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Energy Management and Control Strategies for Parallel Hybrid Electric Vehicle

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ABSTRACT

For the parallel hybrid electric vehicle, the various control strategies for energy management are illustrated with the implementation of fuzzy logic. The controller is designed and simulated in two modes for the economy and fuel optimisation. In order to manage the energy in HEV with three separate energy sources—batteries, Fuel cell and a supercapacitor system, —this article intends to create a fuzzy logic controller. By considering a complete system, the operating efficiency of the components need to be optimized. the control strategy implementation will be performed by the forward-facing approach. The fuel economy is optimised by maximising the operating efficiency in this strategy while other strategies does not have this extra aspect. The ability controller for parallel hybrid vehicles is mentioned in this research to enhance fuel economy. Although the earlier installed power controllers optimise operation, they do not fully utilise the capabilities. Hybrid vehicles can be equipped with a variety of power and energy sources such as batteries, internal combustion engines , fuel cell systems, supercapacitor systems or flywheel systems.

Keywords: *Energy Management Strategies; Fuzzy Logic; Fuel Economy; Forward Facing; Optimising; Power Controller.*

1.0 Introduction

Hybrid vehicles, which combine an internal combustion (IC) engine with an electric motor, have a great deal of promise for increasing fuel efficiency. They do this by controlling the IC engine's operating range to function in the area where it will achieve the highest levels of efficiency.

Basically, a complicated arrangement that combines both series and parallel configurations[1]. The IC engine and generator are utilised in series configuration to power the electric motor with electricity. The control method to securely determine the power split between the primary and auxiliary sources in the vehicle power train is the most difficult item. Numerous solutions have previously been developed with an eye toward improving energy efficiency. The most promising technology today is hybrid because of its many benefits, which include improved fuel efficiency, less emissions, and cost-effective automobiles.

The IC engine and generator are utilised together in series configuration to power the electric motor with electricity. Because the battery and IC engine are not mechanically connected to the

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wheels, they may be operated regardless of the driving situation [2]. The electric motor in this design is added to the drive train in parallel to the ice in order to assist the ICE torque. In the parallel configuration, the ice is mechanically attached to the wheels in order to directly power the wheels.

The fuel economy of the new generation automobiles can be raised by almost three times without sacrificing other qualities like performance standards, safety, cost, comfort and quality etc[3]. The architecture and individual components must be optimised in order to achieve these goals, but the energy management tactics utilised to govern the system are also crucial. In this study, the ability controller for parallel hybrid automobiles is mentioned in order to maximise fuel economy.

Although the earlier installed power controllers optimise ice operation, they do not fully utilise the hybrid cars' capabilities. The ICE, motor, and battery operations can all be optimised by the facility controller. The controller is implemented using fuzzy logic. According to earlier research, the controller's fuzzy logic implementation is ideally suited for HEV control. This approach is useful for understanding the key trade-off between the abilities of all the components[4].

There are two categories involved in conventional energy management strategy EMS which are mainly Logical Rule Based and optimisation based:

- The logical rule-based strategy is easier in terms of implementation as compared tot hat of fuzzy based which is widely in actual production.
- The better efficiency in terms of cost and fuel is achieved in optimisation-based strategy but it is practically difficult to apply.

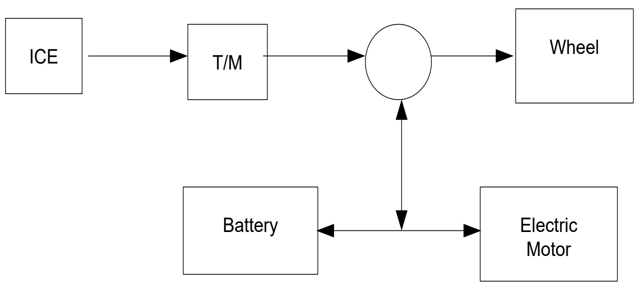
There are many strategies proposed for the energy management in power split HEV. There are some authors who introduced recent EMS and also generalise the basic architectures of different HEV s such as series, parallel, power split etc.

There are some strategies like deterministic rule based which is very popular line rule based technique. The control effect is also introduced in the adaptive rule based strategy . In this technique the energy and emission is optimised through instant cost minimisation .The other strategy have the advantage of parameter control which is possible in adaptive fuzzy logic control. This parameter control is done by adjusting the relative weight . For the above strategies global optimisation is not possible, thus the other strategies based on optimisation are developed including genetic algorithm, dynamic programming , and by using backward recurrence expression [6].

2.0 Parallel HEV Basic

In Figure 1 the schematic of parallel hybrid car is shown which demonstrates that how the IC engine, electric motor and transmission system is connected . the power can be provided with many possible ways which includes only IC engine , only electric motor or by both the EM and the ICE[7].

Figure 1: Schematic of Parallel HEV

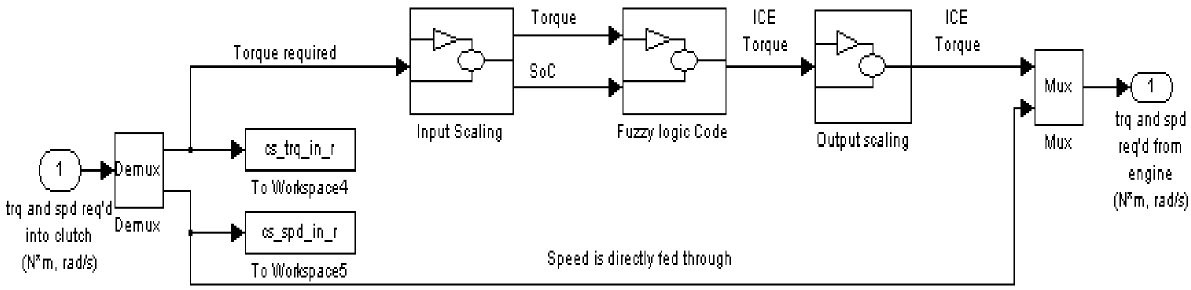


It implies that the management of this power split has a significant impact on how well a parallel HEV system performs. Heuristic control techniques that are based on straightforward rules or maps appear to be lagging behind controllers that are based on minimizing fuel consumption[8]. The latter, usually referred to as optimum controllers, actually offers more generality and minimizes the requirement for extensive tuning of the control parameters.

3.0 Controller Model and Description

The basic aim for controlling HEV is to set the efficiency point at maximum capacity so that it will help in improving the overall efficiency [9]. The two proper modes are efficiency and fuel use which are used to optimize the fuel economy . In the first mode, fuel used is mapped with instantaneous value and consumption of fuel is calculated while in the second mode the engine is made to operate in the region of peak efficiency.

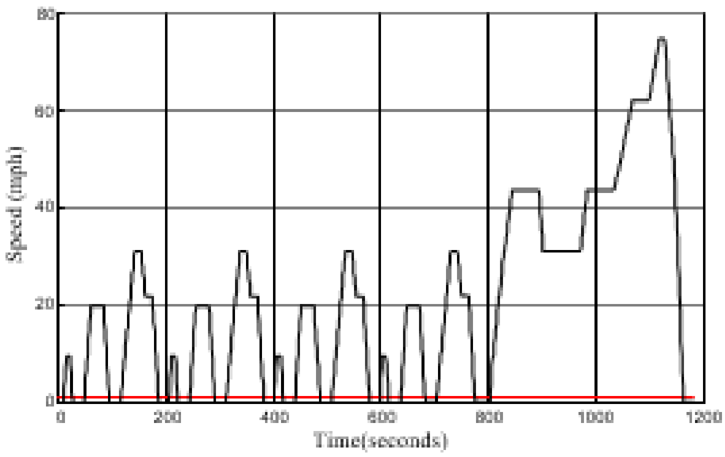
Figure 2: Block Diagram used in the Fuzzy Logic Control Strategy



The NERL is used to develop the models in which the HEV is operated in Simulink environment. This architecture is more appropriate as it uses approach of forward facing instead of backward facing[13-14] . Hence, it makes easier for the driver to easily decide the modulator pedals for acceleration system or for the braking system. The commands given to the controller are the inputs acquired by the driver and this is done by tracking the velocity profile .

4.0 Simulation Results and Discussion

Figure 3: Driving Profile in NEDC Working Condition



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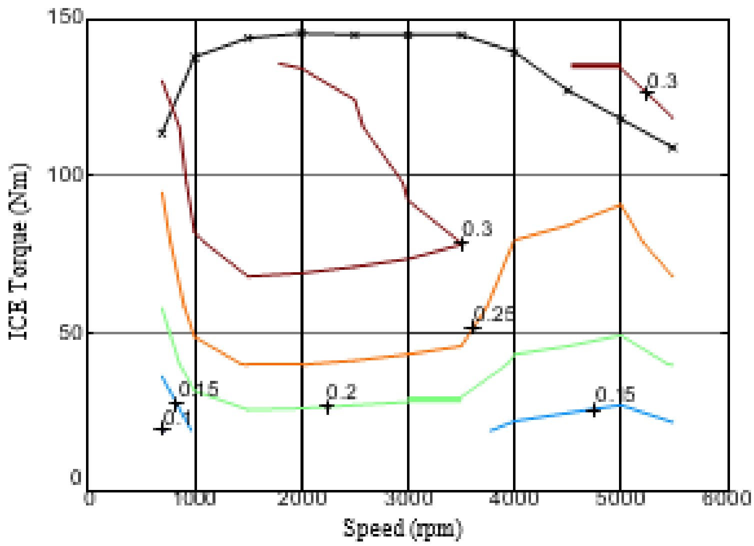
The velocity profile of NEDC has been utilized to simulate the controller for energy and power management . The obtained curves are shown in Figure 3 and Figure 4 and they represent the potential mapping of points which are in operation for IC engine, and electric motor.

To achieve the optimization, two strategies are basically used in this simulation tool –

- *Fuel Use Strategy*
- *Efficiency Strategy*

Due to the fact that vehicle operation is a highly nonlinear and transient process, a fuzzy logic controller will be used in the control strategy. The battery's maximum state of charge and the intended torque of the engine will be used by the FLC controller. Based on the aforementioned inputs, the operating points for the ice are determined, and the simulation is conducted for the reverse loop.

Figure 4: Efficiency Map of ICE for Fuel Use Mode



Efficiency map and optimised curves of the internal combustion engine for the fuzzy logic controller in the fuel usage mode are illustrated in Figure 4 Operative Points. In this mode, the simulation is run using the limiting fuel variable to assess the engine's sizing and, if necessary, to alter the value if the vehicle's performance is being restricted. Until the optimal fuel utilisation figure was reached, this process was repeated. It can also deliver enough torque to meet the trace. If the operating point is below the fuel line, this variable can be decreased until it reaches the required level for us to attain the desired degree of vehicle performance.

5.0 Conclusion

This FLC is used to optimise the power flow within the individual ICE, EM, transmission, and battery components of the parallel HEV. The findings are displayed as efficiency maps for the components that went into designing the controller. Analysis of the simulation findings for the NEDC drive cycle reveals a significant advancement above existing tactics that can simply maximise ice efficiency. This strategy's key benefits are its resilience, ease of adaptation, and high level of tolerance for component differences. Additionally, the prime speed torque curve is used to optimise the internal combustion engine's efficiency for a given power level.

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