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# Optimization of energy management strategy for PHEV powertrain system based on fuzzy control

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This paper mainly analyzes each component characteristics of the power system and optimizes the energy management strategy of the power system to improve the economics of the parallel PHEV. The energy management model mainly includes four modules: control of engine start and stop, energy distribution control during hybrid driving, charging control with the low battery, and energy recovery control during deceleration and braking. According to the model, this article establishes the vehicle dynamic model with control strategies of pure electric and hybrid mode through GT-SUITE for the following simulation and optimization.

When the vehicle run in hybrid mode, the output power of the engine and battery match according to the different work conditions. The simulation and experiment results based on the NEDC driving cycle. The verification conditions include low-power conditions and high power conditions. The results of low and high battery power during NEDC cycle in hybrid mode explain that the simulation model of control strategy is consistent with the working process of physical prototype at different conditions. The above test and simulation results in pure electric mode and hybrid mode match the energy output of the engine and motor, which ensure the power performance and improve the energy consumption economy.

Through the economic analysis, the energy management strategy of power system still has the following problems.The start of the engine is realized by the logical control of the factors such as vehicle speed, torque and SOC of the battery. The start-stop strategy is triggered when a certain factor reaches the threshold, which is not comprehensively considered under different working conditions. Therefore, with the engine turned on, the operating point may not work in low fuel consumption. Meanwhile, the power output of the motor and the engine is distributed according to SOC. When the battery power is high, the power output of the engine may be low, so the engine may not work in a high-efficiency area to result in large engine fuel consumption. The comprehensive power and fuel consumption simulation, the economic simulation results in the pure electric mode and hybrid mode are consistent with the testing, indicating that the simulation results can reflect the vehicle performance.

Based on the above problems, the fuzzy control algorithm is robust and suitable for the control of multi-parameter, nonlinear and time-varying systems, which can improve the fuel economy of the vehicle. Therefore, with the fuzzy control algorithm, the start-stop strategy of the engine and energy management strategy of the power system in hybrid mode are optimized.

In the hybrid power mode, in order to reasonably distribute the output power of the engine and the battery, the engine always works in the high-efficiency area through the assistance of the battery. The optimal fuel consumption power to the required power ratio K_Power is selected as the optimized parameter. At the same time, it is also necessary to control SOC level to avoid over-discharge of the battery. With the high battery, the motor drive can ensure that the engine works near the optimal fuel consumption curve, so SOC of the battery is as the optimized parameter. As shown as Fig.10, two kinds of fuzzy algorithm schemes are designed according to the battery charging strategy. During the battery charging process, there is the constant power to charge the battery in the first scheme, while the variable power in the second.

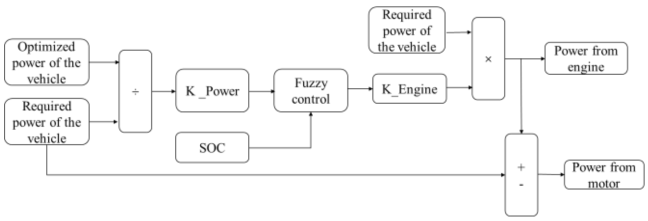


Fig.10 Energy allocation strategy scheme of fuzzy algorithm

With the energy management strategy of the power system based on fuzzy control under the circumstance, the power consumption has little change, but the fuel consumption and total energy consumption reduces in national standard test condition, full SOC range condition or different driving mileage, indicating that the optimization strategy for energy management of the parallel PHEV has great application value. In particular, the third scheme which controlling engine and battery energy distribution & engine start-stop can reduce fuel consumption by 33.33%, 22.58% and 18.92%, respectively under the premise of increasing power consumption by 16.68%, 5.13% and 1.38% in 3, 6 and 9 NEDC cycles.