Design Problem Constraints and Assumptions

• Constraints
  – Acceleration performance
    • 0-60 mph in 9.5s
    • 50-70 mph in 5.1s
  – Gradeability
    • 7.2% @ 50 mph for 15 min
    • 7.2% @ 30 mph for 30 min
  – Electric range
    • 40 miles on UDDS cycle
  – Drive cycle operation in “EV mode”
    • trace miss < 2 mph
  – Drive cycle operation in “hybrid mode”
    • charge sustain above 20% SOC

• Assumptions
  – present-day 5 passenger sedan vehicle characteristics
  – permanent magnet traction motor
  – nickel metal hybrid batteries
  – turbo-diesel engine
Analysis Process

- Define vehicle characteristics
- Size components for active constraints
- Perform parametric analysis of energy management parameters
Component Sizing Results

- Engine size driven by charge-sustaining operation on drive cycle
- Motor size driven by drive cycle requirements
- Battery pack size driven by all-electric range

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<th>Parameter</th>
<th>Value</th>
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<td>Engine Power</td>
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<td>Motor Power</td>
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Energy Management Strategy Parametric Study

- Two design variables
  - cs_hi_soc
  - cs_electric_launch_spd_lo
- Four responses
  - All Electric Range
  - Cumulative EV Miles
  - Fuel Economy
  - Final SOC
Parametric Study Engine State Design Space

- **cs_electric_launch_spd_hi = 26.8**
- **0.4 < cs_hi_soc < 1.0**
- **Engine On**
- **Engine May Be Off**
- **cs_lo_soc = 0.3**
- **0 < cs_electric_launch_spd_lo < 15**
Parametric Study Results
(star = design point)
Parametric Study Conclusions

• All electric range mainly a function of cs_hi_soc

• For cs_electric_launch_spd_lo settings greater than ~11 m/s charge-sustaining SOC falls to undesirable levels

• Equivalent fuel economy seems to be a function of cumulative EV miles and not all-electric range
SAE J1711 Test Procedure

• Purpose is to provide a means of comparison between various hybrid vehicle designs
• Compiles the results from four different tests performed on four different drive cycles
  – UDDS (city)
  – HWFET (highway)
  – US06
  – SC03
SAE J1711 Fuel Economy Results

- Partial Charge Test
- Full Charge Test
- Utility Factor Weighted Full Charge Test
- Final Composite

Drive Cycle: UDDS, HWFET, US06, SC03

Fuel Economy (mpgge)
Conclusions

• Analysis demonstrates that the grid-connected hybrid concept can help reduce consumption of petroleum
• Cost and commercialization issues not quantified in this study
• Demonstrated new capabilities in ADVISOR 3.0