INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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SPECIAL ISSUE FOR NATIONAL LEVEL CONFERENCE "RENEWABLE ENERGY RESOURCES & IT'S APPLICATION"

A REVIEW OF HYBRID ELECTRIC VEHICLES AND TECHNOLOGIES

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Accepted Date: 12/03/2016; Published Date: 02/04/2016

Abstract: To surmount the threat of environmental hazard and to prevent the exploitation of natural resources, hybrid vehicle provide the solution in terms of alternate energy sources like battery, fuel cell or ultra-capacitor. Usage of battery in hybrid electric vehicle reduces the demand of petroleum. The hybrid electric vehicle (HEV) technology is the result of the desire to have vehicles with a better fuel economy and lower tailpipe emissions to meet the requirements of environmental policies as well as to absorb the impact of rising fuel prices. The objectives are met by combining a conventional internal combustion engine (ICE) with one or more electric motors powered by a battery pack that can be charged using an on-board generator and the regenerative braking technology to power the transmission. In this paper technologies that are proposed and developed in the recent years are revisited and reviewed.

Keywords: Hybrid Electric Vehicles (HEV), Internal Combustion Engine (ICE), Regenerative Braking System.

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How to Cite This Article:

Vikas R. Rajoria, IJPRET, 2016; Volume 4 (8): 41-48

PAPER-QR CODE

INTRODUCTION

Hybrid Electric Vehicles (HEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) consist of two power sources, that is, (1) Internal Combustion Engine (ICE) and (2) Battery. Power split between these two is of utmost importance to minimize the fuel consumption without affecting the vehicle speed. The literature reveals that various power split strategies have been developed and implemented. These strategies vary in optimization type (global or local), computational time, structural complexity, a priori knowledge of driving pattern. A survey of these available methods would be of great use for researchers and practitioners working on HEVs/PHEVs

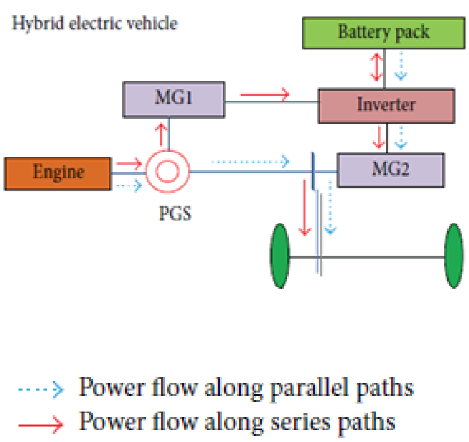
Emergence of Hybrid Electric Vehicle

Automobiles have made great contribution to the growth of modern society by satisfying the needs for greater mobility in everyday life. The development of ICE has contributed a lot to the automobile sector. But large amounts of toxic emissions in the form of carbon dioxide (CO2), carbon monoxide (CO), nitrogen oxides (NO*x*), unburned hydrocarbons (HCs), and so forth have been causing pollution problems, global warming, and destruction of the ozone layer. These emissions are a serious threat to the environment and human life. Also, as petroleum resources are limited, consumption of petroleum needs to be reduced. One prominent solution to these problems is to go for an alternate transportation technology, which uses ICE as primary power source and batteries/electric motor as peaking power source. This concept has brought the new transportation medium such as Electric Vehicles (EVs), HEVs and PHEVs, which are clean, economical, efficient, and environment friendly. The EVs are enabled by high efficiency electric motor and controller and powered by alternative energy sources. The first EV was built by a Frenchman Gustave Trouve in 1881. It was a tricycle powered by a 0.1 hp direct current motor fed by lead-acid batteries. EV is a clean, efficient, and environment friendly urban transportation medium but has limited range of operation. Due to higher battery cost, limited driving range, and performance of EVs, HEVs came into existence. HEVs use both electric machine and an ICE to deliver power during vehicle propulsion. It has advantages of both ICE vehicles and EVs and eliminates their disadvantages [1]. In HEVs battery is the supportive power system to ICE during vehicle propulsion and hence reduces the liquid fuel consumption and toxic emissions. In 1901 Ferdinand Porsche developed the Lohner- Porsche Mixte Hybrid, the first gasoline-electric hybrid vehicle [2]. In HEVs batteries are charged either by engine or by regenerative braking and are not plugged-in externally which limits its electric range. They also take longer time in recharging. PHEVs offer a promising medium-term solution to reduce the energy demand as the batteries are charged through the grid. PHEVs are displacing liquid fuels by storing the energy in a battery with cheaper grid electricity [3]. PHEVs have a large on-board rechargeable battery and larger sized motors compared to HEVs. Presence of larger size battery with high energy capacity increases the fuel efficiency of PHEVs. In PHEVs battery is used as primary power source and ICE as secondary power source. The battery can be recharged through mains power supply anywhere at home, parking lots, or garages.

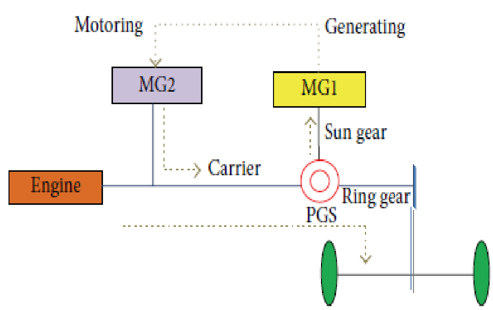
Architecture of Hybrid Electric Vehicles

HEVs are classified mainly into three categories: (1) series hybrid, (2) parallel hybrid, and (3) series-parallel (power split) hybrid. The series configuration consists of an electric motor with an ICE without any mechanical connection between them. ICE is used for running a generator when the battery does not have enough power to drive the vehicle; that is, ICE drives an electric generator instead of directly driving the wheels. Series hybrids have only one drive train but require two distinct energy conversion processes for all operations. These two energy conversion processes are gasoline to electricity and electricity to drive wheels. Fisher Karma, Renault Kangoo, Coaster light duty bus, Orion bus, Opel Flextreme, and Swiss auto REX VW polo use series configuration. In parallel configuration, single electric motor and ICE are installed in such a way that both individually or together can drive the vehicle. Parallel hybrids allow both power sources to work simultaneously to attain optimum performance. While this strategy allows for greater efficiency and performance, the transmission and drive train are more complicated and expensive. Parallel configuration is more complex than the series, but it is advantageous. Honda's Insight, Civic, Accord, General Motors Parallel Hybrid Trucks, BAS Hybrid such as SaturnVAU and AuraGreenline, and Chevrolet Mali by hybrids utilize parallel configuration. Power split hybrid has a combination of both series and parallel configuration in a single frame. In this configuration engine and battery can, either alone or together, power the vehicle and battery can be charged simultaneously through the engine. Basically, it extends the all-electric range (AER) of hybrid vehicle. The current dominant architecture is the power-split configuration which is categorized into two modes: (1) one (single) mode and (2) two (dual)modes. Single mode contains one planetary gear set (PGS) and dual mode contains two PGS which are required for a compound power split. It is further classified into three types: (1) input split, (2) output split, and (3) compound split as determined by the method of power delivery. In the input split power configuration or single mode electromechanical infinitely variable transmission (EVT), planetary gear is located at the input side as shown in Figure 1(a). The input power from the ICE is split at the planetary gear. It gives low efficiency at high vehicle speed [5]. Toyota Prius employs an input split power configuration. The output split power train consists of one planetary gear at the output side as shown in Figure 1(b). The output split system uses power recirculation at low vehicle speed and power splitting at high vehicle speed.

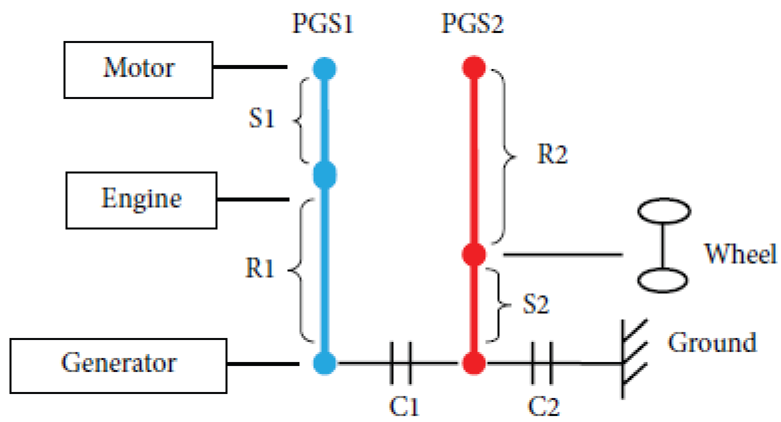
Power recirculation means that a portion of the engine power is recirculated by the charging of any one motor/generator and discharging of the other. Due to charging and discharging efficiency of the motors, recirculated power negatively affects the system efficiency. Hence output split power train displays poor performance at low vehicle speed compared to input split [6]. Chevrolet volt uses output split configuration. In dual mode configuration, the two clutches provide a torque advantage of the motor at low speed while fundamentally changing the power flow through the transmission as shown in Figure 1(c). When the first clutch is applied and the second clutch is open, the system operates as an input split. When the second clutch is applied and the first clutch is released, the system operates as a compound split. This hybrid can shift between these two (input-split as well as compound-split) in a synchronous shift, involving only torque transfer between elements without sharp changes in the speeds of any element. Lexus HS250h, Lexus RX400h, Toyota Camry and Highlander, Lexus GS450h, and Lexus LS600h use compound split configuration. The combination of a compound split and an input split enables a two-mode hybrid system. The use of dual mode solves the problems of the single mode power train and provides better vehicle performance with respect to fuel economy, acceleration, and motor size. In dual mode, PG Sareused for both the input split and compound split [7]. Two-mode hybrids includes General Motors two-mode hybrid full-size trucks and SUVs, BMW X6 Active Hybrid and Mercedes ML 450 hybrid, Allison EV Drive, Chrysler Aspen, Chevrolet Tahoe, and GMC Yukon hybrid (GHC, 2013). All the configurations of HEV can be employed in PHEV's drive trains. In PHEVs battery is initially charged through the mains power supply to the full capacity, which supports HEV architecture to propel it for longer distances with a very less fuel consumption.



(a)



(b)



(c)

Figure 1: Power-split configurations: (a) input split, (b) output split, and (c) compound split.

Regenerative Braking Systems

When a conventional vehicle applies its brakes, kinetic energy is converted to heat as friction between the brake pads and wheels. This heat is carries away in the airstream and the energy is effectively wasted the total amount of energy lost in this way depends on how often, how hard and for how long the brakes are applied. Regenerative braking refers to a process in which a portion of the kinetic energy of the vehicle is stored by a short term storage system. Energy normally dissipated in the brakes is directed by a power transmission system to the energy store during deceleration. That energy is held until required again by the vehicle, whereby it is converted back into kinetic energy and used to accelerate the vehicle. The magnitude of the portion available for energy storage varies according to the type of storage, drive train efficiency, and drive cycle and inertia weight. A lorry on the mom way could travel 100 miles between stops. This represents little saving even if the efficiency of the system is 100%. City centre driving involves many more braking events representing a much higher energy loss with greater potential savings. With buses, taxis, delivery vans and so on there is even more potential for economy. Since regenerative braking results in an increase in energy output for a given energy input to a vehicle, the efficiency is improved the amount of work done by the engine of the vehicle is reduced, in turn reducing the amount of prime energy required to propel the vehicle. In order for a regenerative braking system to be cost effective the prime energy saved over a specified lifetime must offset the initial cost, size and weight penalties of the system. The energy storage unit must be compact, durable and capable of handling high power levels efficiently, and any auxiliary energy transfer or energy conversion equipment must be efficient, compact and of reasonable cost. To be successful a regenerative braking system should ideally have the following properties [4]: Efficient energy conversion An energy store with a high capacity per unit weight and volume A high power rating so large amounts of energy can flow in a short space of time Not require over complicated control systems to link it with the vehicle transmission Smooth delivery of power from the regenerative system Absorb and store braking energy in direct proportion to braking, with the least delay and loss over a wide range of road speeds and wheel torques. There are many new hybrid cars out on the market today and some have new energy recovery systems including flywheel and regenerative brakes. These vehicles try to use as little gas as possible and waste as little energy as possible. These two forms of energy savers just starting to be used have very basic concepts in physics that have been know for many years. Recent advancements have made them possible to be used in realistic ways to save money and energy. Regenerative brakes were first used 100 years ago by a man named Louis Krieger. He put a simple form of regenerative brakes on the front wheels of a horse drawn cab [8]. However, most regenerative brakes started showing up in the 1930 in trains and trolley cars. One train in Scandinavia even creates more power than it uses. The train is loaded up with iron and creates a lot of power as it travels down the steep mountain and applies the regenerative brakes to slow down. It makes so much power that it has enough left over when it gets to the bottom to get the empty train all the way back up the mountain and still put some power back into the power grid [8].Regenerative brakes work by saving energy. As a car stops all the momentum the car built up using precious gas or electricity is wasted using friction based brakes. With regenerative brakes some of that energy can be reused (Everett, Michael). Basically the motor that makes the car move is put in reverse to slow the wheels down. In this process the motor acts as a generator recharging the batteries as an electrical current runs the opposite way through the motor that gave the vehicle the power in the first place [8]. So instead of the energy becoming heat and leaving into the atmosphere, it can be used once again to get the car up to speed. This can over time help with the fuel efficiency of you vehicle or make the electric motor last longer.

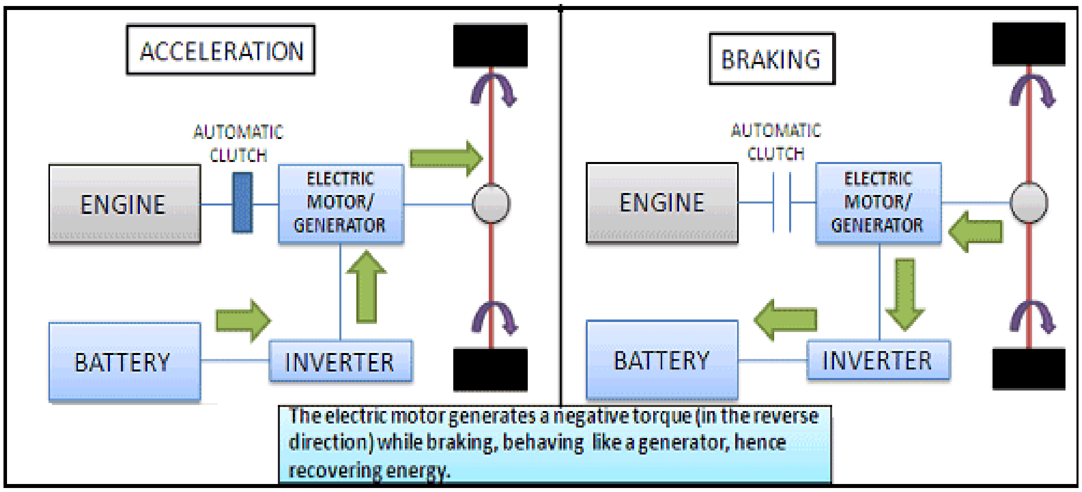


Fig.2. Regenerative Braking System.

CONCLUSION AND FUTURE DIRECTION

As HEVs are gaining more popularity, the role of the energy management system in the hybrid drive train is escalating. A thorough description and comparison of all the control strategies to optimize the power split between the primary and secondary sources of HEVs/PHEVs used are given here. The strategies discussed in this paper are real-time implementable and are robust in nature.. To obtain reduced liquid fuel consumption and larger electric operating range without compromising with the speed and performance of vehicle, a new technology, that is, a PHEV is in practice globally. PHEVs' charge depletion mode of operation is desirable, but a blended mode of operation may be a promising solution to extend operating electric range. HVs were capable of reducing fuel consumption of CVs in all tested traffic conditions and driving styles. HVs are the future of the growing auto industry and are in demand amongst potential Market as HVs do have better fuel Economy along with low maintenance load. Automobiles Manufacturers have to come with Smart Hybrid vehicles to sustain the competition and Recent Product launches like Maruti Suzuki Ciaz and BMW i8 in India indicates to the Future of this Technology in the country.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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