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Fuzzy Logic Controller Based on Electric Variable Transmission for Hybrid Electric Vehicle

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Abstract -This paper's primary contribution is the suggestion of a fuzzy logic global power management strategy for hybrid electric vehicles powered by the machine Electric powertrain. This has been looked into over the course of three aspects. The first is dividing power between internal combustion engines in the best possible way. The second is optimizing the amount of energy the car can absorb while braking. Finally, a reliable ON/OFF controller of the ICE adopts a State of Charge (SOC) of the battery maintenance strategy. Three fuzzy logic (FL) controllers were developed in order to achieve these objectives. The FL controllers are created using the battery's level of charge, the vehicle's speed, traction torque, and the needed power. The simulation model technique, which is based on the programmed MATLAB/Simulink, is used to integrate the researched system.

Keywords: fuzzy logic, State of charge, controller, braking, traction torque

INTRODUCTION

Enhancing energy management in hybrid electric vehicles (HEVs) can have a significant positive impact on the environment by lowering noise pollution, fuel consumption, emissions, and operating costs. Because it can considerably affect a vehicle's performance and component sizing, energy management in automobiles is a crucial topic[1]. It can also improve driving efficiency and user-friendliness. Additionally, the HEV's operation can be intelligently controlled by the intelligent energy management systems, which can observe and learn about driver behaviour as well as environmental and vehicle circumstances. Intelligent controllers have been suggested in a number of studies for the control of HEVs due to the highly nonlinear nature of driving circumstances and vehicle loads, which make them impossible to clearly explain[2-3]. Rule-based and optimization tactics have been the two main themes in control strategy . For the EVT-based

HEV, a rule-based power follower control technique was presented and simulated . The power distribution procedure between the HEV's components has been coordinated using the improved control method based on rules. In accordance with this strategy, the Internal Combustion Engine (ICE) operates in the range of maximum efficiency while providing the vehicle with the minimal amount of necessary power. As a result, the ICE turns ON and OFF in accordance with the upper and lower bounds of the battery's State of Charge (SOC). This work develops a fuzzy logic global control approach for the Electric Variable Transmission (EVT) system. This is regarded as an independent research project on the use of FLC controllers in that system. These tactics ensure that the ICE operates within its maximum efficiency range, maintain the PMSM-EVT machines' and the battery's power ratings below the upper limits, and keep the battery's SOC within the predetermined goal range[4]. A strong regeneration method has been used to capture the most power possible during braking as well. Finally, the driver's requirements under both easy and difficult driving situations have been met.

FUZZY LOGIC GLOBAL CONTROL APPROACH

The EVT-based HEV system is overly complicated, particularly in the areas of nonlinearity, functionality, and switching design. Additionally, it needs to be precisely regulated by an intelligent controller to suit the needs of the vehicle while operating smoothly, ensuring stability, and conserving the power sizing of the system's components [5]. The potential for recovering kinetic energy is one of the HEVs' inherent advantages. Maximizing regenerative energy reduces the need for the ICE, which in turn lowers fuel consumption and emissions. When the torque is less than zero across the vehicle speed range and the battery SOC range, regenerative braking is ordered [6]. For this reason, it's crucial to evenly balance brake power between regenerative and friction braking in order to maximize energy capture while preserving vehicle safety and the smooth operation of its parts (motors, inverters, and battery). This part uses the fuzzy logic control approach to transfer braking torque to regenerative braking as much as feasible in order to accomplish this goal.

VEHICLE PERFORMANCE

The vehicle's simulation results are shown and examined. The simulation's findings demonstrate that a vehicle's speed can track its driving cycle profile in a way that signals its drivability. The torque of the car in the side of final drive and the power demanded at the wheels are shown, which illustrates the driving and regeneration processes [7]. It must be noticed that the horsepower and torque are balanced for EVT and HEVs. This is due to the simulation software using the same data. For the study the parallel HEV is selected, in this vehicle EM is connected with the front axle and the ICE is coupled with automatic transmission and clutch [8]. The power train force acting on vehicle is expressed as-

$$Tr = r\,(\tfrac{1}{\ }\rho C\ \ A^{2} + m\,a + mg(f\ \cos\theta + \sin\theta)$$

The expression for calculation of the traction torques is as

$$T_p = n_f r_f\,(T_m + \eta_{gb}, ir_{gb}, iT_e) + T_b$$

CONTROLLER MODEL DESCRIPTION

The ICE's peak efficiency area should be established as the main objective for managing the parallel HEV in order to increase the power train's overall efficiency . To achieve the objective of increased fuel economy, the fuzzy logic controller is used in two modes, namely fuel use and efficiency[9].

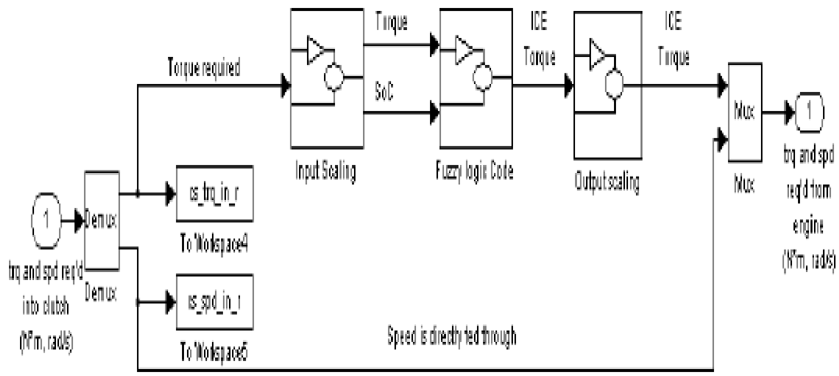

Figure 1: Block Diagram of FLC strategy

For the fuel use mode, a specific value is established, and the instantaneous fuel consumption restriction is imposed to ensure that it stays within the predetermined value. The range of speed and torque that each related engine is permitted to operate within is determined by the fuel use map. For this fuel utilisation mode, the fuzzy fuel variable is set to 1. In this strategy, the IC engine is run in the zone where it will achieve its peak or maximum efficiency. In order to attain the most efficiency for that specific engine speed, the operating points range for this mode is chosen close to the torque area, making it an instantaneous control [10]. The engine is compelled to work in the area in order to limit fuel consumption and maintain battery charge for the majority of the drive cycle.

SIMULATION RESULTS

Figure displays the contour plot for the efficiency mode. The speed and torque characteristics for the ideal values within the designated power level are defined by this curve. The engine speeds with the extreme lowest and highest values have the lowest efficiency points, according to the resultant figure. An efficiency map similar to this one is used to examine the electric motor's efficiency. The engine can always be operated close to its peak efficiency region when in the efficiency mode. This mode's main drawback is that most of its peak efficiency points are located in areas where high torque demands are present. As a result, the engine must produce more torque than what the driving profile demands. The contour plot in Figure displays the electric motor's efficiency characteristics for the speed torque plane. The efficiency plot is identical for both the motoring and generating modes; the only difference is the torque sign. Plots that depict the curves for the peak and continuous power are superimposed on the characteristic curve. Here, the motor speed and vehicle speed are directly associated, therefore it is necessary to manage both the power and the speed of the electric motors to maximize their efficiency.

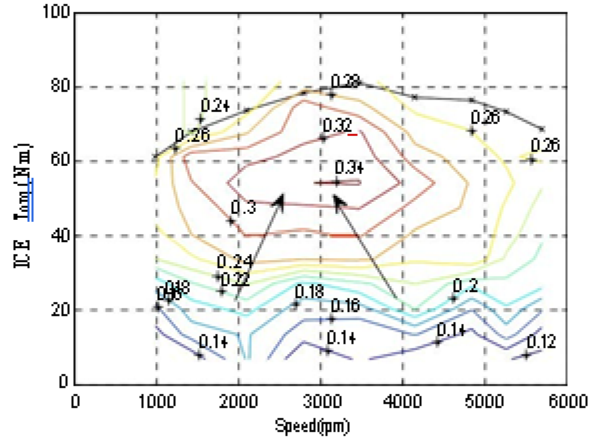

Figure 2: Efficiency Map of ICE

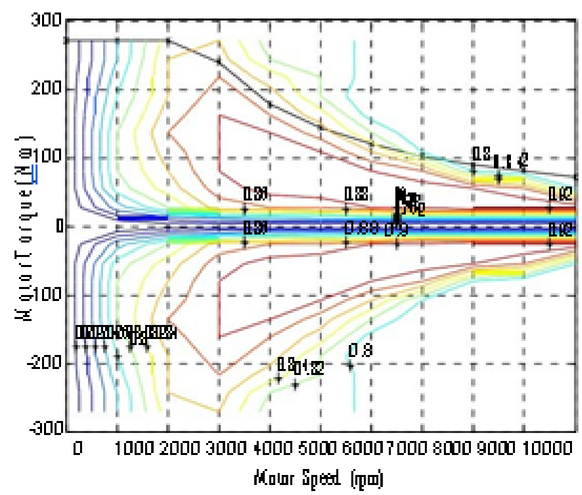

Figure 3: Efficiency Map of Motor

CONCLUSION

This paper presents an energy management plan that includes a secondary advancement in the fuzzy logic optimization technique's advisor. This FLC is used to optimise the power flow within the individual ICE, EM, transmission, and battery components of the parallel HEV. Efficiency maps for the components that make up the controller are shown as the results. This work is seen as a justification for maintaining the trend of energy management of HEVs based on online optimization techniques. The simulation results demonstrated the viability and efficacy of the suggested approach.

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