Can Using a Charge Depleting Strategy Further Decrease a PHEV’s Fuel Consumption When Trip Distance Exceeds All Electric Range?

V.S.
A Charge Depleting Strategy Can Use A Priori Knowledge of Trip Distance to Choose when to Use the Engine
This Is a Specific Case, How Much Can It Be Generalized?

- 1 Configuration – Power Split
- PHEV with 10 mile Range on the UDDS
- Trip Distances - 10, 20, 30, 40, 60 miles on the UDDS
- 3 Control Strategies
- 1 Control Parameter was adjusted (Engine On Power Threshold)
- Did Not Include
  - Temperature Effects – Cold or Hot Battery
  - Emissions
PSAT Modeling Assumptions

Class | Midsize
--- | ---
Curb Weight | 1432 kg
Battery Type | Li-Ion JCS - Saft 19 Ah
0 to 60 mph | 9 sec
Grade | 6% at 65 mph
Range | 10 miles on UDDS
Delta SOC | 90% to 30% SOC
Charge Sustaining at | 30%

Power Split Configuration

10 Miles: Less Than 2 Full UDDS cycles

Vehicle Speed (m/s)

Time (sec)
Each of the Three Control Strategies Partitions the Demanded Road Load between the Engine and Battery Differently

1. Differential Engine Power
   - Engine power < Road Load

2. Full Engine Power
   - Engine power = Road Load

3. Optimal Engine Power
   - Engine power > Road Load
Decreasing the Control Parameter (Engine On Power Threshold) Increases the Trip Distance

- Decrease Engine Start Threshold
- Engine Turns On More Frequently

- Target Distance: 96 km

- Engine On/Off Thresholds

- Increasing Trip Distance

- Power (Watt) vs. Efficiency

- SOC vs. Time (sec)
Driving 32 km with a PHEV 10 in Blended Mode Would Save 9% More Fuel Than in EV Mode!

10 miles AER vehicle run on several UDDS cycles
Four Factors Affecting Consumption

- Increased Engine Efficiency
- Increased Excess Battery Charging
- Increased Transmission Efficiency
- Increased Regenerative Braking

**Engine Peak Efficiency**  
= 35%

- **Converging to Charge Sustaining Behavior**

**Effect on Consumption PHEV32**

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Even Though the Optimal Engine Strategy Has the Highest Average Efficiency, Its Greater Excess Charging Reduces This Advantage

![Graph showing the effect of trip distance on fraction of total engine power.

Effect on Consumption PHEV32

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As Trip Distance Increases, the Transmission Efficiency for the Optimal Engine Strategy Drops below the CS Strategy Transmission Efficiency
As Trip Distance Increases Regenerative Braking over the Cycle Decreases

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Regenerative Braking Decreases Because the Battery Discharges Slower
Conclusion

- A Charge Depleting strategy can improve a PHEV’s fuel economy by up to 9% for a power split configuration.
- Most of the gain is from operating the engine more efficiently.
- The full engine strategy showed the most benefit as a charge depleting strategy.
- Engine benefits are cancelled by excess charging, decreased transmission efficiency and decreased regenerative braking.
- The Optimal engine strategy suffered the most from excess charging.
- The Differential engine strategy suffered from low engine efficiency.