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Comparison of Powertrain Configuration for Plug-in HEVs from a Fuel Economy Perspective

Vincent Freyermuth, Eric Fallas,

Aymeric Rousseau

Argonne National Laboratory

Sponsored by Lee Slezak, U.S. DOE

Outline

- Modeling Assumptions
- Component Sizing
- Control Strategy Algorithms
- PSAT Simulation Results
- Conclusion

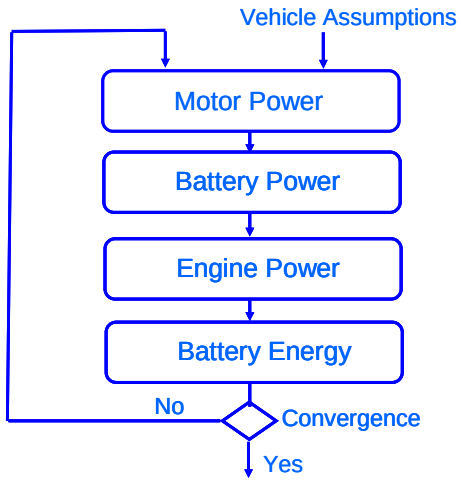
PSAT Modeling Assumptions

Three powertrain configurations were considered
- Pre-transmission parallel
- Power split
- Series

Parameter	Unit	Midsize Car
Glider Mass	kg	990
Frontal Area	m^2	2.1
Drag Coefficient		0.31
Wheel Radius	m	0.317
Rolling Resistance		0.008

Parameter	Unit	Value
0–60mph	s	9 +/- 0.1
0–30mph	s	3
Grade at 60 mph	%	6
Maximum Speed	mph	> 100

Automated Sizing Algorithm

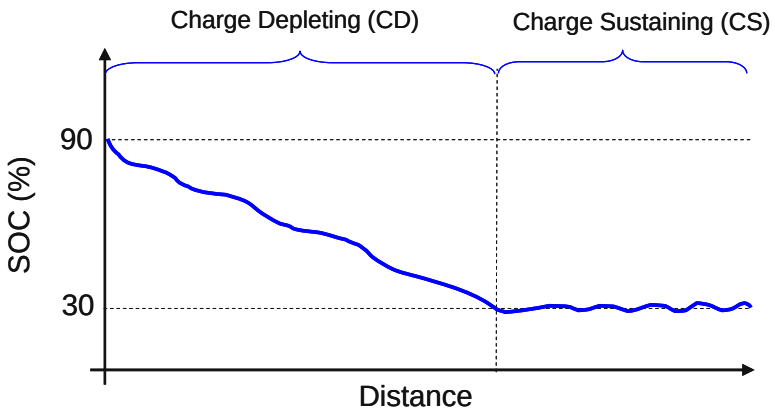


Component Sizing

Parameter	Pre-trans Parallel	Power Split	Series
Engine Power (kW)	76	74	109
Propulsion Motor Power (kW)	48	62	90
Generator Power (kW)	NA	63	106
Battery Power (kW)	58	52	55
Battery Capacity (Ah)	18	21	18
Total Vehicle Mass (kg)	1675	1667	1700

10 miles All Electric Range on UDDS

Control Strategy Algorithms



All configurations share the same modes (CD and CS)

The engine ON/OFF logic are based on similar logics:

- The battery SOC is lower than a threshold
- The requested power is above a threshold
- The electric machine cannot provide the requested wheel torque

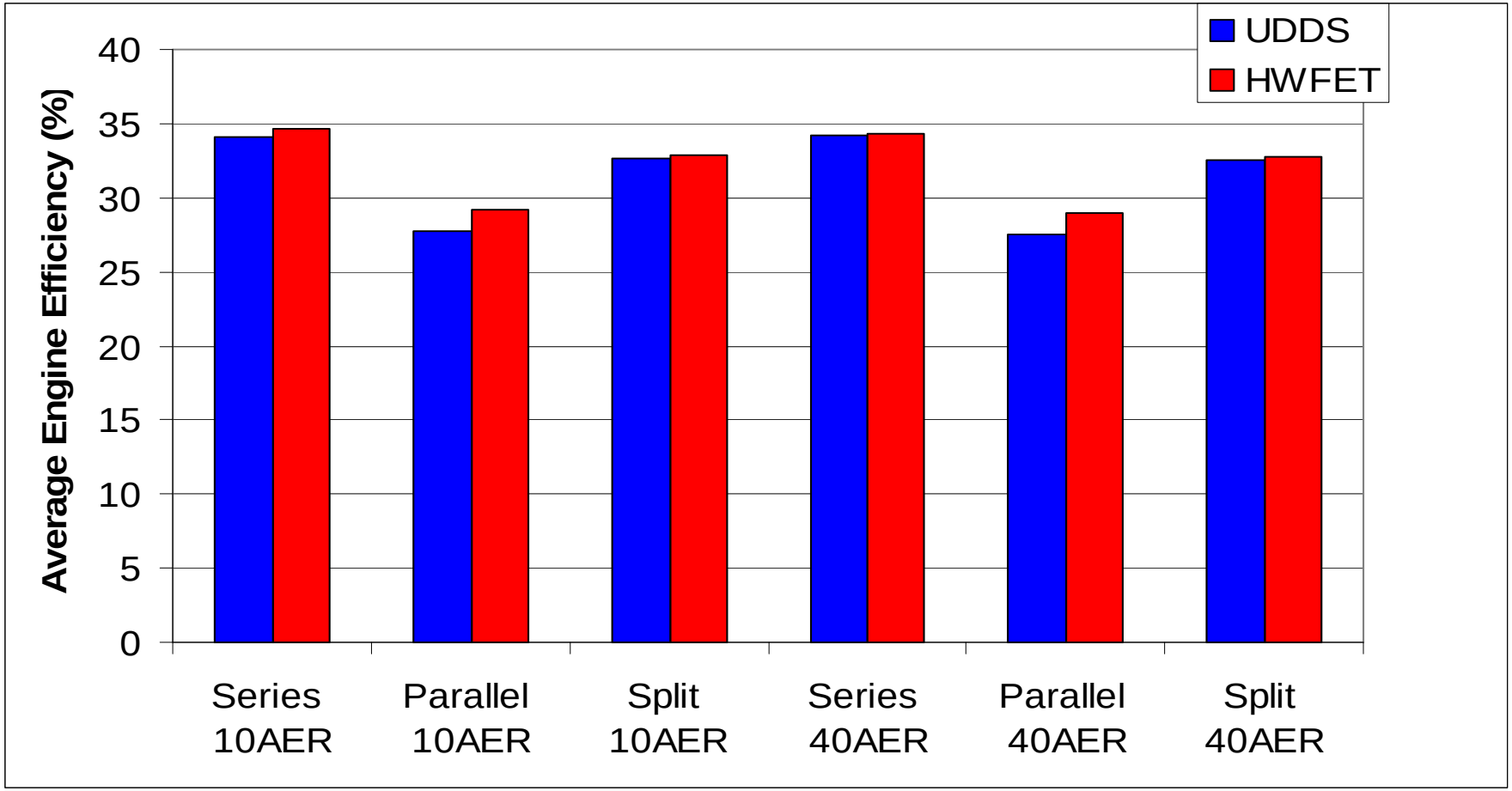
Once ON, the engine is operated close to its best efficiency curve

Simulations Demonstrate Power Split Advantages

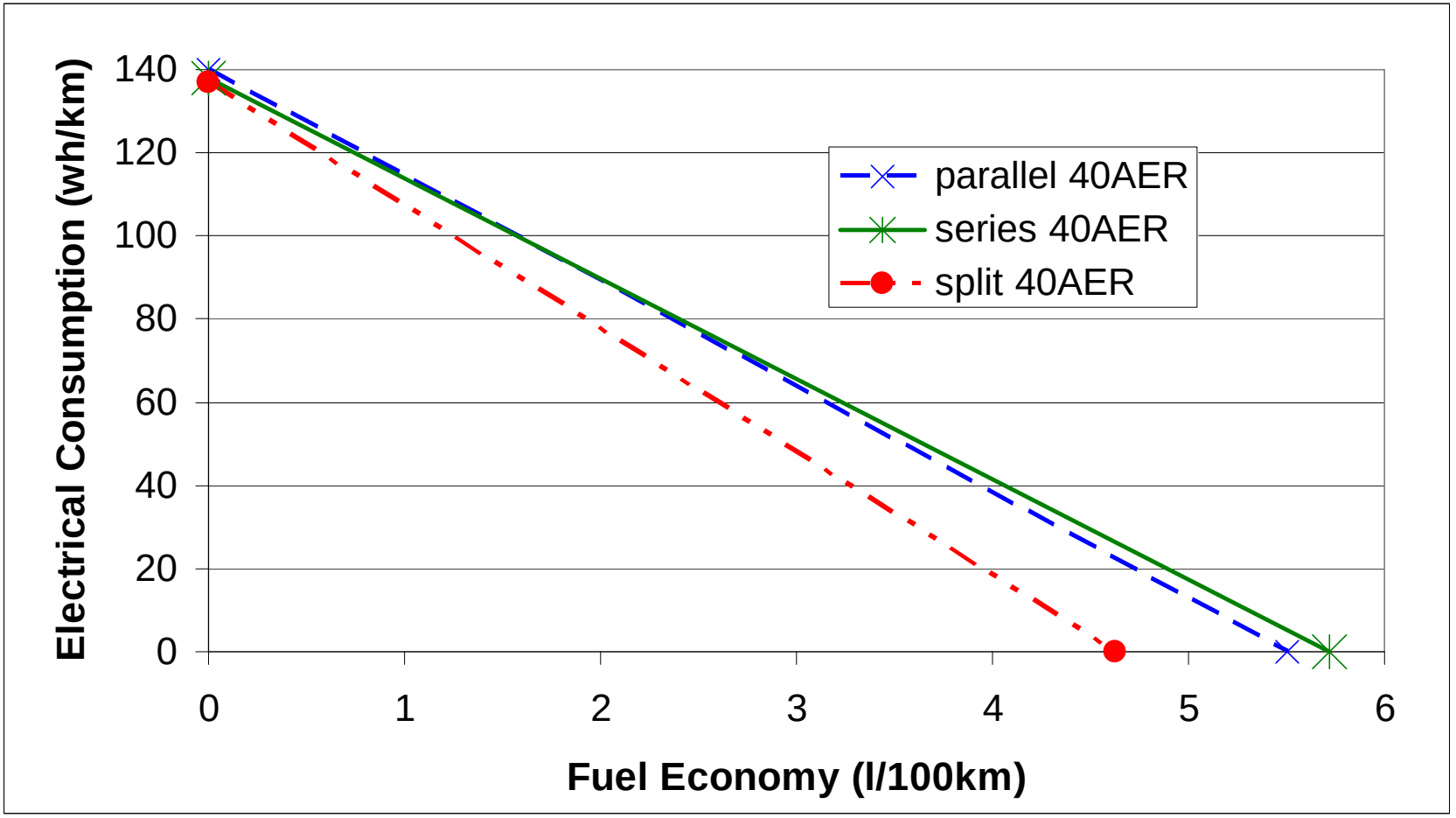
Fuel economy	UDDS		HWFET	
	MPG	L/100 km	MPG	L/100 km
10 miles AER on UDDS				
Series	46.6	5	43.4	5.4
Pre-trans parallel	53	4.4	51.4	4.6
Split	60.4	3.9	50.9	4.6
40 miles AER on UDDS				
Series	64.6	3.6	51.1	4.6
Pre-trans parallel	66.4	3.5	60	3.9
Split	78.9	3	59.1	4

All cycles are run 15 times to ensure that consistent electrical consumption (identical final SOC)

Series Configuration Provides the Highest Average Engine Efficiency



Power Split Achieves Lower Fuel Consumption During Charge Sustaining

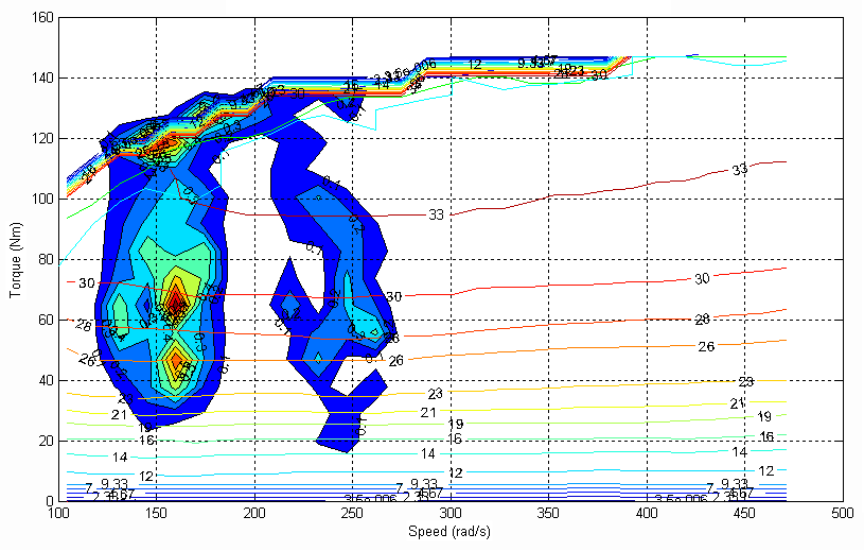


All Configurations Shows Similar Electrical Path Efficiencies

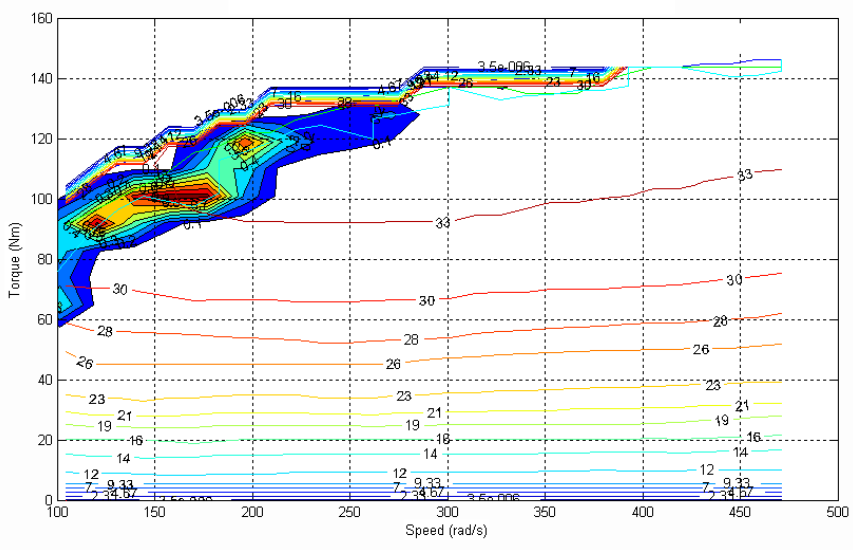
Parameter	Series	Parallel	Split
Electric Machine (%)	83.4	85.8	83.6
Transmission (%)	NA	94.1	96.6
Final drive (%)	97.5	97.5	97.5
Single gear (%)	97.5	NA	NA
Battery (%)	95	95	95

- The single gear losses for the series and the planetary losses lead to comparable powertrain efficiencies.
- The parallel configuration has a lower transmission efficiency, but a higher electric machine efficiency due to the different gears.

During Blended Mode, The Power Split Minimizes Fuel Consumed



Parallel HEV



Power Split HEV

- Power split allows use of engine in narrow operating range compared to the parallel HEV
- Series configuration handicapped by numerous component efficiencies (generator, motor)

Conclusions

- Several powertrain configurations were compared with respect to component sizes and fuel economy for PHEV applications.
- The series configuration, as expected, requires significantly higher component power.
- All of the configurations achieve similar characteristics when operated in electric mode.
- The power split provides the best fuel economy as a result of its dual path of power from the engine to the wheel.
- The series configuration appears to be an appropriate choice for long All Electric Ranges due to its simple control and its ability to operate in EV mode at high vehicle speed.
- The power split configuration is a better option for approaches focused on blended operating mode.