TME095 Assignment

Electric and Hybrid Vehicless

Group 30

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1 Introduction

The ultimate goal of most of the automotive industries is to improve the existing technologies and creating a greener environment thereby improving the efficiency. Electric motors can be used along with engines which can play a major role in improving fuel consumption. Selection of a balanced configuration of IC Engine and electric motor is required in order to achieve sufficient reduction in fuel consumption levels. This assignment work deals with finding the optimum series and parallel driveline configurations for passenger vehicles. The aim of this assignment is to develop our own passenger vehicle model and investigate how much fuel consumption can be improved by hybridizing the vehicle. The investigation is to been performed using the QSS toolbox in design teams.

The task is to study the fuel consumption of a vehicle chosen within a particular European road vehicle segment.

2 Vehicle Specification

In this task the European Vehicle Segment assigned is **City Cars**. Analysis of vehicle specifications were done to meet the limits of city cars and then the **FIAT Punto 1.2** naturally aspirated petrol engine was finalised for this assignment, which is a city car.

The specifications are as given :

Spec's	**Value**
Mass	921 kg
Engine Type	Naturally aspirated Gasoline
Maximum Power	60 kW
Frontal Area	2.4568 mˆ2
Drag coefficient	0.31
Rolling resistance coefficient	0.012
Wheel diameter	0.5842 m
Number of gears	5
Gear Ratio(1st to 5th gear)	[3.909 2.158 2.158 1.121 0.921]
Differential gear	4.071

With the above specifications,a QSS model was built for a conventional, series and parallel driveline model. The maximum power required was calculated using the formula,

$$P_{max} = F_{trac} * V_{max} \tag{1}$$

where the traction force is found using the below given equation.

$$F_{trac} = F_{Aero} + F_{Roll} + (m_{veh} * a_{veh}) \tag{2}$$

The maximum power required was found to be 60kW.

3 Driving Cycle

A custom driving cycle is created for the QSS model which is loaded with the cycle data with values of velocities created to suit city driving conditions which contains a lot of acceleration and braking zones. It was then retrieved from the specified data file and made available to input the vehicle model. For the city car segment a mixture of various acceleration and deceleration pattern has been built with discrete time.

The driving cycle is to been generated in as a .mat file, which is been loaded in a particular directory in order to get the cycle to get the cycle in working in QSS library.

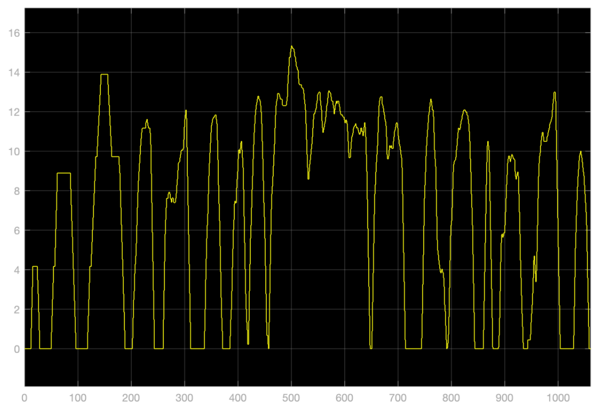

Figure 1

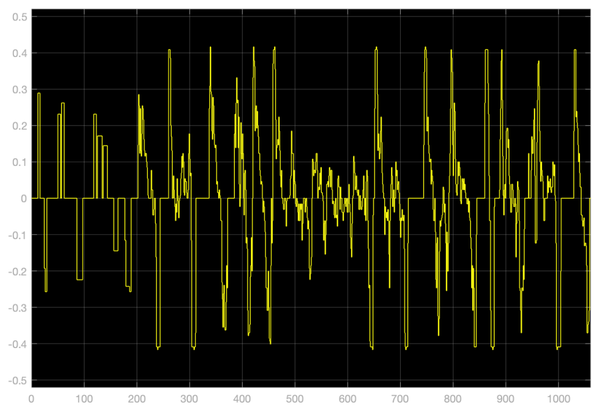

Figure 2

The Figure 1 is the output delivered from the custom cycle which is the the vehicle speed in Km/h from the scope and Figure 3 is the acceleration in m/s^2. It can be clearly depicted that the generated custom cycle consists of unequal intervals of acceleration and braking meaning the vehicle works in the city region.

This custom driving cycle is been is used for conventional and hybrid models in order to attain uniformity throughout the assignment while optimizing for the fuel efficiency, comparison and calculating the traction force to propel the vehicle.

4 Conventional vehicle

In this model the vehicle is propelled purely by one source of energy, the IC engine. The Fuel consumption [liter/100 km] is measured for the IC engine.

4.1 Model

The model uses the custom city driving cycle, with the given specification such as mass, gear ratios, power demand and wheel diameter, a simple QSS block model architecture has been developed to record the Fuel consumption in liter/100 km. It is found out to be the Fuel consumption of the chosen conventional Fiat Punto 1.2 is 7.476 liter/100 km.

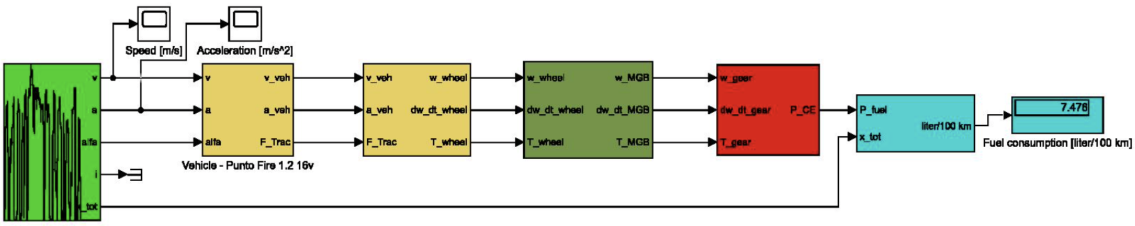

Figure 3: conventional architecture

5 Series HEV

In a series hybrid electric vehicle, the vehicle is propelled by electric motor and the alternative power source which is an IC engine which acts as a generator charging the battery continuously. As the model is converted from conventional to a hybrid vehicle, there will be an addition of the mass of the vehicle due to the larger battery and Electric motor. The added mass was calculated by,

$$Mass_{EM} = 0.83 \cdot P_{EM} + 21.6 \tag{3}$$

$$Mass_{Batt} = \frac{B_{capacity}}{B_{sp.energy}} \tag{4}$$

The values of battery capacity for a given voltage and battery specific energy used are referred values for Lithium ion batteries. The masses of both the electric motor and battery combined was found to be 73.47 kg (46.5 and 26.97 respectively).

5.1 Model

The custom driving cycle is common across the model but a series parallel battery configuration is added to the model thus providing power the electric motor. The IC engine runs as a generator and charges the battery and at times acts as a range extender. The regenerative power also charges the battery.

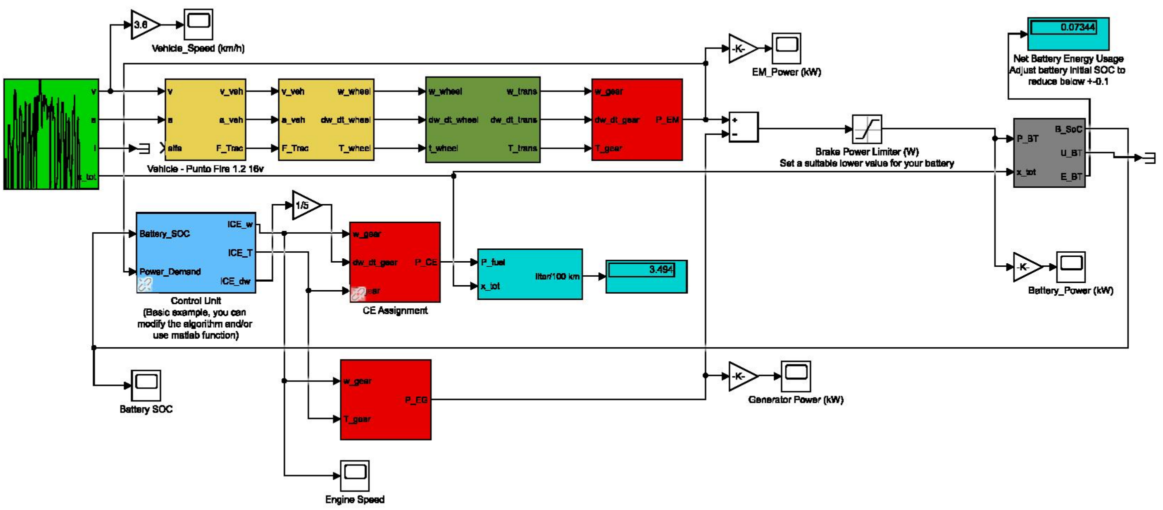

Figure 4: Series Architecture

5.2 Controller

The control logic for the series model is formulated in such a way that the state of charge should be maintained constant throughout or else the battery would drain out and the motors will not have enough power to propel the vehicle. The values of SOC, Power demand and regenerative braking limits were modified to improve the fuel consumption.The bsfc and torque values were also acquired from the engine performance plot and given as input in the controller.

6 Parallel HEV

6.1 Model

The P2 type architecture is made use of during modelling. The variables that are needed to be controlled are engine speed, torque and as well as power flow from and to the battery.

The SOC also must be monitored continuously so that the battery is not overcharged while regeneration. The power of the conventional Fiat Punto 1.2 was 60kW which is split as 35kW for the IC Engine and 25kW for the Electric Motor. The battery comprises of 70 series cells and 5 parallel cells. The masses of both the electric motor and battery combined was found to be 69.32 kg (42.35 and 26.97 respectively)

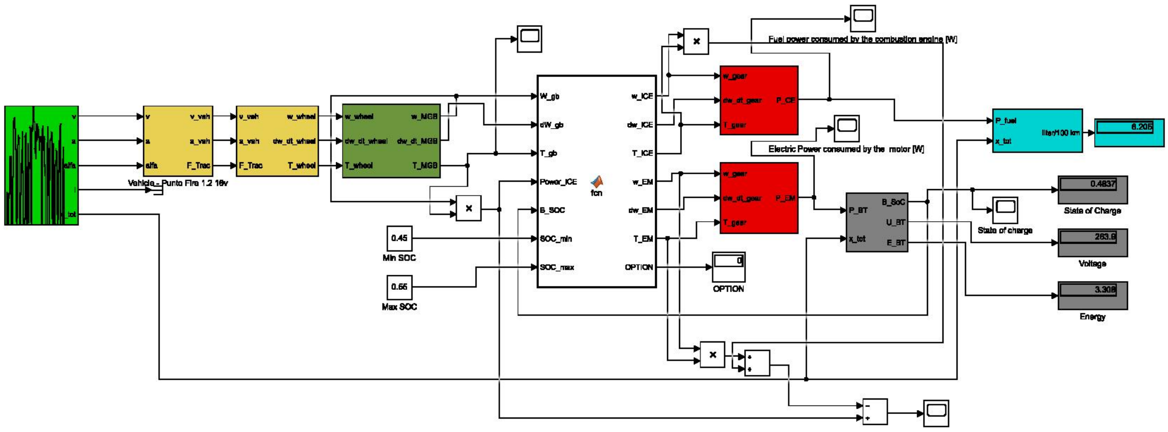

Figure 5: Parallel Architecture

6.2 Controller

Power is divided between the IC Engine and Electric Motor based on the levels of state of charge in the batteries and the torque and power demand obtained from the created custom driving cycle. The SOC limits are also provided to the model. Based on the required torque, the driving can be segregated into six modes.

- High speed driving
- E-Mode
- ICE-Mode
- Charging
- Electric assist
- Regenerative braking

6.2.1 High speed driving - High SOC and High power demand

The power of the internal combustion engine (ICE) and Electric Motor are selected such that the desired top speed can be attained. Due to the high power demand the electric machine (EM) can be used to power the wheels alongside the internal combustion engine (ICE).

6.2.2 E-Mode - High SOC and Low power demand

During launch and low speed driving like in city, the electric motor which is powered by the battery propels the vehicle. This strategy is implemented just because the electric motor can produce very high levels of torque at low speed and though the torque decreases as the speed increases as the fiat Punto 1.2 fire is a city car. The efficiency of the internal combustion engine is very low at low speed driving. Hence, when the SOC is high, for better pick up and improved fuel consumption during low speed driving, the battery is used to propel the vehicle.

6.2.3 ICE-Mode - Low SOC and High power demand

When the battery SOC is low, the power from the engine is used for both propulsion and charging the battery.

6.2.4 Charging

Whenever the SOC of the battery is below the lower limit and the required torque is less than the optimum torque, the engine provides the optimum torque and the electric motor provides a negative torque in order to charge the battery.

6.2.5 Electric assist

If the SOC of the battery is not below the lower limit and the required torque is more than the optimum torque, the Electric Motor assistance is required which provides a positive torque and assists the IC Engine.

6.2.6 Regenerative braking

When the brakes are applied to decelerate, the kinetic energy is used to charge the batteries. The internal combustion engine can also used to charge the batteries when the SOC goes below the lower limit which is pre-defined in the controller. But for simplification purposes, the engine is assumed to be cut off.

7 Optimization Results and Discussion

7.1 Configuration comparison

A vehicle model with a conventional powertrain was created in order to compare the difference in fuel consumption with the vehicle's specifications. The vehicle is capable of achieving a top speed of 172 km/h with an acceleration of 2.436 m/s2 and 921 kg total vehicle mass levels respectively. The simulation results of the vehicle model with this conventional powertrain can be observed in Table.

$\mathbf{P}_{ICE}$ **[KW]**	$\mathbf{P}_{EM}$ **[KW]**	**n_parallel**	**n_series**	**Fuel consumption [liter/100 km]**
60	-	-	-	7.476

The conventional powertrain was then converted to a hybrid powertrain with the addition of an Electric Machine, a battery pack and controller for power management. The addition of mass due to hybridization was taken into account using the mass estimation equations described in section 5. When the series HEV model is ran, the Fuel consumption [l/100 km] of the vehicle has been reduced drastically by 53.3% since the IC Engine plays active role in charging the battery only. The results are provided in the table below.

$\mathbf{P}_{ICE}$ **[KW]**	$\mathbf{P}_{EM}$ **[KW]**	**n_parallel**	**n_series**	**Fuel consumption [liter/100 km]**
60	46	2	84	3.494

Also in the parallel configuration model, since the model was ran in high power demand and in high State Of Charge, both the IC Engine and Electric Motor were involved in torque generation. The fuel consumption improved by 17.18%. The fuel consumption is higher than series configuration since both ICE and EM are running.

$\mathbf{P}_{ICE}$ **[KW]**	$\mathbf{P}_{EM}$ **[KW]**	**n_parallel**	**n_series**	**Fuel consumption [liter/100 km]**
35	25	5	70	6.191

8 References

[1] Lino Guzzella and Antonio Sciarretta, *Vehicle Propulsion Systems*, Introduction to Modeling and Optimization.