Modelling and Analysis of Plug-in Series-Parallel Hybrid Vehicles

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SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS

of the Institute of Transportation Studies

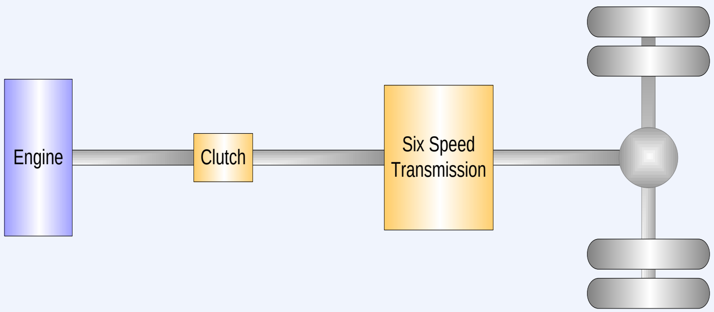
Presentation Outline

- Research objectives
- Analysis of series-parallel hybrid-electric powertrains
- Simulations of medium-duty parcel delivery trucks
- Simulations of Volt-like passenger cars
- Conclusions

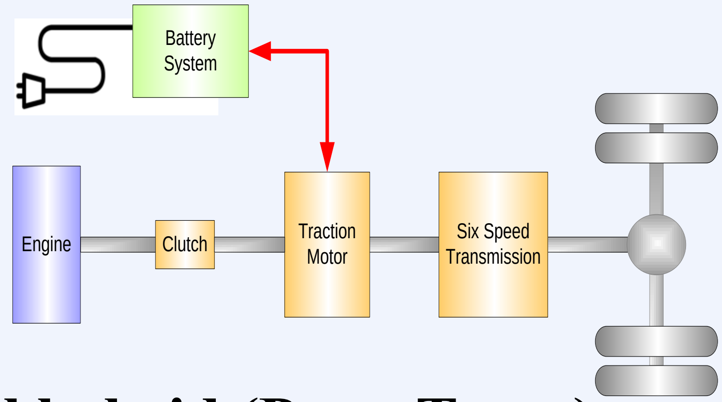
Research Objectives

- Analyze series-parallel powertrain configurations
- Assess technologies for MD & HD vehicle applications and the Chev. Volt
- Support the PHEV technology for specific classes of illustrative vehicles

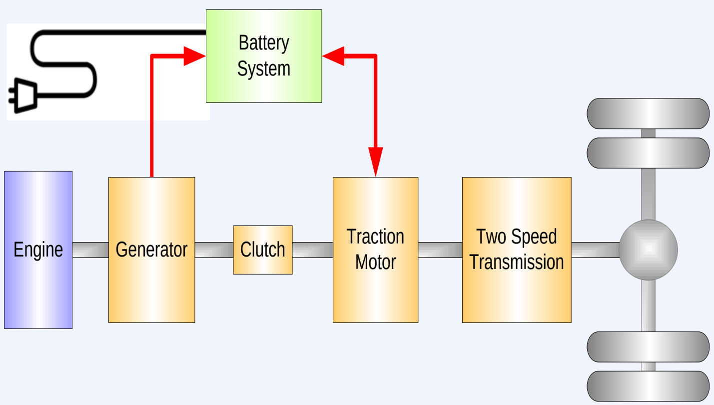
Powertrain Architectures



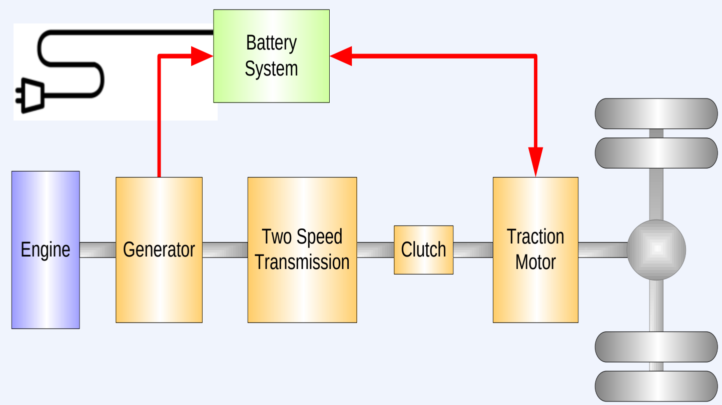
Conventional



Parallel hybrid (Pre – Trans)

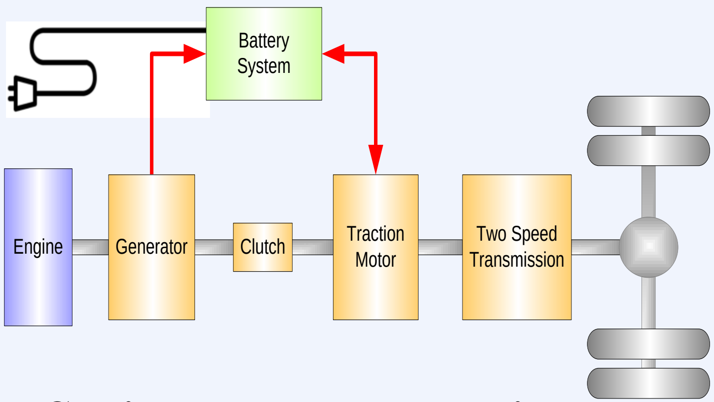


Series-Parallel (Pre – Trans)

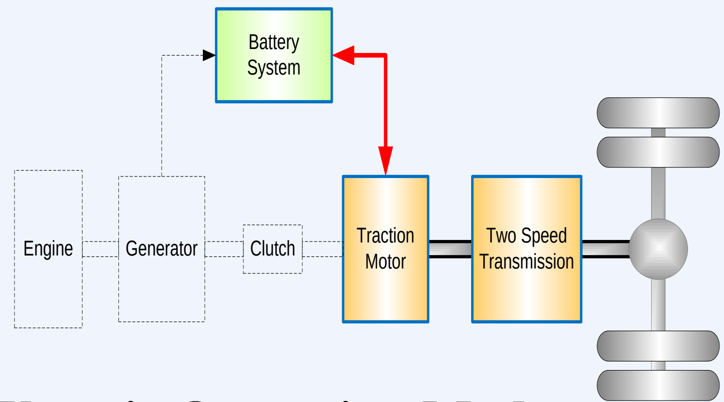


Series-Parallel (Post – Trans)

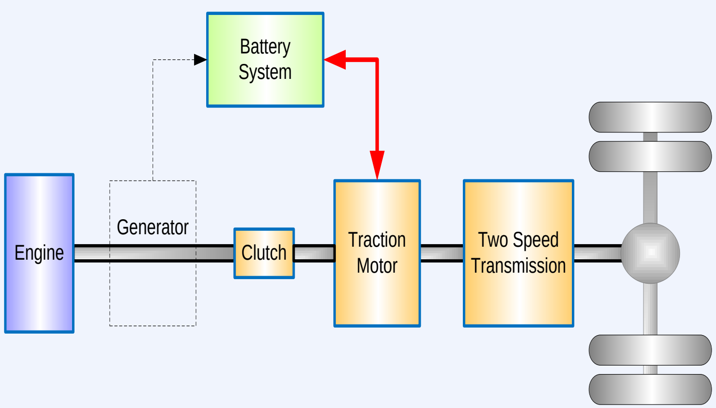
Series-Parallel Operation Modes



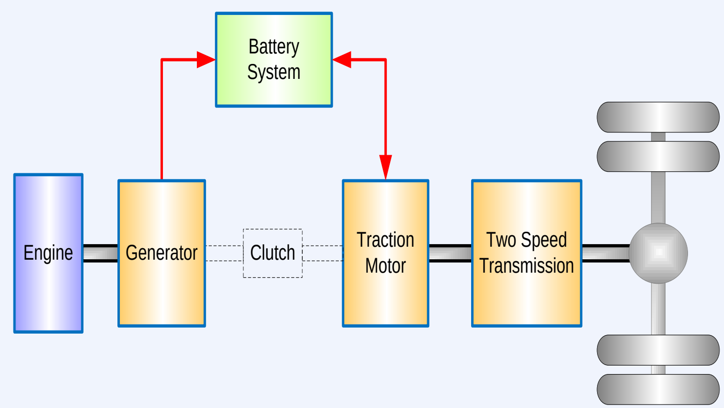
Series-Parallel Hybrid



Electric Operation Mode

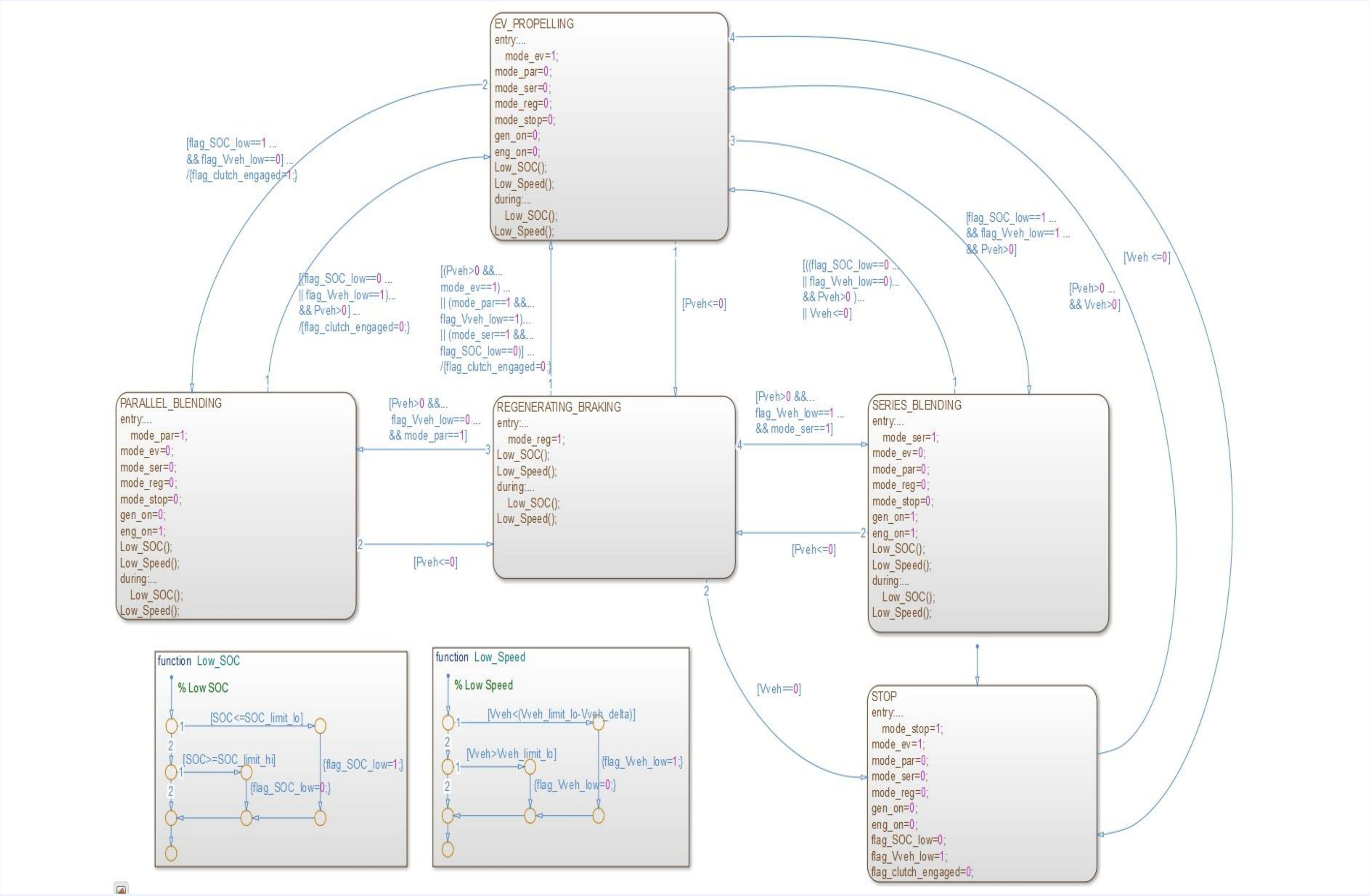


Parallel Blended Operation Mode



Series Blended Operation Mode

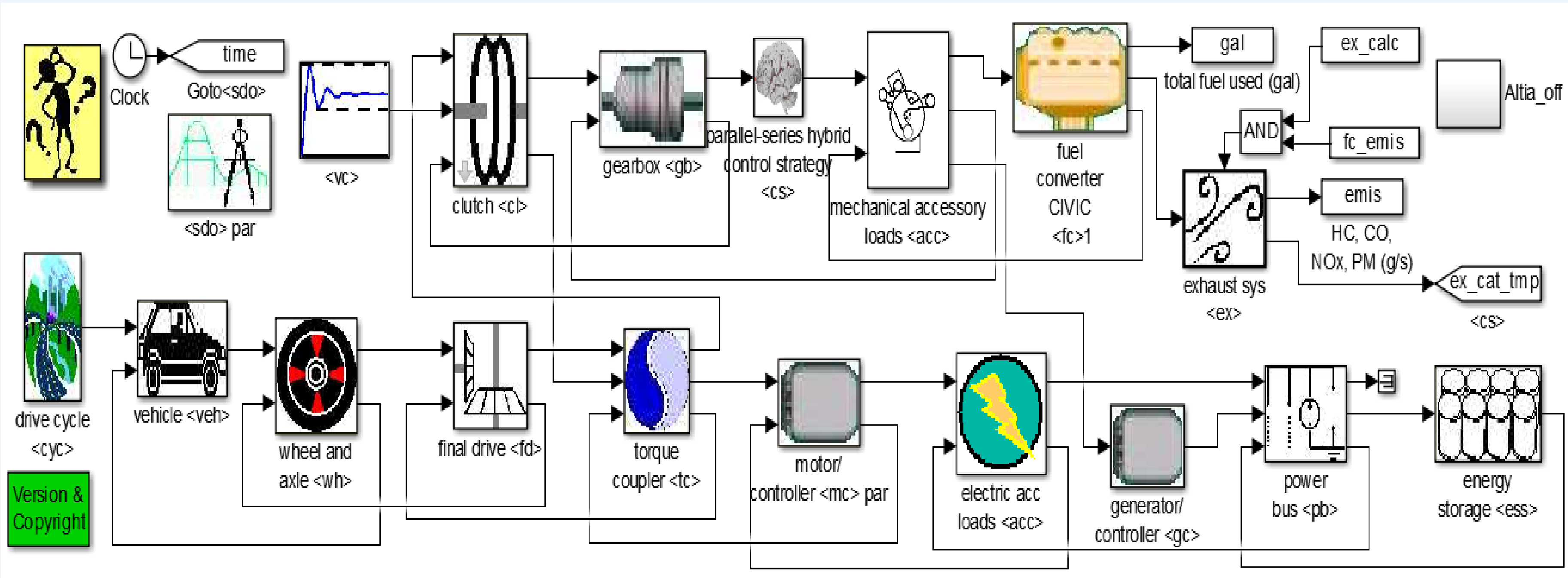
Control Strategy



Vehicle Inputs

Engine	CI 7L 200 HP (2014)
Engine Peak Eff.	0.43
Frontal Area	7.8 m^2
Air Drag Coef.	0.6
Weight	16,000 lbs / 7,257 kg
Wheel Radius	0.378
Rolling Resistance Coef.	0.006
Motor	UQM PM 100kW cont. 150 kW peak
	45 kW for mild hybrid
Generator	PM 70 kW
Energy Storage	31.68 kWh
Transmission	Six-Speed 9.01/5.27/3.22/2.04/1.36/1.0
	Two-Speed 2.04/0.95
Gearbox Peak Eff.	0.97
Final Drive	2.85
Aux. Mech. Power	1 kW
Aux. Elec. Power	0.4 kW

Vehicle Modeling



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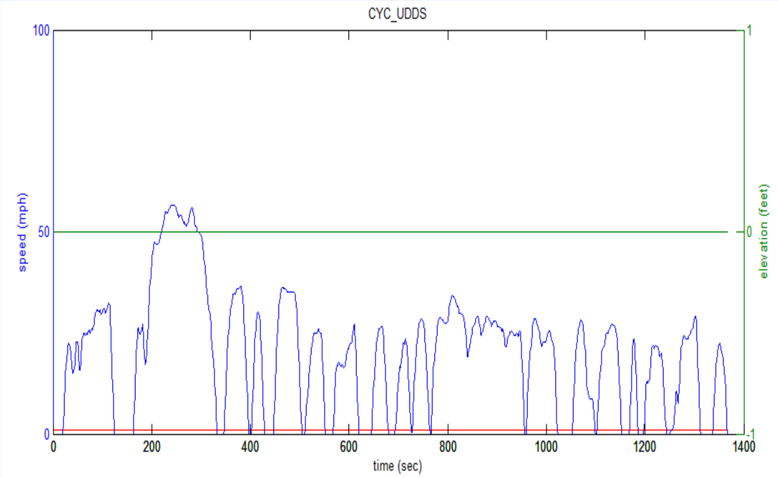
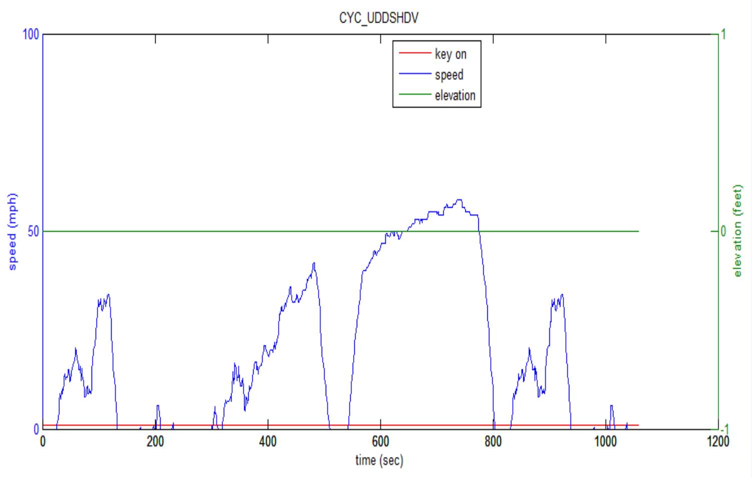
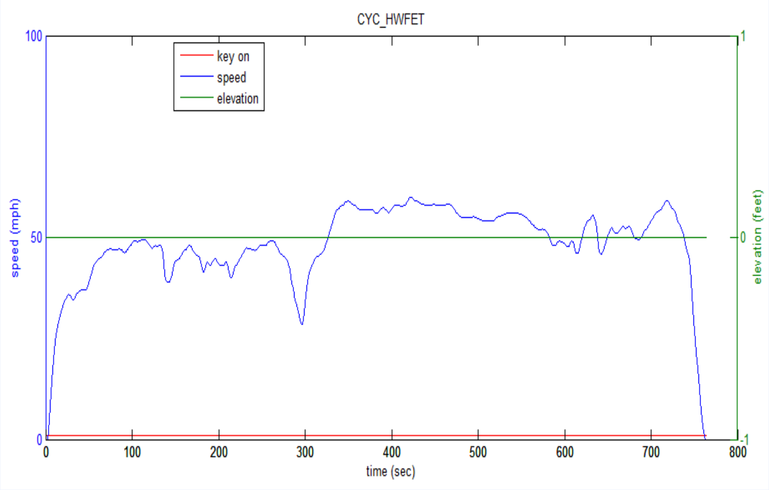
Drive Cycles



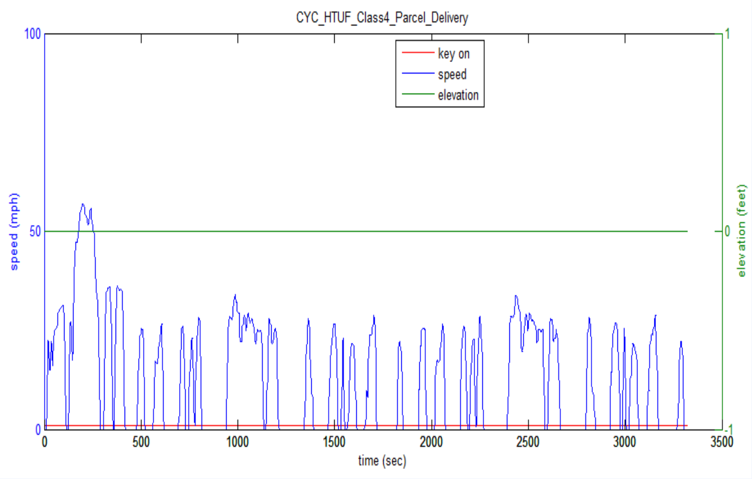
Urban Driving Schedule



UDDS HDV

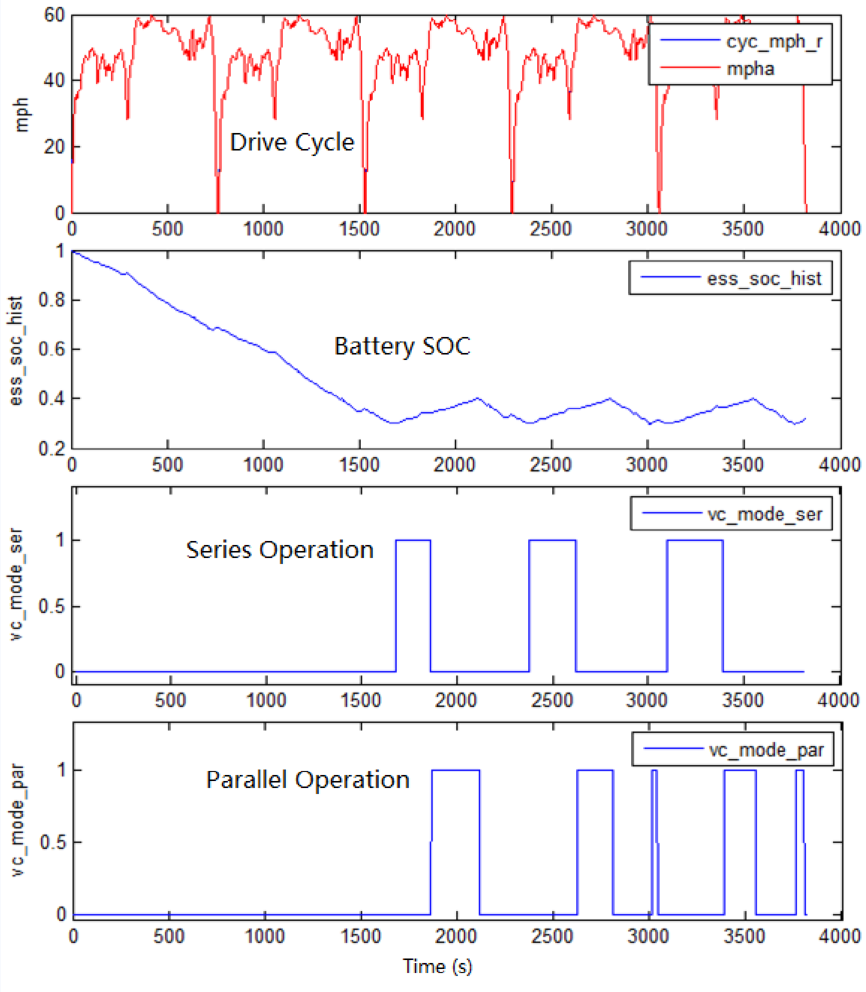


Highway Driving Schedule



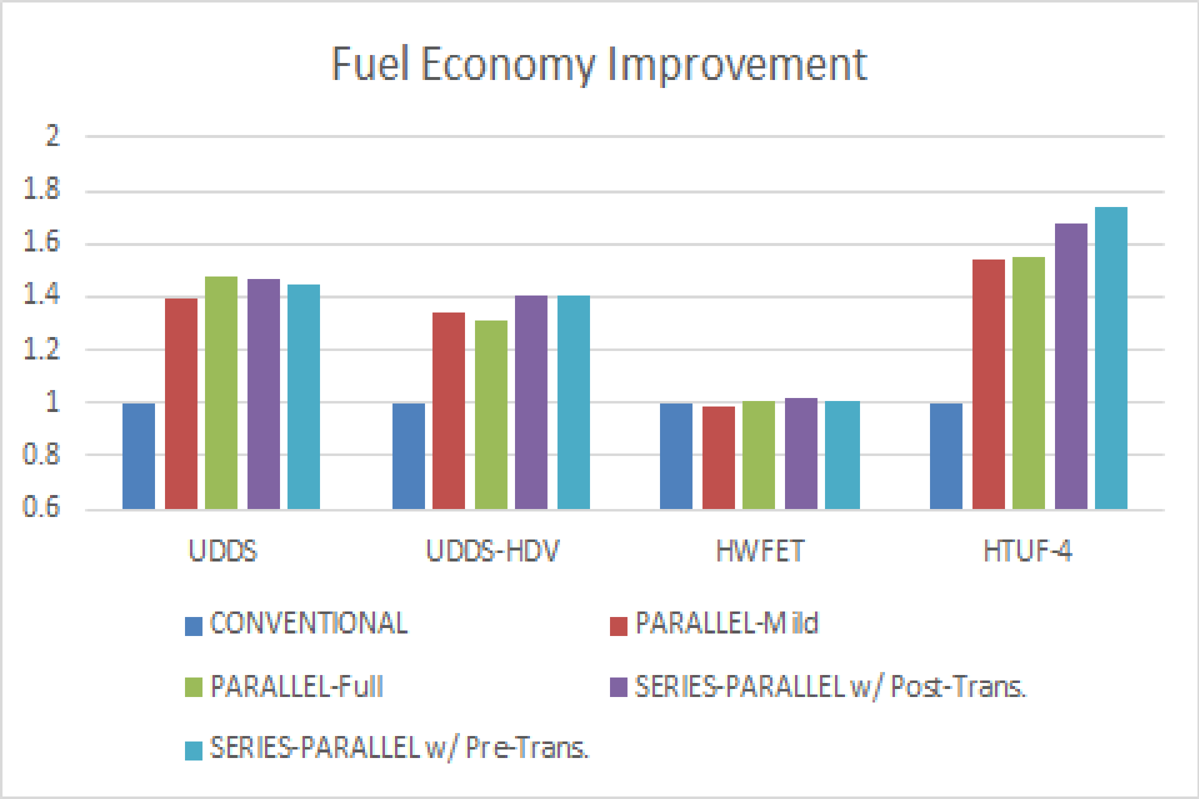
Class 4 Local Delivery

Simulation over short distance drive



MD parcel delivery truck

Fuel economy improvement in charge sustaining operation



Mid-size passenger car (Volt-like)

Vehicle component characteristics for various powertrain configurations

Vehicle	Powertrain	Engine kW	EM kW	Battery kWh	Generator eff.
Volt	**Series-Parallel PHEV**	65	111	17	.95 (65 kW)
Volt	**Single-shaft full parallel PHEV**	65	111	17	.95 (65 kW)
Cruze	**Mild parallel HEV single-shaft**	105	20	1.8	NA
Cruze	**Conventional**	122	NA	NA	NA

Energy characteristics of mid-size cars with various powertrain configurations

Vehicle	Powertrain		Wh/mi electric	Range electric- miles		mpg engine
Volt	**Series-Par PHEV**					
		FUDS	212	52		49
		HW	240	46		43
		HW-Interst.	296	37		36
Volt	**Single-shaft full parallel PHEV**					
		FUDS	206	54		48
		HW	228	48		43
		HW-interst.	289	38		35
Cruze	**Mild HEV single-shaft**					
		FUDS				45
		HW				45
		HW-interst.				37
Cruze	**Convention ICE.**					
		FUDS				25
		HW				37
		HW-interst.				34

Conclusions

- Series-parallel configuration seems ideal for PHEVs – advantages of both an EV and ICE
- Performance/efficiency advantage of series-parallel arrangement in the charge sustaining mode is minimal for most driving cycles, but it permits vehicles to operate efficiently as EVs in the all-electric mode for significant ranges and with good fuel economy for long trips
- The battery required for 50 mile electric range should make PHEVs cost competitive with conventional ICE vehicles
- Possibility of overcome disadvantage of high energy consumption (Wh/mi) of EVs in cold weather by storing waste heat from the engine/generator