

# Hybrid Electric Vehicle Power Management Using Fuzzy Logic Controller

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## Abstract

The article presents a hybrid electric vehicle (HEV) study using a simulation or a QSS (Quasi-static-simulation) approach and a controller for smooth logic energy management for HEV. The software used for HEV modeling and the controller for smooth logic power control is MATLAB / Simulink. A comparative study was conducted to study the ability of a soft logic controller to be compared to a optimal optimized controller optimized by dynamic programming. It has been found that the soft register control indicator shows excellent performance, since the last HEV State of Charge (SOC) battery is within 2.8% of this dynamic programming. A comparative study was then performed after addition of a supercapacitor equipped with this HEV, with only battery power. Following the modified PMC (power management controller) logic to include additional supercapacitors, it was found that fuel consumption improved by 54.34% from 57.6 mpg to 88.9 mpg and total energy consumption reduced by 27.27%.

**Key Words:**Hybrid electric vehicle, HEV, EV, supercapacitor, power management controller.

## 1. Introduction

In recent years, global warming and water-related issues have warned that in many developed countries it is important to reduce fuel consumption. They also called on researchers to find solutions to this problem. Particularly focusing on automotive technology that is fuel-efficient in order to reduce the threat of global warming and energy issues. Among few well-known technologies are hybrid electric vehicles (HEV) and full electric vehicle (FEV) such as Toyota Prius and Tesla Models respectively. Other researchers are working to improve the fuel-efficient transport technology which Provides internal combustion engines with power supply, power recovery systems, super capacitors, and efficient management of energy management. Thus, the HEV vehicle power management controller is essential for the battery or over current to adjust the ideal electrical current from the engine and internal combustion engines. According to the power management controller, the most appropriate energy stream increases HEV fuel savings.

In this area of HEVs, many authors presented their work in recent times are discussed here. In an attempt to use the flux from a magnet machine Lee et al. used a partitioned stator switching mechanism for the HEVs [1]. The vehicle proposed in this method can utilize the complete flux and can be utilized for the outstanding wide-speed operations. In an attempt to match the parameters and continuous variable transmission of target speed ratio optimization for the plug is experimented by Zeng could deliver the desired power performance and optimized target speed ratio of CVT towards economic energy consumption [2]. Later, Xu et al. in another experiment suggested using electric variable transmission (EVT) and Toyota hybrid system (THS) as power split devices and most of the HEVs [3]. Xu et al. used the method of magnetic decoupling of electric variable transmission for HEVs [4]. In a research carried out by Xu et al. to propose a new EVT for HEVs resulted to be very useful due to the usage strong coupling relations in internal magnetic field [5]. A seven switch all in one power electronic topology was proposed recently by Gujarathi et al. for converted plug-in HEVs [6]. Passive power factor was used in this method at the time of plug-in charging mode of operation. On the other side an ultrasonic sensor was used to detect the obstacles by Senthilnathan et al. while designing a smart hybrid electric vehicle [7]. A power-split HEV proposed with a dual-mass flywheel by Tang et al. suggested a novel torsional vibration modelling and assessment method [8]. From the obtained results, the implementation of dual-mass flywheel is having effective impact on decreasing the torsional vibrations of hybrid power train. Also to increase the power train efficiency of the HEV Zeng proposed a real-time control strategy for plug-in HEVs [9]. This method provided a competitive performance with suitable energy consumption in an efficient manner. This paper focuses on the Power Management Controller (PMC) developed by the phase logic method to bring fuel efficiency to a higher level. Furthermore, studies of the supercapacitors effect on improving the energy-efficient energy economy have been studied based on the high energy

demands and the use of regenerative braking. Supercapacitors are less expensive than batteries, but they are capable of accelerating and braking HEV, such as high-energy charging/charging cycles, high-voltage densities, high-voltage charging/charging limits. The Power Management Controller (PMC) for HEV is a heuristic, predictive controller and offline optimization. Multiple methods are boolean logic and fuzzy logic. Based on the logic of the fuzzy logic, PMCs can be simpler and more customizable, but with multiple variables, reducing fuel savings. It depends on the designers' sensitivity. It has a high operating situation and fuel savings. Then it is fuzzy logic based on the truth (0-1) rather than the absolute binary logic (0 and 1). In recent years there are many ways of controlling energy management, but the controlling blunders are still competitively competent. In addition, the simple, prompt decision-making process enables real-time strategy implementation. Fig.1 shows the basic units of HEV System. A current progress inside the HEV segment is the hybridization of the energy storage system (ESS). The development used depends on upon the targets set for the vehicle, which fuses fuel capability, control, driving scope, or reduced ozone hurting substance releases. The achievement of any of the methodologies will be reliant on vitality stockpiling unit (batteries, ultra capacitors) abilities that are power, thickness, life, and cost. Batteries, ultra capacitors are vitality stockpiling gadgets. Ultra capacitors utilize electrolytes and design different measured cells into modules to meet the power, vitality, and voltage necessities for an extensive variety of uses. Be that as it may, batteries store charges synthetically, while ultra capacitors store them electro statically. As of now, ultra capacitors are more costly (per vitality unit) than batteries. The greater part of these vehicles right now advertised to purchasers have both regular fuel and electric engines, with the capacity to control the vehicle by it is possible that one autonomously or couple. Customer situated cross breed vehicles, which have been available for around ten years, are normally tuned for diminished outflows and driving extent. Corporate and government armadas that have been in administration for a long time or more are generally tuned for fuel effectiveness, regularly at the cost of driving reach, power, and hydrocarbon outflows. Joining the cleaner vitality of the electric engine with the long-extend energy of the gas motor yields a half and half vehicle with lower lethal emanations with better efficiency some of the time up to 30 miles a gallon or more than customary autos.

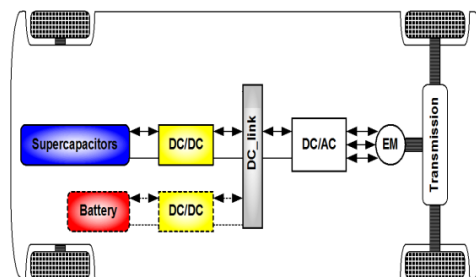


Fig. 1: Basic Units of HEV Using Super Capacitors and Battery

## 2. Methodology

To optimize the experiment, 5% -10% improvements were made on the fuzzy controller to optimize HEV controller. Furthermore, the optimum use of the genetic algorithm (GA) is 4.8% [10]. These are indicative of the effectiveness of the inappropriate controller, but it is not optimal, but it is appropriate. These show effectiveness of fuzzy controller, although it's not optimal, it's very close to optimal. A fuzzy control strategy for regenerative braking system in electric vehicle (EV) presented in [12], the controller shows significant improvement over initial vehicle model in energy recuperated and regenerative braking efficiency 867 kJ compared to 311 kJ and 86% compared to 44.6%. At the same time, the predictive controller, such as the predictive controller (model predictive control – MPC) and similar consumption reduction strategy (equivalent consumption minimization strategy – ECMS), demonstrates the high fuel economy potential. This is based on a prediction of the future power demand of the HEV platform. Although this method allows real-time implementation, however, there is a need for knowledge in the future (land degree, traffic lights, etc.), but this is a problem because it is impossible for all HEV to use GPS with high-priced price tags. The superconducting supplements have proven to be effective and provide additional torque hybrid power supply for electric train systems . The engine is 3.0-liter, 1.8-liter turbocharged (dropped). The results shown in this document prove the voltage system of the supercapacitors with the additional torque required by the 140 Nm when the turbate lagging cycle (RPM <3000). In addition, the energy spent during acceleration is fully recovered during the repayment of approximately 150 kJ. In the experimental study, supercapacitor improved the efficiency of the regenerative braking to 88% [13]. Superchargers also increased fuel economy by 5.79% [13]. These reports have made a substantial change to the HEV to achieve the economy of the supercharged additives. Furthermore, the storage of electrical energy controlled by fuzzy logic controller improves fuel consumption by accelerating acceleration from 13.2 to 12.1 seconds, increasing fuel consumption from 8.1 l / 100km to 7.2 l / km [14]. Thus, logic controller is very good for HEV power between ICE and EM and also included as a combined power supply (battery, supercontroller). Therefore, this study is being selected as an effective energy management coordinator for the high fuel economy growth in HEV.

## 3. Hardware Implementation of the System

The hardware kit consists of a permanent magnet DC motor with internal gear mechanism, rechargeable lead acid battery with 4v,1.5Ah and a super capacitor having 3v 500F. The DC-DC converter utilized is a Buck Boost converter where the N-MOSFETs is utilized as a switch. In support mode the info voltage 12v is helped to 49v and after that connected to the vehicle. On the off chance that the yield voltage is more prominent than the required voltage then the converter will fill in as a buck converter and will diminish the voltage to the required level. In

this the internal resistance is connected, by increasing the internal resistance the output voltage of the system can be reduced.

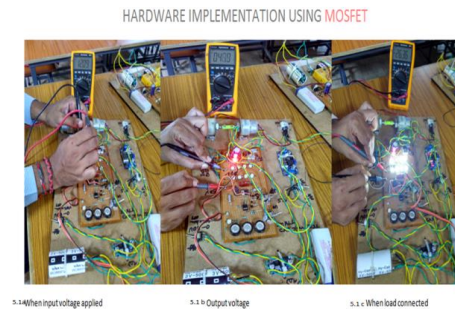


Fig. 2: Experimental Setup Using the MOSFET KIT for Three Stages

The input voltage can be measured by using multimeter and that is represented in fig 2.1a; after applying the triggering pulses to the MOSFET switches then the applied voltage is boosted to 49v and that is represented in fig 2.1b. After applying the load the discharge in voltage is represented in fig2.1c. A Buck – Boost converter has been utilized to recoup the vitality to the Ultracapacitors. At the point when the Ultracapacitors is full, the vitality is dispatched to the battery. On the off chance that the battery voltage or current requirements are abused, the MOSFET chopper associated with the braking resistor will be actuated by a Fuzzy controller. The blend of the controllers and their coordination in the worldwide framework constitutes a vital piece of the general work. The approval of the cross breed vitality stockpiling framework and its journalist controllers has been checked in a more complete recreation demonstrate speaking to the vehicle, including the inverters/engines affiliation and control, the stopping mechanism evaluation and dispersion, and so forth. These tests have approved the controllers amalgamation connected to the DC/DC converters, demonstrating an exact Ultracapacitors voltage and current following execution and quick powerful reaction.

#### 4. Results and Discussion

The below figures 3-5 represents output of the accelerators, brakes and speed sensor respectively. Supercapacitors speed can be estimated in square wave. The frequency of large square wavelengths changed rapidly; Then calculate the vehicle speed as shown in Figure 5. Calculate the total kinetic energy of the brakes. In the braking process, the main drive is powered by the motor, and the supercapacitor is stored at the end of the electrical energy, which consists of kinetic energy. In case of a reduction in the energy curve, the renewable energy stored in the compressor can be calculated. A Ultra-capacitor based vitality administration framework for Electric/Hybrid Electric Vehicle is proposed to enhance its transient execution. The framework utilizes a DC-DC control converter which associated between Ultra-Capacitor & principle battery unit.

Additionally, a vitality administration system of ultra-capacitor in view of PI controlling is proposed [16]. With this technique the condition of charge of ultra-capacitor [17] is measured and is kept at legitimate level as indicated by various velocities of vehicle.

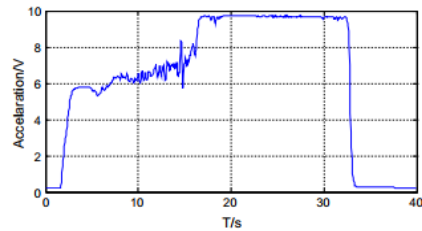


Fig. 3: Accelerator Signal

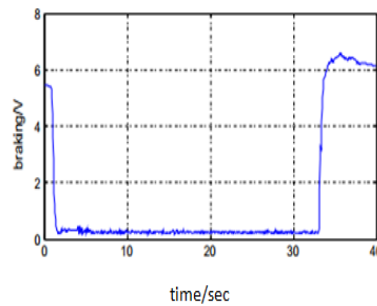


Fig. 4: Braking Signal

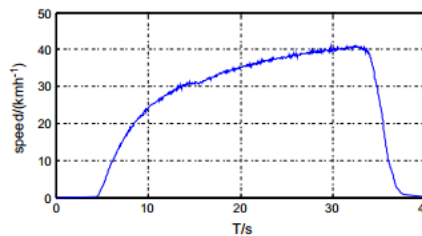


Fig. 5: Vehicle Speed

In addition, the phase logic of PMC makes it possible to power super-cassettes, non-space and internal combustion engines; It improves fuel efficiency (which reduces engine failure with high torque) and battery[18] life. In addition, the supercomputer contributes to the efficiency of the brake regeneration, resulting in a complete reduction of energy; braking is more energy efficient. The results presented herein can have a significant impact on the supercapacitor in the EV / HEV [19] system and may have a flexible logic, but this cost-benefit analysis is not part of the scope of this work. After this the power of the engine begins to gradually decrease. When a quick machine enters the braking rate, the main drive motor is negative. In addition, the main motor is an energy source.

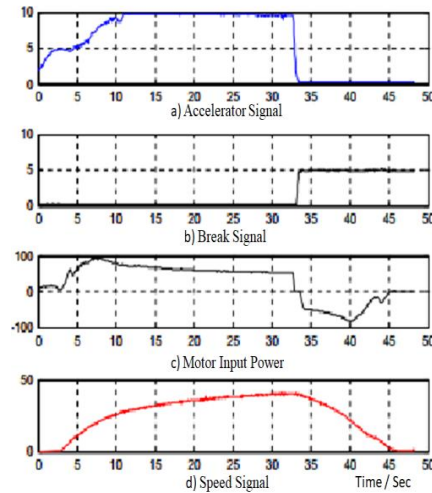


Fig. 6: Main Drive Motor Input Power Curves

## 5. Conclusion

Finally, the use of a soft PMC logic to control the flow of power from the internal combustion engine and the electric motor shows good and practical effects against the optimal ideal controller, it also shows good power management of battery power and supercapacitors. Together there was a soft PMC logic in improving fuel economy and reducing overall energy consumption. In addition, the energy efficiency of the regenerative brake changes along with the driver's behavior. In particular, the brake pedal force is one of the important factors affecting regenerative efficiency. In case of emergency braking, the braking force comes mainly from the front wheels; if we can establish the front and the last regenerative mode of braking, then the effects of energy recovery will be better. In short, the efficiency of power recovery in electric vehicles is ensured by supercapacitor technology. They believe that supercapacitor technology will improve the performance of electric vehicles and electric vehicles in the new phase.

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