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Energy Management Strategies in Hybrid Electric Vehicles (HEVs)

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***Abstract*: -- The hybrid electric vehicle achieves fuel and lower emissions than conventional internal combustion engine vehicles, they have very less and fewer emissions than conventional ICE. The HEV recapture a significant amount of energy during braking that is normally wasted, due to regenerative braking by converting the kinetic energy of the vehicle into electricity depending upon the power rating of the motor. The different techniques are used in HEVs. Fuel economy is improved by ATKISON CYCLE over OTTO CYCLE, shifting down the engine during traffic stops, improved aerodynamics using low resistance tires. Power steering hybrids come in many configurations, for example, a hybrid may receive its energy by burning petroleum, but switch between an electric motor and combustion engine.**

***Index Terms* — ARIMA (Autoregressive Integrated Moving Average), DP(Dynamic Programming), GIS (Geographic Information System), HEV (Hybrid Electric Vehicle), ICE (Internal combustion engine), MPC (Model Predictive Control), OLPT (Operation Line Power Track), PHEV (Plug-in Hybrid Electric Vehicle), RL (Reinforcement Learning), SPSS (Single Point Start-Stop), SOC (State of Charge).**

I. INTRODUCTION

With the increasing attentions an energy efficiency and environmental protection, the development of HEV's has been speeding up. As a core part of HEV the electric machines are expected to provide high efficiency, high power, torque densities, high controllability, wide speed range, maintenance free operation. A HEV is a type of vehicle that combines a conventional IC engine with electric propulsion system [1]. The continuous development of modern technology and culture leads to the growth of HEVs. The growing presence of global warming and irreversible climate change draws increasing amounts of concern from the world's population. Countries around the world are working to reduce carbon dioxide as well as other harmful environmental pollutants. Automobiles are the most notable producers of these pollutants, which are completely run by internal combustion engines. These problems are reduced by the use of HEVs which combines two types of energy sources. The design of such vehicles requires, among other developments, improvements in power train systems, fuel processing, and power conversion technologies. One potential alternative to the world's dependence on standard combustion engine vehicles are hybrid vehicles.

II. METHODOLOGY

Environmental pollution and energy shortage have always been two big problems which restrict the development of automotive industry. As a variable solution of the environment pollution and energy crisis. It has attracted a lot of attentions from organizations and companies control strategy is one of the most important parts in the research of HEV, effecting the fuel economy and exhaust emissions. It has important theoretical significance and practical value to build up an effective control strategy.

There are three major categories of energy management strategy:

(a) A rule-based algorithm.
(b) Intelligent control method.
(c) Optimization algorithm.

The above control methods and algorithms have their own fruitful results and drawbacks.

Considering the rule-based and control techniques can be easily applied in real time control due to their simple structure and strong robustness (quick, efficient etc).

A. A Rule Based Algorithm

The basic theme of this method is to control the working range of parameters through setting threshold the pre-set rules and then the vehicle energy loss can be reduced this method has several advantages some of them as: simple structure, small amount of competition and high efficiency and more suitable for real time energy management [2].

B. Intelligent Control Method

Intelligent control can solve many complex uncertain system control problems by integrating human knowledge into control system [3].

a) Fuzzy logic control has a nonlinear structure that can deal with the non-linear structure of the power split problem. Fuzzy logic has a more robust structure and offers more design flexibility. The problem with the fuzzy logic is the optimization and mathematical manipulation of decussation system because this process consumes memory and time in controller [4].

b) There are also combination of fuzzy logic and artificial neural called neuro fuzzy control

C. Optimization Algorithm

It is based on optimization theory this approach is useful for finding the optimal policy [5].

III. GLOBAL OPTIMIZATION

The global optimization technique for energy management strategy in a HEV requires the knowledge of entire driving pattern which includes battery SOC, driving conditions, driver response and the route. Due to computational complexity, they are not easily implementable for real time applications, here are some methods adopted for resolving HEV management issues are:

(a) Linear programming.

(b) Dynamic Programming.

Based on optimal control theory and assuming that minimizing the fuel consumption reduces the pollutant emissions a global optimization algorithm is developed [6] this offers the quick global optimal solution and minimizes the fuel consumption. To get better optimal solution for HEV design and control another global technique has been suggested [7].

A. Linear Programming

The fuel economy optimization is considered as a non-linear optimization problem, which is finally approximation by linear programming method. Linear programming is mostly used for fuel efficiency optimization problem using linear programming may result in global optimal solution.

In hybrid power trains, better degree of freedom to control exists.by controlling the gear ratio and torque, an optimized design and control of series hybrid vehicle are proposed in [8].

B. Dynamic Programming

Dynamic programming (DP) was originally used in 1940 by RICHARD BELLMAN to describe the process of solving problems where one needs to find the best decisions successively. DP is both a mathematical optimization method and a computer programming method having a dynamical process and the corresponding performance function. There are two ways to approach the optimal solution of problem. One is PONTRYAGAIsNS maximum principle and the other is Bellan's dynamic programming. It has the advantage of being applicable to both linear and non-linear systems as well as constrained an unconstrained problem. But it also suffers from a severe disadvantage called curse of dimensionality which implies the computational burden and limits its application to complicated system. Using rule based approach and a dynamic programming (DP) optimal power split between both of energy sources is obtained for a series HEV [9] LI and KAR use DP to design a lower split device (PSD) in HEV's which minimizes the fuel consumption and enhance vehicle performance [10].

IV. THE ENERGY MANAGEMENT SYSTEM BASED ON ROAD GRADE PREVIEW

The energy crisis increases severely, cleaner and more fuel-efficient vehicles have become the hotspot of automotive technology research. However, conventional ICE (internal combustion engine) vehicles suffer from poor fuel economy during urban driving due to the low efficiency of engine under the stop-and-go urban driving situation. Battery-powered electric vehicles (EV), on the other hand, have some advantages over conventional ICE vehicles, such as high energy efficiency and less pollution. However, due to the lower energy content of the battery compared gasoline, the operation range per battery charge, is far less than ICE vehicles, which is the major disadvantage of EV. Hybrid electric vehicles (HEVs) are widely considered as one of the most viable solutions to the world's need for cleaner and more fuel-efficient vehicle. Environmental issues are pushing the transportation sector to improve the efficiency of road-vehicles. Hybrid Electric Vehicles (HEVs) have a high potential to reduce fuel consumption and emissions. Due to their ability to recover kinetic energy while braking and to operate the engine in a more efficient area, carbon dioxide emissions can be reduced [11].

In order to solve the problem about over discharge of the battery and storage of driving power a pre-charge node is added to the energy management strategy based on road grade preview. The vehicle obtains the slope information from GIS (geographic information system) then opens the pre-charge mode ahead before PHEV enters the slope [12]. Plug-in hybrid electric vehicles (PHEVs) offer an immediate solution for emissions reduction and fuel displacement within the current infrastructure. Targeting PHEV powertrains optimization, a plethora of energy management strategies (EMSS) have been proposed. These algorithms present various levels of complexity and accuracy; they find a limitation in terms of availability of future trip information, which generally prevents from exploiting of full PHEV potential in real-life cycles [13]. For a 4WD-hybrid electric vehicle with front wheels driven by engine and rear wheels driven by In wheel-motor, the engine intervention in driving and the engagement of the transmission during shifting will cause the longitudinal impact and influence the drive comfort. Attribute to the controllable and quick response of the rear in-wheel-motor torque, a disturbance rejection [14].

Two energy management methods for a plug-in serial hybrid electric vehicle. These are the optimal single point start -stop (SPSS) control and the optimal operation line power track (OLPT) control respectively the control logics of the two methods are designed. Performances are verified and compared under simulation condition, which reveals that the power track control strategy performs better energy economy both theoretically and practically [15]. A predictive energy management strategy for a parallel hybrid electric vehicle (HEV) based on velocity prediction and reinforcement learning (RL). The design procedure starts with modeling the parallel HEV as a systematic control -oriented model and defining a cost function [16].

The uncertainty caused by the varying of road grades plays a critical role in impacting the hybrid electric vehicles (HEV) energy management performance, and therefore the fuel economy. Autoregressive integrated moving average (ARIMA) based method, aiming to forecast the near future road grade in real-time with acceptable accuracy for predictive energy management of (PHEVs). Real world road grade data is collected and employed to formulate the ARIMA model and model predictive control (MPC) is used for the powertrain control. The model is integrated into the predictive energy management strategy to investigate and evaluate the potential gain in fuel economy. Simulation results show that the ARIMA method is able to predict the future road grade with high accuracy, and the corresponding fuel consumption is reduced by at least 4.7% [17]. The electrical hybridization of a conventional car can decrease the fuel consumption by various means [18] regenerative braking, Stop & Start or energy management. The energy management strategy impacts the Hybrid Electric Vehicle (HEV) operation particularly in terms of pollutant emissions. Thus, a strategy aiming at reducing the fuel consumption while respecting pollutant emissions standards has to consider the 3-Way Catalytic Converter (3WCC) [19]. For a gasoline engine, the 3WCC temperature dynamics plays a key role in pollutant emission. Historically, the optimal energy management strategies were built to ensure minimal fuel consumption, for a trip known a priority most often a driving cycle. Usually this is done by using either Dynamic Programming (DP), derived from Bellman's principle, Bellman (1956), or the Pontrya-gin Minimum Principle (PMP), Pontryagin (1962), from qualities HEV models. The only dynamics considered in these off-line strategies concerns the electrical Battery State of Charge (SOC) [20].

V. CONCLUSION

The conclusion of this paper is that the energy management in the real time hybrid electric vehicles (HEVs) by using different strategies gets improved. Thus, pollutant emissions and fuel consumption gets reduced. However, here only the off-line strategies concerning the electrical battery state of charge (SOC) is considered.

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