NEW CONTROL STRATEGY FOR EVT HEV

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Abstract

This paper introduced a new control strategy for Hybrid Electric Vehicle (HEV) which is equipped with Electrical Variable Transmission (EVT). EVT integrates two Permanent Magnet Synchronous Motors (PMSM) and just has one electrical port. This equipment can replace the traditional continuously variable transmission, generator and starter motor and make the hybrid vehicle work in parallel mode and serial mode. This paper focused on the strategy to control the Internal Combustion Engine (ICE) and keep the power in the battery which is present as State of Charge (SOC) and control the EVT to improve the efficiency and reduce the emissions of the vehicle. The proposed rules make the ICE work in a high efficiency region and maintain the power in the battery during the given drive cycle and in real random road condition. The simulation and the experiment validate the rules and the strategy.

Keywords: EVT, HEV, SOC, Control Strategy

1 INTRODUCTION

The EVT joint the engine and the battery and the wheel, and make up the hybrid vehicle which settles the engine in an optimal constant work condition as the required power changed. The engine in the hybrid system could reduce the fuel consumption and the emission.

The Fig.1 shows the structure of the EVT vehicle system.

The inner rotor connects to the engine and the outer rotor connects to the wheel. The armature is set in the stator and the inner rotor while the magnet is fixed on both sides of the outer rotor.

T_1 is the torque produced by inner armature, T_2 is the torque produced by stator, the torque on the outer rotor is $T = T_1 + T_2$, the engine speed is w_1, the outer rotor speed is w_2.

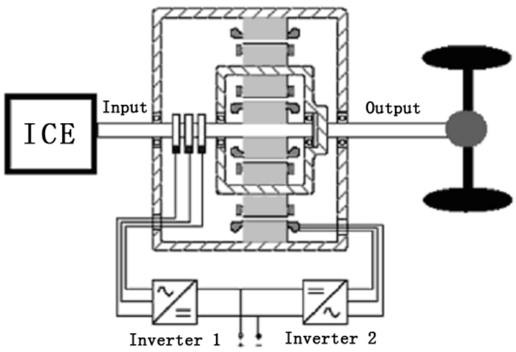

Fig.1 EVT hybrid system

2 EXTENDED OOL AND POWER FLOW

The extended optimal operation line (OOL) is shown in Fig.2.

If the optimal goal of the vehicle efficiency focuses on the engine efficiency, the best range of the engine is shown in Fig.2 CD.

The engine speed and throttle position information as order can be searched by a one dimension table.

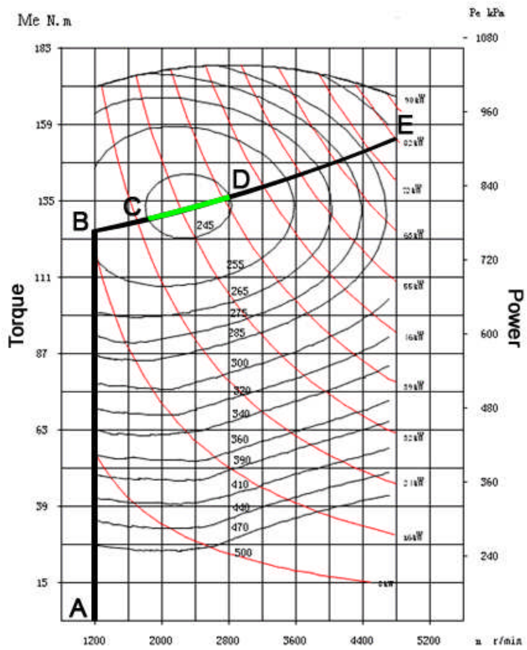

Fig.2 optimal operation line

Sometimes the vehicle should meet the driver's requirement or battery charge limit to extend the range of the working point. The extended OOL is shown in Fig.2 as ABCDE.

EVT is just an equipment to split or combine the power, the engine produce the power, the wheel consume the power and the battery save the redundant power and provide assistant power.

If the wastage is ignored in an ideal state, the total power flow on the dashed should be zero, either the energy, as shown in Fig.3.

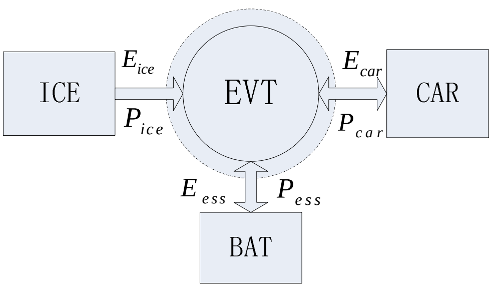

Fig.4 EVT power flow

$$\begin{cases} P_{ice} + P_{ess} = P_{car} \\ E_{ice} + E_{ess} = E_{car} \end{cases} \quad (1)$$

$P_{ice} \geq 0$， $E_{ice} \geq 0$。

The purpose of the control strategy is to regulate the power flow of the EVT to improve the efficiency and meet the power requirement of the vehicle.

The required power of the vehicle is calculated by

$$P_{car} = F_{acc} \cdot V_{car} \quad (2)$$

F_{acc} is decided by the accelerograph, V_{car} means the current speed.

The most important strategy is to decide the charge or discharge power of the battery. The battery power is related to SOC and the limit of the charge or discharge power, and the requirement of the vehicle.

$$P_{ess} = f(SOC, P_{car}) \quad (3)$$

Then the power of the engine can be calculated by formula (1).

3 CONTROL STRATEGY

The simulation cycle is shown in Fig.5, which include the given speed and the actual speed.

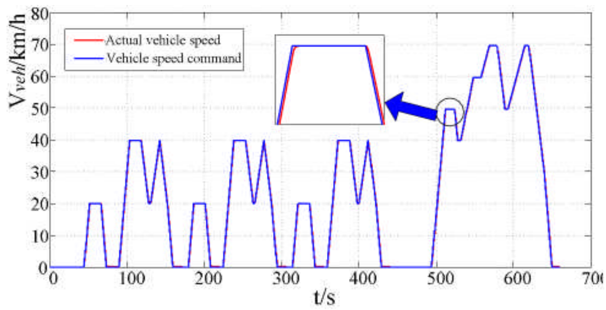

Fig.5 cycle speed

The strategy for the given circle is certain and can be arranged as keep the SOC of the battery constant from the beginning to the end, as shown in Fig.6.

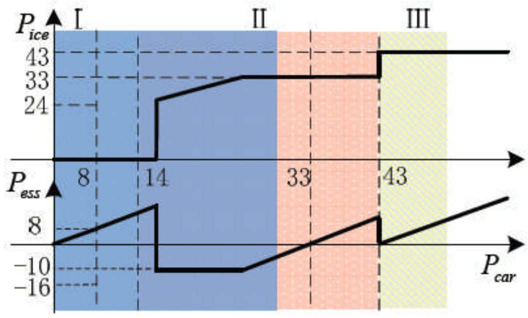

Fig.6 strategy for certain circle

The formula (3) can be simplified as

$$P_{ess} = f(P_{car}) \quad (4)$$

The power percent can be deduced as

$$h = f\left(P_{car}\right) \qquad (5)$$

The formula 4 must meet the equation

$$\int_0^{nT} hP_{ess} = 0 \qquad (6)$$

In fact, the indeed road condition is just random map, and the power distributing is stochastic.

The control strategy for certain circle could not keep the SOC of the battery during the road driving. The SOC of battery must be calculated as a parameter shown in formula 3.

The principle of the control strategy is concluded as follow.

The charge power must decrease while the SOC increase, and there must be a state for zero power for battery during the same required vehicle power.

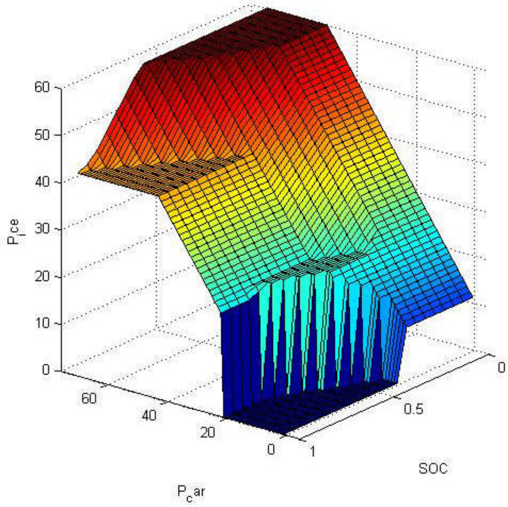

Fig.7 output power of engine

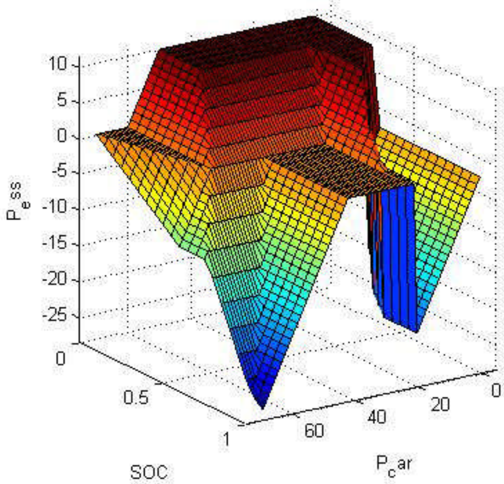

Fig.8 battery power

Fig.7 shows that the engine works in efficient region when battery SOC is in the normal range.

The control strategy shown in Fig.8 meets the principle proposed.

4 SIMULATION

The given simulation speed circle shown in Fig.9. the simulation result shows that the control strategy could regulate the battery SOC to a scheduled ideal state whatever the original SOC is too high or too low.

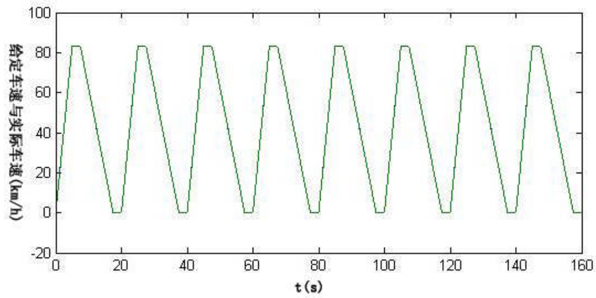

Fig.9 vehicle speed circle

Fig.10 shows the SOC result with the beginning battery SOC=0.75. The final SOC come to a close at 0.76.

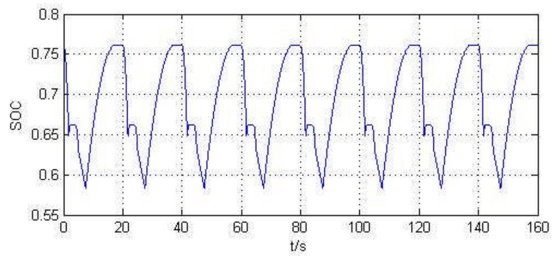

Fig.10 SOC change map

Fig.11 shows the SOC result with the beginning battery SOC=0.9. The final SOC come to a close at 0.78.

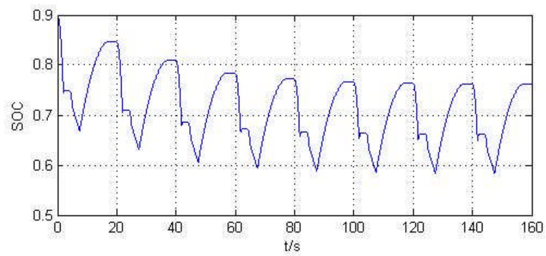

Fig.11 SOC change map

Fig.12 shows the SOC result with the beginning battery SOC=0.3. The final SOC come to a close at 0.75.

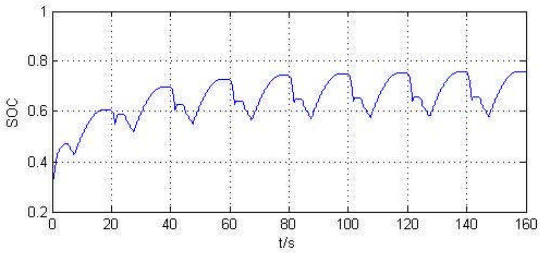

Fig.12 SOC change map

5 EXPERIMENT

First, drive the vehicle in the city 20 minutes and 28.5 km with the beginning battery SOC 0.5, the final SOC come to 0.58 and the consume gas is 2.9 L.
Second, drive the vehicle in the city 30 minutes and 34.3 km with the beginning battery SOC 0.3, the final SOC come to 0.54 and the consume gas is 4.2 L.
Second, drive the vehicle in the city 30 minutes and 31.2 km with the beginning battery SOC 0. 7, the final SOC come to 0.65 and the consume gas is 3.3L.
The experiment result shows that the battery SOC always runs to the ideal state.
The contrastive vehicle consume parameter is 14.3L/100km.

6 CONCLUSION

The proposed principle could keep the battery SOC in a safe range for aperiodic charge or discharge in any road condition with high efficiency; the simulation and the result validate the principle.

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