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ADVISOR Simulation and Performance Test of Split Plug-in Hybrid Electric Vehicle Conversion

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Abstract

With increasing concern over the environment and ever stringent emissions regulations, the electric vehicle has been investigated as an alternative form of transportation. However, the electric vehicle suffers from relatively short range and long charging times and consequently has not become an acceptable solution to the automotive consumer. The addition of an internal combustion engine to extend the range of the electric vehicle is one method of exploiting the high efficiency and lack of emissions of the electric vehicle while retaining the range and convenient refuelling times of a conventional gasoline powered vehicle. The term that describes this type of vehicle is a hybrid electric vehicle. Many configurations of hybrid electric vehicles have been designed and implemented, namely the series, parallel and power-split configurations. This paper discusses the modelling and simulation of split plug-in hybrid electric vehicles. Modelling methods such as physics-based Resistive Companion Form technique and Bond Graph method are presented with powertrain component and system modelling examples. The modelling and simulation capability of existing tools such as ADvanced VehIcle SimulatOR (ADVISOR) is demonstrated through application examples. Hardware implementation has been done and tested on dyno and real road test. An experimental result has been compared to simulation results. Since power electronics is indispensable in hybrid vehicles, the issue of numerical oscillations in dynamic simulations involving power electronics is briefly addressed.

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Keywords: Split-hybrid, Plug-in hybrid, ADVISOR

1. INTRODUCTION

A hybrid electric vehicle draws its propulsion power from an (Internal Combustion Engine)ICE and an electric motor, which can also operate as a generator to charge the onboard electrical energy storage device. Depending on the connectivity of the power sources to the load (wheels), the HEV may have one of the following drivetrain configurations: series hybrid, parallel hybrid or combined series-parallel hybrid[1].

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A series-hybrid Fig. 1 only has the electric motor turning the drive-shaft while the ICE serves as an on-board electric generator to charge the batteries and/or to power the motor directly ('series' connection between the ICE the electric motor, resulting in an electric transmission of power to the wheels)[1].

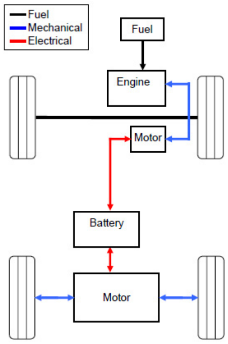

Figure-1. Series-Hybrid Electric Vehicle[2]

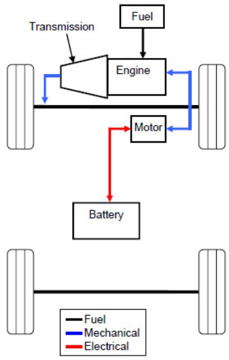

Figure-2. Parallel-Hybrid Electric Vehicle[2]

Instead, a parallel-hybrid vehicle Fig. 2 has the ICE turning the drive-shaft, just like a conventional vehicle, but the drive-shaft can also be turned by the electric motor ('parallel' connection of the ICE and motor to the drive shaft via some form of mechanical coupling and transmission)[1].

A hybrid vehicle typically has the motor-generator onboard the chassis, as in most production hybrids of today, the parallel "through the road" hybrid uses one motor for propulsion assist or to recharge the battery by loading the rear axle with the motor. In contrast, the series hybrid provides power to the wheels by a series path of energy conversion through the engine to the generator, battery, then the rear motor. Note that the series hybrid and through-the-road parallel hybrid can still propel the vehicle without the engine on, sourcing power for the rear motor from the battery[2].

In this paper addressed about how to model split hybrid electric vehicle and simulate it using ADVISOR. All simulation was done by using ADVISOR and the results were discussed through this paper.

2. PROPOSE SYSTEM

The overall objective of this paper is to define a performance for a Split PHEV shown in Fig. 3 by simulates powertrain of the system. Fig. 4 show block diagram of the system. The results of these simulations should define how the vehicle can decrease fuel consumption, while maintaining low vehicle emissions. Because of the hybrid system, just operating an engine in its regions of high efficiency does not guarantee efficient vehicle operation. These results will not give the specific powertrain commands necessary to enable complete vehicle operation, and are meant only to define a literal strategy; that is, an understanding as to why the vehicle should operate in a certain way under the given conditions.

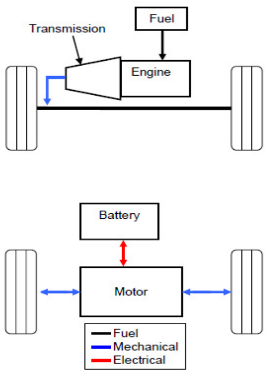

Figure-3. Split Plug-in Hybrid Electric Vehicle [2].

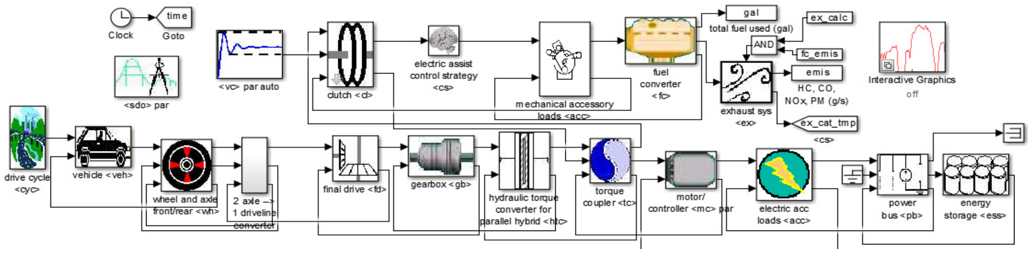

Figure-4. Block diagram of Split PHEV in ADVISOR

The system configuration was shown in table 1 below. Small car Produa Kancil was used in this simulation with default component and rear wheel system was installing the 10kW electric vehicle conversion kit.

Table-1. Split PHEV Configuration

Component	Description
Engine	850CC Gasoline Engine
Motor	10kW AC Motor
Battery	LifePO4 96V 60Ah
Transmission	4 Speed on the front and Rear Axle (Wheel distance 1385mm)Ratio: 10.6:1
Control Strategy	Propelling, Shifting and Breaking
Weight	550kg

3. SIMULATION RESULT AND DISCUSSION

a. Simulation

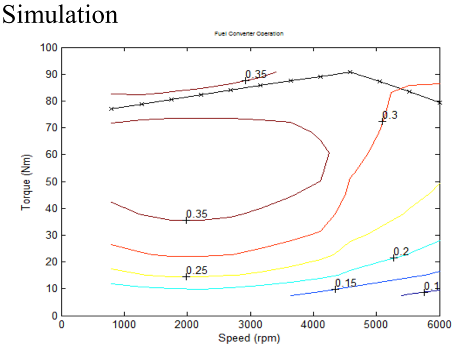

Figure-5. Graph of Fuel Converter Operation

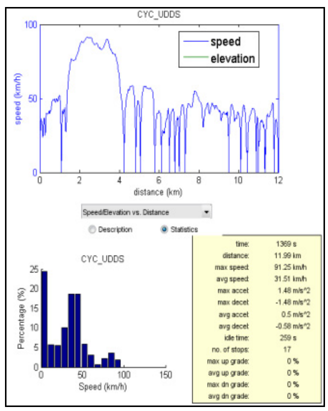

Figure-6. Graph CYC UDDS(Drive Cycle) and Performance of Split PHEV in ADVISOR

Engine operating points are plotted on the Graph of fuel converter operation in Fig. 5. Note that the operating points are mostly concentrated in the high efficiency region of the efficiency map. This is the result of using a vehicle control that deploys the mechanical and electrical paths with a view to improve the overall efficiency.

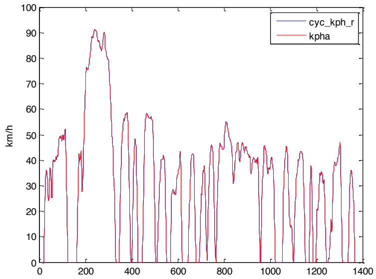

Figure-7. Graph of drive cycle vs speed

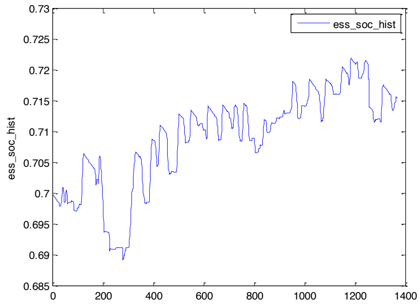

Figure-8. Graph of state of charge(SOC) history

When the battery state-of-charge is below the desired level, the battery storage must be charged, with charging power coming from the ICE. The ICE power is converted to electrical form in the generator and then stored in the battery. The extra power from the generator is again converted back to mechanical form using the electric motor, and is given to wheels. Fig. 8 shows the graph of state of charge(SOC) of the drive-train in this mode of operation.

The Graphs in Fig 5 till Fig 9 shown the performance of propose split PHEV in ADVISOR. The patent of driving showed in Fig. 10 how drive cycle graph perform in speed versus distance. Table 2 show summary result for the propose system. Fuel consumption for this proposes vehicle is approximately 35km/L. The distance for this test is about 12km on city highway road.

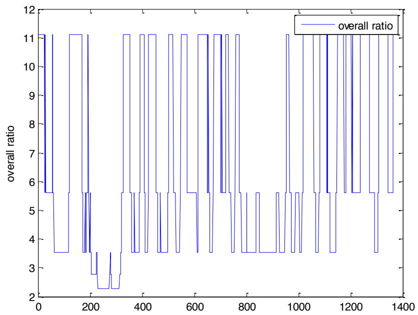

Figure-9. Graph of Overall ratio

Table-2. Result Split PHEV

Fuel Consumption(L/100 km)	**2.85**
Gasoline Equivalent	2.85
Distance (km)	12

b. Hardware Test

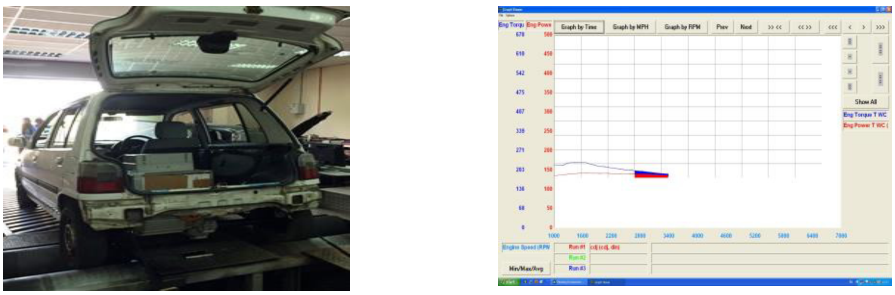

Figure-10. Picture the Car on Dyno and Graph of Performance Test on Dyno

From the graph figure 10 shows that the performance of car on dyno test. The car top speed up to 110kmh and take 10 second from 0kmh to 100kmh. The range for the car was test on dyno about 78km. The car performance higher went test on the road test. Road test top speed up to 120kmh and the range up to 85km. The car has regenerative braking.

4. CONCLUSION

In this paper, a dynamic model for the split PHEV is developed. This model includes detailed representations for the split hybrid system, the vehicle ICE and electric motor. The developed model is simulated in ADVISOR. Using the proposed vehicle controller, the vehicle can be operated in different modes of operation depending on the driving conditions. The transient response of each mode is also studied in this paper. Using this controller and working in different modes of operation, the engine operates in more efficient areas of the efficiency map which implies a higher efficiency in comparison to the conventional drive-trains.

The developed platform can be used for real-time simulation of the drive-train and also for hardware-in-the-loop simulation of the vehicle if implemented on a real-time simulator such as ADVISOR.

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