EVS25
Shenzhen, China, Nov 5-9, 2010

Development for Hybrid MPV Control Strategy

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Abstract

Hybrid MPV control strategy is researched by building simulation model under Matlab/Simulink/Stateflow environment, and auto-generated code is downloaded to vehicle control unit. With this approach, proved by experiment, the development of hybrid MPV control strategy is of high efficiency and reliability, with the performance met the design requirements, and the portability and maintainability of system improved.

Keywords: Hybrid Electric Vehicle (HEV), Control strategy, Simulation Model ,Automatic Generation of Code

1 Introduction

In the 21st century, as the energy resources shortage and environment protection have become the major challenge for the world, it is imperative to alter the energy and power system for vehicle industry, the electric vehicle has become the essential choice for such alteration.
The project of development of LZ6460Q8HEV (Hybrid MPV) comes from the project of national 11th five-year-plan and national 863 plan. Using a conventional two wheel drive MPV, adding electric motors and battery, a four wheel drive function hybrid MPV is developed, it shows good off-road capacity, power performance, fuel economy and good emission performance.
According to conventional power train configuration and 3-D model, using a BSG replacing the conventional starter and generator, using an electric motor assisting to drive the vehicle and regenerate the brake power in the rear wheels, a four wheel drive function hybrid MPV layout is realized, as shown in Figure1.

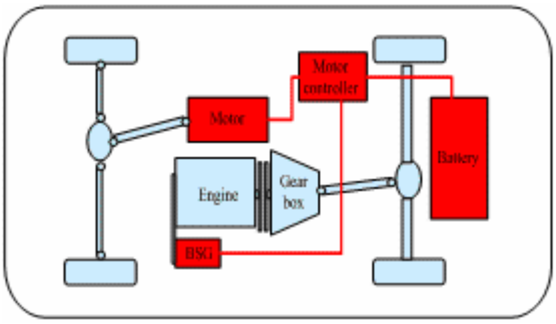

Figure 1: The general arrangement of Hybrid MPV

2 Control strategy and modeling simulation

2.1 Modeling

The simulation model of Hybrid MPV is established via matlab /simulilnk /stateflow.
First, we can calculate the power performance and

the economy performance of the conventional vehicle, then we can adjust and validate the model through the comparison between the simulation results and real experimental results.

Afterward, we can use a validated vehicle model to simulate Hybrid MPV, such as matching motors and battery, researching the energy distribution strategy & regeneration strategy of braking energy, optimizing the work area of engine, motor, and battery, etc. Finally, an optimal control strategy is designed.

Simulation model includes driver's intention submodule, energy distribution strategy submodule, vehicle dynamics submodule, result submodule and so on. Figure 2 shows the model.

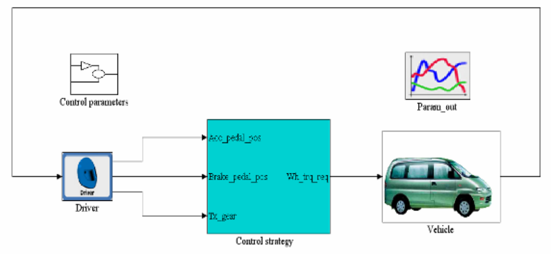

Figure 2: Simulation model of Hybrid MPV

2.2 The operation mode of Hybrid MPV

According to a typical driving cycle of Hybrid MPV, there are several working modes, as shown in Figure3.

1) Starting: Only the pure engine is used for start-up and low speeds.

2) Normal Driving: While cruising, the engine and motor both drive the wheels,power allocation is controlled to maximize efficiency of engine. As necessary, the motor also recharges the battery from surplus engine power.

3) Acceleration: While accelerating or climbing, the engine and motor both drive the wheels.

4) Deceleration: While decelerating or braking, the "regenerative braking system" recovers kinetic energy as electrical energy, which is stored in the high-performance battery.

5) Stopping: At stops, the engine shuts off automatically and the BSG stands ready to power up the vehicle.

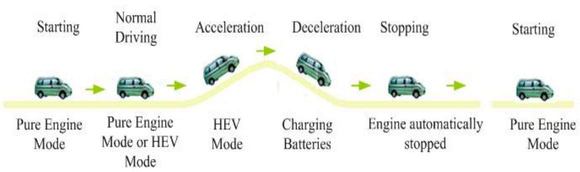

Figure 3: The operation mode of Hybrid MPV

2.3 Control strategy

In the design of the control strategy, different structure hybrid vehicles need different control strategies with reasonable control and adjustment of energy flow distribution.

Therefore, according to different optimization targets, we should select different control strategies of energy management system to achieve optimal design goal under limited conditions.

How to optimize the control strategy is the key technique to reduce fuel consumption and emission after selecting all parts of HEV. On the premise that the requirements of vehicles basic performances(such as power & economy performance) and cost should be met, considering the special features of each part and different operation modes, the energy should be reasonably distributed between engine and motor under control strategy, which makes the whole vehicle system efficient higher, fuel consumption lower and emission lower, and at the same time keep the driveability good.

We adopts the instantaneous optimal control strategy based on the optimal working curve of engine in the project. For the Hybrid MPV under a particular operating point, we optimize the entire power system for optimization goal to get the best instantaneous operating point, then redistribute various state variables dynamically based on instantaneous optimal system operating point. According to the economy and emission characteristics of the engine, an appropriate objective function is established through the optimal control theory. To minimize the objective function,we can achieve good power performance, fuel economy and emission performance.

$$\min(f) = \min\{\omega_1(\frac{a}{a_0}) + \omega_2(\frac{b}{b_0}) + \omega_3(\frac{c}{c_0})\} \quad (1)$$

In Equation (1), f is the objective function; a is the fuel consumption (L/100km); b is actual emission (g/100km); c is acceleration time (s); a_0 , b_0 and c_0 respectively are the aim values; ω_1 , ω_2 and ω_3 are the corresponding weight coefficients. Weight coefficient can be adjusted to change the degree of influence of each parameter.

When designing control strategy, we consider the engine's, motor's and battery's instantaneous efficiency. Combining with the actual running state, Such as the engine's, motor's, battery's temperature and the braking energy recovery, etc, the best combination of energy between engine and motor is obtained. According to the control target, then the optimal engine and motor operating points are determined. Our goal is to make the optimal efficiency of the system.

2.4 Simulation

Using the established simulation model is to get the results of power & economy performance, so we can compare different control strategies and different control parameters and get a better choice of strategy and key parameters.

The following, we choose a better control strategy and simulate the model, then analyze the results. Figure 4 shows the acceleration time from 0 to 100km/h, Hybrid MPV's acceleration time is significantly less than the conventional vehicle's, the power performance of Hybrid MPV is better than the conventional vehicle's.

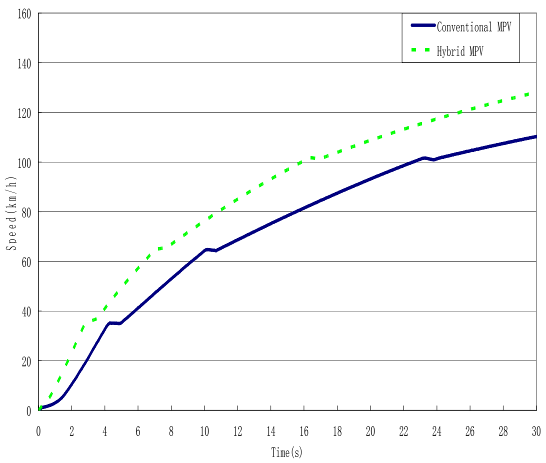

Figure 4. Acceleration time

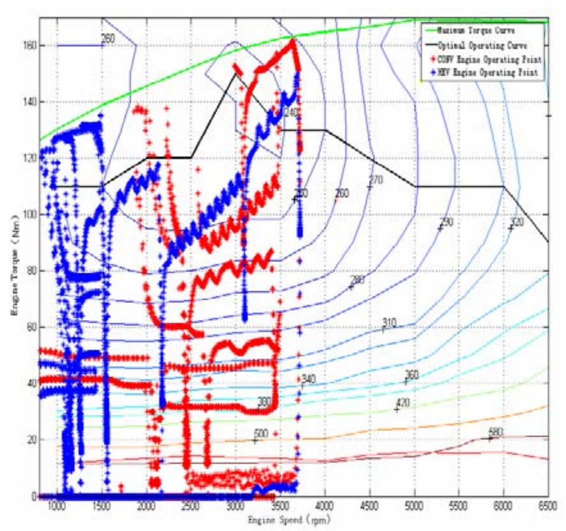

Figure 5. Engine operating points

Figure 5 shows the engine operating points in the engine efficiency map during the vehicle running in one NEDC driving cycle. The optimal engine operating curve is the minimum engine fuel consumption curve which connects the minimum engine fuel consumption speed-torque operating points at different engine speeds. The engine has better operation at the more efficient region in the engine efficiency map. Due to the adjustment of the engine's operating point, Hybrid MPV's engine is more efficient than the conventional vehicle's, as shown in the figure.

The motor operates at the efficient region in the motor efficiency map in the NEDC driving cycle, as shown in Figure 6.

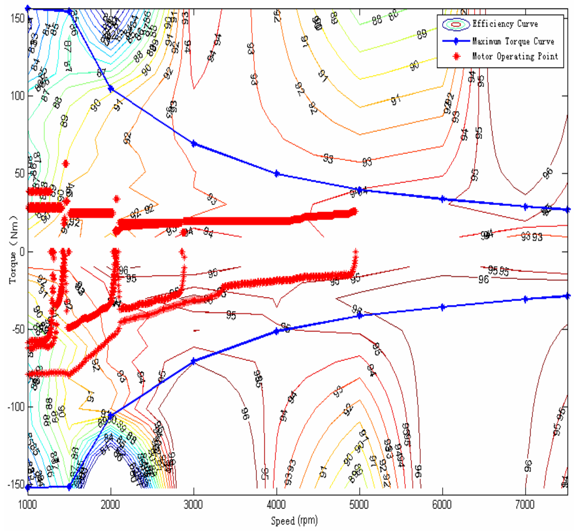

Figure 6. Motor operating points

The high efficiency region of battery for the Hybrid MPV is between 50% and 60%, the battery works in this region in the NEDC driving cycle, and SOC balances at 55%, as shown in Figure 7.

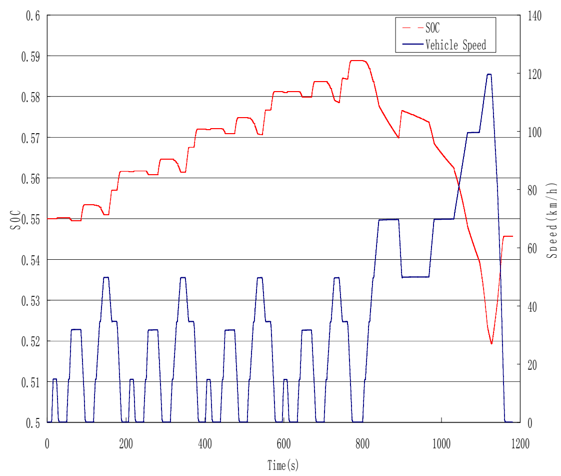

Figure 7. The curve of SOC

3 Code implementation

Hand-written code and automatic generation of code are adopted, and hand-written C language is used in controller driver program which includes input and output signal processing, sensor signal processing, port initialization such as I/O, A/D, PWM, CAN and flash operation. The control strategy simulation model is generated C code under the Real-Time Workshop Embedded Coder environment of MATLAB, then the generated code is integrated into the driver program, compiling the whole code, and downloaded to the HCU. The model of automatic code generation is shown in Figure 8.

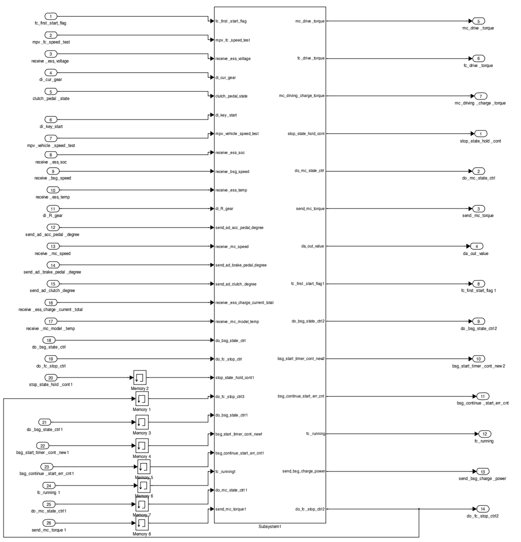

Figure 8. The model of automatic code generation

4 Vehicles experiment

We modify and improve the control strategy through the road test, after the road test, the performance experiment is conducted in National Quality Control & Inspection Center for Automobiles (Xiangfan). The overall parameter of Hybrid MPV is explained in Table 1 , the simulation and experiment result is shown in Table 2 respectively.

There is little disparity between the simulation result and test, which demonstrates that the strategy in simulation model has already taken effect and verifies the correctness and validity of the simulation model in turn. The Hybrid MPV experiment results demonstrate 23% fuel economy improvement contrasting conventional vehicle, and the power performance and economy performance have reached the 863 contract requirements.

Table 1: Hybrid MPV characteristics

Parameter		Value
Gross Mass（kg）	Power performance	2370
	Economy performance	2150
Engine power（kW）		87kW/5500rpm
Motor power（kW）		22kW/1400rpm
Battery		8Ah
Gear ratios	Gear 1	3.968
	Gear 2	2.137
	Gear 3	1.36
	Gear 4	1
	Gear 5	0.857
	Gear R	3.579
Final drive	Front axle	4.875
	Rear axle	4.2727
Wheel radius (m)		0.313
Coefficient of Rolling Resistance (a*v^2+b*v+c)	a	0.098
	b	-2.1198
	c	276.3231

Table 2: The simulation and experiment result

Test Project		Test Method	Traditional Vehicle	Hybrid
Power Performance	Max speed（km/h）	simulation	130	142
		experiment	>120	>120
	0-100km/h acceleration time（s）	simulation	22.6	15.8
		experiment	23.7	16.8
	Grade ability (%)	simulation	41	44
		experiment	>30	40
Fuel Consumption（L/100km)		simulation	12.5	9.8
		experiment	12.9	9.9

5 Conclusion

Hybird MPV control strategy is researched by building simulation model under Matlab/Simulink/Stateflow environment, and automatic code generation of simulation model is successfully applied into the research and development of the Hybird MPV. With this approach, proved by experiment, the development of hybrid MPV control strategy is of high efficiency and reliability, with the performance met the design requirements and the portability and maintainability of system improved, meanwhile the development cost is greatly reduced, and the development cycle is shortened.

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