

# MODELING AND PERFORMANCE ANALYSIS OF PLUG-IN SPLIT HYBRID ELECTRIC VEHICLE

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*Abstract*—Regarding increasing of 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 project 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. Since power electronics is indispensable in hybrid vehicles, the issue of numerical oscillations in dynamic simulations involving power electronics is briefly addressed.

*Keywords*—*Split Hybrid; ADVISOR;*

## 1. INTRODUCTION

Hybrid electric vehicle a development of a system that combination of ICE (internal combustion engine) with a DC/AC motor that stimulate by a battery. At the same time ICE can operate to generate power to charge the on motion electrical storage system which is batteries. The transmission as load depends in the system depends on the connectivity of the power sources, the HEV that have one of the following drivetrain types: series hybrid electric vehicle, parallel hybrid electric vehicle or combination of series-parallel hybrid electric vehicle [1].

In figure 1, shows that a series HEV which means just the electric motor running at one time. While the electric motor running, ICE react as generator to charge the on motion power source for charging the batteries or directly to the motor ('series' connection between the internal combustion engine and the electric motor, stimulating in an electric transmission of the spinning wheels. [1]

Next, a parallel HEV in figure 2 has the internal combustion engine run the drive-shaft, same like a conventional vehicle, but the drive shaft can also be run by the electric motor ('parallel' connection of the internal combustion engine and motor to the drive shaft through the same 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.

## 2. EXPERIMENTAL SET UP

### A. Design of Experiment

First, The overall objective of this paper is to define a performance for a Split PHEV shown in Figure-3 by simulates powertrain 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.

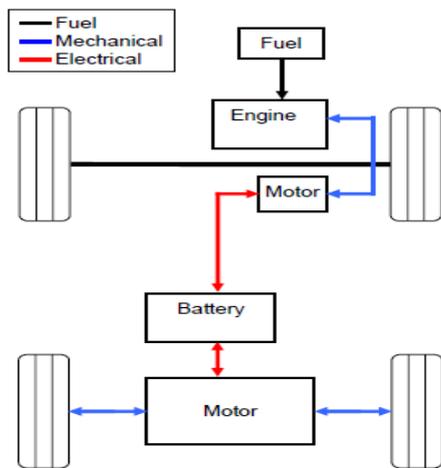


Figure 1 Series-hybrid electric vehicle [2]

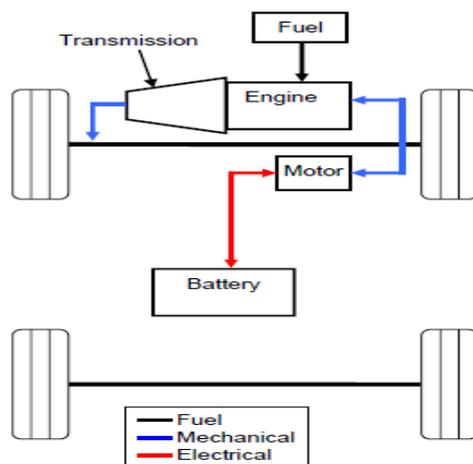


Figure 2. parallel-hybrid electric vehicle [2]

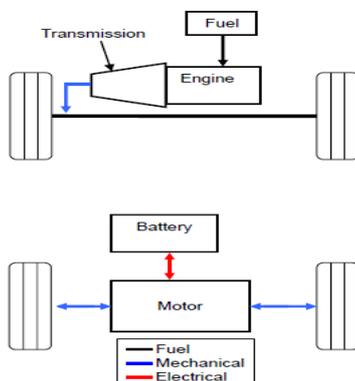


Figure 3. Split plug-in hybrid vehicle [2]

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

*B. Experimental Procedure*

As an application simulated by MATLAB, ADVISOR [3] is a simulator which is used to design/simulate a hybrid system of the vehicle to simulate a hybrid battery/ultracapacitor energy storage system. More extensive applications can be found in, where ADVISOR is used to model hybrid fuel cell/battery powertrain and hybrid fuel cell/ultracapacitor powertrain and simulate their fuel economy and performance. The concept of using a hybrid energy storage system consisting of a battery and an ultra-capacitor (UC) is well known and well documented. In figure 4 shows the interface of ADVISOR.

Table 1. Split hybrid 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



Figure 4. Interface of ADVISOR

In figure 5 shows that the parameter input of the configuration of each model. User also can choose any default or custom model to get the result of simulation or make a comparison with other model.

Firstly the small vehicle (Perodua Kancil) has been diagnosis for checking any problems with the vehicle. The rear axle of the vehicle has been taken off from the vehicle and from that the transmission kit can be plug-in at the same place. The rear seat and spare part type also have been taken off from the vehicle. Mark the some part that will be grinded so that is to setup the transmission kit from the top. The transmission kit installed and some part need to be welded from vehicle body and the kit. After adjusted the position of the transmission kit, the welded part need to paint with black spray so that it can prevent from rusting. The controller needs to be located on top off the transmission kit where the DC motor and gear box located. Before locating the controller, the arms that hold the controller need to be set up. The arm is the metal from the workshop. Measure the length and the position of the hole so that can be screwed to the body. After done with the controller, 96V lithium ion battery which weight 65kg need to locate in the vehicle. The battery located at the position of rear seat. To make the battery keep static and not moving while the vehicle on motion, must put frame that made of aluminum plate from the workshop. Measured and cut the aluminum plate as the size of the battery. After done locate the transmission kit, controller and the battery, medium voltage cable has been used to connect the drive train system. In the figure 6 shows the drive train of the Split Plug-in HEV. After the system has been done, the vehicle test on the dyno test machine.

### 3. RESULTS AND DISCUSSION

#### Simulation

The results of the simulation in the ADVISOR have been released after the button RUN has been click. Engine operating points are plotted on the Graph of fuel converter operation in Figure 7. 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.

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. Figure 10 shows the graph of state of charge (SOC) of the drive-train in this mode of operation.

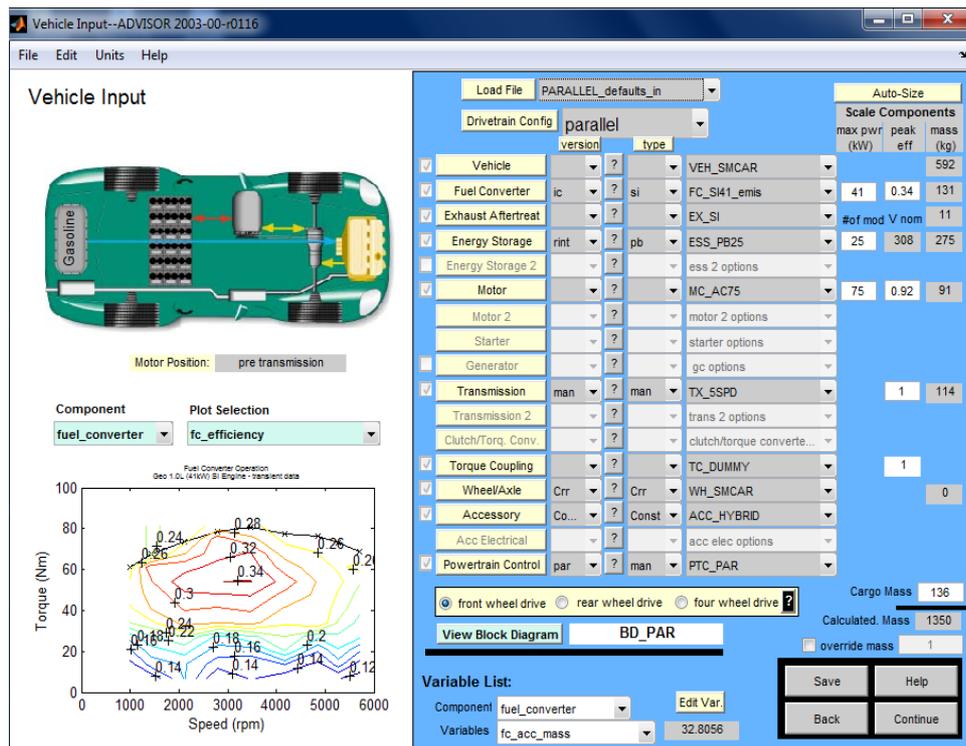


Figure 5. Parameter setting in ADVISOR



Figure 6. The development of the drive train.

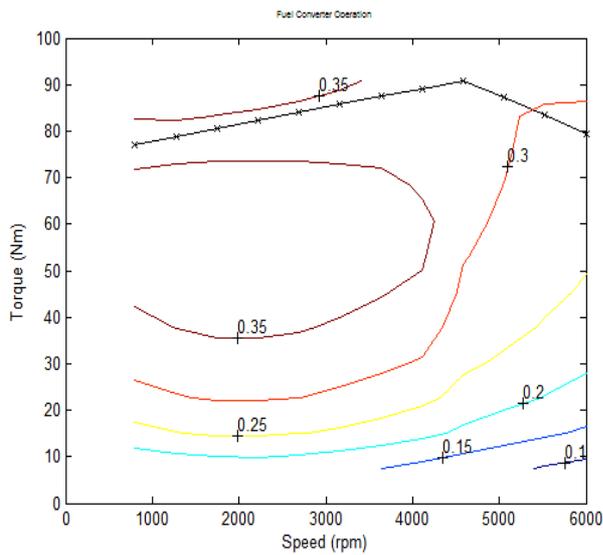


Figure 7. Graph of fuel converter operation.

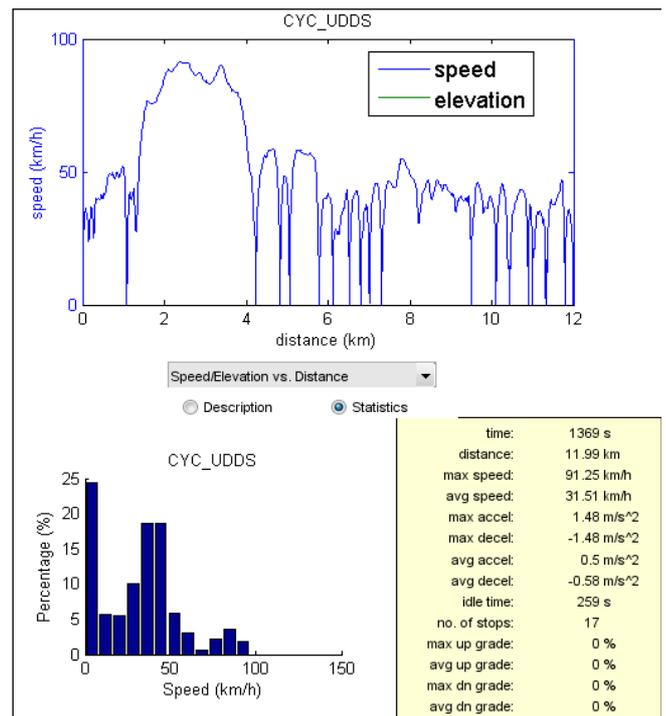


Figure 8. The graph of CYC UDDS (Drive Cycle) and performance of split plug-in HEV in ADVISOR

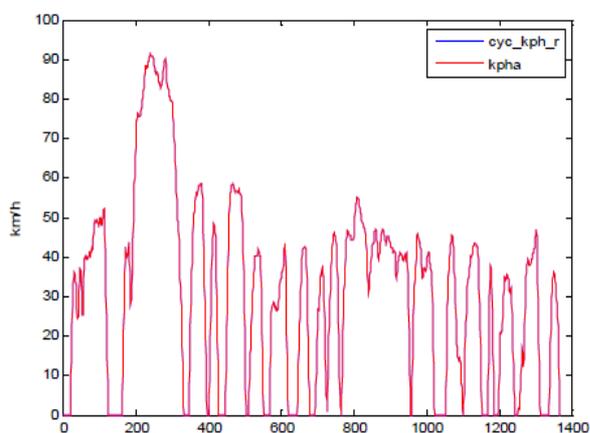


Figure 9. Graph of drive cycle vs speed

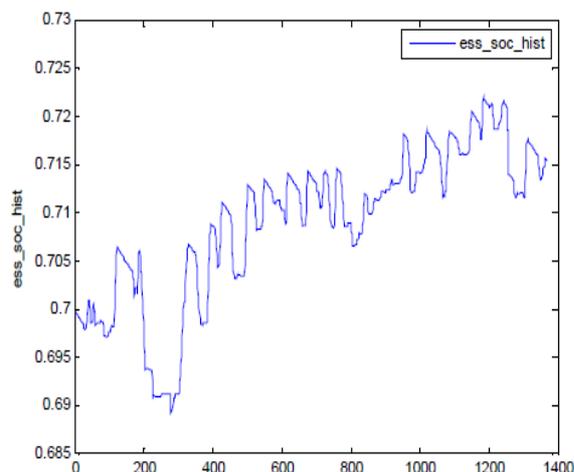


Figure 10. Graph of state of charge (SOC) history

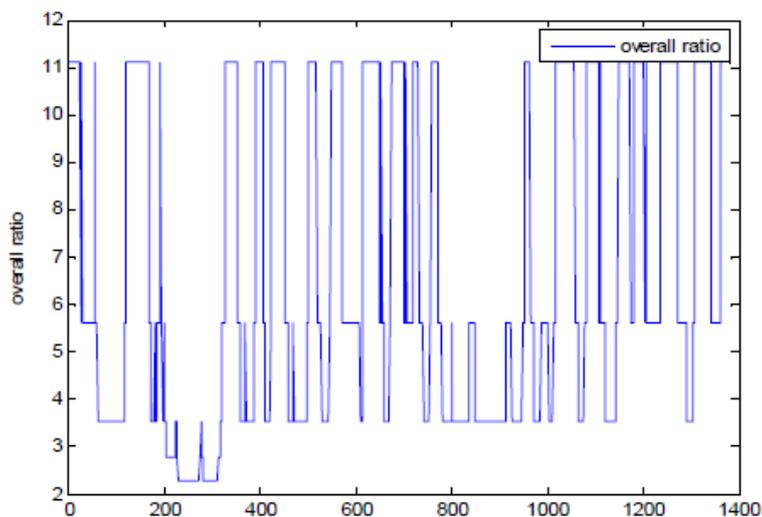


Figure 11 . Graph of overall ratio

The Graphs in Figure-8 till Figure-11 shown the performance of propose split PHEV in ADVISOR. The patent of driving showed in Figure-10 how drive cycle graph perform in speed versus distance. Table 3 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.

Split Plug-in hybrid electric vehicle under a several test after the hardware part have been developed. The result of simulation and the hardware were compared to make sure the result came out almost same. Even there are slight different in result, but the objective of the project has been achieve. There are some parts that will be modifying to get the better result. Firstly the configuration of the hardware supposedly to be compared to the same item but the different type. So that, the different in performance of the system such as the battery, it can be many type of battery that can test on the vehicle, and can be analyse of the different of performance or the vehicle. In figure 7, the graph of the torque versus speed, the value of torque not that much high in fuel consumption as the transmission kit at the rear wheel. So the load for the ICE not that much. It can reduce the fuel consumption while accelerate the vehicle as shown in graph figure 8. After that the value of fuel consumption is 2.85 L for 100km. This value supposedly needs to recalculate for the accurate value. The system of the split plug-in hybrid electric vehicle can be 3 type, ICE run with electric DC motor, ICE single running for front wheel transmission and electric DC motor single gear box running for rear wheel transmission.

Table 2. Result of fuel consumption

Fuel Consumption (L/100 km)	2.85
Gasoline equivalent	0.238
Distance (km)	12

The result supposedly to be in 3 types, ICE and Split plug-in HEV, normal ICE and single DC motor running. But the scope of this project hybrid system, it must be combination of ICE and Split Plug-in HEV. The result came out just combination of the both system. When the vehicle tests on the road, there are some collision between DC motor and the vehicle body. So that, by adding some nuts to the screw that contact between vehicle body and DC motor. It adjusted for some space between vehicle body and the DC motor. The problem of collision can be solving. For future it can be more systematic and more efficient in development of the drive train in the vehicle. The problem figures out has been recorded it will be awareness for the next project.

#### 4. CONCLUSIONS

Hybrid vehicle has 3 type which is series, parallel and split plug-in. The main purpose of this technology is to reduce the consumption of the fuel. Next the increasing of the global warming can be overcome by this technology which called as Green Technology. By using electrical machine can help to overcome the global problems which the sources that easily can be find.

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